Heating the built environment more sustainably by 2050

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Contents

1 Introduction

FINDINGS

Heating the built environment more sustainably by 2050

The Rutte cabinet is aiming at a climatically neutral economy by 2050. One thing needed to achieve this aim is a more sustainable heat supply to the built environment. This study examines how much carbon reduction is achievable by energy-saving measures, such as building insulation and thermal energy storage. Furthermore, it assumes that such measures for buildings and regions are cost-effective for both building owners and heat suppliers.

Main conclusions

Cost-effective construction and local measures together can save 15 to 30 percent of the carbon emissions from the built environment by 2050

The most efficient way to limit carbon emissions from the built environment is a combination of construction and local measures. This results in a greater reduction of carbon than implementing purely construction measures such as insulation or improving the efficiency of heating systems, or purely local measures such as using residual heat, geothermics or thermal energy storage.

Implementing all the cost-effective building and local measures can save 15 to 30 percent of the carbon emitted by the built environment by 2050. The size of the percentage depends on two factors: the price of energy and the costs of investing in energy-saving measures. As trends in energy prices and investment costs are uncertain, the possible cost-effective carbon reduction is presented here as a bandwidth.

Label ‘B’ insulation of existing buildings becomes cost-effective when energy prices are high

In financial terms, the most effective of the construction measures is insulation. Cost-effective insulation can save 20 percent of carbon emitted by the built environment by 2050.

This is achieved by insulating one-quarter of the present housing stock under Label B. Thus a terraced house (accommodating one household) built before 1960, labelled F or G, burns on average 75 percent less natural gas after insulation to Label B. This does assume a situation in which the price of natural gas has risen by EUR 0.64 to EUR 0.80 per cubic metre and that, in addition, the investment costs are relatively low (the costs following a 'project-based' approach). These are mainly dwellings for one household, built before 1960, or apartment housing built before the Second World War. For non-residential buildings such as offices, shops and hospitals, in principle half the existing buildings can be cost-effectively insulated to Label B. This assumes that the current price of natural gas to major consumers has risen from EUR 0.20 to EUR 0.41 per cubic metre. In this case, too, investment costs are fairly low.

In a situation where energy prices have not risen, and investment costs are high (the 'specific' approach), only a few residential and non-residential buildings can cost-effectively be insulated to Label B.

Local measures offer extra cost-effective carbon reduction, on top of construction measures

Local measures use local heat sources, such as residual heat from power stations and industrial plants, and shallow underground thermal energy storage systems. This reduces the natural gas burned for interior heating and showering and cuts carbon emissions.

To make cost-effective use of residual heat and of thermal energy storage, concentrated demand for heat is necessary. Such concentrated demand is lower if all buildings have an energy performance at Label B level. This means, in any case, that they require less heat. Regardless of this, a large proportion of local measures are cost-effective. By 2050, 30 percent of carbon emissions from the built environment can be saved, provided that cost-effective insulation measures are not taken alone, but that use is also made of cost-effective local heat sources. This is 10 percentage points more than when cost-effective insulation takes place alone. This is possible in a situation where energy prices are high and investment costs low.

If energy prices are low and investment costs high, hardly any residential and non-residential buildings can be insulated cost-effectively to energy Label B (see last point). Even then, a further 15 percent of carbon emissions can be saved cost-effectively by using local heat sources.

Geothermics: perhaps one of the most important clean heat sources

In theory geothermics, also known as the Earth's internal heat, can play a major role in the supply of heating to buildings. The viable geothermal heat sources are located deep underground (around 1 to 3 kilometres down). In many cases, there is little knowledge of the precise locations for successful drilling. Hence a budget for cost-effective geothermal projects is fraught with uncertainty. More local exploration is necessary, to add to knowledge of the underground. If the exact locations for successful drilling are known, cost-effective projects can save 1 to 15 percent of the estimated carbon emissions from the built environment. This upper limit shows that geothermics can become just as important as residual heat and thermal energy storage.

Even if not all building owners and users adopt measures, significant carbon emissions are saved

Building owners and users who want to decide whether to take energy-saving measures do not only look at the cost-effectiveness of those measures. Other considerations play their part, such as practical and personal interests and preferences. Some owners and users can hardly be persuaded to fit insulation and/or use local heat sources.

But even if only limited numbers of owners and users adopt cost-effective energy-saving measures, there is still a significant effect on carbon emissions. By 2050, this can save 8 to 15 percent of the carbon emissions from the built environment.

Implications for climate and energy policy

The study shows that cost-effective measures can achieve a 20 to 30-percent reduction in carbon from the built environment by 2050. To achieve this, national climate and energy policy does best to focus on both construction and local measures. Exactly what measures to take in a municipality, and whether these are cost-effective, depends on local (physical) circumstances. To answer these questions, research and customised efforts are then necessary at local level.

Introduction: investing in energy-saving measures

Principle

It is the ambition of the European Commission, by 2050, to achieve an 80 to 95-percent reduction in the 1990 levels of greenhouse gas emissions. In the 2050 Climate Roadmap (*Klimaatbrief 2050,* I&M 2011a), the Rutte cabinet supplements this, by outlining how the Netherlands can make the transition to a climate-neutral economy. For the built environment, this will require a reduction in carbon emissions of the order of 80 percent (PBL and ECN 2011).

Motivation and context

There are two ways of achieving such a reduction in carbon emissions: reduce demand for energy; and/or clean up the energy supply.

Until a few years ago, the primary focus lay on reducing energy demand for buildings. Important **construction measures**, which are being stimulated, are: floor, wall and roof insulation; and improving the energy efficiency of heating systems, such as the energy-efficient boiler.

In recent years, closer attention has also been paid to **local measures**. These involve heating or cooling buildings via a transport and distribution network from sources close to the building. The best-known local measures are the use of residual heat from power stations and industrial plants; deep-level geothermics; thermal energy storage (TES) at shallow level; and the use of energy systems in districts, which produce both heat and electricity (known as combined heat and power, or district CHP).

The question now is not only which measures have most effect on carbon reduction, but which are financially viable and cost-effective. Long-term investment in both construction and local measures is a vital necessity, both on the part of government, housing associations, landlords, utilities, owner-occupiers and other building owners. It is important to know where investment in buildings and heat networks may clash, and where they can complement each other. This depends on the scale of local energy demand and the presence of heat and cold sources.

In addition, the opportunities for reducing demand for heat for buildings are often determined by local circumstances, such as the type and age of housing. In addition, socio-economic parameters such as occupants' incomes and property ownership ratios can play a major role in the financing of energy-saving measures.

Purpose of report

Through this exploratory report, PBL seeks to support the social parties involved, including government, in the further development of climate and energy policy for the built environment. For this purpose, the report examines the possible contribution of construction and local measures to the achievement of the target of an 80 percent reduction in carbon in the Dutch built environment. In addition to these measures, electrical heating systems (at low temperature), which generate clean electricity centrally, and green gas may make a contribution. However, the study does not deal with those options.

Research questions

This research starts from the following three questions:

1. What measures lead to the greatest reduction in carbon: construction measures, local measures or a combination of the two?
2. Which of these measures is most cost-effective?
3. How far is carbon reduction influenced by whether building owners are willing to adopt energy-saving measures?

The Vesta Model

To gain a better understanding of the effect of local energy measures on national emission reduction, and the interaction between construction and local measures, a new energy model has been developed: Vesta. Vesta is a geographical energy model of the built environment, which takes account of local circumstances which are important to energy saving and heat supply.

Justification and method

Carbon emission trend

To estimate the trend in carbon emissions up to 2050, a trend prognosis (PBL 2012) has been used to give a picture of the future population size, housing stock, economy and employment. The development of these sectors determines future energy demand, to a great extent.

The number of inhabitants in the Netherlands is expected to grow by 0.9 million, to 17.5 million, during the period 2010 to 2050. This growth, coupled with smaller households, leads to a growth in housing stock by 1.1 million dwellings, to 8.2 million. For this purpose, 1.2 million dwellings are demolished, and 2.3 million new homes built. Economic growth averages 1.7 percent per year. The number of jobs rises by 0.4 million to 7 million and the area cultivated under glass increases by 800 hectares to 11 000 hectares. This takes account of demolitions and new building of residential and non-residential buildings and greenhouse horticulture. Residential energy consumption is based on Exemplary Homes 2011 (*Voorbeeldwoningen 2011* - Netherlands Enterprise Agency 2011). Exemplary Homes 2011 estimates the reference energy consumption per dwelling type and year of construction according to actual consumption according to CBS (2010). The energy consumption of a non-residential building is based on estimated energy demand per square metre of floor surface for sub-sectors in the energy field (Meijer Energie & Milieumanagement B.V., 2008). In the case of greenhouse horticulture, it is based on the energy demand for flowers, vegetables and other crops per square metre of glasshouse (Rooijers 1994).

Account is also taken of reduced energy demand in future for indoor heating, due to a rise in outdoor temperature caused by climate change. This is based on climate scenarios of the Royal Netherlands Meteorological Institute (KNMI).

Construction and local measures

The potential of residential construction measures to reduce carbon, and their costs, are also based on Exemplary Homes 2011. These are measures to insulate the shell (roof, walls and floor) which bring dwellings to energy performance Label B. Label B is the highest level of energy performance of existing dwellings. It is achievable via insulation measures from Exemplary Homes 2011. Energy performance Label A is achievable if the insulation measures are supplemented by a solar boiler and solar panels. For existing dwellings, the current understanding is that higher energy performance levels cannot be achieved with existing technology, unless the costs fall extremely sharply. For new residential buildings, the reference calculation of the energy efficiency of the shell is based on the current standard.

As a benchmark of boiler efficiency, for both existing and new buildings, it is assumed that the modern high-performance HR107 boiler is the state of the art which will have replaced the existing boilers by 2050. The solar boiler can be used as a booster. In addition, electric heat pumps can be installed as an alternative in new buildings. However, the technology costs are not expected to fall.

The information on local measures in relation to residual heat sources is based on a count of existing power stations, waste processing facilities, refineries and major industrial plants (PBL 2012). Leguijt (2011) and PBL (2012) quantify the costs and key figures for heating networks, geothermics, thermal energy storage and combined heat/power per district (district CHP). For the presence of geothermal sources deep underground, use has been made of the hitherto unpublished probability plots (paragraph 4.3) by the Netherlands Organisation for Applied Scientific Research (TNO). These local measures replace the energy-efficient HR107 boiler.

The Vesta Model calculates which local measures are cost-effective. Its order of priorities is as follows: 1) residual heat; 2) geothermics; 3) thermal energy storage; and 4) district CHP. This means that the first calculation is whether residual heat is cost-effective. If residual heat is cost-effective, no further calculations are made for the other local measures. If residual heat is not cost-effective, the calculation is completed for thermal energy storage, and so on. This priority order has been adopted on pragmatic grounds. It often corresponds to carbon cost-effectiveness, but this may vary widely at local level. In practice, this will lead to a different order of priorities.

Uncertainty of future energy prices and investment costs

The cost-effectiveness of energy-saving measures is closely dependent on investment costs and energy prices. In this study, we assume that the energy-saving measures are adopted between 2010 and 2050. It then makes sense to use the costs and energy prices according to their trends during this period.

In view of the uncertainty of trends in energy prices and investment costs in the period 2010 to 2050, two extreme variants are considered. In variant A, all energy prices and investment costs are calculated at 2010 energy prices. The costs of insulation are also based on an individual approach for private individuals. Variant A usually gives a lower limit for carbon reduction resulting from cost-effective energy-saving measures, because the calculation uses relatively low energy prices and relatively high investment costs.

Variant B uses future energy prices from the latest update of the Energy and Emissions Frame of Reference (*Referentieraming energie en emissie* - PBL 2011). The costs of the insulation measures follow a project-based approach. Therefore Variant B calculates using relatively high energy prices and relatively low investment costs. This variant therefore usually yields an upper limit for carbon reduction from cost-effective energy-saving measures.

Graph

Figuur 1	Fig. 1
CO2-reductie, 2050	Carbon reduction by 2050
Gebouwmaatregelen	Construction measures
Rendabel potentieel bij variant A	Potentially cost-effective in Variant A
Rendabel potentieel bij variant B	Potentially cost-effective in Variant B
Technisch potentieel	Technical potential

Gebiedsmaatregelen	Local measures
Rendabel potentieel bij variant A	Potentially cost-effective in Variant A
Rendabel potentieel bij variant B	Potentially cost-effective in Variant B
Technisch potentieel	Technical potential
Combinatiemaatregelen	Combined measures
Rendabel potentieel bij variant A	Potentially cost-effective in Variant A
Rendabel potentieel bij variant B	Potentially cost-effective in Variant B
Technisch potentieel	Technical potential
Rendabel potentieel	Cost-effectiveness potential
Technisch potentieel	Technical potential
Variant A	Variant A
Lage energieprijzen en hoge investeringskosten bij gebouwmaatregelen	Low energy prices and high investment costs of construction measures
Variant B	Variant B
Hoge energieprijzen en lage investeringskosten bij gebouwmaatregelen	High energy prices and low investment costs of construction measures
Reductie ten opzichte van referentie (megaton)	Reduction from benchmark (megatonne)
pbl.nl	Source: PBL

How energy prices and investment costs will develop in reality is unknown. For example, it is perfectly possible that in 2050 energy prices will be higher than the Frame of Reference. Working through the whole period until 2050, one the one hand with present-day energy prices and high investment costs; and on the other hand with the future energy prices from the Frame of Reference and the low investment costs, the carbon reduction from cost-effective measures is presented as a bandwidth belonging to an energy price and cost trend across the entire period, 2010 to 2050.

In Variant A, the gas price is EUR 0.64 per cubic metre for domestic and small business consumption and EUR 0.20 per cubic metre for major corporations. In Variant B, the gas price is EUR 0.80 per cubic metre for domestic and small business consumption and EUR 0.41 per cubic metre for major corporations.

In addition, local measures are determined which are cost-effective in the event of a doubling of the high energy prices. This price variant determines the technical potential for carbon reduction, for the local measures alone. The technical potential for carbon reduction normally reveals how great the carbon reduction is, even if measures are taken which are not cost-effective. This technical potential usually depends on energy prices. This is the case with the technical potential for carbon reduction from construction measures.

Results

Cost-effective construction and local measures together can lead to a 15 to 30 percent reduction in the carbon emitted by the built environment by 2050

Taking cost-effective construction and local measures can reduce carbon emissions by 6 to 11 megatonnes by 2050. This corresponds to 15 to 30 percent of the estimated carbon emission from the built environment by 2050. The combined measures achieve 3 to 7 more megatonnes of reduction than taking only cost-effective construction measures or only cost-effective local measures (see also Fig. 1).

The profitable part of the construction measures consists of floor, wall and roof insulation. This takes all buildings for which it is cost-effective to a Label B energy performance level. Whether the energy saving for a home is cost-effective is determined by the fall in gas consumption and the level of the costs of investing in the insulation measures. These are connected to the type of dwelling and year of construction. The analysis shows that one-quarter of the current housing stock can be insulated cost-effectively to Label B in Variant B (high energy prices and low investment costs for the insulation measures). This relates primarily to terraced houses built before 1960, and to apartment housing from before the Second World War. For non-residential buildings such as schools and hospitals, if energy prices and investment costs are the same, half the existing buildings can be insulated cost-effectively to Label B. For businesses, cost-effectiveness varies according to sector, because the heat demand per square metre is sector-dependent. These are offices, shops, buildings in the hotel, restaurant and catering trades, hospitals, nursing and care homes. Through cost-effective insulation, the built environment will emit around 8 megatonnes less carbon in 2050. That is 20 percent of the carbon emission to be expected from an unchanged policy. In Variant A (low energy prices and high investment costs), hardly any residential or non-residential buildings can be cost-effectively insulated to Label B. Building insulation to Label C, for example, may well be cost-effective, but the carbon reduction through this has not been investigated.

If construction measures are not taken, but local measures are, the reduction from cost-effective measures is around 4 to 6 megatonnes (Fig. 1). The cost-effective local measures consist of the use of residual heat, geothermics, thermal energy storage and district CHP. They are applied in areas with a concentrated heat and cold demand from residential and non-residential buildings and greenhouse horticulture (see Fig. 2).

However, the greatest carbon reduction which is cost-effective is achieved through a combination of construction and local measures. The amount is 6 to 11 megatonnes. The technical potential of the combination of construction and local measures is even greater: a reduction of approximately 19 megatonnes of carbon. This is at least 50 percent of the carbon emission of the built environment in 2050. However, high costs are associated with this. The construction measures which are not cost-effective cost the building owners EUR 6 to 11 billion per year. On top of this come the costs of the local measures, which only become cost-effective if the high energy prices double.

The reference scenario assumes that 1.2 million existing buildings will have been demolished by 2050, and replaced by new, lean-energy buildings. This makes residential carbon emissions approximately 1 to 2 megatonnes lower than if the present building stock were retained. It is further assumed that the new construction of residential and non-residential buildings and greenhouse horticulture will meet the current energy performance requirements. This new, lean-energy construction on new sites emits around 5 megatonnes. There is no (additional) cost-effective carbon reduction potential from construction measures here. The cost-effective potential of the local measures for these new buildings amounts to around 0.7 megatonnes.

Cost-effective local measures also contribute to renewable energy

The Netherlands is under an EU obligation to generate 14 percent of its energy consumption from renewable sources by 2020. Renewable energy sources include wind power, solar panels, hydro, biomass, geothermics, solar boilers and thermal energy storage. Cost-effective local measures supply 50 to 54 petajoules (PJ) of renewable energy, especially from thermal energy storage (TES) and, to a lesser degree, from geothermics. If cost-effective insulation measures are also taken, domestic demand for heat is less. TES and geothermal projects are less profitable in that case, and supply 42 petajoules of renewable energy. The renewable energy from TES and geothermics thus supplies a 6 to 9 percent proportion of the energy demand from the built environment by 2050.

Buildings can generate much of their own electricity consumption from rooftop solar panels

Electricity-generating solar panels (PV cells) can be fitted on a large scale to the roofs of residential and non-residential buildings. This means fewer coal and gas-fired power stations are needed, driving down carbon emissions. If all roofs of residential and non-residential buildings are covered with solar panels, carbon emissions can be reduced by 22 megatonnes by 2050. This carbon reduction corresponds to 60 percent of the energy demand from the built environment in the reference scenario. The potential is particularly big from non-residential buildings (18 megatonnes), because they offer large roof areas. Within the business sector, the sub-sectors of wholesaling, the motor trade, automotive repairs and education have the largest roof areas.

However, the question is whether all generated electricity is usable, because the electricity generated from solar panels does not necessarily coincide with the demand for electricity from the built environment. Hence the financial benefits are hard to gauge. The trend in procurement costs for solar panels in the period 2010 to 2050 is also uncertain. An analysis of these uncertainties falls outside the scope of this study. Hence the cost-effective potential of solar panels has not been determined.

Locations of new residential estates, business sites and power stations is important to cost-effective heat supply

The use of residual heat can only be profitable if the distance of transport between the heat source and the distribution area is short, and there is large, concentrated demand for heat in the distribution area. When planning new residential and business sites, and power stations, it is therefore important that the town planning should cover the cost-effectiveness of local heat sources, as well as other considerations.

Figuur 2	Fig. 2
Rendabele gebiedsmaatregelen 2050, bij hoge energieprijzen	Cost-effective local measures in 2050, assuming high energy prices
Wonen	Residential
Utiliteit	Business
Glastuinbouw	Greenhouse horticulture
Restwarmte Geothermie Warmte-koudeopslag Wijk-warmtekrachtkoppeling Aardgas	Residual heat Geothermics Thermal energy storage District combined heat and power Natural gas
NB: Stippen tonen de locatie en zijn niet representatief voor het oppervlak van de gebiedsmaatregelen.	N.B: dots show the location but are not a guide to the surface area of local measures.
Bron: PBL	Source: PBL

Figuur 3	Fig. 3
Kans aanwezigheid benutbare geothermie	Probability of a viable geothermal presence
Inzichten 2011	2011 figures
Kans (%) 0 – 10 10 – 30 30 – 50 50 – 70 Meer dan 70 Onbekend	Probability (%) 0 - 10 10 - 30 30 - 50 50 - 70 Over 70 Unknown
Bron: PBL	Source: PBL

The existing residual heat sources are already used to supply heat to buildings. The calculations show that greater use of residual heat sources can cost-effectively achieve three times the reduction of carbon (about 3 megatonnes) than at present. However, it is uncertain how far the current residual heat sources will still be available in 2050 and whether new locations will be added in the future. *A Clean Economy by 2050* (Naar een schone economie in 2050 - PBL 2011) depicts a future in which Dutch greenhouse gas emissions are 80 to 95 percent less by 2050. For this purpose, various residual heat sources are available from power stations, with biomass and thermal energy storage, nuclear power plants, biomass refineries and industrial companies. However, the present study does not investigate whether the quantity of residual heat and the locations of its sources correspond to the existing residual heat sources.

More knowledge necessary underground to exploit geothermics

The sources of the Earth's 'geothermal' heat which are suitable to supply the built environment are located far underground (about 1 to 3 kilometres down). These heat sources are definitely known to be there, but often their exact locations are unknown. Geothermal drilling therefore often entails major financial risk.

TNO has plotted out what the chances are of successful drilling to a geothermal source, for the whole of the Netherlands (see Fig. 3). These TNO probability plots give a first indication, but more knowledge and local exploration may increase the probability of successful drilling. A greater chance of successful drilling reduces financial risk, and therefore makes geothermics cheaper and more usable.
We have used the TNO probability plots to estimate the carbon reduction potential of geothermal heat supply. Fig. 4 shows the locations where geothermics can be used cost-effectively, if a geothermal really is present. The expected value of the cost-effective carbon reduction potential of geothermics is 0.5 to 6 megatonnes, or 1 to 15 percent of the carbon emissions from the built environment in 2050. More knowledge about the underground situation may reduce this bandwidth and increase the chance of successful drilling.

Heating supply from district CHP is less cost-effective at the estimated energy prices

For the supply of heat to buildings, district CHP may be cost-effective at current energy prices, and make an important contribution to reducing carbon emissions (2.5 megatonnes). At the energy prices estimated for 2050, district CHP is less profitable, because the fuel price of this rises more sharply than the returns. Even then, district CHP is cost-effective up to 0.3 megatonne of carbon reduction; at more reduction than that, a loss occurs.

Residual heat, geothermics and district CHP compete but may also strengthen each other

Residual heat, geothermics and district CHP compete with each other where there is strong, concentrated demand for heat. But they may strengthen each other because, if one heat source ceases, another can take over the heat supply. It would then also be worthwhile to invest in heat networks, which can distribute the energy from the various heat sources, even in the long term.

Figuur 4	Fig. 4
Rendabele geothermie	Cost-effective geothermics
Bij lage energieprijzen	With energy prices low
Bij hoge energieprijzen	With energy prices high
Geothermie Kans benutbare geothermie minder dan 10% Aanname: Geothermie overal benutbaar, met uitzondering van 0 – 10% kanscontour	Geothermics Probability of viable geothermics less than 10% Assumption: geothermics viable everywhere, except in the 0 - 10% probability outline
Bron: PBL	Source: PBL

Policy opportunities, even with limited participation from some sectors

If building owners want to choose whether to adopt energy measures or not, the cost-effectiveness of those measures is not the only factor. Other, non-financial barriers play a role. Our analysis has examined what happens when some owners do not join in the implementation of measures which, in themselves, are certainly cost-effective, and what effect that has on potential carbon reduction.

For the existing housing, the following owners can be identified:

- In privately owned housing, all owner-occupiers with income above a certain level join in the construction measures. The reasoning is that owner-occupiers on lower incomes cannot finance the necessary investments.
- None of the privately owned housing joins in the local measures, because owner-occupiers are a diverse group, difficult for heat suppliers to approach.
- This problem does not arise at all for the largest section of landlords, such as housing associations. The rented properties do therefore join in the local measures.
- In the case of owners of let properties, terraced houses and flats, both from the period 1940 - 1990, also join in the construction measures, which are well suited to a large-scale, uniform approach. The other rented properties do not join in the construction measures.

For the existing non-residential buildings, we assume that all buildings from the healthcare and education sectors join in but that, in the other sectors, only companies with more than 100 employees join. The reasoning is that, within these sectors and companies, more attention is probably paid to energy consumption and ways of saving than in the other sectors (such as smaller offices, shops and horeca). The criterion of participation applies to both construction and local measures. In practice, it will probably not happen that one sector joins in fully and another not at all. Participation is dependent on the degree of ambition of the individual companies and organisations within a sector.

Where new buildings are constructed, the assumption is that they do join in the measures because new build finance is easier to control, and non-economic impediments are less important than for existing buildings.

Greenhouse horticulture has not been selected, because many glasshouse growers use not only heating, but CO2 fertilisation. They also need electricity to light their crops. Therefore they give preference to individual CHP which emit more carbon than local measures.

Table 1

Summary of assumed participation by sectors

			Construction measures	**Local measures**
Residential	Privately owned	High incomes	X	-
	Privately owned	Low incomes	-	-
	Rented	Flats and terraced houses 1940-1990	X	X
	Rented	Other	-	X
	New build[a]	New locations	X	X
Non-residential	Major companies, healthcare and education		X	X
	Other		-	-
	New build in new locations		X	X

[a] New build which replaces existing construction is included in the other categories.

If only owners with ‘least resistance’ take part in insulation and more sustainable heat supply (see Table 1), well over half of the carbon reduction from all cost-effective measures can still be realised.

Construction measures can have a big local impact on other local measures

Cost-effective construction measures can have a major and diverse impact locally on the cost-effectiveness of local measures. If local measures are adopted, such as insulation, demand for heating for those buildings decreases. The reduced demand can have the following effects on residual and other heat supplies:

- Residual heat is supplied to fewer localities, because the supply of heat to some localities becomes unprofitable.
- Residual heat is supplied to other localities. Because little or no residual heat is supplied to some areas, there is surplus residual heat which can be supplied cost-effectively to other areas. This changes the ranking of localities where residual heat has most to offer financially. As a result, residual heat is used in other areas where it generates more profit.

These effects are explained below. Based on the Amsterdam and Haarlem region, we show first that there is major cost-effective potential for residual heat supply, both at low energy prices (Fig. 5a) and high energy prices (Fig. 5b). It is then apparent that the cost-effective potential of heat supply at high energy prices (Fig. 5b) changes if cost-effective construction measures are also taken (Fig. 5c) and if some sectors’ participation in construction and local measures is limited (Fig. 5d). At low energy prices, many districts in and around Amsterdam (Haarlem, Wormerveer, Velsen, Purmerend and Zaandam) can be cost-effectively supplied with residual heat (Fig. 5a). In Amsterdam, the full capacity of the residual heat sources present can be used cost-effectively. At high energy prices, the picture for residual heat supply is little different (Fig. 5b). Some localities do join, to the expense of others, because the ranking of the most cost-effective districts changes. At high energy prices, there are almost no districts with district CHP, because the fuel price of district CHP rises more sharply than the returns.

If cost-effective insulation measures are taken, demand for heat falls and the use of residual heat is no longer cost-effective in and around Haarlem and Wormerveer (Fig. 5c). In Amsterdam, however, all residual heat can still be used cost-effectively. Energy saving in buildings also changes the ranking of localities where residual heat earns most money. Thus other areas can be cost-effectively supplied with residual heat (Fig. 5c).

With limited owner participation, the picture for heat supply changes again (Fig. 5d). Because some owners do not participate in the heat supply, and other owners do draw heat but take no insulation measures, the net result is less reduction of heat supply. In and around Haarlem, this does away with most of the areas supplied with residual heat (Fig. 5d). In Amsterdam, all residual heat can always be cost-effectively used. Because demand for heat supply declines, though this differs according to area, the ranking of cost-effectiveness of the residual heat for the areas also changes.

Fig. 5

Cost-effective local measures in Amsterdam and Haarlem in 2050

a. At low energy prices, without construction measures, but with full sector participation	b. At high energy prices, without construction measures, but with full sector participation
c. At high energy prices, with cost-effective construction measures, low investment participation costs and full sector participation	d. At high energy prices, with cost-effective construction measures, low investment costs, and limited sector participation
Residual heat Thermal energy storage District combined heat and power Natural gas	
Source: PBL	

We can see from this that, when participation is limited, residual heat is used in more, and different, locations in Amsterdam (Fig. 5d) than with full participation (Fig. c).

Policy implications

The study shows that cost-effective measures can achieve a 20 to 30 percent reduction in carbon from the built environment by 2050. To achieve this, national climate and energy policy deploy the best, in both construction and local measures. Examples are the energy labelling of existing buildings and the Energy Performance Coefficient (EPC), with which new buildings must comply. Hitherto these standards have sought primarily to improve the energy performance of buildings by construction measures. If local measures can also count, greater carbon reduction becomes achievable at lower cost. This also applies if such local measures can count in the energy saving covenants between government, the energy utilities and industry. Another example is town and country planning. Because the costs of local measures are closely dependent on the transport distance for heat and cold, it is important that buildings and heat sources are close to each other. Town and country planning can take (more) account of this in new building of power stations and industrial and other buildings.

No definitive recommendations can be given locally on the strength of this study, because local circumstances determine what measures are physically feasible and cost effective. PBL plans to investigate local circumstances and possibilities for energy measures using the Vesta Model. It will include an examination of what possibilities exist for improving climate and energy policy and the role of central government and lower authorities.

In-depth analysis

ONE: Introduction

In 2011 the European Commission stated its ambition to reduce greenhouse gas emissions by 80 to 95 percent of their 1990 level by 2050. In the 2050 Climate Roadmap (I&M 2011a), the Rutte cabinet supplements this ambition, outlining how the Netherlands can make the transition to a climate-neutral economy. For the built environment, this will require a reduction in carbon emissions of around 80 percent in comparison with 1990 (PBL and ECN 2011).

The ambition of the European Commission for 2050 has not yet been translated into binding targets. But the European legislation does set binding targets for the Member States of the European Union for 2020. Thus, by 2020, the Netherlands must have reduced greenhouse gas emissions from sectors outside the European Emissions Trading System (ETS)[1] by 16 percent, based on 2005 levels. It must also be obtaining 14 percent of its energy from renewable sources (solar, wind, geothermics, river flow and tidal). The built environment will have to make a substantial contribution to the achievement of these goals.

Until recently, climate policy for the built environment focused mainly on construction measures: floor, wall and roof insulation; more efficient interior heating systems; more efficient electrical appliances and lighting; and solar-powered boilers and panels (photovoltaic - PV). In addition, in recent years, policy has paid increasing attention to the possibility of heating and/or cooling houses, offices and glasshouses with residual or drawn-off heat[2], geothermics or thermal energy storage (TES). In this report we classify these as local measures. Thus the Balkenende IV cabinet in 2008 published the ‘Heat Full Steam Ahead’ (*Warmte op stoom*) work programme. The programme is oriented towards making heat and cold supply sustainable. Since then, a National Centre of Expertise on Heat, a CHP Task Force and a Geothermal Platform have also been set up.

A pertinent question is which route (construction measures, local measures or a combination of both) is most (cost-) effective for forcing emissions from the built environment down by 2050. To gain better insight into the effect of local energy measures on national emission reduction, and the interaction between measures, a new energy model has been developed: Vesta. This is a geographical energy model of the built environment, which takes account of local circumstances which matter to energy saving and heat supply. In addition to the built environment, Vesta makes full allowance for greenhouse horticulture, because the local measures supply heat which is also usable under glass. Vesta does not cover industry, because industrial heat consumption requires higher temperature, and is therefore not compatible with deployment in a built environment.

Another two key measures for the built environment are the use of clean gas and clean electricity. The present study does not deal with those measures, but they are surely necessary supplements if it becomes apparent that construction and local measures will fall short of achieving the 2050 target reduction in carbon from the built environment.

1.1 Guide to the reader

In chapter 2 we develop the above question further, in individual sub-questions. We investigate these using the Vesta Model, based on three possible routes to a low-carbon built environment in 2050. In chapter 3, we briefly examine the Model's function and working, and the starting points used for the scenario. In chapter 4, we describe the heat technology which is central to the Model: residual and geothermal heat and thermal energy storage. Chapter 5 offers a summary of information from the literature about economic parameters (minimum scale, type of construction and location of construction). It also deals with future savings potential of local measures. The chapter seeks to determine how far the results of the Model for the whole technical and economic potential of local measures are valid. In chapter 6, we outline the cost-effective and technical potential of construction measures, as highlighted in other studies. In chapter 7, we discuss the possible obstacles to implementation of cost-effective measures in practice.

The results of the model calculations for the three routes, described in chapter 2, are presented in chapter 8. In the last paragraph of that chapter, we compare the results of the model calculations with the search of the literature.

Annex 1 contains a summary of obstacles to the implementation of cost-effective carbon-reducing measures per sector. In Annex 2, we describe the current policy aims for energy consumption in the built environment and greenhouse horticulture, and the stimulus measures and legislation in the field of energy saving.

Notes

1 The non-ETS sectors are mainly the built environment, transport, agriculture and small industrial firms.

2 Residual heat is heat released in the waste processing industry, in an industrial company or by an electricity utility. Normally it is discharged because it is of no further value to the relevant party. Drawn-off heat is heat generated (as a by-product) in, for example, a power station, where a deliberate choice is made to generate less electricity in favour of heat supply (Netherlands Enterprise Agency 2010c). For the sake of readability, we refer below only to residual heat.

TWO: Analyses carried out using the Vesta Model

2.1 Research questions

As stated in chapter 1, the Vesta Model is used to explore which is the most (cost-) effective route towards ensuring reduced emissions from the built environment and greenhouse horticulture by 2050: construction measures; local measures; or a combination of both types of measure. The analysis covers greenhouse horticulture, because the heat it requires is similar to that of residential and non-residential buildings. The heat supply from the local measures to greenhouse horticulture is therefore also suitable for residential and non-residential buildings.

In our survey of the three routes, the following questions were central in every case:

- How great is the contribution from the built environment and greenhouse horticulture to the achievement of the 2050 climate target?
- What portion of this is achievable by cost-effective measures?
- What is the effect of measures if only a limited group of owners of residential and other buildings takes part?

2.2 Routes explored

The following routes are explored for the demand for heat and cold:

- A route which uses only construction measures (energy saving, heat pumps and solar boilers);
- A route using only local measures (residual heat, geothermics and/or open thermal energy storage (TES)[1]); and
- A route using first construction, then local measures.

For electricity demand for buildings, the analysis is limited to an exploration of the use of solar cells (PV). This technology has a clear spatial dimension, which the Vesta Model is able to analyse: the surfaces of building roofs and walls. Other technology relevant to the development of electricity demand and supply falls outside the scope of the Vesta Model and this study, but would include: use of energy-efficient appliances and lighting and the average carbon emission factor of central electricity generation.

Different degrees of ambition within sectors

Of course 'switching on or off' of entire sectors is an over-simplification of the reality. It does not do justice to the fact that, within sectors in general, the degree of ambition to save energy and consume renewable energy differs. As an illustration, Nyenrode (2008) identified four categories of consumer. The researchers assumed that the categorisation was also applicable to owner-occupiers:

- the 'greens': a very small group (about five percent) for whom the environment is the decisive motive for purchase;
- 'cultural creatives': a group (about 30 percent) who are willing to pay more for sustainability, because they view sustainability as quality. However, a condition of this is that supply is not possible at other quality levels;
- 'ordinary people': the biggest group (about 45 percent), consisting of people who are definitely willing to buy environmentally-friendly products, as long as they do not cost extra, and as long as the quality is comparable to other (cheap) products; and
- 'hedonists': a group (about 20 percent) who see absolutely no environmental argument to buy anything.

Whether these percentages are typical of other sectors, such as landlords and sectors in non-residential building is unknown. On the supply side (contractors and fitters), in principle the majority have little inclination to apply new (sustainable) techniques. Most use mainly technology to which they are accustomed (Nyenrode 2008). Because demand from their customers is very limited, this 'conservative element' still pays little attention to the subject of energy saving, unless forced to do so by the regulations. Contractors and fitters also include a (small) group of trendsetters.

Two variants per route are analysed:

1. In the first variant, the technical and economic potential of *all* sectors is realised. This means that the cost-effective measures, insofar as they fit within the chosen route, are fully realised in both residential and non-residential construction and greenhouse horticulture. This ignores the fact that, in practice, due to non-economic obstacles, not all cost-effective measures are implemented.
2. In the second variant, only the technical and economic potential of a *selection* of sectors from the built environment is realised. The unselected sectors do not then contribute to the potential.[2] The selection was based on an analysis (see chapter 6) of obstructions which can mean that measures, though cost-effective in themselves, are not actually implemented in practice. The analysis shows that such non-economic obstacles impinge less on some sectors within the built environment than on others. Of course the 'switching on or off' of entire sectors is an over-simplification of the reality: see also the text box 'Different degrees of ambition within sectors.'

The selected sectors are:

- *Within the sector of housing construction for purchase*: only owner-occupiers with an income above a certain level. The reasoning is that owner-occupiers on lower incomes cannot finance the necessary investments. This criterion of selection only applies to construction measures, because local measures generally do not have to be financed by home owners.
- *Within the sector of housing construction for rent:* only homes built from the 1940s to the 1990s. The reasoning is that most of these were terraced houses and flats for which a standard, and therefore often cheaper, approach can be followed. Furthermore, no energy performance standard yet applied in the period referred to. Hence these are often not energy-efficient homes. This selection criterion applies to both construction and local measures.
- *Within the non-residential construction sector:* only hospitals, care homes, vocational colleges and universities and, besides, all companies with more than 100 employees. The reasoning is that, within such companies, more attention is probably paid to energy consumption and possible savings than

in the unselected companies (such as smaller offices, shops and horeca). This criterion of selection applies to both construction and local measures.

Largely for practical reasons, the selection does not include greenhouse horticulture. In principle, glasshouse businesses with unlit cultivation can use residual heat, geothermics or TES. For businesses with lit cultivation (and therefore higher electricity demand), in principle heat supplied via purchased electricity can hardly compete, if at all, with combined heat and power (CHP). As the Vesta Model cannot distinguish between businesses cultivating with and without lighting, the decision was made that the second variant should completely ignore greenhouse horticulture.

2.3 Sensitivity analysis

For each of the routes/variants, a sensitivity analysis was carried out to determine the influence of energy price levels and investment costs on construction measures. For energy prices, a bandwidth was assumed in which energy prices in 2010 are used as the lower limit and the estimated energy prices from the latest update of the Energy and Emissions Frame of Reference (PBL 2012) as the upper limit. For the costs of investing in construction measures, the lower limit is taken as the cost of investing in a project-based approach (several buildings at the same time), while the upper limit is an individual approach to a building (which entails higher costs, because there are no economies of scale). Higher energy prices (due to higher market prices, higher energy tax or a possibly future carbon levy on non-ETS sectors) will influence the cost-effectiveness of heat projects in different ways. On the one hand, they will lead to more energy being saved (hence less demand for heat). On the other hand, on the ‘No More than Otherwise’ principle (see Annex 2), higher tariffs may be required for the supplied heat. Higher market prices for energy lead to higher procurement prices for residual heat, geothermal energy and TES.
Higher investment costs for construction measures drive up costs and therefore mean it takes longer to recoup the investment through reduced energy consumption, or that this is not successful.

The levels of energy prices and investment costs therefore both influence the cost-effectiveness of measures. Low energy prices and high investment costs of construction measures (variant A) lead to a situation in which the return on investment can be earned least quickly. However, in the situation which combines project-based costs of construction measures with high energy prices (variant B), investments will yield the highest returns. Vesta uses Variants A and B, with their combinations of energy prices and investment costs, to explore the bandwidth of cost-effective measures. It does not consider cost variance of local measures. Instead of this, a variant is worked out in which energy prices have doubled by 2050. The cost-effective measures calculated for a doubling of energy prices can be viewed in practice as an upper limit on the achievable potential of the local measures. They are presented as technical potential of the local measures.

Notes

1 Open CHP is treated here as a local measure, because more dwelling units are generally connected to it (see paragraph 4.4).

2 In the case of construction measures, the exclusion of the unselected sectors does not influence the potential of the selected sectors. In the case of local measures, the following applies: projects which would be cost-effective if all buildings (i.e. from all sectors) in a locality were to participate may become unviable due to the loss of buildings from the unselected sectors.

THREE: Brief description of the working of the Vesta Model

3.1 Type classification of the Vesta Model

Working with CE Delft, PBL developed Vesta to explore routes which the Netherlands could possibly follow towards a low-carbon built environment and greenhouse horticulture by 2050 (CE 2011; PBL 2012). The Model is able to investigate what mix and priority order of construction and local measures is most cost-effective. Vesta is a spatial model to support policymakers in their decisions. It is not an optimisation model which 'automatically' calculates the most cost-effective route to a low-carbon built environment. It is also not a simulation model which can determine a most probable future.

How Vesta deals with local and construction measures respectively is explained below.

3.1.1 Local measures

The Model determines the potential of local measures (residual and geothermal heat and thermal energy storage - TES) based on cost-effectiveness calculations from the heat supplier's viewpoint. The Model only 'implements' a heat project if this is more cost-effective than heating by natural gas. It calculates the costs using cost figures for the heat source, the heat network and the connection of the building to the heat. The user of the Model can thus determine which type of heat to prioritise: residual, geothermal or TES.

Because heat projects are only likely to be viable if the distance between heat supply and heat demand is limited, the Model contains a spatial distribution of potential heat sources and buyers. On the supply side, it establishes where in the Netherlands companies which can supply the residual heat are located, and where conditions underground are suitable for geothermics and TES. On the demand side, it establishes where residential and non-residential buildings and growers under glass are located, and also where in the Netherlands new building and large-scale

renovation should take place. The distinction between existing buildings, on the one hand, and new build and large-scale renovation on the other hand, is relevant, because the costs of investment in local measures in the latter case will be considerably lower than in the
former. Paragraph 3.2 gives a more detailed description of how the Model determines the economic feasibility of new heat projects.

3.1.2 Construction measures

Unlike construction measures, the degree to which energy saving and building-related energy production[1] take place under the model is *not* based on cost-effectiveness calculations. Instead, it is largely the Model user's choice. The user can choose a maximum deployment of energy-saving measures,[2] but can also opt not to save energy in the existing buildings as a whole.[3]
This involves combinations of insulation measures (roof, floor and wall) and the use of energy-efficient heating boilers (such as the HR107). The user can also opt to deploy solar-powered boilers and/or electric heat pumps. In that case, renewable energy production takes place. The Model includes construction measures for residential and non-residential buildings, but not (yet) for greenhouse horticulture. The costs of using energy-saving packages are calculated based on the investment costs of bringing the buildings' energy performance up to Energy Label B. The type and year of construction of the dwelling, and sub-sectors of non-residential use, are identified here. The costs of the solar-powered boiler and electric heat pump are quoted for each option.

For existing residential buildings, Energy Label B was chosen, because this is the highest energy performance level achievable with insulation measures from Exemplary Homes 2011. Energy performance Label A is achievable if the insulation measures are supplemented with the solar-powered boiler and PV cells. For existing dwellings, the current understanding is that no higher energy performance level is achievable through existing techniques, unless the costs rise to an extreme level. For new-build homes, the reference calculation uses the current standard with regard to the energy efficiency of the shell. The presence of the energy-efficient HR107 boiler in 2050 is taken as a benchmark for the efficiency of the heating boiler, both for existing and new buildings. The solar-powered boiler can be used as a booster. In addition, the electric heat pump can be used as an alternative in new-build projects.

3.2 Calculations of cost-effectiveness of local measures

For each identified locality,[4] the Model calculates the returns and costs of large-scale heat distribution, based on numbers and features of buildings. These include the need for heat and the density and capacity of connection per building. The returns consist of a one-off connection charge and the annual income in the form of standing charge and heat supplied. The No More Than Otherwise principle is used to establish the income from supplied heat. Heat distribution costs consist of the investment[5] and maintenance costs for the transport and distribution network, the sub-stations, auxiliary heat boilers and connection and metering of homes.

The returns and costs take place in cash over the term of the project. The net cash value is the current value of the income and expenditure which take place in future.[6] Allowance is made for the fact that, in the first two years of a project term (typically 30 years), no income is earned, whereas repayment and interest costs are incurred.
This calculation shows at what price a heat supplier can still buy in heat and break even. This maximum procurement price is then compared with the production prices calculated in the Model for the various types of heat source (residual, geothermal and TES):

- The Model calculates residual heat costs on the basis of the one-off costs of investment in the release[7] of the residual heat (euro/kilowatt) and the cost price of heat production (euro/gigajoule). This allows for the fact that heat supply reduces power station output and that, at times of peak demand, this output has to be boosted by gas-fired boilers. In the case of residual heat, input of heat can take place over a longer distance (if cost-effective). In this regard, the Model allows for the losses of heat which occur during heat transport.

- It determines geothermal and TES production costs on the basis of the one-off costs of investment in the source and laying a heat pipe, including connection to customers (euro) and the variable costs of heat supply (euro/gigajoule). The Model assumes that TES does not involve longer-distance transport. The built-up area where the heat and cold generated are used is therefore around the source. In the case of geothermics, the Model does allow heat transport to localities where the underground conditions are not suitable for it (subject to cost-effectiveness).

The user of the Model can determine the priority order of calculation of the cost-effectiveness of the different heat source types. If TES is the first priority, then it is first established where in each district with postcode 6 TES is cost-effective. Then, with the remaining demand in postcode 4, it is established whether the other heat options (geothermal and residual heat) are cost-effective. On the other hand, if the first priority is geothermics or residual heat, whole areas with postcode 4 are allocated to these options (if cost-effective). That leaves no room for TES.

3.3 Starting-points of scenarios

A reference scenario has been used for the trend in carbon emissions to 2050. The reference contains the town and country planning developments in terms of numbers of buildings, hectares cultivated under glass, demolition and rate of replacement, and is based on a trend forecast from planning surveys (PBL 2012) (See Table 3.1).

Table 3.1

Features of the reference scenario

Reference features	2008-2050
Trend forecast	
Economic growth (average per year)	1.7% /year
Population growth (number of inhabitants)	920 000
Growth in housing stock (number of dwellings)	1 138 000
Growth in employment (number of jobs)	426 000

Growth in greenhouse horticulture (ha)	805 000
Demolition (number of dwellings)	1 204 000
Average rise in temperature (long-term average)	1.3ºC

The number of inhabitants is expected to grow by 920 000 to 17.5 million during the period from 2010 to 2050. Driven by this growth, and by a dilution in households, the housing stock will grow by 1.1 million dwellings to 8.2 million. The trend consists of the demolition of 1.2 million dwellings and the construction of 2.3 million new-build dwellings. Economic growth averages 1.7 percent per year. The number of jobs increases by 426 000 to 7 million, and the area cultivated under glass by 805 hectares to 11 000 hectares.

With the aid of the Vesta Model, we investigated what the effect is of the different routes on carbon emissions from the built environment and greenhouse horticulture. For this purpose, the routes were compared with the reference scenario. After replacement of housing (rebuilding), it is assumed that there are no further, autonomous energy efficiency improvements, except that all heating boilers are replaced with the energy-efficient HR107, now on the market.

The parameters for the current functional energy consumption in homes are taken, in the first instance for each type of dwelling and construction period, from Exemplary Homes 2011 (Netherlands Enterprise Agency 2011). Then the functional energy consumed for heating and hot water in existing dwellings is placed on a scale, so that domestic energy consumption together corresponds to actual national energy consumption according to Statistics Netherlands (CBS) and the Energy Research Centre of the Netherlands (ECN) in 2008. Functional energy consumption is placed on a scale, because the key figures from Exemplary Homes 2011 led to an over-estimate of national energy consumption by 40%, compared with actual national energy consumption. The present functional energy consumption of existing buildings in the non-residential sector and greenhouse horticulture are derived from statistics of the Netherlands Enterprise Agency in conjunction with national figures from CBS. They correspond to the actual energy consumption figures according to CBS and ECN in 2008.

The functional energy consumption of existing buildings is maintained equal in the target year, 2050. Finally, the calculation takes account of a 1.3ºC rise in temperature from the long-term average in 2008 until 2050. For more details, see the publication about the Vesta Model (PBL 2012).
Table 3.1 shows the developments which the reference assumes for the period 2008 to 2050, for a number of relevant parameters (PBL 2012).

In 2008 carbon emissions from the built environment and greenhouse horticulture totalled around 73 megatonnes. Demand for heat and cooling accounted for around 38 megatonnes of carbon, while 35 megatonnes was caused by electricity consumption by appliances (excluding air conditioning).

In the reference scenario, carbon emissions due to electricity consumption (excluding air conditioning) rise from 35 to 38 megatonnes in the period from 2008 to 2050. Because consumption per household and workplace is kept constant, this increase is caused by an increase in the numbers of residential and non-residential buildings. The carbon emission caused by demand for heat and cold stays roughly the same, despite the growth in the numbers of households and jobs: from 38 megatonnes in 2008 to 37 megatonnes in 2050. Table 3.2 shows a rise in non-residential carbon emissions and a fall for residential and greenhouse horticulture. Thus, on balance, there is a slight fall in total carbon emissions from the built environment and greenhouse horticulture. The decrease is caused primarily by a 1.3ºC rise in average temperature, based on a KNMI scenario for climate change (PBL 2012). Without this effect, carbon emissions for heating would be around 5 megatonnes higher. Due to the autonomous replacement of existing boilers with the efficient HR107s, carbon emissions fall by 2 megatonnes in relation to the existing boiler stock. Finally, 1.2 million existing dwellings are demolished and replaced with energy-efficient new builds, from which residential carbon emissions are around 1 to 2 megatonnes lower than from the current housing stock. The energy price trend and other starting points are described in CE (2011) and PBL (2012).

Table 3.2

Carbon emissions and energy consumption in the reference scenario

CO_2 (Mton)	2008				2050			
	Total	Residential	Non-residential	Greenhouse horticulture	Total	Residential	Non-residential	Greenhouse horticulture
Total CO_2	73	33	32	9	75	31	36	8
CO_2 heating/ cooling	38	17	16	5	37	15	17	4
Energy (PJ)								
Heat	684	334	260	90	620	275	270	75
Cooling	12		12		14		14	
Equipment	210	88	96	25	245	102	117	26

Notes

[1] e.g. through boilers, solar (PV), heat pumps and micro-heat power.

[2] In that case, all measures are taken which improve the building's energy performance to an average of Label B level.

[3] A new building's energy performance in Vesta is the same as the 2010 requirements in terms of insulation values (EPC 0.8). A new non-residential building has the same energy performance in Vesta as the existing building before 2010. Improvements through new buildings are possible in Vesta, through the use of solar boilers, electric heat pumps and the local measures.

[4] For TES, this assessment takes place at PC6 level; for residual heat and geothermics, at PC4. PC6 stands for postcode 6 (i.e. 1234 AB) and corresponds to the scale of (part of) a street (an average of approximately 15 dwellings). PC4 relates to all dwellings with the same postcode number. This is an area with an average of 1500 dwellings.

[5] In this case the investment costs are worked out on an annuity basis. This means that, over the lifetime, a fixed instalment plus annual interest are calculated. For each party, a different discount rate is calculated (households 5.5 percent; non-residential 8 percent; greenhouse horticulture 8 percent;

and energy utility 6 percent). Building measures and heating networks have a lifetime of 30 years, equipment a lifetime of 15 years.

[6] Formula: net cash value (NCV) = (income - expenditure)/$(1 + i)^t$ where i is the discount rate and t the time in years. For a project with a fixed term, the NCWs for all years are added up.

[7] Release means laying a heat pipe, including connection to the heat producer and customers.

FOUR: Technical description of local measures

In this chapter we briefly discuss the main features of local measures: residual heat, geothermics and thermal energy storage.

4.1 Residual heat

Residual heat is heat which power stations, waste incineration facilities or industrial companies supply to residential and non-residential buildings or glasshouses via a system of transport and distribution pipes (SenterNovem 2007). The distribution network generally also comprises one or more auxiliary boilers and distribution substations. The temperature of the heat for supply often lies between 70 and 120ºC. In addition to pumping energy, in some situations extra fuel is necessary to offset the loss of power generation caused by heat removal (actually this is a case of heat draw-off). In most projects, the heat is destined for interior heating and the supply of hot tap water. The economic feasibility of this heat supply depends primarily on the scope and density of demand for heat, and on the transport distance. The degree of coverage of the heat to be supplied is at least 80 percent. The remaining part is supplied from gas-fired boilers. At the moment, there are 13 large-scale[1] heat networks in the Netherlands. A total of 227 000 consumers are connected to them with a connection smaller than 1 000 kilowatts (CE 2009b).

The energy saving achievable with residual heat depends on the level of performance loss occurring at power stations, waste combustion facilities and industrial companies as a result of heat draw-off, how far heat is lost during transport, the necessary pumping energy and the quantity of natural gas burned in auxiliary boilers. According to SenterNovem (2007), in practice residual heat from waste combustion facilities and power stations represents an average primary energy saving to residential buildings of 50 percent, with a spread of 20 to 60 percent. In the case of industrial residual heat, the energy saving is nearly 100 percent, with a spread of 60 to 100 percent. As for greenhouse horticulture, no energy saving figures could be found.

Fig. 4.1 is a flow chart of a large-scale residual heat network.

4.2 Geothermal

Geothermal (also known as the Earth’s internal heat) is heat stored in the ground. In practice, this will almost always be heat located at depths from 1 500 metres. In the Netherlands, the temperature rises by around 31ºC per kilometre. The temperature of groundwater lying deeper than two kilometres may vary from 40 to 120ºC, according to position (ECN 2009). The Earth’s internal heat is usable for direct heating (without heat pumps) for homes and glasshouses and, from a depth of around three kilometres, also for power generation. The energy saved on heating amounts to 60 to 70 percent according to ECN (2009) and as much as 70 to 80 percent according to Platform Geothermie (2010).

Figuur 4.1	Fig. 4.1
Overzicht grootschalig warmtenet voor restwarmte	Flow chart of a large-scale residual heat network
Elektriciteitscentrale/ afvalverbrandingsinstallatie/industrieel bedrijf	Power station/waste incineration facility/industrial company
Restwarmte	Residual heat
Hulpwarmte	Boost heat
Hulpwarmteketel	Boost heat boiler
Warmteoverdrachtsstation	Heat transfer station
Onderverdeelstation Onderverdeelstation Onderverdeelstation	Distribution substation Distribution substation Distribution substation
Woningen	Residential buildings
Utiliteitsgebouwen	Non-residential buildings
Glastuinbouwkassen	Glasshouses
Warm water	Hot water
Koud water	Cold water
pbl.nl	Source: CE (2009b)

The Earth’s internal heat is tapped by drilling a geothermal reservoir at a few kilometres’ depth. These water-bearing strata are present in large underground areas in the Netherlands. The hot water is brought to the surface using one or more production wells. A heat exchanger releases the energy to a distribution network supplying houses or glasshouses with heat. The cooled water is pumped back into the reservoir in one or more injection wells, far enough away from the production well. A production and injection well together are called a doublet. The Netherlands' first deep geothermal doublet was sunk in 2007 at a tomato glasshouse in Bleiswijk. This company then sank a second doublet in 2009 for another company site at Berkel & Rodenrijs. In 2010 drillholes were started at a pot plant nursery in Pijnacker and at a residential district in The Hague South-West (Platform Geothermie 2010).

Fig. 4.2 is a diagram of a geothermal well doublet.

4.3 Thermal energy storage

There are two different systems in thermal energy storage (TES): open and closed systems. Both are briefly described here. However, the Vesta Model is too approximate to distinguish between open and closed systems.

4.3.1 Open thermal energy storage systems

In open TES systems, in principle two wells are drilled down to a suitable groundwater deposit. Most of these are between 20 and 200 metres down (Taskforce WKO 2009). In summer, heat is pumped out of the cold source (at about 7ºC). The cold is then used directly for cooling. The warmed water is returned to the heat source (15 to 25ºC). In winter, this warmed water and a heat pump heat the building, after which the cooled water flows back into the cold source. The heat pump brings the water up to a temperature of 40 to 55ºC (SenterNovem 2007). This is enough to

Figuur 4.2	Fig. 4.2
Doublet voor geothermie	Geothermal doublet
Woningen	Residential buildings
Utiliteitsgebouwen	Non-residential buildings
Glastuinbouwkassen	Glasshouses
Warmtewisselaar	Heat exchanger
1,5 km	1.5 km
Bron: Platform Geothermie (2010)	Source: Platform Geothermie (2010)

supply homes and buildings with heat at low temperature. This is floor and/or wall heating, which needs an input water temperature of 30 to 55ºC. Ordinary radiators are not suitable, because they need a higher input water temperature of 90ºC. Tap water must be reheated (e.g. with gas or electricity) to a level of at least 65ºC. Open TES systems can achieve a saving of primary fossil energy[2] of 50 percent (ECN 2009) on the combination of heating and cooling.

Open TES systems are larger systems suitable for big offices, residential complexes of around 30 to 50 houses, greenhouse horticulture and industrial sites. The systems radiate into the surrounding groundwater up to several dozen metres, often beyond the boundaries of their own plot of land. Hence such systems may interfere with adjacent TES systems, making the systems perform less well. Around 1 000 open TES systems are known in the Netherlands. Together they shift a volume of water equivalent to the annual quantity of drinking water obtained from groundwater.

Fig. 4.3 is a flow chart of an open TES system.

4.3.2 Closed thermal energy storage systems

Closed thermal energy storage systems work on the same broad lines as open systems. They occur at approximately the same depths. The difference is that no groundwater is pumped (Taskforce WKO 2009). Closed systems have ground loops (two to four per house) through which water is pumped, often with antifreeze such as glycol, to draw heat or cold out of the ground. The energy performance is generally somewhat lower than in open systems. According to ECN (2009), closed systems can save 30 to 50 percent of the energy in the combination of heating and cooling. Closed systems can be set up per house or for several dwellings collectively. They radiate little heat into the groundwater. Estimates suggest that there are 10 000 closed TES systems in the Netherlands at the moment.

Fig. 4.4 is a flow chart of a closed TES system.

Figuur 4.3	Fig. 4.3
Open warmte-koudeopslagsysteem	Open thermal energy storage system

Koudevraag	Demand for cold
Warmtevraag	Demand for heat
Watervoerend pakket	Water-bearing formation
Watervoerend pakket	Water-bearing formation
Warmtewisselaar	Heat exchanger
Bron: Taskforce WKO (2009)	Source: Taskforce WKO (2009)
Tijdens de koudevraag wordt koud water opgepompt en verwarmd op een andere plek teruggepompt. Tijdens de warmtevraag wordt het opgeslagen warme water opgepompt en weer afgekoeld teruggepompt in de oorspronkelijke bron.	During demand for cold, cold water is pumped up and, when warm, is pumped back at a different point. During demand for heat, the stored hot water is pumped up and, when cooled down, pumped back into the original source.

Figuur 4.4	Fig. 4.4
Gesloten warmte-koudeopslagsysteem	Closed thermal energy storage system
Koudevraag	Demand for cold
Warmtevraag	Demand for heat
Bron: Taskforce WKO (2009)	Source: Taskforce WKO (2009)
Tijdens de koudevraag wordt koude ontrokken uit de bodem, waardoor deze opwarmt. Tijdens de warmtevraag wordt warmte onttrokken uit de bodem, waardoor deze afkoelt.	During demand for cold, cold is drawn out of the ground, which warms it up. During demand for heat, heat is drawn out of the ground, which cools it down.

Notes

1 Large-scale means more than 5 000 consumers are connected.

2 Primary energy here means the quantity of energy consumed from a primary energy resource. A primary energy resource is an energy resource obtained from nature, such as crude oil, coal and forms of renewable energy (windmills, hydro). A secondary energy resource is an energy resource derived from conversion of primary energy resources. An example is electricity generated in a power station. Fossil here means crude oil, natural gas and coal.

FIVE: Economic parameters and potential local measures.

A trawl of the literature.

To determine how far the Model results presented in chapter 8 are valid across the whole technical and economic potential of local measures, the literature was trawled for available information on economic parameters (minimum scale, type and location of built-up area) and on future savings potential. The information presented in this chapter is first briefly summarised.

5.1 Summary

It is very expensive to lay out heat networks for the transport of residual and/or geothermal heat in existing buildings. Mostly, therefore, they seem cost-effective in large-scale renovation or new-build projects. Even so, this cost-effectiveness may come under pressure, because the demand for heat in new-build projects always turns out to be lower, as the energy performance coefficient improves.

In principle, TES is only suitable for large-scale renovation or new build, because the relatively low temperature of the heat source of a TES system necessitates floor and wall heating systems (see paragraph 4.3.1). The minimum numerical scale of residual and geothermal heat is a few thousand homes. Closed TES systems are suitable for individual houses and small offices, while open systems suit blocks of around 50 homes and larger offices. In principle, for residual heat, the distance between source and customer must generally be within 15 kilometres. Geothermal seems likely to be viable especially in parts of South Holland, North Holland, Friesland and Drenthe, while TES is applicable nearly everywhere in the Netherlands.

Figures from the literature about the future savings potential of residual and geothermal heat and TES mostly relate to 2020. For the later years, more relevant in the context of Vesta, the only information available is from an unpublished study by Milieu- en Natuurplanbureau (MNP) dated 2009. This only applies to geothermics and TES, but not to residual heat. The study estimates geothermal potential in 2040 at around 25 to 50 petajoules, and the potential of TES at around 10 to 30 petajoules. The bandwidths are caused by different assumptions about the pace of new build and renovation in different scenarios. It can be inferred from other studies that the saving potential of residual heat in 2020 will be about 50 petajoules. This counts residual heat networks, which save around 25 petajoules. The estimate is based on the residual heat sources now known.

5.2 Economic parameters

5.2.1 Minimum scale

Residual heat

The investment costs which have to be incurred to supply residual heat from power stations, industrial companies or waste processing facilities are so high that residual heat projects can only be cost-effective on a certain minimum scale. Still, it is hard to say where the lower limit lies, because the information given about this in the literature is not very clear. A summary of existing large-scale heat networks of Dutch utilities reveals a very wide variance in the number of 'connected customers'[1] per network (CE 2009b). This number ranges from a few thousand to just over 43 000. However, no conclusions can be drawn from this about a 'minimum cost-effective scale.' In fact many heat networks were laid with government support in the 1980s. Even with this support, many projects then encountered financial problems as a result of falling gas prices[2] and problems with project implementation. According to SenterNovem (2007), a project for residual heat from power stations, industry or waste processing facilities must comprise at least 10 000 dwelling equivalents, under the present scheme of subsidies,[3] in order to operate cost-effectively. However, this is unsubstantiated.

Rebel (2010) gives a computation model for the costs and returns of a new (unsubsidised) town heating network. In 10 years, 5 000 new build dwellings and 50 shops are connected to this at a steam and gas-fired power station.[4] The report concludes that this project would not be cost-effective, even starting with more favourable outline conditions.[5] It does not analyse whether larger heat projects can nevertheless be cost-effective.

Artificial manure manufacturer Yara, of Terneuzen, is going to supply an annual 1.6 petajoules of residual heat and CO_2 to an area of 250 hectares cultivated under glass (Dutch Energy Council 2009). No information has been found about a minimum scale for greenhouse horticulture.

Geothermal

According to MNP (2009), the investment costs for a successful geothermal doublet (a set of one production and one injection well) are of the order of EUR 8 to 12 million, but this looks a little high. The investment costs for a doublet of 6 megawatts thermal capacity for the heating of tomato glasshouses in Bleiswijk amounted to EUR 6 million (Ecofys 2009). To be cost-effective, a geothermal doublet must output 100 to 200 cubic metres per hour at a temperature of 60 to 80ºC. The thermal capacity of such a doublet lies roughly between 4 and 15 megawatts (Ecofys 2009).[6] This can meet the heating needs of several thousand homes. According to Ecofys (2007), the minimum scale is 2 400 dwelling equivalents with an average demand of 30 gigajoules. ECN (2009) gives a similar minimum scale of 2 500 dwellings. In South-West The Hague, an urban heating project is under construction with 6 megawatts thermal capacity. In the first stage, this will heat 4 000 houses, and in the second stage, 6 000 (Ecofys 2009).

In greenhouse horticulture, the cost-effective scale amounts to a few hectares. In Bleiswijk, for example, about 7 hectares of tomato glasshouse are heated by a doublet of 6 megawatts thermal capacity (Ecofys 2009). This is unlit cultivation; CO_2 is supplied via the Organic CO_2 for Assimilation by Plants (OCAP) pipeline (Ecofys 2007).

Because a doublet’s heat supply capacity is limited, there may also be a maximum scale. According to Bakker and Campen (2007), the underground space occupied by a doublet of 6 megawatts capacity is around 450 hectares. In concentrated built-up areas (such as high-rise, non-residential and greenhouse horticulture), the demand for heat over such a surface area is probably greater than one doublet can meet. This restriction probably applies to a lesser extent, if at all, to low housing.

TES

At the moment, open TES systems are mainly used in residential complexes, non-residential buildings (e.g. big offices), greenhouse horticulture and on industrial sites (I&M 2011b). According to ECN (2009), the demand for cooling capacity must be greater than 100 kilowatts in order to be cost-effective. This corresponds roughly to offices with a gross floor surface of more than 2 000 square metres or residential complexes of more than 50 dwellings. Small, closed systems are primarily used for individual homes and small offices. As for geothermal sources, there will be a maximum scale, because of the limited storage capacity of the ground, especially in concentrated built-up areas. This restriction probably does not apply to low housing, as this occupies more space above than below ground. According to MNP (2009), the underground space occupied for 1 000 well-insulated homes is 10 hectares, and above ground, 40 hectares.

5.2.2 Type of development

Residual and geothermal heat

From the point of view of cost-effectiveness, residual and geothermal heat are mainly suitable for large-scale new build or renovation. If the EPC rises further, however, it becomes ever more difficult to make these projects cost-effective, even for new build, as these reduce demand for heat, while the costs remain the same. But, for existing buildings, it is very expensive to lay the heat network.[7] Besides, providing a heat supply to new-build districts avoids all kinds of costs already incurred in existing districts, such as a natural gas main, and procurement and installation of central heating boilers. Another drawback with existing districts is that, especially for private owners, 100 percent coverage is rarely achievable (ECN 2011). In greenhouse horticulture, residual and geothermal heat are suitable for concentrated areas of unlit cultivation (especially vegetables) and strong demand for heat. Cheap CO_2 must also be available (Ecofys 2007). When cultivation is lit, heat supply probably cannot compete with combined heat and power, because electricity and CO_2 then have to be procured separately.

TES

In residential buildings (primarily with demand for heat), TES can only be used cost-effectively in new build or large-scale renovations, and not for existing buildings (MNP 2009). Due to the relatively low water temperature (about 40 to 55ºC), in fact, ordinary radiators cannot be used. Instead, floor and wall heating has to be applied. Furthermore, the houses must be well insulated, and a separate supply must be found (gas or electricity) for the supply of hot tap water.

In non-residential buildings, TES is primarily used for cooling. It may then be possible to use the existing air conditioning supply, so that TES is also usable in existing buildings (MNP 2009).

In greenhouse horticulture, TES combined with a heat pump is suitable mainly for closed and semi-closed glasshouses (Ecofys 2007). These need more cooling than heat.

5.2.3 Location of the development

Residual heat

In residual heat projects, it is important that the distance between supplier and customers for the heat is limited. Otherwise, the costs and heat losses become too great. Transport distances greater than 15 kilometres hardly ever occur in practice in the Netherlands (ECN 2010). Exceptions are transport from the Amercentrale power station to Breda and Tilburg.

Geothermal

The geological information to assess where in the Netherlands conditions are right to use geothermics is currently still limited. Inventory research by TNO suggests that locations primarily at Rotterdam, Alkmaar-Hoorn and some areas in Groningen, Friesland and Drenthe are potentially viable (KWR Watercycle Research Institute, 2010). The latest information from TNO is described in chapter 8.

TES

TES systems are used in most of the Netherlands. According to Ecofys (2007), as much as 95 percent of the Netherlands is suitable underground for TES. Regions which are less suitable are the eastern part of the provinces of Gelderland, Overijssel and Drenthe, Peelhorst in North Brabant and parts of Limburg (KWR 2010). Here, the water-bearing formations are too thin or completely missing. Even in those parts of the Netherlands which are suitable, there may be local impediments, such as groundwater catchment and soil contamination.

5.3 Future potential

In this paragraph, three factsheets explain the information found in the literature about the future savings potential of residual and geothermal heat and TES. The potential is expressed in petajoules of primary energy avoided. The factsheets make a distinction between estimates for the short term (2020) and longer term (towards 2050). Apparently, the availability of longer-term information is only limited.

The spread of the reported savings potential is wide. Much of this is because different starting points are used for each estimate of potential. To make this comprehensible, the starting points are briefly stated in the summaries.

Factsheet 5.1

Residual heat

Source	**Current scope**	**Further potential by 2020**	**Further longer-term potential (towards 2050)**	**Starting points**
ECN 2010	25 PJ, of which: • 18.6 PJ for housing (based on CE, 2009a) • 3.5 PJ to the	25 PJ, of which: • 20 PJ for the built environment • 5 PJ for	Not stated	• Relates to additional technical potential (compared with present application of residual heat) • Based on estimated maximum potential of 200 PJ residual heat

	sector of greenhouse horticulture	greenhouse horticulture		from industry and power station, much of which is eliminated: - supply and demand are too far apart - insufficient scale - some of the sources supply heat directly or are unavailable for other reasons • This leaves a residual 20 to 30 PJ of the total potential.
ECN 2011	Not stated	10 to 25 PJ	Not stated	• Relates to reasonably usable potential. Reasonable means that the residual heat usage really saves energy and/or reduces carbon emissions, that the costs are acceptable, and that there are no alternatives which can realise roughly the same energy saving or emission reduction more cheaply or easily. Some of the factors considered in the estimate of potential are temperature (whether or not it matches), coincidence of supply and demand and the distance between heat sources and potential customers.
Senter Novem 2007	Not stated	• 20.3 PJ of which 6.6 PJ for housing (260 000 units) • 0.5 PJ for non-residential building (2 600 000 m2 floor space) • 13.2 PJ for	Not stated	• This concerns the additional technical potential for four localities which meet the following conditions: - Several residual heat sources available (industrial CHP, industrial residual heat, waste processing facilities and/or power stations (baseload only) - heat network present which can be extended - National development area of

		greenhouse horticulture (1 135 ha)		greenhouse horticulture - Locations for expansion within the built environment (more than 1 000 homes): large-scale renovation is ignored due to lack of data - maximum transport distance 15 km • This is based on current specific residential demand for heat, whereas the expected specific heat demand from future dwellings will be lower. On the other hand, existing development is ignored.

Source	Current scope	Further potential by 2020	Further longer-term potential (towards 2050)	Starting points
Ecofys 2007	31 PJ, of which: • 24 PJ from power stations, of which 17 PJ is supplied to the built environment and 7 PJ to greenhouse horticulture (500 ha) • 7 PJ from waste processing facilities. Presumably this is supplied to the built environment.	17 PJ, of which: - 6 PJ from power stations - 11 PJ from waste processing facilities	Not stated	• Utilities expect 6 PJ from power stations, based on contracted and seriously expected expansions (from EnergieNed Energy Agenda 2007-2030) • 11 PJ from waste processing facilities is based on expansion in combustion capacity planned 'with reasonable certainty' and on condition that this includes maximum effort for heat supply. • Ecofys estimates low potential for heat supply to greenhouse horticulture, due to competition with CHP. CHP not only supplies heat, but also electricity (necessary for crop lighting) and CO_2.
CE 2009a	• 18.6 PJ of residual heat delivered • Number of connections in 2004 estimated at 250 000. Around 8 000 connections added per year	11.5 PJ	Not stated	• Based on an inventory of completed and planned projects. • Of the 11.5 PJ, 4.2 PJ is already planned. For the other 7.3 PJ, longer-term ambitions are involved. • This is specifically about supply to residential and non-residential buildings.

Factsheet 5.2

Geothermal

Source	Current scope	Further potential by 2020	Further longer-term potential (towards 2050)	Starting points
Ecofys 2007	At the moment there is one current project based on deep geothermics in greenhouse horticulture (Bleiswijk). This is 7 ha of unlit area (~ 0.1 PJ heat[1]) with CO_2 supply via the OCAP pipeline.	6.2 PJ, of which: • 1.4 PJ in housing • 4.8 PJ in greenhouse horticulture	Not stated	• Housing: it is estimated that 20 projects, of 3 000 new-build dwellings each, are feasible in the period up to 2020. The calculation of the quantity of primary energy avoided allows a COP of 10 for the pumps: for pumping 10 GJ of heat, 1 GJ of electricity is necessary. Ecofys sees greater potential for geothermics for making the existing heat networks more sustainable (on replacement of power stations). • Greenhouse horticulture: based on 50 projects of similar size to Bleiswijk. Ecofys calls this an ambitious but realistic estimate. Geothermics is only suitable for unlit cultivation where cheap CO_2 is available.
Platform Geothermie 2010	Not stated	3 - 15 PJ	Not stated	• Based on 2010 gas prices • Potential 'depends on government policy.' This is not further explained, but presumably the Platform is referring here to a structured guarantee scheme for wrong

				drilling, streamlining the long licensing procedure and evaluation of carbon emissions avoided.
ECN/PBL 2010a	Not stated	11 PJ	Not stated	• Assumption is that geothermics is used only in greenhouse horticulture. The potential corresponds to 100 projects. • Condition is continuation of the guarantee scheme and subsidy under the Market Launch of Energy Innovations (MEI) scheme. • The small number of companies that can carry out geothermal drilling is a factor limiting the application of geothermics: hence the potential may also turn out to be lower.
MNP 2009	Not stated	Not stated	23.5 - 50 PJ in 2040, of which: housing: 8.5 - 20 PJ greenhouse horticulture: 15 - 30 PJ	• Housing: the size of the potential depends on the rate of new build and renovation. The low estimate conforms to the Regional Communities (RC) scenario from Welfare & Environment (*Welvaart en Leefomgeving* - WLO). The high estimate corresponds to the Global Economy (GE) scenario. In both cases, the assumption is that geothermics is used in 50% of new build and 10% of renovation. For GE, the total is 550 000 homes; for RC, 240 000 homes. Only the Randstad is considered, because geothermal supply potential is

				greatest there. - Greenhouse horticulture: estimate based on 150 to 275 market gardeners of similar size to the Bleiswijk company (6 MW, 7.25 ha). This is the maximum national potential, when it has been established how many doublets can be sunk in each municipality (450 ha per doublet) and how great the area above ground is. Both heat demand and supply can be decisive factors in this.

Factsheet 5.3

TES

Source	Current scope	Further potential by 2020	Further longer-term potential (towards 2050)	Starting points
ECN 2009	0.5 PJ (heat)	1.7 PJ		• Estimate based on established policy
CE 2009a	2 PJ (estimate based on 850 locations)		30 PJ (only South Holland)	• Residential building: based on 400 000 heat pumps in 2020 (40% of new build/renovation in the period 2008 - 2020) • Non-residential building: potential if demand for heat and cold from all new build and large-scale renovation is supplemented with TES. Based on demand for 32 PJ of cold, which involves producing the same quantity of heat. • Greenhouse horticulture: based on 3 500 ha of semi-covered cultivation, of which 2 500 ha is cooled (cooling requirement 570 MJ/m^2). TES is used for cooling, because it is cheaper than chillers.
TTE 2009	Not stated	Not stated	13 PJ in 2040 (only Randstad)	• Based on estimated new build and redevelopment projects for the Randstad as per the 'Netherlands Later' scenarios. • Only open systems. • Adjusted for limitations of existing contamination and legislation.

ECN/PBL 2010a	Not stated	19 PJ, of which: • 1 PJ in households • 16 PJ in businesses • 3 PJ in greenhouse horticulture	Not stated	• Potential applies under planned policy, specifically higher EPC for non-residential buildings.
MNP 2009	Not stated	Not stated	8 - 32 PJ by 2040, of which: • Residential: 4 - 8 PJ (RC scenario) or 8 - 16 PJ (GE scenario) • Non-residential: 4 - 8 PJ (RC scenario) or 8 - 16 PJ (GE scenario)	• Residential building: the size of the potential depends on the rate of new build and renovation. The low estimate conforms to the RC scenario from WLO; the high estimate to the GE scenario. In both cases, it is assumed that 50% of newbuild and 10% of renovation use TES. Total for GE: 850 000 dwellings; for RC, 450 000 dwellings. Due to the low temperature (30 to 40ºC), wall and/or floor heating and good insulation are necessary. A separate supply is necessary for hot tap water. • Non-residential building: this is a saving on cooling. It is assumed that, in 2040, around 30% of the total non-residential buildings can use TES. This is based on a higher rate of new build than for residential.
I&M 2011b	• 1 200 open systems • 10 000 closed	11 PJ	Not stated	• 11 PJ based on extrapolation of the growth in recent years: • 10% per year for open systems

	systems			- 30% per year for closed systems - Quantity may be twice as much in 2020, but whether this is achieved depends on 'many factors' (including proposed legislation).

Notes

1 Almost all connections have a heat requirement less than 1 000 kilowatts.

2 On the NMDA principle, the price of gas is a significant determinant of the price of supply to small consumers.

3 Calculation of energy tax, Energy Investment Deduction and Green Investment Scheme (Regeling Groen Beleggen - SenterNovem, 2007).

4 The following starting points apply here: energy demand per home: 30 gigajoules; and per shop: 215 gigajoules; gradual expansion of heat network over 10 years; investments in heat network and connections: EUR 16 million and EUR 5 million respectively (the connection costs are charged to customers); procurement price of heat in the first four years EUR 26/gigajoule (heat of temporary facility); thereafter EUR 10/gigajoule (residual heat from steam and gas-fired power station); 20 percent of heat is supplied from peak boilers; maximum selling price (based on NMDA principle) EUR 18/gigajoule and standing charge EUR 225. The price of gas rises by 1.5 percent per year. The discount rate is 8.1 percent.

5 Annual rise in gas price 3 percent rather than 1.5 percent; procurement price of heat and investment costs are both 20 percent lower.

6 In theory, such capacity can deliver 130 to 470 terajoules of energy per year. Because summer demand for heat is limited, however, the number of full-

load hours will be of the order of 2 500 to 3 000. For greenhouse horticulture, the figure is rather higher: 3 000 to 3 500 hours (SenterNovem 2007).

7 According to Rebel (2010), it costs around twice as much to lay a heat network in an inner-city environment as in a new build situation. Rebel (2010) estimates the costs of laying a distribution network (excluding connections) for 4 000 existing inner-city homes at EUR 31 million; and for laying a distribution network for 5 000 new build homes and 50 shops at EUR 16 million.

8 The temperature of the hot groundwater is around 15 to 25ºC. Heat pumps can raise this temperature to 40 to 55ºC (SenterNovem 2007).

SIX: Potential of construction measures

To be able to determine how far the model results presented in chapter 8 are valid for the potential of construction measures (such as energy saving and building-linked energy production[1]), we investigated what information is available about future savings potential (including costs). Here we first summarise the results from the two main sources, then discuss those sources more thoroughly.

6.1 Summary

In the report Energy Performance Requirements for Existing Buildings (*Energieprestatie-eisen bestaande woningen* - CE 2009c), there is an estimate of what saving is achievable on natural gas if all existing dwellings built before 2000 are upgraded to Label B or higher. The comfort package is used for this purpose. For homes owned by housing associations, the total savings potential is 46 petajoules while, for private homes, it is 114 petajoules. There is also an estimate of what proportion of this potential is cost-effectively realisable. For homes owned by housing associations, this is 42 petajoules while, for private homes, it is 28 petajoules. Although the report set itself 2020 as its target year, the potential can be deemed relevant to later periods, because potential is calculated on the assumption that *all* existing homes are upgraded to Label B. Actually, it makes little difference in which year that is achieved.

The factsheets from the ECN Option Document (*Optiedocument)* give information on energy-saving potential (for 2020) and cost-effectiveness ratings for individual measures. The factsheets show that the savings potential of insulation measures in the existing residential and non-residential buildings is around 90 petajoules. 60 petajoules of this is in residential and 30 petajoules in non-residential buildings. The assumption is that all homes and buildings built before 1995 are insulated. The potential for residential buildings is therefore around 100 petajoules less than estimated in the CE report. The reason for this is unknown. Other construction measures, such as heat pumps and solar boilers, may add a few dozen petajoules of energy savings by 2050. A more precise estimate of the additional energy savings cannot be given. One reason is that the estimates in the factsheets are valid for 2020 and take account of the speed of implementation. Thus 100 percent penetration is not possible by 2020. Another reason is that the figures quoted in the factsheets are only valid if the measures are adopted separately. If they are adopted in combination with insulation, the effect will be less than stated.

6.2 Potential and costs of implementing the comfort package

The main conclusions from the Energy Performance Requirements for Existing Homes report (CE 2009c) are as follows:

- If the existing homes owned by housing associations are upgraded to Label B, a total carbon reduction of 2.6 megatonnes is achievable. That corresponds to around 46 petajoules of natural gas. 2.4 megatonnes of this (42 petajoules of natural gas) is achievable through cost-effective investments, provided that housing associations are given time to invest during renovation and at natural moments; otherwise the costs become much higher.

- 22 percent of the private homes built before 2000 can achieve Label B by cost-effective measures. In that case, the carbon reduction amounts to around 1.6 megatonnes (28 petajoules of natural gas). This cost-effective percentage is much lower than for housing association housing, because the measures can be taken less often during renovations of whole complexes and at natural moments of replacement. This means the costs are higher. The average weighted investment to achieve Label B amounts to around EUR 10 000. In many homes, the investments are lower but, in detached houses, they are necessarily higher. If all private homes, including those which are not cost-effective, achieve B labelling, the carbon reduction amounts to around 6.5 megatonnes (114 petajoules of natural gas).

The following method is used to estimate potential savings and the costs:

- Map out the labelling distribution of the dwellings built before 2000: approximately 8 percent are labelled F or G; 45 percent E; 29 percent D; and 18 percent B or C.

- The potential figures and costings are based on the ‘comfort package.’ This package comprises the following measures: floor insulation; roof insulation (flat or pitched); cavity wall insulation; HR++ glass; and combination boiler for tap water (HR107) and boiler for block heating (HR107). For each type of building, the package prescribes which measures are applicable. The CE report (2009c) also identifies potential and costs for what it calls the ‘comfort plus’ package. This package consists of the comfort package, to which individual or collective solar boilers are added. This makes its potential rather greater than reported above but, in any case, the package is not cost-effective.

- Cost-effectiveness is calculated by deducting from the annual costs (including mortgage for investment costs and VAT) the annual savings in the form of reduced gas consumption and any increase/decrease in electricity consumption. This assumes that a mortgage loan is taken out for the investment costs at an interest rate of five percent.

6.3 Potential and costs of individual measures as per factsheets

Factsheet 6.1 contains figures from the factsheets compiled by ECN in the context of its Option Document.[2] The factsheets quote potential figures for 2020.

In most cases, the quoted potential figures are not cumulative, because of interaction between the described technologies.[3]

Note that there is no factsheet for solar in non-residential buildings (PV) whereas, in Vesta, that is a technology with great potential.

Factsheet 6.1

Potential and costs of individual measures

Measure	**Potential in 2020**	**Costs**	**Starting points**
Limitation of demand in new build	4 PJ on natural gas	• National EUR 1 810/ton CO_2	• Potential if 1.3 million new build homes which,

(residential building)		• End-user EUR 1 898/ton CO_2	according to the GE scenario, are to be built in the period 2010 - 2020, have a shell with twice the heat resistance of an average new build house under the EPC (Rc = 10 versus Rc = 5). • The potential applies in relation to an EPC of 0.8.
Limitation of demand from existing buildings (residential)	61 PJ on natural gas	• National EUR 256/ton CO_2 • End-user EUR 88/ton CO_2	• Potential if all homes built before 1995 are insulated. This involves around 4 million homes. All roofs, walls and floors are insulated to Rc = 2.5.
Energy-efficient boilers with heat pump (residential)	14 PJ on natural gas	• National EUR 1 780/ton CO_2 • End-user EUR 1 700/ton CO_2	• Potential if, by 2020, 30 percent of HR107 boilers are replaced with boilers using a heat pump
Solar-powered boilers in existing (residential) buildings	2.5 PJ on natural gas	• National EUR 982/ton CO_2 • End-user EUR 841/ton CO_2	• Potential if 600 000 existing homes are equipped with solar boilers. This assumes that around 45 percent can be saved on natural gas burned for hot tap water.
Solar PV (residential)	8 PJ on electricity	• National EUR 715/ton CO_2 • End-user EUR 171/ton CO_2	• Potential based on 6.5 percent coverage of available roof surface in the built environment. This corresponds to 26

			million m^2 of solar panels, with 3 GW capacity.
Electric heat pump in new build (residential)	11.8 PJ on natural gas, at a cost of 2.3 PJ extra electricity consumption	• National EUR 485/ton CO_2 • End-user EUR 426/ton CO_2	• Potential if 30 percent of new-build homes, to be built in the period 2010 - 2020 according to the GE scenario (i.e. 35 000 homes) are equipped with an electric heat pump.
Limitation of demand from new build (non-residential)	3.4 PJ on natural gas	• National EUR 1 807/ton CO_2 • End-user EUR 2 624/ton CO_2	• Because of the lack of reliable data, it is assumed that demand for heat from buildings in business, services and government which are built between 2010 and 2020 can be reduced by the same percentage as for residential new build constructed in the same period. Besides, it is assumed that the costs per PJ saved in both sectors are the same. • It does not say how many buildings are built in the period 2010 - 2020. It does say that around 30 percent of the 2020 building stock will have been built since 2005.
Limitation of demand from existing (non-residential) buildings	29 PJ on natural gas	• National EUR 334/ton CO_2 • End-user EUR	Potential if all buildings built before 1995 are insulated. According to the GE scenario, this means 45 percent of the

		469/ton CO_2	building stock by 2020. Because of the lack of reliable data on non-residential buildings, it is assumed that the potential savings percentage is the same as for residential buildings (see above). It is also assumed that the costs per PJ saved are the same in both sectors.
Solar boilers (non-residential buildings)	0.5 PJ on natural gas	- National EUR 982/ton CO_2 - End-user EUR 1 149/ton CO_2	It is assumed that the saving from large solar heating systems (specifically for swimming pools, healthcare institutions and car washes) is three times that of the GE scenario. In that scenario, the saving rises from 0.2 PJ in 2003 to 0.3 PJ in 2020.
Electric heat pumps for heating (non-residential buildings)	2.7 PJ on natural gas, at the expense of 0.7 PJ of extra electricity consumption	- National EUR 224/ton CO_2 - End-user EUR 340/ton CO_2	Heat pumps are mainly used in new-build projects. The assumption is that the pace is three times faster than in the GE scenario.

Source: ECN factsheets, Options Document

Notes

1 Such as heating boilers, solar (PV), heat pumps and micro-heating power.

2 These factsheets can be found at http://www.ecn.nl/nl/units/ps/archive/nes/optiedocument/optiedocument-2010-2020/factsheets/

3 If, for example, heat demand limitation (insulation) and energy-efficient boilers are combined with a higher performance, the total potential is less than the sum of the potential figures quoted in the table.

SEVEN: Non-economic obstacles

7.1 Introduction

Paragraph 2.1 states that the Model has calculated two variants:

- one variant in which the technical and economic potential of *all* sectors is realised;
- and one variant in which only the technical and economic potential of a *selection* of sectors from the built environment and greenhouse horticulture is realised.

This chapter describes what the selection is based on. It outlines obstacles which may mean that measures or projects which are cost-effective in themselves are not implemented in practice. These are known as non-economic obstacles. The analysis summarised in Table 7.1 shows that fewer obstacles apply to some sectors of the built environment than to others. In principle, these are the sectors chosen for the model calculations carried out in the context of the second variant, such as owner-occupiers, offices and greenhouse horticulture. In some cases, however, there are justified deviations from this.

7.2 Behaviour model for the description of non-economic obstacles

For the description of the non-economic obstacles, a model of behaviour used by CE Delft is followed (see, for example, CE 2006 and CE 2010). The starting point is that cost-effective measures are only taken if the sectors meet a number of conditions, summarised as the will, the knowledge and the ability:

- Sectors must have the will (e.g. to get a lower energy bill or through concern for the climate problem).
- The necessary knowledge must be held, either by the client/developer or by the implementing parties (e.g. contractors and fitters).
- Sectors must have the ability to carry out the measures (e.g. be able to fund the necessary investments).

Obstacles apply mainly where no binding policy instruments are in force. If those instruments are in place, it is surely less important whether a sector has the will to adopt carbon reduction measures. The obstacles do not apply so much to new build (where an energy performance coefficient or EPC is usually applicable), but apply above all to existing buildings. At the moment, no obligations apply to existing housing. There are only voluntary agreements, e.g. via the More With Less (*Meer Met Minder*) initiative. The Environmental Management Act (*Wet milieubeheer)* imposes an obligation on non-residential building to implement energy-saving measures with a payback period of less than five years, but this is not enforced very strictly. Of course, the law for existing buildings may become more binding in the period before 2050. However, one condition for the introduction of a mandatory set of instruments is that the sectors should have sufficient knowledge and actually be able to implement the measures, and this includes finance.

Paragraph 7.3 lists the non-economic obstacles separately by sector. The purpose of this is to establish how great the probability is that each sector will actually take cost-effective measures. This has led to the selection of sectors presented in paragraph 2.2.

Although the CE behaviour model (2006, 2010) seeks mainly to describe obstacles to construction measures, in most cases it can be assumed that this also applies to local measures. It is briefly pointed out that the obstacles applicable to local measures for a number of reasons are of a different, more complex nature from those for construction measures. In the case of construction measures, the owner[1] of the home, other building or glasshouse can decide whether to implement these. For local measures, the willingness of potential customers to join a new heat project, especially in cases of large-scale renovation[2], is certainly a necessary precondition, but not itself sufficient to go ahead with a heat project. The decision-making surrounding such projects inevitably involves many more parties, who must all have the will to implement the project. It may be an energy utility, a heat supplier, a project developer and a province and/or municipality. These parties usually have diverging interests and operate on different timescales:

- The sticking point for the investor (usually the heat supplier) is that the long project terms (about 30 years) entails uncertainty about financial risk exposure. Not only the procurement price of heat may vary, but also the price of sale, because this is linked to the price of gas on the No More Than Otherwise principle. The extent of the uptake (and therefore the returns) may be unclear, because potential customers cannot be obliged to connect to a heat network. This lack of clarity applies especially to existing buildings, although that is where the greatest potential lies (CE 2009a). Anyway, the payback periods are long, because the necessary investments are high in relation to annual returns.

- For power stations and industrial companies, in the present situation, there is often insufficient motivation to supply heat. There is no obligation to do so, and companies gain no major financial advantages from it (CE 2009a). When supplying residual heat to a distribution project, there is no question of ordinary market forces and maximisation of returns. Instead, it is a monopoly situation, with supply at cost (or with slight extra returns). For most companies, heat supply is not a core business and it is not an attractive idea to make a long-term commitment to it, because it may limit freedoms in the ordinary course of business. Waste processing facilities do have a strong incentive to supply heat, in the form of obligations under the Environment Management Act and Integrated Pollution Prevention and Control (IPPC). A positive incentive for power stations may arise in the near future, because they will receive free emission rights for heat supply during the third trading period (2013 - 2020) of the ETS.

- Unclear points in the current legislation and long licensing procedures pose a risk for project developers and entrepreneurs in greenhouse horticulture, on the critical schedule of a new-build or renovation project (LEI 2008). To avoid these risks, a project developer will tend to opt for gas heating. The proposed amendments to the legislation (see Annex 2) are designed to make improvements in these points.

The obstacles to local measures are more numerous and complex than to construction measures. But this does not mean, by definition, that these have less chance of success in practice. A key success factor does seem to be the presence of one or more directors who feel committed to launching a large-scale heat project. These directors will map out opportunities and bring stakeholders together, and ensure that a contract is entered into and performed. This seems to be an important role earmarked for local authorities.

Finally, in many cases, clean gas and clean electricity are a good alternative, if the obstacles to construction and local measures are insuperable.

Table 7.1

Evaluation of obstacles to the implementation of cost-effective carbon reduction measures by sector

Sector	**Will**	**Knowledge**	**Ability**
Owner-occupiers	Low	Low	Dependent on financial position (income and assets)
Social rental sector	Present	High	Limited: housing associations are currently in a poor financial position
Private rental sector	Low	Low	Institutional investors: reasonable Private landlords: unknown
Offices	Low	Low	Presumed low: the office market is currently in a bad way

Hospitals and healthcare	High	Reasonable, but declining	Limited, due to relative low standard amounts for building maintenance
Shops	Low	Low	Dependent on financial position
Education: primary and advanced	Low	Limited	Low
Education: universities and vocational education colleges	Present	Present	Unknown
Industrial sheds	Especially low	Limited	Unknown
Horeca	Unknown, but presumed low	Unknown, but presumed low	Unknown
Greenhouse horticulture	Unknown, but presumed high	Unknown, but presumed high	Unknown

7.3 Summary of non-economic obstacles

Table 1 is an evaluation of how far non-economic obstacles apply to the different sectors. The table is a summary of the more thorough descriptions given in Annex 1. The information given is based on CE (2006, 2009a and 2010). Table 7.1 summarises the findings for the aspects ‘will,’ ‘knowledge’ and ‘ability’ by means of quantitative indicators such as ‘low,’ ‘high’, ‘present’ or ‘limited.’

The table is used to establish the sectors selected in paragraph 2.1 in the context of the second variant. In this selection, however, the evaluation in Table 7.1 is not always directly followed:

- In the table, the ‘will’ and ‘knowledge’ of owner-occupiers is rated low; nevertheless, owner-occupiers above a certain income threshold are actually selected for the second variant.

- The table makes a distinction between the social and private rental sectors. The social rental sector scores much better on ‘will’ and ‘knowledge’ than the private rental sector. However, the Vesta Model is unable to make this distinction and makes a selection across the rental sector as a whole, based on period of construction.

- The selection within non-residential building (hospitals, care institutions, vocational colleges and universities can be justified on the strength of the assessment in the table. The selection for the second variant also contains companies with more than 100 employees. These companies are added on the basis of their (own) estimation that, on this scale, non-economic obstacles are going to play a lesser role for shops, offices etc.

Notes

1 In the built environment, this is the owner-occupier or landlord.

2 In the case of new build, the future customers (the occupiers) probably have much less say in the decision-making on how heat is supplied to the home or other building (gas or residual or geothermal heat or TES).

EIGHT: Results of model calculations

8.1 Introduction

Chapter 2 described the routes which may lead to more sustainable demand for heat and cold from the built environment and greenhouse horticulture by 2050. The routes entail two categories of measure: construction, and local. The construction measures comprise both heat saving and heat supply methods set up 'behind the meter,' such as solar-powered boilers and heat pumps. Both bring down the demand for heat for buildings. The local measures, such as residual and geothermal heat and thermal energy storage (TES) ensure a cleaner collective supply of heat and cold to buildings.

The solar (PV) cell, which generates sustainable electricity, can be installed on rooftops and external walls. This measure does not compete with the heat and cold options and can be used without the other measures, but also in addition to them on any other route. We have therefore reviewed the potential of this option separately. We have not examined other options for making electricity consumption more sustainable, such as improving the efficiency of electric appliances and lighting. We also do not cover small windmills on buildings or in districts.

In table 8.1, the different routes calculated with the Vesta Model are worked out further. They are:

- **Construction measures:** a route entailing only construction measures for heat saving and generation.
- **Local measures:** a route which only uses local measures for heat and cold.
- **Combined route:** a route which takes construction measures first, followed by the use of local measures.

For all routes, we examine the cost-effective potential at various energy prices. We also examine the technical potential of all measures.

The results are given in a bandwidth, because trends to 2050 are uncertain. The cost-effectiveness of energy measures is closely dependent on the investment costs and energy prices. In our study, we assume that the energy measures are taken between 2010 and 2050. Then it makes sense to use the costs and energy prices as they develop during this period.

Because of the uncertainty about trends in energy prices and investment costs in the period from 2010 to 2050, two extreme variants are considered. Variant A is 'low energy prices and high investment costs.' Here, all energy measures are calculated from 2010 energy prices. The costs of the insulation measures are based on an approach tailored to individuals. This variant gives a lower limit for carbon emissions avoided by cost-effective energy measures, because relatively low energy prices and relatively high investment costs are used for the calculation.

Table 8.1

The routes and their packages of measures

Route	Measures
Construction measures	Insulation of existing buildings: in 2050 the present buildings are labelled B for energy efficiency. Similar measures are taken to improve existing non-residential buildings. Solar power is used for residential and non-residential buildings. All new buildings are equipped with an electric heat pump. Greenhouse horticulture: no measures
Local measures	Use of local heat in the following order: - residual heat - geothermal - TEO - District CHP

	The choice of this order is dictated by the expected national total and energy-specific carbon emission avoidable through these local measures. This is a robust Netherlands-wide approach, but depends on several specific and local circumstances.
Combination of construction and local measures	First the construction measures, then the local measures, are implemented.
PV option	Use of solar PV: 10 m^2 per roof for residential buildings (if there are several dwellings under one roof, this is divided by the number of dwellings) and 80 percent of the roof surfaces of non-residential buildings.

Variant B is ‘high energy prices and low investment costs.’ It uses the future energy prices from the latest update of the Frame of Reference for Energy and Emissions (PBL 2012). The costs of the insulation measures follow a project-based approach. Therefore this variant allows for relatively high energy prices and relatively low investment costs. The variant therefore gives an upper limit for the carbon emissions avoided through cost-effective energy measures.

In reality, it is unknown how the energy prices and investment costs will develop. For example, maybe energy prices in 2050 will be even higher than in the Frame of Reference. By working for the whole period up to 2050 with, on the one hand, present-day energy prices and high investment costs and, on the other hand, the future energy prices from the Frame of Reference and low investment costs, we can present the carbon reduction through cost-effective measures as a bandwidth appropriate to an energy price and cost trend over the whole period 2010 to 2050.

In Variant A, the price of gas is EUR 0.64 per cubic metre for domestic and small business customers and EUR 0.20 per cubic metre for major corporate customers. In Variant B, the gas price is EUR 0.80 per cubic metre for domestic and small business customers and EUR 0.41 per cubic metre for major corporate customers.

In addition, local heat sources are calculated, with a doubling of the high energy prices. This price variant, for local heat sources only, determines the technical potential of the local heat sources. The technical potential of the construction measures is independent of the energy price and costs of investment in the insulation measures.

8.2 Climate target

It is the ambition of the European Commission to reduce greenhouse gas emissions by 80 to 95 percent of their 1990s levels, by 2050. In the 2050 Climate Roadmap (*Klimaatbrief 2050,* I&M 2011a), the Rutte cabinet supplements this, by outlining how the Netherlands can make the transition to a climate-neutral economy. To achieve this goal will require a more sustainable supply of heat to the built environment (PBL and ECN 2011). The envisaged construction and local measures may contribute to this, by halving the carbon emitted by the heat supply to the built environment and greenhouse horticulture by 2050, compared with 1990.[1]

If only cost-effective construction and local measures are implemented, carbon emissions will be 15 to 30 percent lower in 2050 than in 1990. The bandwidth depends on the trends in the costs of investing in the construction measures, and in energy prices.

Fig. 8.1 shows the carbon reduction potential in 2050, calculated by Vesta for the different routes described in Table 8.1. The cost-effective reduction potential is greatest for the combination of construction and local measures (6 to 11 megatonnes of carbon). The cost-effective reduction potential for the construction measures only is 0 to 8 megatonnes. The cost-effective reduction potential is of the same order of magnitude, namely 4 to 6 megatonnes, but the bandwidth is narrower.

Fig. 8.1

Carbon reduction 2050

Dutch	**English**
Gebouwmaatregelen	Construction measures
Rendabel potentieel bij variant A / B	Cost-effective potential of Variant A / B
Technisch potentieel	Technical potential
Gebiedsmaatregelen	Local measures
Combinatieregelen	Combined measures
Maatregelen	Measures
Zonneboiler	Solar-powered boiler
Isolatie	Insulation
Elektrische warmtepomp	Electric heat pump
Restwarmte	Residual heat
Geothermie	Geothermics
Warmte-koudeopslag	Thermal energy storage
Wijk-warmtekrachtkoppeling	District combined heat/power
Reductie ten opzichte van referentie	Reduction from benchmark

Variant A: low energy prices and high investment costs of construction measures.

Variant B: high energy prices and low investment costs of construction measures.

Source: PBL

Part of the reason why the bandwidth is narrower is that the cost-effectiveness of the local measures is less sensitive to energy prices than the construction measures. Another explanation is that investment costs are treated as a variable in construction measures whereas, with local measures, this is not done.

The technical potential for reduction is considerably greater than the cost-effective potential. The technical reduction potential of the combined construction and local measures is 19 megatonnes of carbon. That makes it nearly twice the cost-effective potential of Variant B, ‘high energy prices and low investment costs.’ The technical potential of construction measures (16 megatonnes) is twice that of the cost-effective potential of Variant B, ‘high energy prices and low investment costs’ (Fig. 8.1). The ‘technical’ potential of local measures, about 8 megatonnes of carbon, is 20 percent greater than the maximum cost-effective potential. The measures are investigated further below.

8.2.1 Construction measures

The cost-effective potential on the route of construction measures consists of floor, wall and roof insulation conforming to Label B, for part of the residential and non-residential buildings. The solar-powered boiler and electric heat pump are not cost-effective in both the low and high energy-price variants. Tables 8.2, 8.3 and 8.4 show the residential and non-residential types for which insulation measures to Label B are cost-effective. This cost-effectiveness differs. In Variant A, energy prices (2010) are low, combined with the high investment costs of construction measures, in an individual approach. In Variant B, energy prices are high, according to the latest updated Frame of Reference (PBL 2012), combined with investment costs of construction measures following a project-based approach.

In Variant A (low energy prices and high investment costs), 1.6 percent of the existing housing is cost-effective for insulation measures. No non-residential buildings are cost-effective for construction measures. Most residential buildings are apartment blocks dating from the period 1900 to 1939. In Variant B (high energy prices and low investment costs), insulation is cost-effective for many more homes.

Non-residential buildings from several sub-sectors can also be brought up to Label B level cost-effectively. Insulation is cost-effective for one-quarter of the present housing stock. These are single-family homes up to 1960 and pre-Second World War apartment blocks. Single-family homes from later years of construction, and apartment blocks (such as gallery flats and retirement flats) with relatively small surface area (less than 80 square metres) from all construction periods are not cost-effective. In the non-residential sector, nearly half the floor surface can be insulated cost-effectively. These are offices of businesses, services and government; hospitals; nursing and care homes; and horeca. Buildings for which the insulation measures are not cost-effective occur in the sub-sectors of shops, education, the motor trade, automotive repairs and wholesaling.

The cost-effective potential for the insulation measures is 0 to 8 megatonnes of carbon by 2050. The range spans cost differences due to a project-based approach to buildings (cheaper) or an individual approach to each building (more expensive), and to the differences in energy prices in Variants A and B. In the case of dwellings, the potential varies between 0 and 3.5 megatonnes of carbon. The potential for non-residential buildings varies between 0 and 4 megatonnes, but this figure is very uncertain, because there is a lack of sound figures for these buildings. The technical potential of construction measures is around 16 megatonnes of carbon. Most of this potential consists of insulation measures, which bring the dwellings to energy performance Label B (12 megatonnes). This is the highest energy performance level for existing dwellings, achievable with insulation measures from Exemplary Homes 2011. The solar-powered boiler and electric heat pump also save 3 and 2 megatonnes of carbon respectively. The solar boiler saves mainly in residential, but also non-residential, buildings, where the need for hot water is much lower. The solar boiler and the insulation measures can achieve energy performance Label A if just one more solar panel is installed. For existing buildings, the current understanding is that higher energy performance levels are not achievable with existing methods, unless the costs rise to an extreme degree. Demolition and rebuilding have been ignored, because the costs are usually high. The route for construction measures does not include greenhouse horticulture.

Table 8.2

Dwellings in which insulation to Label B is cost-effective in Variant A, 'low energy prices and high investment costs.'

Type of dwelling	**Year of construction**	**Number of dwellings**	**Total proportion**
Blocks of flats with less than four storeys	Pre-1800	1 598	0.0%
	1800 - 1899	4 974	0.1%
	1900 - 1919	13 372	0.2%
	1920 - 1939	46 986	0.7%
Flats/flats in canalside houses	Pre-1800	5 341	0.1%
	1800 - 1899	6 325	0.1%
	1900 - 1919	11 581	0.2%
	1920 - 1939	7 558	0.1%
Student houses/flats	Pre-1800	1 003	0.0%
	1800 - 1899	2 071	0.0%
	1900 - 1919	3 566	0.1%
	1920 - 1939	4 319	0.1%
Total		108 694	1.6%

8.2.2 Local measures

On the route using local measures, the reduction from cost-effective measures is about 4 to 6 megatonnes (Fig. 8.1). Most of this potential consists of residual heat and district CHP (3 and 2.5 megatonnes). District CHP has most potential with the low energy prices of Variant A, which are based on actual energy prices for 2010. However, the potential falls sharply to 0.3 megatonnes with the high energy prices of Variant B, which are based on estimated energy price trends (PBL 2012). This is because the estimated price of gas rises more sharply than the electricity price. That means CHP is no longer so cost-effective. TES has a small potential of around 0.5 megatonnes of carbon.[2] The cost-effective potential of geothermics is only 0.1 megatonnes of carbon. In the case of local measures, the 'technical' potential is based on measures which are cost-effective with an estimated doubling of energy prices by 2050. For district CHP, 2010 energy prices are used to determine technical potential because the cost-effective potential is greatest in these circumstances. As energy prices rise, cost-effectiveness falls. The technical potential of local measures is around 7 megatonnes, most of which results from the use of residual heat (4 megatonnes) and district CHP (2.5 megatonnes).

One comment to make on these calculations is that they use a geothermal contour map with a probability of successful drilling of 70 percent or more. Only a very small portion of the Dutch ground meets this criterion. If contours with a probability of 10 percent or more, or an unknown probability, are included, a cost-effective potential from 0.5 to 6 megatonnes is possible (see next paragraph).

Table 8.3

Dwellings in which insulation to Label B is cost-effective in Variant B 'high energy prices and low investment costs'

Type of dwelling	**Year of construction**	**Number of dwellings**	**Total proportion of 2008 housing stock**
Mansions/canalside houses	Pre-1800	11 695	0.2%
	1800 - 1899	16 774	0.3%
	1900 - 1919	27 602	0.4%

	1920 - 1939	20 127	0.3%
	1940 - 1959	4 819	0.1%
Farmhouses/nurseries	Pre-1800	2 963	0.0%
	1800 - 1899	9 369	0.1%
	1900 - 1919	16 773	0.3%
	1920 - 1939	22 539	0.3%
	1940 - 1959	18 604	0.3%
Detached housing/bungalows	Pre-1800	6 587	0.1%
	1800 - 1899	21 020	0.3%
	1900 - 1919	55 464	0.8%
	1920 - 1939	146 525	2.2%
	1940 - 1959	119 335	1.8%
Semi-detached	Pre-1800	1 133	0.0%
	1800 - 1899	3 717	0.1%
	1900 - 1919	18 380	0.3%
	1920 - 1939	87 583	1.3%
	1940 - 1959	93 119	1.4%
Terraced houses/single family	Pre-1800	12 815	0.2%
	1800 - 1899	31 409	0.5%
	1900 - 1919	107 679	1.6%
	1920 - 1939	296 533	4.5%

	1940 - 1959	337 691	5.1%
Blocks of flats with fewer than four storeys	Pre-1800	1 598	0.0%
	1800 - 1899	4 974	0.1%
	1900 - 1919	13 372	0.2%
	1920 - 1939	46 986	0.7%
Flats/maisonettes	Pre-1800	3 895	0.1%
	1800 - 1899	12 487	0.2%
	1900 - 1919	39 789	0.6%
	1920 - 1939	96 376	1.5%
	1940 - 1959	55 039	0.8%
Flats/flats in canalside houses	Pre-1800	5 341	0.1%
	1800 - 1899	6 325	0.1%
	1900 - 1919	11 581	0.2%
	1920 - 1939	7 558	0.1%
Student flats/flats	Pre-1800	1 003	0.0%
	1800 - 1899	2 071	0.0%
	1900 - 1919	3 566	0.1%
	1920 - 1939	4 319	0.1%
Total		1 806 535	27%

Table 8.4

Non-residential sector, where Label B insulation is cost-effective in Variant B, 'high energy prices and low investment costs'

Non-residential sector	Floor surface (gross; million m^2)	Percentage of total
Offices	126	19%
Nursing and care	22	3%
Including hospitals	7	1%
Horeca	55	8%
Other services	95	14%
Total	305	46%

The sequence in which heat techniques are deployed (see Table 8.1) affects the potential. If district CHP or geothermics is allocated first, their potential rises by 75 percent. In the case of TES, there is hardly any change in potential. Apparently only a limited proportion of the TES locations are cost-effective for other heat supply options. The TES locations comprise a limited selection of part of the building stock, because it is only used in the calculations for new build.

8.2.3 Combination

The route combining construction and local measures will have a cost-effective potential of 6 to 11 megatonnes of carbon by 2050. Compared with the separate routes, the combination of both routes offers no extra cost-effective potential for carbon reduction in Variant A, 'low energy prices and high investment costs.' This is because there is no cost-effective potential for construction measures in this variant. A combination of both routes for Variant B, 'high energy prices and low investment costs' does yield extra cost-effective potential for carbon reduction. In fact many other cost-effective residual heat projects are possible after the construction measures are implemented. Part (25 to 30 percent) of the residual heat potential of the construction measures route cannot, however, be cost-effectively used on the combination route, because the result of the construction measures is to reduce demand for heat. The technical potential of the combination route is around 19 megatonnes of carbon: around half the total emissions caused by heating and cooling.

8.2.4 Solar (PV) option

Solar (PV) has great technical potential. With solar (PV) in 2050, the emission of 22 megatonnes of carbon, in other words about half the reference emission from electricity consumption, can be avoided. In non-residential buildings, especially, there is great potential (18 megatonnes). This is because these buildings offer a large roof surface. On existing non-residential buildings, the greatest solar (PV) potential can be found in the sectors of wholesaling (26 percent), the motor trade and repairs (22 percent) and education (16 percent). The question is whether all generated electricity can be used, because the solar cells do not have to generate electricity to coincide with the demand for electricity in the built environment. Hence the financial benefits are hard to estimate. Also, the trend in the costs of procurement of solar cells in the period 2010 to 2050 is (very) uncertain. An analysis of these uncertainties falls outside the scope of this study. Therefore the cost-effective potential of solar cells has not been established.

8.3 Renewable energy target

In addition to the European climate target of an 80 to 95 percent reduction in greenhouse gas emissions, there is no separate target for renewable energy in the Netherlands for 2050. There are European agreements for 2020, under which the proportion of renewable energy in the Netherlands must amount to 14 percent.

Renewable energy techniques in the construction and local measures[3] can achieve a 13 to 18 percent proportion of renewable energy out of the total heat supply to the built environment. Using cost-effective renewable energy techniques[4] alone, a proportion of 6 to 9 percent can be achieved. The bandwidths depend on the total demand for heat, which is influenced by whether buildings are insulated. Solar cells on roofs and walls of residential and non-residential buildings can meet 55 percent of the demand for electricity from the built environment and greenhouse horticulture by 2050. However, whether and how such power generation can be used is not explored (see last paragraph).

The construction measures which contribute to the renewable energy target are the solar-powered boiler and the electric heat pump. The local measures which contribute to it are geothermics and thermal energy storage (TES). In addition, solar (PV) is

Fig. 8.2

Renewable energy, 2050

Dutch	**English**
Gebouwmaatregelen	Construction measures
Rendabel potentieel bij variant A / B	Cost-effective potential of Variant A / B
Technisch potentieel	Technical potential
Gebiedsmaatregelen	Local measures
Combinatieregelen	Combined measures
Maatregelen	Measures
Zonneboiler	Solar-powered boiler
Elektrische warmtepomp	Electric heat pump
Geothermie	Geothermics
Warmte-koudeopslag	Thermal energy storage

Variant A: low energy prices and high investment costs of construction measures.

Variant B: high energy prices and low investment costs of construction measures.

Source: PBL

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treated as a separate option. On the route with construction measures, neither the solar-powered boiler nor the electric heat pump is cost-effective. The technical potential of these is around 110 petajoules. Here, the electric heat pump is the most important option, accounting for 75 petajoules, followed by the solar boiler at 35 petajoules. Most of the potential for the solar-powered boiler lies in residential buildings (80 percent).

The cost effective portion of renewable energy from the local measures will amount to around 42 to 46 petajoules by 2050 (Fig. 8.2) and consists of TES and geothermics. TES has the greatest potential, at around 40 petajoules. The cost-effective potential of geothermics is small (0 to 2 petajoules), with a probability plot of 70 percent or higher on the route with local measures. This is because the contour for the use of geothermics is limited, and because residual heat has priority. If the contour with more than 10 percent or an unknown probability is considered, and geothermics has priority, then this potential may in theory rise to 30 to 115 petajoules at present-day prices, and to 55 to 225 petajoules at 2050 prices (see next paragraph).

The technical potential for sustainable energy is around 70 petajoules in 2050. The options here are TES (62 petajoules) and geothermics (8 petajoules). The order in which heat technologies are deployed (see Table 8.1) affects the potential. If geothermics is allocated first, its potential increases by 75 percent. In the case of TES, there is hardly any change in potential. Apparently only a few of the TES locations are cost-effective for other heat supply options. In combination, the cost-effective potential is around 42 petajoules and is supplied almost entirely by TES (see also Fig. 8.5). The technical potential is around 70 petajoules. The main options here are TES (40 petajoules) and the solar-powered boiler (35 petajoules). Local measures, some of which are not renewable, largely replace the electric heat pump.

The electric heat pump (EHP) and TES are both relatively new technologies. Because they use (very) low temperature systems, which can only be installed in existing buildings at high cost, they are only used as an option in new build, in both residential and other new-build projects. However, most of the potential for TES and the EHP (75 percent) is non-residential. The EHP is not cost-effective, either in Variant A or in Variant B, but does have great technical potential. It is possible that the costs of investment in the EHP will fall further, making the EHP cost-effective, but it is hard to predict the costs of investing in the EHP. TES has a cost-effective potential of about 40 petajoules, in both Variants A and B. In practice, the use of TES increased tenfold, from 0.2 to 2.4 petajoules, in the period from 2005 to 2010 (CBS 2011). The model results are in line with this, because the vast majority of the expected new build has yet to be built. Solar (PV) is an important construction option for the supply of sustainable electricity. This option has a technical potential of 140 petajoules. This will be 55 percent of the electricity demand from the built environment and greenhouse horticulture by 2050.

Table 8.5

Supply of heat and cold by local measures in 2050 (PJ)

	Cost-effective at low energy prices	**Cost-effective at high energy prices**	**Technical potential**
Residential	80	61	113
Non-residential	109	101	124
Greenhouse horticulture	0	1	5

As displayed above, non-residential construction has most of this potential. Whether and how to use the electricity generated by solar (PV), and the cost-effective potential, have not been investigated (see last paragraph).

8.4 Geographical spread of local measures

Local measures supply energy in the form of heat and cold to residential and non-residential buildings and to greenhouse horticulture (Table 8.5). They take place spread across the Netherlands (Figs. 8.3, 8.4 and 8.5).

Because of the necessary size, concentrated demand for heat, and the limitation of the distance over which residual heat can be transported, the use of residual heat is limited to a number of urban areas (marked red in Figs. 8.3 and 8.4). The number of localities with residual heat remains approximately equal if the energy price in Variant A is increased to Variant B. Of course, there are localities where geothermal heat becomes cost-effective due to higher energy prices. On the other hand, there are localities with district CHP which drop out (for an explanation, see paragraph above).

If the high price of energy goes on to double, as used to calculate the technical potential (Fig. 8.5), localities where demand for heat is less concentrated and/or which are further away from the source can cost-effectively be connected to a residual or geothermal heat network (see Figs. 8.3, 8.4 and 8.5). Residual heat networks then expand considerably, especially in localities around residual heat sources in Zeeland (the Sloegebied and Flushing), Europoort, South Limburg (Geleen) and Eemshaven. Most of the expansion in geothermics takes place in the north.

Fig. 8.3

Cost-effective local measures by 2050 at low energy prices

Dutch	**English**
Wonen	Residential
Utiliteit	Non-residential
Glastuinbouw	Greenhouse horticulture
Restwarmte	Residual heat
Geothermie	Geothermics

Warmte-koudeopslag	Thermal energy storage
Wijk-warmtekrachtkoppeling	District combined heat and power
Aardgas	Natural gas

N.B. Dots denote the location and are not representative of the surface area of the local measures.

Source: PBL

Fig. 8.4

Cost-effective local measures by 2050 at high energy prices

N.B. Dots denote the location and are not representative of the surface area of the local measures.

Source: PBL

Fig. 8.5

Technical potential of local measures by 2050

N.B. Dots denote the location and are not representative of the surface area of the local measures.

Technical potential = cost-effective potential when high energy prices are doubled.

Source: PBL

Based on a doubling of 2050 energy prices

Fig. 8.6

Probability of the presence of viable geothermics

2011 calculations

Probability (%)

0 - 10

10 - 30

30 - 50

50 - 70

More than 70

Unknown

Source: PBL

The geothermal contour within which the probability of successful drilling is greater than 70 percent is used as standard. This probability is only greater than 70 percent at a few locations in the Netherlands. They are near Rotterdam, Alkmaar-Hoorn and some localities in Groningen, Friesland and Drenthe (see Fig. 8.6). The potential of these locations is limited (see paragraph 8.3). Outside these locations, successful geothermal projects are also possible, but the overall probability of successful drilling in these localities is less, or unknown.

Local exploration can estimate the chances better, reducing the chance of unsuccessful drilling. For this reason, the possible return from geothermics has been calculated on the different probability plots. In the Vesta Model, this is the geothermics at postcode 4 level. Thus the Model does not include considerations of individual growers under glass, where geothermal heat supply may also be a possibility.

There seems to be major geothermal potential if all contours with a probability greater than 10 percent or an unknown probability are included (Fig. 8.7). Like residual heat, cost-effective projects are calculated primarily in major conurbations.

This is logical, because the investment in geothermal heat supply infrastructure is expensive, and can be recovered fastest by supplying a lot of heat per surface area of the locality. When energy prices are high, the number of locations increases by a factor of 3, and even less densely built-up areas become cost-effective (Fig. 8.7). Major geothermal potential is present in terms of sustainable energy and carbon emissions saved. When adjustment is made for the unsuitable localities in the various contours, the cost-effective potential stands at between 10 and 125 petajoules for renewable energy and 0.5 and 6 megatonnes of carbon emissions saved. The range is wide, because most of the geothermal potential in the Netherlands falls outside the contour, where the probability of successful drilling is unknown (Table 8.6).

The cost-effective potential of this contour is 95 petajoules, followed by the contour with a 30 to 50 percent probability (49 petajoules), and then the contour with a 10 to 30 percent probability (25 petajoules) at high energy prices. Cost-effective potential is greatest here, because there is concentrated demand for heat within these contours.

As stated above, the cost-effective use of TES at high energy prices may rise to 60 petajoules (of which 40 petajoules is renewable). Figs. 8.3 and 8.4 show that TES can be applied cost-effectively at many more non-residential than residential locations. It was clear from the last paragraph that most cost-effective potential lies in non-residential buildings. In the case of technical potential, TES is deployed at more locations, but most of this potential is still non-residential, where energy uptake per location is greater.

Based on figures from the Netherlands Enterprise Agency, it is assumed that TES is feasible almost anywhere in the Netherlands, but that there may be local limitations in the form of clogging, contamination and a lack of cover layers. Because TES works through low-temperature heating and therefore requires a well-insulated building with floor and/or wall heating, it is well-suited to new build, but not to large-scale application in existing buildings. For district CHP, there is major potential when energy prices are low (Fig. 8.3). At higher energy prices, the potential declines sharply (see last paragraph and Fig. 8.4). District CHP is almost unlimited on the supply side, because mains gas is available almost everywhere.

Figuur 8.7	Fig 8.7
Rendabele geothermie	Cost-effective Geothermics
Bij lage energieprijzen	With energy prices low
Bij hoge energieprijzen	With energy prices high
Geothermie	Geothermics
Kans benutbare geothermie minder dan 10%	probability of usable geothermal energy less than 10%
Aanname: Geothermie overal benutbaar, met uitzondering van 0 – 10% kanscontour	Assumption: geothermal can be used everywhere except a 0-10% probability contour
Bron: PBL	Source: PBL

Table 8.6

Cost-effective geothermal potential with different probabilities of successful drilling and energy prices[1]

Variants in terms of probability of successful drilling	Probability unknown; 2050 prices	10 - 30% probability; 2050 prices	30 - 50% probability; 2050 prices	50 - 70% probability; 2050 prices	70 - 100% probability; 2050 prices	All probabilities; present-day prices	All probabilities; 2050 prices
Percentage of surface area with successful drillholes in contour	Unknown	20%	40%	60%	85%	Whole contour	Whole contour
Energy if all locations are suitable (PJ)	95	25	49	4	3	59	177
Energy if a percentage of surface area is successful (PJ)	0 - 95	5	20	3	3	10 - 42	30 - 125
Carbon reduction if all locations are suitable (Mton)	5	1	2	0	0	3	9
Carbon reduction if	0 - 5	0	1	0	0	0.5 - 2	2 - 6

a percentage of surface area is successful (Mton)

Table shows potential with and without adjustment for the probability of successful drilling

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Table 8.7

Summary of group participation

			Construction measures	**Local measures**
Residential	Purchase	High earners	X	-
	Purchase	Low earners	-	-
	Rental	Flats and terraced houses 1940 - 1990	X	X
	Rental	Other	-	X
	New build[1]	Expansion areas	X	X
Non-residential	Major corporations, healthcare and education		X	X
	Other		-	-
	New build (expansion areas)		X	X
Greenhouse horticulture			-	-

[1] New build as a replacement for housing has the same socio-economic characteristics as the replaced housing

8.5 Limited group participation

Chapter 2 identifies groups which have relatively greater hesitations, or resistance to taking certain measures. This paragraph examines what the effect is if these groups or sub-sectors do not join the measures adopted. Table 8.7 lists the groups which do and do not join in certain measures. Purchased homes (owner-occupiers) do join in construction measures but not local measures. Rental homes join in local measures, but only the terraced houses and flats from the period 1940 to 1990 join in the construction measures. New build at expansion locations joins in all measures. When new build is a replacement (redevelopment), it is assumed that the socio-economic characteristics remain the same: this relates mainly to residential property for let. All major corporations join both routes. Greenhouse horticulture does not participate in either route. For small businesses, only the healthcare and education sub-sectors join in, also joining both routes.

Logically, the limited participation of sub-sectors reduces the carbon reduction potential on the routes (compare Fig. 8.8 with Fig. 8.1).

On the route with construction measures, 60 percent of the residential and 70 percent of the non-residential buildings (expressed by numbers of employees) join the energy measures. The cost-effective carbon reduction potential of the construction measures of the selected sub-sectors (Fig. 8.8) is half the cost-effective potential if all sectors fully participate (Fig. 8.1). The relatively sharp drop is mainly caused by the non-participation of purchased homes on low incomes and homes for let built before 1940. A relatively large carbon reduction is achievable for these groups by cost-effective insulation of the homes. The technical carbon reduction potential also falls, but in line with the fall in the proportion of residential and non-residential buildings participating.

On the route with local measures, 33 percent of residential and 70 percent of non-residential join in. Logically, the cost-effective and technical potential is also lower than if all sectors participate fully. Above all, the use of district CHP declines considerably (80 percent). In addition, the use of residual heat is almost halved in the variant with low energy prices. The cost-effectiveness of heat supply projects is in fact sensitive to a loss of heat demand. The use of TES, however, only falls by about 10 percent. This occurs because most TES falls within the group of new build at expansion locations, a group which joins in the local measures fully. Note the major role played by the order of preference of the options in the difference in the drop in heat supply options (see paragraphs 8.1 and 8.2). Just as in the situation of full group participation, the reduction potential of the combined route is greater than the route with local measures. A cost-effective potential of 3 to 6 megatonnes of carbon and a technical potential of 11 megatonnes of carbon remain in 2050 (Fig. 8.8). Because not all buildings are insulated, cost-effective heat projects still have considerable carbon reduction potential, especially in the variant with high energy prices.

Fig. 8.8

Carbon reduction with limited participation by sectors, 2050

Dutch	**English**
Gebouwmaatregelen	Construction measures
Rendabel potentieel bij variant A / B	Cost-effective potential of Variant A / B
Technisch potentieel	Technical potential
Gebiedsmaatregelen	Local measures
Combinatieregelen	Combined measures
Maatregelen	Measures
Zonneboiler	Solar-powered boiler
Isolatie	Insulation

Elektrische warmtepomp	Electric heat pump
Restwarmte	Residual heat
Geothermie	Geothermics
Warmte-koudeopslag	Thermal energy storage
Wijk-warmtekrachtkoppeling	District combined heat/power
Reductie ten opzichte van referentie	Reduction in relation to benchmark

Variant A: low energy prices and high investment costs of construction measures.

Variant B: high energy prices and low investment costs of construction measures.

Source: PBL

Fig. 8.9

Renewable energy with limited participation by sectors, 2050

Source: PBL

Logically, reduced sub-sector participation reduces the potential for generating renewable energy (compare Fig. 8.9 with Fig. 8.2). It remains true that neither the solar-powered boiler nor the electric heat pump is cost-effective on the route with construction measures. There remains a technical potential of 71 petajoules for sustainable energy generation through local measures in 2050. This is 65 percent of the potential given full participation in 2050. The percentage fall is equally distributed across solar boilers and electric heat pumps.

Local measures still have a cost-effective potential for sustainable energy of around 40 petajoules in 2050. Their technical potential is 63 petajoules. This is 90 percent of the potential with full participation from all sectors in 2050. The reason why the fall is only limited is that TES continues to be added in new build at expansion locations (see above). On the other hand, geothermal deployment disappears almost completely.

The picture for combination is roughly the same. Here, the cost-effective potential also stands at around 40 petajoules and the technical potential is approximately 65 petajoules. These figures represent 95 and 80 percent, respectively, of the potential given full participation. The fall with the cost-effective measures is the result of the elimination of geothermics, while the fall with the technical potential is caused by reduced use of solar-powered boilers (35 percent) and TES (10 percent).

With the generation of sustainable electricity by solar (PV), there remains a technical potential of around 60 petajoules. This is about 40 percent of the technical potential given full participation. The sharp decline occurs because, within the non-residential sector, companies with relatively few staff (small businesses) no longer join in, while these have relatively plentiful roof surface. Many small businesses (e.g. in wholesale and the motor trade/repairs) are not accommodated in multi-storey buildings (PBL 2012). Just as with full participation, the cost-effective potential of solar (PV) with limited participation has not been investigated.

8.6 Case studies: Amsterdam and Tilburg

The Vesta Model is able to carry out regional analyses. The model contains full geographical information on energy demand from the built environment and greenhouse horticulture, construction measures, and regional options for local measures such as residual heat, geothermics, TES and district CHP. In addition, the model contains socio-economic information such as ownership relations and incomes, which is important when specific groups are resistant to measures. The Model can map out the possibilities for the different localities in a region, for both construction and local measures.

This chapter illustrates the possible effects of different situations on the cost-effectiveness of local measures in a local context. For this purpose, it examines the Vesta results for different situations in Amsterdam and Tilburg:

- change in energy price
- use of construction measures
- limited group participation.

It seeks to demonstrate possible results, and therefore not to present exact results. In fact it ignores existing heat networks in these localities and uses generic key figures which are not specific to location, and the sequence in which heat technologies are used is decisive to the result (see Table 8.1 and paragraph 1.2).

8.6.1 Amsterdam

Situation a: low energy prices without construction measures

In the variant with low energy prices (2010 energy prices), much of Amsterdam can be cost-effectively supplied with residual heat (Fig. 8.10). The Model calculates that many neighbourhoods can be connected cost-effectively around the sources at Hemweg, the waste incinerator Afval Energie Bedrijf and the Diemen power station complex. In Amsterdam, the whole residual heat capacity of these sources can be deployed. Haarlem can also be cost-effectively supplied with heat from the Velsen cluster and Tata Steel. In residential and non-residential new-build projects (especially redevelopment), there are additional possibilities for TES in Amsterdam. In a number of districts, cost-effective projects are feasible which supply heat through district CHP.

Situation b: high energy prices without construction measures

If energy prices are high, there is little change in the picture of residual heat supply in Amsterdam. In fact the capacity is already assigned at current prices. Only the order of the most cost-effective localities changes. Thus locations with residual heat supply are added at Oostzanerwerf, in Amsterdam North, and in the Western Port

District, while locations disappear elsewhere, such as Buikslotermeer in Amsterdam North and Slotermeer. It is noticeable that higher energy prices do not make district CHP more cost-effective in either Amsterdam or Haarlem. The primary reason for this is that the gas price rises more sharply than the electricity price.

Situation c: high energy prices with construction measures

If cost-effective construction measures are adopted to save energy, the demand for heat declines. In Amsterdam, when energy prices are high, that heat can be cost-effectively deployed in other parts of the city. This can be seen on the map in Amsterdam North, Buikslotermeer and South-East. Localities such as Amstelveen disappear. Perhaps this locality is no longer cost-effective, or others have become more cost-effective. In Haarlem, the result is that a number of residual heat projects are no longer cost-effective. These are locations a long way from the residual heat sources, such as in Zandvoort, or which have low demand for energy.

Situation d: high energy prices and construction measures with limited participation by sectors

There are some groups which are resistant to the measures, or have hesitations when such measures are adopted (see paragraph 8.5). In the case of local measures, they are

Fig. 8.10

Cost-effective construction measures in Amsterdam and Haarlem, 2050

a. At low energy prices, without building measures and full participation of sectors	b. At high energy prices, without construction measures and full participation of sectors
c. At high energy prices, with cost-effective construction measures at low investment cost, and full participation of sectors	d. At high energy prices, with cost-effective construction measures at low investment cost, and limited participation of sectors

Dutch	English
Restwarmte	Residual heat
Warmte-koudeopslag	Thermal energy storage
Wijk-warmtekrachtkoppeling	District CHP
Aardgas	Natural gas

Source: PBL

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owner-occupiers, while for saving, they are owner-occupiers on low incomes, in rented homes built before 1940 or after 1990. In the case of companies, the sectors are other than healthcare and education, or companies with fewer than 100 employees, for both construction and local measures.

If these groups do not join in, on the one hand there is a loss of demand for the supply of heat but, on the other hand, added demand, because no construction measures are taken by some of these groups. Because purchased homes and small businesses do not join the residual heat projects, there is a surplus of residual heat. This residual heat is cost-effectively used in other parts of Amsterdam and in Amstelveen. This is visible because, in many parts of Amsterdam, the use of residual heat is increasing (Fig. 8.10). It is also visible that Amsterdam can again be supplied with residual heat. Because residual heat is used at more locations, the proportion of TES declines. In Haarlem, because of the elimination of demand for heat, many localities have ceased to be cost-effective, and only a small number of cost-effective residual heat projects remain.

8.6.2 Tilburg

Situation a: low energy prices, without construction measures

Tilburg is in a region with a possible geothermal presence. However, there is no 70-percent probability contour around Tilburg. These calculations for Tilburg count all probability contours greater than 10 percent, including the contour with an unknown probability. At low energy prices, there are cost-effective projects for residual heat in Tilburg, such as Oud-Noord and the centre (Fig. 8.11). After the use of this residual heat, there are no cost-effective geothermal options. However, when city districts are redeveloped, there are opportunities for TES and limited use of district CHP in the east of the city.

Situation b: high energy prices, without construction measures

At high energy prices, the distribution of residual heat across Tilburg alters. This is because the order of most cost-effective projects changes. Thus one residual heat locality in Tilburg North and West disappears (Wandelbos), and company site Vossenberg is added as a new locality. Because energy prices are high, Vossenberg has become more cost-effective than the locations in Tilburg North and West, which are further away from the residual heat source (the Amercentrale power station). A higher energy price also opens geothermal opportunities in Reeshof, West, North and Goirle.

Situation c: high energy prices and construction measures

If cost-effective construction measures are taken, demand for heat falls. For this reason, a number of residual heat projects cease to be cost-effective in Tilburg, such as South and part of Oud-Noord. Because less residual heat is needed per locality, there is sufficient capacity to restore residual heat supply to part of Tilburg West. Due to the reduced demand for heat at each location, geothermics only remains cost-effective in Goirle. In Tilburg South, one location can be cost-effectively supplied with heat by TES, because residual heat is no longer an option there.

Situation d: high energy prices, construction measures and limited participation by sectors

There are some groups which are resistant to the measures, or have hesitations when such measures are adopted (see paragraph 8.4). In the case of local measures, they are owner-occupiers, while for saving, they are owner-occupiers on low incomes, in rented homes built before 1940 or after 1990. In the case of companies, the sectors are other than healthcare and education, or companies with fewer than 100 employees, for both construction and local measures. If these groups do not join in, on the one hand there is a loss of demand for the supply of heat but, on the other hand, added demand, because no construction measures are taken by some of these groups. Because there are also groups which do not save, the possible supply of residual heat becomes cost-effective in the centre and west of Tilburg. The priority given to residual heat displaces residual heat TES in Tilburg West and South, compared with the former situation of full participation. Due to loss of demand for heat in Goirle, the use of geothermics is no longer cost-effective.

8.6.3 Comparison of calculated and existing locations of heat networks in Amsterdam and Tilburg

The calculated cost-effective locations of residual heat networks largely overlap with the existing locations in Amsterdam (compare Fig. 8.12 with Fig. 8.10). Vesta calculates that the most cost-effective districts are Amsterdam West, North and South, in addition to the waste and energy utility AEB, the Hemweg power station and, in Amsterdam East, the Diemen power station complex. Heat networks are established at these locations and, in Amsterdam North, there are plans to expand the network. One difference from the current situation is that Vesta identifies attractive locations within the ring road. These comprise districts in and around the centre, where it is technically and organisationally more demanding to lay out heat networks, because the space for the networks underground is limited and it is necessary to negotiate with many different stakeholders. From contact with Amsterdam City Council, it emerged that the council is indeed considering connecting the centre to a heat network.

Fig. 8.11

Cost-effective local measures in Tilburg, 2050

a. At low energy prices, without building measures and full participation of sectors	b. At high energy prices, without construction measures and full participation of sectors
c. At high energy prices, with cost-effective construction measures at low investment cost, and full participation of sectors	d. At high energy prices, with cost-effective construction measures at low investment cost, and limited participation of sectors

Dutch	**English**
Restwarmte	Residual heat
Geothermie	Geothermics
Warmte-koudeopslag	Thermal energy storage
Wijk-warmtekrachtkoppeling	District CHP
Aardgas	Natural gas

Source: PBL

Fig. 8.12

Residual heat situation in 2012

Amsterdam (inclusief gepland)	Amsterdam (planned and actual)

Source: PBL

The calculated location of heat networks in Tilburg North and West and Vossenberg matches the present situation, but Vesta does not identify Reeshof as the most cost-effective location, and gives priority to the Tilburg districts within the ring (compare Fig. 8.12 with Fig. 8.11). The situation at work here is similar to in Amsterdam. Historically it is a difficult locality with many different stakeholders, whereas Reeshof is a new-build district which can be connected to the heat network as a whole. Thus the indications from Vesta seem to correspond well to suitable locations, though proper account must be taken of history and of the various stakeholders in the locality (owner-occupiers, housing associations and owners of the non-residential buildings).

8.7 Costs

8.7.1 Reference scenario

The energy costs are calculated following two approaches of the Environmental Costs Method (VROM 1998): the social cost approach and the end-user approach. The social cost approach offers a perspective for the whole of Dutch society. For this purpose, a low interest rate is used for the annual capital costs of investment, and financial transfers between sectors and government, such as energy tax and VAT, are not counted. The end-user approach determines what the costs are for each sector (residential, non-residential and heat suppliers) and government. The interest rate is based on average interest rates for the sector in practice.[5] In addition, the end-user approach does count energy tax and VAT.

In the reference scenario, i.e. that construction and local measures are not adopted (see paragraph 3.3), the social costs of energy consumption by the built environment and greenhouse horticulture are EUR 18 billion in 2050 in the variant with the low energy prices, and EUR 22 billion in the variant with the high energy prices (Table 8.8).

Table 8.8

Energy costs of the built environment in the reference scenario in 2050 at low energy prices and high energy prices (EUR bn)

Energy prices	Scenario	Social approach	End-user approach	
		Costs	Costs to owners of residential and non-residential buildings and greenhouse horticulture	Government revenue (energy tax and VAT)
Low	Reference 2050	18	28	10
High	Reference 2050	22	35	13

Table 8.9

Costs of energy measures for the built environment in the 2050 reference scenario, at current energy price and estimated energy prices in 2050 (EUR bn)

Energy prices	Energy measure	Social approach	End-user approach	
		Costs	Costs to owners of residential and non-residential buildings and greenhouse horticulture	Government revenue (energy tax and VAT)
Low	Cost-effective construction measures	0	0	0
High	Cost-effective construction measures	0	0	-1
Low	Technical potential construction measures	8	11	-1
High	Technical potential construction measures	5	6	-1

Low	Cost-effective local measures	-1	0	-1
High	Cost-effective local measures	-1	0	-1
Low	Cost-effective construction and local measures	-1	0	-1
High	Cost-effective construction and local measures	0	0	-1

The costs to end-consumers (residential, non-residential and greenhouse horticulture) total EUR 28 billion at low energy prices and EUR 35 billion at high energy prices. Government income consists of the revenue from energy tax and VAT. Depending on the energy prices in question, these are EUR 10 to 13 billion in 2050. The calculation of the energy costs[6] includes: procurement of natural gas, heat and electricity; standing charge for natural gas and heat; depreciation of heating boiler;[7] and costs of connection to heat supply.

8.7.2 Costs of energy measures

The costs of the energy measures are calculated as the balance of the annual capital charges of the costs of investing in them and the annual energy cost savings. The latter are the saved costs of procurement of energy due to reduced energy demand or self-generation of energy, e.g. by a solar boiler or solar cell (PV). The costs to the heat supplier of local heat sources and layout of heat networks are offset by the returns from the sale of heat to the sectors (CE 2011).

Table 8.9 presents the impact of the energy measures on costs in the 2050 reference scenario. The route with cost-effective construction measures, the route with cost-effective local measures and the combined route confer annual social benefits worth between EUR 0 and 1 billion in 2050. For end-consumers, the annual benefits of the cost-effective energy measures also lie between EUR 0 and 1 billion in 2050.

However, the government has less income from energy tax, though this is partly compensated by revenue from VAT on investments in energy measures. The government's loss of income stands at between EUR 0 and 1 billion in 2050.

If the full technical potential of construction measures is exploited, then the social costs range from EUR 5 to 8 billion and the costs to the end-consumer from EUR 6 to 11 billion in 2050. The government's loss of revenue is EUR 1 billion in 2050. The lower revenue from energy tax is very largely compensated by revenue from VAT on the energy measures.

8.8 Comparison of model results with literature

The estimates of potential for construction and local measures in the literature, quoted in chapters 5 and 6, are summarised in Table 8.10. The table also shows the potential as calculated by Vesta for 2050. In this paragraph, we look at the similarities and differences between the various estimates of potential. For residual and geothermal heat and TES, only estimates of potential for 2020 have been found in the literature, and not for 2050 or for other years after 2020.

The Vesta results for residual heat in 2050 differ widely from the estimates of potential given in various studies for 2020: Vesta yields higher estimates of the potential factors. A SenterNovem study (2007) (21 petajoules), however, only examined new build, whereas the main potential in Vesta relates to existing residential and non-residential buildings. Unlike other studies, Vesta links demand for heat and heat sources, based on detailed geographical data. Furthermore, some other sources are more concerned to list existing and planned heat projects, whereas Vesta looks at all possible locations. The recent ECN study ignores the potential for residual heat if other alternatives exist.

For geothermics, the top edge of the bandwidth found in the literature (11 petajoules) approximately coincides with the bottom edge of the bandwidth calculated by Vesta (10 petajoules). The lower Vesta value is based on localities in the Netherlands where, according to TNO, the probability of successful drilling is greater than 70 percent. The top edge of the Vesta bandwidth yields an expected value of cost-effective potential for the localities where the probability of a geothermal presence is greater than 10 percent, or is unknown. Because unsuccessful drillings in practice pose major financial risks, this is a theoretical potential. More (local) knowledge of the geothermal presence is necessary to avoid unsuccessful drilling in such localities.

For TES, the cost-effective potential in Vesta (60 petajoules) is roughly equal to the highest value found in the literature (57 petajoules). This value derives from a study (Ecofys 2007) starting from highly optimistic assumptions about the rate of new build and renovation, and degrees of penetration of TES systems by 2020. Other studies work on less optimistic assumptions and therefore come up with considerably lower estimates of the potential for 2020. Because the reference scenario calculated with Vesta runs until 2050, it assumes more residential and non-residential new build than other studies. As TES is largely used in new build, Vesta identifies greater potential in TES.

The building-related potential from Vesta reasonably matches the estimates from the literature for housing, based on the assumption that the entire housing stock (built before 1995) is insulated. In Vesta the potential is lower, for both cost-effective (8 to 68 petajoules) and technical potential (52 petajoules). The estimate of non-residential savings potential is approximately 30 petajoules higher in Vesta. In the literature, different investment costs are used for measures. The energy prices are different too. Hence the cost-effective potential differs. Besides, the potential in the literature is not adjusted for climate change. Climate change will mean less energy demand for interior heating in 2050. This means that building insulation will save less energy.

Only estimates for 2020 are available in the literature (in this case the factsheets from the 2020 Option Document) for the potential of the electric heat pump, solar-powered boiler and solar PV. This takes account of the degrees of penetration of these technologies, which will not be 100 percent in 2020. That explains why Vesta estimates far higher potential for 2050, because it does assume full penetration of solar-powered boilers in all homes, electric heat pumps in all new build, and solar (PV) on much of the surface of all buildings.

Table 8.10

Additional potential for construction and local measures from the Vesta Model results and in the literature

	Avoided use of primary energy (PJ) 2020	Avoided use of primary energy (PJ) 2050	Comments
Residual heat			
Vesta	-	45 (90)	Cost-effective (and technical) potential. Current use is 25 PJ
Literature	12 - 25	-	
Geothermal			
Vesta		10 - 25	Cost-effective potential with a probability of use of 10 or more percent or unknown probability
Literature	3 - 11		
TES			
Vesta		60 (80)	Cost-effective (and technical) potential
Literature	11 - 57		
Insulation (Label B)			
Vesta	-	2 - 130 [2 dwellings, 62 dwellings and 68 non-	Cost-effective (and technical) potential

		residential buildings]; 200 [108 dwellings and 91 non-residential buildings]	
Literature		70 cost-effective and 160 technical (residential only); 90 (60 residential and 30 non-residential) buildings	Estimate for 2050 is a long-term estimate for the whole housing stock, calculated for 2020
Solar-powered boilers and EHP			
Vesta		94 (75 using electric heat pump; 19 solar boilers)	
Literature		A few dozen PJs	
Solar (PV) (avoiding the use of electrical appliances)			
Vesta		142 (24 residential; 118 non-residential buildings)	
Literature	8 (dwellings)		

Notes

1 Other options are necessary for a further reduction of carbon emissions from these sectors. Examples are: supplementary energy saving in buildings; green gas; and electrification of the heat supply using green electricity. However, this study does not go into these options.

2 TES has great energy potential (Fig. 8.2) but, compared with much more efficient, energy-efficient boilers in the future, it yields relatively little carbon reduction (Fig. 8.1)

3 Solar-powered boilers, electric heat pump, geothermics and thermal energy storage.

4 Geothermics and thermal energy storage.

5 The average sectoral interest rates in practice differ for residential (5.5 percent), non-residential (8 percent), greenhouse horticulture (8 percent), heat suppliers (6 percent) and government (4 percent).

6 The annual costs of energy and measures on the explored routes consist of the capital charges of the investments, operation and maintenance of the installed facilities, energy procurement and the sale of energy by the heat suppliers.

7 Standing charges for natural gas and depreciation of the heating boiler are included in the calculation of the cost-effectiveness of the heat projects. This is based on the No More Than Otherwise principle, in which these items play a role.

Annexes

Annex 1: Summary of obstacles

In this Annex, we give a summary of obstacles to the implementation of sustainable carbon-reducing measures per sector (based on CE 2006, 2009a and 2010 and on the references and our own research mentioned in the table). The obstacles relate primarily to existing buildings. Unless otherwise stated, the requirements of the Energy Performance Coefficient (EPC) apply to new build.

Sector	**Will**	**Knowledge**	**Ability**
Owner-occupiers	Little interest in taking carbon-reducing measures in existing buildings, because they do not find the energy price high and pay little attention to the environment. Especially during major conversions and at the time of replacement of the central heating boiler, there is more willingness to adopt energy-saving measures. Unwillingness due to expected nuisance (dust and workmen all over the floor). Fear worse indoor climate. Many owner-occupiers move house several times during their lives. Hence investments with a long payback time are unattractive to many owners (Nyenrode 2008).	Do not know their own consumption. Owners, contractors, installers and municipalities are unfamiliar with sustainable and energy-saving solutions.	According to ECN and PBL (2010b), 33 percent of owner-occupiers of G-labelled homes have below-median incomes. This group will usually be unable to fund the necessary investments. This obstacle applies only to construction measures.

	Little willingness of contractors and fitters to work in the homeowners' sector. Partly due to liberalisation, utilities are less keen on energy saving.		
Social rental sector	At the time of redevelopment and renovation projects, housing associations pay more attention to durability than to carbon reduction. The question is how far the More With Less covenant with the linked organisation Aedes can stimulate individual associations. Hitherto the costs of carbon-reducing measures have been borne by the landlord, while the tenant reaps the benefits (lower energy bills). This is known as a split incentive. The government plans to adopt energy labelling as part of the home valuation system (see Annex 2). This strikes a better balance between landlord and tenant over costs and benefits.	Contractors, fitters, municipal officials and architects often have little knowledge and ambition. Housing associations have to target these parties.	Tenants are sometimes resistant to consultative processes, so that a project cannot go ahead. Grant payers are slow and unclear. Housing associations are in a bad financial situation at the moment.
Private rental sector	Hitherto the incentive has also been split for private landlords. Including	The private rental sector comprises both property funds and small, private	Institutional investors are probably able to finance investments. It is

	energy labelling in the home valuation system will strike a better balance between landlord and tenant over costs and benefits	landlords. Both categories will generally know little about the ways of reducing carbon. Property funds will be able to commission external expertise, but it is unknown how far this happens.	unknown how far this applies to private landlords.
Offices	From 50 000 kWh/25 000 m^3 the Environment Management Act requires measures with a payback time of less than five years. However, there is insufficient control and enforcement of this. A number of users, such as banks and insurance companies, are party to multi-year agreements (MYA). Non-participants pay very little attention to energy saving. Nearly 60 percent of offices are rented. In that case, different parties share the costs and benefits (a split incentive). Investors and managers do not focus on matters not directly connected with their core activities. There is also little demand from tenants to save energy.	Owners (the user or property funds) know little about carbon-reducing measures. Owners can commission external expertise, but it is unknown how far this happens.	As the office market is in a bad way, there is probably little scope for investment.
Hospitals and care homes	From 50 000 kWh/25 000 m^3 the Environment Management Act requires measures with a payback	In geriatric care, it is a case of fragmented knowledge, because optional matters are	Institutions have relatively limited autonomy in the fields of investment and

	time of less than five years. However, there is insufficient control and enforcement of this. Hospitals and care institutions consume a lot of energy. In around two-thirds of institutions, energy saving is a firm part of corporate policy. Hospitals already apply quite a lot of energy-saving technologies, such as CHP, TES and heat pumps. Care homes lag behind, but often use CHP. Only teaching hospitals (12 out of a total of 131) have so far signed up to the MYA. This reduces attention paid to energy saving and the level of ambition in relation to it. Support from staff is limited, because care is the first priority. There is a misconception that energy saving will be at the expense of comfort and/or care quality.	outsourced to third parties. An institution board often deals with new build or large-scale renovation only once during its term of office. Then many unknown aspects surface, and sustainability and energy efficiency are not the most urgent.	operation. Monitoring the costs of operation and investments is a matter for various stakeholders: the Healthcare Charges Board (*College Tarieven Gezondheidszorg* - CTG) and the Hospital Facilities Construction Board (*College Bouw Ziekenhuisvoorzieningen* - CBG). CTG and CBG follow a standard approach to building maintenance. If this approach is not sufficient, the organisation has to invest itself. Grant applications are complex and time-consuming.
Shops	Unwilling to adopt measures which retailers consider may reduce turnover, such as closed chiller cabinets and chest freezers and closed access doors. Many retail premises are	Probably little knowledge.	Shops in a poor financial position will be unable to fund the necessary investments.

	not owned by the operator: split incentive.		

Sector	**Will**	**Knowledge**	**Ability**
Schools	From 50 000 kWh/25 000 m^3 the Environment Management Act requires measures with a payback time of less than five years. However, there is insufficient control and enforcement of this. In primary and secondary education, the municipality often holds the main responsibility for accommodation costs. The building users pay little attention to energy saving, because they do not stand to gain from it themselves (split incentive). This does not apply to adult education, vocational colleges and universities: here responsibility for the accommodation rests fully with the governors of the educational institution. Most universities now have energy monitoring systems. Energy costs are a very limited part of total expenditure. Hence little attention is paid to energy saving.	In primary and secondary education, there is little knowledge of energy-saving measures. Universities, vocational colleges and adult education institutions are expected to have more in-house knowledge.	Standard practice leaves little room for more investment, even when cost-effective.

Industrial sheds	No EPC applies to industrial sheds. From 50 000 kWh/25 000 m^3 the Environment Management Act requires measures with a payback time of less than five years. However, there is insufficient control and enforcement of this. The client/developer and contractor for the construction of an industrial shed pay little attention to energy saving and have little ambition in this regard. Energy costs represent a small fraction of total operating costs.	The necessary knowledge and skills are present to a limited extent, certainly on the part of developers, for whom the building is a one-off. Developers wrongly think that energy-efficient construction is expensive.	
Horeca	Not researched	Not researched	Not researched
Greenhouse horticulture	There seems to be a will, because energy accounts for a large proportion of total costs.	Should be present, both among glasshouse owners and glasshouse erectors. Membership of the Clean and Efficient Agri-Sectors Covenant contributes to this.	Unknown.

Annex 2: policy aims, stimulus measures and legislation

Introduction

In this Annex we discuss the current policy aims (until 2020), the stimulus measures (such as subsidies) and legislation in relation to energy saving, heat and cold. It is worth emphasising that this is a snapshot, especially of the stimulus measures and legislation. The current stimulus measures and legislation are significant primarily for today and the near future, whereas the Vesta Model looks ahead to 2050. Many subsidy schemes are temporary (if so, this will be stated). For heat and cold, especially, the legislation is being modified at the moment. This means that the descriptions of the relevant legislation are based on bills, and it cannot be ruled out that these may yet be amended.

Policy aims

The 'More With Less' Covenant

To save energy in existing purchased housing, and especially in rented homes, the central government has entered into the More With Less (MMM) Covenant with utilities and the construction and installation sectors. These stakeholders have devised a joint programme, which supports home owners in applying saving measures. Homeowner participation is voluntary (ECN and PBL 2010a). The Covenant sets the aim that the built environment will have saved 100 petajoules of energy consumption by 2020 (an extra in terms of current policy). In an explanatory note to the Covenant, the 100 petajoules amount to an improvement of 20 to 30 percent in at least 3.2 million residential and non-residential buildings (ECN and PBL 2010a). The Covenant aim is based on a feasibility study by McKinsey. That study suggested a whole series of savings measures, including sustainable energy and CHP (23 petajoules), insulation and installations (62 petajoules) and electric appliances (14 petajoules). The saving on electrical appliances must come by tightening standards of use in the context of the European Ecodesign Directive.

The following aims are spread across the various sectors (MMM 2007):

- private homeowners: 43 petajoules;
- housing associations: 27 petajoules[1];
- private and institutional landlords: 8 petajoules; and
- non-residential buildings: 22 petajoules.

A covenant with the social rental sector (Aedes and De Woonbond) specifies what contribution housing associations have to make to the More With Less aim. Linked organisation Aedes has promised that associations will invest a total of EUR 2.5 billion extra to achieve 24 petajoules of energy saving by 2020. To do this, homes must be brought to energy label B level, or improve by at least two labelling grades. The Covenant, entered into at national level, has only translated into agreements with individual associations to a limited extent. It is therefore unclear whether associations are sufficiently aware of the major effort expected of them, and/or whether they have sufficient facilities and financial resources at their disposal to achieve the aim agreed in the Covenant (ECN and PBL, 2010a).

Heat Full Steam Ahead

The work programme ‘Heat Full Steam Ahead’ aims to expedite the changeover to a sustainable heat and cold supply (EZ 2008). The programme ambitions for 2020 are as follows:

- new residential and non-residential buildings that are energy-neutral;
- good insulation for existing residential and non-residential buildings;
- greenhouse horticulture should emit 45 percent less carbon than in 1990;
- cultivation in new glasshouses should be climate-neutral;
- industrial processes should be up to 30 percent more efficient than in 2005, leading to less heat loss;
- wherever cost-effective, residual heat projects should be implemented;

- a big increase in the proportion of sustainable heat through more solar-powered boilers, heat pumps and geothermics;
- save 46 petajoules of energy in the energy sector via collective heat projects, of which 21 petajoules comes from sustainable heat.

When the Rutte cabinet took office, the programme was halted and the aims are lapsing.

Multi-Year Agreements 3 for the service sector

The Energy Efficiency Multi-Year Agreements (MYA3) with various sectors of industry, the food and beverage industry and the service sector is a covenant which seeks to promote energy-efficiency in medium-sized companies. In the service sector, 26 vocational colleges, 8 university medical schools, 14 universities and 18 financial institutions have signed up (Netherlands Enterprise Agency, 2010e). For companies, participation means that they draw up energy-saving plans, take all cost-effective measures and submit the results of this for annual monitoring. The aim of MYA3 is that all stakeholders together achieve a two-percent energy saving per year (accumulating up to 30 percent energy saving on 2005 by 2020).

Agri-Covenant and the Greenhouse As Energy Source Programme

In 2008 the Clean and Efficient Agri-Sectors Covenant (or Agri-Covenant) was concluded between the Dutch Government and the agri-sectors. It includes the following goals (LEI 2010):

- a total emission reduction of at least 3.3 megatonnes of carbon per year in 2020, compared with 1990; about 2.3 megatonnes of this is achieved by using CHP[2], while around 1 megatonne relates to cultivation. The ambition is to reduce emissions by a total of 4.3 megatonnes by 2020, of which 2.3 megatonnes will come from CHP and 2.0 megatonnes at cultivation level;
- improvement of energy efficiency by an average 2 percent per year until 2020;
- a 20% sustainable proportion of energy by 2020.

To achieve the aims and ambitions of this Agri-Covenant, greenhouse horticulture and central government are co-operating in the energy transition programme 'The Greenhouse As Energy Source.' The ambition of this programme is to cultivate in a climate-neutral, cost-effective way in new glasshouses from 2020.

Financial stimulus measures

Many central government financial stimulus schemes are of limited duration. In some cases they change midway, e.g. through amendments by the Lower House of Parliament and on changes of cabinet. For the most accurate summary of the stimulus schemes, reference is therefore made to the plan of approach 'Energy Saving in the Built Environment and the Climate Roadmap 2020.'[3]

Below we give a detailed summary of existing and recently completed stimulus measures. It may occur, however, that schemes are superseded by the time the report comes out.

- In March 2011, the Lower House passed a bill to evaluate energy labels in the home valuation system (WWS) (Aedes 2011). If the Upper House passes the bill, housing associations will be able to claim more rent for energy-efficient homes. Tenants have the advantage that their energy bills come down. In making local agreements about energy-saving measures, associations and tenants can use the 'living cost guarantee.' This has been devised by Aedes and De Woonbond, and gives tenants the guarantee that their living costs will not increase overall.

- In 2011 the cabinet allocated EUR 10 million to the implementation of the national reward scheme, 'More With Less.' Home owners who improve their energy labelling by one grade received a EUR 300 reward. If they improved two grades, the amount was EUR 750. The scheme expired and was terminated on 31 December 2011 (BZK 2011).

- The Green Projects Scheme (*Regeling Groenprojecten)* was adopted in 2008, so that homes improved by at least two energy label increments were eligible for a 'green mortgage.' At the beginning of 2009, the scheme was extended to nonowner occupiers. Under the scheme, banks, utilities and others can offer financial packages based on an interest rate around 1.5 percent below normal (EZ 2008). Besides, the Rutte cabinet plans to end the scheme in 2014 (Netherlands Enterprise Agency 2011).

- Until 31 December 2011, private homeowners were able to draw on an energy saving credit. The government guaranteed loans which banks extended for energy-saving measures, which reduced the rate of interest on the loans. In the period from 2009 to 2011, a maximum of EUR 35 million (including execution costs) was used for the purpose of the guarantee (BZK 2011).

- In non-residential buildings, 44 percent of the investment costs for energy-saving measures are deductible from taxable profit, via the Energy Investment Deduction (EIA). If the measures effect an improvement of at least two labelling grades, or lead to a Label B, the scope for deduction is even wider (Netherlands Enterprise Agency 2010a).

- For owner-occupiers, the rule is that wage costs payable to apply insulation to floors, walls and roofs incur a reduced rate of VAT (6 percent instead of 19 percent). Costs of materials also fell under this low rate until 1 July 2011, if they accounted for more than 50 percent of the total costs. HR++ glass was subsidised (ECN and PBL 2010a).

- The cabinet is going to introduce a block-by-block approach (BZK 2011). The intention of this is to tackle several existing homes simultaneously, with standard packages which achieve an energy saving averaging 30 to 50 percent. Local stakeholders co-operate under the management, say, of a local authority or housing association, and with the involvement of private financiers (e.g. institutional investors). Influencing the behaviour of occupiers and users will also be part of this approach. The intention is to launch a pilot scheme in the coming period, with five projects. Central government will back the pilot with EUR 2.5 million. A small financial contribution will be made to processing costs. The knowledge and experience gained in the pilot phase will spread to other government departments and market players. The pilot will have been a success if it demonstrates that the block-by-block approach is usable for a nationwide roll-out. It will be considered further whether central government has a useful or necessary role in this.

- Within the Energy Research Subsidy Programme (EOS), there is currently a subsidy scheme for industrial heat usage.[4] This is designed to encourage better use of residual and sustainable heat in industry. It offers financial support for specific projects and feasibility studies. In 2010, the budget was around EUR 10 million.[5] However, the programme is not being continued.
- The MEI scheme[6] repays 40 percent of the amount invested in projects which demonstrate innovative energy systems for greenhouse horticulture. The scheme forms part of the Glasshouse as Energy Source programme. In 2010 the budget was EUR 26 million.[7] Around 40 percent of the budget is reserved for semi-enclosed glasshouse systems, and the rest for other energy systems such as the Earth's internal heat, biomass composting, and high-quality thermal storage.
- To encourage the use of sustainable heat from the Earth, the then ministries of Economic Affairs and Agriculture, Nature and Food launched a temporary guarantee scheme in 2009. The aim was to mitigate the financial risk of unsuccessful drilling (Netherlands Enterprise Agency 2010b). In October 2010, the scheme was opened for the second time. The scheme (SEI Aardwarmte[8]) is only valid for geothermics, and not for TES. The drilling initiator pays an advance premium (7 percent of the maximum subsidy amount). In return, 85 percent of the costs of unsuccessful drilling are compensated, up to a maximum of around EUR 7.2 million. Drilling is deemed unsuccessful if the capacity which can be drawn from the ground is lower than expected. To be eligible for the scheme, the applicant must possess a location-specific geological survey report, an exploration or exploitation licence, and a detailed financial plan. Besides, the second round closed as of 1 April 2011 (EL&I 2011), but the guarantee scheme is expected to continue provisionally, in amended form.

- Via the EIA, costs of research into energy-saving measures can be included in any investment resulting from it. This also applies to investments in heat networks and in the release of heat from production sources, including preparation costs (EZ 2008).

- From September 2008, the Sustainable Heat Subsidy Scheme existed, with a budget of EUR 60 million. The scheme applied to existing housing, but has since been stopped. Up to January 2011, a total of 14 700 subsidy applications were submitted for solar-powered boilers and heat pumps, and around 500 applications for micro-CHP. [9]

- Under the old SDE scheme, residual heat obtained from biomass-fired power generation was eligible for subsidy (EZ 2009). For geothermics and TES, however, no subsidy was available.[10] In 2011, a procedure was started to amend the SDE Decree, so that the production of sustainable heat under SDE+ could be subsidised. This related to heat from geothermics, TES, boilers fired with biomass, oil or gas, and CHP facilities. This amendment should come into force in 2012 (EL&I 2010b).

- There are also local subsidy schemes for the provinces and municipalities. These schemes are not examined in the context of this study.

- Non-financial stimulus measures

- The National Heat Centre of Expertise (*Nationaal Expertisecentrum Warmte)* is developing a uniform yardstick to ensure that the environmental performance of various technologies (such as solar boilers, heat pumps, TES, geothermal and residual heat and biomass combustion) are more readily comparable. The yardstick is designed primarily for use in the exploratory stage of development of a housing location. Meanwhile, a 1.0 version of the calculation model has become available on the Internet.[11] A beta version of the protocol is also available (Netherlands Enterprise Agency 2010c).

- From 2009, regional heat maps show heat supply and demand for government authorities, companies and developers. The available residual heat can be displayed, and so can the possibilities for the use of geothermal heat. This makes it clear where possibilities lie to use residual or sustainable heat in the immediate surroundings. Thus it is easier to include heat consumption in decision-making on building permits for companies, greenhouse horticulture, housing and government. The maps are available on the Internet.[12] TNO runs a similar website for geothermics and TES. [13] These Netherlands Enterprise Agency and TNO maps are similar to the introduction of the Vesta Model. However, Vesta can also calculate future trends in heat demand and construction and local measures.

- One aim of the new Town and Country Planning Act is to stimulate sustainable energy. It will urge the provinces to designate residual heat usage as in the provincial interest. This means the province can force municipalities to match supply and demand. Central government also has power to categorise residual heat usage as a major public interest and therefore to support heat networks during licensing (EZ 2008). We would point out that residual heat is not designated as renewable energy in the EU definition.

Legislation

Introduction

The regulations pay specific attention to energy saving, including the Energy Performance Standard, the Environment Management Act, the Ecodesign Directive and the European Building Performance Directive (EBPD). However, because there has been no serious attention to the use of residual and geothermal heat and TES for a number of years, the legislation was recently further targeted on heat projects. Thus, under the Heat Act, a number of General Orders in Council and ministerial regulations are being added. The Mining Act (geothermics) and the Water Act (TES) still contain few specific provisions, or none, for these technologies. In 2011 a bill was tabled for the adaptation of sections of the Mining Act which relate to geothermics. There was also a proposal to amend four TES-related Orders in Council. The Heat Act is also to be amended.

Energy Performance Standard

For new-build offices and homes, energy efficiency requirements are set under the Construction Decree. The Energy Performance Standard (EPN) is the guideline here. The EPN calculates the building performance of a residential or non-residential building. The result of an EPN calculation is the yardstick of energy efficiency: the Energy Performance Coefficient (EPC). Within the EPN, the builder has a free choice of measures to achieve the required EPC value. Consideration is given to measures in the field of spatial heating, the heating of hot tap water, lighting, ventilation and cooling. The EPC requirement is dependent on the function. The EPC for housing has had a value of 0.6 since 2011. According to ECN (personal communication), this corresponds to an average[14] annual gas consumption by a single-family home of around 1 400 cubic metres (for heating, hot water and cooking). For non-residential buildings, different EPC values apply to the different sectors (hospitals, shops, offices and so on). These range from 1.0 for healthcare to 2.6 for shops. As energy consumption is closely dependent on building size, it is not possible to link this to an average gas consumption figure.

In 2008, it was agreed in the Lente Agreement15 to try to reduce building-related energy consumption in new-build homes by 25 percent16 by 1 January 2011, and by 50 percent by 1 January 2015, both in relation to the construction regulation in force on 1 January 2007 (VROM 2008). This means reducing the EPC for new-build homes in two stages from 0.8 to 0.4. The reduction to an EPC of 0.6 has now been implemented.

This means that the EPC of 0.6 has now been implemented. The EPC for non-residential buildings was tightened by an average of 20 percent in 2009, and must halve by 2015 (VROM 2008). The parties also agreed to investigate, at the end of 2014, whether it was feasible to construct energy-neutral new-build locations by 2020. This would conform to the EPBD requirement (see below) that Member States must ensure that all new buildings are nearly energy-neutral by the end of 2020. The cabinet is seeking to have one basic standard, from 1 July 2012, to calculate the energy performance of buildings (both residential and non-residential, new build and existing buildings): the Energy Performance Standard for Buildings (BZK 2011). This will take account of the wishes of market players, such as: ease of use of the method of determination; attention to the relation between calculated energy performance and actual energy consumption; attention to the internal environment; and attention to comfort. Besides, a method of determining the energy performance of measures at local level (EMG) is to be published. Examples of such measures are: collective systems such as TES, CHP, collective heat pumps and other forms of residual heat supply.[17] At the moment, locally-oriented measures are already included in the EPC calculation, though with inaccurate yields or in the form of equivalency declarations.[18] Hence these systems are insufficiently assessed.

Environment Management Act

Under the Activities Decree under the Environment Management Act, companies whose electricity consumption exceeds 50 000 kilowatt-hours, or whose gas consumption exceeds 25 000 cubic metres, are bound to adopt energy-saving measures with a payback period of less than five years. This Decree does not apply to companies which fall under the ETS. If the consumption is greater than 200 000 kilowatt-hours or 75 000 cubic metres of natural gas per year, the operator (normally the municipality) can require them to carry out an energy saving survey, if it can be assumed that due diligence has not been fulfilled. In the Heat Full Steam Ahead work programme, it has been announced that research into the possibilities of residual heat must form part of this survey (EZ 2008). There is evidence that enforcement is only limited, and that the Decree is widely ignored in practice (ECN and PBL 2010b).

Ecodesign and Energy Labels Directives

The European Ecodesign Directive is a binding policy instrument. It sets requirements for the maximum energy consumption of a number of product groups, in the form of implementing measures. These relate primarily to electrical appliances (such as PCs, TVs, dishwashers etc), but energy requirements also apply to central heating boilers. In addition, the Energy Labels Directive requires certain appliances to have energy labels. The writers of this Directive expect this to stimulate energy-efficient purchasing practice (ECN and PBL 2010a).

European Directive on Energy Performance of Buildings

In the context of the revised European Energy Performance of Buildings Directive (EPBD), of 2010, Member States must set minimum requirements for the energy performance of new buildings, for large buildings which are thoroughly renovated, and new systems for installation in existing buildings. Member States must also ensure that, by the end of 2020, all new buildings are nearly energy-neutral,[19] and that an energy performance certificate (or energy label) is issued on construction, sale or lease of a building. The Netherlands has developed the rules for energy labels in the Energy Performance of Buildings Decree and the Rules on Energy Performance of Buildings based on it.

Heat Act

The 2009 Heat Act sets rules for the domestic heat supply. Through the Act, the government prevents companies from charging excessive prices to consumers for heat, or the security of supply of heat, after the liberalisation of the energy market. The Act states that the price which utilities can charge for residual heat used in urban heating cannot exceed the price for firing with gas. This rule, also known as the No More Than Otherwise principle is expected to apply to consumers with connection capacity up to 100 kilowatts (EL&I 2010a). The maximum price consists of fixed costs (such as connection charge) and variable costs (the number of gigajoules supplied). The Act has been passed, but only enters into force when it has been developed in a Heat Decree. A draft Heat Decree is now available and will probably pass through the Lower and Upper House in 2012 (EL&I 2010a).

Mining Act

The Mining Act forms the basis of licensing for the exploration for, and extraction of, the Earth's internal heat at depths greater than 500 metres. The State Mines Supervisory Body is the authority for this.

To date, more or less the same requirements have applied to the geothermal heat under the Mining Act as to oil and gas. There was (at the beginning of 2011) a bill in preparation to amend the sections of the Mining Act which relate to the Earth's internal heat (EL&I 2011). The purpose of the bill is to simplify the licensing for the exploration and extraction of geothermal heat. The geothermal start-up licence replaces the exploration licence under the Mining Act. The difference is that the holder of a geothermal start-up licence can immediately begin to extract geothermal heat, provided it is detected. The term of the geothermal start-up licence provides an opportunity to apply for a geothermal follow-up licence. This licence replaces the extraction plan and the approval of the plan. Hence the licensee can start to recoup its investment earlier. Also, the payment regulation applicable to mineral extraction will not apply to geothermal heat.

Water Act

To date, the Water Act requires a licensing application to be made to the province for open TES systems of any size. For closed systems, no licence is required. The procedure entails research costs and legal fees (together averaging EUR 9 000) and monitoring costs (averaging EUR 3 500 per year) (Taskforce WKO 2009). In support of the application, a study must be compiled to show the effects of the activity on environmental interests. Examples of environmental interests are drinking water catchment, natural areas, construction prone to subsidence, contamination or existing energy storage systems. The current Water Act seeks primarily to conserve groundwater, and does not deal with the responsible and effective use of underground energy storage capacity. Moreover, the extraction licensing rules are not uniform (CE 2009a). At the moment, provinces still apply differing criteria to licensing under the Water Act. Some provinces prohibit the use of existing water-bearing formations and do not permit net extraction of heat or cold from underground (Taskforce WKO 2009). In addition, some provinces brand the use of groundwater for open systems as 'of low value.' Hence this use is much more critically appraised than 'high-value' use as drinking water. The differences lead to a lack of clarity for market players.

At the beginning of 2011, a bill was tabled in the Lower House to adapt four relevant Orders in Council, to remove a number of bottlenecks resulting from the existing legislation (I&M 2011b). The amendments relate not only to the Water Decree (under the Water Act), but also to the Activities Decree (under the Environment Management Act), the Decree on the External Discharge of Facilities (under the Soil Conservation Act) and the Decree on Environmental Law (under the Act on General Provisions of Environmental Law).[20] The most relevant amendments are as follows:

- Creation of a level playing field, as far as possible, for open and closed TES systems, by setting rules for the closed systems, which are not yet regulated. This must prevent a lack of regulation and procedures influencing the choice of a given TES system, rather than performance and quality.

- Streamlining the licensing procedure for open systems. Instead of the extended public preparatory procedure prescribed in the Water Act, the regular preparatory procedure under the General Act on Administrative Law will now apply.[21] The intention is to involve TES systems better in construction projects. In the past, the long licensing procedure jeopardised the critical time schedules of project developers.

- Harmonisation of the divergent provincial regulations on TES systems, by introducing a general level of protection for the whole of the Netherlands. Where necessary, the possibility is offered to devise customised regulations. If there are specific ground values or functions (such as the protection of drinking water catchment), municipalities and provinces retain the option of supplementing this with their own, special level of protection. For groundwater conservancy areas, regulation is mandatory via the provincial environmental ordinance under the Environment Management Act.

- Municipalities and provinces have the option of designating interference areas[22]. In these areas, policy can be operated to promote appropriate use of geothermal energy. The prevention of interference is an important point of attention here, in addition to breaching the principle of ‘First come, first to pump.’ Interference is preventable by a better arrangement of geothermal energy systems underground.

Notes

1 This is re-adjusted later to 24 petajoules.

2 This means at national level: the use of CHP increases emissions from greenhouse horticulture, but those from the electricity sector fall even further. The Covenant ignores that emissions from the electricity sector come under the ETS.

3 See http://www.rijksoverheid.nl/documenten-en-publicaties/rapporten/2011/02/25/plan-van-aanpak-energiebesparing-gebouwde-omgeving.html and, as applicable, http://www.rijksoverheid.nl/documenten-en-publicaties/kamerstukken/2011/06/08/kabinetsaanpak-klimaatbeleid-op-weg-naar-2020.html.

4 Previously this was the Unique Opportunities Programme ‘Making Heat and Cold Sustainable.’

5 http://regelingen.agentschapnl.nl/content/subsidieregeling-industri%C3%ABle-warmtebenutting.

6 The subsidy ‘Market Launch of Energy Innovations” is intended to stimulate the early market launch stage of energy innovations in greenhouse horticulture.

7 http://www.energiek2020.nu/subsidies/markt-introductie-energie-innovaties-mei/

8 In full: subsidy scheme for energy and covering innovation risks for geothermal heat.

9 The target was 55 000 solar boilers, 5 000 heat pumps and 10 000 micro-CHPs.

10 As stated, heat pumps fall under the Sustainable Heat subsidy scheme.

11 http://regelingen.agentschapnl.nl/content/uniforme-maatlat.

12 http://agentschapnl.kaartenbalie.nl/gisviewer/indexlist.do.

13 http://www.thermogis.nl/thermogis.html.

14 Average for all types of housing: detached, semi-detached, corner house, terraced housing and apartment block.

15 The Lente Agreement is a covenant made by VROM with Bouwend Nederland, NEPROM and NVB.

16 This tightening has now taken place.

17 See http://www.nen.nl/web/Actueel/Energieprestatienorm-gebiedsmaatregelen.htm.

18 With regard to the EPC calculations, the Construction Decree allows the possibility of assessing the application of innovations which have not (yet) been evaluated using the computation methodology for the EPC and the energy label, in the form of equivalency declarations.

19 For buildings owned by government bodies, this requirement applies until the end of 2018. A nearly energy-neutral building means a building with a very high energy performance. The near-zero or very low quantity of energy required should be supplied, to a very considerable degree, from renewable sources, and should contain energy generated on site or nearby, from renewable sources.

20 The bundling of amendment provisions is referred to for the sake of brevity in I&M (2011) as the Geothermal Energy Systems Decree. However, this is not an ‘official’ title for that decree.

21 In exceptional individual cases, the authority can follow the extended public preparation procedure, with justification.

22 These are localities in which there is a big energy need per unit of surface area, and a large number of TES systems is expected (often an urban area).

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