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Stage 05
Cost-benefit analysis

Regio1st Training Sessions
23 May 2024

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Welcome!

What you will learn in this training session

- What scope of energy efficiency solutions and energy supply infrastructure should be considered in the CBA?
- What metrics can be used to assess the performance of different technologies and practices?
- How to find input data for CBA?
- How does CBA relate to energy system modelling?
- What is the role of the societal perspective in CBA and the EE1st principle?
- How to involve stakeholders in the CBA process?
- What are scenarios and which ones should be considered?
- How can the wider benefits of energy efficiency be quantified?
- How can the tools of the REGIO1st Planning Framework support you in the CBA process?

Why do we need cost-benefit analysis?

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1 **Optimising resource allocation** | CBA helps to assess the economic viability of different projects before they are implemented. By systematically comparing the costs and benefits of energy efficiency solutions against other energy investments, it helps policymakers and planners to prioritise measures that offer the greatest net benefits.

2 **Assessing wider impacts and sustainability** | In regional energy planning, it is important to consider the long-term impacts of energy decisions. CBA enables planners to assess the sustainability of energy efficiency investments by quantifying not only direct financial savings, but also wider costs and benefits.

3 **Ensuring compliance with legal and policy requirements** | There are now strict legal requirements that mandate the use of CBA when dealing with the energy efficiency first principle. Meeting these requirements is key to successfully integrating energy efficiency into regional energy strategies and securing funding and support.

Some examples of CBA in EU legislation

Regulation (EU) 2018/1999, Art. 2(18)

‘energy efficiency first’ means taking utmost account in energy planning, and in policy and investment decisions, of alternative cost-efficient energy efficiency measures to make energy demand and energy supply more efficient, in particular by means of cost-effective end-use energy savings, demand response initiatives and more efficient conversion, transmission and distribution of energy, whilst still achieving the objectives of those decisions

Directive (EU) 2023/1791

Article 3(1) In accordance with the energy efficiency first principle, Member States shall ensure that energy efficiency solutions [...] are assessed in planning, policy and major investment decisions

Article 3(5) In applying the energy efficiency first principle, Member States shall (a) promote and, where cost-benefit analyses are required, ensure the application of, and make publicly available, cost-benefit methodologies that allow proper assessment of the wider benefits of energy efficiency solutions [...]

Article 25(3) For the purpose of the comprehensive assessment [...], Member States shall carry out a cost-benefit analysis covering their territory, [...] capable of facilitating the identification of the most resource- and cost-efficient solutions to meeting heating and cooling needs, taking into account the energy efficiency first principle.

...

Agenda

1 CBA essentials: Principles and methods

- 1.1 Step: Assess the potential of energy efficiency solutions
- 1.2 Step: Assess the potential of renewable energy sources
- 1.3 Step: Agree on modelling approaches and scenarios with stakeholders
- 1.4 Step: Model future techno-economic options
- 1.5 Step: Monetise benefits and wider impacts
- 1.6 Step: Identify optimal combinations of solutions
- 1.7 Step: Assess the sensitivity of the analysis
- 1.8 Limitations of CBA & outlook to next stage

2 CBA in action: Practical tools

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Overview of Step 5.1

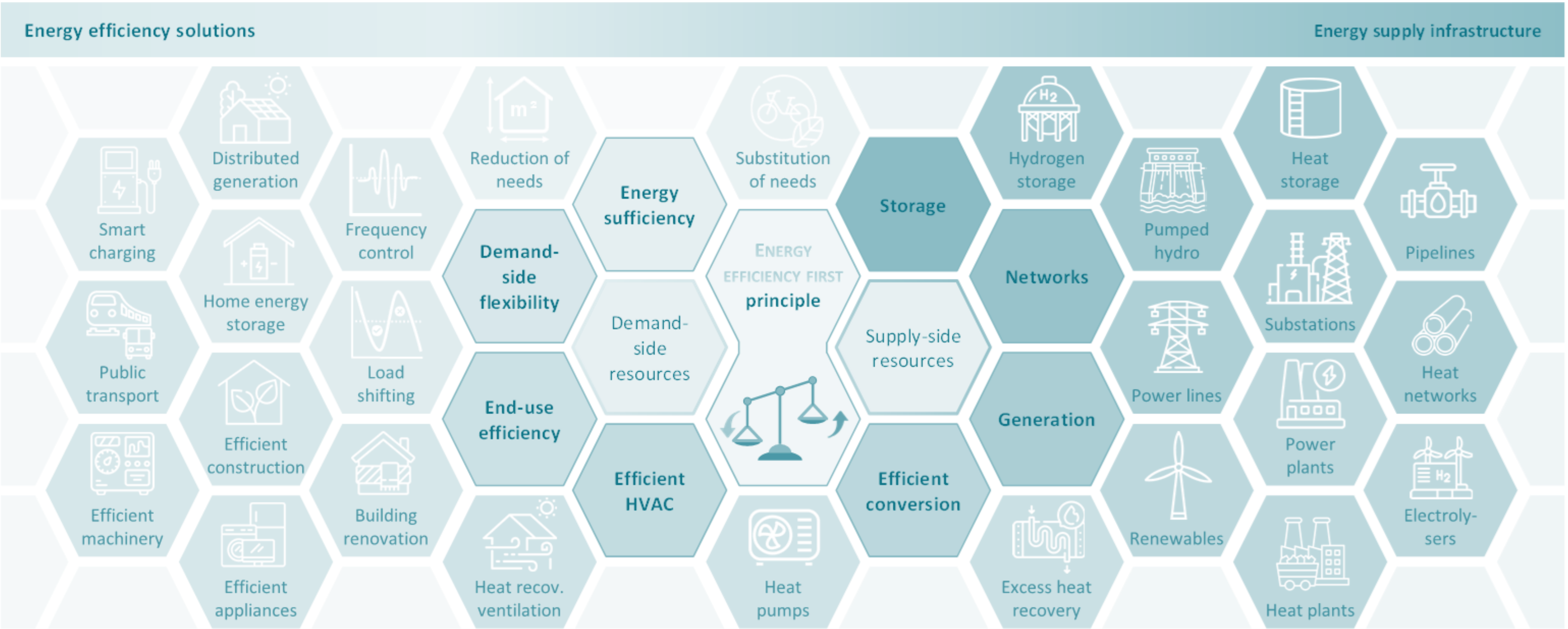
Assess the potential of energy efficiency solutions

In this step, planners should evaluate the potential uptake and impact of energy efficiency solutions. This should include identifying opportunities for energy conservation and energy efficiency improvements in various sectors, such as buildings, transportation, and industry. Planners should consider factors such as cost-effectiveness, technical feasibility, and potential for energy savings and greenhouse gas emissions reductions.

This step is key in properly incorporating the energy efficiency first principle in energy planning, by ensuring that the maximum possible uptake of such solutions is planned.

What are energy efficiency solutions?

Technologies, processes and practices that help us do the same activities (e.g. lighting our offices or powering machines) while consuming less energy.



So which energy efficiency solutions are relevant?

Energy efficiency is relevant across the entire energy conversion chain!

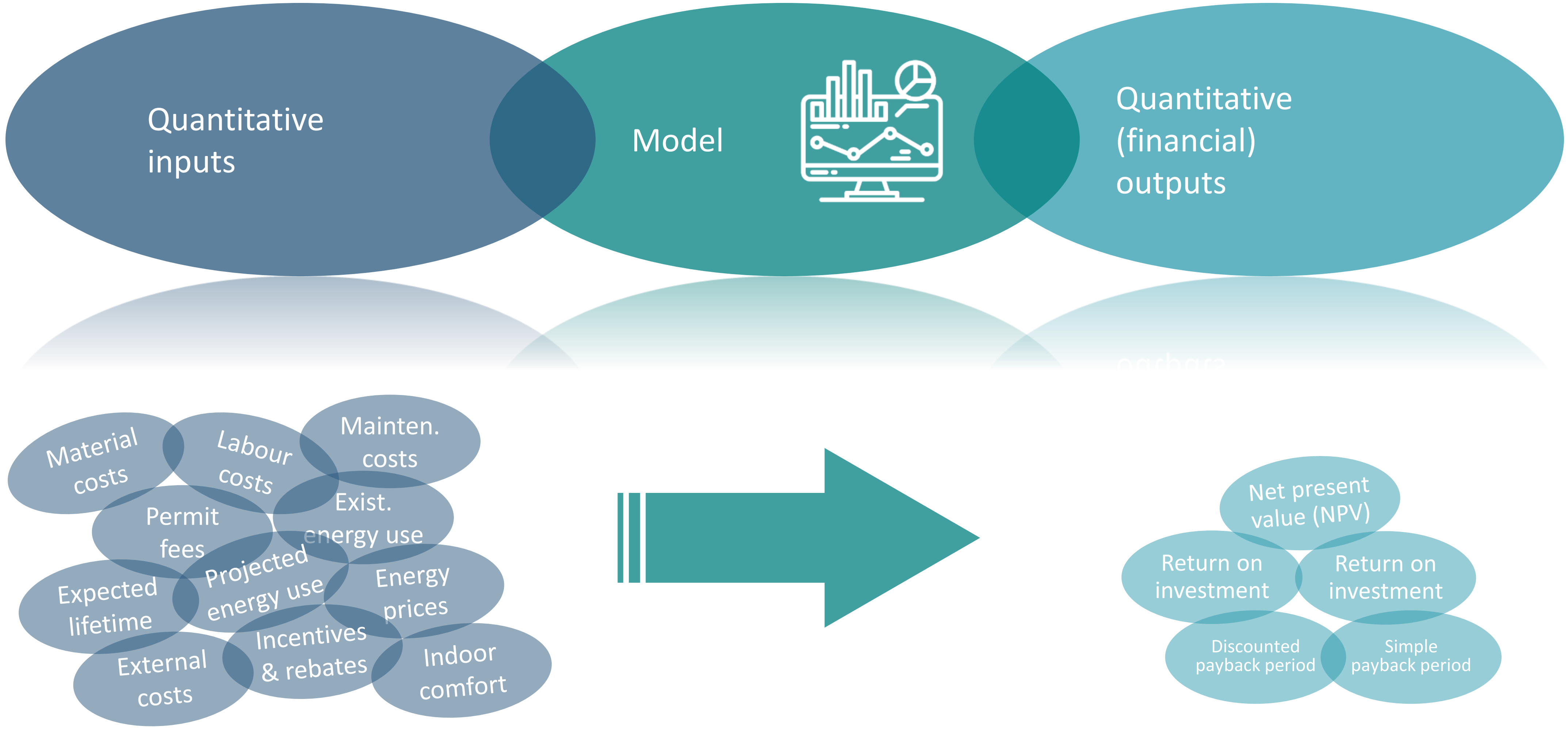
$$\eta = \left(\frac{Secondary\ energy}{Primary\ energy}\right) \times \left(\frac{Final\ energy}{Secondary\ energy}\right) \times \left(\frac{Useful\ energy}{Final\ energy}\right) \times \left(\frac{Energy\ service}{Useful\ energy}\right) \times \left(\frac{Utilty}{Energy\ service}\right)$$

	Conversion efficiency	Distribution efficiency	End-use efficiency	Service efficiency	Energy sufficiency

Example: The energy conversion chain for heating homes

Expressing energy efficiency	Electricity output [MWh] / primary energy input [MWh]	Electricity delivered [MWh] / electricity input [MWh]	heat output [MWh] / electricity input [MWh]	Heated floor space [m^2] / heat output [kWh]	"Happiness" [-] / heated space [m^2]
Efficient variant ✓	Wind turbine	High-voltage direct current (HVDC)	Ground-source heat pump	Modern, well-insulated home	Small, but well-designed home
Relatively inefficient variant ✗	Gas power plant	High voltage alternating current (HVAC)	Electric resistance heater	Old, poorly insulated home	Large, but poorly designed home

How to assess the potential of energy efficiency solutions?



What metrics can be used to assess cost effectiveness?

Metric	Formula		Significance
Net Present Value (NPV)	$NPV = -I_0 + \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t}$	$[EUR]$	Calculates the value of the retrofit in today's euros, considering the time value of money. Essential for economic evaluation.
Internal Rate of Return (IRR)	$0 = -I_0 + \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+IRR)^t}$	$[\%/yr]$	Determines the discount rate that makes the NPV of all cash flows equal to zero. Useful for comparing different investment returns.
Discounted Payback Period (DPP)	$0 = -I_0 + \sum_{t=1}^{t=DPP} \frac{B_t - C_t}{(1+i)^t}$	$[yr]$	Provides a realistic timeline for investment recovery by considering the time value.
Return on Investment (ROI)	$ROI = \frac{B_t - C_t}{I_0}$	$[\%/yr]$	Indicates profitability as a percentage of the investment. Useful for comparing profitability across investments.
Simple Payback Period (SPP)	$SPP = \frac{I_0}{B_t - C_t}$	$[yr]$	Measures the time it takes for the investment to repay its cost from savings. Simple and quick for preliminary assessment.

Simple calculation example: energy-efficient windows

Assumed input data

- Initial investment 5,000 EUR
- Annual energy savings 500 EUR/yr
- Lifetime of windows 20 years
- Discount rate 5%/yr

Net present value (NPV)

$$NPV = -5000 + \sum_{t=1}^{t=20} \frac{500}{(1+0.05)^t} = 1231$$

This indicates that the retrofit is expected to add approximately EUR 1,231 in net present value over its 20-year lifespan, accounting for the time value of money.

Internal rate of return (IRR)

$$0 = -5000 + \sum_{t=1}^{t=20} \frac{500}{(1+0.075)^t}$$

The IRR of 7.75% suggests that the project's return exceeds the discount rate of 5%, making it an attractive investment.

Discounted payback period (DPB)

$$0 = -5000 + \sum_{t=1}^{t=15} \frac{500}{(1+0.05)^t}$$

The DPP of 15 years means it will take 15 years for the cumulative discounted cash flows from the energy savings to cover the initial investment cost.

Simple payback period (SPP)

$$SPP = \frac{5000}{500} = 10$$

The SPP indicates that it will take 10 years for the savings from reduced energy costs to completely cover the initial investment of EUR 5,000.

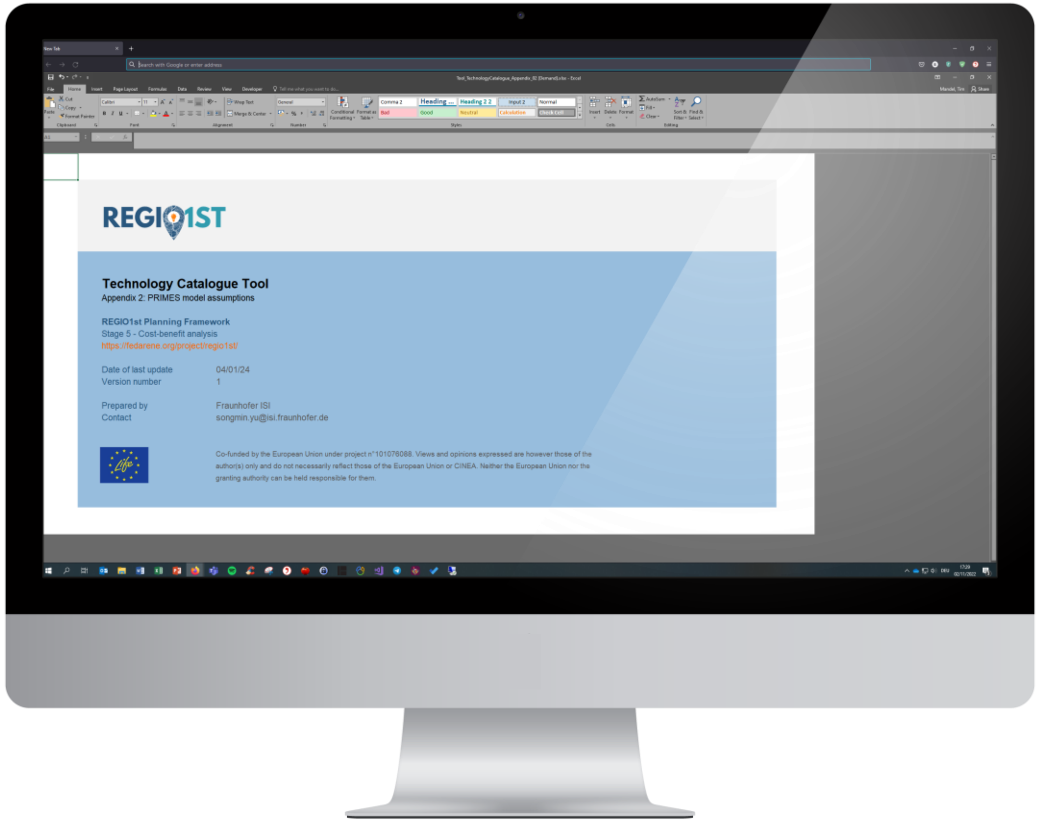
Return on investment (ROI)

$$NPV = \frac{500}{5000} = 0.10$$

The ROI of 10% indicates that each year, the homeowner effectively recoups 10% of the upfront cost through reduced energy expenses.

How to find techno-economic input data for efficiency?

Check out our Technology Catalogue Tool!



It provides a list of demand-side energy efficiency measures, together with available references and websites to collect data on their technical (e.g. savings achieved) and cost (e.g. investment) aspects.

More specifically, the tool brings together three main sources of data:

- EU Reference Scenario 2020 technology assumptions
- De-risking Energy Efficiency Platform (DEEP)
- EPREL - European Product Registry for Energy Labelling (EPREL)

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Overview of Step 5.2

Assess the potential of renewable energy resources

In addition to energy efficiency solutions, planners should also evaluate the potential of available renewable energy resources in the region. This may include solar, wind, biomass, hydro, and geothermal resources, among others. Planners should consider factors such as technical feasibility, environmental impact and potential for regional economic development. This assessment will help identify the most promising renewable energy options to incorporate in the regional energy plan.

What main types of renewables are of interest?

Solar energy

- Photovoltaic (PV) systems
- Concentrated solar power
- Solar heating & cooling

Hydro energy

- Run-of-river
- Pumped-storage
- Dams

Geothermal energy

- Direct use geothermal
- Geothermal power plants

Wind energy

- Onshore wind
- Offshore wind
- Micro wind turbines

Bioenergy

- Solid biomass
- Biogas
- Biofuel

How to determine the potential of renewables?

Approaches and techniques to determine the technical potential of renewables

1 **Resource assessment** | Quantify where the available resources (e.g. solar irradiance) are located using satellite date and historical weather data.

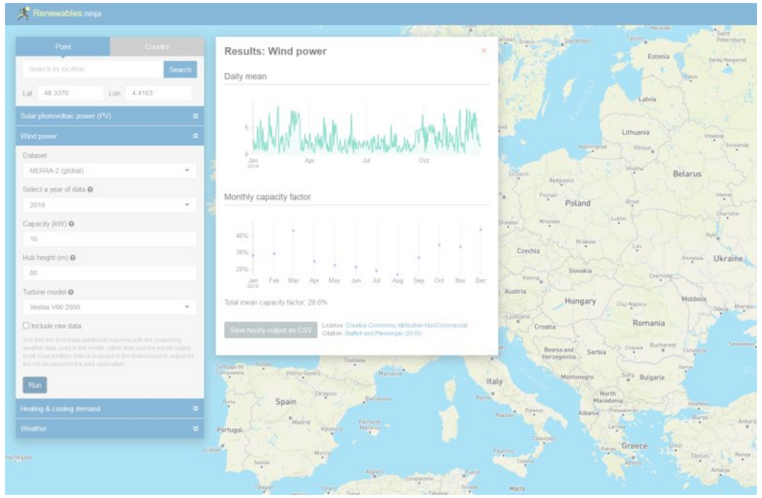
2 **Technological constraints** | Identifying and applying the limits of current technology (e.g. efficiency of solar panels, capacity factors for wind turbines).

3 **Spatial constraints** | Considering geographical and physical limitations where the technology can be deployed (e.g., land availability, env. protection zones).

4 **Performance simulation** | Using dedicated models to simulate the performance of a technology under various conditions to estimate energy output.

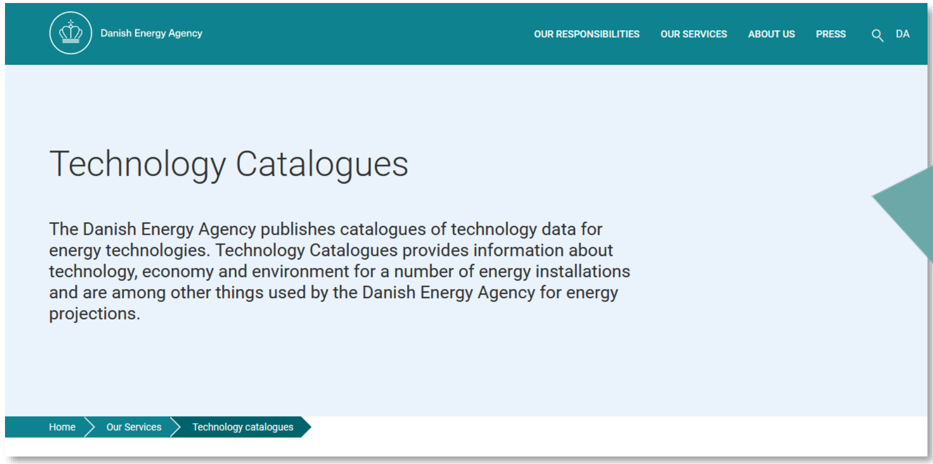
Geographic Information Systems (GIS)

Example tool: https://www.renewables.ninja/



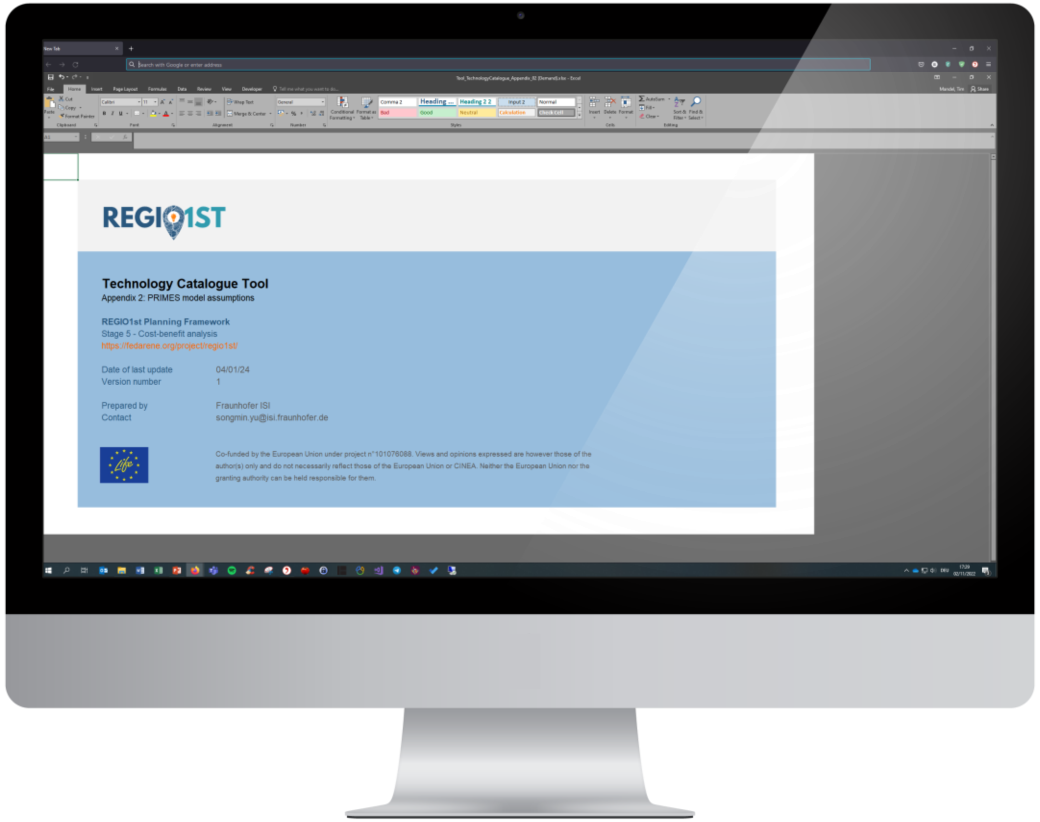
What about economic/financial data for renewables?

Danish Energy Agency | Technology Catalogues



https://ens.dk/en/our-services/technology-catalogues

Technology Catalogue Tool



How to adjust financial data for different countries?

Problem: Let's say an onshore wind turbine in Denmark costs 1,200 thousand EUR per MW_{el} of capacity. In the absence of specific data, how do you find out the equivalent cost of a wind turbine in Spain?

Proxy solution: Price level indices

eurostat

These indices provide a comparison of countries' price levels in relation to the EU average. This helps to understand the differences in price levels for different goods and services between countries.

Example

(1) Get cost data for Denmark

	Nominal investment (2020)	Equipment	Installation	Other
Wind turbine	1,200 $kEUR/MW_{el}$	63% 756 $kEUR/MW_{el}$	8% 96 $kEUR/MW_{el}$	29% 348 $kEUR/MW_{el}$

(2) Get price level indices from Eurostat

	Eurostat code	Unit	Denmark	Spain
Price level for machinery	PRC_PPP_IND	EU27=100	97.7	98.9
Labour cost level	LC_LCI_LEV	EU27=100	45.3	23.0

(3) Calculate cost for Spain

$$= 756 \times \frac{98.9}{97.7} + 96 \times \frac{23.0}{45.3} + 348 = 1162$$

The cost of the wind turbine in Spain can be estimated at 1,162 thousand EUR per MW_{el}.

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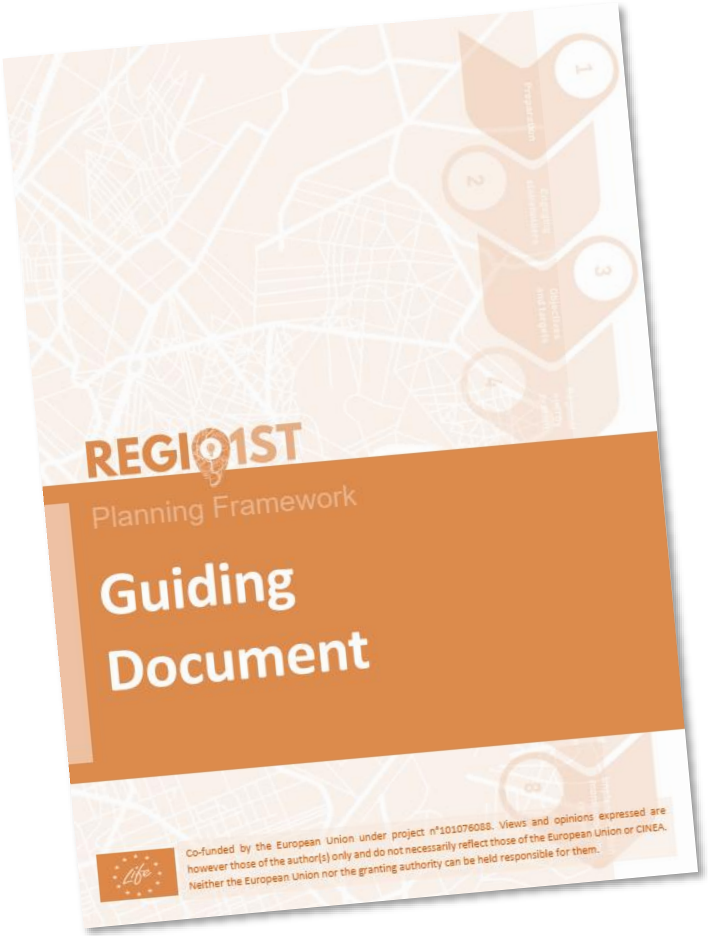
Overview of Step 5.3



Agree on modelling approaches and scenarios with stakeholders

Before conducting the cost-benefit analysis, planners should consult with stakeholders to agree on the modelling approaches and scenarios to be used. This may involve discussing appropriate analytical tools, determining key assumptions, and defining various future scenarios, such as business-as-usual, and energy efficiency-focused scenarios.

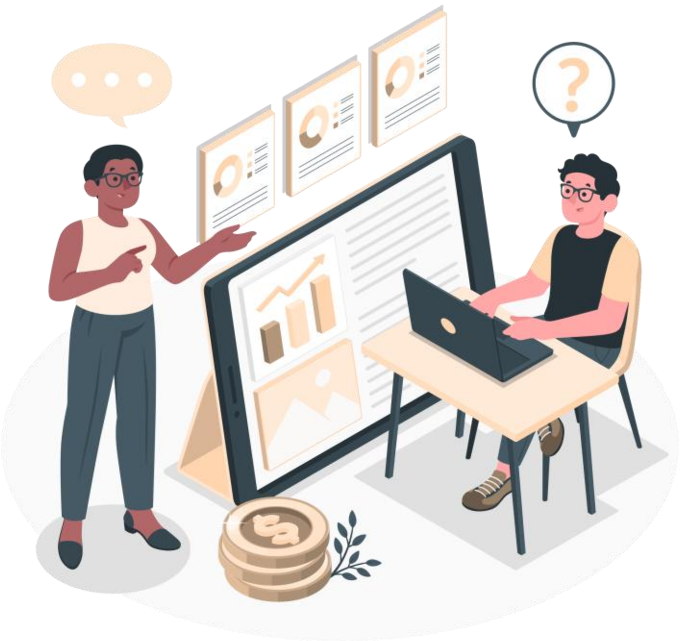
As such, this is an opportunity to communicate the benefits of incorporating the energy efficiency first principle in future scenarios and ensuring stakeholders buy-in.

Furthermore, stakeholders should be given the opportunity at this stage to provide data and evidence to support the cost-benefit analysis. Engaging stakeholders in this step will help ensure the transparency and credibility of the analysis.

What actually is modelling?

Understanding modelling

Modelling, in the context of energy systems and more generally, refers to the creation of a simplified representation of a real-world system in order to better understand, analyse and predict its behaviour under different conditions.



Key aspects of modelling

1 **Abstraction** | Creating a simplified version of the real system that captures the essential components and interactions. This involves identifying key variables, parameters and processes that influence the system.

2 **Mathematical representation** | Expressing the relationships and interactions within the system using mathematical equations, algorithms and logical rules.

3 **Validation and calibration** | Comparing the outputs of the model with real-world data to ensure its accuracy. Adjusting model parameters to better match observed behaviour is known as calibration.

4 **Scenario analysis** | Running the model under different hypothetical scenarios to explore potential outcomes. This can include changes in policy, technology, market conditions and environmental factors.

5 **Decision support** | Using the knowledge gained from the model to support decision making. This can help policymakers, and stakeholders make more informed decisions about investment and operations.

How complex is modelling and should I get help?

Factors that make modelling complex

- **Data collection**: Collecting accurate and comprehensive data on current energy consumption, production, infrastructure and future projections (see *Stage 4*).
- **Modelling tools**: Using advanced modelling tools to simulate different energy scenarios, which requires specialised expertise.
- **Integration of technologies and practices**: Considering the integration of different energy infrastructure (electricity, gas, heat, hydrogen) and energy efficiency options.
- **Cost-benefit analysis**: Assessing the economic feasibility of different energy technologies, including their wider impacts.

Pros and cons of carrying out the energy systems modelling yourself

	Doing it yourself	Getting professional help
+	Lower upfront cost, full control, internal skill development, flexibility	Specialized expertise, access to advanced resources, high-quality results, faster completion, increased credibility
-	Limited expertise, longer completion time, potential for errors, lower credibility	Higher upfront cost, less control, dependence on external help for future projects

Bottom line

Decision depends on the municipality's current **capabilities**, **budget**, **timeline** and long-term strategic **goals**. For complex projects such as developing a comprehensive energy plan for 2050, professional help can ensure a more robust and credible outcome.

What kind of scenarios should be analysed?

Is it absolutely necessary to have a baseline/business-as-usual (BAU) scenario when analysing the EE1st Principle?

No. The EE1st principle emphasises proactive, forward-looking planning rather than reactive measures based on the current trajectory. While a BAU scenario can provide a reference point to measure the impact of energy efficiency measures, the EE1st principle is inherently about finding the most cost-effective solutions from a societal perspective. Therefore, comparing different energy efficiency and energy supply scenarios can sufficiently highlight the benefits without the need for a BAU reference.

Comparing two net-zero emissions scenarios might be adequate for proactive planning.

		Energy Efficiency First Scenario	Net-Zero Energy Supply Infrastructure scenario
Energy supply	Electricity	Reducing demand and optimising usage through efficiency measures and demand-side flexibility.	Large-scale renewable energy projects and grid modernization.
Energy supply	District heating	Improving the efficiency of existing systems through heat recovery, heat pumps, and cogeneration systems.	Expansion of district heating networks with significant integration of renewables (e.g. biomass, geothermal).
Energy supply	Gas	Reduction in natural gas consumption through fuel switching and increased efficiency in buildings and industry.	Gradual transition from natural gas to biogas and synthetic methane.
Energy supply	Hydrogen	Hydrogen usage limited to specific application in industry and transport.	Large-scale development of hydrogen infrastructure and use in industry, transport, and heating.
Energy demand	Buildings	Promotion of building retrofitting, energy-efficient appliances and lighting. Comprehensive adoption of heat pumps.	Increased reliance on electricity from renewable sources for heating. Use of hydrogen for heating in buildings.
Energy demand	Industry	Adoption of energy-efficient machinery and equipment. Waste heat recovery and cogeneration.	Use of renewable electricity and hydrogen to power industrial processes.
Energy demand	Transport	Promotion of public transportation, cycling, and walking. Increased adoption of fuel-efficient and electric vehicles.	Use of renewable electricity to power EVs. Development of hydrogen refueling stations for fuel cell vehicles.

What about the societal perspective?

	Cost type	Example	Private perspective	Societal perspective
Direct (priced) costs	Equipment and installation costs	*Heat pump installation*	✓	✓
	Operation and maintenance costs	*Annual heating system maintenance*	✓	✓
	Fuel costs	*Biomass costs*	✓	✓
	Taxes and levies	*Value-added tax*	✓	✗
	Public grants and loans	*Building renovation grants*	✓	✗
	Policy implementation costs	*Administrative costs*	✗	✓
	Secondary market effects	*Employment effects*	✗	✓
indirect (unpriced) costs	External costs	*Air pollution damage costs*	✗	✓
	Transaction costs	*Time hassle for finding contractors*	✓	✓
	Other costs	*Indoor comfort in buildings*	✓	✓

How to involve stakeholders in the modelling?

Types of stakeholders to involve

- Government
- Utilities & suppliers
- Industry & business
- Research institutions
- Community & NGOs
- Financial institutions
- Technology providers
- General public

Key aspects of modelling for stakeholder input

- Priorities and objectives
- Data collection
- Scenario development
- Assumptions & parameters

Methods for engaging stakeholders

- Workshops & publ. meetings
- Surveys & questionnaires
- Focus groups
- Public consultations

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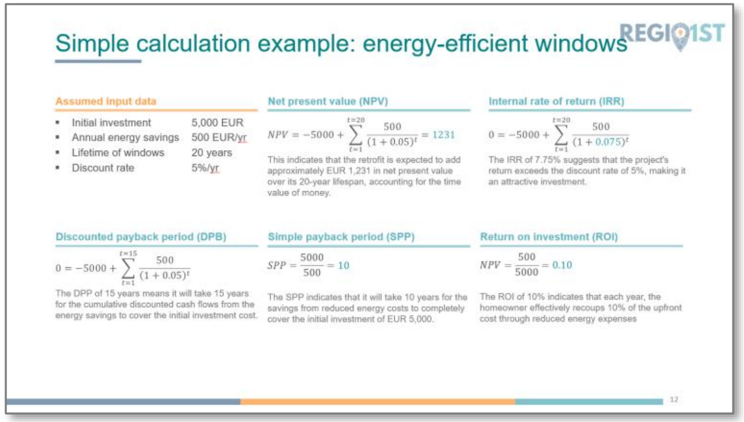
Overview of Step 5.4

Model future techno-economic options

With the modelling approaches and scenarios agreed upon, planners should conduct a cost-benefit analysis. This should involve modelling the future energy system under different scenarios, taking into account the potential of renewable energy resources, energy efficiency solutions, and other relevant factors. The analysis should also consider both direct costs, such as capital and operating costs of the solutions, and indirect costs, in order to identify the most cost-effective mix of solutions.

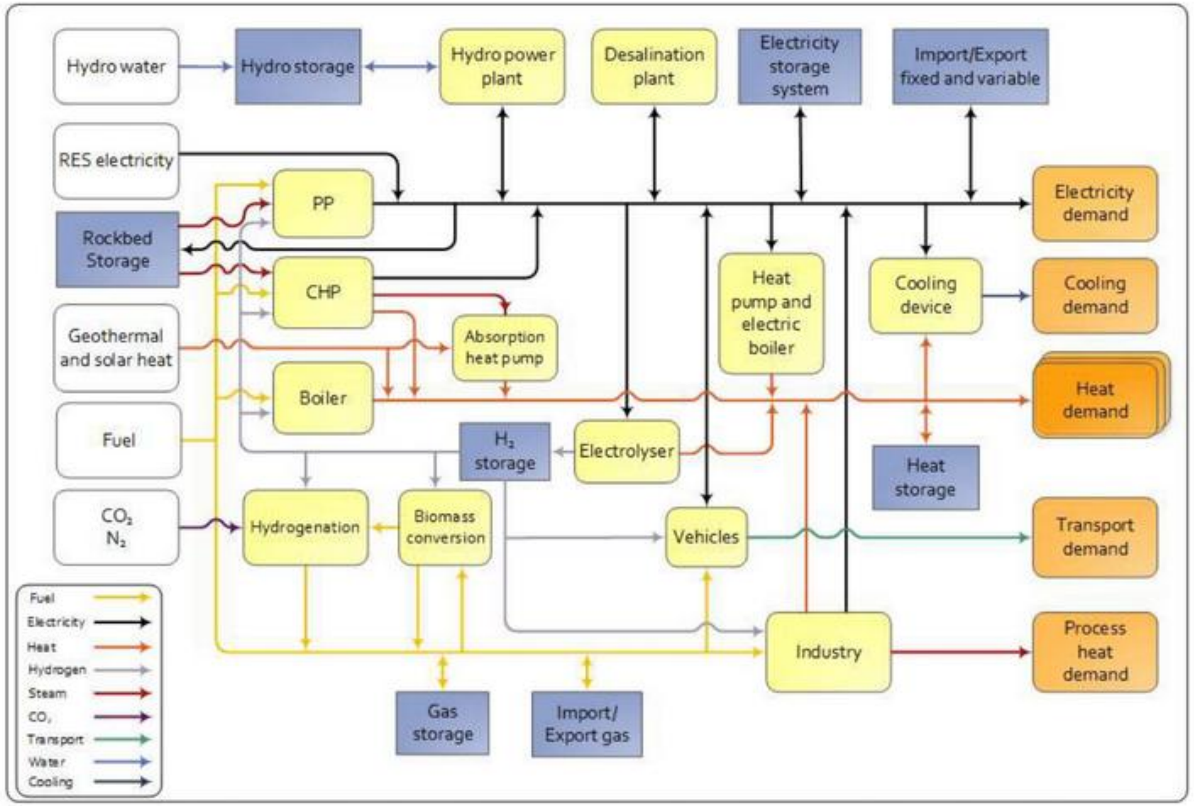
How to measure scenario performance in CBA (1/2)?

Simple situation: Single technology



In planning situations involving a single project such as a building retrofit, simple indicators such as Net Present Value (NPV) and Benefit-Cost Ratio (BCR) are very effective. NPV helps determine the net value created by the retrofit by discounting all future cash flows to the present, thus indicating the profitability of the project. The BCR compares the total present value of benefits to costs. These metrics are ideal for evaluating individual projects, allowing stakeholders to assess financial viability and economic impact directly and concisely.

More common planning situation: Multiple competing technologies



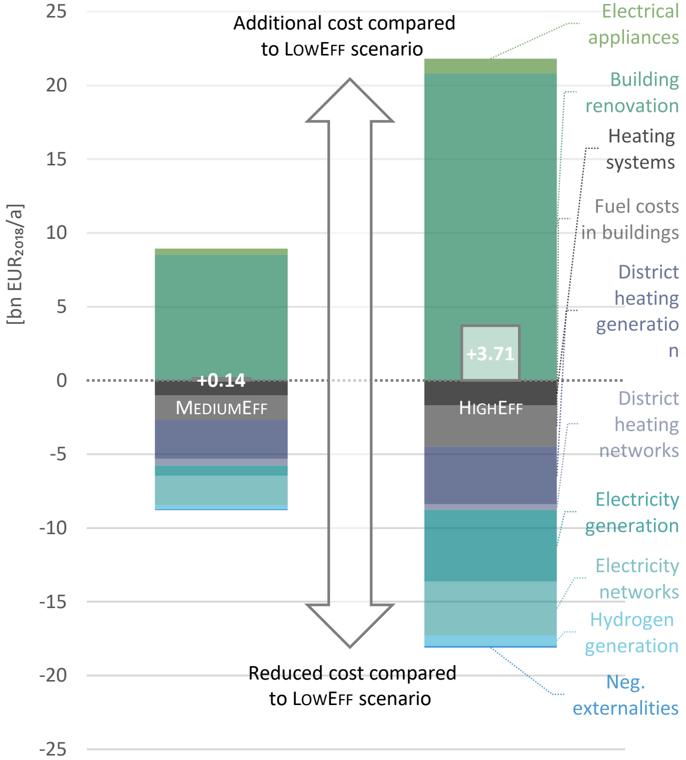
In complex scenarios involving multiple technologies, aggregated metrics such as Energy System Cost (ESC) are more appropriate. ESC evaluates the total costs associated with the entire energy system or a significant part of it. This includes all investments, operating costs, maintenance costs and all other costs involved in the energy conversion chain from generation to final use.

How to measure scenario performance in CBA (2/2)?

Practical example from the ENEFIRST project of using Energy System Cost (ESC) to measure scenario performance

COST TYPES *i*

COST ITEMS *j*	① Capital costs	② Fuel costs	③ O&M costs	④ Other costs
① Building renovation	Renovation measures on walls, roofs, windows, ventilation; etc.	-	-	-
② Electrical appliances	Refrigerators, washing machines, lighting, etc.	-	Fixed O&M	-
③ Heating systems	Decentralised boilers, ovens, heat pumps, solar thermal, etc.	-	Fixed O&M	-
④ Fuel costs in buildings	-	Gaseous/liquid fuels, bioenergy, minus hydrogen generation	-	-
⑤ District heating generation	Centralised boilers, CHP, heat pumps, solar, storage, etc.	Wholesale costs for fossil fuels and bioenergy carriers	Fixed & variable O&M	CO_2 emission certificates
⑥ District heating networks	Heat distribution networks	-	Fixed & variable O&M	-
⑦ Electricity generation	Fossil, nuclear, renewable plants, battery storage, etc.	Wholesale costs for fossil, nuclear, bio energy carriers	Import/export cost, fixed & variable O&M	CO_2 emission certificates
⑧ Electricity networks	Cross-border transmission networks, distribution networks	-	Fixed & variable O&M, system service costs	-
⑨ Hydrogen generation	Electrolysers, hydrogen storage, methanation reactors	-	Import/export cost, fixed & variable O&M	-
⑩ Negative externalities	-	-	-	Air pollution damage cost



ENEFIRST (2022): Quantifying Efficiency First in EU scenarios: implications for buildings and energy supply. Deliverable D3.3 of the ENEFIRST project. Brussels: ENEFIRST Project. Available online at http://enefirst.eu.

Mandel, Tim; Kranzl, Lukas; Popovski, Eftim; Sensfuß, Frank; Müller, Andreas; Eichhammer, Wolfgang (2023): Investigating pathways to a net-zero emissions building sector in the European Union: what role for the energy efficiency first principle? In Energy Efficiency 16 (4), pp. 1–29. DOI: 10.1007/s12053-023-10100-0.

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Overview of Step 5.5

Monetise benefits and wider impacts

In addition to direct (priced) costs, the cost-benefit analysis should also account for unpriced benefits and wider impacts, such as employment generation, local economic development, environmental benefits (e.g. improvements in air quality), public health benefits, and opportunity costs. Monetising benefits and wider impacts will help planners capture the full value of different energy options and inform decision-making.

Understanding wider benefits

What are wider or multiple benefits?

Wider benefits can be understood as the social, environmental and economic effects arising from implementing energy-related technologies and practices which are not immediate personal financial gains or losses that appear on an energy bill.

What multiple benefits are relevant?

ODYSSEE-MURE

https://www.odyssee-mure.eu/data-tools/multiple-benefits-energy-efficiency.html

How to quantify wider benefits (1/3)?

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Social indicators

Benefit	Description	Possible quantification and monetisation approaches
Living comfort	Improved insulation, heating, and cooling systems can make living and working environments more comfortable and contribute to better health	Survey-based measurements of comfort, potentially monetised through health cost savings (willingness to pay/accept method) or productivity gains (revealed preference method)
Energy poverty	Implementing energy efficiency measures can help alleviate energy poverty by making energy more affordable for low-income households	Savings on energy bills, reflected in disposable income of households (direct market valuation)
Property values	Energy-efficient buildings may have higher market value due to reduced energy costs and improved comfort	Change in property values, potentially monetised using real estate market data (hedonic pricing method)
Noise	Energy-efficient building design and insulation can help reduce noise from both external sources and internal systems, improving living and working conditions	Noise reduction quantified in decibels, monetised using property value impacts (hedonic pricing method) or health cost savings (willingness to pay/accept methods)

How to quantify wider benefits (2/3)?

Environmental indicators

Benefit	Description	Possible quantification and monetisation approaches
Greenhouse gases	Energy efficiency solutions can decrease the demand for energy, which often leads to lower greenhouse gas emissions	Quantified in tonnes of CO_2-equivalent reduced, potentially monetised using carbon pricing (direct market valuation)
Air quality	Reducing energy consumption can help decrease air pollution from power plants and industrial processes, benefiting public health and the environment	Quantified in reductions of pollutants, monetised using health impact costs (damage cost avoided method)
Water use	Energy-efficient technologies and practices can help decrease water usage, as water is often required for power generation and energy production processes. This can lead to lower water stress and reduced competition for water resources.	Water savings quantified in volume, potentially monetised using water pricing (direct market valuation)
Waste	Energy efficiency can lead to a reduction in waste generation, as less raw material is required for energy production, and more efficient processes produce less waste by-products.	Waste reduction quantified in weight/volume, monetised using waste disposal or recycling costs (avoided cost method)
Land requirements	By reducing the demand for land and resources associated with energy production, energy efficiency can contribute to the protection of ecosystems and the preservation of biodiversity.	Land savings quantified in area, potentially monetised using land value (direct market valuation) or ecosystem service valuations (willingness to pay method)

How to quantify wider benefits (3/3)?

Economic indicators

Benefit	Description	Possible quantification and monetisation approaches
Job creation	Investments in energy efficiency can create local jobs in areas such as construction, manufacturing, and energy services.	Jobs created, monetised using wage data (direct market valuation)
Workforce productivity	Energy-efficient workplaces can lead to better working conditions, boosting employee productivity and job satisfaction.	Productivity gains quantified using performance metrics, monetised using wage or output data (revealed preference method)
Energy security	Energy efficiency can help reduce a country's dependence on imported energy sources, enhancing national energy security.	Energy savings quantified in energy units, monetised using energy price forecasts (direct market valuation)
Innovation and competitiveness	Investments in energy efficiency can stimulate innovation in technology and business models, helping companies gain a competitive edge in global markets.	Difficult to directly quantify and monetise, but potential indicators include patents filed, new products launched, or changes in market share

Check out the MICATool to help quantify wider benefits.

What is the MICATool?

The MICATool (Multiple Impacts Calculation Tool) is a sophisticated tool designed to help quantify the wide range of benefits associated with energy efficiency measures. It enables a deeper understanding and assessment of not only the direct results, such as energy savings, but also the indirect effects, such as economic growth, environmental benefits and social impacts.

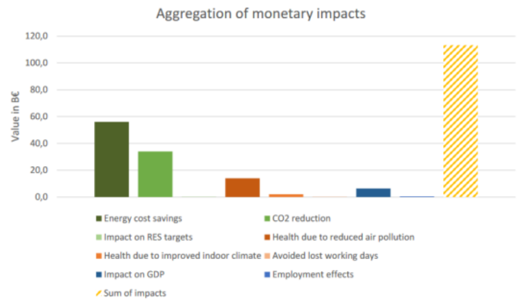
How does the MICATool work?

The MICATool works by integrating different models and data inputs to estimate the wider benefits of energy efficiency initiatives. Users enter custom parameters related to their energy efficiency projects, such as the type of measures to be implemented and the scale of the intervention. The tool then uses predefined methodologies and algorithms to calculate direct impacts, such as energy savings, and indirect impacts, including economic benefits and social improvements. This helps to assess the overall effects of energy efficiency measures.

How to access the MICATool?

The MICATool is available online and free of charge, making it accessible to a wide range of users interested in evaluating energy efficiency projects. It is currently in a beta phase, which means that although it is operational, it is still under development and may be updated and improved based on user feedback. To access the tool, users can visit the official website.

MICAT



https://app.micatool.eu/

https://micatool.eu/

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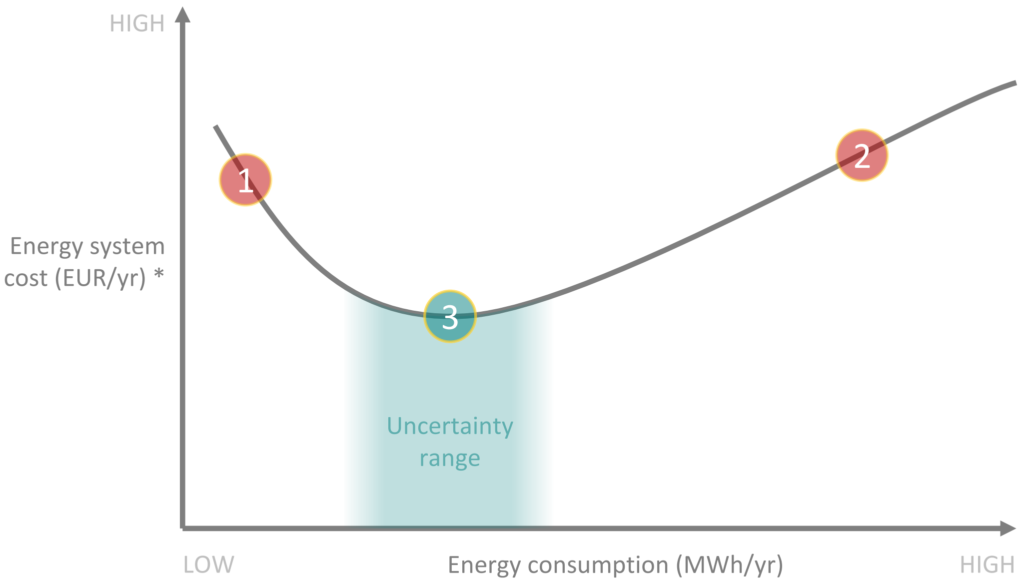
Overview of Step 5.6

Identify optimal combinations of solutions

By undertaking a cost-benefit analysis and comparing the costs and benefits of different options, planners should identify the least cost – greatest net benefits combinations of renewable energy resources and energy efficiency solutions that can achieve the region's energy objectives and targets.

What is the optimal solution in the context of EE1st?

Different combinations of energy consumption and energy system cost



* Total societal costs, including both direct (priced) costs, such as ongoing operating expenses, and indirect (unpriced) costs, such as the socio-environmental impacts of air pollution

1. **Too much energy efficiency** | Over-investment in energy efficiency can lead to diminishing returns. This occurs when the cost of implementing additional energy efficiency measures exceeds the benefits of the energy savings. For example, over-insulating a building may not produce energy savings proportional to the additional insulation costs.

2. **Too much energy infrastructure** | Conversely, over-investment in energy supply infrastructure can lead to under-utilisation and inefficiency. Building more generation capacity than needed can result in stranded assets or an overly expensive system where the capital-intensive nature of energy infrastructure is not fully utilised.

3. **Societal optimum** | The optimal solution involves finding the right mix of investments in energy efficiency and energy supply. This mix would aim to minimise the total cost of energy provided, including both direct and indirect costs (wider benefits), while ensuring reliability and meeting emission reduction targets.

Agenda

Overview of Step 5.7

Assess the sensitivity of the analysis

Finally, planners should assess the sensitivity of the cost-benefit analysis to uncertainties, such as changes in technology costs, energy prices, and policy frameworks. This will help planners understand the robustness of the analysis and identify potential risks and opportunities associated with different energy options.

How to assess the sensitivity of the analysis?

What is sensitivity analysis?

Sensitivity analysis is a technique used to determine how different values of an input variable within a given model may affect the outcome. This technique helps to identify which variables are most influential and how changes to them can affect the results of the model, thereby assessing the robustness of the model's predictions under varying conditions.

What approaches to sens. analysis are there?

Sensitivity analysis can be performed using a variety of approaches, ranging from simple to more complex methods:

- **Scenario analysis** | Scenarios are typically few in number and are chosen to represent different plausible futures or conditions.
- **One-at-a-time (OAT) analysis** | Changing one input variable at a time while holding other variables constant to assess the change in output.
- **Global sensitivity analysis** | Unlike OAT analysis, global methods consider the simultaneous variation of all input parameters. This approach provides a more comprehensive understanding of the effects of inputs over their full range and their interactions.

What input variables/parameters should be considered?

Parameters/Variables	Description
Discount rate	The interest rate used in discounted cash flow analysis.
Fuel prices	Cost of fuel resources over time.
Demand growth	Changes in energy service demand over time (e.g. living space in m²).
Resource availability (e.g., solar, wind intensity)	The availability and intensity of natural resources.
Lifetime of technology	The operational lifespan of energy systems or components.
Public acceptance	Acceptance of technologies or infrastructure can impact project feasibility and timelines.
...	...

Agenda

1 CBA essentials: Principles and methods

- 1.1 Step: Assess the potential of energy efficiency solutions
- 1.2 Step: Assess the potential of renewable energy sources
- 1.3 Step: Agree on modelling approaches and scenarios with stakeholders
- 1.4 Step: Model future techno-economic options
- 1.5 Step: Monetise benefits and wider impacts
- 1.6 Step: Identify optimal combinations of solutions
- 1.7 Step: Assess the sensitivity of the analysis
- 1.8 Limitations of CBA & outlook to next stage

2 CBA in action: Practical tools

What are the limitations of CBA?

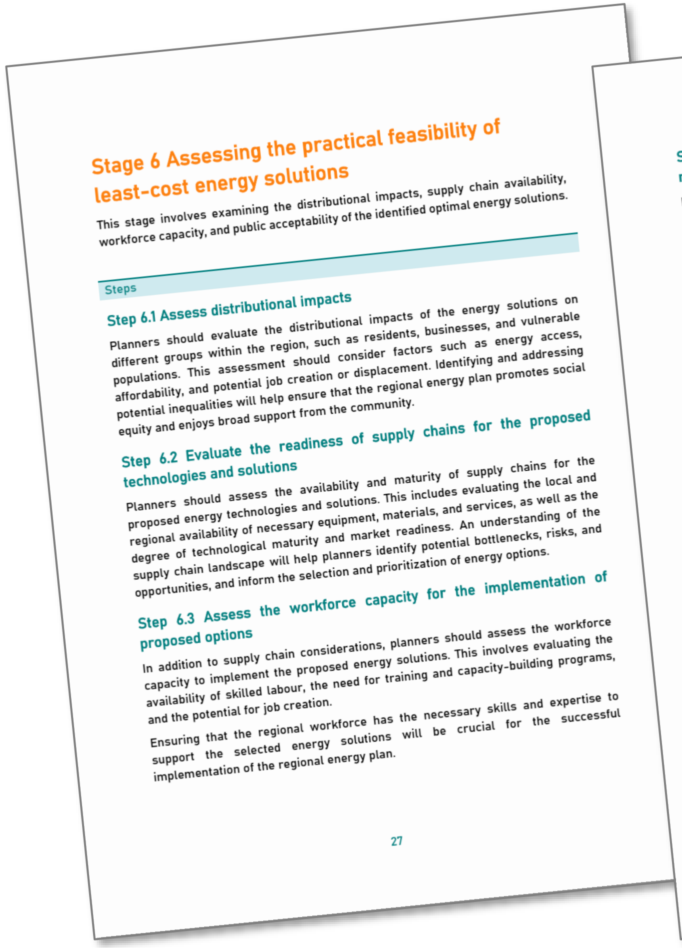
Cost-benefit analysis (CBA) is a valuable tool in the context of energy planning, but it has several methodological limitations:

- **Quantifying wider benefits** | Many of the benefits of energy efficiency and renewable energy, such as improved public health, environmental sustainability and increased energy security, are still difficult to quantify in monetary terms. This can lead to their under-representation in the analysis, potentially biasing decisions against initiatives that have significant non-monetary benefits.
- **Risk and uncertainty** | There is inherent uncertainty in predicting future energy prices, policy impacts and technological advances. This uncertainty can be difficult to incorporate into a CBA, leading to either overly optimistic or overly cautious estimates.
- **Scenario settings** | The results of a CBA can be highly sensitive to the assumptions and scenarios used. Different assumptions about economic growth, energy demand or emissions targets can lead to very different conclusions, making the analysis susceptible to bias or manipulation.
- **Distributional impacts** | CBA generally focuses on aggregate costs and benefits and may not consider how these are distributed among different groups within society. This can obscure the impact on vulnerable groups or fail to address equity concerns.

Criteria that are often hard to monetise and thus hard to integrate in a CBA

Criterion	Description
Technology availability	Availability and accessibility of specific technologies.
Implementation duration	Time required to install the heating solutions and make them operational.
System reliability	Likelihood and frequency of system failures or maintenance needs.
Scalability	Ability of the system to cope with future demands or expansions.
Aesthetics	Impact of the installation measures on the visual appearance of the neighborhood.
Flexibility	Ability of the system to adapt to changing conditions, e.g., fluctuating energy prices.
Regulatory compliance	Compliance with local, national, and international regulations and laws.
Distributional effects	Equity considerations and impacts on vulnerable populations.

Coming up in the Stage 6 workshop



Stage 6 Assessing the practical feasibility of least-cost energy solutions

This stage involves examining the distributional impacts, supply chain availability, workforce capacity, and public acceptability of the identified optimal energy solutions.

Steps

Step 6.1 Assess distributional impacts

Planners should evaluate the distributional impacts of the energy solutions on different groups within the region, such as residents, businesses, and vulnerable populations. This assessment should consider factors such as energy access, affordability, and potential job creation or displacement. Identifying and addressing potential inequalities will help ensure that the regional energy plan promotes social equity and enjoys broad support from the community.

Step 6.2 Evaluate the readiness of supply chains for the proposed technologies and solutions

Planners should assess the availability and maturity of supply chains for the proposed energy technologies and solutions. This includes evaluating the local and regional availability of necessary equipment, materials, and services, as well as the degree of technological maturity and market readiness. An understanding of the supply chain landscape will help planners identify potential bottlenecks, risks, and opportunities, and inform the selection and prioritization of energy options.

Step 6.3 Assess the workforce capacity for the implementation of proposed options

In addition to supply chain considerations, planners should assess the workforce capacity to implement the proposed energy solutions. This involves evaluating the availability of skilled labour, the need for training and capacity-building programs, and the potential for job creation.

Ensuring that the regional workforce has the necessary skills and expertise to support the selected energy solutions will be crucial for the successful implementation of the regional energy plan.

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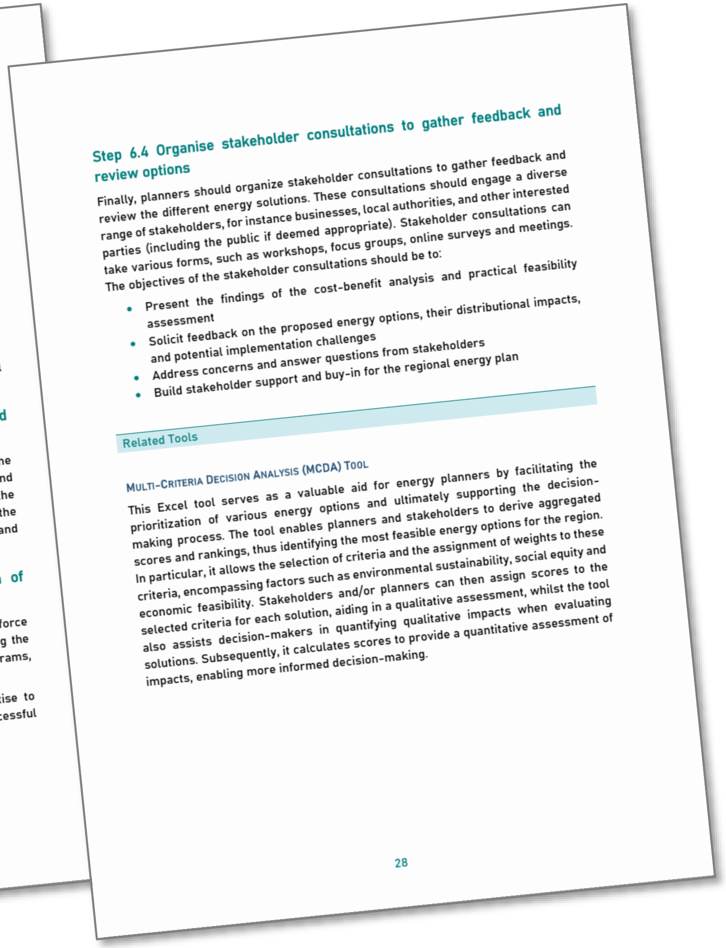

Step 6.4 Organise stakeholder consultations to gather feedback and review options

Finally, planners should organize stakeholder consultations to gather feedback and review the different energy solutions. These consultations should engage a diverse range of stakeholders, for instance businesses, local authorities, and other interested parties (including the public if deemed appropriate). Stakeholder consultations can take various forms, such as workshops, focus groups, online surveys and meetings. The objectives of the stakeholder consultations should be to:

- Present the findings of the cost-benefit analysis and practical feasibility assessment
- Solicit feedback on the proposed energy options, their distributional impacts, and potential implementation challenges
- Address concerns and answer questions from stakeholders
- Build stakeholder support and buy-in for the regional energy plan

Related Tools

Multi-Criteria Decision Analysis (MCDA) Tool

This Excel tool serves as a valuable aid for energy planners by facilitating the prioritization of various energy options and ultimately supporting the decision-making process. The tool enables planners and stakeholders to derive aggregated scores and rankings, thus identifying the most feasible energy options for the region. In particular, it allows the selection of criteria and the assignment of weights to these criteria, encompassing factors such as environmental sustainability, social equity and economic feasibility. Stakeholders and/or planners can then assign scores to the selected criteria for each solution, aiding in a qualitative assessment, whilst the tool also assists decision-makers in quantifying qualitative impacts when evaluating solutions. Subsequently, it calculates scores to provide a quantitative assessment of impacts, enabling more informed decision-making.

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Let’s check out the tool

Cost-Benefit Analysis Tool

REGIO 1st Planning Framework
Stage 5 - Cost-benefit analysis
https://fedarene.org/project/regio1st/

Date of last update	30/10/2023
Version number	2

Prepared by	Fraunhofer ISI
Contact	songmin.yu@isi.fraunhofer.de tim.mandel@isi.fraunhofer.de

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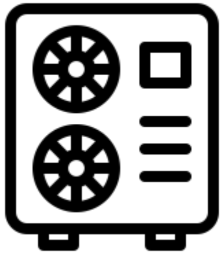
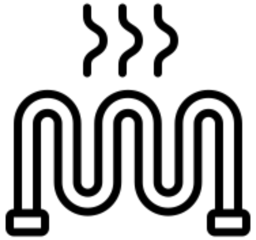
Overall logic of the tool

To maintain the same comfort level (i.e., indoor temperature range), less "useful energy" is needed.

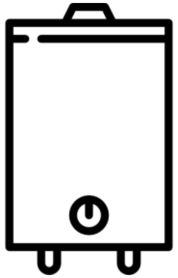
Gas Boiler



Heat Pump



District Heating



Biomass Boiler

levelized cost to reduce (EUR/kWh)

levelized cost to supply (EUR/kWh)

Useful Energy Demand

Definition: the amount of energy that is effectively utilized for a specific purpose or end-use, i.e., the heat radiated from the heating system to the building.

Agenda

1 **CBA essentials: Principles and methods**

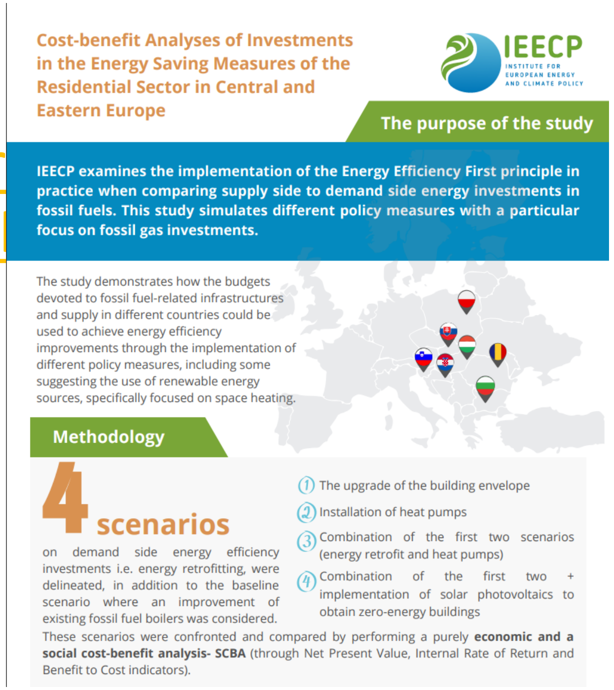
2 **CBA in action: Practical tools**

- 2.1 **REGIO1st CBA Tool**
- 2.2 **IEECP CBA Tool**

Theoretical background of the tool

- Two types of CBA: (Original) CBA and Social CBA
- Original CBA: The **economic** impacts are identified, and the evaluation is performed taking into consideration the impacts of **national economy**. The analysis is based on changes in **market prices**.
- Social CBA: Includes **environmental** and **social** impacts.

Used for the study Cost-benefit Analyses of Investments in the Ener Measures of the Residential Sector in Central and Eastern Europe - I



Cost-benefit Analyses of Investments in the Energy Saving Measures of the Residential Sector in Central and Eastern Europe

IEECP INSTITUTE FOR EUROPEAN ENERGY AND CLIMATE POLICY

The purpose of the study

IEECP examines the implementation of the Energy Efficiency First principle in practice when comparing supply side to demand side energy investments in fossil fuels. This study simulates different policy measures with a particular focus on fossil gas investments.

The study demonstrates how the budgets devoted to fossil fuel-related infrastructures and supply in different countries could be used to achieve energy efficiency improvements through the implementation of different policy measures, including some suggesting the use of renewable energy sources, specifically focused on space heating.

Methodology

4 scenarios

on demand side energy efficiency investments i.e. energy retrofitting, were delineated, in addition to the baseline scenario where an improvement of existing fossil fuel boilers was considered.

1. The upgrade of the building envelope
2. Installation of heat pumps
3. Combination of the first two scenarios (energy retrofit and heat pumps)
4. Combination of the first two + implementation of solar photovoltaics to obtain zero-energy buildings

These scenarios were confronted and compared by performing a purely **economic and a social cost-benefit analysis- SCBA** (through Net Present Value, Internal Rate of Return and Benefit to Cost indicators).

Theoretical background of the tool

Potential result of calculations	Financial NPV	Social NPV	Conclusions	Next steps
1st	≥ 0	≥ 0	Economically and socially beneficial to invest/implement projects/interventions.	Promoting these types of investments/interventions
2nd	≤ 0	≥ 0	Economically is not beneficial. However, socially is important to invest/implement the project/intervention.	Providing financial supports, e.g., subsidies, increasing municipality's equity share in the investment
3rd	≥ 0	≤ 0	Economically is beneficial to invest on a project and not socially beneficial.	Penalty for the investors and imposing the incentives that distribute the economic benefits among different groups, such as tax.
4rth	≤ 0	≤ 0	Economically and socially is not beneficial.	Stop the investments/interventions

Six steps

(1) Identifying system boundaries

(2) Defining the baseline scenario

(3) Specifying the alternative scenarios

(4) Identifying and quantifying the positive and negative externalities

(5) Valuating the economic and environmental costs/benefits

(6) Calculating the NPV, IRR, B/C

Step 1: Define the system boundaries

- Set the CBA boundaries to either **national** or **regional**

Different energy system in each jurisdiction, different energy data and scenarios required!

Step 2: Define the baseline scenario

- Select the investment on the supply side for the expansion of fossil fuels and the current energy efficiency technologies in the buildings

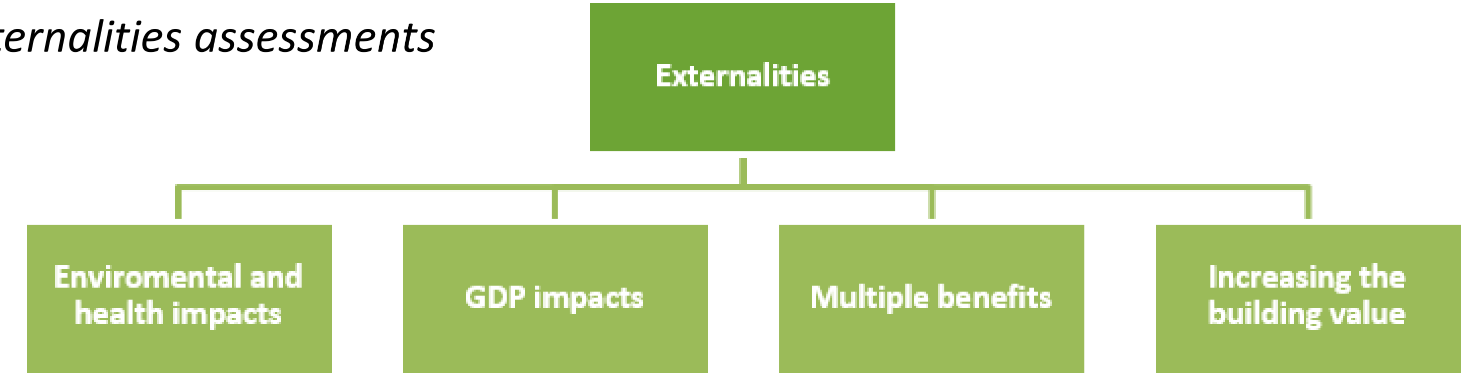
Available budget for fossil fuels	4,350,000,000	€
Unitary investment cost	3,000	€
Unitary investment cost with subsidy	3,000	€
Avoided cost from new fossil fuel boiler	0	€
Number of influenced households	1,450,000	number of households
Unitary energy consumption for space cooling	32	kWh
Unitary energy consumption for space heating	6,312	kWh
Performance ratio of energy efficient boiler	95%	%
Performance ratio existing boiler	85%	%
Energy consumption after the interventions	5,647	kWh
Electricity price	0.17	€/kWh
Existing fuel price for space heating	0.06	€/kWh
Cost of operation and maintenance - Baseline scenario	0	€
Cost of operation and maintenance - Alternative scenario	0	€
Remaining value	10%	% of capital cost
Discount rate	1%	%

Step 3: Specify the alternative scenarios

- The energy efficiency technologies are assessed within the alternative Scenarios and the existing technology within the baseline Scenario (supply side investment).
- For example, in the aforementioned study we selected five scenarios:
  - Scenario 1: Building envelope improvement
  - Scenario 2: Heat pump installations
  - Scenario 3: Photovoltaic solar panels
  - Scenario 4: Building envelope improvement + Heat pump installation (NZEB)
  - Scenario 5: Zero energy buildings

Step 4: Identify and quantify positive and negative externalities

Data from Horizon 2020 PRODESA project – will be enhanced with MICAT tool and other externalities assessments



Data	Oil boiler-existing	Oil boiler-new	NG boiler-existing	NG boiler-new	Coal boiler-existing	Biomass boiler-existing	Biomass boiler-new	HP-existing	HP-new	Electricity-current	PV-new	Solar-new
External cost (EUR/MWh)	32	27.2	20	17.9	27.2	20	11.2	23.5	14.2	48.5	14.1	9.6

Step 5: Quantify the CBA and SCBA components

Cost	Description
Operational and maintenance costs	• Operational and maintenance cost of the new energy efficient equipment/technology
Operational and maintenance benefits	● Avoided operational and maintenance cost of the existing technology for the average-income group of households
Fuel costs	● Fuel cost of the new energy efficient equipment/technology
Fuel benefits	● Avoided fuel cost of the existing equipment/technology
External costs	● Environmental and health cost of the new energy efficient equipment/technology
External benefits	● Avoided environmental and health cost of the existing equipment/technology ● Macroeconomic effects due to the new energy efficient equipment/technology ● Effects due to the improved comfort levels due to the new energy efficient equipment/technology ● Increased market value of the renovated buildings
Capital costs	● Capital cost of the new energy efficient equipment/technology

Step 6: Calculate the evaluation indicators

- Three main indicators will be used to make comparisons:
  - Net Present Value (NPV)
  - Internal Rate of Return (IRR)
  - Benefit to cost ratio (B/C)

Example: Application of the tool in Romania for the 1° income decile

REGIO1ST

- Input data needed (in kWh)

	Total	Total	Heating	Cooling	DHW	Cooking	Electric appliances & Lighting
Romania	Electricity	1,830	16	42	35	1	1,736
	Heating oil	67	0		14	53	
	LPG	465	1		97	367	
	Natural gas	3,955	2,315		899	740	
	Solar thermal	0	0		0		
	Ambient heat	0	0				
	Biomass	4,942	4,232		632	78	
	District heating	1,144	1,144		0		
	Other	66	46		15	5	
	Total	12,467	7,753	42	1,692	1,244	1,736

Example: Input and results from CBA in Scenario 2

Available budget for fossil fuels	4,350,000,000	€	
Unitary investment cost	6,000	€	
Unitary investment cost with subsidy	6,000	€	
Avoided cost from new fossil fuel boiler	3,000	€	
Number of influenced households	725,000	number of households	64.4%
Energy consumption for space cooling	32	kWh	
Energy consumption for space heating	6,312	kWh	
Performance ratio existing boiler	85%	%	
COP heat pump	3.0		
Electricity price	0.17	€/kWh	
Existing fuel price for space heating	0.06	€/kWh	
Cost of operation and maintenance - Baseline scenario	0	€	
Cost of operation and maintenance - Alternative scenario	0	€	
Remaining value	0%	% of capital cost	
Discount rate	1%	%	

NPV	**-1,426,657,108**
IRR	**-13%**
B/C	**0.69**

Example: Illustration of cash flows per year

Year	O&M Cost	O&M Benefit	Fuel cost	Fuel benefit	Investment cost	Remaining value	Net cash flow
0					€ 2,175,000,000		-€ 2,175,000,000
1	€ 0	€ 0	€ 218,595,781	€ 285,085,141			€ 66,489,360
2	€ 0	€ 0	€ 218,595,781	€ 285,085,141			€ 66,489,360
3	€ 0	€ 0	€ 218,595,781	€ 285,085,141			€ 66,489,360
4	€ 0	€ 0	€ 218,595,781	€ 285,085,141			€ 66,489,360
5	€ 0	€ 0	€ 218,595,781	€ 285,085,141			€ 66,489,360
6	€ 0	€ 0	€ 218,595,781	€ 285,085,141			€ 66,489,360
7	€ 0	€ 0	€ 218,595,781	€ 285,085,141			€ 66,489,360
8	€ 0	€ 0	€ 218,595,781	€ 285,085,141			€ 66,489,360
9	€ 0	€ 0	€ 218,595,781	€ 285,085,141			€ 66,489,360
10	€ 0	€ 0	€ 218,595,781	€ 285,085,141			€ 66,489,360
11	€ 0	€ 0	€ 218,595,781	€ 285,085,141			€ 66,489,360
12	€ 0	€ 0	€ 218,595,781	€ 285,085,141		€ 0	€ 66,489,360
Total	**€ 0**	**€ 0**	**€ 2,460,312,455**	**€ 3,208,655,347**	**€ 2,175,000,000**	**€ 0**	**-€ 1,426,657,108**

Example: Input and results from SCBA in Scenario 2

Available budget for fossil fuels	4,350,000,000	€	
Unitary investment cost	6,000	€	
Avoided cost from new fossil fuel boiler	3,000	€	
Number of influenced households	725,000	number of households	64.4%
Energy consumption for space cooling	32	kWh	
Energy consumption for space heating	6,312	kWh	
Performance ratio existing boiler	85%	%	
COP heat pump	3.0		
Electricity price	0.16	€/kWh	
Existing fuel price for space heating	0.06	€/kWh	
Cost of operation and maintenance - Baseline scenario	0	€	
Cost of operation and maintenance - Alternative scenario	0	€	
Remaining value	0%	% of capital cost	
Discount rate	1%	%	

NPV	**2,316,254,457**
IRR	**17%**
B/C	**1.48**

Example: Illustration of cash flows per year

Year	O&M Cost	O&M Benefit	Fuel cost	Fuel benefit	External cost	External benefit	Investment cost	Remaining value	Net cash flow
0						€ 0	€ 1,827,731,092		-€ 1,827,731,092
1	€ 0	€ 0	€ 208,186,458	€ 271,509,658	€ 55,232,386	€ 360,097,283			€ 368,188,096
2	€ 0	€ 0	€ 208,186,458	€ 271,509,658	€ 55,232,386	€ 360,097,283			€ 368,188,096
3	€ 0	€ 0	€ 208,186,458	€ 271,509,658	€ 55,232,386	€ 360,097,283			€ 368,188,096
4	€ 0	€ 0	€ 208,186,458	€ 271,509,658	€ 55,232,386	€ 360,097,283			€ 368,188,096
5	€ 0	€ 0	€ 208,186,458	€ 271,509,658	€ 55,232,386	€ 360,097,283			€ 368,188,096
6	€ 0	€ 0	€ 208,186,458	€ 271,509,658	€ 55,232,386	€ 360,097,283			€ 368,188,096
7	€ 0	€ 0	€ 208,186,458	€ 271,509,658	€ 55,232,386	€ 360,097,283			€ 368,188,096
8	€ 0	€ 0	€ 208,186,458	€ 271,509,658	€ 55,232,386	€ 360,097,283			€ 368,188,096
9	€ 0	€ 0	€ 208,186,458	€ 271,509,658	€ 55,232,386	€ 360,097,283			€ 368,188,096
10	€ 0	€ 0	€ 208,186,458	€ 271,509,658	€ 55,232,386	€ 360,097,283			€ 368,188,096
11	€ 0	€ 0	€ 208,186,458	€ 271,509,658	€ 55,232,386	€ 360,097,283			€ 368,188,096
12	€ 0	€ 0	€ 208,186,458	€ 271,509,658	€ 55,232,386	€ 360,097,283		€ 0	€ 368,188,096
Total	**€ 0**	**€ 0**	**€ 2,343,154,719**	**€ 3,055,862,235**	**€ 621,644,784**	**€ 4,052,922,817**	**€ 1,827,731,092**	**€ 0**	**€ 2,316,254,457**

Example: Input and results from CBA in Baseline Scenario

REGIO1ST

Available budget for fossil fuels	4,350,000,000	€	
Unitary investment cost	3,000	€	
Unitary investment cost with subsidy	3,000	€	
Avoided cost from new fossil fuel boiler	0	€	
Number of influenced households	1,450,000	number of households	128.8%
Unitary energy consumption for space cooling	32	kWh	
Unitary energy consumption for space heating	6,312	kWh	
Performance ratio of energy efficient boiler	95%	%	
Performance ratio existing boiler	85%	%	
Energy consumption after the interventions	5,647	kWh	
Electricity price	0.17	€/kWh	
Existing fuel price for space heating	0.06	€/kWh	
Cost of operation and maintenance - Baseline scenario	0	€	
Cost of operation and maintenance - Alternative scenario	0	€	
Remaining value	10%	% of capital cost	
Discount rate	1%	%	

NPV	**-3,517,848,326**
IRR	**-15%**
B/C	**0.69**

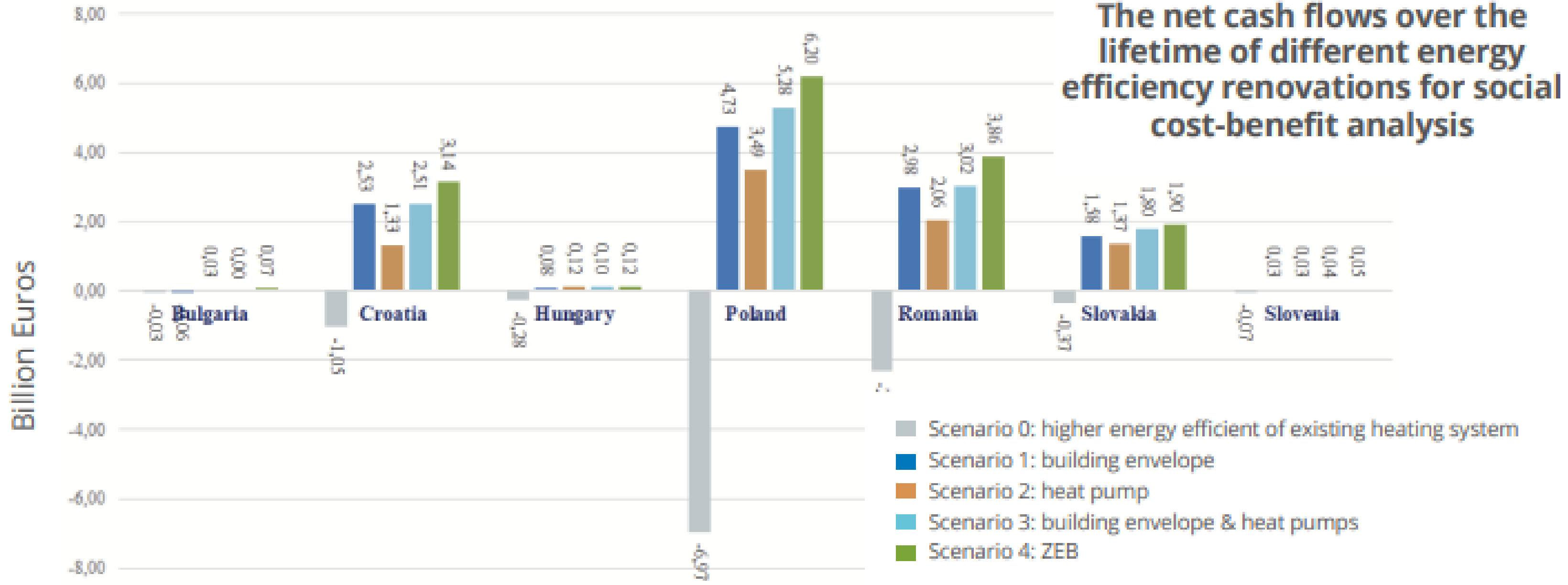
Example: Input and results from SCBA in Baseline Scenario

REGIO1ST

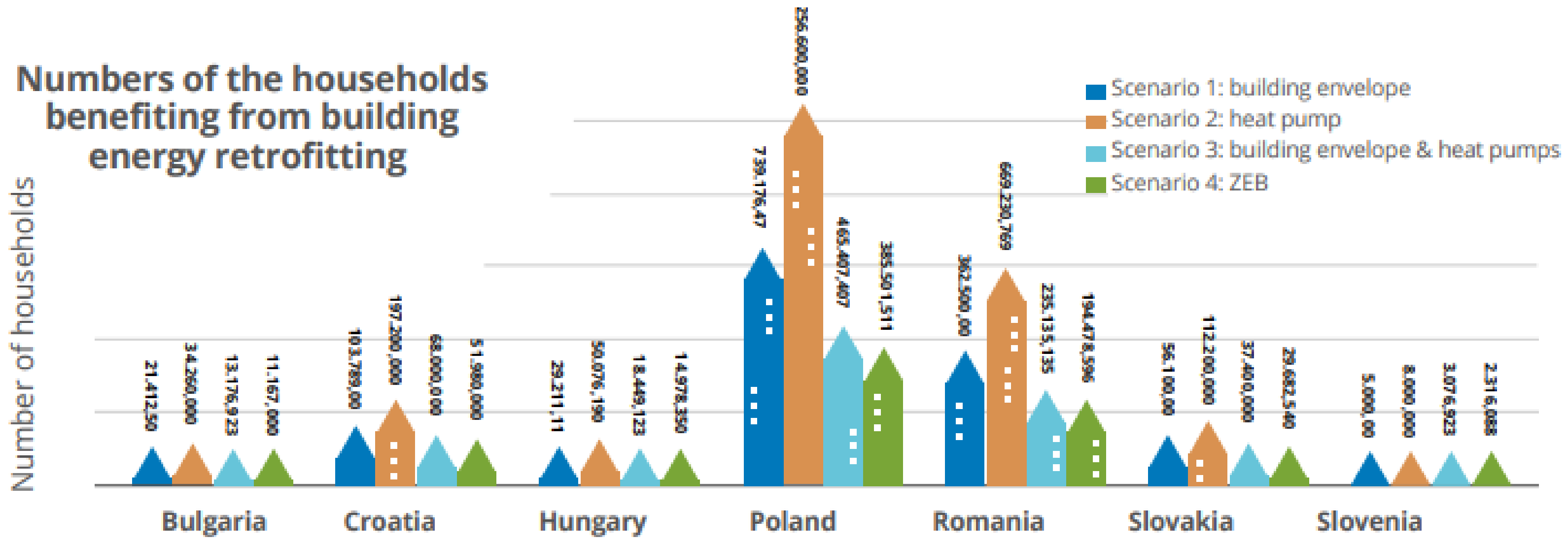
Available budget for fossil fuels	4,350,000,000	€	
Unitary investment cost	3,000	€	
Avoided cost from natural gas boilers	0	€	
Number of affected households	1,450,000	number of households	128.8%
Unitary energy consumption for space cooling	32	kWh	
Unitary energy consumption for space heating	6,312	kWh	
Performance ratio of energy efficient boiler	95%	%	
Performance ratio existing boiler	85%	%	
Energy consumption after the interventions	5,647	kWh	
Electricity price	0.16	€/kWh	
Existing fuel price for space heating	0.06	€/kWh	
Cost of operation and maintenance - Baseline scenario	0	€	
Cost of operation and maintenance - Alternative scenario	0	€	
Remaining value	10%	% of capital cost	
Discount rate	1%	%	

NPV	**-2,341,517,399**
IRR	**-10%**
B/C	**0.81**

Overall results when comparing the scenarios



The net cash flows over the lifetime of different energy efficiency renovations for social cost-benefit analysis



Numbers of the households benefiting from building energy retrofitting