MICAT

Multiple Impacts Calculation Tool

Social Impacts

D2.3 Empirical basis of Social Impacts. Quantification/monetization methodology and derived impact factors.

Lead partner for Deliverable: Wuppertal Institute (WI)

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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 **social impacts** (SoI) (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 social impact category and the respective data requirements.[1]

Social Impacts covered in Task 2.3 involve three main impact categories:

Energy Poverty

The energy poverty alleviation indicator quantifies the impact of policy induced energy savings in the residential building sector in terms of the number of households and persons financially enabled to access a sufficient level of basic energy services and thus escape the state of energy poverty and its negative consequences. Within MICAT, energy poverty is defined as a state in which a household uses a disproportionately low level of energy services due to financial hardship, indicated by a low absolute energy expenditure in comparison to a defined national threshold (M/2 indicator).

Quality of life

Distributional impacts on household consumption and welfare are quantified by E3M. In particular the indicator developd for the project explores the impact of energy saving measures on household's welfare by incomde quantiley for each Member State. The approach approximates the changes in welfare in terms of non-energy expenditures as percentage of household’s income.

Health

Wuppertal Institute calculates health impacts associated with poor building conditions in collaboration with the expert partner from the COMBI project, as a similar modelling approach will be applied. Reduced or avoided excess cold weather mortality (ECWD) due to energy efficiency improvements in the residential building sector is calculated by comparing the ECWD attributed to indoor cold prior to and after the implementation of energy efficiency measures. The indicator avoided burden of asthma due to the reduced exposure to indoor dampness as a result of energy efficiency improvements in the residential building sector is calculated using a standard method for assessing the Environmental Burden of Disease (EBD). To monetise these health co-benefits, tool users can choose between the value of a statistical life (VSL) or value of a life year (VOLY) (non-market values approach).

Impacts on human health due to reduced air pollution (mortality and morbidity) and work loss days (side-impact) will be quantified by IIASA with the GAINS model (cf. task 2.5). The assessment of these impacts resulting from air quality improvement will be performed using the impact pathway approach. The concept of the value of statistical life (VSL) is used for the monetisation of the mortality (and morbidity) effects. Working days lost (impact related to health) are quantified using country-specific concentration response functions and

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[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).

are then monetised by taking a cost-of-illness approach and estimating the reduced productivity due to reduced working time.

TABLE 1 MICAT INDICATORS IN CATEGORY SOCIAL IMPACTS

SoI	Social impact indicators	Lead	Quantification methodology / unit
			Energy Poverty
SoI-1	Alleviation of energy poverty	WI	Based on the difference of absolute energy expenditures to a defined national threshold (M/2 indicator) and the extent to which energy cost savings from EEI actions achieve to close this Energy Poverty Gap Unit: Number of households / persons lifted from energy poverty
			Quality of Life
SoI-2	Alleviation of inequality	E3M	Impact of incomes / expenses by income decile, indices Unit: S80/S20, Income/Consumption by income decile
			Health
SoI-3	Human health due to improved indoor climate	WI	-
SoI-3.1	*Reduced or avoided excess cold weather mortality*	WI	Premature mortality due to inadequate heating Quantification based on COMBI model – comparison of the mortality cases during the cold weather period prior to and projected excess cold weather mortality after the implementation of EEI actions Unit: Number of deaths avoided
SoI-3.2	*Avoided burden of asthma due to the reduced exposure to indoor dampness*	WI	Asthma morbidity Quantification based on COMBI model – comparison of the population suffering from asthma due to indoor dampness prior to and after the implementation of EEI actions Unit: DALY
SoI-4	Human health due to reduced air pollution	IIASA	-
SoI-4.1	*Air pollution-related mortality*	IIASA	GAINS model and impact pathway approach Unit: Number of deaths avoided
SoI-4.2	*Air pollution-related morbidity*	IIASA	GAINS model and impact pathway approach Unit: DALY or restricted activity days (RAD)
SoI-4.3	*Working days lost (impact related to health)*	IIASA	Lost working days due to ill health caused by outdoor air pollution Quantification based on country-specific concentration response functions; monetisation by taking a cost-of-illness approach and estimating the reduced productivity due to reduced working time Unit: Number of days gained

2 ENERGY POVERTY ALLEVIATION

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Executive Summary

Energy poverty has gradually emerged as a central policy issue within the EU, which is reflected in both its legislation as well as research agenda. Against the background of the four strategic pillars of the EU energy transition 1) phasing out of fossil fuel-based energy supported by CO2-pricing, 2) investing in renewable energy sources and associated infrastructure and 3) reducing energy demand via energy efficiency investments and 4) electrification, the equitable distribution of costs and benefits is a central criterion to assess its socially just implementation. Energy poverty levels represent an indication of how well energy policies achieve to fulfil the promise of a just transition that is leaving no one behind.

Within MICAT, energy poverty is defined as a state in which a household uses a disproportionately low level of energy services due to financial hardship, indicated by a low absolute energy expenditure in comparison to a defined national threshold (M/2 indicator). The energy poverty alleviation indicator as proposed and defined in MICAT quantifies the impact of policy induced energy cost savings in the residential building sector in terms of the number of persons financially enabled to access a level of energy services above the energy poverty threshold and thus escape the state of energy poverty and its negative consequences.

The calculation of the energy poverty alleviation impact follows a four-step approach, which slightly differs depending on whether building or household targeted energy efficiency improvement (EEI) actions are modelled: 1) Determine the number and type of EEI actions and the corresponding energy cost savings per household and year, 2) define the share/number of EEI actions implemented in energy poor households (Policy Targetedness Factor), 3) define the share/number of energy poor households, for which energy cost savings enable increased access to energy services beyond the threshold (Impact Factor) and 4) multiply the number of these households with the average household size.

The functional relationship to determine the energy poverty alleviation impact in terms of number of persons lifted from energy poverty (△EP) is as follows:

<u>For household targeted EEI actions:</u>

$$\Delta EP \; = N \; x \; PTF \; x \; IF \; x \; SSH$$

<u>For building targeted EEI actions:</u>

$$\Delta EP \; = \frac{N}{D} \; x \; PTF \; x \; \left(IF_{owner} \; x \; OR \; + \; IF_{tenant} \; x \; (1 \; - \; OR) \right) \; x \; SHH$$

N: Number of EEI actions per year
D: Average number of dwellings per building
PTF: Policy Targetedness Factor
IF: Impact Factor for owner occupiers, tenants or all households
OR: Ownership rate among energy poor households
SSH: Average size of energy poor households

2.1 Scope of MI indicator

2.1.1 Definition

Within MICAT, energy poverty is defined as a state in which a household uses a disproportionately low level of energy services due to financial hardship, indicated by a low absolute energy expenditure in comparison to a defined national threshold (M/2 indicator[2]). The energy poverty alleviation indicator quantifies the impact of policy induced energy cost savings in the residential building sector in terms of the number of persons financially enabled to access a level of energy services above the energy poverty threshold and thus escape the state of energy poverty and its negative consequences, such as most notably both physical and mental health risks (Jessel et al. 2019; Ballesteros-Arjona et al. 2022).

2.1.2 Relevance on EU, national and/or local level

Energy poverty has gradually emerged as a central policy issue within the EU, which is reflected in both its legislation (European Commission 2020) as well as research agenda (Gangale/Mengolini 2019). Against the background of the four strategic pillars of the EU energy transition 1) phasing out of fossil fuel-based energy supported by CO2-pricing, 2) investing in renewable energy sources and associated infrastructure and 3) reducing energy demand via energy efficiency investments and 4) electrification (Agora Energiewende 2019), the equitable distribution of costs and benefits is a central criterion to assess its socially just implementation. Energy poverty levels represent an indication of how well energy policies achieve to fulfil the promise of a just transition that is leaving no one behind[1]. While at EU level, the ex-ante assessment of energy poverty impacts of legislative proposals is established practice (Politt et al. 2016; European Commission 2021), the measures taken to address the issue are designed and implemented at national and local level respectively. Apart from providing guidance for national and local energy (efficiency) policy designers, the indicator can support monitoring and reporting requirements on energy poverty impacts defined in the pertinent EU Directives.

2.1.3 Impact pathway figure

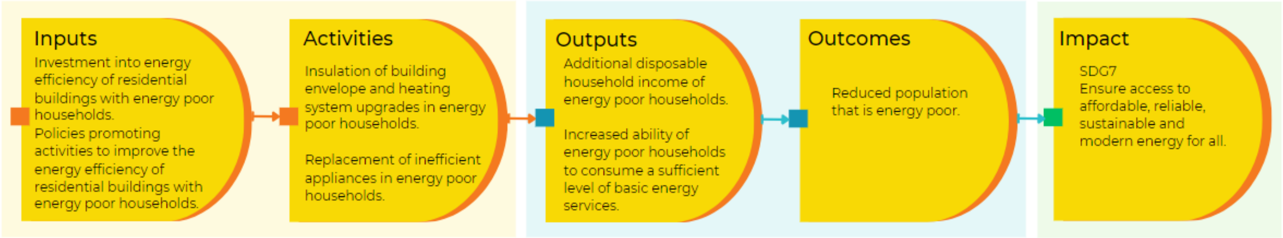

FIGURE 1: LOGIC MODEL (THEORY OF CHANGE) FOR ENERGY POVERTY ALLEVIATION

[1] Cf. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism_en

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

The alleviation of energy poverty results from reduced financial requirements for households to use a sufficient level of energy services. If consumption is increased to improve e.g., thermal comfort, no financial savings materialise.

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[2] The M/2 indicator defines those households as energy poor, whose absolute energy expenditure is below half the national median value. To avoid assigning the status to households, whose low energy expenditure results from high energy efficiency of their dwelling, in MICAT we further restrict the definition to households whose (equivalized) household income is at the same time in the lower five income deciles.

Even if households choose to sustain their current level of energy services and use cost savings for other purposes, These savings are how-ever already captured in the monetised energy savings indicator and should not be double counted. Furthermore, there can be an overlapping effect on public budgets if transfer payments to energy poor households or spending on energy subsidies are reduced. However, similar to the positive health impacts, whether and to what extent public budget spend-ing is reduced depends on the respective existence and setup of welfare state institutions and/or targeted energy poverty policies.

2.2 Quantification method

2.2.1 Description

To quantify the energy poverty alleviation impact of energy efficiency improvement (EEI) actions in the residential sector, different calculation steps are required depending on the type of user request (cf. Figure 2).

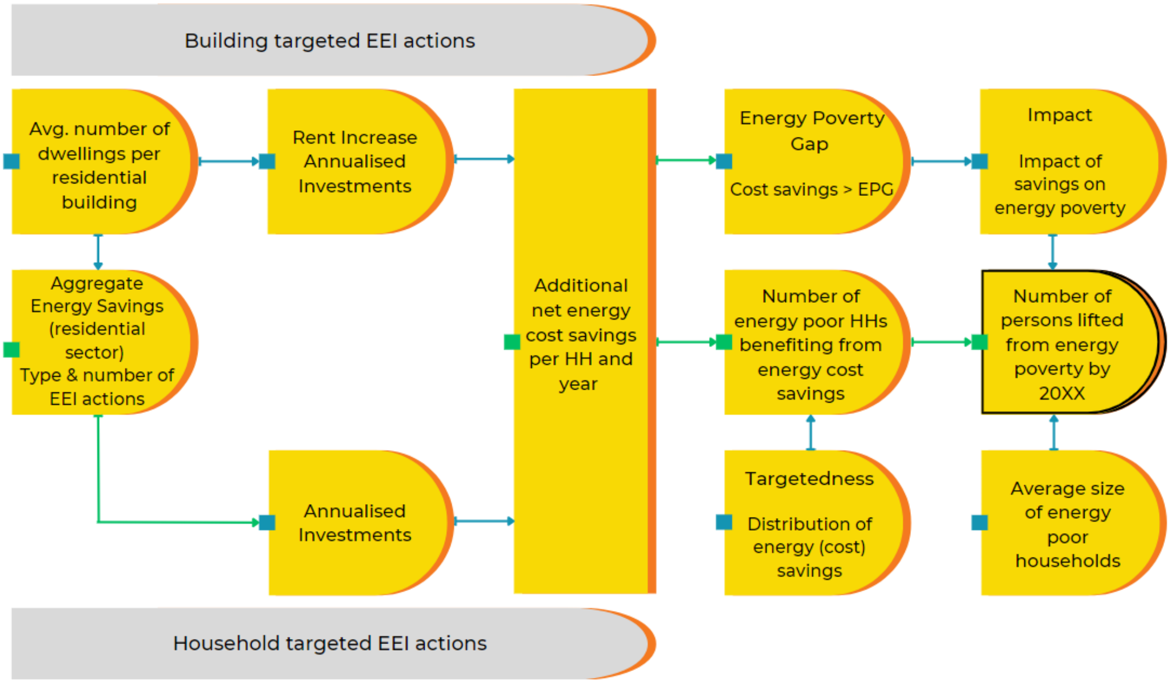

FIGURE 2: MAIN CALCULATION STEPS (GREEN) AND INTERIM STEPS (BLUE) USING USER INPUTS AND DATA IN THE TOOL

In a first step, the number and type of EEI actions and the corresponding energy cost savings per household are determined. Since impacts for this indicator are quantified on the household level, EEI actions directed towards buildings (e.g., insulation) and the corresponding (cost) savings need to be disaggregated, whereas EEI actions that are directly implemented in households (e.g., appliance replacements) equal the number of affected households and household specific savings. In case of building refurbishments, this means to divide the resulting or estimated savings per refurbishment by the average number of dwellings per building. To account for costs accruing to households in the course of the EEI action implementation, the yearly energy cost savings (ΔE) are adjusted by subtraction of annualised average investments for the EEI action (*AI)* minus possible subsidies (for owner occupiers or household targeted EEI actions (e.g., appliance replacements)) or rent increase (for tenants). The latter is defined as a share of the annual rent expenditure of energy poor tenants calculated from the 2015 HBS micro data. Both subsidy rate (*SR*) as well as the renovation rent premium (*RRP*) may be defined by the online tool user, with default values being set for SR at 1 (i.e., no subsidy) and tentative rent premiums from the pertinent literature. The net yearly energy cost savings ($\Delta NECS$) resulting from higher efficiency are calculated as follows:

For household targeted EEI actions:

$$\Delta NECS = \Delta E - AI \; x \; (1 - SR)$$

<u>For building targeted EEI actions:</u>

$$\Delta NECS_{Tenants} = \Delta E - RRP \; x \; REP$$

$$\Delta NECS_{Owners} = \Delta E - \frac{AI}{D} \; x \; (1 - SR)$$

ΔE: Yearly energy cost savings from EEI action
AI: Annualised investment for EEI action
SR: Subsidy rate
D: Average number of dwellings per building
RRP: Average renovation rent premium as percentage of rent
REP: Average rent of energy poor households

Secondly, the share/number of EEI actions implemented in energy poor households is determined. To this end, tool users may insert a political target (here defined as Policy Targetedness Factor (PTF)) as a percentage of EEI actions to be implemented in energy poor households (i.e., taking on values between 0 and 1). In case no political target is explicitly defined, as a default the share of energy poor households in the population in the respective country or region is used, following the provisions of the latest draft of the 2022 recast of the EU Energy Efficiency Directive[3].

Third, to calculate the number of households/persons that are actually lifted from energy poverty due to the EEI action, the number of energy poor households in which EEI actions are/will be implemented is then multiplied with a weighted Impact Factor (IF) taking on values between 0 and 1. This factor is defined with view to the relationship between the net yearly energy cost savings from the EEI actions and the level and distribution of the Energy Poverty Gap[4] among energy poor owner occupiers and tenants and weighted with view to their respective share in the energy poor population. To define the reference values against which energy cost savings are compared, deciles of the Energy Poverty Gap are formed, with the least severely affected in the first and the most severely affected households in the 10th decile (cf. Figure 3 as example with data for Italy).

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[3] According to the newly inserted Article 8 on Energy Saving Obligations "*Member States shall achieve a share of the required amount of cumulative end-use energy savings among people affected by energy poverty vulnerable customers and, where applicable, people living in social housing. This share shall at least equal the proportion of households in energy poverty as assessed in their National Energy and Climate Plan established in accordance with Article 3(3)(d) of the Governance Regulation 2018/1999.*"

[4] Meaning here the difference of energy poor households' absolute energy expenditure to the national M/2 indicator threshold value.

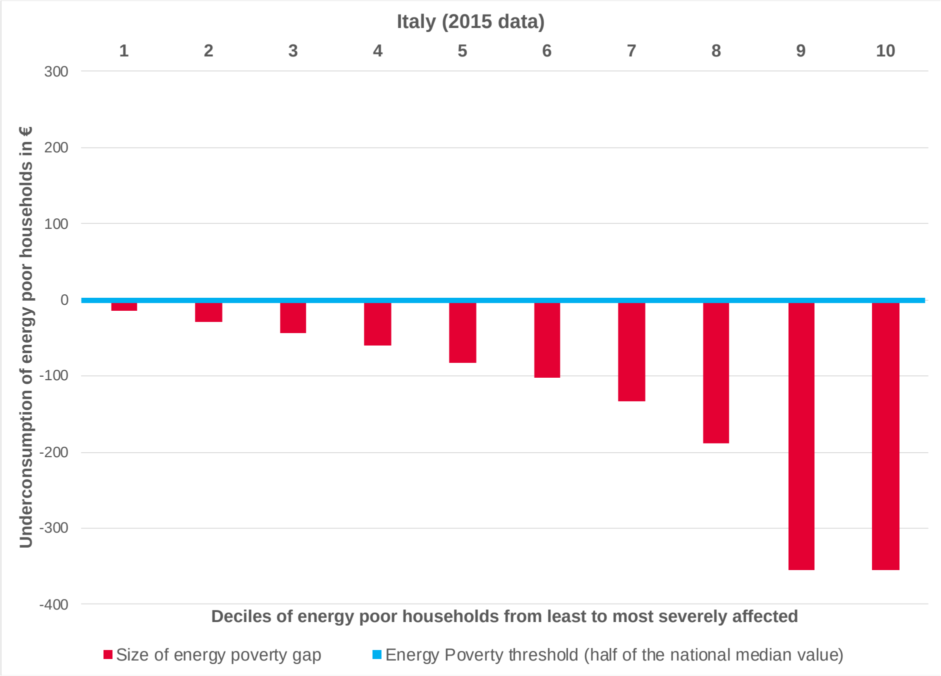

FIGURE 3: VISUALIZATION OF DISTRIBUTION OF ENERGY POVERTY GAP. EXAMPLE: ITALY. SOURCE: HBS 2015

The IF (for owner occupiers and tenants) are then derived by comparing the (adjusted) net yearly energy cost savings with the marginal values of the different deciles. The last decile for which the net energy cost savings are greater than the marginal value defines the respective IF, i.e., the share of energy poor households whose energy expenditure is increased beyond the national energy poverty threshold value. In the exemplary case, net yearly energy cost savings for benefitting households are 200 € on average, which enables 80% of them to increase their energy expenditure/consumption to or beyond the threshold (Figure 4). The IF in this case would thus be 0.8. Once the different IF have been defined, a combined weighted IF is calculated using the share of owner occupier households and its complementary value in the respective energy poor population.

Lastly, the resulting number of households is multiplied with the average household size of energy poor households to provide a number of persons lifted from energy poverty due to the EEI action.

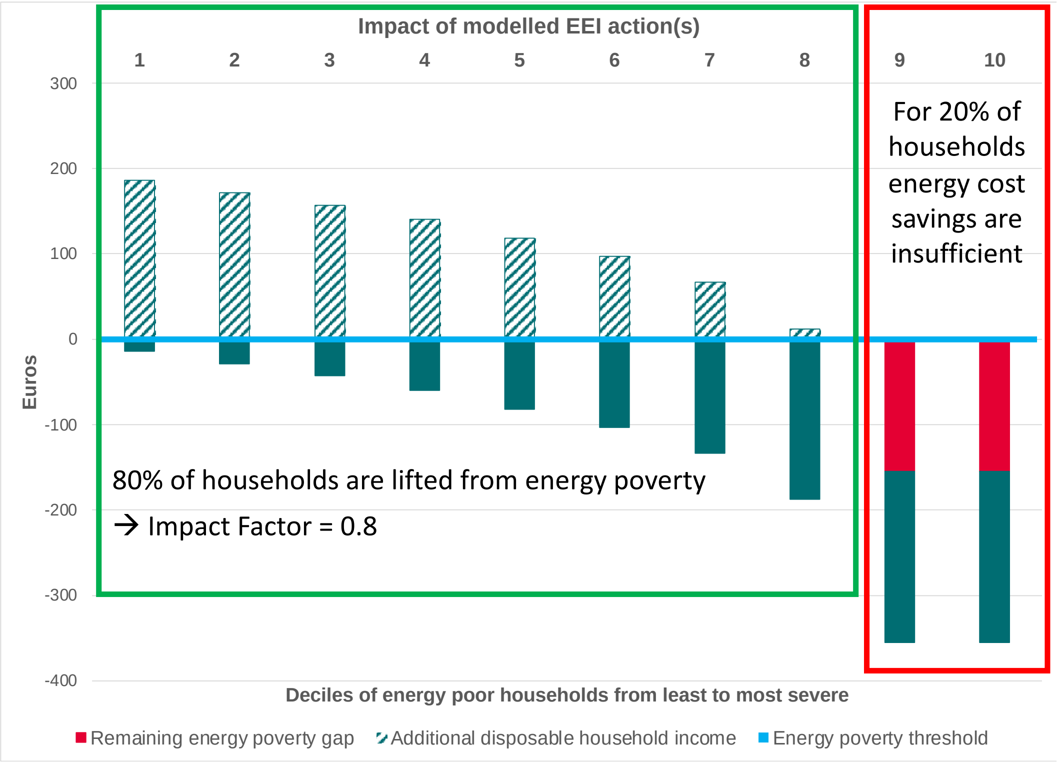

FIGURE 4: VISUALIZATION OF LOGIC TO DETERMINE THE IMPACT FACTOR. EXAMPLE: ITALY

2.2.2 Methodological challenges

Due to its manifestation on the household level, the quantification of energy poverty impacts from EEI actions requires a multitude of data on the building stock, household characteristics, policy design and the EEI actions themselves, which may not be available from one source and/or at the necessary level of disaggregation. Thus, depending on the tool user request (top-down or bottom-up; scenario, policy or action; local, national or EU level) and the correspondingly provided input data, several assumptions must be made, which introduce uncertainty to the model output.

First, in cases where the distribution of EEI actions and corresponding energy (cost) savings within the respective population is unknown or users do not specify, the share of savings or number of EEI actions implemented respectively in energy poor households must be assumed. As a default value, in MICAT we use the national energy poverty shares according to the M/2 indicator for consistency reasons, however knowing that this indicator is rarely used by Member States to capture and report on energy poverty and that the underlying data is rather old (see paragraph below).

Secondly, whether energy poor households fully benefit from the energy cost savings resulting from the energy efficiency improvement of or in their dwelling, depends on the extent to which the associated investments are borne by them either directly as investors or indirectly via increased rents. Accordingly, the share/level of energy cost savings accrued by energy poor households must be assumed as well. If no user input is provided defining the Renovation Rent Premium, adjustments of energy cost savings will have to rely on a rather patchy empirical basis regarding rent increases following renovations, which is not available for all Member States. Furthermore, given the variety of manifestations of and corresponding metrics for measuring energy poverty, the required level of energy cost savings/additional disposable household income to “escape” the state of energy poverty is arguably debatable.

Lastly, the household expenditure data used to calculate some of the variables in the functions such as the national energy poverty threshold values, the Energy Poverty Gap or average rents of energy poor households is from the 2015 HBS micro data, and hence does not reflect current household expenditure against the background of increasing rents and energy prices. To avoid overestimating the impact of energy cost savings of modelled EEI actions, the micro data has been manipulated to current levels using data from the Harmonised Index of Consumer Prices (HICP) for rent and energy expenditure[5]. Since there is no disaggregated information on respective changes available (e.g., by income decile), adjustments have been applied uniformly, thus introducing possible bias in neglect of differing opportunities of households to change expenditure levels (e.g., through investments in EEI actions or acquisition of real estate).

Overall, data used to define default values is mostly available at national level. The calculation of impacts at the local level thus will use these as proxies and in addition requires specific input regarding the number of EEI actions to be modelled by the Tool.

2.2.3 Data requirements

The following data is needed to calculate the energy poverty alleviation impact of EEI actions for different use cases and differing levels of tool user inputs:

TABLE 2: DATA REQUIREMENTS FOR ENERGY POVERTY ALLEVIATION IMPACT CALCULATION

Data	User input	Default value (Source)	In-Tool calculation
Final energy savings in residential buildings by EEI action type per year	Yes	-	-
Number of (induced) EEI actions or households affected by them respectively per year	Yes	-	Calculation based on yearly deep renovation rates (PRIMES) and occupied dwelling stock/household data (Eurostat)
Number/share of EEI actions implemented in energy poor households per year (Policy Targetedness)	Yes	Share of energy poor households according to M/2 indicator (HBS 2015)	-
Subsidy rate for EEI action	Yes	0	-
Renovation Rent Premium	Yes	Based on pertinent literature review	-
Occupied dwelling stock/Number of households	-	Household statistics from the Labour Force Survey (LFS Eurostat)	-
Yearly deep renovation rate	-	Taken from the PRIMES REF2020 scenario (PRIMES)	-
Average rents of energy poor households	-	Average rent expenditure of energy poor tenant households according to M/2 indicator (HBS 2015, adjusted)	-
Average number of dwellings per residential building	-	Derived from Hotmaps database[6] (BPIE 2016-2020)	-
Ownership rate among energy poor households	-	Share of energy poor households according to the indicator "Inability to keep home adequately warm living in their own dwelling (SILC 2020)	-
Average size of energy poor households	-	Size of energy poor households according to the indicator "Inability to keep home adequately warm (SILC 2020)	-
Energy Poverty Gap	-	Calculated based on household energy expenditure data (HBS 2015, adjusted)	
Final energy cost savings per household and year	-	-	Division of aggregate cost savings by standard cost savings per EEI action (and for building targeted EEI actions by the average number of dwellings per building)
Annualised EEI action investments per household	-	-	Calculated from energy savings using standard investment values

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[5] Once the 2020 wave of the harmonized HBS data has been published by Eurostat, the manipulated data will be replaced.

[6] https://gitlab.com/hotmaps/building-stock/-/blob/196a8efc4d8841b7c062440b1fedbc6a963e7d45/data/building_stock.xlsx

			per EEI action (and for building targeted EEI actions divided by the average number of dwellings per building)
Share of energy poor households lifted from energy poverty (Impact)	-	-	Calculated with view to the net yearly energy savings and the marginal values of the Energy Poverty Gap (HBS 2015, adjusted)

2.3 Impact factor/functional relationship

The functional relationship to determine the energy poverty alleviation impact in terms of number of persons lifted from energy poverty (ΔEP) is as follows:

For household targeted EEI actions:

$$\Delta EP \ = N \ x \ PTF \ x \ IF \ x \ SSH$$

For building targeted EEI actions:

$$\Delta EP \ = \frac{N}{D} \ x \ PTF \ x \ \left(IF_{owner} \ x \ OR \ + \ IF_{Tenant} \ x \ (1 \ - \ OR)\right) \ x \ SHH$$

N: Number of EEI actions per year
D: Average number of dwellings per building
PTF: Policy Targetedness Factor
IF: Impact Factor for owner occupiers, tenants or all households
OR: Ownership rate among energy poor households
SSH: Average size of energy poor households

2.4 Monetization

In terms of monetization, the financial benefits of energy refurbishments for energy poor households are captured in the energy cost savings indicator of energy efficiency improvements. While the reduction of household spending on energy may also lead to an unbur-dening of public finances (e.g., via reduced energy subsidies or other public transfers), the extent of this effect is difficult to quantify as both the distribution of cost savings between landlords and tenants as well as state support frameworks are highly context specific.

2.5 Aggregation

The indicator is a standalone indicator and will thus not be aggregated with others and not included into the Cost-Benefit Analysis.

2.6 Conclusion

This indicator reflects a central promise of the EU to implement a just energy transition and can inform energy efficiency policy design with view to key elements, namely which (sub)targets should be set for energy poor households, what level of energy cost savings per household on average should be aimed for and which subsidy level and or regulatory safe-guards to achieve those savings are required or how these elements may be combined to reach a desired outcome. While allowing users to change different variables for this pur-pose is considered a strength of this approach, it also warrants caution regarding the results, as implausible inputs or combinations thereof may lead to inflated outputs.

3 REDUCED OR AVOIDED EXCESS COLD WEATHER MORTALITY DUE TO ENERGY EFFICIENCY IMPROVEMENTS IN THE RESIDENTIAL BUILDING SECTOR

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Reviewer: Fabian Wagner (IIASA), Felix Suerkemper (Wuppertal Institute)

Executive Summary

In Europe, in 2020, around 7 % of the EU population could not keep their houses adequately warm during the winter due to high heating costs and/or poor housing quality (Eurostat, 2023). Evidence shows that prolonged indoor cold has contributed to premature mortality, especially in the cold season (Braubach et al., 2011). Energy efficiency measures applied in the existing residential housing can reduce indoor cold and its associated excess mortality.

The multiple impact (MI) indicator is reduced or avoided excess cold weather mortality due to energy efficiency improvements in the residential building sector. The first step for quantifying this indicator is to calculate the excess cold weather mortality (ECWD) in the EU, a given EU member country, or a city. A second step in modelling is to attribute ECWD to prolonged indoor cold exposure. However, no scientific studies have quantified the relationship between different types of energy retrofits in residential buildings and specific mortality reduction. Thus, assumptions are made between different retrofit types and ECWD reduction potential based on expert judgement (Mzavanadze, 2018).

Indoor cold generally affects the population experiencing energy poverty. Thus, the health benefits from energy efficiency investments will occur only if energy efficiency policies target this group. Accordingly, MICAT introduces a Policy Targetedness Factor to reflect energy renovation targeting households affected by energy poverty.

3.1 Scope of MI indicator

3.1.1 Definition

The indicator measures reduced or avoided excess cold weather mortality (ECWD) due to energy efficiency improvements in the residential building sector.

Excess cold weather mortality (ECWD): excess mortality resulting from indoor cold during the cold season.

ECWD is a result of various factors, for example, “exposure to air pollution due to fossil-fuel-based heat supply in winter, indoor and outdoor cold, increase in winter-related infectious and bacterial epidemics as well as associated indoor crowdedness” (Eurowinter Group, 1997).

3.1.2 Relevance on EU, national and/or local level

Evidence shows that prolonged indoor cold has contributed to premature mortality, especially in the cold season (Braubach et al., 2011). In Europe, in 2020, around 7 % of the EU population could not keep their houses adequately warm during the winter due to high heating costs and/or poor housing quality (Eurostat, 2023). However, the share varies across different countries; for instance, it was more than 23 % in Bulgarian but only 1.7 % in Austria (ibid.).

3.1.3 Impact pathway figure

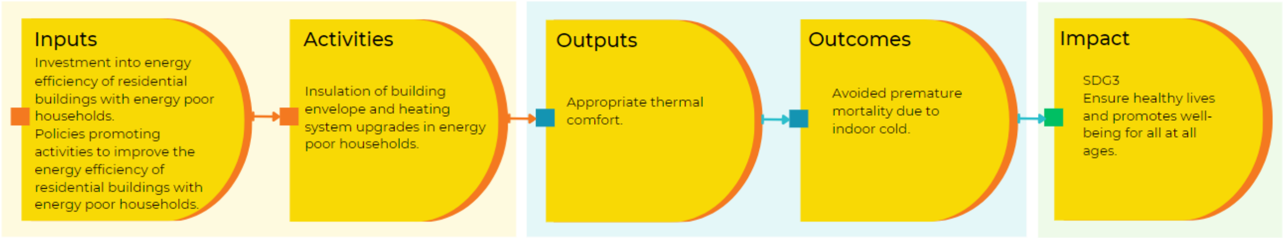

FIGURE 5: LOGIC MODEL (THEORY OF CHANGE) FOR REDUCED OR AVOIDED EXCESS COLD WEATHER MORTALITY DUE TO ENERGY EFFICIENCY IMPROVEMENTS IN THE RESIDENTIAL BUILDING SECTOR

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

Avoided premature mortality due to indoor cold may have an overlapping effect on public budgets and other macroeconomic variables, e.g., through changes in tax revenues, expenditure on public health services, etc. However, whether and to what extent these indicators are influenced by avoided premature mortality is not reliably quantifiable (e.g., dependent on the existence and setup of welfare state institutions in a country). This relationship is thus not taken into account in MICAT.

3.2 Quantification method

3.2.1 Description

The indicator is calculated by comparing the mortality cases during the cold weather period prior to and projected excess cold weather mortality after the implementation of energy efficiency measures.

The first modelling step is calculating excess cold weather mortality (ECWD). MICAT will adopt the estimates of ECWDs from the COMBI project funding from EU Horizon 2020, where a methodological upgrade in excess cold weather mortality was proposed in response to a recent academic critique (Mzavanadze 2018). A cold weather period includes at least 85% of a specific country's average annual heat degree days (HDD). At the city level, ECWD is assumed to be proportion to the share of the city population in the country.

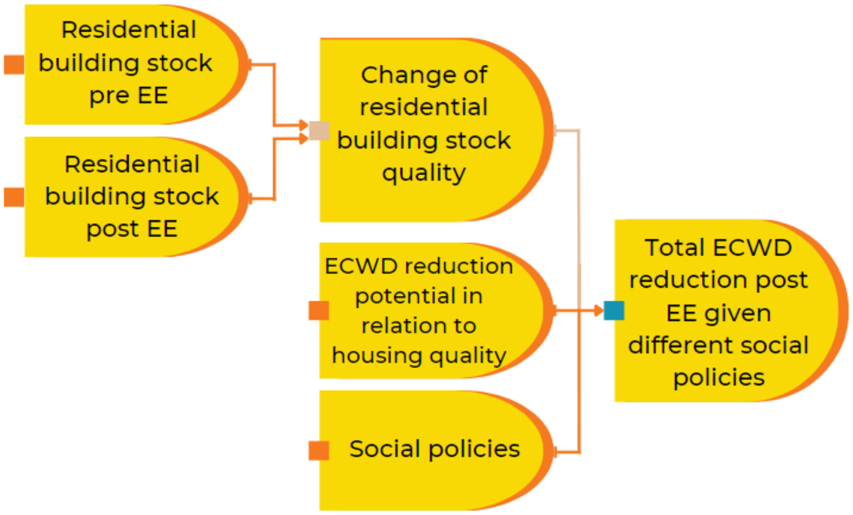

FIGURE 6: MAIN CALCULATION STEPS

According to expert observations, only a part of ECWDs can be attributable to indoor cold (Eurowinter Group, 1997; Braubach et al., 2011). Thus, a second modelling step is the attribution of premature mortality due to indoor cold exposure. It is assumed that this part of ECWDs could be avoided if thermal comfort could be ensured for all members of the population in question. Excess cold weather death due to indoor cold (WDI) is thus calculated as follows:

$$WDI = ECWDc \times AINc$$

EWCDc: Total excess cold weather mortality in a specific country
AINc: Share of ECWDs attributable to indoor cold in a specific country

No robust methodologies are available yet to estimate the attribution of ECWDs to pro-longed indoor cold exposure. Thus, expert observations have been used to estimate excess seasonal mortality. Mzavanadze (2018) found only a few European countries with expert estimates on the excess winter deaths attributed to indoor cold, with a value ranging from 10 % to 50 %. Ideally, such expert observation would be available for every European country. The WHO suggests a universal 30 % attribution value to indoor cold for Europe (Braubach et al., 2011). However, such a universal value for Europe is not robust, considering various social welfare systems and thermal comfort standards in different countries. Thus, MICAT applies a customized attribution as proposed in the COMBI project (Mzavanadze 2018) based on the EU SILC indicator “Population unable to keep home adequately warm by poverty status” of each country (Table 3). The underlying assumption is the more people are exposed to prolonged indoor cold in the society, the bigger the likelihood of a larger share of ECWDs attributable to indoor cold.

TABLE 3: PROXIES FOR ATTRIBUTION OF EXCESS COLD WEATHER DEATHS TO INDOOR COLD

Share of population unable to keep home adequately warm	ECWDs attributable to indoor cold
x< 5%	10%
5%<x<10%	20%
x>10%	30%

Source: (Mzavanadze, 2018)

Ex-ante and ex-post evaluation

The extent of renovation activities and their energy efficiency level are vital for modelling the potential for excess cold weather mortality reduction. Long-term observational studies have observed a generally positive relationship between improved thermal indoor comfort and reduced ECWD (Wilkinson et al., 2001). However, no scientific studies have quantified the relationship between different types of building thermal performance improvements and specific mortality reduction. For instance, deep retrofits are more likely to solve the thermal indoor discomfort rather than light retrofits, which in some cases may be insufficient to achieve thermal comfort. Mzavanadze (2018) proposes a different set of assumptions around different types of housing stock quality changes based on expert judgement. Table 2 shows the assumed relationship between attribution (AIN) reduction (and, thus, WDI reduction potential) and implemented energy retrofits.

TABLE 4: ASSUMPTIONS OF REDUCTION POTENTIAL OF ECWD DUE TO INDOOR COLD IN RELATION TO HOUSING QUALITY

Building energy quality	AIN and WDI reduction potential
No retrofits	0%
Light retrofits	50%
Medium retrofits	80%
Deep retrofits	100%

Source: (Mzavanadze, 2018)

The population experiencing energy poverty suffers mostly from indoor cold due to their limited financial capacity to afford the heating service needed for cold winters. This group often lacks the financial resources for relatively costly energy efficiency interventions. Therefore, we also introduce a Policy Targetedness Factor (value between 0 and 1).[7] It represents the percentage of energy renovation of a specific policy or programme targeting energy-poor households.

3.2.2 Methodological challenges

The following estimates and assumptions are associated with high uncertainties:

- The share of ECWD attributable to indoor cold was derived from a limited num-ber of studies.
- The assumptions on the relationship between ECWD reduction potential and energy retrofits is based on judgement of a small group of experts.

3.2.3 Data requirements

Input data from scenarios/policy measures evaluations

- Default from PRIMES: Deep renovation rate of residential building stock
- Alternatively user defined:
    - Building stock
    - Number of induced / implemented renovations per year (default: all renovations are deep)

External data sources used for quantification

- EWCD of a specific country (Mzavanadze, 2018)
- Population unable to keep home adequately warm
    - National level: EU SILC “share of the population unable to keep home adequately warm”

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[7] See MICAT factsheet “Energy poverty alleviation”.

  - City/local level: downscaling from national data above or based on surveys

Assumptions taken

- Assumptions on the relationship between ECWD reduction potential and en-ergy retrofit levels
- The share of ECWDs attributable to indoor cold
- The assumption on the extent of social policies – to what extent energy efficiency policies and investments reach the population experiencing energy poverty

3.3 Impact factor/functional relationship

$$\Delta WDI = WDI_0 \cdot PTF \cdot \sum_{i=1}^{3} \Delta\% r_i \cdot \Delta WDI_i$$

△WDI: Reduction of excess cold weather mortality attributable to indoor cold
WDI0: Total excess cold weather mortality reduction attributable to indoor cold in the base year
PTF: Policy Targetedness Factor (value between 0 and 1)
△%ri: the change of a specific building renovation type (1: light retrofit; 2: medium retrofit; 3: deep retrofit)
△WDIi: WDI reduction potential due to specific building renovation type

In the default case, we assume an optimal case of energy renovation, i.e., all energy renovations would be deep from 2021 on, with a reduction potential of WDI by 100 %.

The default value of PTF is derived from Article 8 of the proposed EED recast: “Member States shall achieve a share of the required amount of cumulative end-use energy savings among people affected by energy poverty vulnerable customers”. If a Member State had not notified this share as assessed in their National Energy and Climate Plan, the share of the required amount of cumulative end-use energy savings among people affected by energy poverty should at least equal the arithmetic average share of one of the following indicators: the inability to keep home adequately warm, arrears on utility bills, and structure of consumption expenditure by income quintile and COICOP consumption purpose (European Commission, 2021). In the MICATool, the share of population that is unable to keep the home adequately warm of a previous year is selected as the default value for PTF.

3.4 Monetization

The valuation of health benefits, such as the potential to reduce excess mortality, can be based on a) market values (e.g., average cost in the health care system of treating an illness, medication costs, lost productivity due to sick days) and/or b) non-market values based on surveys to determine the value of a statistical life (VSL) or value of a life year (VOLY). The market value approach requires a systematic inquiry into the health care systems of specific countries. Since this information is not available in MICAT, the non-market values approach is applied. VSL represents the individual willingness to pay (WTP) for small changes in the likelihood of death in a specific period. It is not a value placed on preventing a death with certainty, which is often misinterpreted (Robinson et al., 2019).

OECD (2011) recommends using VSL for the monetization of health impacts related to air pollution. Other studies, e.g., Hurley et al. (2005), argue that assigning a full statistical life for short-term exposure to air pollution, causing minor changes in death likelihood, might be exaggerating and suggest to use VOLY. However, little empirical research is available for VOLY.

Due to different stakeholder preferences with respect to monetisation, it is foreseen that users of the MICATool can choose between the two options. Option 1 follows the OECD’s approach, where VSL is applied to monetise both premature mortality and asthma reduction. Option 2 adopts VOLY. This is particularly suitable if the population affected is pre-dominantly elderly people. It represents a conservative approach, which is also recommended for multiple impact assessments of energy efficiency measures by Mzavanadze (2018).

The economic value of avoided premature excess cold weather mortality (VECc) in a specific country is calculated as follow:

$$VEC_c = VOLY_c \times \Delta ECWD_c$$

or

$$VEC_c = VSL_c \times \Delta ECWD_c$$

VOLYc: value of a life year in a specific country
VSLc: the value of a statistical life in a specific country
ΔECWDc: reduced excess cold weather mortality in a specific country

In MICAT, the country-specific VOLY and VSL values of Spadaro et al., (2018) are applied.

3.5 Conclusion

Indoor cold, which generally affects energy-poor households, has direct and immediate impacts on their health, namely, excess cold weather mortality. Thus, if they are targeted, energy renovation policies or programmes would have the most substantial positive impact on this societal segment. This indicator reflects the avoided excess cold weather mortality due to energy renovations with different levels of policy commitment to address energy poor households. While default values from PRIMES are used, users can also define the buildings to be renovated and the share of energy renovations of a specific policy or programme targeting energy-poor households.

4 AVOIDED BURDEN OF ASTHMA

Authors: Chun Xia-Bauer (Wuppertal Institute), Nora Mzavanadze

Reviewer: Fabian Wagner (IIASA), Felix Suerkemper (Wuppertal Institute)

Executive Summary

According to the European Union Statistics on Income and Living Conditions (EU-SILC), in 2021, almost 17% of the total population in the EU27 countries lived in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames or floors (Eurostat, 2022). A large number of studies conducted across many geographical regions show that there is a consistent association between indoor dampness/mould and asthma cases. Energy efficiency retrofits in residential housing can reduce indoor dampness to different extents and thus, potentially, asthma.

The multiple impact (MI) indicator is *avoided burden of asthma due to the reduced exposure to indoor dampness over a certain time period* as a result of energy efficiency improvements in the residential building sector. The standard method for assessing the Environmental Burden of Disease (EBD) is applied (Murray and Lopez, 2017). Since asthma can be attributed not only to dampness but also to many other factors, a key step of quantification is to attribute the share of current asthma prevalence to the exposure to dampness. The *population attributable fraction (PAF)* is an indicator that represents the proportion of the total disease burden that can be ascribed to a specified risk factor among many others (Braubach et al., 2011). The PAF of asthma due to exposure to indoor dampness is a function of the population living in buildings with high dampness, which is projected by the MICAT energy poverty model.

4.1 Scope of MI indicator

4.1.1 Definition

The indicator measures *avoided burden of asthma due to the reduced exposure to indoor dampness* in the EU, a given EU member country, or a city over a certain period due to energy efficiency improvements in the residential building sector.

Asthma: "Asthma is a long-term condition affecting children and adults. The air passages in the lungs become narrow due to inflammation and tightening of the muscles around the small airways, which leads to the following symptoms: cough, wheeze, shortness of breath and chest tightness" (WHO, 2021).

Mould: "all species of microscopic fungi that grow in the form of multicellular filaments" (WHO, 2009).

Dampness: "any visible and measurable outcome of excess moisture that causes problems in buildings, such as mould, leaks or material degradation, mould odour or directly measured excess moisture (in terms of relative humidity or moisture content) or microbial growth" (WHO, 2009). Thus, dampness is a prerequisite for the growth of mould.

Health effects of dampness/mould: A large number of studies conducted across many geographical regions show that there is a consistent association between indoor dampness/mould and asthma (including both children and adults) (Braubach et al., 2011).

4.1.2 Relevance on EU, national and/or local level

According to the European Union Statistics on Income and Living Conditions (EU-SILC), in 2021, almost 17% of the total population in the EU27 countries lived in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames or floor (Eurostat, 2022). Indoor dampness can lead to mould growth; exposure to mould can result in a health problem – asthma.

4.1.3 Impact pathway figure

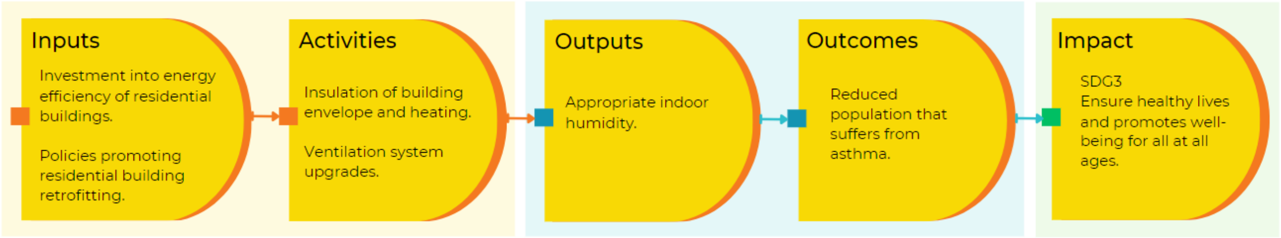

FIGURE 7: LOGIC MODEL (THEORY OF CHANGE) FOR AVOIDED BURDEN OF ASTHMA DUE TO THE REDUCED EXPOSURE TO INDOOR DAMPNESS

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

A lower number of asthma cases may reduce public budget spent on public health services. However, to which extent it reduces public budget spending in this regard varies, depending on the health insurance system, financing sources of public health system, and setup of welfare state institutions in a specific country, etc. In addition, fewer cases of asthma lead to lower absenteeism among employees, which can lead to higher productivity for companies, and thus affect other macroeconomic variables positively. However, these interaction effects cannot be reliably quantified within MICAT and are thus not taken into account.

4.2 Quantification method

4.2.1 Description

The standard method for assessing the Environmental Burden of Disease (EBD) is applied to quantify the impact on asthma due to indoor dampness (Murray & Lopez, 2017). Burden of disease quantifies the amount of a specific disease in the population. The disability-adjusted life year (DALY) is used to calculate the burden of disease. One DALY represents the loss of the equivalent of one year of full health. “Environmental” includes environmental risks and other factors, such as work environment or poverty, that cause diseases (Pruss-Ustun et al., 2003).

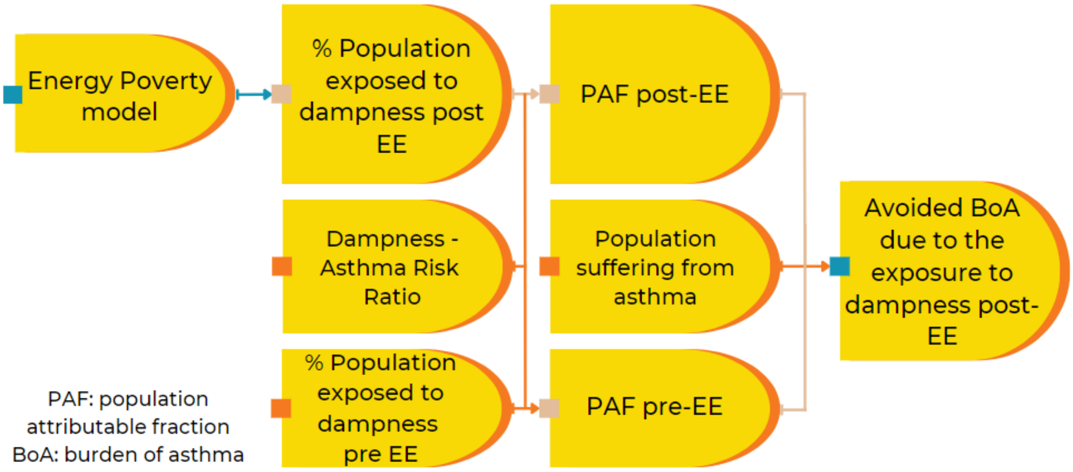

FIGURE 8: MAIN CALCULATION STEPS

Asthma can be caused not only by dampness, but also by many other factors. Thus, a pivotal step to quantify the impacts of energy efficiency measures on asthma morbidity is to attribute the share of current asthma prevalence to the exposure to dampness in a given population. The population attributable fraction (PAF) represents the proportion of the total disease burden ascribed to a specified risk factor among many others (Braubach et al., 2011). In the context of indoor dampness in housing and asthma, PAF represents the proportion of the total asthma disease burden that will be prevented if exposure to dampness is removed:

$$PAF_c = \frac{PDc\times(RR-1)}{PDc\times(RR-1)+1} \quad \text{(ibid)}$$

Where PDc = proportion of the population exposed (to dampness) in a specific country, and RR is the relative risk for the condition in those exposed.

For the current PDc value for the EU-27 countries, we adopt the indicator from the EU-SILC data „the total population living in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames or floor” (Eurostat, 2022). The estimation of the relative risk (RR) in scientific literature varies due to different types of exposure definitions (water damage, dampness, and mould), different climate conditions, and the age of participants (Quansah et al., 2012; Mzavanadze, 2018). Since PDc is based on the EU SILC’s indicator, which only includes the exposure to water damage and dampness without mould, the quantification should adopt RR estimate observed only for indoor dampness. Thus, MICAT uses an estimated RR that considers asthma as a result of exposure to dampness. The value (1.3) was derived from a review of 40 cross-sectional studies by Urlaub and Grün (2016).

As a consequence, the asthma disease burden attributable to exposure to dampness in a specific country *(AEBDAc)* is calculated as follows:

$$AEBDAc = PAFc \cdot EBDAc$$

EDBA: total environmental disease burden of asthma

4.2.2 Methodological challenges

One major methodology challenge is associated with data uncertainty:

- Uncertainty associated with the relative risk (RR) estimates for asthma onset in relation to exposure to dampness. Ideally, RR should be specific to different climate zones and different age groups (Mzavanadze, 2018).
- Uncertainty associated with the data on the prevalence of asthma among the general population of EU member states. According to the European Health Interview Survey (EHIS), the data is based on self-assessment, not officially reported medical diagnoses (Steppuhn et al.,2017). The former is self-reported based on asthma symptoms, such as wheezing, chest tightness, breathlessness, and coughing. However, many other respiratory conditions lead to similar respiratory symptoms. Thus, symptoms-based self-assessment may lead to considerable misclassification and underreporting or overreporting (Braubach et al., 2011).
- Uncertainty of indoor air exchange technologies applied in renovations. Deep renovation technologies without adequate ventilation solutions might create indoor dampness problems in places where they did not exist.

4.2.3 Data requirements

- **Input data from scenarios/policy measures evaluations**
    - Population exposed to dampness projected from the energy poverty model
- **External data sources used for quantification**
    - Total population
    - Population exposed to dampness:

      National level: the total population living in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames or floors (ILC_MDES01).

      City level: downscaling from national data or based on surveys in cities

    - EBD asthma

      National level: Global Burden of Disease Study database: *https://vizhub.healthdata.org/gbd-results/*.

      City/local level: downscaling from national data above or based on survey in cities

- **Assumptions taken**
    - The study assumes that removing a trigger that causes asthma (indoor dampness) would also eliminate asthma morbidity cases.
    - The same relative risk (RR) estimate is applied for all EU member countries and for the general population (not specific for age groups); the RR stays the same throughout the projection period.
    - The EDB stays the same throughout the projection period.

4.3 Impact factor/functional relationship

$$\Delta AEBDA_c = \Delta PAF_c \cdot EBDA_c$$

$\Delta AEBDAc$: the reduced burden of asthma attributable to exposure to dampness in a specific country
△PAFc: the change of the population attributable fraction (PAFc)

The population attributable fraction (PAFc) is a country/city-specific impact factor. The PAFc is a function of the proportion of the population exposed (to dampness) in a specific country (PDc). The projection of PDc is implemented in the projection of the energy poverty indicator.

4.4 Monetization

The valuation of health benefits, such as the potential to reduce excess mortality, can be based on a) market values (e.g., average cost in the health care system of treating an illness, medication costs, lost productivity due to sick days) and/or b) non-market values based on surveys to determine the value of a statistical life (VSL) or value of a life year (VOLY). The market value approach requires a systematic inquiry into the health care systems of specific countries. Since this information is not available in MICAT, the non-market values approach is applied. VSL represents the individual willingness to pay (WTP) for small changes in the likelihood of death in a specific period. It is not a value placed on preventing a death with certainty, which is often misinterpreted (Robinson et al., 2019).

OECD (2011) recommends using VSL for the monetisation of health impacts related to air pollution. Other studies, e.g. Hurley et al. (2005), argue that assigning a full statistical life for short-term exposure to air pollution, causing minor changes in death likelihood, might be exaggerating and suggest to use VOLY. However, little empirical research is available for VOLY.

Due to different stakeholder preferences with respect to monetisation, it is foreseen that users of the MICATool can choose between the two options. Option 1 follows the OECD's approach, where VSL is applied to monetise both premature mortality and asthma reduction. Option 2 adopts VOLY. This is particularly suitable if the population affected is predominantly elderly people. It represents a conservative approach, which is also recommended for multiple impact assessments of energy efficiency measures by Mzavanadze (2018).

Each disease case, such as asthma, or every person with asthma is assigned a disability weight (DW), which represents the magnitude of health loss associated with specific disease (GHDx, 2020). The weights are measured on a scale from 0 to 1, where 0 equals a state of full health and 1 equals death. The disability weight of partially controlled asthma is estimated to be 0.036 (ibid.).

The economic value of *avoided burden of asthma due to the reduced exposure to indoor dampness* (VAc) in a specific country is calculated as follow:

$$VAc = VOLYc \cdot \Delta AEBDAc \cdot DW$$

or

$$VAc = VSLc \cdot \Delta AEBDAc \cdot DW$$

VOLYc: value of a life year in a specific country
VSLc: the value of a statistical life in a specific country
$\Delta AEBDAc$*: the reduced burden of asthma attributable to exposure to dampness in a specific country;*
DW: disability weight

4.5 Conclusion

About one-sixth of the European population lives in buildings with leaking roofs, damp walls, floors or foundations. A large number of studies show that there is a consistent association between indoor dampness and asthma. While energy renovation could reduce dampness, renovations without adequate ventilation solutions might create in-door dampness problems. This indicator reflects the avoided burden of asthma due to a reduced exposure to indoor dampness caused by proper energy renovation. Besides, energy-poor households often live in damp houses. Thus, to assess the impacts of different levels of policy commitment to address energy-poor households, the indicator is calculated using the output of the energy poverty model.

5 IMPACT ON WELFARE

Authors: Ioannis Charalampidis, Zoi Vrontisi (E3Modelling)

Reviewer: Felix Suerkemper (Wuppertal Institute)

Executive Summary

Welfare and inequality are major issues for all societies and the achievement of high welfare levels across all income classes is in the core of policy making. Here we have developed an indicator that examines the impact of energy saving measures on households' welfare. This is derived from a partial equilibrium tool, in the sense that it examines changes in household's consumption and welfare taken as given their income levels and the prices of goods and services. National households are divided in 5 income classes; each class has different preferences and consumption patterns. The approach assumes one representative household by income class. Households' disposable income is allocated into 4 categories of goods: energy, transport equipment, dwelling appliances, and non-energy related goods. The module is based on the latest available statistics (base year set to 2020). As a key methodological step, the indicator allocates total energy saving investments to each income quantile. It then calculates the net present value of investments and the net savings of energy expenditures. It further estimates the consumption of non-energy goods as the residual consumption and approximate the changes in welfare in terms of non-energy expenditures as percentage of household's income.

5.1 Scope of MI indicator

5.1.1 Definition

Welfare and inequality are major issues for all societies and the achievement of high welfare levels across all income classes is in the core of policy making. Traditionally, measures and policies refer to taxes, income transfers and other policy interventions in markets to protect the most vulnerable part of the society (e.g., minimum wages).

The clean energy transition requires a deep transformation of production processes and consumption patterns. Thus, it is equally important to identify both the optimal pathways, from an aggregate perspective to a net zero world but to assess their impact on welfare and inequality. Technological progress and innovation have decreased significantly the relative cost of energy savings. Energy savings, decrease the cost of energy for e.g., heating and cooling, cooking etc. allowing households to spend more on other goods and services (hence increasing their welfare). This transformation comes at higher capital costs, as households are required to replace their energy-related equipment with more efficient one which nevertheless comes at higher costs. The relative costs and benefits are not equally distributed in the economy. Lower income households can have significantly higher gains from energy efficiency compared to higher income households.

To this end, we have developed a tool that examines the impact of energy saving measures on households' welfare. This tool is a partial equilibrium tool, in the sense that it examines changes in household's consumption and welfare taken as given their income levels and the prices of goods and services. National households are divided in five income classes; each class has different preferences and consumption patterns.

5.1.2 Relevance on EU, national and/or local level

The distributional impacts, and in particular the welfare metrics are a key indicator for the socioeconomic impact assessment of clean energy policies both at the EU and at the national level. Compared with aggregate measures of economic performance, such as GDP and employment, the results can help in the identification of optimal pathways. The indicator could also be relevant at a local level, if data availability allows.

5.1.3 Impact pathway figure

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

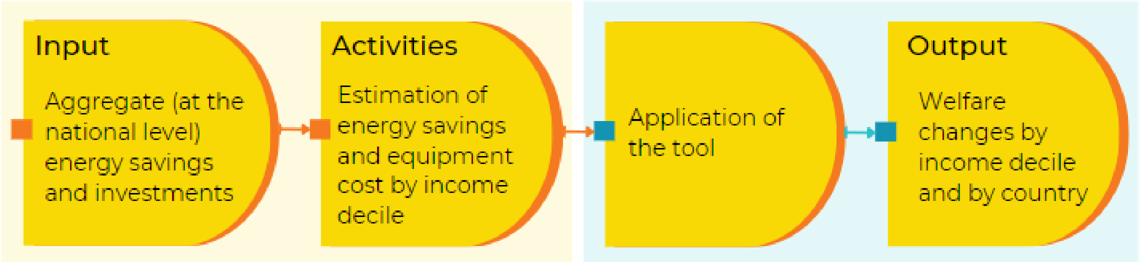

FIGURE 9: QUANTIFICATION STEPS FOR THE ESTIMATION OF THE WELFARE INDICATOR

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

No risk of overlaps or double-counting with other multiple impact indicators as most are not available on income quantile level.

5.2 Quantification method

5.2.1 Description

The tool, as previously mentioned, focuses on households taken as given the level of income and prices in the economy. The module assumes one representative household by income class. Households' disposable income is allocated into 4 categories of goods: energy, transport equipment, dwelling appliances, and non-energy related goods. The module is based on the latest available statistics (base year set to 2020).

To analyse the impact of higher energy saving investments on the welfare of each income class, the following steps are taken:

The first step consists of allocating total energy saving investments to each income quantile. To do so the indicator takes as input the national-level energy savings (by type of measure) of the economy and the national energy saving investment expenditure. These two inputs are then split by income quantile, based on coefficients taken from the PRIMES energy system model and the literature. This adjustment reflects the concept of marginal abatement costs; higher income households are assumed to own higher efficiency equipment relative to the poorer households, hence the cost of equipment for additional energy savings is higher for them.

Combining the net present value of energy savings and equipment spending we use an index to calculate the share of each income group to total national energy savings. For energy savings we assume a time-horizon of 10 years (i.e., we assume that the lifetime of the equipment is equal to 10 years and thus during this period energy consumption is lower compared to a reference case) while for equipment, the costs are repaid within 5 years period.

$$NPV_{iq}^{en} = \frac{ENSAVE_{iq,t}}{(1 + \ df_{iq})^t} \quad (1)$$

$$NPV_{iq}^{eq} = \frac{EQCOST_{iq,t}}{(1 + \ df_{iq})^t} \quad (2)$$

where:

NPV_{iq}^{en}: *net present value of energy savings by income quantile*

$ENSAVE_{iq,t}$: *energy savings expressed in monetary terms (€) by income quantile, split according to country-specific coefficients*

df_{iq}: *discount factor by income quantile*

NPV_{iq}^{eq}: *net present value of equipment by income quantile*

$EQCOST_{iq,t}$: *annualised cost of energy-efficient equipment expressed in monetary terms (€) by income quantile, split according to country-specific coefficients*

The discount factor is a compound interest rate which is a function of national interest rate and of the social time preference by income quantile. The latter denotes the willingness of households to sacrifice part of their present consumption for higher future consumption levels, is lower for low-income households and higher for the richer quantiles. It is calculated as a function of the propensity to consume[8].

The index as well as the allocation of energy efficiency investments are given by the following formulas:

$$RLNPV_{iq} = \frac{NPV_{iq}^{en}}{NPV_{iq}^{eq}} \quad (3)$$

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[8] Data are based on Eurostat's ICW_SR_10 dataset

$$EFEXSHR_{iq} = \frac{efexshr_{iq}^{0} \cdot RLNPV_{iq}^{\varepsilon}}{\sum_{iq} efexshr_{iq}^{0} \cdot RLNPV_{iq}^{\varepsilon}} \quad (4)$$

where:

$RLNPV_{iq}$: *is a benefit to cost index by income quantile*
$EFEXSHR_{iq}$: *share of energy efficiency investment expenditure by income quantile*
$efexshr_{iq}^{0}$: *parameter reflecting status of energy efficiency expenditures by income quantile*
ε: *adjustment factor*

Once the expenditures on equipment and the related energy savings are calculate we adjust the consumption of the relative categories of our datasets. Hence, we have:

$$C_{ener,id} = C_{ener,id}^{0} - EFEXSHR_{id} \cdot ENSAVE\_TOT \ (5)$$
$$C_{equip,iq} = C_{equip,iq}^{0} - EFEXSHR_{iq} \cdot ENCOST\_TOT \ (6)$$

where:

$C_{ener,iq}$: *energy expenditures by income quantile*
$C_{equip,iq}$: *equipment expenditures (transport or household appliances) by income quantile*
$ENSAVE\_TOT$: *total energy savings expressed in monetary terms*
$ENCOST\_TOT$: *total equipment expenditures*

The consumption of non-energy goods is the residual consumption:

$$C_{nener,iq} = INC_{iq} - \sum_{ener} C_{ener,iq} - \sum_{ener} C_{equip,iq} \ (7)$$

5.2.2 Methodological challenges

Energy spendings by income decile and energy carrier are not provided by Eurostat. Furthermore, no index on the stock of equipment by decile is available to our knowledge. This would facilitate the calculation of required spendings on equipment by income group and would allow for a more refined approach regarding the allocation of energy efficiency investments among income deciles.

5.2.3 Data requirements

In terms of data requirements, the model is based on the following inputs:

1. Coefficients to allocate national-level energy savings and associated investment expenditure to the different income classes, i.e. quantiles (PRIMES model and literature)
2. Household income by quantile (Eurostat)
3. Household consumption by income quantile (Eurostat[9])

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[9] Dataset code: *HBS_STR_T223*

4. Savings by income decile (Eurostat's database[10])

5.3 Impact factor/functional relationship

We approximate the changes in welfare by income quantile (WC_{iq}) in terms of non-energy expenditures as percentage of household's income according to the following formula:

$$WC_{iq} = \frac{C^0_{nener,id} - C_{nener,iq}}{INC_{iq}} \quad (8)$$

5.4 Monetization

Monetisation can be approached via the welfare metric that captures the changes in non-energy expenditures (as percentage of income).

5.5 Aggregation

The indicator cannot be directly aggregated with other indicators.

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[10] Dataset code: ICW_SR_10, TEC00131, NASA_10_NF_TR, ILC_DI01, HBS_EXP_T133

6 HUMAN HEALTH DUE TO REDUCED AIR POLLUTION – AIR POLLUTION-RELATED MORTALITY AND MORBIDITY

Authors: Fabian Wagner, Gregor Kiesewetter (IIASA)

Reviewer: Chun Xia-Bauer (Wuppertal Institute)

Executive Summary

Content

- Air pollution-related mortality and morbidity
- This indicator measures the impact of energy efficiency measures on mortality and morbidity due to ambient PM2.5 pollution. It takes into account the relevant local air pollutants (SO2, NOx, pri-mary PM2.5) that are typically emitted in energy-related combustion processes.
- For all sectors and subsectors (e.g. power plants, industrial boilers and furnaces, vehicles, etc) the emission factors used reflect all current EU and national policies that regulate emission sources. The impact factors used for the indicator reflect the atmospheric transport and chemical balance as simulated by the EMEP model, a standard chemical transport model used by the European Commission to assess air quality in its member states. The eventual impacts of PM2.5 concentrations on human health (mortality and morbidity) follows a standard methodology and para-metrization developed for the Global Burden of Diseases studies and the World Health Organization. Impacts can be aggregated from national level to EU level, or downscaled to the more local level, though the latter can lead to over- or underestimations.

6.1 Scope of MI indicator

6.1.1 Definition

This indicator measures the impact of energy efficiency measures on mortality and morbidity due to ambient PM2.5 pollution. It takes into account the relevant local air pollutants (SO2, NOx, primary PM2.5) that are typically emitted in energy-related combustion processes. For all sectors and subsectors (e.g. power plants, industrial boilers and furnaces, vehicles, etc.) the emission factors used reflect all current EU and national policies that regulate emission sources. The impact factors used for the indicator reflect the atmospheric transport and chemical balance as simulated by the EMEP model, a standard chemical transport model used by the European Commission to assess air quality in its member states. The eventual impacts of PM2.5 concentrations on human health (mortality and morbidity) follows a standard methodology and parametrization developed for the Global Burden of Diseases studies and the World Health Organization.

6.1.2 Relevance on EU, national and/or local level

The benefits from reduced mortality and morbidity via improved air quality can be significant. The EU and its member states pursue various strategies to reduce these impacts. Individual member states benefit most from reducing their own national emissions, however, for some countries, especially smaller ones, transboundary fluxes and benefits from reducing the emissions in neighbouring countries are important and can even dominate the effects of national actions. In other words, while pollution can be highly localized, much of the pollution at a given location de-pends on the emissions of non-local sources. Thus, the negative impact of air pollution of say a single city typically can only be reduced by sets of measures that reduce the emissions at the national scale.

6.1.3 Impact pathway figure

The illustrative impact pathway is given in Figure 10.

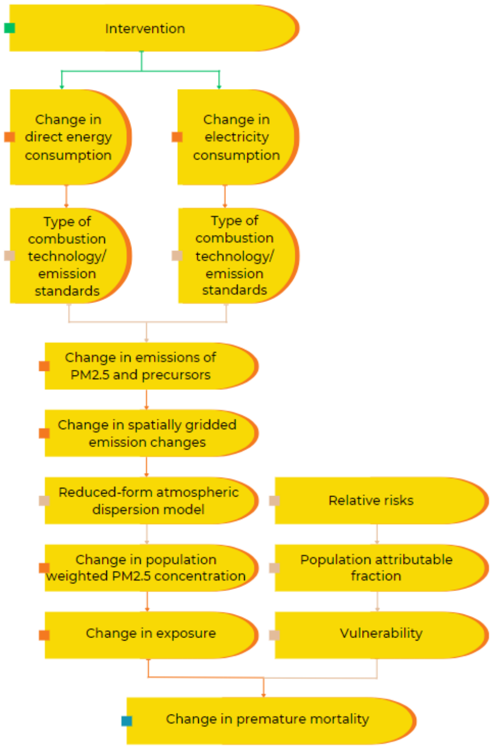

FIGURE 10: IMPACT PATHWAY FOR AIR POLLUTION-RELATED MORTALITY

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

No overlap has been identified.

6.2 Quantification method

6.2.1 Description

Energy efficiency measures affect the mortality from ambient air pollution from fine particulate matter (PM2.5) through the channel described in Figure 11, i.e. via an associated reduction in emissions of primary PM2.5 and relevant precursor substances (SO2, NOx, NH3, VOCs). This bottom-up ex-ante assessment proceeds in six steps:

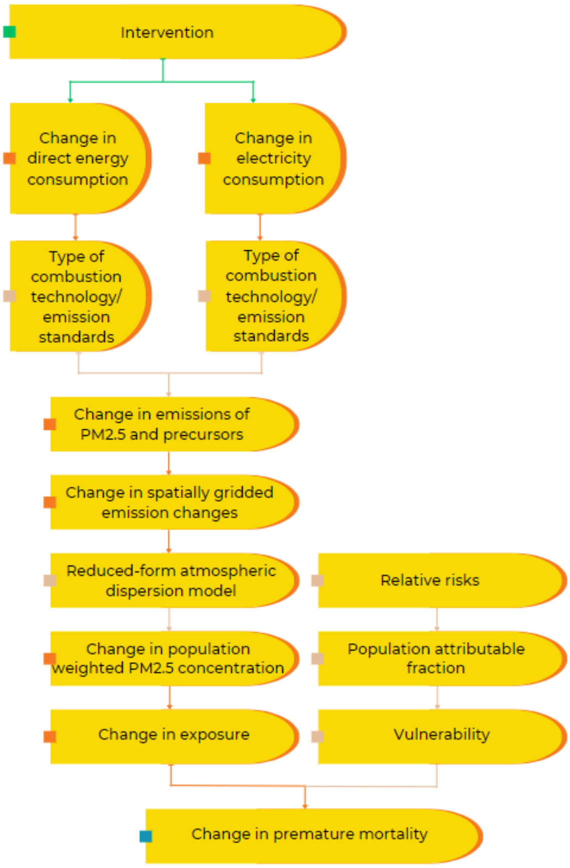

FIGURE 11: IMPACT PATHWAY AND CALCULATION METHOD FOR CHANGES IN PREMATURE MORTALITY FROM AIR POLLUTION FROM ENERGY EFFICIENCY MEASURES.

- Step 1: Quantify the amount of energy (direct combustion and electricity) saved by an intervention. Such an intervention can affect the direct consumption of fuel as well as the consumption of electricity. For example, heat pumps replace direct combustion, but consume electricity.

- Step 2: Determine the corresponding supply-side changes in the use of technologies. For example, saving electricity would result in less electricity being produced. An assumption needs to be made about what kind of source of electricity is being reduced, whether the most carbon-intensive (coal-based electricity), or an average (country) fuel mix, or else. Moreover, for the emission characteristics further assumptions would need to be made, in the case of thermal power plants, whether the cleanest, the dirtiest, or the average device (in terms of air pollutants) are assumed to be reduced. Finally, if the energy efficiency measure reduces direct combustion of fuel, the emission characteristics of that reduction need to be specified. For example, increasing the energy efficiency of a particular process in the chemical industry may result in all direct fuel uses being reduced proportionally, or only one particular fuel (e.g., gas) being reduced, and again the vintage of the installation may be relevant.

- Step 3: Calculate the resulting changes in the emissions of primary PM2.5 and relevant precursor substances.
- Step 4: Calculate the associated changes in the concentration field of ambient PM2.5 and corresponding population-weighted averages. This calculation is per-formed with a reduced-form version of a chemical transport model, and is enhanced by a separate treatment of low-level combustion sources (households and transport sources) of primary PM2.5 that have a characteristic local effect.
- Step 5: Calculate population attributable fractions of mortality related to PM2.5 concentrations from relative risk factors and demographic life tables.
- Step 6: Combine exposure levels and vulnerability parameters from Steps 4 and 5 to calculate the changes in years of life lost and numbers of premature deaths as-sociated with PM2.5 pollution.

All calculations (e.g., energy saved, emissions, concentrations, mortality) are performed on an annual basis and at the level of individual member states of the EU. These results can easily be aggregated. The impact pathways are formulated as linear functions, so that once the characteristics of the interventions are specified, the changes in impact can be calculate using a simple impact factor. The morbidity calculation runs analogously, and identical through steps 1-4, with Steps 5 and 6 modified:

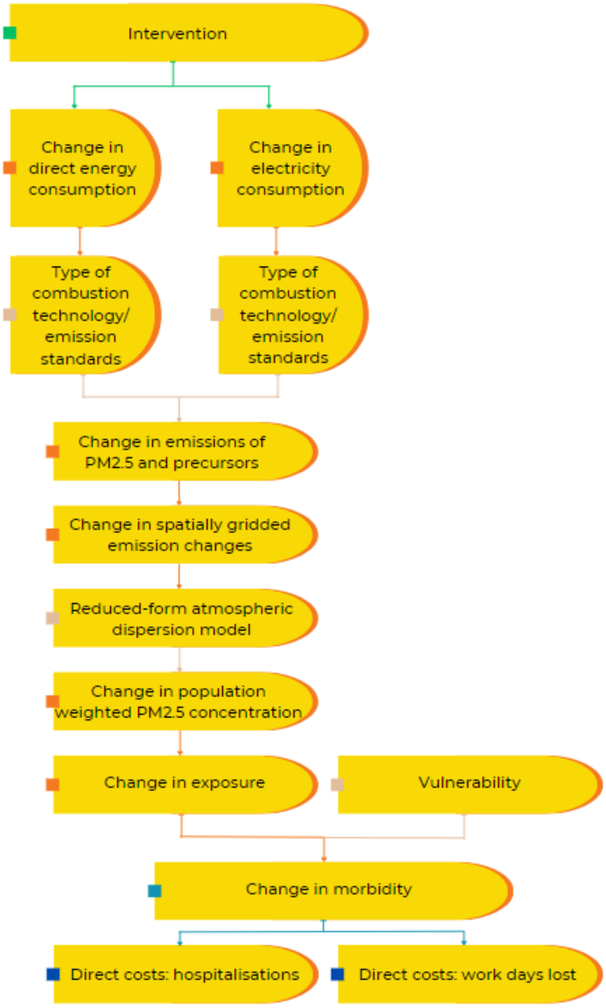

FIGURE 12: IMPACT PATHWAY AND CALCULATION METHOD FOR CHANGES IN MORBIDITY FROM AIR POLLUTION FROM ENERGY EFFICIENCY MEASURES.

Here we use the method developed for the CaRBonH calculation tool (Spadaro et al., 2018), which relates the ambient concentration of PM2.5 to the number of hospitalizations and work days lost (WDL), which in turn can be translated into direct costs, using country-specific values for the unit costs.

6.2.2 Methodological challenges

- The method to calculate premature mortality is well established and has been used by the European Commission in a number of assessments of potential air pollution control policies.
- The relationship between concentration and hazard is currently assumed to be line-ar, while in fact the relation is known to be non-linear and disease-specific. The method may be updated during the course of the project and would result the indicator to be represented as functional relationship rather than a simple impact factor (see below).

6.2.3 Data requirements

- The analysis is performed with GAINS model (Amann et al., 2011) which typically uses, for Europe, PRIMES energy system data for analysis of alternative scenarios, though for the assessment of interventions the link to PRIMES is actually not required.
- The reduced-form chemical transport model is based on the EMEP model and is readily available as part of the GAINS model. In MICAT, at the city level essentially only the values that are proportionally scaled from the national version can be offered.
- As described above, for each energy efficiency measure (intervention) to be analysed the specific impacts on the energy system needs to be given, both in terms of split into effects on electricity and other fuel uses, as well as emission characteristics of the marginal technologies involved. In particular, inputs such as a change in energy or carbon prices, the number of homes being insulated, or efficiency improvements for new vehicles need to be first translated into actual changes in the energy system.
- The health-related methods and data are based on standard and simplified methodologies including the Global Burden of Disease study (Cohen et al., 2017) and (Spadaro et al., 2018).

6.3 Impact factor/functional relationship

- At this stage the change in mortality (number of premature deaths prevented) can be related to the change in energy consumption in the following way:

$$\Delta M_c = \sum_{c',s,u,t,e,p} \Phi_{c,c',p,s} \times \mathrm{EF}_{c',s,u,t,e,p} \times \Delta E^{i}_{c',s,u,t,e,p}$$

where p is the pollutant. The independent variable $\Delta E^{i}_{c'}$ describes how an intervention i in country c' affects the energy consumption of carrier e using technology t for end-use in sector s. The factor EF describes the emission factor relevant for the change in energy consumption ΔE, Φ contains information about the source-receptor relation between emissions of p in country c' and concentration levels of PM2.5 in country c, as well as all relevant health vulnerability characteristics of country c. It also depends on the (aggregate) sector injection characteristic (high-level vs low-level source). Morbidity is directly monetized using the direct, country-specific cost factors of (Spadaro et al., 2018).

- Strictly speaking, the factors EF may depend on scenario assumptions, as they can reflect different air pollution control policies. The factor Φ is scenario-independent for the present purposes. The main scenario dependence actually lies in the independent variables $\Delta E^{i}_{c'}$, i.e., in the narrative and specification of how an energy saving intervention i actually affects the consumption of different fuel uses in different sectors etc.
- As indicated above, Φ may be more appropriately represented as a function of the other two factors (EF, $\Delta E^{i}_{c'}$). However, at relatively moderate concentration levels in the baseline, and given that the indicator will only capture the marginal impact of each intervention i, the linear approach (and factorization above) is fully justified.
- In principle, transboundary effects from country c' to country c are included here. They can, however, be suppressed for national assessments, though they are relevant at the EU level.

6.4 Monetization

- The GAINS model itself does not monetize mortality effects. This is because, while all other parts of the above impact assessment are based on a combination of methods that allow for an objective assessment, a monetization using the concept of the value of statistical life (VSL) introduces an element of value judgement that is fraught with methodological and conceptual difficulties. A choice of the VSL to be used (and possibly a different one in each country can bias an analysis in one way or another.
- However, since the VSL may/will be used for other indicators as well in this project, it is a parameter that the user of the tool will need to choose prior to the analysis.
- Alternatively, mortality (and morbidity) effects could be recorded without monetization and fed into a CGE analysis as reduced labour or foregone consumption. In this way the issues with the VSL could be circumvented.
- Direct morbidity costs (costs for hospitalizations and word days lost) are calculated using the data provided in the CaRBonH tool, as described above.

6.5 Aggregation

- Member state data can strictly be aggregated to the EU level if transboundary effects are included as well. If not, the sum of the benefits across the member states will be lower than the benefits accrued at the EU level.

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