2050

Heat Roadmap Europe

A low-carbon heating and cooling strategy

Method for developing demand cost-potential curves

WP4: Quantifying the Potential for Reducing the Heating and Cooling Demands in the EU

D4.1 Cost curve methodology

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Table of Contents

1. Introduction

In Europe, there is a clear long-term objective to decarbonise the energy system, but it is currently unclear how this will be achieved in the heating and cooling sector. The Heat Roadmap Europe 4 (HRE4) project will enable new policies and prepare the ground for new investments by creating more certainty regarding the changes that are required. HRE4 is co-funded by the European Union, brings together 24 academic, industrial, governmental and civil society partners, and runs from 2016-2019.

The overall objective of the HRE4 project is to provide new capacity and skills for lead users in the heating and cooling sector including policymakers, industry, and researchers at local, national, and EU levels by developing the data, tools, and methodologies necessary to quantify the impact of implementing more energy efficiency measures on both the demand and supply sides of the sector.

The objective of Work Package 4 of the HRE4 project is to calculate cost-potential curves for reducing the heating and cooling demand in buildings and industries for 14 MSs in Europe.[1] Starting point for the cost-potential curves is the HRE4 demand baseline developed with the FORECAST model (Work Package 3). The demand cost-potential curves are input to the EnergyPlan model (Work Package 5) wich is used in the HRE4 project to optimize the energy system in 2030 and 2050. In this report the demand cost-potential curve method is developed. In the following chapters we start with describing the needs of EnergyPlan (Ch.2) and the commonly used cost-potential curve method (Ch.3). Then in Chapter 4 we propose how to align EnergyPlan and FORECAST. In Chapter 5, the Work Package 4 exchange template is discussed.

[1] The word "heat" in this document refers to both heat and cooling.

2. EnergyPLAN

2.1. What type of cost curve EnergyPLAN is looking for?

EnergyPLAN needs a demand cost-potential curve as given in Figure 1. Such curve shows the heat demand[2] (x-axis) which can be reduced by investing in heat savings measures. The deeper the heat savings the higher the investment costs of the next unit of heat savings (reducing marginal utility). As indicated in the figure, a cost curve is needed for 2030 and 2050.

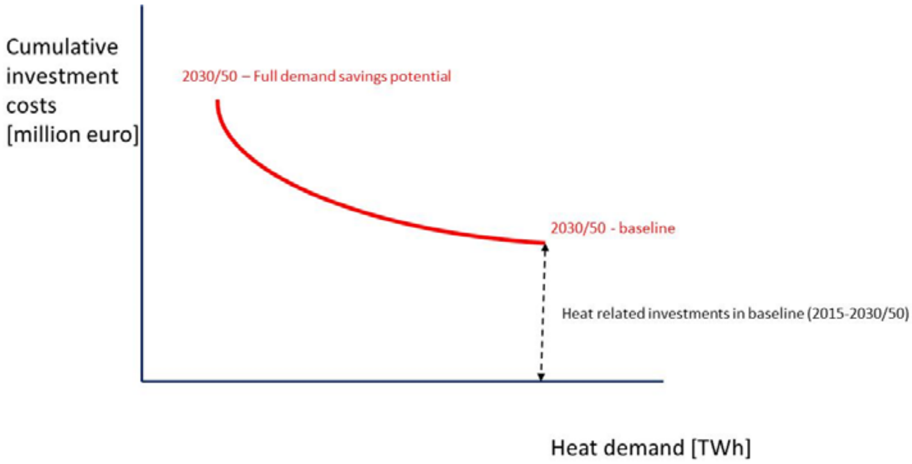

Figure 1. Demand cost-potential curve

The curve should be read from the right to the left. The starting point is the heat demand in 2030/50 in the baseline scenario (which reflects the outcome of current policies in the individual member states). The cumulative investment costs in 2030/50 include all heat related investments in the baseline period (2015-20/3050), being both investments in heat savings and activity growth (more m^2 building stock, more industrial production capacity).[3] The red curve represents all savings measures that can be implemented on top of the baseline scenario.

2.1.1. How is EnergyPLAN using the cost-potential curves?

EnergyPLAN aims to find the least energy system cost (optimum) for 2030/50 by following a step-wise approach:

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[2] Being the delivered energy for space heat , hot water, industrial heat and cooling).

[3] Important to note is that, although new building and new production capacity will generally be more efficient than existing stock, they make heat demand grow.

1. Start with an additional 10% demand reduction compared to the 2030/50 baseline, optimise the supply and determine the total energy system costs.[4]
2. Now implement 20% demand reduction and, again, optimize the supply and determine the total energy system costs.
   a. If the total energy system costs with 20% demand reduction are higher than with 10% demand reduction, iterate between 10 and 20% to find the optimum.
   b. If the total energy system costs are lower compared to 10% demand reduction, implement 30% demand reduction, optimize the supply and determine the total energy system cost.
      i. Etc.

[4] One step earlier is to optimize supply using 0% heat savings compared to the 2030/50 baseline. This would allow to compare the optimization of TIMES versus the optimization of EnergyPLAN. Such exercise is not within the WP4 scope, but will be done in WP5 and WP6.

3. FORECAST cost-potential curve method

Before discussing how to align FORECAST and EnergyPLAN, we briefly explain how normally cost potential curves are developed in FORECAST. With FORECAST two general types of cost curves can be developed:

- A cost potential curve: Such curve only covers energy system costs of technical measures and disregards considerations of investment decisions.
- A marginal abatement cost curve (MACC): Such curve can be calculated as CO_2-price sensitivity by running a number of model runs with varying CO_2 prices. The resulting cost curve then considers all investment inertia and routines included in the model. It, thus, goes beyond only technical energy system cost. Depending on the assumptions of market barriers and discount rates, the resulting energy saving potential can be much lower than in the first type of curves.

Figure 2 shows a typical cost-potential curve of the first type. On the horizontal axis the (potential) savings in the target year are given (TWh/year), whereas on the vertical axis the specific (or: marginal) costs for each of the savings technologies is shown (Euro/MWh). Each bar in the curve represents a savings option. The area of each bar (TWh/year x euro/MWh = keuro/year) represents the costs or benefits for that particular option *in the target year only*. As the FORECAST model includes end-use supply options such as boilers and heat pumps, , the cost-potential curves often include both.

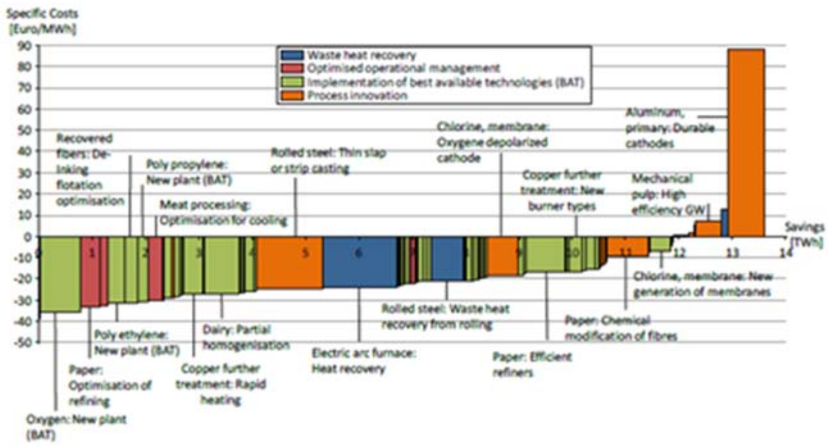

Figure 2. Typical cost-potential curve from FORECAST

The cost-potential curve shows the energy savings potential relative to a baseline scenario. This is illustrated in the Figure 3.

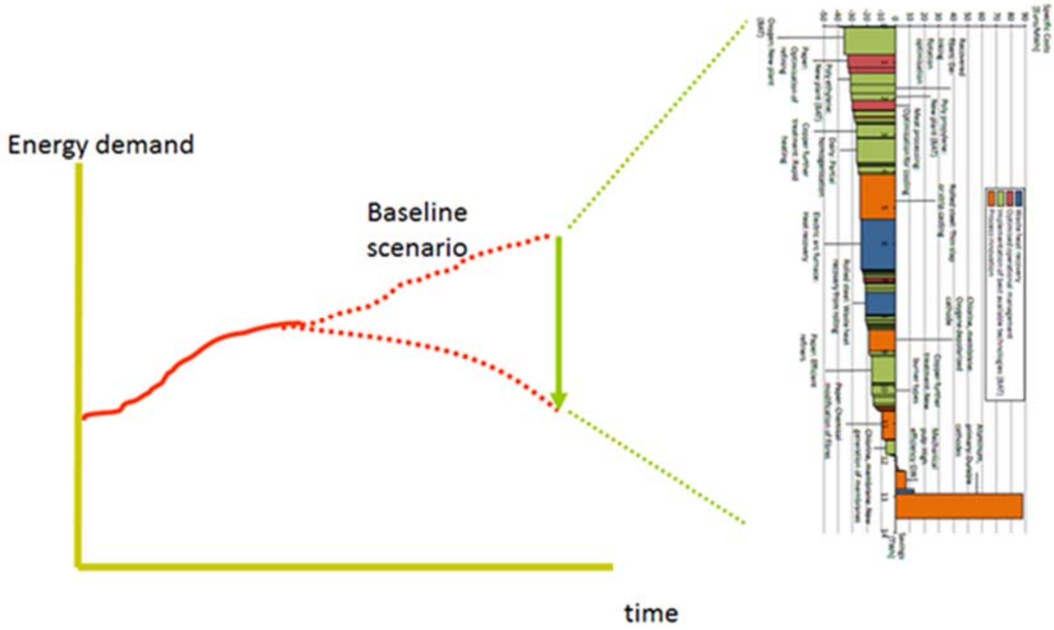

Figure 3. the FORECAST cost-potential curve "at work"

The specific costs (y-axis in the cost-potential curve) are calculated with the following formula[5]:

$$specific\ costs = \frac{\alpha\Delta \mathrm{I} + \Delta(\mathrm{C} - \mathrm{B})}{\Delta E}$$

$$\alpha = \frac{r}{(1-r)^{-\mathrm{L}}}$$

Where:

α= annuity or capital factor, r = discount rate, L = technology lifetime

ΔI = the additional investment of the energy savings technology compared to the reference technology, in real prices (e.g. 2015 euros)

Δ(C-B) = the annual net additional benefits (or costs) of the energy savings technology compared to the reference technology (including O&M costs, fuel costs, etc.), in real prices

ΔE = the annual energy savings of the savings technology compared to the reference technology

[5] Note that the formula becomes more complex in case the annual Δ(C-B) vary (e.g. because of fluctuating fuel prices, the use of nominal values or different lifetime of the energy savings technology compared to its reference technology.

4. Alignment of FORECAST and EnergyPLAN

4.1. Different discount rates: a problem or not?

EnergyPLAN uses a social approach to time-discounting, FORECAST is a private decision making model so uses private decision making discount rates. Given the general objectives of the HRE4 project this makes perfect sense. FORECAST is used in the project to provide a 2015-2050 baseline reflecting the result of private decision making given a set of assumptions regarding economic growth, energy price development and policy, whereas EnergyPLAN is looking for a cost optimized solution (from a societal perspective) when reductions in energy use and emissions beyond the baseline are aimed for.

A FORECAST **cost potential curve** is well aligned with the cost-curve objectives of the HRE4 project. It provides the maximum demand savings that can be deployed in the target period (as it disregards investment decision considerations) and, as such, does not restrict EnergyPLAN in finding the cost optimum between demand savings and efficient supply.

Using a technical scenario means that the discount rates used in the FORECAST model do not interfere with the social discount rate used in EnergyPLAN since only total investment costs are exchanged between the models (see Figure 1) and not the annualized costs ($\alpha \cdot \Delta I$).

4.2. Definition of investment costs

EnergyPLAN aims to find a cost-optimum between (deep) heat demand savings and (efficient & low carbon) supply of heat. To ensure a fair competition between demand and supply technologies it is very important to align the definition of investment costs.

It has been agreed that, both for demand (FORECAST) and supply (EnergyPLAN) options, investment costs include:

- Total investment costs of a technical measure
- Costs for installing a technical measure
- Both cost categories are expressed in 2015 euros (real value)

4.3. Learning

Assumptions regarding learning of both demand (FORECAST) and supply (EnergyPLAN) need to be aligned. This does not mean that the learning rate of different technologies (supply and/or demand) should be same. However, applying conservative assumptions (no learning at all) for supply options and progressive learning for demand options (or vice versa) will violate the level playing field in the calculations. In EnergyPLAN, learning takes place via improved efficiencies and reduced costs for the technology.

5. WP4 exchange template

The following cost curves (one for 2030 and one for 2050) will be be delivered for each of the 14 core Member States:

- Residential Space Heat
- Residential Cooling
- Services Space Heat
- Services Cooling
- Industry: <100˚C
- Industry: 100-X˚C [6]
- Industry: >X˚C
- Industrial Cooling

Cost curves for the other 14 Member States will be developed (based on assumptions taken from the 14 core Member States), but reported in an aggregated way.

Having separate costs curves for, at least, the above mentioned categories allows for a transparent communication of the results, i.e. providing insight in how much demand savings for each of the categories can be added on top of the baseline scenario while minimizing total energy system costs.

Each cost-curve contains the following:

- A qualitative storyline. Each cost-curve is a scenario for which choices have been made. A qualitative storyline makes these choices transparent and as such allows for a more informed discussion about the results.
- Quantitative data (Excel table / graph):
    - Starting point of the cost curve: The total heat related investments in the baseline period (2015-2030/2050), being both investments in heat savings and activity growth (more m^2 building stock, more industrial production capacity). These investment costs are linked to the baseline heat demand in 2030/50 (right hand start of the cost curve, see figure 1).
    - A list of the heat savings measures that can be implemented on top of the baseline
        - The sequence of this list is determined on the heat savings/investment costs ratio. The higher this ratio the higher the ranking of a heat savings measure (positioned at the right side of the curve).

[6] The exact boundaries for industrial heat will be determined during the development of the cost-potential curves. In principal, the same breakdown as used in the baseline scenario will be used.

- For each measure the investment costs (in euro) and heat savings (in TWh) are provided.
- The investment costs are additional to the costs in the baseline to avoid double counting of the costs (as the measures will replace investments made in the baseline).
- For each measure in the list a lifetime need to be provided (to allow EnergyPLAN to annualize the investment costs).[7] For packages of smaller heat savings options, a weighted average lifetime will be used to reduce complexity.
- Each measure in the list should be formulated as precise as possible. E.g. for the insulation measures in the residential and services sector the amount of m^2 and specific building type targeted should be provided.[8]
- Overlap in the curve must be avoided to not overestimate the heat savings potential. This may happen in case of competing savings options.

This list of heat saving measures in each of the cost curves would allow EnergyPLAN to be more flexible in the implementation of the heat savings than described in section 2.2. Rather than steps of 10% and final iteration, one could choose to make bigger or smaller steps in the beginning depending on how flat the curve is.

Specific issues for saving options in industry and built environment which need tailor made solutions, will be dealt with while developing the cost-potential curves.

[7] It is important to well-align the lifetimes used for the heat savings options (FORECAST) and the supply options (EnergyPLAN) to allow for a fair competition in the cost optimization.

[8] If this is not done, measures can be interpreted in different ways by EnergyPLAN. E.g. an insulation measure saving 100 TWh can mean that X houses are modestly renovated or that X/2 houses are deeply renovated. This makes quite a difference when considering the future potential of district heating e.g.