Standard Methods

Calculating Support Needs

Heat Pump User Guide

RETD
IEA - RENEWABLE ENERGY TECHNOLOGY DEPLOYMENT

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Acknowledgments

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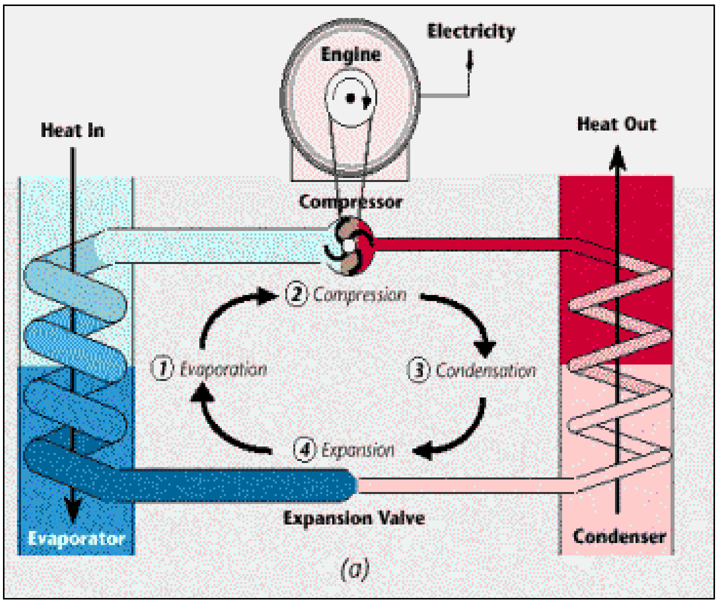
Introduction to Heat Pumps

Heat pumps transfer the heat energy from natural surroundings such as the air, ground or water to buildings or industrial applications by reversing the natural flow of heat such that it flows from a lower to a higher temperature (IEA HPC, 2007). Because they harness natural, renewable heat with a small input of electricity, heat pumps offer an important alternative to conventional fuels for heating in the movement towards reducing greenhouse gas emissions. It is important to recognize that the share of renewable heating and cooling technologies within the energy supply could increase further with improved energy efficiency measures. This introductory chapter serves to brief the reader on the available technologies, current costs and markets and the current barriers which exist in striving for increased heat pump deployment.

Heat pumps transfer the heat from one of three distinct sources: the ground, the air, or water. Ambient, or air-based heat pumps harness the energy from the temperature difference in the surrounding air. The heat from ambient heat pumps may be exchanged directly to indoor air or may be connected to a water-based heat distribution system. Ground source heat pumps (GHP) extract heat from the soil or bedrock by means of horizontal or vertical water pipes in the soil and transfer that heat to a building by means of distribution pipes. These systems which account for most of the installed heat pump capacity worldwide may range from 5 kW_{th} for residential systems to large units of over 150 kW_{th}. Water sourced heat pumps extract heated water from the ground, circulate it through a building and then back to the ground water source (EHPA, 2005).

Most heat pumps function on the principle of a vapor compression cycle although some are based on an absorption process which uses heat rather than mechanical energy as a driver. The Standard Method tool concentrates on vapor compression cycle heat pumps. In such systems, a fluid or refrigerant is circulated through a closed circuit comprised of a compressor, an expansion valve and two heat exchangers referred as the evaporator and the condenser (Figure 1) (IEA HPC, 2007).

Figure 1. Visual representation of a vapor compression cycle heat pump (IEA HPC, 2007).



Because the temperature of the fluid is lower than the temperature of the heat source, heat flows from the heat source to the liquid thereby causing the liquid to evaporate. When this vapor is condensed in the compressor, it gives off useful heat (IEA HPC, 2007). External energy, typically a small amount of electricity, is required to transport heat from the heat source to the heat sink, specifically to drive the compressor engine (Figure 1). Smaller scale heat pumps are estimated to require only 20-40 kWh of electrical energy per 100 kWh of heat supplied. Industrial heat pumps can achieve a higher performance for the same amount of heat with only 3-10 kWh of electricity (IEA HPC, 2007).

The main market for heat pump technologies is new buildings, especially single and two family residences (EHPA, 2005). In 2005, Ground-sourced heat pumps were estimated to have 15,723 MWth of installed capacity with an energy use of 86,673 TJ/annum (Lund *et al*., 2005). The market has been growing steadily with an annual installed capacity increase of roughly 24% since 2000 with most concentration in the USA, Sweden, Switzerland and Germany.

Investment costs for the heat pump and its installation are still relatively high in comparison with conventional technologies. Costs depend on the size of the unit, the source of the heat and whether or not the heat pump will be used for both heating and cooling. It has been estimated that 2005 average investment costs for a heat pump system were on average €500/$kW_{th,}$ but may range between €200-1150/kW_{th} (IEA, 2007). It is expected that heat pump costs will decrease as the technology is perfected and the coefficient of performance increases.

Barriers to the diffusion of heat pump technologies include high investment costs, insufficient training of professional installers, and lack of awareness by potential customers and policy makers. This tool is focused on policies aimed to overcome the first, financial barrier by means of direct subsidies.

The Standard Methods Tool

Background

In the face of market-failures which do not account for the positive aspects of energy generated by renewable sources such as security of energy supply and reduced carbon dioxide emissions, policies are often introduced in an attempt to make up for deficiencies in the market. Policy-makers worldwide are faced with the challenge of determining an adequate level of support in the design of instruments aimed to increase the deployment of renewable heat. The Standard Methods tool was created in order to assist in this process for subsidy-based incentive schemes.

In its design, when examined from the most basic of levels, policies aim to address the cost gap between conventional fuel heating technologies and heat pump technologies including investment costs and running costs. These costs may vary widely depending on the local conditions to which the policy must be suited. A first step then is to determine the cost gap between technologies in these locally specific circumstances. This tool compiles national data among 9 countries by which the cost gap of heat generation costs between heat pump heating and conventional heating technologies is estimated[1]. It is important that the user recognizes and fully understands that the data compiled and presented in this tool is intended be interpreted as strictly indicative.

Purpose

The Standard Methods tool provides policy-makers with assistance in determining an adequate level of support in the design of subsidy-based instruments aimed to increase the deployment of renewable heat. The results of the tool provide the user with a basis upon which they can estimate the total and annual budget of policies tailored to support heat pump heating based on a number of country-specific considerations. However, as the tool has been overly simplified for demonstration purposes, it is important that local conditions and prices are carefully analyzed prior to policy implementation.

Subsidy schemes for renewable heat are one of many methods to increase the deployment of renewable energies. The cost effectiveness of these tools should be carefully weighted against the costs of similar, alternative policy measures. There is no over-arching solution to renewable heating policy design, but the Standard Methods tool offers a preliminary basis upon which subsidy-based policy budgets may be estimated.

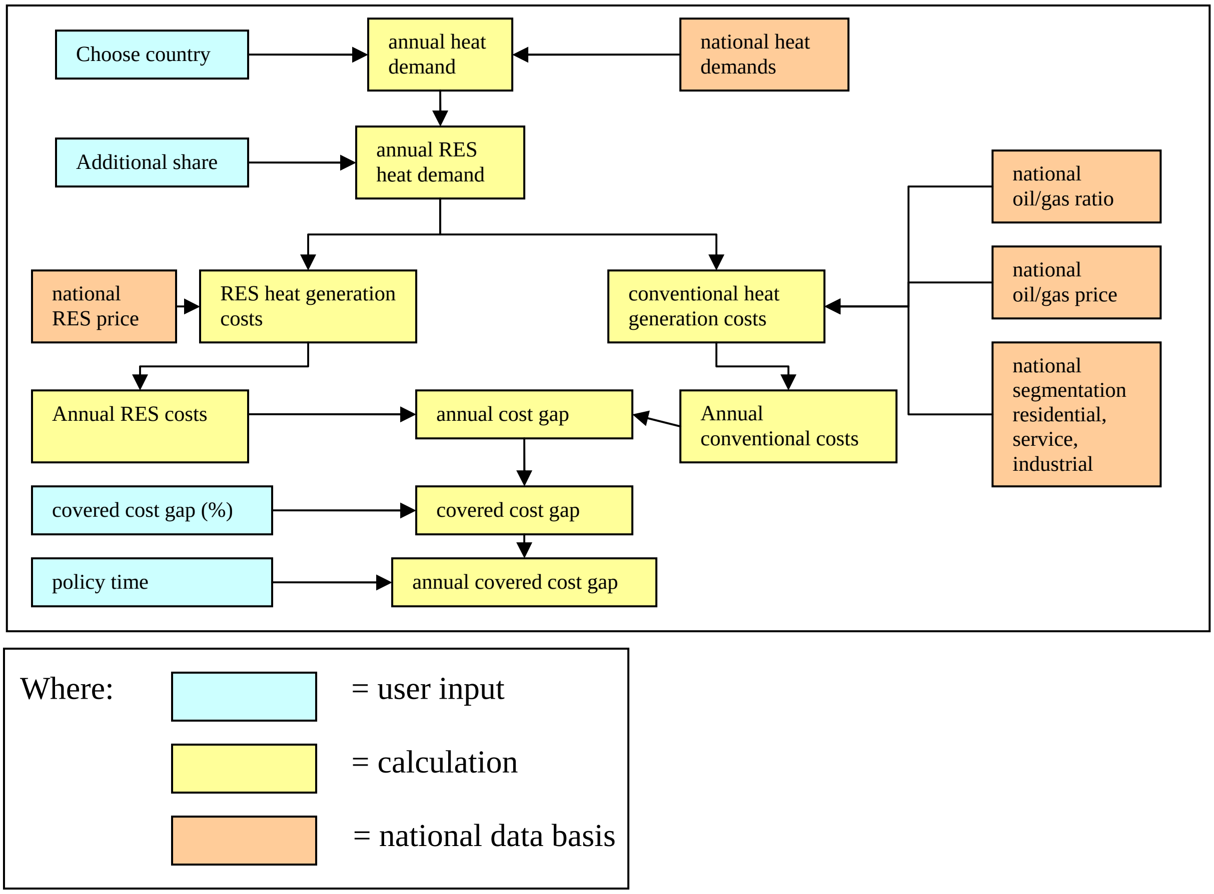
User Guide

The Standard Methods tool has been designed in a simplified, user-friendly schematic diagram in Microsoft Excel format. In using the tool, the user must recognize that it has been overly simplified for demonstration purposes. In designing policies, it is important that local conditions and prices are carefully analyzed prior to implementation. To provide an estimate of the support required, an individual may determine detailed specifics of the timeline and the targeted percentage of renewable heat to give a preliminary figure for the amount of budget which should be allocated with the Standard Methods tool. If it is a goal of the policy to cover only a portion of the cost-gap with conventional fuels, the actor may also specify this. Finally,

[1] Conventional heat generation costs have only included costs for oil and gas systems.

the importance of educational and informational campaigns to promote awareness of the tool itself has been recounted on many occasions. An option to include a certain percentage of the total policy budget for informational schemes has also been included. The methodology utilized in this support tool is represented in Figure 2.

Figure 2. Visual representation of the methodology used to calculate support need.



Via drop-down menus the policy-maker is able to select the information most relevant to their circumstances[2]. A bar-chart on the right simultaneously depicts the cost gap between heat pump heating and conventional heating. The cost of renewable heating installations is assumed to be the same for all countries investigated[3]. The total annual cost per heating system includes the following:

- investment annuity
- annual fuel costs
- auxiliary energy costs (1 % of heat generation)
- operational costs (2,5 % of investment)

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[2] Only drop-down boxes and boxes for data entry within the dialog table are available to individuals. Calculation sheets have been locked to prevent alterations.

[3] Data for the costs of heat pumps are sourced from the German Ministry of Baden-Württemberg, 'Wirtschaftsministerium Baden-Württemberg' publication *Mittelgroße Wärmepumpenanlagen* for commercial and industrial sized systems, Der Bundesverband WärmePumpe website at www.waermepumpe.de for residential sized systems.

Individual coefficients of performance were indicated for the unique sources of heat (Table 1). The Standard Method tool has incorporated all three types of heat pumps. The proportions of air, ground and water based heat pumps are country specific[4].

Table 1. Coefficient of Performance[5] for three differently sourced heat pumps.

Heat Source	Coefficient of Performance
Air/water	2.6
Brine/water	3.5
Water/water	4.0

For the purposes of illustration, a typical example for Italy was selected for use throughout this User Guide. Red ovals throughout the diagrams depict a point within the tool where the user is required to insert their desired policy specifics.

In order for the Standard Methods tool to function properly it is important to assure that the English decimal system has been selected before work with the tool is begun. In order to verify this, in Microsoft Excel on the Tools menu, click Options. Then, on the International tab under Number Handling, clear the Use System Separators check box. Type new separators in the Decimal Separator (.) and the Thousands Separator Box (,). Then, work with the Standard Methods tool may be begun.

The tool is broken into three user-friendly boxes. The first box, 'Data Entry' allows the user to insert unique policy design features and location specifications that produce results which are more specific to their individual circumstances. The second box, 'Results' simultaneously shows the results of the user's decisions and reflects the support need that is required to cover the cost gap (or percentage of the cost gap) with conventional fuels. The third box is a visual representation in graph format of the results of the selections.

Data Entry

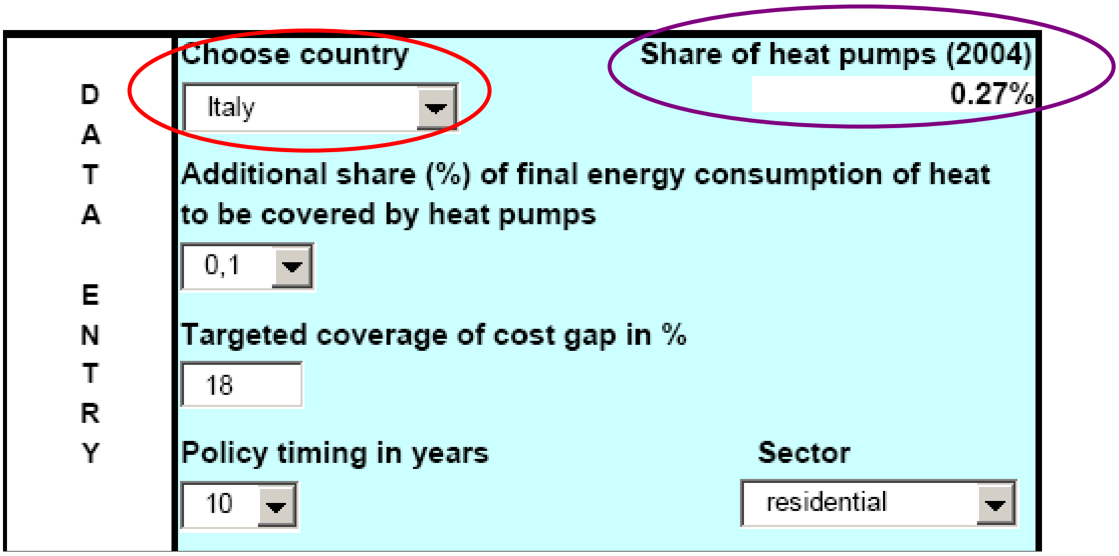
First, the country of residence should be selected. The data that supports the selected country automatically includes the heat demand in that country and the national averages of conventional fuel costs[6]. In addition, for comparison of conventional fuel costs, statistics on the proportion of gas and oil heating systems typical in each country[7] have been integrated.

4 Data for the proportion of heat pump sources is based on proportions of commercial systems published by the Informationszentrum Wärmepumpen und Kältetechnik e.V., Hannover online at: www.izw-online.de/info/heidelk2.pdf.

5 Coefficient of performance = annual heat energy / annual input of electricity

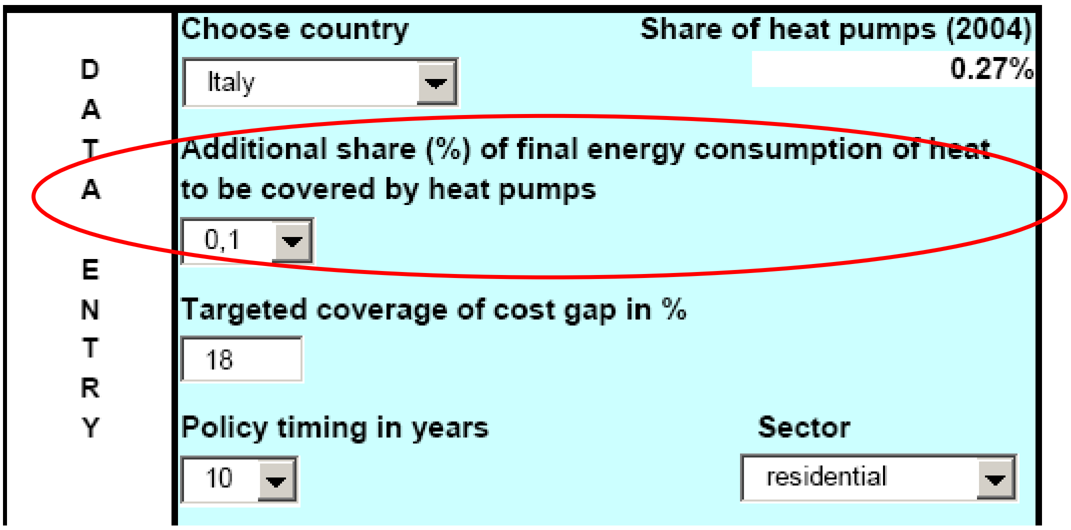
6 Conventional fuel heating costs including oil, gas and electricity for each country originate from the EIA at www.eia.doe.gov.

7 Proportional gas and oil heating system data originated from Eurostat yearly energy statistics at http://epp.eurostat.ec.europa.eu for all countries except Norway and Canada. Norwegian data is based on household consumption and sourced from Statistics Norway at http://www.ssb.no/husenergi_en/tab-2007-05-23-08-en.html while Canadian data originates from the Statistics Canada database at http://www.statcan.ca .



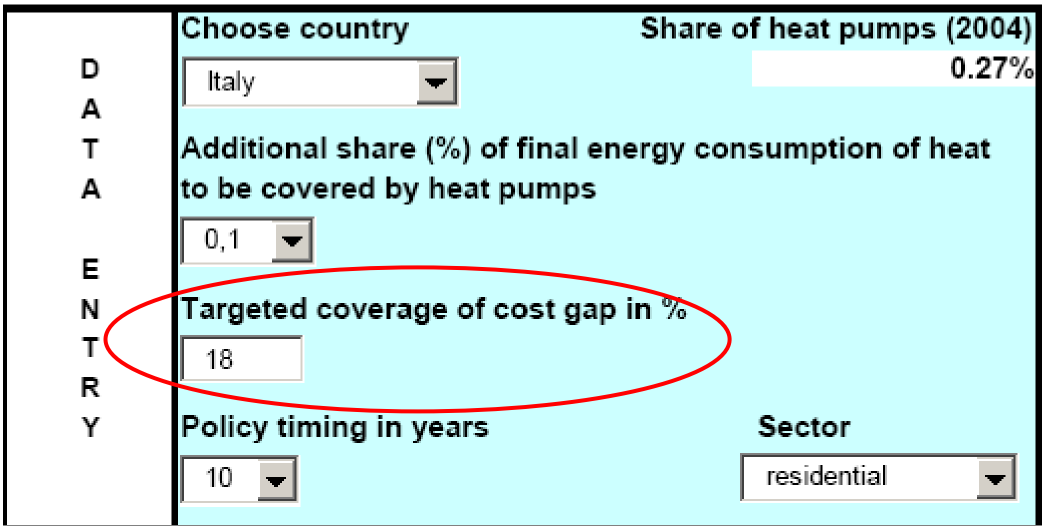
When the country is selected, the share of heat pumps in that country in 2004[8] will automatically and simultaneously appear to the right of the box under the heading titled "Share of heat pumps (2004)", circled in the above graph in purple. This is provided to give the user a reference for the next step of the tool.

Next, the individual must determine what additional percentage of the total heat demand[9] they wish to be covered by ambient heating. A dialog box allows a selection in increments (typically of 5%) up to 50% of the total heat demand. This maximum accounts for immediate restrictions in manufacture and installation.

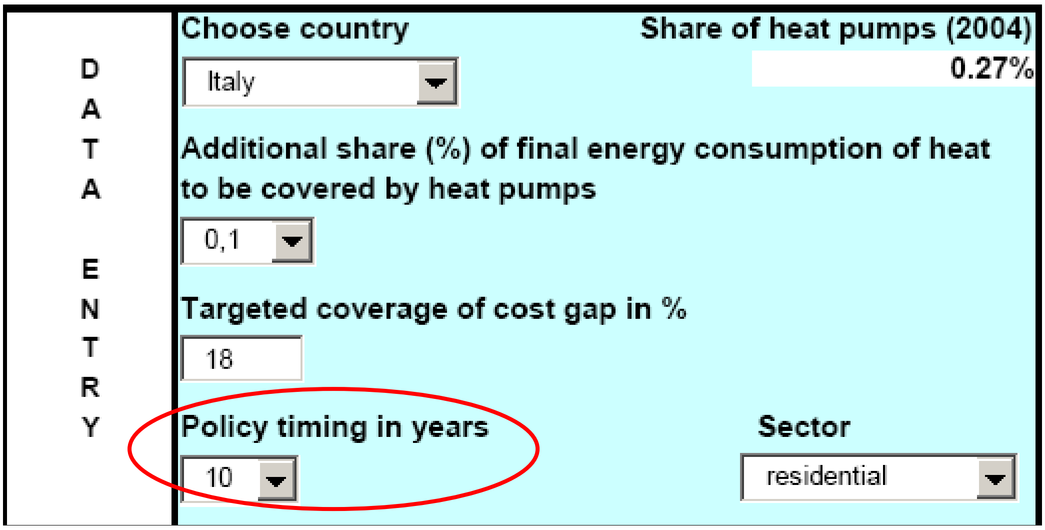


As mentioned above, this tool aims to address the cost gap between conventional fuel heating technologies and heat pump technologies. The next box for data entry allows the user to determine to which extent they wish to cover this gap. If the aim of the policy is to address the full cost gap, the user should enter 100 in the data box (representing 100% of the cost gap). Lesser percentages may be entered in accordance with the wishes of the user.

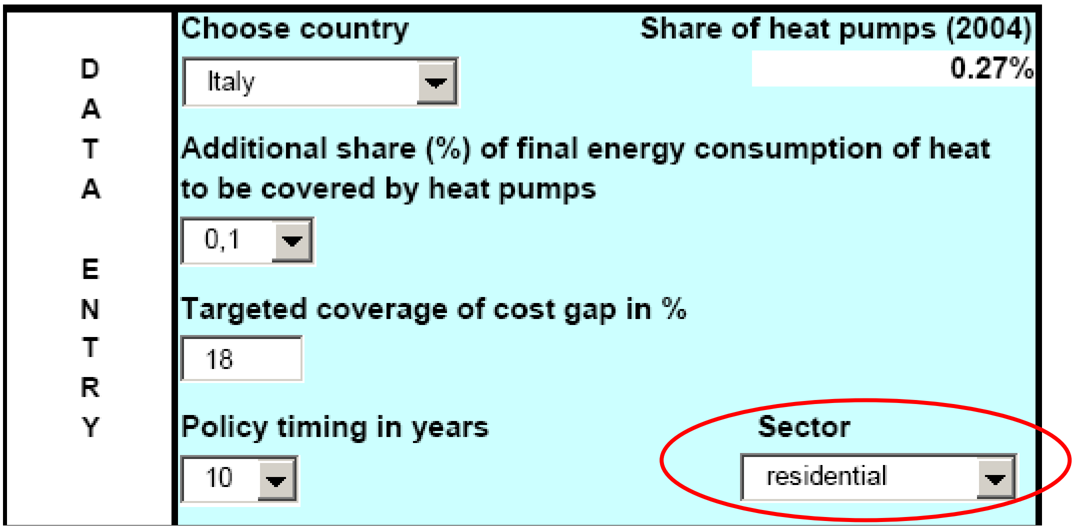
[8] Data on the share of heat pumps in individual countries originates from Lund et al., 2005.
9 Heat demand data for European countries originates from Eurostat at http://epp.eurostat.ec.europa.eu. Canadian data is sourced from the Statistics Canada database at http://www40.statcan.ca/l01/cst01/prim71.htm. Calculations were performed as follows: Final energy consumption – electricity consumption – energy consumption of transport sector + correction value = estimate for final heat consumption.



The Standard Methods Tool has been created to allow for variations in policy timelines. The user should then select from the 'Policy timing' dialog box an estimated timeframe for the life of the policy. Increments of 5 years are possible, to a maximum of 20 years.



Prices vary considerably depending on the sizes of heat pump systems. The next entry allows the user to decide on the size of the system upon which they wish to focus support. The dropdown list provides the following choices: 1) residential 2) service/agriculture 3) industry and 4) total. Residential systems reflect the costs for the smallest, heat pump systems. For this example, systems are assumed to be 8 kW_{el}. Service/agriculture systems reflect the costs for middle sized systems, or 35 kW_{el} systems. Industrial systems are assumed to be industry-scale heating systems, here represented by 110 kW_{el} systems. The final choice, total, automatically selects an average mix of the system costs based upon the heat demand by sector in the country selected.



This method is based upon the assumption that annual heat demand by sector in each country[10] will be reflected in the proportions of industrial, commercial, and residential heat pump systems installed. For example, a country with heat demands in the following proportions; residential 50%, industry 30%, commercial 20%, would reflect these demands in the installations of biomass systems. Half of the systems installed, therefore would be at the smallest residential scale, 30% large, industrial scale, and 20% medium, commercial scale.

If the user selects the final 'total' choice, they must be aware that the assumptions made in the methodology may be reflected in the outcome of the results. Large heat pump systems are often more profitable (as compared to conventional heating systems of the same size) than smaller heat pump systems for single family homes. It results that in countries with a high share of heat demand in the industry sector, due to the assumptions made in this tool the economic advantage of large systems compensates the economic inefficiency of small systems. In other words, in countries with a high share of heat demand in the industry sector the tool may show that less support is needed from a macro-economic point of view, even though small systems may require more support to be cost competitive.

For this example, then the user has chosen to investigate the amount of support required for a 10-year policy in Italy that aims to cover 18% of the cost gap with conventional fuels for a 0.1% over-all increase in solar thermal heating, specified to concentrate support on small, residential heat pump systems.

Results

With each of the above selections, the costs of heat pump heating and conventional heating in €ct/kWh are adjusted accordingly. These changes are reflected in a graph to the right of the dialog table which automatically adjusts to reflect whether the system costs selected are scaled according to residential, commercial or industrial systems (See below).

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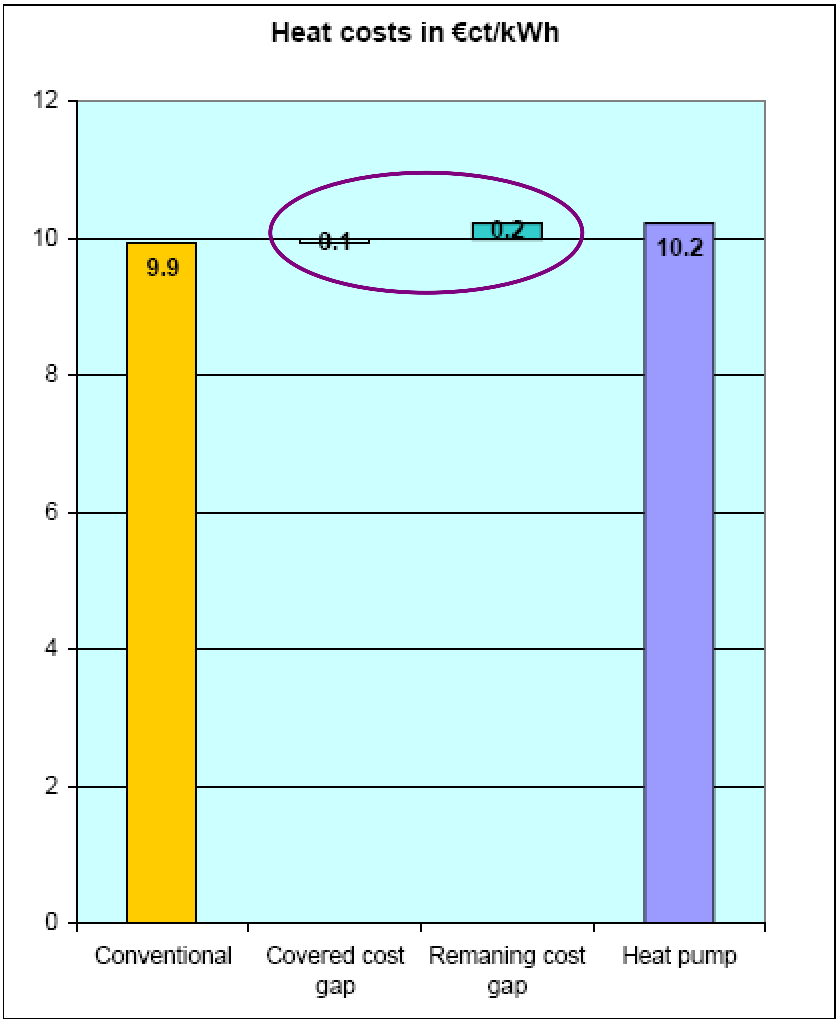
[10] Data on the composition of heat demand in each country was sourced from the IEA member country database available at: http://www.iea.org/Textbase/country/index.asp.



The graph depicts the costs of conventional heat (far left, yellow bar), the costs of heat pump generated heat (far right, light purple bar) and the cost gap between the two (shown here inside a purple oval). The total cost gap would be a combination of the two middle bars, in this example 0.3 €ct/kWh. The left, green bar is a representation of how much of the cost gap the user has chosen to cover with political incentives. The right, blue bar represents the cost gap which remains to be covered.

The second box of the tool, 'Results', is broken into two individual sub-boxes. The first of these sub-boxes tells the user how much support is required per system, in total, and per annum according to the selected timeline.

RESULTS			
	Support need over policy time for:		
	Per kW	Total	Per annum
	3 €/kW	2,387,000 €	239,000 €
	Additional funding for policy marketing (% total)		
	10%	total Funding:	239,000 €
		Funding per annum:	24,000 €
	Support need over policy time including funding:		
	Total	Per annum	
	2,626,000 €	263,000 €	

The final sub-box of the Standard Methods tool pushes the user to consider additional funding which may be desired for marketing of the policy tool. It has been shown that those policies which are the most effective are those where parallel investments were made in guidance and educational programmes in order for the stakeholders (including building owners making personal investment decisions) to better understand the benefits that REHC has to offer. An appropriate percentage of 10% of the total policy spending is automatically selected. As the user enters policy conditions in the "data entry" section of the tool, the budget numbers are simultaneously amended to reflect the funding which would need to be allocated strictly to marketing activities to the right of the percentage box. These totals which match the selected percentage have been given in total and per annum (See below).

Additional funding for policy marketing (% total)		
10%	total Funding:	239,000 €
	Funding per annum:	24,000 €
Support need over policy time including funding:		
Total	Per annum	
2,626,000 €	263,000 €	

The final row of funding totals represents the total funding to cover the cost gap and for marketing activities. All budget numbers in the tool are rounded to the nearest thousand.

Total support need = Cost gap support need + Marketing activities

Where marketing activities = (X%)*Cost gap support need

With the information that this tool provides, the user is able to judge with a rough indication how much funding should be allocated in total and per annum to an incentive-based policy such as a subsidy scheme for ambient heating.

Tool cost comparisons

The investment costs for residential heat pumps in the Standard Methods tool are country-specific, and based upon the national shares of different heat pump types. These costs are presented in the table below and are based on market data of the "Bundesverband WärmePumpe", adjusted upwards according to predictions of the DLR, Stuttgart, for the German Market Incentive Program 2008. Data on the national shares of residential types of heat pumps was sourced from the European Heat Pump Association (EHPA)[11].

Heat pump type	**€/kW**
air/water	2000
brine/water	2700
water/water	3000

This type-specific differentiation is only applied to residential heat pumps. For larger-scaled heat pumps, similar costs for all countries are assumed. These costs originated from the Wirtschaftsministerium Baden-Württemberg[12].

The cost data in the IEA report "Renewable Energy for Heating and Cooling – Untapped Potential" are by three to four times lower in comparison to the residential heat pumps. They describe the estimations of the GIA (IEA Geothermal Implementing Agreement), which do not correspond to the German market at the moment.

The assumed cost data in the RETScreen tool corresponds more closely to the actual German market data.

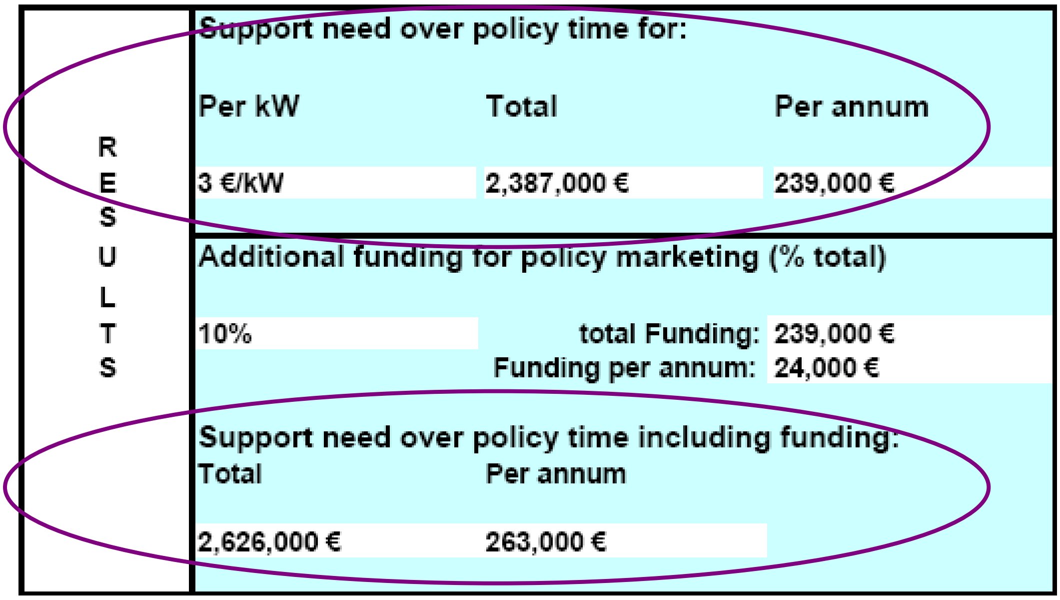
<table>
<tr><th>Heat pumps</th><th colspan="3">Investment costs [€/kW]</th></tr>
<tr><td></td><td>6 kW (residential)</td><td>35 kW (service)</td><td>150 kW (industry)</td></tr>
<tr><td>Excel Tool (excl. VAT)</td><td></td><td></td><td></td></tr>
<tr><td>Canada</td><td>2919</td><td rowspan="9">1300</td><td rowspan="9">620</td></tr>
<tr><td>Denmark</td><td>2700</td></tr>
<tr><td>France</td><td>2697</td></tr>
<tr><td>Ireland</td><td>2700</td></tr>
<tr><td>Italy</td><td>2000</td></tr>
<tr><td>Germany</td><td>2526</td></tr>
<tr><td>Netherlands</td><td>2335</td></tr>
<tr><td>Norway</td><td>2518</td></tr>
<tr><td>United Kingdom</td><td>2000</td></tr>
<tr><td>IEA REHC (excl. VAT)</td><td></td><td></td><td></td></tr>
<tr><td>Minimum</td><td>200</td><td></td><td></td></tr>
<tr><td>Average</td><td>500</td><td></td><td></td></tr>
<tr><td>Maximum</td><td>1150</td><td></td><td></td></tr>
<tr><td>RETScreen</td><td></td><td></td><td></td></tr>
<tr><td>Heat pump - air-source</td><td colspan="3">576-1080</td></tr>
<tr><td>heat pump - ground-source (horizontal loop)</td><td colspan="3">576-2160</td></tr>
<tr><td>heat pump - ground-source (vertical loop)</td><td colspan="3">720-3960</td></tr>
</table>

[11] http://ehpa.fiz-karlsruhe.de/en/info/info212.html
[12] http://www.wm.baden-wuerttemberg.de/fm/1106/Mittelgro%DFe%20W%E4rmepumpen_komplett-2.pdf

Understanding the Results

The Standard Methods tool assists policy-makers as they face the challenge of determining an adequate level of support in the design of instruments aimed to increase the deployment of renewable heat. Focused specifically on subsidy-based incentive schemes, it clearly depicts the cost gap between conventional fuel heating technologies and heat pump technologies including investment costs and running costs. Based on this information and the user inputs for policy timeline and objectives, the tool produces an estimated budget for subsidy-based incentive schemes. It is important that the user recognizes and fully understands that the data compiled and presented in this tool is intended be interpreted as strictly indicative.

The results box provides the user with the following numbers of interest: Support need over policy time (per kW, total and per annum) and Support need over policy time including funding (per kW, total and per annum) (See below).



The first, 'Support need over policy time' tells the user that for the inputs entered (a 10-year policy in Italy that aims to cover 18% of the cost gap with conventional fuels for a 0.1% over-all increase in heat pump heating, specified for residential systems) an estimated total budget of €2,387,000 would be required. This total, divided by its 10 year timeline therefore results in an annual budget of €239,000. Finally, an estimated 3 €/kW is needed. This result breaks down the total budget for the user to understand the cost gap requirements on a more tangible scale. These results show the user only the cost differences between the technologies and does not include administrative costs of the policy. When the policy itself is designed, these costs must be accounted for.

The second, 'Support need over policy time including funding' urges the user to incorporate educational or marketing based funding into the design of the policy tool to allow stakeholders (including building owners making personal investment decisions) to better understand the benefits that renewable energy heating and cooling has to offer. In this example, 10% of the total policy funding (€2,387,000) from the first set of results has been added for marketing purposes resulting in an estimated total policy budget of €2,626,000.

This total, divided by its 10 year timeline therefore results in an annual budget of €263,000. The support needed per kW does not change.

As shown in this tool, heat pumps are, in many cases, cost competitive with conventional heating. This implies that it is not necessarily the cost gap with conventional fuels that hinders further developments of the heat pump market. The running costs of heat pumps which incorporate electricity prices in each country investigated are notably lower than heat produced by oil or gas. An important consideration for further development of the tool is overnight electricity rates which exist in many countries, such as Germany. These rates imply savings in energy costs of up to 50%, which would further lower the running costs of heat pumps.

While the results of the Standard Method tool are considered in the design of subsidy-based policies in support of heat pump systems, the limitations of the tool and its prospects for further development must be taken into account. The cost data for renewable energy systems is assumed to be the same for all countries investigated. A more thorough approach would incorporate country-specific data on heat pump system costs. Although a maximum of 50% has been included, heat pump potential has not been accurately limited based on country-specific data. More specific potential data could be incorporated incorporating information on installation manufacturing facilities and the availability of local installers. As the success of a policy depends in many cases on how well the existing infrastructure has already been developed, a future tool could be designed to take supply chain infrastructure into consideration. Finally, the importance of a variety of renewable heating technologies must not be side-stepped as policies are designed for solar thermal heating. Other renewable heating technologies such as biomass pellet heating and solar thermal heating should also be given thorough consideration and adequate support.

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