MICAT

Multiple Impacts Calculation Tool

Economic Impacts

D2.4 Empirical basis of Economic Impacts. Quantification/monetisation methodology and derived impact factors

Lead partner for Deliverable: E3M

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1 Introduction

In the MICAT project Multiple Impacts (MI) of energy efficiency have been grouped into three overarching categories in line with the three pillars of sustainability (Purvis et al. 2019):

- Social impacts
- Economic impacts
- Environmental impacts

This deliverable contains the different indicators that will be analysed within MICAT in the category of **Economic Impacts** (EcI) (see Table 1 below) and presents the indicator-specific quantification and monetisation methods used. Moreover, the report presents the impact factors/functions that are implemented within the MICATool in order to calculate the indicators in the economic impact category and the respective data requirements.[1] The indicators presented here are developd based on methodologies which can be used independently of more sophisticated modelling approaches (GEM-E3 or PRIMES), in order for the indicator analysis to be able to be integrated into the tool and work in a standalone manner.

Economic Impacts (EcI) covered in Task 2.4 involve three main impact categories:

Economy (Macro)

These cover different aspects on the macro-economy, such as effects on GDP, employment, and sectoral shifts. To assess the impact of energy efficiency investments on the macroeconomic indicators, a range of methods are used depending on the type of analysis (ex-post or ex-ante; top-down or bottom-up; scenario, policy or EEI action; national or EU level indicators). The Indicators have been structured In such a way as to be transformed into factors in order to allow for independent analysis within the MICATool. The main tool for the macro analysis is a static type Input-Ouput analysis that allows tractability and replicability of results and more importantly can be utilized in the tool development with no resource restrictions. Energy Intensity is also covered.

Economy (Micro) & Competitiveness

At the micro-economic level the impacts of energy efficiency on asset value of commercial buildings has been quantified. This category also includes impacts on national industry competitiveness by assessing how energy saving measures change the unit cost of production of key industrial sectors, notably those exposed to high energy costs. Furthermore, the increased turnover of energy efficiency goods is quantified. The impacts on energy and ETS carbon prices, that can potentially drive competitveness effects, are also discussed in the context of energy saving measures.

Energy Security & Energy Delivery

This category includes import dependency and energy security (supplier diversity). For the assessment of these effects, methods directly based on the energy savings are used. The monetisation of energy security indicators, namely import dependency and supplier diversity, is still under research. Following the invasion of Ukraine import dependence and security of supply have become of increasing importance both at EU and national level. The calculation is based on three price-defining components: the difference between domestic and foreign resource exploitation costs, infrastructure expenses to transport and store the resource, and the revenue and security premium collected by companies along the supply chain to insure themselves against the risk of price and supply volatilities. Moreover, the impact of energy efficiency on the integration of renewables (demand-response potentials) and the avoided additional energy generation capacity due to lower energy demand are quantified. For the impact on demand-response potentials, the value is assessed by considering the pricing of companies' voluntary flexibility at peak load times and the alternative costs to ensure the flexibility centrally with additional short-term generation capacity or large-scale batteries.

[1] The quantification of MI in MICAT is based on impacts factors or functions (IF) instead of single model runs due to the high flexibility required. The use of IF will allow to calculate the indicators for various dimensions, at different levels of disaggregation and an assessment of MI based on input data entered by tool users (open data entry in MICATool).

TABLE 1: MICAT INDICATORS IN CATEGORY ECONOMIC IMPACTS

EcI	Economic impact indicators	Lead	Quantification methodology / unit
		Economy (Macro)	
EcI-1	Impact on GDP	E3M	Input-Output analysis Unit: mil. €
EcI-2	Employment effects	E3M	Input-Output analysis Unit: thousand persons
EcI-3	Energy price effect	E3M	Unit: % change (range)
EcI-4	ETS price effect	E3M	N/A
EcI-5	Impact on sectoral Shifts	E3M	Input-Output analysis Unit: mil. € and thousand persons
EcI-6	Energy intensity	Fraunhofer	PRIMES model, Final demand reduced by EEI actions divided by GDP Unit: ktoe/1000€
		Economy (Micro) & Competitiveness	
EcI-7	Impact on the asset value of commercial buildings	IEECP	Valuation of buildings and companies for different end-uses according to energy efficiency benefits Unit: €, % change
EcI-8	Turnover of energy efficiency goods	IEECP	Production statistics Unit: €
EcI-9	Impact on Competitiveness	E3M	Input-Output analysis to derive changes in unit cost of production by industrial sector Unit: % change in unit cost of production and/or % change in demand
		Energy Security & Energy Delivery	
EcI-10	Import dependency	Fraunhofer	Main input is final demand reduced by EEI actions. Relevant output is net imports of fuels multiplied by their respective energy prices (based on PRIMES) Unit: %
EcI-11	Aggregated energy security (supply diversity)	Fraunhofer	Relevant output is net imports. Allocation model to determine country of origin of imports. Use of risk indicators to assess political risks Unit: Herfindahl-Hirschman-Index (HHI)
EcI-12	Impact on demand integration of renewables	Fraunhofer	Demand-response potentials by country Unit: MW / %
EcI-13	Avoided additional energy generation capacity	Fraunhofer	Avoided electric power output & investment costs incl. cost for grid infrastructure Unit: €

2 Impact on GDP

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Executive Summary

The indicator presented in this factsheet describes the impacts of energy saving measures on GDP. GDP or value added implications of planned policies or measures are of primary concern, thus an ex-ante assessment of changes in GDP can serve as an indicator for the performance of specific energy efficiency policies and measures. We follow a static multiplier approach to estimate the creation (or reduction) of Value Added due to the additional demand generated in specific sectors that deliver the investments associated with the energy efficiency measures. Here we limit the analysis to estimating in a static approach the GDP impacts resulting from the demand for energy efficiency goods and consider that the energy saving measures generate additional demand for goods and do not substitute existing demand or investments. Similarly, we do not make any explicit assumptions on the financing of the measures. The analysis does not take into consideration the impacts on GDP from i) changes in fossil fuel imports or changes in overall trade of energy carriers, ii) changes in prices and factor markets, and iii) changes in the fiscal budget. A key step in order to estimate the GDP impacts is the calculation of the output multipliers based on IO-Analysis. The methodology relies on the allocation of investment expenditure to demand by economic activities, which is based on expert judgement and assumed uniform by country and sector that applies the measures. The indicator describes that for each million € invested into a specific energy saving measure, additional GVA is generated.

2.1 Scope of MI Indicator

2.1.1 Definition

Energy efficiency measures create demand for products with subsequent income and value-added implications. GDP or Value Added implications of planned policies or measures are of primary concern, thus an ex-ante assessment of changes in GDP can serve as an indicator for the performance of specific energy efficiency policies and measures. We follow a static multiplier approach to estimate the creation (or reduction) of Value Added due to the additional demand generated in specific sectors that deliver the investments associated with the energy efficiency measures. Here we limit the analysis to estimating in a static approach the GDP impacts resulting from the demand for energy efficiency goods and consider that the energy saving measures generate additional demand for goods and do not substitute existing demand or investments. Similarly, we do not make any explicit assumptions on the financing of the measures. The analysis does not take into consideration the impacts on GDP from i) changes in fossil fuel imports or changes in overall trade of energy carriers, ii) changes in prices and factor markets, and iii) changes in the fiscal budget.

2.1.2 Relevance on EU, national and/or local level

GDP as a standard and the most common national measure, reflects the magnitude of a country's economy. It measures the value added created through the production of goods and services in a country during a certain period. It could also be described as the key indicator which is used to assess national accounts or even as a comparison measure between countries and regions. GDP is a key indicator for the socioeconomic assessment of policies at all levels of policy-making, from the EU to national and even local level. Together with the indicator of Employment, these two can be considered as the primary economic indicators of ex-ante policy impact assessment. The GDP indicator is common in most European Commission Impact Assessment documents for climate and energy policies, including the latest documents associated with the Fit-for-55 policy package. Nevertheless, it is not usual to use aggregated measures in order to capture local level adjustments. Thereby, there is low dependence for GDP indicator and the local level.

2.1.3 Impact pathway figure

The methodology adopted to perform the assessment of the GDP indicator of the different measures is composed from the following steps:

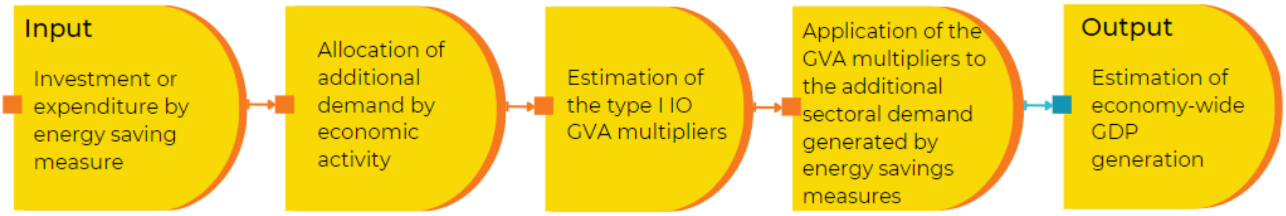

FIGURE 1: QUANTIFICATION STEPS FOR THE ESTIMATION OF THE GDP MI INDICATOR

2.1.4 Overlaps with other MI indicators and potential risk of double-counting

There are strong overlaps with several other economic indicators due to the general, economy-wide coverage of the GDP indicator. Given the strong overlaps, particularly with the MIs Employment effects, Turnover on energy efficiency, Energy price effects, there could be a risk of double-counting.

2.2 Quantification method

2.2.1 Description

A key step in order to estimate the GDP impacts is the calculation of the output multipliers based on IO-Analysis. The GVA Multiplier provides a quantification of the total demand that will be generated in the economy by 1 m. € of additional final demand of a specific sector. This considers the share of imported goods, the direct and indirect effects through the structure of the IO table. In particular the Type I multipliers that are used in this analysis include the direct and indirect impacts, referring to changes in output levels considering sectoral inter-dependencies (IO coefficients) and import dependence by sector. As described in Figure 1, we follow the steps shown below for the quantification of this indicator.

Steps:

1. Receive as input the investment expenditure by type of energy saving measure
2. Calculation of type I gross value added multipliers based on the IO table
3. Associate the investment expenditure to specific demand of goods and services to allocate the additional generated demand by economic activity
4. Application of the respective multipliers by economic activity and estimation of aggregate GVA multiplier by type of energy efficiency measure
5. Estimation of economy-wide GVA generation by applying the multiplier to the level of expenditure by type of measure.

In the second step, the Leontief type I multipliers are calculated by country given the technology coefficients and the consumption preferences of a given economy. This type of analysis does not consider capacity constraints and thus no consideration is taken for the change in prices and the markets of primary factors. The technical coefficient matrix A consists of all technical coefficients as its elements a_{ij}. For every country and for each branch the technical coefficient a_{ij} is calculated as the ratio of the intermediate consumption to total supply for each industry.

The **GVA multiplier** effect is calculated based on the following formula:

$$coeffGVA_j = \sum_i GVART_i \cdot L_{i,j} \quad (1)$$

where:

$GVART_i$: the ratio of gross value added to total supply for the industry I derived by the IO table.

$L_{i,j}$: the ij-element of the Leontief inverse Matrix $L = (I - A)^{-1}$, where i is the sector providing intermediate inputs to the production of sector j

$coeffGVA_j$: the total gross value added that will be generated in the economy for an additional demand of 1 m€ in sector j.

Leontief Inverse Matrix L:

$$L = (I - A)^{-1} \quad (2)$$

where:

I: Identity matrix

A: direct requirements matrix, the ratio of the intermediate consumption to total supply for each industry.

The third step of our methodological approach assumes a table that associates the investment expenditure of each energy efficiency measure to the specific demand of one goods and services. This table aims to allocate the additional generated demand to each of the 65 identified economic activities so that the impacts of energy efficiency measures are dispersed over a number of NACE sectors. The table has been constructed according to expert judgement and thus changing the default assumptions of sectoral allocation by energy efficiency measure can be redefined by the users. Below, in Table 2 we provide a few examples of the allocation of demand by economic activity for the measures of "Building envelope", "Heating fuel switch", and "Energy efficient heating". The numbers in Table 2 express the shares by which the investment expenditure is allocated to each economic activity.

TABLE 2: EXAMPLES OF SECTORAL ALLOCATION OF INVESTMENT EXPENDITURE BY ENERGY SAVING MEASURE

Economic activity	Nace-code	Building envelope	Heating fuel switch	Energy-efficient heating
Other non-metallic mineral products	C23	20%		
Basic metals	C24	20%		
Computer, electronic and optical products	C26			5%
Electrical equipment	C27		15%	5%
Machinery and equipment n.e.c.	C28		50%	50%
Repair and installation services of machinery and equipment	C33		10%	15%
Constructions and construction works	F	40%	10%	10%
Retail trade services, except of motor vehicles and motorcycles	G47	10%	10%	10%
Architectural and engineering services; technical testing and analysis services	M71	10%	5%	5%

As a next step, the GVA multipliers of each of the sectors identified in the table of sectoral allocation are then multiplied by the respective share in Table 2 to provide the overall Employment coefficient in jobs per 1m. € of investments. Finally, to estimate the annual additional employment generated by investment for energy saving measures we multiply the investment expenditure by measure with the above coefficient as shown in the equation (3) below.

$$coeffTOTGVA_{m,c} = \sum_{j} coeffGVA_{j,m,c} \cdot es_{j,m} \quad (3)$$

where,

j : subsector/activities

m : measure / end-use

c : country

$es_{j,m}$: Allocation share of Energy Saving Investment (m) to sector (j)

At the final step, we estimate the economy-wide GDP generation by applying the level of expenditure by type of measure with the gross value added effect generated in the total economy by 1 m€ expenditure, see equation (4).

2.2.2 Methodological challenges

The 2015 SIOT tables from Bulgaria are not available on Eurostat. Czechia, Ireland, Luxemburg and Malta data are deficient. Sweden data are unbalanced (i.e., SIOT is not symmetric) however this country is not excluded. The GVA impact of certain energy saving measures cannot be quantified, thus by default cannot be calculated, as these cannot be associated with the purchase of specific economic activities or are too generic. The methodology assumes only the GVA impacts from the generated additional demand, thus not assuming any other structural changes, e.g. due to the drop of activity in certain sectors, nor the effects of changes in income and prices or the effects on trade balance due to changes in energy imports and exports. Finally, the methodology relies on the allocation of investment expenditure to demand by economic activities, which is based on expert judgement and assumed uniform by country and sector that applies the measures.

2.2.3 Data requirements

The starting point of the analysis is the latest available Symmetric Input Output tables (SIOT) by EU Member State, which are available in Eurostat for year 2015. The sectoral resolution adopted in our analysis is the 64 sectors in NACE rev2. 2-digit, in line with the CPA resolution. Additionally, in order to evaluate the exact effect on the Employment, the sectoral demand contributions should be assumed.

2.3 Impact factor/functional relationship

The associated additional GDP is proportional to the Energy Saving Investments. Every investment in energy saving measure is attributed to sectors and the total effect on GDP is calculated as shown below:

$$GDP_{m,c,y} = coeffTOTGVA_{m,c} \cdot Inv_y \quad (4)$$

where,

m : measure / end-use

c : country

y : year

Inv_y : Energy Saving Investments

In conclusion, GDP effect depends on impact factor coefficient per country and subsectors – which are determined as aggregation of industries or product groups of the IO-table – and the sectoral investment demand assumptions – which are set by default or according to user's choice. Thus, GDP level is determined by the impact factor and the Investment according to energy saving allocation measures.

2.4 Monetisation

The indicator is already expressed in terms of million EUR.

2.5 Aggregation

The indicator could be aggregated with other indicators, though overlaps and double counting should be considered.

2.6 Conclusion

Below we provide examples for the calculation of the impact on GDP for three selected EU Member States, namely Germany, Italy and Poland.

Germany

TABLE 3: CALCULATION OF THE IMPACT ON GDP FOR GERMANY

			Annual energy saving expenditure in million €						
Subsector	Measure	Country	2020	2025	2030	2035	2040	2045	2050
Machinery	Space heating and cooling	Germany	150	150	150	150	150	150	150
			Annual GVA generated by investment for energy saving measures						
Coefficient for GVA Effect in m. € per 1m. € of investments			2020	2025	2030	2035	2040	2045	2050
0.62			93.5	93.5	93.5	93.5	93.5	93.5	93.5

Therefore, it can be derived that for each million € invested into Machinery industry for Space heating and cooling - energy efficient measure, 0.62 million are annually generated as GVA, thus a 150 million € - Investment would annually generate 93.5 million GVA.

Italy

TABLE 4: CALCULATION OF THE IMPACT ON GDP FOR ITALY

			Annual investments in million €						
Subsector	Measure	Country	2020	2025	2030	2035	2040	2045	2050
Average tertiary	Building envelope	Italy	150	150	150	150	150	150	150
			Annual GVA generated by investment for energy saving measures						
Coefficient for GVA Effect in m. € per 1m. € of investments			2020	2025	2030	2035	2040	2045	2050
0.72			108.7	108.7	108.7	108.7	108.7	108.7	108.7

Therefore, it can be derived that for each million € invested into Average tertiary sector for Building envelope - energy efficient measure, 0.72 million are annually generated as GVA, thus a 150 million € - Investment would annually generate 108.7 million GVA.

Poland

Table 5: Calculation of the impact on GDP for Poland

			Annual investments in million €						
Subsector	Measure	Country	2020	2025	2030	2035	2040	2045	2050
Construction	Fuel switch	Poland	150	150	150	150	150	150	150
			Annual GVA generated by investment for energy saving measures						
Coefficient for GVA Effect in m. € per 1m. € of investments			2020	2025	2030	2035	2040	2045	2050
0.49			73.3	73.3	73.3	73.3	73.3	73.3	73.3

Therefore, it can be derived that for each million € invested into Construction sector for Fuel switch energy efficient measure, 0.49 million are annually generated as GVA, thus a 150 million € investment would annually generate 73.3 million € GVA.

3 EMPLOYMENT EFFECTS

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Reviewer: Frederic Berger (Fraunhofer ISI)

Executive summary

The indicator presented in this factsheet describes the impacts of energy saving measures on employment. Employment implications of planned policies or measures are of primary concern, thus an ex-ante assessment of changes in employment can serve as an indicator for the performance of specific energy efficiency policies and measures. We follow a static multiplier approach to estimate the creation (or reduction) of employment due to the additional demand generated in specific sectors that deliver the investments associated with the energy efficiency measures. A key step in order to estimate the employment impacts is the calculation of the employment multipliers based on IO-Analysis. The Employment Multiplier provides a quantification of the employment in persons that will be generated in the economy by 1 m. € of new final demand. This considers the share of imported goods, the direct and indirect effects through the structure of the IO table. The methodology assumes only the employment impacts from the generated additional demand, thus not assuming any other structural changes, e.g. due to the drop of activity in certain sectors, nor the effects of changes in income and prices. Finally, the methodology relies on the allocation of investment expenditure to demand by economic activities, which is based on expert judgement and assumed uniform by country and sector that applies the measures.

3.1 Scope of MI indicator

3.1.1 Definition

Energy efficiency measures create demand for products with subsequent income and value-added implications. Employment implications of planned policies or measures are of primary concern, thus an ex-ante assessment of changes in employment can serve as an indicator for the performance of specific energy efficiency policies and measures. We follow a static multiplier approach to estimate the creation (or reduction) of employment due to the additional demand generated in specific sectors that deliver the investments associated with the energy efficiency measures. Here we limit the analysis to estimating in a static approach the employment impacts resulting from the demand for energy efficiency goods and consider that the energy saving measures generate additional demand for goods and do not substitute existing demand or investments. Similarly, we do not make any explicit assumptions on the financing of the measures.

3.1.2 Relevance on EU, national and/or local level

Employment is a key indicator for the socioeconomic assessment of policies at all levels of policy-making, from the EU to national and even local level. Together with the indicator of GDP or Value Added, these two can be considered as the primary economic indicators of ex-ante policy impact assessment. The employment indicator is common in most European Commission Impact Assessment documents for climate and energy policies, including the latest documents associated with the Fit-for-55 policy package.

3.1.3 Impact pathway figure

The methodology adopted to perform the assessment of the employment indicator of the different measures is composed from the following steps:

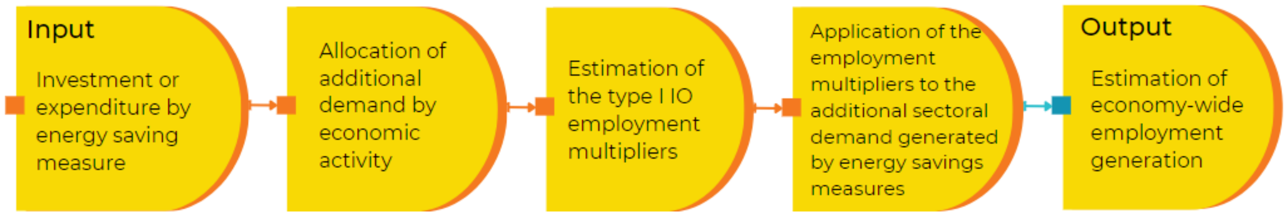

FIGURE 2: QUANTIFICATION STEPS FOR THE ESTIMATION OF THE EMPLOYMENT MI INDICATOR

3.1.4 Overlaps with other MI indicators and potential risk of double-counting

No risk of overlaps or double-counting with other MI indicators.

3.2 Quantification method

3.2.1 Description

A key step in order to estimate the employment impacts is the calculation of the employment multipliers based on IO-Analysis. The Employment Multiplier provides a quantification of the employment in persons that will be generated in the economy by 1 m. € of new final demand. This considers the share of imported goods, the direct and indirect effects through the structure of the IO table. As described in Figure 2, we follow the steps shown below for the quantification of this indicator.

Steps:

1. Receive as input the investment expenditure by type of energy saving measure
2. Calculation of type I employment multipliers based on the IO table
3. Associate the investment expenditure to specific demand of goods and services to allocate the additional generated demand by economic activity.
4. Application of the respective multipliers by economic activity and estimation of aggregate employment multiplier by type of energy efficiency measure
5. Estimation of economy-wide employment generation by applying the multiplier to the level of expenditure by type of measure.

In the second step, the Leontief type I multipliers are calculated by country given the technology coefficients and the consumption preferences of a given economy. This type of analysis does not consider capacity constraints and thus no consideration is taken for the change in prices and the markets of primary factors. The technical coefficient matrix A consists of all technical coefficients as its elements a_{ij}. For every country and for each branch the technical coefficient a_{ij} is calculated as the ratio of the intermediate consumption to total supply for each industry.

The Employment multiplier effect is calculated based on the following formula:

$$coeffEMPL_j = \sum_i EMPLRT_i \cdot L_{i,j} \quad (1)$$

where:

$EMPLRT_i$: the ratio of number of employees to total supply for the industry I, measured in jobs per million € coefficients derived by the IO table.

$L_{i,j}$: *the ij-element of the Leontief inverse Matrix* $L = (I - A)^{-1}$, *where i is the sector providing intermediate inputs to the production of sector j*

$coeffEMPL_j$: *the total number of employees that will be generated in the economy for an additional demand of 1 m€ in sector j.*

Leontief Inverse Matrix L:

$$L = (I - A)^{-1} \quad (2)$$

where:

I: Identity matrix

A: direct requirements matrix, the ratio of the intermediate consumption to total supply for each industry.

The third step of our methodological approach assumes a table that associates the investment expenditure of each energy efficiency measure to the specific demand of one goods and services. This table aims to allocate the additional generated demand to each of the 65 identified economic activities so that the impacts of energy efficiency measures are dispersed over a number of NACE sectors. The table has been constructed according to expert judgement and thus changing the default assumptions of sectoral allocation by energy efficiency measure can be redefined by the users. Below, in Table 6 we provide a few examples of the allocation of demand by economic activity for the measures of “Building envelope”, “Heating fuel switch”, and “Energy efficient heating”. The numbers in Table 6 express the shares by which the investment expenditure is allocated to each economic activity.

TABLE 6: EXAMPLES OF SECTORAL ALLOCATION OF INVESTMENT EXPENDITURE BY ENERGY SAVING MEASURE

Economic activity	Nace-code	Building envelope	Heating fuel switch	Energy-efficient heating
Other non-metallic mineral products	C23	20%		
Basic metals	C24	20%		
Computer, electronic and optical products	C26			5%
Electrical equipment	C27		15%	5%
Machinery and equipment n.e.c.	C28		50%	50%
Repair and installation services of machinery and equipment	C33		10%	15%
Constructions and construction works	F	40%	10%	10%
Retail trade services, except of motor vehicles and motorcycles	G47	10%	10%	10%
Architectural and engineering services; technical testing and analysis services	M71	10%	5%	5%

As a next step, we estimate the annual additional employment generated in the economy by an investment of 1 m € for energy saving measures. The sectoral allocation of demand is derived by the respective share in Table 6 and determines how the additional demand from 1 m€ of investment in energy saving measures is allocated to sectors. Based on this allocation the total effect in the employment from 1 m€ investment in energy saving measures is calculated by multiplying each of the additional demand allocated to sectors with the respective employment coefficient as calculated in step one, see equation (3).

$$coeffTOTEMPL_{m,c} = \sum_j coeffEMPL_{j,m,c} \cdot es_{j,m} \quad (3)$$

where,

j : subsector/activities

m : measure / end-use

c : country

$es_{j,m}$: Allocation share of Energy Saving Investment (m) to sector (j)

At the final step, we estimate the economy-wide employment generation by applying the level of expenditure by type of measure with the employment effect generated in the total economy by 1 m€ expenditure, see equation (4).

3.2.2 Methodological challenges

The 2015 SIOT tables from Bulgaria are not available on Eurostat. Czechia, Ireland, Luxemburg and Malta data are deficient. Sweden data are unbalanced (i.e., SIOT is not symmetric) however this country is not excluded. The employment impact of certain energy saving measures cannot be quantified, thus by default cannot be calculated, as these cannot be associated with the purchase of specific economic activities or are too generic. The methodology assumes only the employment impacts from the generated additional demand, thus not assuming any other structural changes, e.g. due to the drop of activity in certain sectors, nor the effects of changes in income and prices. Finally, the methodology relies on the allocation of investment expenditure to demand by economic activities, which is based on expert judgement and assumed uniform by country and sector that applies the measures.

3.2.3 Data requirements

The starting point of the analysis is the latest available Symmetric Input Output tables (SIOT) by EU Member State, which are available in Eurostat for year 2015. The sectoral resolution adopted in our analysis is the 65 sectors in NACE rev2. 2-digit, in line with the CPA resolution. Additionally, in order to evaluate the exact effect on the Employment, the sectoral demand contributions should be assumed.

3.3 Impact factor/functional relationship

The associated additional Employment is proportional to the Energy Saving Investments. Every investment in energy saving measure is attributed to sectors and the total effect on employment is calculated as shown below.

$$TOTEMPL_{m,c,y} = coeffTOTEMPL_{m,c} \cdot Inv_y \quad (4)$$

where,

m : measure / end-use

c : country

y : year

Inv_y *: Energy Saving Investments*

In conclusion, Employment effect depends on impact factor coefficient per country and measure, which are determined as aggregation of industries or product groups of the IO-table, and the sectoral investment demand assumptions, which are set by default or according to user's choice. Thus, Employment level is determined by the impact factor and the Investment according to energy saving allocation measures.

3.4 Monetisation

No monetisation is expected for this indicator, unless associated with a mean wage by country.

3.5 Aggregation

The indicator cannot be directly aggregated with other indicators.

3.6 Conclusion

Below we provide examples for the calculation of the Employment indicator for three selected EU Member States, namely Germany, Italy and Poland.

Germany

TABLE 7: CALCULATION OF THE EMPLOYMENT INDICATOR FOR GERMANY

			Annual energy saving expenditure in million €						
Subsector	**Measure**	**Country**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Machinery	Space heating and cooling	Germany	150	150	150	150	150	150	150
			Annual additional employment generated by investment for energy saving measures						
Coefficient for employment Effect in jobs per 1m. € of investments			**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
10.14			1521.6	1521.6	1521.6	1521.6	1521.6	1521.6	1521.6

Therefore, it can be derived that for each million € invested into machinery industry for the energy efficiency measure space heating and cooling, 10.14 annual additional employment is generated. Thus an 150 million € investment would annually generate 1521.6 additional employment.

Italy

TABLE 8: CALCULATION OF THE EMPLOYMENT INDICATOR FOR ITALY

			Annual investments in million €						
Subsector	**Measure**	**Country**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Average tertiary	Building envelope	Italy	150	150	150	150	150	150	150
			Annual additional employment generated by investment for energy saving measures						
Coefficient for employment Effect in jobs per 1m. € of investments			**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
13.88			2081.7	2081.7	2081.7	2081.7	2081.7	2081.7	2081.7

Therefore, it can be derived that for each million € invested into average tertiary sector for the building envelope energy efficiency measure, 13.88 annual additional employment is generated. Thus an 150 million € investment would annually generate 2081.7 additional employment.

Poland

TABLE 9: CALCULATION OF THE EMPLOYMENT INDICATOR FOR POLAND

			Annual investments in million €						
Subsector	**Measure**	**Country**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Construction	Fuel switch	Poland	150	150	150	150	150	150	150
			Annual additional employment generated by investment for energy saving measures						
Coefficient for employment Effect in jobs per 1m. € of investments			**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
18.09			2713.1	2713.1	2713.1	2713.1	2713.1	2713.1	2713.1

Therefore, it can be derived that for each million € invested into the construction sector for fuel switch energy efficiency measure, 18.09 annual additional employment is generated. Thus an 150 million € investment would annually generate 2713.1 additional employment.

4 Impact on competitiveness

Authors: Zoi Vrontisi, Kostas Fragkiadakis, Sakis Morfis (E3M)
Reviewer: Frederic Berger (Fraunhofer ISI)

Executive summary

The indicator describes the impacts of energy saving measures on competitiveness. Competitiveness implications of planned policies or measures are of primary concern especially for sectors most exposed to energy-related expenditures. To assess these impacts, we calculate the ratio of energy costs in total unit cost of production per sector based on an IO-Analysis. The analysis is limited to the estimation – in a static manner – of the competitiveness impacts that are associated with energy purchases, and does not consider any changes in expenditures for equipment goods or other types of energy saving investments. Moreover, the analysis does not take into account any subsequent changes in the prices of other intermediate or factor inputs to production.

4.1 Scope of MI indicator

4.1.1 Definition

Energy efficiency measures directly affect the energy costs associated with the production of goods and services, with subsequent implications to the overall cost structure and competitiveness of the sector. Competitiveness implications are a key indicator of the performance of specific policies and measures, of primary importance to sectors most exposed to energy expenditures. Here we assume that the change in energy costs/purchases will be provided as an input for the estimation of the competitiveness implications. Based on this input and the Input-Output tables, we estimate the change in the unit cost of production of each sub-sector defined by the project. Here we limit the analysis to estimating in a static approach the competitiveness impacts that are associated with energy purchases, but do not consider any changes in expenditures for equipment goods or other types of energy saving investments. We also do not take into consideration any subsequent changes in the prices of other intermediate or factor inputs to production.

4.1.2 Relevance on EU, national and/or local level

This indicator is primarily relevant at national level, assuming the country-specific production structure of an industrial good. No data is available at a local level.

4.1.3 Impact pathway figure

The methodology adopted to perform the assessment of the competitiveness indicator of the different energy saving measures is composed by the following steps:

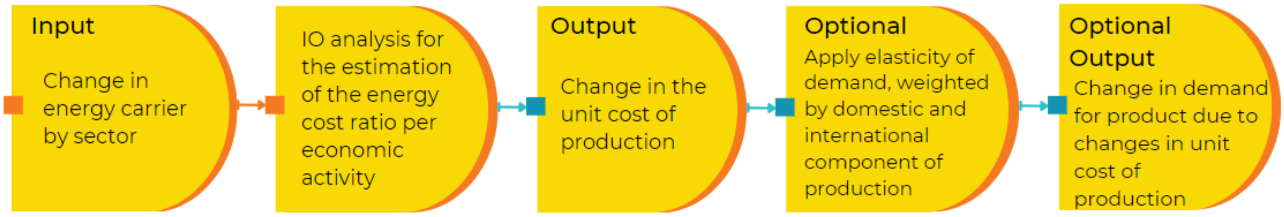

FIGURE 3: QUANTIFICATION STEPS FOR THE ESTIMATION OF THE COMPETITIVENESS MI INDICATOR

4.1.4 Overlaps with other MI indicators and potential risk of double-counting

There is no risk of overlaps or double-counting with other MI indicators.

4.2 Quantification method

4.2.1 Description

A key step in order to estimate the competitiveness impacts is the calculation of the ratio of energy costs in total unit cost of production per sector. This is based on IO-Analysis. The competitiveness indicator provides a quantification of the change of the unit cost of production due to changes in energy costs (or purchases of energy carriers). As described in Figure 3, we follow the steps shown below for the quantification of this indicator.

Steps:

1. Receive as input the change in energy purchases by subsector
2. Calculation of the ratio of energy purchases in total production for each sector/activity based on the IO table
3. Estimation of the change in unit cost of production
4. (optional) Estimation of the change in demand

First, we calculate the ratio of the energy purchases per economic activity, as a ratio of the total energy purchases to the sector's output production level based on IO table and according to the following formula:

$$NRG\_C_j = \frac{E_j}{PROD_j} \qquad (1)$$

where:

j : economic activities in IO table

NRG_C_j : the energy cost ratio per activity j

E_j : the energy carrier purchases consumed per activity j derived by the IO table

$PROD_j$: the total output level of production per activity j derived by the IO table.

To then derive the change in the unit cost of production, we prepare a concordance table between the 65 NACE sectors of our IO analysis and the subsectors defined by the project. We assume that the changes in energy purchases of the subsector (input by user) apply uniformly to all sectors that comprise this subsector.

The final step is to estimate the change in the **Unit Cost of Production** for each subsector. This rate is proportional to the energy cost change assumption as it is shown in the following formula:

$$UC_j = \Delta E_j \cdot NRG\_C_j \quad (2)$$

where:

j : sectors of the economy

NRG_C_j : the energy cost ratio per activity j

ΔE_j : the energy cost change assumption for sector j

4.2.2 Data requirements

The starting point of the analysis is the latest available Symmetric Input Output tables (SIOT) by EU Member State, which are available in Eurostat for the year 2015. The sectoral resolution adopted in our analysis is the 65 sectors in NACE rev2. 2-digit, in line with the CPA resolution. Additionally, in order to evaluate the exact effect on the competitiveness, the energy cost changes, and the elasticities of demand should be assumed.

4.3 Impact factor/functional relationship

The impact functional relationship is provided by equation (2). However an optional further step includes the estimation of the associated **Change in Demand** for each sector. This is based on elasticities of demand that are found in the literature and describe the relationship of changes in a price of good (in this case the unit cost of production) and the derived change in demand. The elasticity can be differentiated for the domestic and international component of production and in its general form can be described by:

$$\frac{\Delta Q}{Q} = -\varepsilon \cdot UC_j \quad (3)$$

where:

$\frac{\Delta Q}{Q}$: the change in demand

ε : Price elasticity of demand (from literature)

j : sectors of the economy

4.4 Monetisation

The indicator can be monetized once the change in demand of goods is estimated (in mil. EUR).

4.5 Aggregation

The indicator cannot be directly aggregated with other indicators.

4.6 Conclusion

Below we provide examples for the calculation of the competitiveness indicator for three selected EU Member States, namely Germany, Italy and Poland.

Germany

Table 10: Calculation of the Competitiveness indicator for Germany

			Change in Energy Cost						
Subsector	**Measure**	**Country**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Average agriculture	Space heating and cooling	Germany	-10%	-10%	-10%	-10%	-10%	-10%	-10%
			Change in Unit Cost of Production						
			2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
			-1.2%	-1.2%	-1.2%	-1.2%	-1.2%	-1.2%	-1.2%

Italy

Table 11: Calculation of the Competitiveness indicator for Italy

			Change in Energy Cost						
Subsector	**Measure**	**Country**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Construction		Italy	-20%	-20%	-20%	-20%	-20%	-20%	-20%
			Change in Unit Cost of Production						
			2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
			-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%

Poland

Table 12: Calculation of the Competitiveness indicator for Poland

			Change in Energy Cost						
Subsector	**Measure**	**Country**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Mining and quarrying		Poland	-30%	-30%	-30%	-30%	-30%	-30%	-30%
			Change in Unit Cost of Production						
			2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
			-5%	-5%	-5%	-5%	-5%	-5%	-5%

5 ENERGY PRICE EFFECT

Authors: Alessia De Vita, Kristina Goborukha, Zoi Vrontisi (E3M)
Reviewer: Marco Peretto (IEECP)

Executive summary

The indicator describes the effect of energy efficiency measures on the energy prices. We discuss which energy prices can be affected by energy efficiency, and whether energy efficiency can have a meaningful impact on energy prices.

We focus the analysis on electricity and heat/steam prices which are produced almost exclusively in the EU and therefore are subject to limited effects from global trade.

We find that different efficiency measures, while contributing to improving overall system efficiency, could have upward and/or downward trends on electricity and steam/heat demand and therefore also different effects on energy prices.

It is clear that only policies with large impacts at national level may have an impact on the prices, but that the direct link between energy efficiency and prices is difficult to establish.

We suggest a functional form, however we explain the limitations of the calculation of such an indicator.

5.1 Scope of MI Indicator

5.1.1 Definition

Energy savings result in reduction of final energy consumption and reduce the amount of energy purchased. Reduction of the energy demand can contribute to the reduction of energy prices, but this contribution is tightly linked to contribution of other factors such as changes in energy mix, fuel substitution potential in economic sectors and trading conditions of main energy carriers. Thus, an effect of energy efficiency measures on energy prices is not easy to isolate.

5.1.2 Relevance on EU, national and /or local level

End user energy prices are composed of multiple components:

- Production cost of energy carrier and market conditions
- Transmission and distribution
- Excise duties and other taxes

Energy carriers should further be split into domestically produced energy carriers and internationally traded energy carriers. From a European perspective, fossil fuels – with the exception of lignite – are mostly imported goods traded on the international energy markets. Electricity, while being traded within Europe, is to a large extent domestically produced in most EU countries. Steam/heat is a domestic – generally local – energy carrier. In future, it is expected that additional energy carriers may be introduced into the market such as hydrogen and e-fuels: similarly to electricity, it is expected that these may be produced domestically, however also international trade is increasingly envisaged.

Single energy efficiency measures in single regions or countries cannot have a significant impact on energy prices; however, energy prices are intrinsically linked to energy demand as the recent developments of the gas price has shown.

The war in Ukraine has caused a huge disruption in the natural gas supply to Europe, leading to extremely high natural gas prices in the first half of 2022. However, since August 2022 prices have been steadily declining in the EU gas market and a downward trend is also expected in the future.[2]

The reduction in gas prices has been linked to the mild winter in Europe (and the US), improved energy efficiency, diversification of gas supply, as well as behavioural changes. However, the triggers for the reduction in gas consumption were the combination of high prices and the mild weather rather than specific energy efficiency policies. Furthermore, other geopolitical factors, such as the low demand from countries such as China have also played a significant role in the development of gas prices.

On general terms, energy efficiency measures can influence energy carrier prices to a limited extent and only for energy carriers sourced within the EU, where geopolitical factors play a relatively minor role.

Further, in order to assess energy carrier prices formed on international competitive markets, one would require a world-wide referencing process, which is not applicable in the current context.

5.1.3 Impact pathway figure

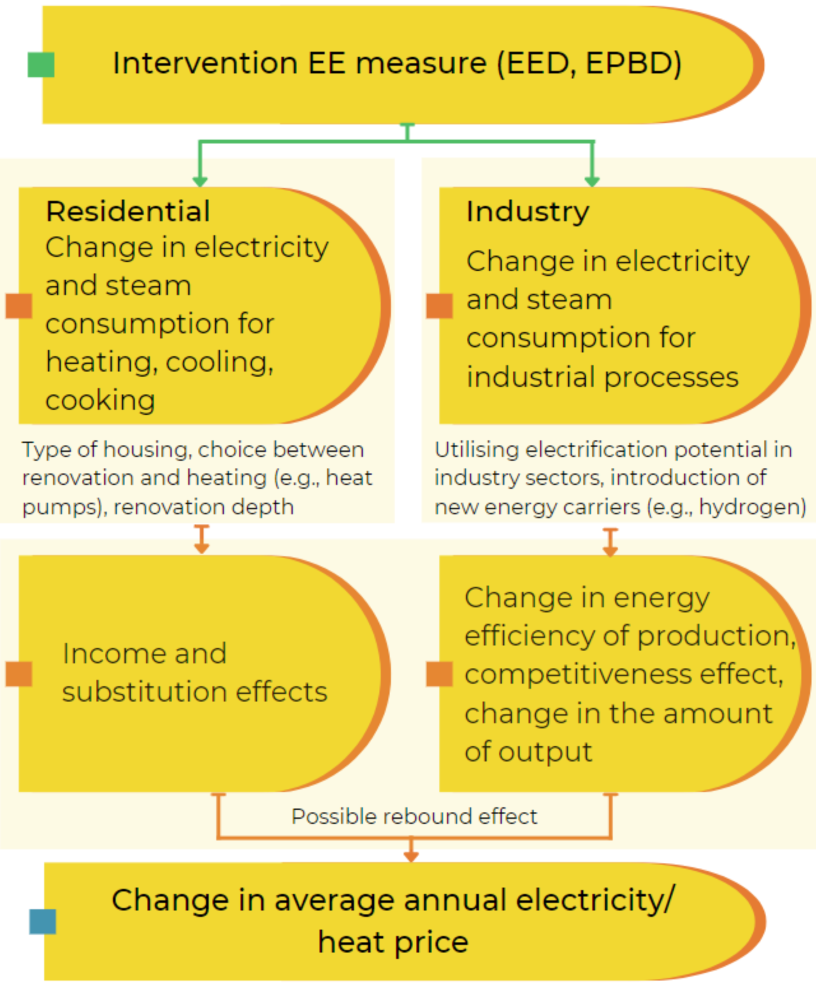

FIGURE 4: POSSIBLE IMPACTS OF ENERGY EFFICIENCY MEASURES ON THE ENERGY PRICES

[2] https://blogs.worldbank.org/opendata/bubble-trouble-whats-behind-highs-and-lows-natural-gas-markets

5.1.4 Overlaps with other MI indicators and potential risk of double counting

This indicator is not directly linked to any other MI indicator. No double counting with other indicators evaluated in the context of MICAT is considered.

5.2 Quantification method

5.2.1 Description

The quantification of the energy price effect relies on the estimation of elasticities of the change in energy prices relative to energy quantities induced by energy efficiency measures.

Only steam/heat and electricity prices are assumed to be affected by the changes in energy efficiency. However, overlapping effects are assumed to take place which do not fully allow to isolate the effect of energy efficiency measures on the energy carriers.

At an individual level policies/measures are not able to modify the energy carrier demand to such an extent so as to influence the energy prices.

Further efficiency measures may have upward and downward effects on the energy quantities and may therefore have "contradictory" effects on the market.

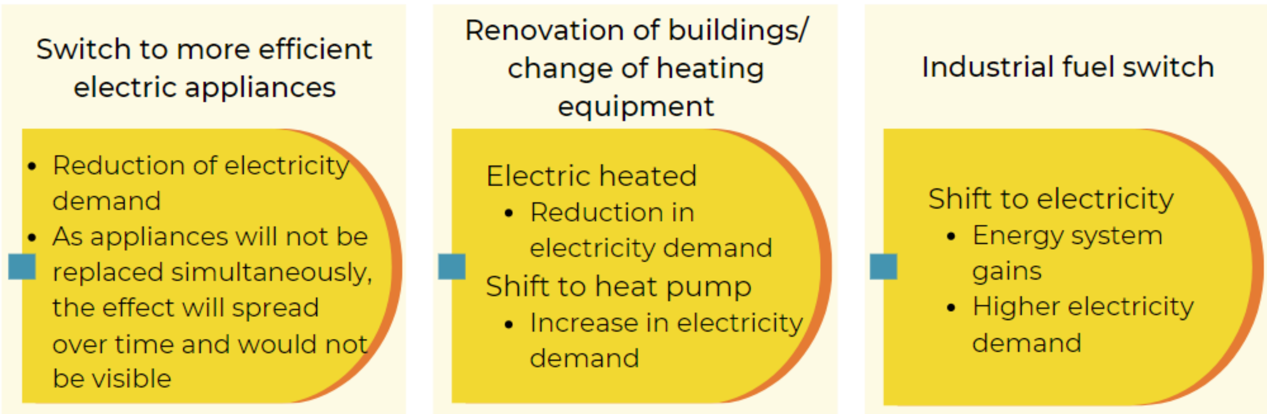

FIGURE 5: EXEMPLARY EFFECTS OF ENERGY EFFICIENCY MEASURES ON ELECTRICITY DEMAND

Also, a shift to district heating or changes in the industrial heat demand will result in overall system-wide energy savings but will lead to an increase in steam/heat demand, so the effect on energy carrier prices is not evident.

Further, the changes in the prices will require also the adaptation of the power system to meet the "new" demand after the application of the energy efficiency measures and it is difficult to isolate what part of the change in prices is due to the change in energy demand compared to what may be due to other policies (e.g. policies increasing RES shares in power generation).

5.2.2 Methodological challenges

The key challenge in linking energy efficiency and energy prices is the multiple effects that energy efficiency may have on energy demand and therefore indirectly on the market for energy carriers.

The main aim of energy efficiency measures is to induce energy savings: energy savings can either reduce demand for the energy carrier which was initially used (less oil, gas, electricity) or induce fuel switching (e.g. a shift to an electric heat pump). Energy efficiency can therefore lead to a reduction in demand for energy carriers, which relieves the stress on the market and therefore reduces prices. On the other hand, if energy efficiency leads to a fuel shift – as is expected in the context of the energy transition – it may lead to higher demand for specific energy carriers e.g., electricity or district heating. In this case, the effect on prices could potentially have both upward and downward trend.

Higher demand for an energy carrier would in general lead to high prices. However, in a number of cases prices might also decrease. In the power market, and the load curve may be smoothed if demand takes place off-peak (e.g., with smart charging for electric vehicles), leading to improved system utilization and thus lower average prices.

5.2.3 Data requirements

The quantification of such an indicator would require information about scenarios with and without the efficiency measures, the relative changes in prices of end user prices.

5.3 Impact factor/functional relationship

To measure an effect of change in electricity (heat) price due to a change in quantity of electricity (heat) consumed, we estimate the price elasticity μ on EU, national and sectoral levels:

$$\frac{P_i^1 - P_i^0}{P_i^0} = \mu_i \frac{Q_i^1 - Q_i^0}{Q_i^0}$$

where Q_i^0 and Q_i^1 are the quantities for the energy consumed in baseline and in scenario with EE intervention in sector i. P_i^0 and P_i^1 are electricity and heat prices in the baseline and EE intervention scenario for the sector i.[3]

5.4 Monetisation

The energy price effect would be directly monetised as it is expressed as a change in prices therefore in €/energy unit.

5.5 Aggregation

This indicator can provide meaningful results at national level for different energy efficiency policy strengths; at local level this indicator does not have a meaningful impact.

5.6 Conclusion

The effect of energy efficiency measures on electricity and heat prices is not easily specified in a quantitative manner: efficiency measures can have both upward and downward effects on energy prices. Often the scale of energy efficiency measures is also not sufficient to trigger a change in the energy prices and the cause effect is not always easy to determine.

Possible price effects from energy efficiency measures are described in this document, however the quantification of this element remains problematic.

[3] Reuter, M., Patel, M. K., Eichhammer, W., Lapillonne, B., & Pollier, K. (2020). A comprehensive indicator set for measuring multiple benefits of energy efficiency. Energy policy, 139, 111284.

6 ETS PRICE EFFECT

Authors: Alessia De Vita, Kristina Goborukha, Zoi Vrontisi (E3M)
Reviewer: Marco Peretto (IEECP)

Executive Summary

The indicator describes the effect of energy efficiency measures on the ETS prices, both ETS I and ETS II.

Being an EU wide scheme the ETS prices are only relevant for EU wide considerations and not for national or local level evaluations.

Based on the findings energy efficiency measures have limited direct impact on the ETS I price formation; changes in overall legislation have a higher and more significant impact on the price formation.

Future analysis will look into the price formation for the ETS II and its relation to EU wide energy efficiency policies, once the details of the ETS II market functioning become clear.

6.1 Scope of MI Indicator

6.1.1 Definition

The EU Emissions Trading Scheme (EU-ETS) is a cap and trade system for emissions within the EU, which gives a price tag to emissions. The indicator is based on the elasticity of the ETS price to changes in the emissions of the energy system derived from the energy efficiency measures.

6.1.2 Relevance on EU, national and/or local level

The EU-ETS is an EU wide scheme therefore changes at local or national level will not have an effect on the resulting ETS price.

The ETS price will only change due to EU wide applications of policies or bundles of policies. Fuel shifting policies (e.g. the RED) can have a direct influence on the ETS prices; energy efficiency policies (EED, EPBD, etc.) have an indirect effect as through the reduction of consumption and through induced fuel shifts emissions decrease.

The ETS, as it is currently implemented, effects the power and steam generation sectors as well as energy intensive industries, with additional measures to aid industries which face international competition. The current legislation is under revision, since the Commission proposal on July 14, 2021 within the context of the "Fit for 55" package. The legislative proposal is currently under trialogue discussion with a political agreement reached in December 2022.

The new proposal foresees the extension of the "old" ETS 1 to the maritime sector, and further the development of a second emissions trading scheme "ETS2" to the buildings, road transport and non-ETS industrial sectors. The ETS2 is planned to be effective as of 2027 and a decision on the merging of the two trading schemes is planned to take place in 2031.

National and local level sectoral policies are not expected to have sufficient weight to modify the ETS prices in any significant manner. Only the EU level is therefore considered for this indicator.

6.1.3 Impact figure

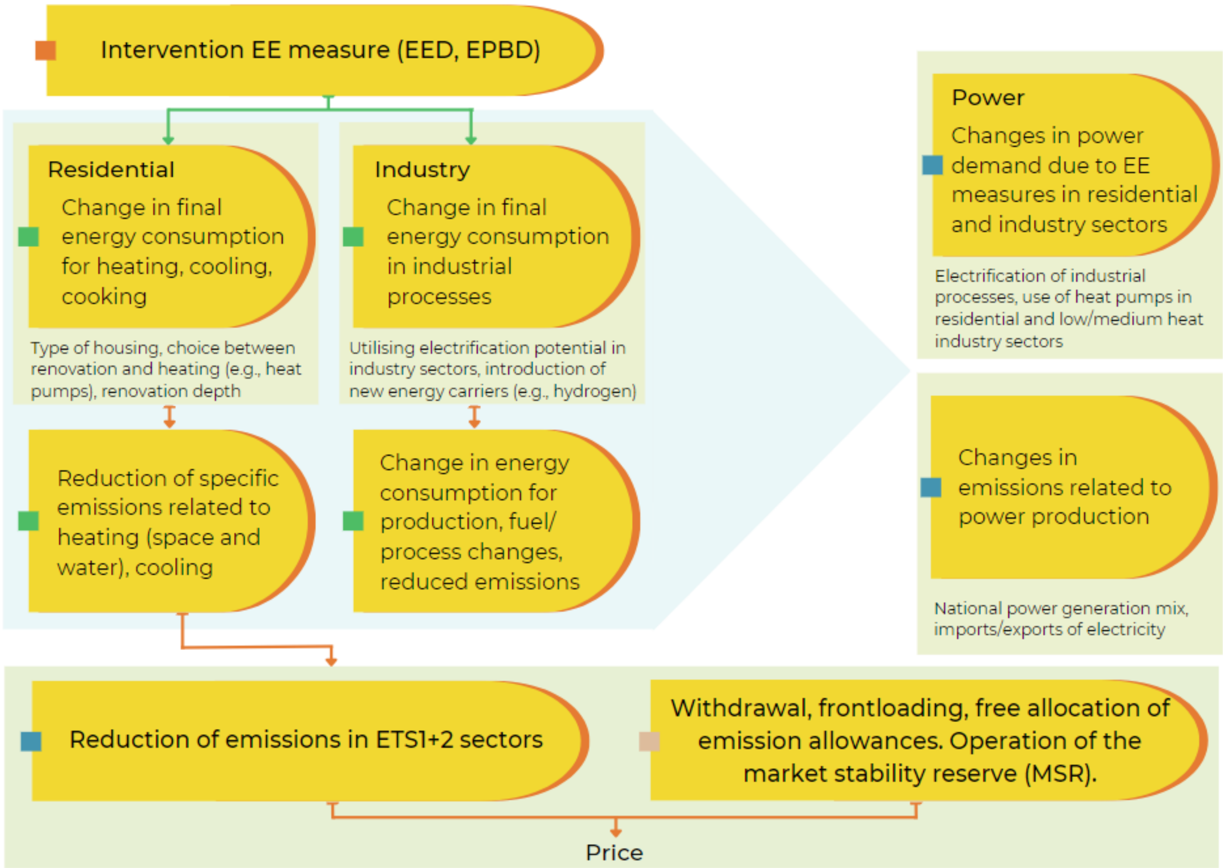

FIGURE 6: POSSIBLE IMPACTS OF EE MEASURES ON THE ETS PRICE

6.1.4 Overlaps with other MI Indicators and potential risk of double counting

This indicator is linked to emission reductions in the ETS sectors and indirectly to changes in electricity demand which can derive from changes in efficiency and fuel shifting.

As this indicator shows potential changes in ETS prices there is no double counting with other indicators evaluated in the context of MICAT.

6.2 Quantification method

6.2.1 Description

The quantification of the ETS price effect relies on the estimation of elasticities of the change in prices of the ETS relative to emission changes induced by an energy efficiency measure.

6.2.2 Methodological challenges

The current ETS covers approx. 40% of EU GHG emissions primarily in power generation and in industry. In power and steam generation the majority of power plants are included and fully subject to the ETS.[4] For the industrial sectors, those industries which are subject to international competition and could therefore be at risk of “carbon leakage” receive free

[4] Over time exemptions for selected power plants have been decreasing.

allowances, based on a benchmarking system. In the first phases of the ETS (until 2012) the large majority of emission allowances were provided for free; additionally, there was an economic crisis in 2008 leading to a high surplus in the ETS and very low prices for the ETS.

In phase 3 (2013-2020) the free allocations were reduced, however, the high pre-existing surplus continued to keep very low prices.

Since 2020 the prices of the ETS have been increasing, this has been attributed to two elements the entering into force of the Market Stability Reserve mechanism and an overall strengthening of the ETS and the overall policy framework including the introduction of the EU Climate Law.

Due to the market size (40% of total EU GHG emissions), there are very few single measures which can trigger changes in the ETS price, as only large-scale changes in emission triggered by EU wide policies have sufficient scale to affect the ETS price from a policy perspective.

Historically, ETS prices have been very low until the last 2/3 years, with prices recently hitting the 100€/tCO2 mark, which was not previously expected until the most recent reforms.[5]

In MICAT, the focus is on energy efficiency measures none of which are expected to have by themselves sufficient leverage to have an effect on the ETS price.

In the following we explain the potential effects of energy efficiency polices on the ETS I price. Further, we make a small discussion on the potential effects of policies on the forthcoming ETS II price, although this is speculative as the final ETS II legislative text is not fully agreed but is a very interesting new field of study.

ETS I

The ETS I covers primarily power and steam generation as well as energy intensive industry; in total it covers approx. 40% of EU GHG emissions. The ETS I is regulated through the ETS directive which includes also the Market Stability Reserve (MSR).

Energy Efficiency Measures in industry

Energy efficiency measures targeting industry will exemplarily address the following elements:

- **Energy efficiency in the overall process**: e.g. waste heat recovery, which has the potential to improve overall system efficiency and reduce the overall heat production needs.
- **Energy Efficiency in the individual processes**: such elements include the improvement of equipment. The modification of equipment can either be a shift towards the best available technology (BAT) of the same equipment, or can result in using a slightly different equipment or process which may lead to a fuel shift. Examples of the latter are shifting from an oil or solid boiler to a gas boiler, or even shift to a heat pump which allows both for energy savings as well as significant emissions savings.

Further **overall process changes**, such as shifting from blast furnaces to DRI processes in the Iron and Steel industry can take place in industry, however such a change is not strictly speaking an energy efficiency measure. Also, **circular economy** measures are expected to affect both energy savings and emissions, but are strictly speaking not energy efficiency measures. All the changes above will lead to energy savings and ultimately emission savings, however individually (undertaken by one industrial complex at a time) none of these elements will be large enough to trigger a change in emissions large enough to affect the ETS price.

Energy Efficiency measures in buildings

Energy efficiency measures in residential and tertiary buildings have the potential to induce significant energy and emission savings. For the purpose of the ETS I sectors this will only be relevant when the changes increase or decrease

[5] https://www.washingtonpost.com/business/eu-carbon-price-passes-symbolic-100-euros-as-reforms-bite/2023/02/22/0ce8423e-b2c0-11ed-94a0-512954d75716_story.html

electricity and/or heat/steam consumption in significant quantities. In the short term and because of individual measures this is unlikely to occur.

However, from a systems perspective a gradual change towards higher electrification rates in stationary (domestic and industry) and mobility (transport electrification) will lead to transformations in the power sector and therefore in the ETS I.

Although individual measures will not have an effect on the ETS I price, the carbon price can help ensure that the additional electricity needs of the demand side sectors will be met by low emission technologies with high shares of renewable energy.

ETS II

The extension of the ETS to cover the buildings and the road transport sector was included in the ETS revision published by the Commission in July 2021.[6] A political agreement has been reached on the ETS legislation in December 2022: this additional ETS system "ETS II" will include the buildings sector and the road transport sector, as well as the industrial sectors currently not included in the ETS.

The political agreement includes a linear reduction factor (LRF) for these sectors, as well as regulations for a Market Stability Mechanism (MSR) for the system and other provisions which may apply under different circumstances, particularly when the prices rise at a very fast pace. The full details of the agreement are not yet in the public domain, however a number of summaries of the agreement are available.[7]

Due to the political agreement being so recent, and a final agreement not being yet reached there are few if any studies yet on the developments of the ETS II prices: in this case the relationship between energy efficiency policies and measures with the ETS II price is potentially expected to be significant; the effectiveness of "bottom-up" energy efficiency measures is expected to influence the levels of the CO_2 prices, together with the behaviour of actors hedging, banking and the relationship between the end-users and the fuel suppliers on whom the obligation to submit allowances lies.

6.2.3 Data requirements

The quantification of such an indicator requires information about scenarios with and without the efficiency measures, the relative emission reductions achieved and the resulting CO_2 price.

6.3 Impact factor/functional relationship

The quantification could follow the following equation:

$$\frac{P_i^1 - P_i^0}{P_i^0} = \mu_i \frac{Q_i^1 - Q_i^0}{Q_i^0}$$

where, Q_i^0 and Q_i^1 are the emission quantities in baseline and with intervention of EE measures, respectively. P_i^0 and P_i^1 are ETS prices in the base scenario and intervention scenario[8][9][10]

[6] The ETS I will also be extended to cover the maritime sector, but this is not relevant for the current document.
[7]Among others: https://ercst.org/eu-ets-review-political-agreement-after-trilogues/
https://michaelbloss.eu/de/presse/themenhintergrund/eu-co2-handel-einigung-ueber-europas-groessten-klimahebel

[9] Reuter, M., Patel, M. K., Eichhammer, W., Lapillonne, B., & Pollier, K. (2020). A comprehensive indicator set for measuring multiple benefits of energy efficiency. Energy policy, 139, 111284.

6.4 Monetisation

The ETS price indicator is a price indicator and therefore directly expressed as €/tCO2. The change in emission amounts can provide directly the monetisation.

6.5 Aggregation

This indicator could provide meaningful results at EU level for different energy efficiency policy strengths for the ETSII. E.g. a higher or lower stringency/effectiveness of the EED implementation at EU level will most likely lead to different levels of ETS II prices.

As the ETS I and II cover the entire EU, a quantification below EU level does not have a meaning.

6.6 Conclusion

The ETS scheme is an EU wide scheme which can be evaluated only for the EU as a whole; individual energy efficiency measures are not expected to have a significant impact on the ETS prices.

In ETS I, the effect of energy efficiency measures is very limited, as with few exceptions it is only indirectly impacted.

The effectiveness/strictness of EU-wide energy efficiency measures has the potential to significantly impact the price formation in the ETS II sectors; however, the details of the price formation and the behaviour of actors is not yet fully analysed.

The ETS price effect is therefore included in this document, but not implemented in the MICAT tool, due to its limited effect. In future, an analysis of the EU ETS II prices and its relation to energy efficiency measures will be highly relevant.

7 IMPACT ON SECTORAL SHIFTS

Authors: Zoi Vrontisi, Kostas Fragkiadakis, Sakis Morfis (E3M)
Reviewer: Frederic Berger (Fraunhofer ISI)

Executive Summary

The indicator describes the impacts of energy saving measures on sectoral employment and value added. Energy efficiency measures create demand for products with subsequent sectoral shift implications for both value added and employment generation. We follow a static multiplier approach to estimate the creation (or reduction) of value added/employment by aggregate sectors due to the additional demand that is to deliver the investments associated with the energy saving measures. A key step is the calculation of the gross value added multipliers based on IO-Analysis, providing a quantification of the employment and the gross value added that will be generated in the economy by 1 m. € of new final demand. The method is then applied on six aggregate sectors of the economy and does not report the economy-wide effect as in the case of the GDP/Employment indicator. The aggregate sectors are: Agriculture, Energy, Manufacturing, Construction, Transport, Services. The approach considers the share of imported goods, the direct and indirect effects through the structure of the IO table. The methodology assumes only the impacts generated from additional demand, thus not assuming any other structural changes, e.g., due to the drop of activity in certain sectors, nor the effects of changes in income and prices. Finally, the methodology relies on the allocation of investment expenditure to demand by economic activities, which is based on expert judgement and assumed uniform by country and sector that applies the measures.

7.1 Scope of MI Indicator

7.1.1 Definition

Energy efficiency measures create demand for products with subsequent sectoral shift implications for both value added and employment generation. We follow a static multiplier approach to estimate the creation (or reduction) of value added/employment by aggregate sectors due to the additional demand that is to deliver the investments associated with the energy saving measures. Here we limit the analysis to a static approach, by assuming the additional generated demand without assuming any crowding out or substitution of existing demand or investments. Similarly, we do not make any explicit assumptions on the financing of the measures, and we do not consider any impacts due to changes in incomes and prices.

7.1.2 Relevance on EU, national and/or local level

Sectoral shifts are of primary importance for all levels of policy assessment, including the EU, national and local level, being also relevant to elements of just transition. The indicator can be applied to all levels depending on data availability.

7.1.3 Impact pathway figure

The methodology adopted to perform the assessment of the sectoral shift indicator of the different energy saving measures is composed by the following steps:

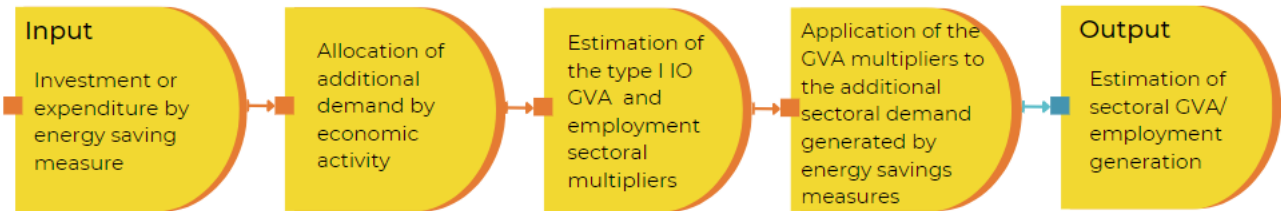

FIGURE 7: QUANTIFICATION STEPS FOR THE ESTIMATION OF THE SECTORAL SHIFT MI INDICATOR

7.1.4 Overlaps with other MI indicators and potential risk of double-counting

There is no risk of overlaps or double-counting with other MI indicators.

7.2 Quantification method

7.2.1 Description

The methodology to estimate the sectoral shifts has as a starting point the method to derive the overall GDP and Employment impacts A key step is the calculation of the gross value added multipliers based on IO-Analysis, providing a quantification of the employment and the gross value added that will be generated in the economy by 1 m. € of new final demand. The method is then applied on six aggregate sectors of the economy and does not only cover the economy-wide effect as in the case of the GDP/Employment indicator. The approach considers the share of imported goods, the direct and indirect effects through the structure of the IO table. As described in Figure 7, we follow the steps shown below for the quantification of this indicator.

Steps:

1. Receive as input the investment expenditure by type of energy saving measure
2. Calculation of type I gross value added/employment sectoral multipliers based on the IO table
3. Associate the investment expenditure to specific demand of goods and services to allocate the additional generated demand by economic activity
4. Application of the respective multipliers by economic activity and by type of energy efficiency measure
5. Estimation of the impacts in the 6 aggregate economic sectors, as shown below

Sectors of the Economy:

sec_1: Agriculture

sec_2: Energy

sec_3: Manufacturing

sec_4: Construction

sec_5: Transport

sec_6: Services

In the second step, the Leontief type I multipliers are calculated by sector and by country given the technology coefficients and the consumption preferences of a given economy. This type of analysis does not consider capacity constraints and thus no consideration is taken for the change in prices and the markets of primary factors. The technical coefficient matrix A consists of all technical coefficients as its elements a_{ij}. For every country and for each branch the technical coefficient a_{ij} is calculated as the ratio of the intermediate consumption to total supply for each industry.

The sectoral multiplier effect is calculated based on the following formula:

$$coeffEMPL_{i,j} = EMPLRT_i \cdot L_{i,j} \; (1)$$

$$coeffGVA_{i,j} = GVART_i \cdot L_{i,j} \quad (1')$$

where:

$EMPLRT_i$: the ratio of number of employees to total supply for the industry I, measured in jobs per million € coefficients derived by the IO table.

$GVART_i$: the ratio of gross value added to total supply for the industry I derived by the IO table.

$L_{i,j}$: the ij-element of the Leontief inverse Matrix $L = (I - A)^{-1}$, where i is the sector providing intermediate inputs to the production of sector j

$coeffEMPL_{i,j}$: the total number of employees that will be generated in the economy for an additional demand of 1 m€ in sector j by sector i.

$coeffGVA_{i,j}$: the total gross value added that will be generated in the economy for an additional demand of 1 m€ in sector j by sector i.

Leontief Inverse Matrix L:

$$L = (I - A)^{-1} \quad (2)$$

where:

I: Identity matrix

A: direct requirements matrix, the ratio of the intermediate consumption to total supply for each industry.

The third step of our methodological approach assumes a table that associates the investment expenditure of each energy efficiency measure to the specific demand of one goods and services. This table aims to allocate the additional generated demand to each of the 65 identified economic activities so that the impacts of energy efficiency measures are dispersed over a number of NACE sectors. The table has been constructed according to expert judgement and thus changing the default assumptions of sectoral allocation by energy efficiency measure can be redefined by the users. Below, in Table 13 we provide a few examples of the allocation of demand by economic activity for the measures of "Building envelope", "Heating fuel switch", and "Energy efficient heating". The numbers in Table 13 express the shares by which the investment expenditure is allocated to each economic activity.

TABLE 13: EXAMPLES OF SECTORAL ALLOCATION OF INVESTMENT EXPENDITURE BY ENERGY SAVING MEASURE

Economic activity	Nace-code	Building envelope	Heating fuel switch	Energy-efficient heating
Other non-metallic mineral products	C23	20%		
Basic metals	C24	20%		
Computer, electronic and optical products	C26			5%
Electrical equipment	C27		15%	5%
Machinery and equipment n.e.c.	C28		50%	50%
Repair and installation services of machinery and equipment	C33		10%	15%
Constructions and construction works	F	40%	10%	10%
Retail trade services, except of motor vehicles and motorcycles	G47	10%	10%	10%
Architectural and engineering services; technical testing and analysis services	M71	10%	5%	5%

As a next step, we estimate the annual additional value added generated in each aggregate sector by an investment of 1 m € for energy saving measures. The sectoral allocation of demand is derived by the respective share in Table 13 and determines how the additional demand from 1 m€ of investment in energy saving measures is allocated to sectors. Based on this allocation the total effect in GVA from 1 m€ investment in energy saving measures is calculated by multiplying each of the additional demand allocated to sectors with the respective gross value added coefficient as calculated in step one, see equation (3).

$$coeffTOTEMPL_{i,m,c} = \sum_j coeffEMPL_{i,j,m,c} \cdot es_{j,m} \quad (3)$$

$$coeffTOTGVA_{i,m,c} = \sum_j coeffGVA_{i,j,m,c} \cdot es_{j,m} \quad (3')$$

where,

i, j : sectors /activities

m : measure / end-use

c : country

$es_{j,m}$: Allocation share of Energy Saving Investment (m) to sector (j)

At the final step, we estimate the employment and GVA generation for each aggregate economic sector by applying the level of expenditure by type of measure with the employment and gross value added sectoral effect generated in the total economy by 1 m€ expenditure, see equation (4).

7.2.2 Methodological challenges

The 2015 SIOT tables from Bulgaria are not available on Eurostat. Czechia, Ireland, Luxemburg and Malta data are deficient. Sweden data are unbalanced (i.e., SIOT is not symmetric) however this country is not excluded. The sectoral employment and GVA impact of certain energy saving measures cannot be quantified, thus by default cannot be calculated, as these cannot be associated with the purchase of specific economic activities or are too generic. The methodology assumes only the impacts generated from additional demand, thus not assuming any other structural changes, e.g. due to the drop of activity in certain sectors, nor the effects of changes in income and prices. Finally, the methodology relies on the allocation of investment expenditure to demand by economic activities, which is based on expert judgement and assumed uniform by country and sector that applies the measures.

7.2.3 Data requirements

The starting point of the analysis is the latest available Symmetric Input Output tables (SIOT) by EU Member State, which are available in Eurostat for year 2015. The sectoral resolution adopted in our analysis is the 65 sectors in NACE rev2. 2-digit, in line with the CPA resolution. Additionally, the sectoral demand contributions should be assumed.

7.3 Impact factor/functional relationship

The associated additional employment and value added per aggregate sector is proportional to the energy saving investments. Every investment in energy saving measure is attributed to sectors and the total sectoral effect is calculated as shown below:

$$SECEMPL_{sec(j),m,c,y} = \sum_{\text{if } i \in \text{sec}(j)} coeffTOTEMPL_{i,m,c} \cdot Inv_y \quad (4)$$

$$SECGVA_{\text{sec}\,(j),m,c,y} = \sum_{\text{if } i \in \text{sec}(j)} coeffTOTGVA_{i,m,c} \cdot Inv_y \quad (4')$$

where,

i : sectors /activities

sec $(j) = 1,2, \dots, 6$ – for example, if $j = 4$ then sec_4 = Construction

m : measure / end-use

c : country

y : year

Inv_y : Energy Saving Investments

In conclusion, the indicator depends on impact factor coefficient per country and subsectors – which are determined as aggregation of industries or product groups of the IO-table – and the sectoral investment demand assumptions – which are set by default or according to user's choice. Thus, the employment and value added additional level is determined by the impact factor and the investment according to energy saving allocation measures.

7.4 Monetisation

The GVA sectoral shifts are already expressed in terms of million EUR. The employment-related shifts can be monetized if associated with a mean wage by country and sector.

7.5 Aggregation

The indicator can be directly aggregated with other indicators but attention should be paid on potential double-counting (e.g. with the economy-wide GDP and employment indicators).

7.6 Conclusion

Below we provide examples for the calculation of the sectoral shifts GVA indicator for three selected EU Member States, namely Germany, Italy and Poland.

Germany

Table 14: Calculation of the Sectoral Shifts indicator for Germany

Annual investments in million €					
Subsector	Measure	Country			
Machinery	Space heating and cooling	Germany	150		
Coefficient for GVA Effect in m. € per 1m. € of investments					
Agriculture	**Energy**	**Manufacturing**	**Construction**	**Transport**	**Services**
0.0003	0.0048	0.2591	0.0539	0.0203	0.2850
Annual GVA generated by investment for energy saving measures					
Agriculture	**Energy**	**Manufacturing**	**Construction**	**Transport**	**Services**
0.05	0.72	38.87	8.09	3.04	42.74

For example, it can be derived that for each million € invested in the energy saving measure of space heating and cooling, 0.259 million (of totally 0.62 m.) additional GVA is generated by the manufacturing sector and 0.285 in the services sector. Thus a 150 million € investment would annually generate 38.87 million (of totally 93.5 m.) GVA in the manufacturing sector.

Italy

Table 15: Calculation of the Sectoral Shifts indicator for Italy

Annual investments in million €					
Subsector	Measure	Country			
Machinery	Building envelope	Italy	150		
Coefficient for employment Effect in jobs per 1m. € of investments					
Agriculture	**Energy**	**Manufacturing**	**Construction**	**Transport**	**Services**
0.0967	0.0735	2.5793	4.3242	0.4409	6.3637
Annual additional employment generated by investment for energy saving measures					
Agriculture	**Energy**	**Manufacturing**	**Construction**	**Transport**	**Services**
14.50	11.02	386.89	648.63	66.14	954.55

Taking another example for the country of Italy, we estimate the impact of the energy saving measure of the building envelope. It can be derived that for each million € invested in this measure, 4.3 additional employment (of totally 13.9 employees) is generated by the construction sector, thus an 150 million € investment would annually generate 648.6 employees (of totally 2081.7) in the construction sector.

Poland

Table 16: Calculation of the Sectoral Shifts indicator for Poland

Annual investments in million €					
Subsector	Measure	Country			
Machinery	Fuel switch	Poland	150		
Coeff Coefficient for GVA Effect in m. € per 1m. € of investments					
Agriculture	**Energy**	**Manufacturing**	**Construction**	**Transport**	**Services**
0.0013	0.0113	0.1968	0.0644	0.0100	0.2047
Annual GVA generated by investment for energy saving measures					
Agriculture	**Energy**	**Manufacturing**	**Construction**	**Transport**	**Services**
0.20	1.69	29.53	9.66	1.50	30.70

Finally, an example for the country of Poland shows the impact of investing in fuel switch energy saving measure. It can be derived that for each million € invested in this measure, 0.21 million GVA and 0.20 (of totally 0.49 m.) is annually generated by the services and manufacturing sectors respectively. Thus an 150 million € investment would annually generate 30.70 million (of totally 73.3 m.) GVA on the services sector.

8 Energy intensity

Authors: Frederic Berger (Fraunhofer ISI)
Reviewer: Alessia De Vita (E3M)

Executive Summary

Energy intensity is an indicator describing the energy necessary for an economy to produce a unit of GDP. It is thus quantified as the ratio between energy consumption and GDP:

$$EI_c = \frac{GIC_c - NE_c}{GDP_c}$$

Taking into account energy savings, the resulting impact relationship is the following:

$$\Delta EI_c = \frac{GIC_c - NE_c - \Delta E_c}{GDP_c + \Delta GDP_c} - \frac{GIC_c - NE_c}{GDP_c}$$

Despite the fact that this indicator is mainly a key performance indicator for an economy, it is relevant to assess the exposure to energy price and availability volatilities. Yet, it can generally merely be assessed on the European and national level, since the required data is predominantly gathered on these governance levels.

The methodology for quantification is clearly defined and does not pose any challenges. Similarly, the required data is overwhelmingly available from Eurostat and PRIMES. However, a monetisation is not recommended, due to the significant risk of double counting. An aggregation would also not be fruitful.

8.1 Scope of MI Indicator

8.1.1 Definition

The energy intensity describes the average amount of energy necessary to generate a unit of GDP. Thereby, it allows to assess the efficiency of an economy with regard to its energy use. Less energy intensive economies or sectors tend to be more resilient to price volatilities, as a smaller portion of expenses is linked to energy costs.

8.1.2 Relevance on EU, national and/or local level

Given the prevalent import dependency of fossil fuels in the EU, an increased resilience towards energy price increases as engendered by a reduced energy intensity is of major importance. This is the case on a European as well as on a national level. However, energy intensity can hardly be calculated on the local level, as GDP is generally not disaggregated to municipalities.

8.1.3 Impact pathway figure

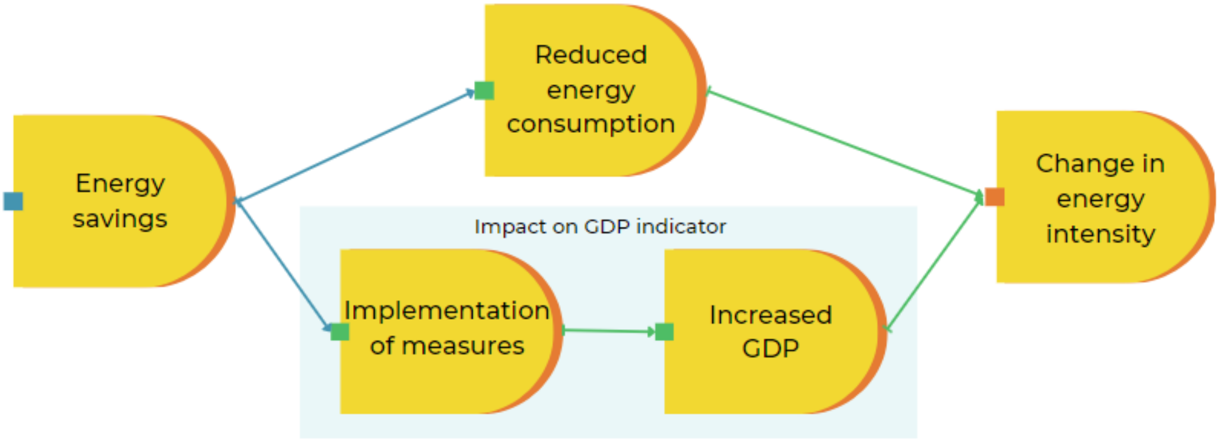

FIGURE 8: IMPACT PATHWAY FOR THE ENERGY INTENSITY INDICATOR

8.1.4 Overlaps with other MI Indicators and potential risk of double counting

Since energy intensity is calculated building on the results of the MI Impact on the GDP, a certain overlap between both indicators exists. Moreover, the main benefit resulting from a reduced exposure to energy price volatilities should rather be monetised within the MI import dependency, although a monetisation in itself is quite challenging (see MI import dependency). Thus, to avoid double counting, this indicator should not be monetised.

8.2 Quantification method

8.2.1 Description

To quantify countries' energy intensity EI_c, their energy consumption (difference between gross inland consumption GIC_c and final consumption for non-energy uses NE_c) is divided by their gross domestic product GDP_c:

$$EI_c = \frac{GIC_c - NE_c}{GDP_c}$$

In order to assess the impact of energy efficiency measures, the status quo is compared with a counterfactual scenario without energy savings.

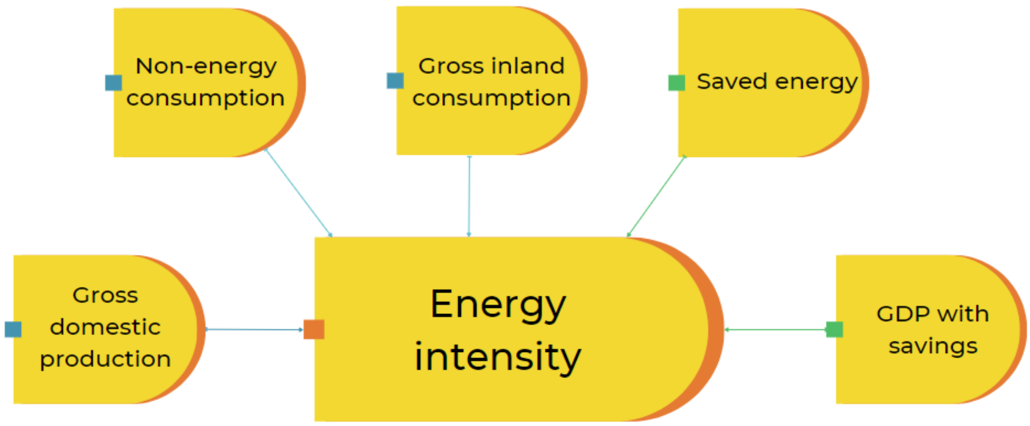

FIGURE 9: QUANTIFICATION OF THE ENERGY INTENSITY INDICATOR

8.2.2 Methodological challenges

The quantification of this indicator is straightforward. Thus, no methodological challenges have emerged.

8.2.3 Data requirements

In order to calculate this indicator, gross inland consumption, non-energy uses, the results from the indicator Impact on the GDP, and the energy savings are necessary. The former two datasets can generally be gathered from Eurostat and PRIMES.

8.3 Impact factor/functional relationship

To calculate the impact of energy savings on a nation's energy intensity, the actual energy intensity is subtracted from a scenario including the energy savings ΔE_c. For the latter, the savings are deducted from the energy consumption and the result from the indictor 'Impact on GDP' is added to the actual GDP:

$$\Delta EI_c = \frac{GIC_c - NE_c - \Delta E_c}{GDP_c + \Delta GDP_c} - \frac{GIC_c - NE_c}{GDP_c}$$

8.4 Monetisation

Since energy intensity is more of a key performance indicator of an economy regarding energy efficiency, no direct benefits can be derived from it. Moreover, there is a considerable risk of double counting. Thus, no monetisation is recommended.

8.5 Aggregation

Since this indicator is mainly an indicator, it should not be aggregated.

8.6 Conclusion

Despite the fact that this indicator is mainly a key performance indicator for an economy, it is relevant to assess the exposure to energy price and availability volatilities. Yet, it can generally merely be assessed on the European and national level, since the required data is predominantly gathered on these governance levels. The methodology for quantification is clearly defined and does not pose any challenges. Similarly, the required data is overwhelmingly available from Eurostat and PRIMES. However, a monetisation is not recommended, due to the significant risk of double counting. An aggregation would also not be fruitful.

9 IMPACT ON THE ASSET VALUE OF COMMERCIAL BUILDINGS

Authors: Ivana Rogulj (IEECP)
Reviewer: Florin Vondung (Wuppertal Institute)

Executive Summary

The change in the asset value of commercial buildings due to energy efficiency measures implementation describes the influence of this particular factor on the total value of the building. The quantification is done using the MB:EE formula, where the only input data is the capitalised avoided energy cost:

$$\Delta AV = \frac{\sum_i ES_i \times P_i}{cr}$$

In this equation ES_i are the annual energy savings of one of the energy carriers *i* (electricity and gas), the price p (for each of the carriers) and the capitalisation rate *cr* (in this case 0.06). The capitalisation rate indicates the rate of return on a real estate investment.

Although the indicator is relevant for the implementation of energy efficiency measures in the commercial sector, the choice of a relevant calculation method is rather complex. The simplified formula used represents the currently best possible methodology, whereas there are many others described in the methodological challenge section. All of them in nature lack the complexity needed or expected, mainly with view to the multiple influences of different factors on the total asset value change. The conclusion is that the chosen method is rather conservative, as it uses only one benefit derived from energy savings.

9.1 Scope of MI Indicator

9.1.1 Definition

This indicator serves to describe the impact of energy efficiency measures on the value of commercial buildings. It includes benefits for the investor from the perspective of total value on the retail market, in its most simplified form.

9.1.2 Relevance of EU, national and/or local level

Buildings are responsible for around 40% of energy consumption in the European Union and 36% of related emissions, thus being the single largest energy consumer. In addition, most buildings in the EU (75%) are energy inefficient and the rate of renovation is rather slow (1% a year) (European Commission, 2023)

In the EU, around 25% of the floor area of buildings is non-residential, representing a significant share contributing to the high energy consumption of the building sector (European Commission, 2013). (Zancanella, Bertoldi, & Boza-Kiss, 2018) conclude from their research that for business and commercial buildings around 10% or even 20% of the sales price depends on the energy efficiency label and status. Energy efficiency measures change many aspects of the buildings and influence multiple impacts, affecting their price, like operational costs or health benefits. However, as opposed to the EU and national level, it is a much bigger challenge to have precise energy savings data from the commercial sector buildings on the local level.

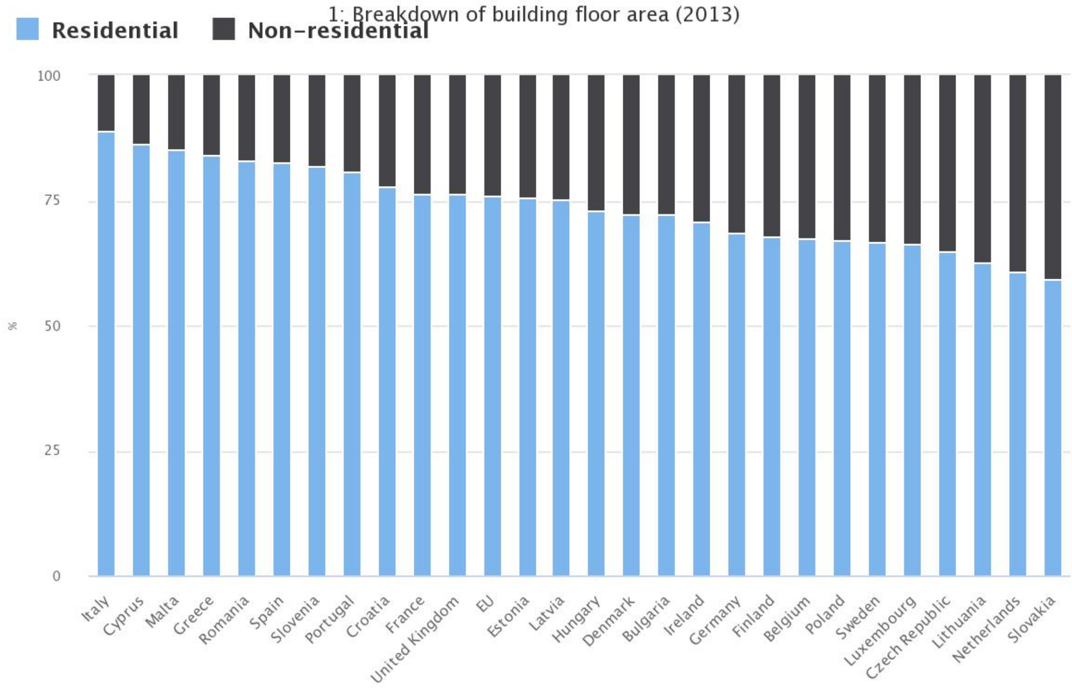

FIGURE 10: BREAKDOWN OF BUILDING FLOOR AREA IN EUROPE (EUROPEAN COMISSION, 2013)

9.1.3 Impact pathway figure

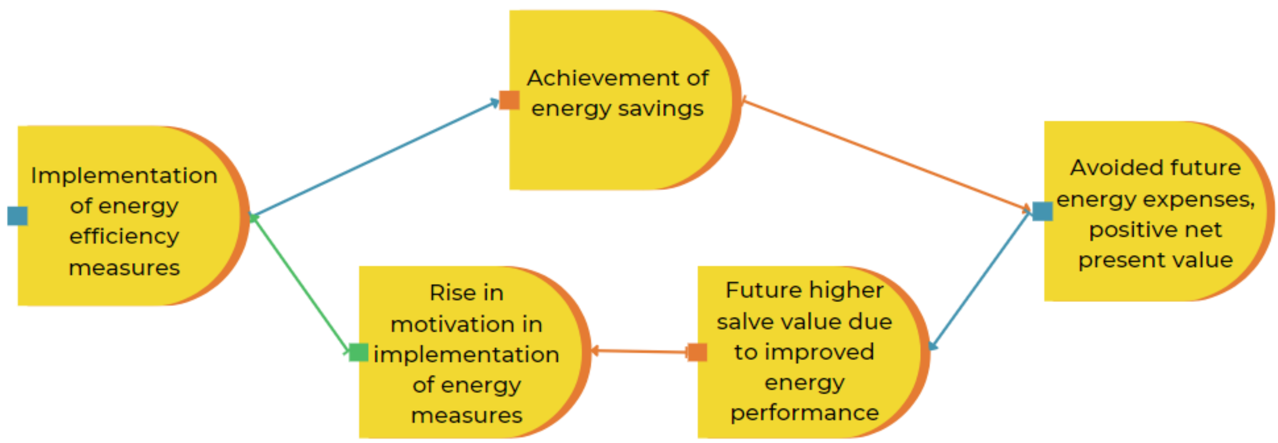

FIGURE 11: IMPACT PATHWAY OF THE ASSET VALUE CHANGE ON THE SYSTEM/PORTFOLIO LEVEL

9.1.4 Overlaps with other MI Indicators and potential risk of double-counting

Since this is a simplified calculation, that is accounting only the capitalization of the avoided future energy expenses, there is no risk of overlaps.

9.2 Quantification method

9.2.1 Description

A review done by the JRC (Zancanella, Bertoldi, & Boza-Kiss, 2018) includes multiple methodologies that could be used for the evaluation of the asset value post energy efficiency project implementation. First of all, they start from the definition of value, which could include market or transaction value of the asset (building). Market value would be the one expected and transaction value the one actually achieved. The methodologies for valuation can be categorized by approaches. JRC uses the study of the opportunities of future higher sales calculation in the economic calculator developed by Popescu et al. (Popescu, Bienert, Schützenhofer, & Boazu, 2012) and three other resources to define possible methods: the hedonic pricing model, the method based on the direct comparison between transaction prices and the method based on the willingness to pay back investments. The hedonic pricing approach could be possibly applied for local level evaluations. However, it is the most complex and the most data intensive methodology. For the second method, we would need data on the modelled transactions to put the prices and the energy savings in relation to each other, which could be possible also on a smaller scale, where there are data available on location, age etc.. In light of the high input requirements of these two methodologies, the most suitable approach within MICAT are methods to calculate the net present values either of energy savings or of energy investments. Since the input data for the MICAT tool are savings, the calculation formula presented is

$$NPV=\sum_{J=1}^{J}\left(ES_J \times CE_J \times \sum_{n=0}^{tR}\left(\frac{1}{1+i}\right)^n\right)$$

ES – annual energy savings

J – type of energy

i – discount rate

tR – lifetime of the retrofitting measure

Reuter et al. (2020) in their paper use an even more simplified methodology with the same presumption of value change. Using average costs of energy for building needs (primarily heating and cooling), they assess the additional average net income due to avoided energy costs, with a capitalization rate of 8%.

$$\Delta AV=\frac{\sum_i ES_i \times P_i}{cr}$$

Where data on lifetimes is available, we will use the previous methodology, whereas otherwise the one developed by Reuter et al. (2020) for the MB:EE calculator will be the default option.

9.2.2 Methodological challenges

The description above and the literature review highlight that the method is not taking into consideration many aspects of value asset gain and is thus not as precise. The problem is that multiple characteristics of a building influence its final worth. This includes age, location, use, but mostly general macroeconomic changes on which the real estate market is highly dependent. (Brocklehurst, 2017) did a literature review of the transactional changes in prices of buildings in cases where energy efficiency measures were either implemented or not. The results are shown in Table 17 and they are referenced in the original paper. It is obvious from the results in the table that the influences of the energy savings are rather diverse, even in a building market in the same country.

TABLE 17: SUMMARIES OF RESULTS OF OTHER STUDIES (BROCKLEHURST, 2017)

Country	Results description
Germany	1 % to 11 % for one category (e.g. C to D) or equivalent improvement.
Italy	"the only significant contribution on prices is exhibited, by moving from high levels, (BC) to low levels (FG)".
Italy	"Average variation in unit price is 3.6 % related to the increase of one step in energy rating, but it is possible to observe a greater influence among the lowest energy classes. Dwelling with a C label have a premium price of 17.4 % with respect of those with a G label, whereas between class A dwellings and those in class C, the premium prices is 4.5 %."
Netherlands	If the energy requirement of a dwelling is reduced by half, the market price of the dwelling increases by around 11 % for an average dwelling in the Dutch housing market.
Norway	There is higher price for higher category, from 15 % B to 1 % E.
Sweden	For each 1 % increase in EE the price increases 0.04 %.
Sweden	A 10 % increase in consumption will increase the price by about 0.7 %.
Scotland	An estimated 0.1 % increase in selling price has been identified for every 1 % fall in energy use per floor area.

The other issue is a lack of precise per country cap rate data.

9.2.3 Data requirements

In order to evaluate the impact of energy efficiency improvement actions on the asset value, only the national IO tables (EUROSTAT) and the past energy savings (Odyssee-Mure) are necessary.

In the equation ESi, the annual energy savings of one of the energy carriers is i (electricity and gas), the price p and the capitalisation rate cr (in this case 0.06).

Reuter et al. use the cap rate in 2020 of 8%, however the newest data from commercial real estate trends and outlook (Yun, 2022) shows a decline towards 6% in 2022.

Cap Rate Outlook in 2022

	2022 Q1 / 1	2022 Forecast / 2
Apartment	4.4%	4.5%
Industrial	5.3%	5.7%
Office	6.1%	6.3%
Retail	6.1%	6.3%

/ 1 Source: Real Capital Analytics
/ 2 NAR

FIGURE 12: CAP RATE OUTLOOK, NAR (YUN, 2022)

More data on the national level cr is available in the paper (Pat McAllister, 2016) discussing capitalisation rates in different EU cities, including some of those in the targeted countries:

- *Barcelona 5.6*
- Berlin 5.24
- Dusseldorf 5.33
- Frankfurt 5.3
- Milan 5.81
- Munich 4.85
- Warsaw 7.73

The formula is used on a national level, where the EU level would represent an aggregation of all the included Member States, as there are no overlaps or cross-country gains.

9.3 Impact factor/functional relationship

The quantification is done using the MB:EE formula, where the only input data is the capitalised avoided energy cost:

$$\Delta AV = \frac{\sum_i ES_i \times P_i}{cr}$$

In this equation ESi are the annual energy savings of one of the energy carriers i (electricity and gas), the price p (for each of the carriers) and the capitalisation rate cr (in this case 0.06). The capitalisation rate indicates the rate of return on a real estate investment.

9.4 Monetisation

The economic indicator is measured in kEUR. Therefore, no additional calculations are required to monetise this indicator.

9.5 Aggregation

This indicator indicates the change in asset value. This is merely relevant in case of a transaction, forfeiting the potential energy savings in return for a higher sale price. Thus, counting both in a cost-benefit analysis would result in double counting. Merely the positive effects on mortgage conditions could be interesting.

9.6 Conclusion

The change in the asset value of commercial buildings due to energy efficiency measures implementation describes the influence of this factor on the total value of the building. The calculation of the total influence is too complex for this modelling exercise due to a lack of available data. Therefore, we use an updated conservative and simplified indicator as applied in the MB:EE project.

10 TURNOVER OF ENERGY EFFICIENCY GOODS

Authors: Marco Peretto (IEECP)
Reviewer: Alessia De Vita (E3M)

Executive summary

The turnover of energy efficiency (EE) goods is an economic indicator aimed at illustrating the amount of capital generated from investments in EE goods. This might be across a specific field/industry or in general, at a local/national/European level. The turnover of EE goods is expressed in billion EUR.

A higher turnover of EE goods can result in more technical innovation in the field, resulting in higher economic gains and ultimately being able to affect the economic development of a region/country/EU. Hence, it is relevant at various demographic levels but especially at a national level, as it can represent how EE improvements affect the GDP.

Two main methodologies to quantify the turnover of EE goods were found in the literature. Both consider energy efficiency in the residential sector. The first definition considered the energy savings, share of space heating in final energy consumption, share of savings due to improved insulation and heating systems, and finally the investments per unit of energy saved. These four factors were multiplied to achieve the turnover of EE goods. A more general definition was found, considering only the energy savings and the investments per unit of energy saved. In both cases, the indicator was measured in billion EUR and thus monetised. Additionally, the indicator was found to be potentially aggregable with indicators analysing the impact EE measures have on the GDP. Indeed, as turnover of EE goods also affects the economic development of a country, these two indicators were found to be comparable.

The turnover of EE goods could be considered as an impact factor itself, as it expresses in billion EUR how much capital is generated through EE goods (and potentially measures). Hence, converting such turnover in proportions of GDP (as a percentage) could be seen as a way to measure the impact factor of this indicator.

Availability of data represents the main challenge when calculating the turnover of EE goods. Indeed, these are rarely available at a national scale, with such measurements found in the literature only for Germany and the Netherlands. Whereas the energy savings per country are usually available for all European countries, data expressing the weighted average of investments per unit of energy saved are not. Therefore, the main obstacle when analysing the turnover of EE goods is the availability of data rather than the technical/mathematical difficulty in expressing the indicator.

10.1 Scope of MI Indicator

10.1.1 Definition

The turnover of energy efficiency (EE) goods is an economic indicator that captures the amount of capital generated associated with the implementation/utilization of EE goods. The latter are products that contribute to the improvement of energy efficiency in general, be it of the product itself or of the whole network/system.

10.1.2 Relevance on EU, national and/or local level

The multiple effects resulting from the turnover of EE goods affect the collective value of companies and firms of a given industry. The effect that EE goods and their development will have on a determined field, such as the residential sector, can be represented at a European, national, and local level. Indeed, depending on the purpose of the analysis, the impact of EE goods could be calculated on a country level and thus considering the economic development of the latter, but also on a local or European level. This depends on the purpose of the study and, perhaps most importantly, on the data available.

10.1.3 Impact pathway figure

In Figure 13 the various impacts that follow from an improvement of the turnover of EE goods is illustrated. The figure summarises in a graphical manner the findings explained above. It differentiates between impacts at an industry level and societal level.

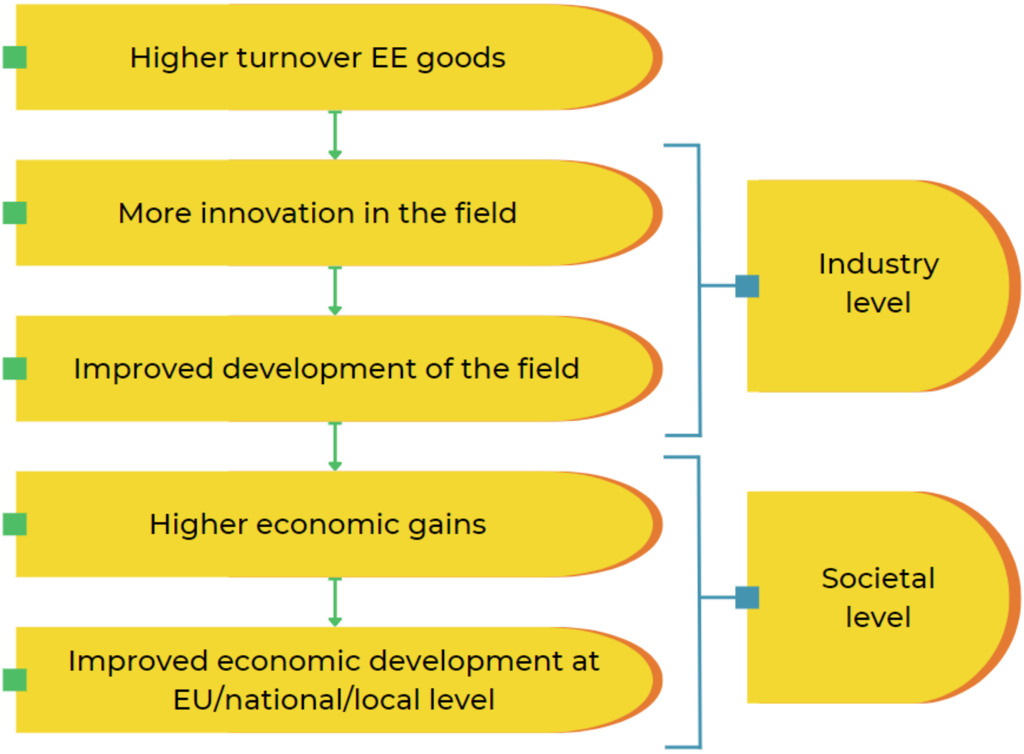

FIGURE 13: IMPACT PATHWAY FOR THE TURNOVER OF ENERGY EFFICIENCY GOODS

10.1.4 Overlaps with other MI Indicators and potential risk of double counting

Whereas the turnover of EE goods will depend on the final energy savings, the latter are usually represented in scientific terms (GJ) and not in economic terms. Therefore, the risk of double counting in this case is rather low, as it is an economic indicator that depends on technical measurements.

10.2 Quantification method

10.2.1 Description

In the literature there have been found two main quantification methods regarding the turnover of EE goods. According to Reuter et al. (2020), the latter can be quantified utilising the following formula:

$$TO = ES \cdot SH_i \cdot f_{in} \cdot IN_{tech}$$

Where *TO* is the turnover of EE goods, *ES* is the energy savings, SH_i is the share of space heating in final energy consumption of country *i*, f_{in} is the share of savings due to insulation and efficient heating systems and IN_{tech} the investments per unit of energy saved. Thereafter, the turnover of EE goods is measured in billion EUR. Such measurement applies strictly to the residential sector.

A more general way of quantifying this economic indicator is proposed by Eichhammer et al. (2018), namely multiplying the weighted average of investments in energy efficiency per unit (GJ) by the amount of energy savings (GJ). Such a quantification method was also proposed by an Odysee-Mure report availble on their website (2022). The investments in energy efficiency can be related for example to space heating, whereas the savings due to new insulation installations. The turnover is still measured in billion EUR.

Figure 14 illustrates the steps involved in calculating the turnover of EE goods by utilising the methodology explained in the present paragraph.

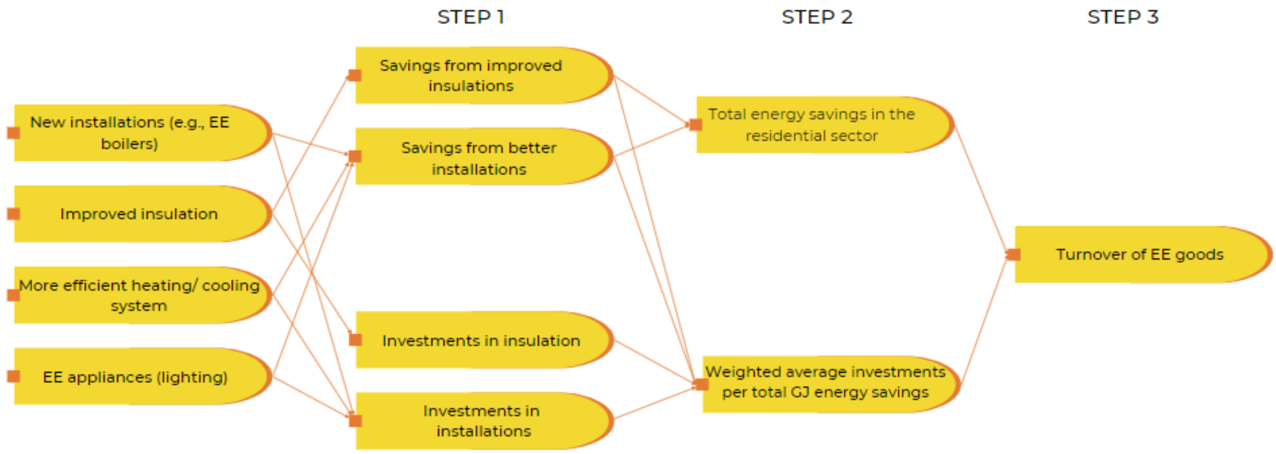

FIGURE 14: STEPS INVOLVED IN CALCULATING THE TURNOVER OF ENERGY EFFICIENCY GOODS

10.2.2 Methodological challenges

This indicator is mostly based on average calculations. As an improvement, such indicator should consider temporal and spatial changes occurring in the system being considered (Reuter et al., 2020). Other limitations include the lack of control data on where and how many investments are devoted to different types of technologies promoting energy efficiency, and annual fluctuations that may be occurring due to structural changes being insufficiently separated from savings in energy end-uses (Eichhammer et al., 2018). Essentially, such indicator is highly dependent on the available data. For example, Reuter et al. (2020) utilised data from the Netherlands to infer data for other European countries assuming a similar split of costs. The lack of availability of such data in other European countries may indeed hinder the importance of the discussed indicator.

10.2.3 Data requirements

According to the second quantification method, to calculate this indicator, the number of investments in energy savings per unit is needed (billion EUR/GJ); but also, the amount of energy saved (GJ). Similarly, according to the first proposed quantification method, the share of space heating per country will be needed, and the share of savings due to efficient insulation and heating systems. These are not always available per country and represent a serious obstacle to the quantification and measurement of the turnover of EE goods.

10.3 Impact factor/functional relationship

It could be argued that the turnover of EE goods is already representing in itself an impact that energy savings will have on the region's/country's/EU's economic performance in a particular field or in general. Nonetheless, to have a better understanding of the impact that the turnover of EE goods will have on one country's GDP, it is hereby suggested to perform a simple proportion, comparing the total turnover generated (in billion EUR) to the country's GDP. Therefore, defining the turnover of EE goods as a percentage of the country's GDP. A similar comparison could be also performed at a local level, for example by comparing the turnover of EE goods as a percentage to a specific local industry's generated capital.

10.4 Monetisation

As previously explained, turnover of EE goods can potentially have an impact on the country's economic performance and development. Additionally, the economic indicator is measured in billion EUR. Therefore, it is possible to monetise this indicator.

10.5 Aggregation

Turnover of EE goods could be potentially aggregated with an indicator calculating the impact of EE measures on GDP. Reuter et al. (2020), consider such an indicator in their study and quantify it as a percentage of GDP. This can be easily converted in billion EUR to make it match with the chosen unit of measure for the turnover of EE goods. Since it was previously explained how the considered indicator can potentially improve the national economic development, it could be also calculated how much of the increase in GDP resulted from EE goods. This would allow to thereafter aggregate the two indicators. Additionally, many EE measures aim at enhancing investments in EE goods, ultimately having a positive impact on the GDP, hence justifying the suggested correlation and aggregation of indicators.

10.6 Conclusion

After performing an extensive literature review, it was found that the main challenges related to analysing and calculating the turnover of EE goods are related to the availability of data. Indeed, data describing the investments performed in EE goods are rarely available at a national scale, whereas at a European level are not available at all. Nonetheless, data related to annual energy savings per country in the residential sector are available. Therefore, the challenge is rather in understanding the number of investments in EE goods and representing its trend. Indeed, the mathematical formulas to quantify the latter are available and are not technically demanding. Additionally, the impact such investments have on the GDP and the national economic trend in general could also be obtained. It is suggested to focus on the national level where possible, as local level involves various ramifications and is rather case-specific. Essentially, the local turnover of EE goods per given municipality/region would not provide the same impactful insights as at a national scale. Additionally, the availability of such data at a local level is also deemed to be another possible unknown.

11 IMPORT DEPENDENCY

Authors: Frederic Berger (Fraunhofer ISI)
Reviewer: Alessia De Vita (E3M)

Executive Summary

The indicator describes the share of an energy carrier's domestic consumption which needs to be imported from abroad. It is generally calculated using primary production (PP), gross inland consumption (GIC), and non-energy uses (NE) as inputs in the following formula:

$$ID_e = 1 - \frac{PP_e}{GIC_e - NE_e}$$

Thus, the impact relationship taking energy savings into account results in the following equation:

$$\Delta ID_{c,e} = PP_{c,e}\left[\frac{1}{GIC_{c,e} - NE_{c,e}} - \frac{1}{\left(GIC_{c,e} - \sum_u \Delta E_{c,u} \cdot k_{c,e,u}\right) - NE_{c,e}}\right]$$

Import Dependency is very relevant and has been pushed even further into the political spotlight by Russia's war in Ukraine. Nearly exclusively relevant on the European and national level, the data needs are generally covered by Eurostat and PRIMES.

It might be worth discussing which quantification approach is most fruitful, the classical or one basing itself on the Energy Efficiency First principle. Moreover, an aggregation with the MI supplier diversity would enhance the meaningfulness of this indicator. However, a monetisation of the impact is not recommended, since the correct inclusion of monetary benefits of the indicator would significantly exceed the scope of this project.

11.1 Scope of MI Indicator

11.1.1 Definition

A country's import dependency describes its reliance on non-domestic energy carriers. Thereby, it can be vulnerable to supply disruptions it cannot compensate for and energy price volatility. It is defined by the share of combusted energy carriers originating from abroad. The indicator can also be calculated for single energy carriers.

11.1.2 Relevance on EU, national and/or local level

Given the generally low primary production in the majority of EU countries, the issue of import dependency has been picked up by the European Commission in their 2014 Energy Security Strategy. Relying on instruments and directives such as the EU ETS, the EED, and the EPBD, the Commission emphasises the role of energy efficiency in reducing energy needs and thereby import dependency (European Commission, 2014).

Depending on the degree of import dependency, the problem is more central to some member states than to others, also placing it on the national agenda. A lack of supplier diversity often further exacerbates this issue (see MI supplier diversity).

Given the fact that wholesale energy markets operate nationally, import dependency is not of any major relevance on a local level. Moreover, the benefits of reduced exposure to the associated risks of energy price volatility and outages through local measures are not described in this indicator, which is calculated at least on a national level.

11.1.3 Impact pathway figure

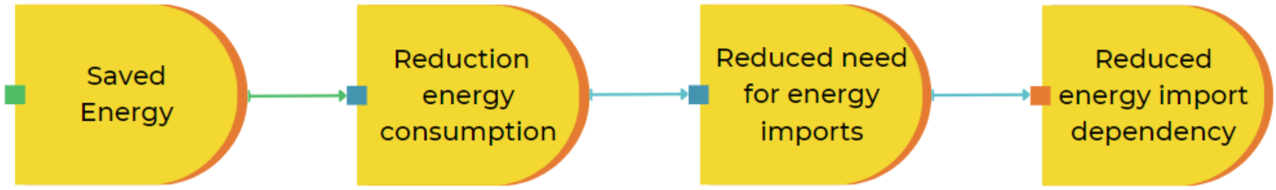

FIGURE 15: IMPACT PATHWAY FOR THE INDICATOR IMPORT DEPENDENCY

11.1.4 Overlaps with other MI Indicators and potential risk of double counting

This indicator is strongly linked to general energy savings. Since the impacts of import dependency are internalised in wholesale energy prices, their effect is overwhelmingly included in the economic benefits for consumers. Furthermore, the impacts of an elevated import dependency on energy prices inevitably depends on the prevalent supplier diversity, therefore it is difficult to clearly attribute price effects to either indicator. However, the proposed formula accounts for the benefits from energy savings for customers and only considers the surcharge on the imported share of energy carriers. Possibly, these effects are also assessed within the MI energy price effects, which could engender double-counting.

11.2 Quantification method

11.2.1 Description

Generally, in order to calculate import dependency, inland primary production is divided by the domestic consumption for energy uses (as non-energy uses have been subtracted, such as resources as feedstock). This share of domestically covered energy consumption is then subtracted from one to calculate the share of energy consumption covered by imports, thus the import dependency.

Therefore, the import dependency of a member state for an energy carrier can be calculated by subtracting the relevant primary production (PP_e) divided by the difference between gross inland consumption (GIC_e) and non-energy uses (NE_e) from one:

$$ID_e = 1 - \frac{PP_e}{GIC_e - NE_e}$$

Potential savings $\Delta E_{s/u}$ (either disaggregated to sector (s) or end-use (u) level) to that specific energy carrier (with a relevant fuel mix $k_{e,s/u}$) would reduce gross inland consumption without altering any other variable:

$$ID_e = 1 - \frac{PP_e}{(GAE_e - \sum_{s/u} \Delta E_{s/u} \cdot k_{e,s/u}) - NE_e}$$

This figure can then be calculated for every relevant energy carrier. Although an aggregation by weighting with the combusted energy quantity is possible, it would cushion stark import dependencies for certain energy carriers, which is particularly important in member states with different level of dependence for fossil fuels and given the different predominant exporting countries of the resources.

A differentiation between sectors or end-uses would not be expedient, since all savings impact the overall wholesale market for the related energy carrier in the same way and no sectoral targets regarding import dependency exist.

The quantification should be done using a top-down approach, with the majority of required data available on a national level from Eurostat and Odyssee-Mure.

The issue linked to this formula is that for very import dependent resources significant actions regarding energy efficiency entail little to no changes in the indicator. Thereby, important reductions in import volumes cannot be accounted for within this indicator. Therefore, an additional second approach is proposed, based on the idea of energy efficiency as 'first fuel'. Instead of reducing the value of the energy consumption by the related savings, the savings are accounted as primary production, as if they replaced the originally used fuel in a scenario with a constant business-as-usual energy consumption:

$$ID_e = 1 - \frac{PP_e + \sum_{s/u} \Delta E_{s/u} \cdot k_{e,s/u}}{GIC_e - NE_e}$$

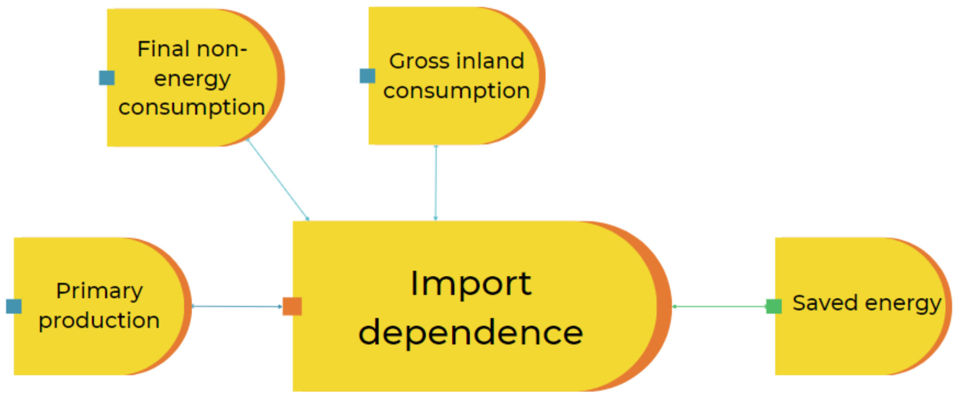

FIGURE 16: QUANTIFICATION OF THE INDICATOR IMPORT DEPENDENCY

11.2.2 Methodological challenges

In order to properly monetise the impacts of import dependency, the local cost difference between imported and locally extracted fossil fuels is to be known. Alternatively, a European average could be determined using a bottom-up approach, but this would lead to significant inaccuracies, since this difference is strongly correlated to the degree of integration and connection of a country, as well as to its supplier diversity and general geopolitical situation.

However, the main benefit of a reduced import dependency lies in the diminished supply vulnerability and the associated risk of price volatility or even outages. Since these associated benefits only occur sporadically and depend on a multitude of factors involving inter alia energy and climate policies in other countries and geopolitical conflicts, implementing a sound monetisation of this benefit would go beyond the scope of this project. Furthermore, the need for strategic reserves and hedging of potential future fluctuations decreases through energy efficiency. Yet again, the relevant monetisation is nearly impossible, since no figures for the premium necessary for volatility internalisation in the European Union are to be found.

11.2.3 Data requirements

Two approaches with a different level of sophistication present themselves. If the envisaged measure aims at the reduction of the consumption of a single energy carrier, a standalone calculation for this specific product can be performed. The assessment of the measure's impact on import dependency is therefore significantly more accurate, since strong variations between import ratios for different energy carriers within a single country are common. This method can and should also be used if the mix of saved energy carriers is known. It would require the primary production, gross inland consumption, and non-energy uses for the examined fuel(s). If electricity or heat is saved, the respective local generation energy carrier mix is to be used. If unknown, the mean national mix can be used as a substitute. Another option can be to determine the saved energy carriers for electricity and heat generation on a merit-order basis.

Alternatively, in case the mix of saved energy carriers is unknown, the general unspecific equation can be employed using the same data but with total values. The underlying assumption is then that the ratio of saved fuels corresponds to the national energy carrier mix.

11.3 Impact factor/functional relationship

- **Total aggregation:**

$$\Delta ID_{c,e} = PP_{c,e}\left[\frac{1}{GIC_{c,e} - NE_{c,e}} - \frac{1}{(GIC_{c,e} - \Delta E_c \cdot k_{c,e}) - NE_{c,e}}\right]$$

- **Sectoral disaggregation:**

$$\Delta ID_{c,e} = PP_{c,e}\left[\frac{1}{GIC_{c,e} - NE_{c,e}} - \frac{1}{(GIC_{c,e} - \sum_s \Delta E_{c,s} \cdot k_{c,e,s}) - NE_{c,e}}\right]$$

- **End-use disaggregation:**

$$\Delta ID_{c,e} = PP_{c,e}\left[\frac{1}{GIC_{c,e} - NE_{c,e}} - \frac{1}{(GIC_{c,e} - \sum_u \Delta E_{c,u} \cdot k_{c,e,u}) - NE_{c,e}}\right]$$

- **First fuel approach:**

$$\Delta ID_{c,e} = \frac{-\Delta E_c \cdot k_{c,e}}{GIC_{c,e} - NE_{c,e}} = \frac{-\sum_s \Delta E_{c,s} \cdot k_{c,e,s}}{GIC_{c,e} - NE_{c,e}} = \frac{-\sum_u \Delta E_{c,u} \cdot k_{c,e,u}}{GIC_{c,e} - NE_{c,e}}$$

11.4 Monetisation

Because the scale of the unquantifiable benefits significantly exceeds the quantifiable benefits (which would also come alongside significant methodological challenges), a monetisation of the import dependency is not recommended. Issuing a figure for the monetary value of the quantifiable share of the indicator would sell the benefits at less than fair value and undermine the central point of this indicator.

11.5 Aggregation

An aggregation of results with the indicator supplier diversity would be very expedient. A high import dependency can be cushioned by a variety of reliable supplying countries, while a low supplier diversity is generally not particularly problematic in case of a low import dependency. Thus, merely the combination of both MI is really meaningful and useful.

11.6 Conclusion

The indicator import dependency is very relevant and has been pushed even further into the political spotlight by Russia's war in Ukraine. Nearly exclusively relevant on the European and national level, the data needs are generally covered by Eurostat and PRIMES. It might be worth discussing which quantification approach is most fruitful, the classical or one basing itself on the Energy Efficiency First principle. Moreover, an aggregation with the MI supplier diversity would enhance the meaningfulness of this indicator. However, a monetisation of the MI is not recommended, since the correct inclusion of monetary benefits of the indicator would significantly exceed the scope of this project.

12 AGGREGATED ENERGY SECURITY (SUPPLY DIVERSITY)

Authors: Frederic Berger (Fraunhofer ISI)
Reviewer: Alessia De Vita (E3M)

Executive Summary

The MI supplier diversity is an important indicator to assess a country's energy security, describing the variety and reliability of energy suppliers. The quantification is done using the Herfindahl-Hirschman-Index (IE_p describing the amount of imported energy from country p) with the addition of a reliability coefficient (k_p):

$$HHI_{c,e} = \sum_{p=1}^{N_p} \left(\frac{k_p \cdot IE_{c,e,p}}{IE_{c,e}} \right)^2$$

This results in the following primary functional relationship, subtracting the saved energy ΔE from the largest supplier:

$$\Delta HHI_{c,e} = \sum_{p=1}^{N_p} \left(\frac{k_p \cdot IE_{c,e,p}}{IE_{c,e}} \right)^2 - \left[\left(\frac{k_1 \cdot (IE_{c,e,1} - \Delta E_{c,e})}{IE_{c,e} - \Delta E_{c,e}} \right)^2 + \sum_{p=2}^{N_p} \left(\frac{k_p \cdot IE_{c,e,p}}{IE_{c,e} - \Delta E_{c,e}} \right)^2 \right]$$

While merely relevant at the EU and national level, the quantification of the indicator is quite complicated, as the saved energy has to be attributed to (ex-post) or subtracted from (ex-ante) partner countries. This allocation is not really straightforward and could turn out to be a major source of error. Besides, the indicator is not really meaningful unless combined with the impact import dependency. A monetisation of this indicator is probably not going to be possible in the framework of this project, getting data on imports by partner countries for the future could already become quite a struggle.

12.1 Scope of MI indicator

12.1.1 Definition

The multiple impact indicator supplier diversity describes the composition of countries energy carriers are imported from. It also takes the respective share of imports into account. A limited supplier diversity can lead to higher energy prices and a dependent relationship. However, the indicator is insensitive to the geopolitical relation to the supplier countries.

12.1.2 Relevance on EU, national and/or local level

The low supplier diversity for some energy carriers was a driver of the EU Commission's 2014 Energy Security Strategy, emphasising the central role of energy efficiency in reducing the import shares of major supplying countries and associated dependent relationships (European Commission, 2014).

Given the more severe situation of some member states in this regard, supplier diversity is of major relevance to several countries on a national level.

It is not expedient to determine supplier diversity on a local level, since energy contracts are generally entered nationally and energy markets operate on larger scales. Nevertheless, it can make sense for local authorities to foster adaptation measures in case of a low national supplier diversity in order to be prepared in case of energy price spikes or even shortages.

12.1.3 Impact pathway figure

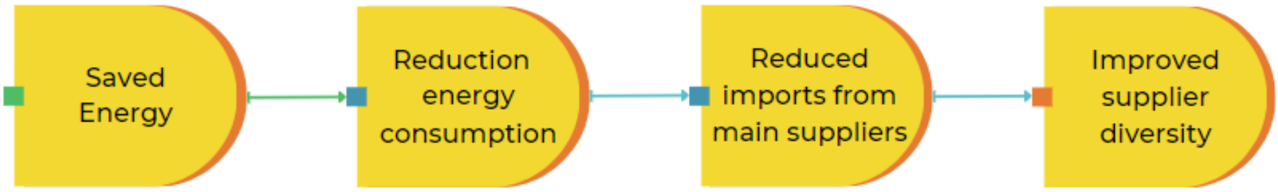

FIGURE 17: IMPACT PATHWAY FOR THE INDICATOR AGGREGATED ENERGY SECURITY (SUPPLY DIVERSITY)

12.1.4 Overlaps with other MI Indicators and potential risk of double counting

This indicator is connected to the MI import dependency, since it can exacerbate the latter's severity. Particularly when it comes to energy price surges and shortages, the two indicators are strongly intertwined. However, since both are not recommended for monetisation, the risk of double-counting is averted. No overlap with any other indicator is found.

12.2 Quantification method

12.2.1 Description

In order to quantify the supplier diversity for energy carrier *e*, a modified version of the Herfindahl-Hirschman-Index (HHI) is used:

$$HHI_{c,e} = \sum_{p=1}^{N_p} \left(\frac{k_p \cdot IE_{c,e,p}}{IE_{c,e}} \right)^2$$

In this equation, $IE_{e,c}$ represents the amount of caloric value of imported energy carrier *e* originating from country *p*, while $IE_{e,tot}$ stands for the total caloric value of the imported energy carrier *e*. A problem of the HHI is that it does not differentiate between reliable and unreliable partner countries. Therefore, the risk-coefficient k_c is introduced, quantifying the risk of supply disruptions. Since a high HHI is bad, a value of 0.5 is assigned for EU countries, 0.7 for EFTA countries and the UK, and 1 for the rest of the world. At a later stage, a consideration of figures from the World Energy Council's Energy Trilemma, taking particularly the energy security dimension into account. The adapted HHI is normalised to values between 0 (exclusive) and 1, the latter describing a monopoly held by a country that is neither part of the EU nor of the EFTA and the UK. This method can also be used for all energy carriers combined by adding the relevant energy carriers' caloric value for each country:

$$HHI_c = \sum\nolimits_{p=1}^{N_p} \left(\frac{k_p \cdot \sum_{e=1}^{N_e} IE_{c,e,p}}{IE_c} \right)^2$$

However, an aggregation obfuscates strong dependent relationships for single energy carriers by averaging. A top-down approach is most expedient for this quantification, the data being available from Eurostat.

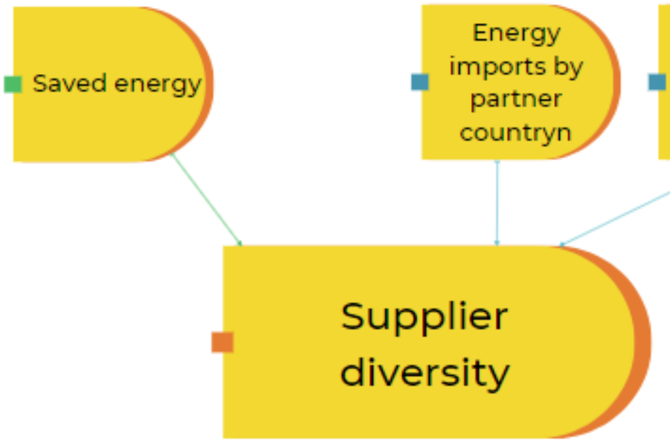

FIGURE 18: QUANTIFICATION OF THE INDICATOR AGGREGATED ENERGY SECURITY (SUPPLY DIVERSITY)

12.2.2 Methodological challenges

The calculation of energy savings' impact on the HHI is rather inaccurate. Firstly, subtracting energy savings from the largest supplier could lead to a change in the supplying order if the difference between the two leading countries is smaller than the saved energy. Secondly, a country could be keen on reducing the quota of a supplier deemed unreliable or with which the political relation is brittle, rather than just reducing the main supplier's share. In order to alleviate these issues, a more complicated equation striving to minimise the overall HHI could prioritise which country's imports to reduce. However, this would lead to a more complex determination process, contradicting the overarching idea of a simple easy-to-use tool.

12.2.3 Data requirements

Independent of sophistication or of whether the energy carriers are aggregated or broken down, the same data is required from Eurostat, namely the "Imports of [energy carrier] by partner country" for each examined energy carrier. The same data would be necessary for the future from PRIMES, which is likely going to be difficult to get.

12.3 Impact factor/functional relationship

In order to assess the impact of energy savings of energy carrier *e* on the relevant supplier diversity, the status quo is compared to the expected scenario with the projected energy savings. In the latter, the largest non-EU/EFTA/UK supplier's quota (*p=1*) is reduced (or increased for ex-post) by the additional relevant energy savings ΔE (if there is no non-EU/EFTA/UK supplier, then the largest EFTA/UK supplier and then the largest EU supplier are selected instead). This leads to the following equation:

$$\Delta HHI_{c,e} = \sum_{p=1}^{N_p} \left(\frac{k_p \cdot IE_{c,e,p}}{IE_{c,e}} \right)^2 - \left[\left(\frac{k_1 \cdot (IE_{c,e,1} - \Delta E_{c,e})}{IE_{c,e} - \Delta E_{c,e}} \right)^2 + \sum_{p=2}^{N_p} \left(\frac{k_p \cdot IE_{c,e,p}}{IE_{c,e} - \Delta E_{c,e}} \right)^2 \right]$$

The nomenclature is equivalent to the formula in the Quantification method section.

12.4 Monetisation

As is the case for the MI import dependency, a monetisation of supplier diversity is not deemed expedient and therefore not recommended. The major economic factor linked to this indicator is the risk of energy price surges and shortages or even outages. The costs of internalisation of such risks are very difficult and inaccurate to determine, particularly since the energy price increases of 2021 point towards the fact that the chosen internalisation rate has been insufficient. Furthermore, it is difficult to determine a relationship between HHI and energy prices, since it can strongly depend on the geopolitical relation to the supplying country and their political agenda. However, if a monetisation is imperative, it should apply to the aggregated value of import dependency and supplier diversity, since this combination is most closely linked to the risk of supply shortages and price surges.

12.5 Aggregation

An aggregation of this MI with the MI import dependency would be expedient, since a lack of supply diversity is a factor aggravating the latter. Therefore, a simple multiplication would suffice to determine the weighted import dependency *WID* for a given energy carrier *e*. Yet, this formula should only apply if the import dependency for an energy carrier is positive, since a potential HHI calculated for a small proportion of imported energy does not diminish the benefit of a net surplus of the examined energy carrier:

$$WID_{c,e} = \begin{cases} ID_{c,e} \cdot HHI_{c,e}, & ID_{c,e} > 0 \\ ID_{c,e}, & ID_{c,e} \leq 0 \end{cases}$$

It is to be noted that this reduces the overall range of values, leading to a lower perceived import dependency. Furthermore, the weighted import dependency is not normalised, as import dependency values can exceed the boundaries 0 (net exporter) and 1 (building up reserves).

12.6 Conclusion

The MI Supplier Diversity is an important indicator to assess a country's energy security, describing the variety and reliability of energy suppliers. While merely relevant at the EU and national level, the quantification of the indicator is quite complicated, as the saved energy has to be attributed to (ex-post) or subtracted from (ex-ante) partner countries. This allocation is not really straightforward and could turn out to be a major source of error. Besides, the indicator is not really meaningful unless combined with the MI import dependency. A monetisation of this indicator is probably not going to be possible in the framework of this project, getting data on imports by partner countries for the future could already become quite a struggle.

13 IMPACT ON DEMAND INTEGRATION OF RENEWABLES

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Reviewer: Wolfgang Eichhammer (Fraunhofer ISI)

Executive Summary

While the rise of renewable energy sources has helped reduce the carbon intensity of Europe's electricity grids, it also entails a higher volatility of electricity supply. Thus, potentials for demand-response are getting increasingly important. This indicator assesses how energy efficiency measures affect demand-response potentials and thereby, the impact on the integration of renewables in electricity grids.

This impact is predominantly important on the national level, since the vast majority of electricity grids mainly operate nationally.

In light of the necessary investments in renewables across the bloc, this indicator might still be interesting on a European level to showcase the effect energy efficiency can have in integrating new renewables.

In order to assess these changes in demand-response potentials $\Delta \mathrm{P}_{DR,c,ss,u,t,y}$, additional as well as lost potentials are allocated to improvement actions across the different sectors. This is done by attributing every combination of (sub-)sector and improvement action a coefficient $k_{DR,ss,u}$:

$$\Delta \mathrm{P}_{DR,c,ss,u,t,y} = k_{DR,ss,u} \cdot \Delta \mathrm{E}_{c,ss,u,y} \cdot s_{flex,t}$$

In this equation, $s_{flex,t}$ describes the feasibility of flexibilisation.

In order to monetise the demand-response potentials, the price of alternatives providing the same demand-response service with a similar potential is used. This is done for increases as well as decreases in demand-response potentials:

$$M_{\mathrm{DR},c,ss,u,y} = a_{DR,c,y} \cdot \Delta \mathrm{P}_{DR,c,ss,u,t,y}$$

In this equation, $M_{\mathrm{DR},c,ss,u,y}$ specifies the monetary benefit (positive or negative), whereas $a_{DR,c,y}$ represents the cost per demand-response potential unit of an alternative service.

The indicator can help pinpoint how energy efficiency can help integrate additional renewable energy sources. However, given the coarse approach to an impact that is better assessed in a fine-grained way, certain margins of error can be expected. Besides that, the indicator can be monetised and aggregated without risk of double counting.

13.1 Scope of MI indicator

13.1.1 Definition

While the rise of renewable energy sources has helped reduce the carbon intensity of Europe's electricity grids, it also entails a higher volatility of electricity supply. Thus, potentials for demand-response are getting increasingly important. This indicator assesses how energy efficiency measures affect demand-response potentials and thereby, the impact on the integration of renewables in electricity grids.

Examples of effects of energy efficiency measures on demand-response potentials are increases in heat pumps and thermomodernisations, allowing to heat homes at times of low energy consumption, but also improvements of efficiency in industries willing to move their production from peak- to low-consumption periods.

13.1.2 Relevance on EU, national and/or local level

This impact is predominantly important on the national level, since the vast majority of electricity grids mainly operate nationally.

In light of the necessary investments in renewables across the bloc, this indicator might still be interesting on a European level to showcase the effect energy efficiency can have in integrating new renewables.

On the local level, this indicator is less relevant, although a flexible regional grid can prevent the need for redispatches and might in the future avert the necessity to throttle down residential end uses, such as electric vehicle charging.

13.1.3 Impact pathway figure

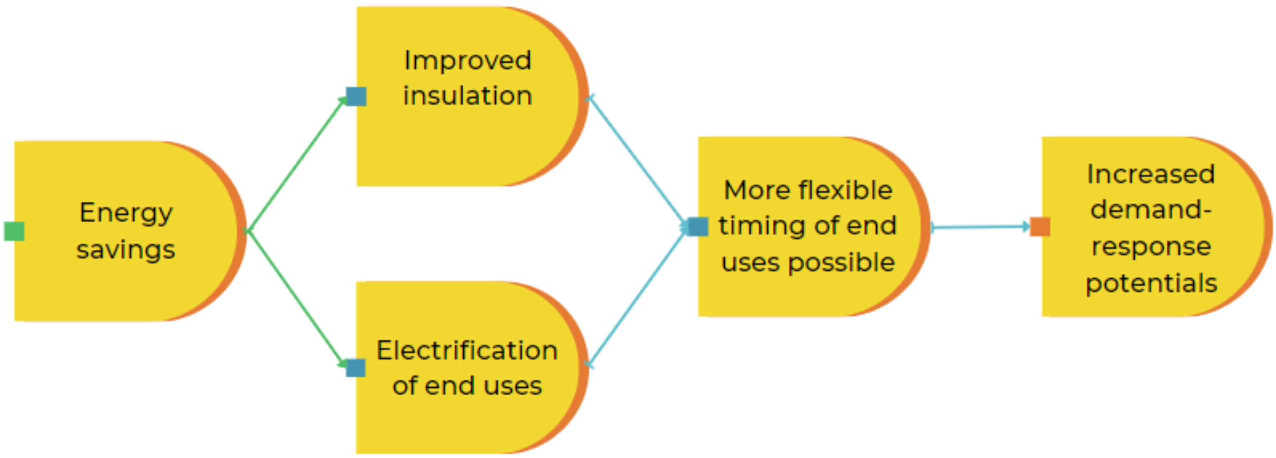

FIGURE 19: IMPACT PATHWAY FOR THE IMPACT ON DEMAND INTEGRATION OF RENEWABLES

13.1.4 Overlaps with other MI indicators and potential risk of double-counting

This indicator does not have any overlaps with other impacts. Thus, there is no risk of double counting.

13.2 Quantification method

13.2.1 Description

In order to assess these changes in demand-response potentials $\Delta \mathrm{P}_{DR,c,ss,u,t,y}$, additional as well as lost potentials are allocated to improvement actions across the different sectors. This is done by attributing every combination of (sub)sector and improvement action a coefficient $k_{DR,ss,u}$:

$$\Delta \mathrm{P}_{DR,c,ss,u,t,y} = k_{DR,ss,u} \cdot \Delta \mathrm{E}_{c,ss,u,y} \cdot s_{flex,t}$$

In this equation, $s_{flex,t}$ describes the feasibility of flexibilisation. In a second step, the "moved" electricity consumption can be calculated by accounting for the possible frequency f_t and time period Δt_t of demand-response measures, which are dependent on the technologies involved:

$$E_{DR,c,ss,u,t,y} = k_{DR,ss,u} \cdot \Delta P_{DR,c,ss,u,t,y} \cdot f_t \cdot \Delta t_t$$

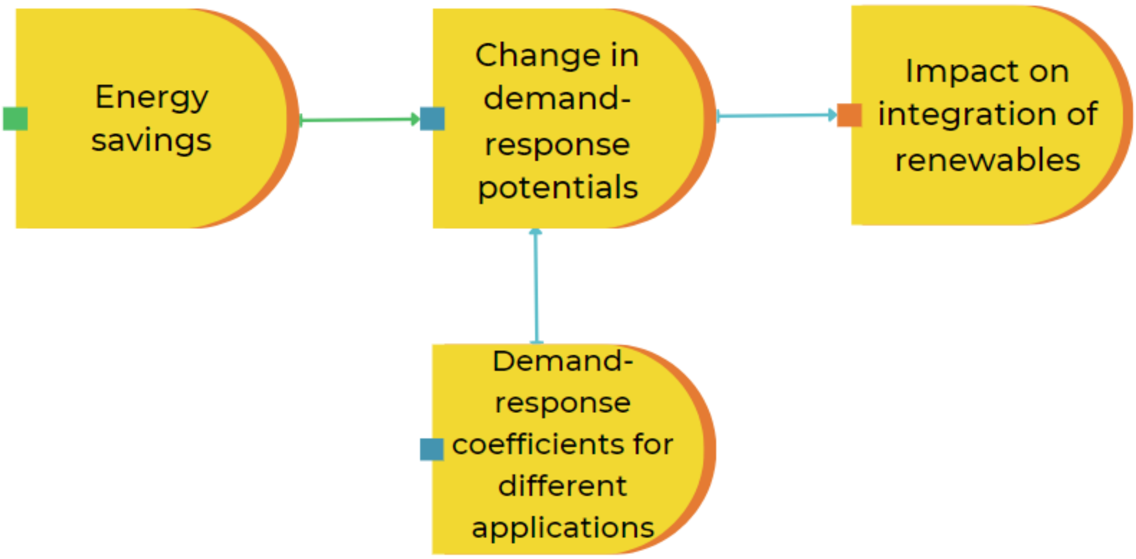

FIGURE 20: QUANTIFICATION OF THE IMPACT ON DEMAND INTEGRATION OF RENEWABLES

13.2.2 Methodological challenges

Demand-response potentials are strongly linked to temporal patterns. However, the MICATool does not allow for such a fine-grained analysis. Thus, several values are averaged over a long period. Furthermore, the value of demand-response strongly differs between regions and timings, as the value is strongly linked to the alternative that is necessary, for instance the ramp-up of a power plant.

13.2.3 Data requirements

This indicator mainly looks at the energy savings generated in certain (sub-)sectors and improvement action to match them with probable implemented actions and how these might affect demand-response potentials. Such coefficients are calculated for all (sub-)sector-improvement action combination.

13.3 Impact factor/functional relationship

The functional relationship is shown in the equation of the quantification section.

13.4 Monetisation

In order to monetise the demand-response potentials, the price of alternatives providing the same demand-response service with a similar potential is used. This is done for increases as well as decreases in demand-response potentials:

$$M_{\mathrm{DR},c,ss,u,y} = a_{DR,c,y} \cdot \Delta P_{DR,c,ss,u,t,y}$$

In this equation, $M_{\mathrm{DR},c,ss,u,y}$ specifies the monetary benefit (positive or negative), whereas $a_{DR,c,y}$ represents the cost per demand-response potential unit of an alternative service.

13.5 Aggregation

The indicator's monetisation can be aggregated with other impacts.

13.6 Conclusion

The indicator can help pinpoint how energy efficiency can help integrate additional renewable energy sources. However, given the coarse approach to an impact that is better assessed in a fine-grained way, certain margins of error can be expected. Besides that, the indicator can be monetised and aggregated without risk of double counting.

14 AVOIDED ADDITIONAL ENERGY GENERATION CAPACITY

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Reviewer: Alessia De Vita (E3M)

Executive Summary

Against the backdrop of the electrification of large parts of our economies and the decommissioning of legacy fossil fuel-combusting power plants, the need for additional renewable energy capacities is expected to rise in the years to come. However, by saving energy with energy efficiency and sufficiency measures, the need for additional capacities can be reduced. This indicator assesses the impact of energy savings on the need for additional capacities, taking regional full load hours of different technologies into account.

This impact is predominantly important on the national level, since the vast majority of electricity grids mainly operate nationally.

In light of the necessary investments in renewables across the bloc, this indicator might still be interesting on a European level to showcase the effect energy efficiency can have in decreasing the pressure on renewables expansion.

To quantify the reduced need for additional capacities, the regional respective full load hours of PV, onshore and offshore wind are considered in the form of a utilisation factor $u_{c,t}$:

$$u_{c,t} = E_{act,c,t}/E_{opt,t}$$

In this equation, $E_{act,c,t}$ describes the actual energy generation of a given RES technology in a specific country, whereas $E_{opt,t}$ specifies the RES technology's optimal energy output. Then, the shares of the different RES technologies in new electricity capacities $\lambda_{c,t}$ are taken into account, using the average of the PRIMES projections for 2020, 2025, and 2030:

$$\lambda_{c,t} = \emptyset_y(\lambda_{c,t,y})$$

These intermediate results can be used to calculate the change in additional capacity $\Delta C_{c,t}$ triggered by electricity savings $\Delta E_{el,c}$:

$$\Delta C_{c,t} = \frac{\Delta E_{el,c} \cdot \lambda_{c,t}}{u_{c,t} \cdot 8760\ \mathrm{h}}$$

To monetise this impact, the reduced capacity is multiplied with the technologies' marginal investment prices P_t:

$$M_{\Delta C,c} = \sum_t \Delta C_{c,t} \cdot P_t$$

The only issue is the overlap of this impact with "Energy savings", suggesting not to aggregate the monetised values by default and excluding it from the cost-benefit-analysis.

14.1 Scope of MI indicator

14.1.1 Definition

Against the backdrop of the electrification of large parts of our economies and the decommissioning of legacy fossil fuel-combusting power plants, the need for additional renewable energy capacities is expected to rise in the years to come. However, by saving energy with energy efficiency and sufficiency measures, the need for additional capacities can be reduced. This indicator assesses the impact of energy savings on the need for additional capacities, taking regional full load hours of different technologies into account.

14.1.2 Relevance on EU, national and/or local level

This impact is predominantly important on the national level, since the vast majority of electricity grids mainly operate nationally.

In light of the necessary investments in renewables across the bloc, this indicator might still be interesting on a European level to showcase the effect energy efficiency can have in decreasing the pressure on renewables expansion.

On the local level, this indicator is less relevant.

14.1.3 Impact pathway figure

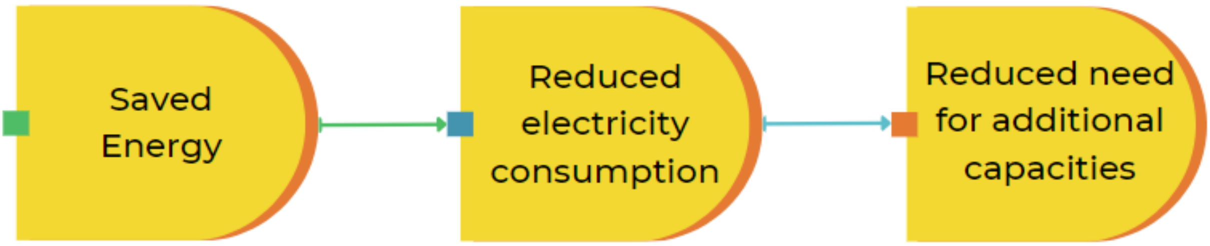

FIGURE 21: IMPACT PATHWAY FOR THE INDICATOR AVOIDED ADDITIONAL ENERGY GENERATION CAPACITY

14.1.4 Overlaps with other MI indicators and potential risk of double-counting

The monetisation of this indicator has slight overlaps with two other indicators:

- Energy (cost) savings: since the investment costs are internalised in energy costs, the costs of additional capacities are comprised in the energy cost savings, which would have originated from these additional capacities. However, since the investment costs of renewables are currently extremely low and the payback times have gone along with them, significantly underbidding the technologies' lifetimes, the energy costs include far more price components than just the investment costs.
- RES share: this indicator monetises the costs of missing the Renewable Energy Directive's targets. However, since the monetisation refers to statistical transactions of renewables, meaning surplus volumina can be sold whereas shortfall volumina can be purchased, the transfer is independent of actual physical values. This monetisation does not relate to the amount of generated electricity but merely to the way it was produced, renewably or not. Thus, the risk of double counting can be neglected for this impact.

14.2 Quantification method

14.2.1 Description

In order to assess this impact, the underlying assumption is that the energy savings merely cushion the need for additional renewable energy sources. This is mainly due to two reasons: new electric capacities should be renewable to comply with the Paris Agreement and the Fit-for-55 package and predominantly include photovoltaics (PV), onshore and offshore wind; the fact that the decommissioning of fossil fuel and nuclear power plants is mainly planned politically rather than as a response to market signals.

To quantify the reduced need for additional capacities, the regional respective full load hours of PV, onshore and offshore wind are considered in the form of a utilisation factor $u_{c,t}$:

$$u_{c,t} = E_{act,c,t}/E_{opt,t}$$

In this equation, $E_{act,c,t}$ describes the actual energy generation of a given RES technology in a specific country, whereas $E_{opt,t}$ specifies the RES technology's optimal energy output. Then, the shares of the different RES technologies in new electricity capacities $\lambda_{c,t}$ are taken into account, using the average of the PRIMES projections for 2020, 2025, and 2030:

$$\lambda_{c,t} = \emptyset_y(\lambda_{c,t,y})$$

These intermediate results can be used to calculate the change in additional capacity $\Delta C_{c,t}$ triggered by electricity savings $\Delta E_{el,c}$:

$$\Delta C_{c,t} = \frac{\Delta E_{el,c} \cdot \lambda_{c,t}}{u_{c,t} \cdot 8760\ \text{h}}$$

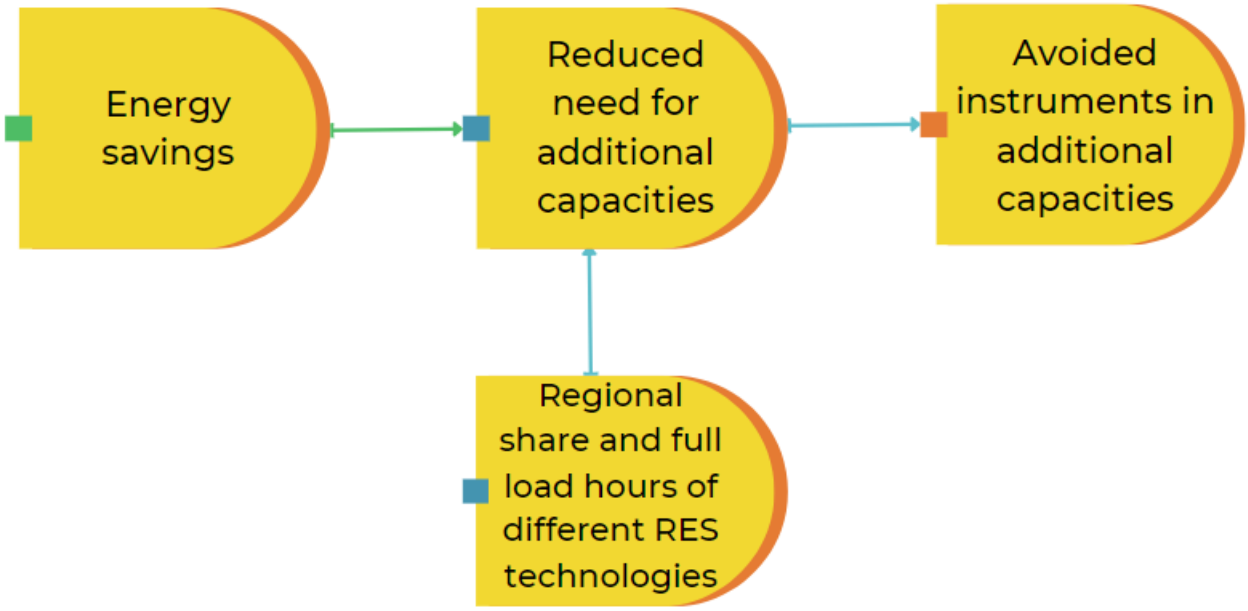

FIGURE 22: QUANTIFICATION OF THE INDICATOR AVOIDED ADDITIONAL ENERGY GENERATION CAPACITY

14.2.2 Methodological challenges

There are no methodological challenges.

14.2.3 Data requirements

This indicator mainly needs electricity savings as generated by the indicator "Energy savings". Furthermore, the changes in additional capacity triggered by electricity savings have been calculated for all EU countries.

14.3 Impact factor/functional relationship

The functional relationship is shown in the last equation of the quantification section.

14.4 Monetisation

To monetise this impact, the reduced capacity is multiplied with the technologies' marginal investment prices P_t:

$$M_{\Delta C,c} = \sum_t \Delta C_{c,t} \cdot P_t$$

The latter are issued and averaged from two publications (Table 18).

TABLE 18: MARGINAL COSTS OF RES TECHNOLOGIES

Source	Onshore wind [€/kW]	Offshore wind [€/kW]	PV [€/kW]
IRENA (IRENA 2016)	1370	3950	790
European Commission (Tsiropoulos I, Tarvydas, D, Zucker 2017)	1290	2950	800
Assumption for the cost in this work by the author	1330	3450	795

14.5 Aggregation

The indicator's monetisation should not be aggregated with other impacts, since the benefits of this indicator are already reflected in the monetisation of "Energy savings".

14.6 Conclusion

The indicator can help pinpoint how energy efficiency can reduce the pressure on the expansion of renewables. Both the methodology of the quantification and of the monetisation are straightforward. The only issue is the overlap of the monetisation of this impact with and of "Energy savings", suggesting not to aggregate it by default and excluding it from the cost-benefit-analysis.

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