The relevance of multiple impacts of energy efficiency in policy-making and evaluation

Johannes Thema
Wuppertal Institute for Climate, Environment and Energy
Germany
johannes.thema@wupperinst.org

Felix Suerkemper
Wuppertal Institute for Climate, Environment and Energy
Germany

Johan Couder
University of Antwerp
Belgium

Nora Mzavanadze
University of Manchester
United Kingdom

Souran Chatterjee
Central European University
Advanced Buildings and Urban Design
Hungary

Jens Teubler
Wuppertal Institute for Climate, Environment and Energy
Germany

Martin Bo Hansen
Copenhagen Economics
Denmark

Diana Ürge-Vorsatz
Central European University
Advanced Buildings and Urban Design
Hungary

Stefan Thomas
Wuppertal Institute for Climate, Environment and Energy
Germany

Jana Rasch
Wuppertal Institute for Climate, Environment and Energy
Germany

Stefan Bouzarovski
University of Manchester
United Kingdom

Sabine Wilken
Copenhagen Economics
Denmark

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Abstract
Improvements in energy efficiency have numerous impacts additional to energy and greenhouse gas savings. This paper presents key findings and policy recommendations of the COMBI project ("Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe"). This project aimed at quantifying the energy and non-energy impacts that a realisation of the EU energy efficiency potential would have in 2030. It covered the most relevant technical energy efficiency improvement actions in buildings, transport and industry. Quantified impacts include reduced air pollution (and its effects on human health, eco-systems), improved social welfare (health, productivity), saved biotic and abiotic resources, effects on the energy system and energy security, and the economy (employment, GDP, public budgets and energy/EU-ETS prices). The paper shows that a more ambitious energy efficiency policy in Europe would lead to substantial impacts: overall, in 2030 alone, monetized multiple impacts (MI) would amount to €61 bn per year in 2030, i.e. corresponding to approx. 50 % of energy cost savings (€131 bn). Consequently, the conservative CBA approach of COMBI yields that including MI quantifications to energy efficiency impact assessments would increase the benefit side by at least 50–70 %. As this analysis excludes numerous impacts that could either not be quantified or monetized or where any double-counting potential exists, actual benefits may be much larger. Based on these findings, the paper formulates several recommendations for EU policy making: (1) the inclusion of MI into the assessment of policy instruments and scenarios, (2) the need of reliable MI quantifications for policy design and target setting, (3) the use of MI for encouraging inter-departmental and cross-sectoral cooperation in policy making to pursue common goals, and (4) the importance of MI evaluations for their communication and promotion to decision-makers, stakeholders, investors and the general public.

Multiple impacts in the European policy discourse
Energy Efficiency (EE) has always been a means to achieve higher ends such as fossil fuel savings for saving greenhouse gas (GHG) emissions. In Europe, with the adoption of the EE first principle under the 2012 Energy Efficiency Directive (EED, 2012/27/EU), the first preamble already included many policy targets, and they have been put more concretely in the proposal that started the recent revision for the EED:

> [The 30 % EE target] will increase economic growth, leading to an increase in GDP of around 0.4 % (€70 billion). Greater energy efficiency will help European companies improve their competitiveness by keeping their costs down, with electricity prices for household and industry expected to be reduced on average from €161 to €157/MWh. It will create local business opportunities and jobs, with an estimated 400,000 additional jobs in all sectors by 2030, especially in the construction sector, including by increasing the demand for skilled manual labour. Buildings are the largest single energy consumer in Europe, consuming 40 % of final energy, so a 30 % efficiency target has great potential in the sector. Finally, pollution control costs & health damage costs

should be reduced by €4.5–8.3 billion and energy security will be greatly improved, reducing gas imports by 12 % in 2030. (EC 2016)

The multiple impacts[1] (MI) are thus already as much a motivation for European policy action on EE as savings on energy costs – but in the discourse and negotiations between institutions and national representatives, they are often out of sight. This may be because the causal link from investments in EE to the impacts is often very complex and indirect, and effects cannot be seen immediately.

Early reports already quantified certain impacts for certain sectors, e.g. the buildings sector (Renovate Europe 2012). Since then, efforts to quantify MI at European level have increased. In 2014, the IEA published a widely recognised book on "Capturing the Multiple Benefits of Energy Efficiency", the first comprehensive collection of knowledge and approaches on their quantification. Also on a national level, e.g. for Sweden (Copenhagen Economics 2016) or Thailand (Suerkemper et al. 2016). As part of the 2016 "Winter Package" of EU energy legislation, the Energy Efficiency Directive (EED) and Energy Performance of Buildings Directive (EPBD 2010/31/EU) have been redrafted. In this context, the usual impact assessments were done – and in this case also contain numerous other impacts such as economic ones (labour market, GDP), energy imports and air pollution. In 2017, a separate EU-Commission report (EC 2017) quantified additional impacts of EE policy. However, it remains a big task for science and policy to understand causality and size of MI, so that they can really be put at the heart of policy decisions.

Two main reasons for quantifying and monetising as many MI as possible are frequently named – again by representatives from the European Commission and other experts at the COMBI final project conference:

- Including MI into the assessment of policy scenarios makes more ambitious EE targets more cost-effective.
- MI that concern policy targets of non-energy departments (e.g. health, social welfare, economy) may lead to a convergence of interest. Thus, inter-departmental cooperation should be forged to pursue common goals.

In 2015, the COMBI project started with the ambition to close this gap. This paper presents the COMBI approach and key findings. The following section outlines important challenges of the multiple impacts quantification in general. We then present the COMBI approach, data basis and models applied, together with the options COMBI gives for visualising quantification results and cost-benefit analysis and in a separate section key findings and results of project quantifications. Multiple impacts have already been the motivation for various implemented policies, a selection of policy cases is discussed in the last section. We conclude with a short summary, why MI quantification and accounting in policy-making is necessary.

1. In an early project phase, research partners decided to not only analyse positive impacts ("benefits") but also possibly negative impacts. Therefore we use the neutral term *multiple impacts*.

Multiple impacts: A complex task for evaluation

This section describes briefly the main steps to been taken to quantify and evaluate MI. Within the project a common data basis with resulting energy scenarios has been elaborated. partners then quantified different sectoral impacts, which are later synthesised in a comprehensive cost-benefit analysis and a visualisation tool.

EVALUATION PERSPECTIVE

For any evaluation of MI, the perspective of the assessment needs to be defined, i.e., from which stakeholder perspective the analysis is undertaken. Theoretically, many different perspectives of analyses or "cost tests" (the usual US term) are available. For understanding investment decisions, the individual investor/end-user perspective is most important. The aim of COMBI was primarily to inform policymakers and analyse EE from an overarching societal perspective instead of the investor/end-user point of view. COMBI thus applies a "societal evaluation perspective", i.e. an analysis of societal impacts and prices excl. taxes instead of multiple impacts from the investor perspective and end-user prices (Thema and Rasch 2018, 7; Chatterjee et al. 2018, 7)).

SELECTING IMPACT INDICATORS

As outlined above, the quantification of MI of EE aims at drawing the most complete picture of evaluating costs and benefits. The challenge is thus to include as many impacts as possible, from as many as possible impact categories. Guidance on which indicators to include comes from the evaluation perspective and existing strands of literature and quantifications such as the Green Economy literature (Ürge-Vorsatz et al. 2016), the IEA hallmark book on Multiple Benefits (IEA 2014) or the European Commission quantification efforts (EC 2016a, EC 2016b). The impacts then have to be operationalised to indicators that are possible to measure or to model. The choice of indicators is on the other hand limited by data availability and sufficient evidence that can be translated to quantification approaches.

The COMBI project resulted with a total of 32 impact indicators covering the categories of air pollution (with ecosystems and human health impacts), resource impacts (fossil fuels, metals, minerals, biotic materials and unused extraction and carbon footprint), energy poverty (human health) and productivity, macro-economic impacts (aggregate demand/GDP, employment, price effects) and energy system impacts (security and system impacts). For a full list, see Thema and Rasch (2018).

QUANTIFICATION AND MONETISATION

In order to evaluate the size and significance in size of impacts, the indicators need to be quantified, either in absolute figures or in relative changes. Most indicators are of physical nature (with the exception of some economic indicators) and are quantified in physical units respectively, such as tonnes of CO_2 equivalents, tonnes of air pollutants, savings in lost life-years, additional employment in job-years etc. For many applications such as comparison and discussion of different policy options and their respective impacts, a comparison of impacts on a physical level can already be of significant added value (done e.g. in the EU EED impact assessments, EC 2016a).

Table 1. List of selected end-use technical EEI actions for the COMBI project.

#	End-use energy efficiency action – improving energy efficiency in or through:
Action 1	residential refurbishment of the building shell + space heating + ventilation + space cooling (air-conditioning)
Action 2	residential new dwellings
Action 3	residential lighting (all dwellings)
Action 4	residential cold appliances (all dwellings)
Action 5	non-residential refurbishment of building shell + space heating + ventilation + space cooling (air-conditioning)
Action 6	non-residential new buildings
Action 7	non-residential lighting (all buildings)
Action 8	non-residential product cooling (all buildings)
Action 9	passenger transport – modal shift
Action 10	passenger transport – motorized two-wheelers
Action 11	passenger transport – cars
Action 12	passenger transport – public road/buses
Action 13	freight transport – modal shift
Action 14	freight transport – light duty trucks (LDT)
Action 15	freight transport – heavy duty trucks (HDT)
Action 16	industry (7 sectors) – high temperature process heating
Action 17	industry (7 sectors) – low and medium temperature process heating
Action 18	industry (7 sectors) – process cooling
Action 19	industry (7 sectors) – specific process electricity
Action 20	industry (7 sectors) – motor drives
Action 21	industry (7 sectors) – HVAC in industrial buildings

Standard cost-benefit accounting is done in monetary values. For most impacts, established monetisation approaches are available, but in some cases there are ethical concerns or approaches are otherwise controversial, such as with the valuation of life-years (monetisation often includes country-wise income levels). For some indicators monetisation thus remains a major challenge and their possible inclusion to CBA is contingent on available methodologies (see quantification reports D3.4, D4.4, D5.4, D5.4a, D6.4, D7.4). COMBI accepts the caveats, but however sees the value added in proceeding with monetisation for the sake of better communication of MI importance. In total 17 out of 32 impact indicators were possible to monetise within the project.

COMBI: data and methods

COMBI ENERGY EFFICIENCY IMPROVEMENT ACTIONS AND SCENARIOS

COMBI covers EEI actions that sum up to a scenario similar to the EUCO+33 to EUCO+35 EU scenario as explained by E3Mlab and IIASA (2016) (scenarios are not directly comparable due to different methodologies, more details below). For each sector of buildings, transport and industry, technological (and some behavioural) energy improvement options have been grouped to form 21 EEI actions. Table 1 provides an overview. For the selection process and description see University of Antwerp (2018) and its Annex.

COMBI originally planned to draw directly on detailed scenario data used for the European Commission's EED Impact Assessment and its annexes. As detailed PRIMES data was not made available and scenario projections were disclosed to the COMBI team too late, we had to develop a separate COMBI reference scenario reflecting PRIMES 2016 and a COMBI efficiency scenario. COMBI input data modelling was done with three sectoral (buildings, transport, industry) bottom-up stock models. These are based on latest available technology data mostly from other European research project and to the extent possible on historical statistics to inform activity level assumptions. Details on different modelling techniques and approaches are elaborated in Couder and Verbruggen (2018). The exercise produced a baseline scenario (accounting for existing EU legislation and based on dynamic baseline assumptions) and an efficiency scenario (based on more ambitious assumptions on technology implementation following more ambitious policies). The difference between the baseline and efficiency scenario is used as input data (i.e. additional energy savings, investment costs, stock data) for quantifying MI in 2030. This data was transferred to the other COMBI partners for application in their respective models. Also, main modelling results include additional MI, i.e. the impacts of additional policy action. The ambition (amount of energy savings vs. the reference scenario of around 8 %) of the COMBI EE-scenario is between the EU 33 % and 35 %-target (EUCO+33 to EUCO+35 EU scenario, E3Mlab and IIASA (2016)).

METHODS FOR MULTIPLE IMPACT ANALYSIS

The COMBI project quantifies 32 different MI[2] of EEI actions, which require different type of assessment approaches (methodologies). Table 2 summarises the quantification methodologies of the different work packages (WP). The models are always used for quantifications in the year 2030 of the avoided extent of the respective impact due to accelerated EE interven-

2. 1 Energy- and 31 (non-energy) multiple impacts.

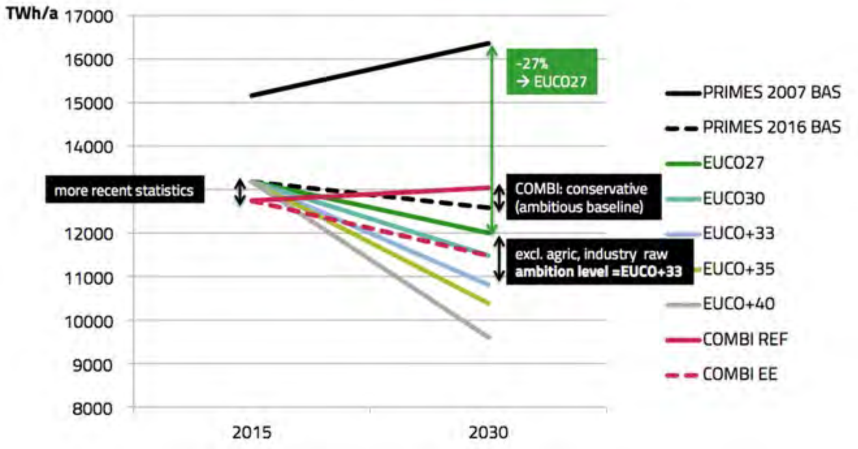

Figure 1. Energy efficiency scenarios (TWh/a final energy consumption).

tions (COMBI efficiency scenario resulting from 21 EEI actions). The overview on individual methodologies is available in greater detail in Chatterjee et al. (2018). Details on the respective methodologies for the different impact quantifications by each WP can be found in the final quantification reports on the COMBI website.

As an example for impact modelling, we outline the approach for air pollution impacts. These have been quantified using IIASA's GAINS model. To this end, data input templates for the GAINS model had to be filled for each EU country with energy carrier-specific consumption data – for the baseline and the COMBI efficiency scenario, involving the setup of a complex model interface between COMBI and GAINS. Then, IIASA ran the GAINS model on the COMBI input data. Modelling outputs were transferred back to the COMBI database, including outputs on specific air pollutants, impacts on eco-systems and human health. The *difference* between both scenario runs was included to the COMBI output database as additional impacts and allocated to the efficiency actions according to their contribution share to total energy savings by country.

RESULTS PRESENTATION AND VISUALISATION

Due to the complexity of research and its goals entailing/permitting different degrees of disaggregation, COMBI research results take three distinct shapes and associated visualization solutions. However, with an increasing number of indicators, units and possible disaggregations e.g. as in the COMBI case by 28 EU member states and 21 energy efficiency improvement (EEI) actions, graphical presentation of results becomes necessary to allow for better interpretation and comparisons. The available options for visualisation depend on whether outputs are in (different) physical units, in monetised values or for CBA. We thus briefly present the options that COMBI proposes along these three quantification steps.

Physical unit outputs

As physical quantification outputs come in different units (TWh, job-years, tCO_2eq etc.), different impacts cannot be meaningfully combined in one graph. We thus propose to only display one indicator at a time. In COMBI, outputs are available by 21 different EEI actions and by all 28 EU member states, we thus propose to allow comparison across both dimensions (see example Figure 2[3]). For country-comparisons, results can additionally be re-calculated to present relative figures e.g. per capita or per GDP.

We present annual figures of impacts in the year 2030 (i.e. differences between reference and efficiency scenarios in 2030) and additionally life-time values applying average product lifetimes and discounting.

Monetised outputs

For all impact indicators that can be monetised and thus have a common monetary unit, these can additionally be combined into a common graph, e.g. using stacked bar charts. As with the physical indicators, the results can be presented by EEI actions (stacking impacts and countries) or by countries (stacking impacts and actions) – and additionally by impacts (stacking actions and countries). Also, halo graphs as with physical units are possible.

Cost-benefit analysis

The principle of CBA is the aggregation of impacts, together with investment costs needed for the implementation of EEI actions (as negative values). This has two major complications, one related to the logic of aggregating impact indicators and avoiding double-counting and one related to the calculation of CBA.

Even if effects are operationalised through monetised indicators and could be included to CBA, they can feed into other impacts, or be already covered (partly) by other indicators. Therefore, there is a danger of double-counting and resulting over-estimation. To avoid this, COMBI proposed an impact pathway approach that carefully assesses interdependencies between impacts (see Chatterjee et al. 2018, p. 16). The first-best cure to double counting would be to quantify overlaps between impacts, but this was not possible within COMBI. As a consequence, all impacts where a danger of double counting exists are omitted from CBA. This yields then a very conservative estimation of total MI. As an example from COMBI, the largest quantified impact is aggregate demand/GDP increase. This impact however conceptually entails many other impacts such as

3. View graph by EEI actions in COMBI tool (CBA graph): https://tinyurl.com/ydxxw6hv. View graph by EU28 MS in COMBI tool (CBA graph): https://tinyurl.com/ydxweb2p.

Table 2. Summary of quantification methodologies (impacts modelled are changes in impact indicators). (Source: Own elaboration – data provided by COMBI partners).

WP	Impact indicators	Description of the quantification methodology
Air pollution	Human health (reduction in premature mortality due to different outdoor pollutants)	GAINS model
	Eco-systems: acidification (spared km²)	GAINS model
	Eco-systems: eutrophication (spared km²)	GAINS model
	Air pollution: Emissions (impact mid-points)	GAINS model
Resources	Material Footprint (total of fossil fuels, (biotic) minerals, metal ores, unused extraction)	Material Flow Accounting (MFA)
	Fossil fuels (economic use)	Material Flow Accounting (MFA)
	Minerals (economic use)	Material Flow Accounting (MFA)
	Metal ores (economic use)	Material Flow Accounting (MFA)
	Biotic raw materials (economic use)	Material Flow Accounting (MFA)
	Unused extraction (not translocated from site or put to a direct economic use. Includes overburden, by-catch and waste on site.)	Material Flow Accounting (MFA)
	Direct carbon emissions	based on emission factors from IPCC
	Carbon Footprint (GWP, life-cycle missions incl. direct emissions)	Life-cycle Assessment of GHG and global warming potential (GWP) in 100 years (GWP 100a). Based on IPCC reports.
Social welfare	Excess winter mortality attributable to inadequate housing (thermal comfort)	COMBI model
	Asthma burden of disease attributable to inadequate housing (indoor humidity)	COMBI model
	Active days (impact through health- asthma, allergy, cardiovascular disease, cold and flu, traffic time saved)	COMBI model
	Workforce performance	Basic performance improvement equation, COMBI model.
Macro-Economic impacts	Temp. (business-cycle) aggregate demand (potential GDP increase)	Input/output analysis and fiscal multiplier analysis
	Temp. (business-cycle) employment	Input/output analysis and fiscal multiplier analysis
	Temp. (business-cycle) public budget effects	Input/output analysis, fiscal multiplier analysis, budgetary semi-elasticities
	Fossil fuel price effects	General equilibrium modelling (CECEM)
	Changes to marginal abatement costs	General equilibrium modelling (CECEM)
	Terms of Trade effect	General equilibrium modelling (CECEM)
	Sectoral shifts	General equilibrium modelling (CECEM)
Energy security	Energy intensity	Final energy demand divided by GDP
	Import dependency (net imports, import costs)	COMBI Energy balance model
	Aggregated energy security (net imports, country of origin, risk)	COMBI Energy balance model
	Avoided electric power generation & investment costs	COMBI Energy balance model. Power sector model
	Derated reserve capacity rate (peak loads and reserve capacities based on annual load duration curves)	COMBI Energy balance model and power sector model

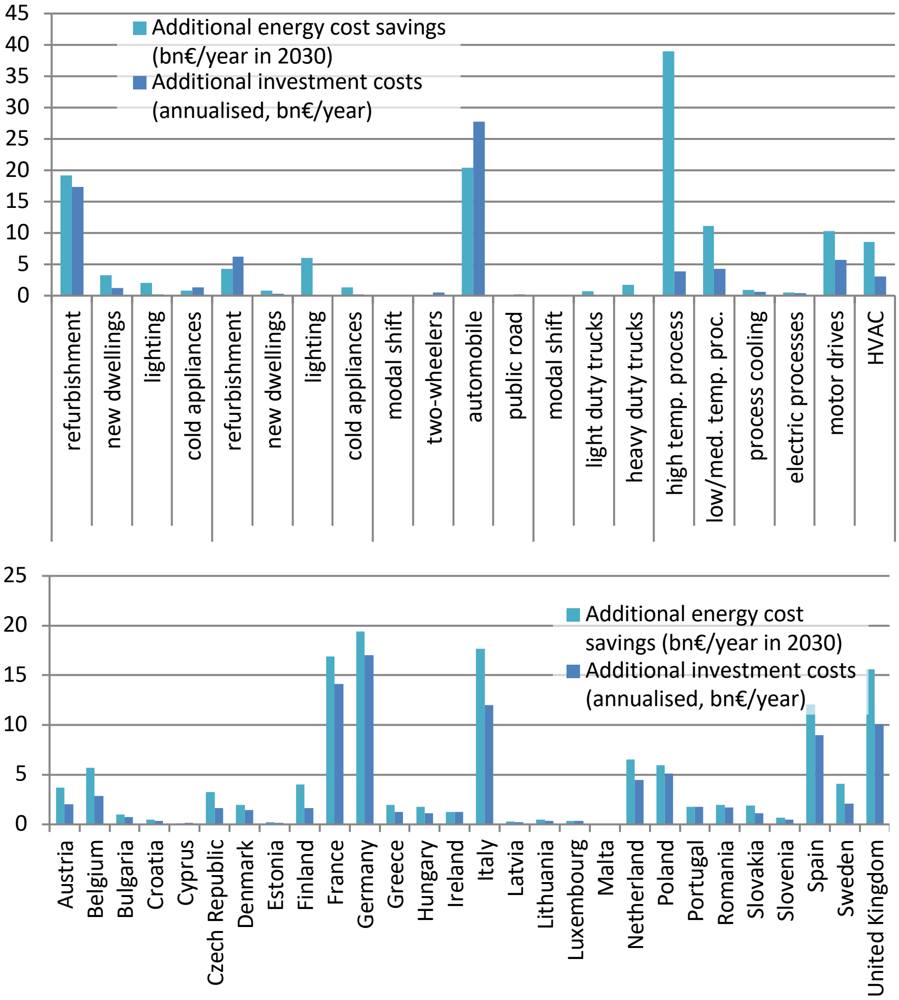

Figure 2. The picture without MI: Additional energy cost savings and (annualised) incremental investment costs in bn€/year in 2030 by EEI action and by EU28 member states.

health, productivity, resource consumption or import expenses – we therefore decided to omit aggregate demand from CBA.

The second challenge refers to the actual CBA accounting. CBA can be done on an annual basis (comparing *annual* impacts and *annualised* investments) on from a lifecycle perspective (comparing *lifecycle* impacts with *total* investments). For both cases, assumptions on technical life-times by efficiency action and on discount rates are needed – for investment annualisation in the first case and for calculating lifecycle impacts in the latter case. For most impacts, COMBI allows for annualised and lifecycle presentations of findings in bar charts and for sensitivity analyses on the discount rate. CBA formulae are explained in Thema and Rasch (2018, p. 21) and Thema (2018, p. 10ff).

Figure 3[4] shows a standard CBA graph on the example of buildings with annualised MI and the net value as red horizontal line. An additional graphical output of CBA calculations is to combine annualised net values the energy or GHG emission savings potential and to display this as marginal cost curve. COMBI allows for both marginal energy savings and GHG savings cost curves (Figure 6).

COMBI: key insights on multiple impacts

Table 3 gives an overview on key physical and monetary impacts quantified by the COMBI project for the difference between reference and efficiency scenario, as annual values in the year 2030. As an example from the below table, additional policies that lead to the implementation of COMBI EEI actions from 2015 to 2030 may avoid 3,000 to 24,000 premature deaths in the year 2030 in comparison to the reference scenario – the figure on the lower end, if policies are not targeted at vulnerable households, the high figure if policies are especially targeted to vulnerable households (more details see Mzavanadze 2018, D5.4). If monetised, this impact amounts to €0.3–2.5 bn in the year 2030 from a societal perspective.

Physical impacts are substantial. To name central outcomes: Especially through reduced air pollution, substantial health gains can be achieved throughout the EU: an annual reduction of more than 10,000 premature deaths due to lower PM2.5 emissions and 230,000 years of lives lost can be avoided. Additionally, thousands of energy-poor households could experience signifi-

4. View graph in COMBI tool: https://tinyurl.com/y8dzxn9q.

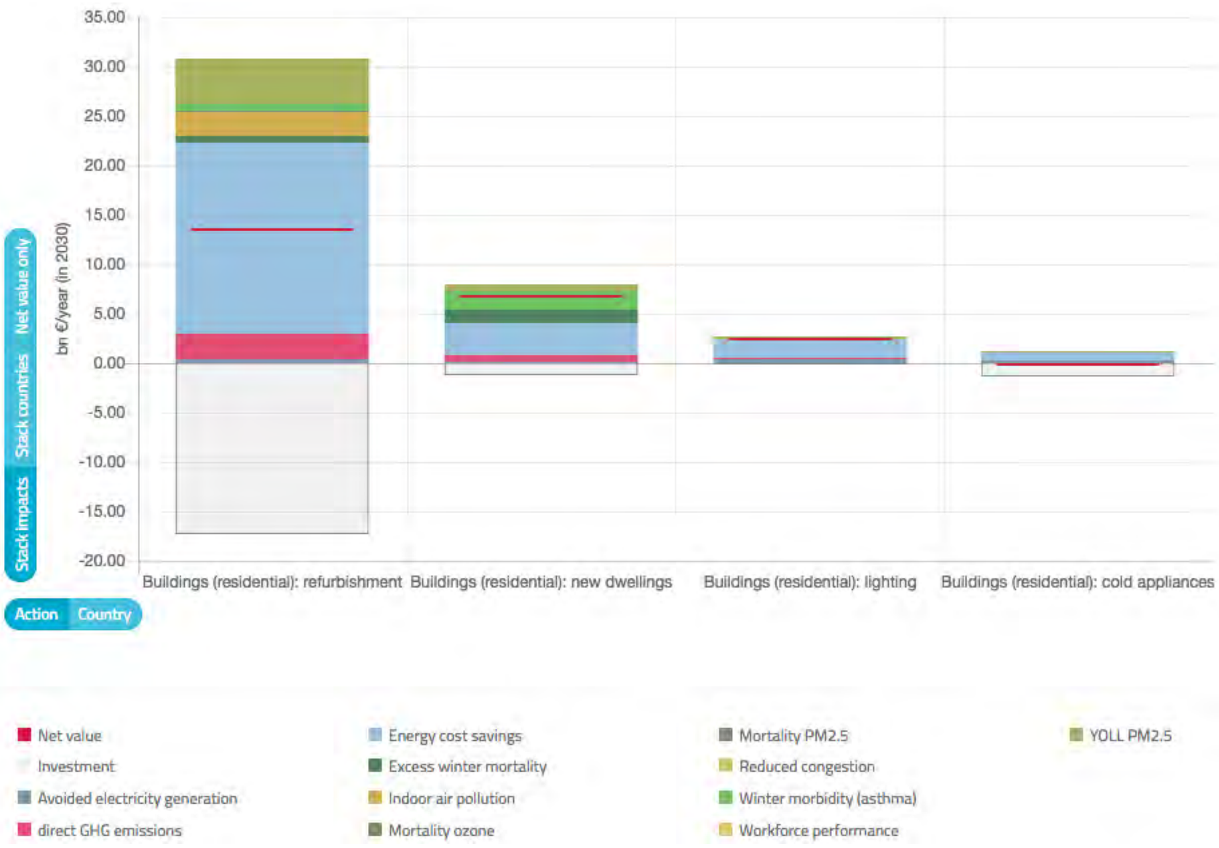

Figure 3. Annualised net present value (bn€ per year in 2030) for buildings in the residential sector.

Table 3. Key results from MI quantification in COMBI (annual values in 2030) – avoided damage or additional benefits in 2030 as a result of additional EEI actions implemented during the period of 2015–2030 expressed as a difference between COMBI Reference and COMBI Efficiency scenario.

Air pollution	Resources	Social welfare	Economy	Energy system
>10,000 avoided premature deaths due to PM2.5 (€460 mn) and 442 due to O3 (€46 mn) 230,000 YOLLs of avoided life expectancy loss (€26 bn) 300 Mt avoided direct CO_2eq emissions (€17 bn)	850 Mt savings of material resources	3,000–24,000 avoided premature deaths due to indoor cold (€323 mn to €2.5 bn) 2,700–22,300 avoided DALYs due to indoor dampness related asthma (€338 mn to €2.9 bn) 39 mn additional workdays (€4.7 bn)	1 % rise in GDP (+€161 bn in GDP) 2.3 mn job-years +€86 bn for public budgets Decrease in fossil fuel prices (-1.3 % oil, -2% coal, -2.9 % gas)	Avoided generation of power from combustibles 257 TWh (€11 bn of avoided investment) Improved energy security up to 5 % lower fossil fuel import costs (€48 bn)
WP3 report	WP4 report	WP5/WP5a report	WP6 report	WP7 report

Note on units: PM = particulate matter emissions, YOLL = years of life lost, DALY = disability-adjusted life years.

cant health gains (if policies are targeted). Moreover, 4.4 thousand km^2 would be spared from acidification, and 13.3 thousand km2 from eutrophication. In terms of direct CO_2 emissions, 300 Mt could be avoided, 500 Mt if upstream emissions are accounted for (not restricted to the EU). Over 250 TWh of annual electricity from combustion plants can be avoided and fossil fuel imports reduced by up to 5 %. Finally,economic activity could rise up to 1 %, producing 2.3 mn additional job-years and public budgets in EU countries increase by around €86 bn/yr.

COMPARISON OF MONETIZED IMPACTS

As discussed above, not all impacts were possible to monetize. All those that could be monetized can be viewed and selected in the "monetary" mode of the tool, irrespective of possible double counting. Figure 4[5] illustrates all impacts in monetary values

5. View graph in COMBI tool (incl. colour legend: EEI impacts)(in expert mode): https://tinyurl.com/y6vglyqe. View graph in COMBI tool (pre-aggregated version in standard mode): https://tinyurl.com/ycufy5me.

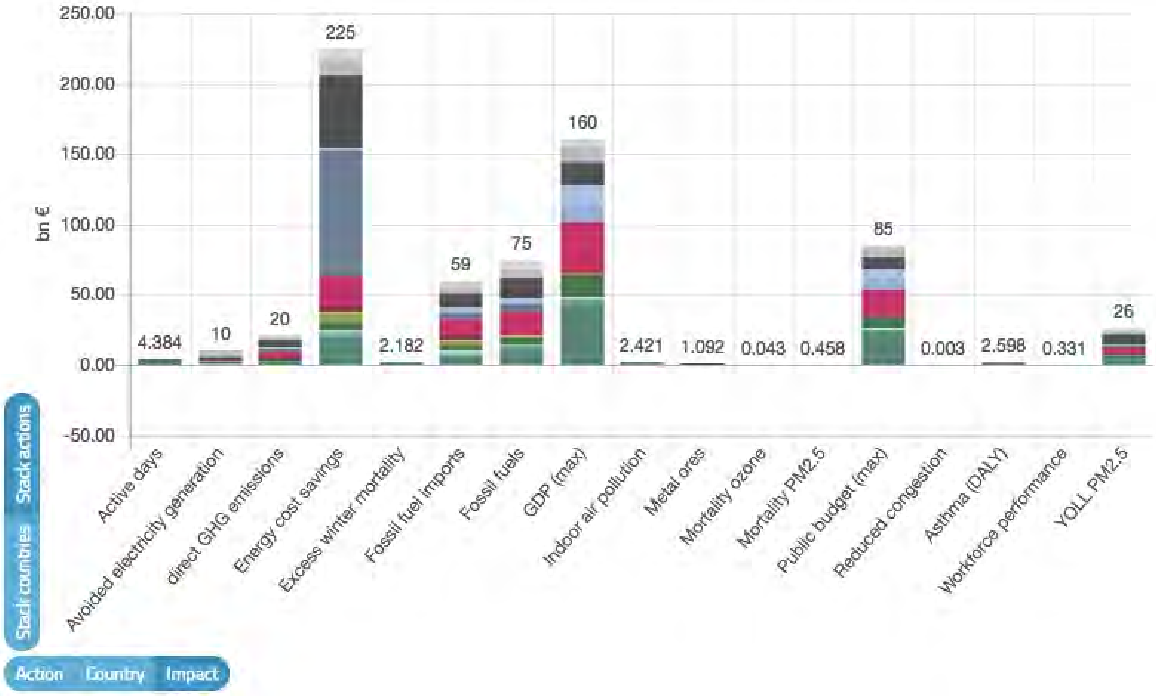

Figure 4. Selected impacts that can be monetised (in bn €/yr in 2030) by impact (stacking: by action). Note: stacked coloured bars are EEI actions. For legend, please follow links in footnote 5.

in bn € and disaggregated to monetized impacts for the "expert mode" of the tool. Energy cost savings remain the largest monetary impact, followed by the economic impacts (GDP, public budget). These are followed by fossil fuel imports and health impacts.

COST-BENEFIT ANALYSIS OF COMBI EEI ACTIONS

As explained above, a significant number of (monetized) impacts overlap with each other or with direct energy cost savings (e.g. energy cost savings overlap with energy import costs and fuel resource costs). In COMBI, only impacts with no danger of double counting (i.e. additional impacts) are included in the CBA and the respective mode in the tool. However, many impacts only partially overlap, i.e. are partially additional (for example, aggregate demand conceptually includes many other impacts such as health, investment costs etc., but may also include other impacts that are not quantified here, would be additional). Excluding them entirely as does COMBI is hence a very conservative approach.

Based on the user's selection of EEI actions, EU28-member states and impacts, the online tool will execute a calculation of net values resulting from costs (investments) and benefits (energy cost savings and MI). Details of the calculation are explained in Thema (2018).

The online tool also offers levelisation of net values by TWh-savings and CO_2eq-savings, i.e. relating the net value per EEI action to energy and GHG emission savings. As a result, the tool offers for each action an indicator of

- net cost per kWh energy saved
- net cost per tCO_2eq mitigated

These are standard indicators often used for comparing energy saving options with energy supply options. Combining these indicators with the savings potential (total kWh or tCO_2eq) and ranking EEI actions by net marginal cost, they can be turned into marginal cost curves of energy or GHG emission savings (see Figure 5[6]).

Key results

Even without MI, already most EEI actions are cost-effective according to the COMBI input data, except for Buildings (tertiary): refurbishment, Transport (passenger): cars, Transport (passenger): public roads/buses, Buildings (residential): cold appliances and Transport (passenger): two wheelers.

Including MI, almost all EEI actions included become cost-effective, except for 'Buildings (residential): cold appliances' (COMBI action is A+++ only) and 'Transport (passenger): two wheelers' (costly action, but limited savings potential). No analysis can be undertaken for modal shift and freight transport actions (see above).

Figure 6 summarises the results. If including only those monetized impacts to a CBA where COMBI is entirely sure that no overlaps exist, the analysis yields that annually

- for all COMBI actions (excl. modal shift and trucks), MI amount to €61 bn plus €131 bn of energy cost savings, i.e. MI add approx. 50 % of energy cost savings to the benefits
- for the residential buildings refurbishment example, MI amount €13.6 bn plus €19.2 bn of energy cost savings, i.e. MI add approx. 70 % of energy cost savings to the benefits

However, macro-Economic impacts (aggregate demand/GDP and public budget) and some others such as fossil fuel imports

6. View graph in COMBI tool (excl. MI, incl. colour legend): https://tinyurl.com/y9c7rslr. View graph in COMBI tool (incl. MI, incl. colour legend): https://tinyurl.com/ycw7s2hy.

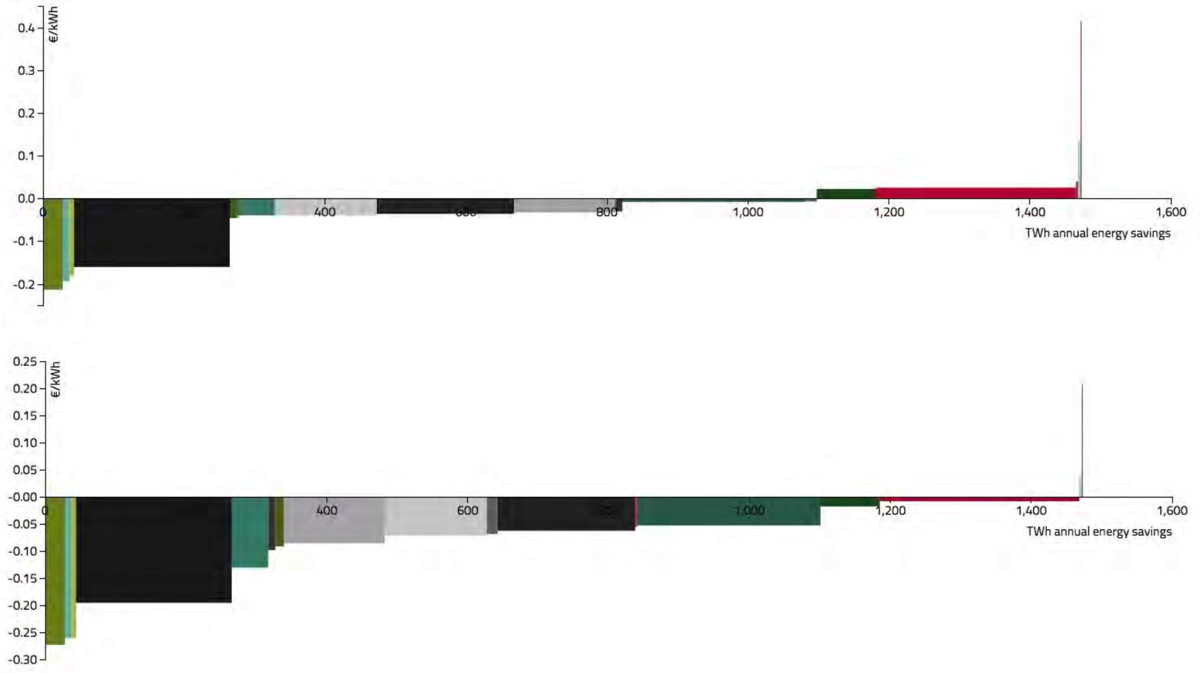

Figure 5. Net marginal energy cost savings (total) by EEI action for EU28 in 2030 (upper graph: excluding and lower graph: including MI) (excluding modal shifts and trucks) (expert mode).

Note: Because net costs = costs - benefits → if benefits > costs, then net costs are negative → EEI actions are cost effective.

and resource impacts are not included in the CBA due to partial overlaps (that could not be quantified) and uncertain valuability (will only become effective, if the national economy has idle resources). However, those are the potentially highest impacts. The figure demonstrates that

- for all actions (excl. modal shift and trucks), GDP may add value with the size of another 100 % of energy cost savings, and public budget another 50 % (which however should be part of GDP increases)
- for residential buildings, this relation is even higher, namely 220 % of energy cost savings GDP effect and 120 % public budget effect.

To conclude, the conservative CBA approach of COMBI as included in the online tool yields that at the very least, including MI quantifications to EE impact assessment would increase the benefit side by 50–70 %. This analysis excludes numerous impacts that could either not be quantified or monetized or where any double-counting potential exists. The quantified economic impacts of GDP and/or public budget may double or triple the size of MI – but because of their double-counting potential and uncertain realisation (they depend on idle resources in national economies in 2030), they have not been included in the COMBI CBA.

With further research, especially on impacts that could not be quantified or monetized and on determining the size of overlaps, so that the additional fraction of impacts can be included to a CBA, it is very likely, that MI will increase to 100 % or more of pure energy cost savings. In any case, the cost-effectiveness of EEI actions improves substantially from a societal perspective when including MIs.

Figure 6. Investments, energy cost savings and MI (bn€ annual in 2030). a) All EEI actions except modal shifts which cannot be included to CBA due to no availability of infrastructure investment costs and trucks due to unreliability of out-dated investment costs.

Multiple impacts can make a difference: policy cases

MI have already motivated the implementation of EE policies either by institutions directly responsible for energy policy or by other departments, ministries or organisations not responsible for energy policy, but promoting EE because of the associated multiple benefits. A selection of such case studies included in Thema et al. (2018) is presented in the following. The first example illustrates a policy from an energy department, which aimed not only at realising energy savings, but also multiple benefits.

- **Warm Up New Zealand:** healthy home standard (provisions for landlords to comply with minimum indoor temperatures and standards for heating, insulation, ventilation and others), grants of 50 % of the costs of insulation[7]. Eligibility criteria for grant application: low-income owner-occupiers or landlords with low-income tenants.

The following two examples demonstrate how non-energy departments, ministries or organisations provide EE policies for multiple benefits reasons.

- Warmth and Wellbeing[8] is a Dublin joint pilot initiative by the Department of Communications, Climate Action and Environment (DCCAE) and the Department of Health and the Health Services Executive (HSE), administered by the Sustainable Energy Authority of Ireland (SEAI). Grant eligibility: one household member younger than 12 or older than 55, diagnosed with a chronic respiratory disease and the household must receive the fuel allowance. If eligible, SEAI initiates EE improvements of the home at no cost to the owner or tenant.
- Low Income Home Energy Program (LIHEAP) is a 3.39 billion USD program administered by the US Department of Health & Human Services[9]. The biggest budget share is used to support energy bill payments of low income households. Up to 15 % or 25 % (in 2014, more than USD 300 million in 14 states) is used for 'weatherization assistance'. LIHEAP is an example for a policy by a department responsible for health and human service, also funding EE to alleviate the effects of poverty.

The examples presented above demonstrate that MI of EE can be the link between different policy actors: for other-than-energy departments, those are rather the main impacts that motivate action. The common goals can serve to also motivate joint action. Such constellations of common goals should be systematically analysed and targeted. Examples include for example the nexus of energy with clean air/health, energy poverty, economic development, energy security and resources/circular economy. To this end, European and national policy-makers should push for an encompassing evaluation of multiple impacts of energy efficiency and analyse policy areas for joint legislative and supportive action across policy departments.

Conclusions for policy making

The COMBI results show that the MI of EE are of substantial size. Evaluating them as comprehensively as possible – in physical and ideally in monetary terms – is therefore essential for the following reasons:

- A more complete picture of the various (positive and negative) impacts of EE is a precondition for a more complete assessment of policy impacts on a number of policy targets. Reliable quantifications of MI will thus support policy makers to make the right choice in prioritising EE vs. expanding sustainable energy supply (incl. their multiple positive and negative impacts), but also in EE policy design and implementation, i.e. help selecting those instruments and targets that maximize social welfare.
- An omission of MI in CBA reduces the cost-effectiveness of EEI actions below their actual value and leads to an under-investment (sub-optimal level) in EE from a societal perspective. The same is true if not all impacts are included or are underestimated. If MI are included into the assessment of policy scenarios, higher ambitions on EE targets are more cost-effective.
- EE is a case not only for cost savings and GHG mitigation but also for improvements in human health, environment, agriculture, and could have positive stimulating effects on the economy. Making more explicit the MI that concern policy targets of non-energy departments (e.g. health, social welfare, economy) may lead to a convergence of interest and may encourage inter-departmental and cross-sectoral cooperation in policy making to pursue common goals.
- Quantified values of MI will be beneficial for their communication and promotion to decision-makers, stakeholders and the general public in order to gain support for the implementation of respective EE policies and to increase the attractiveness of investments in EE for potential investors.

For these reasons, a more complete consideration of MI in policy making is necessary. An important future goal should therefore be to improve the knowledge base and make an assessment of as many MI as possible the standard in policy evaluation (ex ante and ex post). For this, where complex MI assessments are not viable, pragmatic methodological solutions e.g. standard methods and default values will be needed that address the underlying complexities, such as nonlinearities, in a reasonable way.

7. https://www.energywise.govt.nz/funding-and-support/funding-for-insulation/
8. https://www.seai.ie/grants/home-grants/warmth-and-wellbeing/
9. https://liheapch.acf.hhs.gov/pubs/LCIssueBriefs/FinalLIHEAPPrimer.pdf

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