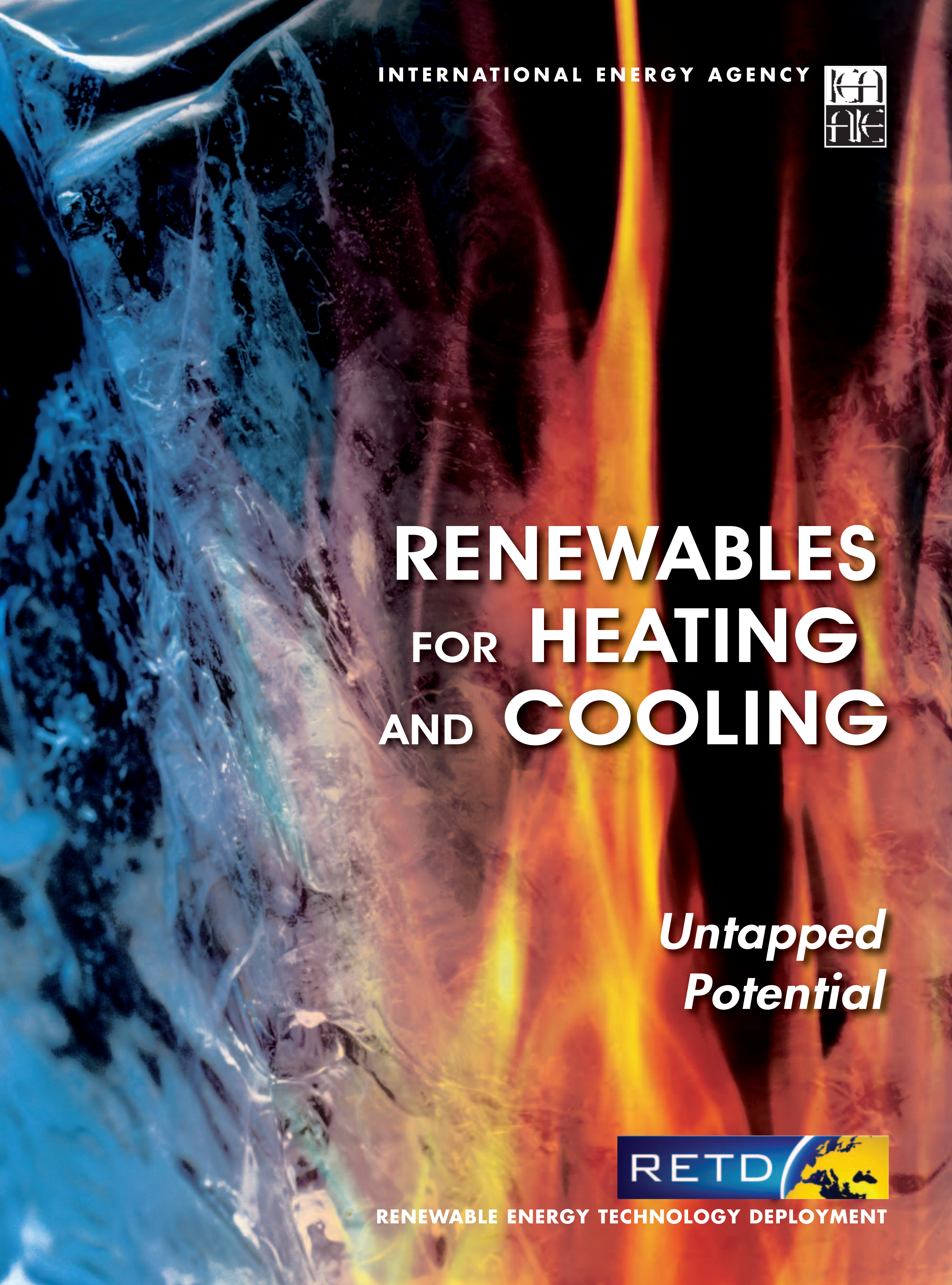

INTERNATIONAL ENERGY AGENCY

RENEWABLES FOR HEATING AND COOLING

Untapped Potential

RETD

RENEWABLE ENERGY TECHNOLOGY DEPLOYMENT

The use of renewable energy systems for both domestic and industrial heating and cooling applications has received relatively little attention compared with renewable electricity or transport biofuels. Where a good biomass, geothermal or solar thermal resource exists, heating technologies can often be competitive with those using fossil fuels. In a few countries their natural deployment has occurred with little if any policy support, resulting in greenhouse gas reductions. Elsewhere, several of the few national policies in place to remove barriers and encourage the greater deployment of renewable heat, (such as from using wood-burning boilers, geothermal ground-heat pumps, and solar water heaters) have proved to be cost-effective, yet other countries have been slow to replicate them. In regions where cooling has a greater energy demand than heating, especially during peak summer periods, renewable energy cooling systems show good potential for further development.

This timely report examines the technologies, current markets and relative costs for heat and cold production using biomass, geothermal and solar-assisted systems. It evaluates a range of national case studies and relevant policies. Should the successful and more cost-effective policies be implemented by other countries, then the relatively untapped economic potential of renewable energy heating and cooling systems could be better realised, resulting in potential doubling of the present market within the next few years.

INTERNATIONAL ENERGY AGENCY

RENEWABLES FOR HEATING AND COOLING

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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-six of the OECD thirty member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on the international oil market.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To promote international collaboration on energy technology.
- To assist in the integration of environmental and energy policies.

The IEA member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. The Slovak Republic and Poland are likely to become member countries in 2007/2008. The European Commission also participates in the work of the IEA.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. The European Commission takes part in the work of the OECD.

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Preface

In April 2006 the IEA hosted a seminar "*Renewable heating and cooling – from RD&D to deployment technology and policy*" aimed at exploring guidelines and policy initiatives that could accelerate technology development and market deployment for renewable heating and cooling (REHC). The IEA Renewable Energy Working Party (REWP) and the related Bioenergy, Geothermal, and Solar Heating and Cooling Implementing Agreements agreed to collaborate in order to present the current status of technologies, markets and successful policies and to explore future technology and policy trends. The REWP then determined that REHC is of such high importance that it merited the preparation of a full IEA report, prepared by the IEA Renewable Energy Unit, and based on the presentations and the discussions of the workshop.

Coincidentally a second report "*Renewable energy technology in heating markets - Policy status*" had been commissioned by the Implementing Agreement on Renewable Energy Technology Deployment (RETD; www.iea-retd.org). This was being researched and written by the Centre for Solar Energy and Hydrogen Research, Baden-Württemberg (ZSW) in early 2007.

It was considered that it would be most useful for the potential readership of these two reports, one emphasising technologies and markets and the other concentrating more on policies, if they were combined into one. This concept was put to the authors of the reports, members of REWP and members of the Executive Committee of the RETD implementing agreement by the IEA secretariat. There was full agreement that a single report, with due acknowledgement of all authors and organisations involved in its preparation, would be the preference. This report is the result of merging the two original studies.

By means of this report the IEA intends to emphasize the importance of renewable heating and cooling in reaching towards the renewable energy goals of energy security, climate change mitigation, reduced environmental impacts and cost competitiveness. The report aims to provide guidance to policy makers on how to successfully deploy renewable energies mainly for heating, but also for cooling purposes wherever appropriate.

This paper reflects the views of the IEA Secretariat and its Renewable Energy Unit (REU). It does not necessarily represent the views of the IEA, the RETD or their individual member countries. Nor is it intended to prejudge the views of countries participating in the RETD. Rather, it is intended to be an informative paper for IEA member countries, for the RETD audience, and for non-member countries interested in meeting their heating and cooling demands using local renewable energy sources.

Prepared as a joint report for the Renewable Energy Technology Deployment
Implementing Agreement and the Renewable Energy Working Party
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This paper was prepared by Ole Langniß and Kristin Seyboth of the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW), Luuk Beurskens and André Wakker of the Energy research Centre of the Netherlands (ECN), Ralph Sims and Frieder Frasch of the International Energy Agency (IEA) Renewable Energy Unit (REU) and Lex Bosselaar (SenterNovem). Many of the findings are based on presentations by Christophe Jurczak, Michel Francoeur, Kyriakos Maniatis, Michael Rantil, Ladislaus Rybach, Richard Schimpf, Samuele Furfari, Kaoru Yamaguchi, Michael Nast and Birger Lauersen, held at the workshop on Renewable Heating and Cooling in April 2006. Final compilation and editing of the report was undertaken by Ralph Sims of the REU who also coordinated its publication. Direct guidance in the publication was provided by Neil Hirst (Director, ETO), Antonio Pflüger (Head, ETC), Nobuyuki Hara and Piotr Tulej of the IEA Secretariat.

The Dutch Ministry of Economic Affairs funded SenterNovem and ECN to undertake their contribution as arranged by REWP member Willem van der Heul. The Deutscher Akademischer Austauschdienst (DAAD) supported the first draft of the technical report prepared by the IEA Renewable Energy Unit. The Renewable Energy Technology Deployment (RETD) Implementing Agreement contracted ZSW to do their part of the work.

Review comments were gratefully received from Executive Committee members of the IEA Bioenergy, Geothermal, Solar Heating and Cooling, SolarPACES and RETD Implementing Agreements as well as from members of the IEA Renewable Energy Working Party. The authors would like to thank Marco Calderoni (Ambiente Italia), Finn Bertelsen (DEA), Michael Nast (DLR), Uwe Trenker and Raffaele Piria (ESTIF), Hirofumi Muraoka (GREEN), Tesuji Tomita (IEEJ), Kes McCormik and Lena Neij (IIIEE), Pierre Ungemach (GPC IP), Michael Paunescu (Natural Resource Canada), John Lund (Oregon Institute of Technology), Erik Frints (SenterNovem), Antonia James (UK Parliament), Julita Klink and Amber Sharick (ZSW) for the information, comments, and ideas they provided.

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For further information on this report please contact the IEA Renewable Energy Unit of the Energy Technology Collaboration division, ralph.sims@iea.org.

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Executive Summary

Renewable energy heating and cooling (REHC) has been described as the “sleeping giant” of renewable energy potentials from the global perspective. Mature REHC technologies using solar, biomass and geothermal resources are currently available as cost-effective means of reducing both carbon dioxide emissions and fossil fuel dependency under many circumstances. Other technologies are close to mass-market deployment. Governments, including those endeavouring to meet challenging greenhouse gas (GHG) emission reduction targets, could find that considerable mitigation potential exists through the displacement of fossil fuels, usually, but not always, at relatively low costs per tonne of CO_2 emission avoidance.

In recent years, and in many regions, policies developed to encourage the wider deployment of renewable electricity generation, transport biofuels and energy efficiency have over-shadowed policies aimed at REHC technology deployment. Yet heating and cooling demands by the industrial, commercial, and domestic sectors constitute around 40-50% of the total global 320 EJ (7 639 Mtoe) final energy demand in 2004. REHC technologies have the potential to gain a greater share of this large market. Several countries have already exploited this opportunity such as Sweden where biomass supplied 62% of fuel for district heating in 2006.

In broad terms, world solar thermal heat use is currently around 200 -210 PJ/yr (4.8 - 5 Mtoe), geothermal heat is 260 – 280 PJ/yr (6.2 – 6.7 Mtoe) and heat from modern bioenergy probably almost 10 times the total of solar thermal and geothermal together (~4 000 PJ/yr; 80 - 100Mtoe) (excluding the use of traditional biomass which is around 9-10% of world primary energy). This compares with global biofuel production in 2006 of around 1 200 PJ (28 Mtoe) and renewable electricity generation (excluding large hydro) of around 1 800 PJ (500 TWh).

Based upon case study, country analyses of increased heating and cooling project deployment as a result of cost-effective policies, there appears to be good potential for many other countries with similar resources to follow suit and to significantly increase their current REHC contribution within the next decade or so.

The over-riding message from the analysis contained in this report is that, particularly where good renewable energy resources are available, governments should take strong action with respect to policy development that supports both the increased deployment of commercially available and cost competitive REHC technologies and the further development of those at the early-market stage.

This joint report, prepared by the International Energy Agency (IEA) Renewable Energy Technology Deployment (RETD) Implementing Agreement and the IEA Renewable Energy Unit with major contributions from several other relevant IEA Implementing Agreements, presents an overview of the status of available renewable technologies and markets for active heating and cooling, an analysis of their relative costs, and an evaluation of a wide range of current supporting policies. Passive solar heating and cooling of building space resulting from good design can reduce the demand for imported energy, but is not included in this analysis.

In regions with favourable resources and market conditions, several mature solar thermal, biomass and geothermal heating technologies entered the mass market many years ago since they were cost competitive with electricity, oil and gas. Other technologies are near-market and yet more are under development, including solar cooling technologies. REHC systems at the small domestic scale (solar water heaters, solid-fuel stoves and geothermal heat pumps) are distributed and more flexible in terms of being able to utilise the local renewable energy resources available than at the larger industrial scale of heating demand.

The analysis shows that well designed supporting policies have been highly effective in obtaining market expansion of REHC technologies. For example, solar water heater installations can compete with conventional heating fuels and are growing rapidly in a number of regions even where solar radiation levels are relatively low. Strong national policies have proved to be successful in high latitude countries such as Germany and Austria for example that have relatively low solar radiation levels and cheap conventional energy alternatives. The uptake of small scale, geothermal heat pumps used for both heating and cooling could continue to increase as the technology moves from near-market to mass-market in more countries. However, due to their current higher costs, this will only be in countries where strong supporting policies exist, as exemplified by Sweden.

Current policies to support greater deployment of REHC are mainly in the form of incentives ("carrots"), although good examples also exist of successful regulatory ("stick") and education ("guidance") policies. Policies in place across 12 OECD countries (Canada, Denmark, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, and United Kingdom, selected due to their varying approaches to policy development in this area), were reviewed, along with relevant policies of the European Union. The number of policies in support of solar thermal and biomass heating appears to be increasing with less comparable support for geothermal.

Examples of good practice policies for each technology are elaborated in the report for each kind of policy. Market-led examples are given for China, New Zealand and Iceland where REHC technology deployment has occurred without the need for policy support due to particularly abundant renewable energy resources, or where conventional alternatives are relatively expensive or unavailable (especially in rural areas). The stage of maturity of a specific REHC technology can also affect the choice of policy support mechanism. Additional policy support for district heating and combined heat and power (CHP) systems can also be combined with renewable heat deployment.

Detailed analysis of policies and measures used to support REHC technology development and deployment in the 12 OECD countries, including how they have evolved over time, has enabled recommendations to be made. These are aimed at policy makers who are intent on increasing national and regional REHC markets in order to gain a range of benefits as a result.

Recommendations and Conclusions

- Solar water heating, biomass for industrial and domestic heating, deep geothermal heat and shallow geothermal heat pumps are amongst the lowest cost options for reducing both CO_2 emissions and fossil fuel dependency. In many circumstances these technologies offer net savings as compared to conventional heating systems in terms of life-cycle costs.
- Deployment of REHC technologies is very variable, even amongst countries with similar conditions. Costs of REHC systems vary considerably with location depending on the availability of natural resources. Local energy prices for conventional electrical and fossil fuel heating systems impact on their cost competitiveness. Undertaking local cost/benefit analyses are therefore recommended.
- Well designed policies have achieved encouraging results in leading countries. For instance, Germany has nearly 5 GW of solar water heaters installed (around 750 000 units); about 30% of houses in Sweden have geothermal heat pumps with a total capacity of nearly 4 GW; and Canada has over 3 million homes producing around 100PJ (2.4 Mtoe) of heat from woody biomass each year with four times this amount produced for industrial heat giving a total equivalent to around 12 Mt of oil each year. Yet other countries with similar conditions make minimal use of their renewable energy resources.

- In regions with good solar radiation levels, governments should consider making solar water heaters mandatory on all new buildings with limited exemptions, as is the case in Spain where, for relatively low government expenditure, installed capacity doubled in 3 to 4 years. Such mandatory regulations could be widened to include other REHC technologies to allow for least cost applications depending on the local resources available.
- In countries where the use of REHC technologies is still very limited or at the early market stage, an initial policy objective should be to move them to mass market deployment leading to high penetration rates and sharp cost reductions. Policies should be designed to provide greater incentives for the better performing, more efficient designs of appliances.
- In countries where a lack of awareness, shortage of skilled trades people or difficulties gaining a local planning consent are a significant barrier to mass deployment of REHC technologies, governments should consider how these can be eased.
- Solar cooling technologies remain comparatively expensive at present and although commercially available, are likely to remain uneconomic in the future without considerable further R D & D investment.
- Obtaining the greatest increase in REHC for the lowest societal cost ($ government investment /GJ heat generated) should be the goal, but also taking into account all potential co-benefits including security of energy supply, greenhouse gas reduction, industry development, employment, improved health etc.
- While the most appropriate policies will vary from country to country, the evidence suggests that a comprehensive package can be the most effective. The mix of measures could include financial incentives, certification, labeling, and minimum performance standards, as well as guidance, public information and training of trades people and installers.
- Governments are recommended to review their national policies for renewable heating and cooling in the light of these findings and to consider how they can best promote these technologies. This is especially important for countries with demanding CO_2 savings and renewable energy targets.

Further analysis Governments are encouraged to improve the accuracy of their national data collection relating to heat supply in order to better inform development of policies. More analytical studies are needed to develop indicators that more accurately assess the cost effectiveness of individual policies and identify opportunities with the greatest impacts.

1. Introduction to Renewable Energy Heating and Cooling

Demand for heating accounts for a significant portion of world total energy demand. The building sector consumes 35.3% of final energy demand of which 75% is for space and domestic water heating (IEA 2006a). In Europe the final energy demand for heating (48%) is higher than for electricity (20%) or transport (32%) (EREC, 2006). It can be even higher in regions with long, cold winters such as northern North America. For cooling of buildings and refrigeration applications the demand for energy is growing but the data are uncertain.

Renewable energy sources (RES) (Box 1) used for heating and cooling purposes have received relatively little attention compared with those used to generate electricity and produce transport fuels. This is surprising because the demand for heat consumes the largest share of primary energy supply and RES can offer a practical alternative to fossil fuels under many circumstances. The potential to increase the use of solar, geothermal and biomass resources for renewable energy heating and cooling (REHC) is therefore large (Jurczak, 2006). This report outlines the technologies, existing markets and future potential for REHC and provides policy experiences and recommendations to support enhanced market deployment. It does not include the traditional combustion of biomass for cooking and heating in developing countries, though this is the highest contributor to renewable heat generation.

Box 1 • *Definition of Renewable Energy*

The IEA (2006e) defines renewable energy as *energy derived from natural processes that are replenished constantly*. This definition applies to a wide range of energy sources derived directly or indirectly from the sun including solar, hydro, wind, wave, biomass and ambient heat, but also includes non-solar sources such as geothermal, tidal and ocean currents.

Solar, geothermal and biomass can all be used as direct sources of heat (Box 2) and heat can also be extracted from the air, water or ground (Box 3). Heat can be used to drive absorption chillers for cooling. In addition any form of renewable-based electricity can be used to power heating or cooling appliances but these applications are not considered in this report.

The IEA, in acting as energy policy advisor to its 26 member countries that are aiming to ensure reliable, affordable and clean energy for their citizens, emphasises the "three E's" of balanced energy policy making: *energy security*, *economic development* and *environmental protection*. In order to secure its objectives, the IEA aims to create a policy framework consistent with a number of *'shared goals'* (IEA, 2007a). These are largely based upon international collaboration towards the development and dissemination of energy technologies, including for REHC. Industry participation, co-operation with non-member countries and communications between all energy market participants would help to improve information and understanding, and encourage the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

Without rigorous policy interventions, fossil fuels will probably remain dominant in the future fuel mix, having a projected continuing share of about 80% of total primary energy supply between 2004 and 2030 in the IEA *World Energy Outlook 2006* reference scenario.

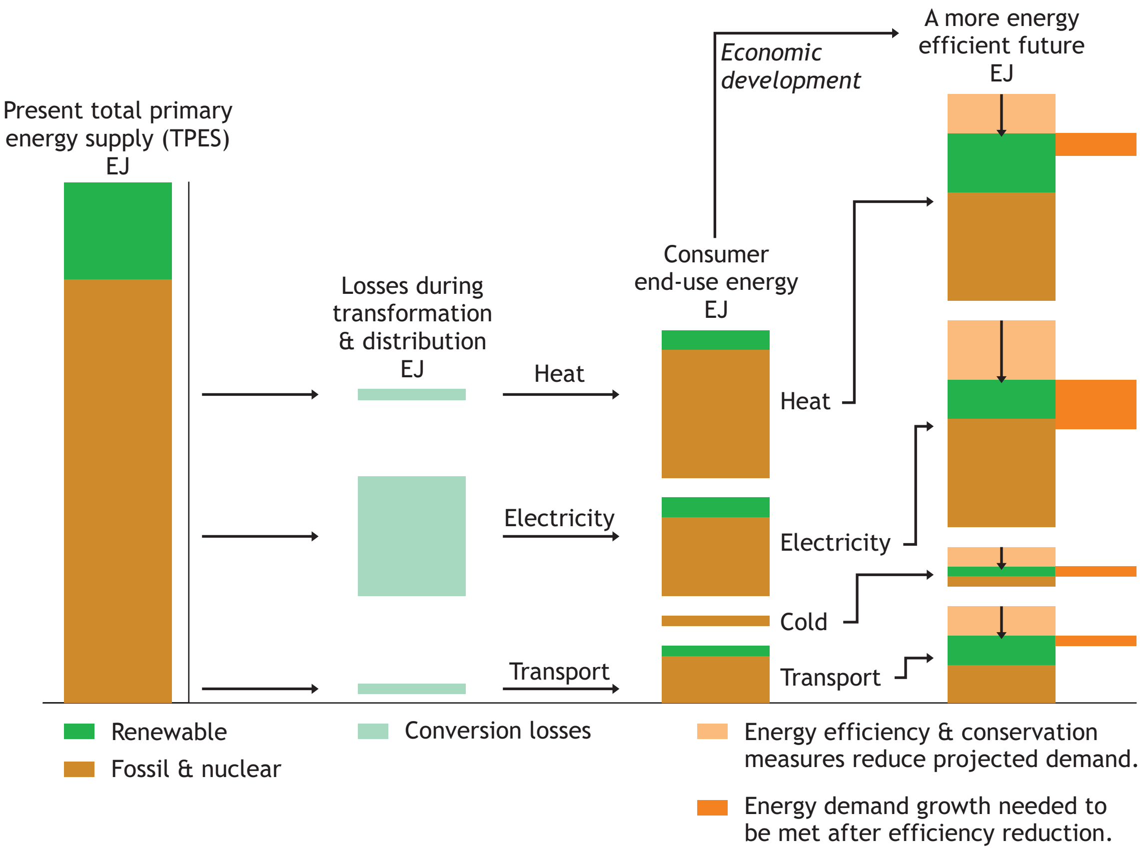
Box 2 • *Renewable Energy Sources used for Heating and Cooling*

Solar thermal	*Solar radiation*. Heat exploited for hot water production or air heating system is made available to the heat transfer medium minus any optical and collector heat losses. Solar thermal can also be applied for space heating, space cooling and process heat generation. Passive solar energy used for space heating, cooling, and natural lighting of dwellings or commercial buildings is useful but not included in IEA statistical data or in this report.
Biomass Biomass exists in solid, liquid or gaseous forms derived from a variety of feedstocks.	*Solid biomass*: Organic, non-fossil material of biological origin which may be used as fuel for heat production and/or electricity generation. It includes wood chips, residues from forests or wood processing, purpose-grown energy crops (poplar, willow, eucalyptus etc.), agricultural crop and animal residues, and the biogenic fraction of municipal solid waste (MSW). *Charcoal:* The solid residue from the destructive distillation and pyrolysis of wood and other vegetal material. The net calorific value (lower heat content) of solid biomass feedstock material is usually used on the input side (Table 1). The exception is charcoal where the material after carbonisation is used to determine the heat value and not that of the original biomass source. Industrial and MSW use the net calorific value of the heat content of the proportion of the biomass material used for fuel. *Biogas*: Gases composed principally of methane and carbon dioxide produced by anaerobic digestion of biomass and combusted to produce heat and/or power. The calculated lower heat content of biogas, includes gases consumed in the process but excludes flared gases. Gasification of biomass under restricted air supply conditions produces synthesis gas (mainly CO and H_2) that can be used for a range of applications. *Biofuels*: Liquid fuel produced from biomass transformation, mainly used in transport applications. The net heat value is determined from the finished product exiting the processing plant. *Waste*: Combustible or wet organic materials arising from industrial, institutional, hospital and households including rubber, plastics, used lubricating oils and other similar materials are termed "wastes". They can be either solid or liquid in form, renewable or non-renewable, biodegradable or non-biodegradable. MSW produced by the residential, commercial and public service sectors comprises wastes that can be either incinerated in specific installations to produce heat and/or power or disposed of in landfills. Only the fraction derived from biogenic materials can be considered renewable, defined by the energy value of combusted biodegradable material expressed in terms of mass or volume.
Geothermal	*Geothermal energy*: Heat contained in or discharged from within the Earth's crust, mainly by heat conduction, but also in the form of hot water or steam at particular locations. It is exploited at suitable sites for electricity generation after transformation, or directly as heat for geothermal heat pumps, district heating, bathing/swimming, greenhouse heating, aquaculture pond heating, agricultural drying, industrial process heat, etc. The energy content is measured by subtracting the heat of any fluid re-injected from the heat of the fluid or steam upon its extraction. A distinction is made between deep geothermal and shallow geothermal (Section 2).

Source: IEA, 2006b.

In energy supply systems, primary energy from fossil fuels, nuclear and renewables is converted to energy carriers (heat, electricity, transport fuels) that are then consumed to meet end-use energy services. This energy conversion process from primary to consumer energy involves unavoidable transformation and distribution losses that decrease the overall efficiency of the energy system (Figure 1). Continued economic development will increase future consumer demand but this can be offset to some degree by improved energy efficiency measures (arrows in column on the right). Conversely growing environmental and energy security concerns can contribute to a shift towards REHC. This report concentrates on the consumer end-use heat and cold supplied from renewable energy today (third column from left) and the potential to increase this supply in the future and thereby displace fossil fuels to some degree (column on the right).

Figure 1 • *Representation of the present energy system (left three columns) and the potential for transition to a more efficient energy system in the future (right column) as economic development occurs. (Indicative and not to scale)*



As global demand for energy services increases over time, growth in supply will be counter-acted by more energy efficiency and conservation measures. However, overall the global demand for heat and cold is expected to increase. To meet this demand, REHC could achieve an increased share of the total world energy supply during the next several decades, thus reducing the share of fossil fuels and reducing greenhouse gas emissions.

Several factors can influence the overall performance of a heating and cooling energy system.

- *Energy conservation and efficient energy use* can reduce future energy demand growth significantly, and thus improve environmental protection and energy security.

- *Introduction of renewable technologies* can contribute to the "three Es" by substituting for conventional energy sources. Renewables are low- or zero-carbon emitters, they can add to security of supply (Ölz *et al*, 2007) and are, in many cases, cost competitive.
- *Use of residual heat*. The conversion efficiency of primary fuel for thermal generation of electricity is in the order of 35-40%. During the conversion process, residual heat is discharged to the atmosphere or cooling waters of the power plant. Overall improvement of the energy system is possible where this heat can be collected and used to meet local demand such that less primary energy will therefore be required for heating purposes. Residual heat from industry or electricity production could be used in district heating systems. This can include the use of renewable energy carriers and hence a higher fuel flexibility.
- *Central versus decentralised, distributed generation.* Renewable energy options used to produce heat are in most cases decentralized with the heat used directly by the end-user. In the case of cold production, when substituting for conventional electrically driven refrigeration, renewable cooling options can yield considerable reductions of primary energy use due to the avoidance of losses from electricity conversion and distribution.

Box 3 • *Heat Pumps*

Heat pumps play an important role for space and water heating in the building and industry sectors. They are used to transport heat against the natural direction of thermal energy (from low to high temperatures). This process needs energy input from electricity or heat. The amount of heat that a heat pump can supply depends on the amount of energy that is in the original heat source, usually from natural surroundings of the air, water or ground.

Since heat pumps use less energy than conventional gas, coal or electrical heating systems they can contribute to significant energy savings. However overall savings depends on the coefficient of performance (COP), the source of the electricity, and efficiency of generation plants used to power them. The heat value of the primary energy used to generate the electricity consumed by a heat pump should be subtracted from the heat produced by the heat pump to obtain the overall energy savings and the portion of renewable energy of the system depends on the generation source of electricity. During times of extreme hot or cold weather conditions they can also lead to peak electricity demands. Energy efficient buildings can use heat exchangers or heat pumps in winter to retain the heat in the expelled air being transported outside by a ventilation system, to warm the fresh air coming in. This energy efficiency measure can reduce heat demand effectively (IEA, 2006c). The same principle applies for cooling during hot periods: heat exchangers and heat pumps retain the lower temperature from the inside to cool down the warmer fresh air coming in. Heat pumps can also be applied to maximise the use of process heat in the industrial sector (IEA, 2006c; HPC, 2007). This report focuses on geothermal heat pumps (GHPs), as the ambient heat provided from air and water sources is lower grade and usually considered under energy efficient end-use technologies.

Space and water heating make up the main share of energy consumption in the residential area. An increased share of renewables to meet those demands could contribute to a more sustainable energy future. REHC can therefore help make a significant contribution to reach the IEA's shared goals for all countries by:

- diversifying the energy supply;
- improving the security of energy supply since the renewable energy resources are mainly domestic and unlimited;
- increasing overall system efficiency since there are minimal conversion and distribution losses; and

- helping the transition to low-carbon energy systems and avoiding greenhouse gas emissions from the use of fossil fuels.

This report aims to draw the attention of all stakeholders, including policy makers, to the potential increased contribution that REHC technologies could make to future energy supplies. It also aims to encourage further collaborative research development and deployment (R D & D) investment, and to overcome the barriers and challenges identified to more rapid technology deployment.

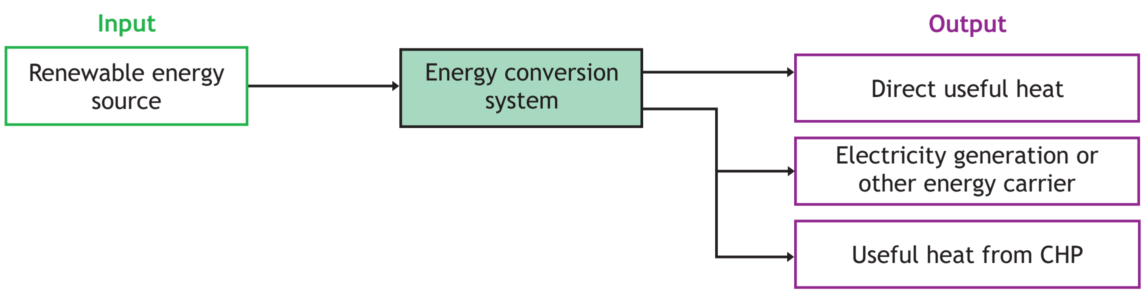
An overview of the relevant REHC technologies and their maturity (Section 2) and current market situation (Section 3) is provided. Reaching the potential contribution to total supply depends upon cost competitiveness and measurability as well as overcoming institutional, legal and behavioural barriers. R D & D needs are discussed with experience from policy support mechanisms described for selected countries (Section 4). Recommendations for policies that could enhance the greater deployment of REHC technologies are provided.

Political instruments and experiences to promote REHC are reported for Austria, Canada, Denmark, France, Germany, Ireland, Italy, Japan, Norway, Netherlands, Spain, Sweden and the United Kingdom. Relevant policy targets, measures, budgets and experiences are included where possible. In addition market led examples are provided from China, New Zealand and Iceland. The Annex to this report contains a compilation of 12 detailed country studies.

What is Renewable Heating?

Conversion of a renewable energy source to useful heat has been elaborated by the IEA together with industry (EU-project Therra, 2006) (Figure 2).

Figure 2 • *Renewable energy heat production options*



Definitions for input and output sides differ. In this report the input definition is used for data that concerns primary energy use and the output definition for data concerning final energy demand (Table 1).

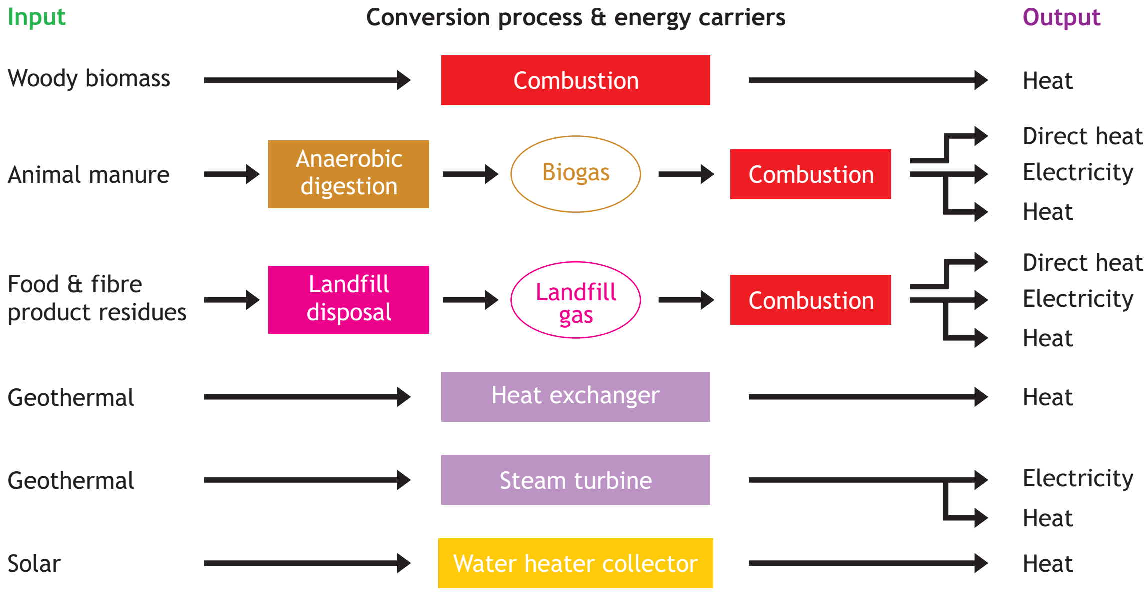
Table 1 • *Comparison of input and output side definitions of renewable heat*

Input	Output
Renewable heat is the energy content of a renewable source that is converted/transferred* into useful heat	Useful renewable heat output is the heat coming from conversion/transfer* of a renewable energy source that is used by an end user or in a follow-up conversion process
Primary energy use	Energy services

** For "shallow geothermal" there can be a "free cooling" mode where in summer the ground is cooler than ambient air. Thus the geothermal installation collects heat from buildings in summer and stores it in the ground. In winter, the heat is extracted from the warmer ground and transfers it to the buildings. In this case, there is no conversion, only transfer of heat.*

Renewable energy sources converted to energy carriers that are then used to provide useful heating services are wide ranging (Figure 3). When a renewable source is used to produce heat and another product such as electricity, the source is split into a fraction used for heat and a fraction used for the other product. If heat is produced by a renewable and a non-renewable source (as for the co-firing of biomass with coal in a CHP plant), the heat output should be split proportionally into renewable and non-renewable fractions.

Figure 3 • *Examples of renewable energy resource inputs selected to show how they can provide useful heat outputs as direct heat or as combined heat and power (CHP).*



Ambient heat transferred to a useful temperature level using a heat pump is renewable (although fossil fuel or nuclear primary energy inputs are often used to generate the electricity needed to drive the appliance). The same is true for shallow geothermal heat that is used via heat pumps. However, neither source has been integrated into IEA energy statistics in a systematic and consistent way due to measurement problems. Data on the contribution from passive solar building systems faces similar problems. The IEA acknowledges its importance and has referred to it in several publications, but it has not been included in statistics due to the difficulties in collecting or estimating the amount of passive solar energy.

What is Renewable Cooling?

In line with the definition for renewable heating, renewable cooling can also be defined from the input and output side similar to that shown in Table 1.

Typical examples of renewable cooling (Yamaguchi, 2006) include:

- seasonal storage of cold during winter for use in summer through aquifer storage, snow or ice storage, cold water taken from the sea or deep lakes;
- production of cold through absorption cooling driven by a renewable source such as solar energy.

Renewable cooling can also include electricity generated from renewable energy sources such as photovoltaics, wind or hydropower that is then used to power refrigeration appliances and cool stores, although this is not included here.

Box 4 • *Modern Building Energy Demand: less heating and more cooling*

In the past decades, thermal insulation of modern buildings has improved significantly. This has led to a lower heating demand and enabled the introduction of lower temperature heating, such that the use of ambient heat and heat pumps becomes feasible. On the other hand district heating systems become less attractive as less heat per consumer is purchased annually, though this can possibly be partly compensated for by an increase in use of floor space per consumer.

Insulation also can reduce the cooling demand in summer. Cooling demands have grown because of increased internal heat loads from computers and other appliances, more rigorous personal comfort levels, and more glazed areas on modern commercial and domestic building designs that increase the heat influxes (IEA, 2006c). The ratio of building surface to volume has also been rising, especially in the service sector and often in combination with glazed facades (IEA, 2005). In effect, modern building designs have increased the demand for cooling but reduced the demand for heat energy. This trend has been amplified by recent warmer summers in many areas, increased demand for comfort, particularly by those living in developing countries and economies in transition, and the recent availability of low cost, air-conditioning systems.

The reduction of heating loads should be encouraged as a positive aspect, but the increased application of conventional cooling equipment should be avoided. In order to decrease the cooling load, building design should focus more on the use of passive cooling options. The electricity peak load experienced in summer could then be reduced.

Products and services

Renewable energy sources and carriers can be used to produce energy products and services such as the delivery of direct heating, cooling and electricity (Table 2). Generally speaking there is a trade-off between the value of a service or product, its cost, and the complexity of the process required to produce it. For example, heat is usually a low-value product available at relatively low cost compared with higher-value electricity (see Merit order below). The possible uses of biomass, geothermal and solar thermal energy sources and energy carriers will be discussed in more detail in Section 2.

Table 2 • *Energy products and services from renewable energy sources.*

Renewable energy source	Technology	Direct heating	Cooling	Electricity*
Biomass	Combustion for heat only	X		
	Combustion for heat and power	X		X
	Integrated bioenergy systems (tri-generation)	X	X	X
	Municipal solid waste incineration	X		X
	Anaerobic digestion for biogas	X		X
Geothermal	Deep – higher temperatures	X		X
	Shallow – lower temperatures	X	X	
Solar thermal	Passive cooling building designs		X	
	Passive heating building designs	X		
	Active thermal heating	X		
	Solar assisted cooling	X	X	
	Integrated PV-thermal collector	X		X
	Concentrating solar heat (CSH)	X	X	X

**Electricity can be used to power appliances used to provide heat and cold including refrigerators and heat pumps (Box 3).*

Merit order of REHC options

Temperature is an indication of the 'value' of heat as classified by high (over 250°C), medium (between 80°C and 250°C) and low (below 80°C)[1]. When a certain amount of heat needed for a low temperature energy service (for example space heating) is supplied from high value, high temperature heat, the "quality" (or exergy) of the energy is irreversibly lost. As a consequence, the higher quality energy does not present its maximum possible effect in the energy system.

Heating

To use renewable heat most efficiently from a quality perspective it is possible to set up a merit order of preference, although this may often differ from an economic point of view.

1. Energy efficiency and conservation options in buildings and industry sectors.
2. Passive solar heating building designs (Box 4).
3. Solar thermal or geothermal where sufficient resources exist.
4. Geothermal heat pumps where possible, preferably powered by renewable electricity.
5. Biomass in integrated bioenergy systems for cogeneration of electricity and heat (combined heat and power, CHP) where there is a heat demand (and also the tri-generation of cold).
6. Biomass combustion, incineration and anaerobic digestion with the biogas used for heat only production.

Note that in all the preference options for heat demand, residual heat from thermal power plants etc could also be a source as it is often abundantly available at low cost. The heat demand however needs to be located reasonably close to the heat source (up to several kms maximum) for practical uptake.

Cooling

Based on similar considerations the following merit order of preferred cooling technologies emerges.

1. Energy efficiency and conservation options in buildings and industry sectors.
2. Passive cooling options *e.g.* passive building design measures, summer night ventilation without the need for auxiliary energy.
3. Passive cooling options using auxiliary energy, *e.g.* cooling towers, desiccant cooling, aquifers.
4. Solar-assisted, CSP or shallow geothermal all driving active cooling systems.
5. Biomass integrated systems to produce cold (possibly as tri-generation).
6. Active compression cooling and refrigeration powered by renewable electricity.

1. As defined in IEA Solar Heating and Cooling Task 33 (http://www.iea-shc.org/task33).

2. REHC Technologies

This section provides an overview of the maturity stage of REHC technologies before describing the individual technologies for solar, bioenergy and geothermal sources and their future developments.

Solar-thermal

Solar thermal is a relatively mature technology that has proven to be reliable and cost-competitive under certain circumstances since solar water heaters first became commercially available over thirty years ago. They have already reached a significant market share in some countries (Section 3). Other solar thermal applications are for crop drying, heating of large buildings[2], and higher grade industrial heat purposes, possibly from concentrating solar heat systems (Rantil, 2006). Barriers to deployment in some situations include planning constraints on roof installations, high up-front capital costs, and a deficit of skilled trades people.

Active heating

Water, or another heat transfer fluid, is circulated through a duct and heated by transfer from direct solar radiation on the collector panel. Various designs of collectors are utilized in order to concentrate the solar radiation on the fluid duct and to maximize solar gains (Figs. 4, 5 and 6). The amount of heat energy captured per square metre of collector surface area varies with design and location but typically can range from 300 - 800 kWh/m^2/yr.

Figure 4 • *Flat plastic plate collectors for swimming pool water heating*

Source: SHC, 2007.

Figure 5 • *Glazed flat plate collectors*

Note: Roof based on the heat pipe principle mounted on a single dwelling (top left: Thermocell, New Zealand); incorporated into the building façade (top right: Aks-Doma); and integrated into the roof of a multi-apartment dwelling in Austria (bottom: SHC, 2007).

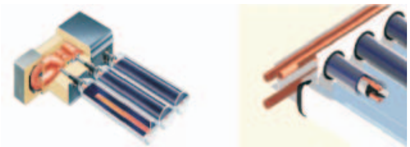
Some designs use a heat transfer fluid that when warmed flows to a storage tank or a heat pump where the heat is then transferred to water that can then be used as hot water or for space heating. Full potential for solar thermal systems has not been reached in most IEA countries due to the relatively high capital costs compared with conventional water heating systems. Depending on water use behaviour

2. See for example www.solarwall.com/home

and number of people in a household, solar water heaters can give long payback periods of around 5 to 10 years or longer. Elsewhere, such as in China, simpler, cheaper systems (often without freeze protection for example) are manufactured that have reached the mass market and can compete since conventional hot water systems are not always available.

Under optimal conditions, it has been estimated that the use of conventional energy inputs of gas or electricity for water heating could be cut by around 50% in applications which require temperatures up to 250ºC and by around 60-70% for domestic water heating energy with temperatures up to around 60ºC when sited in low latitudes below 40 degrees. The amount of savings however is partly dependent on the users' behaviour and the time of the hot water draw-off. A review of the limited literature available on hot water use together with comparative practical testing of three designs of solar thermal systems and a heat pump at 40ºS latitude (Kerr et al., 2007) identified disappointing performance of the solar systems, particularly where hot water was drawn off mainly during the daytime. The use of auxiliary controllers (on/off timers) to prevent the back-up gas or electric heating system coming into play during the daytime made a significant difference to the amount of useful solar energy gain obtained in some situations. The coefficient of performance (COP) of the solar water heaters compared with the heat pump were then similar, although there was a tendency for heat pumps to be the better performer in regions with less than around 2000 hours of sunshine a year. The complex relationships between highly variable times and rates of draw-off, and possible interaction with utility load control strategies, can all impact on the useful heat savings achieved in practice from solar thermal systems and further analysis is required.

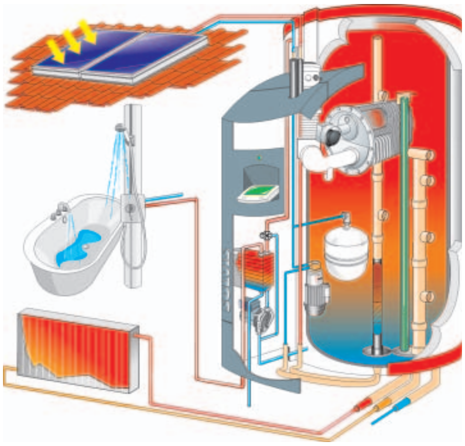
Figure 6 • *Chinese roof mounted domestic evacuated tube collector*



construction details from a Vitosol 300 heatpipe (left) and direct coupled collector (right).

Source: www.viessmann.com.

Figure 7 • *A solar heater combi-system, combining water heating and space heating through room radiators*



Source: www.solvis.com.

When solar heating is combined with energy saving and efficiency measures, even more significant energy savings can be achieved (Rantil, 2006). However to reach solar fractions above 90%, large scale solar thermal seasonal storage technologies and small scale more advanced high capacity thermal storage technologies are necessary.

Promising new designs include “combi-systems” that combine water and space heating (Figure 7). This extends the operation period and thus improves profitability. Active solar space and water heating systems usually need a back-up of gas, electricity or wood stove and wetback system to provide sufficient amounts of warm water during periods of low insolation. These back-ups add to the overall system costs (IEA 2006b).New technology integrates a solar-assisted heating system with a heat pump resulting in an ‘ultra-high efficiency’ system between 125-145% compared with the common condensing boiler at around 107% (Daniëls and Farla, 2006).

Concentrating solar heating systems

These solar collection devices are usually used for medium scale heat application systems in industry, agriculture and food production. Similar to concentrating solar power (CSP) systems for electricity generation, a concentrating solar heater (CSH) device consists of a concentrator, receiver and transport-storage system. The concentrator captures solar radiation and directs it to the receiver where the heat energy is absorbed by a fluid – normally a special type of oil. The hot fluid is then transported in a pipe to enable the heat to be used directly via a heat exchanger or stored for later use at night or during less sunny days.

A popular design consists of parabolic troughs in long arrays of identical concentrating modules, resembling trough shaped glass mirrors that track the sun daily from east to west. They concentrate the solar radiation on to the absorber pipe located in the focal line of the installation. Parabolic dish collectors also track the sun on two axes but the system units are usually smaller consisting of a dish and a receiver unit installed at its focal point (IEA, 2006c; SolarPaces, 2007).

Active solar cooling

Solar-assisted cooling for air-conditioning and refrigeration systems are gaining in interest as they have reached the near-market stage of development. This thermally driven process is more complex, being based on a thermo-chemical sorption process. A liquid or gas can either be attached to a solid, porous material (adsorption) or absorbed by another liquid or solid material (absorption). Closed systems including both adsorption and absorption chillers can be used for central or decentralized conditioning. Open cooling cycles use desiccant and evaporative cooling systems that directly condition air. The technology has not been widely applied and needs more RD&D efforts to give reliability and to reduce costs that can compete with conventional cooling technologies. One advantage of solar-assisted cooling technologies is that peak cooling demands often correlate with peak solar radiation and hence with peak electricity loads for conventional air conditioners (IEA, 2006c). A different route could be to first generate electricity using solar photovoltaics to power a conventional refrigeration device. This option can be relatively costly and is not considered further here.

The cost of solar-assisted cooling (SAC) is declining with experience in system design and the interest from refrigeration companies, solar thermal system manufacturers, policy makers and utilities has grown as peak power demands increase during periods of hot weather. Solar cooling tends to be effective during such periods since the peak demand for cooling coincides with peak solar radiation levels.

District cooling systems from 5 to 300 MW are used in several cities including Paris, Amsterdam, Lisbon, Stockholm, and Barcelona using chiller/heat pumps, absorption chillers, compression chillers or a cold water distribution network, but solar energy is not currently utilised at this scale. Where natural aquifers or waterways are utilised as the source of cold, then this could conceivably be classed as a form of renewable energy. For example in a US$ 58M scheme, Cornell University, USA, extracts water from the bottom of a nearby lake at around 4 – 5°C and passes it through a heat exchanger before storing it in a 20 000 m^3 stratified thermal storage tank used to cool the incoming air from 75 campus buildings.

Passive solar heating and cooling

Passive solar technologies that focus on avoidance of heating and cooling loads are not discussed here in detail. However the IEA is very active in the field of energy efficient building designs (IEA, 2005) and passive solar heating and cooling as shown by the *Energy Conservation in Building and Community Systems* and *Solar Heating and Cooling* implementing agreements.

Bioenergy technologies

Biomass offers good future potential as an energy source since it is the only renewable energy carrier that can directly replace fossil fuels (Maniatis, 2006). The stored solar energy in biomass from biodegradable matter can be converted into usable forms of bioenergy used for heating, and cooling, or into other energy carriers as well as for materials and chemicals. Biomass is very diverse and includes wood residues, organic wastes, crop residues, crops grown specifically for energy production, animal wastes, black liquor (the lignin-containing sulphite lyes in the alkaline-spent liquor from pulp and paper production) and municipal solid waste (MSW). Due to the limited availability of land biomass production for energy must be balanced against the need for food, fibre, animal feed, materials, biochemicals and soil carbon and forest sinks.

Barriers to deployment of bioenergy projects include:

- increasing concerns that the source of biomass is sustainably produced;
- the logistics and costs of transport, storage and handling of bulky volumes;
- variable fuel quality in terms of moisture content and piece size, and
- the difficulties in negotiating long term fuel supply contracts and resource and planning consents for plant construction (IEA, 2007b).

Biomass conversion technologies, fuel types, prices and emissions are discussed below (IEA, 2006c).

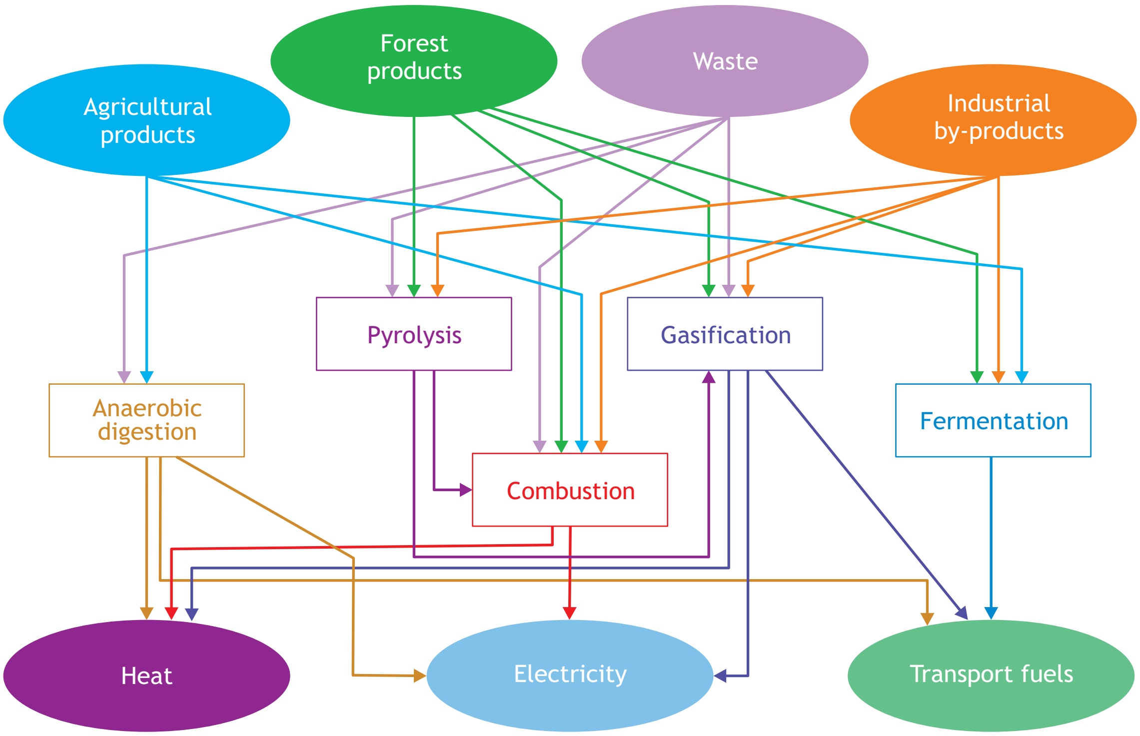
Conversion technologies

Generating bioenergy heat can involve complex pre-treatment, upgrading and conversion processes that can follow many possible pathways from raw feedstock material through to energy carriers (Figure 8). Production of materials and chemicals from biomass feedstocks are competing pathways for the various limited sources of biomass that add to the complexity.

Biomass combustion to produce heat is a mature technology and in many cases competitive, or nearly so, with fossil fuels. Examples include wood burning stoves, MSW incineration (the biogenic component being considered a renewable energy technology), pellet boilers and anaerobic digestion to produce biogas. In future, a bioenergy application could aim for tri-generation to produce electricity, heating and cooling simultaneously and hence maximize the overall conversion efficiency per unit of biomass. The additional costs involved are unclear, so in practice it is difficult to identify precise circumstances in which tri-generation can be applied under current economic conditions. Technological challenges of new materials, fuel handling and storage and the cost-gap for pellets, tri-generation etc. in relation to conventional processes using fossil fuels remain as barriers. An advantage of many forms of biomass in comparison to most other renewables is that they can be easily stored over long periods of time.

Combined heat and power (CHP) however is a well-proven technology, which is reasonably efficient in terms of benefit per unit of biomass. From an energy quality point of view, it is more beneficial than production of only electricity or heat alone with overall conversion efficiencies of around 70-90% possible where the heat can be usefully employed.

Figure 8 • *Pathways for converting energy from biomass material into usable forms of heating and cooling or into other energy carriers (e.g. transport biofuels, electricity)*



Biomass fuel types and prices

The cost share of the biomass feedstock compared with the total energy cost can be considerable. Generally biomass is not freely available as even wastes and residues need to be collected and stored. However agricultural residues, animal wastes, or MSW can have very low costs or possibly even negative costs in situations where a disposal or treatment cost is avoided. MSW streams are technically more difficult to deal with due to the control needed to minimize and monitor polluting emissions. In comparison to fossil fuels, biomass also has a relatively lower energy density. This leads to higher transport costs. Hence overall, the €/GJ of delivered energy can be very wide ranging depending on biomass type, transport distance and storage costs.

For biomass produced from purpose-grown energy crops, the energy content can be higher than for residues but their fuel characteristics less variable. Producing energy crops does however require a long chain of activities, from planting and harvesting to storage and drying, which add to the costs.

Emissions

The largest contribution to renewable energy is the use of traditional biomass combusted in open fires by around 2.5 billion people living in developing countries who rely on biomass for household uses

(IEA, 2006f). An estimated 1.3 million die prematurely each year from resulting indoor air pollution from carbon monoxide, hydrocarbons and particulate matter. These can be reduced by the use of well designed stoves that can better control the combustion process and filtering of exhaust gases. Emissions from modern designs of enclosed wood stoves as used for domestic heating in developed countries can also produce emissions which can cause local air pollution, especially when firewood with higher moisture contents is used. When well designed, enclosed, domestic stoves are operated correctly, then these emissions can be minimized, but due to the wide range of fuels used, and the varying ability and understanding of the operators, this is often not the case in practice. Commercial bioenergy heat production plants produce around 5 – 15 g/GJ of particulate matter whereas domestic wood stoves can emit up to 150 g/GJ (de Wilde, 2006).

Although biomass is defined as a carbon-neutral energy carrier, due to the short-cycle carbon loop, atmospheric emissions should not be ignored (Table 3). They differ for each type of biomass. The related CO_2 emissions however are not accounted for in national emissions registers and are not considered in the European CO_2 Emissions Trading Scheme. When applying carbon dioxide capture and storage, bioenergy offers the only option to actually withdraw CO_2 from the environment. In addition soil carbon levels can be increased or decreased by growing energy crops depending on the crop type and the cultivation and harvesting methods used.

Table 3 • *Energy carriers and standard CO_2 emissions factors as defined by the Netherlands in Autumn 2006*

	Unit	Typical lower heat values (MJ/unit)	CO_2 emission factors (kg/GJ)
Solid biomass	kg	15.1	109.6
Liquid biomass	kg	39.4	71.2
Gaseous biomass	Nm3	21.8	90.8
Biogas from wastes	Nm3	23.3	84.2
Landfill gas	Nm3	19.5	100.7
Industrial organic waste gas	Nm3	23.3	84.2

Source: Bosselaar, 2006.

Geothermal technologies

On a human timescale, geothermal heat is an inexhaustible source of energy. It has an extensive global distribution, and is independent of weather, season, or energy demand patterns. Market growth was highest in the late 1970s. From the early 1980s a decrease occurred leading to a more stable state until the technology received renewed interest from 1995 onwards. Efficiency and cost-effectiveness of geothermal systems are greatest when high temperature sources can be used for electricity generation and the lower grade residual heat can be used for other heating or cooling demands.

Deep geothermal systems use heat from depths of 500 - 5000 m drilled at favourable geologic conditions. Shallow geothermal systems provide low grade heat from depths of less than 300m for use in association with heat pumps. These domestic scale systems currently remain capital intensive but can be installed virtually anywhere to provide heating and cooling for low on-going operational and maintenance costs (Rybach, 2006).

Identifying a potential geothermal resource through mapping and 3D seismic exploration tools is advancing, but exploration risks remain that identified faults for example do not carry water and are therefore not usable for heat extraction.

Deep geothermal

The origin of deep geothermal heat can be found in the Earth's interior (where central temperatures reach about 6 000°C) due to the gradual decay of long-lived radioactive isotopes (^{40}K, ^{232}Th, ^{235}U and ^{238}U). Heat energy continuously flows from the Earth's interior to the surface. The resulting heat flux is not distributed uniformly over the Earth's surface but is concentrated along active tectonic plate boundaries where volcanic activity has transported high temperature molten material nearer to the surface. Under the right conditions, water penetrates deeply into the surrounding hot rock zones resulting in the formation of high temperature geothermal systems containing hot water and/or pressurised steam. In addition groundwater naturally circulating through deep fracture zones can collect heat from large volumes of rock and concentrate it in shallow reservoirs, even if far away from plate boundaries. In some cases, the water is discharged as hot springs. The heated water is typically at a lower temperature than when produced in deeper volcanic-based systems (IEA, 2006c; IEA, 2006d).

Where high temperatures exist, the heat can be used in conventional geothermal developments for electricity generation or for direct heat use applications. Cascade methods can be incorporated to utilise the hot water remaining from electricity generation in successively lower temperature processes, which may include binary systems to generate further power as well as a range of direct heat uses including for providing industrial process heat, district heating, greenhouse heating, open ground heating, swimming pools, and space heating (IEA, 2006c; IEA, 2006d). In Iceland, 88% of all households use geothermal energy directly due to the favourable geologic conditions and efficient hot water distribution networks (Rybach, 2006).

Enhanced geothermal systems

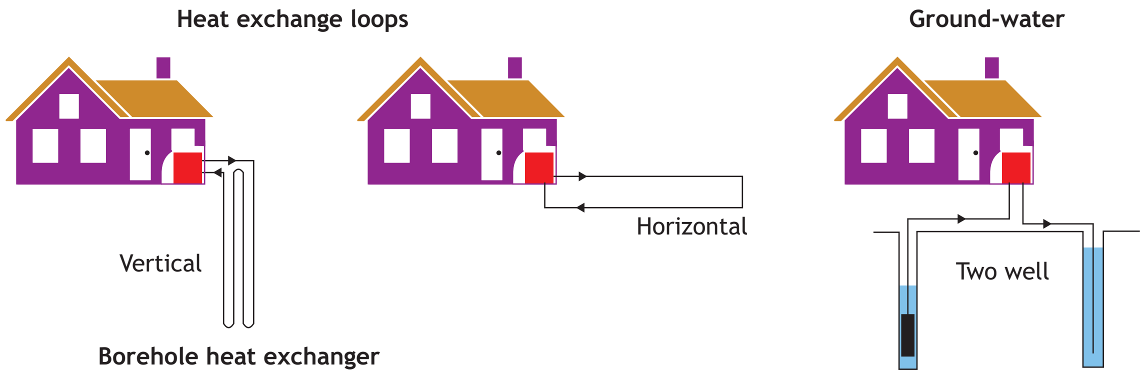
Vast amounts of heat present in rock at accessible depths up to around 5000 m constitutes a potentially significant worldwide resource. Investigation into its development and utilisation using enhanced geothermal system techniques (EGS, formerly known as "hot-dry rock") is currently at the cutting edge of geothermal research (IEA, 2006c; IEA, 2006d). However challenges still prevail, as for example with the €50 million project in Basel, Switzerland designed to extract enough super-heated water to drive a power plant providing electricity for 10 000 homes and heat for 2 700 others. Injecting water at high pressure into the 5 000m deep borehole in December 2006 caused an earthquake of 3.4 magnitude on the Richter scale. In addition suitable permeability of the bedrock is also necessary.

Shallow geothermal

Ambient heat stored at shallow depths (~300 m) can be an essential component of energy-efficient heating and cooling systems in buildings. Aquifer thermal energy stores (ATES) occur when heat is stored naturally in ground water layers. Both heat sources can be extracted with heat pumps and then usefully applied for space or water heating (IEA, 2006c; IEA, 2006d; Bosselaar, 2006). The past decade has seen increased deployment of geothermal heat pumps (GHP). These are a fully developed technology with a relatively low cost-gap, but this depends on the price of the conventional fuels to be substituted. In most cases the stored heat can be collected or replenished to provide a seasonal source for both heating and cooling.

Heat pumps can transform low temperature heat from the subsoil, underground water or rock source to a higher level that can be useful for low-temperature heating (Figure 9). In summer, when the ground is cooler than ambient air, shallow geothermal systems circulate the heat carrier fluid between building and ground, hence by-passing the heat pump. In effect the heat of the building is transported to the ground to be stored for extraction in winter ("free cooling"). Thus the same shallow geothermal system performs heating and cooling services. Reversible heat pumps in small air conditioners are mostly used for cooling only and are therefore not considered as renewable heat from ambient sources.

Figure 9 • *Shallow geothermal systems are available in a range of types to match the local heat source whether in wet or dry ground*



Note: The vertical borehole heat exchanger system is the most common.
Source: Rybach, 2006.

A geothermal heat pump needs electricity to drive it. The coefficient of performance (COP) is the ratio of heat output to energy input. A conventional ground-coupled system has a COP of 3 to 4, although, depending on the system configuration, a COP up to 7 can be attained, for example by minimising the temperature lift and applying a low temperature radiant heating system. Heat pumps extracting heat from air or surface water are less effective due to the more variable temperature of the source.

ATES can store surplus low temperature heat in summer (when there is a low heat demand) for use in winter when heat demand is higher. To achieve this, suitable hydro-geologic conditions are required which are not available everywhere. Other types of storage used as a source for renewable heating or renewable cooling or both depending on the seasonal needs, include ice banks, phase change materials (PCM), and thermo-chemical systems.

Heat and cold storage technologies have their own typical efficiency and energy losses. Whether or not the energy output can be regarded as renewable depends on the origin of the heat. For example regenerating ATES systems using residual heat from fossil fuel-fired industrial processes or thermal electricity generation are not considered to be renewable.

Applications and competitiveness

REHC applications can be divided into single- and multi-family dwellings, settlements, commerce and services, agriculture, and industry. Each category has different heating and cooling requirements (Table 4).

REHC options have to compete with conventional heating and cooling technologies in order to achieve a high penetration in modern energy systems. However, renewable energy options can be more expensive than conventional technologies (Section 3). Each heat demand sector has its own range of typical energy prices. For example a steel or aluminium industry consumes relatively large quantities of energy which can result in bulk purchase discounts. Conversely, households often pay high prices for their heat energy, a major share being for distribution fees and end-user taxes. The agriculture, commerce and service sectors can benefit from buying larger amounts of energy compared to households to gain discounts and are also often exempted from sales taxes. These price differentials lead to REHC technologies competing in, for example, households better than in the industrial sector.

Table 4 • *Suitability of renewable energy resources to meet various categories and scales of heating and cooling applications*

Application	Solar thermal	Solid biomass	Biogas*	Biomass from waste	Shallow geothermal	Deep geothermal
Dwellings	x	x	(x)		x	
Settlements (district heating)	x	x	x	x	x	x
Commerce and service	x	x	x		x	
Agriculture	x	x	x	x	x	x
Industry	x	x	x	x		x

** Biogas for cooking is produced at the micro-scale in developing countries using domestic and animal wastes. At the other extreme using large scale plants scrubbed biogas can be fed into gas grid pipelines. Neither of these options is considered in detail in this report.*

Each conventional energy carrier has its own price range (Table 5) so substitution opportunities using renewable energy vary widely. For example, electricity is a relatively high-priced energy carrier whereas fuel oil, especially when used in oil-producing countries, has been relatively cheap. Cost effective opportunities for REHC are therefore greater when substituting for electricity rather than for fuel oil. The price of the energy carrier is determined by the primary fuel cost plus transportation and distribution costs and any excise taxes imposed by governments. In remote regions where energy is provided from diesel fuel or bottles of liquified petroleum gas (LPG), the use of local renewable energy can add value by avoiding the relatively high transport costs. Traditional biomass used for basic cooking and heating is usually locally available at very low cost but is converted to heat at very low efficiencies of less than 10% on open fires. Using a more efficient enclosed cooking or heating appliance with a flue can reduce the fuel input and also add value from improved health benefits. However investment costs for such appliances, even if very simple, are often difficult to meet for the very poor.

Table 5 • *Real and indexed electricity, gas and light fuel oil prices (average values for OECD countries) when delivered to industry or households*

	Real prices		Indexed prices	
	Industry	Households	Industry	Households
Natural gas USD/GJ	3.8	8.4	100	220
€/MWh	11.0	24.3		
Electricity USD/kWh	0.06	0.10	100	167
€/MWh	48.0	80.0		
Light fuel oil USD/toe	279	423	100	152
€/MWh	19.2	29.1		

Source: IEA, 2006c (2002 data chosen for consistency). 1 USD = € 0.8 (2006)

Successful competition of REHC options are dependent on the cost of delivering heating and cooling, the energy prices paid in each demand sector, on the fuel type to be substituted and its costs. However factors besides price can influence the competitiveness of heating and cooling technologies including energy security, improved human health and GHG emission reductions.

Industry and commercial buildings

Industrial heat is a large portion of total energy demand. In the EU for example, 30% of final energy is used by industry of which two thirds is in the form of heat (SHC, 2007). Industrial process heat applications will therefore play a crucial role in global markets, though higher grade temperature demands may restrict the application of some renewable energy heat sources.

Large industrial heating and cooling demands can make REHC applications more attractive due to the large scale of operation. At the small end of the scale, MSW incineration and deep geothermal technologies are unsuitable for single or multi-family dwellings with small heat loads because these technologies usually need a certain minimum capacity to be economically viable. District heating to supply apartment and office blocks, institutions as well as industry can have the advantages of fuel flexibility (thereby allowing the use of seasonal sources), utilisation of local sources, centralised heat load produced under controlled circumstances, and deployment of CHP (Lauerson, 2006). Landfill gas and biogas can also be injected into the distribution grid as a means of distributing renewable energy for use as domestic heat. In the agricultural sector large scale solar thermal applications for crop drying or the use of biomass residues to generate heat on-farm can also be cost-effective options, depending on the resource availability and magnitude of the heat demand (Rantil, 2006).

Price relativities can change quickly. Oil, natural gas and electricity prices have shown some volatility in the last few years, whereas cost reductions for renewable energy technologies have also occurred due to learning experience induced by further market uptake. Typically a doubling of installed capacity can result in a 10-20% cost reduction per unit of energy. International efforts to internalize the neglected external costs of fossil fuels might also contribute to better competitiveness of REHC in the future. Environmental taxes, carbon emission charges, or the transfer of subsidies from fossil fuels could all serve to further strengthen the position of REHC (Section 4).

Maturity

Historically heat energy was mainly supplied from biomass but ancient solar architecture shows that passive solar heating and cooling are also nothing new. More recently however three generations of renewable technologies can be defined: development, early market and mass market (Figure 10) (IEA 2006c; Ros 2007). Developing technologies have a high cost-gap relative to conventional technologies in the market and still need policy support. Early market “second-generation” technologies have a relatively low cost-gap and learning experience often helps them become more cost-effective. By the time they reach the mass market they are usually cost competitive.

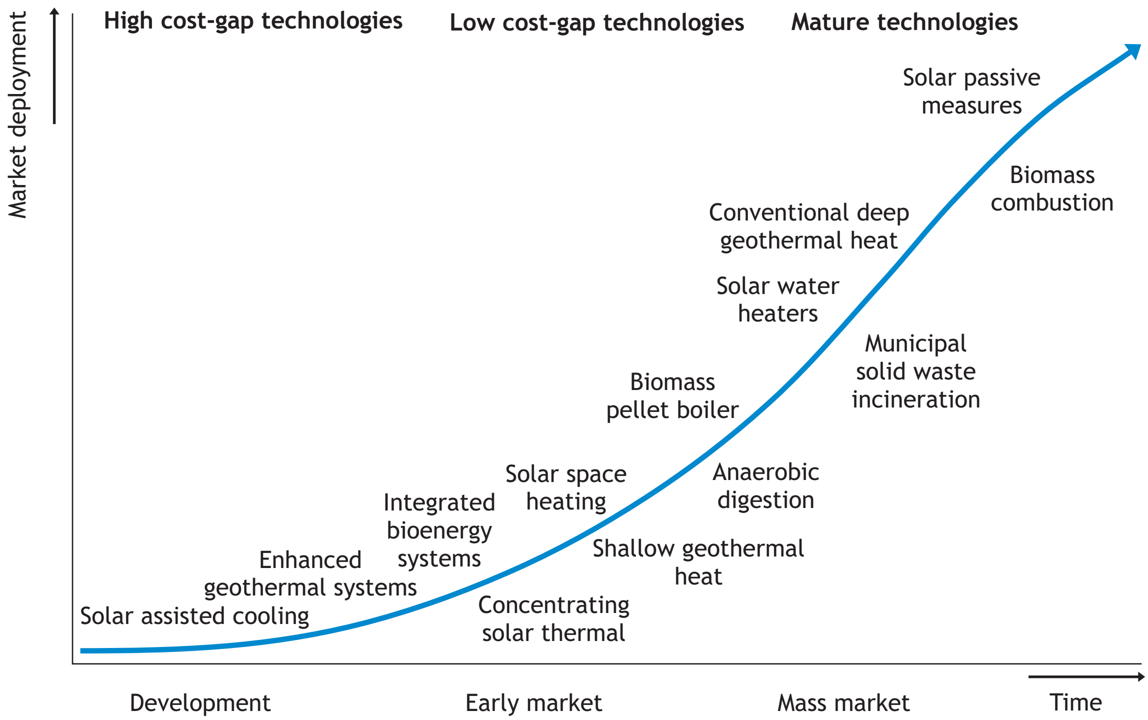
Mass market

Renewable energy technologies that are commercially mature and can compete with conventional technology are referred to as mature (“first-generation”) technologies. Examples include passive solar building design, solar water heaters, biomass combustion and deep geothermal power generation and cascade heat utilisation.

- Passive solar heating and cooling can be considered commercially viable but often considered as demand-reducing technologies. They integrate various building designs and technologies rather than make use of mechanical components, a simple example being the glazing of open verandas on an old house. This option is not discussed in detail in this report but many books and journals are available on energy efficient building designs. Solar water heaters are mature and readily available in many countries, though not in all regions even where solar irradiation levels are high. Often support policies are in place to encourage uptake by building owners, especially if the payback period is longer than 5 years.

- Biomass combustion offers an economic heating option for many applications as well as a disposal mechanism for organic wastes from municipal, agricultural and industrial sources. Demand for biomass (mostly wood) continues to increase especially in developing countries. Improved combustion technologies have alleviated some of the health and environmental problems from pollutants such as micro-diameter particulate matter that affects the respiratory tract. Where any biomass used is replaced by planting new crops or forests, it can be considered to be carbon neutral. This however is not always the case when deforestation results (IEA, 2007b). Landfill gas is often used for direct heat applications can also be injected into natural gas distribution networks.
- Conventional high temperature geothermal resources can be developed only in limited areas of the world including United States, Philippines, Central America, Indonesia, Iceland, Italy, New Zealand, Japan and East Africa. They can be cost competitive when producing electricity or for direct heating applications where or the heat source is at lower temperatures.

Figure 10 • *Indication of the current state of deployment of REHC technologies from development to application in the mass market*



Early market

These technologies have not reached a sufficient level of maturity to compete in the mass market without some form of support mechanism. Typically they entail only relatively low additional government support, perhaps to encourage further RD&D to provide favourable technological and economic conditions, in order for them to reach the mass market. Further improvements of performance can often be made due to different mechanisms that contribute to cost reductions over time (technology learning). Solar active heating, biogas digestion, pellet combustion, and shallow geothermal heat using heat pumps are now entering markets as a result of worldwide RD&D investments together with increased prices for conventional energy sources.

- Solar thermal systems are already widely used in countries such as Cyprus, China, Germany, Austria, Turkey and Israel, primarily for hot water supply, but also for heating swimming pools and residential space heating. Elsewhere, without government incentives, they remain at the early market stage. Unglazed, glazed and evacuated tube water collectors have market shares of 15%, 40% and 45% respectively following recent growth in the latter (SHC, 2007).
- Anaerobic digestion to produce biogas relies on a well-known technology, but due to technical and market barriers, in many countries it still needs some policy support to reach competitiveness (with the exception of sewage treatment plants perhaps). Biomass-fired heat production at the small to medium scale is growing with the advent of convenient pellet stoves. By contrast the long established biomass gasification process (that is more efficient than combustion) is reasonably well understood but few plant manufacturers exist and design improvements continue, especially to reduce tar formation. Improved technologies may still require support to overcome public acceptance and small-scale issues.
- Shallow geothermal (< 300m depths) exploits near-surface heat using heat pumps. These transform low temperature heat from the ground source to a level that can be used for low grade space or water heating. Geothermal heat pumps can also use the ground as a low-temperature heat sink in summer when they are applied for cooling rather than heating. In a few countries with strong government support, they have already reached the mass market.

Under development

Technologies in the R&D and demonstration phase (third generation) have a far larger cost-gap relative to conventional technologies, and therefore need stronger support measures mainly in the form of R D & D investment. Examples include solar active cooling, integrated bioenergy systems, and enhanced geothermal systems (EGS). Thermal energy storage options to allow higher shares of renewable contributions in situations of a de-phased demand and supply that do not closely match over time are also mainly at the development stage. Solar systems are an example for which storage could improve performance where for example the heat is required after sunset or during cloudy periods.

- Concentrating solar power (CSP) is a rapidly developing technology for electricity production, but there are also promising developments for concentrating solar heat (CSH) to supply water at high to medium temperatures for industrial process heat purposes (SolarPaces, 2007). This solar thermal energy can also be used to provide cooling and dehumidification.
- Cooling technologies include single- and double-effect absorption chillers, adsorption chillers, and solid or liquid desiccant systems. Use of an evaporative cooler has resulted in energy savings in California. In more humid climates the energy savings would be less, although these savings could be enhanced using liquid desiccants that can be regenerated with solar thermal energy. Capital costs, however, are a significant impediment to solar air conditioning being several times higher than conventional electric vapour-compression systems as used in most conventional air conditioners. Capital costs per unit could be reduced where a solar thermal collector can be used for both summer cooling and winter heating. Overall solar cooling will require a substantial RD&D effort before it reaches the early market stage.
- The biorefinery concept for biomass feedstocks has potential to meet a large proportion of future energy demand, particularly once dedicated crops can be tailored to meet biorefinery requirements. Current RD&D efforts focus on reducing the costs of producing consistent biomass from dedicated

plantations, mitigating the potential environmental impacts, and creating an integrated bioenergy industry that links biomass resources with the production of a variety of other energy and material products. Flexible generation of power, heat, cold and synthetic natural gas (SNG) is technically possible, but at an early stage of development requiring further R&D investment.

- EGS technology (also called hot dry rock) exploits geothermal resources that are uneconomic using the mature, conventional deep geothermal technology. It is primarily focused on electricity production using low-temperature cycles, but can also be used for the production of heat. These systems are still in the research phase and require additional RD&D to improve existing approaches and to develop new ones, as well as to develop smaller modular units that will allow economies of scale at the manufacturing level.

Heat storage technologies for solar thermal systems could help a system provide up to 50% of the heat demand for domestic heating and hot water by increasing the solar fraction. To provide a greater share of the heat demand from solar thermal energy, even possibly up to 100%, thermal storage systems are required[3]. Excessive solar heat, captured at times when the heat load is low, can be used later during the night, the next cloudy period, or even the next winter. Advanced heat storage technologies can help increase the economic and energetic performance of solar thermal systems, district heating schemes and possibly in some cases, for biomass and geothermal to meet peak demands. Sorption technologies and thermo-chemical storage technologies in principle can be the basis for sufficiently compact systems but are still in the very early stages of development.

Research needs and priorities

RD&D is important for all energy technologies that have not been able to exploit their full market potential. Improved cost effectiveness and ease of use should be the goals in order to produce widespread deployment.

Public RD&D investment by IEA countries for renewable energy was relatively high after the oil price shocks in the 1970s but then decreased by 30% by the early 1990s and has remained around that level since (Figure 11) (though some increase has been observed more recently). Although public research investment in biomass has remained reasonably consistent, solar heating and cooling received around USD 400M in 1979, decreasing to USD 30M by 2002; geothermal received around USD 450M decreasing to USD 58M over the same period. Overall the investment in RD&D for REHC technologies has decreased, in part due to the prioritization of renewable energy power generation and biofuels. If the challenges of growing energy demand, energy security and environmental concerns are to be met, then greater investment in renewable energy RD&D, and in particular in REHC that has recently lagged behind, is needed by both the public and private sector (IEA, 2006c; RD&D 2006; Jurczak, 2006).

RD&D for solar thermal technologies

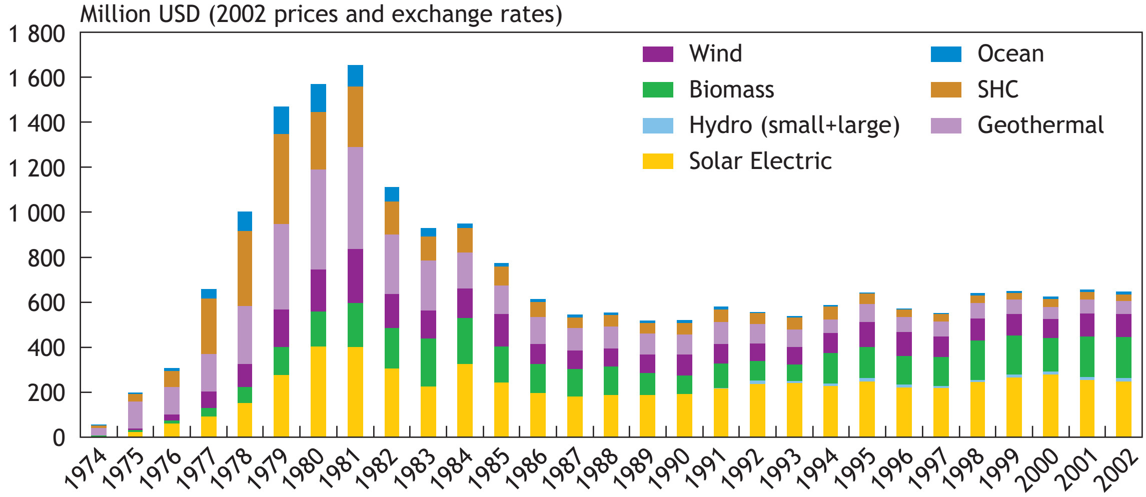
Improved competitiveness is necessary for moving from early markets to mass markets. Solar heating and cooling technologies are already close to full competitiveness with the potential for a quick return on investment. Solar water heating technologies are reliable but their capital costs can make them appear more expensive to the potential purchaser compared to conventional water heating systems. However if costed over a full life cycle, then this is not the case, particularly if future projected electricity or gas charges are taken into account. During the last decade capital cost reductions of around 20% have been

3. Demonstration projects have shown that it is possible to meet 90% of domestic heat demand using solar thermal if large scale seasonal storage technologies are used.

observed for each doubling of installed capacity of solar water heaters. Combi-systems in particular have profited from this cost-reduction and consequently increased their market share. Further RD&D investment can help to drive these costs down further.

The IEA implementing agreement on Solar Heating and Cooling identified four priority fields for RD&D activities.

Figure 11 • *RD&D investment in renewable energy by IEA member countries from 1974 to 2002*



Materials and components

Effective optical coatings on surfaces and anti-reflective, self-cleaning, glazing materials need to be developed. In order to prolong service intervals and lifetime the ability of materials and components to withstand high temperature could be improved. Innovative plastic materials with such characteristics together with better insulation materials could reduce costs and increase efficiency. New flat-plate collectors that can be integrated into building facades and roofs more easily need to be designed. Further market potential is seen in photovoltaic-thermal combined collectors that can deliver warm water as well as generate electricity.

Advanced systems

Mainly small scale water heating applications in single-family houses dominate the solar thermal market. To broaden the market for solar heating systems, the range of uses needs to be enlarged to include hotels, schools, commercial buildings etc. Current solar heating systems often have a back-up system. This means that users can profit directly only from fuel savings compared with a conventional system. Stand-alone systems without back-up could be used in combination with high-efficiency storage applications and well-insulated buildings to improve their competitiveness.

Larger scale systems with capacities of several hundred kW for solar-assisted, district heating schemes, or for industrial applications with capacities in the MW scale, need further development, possibly based on concentrating solar heating (CSH) technologies.

CSH technology is at the early development stage with several promising collector designs close to demonstration but with industrial applications needing to be identified. Collector and component designs need to be optimized for medium temperature use and to meet the requirements of industrial applications. Testing procedures for the durability of the materials and components also need to be developed (SolarPaces, 2007).

Building design integration

Architectural design plays a major role for a broader market penetration of solar heating and cooling options. The components need to become standardised elements of modern buildings rather than retrofitted. In well-insulated energy efficient houses, less energy is consumed and the length of heating period changes. This means that the heat loads can shift to the season when solar gains are minimal – especially in high latitude countries. Passive solar building designs vary widely but some basic principles exist and REHC can be integrated, particularly for water heating. Poor building design could change the behaviour of the inhabitants due to such issues as glare.

Standards, regulations and test procedures

Some solar heating installations have not shown the performance promised by the manufacturer (Philibert, 2006). New standards, regulations and testing procedures, coupled with appropriate labelling, could aid accelerated market uptake by building up consumer trust in the manufactured products. This is especially important for new solar technologies such as evacuated tubes and combi-systems where many manufacturers are entering the market so that discerning a quality product is difficult for the consumer. Standard testing procedures on such details as hail resistance of the solar collector panel could also enhance international trade of the technologies.

RD&D for biomass and bioenergy technologies

Production of biomass feedstocks needs to be balanced against food and fibre production and biodiversity concerns. Bioenergy heat and power generation and co-firing with coal or gas are advanced and competitive, normally using crop and forest residues and organic wastes. Research on innovative ways of providing a sustainable and stable feedstock base is essential to enable a substantial market penetration of biomass for heating purposes, (and also for other competing biomass uses). Short-term research priorities could support the development of biomass production and certification so that sustainably produced biomass can be traded locally, nationally and internationally. Furthermore, minimum standards and norms relating to biomass fuel quality should be developed in order to guarantee an efficient conversion processes. Currently 34 different standards for transport biofuels are under development (Maniatis, 2006) but for heat a more simple process could be feasible.

Biomass combustion is a fully mature technology competitive with other forms of heat production depending on specific circumstances of feedstock costs and availability. RD&D inputs could target reducing air pollutants in both small and large scale heat plants. Current EU legislation attempts to limit particulate matter concentrations as does the US Clean Air Act. However emissions to the air are also a problem in less developed parts of the world where inefficient biomass use and older Bioenergy plants dominate the residential and industrial sectors.

Poly-generation in bio-refineries to simultaneously produce heat, power, transport fuels and chemicals needs considerable RD&D in order to extend existing uses and to minimize conversion losses.

RD&D for geothermal technologies

Large scale applications have been in use for electricity production and direct heat for more than 45 years, demonstrating long-term sustainable potential. However although deep geothermal is mature, research efforts are still needed to reduce operational costs, devise strategies to avoid or mitigate adverse environmental effects, better understand reinjection and resource use, improve efficiency of energy extraction, develop more efficient binary and organic Rankine cycles, and improve sustainable utilization strategies.

Further RD&D efforts could make the use of geothermal more attractive in more regions located away from tectonic plate boundaries. During the last 20 years capital costs /MW installed of geothermal projects have decreased by about 50% as the easier problems have been resolved. As a result of RD&D investment, refinements in exploration techniques continue to improve the success rate of drilling, and reduce development risk and costs. Refinements in treatment processes of waste waters and gases continue to provide cost-effective options that are environmentally preferable. For example full re-injection of waste fluids is becoming more widespread, and even an obligation in some countries.

General RD&D priorities for geothermal include life-cycle analysis of direct heat use systems, sustainable production from geothermal resources and the use of shallow geothermal resources for small-scale individual users. More specific research tasks are the development of better exploration, resource confirmation and management tools, the development of deep (> 3000 m) geothermal resources and co-generation of heat and power. Costs for geothermal well drilling, logging and completion also need to be reduced. Also relevant is research on local geothermal resources used for space and district heating as well as multi-purpose heat "cascading".

Methodologies and tools to better determine a geothermal resource without drilling and to better assess its financial viability need to be developed. Expertise in geothermal exploration and equipment installation is lacking in many countries and capacity building is required. This can be achieved in part through co-operation, exchange of information and joint workshops with experienced countries such as Italy, Iceland and New Zealand.

RD&D for cooling

Solar assisted cooling (SAC) was developed in the 1980s but only a relatively few systems are running today, mostly from demonstration projects. SAC is therefore still mainly in the development stage and few policies are yet in place to encourage deployment (Section 4). Additional RD&D efforts are necessary to design small-scale applications that can replace conventional air-conditioning appliances. Synergies could lie in combining solar heating and cooling systems that provide space and water heating and energy for solar cooling at the same time.

Cooling loads will probably increase in the summer due to increased comfort demands from air conditioning, more glazed buildings and climate change. This can result in peak power demands creating stress on a given electricity generation and distribution system. Therefore alternative cooling applications deserve more RD&D investment. SAC seems to be especially promising because high solar irradiation levels often correlate with high cooling loads and peak load shaving is possible (EREC, 2007).

Other renewable systems can contribute too since the fundamental cooling appliance designs are similar regardless of the heat source being used to drive them. This opens up synergetic potential that could be tapped through increased RD&D efforts. The cost and efficiency of GHPs used for cooling in summer by taking some heat from the air and storing it in the ground for use in winter can be further improved. Cooling can also contribute to an increase in the profitability of district heating systems and increase their capacity factor.

District cooling systems based on utilizing renewable energy resources are under development and could contribute to the future increased uptake of the use of REHC (Ecoheatcool, 2006).

RD&D for storage technologies

Thermal energy storage is important for heating and cooling especially for solar thermal due to its variable characteristics but also for bioenergy. Solar thermal applications would gain from improved storage possibilities both in the medium and longer term. Therefore heat storage is considered the key technology for the future success of REHC (Rantil, 2006). Currently obtaining materials and components that allow a three times smaller storage volume than water for the same amount of heat stored would be a rewarding research goal. Possible applications are ice storage and heat storage in aquifers. New technologies need to be developed not only for seasonal, but also for short term storage, especially for solar heating and cooling which is characterized by more variable production patterns than biomass or geothermal options.

In summary

- At the energy system level, considerable synergies exist between energy saving, renewable energy technologies and efficient heat and cold generation. Uptake of energy efficiency opportunities are crucial to maximise the share of REHC demands.
- A wide range of heating technologies are available at large and small scales ranging from district heating schemes to geothermal heat pumps.
- Several solar thermal, biomass and geothermal technologies are cost-competitive and available on the market with others at various stages of early development.
- Many technologies have good potential to replace conventional fossil fuels used for heating.
- Industrial process heat applications offer important potentials in global heat markets because industrial energy is a significant part of total energy use.
- Renewable cooling is less mature than renewable heating – perhaps with the exception of passive solar cooling. Shallow geothermal cooling is gaining increased application. Active solar cooling technologies are proven, but still in the development stage. Heat from deep geothermal resources or biomass can seldom be practically used for cooling purposes, although similar cooling technologies can be applied.
- REHC technologies bring environmental and social benefits from energy supply security, climate change mitigation and improved health. Detailed cost-benefit analyses would be useful with such co-benefits further quantified.
- Increased RD&D investment in REHC technologies has good potential for cost reductions to increase competitiveness against fossil fuel technologies.
- Over recent decades in spite of considerable technological and economic progress, some markets remain relatively small and widely diversified. The primary aim should be to move more REHC technologies from early markets into mass markets.
- District heating and cooling systems can contribute to increased uptake of the use of REHC.

3. Markets: current status and outlook to 2030

The share of heat across all sectors is estimated to be between 40-50% of total final energy demand (Philibert, 2006). This includes cooking and high-temperature process heat for industry. Most of this heat currently comes from fossil fuels, which indicates that there could be a significant market potential for displacement by REHC technologies. Of the total energy consumption used in buildings and for appliances, around 55% is used for space heating and a further 20% for water heating (IEA, 2006b). In 2004, 35% of total global final energy consumption occurred in commercial, public and residential buildings which was more than in the industry (32%) and transport (26%) sectors (IEA, 2006b).

The data availability for REHC markets is generally limited due to decentralized heat generation facilities and the associated problems of measurement. Taking bioenergy as an example, due to the wide dispersion of large and small scale burners and boilers, it is not easy to ascertain the total installed heat capacity, even though the name-plates on the appliances usually provide such information. Even more difficult is assessing for how long each boiler is actually operational when providing useful heat and whether it is working at full capacity or not. Whether a burner or boiler is operated for 10, 100, or 8 000 hours a year can only be found from a detailed survey of users since, unlike electricity or transport fuels, metering of the heat output rarely occurs. Except in the case of district heating, there is little commercial trade in heat. For heat from solar and geothermal sources, the IEA Solar Heating and Cooling (SHC) and Geothermal implementing agreements have collected data based on an assessment of installed capacity for several IEA and non-IEA countries. What data there is available for commercially distributed biomass heat is included in IEA statistics but it is far from complete.

Current market status

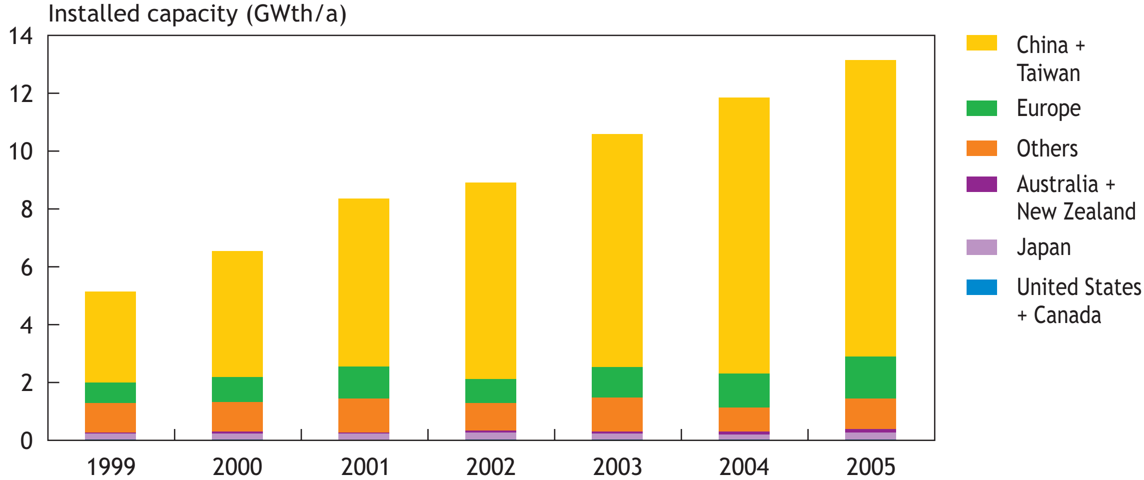
Solar thermal

Solar drying of crops and timber is common worldwide, either by using natural processes or by concentrating the heat in specially designed storage buildings. No attempt has been made to assess the market for these technologies in this report since data is not available. Similarly passive solar space heating has been excluded, leaving emphasis on solar water heating.

For water heating, the annual incremental growth in global installed capacity of solar thermal systems has increased significantly each year from 1999 till 2005 (Figure 12) to reach close to 90 GW_{th} total installed capacity in 2005 (Figure 13; REN21 2006). Accounting for retirements, over 15 GW_{th} of new capacity was added in 2006 increasing total installation capacity by 16 % to 102 GW_{th} excluding unglazed solar swimming pool heaters (REN 21, 2007). When these are included, total capacity reached 110 GW_{th} in 2005 providing around 200 PJ of heat (SHC, 2007). China had the greatest increase in solar hot water capacity in 2005 with Europe increasing by more than 1.8 GW_{th} and India and several other countries also experiencing accelerated growth.

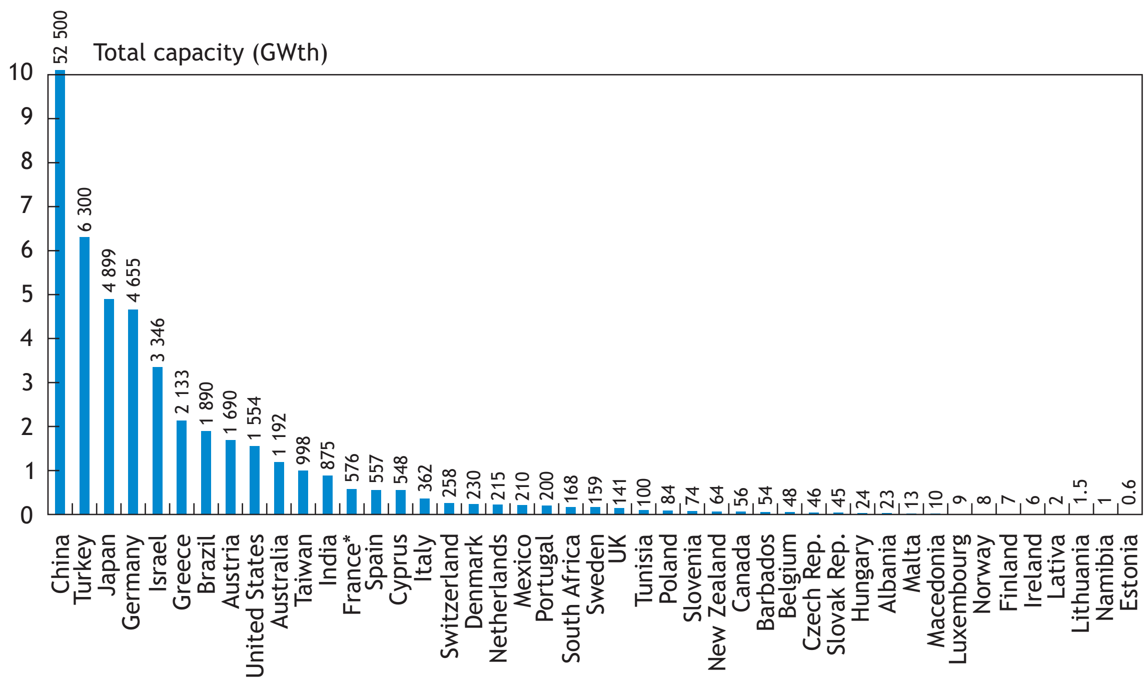
For solar thermal water heating, regional capacity growth varies each year. China has experienced fairly consistent growth and has by far the largest market, with around 60% of total global capacity installed (Figure 13) (Philibert, 2006; REN21, 2006). In Turkey solar thermal collectors to provide domestic hot water are popular mainly because they are the cheapest option due to relatively high commercial energy prices for conventional heating sources and high solar insolation inputs.

Figure 12 • *Annual incremental capacity of plate and evacuated tube solar collectors installed by region 1999-2005* [4]



Source: SHC, 2007.

Figure 13 • *Total capacity of glazed flat plate and evacuated tube water collectors in December 2005*

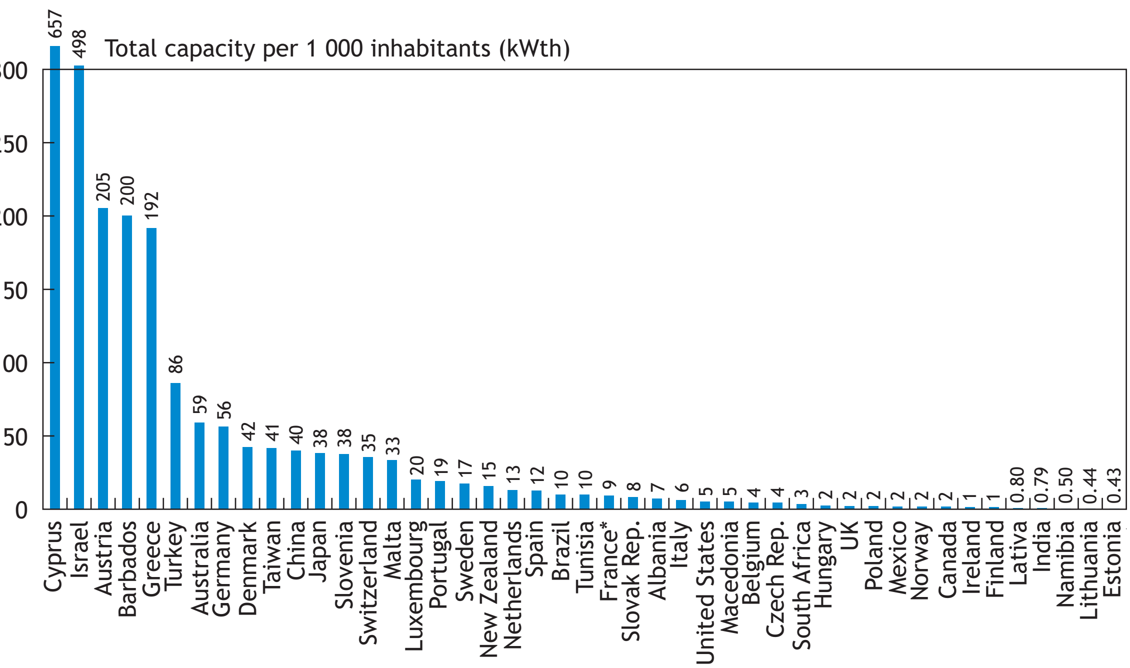


Source: SHC, 2007.
Note: China's capacity is not shown in full on the chart due to scaling factors.

4. Data for Australia, Barbados, Brazil, Cyprus, India, Ireland, Israel, Macedonia, Taiwan and South Africa were not available for 1999. Data for Estonia, Hungary, Malta, Slovenia, Sweden and Poland have only been available since 2002; Latvia, Lithuania, Luxemburg, Czech Republic and Slovak Republic data since 2003.
"Europe" is EU 27 plus Switzerland, Norway, Albania, Macedonia, oversea departments of France.
"Others" are Barbados, Brazil, India, Israel, Mexico, Namibia, South Africa, Tunisia, Turkey.

When market development is expressed on a per capita basis, the rankings change drastically with small, hot countries such as Cyprus and Israel becoming the leaders (Figure 14). This is mainly due to their good solar resource conditions and high competing conventional energy prices but also due to successful policies. The relatively high rankings of higher latitude Austria, Germany and Denmark confirm that solar resource availability might not always be the most important factor if strong supporting policies to encourage deployment are in place. To illustrate the importance of supporting policies, it can be noted that the comparatively small country of Israel at around 30 degrees latitude has more solar thermal capacity installed than Brazil, with a much larger population and located at lower latitudes just south of the equator.

Figure 14 • *Total installed capacity of glazed flat plate and evacuated tube water collectors in December 2005 per 1 000 inhabitants*



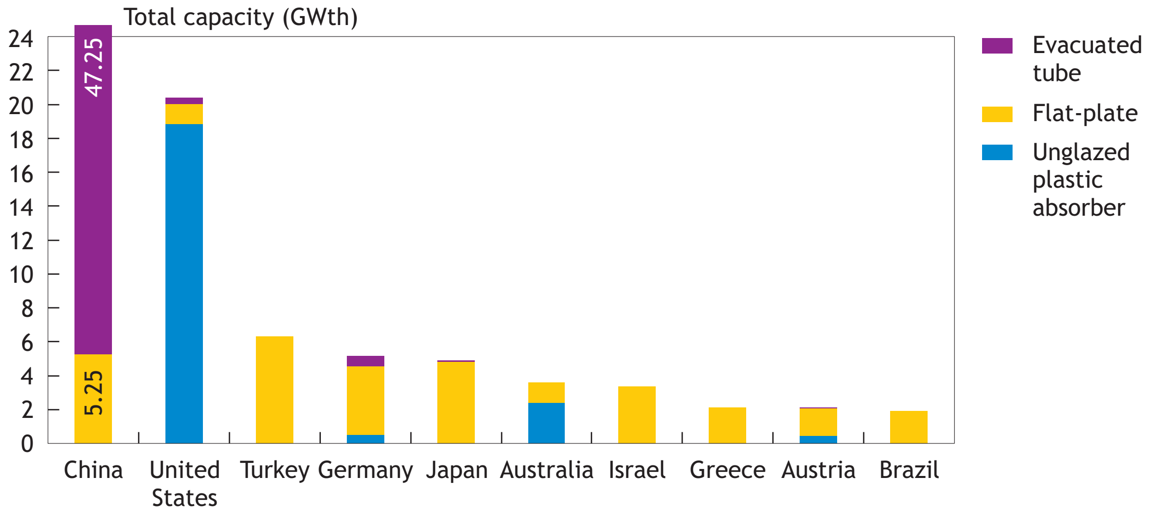
Source: SHC, 2007.
Note: Cyprus and Israel data is not shown in full on the graph due to scaling factors.

In the US, unglazed plastic flat plate collectors for swimming pool heating dominate the scene whereas the installed capacities in China are mainly for evacuated tubes whereas in Turkey, Germany, Japan, Israel etc. mainly glazed flat plate collectors are installed (Figure 15). Growth in annual installed capacity of glazed flat plate and evacuated tubes has occurred in most regions (Figure 16).

Solar thermal hot water systems are generally more competitive in sunny regions but this picture changes for space heating due to its usually higher overall heating load. In colder regions capital costs can be spread over a longer heating season and solar thermal can then become more competitive (IEA, 2006c).

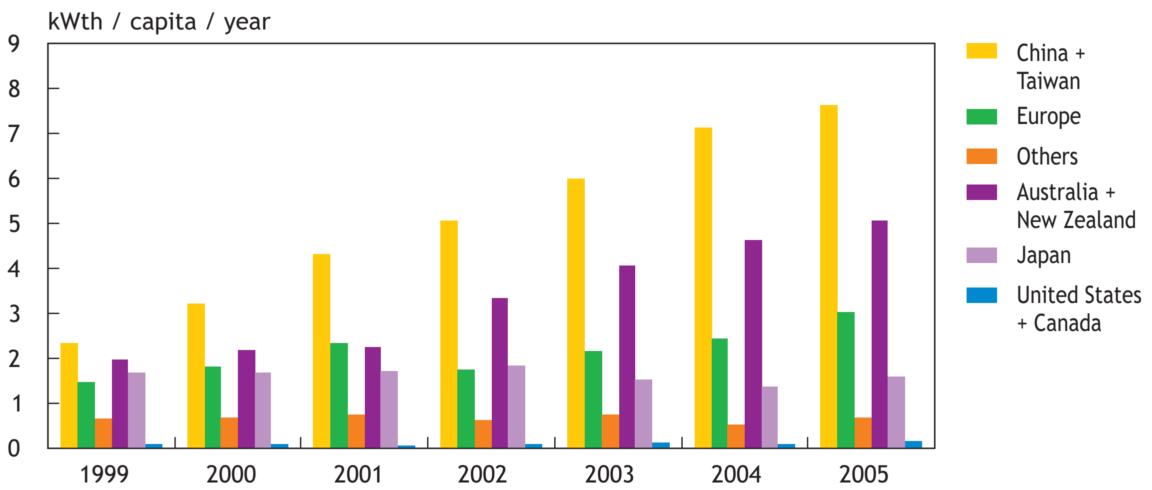
There are only a few concentrating solar heat applications in operation at present so they are not included in the data presented here.

Figure 15 • *Total installed capacity of water collectors and market shares by type for the 10 leading countries at the end of 2005*



Source: SHC, 2007.
Note China's 52.5 GW capacity is not shown in full on the chart.

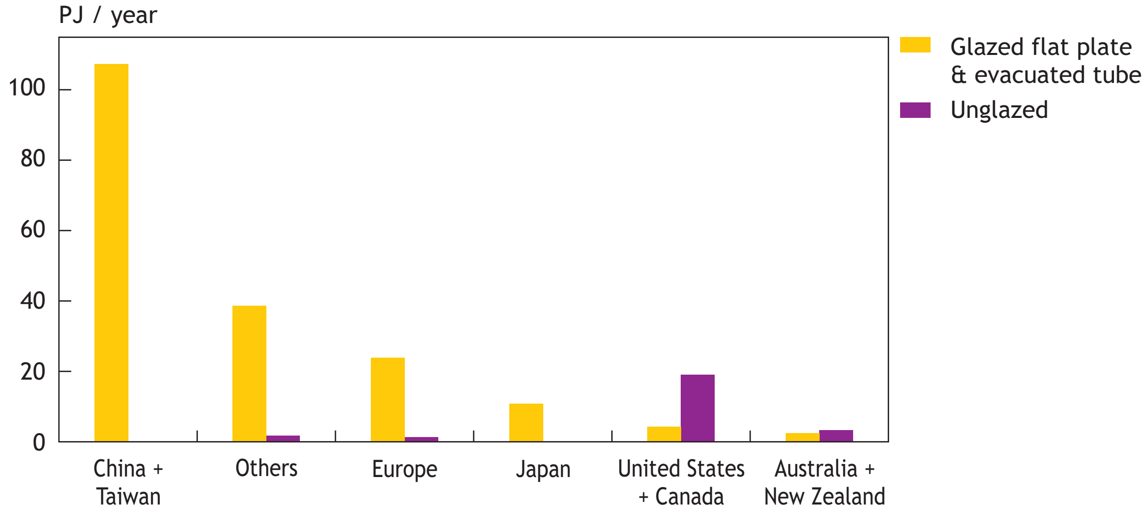
Figure 16 • *Annual installed capacity of flat plate and evacuated tube collectors in kW_{th} per 1 000 inhabitants[5].(SHC, 2007)*



The calculated yield of total heat energy generated by solar collectors is closely linked with the installed capacity (even allowing for variations in annual output of a given collector design with latitude). China is the current leader for solar energy collected utilising around 115 PJ/year with the US next approaching 25 PJ/year, but mainly from unglazed systems (Figure 17).

5. Here "Europe" is EU 27 plus Switzerland, Norway, Albania, Macedonia, oversea departments of France. "Others" are Barbados, Brazil, India, Israel, Mexico, Namibia, South Africa, Tunisia, Turkey.

Figure 17 • *Annual collector yield of heat from glazed flat plate and evacuated tube collectors and from unglazed systems in operation at the end of 2005 by economic region.*[2]



Solar cooling

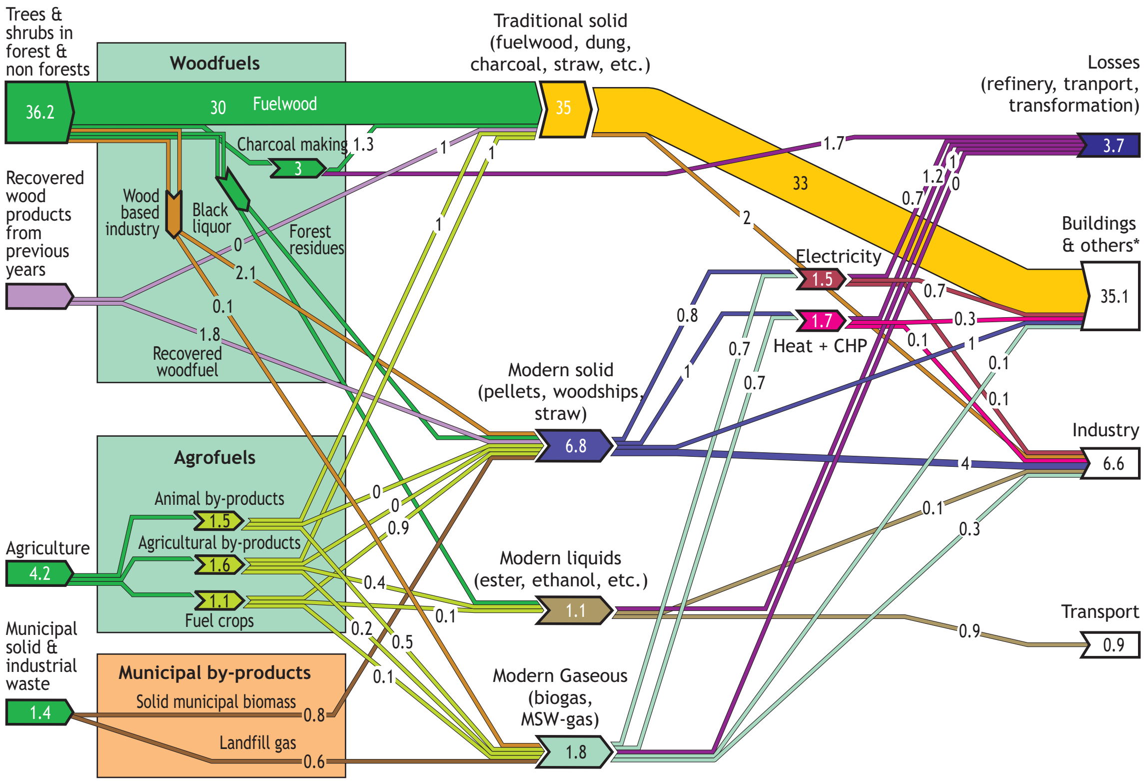
Data on solar-assisted cooling systems (SAC) are hard to find but the total capacity is likely to be very small. Currently Europe has at least 40 systems in service for air conditioning of buildings (25 of them in Germany) with a combined collector area of approximately 17 000 m^2 and total capacity of 4.4 MW_{th}. (REN21, 2007). Other assessments claim around 120-150 systems are operational in Europe with capacity over 12 MW_{th} and collector area 36 000 m^2 giving 3 m^2/kW of cooling capacity mainly used in buildings but some by industry such as for wine cooling (Piria, 2007; Henning, 2007). Other regions are also showing a growing interest in the promising application of SAC that is also attracting increasing interest from private customers, hotel owners and industry (Sarasin Bank, 2005). Significant market growth is expected once the costs are further reduced as a result of continued RD &D investment.

Biomass

The variety of biomass resources are widely distributed so much of the data on heat applications is very uncertain. Estimates of solid biomass used for the production of heat (excluding traditional biomass) range from 5 to 10 times the amount of the total heat produced from both solar and geothermal sources (REN 21, 2006). Total biomass resources used for heat, including liquid and gaseous forms, may reach far higher levels (Figure 18) (IPCC, 2007). This useful indication of biomass resource flows and bioenergy outputs shows around 35 EJ/yr of traditional biomass resources are consumed annually and a further 9.7 EJ/yr is used for "modern" bioenergy applications (IPCC, 2007). Of this around 3 EJ is thought to be used in the building and industry sectors for heat production, including the heat component from combined heat and power (CHP) and that used for the drying of agricultural and forest products.

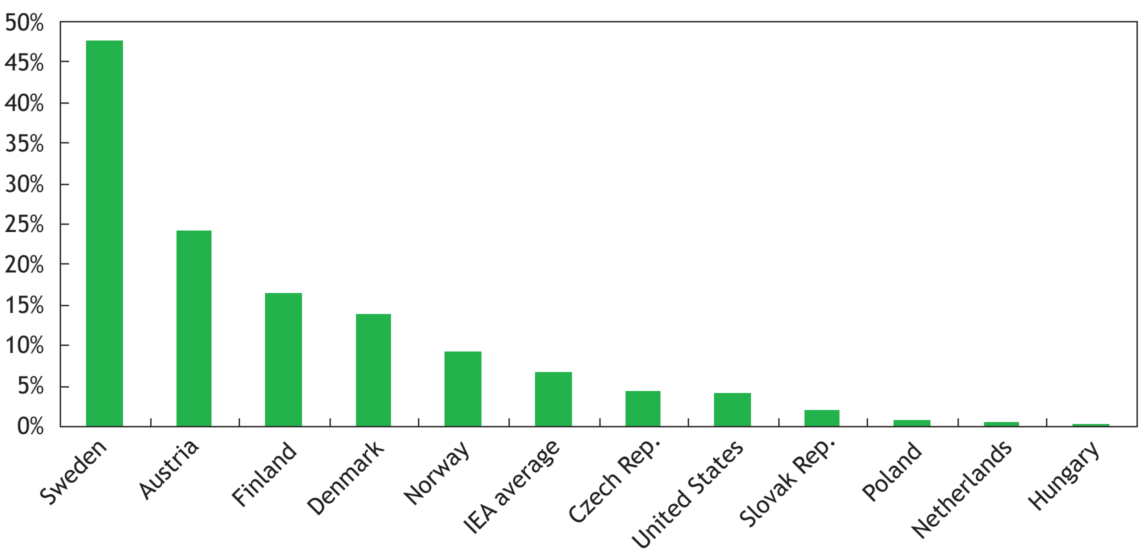
Biomass heating is mainly used in countries with a good resource availability and particularly where district heating systems are already utilised, mainly in Sweden, Austria, Finland, Denmark and Norway (Figure 19). Biomass used in individual buildings for water heating and space heating is not included in these figures since the data is difficult to obtain and typically not covered in national statistics. It is therefore very difficult to estimate the total value of biomass used for heating with more accuracy than is given above.

Figure 18 • *World biomass energy flows (EJ/yr) in 2004 and their thermo-chemical and biochemical conversion routes to produce heat, electricity and biofuels for use by the major sectors*



Source: IPCC, 2007.

Figure 19 • *Solid biomass share in large scale heat production of leading countries*



Source: IEA, 2007a.

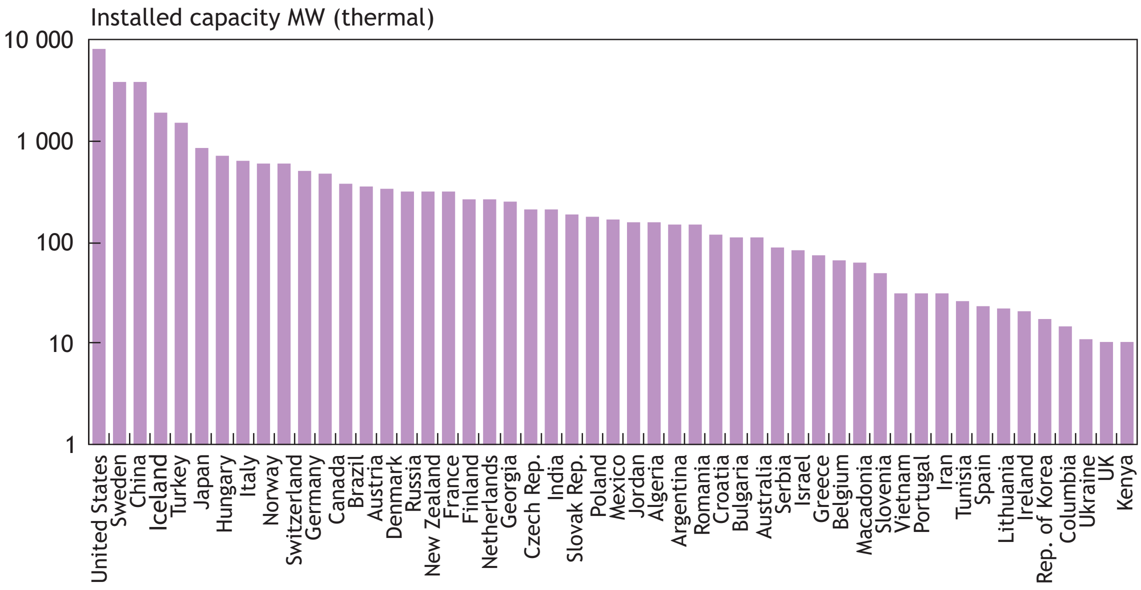
Geothermal

In Turkey, New Zealand, Iceland, France and elsewhere that deep geothermal resources are available, the heat, other than for electricity generation, is used mainly for large scale applications such as pulp and paper plants and district heating schemes. Elsewhere, where only shallow sources are available, as for example in Sweden, Switzerland, Germany, Denmark and Norway, there is a growing trend towards the use of small scale GHPs. The US has considerable deep geothermal resources but also a high capacity of GHPs installed.

In 2005, geothermal energy was used to generate 56.8 GWh of electricity with an installed capacity of 8.9 GW_e in 24 countries worldwide. However, three times as many countries (72) reported direct use of geothermal energy for heat applications, with a total installed capacity of over 28 GW_{th} (Figure 20). These installations produced over 273 PJ/y of useful thermal energy (Figure 21) (Lund *et al.*, 2005). The installed heat capacity grew by almost a factor of 2 between 2000 and 2005, with energy use increasing by 43%. Around 70% of the source of heat was from shallow geothermal systems with the remainder derived from deep geothermal sources.

World leaders in geothermal direct heat use in 2005 were China, Sweden, US, Turkey, Iceland and Japan, with utilization ranging from 45 PJ/y (China) to 10 PJ/y (Japan) with corresponding installed capacities of 3.7 GW_{th} to 0.8 GW_{th} respectively. Though the world geothermal installed heat capacity (28GW_{th}) is around one third that of the total installed solar thermal capacity, the heat energy yields are similar due to the typically higher load factors. Each MW of solar thermal capacity provides around 0.5-0.7 GWh/y of heat depending on location whereas each MW of geothermal capacity produces about 2.5 GWh/y, giving a load factor over 4 times higher.

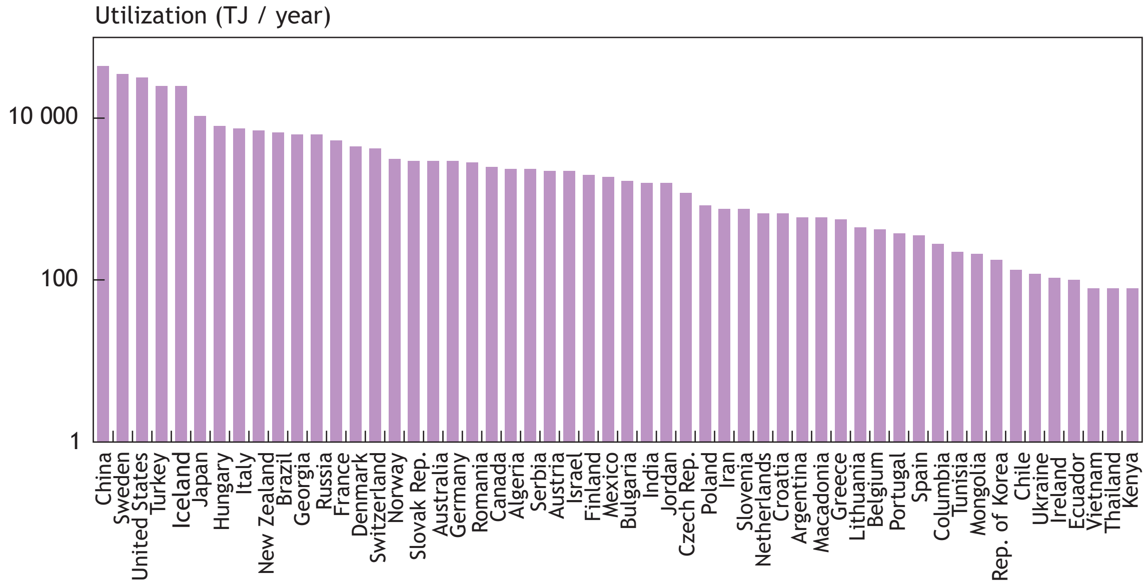
Figure 20 • *Installed geothermal heat capacity by country*



Source: GIA, 2006.

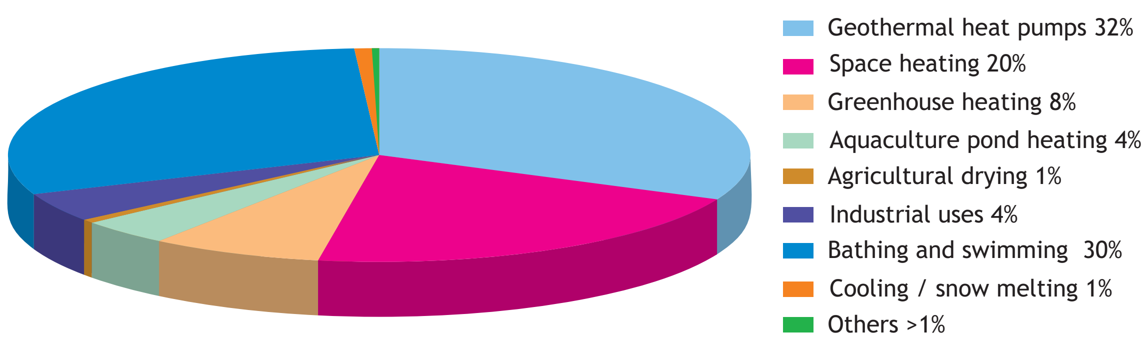
Direct applications of geothermal energy are diverse with around 32% of the energy (88 PJ) provided by heat pumps for space heating, 30% (83 PJ) used for bathing and swimming and 20% (55 PJ) for direct space heating (Figure 22). This total of 226 PJ/yr (GIA, 2006) does not tally closely with the 273 PJ/yr quoted above (Lund *et al.*, 2005), since several types of heating applications were excluded but also exemplifying the difficulty of obtaining accurate heat data.

Figure 21 • *Annual utilization of geothermal heat by country*



Source: Lund et al., 2005.

Figure 22 • *Uses of geothermal energy for heating purposes*



Source: GIA, 2006.

Geothermal heat pumps were used in 33 countries in 2005 having risen from 26 countries in 2000 with a 3 fold increase in installed capacity (Lund *et al.*, 2005) (Figure 23). The corresponding heat utilization increase was estimated to be almost 4 fold. Geothermal heat pumps have been taken up quickly in some markets (*e.g.* Sweden, US, Denmark, Norway, Switzerland, Canada) and very slowly or not at all in others even where good resources are evident (*e.g.* Turkey, New Zealand) (Rybach, 2006) (Figure 24).

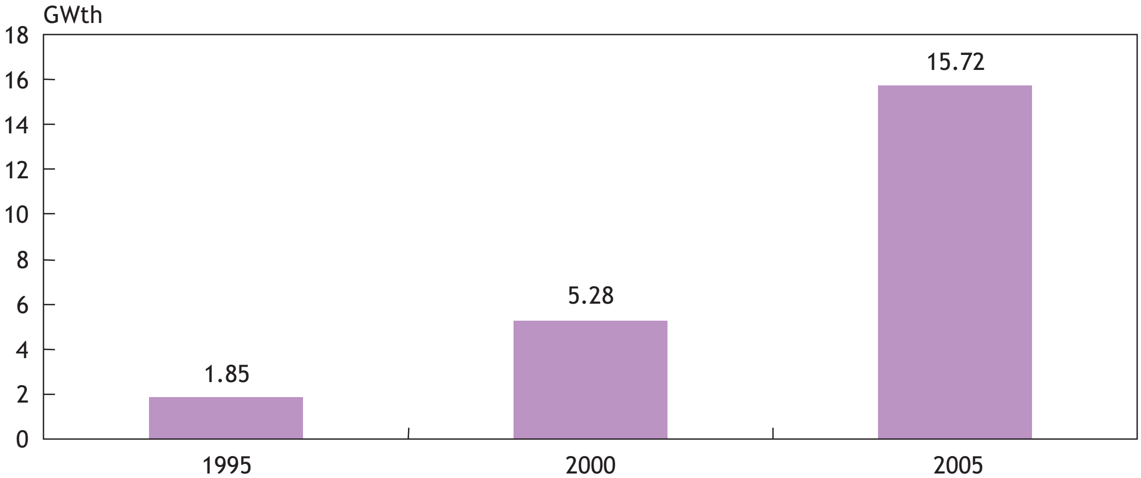
Challenges and barriers

Information and dissemination

Lack of awareness is a general problem for the greater uptake of REHC technologies. It is why they are often not taken into account in municipal planning or in private building investments (IEA, 2007b). Appropriate labelling of REHC appliances could help to overcome this information barrier (Maniatis, 2006).

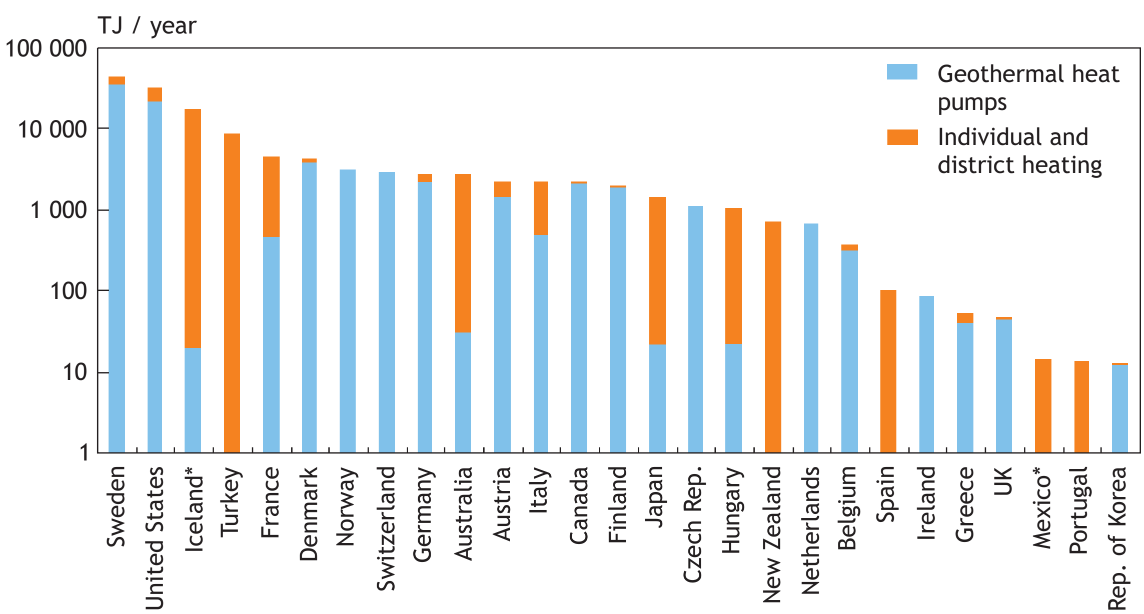
Commerce, service and industry sectors are increasingly showing greater awareness of REHC options but their financial performance requirements for a comparative investment are often high. Technologies that are not yet competitive are seldom applied unless some form of government support exists.

Figure 23 • *Worldwide annual incremental growth of shallow geothermal capacity coming mainly from geothermal heat pumps*



Source: Rybach, 2005; Lund et al, 2005.

Figure 24 • *Geothermal heat use in IEA countries for heat pumps and direct space heating applications*



Note: data from Lund et al., 2005.

Capacity building

Training, especially of engineers and installers, is important for the deployment of REHC technologies. Lack of knowledge and competence of professionals working in energy service companies or as heating installers, architects, building developers or city planners is a barrier to diffusion. To have enough competent installers located close to customers is also crucial to provide on-going repairs and maintenance services of the installed systems.

One of the circumstances hindering REHC by the manufacturing industry is that in many cases production has not yet reached sufficiently high volume to gain economies of scale. Often, manufacture is not fully automated and enterprises remains small and local. The lack of standardisation at the regional or global level (for example from regulations, labelling, normalisation, testing requirements, certification procedures) results in companies having difficulties penetrating markets abroad. Most suppliers therefore remain as small and medium sized enterprises (SMEs) which limits the future growth of their capacity.

Behaviour

Path dependency

In some countries REHC is already widespread. This can be partially explained by existing path dependencies such as woody biomass used for district heating in Sweden. In countries where there is no history of district heating, then it would be more difficult to introduce a biomass district heating system because the paradigm shift from distributed heating systems would be unattractive for the current owners of conventional appliances. A shift could be even more difficult when there are no successful examples that planners can refer to; hence the value of demonstration plants even though their capital costs may be high.

Path dependency for solar thermal in countries such as Cyprus, Israel and Greece resulted from strong public support gained over the past decades through different policy instruments including awareness raising (Cyprus), regulation (Israel) and financial (Greece) (Piria, 2007). The resulting critical mass market resulted from trained installers, wide awareness by potential users, and marketing structures on the supply side. This resulted in self-sustaining markets that no longer need strong policy incentives.

Split incentives

In rental properties there is little incentive for the landlord to invest in efficient REHC technologies that would reduce on-going heating and cooling bills because these are carried by the lessee. Conversely, the lessee has little possibility to benefit from any incentives to invest in fixed equipment for a rental property because there is a risk of moving out before the end of the payback period.

Cost structure

REHC technologies may become more cost-efficient in the longer term but a current barrier can be the relatively high up-front costs of the installation. If the simple payback method is used to estimate the attractiveness of a REHC technology investment, it could seem less valuable than if the net-present-value method is used that takes into account any value created after the payback time.

Measurability

Sound statistics on renewable energies are important in order to ascertain energy balances at the country level, being the essential basis for market analysis, successful policy-making and evaluation. Heat production is not usually metered, but can be crudely assessed on the basis of total capacity of the number of installed systems and an estimate of heat outputs. The availability and quality of even these crude basic statistics varies from country to country but few offer reliable information on how the significant part of primary energy used for heating is consumed. Data on heat production per system using the relevant conversion efficiencies is lacking. Bearing in mind the significant potential of REHC technologies in total primary energy use, adapting the way statistics are produced to obtain an improved data basis that allows thorough policy evaluation would be useful.

Renewable energy carriers that flow through commercial energy distribution systems can be measured and monitored. However where there is a multitude of individual installations for domestic and small industry players, heat production and consumption measurements are challenging due to the relatively high cost of metering. A data collection framework for the monitoring and reporting of the renewable energy heat and cold markets is therefore needed, though an obligation to install costly measuring equipment or procedures should not become a barrier to uptake. The IEA is currently attempting to better quantify the heating and cooling data streams by bringing additional market expertise to help develop a better estimation for the reporting of non-measured production and consumption (Francoeur, 2007).

Evaluation of the total amount of REHC in IEA countries is difficult due to the following reasons (as outlined in EU-project Therra).

1. The statistical data on heat options, especially from traditional biomass use, are poor.
2. The values used for conversion efficiencies vary by country; some use the average values found in the field from surveys, others the best values realised in the laboratory.
3. The methodology to determine the biodegradable share of MSW is not yet well defined and varies widely.
4. The use of ambient heat through heat pumps is not included in IEA data although a method to include it is under development.
5. Data on cooling in general and renewable energy cooling in particular (including district cooling, both free cooling and absorption) is not available.

More sophisticated and cost-effective metering instruments are needed for a national analysis of REHC measures (Furfari, 2006). The greater use of metering could also help convince consumers of the benefits that the REHC applications might have. Currently there are no low-cost methods to measure flows of heat or cold, which makes it difficult for consumers to evaluate the benefits obtained from an existing REHC application or to calculate the benefits when considering different investment options.

Cost and competitiveness

In order to illustrate "cost gaps" (Section 2), an overview of the costs involved to provide REHC services was undertaken. A similar methodology to estimate the costs of the energy delivered was applied for all technologies.

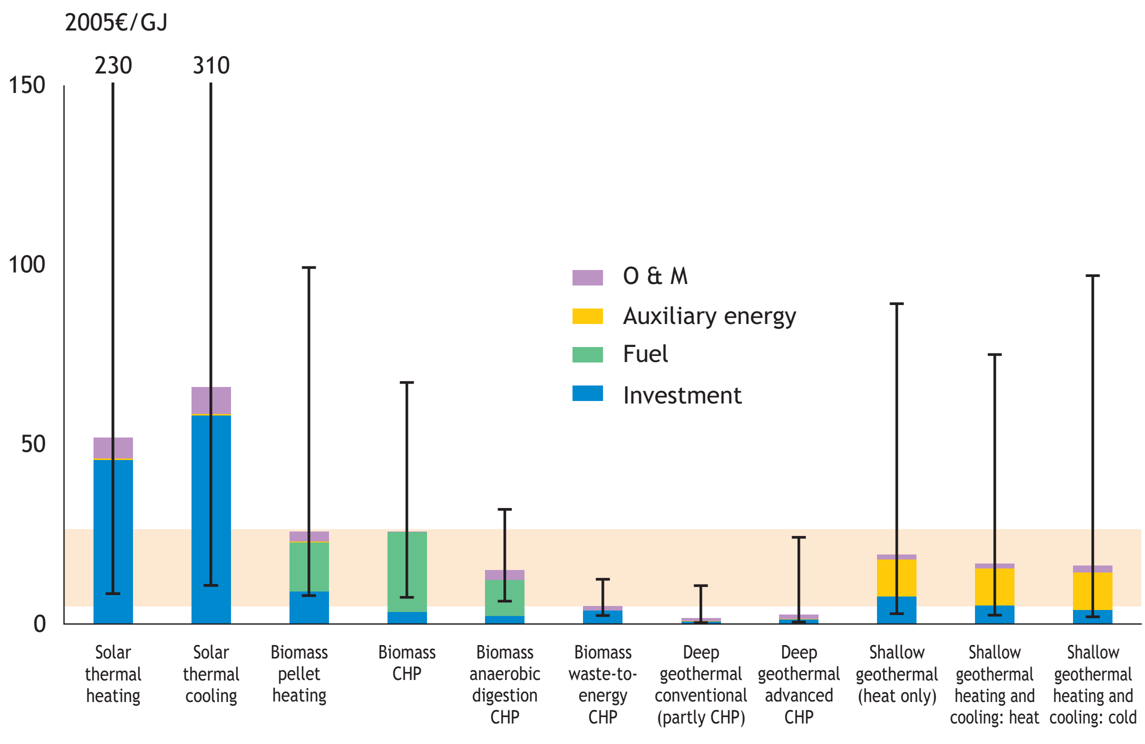
To compare the costs of providing REHC energy services systems with similar services provided by conventional fuels (Table 5) appropriate conversion efficiencies were used, varying for large scale industrial and small scale domestic applications (Table 6; Ecoheatcool, 2006). Full economic analyses using capital investment costs and appropriate discount and depreciation rates were then undertaken for a range of REHC options. The resulting 2005 cost data were then compared with the range of costs for supplying heat from conventional heating systems (Figure 25). All input data, assumed interest rates, intermediate results and outcomes are presented in Annex A.

Table 6 • *Typical fuel prices for delivered energy from fuel oil, gas and electricity used for heating by industry and residential building sectors allowing for losses through conversion efficiencies but excluding investment and depreciation costs*

	Conversion efficiencies of energy carrier to heat		Comparative prices for delivered heat energy €/GJ	
	Industry	Buildings	Industry	Buildings
Natural gas	90%	85%	3.4	7.9
Electricity	100%	100%	13.7	22.2
Fuel oil	85%	78%	6.3	10.4

Source: Prices from IEA, 2006g. Conversion factors from Ecoheatcool, 2006.

Figure 25 • *Cost breakdowns and ranges (excluding VAT) in 2005 for a selection of REHC systems compared with the reference energy price range (shaded bar) for gas, fuel oil and electricity heat energy carriers for the domestic (top of range bar) and industrial (bottom) sectors*



Notes: The conventional energy carrier costs are only based on fuel costs and conversion losses because investment and depreciation costs of appliances per GJ of heat are relatively small. Neither reference system nor avoided costs due to fuel savings are incorporated. Installation costs are included but heat distribution costs and costs allocated to electricity generation for CHP technologies are not. Details on cost assumptions are given in Annex A.

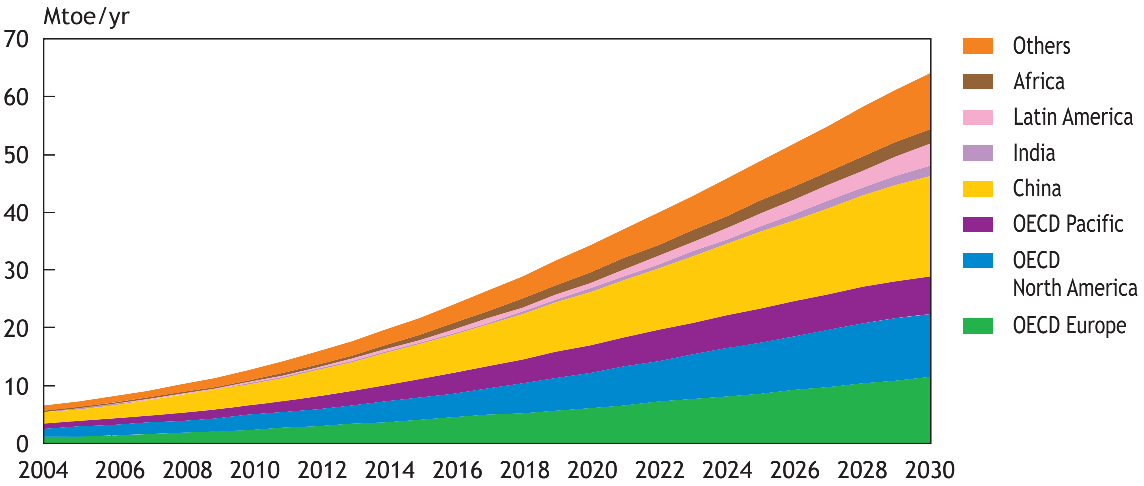
Biomass and deep geothermal technologies are the most cost competitive for heating applications. Solar water heating costs can be competitive under certain conditions (as shown by the range bar). Shallow geothermal technologies applied for both heating in winter and cooling in summer can be cost-competitive when evaluated on a life-cycle cost basis, whereas solar assisted cooling has the greatest cost gap.

Projections to 2030

Policies for the support of renewable energy to abate GHG emissions and increase security of supply are currently being developed in many countries. The Alternative Policy scenario (APS) of the IEA 2006 World Energy Outlook included projections for renewable energy technologies (IEA, 2006f). It assumed all the policies currently under consideration will have been implemented by 2030. The use of heat from renewables in the industry and building sectors was assumed to increase 20% by 2030 relative to 2003. More ambitious policies to be developed in future could boost the share of REHC technologies even further beyond these projected levels. Deepening the analysis to assess the potential uptake of REHC is possible, particularly if better data relating to heating and cooling demand becomes available.

Heat from solar thermal collectors in the APS was projected to increase from approximately 280 PJ to 3000 PJ in the period 2003 – 2030 due to the rapidly growing installed capacity (Figure 26).

Figure 26 • *Deployment of solar thermal collectors in terms of energy outputs projected out to 2030 by region*



Source: IEA, 2006f. 1Mtoe = 42 PJ.

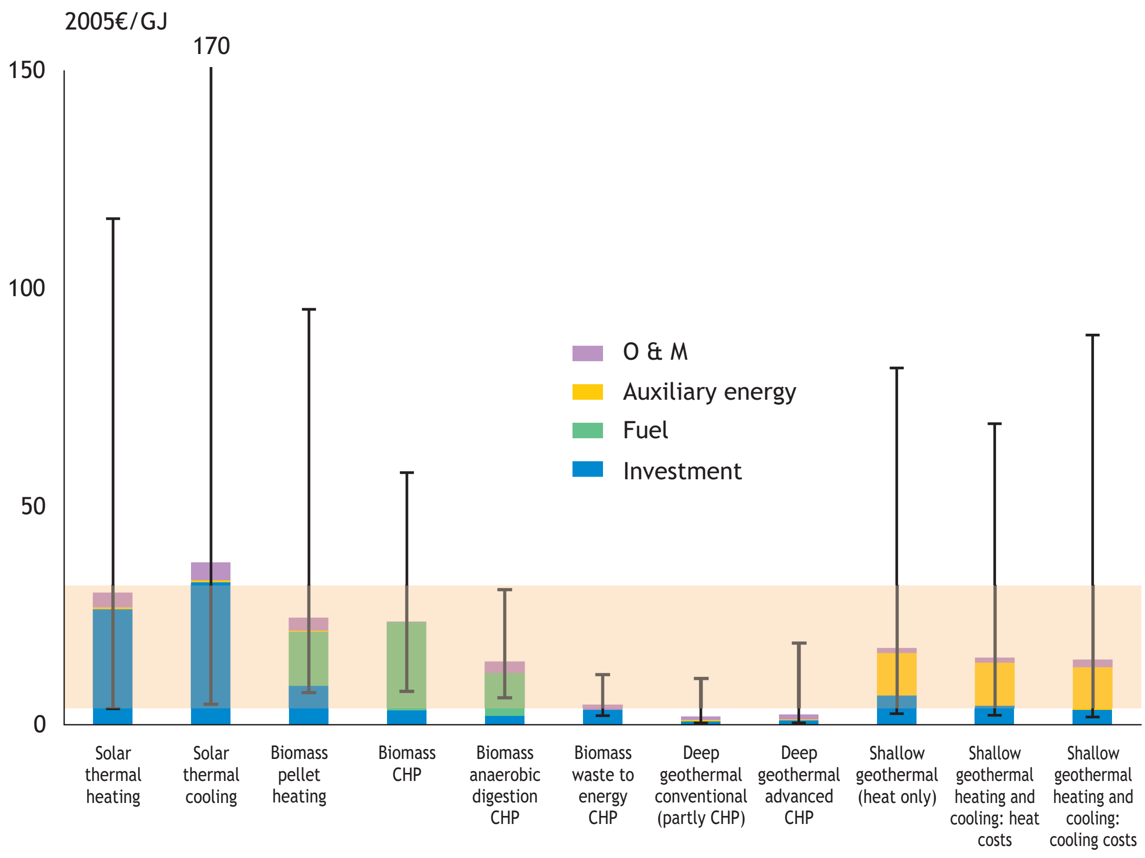
In the APS a shift towards more efficient bioenergy technologies by 2030 was expected with CHP electricity generation quadrupling from 121 TWh/yr in 2003 to 539 TWh/yr by 2030 with a comparable increase in available heat (Figure 27). Special attention was paid to the uncertainties of biomass supplies due to their sustainability and competing uses for them for electricity, biofuels, materials, food and fibre as well as for heating. The potential for integrated processes relying on biomass was also considered.

Figure 27 • *Electricity from bioenergy CHP in 2004 (225 TWh total) and projections to 2030 (983 TWh total) by region*

Source: IEA, 2006f.

Geothermal heat is projected in the APS to increase from 185 PJ in 2004 to over 1000PJ by 2030, although other estimates indicate that the technical potential for geothermal is about 150 EJ/y for electricity generation and 350 EJ/y for direct heat uses (GIA, 2006). Based on these various estimates of growth in demand for REHC technologies by 2030, the future costs are compared (Figure 28), based on underlying assumptions as detailed in Annex A. It was assumed that 25% price increases in real terms will occur for conventional energy supplies over this period.

Figure 28 • *Cost breakdowns and ranges (excluding VAT) in 2030 for a selection of REHC systems compared with the reference energy price range (shaded bar) for gas, coal and electricity heat energy carriers for the domestic (top of range bar) and industrial (bottom of bar) sectors*



Notes: The conventional energy carrier costs are only based on fuel costs and conversion losses because investment and depreciation costs of appliances per GJ of heat are very small. Neither reference system nor avoided costs due to fuel savings are incorporated. Installation costs are included but costs for heat distribution and allocated to electricity generation for CHP technologies are not. Details of cost assumptions are given in Annex A.

Based on the assumptions made (Annex A), conventional energy prices in real terms are projected to increase by 2030 (partly due to carbon taxes) whereas the costs of REHC technologies could decline considerably by that time due to further learning experience, particularly for the technologies currently at an early stage of development (Figure 10). This however could be partially offset by the future prices of materials such as steel and aluminium.

In summary

- There are excellent opportunities for the market expansion of many REHC technologies, particularly in developing countries.
- The dispersed nature of the heat markets makes accurate quantification difficult, as is also the case for solar cooling. Collecting statistical information is an important element in understanding the deployment of technology and poses a challenge.
- Lack of information and understanding can restrict the rates of penetration and some technologies still suffer from poor perceptions of reliability that occurred at an early stage of development.
- There has been considerable REHC technological development and cost reductions over recent decades but markets are still relatively small and widely dispersed.
- Many countries have good solar thermal potential that is relatively easy to access to reach the level achieved by the leading countries at a similar latitude.
- There is potential for traditional biomass for heating and cooking to be partly replaced by modern biomass and other REHC technologies.
- Market growth is anticipated for concentrating solar heat and geothermal heat pumps. Solar cooling is also near market and projected to increase, but from a low base, as greater system experience is gained from an increasing number of installations.
- Costs vary widely for specific applications, but several REHC technologies, if well designed, can be competitive over the life of the technology.
- System costs for REHC continue to decrease, especially for developing technologies in niche markets, but market uptake remains relatively slow.
- Barriers to REHC deployment include existing infrastructure constraints, landlord/tenant incentives and use of too simplistic cost accounting methods.

4. Policies and measures

Renewable energy technologies available for meeting heating and cooling demands in many locations currently lack cost competitiveness with conventional systems that are based on relatively cheap electricity, gas or coal (Section 3). Public support is therefore necessary to ensure a growing deployment of REHC. Historically in most countries, renewable heating has not received comparable policy support as has renewable electricity or biofuels for transport. This disparity is, at least in part, due to a lack of legislative tools and policies to support the market development of specific heating and cooling technologies.

Policies in support of REHC may be inherently different than those which address renewable electricity generation thereby reflecting the somewhat different characteristics of the electricity and heating markets. Electricity markets are clearly assigned to one or more centralized grid operator whereas, with the exception of district heating systems, heat is often the responsibility of individual producers. Moreover, the heat generated from renewable energy sources (RES) must be utilized locally as it is not possible to feed heat back into an extensive distribution grid, as is common practice with renewable electricity. Therefore, policy instruments need to be specifically addressed to meet the unique, local characteristics of REHC resources, the small-scale technologies involved, and the widely distributed demand.

Experience has shown that the status of the market greatly influences the levels of required support and degree of successful product deployment. For technologies that have reached a critical mass, comparative intensities of support lead to higher levels of deployment (Piria, 2007). Therefore in a supportive policy environment, a cycle of technology and market development becomes self-enforcing in terms of economies of scale, falling costs and public awareness (IEA, 2003; Figure 29). Markets that have not yet reached a critical mass (or are in decline) are not subject to such benefits so will require stronger policy support to gain more rapid diffusion. Cycles function differently depending on the stage of maturity of a technology and how far its market has progressed. Careful policy design is necessary to incorporate these factors.

This section provides an overview of the policies which have been utilized to promote an increased use of renewable resource for heating. The types of policy deployment instruments which have been used are introduced and grouped into categories (Figure 30):

1) Carrots - financial incentive schemes

2) Sticks - regulatory schemes, and

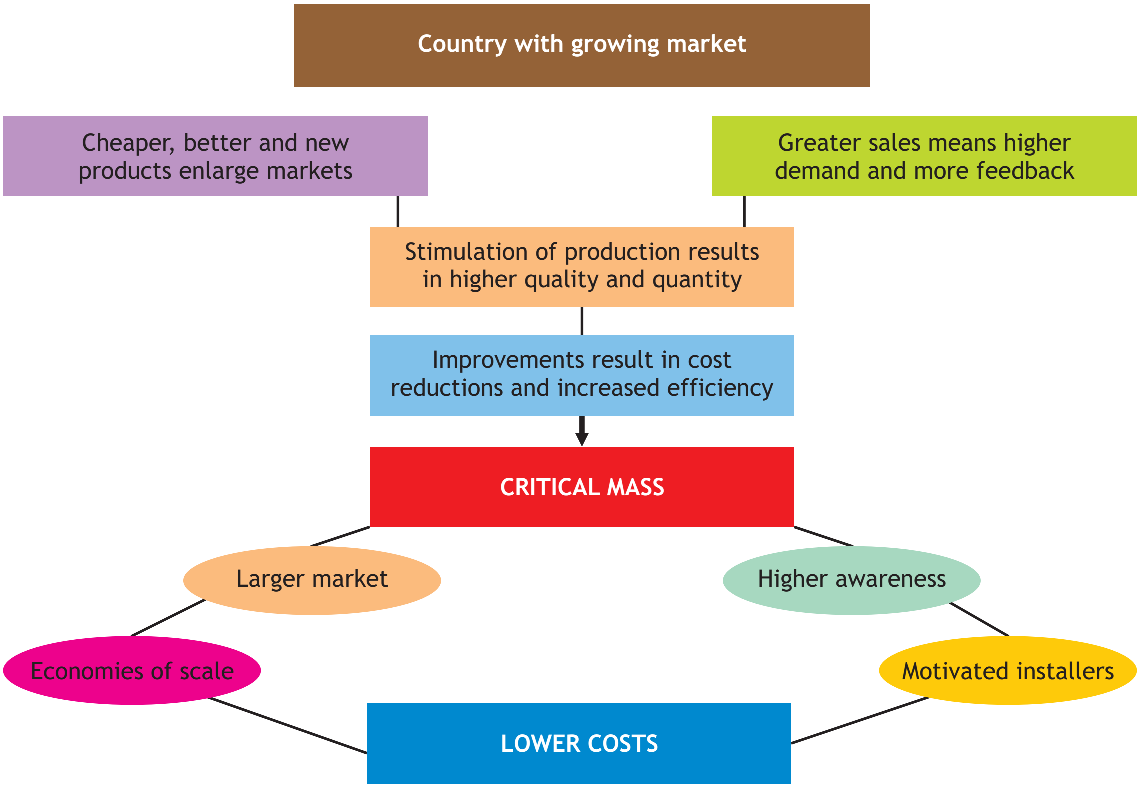
3) Guidance, or educationally based schemes[6].

Policy instruments for renewable heating have also taken the form of voluntary agreements between the private sector and the public sector. These have been employed in all three categories, but typically involve the voluntary development and purchase of renewable energy technology (RET) installations or the purchase of "green energy".

All three categories are designed to support the same goals, but they address the barriers in different ways. Policies for renewable heating are emphasised in this section as very few policies have been offered in support of renewable cooling to date.

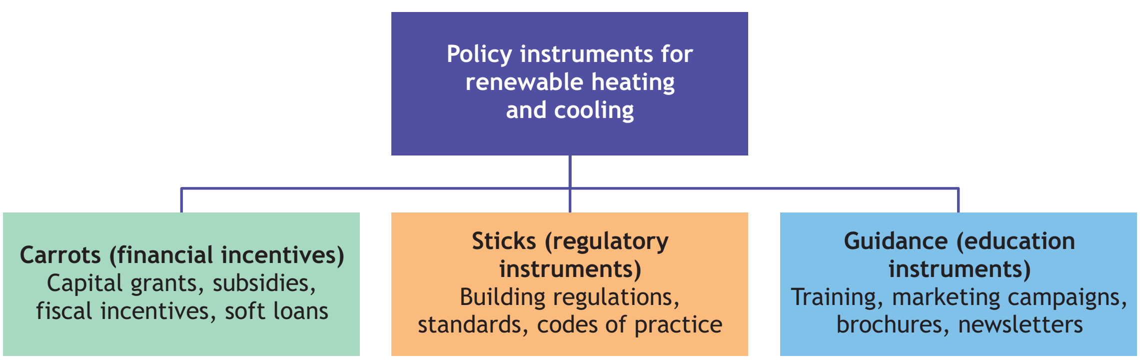
6. This grouping structure is based upon "*Carrots, Sticks, and Sermons: Policy Instruments*", Vedung *et al.*, 1998.

Figure 29 • *Technology development, industrial development and market deployment are linked to produce a market with critical mass which then becomes self-sustaining*



Based on IEA, 2003.

Figure 30 • *Policy instruments categories for renewable heating and cooling with examples*



Carrots: incentive schemes

Typically carrots act to entice a customer into utilizing RES to meet local heating needs and aims to address the cost gap between RETs and conventional technologies used for either direct or indirect heating. Such incentives schemes may be further categorized into:

1) financial incentives – based on direct financial support such as capital grants used to reduce the capital cost of deploying renewable energy technologies, or investment risk reduction using soft loans (IEA, 2004), and
2) fiscal incentives such as tax benefits.

Generally these types of incentive are funded out of government budgets. In order to be effective the design of these incentive schemes needs to allocate sufficient levels of funding to bridge the gap between the market price of heat energy and the costs for RETs. The incentives should be predictable and consistent over the life of the policy to provide investment confidence.

Investment incentives

Capital grants and rebates

Solar thermal and geothermal heating installations are usually capital intensive but with relatively low running costs. Bioenergy heat plants can be similar where the source of biomass is free-on-site but the fuel usually needs to be collected or purchased, often resulting in higher running costs. Capital grants are a straightforward incentive to reduce the up-front investment costs. This is a very common type of support relatively easy to administer.

Grants, or subsidies, may be offered either to the developers or owners of the renewable heating installations, or directly to the manufacturers of the renewable heating technologies. It is recommended that grants are offered in support of the demand-side market as grants for manufacturing may interfere with competition. For the plant owners, grants may be offered in terms of:

1) capacity installed (€[7]/MW) directly targeting the capital investment costs for plant and installation;
2) subsidies set as a percentage of total investment;
3) a fixed payment incentive per installation;
4) rebates in the form of the refund of a specific percentage of the cost of installation; or
5) the refund of a certain amount of money per unit of capacity installed (Sawin, 2006).

Where a budget limit is imposed, grants may be awarded on a first come, first served basis or auctioned. A risk lies in providing grant funding for the installation as this does not guarantee how much heat energy, if any, will be generated. Moreover, limited funding per grant may provide a disincentive for investment in higher quality technologies.

Operation grants

Such heat production incentives provide cash payments based on an energy generation basis, typically on a €/kWh basis for the production of renewable electricity. However, targeting the end energy product of heat is also a possibility, normally in terms of €/GJ. Payments based on energy generation and hence plant performance, rather than on capital investment, may place more emphasis on choosing better quality installations. Moreover, funding the energy generation ensures that renewable heat is actually generated.

The distributed nature of heat supply complicates the implementation of operation grants due to a lack of cost-effective metering and monitoring procedures often only cost-effective and practical for larger systems.

7. The currency used is country specific.

Box 5 • *Innovative Instruments – fixed-heat tariffs and renewable heat certificates*

To date there have only been discussions surrounding the possibilities of designing policy instruments for renewable heat based on a feed-in tariff system. However, it may become an option to consider as renewable heating becomes a higher priority.

a) *Feed-in tariff* systems are price-driven policies which historically have been designed to support renewable electricity. Much of the capacity installed has resulted from their implementation, most notably in Germany, Spain, and Denmark. Under such a system, electricity generated from RES is paid a premium price for delivery to the grid. The government sets the price per kWh and utilities are then obligated to purchase a given amount of this energy at this premium price which they then pass on to consumers.

A similar fixed heat tariff would require additional practical measures because of the distributed, local nature of the heat market. For district heating systems the heat is metered after distribution and there is a central operator upon which the obligation can be placed. This is not the case for the majority of heating systems as they are individually owned and widely distributed. District heating systems compete with these and any obligation placed on them should not negatively affect its competitive position. Ideally an obligation, if and when employed, should be placed on parties that are actively involved in the heat market and relatively few in number; for example, the suppliers of conventional fuels (*e.g.* natural gas suppliers) based on their market shares. The specific actors involved will vary by country and by the variable composition of the conventional fuel markets.

b) Heat can be measured by meters similar to those used to monitor and reconcile the generation and sale of electricity that is ultimately fed into the grid. Based upon the verified data from heat meters, a *renewable heat certificate system* could be introduced as has been successfully achieved in Australia, the UK and elsewhere for renewable electricity purchasing. Owners of renewable heat installations would receive a certificate for the amount of heat generated. Suppliers of conventional heating fuels would then purchase these certificates, priced at an amount per kWh usually set by an authority in order to fulfil their mandated obligation.

This type of system could also be designed to promote long-term structural changes in the heating market. For example, a higher compensation rate could be set for certificates based upon renewable heat fed into district heating systems, thus offering additional incentives to develop more community-scale heat projects (Nast *et al.*, 2007). However the unpredictability, complexity and risk of implementing a certification system for distributed heat could inhibit successful REHC deployment.

Verifying the production of renewable heat is a challenge to fulfilling either a feed-in tariff or certificate scheme. Staff will need to be trained to collect and verify data, provide payments, and feed the data into a register of certificates. Design features of the proposed German Renewable Energies Heating Act (Annex B4) have been suggested including establishing variations for different capacities. For example, smaller size systems might be given a simple rated output level, therefore removing the requirement for regular data collection and monitoring. Then, it would only be necessary to verify that the system is still operating, possibly on an annual basis (DLR, 2006). In Australia, domestic solar water heaters have each been allocated a single annual 1 MWh certificate given in bulk to suppliers to represent the assumed average avoided power demand. They can then trade these certificates into the renewable electricity scheme.

Soft loans and loan guarantees

Financial assistance in the form of low-interest or no-interest loans, long-term loans, and/or loan guarantees effectively lowers the cost of capital. Since the high up-front cost is often an important consideration for potential REHC investors, lowering it can effectively bring down the average cost per unit and hence reduce the investment risk. Loans offered at subsidised interest rates, lower than the market rates (defined as soft loans), may also incorporate long repayment periods and/or payment holidays or deferments.

An advantage associated with this type of incentive is that it is easily implemented by banking institutions that normally provide investment support to developers. Banks often hesitate to provide loans for equipment which is still developing a market presence but when "bankability" by established institutions is assured, then this may pave the way for project developers to accrue additional funding sponsorship. Very little risk for the administrative body is associated with soft loans and loan guarantees. However, they do not necessarily encourage investors to purchase the most reliable systems available or to maintain them adequately and produce as much heat as possible from the RES.

Fiscal incentives

Tax incentives including tax credits, reductions, and accelerated depreciation, may be based on investment costs or energy production. A wide array of tax incentives exist and these increase the competitiveness of renewable heating. Fiscal incentives typically present a lower financial burden for administrating and transaction costs and are thus an attractive option, but the overall level of fiscal incentive needs to be carefully established to achieve successful outcomes.

Where value added tax (VAT) or carbon charges are in place, these can affect the cost-competitiveness of REHC technologies. VAT rates are often reduced for electricity and gas but a full rate is applied to REHC technologies. Where possible, government regulations for VAT reductions should be adjusted to include REHC technologies.

Tax credits

Under the definition of a tax deduction support scheme, renewable heating installations represent an expense to a tax payer. Credits, or deductions, may be a percentage of the total investment or a pre-defined fixed sum per installation. The expense of the installation (as defined by the policymaker) is deducted from the gross total amount of taxable capital and thus results in a lower overall taxable income. Accelerated depreciation can also support investments where taxes employed on income or property are limited to a pre-determined number of years following the installation. Tax credits may provide a greater benefit to people and businesses with higher income levels and tax loads. Only those parties with an income or property tax may benefit which therefore provides no incentive to potential investors without such tax liabilities.

Investment tax credits that cover either a percentage or the full costs of installation are especially good for the early diffusion of early market technologies (Section 2) whose costs are relatively high (Sawin, 2006). Alternatively, *production tax credits* can provide tax benefits for the amount of renewable heat or cold actually produced, therefore increasing the rate of return or decreasing the payback period. In general, production incentives are preferable to investment incentives because they promote the desired outcome of increased renewable heat generation.

Tax reductions and exemptions

A tax reduction or exemption system reduces the amount of tax that must be paid in total, thus reducing the total cost of investment in REHC. Tax reduction systems include relief from taxes on sales and property and value added tax exemptions. External benefits provided for REHC could also occur in the form of exemptions for eco-taxes, carbon charges, or energy taxes imposed on conventional heating fuels. Such exemptions act as an indirect support making REHC more cost competitive. This policy instrument has been notably successful in Sweden where the exemption of biomass from the energy tax in the 1990s levelled the playing field such that today the majority of heat is generated from biomass.

Box 6 • *Innovative Instruments - quota obligations for heat*

Also known as Renewable Portfolio Standards, quota obligation schemes, first introduced in the late 1990s, place an obligation on electricity suppliers to provide a set quantity or percentage of their total supply from renewable energy sources. Governments set the targets for renewable energy over time and allow the market to determine the price. Least-cost technologies closest to market competitiveness are therefore encouraged by quota obligation systems.

The success of such policies depends largely on the specific design features. Penalties for non-compliance must be sufficiently high and well enforced. Quotas should not be set so high that they exceed the readily available potential supply of REHC. Poor policy design features have inhibited the success of past policies as a result of application to only a small segment of the market, uncertainty in the structure of purchase obligations, uncertainty around the end-date, and a lack of enforced penalties.

It is common practice for electricity to include a Green Certificate trading scheme in association with quota obligations. Producers receive a "Green Certificate" credit for the renewable electricity they generate representing its renewable attributes. A market is created for trading the certificates, driven by the obligation placed upon energy suppliers for a mandated amount of renewable energy. The certificates are proof of meeting a legal obligation and may be sold or banked.

Due to the distributed nature of heat, it would be necessary to place a similar obligation for renewable heating quotas not on a centralized, grid-based heat supplier, but rather on suppliers of conventional heating fuels such as oil, coal and natural gas. Based on their market share, these suppliers would be required to ensure that a certain amount of renewable heat is also generated. This type of instrument would encourage only limited incentive for large heat generation units and district heating networks.

Conventional fuel suppliers would not necessarily be required to generate renewable heat themselves. They could buy certificates from other renewable heat producers, as for a standard electricity quota obligation policy. Certificates would be allocated to the producers of renewable heat who can sell them to the obligated parties or trade them on an open market (Nast *et al.*, 2007). Such a scheme for REHC could require making separate quantity obligations for solar, biomass and geothermal heat. As for renewable heat certificates (Box 5), creating barriers for REHC deployment should be avoided by careful policy design.

The quota obligation could also be designed so that it can support REHC in community or industrial applications. However, like the fixed-heat tariff, such a system would require adaptation of specific design features because of the distributed nature of heat plants. Discussions on the incorporation of a quota obligation system for heat are currently in progress in the UK and Germany (Annex B12 and B4).

Sticks: Regulatory schemes

Generally implemented by means of regulation, governments can intervene in the market by placing requirements on specified sectors. This type of instrument forces REHC deployment by directly requiring the development of specified technologies. The legal and administrative costs of political incentives are often kept to a minimum for governments, although monitoring and enforcement may be required at the local or regional level.

Box 7 • *Innovative Instruments – links to energy efficiency schemes*

Policies in support of energy efficiency measures have introduced a "White Certificate" scheme to facilitate achieving energy saving targets. An artificial market for tradable energy efficiency measures is created as a tool to promote energy efficiency. Certification of defined measures enhances the likelihood of meeting efficiency targets. The tradability aspect ensures that objectives are met in a cost-effective way. White certificate schemes, based on regulations on energy efficiency, are currently in place in the UK, Italy, and France.

Energy efficiency schemes may be linked to promotional schemes for REHC by including them in the definition of measures eligible to receive the certificates, thus supporting the REHC market.

Such a system, with links to renewable heat, has been in place in Italy since January 2005. It includes solar thermal applications, heat pumps, and biomass heat as eligible measures for achieving energy savings. District heating and CHP have also been given specific qualifications under this scheme. A calculation sheet has been produced by the Italian Authority for Gas and Electricity (AEEG) to report the gross specific savings expressed in tonnes of oil equivalent (toe) per technology, (for example, toe / m^2 of solar thermal collectors installed) (ESTIF, 2006a).

Building regulations

These typically apply to either a specific renewable heating technology or take the form of more general regulations to promote energy savings. Regulations requiring solar thermal systems for hot water in new or renovated buildings have become increasingly common in recent years. Regulations could also be used to require home owners to connect to a district heating grid fuelled by renewable energy. Building permission could be withheld if plans do not incorporate the necessary installation.

Such regulations are justified where renewable heating technologies are more cost-effective if installed during construction rather than retro-fitted. The impact on the total building cost is therefore relatively low (EREC, 2004b). Moreover, the obligation on new buildings creates a minimum critical mass within the market, thus leading to lower costs and higher use of renewable heating technologies (ESTIF, 2006c). Such type of ordinance has the additional advantage of being easily understood by the obligated party.

Supplying a portion hot water demand in a building using solar thermal technologies is relatively straightforward. However regulating for the supply of heat for both water and space is more difficult, though often more cost effective for geothermal or biomass heating systems. Building regulations may also be criticized in that they encourage individual heating systems rather than district heating (Nast *et al.*, 2007).

Standards

Standards for heating and cooling equipment as set by governments would prevent less efficient technology designs from entering the market (as has been successfully achieved with various domestic appliances and electric motors). Greater confidence in the reliability of the technology is thereby created, thus reducing investment risks. Standards may be established for performance, safety, or siting of heating or cooling plants.

Guidance: education-based schemes

Education to promote REHC aims to enhance the awareness of the public by information campaigns and providing training to increase installer knowledge. This type of support may take the form of technical assistance, financial advice, labelling of appliances, or information distribution. Information on resource availability, the benefits and potential of renewable energy, plant type, capacity and heat production statistics, and available government incentives, may be distributed in a variety of forms. For example, Canada's Office of Energy Efficiency has produced the free download web-based RETScreen tool and numerous free publications on energy efficiency and renewable energy. Other web sites have also been developed in many countries.

In addition, training programmes may be established in schools, universities, or amongst key professional groups so they consist of well-informed, skilled individuals and networks. Professionals within the supply chain for heat and cold include equipment installers, heating engineers, and architects who should be encouraged to incorporate REHC systems into their designs. Information provision and knowledge-based promotion needs to work in conjunction with other political tools. A lack of information regarding renewable energy resource availability, technology development, and product availability may inhibit investment in REHC applications simply due to a lack of awareness.

Experiences with policies for REHC

Twelve OECD country studies were compiled to investigate national strategies in place to promote REHC, in particular heating (Annex B). Canada, Denmark, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, and United Kingdom were selected due mainly to their current policies and interests in deploying REHC. The following sections summarize the current policies of these countries in order to present lessons learned from experiences. A brief overview of effectiveness indicators is then presented followed by a matrix of good policy practice examples.

Summary of current policies

Historically, most policies in support of renewable energy has been focused on renewable electricity and biofuels for transport. Renewable heating has gained support in recent years as awareness of its potential has been increasingly recognized. Of the supporting policies identified within the 12 countries analysed, only 5 were in place in 1990 whereas by May 2007, more than 55 policies had been introduced to support renewable heat either directly or indirectly. Renewable cooling was rarely featured.

Two thirds of policy instruments identified to date directly supporting renewable heat have been technology specific, carrot-based, incentive schemes (Figure 31). All policies have been markedly variable with no obvious pattern relating to their time-spans, total budget per capita, annual budget per capita, applicable technologies or eligible parties.

The success of carrot schemes is difficult to measure but appears to have been mixed, often depending upon the specific design features of the policy and the existence of accompanying stick and/or guidance policies. (Effectiveness indicators are discussed below).

Between 2000 and 2005, the average annual investment of the carrot based incentive schemes ranged between €0.07 and €2.50 per capita[8] (Figure 32). In many cases guidance policies were employed in conjunction with carrot incentives by allocating a portion of the budget towards information distribution and public awareness. Budget information for stick policies in association with guidance policies was generally unavailable.

Many policies target multiple renewable heating technologies. In several circumstances an over-arching policy was implemented covering renewable technologies as a whole, with individual specifications made for renewable heating technologies such as solar thermal panels or geothermal heat pumps. For example, in 2006 Ireland deployed a €65 million budget for multi-annual investments in renewable

8. Reliable budget data was available for less than half of the policies surveyed.

energy as a whole with individual schemes, (the Greener Homes Scheme and Bioheat Boiler Deployment Programme), implemented specifically for renewable heating by using an allocated portion of the total budget (Annex B5).

Figure 31 • *Representation of existing instruments for renewable heating by category*

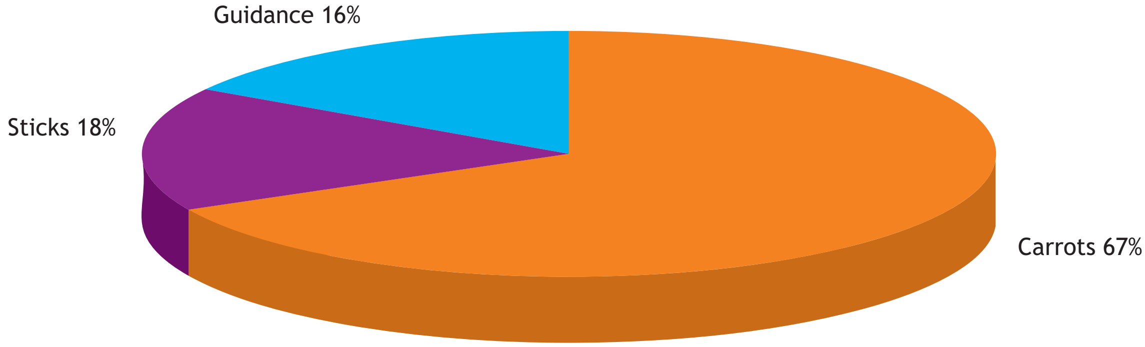
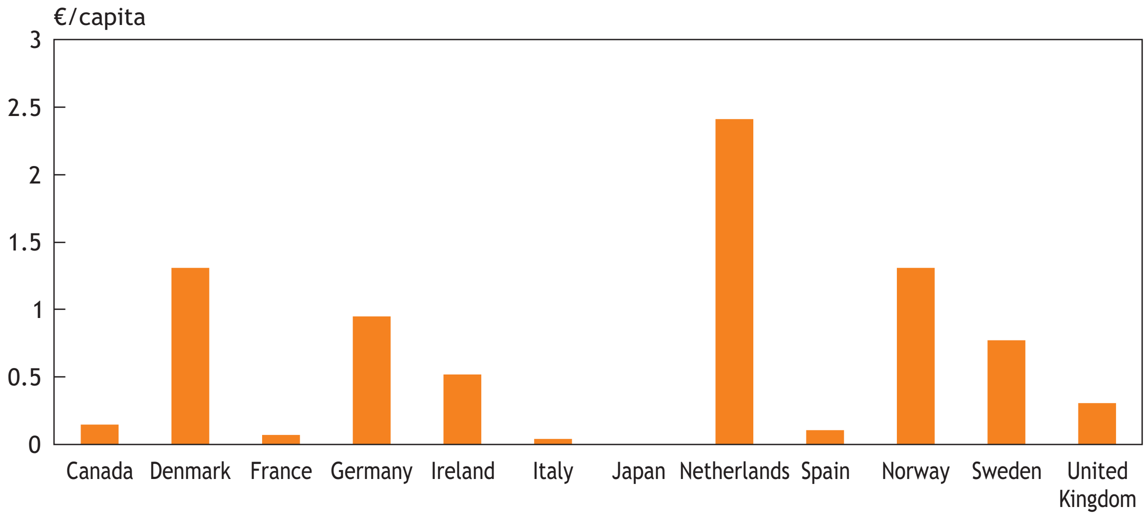


Figure 32 • *Average annual budget invested in carrot-based policies across 12 OECD nations, 2000-2005*



Notes: 2005 €/capita. Not all policies have been captured and budget data was often unreliable. Therefore any comparison between countries can be only broadly indicative.

Most policies to support renewable heat targeted solar thermal and biomass with geothermal receiving much less political attention. Indirect incentives to promote CHP, energy efficiency of heating, and renewable contributions to district heating systems were evident in less than 13% of policies surveyed. Policies targeting individual heating technologies are summarized below.

Solar thermal

Solar thermal technologies contribute 2% of the total renewable heat supply for the 12 OECD nations evaluated. However, continued market growth as in recent years may lead to a more substantial contribution in the future.

The number of policies to support solar thermal technologies has been roughly equal to the number of those in support of biomass heat, although the total financial contribution has been less. In those countries with the most successful solar thermal heat deployment, a federal carrot subsidy/grant based scheme has been employed with the support of guidance policies. In Germany for example (Annex B4), the Market Incentive Program (MAP) subsidy scheme allocated €588 million between 1999 and 2005 in support of solar thermal development, also supported by awareness raising campaigns at federal and local levels. As a result, the solar thermal market has shown substantial growth.

The contribution in political support from regional governments has been especially important for the growth of the solar thermal heating market. In addition to subsidies offered at a regional level, stick-based incentives for solar thermal have been initiated in Spain (Annex B10) and Italy (Annex B6) and discussed at the regional level in Germany (Annex B4). Often in the form of building codes, these regulations require the installation of solar thermal heating technologies on all new or renovated buildings. A regulation can specify for enough solar thermal capacity to supply a certain percentage of heat (most often as a percentage of domestic water heating). These incentives symbolize an important shift in the focus of political instruments from carrot-based incentives to stick-based regulations which are especially well suited to areas of strong solar resource. The recent adaptation of the Barcelona model solar thermal ordinance[9] by the federal government in Spain has shifted much of the financial burden of support for this renewable heat technology away from the public purse.

When defining policy mechanisms for solar thermal, ideally they should be based on energy yield (GJ or kWh) rather than on collector surface area installed (m^2) even though this is easier to measure. Various designs of solar thermal collector technologies exist (Section 2) each providing a different energy yield (GJ/m^2) for the same level of solar irradiation. Policy support based on surface area rather than yield disadvantages collectors with a higher performance such as vacuum collectors since these generate more heat/m^2 than an equivalent surface area of an alternative design. The more efficient technology would not be compensated for the additional heat produced. Moreover, since the roof surface area available for solar thermal installations is not usually limiting, the area of solar thermal panels installed is less relevant than the production of heat.

Due to the intermittent nature of the solar resource, with an abundant supply in summer when heating needs are generally low and a reduced supply in winter when heating needs are high, solar storage is an important consideration not yet addressed in policy making. In some regions, future policies designed to support solar thermal heat could therefore include a component for seasonal heat storage.

Biomass

On average, biomass accounts for around 95% of the renewable heat produced today (Section 3). The contribution of traditional biomass for household heating and cooking plays a large role but is excluded from this discussion (Section 2). Modern biomass combustion is one of the more mature and cost-competitive renewable heating technologies so may require less political support than for others.

The reliability of biomass resource supply is an important consideration for potential investors in biomass heat (IEA, 2007b). The supply of consistent quality biomass fuel must be secured for an investor to finance a biomass fuelled heating project. If the supply chain for biomass-based heat cannot be guaranteed, or the biomass not guaranteed to a specific quality, a barrier to project deployment exists. Support mechanisms for the development of biomass supply chains including fuel supply and transport need to be considered by policy-makers targeting biomass-based heating. For example, the UK allocated €5.25 million between 2005 and 2008 to develop the supply chain and market infrastructure for wood and straw fuels under its Bioenergy Infrastructure Scheme (Annex B12). This policy aims specifically to develop the supply chain required to harvest, store, process, and supply the biomass for CHP plants.

9. The installed surface area increased from 1.1 m^2/1 000 inhabitants to 16.5 m^2/1 000 inhabitants in Barcelona between 2000 and 2005.

The growth of the biomass heat market has been most successful in countries which have employed a combination of support schemes including indirect incentives for district heating and CHP. For example, Sweden (Annex B11) and Denmark (Annex B2) have both seen impressive growth in their biomass heat markets on a per capita basis due to employing energy taxes to level the playing field and offered direct subsidies for biomass heat generated in CHP plants connected to district heating grids. As such, these high latitude countries with many residents living in high density, apartment blocks, have successfully developed policy support for the generation of biomass heat on a community scale, rather than targeting small individual households.

District heating infrastructure has been key in increasing the share of renewable heat in a number of countries. With immediate access to a large number of customers, district heat reduces the more usual distributed nature of heat generation and allows for metering. In addition it can provide an outlet for waste heat from electricity generation to encourage CHP facilities.

Policies directly in support of renewable heat via district heating systems are less common than those which support the renewable heating technologies themselves. However, several exemplary schemes have been implemented. For example, between 2001 and March 2007, the Community Energy Programme of the UK provided grants for district heating systems, with roughly 16% of the funding allocated for biomass support. Geothermal heat is not often used in district heating but could be where suitable resources exist such as in Iceland.

Geothermal

Geothermal heat (primarily from shallow, low-temperature sources) is responsible for 3% of the total renewable heat supply in the 12 nations examined. Most of the heat generated is captured in geothermal heat pumps whose markets have grown considerably in recent years (Section 3). Good potential exists for the expansion of both shallow and deep geothermal technologies.

Less policy attention appears to have been directed toward geothermal heat than either solar thermal or biomass. Most political support for geothermal technologies has been based around electricity production and the limited support for geothermal heat has mainly focused on heat pumps. Geothermal heating can also encounter political barriers inapplicable to the other renewable heating technologies such as fees placed on mining/drilling and groundwater use that increase the gap between the costs of geothermal and conventional heat.

Less that half of the global geothermal direct heat use is provided from deep geothermal resource development and much of this comes from the use of separated hot water from geothermal power developments (a form of CHP), or from deep wells drilled into geothermal resources that were previously proven as part of exploration for electricity generation. For the few cases where unproven deep geothermal resources are specifically developed to provide heat, resource exploration incurs significant additional costs. Unproven resource availability implies a high degree of uncertainty as to the success of geothermal development (Firke-Mariam, 2006). As such, there is perhaps a higher degree of economic risk for geothermal heat than for either solar or biomass heat. Risk guarantee funds that offer to cover the loss of unproductive geothermal wells are one solution to mitigate the risk of geothermal exploration. The German development bank, KfW, offers such incentives for projects in developing nations.

In summary most of the policies in place today to support renewable heat generation are carrot-based incentives offering direct financial support. The budget allocated per capita vary significantly for each policy and national package of policies as do their time-spans, technologies applicable, and eligible parties. Policies are generally technology specific and most have been focused on support for solar thermal and biomass heat. The few policies supporting geothermal heat have concentrated on geothermal heat pumps.

Countries which have been most successful with biomass heat uptake have employed a combination of support schemes, often including incentives for CHP and district heating. The whole supply chain needs to be addressed when designing policies in support of biomass. In addition to direct financial support, the importance of guidance-based policies has been marked regarding the development of solar thermal. Stick-based policies have become more common, mainly based on regional policies supporting solar thermal heat. Such regulations may be a good basis for the future design of policies as much of the public financial burden is removed. Policies designed to support solar thermal should incorporate aspects for heat storage because of the intermittent nature of the solar resource, although few countries have done so.

REHC is an opportunity for countries to fulfil their overall renewable energy targets. As the support for renewable heat increases, more and more policies are tailored to individual technologies, resource availability, and numerous external factors compromising individual national frameworks. Since REHC technologies are at different development stages and levels of cost competitiveness, it follows logically that the types and packages of support should vary by technology type. In other words, policies well-suited for biomass may not necessarily be suitable for the development of solar thermal or geothermal heat. Therefore, the definition of national goals is important so that the design of incentive schemes can be tailored appropriately.

Lessons learned from current policies

It has been argued that a well-balanced set of focused, transparent and stable policies may be preferable for the successful deployment of renewable electricity, transport and heat technologies. The success of an individual policy depends on its design and the supporting levels of enforcement. In order to promote strong, substantial growth in each renewable sector, policies must be reliable and long-term (often quoted as "loud, long and legal"). Targets for definitive quantities or percentages of renewable energy should be clearly outlined and verifiable. This analysis did not assess the impact of policies over time and further work is recommended.

Policies to support REHC need to address the specific challenge of the distributed nature of local heat demand and variability of use, especially for hot water. In contrast to large scale renewable electricity projects, policies in support of renewable heating should address to a greater extent the availability of local information, the success (or otherwise) of local projects, and local circumstances. In addition bureaucratic and administrative barriers, such as needing planning permission even for simple solar collector roof installations, or mining rights for geothermal heat extraction, may inhibit deployment and should be minimised.

Each country and state has a unique set of circumstances, needs, and resources that play an important role in the design and success of policies for renewable heating and may influence the appropriateness of a policy for a given area. For example, Sweden has had much success with the implementation of a tax exemption for biomass, increasing the levels of biomass-based heat (see Good Policy Practices section below) because the country has a strong forestry industry and well-developed infrastructure for biomass upon which the tax incentives could stand. Similarly the *Barcelona Solar Thermal Ordinance* has received much international attention for its innovation and success in promoting solar thermal panels. The ordinance, requiring new buildings or buildings undergoing heavy renovation to fulfil 60% of their hot water demand with solar heat, has been successful in part due to the expanding building and construction industry. In countries where the forestry and building industry sectors are less dominant, similar policies may have substantially different results. Therefore, each nation must design its own system and combination of policies based on its individual situation, resources and set of goals.

Increasing supply-side confidence may have a positive impact on deployment. Private investment in facilities, marketing and distribution structures and the training of installers tends to accompany stable, predictable and long term policies. In the medium term this leads to a higher market presence, economies of scale, lower costs and improved product quality (Figure 29). Poor quality systems and inferior installations compromise the reputation of the technology and can produce a lack of consumer confidence. Generally a mix of instruments is essential for success. For example, carrot-based instruments in combination with information campaigns and training programmes can be structured to build professional support for the growing REHC technological demands.

Carrots

A lesson can be drawn from the German Market Incentive Program (MAP) and its fluctuating budget for renewable heating (Annex B4). The policy was successful in stimulating the market for solar thermal and was supported by the majority of the financial subsidies available under the programme. However, fluctuations in the available budget were reflected in the varying number of applicants and therefore reduced the total number of projects supported. Once the budget remained stable, thereby ensuring investor confidence, the number of solar thermal installations would increase. This demonstrates the need to provide stable, long-term policies in order to maximize the development of REHC.

The French experience with solar thermal offers a relevant example of the importance of ex-ante and ex-post incentives[10] (Annex B3). Prior to 2005 the French depended primarily on ex-ante incentives to support solar thermal, notably with the Chauffe-eau Solaires Programme (1999) and the Plan Soleil (2000). In other words, investors wishing to install a solar thermal plant were required to apply for funding through these subsidy programmes *before* installation. However with the implementation of the 2005 Finance Law, the primary support for solar thermal was altered to an ex-post tax rebate scheme offering incentives for 50% of the cost of solar thermal systems recovered by means of an income tax declaration *after* installation. Because financial support for solar thermal installations no longer required pre-approval, incentives were more attractive. As a result, the annual installation of solar thermal increased significantly[11]. and is expected to increase further in coming years. This jump in market growth suggests that an ex-post financial support scheme may have pragmatic advantages (i.e. investors are able to receive financial compensation after they have installed their solar thermal plant, rather than having to wait for approval before construction begins). It can therefore be assumed that ex-post incentives are more attractive to potential investors who may be otherwise dissuaded by bureaucratic application procedures. This example demonstrates the need for simple, straight-forward application procedures to suit both applicants and administrators.

Capital grants and subsidy programmes cannot assure investment certainty in the long-term without a large investment budget. Although such carrot-based support schemes have been successful in the growth of sector-specific renewable heating, the significant burden on public finance inherent in the design of these schemes may require further consideration of stick-based schemes.

Sticks

The success of the *Danish Biomass Agreement*, requiring utilities to buy and incinerate specified amounts of straw and woodchips, was due in large part to the flexibility introduced in 1997 (see Good Policy Practice section below). Initially when the policy was introduced, requirements were set for 1 Mt of cereal straw. Because of price hike problems associated with limited market competition, greater

10. Ex-ante incentives are those which require action prior to the installation of a renewable unit. Ex-post incentives allow actions for incentives to follow installation. Ex-ante incentives are forward looking; ex-post incentives are backward looking.

11. Annual solar thermal installations in France in 2000 were 23 500 m^2, 12 000 m^2 in 2001, 27 000 m^2 in 2002, 38 900 m^2 in 2003, 52 000 m^2 in 2004, increasing to 121 500 m^2 in 2005 following the shift to tax incentives.

flexibility introduced into the policy amendment allowed more choice in the type of biomass. The lesson that can be drawn is that a degree of flexibility should be incorporated in regulations to prevent unpredictable price hikes and supply chain complications.

In order to ensure quality of hardware, installation, and design planning when implementing obligations for renewable heat, a monitoring system, including periodic examinations of installations and/or minimum quality standards is advisable.

The costs are often substantially better if REHC technologies are integrated from the early stages of planning, thereby justifying the early support inherent in building regulations. However, as regulatory schemes tend to require the installation of only one type of renewable heating technology, complementary technologies may lack any support.

Guidance

The importance of including a guidance-based scheme with the implementation of carrot incentives to educate the public and simultaneously promote the concepts was demonstrated in Italy's *Bando Nazionale per Enti Locali e Aziende Distributrici Gas* (BNELADG) policy (Annex B6). It offered subsidies to local authorities and municipally owned gas-distribution companies for 30% of the installation costs for solar thermal. There has been very low response to this €6 M programme begun in 2002 with only €1.5 M allocated. The successful German Market Incentive Program offered subsidies for only an average of 15% of installation costs. It can therefore be assumed that the relatively poor success of Italy's BNELADG policy was not due to the level of support offered. Rather, the lack of any accompanying awareness-raising campaign, nor support programme to train personnel how to install solar thermal systems, may have been a serious impediment to success.

It is therefore recommended to include a framework for information distribution in accordance with other policies which promote REHC. Instruments such as information campaigns, training, and demonstration projects ensure that a lack of awareness does not impede the success of a policy.

In summary, policy makers should be cognizant of the technologies they are trying to promote. Policies geared towards REHC technologies that are cost efficient on the small scale (such as solar thermal and geothermal heat pumps) should be targeted to the end consumer while those geared towards technologies that are more cost efficient at the larger scale, (such as biomass and geothermal), may be better targeted towards large entities or companies. Policies that support an increase in the number of small, replicable heating systems (solar hot water, wood stoves and heat pumps) should supplement systematic policies that support large scale heating infrastructure changes to encourage district heating and thermal power plant waste heat utilization.

It is recommended to base policy targets on the actual generation of heat rather than on total capacity or number of installations. This ensures that the specific goal of the policy is to promote renewable heat. Basing incentives in terms of plant capacity alone may risk the installation of REHC technologies that are not actually utilized.

The implementation of support schemes based on quota systems or feed-in tariff systems (as used for electricity generation) may become important instruments to promote renewable heating. Although such policies have been proposed by several nations (in particular UK and Germany) their implementation is complicated due to the many adjustments necessary to tailor such policies to the distributed nature of the heat supply and demand.

Effectiveness indicators

An analysis on the effectiveness of a given policy or package of policies is an important component of policy review. In this section, the REHC policies from the 12 OECD nations are presented in a format which provides a preliminary basis on which to judge their effectiveness. An explanation of the methodology used and its limitations is first provided, leading into a discussion of the results of the effectiveness analysis.

Methodology

It is desirable to design a REHC policy that achieves the maximum amount of deployment for a given amount of public expenditure. This was the basic assumption for this analysis of the costs and effectiveness for REHC deployment. Emphasis was once again placed on heat, there being few policies relating to cooling.

Around two thirds of the policies surveyed offered direct financial incentives for investment in renewable heating technologies, mostly as subsidies or grants up to a limited total amount. The success of deployment often depends on the package of incentives offered. However, in large part due to the non-availability of published budget information, only individual carrot-based subsidy/grant incentives were examined. Information needed to enable full analysis of policies includes the annual government budget for each policy and the amount of REHC deployment resulting from this finance. This study however, was limited to using only readily available information from individual nations. It was therefore not possible to link individual policies to the resulting quantities of renewable heat generated. Policies also over-lapped in time making direct comparison even more difficult. Therefore, the package of carrot-based subsidy/grant schemes offered by any country was examined as a whole and simply compared against the total renewable heat generated in that country.

For a true international comparison, it is necessary to present information such that any discrepancies between nations are minimized to the best extent possible. For this reason, budgetary information is here presented as the average annual €/capita over the period 2000-2005, the 6 year period being chosen to give an accurate overview of recent political activity and consequent deployment of renewable heating.

The annual renewable heat generated in terms of TJ per 1 000 capita was chosen as the indicator assuming that a successful policy would stimulate an increase of heat generation. If a decrease occurred, a policy could be presumed to be less successful. For example, if in country X, 150 PJ of renewable heat was generated in 2004, 160 PJ in 2005, and 165 PJ in 2006, then the total amount of renewable heat demand over the 3 years increased by around 10%. However, there was a greater increase in renewable heat generated between 2004 and 2005 (10 PJ) than was witnessed between 2005 and 2006 (5 PJ). Therefore, the *change* in renewable heat deployment is most clearly evident when the data is presented as TJ per 1 000 capita per year which also minimizes the inherent differences in size and natural resource availability across countries.

Limitations

This analysis made it possible to obtain a generalized perception of the effectiveness of the levels of carrot-based incentive across the 12 nations. However, a lack of readily available information on both government investment and renewable heat generated as a result of individual policies limited the accuracy. Hence, the information presented here is not exhaustive, but was felt to be sufficient to draw at least preliminary conclusions.

A comparison of policies across nations is complicated by the inherent differences in the availability of natural resources (*e.g.* the forest biomass resource in Sweden or the solar resource in Spain). These dampen the opportunity to make country comparisons on the amount of renewable heat generated alone. For example, if a given budget €X was invested in subsidies to encourage the installation of a similar number of solar water heaters in Spain or in the United Kingdom, the amount of heat that would be generated as a result would be much higher in Spain, simply because of the higher solar radiation level. Differences in land area and population add further factors for consideration. Again, it was felt that the simple analysis of effectiveness as presented here is sufficient to provide a basis for drawing conclusions regarding designing a policy for renewable heat, but the key national differences also need to be taken into account.

The compounding influence of complimentary stick and guidance-based policies must not be forgotten. Although this analysis is based strictly upon government budgets for subsidy/grant carrot-based incentive schemes, the renewable heat generated is undoubtedly influenced by the presence of additional support mechanisms. In Sweden for example, in addition to the subsidies for biomass, the high energy taxes placed on conventional fuels also have an effect by increasing the cost-competitiveness of biomass heat. Such factors have not been accounted for in this analysis.

Results

In this preliminary analysis, national policies were categorised in terms of government investment budget (averaged over the 6 year period 2000-2005) and heat generated for each specific technology over the same period. There was no clear correlation amongst the data presented for solar thermal, bioenergy or combination of technologies (Figs. 33, 34 and 35) which may be explained, at least in part, by quantitative uncertainties. Several broad conclusions may nevertheless be drawn. More financial support was allocated for biomass heat than for solar thermal or geothermal heat. As a result, there was a significantly higher annual increase in biomass heat generated per capita than for the other technologies.

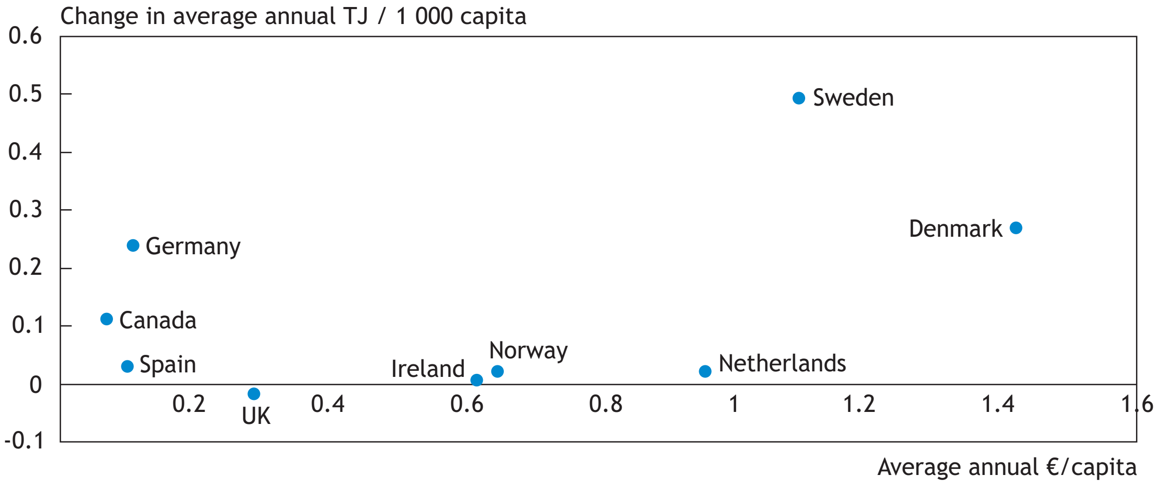
Sweden and Denmark had the highest average annual increase in biomass heat having invested most heavily in subsidies and grants for biomass technologies on a per capita basis (Figure 33). In contrast, Germany and Canada also saw an increase in biomass heat (possibly due to the good resources available), but with significantly lower financial support.

The amount invested per unit change of renewable heat generated from the 2000 baseline is of greatest interest: the lower the financial contribution per increase in heat the better.

For biomass, Germany and Canada are the leaders with Sweden and Spain as a distant third and fourth. The effectiveness of Swedish and Canadian policies is not surprising given the resource is exceptional in comparison with others countries surveyed. Germany, with a somewhat lower biomass resource, also had a good increase in biomass heat generation in terms of investment per capita. Both Germany and Sweden have implemented an Ecotax on fossil fuels which has supported biomass heat generation. Germany has additional incentives through its Combined Heat and Power Law, financed by the final consumer rather than through the public purse. As such, the results of German incentives are not all reflected in the government budget.

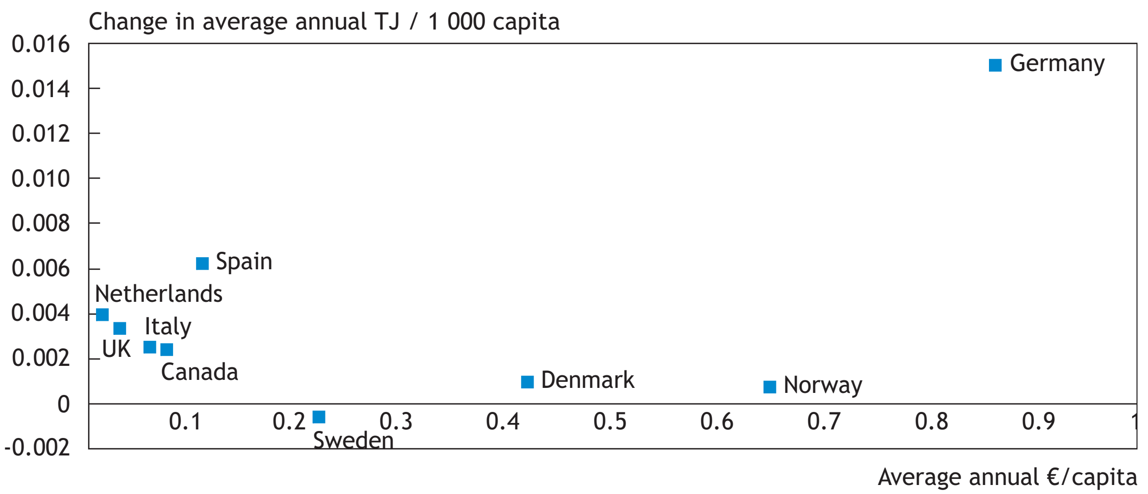
For solar thermal technologies a much lower public budget was allocated between 2000 and 2005 by all the countries surveyed. The amount of heat generated by solar thermal is also on a much lower scale. Germany achieved the highest increase in solar water heating, but invested more per capita than any other nation surveyed (Figure 34).The UK and Spain were most successful in stimulating solar thermal heating for the lowest per capita investment. The primary mechanisms for support in the UK are subsidy/grant schemes, but education and guidance schemes have also been an important component of the support package. Investment in creating greater public awareness may have contributed to this successful uptake, which is especially remarkable due to the relatively poor solar resource. Spain, by contrast, has a better solar resource and much of the development has been the result of their regional obligations for solar thermal heat. These mandates require very little if any public investment, thus improving the amount of solar heat generated per € invested.

Figure 33 • *Coarse indication of policy effectiveness obtained by comparing average annual government investments per capita between 2000 and 2005 against the average annual change in total biomass heat generated per 1 000 capita for selected nations*



Note: 2005 € and exchange rates

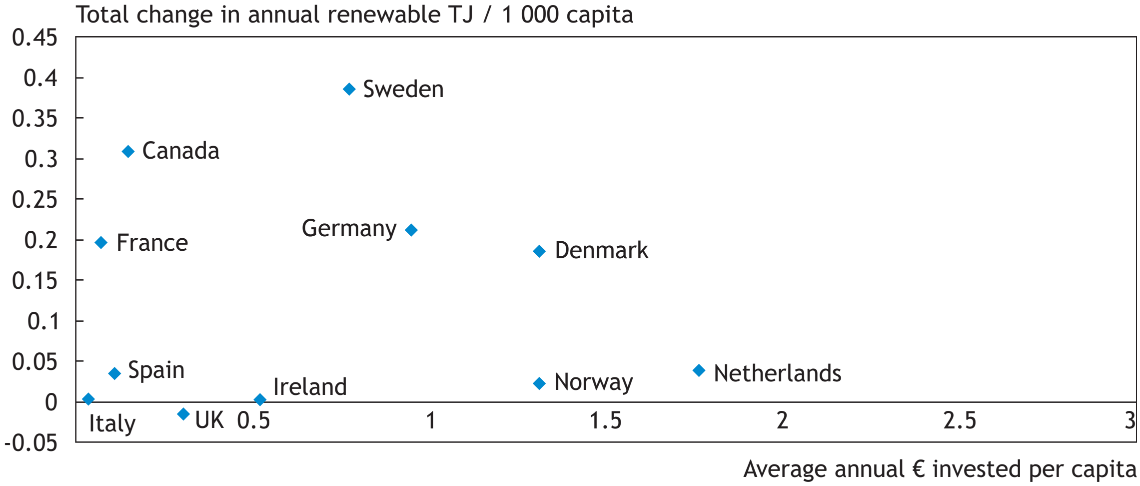
Figure 34 • *Coarse indication of policy effectiveness obtained by comparing average annual government investments between 2000 and 2005 against the average annual change in solar thermal heat generation per 1 000 capita across selected nations*



Notes: *2005 € and exchange rates*. Scale differs from Figure 33.

The total renewable heat produced from solar, biomass, and geothermal together was compared against the average annual investment per capita for renewable heat. Most countries invested less than €2/capita with the Netherlands highest at around €1.7 (Figure 35).

Figure 35 • *Coarse indication of policy effectiveness obtained by comparing the total average annual government investment between 2000 and 2005 in grants and subsidies against the annual average change in renewable heat generation per 1 000 capita from the base year across selected nations*



Note: scale differs from Figs 33 and 34.

Data from France is uncertain and a breakdown into individual technologies as for other countries could not be made. However, overall both France and Canada were the most successful in terms of investment per heat output across all technologies. Across all countries, for biomass €0.02 was invested to gain 1 TJ of increased heat output on average, compared with €0.12 /TJ for solar thermal heat output. Therefore in general terms, countries that invested most heavily in solar thermal such as Germany have received a lower return of heat output than those that favoured investment in biomass heat such as Sweden, Denmark, and Canada. Investment data for geothermal heat was available for only the Netherlands and Denmark but included for them in Figure 35, thus inflating their total annual investment slightly above the other nations where such data was not available.

Poor correlation between government investment in financial incentives and the change in renewable energy heat generated indicates such policies are only one of a number of factors influencing the development of renewable energy heat markets. In order to accurately compare national investment per unit of renewable heat generated, other external factors that could have had an influence should also be considered including:

- the status of the technology in the market and whether or not a critical mass has been reached;
- the natural resource availability which, if not abundant, may need greater government subsidies or grants to gain REHC deployment;
- the influence of related policies, possibly those including other fiscal incentives that are difficult to quantify specifically;
- regulations that might impact on REHC deployment such as tighter air emission controls in the UK that led to industry replacing old biomass boilers with clean gas; and
- excluding possible longer term developments from a short term evaluation, for example the 2005/06 REHC policies implemented in Ireland not yet having their full impact in terms of full public awareness, development of infrastructure and training.

Recognising that financial incentives are only one of many influencing factors, in order to obtain the greatest increase in REHC per € of investment, it is recommended to implement a package of incentives, possibly including carrot, stick and guidance measures. The policies should be long term and coherent and aimed at specific technologies. Since solar thermal technology, for example, is less mature than say biomass combustion, it can require greater government investment per unit of useful heat output. Moreover, for policies to be best suited to a given region, they should relate to any external factors, including the local status of a technology and its market.

Good policy practices

Examples of successful policies for solar, biomass and geothermal technologies for each category of policy instrument, were selected to indicate the potential for resulting deployment of REHC projects (Table 7). In addition market-led examples were included in order to provide an understanding of external influences on the growth of renewable heating markets, such as the good availability of competitive renewable resources and the unreliability of some conventional heating fuels.

Examples were chosen based upon the status of the technology market in a given country (market leaders), degree of innovation, relevance to the category, and on the advice of the IEA implementing agreements for Solar Heating and Cooling, Bioenergy and Geothermal.

Table 7 • *Examples of good policy practices for solar, biomass and geothermal heat across carrot, stick, and guidance policies together with market-led examples.*

	Solar thermal	Biomass heat	Geothermal
Carrots	Germany: Market Incentive Programme	Sweden: Tax Incentives	Switzerland: SwissEnergy Programme
Sticks	Spain: Barcelona Solar Thermal Ordinance	Denmark: regulations for biomass heat supply	[12]
Guidance	Austria: Subsidies & Information Scheme	Canada: REDI Information and Capital Subsidy Program	Sweden: Technology Procurement
Market-led	China	New Zealand	Iceland

Carrots (Table 7)

Solar thermal: The German market incentive programme

The Marktanreizprogramm (MAP) has successfully supported the growth of the solar thermal market since September 1999. Although it has been criticized for there being fluctuations in annual funding (see below), it has brought Germany to the forefront of worldwide solar thermal market penetration by means of long-term support grants; long-term and low interest loans (to a lesser extent); and the partial release of debts for solar thermal installations. Additional support for solar thermal was provided by the parallel Solarthermie 2000 programme and the subsequent 2004 Solarthermie 2000 plus programme that focused on larger applications and connections to district heating grids.

12. No relevant example could be found within the timeframe of the project for a stick-based policy in support of geothermal.

The MAP was not designed exclusively for solar thermal and no quota was established in terms of specific technologies. Most of the funding available, however, was allocated to solar thermal installations, in spite of the greater cost gap between solar thermal and conventional fossil-fuel based heating technologies than for biomass installations. This may be due, at least in part, to the strong establishment of the solar thermal market in Germany. The technology has been supported by successful awareness campaigns and has a strong industrial lobby. Therefore the visibility and the public preference for solar thermal may account for it receiving a significant proportion of MAP funding.

Targets were not specified for the MAP. However, in 2002 a general target was set to double the amount of solar thermal in Germany, aiming for 10 million m^2 of collectors installed by 2006 (ESTIF, 2006a). Homeowners, small and medium-sized businesses, municipalities, and other registered associations are eligible to apply for grants. Soft loans are available for solar thermal collectors. Over the course of the programme, the administrative processes have been streamlined and simplified such that an application for a subsidy may now be processed and authorized within 2-4 weeks. As part of this streamlining process the distinction between flat-plate and vacuum collectors was abandoned in 2001, thereby putting vacuum collectors at a disadvantage in terms of their share of the grant per total investment (Langniss and Seyboth, 2007).

The German Federal Ministry for the Environment (BMU) is responsible for establishing the guidelines and stipulations of the MAP. Grants for solar thermal collectors are available through the German Federal Office of Economics and Export Control (BAFA) that is responsible for implementation. Grants provided on a €/m^2 collector area basis supply averaged roughly 15% of investment and installation costs.

A performance requirement for eligibility of a minimum annual heat yield of 525 kWh/m^2 was introduced to ensure minimum technical standards, thereby excluding low performing solar thermal collectors. As a result, unglazed and plastic absorber collectors typically used for swimming pool heating were ineligible for funding (ESTIF, 2006a). The performance requirements were increased in 2004 to fulfil European Union State Aid regulations.

Financing

Much of the funding for the MAP originated from the revenues of Germany's Eco-tax[13]. As this funding is from the public purse, financing levels must be approved by the German parliament each year as part of the federal government budget. When the programme began in 1999, an annual budget of €100 M was allocated for all supported technologies. The annual budget available for solar thermal installation grants fluctuated between €40 M and €110 M with €94 M provided in 2006. At the same time, the average level of support granted per installation decreased from €1588 in 2000 (16.1 % share of average investment costs) to €917 in 2006 (12.6% share of average investment costs). Most grants went to the installation of flat-plate collectors with vacuum tube collectors accounting for only 12% of the total supported collector area.

Public funding totalled €588 M from 1999-2005, triggering a total investment of €4.7 billion (ZSW, 2006). Grant levels were increased in 2002, 2003, and 2005 (Table 8) primarily in an attempt to compensate for insufficient annual budgets, or to allow for higher grants per unit and therefore stronger support for market growth. Grant levels were decreased in 2001 due to insufficient available funding and in 2004 when decision-makers assumed that the support available under a successful incentive should be continuously reduced to reflect the development of the technology, thereby meeting the requirements of European State Aid regulations. The levels of MAP funding depend on the technology and plant size. In 2007 grants available ranged from €40/m^2 to €70/m^2 of solar installation.

13. The German EcoTax implemented in 1999 places a tax on conventional fuels for transport and electricity generation.

In 2005, in addition to increasing the levels of grants available, the focus of the grant scheme was shifted. A higher level of financial incentive was made available for domestic space and water heating combination-systems while a lower incentive was available for solar water heating systems. As a result the combination, solar thermal systems showed a notable increase in average size installed[14]. Higher levels of support are required as typically, larger combination systems are purchased by commercial entities rather than private households. Hence, requirements are higher on their economic feasibility. As a result, beginning in 2007 larger space heating combination installations with an area of 20 m^2 to 40 m^2 that supply heat to buildings with at least three apartments are eligible to receive a higher grant of €210/m^2 whereas installations larger than 40 m^2 are eligible to receive a grant worth 30% of the total investment (Langniss and Seyboth, 2007).

Table 8 • The development of grant allocations from 1999 until 2007 for solar thermal collectors within the German MAP policy.

Date of coming into force	Investment grant (€/m^2) Hot water only	Investment grant (€/m^2) Space heating combination	Remarks
01-09-1999	Flatplate: €128 /m^2 Vacuum: €167 /m^2		Minimum yield: 350 kWh/m^2/yr; Expansion of existing plants: €50 /m^2
25-07-2001	€87 /m^2		Minimum yield: 350 kWh/m^2 /yr; no expansions
23-03-2002	€92 /m^2		
01-02-2003	€125 /m^2		
01-01-2004	€110 /m^2		Minimum yield: 525 kWh/m^2/yr; Expansion of existing plants: 60 €/m^2
01-07-2005	€105 /m^2	€135 /m^2	
21-03-2006	€84 /m^2	€108 /m^2	Minimum yield: 525 kWh/m^2/yr; Expansion of existing plants: 48 €/m^2
21-06-2006	€54.60 /m^2	€70.20 /m^2	
12-01-2007	€40 /m^2 Minimum € 275	€70 /m^2 (< 20 m^2) €210 m^2 (20-40 m^2)*	Minimum yield: 525 kWh/m^2/yr; Expansion of existing plants: 30 €/m^2

Source: (Langniss and Seyboth, 2007)
**The higher grants for larger space heating combination systems are eligible only for community dwellings.*

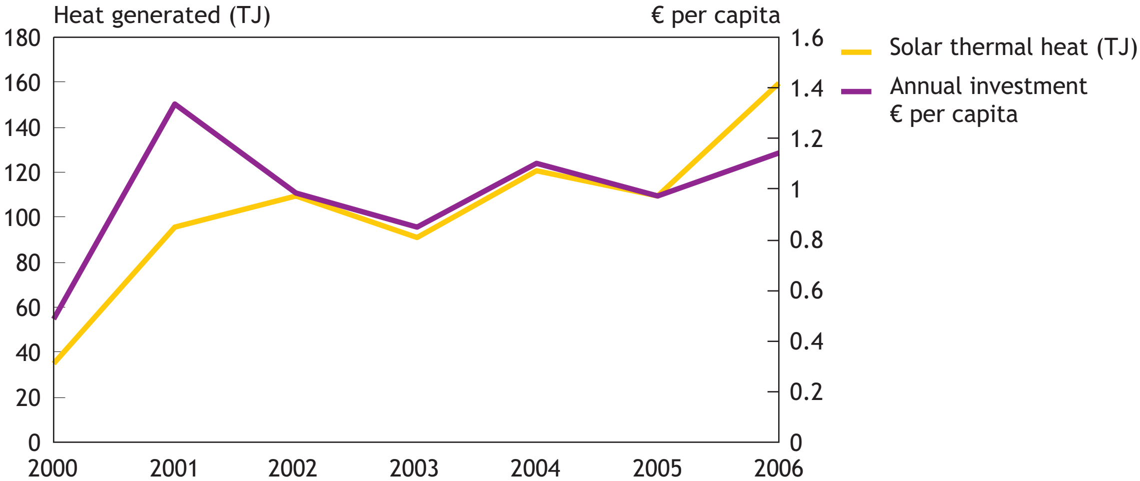
Market growth

The number of solar thermal installations supported by the German MAP increased from 26 000 in 2000 to more than 102 000 in 2006. The total solar thermal collector area supported increased from nearly 200 000 m^2 in 2000 (equivalent of 32.6 TJ/yr) to 978 000 m^2 in 2006, (159.7 TJ/yr) (Figure 36). If MAP budget restrictions had not precluded the allocation of additional grants to applicants, the annual installation in 2006 could possibly have been even higher.

Over 90% of all solar thermal installations in Germany have received financial incentives allocated through this programme, with approximately 75% of funding used for domestic hot water systems and 25% for combination systems including space heating. The correlation between the number of applications and the grant levels available clearly demonstrates the importance of the MAP for market deployment (Figure 37).

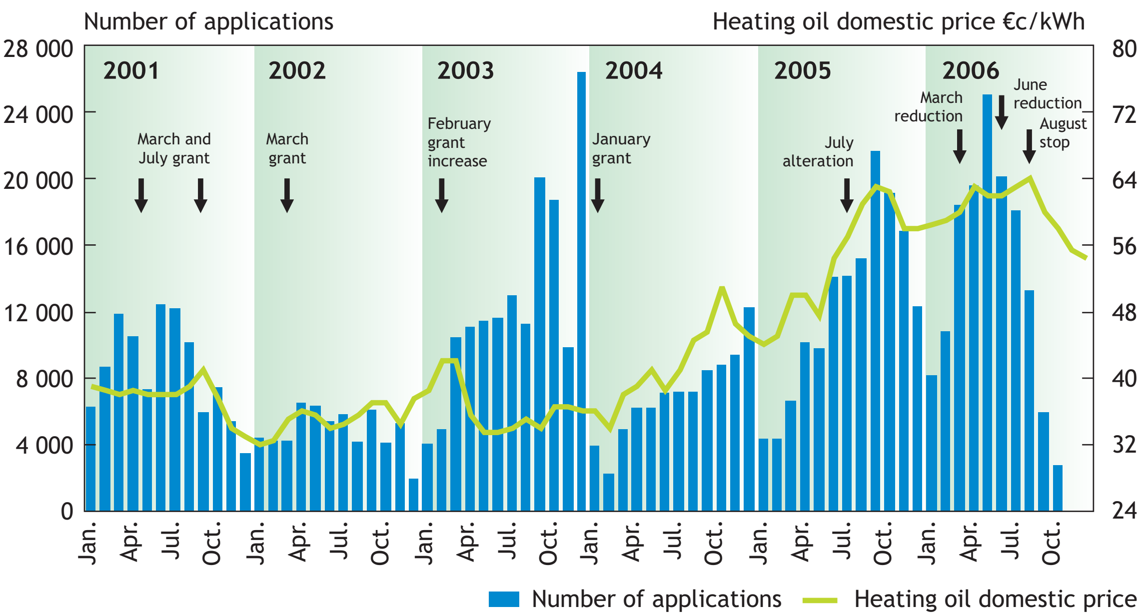
14. In the first 4 months of 2006, applications for collector area averaged 11.4 m^2 of collector area per system, up from 10.1 in 2005 and 9.7 in 2004 (ZSW, 2006).

Figure 36 • *Solar thermal heat generated annually from 2000 to 2006 and the coinciding annual total of grants allocated per capita as supported by the German MAP policy*



Source: BAFA, 2007.

Figure 37 • *Variation in the number of monthly MAP grant applications as compared to the development of conventional heating oil prices and reflecting changes in MAP funding (as shown by arrows and month)*



Source: BSW, 2007. Note: details of MAP and policy changes can be found in Annex B4.

The strong demand for solar thermal collectors and for grant support has put a great deal of stress on the available budget. Consequently, grants were substantially decreased twice in 2006 before the programme was entirely exhausted for the year in August 2006. Despite the insufficient source of funds to meet demand, record levels of annual installations were set in 2006 in Germany with 1.5 M m^2 installed against 1 M m^2 in 2005 (BSW, 2007).

In summary

The MAP has been successful in stimulating the solar thermal heat market such that the German market is now the largest in Europe and the second largest worldwide (Section 3). Annual fluctuation in available funding, causing insecurity in the reliability of the fund, has reflected in fluctuations in application rates. The inability of the available funding to assure financing to all applicants may have restricted the growth of the market. This exemplifies the difficulty in providing appropriate levels of funds in annual government budgets. The MAP was also criticized for inadequately communicating the availability of funding to potential investors, being publicized primarily through the solar thermal industry, associations, and installers.

Although the MAP provided around only 15% of investment costs, this subsidy to help reduce the cost gap between conventional heating was sufficient to catalyse development of the market. In addition, simplifying the administrative process and implementing a well-designed, carrot-based, government funded policy mechanism supported the development. However, it is apparent that stop-&-go type policies discourage long-term investment and disrupt market development. Reliable, long-term policies are necessary to instil ongoing confidence by investors.

Biomass: Swedish tax incentives

Substantial energy taxes have been employed in Sweden since 1973 when the first tax was levied on oil following the first oil crisis. Through the 1980s there was a reduction in oil consumption and an accompanying increase in the use of coal, electricity and biomass, to a limited extent, as a result.

Carbon dioxide (CO_2) and sulphur taxes on fossil fuels were introduced in 1991 as part of an energy tax reform to target environmental objectives[15]. In 2006 CO_2 tax levels were approximately €100/t CO_2, being around 250% higher than when the policy was first introduced. These high taxes have had significant repercussions on the development of biomass because when used in district heating systems, it is exempt from the combination of oil, CO_2, and sulphur taxes. The *Energy Tax Exemption for Biomass* has created a cost competitive advantage such that in district heating systems biomass-based heat can be produced at a much lower cost than heat produced from fossil fuels (Johannson *et al.*, 2002). Biomass has become less expensive than coal as a heating source from 1991 as a result of these legislative incentives (Ericsson *et al.*, 2004).

To maintain the competitiveness of Swedish industry, exemption from the electricity tax and reduction in environmental taxes were granted. The levels of these tax reductions have fluctuated over the lifetime of the energy taxes (Johannson *et al.*, 2002). A CO_2 tax reduction of 25% (€20/ton CO_2) was granted to the industrial and manufacturing sectors in 1993 but for industry it was increased to 50% in 1997 and to 70% in 2002. The exemption was extended in 2000 to include the agriculture, forestry, and aquaculture sectors. As a result of these exemptions biomass heat is not as cost competitive for industry as heat produced from fossil fuels. These tax exemptions for industry have thereby dampened the effect of the tax exemption for biomass, especially for use by industry. For CHP plants which feed into district heating systems, a full CO_2 tax and 50% energy tax is imposed on fossil fuels.

Energy taxes have been increased incrementally with increases in the CO_2 tax levied in 1996, 1997, and 2001. In the spring of 2000, a total of €3.3 billion[16] of tax revenue was shifted from employment (taxing the good) to energy use (taxing the bad) over a ten year period. Energy and environmental taxes were increased, offsetting a corresponding reduction in taxes on employment (SEA, 2006). The revenue from energy taxes since 1993 has totalled €53.5 billion. CO_2 taxes have generated €25.7 billion since 1993 and sulphur taxes have generated €219 million since 1993 (Statistics Sweden, 2007).

15. A charge was also employed on emissions of nitrogen oxides (NOx) in 1992. Biomass was not exempted from the NOx charges but only negligible effects result so they are not discussed in detail. In addition, taxes have also been employed on electricity consumption.

16. SEK 30 billion. Currency exchange rate based on average trade value for 2006. 1 SEK = €0.11.

Infrastructure

Sweden is a country rich in natural biomass resource and has a long history of large-scale forest production. Around 52% of total land area is composed of productive forest land. As a result, much of the biomass heat resource comes directly from the forest industry including woody biomass fuels and black liquor used in pulp mills. Around 40% of the timber and pulpwood logs consumed by the forestry industry ends up as process by-products and residues that are used for bioenergy (Ericsson and Nilsson, 2004). The combination of abundant biomass resources and a well-developed infrastructure for their delivery has contributed significantly to the success of the biomass heat market. Policies developed originally to support the Swedish forest industry were exploited for the biomass heat supply chain. Support by the forest industry for biomass heat also had an impact on the design of supporting legislation.

The extensive district heating infrastructure also facilitated the rapid deployment of biomass. Large-scale district heating was first employed in the 1960s when the fuel mix was completely dominated by oil. Between 1982 and 1994 the Solid Fuel Act required that new district heating plants with more than 50 GWh (180 TJ) of production capacity had to be designed to be compatible with solid fuels (Ericsson and Nilsson, 2004). Hence, the heating infrastructure could be easily converted to make use of the biomass resource. The existence of established actors and structure in forestry and district heating has facilitated the response to strong and long-standing policy commitments to biomass (Ericsson *et al.*, 2004).

Market growth

The use of biomass for heat in Sweden has increased significantly since 1990 (Figure 38) reaching 48% of total heat for industry, 30% for district heating and a further 12% by the residential sector. Most of the biomass is produced from the expansive forests. However, in order to fulfill the increasing demand for wood-chips and wood-pellets in the early 1990s, Sweden began to import these fuels (estimated to be between 12.6 PJ-32.4 PJ (4 - 9 TWh) of energy equivalent per year) from the Baltic States, Russia, and Canada[17]. This shifted the traditional patterns of regional consumption and use. Peat, municipal waste, straw, and vegetative grasses[18] are also incinerated to produce heat, although they play a minor role.

The use of biomass in district heating systems has increased substantially since the taxation scheme only supported the use of biomass for heat production. Since the early 1980s the use of biomass in district heating systems has increased from 18 PJ (5.0 TWh) in 1984 to 150 PJ (42.1 TWh) in 2004 (Figure 39). Rapid expansion of biomass used in district heating began after the Energy Tax Reform of 1991 (Ericsson and Nilsson, 2004). By 2006 biomass accounted for 62% primary fuels used for district heating (SEA, 2006).

As electricity is taxed regardless of fuel-type, biomass has no advantage in power or CHP production. Due to the low cost of electricity which resulted from the liberalization of the electricity market in 1996, only biomass CHP plants that received a subsidy have been constructed (Johansson *et al.*, 2002).

In summary

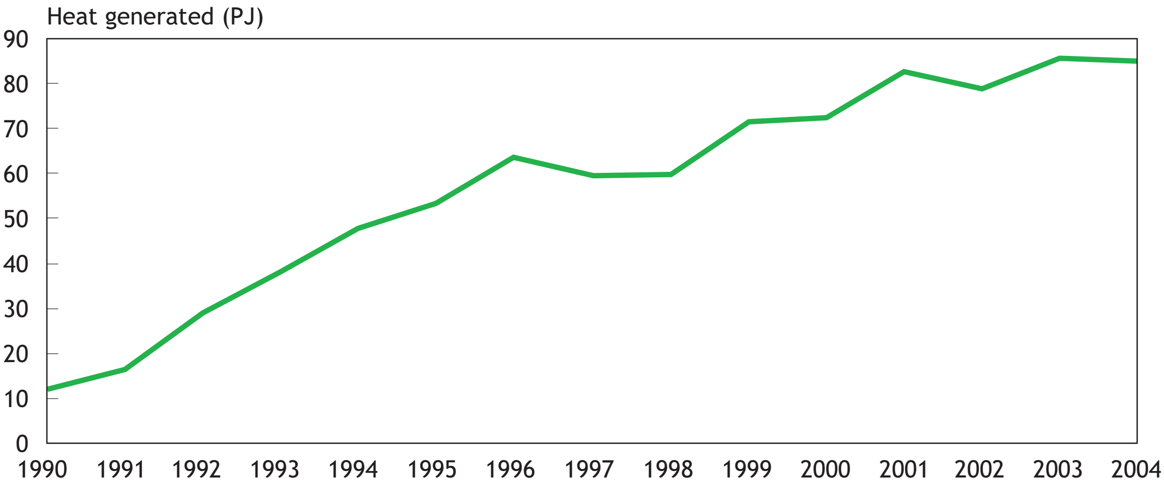
By exempting biomass from Swedish energy taxes, the government provided strong, indirect support for biomass heat. Biomass became the least-cost option for district heat production in 1991 due to these exemptions, effectively levelling the playing field with conventional fuels. Subsidies were also offered for biomass installations, technology demonstrations, and long-term RD&D efforts. Due to the package

17. In 2000 it was estimated that 760 000 tonnes of wood fuel was imported into Sweden, equivalent to 14.3 PJ (Ericsson and Nilsson, 2004).

18. The increased use of energy crops (including coppice Salix) may have been impeded by the common agricultural policy which gives preference to annual food crops over perennial energy crops. Following the implementation of this policy the levels of short-rotation forestry production in Sweden stagnated.

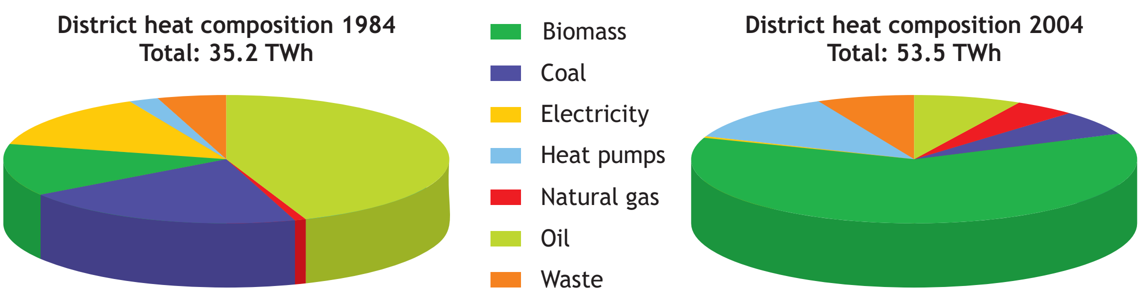
of government incentives, for the existing forest industry infrastructure to produce biomass fuel sources and the adaptability of the district heating systems (facilitated by the 1982 Solid Fuel Act), Sweden is a global leader in biomass heat generation.

Figure 38 • *Heat generated by biomass sources in Sweden from 1990 to 2004*



Source: IEA, 2004. Note: Increased subsidies for CHP in 1998 and biomass energy tax exemption in 2000 gave increased deployment (Annex B11).

Figure 39 • *Fuel resources used by Swedish district heating systems in 1984 and 2004 showing the growth of biomass*



Source: SEA, 2005

Geothermal: Swiss subsidies

The successful deployment of geothermal heat energy in Switzerland resulted from the Energy 2000 Action Plan (1991-2000) and its successor, the Swiss Energy Action Plan, or "SwissEnergy" (2001-present). These programmes cover many energy areas including energy efficiency, transport and industry with the promotion of renewable heat being an important component.

The Energy 2000 Action Plan aimed to increase the contribution of renewables for heat production by 3%. At its conclusion in 2000, renewable heat had increased by 2.1%, being 0.9% short of its target (IEA, 2004). The SwissEnergy successor programme aims to increase the contribution of renewable heat[19] by a further 3% by 2010 compared to 2000 levels. This is equivalent to roughly 10.8 PJ (3 TWh)

19. SwissEnergy also aims to reduce the consumption of fossil fuels by 10% by 2010; limit the increase of electricity consumption to 5%; and increase the share of non-hydro renewables in electricity production by 1.8 PJ (0.5 TWh).

of renewable heat. Although there are no fixed targets, SwissEnergy has identified possible annual increased contributions of heat from solar thermal to be 15% growth per year, 1.8 PJ /yr from GHPs, and 10 MW new capacity per year from geothermal.

A Swiss Heat Pump Promotion Group was established as part of the marketing strategy of the Energy 2000 Action Plan and to lead promotional efforts such as training, quality assurance, and after-sales service. Subsidies of €200 per kW[20] were offered.

SwissEnergy, the successor program to the Energy 2000 Action Plan, builds cooperation between the federal government, Swiss cantons, and local authorities with industrial, consumer, and environmental organizations and public and private sector agencies by implementing voluntary measures based on performance mandates. Based upon these performance mandates, target agreements are established with companies and sectors specifying binding targets for each partner involved (SwissEnergy, 2004). In addition, SwissEnergy provide lump sum payments for cantons, information campaigns, and RD&D programs and continued many of the activities of the Energy 2000 Action Plan. Although all direct incentives for renewable energies available under the Energy 2000 Action Plan were eliminated, SwissEnergy established important voluntary financial contributions to cantonal programs for renewable heat (IEA, 2004). A new phase of the SwissEnergy programme for the period 2006-2010 was designed in 2005 and was implemented at the beginning of 2006.

Under SwissEnergy, the Swiss Geothermal Society was given the responsibility of promoting geothermal energy at the national level. The network of experts that was created under this framework aimed to target 4 main activity areas within its promotional scheme: information, marketing, education, and quality assurance. As part of this national promotional scheme, various brochures on geothermal heat have been produced, Geothermie Newsletters have been published, and a database created with people and organizations in Switzerland involved in geothermal energies as part of the information branch. Regular university lectures and various workshops have been organized as part of the education support. In addition, a quality label was introduced in 2002 for the entire geothermal heat pump system as part of the quality assurance activity requirements. The activities of the Swiss Geothermal Society helped enforce the success of this package of incentives.

Financing

Approximately half of the total budget of the Energy2000 Action Plan was allocated to renewable energies. Between 1990 and 1997 the average annual expenditure for renewables was €13.7 M. This increased by 2000 in the last 3 years of its lifetime to between €21.5 M and €22.9 M. Approximately 46.5% of funding for this early programme went to promotional activities including direct incentives for the purchase of new renewable systems. A further 37.5% went to RD&D and 16% to pilot and demonstration projects (IEA, 2004).

In 2003 the total SwissEnergy budget was €33.6 M but dropped to €27.5 M in 2004. For all renewables, a voluntary annual investment of €6.1 M has been allocated from private companies and the Swiss cantons.

Heat pumps, based on air and water as well as geothermal, received €0.82 M in 2003 (SwissEnergy, 2004). In addition the promotional programme for geothermal energy was allocated a budget of €170 000 in 2001 and €310 000 in 2002, the first two years of its operation.

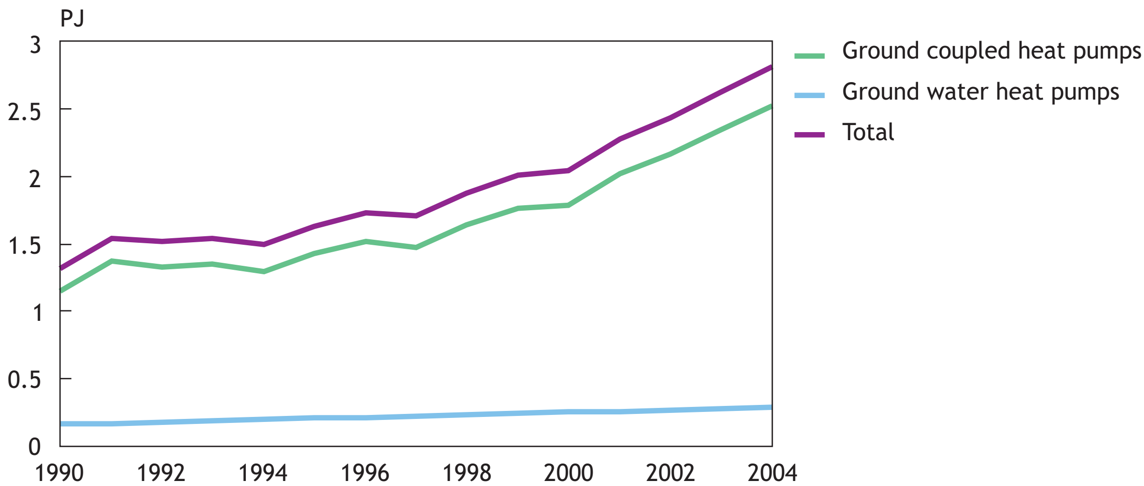
Market growth

Roughly 18% of the renewable heat generated in Switzerland is from geothermal heat pumps (SwissEnergy, 2004). In 2005 Switzerland had an installed capacity of 609 MW of direct geothermal heat, generating

20. Exchange rate: CHF 1 = €0.61.

4.7 PJ of heat annually (GIA, 2006). The key achievement of the Swiss policies relating to geothermal heat has been in the significant growth of the GHP market (Figure 40). In addition there is a trend towards increased utilization of larger geothermal systems for heating and cooling (GIA, 2006).

Figure 40 • *Heat generated by geothermal heat pumps in Switzerland from 1900 to 2004*



Adapted from Signorelli et al., 2004

Roughly 25% of the heat pump sales in Switzerland have gone towards renovation. There is no geothermal electricity production in Switzerland at present.

In summary

The 1991 Energy 2000 Action Plan, and its successor SwissEnergy programme have helped grow the geothermal heat pump market in Switzerland (Figure 40). In addition to external influencing factors, such as increasing costs of electricity and heating oil, the combination of financial support, voluntary measures, and marketing campaigns through the Swiss Heat Pump Promotion Group created a solid framework for growth of the market.

Energy contracting by Swiss public utilities is an additional success factor whereby utilities plan, install, operate and maintain the heat pump systems, then sell the heat to the property owner at a contracted price per unit (€/kWh or €/GJ).

Sticks (Table 7)

Solar thermal: Spanish regulations

The *Barcelona Solar Thermal Ordinance* was implemented in August 2000. It requires that at least 60% of hot water demand is met from solar thermal energy in all new buildings or buildings undergoing major renovation. The objective is for 100 000 m^2 of solar thermal collector surface area to be installed by 2010 (EC, 2006a). It is a requirement that the best available solar thermal technology is used and compliance must be verified with measured data. Exemptions are considered where it is not possible to meet the entire 60% of hot water demand.

The Ordinance was originally only applicable to new and renovated buildings above a specific size category (greater than 292 MJ/day of hot water energy consumption). In early 2006 Barcelona approved an amended ordinance eliminating the minimum energy requirements and setting explicit fines for violations ranging from €6 000 to €60 000. The revised ordinance also established improved maintenance and architectural integration requirements and required swimming pool heating to be 100% solar (REN21, 2006).

Monitoring and assessment has been carried out by the Barcelona Energy Agency (BEA) since 2003. In conjunction with its responsibilities, the BEA published a *Guide to Solar Thermal Energy Facilities* using simple language and graphics to explain the technical aspects of solar thermal as well as its benefits.

Seville and Pamplona in 2002, and Madrid in 2003, followed Barcelona's example. Pamplona's solar ordinance entered into force in mid-2004 and caused a 50% regional increase in solar thermal collectors in one year (REN21, 2006). Twenty municipalities in Catalonia have adopted similar regulations which has increased the installed surface area of solar thermal collectors in the region by 20 000 m^2 in 2003 and by a further 25 000 m^2 in 2004. In addition, 22 Catalan municipalities and the Catalan Institute of Energy (ICAEN) set up a Solar Ordinance Support Centre, to pool experience and technical solutions for the use of local authorities who chose to implement similar policies. As of 2006, more than 70 municipalities and cities in Spain including Valencia and Burgos adopted similar ordinances. These municipal solar obligations will remain in force as long as they are stronger than the new national obligation included in the Spanish *Technical Building Code* (REN21, 2006).

In March 2006 the government adopted a federal solar thermal ordinance or *Technical Building Code* **(**Código Técnico de la Edificación). It obliged owners of all new buildings and those undergoing renovation, to provide 30-70% of their domestic hot water demand by solar thermal energy. The code is applicable to all buildings, independent of their use. The specific percentage of heat requirement for a building depends on its geographic location and individual demand by the residents for hot water. This technical code was established under the *Spanish Royal Decrees 314 and 315* of 17 March 2006 that also created a Council for Building Sustainability, Innovation and Quality (CSICE) responsible for ensuring compliance and participation (ESTIF, 2006b).

Market growth

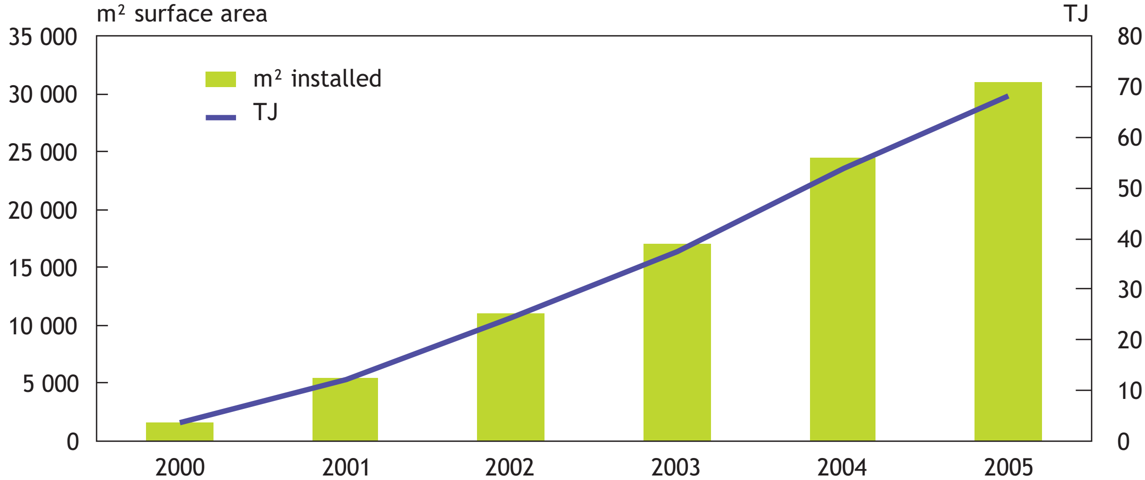
As a result of the Barcelona Ordinance, around 40% of all new buildings supply their hot water from solar thermal panels. The capacity of installed solar thermal grew 15-fold in its first four years (Figure 41) from 1.1 m^2 per 1 000 people in 2000 to 26.9 in 2006 as a result of 597 new installations. This had increased from 2004 when a total of 31 050 m^2 of collector surface area provided 894 TJ (24.8 GWh) of heat (EC, 2006a).

Most of the solar thermal market resulting from the Ordinance has been in the residential sector (Figure 42). The framework conditions in Spain were ideal for regulatory solar thermal ordinances since the booming housing and construction industry provided opportunity to place a solar thermal ordinance on new buildings. In countries with a slower building sector growth rate, the conditions for such an ordinance may not be so well suited and more emphasis could be placed on regulations for the refurbishment and replacement of heating systems in existing buildings.

The growth of the entire Spanish solar thermal market (Figure 43) could be largely due to the strong regional support through the local obligations for installation. In addition, finance was made available at the federal level in the form of subsidies through the 1999 Plan for the Promotion of Renewable Energy and the 2005 Renewable Energy Plan for 2005-2010 (PER).

Despite the increases in solar thermal heat demand, the growth of the Spanish market has been less than for Germany over the same time period, with an estimated approximate increase between 1995 and 2005 of 1.5 PJ in Spain and 8.0 PJ in Germany. However, the Spanish solar thermal obligation was only implemented nationally in late 2006, and prior to the Barcelona Solar Thermal Ordinance, per capita numbers of solar thermal capacity were exceptionally low, thus potentially inflating annual growth data.

Figure 41 • *Evolution of solar thermal development in Barcelona following the implementation of the city ordinance in 2000*



Heat values (TJ) were extracted from installed capacity data and the average annual energy yield in Spain as reported by the IEA (SHC, 2007).

Figure 42 • *Solar thermal installations in Barcelona by sector*

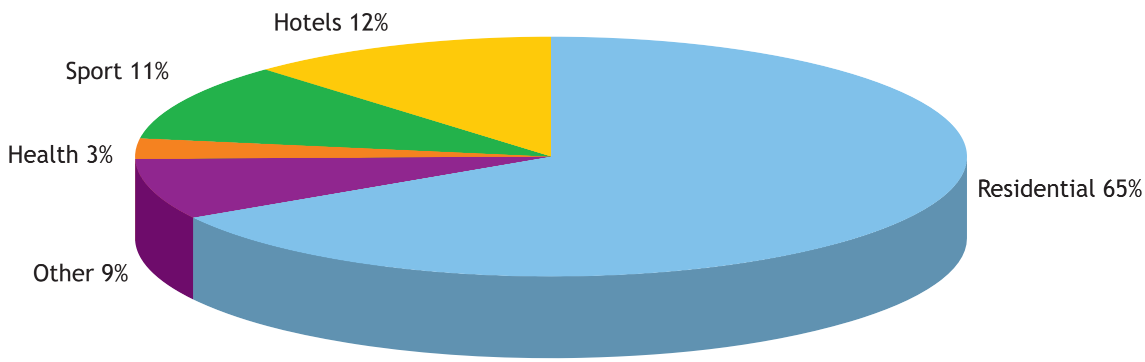
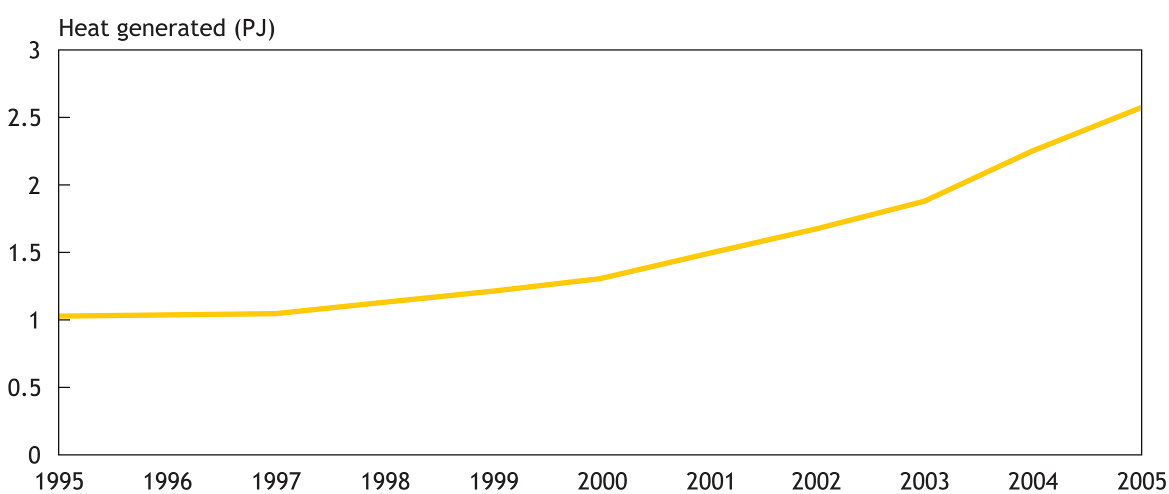


Figure 43 • *Solar thermal heat generation growth in Spain from 1995 till 2005*



In summary

Spain is a pioneering nation in requiring the implementation of solar thermal technologies in all new and refurbished buildings. The 2006 national Technical Building Code obligation applicable only to new and renovated buildings will have an impact on the solar thermal market in the future. However, based on the successes of regional policies in promoting solar thermal heating, in addition to the strong subsidy support available through PER, it is expected that renewable solar thermal heating in Spain will increase significantly.

Biomass: Danish regulations

In June of 1993 the Danish government established the *Biomass Agreement* with the aim of expanding the use of biomass in centralized electricity and heat production. Utilities were obliged by this government decree to replace 6% of their coal consumption with straw and wood and hence CHP facilities had to purchase and utilize biomass as an energy source. Denmark does not have a major forest industry so straw was selected as the main biomass resource although it is less ideal for combustion. Specific requirements were stipulated for the purchase and combustion of at least 1.2 Mt of straw and 0.2 Mt of wood chips per year by 2000 to provide 19.5 PJ of heat energy (DEA, 2005).

Following the implementation of this Biomass Agreement, price hikes due to a limited biomass market complicated compliance with the policy. The agreement was therefore amended in July 1997 to provide greater flexibility in the ratio of straw to wood-chips in an attempt to mitigate pricing problems. This amendment allowed more flexibility of choice by utilities, while the total annual biomass to be supplied remained at 19.5 PJ by 2000. New stipulations were defined as: 1 Mt straw, 0.2 Mt wood chips, and the choice of a further 0.2 Mt from either straw, wood chips, or chips from *Salix* (willow) crops (DEA, 2005).

The successful implementation of the Biomass Agreement took longer than intended. When the policy was first implemented in 1993, CHP biomass-fired technology had not been developed for large scale implementation, and when legislation was passed to liberalize the electricity market in 1999, the Biomass Agreement was destabilized. Lower electricity prices resulted so biomass required additional support to remain cost-competitive (Bertelsen, 2007). This was provided through the 2000 amendment to the Biomass Agreement although the time taken for this support to come into place postponed the effectiveness of the agreement itself.

Further amendments to the Biomass Agreement were made in March, 2000 postponing the target date for biomass conversions to 2004. In addition, 2 or 3 new, large, biomass-compatible CHP plants were targeted for completion by the end of 2005. Finally, in response to liberalization of the electricity market, feed-in tariffs of €0.04/kWh[21] for the electricity generated from biomass in CHP facilities were set for a 10 year production period. A guaranteed minimum price for green certificates of €0.01[22] was established (IEA, 2005). These amendments, together with the introduction of the feed-in tariff for biomass, saw renewed growth of biomass heat generation (Figure 44).

Market growth

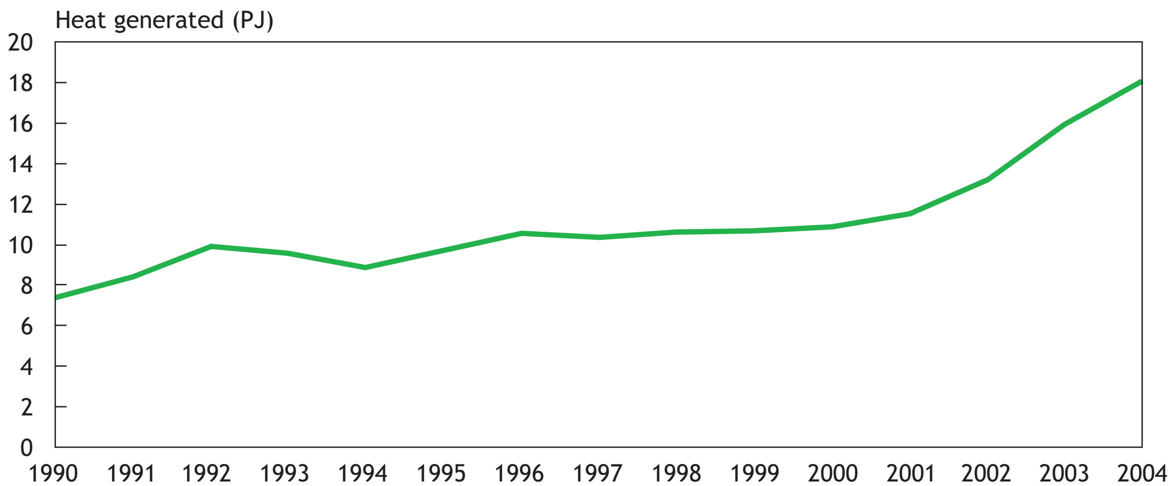
The production of biomass heat in Denmark has doubled since the implementation of the Biomass Agreement in 1993. Several centralized biomass CHP facilities have been constructed and a new plant is in the planning stages (as of May 2007). In addition, the already extensive use of biomass in independent heat generating installations has also been increasing, especially small wood-pellet boilers. In 2007, the Danish Energy Agency (DEA) estimated that 500 000 wood-burning stoves, 70 000 wood-burning boilers, 30 000 wood pellet furnaces, and 9 000 straw-burning furnaces were producing heat.

21. DKK 0.33/kWh (DKK 1 = ~ € 0.1)
22. DKK 0.10

Most Danish biomass consumption uses residues from agriculture, forests, industry, and households (DEA, 2005). Wood pellets and chips are also popular fuels for individual boilers and district heating systems[23]. As a result, there has been an increase in this resource imported from Baltic States and Canada to meet the growing energy demand. In 2005, 13.8 PJ of energy was provided by imported wood pellets, wood chips, and fuel wood (DEA, 2006) (Figure 45).

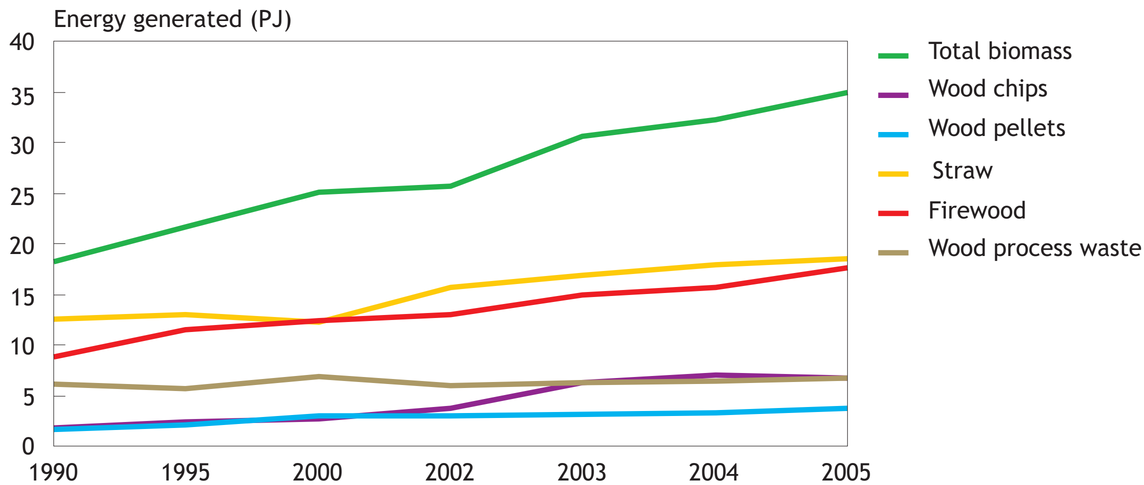
Although by 2000 only half of the planned annual biomass volume was being utilized in central CHP plants, as of May 2007, the target of 19.5 PJ was met. Contrary to the expectations of the original agreement, the amount of straw combusted in CHP plants has been lower and the amount of wood-chips greater, probably due to competitive pricing and the suitability of existing CHP boilers for co-firing with a biomass product similar in characteristics to coal.

Figure 44 • *Growth of biomass heat production in Denmark from 1990 till 2005*



Source: IEA, 2004; IEA, 2006b.

Figure 45 • *Biomass heat energy production in Denmark from 1990 till 2005 categorized by resource type*



Source: DEA, 2006. Note: Data include biomass used for electricity generation.

23. Biomass currently accounts for around 38% of heat generated by district heating systems in Denmark (DEA, 2006).

In summary

Denmark has been innovative in its support for renewable heating with the 1993 Biomass Agreement, one of the only stick-based support schemes in existence requiring the purchase of a renewable heating supply. It has successfully increased the use of biomass in CHP generation facilities and reached its 19.5 PJ target, although a little behind schedule. Biomass has also been supported directly through other Danish political incentives such as *Energy 21* that set targets for 85 PJ and 145 PJ of total biomass use by 2005 and 2030 respectively. The original Biomass Agreement is therefore part of a package of incentive schemes for the development of biomass.

A target for 30% of total primary energy coming from RES by 2030 was declared by the Danish government in February 2007, and biomass as a CHP fuel is seen as one of the most cost efficient options. Therefore, it is likely that the original target of the Biomass Agreement will be greatly exceeded as Denmark works towards its new targets for renewable energy.

Guidance (Table 7)

Solar thermal: Austrian research, training, and education campaigns

Austria, as a pioneering nation in its use of solar thermal energy, is the leading producer and exporter of solar water heating panels in Europe. Its stable domestic market developed since the 1990s and has been greatly influenced by a combination of carrot- and guidance-based government programmes at the federal, regional (Länder) and community levels.

Subsidies for solar thermal are available for firms, associations and public entities, which, in conjunction with financial support from local governments, may cover up to 66% of project costs. Administered by the Kommunalkredit Public Consulting (KPC) bank, federal subsidies for installations over 10 m^2 collector area typically constitute 30% of project costs. Subsidies have been available since the 1993 Umweltförderungsgesetz (Environmental Support Act)[24]. In 2006 €7.4 M was allocated to support 857 solar thermal installations. The Länder often offer their own financial incentives and set individual targets. For example, the Tyrol region aims to double its installed solar thermal capacity by 2010. In 2006 Länder subsidized almost 19 000 installations costing approximately €36 M.

In addition to financial incentives, campaigns and training measures for solar thermal have received much support from many government levels. The largest federal solar campaign is the *Klima: Aktiv Programm Solarwärme* (Climate: active programme on solar heat), begun in September 2004. The 4-year programme, with a €2.6 M budget, was intended to strengthen the Austrian market for solar thermal energy, thereby securing the basis for expansion abroad. It is financed by the Federal Ministry of Agriculture, Forestry, Environment and Water Management, the Austria Solar Association, and a sponsoring group of seven solar thermal companies. Individual organizations within a consortium are responsible for administrating the campaign[25]. The aim is to support regional campaigns; information and promotional events (including trade fairs); training measures for installation and technical staff, planners, and energy consultants; planning support for large solar thermal systems; expert workshops; presentations; information website; information brochures; and a free solar thermal consultation hotline. In its first two years approximately 100 000 brochures were distributed; 400 000 visitors used the website; the consultation hotline was contacted about 3 000 times; consulting services were offered at 10 trade fairs; and 6 000 visitors attended roughly 80 sponsored workshops and presentations.

24. Although most projects subsidized at the beginning of its implementation were for cleaner air and waste prevention, a majority of the budget has since been shifted toward renewable energy projects (approximately 90% in 2005, and 96% in 2006).

25. The Austria Solar Association runs the programme for private single home owners; the AEE – Institute for Sustainable Technologies, for apartment houses with multiple dwelling units; and a group of Austrian research centres organise professional training and also for the hotel and restaurant industries.

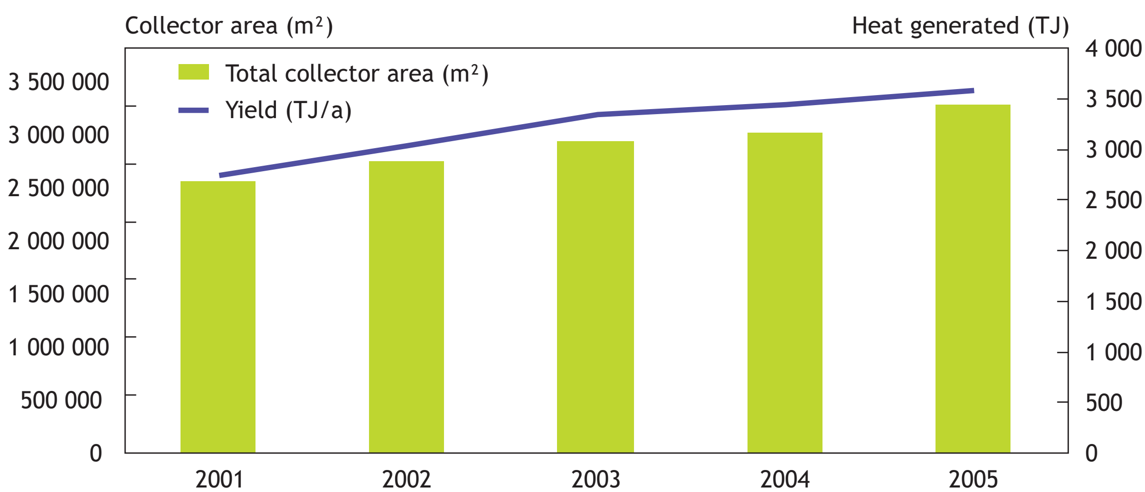
The professional training programme *Certified Solar Heat Installer and Planner* was introduced to promote quality solar thermal systems. In addition, because subsidies for larger solar thermal systems have been increasingly connected to quality criteria, further incentives for certified training programmes existed. Training, performed by experts within the Austrian solar industry, focused on technological aspects of installation and on marketing and sales. The courses included detailed descriptions of the lessons learned from experience with system installation. Once an installer graduates from the programme and is accredited as a *Certified solar heating installer*, he/she is monitored in order to gain continued competence. After the first two years of the programme, 245 installers and planners have attended the training sessions and 85 have qualified as certified installers. This certification is actively marketed as part of the *Klima:aktiv Programme solarwärme* which has been very successful.

Many Austrian länder and cities have also actively promoted solar thermal energy independently, including programmes such as *Sun for Vienna*, *Yes to Solar*! in Tyrol, *Save with Solar* in Styria, *Get yourself the Sun* in Lower Austria, *Initiative program sun region Carinthia*, *Solar Activities of the Vorarlberg region*, *Solar Campaign OÖ* in Upper Austria, and the *Energy Active* programme in Salzburg. These campaigns promote solar thermal by means of information dissemination activities and consultation services.

Market growth

The total installed solar thermal collector area in Austria increased from around 2.2 M m^2 in the year 2000 to over 3.3 M m^2 in 2006. Annual installations have also been increasing: the collector area of 167 682 m^2 installed in 2000 had increased by almost 80% to 299 604 m^2 installed in 2006 (Figure 46).

Figure 46 • *Installed solar thermal collector area in Austria from 2001 till 2005 and corresponding heat generated*



Source:SHC Solar Heat Worldwide 2001, 2003, 2004, 2005. Where data was unavailable numbers were extrapolated.

In 2006, roughly 1.1 M m^2 of collector area was produced in Austria of which nearly 75% was exported. Only 299 000 m^2 of this total (about 25%) was installed domestically. Most of the Austrian export market goes to Germany (68.3%), Italy (9.6%), France (6.2%), and Spain (5.6%).

In summary

Austria's domestic solar thermal market has been greatly influenced by government subsidies and information programmes at both federal and regional levels. The federal *Klima: aktiv Programm*

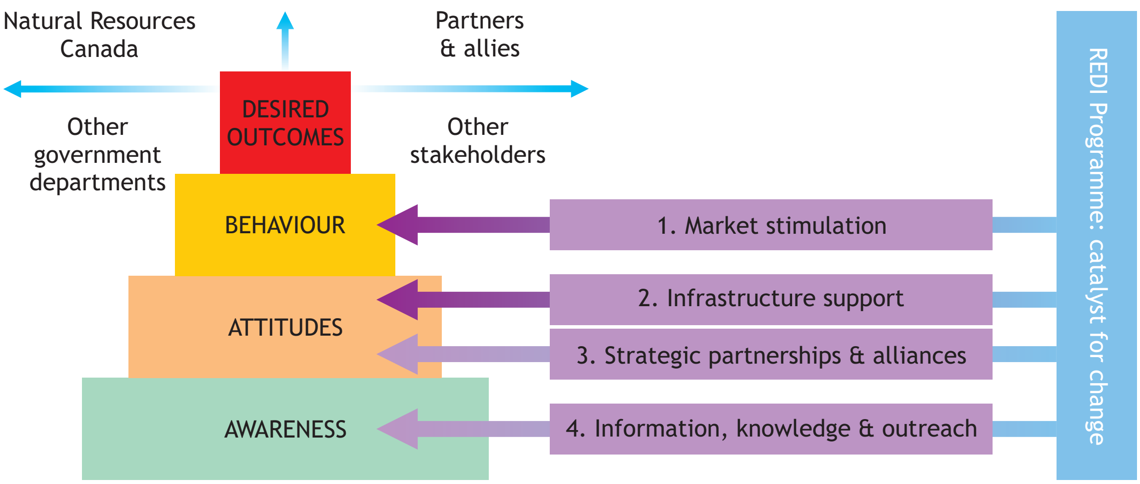
Solarwärme campaign and numerous regional efforts to foster public interest in solar thermal by means of marketing and training measures have resulted in a notable growth in the market. The focus of the programmes is to include information and consultation services on a broad scale for private and business investors, as well as to provide professional training to improve quality standards. This was possibly a key component of the success of these guidance-based schemes.

Biomass: Canadian REDI programme

In December 1997 as part of Natural Resource Canada's (NRCan) Renewable Energy Strategy, the *Renewables Energy Deployment Initiative (REDI)* was announced to begin on April 1st 1998 and continue until March 31st, 2007. The REDI programme was designed to stimulate demand for water heating, space heating and industrial process heating generated from renewable energy systems. In 2007 it was replaced by the *ecoENERGY for Renewable Heat Programme*. REDI's mission was to increase consumer confidence in renewable energy technologies, increase their market share, decrease their costs, and increase industrial design, infrastructure, and capacity to supply renewables (NRCan, 2006). It is administered by the Renewable and Electrical Energy Division of the Electricity Resources Branch of NRCan, the division responsible for providing information, analysis and advice to further the development and use of renewable energy.

REDI was divided to focus on market stimulation, industry infrastructure support, and market development (Figure 47).

Figure 47 • *Design and structure outline of Canada's REDI programme*



Source: NRCan, 2005.

Under its market development pillar, REDI promoted awareness and outreach for solar, biomass, and geothermal heating technologies[26] by being actively involved in industry trade fairs; funding studies to identify target markets; publishing informative pieces such as buyers' guides and promotional materials; and providing training seminars. Moreover, REDI actively collaborated with partners from renewable energy industry associations and municipalities (NRCan, 2005).

26. Ground-source heat pumps were supported under the market development pillar, but were not eligible for financial support under the market stimulation pillar.

An important component of market development was to actively form strategic partnerships and alliances with the aim of strengthening infrastructure, supporting organizations positioned to influence the uptake of renewable heating, and encouraging the development of strategic plans to speed renewable heating growth. In addition REDI actively targeted support for the entire biomass supply chain. Training was provided for technicians, installers, architects, designers, dealers, developers, and engineers covering the infrastructure of renewable heating.

Symposiums for industry and government, with a focus on biomass support, were sponsored by REDI in 2000 and 2001 with discussions surrounding the formation of an industry-based association. In addition REDI was responsible for the publication of consumer guides for biomass heating including *An Introduction to Home Heating with Wood*, *Guide to Residential Wood Heating*, *Buying a High-Efficiency Wood-Burning Appliance*, *Discover Large-Scale Biomass Energy* and *Getting the Most out of Your Woodstove*. More than 40 000 copies of the most popular *Guide to Residential Wood Heating* were distributed each heating season to Canadian residents free of charge. REDI also supported a national educational and social marketing campaign entitled *Burn it Smart*, which encouraged Canadians who heat their home with wood to burn it more efficiently and cleanly. This campaign hosted 359 workshops across 28 regions in Canada.

Over its lifetime, the focus of the programme was shifted from market development to market stimulation. The early emphasis on market development helped change customers' awareness and influence the market acceptance of renewable heating technologies. Market stimulation coupled the guidance-based incentives from market development with a carrot-based incentive, by providing subsidies for the cost of purchasing and installing renewable heating systems. On average, 25% of these costs were available through REDI to government departments, public institutions (including schools), municipalities and non-profit organizations. Installations in remote communities were eligible for 40% of the purchase price and all the installation costs of a qualifying system. Funding was made available for solar heating systems and for high-efficiency, low emissions, biomass combustion systems between 75 kW and 2 MW_{th} up to a maximum refund of €52 000[27] per project or €162 500 per corporate entity for multiple installations. Geothermal heat pumps were ineligible for direct financial incentives. The funding available was advertised in magazines and newspapers and was promoted at various tradeshows and conferences (NRCan, 2006).

Financing

REDI was first established as a 3-year, €7.8 M[28] programme. The *Action Plan 2000 on Climate Change* began a second three year cycle in 2001 with an additional €9.1 M. A third three-year cycle began in 2004 with €16.25 M ending in March 2007. Over its 9-year lifetime REDI allocated €33.15 M from the Canadian government (NRCan, 2005) (Table 9).

Table 9 • *Distribution of REDI funding from its onset in 1999 to completion in 2007*

Time period	Total funding allocated € million	Annual funding € million	Annual funding €/capita*
1999-2001	7.8	2.6	0.08
2001-2003	9.1	3.0	0.09
2004-2007	16.25	5.4	0.16
1999-2007	**33.15**	Average: 3.7	Average: 0.11

*Source: (NRCan, 2005) *Per capita numbers based on 2006 population levels of 32 825 100.*

27. Conversion factor based on the average exchange rate in 2006, 1 CAN$ = €0.65

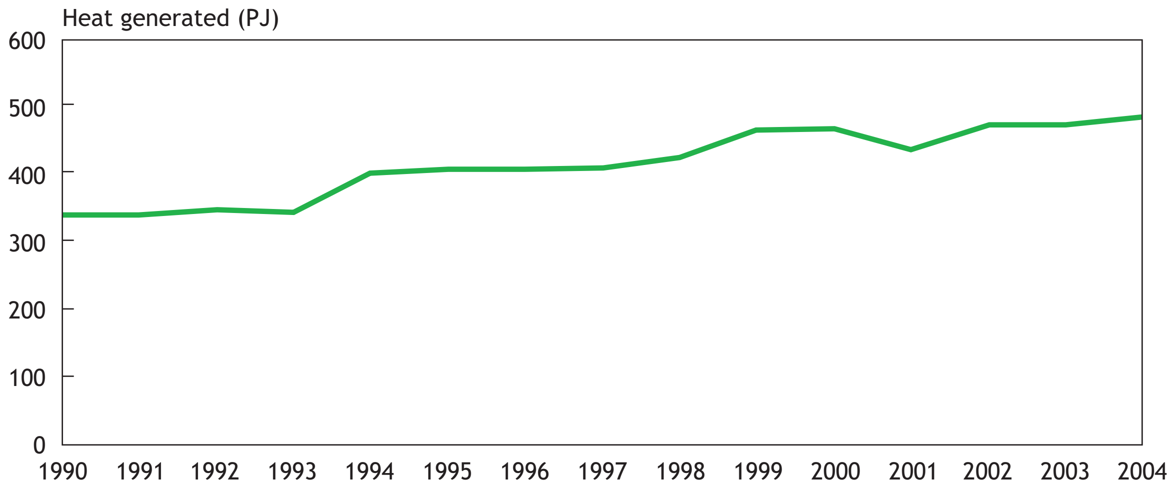
28. The first 3-year REDI cycle was allocated CAD 12 million, the second, CAD14 million and the third CAD25 million

Nearly 50% of REDI´s funding was allocated to financial incentives under the market stimulation pillar. In the first two cycles €4.03 M of REDI contributions leveraged €22.4 M[29] of investment (NRCan, 2005). The number of applications for REDI funding has increased steadily since. In the first REDI cycle, most supported systems were for biomass, the size and average support cost of €133 900 per project supported being much larger than for solar thermal.

Market growth

With millions of hectares of managed forests, Canada supports a significant natural resource potential for biomass heat. Unsurprisingly, solid biomass constitutes a majority of Canada's renewable heating supply. Wood product and pulp and paper industries accounted for the majority of solid biomass use in Canada, primarily in the forms of wood waste and black liquor (IEA, 2004). In addition to the use of wood for residential space heating[30], biomass waste collection facilities have been established and are used for industrial process heat and CHP systems. Partly due to the large and significant biomass resource available from forests, Canada generates comparatively high levels of heat from this renewable resource (Figure 48).

Figure 48 • *Heat generation from biomass sources between 1990 and 2004 in Canada*



Most of REDI funding has been allocated to support public awareness of biomass heating. However it is difficult to discern how much capacity or heat generation has actually been supported as a result of this investment although an indicator may be taken from the capacity installed, based on the portion of funding in support of market stimulation. After completion of the first and second cycles in 2003, REDI had supported the installation of 66.17 MW_{th} of biomass capacity investing €0.78 M for 35 individual projects. By March 2006, capacity had risen almost 4-fold to 246 MW_{th} and the programme had supported 128 biomass heating projects.

In summary

REDI played an important role in developing the market for high-efficiency/low-emission biomass combustion systems (IEA, 2004). Although the total budget for REDI has not been as high compared with

29. In the first two cycles CAD 6.2 million of REDI funding had leveraged CAD34.5 million

30. Wood is used for primary or secondary residential space heating in roughly 3 million households in Canada. This equals roughly 90-100 PJ of annual energy production.

other incentive programmes (*e.g.* the German MAP), the emphasis on education and public awareness of renewable heating technologies has been important for their growth, supported with financial incentives accompanied by strong advertising campaigns. Since the number of applications has increased annually, as has the number of installations supported, it appears that REDI has been successful in promoting renewable heat and increasing consumer confidence. The large distribution of publications in response to requests verifies a sizable audience.

The subsequent April 2007 programme, *ecoENERGY for renewable heat,* extends many of the principles of REDI with an increased budget of €23.4 M for the first four years[31]. It is expected that it will build on the success and awareness initiated by REDI to achieve a strong growth in renewable heating.

Geothermal: Swedish geothermal heat pump procurement programme

The Swedish Agency for Economic and Regional Growth (NUTEK) began a *Technology Procurement* programme for small, brine-water heat pumps in 1993. Although the Swedish market for heat pumps first began to grow in the 1980s, low quality, poorly performing heat pumps led to a negative public view of the technology's reliability. Consequently, the market declined in the late 1980s and early 1990s. In response, NUTEK sponsored the procurement programme with the aim of developing reliable, improved heat pumps for detached houses. This programme successfully stimulated the sales of geothermal heat pumps (GHPs) until it finished in 1996.

The technology support programmes were first introduced in the late 1980s designed to support energy efficient technologies. NUTEK managed all technology procurements until 1998 when their energy responsibilities were handed to the Swedish National Energy Administration. In addition to heat pumps, other technologies have been supported including energy efficient washing machines, lighting and other household appliances.

Procurement programmes act as a starting engine for market transformation (Suvilehto and Öfverholm, 1998). As the first step, a contest was announced indicating a future market for manufacturers (Olerup, 2001) and a list of performance parameters and other requirements compiled from purchasers and energy experts. Examples of requirements for heat pump technology procurement included a minimum energy savings of 28.8 GJ /yr (8 MWh/yr), chlorine-free refrigerants, and price restrictions. Manufacturers then submitted model prototypes which were tested free of charge according to the specified requirements. The two models of GHPs that won the competition were 30% more efficient at 30% less capital cost than previous models.

Winning heat-pump models were then supported by a package of incentives, both carrot- and guidance-based. NUTEK provided information folders for consumers, developed a labelling system identifying products that met specified requirements, offered telephone consumer advice (a consumer hot-line), education, trade exhibitions and campaigning on national, regional and local levels. Informational campaigns took place in Sweden, Denmark, Norway, and Finland. In addition the sale of 2 000 units of the winning, most efficient, technology was guaranteed, and supported with €0.1 M in subsidies which were provided for the first trial batch (Suvilehto and Öfverholm, 1998; Olerup, 2001).

Financing

The Swedish budget allocated to technology procurement programmes (of which the heat pump programme was only one) has varied over time. In 1988, €16.5 M[32] was allocated which increased to €82.5 M /yr from 1991 to 1998. Then, from 1998-2002 the levels were drastically decreased to €11 M (Olerup, 2001).

31. This is an equivalent to €5.85 M per annum or €0.18 per capita per year.

32. In 1988 the budget was SEK 150 million. This was increased to SEK 750 million per year from 1991-1998. From 1998-2002 it was decreased to SEK 100 Million.

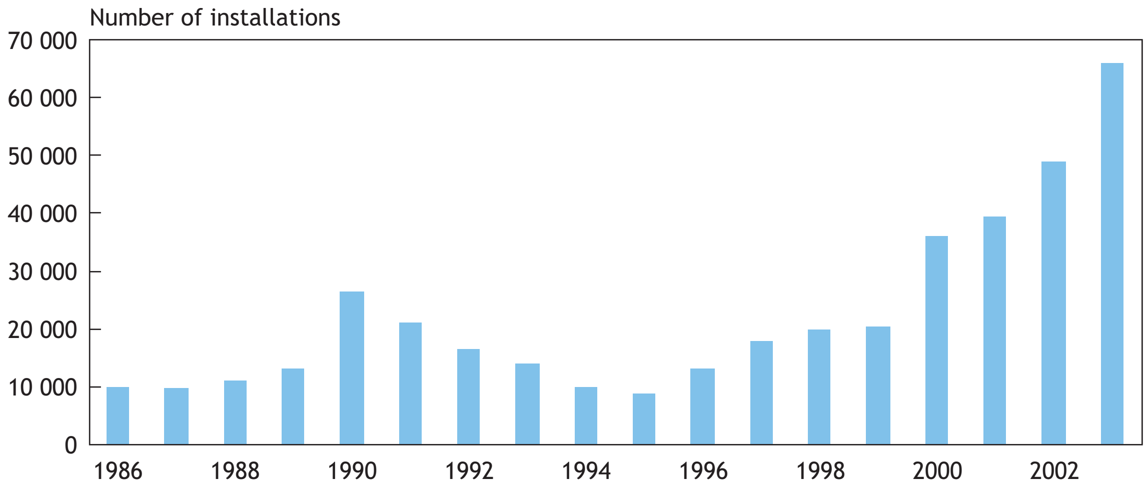
Market growth

Most of the heat pump sales in Sweden at that time used ambient heat resources but the technology available had established a poor reputation. This, plus the withdrawal of subsidies for heat pump technologies in the early 1980s, caused the heat pump market to decline significantly through to the early 1990s.

Following the completion of the technology procurement programme in 1996, the market began to grow significantly (Figure 49). By 2000, total capacity of low temperature, geothermal capacity had reached 377 MW with growth continuing to reach 3 840 MW by 2005 after which the annual increase in the market declined significantly from 47% to only 1%. Today Sweden has the greatest installed geothermal heat pump capacity in the EU (EC, 2006b).

The Technology Procurement programme caused a shift in the technology. Prior to the programme, ambient air heat pumps accounted for 73% of the market but after several years water-based GHPs became the dominant technology reaching 62% of the market share (Figure 50).

Figure 49 • *Geothermal heat pump market development in Sweden from 1988 till 2003*



Source: EGEC, 2007.

Annual sales of GHPs supported by the Technology Procurement programme quickly exceeded the guaranteed level of 2 000 units. By the end of the programme in 1996 between 4 000-5 000 units had been sold and another 12 000 were sold in 1997 (Olerup, 2001). The market then grew to the extent that models are being exported to several Nordic countries, Switzerland, and the Netherlands. Manufacturers estimated that 30% of their production was for export (Olerup, 2001).

In summary

The growth of the Swedish GHP market began as a result of technology procurement support in 1993. The promotion of energy efficient, reliable, low cost models of GHPs by the government restored the reputation of the heat pump. Economies of scale have now begun to appear from production and the Swedish market has grown significantly to become the largest in the EU with exports playing a larger role.

Figure 50 • *The market transition from ambient air-source heat pumps in 1993 to ground-source geothermal heat pumps in 2003 resulting from the Technology Procurement Programme*

Source: Karlsson et al., 2003.

Market led applications (Table 7)

The above case studies have elaborated good policy practices which have, in most cases, resulted in a significant increase in renewable heat. In addition to the influence of policy, there are important external factors which may also contribute to the development of renewable heat. The following examples, solar thermal development in China, biomass development in New Zealand, and geothermal development in Iceland, are cases where the successful growth of renewable heat has not necessarily been the result of political influence. Rather, external factors such as poorly developed conventional heating infrastructure in China, a strong forest industry in New Zealand, and abundant geothermal resources in Iceland have been the main drivers.

Solar thermal in China

With an annual production of 15 M m^2 of solar thermal collectors at an estimated annual value of €1.495 billion[33] , the market for solar thermal in China is the largest in the world by far (Wallace, 2006). This market has developed since the 1980s with essentially no political backing and continues to have an annual average growth rate of nearly 27% per year (SHC, 2007). The drivers for solar water heater market penetration include an abundant solar resource in many regions, a lack of reliable conventional heating options, a well-developed domestic manufacturing industry, and changes in population demographics increasing the demand for hot water.

1) An abundant solar resource translates into an excellent opportunity for the use of solar thermal heating. Two-thirds of China has more than 2 200 hours of full sunshine per year, an annual radiation greater than 5 020 MJ/m^2 and around 50 000 EJ of heat absorbed at the surface annually[34] (Xiao *et al*, 2004).
2) Many Chinese lack access to reliable conventional energy resources, especially in the more rural regions of China[35]. Even where gas and electricity are available for heat production, the distribution system is often unreliable. Moreover, conventional energy prices are volatile and are expected to rise, making solar thermal a more viable solution in terms of both economic and energy security (Wallace, 2006). Therefore solar thermal has become the most practical, and economic means of supplying domestic hot water in many locations.
3) Over 1 300 manufacturers of solar thermal products are operating across China (Wanxing, 2007) with the top eight having an annual turnover of more than €2.9 billion. This strong manufacturing base has implications for both domestic and export markets. In 2003, 75% of solar thermal collectors produced worldwide were manufactured in China (ESTIF, 2006c) and in 2005, exports of them were valued

33. Exchange rate 1 RMB= €0.097.

34. Solar radiation rates in Germany average only 4000MJ/m^2/year and in Japan 4500MJ/m^2/year.

35. In provinces such as Yunnan where coal and gas are unavailable, solar is the only abundant energy resource (Xiao *et al*, 2004).

around €7.45 M. The domestic solar thermal market therefore enjoys strong domestic manufacture with competitively low prices.

4) The quickly developing Chinese economy is well-known[36], with associated increase in the standard of living, amplifying the demand for heat. Moreover, as the population shifts to urban areas and the standard of living improves, the demand for residential space and water heating services also increases (Hua, 2002). With the increased demand for heat, conventional heating supplies from electricity and fossil fuels have also been increasing. For example, between 1999 and 2002 the annual demand for electric heaters grew by 36% and natural gas heaters by 7% (Hua, 2005). Where such conventional heating sources are unavailable, unreliable, or comparatively expensive, the demand for solar thermal heat has risen.

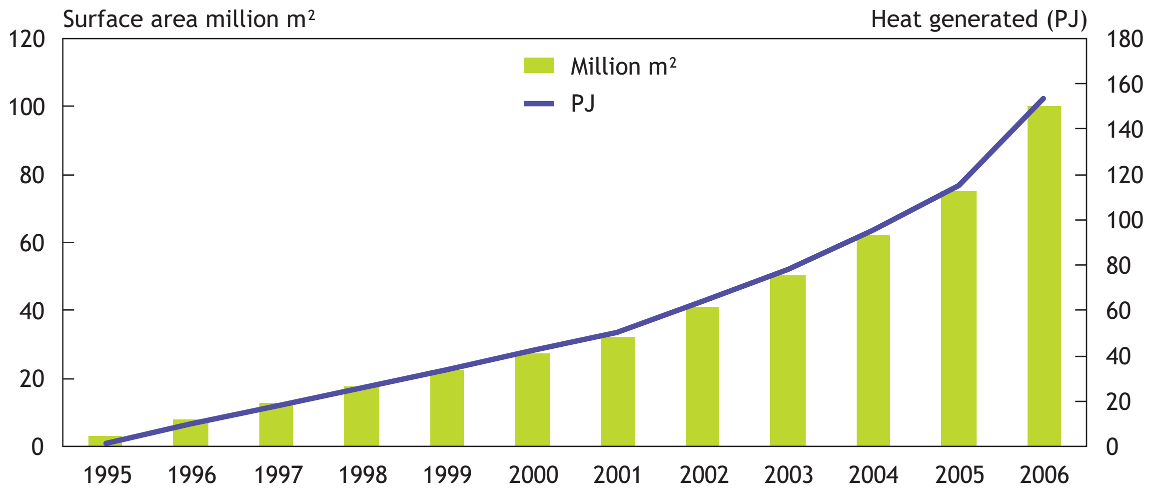
5) The burning of coal has contributed significantly to the recent growth of the Chinese economy but it produces relatively high emissions of CO_2 and particulates. Substituting solar thermal heat for coal offers an opportunity for the Chinese to mitigate their emissions. In 2001, solar thermal systems for hot water and space heating accounted for 6.01 Mt CO_2 avoided, increasing to 13.82 Mt in 2005 (SHC, 2006; SHC, 2007). This could become increasingly important in the future as concerns over climate change and air quality increase.

Market growth

Although solar thermal technologies supply less than a tenth of China's domestic heat demand, (a market dominated by gas and electric heaters) the increasing market for solar thermal heat has implications for the future structure of the heat supply.

By 2006, the total installed capacity in China reached 100 M m^2 producing 153.8 PJ of heat (Wanxing, 2007). Over 30 million households utilize solar thermal systems to supply domestic hot water (Wallace, 2006). Installations per capita however remain relatively low. For example, in 2006 China had roughly 69 m^2 of solar thermal surface area installed per 1000 inhabitants whereas Cyprus had 900 m^2/1 000 and Austria 268 m^2/1 000.

Figure 51 • *Solar thermal market development in China from 1995 till 2006*



*Source: SHC, 2007; Li, 1997. *Where data was unavailable numbers have been extrapolated.*

36. With a population of over 1.3 billion, China has become a global manufacturing centre with exports totaling €726 billion/year.

More than half of the Chinese market for solar thermal heating is specifically for domestic hot water with space heating and crop drying[37] accounting for the rest. Solar hot water accounted for 63% (26 M m^2) of the total installation in 2002 rising to 69% of the 2005 75 M m^2 total (Figure 51).

Kunming in Yunnan Province is typical of the market penetration in China with around 30-40% of households having solar hot water systems. Located in the southwest of China, Yunnan has an excellent solar resource and lacks reliable conventional heat energy resources. The Province has around 150 solar thermal manufacturers which supply readily available, simple, cost-competitive systems for around €145 / unit (Xiao *et al*, 2004; Hua, 2005).

Much of the solar thermal development in China has been in rural areas rather than the more urban areas. In Beijing for example, there is a notable lack of solar thermal market penetration because reliable, conventional, natural gas boilers dominate the market. The solar thermal market in cities is also inhibited by a lack of consumer confidence and problems integrating systems with pre-existing, densely-occupied apartment buildings (Hua, 2002).

With the exception of some RD&D funding, the solar thermal market in China has developed with little, if any, official government support and no subsidies (Hua, 2002). In every *Five Year Plan* of the Chinese government, RD&D funding for solar thermal technologies has been addressed but the real aim is to increase the uptake of solar thermal due to the strong solar resource and the success of the domestic manufacturing industry (Hua, 2005).

In the *Tenth Five Year Plan of New and Sustainable Energy Sector Development* 2005, the Chinese government set national targets for solar thermal of 230 M m^2 by 2015 which, if achieved, would significantly increase the 2005 total (Hua, 2002). The 2005 *Renewable Energy Law*, passed by the National Peoples' Congress, also directly supported these targets by requiring national solar resource assessment and inventories, and requiring new buildings to provide access for and integration of solar water heating systems under the jurisdiction of the Ministry of Construction[38] (Wallace, 2006; CRS, 2005).

The government also developed a set of standards for solar thermal installations including two general standards, four sector-wide standards, five product standards and five performance/test standards (Hua, 2002; Hua 2005). In order to increase product quality and boost consumer confidence, a "Gold Star" certification and labelling system has been implemented based on a pass/fail system similar to the Solar Keymark programme for Europe. The China Jianheng Certification Center envisions that the program will eventually expand to an energy labelling system (Wallace, 2006).

In summary, China's leadership in the solar thermal market is driven by consumer demand for water heating systems rather than by political incentives. An abundant solar resource, unreliable conventional heating options, changing population demographics, and a well-developed manufacturing industry have created the current market for reliable and cheap hot water for household and commercial applications. The solar thermal market has grown throughout the past two decades despite very limited government funding. International lending and development organizations continue to take an interest in China's burgeoning solar thermal markets and could serve to further enhance the future development of the industry (Hua, 2002).

Bioenergy in New Zealand

The plantation forest estate of New Zealand (excluding the indigenous forests) covers around 1.6 Mha or 17% of total land area. To process the wood products a relatively large industry has developed

37. Deployment of low temperature solar dryers (below 70˚C) primarily used for agricultural purposes has begun. However in 2004 only approximately 15 000 m^2 were in use.

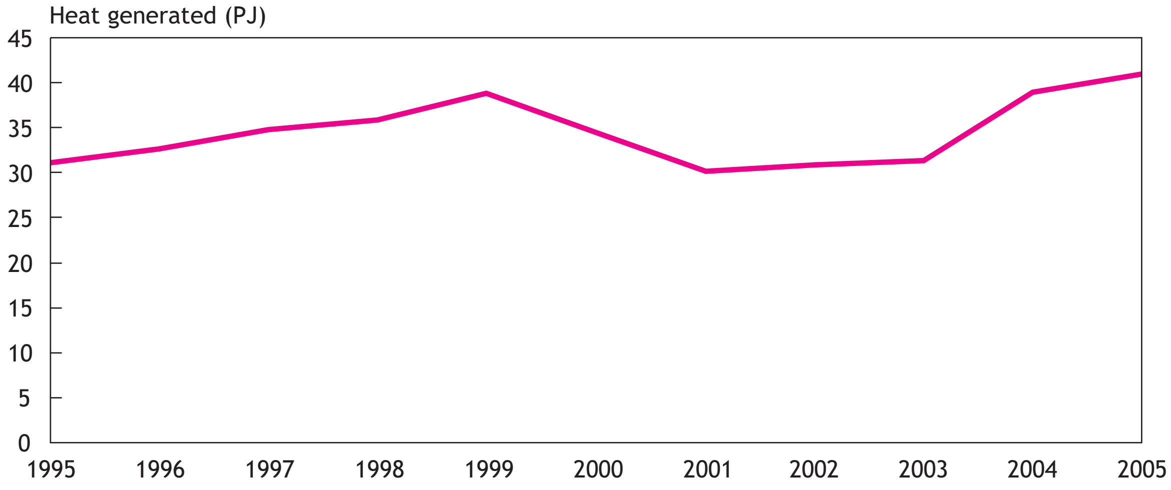
38. Additional targets set by the Renewable Energy Law include an increase in primary energy from renewables target to 16% by 2020.

since the 1930s including sawmills, pulp and paper mills, panel board manufacturers and log exporters. Forest products are now the third largest export earner. In addition to the forests, many farms in this agricultural economy have small plantations or shelter belts from which woody biomass is also sourced as a result of regular pruning regimes, felling of old trees etc. With the temperate climate providing very fast growth rates, there is consequently an abundance of woody biomass resource available from farm woodlots, forest arisings (remaining on the ground after stemwood extraction) and wood process residues such as bark, sawdust and off-cuts.

In total, and without any government intervention, around 40PJ per year (Figure 52), or 8% of total primary energy demand, is supplied by biomass products (including black liquor). This market-led heat demand is in direct competition with relatively cheap electricity, coal and natural gas by international standards. The bioenergy market is focused mainly on heat production with approximately 96% of solid biomass used for generating heat by the forest industry, mainly on-site, and only 4% used for electricity generation in CHP plants. The timber sector accounts for most of the industrial process heat demand from biomass by combusting wood process residues on-site for heat applications such as the kiln drying of timber.

Most of the biomass heat produced is used for industrial processing, but firewood, at over 8PJ per year, provided around one third of total domestic space heating in 2005. This data is uncertain as much of the firewood resource is scavenged from gardens and farms rather than sold commercially, but it is thought that the average household in New Zealand consumes somewhere between 4 GJ and 13 GJ of firewood annually for space and water heating (MED NZ, 2007).

Figure 52 • ***Annual heat production from woody biomass in New Zealand between 1995 and 2005***



Source: (MED, 2007; BANZ, 2007)

Since coal and natural gas have been abundant and are relatively cheap sources of energy in New Zealand, few industries other than the forest sector have considered the use of biomass for heating. However as fossil fuel prices have risen and future gas supplies are now uncertain, there is growing interest in the woody biomass resource which is likely to double in the next one or two decades as more plantation forests reach maturity. Several manufacturers of industrial scale wood heating plants are based in New Zealand and forest harvesting contractors continue to devise novel ways for integrating the harvesting of both stemwood and the residual fuel wood component of a forest.

At the domestic scale, the novel design and development of more fuel efficient, enclosed wood-burning stoves in the 1970s (following successful government R&D investment) led to several stove manufacturers starting up. Several of these still exist and the export market for stoves is growing. Careful operation of the stove and the use of dry firewood can minimise emissions and several education campaigns to this effect have been conducted.

As part of its Climate Change Policy, the government of New Zealand has recently announced its intentions to employ a tax on CO_2 emissions from fossil fuels of around €13 /tCO_2 [39], beginning in the period 2008-2012. Biomass fuels will be exempted from this tax. As a result, this tax is expected to increase the cost competitiveness of biomass heat and provide an important means of political support. This may increase the future demand for woody biomass.

In summary

Overall it appears that even where a good natural energy resource creates a market-led demand, some government intervention can help aid further development and nurture its greater use in an efficient and sustainable manner. New Zealand wood processing plants often use their extensive, locally produced biomass resource on-site as a cheaper option than disposing of it in other ways such as by transporting it to landfills. Thus no government policy has been necessary to encourage the biomass heat market to date.

Meeting domestic heat demand using locally available, free or cheap firewood has also been popular for decades without any policy measures needed. Similarly the domestic heat market quickly adopted the efficient stove technology after its development in the 1970s because these designs use perhaps a quarter of the firewood compared with an open fire to produce a similar amount of heat. Even without any subsidies or regulations, wide deployment has occurred. Regulations do exist in relation to stove installation, chimney heights, and in some cities, regarding related air pollution levels. So overall the uptake of woody biomass by both the domestic and industrial sectors has largely been market led, procuring the resource and investing in the necessary conversion plants being a cheaper overall option than burning coal or gas in conventional heaters or boiler designs.

Geothermal in Iceland

Iceland lies on the Mid-Atlantic ridge, one of the Earth's major fault lines. The country therefore has a strong indigenous geothermal resource with high-temperature areas including volcanoes and hot springs having an average base temperature over 200°C. Numerous low-temperature zones also exist with an average base temperature below 150°C. The continuous tectonic activity in the area not only provides a continuous heat source, but also provides channels through which naturally heated water flows.

Due to this abundant resource, geothermal energy accounts for over half of Iceland's primary energy needs including nearly 90% of its space heating needs. Early in the 20th century, geothermal had already been utilized for greenhouses, swimming pools, and to a lesser extent, building space heating. Utilization of geothermal energy for space heating on a commercial scale began in 1930 with the laying of 3 km of hot water piping from the hot springs of Laugardalur to an area of 60 households, 2 schools, and a hospital near Reykjavík. The formal operation of district heating began in 1943 when 18 km of hot water piping was laid to heat 2 850 homes (Orkustofnun, 2006b).

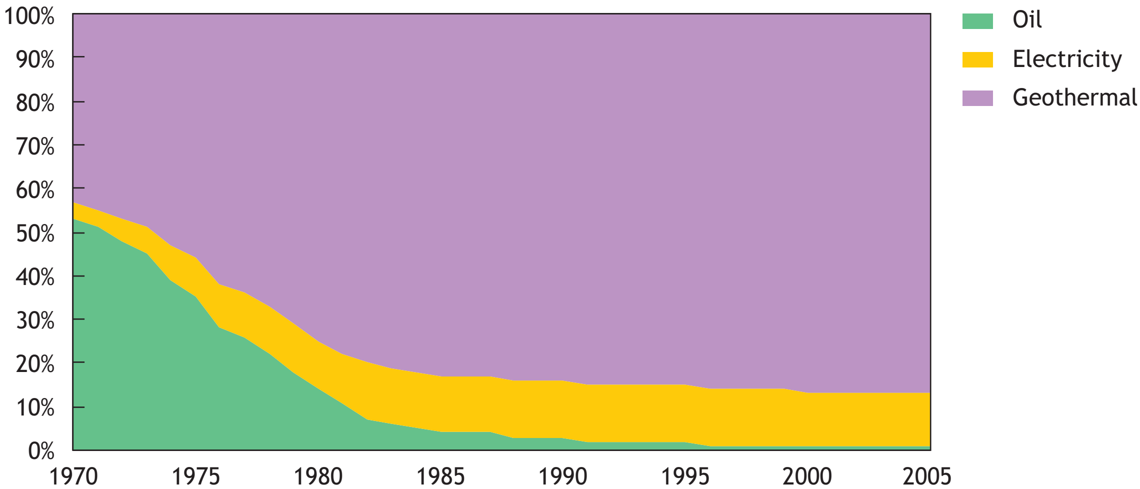
The Icelandic government assisted in the development of the extensive geothermal heating system in the nation beginning in the 1940s by supporting the exploration of geothermal resources and research to identify the options for their exploitation. This R&D investment has continued through to the present, although the administrative authority has been transferred over its lifetime, initially in 1967 being the responsibility of the State Electricity Authority, then transferring to the National Energy Authority, and

39. Currency exchange rates of NZ$1=€0.54 were used based on 2007 values.

finally in 2003 to the Iceland Geosurvey. In addition an energy fund was established in 1967 from which loans and grants were allocated for geothermal exploration and drilling. This fund has continued to the present under the Icelandic National Energy Authority (Orkustofnun, 2006b).

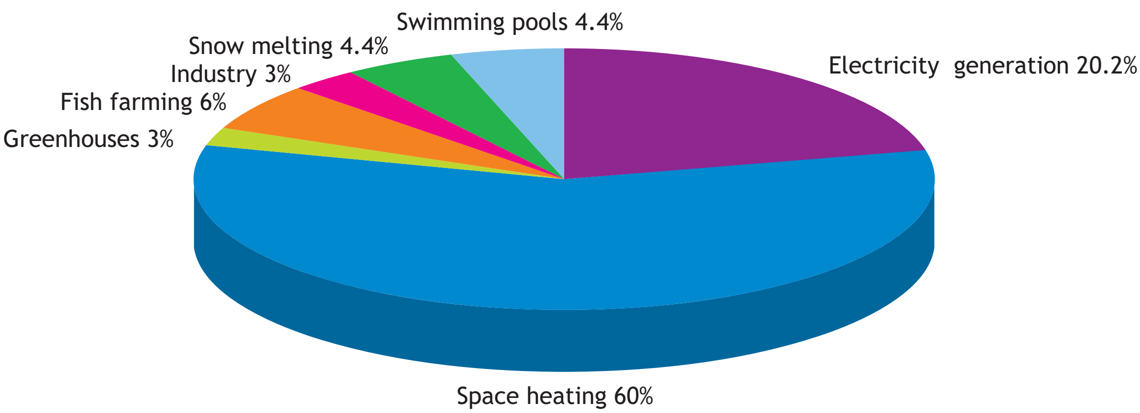
Following the oil crises of the 1970s the Icelandic government altered its energy policy to actively expand its domestic geothermal heat use. New resources were sought, district heating grids constructed, and transmission pipelines (often 10-20 km long) were built. This expansion was accompanied with an increase in the utilization of geothermal heat from 43% of energy used for space heating in 1970 to 89% in 2005 (Figure 53). The rate of new geothermal resource exploitation for space heating however has slowed since the 1980s despite the significant remaining resource potential.

Figure 53 • *Energy source mix for space heating in Iceland between 1970 and 2005*



Source: Orkustofnun, 2005.

Figure 54 • *Use of geothermal heat energy in Iceland in 2006*



Source: Orkustofnun, 2006a.

The government's long term R&D investment has contributed to the continued development of the geothermal resource so that the utilization of the heat has become more cost competitive. As a result, the government now takes a lesser role in further exploitation and power companies are now taking the lead.

In 2005, Iceland used 27.7 PJ[40] of direct geothermal heat mainly for space heating (19.9 PJ) but also for swimming pool heating (1.3 PJ), industry (1.6 PJ), greenhouse heating 1.0 PJ, fish farming (2.0 PJ) and for melting snow (1.3 PJ) (Orkustofnun, 2006a) (Figure 54). A further 2-3PJ of high-temperature heat was used for power generation.

Because there is sufficient, low-cost geothermal water for space heating there has been a limited market for GHPs with only three locations reported. The main geothermal activity in recent years has been invested in the exploitation of high-temperature resources, usually for the production of electricity.

Iceland has an outstanding natural endowment of geothermal resource which has been heavily exploited for heating and more recently for the production of electricity. Although largely market led, particularly since the oil price shocks of the 1970s, the government encouraged resource use by supporting investments in exploitation and technological developments. The combination of an abundant natural resource and long term R&D support has made geothermal heat cost-competitive and hence more widely utilized.

40. PJ heat values were calculated from heat use percentages and total heat demand as reported by Orkustofnun (2006a).

5. Conclusions

Providing heating, and to a lesser degree cooling services, accounts for around 40-50% of global consumer energy demand each year, yet policies to encourage REHC technology development and deployment have often been neglected compared with those supporting energy efficiency, renewable electricity, or biofuels for transport.

There appears to be high potential for heating services to be provided from solar thermal, biomass and geothermal resources by displacing conventional fossil fuels and hence reducing greenhouse gas emissions as well as, under certain specific conditions, improving security of energy supply and reducing related risks to human health. Global REHC markets already exist (Table 10) and contribute around 1% of global primary energy supply each year (with possibly another 10% coming from conventional biomass used for traditional heating and cooking).

Table 10 • *Summary of estimated installed global capacities, energy outputs and 2005 and projected costs out to 2030 of solar thermal, bioenergy (excluding traditional biomass combustion) and geothermal technologies*

	Installed capacity	Energy output	Costs 2005 Range	Costs 2005 Average	Projected average cost reduction by 2030
	GW_{th}	PJ/yr	€/GJ	€/GJ	% 2005 costs
Solar thermal	**100-110**	**200-220**			
- water and space heating			8 to 226	52	-42
- solar assisted cooling	<0.05		11 to 307	66	-44
Bioenergy	**1000-1200**	**3000-4000**			
- pellet heating			8 to 99	26	-5
- CHP			7 to 67	26	-8
- anaerobic digestion			6 to 32	15	-3
- MSW waste-to-energy			2 to 12	5	-9
Geothermal	**25-30**	**270-280**			
- deep conventional			0.5 to 11	2	+11*
- deep advanced			1 to 24	3	-13
- shallow geothermal					
-heat only			3 to 89	19	-9
-h+c: heating			2 to 75	17	-8
-h+c: cooling			2 to 97	16	-8

**Increase costs due to scarcity of sites and many of the good sites already developed.*

Several REHC technologies are mature, their markets are growing, and their costs relative to conventional systems continue to decline. The solar thermal market, for example, continues to grow steadily and equipment performance increases. China dominates the world market and also has the greatest solar water heater manufacturing capability. Currently modern biomass combustion (excluding traditional domestic biomass as used in many developing countries) contributes most of the renewable heating, particularly in the building and industry sectors. Deep geothermal heat is used mainly by industry and district heating schemes in regions where resources are available, whereas shallow geothermal heat is used more extensively, mainly for small-scale domestic applications. Projections out to 2030 show a significant increase in all of these commercially available technologies.

For early-market technologies and those still under development, in countries where good resources exist, one primary policy aim should be to move appropriate REHC technologies closer to the mass-market stage. Strong policy support at the early market stage has played a key role in successful deployment in all leading countries. However specific heating and cooling costs vary widely with resource availability and location as well as the stage of development of the technology, so careful assessment is recommended prior to policy implementation. For example in countries where shallow geothermal heat pumps are in their infancy or at the early-market stage, incentive guidance policies could possibly be used to stimulate learning experience, educate potential customers and train installers. However in countries where they are already close to mass-market, as their reliability increases and costs further decline, regulatory policies may become more applicable.

Providing cooling services from renewable energy sources remains at the early development stage for many technologies (with perhaps the exception being passive solar building designs used extensively throughout some hot regions and naturally cold water distributed through existing district heating networks in summer). Even the most promising technologies remain largely at the research and demonstration stage with further government and private-funded R&D support required.

Policies to support renewable heating systems have been developed in several OECD countries with varying degrees of success. Of the twelve selected countries studied in detail, the majority of policies were based on incentives (carrots) rather than regulations (sticks). The more successful policies can be defined as those having the greatest effect for the lowest government investment. Measuring their effectiveness using various indicators is difficult since good databases showing annual heat demand do not usually exist because, unlike electricity or transport fuels, heat is rarely sold off-site; hence there is no need for costly metering. Comparing average annual public investment in REHC per capita with the subsequent change in average annual REHC demand per capita over time for a country where such data is available is a fairly coarse measure, but it can be a useful indicator.

Where a good natural solar, biomass or geothermal resource exists, government investment is less essential in order to bring the technology to the market. Where the resource is relatively poor, then more stringent and costly policies may be required. Regardless of the resource availability, and whether stick or carrot policies are chosen, the most effective often proved to be those where parallel investments were made in guidance and educational programmes in order for the stakeholders (including the general public) to better understand the benefits that REHC has to offer. This is particularly the case for investment in domestic heating and cooling systems such as solar water heating, wood stoves and geothermal heat pumps where personal investment decisions are made by the owner of the dwelling.

Good policies for market development have proved successful for each of solar, bioenergy and geothermal technologies, even in locations where the resource is not particularly abundant. Under these conditions energy costs can be relatively high compared with using oil-, coal- or natural gas-fired heating appliances so more stringent policies are needed. Overall the type of policy to best stimulate the market has to be developed for each energy resource, conversion technology and location. The resulting market uptake also depends on the competing prices for fossil fuels in the region. There is therefore no single solution. Therefore evaluating policies used elsewhere with varying degrees of success, but adapting them if necessary to suit the local conditions, is the approach recommended.

Recommendations for future work

- Governments are encouraged to improve the accuracy of their national data collection relating to heating and cooling supply and demand in order to better inform development of policies. Due to the distributed nature of heat supply and the local demand, this may be difficult to achieve without extensive user surveys or national sales figures.
- More analytical studies could be undertaken by researchers to develop better effectiveness indicators so that successful outcomes (or otherwise) and the cost effectiveness of individual policies can be better assessed.
- Countries currently without any REHC policies in place should assess their local renewable energy resources and, where appropriate, policy-makers should review existing policies elsewhere (as outlined in this report) in order to identify the most suitable policy mix necessary to stimulate the local market.
- A review of best practices and lessons learned in developing and implementing technology standards and labelling in association with other policies would be a useful guide for countries wishing to emulate the leaders.
- Evaluation of REHC technologies deployed in the residential sector compared with the industry, commercial and institutional sectors is needed to determine which policy approaches could be most relevant for each sector.
- Replication of successful and cost-effective policies by countries with similar levels of specific renewable energy resources should be encouraged, but would first require detailed analysis of the rationale behind policy designs. (This will be undertaken within the *Global Renewable Energy Markets and Policies – past trends and future prospects* study currently in preparation by the IEA Renewable Energy Unit).

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Abbreviations

ADEME – French Environment and Energy Management Agency

BIG – United Kingdom National Lottery Big Opportunities Fund

CBIP – Canada Commercial Buildings Incentive Program

CHP – Combined heat and power

CO_2 – Carbon dioxide

COP – Coefficient of performance

CSICE – Spain Council for Building Sustainability, Innovation and Quality

DEFRA - Department for the Environment, Food and Rural Affairs, United Kingdom

DTI – Department of Trade and Industry, United Kingdom

EIA – Energy Investment Allowance, Netherlands

EPA – Energy Performance Advice, Netherlands

EPR – Energy Premium, Netherlands

FIDEME – France Fonds d'Intervention pour l'Environnement et la Maîtrise de l' Énergie

FOGIME – France Crediting System in Favour of Energy Management

GHP – Geothermal (or ground-source) heat pump

LCBP – Low Carbon Buildings Programme, United Kingdom

MAP – Marktanreizprogramm, Market Incentive Programme, Germany

MATT - Ministry of Environment, Italy

MSP – Market Stimulation Programme, Germany

MTOE – Million Tonnes of Oil Equivalent

PAEE – Energy Saving and Efficiency Plan, Spain

PBE - Programme Bois Energie, (Wood energy action plan), France

PFER – Plan for the Promotion of Renewable Energy, Spain

PLINE – Promotion for the Local Introduction of New Energy, Japan

PSNEO – Project for Supporting New Energy Operators, Japan

REDI - Renewables Energy Deployment Initiative

REHC – Renewable energy heating and cooling

RETs – Renewable energy technologies

SMEs – Small and medium size enterprises

UK – United Kingdom

Annex A. Cost data for REHC options

Various reference sources of cost data for REHC technologies were taken and converted into common units of capacity (Watt) and energy (Joule). Input and review was provided by the IEA Solar Heating and Cooling, Bioenergy and Geothermal Implementing Agreements.

The aim was to use a consistent set of data inputs for the analysis: investment costs, fuel costs, operation and maintenance (O&M) costs, conversion efficiencies and annual yields. These inputs were then evaluated using a consistent set of assumptions of interest rates, auxiliary energy costs and plant lifetimes (Table A1). The technology-specific data are discussed below.

From these input data and assumptions, the cost of providing heat energy from various systems was compared in terms of €/GJ based on a simple calculation method. In order to deal with uncertainties in the assumptions and in the technology parameters, data-ranges were used. The results are therefore presented as ranges and are to be interpreted as indicative only.

Table A1 • *Overview of general assumptions used when calculating the cost of providing heat energy*

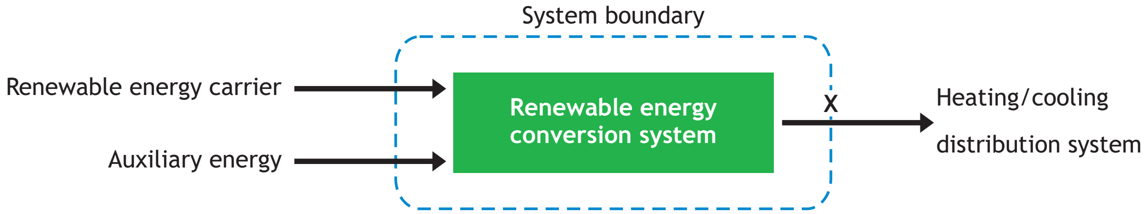
Parameter		Value
Interest rate		5% to 15% (average 10%)
Auxiliary energy cost (electricity)		€5 /MWh to €20 /MWh (average €15 /MWh)
Plant lifetimes:		
solar technologies		15 to 25 years (average 20 years)
biomass technologies		10 to 20 years (average 15 years)
geothermal technologies	deep:	25 to 55 years (average 35 years)
	shallow:	20 to 30 years (average 25 years)

For bioenergy and geothermal CHP technologies that deliver both heat and power, data only refer to the heating component. (Data referring to components for electricity production were allocated to electricity costs). For ground heat pumps that deliver both heating and cooling, the costs were allocated to either function. Any costs of heat distribution within a system (such as for district heating or for space heating) were not considered as it was assumed that the REHC source would simply displace the conventional energy source in an existing heating or cooling distribution system.

For new build projects such as solar water heaters in new housing developments, or a new district heating system fuelled with biomass, the assumption was made that the heating system infrastructure would be paid for regardless. Only any additional REHC costs for investment, O&M, or fuel were accounted for. Avoided costs due to savings of technical components in a reference system have not been considered, nor savings due to avoided fuel use. The costs included all those relating to integration of the technology such as the pipes and plumbing costs for connecting a solar thermal system to an existing hot water distribution system or drilling the borehole for a ground-coupled heat pump, or installing a system ready for use by the consumer.

Heat or cold production costs are calculated from the location where the heat or cold leaves the conversion system (marked as X in Figure A1).

Figure A1 • *System bounds applied in the data overview*



Where data is not available expert judgements from members of the IEA Implementing Agreements were sought. Data was aggregated into the global level due to limited data availability, but local conditions and resource availability can affect the REHC costs considerably. Further analysis at the national level is therefore recommended. Data ranges (minimum, average and maximum values) were used to calculate the costs across different kinds of systems and the range of available resource levels made for 2005 as the base year. This extreme value approach yields quite large data ranges. In order to narrow the resulting data ranges, a Monte Carlo uncertainty propagation analysis could be performed assuming a simple triangular distribution. However this was not undertaken and will be a recommended future step of the overall analysis yet to be undertaken.

When projecting future data and trends out to 2030, based on the literature or expert judgements the costs for some REHC technologies were expected to decrease over time in most but not all cases, whereas some conventional energy prices were generally anticipated to increase based on current trends and the possibility of carbon charges. Percentage changes were used to indicate the assumed order of magnitude of an increase or decrease with respect to the base year.

Solar thermal

The following technologies were considered:

Annex A.1 Solar thermal heating

Annex A.2 Solar thermal cooling

Assumptions:

- Hot water preparation, combi-systems for water and space heating, large scale systems and thermo-siphon systems were all included resulting in large data ranges.
- Heat storage components were included in the costs.
- Cost data were mainly based on reported costs from Germany, Austria and Greece.
- System bounds were applied as indicated in Figure A1. Heat distribution costs and avoided costs due to investment or operational savings on a reference energy system were not considered.

Biomass

Annex A.3 Biomass pellet heating (heat only)

Annex A.4 Biomass CHP heating

Annex A.5 Biomass anaerobic digestion (CHP)

Annex A.6 Biomass municipal solid waste-to-energy (CHP)

Assumptions:

- Cost data were mainly based on reported costs from Austria, Denmark, Germany and the Netherlands.
- Where no literature references were available, expert judgements were made by IEA Bioenergy Task32 (Biomass Combustion and Co-firing).
- System bounds apply as indicated in Figure A1. Heat distribution costs and avoided costs due to investment or operational savings on a reference energy system were not considered.

Geothermal

The following technologies were considered:

Annex A.7	Conventional deep geothermal (CHP)
Annex A.8	Advanced deep geothermal (CHP)
Annex A.9	Shallow geothermal heating and cooling
Annex A.10	Shallow geothermal heating only

Assumptions:

- Data for conventional deep geothermal were based upon values reported for the USA, New Zealand, Switzerland and Europe. A large range of national costs exists between countries like Germany and Switzerland with high standards of living and labour costs, compared to other countries such as New Zealand.
- Large ranges exist between minimum and maximum values due mainly to including a range of installation types such as district heating and industrial heat.
- Drilling costs of bores have been included.
- Where rejected hot water from geothermal power generation schemes is used as direct heat, the costs can be relatively low or zero. Nonetheless, in these cases part of the total costs of the installation was allocated to heat production.
- The ranges were based mainly on estimates made by the Geothermal Implementing Agreement (GIA). No specific data references could be provided. There is a lack of published information on direct use costs as they are usually considered confidential by project developers.
- System bounds apply as indicated in Figure A1. Heat distribution and avoided costs due to savings on a reference energy system were not considered;

The GIA is considering conducting a detailed investigation into geothermal electricity generation and direct heat use costs that should result in more reliable and technology-specific cost data.

For all technologies the overview was assumed to cover worldwide systems for the base year 2005, and to project relative differences to the year 2030. The calculations did not take into account a reference system, nor were avoided costs due to fuel savings incorporated. Cost data excluded any value added tax (VAT) that a government might impose. Installation costs were included whereas heat distribution costs were not.

A1. Solar thermal heating

Based on current German cost data, system costs for a domestic hot water system with 6 m^2 collector area can be up to €1 000 per m^2 or €6 000 per system. The cost of a combi-system with 15 m^2 collector area at €900 per m^2 can reach €13 500 per system (Drück, 2007).

Current Austrian system costs (hot water only) vary from €610 /m² (15 m² collector area, 1000 litre storage tank) to €765 /m² (6 m² collector area, 300 litre storage tank) (Solarwärme, 2007). For larger systems up to 100 m² collector area, the cost range (including installation but excluding VAT) is between €420 – 570 /m². For systems with >100 m² collector area the costs range is €370 – 500 /m² (Fink & Riva, 2004).

A typical 2.4 m² collector, thermo-siphon system in Greece with storage volume of 150 litres costs around €400 /m² installed (Drosou and Aidonis, 2006), with systems in Macedonia and Turkey around €300 /m² and elsewhere in the region up to €1 000 /m² (Drück, 2007).

The investment costs for all these types of systems (domestic hot water, combi-, thermo-siphon) are assumed to range from €300 to 1000 /m², with an average of €630 /m². By 2030 system costs could decline by 35% - 50% to an average of €400 /m², based on a global installed capacity of 200 GW_{th} (investment cost range €150 - 600 /m²).

Assumed energy yields range from 250 kWh/m²/yr for a combi-system with a low solar fraction in, for example, central or northern Europe, up to 800 kWh/m²/yr for a domestic hot water system with high solar fraction in southern Europe. The worldwide average yield is assumed to be 450 kWh/m²/yr based on regions with relatively favourable solar gains. By 2030, energy yield could increase by 11% - 20% (depending on system type) to an average of 500 kWh/m²/yr (energy yield data range 300 - 900 kWh/m²/yr).

Other studies used include ESTIF (2003 volumes I and II), the IEA Solar Heating and Cooling (SHC, 2006) and also expert judgements from members of this Implementing Agreement (Weiss, 2007).

The most dominant factor in the resulting solar water heating costs (Table A2) is capital investment. Fuel costs are obviously zero, but a very small cost share exists for auxiliary energy. Based on the expected future cost reductions, the average costs for solar thermal heating could reduce from the current €52/GJ to €30 /GJ by 2030, but ranging between €4 - 116 /GJ depending on location and solar resource.

Table A2 • *Cost parameters for solar heating in 2005 (excluding VAT) and projections to 2030**

		Data for base year 2005				Extrapolation
		Minimum	Average	Maximum	Unit	to 2030
Input data	Investment cost	300	630	1000	2005€/m²	-50% to -35%
	Energy yield	250	450	800	kWh_{th}/m²/yr	+11% to 20%
	Auxiliary energy needed	2	5	10	kWh_e/m²/yr	-40%
	- cost	0.05	0.15	0.2	2005€/kWh_e	+25%
	O&M	1.0	1.5	3.0	% of investment	0%
	Life of plant	15	20	25	Yr	+20%
	Interest rate	5	10	15	%/yr	+10%
Intermediate results	Annuity	7.1	11.7	17.1	%/yr	
	Annual investment payment	21	74	171	2005€/m²/yr	
	Annual auxiliary energy cost	0.1	0.8	2	2005€/m²/yr	
	Annual O&M cost	3	9	30	2005€/m²/yr	
Output data	Total energy cost					
	- investment	7.4	45.7	190	2005€/GJ	-57% to -42%
	- fuel	0.0	0.0	0	2005€/GJ	0%
	- auxiliary energy	0.0	0.5	2	2005€/GJ	-38% to -33%
	- O&M	1.0	5.8	33	2005€/GJ	-56% to -43%
	Total	**8.5**	**52.0**	**226**	**2005€/GJ**	**-57% to -42%**

** Covers worldwide systems for the base year 2005, and projected relative differences by 2030. Neither a reference system nor avoided costs due to fuel savings are incorporated. Installation costs are included but heat distribution costs are not.*

A2. Solar thermal cooling

Total investment costs for a solar cooling installation are based on two important components: the solar collectors and the sorption cooling device. Collector investment costs were assumed to equal the solar heating costs (€300 to 1 000 /m^2). The additional cooling equipment was assumed to have an investment cost ranging from €80 to 640 /m^2 with an average value of €260 /m^2. These values were based on different system layouts: relatively cheap are the systems with a large cooling capacity and a high value of specific collector area (m^2/kW cooling capacity); relatively expensive are the systems with a small cooling capacity and a small specific area. The assumed specific collector area ranges from 2.5 to 4.5 m^2/kW cooling capacity. Combined, the resulting range in investment costs is €380 to 1 640 /m^2, with an average value of €890 /m^2.

To meet consumer energy needs, both heating and cooling functions are considered. The minimum energy yield is slightly higher than the heating-only mode of 300 kWh/m^2/yr due to additional cooling energy demand. The average value was assumed to be 500 kWh/m^2/yr. However a well designed system, located in a region with high solar irradiation and with high heating and cooling requirements can yield up to 800 kWh/m^2/yr (equal to solar heating).

The auxiliary energy needed for solar cooling is higher than for solar heating and was assumed to range from 3 to 12 kWh_e/m^2/yr (average 6 kWh_e/m^2/yr).

For projections out to 2030 it was assumed that the collector investment cost reduction was equal to the case for solar heating. The additional cooling equipment cost was assumed to be reduced by 35% to 45% resulting in a range of investment costs from €210 to 1 080 /m^2 (average €590 /m^2). The energy yield was assumed to increase by 20% in the period to 2030, resulting in a range of 360 to 960 kWh/m^2/yr (average 600 kWh/m^2/yr).

Table A3 • *Cost parameters for solar cooling in 2005 (excluding VAT) and projections for 2030**

		Data for base year 2005				Extrapolation
		Minimum	Average	Maximum	Unit	to 2030
Input data	Investment cost	380	890	1 640	2005€/m^2	-45% to -35%
	Energy yield	300	500	800	kWh_{th}/m^2/yr	+20%
	Auxiliary energy needed	3	6	12	kWh_e/m^2/yr	-30%
	- cost	0.05	0.15	0.2	2005€/kWh_e	+25%
	O&M	1.0	1.5	3.0	% of investment	0%
	Life of plant	15	20	25	yr	+20%
	Interest rate	5	10	15	%/yr	+10%
Intermediate results	Annuity	7.1	11.7	17.1	%/yr	
	Annual investment payment	27	105	280	2005€/m^2/yr	
	Annual auxiliary energy cost	0.2	0.9	2.4	2005€/m^2/yr	
	Annual O&M cost	4	13	49	2005€/m^2/yr	
Output data	Total energy cost					
	- investment	9	58	260	2005€/GJ	-55% to -43%
	- fuel	0	0	0	2005€/GJ	0%
	- auxiliary energy	0	1	2	2005€/GJ	-27%
	- O&M	1	7	46	2005€/GJ	-54% to -45%
	Total	**11**	**66**	**307**	**2005€/GJ**	**-55% to -44%**

**Covers worldwide systems for the base year 2005, and projected relative differences by 2030. Neither a reference system nor avoided costs due to fuel savings are incorporated. Installation costs are included but heat distribution costs are not. In the investment costs the sorption heat pump is included. The energy yield covers both heating and cooling production.*

The resulting cost of energy ranges from €11 to 307 /GJ (average €66 /GJ, Table A3) meaning that, despite a much higher level of investment cost (due to the larger collector surface and the cooling installation), the resulting cost of energy (for both heating and cooling operation) is similar to the cost of solar water heating only. Most dominant factor in the resulting solar energy costs is the capital investment. Based on the expected future cost reductions (for both collector and cooling equipment), the average costs for solar thermal heating could reduce from €66 /GJ in 2005 to €37 /GJ by 2030 (range €5 - 174 /GJ).

The literature references used for solar collector cooling costs are similar to those for solar heating collector costs with additional information provided by Henning (2007).

A3. Biomass pellet heating

Biomass pellet heating systems typically have a capacity ranging from 5 kW (low-energy single-family dwelling) to 100 kW (apartment building) and are used for heat only (not CHP). The data in the overview below are based on German systems and exclude VAT. Note, that small systems have a low number of full load hours since there is no backup available that has a capacity large enough to cover the full peak demand, as is usually the case for larger systems.

Table A4 • *Cost parameters for biomass pellet heating in 2005 (excluding VAT) with projections out to 2030**

		Data for base year 2005				Extrapolation to 2030
		Minimum	Average	Maximum	Unit	
Input data	Investment cost (combustion plant only, including control)	120	380	800	2005€/kW_{th}	0%
	Total investment including civil works, fuel and heat storage	250	500	1 000	2005€/kW_{th}	0%
	Conversion efficiency**	86	92	95	%	+10%
	Fuel cost	9.7	12.5	15.3	2005€/GJ	0%
	Auxiliary energy needed	10	14	20	kWh_e/kW/yr	+5%
	Cost of auxiliary energy	0.05	0.15	0.2	2005€/kWh_e	+25%
	O&M	10	20	30	2005€/kW_{th}/yr	0%
	Full load hours heating	1 100	2 000	2 500	hrs/yr	0%
	Lifetime	10	15	20	yr	+20%
	Interest rate	5	10	15	%/yr	+10%
Intermediate results	Annuity	8.0	13.1	19.9	%/yr	
	Annual investment payment	20	66	199	2005€/kW_{th}/yr	
	Annual auxiliary energy cost	0.5	2.1	4	2005€/kW_{th}/yr	
	Annual O&M cost	10	20	30	2005€/kW_{th}/yr	
	Fuel input	4.2	7.8	10.5	GJ_{input}/kW_{th}/yr	
Output data	Total energy cost					
	- investment	2	9	50	2005€/GJ	-5% to -1%
	- fuel	5	14	40	2005€/GJ	-9% to -8%
	- auxiliary energy	0	0	1	2005€/GJ	+31%
	- O&M	1	3	8	2005€/GJ	0%
	Total	**8**	**26**	**99**	**2005€/GJ**	**-6% to -4%**

** Covers worldwide systems for the base year 2005 and projected relative differences by 2030. Neither a reference system nor avoided costs due to fuel savings are incorporated. Installation costs are included but heat distribution costs are not.*

*** The maximum achievable conversion efficiency in 2030 is 103%.*

Fuel costs are a dominant factor in the total heating cost along with system investment costs. Increasing lifetime and fuel efficiency could yield a 4% to 6% cost reduction in the year 2030 (a decrease from €26 /GJ to €25 /GJ (range €7 to 95 /GJ) assuming constant fuel prices.

Combusting wood chips for district heating is applied on a wider scale than are pellet burners. It can have higher investment costs but lower fuel prices. No separate cost overview is presented.

The data overview was compiled by IEA Bioenergy Task32 (Biomass Combustion and Co-firing) (Koppejan, 2007) using Hansen (2006) and Hartmann (2003) as sources.

A4. Biomass CHP heating

Costs for biomass CHP heating systems are based on steam-turbine configurations (Obernberger, 2004). The data ranges have been mainly based on two plants in Denmark and in Austria. System sizes range from 12 to 14 MW_{th} and costs exclude VAT.

Table A5 • *Cost parameters for biomass CHP heating in 2005 (excluding VAT) with projections out to 2030**

		Data for base year 2005				Extrapolation to 2030
		Minimum	Average	Maximum	Unit	
Input data	Investment cost**	1 200	1 400	1 600	2005€/kW_{th}	0%
	Share investment cost for heating	25	40	50	%	0%
	Conversion efficiency	10	18	40	%	+10%
	Fuel cost	3	4	5	2005€/GJ	0%
	Auxiliary energy needed	0	0	0	kWh_e/kW/yr	+5%
	Cost of auxiliary energy	0.05	0.15	0.2	2005€/kWh_e	+25%
	O&M	1	1.5	2	2005€/kW_{th}/yr	0%
	Full load hours heating	5 500	6 000	6 500	hrs/yr	0%
	Lifetime	10	15	20	yr	+20%
	Interest rate	5	10	15	%/yr	+10%
Intermediate results	Investment heat-related	300	560	800	2005€/kW_{th}	
	Annuity	8.0	13.1	19.9	%/yr	
	Annual investment payment	24	74	159	2005€/kW_{th}/yr	
	Annual auxiliary energy cost	0	0	0	2005€/kW_{th}/yr	
	Annual O&M cost	1	1.5	2	2005€/kW_{th}/yr	
	Fuel input	50	120	234	GJ_{input}/kW_{th}/yr	
Output data	Total energy cost					
	- investment	1	3	8	2005€/GJ	-51% to +90%
	- fuel	6	22	59	2005€/GJ	-9%
	- auxiliary energy	0	0	0	2005€/GJ	0%
	- O&M	0	0	0	2005€/GJ	0%
	Total	**7**	**26**	**67**	**2005€/GJ**	**-14% to +5%**

**Covers worldwide systems for the base year 2005, and projected relative differences by 2030. Neither a reference system nor avoided costs due to fuel savings are incorporated. Installation costs are included but heat distribution costs and costs allocated to electricity generation are not.*

*** Investment costs are defined here as total investment relative to thermal output of CHP plant.*

Fuel costs are a very dominant factor of total costs. Increasing fuel efficiency could result in a 9% cost reduction in the year 2030, assuming constant fuel prices. The overall cost of heat could change from €26 /GJ in 2005 to €24 /GJ by 2030 (range €8 to 58 /GJ).

The data overview was compiled by IEA Bioenergy Task32 (Biomass Combustion and Co-firing) using Koppejan (2007) and Obernberger (2004) as main sources.

A5. Biomass anaerobic digestion (CHP)

The data were mainly provided by Wellinger (2007) and refer to agricultural plants digesting animal waste, combined with other biomass (co-substrate like corn, grains, grass, etc.). Other biogas feedstocks not considered here include source-separated wastes and landfill gas.

The investment costs (expressed in €/kW_{th}) are based on literature cost data expressed in €/kW_e and ranging from 2000 to 4100 €/kW_e (average 3 500 €/kW_e). For converting these data to kW_{th}, an electrical efficiency of 37% and a thermal efficiency of 50% to 55% (based on biogas combustion) were used. In the analysis 10 to 30% of the total investment and O&M costs were allocated to heat production, with the remaining share to electricity generation not considered here. Thermal efficiency (based on the energy content of the biomass) was assumed to be 20% to 30%, the auxiliary heat input (8 to 20% for process heat) having already been included, as well as the use of any co-substrate feedstock which might increase the overall process efficiency. For source-separated wastes, the efficiency would be lower. The assumed fuel price range (based on a mix of green crop maize and manure feedstocks) was €2 to 3 /GJ. Extrapolation of costs out to 2030 is very uncertain.

Table A6 • *Cost parameters for biomass anaerobic digestion in 2005 (excluding VAT) with projections out to 2030**

		Data for agricultural plants base year 2005				Extrapolation to 2030
		Minimum	Average	Maximum	Unit	
Input data	Investment cost**	1 300	2 400	2 800	2005€/kW_{th}	-10%
	Share investment cost for heating	10	20	30	%	0%
	Conversion efficiency	20	25	30	%	0%
	Fuel cost	2	2.5	3	2005€/GJ	0%
	Auxiliary energy needed**	n/a	n/a	n/a	kWh_e/kW/yr	0%
	Cost of auxiliary energy	0.05	0.15	0.2	2005€/kWh_e	+25%
	Total O&M	300	340	380	2005€/kW_{th}/yr	-10%
	Full load hours heating	6 000	7 000	8 000	hrs/yr	0%
	Lifetime	15	20	25	Yr	+20%
	Interest rate	5	10	15	%/yr	+10%
Intermediate results	Investment heat-related	130	480	840	2005€/kW_{th}	
	Annuity	7.1%	11.7%	17.1%	%/yr	
	Annual investment payment	9	56	144	2005€/kW_{th}/yr	
	Annual auxiliary energy cost***	n/a	n/a	n/a	2005€/kW_{th}/yr	
	Annual O&M cost	30	68	114	2005€/kW_{th}/yr	
	Fuel input	72	101	144	GJ_{input}/kW_{th}/yr	
Output data	Total energy cost					
	- investment	0	2	7	2005€/GJ	-13% to -7%
	- fuel	5	10	20	2005€/GJ	0%
	- auxiliary energy***	0	0	0	2005€/GJ	0%
	- O&M	1	3	5	2005€/GJ	-10%
	Total	**6**	**15**	**32**	**2005€/GJ**	**-3% to -2%**

** The calculation does not take into account a reference system, nor are avoided costs due to fuel savings incorporated. Installation costs are included. Heat distribution cost and costs allocated to electricity generation are not included.*
***Investment costs are expressed in terms of kWh_{th} output.*
**** The auxiliary heat use has already been considered in the efficiency figure.*

In the resulting analysis feedstock costs are again a dominant factor. Applying a co-substrate with a lower value could help reduce the costs but using a source of lower quality could also reduce the process efficiency. The average overall cost of heat could change from €15 /GJ in 2005 to €14 /GJ in 2030 (ranging from €6 to 31 /GJ).

A6. Biomass municipal solid waste-to-energy

By using municipal solid waste (MSW) as feedstock for a waste-to-energy (WTE) process, the waste stream can be reduced in volume and the waste disposed. The thermal energy that is released during combustion can be used as direct heat or converted to electricity using a steam turbine. Only the fraction derived from biogenic materials can be considered renewable. Important issue remains to reduce, recycle and re-use waste material streams as much as possible, and to prevent the emission of polluting substances. An alternative route for MSW is to dispose of it in a landfill site. Anaerobic digestion occurs naturally over time to produce methane biogas that can be used for energy purposes, usually for power generation, so landfill gas is not considered here.

Table A7 • *Cost parameters for a modern waste-to-energy facility for incineration of municipal solid waste in 2005 (excluding VAT) with projections out to 2030**

		Data for base year 2005				Extrapolation
		Minimum	Average	Maximum	Unit	to 2030
Input data	Investment cost	2 000	4 000	7 000	2005€/kW$_{th}$	-10%
	Share investment cost for heating	15%	20%	35%	%	0%
	Conversion efficiency	20%	30%	40%	%	10%
	Fuel cost	0	0	0	2005€/GJ	0%
	O&M	80	150	300	2005€/kW$_{th}$/yr	0%
	Full load hours heating	7 000	7 500	8 000	hrs/yr	0%
	Lifetime	10	15	20	yr	+20%
	Interest rate	5	10	15	%/yr	+10%
Intermediate results	Investment heat-related	700	800	1 050	2005€/kW$_{th}$	
	Annuity	8.0%	13.1%	19.9%	%/yr	
	Annual investment payment	56.2	105.2	209.2	2005€/kW$_{th}$/yr	
	Annual auxiliary energy cost	0	0	0	2005€/kW$_{th}$/yr	
	Annual O&M cost (heat share only)	12	30	105	2005€/kW$_{th}$/yr	
	Fuel input	63	90	144	GJ$_{input}$/kW$_{th}$/yr	
Output data	Total energy cost					
	- investment	2	4	8	2005€/GJ	-15% to -11%
	- fuel	0	0	0	2005€/GJ	0%
	- auxiliary energy	0	0	0	2005€/GJ	0%
	- O&M	0	1	4	2005€/GJ	0%
	Total	**2**	**5**	**12**	**2005€/GJ**	**-12% to -8%**

**Covers worldwide systems for the base year 2005, and projected relative differences by 2030. Neither a reference system nor avoided costs due to fuel savings are incorporated. Installation costs are included but heat distribution costs and costs allocated to electricity generation are not.*

The current situation for waste disposal differs from country to country. Where landfills are common practice, a new reference situation could be to construct an advanced WTE installation. Where incineration is used for volume reduction without energy recovery, the additional investments needed to give WTE indicate the cost of heat and/or power generated. In a situation in which electricity is already generated, additional investments for heat generation are relatively small but must also account for the losses from the resulting reduced electricity generated[41].

The economics of a WTE process (Table A7) are primarily based on the income from waste treatment, with a tariff that should cover the operational costs of the plant. In other words, the cost of the heat and electricity generated strongly depends on other revenue generated from waste disposal as well as the additional cost for disposal of residue streams such as ash. In some situations the *cost* of producing the heat leaving the plant could be practically zero.

The often high capital costs for the heat distribution system were not included in the methodology (Figure A1). The *price* for heat at the end-user level is generally similar to that supplied from other technologies. So in practice the economics of heat utilisation are basically determined by selling the heat to pay back the initial investment of the heat distribution system (Koppejan 2007).

In this current analysis, the reference situation chosen was construction of a new, technically advanced WTE plant, with an electrical efficiency of 15% to 30% and a thermal efficiency of 20% to 40%. Note, that a heat-only MSW incinerator (as used in Denmark and Sweden) could have a thermal efficiency of 70% to 80% but was not considered here. The investment costs of a MSW installation are mainly determined by the flue gas cleaning costs that can be allocated to the core process of waste treatment rather than to the heat production process. Data used were based on Tilburg (2006) and Gerlagh (2007).

In the resulting cost analysis, fuel costs have been set at zero so that the dominant cost factors are for capital investment and O&M. The overall average cost of heat could reduce from €5.0 /GJ in 2005 to €4.6 /GJ in 2030 (with ranges remaining similar at €2 to 12 /GJ). It should be noted that a WTE plant continuously offers heat supply so that where the heat demand fluctuates, this can influence the cost of delivered heat, but since it is very site-specific, was not considered here.

A7. Conventional deep geothermal

Different applications for which geothermal direct heat is used include ground heat pumps, bathing/swimming, space heating (mostly provided by district heating), greenhouse and open-ground heating, industrial process heating, aquaculture pond heating and agricultural drying. There is also a very wide range of capacity factors (18 to >70%) for these uses. Consequently, the range in investment and calculated energy costs for deep geothermal direct use as presented below are large. They reflect some uncertainty as well as a real range of costs due to significant variations also arising from differences in the type of use.

In order to correct for the share in investment costs that is related to electricity production, only part of the investment costs is allocated to heat production. All data are based on estimates by GIA (Mongillo, 2007).

The costs of available heat from conventional deep geothermal projects (Table A8) is very low at €1.7 /GJ with a range of €0.4 to 11 /GJ. In future, due to the fact that some remaining geothermal sources will be more difficult to unlock than those already developed, costs are likely to increase to an average of €1.9 /GJ (range €0.4 to 12 /GJ).

41. Where steam is withdrawn from the electricity generating cycle, a reduction of electricity yield results. Depending on the process conditions around 7 GJ of heat can be withdrawn from the process to the detriment of 1 GJ of electricity generated. At a cost of €50 to 100 /MWh, this results in an 'opportunity cost' of heat of €2 to 4 /GJ without considering the additional investments for heat use (Koppejan 2007).

Table A8 • *Cost parameters for conventional deep geothermal* in 2005 (excluding VAT) with projections out to 2030***

		Data for base year 2005				Extrapolation to 2030
		Minimum	Average	Maximum	Unit	
Input data	Investment cost	50	200	500	2005€/kW_{th}	+10%
	Share investment cost for heating	30	50	100	%	0%
	Conversion efficiency	100	100	100	%	0%
	Auxiliary energy needed	5	20	40	kWh_e/kW/yr	0%
	- cost	0.05	0.15	0.2	2005€/kWh_e	+25%
	O&M	8	11	15	2005€/kW_{th}/yr	0%
	Full load hours heating	1 200	4 100	8 000	hrs/yr	0%
	Life of plant	25	35	55	Yr	+20%
	Interest rate	5	10	15	%/yr	+10%
Intermediate results	Investment heat-related	50	100	150	2005€/kW_{th}	
	Annuity	5.4	10.4	15.5	%/yr	
	Annual investment payment	3	10	23	2005€/kW_{th}/yr	
	Annual auxiliary energy cost	0.3	3	8	2005€/kW_{th}/yr	
	Annual O&M cost	2.0	2.2	2.4	2005€/kW_{th}/yr	
	Energy produced per year	1 200	4 100	8 000	kWh_{th}/kW/yr	
Output data	Total energy cost	0.1	0.7	5.4	2005€/GJ	+16% to +19%
	- investment					
	- fuel	0.0	0.0	0.0	2005€/GJ	0%
	- auxiliary energy	0.0	0.2	1.9	2005€/GJ	0% to +25%
	- O&M	0.3	0.8	3.5	2005€/GJ	0%
	Total	**0.4**	**1.7**	**10.7**	**2005€/GJ**	**+5% to +14%**

**The deep geothermal direct uses included here are district heating (17%), aquaculture pond heating (4%), agriculture (0.7%) and industrial uses (4%) (percentages are relative to total direct use). The large ranges are mainly due to these different uses. The average full load hours has been weighted according to use and capacity factor.*

***Covers worldwide systems for the base year 2005, and projected relative differences by 2030. Neither a reference system nor avoided costs due to fuel savings are incorporated. Installation costs are included but heat distribution costs and costs allocated to electricity generation are not.*

A8. Advanced deep geothermal

The applications for advanced deep geothermal systems are also very diverse, but costs are more widely spread than for conventional heat energy systems. All data in the overview (Table A9) are based on estimates by GIA (Mongillo, 2007). Costs in the year 2030 might have come down to €0.5 to 20 /GJ (average €2.3 /GJ) mainly due to expected lower investments.

A9. Shallow geothermal heating and cooling

All data in the overview (Table A10) are based on estimates by GIA (Mongillo, 2007). Costs by 2030 might have come down to €15.4 /GJ (range €2.2 to 69 /GJ) for heating and €15 /GJ (range €1.8 to 89 /GJ) for cooling, mainly due to expected lower investments and increased coefficient of performances (COP). Based on the assumptions used, average costs appear reasonable, but the maximum costs seem high.

Table A9 • *Cost parameters for advanced deep geothermal* in 2005 (excluding VAT) with projections to 2030***

		Data for base year 2005				Extrapolation to 2030
		Minimum	**Average**	**Maximum**	**Unit**	
Input data	Investment cost for CHP plant	750	1 230	2 400	2005€/kW_{th}	-25%
	Share investment cost for heating	10	15	20	%	0%
	Conversion efficiency	100	100	100	%	0%
	Auxiliary energy needed	0	15	30	kWh_e/kW/yr	0%
	- cost	0.05	0.15	0.2	2005€/kWh_e	+25%
	O&M	12	18	24	2005€/kW_{th}/yr	-10%
	Full load hours heating	1 200	4 100	8 000	hrs/yr	0%
	Life of plant	25	35	55	yr	+20%
	Interest rate	5	10	15	%/yr	+10%
Intermediate results	Investment heat-related	140	375	920	2005€/kW_{th}	
	Annuity	5.4	10.4	15.5	%/yr	
	Annual investment payment	4	19	74	2005€/kW_{th}/yr	
	Annual auxiliary energy cost	0	2	6	2005€/kW_{th}/yr	
	Annual O&M cost	12	18	24	2005€/kW_{th}/yr	
	Energy produced per year	1 200	4 100	8 000	kWh_{th}/kW/yr	
Output data	Total energy cost					
	- investment	0.1	1.3	17	2005€/GJ	-21% to -19%
	- fuel	0.0	0.0	0	2005€/GJ	0%
	- auxiliary energy	0.0	0.2	1	2005€/GJ	0% to +25%
	- O&M	0.4	1.2	6	2005€/GJ	-10%
	Total	**0.6**	**2.7**	**24**	**2005€/GJ**	**-15% to -13%**

Deep geothermal direct uses included here relative to total direct use are district heating (17%), aquaculture pond heating (4%), agriculture (0.7%) and industrial uses (4%). The large ranges are due in part to these different uses and a wide range of capacity factors (from <20 to >70%). The average full load hours was weighted according to both use and capacity factor. Where waste heat from geothermal electricity generation plants is utilised, the investment costs, including drilling of deep wells, was allocated to the power plant since the "waste" hot water would otherwise be discarded. In a heat only plant, drilling costs are included giving a high investment cost and hence a wide range.

***Covers worldwide systems for the base year 2005, and projected relative differences by 2030. Neither a reference system nor avoided costs due to fuel savings are incorporated. Installation and drilling costs are included but heat distribution costs and costs allocated to electricity are not.*

Table A10 • *Cost parameters for shallow* geothermal heating and cooling in 2005 (excluding VAT) with projections to 2030**

		Data for base year 2005				Extrapolation to 2030
		Minimum	Average	Maximum	Unit	
Input data	Investment cost	200	500	1 150	2005€/kW$_{th}$	-15%
	Share investment cost for					
	- heating	67	67	67	%	0%
	- cooling	33	33	33	%	0%
	Coefficient of performance***	3	4	5		+33%
	Auxiliary energy needed for					
	- heating	240	500	930	kWh$_e$/kW/yr	0%
	- cooling	120	325	670	kWh$_e$/kW/yr	0%
	Cost of auxiliary energy	0.05	0.15	0.2	2005€/kWh$_e$	+25%
	O&M	4	9	15	2005€/kW$_{th}$/yr	-15%
	Full load hours				hrs/yr	0%
	- heating****	1 200	2 000	2 800		
	- cooling****	600	1 300	2 000	hrs/yr	0%
	Life of plant	20	25	30	yr	+20%
	Interest rate	5	10	15	%/yr	+10%
Intermediate results	Investment				2005€/kW$_{th}$	
	- heating-related	133	333	767		
	- cooling-related	67	167	383	2005€/kW$_{th}$	
	Annuity	6.5	11.0	16.0	%/yr	
	Annual investment payment					
	- heating-related	9	37	122	2005€/kW$_{th}$/yr	
	- cooling	4	18	61	2005€/kW$_{th}$/yr	
	Annual auxiliary energy cost					
	- heating	12	75	187	2005€/kW$_{th}$/yr	
	- cooling	6	49	133	2005€/kW$_{th}$/yr	
	Annual O&M cost	4	9	15	2005€/kW$_{th}$/yr	
	Energy produced per year					
	- heating	1 200	2 000	2 800	kWh$_{th}$/kW/yr	
	- cooling	600	1 300	2 000	kWh$_{th}$/kW/yr	
Output data	Total energy cost heating					
	- investment	0.9	5	28	2005€/GJ	-16% to -10%
	- fuel	0.0	0	0	2005€/GJ	0%
	- auxiliary energy	1.2	10	43	2005€/GJ	-25%
	- O&M	0.4	1	3	2005€/GJ	-15%
	Total - heating	**2.4**	**17**	**75**	**2005€/GJ**	**-20% to -19%**
	Total energy cost cooling					
	- investment	0.6	4	28	2005€/GJ	-16% to -10%
	- fuel	0.0	0	0	2005€/GJ	0%
	- auxiliary energy	0.8	10	62	2005€/GJ	-25%
	- O&M	0.6	2	7	2005€/GJ	-15%
	-Total - cooling	**2.0**	**16**	**97**	**2005€/GJ**	**-21% to -19%**

**The other major shallow direct uses not included here are bathing/swimming pools (30.4% of total direct use) and non-district space heating (3.4%).*

***Covers worldwide systems for the base year 2005, and projected relative differences by 2030. Neither a reference system nor avoided costs due to fuel savings are incorporated. Installation costs are included but heat distribution costs are not.*

**** Assumed geothermal heat pumps only and higher COPs for future technologies.*

***** Assumed 1200 hrs/yr for USA; 2000 hr for Europe; 2 800 hr for northern Europe and Canada.*

A10. Shallow geothermal heat only

All data in the overview (table A11) are based on estimates by GIA (Mongillo, 2007). Costs in 2030 might have come down to €18 /GJ (range €2.5 to 82 /GJ) mainly due to expected lower investments and an increased coefficient of performance (COP).

Table A11 • *Cost parameters for shallow* geothermal heat only in 2005 (excluding VAT) and projections to 2030***

	Shallow geothermal heat only	Data for base year 2005				Extrapolation to 2030
		Minimum	Average	Maximum	Unit	
Input data	Investment cost	200	500	1150	$2005€/kW_{th}$	-15%
	COP*	3.0	4.0	5.0	-	+33%
	Auxiliary energy needed	240	500	933	$kWh_e/kW/yr$	n/a
	- cost	0.05	0.15	0.2	$2005€/kWh_e$	+25%
	O&M	4	9	15	$2005€/kW_{th}/yr$	-15%
	Full load hours heating****	1 200	2 000	2 800	hrs/yr	0%
	Lifetime	20	25	30	yr	+20%
	Interest rate	5	10	15	%/yr	+10%
Intermediate results	Investment heat-related	200	500	1 150	$2005€/kW_{th}$	
	Annuity	6.5	11.0	16.0	%/yr	
	Annual investment payment	13	55	184	$2005€/kW_{th}/yr$	
	Annual auxiliary energy cost	12	75	187	$2005€/kW_{th}/yr$	
	Annual O&M cost	4	9	15	$2005€/kW_{th}/yr$	
	Energy produced per year	1 200	2 000	2 800	$kWh_{th}/kW/yr$	
Output data	Total energy cost - investment	1.3	8	43	2005€/GJ	-16% to -10%
	- fuel	0.0	0	0	2005€/GJ	0%
	- auxiliary energy	1.2	10	43	2005€/GJ	-6%
	- O&M	0.4	1	3	2005€/GJ	-15%
	Total	**2.9**	**19**	**89**	**2005€/GJ**	**-12% to -8%**

**The other major shallow direct uses not included here are bathing/swimming pools (30.4% of total direct use) and non-district space heating (3.4%).*

***Covers worldwide systems for the base year 2005, and projected relative differences by 2030. Neither a reference system nor avoided costs due to fuel savings are incorporated. Installation costs are included but heat distribution costs are not.*

**** Assumes geothermal heat pumps only which make up 32% of total direct heat use (current technology provides the higher COPs listed here)*

***** 1200 hours operation assumed for USA; 2 000 hrs for Europe; 2 800 hrs for northern Europe and Canada.*

Annex B. Country Profiles

This compilation of 12 country studies presents national strategies to promote renewable heating and, where available, cooling. Canada, Denmark, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, United Kingdom and the European Union were selected due to them having in place a range of REHC policies of relevance to the study. The accuracy of renewable energy data varies depending on the statistical resources available from each country. Most policy data was collected directly from government documents or web sites. IEA data was also a primary source of information with additional input received from country representatives. Even so heating and cooling data is sparse. The IEA Solar Heating and Cooling, Bioenergy, and Geothermal Implementing Agreements were consulted to ensure greater accuracy, complete coverage, and relevance of the various technologies. Despite these measures, data as reported can not be taken as definitive and precise assessments, but rather as indicative measures of the magnitude of budgets, costs and renewable energy resources involved.

The aim of this Annex is to outline the political experiences of the various nations in the promotion and deployment of REHC based on a review of the type and structure of implemented policies as well as assessing the renewable heat and cold that was generated as a result. The information was used to bring forward critical experiences, lessons learned, effectiveness indicators, and good policy practice examples as were presented in Section 4 of the main report.

Policies which indirectly promote renewable heat production (such as those supporting renewables in CHP) are included. Policies specifically targeting renewable electricity production are not, except where remarkable promotion of renewable heating technologies has also been exhibited. Electricial heating and air-conditioning systems were not taken into consideration, but offer an opportunity for further study.

The major focus of the report is on political tools for the promotion and increased deployment of market-ready renewable energy technologies (RETs), thereby excluding RD&D policies.

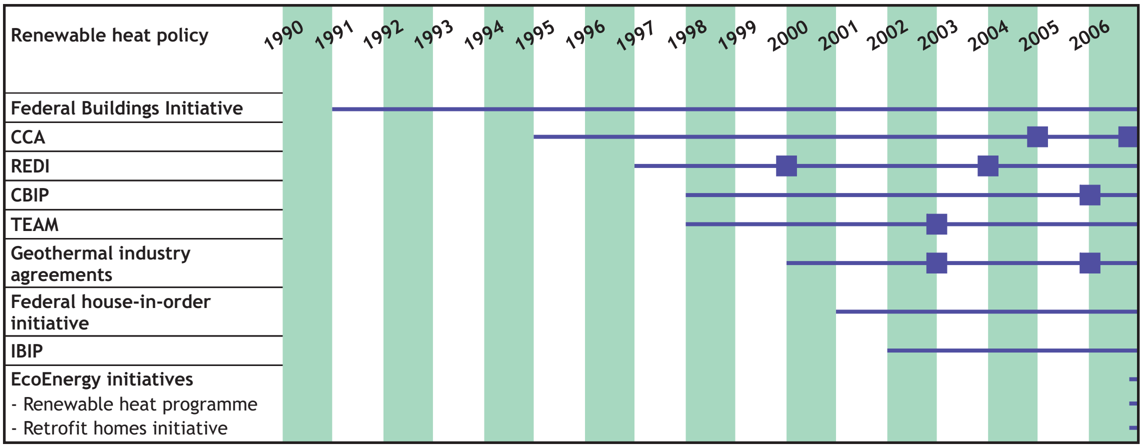
For each country listed below, policies are classified as “Carrot” incentives, “Stick” regulations and “Guidance” education, promotion and training. A graphical historic timeline showing policy development since 1990 is provided at the top of the section for each country study. It gives an overview of national strategies and enables a broad comparison between countries to be quickly made. A horizontal line for each policy represents the year of it being implemented and finishing (where appropriate). The squares along this timeline indicate the time of a significant amendment to, or development of, the policy that is described in the associated text. Each policy listed is then described in more detail in the text below the figure.

For ease of comparison all costs have been converted from the local currency to Euros using the exchange rate as given in each case. The conversion factors used were based on the average exchange rates in 2006.

Energy units can be confusing as several options are used synonymously in the literature and by governments. In this study the Joule was taken as the standard international energy unit for all energy sources and all data taken from the literature was converted using 1 Nm/s = 1J; 1kWh = 3.6 MJ; 1TWh = 3.6 PJ; 1ktoe = 42 TJ; 1Mtoe= 42 PJ etc.

Annex B1. Canada

Instruments



In Canada, provincial governments have exclusive jurisdiction over the energy production and distribution within their provinces. As a consequence, specific decisions regarding the use of renewable energy sources are made within each province, tailored to their unique circumstances. The federal government promotes the sustainable development of all of Canada's natural resources, is responsible for international trade and other inter-jurisdictional energy issues, and has a direct role in the development and management of resources on aboriginal and other federal lands and off-shore.

Natural Resources Canada (NRCan), through the Renewable and Electrical Energy Division (REED) and the Office for Energy Efficiency (OEE), is responsible for most of the federal initiatives in support of renewable energy, including financial and information measures and programs.

Guidance. The **Federal Buildings Initiative (FBI)** is a voluntary program developed and administered by NRCan[42]. This ongoing programme, first established in November 1991, assists federal departments and agencies to plan and implement cost effective comprehensive energy efficiency improvement projects in their facilities. The programme provides departments and agencies of the Government of Canada with technical assistance such as project facilitation services, energy audits, model tendering and contract documents as well as a model framework for updating their facilities with energy efficient technologies and practices.

The initiative is broken into **Energy Performance Contracting** and **Tailored Executive and Managerial Support.** Through the former, the departments and agencies of the Government of Canada are given access to private sector capital used to finance energy efficiency improvement projects. As it is a voluntary programme, measures are paid for through the energy savings generated by the projects themselves. By March 2006, the FBI had fostered more than 80 projects, attracted €172 M (CAD 265 M)[43] in private sector investment, and generated €25 M in annual energy cost savings.

Carrot. In Budget 1994 an **Accelerated Capital Cost Allowance** (CCA) was created under Class 43.1 to encourage industries to invest in equipment using a renewable energy source. This early CCA provided 30% allowance for some forms of biomass and waste heat generation. In Budget 2005 a new CCA was

42. See www.oee.nrcan.gc.ca/fbi

43. 1 Canadian dollar (CAD) = €0.65

approved for a 50% allowance on a declining basis under Class 43.2 supporting wind, solar, small hydro and the use of waste fuel such as landfill gas, manure, and wood waste. Budget 2007 extended the 50% Class 43.2 eligibility for active solar systems to include other commercial and residential applications such as space heating of commercial and apartment buildings, and hot water heating for laundries, car washes and hotels, but not swimming pool heating. Some equipment may be treated as part of the building for CCA purposes (*e.g.* solar collectors integrated into the building). Solar collectors, solar energy conversion equipment, solar water heaters, energy storage equipment, control equipment and equipment designed to interface solar heating equipment with other heating equipment are eligible. Equipment that distributes heated air or water within a building, and structural components such as framing or windows, continue to be considered part of the building and therefore ineligible. The changes apply to eligible assets acquired on or after March 19, 2007.

Carrot and *Guidance*. In December 1997, as part of NRCan's Renewable Energy Strategy, Canada announced the **Renewables Energy Deployment Initiative (REDI)**. Initiated on April 1 1998, REDI was a programme designed to stimulate demand for water heating, space heating and industrial process heating generated by renewable energy systems. REDI was first established as a 3-year, €7.8 M programme. Incorporated with the **Action Plan 2000 on Climate Change,** a second three year cycle began in 2001 with an additional €9.1 M funding, and a third three-year cycle beginning in 2004 with €16.25 M of additional funding and ended in March 2007. Over its 9-year lifetime REDI was allocated €33.15 M by the government (NRCan, 2005).

The Renewable and Electrical Energy Division of the Electricity Resources Branch is responsible for administering REDI´s funding that was directed into market stimulation, industry infrastructure support, and market development. Under market stimulation, nearly 50% of the funding was allocated to provide financial incentives for the adoption of renewable heating systems. Technologies eligible for funding included active solar air and water thermal systems, and high-efficiency/low-emission biomass combustion systems between 75 kW and 2 MW. Businesses were eligible for a refund of 25% (40% in remote communities) of the purchase and installation costs of active solar and large biomass combustion systems up to a maximum refund of €52 000 per project or €162 500 per corporate entity for multiple installations. Remote communities, business, institutions and other organisations were eligible for a refund of 40% of the purchase and installation costs of a qualifying system to a maximum refund of €52 000. Geothermal heat pumps were not eligible for direct financial incentives.

In addition to direct financial support, REDI supported training, standards development, and solar technology certification activities and market activities in support of the infrastructure and market development courses (roughly 5% of REDI funding)[44]. REDI targeted public awareness through participation in industry trade fairs, funding of studies to identify target markets, publication of information pieces and communication products such as buyers´ guides and promotional materials. Moreover, REDI actively collaborated with partners from the renewable energy industry associations and Canadian municipalities (NRCan, 2005).

Carrot. NRCan's 1998 **Commercial Buildings Incentive Program (CBIP)** provided financial incentive for the energy efficient design of new or retrofit commercial buildings. Buildings eligible for funding are 25% more energy efficient than a similar building meeting the Energy Code requirements. Incentives are available for twice the difference of the estimated annual energy costs for the approved efficient design and the estimated annual energy costs if a building is constructed to the Model National Energy Code for Buildings (MNECB) standard, to a maximum of €39 000 or the total design cost, whichever is less. Passive solar systems are eligible for funding under this programme (SHC, 2006; NRCan, 2006). In July 2006 CBIP funding was approved through March 31 2007. The total budget allocated for this fund is €16.6 M over its 10 year lifetime.

44. The remaining REDI funding was used to form strategic partnerships and alliances, and program management and support.

Carrot. The **Technology Early Actions Measures (TEAM)** programme was established in 1998 with €42 M as a federal inter-departmental technology investment programme and has continued through to 2007. TEAM was allocated an additional €65 M in 2003 from the Canadian Federal Government in its efforts to support climate change initiatives[45]. TEAM, as part of the Technology and Innovation component of the Climate Change Plan for Canada, supports projects that are designed to demonstrate technologies that mitigate GHG emissions nationally and internationally, and that sustain economic and social development. TEAM brings together the public and private sector to identify, develop, and support technologies which reduce GHG emissions. Project applicants must prove that the installation of a given technology will contribute to GHG reductions. If a project is approved, TEAM may contribute up to 75% of the total amount of federal government funding contributions to the project.

Since its inception TEAM has contributed €69 billion in funding towards a total investment of €661 billion in GHG reducing projects for fuel cells and hydrogen (13% of total fund), decentralized energy (25%), cleaner fossil fuels (8%), biotechnology (22%), and advanced end-use efficiency (32%). Those projects relating to renewable heating fall under the categories of decentralized energy and advanced end-use efficiency. Based upon the proportionate percentages of project funding, €39 billion in TEAM funding has been allocated to projects, all or part of which may have been invested in renewable heating (SHC, 2006; NRCan, 2006).

Guidance. In 2000 the Canadian government signed a three-year agreement with the Geothermal Heat Pump Consortium under the REDI program for the promotion and the use of geothermal energy for heating. This voluntary initiative developed a package of marketing services to accelerate take-up of geothermal energy systems (IEA, 2004).

Carrot and *Guidance*. The **Federal House in Order Initiative** in 2001 was created as part of Canada's action plan to reduce greenhouse gas emissions. This programme acts primarily through technology demonstration projects, seminars, workshops, technical advice and assistance, information distribution, standards and detailed tracking and reporting. Solar energy, biomass, geothermal technologies, on-site wind power generation, micro-hydro generation, integrated design, alternative transportation fuels, and green procurement practices were implemented and promoted through this initiative (NRCan, 2006).

Carrot. Since 2002, NRCan has provided financial incentives up to €52 000 under the **Industrial Buildings Incentive Program (IBIP).** The programme expired on March 31 2007. It aimed to foster the energy efficient design of industrial buildings by fostering the integration of industrial building and process design. Incentives were awarded to industrial buildings with new designs for energy efficiency (NRCan, 2006). The design must be 25% more efficient than the standard model in order to receive funding.

Carrot and *Guidance*. In 2003, under REDI programme NRCan and the Canadian **GeoExchange Coalition** (CGC) signed a three-year **Contribution Agreement** for €6.83 M. This agreement accelerated the transformation of the Canadian market for GHP systems through an industry coalition that stimulated higher demand. NRCan also supported the CGC to develop and manage implementation of a geoexchange training and quality assurance initiative in collaboration with national and regional partners that set a recognized Canadian professional and industry standard for design and installation methods and training.

In 2006, NRCan and the CGC signed an agreement and €310 375 funding was provided to CGC to develop national training material and courses to meet national and provincial requirements, together with taking the necessary steps and measures to develop a certification programme. Under this agreement, the CGC will also conduct an industry survey and undertake targeted and business development projects.

45. The government allocated a total of €650 M for climate change initiatives in 2003, a part of which was allocated to TEAM.

Guidance. NRCan has also developed consumer guides for solar domestic hot water systems and solar pool heating systems (SHC, 2006). The Office of Energy Efficiency (OEE) is responsible for numerous publications available free to the general public on topics related to energy efficiency and alternative energy (NRCan, 2006).

Guidance. The Canadian Renewable Energy Network (CanREN) provides information on renewable energy sources and highlights renewable technologies and applications for the purpose of increasing the understanding of renewables and accelerating the development and commercialisation of RETs. Canada's **RETScreen International Clean Energy Decision Support Centre**, provides information to policy makers and the public by developing decision-making tools that reduce the cost of pre-feasibility studies. Training is provided on how to better analyse the technical and financial viability of possible projects which include solar thermal, geothermal, and biomass (IEA, 2006c).

Carrot and *Guidance*. In 2007, the Government of Canada announced more than €1.3 billion funding for a series of **ecoENERGY Initiatives**[46], including the €1 billion *ecoENERGY Renewable Initiative* and the €200 M *ecoENERGY Efficiency Initiative*.

One component of the ecoENERGY Renewable Initiative, the €24 M **ecoENERGY Renewable Heat Program**, will support the adoption of clean renewable thermal energy technologies for water and space heating in buildings through (1) deployment incentives for solar heating systems in the industrial, commercial and institutional (ICI) sectors (up to 25% of the purchase, installation and other costs); (2) industry capacity building by supporting the development of standards and certification; building codes and provincial and municipal regulations, and training for energy designers, technicians and installers; and (3) residential pilot projects supporting solar hot water systems in residential sectors. It was expected that this new initiative would result in up to 700 solar thermal units in the ICI sectors, up to 8 residential pilot projects, and thousands of solar thermal units installed across the country with total energy savings of more than 0.35 PJ/yr.

The €150 M **ecoENERGY Retrofit-Homes Initiative** was designed to help homeowners of existing low-rise properties make smart energy retrofit decisions that will result in significant energy savings and a cleaner environment. EcoENERGY Retrofit Incentives apply to a range of technologies including energy efficient cooling systems, as well as solar water heaters and geothermal systems. The maximum grant for one home or multi-unit residential building is €3 300.

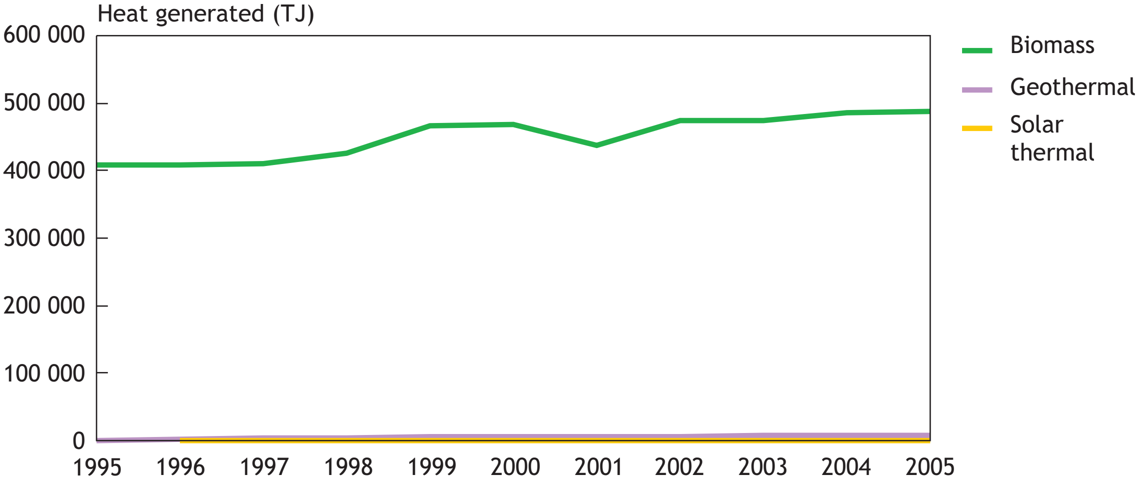
Provincial governments and electric utilities have also played a significant role in Canada's incentives for renewable energy for heating.

Evaluation

In 2004, 41,102 TJ of heat was produced and consumed in the industrial and commercial sectors (IEA, 2007a). Canada's winter climate creates intense space heating demands so that 80.2% of residential energy use is for space and water heating (NRCan, 2005). This high per-capita consumption may also have been amplified by the relatively low historic costs for conventional, carbon-based heating fuels that provide most of this heat. Where renewable energy heating has been economically competitive (*e.g.* biomass residues for thermal applications and solar thermal for swimming pools), the market has grown steadily (Figure B1) (IEA, 2004).

46. http://www.ecoaction.gc.ca/

Figure B1 • *Renewable heat production in Canada from 1995 till 2005*



Sources: IEA, 2006b; ESTIF, 2006a; Lund et. al, 2005. Where geothermal data was unavailable extrapolations were made.

Biomass

Largely due to the significant natural resource of biomass, solid biomass constitutes a majority of Canada's renewable heating supply. Wood products and pulp and paper industries account for the majority of solid biomass use, primarily in the forms of wood waste and black liquor (IEA, 2004). In addition to the use of wood for residential space heating[47], biomass waste facilities have been established for process heat and in CHP systems. Although a significant resource potential exists, the growth of biomass heating in Canada has not been exceptionally high.

Despite voluntary programmes and information schemes in place, the direct financial support for renewable heating has relied heavily on the support of one government initiative, REDI (1997). As of March 2006, REDI had supported 128 biomass heating projects (equivalent to 246 MW of capacity) between the years 1998 and 2002. Additionally, several biomass waste demonstration projects were supported by the TEAM programme. Regional programmes have also played an important role in the development of biomass although considering the large natural resource potential and the significant heating demand, the share of biomass in the Canadian heat supply could be higher.

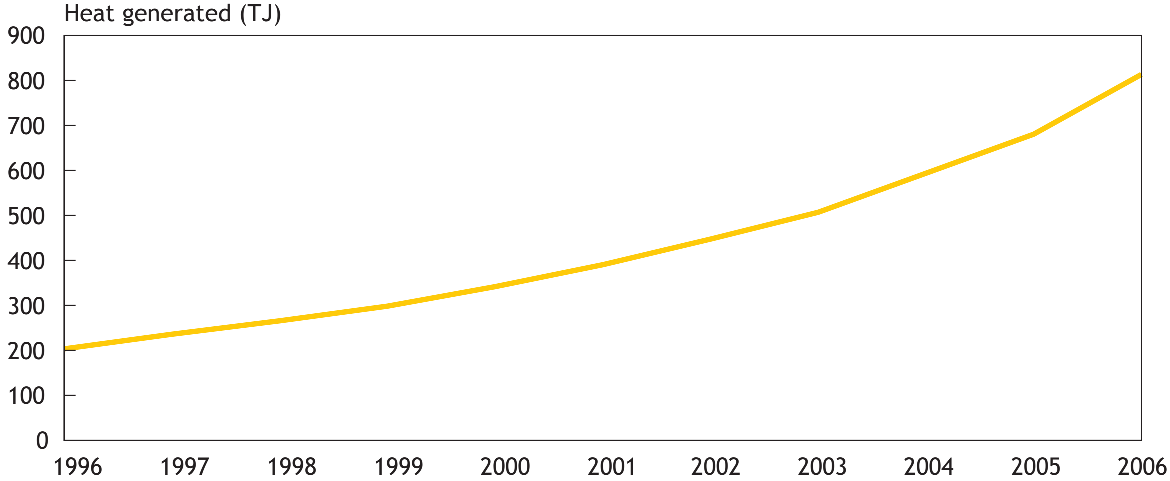
Solar thermal

In 2001, 170 MW of solar thermal heating capacity had been installed and by 2004 the market had grown by over 50% (Figure B2) equivalent to 258 MW (368 000 m^2) (SAIC, 2006). Around two thirds of the solar thermal market is comprised of unglazed solar collectors for heating swimming pools (SHC, 2006).

The development of solar energy in response to the REDI programme was initially modest. Between 1998 and 2002, 59 water and air heating projects were supported with REDI funding. (SHC, 2006). By March 2006, approximately 300 commercial solar heating projects had been completed giving a solar thermal capacity of 36 MW (50 000 m^2) (SHC, 2006). In addition, approximately €2 M public investment leveraged €6.4 M of investments from active solar thermal system businesses (NRC, 2005).

47. Wood is used for residential space heating in roughly 3 million households in Canada equaling roughly 90-100 PJ/yr.

Figure B2 • *Solar thermal heat in Canada*



Sources: SAIC, 2006; SHC, 2006. Figures were calculated based on annual sales and conversion factors for solar output in Canada as reported by the IEA SHC.

Geothermal

The direct-use of geothermal energy[48] in Canada increased from 1.68 MW thermal capacity in 1995 to 377.6 MW in 2000 and 461.0 MW in 2004, providing 2 546 TJ/yr of heat (Lund, *et al.*, 2001). Between 2004 and 2006 the geothermal market grew by nearly doubling its revenue and total capacity. Over 3 000 geothermal heat pump (GHP) units were installed in 2006 alone. The market for geothermal installations has been shifting to larger capacity units. In addition, although most of the geothermal resources are in the western portion of Canada, regional variations in sales seem to be the result of product awareness, rather than available resource (SAIC, 2006).

GHPs account for the majority of geothermal heat and have been growing substantially (Table B1). The growth rate increased from 10-15% in 2000 to 40% in each of 2005 and 2006 and they are now estimated to produce 2.5 PJ/yr (Lund *et al.*, 2005). They are mostly imported from the United States (SAIC, 2006) and are in use in every Canadian province, especially Manitoba and Ontario where a 'creative financing environment' has helped investors pay back the up-front capital expenditures from substantial savings in operating costs (Lund *et al.*, 2005).

Additional geothermal heat in Canada is sourced from hot spring resorts (360 TJ/yr), and heated water from abandoned mines (11 MW capacity producing 26 TJ/yr).

Table B1 • *Growth of Canadian geothermal heat (including heat pumps)*

	1995	2000	2004
MW installed	1.68	377.6	461.0
TJ estimated	9.27	1 023	2 546

Source: Lund et al., 2001; Lund et al., 2005.

48. Direct-use infers the use of relatively low-temperature geothermal resources for GHPs, geothermal driven district heating, crop drying, space heating, snow melting, bathing, and low-grade industrial process heat.

GHPs are not eligible for financial support from REDI. However, a voluntary agreement signed with the Geothermal Heat Pump consortium occurred at the same time as substantial growth in the geothermal heat market in Canada. Geothermal has been promoted through information campaigns through the Federal House in Order Initiative (2001).

The geothermal industry in Canada has been quoted as viewing the greatest perceived barrier to further growth as a lack of understanding and awareness among builders, developers and consumers (SAIC, 2006).

Conclusions

Most of the political support for REHC in Canada consists of financial subsidies established under various programmes. A majority of these schemes include a maximum limit of the amount payable. Information schemes and voluntary agreements have played a primary role in the portfolio for promoting REHC. Incentives provided by Canadian provinces have also played a role in the development of the renewable heat market.

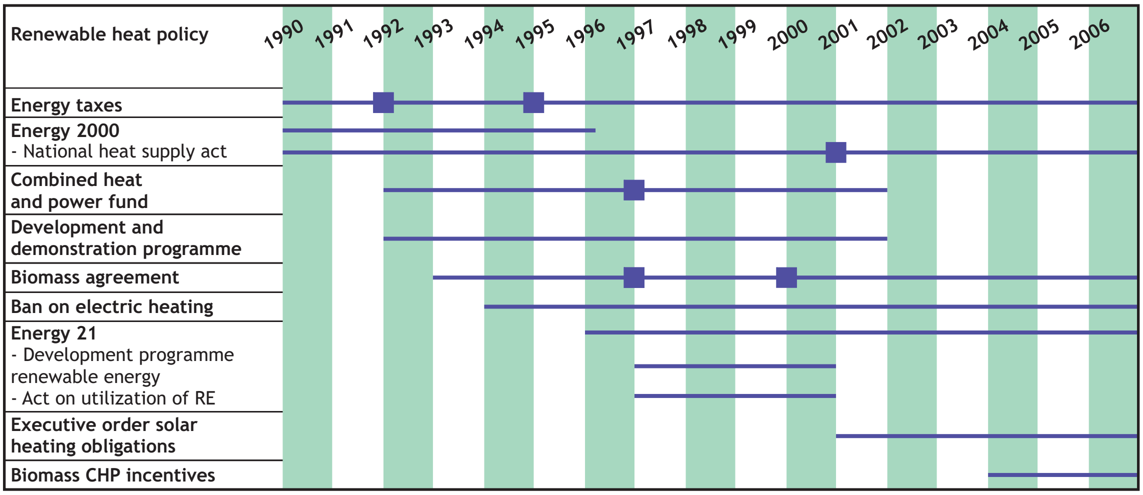
REDI helped develop the market for solar water and space heating systems, GHPs, and high-efficiency/low-emission biomass combustion systems (IEA, 2004). A total of 426 REHC projects were supported with funds from REDI between 1998 and 2005. According to the 2004-2007 REDI Business Strategy, €4.03 M of REDI contributions has leveraged €22.4 M of corporate investments since its inception.

Energy efficiency has been an important focus of the Canadian government for improvement with the IBIP and CBIP specifically targeted towards these measures. Additionally, the FBI is reported to have financed €162.5 M in energy efficiency improvements. The importance of political instruments to support energy efficiency and REHC technologies is discussed in Section 4 of the main report.

Building on the momentum created by previous programmes, the new ecoENERGY Initiative exemplifies continued federal government commitment to further the deployment of REHC technologies and also increase energy efficiency in homes and buildings.

Annex B2. Denmark

Instruments



Stick. Prior to its first Heat Supply Law in 1979 that was part of the **Danish Energy Policy**, most Danish consumers had oil furnaces for heating. This law required local authorities to report on their heat requirements, methods, and energy consumed. Plans were then drafted with an emphasis on public planning of heat supply (DEA, 2005). The vast use of district heating was thereby promoted by giving local governments the authority to mandate connection of new and existing buildings to district heating networks. Since its enforcement in 1982, this law has remained in place with minor amendments in 2000 (laws 581 and 582; see below).

The second major energy policy in Denmark, **Energy Plan 81,** was drafted in 1981 offering further support for the environmental considerations of heat and energy generation.

Carrot and *Guidance*. From 1979 to 2002 Denmark provided subsidies for up to 30% of installation costs of solar water heating systems for households in areas not served with district heating (SHC, 2006). Between €2.6 - 3.25 M (DKK 20-25 M[49]) were invested from 1998-2000 with an additional €260 000 invested per year on information campaigns. On average approximately €1.2 M was provided annually giving a total contribution of roughly €30 M. After 25 years the programme was ended on the basis that after such a long period of support, the technology should have been mature enough for commercial competition.

Carrot. **Energy taxes** have been imposed in Denmark since 1986. In 1992 a CO_2 tax extended the taxation on fossil fuels to include the private sector. In 1995 green taxes were applied which increased the CO_2 and energy taxes and created a SO_2 tax. Biomass heat is exempted from all these aforementioned taxes except the SO_2 tax of €2.47/t. The average tax on fuel oil is €308/t and on coal €199/t. Solar thermal plants are also exempted from both energy and CO_2 taxes (EC, 2006b). These energy taxes have created a more level playing field for renewable heating, making it more cost competitive with conventional heating fuels.

Stick. In April 1990, Denmark's third energy action plan, **Energy 2000**, created a **building code** with a target of reducing 25% of the net heat demand and requiring low temperature heating systems such as district heating systems, condensing boilers, solar energy, and heat pumps. This code entered into force in 1996 for large buildings and 1998 for small buildings.

49. 1 Danish krone (DKK) = €0.13

Stick. On June 3rd, 1990 the **National Heat Supply Act** was passed targeting the goals of Energy 2000. This act gave the Minister of Energy authority to control the choice of fuel in block heating units, district heating plants, and decentralised CHP plants to promote the expansion of decentralized CHP. Existing installations were to be converted to CHP and the use of natural gas and environmentally friendly fuels such as biomass were to be increased. This conversion away from coal and oil took place in 3 phases: from 1990-1994, 1994-1996, and beginning in 1996.

Carrot. Subsidies for biomass heating plants were offered until 2001. Up to 21% of installation costs for households and 26% for businesses were available in areas not covered by the collective supply system.

Carrot. The **Combined Heat and Power Fund** was established in 1992 (January 3) under Law Number 3 supporting conversion of district heating systems from conventional-fuel to biomass-based CHP by subsidizing 10-25% of the costs of conversion. A ceiling subsidy of 50% was established for development-oriented projects. In its first fiscal year €1.69 M was disbursed and around €3.25 M each subsequent year (Lorenzen, 2000). It was originally scheduled to expire in 1997 but was extended until 2002.

Carrot. Law no. 837, the **Development and Demonstration Programme for Renewable Energy** (October 7, 1992), established investment subsidies between 15% and 30% for the construction costs of renewable installations including solar thermal, heat pumps, and straw and wood based boilers (but not for residential wood stoves already common in Denmark). The programme is scheduled to cease activities in accordance with the commercialisation of renewable technologies. Average annual contributions to renewable investments are around €5.9M.

Stick. In June of 1993 the **Biomass Agreement** was established with the aim of expanding biomass in electricity and heating supply sectors (see Section 4 on Good Policy Practices). Utilities are required to buy and incinerate at least 1.2 Mt of straw and 0.2 Mt of wood chips per year by 2000, thereby replacing 6% of their total consumption of coal with straw and wood (Odgaard, 2000). In addition, a feed-in tariff of €0.05 /kWh was set for a 10 year production period. In the following 10 year period, a subsidy of €0.01 was offered as a supplement to the market price for electricity.

Following its implementation, power companies and district heating plants faced problems with price hikes due to a limited market competition leading to a 1997 amendment allowing utilities more flexibility in their choice of biomass supply. The targets for the end supply of biomass remained the same at 19.5 PJ by 2000. New stipulations were defined for 1.0 Mt of straw, 0.2 Mt of wood chips, and the choice of 0.2 Mt of either straw, wood chips, or chips from willow (Odgaard, 2000). Further amendments were made in 2000, making new stipulations for the conversion to biomass to take place not before 2005, but when the conversion is technologically and economically feasible.

Stick. On May 6 1994, Denmark implemented a **Ban on Electric Heating** prohibiting existing households from installing electric heaters especially in areas of publicly supplied natural gas or district heating. Properties with central-heating installations were prohibited from removing radiators and hot-water tanks and replacing them with electric heating appliances. Individual residences that had installed electric heating prior to the ban were not affected (DEA, 2005).

Carrot. The subsequent energy plan of April 1996, **Energy 21,** expanded upon the goals of Energy 2000 and established a long-term perspective based on new assessments of natural resources. Targets were set for an increased use of biomass (including municipal solid waste) from 52 PJ by year in 1995 to 85 PJ by 2005 and 145 PJ by 2030. This plan also set a target for 1 million m^2 solar thermal collector area.

In 1997 under the umbrella of Energy 21, the **Development Programme for Renewable Energy** was established in accordance with the rules of the Development and Demonstration Programme for Renewable Energy. This new program allocated €7.4 M of basic grants in support of solar thermal installations and €780 000 annually for biomass-fired district heating and large solar heating systems (IEA, 2004). These grants were cancelled in 2001.

Carrot. The **Act on Utilisation of Renewable Energy Sources** subsidized biomass equipment up to 16% of construction costs with a maximum of €132 000 per plant between 1997 and 2001.

Stick. An amendment to the 1988 National Heat Supply Act, the **Executive Order on Connection to Public Heat Supply Installations** and on **Heat Planning and Approval of Installation Projects for Public Heat Supply Installations** (no. 581 and 582 of June 22, 2000) gave local authorities the authority to require all or part of a local jurisdiction to connect either to a natural gas supply or district heating system. This obligation was applicable to both new and existing buildings[50]. Property owners were thereby always obliged to

- allow the supply company to install the necessary technical installations;
- pay a lump sum to cover related connection expenses and
- pay a standard charge that is part of the heating bill (DEA, 2005).

Buildings whose heat demands were already supplied with more than 50% of renewable sources were exempted.

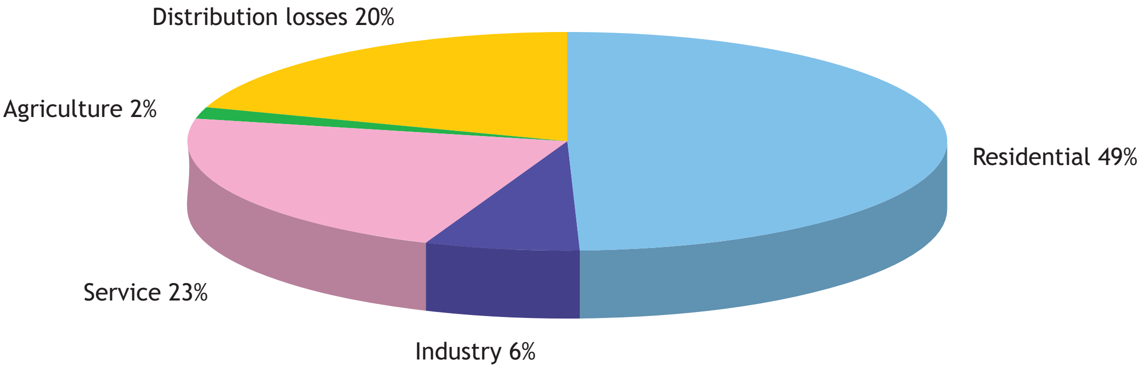
Stick. In 2001 buildings not connected to district heating networks were required to supply between 25-60% of their total demand for hot water with solar thermal systems under the **Executive Order Solar Heating Obligations in New Buildings Outside the District Heating Areas** (no. 337). Percentage requirements depended upon the size of the building (BMU, 2006).

Carrot. CHP generation facilities receive a surcharge for incinerating fuels which are considered more environmentally friendly. The level of surcharge depends on the type of fuel. Plants installed after April 21 2004 and that use wood chips or straw are eligible to receive a total of €0.08/kWh over a period of 15-20 years. CHP installations fired with biogas are eligible to receive €0.08/kWh during the first 10 years and €0.05/kWh in the following 10 years. Biogas fired CHP plants are only eligible for this surcharge if the plant was connected to the grid between April 22 2004 and the end of 2008. CHP plants which utilize both biogas and natural gas are subject to special regulations and a lesser surcharge (DEA, 2005).

Evaluation

Heat in Denmark accounted for 16% of total final energy consumption. In 2004 129.4 PJ of heat was produced, 6% was consumed by the industrial sector, 50% in the residential sector, 23% in commercial and public services, and 2% in agriculture and forestry (Figure B3). Due in large part to its district heating infrastructure, roughly 20% of the heat produced is lost in the distribution network (IEA, 2007a).

Figure B3 • *Distribution of heat in Denmark by sector*



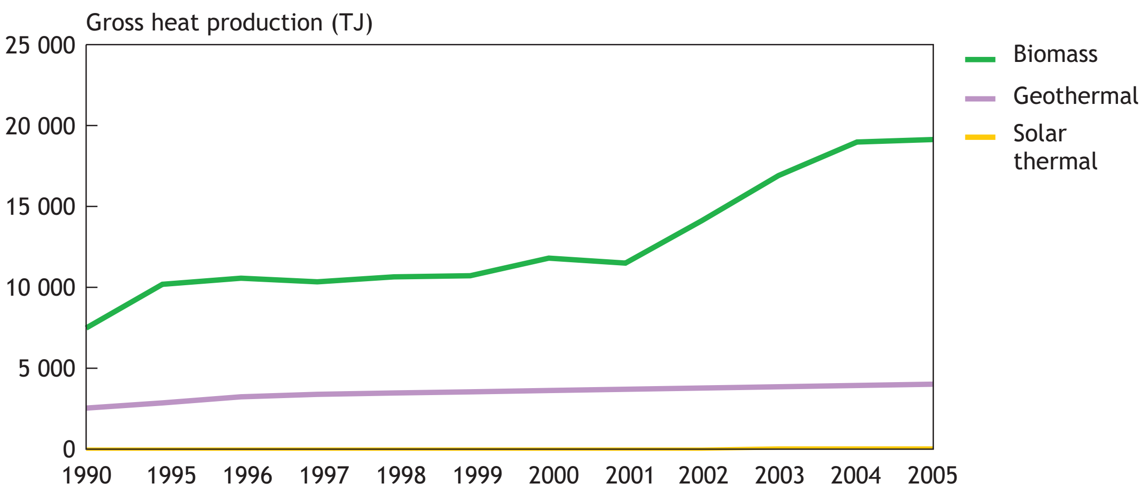
50. For existing buildings, the obligation takes effect 9 years after the owner of the property has been informed of the regulation.

The percentage of heat supplied through the district heating infrastructure has increased from 30% in 1980 to 50% in 2001. By 2006, most of the densely populated areas in Denmark were served by district heating networks. The allocation of authority to local governments to mandate connection to district heating systems, first in 1988, then in 2000, was implemented by most of Danish regions and has spurred much of the district heating infrastructure. Most (241 of 275 or 88%) local authorities have applied the 2000 Executive Order on Connection to Public Heat Supply Installations although this varies by region (DEA, 2005).

Over 80% of heat produced is generated by CHP (DEA, 2005). Despite complications in converting CHP plants to be biomass compliant and uncertainties of payment for deliverable heat, there was widespread conversion from heat production using oil and coal to natural gas based CHP and biomass-based heat production in the 1990s (DEA, 2005). The supply of biomass in district heating grids has been increasing. The gross district heat production from solid biomass (including bio-degradable waste and excluding biogas) increased from 18.4 PJ (0.44 Mtoe) in 2004[51] to 38.5 PJ (0.92 Mtoe) in 2005 being 38% of the total district heat supply (DEA, 2006). About 25% of Danish residences and buildings were supplied with biomass-based district heating in 2005.

Biomass accounts for most of the renewable heat supply in Denmark (Figure B4). Despite growth in solar thermal and geothermal markets since 1997, their contribution to the total heat supply has remained negligible.

Figure B4 • *Renewable heat generation in Denmark by sector from 1990 till 2005*



Sources: IEA, 2006b; IEA, 2004. Note: "Geothermal" includes heat pumps in the residential sector.

Solar thermal

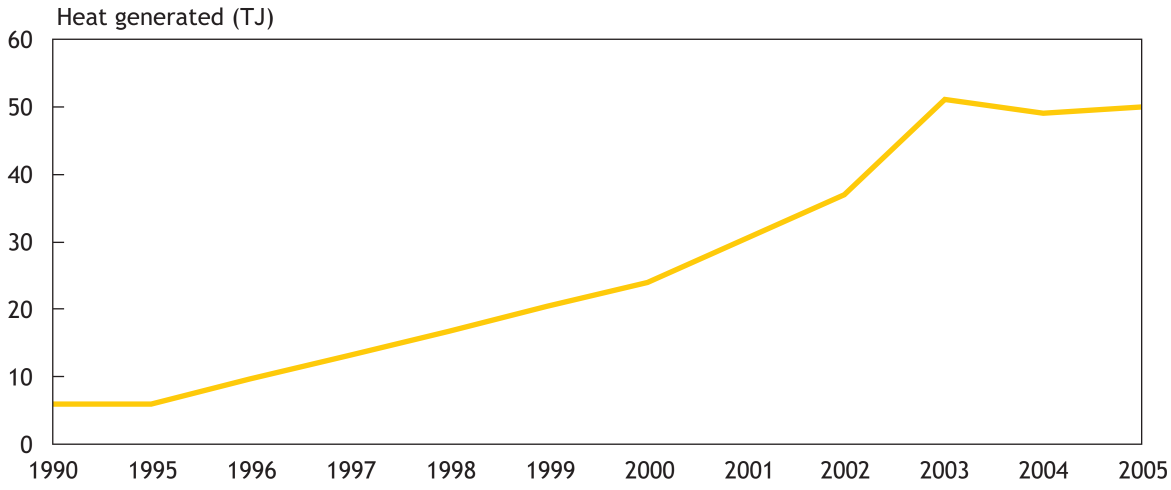
Solar thermal installations increased three-fold between 1990 and 2001 with further increases early this century (Figure B5) (EurObserv'ER, 2006). Installed capacity increased from 13 MW in 2003 to 235 MW in 2005 most of which was on single family houses (ESTIF, 2006c).

The subsidies available for solar thermal from 1979-2002 and those available under the 1997 Energy 21 energy plan likely contributed to the strong growth in the solar thermal market. To accompany these carrot-based incentives, stick-based regulations were initiated. The 2001 Executive Order for

51. 9.6 PJ of this total was generated in dedicated biomass plants, 8.4 PJ of which was generated in CHP plants.

Solar Heating Obligations in New Buildings Outside District Heating Areas was accompanied by an approximately 5% annual increase in solar thermal heating. Despite this increase, the instrument fell short of expectations as only moderate growth was witnessed in comparison with neighbouring European nations (BMU, 2006).

Figure B5 • ***Solar thermal heat production in Denmark from 1990 till 2005***



Source: IEA, 2006a.

Today, there is no available subsidy for solar thermal and the growth of solar thermal heat has levelled without the support of limited stick-based incentives (SHC, 2006). The importance of a package of incentives is thereby demonstrated with the increase in solar thermal heat resulting from the combination of carrot and stick-based schemes which plateaued with the removal of the subsidies.

Biomass

Consumption of biomass for energy production quadrupled between 1980 and 2004, increasing by 2.3% per year between 1990 and 2001 (Figure B4). It rose from 19 PJ in 1994 to 38.6 PJ by 2005. Biomass is used extensively for individual heat installations with an estimated 500 000 wood-burning stoves, 70 000 wood-burning boilers, 30 000 wood pellet furnaces, and 9 000 straw-burning furnaces across the nation in 2006 (DEA, 2006).

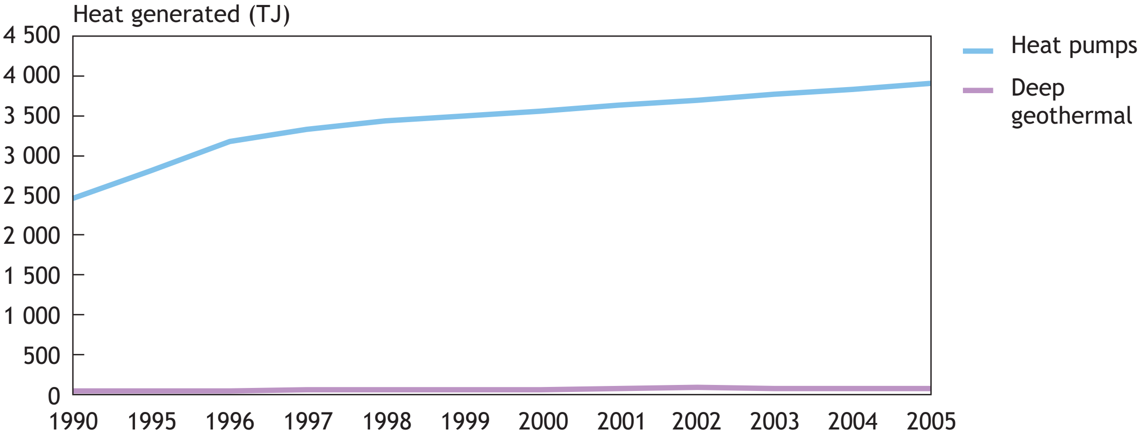
Most biomass is surplus from agriculture, forestry, industry, and households (DEA, 2005). Woodchips and wood pellets are commonly used in small boilers, district heating systems, and CHP plants (IEA, 2004). The first public biogas and straw-burning plants began operation in 1988 (DEA, 2005). Straw has been used in district heating plants since the 1980s and in CHP plants since the 1990s.

Denmark has been relatively novel in its support for biomass heat with the Biomass Agreement of 1993, one of the only support schemes requiring the purchase of renewables for heating supply. The liberalization of the electricity market and low electricity prices may have destabilized this agreement as only half of the targeted biomass volume utilized in central power plants by 2000. However, it is expected that targets will be achieved in 2007 (Meyer and Koefoed, 2003). Subsidies provided since the 1997 Act on the Utilisation of Renewable Energy Sources was accompanied with a noticeable increase in biomass heat generation capacity. Additionally, the 2004 incentive scheme offering a surcharge to consumers for bioenergy utilized in CHP plants may also have played an important role in the development of the biomass market.

Geothermal

From 1995 to 2005 the capacity of geothermal heat increased from 3.5 MW to 330 MW respectively, at a rate of nearly 43% per year (Lund *et al*, 2005; EurObserv'ER, 2005; EC, 2006b). While deep geothermal heat generation has shown only marginal growth in Denmark (Figure B6) the market for GHPs has grown substantially.

Figure B6 • *Geothermal heat generation in Denmark from 1990 till 2005*



Source: IEA, 2006b.

About 88% of heat pumps are installed in single family homes (DEA, 2005). GHPs account for approximately 3 940 TJ/year, being most of the geothermal heat production in Denmark. In addition, two district heating plants currently use absorption heat pumps: the first in operation since 1984, the second since 2004 (Lund *et al.*, 2005).

The 1996 code for low temperature heating systems, part of Energy 2000, may have impacted the growth of geothermal heat.

Conclusions

Denmark was one of the first nations to utilize regulations (sticks) to encourage the development of renewable heat, especially from biomass. Regulations such as mandates for connection to district heating grids and bans on electric heating appliances have played an important role in the transition of Denmark's heat portfolio to include renewable energies.

Support for renewable heat was disrupted by the liberalization of the electricity market and the shift of political power in 2001 which discontinued many subsidies.

In 2007 the Danish government presented an energy plan, **A Visionary Danish Energy Policy**, outlining energy policy objectives until 2025 including targets related to renewable heat:

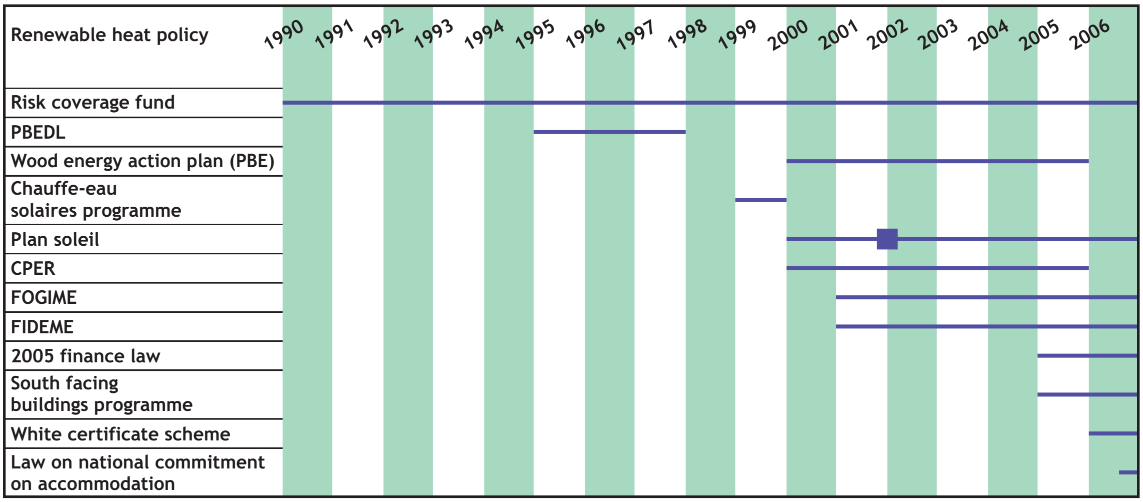
- the contribution of energy from renewable sources will double to 30%;
- the energy saving initiative will be tightened to 1.25%/year;
- investment in energy research will be doubled to €130 M.

This policy is expected to be accompanied with an increase in renewable heat.

Some of these targets will possibly be strengthened further during the summer of 2007 since a broad political agreement on the new energy strategy is envisaged. New subsidy schemes may become part of this agreement in order to obtain even more ambitious targets for heat pumps and other forms of REHC.

Annex B3. France

Instruments



Thermal Regulations for new buildings have been in place in the residential sector since 1974 and in the commercial sector since 1989 (EREC, 2004a).

Carrot. A **Risk Coverage Fund** was developed in the 1980s for risks associated with the long-term exploitation of geothermal resources. It supports low enthalpy geothermal plants with heat distribution networks. In 2000 the fund was extended until 2012 (IEA, 2006e).

Guidance. In 1995 the **Programme Bois Energie et Développement Local (PBEDL)** was developed for wood-based heat in the commercial and industrial sectors of 11 selected regions. In place until 1998, it supported the development of a wood fuel supply chain and the installation of new automated-feed, wood-fired boilers (EREC, 2004a).

Carrot. In 1999 the **Chauffe-eau Solaires Programme** was implemented providing investment grants for solar thermal installations in French overseas departments. Its primary target for 13 000 installations (45 000 m^2 of solar collector area) was met in 2000 (IEA, 2004).

Carrot and *Guidance*. In 2000, **Plan Soleil,** a national financial and information programme, was launched by the French Agency for the Environment and Energy Management (ADEME). It provides grants for the purchase of individual and collective solar thermal systems in France. Targets, specific to the type of system, were established for 2006 and 2010. (Table A2).

Table B2 • *Programme goals of the Plan Soleil by small and large scale solar thermal technology*

	2006 Installation target (m^2)	2010 Installation target (m^2)
Domestic hot water - individual units	330 000	480 000
Medium/large scale hot water systems	48 000	Not available
Individual combination systems	78 000	180 000
Total	**441 000**	**660 000**

Source: SHC, 2006

Plan Soleil aimed to counter the history of short-term support schemes that had characterized the French solar incentive portfolio throughout the 1990s by offering a "long-term" framework of seven years. The plan aimed to emphasize the development of partnerships between industry and installers, and between national and local public authorities (SHC, 2006). Targets were to be achieved through a combination of financial incentives, professional training, quality control and publicity campaigns (WEC, 2004). Although early in the programme most support was given to individual solar hot water systems, other applications were targeted from 2002 until 2004. Grants ranging from €690 to €1,150 (depending on the size of installation) are available on the condition that the system meets certification standards and is installed by Qualisol certified professionals (IEA, 2004; EREC, 2004a).

Carrot. France placed a 19.6% VAT on district heating network subscriptions, compared to a 5.5% VAT on gas and electricity. To combat this, ADEME implemented a policy to extend existing geothermal-based networks in 2000 offering a maximum of €400 /tC for connection to geothermal based heating networks (EurObserv'ER, 2005).

Carrot. **Contrat de Plan Etat (CPER)** (State-Region Plan Contracts) between ADEME and regional governments were signed for 2000-2006. They established specific targets of renewable energy deployment and allocated a total of €135 M for capital grants, available to all RETs including geothermal heat pumps (GHPs) and geothermal-based district heating. Regional governments and the EU supply additional funding. Targets for 10 geothermal demonstration projects and 500 000 additional GHPs were set for 2010 (EGEC, 2006).

Carrot and *Guidance*. In 2000 the **Programme Bois Energie (PBE)** (Wood Energy Action Plan) was implemented under the framework agreements of CPER for a six year period. It extended beyond the 1995 PBEDL bioenergy programme to include all of France. It aimed to develop the thermal uses of wood waste and forest residues for domestic, collective and industrial applications. Technical advice on best combustion practices for public/private operators and investment subsidies was available. In addition, quality labels for wood burning devices were established. A target was set for 1 000 wood-fired heating plants operating by 2006, generating 300 12.6 PJ annually (IEA, 2004; EREC, 2004a).

Carrot. In 2001 the **Crediting System in Favour of Energy Management (FOGIME)** was established with a total budget of €17.8 M. ADEME, in cooperation with BDPME, the French development bank for small and medium size enterprises (SMEs), provides an additional financial guarantee to bank loans requested by companies for renewable energy and energy efficiency projects. Funds may be guaranteed up to €242 M for loans in the private sector up to 70% of the total investment, thereby covering medium and long-term risks taken by the loan-providing financial institution (IEA, 2004; ADEME, 2006).

Carrot. **Fonds d'Intervention pour l'Environnement et la Maîtrise de l'Energie (FIDEME)** was created in 2001 to promote investment in environment and energy efficiency projects according to classic financial appraisal techniques. Higher levels of risk acceptance are balanced by higher commissions and interest rates. The fund acquires subordinated bonds from companies undergoing rapid development, providing quasi-capital (WEC, 2006). A maximum of 25% of the total renewable energy project costs is available. (EGEC, 2006). In its first year €45 M was allocated from private and public funding and €15 M from ADEME.

Carrot. La loi de finances, **2005 Finance Law**, Article 90 & Article 83, created a tax credit[52] for renewable energies of a specified standard. This new scheme switched the primary financial support mechanism for renewable heat from direct investment incentives to a tax rebate system by which costs are recovered with an income tax declaration (ESTIF, 2006c). Tax credits are available for up to 50% of the capital costs of renewable heating equipment and materials (including biomass, geothermal, and solar thermal)

52. A successor policy to the 2000-2006 Wood Energy Plan.

between 2005 and 2009 with specific amounts depending on the type of technology installed[53]. For individual GHPs 40% is available, or 25% for connection to heat networks and CHP plants (EGEC, 2006). Tax credits available for solar and bioenergy technologies were increased from 40% to 50% in 2006. Solar thermal installations are granted a tax credit only after the project has been officially certified (French, European Solar-Keymark or equivalent) (ESTIF, 2006a; SHC, 2006). A maximum of €8 000 for individual applications and €16 000 for multiple-person dwelling applications has been established for renewable heat and/or energy efficiency projects. This tax credit scheme may be complemented by regional and local incentives.

Carrot. In July 2005 Face Sud, or the **South-Facing Buildings Programme** was approved with targets for 200 000 units of domestic solar hot water systems and 50 000 solar roofs (including PV, thermal, and hybrid solar systems) This programme is in place until 2010 (SHC, 2006).

Stick. In January 2006 a system of energy saving obligations and tradable white certificates was introduced under the **White Energy Saving Certificate Scheme.** Providers are required to initiate energy savings by their end consumers in proportion to their market quota (sales) in the residential and tertiary sectors. Certificates are issued when energy providers meet their required savings targets or they are fined for not meeting their mandated targets. A maximum price of €0.02/kWh was established for certificates.

For 2006-2008, an energy saving target of 54 TWh (194.4 PJ) in final energy use was established. Targets were extended to an overall reduction of 2% by 2015 and 2.5% by 2030 of energy intensity with respect to present consumption levels. Renewable heat installations such as solar thermal systems qualify as eligible measures to meet energy conservation requirements. This is a relatively novel instrument for the promotion of renewable heat.

Carrot. In July of 2006, the **Engagement National sur le Logement,** (Law on National Commitment on Accommodation) was published in the Official Journal, Number 163, of July 16th, 2006. It reduced the VAT rate to 5.5% for subscriptions to district heating grids with a heat supply of at least 60% biomass, geothermal energy, waste and/or recovered energy. Compared with a normal VAT rate of 19.6%, this offers significant incentives for making renewable heat more cost competitive with conventional fuels.

Regional governments have also played a significant role in French incentives for renewable heat.

Evaluation

The total demand for heat in France amounted to 26.9 PJ in 2004 (IEA, 2007a) with markets showing growth in recent years (Figure B7). About 80% of renewable heat generated in France is utilized in the domestic sector, 2% in community heating systems, and 18% by industry.

Solar thermal

The market for solar thermal was relatively static in the 1990s, but began to grow substantially in the early 21st century (Fig B8), with 134% increase in sales in 2005[54] [55] and 81% in 2006. Market growth in 2005 of 85 MW (122 999 m^2) increased the total to 640 MW (913 868 m^2) (ESTIF, 2006a; REW, 2006).

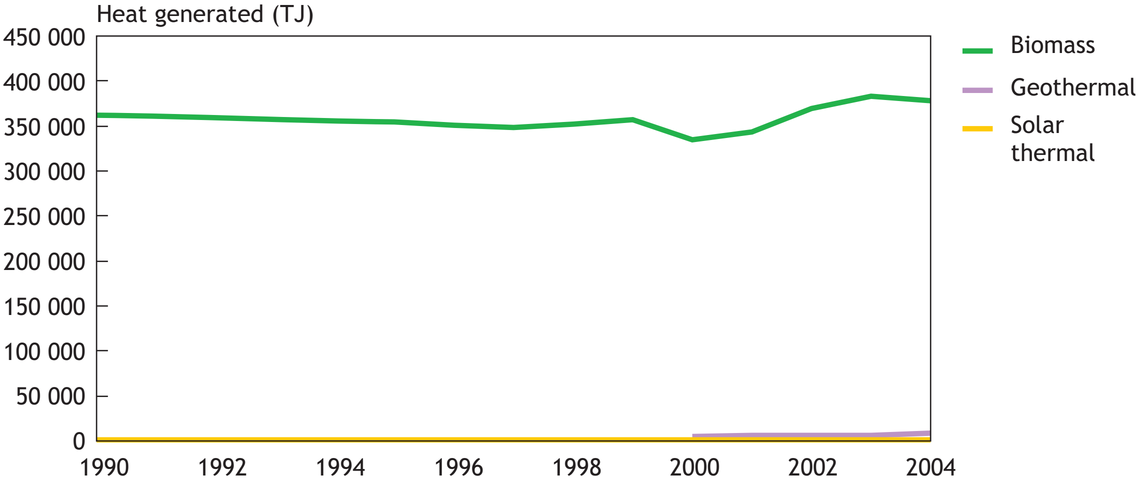
The 2000 Plan Soleil was accompanied with an installation of 250 000 m^2 of solar glazed collectors, about 95% of which were on existing residences. The campaign and national training programme for solar hot water system installers, Qualisol, clearly contributed to increased awareness and market confidence. The plan's 2006 target of 441 000 m^2 was nearly reached, although may have also been influenced by the 2005 tax incentive scheme (SHC, 2006).

53. See www.industrie.gouv.fr/energie/developp/econo/textes/credit-impot-2005.htm.

54. In 2004 the market increased 36% with 78.5 MW (112,147 m^2) of new installation bringing the total to 555 MW (792,500 m^2).

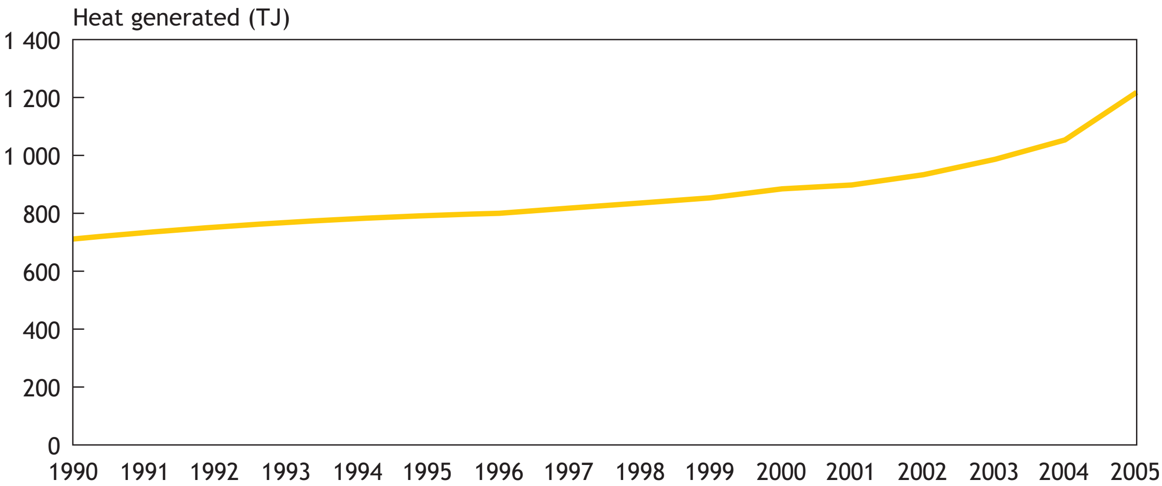
55. 115.1 MW (164 389 m^2) thermal of new solar thermal capacity was installed in the year 2005.

Figure B7 • *Renewable heat generation in France*



Sources: IEA, 2006b; ADEME, 2006; EurObserv'ER, 2005.

Figure B8 • *Solar thermal heat generation in France from 1990 till 2005*



Source: ESTIF, 2006c.

Note: Heat generation is reported by using a conversion factor of the capacity as reported by the SHC (2007).

The French Minister of Industry announced in 2006 that France aims to be the leading solar thermal market in Europe by 2010 (ESTIF, 2006c).

Biomass

For most of the 1990s the production of biomass heat fluctuated around 350 PJ, increasing slightly in the early 21st century (Figure B7). The wood fuel market is especially strong with nearly half of French households equipped with wood-fired boilers. However, these boilers are often of poor efficiency standard and are used in conjunction with an electric heat supply.

Although the 1995 PBEDL scheme did not cause an immediate increase in biomass heat generated, it made important strides in establishing a reliable wood fuel supply chain. With the implementation of the Wood Energy Action Plan in 2000 and FOGIME and FIDEME in 2001, offering crucial investment support for the upfront costs of biomass heating installations, the production of biomass heat began to show important growth. Through the Wood Energy Plan, 1 398 boiler plants were installed between 2000 and 2005 to exceed the target of 1000 by 2006 (ADEME, 2006). The Wood Energy Action Plan guidance scheme created a "green flame" label for highly efficient heating appliances, assuring a high quality standard. The 2005 tax credit which offered further financial support for biomass, was accompanied with a 23.6% increase in annual sales of biomass heating appliances in 2005[56].

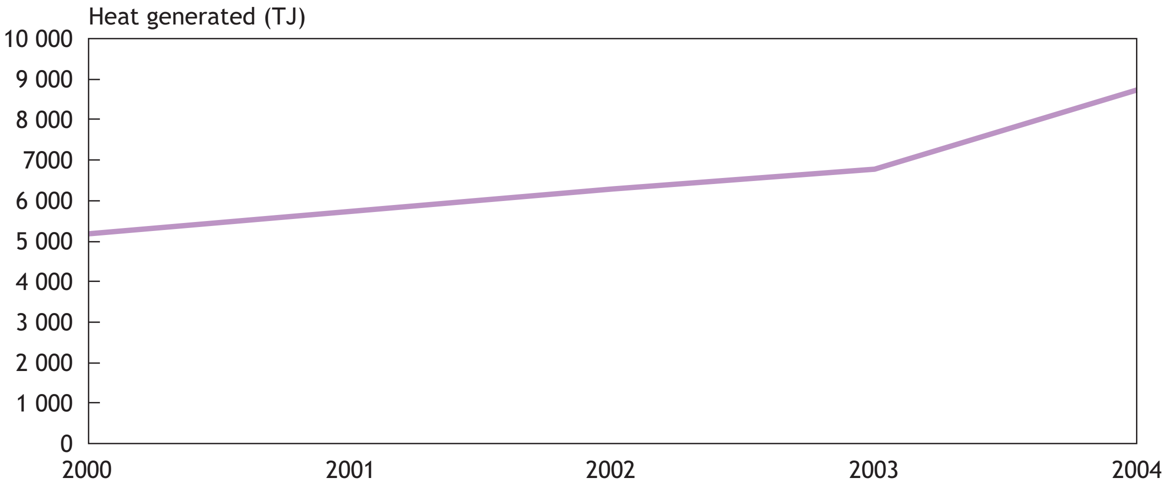
Geothermal

The geothermal heat market has grown continuously since 1998, about 97% of which is used for space heating[57] (Fig B9) (WEC, 2004). A total of 326 MW had been installed by 2000, 396 MW by 2002, 421 MW by 2003, and 841 MW by the end of 2004 of which 550 MW was direct-use heat such as GHPs (EREC, 2004a; EurObserv'ER, 2005). ADEME estimated that 2 000 to 3 000 new homes are connected to geothermal heating per year[58]. In 2005, about 83% of direct-use geothermal heat capacity (243 MW) was connected to district heating to give 4 030 TJ/yr of heat.

The development of direct-use (low-temperature) geothermal heating capacity, specifically geothermal district heating systems and GHPs has grown due to the support of the French Electricity Board, the French Ministry of Environment and ADEME.

French policy in support of geothermal heating began in the 1980s with the implementation of the Risk Coverage Fund. The high 19.6% VAT tax on heating network subscriptions created a barrier to the development of geothermal energy heating which was successfully countered by ADEME's 2000 plan for direct financial compensation for connection to geothermal based heating networks. This policy supported the connection of 10 600 households to a geothermal heating network by 2004 (EurObserv'ER, 2005). Moreover, 30 000 additional residences were connected to existing geothermal district heating systems by 2006 through CPER (EGEC, 2006). Additional incentives, including a tax credit in the 2005 Finance Law and a reduction in VAT in 2006, are expected to further enhance the development of geothermal heating.

Figure B9 • *Heat generated from direct-use geothermal in France from 2000 till 2004*



Source: EREC, 2004a; EurObserv'ER, 2005.

56. 430 000 biomass installations were sold in 2005, accounting for this increase.

57. Greenhouse heating accounts for 2%, and fish and animal farming 1% of the French geothermal energy use.

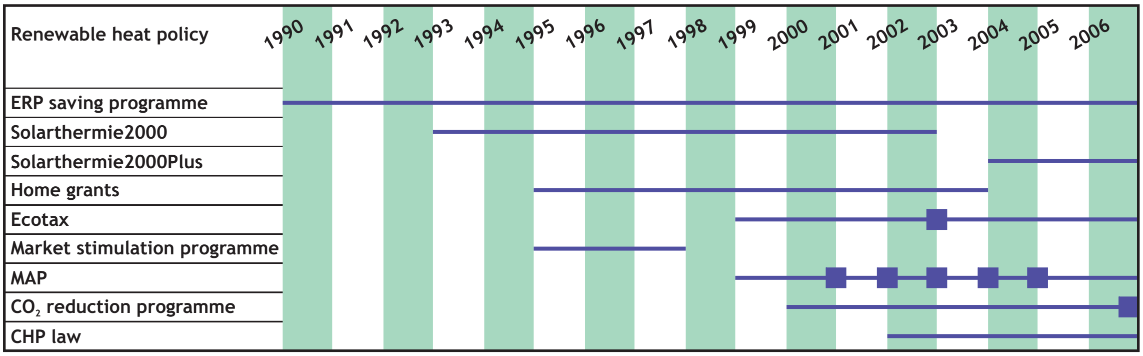
58. At the end of 2004, 150 000 French homes utilized geothermal heating technologies.

Conclusions

Renewable heat in France has been supported by tax credits for renewable heating, reduction in VAT, and direct subsidies. Following the 2005 switch in financial support from direct investment incentives to a 40% tax rebate (recovered with an income tax declaration), the solar thermal market growth in France has grown significantly (ESTIF, 2006c). The tax rebate scheme has simplified the process for consumers, because it is no longer necessary to apply for incentives prior to the installation of the system (REW, 2006).

Annex B4. Germany

Instruments



Carrot. Under the 1990 ERP-Umwelt und Energiesparprogramm, **Environment and Energy Saving Program**, soft loans generally 2% below market levels were established for a range of RETs. Low-interest loans are available to private companies for up to 50% of the cost of renewable installations from the German public bank, Deutsche Augleichsbank (DtA). Credit terms range between 10 and 20 years, with a 2 to 5 year redemption holiday (IEA, 2004). While most of the funding has gone to support wind energy and solar PV, solar thermal and biomass heat are also eligible for support. Loans offered under this programme can be combined with loans offered under the Kreditanstalt für Wiederaufbau (KfW) Environment Programme. Between 1990 and 2005 €10.7 billion in support was provided for RET.

Guidance. In January 1990, an **Information Centre for Heat Pumps and Refrigeration**, (Informationzentrum für Wärmepumpen und Kältetechnik), was established to improve information distribution for consumers, manufacturers and energy suppliers in support of the heat pump market. Running through 2001 with partial government funding, the Centre now runs as an independent association without government support.

Carrot. In 1993 **Solarthermie 2000** was launched to improve the economic viability of solar thermal systems with grants for up to 50% of investment costs. Its primary aim was to demonstrate the feasibility of 1) large-scale solar thermal heating systems in residential and public buildings and 2) solar driven small district heating systems. The programme included long-term monitoring to show the operational performance, the technical feasibility of the concepts, and the cost/benefit ratio of large-scale solar thermal plants. This was 1) Long term behaviour of solar-thermal systems 2) Solar-assisted demonstration plants in public buildings and 3) Large scale solar-assisted district heating plants with seasonal storage. (SHC, 2006) A target cost level for future installations of €13/kWh thermal was established. After 10 years of successful execution, the programme was completed in 2003.

Carrot. **Solarthermie2000plus** was launched in February 2004 as a successor programme to Solarthermie 2000 aiming to increase the percentage of heat and hot water demand supplied by solar thermal technologies from 10-30% to 60% by 2012. As in the original Solarthermie 2000 programme, grants for up to 50% of investment costs are available to public institutions, foundations, public utilities, and private companies. The mechanism focused on large scale central, solar thermal plants, especially solar assisted district heating (with and without seasonal storage) solar air-conditioning and process heat. A particular focus of the programme has been placed upon pilot systems, enabling researchers to test results under real conditions then to modify the technology to develop well-functioning and market orientated systems. Eligible solar thermal collectors must have a minimum area of 100 m^2 (IEA, 2004; SHC, 2006). €4 M is to be provided annually from 2004 to 2012 giving a total investment of €36 M.

Carrot. Under the 1995 **Home Grant**, (Eigenheimzulage), federal grants were provided for the purchase of houses and flats if solar thermal collectors or heat pumps are installed. Up to €256 per year over a period of eight years was available. This program was completed in 2004.

Carrot. From 1995 until 1998 a subsidy was paid per kW renewable heating capacity installed as part of the Market Stimulation Programme. Also known as the 100 Million Programme, the MSP provided capital grants of up to 30% of the investment costs of solar collectors and heat pumps. Over its lifetime more than €47.7 M (93 M DM[59]) were invested in renewable energies. €8 M was allocated to GHPs (ISI, 1999). A subsidy of €300/kW of installed thermal capacity was paid at the start of the programme, later decreased to €200/kW (EGEC, 2006). Solar water heaters for swimming pools were initially excluded. Subsidies for geothermal installations were subject to certain standards. The programme was phased out in 1999 and replaced with the German Market Incentive Programme (EGEC, 2007).

Carrot. An **Ecotax** was implemented in Germany in 1999 incrementally increasing the tax on fossil fuels and electricity from €0.0205/litre light fuel oil or €0.0064/kWh gas (SHC, 2006). The ecotax was expanded in 2003. Beginning in 2002, bioenergy has been exempted thereby increasing the price of conventional fuels, and effectively lowering the playing field for renewable heat.

Carrot. The successor to the Market Stimulation Program was the Marktanreizprogramm **(MAP)** (German Market Incentive Programme) that came into force on September 1 1999 (see Good Policy Practices, Section 4). This programme provides grants, long-term and low-interest loans, and/or partial release of debts in support of renewable energy-based heating systems. Individuals and small and medium-sized businesses are eligible to apply for grants and soft loans for solar thermal collectors, biomass boilers, biogas plants, heat pumps driven with renewable electricity, and geothermal heating systems. MAP has also provided incentives for large-scale systems for apartment buildings, district heating systems, generating process heat, and solar cooling systems. Although it was designed to support a number of renewable heating technologies, most of the funding available has been allocated to support solar thermal installations.

MAP funds are mainly sourced from the revenues of Germany's Eco-tax[60]. It has been amended several times since its introduction, altering the eligible technologies and the level of support (Langniss and Seyboth, 2007). An annual budget of €100 M was allocated in 1999 for all supported technologies. By 2005, this had increased to €180 M and €217 M in 2007 (European Biomass Association, 2006; ZSW, 2007). Grant levels for individual technologies fluctuated in response to annual changes in the budget (Table B3).

Table B3 • *MAP grants available by technology type in 2007*

Technology	Size	Grants available in 2007
Solar		€40/m^2 (minimum €275)
Hot water	<40 m^2	€70/m^2
Combined hot water and space heating	<40 m^2	
Process heat	<40 m^2	€70/m^2
Cooling	<40 m^2	€70/m^2
Biomass		
Wood pellet and/or combined pellet boilers	<100 kW	€24/kW (minimum €1 000)
Wood chip boilers		€500/system
Wood gasification boilers	Between 15 kW and 30 kW	€750/system

Note: Large scale solar collectors and biomass systems over 100 kW may receive a bonus for using innovative technologies in addition to basic grants.

Source: ZSW, 2007

59. €1=1.95 DM.

60. Although the MAP programme is administered by the German Federal Office of Economics and Export Control (BAFA), MAP grants are administered by the Bundesamt für Wirtschaft and loans by the Kreditanstalt für Wiederaufbau (IEA, 2004).

Between 2000 and 2005, the MAP had supported a total of 482 374 projects with an investment volume of over €4.6 billion (BMU, 2006). Without specification, a majority of funding went to support solar thermal heat (Table B4).

Table B4 • *Number of applications that received funding under the German MAP 2000-2005*

	Solar thermal	Biomass	GHPs	Total
2000	26 056	3 228	111	29 395
2001	72 098	6 660	543	79 301
2002	82 150	9 903	181	92 234
2003	68 541	6 023	3	74 567
2004	90 496	12 049	1	102 546
2005	82 175	22 156		104 331
Total	**421 516**	**60 019**	**839**	**482 374**

Source: BMU, 2007

Although the MAP grant and subsidies are attributed credit for much of the success of the policy, loans were also offered through the programme (Table B5).

Table B5 • *Loans approved by renewable technology through the German MAP from 2000-2005*

Resource technology	Number of loans approved	Value (€)
Biogas	1 218	509 623 205
Biomass	1 081	166 189 280
Hydropower	251	45 587 754
Geothermal	8	18 371 420
Solar thermal	3	225 656
Total	**2 561**	**739 997 315**

Source: BMU, 2007.

Guidance. Since 1999 solar thermal information campaigns have been publicly co-financed, typically for 50% of campaign costs. The "Solar – naklar!" campaign has been supported since its inception; the "Initiative Solarwärme Plus" since 2003; and the "Wärme von der Sonne" campaign since 2005 (ESTIF, 2006a).

Carrot. The 2000 CO_2 Reduction Programme, (CO_2 Gebäude Sanierungsprogramm), was established to support energy saving measures in the residential sector. Although the programme targets energy efficiency, low-interest loans with interest rates 2% below market interest levels are available through KfW for renewable heating technologies. Renewable installations receive only 2% of the total credit volume awarded (IEA, 2004). In January 2007, grants were also made available under this programme.

Carrot and Stick. In 2002 the Combined Heat Power (CHP) Law, (KWK Modernisierungsgesetz), was established[61] mandating the purchase of electricity generated in CHP plants. In addition, premium prices (levels of which depend on the technology and age of the plant) for CHP generated electricity were established, reflecting the mechanism of the German feed-in law, (EEG). Only those renewables exempted from the EEG are eligible for support under the CHP Law. Biomass co-firing in fossil-fuelled power plants and biomass-fired CHP plants larger than 20 MW benefit.

61. This law replaced the 2000 KWK Vorschaltgesetz law on combined heat power.

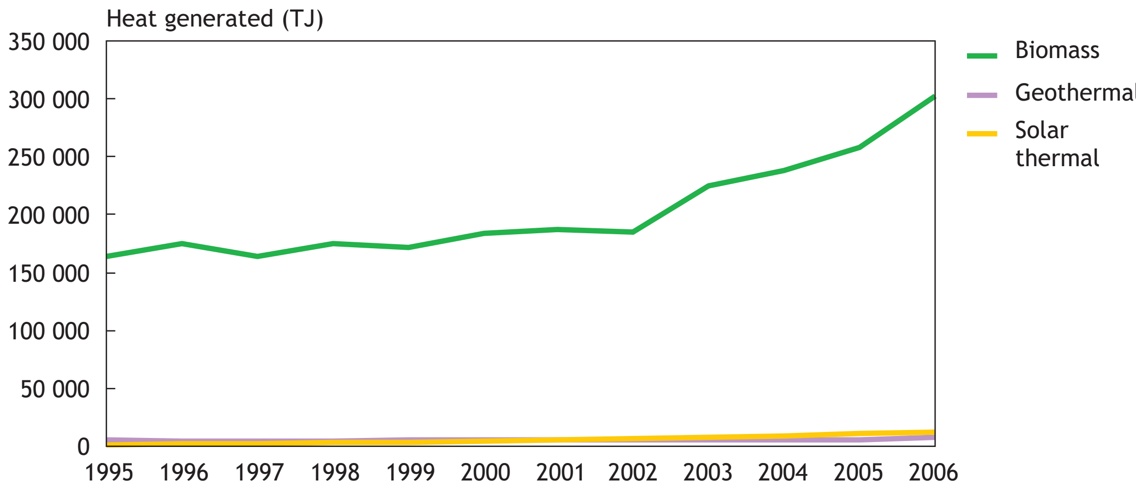
German Federal states (Länder) have also contributed significantly in support of renewables for heat production.

Evaluation

A total of 621.9 PJ of heat was produced in Germany in 2004. Just over 13% was consumed by the industrial sector with the remaining 85% by the residential sector (IEA, 2007a).

The percentage of renewable energies within the total energy demand for heat in Germany has been increasing steadily from 3.5% in 1998 to 5.9% by 2006 (BMU, 2007). Most renewable heat is generated from biomass although, the solar thermal and geothermal markets have also shown important growth (Figure B10).

Figure B10 • *Renewable heat generation in Germany by sector from 1995 till 2006*



Sources: ZSW, 2006; ESTIF, 2006a.

Complications in the design of the MAP lay in its stipulations for mandatory co-financing for district heating plants. State-level support programmes do not exist to supply co-financing thereby disqualifying MAP funding for district heating plants through until 2005 when these conditions were mended (EGEC, 2006).

Solar thermal

The growth of the solar thermal market has been rapid, although the contribution to the total heat supply is negligible (only 0.2% in 2006) (BMU, 2007). Germany is now a leader in the European solar thermal market, with the most installed capacity in 4% of German homes, primarily for solar hot water although installations of combination systems for both water and space heating are increasing.

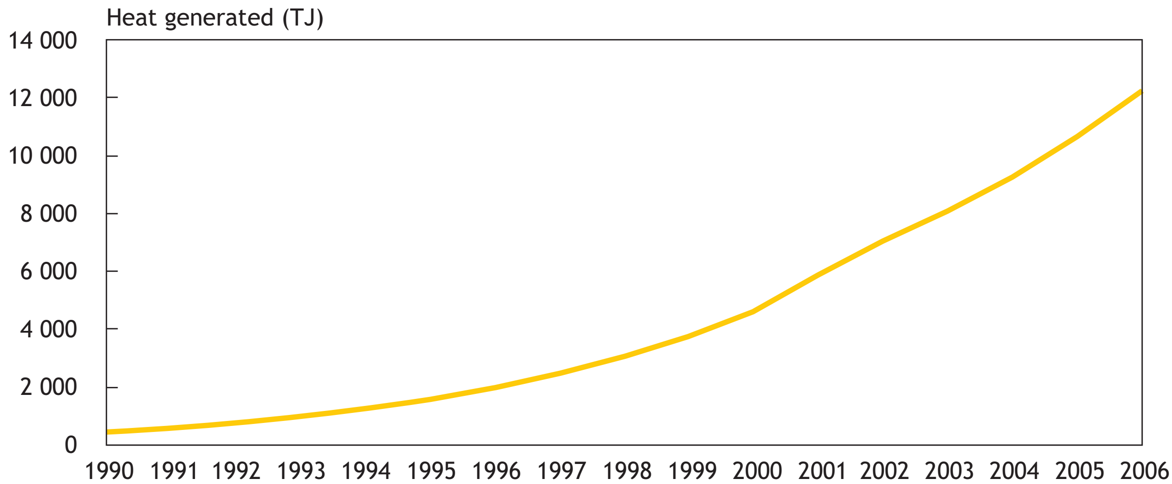
Solar thermal production grew by 25%-50% per year from 1990 to 2001 (Figure B11). Annual growth rates in the 21st century have fluctuated in accordance with the funding of the MAP, but have remained positive. By the end of 2006, over 5 600 MW (8 Mm^2) of solar thermal capacity had been installed (SHC, 2006; EurObserv'ER, 2006; BMU, 2007).

Low-interest loans in the 1990 ERP Environment and Energy Saving Program provided support for solar thermal systems from 1990. Grants of the 1993 Solarthermie 2000 programme,[62] the 1994 Solarthermie200

62. Solarthermie 2000 during 10 years of operation funded 63 large solar and 7 district heating systems by 2003 (IEA, 2004).

Plus programme, and the Home Grant Scheme also furthered solar thermal market growth, but the largest increase was seen after the 1999 implementation of the MAP and the initiation of information campaigns. Low interest loans available through the 2000 CO_2 Reduction Programme were utilized only to a very limited extent (ESTIF, 2006a).

Figure B11 • *Solar thermal heat generated in Germany from 1990 till 2006*



Source: ESTIF, 2006c. Heat values were calculated based on capacity conversion factors for Germany as reported in SHC, 2007.

Most of the funding available through the MAP was allocated to solar thermal, a contribution of public funding worth €588 M between 1999-2005, triggering a total investment of €4.7 billion for an average annual solar yield of 6.2 PJ (ZSW, 2007). Over 90% of the solar thermal installations in Germany have received financial incentives allocated through MAP (IEA, 2004). The stop-and-go funding available through the MAP has been criticized for the fluctuation in applications and solar thermal installations that resulted (Figure 36). The flux in installations may also have been due to a strongly increased feed-in tariff for solar PV systems in 2004, causing consumers to favour PV systems (ESTIF, 2006a). Amendments to the MAP in 2005 provided a higher incentive to larger, combination solar thermal systems and a lesser incentive to domestic hot water systems, causing the average system size to increase.[63] Despite a reduction in MAP support in March 2006, consumers are continuing to invest heavily in solar thermal technology.

Biomass

About 94% of German renewable heat is biomass,[64] with roughly half consumed in the residential sector (Figure B10). Currently, biomass generates over 302.0 PJ of heat (BMU, 2007). Most biomass heat comes from forest and wood processing residues. In addition, there is a strong tradition of residential woodstoves with approximately 7 M fireplaces and woodstoves installed in private households as of 2007, though they are not the main form of heating and used irregularly.

Between 1990 and 2001 the production of biomass heat increased at a steady rate of 4% per year[65] and began to grow substantially in 2002. Although support provided from the 1990 ERP Environment and Energy Saving Programme's low interest loans was accompanied with some market stimulation, most of the market growth occurred with the introduction of MAP subsidies and Ecotaxes. The MAP

63. In early 2006, applications averaged 11.4 m^2 per system collector area, up from 10.1 in 2005 and 9.7 in 2004 (ZSW, 2006).

64. Ninety-five percent of available solid biomass in Germany is used for heating purposes.

65. 9 000 pellet boilers less than 35 kW and 80 large CHP plants were installed between 1998 and 2001.

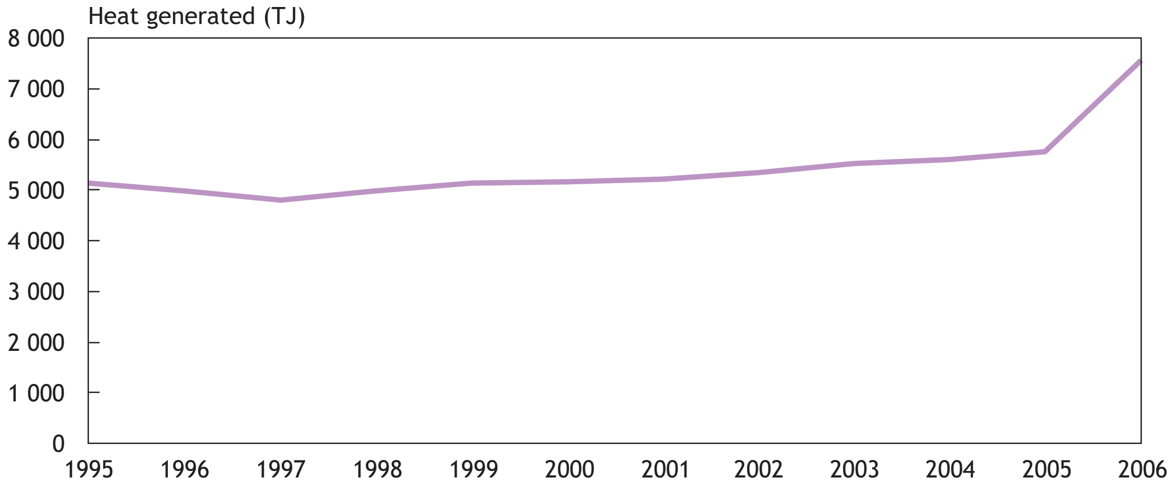
has been the main driver behind the recent improvement in modern biomass boiler technology with 15 700 biomass-fired heating systems supported between 1999 and 2002. By 2006, biomass systems received €96.1 M from MAP funding. MAP support was further supplemented by the 2002 CHP Law and from the federal states that contributed about €235 M in state funding between 1991 and 2001 (European Biomass Association, 2006).

The German package of incentives created a more level playing field with conventional fuels especially through the implementation of the Ecotax and the subsidies offered through the MAP.

Geothermal

Despite the increases in geothermal heating capacity, the supply of geothermal heat accounts for only a small percentage (0.1%) of the total heat energy demand. The total production of geothermal heat increased from 5.4 PJ in 2003, to 5.76 PJ in 2005, and 7.6 PJ in 2006 (Figure B12) (IEA, 2004; BMU, 2007). Barriers to the development of geothermal heat in Germany include high costs of resource drilling and the high salinity of German resources (IEA, 2006d).

Figure B12 • Generation of geothermal heat in Germany from 1995 till 2006



Source: ZSW, 2006.

While deep geothermal heating market growth has been slow, the market for heat pumps has grown substantially, bringing Germany to the top of the European market. Installations of direct-use, low-temperature applications (including geothermal heat pumps, district heating, space heating, and bathing) grew from 32 MW in 1995 to 505 MW in 2005[66] (WEC, 2004; Lund *et al.*, 2005). An additional 126 MW of geothermal direct-use capacity is planned for installation between the years 2005 and 2010.

Prior to the introduction of subsidies offered under the MSP, an important support mechanism for geothermal heat, almost 53% of heat pump installations used an ambient resource. Reflecting the subsidies for ground-source heat pumps in 1995, the market shifted away from ambient resource heat pumps. The 1995-1999 MSP subsidies supported the development of roughly 1 000 new geothermal plants each year, leading to a modest, but stable market development (EGEC, 2006).

66. 2 200 TJ/yr (79%) of low-temperature geothermal heat supply comes from 400 MW capacity of GHPs. The remaining comprises individual space heating, (15 TJ/yr); 89 MW of district heating (589 TJ/yr); and swimming and bathing (106 TJ/yr) (Lund *et al.*, 2005).

When MAP was first established, subsidies were not available for public municipalities. As most geothermal district heating companies in Germany are owned by municipalities no funding was allocated for the development of geothermal district heating systems through the MAP until 2005 when these conditions were clarified (EGEC, 2006). However, even then financing was only made available to plants completed in the same fiscal year of application. As the construction of geothermal plants often requires lengthy time-lags, the MAP has not offered significant support for geothermal heat (EGEC, 2006).

Conclusions

Most of the support to date for renewable heating in Germany has been in the form of carrot-based financial incentive schemes which have been successful in stimulating the development of renewable heat. Marketing campaigns for solar thermal contributed significantly to the development of this market.

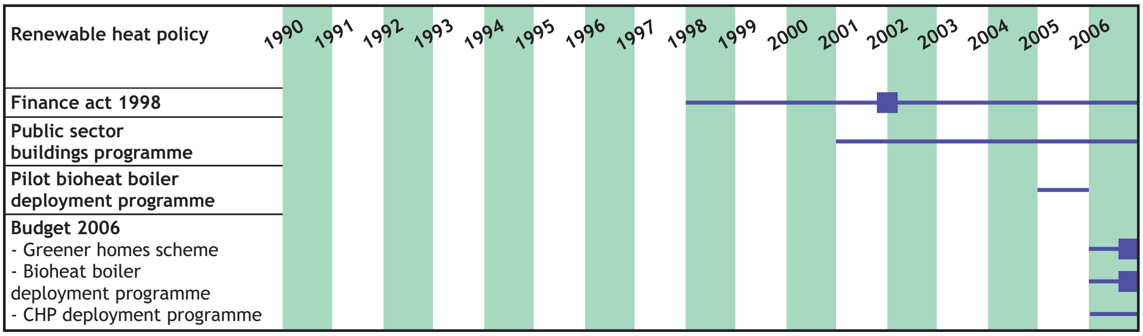
MAP subsidies for renewable heat successfully stimulated growth in solar thermal and small scale biomass heating markets with a total investment of €665.4 M in renewable heating projects. Support for geothermal heat through the MAP has remained minimal, primarily due to complications in the language and stipulations of eligibility. Most of the support for geothermal heat may be attributed to the precursory MSP programme.

Funding from the MAP budget has been unreliable. In addition to criticism for inadequate communication of funding to potential investors; stipulations for mandatory co-financing for district heating plants from German states often disqualifying district heating systems; and the burden on the public budget; have led to discussions in the revision of support for renewable heat in Germany. Several innovative instruments are under consideration for a new Renewable Heating Law, possibly to be implemented in 2009:

- administrative ordinances to regulate the use of renewable energies;
- price regulations which set a minimum price for renewable energies; and
- quantity regulations which set the amount of renewable energy to be generated each year (Nast *et al.*, 2007).

Annex B5. Ireland

Instruments



Carrot. Section 486B of the **Finance Act 1998** offers a tax relief to corporate investors for investment in renewable energy projects. During the lifetime of the incentive, the corporate tax was reduced to 12.5%. In 2002, an amendment restricted the eligibility for tax relief on capital assets to active participants in projects (DCMNR, 2003).

Carrot. Since 2001, the Irish **Public Sector Buildings Programme** promoted energy efficient design, technologies and services in new and retrofit public sector projects with direct financial support. €12.7 M was available through 2006 to cover up to 50% of the costs of implementing energy efficiency measures including solar thermal technologies. The Model Solutions Investment Support Scheme also demonstrates energy efficient solutions in new and existing public sector buildings and offers good practice examples to encourage replication in the wider commercial building market (IEA, 2006e).

Carrot. Sustainable Energy Ireland (SEI), the government authority responsible for the promotion of renewable energy, introduced the **Pilot Bioheat Boiler Deployment Programme** in 2005. This programme provided grants of up to 25% of specific capital costs for biomass boilers for large buildings and small industrial sites with the aim of accelerating the uptake of biomass boilers for space heating in Ireland. It was in place from November 2005 to June 2006 (IEA, 2006e).

In the **Budget 2006** the Irish Minister of Finance announced a €65 M multi-annual investment programme for the period 2006-2010 that included financial support through grant schemes for renewable heating technologies (SEI, 2006a). Programmes that were developed included the **Greener Homes Scheme**, the **Bioheat Boiler Deployment Programme** and the **Combined Heat and Power Deployment Programme**. Following a high level of initial demand, a further €24 M was allocated in Budget 2007, bringing the total level of subsidy-based support for REHC technologies to €89 M.

Carrot. The **Greener Homes Scheme**, launched in 2005, provides grants to Irish households for the purchase of renewable energy heating systems for new or existing residences. Grants are intended to cover approximately 30-40% of installation costs. Administered by Sustainable Energy Ireland, the scheme allocates funding for REHC technologies:

Solar thermal space or water heating:	€300/m^2 to a maximum of 12 m^2
Geothermal heat pumps:	€4 000-€6 500 depending on the source
Biomass stoves and boilers:	€1 100-€4 200 depending on the resource and boiler type.

A total of €27 M was allocated and grants have been available since March 27 2006 (SEI, 2006a). The novel program saw an uptake in the first year of 7 times that which was anticipated, with 13 000 applications. Roughly 45% of the funding is for biomass boilers, GHPs acount for 28% and solar thermal installations 27% of funding support (DCMNR, 2006).

Carrot. The **Bioheat Boiler Deployment Programme**, launched in 2006, replaced the **Pilot Bioheat Boiler Deployment Programme.** This new programme, administered by Sustainable Energy Ireland, provides grants up to 30% of specific capital costs of boilers fuelled by wood chips and wood pellets in large buildings and small industrial sites until 2010. Grant eligibility is primarily for boilers of size 60 kW to 1 000 kW (SEI, 2006a).

A total of €22 M was allocated for the Bioheat Boiler Deployment Programme from 2006-2010 under budget 2006. Grants have been available since June 6th, 2006. The program was extended in 2007 to enable community and voluntary groups to apply for funding and to include other renewable technologies (see Budget 2007 below).

Carrot. The **Combined Heat and Power Deployment Programme** launched in 2006 is administered by SEI. It provides grants for both biomass- and fossil-fuelled CHP, with the larger portion of the funding to be directed at biomass. Grants up to 35% of specific capital costs (in the case of biomass CHP) and 30% (in the case of fossil-fuelled CHP) will be provided until 2010. There is no limit on the size of biomass-fired CHP installations that are eligible for funding (DCMNR, 2006). The programme aims to deliver 10 to 15 MW_e of biomass CHP as well as 100 to 200 small-scale fossil fuel CHP installations.

A total of €11 M was allocated for the five year period. Grants have been available for fossil fuelled CHP since August 3 2006, while grants for biomass CHP will be launched in April 2007 (SEI, 2006a).

Carrot. In **Budget 2007** the Irish Minister of Finance announced additional funding for renewable heating technologies. An extra €20 M was allocated to the **Greener Homes Scheme;** and renewable heating in large buildings and small industrial sites was allocated an additional €4M. The Bioheat Boiler Deployment Programme was replaced with the **Renewable Heat Deployment Programme (ReHeat)**, with the addition of solar thermal collectors and GHPs as eligible technologies and the expansion of the programme to include community organisations as eligible applicants. The lower 60 kW limit on biomass boiler size was also removed.

Evaluation

Heating demands accounted for 45% of the energy market in Ireland, equivalent to 218.2 PJ (SEI, 2006a). Growth of renewable heating has been slow in Ireland, although around 8.4 PJ (200ktoe) thermal energy was supplied from renewables over the past few years, mostly biomass. Virtually no solar thermal or geothermal heating existed in the country in the 1990s (Figure B13), but now some growth is being witnessed.

Solar thermal

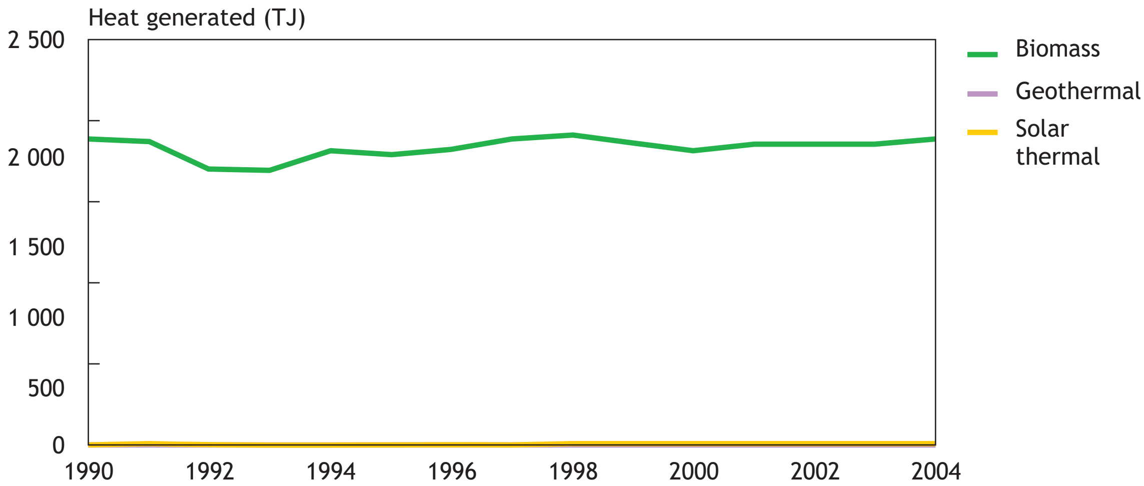
The market for solar thermal has seen important growth in Ireland since the beginning of the 21st century (Figure B14). However, despite the current growth rates, the penetration of this technology remains relatively small as compared with neighbouring European states. Only 0.84 MW of new solar thermal capacity was installed in 2003 and 1.4 MW[67] in 2004 giving the total installed capacity at 5.3 MW. A 75% growth rate in the market between 2004 and 2005 brought estimates of total installed capacity to 7.5-7.8 MW[68] (EurObserv'ER, 2005; ESTIF, 2006c).

67. Equivalent to around 2000 m^2 of solar collector area.

68 .Resulting from an annual increase of 3 500 m^2 of installed surface area, or 2.5 MW.

The first incentives offered specifically for renewable heat in Ireland were in support of solar thermal technologies in 2001. Since that time, additional capital grants and subsidies have been offered for solar thermal through the **Greener Homes Scheme** and **Renewable Heat Deployment Programme (ReHeat)** arising out of Budget 2006 and Budget 2007.

Figure B13. *Renewable heat generation in Ireland by sector from 1990 till 2004*



Source: SEI, 2006a.

Biomass

Biomass accounts for almost all of the renewable heating, although the total contribution of this renewable heat resource has been limited, accounting for approximately 4% of total process/space heating in 2005. Most of the biomass was solid biomass, 70% of which was utilized for industrial heat at panel board mills and sawmills and the remainder as firewood used for domestic heating (SEI, 2006a).

Substantial incentives for biomass based heating were not offered until 2005 with the initiation of the Pilot Bioheat Boiler Deployment Programme. Between 2005 and 2007 the Irish government implemented several support schemes for biomass heat technology development. The Renewable Heat Deployment Programme (2007) and the Greener Homes Scheme (2006) constitute significant steps forward for support that has historically been very low.

Geothermal

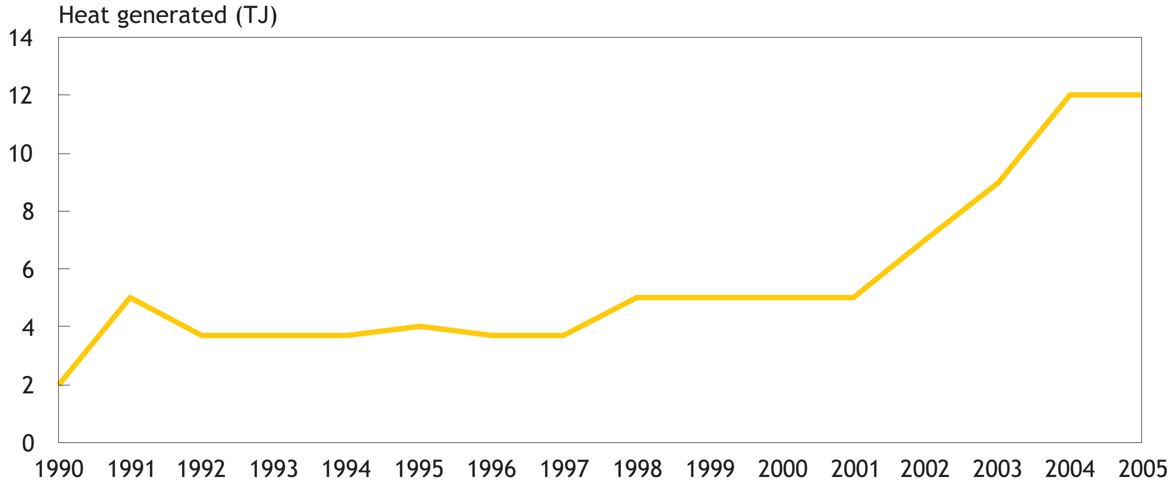
Most of the geothermal use in Ireland is for space heating using GHPs (Lund *et. al*, 2005). In 2000 there was no reported low-temperature geothermal heating capacity. However, both the **Greener Homes Scheme** and **Renewable Heat Deployment Programme (ReHeat)** support deployment of geothermal heating technologies so growth has since been fairly strong. In 2005, 20 MW of geothermal direct-use capacity had been installed, most as GHPs (Lund *et al.*, 2005).

Conclusions

For most of the 1990s no incentive schemes existed for REHC in Ireland. All initiatives implemented since 2000 have been financial incentive schemes. The previous lack of incentives resulted in insignificant growth of the technologies but more recently, incentive schemes have initiated the growth of biomass, solar thermal and GHP markets.

Recent policy development targeting renewable heating constitutes an important step forward. However, due to the novelty of the instruments, it is likely that their effects will not be quantifiable for several years to come.

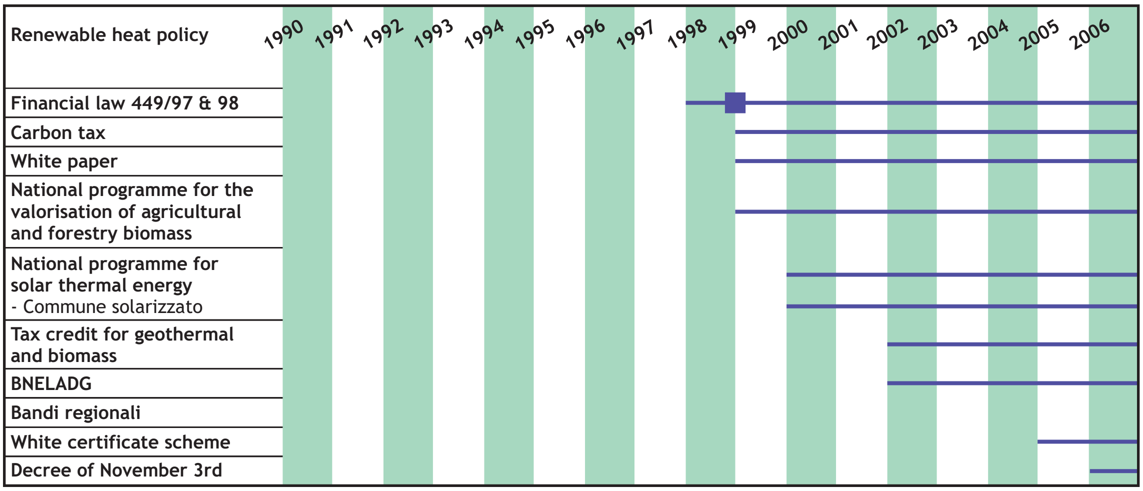
Figure B14 • *Solar thermal heat production in Ireland from 1990 till 2005*



Source: SEI, 2006a.

Annex B6. Italy

Instruments



Carrot. In 1991 Decrees of the Italian Ministry of Industry (17/7/1991) established norms for awarding subsidies for up to 50% of the costs of district heating systems. These grants are part of articles 11, 12, and 14 of Law 10/91. This law defined renewable energies and efficient technologies in public buildings as a "crucial" and "urgent" target but despite mandatory targets the law was barely applied (Corrado, 2007)

Carrot. **Financial Law 449/97** passed in 1998, created a tax deduction for individuals and private companies for costs related to renewable energy installations including solar thermal and biomass. Designed in support of the construction sector, it allowed a fiscal reduction of 41% for costs related to building restructuring for renewables carried out during 1998 and 1999. For projects installed up until 2006 the reduction was 36% (Calderoni, 2007). Deductions were taken from the taxable base of individual revenues within 10 years and limited to €77 468 per building unit, per applicant, per year (IEA, 2004). **Financial Law 448/98** reduced the percentage deduction established in Financial Law 449/97 from 41% to 36% (IEA, 2006e).

Carrot. A **carbon tax** on coal, natural gas, and fuel oil was approved by the Italian government in 1998. This tax was inaugurated in 1999 and then completely phased in over a period of 5 years (IEA, 2004).

Guidance. The Presidenza del Consiglio dei Ministri (CIPE) approved the Italian **White Paper for the Valorisation of Renewable Energy Sources** on August 6 1999 outlining specific targets for each renewable sector, including solar thermal, geothermal, and biomass heat. Guidelines, strategies, and objectives for renewable development were established. The targets for renewable heating generation were defined 60.6 PJ by 1997, 88.2 PJ by 2002, 113.7 PJ by 2006, and 147.0 PJ by 2010 (Altener Programme, 2001).

On December 21 1999 CIPE approved the **National Programme for the valorisation of Agricultural and Forestry Biomass**. The primary goal of this legislation is to promote the use of agro-zoo-technical-forestry biomass for the production of electricity, heat, and biofuels for transport. This programme set targets to produce 334.9 PJ- 418.7 PJ of energy from biomass by 2012.

Carrot and *Guidance*. The **National Programme for Solar Thermal Energy**, administered by the National Agency for New Technologies, Energy, and the Environment (ENEA), was established on December 22 2000 as part of the Decree of the Ministry of the Environment number 99. This programme establishes norms, functions of actors, and funds for installing solar thermal systems on buildings. By creating a qualified network of designers and installers, the programme aimed for 1.5 M m^2 solar thermal surface area by 2005 and 3 M m^2 by 2010. The 2005 target was not met with a total installed capacity of only 550 000 m^2, suggesting that 2010 targets may be difficult to achieve (Calderoni, 2007). Funds for the Thermal Solar Energy Programme originate from the national incomes of Carbon Tax and regional budgets (Altener Programme, 2001).

In conjunction with the National Programme for Thermal Solar Energy, the Ministry of the Environment established the **Communi Solarizzato Programme**, a tax and financial incentive system for solar thermal installations especially within the central and southern regions of Italy. The aim was to support the installation of solar thermal plants on public buildings and the creation of new, small companies in the environmental sector (Calderoni, 2007).

The subsidies and tax incentives offered are available to investors simultaneously so that they may take advantage of both. 41% of investment costs are eligible for deduction from income tax[69] and in addition, €9 M was allocated in the form of subsidies available for up to 50% of the investment cost of a system.

Although a total installation of 72 000 m^2 collector area was projected for support, relatively low interest by Italian public administrations has led to a total installation of only 12 000 m^2 (Calderoni, 2007). The programme has been criticized for allocating sums which are too low, thus restricting the number of possible installations which could have received funding (EubObserv'ER, 2006).

Carrot. In 2000 the Italian Financial Law (Article 29, Finance Law 2001) created a **Tax Credit for Geothermal Energy and Biomass** of €20.65 /MWh available to users connected to a geothermal or biomass fuelled district-heating grid (IEA, 2004).

Quantitative targets were established by the Italian government in the **Decrees of Ministry of Industry 24 April 2001 and Ministry of Production Activities 20 July 2004**. Initially the 2001 Decree was established to support REHC technologies from 2002-2006. Due to a delay in the application of these decrees, they were replaced by the 2004 Decrees of the Ministry of Production Activities which postponed targets through the period 2005-2009 (IEA, 2006e).

Carrot. In 2002 the Italian Ministry of Environment (MATT) initiated a subsidy programme **BNELADG (Bando nazionale per Enti Locali e Aziende Distributrici Gas)** targeted towards local authorities and municipally owned gas-distribution companies. It provided 30% of design, component, and installation costs of low-temperature solar thermal units for domestic hot water, swimming pool heating and space heating and cooling. In addition, 100% of the costs for monitoring systems were provided, to a maximum of 10% of total project cost. Approximately €6 M was made available, €4 M for public authorities and €2 M for natural gas utilities (ESTIF, 2006a; Calderoni, 2007). Minimum requirements were established: the total surface area of a qualifying installation must be above 20 m^2, although several smaller installations of a minimum 6 m^2 can also added in order to qualify; and the owner must assure that the plant will remain in operation for at least 10 years. Targets were established for a total solar thermal installation of 21 MW, or roughly 30 000 m^2.

€1.5 M of the available €6 M has been assigned to solar thermal projects leading to a total investment of €3.3 M for 3.5 MW total solar thermal installations, far below target. No awareness campaigns were created upon inception of the programme, possibly accounting for the low response and interest (ESTIF, 2006a). Hence the remaining finances were refunded on June 2nd, 2007 and allocated to a new

69. Tax deductions are spread over a period of five years.

programme, **Il sole negli Enti Pubblici** with a total budget of €10 M used to increase available subsidies to 50% of installation costs (Corrado, 2007).

Carrot. Also in 2002, the Italian government began to provide regional subsidies to both the public and private sector to support solar thermal under the Governmental Decree of July 24 2002 entitled **Bandi Regionali per Enti Pubblici e Privati**. This programme, worth €15.5 M was financed in part from federal and regional governments. On average, contributions to the total costs of a solar thermal installation are in the order of 30%. Regions are free to choose whether the subsidy will be provided in terms of installation costs or energy generated. This program targeted a total investment of €54 M to support an equivalent of 75 000 m^2 of solar collector area (Calderoni, 2007).

As of May, 2007 roughly 50% of the funding had been allocated with that remaining transferred to support a new programme of €10 M for up to 50% of costs for solar thermal installations in public buildings. 75% of costs are eligible for funding for installations by Italian energy service companies.

Carrot. The Italian government gave a VAT reduction from the usual 20% to 10% for solar thermal systems. Until 2005, 36% of total installation costs could also be deducted from taxes for a period of 10 years. This was increased to 55% over a 3 year period in January of 2007.

Carrot. In January 2006 the **Italian Governmental Decree of November 3** established capital contributions up to a total of €30 M for biomass or natural gas based high efficiency, CHP plants. The specific capital amount allocated depends on the type of energy source used with 30% of capital costs (up to a maximum of €300 000) available for units fed by biomass or by hybrid natural gas and biomass units (European Biomass Association, 2006).

Stick. **Law number 192/05** made it mandatory for new or refurbished public buildings to supply 50% of their domestic hot water needs with solar thermal. New private building owners were required to design the conventional heating system such that solar thermal systems could be easily integrated in the future (Corrado, 2007). This law was revised with **Law 311/06** which strengthened the obligation and extended it to include mandatory installations on private buildings. With this revision, renewable heat no longer had to be supplied strictly by solar thermal, but rather from a choice of renewable technologies.

Stick. On January 1 2005 the Italian government established a **White Certificate Scheme** primarily for energy savings and energy efficiency targets. Large gas and electricity supply companies with more than 100 000 customers must meet mandatory targets for energy savings in end-users under this scheme. Unlike other white certificate schemes in France or the U.K., Italy placed its obligation on distribution companies rather than on electricity and gas retail suppliers. Targets were set for a total savings of 120 PJ by 2009[70], or 230 PJ in total between 2005 and 2009. Certificates are issued to obliged parties who have paid for energy efficiency measures. A minimum price for white certificates (or a guaranteed cost of recovery) was fixed at €0.017/kWh energy saved. In addition, a penalty has been imposed in the case of non-compliance.

Solar thermal applications have been specifically included in the Italian White Certificate scheme and energy savings that result from solar thermal technologies are explicitly outlined. GHPs and biomass systems are also eligible energy efficiency measures. District heating and CHP have also been given specific qualifications under this scheme. A calculation sheet has been made available from the Italian Authority for Gas and Electricity (AEEG) to assess the gross specific savings in toe /m^2 of solar thermal collectors installed (ESTIF, 2006a). This instrument is relatively novel for promoting REHC.

Guidance. The National Commission for Solar Energy (CNES) was established by the Minister of Environment in August 2006 with the aim of defining the mid- and long-term strategies for the diffusion of solar technologies (Corrado, 2007).

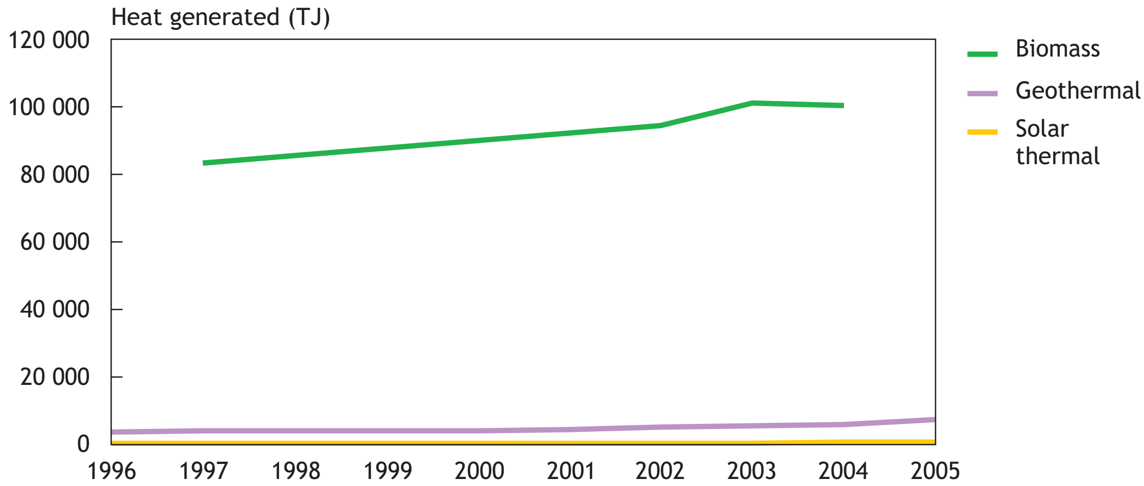
70. Annual mandatory targets of the White Certificate Scheme are monitored by the AEEG.

Noteworthy support for renewable heating has also originated from regional and local governments. For example, the local government of Turin province allocated €100 000 as 30% of the installation costs for each of 3 large-scale solar thermal systems and also provided planning and installation design support (Calderoni, 2007).

Evaluation

Total thermal energy production from renewable energy resources grew from 131.7 PJ in 2002 to 148.8 PJ in 2003 (Figure B15) (IEA, 2007a).

Figure B15 • *Renewable heat generation in Italy by sector from 1996 till 2005*



Source: EC, 2006b; SHC, 2006. Where data was unavailable, numbers have been extrapolated.

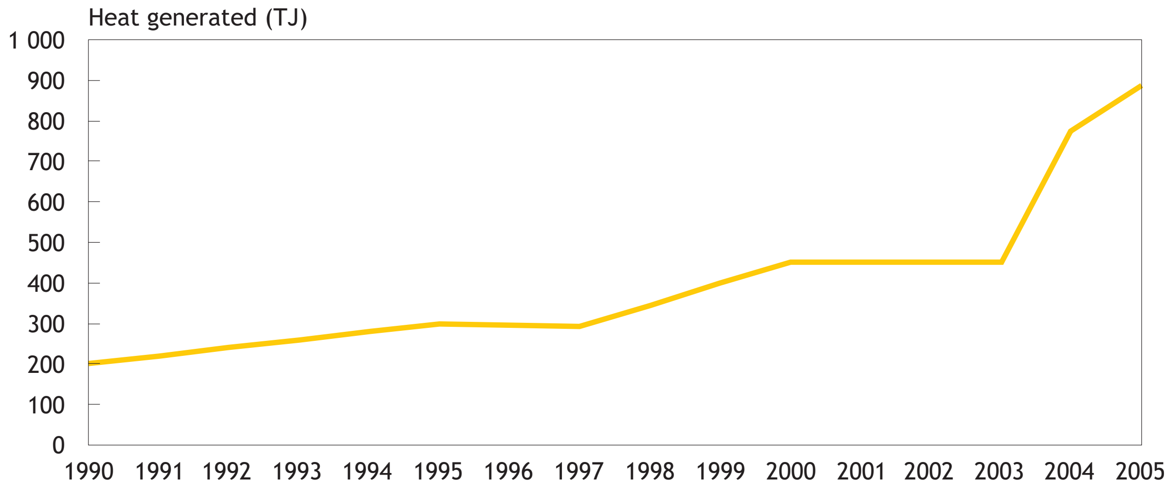
Solar thermal

Solar thermal heating has grown significantly in Italy (Figure B16) although its contribution to the total heat supply remains negligible. Solar thermal heat production increased from only 293 TJ in 1997 to 586 TJ in 2002 and 669 TJ in 2003 (SHC, 2006). In 2004 nearly 38.5 MW (60 000 m^2) was installed, bringing the total to 320 MW, an annual increase of 14% (EuObserv'ER, 2005; SHC, 2006). In 2005, a 25% increase in installations of 50.4 MW (72 000 m^2) brought the total to 371 MW. In 2007 a study of the Italian solar thermal market suggested that it had historically been underestimated with 130 MW (186 000 m^2) of new capacity installed in 2006 and 200 MW (286 000 m^2) forecast for 2007 (Zingale, 2007).

Nearly 30% of Italian solar thermal installations have been in Trento and Bolzano regions due to the subsidies offered by regional governments and the proximity to the well-developed Austrian market (SHC, 2006). Nearly half of the systems installed are imported, mainly from Austria, Australia, Germany, Greece and Israel, and roughly 84% are flat plate collectors (Zingale, 2007).

Support schemes for solar thermal began in 1998 with the Financial Law 449/97 tax reduction. Subsidies were first provided in 2000 as part of the National Programme for Thermal Solar Energy which also aimed to create a network of qualified expert designers, engineers and installers. Further financial incentives were available from 2002 with the MATT subsidy programme and the 2004 Comuni Solarizzato programme. Although MATT funding contributed to a total investment of €3.3 M in solar thermal installations, roughly 3.5 MW, only €1.5 M of the original €6 M budget was allocated and installations were far below target. As such, an important opportunity to develop the solar thermal market in Italy has been missed, although the subsequent program, Il sole negli Enti Pubblici may enable the Italian solar thermal industry to recover this lost support. The Italian White Certificate Scheme indirectly promotes solar thermal installations by qualifying these technologies as eligible energy savings. The anticipation of the energy efficiency requirements may have stimulated the significant growth in the solar thermal market in 2005.

Figure B16 • *Solar thermal heat production in Italy from 1990 till 2005*



Source: SHC, 2006. Where data was unavailable, numbers were extrapolated.

Biomass

Over 92% of renewable heat in Italy is from solid biomass, primarily wood, most of which is burned in domestic heaters (SHC, 2006). Biomass based district heating has grown since the late 1990s with 210 MW installed as of 2006 (European Biomass Association, 2006). Pellets, traditional firewood and gross agricultural residues are widely used. Although there is significant domestic pellet production of roughly 160 000 t/yr (increasing by 14-15% annually on average), annual production cannot satisfy growing demand for nearly 300 000 t/year. As such, Italy imports large quantities of pellets annually (European Biomass Association, 2006).

Biomass heat has been supported since 1998 with the Financial Law 449/97 tax reduction scheme. Further tax credits were approved in 2000, although delayed to 2002 due to administrative complications. Capital contributions were first offered for biomass fuel in CHP plants in 2006 after approval in 2004. Additional support was included in the 2005 White Certificate Scheme with special qualifications for biomass CHP and district heating. Despite several incentive schemes intended for biomass heat in Italy, the growth of the market has been slow due to the lack of concrete, long-term measures in support.

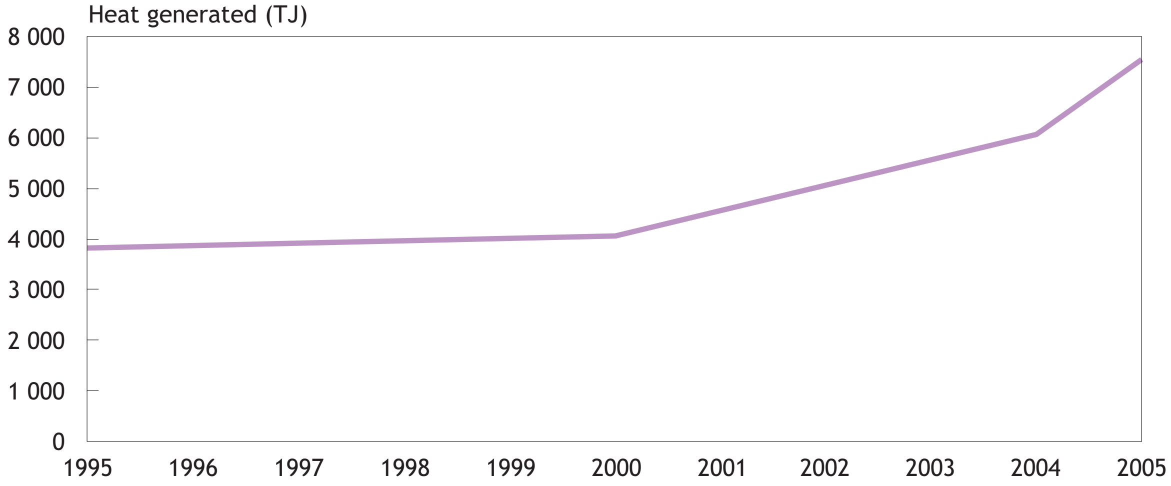
Geothermal

Most geothermal resources in Italy are utilized in the production of electricity. In 2005 geothermal heat totalled 11.1 PJ (IEA, 2006d). Most geothermal heat is dedicated to low-temperature bathing (158.8 MW in 2005) and heat pumps (120 MW in 2005)[71]. The total capacity of direct-use, low-

71. Direct-use geothermal is also used in individual space heating, district heating, greenhouse heating, fish farming, and industrial process heat.

temperature geothermal applications[72] increased from 307 MW in 1995, to 325.8 MW in 2000, 487 MW in 2004, and 606.6 MW in 2005 giving 7.6 PJ of heat (Figure B17).

Figure B17 • *Direct-use, low temperature geothermal heat production in Italy from 1995 till 2005*



Source: Lund et al., 2005. Where data was unavailable numbers were extrapolated.

The only noteworthy incentive policy for geothermal heat was a tax incentive, offered since 2000. Despite the relatively low incentive for direct-use geothermal heat the market has continued to grow.

Conclusions

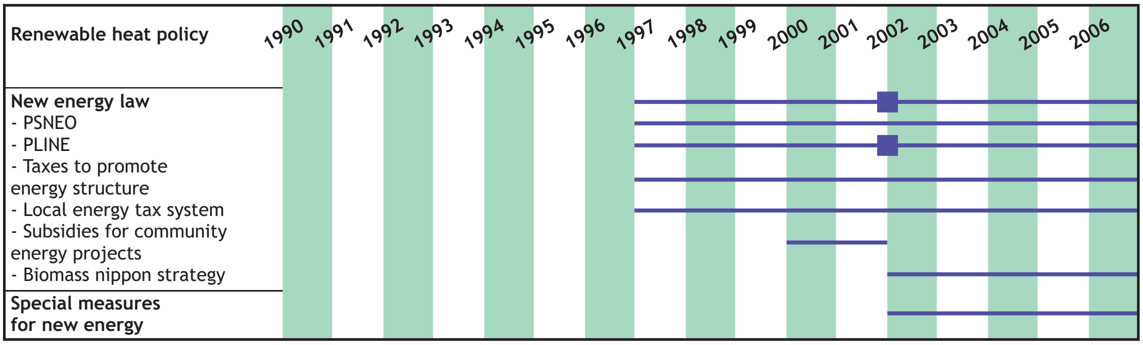
Italy offered an important incentive for solar thermal under its 2002 MATT subsidy programme which primarily due to poor awareness of possible constituents and its small budget has been unsuccessful in allocating the entirety of its resource. As such, the MATT experience provides a relevant example for the importance of well-established information campaigns to accompany carrot-based incentive schemes.

National legislation in support of renewable heat has not been strongly developed. Biomass constitutes the majority of Italian renewable heat although legislation to support this technology and supply chain has been poorly developed. Capital incentives have been available for solar thermal since the late 1990s but the market did not show significant growth until the implementation of the White Certificate Scheme in 2005. Most of the geothermal potential in Italy is utilized for electricity production, and not heat. Despite a lack of supportive instruments, the geothermal heat market has continued to grow.

72. The energy utilized from the installed capacity is often far less than the maximum potential and may therefore be misleading.

Annex B7. Japan

Instruments



In 1993 the Japanese government gave the responsibility of promoting new energy and energy conservation technology to the New Energy and Industrial Technology Development Organization (NEDO)[73].

In June of 1997 a **New Energy Law** was introduced defining "New Energy" as an oil-alternative energy resource including hydrogen fuel-cells, renewables, waste power, and CHP facilities. The law was revised in 2002 to include biomass and cold energy from snow and ice. In May 2006 it was proposed that the definition include geothermal, small-scale hydro, and waste energy from fossil fuels. The New Energy Law acts as an umbrella policy under which a number of more specified policies exist. Incentives were designed as grants and subsidies, preferential tax treatment, and loan schemes. Each category is the responsibility of one of the Ministry of Economy, Trade and Industry (METI), Ministry of Environment (MOE), Ministry of Agriculture, Forestry and Fisheries (MAFF), and the Ministry of Land Infrastructure, and Transport (MLIT)

The first pillar of the New Energy Law, offers grants and subsidies for technological development (RD&D), demonstration and field test projects, and introduction and dissemination. In addition to several of the policies listed in detail below, the **Subsidization for the Development and Promotion of Biomass Utilization** programme €8.6 M (¥14 400 M[74]) in 2005 and €9.6 M in 2006 and the **Project for Promoting the Introduction of High-efficiency Housing/Building Energy Systems,** offering subsidies for geothermal heat-pumps (GHPs) of €31,200 in 2006, have also been designed in support of renewable heat, at least in part.

Carrot. Under the umbrella of the New Energy law, the **Support Programs for Assisting New Energy-Related Businesses (PSNEO)** scheme was created. An incentive of one third of installation costs and a guarantee for 90% of any debt accrued is provided. These incentives are available to private sector firms that invest in advanced new energy technologies and facilities including solar thermal, differential temperature energy, and waste heat (IEA, 2004). In 2004, an annual budget of €28.9 M was allocated for all renewables including solar PV, natural gas co-generation, and others in addition to renewable heat decreasing to €20.7 M in 2005 and increasing to €23.7 M in 2006 (Tomita, 2007).

Carrot and *Guidance*. The **Project for Promoting the Local Introduction of New Energy (PLINE)** scheme under the New Energy Law offers subsidies for renewable energy projects including solar thermal, waste thermal, water-source heat pumps, and biomass. Small hydro and geothermal energy generation are ineligible.

73. NEDO was established initially in 1980 by the Japanese government to develop new oil-alternative energy technologies.

74. 1000 ¥ = €6

This project aims to promote the accelerated introduction of the "New Energy Facility Introduction Project" as well as the "New Energy Introduction Promotion/Dissemination Project," both of which will be implemented by local governments. Subsidies are available under the jurisdiction of local governments for up to 50% of the costs of installation, deployment, promotion of public awareness and related activities of renewable energy facility costs up to €120 000. The public sector, private companies, and non-governmental organizations are eligible to receive subsidies (Hirofumi, 2007; IEA, 2006e).

In 2002 amendments were introduced to the PLINE program. An annual budget of €99.6 M was allocated in 2002, only part of which supported renewable heating technologies. (IEA, 2004) The PLINE scheme is ongoing and in 2006 the budget was €27.6 M. By 2005, PLINE had supported 65 solar thermal plants, 4 biomass thermal plants, 9 biomass projects for snow/ice melting, and 7 waste thermal stations in addition to 624 projects for renewable electricity production (Hirofumi, 2007).

Carrot. Under the New Energy umbrella the Japanese government allocated €4.5 M in 2000 under the **Subsidies for Environmentally-Friendly Community Energy Projects** programme. These funds are allocated for regional heat supply systems and waste power generation plants. It was the aim of this policy to make the best possible use of waste heat or surplus electricity production (IEA, 2004) but was terminated in 2002.

Carrot. Also under the New Energy Law, in December 2002 the **Biomass Nippon Strategy (BNS)** was implemented in Japan through 2010. In 2005 the BNS budget had been allocated €12.2 M for RD&D, and €143.3 M for biomass conversion facilities. The BNS targets the utilization of 80% of waste (including paper waste, livestock waste, construction derived wood wastes, black liquors and sewage sludge) and 25% utilization of energy crops and other specified biomass energy sources. As part of the BNS a Biomass Information Headquarters agency was established to act as a central base of information on biomass in Japan. The government allocated approximately €600 000 in 2006 in support of biomass under this strategy to include demonstration projects and subsidies for biomass projects conducted by municipal governments and other private organizations (Kobayashi, 2004).

The second pillar of the New Energy Law offering preferential tax treatment for new energies offers a 7% tax deduction of the standard purchase price of new energy facilities under the law titled **Tax to Promote and Invest in Reforms in the Energy Supply-Demand Structure**. Under this system, installation owners may chose a 7% tax deduction or a special accelerated depreciation wherein an amount equivalent to 30% of the base acquisition value may be included as a non-taxable expense. Under the law titled **Local Energy Taxation System**, the standard taxable value for property tax may be abated by one-sixth for any individual or business entity that has installed a new facility for the duration of 3 years after installation. Special tax measures are available to individuals or business entities which have installed biomass facilities. For such systems, owners are allowed to choose between a 7% tax deduction and an accelerated depreciation schedule, similar to above. In addition, with regards to the Local Energy Taxation System, the standard taxable value for property tax may be abated by one-half for a period of three years following installations and a further abatement of the standard taxable value for the business office tax by one-half on both the asset-based and employment-based assessment is offered.

Under the third pillar of the New Energy Law, the Development Bank of Japan and the Japan Finance Corporation for Small and Medium Enterprises offer loans for investment in renewable energy facilities up to 40% of project costs to large companies and up to €4.3 million to SMEs.

Guidance. Awards have been provided by the MOE each year since 1998 to each renewable energy sector. These awards target public awareness of renewables and introducing new technologies.

Stick. In May of 2002 the **Law on Special Measures for the Utilization of New Energy** established an RPS for renewable energy. This law set targets for 760PJ (19.1 billion litres of oil equivalent) or roughly 3% of the total primary energy supply to be sourced from new energy forms by 2010 with an obligation for renewables including solar PV, solar thermal, wind, waste power and thermal and biomass power and thermal. Specific targets for heating technologies were established as follows: solar thermal, 36PJ (from 30PJ in 2002); MSW 64PJ (from 65.6 PJ in 2002), and bioenergy heat of 123 PJ (IEA, 2004).

Evaluation

Japan generated approximately 256 PJ of heat in 2004, only 5% of which was consumed in the residential sector. The remaining 95% was consumed in the commercial, public and industry sectors (IEA, 2007a).

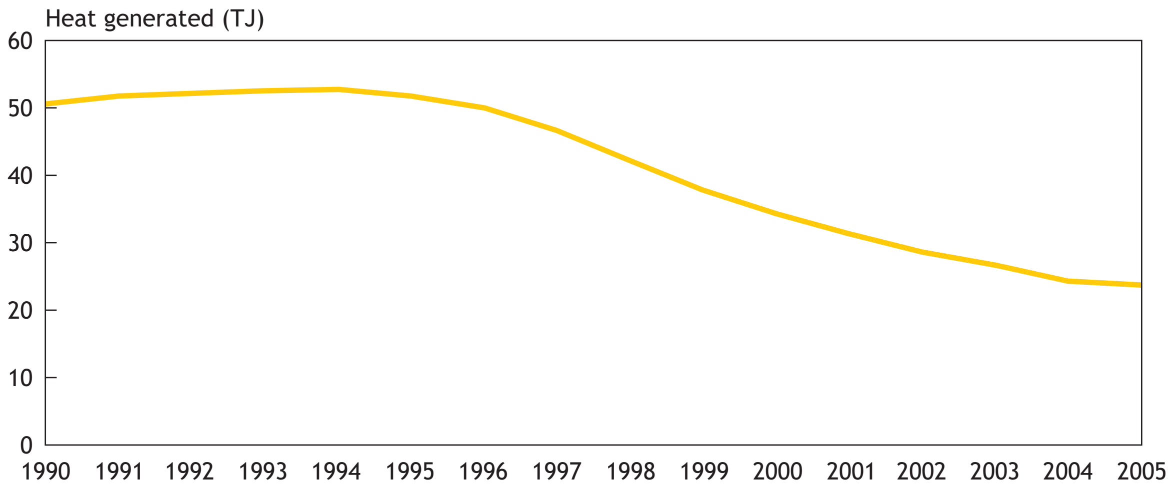
Solar thermal

Production and deployment of solar hot water systems began more than 50 years ago in Japan, ensuing three decades of solar thermal market development. However, in the late 1990´s growth in the solar thermal market began to stagnate, in part due to the government's termination of low-interest loans (WEC, 2004). Because of the strength of the yen and the comparatively low world petroleum prices in the 1990s, solar thermal heating was not as economic as gas or oil water heaters (Tomita, 2007). Moreover, 0.67 million m^2 of solar thermal surface area installed prior to 1990 were retired, accounting for a decline in the total surface area and the total heat produced (Figure B18) (REN21, 2006).

At the end of 2001 around 7.360 M m^2 of glazed solar thermal collectors had been installed[75] (WEC, 2004). The Japan Solar System Development Association recorded an installed total of 7.6 M m^2 in 2004[76] with 0.2 M m^2 added in 2005. However due to retirement, the total decreased to 7.2 M m^2 or 5.0 GW capacity.

Although the 1997 New Energy Policy offered support in the form of subsidies, tax incentives and informational campaigns, it has been unsuccessful in countering the strong influence of cost competitiveness with conventional heating technologies. Most of the incentives for solar energy in Japan have been directed towards PV technologies and only in 2006 did the government began to target renewable heat directly. Future deployment of renewable heat may therefore be able to reverse the downward trend.

Figure B18 • *Solar thermal heat production in Japan from 1990 till 2005*



Source: METI and IEEJ energy balance tables for Japan, 2006.

75. 7.219 M m^2 were flat plate collectors, and 0.141 M m^2 evacuated tube collectors.

76. This reflects an incremental increase of 0.3 M m^2 in 2004.

Biomass

There were no field surveys on the utilization of biomass in Japan prior to 2001 (Tomita, 2007). As such, data on the growth of this important renewable heat resource is limited, and conclusions as to the success of Japanese policies in this regard can only be taken with relative levels of assurance. The thermal utilization of biomass in Japan increased from 27.2 PJ in 2002 to 32.6 PJ in 2003. The biomass resource has been reported as having a relatively high moisture content, which may account for its limited utilization for combustion.

Under the original 1997 New Energy Law biomass did not qualify for public support. It was not until the 2002 revisions that biomass heat was able to receive funding from projects such as PLINE and the BNS so it is expected that the level of biomass use in Japan will increase. However, to meet 2010 targets will require the 2007 demand levels to more than double.

Geothermal

Japan is a country of significant geothermal resources being one of the most tectonically active countries in the world with more than 200 volcanoes. The direct use of geothermal hot water for natural baths has a long tradition (WEC, 2004) that has influenced the geothermal heat market.

About 51% of total geothermal heat is used for space and domestic hot water supply[77]. In 1995, 319 MW of direct heat capacity had been installed increasing to 822 MW by 2004 and accounting for 10.3 PJ/yr (including 409 MW of direct use for bathing) (Lund *et al*. 2005). It is estimated that GHPs accounted for 13.3 MW of installed capacity in 2006, producing 67.8 TJ/yr of heat (NEF, 2007). Direct use of geothermal heated springs for hot water accounted for a total of 4.9 PJ of heat in the same year.

Most of the incentives offered for renewable heat generation are not applicable to geothermal heat as it has not been defined as a 'new energy' under the 1997 New Energy Law. As such, geothermal heat has missed out on important support available to other technologies. However, proposals to include it in the definition may have important implications for the future.

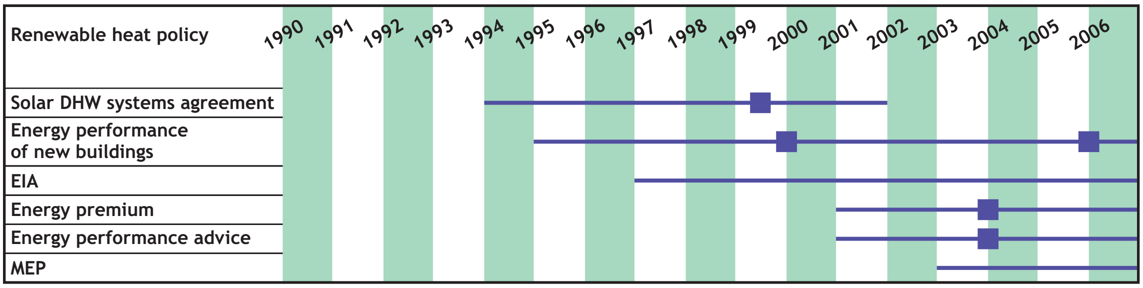
Conclusions

Japan has relied on one overarching policy in its support of renewable technologies, the New Energy Law. This policy as it was first designed did not include biomass and geothermal heat. As such, these technologies have lacked public support. This is likely to change, however, as the definitions were amended in 2002 to include biomass, and the suggestion was made in 2007 to include geothermal heat. The structure of the New Energy law that included 3 carrot-based mechanisms also included guidance-based schemes. In order to reach targets set for 2010 under the Law on Special Measures for the Utilization of New Energy, the use of renewable heat in Japan must increase substantially.

77. The remaining geothermal heat is used for bathing (11%), greenhouse heating (13%), snow melting (12%), fish breeding (9%), air conditioning/cooling (2%) and industrial process heat (1%) (WEC, 2004).

Annex B8. Netherlands

Instruments



SenterNovem, the Dutch agency for energy and innovation under the Ministry of Economic Affairs, is responsible for programmes on renewable energy and energy savings.

Carrot and *Guidance*. In 1994 the Dutch Government signed a long-term Agreement with the solar industry and energy utilities for the implementation of solar hot water systems with objectives for 11 000 hot water systems by 1998 and 17 000 by 1999. Targets were not reached, with only 7 600 systems installed in 1998 and 8 500 in 1999 (Novem, 2000). The total budget allocated was €2.95 M (6.5 M Dutch Guilders[78]) over its four year lifetime. A subsequent **Solar Domestic Hot Water Systems Agreement** was implemented in 1999 which increased 1994 targets to 5 PJ solar thermal of solar thermal energy by 2007 and 400 000 domestic hot water systems in 2010 (Novem, 2000).

In conjunction with this support for solar thermal systems, Novem (the precursor to SenterNovem) was involved in information campaigns, radio programmes, and a contest. Over 5 000 professional players in the construction field (housing associations, project developers, architects, consultancies, local authorities and power distribution companies) received an invitation to nominate a municipality to receive the title of 'Solar System City 1999'. Novem supported initiatives from other players in order to introduce the consumer to the technology (Novem, 2000) and through its **Solar Domestic Hot Water System Offer**, quotations for solar thermal systems were made available. More than 4 000 consumers made use of these quotation services, leading to 1 500 installations.

Stick. In 1995 under the **Energy Performance of New Buildings,** the Dutch government established requirements for all new buildings to reach a performance standard. Solar thermal technologies and heat pumps were included in the definition of how to reach a lower practical energy coefficient level. In 2000 and 2006 the acceptable level of this coefficient was lowered to 1.0 and 0.8 respectively (IEA, 2006e)

Carrot. The 1997 **Energy Investment Allowance (EIA)** supports sustainable energy use by industry. Investment in certain renewable energy technologies (lists of eligible technologies are updated annually) may be deducted from the taxable profit of financially independent tax-paying entrepreneurs. In 2006, 44% of investment costs in renewable heating construction and equipment, and/or CHP were eligible for deduction. Eligible energy investments must be in excess of €2 100 per calendar year. A total tax relief up to €108 M in energy investments is available. The EIA scheme is implemented by the Belastingdienst (Dutch tax authorities) and SenterNovem (2006).

In addition to the fiscal incentives offered through the EIA, a budget of €99 M was allocated for businesses investing in energy efficiency and renewable energy with 84% of applications coming from SMEs. A majority of the funding has historically gone to support renewable electricity but CHP installations have

78. Exchange rate based on 2002 values when Dutch Guilders (*f*) were replaced with the Euro: €1 = *f*2.20.

also been subsidized (SenterNovem, 2006). Based on 2005 project values, roughly €31 M was allocated in support of renewable heat generation. Only a small percentage of the total EIA allocation was allocated for renewable heat projects between 1997 and 2006 in the order of €211 M (SenterNovem, 2005).

Carrot and *Guidance*. In 2001 **Energy Premium (EPR)** and **Energy Performance Advice (EPA)** schemes were established. The EPR provides a subsidy of 50% for renewable energy projects including heat pumps and solar boilers in households and social housing corporations. EPA is a consultation service to provide possible measures that may be taken to improve the energy performance of a dwelling or office building. If and when the suggested measures are carried out, the EPR will subsidize part of the project. Both the EPR and the EPA were financed by means of an energy tax (REB). As the growth of renewable energy systems did not achieve intended targets, the government ended EPR funding in 2002 (IEA, 2004). Funding for EPA energy consultations continued, but in 2004 the budget was cut to €20M (IEA, 2004).

Carrot. July 2003 saw the passing of the **Environmental Quality of Electricity Production Act (MEP)**, subsidizing the production of renewable energy, especially from biomass. This replaced the former producer compensation Regulating Energy Tax. The reduction in fiscal advantage was theoretically replaced with an equal rise in feed-in subsidies from the MEP financed through a levy placed upon all electricity consumers of €52 in 2005. Biomass heat production is indirectly supported through the feed-in subsidies offered for CHP energy production. Subsidies for biomass energy production have ranged from €0.41 to €0.70 per kWh.

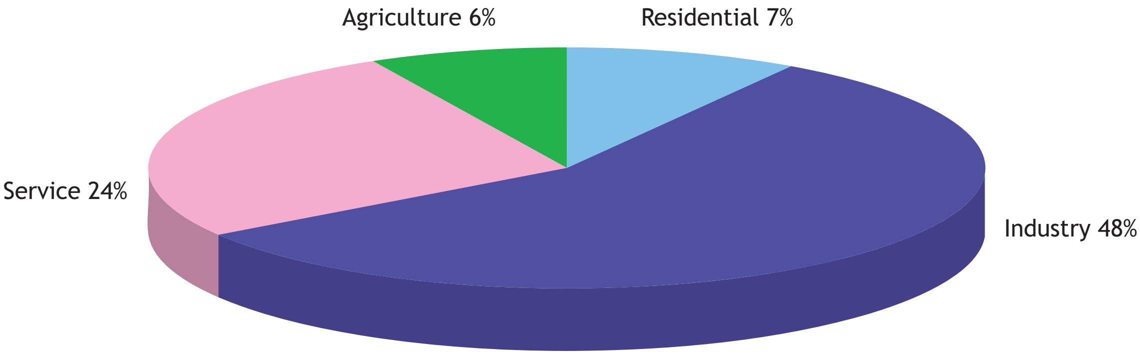
Stick. **Energy Performance Requirements**, employed in 2006 for new buildings, require the calculated total energy consumption to be below a specified level. The 20% reduction of energy allowance announced is expected to lead to a higher use of solar collectors and heat pumps. There is not yet a requirement for existing buildings due to administrative costs (SHC, 2006).

Guidance. Demonstration projects have been undertaken to encourage the development of deep geothermal energy projects (EGEC, 2006).

Evaluation

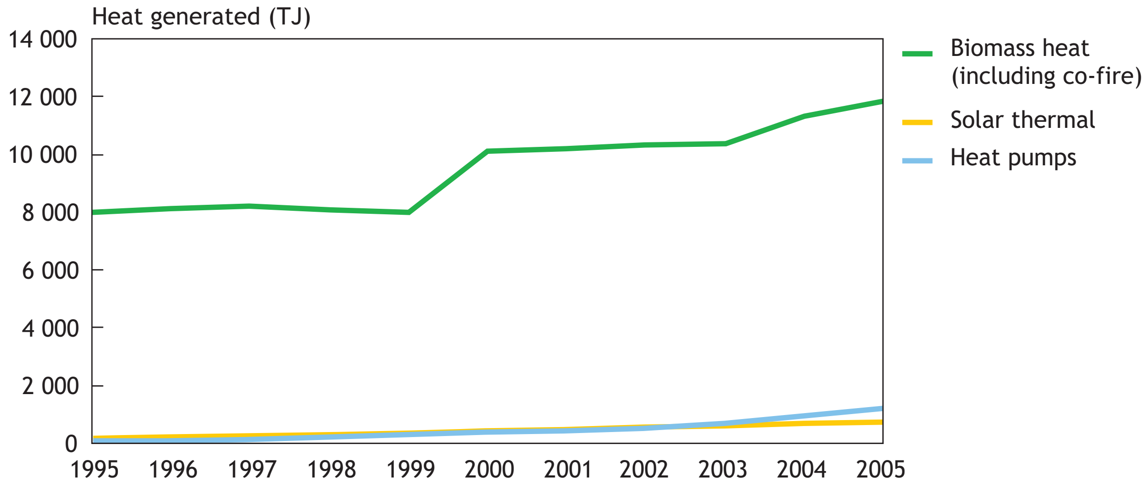
The Netherlands consumed 125.9 PJ of heat in 2004, 48% in the industrial sector, 7% in the residential sector, 24% in commercial and public services, and 6% in agriculture and forestry (Figure B19) (IEA, 2007a).

Figure B19 • *Heat consumption in the Netherlands by sector in 2004*



Biomass accounted for the majority of renewable heat in the Netherlands, solar thermal and geothermal heating markets have also shown growth (Figure B20).

Figure B20 • *Renewable heat generated in the Netherlands by sector from 1995 to 2006*



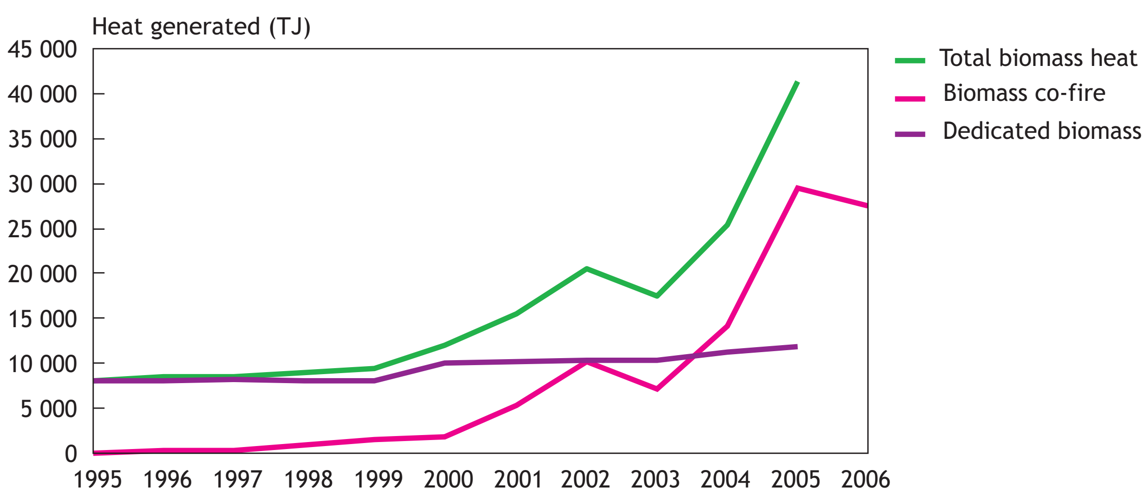
Sources: Statline, 2007.

Biomass

The gross heat production from solid biomass was 5.0 PJ in 2004, most of which was generated in CHP plants (EurObserv'ER, 2005). Most of the biomass market growth has been the result of a growing demand for its use in CHP, while dedicated biomass has not increased significantly since 1995 (Figure B21).

Although some growth in biomass CHP was stimulated with the ongoing 1997 EIA policy scheme, most market growth accompanied the 2003 MEP subsidy. All support for biomass heat has been in the form of carrot-based subsidies.

Figure B21 • *Biomass heat generated in the Netherlands: a comparison of dedicated biomass heat to biomass CHP from 1995 till 2006*



Source: Statline, 2007.

Solar thermal

Deployment of solar thermal began in the mid 1970s especially for larger installations, then declined in the 1980s (WEC, 2004). Following the implementation in the 1990s of the Solar Domestic Hot Water Systems Agreement and its precursor, solar thermal installations increased steadily at a rate of 30 000-35 000 m^2/yr until 2003. Despite this increase, the targets were not met. In the early 1990s the market increased again with the establishment of a voluntary agreement between the solar energy industry and energy utilities. In 1995 further support was offered through the regulation for Energy Performance of New Buildings for which solar thermal technologies offered an opportunity for buildings to reach given performance standards. The extension of these performance requirements in 2006 is expected to encourage further market development.

By 2001 nearly 15% of all new residential dwellings used solar hot water with a total of 269 112 m^2 of installed surface area[79] (SHC, 2006). Residential installations account for 66%, large collective systems 14%, and swimming pools 20% (WEC, 2004).

The 2001 EPR subsidy scheme further boosted investments in solar thermal systems, although subsidies were removed in 2002 (IEA, 2004). Following the decrease in available funding, the number of solar thermal installations declined 40% between the years 2003 and 2004 with an annual installation of only 40.8 MW (58 304 m^2) bringing the total to 353 MW, (EurObserv'ER, 2006). In 2004 all financial support for solar thermal was ceased (ESTIF, 2006a) and as a result, market growth fell in 2005 with only 27.6 MW (39 500 m^2) of new installations bringing the total to 375 MW (EurObserv'ER, 2005). The Energy Performance Standards, acting alone were not sufficient to support solar thermal market development at the rates that had been witnessed in prior years.

Geothermal

Prior to 1995 there was no shallow or deep geothermal capacity reported in the Netherlands. By 2000, 10.8 MW of GHP capacity had been installed, increasing to 253.5 MW by 2004 (Lund *et al.*, 2005). Support was received through the 1995 Energy Performance of New Buildings scheme. Heat pumps were an important alternative to assist buildings in reaching the required energy efficiency performance standard. Subsidies and information schemes were also offered in 2001. Additionally, demonstration projects have been employed to encourage the development of deep geothermal energy projects[80].

Conclusions

Support for renewable heat in the Netherlands was initiated in the 1990s with schemes for solar thermal. The largest contribution of renewable heat comes from biomass with significant growth in the amount of biomass utilized in CHP. While direct subsidy schemes have contributed to this growth, feed-in tariffs for biomass electricity generation in CHP also offered an attractive incentive (EC, 2006b).

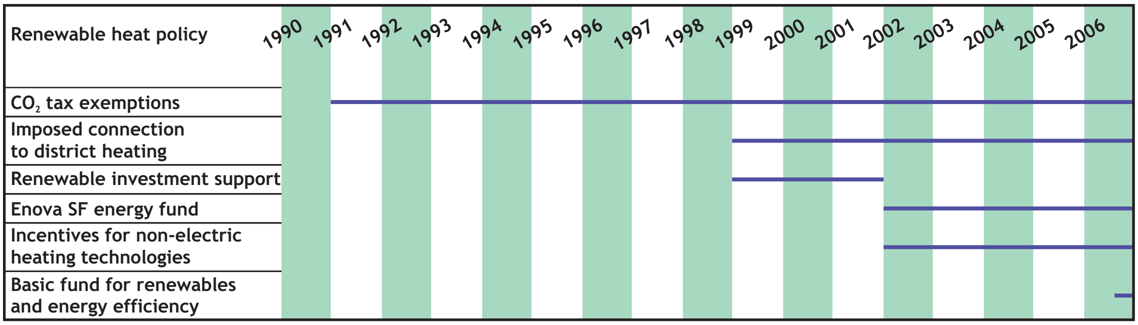
Currently there is very little support for renewable heat although some support remains for renewable heating installations through the EIA. The main instrument is the energy performance requirement for new buildings which is incorporated in the implementation of the Energy Performance of Buildings Directive.

79. 201 877 m^2 were flat plate collectors, 2 000 m^2 evacuated tubes and 65 235 m^2 unglazed.

80. No data is available on the total installation of deep geothermal capacity in the Netherlands.

Annex B9. Norway

Instruments



Carrot. A CO_2 tax has been imposed in Norway since 1991 from which renewable energy projects are exempt (IEA, 2005).

Stick. As of 1999, local authorities were given the ability to impose a mandatory connection of new buildings to district heating plants. This regulation, **Imposed Connection to District Heating**, applies to district heating plants greater than 10 MW (IEA, 2004).

Carrot. From 1999-2002 the Norwegian government exempted investments in renewable energy, heat pumps, and district heating from the general 7% investment tax under a **Renewable Energy Investment Support (RE Tax Treatment)** scheme. With the abolition of the general investment tax in April 2002, this support scheme was also completed (IEA, 2004).

Carrot. Enova SF, a new state-owned central agency of the Norwegian Ministry of Petroleum and Energy, was established in June, 2001 to manage the Ministry's energy fund. The **Enova SF Energy Fund** has provided investment support for new energy technologies and education measures for industry commercial and household sectors since January 2002. Its aim is to reduce the use of electricity for heating purposes and to promote new environmentally friendly forms of energy production (SHC, 2006). A target for renewable heat was set at 14.4 PJ annually, being equivalent to the heat requirements of over 100 000 Norwegian households. This target was based on a total renewable energy goal of 43.2 PJ by 2010.

A budget of €680 M (NOK 5.6 billion)[81] was established for the first ten-year period from which the Enova Energy Fund received approximately €81.6 M in 2006. Initially funds came in part from a €0.0012 /kWh levy on electricity transmission tariffs and in part from the national budget (IEA, 2004; SHC, 2006). From 2005 the Energy Fund is fully financed by the grid tariff supplement. Because there is a time gap of typically 2-3 years between the confirmation of funding from Enova and the initiation of project construction when the subsidies are awarded, there is a discrepancy between the yearly amount granted and paid (Table B6).

Enova has designed a programme specifically for renewable heating in order to achieve its specified targets by supporting new heating plants, distribution systems for heating, and sustainable supplies of biomass. It provides economic support for projects throughout the value-chain from extraction, transport and production of biomass, to the development of heating plants and distribution systems. Very little support is available for solar thermal.

81. 1 Norwegian krona (NOK) = €0.12

Table B6 • *Funds allocated for renewable heat generation under the Enova SF Energy Fund in Norway*

	TJ	Granted € M	Granted €/capita	Paid out € M	Paid out €/capita
2002	597.6	6.12	1.32	5.16	1.11
2003	943.2	4.92	1.06	2.64	0.57
2004	943.2	11.16	2.42	3.96	0.85
2005	1 065.6	13.92	3.01	1.8	0.39
2006	2 451.6	42.12	9.13	0.96	0.20
Total	**7 182**	**78.24**		**14.52**	

Source: Enova SF Annual Report, 2007

The level of funding available for renewable heating projects has fluctuated. Initial investment subsidies of 20-25% for projects based on bioenergy, waste heat, solar and heat pumps were reduced to 10% in 2003. Currently Enova contributes up to 15% of the project costs for heat distribution and heat generation based on renewable energy. Stipulations exist for the financial eligibility of this funding. For example, subsidies for heat production based on wood chips are available only to installations which produce at least 216 TJ /yr; for sawmill waste at least 36 TJ /yr; and for GHPs over 7.2 TJ/\yr (IEA, 2005).

Carrot. In 2002 the Norwegian State Housing Bank began to offer **Incentives for Non-electric Heating Technologies** in the form of loans available for builders to incorporate solar thermal systems, biomass boilers and GHPs in new constructions[82]. Other incentives are offered for water-based central heating distribution systems and heat pumps which may be combined with solar heating systems, and bioenergy. Levels of available support depend on individual cases. Development and pilot projects with high environmental ambitions may receive grants and loans up to 80 – 90 % of project costs. The bank has stated a goal of a 50% reduced energy demand in half of all new houses built in 2010 (SHC, 2006).

Carrot. From January 1 2007, the **Basic Fund for Renewable Energy and Energy Efficiency**, managed by Enova, was established to provide subsidies for renewable energy in terms of actual energy generated (€ /kWh). This fund, supporting all renewable resources, was allocated €1.2 billion in 2007. It is estimated that the annual contribution to the Basic Fund will be around €105 M.

Evaluation

Heat production in Norway in 2004 totalled 11.4 PJ which 15% was used by industry, 17% in the residential sector, 67% in the commercial and public services sector, and less than 1% in agriculture and forestry (Figure B22). Due to the abundant hydro resource, electricity prices are comparatively low in Norway, which has led to popular use of electric heat. With the deregulation of the electricity market in the early 1990s electricity prices dropped further, hence electricity remains the most common source of heat.

Beginning in 2000, renewable heat, primarily biomass, began to increase noticeably (Figure B23). Geothermal heat, especially from heat pumps increased in this timeframe, coinciding with the beginning of the Enova SF Energy Fund. Solar thermal grew slowly in comparison with other RETs for heat. Prior to the implementation of the Enova SF Energy Fund, the comparatively low price for electrically-based heat generated from hydro possibly inhibited the growth of renewable heat.

According to the Norwegian Water Resources and Energy Directorate, district heating systems produced 3.3 PJ of heat in 1990, 5.7 PJ in 2000, and 9.1 PJ in 2004. In 2005, solid biomass accounted for 15% of the district heat supply and heat pumps 6% with most of the energy coming from refuse incineration

82. See www.husbanken.no.

plants (Statistics Norway, 2007). The amount of biomass and heat pump energy in the district heating systems is increasing. The 1999 mandate for new buildings to be connected to district heating systems and the 7% investment tax exemption available between 1999-2002 are likely to have influenced the increase in district heating infrastructure.

Figure B22 • *Heat consumption in Norway by sector*

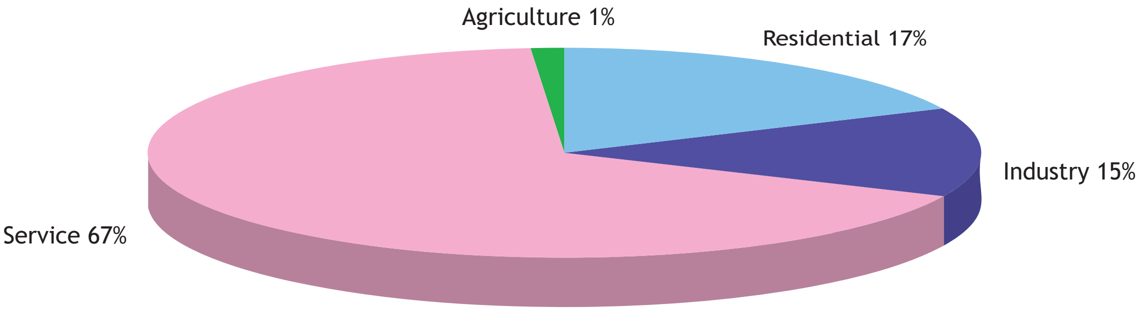
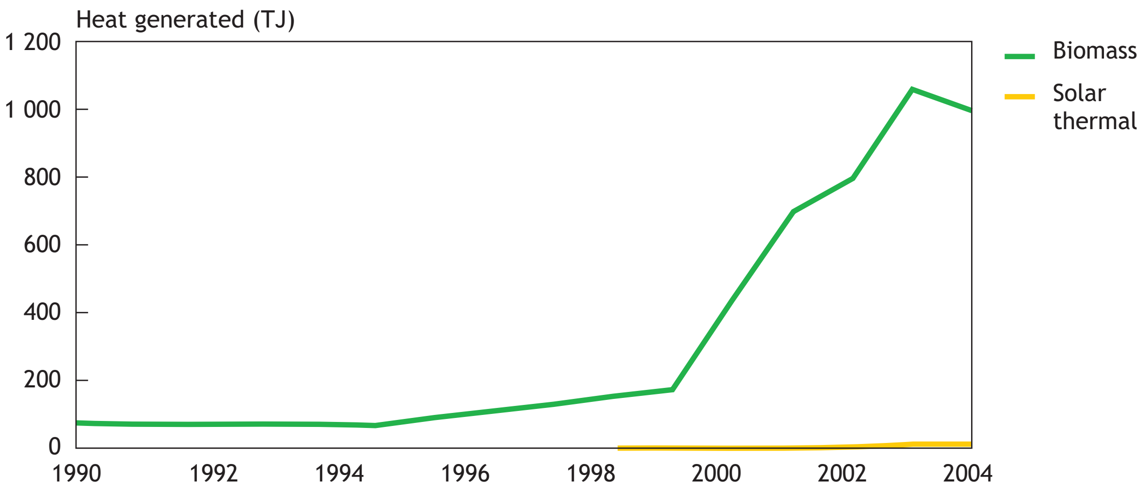


Figure B23 • *Renewable heat generation in Norway from 1990 till 2005*



Source: IEA, 2006b

Solar thermal

As of 2005, approximately 7.2 TJ of heat was generated by solar thermal in Norway so the commercial market for solar heating remained relatively small (SHC, 2006).

Solar thermal was offered direct financial incentives under the 2002 Incentives for Non-Electric Heating Technologies scheme. While the Enova SF Energy Fund does offer some support for solar thermal, it is comparatively low compared with bioenergy and geothermal.

Biomass

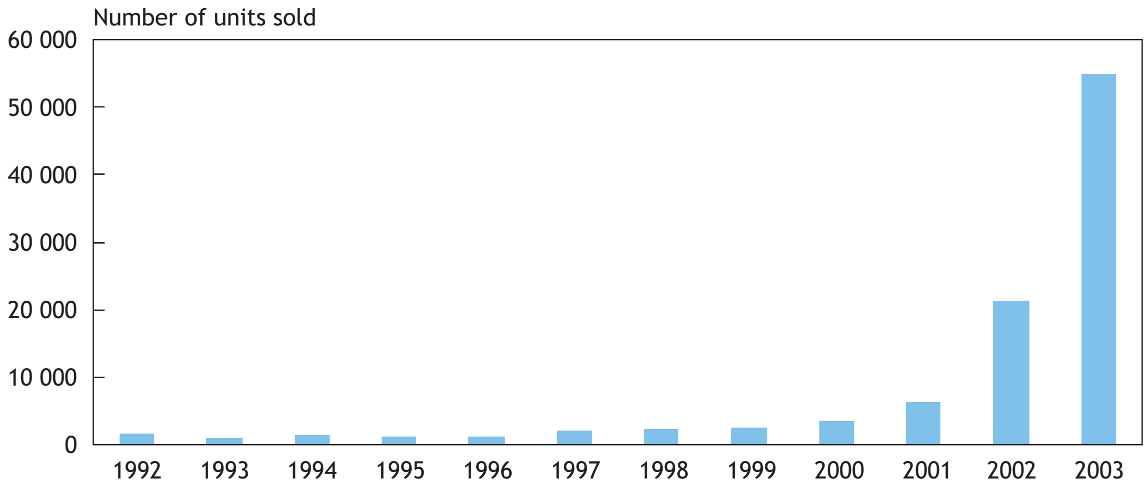
Norway has a considerable domestic biomass resource. However, its exploitation for heat was low prior to 2000. About 25.9 PJ of biomass heat was generated in 2003 by the many households that combust wood for space heating (IEA, 2004). Combustion of biomass in district heating systems is complicated by the dispersed nature of Norwegian settlements, and is therefore only possible in a few locations (IEA, 2005).

Since the implementation of the Enova SF Energy Fund and its investment support for heat generated from wood chips and saw mill waste in 2001, biomass heat increased significantly. ENOVA has contracted a total of 2.9 PJ of biomass heat projects with around 1.8 PJ supported in 2004 alone (IEA, 2005). In 2006 an additional 3 biomass heat projects were granted €480 000 for 360 TJ of heat production.

Geothermal

There was no shallow or deep geothermal capacity reported in Norway in 1995. By 2000, however, 6 MW of shallow, geothermal heat-pump capacity had been developed, and 600 MW by 2005 (an estimated 3.0 PJ/year). Geothermal installations are reported to be primarily large geothermal heat pump systems for commercial building or community dwellings, most of which are ground-water based (Lund *et al.*, 2005). The market for GHPs has been growing since 2001 (Figure B24), mostly for residential installations.

Figure B24 • *Annual geothermal heat pump sales in Norway from 1992 till 2003*



Source: HPC, 2004.

GHPs were included in the 1999-2002 exemption from the 7% investment tax. The combination of incentives offered under the Incentives for Non-Electric Heating Technologies scheme and the Enova SF Energy Fund in 2001 has seen significant growth in geothermal heat.

Conclusions

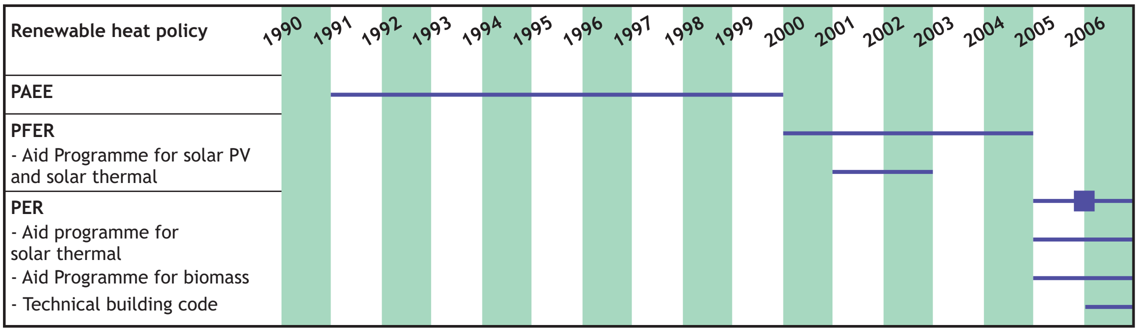
Norway has had abundant access to inexpensive and clean hydro power which has lead to extensive use of cheap electrical heating. Due to constraints on further local expansions of hydro power, various policies have been introduced in support of alternative energies, including a package of regulation, tax measures and subsidies for renewable heat. In addition, a major policy shift was introduced in 1998 aimed at curbing electricity-use patterns. As a result, Enova was established to manage the subsidies for energy saving, renewable heat and new renewable electricity production.

Enova has been crucial for the growth of renewable heat in Norway, allocating more than €142 M for 7.2 PJ of contracted energy generation between 2001 and 2006[83]. As funding for renewable heat continues to increase under the Enova SF Energy Fund, it is expected that renewable heat in Norway will increase in the future.

83. A total of €70.9 M was allocated for renewable heat in 2001; €4.7 M in 2002; €11.3 M in 2003; €13 M in 2004; and €42 M in 2006. In 2006 59 projects were supported to produce 2.5 PJ of heat.

Annex B10. Spain

Instruments



Carrot. In 1991 the Spanish government approved a National Energy Plan which included an **Energy Saving and Efficiency Plan (PAEE)** and set the objective to increase renewable energy to 46.0 PJ by 2000, 20.9 PJ of which was specified for renewable heat. Individual targets were established by sector. Subsidies offered through PAEE were managed by the Institute for the Saving and Diversification of Energy (IDAE)[84]. Although PAEE had targeted a 12% increase in energy efficiency by 2000, only 4.4% had been achieved by 1995.

Carrot. In December 1999 Spain's **Plan for the Promotion of Renewable Energy (PFER)** (Instituto para la Diversificacion y Ahorro de la Energia) came into force for the period 2000-2010. It applies to all forms of renewables, each with individual targets. It is divided into one stage running from 1999-2006 and the next from 2006-2010. A 37.6 PJ target for biomass applications was established (IEA, 2005); a target for 200 MW of high-temperature solar thermal installation was set for 2010 to give an estimated an annual output of 1.5 PJ (WEC, 2004); and a 2010 target of 4.5 M m^2 low-temperature solar thermal surface area was set for the residential sector, new homes, apartment blocks, and hotels. Based on 2006 population levels, this target would translate into 0.11 m^2 /capita of solar thermal capacity.

A budget of €60 million was made available in financial incentives under PFER including €300 million in loans from the Instituto Oficial de Credito (ICO) for RET. In 2005, solar thermal technologies received €13.39 M and biomass €12.7 M through various support programmes (IDAE, 2006a). The **Aid Programme for Solar PV and Solar Thermal**, established as a financial incentive under PFER, provided subsidies for solar thermal projects that were initiated in 2002 and completed before October 2003 (IEA, 2004). The financing available under PFER was amended under the provisions of PER (see below) in May 2005.

Carrot. A revised PFER policy, the **Renewable Energy Plan for 2005-2010 (PER),** was approved in August 2005. 2010 renewable targets were increased to more than 837 PJ, or 12.1% of the total final energy demand[85] with technology specific renewable heating targets set for 186.2 PJ, 146.5 PJ levels in 2004. Solar thermal targets were set for 4.2 M m^2 surface area, which would bring the Spanish total to 4.9 M m^2 by the end of 2010. Biomass heat was targeted to increase by 24.4 PJ /yr until 2010 with 15.8 PJ in the industrial sector and 8.6 PJ in the domestic sector.

A broad package of measures has been incorporated in PER which includes €681 M in public investment and €2.8 M in tax incentives. However, based on 2005 spending data, only 9% of the total was allocated

84. IDAE is a public business entity, established in 1984, in support of energy efficiency and the rational use of energy across Spain.

85. Due to the unexpected increase in energy consumption and energy intensity in Spain, the targets for renewable energies established under PFER, set at 12%, were revised.

to solar and biomass[86]. Should this trend continue, roughly €61 M will have been made available for renewable heat by 2010 (IDAE, 2006a). The energy industry finances 77% of PER, the private sector 20%, and the public budget the remaining 3% (IEA, 2006e).

The **Aid Programme for Solar Thermal,** part of PER, offers direct financial support for a maximum of 37% of the cost of equipment and installation. Innovative projects are eligible for up to 50% of total costs (IDAE, 2006b). For the 5-year lifetime of PER, contributions, paid in terms of capacity installed, depend upon the size and type of installation (Table B7).

Table B7 • *Specifications for solar thermal funding eligibility under the PER Aid Programme incuding for solar cooling*

Category	Available disbursement	
Entire solar thermal system	€1 160/kw or €812/ m²	
System components	Up to 14 kW or 20 m²	€1 160/kW or €812/m²
	Over 14 kW or 20 m²	€1 015/kW or €710.5/m²
Solar cooling	€1 450/kW or €1,015/m²	

Source: IDAE, 2006a

The Aid Programme for Solar Thermal offers a greater incentive for solar cooling installations and is one of the few programmes to do so. About €348 M was allocated for this programme, an equivalent of €70 M /yr. Reflecting PER's allocation of financial responsibility, industry will supply €1.8 M, the private sector €536 922, and the public budget, €348 078.

The **Aid Programme for Biomass**, also part of PER, provides a maximum of 30% of the costs of biomass equipment, installation, and project engineering for installations in domestic and commercial buildings to a maximum of €500/kW of installed capacity. The amount of allocated subsidy was calculated based on additional costs of biomass systems minus the net economic benefit of the first five years of operation (IDAE, 2006b). An estimated €283 M is available for biomass installations through this programme, equivalent to €56.6 M/yr.

Stick. In March 2006 the **Technical Building Code,** (Código Técnico de la Edificación) was adopted in the Spanish Royal Decrees 314 and 315 of 17 March 2006 under the auspices of PER. Implemented in September 2006, it requires that all new buildings and all those undergoing renovation cover 30-70% of their hot water demand with solar thermal energy. It applies to all buildings, independent of their use. Specific percentage requirements depend on geographic location and individual demand of the building for domestic hot water. Simultaneously, a Council for Building Sustainability, Innovation and Quality (CSICE) was established to ensure compliance and participation in Spain (ESTIF, 2006b).

Regional incentives for renewable heat have been especially successful. The template for the national Technical Building Code, Barcelona's Solar Thermal Ordinance, was established in 2000 (see Good Policy Practices in Section 4).

Evaluation

Biomass accounted for an estimated 172.6 PJ of heat in 2005, the highest renewable energy contribution (EurOberv'ER, 2006). Although solar thermal markets have grown in recent years, the total contribution has remained comparatively small with only 2.6 PJ in 2005 (SHC, 2007). Geothermal heat is negligible with only 347 TJ produced in 2005.

86. 2005 budget allocations did not include geothermal heating technologies.

Although there were no large scale public CHP plants in Spain as of 2004, small, industry-operated plants are common with roughly 4.54 GW_e of new capacity installed between 1991 and 2001. By 2004, almost 25.1 PJ of biomass energy was combusted in CHP plants (IEA, 2006e). The development of CHP has been supported by PFER's third party finance (for 6.7% of the installation costs) and premium prices made available for CHP energy generation[87] (EREC, 2004c).

Solar thermal

Despite an abundant solar resource, the solar thermal market in Spain did not begin to grow significantly until early in the 21st century. The total installed capacity grew from 58.3 MW (83 285 m^2) in 2002 to 383 MW (546 900 m^2) in 2005[88] (SHC, 2006) providing around 2.6 PJ of heat (Fig B25).

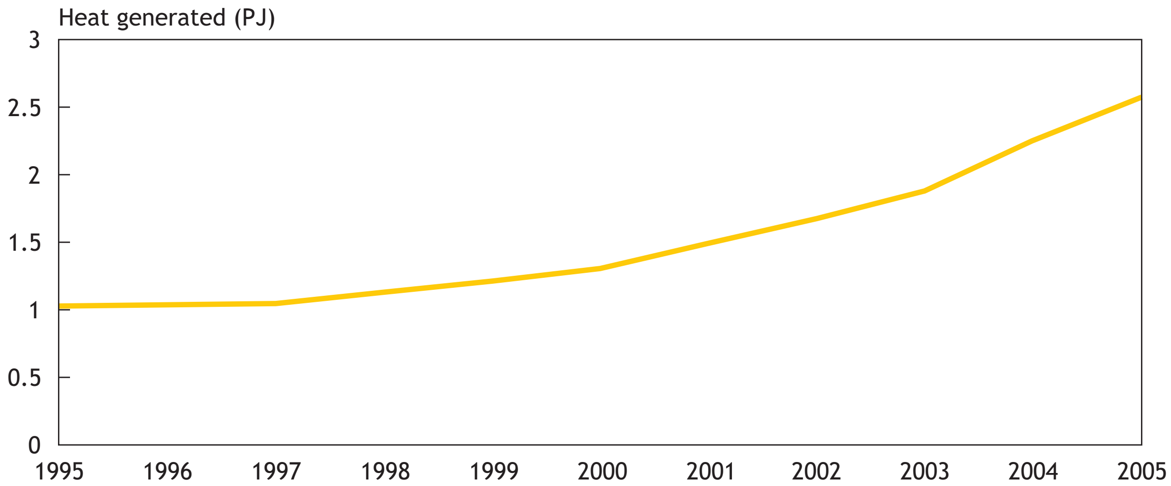
Much of the solar thermal development has been the result of local or regional incentives as well as federal policy instruments. Federal incentives for solar thermal were introduced in 2002 under the Aid Programme for Solar PV and Solar Thermal. Further support for solar thermal was introduced in 2006 with the Technical Building Code that, building on the model of Barcelona, is expected to result in significant growth of the market.

Following the Barcelona Solar Thermal Ordinance, 40% of all new buildings in the area included solar hot water. Per-capita installed capacity (m^2/1 000 people) leapt 15-fold, from 1.1 in 2000 to 16.5 in 2004. This Ordinance initiated 428 solar thermal installations, a total of 31,050 m^2 of solar thermal surface area by December 2005, reflecting an increase of 1.78% (EC, 2006a). Pamplona's solar ordinance, which entered into force in mid-2004, caused a 50% increase in solar thermal collectors in one year (REN21, 2006).

Biomass

The biomass resource comes primarily from the agricultural sector. Nearly 60% is consumed in the residential sector, estimated to be over 84.5 PJ. Most of the remainder is combusted for heat by industry (IEA, 2006e) with consumption increasing with estimates of 165.2 PJ in 2004 and 172.6 PJ in 2005.

Figure B25 • *Solar thermal heat generation in Spain from 1995 till 2005*



Source: IEA, 2006b. Where data was unavailable, numbers have been extrapolated.

87. In 2001 the premium paid to small CHP generators was €0.24 /MWh for a maximum of 70% of total annual production (EREC, 2004c).

88. The annual installation in 2005 was 106 885 m^2 or 74.8 MW thermal (EurObserv'ER, 2005).

Spain has exported biomass to the UK for use in co-firing boilers, has evaluated ways to increase the domestic use of biomass for power generation, and is encouraging power generators to explore co-firing (IEA, 2005). Political support for biomass heat was begun in 1991 with the introduction of PAEE and its targets for 20.9 PJ of renewable heat. Further support was offered within the PFER and PER programmes, specifically the Aid Programme for Biomass initiated in 2005. With the additional €283 M in subsidies for biomass installations, it is expected that biomass use for heat will increase further in the coming years.

Geothermal

In 2000 there was no reported low-temperature geothermal heating capacity in Spain. By 2005, 22 MW of low temperature, shallow geothermal capacity had been installed for uses including greenhouse heating (69%), space heating (22%), and swimming and bathing (12%) to give a total heat demand of about 347 TJ/yr. There has been no development of geothermal heat pumps reported in Spain (Lund *et al.*, 2005).

Political interest in the development of geothermal heating projects has been limited. Most of the financial incentive schemes do not include geothermal energy (IEA, 2005) and the PAEE initiated the development of only two geothermal heat plants (EGEC, 2006). The small geothermal heat market in Spain reflects apparent disinterest or lack of resource.

Conclusions

While Spain has made a strong effort to develop renewable energy production in recent years, most of the political focus has been on renewable electricity. Much of the growth in renewable heating has been at levels insufficient to reach national targets.

The 2000-2010 Spanish PFER has been only partially successful in achieving its targets. Although the consumption of renewable energy in Spain had increased by 113.0 PJ between the 2000 programme initiation and 2005, the increases have not been sufficient to meet the ambitious targets of the plan. For example, by the end of 2003, only 42% of the overall objectives of renewable energy installations for the first period of the plan (1999-2006) had been achieved. In addition, the benefits and growth of individual RETs has been disproportionate. Only 18.3% of 2006 targets for solar thermal installations were achieved by the end of 2003 and by 2004 only 18% of the 2010 objective for biomass (6.6 PJ) (IEA, 2005; IDAE, 2006b). Solar thermal installations remained below target in 2005, installing only 700 000 m^2 of the 2010 targeted 4.8 M m^2 (SHC, 2006).

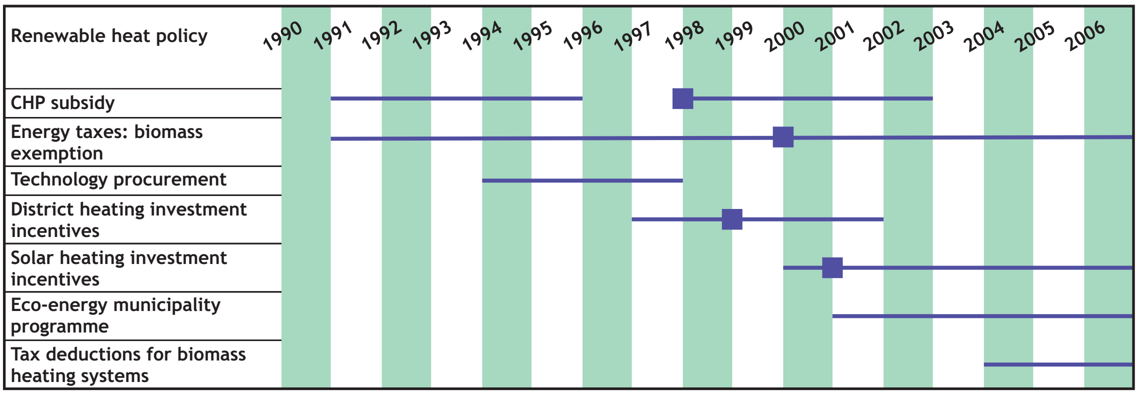
The energy consumption and energy intensity in Spain have been increasing more quickly than the government had anticipated when it established its 12% targets for renewable energy under PFER and PER. This increase in energy demand has further complicated the ability of the policies to reach their intended targets (IDAE, 2006b).

Incentive schemes of the regional governments such as those in Andalusia, Barcelona, Catalonia, and the Canary Islands have been responsible for most of the growth of the solar thermal industry (SHC, 2006). The success of regional programs initiated in support of solar thermal technologies and based on stick, regulatory schemes, has led to the implementation of a similar federal program.

Spain is a pioneering nation in making the implementation of solar thermal technologies obligatory in new and refurbished buildings. Because the Technical Building Code obligation at the national level has only recently been implemented and is applicable only to new and renovated buildings, the impact on the solar thermal market is most likely to be felt only in the coming years. However, this policy is a milestone in the political support for renewable heating.

Annex B 11. Sweden

Instruments



Carrot. Between 1981 and 1985, interest-free state loans were available to single family and multi-family dwellings in support of geothermal heat-pumps (GHPs). Direct reimbursement subsidies and income tax reductions were also offered in step with the total cost of installations (EGEC, 2006).

Carrot. From 1991-1996 **CHP subsidies** were provided for investment in biomass-fired plants. In order to be eligible, the CHP plant was required to use at least 85% biomass for a period of five years for a total of €440 /kW_e (SEK[89] 4 000 /kW_e). Existing heating plants that were retrofitted to CHP based on biomass were eligible for 25% of retrofit costs up to a maximum of €440 /kW_e. Fossil fuel CHP plants that were converted to biomass were eligible to receive 25% of the conversion costs to a maximum of €440 /kW_e. Funds for these subsidies were exhausted by 1994.

An additional €49.5 M was allocated in 1998 for a five year period (Helby, 1998) with a maximum of €330 /kW_e available per installation. Subsidies were limited to new plants and CHP plants that were retrofitted for biomass. Within one month of the beginning of the programme applications had been filed for more than 3 times the amount of funding available.

Carrot. Substantial **energy taxes** have been employed since 1991. In addition, a carbon dioxide tax and a sulphur tax were introduced at this time to target environmental objectives. In the spring of 2000 €3.3 billion of tax revenue was transferred to focus on energy use over a ten year period. In other words, taxes on energy use and emissions were increased, offsetting a corresponding reduction in taxes on employment (Swedish Energy Agency, 2006). About €2.2 billion in revenue was collected in 2002 and €3 billion in 2003. The high CO_2 taxes (around €100/t CO_2 in 2006) had the most significant repercussions due to the exemption of bioenergy (see below) (Ericsson *et al.*, 2004).

For district heating systems, a full CO_2 tax and 50% energy tax is employed on fossil fuels used for heat and in CHP plants (Johannson *et al.*, 2002). To maintain competitiveness, Swedish industry was exempted from the energy tax in 1993 and the CO_2 tax was reduced to 25% for the industrial sector.

The **Energy Taxation Exemption for Biomass** when used in district heating created a cost competitive advantage for biomass since biomass-based heat can be produced at a much lower cost than heat from fossil fuels (Johannson *et al.*, 2002). However, in industrial sectors that are not subject to the full CO_2 tax, biomass based heat is not cost competitive with heat produced from coal and gas.

89. 1 Swedish krone (SEK) = €0.11

Carrot and *Guidance*. The Swedish National Board for Technical Development (NUTEK) issued a **Technology Procurement** in 1994 for heat pumps with the intention of promoting energy efficient technologies and assisting their market development. This system of support, first introduced in 1984, is managed by the Swedish National Energy Administration and reviewed periodically. €0.1 M was allocated to a heat pump procurement competition as a grant for the winning, most efficient technologies with guaranteed sales of 2 000 units. In addition, information campaigns were created as a follow-up (Olerup, 2001). Two designs of GHPs won this award and spurred the market for this technology.

Carrot. In 1997 grants were introduced for investment in district heating systems and connection of group and individual heating systems to reduce the amount of electric heating in Swedish residences. Subsidies were available to a maximum of €1 100-€3 300 per district heating system connection, dependent upon connection specifications and central boilers. These grants were temporarily withdrawn in 1999, reinstated, and then removed in 2002 (IEA, 2004).

Carrot. Grants have also been provided in support of biomass energy crops for use in energy systems. €550 /ha is provided for growing short rotation forest plantations such as *Salix*.

Carrot. An **Investment Grant for Solar Heating** has been available since June 1 2000. This grant of €0.27 /kWh of calculated yearly supply is available as a one-off payment to subsidize the cost of installations of solar heating systems for space heating and/or domestic hot water production. Grants, administered by the county councils and the National Board of Housing, Building, and Planning, are available to Swedish home owners, apartment buildings, and certain types of commercial premises (IEA, 2004; SNEA, 2006). A total of €1.1M was available in 2000 and increased to €2.2 M in 2001 (IEA, 2006e).

Guidance. In March 2001, the **Eco-energy Municipality Programme** began, providing information on renewable energy resources aiming to contribute to the decisions of Swedish Energy Policy. Through this programme municipalities are offered seven different educational packages (IEA, 2006e).

Carrot. A **Tax Deduction for Installation Costs of Biomass Heating Systems (Proposition 2003/2004:19)** was in place from January 1 2004 through to December 31 2006. This tax credit, applicable to income tax returns for 30% of the equipment and installation costs of biomass heating systems (IEA, 2004), was available to household space and water heating distributed via a central piping network and was limited to roughly €1,600 per household (European Biomass Association, 2006). A formal action plan for biomass was introduced in December 2005 and adopted in June 2006 (COM2005 628).

Carrot. A **conversion grant** was introduced on January 1 2006 aimed at reducing the use of oil and electricity for heating purposes in residential and commercial buildings. It is available through 2010 for conversions to district heating, biomass-fired heating systems, GHPs and/or solar heating (SNEA, 2006).

Evaluation

In 2006 the demand for space heating and domestic hot water was about 306.0 PJ of which 10% was consumed by industry, 57% by the residential sector, 29% by commercial and public services, and less than 1% by agriculture and forestry (Figure B26). Roughly 4% of heat is lost in the substantial district heating network (IEA, 2007a).

Overall the Swedish heating system is exemplary in its use of renewables, primarily biomass. Although solar thermal and geothermal contributions have been comparatively small, the markets have shown growth in recent years (Figure B27).

Sweden has developed an extensive district heating sector, influenced by grants offered in support. Between 1990 and 1999 there was a fourfold increase of the use of bioenergy district heating systems (Johansson *et al.*, 2002). Today district heating accounts for approximately 40% of the heat market.

Figure B26 • *Distribution of heat demand in Sweden by sector in 2006*

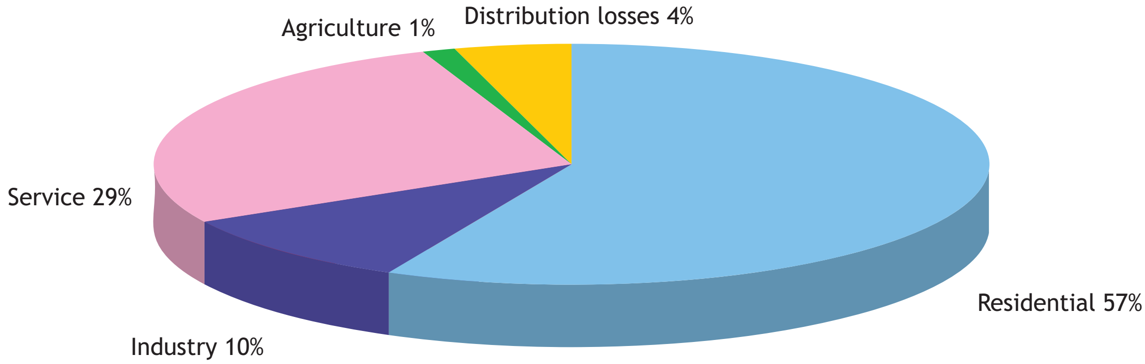
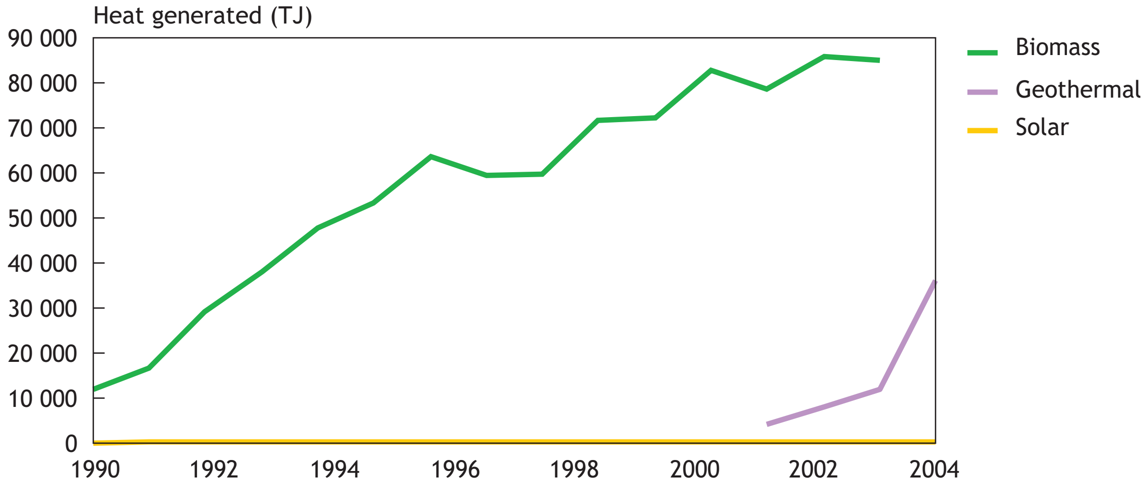


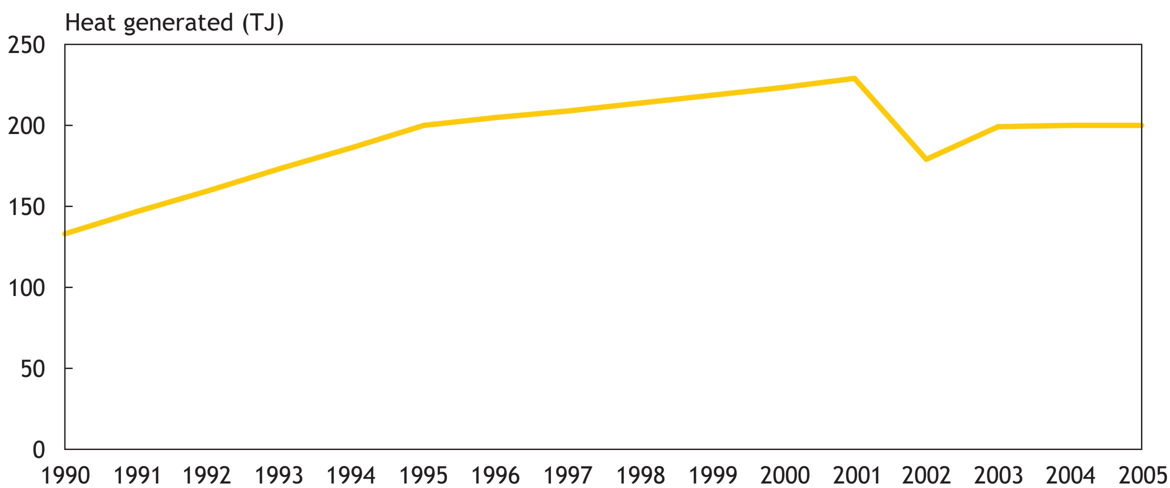
Figure B27 • *Renewable heat generation in Sweden by sector from 1990 till 2006*



Sources: IEA, 2006b; IEA, 2004; Lund et al., 2005; WEC, 2004.

Note: Geothermal data has been combined from several sources for illustrative purposes.

Figure B28 • *Generation of solar thermal heat in Sweden from 1990 till 2005*



Source: IEA, 2006b.

Solar thermal

Historically the market for solar thermal systems in Sweden has not been strong although growth has been evident in recent years. Between 2001 and 2005 the installed capacity of solar thermal increased from 135 MW (192 157 m^2)[90] to 145.8 MW (220 000 m^2) (Figure B28) (ESTIF, 2006c).

Investment grants for solar thermal introduced in 2000 were an important support mechanism. Following the implementation of this financial incentive scheme, the declining trend in the solar thermal heating market was reversed.

Biomass

The forest industry is a major economic sector in Sweden which may have had a significant role in the success of the political support for biomass. Utilization of forest by-products for heat was supported by this strong industrial lobby.

The use of biomass for heat has increased significantly since 1990 (Fig. B27), primarily coming from wood fuels including short rotation Salix, black liquors in pulp mills, peat, MSW, straw, and energy grasses (IEA, 2004). Most of this heat production is from solid biomass utilized in CHP plants that increased from more than 50% of total fuel by energy in 2004 to more than 62% in 2006. The gross biomass heat production was 92.1 PJ in 2004, 32.7 PJ of which was generated in dedicated biomass plants and 60.3 PJ in CHP plants. Biomass utilization in CHP declined slightly from 60.3 PJ in 2004 to 59.0 PJ in 2005 (EurObserv'ER, 2005).

Support for biomass heating from the Swedish government has been largely indirect through the exemption from the high energy and CO2 taxes employed making it the least cost option for heat production in many instances. Subsidies offered for biomass based CHP since 1999 have successfully led to a majority of heat production originating from biomass.

Geothermal

Sweden has more installed GHP capacity than any other EU nation (EC, 2006b), gaining in popularity since the 1980s. Most heat pump sales in the 1980s and early 1990s were ambient resource (air) heat pumps. In 1994 however, the total 47 MW installed capacity for ground-source GHPs began to grow substantially (Figure B29) to reach 377 MW in 2000 and 3 840 MW by 2005, and accounting for approximately 36 PJ/yr (Lund *et al*., 2005). However in 2005 the market stagnated from an annual increase of 47% to only 1%. Overall GHPs have become an important export product.

About 30% of all single-family houses in Sweden use a GHP (Hellström, 2006). Residential geothermal heating applications are the most common with an average size of 12 kW, but several large-scale installations for district heating networks have also been constructed with an average size of 900 kW (Lund *et al*., 2005).

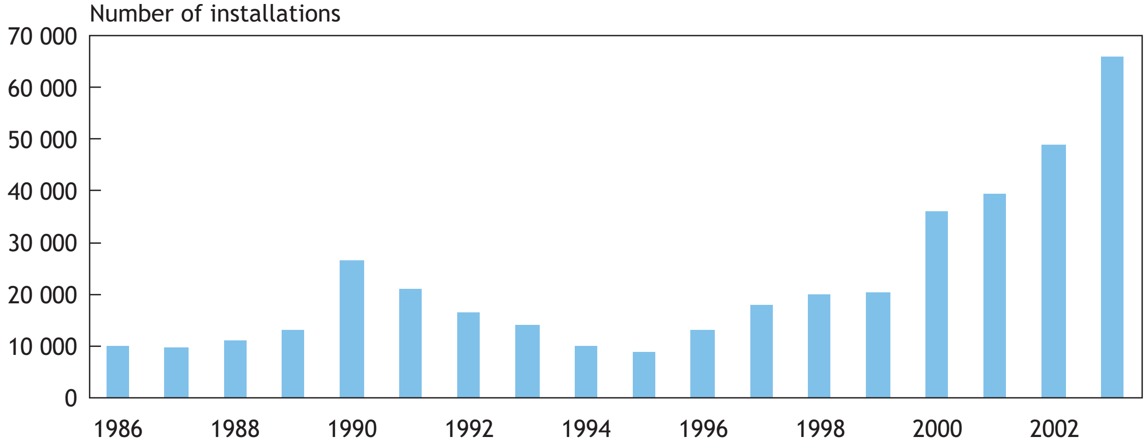
Government subsidies and interest-free state loans provided for geothermal heating installations from 1981 to 1985 contributed to an increase in heat pump sales (EGEC, 2007). The growth of the heat pump market, however, truly began in the early 1990s as a result of the government procurement scheme and competition that promoted the technology (Olerup, 2001).

Conclusions

Strong support measures for renewable heating in Sweden have brought the country into an exemplary position. Exemption of biomass from the high energy taxes resulted in bioenergy deployment, direct investment grants for solar thermal have stimulated the market, and GHPs have been extensively deployed to meet domestic heat demands.

90. 156 522 m^2 were flat plate collectors; 1 704 m^2 evacuated tubes and 33 931 m^2 unglazed (WEC, 2004).

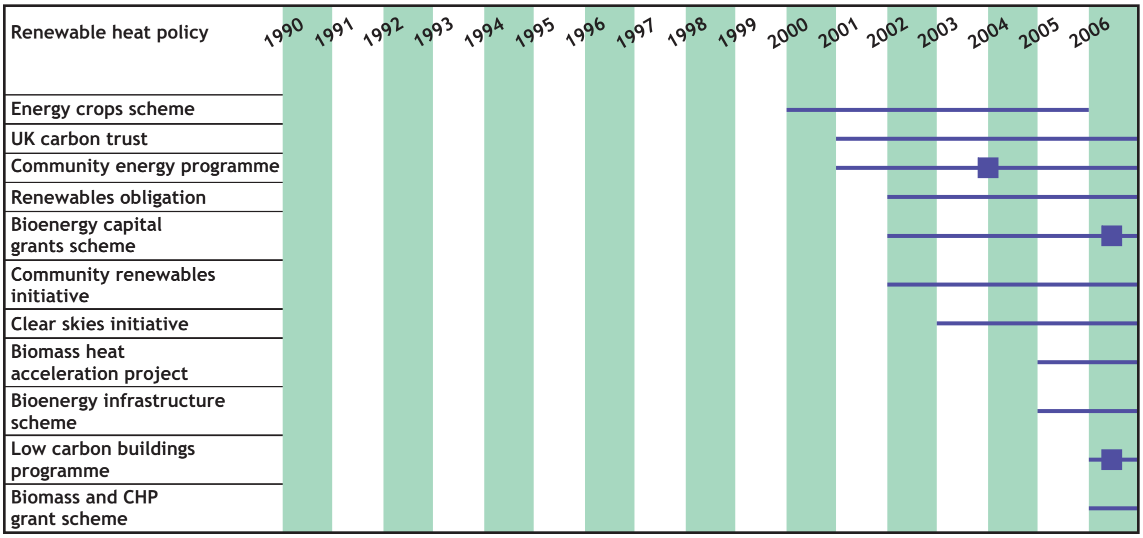
Figure B29 • *Geothermal heat pump market development in Sweden*



Source: EGEC, 2007.

Annex B12. United Kingdom

Instruments



Financial support and installation advice is provided through the Energy Saving Trust and Energy Efficiency Best Practice in Housing programme. Action Energy also provides information and advice for businesses on geothermal installations (EGEC, 2006).

Carrot. In 2000 the **Energy Crops Scheme**, a 6-year grant scheme worth a total of €26.9 M (£17.9 M[91]) was implemented. Grants of €2 400 /ha for willow (*Salix*) or €1 500 /ha for poplar (*Populus*) were available for the establishment of short rotation coppice and €1 380 /ha for the vegetative grass *Miscanthus*. Grants were also allocated for legal costs, office accommodation, office equipment purchase, IT equipment, recruitment costs and the purchase of harvesting machinery. To be eligible for a grant, crops had to be grown for power generation, CHP, or heat production. Additionally, there needed to be evidence of an end use or market within a reasonable radius of the cropping land (IEA, 2004).

Carrot and *Guidance*. In 2001 the British government launched the **UK Carbon Trust**, a private company to assist businesses and the public sector in making carbon reductions. Through this programme financial incentives are available for renewable heating, as well as information services including a helpline, publications, seminars, and training events. The Carbon Trust has annual government funding in excess of €103.5 M in grants through the Department for the Environment, Food, and Rural Affairs (DEFRA), although much of this funding goes to energy efficiency projects (Carbon Trust, 2007).

Carrot. The **Community Energy Programme** announced in 2001 provides capital grant support primarily for public sector district heating systems but also the use of biomass for heat[92]. Approximately 16% of the funding allocated for this programme has financed biomass. Until March 2007, the €75 M programme aims to improve and refurbish community and household heating systems with a primary focus on CHP plants. Financed by the Treasury's Capital Modernisation Fund, the Community Energy Programme was to be extended by €15 M in 2004. However, the Climate Change Programme Review opted to allow this

91. 1 pound sterling (£) = €1.50

92. See http://www.defra.gov.uk/environment/energy/communen.htm.

programme to expire on schedule and to revoke the additional funding based on the assumption that other financing schemes such as the Bio-Energy Capital Grants Scheme would be a more cost-effective means of delivering carbon savings.

Carrot. In April 2002 the UK **Renewables Obligation** required that all electricity generators supply a certain percentage of their electricity generation with renewables. Although designed in support of renewable electricity, biomass heat generation in CHP plants received indirect support.

Carrot. The **Bio-Energy Capital Grants Scheme**, implemented in 2002 promoted the efficient use of biomass, particularly energy crops, by awarding capital grants for the cost of biomass-fuelled heat equipment. This scheme is only open to industrial, community, and commercial sectors in England (DEFRA, 2006a). Of the €99 M allocated, €15 M is for electricity generation, €27 M to demonstrate advanced energy crop technologies and production of energy crops and wood fuel for CHP, €3 M for industrial heat produced by energy crops and forest wood fuels, and €4.5 M for CHP projects using energy crops and biomass (IEA, 2004).

Initially, the Bio-Energy Capital Grants Scheme was jointly funded by the Department of Trade and Industry (DTI) and the National Lottery's Big Opportunities Fund (BIG). The second round of the scheme was funded entirely from BIG, with the third, most recent round sourcing its funds from DEFRA. This round also introduced competition, applicants being required to bid for the minimum percentage of grant aid that will enable their project to succeed. Individual grants can be allocated in amounts between €37 500 and €1.5 M. An additional €3 M was provided in April 2006 for an extension of the scheme focused on biomass heat and CHP (DTI, 2006b).

Guidance. The **Community Renewables Initiative (CRI)** was allocated €3 M over 2002-2006 for providing information and facilitating community based partnerships to promote small-scale renewable energy (Biomass Task Force, 2005). With this DTI funding, 10 local teams were established to provide advice and support for the development of community-based, renewable energy projects. After successful monitoring and evaluation of the process and outcomes, the CRI secured further funding through to April 2007.

Carrot and *Guidance*. The **Clear Skies Initiative**, launched in 2003, provides grants and information to household and community renewable energy projects including solar thermal and biomass installations. Support for geothermal demonstration projects was also provided through the Clear Skies Initiative (IEA, 2004; EGEC, 2006). From 2003-2008 a total of €18.75 M is to be allocated for all renewable projects (Biomass Task Force, 2005). Households can receive grants in the range of €750-€7 500 and non-profit community organizations can receive up to €150 000 for grants and up to €15 000 for feasibility studies.

Guidance. In 2005 the **Biomass Heat Acceleration Project** was launched by the Carbon Trust. With a budget of €7.5 M for five years, it aims to accelerate the commercial development of biomass heat by addressing supply chain risks and raising awareness. The UK Carbon Trust will partner with new and existing biomass sites and their supply chains to develop case studies on how to best deploy biomass technology. Performance benchmarks are to be established and potential cost reductions will be outlined. Supply models and risk mitigation strategies are analyzed in order to make recommendations on optimal design, installation, and operation options for new biomass heating sites (Carbon Trust, 2007).

Carrot. The **Bio-Energy Infrastructure Scheme** was allocated €5.25 M to help develop supply chain and market infrastructure for wood and straw energy fuels. Under this scheme, up to €300 000 per group or business is available for 100% of training costs; up to 40% for specialist machinery; and a sliding scale established (100% the first year, 80% the second, 60% the third) for administrative set-up costs for producer groups. Administered by DEFRA, the scheme aims specifically to help develop the supply chain required to harvest, store, process and supply biomass for heat, CHP, and electricity end users. Funding is available from 2005-2008 (DEFRA, 2006b).

Carrot. On April 1 2006 the **Low Carbon Buildings Programme (LCBP)** was launched to replace the Clear Skies Initiative[93]. This programme, managed jointly by the UK Carbon Trust and DTI, offers grants to two categories of applicants: households and community organizations, and medium and large generation projects by public, not-for-profit, and commercial organizations. Grants are awarded under the first category up to 50% of the cost of purchase and installation of renewable energy installations to a maximum of €45 000. A total of €45 M was budgeted for an initial three year period and in March 2007, an additional €75 M was announced. Funds are available for household renewable energy heating technology installations:

- solar thermal hot water, €600 maximum regardless of size and subject to a 30% limit;
- heat pumps, €1 800 maximum regardless of size and subject to a 30% limit;
- wood pellet heaters and stoves, €900 maximum regardless of size and subject to a 20% limit; and
- wood-fired boiler systems, €2 250 regardless of size and subject to a 30% limit.

Grant levels for CHP plants have yet to be defined.

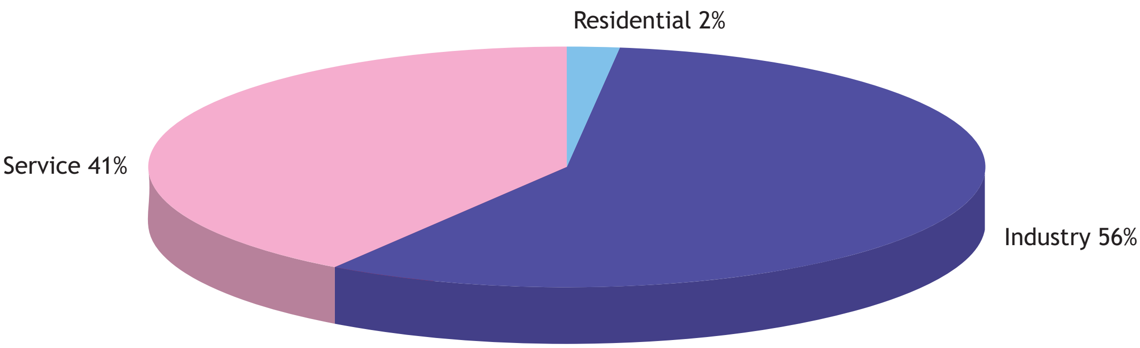
Carrot. As part of the Climate Change Programme Review a **new grant scheme** was announced in support of biomass boilers and CHP in the commercial, industrial and community sectors. For the first two years of the five-year programme, €15-€22.5 M has been introduced at the end of 2006 to complement the extension of the Bioenergy Capital Grants Scheme (DTI, 2006b).

Regional governments have also offered incentives in support of renewable heating in the UK.

Evaluation

Approximately 30% of total energy demand is for space and process heating. In 2004, 92.2 PJ of heat was generated, 56% of which was consumed by industry, just over 2% in the residential sector, and 41% in commercial and public services (Figure B30) (IEA, 2007a).

Figure B30 • *Heat consumption by sector in the UK*

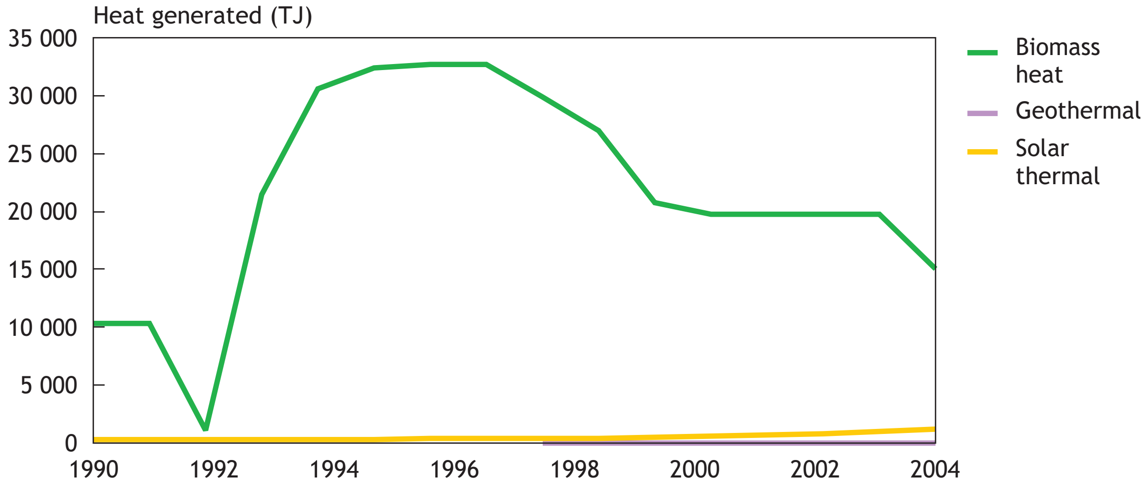


As of 2005, only 1% of total demand was supplied by renewable sources and 8% met by CHP systems which utilize a combination of conventional and renewable fuels (Future Energy Solutions, 2005). Despite a number of existing support mechanisms for CHP including the Climate Change Levy exemption, capital allowances for CHP equipment, and the Community Energy Programme, there has been little growth in CHP (Future Energy Solutions, 2005).

Most renewable heat is from solid biomass, primarily wood with very little heat currently generated by geothermal or active solar heating (Figure B31).

93. See http://www.lowcarbonbuildings.org.uk/home/.

Figure B31 • *Renewable heat generation in the UK by sector from 1990 till 2005*



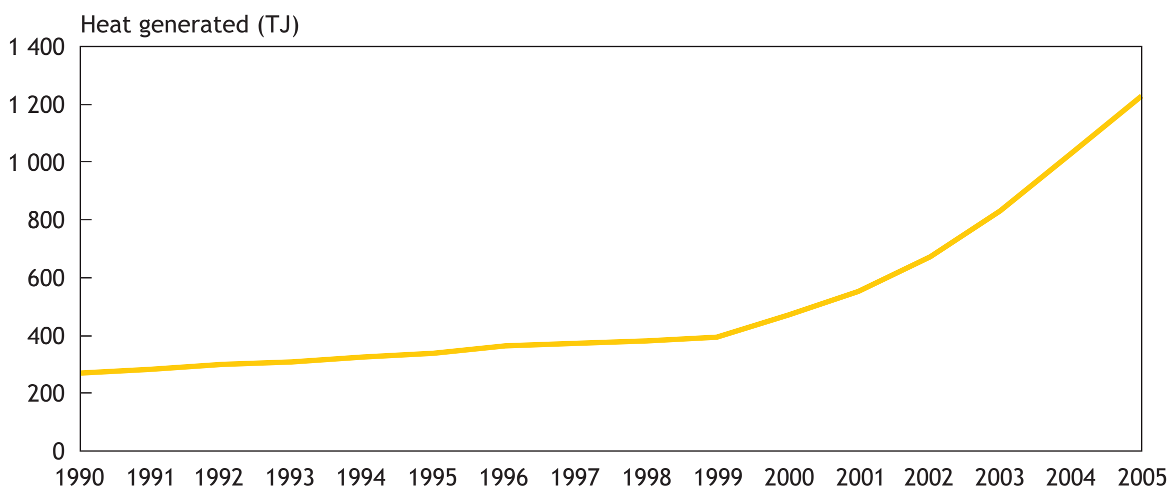
Source: DTI, 2006a.

Solar thermal

Historically, solar hot water (SHW) collectors have been used only to a limited extent. Until 2001, most solar thermal installations were for swimming pool heating (WEC, 2004). However, the market has grown in the past five years by 160% (Figure B32) (DTI, 2006a).

Until 2003, virtually no federal incentives were offered in the UK for solar thermal. Then following grants and information support programmes offered under the 2003 Clear Skies Initiative, the solar thermal market began to increase with annual installations going from 15.4 MW in 2003 to 17.5 MW in 2004. Total capacity increased by 12% from 123 MW[94] in 2004 to 137.8 MW in 2005 (EurObserv'ER, 2005; ESTIF, 2006c). Further support offered under the 2006 Low Carbon Buildings Programme financing up to 30% of solar thermal installation costs is likely to encourage important development in this market.

Figure B32 • *Generation of solar thermal heat in the UK from 1990 till 2005*



Source: DTI, 2006a.

94. In 2004, solar thermal generated 266 TJ for domestic hot water (DTI, 2006a)

Barriers to the development of solar thermal in the UK include a lack of cost competitiveness with conventional technologies, informational barriers, and a shortage of skilled installers.

Biomass

In 2003, biomass provided 1% of total heat supply (DTI, 2006b), mostly used for residential space heating. Industries producing surplus wood have historically utilized this excess for space and process heat. However, with the tightening of environmental legislation and emission controls in the late 1990s, it became more cost competitive for industries to switch to fossil fuel heating systems than to upgrade wood heat combustion systems, thereby causing a decrease in biomass heat generation (Figure B31) (Future Energy Solutions, 2005). As a result of fuel substitution by industry, present biomass heat demand is only half what it was 10 years ago.

Most of the political incentives for renewable heat have been in support of biomass, several initiated by 2000. In addition to the 2000 Energy Crops Scheme offering grants for biomass supply, the 2001 Community Energy Programme, the 2002 Bio-Energy Capital Grants Scheme, the 2003 Clear Skies Initiative, the 2005 Bio-Energy Infrastructure Scheme, the 2006 Low Carbon Buildings Programme, and the grant scheme included in the 2006 Climate Change Programme Review, all offer financial incentives for the upfront capital costs of bioenergy equipment and installations. The Bio-Energy Infrastructure Scheme also offers funding for training costs. Information programmes were included in the Community Renewables Initiative (2002) and the Clear Skies Initiative (2003).

The 2000 Energy Crops Scheme had provided grants for 668 ha of Miscanthus and 660 ha of short rotation coppice until 2005. The 2002 Bio-Energy Capital Grants Scheme had allocated €6.3 M for biomass boilers by 2005 with funding for the construction of 22 MW of biomass fuelled heating installations earmarked in 2006[95] and 73 MW of biomass-fired power stations in 2007[96] (DTI, 2006b). The 2003 Clear Skies Initiative provided around €80 000 for domestic wood-fuelled heating projects by 2005 and €2 M for community biomass projects[97]. The Community Renewables Initiative provided information in support of the construction of 89 bio-energy projects by way of over 3 000 phone calls and emails by 2005 (Biomass Task Force, 2005).

Despite overall growth of biomass heating capacity, the number of annual installations has fluctuated unpredictably (Fig B33). During the 1990s when no federal incentives existed, annual installations were static. With the initiation of several supportive instruments in the late 1990s and early 21st century, annual installations began to increase. The 2002 Renewables Obligation implemented for renewable electricity likely also influenced the growth of biomass in CHP (Future Energy Solutions, 2005).

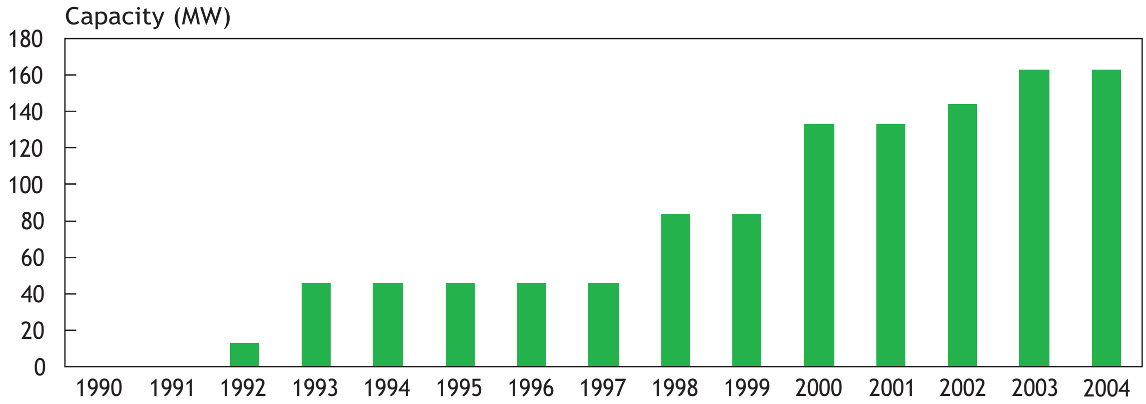
The lack of a well established supply chain remains a barrier for biomass heat as it is necessary to assure a reliable quality and supply within a reasonable transport distance. Biomass supply must be "processed economically to the right specification for the boiler application concerned" (Future Energy Solutions, 2005). Support for the biomass supply chain is therefore an important component for furthering biomass heat production.

95. Total funded-installations in 2006 included 100 biomass boilers with a total capacity of 12 MW and a biomass CHP system with 2.7 MWe and 10 MWth capacity.

96. Power stations are planned at Lockerbie (43 MW) and Wilton (30 MW).

97. Clear Skies funding went to 59 domestic projects (25 wood-fuel boilers and 34 wood-fuel stoves) and 61 community biomass projects.

Figure B33 • *Growth of the solid biomass capacity in the UK from 1990 till 2004*



Source: IEA, 2004.

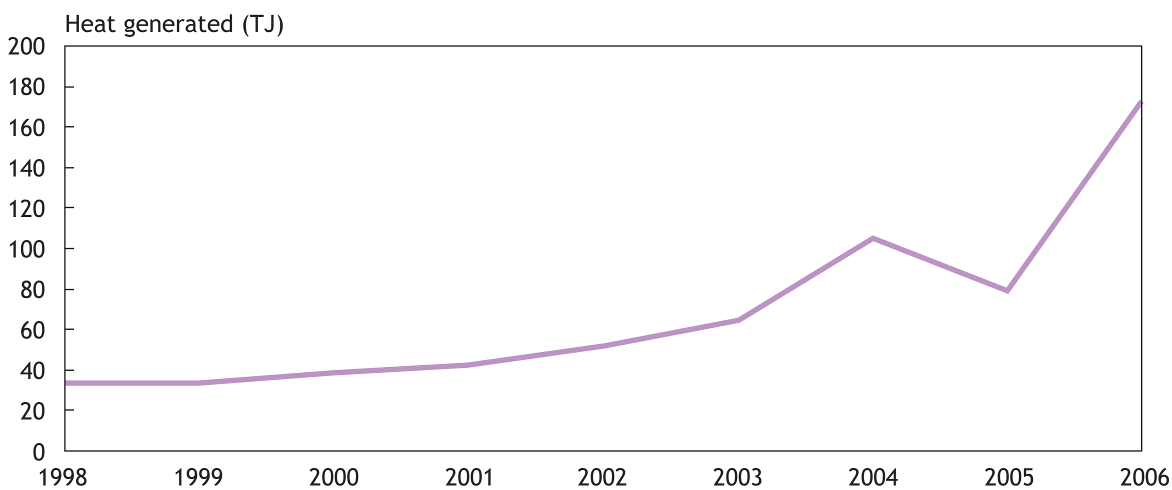
Geothermal

Very little geothermal heat production capacity has been installed in the UK. No deep geothermal heating sources exist, and very few low-temperature, shallow geothermal installations have been developed, although the heat pump market has begun to increase (Figure B34) (EGEC, 2006; Lund *et al.*, 2005). Most geothermal heat comes from individual heat pump installations with only one community, 2 MW_{th}, geothermal district-heating plant in Southampton (Future Energy Solutions, 2005).

The amount of low-temperature, shallow geothermal heat capacity (primarily ground-source heat pumps) increased from between 2.3 MW-2.9 MW in 2000 to 10.2 MW by 2004, producing an estimated 45.6 TJ/year (EurObserv'ER, 2005; Lund *et al*, 2005).

Long-term federal support for geothermal heat has been negligible. However, financial support for demonstration projects under the 2003 Clear Skies Initiative and grants for heat pumps under the 2006 LCBP have begun a new trend could initiate further market growth. The comparatively low levels of geothermal heat development in the UK likely reflect the lack of public support. An increasing awareness of shallow geothermal, specifically the use of groundwater for heating domestic, commercial and public buildings and GHPs has been reported (Lund *et al.*, 2005).

Figure B34 • *Generation of geothermal heat in the UK from 1998 till 2006*



Sources: EurObserv'ER, 2005; Lund et al, 2005.

Conclusions

As confirmed in the 2004 Royal Commission report on Environmental Pollution "there is a significant gap in government energy policy regarding heat production". Policies for renewable heat have been slower to develop than in many other EU countries but are now numerous. Most support has been in the form of financial subsidies for the development of biomass heat and CHP. Despite these incentives, the biomass heat market has remained relatively small in comparison with other European nations.

Until the Clear Skies Initiative in 2003 and its 2006 LCBP successor, there was virtually no political support for the development of solar thermal or geothermal heating in the UK. Growth in these markets has begun in recent years, although they remain in the early stages of development.

A Renewable Heat Energy Obligation was considered by Parliament in 2005 in association with the passage of the Energy Act[98]. Parliament allowed the Secretary of State to introduce requirements for retail suppliers of heat to demonstrate the contribution of a certain percentage of biomass, geothermal and solar thermal energy resources to the heat supply. In conjunction with a full review of the possibilities for promoting renewable energy, an assessment of a Renewable Heat Obligation was published in April 2007. If established, such an obligation would mark an important innovative milestone in the promotion of renewable heat.

98. The proposal for a renewable heat obligation has been strongly promoted by the Renewable Power Association and Friends of the Earth.

Annex B13. European Union

Instruments

Developments by the European Union (EU) in support of renewable energy were initiated in 1997 with the Commission White Paper 'Energy for the Future: Renewable Sources of Energy – **White Paper for a Community Strategy and Action Plan**'. This paper formulates indicative targets for 12% of total energy consumption to be supplied by renewables in Member States by 2012 based on their own potential. Following the establishment of unique national objectives, strategies are developed in order to achieve them.

White Paper targets were set implicitly recognizing that 5% must be renewable heat. Technology specific targets were set in Annex II of the White Paper as: solar thermal, 100 M m^2 by 2010; biomass, 5 652 PJ by 2010; direct geothermal heat 9 TJ and geothermal heat pumps (GHPs) 9 TJ also by 2010. The White Paper also contains a strategy and action plan towards these goals. Although technology specific targets were outlined in the White Paper, they were never included in the EU legislation. It has been estimated that the renewable contribution to the total primary energy supply is unlikely to be met. Based on current trends the EU will not exceed 10% by 2010 (EC, 2007a).

The **Buildings Directive** (2002/91/EC) targets energy performance in buildings through minimum efficiency standards for new buildings and a new system of certification. Member states are advised to examine the feasibility of alternative energy systems including CHP, district heating, and heat pumps.

The **EU CHP Directive** (2004-8 EC) for the *promotion of cogeneration based on a useful heat demand in the internal energy market* provides a range of measures to promote CHP, aiming in the short term to support existing installations by creating a level playing field in the market. It creates a framework for a scheme of guarantees of origin of CHP electricity. In addition, it requires that Member States ensure transparent, non-discriminatory access to the electric grid. Guidelines for the implementation of this Directive are established, and Member States must report regularly on their actions and progress in supporting CHP.

In January 2005 the **European Union Emissions Trading Scheme (EU ETS)** was established as the first multi-national emissions trading scheme in the world. CO_2 emissions from energy-intensive companies are limited, or capped and companies which emit less than their allocated amount of allowances may sell credits to companies which exceed their limits. Companies are thereby offered an incentive to invest in projects which limit their CO_2 emissions. The EU ETS therefore acts indirectly to support renewable heating markets, especially biomass heat.

The **EU Biomass Action Plan** (COM(2005) 628 Final), adopted in December 2005, proposes actions to increase bioenergy deployment in heat, electricity, and transport. Designed to increase the contribution of energy from forestry, agriculture, and waste materials in EU Member States, the plan set targets to double biomass heat production by 2010 to 3 140 PJ. When the plan was adopted in 2005, the EU supplied 4% of its energy needs from biomass.

The European Parliament adopted a resolution[99] in February 2006 asking the European Commission (EC) to table a Directive Proposal to promote renewable heating and cooling. The EC responded by initiating an impact assessment of different options for a renewable heating and cooling directive. A specific proposal for heating and cooling was not included in the 2007 Energy Climate Change

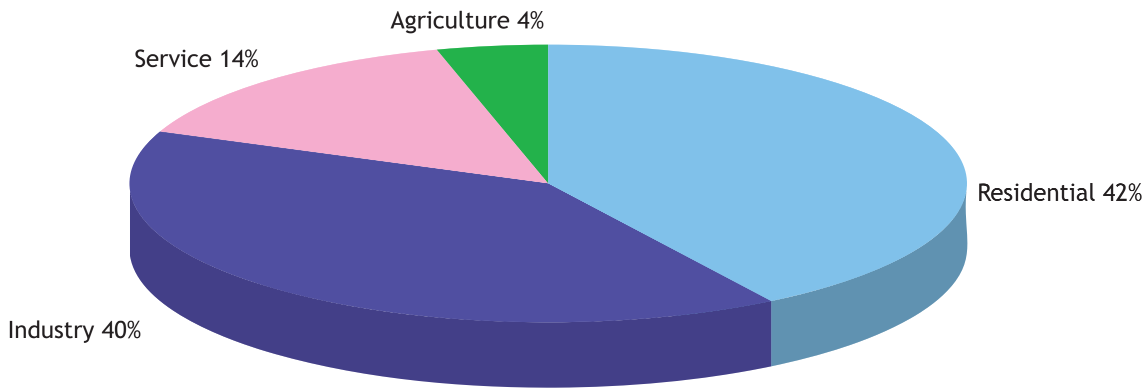
99. European Parliament Resolution P6_TA (2006)0058 with recommendations to the EC on heating and cooling from renewable sources of energy

Package. However, in March 2007 the European Commission agreed on 20% binding targets of the EU's overall energy consumption to be supplied by renewable energy by 2020 as part of the **Renewables Roadmap**. Although no specific targets were set for electricity and heat, a binding minimum target of 10% was established for transport fuels to be supplied with biofuels. The Roadmap states that in order to meet the 2020 target, the contribution of renewable heating and cooling could more than double, compared with the current share of 9%. Most of this could come from biomass and will involve more efficient household systems and highly efficient biomass-fired CHP with smaller contributions from solar thermal and geothermal. Differentiated national targets are to be derived for individual Member States (EC, 2007a).

Evaluation

The total estimated heat demand in the EU was 16 517 PJ in 2003 and is growing at an average rate of 1.9% annually (Ecoheatcool, 2006). About 40% of the heat demand originates from industry, 42% from the residential sector, 14% in the service sector, and 4% in agriculture (Figure B35). The gross renewable heat generation has increased since 1995.

Figure B35 • *Heat demand by sector in European Union Member States*



Source: EcoheatCool, 2006.

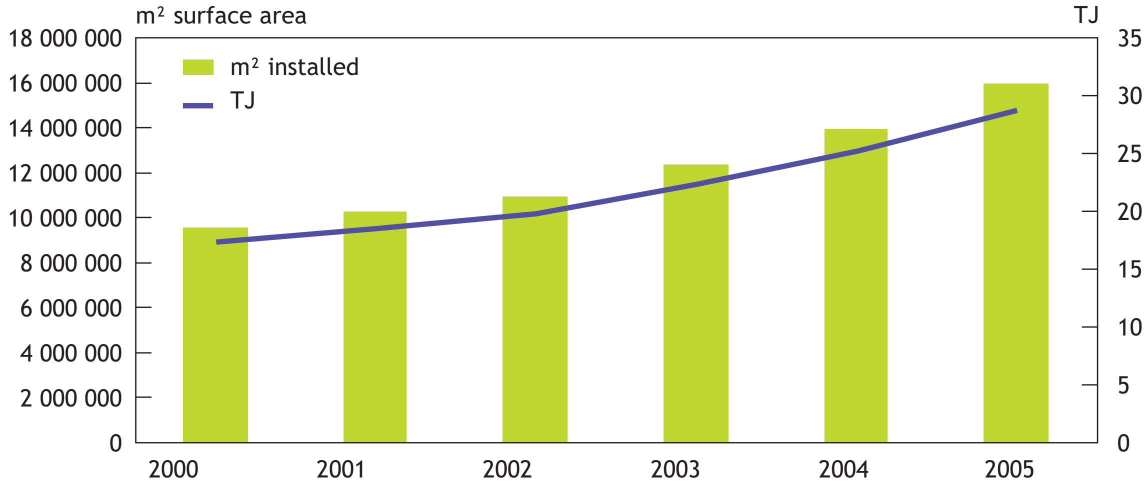
Solar thermal

Although Europe accounts for 10% of the worldwide market and growth is occurring (Figure B36), solar thermal heat accounted for only 0.2% of the heat market in 2006 (EC, 2007). In addition to domestic SHW deployment, there are 87 large scale solar thermal collectors in Europe with a total installed capacity of 120 MW. The largest plants are in Denmark (13 MW) and Sweden (7 MW).

By 2005, 16 Mm^2, or 11.2 GW of solar hot water capacity had been installed, with most development in Cyprus, Malta, Greece, and Austria (Figure B37).

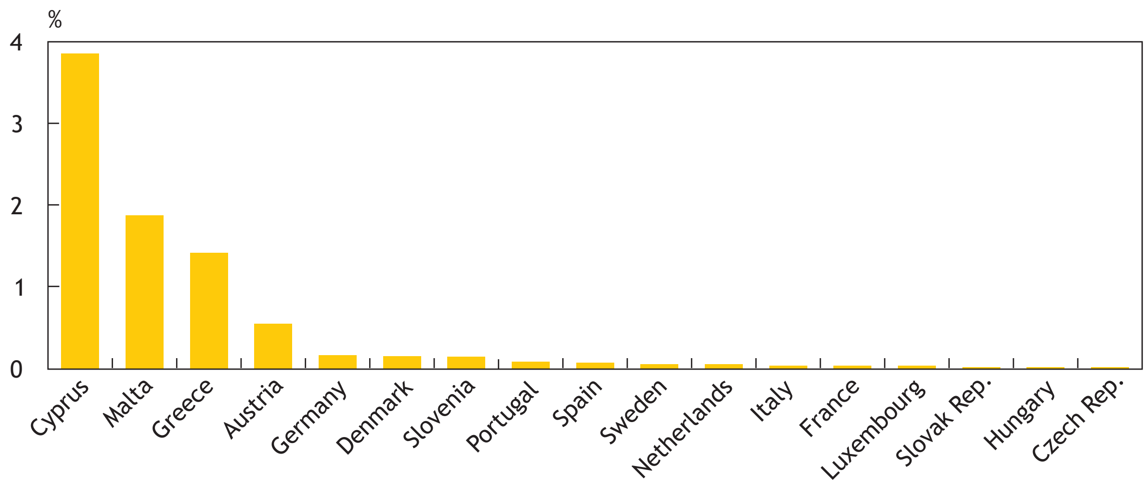
Although several directives may have provided indirect support for solar thermal, the EU White Paper was the only one to set technology specific targets. Despite increases in solar thermal markets across the EU, especially in Germany, Austria, and Greece, the target of 100 Mm^2 of solar thermal surface area by 2010, as established in the White Paper of 1997, is unlikely to be met. The surface area installed has increased from 6.5 Mm^2 in 1995 to 9.6 Mm^2 in 2000 and to 14 Mm^2 by 2005 (ESTIF, 2006c). Therefore, to reach 2010 targets would necessitate 17.2 Mm^2 of solar thermal panels being installed across the EU annually beginning in 2006.

Figure B36 • *Development of the solar thermal market in the EU-15 from 2000 till 2005.*



Source: EurObserv'ER, 2006. Where data was unavailable numbers were extrapolated.

Figure B37 • *Share of total heat market by solar thermal in EU Member States*



Source: EC, 2007.

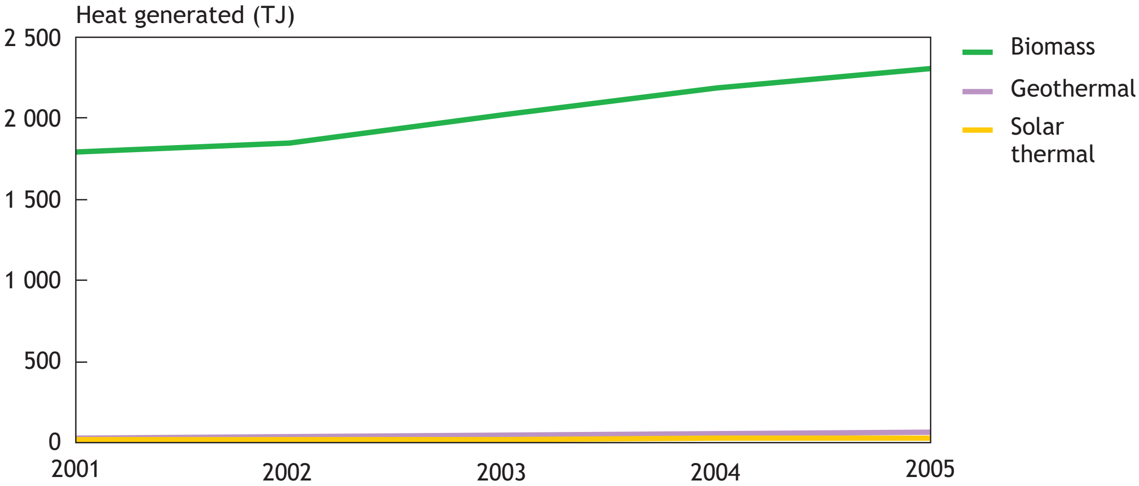
Biomass

Most renewable heat is generated from biomass (Figure B38), but with wide ranging shares across member states (Figure B39).

Wood chips and pellets accounted for 5.7% of renewable heat generation in 2006 (EC, 2007). Most of the biomass market growth was in Germany with 71.1 PJ added between 2004 and 2005.

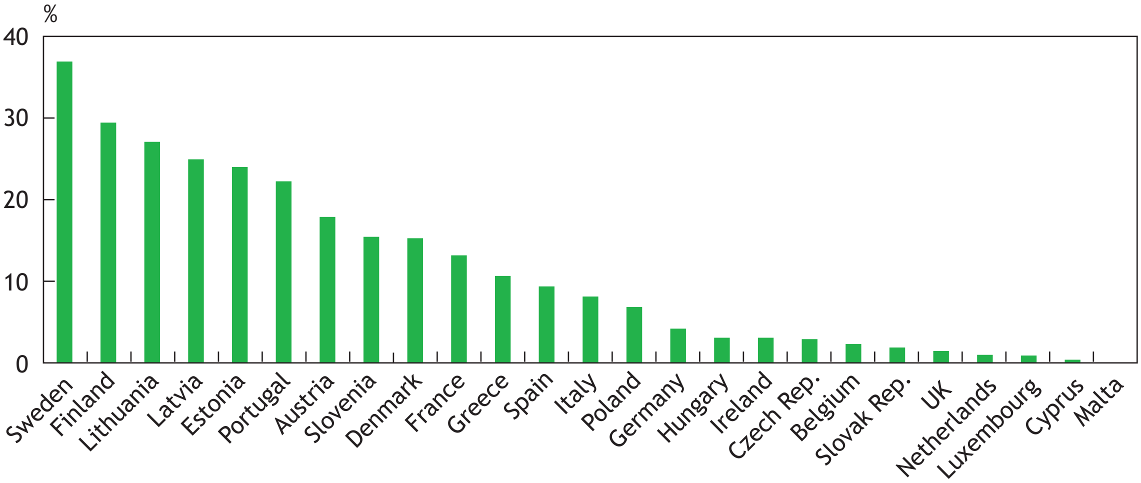
The first EU directive to influence the growth of the biomass heat market was the White Paper with biomass specific targets. Other directives such as the EU ETS may have had indirect influence, for example by granting biomass heat eligibility from CO_2 reduction measures. The 2005 Biomass Action Plan was the first concrete support offered at an EU level. Despite increasing national initiatives in support of bioenergy, likely to have been influenced by EU Directives, it is unlikely that the 2010 targets for bioenergy will be met.

Figure B38 .• Gross heat production from RES in EU-15 from 2001 till 2005



Source: EurObserv'ER, 2006.

Figure B39. Share of biomass heat in EU Member States



Source: EC, 2007.

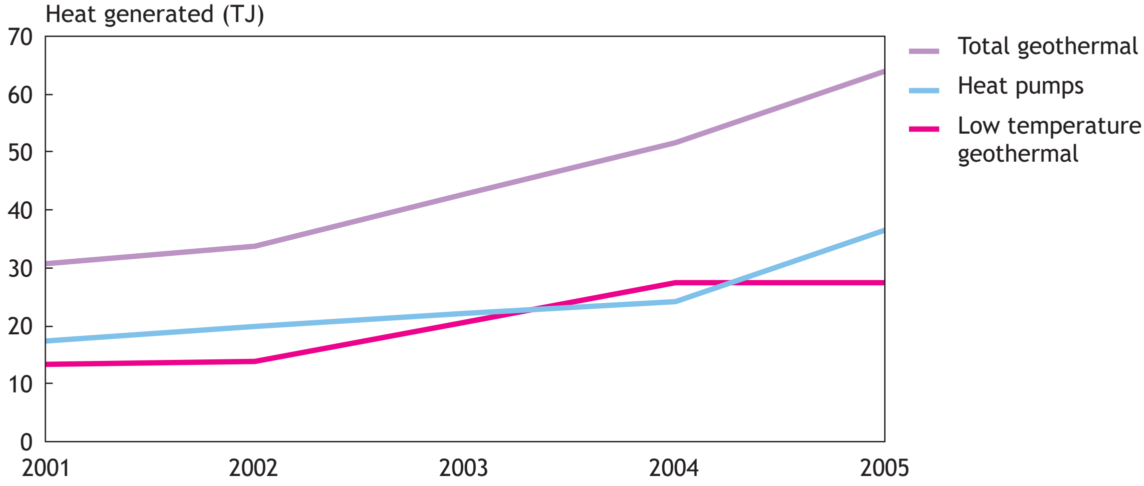
Geothermal

Geothermal heat production has been increasing steadily with over 64 PJ in 2005 generated by approximately 7 488 MW of installed capacity (Figure B40). GHPs accounted for much of this heat (36.6 PJ) with an installed capacity of 5 379 MW (EurObserv'ER, 2006). However, the total contribution of geothermal heat has remained negligible at only 0.4% of 2006 total heat supply (EC, 2007).

Hungary (690.2 MW), Italy (486.6 MW), and France (291.9 MW) had the highest levels of installed capacity in 2005 (GIA, 2006). The highest contribution of heat from heat pumps is largely in Sweden with an installed capacity of 1 700 MW, France (549.5 MW), Germany (632.6 MW), and Austria (611.5 MW) (GIA, 2006) (Figure B41).

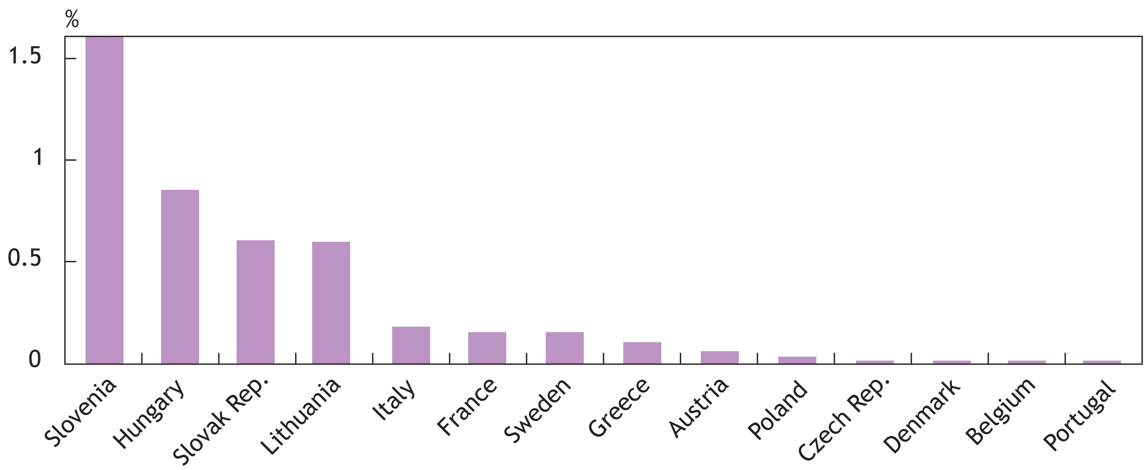
Most support for geothermal heat has been in the form of installation targets and support for research activities such as the Enhanced Geothermal Innovative Network for Europe and the Soultz-sous-Forêts pilot project involving France, Germany, Italy, Switzerland, Japan and the US.

Figure B40. Geothermal heat generation in the EU from 2001 till 2005



Source: Eurobserv'ER, 2006.

Figure B41. Share of geothermal heat in EU Member States



Source: EC, 2007.

Conclusions

Renewable heat has not received the same level of political attention from the EU as has renewable electricity. Although a new directive is under discussion which would for the first time direct substantial attention to renewable heat, current directives on CHP, biomass, buildings, emissions trading, and the White Paper encourage coherent policies at the national level in support, although often indirectly.

Steps have been taken by the EU to support renewable heat although development has not matched the intended objectives. In May 2004, the Commission concluded that the 2010, 12% target for total renewable energy consumption established in the White Paper would not be reached because of a lack of deployment of renewable heating technologies.

EU directives may act as substantial drivers for the development of policies in Member States in support of renewable heat. There is good potential at this level to initiate substantial increases in the future.

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