ODYSSEE-MURE

Definition of ODEX indicators in ODYSSEE data base

Content

1. Introduction

1.1. General definition

ODEX is the index used in the ODYSSEE-MURE project to measure the energy efficiency progress by main sector (industry, transport, households) and for the whole economy (all final consumers).

For each sector, the index is calculated as a weighted average of sub-sectoral indices of energy efficiency progress; sub-sectors being industrial or service sector branches or end-uses for households or transport modes.

- The sub-sectoral indices are calculated from variations of unit energy consumption indicators, measured in physical units and selected so as to provide the best “proxy” of energy efficiency progress, from a policy evaluation viewpoint. The fact that indices are used enables to combine different units for a given sector, for instance for households kWh/appliance, koe/m2, tep/dwelling…
- The weight used to get the weighted aggregate is the share of each sub- sector in the total energy consumption of the sub –sectors considered in the calculation.

A value of ODEX equal to 90 means a 10% energy efficiency gain.

Box 1: Principle of calculation of ODEX[1]

Considering two sub-sectors with a share of the consumption of 60% and 40% respectively in the base year and a change in the unit consumption from 100 to 85 for the first sub-sector and 100 to 97.5 for the second, the weighted average index with a simple weighting system is:
0.6*(85/100)+0.4* (97.5/100) = 90

ODEX indicators represent a better proxy for assessing energy efficiency trends at an aggregate level (e.g. overall economy, industry, households, transport, services) than the traditional energy intensities, as they are cleaned from structural changes and from other factors not related to energy efficiency (more appliances, more cars…).

- **How to manage negative energy efficiency improvement (NEW)**

A decrease in the specific energy consumption indicators indicates that energy efficiency has been improving. However, in some cases the observed indicator trend shows an increase, resulting in negative energy efficiency improvement.

This increase in the specific consumption may be due to an inefficient use of the equipment, as it is often observed during economic recession; this is particular true in industry or transport of goods. For instance in industry, in a period of recession, the energy consumption does not decrease proportionally to the activity as the efficiency of most equipment drops, as they are not used at their rated capacity, and, in addition, part of this consumption is independent of the production level. In that case, the technical energy efficiency does not decrease as such, as the equipment is still the same, but it is used less efficiently. It is therefore suggested to separate the technical efficiency from the observed (or apparent) energy efficiency. The apparent energy efficiency index can be replaced by a **technical**

[1] As explained below the exact weighting system is slightly different to guarantee a convergence with the mode of calculation of energy savings in top-down methods.

energy efficiency index, by considering that if the specific consumption for a given sub sector increases its value will be kept constant in the calculation of the technical index.

When publishing results for the index, it should be specified if it measures the apparent or technical energy efficiency and what end-uses may have been removed for the calculation because of hidden structural changes.

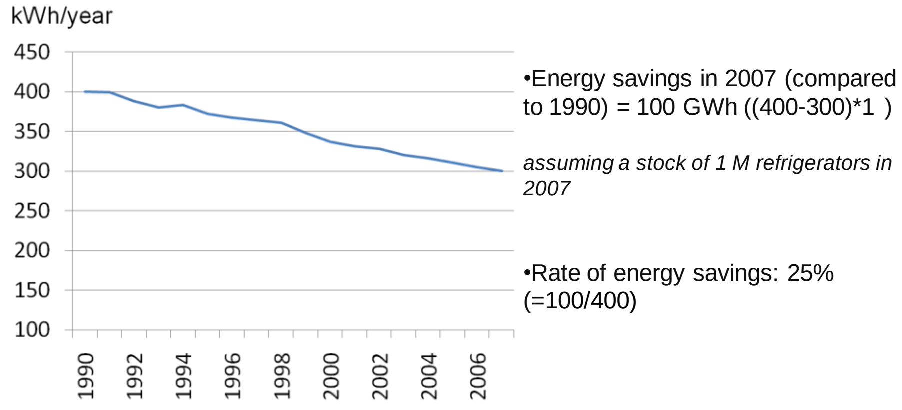
1.2. ODEX and energy savings

1.2.1. Energy savings

Top-down energy savings are derived from the multiplication of the variation of a unit energy consumption by an indicator of activity over a reference period. For instance, the energy savings of a given appliance (e.g. refrigerators) are derived from the variation in the average specific energy consumption per appliance (in kWh/year) multiplied by the stock of refrigerators[2]; for example, a reduction of the specific consumption of refrigerators from 400 to 300 kWh in a country with one 1 million of refrigerators will result in total electricity savings equal to 100 GWh (Figure 1).

[2] For market diffusion indicators, the energy savings are derived from the increase in the market share; for instance, energy savings from solar water heaters will be calculated from the diffusion of solar water heaters (in terms of installed stock in m^2) multiplied by a coefficient expressed in terms of kWh/m^2.

Figure 1: Example of calculation of top-down energy savings (refrigerators)



1.2.2. Choice of the weighting system

The weighting system used to calculate ODEX has been defined in such a way that ODEX is equal to a rate of energy savings, i.e. the ratio between the actual energy consumption (E) of the sector in year t and actual energy consumption (E) without energy savings (ES):

$$ODEX = (E/(E+ES)) * 100.$$

The energy savings are calculated as the sum of energy savings of each underlying sub-sector /end-use without:

$$ODEX = E/(E+ES) * 100$$

For instance, if the actual consumption of the sector is 50 Mtoe and if the energy savings are 10 Mtoe, ODEX is equal to (50/ 60)*100 = 83.3. Such an index of 83.3 is thus equivalent to a rate of energy savings of 16.7%.

Energy saving (ES) can be easily derived from the index from the previous formula:

$$ES = E*((100/ODEX)-1)$$

For instance , if the actual consumption of the sector is 50 Mtoe and if the ODEX is equal to 90, the energy savings are equal to 50*((100/90)-1)= 5.56 Mtoe

Table 1 illustrates the calculation in the case of the cement industry.

Table 1: Energy efficiency index and energy savings: case of cement

		t_0 = 2000	t = 2005
Production (A)	Mt	25	30
Consumption (E)	Mtoe	1.9	2.1
Unit consumption (UC)	toe/t	0.076	0.070
Energy savings	Mtoe		0.18
Energy effcicncy index	index		92

The energy savings measures the impact of the variation of the unit energy consumption per tonne of cement. It is calculated by multiplying the cement production by the variation of unit consumption (UC) between the base year 2000 and year t= 2005: $A_t * (UC_0 - UC_t)$ = (0.076-0.07)*30= 0.18 Mtoe.
The energy efficiency index of the cement industry in 2000 is then 2.1/(2.1+0.18)=92, which means that energy efficiency improved by 8%.

1.2.3. Weighting system in ODEX

The variation of the weighted index of the unit consumption between t-1 and t is defined as follows: $I_{t-1}/I_t = \sum_i EC_{i,t} .* (UC_{i,t} / IUC_{i,t-1})$ with UC_i: unit consumption index of sub-sector i and EC_i: share of sub-sector i in total consumption.

The value at year t can be derived from the value at the previous year by reversing the calculation: $I_t / I_{t-1} = 1/(I_{t-1}/I_t)$,

ODEX is set at 100 for a reference year and successive values are then derived for each year t by the value of ODEX at year t-1 multiplied by I_t / I_{t-1}.

Table 2 illustrates the calculation in a simple example of two transport modes.

Table 2: Weighted energy efficiency index: simplified case of industry with 2 branches

Energy efficiency index	1990	1991	1992	1993
Chemicals	100	98	96	96
Steel	100	97	87	83
Total	100	97,4	90,9	88,6

$IE_{91} = IE_{1990}$ x (98 x 0.48 + 97 x 0.52) = 97,4
$IE_{92} = IE_{1991}$ x (96/98 x 0.44 + 87/97 x 0.56) = 90.9
$IE_{93} = IE_{1990}$ x (96/96 x 0.46 + 83/87 x 0.54) = 88,6
➔ gains of 11.4% in 1993 compared to 1990

Annex 1 gives more details on the convergence between the ODEX and the rate of energy savings.

1.3. Base year for the ODEX calculation: 1990 versus t-1

Two alternative reference years can be used: a fixed base year or a sliding reference year (year t-1).

In the fixed base year approach, all variations in unit consumption are measured in relation to a fixed base year (e.g. 1990); in other words, energy efficiency progress is measured compared to the situation of 1990 (i.e. the energy performance of 1990). The variation of the ODEX is obtained by weighting the gains of each sector between t and 1990. The drawback of this approach is that the results are strongly influenced by the situation at the reference year.

The calculation used in ODYSSEE is based on a sliding base year, which means that energy efficiency gains are measured in relation to the previous year. ODEX cumulates the incremental energy savings from one year to the other.

1.4. Calculation of ODEX as a 3 years moving average

The trends observed for some sectors or end-uses, especially for space heating are very irregular, which results in strong fluctuations in the ODEX, that are difficult to understand as energy efficiency progress should normally change smoothly (incremental technical change). Such fluctuations can be linked to various factors: imperfect climatic corrections, especially with warm winters, behavioural factors, influence of business cycles, imperfection of statistics, especially for the last year.

To reduce the fluctuations, ODEX is calculated as a 3 years moving average. The value used for year t is the average of t-1, t and t+1. This method is traditionally used in statistics[3].

1.5. Case of sub-sectors not accounted for in ODEX

Some sub-sectors are not accounted for in ODEX, such as mining, construction, other manufacturing industries, small electrical appliances, lighting, services. The reason is that energy efficiency progress is difficult to capture with the existing indicators (e.g. electricity consumption per dwelling or employee), that are usually increasing because of more appliances and the diffusion of air conditioning in services. The implicit assumption in the mode of calculation of the ODEX is that all these sub-sectors have the same energy efficiency gains as the sector average.

2. Industry

For industry, the evaluation is carried out at the level of 10 branches:

- 4 main branches: chemicals, food, textile & leather and equipment goods;
- 3 energy intensive branches: steel, cement and pulp & paper
- 3 residual branches: other primary metals (i.e. primary metals minus steel), other non-metallic minerals (i.e. non-metallic mineral minus cement) and other pulp, paper and printing (i.e. mainly printing).

The unit consumption is expressed in terms of energy used per ton produced for energy intensive products (steel, cement and paper) and in terms of energy used related to the production index for the other branches.

Unit energy consumption captures the energy efficiency development better than traditional energy intensities (per unit of value added). For some branches the trends shown include also some non-technical changes, especially in the chemical industry the shift to light chemicals, due to the fact that this sector is not sufficiently disaggregated.

[3] For the last year, the average is based on 2years only as well as for the second year. A second method could have been to take for year t the average of t-2, t-1, and t. This method, which is used officially in the Netherlands, however always underestimates the gains achieved.

3. Transport

For the transport sector, the evaluation is carried out at the level of 8 modes or vehicle types: cars, trucks, light vehicles, motorcycles, buses, total air transport, rail, and water transport. The overall energy efficiency index aggregates the trends for each transport mode in a single indicator for the whole sector.

For cars, the energy efficiency is measured by the specific consumption, expressed in litre/100km.

For the transport of goods (trucks and light vehicles), the unit consumption per ton-km is used, as the main activity is to move goods.

For other modes of transport various indicators of unit consumption are used, taking for each mode the most relevant indicator given the statistics available:

- toe/passenger for air transport,
- goe/pass-km for passenger rail,
- goe/t-km for transport of goods by rail and water,
- toe per vehicle for motorcycles and buses.

4. Households

For households, the evaluation is carried out at the level of 3 end-uses (heating, water heating, cooking) and 5 large appliances (refrigerators, freezers, washing machines, dishwashers and TVs).

For each end-use, the following indicators are considered to measure efficiency progress:

- Heating: unit consumption per m2 at normal climate (toe/m2)[4]
- Water heating: unit consumption per dwelling with water heating
- Cooking: unit consumption per dwelling
- Large electrical appliances: specific electricity consumption, in kWh/year/appliance

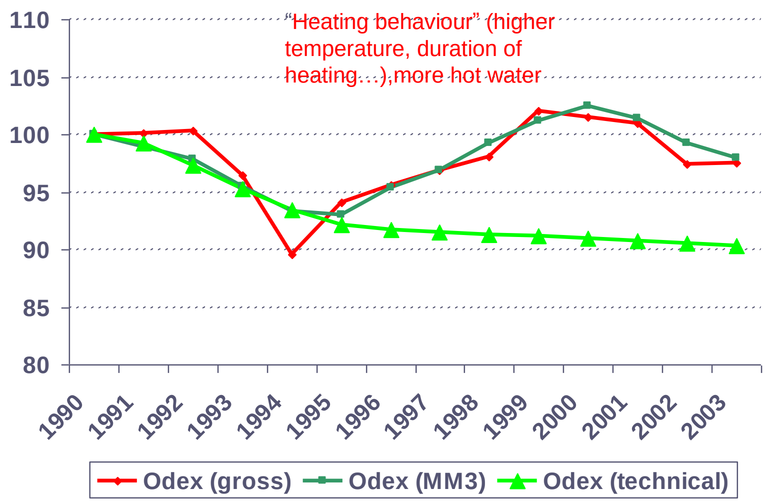
In some countries, there is a slow down or even a deterioration of energy efficiency progress for heating since the mid-nineties. In a few other countries, there is even an overall increase in the ODEX since 1990. Such changes should not be interpreted as a reduction of energy efficiency, as technical savings have not actually stopped, with all the extra policy measures implemented in the late nineties and the continuous addition of new dwellings that are much more efficient. This situation rather reflects negative behavioural savings, due to higher indoor temperature. This means that the actual energy efficiency progress is under estimated, with the standard calculation of the ODEX, as proposed above.

To separate out the influence of behavioural factors, a technical ODEX is calculated and used to measure the energy efficiency progress.

- First of all, by accounting for energy efficiency gains linked to the penetration of more efficient new dwellings

- Secondly, by separating behavioural and technical changes by assuming that technical efficiency cannot reverse: it may not improve from one year to the other but cannot be "worse"

The difference between the technical ODEX and the gross ODEX shows the influence of behavioural factors (see Figure below). This calculation of a technical ODEX could even be further improved by estimating the technical gains associated to the diffusion of efficient technologies (eg CFL, condensing boilers).



Annex 1[5]

Methodology of calculation the energy efficiency index: equivalence between an average index and the method of effects

Assume an energy efficiency index is available for each of a number of energy consuming sectors[6]. At the most detailed sector disaggregation level, this index would be a specific energy consumption (e.g. an number of TJ/t of flat glass), a ‘unit consumption’ (energy consumption/activity variable) or an index proportional to one of those.

This note suggests a way of constructing an *aggregate energy efficiency index*, i.e. an energy efficiency index for the aggregation of these sectors. It is a *bottom-up* index, because constructed from specific energy consumptions or unit consumptions at the most detailed sector disaggregation level allowed by the available data.

This aggregate index is defined as follows. If I_t is its value for year t, then the ratio I_t/I_{t-1} is defined as the energy consumption of year t divided by the energy consumption that would have taken place in year t had the unit consumptions been those of year t-1.

Hence the formula:

$$\frac{I_t}{I_{t-1}} = \frac{\sum_i EC_{i,t}}{\sum_i A_{i,t} \,.\, UC_{i,t-1}} \qquad (1)$$

where :

i :	sector
$A_{i,t}$:	activity variable of sector i in year t
$UC_{i,t}$:	unit consumption of sector i in year t

This formula can be generalized by noting that for sector i it becomes :

$$\frac{I_t}{I_{t-1}} = \frac{UC_t}{UC_{t-1}} \qquad (2)$$

For the individual sector, the energy efficiency index can be considered as an index of unit energy consumption.

Equation (2) can be written as follows:

$$UC_{t-1} = \frac{I_{t-1}}{I_t} \,.\, UC_t \qquad (3)$$

Replacing UC_{t-1} by its value in (1) leads to:

[5] Prepared by F Altdorfer from ECONOTEC
[6] ‘Sector’ is taken here in a general sense, representing an energy consumption category, like ‘cement production’, ‘space heating in new appartments’, ‘road transportation of goods’…

$$\frac{I_t}{I_{t-1}} = \frac{\sum_i EC_{i,t}}{\sum_i A_{i,t} \, . \, UC_t \, . \frac{I_{t-1}}{I_t}}$$

or:

$$\frac{I_t}{I_{t-1}} = \frac{\sum_i EC_{i,t}}{\sum_i EC_{i,t} \, . \frac{I_{i,t-1}}{I_{i,t}}}$$

Inverted, this gives:

$$\frac{I_{t-1}}{I_t} = \frac{\sum_i EC_{i,t} \, . \frac{I_{i,t-1}}{I_{i,t}}}{\sum_i EC_{i,t}}$$

or:

$$\boxed{\frac{I_{t-1}}{I_t} = \sum_i ec_{i,t} \, . \frac{I_{i,t-1}}{I_{i,t}}}$$

where $ec_{i,t}$ is the share of sector i in the total energy consumption of year t.

This last formula shows that I_{t-1}/I_t is the average value of the sectoral ratio $I_{i,t-1}/I_{i,t}$ weighted by the share of each sector in the total energy consumption.

Comments

- This relationship has interesting mathematical properties, which allow in particular to calculate the aggregate energy efficiency index in several steps, each with a different level of aggregation. It is possible for example to calculate first separate indexes for industry, transport, residential and tertiary, and afterwards, based on these indexes, a general index for all these sectors together.

- The aggregate index does not require an activity variable for the aggregate sector (which is an advantage, as such an activity level is often not available).

- The unit consumptions used at the most disaggregated levels can be expressed in different units (GJ/t, l/100 km…).

- A complete index can be constructed year by year, by assigning an arbitrary value to any particular year. Say $I_0 = 100$. Then:

$$I_1 = 100 \, . \, \left(\frac{I_1}{I_0}\right)$$

$$I_2 = I_1 \, . \, \left(\frac{I_2}{I_1}\right)$$

…

- The above definition is based on two subsequent years. But the formula remains valid if any two different years are considered, for example a base year 0 and a current year t. However, the index calculated directly between year 0 and year t, say J, would not be the same as the one obtained year by year:

$$\frac{J_t}{J_0} \neq \frac{I_t}{I_0} = \frac{I_t}{I_{t-1}} \cdot \frac{I_{t-1}}{I_{t-2}} \cdot \quad ... \quad \cdot \frac{I_1}{I_0}$$

- The value of an energy efficiency index will depend on the degree of sector disaggregation. Efficiency indexes based on unit consumptions calculated at levels that are too aggregated will be influenced by structural effects, which should generally be avoided. The greater the disaggregation, the more structural effects will be removed from the indicator and the closer this indicator will get to the ‘real’ energy efficiency.

However, some structural effects might be considered as energy savings, for example the shift from one process to another. If the cement sector is considered as a single sector, the shift from the wet process to the dry process will be considered as an efficiency improvement in the above formula. If the dry and the wet processes are considered as two different sectors, it will not.