Comparison of Odyssee methodology for the decomposition of energy consumption variation with other methods

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Introduction

- The decomposition of energy consumption variation aims at identifying the role of different factors.
- The methodology used in ODYSSEE focuses on energy savings as one of the main driver and was developed so as to be consistent with the calculation of energy savings, in particular technical savings and to be easy to understand.
- Other methods used in other studies rely on the Divisia decomposition methodology, with the most common one is referred to as LMDI* (e.g. IEA, JRC ISPRA, Fraunhofer ISI).

**Logarithmic Mean Divisia Index*

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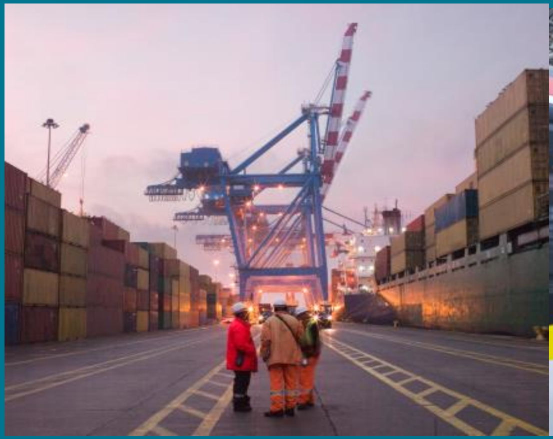

Energy savings at sector level in ODYSSEE

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Calculation of energy savings at sector level

Two methods that give exactly the same results are used in ODYSSEE to calculate energy savings by sector (in ktoe or GWh):

- Direct calculation at sector level with ODEX indicator as ODEX is equal to the ratio between the energy consumption at year t (E) and a fictive consumption that would have happened without energy savings*: ES = E x ((100/ODEX)-1);

- Sum of the energy savings for each sub-sector (or end-use)***.

**ODEX = E/(E+ES)*100*
***If E = 50 Mtoe and ODEX = 80 → ES = 50* ((100/80)-1) = 12,5 Mtoe*
*** Method recommended to calculate the energy savings for the monitoring of the ESD Directive with the top-down approach;

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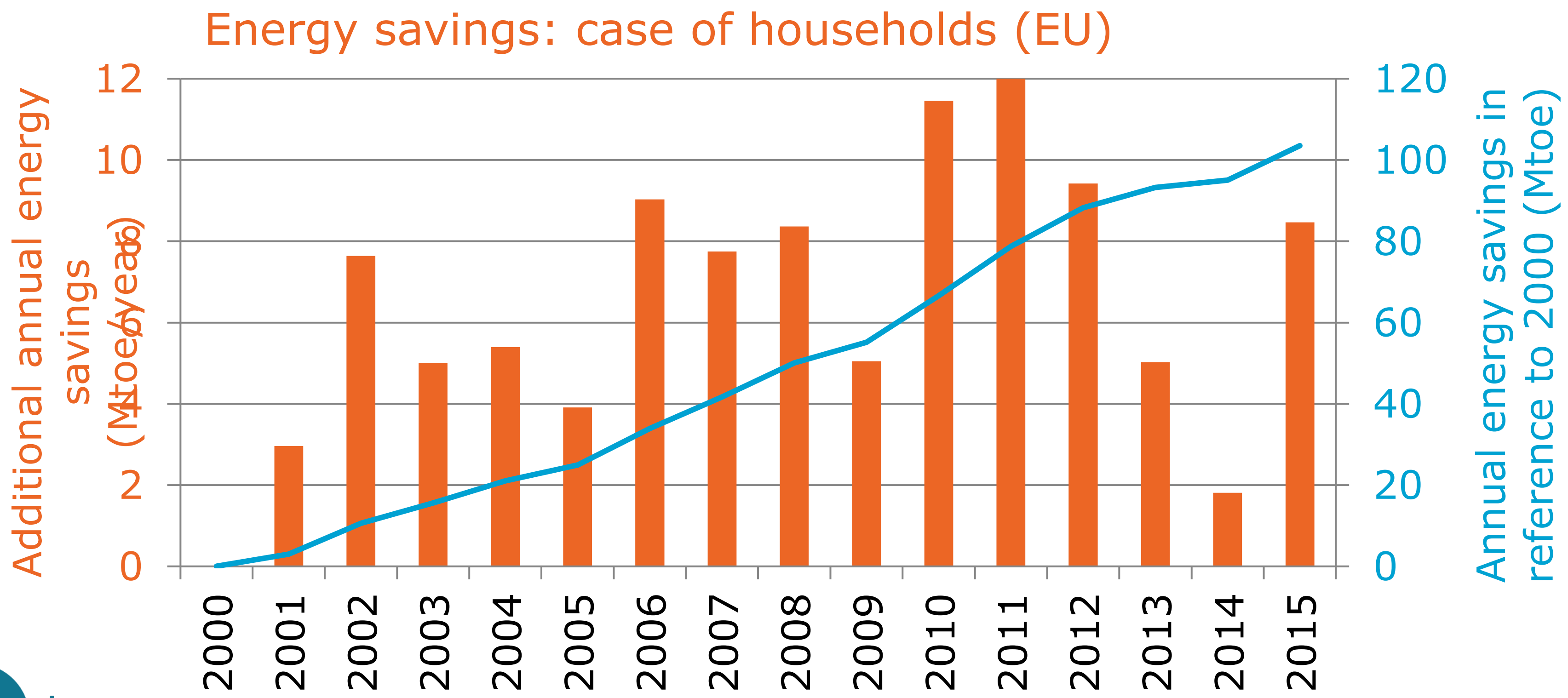
Different definition of energy savings

- (compared to previous year) are shown on left axis (Additional annual energy savings in orange) : they fluctuate quite a lot .
- Annual savings can also be expressed in reference to a base year (e.g. 2000) (right axis in blue): in 2015, annual savings for households reached 105 Mtoe compared to 2000: without savings 2000, energy consumption would have been 105 Mtoe higher in 2015.
- Savings can also be cumulated over a period (as in Article 7): the cumulated savings for households exceeded 800 Mtoe since 2000.



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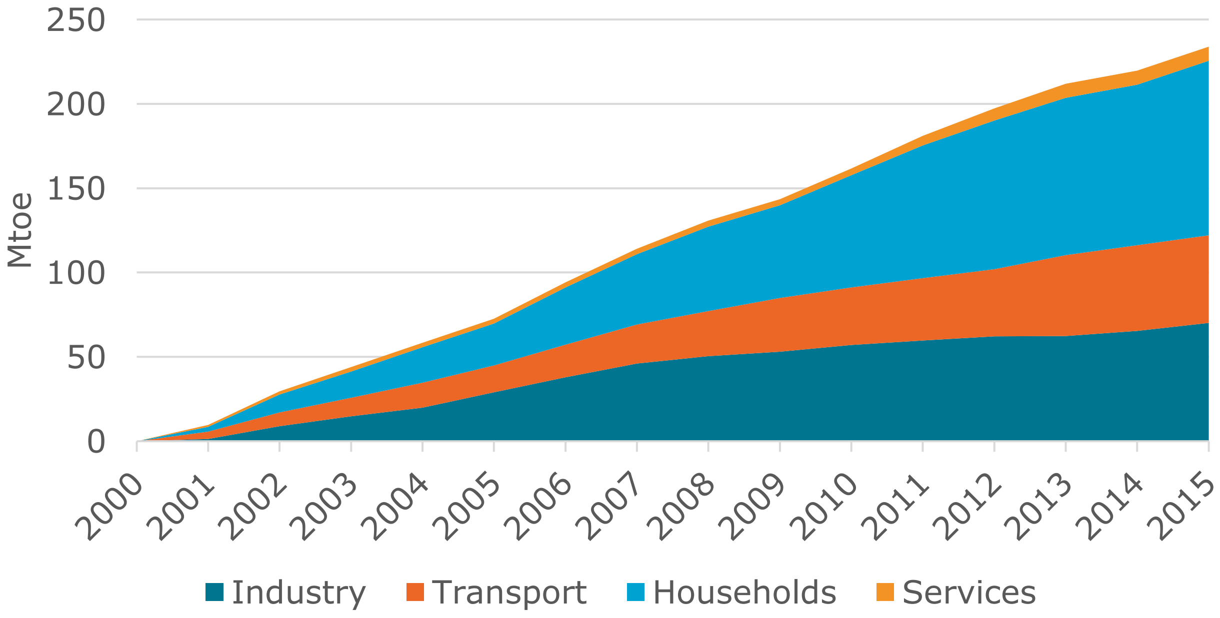
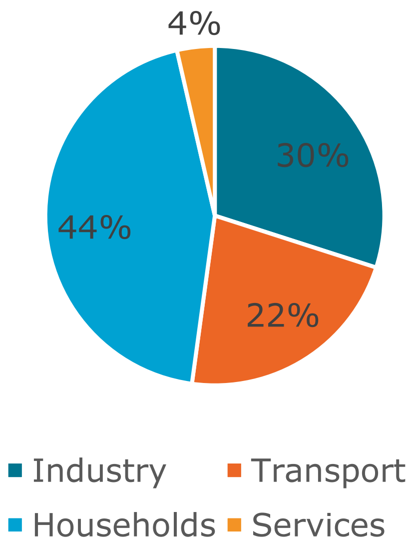
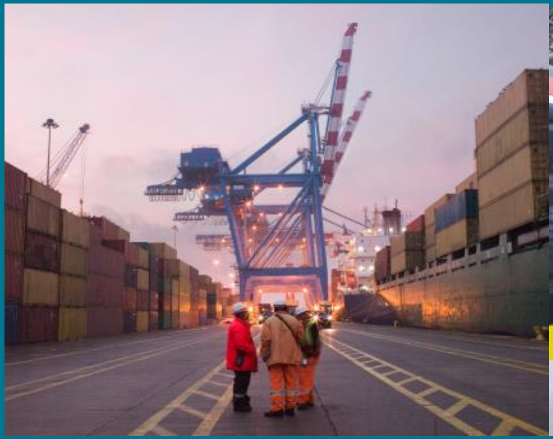
Total annual final energy savings at EU level

- Around 230 Mtoe energy savings in 2015 compared to 2000 (i.e. 20% of final energy consumption).
- Without these savings the final energy consumption would have been 20% higher in 2015.
- Most of these savings come from households (44%), 30% from industry, 22% from transport and 4% from services.

Annual energy savings for all final consumers compared to 2000 (EU)







Decomposition of energy consumption variation

Industry, Households, Transport, Services

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Decomposition of the energy consumption variation in industry

Industrial energy consumption is changing under the influence of various factors:

- Change in total industrial activity, measured with the production index (IPI) ("activity effect");
- Structural changes, i.e. the fact that the production* of individual branches with different specific consumption are not growing at the same rate (e.g. if production of machinery is growing much faster cement production, this will decrease the overall consumption of industry, all things being equal, as machinery less energy intensive);
- Technical energy savings (i.e. change in the branches' specific energy consumption) (calculated from ODEX);
- Other effects: mainly "negative" savings due to inefficient operations in industry.

*Production measured in physical units or with IPI

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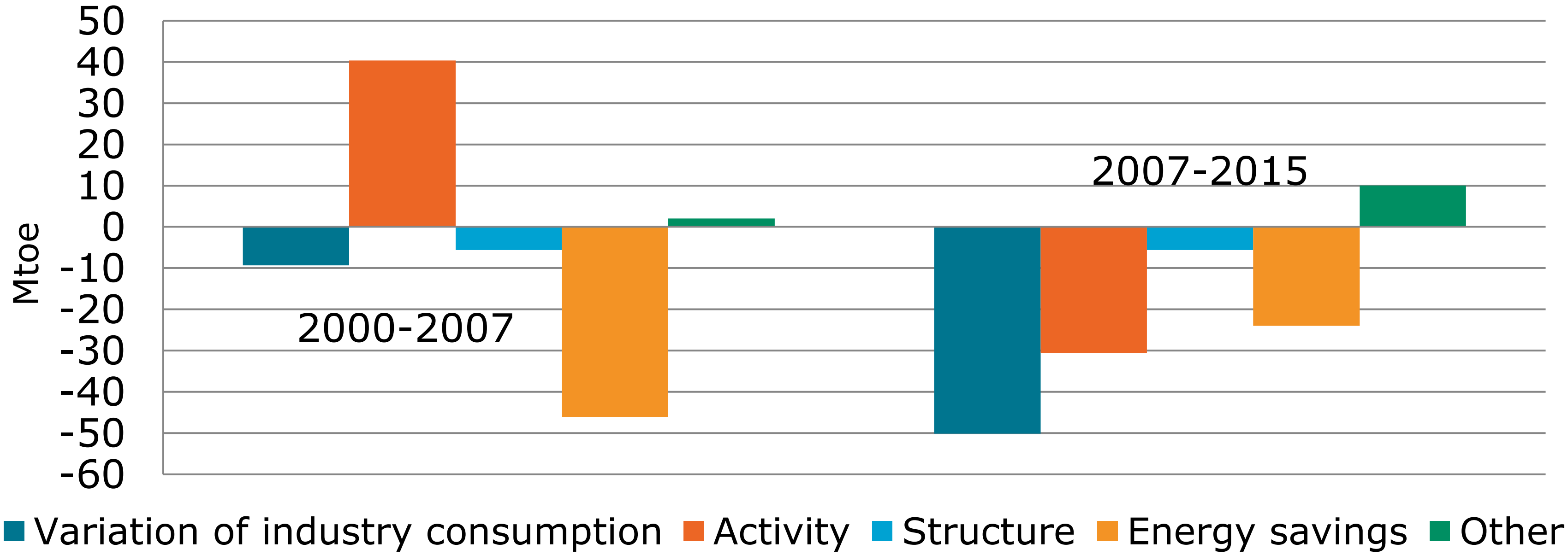
Decomposition of the energy consumption variation in industry

- Since 2007 the reduction of activity is the main driver of the decrease of consumption (-50 Mtoe);
- Energy savings had a much lower impact since 2007 (3.4 Mtoe/yr compared to 7.6 Mtoe/yr over 2000-2007).
- Structural effects had a low impact on the consumption variation.



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Energy savings: technical savings; based on specific consumption per unit of production (in physical terms or production index)
Other: "negative" savings due to inefficient operations

Decomposition of the variation of the energy consumption in households

Energy consumption of households between two years, t and t_0 is changing under the influence of various factors :

- Climatic effect (due to climatic difference between years t and t_0);
- Change in number of occupied dwelling ("more dwellings effect");
- Evolution of lifestyles:
  - Average floor area of dwelling for space heating ("larger homes");
  - More appliances (electrical appliances, central heating);
- Technical energy savings (calculated from ODEX);
- Change in heating behaviors.

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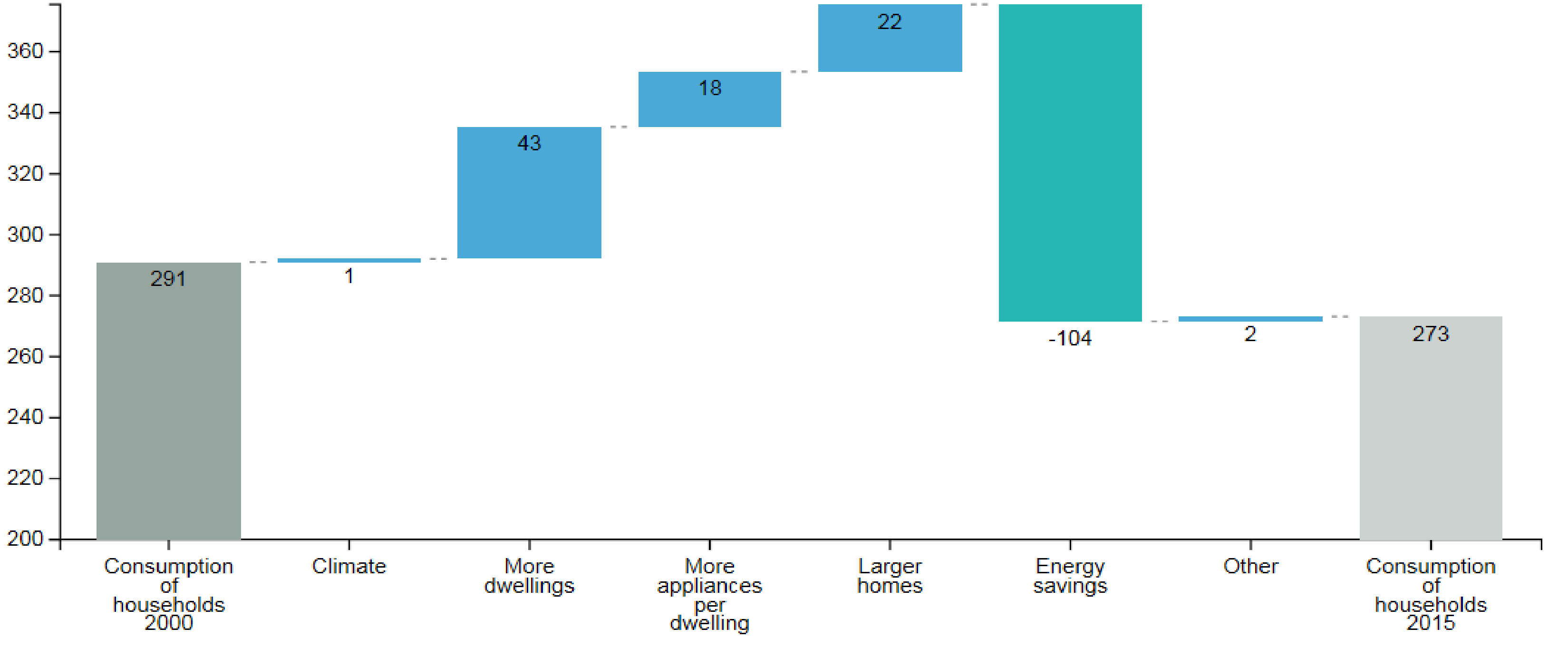
Decomposition of the variation of the energy consumption in households

- Two factors contributed to increase the household consumption since 2000:
  - Increasing number of dwellings (43 Mtoe);
  - Growing comfort due to the increase in the number of household appliances and dwelling size (18 and 22 Mtoe, respectively).
- Energy savings (technical) lowered consumption by 104 Mtoe (~7 Mtoe/yr).
- Other effects or behavioural effect are mainly due to the combined effect of price increases and of the economic recession

EU 2000-2015



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Decomposition of the energy consumption variation in transport

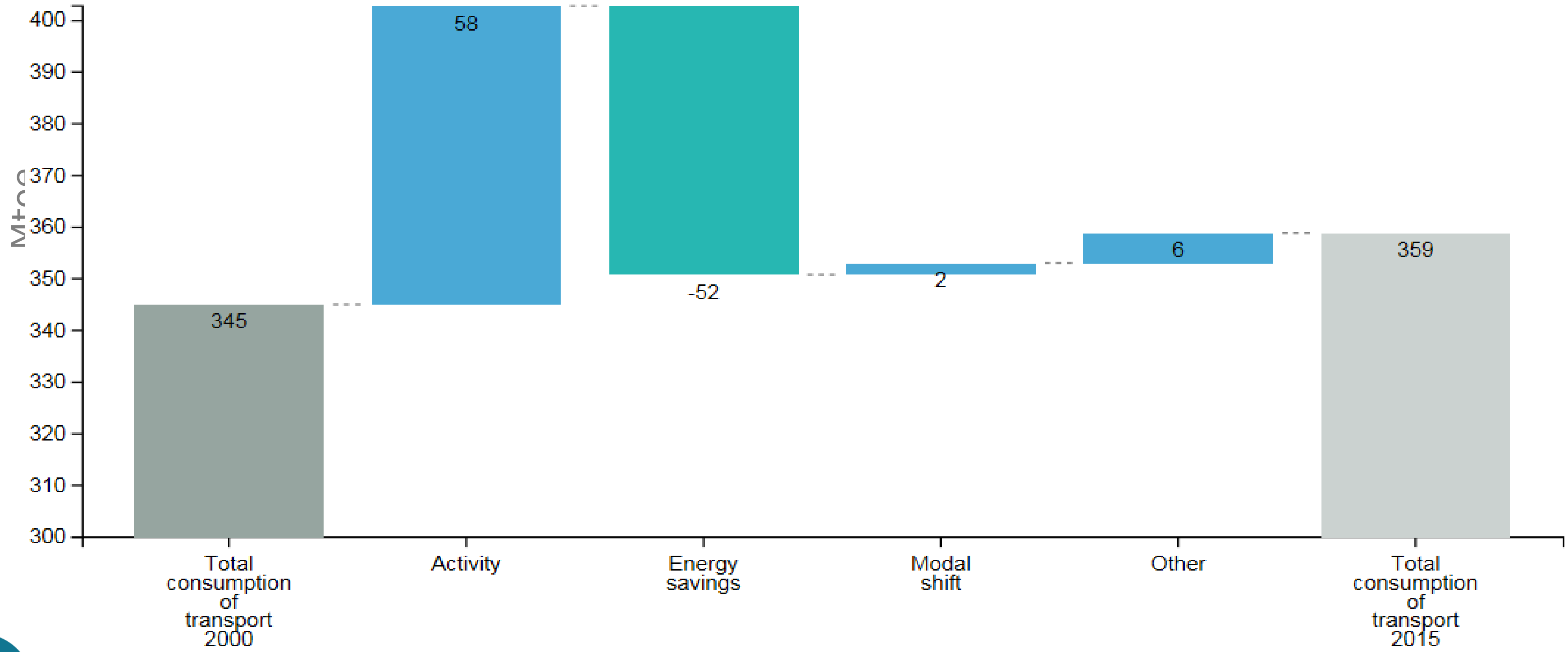
Energy consumption in transport is changing under the influence of the following factors :

- Change in passenger traffic including air and traffic of goods ("activity effect");
- Technical energy savings (i.e. change in the efficiency of cars, trucks, airplanes etc.) (calculated from ODEX);
- Modal shift for land transport, i.e. change in the share of each transport mode in the total land traffic;
- Other effects, i.e behavioral effects and "negative savings" in freight transport due to low capacity utilization.

Decomposition of the energy consumption variation in transport

- In 2015 the energy consumption of transport was 15 Mtoe higher than in 2000
- Increase of traffic contributed to raise consumption by 58 Mtoe .
- Energy savings decreased the consumption by 52 Mtoe.
- Other effects: behavioral effects and "negative savings".

Drivers of energy consumption variation in transport (Mtoe, EU 2000-2015)



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Energy savings: technical savings; based on specific consumption per unit of traffic

Decomposition of the energy consumption variation in services

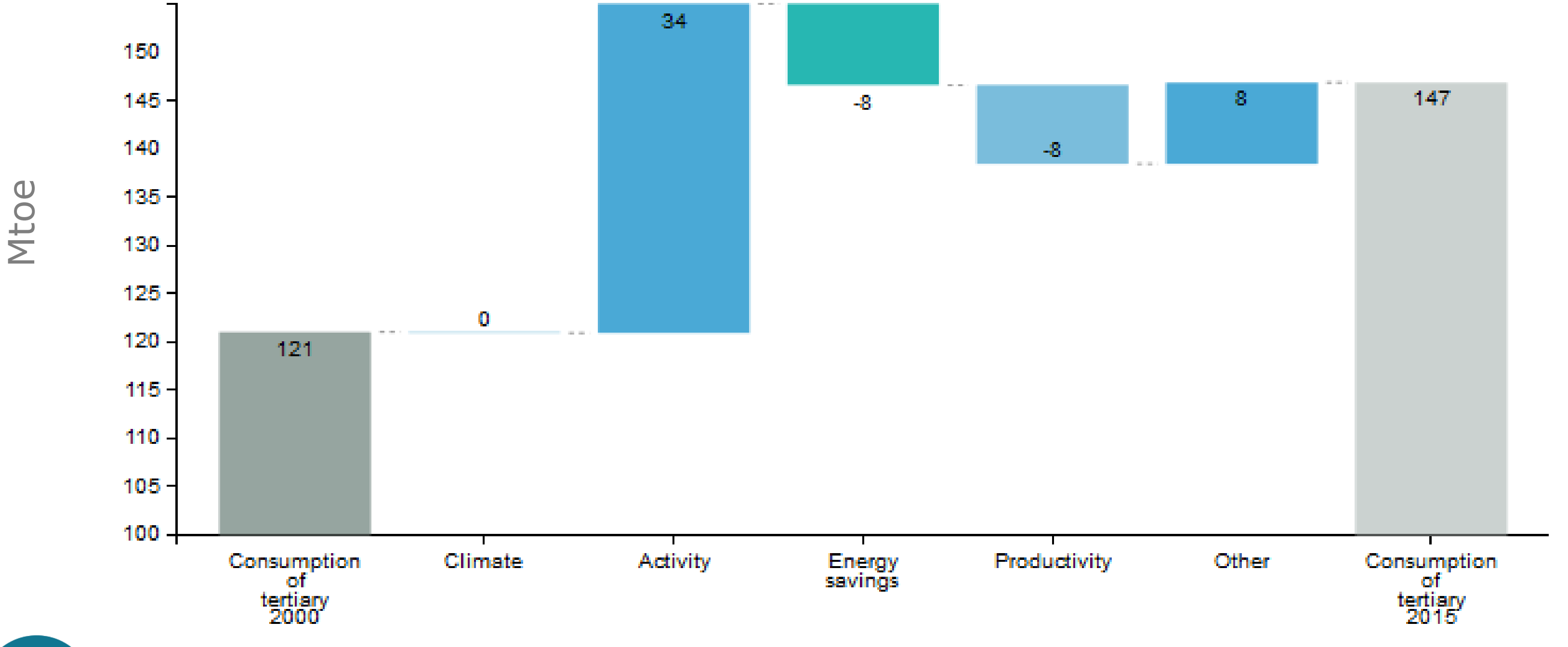
Energy consumption in services is changing under the influence of various factors :

- Change in economic activity (increase in value added);
- Energy savings (reduction in energy consumption per employee);
- Productivity effect (change in VA per employee);
- Climatic effect (due to climatic difference between years t and t_0).
- Other effects (behavioral effects and “negative savings”).

Decomposition of the energy consumption variation in services

- The energy consumption of services increased by 26 Mtoe from 2000 to 2015.
- Increase of the value added contributed to raise consumption by 34 Mtoe.
- Energy savings and labour productivity gains (VA/employee) decreased the consumption by around 8 Mtoe each.

Drivers of energy consumption variation in services (Mtoe, EU 2000-2015)



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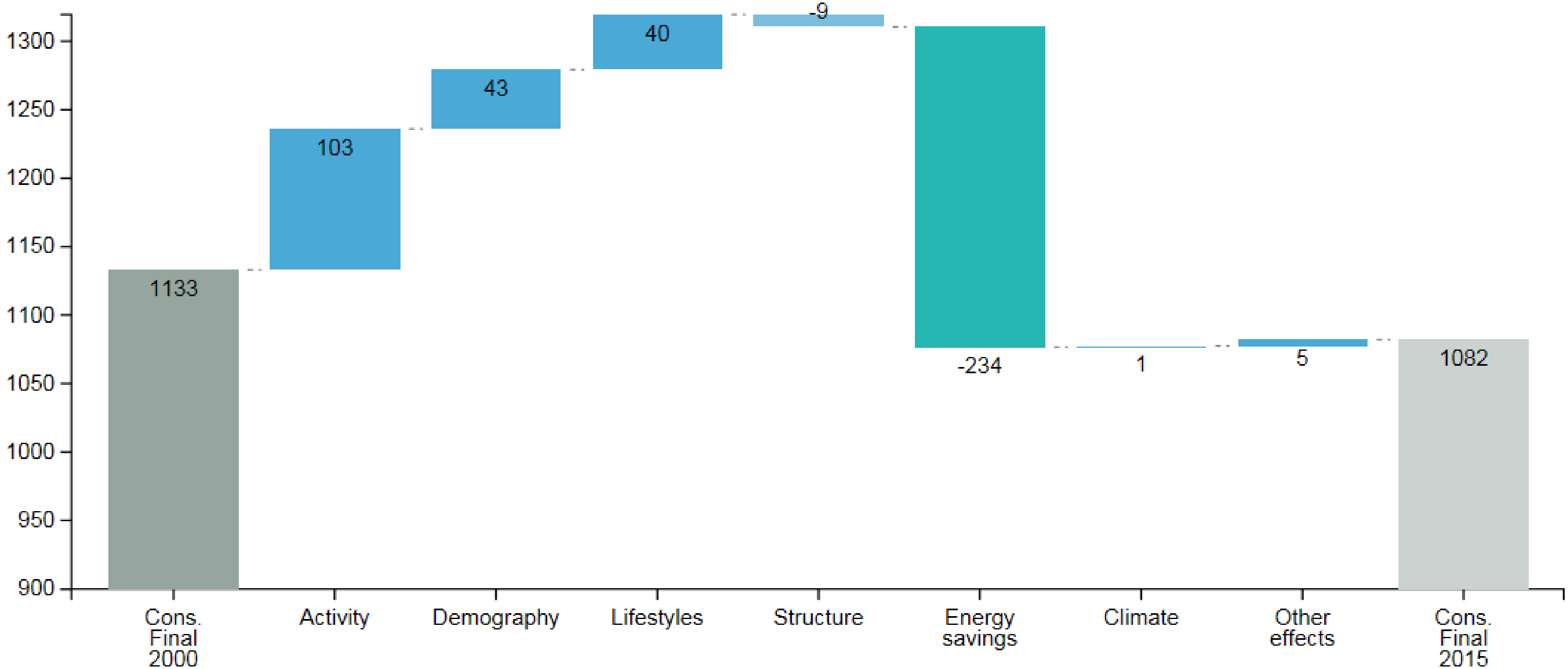
**Energy savings: technical savings; based on specific energy consumption per employee*

Decomposition of total final consumption

- The final energy consumption decreased by 51 Mtoe between 2000 and 2015.
- Increase in activity contributed to raise consumption by 103 Mtoe, lifestyles and demography by around 40 Mtoe each.
- Technical energy savings decreased the consumption by 234 Mtoe.

Drivers of final energy consumption variation (Mtoe, EU 2000-2015)



Decomposition of energy consumption variation

Power sector

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Principles of the decomposition of the consumption of the power sector

Four main effects explain the variation of the net consumption for power generation over a period*:

1. The increased consumption of electricity, that all things being equal, contribute to increase the losses in power generation.
2. Change in the electricity trade.
3. Changes in the power mix between different sources with very different efficiencies:
   - Wind, hydro, PVs (100% efficiency);
   - Thermal (between 30 and 50% depending on fuel mix and technology);
   - Geothermal and nuclear (respectively 10% and 33%);
4. Variation in the efficiency of thermal power generation.

**net consumption for power generation= sum of input and outputs for electricity generation (including cogeneration and district heating)*

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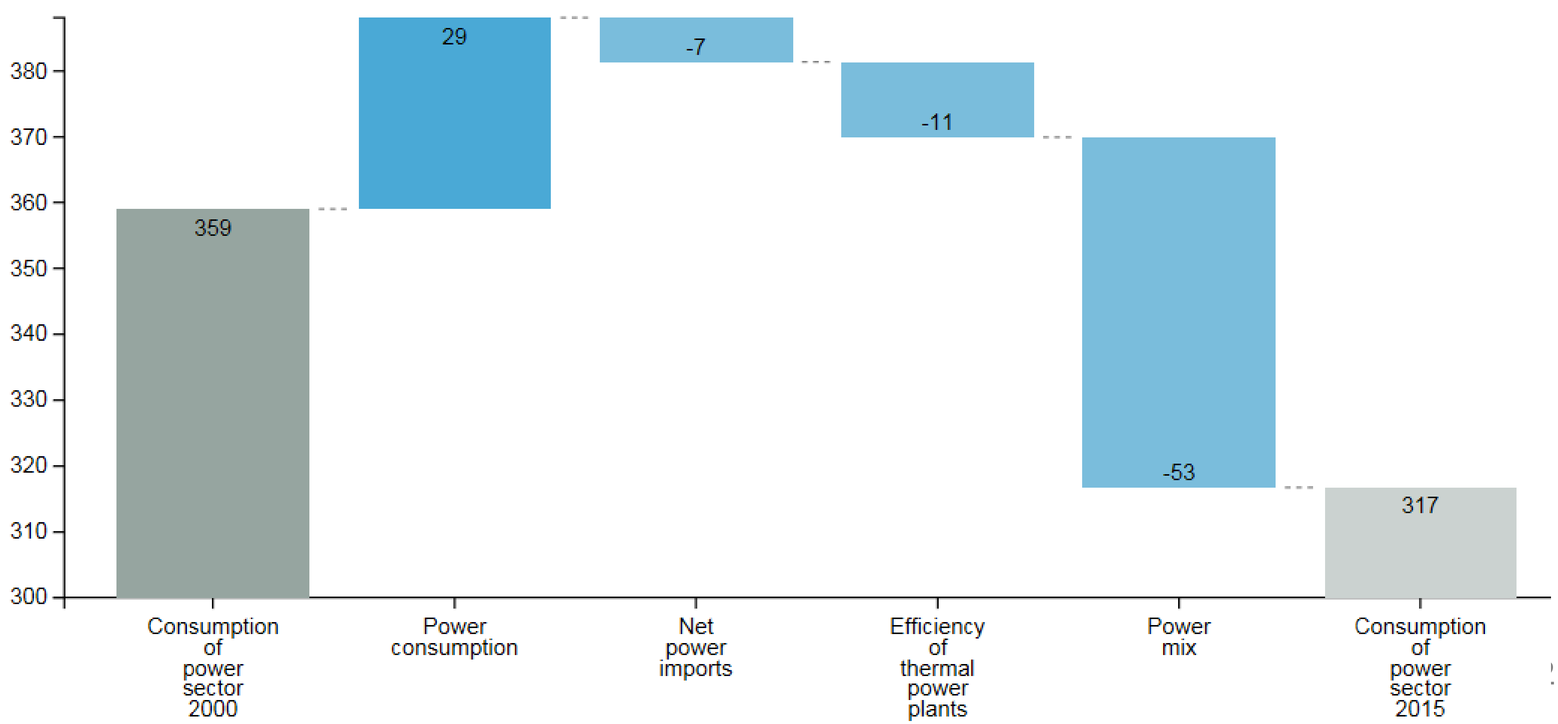
Decomposition for the power sector

- The increase in electricity consumption between 2000 and 2015 (+215 TWh) increased the power sector consumption by 29 Mtoe, all things being equal.
- The increasing share of renewables (from 14 to 24%) contributed to decrease the power sector consumption, by 53.
- The low increase in thermal power efficiency (+ 1 point to 38.5%) had a marginal impact (-11 Mtoe).

Drivers of the net energy consumption variation of the power and heat sector (Mtoe, EU 2000-2015)



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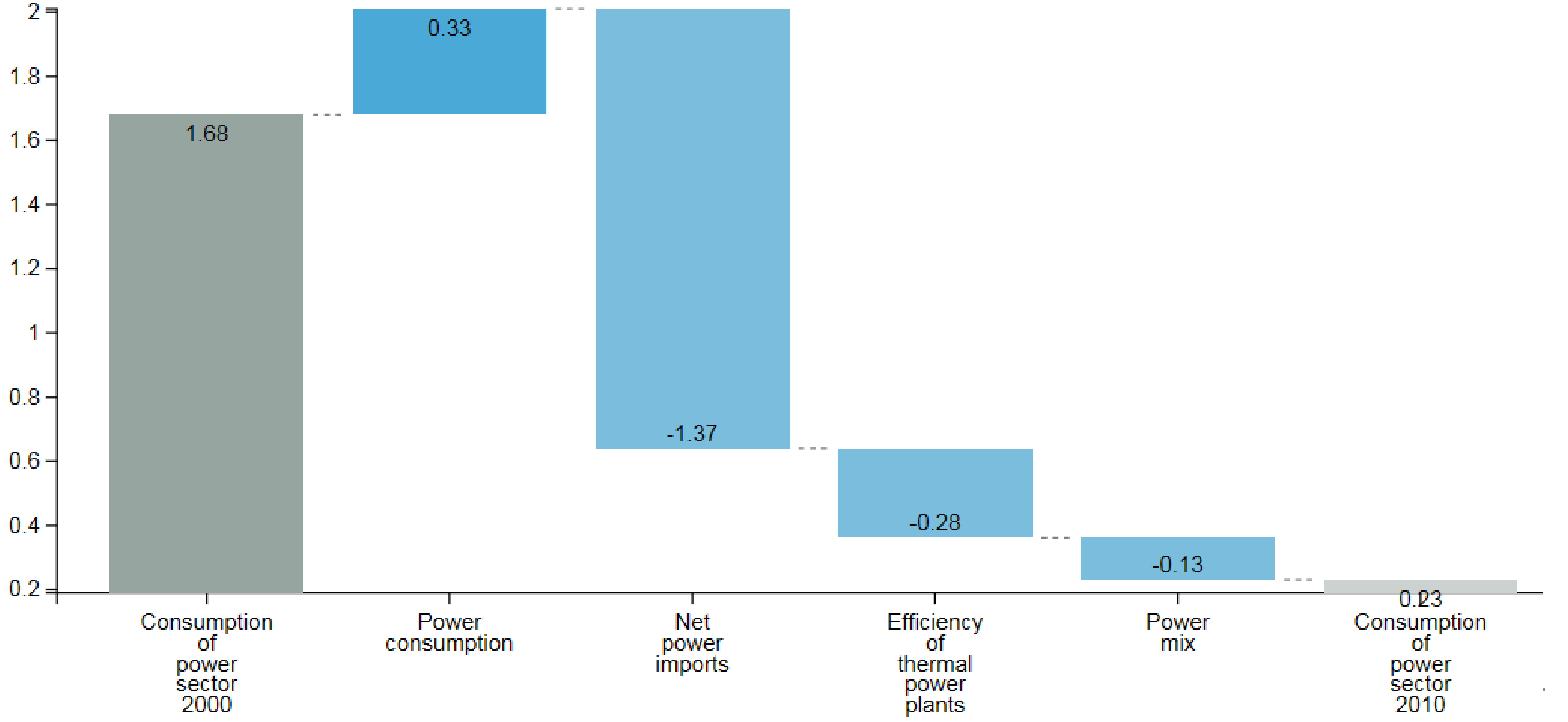
Decomposition for the power sector: case of Lithuania

- The net power consumption decreased a lot between 2000 and 2010 in Lithuania because of a drop in power exports linked to the closure of the nuclear plant. It contributed to decrease the power sector consumption, by80% (- 1.37 Mtoe).

Drivers of the net energy consumption variation of the power and heat sector for Lithuania (Mtoe, 2000-2015)



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Decomposition of energy consumption variation

Primary consumption

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Decomposition of the primary and gross inland energy consumption

- Gross inland energy consumption (Eurostat or TPES at IEA) includes non energy uses whereas, according to EED, primary energy consumption excludes them.

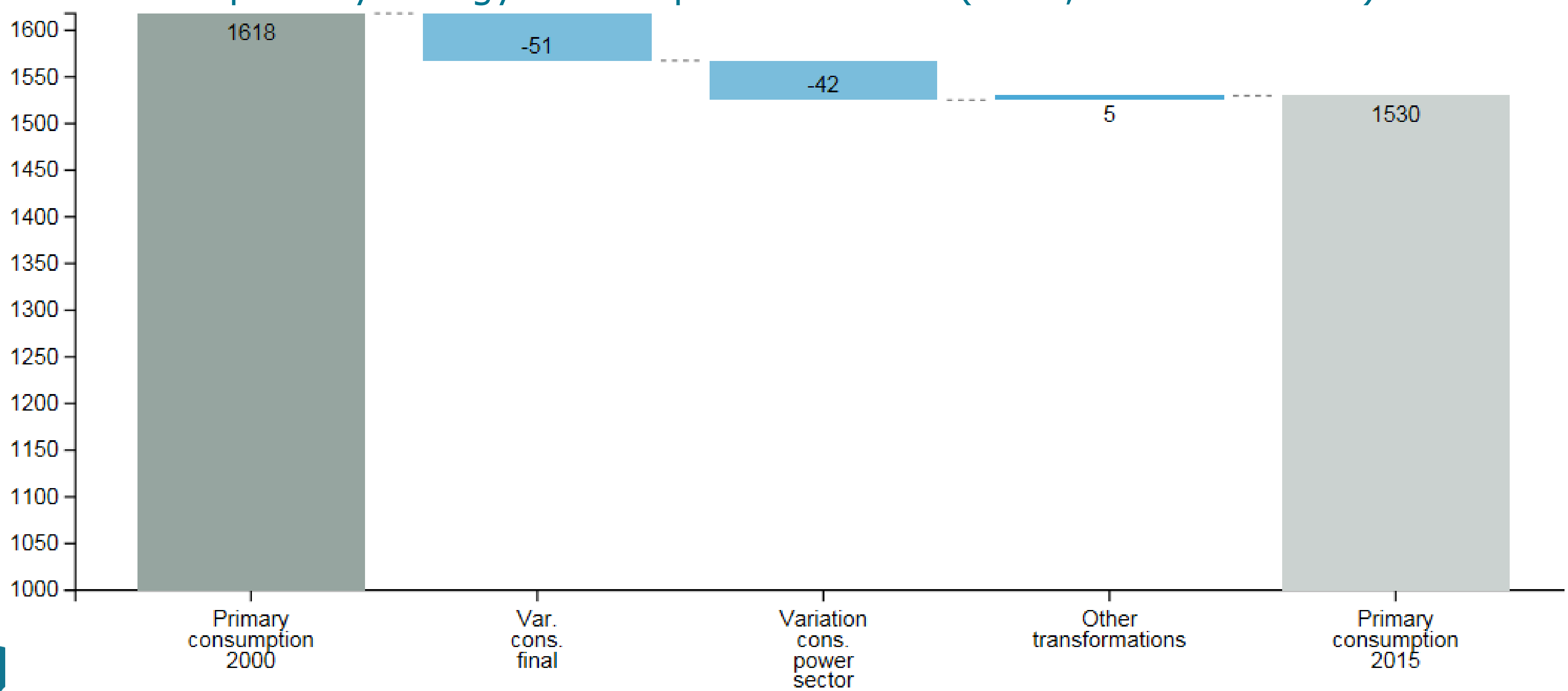
- The variation of the **primary energy consumption** is explained by:
  - the variation of the final energy consumption;
  - the variation of the net consumption of the power sector;
  - the variation of the consumption for other transformations.

- The decomposition of the final energy consumption is done by summing the effects in the different end-use sectors: industry, households, transport, services and agriculture.

Decomposition of the primary energy consumption

- The primary energy consumption decreased by 88 Mtoe between 2000 and 2015: this is the combined effect of a reduction in the final consumption (-51 Mtoe) and of lower consumption in the power sector (-42 Mtoe).

Drivers of primary energy consumption variation (Mtoe, EU 2000-2015)



at normal climate



Annex 1 : Methodology of decomposition of energy consumption variation at sector level in ODYSSEE

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Industry

$$\Delta E_{ind} = Activity\ effect + Structure\ effect + Energy\ savings + Other\ effect$$

Calculated as residual

$$Activity\ effect\ (EQ_{t/t_{-1}}) = IPI_{t/t_{-1}} * (\frac{C_{t-1}}{IPI_{t-1}})$$

$$Structure\ effect) \quad SE_{t/t_{-1}} = \sum_{i=0}^{n} (\Delta IPI_{t/t_{-1}} * \left(\frac{C_{t-1}}{IPI_{t-1}}\right)) - EQ_{t/t_{-1}}$$

$$Energy\ savings = E_t * (1 - \left(\frac{ODEX_{t-1}}{ODEX_t}\right))$$

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Transport (goods)

$$\Delta E_{tra} = Activity\ effect + Modal\ shift + Energy\ savings + Other\ effect$$

Other effects is calculated as the residual

Goods :

$$Activity\ effect = \sum_{i=0}^{m}(\Delta tkm_{m,t/t_{-1}} * CUn_{,t-1})$$

$$Energy\ savings = \sum_{i=0}^{m}\left(\Delta CU_{m,t/t_{-1}} * tkm_{m,t}\right)$$

$$Modal\ shift = Energy\ savings - \left(\Delta CU_{t/t_{-1}} * tkm_t\right)$$

tkm_m: number of tonne kilometre of goods by mode
CU_m: energy consumption by mode per tonne kilometre
m: trucks & light vehicles, rail for goods, inland waterways

Energy savings are « technical » savings: if unit consumption by mode increases, it is kept constant.

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Transport (passengers)

$$\Delta E_{tra} = Activity\ effect + Modal\ shift + Energy\ savings + Other\ effect$$

Other effects is calculated as the residual

Passengers :

$$Activity\ effect = \sum_{i=0}^{n} \left(\Delta pkm_{n,t/t_{-1}} * CU_{n,t-1} \right)$$

$$Energy\ savings = \sum_{i=0}^{n} \left(\Delta CU_{n,t/t_{-1}} * pkm_{n,t} \right)$$

$$Modal\ shift = Energy\ savings - (\Delta \mathrm{CU}_{t/t_{-1}} * pkm_t)$$

pkm_m: number of passenger kilometre by mode
CU_m: energy consumption by mode per passenger kilometre
m: cars, bus, rail for passengers

Energy savings are « technical » savings: if unit consumption by mode increases, it is kept constant.

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Households, services, agriculture, final consumption, primary and power

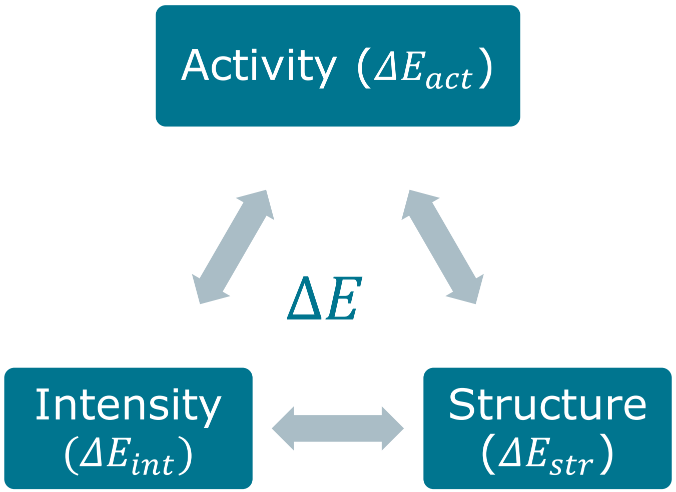
- Specific formulas for the other sectors covered by the decomposition tool in ODYSSEE project are given in the methodological report *Understanding variation in energy consumption*

https://www.indicators.odyssee-mure.eu/decomposition.html

Annex 3 : LMDI methodology and comparison with ODYSSEE

The Divisia method (2/2)

Consumption variation (ΔE) is decomposed into 3 factors:



$$\Delta E = \Delta E_{act} + \Delta E_{str} + \Delta E_{int}$$

$$\Delta E_{act} = \sum_i w_{i,t} * \ln\left(\frac{Q_t}{Q_0}\right) \qquad \Delta E_{str} = \sum_i w_{i,t} * \ln\left(\frac{S_{i,t}}{S_{i,0}}\right) \qquad \Delta E_{int} = \sum_i w_{i,t} * \ln\left(\frac{I_{i,t}}{I_{i,0}}\right)$$

Where $w_{i,t}$ is the weighting factor

The Divisia decomposition method

- Existence of 3 Divisia methods, namely AMDI*, LMDI** I and LMDI II, which differ mainly in the weighting function ➔ LMDI I is the most common method using the logarithmic mean as the weighting function.

LMDI I	LMDI II	AMDI
$w_{i,t} = L\left(E_{i,t}, E_{i,0}\right)$	$w_{i,t} = \dfrac{L\left(\frac{E_{i,t}}{E_t}, \frac{E_{i,0}}{E_0}\right)}{\sum_i L\left(\frac{E_{i,t}}{E_t}, \frac{E_{i,0}}{E_0}\right)} * L(E_t, E_0)$	$w_{i,t} = \dfrac{E_{i,t} + E_{i,0}}{2}$

Where :
$E_{i,t}$ is energy consumption of sub-sector i at year t
E_t is energy consumption of the whole sector

$$L(a,b) = \frac{(b-a)}{\ln(b) - \ln(a)}$$

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**AMDI: Arithmetic Mean Divisia Index*
***LMDI: Logarithmic Mean Divisia Index*

Comparison of ODYSSEE and LMDI decomposition methodologies

	LMDI	ODYSSEE
Formulas	General formulas	Specific formulas by sector and by explanatory factors
Documentation, transparency	Yes but difficult to understand for non specialists	Methodological report available at https://www.indicators.odyssee-mure.eu/php/odyssee-decomposition/documents/interpretation-of-the-energy-consumption-variation-glossary.pdf
Consistency	No residual term	Residual term, which gather various effects
Energy savings calculation	Often energy intensity effect with a general formula	Derived from ODEX indicator

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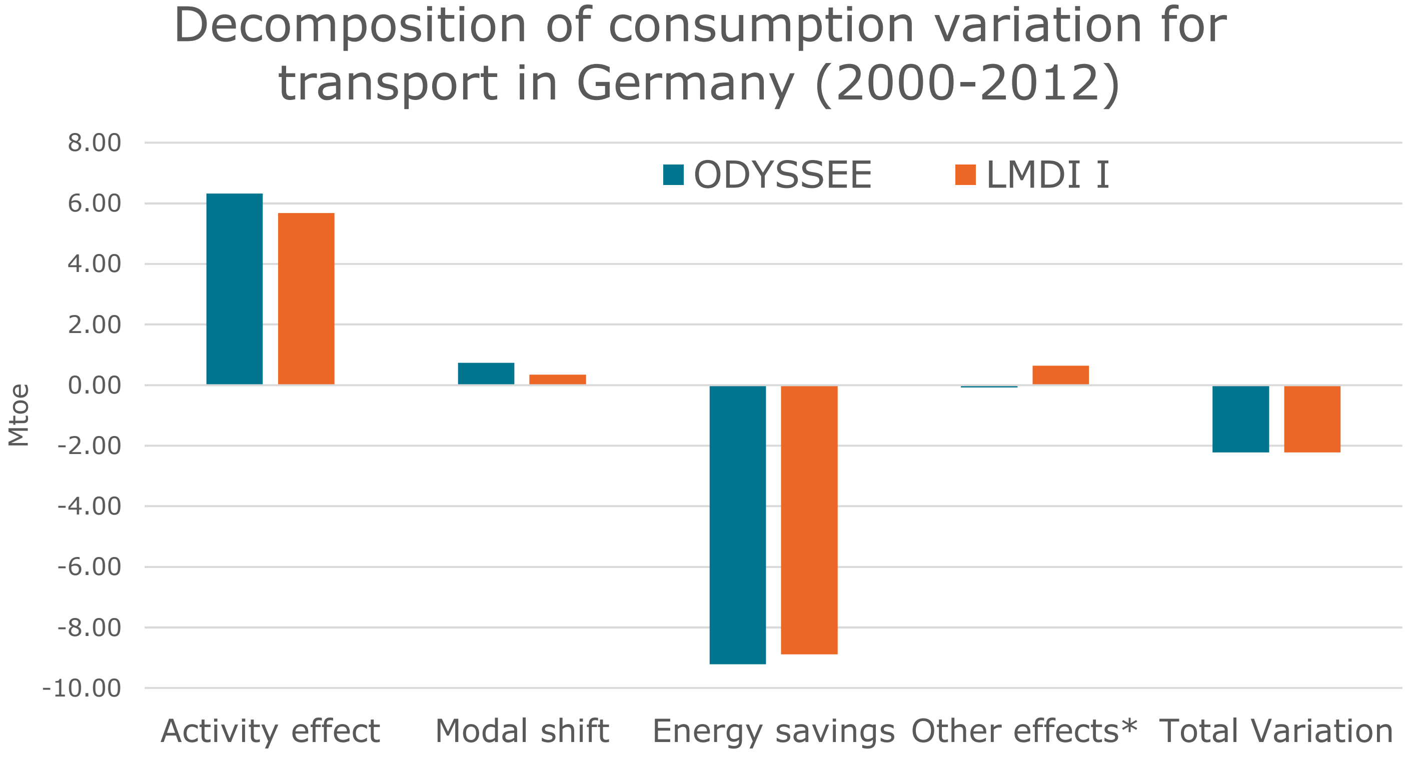
Comparison of ODYSSEE and LMDI decomposition methods: transport

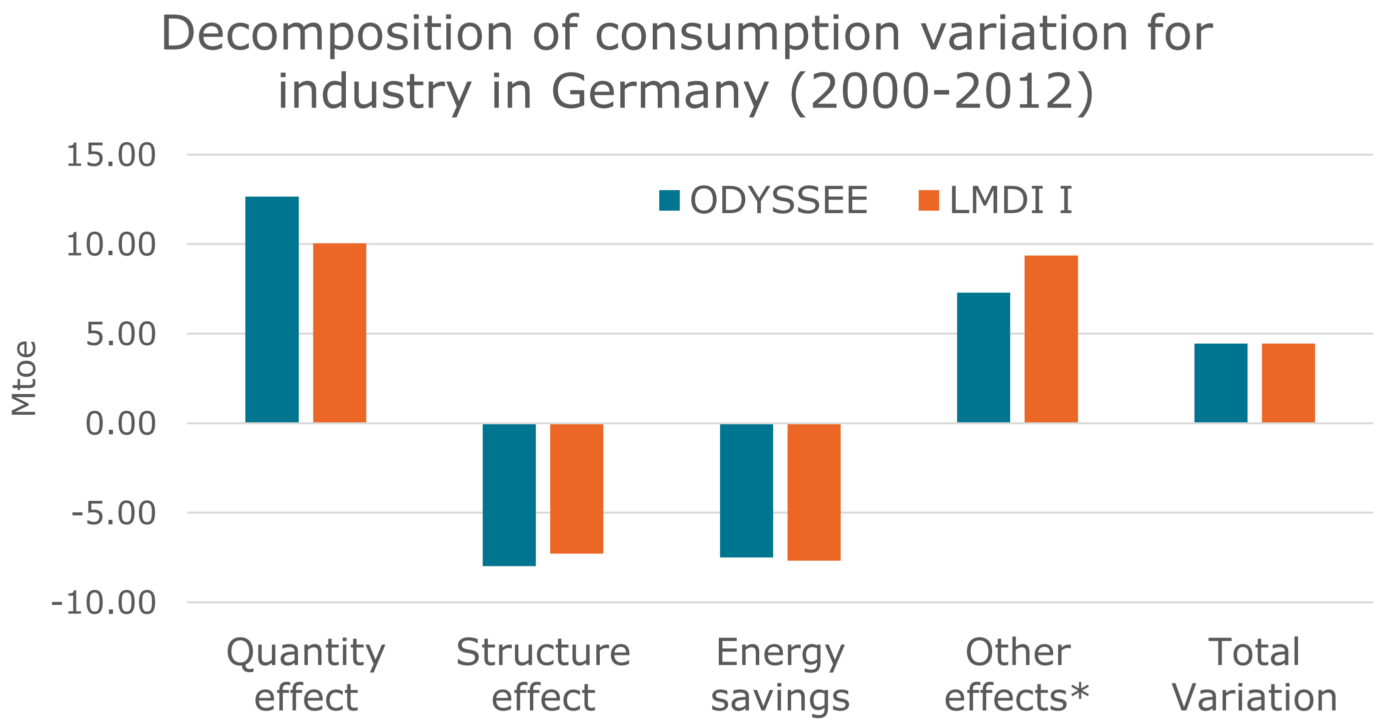


Source: Enerdata estimation

- *Energy savings are calculated as technical savings in both methods.*
- *Other effects in LMDI method represent negative energy savings*

Enerdata

Comparison of ODYSSEE and LMDI decomposition methods: *industry*



Source: Enerdata estimation

- *To allow comparison with ODYSSEE, IPI or physical production was used as activity variable, instead of VA as usually done in LMDI I method.*
- *Energy savings are calculated as technical savings in both methods.*
- *Other effects in LMDI method represent the negative energy savings.*

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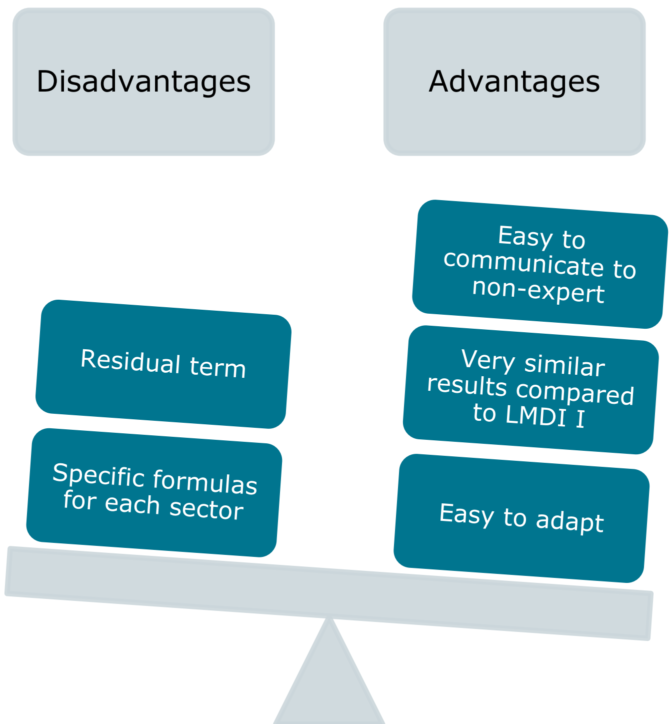
Learnings from the comparison

- LMDI I and ODYSSEE give very similar results.
- Even if ODYSSEE methodology is not based in general formulas that can be applied for all sectors, it can be adapted for each sector and sub-sector depending on the data availability and relevance.

Summary of disadvantages and advantages of ODYSSEE method



Annex 4 : JRC ISPRA methodology and comparison with ODYSSEE

Disagregation level in JRC

- Decomposition analysis proposed by **JRC in 2017** based on the LMDI method and using mainly the statistical database of the European Commission Eurostat (ESTAT).
- ODYSSEE data were also used by for detailed data in transport (energy consumption by mode, traffic) and residential sector (dwelling floor area).

- Two options for the decomposition analysis by sector:
  - Option 1 : aggregate level by sector with transport (3 modes), industry (8 branches), residential, services and agriculture.
  - Option 2: transport (6 modes), residential (2 end-uses) and a sector called "commercial" (grouping of industry with 6 branches, services, agriculture).

* Detailed level of the 2 options given in Annex 1

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Comparison of calculations between JRC and ODYSSEE : industry (1/4)

	JRC	ODYSSEE
Number of branch	6 or 8	12
Decomposition	Activity, structure, intensity	Activity, structure, energy savings, other
Measurement: - Activity - Structure - Intensity	- VA - VA_i /VA - FEC_i/VA_i	- Production index, physical production by branch - Savings based on ODEX
Explanation of the main difference	Higher level of disaggregation and use of physical indicators of activity in ODYSSEE	

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With VA : Value Added, FEC Final Energy Consumption

Comparison of calculations between JRC and ODYSSEE : residential (2/4)

	JRC		ODYSSEE
End-uses	**Option 1** no end-use	**Option 2** heating, other uses	Heating, water heating, cooking, individual large electrical appliances.
Activity	GDP	Floor area, income	Number of occupied dwellings;
Structure	-	-	More appliances per dwelling Floor area of dwellings
Intensity	FEC/GDP	HEC/GDP, OEC/GDP	Energy savings,
Weather	YES	Yes	Yes Other effects (mainly change in heating behaviors);
	More explanatory effects in ODYSSEE and savings measured at detailed level. No savings calculation with JRC		

Comparison of calculations between JRC and ODYSSEE : transport (3/4)

	JRC		ODYSSEE
Modes	**Option 1** Land, air, water	**Option 2** Road, rail, water (passenger, freight),	4 road vehicles, rail (passenger, freight), air, water
Activity Structure Intensity	VA FEC_i/GVA_i	TRF TRF_i /TRF FEC_i/TRF_i	TRF; TRF_i /TRF FEC_i/TRF_i with technical energy savings; Other effects: “negative savings” in freight transport.
Explanation of the main difference	More detailed for road transport in ODYSSEE and measurement of technical savings		

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TRF : traffic in passenger-km and tonne-km, FEC Final Energy Consumption

Comparison of calculations between JRC and ODYSSEE : services (4/4)

	JRC	ODYSSEE
Number of branch	1 branch	6 branches or 1 depending on country
Activity Structure Intensity	VA FEC/VA	VA Energy savings (energy consumed per employee by branch) Productivity effect (ratio VA per employment) Other effects: negative savings Weather
Explanation of the main difference	More effects in ODYSSEE; savings based on employment a proxy for floor area	

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