GreenNet-EU27

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GreenNet-EU27

GUIDING A LEAST COST GRID INTEGRATION OF RES-ELECTRICITY IN AN EXTENDED EUROPE

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Database on Potentials and Cost of RES-E and Energy Efficiency for the EU-25 Member States (+ NO, CH, RO, BG, HR)

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1 INTRODUCTION

The core objective of the project **GreenNet-EU27** is to derive least cost strategies for RES-E grid integration into the European electricity grids. Further important objectives are the dissemination of the project results and practical guidelines to a broad audience, especially to key stakeholders as there are decision makers, regulators, grid companies and RES-E generators. Besides a variety of other dissemination channels the project website www.greennet-europe.org is a core dissemination tool of the project **GreenNet-EU27**.

This report mainly studies potentials and cost of RES-E and energy efficiency (EE) for the EU Member States including the Candidate Countries Bulgaria, Romania and Croatia as well as Norway and Switzerland. The basis therefore is the existing database for RES-E and EE potentials and cost developed within the predecessor IEE-project **GreenNet**. This database was updated, improved and extended to cover several countries addressed in the present project and contains the basic input data used within the software tool **GreenNet-EU27**. Besides this report a comprehensive data base on disaggregated level (Deliverable D1) is available for download on the project website www.greennet-europe.org.

The report is organised as follows:

- In chapter 2 potentials and cost of RES-E for the EU-25+ countries are addressed. After the description of the analytical framework for the model implementation an overview on potentials and cost for the EU-25 Member States on aggregated as well as disaggregated level is given. Finally the remaining countries, not covered in the project **GreenNet** are characterised separately including a description of the power system structure, future RES-E targets, implemented promotion schemes and achieved as well as future RES-E potentials.

- Chapter 3 addresses potential and costs for EE-DSM in EU-25+ countries. After an explanation of the steps taken for producing the dynamic electricity demand curves, sources of data are characterized and assumptions are explained. Resulting potentials and costs for EE-DSM are reported.

2 POTENTIALS AND COSTS FOR RES-E IN EU-25+ COUNTRIES

A broad set of different technologies in the field of electricity generation based on renewables (RES-E technologies) exists today. Obviously, for a comprehensive investigation of the future development of RES-E in EU-25+ countries it is of crucial importance to provide a detailed investigation of the country-specific situation, e.g. with respect to the potential of the certain RES-E in general as well as their regional distribution and the corresponding economic aspects. Therefore based on the existing database on potentials and cost of RES-E for the EU-15 Member States incl. the Czech Republic, Hungary, Poland and Slovakia developed under the predecessor project **Green*Net*** an actualised and extended database was developed under WP1 of the present project that covers several EU Member states, the Candidate Countries Bulgaria, Romania and Croatia as well as Norway and Switzerland. The result of the EU-wide assessment is presented in the following addressing in particular: (i) the general framework for model implementation in **Green*Net*-EU27**, (ii) an overview on the historical development, achieved and future potentials and cost of RES-E in the EU-25+ countries and (iii) a brief description of several countries not being covered within **Green*Net*** containing information on the power system structure, RES-E targets, implemented promotion schemes and achieved (until end of 2004) as well as future RES-E potentials (up to 2020).

General Remarks

Calculation of electricity costs

In the model **Green*Net*-EU27** the calculation of electricity generation costs for the various generation options is done by a rather complex mechanism as described later – internalized within the overall set of modelling procedures. Thereby, band-specific data (e.g. investment costs, efficiencies, full load-hours, etc.) is linked to general model parameters like interest rate and depreciation time. The later parameters depend on a set of user input data like policy instrument settings, etc. Nevertheless, for a better illustration of the band-specific set of data presented in the following, marginal electricity generation costs are exemplarily depicted. Thereby, for long-run marginal generation costs (as applied for new plants) a default capital recovery factor is used – based on the following settings:

- Interest rate z = 6.5%
- Pay-back time PT = 15 years

Cost-data with respect to CHP-plants

In case of CHP, investment costs, etc. refer to the power plant only – i.e. costs for district heating network are excluded. Hence, the assumed heat price in default size of 20 €/MWh must be seen as price according to the defined hand-over point. In this context, this price represents the additional revenue for the power producer due to selling of heat in case of combined heat production, but, of course, does not indicate the final consumer price for heat.

Classification of RES-E

Initially, in order to increase the legibility of this report and to avoid any misinterpretation, an overview on the investigated RES-E technologies and their classification used within the project **GreenNet-EU27** is given (see table below).

Table 2.1. Overview on classifications applied for the various RES-E

Detailed classification (in accordance with 'RES-E Directive' & sub-categories of **GreenNet-EU27**)	**Common classification**
Agricultural biogas[1]	**Biogas**
Landfill gas	
Sewage gas	
Forestry products (wood)	**Solid biomass**
Forestry residues (bark, sawmill by-products etc.)	
Agricultural products (energy crops)	
Agricultural residues (incl. vegetal and animal substances, e.g. straw)	
Biodegradable fraction of waste (MSW+ISW)	**Biowaste**
Geothermal electricity	**Geothermal electricity**
Small scale hydro power (<10 MW)	**Small hydro**
Large scale hydro power (>10 MW)	**Large hydro**
Photovoltaics	**Photovoltaics**
Solar thermal electricity	**Solar thermal electricity**
Tidal energy	**Tidal & wave**
Wave energy	
Wind on-shore	**Wind onshore**
Wind off-shore	**Wind offshore**

The resource definition, representing the most detailed classification (left), is done in accordance with the 'RES-E directive' (European Council and Parliament, 2001). A similar categorization is applied in the computer model **GreenNet-EU27** and the accompanying database. For most graphical representations, e.g. of results, databases, etc. the common classification will be used in this document.

[1] Fuel sources are in this case farm slurries, usable agricultural residues (i.e. from sugar beet production), residues from pasture and the separated biodegradable fraction of municipal wastes.

2.1 Model implementation - Analytic framework

In the model **GreenNet-EU27** generation costs and corresponding potentials of all RES-E (for each EU country) are described by 'dynamic cost-resource curves' being subject to this section. Firstly, the calculation of electricity generation costs from RES will be explained, followed by a description of the potentials. Finally, the methodology used for the specification of dynamic 'cost-resource curves' is outlined.

2.1.1 Calculation of electricity generation costs

When calculating the generation costs a distinction must be made between already installed and potentially new plants. For existing plants, the running costs (short-term marginal costs) are relevant only for the economic decision whether or not to use the plant for electricity generation. On contrary, for new capacities the long-term marginal costs are important.

2.1.1.1 Existing plants

The annual running costs are split into two parts: fuel costs and operation/maintenance (O&M) costs. The fuel costs are a function of the fuel price of the primary energy carrier and the efficiency. In the toolbox **GreenNet-EU27**, the O&M-costs must refer to the electricity output. Hence, the O&M costs, referring to the energy unit in the database, must be coupled with the full-load hours.[2] In general, one average operation time (full-load hour) is taken for each technology band. Analytically, the generation costs for existing plants are given by:

$$C = C_{VARIABLE} = C_{FUEL} + \tilde{C}_{O\&M} - R_{HEAT} = \frac{p_{FUEL}}{\eta_{el}} + \frac{C_{O\&M}}{H} * 1000 - p_{HEAT} \frac{\eta_{heat}}{\eta_{el}} \cdot \frac{H_{heat}}{H_{el}} \qquad (1)$$

where:

C ..... Generation costs per kWh [€/MWh]

$C_{VARIABLE}$ ..... Running costs per energy unit [€/MWh]

C_{FUEL} ..... Fuel costs per energy unit [€/MWh]

$\tilde{C}_{O\&M}$ ..... Operation and maintenance costs per energy unit [€/MWh]

$C_{O\&M}$ ..... Operation and maintenance costs per energy unit [€/(kW*a)]

R_{HEAT} ..... Revenues gained from purchase of heat [€/MWh]

p_{FUEL} ..... Fuel price primary energy carrier [€/$MWh_{primary}$]

p_{HEAT}..... Heat price [€/MWh_{heat}]

η_{el}..... Efficiency – electricity generation [1]

η_{heat} ..... Efficiency – heat generation [1]

H_{el}..... Full-load hours – electricity generation [h/a]

H_{heat}..... Full-load hours – heat generation [h/a]

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[2] The full-load hours represent the equivalent time of full operation in a year. It is calculated for a certain power plant by dividing the amount of electricity generated per year by its nominal power capacity. For the theoretical cost-resource curves, this term reflects an important aspect, namely the suitability of sites (e.g. for wind energy). The full-load hours in the case of wind energy are determined by the wind speed distribution and the rated wind speed of the machines. Knowing the expected full-load hours, the quantity of electricity to be generated can be calculated. Hence, costs per unit are determined. 'Full-load hours' divided by the number of hours in a year (8765h on average) equals the dimensionless 'capacity factor'.

General remarks:

- Apart from all kinds of biomass (biogas, solid biomass, sewage and landfill gas), renewables have zero fuel costs, so running costs are determined by operation & maintenance costs only. Therefore the running costs for RES-E are normally low compared to fossil fuels.
- In the toolbox **GreenNet-EU27**, primary fuel prices are given exogenously on a yearly basis. For the sensitivity analysis, however, these default values can be adapted.
- In the case of simultaneous electricity and heat generation (i.e. CHP), electricity generation costs are calculated by considering the revenues gained from the sale of the heat.

2.1.1.2 New plants

The calculation of the generation costs of electricity consists of two parts, variable costs and fixed costs. In more detail, the generation costs are given by:

$$C = C_{VARIABLE} + \frac{C_{FIX}}{q_{el}} = \left(C_{FUEL} + \frac{C_{O\&M}}{H_{EL}} * 1000 - R_{HEAT} \right) + \frac{1000 * I * CRF}{H_{EL}} \qquad (2)$$

where:

C ..... Electricity generation costs per kWh [€/MWh]

q_{el} ..... Quantity of electricity generation [MWh/a]

$C_{VARIABLE}$ ..... Running costs per energy unit [€/MWh]

C_{FIX} ..... Fixed costs [€]

C_{FIX} / q_{el} ..... Fixed costs per energy unit [€/MWh]

C_{FUEL} ..... Fuel costs per energy unit [€/MWh]

$C_{O\&M}$ ..... Operation and maintenance costs per energy unit [€/(kW*a)]

R_{HEAT} ..... Revenues gained from sales of heat[3] [€/MWh]

I ..... Investment costs per kW [€/kW]

CRF..... Capital recovery factor: $CRF = \frac{z * (1+z)^{PT}}{\left[(1+z)^{PT} - 1\right]}$

z ..... Interest rate [1]

PT ..... Payback time of the plant [a]

H_{EL} ..... Full-load hours electricity generation [h/a]

A more detailed description of the running costs is given in the previous chapter. Fixed costs occur independently whether or not the plant generates electricity. These costs are determined by investment costs (I) and the capital recovery factor (CRF).

Investment Costs

The investment costs differ by technology and energy source. In general, investment costs per unit capacity for RES-E are higher than for conventional technologies based on fossil fuels. Also differences occur between RES-E technologies, e.g. investment costs per unit

[3] In case of CHP, the calculation of the revenues gained from sales of heat is described in equation (1).

capacity for small hydropower plants are generally at least twice those for wind turbines. Since most RES-E technologies (with the exception of (large-scale) hydropower) are still not mature, investment costs decrease over time. This evolution is taken into consideration in the toolbox **GreenNet-EU27**, i.e. investment costs are derived annually.[4]

Forecasting technology development is a crucial activity, especially for a long time horizon. Considerable efforts have been made recently to improve the modelling of technology development in energy models. A rather 'conventional' approach relies exclusively on exogenous forecasts based on expert judgements of technology development (e.g. efficiency improvements) and economic performance (i.e. described by investment and O&M-costs). Recently, within the scientific community, this has often been replaced by a description of technology-based cost dynamics which allow endogenous forecasts, at least to some extent, of technological change in energy models: This approach of so-called 'technological learning' or 'experience/learning curves' method takes into account the "learning by doing" effect.[5]

Within the model **GreenNet-EU27** the approach chosen differs by technology. In principle, the database is prepared to include two different approaches: Standard cost forecasts or endogenous technological learning. Default settings have been applied as follows:

- For conventional power generation technologies – as well as some renewable energy technologies - it was decided to adopt well-accepted expert judgements.
- For a set of renewable energy technologies like, e.g. wind power or PV, it was decided to adopt the approach of technological learning. Learning rates were assumed at least for each decade[6] separately.

The default approach chosen to determine future investment costs is summarised by technology in Table 2.2.

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[4] The 'yearly' determination of the investment costs represents an important input to the data-tables. In more detail, the following parameter must be derived for each country and technology according to the given situation for the year n-1 and the year n:

- quantitative values for investment costs over time.
- quantitative values for the development of efficiency over time.

[5] In principle the so-called 'learning effect' - being empirically observed in several fields of technological development – states that for each doubling of producing / installing a certain technology, a decline of the costs can be expected by a certain percentage, the learning rate. For a brief description of the learning / experience curve approach, see e.g. Wene et al., 2000.

[6] In many cases experience has shown that the rate of technological learning is often closely linked to the development stage of a certain technology – i.e. at an early stage of development, if a technology is 'brand new', high learning rates can be expected and later, as the technology matures, a slowdown occurs.

Table 2.2. Overview of the methodology to derive investment costs for different technologies.

Dynamic cost development	Methodology to derive investment costs year n
Biogas	learning curve–approach or forecast
Biomass	Forecast
Geothermal electricity	Forecast
Small scale hydropower (<10 MW)	Forecast
Large scale hydropower (>10 MW)	Forecast
Landfill gas	learning curve–approach or forecast
Sewage gas	learning curve–approach or forecast
Photovoltaics	learning curve–approach
Solar thermal electricity	Forecast
Tidal energy	Forecast
Wave energy	Forecast
Wind on-shore	learning curve–approach
Wind off-shore	learning curve–approach
Nuclear power stations	Forecast
Steam	Forecast
Gas turbine	Forecast
Combined cycle power turbines	Forecast
Internal combustion engine plants	Forecast

Capital recovery factor CRF

The CRF allows investment costs incurred in the construction phase of a plant to be discounted. The amount depends on the interest rate and the payback time of the plant. For the standard calculation of the generation costs these factors are set for all technologies as follows:

- payback time (PT) of all plants: 15 years
- interest rate (z) equals 6.5%

Note, in the toolbox **GreenNet-EU27**, different interest rates will be applied. The interest rate depends on stakeholder behaviour and is a function of

- guaranteed political planning horizon
- promotion scheme
- technology
- investor category

General remarks:

- As the generation costs are calculated per energy output, the fixed costs must also be related to electricity generation q_{el}, compare equation (2). Hence, the fixed costs per unit output are lower if the operation time of the plant - characterised by the full load-hours - is high.
- Deriving the generation costs for CHP plants is similar to the calculation for plants producing electricity only. Beside the short-term marginal costs, i.e. the variable costs, fixed costs must be considered for new plants. Of course, equivalent to the case for existing plants, variable costs differ between CHP and conventional electricity plants, as the revenue from selling heat power must be considered in the first case.
- In general, no taxes are included in the various cost-components.

2.1.2 Determination of the (additional) mid-term potential

The starting point for deriving the dynamic potential is the determination of the additional mid-term potential for electricity generation for a specific technology in a specific country.[7] The additional mid-term potential is the maximal additional achievable potential assuming that all existing barriers can be overcome and all driving forces are active. The so-called 'dynamic potential' is the maximal achievable potential for the year n. This means advantage must have been taken of all existing promotion strategies both on the investor and the consumer side. To illustrate this more clearly, the connections between the different potential terms are depicted in Figure 2.1.

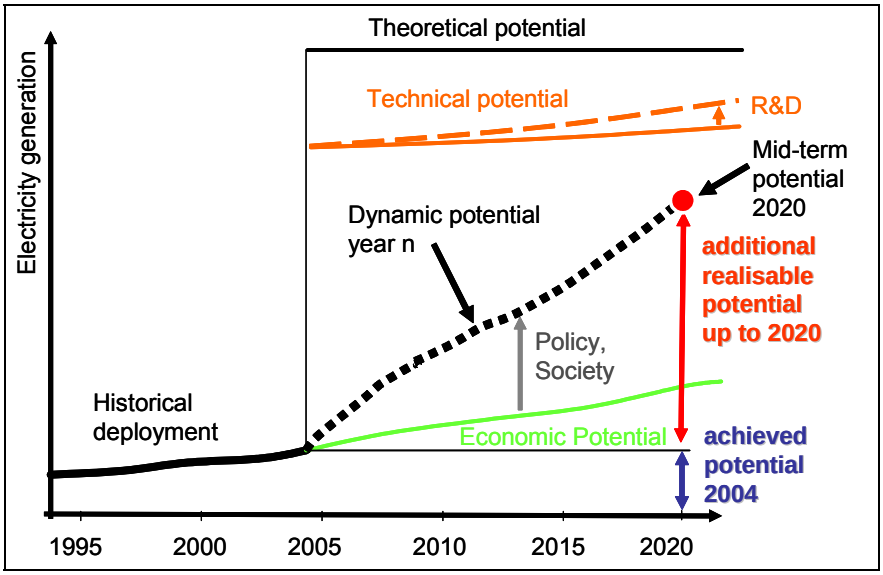


Figure 2.1. Methodology for the definition of different potentials

In the toolbox **GreenNet-EU27** the additional mid-term potential for electricity generation refers to the year 2020. The methodology for the analysis of the potential varies significantly from one technology to another.

In most cases a 'top-down' approach is used (e.g. for wind energy, photovoltaic). In a first step the technical potential for one technology in one country for 2020 has to be derived by determining the total useable energy flow of a technology. Secondly, based on step one, the mid-term potential for the year 2020 is determined by taking into consideration the technical feasibility, social acceptance, planning aspects, growth rate of industry and market distortions. The additional mid-term potential is given by the mid-term potential minus existing penetration plus decommissioning of existing plants.[8]

For a few technologies, a 'bottom-up' approach has been more successful (e.g. for geothermal electricity), i.e. by looking at every single site (or band) where energy production seems possible and by considering various barriers, the additional mid-

[7] Note: While the additional mid-term potential represents an important input parameter in the **GreenNet-EU27** database, the additional annual potential (dynamic potential) is one of the essential output parameters of the cost curve development.

[8] To use the potential in the database of the toolbox **GreenNet-EU27**, the additional mid-term potential obtained on the technology level (in one country) must be broken down to the band level.

term potential is derived. The accumulated value of the single band yields the additional potential for one technology in one country.[9]

In this context, one specific problem occurs with respect to biomass. The total primary energy potential for biomass is restricted. The actual distribution among the different options - pure electricity generation, CHP generation, heat generation or biofuel - depends on the net economic condition. As for the economic assessment, various support schemes must be considered, the final decision as to which options will actually be implemented is only feasible after including this step. To solve this problem, the values and the different options are linked in the database.

For a detailed description of the resource-specific approaches used within the project **GreenNet-EU27** for the assessment of future RES-E potentials see Resch (2005), p. 80-93.

2.1.3 Assessment of the economic data for RES-E

The assessment of the economic parameters and accompanying technical specifications of the various RES-E technologies comprises a comprehensive literature survey and an expert consultation. With respect to existing plant, representing the already achieved potential at the end of 2004, also project specific information is taken into account. References of major relevance are discussed below.

A set of studies can be listed which provide a comprehensive survey on RES-E technologies, thereby including detailed economic and technical data with respect to most common technologies. Namely these are, listed in chronological order: (DTI/ETSU, 1999) (DLR/WI/ZSW/IWR/Forum, 1999), (Neubarth et al., 2002), (Haas et al., 2001), (Resch et al., 2001), (Nowak et al., 2002), (Kaltschmitt et al., 2003), (BMU, 2004).

References with a focus on selected technologies are listed in the following by RES-E category:

- Biogas and Biomass: (Enquete, 2002), (EUBIONET, 2003)
- Geothermal electricity: (BMU, 2002)
- Hydropower: (Lorenzoni, 2001)
- Photovoltaics: (Alsema, 2003), (Schäffer et al., 2004)
- Solar thermal electricity: (Quaschning, Ortmann , 2003)
- Wind energy: (Greenpeace, 2001), (Neij et al., 2003), (BTM, 1999-2003), (Beurskens, Noord, 2003)
- Tidal and wave energy: (Thorpe, 1999), (DTI/ETSU, 2001), (Michael, 2002)

2.1.4 Development of the 'static' cost-resource curve

A cost-resource curve shows the correlation between electricity generation costs per unit and the potential (in terms of capacity or electricity generation) for one specific technology in one country per annum. Hence, the development of a cost curve implies knowledge of the two items explained above:

- costs for electricity per unit;

[9] For the toolbox **GreenNet-EU27** the addition of the single band is not necessary as the information must be available on band level.

- total quantity of electricity that can be generated or capacity that can be installed, respectively, per annum at certain cost levels. The cumulated sum of these amounts is equal to the totally available potential of a certain technology.

Cost curves for one technology (and country) are divided into different bands, see Figure 2.2.

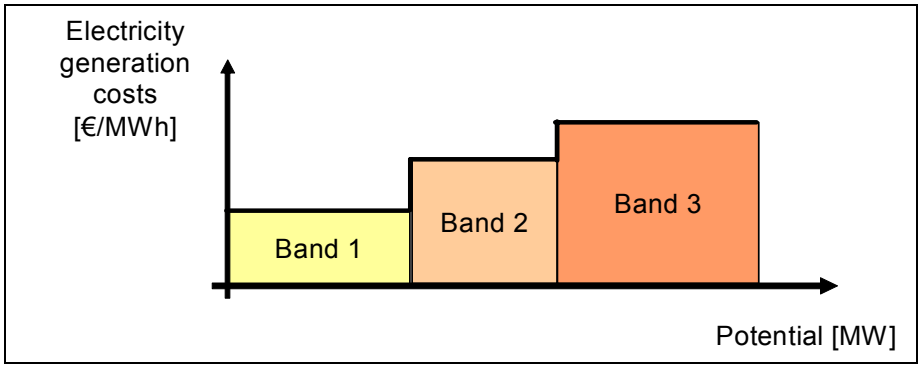


Figure 2.2. Relation between costs and potential for one technology

Bands are characterised by:

- same fuel input, e.g. biomass wood: forestry products (wood) – forestry residues (bark, sawmill by-products) – agricultural products (energy crops) – agricultural residues (straw etc.) – biogenic fraction of waste (MSW+ISW),
- same sub-technology and energy efficiency categories, e.g. photovoltaic systems: facade integrated systems – roof system,
- same range of full-load hours, e.g. wind energy onshore: 2600 h/a – 2500 h/a – 2400 h/a – 2100 h/a – …. – 1500 h/a.

Figure 2.3 depicts a characteristic run of a cost-resource curve. Thereby, all costs and potentials are threaded according to costs, i.e. the cheapest first and the most expensive last. It can be seen that it is helpful to show a separate development of the cost curve for already implemented capacities and for potential new plants.

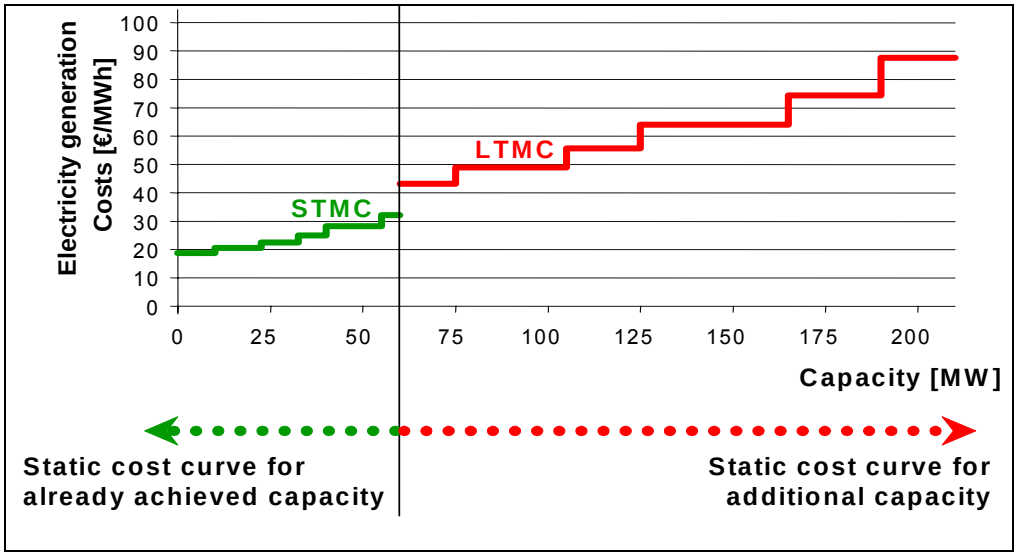


Figure 2.3. Cost curve for achieved and additional potential of technology x

2.1.4.1 Cost-resource curve – existing plants

A characteristic cost-resource curve for already achieved capacities is depicted in Figure 2.4. In this example the portfolio of existing plants of technology x consists of 4 different categories - bands B1 (efficient plant / good size) to B4 (inefficient plant / bad size). For each band the short-term marginal generation costs (STMC) and the long-term marginal generation costs (LTMC) are shown sorted by rising STMC.

The calculation of the STMC follows equation (1) explained above. The LTMC are derived according to equation (2), i.e. all cost parts, both investment and running costs, have to be taken into account. Note that the investment costs for existing plants refer to the year of installation and not to the year n.

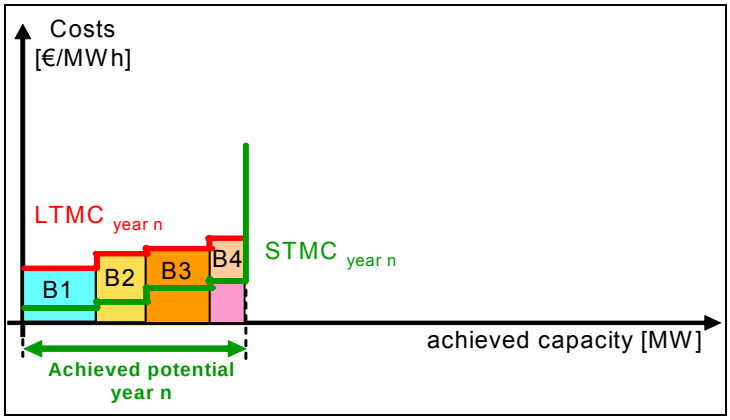


Figure 2.4. Cost curve for already achieved potential of technology x

As already mentioned, the short-term marginal generation costs (STMC) are relevant only for the economic decision whether or not to produce electricity with a certain capacity (represented in the model by the band). This is because for existing plants the investments in the capacity are already (irreversibly) sunk.[10]

Nevertheless the long-term marginal generation costs are still important for the calculation and evaluation of important results, e.g. the derivation of the producer's profit. More precisely, as long as the plant is not fully depreciated, the actual investment cost influences (significantly) the actual full generation costs and, hence, the producer's profit.

2.1.4.2 Cost-resource curve – new plants

As already mentioned, electricity generation costs for new installations are characterised by the long-term marginal costs. The costs are derived according to equation (1) and (2), respectively. In contrast to already existing plants, the investment costs decrease over time according to the derived learning curve of the technology for the year n. The stepped function depicted in Figure 2.5 indicates the different cost/potential levels (bands). For instance, in the case of wind energy, sites have a known average wind speed and wind availability, so the load factor (or full-load hours) and hence the costs can be predicted. In the example shown

[10] It is assumed that the capacity cannot be rebuilt and sold to a third party.

in Figure 2.5, seven different bands (characterised by different full-load hours) are defined starting with high wind speeds and hours (band B1) through to poor wind conditions (band B7).

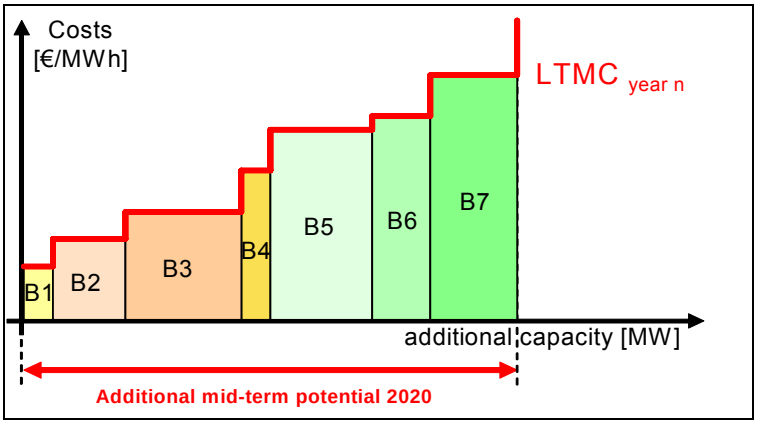


Figure 2.5. Cost curve for additional mid-term potential of technology x

Some technologies can be used either to produce electricity only or both electricity and heat. Therefore, information with respect to the mix of 'pure' electricity generation to combined heat and power production is of high relevance. In the toolbox **GreenNet-EU27**, the ratio of CHP plants to pure electricity generation plants depends on the competitiveness of each technology. To keep the simulation time short, it is assumed that the electricity to heat generation ratio is constant within one band. The power to heat ratio, however, differs among the bands of a certain CHP technology.[11]

[11] An alternative option would be the assumption that the ratio of pure electricity generation plant to CHP plant is constant. In this approach, the ratio must not be derived in the computer model itself. Therefore, the implementation in the computer model requires much less methodological effort. The advantage is a shorter running time of the simulation compared to the other method and, subsequently, resulting in improved user-friendliness of the toolbox. The disadvantage of this approach is: Firstly, some divergences occur between the estimated and the actual possible ratio of pure electricity and combined heat and power generation. Secondly, the grid connected heat demand (for CHP and heat plants) is given as an exogenous variable in the toolbox **GreenNet-EU27**. Hence a restriction of CHP plants (by heat demand) leads to a restriction of pure electricity generation, too. The reason is that the power to heat ratio is also restricted. This means, it is economically inefficient to produce a substantial electricity output and a low heat output with a CHP plant.

2.1.5 Development of the dynamic cost-resource curve

In general, in the toolbox **GreenNet-EU27** dynamic effects will be considered covering the areas of:

- costs for new plants
- available / achievable potential for existing and new plants, respectively.

The dynamic adaptation of the costs (investment costs and operation/maintenance costs) will take place at the end of one simulated year, i.e. the investment costs for the year n will be determined at the end of the year n-1. The methodology used to derive the new investment costs has been already described before.

The dynamic assessment of the potential will take place at two different stages in the model. The evaluation of the available potential of existing plants for the year n will be made - similar to the cost evaluation – at the end of the simulation run in the previous year. For new plants, the assessment of the maximal achievable potential for the year n will be made after the creation of the static cost-resource curve in the year n. The reason this step cannot be carried out also at the end of the year n-1 – as for all other dynamic evaluation steps - is that information about assessment parameters is necessary which is only available at the beginning of the year n. In more detail the following inputs must be available:

Input database supply
- Input database – existing plants
- Input database – new plants

Stakeholder behaviour
- Investor
- Society

Policy instruments
- Supply-side strategies
- Demand-side strategies

Based on the development of the static cost-resource curves for existing and new plants, dynamic cost curves will be derived by applying a dynamic parameter assessment.

2.1.5.1 Dynamic parameter assessment – new plant

As already mentioned, the starting point for deriving the dynamic potential is the additional mid-term potential for the year 2020. These data will be used directly from the 'input database – new plants'.

In a first step, the restricting factors of the dynamic potential for the year n must be analysed compared to the given additional mid-term potential, i.e. existing barriers must be determined. Secondly, the additional potential for the year n can be derived by applying a dynamic parameter assessment. More precisely, for each band, the available potential for the next year compared to the year 2020 will be evaluated taking various barriers into consideration.

In the toolbox **GreenNet-EU27** the following obstacles are considered:

<u>Social barriers (social acceptance of additional generation)</u>

In some cases the acceptance is a function of the policy strategy, e.g. the acceptance of big wind projects (e.g. in Ireland) is more restricted knowing that most of the

electricity generated will be exported (e.g. due to an international TGC market) rather than be consumed locally or at least domestically.

Industrial barriers

The availability of the technology in one country depends on the total global demand. This means that the total demand for a certain technology depends on the level of the worldwide (EU–wide) promotion scheme for this technology. If there is (suddenly), e.g. a high quota for wind energy in Europe (or worldwide) then the production of this technology (supply) cannot follow the demand because the growth of the industry is restricted. Hence, less capacity can be built in one country.

Technical barriers (technical feasibility)

e.g. the need of additional grid extension measures.

Market barriers (market and policy distortions)

e.g. less transparency of subsidy scheme, no stable planning horizon.

Administrative barriers (high bureaucracy)

e.g. long commissioning time of a plant.

Availability of the resources

e.g. the available potential for biomass increases over time due to the time gap (delay) between cultivation (afforestation) and harvesting of the biomass. In the case of landfill gas, the potential decreases over time due to changes in waste management.

Table 2.3 gives an overview of the analysis of barriers and their consideration.

Table 2.3. Summary: characterisation of dynamic barriers

Dynamic parameter & their characterisation		Techno-logy - specific	Country specific	Band-specific	Link to policy	Impact on costs	Impact on poten-tials	Methodology to implement
Industrial constraints	Growth rate of industry	X					X	EU-wide limitation of annual installations…
	…							
Technical constraints	Grid constraints (i.e. extension necessary)	X	X	X		X	(X)	Band-specific limitation of annual installations
	…							
Market constraints	Market trans-parency	X	X				X	Increased interest rate
	Investors behaviour	X	X		X		X	Increased interest rate
	…							
Admini-strative constraints	Bureaucracy (	X	X		X		X	Country and technology specific limitation
Societal constraints	'Willingness to accept'	X	X	X	X		X	(Band-specific) limitation of annual realisable potential
	…							

$$P_{add\ n} = P_{add\ n\ 2020} * f_{barrier}(\text{Industry, Technique, Market, Society, Administration}) \quad (3)$$

where:

$P_{add\ n}$ ..... Additional dynamic potential year n [GWh/a]

$P_{add\ n\ 2020}$ ..... Additional remaining mid-term potential (2020) in year n [GWh/a]

$f_{barrier}$ ..... Limitation factor [1]

Similar to the additional mid-term potential for the year 2020[12], the maximal actual achievable potential for the year n takes into consideration several described obstacles and drivers. The dynamic potential for the year n ($P_{add\ n}$) can be derived by multiplying the remaining additional mid-term potential in year n ($P_{add\_n\_2020}$) by a factor ($f_{barrier}$) indicating the maximum constraint of all considered obstacles, i.e. the residual potential is available for the year n.

This procedure is depicted in Figure 2.6; the red lines represent the additional mid-term potential, the blue lines the additional potential being available for the next year (year n) for each band. Of course, the actual availability can vary between the single bands.[13]

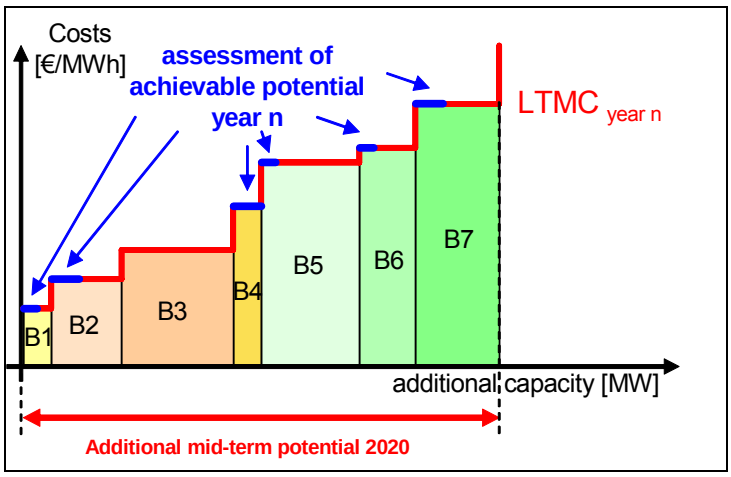


Figure 2.6. Cost curve assessment for additional potential year n of technology x

By adding the additional potential of each band for year n, the dynamic cost curve can be constructed. In the example, the blue lines in Figure 2.6 are put together with the available cost curve for the year n, see Figure 2.7.

[12] Note, that the mid-term potential is equivalent to the dynamic potential for the year 2020 (since all barriers are already considered).

[13] E.g. in Figure 2.6 no additional potential for band 3 is available for the next year. Note, that the cost level of the individual bands remains not effected by the dynamic parameter assessment because the costs (referring to the mid-term as well as the dynamic potential) already refer to the year n for every cost curve.

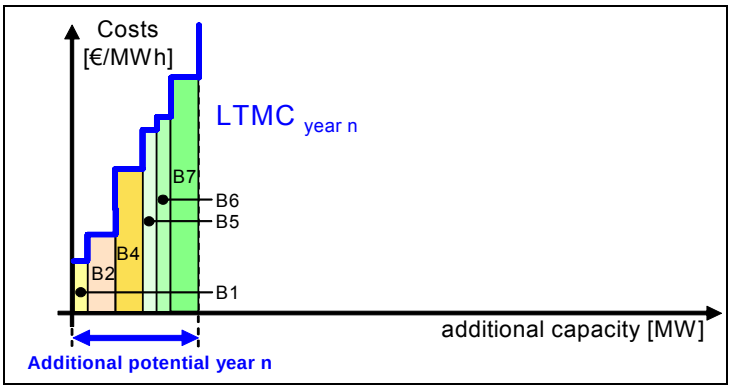


Figure 2.7. Cost curve for additional potential year n of technology x

2.1.5.2 Dynamic cost curves for the year n

The overall cost curve for the year n can be derived by horizontal addition of the already achieved potential (existing plants) and the available additional potential (new plants). This procedure is shown in Figure 2.8.

In general, it can be stated that generation costs of electricity from RES-E technologies are higher than those of conventional energy sources. Moreover, costs as well as achievable potentials differ widely among the specific RES-E technologies. The combination of the cost curves for potentially new and already achieved plants represents the output of the database 'dynamic cost curve'.

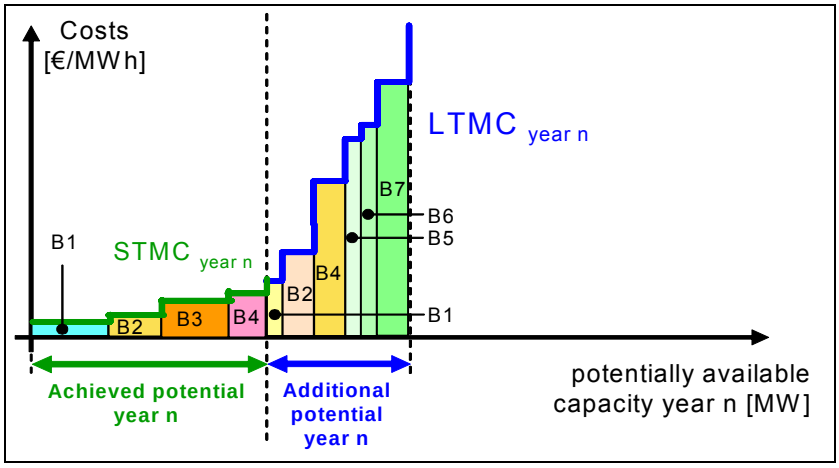


Figure 2.8. Combination of cost curve for already achieved and additional potential for the year n and technology x

Summing up, the future penetration of a certain technology depends on how it overcomes two categories of existing obstacles:

- economic barriers – they are reflected by the net generation costs, i.e. inclusive policy strategies.
- other barriers as described above – they restrict the available potential of electricity generation in year n.

Penetration of a technology will only take place if both categories of barriers can be overcome. So, on the one hand, it does not help to support a certain technology via a quota obligation, a guaranteed feed-in tariff or a tender scheme without preparing the framework conditions to overcome remaining existing barriers, e.g. increasing the social acceptance using information campaigns, or decreasing administrative burdens for commissioning new plants, etc.. In other words, low (net) generation costs, but a low existing potential, still results in less additional penetration.

On the other hand, providing a good environment at administrative, social, industrial and technical levels (i.e. admitting a huge potential) without economic incentives does not increase the future penetration rate of a certain technology. A high potential of electricity generation, but high generation costs, also results in a low market share.

Up to now, economic support schemes have not been considered in the toolbox **Green*Net*-EU27**, i.e. the influence of the support schemes and policy framework on the economic cost for an investor and an enterprise has not yet been analysed. This important step will be carried out in the economic assessment. The costs will be adapted in such a way that they agree with the promotion schemes for renewables, conventional power, CHP environment and climate change policy. Note, the costs correspond after the economic support assessment to the market conditions, i.e. they represent the offered prices / bids on the market. In other words, a transition from generation costs to offer prices takes place by applying the economic assessment.

For the description of the methodology used for the economic evaluation see Huber et al. (2004).

2.2 Overview on potentials and cost for RES-E in the EU-25 Member States

2.2.1 Historical development

Electricity generation from renewable energy sources (RES-E) in the EU-25 Member States was 393 TWh in 2003 (i.e. a share of 12.8% of gross electricity consumption). In this context, EU-15 Member States contributed with 377.5 TWh (13.8% of total demand) whereas in the new EU-10 Member States RES-E generation was 15.5 TWh (4.8% of total demand).

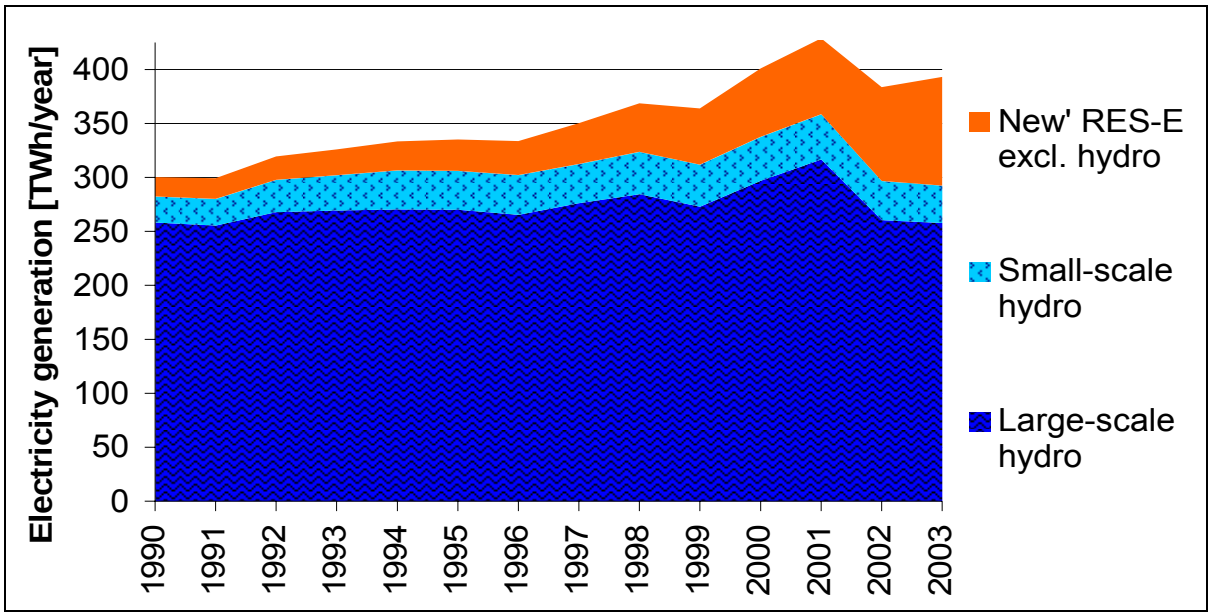


Figure 2.9. Historical development of electricity generation from RES-E (incl. small-scale and large-scale hydropower) from 1990 to 2003 in the EU-25 Member States

Figure 2.9 depicts the historical development of RES-E[14] in the EU-25 Member States for the period 1990 to 2003. Hydropower is the dominant source, but 'new' RES-E[15] such as biomass or wind are getting rapidly important.

The following figures provide further insights on several 'new' RES-E technologies. Figure 2.10 depicts their historical development, whereas Figure 2.11 indicates a breakdown of their generation on country-level. Wind energy is the RES-E technology with the highest yearly growth rates of about 35% in electricity generation over the last decade. Especially in the EU-15 Member States wind energy is predominant in recent portfolios of 'new' RES-E technologies, whereas biomass is dominant in the new Member States.

[14] The RES-E development is based on EUROSTAT 2003 data. For many RES technologies (e.g. wind-onshore, PV), more recent data from sector organisations and national statistics have been used.

[15] In general, definitions of RES-E sources are made in accordance with the Directive for the promotion of electricity produced from renewable energy sources in the internal electricity market, 2001/77/EC. The technologies assessed include hydropower (large-scale and small-scale), photovoltaics, solar thermal electricity, wind energy (onshore, offshore), biogas, solid biomass, biodegradable fraction of municipal waste, geothermal electricity, tidal and wave energy.

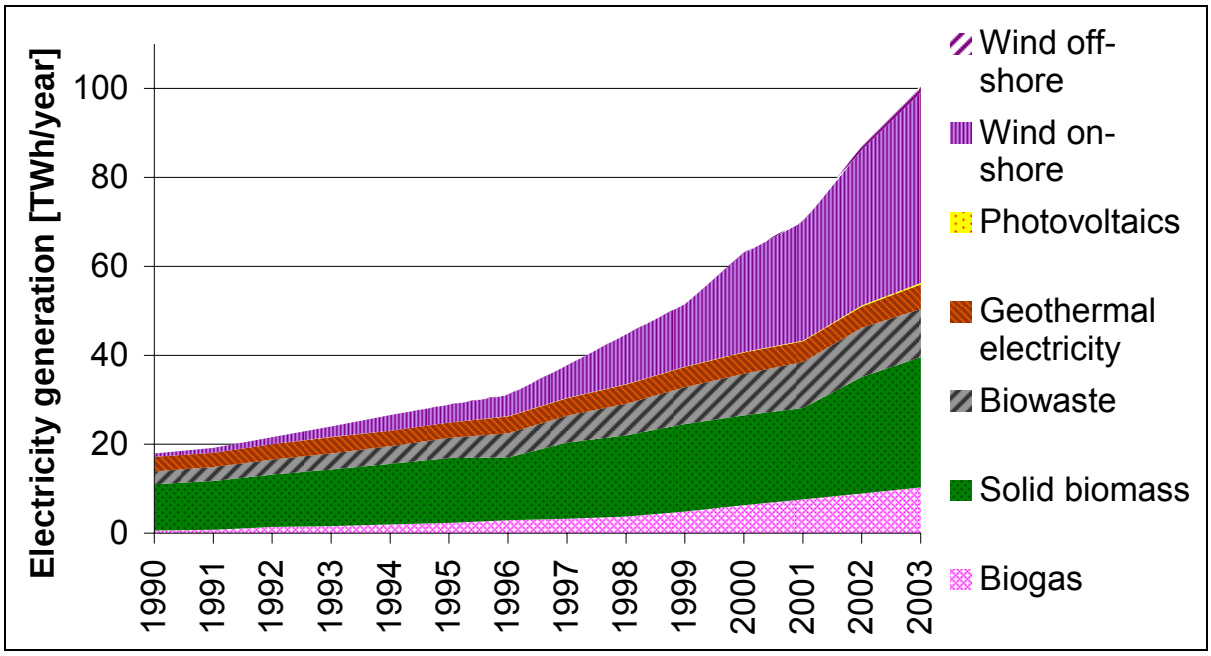


Figure 2.10. Historical development of electricity generation from 'new' RES-E (excl. hydro-power) from 1990 to 2003 in the EU-25 Member States

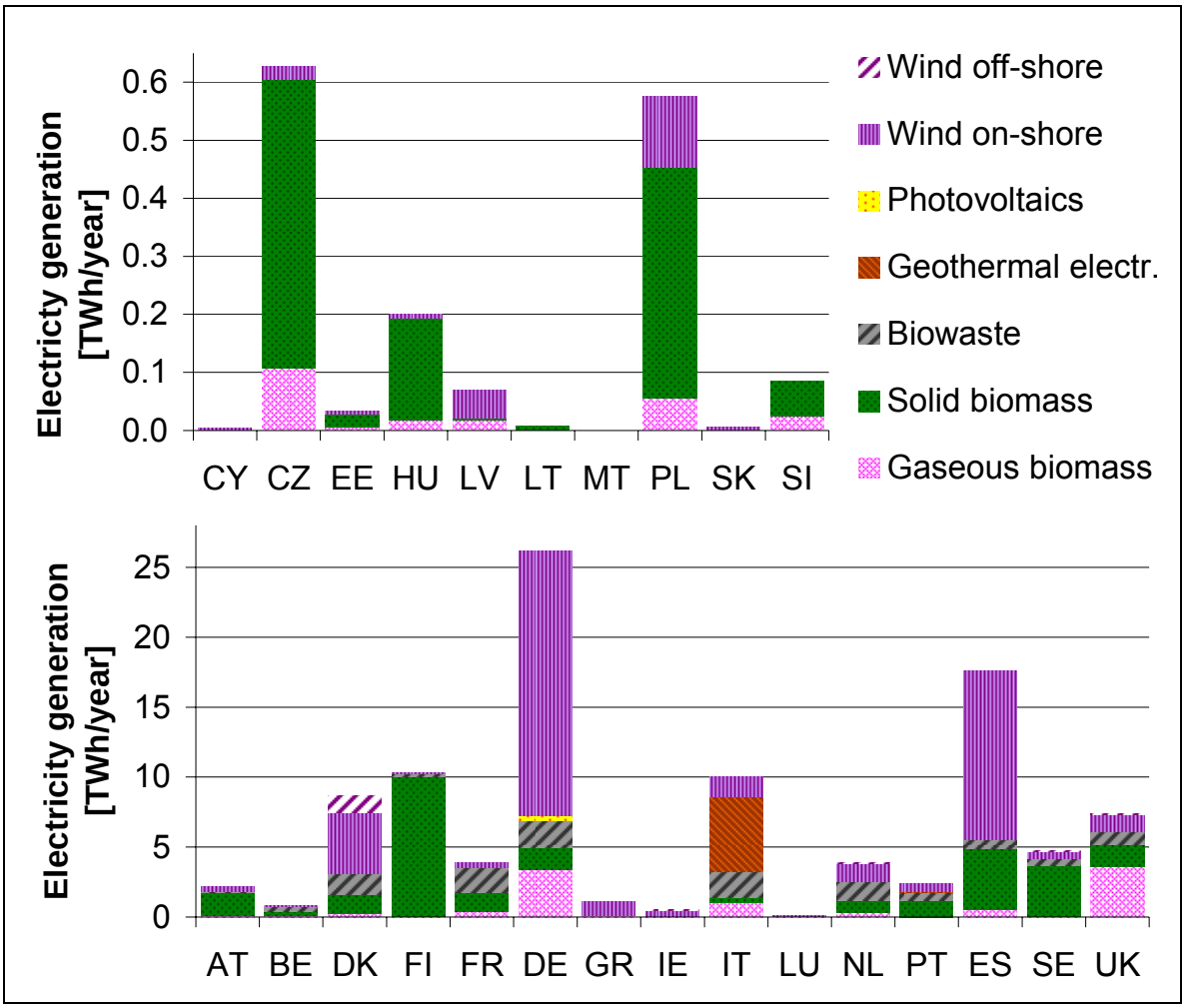


Figure 2.11. Breakdown of electricity generation from 'new' RES-E in the EU-25 Member States on country-level

2.2.2 Future potentials

Please note that future RES-E potentials given in this chapter do not represent policy targets or expected potentials for the year 2020. The additional mid-term potential is the maximal additional achievable potential assuming that all existing barriers can be overcome and all driving forces are active (see also chapter 2.1.2 in this report). As economic as well as non-economic barriers are implemented in the **GreenNet**-model the simulated RES-E potentials for the year 2020 may be considerably lower depending on the corresponding policy and barrier settings.
As this report is intended to summarise the status quo of the updated and extended **GreenNet** database it is not foreseen to give a detailed description of the methodology used for the assessment of diverse RES-E potentials. For more detailed information it is therefore referred to the WP1 report of the project **GreenNet** (available on www.greennet.at).
The main sources of data used for the assessment of RES-E potentials and cost are given for the "new countries" only (see corresponding country profiles in the following chapter). For a complete overview on data sources used it is again referred to WP1 report of the project **GreenNet**.

RES-E technologies such as hydropower or wind energy are energy sources characterised by natural variability. Therefore, in order to provide accurate forecasts of the future RES-E deployment, historical data for RES-E deployment have to be translated into electricity generation potentials, i.e. the achieved potential. More precisely, this potential data refer to the year 2004. Thereby, a forecast is undertaken to deliver missing data on country and technology level for the year 2004.[16] Additionally, future potentials are assessed taking into account the country-specific situation as well as constraints in implementing them. Figure 2.12 depicts the achieved and additional mid-term potential for RES-E technologies in the EU-15 on country-level (left) as well as by RES-E technology (right). A similar picture is shown for the new Member States (EU-10) and additional countries covered within **GreenNet-EU27** (i.e. Bulgaria, Romania, Croatia, Switzerland and Norway) in Figure 2.13. For EU-15 Member States, the already achieved potential for RES-E generation equals 441 TWh[17], whereas the additional realisable potential up to 2020 is 1056 TWh (about 38% of gross electricity consumption in 2004). Corresponding figures for the EU-10 Member States are 19 TWh for the achieved potential and 118.7 TWh for the additional mid-term potential (about 36.1% of current gross electricity consumption in 2004).

[16] On technology-level, actual data for the year 2004 is only available for wind energy and photovoltaics for several countries of investigation.
[17] The electricity generation potential represents the output potential of all plants installed up to the end of each year. The figures for actual generation and generation potential differ in most cases – due to the fact that, in contrast to the actual data, the potential figures represent normal conditions (e.g. in case of hydropower, the normal hydrological conditions), and furthermore, not all plants are installed at the beginning of each year.

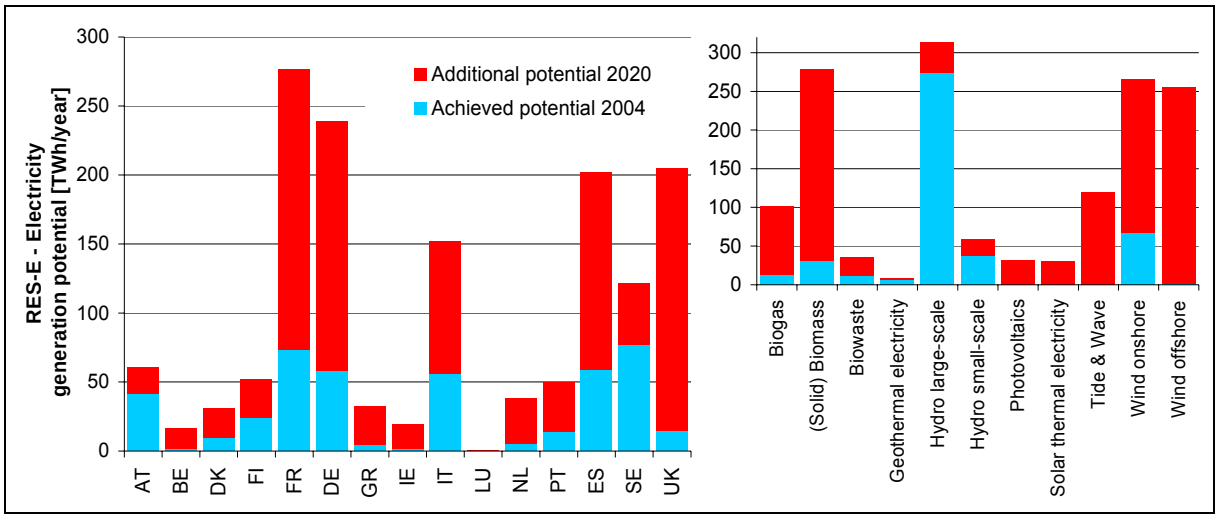


Figure 2.12. Achieved (2004) and additional mid-term potential 2020 for electricity from RES in the EU-15 Member States on country-level (left) and RES-E technology (right)

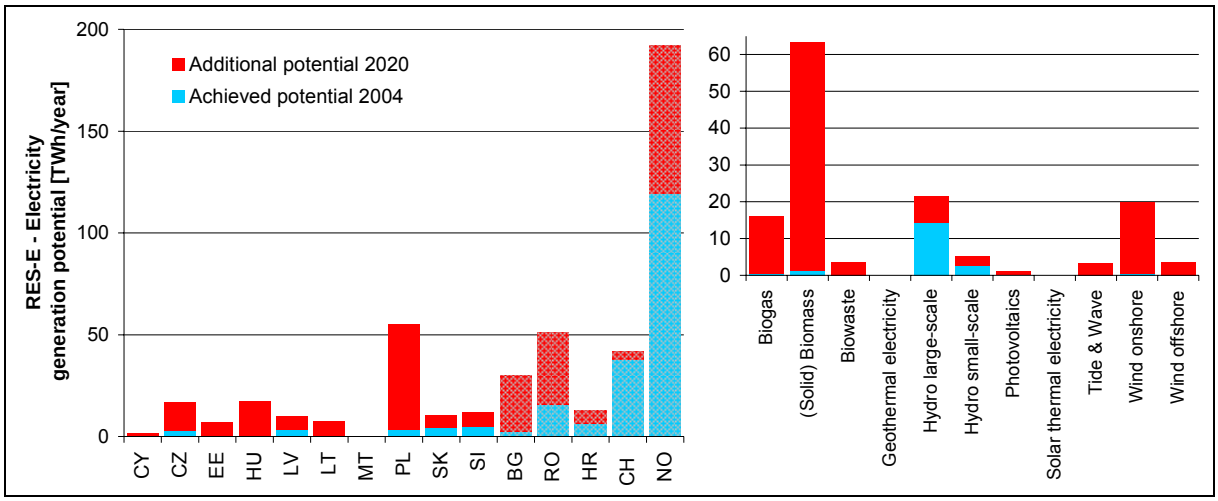


Figure 2.13. Achieved (2004) and additional mid-term potential 2020 for electricity from RES in EU-10 Member States and Bulgaria, Romania, Croatia Switzerland and Norway on country-level (left) and RES-E technology (for EU-10 Member States only; right)

The country-specific situation with respect to the future potential of available RES-E options is depicted below in more detail.

Figure 2.14 depicts the share of *additional* RES-E mid-term potential for the EU-15 Member States in 2020. The largest potential is available in the sector of wind energy (43%) followed by solid biomass (23%), biogas (8%) as well as promising future options such as tidal and wave (11%) or solar thermal energy (3%).

Figure 2.15 illustrates the share of *additional* RES-E mid-term potential up to 2020 for the EU-10 Member States incl. Bulgaria, Romania, Croatia, Norway and Switzerland. In contrast to the EU-15 Member States, the largest potentials for these countries exist in the sectors of solid biomass (52%) and wind energy (19%), followed by biogas (13%). Unlike the situation in the EU-15 Member States, refurbishment and construction of large hydro plants is supposed to be significant (6%).

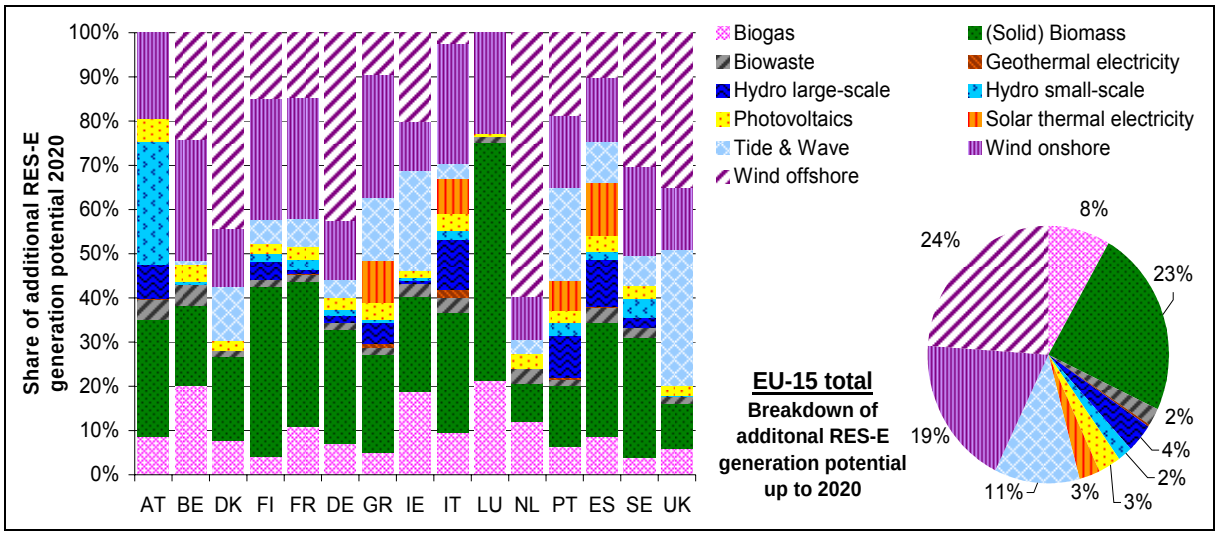


Figure 2.14. RES-E as a share of the total additional realisable potential in 2020 for the EU-15 Member States on country-level (left) as well as for the EU-15 in total (right)

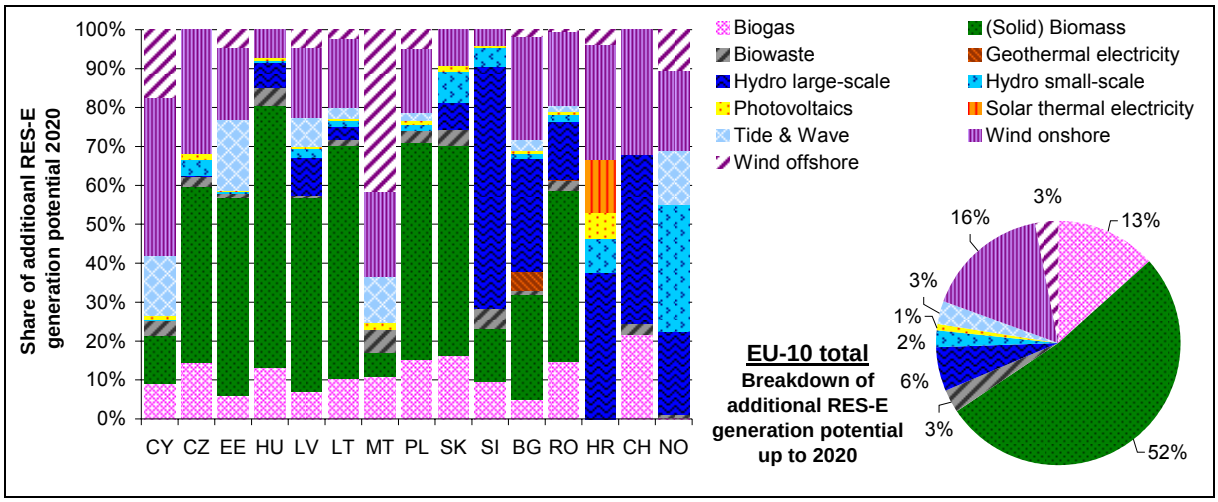


Figure 2.15. RES-E as a share of the total additional realisable potential in 2020 for the EU-10 Member States incl. BU, RO, HR, CH, NO on country-level (left) as well as for the EU-10 in total (right)

2.2.3 Economic data

The high investment cost (and low fuel and O&M cost) of almost all RES-E technologies have been an impediment for broad market penetration. In recent years, investment cost decreased substantially for many RES-E technologies. The main drivers for cost reductions have been research and development as well as economies of scale. Also interest rates have been decreasing over the past two decades.

Figure 2.16 depicts long-run marginal generation cost[18] by RES-E technology. Two different settings are applied describing the payback time:[19] On the one hand, a default setting of 15

[18] Long-run marginal generation cost is the indicator whether or not to build a new power plant.
[19] For both cases an interest rate of 6.5% is used.

years for all RES-E options (Figure 2.16 (left))[20], on the other hand, the payback is set equal to the RES-E technology-specific life time (Figure 2.16 (right)). The broad range of cost for several RES-E technologies represents resource-specific conditions in different regions (countries). Costs also depend on technological options available (e.g. compare co-firing and small-scale CHP plants for biomass).

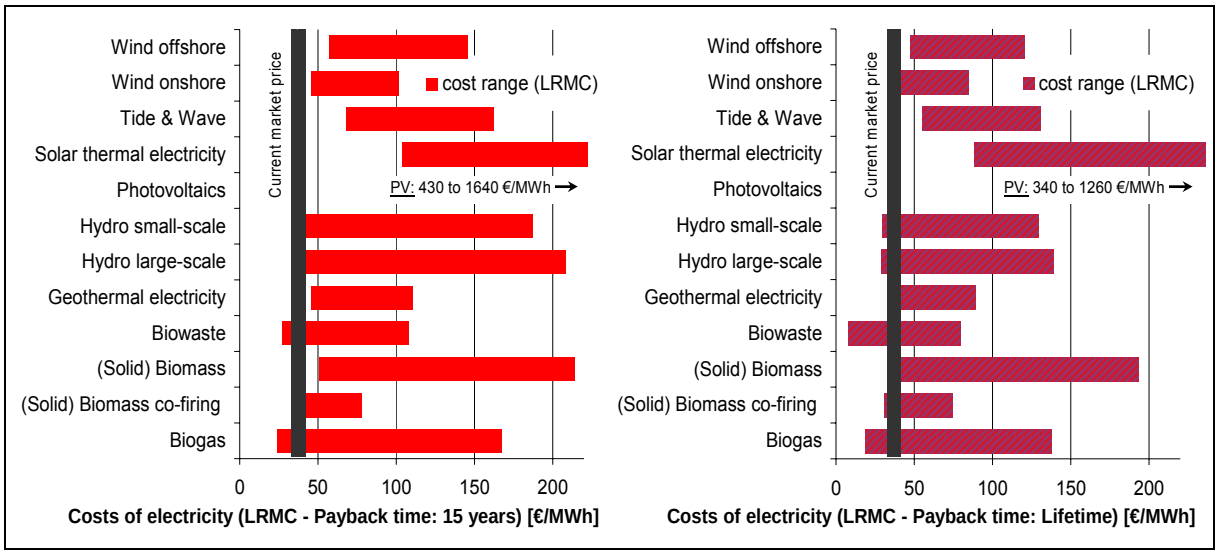


Figure 2.16. Long-run marginal generation cost (for the year 2005) of different RES-E technologies in EU-25 Member States (+ BG, RO, HR, NO, CH) – based on a default payback time of 15 years (left) and payback time equal to lifetime (right).

2.3 Achieved and future RES-E potentials on country-level

This chapter gives an overview of achieved (at the end of 2004) and additional mid-term potentials on country level for several countries not covered in the original **GreenNet** database[21]. Further, within a short introduction the current power system structure, RES-E targets for 2010 and major support schemes in use to reach these targets are addressed.

[20] A payback time of 15 years aims to reflect the investor's point-of-view in competitive, liberalised markets.

[21] Besides the remaining EU Member States Cyprus, Estonia, Latvia, Lithuania, Malta and Slovenia the Candidate Countries Bulgaria, Romania and Croatia as well as Switzerland and Norway are characterised in this chapter.

2.3.1 Remaining EU-25 Member States

2.3.1.1 Cyprus

In Cyprus 100% of the demand for electricity has to be met by own production, as there are no interconnections with other systems. Fossil fuel power plants are currently playing the major role for electricity production on the island. To lower the dependency on oil imports an Action Plan for promoting RES was developed that defines among others the RES-E target for 2010 with 6 % of the gross electricity consumption. The major promotion schemes set up to reach this target are financial incentives as well as feed-in tariffs which are guaranteed for a period of 15 years.

Achieved potentials

Current achieved RES-E potentials in Cyprus are very modest with a share of 0.1% of gross electricity consumption. The only RES-E technologies used so far are wind onshore and PV with a production of 5 GWh and 0.16 GWh in 2003 respectively.

Additional mid-term potentials

The additional mid-term potential for RES-E production accounts for 1.55 TWh or nearly 30 % of the gross electricity consumption in 2020. The highest potentials can be observed for wind onshore and offshore, tidal and wave energy as well as solid biomass and biogas.

RES-E - Electricity generation potential in TWh/a	**Achieved potential** (end of) 2004	**Additional realisable potential** (up to) 2020
Biogas	0.00	0.14
(Solid) Biomass	0.00	0.19
Biowaste	0.00	0.06
Geothermal electricity	0.00	0.00
Hydro large-scale	0.00	0.00
Hydro small-scale	0.00	0.00
Photovoltaics	0.00	0.02
Solar thermal electricity	0.00	0.00
Tide & Wave	0.00	0.24
Wind onshore	0.00	0.63
Wind offshore	0.00	0.27
RES-E TOTAL	**0.00**	**1.55**

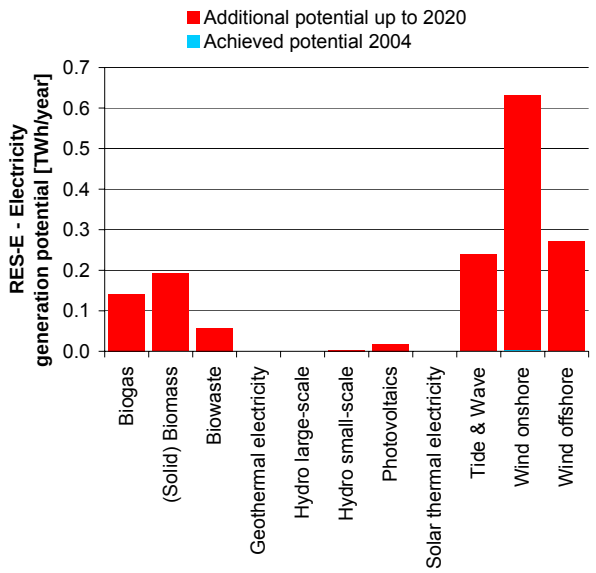


Figure 2.17 Cyprus – achieved (end of 2004) and additional mid-term (up to 2020) RES-E potentials.

2.3.1.2 Estonia

The Estonian electricity production is dominated by power plants based on oil shale with over 90 % of total production. The oil shale industry has grown historically and today it is a considerable economic factor with over 10,000 employees. However there is the aim to increase the current very low RES-E share up to 5.1 % in 2010. To support RES-E technologies besides a green certificate system there are guaranteed price that are oriented on the price of the conventional market, i.e. RES-E receive a price that is 1.8 times the market price of electricity. This price is guaranteed for 7 years for small hydro and biomass and for 12 years for production from other RES-E.

Achieved potentials

Currently used RES-E technologies are wind onshore, solid biomass, biogas and small hydro power. In 2003 there were 6 MW of wind power installed in Estonia, further 4 MW of small hydro and 5 MW of biomass. The current share of RES-E production on the gross electricity consumption is about 1 %.

Additional mid-term potentials

Solid biomass has the highest mid-term potential with around 3.5 TWh followed by wind onshore and tidal & wave energy with more than 1 TWh each. Further potentials are identified for wind offshore and biogas and very modest numbers are indicated for biowaste, small hydro and PV. The exploitation of the whole mid-term potential would lead to a share of over 60 % of gross energy consumption in 2020.

RES-E - Electricity generation potential in TWh/a	**Achieved potential** (end of) 2004	**Additional realisable potential** (up to) 2020
Biogas	0.01	0.40
(Solid) Biomass	0.02	3.43
Biowaste	0.00	0.07
Geothermal electricity	0.00	0.00
Hydro large-scale	0.00	0.00
Hydro small-scale	0.02	0.04
Photovoltaics	0.00	0.02
Solar thermal electricity	0.00	0.00
Tide & Wave	0.00	1.22
Wind onshore	0.04	1.25
Wind offshore	0.00	0.31
RES-E TOTAL	**0.10**	**6.74**

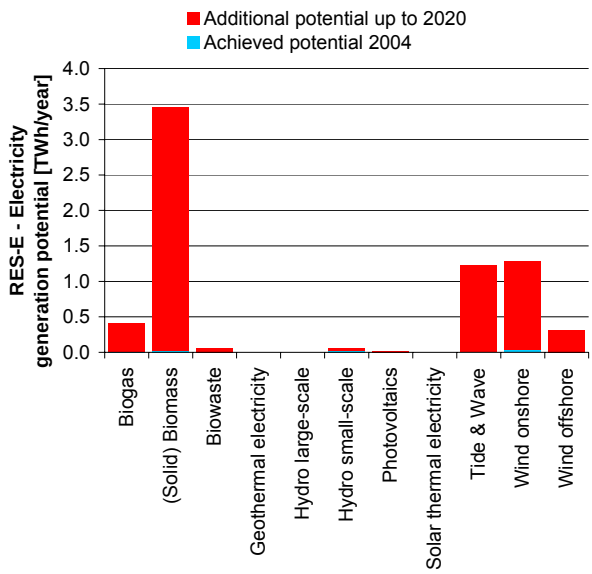


Figure 2.18 Estonia – achieved (end of 2004) and additional mid-term (up to 2020) RES-E potentials.

2.3.1.3 Latvia

In Latvia the share of electricity produced by hydro power plants is about 40%. Furthermore there are notable capabilities for heat and electricity production by means of biomass and wind resources. The aspired future energy mix intends a share of 49.3% covered by renewable energy sources. According to the political surroundings a decisive change in the support system was fixed in 2003. For that the double tariff system has been changed to a yearly quota. For new projects this quota must be assigned by the Ministry of Economy and due to bureaucratic contradictions there's a lack in investment certainty.

Achieved potentials

In 2003 the achieved RES-E installations in Latvia were about 1570 MW with a contingent of 1510 MW masked by large hydro power plants. The use of solar power is because of the geographical location hardly given. Also the share of small scale hydro power and wind energy is relatively low (100MW of newly planned wind capacity are excluded).

Additional mid-term potentials

The additional mid-term potential for electricity production lies in wind, biomass and small scale hydro power. The highest potentials – in total 6.85 TWh - are identified in the biomass and wind onshore sector.

RES-E - Electricity generation potential in TWh/a	**Achieved potential** (end of) 2004	**Additional realisable potential** (up to) 2020
Biogas	0.03	0.48
(Solid) Biomass	0.00	3.42
Biowaste	0.00	0.03
Geothermal electricity	0.00	0.00
Hydro large-scale	3.07	0.68
Hydro small-scale	0.06	0.16
Photovoltaics	0.00	0.02
Solar thermal electricity	0.00	0.00
Tide & Wave	0.00	0.53
Wind onshore	0.05	1.23
Wind offshore	0.00	0.30
RES-E TOTAL	**3.21**	**6.85**

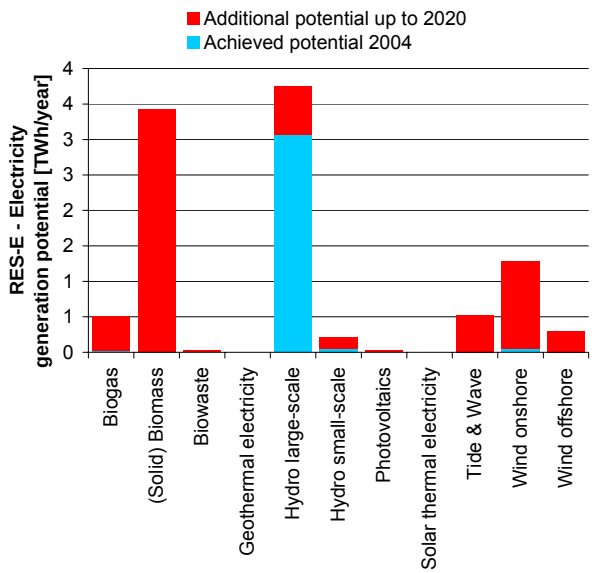


Figure 2.19 Latvia – achieved (end of 2004) and additional mid-term (up to 2020) RES-E potentials.

2.3.1.4 Lithuania

Since the mid 1980s the electricity production of Lithuania is dominated by the Ignalina nuclear power plant which held a share of up to 88 % of total electricity. Since the end of 2004, there is only Unit 2 remaining in operation with a nominal power of 1300 MW. Closure of Unit 2 is planned for 2010 which would change the situation of electricity supply in Lithuania significantly.

The RES-E target for 2010 is set at 7 %. This target is broken down on goals for installed capacities of hydro power (132 MW), wind power (200 MW) and biomass (33 MW).

Since 2002 there is a feed-in tariff scheme in force that supports small hydro, wind and biomass over a guaranteed period of 10 years.

Achieved potentials

Hydro power holds a share of over 95 % of current achieved RES-E potentials. The major part comes from large hydro power plants with an installed capacity of 101 MW. The currently used small hydro potential is about 50 GWh produced by plants with a total nominal capacity of 18.7 MW. First small wind projects were realised in 2004.

Additional mid-term potentials

The highest potential for green electricity production was identified for biomass with 4.2 TWh. Wind onshore is referred to as the second most important source of green electricity in Lithuania with an additional mid-term potential of 1.3 TWh. Biogas holds a share of about 10 % of the additional potential which complies with a generation of 0.74 TWh.

RES-E - Electricity generation potential in TWh/a	**Achieved potential** (end of) 2004	**Additional realisable potential** (up to) 2020
Biogas	0.01	0.74
(Solid) Biomass	0.01	4.20
Biowaste	0.00	0.11
Geothermal electricity	0.00	0.00
Hydro large-scale	0.35	0.22
Hydro small-scale	0.05	0.11
Photovoltaics	0.00	0.03
Solar thermal electricity	0.00	0.00
Tide & Wave	0.00	0.20
Wind onshore	0.00	1.26
Wind offshore	0.00	0.15
RES-E TOTAL	**0.41**	**7.02**

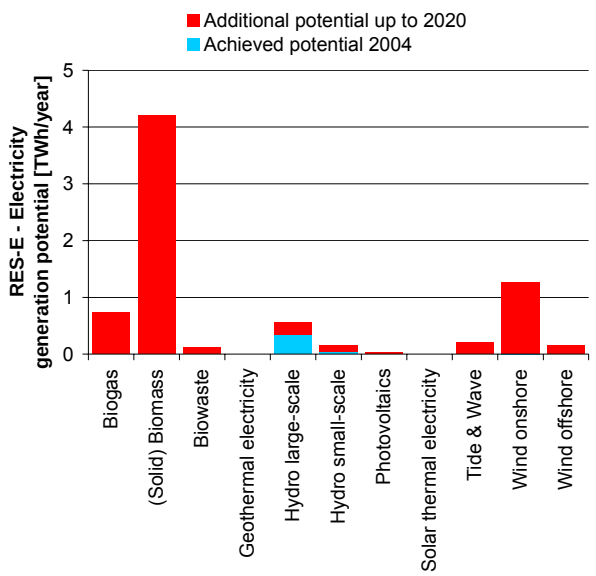


Figure 2.20 Lithuania – achieved (end of 2004) and additional mid-term (up to 2020) RES-E potentials.

2.3.1.5 Malta

To reduce the nearly 100% dependency on oil-imports the identification and installation options of renewable energy sources lead to a 5% RES-E target in 2010. Actually there are no support models for green energy in Malta. In fact a "Consultation paper on the Development of a strategy for the Exploitation of RES for Electricity Generation in Malta" was presented in 2002 (Malta Resource Authority) but is not yet implemented.

Achieved potentials

The use of renewable resources in Malta is due to the high oil usage effectively zero. Besides the conventional thermal plants (582 MW) new photovoltaic systems are planned and in demonstration phase, effecting wide-ranging interest in renewable energy projects due to possible future regulations. Also mentionable offshore wind energy possibilities are given.

Additional mid-term potentials

The additional mid-term potential lies in wind offshore, tidal / wave and biogas energy followed by biomass and solar power. In total the RES-E generation will be 0.51 TWh in 2020.

RES-E - Electricity generation potential in TWh/a	**Achieved potential** (end of) 2004	**Additional realisable potential** (up to) 2020
Biogas	0.00	0.05
(Solid) Biomass	0.00	0.03
Biowaste	0.00	0.03
Geothermal electricity	0.00	0.00
Hydro large-scale	0.00	0.00
Hydro small-scale	0.00	0.00
Photovoltaics	0.00	0.01
Solar thermal electricity	0.00	0.00
Tide & Wave	0.00	0.06
Wind onshore	0.00	0.11
Wind offshore	0.00	0.21
RES-E TOTAL	**0.00**	**0.51**

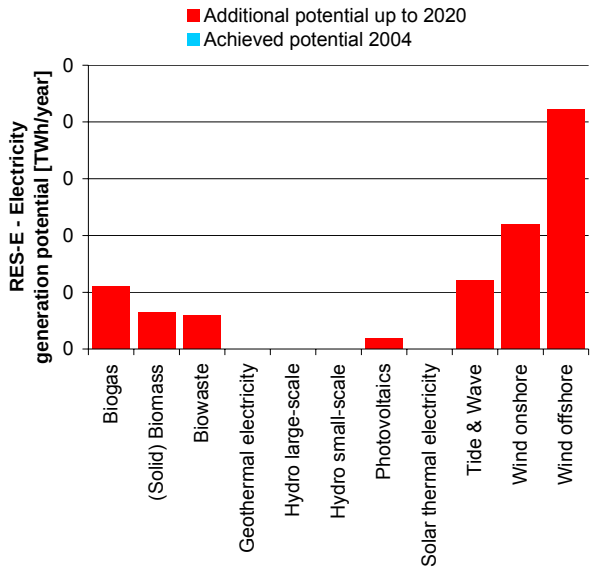


Figure 2.21 Malta – achieved (end of 2004) and additional mid-term (up to 2020) RES-E potentials.

2.3.1.6 Slovenia

In Slovenia the dependency on energy-imports is highly given. The own energy resources consist for the most part of hydropower, biomass and coal. Especially in the hydropower sector many renewals on existing systems have to be made to gain 150 MW of extra capacity. On the other hand the National Energy Program (2004) intends an increase of RES-E related generation up to 33.6% in 2010. Actually the share of RES-E generation is about 25% consisting of 97% hydropower and 3% biomass. Referring to the support mechanisms Slovenia guarantees following feed in tariffs:

Biogas:	4.90 – 12.1 €cents / kWh;	Biomass:	6.82 – 7.04 €cents / kWh
Hydro:	6.00 – 6.22 €cents / kWh;	Solar:	37.84 – 6.52 €cents / kWh
Wind:	5.93 – 6.14 €cents / kWh	Geothermal:	5.93 €cents / kWh

These tariffs are yearly adopted considering inflation and other economic factors.

Achieved potentials

The use of renewable resources in Slovenia is divided into following shares:

Most green electricity is produced by large scale hydropower (in 2003 about 3200 GWh) supported by small scale production, which was about 464 GWh. Another mentionable energy resource presents biogas with 3.5 MW installed capacity in 2003. There are no wind installations in Slovenia and hardly any solar projects.

Additional mid-term potentials

The additional mid-term potential consists of solid biomass, biogas, large- and small scale hydro installations. Wind, bio-waste and solar techniques on the other hand will not influence the energy balance significantly. The total additional RES-E potential will be about 7.37 TWh in 2020.

RES-E - Electricity generation potential in TWh/a	**Achieved potential** (end of) 2004	**Additional realisable potential** (up to) 2020
Biogas	0.03	0.71
(Solid) Biomass	0.07	1.01
Biowaste	0.00	0.38
Geothermal electricity	0.00	0.00
Hydro large-scale	4.04	4.58
Hydro small-scale	0.54	0.36
Photovoltaics	0.00	0.03
Solar thermal electricity	0.00	0.00
Tide & Wave	0.00	0.00
Wind onshore	0.00	0.30
Wind offshore	0.00	0.00
RES-E TOTAL	**4.68**	**7.37**

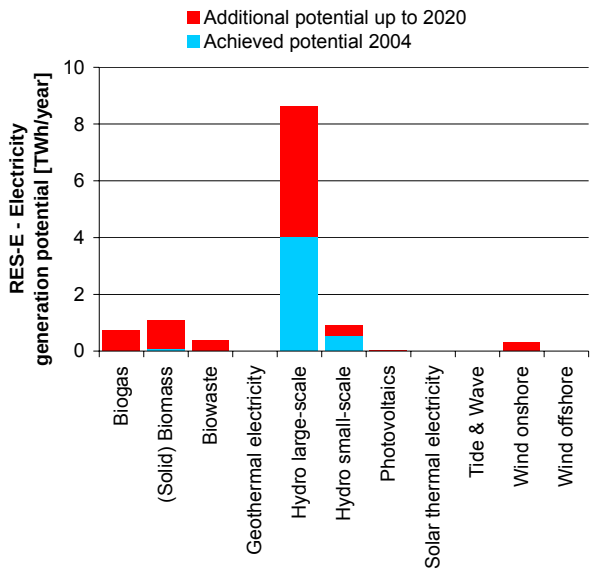


Figure 2.22 Slovenia – achieved (end of 2004) and additional mid-term (up to 2020) RES-E potentials.

2.3.2 Candidate Countries

2.3.2.1 Bulgaria

More than half of the Bulgarian electricity production comes from power plants fired with fossil fuels whereas coal is the major primary energy resource with a share of 46 % of total production. The second important source is nuclear power with a share of 41 % of total production in 2003. The remaining 8 % is green electricity mainly coming from large hydro power. The RES-E target for 2010 is set at 11 % of total consumption and therefore a combination of support mechanisms, namely feed-in tariffs, tax incentives and purchase obligations were implemented.

Achieved potentials

Currently green electricity in Bulgaria comes exclusively from hydro power. In 2004 large hydro power accounted for 1.95 TWh while the small hydro power production was 0.46 TWh.

Additional mid-term potentials

The highest future potentials for RES-E are identified for solid biomass, large hydro power and wind onshore with more than 7 TWh each. Currently it is planned to install 500 MW of wind power in the Black Sea Region and in Dobrudja. For biogas and geothermal electricity the additional mid-term potential is more than 1 TWh.

RES-E - Electricity generation potential in TWh/a	**Achieved potential** (end of) 2004	**Additional realisable potential** (up to) 2020
Biogas	0.00	1.36
(Solid) Biomass	0.00	7.48
Biowaste	0.00	0.29
Geothermal electricity	0.00	1.29
Hydro large-scale	1.95	8.01
Hydro small-scale	0.46	0.40
Photovoltaics	0.00	0.16
Solar thermal electricity	0.00	0.00
Tide & Wave	0.00	0.80
Wind onshore	0.00	7.34
Wind offshore	0.00	0.43
RES-E TOTAL	**2.42**	**27.56**

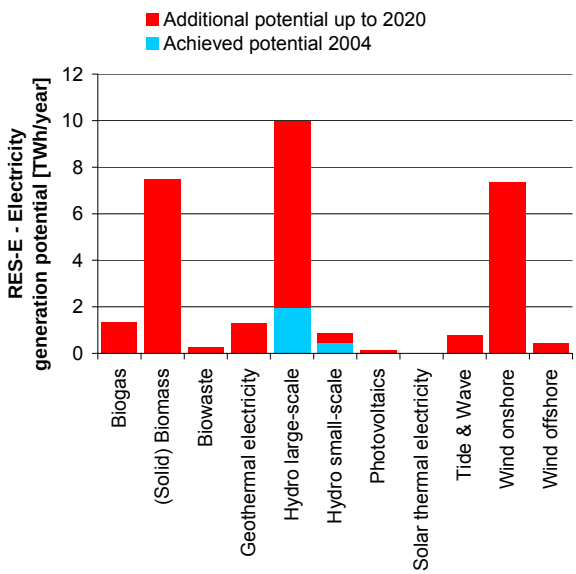


Figure 2.23 Bulgaria – achieved (end of 2004) and additional mid-term (up to 2020) RES-E potentials.

2.3.2.2 Romania

The Romanian electricity system mainly relies on fossil fuels which contribute more than two thirds of total electricity generation. Further 9 % of total production comes from nuclear power plants. The government wants to raise the RES-E share from currently 24 to 33 % in 2010 by supporting RES-E with subsidy funds and feed-in tariffs.

Achieved potentials

Currently the only renewable technology used for electricity production in Romania is hydro power with an installed capacity of about 6300 MW. Generation from small-scale hydro power accounted for 0.56 TWh in 2004.

Additional mid-term potentials

Solid biomass has the highest additional mid-term potential with 15.43 TWh followed by wind onshore, large hydro and biogas with more than 5 TWh each.

RES-E - Electricity generation potential in TWh/a	**Achieved potential** (end of) 2004	**Additional realisable potential** (up to) 2020
Biogas	0.00	5.20
(Solid) Biomass	0.00	15.43
Biowaste	0.00	0.93
Geothermal electricity	0.00	0.10
Hydro large-scale	15.32	5.20
Hydro small-scale	0.56	0.67
Photovoltaics	0.00	0.27
Solar thermal electricity	0.00	0.00
Tide & Wave	0.00	0.51
Wind onshore	0.00	6.69
Wind offshore	0.00	0.15
RES-E TOTAL	**15.88**	**35.15**

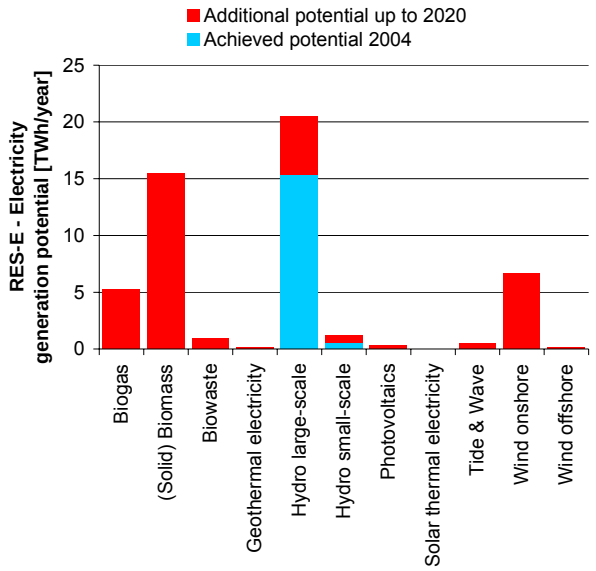


Figure 2.24 Romania – achieved (end of 2004) and additional mid-term (up to 2020) RES-E potentials.

2.3.2.3 Croatia

In Croatia the highest share of total electricity production comes from hydro power with 47 % followed by thermal power, mainly from gas and oil with 36 %. The remaining 17 % are produced in the Krsko nuclear power plant. Within the *Croatian Energy Development and Organisation Programm (PROHES)* that aims on improving energy efficiency and raising the share of renewable energy sources subprograms for the following RES-E technologies were initiated: Biomass (BIOEN), solar (SUNEN), wind (ENWIND), geothermal energy (GEOEN) and small hydro (MAHE). The promotions scheme in use for small hydro and wind onshore is a guaranteed price scheme where the tariff is set as a percentage of the average power system price.

Achieved potentials

Current RES-E generation mainly comes from large-scale hydro power with an installed capacity of 2079 MW of which only 28.7 MW is classified as small hydro. Further green electricity is produced by the incineration of biowaste.

Additional mid-term potentials

Considerable additional mid-term potentials are identified for large hydro with about 2.5 TWh and wind onshore with 1.9 TWh. The electricity generation potential from solar thermal electricity and PV is more than 1 TWh.

RES-E - Electricity generation potential in TWh/a	**Achieved potential** (end of) 2004	**Additional realisable potential** (up to) 2020
Biogas	0.00	0.00
(Solid) Biomass	0.00	0.00
Biowaste	0.32	0.00
Geothermal electricity	0.00	0.00
Hydro large-scale	6.11	2.43
Hydro small-scale	0.09	0.57
Photovoltaics	0.00	0.44
Solar thermal electricity	0.00	0.88
Tide & Wave	0.00	0.00
Wind onshore	0.00	1.90
Wind offshore	0.00	0.25
RES-E TOTAL	**6.52**	**6.47**

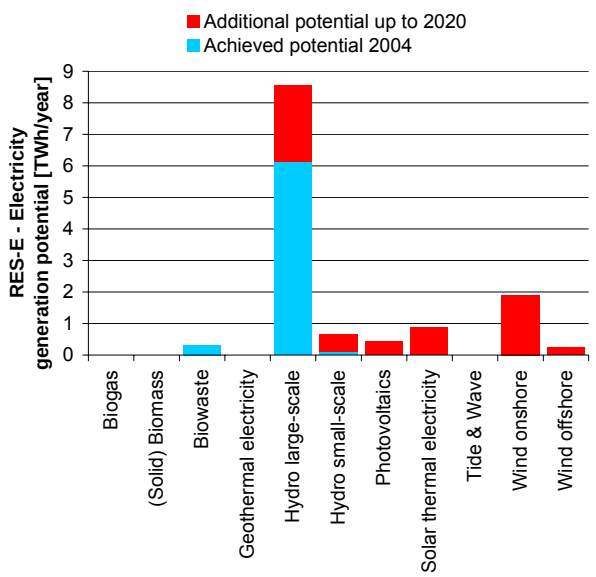


Figure 2.25 Croatia – achieved (end of 2004) and additional mid-term (up to 2020) RES-E potentials.

2.3.3 Other countries

2.3.3.1 Norway

The Norwegian electricity supply relies on almost 100 % of renewable electricity from hydro power plants. In 2003 for instance electricity from hydro power held a share of 98.9% of the total inland production. Depending on the hydrological year Norway is a net importing or exporting country for electricity. The renewable target for 2010 foresees 7 TWh from wind power and for heat production. The two technologies that are of major interest for the future supply with green electricity are hydro power and wind energy. Whilst small hydro is supported by tax exemptions, there is a tendering system for wind onshore. By the end of 2004 the Norwegian regulator NVE granted concession for more than 1000 MW of wind power.

Achieved potentials

Norway has the highest average electricity production from hydro power in Europe with about 120 TWh of which about 4 % comes from small hydro. Besides hydro, wind power penetration grew continually from the beginning of the 1990s up to a current level of 160 MW by the end of 2004. Electricity production from biowaste, solid biomass and biogas is very modest with an annual production of 12.1 GWh.

Additional mid-term potentials

Notable additional mid-term potentials for green electricity production are identified for large scale as well as small hydro power with 15.4 and 23.8 TWh respectively. Within the next decades hydro power will compete with wind onshore as well as offshore as there are considerable potentials to comparable cost for these technologies too. Because of high hydro and wind potentials other RES-E are going to play a minor role for the future Norwegian electricity supply.

RES-E - Electricity generation potential in TWh/a	**Achieved potential** (end of) 2004	**Additional realisable potential** (up to) 2020
Biogas	0.00	0.23
(Solid) Biomass	0.00	0.00
Biowaste	0.01	0.59
Geothermal electricity	0.00	0.00
Hydro large-scale	114.53	15.40
Hydro small-scale	4.46	23.80
Photovoltaics	0.00	0.00
Solar thermal electricity	0.00	0.00
Tide & Wave	0.00	10.00
Wind onshore	0.48	15.00
Wind offshore	0.00	7.50
RES-E TOTAL	**119.49**	**72.53**

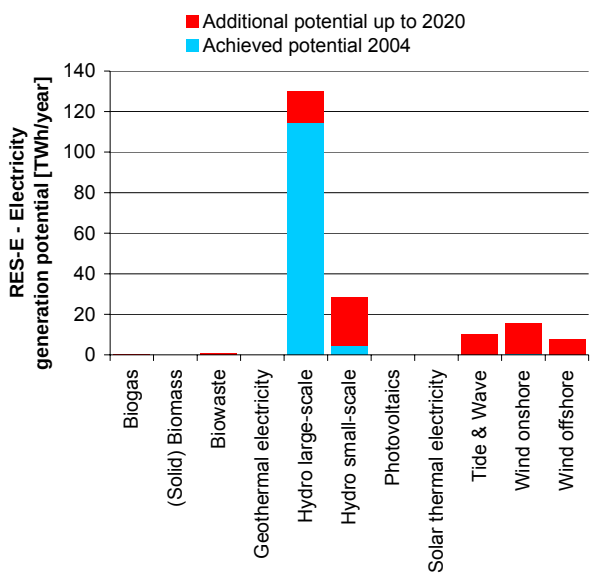


Figure 2.26 Norway – achieved (end of 2004) and additional mid-term (up to 2020) RES-E potentials.

2.3.3.2 Switzerland

The highest share of electricity production in Switzerland comes from hydro power with 55 % followed by nuclear with 40 % and conventional thermal power plants delivering the remaining 5 % of total electricity production. The Swiss power system is futher characterised by high transits in the range of two thirds of total yearly consumption from France to Italy. Within the SwissEnergy Action Plan in 2001 the target for additional green electricity in 2010 was defined with 500 GWh from which 50-100 GWh should come from wind energy. The main instrument for RES-E support is a feed-in tariff system where an average value of 0.15 CHF/kWh is defined that might be adjusted seasonally as well as regionally and according to the cost of different RES-E.

Achieved potentials

The current RES-E production comes mainly from hydro power with an installed capacity of 11,500 MW of which about 7.5 % is small hydro power. Electricity production from biowaste in 2004 accounted for 798 GWh.

Additional mid-term potentials

Additional RES-E potentials in Switzerland are moderate. Hydro power potentials are already utilized to a high extent, so there is an additional mid-term potential of only 1500 GWh identified. Further notable potentials are identified for wind power with 1157 GWh and solid biomass.

RES-E - Electricity generation potential in TWh/a	**Achieved potential** (end of) 2004	**Additional realisable potential** (up to) 2020
Biogas	0.15	0.79
(Solid) Biomass	0.03	0.00
Biowaste	0.80	0.10
Geothermal electricity	0.00	0.00
Hydro large-scale	34.19	1.57
Hydro small-scale	2.77	0.00
Photovoltaics	0.02	0.00
Solar thermal electricity	0.00	0.00
Tide & Wave	0.00	0.00
Wind onshore	0.01	1.16
Wind offshore	0.00	0.00
RES-E TOTAL	**37.96**	**3.62**

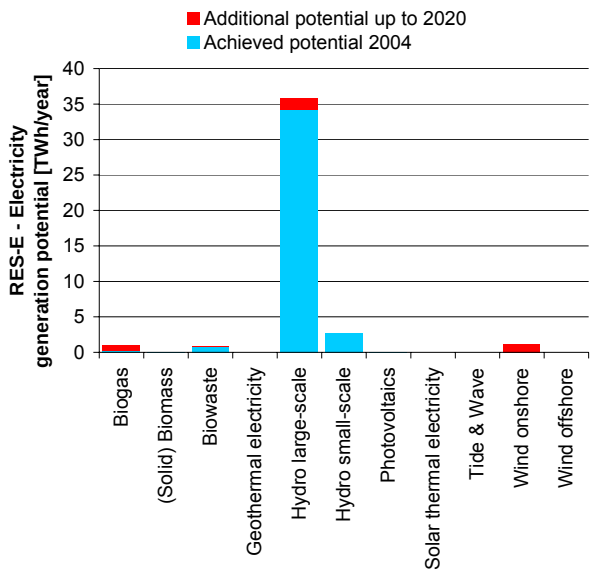


Figure 2.27 Switzerland – achieved (end of 2004) and additional mid-term (up to 2020) RES-E potentials.

3 POTENTIALS AND COSTS FOR EE IN EU-25+ COUNTRIES

In this section, we explain the steps taken for producing the dynamic electricity demand curves. Step 1: Strategic review. Step 2: information required for the demand database. Step 3: Criteria for setting the cost level for using energy saving technologies. Step 4: the development of the electricity demand curve.

3.1 Methodology

In contrast to capacities and costs of power supply (for details see Resch et al. 2003), demand is not fully specified from data within the **GreenNet-EU27** toolbox. Consequently, specific details of the total electricity demand have to be entered exogenously.[22] This allows flexibility, so users of the software can change the suggested demand forecast (i.e. default value) for their own simulation runs. Nevertheless, electricity demand can be influenced within the toolbox due to the consideration of demand-side activities.

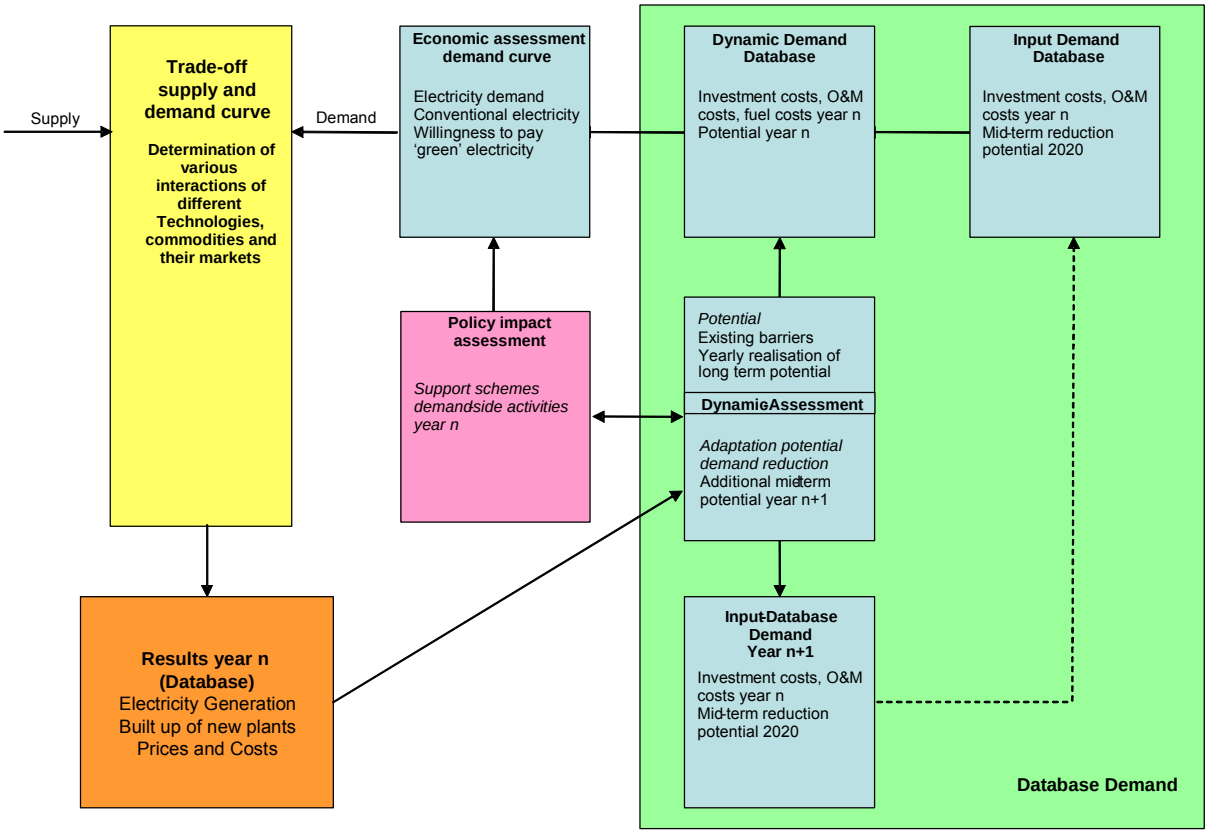


Figure 3.1. Overview of creating dynamic demand curves for electricity generation

[22] The default electricity demand forecast in the GreenNet toolbox is based on "European Energy and Transport Trends to 2030" (Mantzos et al., 2003)

Dynamic demand curves for different groups of technology in each country are developed within the **GreenNet-EU27** toolbox. They are characterised so (a) the price level at which it is rational to use energy saving technologies and (b) the potential for electricity saving, can both change year by year. In contrast with the supply side, the magnitude of these changes is given exogenously (as costs) and endogenously in the model (as potential), i.e. the differences in the values compared with the previous year depend on the outcome of the simulated year. The procedure for deriving the dynamic cost curve takes place on four levels, see Figure 3.1.

(i) Determination and calculation of the "input demand database"

For simulating the first year (i.e. year 2004), the **GreenNet-EU27** program goes back to the "input demand database". This database contains information according to technology group within the different sectors (e.g. households, industry and tertiary) and the different countries. This information includes potential electricity savings when using standard technology. Key information includes (i) investment costs, (ii) O&M costs, (iii) electrical efficiency, (iv) full-load-hours, and (v) additional potential of electricity saving to year 2020. For years beyond 2020, the "input demand database" becomes the "adapted input demand database". This database considers the simulation results with respect to the available long-term potential; see step (iv) below.

(ii) Derivation of "dynamic demand database" for the simulation year

The dynamic database for the simulation year is derived by combining the "input demand database" with dynamic parameters, which can be varied or adapted within the model for each year.[23] The assessment for the demand-side is less complex than for the supply side, because the existing barriers and obstacles are given exogenously in the **GreenNet-EU27** toolbox and are not derived within the simulation process. This dynamic database contains technology-specific information about the electricity price at which (a) it is cost effective to use electricity saving technologies and (b) the possible potential for electricity demand reduction for the simulated year. The detailed procedure deriving the cost-resource curve is described in a following sub-section.

(iii) Consideration of policy support and economic assessment

Before the analysis of the interaction of different promotion schemes and market conditions, a further adaptation of the ‘dynamic’ demand curve is necessary, namely an economic assessment of the demand curve. Within this step, a possible technology and country-specific policy support mechanism will be considered. In general, such a mechanism reduces the electricity price at which it becomes economic to use the electricity saving technology as compared with the standard technology.

(iv) Adaptation of the "input demand database"

At the end of the simulation run for the year n, the "input demand database" for the following year (n+1) is created by adapting the "input demand database" for the year n. Changes are necessary with respect to the remaining additional electricity saving potential. It must be reduced if part of this potential has already been achieved in the simulated year n

As already mentioned, this adapted "input demand database" serves as a starting point for the subsequent year, see step (i).

[23] These values are available as time-series in a country and technology specific database.

Based on the total electricity demand, a division into sub-demands might be necessary if market separations take place in the simulation with the **GreenNet-EU27** toolbox. More precisely, for RES-E[24] and combined-heat and power (CHP) strategies[25] sub-markets can occur. If this is the case, the conventional electricity demand serves as the residuum.

Before explaining the single steps in more detail, the data requirements for the demand side will be described.

3.1.1 Necessary Data

The database for calculating the cost curve for electricity-saving of demand is less complex than for supply. On the demand-side, only information for the electricity-saving potential and its costs needs to be available at two levels, namely:

1. by country
2. by technological or economic band.

The data requirements for each of these levels will be outlined below.

3.1.1.1 Country level

Country-specific data are characterised by being, valid for all the technologies considered, but varying between different countries and over time. For the derivation of the demand curve, only few data on country level are necessary, see Table 3.1.

Table 3.1. Summary of demand side country-specific data

Parameter	Aim: to determine
Total electricity demand (scenario 1)	Electricity demand for baseline scenario
Total electricity demand (scenario 2)	Electricity demand for CO_2 stabilisation scenario
Total electricity demand (scenario 3)	Electricity demand for Kyoto scenario
Price elasticity	Electricity demand for one country
Investor behaviour / interest rate	Electricity demand for one country
Total heat demand from CHP	CHP demand / capacity

3.1.1.2 Technology band level

Due to the wide variety of applicable energy saving technologies, most parameters are determined for the particular technology band (see sub-section 3.1). In contrast to the supply-side, DSM activities that have already been implemented are not considered, except

[24] E.g. if it is assumed in the simulation run that a RES-E quota is implemented.

[25] In the model a certain heat demand must be covered by CHP plants. Therefore, also a certain electricity supply from CHP – following the heat to power ratio of individual plants – is available.

implicitly through the sector-specific electricity demand. This means that only the energy saving potential and the price at which its implementation is economic, will be derived for new measures.[26]

[26] If all or part of the band will be achieved in the simulation year, total additional potential of electricity demand reduction will be reduced in the following year. Similarly, if this whole or part of the achieved band (technology) is at the end its lifetime (e.g. a bulb after 3 years) the newly free potential for electricity demand reduction is again available in the next year. However, the cost structure and the potential may differ compared to the initial band due to technological progress, i.e. different / lower investment costs and higher efficiency.

Table 3.2. Summary of band-specific data

Band Parameters	Input (In) / output (Out) data	Aim: to calculate
Technology parameter		
Lifespan of energy saving technology	In	Capital recovery factor for energy saving technology[27]
Lifespan of alternative technology	In	Capital recovery factor for energy saving technology
Cost parameter		
Investment costs energy saving technology per output	In	Electricity price at which DSM measure is economically efficient
Investment costs alternative technology per output	In	Electricity price at which DSM measure is economically efficient
Operation and maintenance costs independent of electricity consumption energy saving technology per output	In	Electricity price at which DSM measure is economically efficient
Operation and maintenance costs independent of electricity consumption alternative option per output	In	Electricity price at which DSM measure is economically efficient
Payback time energy saving technology	In	Electricity price at which DSM measure is economically efficient
Payback time alternative technology	In	Electricity price at which DSM measure is economically efficient
Interest rate	In	Electricity price at which DSM measure is economically efficient
Level of electricity price at which DSM measure is economically efficient (willingness to invest)	Out	Electricity price at which DSM measure is economically efficient
Potential parameter		
Energy consumption per unit output	In	The mid-term energy saving potential
Energy consumption per unit output of alternative technology	In	The mid-term energy saving potential
Energy saving potential per unit output	In	The mid-term energy saving potential
Dynamic restriction of yearly implementation	In	Link with dynamic restriction calculation tool
Mid-term energy saving potential compared to BAU scenario	Out	The annual energy saving potential
Energy saving potential year n:	Out	The maximal energy saving potential of the band for the simulation year n

[27] In the model the minimum level of the lifespan and the payback time will be used.

3.1.1.3 Summary

Figure 3.2 summarises the demand side data-structure. In contrast to the supply side, only country- and band-specific data are required.

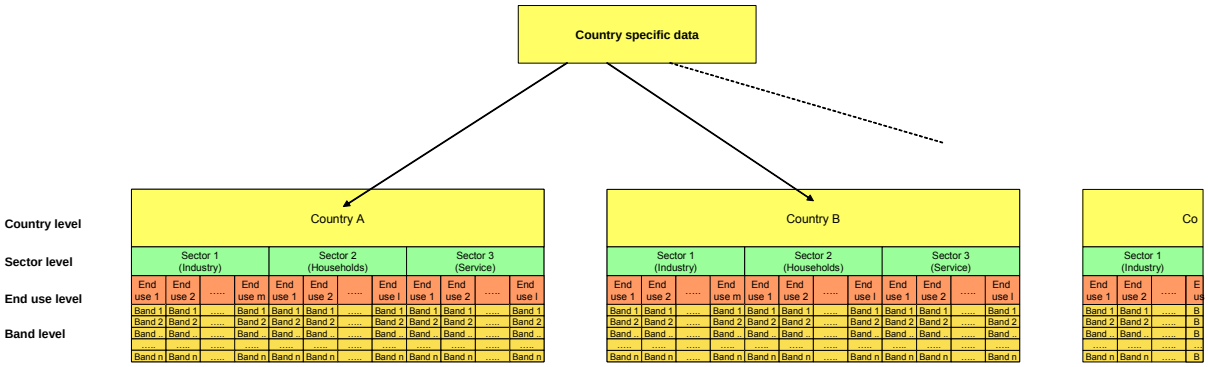


Figure 3.2. Overview of demand-side data classification

3.1.2 Willingness to invest in demand-side activities

In the **Green*Net*-EU27** toolbox, consumers are assumed to invest in energy saving technologies if these investments are cost effective for them. Consequently, per unit of output[28], the total life-cycle cost of the energy-saving technology must be less than, or at least equal to, the total life cycle cost of the equivalent energy demand scenario. In general, accepting the energy saving option as the most cost effective depends on the electricity price. In general, if electricity prices become cheaper, then energy saving technology becomes less economic. The willingness to invest is characterised by the electricity price at which both energy saving by DSM and the status quo are equally 'economic'.

To analyse this for a commercial 'product', let:

p_e..... Minimum electricity price at which DSM measure is economic, i.e. the switch price [€/MWh]

q_{el} ..... Electricity consumption per unit product output [MWh/output]

I ..... Investment costs of energy saving technology per unit product output [€/output]

CRF..... Capital recovery factor: $$CRF = \frac{z * (1+z)^{PT}}{\left[(1+z)^{PT} - 1\right]}$$

z ..... Interest rate per year

PT ..... Life time of energy saving technology [y]

[28] Output may be, for example, per tonne of steel, or per luminous intensity, per GJ mechanical energy

$C_{O\&M\ Nel}$ ..... O&M costs independent of electricity consumption per unit output energy saving technology [€/output]

q_{Ael}..... Electricity consumption of status quo or of alternative technology, per unit output [MWh/output]

I_A ..... Investment costs of alternative energy saving technology per unit output [€/output]

CRF_A..... Capital recovery factor of alternative: $CRF_A = \frac{z*(1+z)^{PT_A}}{\left[(1+z)^{PT_A}-1\right]}$

PT_A ..... Life time of the alternative technology [a]

$C_{A\ O\&M\ Nel}$..... alternative technology O&M costs, independent of electricity consumption, per unit output [€/output]

The criteria at which both technologies – the energy saving and the alternative option are equally economic, is given by:

$$p_e * q_{el} + I * CRF + C_{O\&M\ Nel} = p_e * q_{A\ el} + I_A * CRF_A + C_{A\ O\&M\ Nel}$$

Hence, the electricity price at which the investment will be initiated can be derived by re-arranging the above equation.

$$WTI = p_e = \frac{(I * CRF - I_A * CRF_A) + (C_{O\&M\ Nel} - C_{A\ O\&M\ Nel})}{q_{Ael} - q_{el}} \quad (3)$$

Note, unlike the calculation of the electricity generation costs, important parameters, such as the investment costs or the O&M costs, are normalised per unit of output produced.

– **Investment Costs**

The additional DSM capital investment costs differ by technology and sub-sector. In addition, since most DSM technologies are still not mature, the unit investment costs can be expected to decrease over time. However determinating the investment costs is crucial. Moreover, for DSM measures, the number of potential technologies is very large. Therefore it is reasonable to attempt a 'learning curve approach' for each DSM technology option. Therefore the present published investment costs of most DSM technologies will be used, unless there are credible cost development forecasts in the literature. The investment costs for the year n are calculated by forecasts made in other studies (e.g. MURE or IKARUS), otherwise they are assumed constant.

– **Capital recovery factor**

As the lifespan may vary between the energy saving technologies, the payback time

against the status quo may vary too.[29] This difference also influences the economic cost assessment of the investment costs.

3.1.3 Development of the demand-curve for electricity

In contrast to power supply data, information about demand is usually less reliable. In principle, demand depends on the unit price of electricity, the portfolio of technologies generating the electricity, the country (region) and the time (i.e. demand changes over time). For the time t_1, the only certain information is the present demand. The marginal unit price is given by the intersection of market price p_M and the quantity of electricity demand q_{el}, see Figure 3.3.

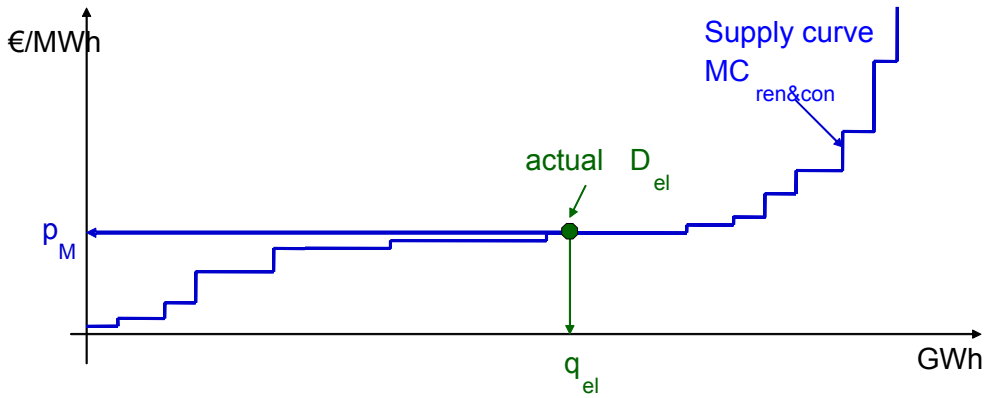


Figure 3.3. Knowledge about supply and demand

Analysing electricity prices over time and between different countries, the following can be concluded:

– demand decreases if power prices increase, i.e. all consumers try to control expenditure. The reason for the reduction in the electricity demand can be threefold:
  - inefficient and careless use is reduced, e.g. lights are switched off when rooms are empty, machines are not left on needlessly. In practice there are many opportunities for this, but our analysis assumes such practices already occur.
  - Hence, for our study, decrease in service: in the short term; this is the only immediate reaction for efficient consumers to counteract price increases,
  - demand-side activities: in the long run, consumers take measures to save electricity by replacing all or part of their applications and technologies by systems consuming less electricity. In practice, only a few of the existing demand-side reduction options will be used, especially if price increases are temporary. This is because there are many obstacles which impede change in consumer equipment and behaviour, namely:
    - consumer complacency and carelessness
    - incomplete information

[29] E.g. while the lifespan of a standard light bulb is one year, an energy saving lamp lasts - on average - 5 years.

- low transparency of the DSM market
- high uncertainty about the electricity price development in the future.

– The price elasticity decreases over time and with higher incomes (Zoechling, 1998).

– The value of price elasticity depends on whether electricity prices increase or decrease. Normally elasticity is less if prices decrease. The reason is that it is not sensible to reverse already-implemented demand-side benefits, e.g. if the consumer replaced an inefficient refrigerator by purchasing an efficient one and then the electricity unit price reduces, the consumer will still use the new, efficient refrigerator since there will always be a cost benefit.

– Price elasticity changes with the absolute price level.

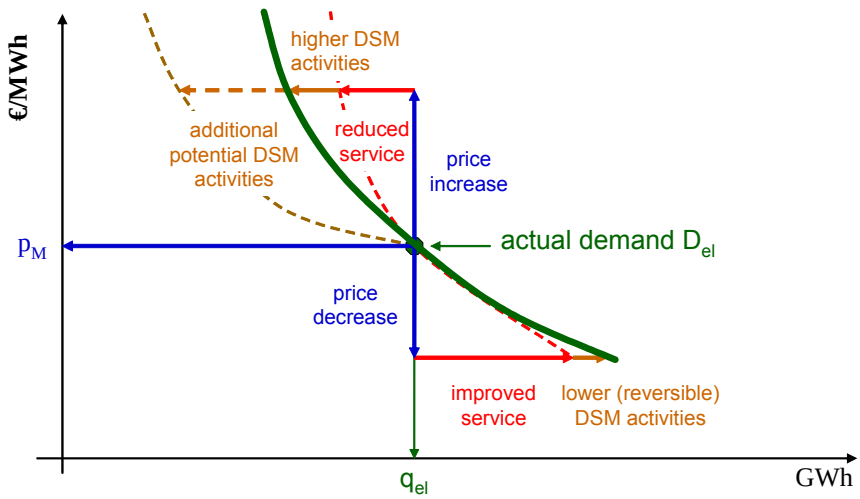


Figure 3.4. Interpretation of the demand curve

Figure 3.4 depicts the character of a demand curve. The total demand consists of both service and demand side measurement. In practice, only some parts of the demand side activities can be implemented; compare arrows indicating 'additional potential DSM' and ‘implemented DSM activities’. In addition, due to irreversible DSM measures, the demand increase is less than the demand reduction, assuming the same increment of price change. Also experience shows that national demand increases with time for a growth economy, as most consumers purchase more appliances and power consuming services. This means the whole demand curve shifts to the right with increase in time.

In the **GreenNet-EU27** toolbox , three effects are considered:

(i) electricity demand changes (increase) with time,
(ii) demand reaction to short-term electricity price changes (service demand),
(iii) demand changes due to demand-side measures.

Similar to the supply curve, the demand curve is modelled as a stepped function.

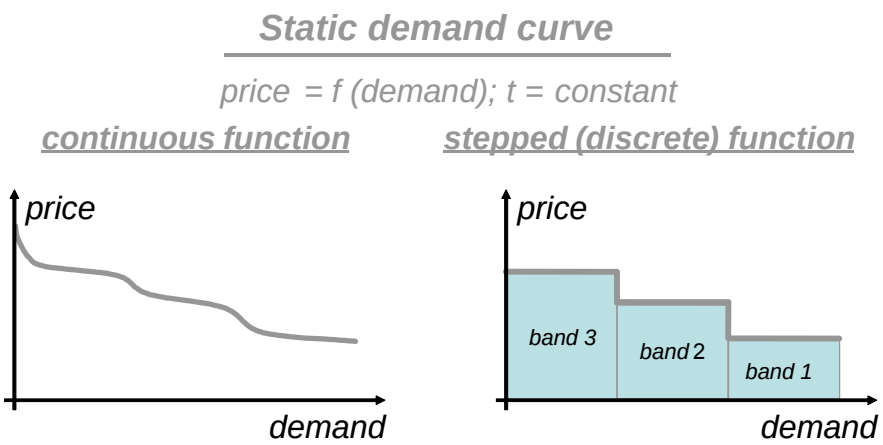


Figure 3.5. Characteristic run of a static demand curve: Continuous (left-hand side) and stepped function (right-hand side). ('Price' is the tariff 'unit price' at the margin, e.g. euro/kWh)

On the left-hand side of Figure 3.5 a realistic continuous static demand curve is depicted as a response to common tariff structures. The stepped function on the right-hand side of Figure 3.5 represents a practical function for modelling.[30] Thereby, sites with "similar conditions" are described by one band.

In the model, bands are characterised by a single energy saving option / technology (e.g. low energy lighting) in a certain area (e.g. household, industry or tertiary sector).

3.1.3.1 Modelling electricity demand increase

The most important factor is that demand changes with time. Also, different demand scenarios are considered because electricity demand is dependent on the general economic, political and social conditions, Business as usual (BAU) is the baseline, with the scenario given by the EC (Mantzos et al., 2003); this reflects current policies and trends, but without the inclusion of additional policies to reduce CO_2.[31]

The data for the electricity demand forecast will not be considered in absolute terms in the toolbox. The model is able to consider DSM activities using relative changes. The calculation of the reference point of electricity demand for a certain year n is given by:

$$D_n = D_{n-1}\left(1+\frac{D_n^* - D_{n-1}^*}{D_{n-1}^*}\right) \tag{4}$$

[30] In addition, considering the uncertainty of the demand forecast in the future (total demand), the accuracy applying a stepped demand function instead of a continuous curve can be neglected.

[31] Other scenarios, which can be used as default scenarios for the model runs – if data are available – are: . Other scenarios modelled are:

- CO_2 emissions remain at their 1990 level throughout the projected period, compared to the baseline this means approximately a 12% reduction in 2020.
- CO_2 emissions drop by 6% compared to their 1990 level until 2010 and remain at this level until 2020, compared to the baseline this means an approx. 18% reduction in 2020.

where:

D_n ..... Assumed electricity demand in year n [GWh] - input value for the simulation year n

D_{n-1} ..... Actual electricity demand in year n-1 [GWh] - result from the simulation year n-1

D^*_n ..... Forecast of the electricity demand year n [GWh] – value from database

D^*_{n-1} ..... Forecast of the electricity demand year n-1 [GWh] – value from database

The assumed electricity demand for the year n (D_n) depends on two factors:

1. the actual electricity demand for the year n-1. This value directly results from the **GreenNet-EU27** toolbox calculation for the year n-1.
2. the growth rate of the electricity demand. The growth rate is determined by demand forecasts for the year n-1 and the year n.

These values are given exogenously in the **GreenNet-EU27** toolbox by an external demand scenario.

However, by considering the simulation results, the assumed demand forecasts, as given by different demand scenarios, are adapted. Hence, despite the exogenous nature of the demand forecast, an "internalisation" takes place.

3.1.3.2 Modelling service demand changes

The service demand D_{ser} only reacts to changes in the service level, i.e. demand-side measurements are not relevant. Figure 2.6 shows a characteristic demand curve. In the **GreenNet-EU27** toolbox, it is assumed that (i) changes in the service are characterised by the electricity price elasticity, and (ii) this elasticity does not vary with unit price. However, both the elasticity and the unit price can vary by time and country.

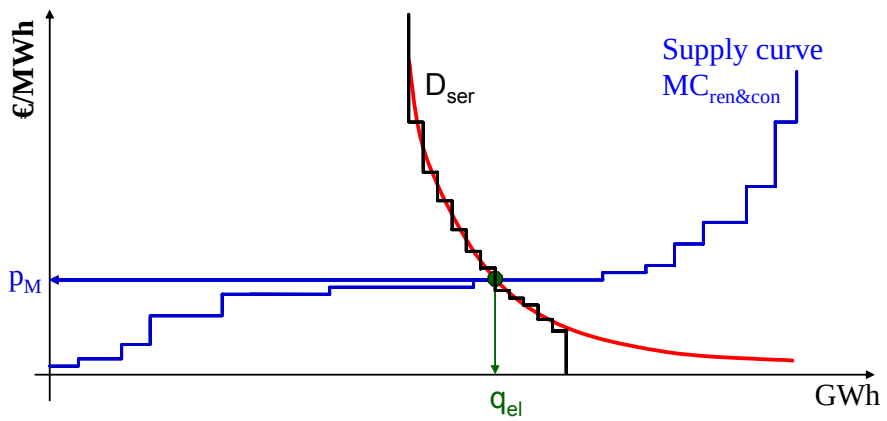


Figure 3.6. Modelling the response of demand to changes in the unit price of electricity in the **GreenNet-EU27** toolbox

3.1.3.3 Modelling demand-side activities

The methodology for deriving the third component of a demand curve, the change due to demand side measures, is explained below.

In the **GreenNet-EU27** toolbox, it is assumed that reductions in electricity demand will be made within the modelled time interval they become economically justified, e.g. within one year. However, in practice, this is seldom the case, since old equipment and practices remain in use because of consumer lethargy and incompetence. Nevertheless, we assume perfection in this respect as a 'base case' study. As already explained in the previous section for the derivation of the demand curve, neither generation costs nor energy saving costs are important by themselves. The criterion that is of importance is the electricity unit *price* at which the application of an energy saving technology becomes economic.

The demand-side activity curve represents the relationship between energy saving potential (= potential of reduced demand) and the price at which this potential will be used. Similar to the supply curve, the measures can be ordered according to the electricity price, starting with low prices, see Figure 3.7.

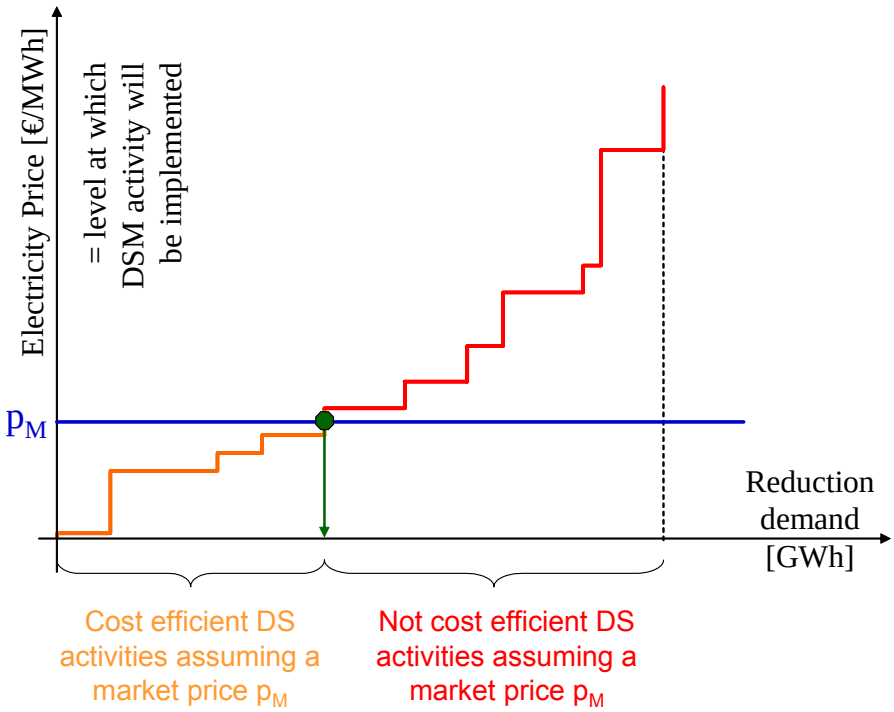


Figure 3.7. Development of the demand curve due to demand-side activities as a function of electricity unit price

In the **GreenNet-EU27** toolbox, it is assumed that all activities giving benefits at less than the actual electricity price are already implemented; see left part of the reduction demand curve in Figure 3.7. It can be seen that the "costs" of implementing some parts of the electricity saving potential are less than the current unit electricity price (p_M). Under static conditions, this potential should have already been achieved in the past. Assuming, however, a dynamic environment, "cheap" electricity saving potential still exists. The reasons are:

1. due to existing barriers, only part of the potential savings can be achieved within the year,
2. some aspects of the energy saving potential will involve new techniques not previously available. Hence, that particular potential saving was not available in the past and so would not have been implemented.

An increase of the electricity demand due to previously implemented demand-side measures becoming uneconomic is neglected in the **GreenNet-EU27** toolbox. The reasons are (i) the available potential for this is very small, and, (ii) it can be assumed, at least for almost all the simulation runs, that future electricity unit price will not decrease significantly. [32]

However, the **GreenNet-EU27** model requires the actual electricity demand as input, not the potential savings. Hence, the curve of Figure 2.7 must be turned around the ordinate (y) axis, see Figure 3.8, to appear as a function of actual demand (i.e. savings are a negative demand).

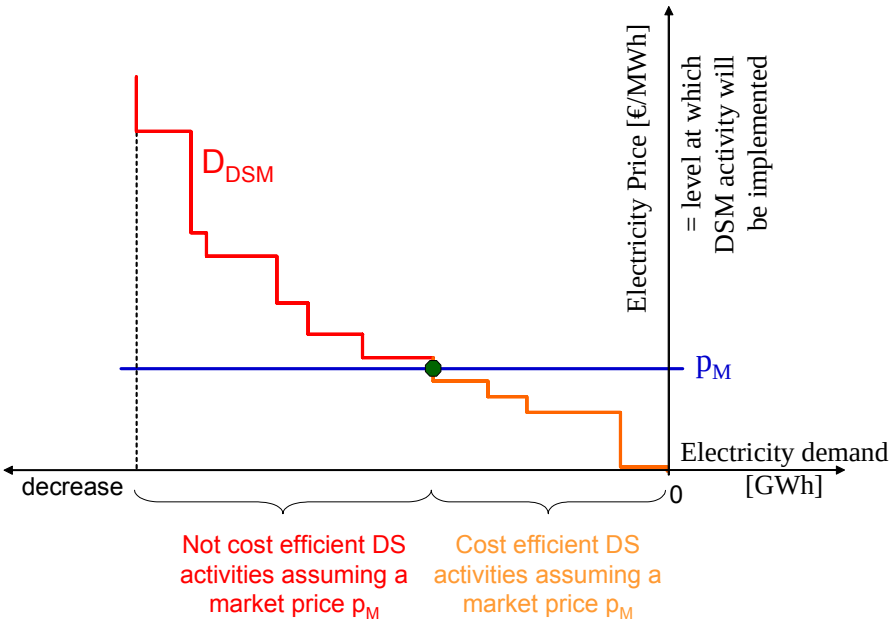


Figure 3.8. Development of the demand curve due to demand-side activities

Note: cost curve of DS activities in the form used in the GreenNet-EU27 toolbox - left hand side: reduction of demand, right-hand-side increase of demand

Similar to the supply-side, in practice only part of the energy saving potential for demand-side measures can be implemented within a year. Hence, dynamic assessments must again be taken into account. Figure 3.9 depicts this schematically; the red lines represent the mid-term energy saving potential, the green lines the additional potential, which can be used in

[32] In general, it can be assumed that these measures lead to an increase in electricity price.

the next year (year n) for each band. Of course, the actual availability may vary between the single bands.

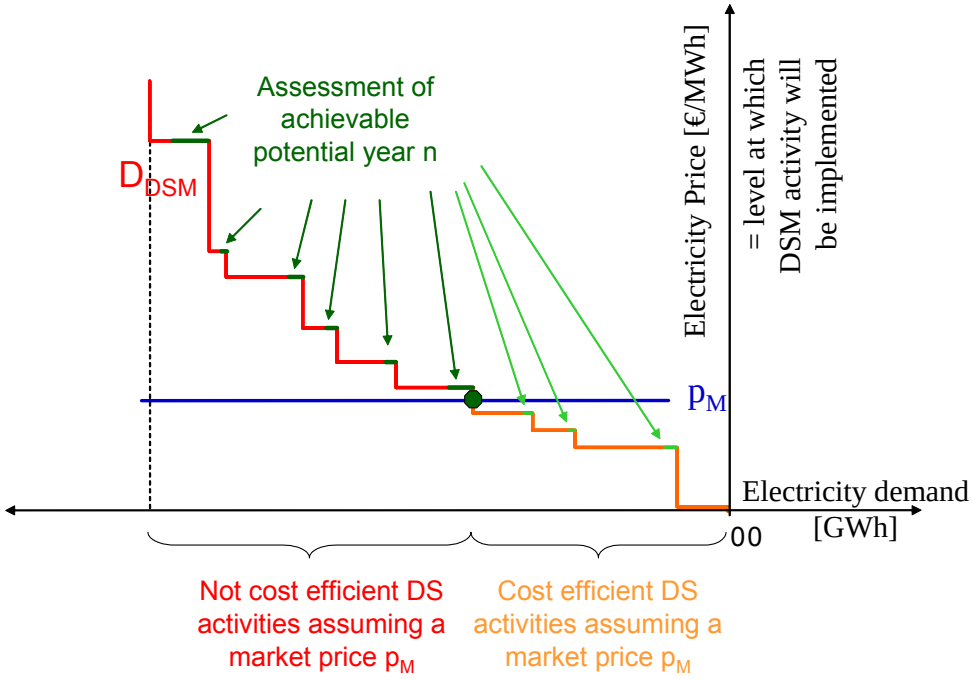


Figure 3.9. Cost curve assessment for additional energy saving potential year n

In contrast to the dynamic assessment for the supply-side, the evaluation of the existing barriers is modelled in a less complex manner for the demand-side. Firstly, the barriers are given exogenously, that is the actual saving potential for the next year are not determined by the toolbox, and, secondly, just one parameter per band is specified. Of course, this parameter can change over time. Figure 3.10 shows the dynamic demand curve due to demand side measures for the year n, by adding the green lines in Figure 3.9

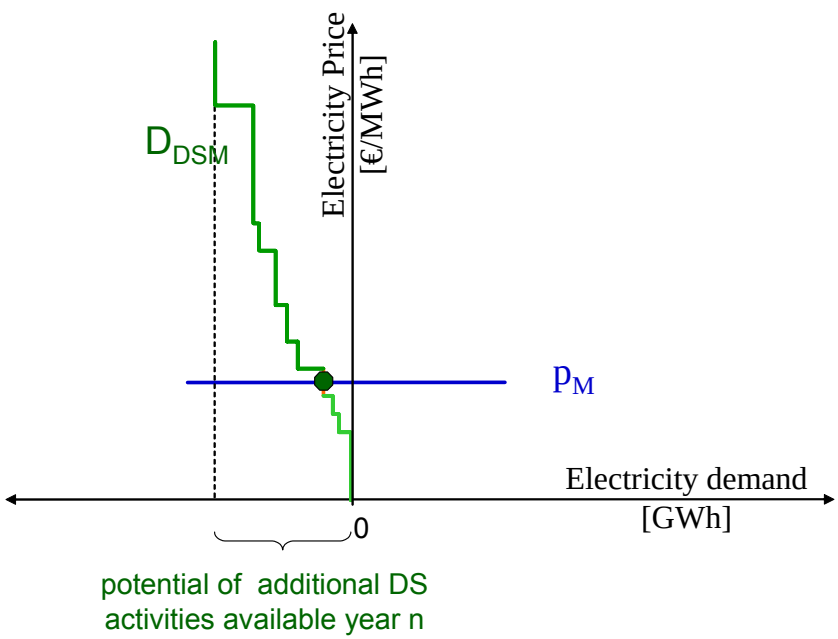


Figure 3.10. Dynamic demand curve due to demand side measures for the year n

One use of the DSM curves in the **GreenNet-EU27** toolbox is to analyse the effects of DS policies on both electricity supply and demand. Therefore, it is necessary to include DSM policy options in the model.

3.1.3.4 Modelling total demand

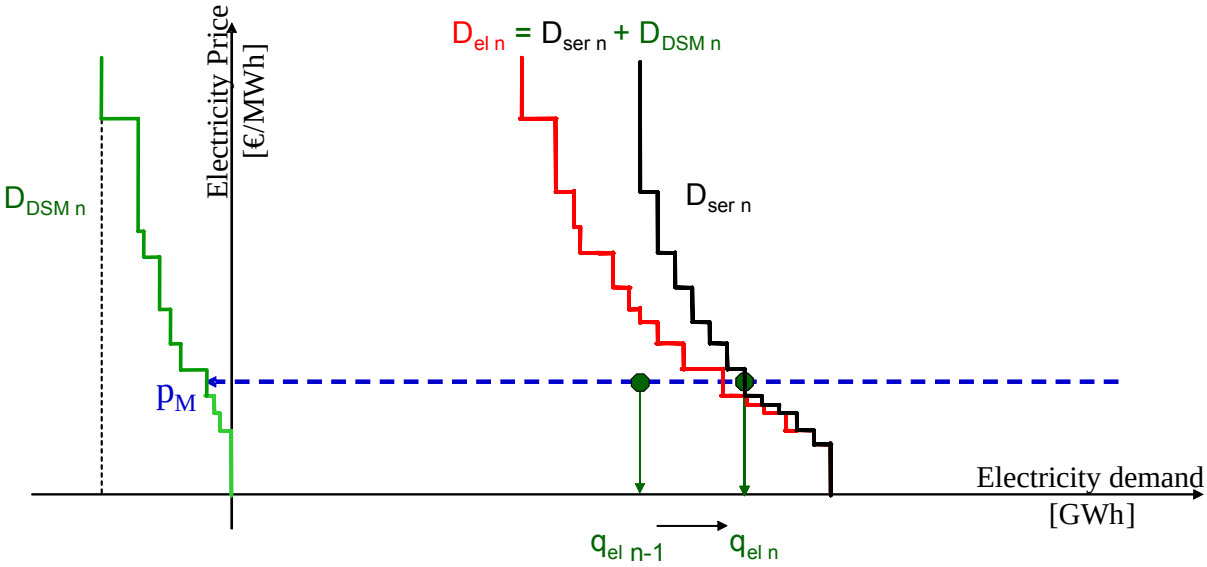


Figure 3.11. Construction of the total dynamic demand curve for the year n

The total demand curve for year n can be derived by adapting the demand for the previous year n-1. Mathematically, $q_{el\ n-1}$ => $q_{el\ n}$[33]. Here, $q_{el\ n}$ represents the expected demand, assuming that the electricity price remains unchanged in year n from year n-1.

Based on $q_{el\ n}$, the service demand curve can be created according to the assumed price elasticity for the year n ($D_{ser\ n}$). In addition, the total dynamic demand can be derived by 'horizontal' addition of, (1) the service demand curve and, (2) the demand curve for demand-side activities. Analytically,

$$D_{el\ n} = D_{ser\ n} + D_{DSM\ n} \qquad (5)$$

The construction of the total demand curve, for the case with no policy support, is depicted in Figure 3.11.

[33] Note: The change in the electricity price in the demand forecast has to be considered by adapting the demand for the year n. In the case that in the demand forecast for the year n a higher electricity price is assumed, the additional demand for the year n compared to the year n-1 must be adjusted appropriately.

The situation assuming a constant[34] promotion of measures for reducing electricity demand is depicted in Figure 3.12. As with the argument for equation (5), but not explicitly mentioned there is a so called "economic rebound effect". This effect can be modelled within the **GreenNet-EU27** toolbox using the split of the total demand into 'service demand' and into 'demand reduction based on DSM'. More precisely, the total "theoretical" demand reduction resulting from the mechanisms for DSM (Δq_{el} in Figure 3.12) cannot be fully used, because, at the same time, the service level (Δq_{ser}) rises due to the reduced electricity price. Hence, the actual demand reduction is given by the difference between the 'demand reduction DSM' and the 'demand increase due to improving the service', see Figure 3.12. Analytically,

$$\Delta q_{el} = \Delta q_{el\ DSM} - \Delta q_{ser} \qquad (6)$$

The net effect depends on the slope of the total demand curve. With a flat curve, the "economic rebound" is very large.

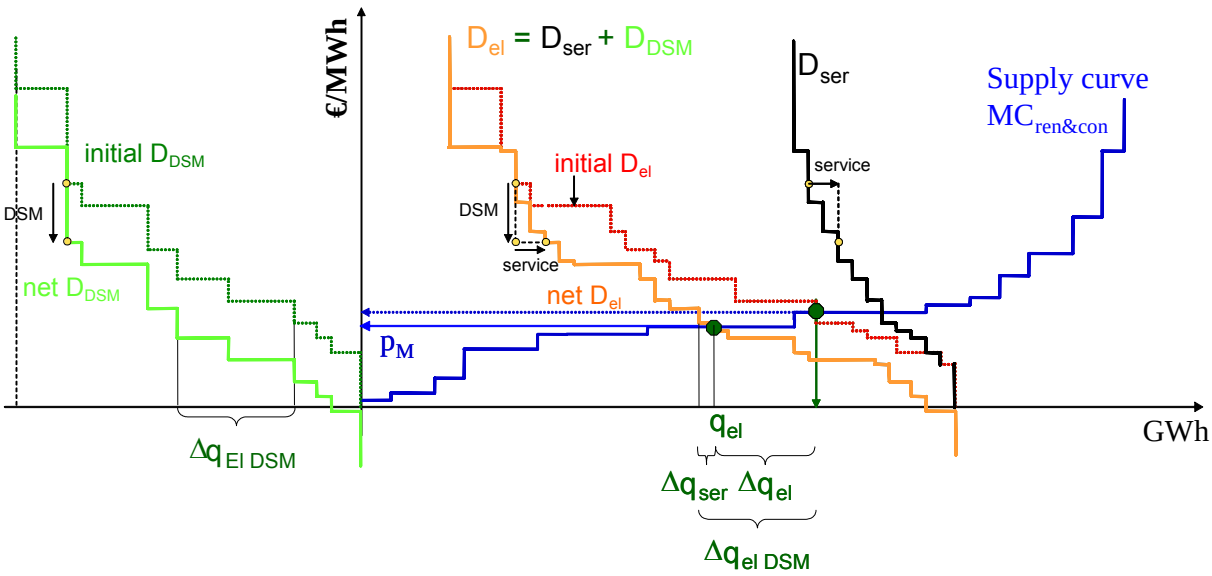


Figure 3.12. Construction of the total dynamic demand curve for the year n, assuming a constant financial incentive for demand-side measures

In addition, a similar effect occurs if the demand-side measures are promoted, e.g. by financial and/or political) mechanisms. As a result of reduced DSM costs (indicated by the "DSM"-arrow), consumers react with an additional demand (increase of the service level, as indicated by the "service"-arrow). Consequently, parts of the demand reduction due to demand-side measures will be compensated by increased demand, due to reduced electricity price, see also Figure 3.12.

[34] This means that each technology in each sector receive the same financial support – constant reduction independent from the band (technology) in the magnitude of "DSM".

3.2 Resulting Potentials and Costs for EE in EU-25+ countries

3.2.1 Choices and assumptions

3.2.1.1 Residential sector

EU-25+ countries are not present in MURE database, apart from Norway. In addition, data collecting for EU-25+ countries has been difficult since the depth, precision and, in general, the effort in the statistical science is at a different level from EU15 countries. As a consequence it has not been possible to apply the same methodology adopted in the previous project **Green*Net*** Work Package 5[35]. When neither National Statistical Offices, nor National Energy Institutes or similar were able to provide requested data, several sources of data have been used numerous assumptions have been made. Here is a brief explanation of assumptions common to all countries or most of them. In the next paragraphs each country's specific assumptions are reported

Similarly to assumptions made in the **Green*Net*** project, following fields have been put at the same value for all countries.

- Life time of implemented technology,
- Share of realisable energy saving potential compared to long-term potential,
- Investment costs of alternative option (year n),
- O&M costs independent from electricity consumption alternative,
- Interest rate,
- Life time alternative option:

Investment costs are the same for all EU-15 except from Mediterranean countries, whose values differ from those of other countries and among them. Thus, for non-mediterranean countries, old values have been adopted while, for Mediterranean countries (Cyprus, Malta), the average of previously used values for Spain, Italy, Portugal and Greece have been adopted.

Analogously to **Green*Net*** project study, the field "Energy consumption per unit service output", for bands:

- heating, fuel substitution
- lighting, efficient bulbs
- efficient washing machine
- efficient dish washer
- efficient TV
- efficient refrigerator

is assumed to be the same for all EU-25+ countries. Specified bands refer both to "multiple houses" bands (MH) and to "single houses" ones (SH)

The same as been assumed for parameter "Energy consumption of alternative per unit service output", as regards bands (both MH and SH)

- lighting, efficient bulbs
- lighting, efficient bulbs
- efficient washing machine
- efficient dish washer

[35] See also the report "Potential and costs of DSM-measures" Work Package 5 Report within the project Pushing A Least Cost Integration Of Green Electricity Into The European Grid GreenNet supported by DG TREN 5th Framework Programme of the European Commission

– efficient TV
– efficient washing machine
– efficient dish washer
– efficient TV
– efficient refrigerator
– efficient freezer

and for parameter "Investment costs" , as regards bands

– heating, wall insulation (MH and SH)
– heating, windows technologies (MH and SH)
– heating, control devices (MH and SH)
– heating, fuel substitution (MH)
– lighting, efficient bulbs (MH and SH)
– efficient washing machine
– efficient dish washer
– efficient TV
– efficient refrigerator
– efficient freezer

For the field "Appliances stock yearly growth rate" assumptions have been made on the basis of other European countries' data in MURE database, since nobody among contacted experts could provide these data. Similitudes have been noted among three groups of countries: Mediterranean countries, Central European countries, Northern countries. Average values for each of the three groups have been adopted respectively for

– Cyprus, Malta;
– Slovenia, Hungary, Bulgaria, Romania, Croatia
– Estonia, Lithuania, Latvia.

Consultant from Slovenia is the unique who was able to provide these data.

Fields "Stock of dwellings average yearly growth rate" and "Stock of dwellings annual rate of stock demolition" have been calculated on the basis of UNECE (United Nations Economic Commission for Europe) data (http://w3.unece.org/stat/HumanSettlements.asp). Future growth rates have been adopted equal to the latest available. Croatia (whose consultant provided these data, and Malta (data not available neither in UNECE database) are the exceptions.

The field "Consumption of efficient technology (% of alternative)" was calculated in **GreenNet** project with data obtained by mean of MURE simulations. Here average percentages of that data have been proposed to consultants in order to receive corrections based on available data and experience. Only Croatian consultant was able to make this correction, for other countries average values have been used.

When data was sufficient to calculate values for the band "heating, fuel substitution", it was always more feasible the use of gas rather than other fuels. The source of Energy prices for gas in different countries is Eurostat. Data refer to 2003.

Reports of the project Energy Efficiency Indicators for Central and Eastern European Countries (http://www.ceec-indicators.org) were a valuable, and unique source – referring to year 2002, to estimate the distribution of dwellings among different fuels for heating, and the distribution of consumption for heating among fuels. In some cases no clear data was declared (only charts), but it was sufficient to estimate that in some countries electric consumption for heating is not relevant. This is the case of Bulgaria, Estonia, Lithuania,

Romania. For Cyprus and Latvia there are no sufficient data to calculate bands referring to heating, and neither to say that these are not relevant.

In all EU-25+ countries there are no sufficient data to estimate potential and costs of "hot sanitary water" bands.

When no data about multiple and single housing stock was available, the overall stock have been equally split in the two fields.

3.2.1.2 Industrial and Tertiary sector

Potential savings are calculated as:

- **Consumption per sector / final use:** derived from national statistics (where available) or from IEA statistics and may differ from country to country. Countries are grouped by similarity: for Cyprus, Malta, Norway no data were available, general values (EU average) were adopted. (Total consumption for final use) * (% saving from specific technology) * (maximum possible penetration rate - actual penetration rate)

Tertiary sector Consumption per final use	Estonia, Lithuania, Latvia	Slovenia, Croatia	Cyprus, Malta, Norway	Bulgaria, Romania	Switzerland
Lighting	45.0%	27.0%	27.0%	35.0%	28.9%
Other Motors – Drives	17.0%	15.0%	15.0%	15.0%	22.4%
Office machinery	3.0%	10.0%	10.0%	10.0%	5.4%
Refrigeration	12.0%	8.0%	8.0%	8.0%	10.0%
Space heating - Warm water	3.0%	18.0%	18.0%	18.0%	7.8%
Ventilation - Air conditioning	5.0%	16.0%	16.0%	8.0%	25.6%
Other	15.0%	6.0%	6.0%	6.0%	0.0%

Industrial sector Consumption per final use	Estonia, Lithuania, Latvia	Slovenia, Croatia	Cyprus, Malta, Norway	Bulgaria, Romania	Switzerland
Air conditioning	1.0%	8.8%	7.0%	1.0%	9.0%
Compressed air	2.3%	8.8%	7.0%	3.0%	3.7%
Lighting	15.0%	2.5%	6.0%	30.0%	10.0%
Other Motors – Drives	60.0%	69.4%	55.0%	50.0%	49.0%
Refrigeration	2.0%	0.8%	2.0%	2.0%	5.9%
Space heating - Warm water	0.7%	2.1%	5.0%	1.0%	4.5%
Other	19.0%	7.6%	18.0%	13.0%	17.9%

- **Saving from specific technology; maximum possible penetration rate; actual penetration rate, % of potential reachable per year**: are the same already adopted in **GreenNet** project, depending on technology, generally not on country
- **Cost of kWh saved:** International literature - assumption or calculation already adopted in **GreenNet** project - average values depending on the technologies (generally not depending on country)
- **Interest rate**: Assumption (8% for industry and commercial tertiary, 5% for public service tertiary)

3.2.2 Remaining EU-25 Member States

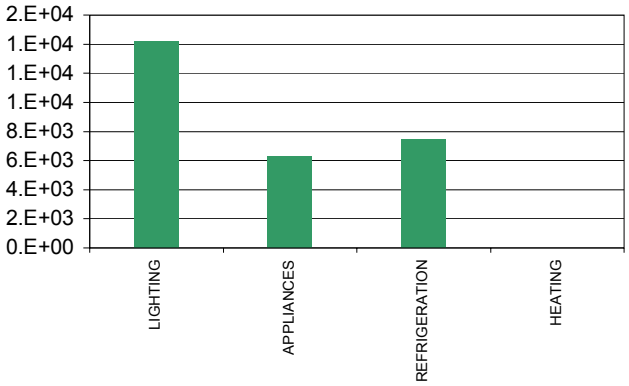
3.2.2.1 Cyprus

Data assumptions and sources:

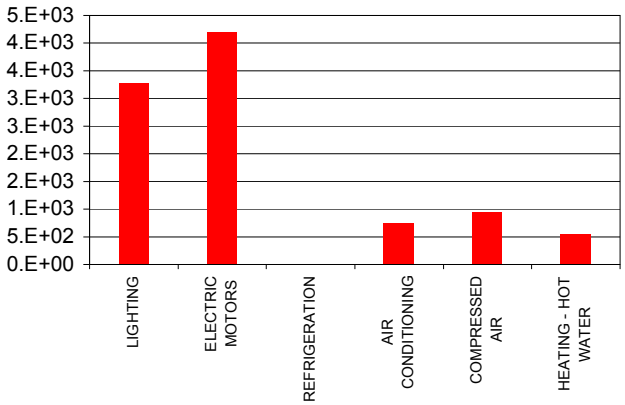
- Reference stock of dwellings: only overall stock available (UNECE, 2003).
- Annual rate of dwelling stock demolition: source (UNECE, 2004).
- Lighting units: the same overall amount as the total number of dwellings have been adopted.
- Appliances stock: in absence of any data, the average value of appliances per dwelling for EU15 countries have been determined for each appliance and applied to the overall stock of dwellings to eventually determine the appliances stocks
- There are no data about distribution of dwellings among different fuels for heating, neither to state that heating bands are not relevant in this country.

Results:

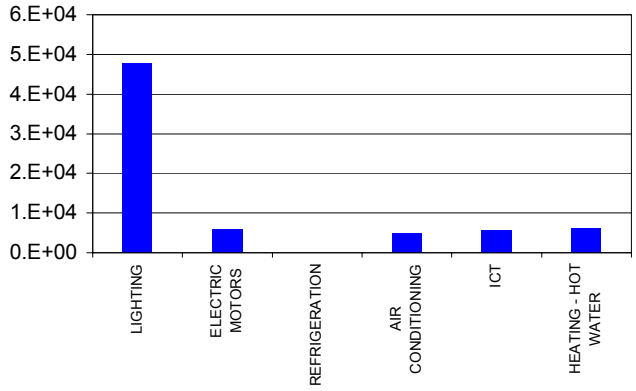
	E-DSM-RE Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	14 172
APPLIANCES	6 287
REFRIGERATION	7 469
HEATING	
TOTAL	*27 928*



	E-DSM-IN Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	3 293
ELECTRIC MOTORS	4 196
REFRIGERATION	0
AIR CONDITIONING	753
COMPRESSED AIR	949
HEATING - HOT WATE	545
TOTAL	*9 735*



	E-DSM-TS Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	47 758
ELECTRIC MOTORS	6 078
REFRIGERATION	0
AIR CONDITIONING	4 793
ICT	5 637
HEATING - HOT WATE	6 275
TOTAL	*70 541*



Level of electricity costs where DSM measure is economical efficienct RESIDENTIAL SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-RE-MH-H-1		heating, ground insulation
E-DSM-N-RE-MH-H-2		heating, roof insulation
E-DSM-N-RE-MH-H-3		heating, wall insulation
E-DSM-N-RE-MH-H-4		heating, windows technologies
E-DSM-N-RE-MH-H-5		heating, control devices
E-DSM-N-RE-MH-H-6		heating, fuel sobstitution
E-DSM-N-RE-SH-H-1		heating, ground insulation
E-DSM-N-RE-SH-H-2		heating, roof insulation
E-DSM-N-RE-SH-H-3		heating, wall insulation
E-DSM-N-RE-SH-H-4		heating, windows technologies
E-DSM-N-RE-SH-H-5		heating, control devices
E-DSM-N-RE-SH-H-6		heating, fuel sobstitution
E-DSM-N-RE-MH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-SH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-MH-E-1	475.9	efficient washing machine
E-DSM-N-RE-MH-E-2	198.4	efficient dish washer
E-DSM-N-RE-MH-E-5	0.0	efficient TV
E-DSM-N-RE-SH-E-1	475.9	efficient washing machine
E-DSM-N-RE-SH-E-2	198.4	efficient dish washer
E-DSM-N-RE-SH-E-5	216.6	efficient TV
E-DSM-N-RE-MH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-MH-R-2	172.3	efficient freezer
E-DSM-N-RE-SH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-SH-R-2	172.3	efficient freezer

With the methodology assumed, values of resulting costs are the same for all countries, thus they are presented only once, in the two following figures.

Level of electricity costs where DSM measure is economical efficienct RESIDENTIAL SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-RE-MH-H-1		heating, ground insulation
E-DSM-N-RE-MH-H-2		heating, roof insulation
E-DSM-N-RE-MH-H-3		heating, wall insulation
E-DSM-N-RE-MH-H-4		heating, windows technologies
E-DSM-N-RE-MH-H-5		heating, control devices
E-DSM-N-RE-MH-H-6		heating, fuel sobstitution
E-DSM-N-RE-SH-H-1		heating, ground insulation
E-DSM-N-RE-SH-H-2		heating, roof insulation
E-DSM-N-RE-SH-H-3		heating, wall insulation
E-DSM-N-RE-SH-H-4		heating, windows technologies
E-DSM-N-RE-SH-H-5		heating, control devices
E-DSM-N-RE-SH-H-6		heating, fuel sobstitution
E-DSM-N-RE-MH-L-1	31	lighting, efficient bulbs
E-DSM-N-RE-SH-L-1	31	lighting, efficient bulbs
E-DSM-N-RE-MH-E-1	476	efficient washing machine
E-DSM-N-RE-MH-E-2	198	efficient dish washer
E-DSM-N-RE-MH-E-5	217	efficient TV
E-DSM-N-RE-SH-E-1	476	efficient washing machine
E-DSM-N-RE-SH-E-2	198	efficient dish washer
E-DSM-N-RE-SH-E-5	217	efficient TV
E-DSM-N-RE-MH-R-1	283	efficient refrigerator
E-DSM-N-RE-MH-R-2	172	efficient freezer
E-DSM-N-RE-SH-R-1	283	efficient refrigerator
E-DSM-N-RE-SH-R-2	172	efficient freezer

Level of electricity costs where DSM measure is economical efficienct TERTIARY SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-TS-CS-L-1	115.8	High efficiency Lamps
E-DSM-N-TS-CS-L-2	89.8	High efficiency Fixtures
E-DSM-N-TS-CS-L-3	67.0	High Efficiency Ballasts
E-DSM-N-TS-CS-L-4	128.0	Occupancy Sensors
E-DSM-N-TS-CS-L-5	170.3	Daylight Control
E-DSM-N-TS-CS-L-6	115.8	High efficiency Lamps
E-DSM-N-TS-CS-M-1	45.3	High Efficiency Motors
E-DSM-N-TS-CS-M-2	69.4	Variable speed drives
E-DSM-N-TS-CS-M-3	72.8	Whole system redesign
E-DSM-N-TS-CS-I-1	395.7	LCD Monitors
E-DSM-N-TS-CS-R-1	101.3	Thicker Insulation
E-DSM-N-TS-CS-R-2	937.6	Improved Insulation
E-DSM-N-TS-CS-R-3	22.0	Floating Head Pressure
E-DSM-N-TS-CS-R-4	48.4	Antisweat Heat Controls
E-DSM-N-TS-CS-R-5	39.8	Defrost Controls
E-DSM-N-TS-CS-R-6	3.1	High-Efficiency Fan Blades
E-DSM-N-TS-CS-H-1	13.3	Auto-Manual control
E-DSM-N-TS-CS-H-2	66.0	Insulation
E-DSM-N-TS-CS-C-1	1.2	Auto/manual control
E-DSM-N-TS-CS-C-2	66.0	Insulation
E-DSM-N-TS-PS-L-1	108.2	High efficiency Lamps
E-DSM-N-TS-PS-L-2	68.1	High efficiency Fixtures
E-DSM-N-TS-PS-L-3	50.7	High Efficiency Ballasts
E-DSM-N-TS-PS-L-4	105.5	Occupancy Sensors
E-DSM-N-TS-PS-L-5	140.4	Daylight Control
E-DSM-N-TS-CS-L-6	108.2	High efficiency Lamps
E-DSM-N-TS-PS-M-1	37.3	High Efficiency Motors
E-DSM-N-TS-PS-M-2	57.3	Variable speed drives
E-DSM-N-TS-PS-M-3	60.0	Whole system redesign
E-DSM-N-TS-PS-I-1	360.4	LCD Monitors
E-DSM-N-TS-PS-R-1	88.7	Thicker Insulation
E-DSM-N-TS-PS-R-2	824.4	Improved Insulation
E-DSM-N-TS-PS-R-3	19.1	Floating Head Pressure
E-DSM-N-TS-PS-R-4	42.0	Antisweat Heat Controls
E-DSM-N-TS-PS-R-5	34.7	Defrost Controls
E-DSM-N-TS-PS-R-6	2.7	High-Efficiency Fan Blades
E-DSM-N-TS-PS-H-1	13.3	Auto-Manual control
E-DSM-N-TS-PS-H-2	66.0	Insulation
E-DSM-N-TS-PS-C-1	1.2	Auto/manual control
E-DSM-N-TS-PS-C-2	66.0	Insulation

3.2.2.2 Estonia

Source of data (where not differently specified): LEI - Lithuanian Energy Institute. (http://www.lei.lt).

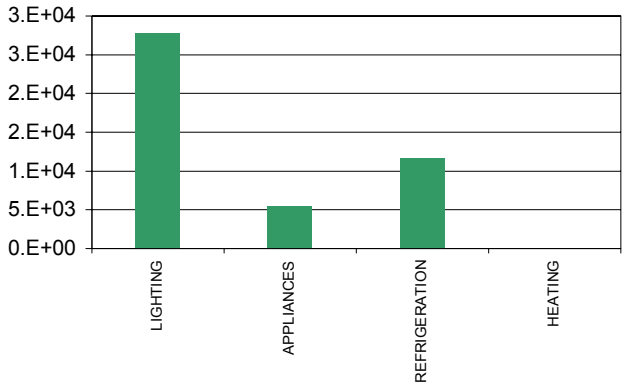
Reference contact: Romualdas Skema, skema@isag.lei.lt

Data assumptions:

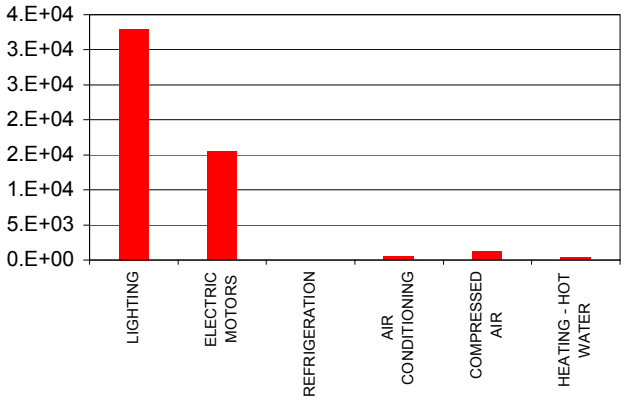
- Reference stock of dwellings: only overall stock available (UNECE, 2003).
- Consumption of heating by fuel: from CEEC report about Estonia it is possible to argue that heating by electricity is not relevant in this country.
- Lighting units: the same overall amount as the total number of dwellings have been adopted.
- Appliances stock: source of data CEEC, year 2002.

Results:

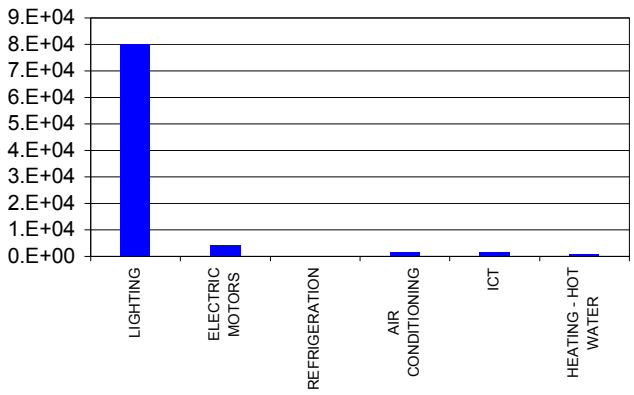
	E-DSM-RE Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	27 825
APPLIANCES	5 483
REFRIGERATION	11 611
HEATING	
TOTAL	*44 919*



	E-DSM-IN Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	32 978
ELECTRIC MOTORS	15 427
REFRIGERATION	0
AIR CONDITIONING	433
COMPRESSED AIR	1 249
HEATING - HOT WATE	303
TOTAL	*50 391*



	E-DSM-TS Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	80 035
ELECTRIC MOTORS	4 338
REFRIGERATION	0
AIR CONDITIONING	1 506
ICT	1 701
HEATING - HOT WATE	1 052
TOTAL	*88 631*



Level of electricity costs where DSM measure is economical efficienct RESIDENTIAL SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-RE-MH-H-1		heating, ground insulation
E-DSM-N-RE-MH-H-2		heating, roof insulation
E-DSM-N-RE-MH-H-3		heating, wall insulation
E-DSM-N-RE-MH-H-4		heating, windows technologies
E-DSM-N-RE-MH-H-5		heating, control devices
E-DSM-N-RE-MH-H-6		heating, fuel sobstitution
E-DSM-N-RE-SH-H-1		heating, ground insulation
E-DSM-N-RE-SH-H-2		heating, roof insulation
E-DSM-N-RE-SH-H-3		heating, wall insulation
E-DSM-N-RE-SH-H-4		heating, windows technologies
E-DSM-N-RE-SH-H-5		heating, control devices
E-DSM-N-RE-SH-H-6		heating, fuel sobstitution
E-DSM-N-RE-MH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-SH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-MH-E-1	475.9	efficient washing machine
E-DSM-N-RE-MH-E-2	198.4	efficient dish washer
E-DSM-N-RE-MH-E-5	0.0	efficient TV
E-DSM-N-RE-SH-E-1	475.9	efficient washing machine
E-DSM-N-RE-SH-E-2	198.4	efficient dish washer
E-DSM-N-RE-SH-E-5	216.6	efficient TV
E-DSM-N-RE-MH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-MH-R-2	172.3	efficient freezer
E-DSM-N-RE-SH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-SH-R-2	172.3	efficient freezer

3.2.2.3 Latvia

Source of data (where not differently specified): LEI - Lithuanian Energy Institute. (http://www.lei.lt).

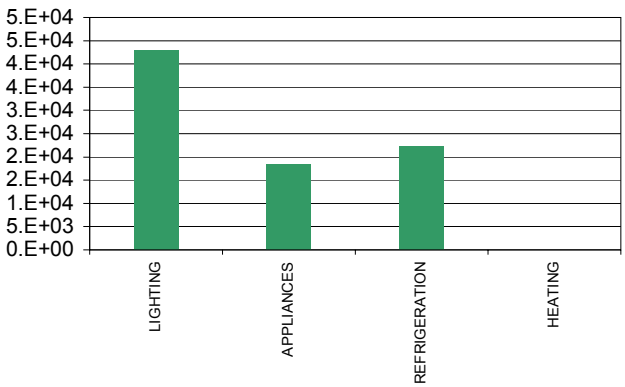
Reference contact: Romualdas Skema, skema@isag.lei.lt

Data assumptions:

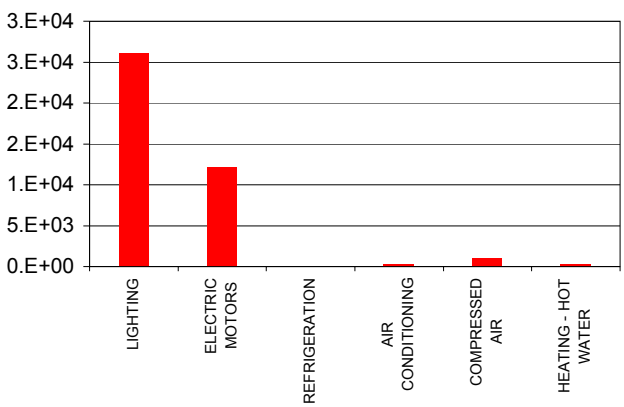
- Reference stock of dwellings: only overall stock available (UNECE, 2003).
- Consumption of heating by fuel: some data is available from CEEC reports but not enough to evaluate heating bands neither to state that they are not relevant.
- Lighting units: the same overall amount as the total number of dwellings have been adopted..
- Appliances stock: in absence of any data, the average value of appliances per dwelling for EU15 countries have been determined for each appliance and applied to the overall stock of dwellings to eventually determine the appliances stocks

Results:

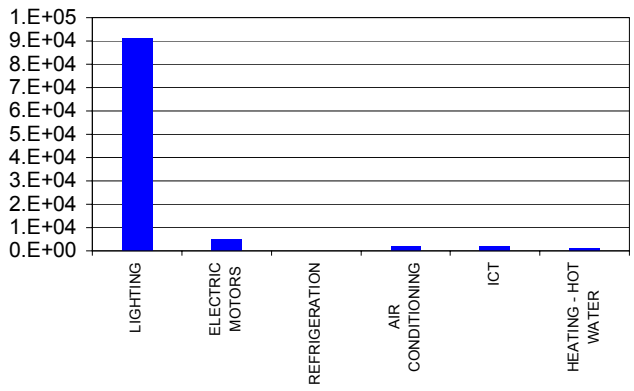
	E-DSM-RE Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	42 982
APPLIANCES	18 509
REFRIGERATION	22 202
HEATING	
TOTAL	*83 693*



	E-DSM-IN Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	26 061
ELECTRIC MOTORS	12 192
REFRIGERATION	0
AIR CONDITIONING	342
COMPRESSED AIR	987
HEATING - HOT WATE	240
TOTAL	*39 822*



	E-DSM-TS Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	90 849
ELECTRIC MOTORS	4 924
REFRIGERATION	0
AIR CONDITIONING	1 710
ICT	1 930
HEATING - HOT WATE	1 194
TOTAL	*100 606*



Level of electricity costs where DSM measure is economical efficienct RESIDENTIAL SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-RE-MH-H-1		heating, ground insulation
E-DSM-N-RE-MH-H-2		heating, roof insulation
E-DSM-N-RE-MH-H-3		heating, wall insulation
E-DSM-N-RE-MH-H-4		heating, windows technologies
E-DSM-N-RE-MH-H-5		heating, control devices
E-DSM-N-RE-MH-H-6		heating, fuel sobstitution
E-DSM-N-RE-SH-H-1		heating, ground insulation
E-DSM-N-RE-SH-H-2		heating, roof insulation
E-DSM-N-RE-SH-H-3		heating, wall insulation
E-DSM-N-RE-SH-H-4		heating, windows technologies
E-DSM-N-RE-SH-H-5		heating, control devices
E-DSM-N-RE-SH-H-6		heating, fuel sobstitution
E-DSM-N-RE-MH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-SH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-MH-E-1	475.9	efficient washing machine
E-DSM-N-RE-MH-E-2	198.4	efficient dish washer
E-DSM-N-RE-MH-E-5	0.0	efficient TV
E-DSM-N-RE-SH-E-1	475.9	efficient washing machine
E-DSM-N-RE-SH-E-2	198.4	efficient dish washer
E-DSM-N-RE-SH-E-5	216.6	efficient TV
E-DSM-N-RE-MH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-MH-R-2	172.3	efficient freezer
E-DSM-N-RE-SH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-SH-R-2	172.3	efficient freezer

3.2.2.4 Lithuania

Source of data (where not differently specified): LEI - Lithuanian Energy Institute. (http://www.lei.lt).

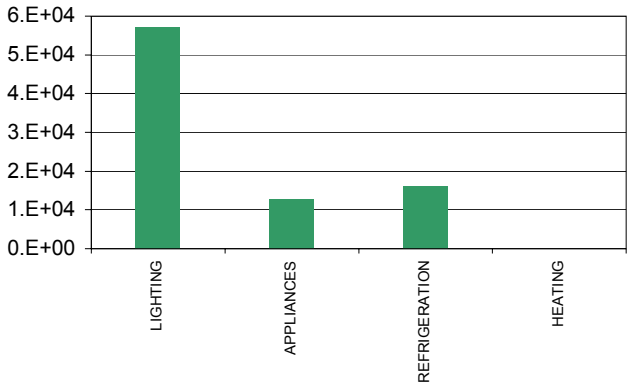
Reference contact: Romualdas Skema, skema@isag.lei.lt

Data explanation and assumptions:

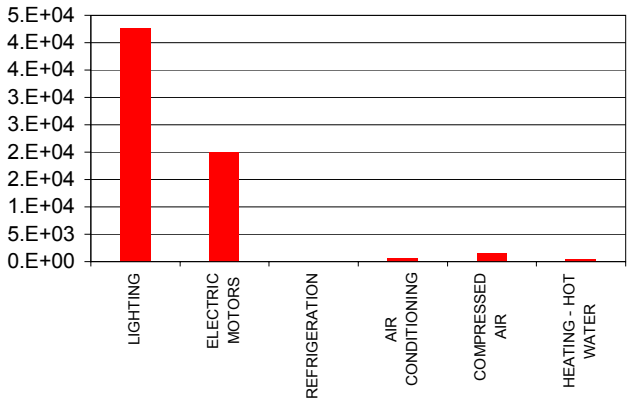
- Reference stock of dwellings: only overall stock available (UNECE, 2003).
- Consumption of heating by fuel: from CEEC report about Lithuania it is possible to argue that heating by electricity is not relevant in this country.
- Dwelling stock yearly growth rates: the contact only gave us rates related to the past, future ones have been assumed equal to the latest.
- Consumption of heating by fuel: consumption for each fuel has been equally split into multiple and single dwellings.

Results:

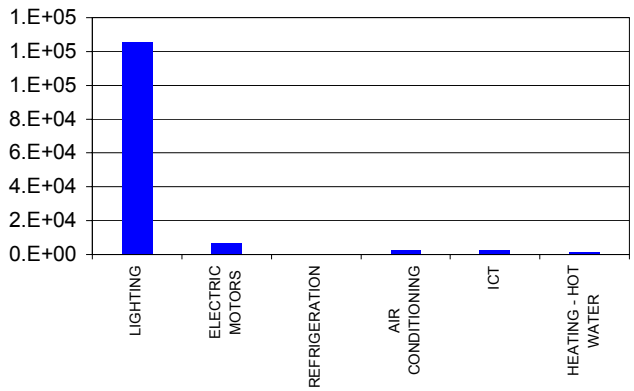
	E-DSM-RE Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	57 115
APPLIANCES	12 746
REFRIGERATION	16 070
HEATING	
TOTAL	*85 931*



	E-DSM-IN Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	42 705
ELECTRIC MOTORS	19 977
REFRIGERATION	0
AIR CONDITIONING	561
COMPRESSED AIR	1 617
HEATING - HOT WATE	393
TOTAL	*65 253*



	E-DSM-TS Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	125 191
ELECTRIC MOTORS	6 785
REFRIGERATION	1
AIR CONDITIONING	2 356
ICT	2 660
HEATING - HOT WATE	1 645
TOTAL	*138 637*



Level of electricity costs where DSM measure is economical efficienct RESIDENTIAL SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-RE-MH-H-1		heating, ground insulation
E-DSM-N-RE-MH-H-2		heating, roof insulation
E-DSM-N-RE-MH-H-3		heating, wall insulation
E-DSM-N-RE-MH-H-4		heating, windows technologies
E-DSM-N-RE-MH-H-5		heating, control devices
E-DSM-N-RE-MH-H-6		heating, fuel sobstitution
E-DSM-N-RE-SH-H-1		heating, ground insulation
E-DSM-N-RE-SH-H-2		heating, roof insulation
E-DSM-N-RE-SH-H-3		heating, wall insulation
E-DSM-N-RE-SH-H-4		heating, windows technologies
E-DSM-N-RE-SH-H-5		heating, control devices
E-DSM-N-RE-SH-H-6		heating, fuel sobstitution
E-DSM-N-RE-MH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-SH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-MH-E-1	475.9	efficient washing machine
E-DSM-N-RE-MH-E-2	198.4	efficient dish washer
E-DSM-N-RE-MH-E-5	0.0	efficient TV
E-DSM-N-RE-SH-E-1	475.9	efficient washing machine
E-DSM-N-RE-SH-E-2	198.4	efficient dish washer
E-DSM-N-RE-SH-E-5	216.6	efficient TV
E-DSM-N-RE-MH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-MH-R-2	172.3	efficient freezer
E-DSM-N-RE-SH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-SH-R-2	172.3	efficient freezer

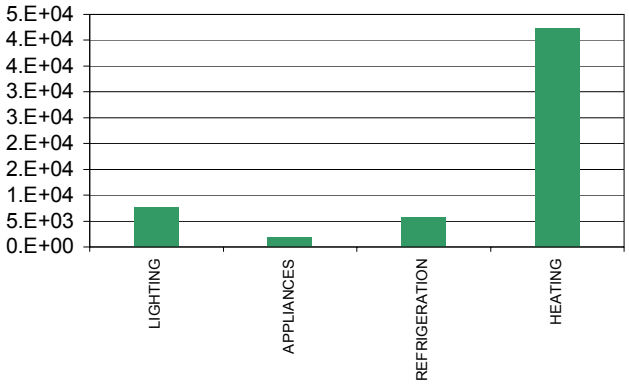
3.2.2.5 Malta

Data assumptions and sources: :

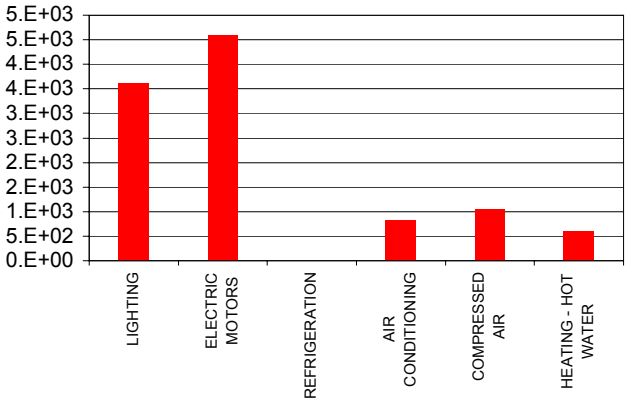
- Stock of dwellings by fuel: obtained from National Statistics Office, year 1995.
- Consumptions for heating by fuel have been calculated assuming the same unitary consumption for each fuel as in Greece.
- Average yearly growth rate and Annual rate of stock demolition: data not available, zero assumed.
- Appliances stock: source of data is National Statistics Office, year 1995.

Results:

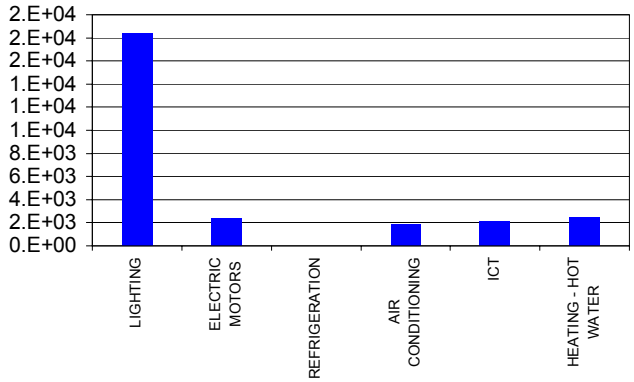
	E-DSM-RE Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	7 643
APPLIANCES	1 792
REFRIGERATION	5 656
HEATING	42 206
TOTAL	*57 296*



	E-DSM-IN Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	3 611
ELECTRIC MOTORS	4 601
REFRIGERATION	0
AIR CONDITIONING	826
COMPRESSED AIR	1 040
HEATING - HOT WATE	598
TOTAL	*10 676*



	E-DSM-TS Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	18 384
ELECTRIC MOTORS	2 340
REFRIGERATION	0
AIR CONDITIONING	1 845
ICT	2 170
HEATING - HOT WATE	2 415
TOTAL	*27 155*



Level of electricity costs where DSM measure is economical efficienct RESIDENTIAL SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-RE-MH-H-1	66.0	heating, ground insulation
E-DSM-N-RE-MH-H-2	36.1	heating, roof insulation
E-DSM-N-RE-MH-H-3	53.0	heating, wall insulation
E-DSM-N-RE-MH-H-4	70.7	heating, windows technologies
E-DSM-N-RE-MH-H-5	51.0	heating, control devices
E-DSM-N-RE-MH-H-6	113.9	heating, fuel sobstitution
E-DSM-N-RE-SH-H-1	285.8	heating, ground insulation
E-DSM-N-RE-SH-H-2	142.4	heating, roof insulation
E-DSM-N-RE-SH-H-3	169.2	heating, wall insulation
E-DSM-N-RE-SH-H-4	224.7	heating, windows technologies
E-DSM-N-RE-SH-H-5	101.9	heating, control devices
E-DSM-N-RE-SH-H-6	175.6	heating, fuel sobstitution
E-DSM-N-RE-MH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-SH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-MH-E-1	475.9	efficient washing machine
E-DSM-N-RE-MH-E-2	198.4	efficient dish washer
E-DSM-N-RE-MH-E-5	0.0	efficient TV
E-DSM-N-RE-SH-E-1	475.9	efficient washing machine
E-DSM-N-RE-SH-E-2	198.4	efficient dish washer
E-DSM-N-RE-SH-E-5	216.6	efficient TV
E-DSM-N-RE-MH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-MH-R-2	172.3	efficient freezer
E-DSM-N-RE-SH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-SH-R-2	172.3	efficient freezer

3.2.2.6 Slovenia

Source of data (where not differently specified): APE. http://www.ape.si

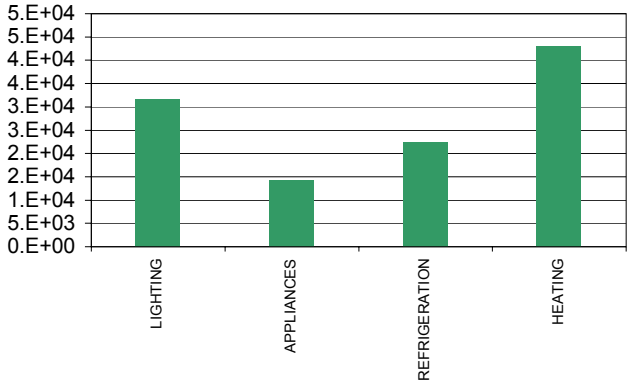
Reference contact: Katarina Vertin, katarina.vertin@ape.si

Data explanation and assumptions:

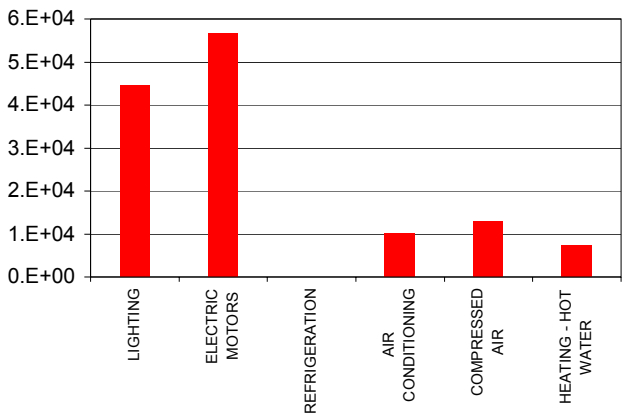
- Lighting units: the same overall amount as the total number of dwellings have been adopted.
- Appliances stock growth yearly rate: only 1995 value provided by contact. Future values equal to this one.

Results:

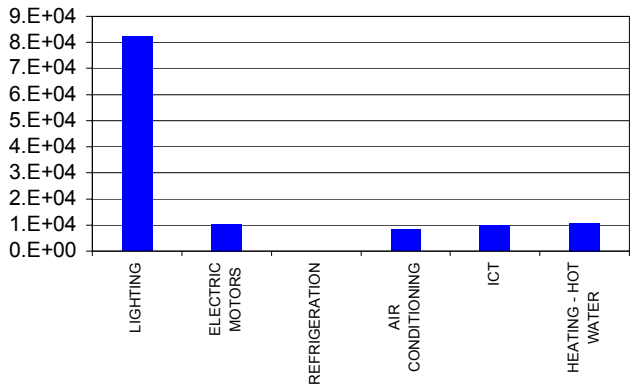
	E-DSM-RE Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	31 740
APPLIANCES	14 269
REFRIGERATION	22 390
HEATING	42 989
TOTAL	*111 388*



	E-DSM-IN Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	44 536
ELECTRIC MOTORS	56 743
REFRIGERATION	0
AIR CONDITIONING	10 181
COMPRESSED AIR	12 832
HEATING - HOT WATE	7 373
TOTAL	*131 665*



	E-DSM-TS Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	82 188
ELECTRIC MOTORS	10 461
REFRIGERATION	0
AIR CONDITIONING	8 249
ICT	9 701
HEATING - HOT WATE	10 798
TOTAL	*121 397*



Level of electricity costs where DSM measure is economical efficienct RESIDENTIAL SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-RE-MH-H-1	64.2	heating, ground insulation
E-DSM-N-RE-MH-H-2	40.5	heating, roof insulation
E-DSM-N-RE-MH-H-3	44.5	heating, wall insulation
E-DSM-N-RE-MH-H-4	59.5	heating, windows technologies
E-DSM-N-RE-MH-H-5	42.8	heating, control devices
E-DSM-N-RE-MH-H-6	71.3	heating, fuel sobstitution
E-DSM-N-RE-SH-H-1	278.2	heating, ground insulation
E-DSM-N-RE-SH-H-2	184.2	heating, roof insulation
E-DSM-N-RE-SH-H-3	142.3	heating, wall insulation
E-DSM-N-RE-SH-H-4	188.9	heating, windows technologies
E-DSM-N-RE-SH-H-5	85.7	heating, control devices
E-DSM-N-RE-SH-H-6	117.0	heating, fuel sobstitution
E-DSM-N-RE-MH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-SH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-MH-E-1	475.9	efficient washing machine
E-DSM-N-RE-MH-E-2	198.4	efficient dish washer
E-DSM-N-RE-MH-E-5	0.0	efficient TV
E-DSM-N-RE-SH-E-1	475.9	efficient washing machine
E-DSM-N-RE-SH-E-2	198.4	efficient dish washer
E-DSM-N-RE-SH-E-5	216.6	efficient TV
E-DSM-N-RE-MH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-MH-R-2	172.3	efficient freezer
E-DSM-N-RE-SH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-SH-R-2	172.3	efficient freezer

3.2.3 Candidate Countries

3.2.3.1 Bulgaria

Source of data (where not differently specified): BSREC – Black Sea Regional Energy Centre. http://www.bsrec.bg

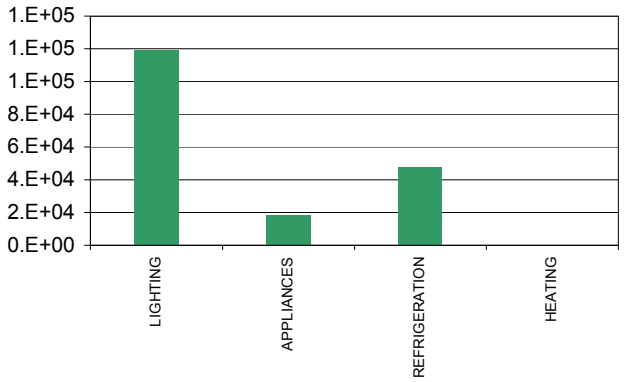
Reference contact: L. Radulov, radulov@bsrec.bg

Data assumptions:

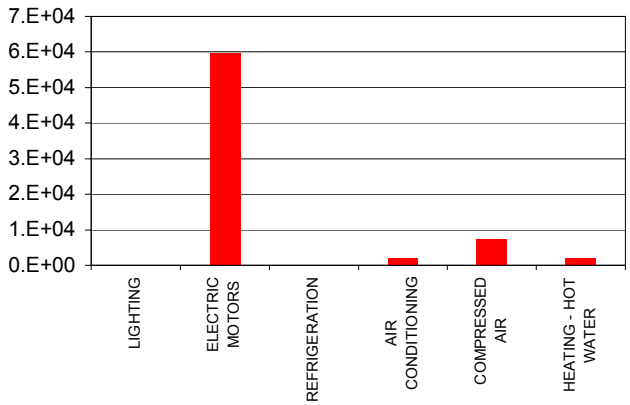
- Reference stock of dwellings: only overall stock available (UNECE, 2004).
- Consumption of heating by fuel: from CEEC report about Bulgaria it is possible to argue that heating by electricity is not relevant in this country.
- Appliances stock: source BSREC, year 2001
- Annual rate of stock demolition: source UNECE; year 2004.

Results:

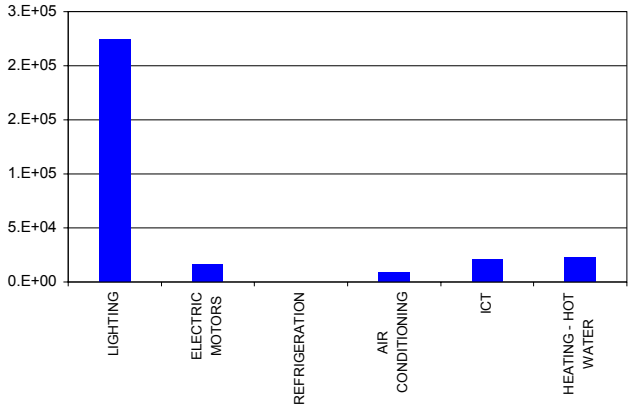
	E-DSM-RE Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	119 025
APPLIANCES	17 920
REFRIGERATION	47 452
HEATING	
TOTAL	*184 397*



	E-DSM-IN Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	
ELECTRIC MOTORS	59 610
REFRIGERATION	0
AIR CONDITIONING	1 962
COMPRESSED AIR	7 378
HEATING - HOT WATE	1 962
TOTAL	*70 912*



	E-DSM-TS Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	224 370
ELECTRIC MOTORS	16 345
REFRIGERATION	1
AIR CONDITIONING	8 686
ICT	20 431
HEATING - HOT WATE	22 740
TOTAL	*292 573*



Level of electricity costs where DSM measure is economical efficienct RESIDENTIAL SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-RE-MH-H-1		heating, ground insulation
E-DSM-N-RE-MH-H-2		heating, roof insulation
E-DSM-N-RE-MH-H-3		heating, wall insulation
E-DSM-N-RE-MH-H-4		heating, windows technologies
E-DSM-N-RE-MH-H-5		heating, control devices
E-DSM-N-RE-MH-H-6		heating, fuel sobstitution
E-DSM-N-RE-SH-H-1		heating, ground insulation
E-DSM-N-RE-SH-H-2		heating, roof insulation
E-DSM-N-RE-SH-H-3		heating, wall insulation
E-DSM-N-RE-SH-H-4		heating, windows technologies
E-DSM-N-RE-SH-H-5		heating, control devices
E-DSM-N-RE-SH-H-6		heating, fuel sobstitution
E-DSM-N-RE-MH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-SH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-MH-E-1	475.9	efficient washing machine
E-DSM-N-RE-MH-E-2	198.4	efficient dish washer
E-DSM-N-RE-MH-E-5	216.6	efficient TV
E-DSM-N-RE-SH-E-1	475.9	efficient washing machine
E-DSM-N-RE-SH-E-2	198.4	efficient dish washer
E-DSM-N-RE-SH-E-5	216.6	efficient TV
E-DSM-N-RE-MH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-MH-R-2	172.3	efficient freezer
E-DSM-N-RE-SH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-SH-R-2	172.3	efficient freezer

3.2.3.2 Romania

Source of data (where not differently specified): BSREC – Black Sea Regional Energy Centre. http://www.bsrec.bg

Reference contact: L. Radulov, radulov@bsrec.bg

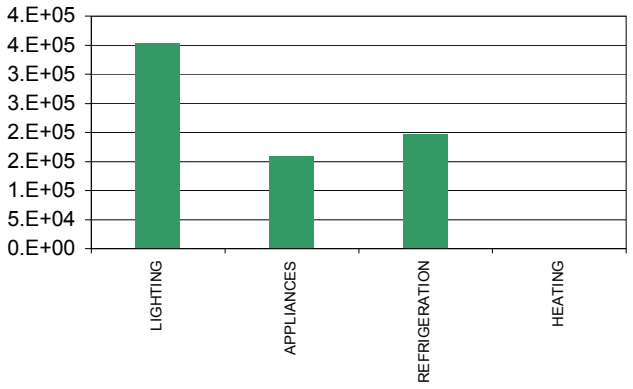
Data assumptions:

Reference stock of dwellings: only overall stock available (UNECE, 2003).

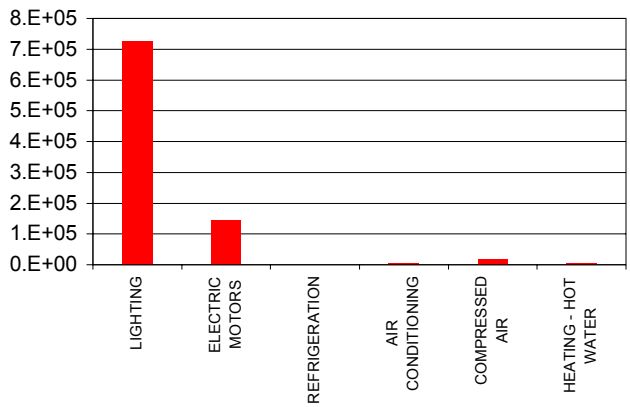
- Consumption of heating by fuel: from CEEC report about Bulgaria it is possible to argue that heating by electricity is not relevant in this country.
- Lighting units: the same overall amount as the total number of dwellings have been adopted.
- Appliances stock: in absence of any data, the average value of appliances per dwelling for EU15 countries have been determined for each appliance and applied to the overall stock of dwellings to eventually determine the appliances stocks

Results:

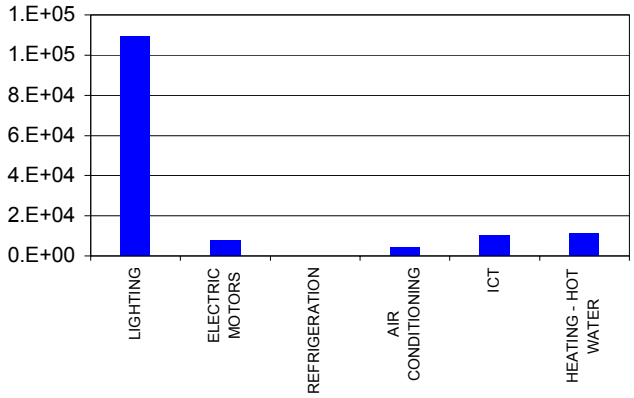
	E-DSM-RE Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	354 525
APPLIANCES	158 565
REFRIGERATION	196 017
HEATING	
TOTAL	*709 107*



	E-DSM-IN Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	725 395
ELECTRIC MOTORS	144 744
REFRIGERATION	1
AIR CONDITIONING	4 765
COMPRESSED AIR	17 914
HEATING - HOT WATE	4 765
TOTAL	*897 584*



	E-DSM-TS Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	109 116
ELECTRIC MOTORS	7 949
REFRIGERATION	1
AIR CONDITIONING	4 224
ICT	9 936
HEATING - HOT WATE	11 059
TOTAL	*142 285*



Level of electricity costs where DSM measure is economical efficienct RESIDENTIAL SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-RE-MH-H-1		heating, ground insulation
E-DSM-N-RE-MH-H-2		heating, roof insulation
E-DSM-N-RE-MH-H-3		heating, wall insulation
E-DSM-N-RE-MH-H-4		heating, windows technologies
E-DSM-N-RE-MH-H-5		heating, control devices
E-DSM-N-RE-MH-H-6		heating, fuel sobstitution
E-DSM-N-RE-SH-H-1		heating, ground insulation
E-DSM-N-RE-SH-H-2		heating, roof insulation
E-DSM-N-RE-SH-H-3		heating, wall insulation
E-DSM-N-RE-SH-H-4		heating, windows technologies
E-DSM-N-RE-SH-H-5		heating, control devices
E-DSM-N-RE-SH-H-6		heating, fuel sobstitution
E-DSM-N-RE-MH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-SH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-MH-E-1	475.9	efficient washing machine
E-DSM-N-RE-MH-E-2	198.4	efficient dish washer
E-DSM-N-RE-MH-E-5	0.0	efficient TV
E-DSM-N-RE-SH-E-1	475.9	efficient washing machine
E-DSM-N-RE-SH-E-2	198.4	efficient dish washer
E-DSM-N-RE-SH-E-5	216.6	efficient TV
E-DSM-N-RE-MH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-MH-R-2	172.3	efficient freezer
E-DSM-N-RE-SH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-SH-R-2	172.3	efficient freezer

3.2.3.3 Croatia

Source of data (where not differently specified): Energy Institute Hrvoje Pozar, Zagreb, Croatia. www.eihp.hr

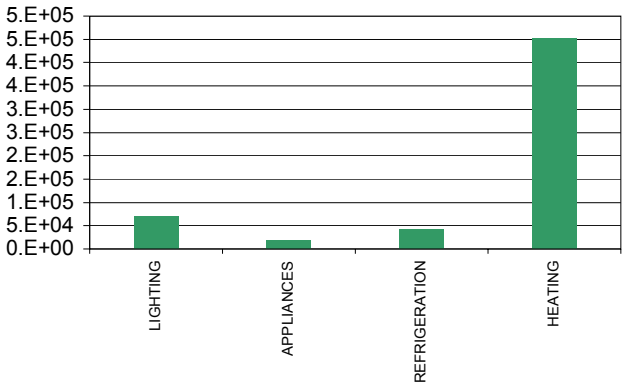
Reference contact: Helena Bozic, hbozic@eihp.hr

Data assumptions:

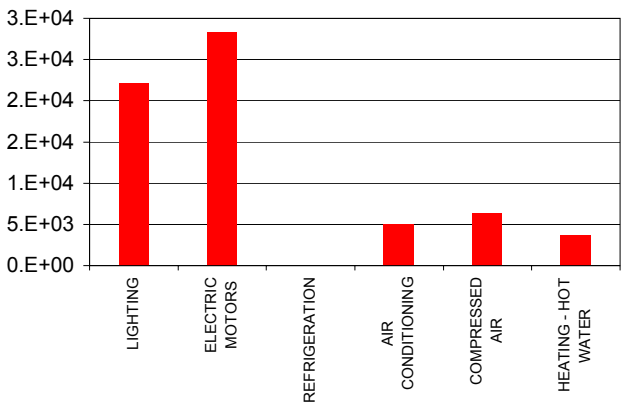
- Residential consumption for heating by fuel: the year of reference is 2003. Consumption have been split into different fuel types according to distribution of dwelling stock between different fuels.
- Dwelling stock yearly growth rates: the contact only gave us rate related to the past, future ones have been assumed equal to the latest.
- Lighting units: the same overall amount as the total number of dwellings have been adopted..
- Consumption of efficient technology (% of alternative): data provided by Energy Institute Hrvoje.

Results:

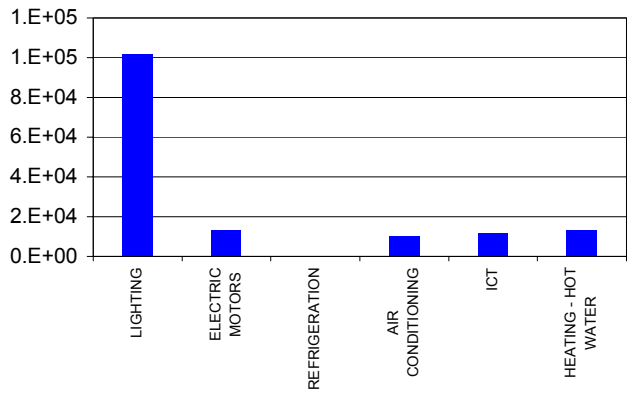
	E-DSM-RE Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	71 499
APPLIANCES	19 951
REFRIGERATION	41 840
HEATING	451 755
TOTAL	*585 046*



	E-DSM-IN Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	22 174
ELECTRIC MOTORS	28 252
REFRIGERATION	0
AIR CONDITIONING	5 069
COMPRESSED AIR	6 389
HEATING - HOT WATE	3 671
TOTAL	*65 554*



	E-DSM-TS Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	101 829
ELECTRIC MOTORS	12 960
REFRIGERATION	1
AIR CONDITIONING	10 220
ICT	12 020
HEATING - HOT WATE	13 379
TOTAL	*150 408*



Level of electricity costs where DSM measure is economical efficienct RESIDENTIAL SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-RE-MH-H-1	50.7	heating, ground insulation
E-DSM-N-RE-MH-H-2	18.9	heating, roof insulation
E-DSM-N-RE-MH-H-3	27.1	heating, wall insulation
E-DSM-N-RE-MH-H-4	45.5	heating, windows technologies
E-DSM-N-RE-MH-H-5	33.2	heating, control devices
E-DSM-N-RE-MH-H-6	56.5	heating, fuel sobstitution
E-DSM-N-RE-SH-H-1	248.9	heating, ground insulation
E-DSM-N-RE-SH-H-2	58.2	heating, roof insulation
E-DSM-N-RE-SH-H-3	90.5	heating, wall insulation
E-DSM-N-RE-SH-H-4	130.9	heating, windows technologies
E-DSM-N-RE-SH-H-5	58.9	heating, control devices
E-DSM-N-RE-SH-H-6	82.3	heating, fuel sobstitution
E-DSM-N-RE-MH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-SH-L-1	30.9	lighting, efficient bulbs
E-DSM-N-RE-MH-E-1	475.9	efficient washing machine
E-DSM-N-RE-MH-E-2	198.4	efficient dish washer
E-DSM-N-RE-MH-E-5	0.0	efficient TV
E-DSM-N-RE-SH-E-1	475.9	efficient washing machine
E-DSM-N-RE-SH-E-2	198.4	efficient dish washer
E-DSM-N-RE-SH-E-5	216.6	efficient TV
E-DSM-N-RE-MH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-MH-R-2	172.3	efficient freezer
E-DSM-N-RE-SH-R-1	282.8	efficient refrigerator
E-DSM-N-RE-SH-R-2	172.3	efficient freezer

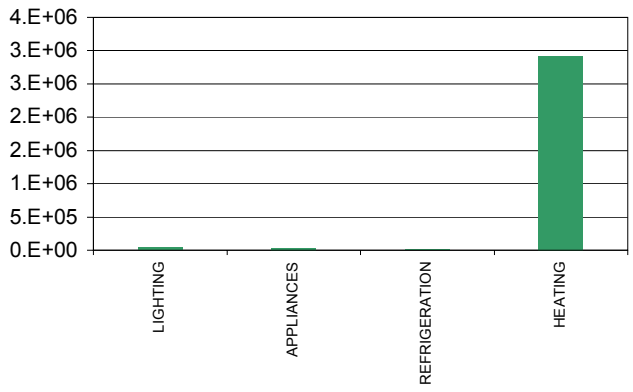
3.2.4 Other Countries

3.2.4.1 Norway

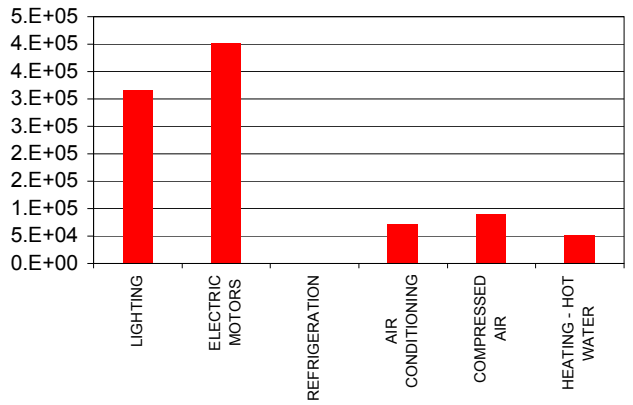
Data assumptions: the same methodology bases on MURE database and simulations as EU-15 study have been used. When MURE database was missing some data, average values resulting from other countries' simulations have been used.

Results:

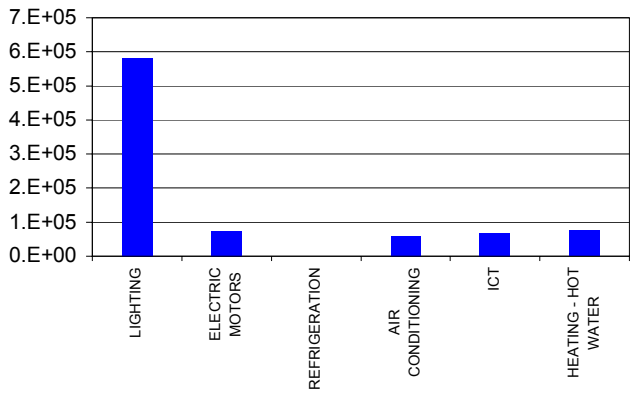
	E-DSM-RE Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	40 346
APPLIANCES	28 424
REFRIGERATION	14 267
HEATING	2 924 104
TOTAL	*3 007 141*



	E-DSM-IN Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	315 242
ELECTRIC MOTORS	401 645
REFRIGERATION	2
AIR CONDITIONING	72 066
COMPRESSED AIR	90 827
HEATING - HOT WATE	52 186
TOTAL	*931 968*



	E-DSM-TS Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	581 862
ELECTRIC MOTORS	74 058
REFRIGERATION	4
AIR CONDITIONING	58 397
ICT	68 683
HEATING - HOT WATE	76 447
TOTAL	*859 449*

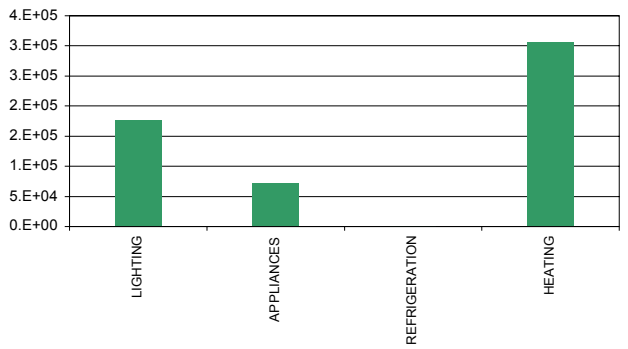


Level of electricity costs where DSM measure is economical efficienct RESIDENTIAL SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-RE-MH-H-1	35.9	heating, ground insulation
E-DSM-N-RE-MH-H-2	19.3	heating, roof insulation
E-DSM-N-RE-MH-H-3	26.5	heating, wall insulation
E-DSM-N-RE-MH-H-4	35.4	heating, windows technologies
E-DSM-N-RE-MH-H-5	25.5	heating, control devices
E-DSM-N-RE-MH-H-6		heating, fuel sobstitution
E-DSM-N-RE-SH-H-1	62.2	heating, ground insulation
E-DSM-N-RE-SH-H-2	30.4	heating, roof insulation
E-DSM-N-RE-SH-H-3	33.9	heating, wall insulation
E-DSM-N-RE-SH-H-4	45.0	heating, windows technologies
E-DSM-N-RE-SH-H-5	20.4	heating, control devices
E-DSM-N-RE-SH-H-6		heating, fuel sobstitution
E-DSM-N-RE-MH-L-1	29.0	lighting, efficient bulbs
E-DSM-N-RE-SH-L-1	29.0	lighting, efficient bulbs
E-DSM-N-RE-MH-E-1	244.6	efficient washing machine
E-DSM-N-RE-MH-E-2	178.6	efficient dish washer
E-DSM-N-RE-MH-E-5		efficient TV
E-DSM-N-RE-SH-E-1	244.6	efficient washing machine
E-DSM-N-RE-SH-E-2	178.6	efficient dish washer
E-DSM-N-RE-SH-E-5	86.6	efficient TV
E-DSM-N-RE-MH-R-1	229.9	efficient refrigerator
E-DSM-N-RE-MH-R-2	238.4	efficient freezer
E-DSM-N-RE-SH-R-1	229.9	efficient refrigerator
E-DSM-N-RE-SH-R-2	238.4	efficient freezer

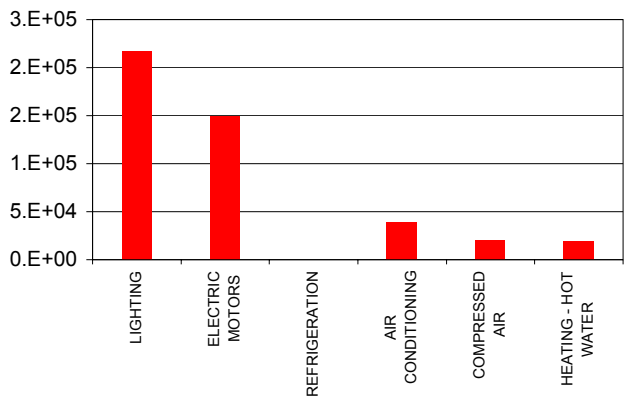
3.2.4.2 Switzerland

Data were already collected during the GreenNet project.

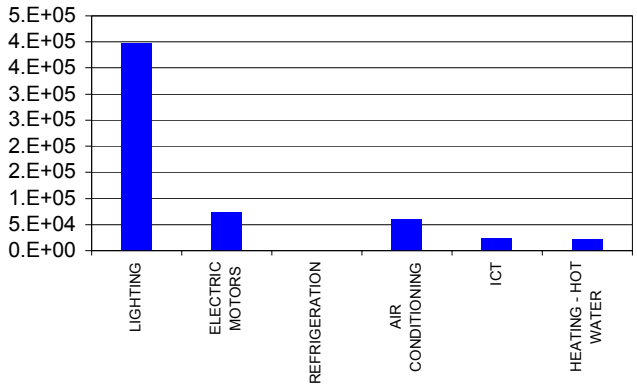
	E-DSM-RE Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	176 883
APPLIANCES	72 657
REFRIGERATION	1 159
HEATING	306 760
TOTAL	*557 459*



	E-DSM-IN Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	217 804
ELECTRIC MOTORS	149 609
REFRIGERATION	3
AIR CONDITIONING	38 786
COMPRESSED AIR	20 050
HEATING - HOT WATE	19 393
TOTAL	*445 644*



	E-DSM-TS Maximum yearly realisable penetration of energy saving compared to BAU *[MWh/year]*
LIGHTING	397 999
ELECTRIC MOTORS	73 179
REFRIGERATION	3
AIR CONDITIONING	59 628
ICT	23 773
HEATING - HOT WATE	21 117
TOTAL	*575 699*

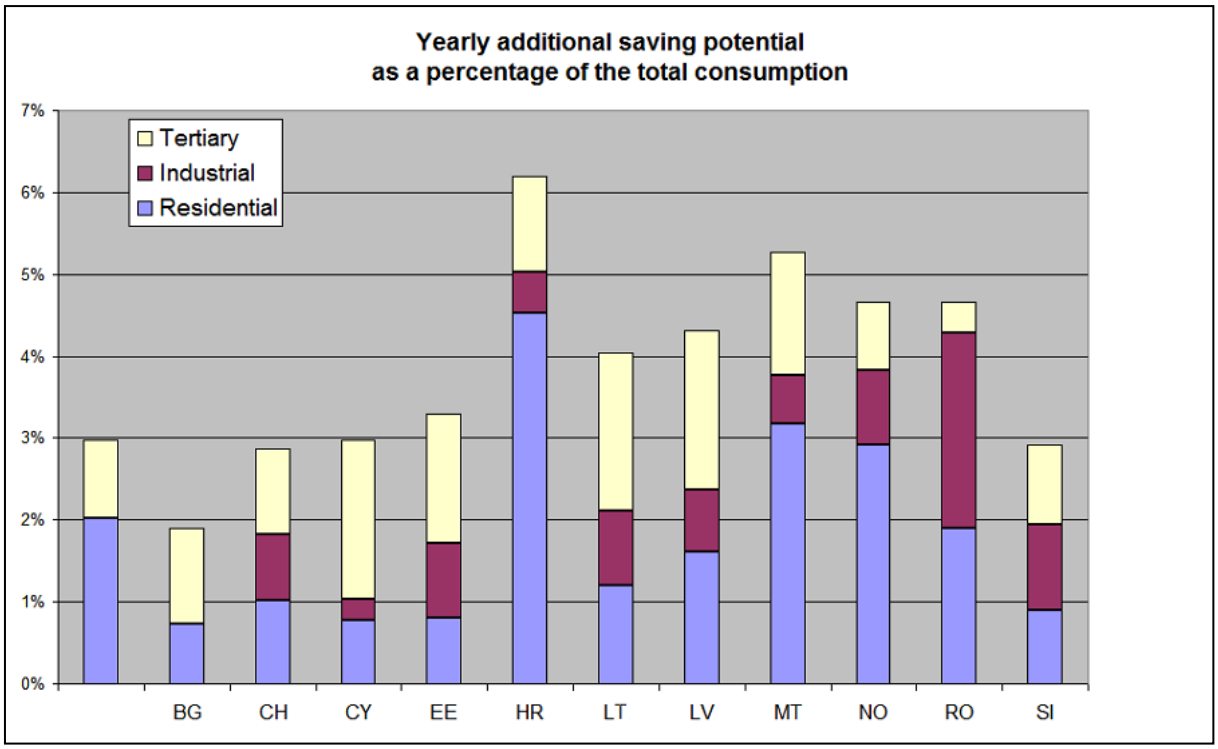


Level of electricity costs where DSM measure is economical efficienct RESIDENTIAL SECTOR		
Band Name	[€/MWh]	Description
E-DSM-N-RE-MH-H-1	83.1	heating, ground insulation
E-DSM-N-RE-MH-H-2	42.3	heating, roof insulation
E-DSM-N-RE-MH-H-3	90.7	heating, wall insulation
E-DSM-N-RE-MH-H-4	71.7	heating, windows technologies
E-DSM-N-RE-MH-H-5	46.8	heating, control devices
E-DSM-N-RE-MH-H-6	83.7	heating, fuel sobstitution
E-DSM-N-RE-SH-H-1	94.1	heating, ground insulation
E-DSM-N-RE-SH-H-2	47.9	heating, roof insulation
E-DSM-N-RE-SH-H-3	102.5	heating, wall insulation
E-DSM-N-RE-SH-H-4	80.9	heating, windows technologies
E-DSM-N-RE-SH-H-5	31.0	heating, control devices
E-DSM-N-RE-SH-H-6	68.0	heating, fuel sobstitution
E-DSM-N-RE-MH-L-1	17.1	lighting, efficient bulbs
E-DSM-N-RE-SH-L-1	17.1	lighting, efficient bulbs
E-DSM-N-RE-MH-E-1	245.5	efficient washing machine
E-DSM-N-RE-MH-E-2		efficient dish washer
E-DSM-N-RE-MH-E-5	0.0	efficient TV
E-DSM-N-RE-SH-E-1	245.5	efficient washing machine
E-DSM-N-RE-SH-E-2		efficient dish washer
E-DSM-N-RE-SH-E-5	128.7	efficient TV
E-DSM-N-RE-MH-R-1	851.4	efficient refrigerator
E-DSM-N-RE-MH-R-2		efficient freezer
E-DSM-N-RE-SH-R-1	851.4	efficient refrigerator
E-DSM-N-RE-SH-R-2		efficient freezer

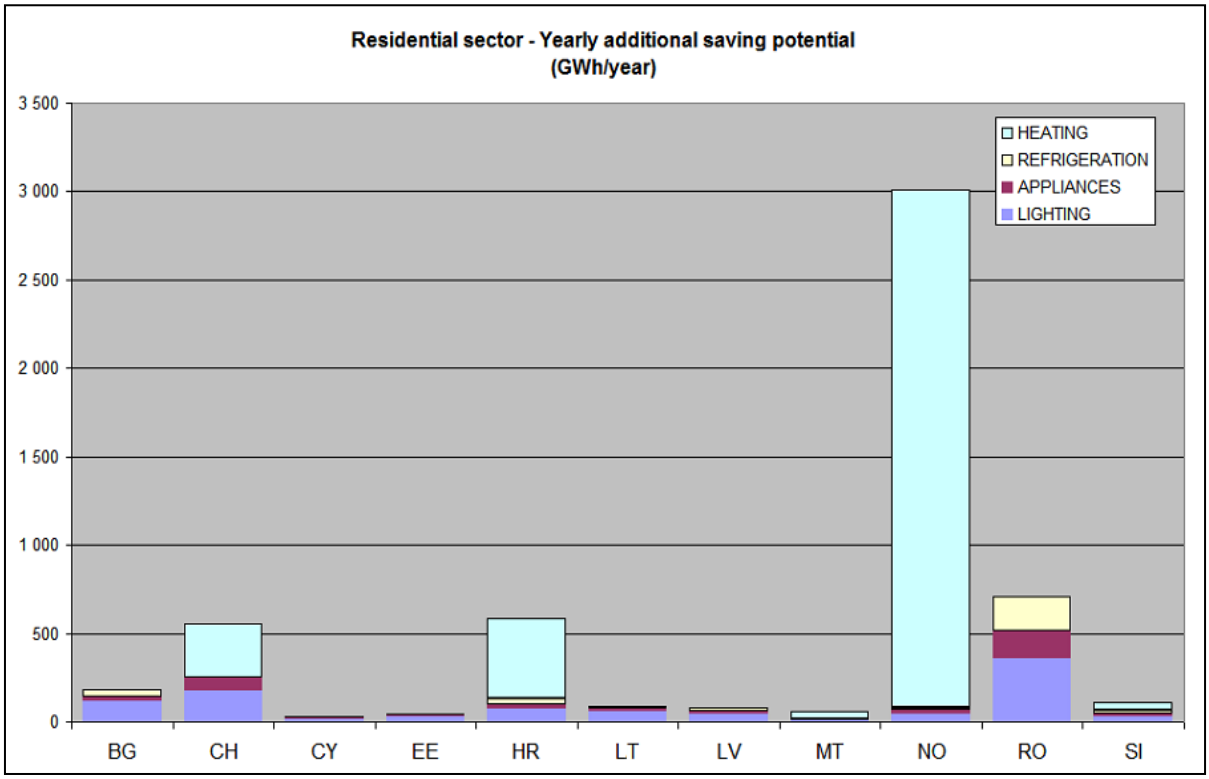
3.2.5 Overview of resulting Potentials and Costs for EE in EU-25+ countries

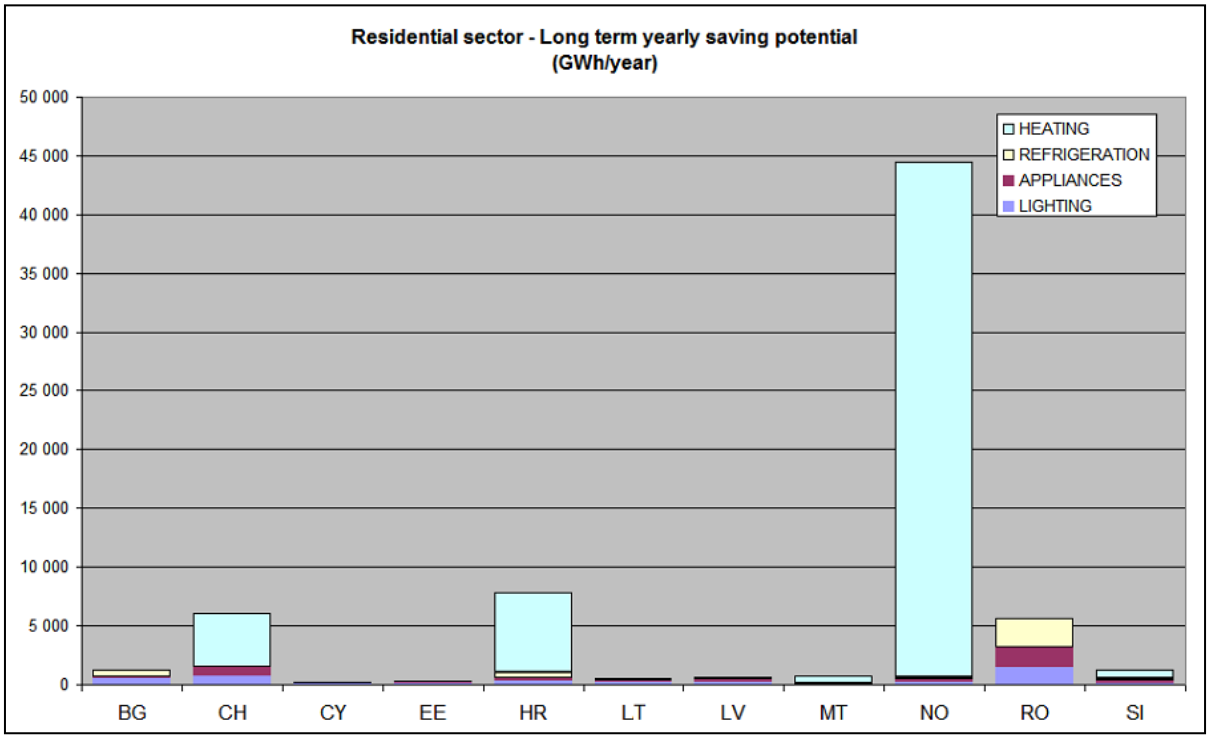
3.2.5.1 Potentials

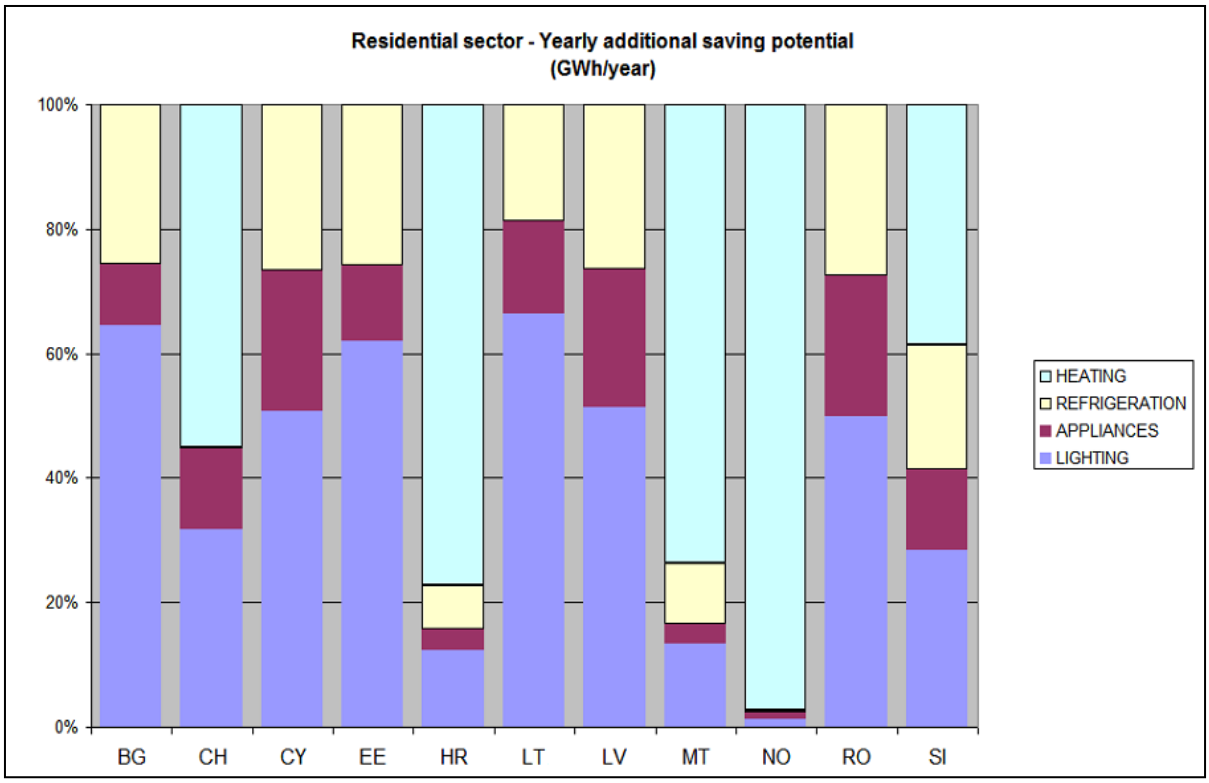
The following figures represent an overview of resulting potentials and costs, as a comparison among EU25+ countries' absolute and relative potentials and their distributions among sectors of intervention and in each sector.

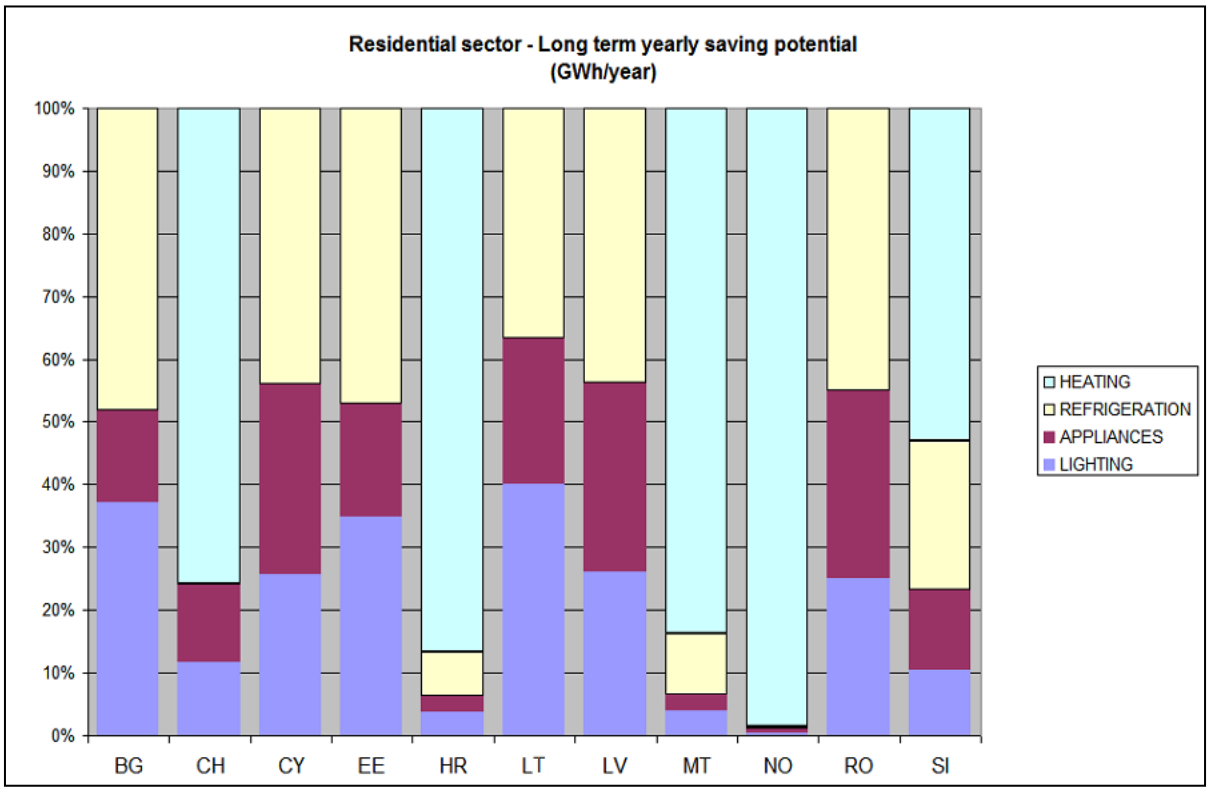


Residential Sector

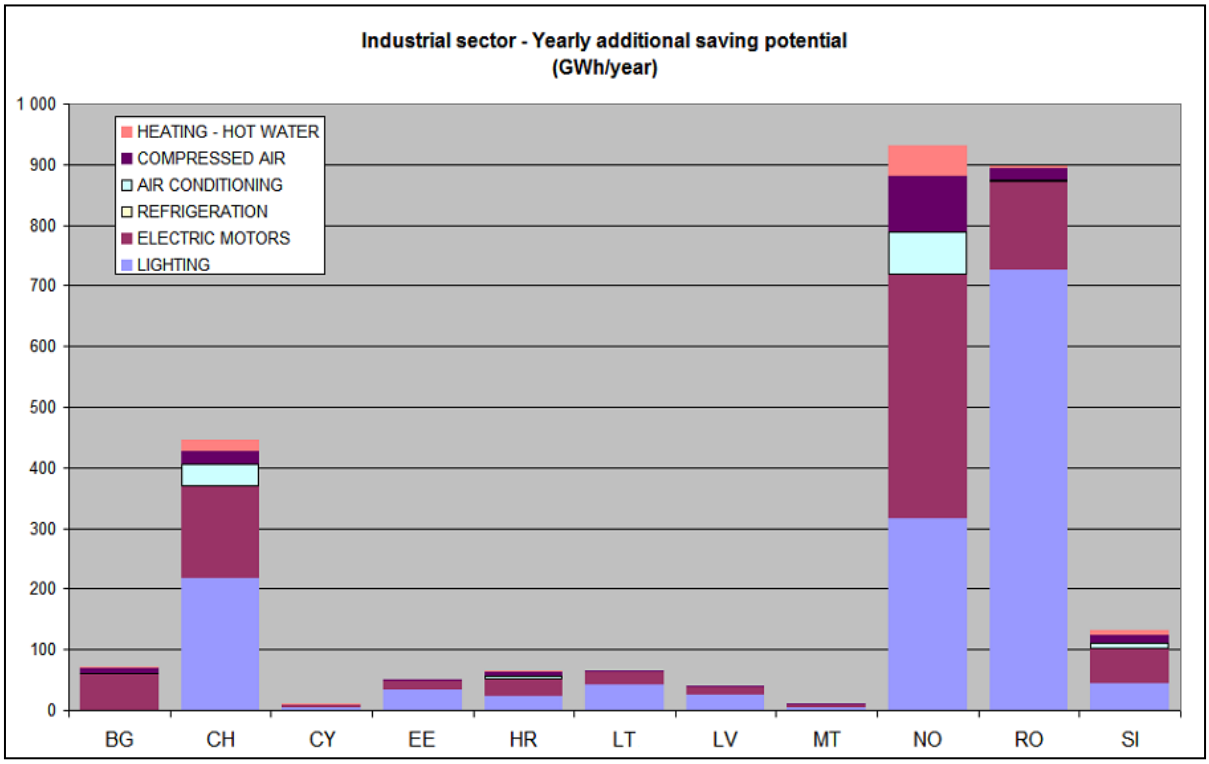


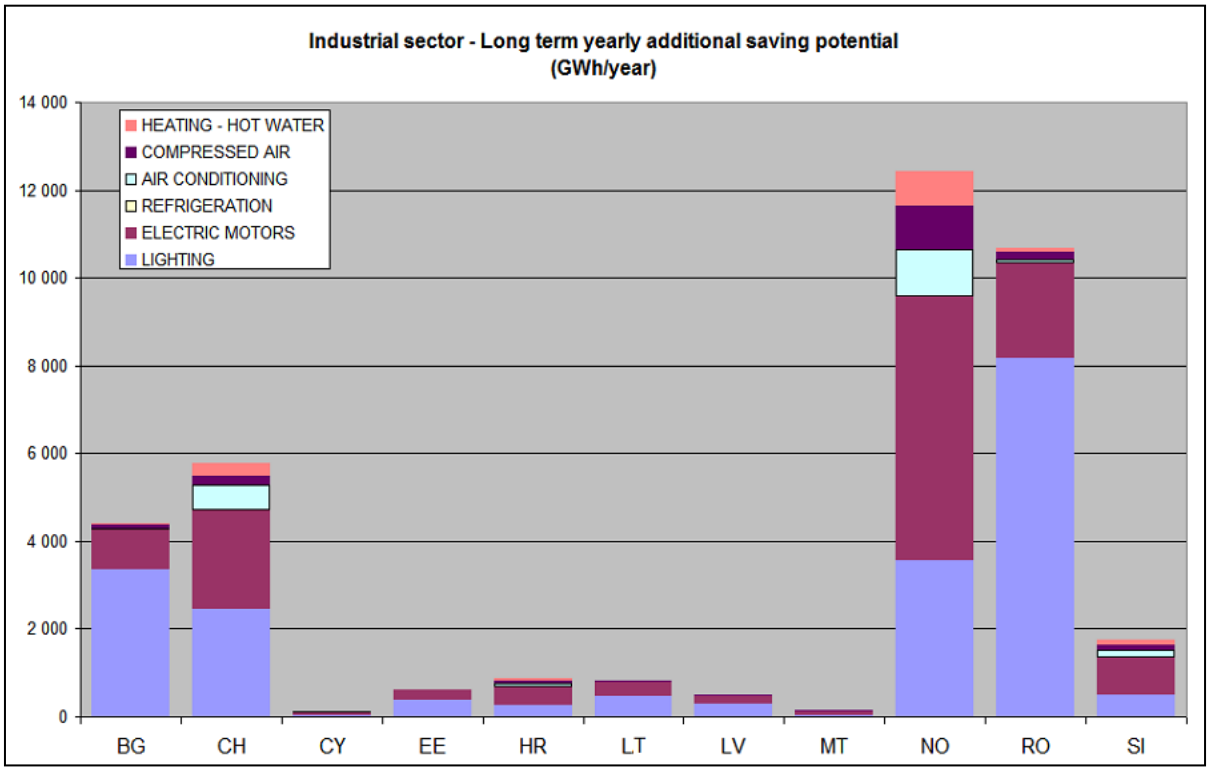


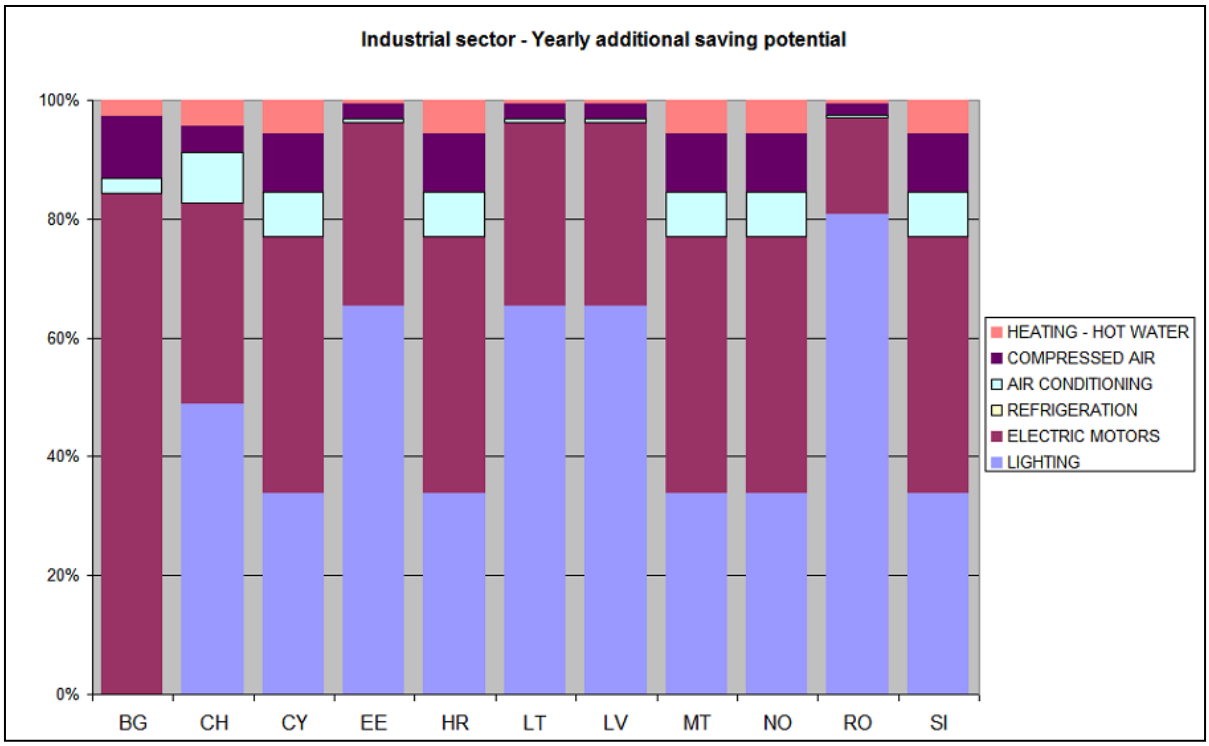

Residential sector - Yearly additional saving potential
(GWh/year)
100%
80%
60%
40%
20%
0%
BG
CH
CY
EE
HR
LT
LV
MT
NO
RO
SI
HEATING
REFRIGERATION
APPLIANCES
LIGHTING

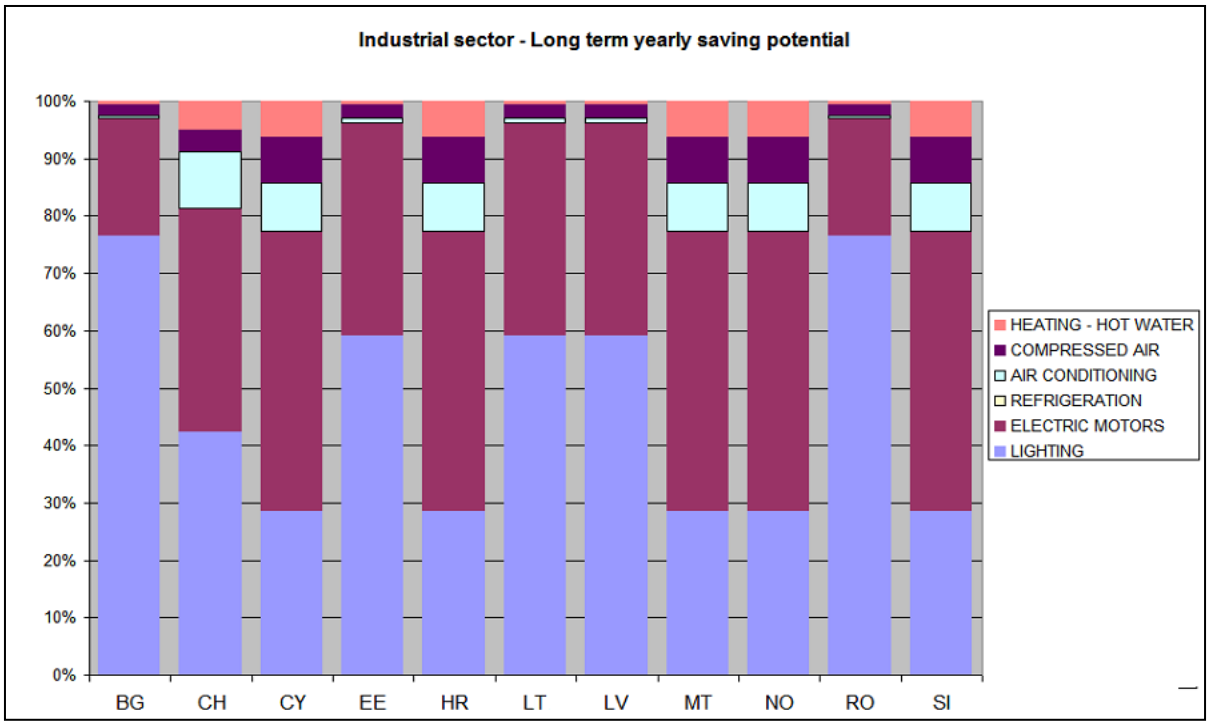

Residential sector - Long term yearly saving potential
(GWh/year)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
BG
CH
CY
EE
HR
LT
LV
MT
NO
RO
SI
HEATING
REFRIGERATION
APPLIANCES
LIGHTING

Industrial Sector

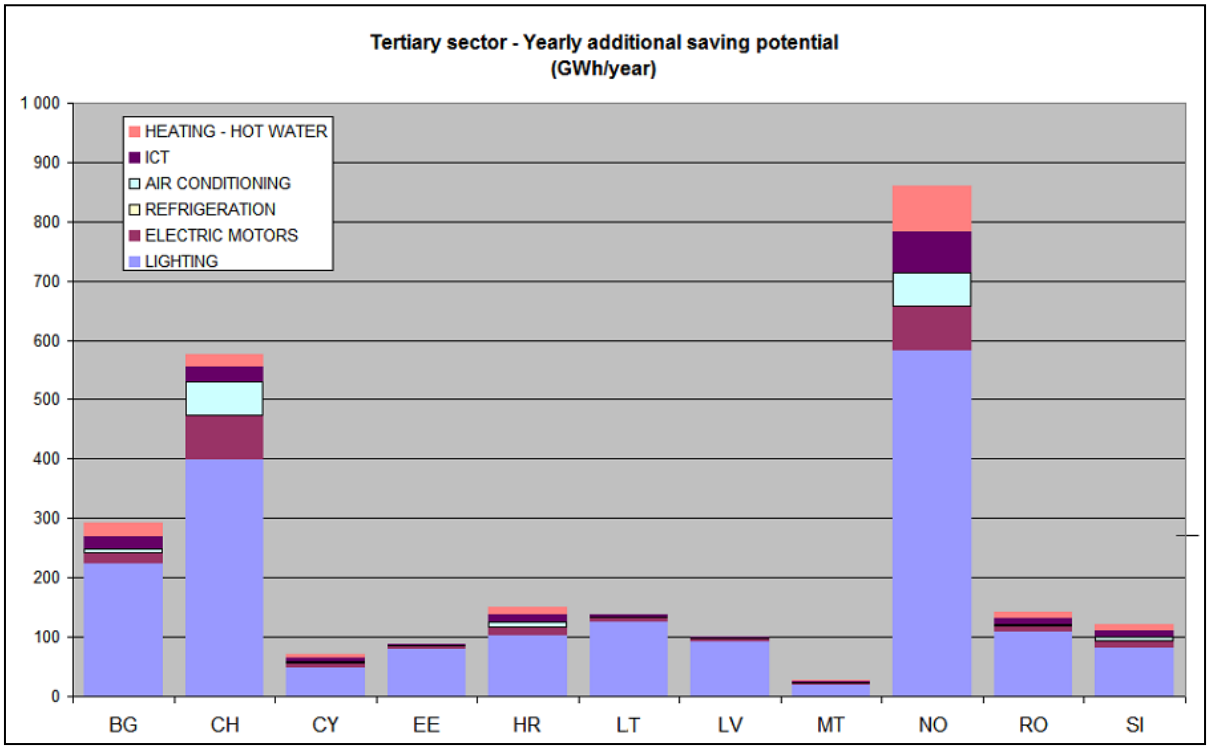


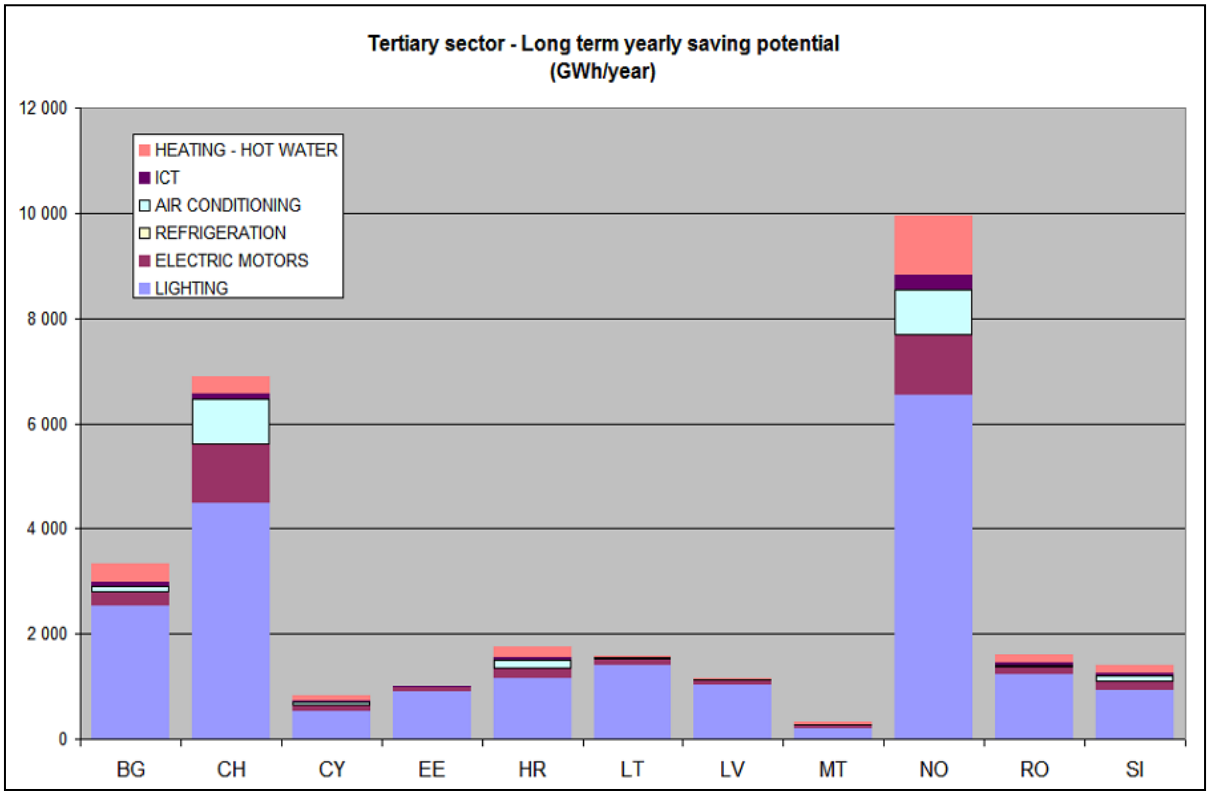


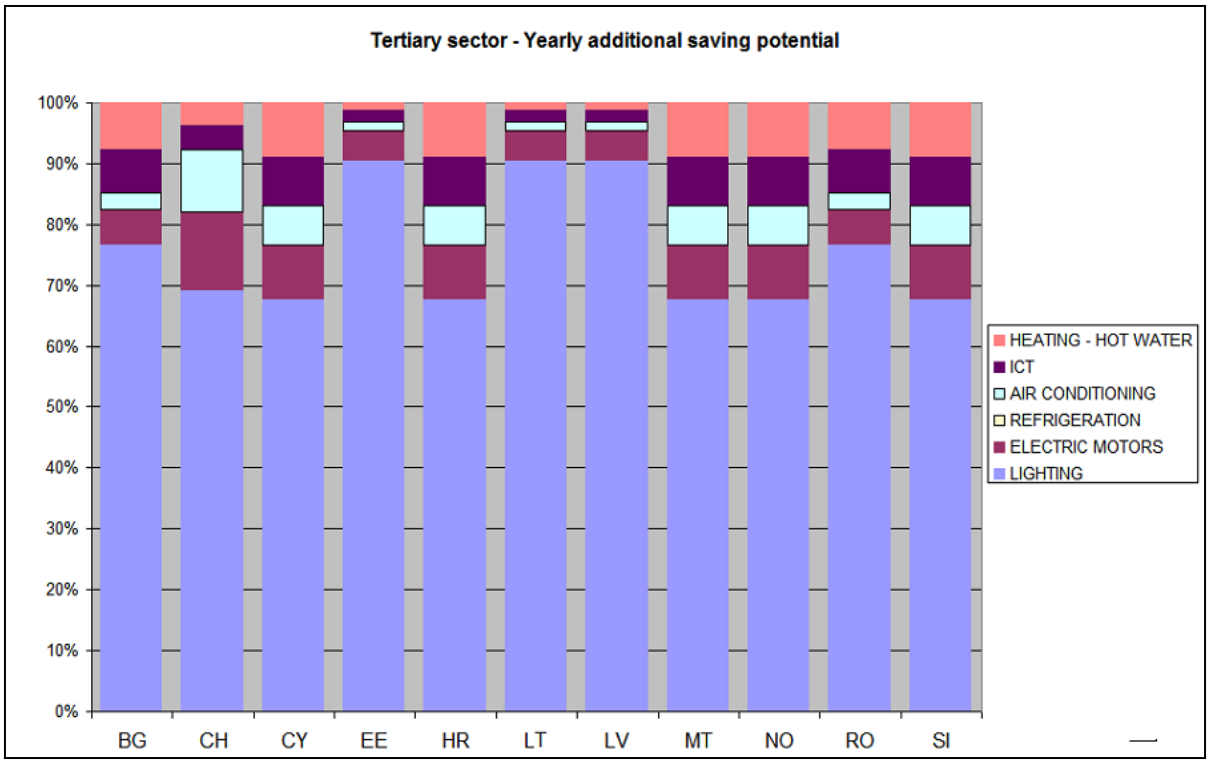

Industrial sector - Yearly additional saving potential
100%
80%
60%
40%
20%
0%
BG
CH
CY
EE
HR
LT
LV
MT
NO
RO
SI
HEATING - HOT WATER
COMPRESSED AIR
AIR CONDITIONING
REFRIGERATION
ELECTRIC MOTORS
LIGHTING

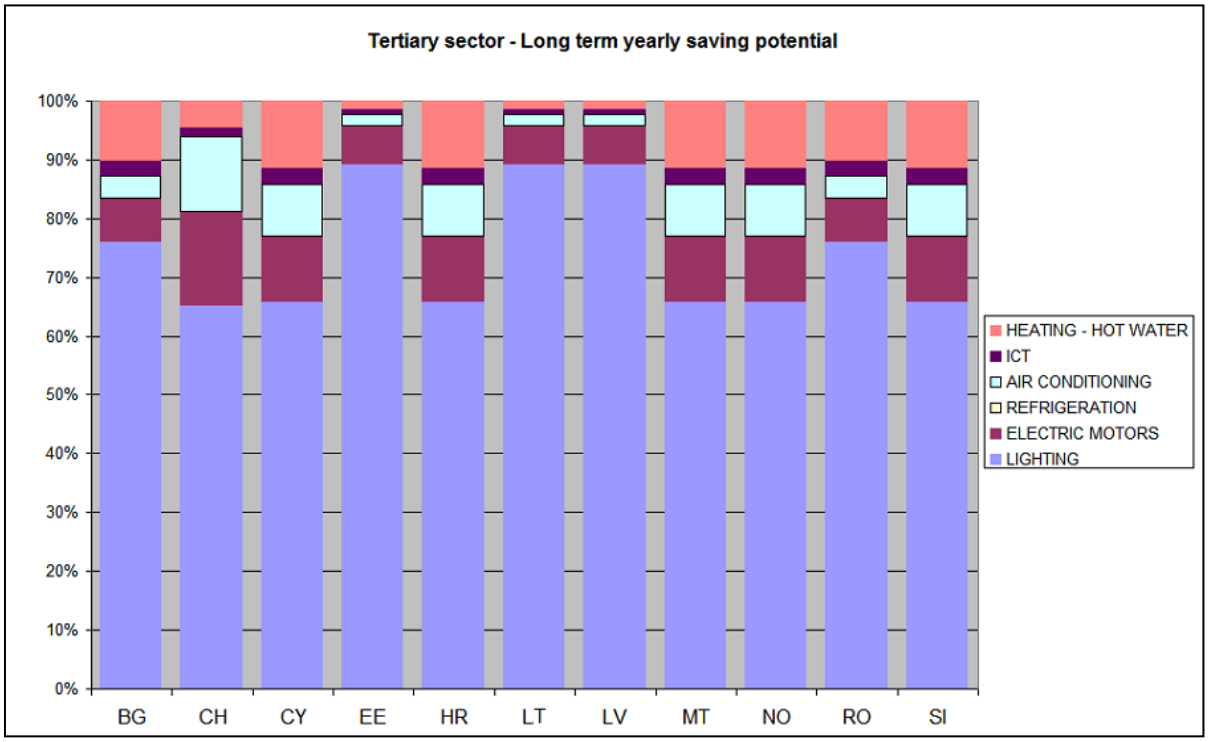

Industrial sector - Long term yearly saving potential
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
BG
CH
CY
EE
HR
LT
LV
MT
NO
RO
SI
HEATING - HOT WATER
COMPRESSED AIR
AIR CONDITIONING
REFRIGERATION
ELECTRIC MOTORS
LIGHTING

Tertiary Sector



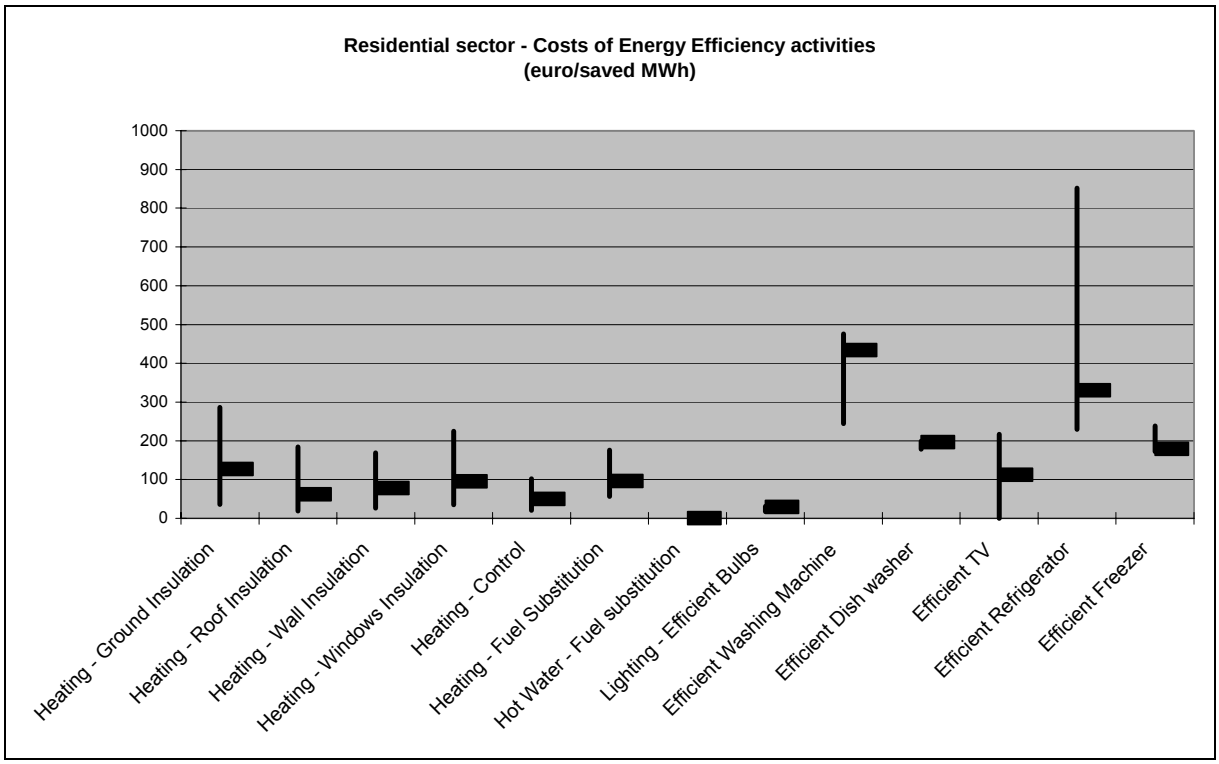


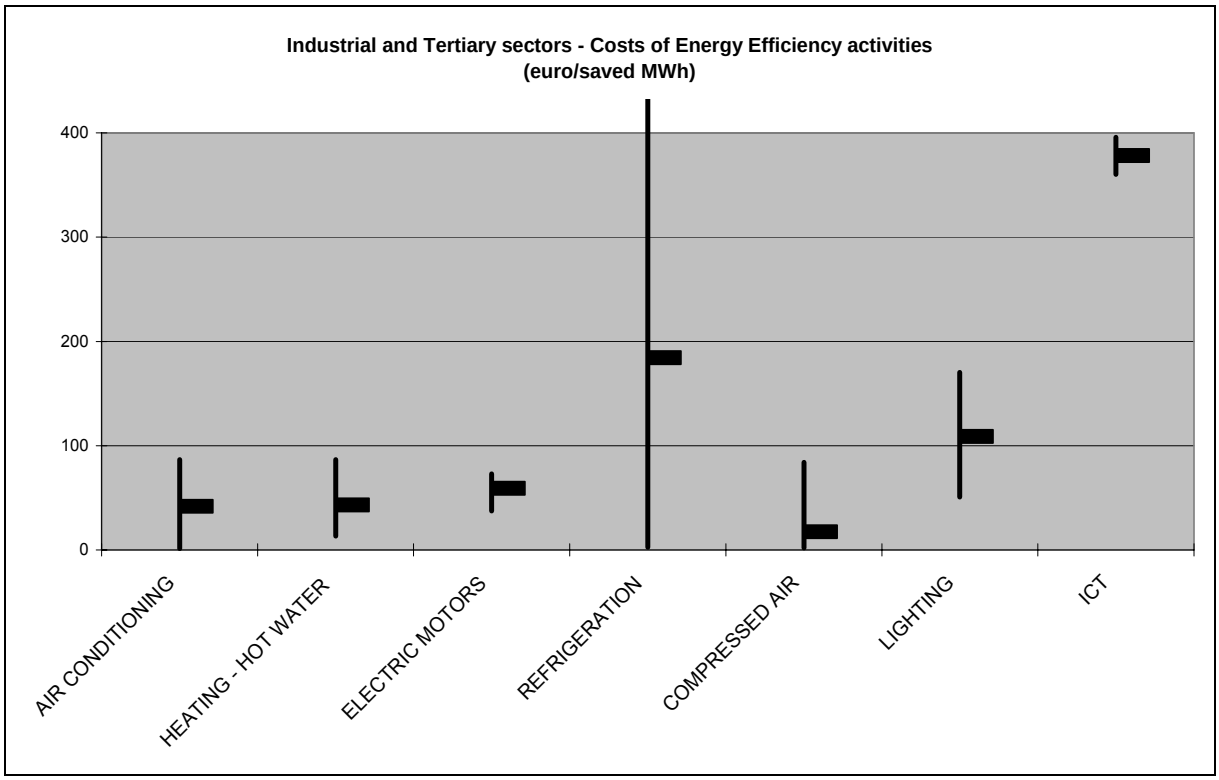

Tertiary sector - Yearly additional saving potential
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
BG
CH
CY
EE
HR
LT
LV
MT
NO
RO
SI
HEATING - HOT WATER
ICT
AIR CONDITIONING
REFRIGERATION
ELECTRIC MOTORS
LIGHTING


Tertiary sector - Long term yearly saving potential
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
BG
CH
CY
EE
HR
LT
LV
MT
NO
RO
SI
HEATING - HOT WATER
ICT
AIR CONDITIONING
REFRIGERATION
ELECTRIC MOTORS
LIGHTING

3.2.5.2 Costs

The following figures show an overview of minimum, maximum and average values of costs in each sector of intervention.





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