Vesta: a spatial energy model for heat supply in the built environment in the Netherlands

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Abstract

The Vesta model is a spatial energy model of the built environment in the Netherlands. The aim of Vesta is to explore options to reduce energy consumption and CO_2-emissions in the period up to 2050. Both building and district heat measures can be calculated taking into account local conditions throughout the Netherlands. Simulation and optimization can provide insight into the technical-economic potential of options for energy saving, renewable energy and district heating. This provides insight into the CO_2-reduction and the costs and benefits for the actors involved, e.g. energy producer, consumer and investor. Energy companies, consultants and universities also increasingly use the model for more regional case studies. This requires thorough knowledge of the local situation and some limitations of the model.
Keywords: Energy modelling, CO_2-emissions, GIS, District heating, Energy savings, Built environment

1 Introduction

The Vesta-model geographically covers the whole of the Netherlands and uses Dutch open data. Spatial calculations are made using geographical data of the built environment and socio-economic indicators in combination with energy use data and possibilities for energy saving measures and district heat networks (van Bemmel et al., 2013).

It is programmed in The Geo Data and Model Software (GeoDMS) modelling framework from ObjectVision written in C ++ and Delphi (GUI). DMS-Scripting is done in configuration files which were made available as open source in 2017 at the github-platform (GitHub 2018). At present the time step in the model is 10 years but this can be changed. The software is typically characterized by transparency, reproducibility, fast calculation times and easy to use big calculation schemes.

2 Data and calculations

The energy demand is modelled geographically for homes (8 million objects), utilities (1 million objects) and greenhouses taking into account local conditions. Scenarios of future developments in the amount of homes and utilities are geographically allocated by taken the Land Use Scanner-results (Hilferink and Rietveld, 1999; Koomen et al., 2008). The Land Use Scanner is known as an integrated land-use model that is also programmed in the GeoDMS-software and forms at present a model-chain with Vesta.

Energy demand and costs for energy savings are calculated for each object depending on home or utility type and building age (van Bemmel et al., 2017). Each building has an energy label (see Figure 1) showing how well it is isolated (label G – worst, label A - best).

The district heat network (see Figure 2) begins at the heat source and is subdivided into a primary network, a secondary network and substations of heat exchange and auxiliary heat boilers. For each component the costs are calculated based on the local circumstances like heat demand and length of pipelines.

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2.1 Building measures

In Vesta there are two main categories of measures which can be taken: reduction in the heat demand (energy conservation) of buildings and district heating measures.
Most important possible building specific measures to be set in Vesta are:

- Insulation and installation efficiency improvement;
- Solar panels;
- Solar thermal collector;
- MicroCHP (local cogeneration);
- Heat Pump.

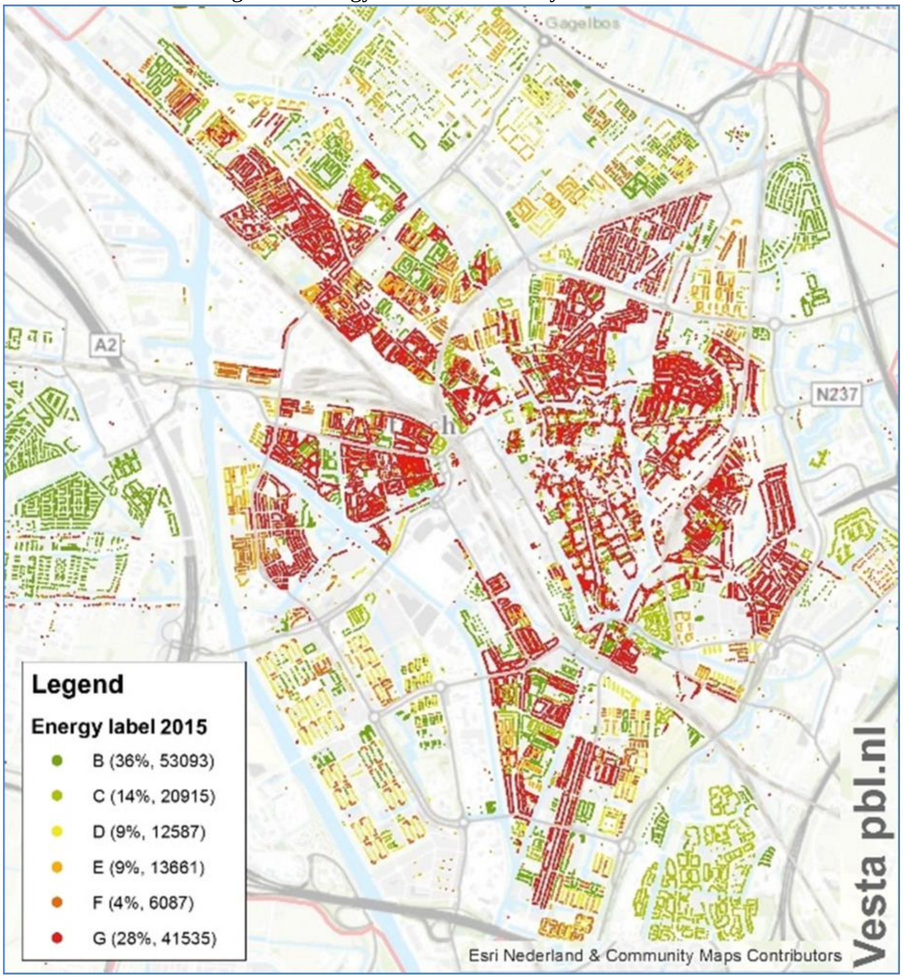
The user of the model can set two ways to let the model take energy conservation measures. The first is to take only profitable measures. The second by assigning the measures. The model can be used to analyse the effect of the energy savings on the profitability of district heating measures.

2.2 District heat measures

Feasibility of district heating is determined by local conditions, the presence of heat sources and the amount of energy demand. The model supports the following heat sources:

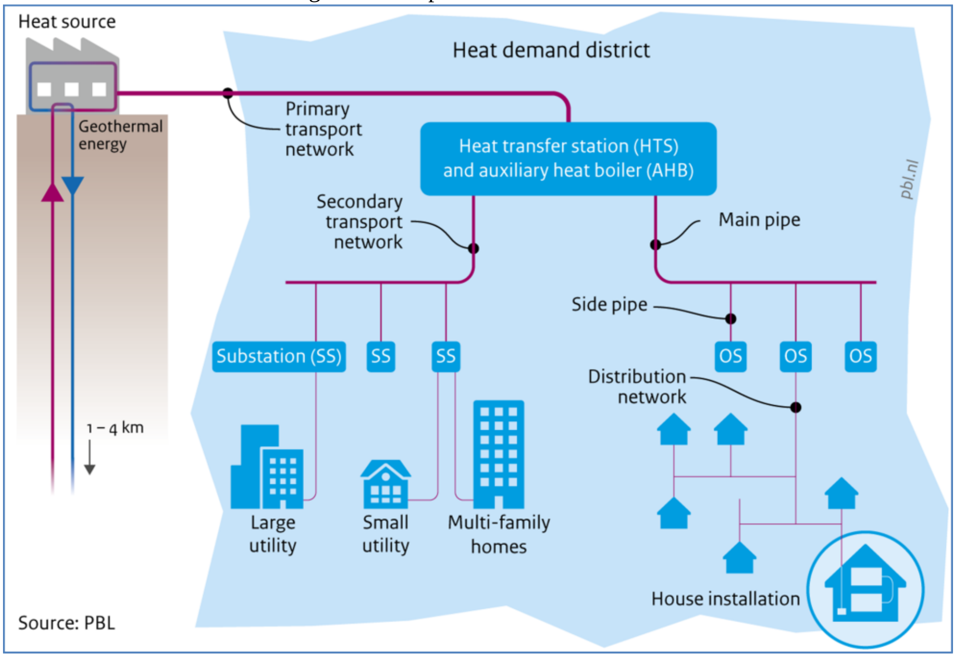
- Waste heat;
- Geothermal heat;
- ATES: Aquifer Thermal Energy Storage;
- CHP-DH-natural gas: Combined Heat and Power District Heating natural gas;
- CHP-DH-biofuels: Combined Heat and Power District Heating biofuels.

Figure 1: Energy label homes in city of Utrecht.



Source: Vesta, PBL.

Figure 2: Components heat network..



Source: Vesta, PBL.

At the moment up to 96% of the houses and utilities in the Netherlands have a natural gas-connection. The Vesta model calculates the districts where heat networks are profitable in case of changing circumstances like increases of energy prices, taxes and subsidies or lower interest rates of investors. Allocation of the heat network is done at the district-level on the size which is common practice in the Netherlands (around 3 km2). For each of the districts (12000 in the Netherlands) the profitability is calculated for a heat source according to a pre-defined order of the above mentioned sources. The first measure which is profitable (within 30 years with a positive Net Present Value) is assigned to the homes and utilities in the district. Sources of waste heat, geothermal heat and ATES has to be available in the neighbourhood of the district. ATES can be assigned at lower scales than districts e.g. a group of homes and utilities.

3 Results

The results of the Vesta model are (GIS-)maps, tables and postprocessed-graphs about the energy consumption and costs of actors within the built environment. In the produced results socio-economic characteristics of households and companies can be taken into account. The main outcomes of the model for each future decade are:

- Energy use, energy savings and CO_2-emissions of actors;
- Investment and energy saving costs of actors;
- Potential of cost-effective building and district heating measures.

Results are illustrated in Figure 3 and 4. In Figure 3, payback times are calculated for building measures for different scenarios thereby giving insight in the degree of feasibility of a measure. Figure 4 illustrates the possibilities of applying district heating measures in the future in the Netherlands under certain conditions. Finally, the Figure 5 shows the potential of CO_2-reduction and the associated costs which can be calculated with the model.

Although Vesta is a national model, increasing efforts are made by researchers to apply it to a more regional level. This requires thorough knowledge of the local situation and data import of local circumstances.

4 Conclusion

Vesta has already shown its value in several different studies. It is one of the few models in the Netherlands, if not the only model that takes geographical data at such high leveled detail in combination with climate and energy cost optimization calculations. Since Vesta became open source at the beginning of 2017, an increasing number of energy companies, consultants and universities are beginning to use Vesta. Future planned improvements are the incorporation of low temperature heat networks, emissions to air; and gas and electricity networks in the model.

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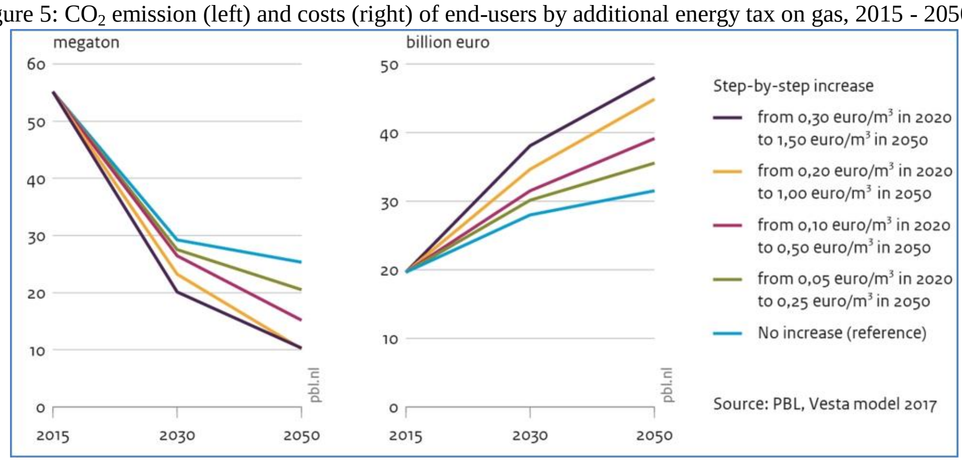
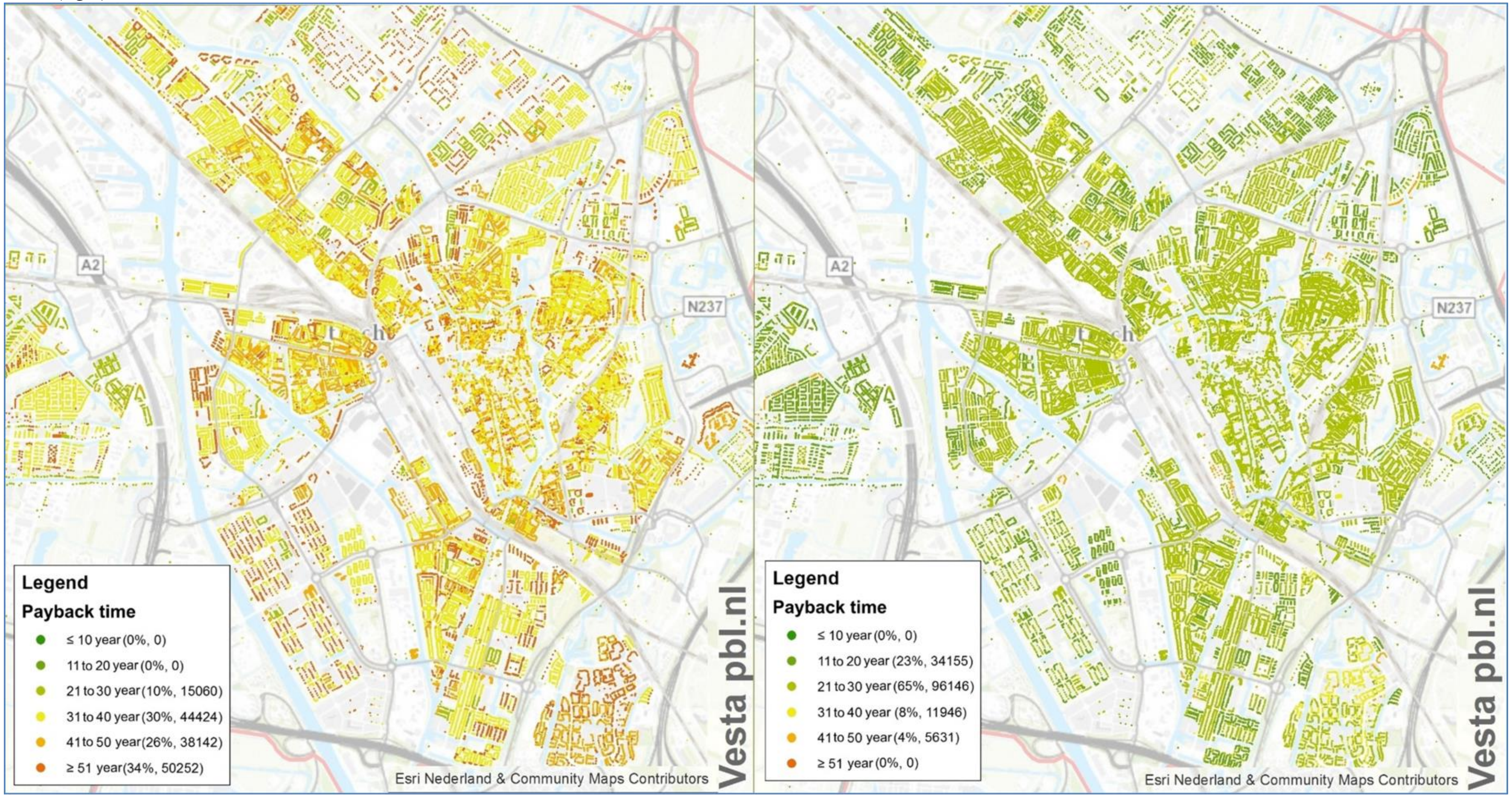
Figure 5: CO_2 emission (left) and costs (right) of end-users by additional energy tax on gas, 2015 - 2050.



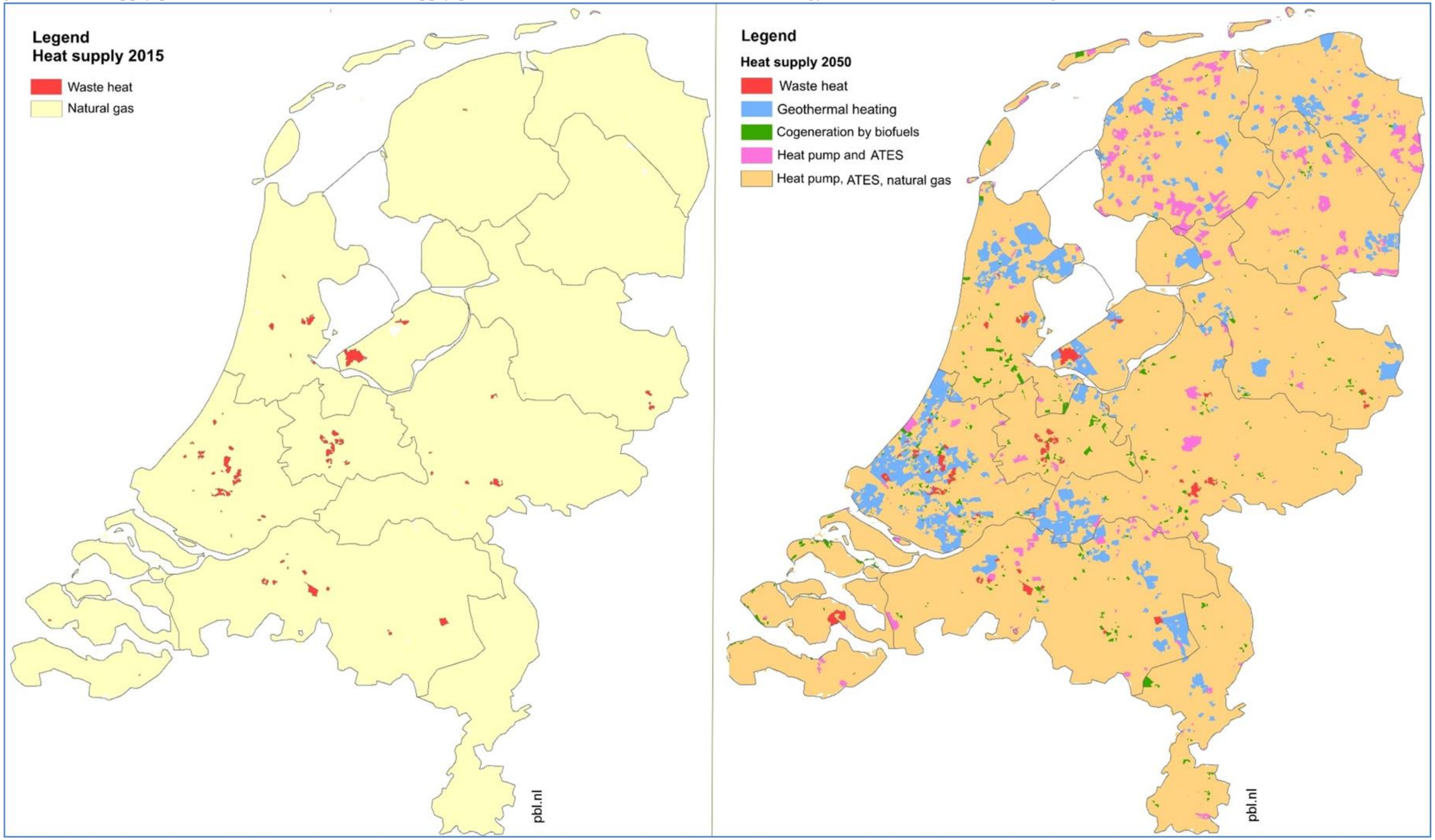
Source: Vesta, PBL.

Figure 3: Payback time for renovation of homes from current energy label to A^+ including heat pump. City of Utrecht, Scenario additional energy tax 0,50 euro/m^3 (left) and 1,00 euro/m^3 (right).



Source: Vesta, PBL. BAG, Kadaster.

Figure 4: Heat supply per district in 2015 (left). Heat supply per district in 2050; Scenario additional energy tax 1,50 euro/m^3 on natural gas (left).



Source: Vesta, PBL.