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Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services

Top-down evaluation methods of energy savings

Case studies summary report

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coordinated by

Wuppertal Institute for Climate, Environment and Energy

supported by

Intelligent Energy Europe

The Project in brief

The objective of this project is to assist the European Commission in developing harmonised evaluation methods. It aims to design methods to evaluate the measures implemented to achieve the 9% energy savings target set out in the EU Directive (2006/32/EC) (ESD) on energy end-use efficiency and energy services. The assistance by the project and its partners is delivered through practical advice, technical support and results. It includes the development of concrete methods for the evaluation of single programmes, services and measures (mostly bottom-up), as well as schemes for monitoring the overall impact of all measures implemented in a Member State (combination of bottom-up and top-down).

Consortium

The project is co-ordinated by the Wuppertal Institute. The 21 project partners are:

Project Partner	Country
Wuppertal Institute for Climate, Environment and Energy (WI)	DE
Agence de l'Environnement et de la Maitrise de l'Energie (ADEME)	FR
SenterNovem	NL
Energy research Centre of the Netherlands (ECN)	NL
Enerdata sas	FR
Fraunhofer-Institut für System- und Innovationsforschung (FhG-ISI)	DE
SRC International A/S (SRCI)	DK
Politecnico di Milano, Dipartimento di Energetica, eERG	IT
AGH University of Science and Technology (AGH-UST)	PL
Österreichische Energieagentur – Austrian Energy Agency (A.E.A.)	AT
Ekodoma	LV
Istituto di Studi per l'Integrazione dei Sistemi (ISIS)	IT
Swedish Energy Agency (STEM)	SE
Association pour la Recherche et le Développement des Méthodes et Processus Industriels (ARMINES)	FR
Electricité de France (EdF)	FR
Enova SF	NO
Motiva Oy	FI
Department for Environment, Food and Rural Affairs (DEFRA)	UK
ISR – University of Coimbra (ISR-UC)	PT
DONG Energy (DONG)	DK
Centre for Renewable Energy Sources (CRES)	EL

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Contents

1. Introduction

This report presents the main results of the 14 top-down case studies considered in the EMEEES project. These case studies were classified according to the statistical indicator used to calculate the energy savings, as energy savings are derived from the indicators variations.

Six case studies have been selected to test in a **comprehensive** way the methodology so as to cover the different sectors and the different types of statistical indicators used to measure energy savings; they are the following by sector.

Table 1: Comprehensive top-down case studies in EMEEES

Sector and indicators
Residential sector :
▪ Solar thermal collectors (market diffusion indicator)
▪ Specific uses of electricity (unit energy consumption indicator)
Transport sector:
▪ New cars (specific energy consumption indicator)
▪ Modal shift in goods transport (market diffusion indicator)
Industry sector:
▪ Industrial thermal energy use (excl. electricity) (unit energy consumption indicator);
Tertiary sector:
▪ Electricity end- uses (excl. thermal uses) (unit energy consumption indicator);

The **other** case studies have been considered in a less comprehensive way to identify if additional issues would come up:

Table 2: Less comprehensive top-down case studies in EMEEES

Sector and indicators
Residential sector :
▪ Specific white goods (refrigerators) (specific energy consumption indicator)
▪ Building shell and heating (unit energy consumption indicator)
Transport sector:
▪ Cars, bus and trucks (specific energy consumption indicator)
▪ Modal shift in passenger transport (market diffusion indicator)
Industry sector:
▪ Industrial electricity use (unit energy consumption indicator)
▪ Industrial CHP (market diffusion indicator)
Tertiary sector:
▪ Building shell and heating (unit energy consumption indicator)
General policy instruments:
▪ Energy taxation (energy consumption indicator)

All case studies were carried out in a standardised way in 9 steps, as follows:

1. Identification of relevant indicators from ODYSSEE to measure total energy savings for the sector or end-use/equipment;
2. Review of all possible variables that could be considered to correct total energy savings, independently of the data availability;
3. Review of available data sources;
4. Selection of variables to model energy savings, taking into account the data constraint;
5. Analysis of indicator trend for each EU country and grouping of countries in homogeneous groups; selection of representative countries to be studied in the case studies to adapt and validate the methodology;
6. Identification of existing energy efficiency policies (including early actions?), from MURE data base and other sources;
7. Econometric analysis for each country case study:
   - Selection of the regression period (accounting for policy if any);
   - Selection of relevant explanatory variables, both from statistical (statistical test) and economic point of views (meaningfulness);
   - Quantification of parameters;
8. Calculation of additional energy savings[1] as “total” savings minus savings linked to market energy price and trends;
9. Conclusions and issues for replication to all countries

The following chapters present the results for the 14 case studies, one by one.

[1] Additional savings are understood as those that are additional to autonomous energy savings (i.e., to savings that would occur without energy efficiency programmes, energy services, and other energy efficiency policies such as building codes or energy efficiency mechanisms).

2. Solar thermal collectors

2.1 Indicators and variables to estimate energy savings

Total energy savings at year t are calculated from the variation in the number of m² per 1000 inhabitants between 2016 and 2007, multiplied by the population and a coefficient toe/m2 (corresponding to the average useful energy provided by the solar energy divided by the average conversion efficiency from final to useful energy for water heating. This coefficient needs to be determined at each Member State's level).

2.2 Modelling of additional savings: capacity of solar collectors

To capture the trend and price effect, the regression analysis has to be made over a period, over which policy measures either are negligible or had a limited impact.

Taking into account the data usually available, the installed capacities in solar collector per 1000 inhabitants was modelled with two main variables:

- Time to capture an autonomous trend
- Average energy price to measure the impact of prices

Furthermore, the cost of solar water heaters could be an explanatory variable; however, as it is not possible to have time series by country, this factor will be neglected.

The modelling equation is as follows : Ln (IC) = T * ln(t) + A * ln (P) + K

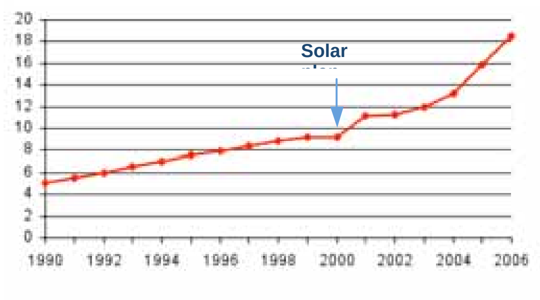
- IC : Installed capacities of solar collector (m2/1000 inhab)
- T : trend
- A: price elasticity (>0 as price increase should increase penetration of solar water heaters)
- P: Average energy price for sanitary water heating (including changes in energy taxation)[2];

2.3 Classification of countries

Three groups of countries were considered:

"Policy pushed markets": countries for which a policy was implemented after the mid –nineties period with autonomous trend clearly visible (net and rapid take off from one year). Case of France, Belgium, Italy, Finland, Ireland, Netherlands, Spain, UK, Hungary, Sweden, Portugal

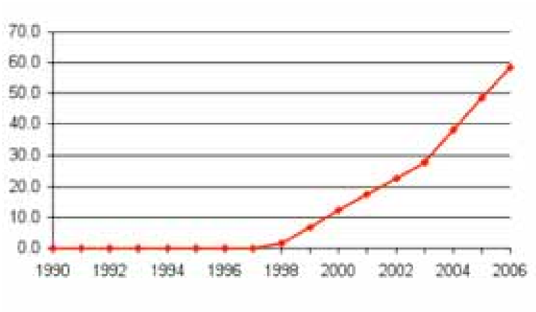
France installed capacity per capita (m2/1000inhab)



[2] The resulting contribution to total energy savings needs to be split up into the part due to changes in energy market prices and those due to changes in energy taxation.

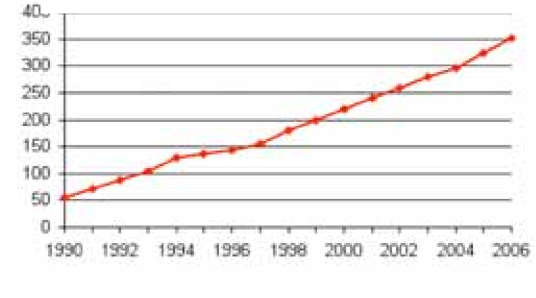
New markets": recent policies (same as above but diffusion starting from a very low level close to zero - autonomous trend negligible). Case of most new EU member countries

Malta installed capacity per capita (m2/1000inhab)



"Mature markets" with already a high penetration of solar water heaters resulting from policies implemented before 1995: autonomous trend difficult to define (what is part of the trend and what is linked to policies?). Case of Germany, Austria, Cyprus, Greece, Slovenia and Denmark

Austria installed capacity per capita (m2/1000inhab)

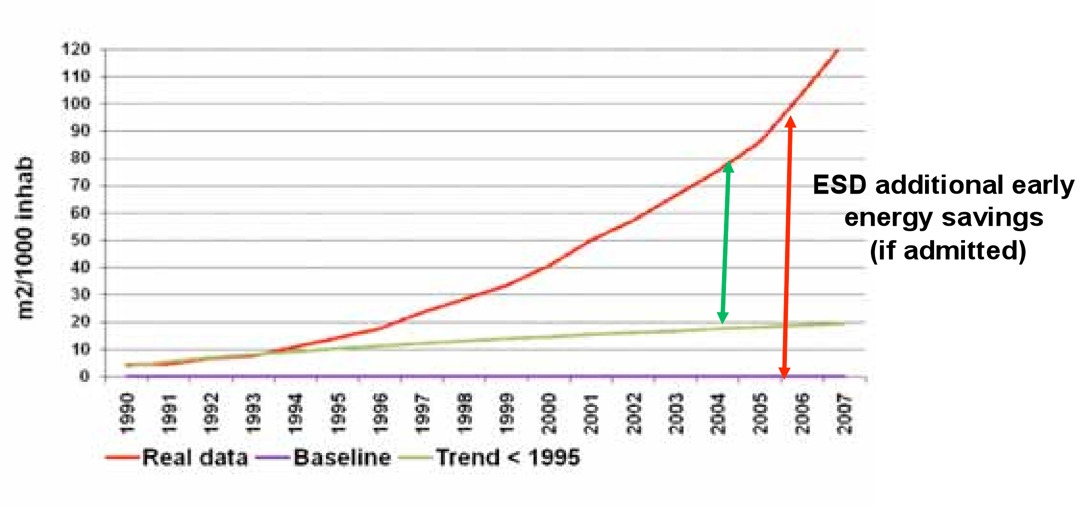


2.4 Econometric analysis

The definition of trends or baseline is easy for countries with rapid take off following measure implementation. It is however difficult for countries with mature markets (several policies implemented regularly before and after 1995). There are three potential solutions to face this problem: use of a national trend before 1995, but some policies are not credited for, or use of a trend based on countries with similar climate, or finally no autonomous trend if one considers that most of the diffusion is policy driven.

The role of the energy price P is generally not statistically significant (i.e. not validated by statistics tests) or even significant but strange from an economic viewpoint (negative elasticity instead of positive or too high elasticity not really relevant economically). Indeed, the quality of the estimate of price elasticity is questionable, as the period of regression is short and prices were not changing so much over the period of regression. The price effect can only be measured with an exogenous deemed default value for price elasticity (0.1 or 0.2).

Modelling of the diffusion of solar water heaters: example



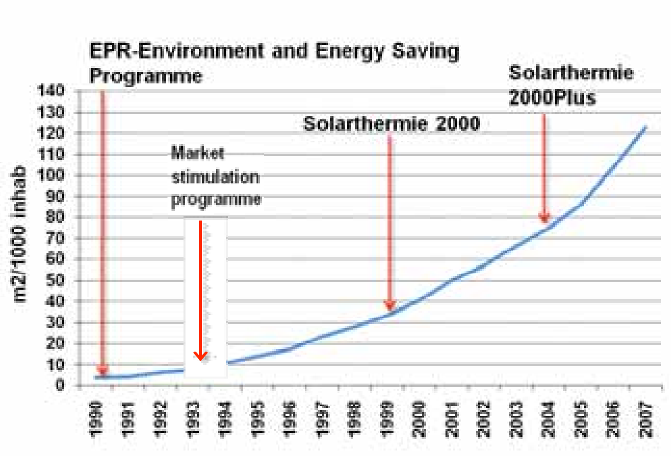
2.5 Example of calculation of additional savings

The calculation at year n will be carried out in 3 stages, as follows:

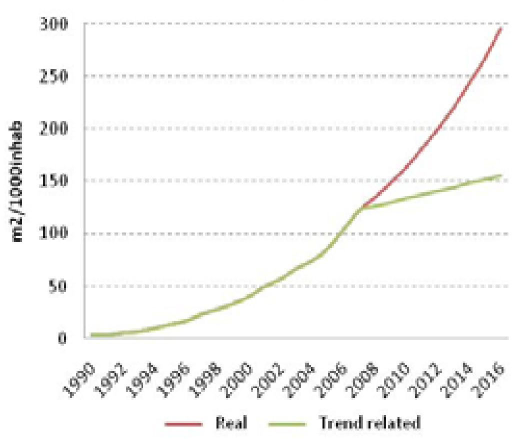
- **Stage 1** : calculation of the total energy savings from the variation in the number of m² per 1000 inhabitant between year n and 2007, multiplied by the population and a coefficient toe/m2 (corresponding to the average useful energy provided by the solar energy, divided the average conversion efficiency from final to useful energy for water heating. This coefficient needs to be determined at each Member State's level)
- **Stage 2** : Calculation of the energy savings induced by the autonomous trend from the difference in m2 per 1000 inhabitants between the estimation of installed capacities induced by trend in year n and the actual indicator value multiplied by the population and the coefficient toe/m2.
- **Stage 3**: Additional savings are calculated by difference : total savings minus trend savings

2.6 Example : Germany case study

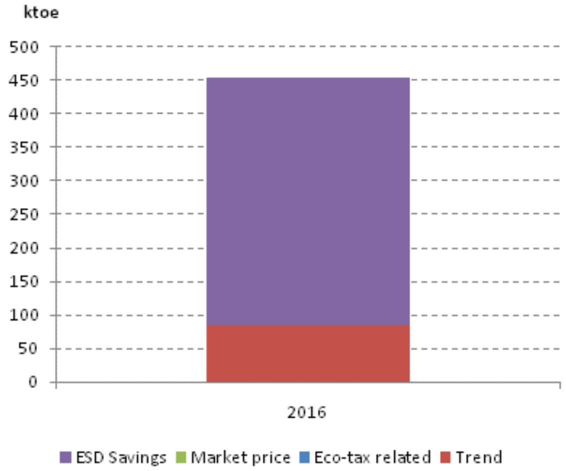
Historical trend of installed capacities in solar collector per 1000 inhabitant



Real*" and trend related evolution of installed capacities up to 2016 (example calculation)



Estimation of additional savings (result of example calculation)



*Estimation of real data in the future made for the example;

3. Specific uses of electricity

3.1 Indicators and variables to estimate energy savings

'Apparent total' energy savings should be calculated from the variation of the unit electricity consumption per dwelling for lighting and electrical appliances between 2007 and 2016. However, to account for the fact that this indicator is increasing due to lifestyles changes but that in the future measures could slow down this increasing trend, a value of energy savings in 2016 could only be calculated as the inflexion compared to a historical trend.

Additional energy savings may be calculated by removing the effect of electricity market prices (net of changes in energy taxation).

3.2 Modelling of additional savings: electricity consumption per dwelling

To capture the trend and price effect, the regression analysis has to be made over a period, over which policy measures either are negligible or had a limited impact.

The unit electricity consumption per dwelling for lighting and electrical appliances was modelled with three main variables:

- Time to capture an autonomous trend
- Average electricity price to measure the impact of prices
- Private household consumption to model the impact of increased ownership of small appliances

The price of electric appliances compared to the income could be a good explanatory variable as it represents the purchasing power, but time series by country were not available. So, the variable was not considered.

The modelling equation is as follows : Ln (UC) = T * t + A * ln (P) + B * ln (PC)+ K

- T: trend
- A: price elasticity (<0)
- P: electricity price
- PC private consumption
- B income elasticity

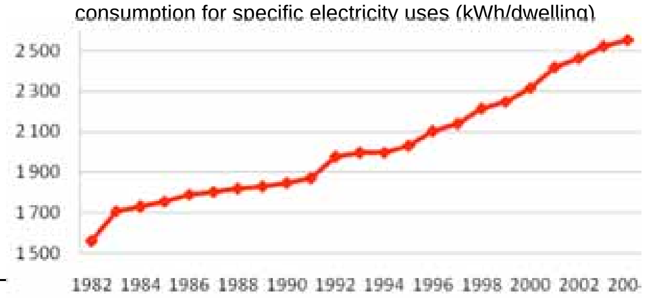
3.3 Classification of countries

Two groups of countries were considered:

Countries with a regular increase of the unit consumption: case of Finland, Greece, Germany, Italy, Portugal, Spain, Sweden, Bulgaria, Lithuania, and Slovenia (since 2000). This group also includes countries with an acceleration of the unit consumption: France (since 1995), Austria (since 1998) and the Netherlands (since 1990)

Case of country with regular increase: Portugal's unit electricity consumption for specific electricity uses (kWh/dwelling)

Case of country with an acceleration: France's unit electricity consumption for specific electricity uses (kWh/dwelling)



Countries with a slowdown of the growth of the unit consumption: case of Denmark since 1995) and United Kingdom (since 1989)

Case of country with a saturation or slow down: Denmark's unit electricity consumption for specific electricity uses (kWh/dwelling)

3.4 Econometric analysis

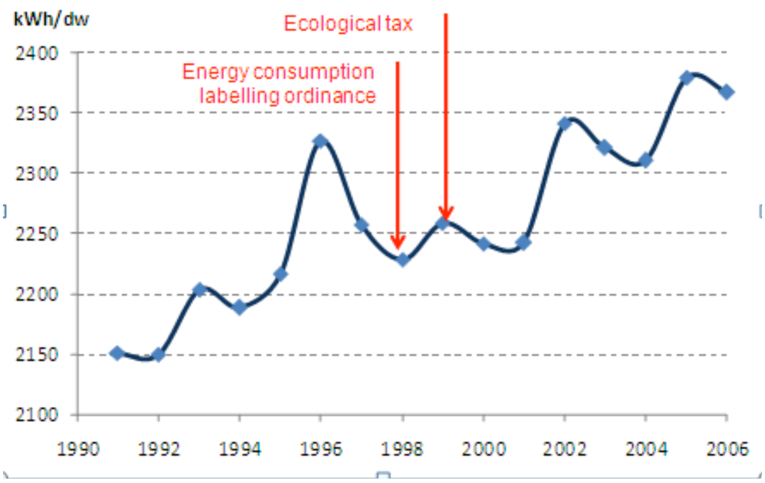
The role of electricity price is generally not statistically significant. This is not surprising as the price did not change much at least in EU-15 countries. Our conclusions are confirmed by an IEA study showing that there was no statistical evidence of the impact of electricity price on energy efficiency improvement of electrical appliances.

3.5 Example of calculation of additional savings

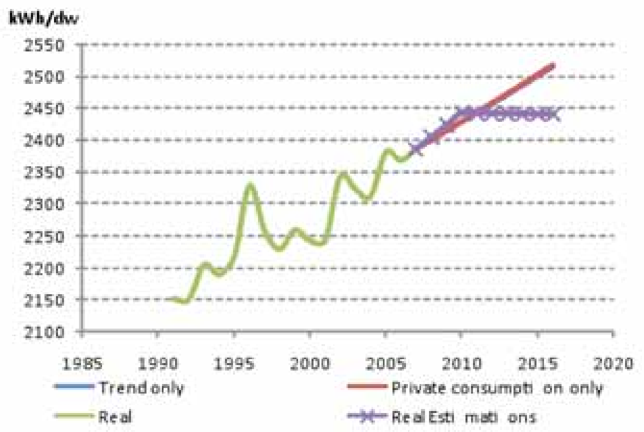
- **Stage 1**: Modelling of the effect of a rising trend and the income effect over a period without national measures.
- **Stage 2**: Calculation of 'uncorrected' energy savings from the difference between the actual value of the indicator and value calculated using the trend and income effect modelled in stage 1.
- **Stage 3**: Calculation of price effect over the period 2008 – 2016, using a deemed default value for the price elasticity of -0.1 or -0.2
- **Stage 4**: Calculation of additional savings as the difference between 'uncorrected' energy savings and savings induced by changes in energy market prices in 2016.

3.6 Example: case study of Germany

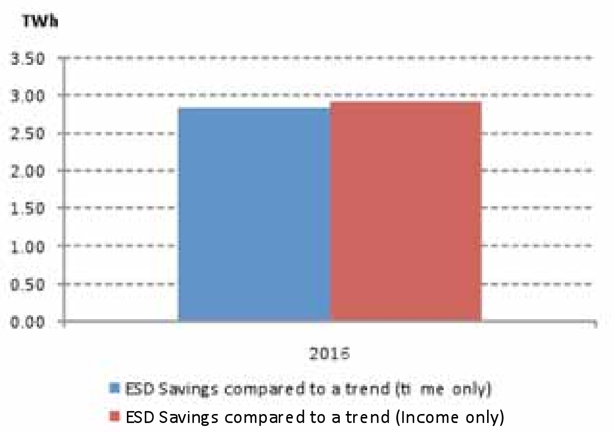
Historical trend of the unit cons. per dwelling for lighting and electrical appliances



"Real*" vs. trend and income related evolution of unit electricity consumption (example)



Example of calculation of savings



4. New cars

4.1 Indicators and variables to estimate energy savings

'Apparent total' energy savings at year t are calculated as the difference of the test specific consumption of new cars between year t and t=2007 (t over 2008-2016) multiplied by the average distance travelled by car at year t, the number of registered new cars at year t and a technical coefficient accounting for the difference between the test value and the actual value for the specific consumption. Apparent total energy savings in 2016 are the sum of apparent total energy savings calculated each year.

To clean the impact of fuel substitution between gasoline and diesel, apparent total energy savings are calculated separately for gasoline and diesel vehicles. For new cars, 'apparent total' energy savings can be considered to be a good approximation for all energy savings.

4.2 Modelling of additional savings: test specific consumption of new cars

The test specific consumption of new cars is modelled with two main variables:

- Time to capture an autonomous trend
- Motor fuel price to measure the impact of prices

The direct rebound effect was not taken into account. It may be introduced through the annual distance travelled by new car, but the data is not available in time series by country.

It is better to consider the effect of change in the size of vehicles in the modelling, but data are rarely available as time series. So if change in car size is not taken into account, energy savings are underestimated in case of a trend towards larger or more powerful cars; and in case of trends towards smaller or less powerful cars energy savings are overestimated.

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Two approaches may be considered to model the test specific consumption of new cars depending on the availability of data on the car size:

- Countries without data on engine size: Ln (SC) = T * (t) + A * ln (P) + K
    - SC : Specific consumption of cars in litre/100km
    - T: trend
    - A: price elasticity (<0)
    - P: motor fuel price

- Countries with data on engine size: Ln (SC) = T * (t) + A * ln (P) + K
    - SC : Specific consumption of cars in litre/100km/cm^3 or in litre/100km/kW
    - T: trend
    - A: price elasticity (<0)
    - P: motor fuel price

The energy savings associated to price changes will then be split into two components: energy savings linked to tax increase (policy related) and savings (>0 or <0 savings depending on the variation) linked to change in ex-tax fuel price (market related).

4.3 Classification of countries

Two groups of countries were considered according to whether countries have or not national measures.

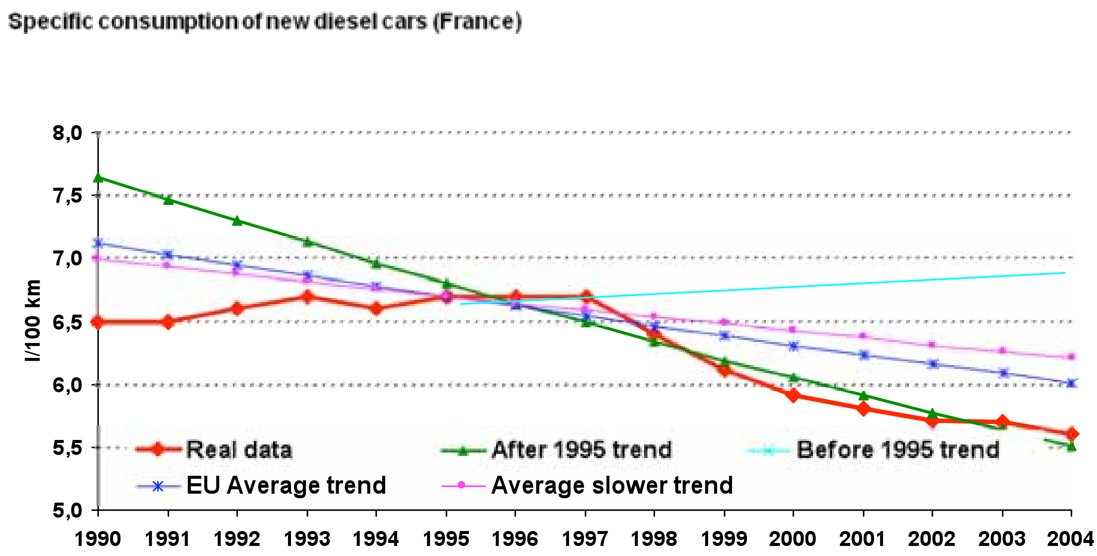
Countries with national measures are: Germany, UK, Finland, Sweden, Austria, Denmark, and France:

- Tax on motor fuels (increased or new) : Germany, UK, Finland, Sweden
- Tax on car purchase linked to energy efficiency and/or CO2 emissions[2]: Austria, Denmark, UK
- Annual registration tax linked to energy efficiency and/or CO2 emissions[3]: Germany, Denmark, UK, Sweden

For countries without national measures, the trends observed are mainly influenced by the ACEA/JAMA/KAMA agreement, market price and autonomous trend.

4.4 Econometric analysis

To capture the trend and price effect, the regression analysis has to be made over a period, over which policy measures either are negligible or had a limited impact. However, trends are very different before and after 1995, mainly as result of the ACEA/JAMA/KAMA agreement. Therefore, the question is what is the autonomous trend? Before or after 1995? Do we use national trends or a default reference trend (which could either be the EU average trend or the trend of the average of the three countries with the slowest decreasing consumption trend)?



2 Measure has existed in France since 2006 on commercial cars
3 Measure has existed in France since 2006 on commercial cars

The impact of motor fuel prices is generally not validated by statistic tests. Although price elasticities are not statistically significant, prices have certainly an effect and should be introduced. The price effect can be considered with a 'default value" price-elasticity calculated with a pooling method across all EU countries or by taking an average value of EU countries with relevant data ("EU average"). In this case study, the pooling methodology was not validated by econometric tests. An EU average elasticity was used:

- -0.35 for specific consumption of new diesel cars
- -0.25 for specific consumption of new gasoline cars

4.5 Example of calculation of additional savings

The calculation at year n will be carried out in 4 stages, as follows:

- **Stage 1 :** The (apparent) **total** energy savings are calculated over the 2008-2016 period for gasoline and diesel new cars separately with the following equations:

  $TESt = \text{Somme}\ TESfuel_t$ with
  $TESfuel_t = TESfuel_{t-1} + TESNCRfuel_t$
  With : $TESNCRfuel_{t=0}=0$
  $TESNCRfuel_t = (SCfuel_t - SCfuel_{t=0}) * (1+ TCfuel) * NCRfuel_t * ADTfuel_t * Conv$

  With TES : Total Energy Savings (in ktoe)
  fuel: gasoline or diesel
  TESNCR : Total Energy Savings from New Cars Registered
  SC = Specific Consumption (in l/100km or l/100km/cm^3 or l/100km/kW)
  TC : Technical coefficient
  NCR : Number of New cars registered[4]
  ADT : Average Annual Distance travelled
  Conv : Conversion coefficient (1.07 * 0.75 for gasoline and 1.035 * 0.85 for diesel)

- **Stage 2:** The energy savings induced by the technological trend and prices effects are calculated for gasoline and diesel new cars separately with the same methodology as the total energy savings, based on the estimation of specific consumption induced by trend and prices, i.e, using $SCfuel\_trend_t$ in the above formula instead of $SCfuel_{t=0}$.

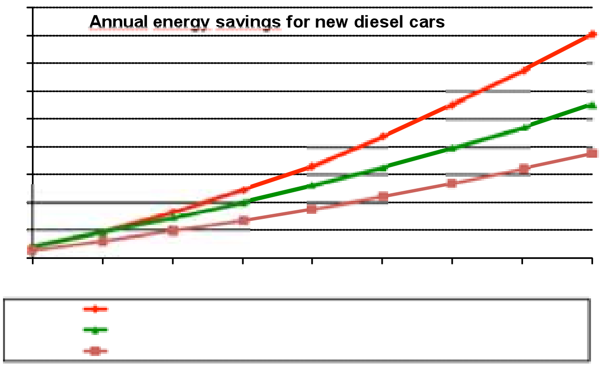
- **Stage 3:** The apparent total energy savings for all cars are obtained by summing the total energy savings for gasoline cars and for diesel cars; the energy savings induced by technological trend and price effect are obtained by summing what is calculated for gasoline and diesel cars.

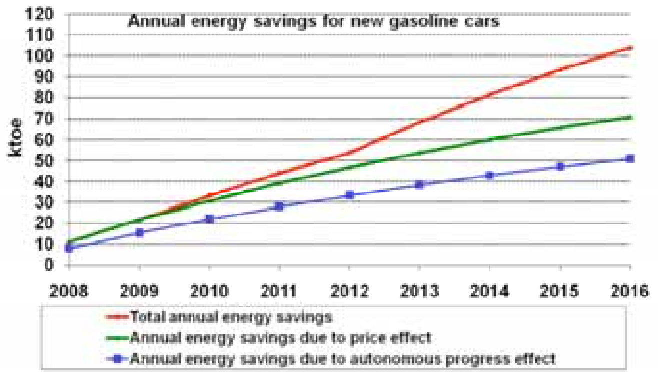
- **Stage 4:** The additional energy savings for all cars are calculated by difference for gasoline and diesel new cars separately, as the apparent total savings minus trend- and price-related savings.

[4] multiplied by average cm^3 or kW if available

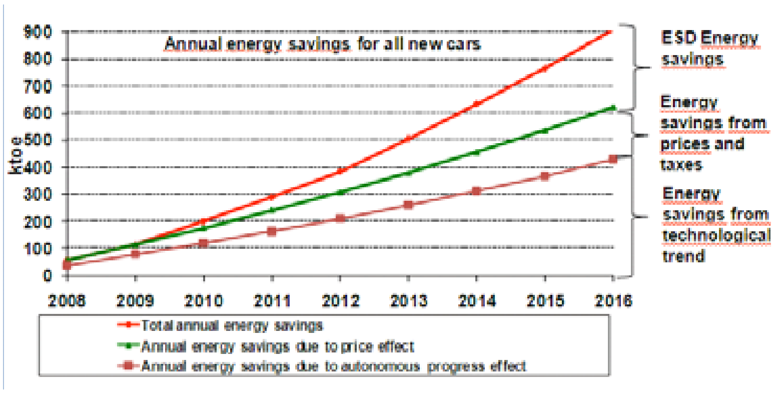
4.6 Example

For gasoline cars, the energy savings due to technological progress are based on a 0.8%/year decreasing trend and the energy savings due to prices are based on an elasticity of -0.25. For diesel, the technological progress is assumed to be 1.2%/year and the price elasticity to be -0.35.





The (apparent) total energy savings over the 2008-2016 period are about 1000 ktoe/year in this example; additional savings are about 300 ktoe/year



5. Modal shift in goods transport

5.1 Indicators and variables to estimate energy savings

Apparent total energy savings at year t are calculated from the variation in the share of rail and water transport between year t and reference year/t-1 multiplied by the total traffic of good transport at t (in tkm) and unit energy consumption difference between road and rail/water at t (toe/tkm).

5.2 Modelling of additional savings: modelling of the share of non road traffic

The modelling of the share of non road traffic is done through a regression analysis with two variables:

- Time to capture an autonomous trend
- Average diesel price used to capture price differential

The modelling equation is as follows: Ln (WRS) = T * t + A * ln (P) + K

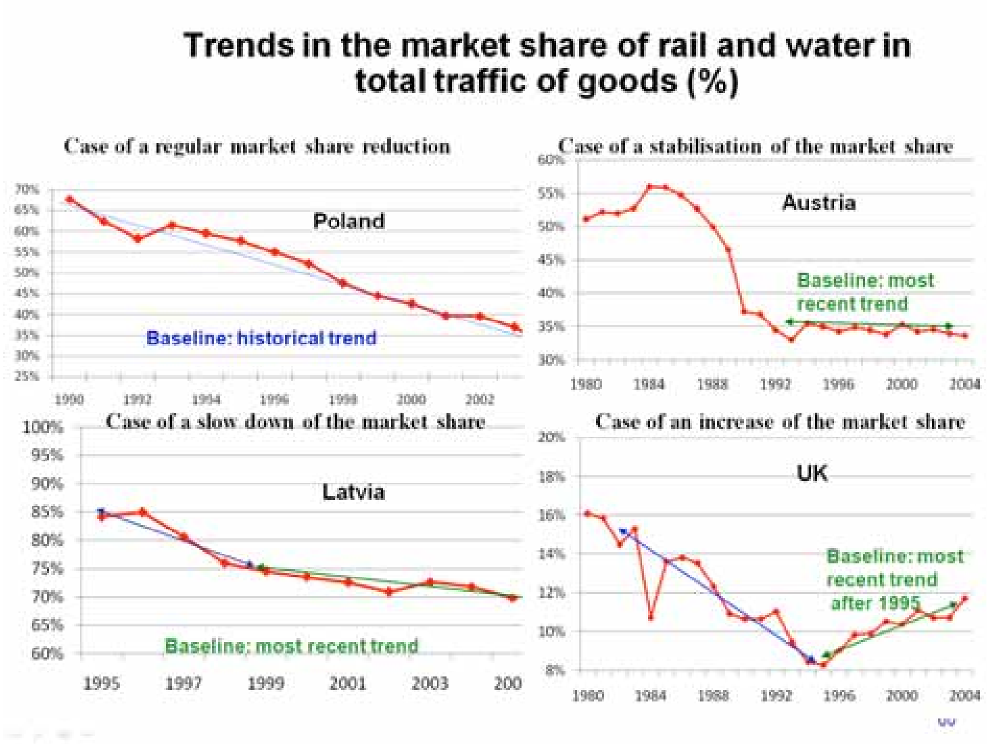
- ✓ T: trend
- ✓ A: price elasticity (>0)
- ✓ P: diesel price

5.3 Classification of countries

Four groups of countries can be considered:

1. Countries with a regular market share reduction for non road traffic: case of France, Ireland, Spain, Czech Republic, and Poland;
2. Countries with a slowdown in the market share reduction: case of Latvia (since 1998) and Bulgaria (since 1998) ;
3. Countries with a stabilisation of the market share: case of Austria (since 1992), Belgium (between 1994 and 2001), Greece (since 1997), Germany (since 1999), the Netherlands (since 1993), Hungary (since 1998), Lithuania (since 1999), Finland (since 2000) and Slovenia (since 2001);
4. Countries with a market share increase: case of Sweden (since 1999), UK (since 1995) and Belgium (since 2001) ;

Only the last group of countries corresponds to a modal shift that generates energy savings.



5.4 Econometric analysis

Only a small number of countries have national measures specifically targeted to modal shift for freight transport and most of them have a low impact. Thus, until now the role of measures was negligible and the trends were mainly influenced by other factors (autonomous trend and diesel prices). It is not necessary to make the regression analysis over a period over which policy measures either were negligible or had a limited impact.

Price elasticity calculated from regression is not significant for most countries (e.g. <0 despite an important increase of diesel prices)

It is proposed to use a deemed exogenous and asymmetric price elasticity, with a lag of 3 years to well capture the impact of price:

- ✓ 0.46 if prices increase (EU average between 2001 and 2005)
- ✓ and 0 if prices decrease

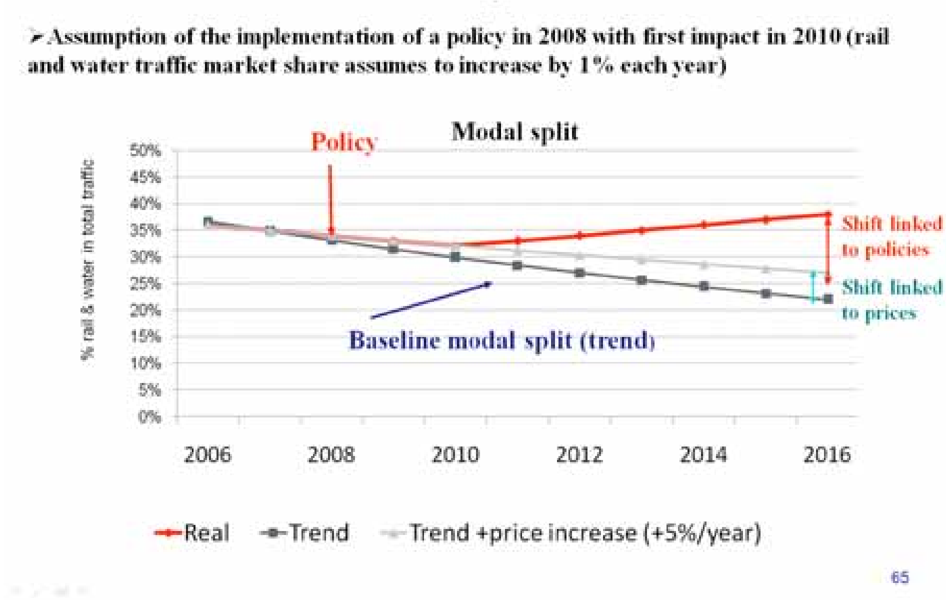
5.5 Example of calculation of additional savings

The calculation at year n will be carried out in 3 stages, as follows:

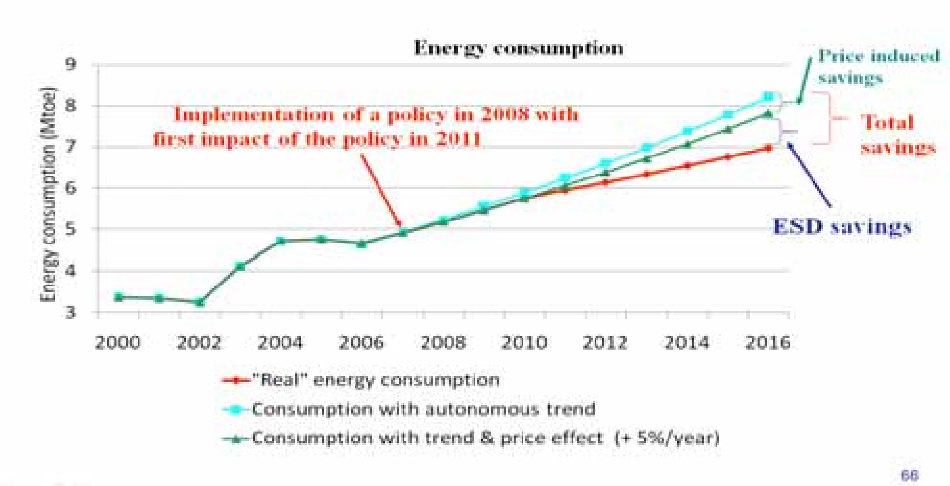
- **Stage 1**: Modelling of baseline modal split, i.e., change in modal split linked to autonomous trend and energy market price effect;
- **Stage 2**: Modelling of baseline energy consumption, using the baseline modal split
- **Stage 3**: Modelling of baseline energy savings (can be negative!) and calculation of additional savings as the difference between actual energy consumption (using the actual modal split) and baseline energy consumption

5.6 Example:

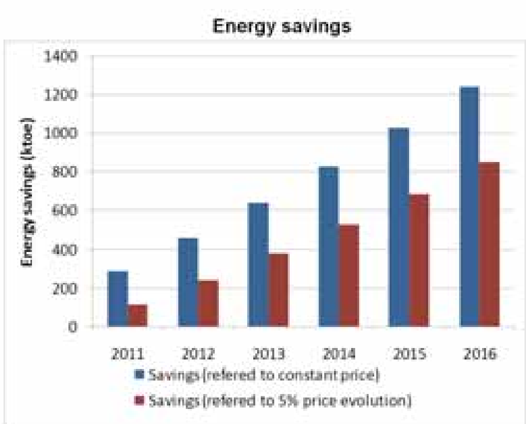
- **Stage 1** : Modelling of baseline modal split;



- **Stage 2** : Modelling of baseline energy consumption



- **Stage 3**: Modelling of baseline energy savings and calculation of additional savings as the difference between actual energy consumption and baseline energy consumption



6. Industrial thermal energy use[5]

6.1 Indicators and variables to estimate energy savings

Apparent total energy savings are calculated from the variation of ODEX. ODEX is an index that aggregates the variation in the unit consumption index (thermal uses consumed/index production) of each industrial sector between t-1 and t at the level of all sectors concerned by the ESD (i.e. excluding ETS sectors). Such an indicator is cleaned from structural changes between industrial sectors. It does not fully match ETS but no other data are available so far.

As this indicator is complex to calculate, the test was done on 2 countries: The Netherlands and Germany.

6.2 Modelling of additional savings: modelling of the ODEX

To capture the trend and price effect, the regression analysis has to be made over a period, over which policy measures either are negligible or had a limited impact and for which there is no exceptional business cycle.

The modelling of the ODEX indicator was done through regression analysis with three variables:

- Time to capture an autonomous trend
- Average price of fuels to measure the impact of prices
- Value added of industry to measure the impact of business cycles (yearly fluctuations)

The modelling equation is as follows: $\text{Ln (ODEX)} = T * t + A * \ln(P) + B * \ln(VA) + K$

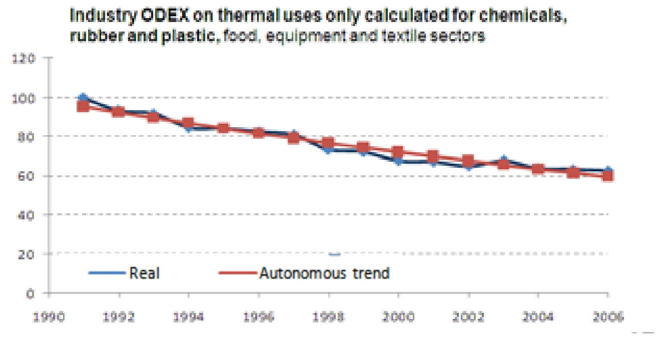
- T : trend
- A: price elasticity (<0)
- P: electricity price
- B : value added elasticity (A < 0)
- VA : value added of industry

6.3 Econometric analysis

The trend obtained with the regression is -1.2%/year. It includes the effect of policy measures, in particular voluntary agreements; additional savings are by consequence underestimated.

Price elasticity data calculated from regression were not significant, but prices have certainly an effect and should be introduced. The price effect can be considered with a ‘default value’ price-elasticity between -0.1 and -0.2.

[5] excluding electricity



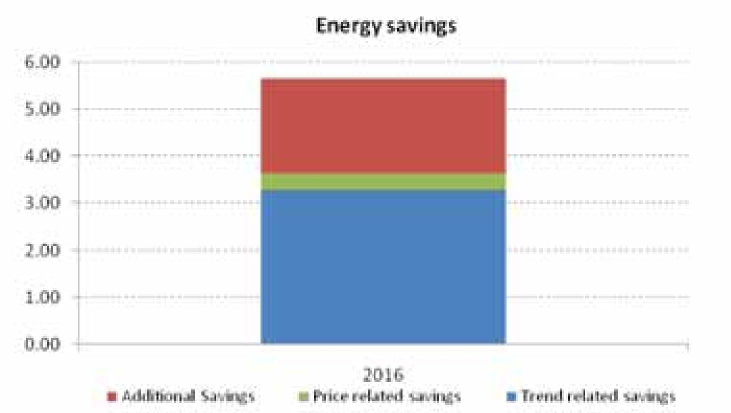
6.4 Example of calculation of additional savings

The calculation was carried out in 3 stages, as follows:

- **Stage 1**: Modelling of a trend and the price and value added effects over a period without national measures
- **Stage 2**: Calculation of the energy market price effect over the period 2008 – 2016, based on a forecast of fuel market prices
- **Stage 3**: Calculation of additional savings as the difference between apparent total energy savings and savings induced by value added and changes in energy market prices at 2016.

6.5 Example

The regression was carried out over the period 1998 – 2006. The parameters of the regression were then applied from 2007. A price elasticity of -0.1 was applied. The national trend calculated on the 1998-2006 period was applied (-1.2%/year)



*Estimation of real data in the future made for the example

7. Electricity end-uses for the tertiary sector

7.1 Indicators and variables to estimate energy savings

Total energy savings are calculated from the variation of the unit electricity consumption per employee (excluding electricity for thermal uses when data available). The energy savings can be calculated in two ways:

- As the sum of energy savings by subsector, ie from the variation of unit electricity consumption per employee by sub-sector (detailed approach) to clean the changes in the structure of service sector activities ("hidden structure effect") ➔ the best approach but data available only for few countries
- Or directly from the total unit electricity consumption of the service sector (aggregated approach) if data by subsector are unavailable.

Savings were calculated from the unit electricity consumption per employee because

- Physical indicators are more relevant than economic indicators and energy needs are more related to working conditions than to value added.
- Employment data are more robust than building surface data.

7.2 Modelling of additional savings: modelling the total unit electricity consumption

To capture the trend and price effect, the regression analysis has to be made over a period, over which policy measures either are negligible or had a limited impact.

The modelling of the unit electricity consumption was done through a regression analysis with two variables:

- Time to capture an autonomous trend
- Electricity price to measure the impact of prices

The modelling equation is as follows: $Ln\ (UC) = T * t + A * ln\ (P) + K$

- UC : Unit electricity consumption of tertiary sector
- T : trend
- A: price elasticity (<0)
- P: electricity price

7.3 Classification of countries

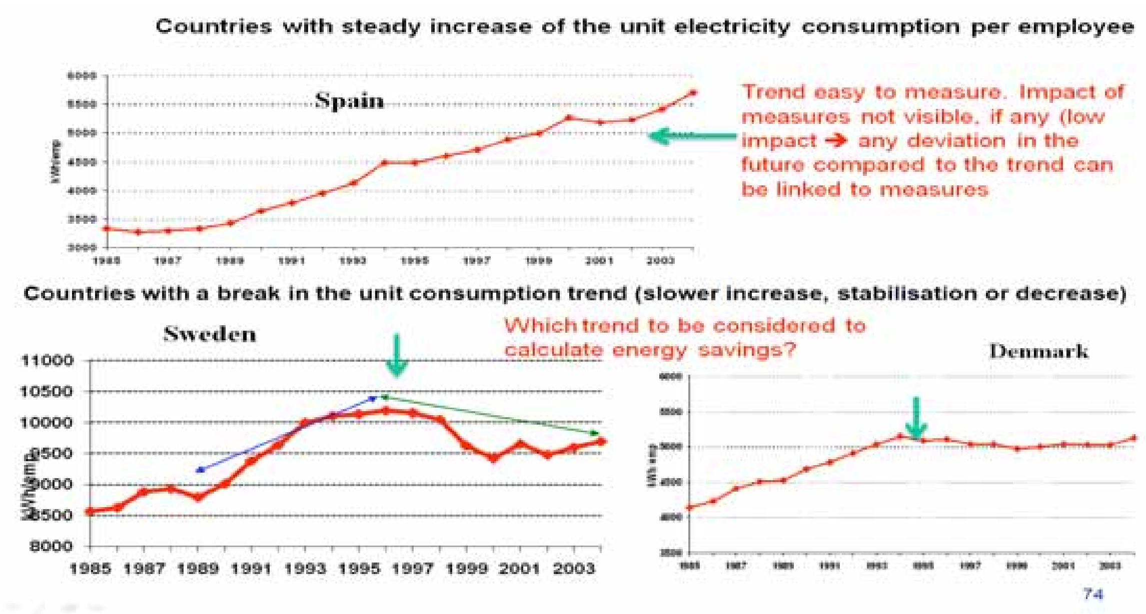
Few countries have national measures (Belgium, Finland, France, Germany, Ireland, Spain and Sweden, as reported in MURE; in addition, Denmark has had measures since about 1995)

Four groups of countries can be considered as to the trend in the unit electricity consumption per employee:

1. Countries with national measures and a slower increase, a stabilisation or a decrease of the unit consumption after the implementation of the policy (Belgium, Germany, Sweden, Denmark). For these countries, there are savings but is difficult to know if they were induced by policy measures or by a saturation of electricity uses?
2. Countries with national measures and the same trend after the implementation of the policy (Finland, France, Spain). There seems to be no impact of the policy, or the measures have been too weak.
3. Countries without national measures and a steady increase of the unit consumption (Austria, Greece, Italy, Netherlands, Portugal, Bulgaria, Cyprus, Czech Republic, Estonia,

Latvia, Lithuania, Slovak Republic and Slovenia); the trend is mainly influenced by energy market price and autonomous trend. It is necessary to take into account a saturation level.

4. Countries without national measures and a rupture in the trend not linked to policies (Luxembourg, Poland and Hungary)



7.4 Econometric analysis

The price effect is generally not validated by statistics tests, as electricity prices did not change enough in the past.

7.5 Example of calculation of additional savings

For the aggregate approach the calculation was carried out in 3 stages, as follows:

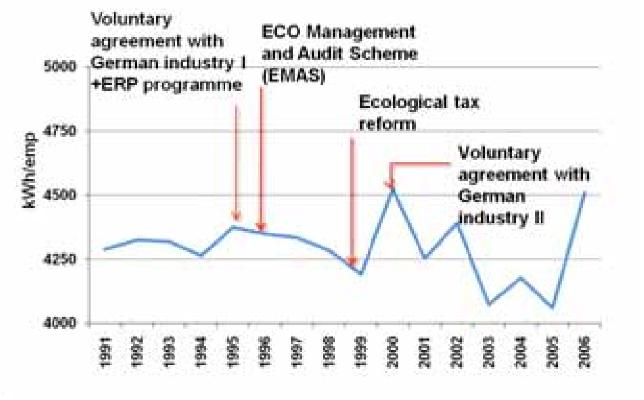
- **Stage 1:** Calculation of the 'apparent total' energy savings at year t from the variation in unit electricity consumption between 2016 and 2007 multiplied by the number of employees; these 'apparent total' energy savings may be negative, if the unit electricity consumption is increasing.
- **Stage 2:** Calculation of the energy savings induced by the autonomous trend and price effects with the same methodology as the total energy savings, based on the estimation of change in unit consumption induced by trend and prices;
- **Stage 3:** Calculation of additional savings by difference: 'apparent total' savings minus trend and price-related savings.

For the detailed approach the calculation will be carried out in 4 stages, as follows:

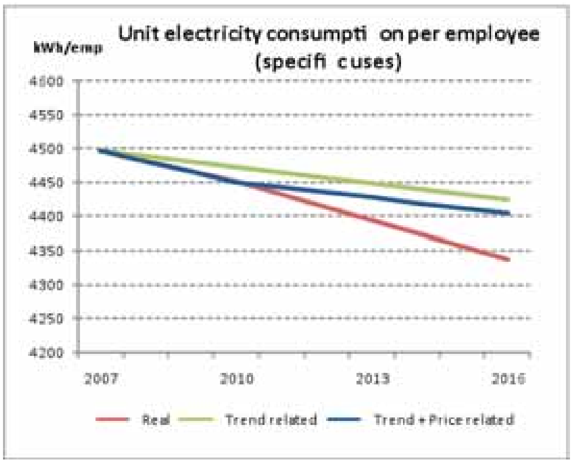
- **Stage 1 :** Calculation of the 'apparent total' energy savings at year t from the variation in unit electricity consumption by tertiary subsector between 2016 and 2007 multiplied by the number of employee for each branch;
- **Stage 2 :** Calculation of the energy savings induced by the autonomous trend and price increases for each subsector
- **Stage 3 :** Calculation of additional savings for each subsector by difference : apparent total savings minus trend- and price-related savings
- **Stage 4 :** Additional savings for all the tertiary sector is calculated by summing the savings by subsector.

7.6 Examples

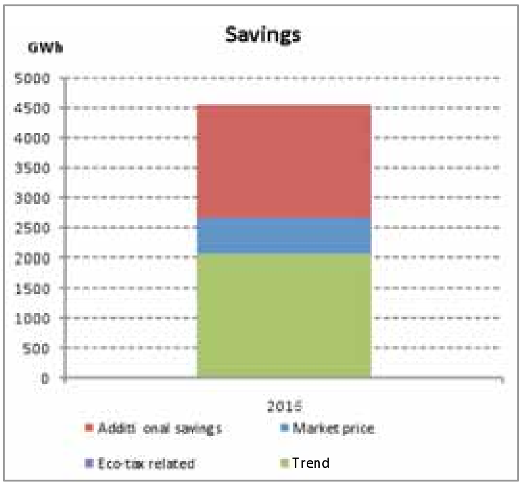
Historical trend of unit electricity consumption per employee (Germany)



Real*" and trend related evolution of installed capacities up to 2016 (example of calculation)

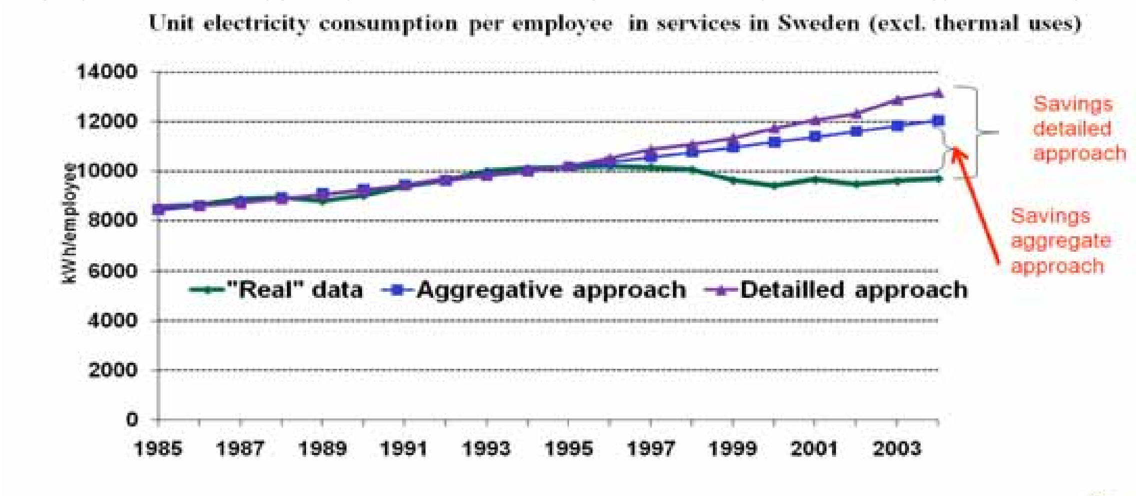


Estimation of Additional savings (example of calculation)



*Estimation of real data in the future made for the example;

A case study was done in the case of Sweden with the two approaches, by sub-sector or aggregate, to see the impact of the disaggregation on the evaluation. Energy savings calculated over the period 1995-2004 give less energy savings (by more than 2 TWh) with the aggregate approach (i.e. direct calculation at the level of the whole sector) than with the detailed approach (i.e. calculation as the sum of energy savings by sub-sector (e.g. offices, hospitals, trade): the difference is due to a shift of activity to sub-sectors with higher electricity consumption per employee, which is typically a structural change without any link to energy efficiency.



8. Refrigerators

8.1 Indicators and variables to estimate energy savings

'Apparent total' energy savings at year t are calculated from the variation in the specific consumption for refrigerators between 2016 and 2007 multiplied by the stock of refrigerators. For refrigerators, 'apparent total' energy savings can be considered a good approximation of all energy savings.

8.2 Modelling of additional savings: specific consumption of refrigerators

To capture the trend and price effect, the regression analysis has to be made over a period, over which policy measures either are negligible or had a limited impact.

The modelling of the specific consumption for refrigerators is done through a regression analysis with two variables:

- Time to capture an autonomous trend
- Average electricity price for households

The modelling equation is as follows: Ln (SC) = T * (t) + A * ln (P) + K

- SC : Specific consumption for refrigerators
- T: trend
- A: price elasticity (<0)
- P: electricity price for households

The cost of a more efficient refrigerator may have an impact on the average specific consumption of refrigerators; it is however not taken into account because of a lack of information.

8.3 Methodology of calculation of additional savings

For the aggregate approach the calculation is carried out in 3 stages, as follows:

- **Stage 1:** Calculation of the 'apparent total' energy savings from the variation in the specific consumption for refrigerators between 2016 and 2007 multiplied by the stock of refrigerators.
- **Stage 2:** Calculation of the energy savings induced by the technological trend and prices effects with the same methodology as the total energy savings, based on the estimation of specific consumption induced by trend and energy market prices; EMEEES proposal: use the trend of the three EU Member States with the slowest decrease in specific consumption over time
- **Stage 3:** Calculation of additional savings by the difference: 'apparent total' savings minus trend- and price-related savings

9. Building shell and heating for residential sector

9.1 Indicators and variables to estimate energy savings

'Apparent total' energy savings are calculated from the variation of the unit energy consumption per m² for thermal uses, with climatic corrections, between 2007 and 2016.

Additional savings may be calculated by removing the effect of the trend and the average market price variation of heating fuels.

9.2 Modelling of additional savings: unit energy consumption per m² for heating

Since national measures are related to legislation for building renovation or equipment, it is difficult to capture a direct impact.

The modelling of the unit consumption is done through a regression analysis with an average fuel price, a trend and the income (represented by the private consumption):

$$Ln(UC) = A * Ln(P) + B * t + C * ln(PC) + K$$

with : UC : Unit consumption per m² for thermal uses

A: price elasticity ($A < 0$)

P : average fuel prices for households (price of light fuel oil, coal, gas, and electricity weighted by the energy consumption)

B: trend ($B < 0$)

C: income elasticity ($C > 0$)

PC: private consumption

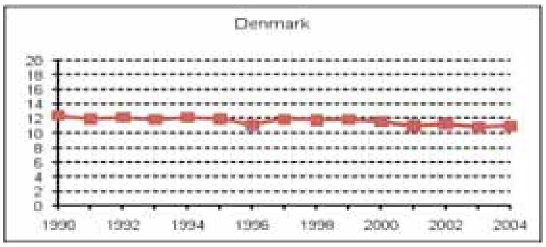
9.3 Classification of countries

Three groups of countries can be identified:

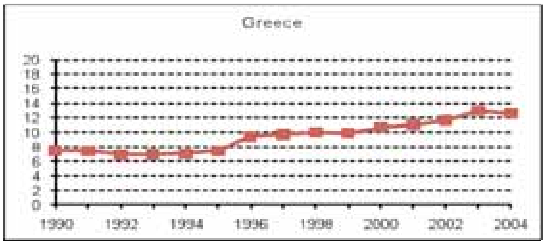
1. Countries with a stabilisation of the unit energy consumption (i.e., with no 'apparent total' energy savings): case of Italy, Sweden, Denmark, Finland, Germany, UK.
2. Countries with a decrease of the unit energy consumption, i.e. with positive 'apparent total' energy savings: case of Austria, France
3. Countries with an increase of the unit energy consumption: case of Greece; for this group, it is difficult to measure energy savings. Only additional energy savings could be measured compared to the trend and the effect of energy market prices.

Unit energy consumption per m² for heating (koe)

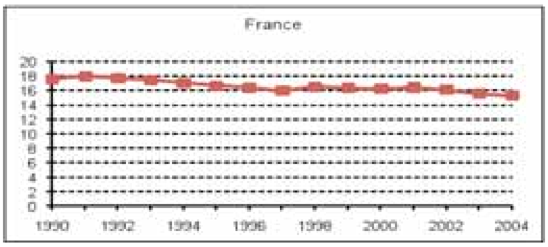
Case of a stabilisation



Case of an increase



Case of a reduction



9.4 Example of calculation of additional savings

The calculation is carried out in three stages, as follows:

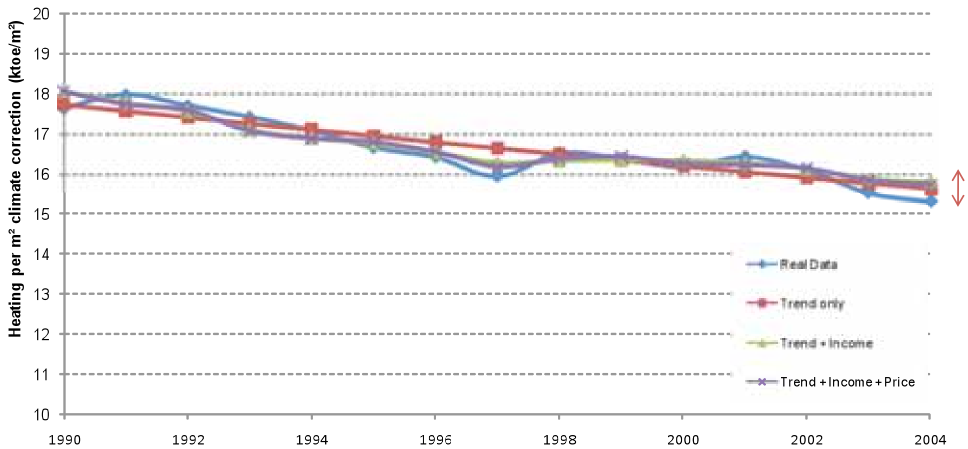
- **Stage 1:** Modelling of a trend and the price effect (see figure below in the case of France)
- **Stage 2 :** Calculation of the price effect over the period 2008 - 2016
- **Stage 3:** Calculation of additional energy savings as the difference between 'apparent total' energy savings (cf. chapter 9.1; may be negative) and savings induced by price and trend (which may be negative as well).

➢ **Final regression with a lag time of 2 years for the fuel price:**

ln(RBS) = -0.025 t – 0.086 ln(P) + 0.88 ln(I) – 8.5

➢ Measures taken in 2001: Building insulation standard of 2001 and Energy information centers → Energy Savings

France



10.Car, bus and truck stock

10.1 Indicators to estimate energy savings

Change in vehicle efficiency is measured:

- from the variation in the average specific energy consumption of the stock of cars (l/100km) (with a correction on car size if data available)
- from the variation in the unit energy consumption per tkm (koe/tkm) for trucks or specific energy consumption (l/100 km) for trucks and buses

'Apparent total' energy savings in 2016 (or at year t) are calculated as:

- For cars: the difference of specific energy consumption between 2016 and 2007 multiplied by an average distance travelled by car and the number of vehicles
- For trucks: the difference of unit or specific energy consumption between 2016 and 2007 multiplied by the road traffic of goods (tkm or km, depending on the indicator used,

It should be noted that this indicator includes the energy consumption of new cars sold between 2007 and 2016. The results of a calculation of the energy savings for new cars (cf. chapter 4) must, therefore, not be added to the results of the calculation with this indicator.

The effect of change in the size of cars is interesting to consider but difficult to implement due data limitations. If the trend is towards larger or more powerful cars, the energy savings are underestimated by taking into account the variation in the specific consumption. If there is a trend towards smaller or less powerful cars, the resulting savings are included in the measured savings. Within these limits, the 'apparent total' energy savings may be a good approximation of all energy savings.

10.2 Modelling of additional savings: specific consumption of vehicles

The modelling of the trend in the specific consumption of vehicles is done through a regression analysis with two variables:

- Time to capture an autonomous trend
- Average price of gasoline and diesel

The modelling equation is as follows: $\ln(SC) = T * t + A * \ln(P) + K$

- SC : specific/unit consumption
- T: trend
- A: price elasticity (<0)
- P: motor fuel price

10.3 Methodology of calculation of additional savings

The calculation is carried out in 3 stages, as follows:

- **Stage 1 :** The energy savings induced by the technological trend and price effects are calculated for each type of vehicle separately with the same methodology as the total energy savings, based on the estimation of specific energy consumption induced by trend and energy market prices.

- **Stage 2 :** 'Apparent total' energy savings for all vehicles are obtained by summing 'apparent total' energy savings for gasoline cars, for diesel cars, and for trucks; Energy savings induced by technological trend and price effect is then obtained by summing what is calculated for gasoline cars, diesel cars, and trucks.
- **Stage 3:** Additional savings for all vehicles are calculated by the difference for each type of vehicle separately between 'apparent total' energy savings and trend- and price-related savings

The following equations are used for cars (results are in ktoe):
TES = Total of TEScars with

$$TEScars = (SCcars_{2016} - SCcars_{2007}) * NCRcars_{2016} * ADTcars_{2016} * Conv$$

With TES : Total Energy Savings
cars: gasoline cars, diesel cars
SC = Specific energy Consumption (in l/100km)
NCR : Stock of vehicles
ADT : Average Annual Distance travelled
Conv : Conversion coefficient (1.07 X 0.75 for gasoline and 1.035 X 0.85 for diesel)

The following equations are used for trucks and light duty vehicles:

$$TES = (UC_{2016} - UC_{2007}) * RTG_{2016}$$

With TES : Total Energy Savings
UC = Unit energy Consumption (in koe/tkm)
RTG : Road traffic of goods (in Gtkm)

11. Modal shift in passenger transport

11.1 Indicators and variables to estimate energy savings

Modal shift is captured by the variation of the share of land public transport (rail, tram, metro and bus) in total traffic of passengers measured in passenger-km (total includes cars, domestic air and public). Energy savings are linked to an increase in the share of public transport.

'Apparent total' energy savings in 2016 (or at year n) are calculated as the difference of public transport's share between 2016 and 2007 multiplied by the total traffic (in passenger- km) in 2016 multiplied by the difference of unit energy consumption of cars/air and public transport in 2016 (Mtoe/pkm).

11.2 Modelling of additional savings: share of public transport

Change in modal shift, and thus the related energy savings, can be explained by the following factors:

- Autonomous trend
- Cost difference by mode
- Facilitating measures to promote modal shift in passenger transport (After / before 1995)
- Other transport measures (relative investment in road/rail infrastructure

Taking into account the data availability as time series, the modelling of the share of public transport (%) has been done through a regression analysis with two variables:

- Time to capture an autonomous trend
- Average fuel price to capture price differentials

The price elasticity was introduced with a lag time of 2 years to well capture the impact of price.

For modelling the trends, 3 methods have been used:

- A log-linear trend : Ln (RBS) = T * ln(t) + A * ln (P) + K

with T: trend; A: price elasticity (>0) ; P: average fuel price

- A logistic trend to account for a lower limit in the share of public transport

RBS = RBS(0) – (1 - RBS(0)) / (1+exp(T * ln(t) + A * ln (P) + K))

with: RBS(0): the lowest limit for rail and bus share

- A trend explained by the GDP/capita (GDP replaces time in regression analysis) (Schafer method) : Ln (RBS) = T * ln(GDP/cap) + A * ln (P) + K

11.3 Classification of countries

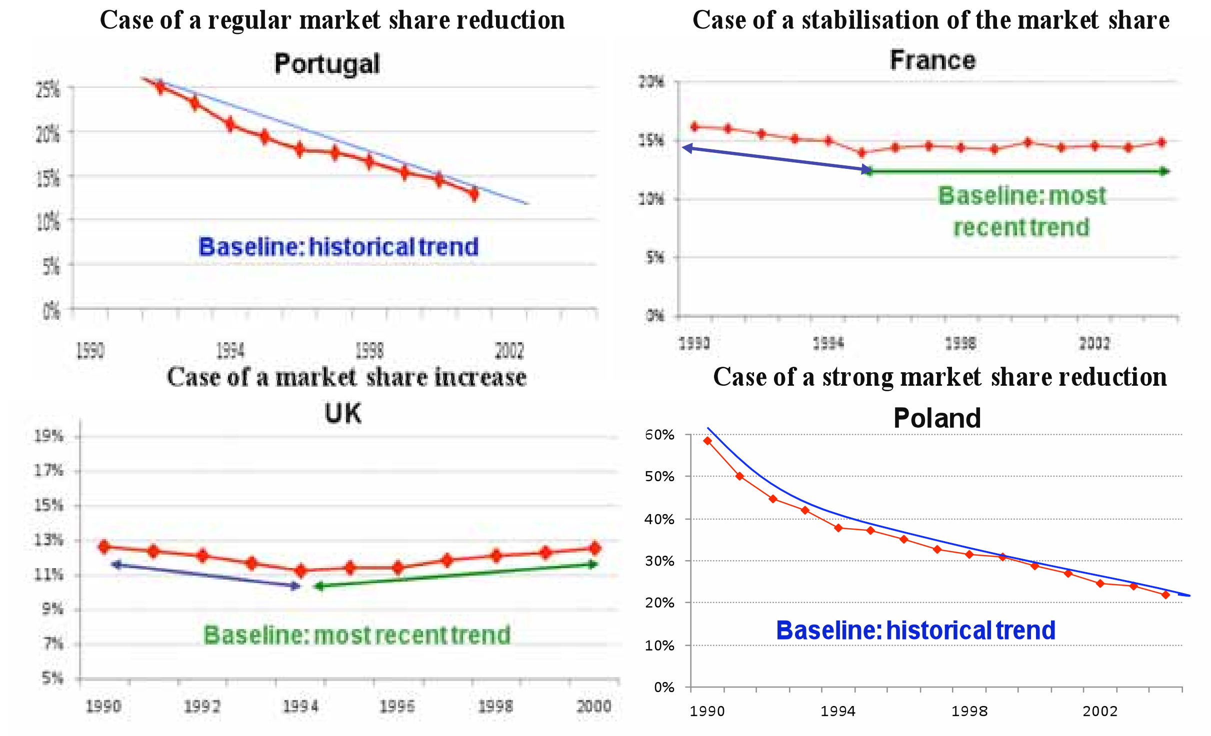
Four groups of countries can be considered:

1. Countries with a strong market share decrease, mainly new EU member countries: case of Estonia, Czech Republic, Slovak Republic, Slovenia, Poland, Lithuania

2. Countries with a slow and regular market share reduction: case of Luxembourg, Ireland, Finland, Portugal
3. Countries with a stabilisation of market share: case of France, Greece, Norway, Italy, Germany, Denmark, Austria, Netherlands
4. Countries with a market share increase (i.e. with already energy savings): case of Belgium, UK, Sweden, Hungary, Spain

A case study was carried out on 4 countries representative of the four groups: Poland, Portugal, France, and UK.

Trends in the share of public transport in total passenger traffic



11.4 Example of calculation of additional savings

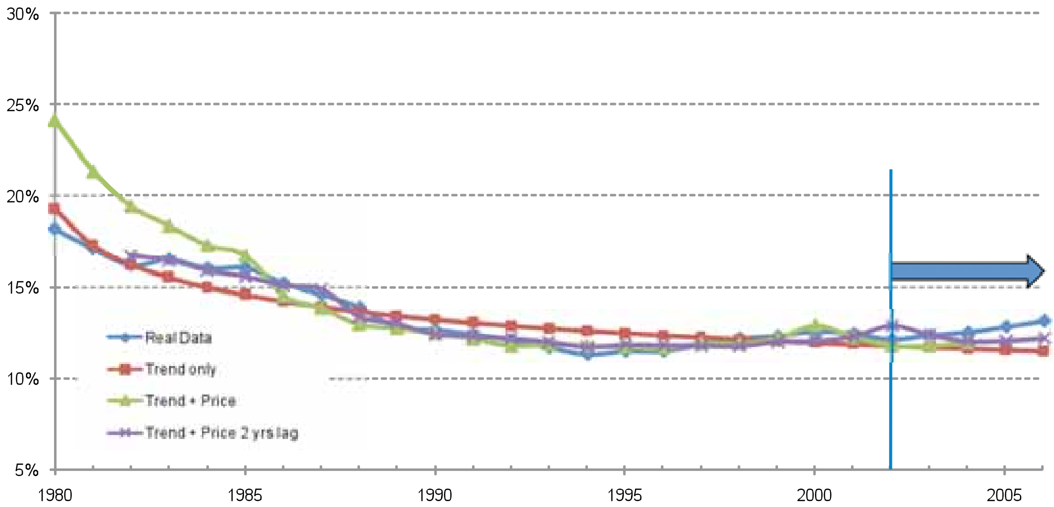
The calculation at year n will be carried out in 3 stages, as follows:

- **Stage 1**: Modelling of baseline modal share, i.e., change in modal share linked to autonomous trend and energy market price effect;
- **Stage 2**: Modelling of baseline energy consumption, using the baseline modal share
- **Stage 3**: Modelling of baseline energy savings (can be negative!) and calculation of additional savings as the difference between actual energy consumption (using the actual modal share) and baseline energy consumption

11.5 Case studies

- **Modelling of baseline modal share: case of a log-linear trend**

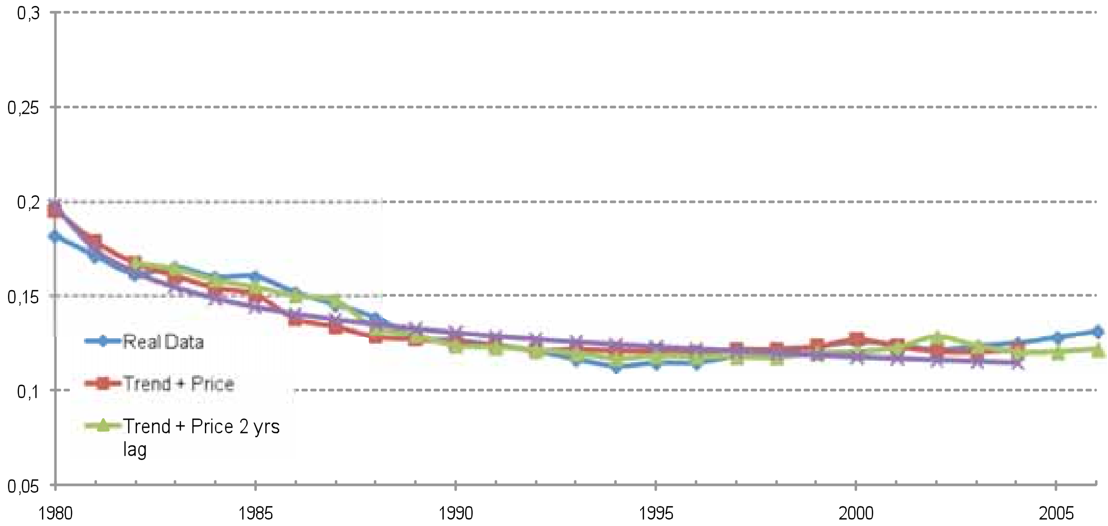
For UK[6], the final regression with a lag time of 2 years for the fuel price is: ln(RBS) = -0.16 ln (t) + 0.46 ln(P) – 1.48 with R^2 = 0.95



- **Modelling of baseline modal share: case of a logistic trend**

The final regression with a lag time of 2 years for the fuel price is:

RBS = 0.05 – (1 – 0.05)/(1 + exp(-0.27 ln (t) + 0.8 ln(P) – 1.42)) with R^2 = 0.95

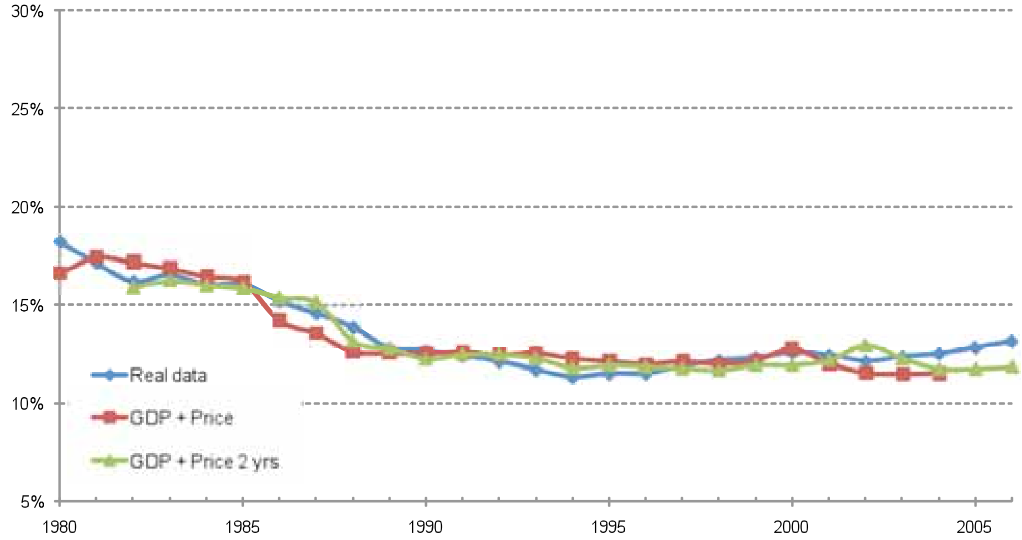


[6] A Ten Year Transport Plan has been implemented in 2000 with effects possibly starting as of 2002.

➢ **Modelling of baseline modal share taking into account the GDP/cap**

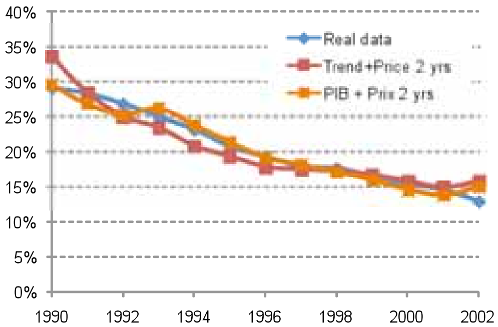
The final regression with a lag time of 2 years for the fuel price is:

$$\ln(RBS) = -0.6 \ln(GDP/cap) + 0.61 \ln(P) - 0.06 \text{ with } R^2 = 0.93$$



➢ **Other case studies**

Case of Portugal



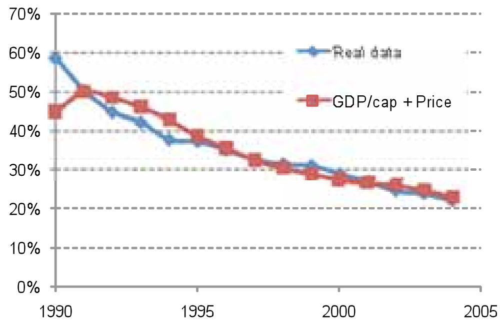
➢ **Final regression with a lag time of 2 years for the fuel price (Trend + Price)**

$$\ln(RBS) = -0.21 \ln(t) + 0.81 \ln(P) - 0.948$$

➢ **Final regression with a lag time of 2 years for the fuel price (GDP/cap + Price)**

$$\ln(RBS) = -1.75 \ln(GDP/cap) + 0.87 \ln(P) + 2.96$$

Case of Poland



➢ **Final regression with a lag time of 2 years for the fuel price (GDP/cap + Price)**

$$\ln(RBS) = -1.43 \ln(GDP/cap) + 0.03 \ln(P) + 0.88$$

11.6 Conclusion

Price elasticities are not significant for countries from groups 1 and 2: for these groups, test statistics are much better considering the GDP/cap as a variable.

In general, logistic trends give better results than log-linear trends.

12. Industrial electricity use

12.1 Indicators and variables to estimate energy savings

The indicator used to measure electricity savings is the ODEX indicator. ODEX is an index that aggregates the variation in the unit energy consumption index (electricity consumption/index production) of each industrial sector between t-1 and t at the level of the whole sector. Such an indicator is cleaned from structural changes between industrial sectors. If ODEX increases, it may indicate negative energy savings but also and more probably reflect the impact of other factors (decrease in the load factor of plants due to a slowdown in industrial growth, increased automation…).

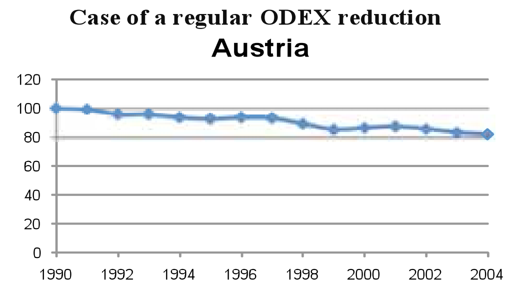
For calculating savings related to ESD, the electricity ODEX is calculated for all non-ETS branches: chemicals, food, textile/leather, machinery, transport equipment, other manufacturing industries, mining, wood, construction.

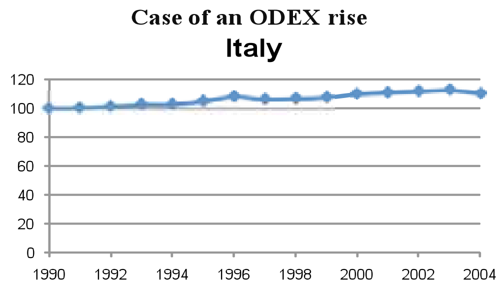
12.2 Classification of countries

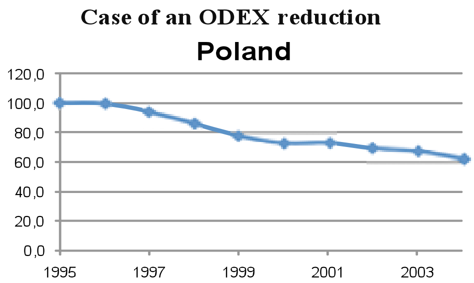
Three groups of countries can be considered with respect to the trend in the indicator:

1. Countries with a regular reduction of the indicator value: case of Austria, Luxembourg, Sweden, Slovenia, Norway, Greece
2. Countries with a strong decrease of the indicator value: case of Poland, Bulgaria, Estonia, Hungary, Latonia, Lithuania, Romania, Slovakia
3. Countries with an ODEX rise: case of France, Italy, UK, Germany, Belgium, Spain, Denmark, the Netherlands, Czech Republic

Countries of group 1 and 2 have apparent electricity savings, whereas for countries of group 3 there is an increase in the electricity use per unit of output. For this last group, this does not necessarily mean that there is no saving, as part of the increase may be due to substitutions from fuels to electricity; for these countries, 'apparent total' electricity savings cannot be measured in reference to a value at a base year, as done usually with top-down methods; however, a change away from the baseline trend may be considered as additional energy savings, as tested in a case study below.







12.3 Modelling of additional savings: ODEX

The modelling of the ODEX indicator is done through regression analysis with three variables: time to capture an autonomous trend, the average electricity price and the value added to measure the impact of business cycle. The modelling equation is as follows:

Ln (ODEX) = A * Ln (VA) + B * t +C * ln(P)+ K

with

A, value added elasticity (A < 0) ;

B, trend (B > 0) and

C, Price elasticity(C < 0)

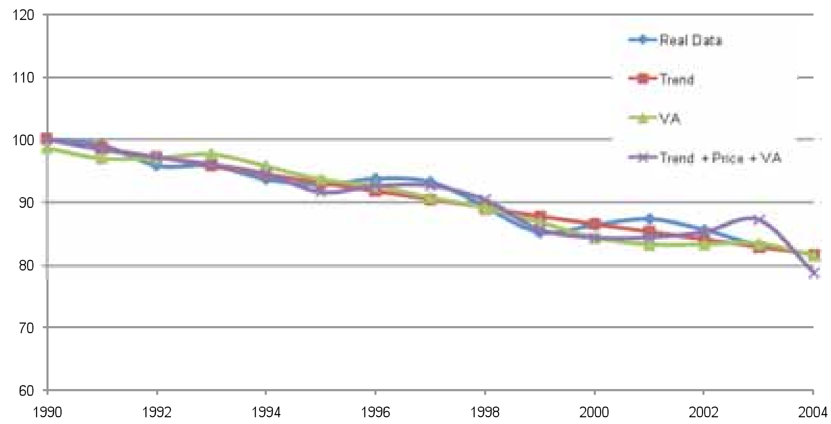
Case of Austria

- **Final regression :**

ln(ODEX) = -0.014 t + 4.62

Or ln(ODEX) = -0.49 ln(VA) + 9.63

Or ln(ODEX) = -0.012 t – 0.94 ln(VA) – 0.63 ln(P) + 15.38



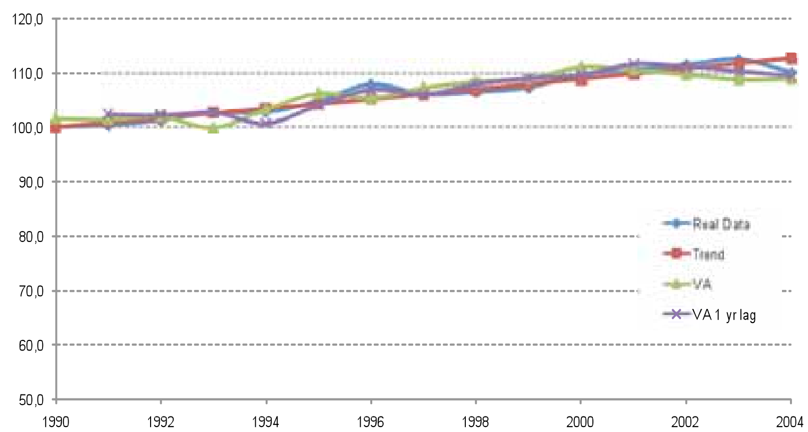
Case of Italy

- **Final regression :**

ln(ODEX) = 0.008 t + 4.6

ln(ODEX) = 0.59 ln(VA)- 2.63

ln(ODEX) = 0.57 ln(VA (t-1)) - 2.39

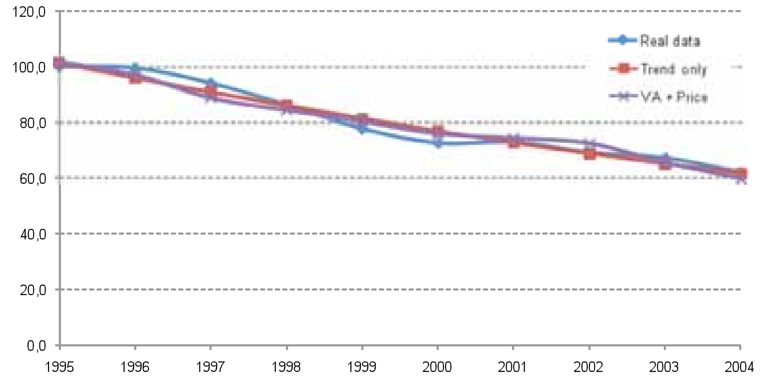


Case of Poland

- **Final regression :**

ln(ODEX) = -0.05 t + 4.95

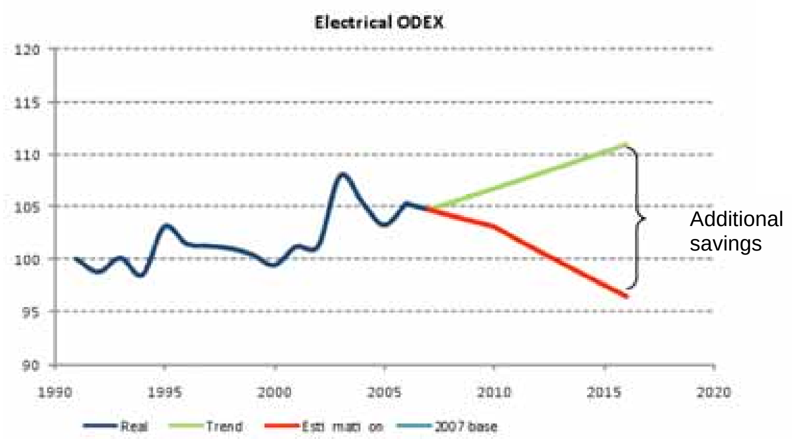
Or ln(ODEX) = -0.77 ln(VA) - 0.29 ln(P) + 12.6



12.4 Example of calculation of additional savings

The calculation is carried out in 3 stages, as follows:

- **Stage 1:** Modelling of a trend and price effect over a period without national measures
- **Stage 2:** Calculation of the price effect over the period 2008 - 2016
- **Stage 3:** Calculation of additional savings as the difference between 'apparent total' energy savings (which may be negative, cf. chapter 12.2) and savings induced by trend, energy market price increases, and value added at 2016.

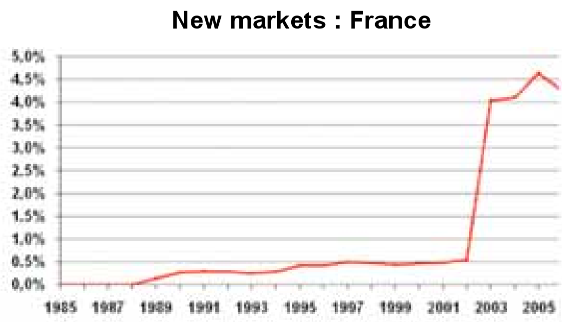


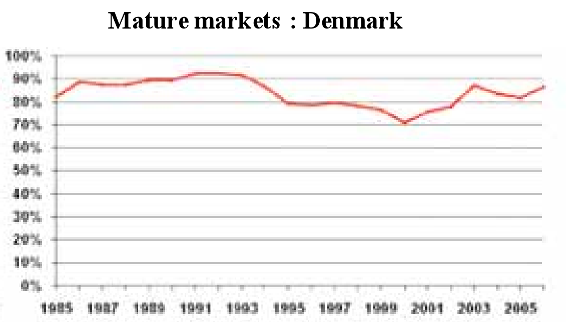
13. Industrial CHP

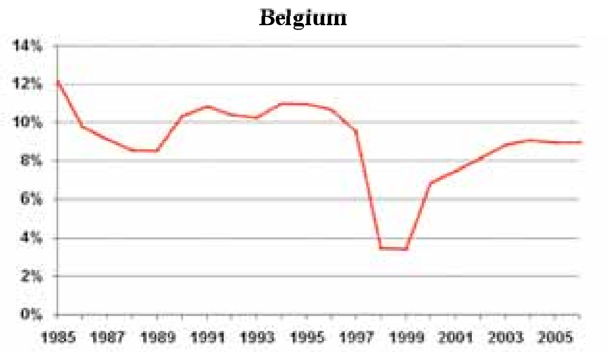
13.1 Indicators and variables to estimate energy savings

The indicator used to calculate the energy savings is a diffusion indicator: the share of industrial electricity production from CHP in electricity consumption of industry (%).

'Apparent total' energy savings at year t are calculated from the variation in the share of electricity production from CHP between 2016 and 2007 multiplied by the electricity consumption of industry in 2016 and the relative efficiency ratio between heat and electricity. It corresponds to the amount of heat indirectly produced by CHP power plants.







13.2 Modelling of additional energy savings: share of industrial CHP

The modelling of the share of industrial electricity production from CHP in electricity consumption of industry is done through a regression analysis with one variable: the average electricity price in industry.

The autonomous trend is in general negligible: the diffusion of CHP is linked to the implementation of recent policy measures.

The modelling equation is as follows: Ln (CHP) = A * ln (P) + K

- CHP : Share of electricity production from CHP
- A: price elasticity (>0)
- P: electricity price for industry

13.3 Example of calculation of additional savings

The calculation is carried out in 3 stages, as follows:

- **Stage 1:** Calculation of the 'apparent total' energy savings from the variation in the share of electricity production from CHP between 2016 and 2007 multiplied by the electricity consumption of industry in 2016 and the relative efficiency ratio between heat and electricity. It corresponds to the amount of heat indirectly produced by CHP power plants.
- **Stage 2:** Calculation of the energy savings induced by energy market prices effects
- **Stage 3:** Calculation of additional savings by difference : 'apparent total' savings minus price-related savings

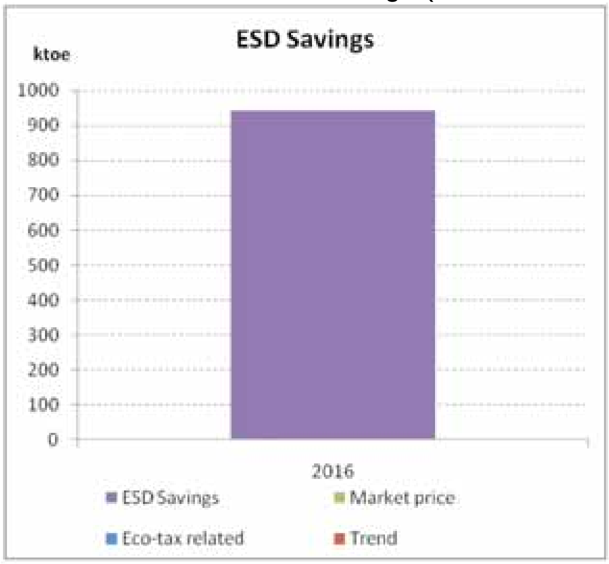
13.4 Case study

To illustrate the calculation of energy savings linked to the diffusion of cogeneration a, a case study was simulated assuming the following development up to 2016[7]:

- Increase of the share of CHP electricity from 11% in 2007 to 15% in 2016
- Increase of the electricity consumption of industry by 0.15%/year
- No autonomous trend (i.e. outside of market price effect, all development is assumed to be policy driven)
- Price elasticity equal to 0.1

Price related savings represent only 0.5% of energy savings in 2016.

Estimation of Additional savings (result of example calculation)



[7] In reality, the calculation will have to be made on observed data over the period 2007-2016.

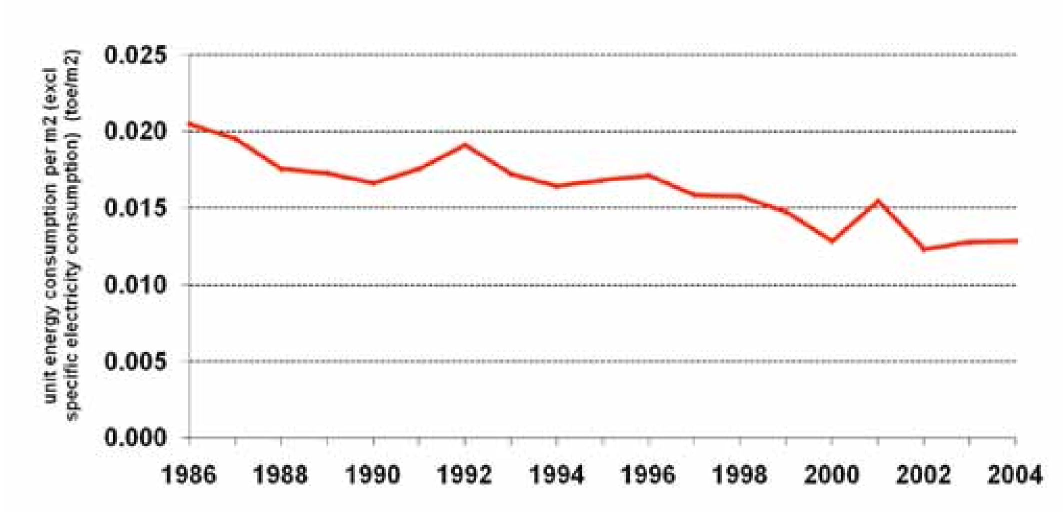
14.Building shell and heating for tertiary sector

14.1 Indicators and variables to estimate energy savings

'Apparent total' energy savings at year t are calculated from the variation in the unit energy consumption (per m² or employee) between year t and reference year/t-1 multiplied by the m2 area or number of employee

Additional savings are calculated by difference: 'apparent total' energy savings minus trend- and price related savings.

Case of France



14.2 Modelling of additional energy savings: unit consumption per m² for thermal uses

The indicator in modelled through a regression analysis with two variables:

- Time to capture an autonomous trend
- Average fuel prices for heating

The modelling equation is as follows : $\text{Ln}(UC) = A * t + B * \ln(P) + K$

with : UC : unit consumption per m² or employee for thermal uses
A, trend ($A < 0$)
B, price elasticity ($B < 0$)

14.3 Example of calculation of additional savings

The calculation is carried out in 3 stages, as follows:

- **Stage 1:** Modelling of a trend and the price effect over a period without national measures
- **Stage 2:** Calculation of the price effect over the period 2008 - 2016
- **Stage 3:** Calculation of additional savings as the difference between 'apparent total' energy savings and savings induced by trend and energy market prices at 2016.

15. Energy taxation

15.1 Indicators and variables to estimate energy savings

'Apparent total' energy savings at year t are calculated from the variation of the total final ODEX between t and 2007. To avoid double counting, such savings cannot be cumulated with other savings that already include the effect of taxation at the end-use or sectoral level.

15.2 Modelling of additional savings: modelling of the ODEX

Additional savings will be linked to tax variation. To capture the trend and price effect, the regression analysis has to be made over a period, over which the taxation did not change. The modelling of the ODEX is done through a regression analysis with two variables:

- Time to capture an autonomous trend
- Average energy price for final consumers to measure the impact of prices

The modelling equation is as follows: Ln (ODEX) = T * t + A * ln (P)+ K
With T: trend, A: price elasticity (<0) and P: energy price

The savings linked to energy price increase will be divided into two parts: one linked to the energy market price increase and one linked to the energy tax increase.

15.3 Methodology of calculation of additional savings

The calculation is carried out in 3 stages, as follows:

- Stage 1 : Calculation of the 'apparent total' energy savings from the ODEX variation;
- Stage 2: Calculation of the energy savings induced by price increase using a price elasticity (default value)
- Stage 3: Calculation of tax related energy savings by applying the price elasticity to the variation of the tax.

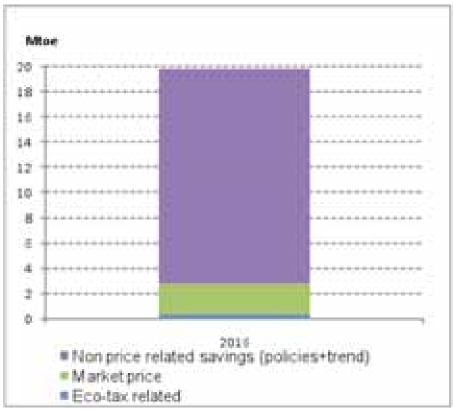
15.4 Case study

To illustrate the calculation of energy savings linked to a tax increase, a case study was simulated assuming the following development up to 2016[8]:

- Decrease of the ODEX by 1%/year until 2016
- Increase of the average energy price by 1.4%/year until 2016, including a tax increase by 10% in 2010
- Price elasticity = -0.1 ("default value")

In this case study the impact of tax on energy savings is quite low: it contributes for 0.31% to the total energy savings in case of an increase by 10% in 2010; 1% for an increase by 30% and 1.6% for an increase by 50%

[8] In reality, the calculation will have to be made on observed data over the period 2007-2016.


Mtoe
20
18
16
14
12
10
8
6
4
2
0
2016
Non price related savings (policies+trend)
Market price
Eco-tax related