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COMBI
Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

Estimating impacts of energy efficiency

More than energy and greenhouse gas savings

Wuppertal Institut

Johannes Thema

17 May 2018

COMBI conference and tool launch 2018

DG ENER/First Euroflat Hotel, Brussels

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649724.
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Project background & objectives

Quantification of multiple impacts of EE

Coordinated by Wuppertal Institut

- Quantification & monetization of multiple impacts
- By EU member state & 21 EEI actions
- Common framework scenarios: based on 21 energy efficiency improvement (EEI) actions
- Extended Cost-Benefit analysis

Air pollution	Resources	Social welfare	Macro economy	Energy system
air pollutants	material footprint	energy poverty/health	employment/ GDP	energy system costs
health from air pollution	abiotic/biotic	productivity	public budget	energy security
eco-system	energy/non-energy		Fossil fuel/ETS prices	
	unused extraction		Terms of Trade	
MANCHESTER 1824 The University of Manchester	Wuppertal Institut	MANCHESTER 1824 The University of Manchester ABUD	Copenhagen Economics CE	Universiteit Antwerpen

Funded by EU Horizon 2020 EE12 (GA 649724, approx 1M€)

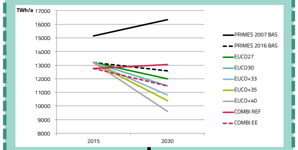
- March 2015 – May 2018

COMBI structure

user settings

Input data

COMBI stock models
→ BAS & EE scenario



- 2030 energy savings
- energy cost savings
- total investment costs

additional data: stocks, scenario levels etc.

Impacts modelling

Dedicated models
- air pollution (health, eco-systems)
- resources
- health (indoor air quality)
- productivity
- economy (short/long-term)
- energy system
- energy security

COMBI online tool

- Physical impacts
- Monetary impacts
- Cost-Benefit calculations

D2.2 EEI action description (+ Annex on scenarios)

D#.1 Literature reviews

D#.4 Quantification reports

D2.1 Synthesis lit. review

D2.4 Synthesis methodology

D2.7 Quantification report

D8.1 Tool manual & document.

D8.2 Policy report

D8.3 Summary brochure

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COMBI input data: energy efficiency actions & scenarios

Universiteit Antwerpen

Johan Couder
May 17, 2018
Brussels

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COMBI input data: energy efficiency actions & scenarios

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List of COMBI actions

- Principles behind selection of energy efficiency improvement actions
  - Focus on "energy services" (heating, cooling, lighting, passenger & freight transport, process heat, etc.), within a "whole system approach";
  - Rely as much as possible on 'existing' EU scenarios (e.g. PRIMES, JRC);
  - Focus on 'technical' improvements (rather than 'behavioural' ones)
  - Cover 80% of the assumed energy saving potential (based on existing scenarios).
- Based on the above principles, a list of 21 COMBI 'actions' was compiled, for four sectors: households, tertiary or 'services', transport and industry (see WP2 report)
- A *qualitative* description of each COMBI action is given in the WP2 deliverable: "D2.2 Description of end-use energy efficiency improvement actions in the residential, tertiary, transport and industry sectors".
- A *quantitative* description required extensive original (modelling) work, in spite of principle 2 (rely on existing EU scenarios).

COMBI scenarios

- Unanticipated extensive and original scenario building in COMBI was required, because:
  - The COMBI work packages required very detailed information, beyond energy savings and associated costs;
  - Available data from existing EU scenarios were insufficient, and more extensive data could not be obtained in spite of multiple requests.
- COMBI provides two scenarios:
  - one REFERENCE scenario (based mostly on PRIMES), which serves as a baseline in 2030;
  - A HIGH ENERGY EFFICIENCY scenario by 2030.

  In all cases, the assumed base year is 2015
- COMBI scenario building relies on two principles:
  - *Decompositition analysis*: energy demand changes are the results of 1) changes in activity levels; 2 structural changes and 3) changes in energy intensities (efficiencies);
  - Detailed *stock analysis* for buildings (households, tertiary) and transport. Stock analysis for industry was not possible due to time and budget constraints in COMBI
- Data for the decomposition and stock analysis were obtained as much as possible from existing EU studies for the 28 EU member states. Assumptions on scenario assumptions such as shares of particular technologies in annual new sales (stock analysis) were obtained from existing EU scenarios whenever possible as well as from internal COMBI deliberations. Time and budget constraints did not allow active stakeholder involvement in this stage.

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Thank you very much for your attention!

Universiteit Antwerpen

University of Antwerp

Prof. Dr. emeritus Aviel Verbruggen
Prinsstraat 13, B-2000 Antwerpen
aviel.verbruggen@uantwerpen.be

Quantifying the air pollution, health and ecosystem impacts of energy efficiency

COMBI
Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

MANCHESTER 1824
The University of Manchester

Nora Mzavanadze, Stefan Bouzarovski, Sergio Tirado Herrero

Brussels, 17 May 2018

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Context and methods

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- 2015: 285 000 premature deaths due to to $PM_{2.5}$ exposure
- 2015: 21 000 premature deaths due to ground level ozone exposure
- 2015: 103k km^2 of ecosystem area were exposed to excess acidification pressures, and 1122k km^2 to excess eutrophication
- Reference scenario: energy demand changes, fuel mix changes and business as usual energy efficiency adoption between 2015 and 2030
- Efficiency scenario: accelerated investment
- Advanced modelling: *Greenhouse Gas - Air Pollution Interactions and Synergies - GAINS model*, 2017

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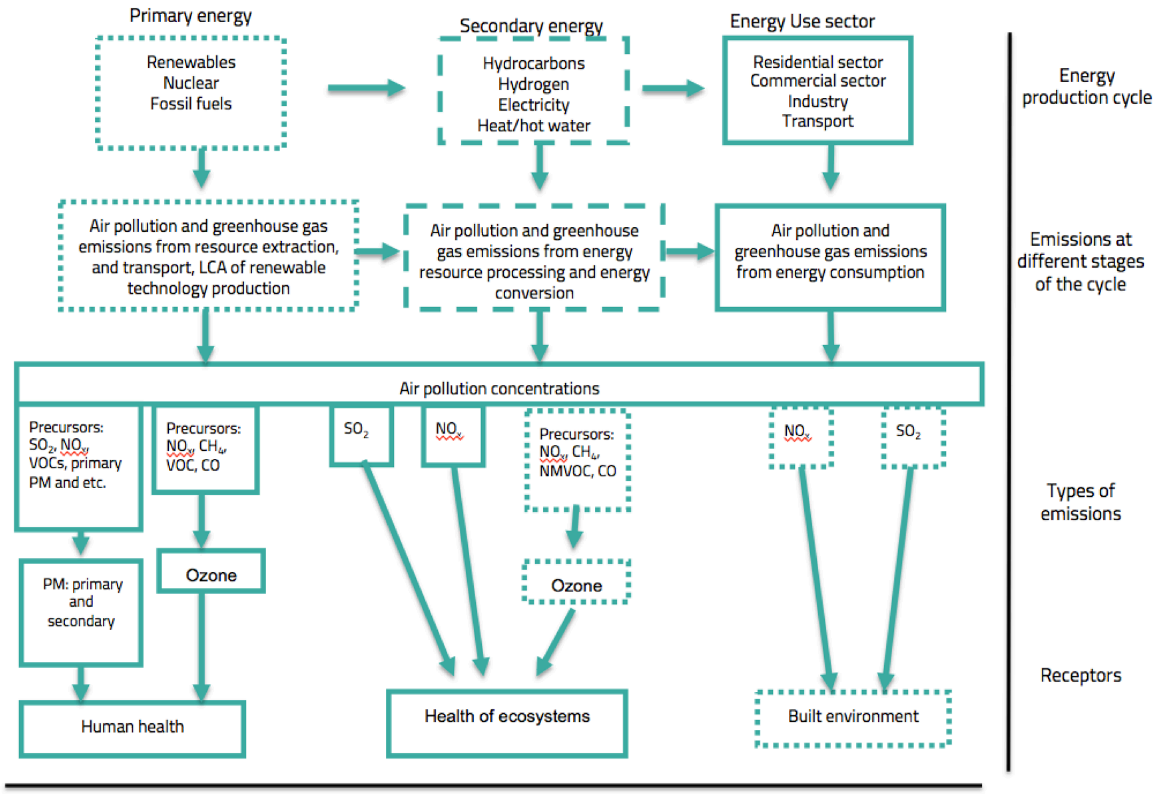
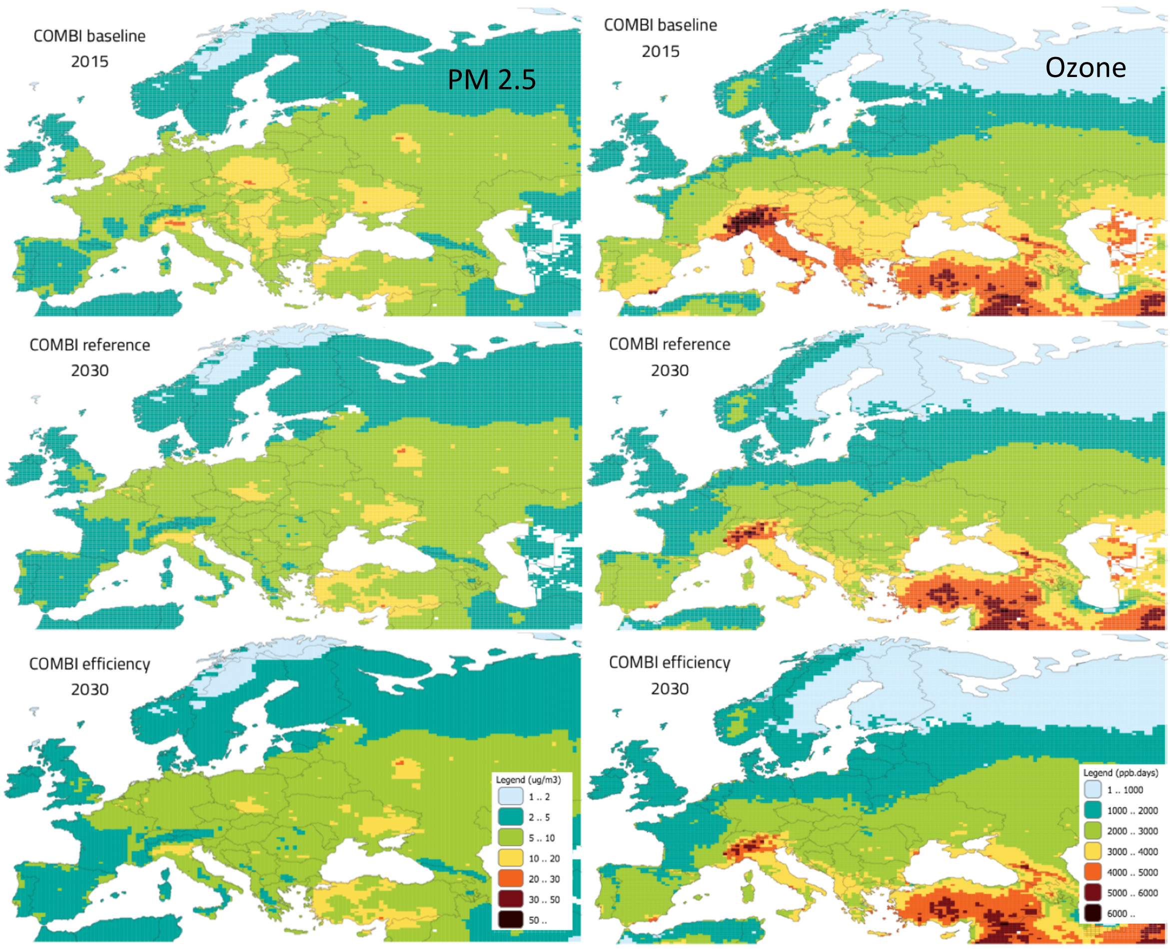


Sources: (Guerreiro et al., 2014; Wilkinson et al., 2007)



Key findings

COMBI
Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

- COMBI reference scenario: 25% reduction in SO_2 emissions, 37% reduction in NO_x emissions, 18% reduction in VOCs emissions, 19% reduction in PM_{10} emissions and 30% reduction in $PM_{2.5}$ emissions. 23% decrease in premature deaths due to $PM_{2.5}$ exposure, 18% due to ground ozone
- Energy efficiency scenario: *additional* reductions in total air pollutant emissions: 7% for SO_2, 5% for NO_x, 3% for VOCs, 4% in PM_{10} and 4% in $PM_{2.5}$ compared to 2015. Further reduction of 4% in $PM_{2.5}$ premature deaths and 2% ground ozone premature deaths
- Significant ecosystem impacts: *Additional* 4.4k km^2 spared from acidification and 13.3k thousand km^2 spared from eutrophication in COMBI efficiency scenario
- Avoided mortality due to *additional* energy efficiency impact actions: 460 million EUR due to $PM_{2.5}$ and 46 million EUR due to ground level ozone

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Conclusions and implications

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Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

- Although significant air quality improvements have been achieved in the last decades in Europe, air pollution is still the single largest environmental threat to human health in Europe
- Estimates produced by our calculations are conservative, due to non-inclusion of morbidity in the GAINS model
- Also not included: actual market values of productivity loss, costs of hospitalization, medication and medical care
- Avoided damages may be different depending on intra-state geographical distribution of impacts: GAINS only works at the national and regional scale

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Thank you for your attention!

The University of Manchester

Contact

Professor Stefan Bouzarovski
@stefanbuzar
www.energystudies.net

Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

Resources (WP 4)

Wuppertal Institut

Jens Teubler (jens.teubler@wupperinst.org)
Brussels, 17th of May 2018

Wuppertal Institut für Klima, Umwelt, Energie gGmbH
Division: Sustainable Production and Consumption (SCP)

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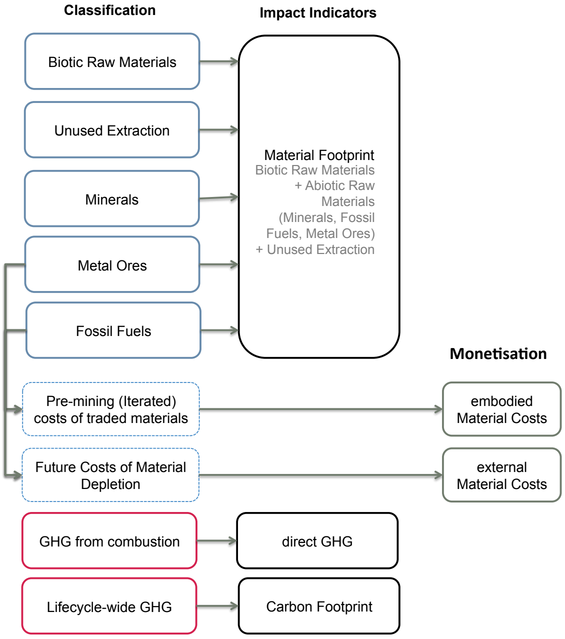
Impact Indicators and Models for WP4

Bottom-up modelling of all actions & countries for material resources (input, material flow analysis) and GHG emissions (output, life-cycle assessment)



Input Data (WP 2)

- Final energy use for all EEI's
- Gross electricity production (per country and source in 2030 based on PRIMES)
- Lighting systems: stocks, types, lights per dwelling
- Vehicles: stocks, types, size, loading factors

Models

- 1 Model for **electricity supply** (country-specific per energy source)
- 1 Model for **heat supply** (EU average per heat source)
- 1 Model for **fuel supply** (EU average per fuel type)
- 1 Model for **lighting systems** (EU average per type)
- 1 Model for **vehicles** (EU average per type)

Important Results (WP4)

Energy-efficiency reduces the required amount of material resources, saves material costs and helps to achieve goals for GHG reductions

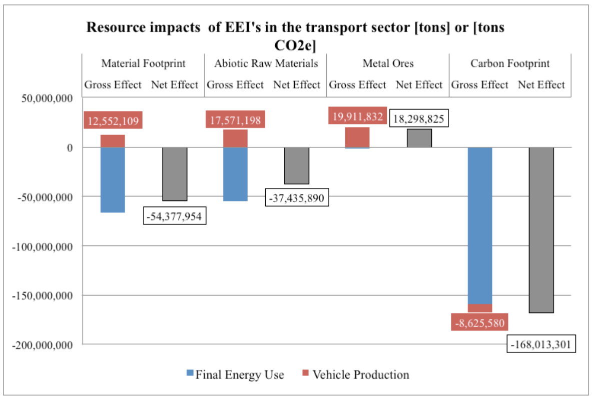
Sector (use phase)	Material Footprint Savings	Raw Material Savings (only used extraction)	Carbon Footprint (global GHG) Savings	direct GHG Savings (within Europe)	Driver
Residential & Tertiary Buildings	236 Mt	21 Mt	121 Mt CO2e	80 Mt CO2e	retro-fitting & lighting
Private & Freight Transport	67 Mt	57 Mt	159 Mt CO2e	95 Mt CO2e	car transport & modal shift
Industry	564 Mt	94 Mt	229 Mt CO2e	147 Mt CO2e	motor drives & process heating

- These (annual) savings occur during the use phase, when a lower final energy use leads to lower „Footprints" in the supply systems for electricity, heat, and transport fuels.
- Some savings would be even higher, if less coal was used to produce electricity (in particular for Czech Rep., Bulgaria, Estonia, Slovenia, Poland, Germany).

Trade-offs (WP4)

Some EEI's were not only looked at from the supply side of energy systems (**use phase** including power plants, grids etc.)

Example Vehicle Production: Production of cars, busses, duty trucks, trains contributes to savings for GHG emissions, but requires additional metal ores
(even with less cars overall in the efficiency scenario)



28 Mt of additional metal ores in the private transport sector
(18 Mt with savings in the freight transport sector):

- 12 Mt from semi-precious metals, 9 Mt from precious metals, 12 Mt from minor metals (e.g. lithium), BUT iron ore savings of -5 Mt
- 148,000 tons per annum copper input
- 12 tons per annum gold input
- 103,000 tons per annum lithium carbonates (50 % of production in 2012)

Teubler et al. (2018): Metals for Fuels? – The raw material shift by energy efficient transport systems in Europe (submitted to Journal Resources)

There might negative trade-offs for other EEI's, as the **production phase** could not be analysed in detail for most actions (e.g. refurbishment of buildings).

Insights from WP 4 research

(1) Some impacts are also a global problem – being caused by imports into the EU nonetheless (e.g. GHG emissions)

(2) Energy efficiency can be also a driver for material efficiency, but some trade-offs are to be expected

(3) The extent of (physical) benefits also depends on the transformation pathways of the surounding systems (with additional positive and negative synergies)

(4) Lower material demands from energy efficiency might not be the case for every material, as reserves might deplete and materials might also be needed by other sectors. On the other hand, increased recovery, recycling and material efficiency might cause even larger material resource benefits

(5) Many resource aspects could not be accounted for (in particular damage to water and land resources)

(6) COMBI applies a technological & economic point of view, where investments lead to technological improvements (a direct cause-effect chain for Resources).
It does not account for new trends and socio-economic changes in its basic mechanic and scenarios (e.g. digitalization, urbanization, circular economy etc.)

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Thank you very much for your attention!

Contact

Wuppertal Institut

Jens Teubler
Doeppersberg 19, D-42103 Wuppertal
jens.teubler@wupperinst.org
http://wupperinst.org

Quantifying the energy poverty-related health impacts of energy efficiency improvements

Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

MANCHESTER 1824
The University of Manchester

Nora Mzavanadze, Stefan Bouzarovski, Sergio Tirado Herrero

Brussels, 17 May 2018

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Context

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- Energy poverty: inability to secure a necessitated level of energy services in the home (Bouzarovski 2018)
- 9.4% of EU population unable to keep home warm, 15.2% living in housing with leaking roof, damp or rot in 2015
- Indoor cold exposure – a direct consequence of energy poverty – estimated additional mortality by an average of 70,000/year between 1996-2014 in EU-28
- The burden of disease of asthma attributable to indoor dampness amounted to over 71 000 Disability Adjusted Life-Years (DALYs) in 2015 in the EU-28

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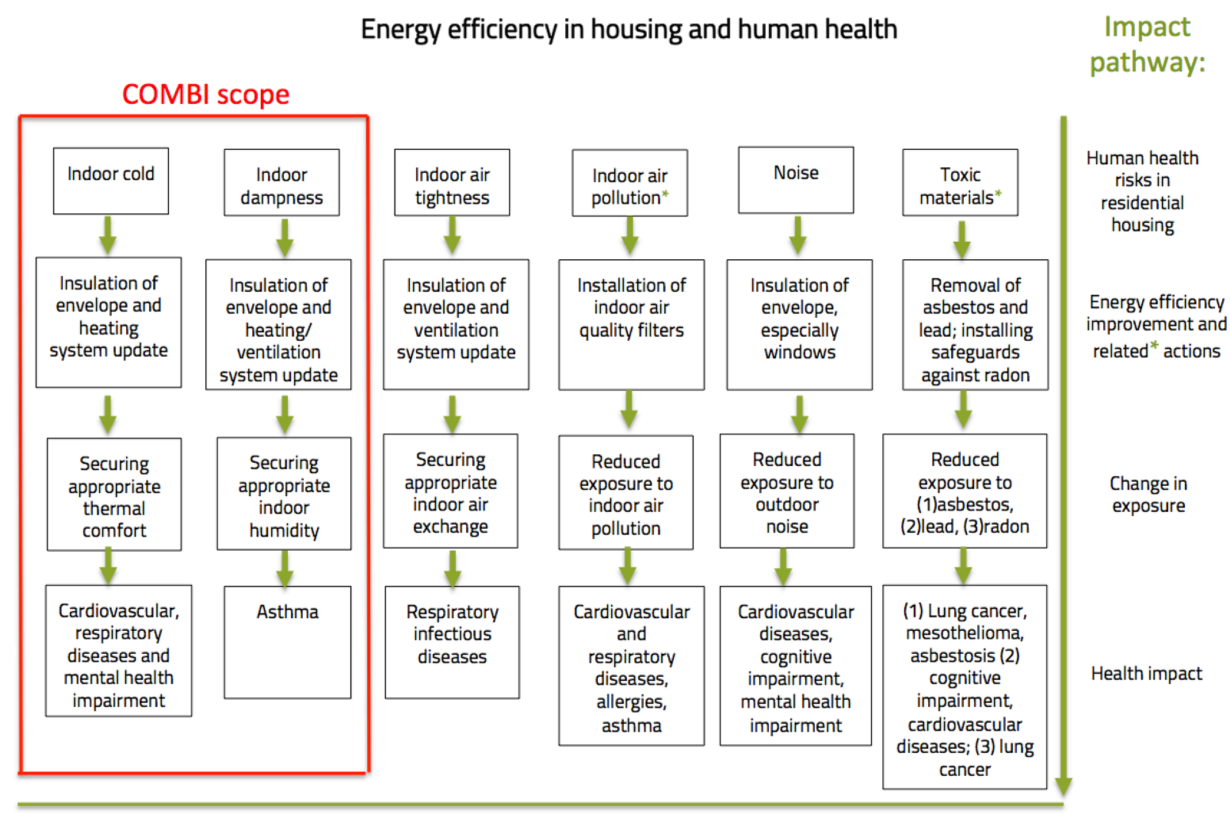

Sources: (Braubach, Jacobs, Ormandy, World Health Organization, & Regional Office for Europe, 2011; Hänninen & Asikainen, 2013; Theakston & World Health Organization, 2011; WHO regional office for Europe, 2013; World Health Organization, 2009)

Methods

COMBI
Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

- Monthly data on hospitalizations, general practitioner visits or incidence of disease not publicly available. Work-around not accepted by COMBI advisors
- Excess Cold Weather Deaths (ECWD): Re-calculation of excess cold weather mortality, including at least 85% of heat degree days for each EU member state
- Customized energy poverty-related mortality attribution rate depending on the EU SILC indoor cold exposure indicator
- Universal relative risk estimate for asthma onset as a result of exposure to dampness for all age groups - 1.33 (95% Confidence interval: 1.12-1.56) (Quansah et al. 2012)
- Excess mortality co-benefits modelled on the basis of building renovation activities, building types and the potential to incur health improvements
- Scenarios:
  - No emphasis on social policy scenario (NESP)
  - Prioritizing the socially vulnerable (PSV)

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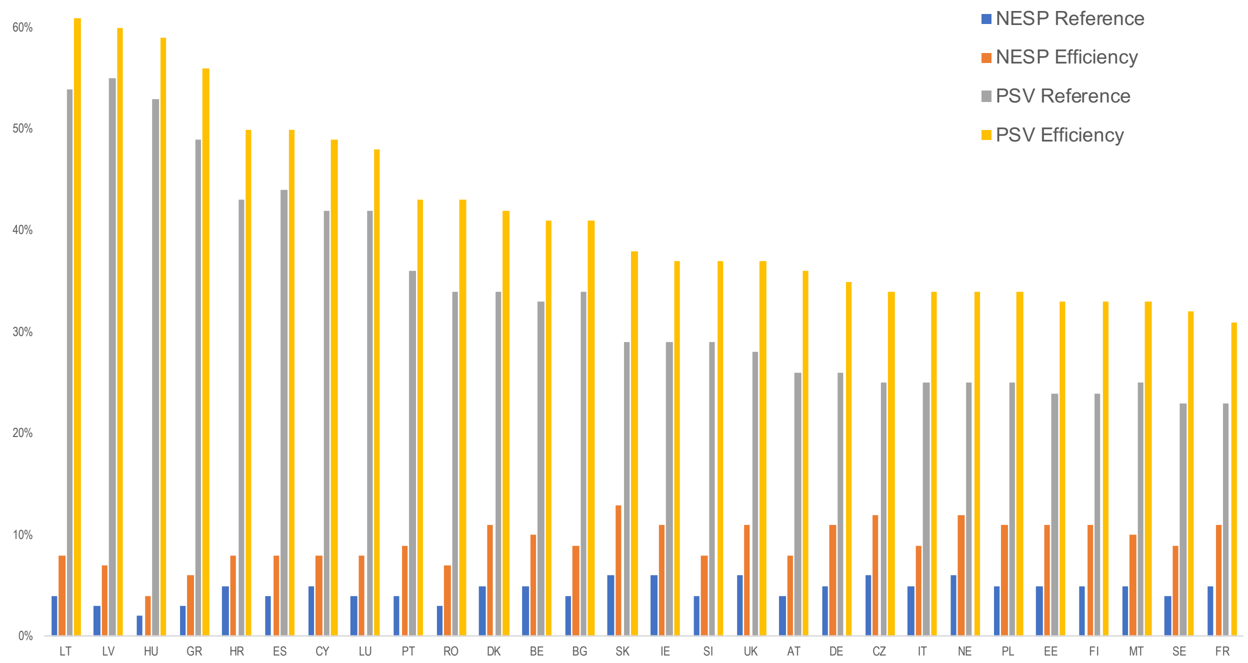
Comparison of key factors in COMBI scenarios

COMBI retrofit scenarios (↓) versus social policy scenarios (→)	"No emphasis on social policy"	"Prioritizing the socially vulnerable"
Reference	Lower extent of residential housing retrofits+lower depth of retrofits[4]+no social policy towards socially vulnerable	Lower extent of residential housing retrofits+lower depth of retrofits+strong social policy towards socially vulnerable
Efficiency	Higher extent of residential housing retrofits+higher depth of retrofits+no social policy towards socially vulnerable	Higher extent of residential housing retrofits+higher depth of retrofits+ strong social policy towards socially vulnerable



Excess cold weather mortality reduction potential in relation to social aspects of COMBI reference and efficiency scenarios in 2030.

Key findings

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Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

- Public health impact of energy efficiency improvement actions in 2030 in the EU-28
  - just over 3 000 of premature deaths avoided due to indoor cold under NESP scenario
  - ca. 27 500 of avoided premature deaths under PSV scenario
  - min. 2 700 DALYs of asthma morbidity avoided due to indoor dampness (NESP)
  - 25 000 DALYs of asthma morbidity under PSV
- The associated economic value of avoided annual public health damage in 2030 ranges
  - from 323 million EUR to 2.5 billion EUR (premature mortality due to indoor cold)
  - from 338 million EUR to of 2.9 billion EUR (asthma morbidity due to indoor dampness)
- Additional co-benefits of PSV scenario:
  - 24 500 avoided premature deaths due to indoor cold and associated avoided economic damage of 2.2 billion EUR
  - Ca. 22 300 DALYs of avoided asthma due to indoor dampness and the associated avoided economic damage of 2.6 billion EUR.

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Conclusions and implications

Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

- Value of co-impacts is likely to have been underestimate
- More research needed on burden of disease attribution
- Needed: pan-European study to assess the extent of public health improvements accounting for climatic differences and differences in building standards
- Effects on mental health and well being overlooked
- Not included: effects of hot weather events, productivity loss, costs of hospitalization, medication and medical care

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Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

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The University of Manchester

Contact

Professor Stefan Bouzarovski
@stefanbuzar
www.energystudies.net

Productivity Quantification Results WP5a

ABUD

Souran Chatterjee

17th May 2018

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Research Overview

- Two EEI actions in two different sectors:

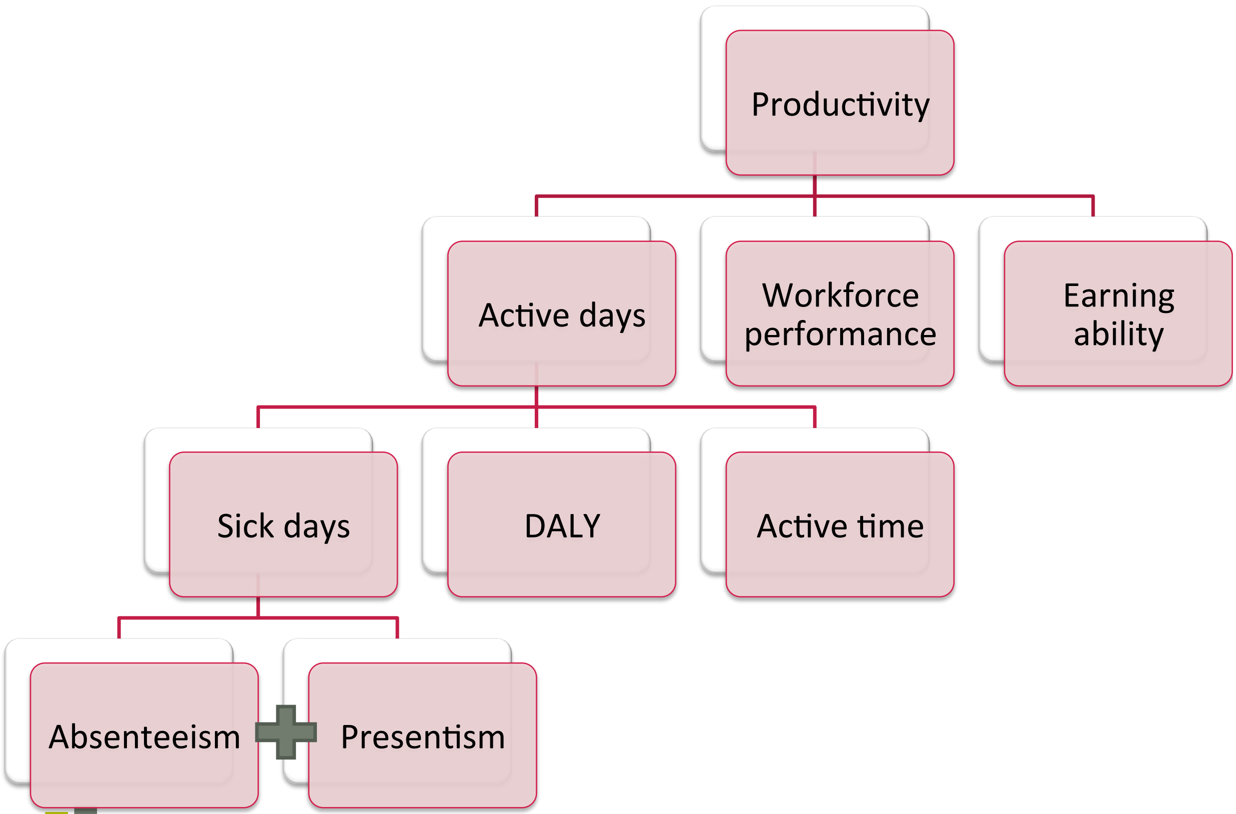
1. HVAC system with proper building envelope for building sector (both residential and tertiary buildings)
2. Modal shift towards active transportation

- Each of these actions leading towards productivity

- However, productivity impact is underrated because of lack of metrics to quantify productivity

- Impact on productivity- incremental effect quantification

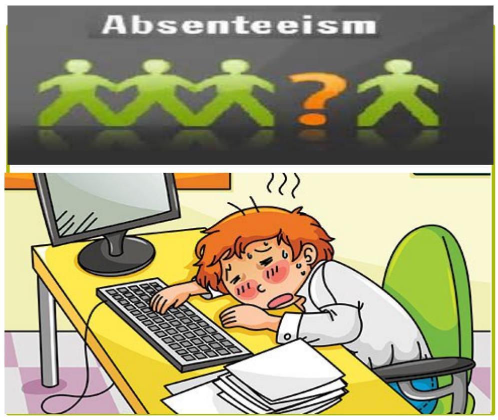
Productivity indicators

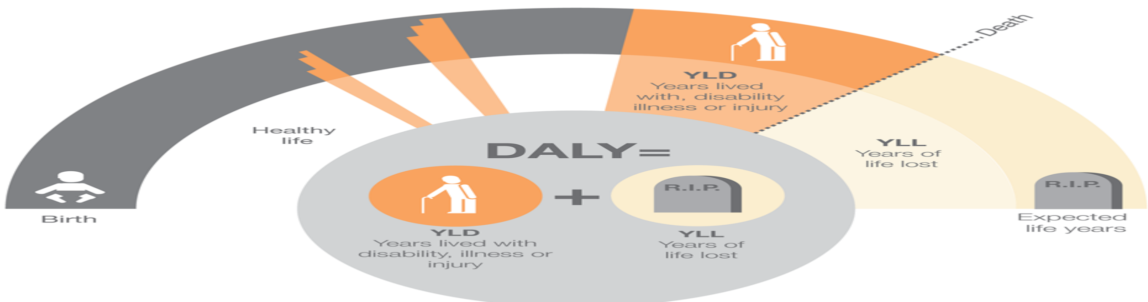


Active days

- **Absenteeism:** Absent from work due to building related illness**.**

- **Presenteeism:** Presenteeism can be referred as working with illness or working despite being ill. For example, a person might work slowly than usual with respiratory diseases or make mistakes in work during his illness.
- **Time spent in congestion**





Workforce performance

There are mainly three reasons behind work performance improvement which are discussed below:

1)Reducing mental disorder: Improvement in indoor air quality helps in reducing mental stress which results in more labour input.

2)Improvement in mental health conditions: Thermal comfort helps to improve a person's concentration ability which improves the work performance (Wargocki, Wyon, et al. 2000).

3)Better concentration ability: Concentration ability may get disrupted by certain symptoms such as eye irritation (eye tears and eye blinking), skin irritation which affects the work performance (Mølhave, Bach and Pedersen 1986).

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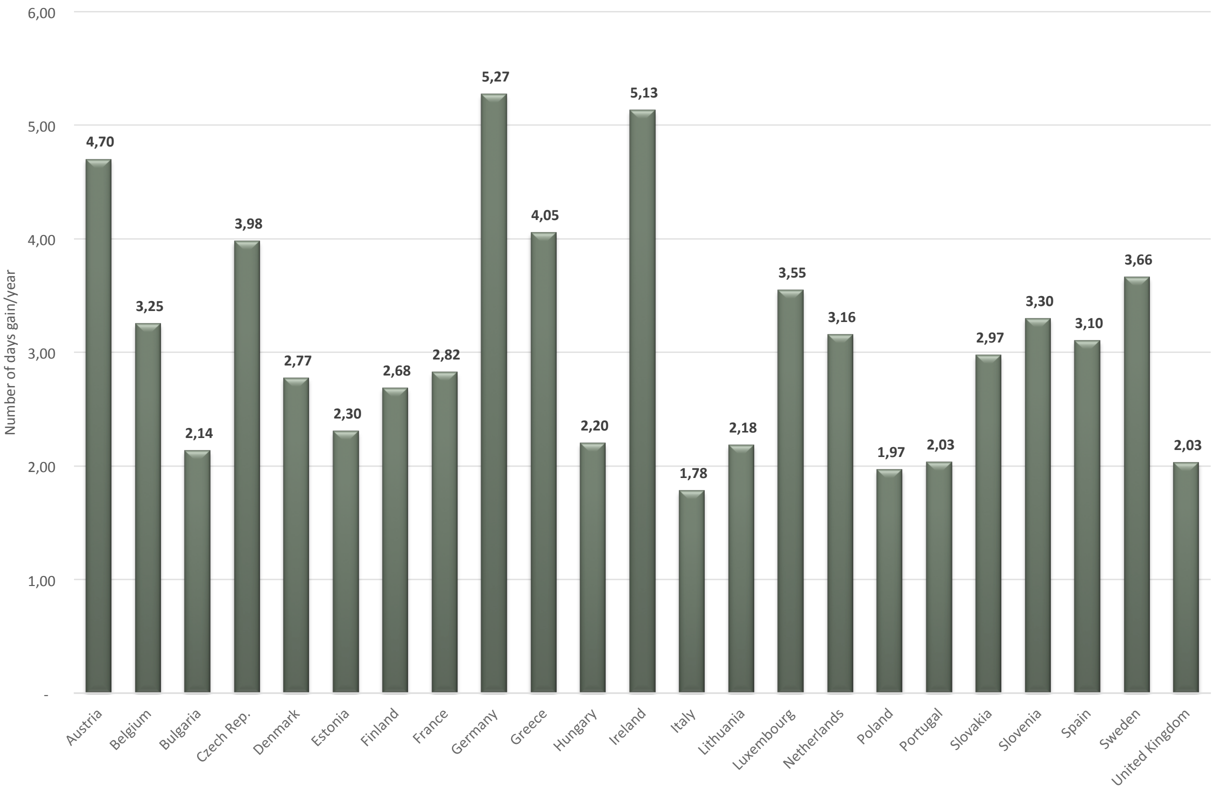
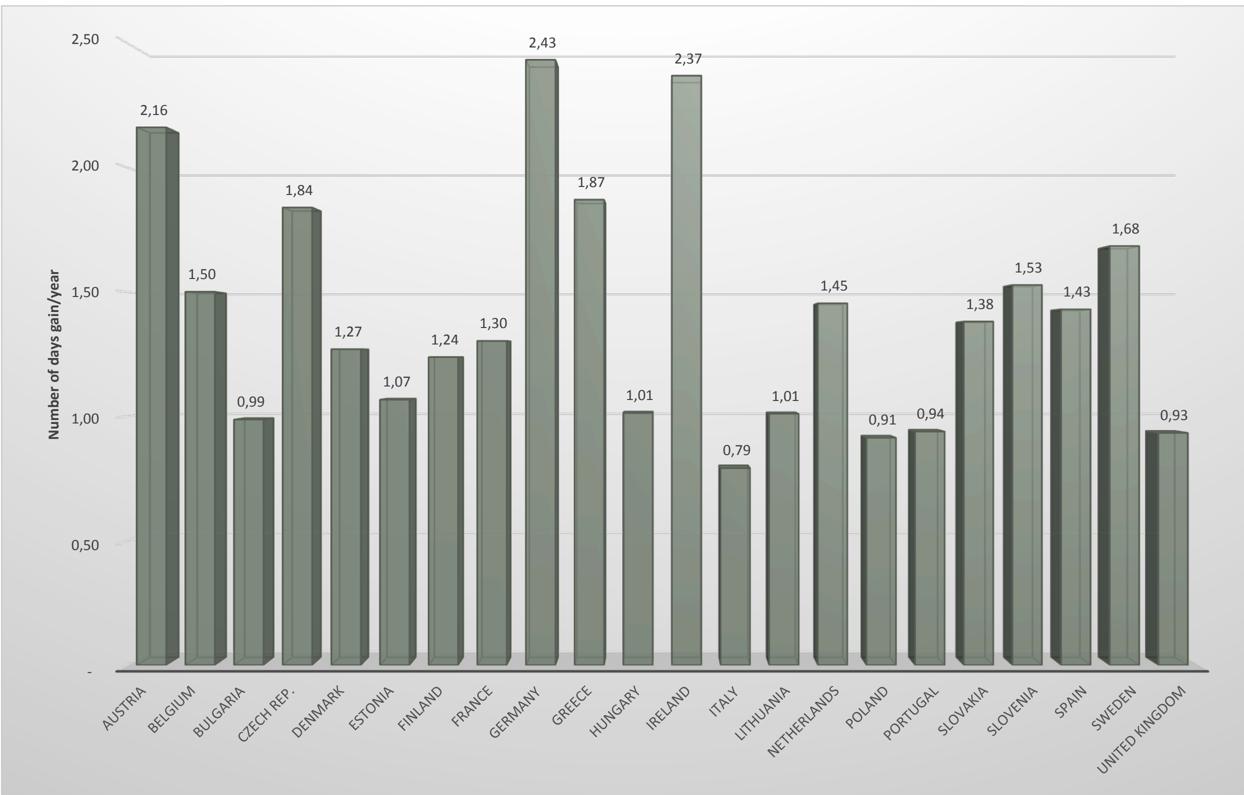
Results

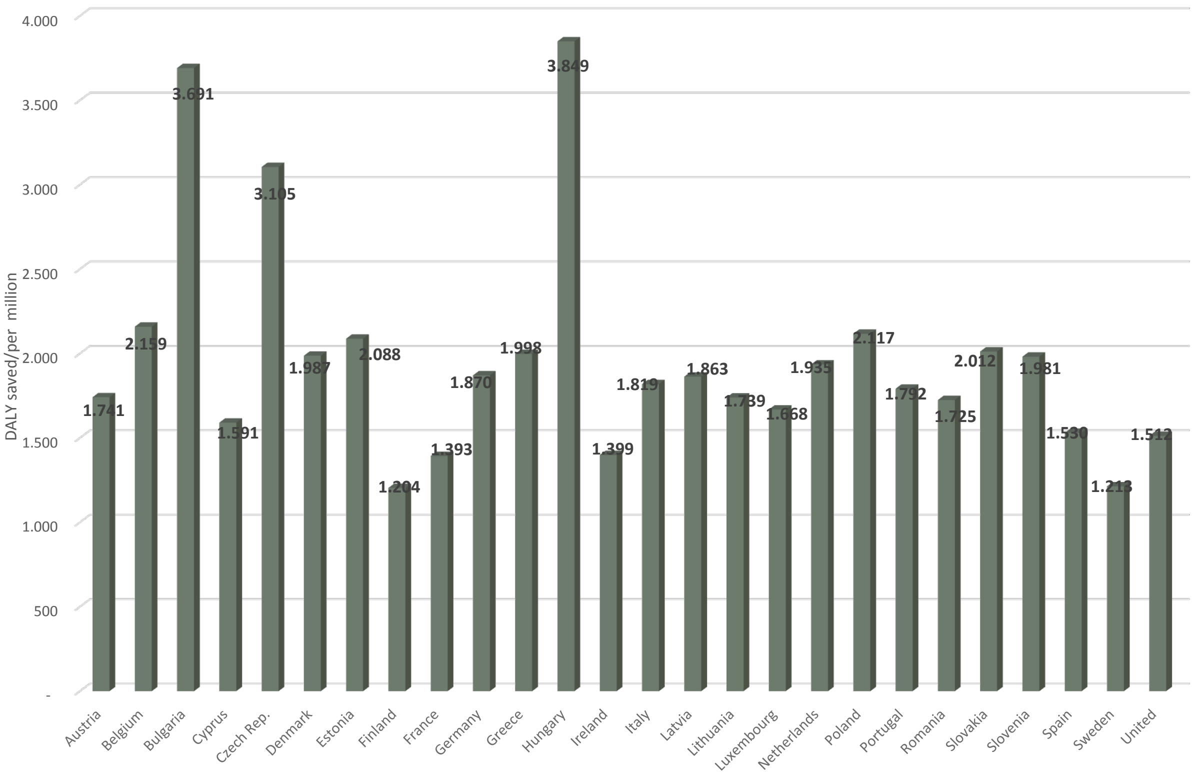
Per-capita active days gain-Residential building sector



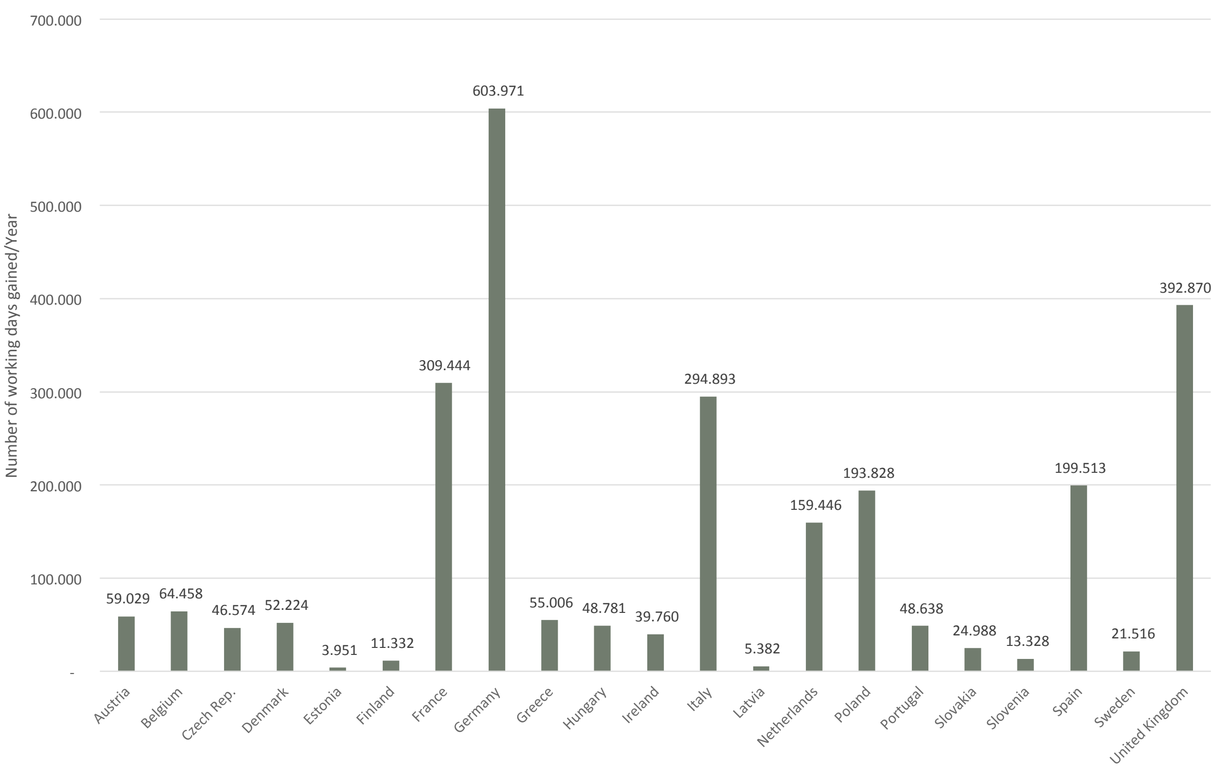
Per-capita active days gain-Tertiary building sector



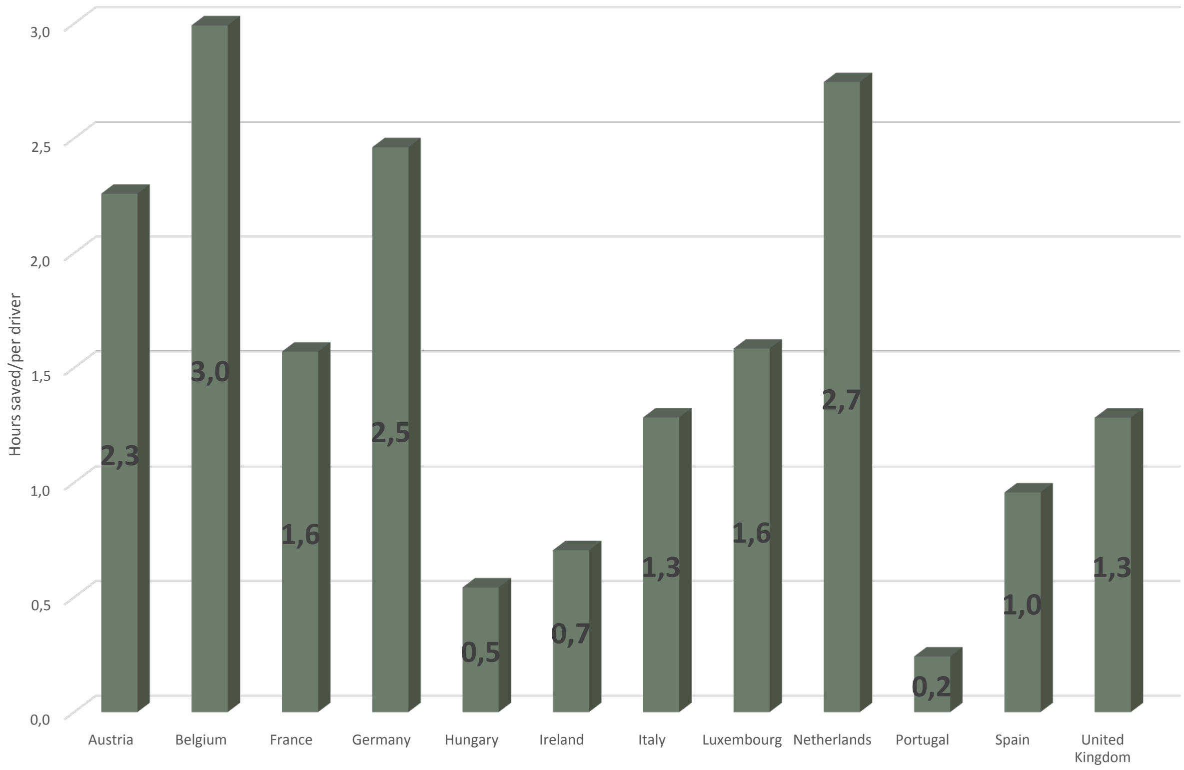
DALY /million population



Number of working days gained/per country



Active time saved in hours annually from road congestion



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Souran Chatterjee
Chatterjee_Souran@phd.ceu.edu
ABUD

Appendix

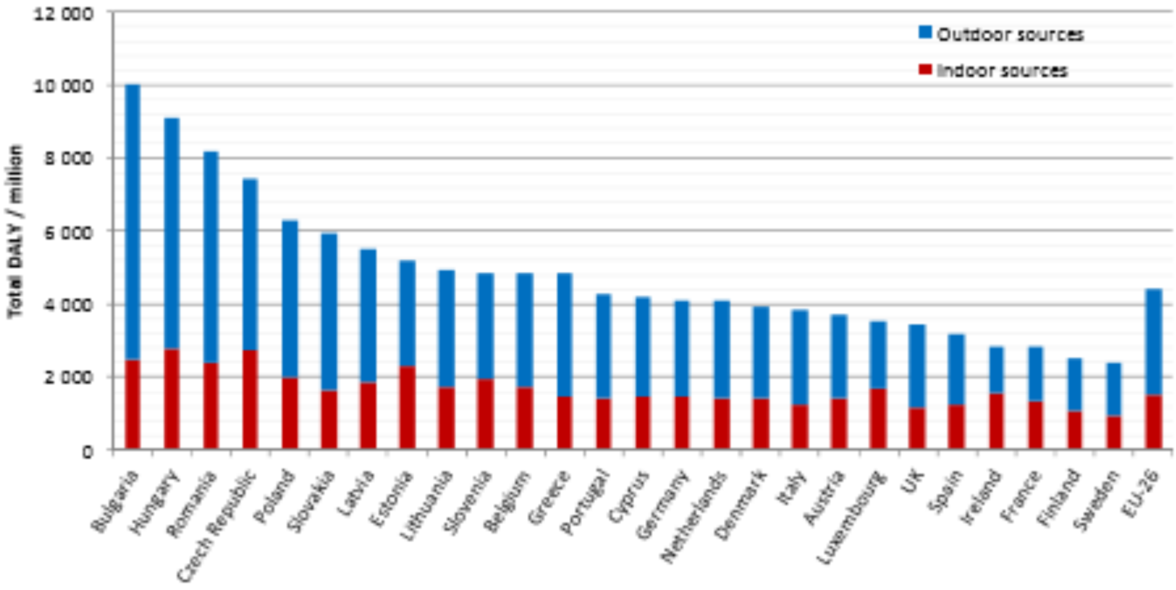
Building sector EE action-HVAC system with proper building envelope

- WHO 2006 guidelines for indoor air quality identifies three issues which are affecting indoor air quality and human health. These three key issues are

1) Biological indoor air pollutants such as dampness and mould
2) Chemical indoor pollutants such as radon, carbon monoxide etc.
3) Pollutants from indoor combustion of fuels

- Studies show that sufficient mechanical ventilation is one of the key tool in order to remove humidity, carbon dioxide, bioeffluents and other pollutants from indoor air (WHO 2006) (Asikainen, et al. 2016).
- There exists an inverse relationship between indoor air pollutant concentration and rate of ventilation i.e. higher rate of ventilation lowers the corresponding indoor concentration but it never reaches to zero (Atkinson 2013).

Total burden of disease as DALY/million population from indoor exposures in European countries



Source: Hänninen & Asikainen 2013

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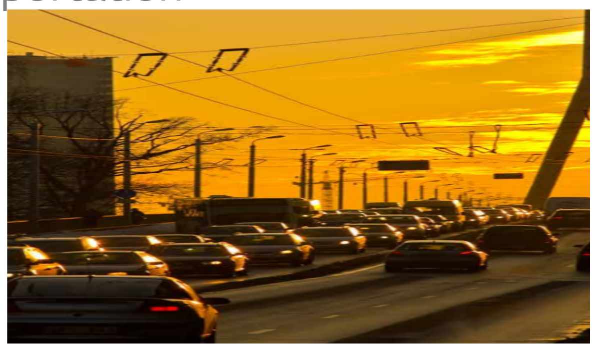
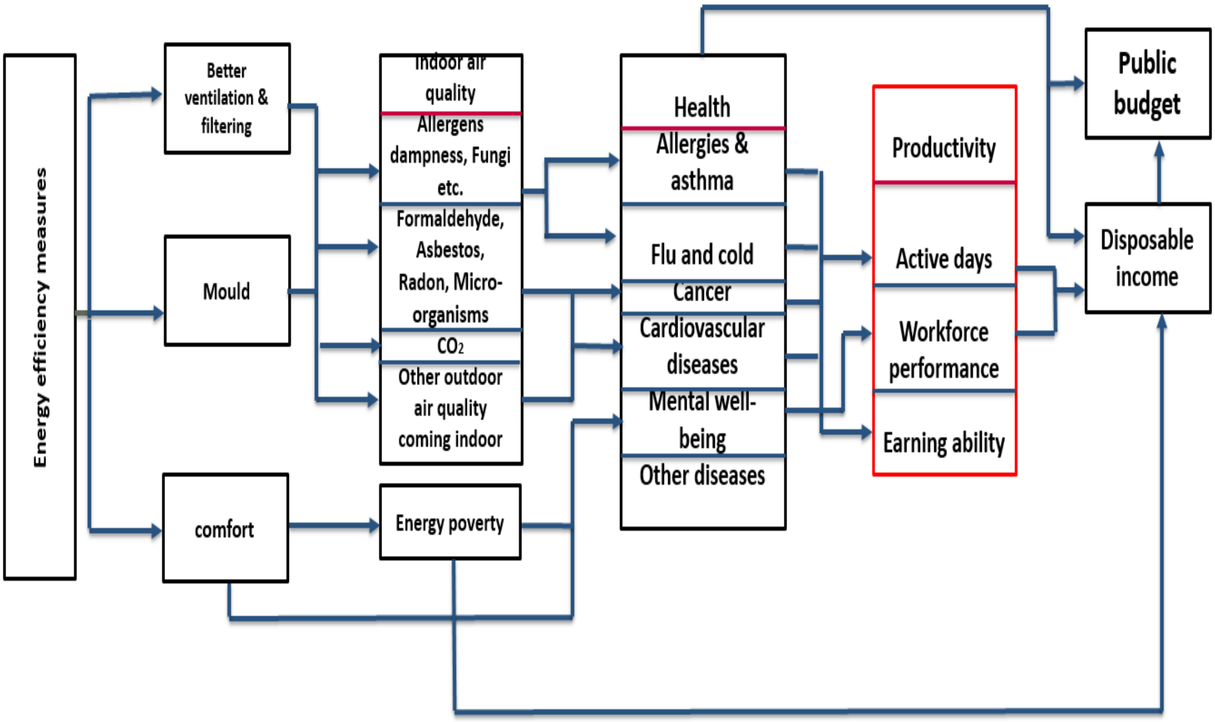
Transport sector EE action-Modal shift towards active transportation

- **Congestion aspect –**Time saved from traffic
- **Health aspect –** Through physical activity and less outdoor pollution exposure
- However, there are some **negative impact** as well

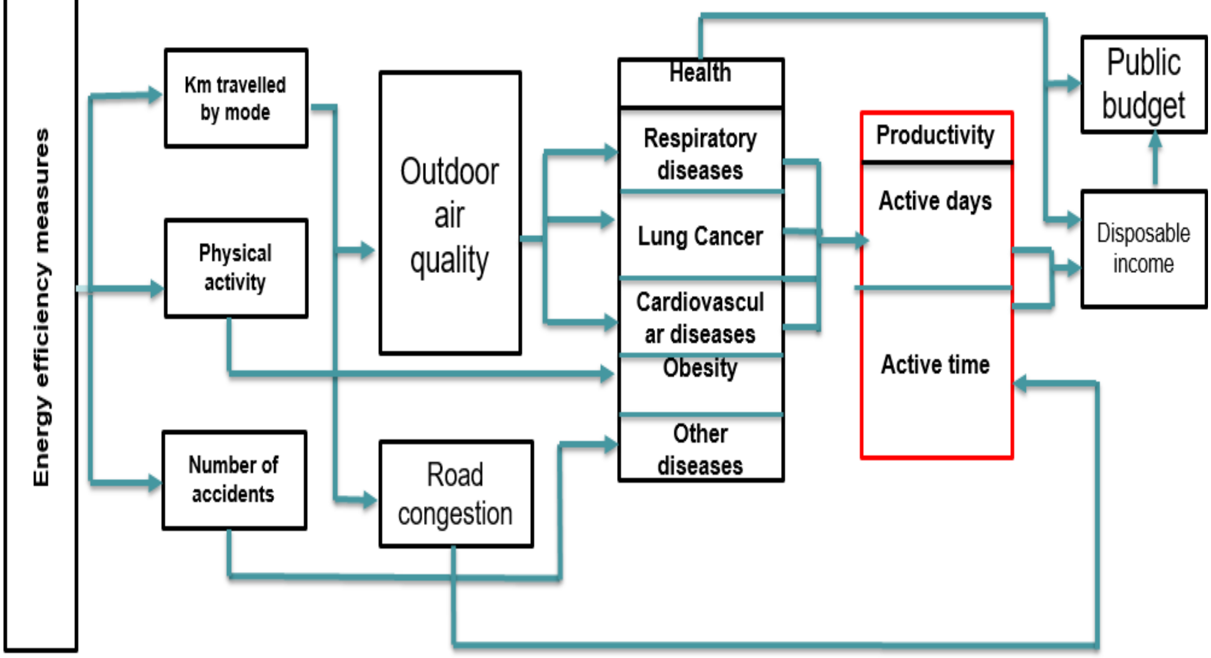
>>Net impact<<



Impact pathway map-Building sector



Impact pathway map-transport sector



Methodology framework

Identification

- Impact pathway map staring from energy efficiency measure
- Identify the overlaps between the impacts

Scenario analysis

- Reference scenario
- Efficient scenario

Assessment

- Impact assessment by comparing between two scenarios
- Uncertainty analysis

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Indoor air pollutants and their sources

Pollutants	Source	Affected health aspect
Allergens	Indoor dust, domestic animals, and insects	Respiratory disease, skin and eye irritation
Asbestos	Fire retardant material and insulation	Lung and kidney cancer
Formaldehyde	Particleboard, insulation, furnishings	Cancer, skin and eye irritation
Micro-organisms	People, animals, plants, air conditioning systems	Cancer and heart disease
Pollens	Outdoor air, trees, grass, weeds, plants	Respiratory disease
Radon	Soil, building construction materials (concrete, stone)	Lung cancer
Fungal spores	Soil, plants, foodstuffs, internal surfaces	Respiratory disease

Source:(A. Jones 1999), (W. J. Fisk 2000), (Katsouyanni 2003) (Sundell 2004) (W. J. Fisk 2009) and own adaptation

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Outdoor air pollutants and their sources

Pollutants	Source	Affected health aspect
Nitrogen dioxide	Outdoor air, fuel burning, motor vehicles in garages	Respiratory and Cardiovascular disease
Particles	Tobacco smoke, combustion products	Respiratory and cardiovascular disease
Polycyclic aromatic hydrocarbons	Fuel combustion, tobacco smoke	Cancer
Sulphur dioxide	Fuel combustion	Respiratory disease
Ozone	Fuel combustion	Respiratory disease
Carbon monoxide	Fuel combustion	Headache, dizzy feeling which affects productivity

Source: (Schwartz and Morris 1995) (Jones 1999), (R. D. Brook 2004)(EPA 2015), Own elaboration

Active days

$$1)\ \sum_{v=0}^{4}\sum_{i=0}^{p} AD_{Xv}^{riti} = \sum_{v=1}^{4}\sum_{i=0}^{p}\left[\{SD_{Xv}^{riti}\times(1-CF_i)\}\times TSF_c\right]$$

$$Ab+Pr = \sum_{v=0}^{4}\sum_{i=0}^{p}\{(AVS\times ri)\times X_v\} + \sum_{v=0}^{4}\sum_{i=0}^{p}\{(APS\times ri)\times P_v\times\mu_v\}$$

$$2)\ \sum_{v=0}^{4}\sum_{i=0}^{p} AD_{Xv}^{ri} = \sum_{v=1}^{4}\sum_{i=0}^{p}\left[\{DALY_{Xv}^{ri}\times(1-CF_i)\}\right]$$

- Where i represent type of retrofits and v represent type of diseases

Variables	Explanations
	Active days loss due to illness per year of the residential and commercial working adult population of each types of retrofitted buildings
ri and ti	ri and ti represent the number of working population lives in type i retrofitted buildings and number of workers working type I retrofitted commercial buildings respectively per year per country.
CF	Conversion factor i.e. health gain factor from EE measures
AVS	Average sick days taken per person per year per country
Xv	Percentage of sick leave taken due to disease v per year
APS	Average number of presenteeism days taken per person per year in Europe
Pv	Percentage of presenteeism days taken due to disease v
µ	Productivity loss factor due to disease v
TSF	Time spent factor i.e. time spent in the residential and commercial buildings.

Workforce performance:

$$\sum_{i=0}^{p} \boldsymbol{WKP_{ti}} = \sum_{i=0}^{p} \{ (\boldsymbol{AVH} \times \boldsymbol{t_i}) + ((\boldsymbol{AVH} \times \boldsymbol{t_i}) \times \boldsymbol{PI}) \}$$

- Where, WKP_{ti} represents Workforce performance in different types of commercial retrofitted buildings, AVH represents average annual hours actually worked per worker and ci represents working population in different types of commercial retrofitted buildings.
- PI implies productivity improvement per hour in a year due to improve in mental well-being.

Active time

$$\boldsymbol{ATL_{Ri}} = [(\boldsymbol{TTL} \times \boldsymbol{R_i}) - \{(\boldsymbol{TTL} \times \boldsymbol{R_i}) \times \boldsymbol{TS}\}]$$

- Where, TTL represents travel time loss due to traffic congestion per driver in a year and Ri is the average number of drivers stuck in traffic congestion during peak hours per year. TS is the travel time saved factor due to modal shift towards active transportation.

Assumptions

- In order to conduct a complex empirical study, the below assumptions need to be assumed to simplify the study in view of the time and resource constraints;
- Ceteris paribus prevails. Otherwise, it will be too complex to calculate productivity impact of improved energy efficiency measure.
- Employment opportunities will remain same until 2030 (compared to 2014) because the number of presenteeism days depends on economic condition such as job opportunities available in the economy, rate of inflation etc.
- The HVAC system needs to be properly maintained. Otherwise the health effect will be minimum since, then HVAC could itself be a source for indoor air pollutants.
- HVAC system would be installed with few other system control measures such as temperature control, sensors etc. to monitor the indoor air quality properly.
- Radon safe constructions are assumed in radon prone areas
- Since this study project the productivity gain values in the year 2030, the average sick leave data/ per person and presenteeism data are assumed to remain the same as for 2014/2015 data
- Before modal shift towards active transportation, there are some pre-requirements which are assumed to be maintained. Pre-requirements such as proper cycling and walking road needs to be there while cycling people are maintaining proper safety measures etc.
- Marginal utility of leisure is equal to marginal utility of income. This assumption is taken for monetization of active time loss due to road congestion.

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Existing methodologies and their weakness

Name of method	Limitations
Cost-Benefit Analysis and cost effectiveness analysis	Ceteris paribus approach intended for small scale projects and monetization of impacts is controversial
Energy Conservation Supply Curve or Marginal Abatement Cost Curve	Mostly calculated for direct cost savings and GHG reduction cost.
Multi-criteria Analysis	Subjectivity of weighting (if done) with no real scientific/ disciplinary basis
Life-Cycle Assessment	Lack of consistent theoretical basis in reducing different impacts to a single score
Integrated Assessment Models	Highly simplified
Computable General Equilibrium models	Mainly focuses on market
Input-Output models	No behavioral characteristics of agents
Partial equilibrium analysis	Lack of focus on macro-economic interactions

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Data source-Absenteeism

Data	Data Source
Average sick days taken per person per year per country	OECD
Number of working population who live in non-retrofitted buildings per year per country (and number of workers working in non-retrofitted commercial buildings (	COMBI input data
Number of working population who live in low retrofitted buildings per year per country and number of working population who work in low retrofitted buildings per year per country	COMBI input data
Number of working population who live in medium retrofitted buildings per year per country and number of working population who work in medium retrofitted buildings per year per country	COMBI input data
Number of working population who live in deep retrofitted buildings per year per country and number of working population who work in deep retrofitted buildings per year per country	COMBI input data
Number of working population who live in new nearly zero energy buildings per year per country and number of working population who work in new nearly zero energy buildings per year per country	COMBI input data
Number of working population who live in passive houses per year per country and number of working population who work in passive houses per year per country	COMBI input data
Percentage of sick leave taken due to asthma among total sick leave taken by working population per year	(Alexopoulos and A Burdorf ,2001) –it is a Europe based study with sample size of around 400 workers (both blue and white collar workers)
Percentage of sick leave taken due to cold and flu among total sick leave taken by working population per year	(Alexopoulos and A Burdorf ,2001) –it is a Europe based study with sample size of around 400 workers (both blue and white collar workers)
Percentage of sick leave taken due to allergies among total sick leave taken by working population per year	(Lamb, et al. 2006)
Percentage of sick leave taken due to cardiovascular disease among total sick leave taken by working population per year	(Leal et al 2006)- Europe based study

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Data source-Presenteeism

Data	Data Source
Average number of presenteeism days taken per person per year in Europe	IES report 2016 http://www.employment-studies.co.uk/system/files/resources/files/507_0.pdf
Percentage of presenteeism days taken due to disease asthma (Pv)	(JOHNS. 2010)
Percentage of presenteeism days taken due to disease cold and flu (Pv)	(JOHNS. 2010)
Percentage of presenteeism days taken due to disease allergies (Pv)	(Lamb, et al. 2006)
Value of μ i.e. the productivity loss factor due to disease V	(Lamb, et al. 2006)

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Data source- workforce performance

Data	Data Source
Average annual hours actually worked per worker per country	OECD (https://stats.oecd.org/Index.aspx?DataSetCode=AVE_HRS)
Number of people who work in r1 buildings per year per country	COMBI input data
Number of people who work in r2 buildings per year per country	COMBI input data
Number of people who work in r3 buildings per year per country	COMBI input data
Value of productivity improvement factor	(Singh 2005)

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Data source- Active time loss

Data	Data Source
Number of drivers stuck in traffic during peak hours per country per year	COMBI input data
Average Hours wasted in traffic in 2015	INRIX 2015 (http://inrix.com/scorecard/)
Travel saved factor	(Cairns, et al. 2004)

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Earning ability

- Earning ability here refer to as future earning ability loss of a child and parent's present earning opportunity loss.

- This part of productivity mainly concerns with two aspects;

1) Future impact on earning ability due to loss of school days
2) Parents absenteeism and presenteeism due to take care of his sick child.

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Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

Estimating macroeconomic effects [WP 6]

Multiple impacts of energy efficiency measures

Copenhagen Economics CE

Bjarke Modvig Lumby

17 May 2018

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649724.

Our objective: assess the macroeconomic effects of a particular energy efficiency programme

Our starting point:
An **energy efficiency programme** which
- Is running until 2030
- Covers more than 1,600 TWh of energy savings annually
- Includes a total investment of1,330 billion EUR

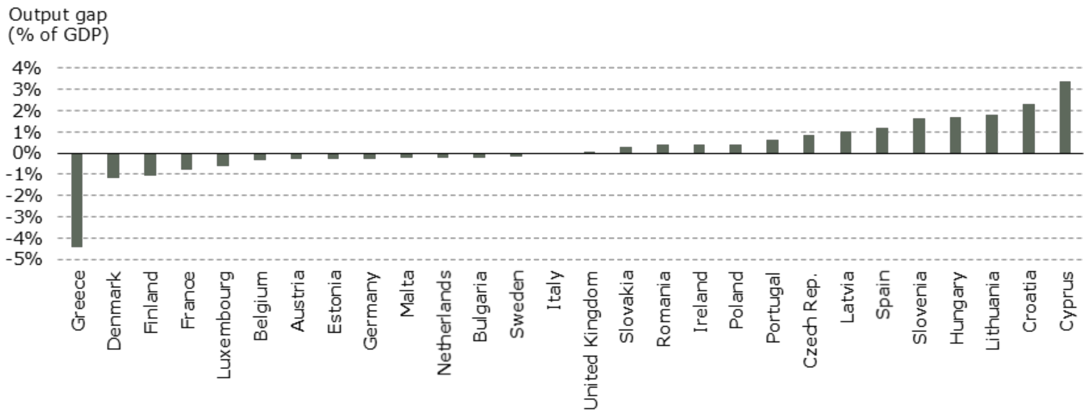
Macroeconomic effects

	A) Business cycle effects	B) Structural effects
	'short run'	'long run'
Impacts	GDP; Employment; Public budget	Fuel prices and marginal abatement costs; Structural change (economy, competitiveness); Total value created
Main method	Input-Output-model (+adjustments)	General equilibrium model (+adjustments)

A) Business cycle effects
The programme is estimated to have the potential of creating more than 2 m. job-years in 2030

GDP	Employment	Public budget
161 bn. EUR	2.3 m. job-years	86 bn. EUR

A) Business cycle effects
Stimulus will only materialize if there are idle resources in each country. Increase EU GDP by 35 bn. EUR in 2018



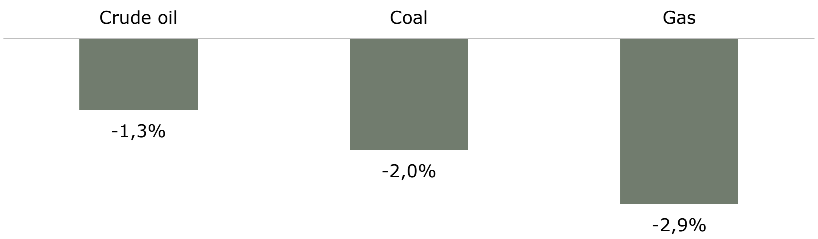
GDP
35 bn. EUR

Employment
0.5 m. job-years

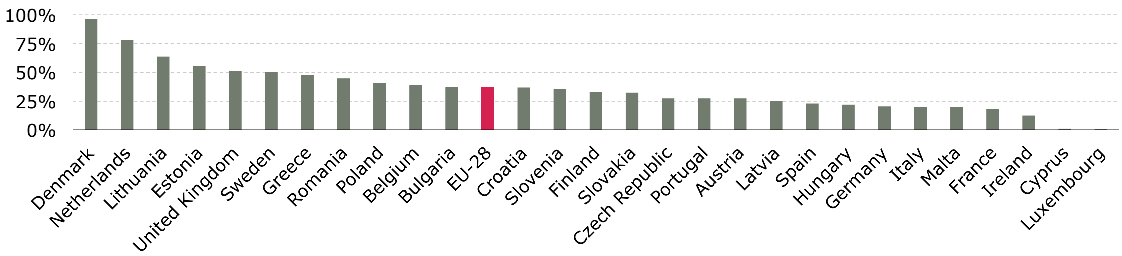
Public budget
20 bn. EUR

B) Structural effects
Significant reductions in fossil fuel prices, and gains in terms-of-trade

EU fossil fuel prices



Export/import ratio of fossil fuels



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Thank you very much for your attention!

Bjarke Modvig Lumby
bml@copenhageneconomics.com
+45 4236 8898

Copenhagen Economics

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Calculating and Operationalising
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Energy Efficiency in Europe

Energy system and security impacts

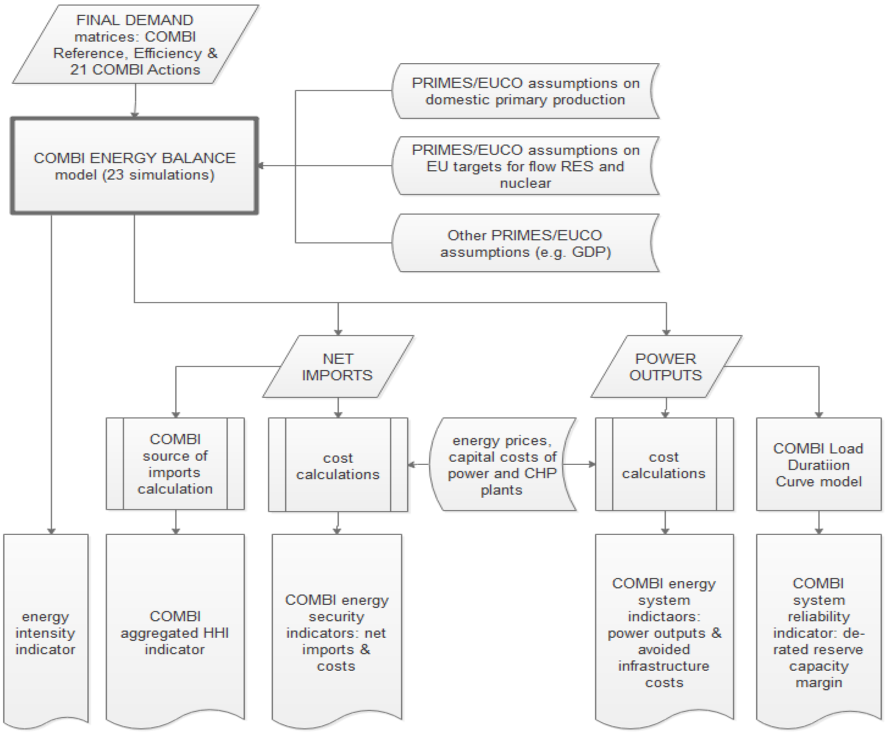
Universiteit Antwerpen

Johan Couder

May 17, 2018
Brussels

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649724.
This document reflects only the author's view. The Agency is not responsible for any information it contains.

Overview of methods & impacts quantified



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Main finding: Interconnectedness ('holistic' principle)

- Interconnectedness 1: There is a deep interconnectedness between:
  - Required net imports and associated costs (energy security);
  - Required power output and associated – avoided – investment costs (energy system);
  - Required reserve capacity (system reliability).
- Interconnectedness 2: There is a deep interconnectedness between:
  - Energy efficiency policies;
  - Climate change and environmental policies;
  - Economic policies.
- Interconnectedness 3: the effects of COMBI actions on an energy system and security impact indicator are *non-additive*, meaning the existence of synergies and/or anergies between COMBI actions

Example: Energy efficiency improvements not only lead to energy demand reductions, but to changes in energy carrier mix as well (less fossil fuels). Both lead to changes in the level and mix of energy imports as well as power plant production. A change in the power plant mix (increase in the use of intermittent renewables) may lead to changes in required reserve capacity. Changes in import levels influences energy prices, which in turn co-determine profitability of investments in power supply (and storage) systems.

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Policy planning implications of interconnectedness

- One COMBI action will *directly* and *indirectly* influence more than one energy system and security impact indicator; and one impact indicator will be influenced by more than one COMBI action. Thus:
  - One energy system and security impact indicator should never be interpreted in isolation of the other impact indicators. Whereas a COMBI action may have a clear beneficial effect on one indicator, it may also have a less beneficial impacts on one or more other indicators;
  - The interpretation of one 'comprehensive' indicator would be very difficult, given that the 'forces' (i.e. the effects of one or more COMBI actions) acting on this indicator would not necessarily all point in the same direction (see e.g. the COMBI aggregated (Herfindahl-Hirschmann Index) indicator).
- Policy planning should not only combine energy efficiency 'actions', but also explicitly consider climate and environmental and economic policies in one comprehensive 'package'.
- For energy policy planning support the models would not only have to be highly detailed, but also highly *integrated*:
  - Not only the 28 EU member states have to be modelled in detail, but also how they are connected a) to each other and b) to the outside world (e.g. power and gas grids);
  - The models should not only cover energy efficiency aspects but also those related to climate change and the environment, as well as to the macro-economy, meaning that dynamic *feedbacks* should explicitly be taken into account.

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Example 1: COMBI aggregated energy security indicator

	lower is better	higher (+) is better	higher (+) is better	lower is better	higher (+) is better	higher (+) is better
	[-]	[-]	[%]	[-]	[-]	[%]
	COMBI AGGREGATED ENERGY SECURITY INDEX (net import from all countries)	IMPROVEMENT in COMBI AGGREGATED ENERGY SECURITY INDEX (net import from	RELATIVE IMPROVEMENT in COMBI AGGREGATED ENERGY SECURITY	COMBI AGGREGATED ENERGY SECURITY INDEX (net import from outside EU28)	IMPROVEMENT in COMBI AGGREGATED ENERGY SECURITY INDEX (net import from	RELATIVE IMPROVEMENT in COMBI AGGREGATED ENERGY SECURITY
Austria	13,50	0,883	6,14%	13,71	0,967	6,58%
Belgium	12,82	-1,260	-10,91%	14,35	-1,318	-10,11%
Bulgaria	27,60	3,844	12,23%	28,01	3,820	12,00%
Croatia	11,17	-1,181	-11,81%	11,41	-1,185	-11,59%
Cyprus	28,42	-1,413	-5,23%	28,42	-1,413	-5,23%
Czech Republic	14,59	0,603	3,97%	14,62	0,599	3,94%
Denmark	5,63	1,442	20,39%	5,86	1,484	20,21%
Estonia	7,12	0,627	8,10%	7,12	0,627	8,10%
Finland	27,30	2,427	8,17%	28,65	2,398	7,72%
France	3,77	-0,143	-3,95%	4,26	-0,249	-6,21%
Germany	9,78	0,415	4,06%	12,71	0,653	4,89%
Greece	17,09	-0,431	-2,58%	17,09	-0,431	-2,58%
Hungary	38,95	0,045	0,12%	38,96	0,247	0,63%
Ireland	7,39	0,651	8,10%	8,83	0,532	5,68%
Italy	12,38	-0,855	-7,42%	13,78	-0,998	-7,81%
Latvia	20,50	1,417	6,47%	20,50	1,417	6,47%
Lithuania	46,60	5,200	10,04%	46,71	5,187	10,00%
Luxembourg	3,15	0,493	13,52%	3,15	0,493	13,52%
Malta	0,99	0,056	5,32%	0,99	0,056	5,32%
Netherlands	14,21	-1,064	-8,09%	16,69	-1,562	-10,32%
Poland	29,12	0,339	1,15%	31,46	0,533	1,66%
Portugal	13,49	-2,294	-20,49%	13,49	-2,294	-20,48%
Romania	8,43	-0,263	-3,22%	8,79	0,373	4,07%
Slovakia	36,42	2,490	6,40%	38,56	1,351	3,39%
Slovenia	1,24	0,185	13,01%	4,00	0,598	13,01%
Spain	13,04	-1,961	-17,71%	13,40	-2,061	-18,17%
Sweden	4,69	1,142	19,57%	5,95	1,292	17,83%
United Kingdom	7,85	0,180	2,24%	8,10	0,144	1,75%
EU28	6,11	0,093	1,50%	7,01	0,042	0,59%

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Example 2: Avoided costs of power infrastructure

	Million EURO	Million EURO	Million EURO	Million EURO	Million EURO	Million EURO	Million EURO	Million EURO	Million EURO
	AVOIDED non-discounted CAPITAL COSTS of COMBUSTIBLES based power and CHP plants	AVOIDED non-discounted CAPITAL COSTS of COAL based POWER ONLY	AVOIDED non-discounted CAPITAL COSTS of OIL based POWER ONLY	AVOIDED non-discounted CAPITAL COSTS of GAS based POWER ONLY	AVOIDED non-discounted CAPITAL COSTS of STOCK RES / WASTE based POWER ONLY	AVOIDED non-discounted CAPITAL COSTS of COAL based CHP	AVOIDED non-discounted CAPITAL COSTS of OIL based CHP	AVOIDED non-discounted CAPITAL COSTS of GAS based CHP	AVOIDED non-discounted CAPITAL COSTS of BIO / WASTE based CHP
Austria	**192**	20,668	0,474	35,035	19,588	18,970	-	52,851	44,457
Belgium	**308**	0,259	2,752	258,108	26,738	0,003	-	16,361	4,138
Bulgaria	**117**	76,595	-	0,012	0,223	29,559	-	7,569	2,558
Croatia	**29**	8,080	1,917	12,093	0,302	-0,000	-	4,571	2,157
Cyprus	**23**	-	0,325	22,325	0,647	-	-	0,019	0,001
Czech Republic	**286**	176,052	-	-	19,969	67,156	-	22,470	-0,000
Denmark	**122**	5,330	1,514	4,649	8,796	19,250	-	7,178	74,834
Estonia	**24**	16,150	1,267	0,100	3,756	-	-	0,355	2,163
Finland	**249**	37,219	1,817	20,931	53,482	33,269	-	29,701	72,321
France	**941**	-	33,088	218,779	533,340	-	-	32,207	124,070
Germany	**1 953**	1 214,638	23,992	281,264	155,733	-0,000	-	198,814	78,917
Greece	**215**	127,063	5,024	69,248	6,354	2,200	-	0,040	5,467
Hungary	**107**	44,852	-	8,260	27,006	4,472	-	7,426	15,049
Ireland	**101**	18,292	0,094	72,870	5,500	0,000	-	4,178	-0,000
Italy	**1 855**	231,049	48,451	961,688	279,293	-0,000	-	269,416	65,518
Latvia	**10**	0,036	-	1,203	0,508	0,428	-	5,063	3,250
Lithuania	**-4**	-	-	-1,441	-0,801	-	-	-0,846	-0,714
Luxembourg	**4**	-	0,007	3,302	0,168	-	-	0,860	0,112
Malta	**2**	-	-	2,340	0,016	-	-	0,002	0,000
Netherlands	**505**	102,000	0,538	222,576	26,294	19,736	-	94,325	39,765
Poland	**438**	183,637	0,454	45,753	37,840	158,558	-	10,751	0,905
Portugal	**231**	-	58,677	24,338	115,112	-	-	8,703	24,430
Romania	**257**	115,441	0,219	8,517	5,870	98,669	-	6,616	21,546
Slovakia	**143**	40,120	1,202	9,613	29,126	45,052	-	1,361	16,173
Slovenia	**84**	40,606	-	6,448	7,773	28,536	-	0,228	0,586
Spain	**1 084**	353,926	109,448	269,140	232,732	4,308	-	81,425	33,050
Sweden	**343**	2,078	1,608	23,666	68,770	10,782	-	43,420	192,950
United Kingdom	**1 009**	23,375	7,421	428,906	390,596	-0,000	-	112,703	46,171
EU28	**10 631**	2 837,465	299,023	3 010,888	2 051,076	544,704	-	1 017,768	869,874

Example 3: De-rated reserve capacity rate

	[%]	[%]	%	[MW]	[MW]	[%]
	DERATED RESERVE CAPACITY RATE	INCREASE in DERATED RESERVE CAPACITY RATE	**RELATIVE INCREASE** in DERATED RESERVE CAPACITY RATE	ANNUAL MAXIMUM DEMAND or PEAK LOAD CAPACITY	DECREASE IN ANNUAL MAXIMUM DEMAND	RELATIVE DECREASE in ANNUAL MAXIMUM DEMAN
Austria	59,3%	1,00%	1,71%	11 485	-811	-6,6%
Belgium	60,1%	1,27%	2,16%	12 358	-985	-7,4%
Bulgaria	37,1%	1,66%	4,68%	8 565	-497	-5,5%
Croatia	51,4%	1,13%	2,25%	1 938	-128	-6,2%
Cyprus	42,4%	1,52%	3,72%	935	-87	-8,5%
Czech Republic	33,0%	0,94%	2,93%	11 852	-1 064	-8,2%
Denmark	46,1%	2,19%	5,00%	5 658	-574	-9,2%
Estonia	26,1%	0,35%	1,37%	1 450	-96	-6,2%
Finland	16,8%	-0,47%	-2,72%	10 442	-1 058	-9,2%
France	32,2%	-1,05%	-3,15%	100 414	-4 120	-3,9%
Germany	61,5%	1,72%	2,87%	94 002	-7 831	-7,7%
Greece	53,8%	2,89%	5,68%	9 047	-942	-9,4%
Hungary	27,3%	-1,43%	-4,95%	4 643	-412	-8,1%
Ireland	31,3%	1,75%	5,92%	4 598	-381	-7,6%
Italy	56,4%	2,59%	4,82%	58 122	-7 696	-11,7%
Latvia	44,0%	0,54%	1,24%	1 271	-57	-4,3%
Lithuania	43,1%	-0,26%	-0,61%	1 055	16	1,6%
Luxembourg	72,6%	0,69%	0,95%	490	-16	-3,1%
Malta	42,0%	1,18%	2,90%	153	-9	-5,4%
Netherlands	42,8%	1,12%	2,68%	22 357	-1 955	-8,0%
Poland	25,6%	0,41%	1,65%	31 478	-1 509	-4,6%
Portugal	50,1%	2,20%	4,60%	10 008	-909	-8,3%
Romania	44,0%	-0,38%	-0,85%	13 359	-921	-6,5%
Slovakia	26,8%	-1,24%	-4,43%	5 577	-490	-8,1%
Slovenia	43,9%	1,29%	3,02%	2 627	-279	-9,6%
Spain	32,8%	0,99%	3,10%	52 090	-4 301	-7,6%
Sweden	22,4%	-2,94%	-11,59%	26 040	-1 738	-6,3%
United Kingdom	24,9%	0,65%	2,67%	64 629	-4 379	-6,3%
EU28	44,4%	1,04%	2,40%			

Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

Thank you very much for your attention!

Contact

University of Antwerp

Universiteit Antwerpen

Prof. dr. emeritus Aviel Verbruggen
Prinsstraat 13, B-2000 Antwerpen
aviel.verbruggen@uantwerpen.be

Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

online tool
short introduction

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