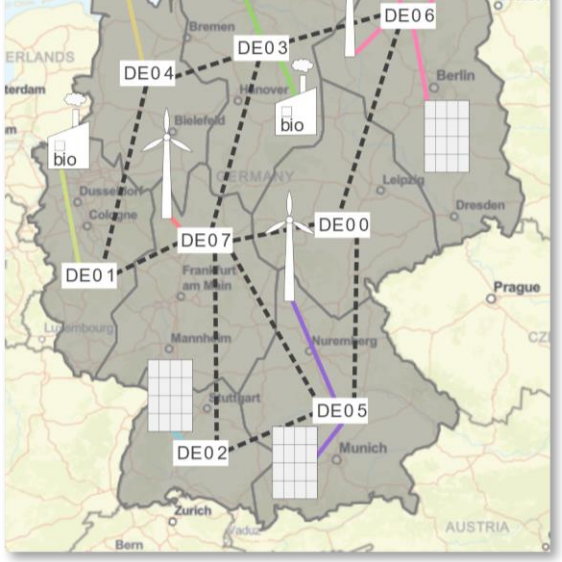

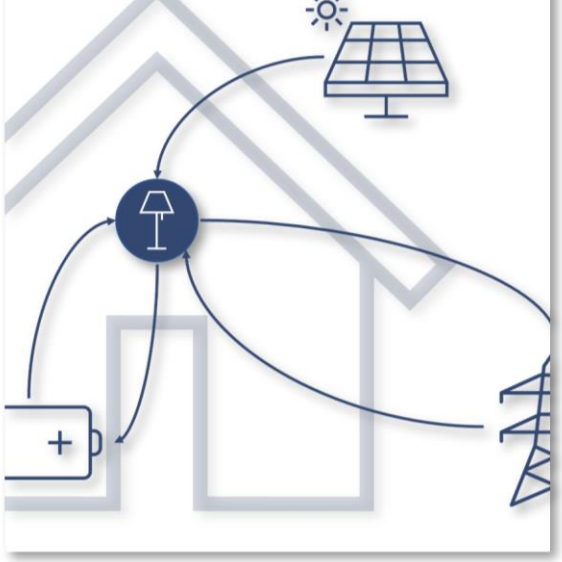

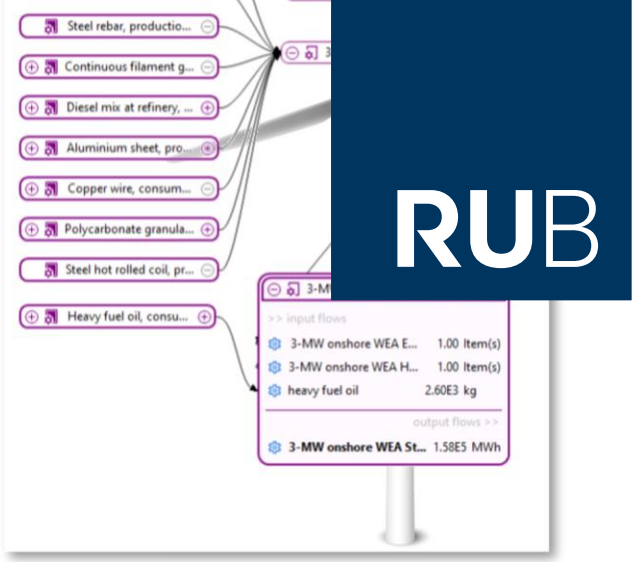

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Teaching Operations Research for Energy System Research: Challenges and Real-Life Examples

Sophie Pathe, Leonie Plaga, Christine Nowak, David Huckebrink, Konrad Telaar, Valentin Bertsch

Aug 31, 2023

Ein Kooperationsvorhaben empfohlen durch die:
DIGITALE HOCHSCHULE NRW
INNOVATION DURCH KOOPERATION

Ministerium für Kultur und Wissenschaft des Landes Nordrhein-Westfalen

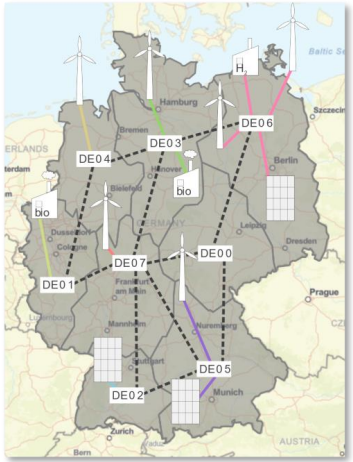
ORCA.nrw
Das Landesportal für Studium und Lehre.

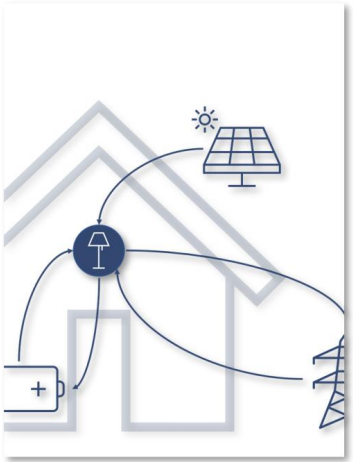
Chair of Energy Systems & Energy Economics

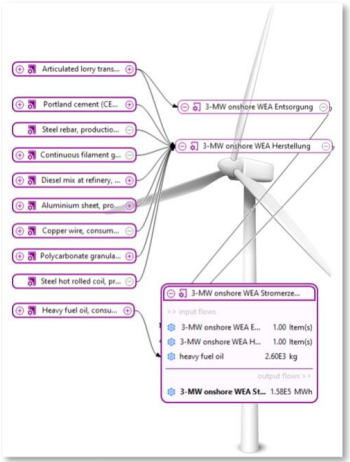
Agenda

1. Case studies: Overview
2. Procedure & examples
3. Challenges
4. Evaluation
5. Conclusions

Implementation examples, challenges & feedback for three case studies



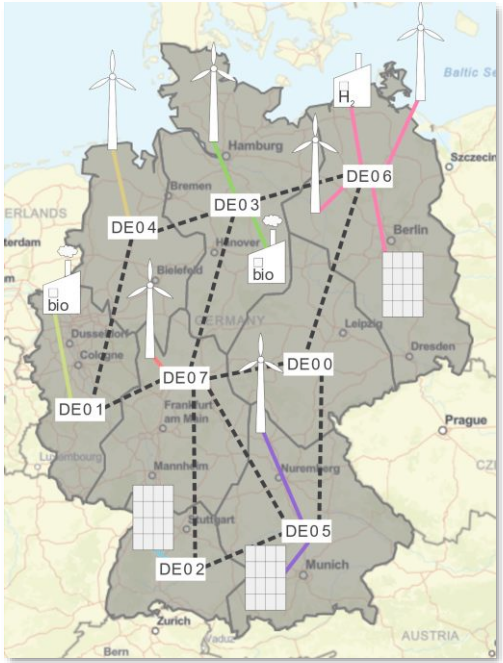


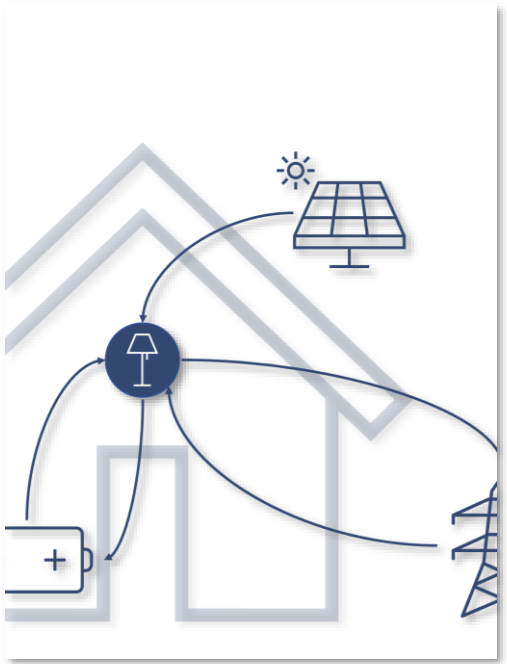


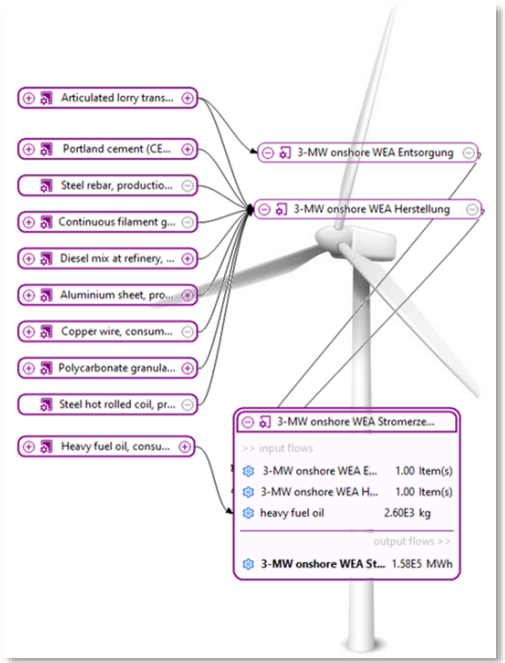
Case studies: Overview

Case study

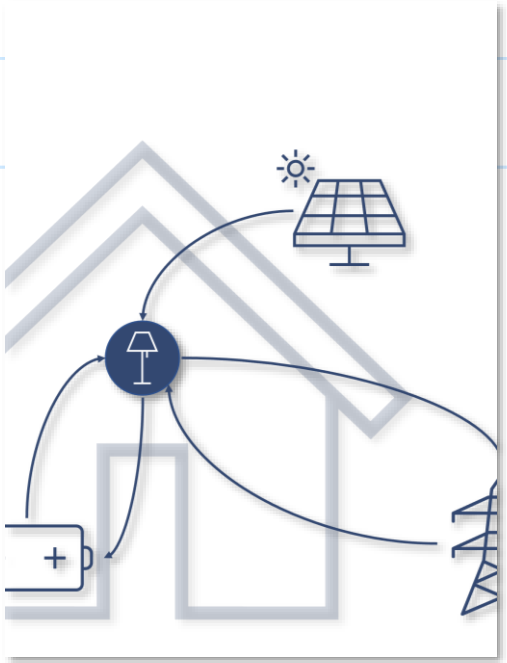
Different flexibility options in the German electricity system	Exploring possibilities for decarbonising households' energy demands	LCA and multi-criteria evaluation exemplified by a wind turbine

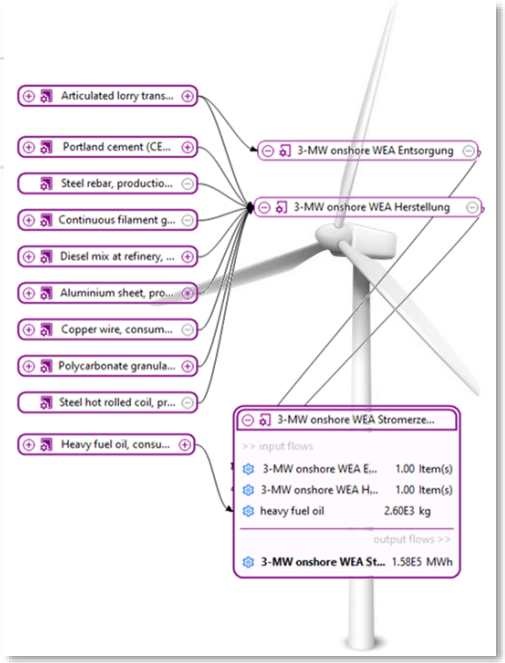




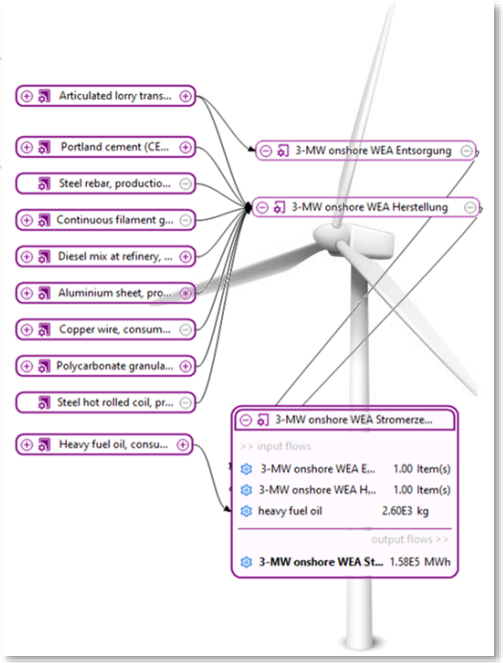


Case study	Different flexibility options in the German electricity system	Exploring possibilities for decarbonising households' energy demands	LCA and multi-criteria evaluation exemplified by a wind turbine
OR Method	**LP**		
Tools	**Backbone (optimizing ESM, GAMS)**		
Learning goals Students…	… can use a national energy system model for investment and deployment decisions. … can compare the results of different scenarios and draw conclusions. … use sensitivity analyses to investigate the influence of uncertain input variables on the result.		





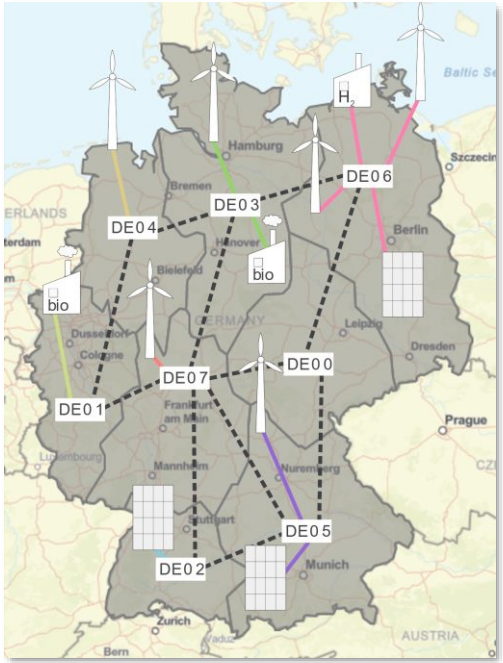
Case study	Different flexibility options in the German electricity system	Exploring possibilities for decarbonising households' energy demands	LCA and multi-criteria evaluation exemplified by a wind turbine
OR Method	LP	LP	
Tools	Backbone (optimizing ESM, GAMS)	Python-based optimization tool (with GUI in browser)	
Learning goals Students…	… can use a national energy system model for investment and deployment decisions. … can compare the results of different scenarios and draw conclusions. … use sensitivity analyses to investigate the influence of uncertain input variables on the result.	… are familiar with energy system optimization and the influence of input data on the optimized results. … comprehend how demand and supply of electricity are formed at household level. … are familiar with the concept and effects of demand response. … are familiar with and calculate economic indicators.	

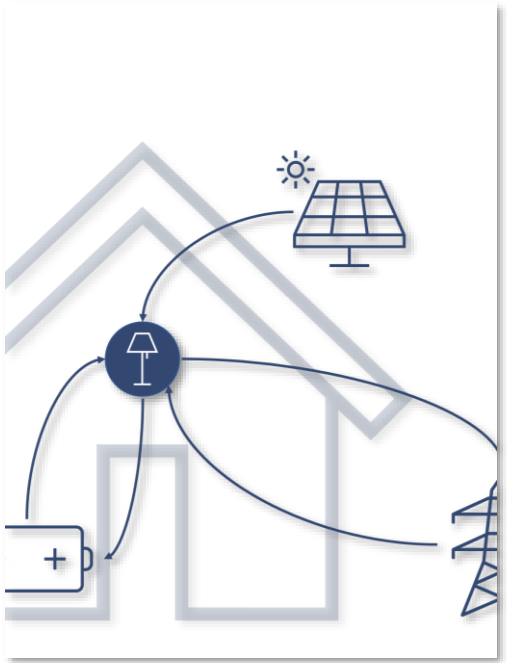


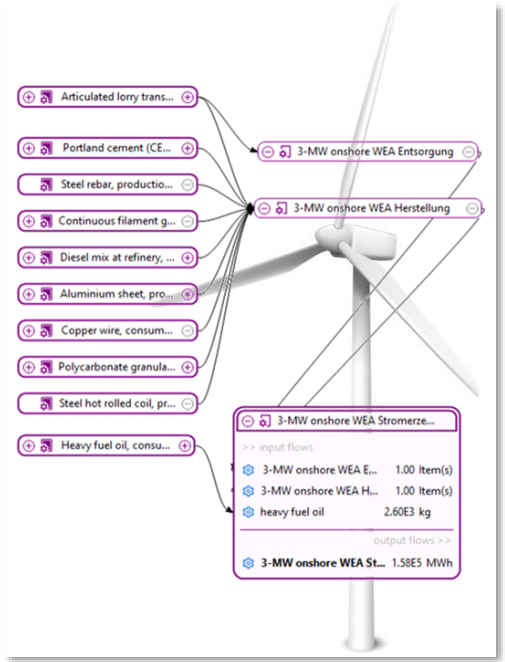
Case study	Different flexibility options in the German electricity system	Exploring possibilities for decarbonising households' energy demands	LCA and multi-criteria evaluation exemplified by a wind turbine
OR Method	LP	LP	LCA, MCDA
Tools	Backbone (optimizing ESM, GAMS)	Python-based optimization tool (with GUI in browser)	openLCA
Learning goals Students…	… can use a national energy system model for investment and deployment decisions. … can compare the results of different scenarios and draw conclusions. … use sensitivity analyses to investigate the influence of uncertain input variables on the result.	… are familiar with energy system optimization and the influence of input data on the optimized results. … comprehend how demand and supply of electricity are formed at household level. … are familiar with the concept and effects of demand response. … are familiar with and calculate economic indicators.	… are familiar with the methodology and practical application of LCA. … know and are able to use selected methods of multi-criteria evaluation, decision making and sensitivity analyses.

Case study

Different flexibility options in the German electricity system	Exploring possibilities for decarbonising households' energy demands	LCA and multi-criteria evaluation exemplified by a wind turbine







Procedure & examples

Procedure

- Completion of the case studies in self-study (individual or group work)
- Information, tasks and self-assessments in Moodle
  - Moodle “book“/ “H5P-interactive book“

Moodle Book

Total score
0 / 45
0 of 27 interactions

Book progress
55%
12 of 22 pages

Interactions progress
0%
0 of 27 interactions

Submit Report | Restart

Summary — All interactions

Scope
No interactions

Introduction
0 of 2 interactions completed

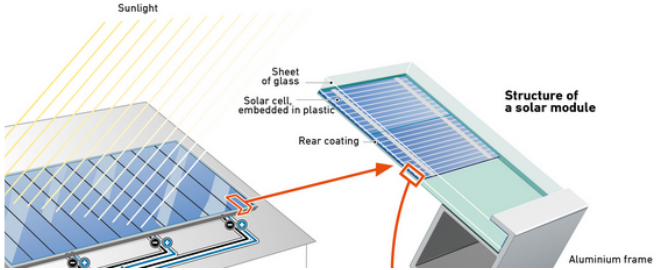
	Score
Quiz: Energy demand	0 / 1
Quiz: Decarbonisation	0 / 1

Background
No interactions

arbonising households' energy demands

2 / 23

hange, the indispensability of switching to renewable energies to avoid emissions is
r, this is not only an important task at national level, but also at a personal household
or about 25% of final energy demand in Germany in 2020 (Umweltbundesamt 2022). Even
ousehold level occur for heat supply, looking at household electricity supply still offers a
2) emissions from household electricity use were 18,725,000 tons (direct and indirect CO2
issions arising in households for electricity and heating (Statistisches Bundesamt 2022). One
invest in renewable energies for electricity supply, such as photovoltaics (PV). Furthermore,
ort decarbonisation (Symeonidou et al. 2021).

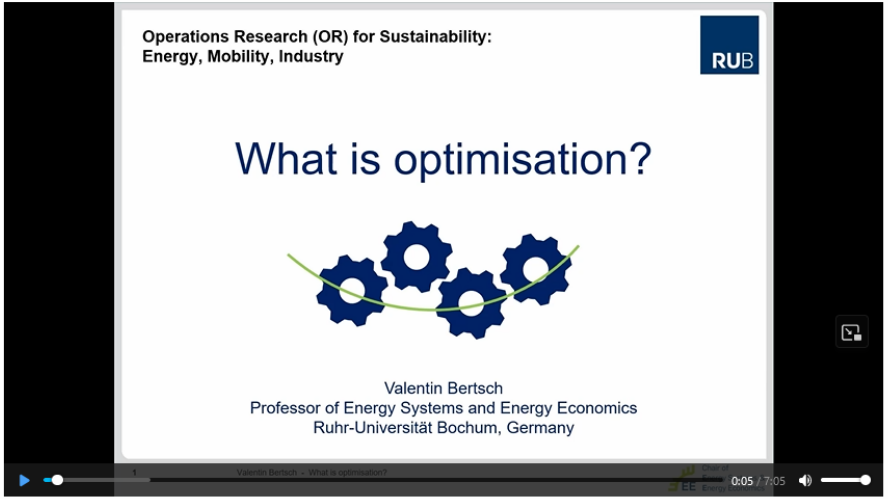


Information

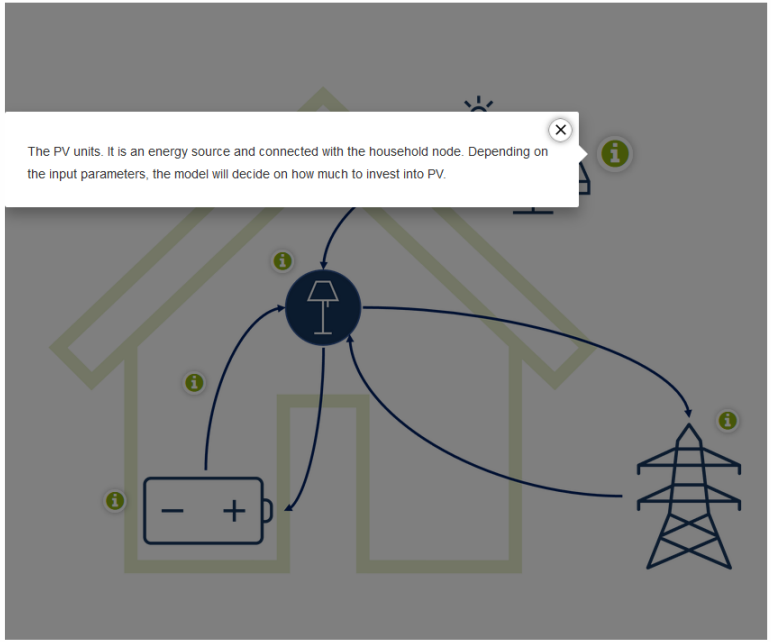
Videos, texts, pictures, interactive elements…

What is optimisation?

In this video you will get basic information on energy system optimisation and its purposes.



Below, you can find the **scheme**. When clicking on the info icons, you will get more information.



Grids, nodes and units

Grids

Grids are essentially groups of nodes with a common form of energy. The primary purpose of the grid dimension is to organize the nodes into grids so that the results are easier to deci
diffusion and transfer of energy between nodes located in different grids is not permitted directly. Instead, controlled transfer of energy between grids is referred to as "conversion" and
types of units, which will be explained later. However, it would make no difference for the functioning of said conversion unit even if all the nodes were included in the same grid. Diffu
not currently possible, even though it could possibly have some niche applications.

Source: VTT. *Energy Network Structure: Introduction to Grids, Nodes and Units*. Gitlab.vtt.fi/backbone, 2019.

Quiz

Single-/ multiple choice, short questions, cloze, index card...

Participation in a demand response program may require the installation of enabling technologies, such as smart thermostats, peak load controls or energy management systems (Albadi & El-Saadany, 2008).

○ True ○ False

Überprüfen

An investment decision is to be made. Please calculate the NPV for an investment of 5,000 € in time period 0, yearly expenditures of 50 € and yearly revenues of 400 €. Use an interest rate of 5% and assume a

Quiz: Test your gained knowledge with the following quiz questions!

Drag the words into the correct boxes!

The scheme shows the _____ of this case study. There is one _____ for the household. Here, the _____ is associated. The household node is connected to the energy supply transformation units via _____. Each of these stands for one energy flow direction.

As a status quo, there is the possibility to purchase electricity — via the _____. Here, _____ are associated with each _____ purchase.

We also have some investment options! Depending on the _____, the model can decide to invest into _____ units. No emissions are associated here as we only consider the use phase of all technologies. But for each investment, there will be costs accruing.

As there is PV in the system, there might be _____ when the demand is low but the PV energy supply is high. Therefore, the model can store the electricity in the battery storage units. But we also have the possibility to _____ the electricity into the upstream grid. When doing so, we get a feed-in tariff.

- PV and battery storage
- feed-in
- energy surplus
- input parameters
- lines
- electricity demand
- upstream grid
- kWh electricity
- household energy system
- node
- costs and emissions

Überprüfen

en Wirkungskategorien unterscheiden sich die WEA am deutlichsten?

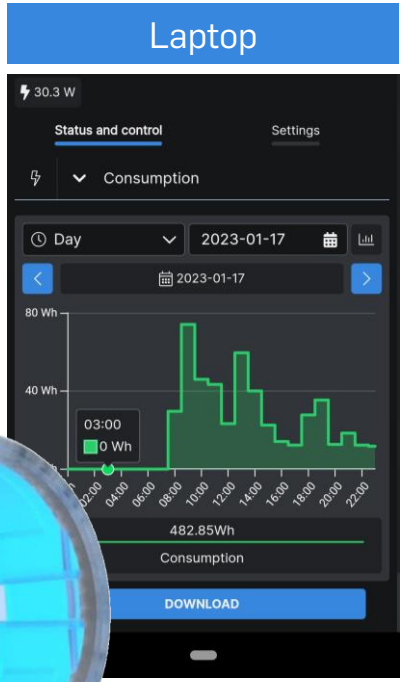
h den Einsatz der 3 MW WEA gegenüber dem deutschen Strommix 2022 erden? Wieviel durch die Referenz WEA? (3 MW WEA / Referenz WEA)

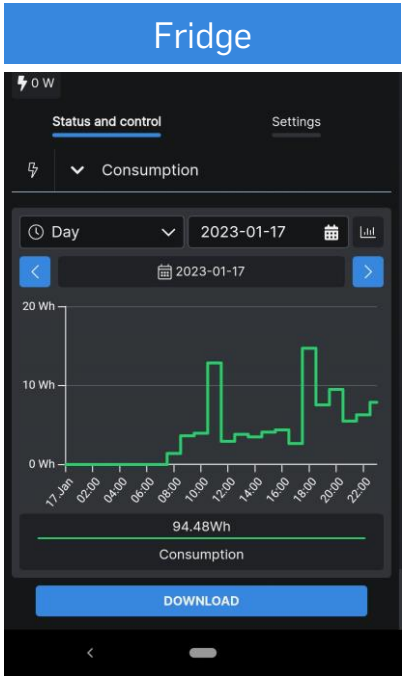
Procedure

- Completion of the case studies in self-study (individual or group work)
- Information, tasks and self-assessments in Moodle
  - Moodle “book“/ “H5P-interactive book“
- Solve tasks with tools (ESM Backbone, Python, openLCA)
  - Short tutorials for used tools
  - Optional use of power measurement devices

Measurement Devices

- Measurement of electricity consumption of household appliances
- Easy-to-use measuring devices loaned by chair
  - Integration in WiFi network through an app
  - Export of data
- Data can be used as input for case study (optional)



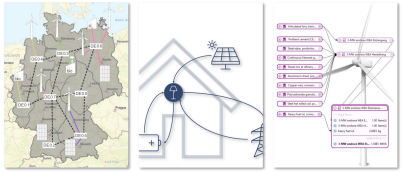


Procedure

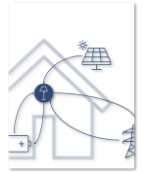
- Completion of the case studies in self-study (individual or group work)
- Information, tasks and self-assessments in Moodle
  - Moodle “book“/ “H5P-interactive book“
- Solve tasks with tools (ESM Backbone, Python, openLCA)
  - Short tutorials for used tools
  - Optional use of power measurement devices
- Preparation time about two to four weeks
- Incentives for participation
  - Requirement for exam participation
  - Possibility to achieve bonus points for exam
- Moodle “exam“ for results/ interpretation/ test for exam bonus points
- Evaluation: if possible mandatory or in attendance period

Challenges

Challenges



- Balancing necessary complexity and workload (for students)
- Using open data (for LCA, ESM)
  - Realistic data important for practical relevance of the case study
  - Best: using high quality open-data or own data (electricity consumption measurement)
  - Sometimes generalizations and assumptions are inevitable
- Own tools → Hosting of Python-tool
  - Available as Python code, but also hosted on the chair's website with HTML-based GUI
    → Helps students to get started with the tool
  - Link to the chair's website must not be shared via ORCA.nrw
    → The tool will be provided as Python code only on ORCA.nrw



Evaluation

Evaluation results across all three case studies

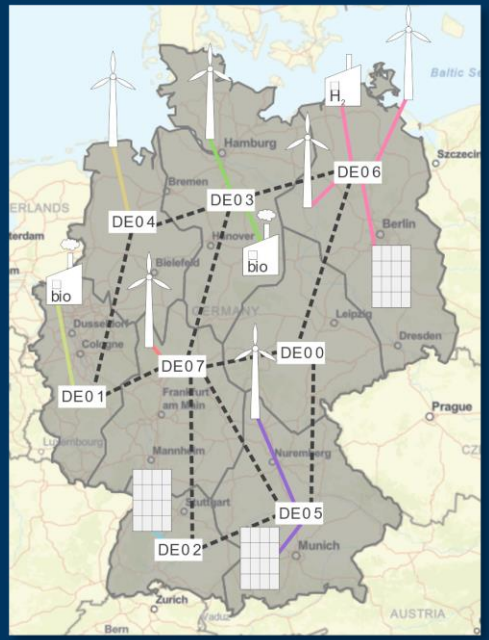
- 75 participants in total (29 + 22 + 24)
- What did you like most about the case study?
  - Application of contents from the lectures
  - Learning new methodologies and using tools (ESM, Python-tool, openLCA)
  - Real world data and application, practical relevance
  - Step-by-step approach
  - Moodle (H5P book) format: versatility (videos, short chapters, quizzes…)
- What might be improved?
  - Case study too long, too much workload
  - Wish for more explanations, examples and support
  - Unclear whether completing the case study gives advantages for the exam
  - Case study could be even more complex

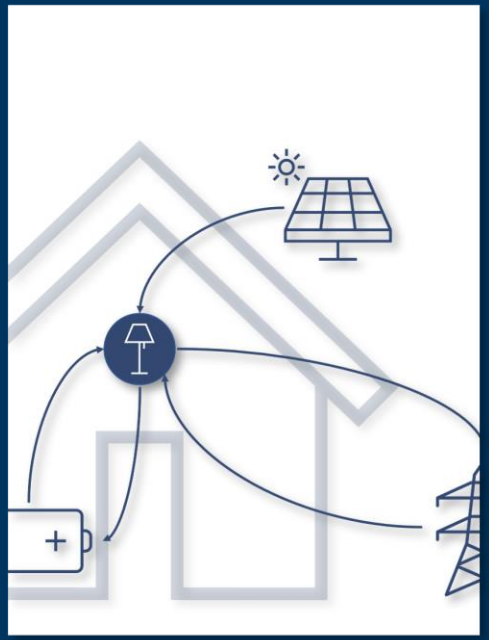
Conclusions

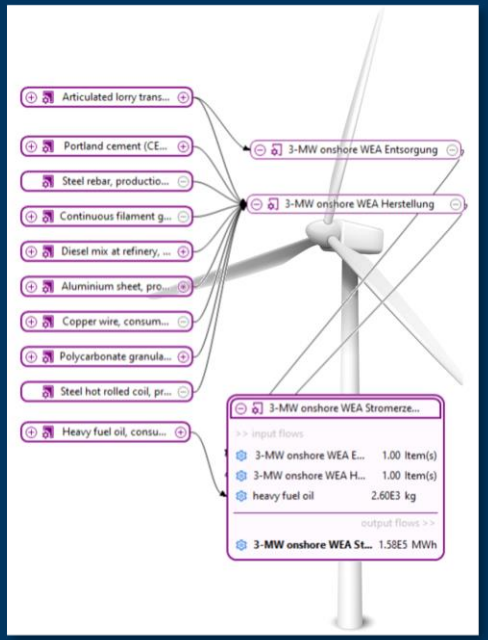
Conclusions

- H5P book format in Moodle well suited (versatile)
- Student feedback is valuable → incentive for participation in evaluation
- Self-study material must be very comprehensible
- Use of real-life data sometimes difficult but valuable for students
- Own Python tool liked by students, but problems with hosting
- The case study format was generally rated very good and wished to be continued and/ or extended.

...more Lessons Learned at the end of the session.







Thank you very much!

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