WE WALK THE TALK

TUM Sustainability Day
June 12, 2024
Posters by Doctoral Students

www.tum.de/sustainability-day-2024

TUM is committed to a sustainable future and invites you to a spectacular festival of sustainability on June 12th, 2024: Experience the diversity of our university and network with over 100 TUM initiatives, researchers, teachers and partners in the field of sustainability.

- ✓ When: June 12, 2024; 12:00 noon–10:00 pm
- ✓ Where: Boltzmannstraße 15, Campus Garching
- ✓ Lecture free from 12:00 noon
- ✓ Language: English (some workshops in German)

TUM Sustainability Day 2024
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Dear friends and supporters of the sustainable transformation of our university,

We welcome you to the Sustainability Day at the Technical University of Munich (TUM) with great pleasure and a deep sense of responsibility towards a sustainable future. Today, we gather not just as a community of scholars, students, and professionals but as forward-thinkers and change-makers committed to the cause of sustainability.

This collection showcases the innovative research and dedication of our doctoral students through an impressive array of posters. Each poster represents not just hard work and scholarly excellence but a beacon of hope for sustainable solutions in our global quest for a better tomorrow.

Once again, welcome to the Sustainability Day at TUM. Let's embark on this journey together, fostering a culture of sustainability that resonates within and beyond our university walls.

Thank you for taking part in this journey and for your commitment to making a difference.

Prof. Dr.-Ing. Werner Lang
Vice President Sustainable Transformation
Technical University of Munich

TUM Sustainability Day 2024

The Technical University of Munich (TUM) is deeply committed to creating a sustainable future, a dedication that is showcased at the TUM Sustainability Day 2024.

Our motto is simple: we want to lead by example. To reach our ambitious sustainability targets, we have rallied the collective passion and resources of our entire university community. This is a journey we are fully dedicated to embarking on together. Our engagement in sustainable practices and initiatives showcases our commitment not just in words, but in real, impactful actions. Together, we can make a significant difference in the world, starting with our own campus.

TUM Sustainability Day extends an open invitation to anyone interested – students, staff, professors, and external guests are all welcome. Only by uniting we can steer our university towards a more sustainable future.

This event isn't just a one-time effort. It's an integral part of TUM's broader path of sustainable transformation. Through the TUM Sustainable Futures Strategy 2030, we are charting a course for a greener, more sustainable future, supported by specific, achievable actions.

TUM Sustainability Day acts as a diverse networking platform, bringing together individuals from different schools and departments. It presents a unique opportunity for the entire TUM community to come together, exchange ideas, and collaborate on sustainability initiatives. By fostering a network of shared knowledge and commitment across various academic disciplines and administrative units, we are integrating sustainability into everything we do at TUM.

**WE
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TALK**

Technical University of Munich - Sustainability Day 2024

Are farmers willing to adopt climate-smart Water-Energy-Food-Environment designs?

Olha Halytsia, Chair of Agricultural Production and Resource Economics

Background

- There is a rapidly closing window of opportunity to address threats posed by **climate change**.
- To avoid climate change maladaptation, flexible, **multi-sectoral**, inclusive, long-term planning, and implementation of adaptation actions, with **co-benefits to many sectors and systems,** should be implemented (IPCC, 2023).
- Our study aims to contribute to the emerging stream of the literature dealing with climate and Water-Energy-Food-Environment Nexus by providing the first attempt to **investigate farmers' preferences for groups of Water Energy-Food-Environment Nexus climate-smart practices.**

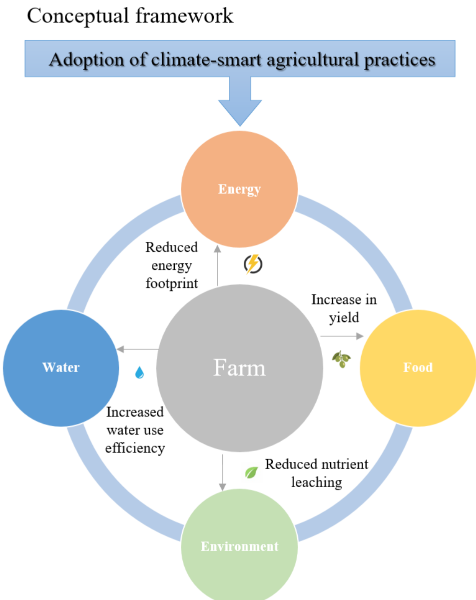

Fig. 1 The conceptual framework of the study.

Case study area

- Olives are a **major** crop for Cretan agricultural production, and their cultivation is vulnerable to **climate change**.
- The majority of farmers in our case study area
- have heard about climate change;
- are **concerned** with the negative consequences of climate change to a different extent (Fig. 2).

Methodology

- To address the research question, a **discrete choice experiment** was designed with attributes reflecting good agricultural practices as a means of adaptation of Mediterranean olive growing to climate change, their cost of adoption, and the expected increase in crop per drop (Fig.4).
- The probability of an olive producer adopting the climate-smart WEFE Nexus design was estimated as a function of its attributes using **the rank-ordered logit model**.
- Using perception, environmental performance, and socio-economic variables, **multiple correspondence analysis and clustering** were performed to identify different groups of olive producers.

Results

- **Traditional olive producers** highly value the adoption of pruning and perceive a negative marginal utility for the adoption of pressure-compensated drippers, a more costly and technology-intensive practice.
- At the same time, the utility of **transitioning farmers** tends to increase not only when adopting conventional practices, such as pruning, but also potential adoption of fertigation brings them a positive marginal utility. Moreover, the magnitude of disutility for higher costs of adoption is the lowest for them.
- Finally, **environmentally conscious farmers** perceive the biggest positive marginal utility for the adoption of biostimulants (compared with the baseline nutrient), which contributes to soil health and minimization of environmental impact.

Key message

- The main recommendation stemming from our results for the policy-makers is to **increase awareness** among farmers about more technology-intensive climate-smart practices, such as **fertigation and pressure-compensated drippers**, and highlight the expected benefits from their adoption.

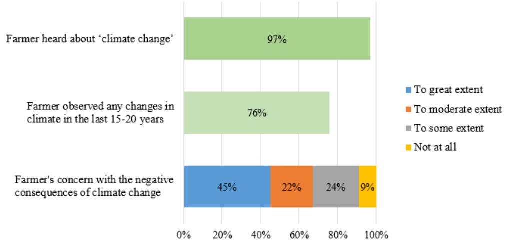

Fig. 2 Farmers' perception of climate change in the case study area.

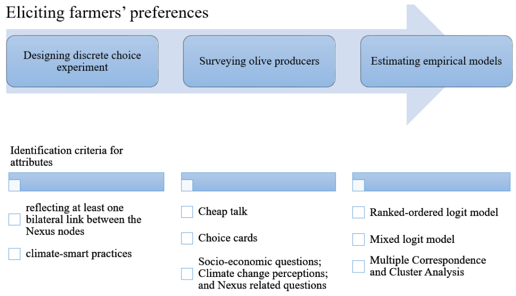

Fig. 3 The framework of the research methodology.

ID.B1.C1.	Link with WEFE Nexus	Expected positive effect	Group of Practices 1	Group of Practices 2	Group of Practices 3
Pruning	Water - Food	↓water loss by transpiration	Yes	No	Yes
Fertigation	Energy-Ecosystems (Soil) - Food	- ↑ the efficiency of fertilizing/↓ mineral nutrient leaching; - ↓ energy footprint	Yes	No	No
Nutrients	Water-Ecosystems (Soil) - Food	- ↓ heat stress/↑ leaf functioning and ↑ water use efficiency; - ↑ water-holding capacity	Biostimulants	Aluminium silicate	Compost
Pressure-compensated drippers	Water - Food	↓ irrigation leak; ↑ water use efficiency	No	Yes	Yes
Expected increase in crop per drop	Food		40%	10%	30%
Cost			150 euro per stremma	50 euro per stremma	200 euro per stremma
I am most likely to adopt (check one)			☐	☐	☐
I am least likely to adopt (check one)			☐	☐	☐

Fig. 4 Attributes of the choice experiment and example of the choice card.

Parameters	Rank-ordered logit model: Traditional olive producers		Transitioning olive producers		Environmentally conscious olive producers	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Cost	-0.013***	0.001	-0.004**	0.002	-0.007***	0.001
Pruning (base: none)	0.718***	0.096	1.062***	0.158	0.156	0.116
Fertigation (base: none)	0.027	0.093	0.459***	0.163	-0.170	0.116
Nutrients						
Compost (base: Aluminum silicate)	0.048	0.096	0.183	0.153	0.092	0.120
Biostimulants (base: Aluminum silicate)	0.061	0.099	0.085	0.154	0.388***	0.120
Pressure-compensated drippers (base: none)	-0.187**	0.089	-0.195	0.140	-0.017	0.109
Expected increase in crop per drop	0.039***	0.006	0.028***	0.009	0.033***	0.007
Log-likelihood	-663.224		-271.994		-433.876	
Observations	1278 (71 producers, 6 choice tasks, 3 alternatives in each)		522 (29 producers, 6 choice tasks, 3 alternatives in each)		774 (43 producers, 6 choice tasks, 3 alternatives in each)	

Fig. 5 Results from Rank-ordered logit model for 3 groups of olive producers.

Supervision

Prof. Dr. Johannes Sauer, Chair of Agricultural Production and Resource Economics, Technical University of Munich

Dr. Maria Vrachioli, Chair of Agricultural Production and Resource Economics, Technical University of Munich

Acknowledgement: This work was done within the SIGMA Nexus project that has received funding from the PRIMA Foundation and European Union's H2020 research and innovation program under Grant Agreement No. 1943.

Sources

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Multi-objective decision support for neighborhoods

Roland Reitberger – TUM School of Engineering and Design
Department of Civil and Environmental Engineering

Background

With the Green Deal, the European Union highlights the urgency of climate change mitigation and adaptation. The building sector is responsible for 38% of CO_2 emissions worldwide and offers high potential for improvement [1]. However, previous approaches to neighborhood development often take a one-sided view, as a holistic assessment of the complex urban system seems hardly feasible. Therefore, it is important to identify frameworks that combine climate change mitigation and adaptation while contributing positively to the regeneration of our planet's biocapacity.

The Social-Ecological-Technological Systems (SETS) approach represents a common base for achieving such a holistic view of the built environment (Fig. 1). It fosters the systemic consideration of urban areas and provides a framework for allocating interactions [2].

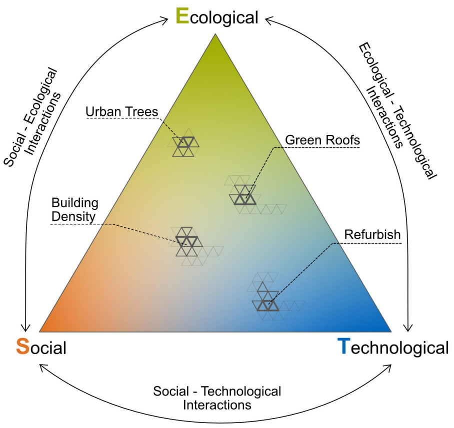

Fig. 1 Exemplary character of neighborhood interventions in the Social-Ecological-Technological Systems framework. Own illustration based on [2].

Goals of the Research

This dissertation aims to:

- Define the terms 'Synergy' and 'Trade-off' with regard to the built environment
- Develop a simulation model that can simulate the interactions between buildings and outdoor space from a lifecycle perspective
- Show the relevance of these interactions for decision-making in urban neighborhood development
- Make the knowledge of resulting synergies and trade-offs accessible to professionals in urban planning

Methodology

First, existing usages of the terms synergy and trade-off in various disciplines are analyzed. These interpretations are then transferred to the building sector and allow to derive corresponding evaluation indicators and establish a generic process for optimized multi-objective decision support in neighborhood development, called here the *Urban Systems Exploration* [3]. Parametric building and neighborhood models allow to investigate the synergetic effect of measure combinations as well as multi-objective trade-offs with regard to lifecycle-based global warming potential, lifecycle costs, and outdoor thermal comfort (Fig. 2). Finally, expert interviews are conducted to ensure the findings' usability.

Results

The application of *Urban Systems Exploration* reveals a trade-off between the three objectives. Figures 3 and 4 show the Pareto Front and exemplarily inputs of a selected area of Pareto-optimal solutions.

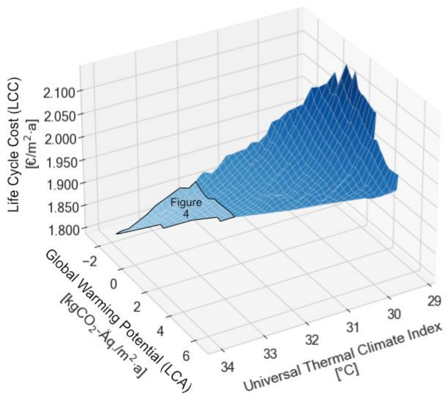

Fig. 3 Pareto Front of the neighborhood model for the three target dimensions global warming potential, life cycle costs, and outdoor thermal comfort.

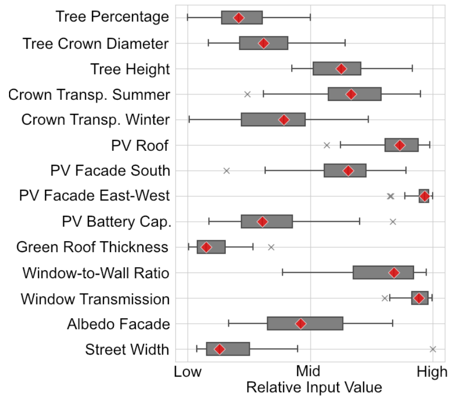

Fig. 4 Distribution of the input values of an area with low costs and low global warming potential but high outdoor heat stress. The corresponding Pareto Front area is highlighted in Fig. 3.

Key Findings

- Urban vegetation, high building energy standards, and photovoltaic surfaces contribute to the **parallel improvement** of lifecycle-based global warming potential, lifecycle costs, and outdoor thermal comfort.
- These planning variables are well suited to control Pareto-optimal trade-offs and thus **adapt designs to the neighborhood context**.
- The need for a **systemic view of urban space** for the sustainable transformation of the building sector is evident.
- It is recommended to adopt a **multi-objective approach in planning** processes and to base decisions on a complete exploration of the scope for action.

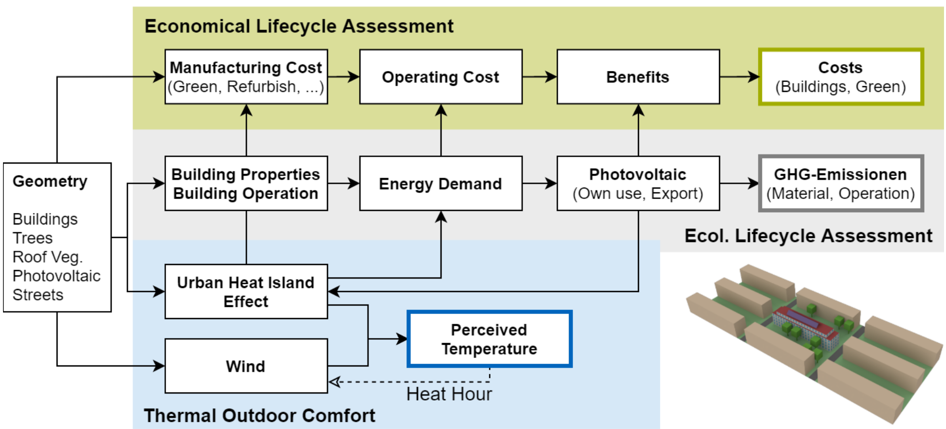

Fig. 2 Simplified representation of information flows within the developed neighborhood simulation model.

Supervision

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Prof. Dr. rer. nat. Herbert Palm, Institute for Sustainable Energy Systems, University of Applied Sciences Munich

Acknowledgement: This work was carried out within the research training group Urban Green Infrastructure, funded by the German Research Foundation under grant 437788427 - RTG 2679.

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Technical University of Munich - Sustainability Day 2024

Ride Parcel Pooling – Sustainable Integration of Parcel Services into Mobility-on-Demand Systems

Fabian Fehn – TUM School of Engineering and Design

Background

This dissertation addresses the pressing challenges of climate change, urbanization, e-commerce growth, and evolving urban mobility patterns, emphasizing the need for a comprehensive strategy to mitigate their environmental and societal impacts. It introduces Ride Parcel Pooling (RPP), an on-demand mobility service that integrates passenger ride-pooling and urban parcel transportation to deliver environmental, economic, and social benefits. Through thorough analysis, simulation, and real-world testing, the thesis demonstrates the feasibility and benefits of RPP, highlighting its potential to transform urban mobility into a more sustainable system.

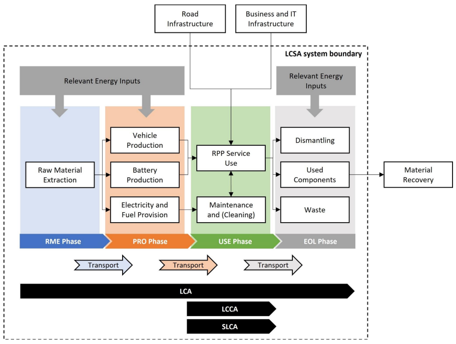

Fig. 2 – System representation of the LCSA evaluation approach for a RPP mobility service

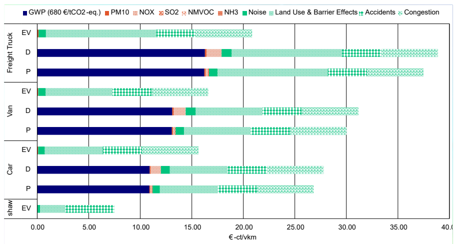

Fig. 5 – External costs for the USE phase in €-ct/vmk per vehicle category and drive technology, assuming a price of 680 €/kgCO_2e.

Fig. 6 – Set up of the RPP test vehicle during real-world field test.

Research Scope

In the European Union, transportation-related CO2e emissions come from passenger transport (60%) and freight transport (40%) making up a share of 27% of the total world-wide global warming potential (GWP). On an urban level, which is the scope of this study [1], a significant part (23%) of transport-related CO_2e emissions are generated, consisting of 17% for passenger and 6% for freight transport.

While recent studies focused on exploiting the idle time of mobility-on-demand (MoD) fleets explicitly for logistics services and modeled the logistics service as an "as soon as possible" delivery service (i.e. using strict time constraints on parcel pickup and delivery), the goal of this work is to actively integrate parcel pickup and delivery into already existing vehicle routes. No explicit time constraints on parcel pickup and delivery are enforced, as the goal is to integrate parcel pickup and delivery into the scheduled vehicle routes resulting from the underlying ride-pooling service to minimize the additional vehicle kilometers driven [2].

Simulation Results

The simulations proof that the integration of logistics services into a ride-pooling service is possible and can utilize unused system capacity without degrading passenger service. Depending on the chosen assignment strategy and vehicle category, almost all parcels can be served up to a parcel-to-passenger demand ratio of 1:10, while the total fleet kilometers can be reduced compared to the status quo, i.e. two separate fleets for passenger and parcel transport.

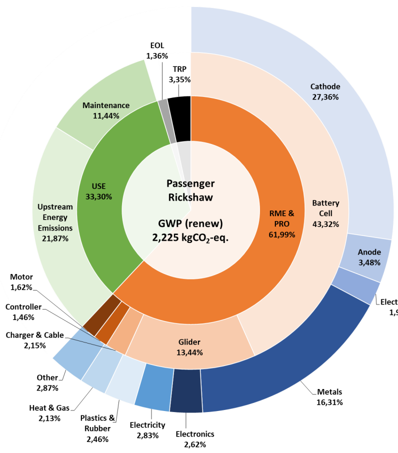

Fig. 3 – Representation of an LCA evaluating an electric bicycle rickshaw.

Key Contributions

- The RPP service is defined, conceptualized (Fig. 4), simulated, and tested in the real world (Fig. 6).
- The LCSA fleet evaluation tool (Fig. 2) aims at a new way of assessing vehicle fleets' sustainability in urban environments over their entire life cycle, considering economical, ecological (Fig. 3), and social (Fig. 5) dimensions.
- Three different vehicle categories (rickshaw, car, and van) are introduced and compared to the status quo (Fig. 5).
- The case study shows significant savings in GWP, fleet operating costs, and social impacts compared to the status quo.
- Electric vehicles have an advantage over internal combustion engine vehicles, especially in the environmental and economic dimensions (Fig. 3), but also in the social dimension (Fig. 5).
- The real-world test proofed the RPP service's functionality and real-world applicability (Fig. 6).

Methodology

The overall research objective is to explore and investigate the integration of urban passenger and freight transportation for sustainable urban transportation systems. Furthermore, the thesis conceptualized the RPP service and investigates its impacts and real-world applicability in an agent-based simulation model, a life cycle sustainability assessment, and a real-world test (Fig. 1).

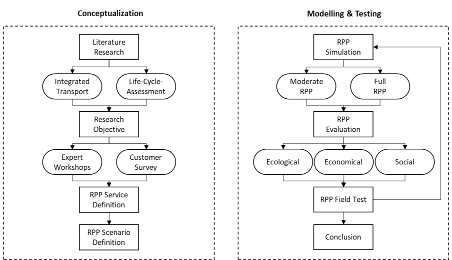

Fig. 1 – High-level structure of the dissertation.

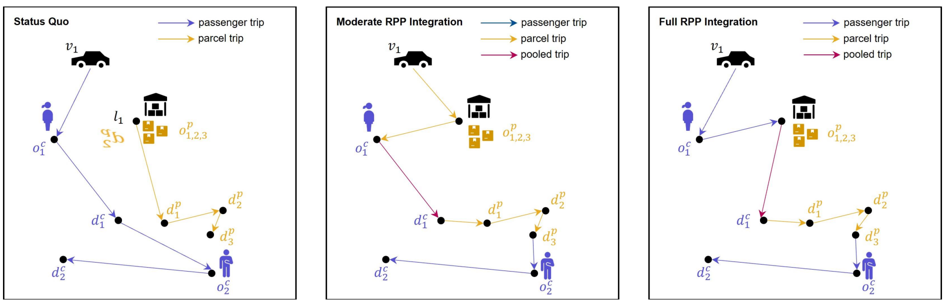

Fig. 4 – Simulation scenarios derived from expert interviews and a potential customer survey to frame the RPP mobility service and operational framework [3].

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Supervision

Univ . Prof. Dr.-Ing. Fritz Busch, Chair of Traffic Engineering and Control

Univ. Prof. Dr.-Ing. Johannes Fottner, Chair of Materials Handling, Material Flow, Logistics

Sources

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Technical University of Munich - Sustainability Day 2024

Collaborative Machine Learning for the Energy Transition

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Background

Future energy systems powered by renewables will be much more complex and volatile than current ones. A big factor is the weather dependence of renewable energies. To ensure a reliable energy supply, we need to forecast the weather, the consumption and control energy systems in a flexible manner. Machine learning (ML) can deliver on all of these, as long as enough data is available. Modern sensors are able to produce a lot of data, but this data for renewable energy ML applications is often spread out across various stakeholders who might be unwilling to share access. Hence COMET (Collaborative machine learning for the energy transition) investigates solutions to this problem by:

- Researching federated ML pipelines for renewable energies **(federated learning)**
- Designing incentive schemes for participation in ML training **(data markets)**
- Finding methods to value data **(data valuation)**

Federated Learning

Federated Learning [1] is a method to train machine learning models in a decentralized fashion. The main reason for this is data privacy and sensitivity, i.e. data owners are not comfortable with sending their data to a central server. So if the data can't come to the model, the model hast to go to the data!

For renewable energy applications, we envision that data from households (load, occupancy), solar and wind farms (solar irradiance, wind strength, clouds) as well as various other data sources are of such sensitive nature.

Models can be fine-tuned according to different needs (see Fig. 1), depending on the specific renewable energy application. .

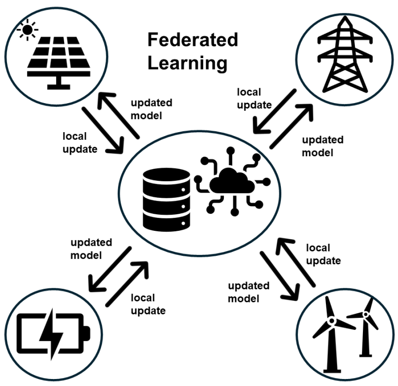


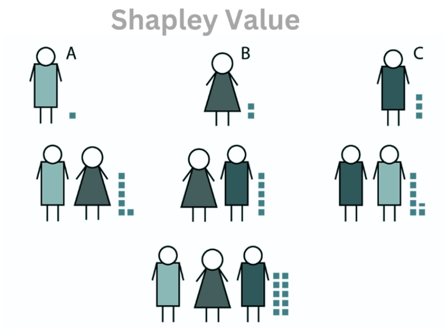
Fig. 1: Federated learning in the renewable energy machine learning context.

Data Markets

Why would one participate in federated learning? There are different incentives:

- Benefit from an improved joint model
- Access to better service
- Monetary reward for data sharing

The latter is very important: often data can be shared without a direct benefit to one's own activities. In particular, data can be useful for competitors, for example a solar farm sharing data from its weather sensors with a nearby wind farm. Without a monetary incentive and privacy guarantees, data sharing will not happen. But data sharing is desirable: an improved wind power generation forecast leads to more predictable energy production. Due to the interconnectedness of data and renewable production, we imagine that future electricity markets [2] will go hand in hand with data markets.



$$\varphi_i(v) = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|!\,(n - |S| - 1)!}{n!}\,(v(S \cup \{i\}) - v(S))$$

Fig 2. (from https://www.wallstreetmojo.com/shapley-value/): The Shapley Value computes the marginal contribution of each player A, B and C to any possible coalition. In this case the Shapley values are 3.3 for A, 2.8 for B and 3.8 for C.

Data Valuation

Data is a different commodity than others. Its value depends on the machine learning model, the achieved accuracy, other data [3] and whether others have access to that data as well or not. It can be easily replicated as well as poisoned and is time-sensitive. Hence finding its valuation is highly non-trivial.

The Shapley value (see Fig. 2) has many (mathematically) desirable properties but requires exponentially many training runs to determine the different values of each coalition. A way forward can be efficient estimation of the Shapley value [4] or finding training-free data valuation scores such as the CG-score [5].

Goals of the research

For **federated learning** I aim to investigate the following research questions:

- How can federated learning be incorporated into the ML algorithms used for renewable energy forecasting?
- How can federated learning improve control performance of energy systems (i.e. smart grids, HVAC (heating, ventilation, air conditioning and cooling) systems?

For **data markets** I aim to investigate the following research questions:

- How can data markets be designed to incentivize participation?
- What characteristics do data markets need to be robust and resilient against malicious actors?

For **data valuation** I aim to investigate the following research questions:

- Based on which metrics should data be valued in the energy context? How to quantify these metrics?
- How can one compute fast data valuation without needing to re-train expensive models?

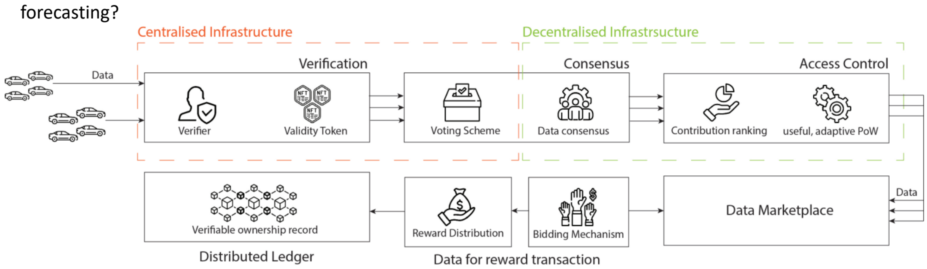


Fig 3. (from [6]): Their data market is organized using three key algorithms: a verification algorithm, a reputation-based voting system, and an access control mechanism. Agents within spatial coalitions aggregate their data-points, and the Shapley value determines the fair distribution of rewards based on each agent's contribution. Data consensus is achieved through a decentralized mean-median algorithm, ensuring privacy and robustness against faulty or malicious data submissions.

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Supervision
Prof. Dr. Christoph Goebel, Professorship of Energy Management Technologies, Technical University Munich
Prof. Pierre Pinson, PhD, Dyson School of Design Engineering, Imperial College London

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Financial Health Scoring and Personal Finances

Emanuel Renkl, Finance & Accounting, TUM School of Management

Background

The Principles of Responsible Banking - the world's leading sustainable banking framework - recommend that **banks score the financial well-being of their customers to monitor the effect of their products and services on their customers' finances** [1]. Moreover, banks use such scores not only for steering and reporting purposes, but also directly **disclose them to their customers, in order to encourage them to reflect on their finances and push them towards sources of financial advice** [2]. However, so far no study has investigated **how the disclosure of a financial well-being score affects consumer financial behavior**. Given the increasing promotion, distribution, and accessibility of such scores, answering this question is relevant to policy, industry, and consumers alike.

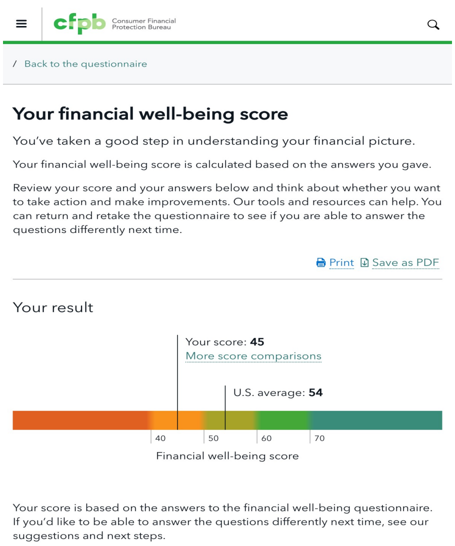

Fig. 1 The financial well-being score of the CFPB [3] self-administered online (see https://www.consumerfinance.gov/consumer-tools/financial-well-being/)

Key Findings

- Solely providing a financial well-being score does not seem to influence consumer financial behavior as measured by the marginal propensity to save out of an unexpected windfall equal to the monthly household income.
- Adding information on the national average to the financial well-being score increases the marginal propensity to save by 6.47 percentage points on average as compared to a control group who does not receive a treatment. The coefficient is statistically significant at the ten percent level.
- When disclosing financial well-being scores to consumers, banks should add information on peer scoring to increase consumer savings.

Experimental Design

Disclosing financial well-being scores can **"provoke self-reflection, creating a teachable moment to steer consumers toward sources of financial advice or coaching."** [2] We investigate this hypothesis by **examining the effect of the financial well-being score of the Consumer Financial Protection Bureau (CFPB) on personal finances** (see Fig. 1) [3]. The score is widely used, easy to administer, and the CFPB provides the scoring mechanism as well as information on the national average score. Further, the score is survey based and calculated from answers to ten Likert scale questions. To examine the effects of the questions, the score, and the peer information on consumer financial behavior, we run an **online experiment with American participants recruited through Prolific**.

Treatment	Group 1	Group 2	Group 3	Group 4
Questions to calculate the financial well-being score	-	✓	✓	✓
Financial well-being score	-	-	✓	✓
Information on the national average	-	-	-	✓

Tab. 1 The experimental design

As depicted in Tab. 1, **participants are randomly assigned to four groups**. The first group does not receive a treatment but only our outcome variables are elicited. Hence, this group serves as our **control group**. The second group receives the **questions used to calculate the financial well-being score**. Participants in the third group receive the **questions and their corresponding scores** as depicted in Fig. 2.

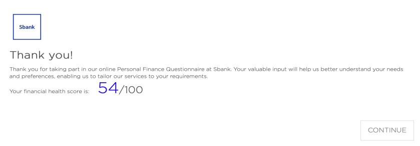

Fig. 2 The treatment in group 3

Participants in the fourth group receive the **questions, their scores, and information on the national average score** as depicted in Fig. 3.

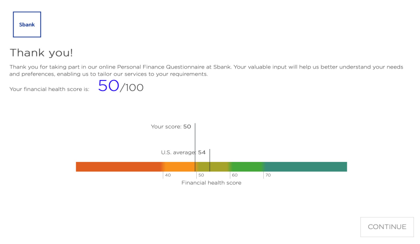

Fig. 3 The treatment in group 4

Empirical Strategy

To measure the effect of the treatments on the financial behavior of our participants, we measure the **marginal propensity to save** out of an unexpected windfall by asking how much a participant would save if they would unexpectedly receive a reimbursement equal to the monthly household income. Further, we obtain several control variables like age, gender, income and wealth among others. Our **regression equation is a linear regression model** of the following form:

$$Y_i = \beta_0 + \beta_2 D_{2i} + \beta_3 D_{3i} + \beta_4 D_{4i} + \boldsymbol{\eta} \boldsymbol{X}_i + \epsilon_i$$

Equ. 1 The regression equation

The outcome Y_i for user i is regressed on dummy variables D_{2i}, D_{3i} and D_{4i} representing the treatment groups 2, 3 and 4. The reference category is group 1. The vector $\boldsymbol{X}_i$ contains control variables. ϵ_i represents an unobserved disturbance term. Standard errors are robust.

Results

Preliminary regression results as depicted in Tab. 2 indicate that **solely providing the score to participants does not influence their financial behavior** as measured by the marginal propensity to save out of an unexpected windfall. However, **adding information on the national average to the score increases the marginal propensity to save of participants by 6.47 percentage points on average**. The coefficient is statistically significant at the ten percent level.

	Marginal propensity to save
(Intercept)	47.50***
	(6.897)
Group 2	1.311
	(3.354)
Group 3	1.113
	(3.329)
Group 4	6.474*
	(3.368)
Observations	599
R^2	0.07411
Adjusted R^2	0.05353
F Statistic	3.602***

Tab. 2 The regression results

Conclusion and Next Steps

Banks should provide consumers with peer information when they disclose their financial well-being scores in order to increase consumer savings. To provide further recommendations, we explore the effect of peer information on consumer financial behavior in more detail and record additional outcome variables related to financial behavior in a refined version of the experiment.

WE WALK THE TALK

Supervision
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Dr. Benjamin Loos, Senior Lecturer in Finance, University of New South Wales

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Technical University of Munich (2024)
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Renewable Pull Effect in Future Location Decisions

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Chair of Corporate Management

I. Introduction and Objective

The Paris Agreement's climate objectives necessitate significant emission reductions within the industrial sector, which accounted for 34% of global emissions in 2019 [1]. Particularly, the production processes of energy-intensive industries (EIIs), e.g., steel or chemistry, face a complex green transition. The substitution of fossil fuels with green hydrogen (GH2) is emerging as a promising solution. However, the potential high demand for GH2 in industrialized countries, e.g., Germany, Japan or the United States, coupled with local limited renewable energy resources (RER), leads to expensive import strategies [2].

This situation has given rise to a phenomenon described as the renewable pull effect, wherein regions abundant in RER can attract EIIs to locate or relocate their green production facilities, aiming for more cost-efficient production. In contrast to carbon leakage, such green intended facility shifts are defined as green relocations [3]. So far, researcher have only conducted non-empirical analyses to display potential cost-benefits of green relocations for different energy-intensive products. Egerer et al. calculated potential production cost-benefits in steel of 10%, in urea of 19,7% and in ethylene of 16,2%. However, researcher still question that the renewable pull effect genuinely leads to green relocations [3]. The literature is lacking empirical evidence, that no other location factors, e.g., labor costs or political stability, outweigh the cheaper production potential of RER-rich sites. Thus, the relevance of the renewable pull factor in the overall future production location decision of EIIs is queried. This study is driven by filling this research gap and evaluating the renewable pull effect as an enabler towards more cost-efficient green production.

II. Methodology

The study applies a mixed-method approach, focusing on the Analytical Hierarchy Process to gain in-depth insights into the decision-making processes of EIIs. The research investigates the perceived relevance of the renewable pull factor in future green production location decisions [4]. The Analytical Hierarchy Process has been identified as an effective and practical decision approach method, designed to solve complex multiple criteria problems, such as a production location decision. The study follows the classical Analytical Hierarchy Process approach applying three subsequent steps.

In the first step, a decision framework for future green production location of EIIs was developed, including 7 strategic considerations and 34 factors. This framework, shown in Figure 1, has already been validated with industry experts. The second step involves utilizing primary data from 10 to 15 exploratory semi-structured interviews with top-managers from EIIs, predominantly from the steel and chemistry industry in Germany. In the interviews, which are scheduled for summer 2024, the interviewee will pairwise judge the relative importance of a factor on a 'Saaty scale' [4], shown in Table 1. Moreover, the interviews serve to further validate the decision framework and to obtain qualitative data, clarifying the reasonings of the collected judgments. This data is used for the paper's interpretation of the Analytical Hierarchy Process outcomes. The third step, involves the synthesis of priorities derived from the comparative judgment data to calculate the individual relevance of the factors in the decision process. This synthesis provides a relative ranking for each level of the hierarchy and identifies the most relevant factors.

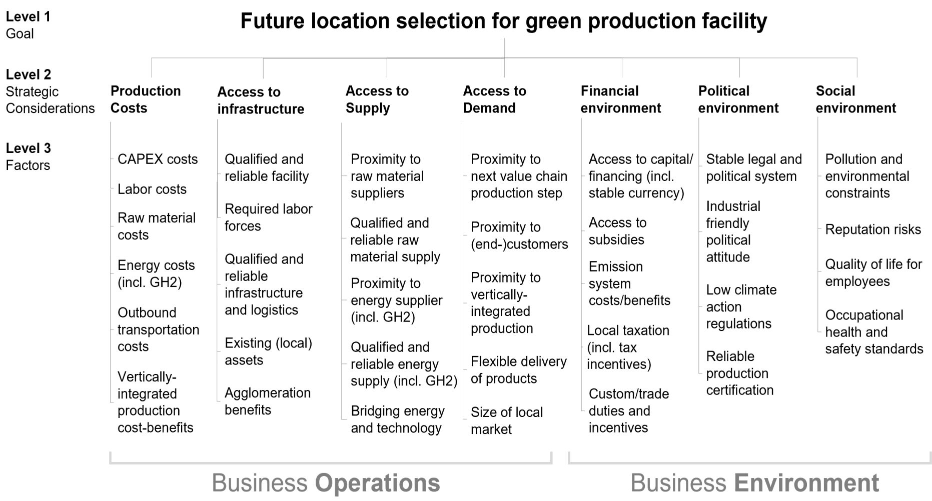

Figure 1: Analytical Hierarchy Process decision framework

Numerical value	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate values

Table 1: Classical Saaty scale [4]

III. Results and Contribution

Anticipated results of this study include the development of a validated decision framework for future green location decision, covering most relevant factors. Further, the research potentially demonstrates that the derived renewable pull factors, 'energy costs (incl. GH2), 'proximity to energy supplier (incl. GH2)' and 'qualified and reliable energy supply (incl. GH2)', play an above-average high relevance in the overall location decision of EIIs. However, at least comparable high scores are expected for the 'access to qualified and reliable production facilities', the availability of 'required labor forces', a 'stable legal and political system', and the 'access to subsidies'. Followed by only slightly less relevant factors such as 'qualified and reliable raw material supply' and 'flexible delivery of products to customers'.

The results of this paper will potentially contribute to four main groups. Firstly, for academia, it starts to fill a literature gap by applying empirical studies to present new insights for the ongoing discourse of the renewable pull effect in the location decision theory. For future research in e.g., industry-, case- or regional-specific analyses, it provides a developed theoretical framework for green location decision as a research base. Secondly, for the top-management of EIIs located in industrial nations, it supports the complex decision process for their future location choices. Thirdly, for policy maker in industrial nations, the study indicates the level of risk that EIIs will emigrate due to the relevance of the renewable pull effect. Further, regulations leveraging other relevant factors to counteract the renewable pull factor can be derived. Lastly, for policy maker in countries with high RER, the results provide insights into which institutional settings are required to attract EIIs.

IV. Key Findings

- The research potentially demonstrate that factors such as energy costs, proximity to energy supplier, and qualified and reliable energy supply play a crucial role in the overall location decision of EIIs
- A higher probability that EIIs decide to build green production facilities not in industrialized nations (e.g., Germany or Japan) but instead in regions with high RER (e.g., Global South) is potentially shown

WE WALK THE TALK

Supervision
Prof. Alwine Mohnen

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8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION

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TUM

Operando GIWAXS & GISAXS Observation of Suppressed Degradation Process with Solid Additive EH-P in Organic Solar Cells

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Sergei Vagin, Bernhard Rieger - TUM School of Natural Sciences, Department of Chemistry
Matthias Schwartzkopf, Stephan V. Roth - Deutsches Elektronen-Synchrotron (DESY)

Background – Solvent additives in NFA solar cells

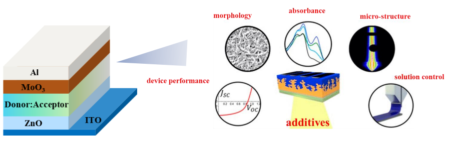
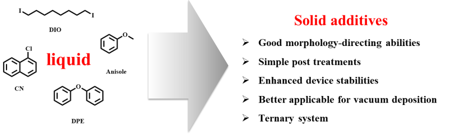


Figure 1 – Importance of additives in active layer

Additives plays a significant role in the film morphology and device performance. [1] Solid additives show various advantages compared with liquids used now. [2]



Research Questions

How to trace the film morphology change during degradation process, which would be ignored with ex-situ measurements.

Methodology - Operando GIWAXS & GISAXS at DESY

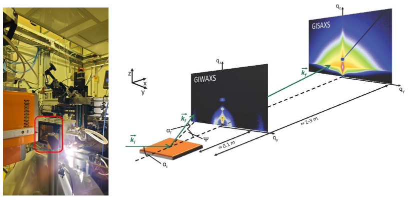


Figure 2 – Scheme of operando setup [3]

The operando setup could realize in-situ observation of GIWAXS & GISAXS patterns as well as recording J-V curves during the cell degradation under illumination.

Materials

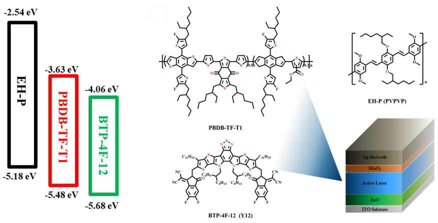


Figure 3 – Materials used in this work

PBDB-TF-T1 and BTP-4F-12 are used as donor and acceptor due to their applicability in non-halogenated solvents (e.g. THF), EH-P is used as solid additive. [4]

Results and discussion

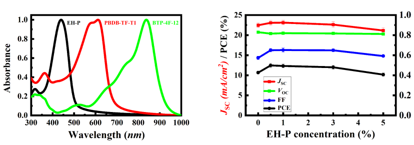


Figure 4 – UV-vis absorbance spectra of materials and device performance with different amount of EH-P

The doping of EH-P could increase the J_{SC} and FF of the devices towards higher PCE.

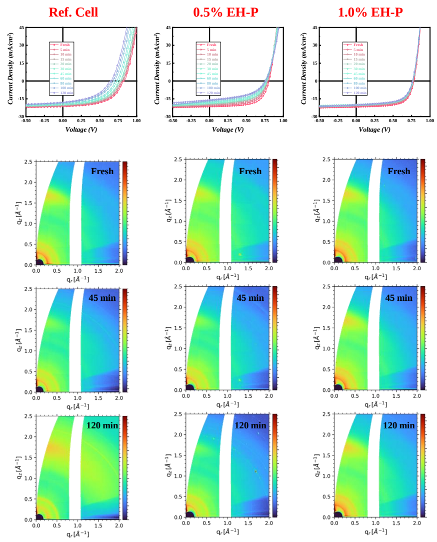


Figure 5 – Operando J-V curves as well as selected 2D-GIWAXS patterns under illumination

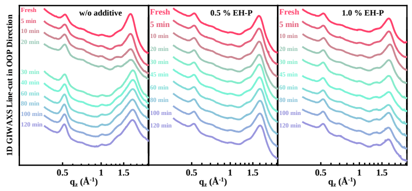


Figure 6 – Line-cuts in out-of-plane direction of operando 2D-GIWAXS patterns

The line-cuts in out-of-plane (OOP) direction refers to the π-π stacking of donor/acceptor, which donates to charge transfer and device performance. This peak was separated into several peaks and stacking distance (d_C) as well as crystal coherent length (L_C) were calculated to analysis donor or acceptor individually with the following formulas.

$$d = \frac{2\pi}{q} \qquad L_C = \frac{2\pi k}{FWHM}$$

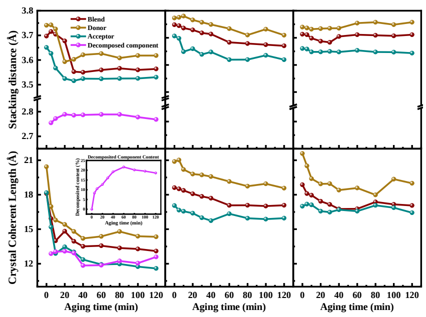


Figure 7 – Line-cuts in out-of-plane direction of operando 2D-GIWAXS patterns

For the reference, the degradation could be divided into two stages, where d_C and L_C shown great evolution at beginning and a decomposed component appears, then remained consistent in the following degradation, which can be suppressed with EH-P doping.

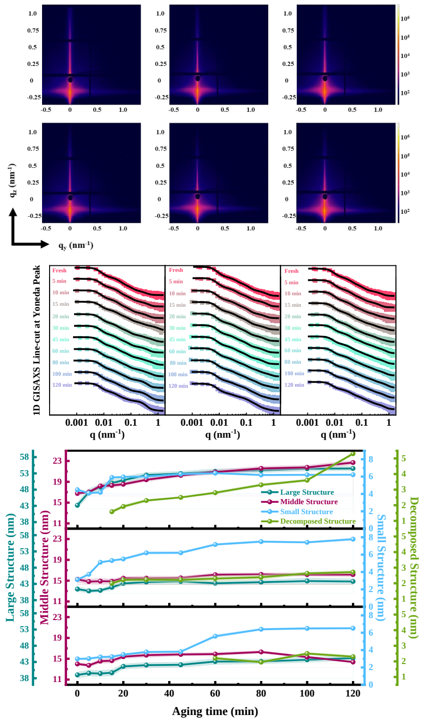


Figure 8 – Fresh and aged 2-D GISAXS , horizontal line-cuts of operando GISAXS patterns, as well as fitted parameters from horizontal line-cuts at yoneda peaks

Three sets of structures were used to fit the common curves. The dimension of phases swollen a lot during the aging process, which would go beyond the charge diffusion distance and is not conducive to the charge diffusion and transfer. A decomposed component also appeared in the second stage. EH-P doping could suppress the decomposition of the materials and the swelling of each phases.

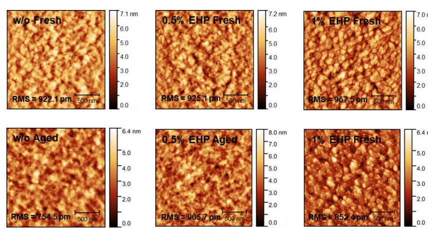


Figure 9 – AFM images of fresh/aged films with different amount of EH-P doping

Improved phase separation was got with EH-P doping and enhanced stability was found after aging, which is consistent with GIWAXS & GISAXS results, while almost no difference was found in roughness.

Conclusions

PBDB-TF-T1:BTP-4F-12 solar cells would show a two-stage- degradation process under light in air, where the charge transfer would get decreased due to the evolution of crystallinity and micro-structures of active layer films, and EH-P could stable crystallinity and molecular stacking.

Supervision
Peter Müller-Buschbaum, Chair of Functional Materials, Technical University of Munich

Acknowledgement: TUM E13 members, Prof. Changqi Ma, CSC scholarship

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WE WALK THE TALK

7 AFFORDABLE AND CLEAN ENERGY

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doi: 10.14459/2024md1743237

Multi-criteria decision making for sustainable building parts

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Background

In addressing climate change and its impacts, a significant reduction in greenhouse gas emissions is necessary. Addressing global climate goals, the EU aims for a net reduction of greenhouse gas emissions of at least 55 per cent by 2030 compared to 1990 levels [1]. The building sector plays a critical role in the transition to a climate-neutral and circular economy, as it is a major source of greenhouse gas emissions and resource consumption: In 2022, buildings were responsible for 37 per cent of global energy and process-related carbon dioxide (CO_2) [2].

In the design of building parts, planners must consider lots of aspects simultaneously, see Fig. 1 and Fig. 2. In addition to climate change, there are many quantitative (e.g., global warming potential, other environmental impacts) and qualitive criteria (e.g., user preferences). With an increase of energy retrofits and an operational energy use with renewable energies, embodied emissions are getting more important. Hence, a life cycle-based approach is essential and an approach for multi-criteria decision making (MCDM) for planners is needed [3].

Focus on single criteria

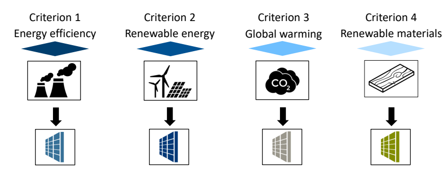

Fig. 1 Consideration of exemplary, single criteria in the design of building parts (own representation, icons from noun project).

Multi-criteria decision making (MCDM)

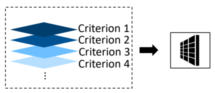

Fig. 2 Multi-criteria decision making in the design of building parts (own representation, icons from noun project).

Research questions

This dissertation aims to:

- Identify methods of multi-criteria decision making (MCDM) which are suitable for the selection of building parts
- Examine how MCDM methods can be used in the planning process of building parts
- Evaluate the influence of the selection and weighting of climate and environmental protection criteria on the result of MCDM
- Compare the results of different MCDM methods
- Discover the contribution of MCDM to the selection of climate and environmentally friendly building parts

Methodology

Within this research, life cycle assessment (LCA) and MCDM are combined. So far, relevant environmental criteria for building parts were identified throughout a systematic literature review. In addition, MCDM methods in the built environment were analyzed. For various building parts from research projects, selected criteria were determined and implemented in different MCDM methods to show the ranking of the building parts' performance and hence the best alternative(s) [3, 4].

Results

As displayed in [3], environmental criteria for building parts can be categorized into four main areas: (i) emissions, (ii) energy, (iii) resources, and (iv) circularity. In total, 26 criteria regarding environmental protection are identified. The global warming potential is rated as extremely important, yet not the only criterion.

As for MCDM methods, the Analytic Hierarchy Process (AHP) is widely used. However, a standardized method for planning processes has yet to be established. A case study comparing the Analytic Network Process (ANP) and AHP shows similar rankings for the best and worst alternatives when selecting the optimal ceiling structure [3].

Another suitable MCDM method is the utility analysis. The general procedure is shown in Fig. 3 and was applied for the selection of the best timber constructions in the TUM research project EDUwood (for more information, see https://www.cee.ed.tum.de/en/enpb/research/current-research-projects/eduwood/). For practicability reasons, not only environmental criteria were considered, but also building physics, structural aspects, and material costs. Comparing the costs to the results of the utility analysis is called cost-utility analysis. The comparison is especially helpful when cost limits are critical, as the best alternative (high utility value and low costs) can simply be identified. [4]

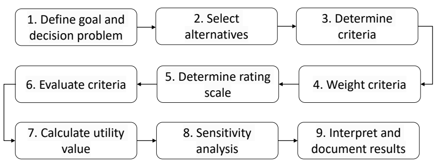

Fig. 3 General procedure of the utility analysis (adopted from [4]).

To achieve sustainable buildings and building parts, designers must consider a wide range of criteria. The developed approach as shown in Fig. 4 helps to structure the decision-making problem and navigate through the resulting complexity when considering multiple criteria simultaneously.

Key Messages

- Multi-criteria decision making (MCDM) methods support complex decision-making in building design.
- Combining life cycle assessment and MCDM is crucial to achieving a high impact on the environmental quality of buildings and building parts.
- The ranking of alternatives (building parts) depends on the choice of criteria and their weighting. Thus, apparently objective decisions are based on subjective assessments Therefore, a transparent documentation and sensitivity/scenario analyses are crucial.
- Alternatives listed in the ranking must be examined in relation to (local) building regulations and practices.
- The comparison of different MCDM methods regarding their applicability, transparency, and ranking of alternatives is planned in further studies.

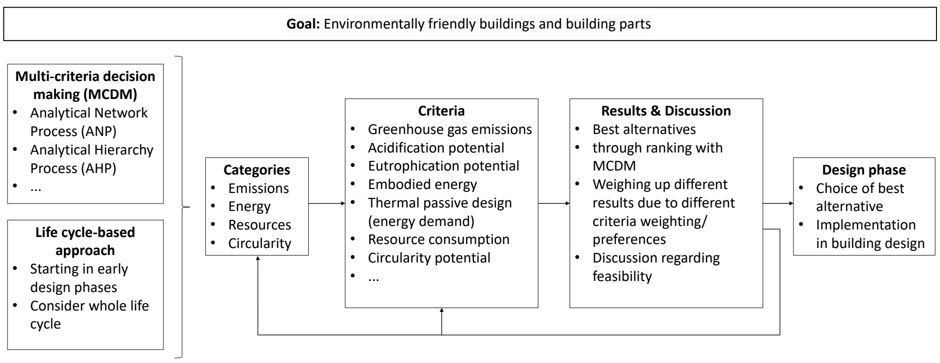

Fig. 4 Systematic approach for life cycle-based MCDM in the planning and design process with the goal of environmentally-friendly buildings and building parts (adjusted from [3]).

Supervision

Prof. Dr.-Ing. Werner Lang, Chair of Energy Efficient and Sustainable Design and Building, Technical University of Munich
Prof. Dr.-Ing. Jutta Albus, Department EKNB - Design and Construction/Sustainable Building, Bochum University of Applied Sciences

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WE WALK THE TALK

Technical University of Munich (2024)
Contribution number: 8
doi: 10.14459/2024md1743237

Catalog for Climate-Friendly Planning Competitions

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Background

Around 78 % of the population in Germany lives in cities [1]. This leads to challenges, and the need for new urban neighborhoods is emerging. These new urban neighborhoods must comprehensively and consistently consider the consequences of climate change. and enhance their climate resilience through various measures of climate protection (mitigation) and adaptation. In this context, it is crucial to integrate open spaces ("green infrastructure"), water management ("blue infrastructure"), and the built environment ("grey infrastructure") from the beginning. Planning competitions can address this challenge: The instrument of planning competitions intends to enable a professional, anonymous, and fair comparison of designs to find the best solution in the early stages as the basis for the upcoming construction contract [2].

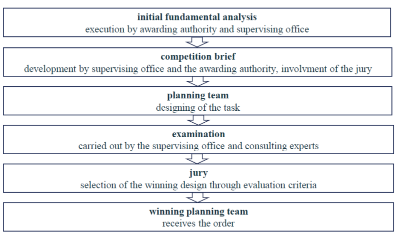


Fig. 1 shows an exemplary process of an architectural competition with different actors according to the guidelines for planning competitions (short: RPW 2013)

Goals of the Research

This study aims to verify the hypothesis:

Planners can implement climate-friendly (climate-friendly = impacts regarding climate adaptation and climate protection) aspects in their designs without additional workload compared to what is necessary to fulfill the regulations, as long as the criteria are addressed in the basic investigation and competition brief.

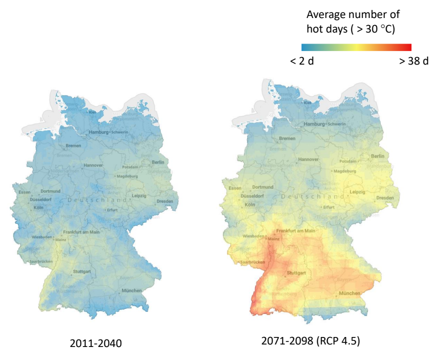
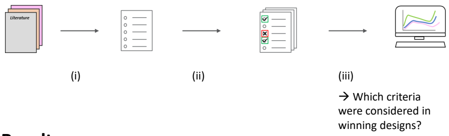


Fig. 2 shows heat waves in Germany

Methodology

We divide the methodological approach into three steps: (i) literature review and development of a criteria catalog with a focus on climate-friendly building, (ii) test of the criteria based on seven real model projects in Bavaria, and (iii) evaluation of the criteria for practical suitability regarding revised deliverables.



Results

We confirm the hypothesis that planners can implement climate-friendly aspects in their designs without significant additional workload according to the regulations, as long as the criteria are addressed in architectural competitions' initial fundamental analysis and competition brief. Collaborating with landscape architects is essential as part of the competition process. To keep the submission workload and deliverables manageable for the planners, it is necessary to provide expert reports and assessments, such as cold air corridors and microclimatic modeling. Recommendations for action or benchmarks should be formulated in all expert reports as a basis for the planning team. However, the additional costs for the initial fundamental analysis justify the quality of the climate-friendly design. Through the scientific monitoring of exemplary subsidized housing projects, we develop a catalog of criteria focusing on climate-friendly construction based on literature research. We test the set criteria for practical suitability by making them available to the authorities from the beginning of the architectural competition. Our research shows that raising awareness of the criteria early is essential to ensure they are considered when developing a competition brief. It was identified that some of the criteria describe objectives, and some also describe measures. However, this distinction is maintained to address the intent of each criterion. The classification according to sections helps to provide an overview, but in some cases, criteria can be assigned to multiple sections.

Fig. 5: Interdisciplinary Criteria Catalog for Climate-Friendly Architectural Competitions – Test and Evaluation at Case Studies based on [3]

Fig. 3 shows an exemplary selection of the winning design by the jury in Deggendorf, Bavaria

criteria catalog			test and evaluation		lessons learned	
criteria	goal of the criterion	examples of measures	competition brief	winning designs	reports	possible proof in the following deliverables
urban setting	reduction of the heat island effect, keep cold air corridors free	preservation of existing cold air corridors, open green spaces within the urban structure, relation to the adjacent park, agricultural, forest, and water areas, green roofs and façades, tall trees, no ground level barriers, consideration of topography, shading	100%	83%	01 02 03 09 10	figure-ground diagram, site plan, conceptual explanation of cold air corridors considering the climate function map provided
density	double brownfield development	densification, preserving tree stock, planning new trees	100%	100%	03 10	coverage ratio, floor space index, site plan, views, sections
land sealing	reduction of land sealing	alternative mobility concepts to reduce the parking space, avoid underbuilt areas, creation of short distances, concept of shared spaces, greening of built-up or underbuilt area	89%	83%	04 05 10	site plan, textual and conceptual explanation, sealed vs. unsealed area in %, underbuilt area vs. not built
local water balance	the water balance in the developed state should be as close as possible to the undeveloped reference state	reduction of land sealing, on-site stormwater management, maximizing greening	83%	17%	04 - 07	textual explanation, site plan
greenery	reduction of the heat island effect by preserving the tree population and existing green structures and planting new ones.	preservation of the healthy tree stock and existing green spaces, interlinking with existing green structures, increase of the green share through unsealing, greening of underbuilt areas, creation of new green and water areas	100%	100%	03 04	site plan: presentation of existing tree stock and new plantings
shading and exposure	reduction of overheating of open spaces and buildings	placement of buildings taking into account adequate exposure to light, new trees in previously identified heat islands	100%	100%	01 02 03 10	site plan with demonstration of shading

Fig. 4 shows the criteria for the section “urban planning.”

Key Findings

- This study aimed to demonstrate that the issue of climate-friendly construction can be considered in early planning phases without leading to additional effort for planners.
- Based on the testing of criteria on real model projects, we were able to show that
- Most of the criteria that are necessary for climate-friendly planning can be requested from planners as part of deliverables that have to be provided anyway
- By sensitizing planning teams to the importance of the topic, it is possible to ensure that it is taken into account in the designs submitted
- Our study helps municipalities, builders, and planners integrate climate-friendly aspects from the start and create healthy and climate-resilient neighborhoods.

Supervison

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3 GOOD HEALTH AND WELL-BEING
7 AFFORDABLE AND CLEAN ENERGY
11 SUSTAINABLE CITIES AND COMMUNITIES
13 CLIMATE ACTION
15 LIFE ON LAND

WE WALK THE TALK

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