Assessment and improvement of methodologies used for Greenhouse Gas projections

Annex C of the final report to DG Environment under service contract no. ENV.C.2/SER/2006/0008

Additional information guidelines residential sector

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Authors

Jan Duerinck (VITO)
Nele Renders (VITO)
Karla Schoeters (VITO)

Vlaamse Instelling voor Technologisch Onderzoek
Boeretang 200
2400 Mol
Belgium

Öko-Institut e.V.
Berlin Office
Novalisstr. 10
10115 Berlin
Germany

Institute for European Environmental Policy
Quai au Foin 55
1000 Brussels
Belgium

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1 Annex C-1: Correction for heating degree days

1.1 Statistical relationship between HDD and residential energy use

Econometrically, we can observe a log-linear relationship between the residential fuel use for space heating & sanitary hot water (SHW) and the heating degree days. This relationship is explained in Annex C-3.

The resulting, statistical significant elasticity for different MS have been listed in Table 1. These values express the % average increase/decrease of the residential energy consumption for an increase/decrease of 1% for the number of degree days.

We have to remark that these numbers are based on fuel statistics for heating and SHW, so electricity consumption for heating is not considered.

Table 1 Residential energy use for heating and SHW: heating degree days elasticity for selected EU MS

Member State	**HDD elasticity**
At	0.84
Be	0.73
Cz	0.73
De	0.52
Dk	0.62
Es	0.23
Fi	0.58
Fr	0.52
Gr	0.21
Hu	0.34
Ie	0.33
It	0.59
Lt	0.27
Lu	0.41
Lv	0.82
Nl	0.72
Uk	0.73
Average value	**0.55**

These figures are all smaller than 1%, which implies that changes of the outside temperature are not completely translated into a higher/smaller energy use.

It should be emphasized that the above numbers are based on fuel statistics for heating and SHW, so electricity consumption for heating isn’t considered.

1.2 Temperature corrections of historical figures

Fluctuation of degree days is the most significant parameter explaining short term fluctuations of residential energy consumption for heating. In order to determine (changes in) trends in historical energy consumptions (other than temperature), it is recommended to calibrate the historical figures to normal temperature calibrated historical energy uses, by means of the following formula:

$$Xcal_t = Xhist_t * CF_t \text{ with: } CF_t = [\ HDD_n / HDD_t\ ]^{\tau}$$

With: τ = HDD elasticity value, taken from Table 1 or a default value;
$Xcal_t$ = normal temperature calibrated historical energy use for heating and SHW in year t;
$Xhist_t$ = historical observation of heating and SHW in year t;
CF_t = correction factor year t;
HDD_t = observed degree days in year t;
HDD_n = long term average degree days (e.g. average of 1990-2005).

1.3 Errors in historical figures of fuel consumption

Historical figures of fuel consumption are mostly based on purchase number. These purchases of fuel do not completely reflect the real consumption of fuels in one year, because (voluntary and involuntary) yearly stock movements should be considered too. In general, the following equation holds true on a yearly basis:

consumption = purchases - changes in stocks hold by households

An increase in stocks is likely to be followed by a decrease in stocks in the following year. Therefore, it might be useful to plot a three yearly moving average of the historical energy consumption (corrected for HDD):

$$Xcal_{t,av} = \text{average } (Xcal_{t-1}, X\ cal_t, X\ cal_{t+1})$$

1.4 Heating Degree Days assumptions in GHG projections

GHG projections are explicitly or implicitly based on expectations of degree days. Preferably, the energy projections for heating and SHW depart from an average value over a longer period, for instance the average value of 1990-2005.

1.5 Summary

How to handle heating degree days in the projections of the residential energy consumption for space heating and SHW?

- First of all, the historical energy consumptions for heating & SHW must be corrected for HDD. Therefore, the historical observations can be calibrated to normal temperature calibrated historical observations by means of HDD elasticity.

- Secondly, a three yearly moving average of the calibrated historical consumptions is recommended to correct for the discrepancy between fuel stocks and fuel consumption.
- As a result, a time series of calibrated historical fuel consumption will be obtained which can be used for the projections.

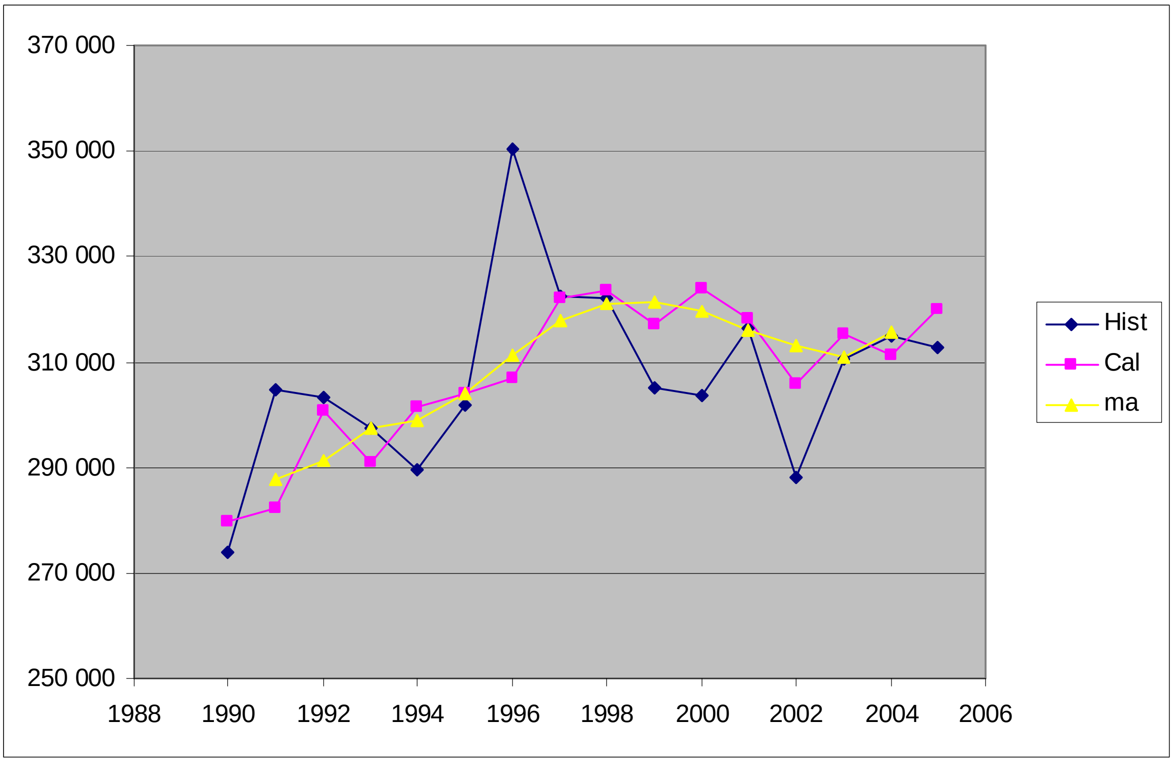
Concerning the projections, these are preferably based on the average HDD over a longer period (e.g. 1990-2005).

1.6 Examples

The following examples demonstrate the relative importance of the corrections mentioned above. The graphs depict the residential fuel use for heating and SHW[1] between 1990 and 2005 for a number of countries. The blue line 'Hist' represents the original observations, the pink link 'Cal' describes the normal temperature calibrated consumptions and the yellow line 'ma' is the three yearly moving average of 'Cal'.

In the case of France (Figure 5), historical figure for 2005 is 4% higher compared to the value for 2000. However, the temperature calibrated figures show a 1.5% decrease in the same period.

Figure 1 Belgium, historical residential fuel use 'Hist' 1990-2005 (TJ), temperature calibrated data 'Cal' (TJ) and three yearly moving average 'ma' (TJ)



[1] This concerns fuel use, so electric heating isn't considered.

Figure 2 Latvia, historical residential fuel use 'Hist' 1990-2005 (TJ), temperature calibrated data 'Cal' (TJ) and three yearly moving average 'ma' (TJ)

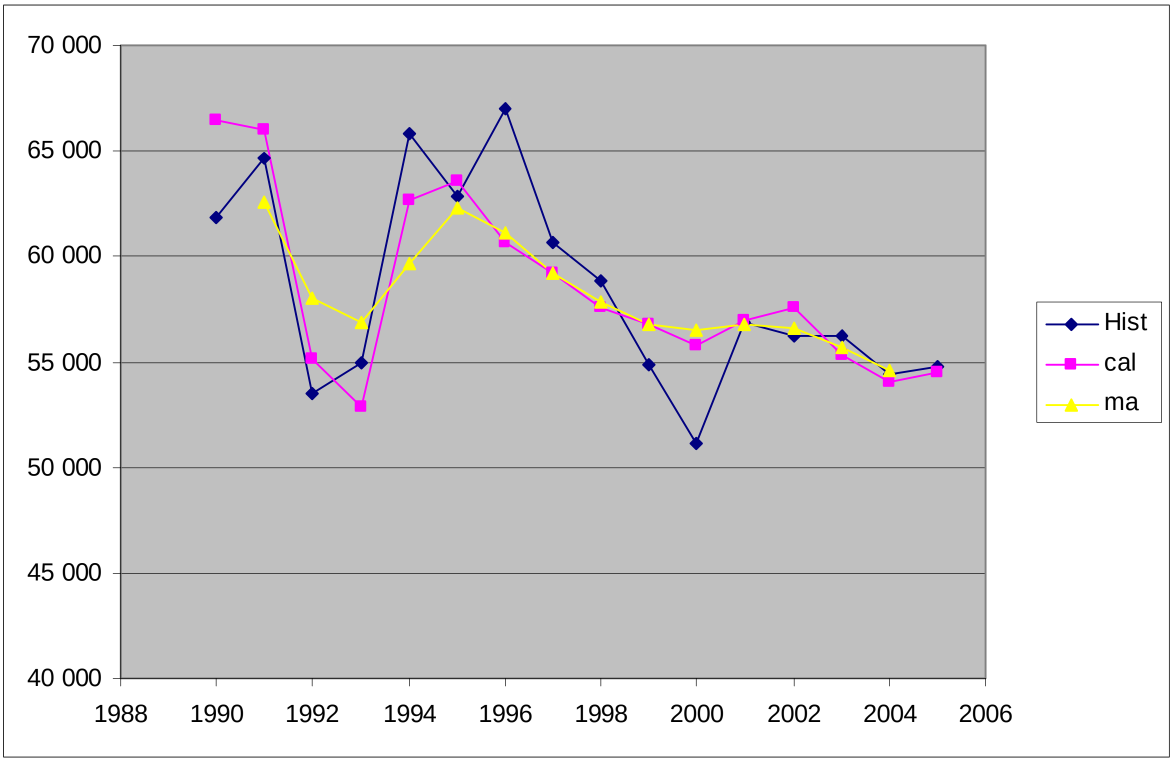


Figure 3 Poland, historical residential fuel use 'Hist' 1990-2005 (TJ), temperature calibrated data 'Cal' (TJ) and three yearly moving average 'ma' (TJ)

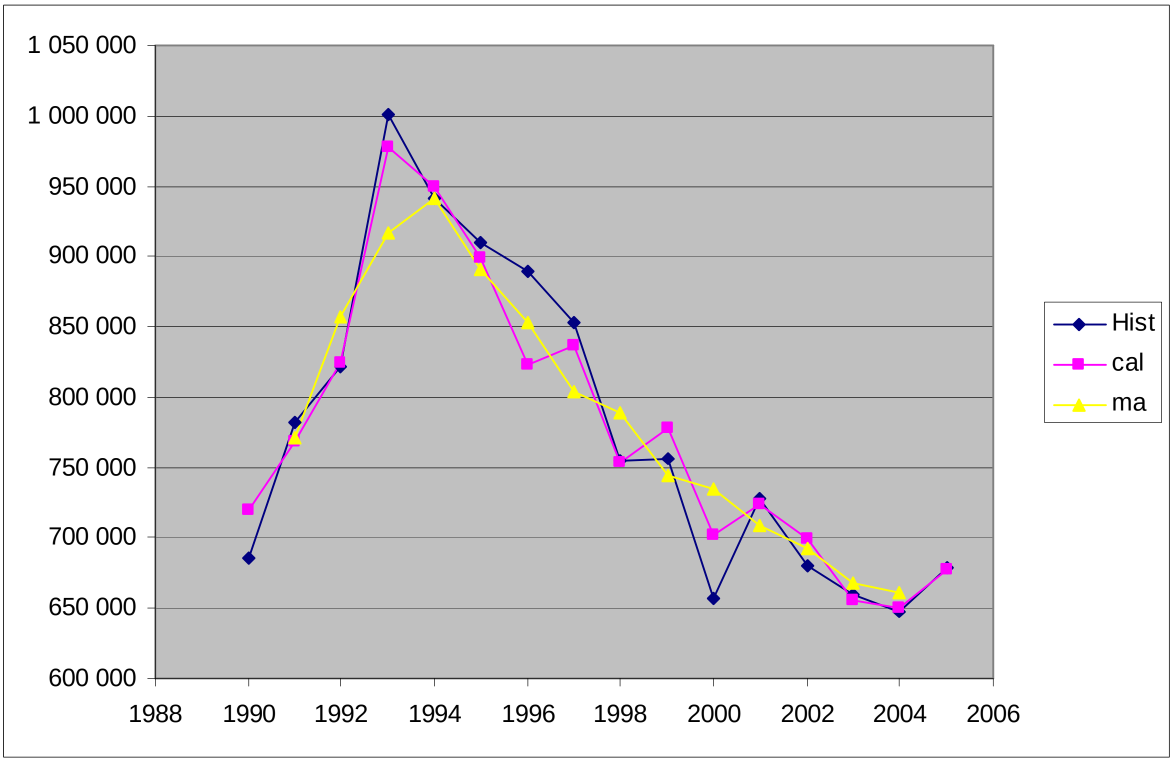


Figure 4 Hungary, historical residential fuel use 'Hist' 1990-2005 (TJ), temperature calibrated data 'Cal' (TJ) and three yearly moving average 'ma' (TJ)

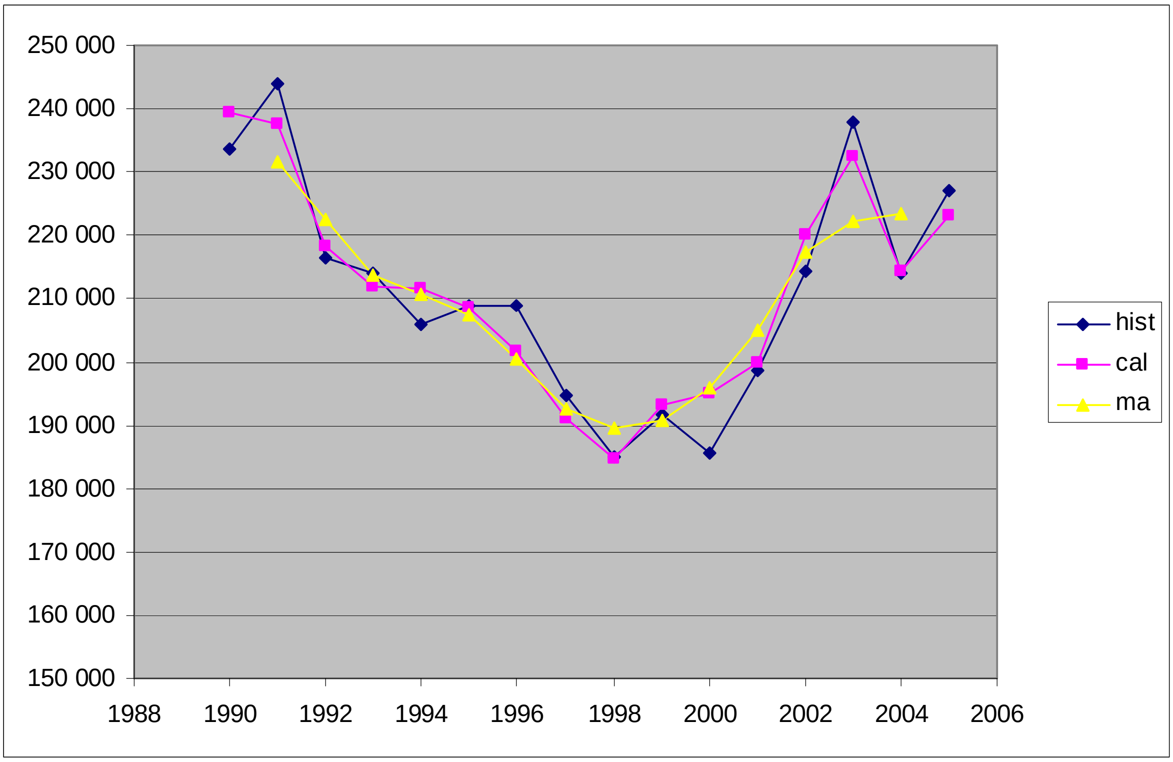
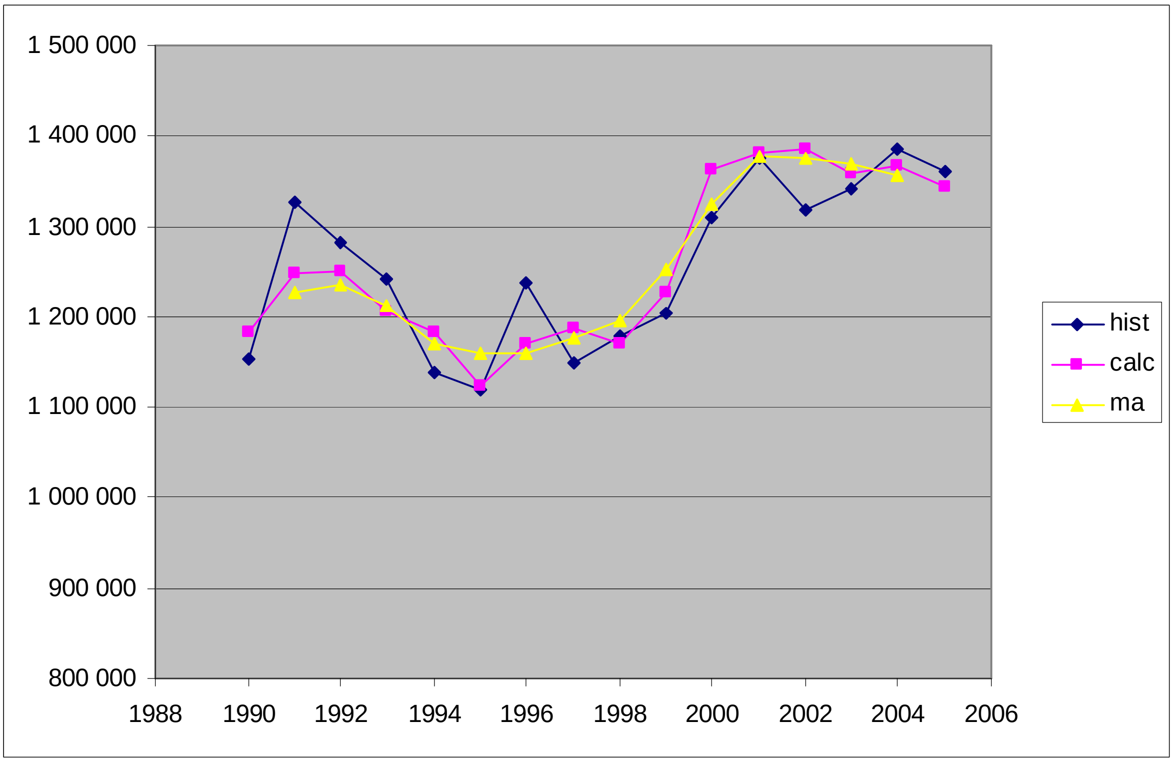


Figure 5 France, historical residential fuel use 'Hist' 1990-2005 (TJ), temperature calibrated data 'Cal' (TJ) and three yearly moving average 'ma' (TJ)



2 Annex C-2: Correction for price effects

To account for the impact of changes in fuel prices on the energy projections, price elasticity will be used. Short term fuel price elasticity have been estimated econometrically based on a weighted averages of oil and gas prices. This regression is explained in Annex C-3.

Statistical significant values have been obtained with variable success. The average of these significant values amounts -0.11 what indicates only a limited reaction on changes in fuel prices. A MS can use this average value as a default value for price elasticity, if no other country-specific value can be estimated.

3 Annex C-3: Econometrical estimation of HDD and price elasticity

The regression analysis to determine the HDD and fuel price elasticity of each member state is based on the following equation:

$$\mathit{Log(energy\ use)} = \alpha_0 + \alpha_{cpo} * \mathit{log(CPO)} + \alpha_{HDD} * \mathit{log(HDD)} + \alpha_p * \mathit{log(energy\ price)}$$
$$\text{\textit{for year x in member state y}}$$

With: energy use = fuel use of member state y in year x
α_0 = scaling parameter (regression constant);
α_{cpo} = long term CPO elasticity – This is closely related to GDP elasticity;
CPO = private consumption of households in constant prices of year x;
α_{HDD} = HDD elasticity;
HDD = number of heating degree days in year x;
α_p = fuel price elasticity;
energy price = weighted average of oil and gas price in year x.

The required statistics for this analysis are based on Eurostat data of 1990 to 2005. Table 2 presents the results from this regression analysis. The first row contains the point estimates, the second row the standard errors (se) of the point estimates. The parameter λ is used to incorporate system dynamics, namely the parameter $\alpha_{cpo} * (1-\lambda)$ corresponds the short term CPO elasticity. This parameter is only used in the analysis of the member states Hungary and Ireland. Grey zones mean that this parameter couldn't be estimated accurately for this country.

It should be remarked that the above mentioned elasticity can change when another reference period than 1990-2005 is used, when the data are expressed in a different kind of HDD than 18-15,…Therefore, it is recommended to check if the resulting elasticity reflects the historical energy uses quite well. This requires a good understanding of the historical energy statistics.

Table 2 Residential energy use for heating and SHW: statistical parameters of the regression analysis to determine HDD and price elasticity

Member State		α_0	α_{cpo}	α_{HDD}	α_p	λ	*ser*[2]	*R²*	*DW*[3]
at		-3.060	0.430	0.840	-0.140		1.7%	90%	2.52
	se	1.520	0.100	0.085	0.054				
be		-3.068	0.600	0.730	-0.120		2.7%	80%	1.60
	se	2.120	0.150	0.110	0.066				
cz		-8.700	0.810	0.730	-0.110		3.6%	83%	2.07
	se	4.100	0.310	0.160	0.100				
de		-0.930	0.550	0.520	0.000		2.4%	81%	1.95
	se	1.600	0.092	0.091					
dk		0.710	0.180	0.620	0.000		1.2%	93%	2.00
	se	0.630	0.036	0.046					
es		-1.770	0.710	0.230	0.000		2.8%	94%	1.99
	se	0.880	0.048	0.081					
fi		3.800	0.000	0.580	-0.350		8.0%	59%	1.30
	se	6.400		0.740	0.110				
fr		0.000	0.500	0.520	0.000		3.5%	69%	1.74
	se		0.400	0.100					
gr		-7.100	1.180	0.210	0.000		4.8%	96%	2.12
	se	2.070	0.073	0.210					
hu		-1.441	0.637	0.344	-0.215	0.634	3.9%	81%	1.97
	se	1.249	0.277	0.156	0.158	0.114			
ie		0.261	0.408	0.332	0.000	0.575	3.5%	87%	2.60
	se	0.954	0.111	0.223		0.152			
it		-6.260	0.880	0.590	0.000		2.8%	85%	1.75
	se	1.880	0.110	0.110					
lt		3.040	0.260	0.270	-0.520		7.0%	81%	2.50
	se	3.260	0.110	0.330	0.075				
lu		-0.330	0.370	0.410	0.000		3.5%	62%	1.61
	se	2.040	0.100	0.180					
lv		-0.440	0.160	0.820	-0.310		6.6%	58%	0.97
	se	3.230	0.110	0.330	0.110				
nl		1.660	0.170	0.720	-0.170		1.9%	94%	1.51
	se	1.200	0.083	0.067	0.040				
uk		0.840	0.280	0.730	0.000		1.9%	82%	1.57
	se	1.320	0.040	0.120					
Average			**0.478**	**0.541**	**-0.11**				

[2] Standard error of regression

[3] Durbin Watson parameter

4 Annex C-4: General description optimization and engineering model

4.1 Optimization models (Linear programming models)

Linear programming models are a popular instrument to develop GHG scenario's, especially in the energy sector. They represent the energy system of a MS by a detailed set of technology options. These options are characterized by physical parameters such as fuel type, efficiency, lifetime of technology and cost components. The demand for energy is determined exogenously in a reference scenario (basically corresponding to a without measures scenario). The model is solved by choosing the cheapest solution (choices of technologies) that satisfies the demand for energy in all subsectors and satisfying environmental and technological constraints.

Although optimization models primarily focus on engineering aspects of energy systems and the results have some prescriptive nature due to the optimization procedure, some economic interpretation of the results can be given. Indeed, its optimization procedure simulates perfectly competition among technology options and fuels, driven by demand in each sector and subsector. Some models assume perfect foresight and other models are myopic.

These models are useful for assessing and identifying efficiency potentials and for assessing supply and demand-oriented policies to curb energy related emissions. However, they neglect feedback effects on the rest of the economy and undervalue transaction costs of mitigation polices. In some cases, they are linked into top-down economic models to help overcome some of the limitations.

4.2 Engineering models

These are usually for specific sectors such as waste, agriculture, residential and the tertiary sector and transport. At their simplest, projections are made based on measures of activity, such as livestock numbers and types, and emissions factors. Changes in efficiency can be taken into account through the emissions factor. The strengths of these models lie in the detail that can be included and their relative simplicity. Their formulation is not necessarily linked directly with past trends. The representation of global policies and measures, particularly economic measures, is limited and feedback to the rest of the economy is not included. However, sector specific reduction measures can by assessed most appropriately.

The parameters needed for the models include activity data and emissions factors, plus technology data. Frequently, engineering models are used in the preparation of a linear programming model.

5 Annex C-5: Example of Tier IV: Optimization model

5.1 Energy projections of Flanders by Environmental Cost Model ECM

The ECM relies on the linear programming model Markal. An appropriate model structure was defined so the total residential sector (existing and new dwellings) could be integrated and optimized. In the next paragraphs, the model of the existing building stock will be described briefly.

The output of the residential ECM is heating demand, which expresses the comfort level of a house. This heating demand is dependent on the energy losses through the roof, walls, floor and windows, as well as on the use of SHW. Boiler efficiencies translate this heating demand into energy use. The next figure shows this structure. The figure also presents the integration of reduction measures in ECM. For instance, a dwelling can have no roof insulation, roof insulation with U-value = 0.6 W/(m².K) or roof insulation with U-value = 0.4 W/(m².K). The placement of insulation or a solar boiler, lowers the heating demand of a dwelling. The energy consumption will decrease by the installation of an efficient heating boiler.

Besides the general structure, data on the dwelling stock and reduction measures are also required. For the year 2000, a lot of data of the existing dwelling stock are available, which are mostly based on the socio-economical survey of 2001 performed by the National Statistics Bureau NIS and the Energy Balance of 2000. Concerning ECM Climate, an aggregation of this detailed database was necessary. As a consequence, the following division into dwelling categories was employed for the model:

Table 3 Subdivision of the existing dwelling stock into dwelling categories used for ECM (heating and SHW)

Dwelling type	**Dwelling age**	**Type of boiler**	**Fuel type**
Apartment	'≤1970-fuel type' '>1970-fuel type'	Average heating boiler/stove	Natural gas Fuel oil Wood Coal LPG Electricity
Single-family dwelling	'≤1970-fuel type' '>1970-fuel type'	Average heating boiler/stove	Natural gas Fuel oil Wood Coal LPG Electricity

Figure 6   Model structure of ECM Flanders (heating and SHW)