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Energy savings calculations: Impact of a higher data granularity on top-down methodology: The case of the French industry

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EXTENDED ABSTRACT

France is strongly engaged in the decarbonisation of its industry through the implementation of large set of measures (25 according to the MURE database) including national ones such as the decarbonisation and heat recovery funds, EEOs etc. in addition to the EU Directives (ETS and EED). To evaluate and monitor the impact of these several annual billions of EE investments, the ADEME's industry department disposes of two top-down monitoring systems of energy efficiency policies both inspired by the ISO 50047 on energy saving calculations. This presentation of a methodological nature will discuss and compare in detail the respective merit of these two approaches, in particular about the so-called "decomposition analysis of energy demand variation" which is broadly implemented worldwide. The first one is based on the European ODYSSEE data base using Eurostat data set (15 branches) and the second one from CEREN supported by a consortium of utilities, ADEME and the French government with a dataset with a very high granularity (240 Process-products). The difference of granularity allows us to explore its impacts on energy savings calculation, on the type of indicators and discuss the importance of additional explanatory factors such as intra-sectoral structural changes, fuel substitution effect and climatic effect. Comparative results show a significant gap between the two methodologies that will be commented for the whole French industry sector for the period 2018-2019. Despite this short period of analysis, recommendations will be drawn on the importance of implementing a national specific monitoring system considering national circumstances in particular focusing on high consuming industries to reduce the cost of the data collection.

Keywords

Energy savings calculation; decomposition analysis, indicators.

Introduction / background

The Energy Service Directive (ESD Directive, 2006) and then the Energy Efficiency Directives (EED, 2012 and 2023) imposed energy efficiency targets on Member States that are increasingly ambitious. The nature of these objectives has evolved from global energy savings to multiple targets: on the levels of primary and final consumption (Article 4), on energy savings linked to policy measures (Article 8), and on sectoral objectives (e.g. for public buildings in Article 5), they also require more detailed regular reports on the measures implemented to reach the objectives (from NEAAP to NECP and NECPr). This requires the implementation by EU countries of a reporting system using either bottom-up (at the policy level) or top-down methodologies (energy efficiency indicators). Among top-down analysis of the factors behind the variation of the energy consumption, the so "called decomposition analysis ", is especially appreciated to monitor how the targets on final and primary consumption are being met. This article will discuss some aspects of the decomposition methodology in the case

of the industry sector in France based on two statistical sources (ODYSSEE[1] and CEREN)[2], in particular the impact of the level of detail of energy consumption data on the evaluation of energy savings and their respective contribution in the variation of energy demand.

Methodology

General methodology of decomposition analysis

The construction of energy efficiency indicators is basically based on a ratio between energy consumption at the most detailed level possible, given the information available (for example by end-uses for households, sub-sectors in industry or services or even products and processes in the case of industry) to activity data that are preferably measured in physical units. For instance in industry, the activity will be measured in tons, particularly for intensive industries (e.g. steel, paper, cement), or IPI (Industrial Production Index) in the case of multi-product sectors (e.g. food industry). This ratio must be established under the constraint of a consistency in the level of classifications between energy consumption data and economic activity data, which are increasingly homogeneous (e.g ISIC, NACE). These indicators, calculated at the finest level, are then reaggregated to assess, for example, the total savings of industry for a country. The next step is to place the contribution of these energy savings into the total variation in energy demand over a given period. To do this, the methodology of decomposition is used. Energy efficiency indicators are broadly implemented through international organisations (DGEN, EEA, IEA, APERC, UN-ECLAC, Medener etc), but also at national level through different projects. This methodology has also been the subject of a series of ISO standards, including ISO 500049 standard on the calculation methods on energy efficiency and energy consumption variation at national level.

General methodology of decomposition analysis in industry

Principle of decomposition analysis in industry

In industry, the decomposition of the energy consumption variation aims at showing the relative impacts of three main factors: the level of activity (“activity effect”), changes in the structure of industry, (“structural effect”), and changes in unit consumption (i.e. ratio energy consumption per unit of output) (“unit consumption effect”). The structural effect measures the fact that all industrial branches do not grow at the same rate: for instance, if branches with low unit consumption grow faster than energy intensive branches this will, all things being equal, reduce the energy consumption of industry. This unit consumption effect will capture energy savings, due to energy efficiency improvements at the level of each branch but also other factors, such as fuel substitution between energy with different end-use efficiency, climate variations from one year to the other (“climate effect”), and changes in the products mix within industrial branches (“intra sectoral structural changes). The results of the decomposition will depend on several factors:

- the way the activity is measured (monetary units, such as value added, physical production or industrial production index);
- the level of disaggregation of the industry sector, i.e. the number of branches;
- the number of additional effects, in which the unit consumption effect is separated.

[1] ODYSSEE Data base :https://www.indicators.odyssee-mure.eu/ ;https://www.indicators.odyssee-mure.eu/co2-decomposition.html

[2] CEREN : Centre d’études et de recherche économiques sur l’énergie. Private consultant company specialised on end-used data collection and mainly sponsored by energy utilities, ADEME and ministries. https://www.ceren.fr/ ;

Comparison of methodology between ODYSSEE and CEREN.

This article focuses on two methods used in the decomposition of energy consumption in the French industry, which are differentiated by the level of disaggregation of industry (i.e., the level of granularity), and the number of effects considered: Odyssee and CEREN. It will present the two methods and then compare the results obtained in the case of France.

Considering that energy efficiency policies and measures do not affect the consumption of non-energy uses, both methods only consider the final consumption for energy uses, excluding non-energy uses.

Impact of the level of granularity

The assessment of explanatory effects of consumption variation can be impacted by the level of disaggregation i.e. the level of granularity. The issue is not necessarily to work at a very high level of disaggregation but to make sure that the most important branches in terms of energy consumption are well disaggregated (e.g. in the case of chemicals). Therefore, when presenting the results, it is important to specify at which level of disaggregation the structure effect has been calculated (i.e. 10 or 20 branches) Despite the legal constraint imposed by Eurostat on data collection for each Member State (MS), the national data collection practices and data availability strongly vary among countries.

In ODYSSEE, the industry data collection mainly relies on Eurostat data both for energy and activity data and the level of disaggregation adopted relies on two criteria. On the one hand, due to the objective to perform cross country comparison among 40 European countries with harmonised data and to use the maximum of "official data"), the granularity relies on the level of disaggregation used by Eurostat (13 branches) which correspond roughly to ISIC 2 Digits. Only two branches rely on national data (cement and water desalination). In total there are up to **15 branches**.

For CEREN, the data collection relies on a combination of several surveys (from ministry and own surveys). A first particularity is that some data coming from by the national statistical office (INSEE) are extrapolated based on energy end-use data from CEREN. Secondly, this data set is complemented by CEREN's on site end-uses surveys performed by surveyors allowing detailed data by products/process for instance. In total, the level of disaggregation reaches **243** Process/products[3].

The number of effects

In ODYSSEE, four effects are considered ; (Activity, Structure, Energy Savings and others) for which the definition differs if the energy savings are «technical savings" (**see Annex 1 for further explanation**) or «gross» savings.

For CEREN, due to the high level of disaggregation available, **5 additional** explanatory effects are considered beyond energy savings **(see Annex 2**): the infra structural effects within branches; the inter-fuel substitution effect; the self-production effect which takes into account the variation of the share of self-produced electricity; the climatic effect (data are climate corrected).

It can be noted that CEREN provides figures of these effects **by fuel types**. This clearly can be very interesting for policies evaluation (i.e. energy savings obligation on specific fuels) and for utilities.

The method of decomposition

There exist different methods of decomposition, depending on the base year for the calculation of effect: Laspeyres-Pasches, Pasches-Laspeyres and Divisia methods (See **Annex 2** for further explanations).

ODYSSEE and CEREN both uses the Laspeyres-Pasches method. However, CEREN plans to use LDMI method.

[3] In the the next study, the use of an « Annual Production Survey » will be integrated which includes 4,000 industrial products and their annual production quantities.

Apart from the method of decomposition used, the results of the calculation also depend on the disaggregation level, especially for energy intensive subsectors. For CEREN, data are corrected for climate variations.

Comparing the result of the two methodologies for France

Due to delay in CEREN data provision for the more recent years, and the facts that publications only focus on two consecutive years, we can only perform the comparison for a one year period 2018-2019 (we excluded 2020, which was not a normal year). This is clearly a strong limitation on the conclusion that we can draw on the impact of the level of disaggregation.

In **Table 1**, the reference level of the total consumption of industry across the two data sources amounts 27.7 Mtoe and 27.2 Mtoe respectively for 2018 and 2019 for ODYSSEE versus 28.1 Mtoe in 2018 and 27.6 Mtoe for CEREN. We can consider that data are sufficiently close to perform a workable analysis of the comparison.

Table 1. Explanatory factors of the French industry consumption variation (2018-2019).

(all values in Mtoe)	CEREN	ODYSSEE
Energy consumption variation	-0,41	-0,49
Activity effect	0,16	0,15
Structural effect (between branches)	-0,40	-0,46
Structural effects (within branches)	-0,55	
Process substitution	-0,02	
Substitution auto production	0,04	
Climatic effect	0,01	
Balance ("gross savings")	0,33	-0,267
Technical Savings		-0,04

Sources : Authors from ODYSSEE and CEREN

From Table 1, the following analysis can be done:

- The activity effects are very similar
- Despite an important difference of disaggregation (12 branches for ODYSSEE vs 24 for CEREN), the inter-branch structural effects are also comparable and contribute to reduce the consumption.
- Interesting enough is the evaluation of the infra-branch structural effect by CEREN which amounts to -0.55 Mtoe, i.e. a value very similar to the inter-branch effect.
- The main difference is visible on the « gross » energy savings effect assessment with a « non-saving » evaluation for CEREN (+0.3 Mtoe, called balance by CEREN) and some energy savings for ODYSSEE (-0.28 Mtoe) confirmed by technical savings (-0.4) Mtoe .
- Finally, the 4 additional effects provided by CEREN are negligeable. The shortness of the period analysed may explain this.

Conclusions

The assessment of energy savings through the « top down » approach depends on the methodology used. This statement is clearly confirmed by our analysis based on the comparison of two sources of data for the French industry with an important difference of the level of disaggregation.

The advantage of the ODYSSEE approach is to calculate the « technical saving[4]» that can be considered more informative that "gross savings", which can strongly evolve year by year. ODYSSEE also provides a user-friendly interface allowing to play with the period of analysis and easily compare the countries. A national monitoring, illustrated in this article by the «CEREN approach» based on a more disaggregated set of data, allows a more specific and customized methodology of energy saving calculation. For instance in case of the French industry, four new explanatory factors can be performed of which of a particular interest the intra-branch structural effect. However, due to the too short period of our analysis, we cannot demonstrate their quantitative importance of their impact. We consider that countries should encourage the development of more detail data collection (by products, process etc.). However, since a detailed data collection and its related determinants has a cost, we suggest to focus the monitoring on the most energy consuming sectors such as chemical and food industry in France, or on the paper industry in Finland or else on chemicals in The Netherlands for instance, because it will lead to the most important impact on energy saving assessment. This comparative analysis will be shortly largely improved since we will dispose of 4 more years of data collection and for CEREN a data collection set of 4000 process/products allowing very detail sectoral assessments.

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[4] Technical savings correspond to achieved savings that cannot reverse.

Annex 1: Detailed methodology of the « Decomposition analysis » in ODYSSEE

In Odyssee, the decomposition analysis in industry is explained by 4 effects:

- activity effect, measured by the change in industrial activity (measured with the production index);
- structural changes, measured by the change in the structure of the industrial by branch (based on production index);
- energy savings, measured by the ODEX, i.e. calculated from changes in unit energy consumption at branch level;
- other effects: mainly “negative” savings due to inefficient operations in industry.

The unit consumption effects are thus disaggregated into two effects: "energy savings" and "other effects". The calculation of these effects are reported below.

The **activity effect** captures the changes in the production. It is calculated by multiplying the energy consumption related to production index (previous year, t-1) by the variation of the production between t and t-1.

Activity effect: $EQt/t{-}1 = IPIt/t{-}1 * (C\text{t}{-}1/IPI\text{t}{-}1)$

Where:

EQ: activity effect

IPI: production index of industry

C: Energy consumption of industry

The **structural effect** is equal to the variation in energy consumption that would have taken place if the unit consumption of each branch had stayed “constant” (compared to the previous year t-1) minus the activity effect. The first component (named quantity effect) is calculated as the sum of the variation of the production index (between t and t-1) multiplying by the energy consumption per production index of the previous year (of the previous year t-1) for each branch.

Structural effect: $SEt/t{-}1 = \sum (ni{=}0\ \Delta IPIt/t{-}1 * (C\text{t}{-}1IPI\text{t}{-}1)) - EQt/t{-}1$

Where:

IPI: production index of industry

C: Energy consumption of industry

Energy savings are derived from ODEX, an indicator specific to Odyssee that measures energy efficiency progress at sector level. ODEX is calculated as a weighted average of variation of index unit energy consumption by industrial branch. Unit consumption are 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. The weight used to get the weighted aggregate is the share of each sub- sector in the total energy consumption of the sectors.

The direct calculation provides the value of what is called the “gross” ODEX. This gross ODEX is then converted in a “technical” ODEX by correcting the gross ODEX of the negative efficiency trends due to inefficient operation of facilities, in a period of recession or low economic growth, or changes in product mix within branches. An increase in unit consumption by sub-sector is not associated to a decrease in efficiency, but as no

energy efficiency progress, from a technical point of view: this technical ODEX is closer to the actual energy efficiency progress.

Energy savings by sector in absolute values (ktoe, GWh) are calculated from ODEX, as follow, considering that ODEX represents the ratio between the energy consumption at year t (E) and a fictive consumption that would have happened without energy savings (ES):

ES= $\boldsymbol{Ct} * ((\boldsymbol{ODEX\ t\ /ODEX\ t}-\mathbf{1}) - \mathbf{1})$

Where:

C: Energy consumption

ODEX: Energy Efficiency Index

t: year

The last effect ("others") represents "negative" savings due to inefficient operations in industry and changes in the mix of products within each branch.

Annex 2: Detailed methodology of the « Decomposition analysis » for CEREN

CEREN considers several effects, such as production, structure, energy substitution, climatic , scope and energy intensity variation. The method relies on specific calculations to determine the impact of variations in industrial activity and sector structure.

« The production effect » is calculated based on the evolution of production by sector, while the structure effect focuses on internal variations (within sub-sectors) and external variations (between sectors) that influence energy consumption. For example, the inter-branch structure effect measures the impact of changes in the distribution of industrial activities across different sectors.

The « **energy substitution »** analysis examines the impact of replacing fossil fuels with electricity in thermal industrial processes. This calculation is based on substitution coefficients, which quantify the amount of fuel that would have been used if electricity had not been substituted in the process. The model also considers the specificities of each industrial sector, such as differences in processes used in manufacturing industries.

The « **climatic effect »** measures the impact of temperature variations on heating consumption. Climatic variations can indeed alter the energy needs of industrial sectors, particularly for heating, depending on the specific weather conditions of each period.

« **The scope effect »** is calculated to account for changes in industrial establishments, such as closures or modifications to main activities, which can influence energy consumption in the studied industrial sectors. It is not considered in this article

« **The energy intensity variation effect** » measures the evolution of the amount of energy consumed per unit of production or in relation to another economic variable, thereby capturing the dynamics of energy efficiency. For instance, an increase in energy intensity could indicate a loss of efficiency or greater reliance on more energy-intensive sources, whereas a decrease would signify an improvement in energy efficiency in industrial processes. The benefit of this addition lies in its ability to provide a finer analysis of the factors affecting energy consumption, considering resource optimisation and more efficient technologies. By including this effect, the study becomes more comprehensive by measuring not only the impact of variations in activity and structure but also the evolution of energy consumption relative to production, providing a more precise understanding of the underlying forces influencing energy consumption trends.

Annex 3: Comparison of Method of calculation

The Laspeyres and Pasches method use the same base year for all effects. The Laspeyres-Pasches combines two base years depending on the effects. The Divisia method was introduced by Ang in 2000 to improve the Laspeyres, Pasches or Laspeyres-Pasches type decomposition methods by reducing the decomposition residue; it was initially developed to measure structural effects in industry. There exists three Divisia methods, namely AMDI (Arithmetic Mean Divisia Index), LMDI I (additive log mean divisia) and LMDI II (multiplicative log mean divisia), which differ mainly in the weighting function. The most common one is LMDI I. The impact of the choice of method on the results is more limited if the calculation is done with annual steps (ie between year t and t-1).

Odyssee uses the Laspeyres Paasches method, which considers implicitly an order of effects. We can speak of a method of successive decomposition of effects. This method has the advantage of being easier to understand than LMDI and allows more flexibility in its implementation.