UNIVERSITY OF GRAZ

Department of Environmental Systems Sciences

Annual Report 2023

Department of Environmental Systems Sciences
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Department of Environmental Systems Sciences
University of Graz
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Editorial

In 2023, Nina Hampl was appointed as a professor of active mobility at the Department of Environmental Systems Sciences, which greatly extends the Department's scope of research and teaching competencies. The year 2023 was also marked by an extraordinary number of pre-/post-doc researchers who started their activities at the University of Graz– we warmly welcome Alina Delitz, Victoria Yavorskaya, Veronika Dworzak, Nina Hampl, Nicolas Katzer, Tasya Oka Putu, Robert Sposato, and Edvard Sveum as new members of the Department. Furthermore, three dissertations were completed this year, for which we offer our sincere congratulations to Anna Diaz Tena, Magdalena Rusch, and Lukas Stumpf (for a description of their projects see section 2.5).

In 2023, an impressive series of research projects has started, encompassing various domains such as digital innovation and industry 4.0, forest ecosystem services, product design and construction, active mobility and traffic avoidance, circular economy and bioeconomy, hydrogen imaginaries, wholesome gaming, and alpine resilience. The series includes:

EDIH innovATE – The European Digital Innovation Hub for Agrifood, Timber and Energy; Forest EcoValue – Supporting multiple forest ecosystem services through new circular/green/bio markets and value chains; E-Track – Safe, sustainable and cost-optimized traction battery; TransBuild – Developing transition pathways for deep transformative changes in the building sector; CarryMeHome – Energy-efficient, modular and seamless transport of people and goods with a focus on active mobility; iNEVER – Innovation network on traffic avoidance; SuESS – Safe- and sustainability-by-design approaches for energy storage systems in a green and circular economy; SwarmIn – Swarm Intelligence and Combinatorial Optimization for Energy Efficient and Adaptive Industry 4.0; HydroFRAME – The framing of national hydrogen imaginaries; BELOW – Austrian bioeconomy futures: Limits to green growth; Bridge-PhD Position – Wholesome Gaming: Identifying positive human-media interactions using community trace data; Mobility paths that move: Styrian access to people, goods and services in the context of global megatrends (Z-T-G 001); Hydrogen and Styria: Regional pathways in the context of international technology development; and BioPV – Photovoltaics, Humans and the Biosphere: A transdisciplinary approach fostering Alpine resilience.

The department is responsible for 678 bachelor students as well as 608 master students. 48 master theses were completed or submitted under the supervision of department members during 2023. In addition to the Environmental Systems Sciences program – which form the core of the department's teaching activities – the ESS coordinates the international Joint Master Programs in Sustainable Development (SD) and Circular Economy (CE) as well as the Global Studies. In 2023, 21 students from 12 different countries started the SD program in Graz, while two intakes of CIRCLE students met face-to-face for their summer school and graduation ceremony, organized in Selbu in Norway. Concurrently, Global Studies sustained an enrollment exceeding 300 students across its three programs.

We thank you for your interest in our work and wish you an informative read!

Contents

1 The department

1.1 Mission statement

The Department of Environmental Systems Sciences investigates possibilities for the *transition towards a more sustainable future*. Therefore, we study transition, innovation, and adaptation processes within socio-technical and socio-ecological systems at various levels. We base our research on systems sciences, innovation, and transition sciences as well as on sustainability science, and develop and apply *inter- and transdisciplinary* methods to analyze and model complex systems, establish scenarios and transition pathways, and assess policies and strategies.

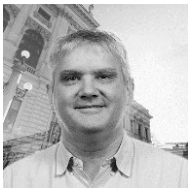
The department is characterized by the *disciplinary diversity* of its members. Highly motivated and excellent researchers originating from diverse fields of natural, social and formal sciences collaborate on real-world problems. We are highly committed to the promotion of *young scientists* and to research-led teaching in the study programs of Environmental Systems Sciences, the international Joint Master Programs in Sustainable Development and Circular Economy as well as Global Studies.

All members are actively engaged in national and international (stakeholder) networks, in terms of teaching, research, and practice. We interact with different stakeholders, policy makers, professionals and the general public, and initiate *mutual learning processes* and exchange of knowledge.

Department staff (2024). Photo: Leonhard Dürrer

1.2 Faculty and Staff members

1.2.1 Professors



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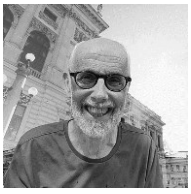

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1.2.4 Project Staff

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Gerald Maurerbauer BSSc
Madeleine Martinz
Michael Klaus Mayr
Nina Neundorfer
Karl Reimer BSc
Viktoria Schett BA BSc
Anika Schmitt BA
Marlena Schöttl BSc
Daniela Schweiger
Jan Stalzer BSc
Juliane Stumpf BA.

1.3 “ESS Science Talk”

For the “ESS Science Talk,” the department is inviting external experts to give a presentation on core research topics (i.e., systems sciences, innovation, transition and sustainability research). These presentations are followed by a discussion and a small buffet. This event is held in English and open for the entire URBI Faculty, other interested colleagues and students and any friends of the department.

Three talks could be offered in 2023:

- “Why is Climate Literacy critical knowledge for workers in a sustainable economy?”, Dr. Vivian Price, 28 March 2023
- “Future-oriented collaborative business models as facilitators of sustainability: insights from the project aiming for transition framework development”, Dr. Annukka Näyhä, 4 April 2023
- “Go vegan? Ideological resistance to plant-based food advocacy”, Dr. Ben De Groeve, 25 April 2023

Up-to-date information and the whole list of speakers can be found on our website at https://ess.uni-graz.at/en/research/ess-science-talk/.

1.4 Other events

In addition to the ESS Science Talk, the following events were organized by the Coordination Office for Environmental Systems Sciences (USW Koordinationsbüro):

- How to write a bachelor thesis
- Study Abroad
- USW application check
- USW specials
- Chat4Future
- Participation in the Open Day
- Masters Welcome
- Participation in the Sustainability Days
- Participation in the Welcome Week
- Time and self-management
- Master award

Up-to-date information on events organized by the Coordination Office for Environmental Systems Sciences can be found at http://umweltsystemwissenschaften.uni-graz.at/.

2 Research Projects and Activities

2.1 Research profile

Three core research areas are combined in the Department of Environmental Systems Sciences:

- systems research with a focus on methods development
- innovation- and transition research with a focus on innovation systems and diffusion
- sustainability research with a focus on sustainability management and assessment

These are the research areas and foci of our department (in alphabetical order):

2.1.1 Active Mobility

Active Mobility (AM) as part of the Sustainable Energy and Mobility Transition research field has become a specific research focus of the department within the last couple of years. Major milestones have been the appointment of the professorship for active mobility (financed by the federal state of Styria) and the foundation of the Center for Active Mobility (CAM) in collaboration with the Institute of Urbanism of the Graz University of Technology and co-financed by the City of Graz and Merkur Versicherung. The objective of the CAM is to establish active mobility as an inter- and transdisciplinary research field and achieve visibility on a national and international level. Research at the ESS focuses on topics such as increasing our understanding of the prerequisites/drivers and barriers of active mobility (mainly individual travel behaviour and mode choice), the role of technology and digitalization to support the shift to active mobility modes and how corporations can foster active mobility of their employees.

2.1.2 Bioeconomy – bio-based economy

The term bioeconomy refers to a prominent political-economic concept for sustainable development. Different understandings of the concept reach e.g. from the substitution of fossil resources by bio-based ones, the strengthening of bio-based sectors, the future role of life-science-based innovations to a radical reorientation of economies by considering to a radical reorientation of economies by considering the limited availability of natural resources (see Georgescu-Roegen). The adherent causes, dynamics and consequences of the increasing use of biomass and bio-based innovations are in the focus of the department's research activities.

2.1.3 Circular Economy

Circular Economy (CE) is an emerging topic and highlights the importance of an intelligent design, manufacturing, distribution, use and end-of-life management of resources along the entire value chain of products and services. The European Commission's "Circular Economy Action Plan" underlines the relevance for CE and supports the "European Green Deal" with its ambitious targets for 2050, such as the decoupling of economic growth from resource use. Within the last years, CE has advanced to one of the department's research and teaching foci, which is reflected in dealing with circular business models, or contributing to the development of methods and concepts for the collection of environmental and social data of certain products and services. One example for our teaching activities is the co-ordination of an

international master's program on CE. The department's CE research and teaching activities are not restricted to the industrial level, but involve those at the level of society at large, including co-operation with civil society.

2.1.4 Complex Networks and Multi-Agent Systems

Systems Science offers many methods that are well suited to simulate complex systems in the field of sustainability research and beyond. One focus of the department is the development and application of agent-based models, i.e., models that start out from individual components and describe their interaction with each other and their environment. This way of modeling is not only successful when describing all kinds of human systems like opinion dynamics, the labor market, or mobility systems, but can also be used beyond that scope.

Complementary to this technique, network science is used to describe systems in which the links between the components are more important than the components themselves. Examples of such systems include traffic networks or social networks.

Additionally, the combination of different modeling methods is used to gain a more complete picture of the investigated systems.

2.1.5 Data Science & Artificial Intelligence

For most systems that are investigated by the department, a large amount of data is required to gain a sufficient understanding. Therefore, Data Science is a focus for the Systems Sciences. This includes data collection via text mining as well as processing and interpretation using techniques like topic modeling or sentiment analysis. Additionally, the gathered data is integrated into existing or newly developed models.

Furthermore, other kinds of machine learning methods and techniques from artificial intelligence are employed and developed. This includes for example artificial neural networks that are used to solve various classification or regression problems. Such methods are not only used to process and interpret data, but can also enhance computer simulations or enable us to develop models that would not be possible without AI assistance.

2.1.6 Digitalization

Research on the possibilities and consequences of digitalization relates on the one hand to accessing and processing of data that can be used for, among others, gaining insights into regularities of environmental relevant human decisions and behaviors or into the specifics of certain business activities or production particularities. In other words, this branch deals with data and text mining. On the other hand, systems sciences are also concerned with the use, the research and the development of analysis methods that are currently discussed under the keyword machine learning. One focus here, for example, is on the model-based screening of large spaces of possibilities and the anticipation of sustainable options, summarized under the term Future State Maximization. Additionally, systems sciences are involved in the research network "Human Factor in Digital Transformation", in which digital developments are tested and investigated in the context of their significance for the human sphere.

Digitalization also goes beyond data accessing and processing of data including emerging technologies and their societal implications.

2.1.7 Humans in sustainability transitions

Sustainable societies cannot be achieved through technological innovations alone. Transitions need to bring on board citizens, consumers, households and decision makers, and involve them beyond awareness raising or providing information about sustainability and climate change. We seek to understand the decision processes of citizens, consumers and organizations and aim to identify the necessary circumstances for sustainable living. We also investigate potentially adverse side-effects of transitions and factors related to acceptance and acceptability of sustainability transitions in different groups of society. This also includes a two-sided perspective including production and consumption patterns, but also the acting of citizens on all levels of their living.

2.1.8 Resilience research

Research on resilience predominantly relates to methods for analyzing and predicting phase transitions in complex dynamic systems, so-called critical transitions. One focus here is on computer-based modeling, which offers the possibility of mapping component interactions, i.e. the actual cause of the behavior of specific systems, in detail. Additionally, network representations are considered to analytically capture system relevant interactions. This allows, on the one hand, to test resilience by systematically perturbing certain parameters in computer-based system models. On the other hand, various statistical metrics, summarized under the term Early Warning Signals, are used to gain insights into the robustness and stability of a large number of different systems.

We also apply the idea of resilience and the respective research concepts on an applied level, trying to support organizations of all kinds in strengthening their ability to anticipate, withstand, cope with and even thrive in the face of challenges. In this context, resilience is an implicit part of many of our research projects.

2.1.9 Sustainability on the business and product level

The central interest in this research area is to support the diffusion and application of sustainable development by integrating it into the company activities, strategies, and products while highlighting the consequences of such integration. This implies that research is conducted on the operationalization of sustainable development at the corporate level (i.e., concepts and frameworks of corporate sustainability management), the motivation of companies to act in (more) sustainable ways, sustainability strategies and sustainable business models, sustainable innovation, sustainability assessment, sustainability design and inter-organizational management related to sustainable development.

2.1.10 Sustainable Energy and Mobility Transition

Both the energy sector and the closely related mobility sector are particular relevant fields for promoting sustainability and in particular for mitigating climate change. The shift from fossil fuel-based energy and transport systems to renewable energy sources and powertrains is

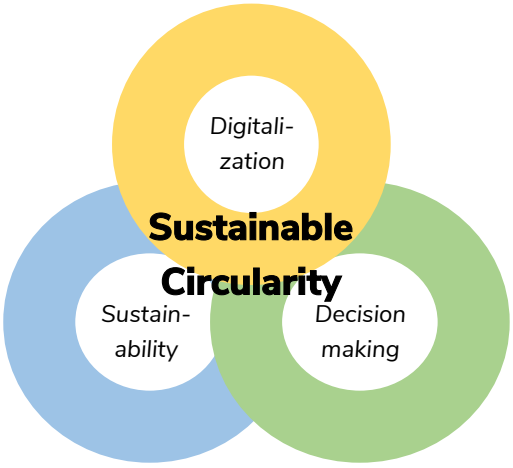
urgently needed. However, in the context of the broader sustainability debate, the strong focus on promoting (supply-side) technological innovations has been criticized. Scholars have increasingly recognized the role of behavioral change on the demand side as a necessary component of the required sustainability and low-carbon solutions. Therefore, in our work we consider both perspectives and explicitly integrate the relevant aspect of behavior change by tackling different roles, such as consumers, citizens, policy makers, industry, etc. in close connection with the research field of "humans in sustainability transitions" outlined above. This includes both self-driven as well as policy-driven behavior changes, but also the public acceptance of relevant policy measures or low-carbon technologies as well as innovations in the context of energy and mobility.

2.2 Research Projects

2.2.1 Christian Doppler Laboratory for Sustainable Product Management enabling a Circular Economy

Introduction

To support the ambitious Circular Economy Action Plan adopted by the European Union, this research laboratory acts as a creative space for developing and conducting research in Sustainable Product Management, the results of which will support the transition toward a Circular Economy.



This research laboratory aims to support companies with new and improved methods and frameworks to maximize the sustainability performance and circularity of their products and services. The research team conducts basic research in the fields of sustainability sciences and social sciences (interdisciplinary research approach) in order to

- operationalize the concepts of Sustainable Development and Circular Economy on the corporate and product level,
- to use the full potential of digitization for Sustainable Product Management, and
- to understand decision-making processes in companies and in supply networks as basis of a lifecycle-wide implementation of Sustainable Product Management.

As a result of the research work, methods and concepts are developed for the collection of environmental and social data on products and services from the supply chain, the use phase and the end-of-life phase. This data will be used for the social and ecological evaluation and design of products and services, as well as for further applications.

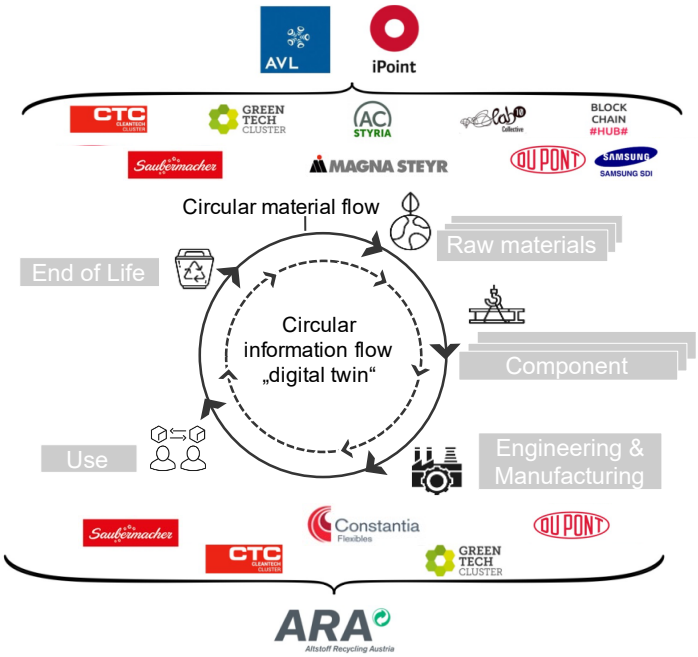
Unique project setting

In Christian-Doppler-Laboratories application-oriented basic research is pursued at a high level and scientists cooperate with innovative companies. The Christian-Doppler Research Association is an international best practice example for promoting this collaboration.

Christian Doppler Laboratories are financed jointly by the public purse and the participating companies. The most important public sponsor is the Federal Ministry of Digital and Economic Affairs.

Use cases

The research in the CD-Laboratory can be distinguished into two overarching use cases. The first automotive-oriented use case with AVL and iPoint focuses on the question: "How can sustainable circular economy practices be realized along a full value chain?" and for the second, packaging-oriented use case the following questions are of interest: How can companies such as the ARA AG use the methods and tools developed in this CD-Laboratory to – (1) assess how sustainable and circular existing packaging solutions are – (2) to optimize packaging solutions from the viewpoint of sustainability and circularity?



Graphical presentation of the two use cases and the involved industry partners (top = automotive, bottom = packaging)

Ongoing research activities

The current research activities focus on (1) the development of a decision-support approach for the early stages of heavy-duty powertrain development that allows the determination of sustainability-related optimal designs in the context of varying use cases, (2) the conceptualization of a digital product passport for vehicle traction batteries, (3) the utilization of probabilistic machine learning for the protection of confidential information in sustainability assessment and product passports, (4) the assessment of the effect of inter-organizational collaboration and digital technologies on circular economy and firm performance, as well as (5) the experimental investigation of the influence of environmental and social information on corporate decision-making.

Recent publications

The recently produced research output concerned itself, for example, with investigating the effect of digital technologies and inter-organizational collaboration on the implementation of circular economy practices in companies (Link), deriving and prioritization of the 15 most

important barriers to sustainable and circular product design (Link), or a framework for deploying corporate sustainability strategies and operational excellence (Link).

Furthermore, in the area of digitalization, the stakeholders' data availabilities and requirements for a digital product passport were assessed (Link), the potential of different digital technologies (IoT, AI, big data, blockchain) for supporting corporate sustainability management was estimated (Link), and the degree of implementation of these digital technologies in Austrian manufacturing firms was investigated (Link).

Head of the Laboratory	
	Univ.-Prof. Dr. Rupert J. Baumgartner
Project team 2023	Magdalena Rusch, BA MSc, Katharina Berger, BSc, MSc, Katharina Roche, MSc, Moritz Kettele, BSc, BSc, MSc, Julius Ott, MSc, Josef-Peter Schöggl, PhD, Tanja Untergrabner
Duration	2018 – 2025
Website	https://circular.uni-graz.at/en/
Project partners and funding	
	Austrian Federal Ministry for Digital and Economic Affairs, National Foundation for Research, Technology and Development Christian Doppler Research Association, iPoint-systems GmbH, AVL List GmbH, ARA AG

2.2.2 EDIH innovATE – The European Digital Innovation Hub for Agrifood, Timber and Energy

Small and medium-sized enterprises (SME) are the backbone of the Austrian and European economy, drivers of innovation and essential for our prosperity. Digitalization and innovation skills are crucial for SME to be able to survive international competition in the future and to achieve the European Union's (EU) twin objective of a green transition and digital transformation. The European Digital Innovation Hub (EDIH) innovATE aims to support these objectives by accelerating the digital transformation of SME in the agriculture, food, timber, and energy sector (ATE) by focusing, for instance, on Artificial Intelligence (AI), Cyber-Physical Systems (CPS) and Advanced Digital Skills.

By improving digitalization in the ATE industries EDIH innovATE strengthens the world's ability to feed a growing population, prevent forest decline, use resources efficiently, generate green energy and keep a thriving ecosystem. EDIH innovATE's goal is to advance Austria and

Europe as a location for innovation by training highly qualified SME workers, creating new companies and jobs, counteracting rural exodus, and creating opportunities for exchange with the best in Europe through the EDIH network. Through increased digitalization, we also promote resilience in crises, e.g., climate change, globalization, COVID-19 crisis.

That is why EDIH innovATE acts as one-stop-shop for digital innovation in the ATE industries for SME offering hands-on trainings, workshops, test-before-invest activities, networking events, prototype projects, SME accelerator and access to finance. EDIH innovATE builds its experience on an exceptional track record of the national Digital Innovation Hub (DIH) innovATE and its renown digitalization and industry expert partner organizations that together with the DIH build the EDIH innovATE consortium.

Project team	Univ.-Prof. Dr. Nina Hampl Dr. Robert Sposato Marina Bartoletti, MA MSc
Lead institution	Digital Innovation Hub innovATE
Scientific partners	SBA Research gemeinnützige GmbH, Josephinum Research, Montanuniversität Leoben, University of Graz (ESS), Kompetenzzentrum Holz GmbH, FH Salzburg GmbH, OÖ Wirtschaftsagentur GmbH, THI Techhouse GmbH, Blue Minds Solutions GmbH
Duration	October 2022 – September 2025
Funding	EU (European Digital Innovation Hubs, DIGITAL Europe Programme), BMAW/FFG

2.2.3 Forest EcoValue – Supporting multiple forest eco-system services through new circular/green/bio markets and value chains

Forests play a key role for climate change mitigation and resilience in the Alpine region, offering multiple ecosystem services, environmental social benefits, like CO2 absorption, air pollution reduction, increase of biodiversity, resilience to natural risks and many others. Alpine forests are threatened by abandonment, climate change and territorial degradation that progressively lead to a pauperization of natural resources and to a decrease in the provision of forest ecosystem services (FES). As a result, forests maintenance costs are high and economic sustainability for the public and private owners is unsatisfactory: public funds and the revenues generated by the traditional wood value chains are no longer sufficient and the

attraction of additional resources becomes an evident need. Along these lines, the definition of economic valuation methods and the development of payment schemes are widely debated, but only occasionally successfully applied.

The Forest EcoValue project is based on the acknowledgment that restoring and maintaining healthy forests can generate a value for the benefit of the whole Alpine region, as well as green businesses and sustainable job opportunities for the alpine communities. The Forest EcoValue project intends to tackle this challenge and turn it into an opportunity, by developing innovative sustainable win-win business models for forest management and maintenance, based on new value chains, and involving different sectors (energy, construction, chemistry/pharma, food, recreation etc.), public and private actors, as well as citizens. The project will propose new frameworks for public-private markets and payment schemes, maximizing the value of FES towards the regional value chains. The proposed solutions will be tested in a pilot action consisting of a network of five Living Labs in Austria, France, Italy, Slovenia and Germany.

The Department of Environmental Systems Sciences is responsible for developing of methodology of the economic assessment of FES in the Alpine region. As a result, conditions for efficiently developing FES markets and business model archetypes will be elaborated and the social value of FES will be identified. In this way, payment schemes for public and private players will be identified. In addition, policy/governance enabling factors will be further addressed. Subsequently, the proposed economic approach will be tested in the Living Labs, and lessons will be drawn and exchanged in the interregional network. As the last step, a national/regional capacity building workshop and Alpine Region Summer School on FES

Markets will be organized in order to foster capacity development and knowledge transfer between target groups at different territorial level.

Project team	Univ.-Prof. Dr. Tobias Stern Victoria Yavorskaya, MSc
Lead institution	Finpiemonte SpA
Partners	Finpiemonte SpA – Regional financial and development agency, FLA – Lombardy Foundation for the Environment, Lombardy Green Chemistry Association, Biobase – Austrian innovation platform for bioeconomy and circular economy, University of Graz, Slovenia Forest Service, Ifuplan – Institute for Environmental Planning and Spatial Development GmbH & Co. KG, INRAE National Research Institute for Agriculture, Food and the Environment, Regional Centre for Forest Property Auvergne-Rhône-Alpes, Forests National Office, Woodcluster Styria
Duration	October 1st, 2022 – September 30, 2025
Funding	Interreg Alpine Space, co-funded by European Union

2.2.4 ELANET

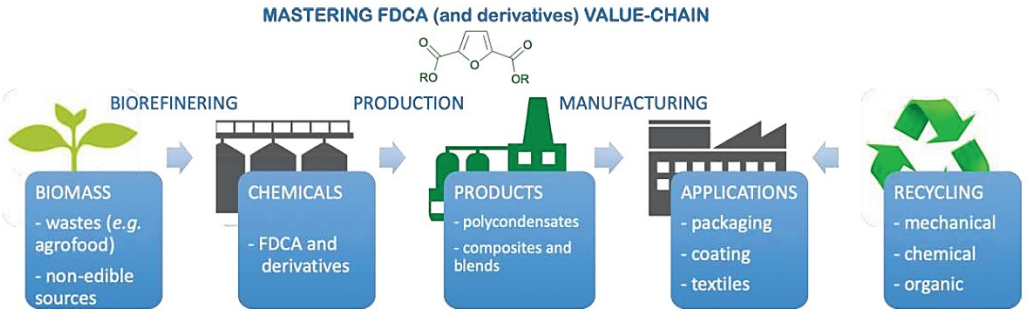
The European Latin American Network in Support of Social Entrepreneurs (ELANET) has the ambition to become a leading platform in support of social entrepreneurs (SEs). This project will lead partner universities to implement an IT-based platform that consolidates already existing tools, resources, and coaching material for SEs. Our consortium involves 17 project partners (among which 4 European Universities and 12 Latin American Universities) and 35 associated partners. Through ELANET, partners institutions will seek to develop exchange best practices for the support of SEs and stimulate the internationalization of SEs, and their solutions to social challenges. The project is for 3 years (2021-2023) and is funded by the Erasmus + Capacity Building Program. University of Graz is playing an advisory role in the project.

Project team	Univ.-Prof. Dr. Rupert J. Baumgartner Dipl.-Ing. Dr. Ralf Aschemann Arijit Paul, PhD
Project Partners	Vrije Universiteit Brussel (Belgium), Ashoka BelgiumKoalect (Belgium) University of National and World Economy (Bulgaria), LIBERA Universita Maria Ss. Assunata (Italy), Universidad Catolica Boliviana San Pablo (Bolivia), Universidad Mayor de San Simón (Bolivia), Colegio De Estudios Superiores De Administración (Colombia), Universidad de La Sabana (Colombia), Fundación Universidad del Norte (Colombia), Technological University of Bolívar (Colombia), Universidad del Magdalena (Colombia), Escuela Superior Politécnica del Litoral (Ecuador), Universidad de Cuenca (Ecuador) Universidad de Piura (Peru), Universidad Continental (Peru)
Duration	15/01/2021 – 14/01/2024
Funding	European Commission's grant under Erasmus+ capacity building in the field of higher education agreement number 617788-EPP-1-2020-1-BE-EPPKA2-CBHE-JP

2.2.5 European network of FURan based chemicals and materials FOR a Sustainable development (FUR4Sustain) CA18220

The main goal of this COST Action is the international linking of research activities in relation to 2,5-furanedicarboxylic acid and its derivatives. Innovation at the current level of research and development is to be promoted in order to overcome scientific, technological and industrial barriers that hinder the widespread use of new FDCA products. To achieve this goal, FDCA synthesis, polymers, development and characterization of polymer materials as well as the most important technical, economic, ecological and social factors are considered together. In addition, the COST Action supports the exchange of cross-sector knowledge through dissemination and networking tools. The aim is to create an open platform for cooperation and a common vision in relation to research, qualification of human resources and industrial implementation.

The University of Graz is involved in Working Group 3 (WG 3) and also provides the working group leader.



Concept of the FDCA value chain

WG 3 aims at contributing to the Cost Action by identifying the main economic obstacles, market demands, supply chain challenges, environmental hotspots as well as legislative restrictions that need to be addressed. This requires a holistic approach that includes the consideration of the entire value chain from resource to end-of-life.

Project Team	Univ.-Prof. Dr. Tobias Stern Julia Wenger, MSc. Verena Haas, BSc.
Lead Institution	University of Aveiro
Partners	Universities and Companies from Austria, Czech Republic, Germany, Italy, Netherlands, Serbia, Sweden, Belgium, Denmark, Greece, Latvia, Poland, Slovakia, Switzerland, Bulgaria, Finland, Iceland, Luxembourg, Portugal, Slovenia, United Kingdom, Cyprus, France, Ireland, Malta, Romania, Spain
Duration	November 2019 – November 2023
Funding	European Cooperation in Science and Technology (COST) supported by Horizon 2020 Framework Program of the European Union

2.2.6 FREE4LIB – Feasible recovery of critical raw materials through a new circular ecosystem for a Li-Ion Battery cross-value chain in Europe

Since 2022 the Department of Environmental Systems Sciences at the University of Graz is part of the Horizon Europe project FREE4LIB (Feasible Recovery of critical raw materials through a new circular Ecosystem FOR a Li-Ion Battery cross-value chain in Europe). FREE4LIB aims to develop at TRL 5-6 technologies to achieve six new sustainable and efficient processes to recycle end-of-life (EoL) LIBs (dismantling, pre-treatment and four materials recovery processes). This results in the delivery of very innovative recycling solutions to reach highly efficient materials recovery (metal oxides, metals and polymers) improving the supply of secondary resources at EU level. FREE4LIB will also deliver technologies to improve three processes aimed at the reuse of metals and polymers and electrode synthesis in the same value chain as secondary raw materials for the recovery of greener batteries, and it will explore options to utilize non-reusable elements in other areas.

As the leader of FREE4LIB work package 5, the Department of Environmental Systems Sciences developed a digital battery passport concept that is now used for a digital battery passport prototype to improve process traceability, process design and sustainability. Further, the Department of Environmental Systems Sciences assesses the social impacts of the developed battery recycling processes (e.g., generic S-LCA, comparative S-LCA, MRIO analysis) and an additional aim of this work package is to carry out a systemic sustainability assessment. This systemic sustainability assessment aims to evaluate the respective EoL scenarios in order to move away from a narrow to a systemic perspective.

FREE4LIB

Funded by the European Union

Project Team	Univ.-Prof. Dr. Rupert Baumgartner Josef-Peter Schöggl (PhD) Julius Ott Martina Zimek
Lead institution	Fundación CARTIF
Project partners	CARTIF, ACCUREC, ALIENOREU, AIMPLAS, Kellen, AVL, CSIC, ERION, Fraunhofer, EURECAT, IREC-CERCA, FBK, ITL, LUREDERRA, NextMove, NESSTEC, POLIMI, RECYCLIA, SAKARYA, TORRECID, UNIGRAZ, Watt4Ever
Funding	Horizon Europe
Duration	September 2022 – August 2026
Website	https://www.freeforlib.eu/

2.2.7 RESONATE: Resilient forest value chains – enhancing resilience through natural and socio-economic responses

Climate change poses a growing threat to European forests as evidenced by the increasing frequency and severity of heat waves, extended periods of drought, storms and other natural disturbances over an increasingly larger scale. As a result, forest ecosystem dynamics, ecological resilience and tree species suitability are altered at minimum and likely deteriorated. As climate change continues, forest management has to cope with short-term and likely long-term impacts on the stability and the capacity to deliver ecosystem services. As a result, it is necessary to increase knowledge on how value chain resilience interlinks with the natural resilience of ecosystems and how this feeds back into operational guidance towards enhancing resilience in European forests and their associated forest-based value chains.

The RESONATE project aims to generate such needed knowledge and practices for making European forests, the services they provide, and related economic activities more resilient to future climate change and disturbances. Hereby, the H2020-project aims to guide decision-making towards enhancing resilience of forests and forest value chains in response to four resilience challenges: First, changing suitability of tree species due to climate change; Second, increased risks of forest disturbances; third, changing societal demand on forest products and ecosystem services; and fourth, biodiversity decline.

The Department of Environmental Systems Sciences is responsible for assessing the current resilience of European forest-based value chains to short-term and immediate stressors (e.g., disturbances) and more gradual effects over a longer term (e.g., climate change). More precisely, the stability of different value chains in terms of product output volumes and service provisioning will be investigated, after which factors will be derived that have a positive effect on value chain resilience. Taken together these factors will form the basis of a framework for achieving resilient forest-based value chains. As a last step, the framework will be evaluated by forest sector decision makers and stakeholders.

Project team	Univ.-Prof. Dr. Tobias Stern Raphael Asada, PhD Annechien Dirkje Hoeben, MSc.
Lead Institution	European Forest Institute (EFI)
Project partners	University of Vigo, Galician Forestry Industry Agency, Papierholz Austria GmbH, University of Natural Resources and Life Sciences (BOKU), Czech University of Life Sciences Prague, Prospex Institute, University of Helsinki, University of Copenhagen, Wageningen Environmental Research, Technical University of Munich, Albert Ludwig University of Freiburg, National Resource Institute Finland, Bournemouth University, Croatian Forest Research Institute, Ecological and Forestry Applications Research Centre, French National Research Institute for Agriculture, Food and the Environment, Agriculture and Food Development Authority Ireland, Innova Wood, Forestry Commission.
Duration	April 2021 – March 2025
Funding	Horizon 2020
Website	https://resonateforest.org

2.2.8 E-Track – Safe, sustainable and cost-optimized traction battery

The European Union has a target to reduce greenhouse gases (GHG) in the transport sector. The emissions in private transport can be significantly reduced by using electric vehicles compared to combustion engines, especially in urban areas. A switch from cars to powered two-wheelers would further reduce traffic congestion and the resulting emissions. In addition, compared to the powered two-wheelters (PTWs), electrified two-wheelers can reduce the CO2Reduce emissions during use by 50%. The current share of electric-powered two-wheelers (EPTWs) in all registered vehicles is still low, but the increasing number of new registrations confirms their relevance.

To get a complete picture of the environmental performance, the scope of environmental assessment of traction batteries of electric two-wheelers has to take into consideration the manufacturing, use and disposal stage. Within the manufacturing stage, Eco-design can be implemented to identify and reduce possible negative environmental impacts during product development which will also influence the use and disposal of the battery. As an example,

composite materials can improve the ecological and economic performance during the use stage by reducing the weight, energy consumption and production costs but on the other hand, increase the recycling effort.

Expanding from a sustainability perspective, the implementation of eco-design should also ensure crash safety of the battery. The loads that occur in an accident can lead to fire or explosion which can be detrimental to the user as well as the environment. This way we are able to ensure that the environmental and cost savings in the product development stage are not compensated by the other stages such as use (e.g. premature damage due to less safety) and disposal (complex recycling).

This project aims to improve the traction battery's safety, sustainability and cost which will promote the switch to a climate-neutral mobility system and reduce pollutant emissions. The development of safety systems as well as the analysis and improvement of the repairability of the traction battery extends the service life, reduces the ecological footprint and increases resource efficiency. Safe, sustainable and cost-optimized traction batteries also strengthen the competitiveness of the Austrian transport sector, since safe, efficient and sustainable e-vehicles will account for a significant proportion of private transport in the future.

Project team	Univ.-Prof. Dr. Tobias Stern Claudia Mair-Bauernfeind PhD Tasya Oka M.Sc.
Lead institution	Graz University of Technology (TU Graz), Vehicle Safety Institute
Company partners	KTM
Scientific partners	University of Graz
Duration	January2023 – June 2025
Funding	FFG

2.2.9 TransBuild – Developing transition pathways for deep transformative changes in the building sector

The building sector is among the biggest emitter of direct emissions and also indirect emissions caused by the materials used for construction. The spatial structures have impacts on the infrastructure and mobility requirements. Finally, buildings are becoming an active component of the energy systems, by providing structures for renewable energy and thermal storage.

The TransBuild project therefore promotes the role of buildings from a systemic and fact-based perspective, and aims to develop pathways to respond to climate change challenges. The goal of the project is to provide policy insights for planning and triggering a rapid and sustained transformation of Austria's building sector. To that end the project quantitatively explores potentials of a broad range of transition-enabling measures and chart future emission pathways for the building sector. With this methodological approach, the paths

within the physical, institutional and economic dimensions will be analyzed. The physical layer will quantify the innovations and corresponding pathways in the existing and newly constructed building stock, and changes for design, land use and technical as well as material related low carbon solutions in the building sector will be identified. The institutional layer assesses which regulatory or legal framework conditions support a building sector that is aligned with climate targets and which regulations represent barriers that need to be overcome. Finally, the economic layer, the economic-wide consequences of the transition scenarios of the building sector, including employment, potential price changes, and financial stability of the economic system will be modeled and thus provide a quantitative economic assessment for the transition pathways. (Figure 1)

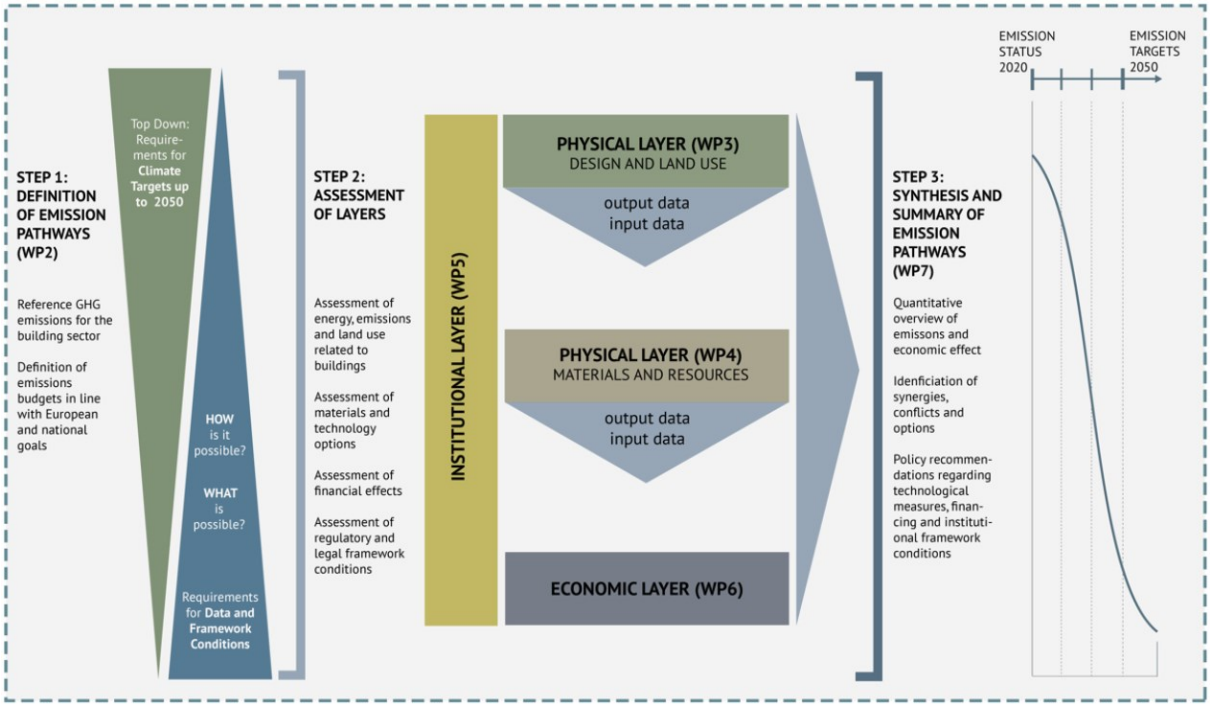


Figure 1:TransBuild Structure and Methodology

The TransBuild project aims to determine the significance of buildings in terms of climate change and transformation processes and to direct the perspective to the entire value chain of buildings. This value chain starts with the building materials, over the design and land use, emphasizing the service of a building. The Transbuild project deepens the research on the importance of buildings for the transformation to climate neutrality by applying an interdisciplinary approach, combining the expertise of architecture, sustainability sciences, economics and different methodological approaches to the project. The outcome will be a quantitative overview of emissions and the economic effect, the identification of synergies, conflicts and options resulting in policy recommendations regarding technological measures, financing, and institutional framework conditions. The pathways will outline concrete and quantifiable systemic measures that will provide institutional and regulatory leverage points and recommendations for changes based on a systemic view of the building sector. In this way the research will provide clarity on the quantification of specific measures as well as

actions and policies required to achieve the climate targets and subsequently provide a sound basis for decision makers.

Project team	Univ.-Prof. Dr. Rupert J. Baumgartner Josef-Peter Schöggl, PhD Moritz Kettele, BSc BSc MSc
Lead institution	University of Natural Resources and Life Sciences, Vienna; Institute of Spatial Planning, Environmental Planning and Land Rearrangement (IRUB)
Scientific partners	University of Natural Resources and Life Sciences, Vienna; Austrian Institute of Economic Research (WIFO); International Institute for Applied Systems Analysis (IIASA)
Duration	September 2023 – August 2026
Funding	Klima- und Energiefonds of the Austrian Climate Research Programm (ACRP)

2.2.10 CarryMeHome – Energy-efficient, modular and seamless transport of people and goods with a focus on active mobility

The project "CarryMeHome" is divided into two sub-projects. In sub-project I, a mobility concept is developed for two model regions (Weiz, Feldkirchen). In sub-project II, a vehicle concept ("CarryMeHome") is developed specifically for this mobility concept. The mobility concept addresses the main findings from the "Flademo" project, first and foremost "active mobility". Furthermore, the mobility concept has the following characteristics:

- Requirement-oriented: Sharing covers all essential requirements regarding private and commercial transport of people and goods: Accordingly, different vehicle categories are provided: Trolleys ("CarryMeHome"), bicycles, e-load bikes, e-transporters and e-light vehicles. Active and semi-active mobility shall be in the foreground. The focus should also be on vehicles that have a favourable ratio between payload and dead weight.
- Regional: All vehicles should come from Austrian or European production as far as possible.
- Compatible: the "CarryMeHome" trolley covers various requirements: Shopping trolleys for supermarkets, shopping centres and pedestrian zones, bicycle trailers, and for public transport. In other words, the form and function of the "CarryMeHome" are adapted to these requirements. "CarryMeHome" is designed to significantly lower the threshold for using public transport for medium weight and volume shopping.
- Flexible and digital: For the model regions, the mobility services are offered in an integrated way: Public transport, on-demand transport, bike sharing, car sharing and delivery services. This is to be based on the existing system "Scotty" (Postbus/Bahn).

- Integrative: For the maintenance of the vehicles and stations, social services will be integrated (e.g. Lebenshilfe), but also rely on the services of volunteers.
- Social ("airDrive"): Everyone can also act as a delivery person. In the sense of a "delivery exchange", purchases are delivered. Rewards are given in the form of a regional currency in order to regionalise the added value. Likewise, the "collection" of "CarryMeHomes" is to be compensated accordingly.
- Push initiatives: Expansion of cycle paths and pedestrian areas as well as traffic calming in the core zones. Conversion of supermarket and shopping centre car parks into trolley/bike/car sharing hubs.

Sub-project II concerns the development of a universal transport trolley ("CarryMeHome"). "CarryMeHome" should offer a possibility to transport purchased goods comfortably and continuously to the door across all means of transport (on foot, by bike, by public transport). The vehicle should be equipped with an electric motor to overcome slopes. Furthermore, it should be manufactured regionally and with sustainable materials. The vehicle charging infrastructure should be based on regional, decentralised energy supply. This means that overproduction of electricity from local solar collectors will be used to charge the vehicles and thus represent an alternative to feeding electricity into the grid, which is not very profitable.

An essential pillar of the project is the development of commercial and especially supermarket places as transport hubs: solar panel shaded parking spaces (which also protect the vehicles from heat and weather), parcel stations, vehicle rental ("CarryMeHome" trolley, bicycle, cargo bike, small e-vehicles and small e-transporters) and charging stations. In summary, "CarryMeHome" addresses mobility and vehicle concepts for travel distances up to 10km or 30min travel time. It addresses concepts that can be accessed by as many users as possible, whereby the transport of shopping goods is also taken into account.

Project team	Univ.-Prof. Dr. Nina Hampl Univ.-Prof. Dr. Tobias Stern Gloria Bumhofer Ass.-Prof. Dr. Georg Jäger Claudia Mair-Bauernfeind, BSc MSc PhD Viktoria Schett, BA BSc MA
Lead institution	Innovationszentrum W.E.I.Z.
Scientific partners	Innovationszentrum W.E.I.Z., Graz University of Technology (Vehicle Safety Institute), University of Graz (ESS), Stadtgemeinde Weiz, Stadtgemeinde Feldkirchen, Weitzer Wood Solutions GmbH, Autonomous Robot Technology GmbH, MLG Mikromobilitäts- und Logistikmanagement GmbH, Verkehrplus GmbH, ANEXIA Internetdienstleistungs GmbH, LEAN MC, Verein Kümmerei
Duration	October 2023 – September 2026
Funding	FFG (Mobilität (2022) Regionen und Technologien)

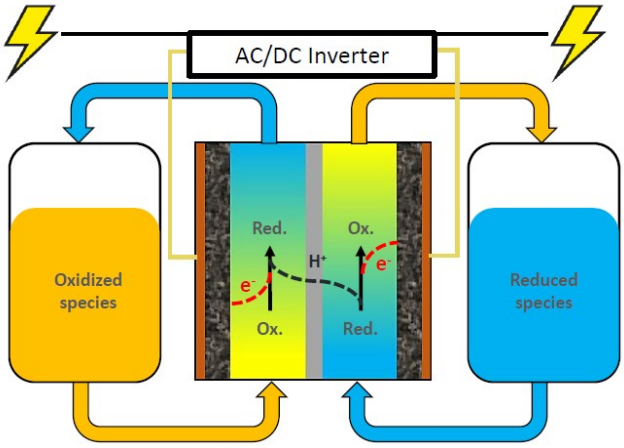
2.2.11 iNEVER – Innovation network on traffic avoidance

Various strategies exist to implement the necessary emission reductions to achieve Austrian climate goals in line with the Mobility Masterplan. Traffic avoidance plays a central role in a successful transportation transition, yet it has been relatively neglected in research and practice compared to traffic improvement and shifting approaches. However, rethinking mobility fundamentally, with traffic avoidance as a cornerstone, is essential for sustainable mobility amidst rising demand and induced traffic. Therefore the iNEVER Innovation Network for Traffic Avoidance focuses on anchoring traffic avoidance successfully in Austria's actor and research landscape. It explores opportunities in behavioral changes in passenger transportation, freight transportation, digitalization/virtual mobility, and their interactions. The project aims to create and continuously develop an Actor and Competence Map and gather and structure national and international best practices. It aims to develop action and measure fields for passenger transportation, freight transportation, digitalization/virtual mobility and establish an innovation ecosystem for the network's continuation and institutionalization.

Project team	Univ.-Prof. Mag. Dr. Alfred Posch Annina Thaller, PhD Alina Delitz, MSc Eva Fleiß, PhD Dr. Holger Hoff
Lead institution	University of Graz, Department of Environmental Systems Sciences
Company partners	Kompetenzzentrum für Digitalisierung, Resilience Consult GmbH
Scientific partners	Institute for Industrial Management – FH JOANNEUM
Duration	June 2023 – June 2024
Funding	FFG, MOBILITÄT – Regionen und Technologien

2.2.12 SuESS – Safe- and sustainability-by-design approaches for energy storage systems in a green and circular economy

The SuESS research project aims to address the issues surrounding the safety and sustainability of stationary energy storage systems (ESS) in the context of a sustainable energy transition. With the increasing deployment of renewable energy sources like wind and solar, the need for reliable ESS to manage grid fluctuations has become paramount. However, concerns have arisen among stakeholders about the safety and sustainability of battery technologies, especially regarding the import dependence of critical raw materials as well as their possible ecological and socio-economic impacts. Although there has been some progress in developing safe and sustainable ESS, the environmental performance and social impacts along the whole value chain of different ESS technologies are still underexplored topics. Therefore, this project focuses on implementing a safe- and sustainable-by-design (SSbD) approach using life cycle assessment (LCA) and social LCA methodologies looking at the whole life cycle of different ESS. The focus is on flow batteries (e.g., vanadium- or vanilla-based) and lithium-ion battery systems, including possible substitutes (e.g., sodium-ion batteries) with a storage capacity > 80 kWh. Through LCA and social LCA, environmental and social hotspots will be identified, and the advantages and disadvantages of different ESS technologies can be determined. After the comparative impact assessment, the implementation of the SSbD concept, which includes a data review regarding occupational health and safety aspects, can take place. Further activities include toxicological testing of battery material and compounds and the collection and analysis of data on real-life ESS and End-of-Life management for a life cycle management model. Finally, based on the project results, guidelines for risk, sustainability, and circularity assessment can be derived. These guidelines aim to inform decision-making processes regarding investments in ESS as part of the Green Deal initiative.



Redox Flow Battery System © Schlemmer W. | TU Graz

The comprehensive approach in SuESS of assessing toxicology, social and environmental impacts, criticality of materials, technical performance parameters, and setting all this information in the context of SSbD will therefore be a valuable contribution to a standardized approach for the comparative assessment of (new) safe and sustainable ESS.

Project team	Claudia Mair-Bauernfeind PhD Julia Wenger M.Sc. MSc Sarah Wünscher, BSc Univ.-Prof. Dr. Tobias Stern
Lead institution	University of Graz
Company partners	BioNanoNet, Ecolyte GmbH, Biobide
Scientific partners	University of Natural Resources and Life Sciences
Duration	September 2023 – August 2025
Funding	FFG, SAF€RA

2.2.13 SwarmIn – Swarm Intelligence and Combinatorial Optimization for Energy Efficient and Adaptive Industry 4.0

Climate goals, rising energy and resource demand and a history of supply difficulties, motivate the identification of energy and resource efficiency potentials as one of the main priorities of the industrial sector in the near future. A sustainable Industry 4.0 and cyber-physical manufacturing systems not only enable real time interaction, machine-learning (artificial intelligence) and eased monitoring, they are viewed as potentially energy and resource efficiency-enhancing based on their ability to provide real time data via computation on the edge. A high mixture of product diversity together with historical growth of the industrial plant further induce complexity leading to an NP-hard problem. In the current exemplary situation of a semiconductor plant, multiple machines need to be scheduled (between 400 and 1,200 different stations). They typically produce more than 1,500 different products in around 300 different process steps. Linear optimization methods cannot cope with the highly complex, large, and dynamic search space due to excessive computation time. These methods can only be used on a subset of the plant, do not consider the entire system behavior, and thus, do not exploit the optimization potential.

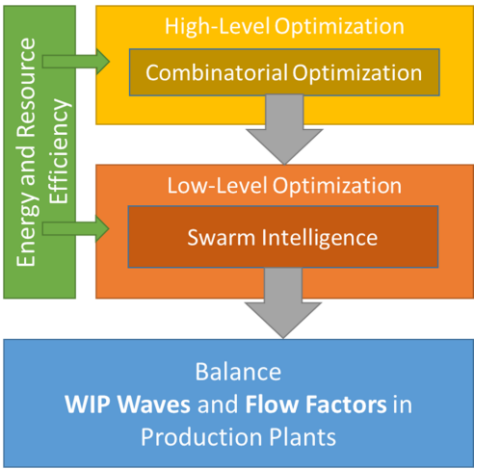
In SwarmIn the overall goal is to balance WIP waves and flow factors along with production plant optimization featured with energy- and resource-efficiency parameters. To reach this goal we design a new architecture to combine different methods of artificial intelligence (AI) in an advantageous way: first, we apply combinatorial optimization as a high-level optimization

approach for a global estimation of configuration parameters. It reduces the solution space that is used as input for second, the low-level optimization that applies swarm intelligence as a multi-agent, bottom-up approach. This is an innovation, as a mixed-swarm approach that considers both cyber-physical systems (CPSs, e.g., machines, lots) and humans as agents impacting energy and resource efficiency in an industry 4.0 setting has not been investigated in this field before. In the low-level optimization, each agent is equipped with a set of local rules. The connection between high- and low-level optimization is a novelty, for which we model the production plant as a self-organizing system of agents that work together.

Low-level optimization based on swarm intelligence (which is a subfield of AI) is performed locally (on machines/lots, close to the process), whereas the high-level optimization (combinatorial optimization) is done centrally, e.g., as a cloud-based service closely connected to a factory-ERP system. Both levels strongly interact with means of (wireless) communication where 5G can be the technology to provide industry 4.0 requirements in terms of latency and reliability. Additionally, parameters to measure energy and resource efficiency via retrofit sensors in the production process and feedback from human actors are identified. Beside the analysis of these parameters, one innovation is to include them into high- and low-level optimization to produce energy- and resource based reactive behavior for CPS and human(-machine) interaction in the production process. The overall result of SwarmIn will be algorithms and simulations for high- and low-level optimization to cope with the high complexity in production in industry 4.0 and with energy- and resource-efficient requirements in the form of a software library. In contrast to other projects in this field SwarmIn builds a radically new architecture to combine different AI approaches for the first time (combinatorial optimization and swarm intelligence) according to their advantages. Additionally to that, the SwarmIn architecture includes humans as swarm members as well as resource and energy efficiency as another dimension for the optimization of a sustainable production plant of the future.

The Department of Environmental Systems Sciences (ESS) leads the work package “4. Energy and Resource Efficiency” that has the following objectives:

- Information and data gathering related to the energy and resource efficiency KPIs in the production process
- Identification and measurement of the impact of human behavior and human-machine interaction on the energy and resource efficiency KPIs in the production process
- Breakdown of energy and resource efficiency KPIs to agent-based measures for the high- and low-level optimization



Project team	Univ.-Prof. Dr. Nina Hampl Dr. Robert Sposato Rafaela Klič, BA MA Karl Reimer BSc
Lead institution	Lakeside Labs GmbH
Company partners	Infineon Technologies Austria GmbH
Scientific partners	University of Graz (ESS), University of Klagenfurt (Department of Artificial Intelligence and Cybersecurity, Production Systems Unit), Novunex GmbH, Messfeld GmbH
Duration	September 2022 – August 2025
Funding	FFG (Produktion der Zukunft)

2.2.14 HydroFRAME – The framing of national hydrogen imaginaries

While the vision of using hydrogen as an energy carrier is not new, the decarbonization goals set in the Paris Agreement have caused expectations about hydrogen to rise to unprecedented levels. By 2023, 41 countries have published national hydrogen strategies and more than 1000 hydrogen projects with a total volume of USD 320 billion have been planned all over the world. However, despite this increasing momentum, several important questions remain open, such as how hydrogen should be produced, where and for what purpose. What is more, countries provide different answers to these questions and thus envision different future trajectories.

In the HydroFRAME project, the examples of Germany, UK and Chile are used to better understand the processes by which nations develop desirable visions of hydrogen futures. Conceptualizing the emerging future images associated with the countries' hydrogen strategies as politically legitimized 'imaginaries' in the making, the following questions will be addressed:

- What expectations and visions are associated with the emerging hydrogen imaginaries, and which framing processes in the policy arena have driven their formation?
- Which alternative or competing hydrogen visions exist in these countries, and what are the country-specific differences?
- Which narratives are associated with the countries' 'incumbent' energy imaginaries, and how do these narratives relate to the emerging hydrogen imaginaries?
- How did the public framing of hydrogen futures evolve over time, and what has been the roles of these framing processes in shaping the emerging hydrogen imaginaries?

By shedding light on how the emerging hydrogen imaginaries relate to discursive processes, the project gains important insight into the interplay between two different types of expectations: institutionally stabilized, and politically legitimized, expectations on the one hand, and expectations that are shared rhetorically through 'language in use' on the other. Furthermore, the project provides a decision basis for countries and regions that currently think about their own hydrogen futures.

Project team	Univ.-Prof. Dr. Tobias Stern
	Michael Kriechbaum, PhD
	Paula De Pablos Sanz
Lead institution	Graz University of Technology
Duration	January 2023 – December 2025
Funding	FWF Austrian Science Fund

2.2.15 BELOW – Austrian bioeconomy futures: Limits to green growth

Priority of the research project: Green growth can be defined as a transformation in existing production- and consumption systems that results in a reduction of anthropogenic environmental stress and a simultaneous increase in economic activity. In this context, the concept of the bioeconomy has received increasing attention. Four distinct bioeconomy transition pathways are currently envisioned, aiming at fossil fuel substitution, primary sector productivity, new and efficient uses of biomass, and low-bulk high-value applications. The growth limits of these pathways have not yet been systematically investigated along physical, technological, economic and socio-political dimensions.

Content of the research project: Using Austria as an example, BELOW aims at assessing the potential of each transition pathway to reduce anthropogenic environmental stress while contributing to economic growth, considering all growth limit dimensions. The temporal scope spans over the period of 2020 to 2050. The project will focus on anthropogenic greenhouse gas (GHG) emissions and land use as environmental stressors. Gross domestic product (GDP) is employed as an indicator of economic activity, together with sectoral indicators such as labor compensation by skill level and gross value added. BELOW follows a scenario-based approach, i.e., the quantification of growth limits as well as other outcomes reflect underlying assumptions, which are made transparent during each phase of the project.

Project team	Raphael Asada, PhD Edvard August Eggen Sveum, MSc Julia Wenger, BSc. MSc. MSc Univ.-Prof. Dr. Tobias Stern Michael Kriechbaum, MSc. PhD
Lead institution	University of Graz
Scientific partners	Austrian Institute of Economic Research
Duration	March 2023 – April 2026
Funding	Austrian National Bank's Anniversary fund
Website	https://below.uni-graz.at/en/

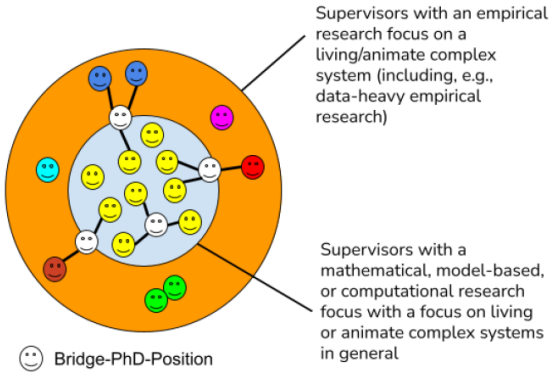
2.2.16 Bridge-PhD Position – Wholesome Gaming: Identifying positive human-media interactions using community trace data

Gaming is widely enjoyed for its mood-enhancing effects, with over five million Austrians engaging in it, and playtime increasing in the last years to about 13 hours per week. Some studies suggest gaming could even aid mental health. However, selecting games with such benefits is challenging due to their complexity and rapid evolution, exacerbated by the release of over 11,000 games on Steam in 2021 alone. User comments and reviews on platforms like Steam, Twitter, and Reddit provide valuable insights into gaming experiences and preferences. Leveraging these data, our project aims to develop a novel method for identifying games that positively impact mental health. Through content and network analysis of player interactions, we aim to provide a scalable and efficient means of identifying such games, ultimately evaluating them through lab studies.

Phase 1 – Micro and Macro Perspectives: Content analysis on community trace data
User reviews on platforms like Steam are analyzed to find games with positive mental health effects. Then, using network analysis, relationships between these games are explored, considering users who provide multiple reviews.

Phase 2 – Empirical Evaluation: Proof of principle using lab experiments and process data
The selected games are tested in lab experiments. Participants play either a selected game or a control. Mental health and physiological data are collected during gameplay for analysis.

The proposed project integrates systems science techniques like text mining and natural language processing (supervision: Marie Kogler) with psychological methods such as psychophysiology and experiments (supervision: Manuel Ninaus), focusing on research areas like mental health and media use. This interdisciplinary approach aims to advance the current state-of-the-art in media effect research.



Project team	Ass.-Prof. Dr. Manuel Ninaus Dr. Marie Lisa Kogler
Lead institution	University of Graz, Department of Psychology
Scientific partners	University of Graz, Department of Environmental Systems Sciences
Duration	December 2023 – November 2027
Funding	Complexity of Life in Basic Research and Innovation (COLIBRI) – Field of Excellence, University of Graz

2.2.17 Mobility paths that move: Styrian access to people, goods and services in the context of global megatrends (Z-T-G 001)

Mobility moves. Not only physically, but also figuratively. The competition for sufficient and affordable energy for transportation purposes, as well as the sharing of infrastructure and its financing, are conflicting issues. Digitalization trends have been further intensified by the pandemic, raising complex issues. Work, education and consumption, as well as logistics and the transport of goods, are changing. The consistency of migratory movements within Styria (increased desire to live/work/learn in the countryside, i.e. ruralization) as well as the chosen means of transport (increase in active mobility and decrease in occupancy rates of means of transport) are associated with uncertainties. The overall implications for Styria's contribution to meeting the carbon budget available for the transport sector are unclear.

Against the background of the need to create a sustainable mobility system, this project will develop and evaluate different mobility paths for the coming decades.

To this end, an interdisciplinary, multidimensional view of the future development of mobility in Styria will be taken, considering both passenger and freight transport as well as the implications for Styria as a production location. The future projections should be flexible enough to integrate recent developments, to reinforce relevant trends and to change course according to the principle of avoid-shift-improve. The projection period covers the next 20 years, in line with the federal target of climate neutrality by 2040.

The analysis will answer specific questions such as

- What new governance structures and fiscal requirements will emerge for spatial, urban, and transportation planning?
- What are the requirements for the distribution patterns of housing, jobs, and infrastructure?
- How do the different projections affect social inclusion and socio-spatial inequalities?
- What is the significance of new social practices, such as the use of "Mobility as a Service" (MaaS) offers, for the Styrian economy?

The project Z-T-G 001 Mobility Paths approaches this question by means of a broad-based, transdisciplinary backcasting process. With the involvement of stakeholders, the neuralgic points of possible development paths are identified and quantitative projection calculations are validated. In addition, the project links backcasting and scenario analysis in a contrasting and synthesizing way.

Project team	Univ.-Prof. Dr. Alfred Posch Thaller Annina, BSc, MSc, PhD Simone Schreiegg, BSc MSc
Project Partners	Wegener Center for Climate and Global Change (Univ.-Prof. Mag. Dr.rer.soc.oec Karl Steininger, Samuel Duelli, BSc MSc, Mariana Riviera MSc, Elisa Freisinger BSc); University of Technology (Mag. Dr.phil. Christian Dayé, Roman Prunč, Bakk.rer.soc.oec.)
Lead Institution	University of Technology, STS Unit
Duration	March 2023 – March 2025
Funding	Land Steiermark

2.2.18 Hydrogen and Styria: Regional pathways in the context of international technology development

Although the vision of a hydrogen economy has been researched and discussed for several decades, expectations regarding the use of hydrogen-based technologies have risen significantly as part of international efforts to limit man-made global climate change. The International Energy Agency (IEA), for example, speaks of "unprecedented growth momentum" in the field of hydrogen technologies and multinational companies such as Toyota, Bosch and Siemens see hydrogen as the growth driver of the coming decades. In addition, more and more countries are adopting national hydrogen strategies in which the targeted expansion paths are set out.

Against this background, this project analyses the opportunities for the Styrian region with regard to the increased use of hydrogen (and the associated R&D&I activities). As in all processes of socio-technical change, different logics – and thus different visions of the future

– come together in the utilization of hydrogen. The aim of this project is to systematically map these and critically confront them with feasibility considerations. The central result is therefore the description and evaluation of potential future paths for the Styrian region and the comparison of these with current R&D&I activities as well as with developments in the wider context (Austria, EU, global). The results of this research project can subsequently be used as a basis for the ongoing design of a Styrian future strategy in the field of hydrogen.

Specifically, the following questions are addressed:

(1) What are the different priorities of the 40 national hydrogen strategies worldwide?
(2) How can the interaction of international developments be described and its consequences – economic, social, ecological – assessed?
(3) What synergies can be identified between potential future paths in the field of hydrogen and Styrian R&D&I activities?
(4) In view of the foreseeable international developments, what will it take for Styria to establish itself sustainably in the international arena?

Project team	Michael Kriechbaum, PhD Peter Obersteiner
Lead institution	Graz University of Technology
Duration	Juli 2023 – Dezember 2024
Funding	Steiermärkische Landesregierung

2.2.19 BioPV – Photovoltaics, Humans and the Biosphere: A transdisciplinary approach fostering Alpine resilience

BioPV conducts an inter- and transdisciplinary research on the potentials of ground-mounted photovoltaics in transition zones of Austrians biosphere reserves by addressing conflicts and synergies of an integrated sustainable development. Techno-economic modelling, ecological analyses and habitat surveys, social-scientific quantitative and qualitative methods of social acceptance, and participatory planning exercises are combined to offer a significant contribution, both in theory, as well as in practice. The project is designed to increase renewable energy capacities in Austria based on the concepts and goals of sustainability and resilience. With its strong emphasis on developing a sustainable relationship between humans and the environment, BioPV will provide a major contribution to reach the goals of SDG 15 'Life on Land' of the United Nations, of the EU's biodiversity strategy for 2030 and the Austrians target of climate neutrality in 2040.

In general, alpine regions serve as a prime example of highly sensitive areas to impacts of infrastructure buildings. In this context, BioPV focuses on social, ecological and land use conflicts and elaborates possible solutions for these problems. The project will start with a spatio-temporal analysis of the techno-economic potential of both rooftop and ground-

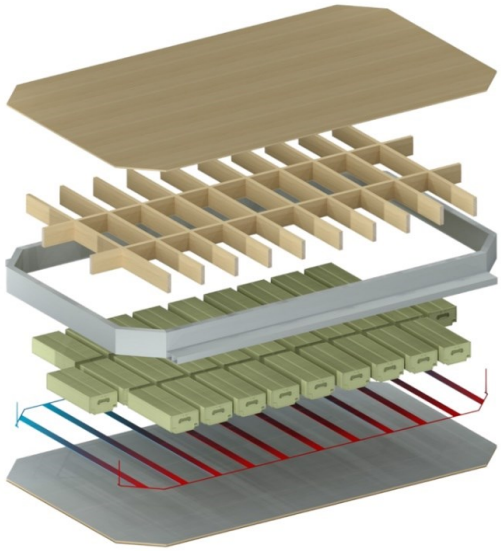
mounted PV in all three Austrian biosphere reserves followed by a stocktaking of habitats in specific test sites and an assessment of possible ecological impacts of PV on biodiversity. In addition, qualitative and quantitative studies of social acceptance will be conducted. After the exploration of techno-economic, ecological and societal potentials and limitations a participatory landscape planning approach will be developed. Public involvement will be facilitated through the so-called laboratories, which will engage regional stakeholders and citizens from the selected case study regions. This element of transdisciplinarity is mirrored on a project management level by the constitution of an advisory stakeholder group, which will accompany the research, providing feedback but equally gaining insights as the project progresses. Overall, BioPV investigates scenarios of ground-mounted PV systems in ecologically and aesthetically sensitive landscapes.

The project focuses on investigating the relationship and potential contradictories of nature conservation, climate protection and renewable energy development. Social and ecological aspects are emphasised, because these issues often prevent projects from being implemented. As the energy transition depends on many local decisions, there is a strong need for better conflict management and participation in planning and decision-making processes. By considering adequate processes to apprehend potential impediments, BioPV offers valuable insights in the field of sustainable energy production while fostering resilience.

Project team	Univ.-Prof. Dr. Nina Hampl Dr. Robert Sposato Veronika Dworzak, BSc MSc
Lead institution	BOKU (InFER)
Scientific partners	BOKU (ILEN, INF, InFER, INWE), University of Graz (ESS)
Duration	May 2023 – October 2025
Funding	ÖAW (Österr. Akademie der Wissenschaften)

2.2.20 Biolib – Biobased Multifunctional Laminates in Battery housings

The long-range batteries of modern electric vehicles offer ever-increasing capacities while occupying the whole underfloor space between back axle and subframe. Correspondingly, the battery has a significant impact on weight, volume and costs of an electric vehicle. To optimize the weight of the vehicle, the battery and its compartment are not only being used as a supporting structure but also to function as a thermo management system, to prevent catastrophic battery failure, to protect the battery from vibrations & impact and to increase the durability and failure safety. Current battery compartments are manufactured from steel and aluminum which may not be as sustainable as wooden based alternatives. Besides a potentially lower environmental footprint the choice of material also needs to account for the safety of the occupants, weight and economic viability. Wood may be a very promising alternative as it has favorable characteristics such as a low thermal conductivity, high specific strength, comparatively low material cost and a lower environmental footprint.



The project aims to develop a demonstrator of a segment manufactured from a steel-wood hybrid and verify its properties regarding thermo-management, vehicle safety and sustainability. To achieve this, the research focus lies on connection technology between wood and steel, wood modification to enhance certain properties of wood, the behavior of the hybrid material in case of fire, its environmental footprint and potential socioeconomic consequences of the broad utilization of wood in the modern automotive sector. The Department of Environmental Systems Sciences will assess the environmental impact by conducting a Life Cycle Assessment (LCA) of the defined application case. To investigate potential socioeconomic consequences an Input-Output analysis will be performed.

Project team	Univ.-Prof. Dr. Tobias Stern Claudia Mair-Bauernfeind, PhD DI Paul Krassnitzer
Lead institution	Graz University of Technology (VSI)
Company partners	FILL, Weitzer Wood Solutions, nolax, business upper austria
Scientific Partners	University of Natural Resources and Life Science, University of Graz (ESS), Graz University of Technology (VSI), Innovationszentrum W.E.I.Z
Duration	April 2021 – March 2024
Funding	FFG

2.2.21 CE-PASS – Circular Economy – Digital Product Passport

CE-PASS is an industrial research project focusing on the issue of sustainability-aware automotive design for the circular economy. It contributes to the twin transition to a digital and sustainable economy, in line with the European Green Deal. The project goal is to evaluate the feasibility of digital product passports to improve the sustainability and circularity of automotive products and to facilitate the information flow from end-of-life actors to beginning of life actors to increase refurbishing and recycling possibilities and the shares of secondary materials. Specific use cases of the project are the Electric Vehicle Battery and the Internal Combustion Engine.

The University of Graz has the lead of two work packages. Work Package 2 focuses on the analysis of the use cases' value chain actors and the data requirements that need to be included into a digital product passport for the use cases Work package 3 is dedicated towards the topic of Sustainability, CE and Lifecycle Assessment, dealing with the development of a data-driven design for sustainability and circularity approach and aims at the integration of data from digital product passports into LCA and circularity assessment.

Project team	Univ.-Prof. Dr. Rupert Baumgartner Josef-Peter Schöggl, PhD Antonia Pohlmann, MSc Martin Popowicz, MSc
Project partners	Salzburg Research Forschungsgesellschaft m.b.H, iPoint-Austria GmbH, AVL List GmbH
Duration	January 2022 – December 2024
Funding	FFG, IKT der Zukunft – 9. Ausschreibung (2020)

2.2.22 Innovationscamp "BIG Bio" (Intelligently designing the circular bioeconomy. Biogenic innovation with a sustainable orientation)

BIG Bio's goal is to empower sustainable biobased innovations (e.g. products, processes, business models) through the transfer of competencies, assessment of potential

consequences, and integration into development. This is achieved through training courses guided by research institutions and implemented through specific case studies provided by corporate partners. These case studies will examine topics such as the assessment of new or modified recycling processes, comparison of innovative biobased product systems with non-biobased substitutes, and modeling of business-related carbon flows and their changes.

The acquired competencies will be implemented directly by production-oriented corporate partners and further conveyed by service sector partners to advise other companies. The documents and experiences generated through the project, including feedback from companies, will result in the development of further education opportunities on sustainability-driven innovation.

Structure of the modules and selected topics are:

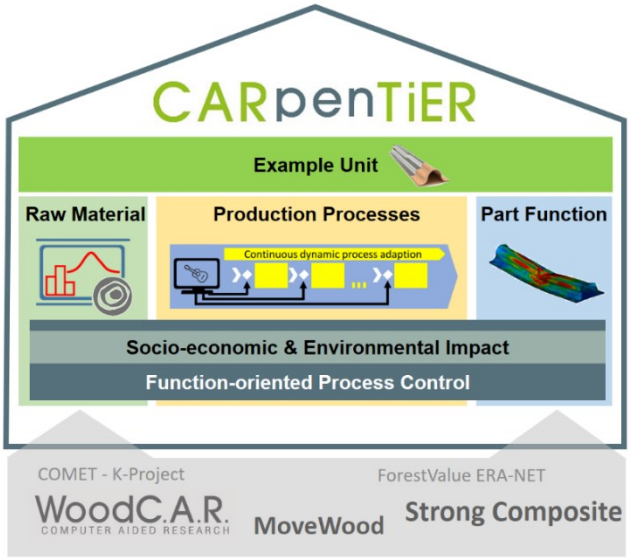
- Mission and Vision: Basic introduction to fundamental contents, concepts & topic-specific deepening
- Eco-Design Paradox: Introduction to methods of sustainability assessment to counter the Eco-Design Paradox
- Sustainability modelling: multi-criteria (ecological, economic, social) sustainability assessment of innovations
- Technology impacts: Consequences and impacts of the use (conflicts) of biomass

Project team	Univ.-Prof. Dr. Tobias Stern Daniel Holzer, BA MA
Lead Institution	University of Graz (ESS)
Scientific Partners	FH Kufstein, Innovationszentrum W.E.I.Z, Institut für Industrielle Ökologie, Kompetenzzentrum Holz – Wood Kplus,
Company partners	Holzcluster Steiermark GmbH, Larix Engineering GmbH, Kobzina Consulting, Lean MC, PROJEKTkompetenz.eu, STRATECO OG, Team 7 Natürlich Wohnen GmbH, Vinzenz Harrer GmbH, Weitzer Wood Solutions GmbH,
Duration	November 2022 – October 2024
Funding	FFG, Innovationscamp M

2.2.23 Modelling, Production and further Processing of Eco-Hybrid Structures and Materials – CARpenTiER

The aim of CARpenTiER is the development of production technologies for wood-based hybrid constructions in automotive, systems and mechanical engineering. Applications include hybrid structures made of laminated wood, plywood or strand materials, which can be reinforced with natural fibers. In previous research activities of the consortium, various demonstrators for the mobility sector in multi-material mixed construction have been successfully developed. The results show that 10 to 40% of the dead weight can be saved by using wood-based materials without losing performance. In future this can make a positive contribution to climate goals, as weight reduction has the highest impact on avoiding greenhouse gas emissions.

Although former research work has laid a solid basis in finite element modelling, there is a lack of suitable production technologies for industrial implementation. For this reason, the continuing research program will focus primarily on process development and process control. Both, process and component are represented as digital twins (i.e. digital reproduction of product and process).



The Department of Environmental Systems Sciences is looking into sustainability requirements within the project. Designing and developing processes dealing with material variability as well as the potential effects, thresholds and constraints in regards to resource availability, recycling technologies, rejection rates or process design decisions is complex and needs to be simulated in a dynamic model to solve the various (and sometimes contradictory) requirements. The model also allows to support the technical R&D by providing continuous information on thresholds, changes and impacts along the life cycle of the wood-based hybrids.

Project team	Univ.-Prof. Dr. Tobias Stern Claudia Mair-Bauernfeind PhD Theresa Boiger MSc
Lead Institution	Innovationszentrum W.E.I.Z
Company Partners	AC-Styria, IB Steiner, DYNAmore, FHP, FILL, Glanzstoff, HC-Styria, Klumpp, Lean MC, VW, Weitzer Woodsolutions
Scientific Partners	University of Natural Resources and Life Science, University of Graz (ESS), Graz University of Technology (IMAT), Virtual Vehicle (Vif), Innovationszentrum W.E.I.Z
Duration	May 2021 – May 2025
Funding	FFG, COMET-Projects
Website	Further information: http://www.carpentier.at/project.html

2.2.24 WEGBEREITER – MOPI-Lab "Active mobility and MaaS as an enabler"

Most of the passenger transport takes place in suburban and rural areas. Especially there, motorized individual transport continues to dominate, as attractive alternatives are often lacking. For a successful implementation of the climate and sustainability goals, it is therefore indispensable to understand people's realities of life outside of large cities and to find targeted mobility solutions adapted to the respective region. This involves measures to shift and avoid private transport through targeted spatial planning and the strengthening of intermodal mobility offers, consisting of active mobility (cycling and walking), innovative and flexible Mobility-as-a-Service (MaaS) offers and public transport. In addition to incentives and offers, such a package of measures will also have to include restrictions in order to mitigate the dominance of private transport and create equal opportunities for other modes of transport.

The projects one-year exploratory phase, which was carried out in close cooperation between the Weiz-Gleisdorf energy region, the University of Graz and Graz University of Technology, ended in September 2023. During this phase, intensive discussions were held with mayors and mobility experts of the region in order to understand their perspectives and concerns in the field of mobility. Barriers and supporting factors on the part of mobility providers were also identified. Field visits provided a practical insight into the current situation on the ground, while the exchange with a buddy mobility lab provided valuable insights and best practices.

During the exploratory phase of the Mobility Policy Innovation Lab, three main areas of action were identified:

1. Active mobility as a health factor and starting point for social interaction: The focus is on promoting active mobility that not only supports health but also enables social interaction.
2. Traffic avoidance through multifunctional and lively spaces and anchor points: This area aims to reduce traffic by creating multifunctional and vibrant places that serve as focal points and hubs.

3. Enabling mobility as a service and route chains in the environmental network: The focus here is on providing mobility as a service and integrating means of transport into environmentally friendly networks.

Although the project cannot be continued for the time being due to a lack of co-funding, we can consider the exploratory phase to have been extremely successful. The lessons learned and the collaboration between the partners involved have laid a foundation for future mobility innovations.

Project team	Univ.-Prof. Dr. Alfred Posch Thaller Annina, BSc, MSc, PhD Eva Fleiß, MA PhD; Simone Schreiegg, BSc MSc
Project partners	Wegener Center for Climate and Global Change (Raphaela Maier, BSc MSc, Mag. Doris Wiederwald, Dr.rer.nat Holger Hoff); University of Technology Graz (Dipl.-Ing. Dr.rer.nat. Eva Schwab, Markus Monsberger)
Lead Institution	University of Graz, Department of Environmental Systems Sciences
Duration	September 2022 – September 2023
Funding	FFG, Mobilität der Zukunft, 18.Ausschreibung

2.2.25 UniStrand – Structural timber construction material of the next generation

Short description: In recent years, timber construction has been able to prove its suitability for multi-story construction through various lighthouse projects (e.g. HoHo, LCT ONE, etc.). The use of wood in the construction sector is not only supported by the substitution of energy-intensive raw materials with simultaneous carbon storage, but also by the need to satisfy the enormous additional demand for building materials. A significant increase in the utilization of the resources used is just as essential as an efficient design and dimensioning of the components. Currently successful timber construction products such as cross-laminated timber are mainly based on sawn softwood and have a low raw material yield (30-40%) due to the process. With the project “UniStrand” the technological and constructive foundations for a (approx. 7-20cm) thick, panel-shaped timber construction material for multi-story, structural construction applications are to be sketched and researched. The starting material is long, thin wood particles (strands), which can be produced with a high raw material yield (over 75%). The main raw material is to be hardwood assortments or a combination of softwood and hardwood. By bonding as unidirectionally as possible to beach plates of different densities, a predictable intermediate product with improved mechanical properties compared to already established beach-based products (OSB, LSL) is to be created. By crosswise layer bonding of the panels, the required “barrier” effect and material thickness of the layered wall and ceiling elements is finally achieved. On the basis of the constructive optimization of the finished elements, coupled with an application-oriented cutting optimization, targeted

elements can be produced that use high-performance panel material only where this is statically necessary. The results are evaluated in parallel by a process-oriented life cycle assessment (LCA). The foundations created form the basis for large-scale industrial implementation and pave the way for a resource-efficient wood-based construction material of the next generation.

Project team	Univ.-Prof. Dr. Tobias Stern Claudia Mair-Bauernfeind PhD Tasya Oka M.Sc.
Lead institution	University of Natural Resources and Life Sciences (BOKU) Institute of Wood Technology and Renewable Materials
Company partners	Dieffenbacher GMBH; Dynea AS; Fachverband der Holzindustrie Österreichs; Hasslacher Holding GmbH; Henkel & Cie. AG; Holzcluster Steiermark GmbH; Huntsman Belgium BV; Division Polyurethanes; Kaindl Flooring GmbH; Bereich Massivholz und Holzverbundwerkstoffe; Metadynea Austria GmbH; Österreichische Bundesforste AG; RWT PLUS ZT GmbH.
Scientific partners	University of Graz; Kompetenzzentrum Holz GmbH
Duration	December 2022 – November 2025
Funding	FFG

2.2.26 TransFair – Low-carbon transition in Austria: Exploring social, financial and ethical dimensions of ambitious climate policy

ACRP Project Nr. KR20AC0K18211

Ambitious climate change mitigation policies will require substantial cuts in greenhouse gas emissions. If taken seriously, these policies will radically transform energy systems, economic circumstances and eventually impact social systems. Although the overall long-term impacts of such policies are expected to be positive, as in sustaining modern civilization, there will also be adverse effects (particularly in the short term), and it is likely that neither the benefits nor the costs will be distributed equitably. The implementation of ambitious climate policies is thus inherently linked with issues of social fairness and equity, and requires strategies that allow for dealing with vulnerable groups and potentially adverse impacts.

The key objectives of this project are to explore the structure of adverse social effects of ambitious climate policy in Austria and to develop strategies to mitigate them. The project moves beyond traditional financial considerations and explicitly considers non-financial impacts. We will analyze currently planned and discussed climate policies, identify vulnerable groups, and examine the adverse effects that these groups potentially face by means of methods from economics, social sciences and philosophy (discourse analysis, CGE modeling, Q-sorting, discrete choice experiments, normative assessments).

The added value of the project is that it does not merely focus on economic and financial effects. It explicitly considers the non-financial impacts, social perceptions and citizen

preferences related to the selection of policies, complemented by normative assessments regarding the legitimacy of citizen's expectations. Thereby, the project will also shed light on strategies and response mechanisms that go beyond standard measures of financial compensation such as compensation payments, tax exemptions or increased commuting allowances, and include non-financial measures as well.

Project team	Thomas Brudermann (ESS / Project lead) Michael Kriechbaum (ESS) Katharina Trimmel (ESS) Tobias Stern (ESS) Birgit Bednar-Friedl (Wegener Center) Stefan Nabernegg (Wegener Center) Teresa Lackner (Wegener Center) Lukas Meyer (Institute for Philosophy) Rutger Lazou (Institute for Philosophy)
Duration	January 2022 – September 2024
Funding	Austrian Climate Research Program

2.2.27 TRANSFLIGHT – Shaping the future of air travel

All sectors and areas of life must reduce greenhouse gas emissions in order to achieve climate targets. The area of mobility is facing especially great challenges due to rising emission figures. In the case of air travel in particular, so-called "carbon lock-in", i.e. a situation in which it is difficult to break out of emission-intensive systems, in conjunction with increasing globalization and networking, is leading to a steadily rising demand for air travel around the world.

While air travel has in principle become indispensable for leisure, corporate, or academic research, the COVID-19 pandemic has drastically changed this situation. Travel restrictions to limit the risk of infection have brought global air travel to a standstill, and trips have been canceled, postponed, conducted using other transportation methods, or replaced with digital solutions.

Against this backdrop, the TRANSFLIGHT project tackles air travel from a comprehensive perspective, including the three areas of leisure, business and academic travel, by acknowledging differences and uncovering mutual learning potentials. It is characterized by an intensive stakeholder integration process throughout the whole project duration, aiming at co-design and co-generation of socially robust and highly relevant knowledge. We provide data on the current travel behavior and future behavior intentions by using different carbon lock-in levels and scopes of personal action as an innovative theoretical background. For this, we integrate practitioners' views and preferences with scientific approaches. We apply different quantitative and qualitative methods from social science and modelling in an

interdisciplinary and international project team. Lastly, we will develop roadmaps and emission pathways for all three areas of air travel, which are expected to have high societal response.

Project team	Univ.-Prof. Dr. Alfred Posch Thaller Annina, BSc, MSc, PhD Assoc. Prof. Dr. Romana Rauter Dr. Marie Kogler, BSc M.Sc. Eva Fleiß, MA PhD Mag. Dr. Anna Schreuer Lydia Maria Lienhart, B.A.(Econ.), MAIS
Lead Institution	University of Graz, Department of Environmental Systems Sciences
Scientific partner	Centre for Climate and Energy Transformation, University of Bergen (P1)
Duration	March 2022 – September 2024
Funding	ACRP, 13th Call

2.2.28 METSET – Identification of opinions, enabler technologies, and technology adoption paths of smart energy technologies

With the Green Deal, Europe aims to become the first climate-neutral continent by 2020, with the energy transition playing a major role. In order to establish a decentralized, secure energy system based on renewable energy sources, the Green Deal relies on the development of a fully integrated and digitalized EU energy market. At the household level, intelligent technologies, such as smart home applications are important. In addition to smart entertainment, security or comport applications, smart energy technologies (SET) (e.g., smart meter or energy management systems (EMS)) enable energy efficiency, promote sector coupling (e.g., e-mobility), communicate with the energy system or enable the integration of renewable energies.

SET can contribute to optimizing, stabilizing, and increasing resilience of the energy system, as they components, grids and actors to interact with each other. The contribution of digitalization to the green transformation is subject of the research.

METSET focuses on two questions:

1) **What types of SET opinions are present?** The prevailing opinion on SET influences individuals' acceptance and willingness to use SET, and consequently the diffusion of the technologies at the macro level. To make a statement about the contribution of digitalization, i.e., specifically SET, to the green transformation, it is relevant investigate the prevailing opinion about SET (i.e., attitudes, values, needs, etc.) amongst (potential) users.
2) **What is the role of SET in the individuals' technology adoption paths (TAP)?** With their decisions to buy and use SET, households act as active players in the energy transition. To date, the relation between adopting SET and other (smart) technologies is

still unclear. Does the adoption of one technology influence the adoption of another? Are there patterns in individuals' adoption decisions over time, and if so, how does such a TAP look like?

Project Team	Eva Fleiß, MA PhD Katharina Trimmel, Dipl.-Ing. BSc
Lead Institution	Campus 02, University of Applied Sciences, Information Technologies & Business Informatics
Duration	October 2021 – February 2023
Funding	Land Steiermark, Green Transformation

2.3 Research cooperation and networks

2.3.1 Climate Change Graz

Climate Change Graz works on anthropogenic climate change, which is widely regarded as one of the greatest challenges of the 21st century. In order to limit rising temperatures to an increase of 1.5 to 2 degrees, in line with the targets set by the Paris Agreement, CO_2 emissions must be reduced by at least 50 percent by the year 2030, and around 90 percent by 2050. Making the transition to an almost emission-free and climate-stable economy and society requires a fundamental change of direction. At Climate Change Graz, one of the university's profile-building areas, a team of over a hundred researchers is exploring what economic, production engineering, social, political and legislative changes are needed to make this profound and sustainable transformation possible.

2.3.2 Complexity of Life in Basic Research and Innovation (COLIBRI)

Complexity of Life in Basic Research and Innovation (COLIBRI) is concerned with the profound changes that lie ahead in our living environment. Research findings from the science of complexity will soon provide a vital basis for decisions in business and policy-making. The findings come from modelling and computer simulation of complex systems in humans and nature, such as the optimization of transport and logistics systems, the investigation of vulnerabilities in ecosystems and the fields of biologically-inspired technologies and research into swarm intelligence.

2.3.3 HFDT – Human Factor in Digital Transformation

Digital "information and communication technologies" have found their way into the last corner of our lives and private spheres. They open up unimagined new possibilities, often facilitate our activities, accelerate exchanges between people and potentially raise them to a global level. At the same time, these developments are also associated with dangers and risks. The interdisciplinary network "Human Factor in Digital Transformation" pursues the goal to raise awareness for these risks and to enhance the consideration of the "human factor" in the development and implementation of ICT products and services ("SSH in ICT"). This goal is to be achieved by bringing together existing competences at the University of Graz. The network has been established since 2017 as an intra-university project with a strong interdisciplinary focus.

2.3.4 Early Career Researchers Network of Networks

Early Career Researchers Network of Networks (ECR NoN) is uniting early career researcher organizations from all over the world to facilitate cooperation, to break silos across disciplinary backgrounds and engage with interdisciplinary issues. ECR NoN also addresses science-policy translation issues and provides early career researcher opinion in initiatives like Future Earth, the International Social Science Council (ISSC) and other relevant groups and organizations.

Department of Environmental Systems Sciences (ESS) is part of this ECR NoN since mid-2016, with another 27 international networks involved. Each of the member organizations has the freedom to create working groups for certain topics of interest. ESS, represented by Arijit Paul and Victoria Yavorskaya. Arijit Paul is currently serving as the working group coordination committee chair at the executive committee of the ECR-NoN.

2.4 Ph.D. projects (ongoing)

2.4.1 Sustainability assessment from a systemic perspective – operationalising a systemic definition of environmental and social sustainability performance

Progress towards sustainable development to preserve natural systems and fulfil human needs is a prerequisite and of great importance. Simply reducing negative impacts may be too narrow; sustainable processes and actions are required to contribute to sustainable development. Whether certain processes or actions contribute to sustainable development must be evaluated as part of a sustainability assessment. Sustainability assessment comprises procedures for identifying and measuring sustainability impacts in order to support decision-making processes. In order to overcome the global sustainability challenges, it is important to move from a narrow perspective to a systemic perspective in sustainability assessment. There are already several tools for sustainability assessment, but it is questionable whether and how they integrate a systemic perspective. Therefore, this cumulative dissertation addresses the challenges of sustainability assessment with the overall research aim of developing a framework that enables decision-makers to capture the complexity of sustainable development with a relatively simple method by considering systemic dimensions in the assessment. From this, two main research aims can be derived:

Aim 1: To investigate the comprehensiveness of existing sustainability assessment tools (Life Cycle Sustainability Assessment, Multi-Regional Input-Output analysis)

Aim 2: To develop a sustainability assessment framework as an initial step towards a systemic sustainability assessment

Three dimensions identified as relevant form the basis of the framework: the first dimension relates to the sustainability principles as the basis for an accurate definition of sustainability, the other two dimensions relate to the scale (narrow and systemic sustainability performance) and the decision horizon (short, medium and long term). The sustainability assessment framework proposed in this dissertation is a first approach to integrate a systemic perspective into an assessment tool to operationalise the concept of first- and second-order sustainability performance. It is proposed to conduct the assessment by formulating specific questions that depend on the particular processes or actions being assessed for each sub-dimension. This rather simple method allows for a sustainability assessment that takes into account the complexity of the sustainability concept and emphasises the need to integrate a systemic perspective.

PhD student	Martina Zimek
Duration	2016 [break – maternity leave: 2019 – 2023] – 2024
Supervisor	Rupert Baumgartner

2.4.2 Drivers and Challenges of Sustainability in Establishing New Ventures

For more than a decade, scholars have increasingly paid attention to the motivations, existence and conditions under which new ventures shape the economic transformation towards sustainable development. This inclination to focus on early-stage ventures and their founders is an appropriate countertrend to the inherent focus on established firms in the existing sustainability literature.

Early-stage ventures are described as change agents and important catalysts, capable of disrupting the established, unsustainable order of industries by addressing challenges to promote sustainability and contribute to solving environmental and social issues. Striving for sustainable development provides early-stage ventures as a valuable source of differentiation, enables new business opportunities and provides them credibility when claiming to be part of the solution and not part of the problems caused by established firms. As newcomers, however, early-stage ventures are under enormous pressure due to their limited business experience, their lack of access to critical resources and the attempts they make to reconcile often multiple competing sustainability goals. For this purpose, a business model is required that enables the implementation of the business strategy with regard to sustainability.

With this background in mind, my PhD dissertation focuses on the business model development of early-stage ventures that strive for sustainability, mainly articulated around three research projects:

- In the first project of the dissertation, business models of aspiring ventures were investigated with regard to sustainability aspects. In this context, this work sheds light on early development phases of business models by illustrating (1) how sustainability was allocated to individual business model elements and (2) reveals the drivers that encouraged early-stage ventures to include sustainability aspects in their business models from an imprinting theory perspective.
- The second project investigates tensions, early-stage ventures face when striving for sustainability. In this context, a paradoxical lens is used to shed light on (1) the type of sustainability tensions and (2) how ventures use different coping strategies to deal with them.
- The third research project focuses on exploring the interdependencies and potential contradictions within business models of new ventures that strive for sustainability through the lens of Activity Theory. By adopting the Activity Theory, this study enriches thinking and articulating of sustainability-oriented business models originating from entrepreneurial activities. This contribution develops the theoretical connection between the business model and the Activity Theory and illustrates it in the context of the business modelling activity of a new venture with a focus on the triple bottom line.

PhD student	Martin Glinik
Duration	2018 – 2024
Supervisor	Romana Rauter

2.4.3 What, How and Why? A Cross-Sectoral Perspective on the Perception and Implementation of the Circular Economy

In a profound exploration of the circular economy (CE), this thesis delves into the complexities of Austria's shift towards a more sustainable system, countering the traditional "take-make-dispose" linear economic model. employing a two-fold analysis that integrates insights from various sectors to illustrate the multifaceted perception and implementation of CE.

In its initial segment, the research focuses on Small and Medium-sized Enterprises (SMEs) across various industries in Austria. This examination is crucial, considering SMEs constitute the majority of European enterprises and are significant contributors to industrial pollution and emissions. Unlike larger organizations, SMEs face unique challenges due to their limited resources, technological capacities, and research and development capabilities. These differences are pivotal in understanding how SMEs interact with and contribute to the circular economy. The thesis initially casts a wide net, scrutinizing the general patterns and divergences in CE practices among SMEs. It uncovers a notable gap between the aspirations for a CE and the reality of its implementation, especially apparent in resource efficiency and stakeholder collaboration. This disparity raises questions about the barriers to and drivers of CE among Austrian SMEs, the influence of various contextual factors like company size, sector, and external pressures, and how these elements shape the perception and performance in CE initiatives.

The thesis then focuses on the plastic and wood-based industries. These sectors, characterized by their distinct feedstocks – fossil-based for plastics and bio-based for wood – provide a contrasting landscape for CE practices. The wood industry, closer to bio-based materials, naturally gravitates towards efficiency and prolonging product lifespans, influenced by market forces and innovation. In contrast, the plastic industry, bound by its non-bio-based nature, grapples with the challenges of technical recycling, pushed by external pressures and societal expectations. This comparison not only highlights sector-specific challenges but also reflects the broader socio-economic and cultural factors influencing CE adoption.

Overall, this PhD thesis, part of the INTERREG project "Start Circles," contributes significantly to the scientific discussion on the CE. By combining a broad analysis of SMEs with an in-depth study of specific industries, it provides a comprehensive understanding of the multifaceted challenges and opportunities in Austria's transition to a CE. The findings are poised to guide decision-makers and industry stakeholders in formulating more effective and sustainable CE strategies.

PhD student	Daniel Holzer
Duration	2018 – 2024
Supervisor	Tobias Stern

2.4.4 Process and product innovations in advanced biorefineries: assessing factors, interrelationships and opportunities towards a sustainable knowledge-based bio-economy

To cope with the problems associated with the fact that today's energy carriers and chemicals are to a large extent based on fossil resources, and to promote regional and rural development, moving towards a more bio-based economy is discussed as a potentially viable option. For this, biorefining, defined as the *sustainable processing of biomass into a spectrum of marketable bio-based products and bioenergy*, is expected to play an important role. A future economy that uses bio-based resources also in an environmentally and socially sustainable way will depend on the production of a variety of products such as food, feed, materials, chemicals and energy from limited resources.

Research plays a major role in the development of new technologies, but most ideas that are followed in research fail to reach the market. One reason for that might be that research projects are often strongly focused on technological development, but for the development of profitable and sustainable biorefineries, challenges along the whole value chain need to be tackled, involving a range of different disciplines and stakeholders.

Lignocelluloses and, in particular, lignocellulosic residues are the dominant feedstock mentioned in published biorefinery research. Technical lignin is a relatively large (estimated at 50 million tons per year) and underutilized residue stream from the pulp and paper industry, which is now mainly burnt on site for the purpose of gaining energy. Investigations on technological aspects of lignin for several conceivable applications have been the focus of research for many years, whereas the level of knowledge in the field of markets and innovation diffusion of lignin is rather low. Currently, only a limited market for lignin exists, but it is said to play a major role in biorefinery conception in that it is a residue that could be further valorized and a promising substance which in future could replace certain petrochemical products in a more sustainable way.

In order to fill the knowledge gaps between the technical research on the other hand and economic and sustainability approaches on the other hand and to investigate the discrepancies between biorefinery research and biorefinery implementation, the following main objectives are pursued:

- Investigation on how different feedstock classes, products, and regions have been described in the scientific literature on the development of biorefineries, comparison of these results with information on the practical implementation of biorefineries, discussion of trends and discrepancies (systematic literature review);
- Investigation of the diffusion of selected technical-lignin-based innovations:
    - Identify the relevant decision-makers and their relevant attributes, behaviors, and interactions (several approaches);
    - Exploration of how the diffusion of certain lignin-based innovations on the market could look like in different future scenarios, taking into account economic and technological factors (agent-based model).

The Ph.D. thesis is embedded in the activities in the course of the report "Natural Fibers and Fiber-based Materials in Biorefineries" and the COMET-project Flippr[2].

PhD student	Julia Wenger
Duration	2018 – 2024
Supervisor	Tobias Stern

2.4.5 Innovation strategies of companies in the mobility sector to reduce GHGs emission

In order to limit the impacts of climate change, deep cuts in global transport GHGs emissions are direly necessary. The topic has moved into the focus of policy makers, non-governmental organizations (NGOs), businesses and society as a whole. Increased competition, uncertain technological trends, long development cycles, highly capital-intensive product development, saturated markets, and environmental and safety regulations have subjected the sector to major transformation and innovation race. Consequently, technological innovations like electric vehicles are emerging as mobility company's major strategy to deal with climate change. Broadly, in the context of the mobility eco- system not only specific clean technologies but approaches and input from various companies related to mobility management are also significant. Not only low carbon but for the overall sustainable mobility system, strategies like Avoid-Shift-Improve (ASI) is considered as one of the best and holistic solutions. Aligning to this framework, the study aims to investigate on the innovation strategies of automotive firms exploring both technological and non-technological innovations for the achievement of the low carbon sustainable transport system.

For this, one aspect of the study investigates the technological innovation through the lens of patents through patent landscape analysis. With the aim of generating state-of-the-art of sustainable mobility innovations and understand its future trajectory in paper I, I used the systemic perspective of the sustainable mobility paradigm Avoid-Shift-Improve to present a patent landscape of the entire land transportation system. Paper I is entitled "*A patent landscape of sustainable mobility innovations in land transportation*" and is currently under second round of review.

My second study is based on the improve related strategy of the sustainable mobility paradigm. In order to understand the potential for a zero-emissions transportation future for incumbent automotive original equipment manufacturers (OEM), the second paper is based on the investigation of firm's innovation performance in the successful commercialization of their ZEVs. As the conference paper, the primary version of the paper entitled "*Innovation performance of incumbent automotive firms in climate change mitigation*". has been accepted at the "Academia of Management" annual conference on August, 2023. As a third paper, the writing of the full-length manuscript is currently at progress. .

Additionally, a case study was carried on the plausible low carbon sustainable transport system policies. The paper entitled "*Policy options for low-carbon sustainable transport systems in the Kathmandu Valley, Nepal: A survey-based study*" is currently under review.

Through this study, I tend to add the overall stakeholder perspective supplementing the firm perspective of my PhD study.

PhD student	Jyoti Prajapati
Duration	2019 – 2024
Supervisor	Rupert Baumgartner
Reference/Project	FWF Doctoral College Climate Change

2.4.6 Information and Knowledge Retrieval with NLP in Environmental Systems Sciences

While computers can handle large and structured data, such as tables, with ease, working with unstructured data or in other words raw text proves to be far more difficult. Unfortunately, most information on the internet is mainly available in this unstructured form. In order to use this vast amount of data the field of Natural Language Processing (NLP) has been formed and found an increasing number of uses across several disciplines over the last decade.

A powerful driving force in the recent progress of NLP has been the use of neural networks to transform words into numeric vectors, which contain semantic information and therefore make it possible for a computer to understand their meaning. With the help of these word vectors applications such as topic clustering, keyword extraction and text similarity calculations as well as more common machine learning processes such as supervised classification can be utilized to extract information. This is especially helpful when it comes to data sources, that are too large to be processed by hand, for example the plethora of scientific articles released each year.

In fields with highly congruent vocabularies such as medicine or material sciences, many of these methods have been used to produce very promising results. But when it comes to system sciences, a field where many specializations intersect, the use of different descriptions for the same overarching point of interest becomes more likely. This in turn increases the difficulties when trying to extract knowledge from these works with help of NLP. However, this also means the potential gains could be of significant assistance when it comes to further research and to assisting policy makers in making informed decisions.

As such the main focus of my PhD work will be on how to make these applications feasible and determine in which areas they may provide the biggest benefit. Additionally, it will also be investigated if the results provided can be further applied as input for scientific models.

PhD student	Raven Adam
Duration	2020 – 2024
Supervisor	Manfred Füllsack

2.4.7 Digital product passports as enablers of more sustainable and circular value chains: The case of electric vehicle batteries

Decision processes in the context of sustainable product management (SPM) affect different production and consumption system levels. Decision-makers along the product life cycle are thus confronted with complex decision situations. Control over high-quality product life cycle data is clearly of interest when attempting to support SPM. In light of the current lack of such data, digitalization and digital technologies (DTs) provide promising solutions for the generation, processing, and transferal of product life cycle data along the product life cycle.

This cumulative dissertation investigates how DT-based tools can support SPM. This is exemplified by investigating how digital product passports (DPP) can support the sustainability-oriented management of an electric vehicle battery (EVB). The research process was guided by a set of methods, ranging from (semi-)quantitive to qualitative. The results derived are presented in four research papers. These provide the backbone of the present thesis. The findings systematically delineate the data needs and requirements entailed in sustainability-oriented EVB management based on secondary data. This served as a foundation for systematically deriving the first ever DPP concept with an SPM focus. The findings further comprise empirical insights into the data needs and requirements of decision-makers along the EVB value chain with respect to both SPM support, and the respective data availabilities and accessibilities. This allowed for the identification of data gaps along the EVB life cycle and of potential contributing factors. Lastly, empirically-derived factors which may enable or hinder the deployment of DPPs as instruments in SPM are also presented.

Based on the findings, it can be deduced that various fields of tension characterize the conceptualization and development of a DT-based SPM tool. These comprise, for instance, the lack of awareness of available SPM strategies and options, or the different perceptions of SPM roles and responsibilities amongst decision-makers. This serves to highlight the need to combine a sustainability research and practitioner perspective when aiming to exploit DTs for SPM support. Furthermore, the factors identified in association with data gaps along the product life cycle reveal how insufficient a technocentric viewpoint regarding establishing information flows for SPM is likely to be. The findings allow to conclude that DT-based solutions are unlikely to be the sole enabler of more sustainable production and consumption systems. Further research is also encouraged in order to identify those factors contributing to data gaps along the product life cycle, technical implementation, and sustainability assessments of DT solutions for SPM.

Included papers:

Berger, K., Schöggl, J.-P., & Baumgartner, R.J. (2022). Digital battery passports to enable circular and sustainable value chains: conceptualization and use cases. Journal of Cleaner Production, 353. https://doi.org/10.1016/j.jclepro.2022.131492

Berger, K., Baumgartner, R. J., Weinzerl, M., Bachler, J., Preston, K., & Schöggl, J.-P. (2023). Data requirements and availabilities for a digital battery passport – A value chain actor

perspective. Cleaner Production Letters, 4, 100032. https://doi.org/10.1016/j.clpl.2023.100032

Berger, K., Baumgartner, R. J., Weinzerl, M., Bachler, J., & Schöggl, J.-P. (2023). Factors of digital product passport adoption to enable circular information flows along the battery value chain. Procedia CIRP, 116, 528–533. https://doi.org/10.1016/j.procir.2023.02.089

Berger, K., Baumgartner, R. J., Weinzerl, M., Bachler, J., & Schöggl, J.-P. (2023). Digital battery passport information content for end of (first) battery life management support. In: Proceedings of the 5th Product Lifetime and the Environment (PLATE) 2023, Aalto, Finland.

PhD student	Katharina Berger
Duration	2020 – 2024
Supervisor	Rupert Baumgartner
Reference/Project	Christian Doppler Laboratory for Sustainable Product Management enabling a Circular Economy

2.4.8 Resilience in food supply chains against external shocks: the case of Covid-19

Supply chain management has moved to the spotlight of research over the last decades and demands corporations to extend their view outside the organization. Increased competition and globalization force closer relationships and stronger cooperation. Furthermore, the Covid-19 pandemic hit the world by surprise and, apart from the devastating health impacts, caused major disruptions in business operations. Unemployment spiked in multiple countries, world trade declined suddenly, and the consequences are far-reaching. Supply chains struggled to keep operating. This research project aims to learn from these events to be better prepared for the future. The intersection of supply chain management, food processing, and resilience is analyzed to achieve this objective. Food supply chains proved to be especially vulnerable to pandemic disruptions, as they got hit by multiple disruptions simultaneously. Maintaining a constant supply of food is vital to avoid more detrimental effects on people and society in general.

To analyze the behavior of food supply chains, modelling approaches to detect weaknesses and increase resilience are applicable. Simulation-based supply chain modeling has already been well researched; therefore, an agent-based modeling approach will be applied. Simulations enable the analysis of dynamic and complex behavior over time to optimize the outcome and identify performance issues or vulnerabilities. In this case the simulation will pursue a micro level approach focusing on the Austrian milk supply chain, with input data based on secondary data sources as well as expert-interviews.

To address the previously described problem the following research questions are framed around three major topics:

- Gain knowledge insights by simulating the behavior of the supply chain actors.

- How can an agent-based approach be implemented to analyze the behavior of the Austrian milk supply chain?
- How can food supply specific characteristics be considered during the modelling and simulation of supply chain behavior? Which actors are part of such a chain and how is their performance influenced by disruptions?

- Gain insights on resilience management and quantification.
  - How can resilience within a food supply chain be quantified? What indicators can be used to quantify the impact and recovery of a disruption?
  - Which countermeasures can be developed to increase the quantified resilience? Which effects on the supply chain stability can there be measured?
- Derive managerial implications based on the increased knowledge.
  - How can multiple simultaneous disruptions within a supply chain be managed? What decisions can be made? How can the decision-making process be supported?
  - What strategies do exist for each of the actors within the supply to mitigate risks before a disruption, during the disruptive events and what can be derived afterwards?

As these disturbances are unparalleled, the consequences on supply chains have rarely been witnessed before. The uniqueness of these events creates new research opportunities. Amongst others the analysis of rare and high impact disruptions, the assurance of food supply & security and the application of quantitative approaches to measure resilience. The goal of this research project is to take advantage of these opportunities and explore strategies to create more resilient food supply chains in the future.

PhD student	Moritz Kettele
Supervisor	Rupert Baumgartner
Duration	2020 – 2024

2.4.9 Criticality and Computation: Understanding sudden state transitions in complex networked systems

This project revolves around the study of critical transitions and possible ways to anticipate them. We study critical transitions using the concept of complex networked systems, where the term “networked” acknowledges the inclusion of network properties between system components, and the term “complex” the importance of emergent properties arising from component interactions. Critical transitions can be conceptualized as a form of sudden state transition, where the system abruptly shifts from one stable state to an alternative stable state (Scheffer, 2020). They are observed in many sociological, biological, ecological, and physical systems, and understanding them plays an important role in avoiding transitions to detrimental stable states. A prominent example from the field of ecology is tipping in shallow lakes (Scheffer, 2020). Shallow lakes are known to exhibit two alternative stable states, one in which the lake is clear and features high vegetation, and one in which the lake is turbid and features low vegetation (Scheffer, 1993). Both the clear and the turbid states are self-reinforced through stabilizing feedback loops. To illustrate, a clear lake provides sunlight for the development of submerged water plants which in turn improve the lake’s water clarity by

absorbing nutrients (Scheffer, 1993). On the other hand, a turbid lake prevents the growth of submerged water plants which in turn leads to an elevated levels of algae in the lake that increase its turbidity (Scheffer, 1993). Interestingly, there exists a sharp transition between the clear and the turbid states which can be induced by changing the nutrient load of the lake. The exact amount of nutrients required to induce this transition marks the tipping point of the lake system. Note that the transition itself happens quite abruptly, meaning that it is usually not possible to intervene during the transition. Therefore, it is highly important to identify the factors that determine and shape the transition, and subsequently, to devise methodologies capable of anticipating the tipping point of a system. Within this project, we aim to contribute to both of these aspects. In particular, we aim to answer the following research questions:

- **Research Question 1**: How does the underlying network structure of a system, that is, the detailed description of all connections between system components, shape the transition behavior of the system?
- **Research Question 2**: How can these insights be leveraged to improve early warning signal analysis, that is, the methodology to anticipate tipping points?

* The above text is an excerpt from the current thesis draft

PhD student	Daniel Reisinger
Duration	2020 – 2024
Supervisor	Manfred Füllsack

2.4.10 Sustainable Operations Management: Linking Sustainability with Operational Excellence

Operations management is essential for fulfilling an organization's sustainability goals. However, research has so far has not been able to provide practical models that include sustainability objectives into several aspects of operations management – an obstacle for any organization that must meet business requirements in a short period of time. At the same time, a corporation must create, or maintain, an adequate organizational culture, appropriate leadership skills, and operational excellence, all of which are required for long-term success. Therefore, within sustainable operations management, models that combine operational excellence with sustainability are essential.

To that purpose, the thesis examines existing, holistic frameworks for both operational excellence as well as sustainability as a basis and attempts to adapt and test them for a potential framework linking sustainability with operational excellence. Hoshin kanri, a special form of strategy deployment, is a potential management system for linking strategy and implementation. Hoshin kanri is a process-based framework that incorporates environmental aspects (i.e., to eliminate waste) as well as social aspects (e.g., integrating all employees and levels of decision making), with great potential in combining operations management with sustainability. The Framework for Strategic Sustainable Development was chosen as the framework for sustainability to be combined with hoshin kanri. This framework aims to help

organizations and institutions become more sustainable. It is used in this research due to its practicality, its clearly defined sustainability principles, and planning process as well as combination possibilities with other management methods and tools.

The goal of this thesis is to provide a comprehensive framework to support sustainable transformation in companies, within sustainable operations management. This will be done through three interconnected research steps: (1) literature review for framework development, (2) case-study approach testing and refining the framework, and (3) identifying benefits and barriers of applying the framework.

The main research questions that this research project addresses are:

- How to develop a strategy deployment framework connecting operational excellence and sustainability through hoshin kanri?
- Where and how is hoshin kanri applied for implementing corporate sustainability?
- What are the main benefits and challenges in applying the strategy deployment framework for corporate sustainability and operational excellence?

PhD student	Katharina Roche
Duration	2020 – 2024
Supervisor	Rupert Baumgartner

2.4.11 Modeling the life cycle system of wood: Multi-objective optimization of sustainability objectives

Wood as a renewable resource is used in several applications, both as material and energy. It can contribute to climate change mitigation by the carbon sink function of forests and carbon capturing and storage of harvested wood products. Wood also has the potential to substitute non-renewable materials and energies. It is not known how wood is used in the best way from a sustainability view. Considering the problem from a system perspective, it is not clear which application of wood is more sustainable and if wood or alternatives should be preferred. This becomes especially relevant when new applications like using wood for the automotive industry come up. It is not known whether wood for vehicles is sustainable on a macro-level and how the design of components and processes influences their sustainability.

The aim of this PhD project is to analyze and optimize the system of wood use from a holistic perspective, looking at wood uses and its substitutions simultaneously and including existing and innovative applications. All three dimensions of sustainability, environmental, social and economic aspects, are included in the assessment to find an optimal wood distribution for the whole system (Austrian market).

A system dynamics model is used to describe the dynamics of the system including wood availability, wood use and substitution combined with environmental, economic and social impacts. A sub-model of the innovative wood application for the automotive industry depicts the life cycle including production processes. Multi-objective optimization is used to identify the optimal process design of a component over the whole life cycle for the use in the

automotive industry and to compare it to the overall sustainability effects on the system (Austrian wood uses). The model of the overall system is optimized with multi-objective optimization to balance environmental, economic, and social goals and to find the optimum for a sustainable use of wood.

This research contributes on the one hand to provide insights on the effects when designing products and processes in the automotive industry and to make wood products for vehicles more sustainable and competitive. On the other hand, the assessment of the overall system will show the dynamics and the optimum (environmental, social, economic) of the system of wood use and present ideas on how to create a more sustainable future.

PhD student	Theresa Boiger
Duration	2021 – 2025
Supervisor	Tobias Stern

2.4.12 Sustainability assessment of different Li-Ion battery recycling techniques integrated into a digital battery passport framework

Li-Ion batteries (LIBs) have a globalized value chain and are a central technology for decarbonization. Therefore, sustainability topics are of core interest along the whole life cycle of LIBs. Due to technological advancement, governmental programs and decreasing prices, the demand and use of LIBs has increased in recent years and this growth is expected to continue in the coming years. With the increase of production comes a need for End-of-Life treatment to avoid waste and to reduce the environmental and social impacts of material extraction and production, through the reuse of raw materials of previous batteries.

The method sustainability assessment is partly standardized, but methodic contributions are still possible. Therefore, the dissertation project targets both, methodic options and the results of applying the selected method.

The process starts with the prioritization of sustainability aspects and the selection of related indicators. This is followed by the generation of the End-of-Life process inventory, where a detailed understanding of the technologies available and its role in the value chain is necessary. The current developments regarding a digital battery passport can facilitate the generation of such a process inventory and the subsequent impact assessment. The impact assessment is then executed on process scale using social hotspot database and economy wide scale using multi regional input output tables.

In more detail, the following research questions are targeted in the dissertation project:

1. Which sustainability aspects should be prioritized for the recycling of Li-Ion batteries and how can such a prioritization methodically be done?
2. What are the sustainability risks and benefits of Li-Ion batteries recycling and what are the implications of a large-scale implementation for the economy?

3. How can environmental and social life cycle assessment be combined in a systemic sustainability assessment and what are the chances and limitations of using a digital battery passport to convey this information?

The research is embedded into the Horizon Europe project FREE4LIB which provides the benefit to gain first source information from organizations involved in these recycling processes.

PhD student	Julius Ott
Duration	2022 – 2025
Supervisor	Rupert Baumgartner
Reference/Project	FREE4LIB

2.4.13 Improving circular economy and sustainability along the value chain via Digital Product Passports

Circular economy (CE) has become an increasingly discussed concept over the past decades, both by politicians as well as scientists. It aims at extending products' lifetimes and retain the value and quality of products and materials throughout their life cycle while keeping them in the cycle as long as possible. Hence, CE is related to how products are designed and how business operations are organized. The practical implementation of CE requires vast amounts of relevant, up-to-date and data trustworthy data along products' value chains. As digital technologies, and more specifically, digital product passports (DPPs), may facilitate data collection and the tracking of resources, materials and products, they may be considered an essential enabler for accomplishing the transition towards CE. The main prerequisite for DPPs is complete, reliable and available information and therefore, the involvement of all relevant actors along the respective value chains is essential.

Hence, the overall research goal of this thesis is to assess how the targeted use of DPPs and the related systematic integration of multiple stakeholders' perspectives can effectively promote CE and sustainability along products'/components' lifecycles. The aim is to explore the potentials of digitalization, and more specifically, of digital product passports to facilitate information collection and exchange. In order to gain an in-depth understanding of DPPs, two concrete use cases are chosen: the electric vehicle battery and the internal combustion engine. Here, it is the objective of the presented research to get a deep understanding of the information requirements of each stakeholder along the use cases' value chains in order to support CE-oriented decision-making. Furthermore, due to the huge importance of available data for the effective implementation of DPPs, this research also deals with the enhancement of information sharing between value chain actors. It considers influencing factors, challenges, obstacles and incentives with regards to information sharing. Thereby, this thesis delivers an important contribution to foster information exchange and thereby support the transition towards circular economy.

PhD student	Antonia Pohlmann
Duration	2022 – 2025
Supervisor	Rupert Baumgartner
Reference/Project	CE-PASS

2.4.14 Digitalization and circular economy: Digital product passports as transition enablers

The increasing use of natural resources causes severe environmental challenges, which need to be dealt with for achieving a more sustainable future. One of the concepts contributing to sustainable development is the so-called circular economy. Although a transition towards a circular economy could contribute to a more sustainable future, the worldwide implementation is still in its early stages Therefore, possibilities and enablers have to be found in order to accelerate the transition towards a more sustainable and circular economy. For achieving a circular economy, another ongoing transition, the transformation from an analogue to a digital economy, commonly referred to as digitalization, can play a crucial role. In the context of digitalization, one possible facilitator are technologies, which increase the availability of information for value chain actors in a circular economy. Effective planning and management, for instance planning of reuse or recycle scenarios, require reliable information, which is in most cases not available for decision makers, rooted in the fact, that most companies are nowadays interlinked in increasingly complex supply chains.

Therefore, this thesis focuses on how digital technologies can help in providing decision makers all along the life cycle of products with the needed information to enable effective decision support with regards to sustainability and circularity. A special focus is thereby put on the design phase pf products, given that most of environmental impacts are determined during this stage of the product life cycle. The research aim of this thesis is to facilitate the development of digital product passports, as means of information providers, by identifying different stakeholders and their corresponding information requirements and to identify tools for sustainability assessments, which use data provided by digital product passports for early-stage sustainability assessments to enable sustainability improvements in the early design phase.

PhD student	Martin Popowicz
Duration	2022 – 2025
Supervisor	Rupert Baumgartner
Reference/Project	CE-PASS

2.4.15 On the Road to Sustainable Passenger Transport – across Ecological, Economic and Social Dimensions

The shift towards sustainable passenger transport necessitates consideration not only of its environmental aspects but also of the social and economic dimensions involved in this

transformation. Within my dissertation, I aim to address this complex interplay by making the following contributions:

1. Overcoming barriers facing innovative sustainable mobility offers in rural areas

The transportation sector in Europe contributes significantly to greenhouse gas emissions, with private car use playing a substantial role. Certain rural areas face unique challenges in terms of emissions and transportation disadvantages that affect vulnerable groups. To address these challenges and promote sustainable transportation, this paper describes barriers and enablers encountered when offering innovative mobility services in rural regions. By conducting semi-structured interviews with policy makers and service providers, the study examines the role of rural characteristics, demand-side challenges and supply-side issues. Based on these interviews, we introduce a classification of barriers according to their temporal occurrence which encompasses barriers that arise before, during and after innovative and sustainable mobility services are provided. The paper concludes with insights into potential enablers that can be used to overcome these barriers and promote the successful use of innovative mobility services, ultimately fostering a shift toward sustainable transportation in rural areas.

2. A Typology of Fairness Perceptions Regarding Restrictive Leisure Aviation Policies

In the pursuit of achieving climate goals outlined in the Paris Agreement, this paper delves into the imperative need for reducing emissions across all sectors, with a particular focus on the burgeoning environmental impact of global air travel. As aviation emissions rise rapidly, constituting a significant portion of global CO2 emissions, policy measures are crucial to curtail its contribution. Recognizing the complex interplay of perceived fairness and perceived effectiveness in policy implementation, we explore the perceptions and arguments of leisure air travelers through a series of focus group sessions. Our study evaluates the perceived fairness and perceived effectiveness of four distinctive restrictive policies: an air ticket tax, a ban on short-haul flights when there is a well-established train connection, the introduction of personal carbon budgets for leisure air travel, and a minimum price for air tickets. The results offer valuable insights into the multifaceted considerations that shape individuals' perspectives on fairness and effectiveness of restrictive policy measures.

3. Envisioning pathways to climate neutral passenger transport in 2040

How will passenger transportation evolve in the face of new megatrends such as digitalization and technological innovation? What do people want for their future mobility and how can this be reconciled with the goals of climate-neutral transport? These questions were discussed with citizens in a future workshop. Together, they formulated a vision for future personal mobility in 2040 and developed paths for realizing this vision through backcasting. These paths included considerations of electrification rates, hydrogen propulsion, mobility-as-a-service, and digitalization.

The vision developed in the future workshop was then critically evaluated by local decision makers and compared with existing literature. Finally, social costs, which include the total societal costs of personal mobility (including vehicle costs, externalities, and cross-modal

travel time costs), were calculated for both a "business-as-usual" scenario and a desired "visionary 2040" scenario. This innovative approach, which combines qualitative participatory technology assessment methods with quantitative economic methods, allows for a comprehensive examination of the social impacts of changes in the personal mobility system.

PhD-student	Simone Schreiegg
Duration	2022 – 2026
Supervisor	Alfred Posch

2.4.16 Social justice and fairness dimensions of ambitious climate policy and discourse

Mitigating global climate change is crucial for securing safe living conditions for human and non-human life. At the same time, climate change mitigation poses a challenge to governance systems on any scale and relies on public support for ambitious climate change mitigation policies. Since the transition to a low carbon society creates benefits and costs that can be unequally distributed across time scales and actor groups, it is relevant to account for potentially adversely affected actor groups and fairness concerns.

The objective of this research project is therefore to examine contested climate change mitigation policies within the broader context of a just transition to carbon neutral production and consumption modes. The aim is to understand different social perspectives on their acceptability as well as potential constraints for policy acceptance for affected groups in order to develop policy recommendations and increase policy acceptance, effectiveness and efficiency.

This will be accomplished through a mixed methods approach: a discourse analysis spanning multiple discursive arenas, a Q methodological study examining social perspectives, and survey research to, inter alia, increase understanding of policy acceptance.

To summarize, this research project aims to answer the following research questions:

- How does the discourse on climate policies look like in Austria and which groups are potentially adversely affected by those policies that dominate the discourse?
- How do actors within the groups make sense of the contested policies and which expectations about future states of affairs are perceived as potentially frustrated?
- What are the affected actor groups' preferences for climate policies, and which parameters determine acceptance?

PhD student	Katharina Trimmel
Duration	2022 – 2026
Supervisor	Thomas Brudermann
Reference	TransFair Project

2.4.17 Legitimizing Hydrogen Imaginaries: a critical comparison of the cases of the United Kingdom and Chile

Hydrogen Future is a rather old vision. Nevertheless, it is currently gaining special momentum since numerous countries are developing national hydrogen strategies; mobilizing resources and narrowing down the traditionally abstract meaning around hydrogen. How hydrogen is produced is country-specific; conditioned by the availability of natural resources and geographical particularities. Nevertheless, this paper focuses on how socio-technical imaginaries (STIs) also influence the policy-making processes of hydrogen trajectories.

UK and Chile envision themselves as global hydrogen leaders. Yet, the means to achieve it differ widely. This study employed discourse analysis of hydrogen policy documents (2015-present) to study how STIs shape policy-making processes. Despite both countries are privileged with renewable sources potential, UK pursue blue and green hydrogen while Chile only green. UK approach has been heavily criticized, pointing to the oil and gas industry interests in natural gas and using blue hydrogen for this purpose. The Chilean strategy envision hydrogen as an opportunity to modernize the country, become a relevant geopolitical actor, and pursue societal justice concerns.

Current findings of this study suggest that decarbonizing concerns are not the main drivers for developing hydrogen futures in neither country. On the contrary, hydrogen serves as the legitimate pathway to achieve different national goals. UK endeavours to maintain the oil and gas industry while Chile is imaging a modern and robust country. The exploration of STIs in both counties contributes to elucidate Global North and Global South dynamics in transitions, and it may also contribute to understand how hydrogen could help social justice concerns.

PhD student	Paula De Pablos Sanz
Supervisor	Tobias Stern
Duration	2023 – 2026

2.4.18 Life Cycle Sustainability Optimization in the conceptual development stages of Heavy-Duty Vehicles

Climate change is a global challenge that has far-reaching effects on our planet and human society (Sachs, 2015). The road transportation sector, in particular, plays a central role in efforts to reduce greenhouse gas emissions, as it accounts for a significant share (11,9 %) of total emissions (World Resource Institute, 2023). Given the urgency of the problem and the need for sustainable solutions, the study of propulsion concepts in the transportation sector is becoming increasingly important.

The most applied method to determine the environmental impacts of different Heavy-Duty Vehicles (HDVs) is Life Cycle Analysis (LCA). LCA is an essential tool that enables the environmental impact of a product or process to be assessed over its entire lifecycle – from the extraction of raw materials, through production and specific use-phase(s), to recycling and disposal. However, some challenges emerge when applying LCA to the transportation sector.

Furthermore, it makes the most sense to optimize new propulsion systems regarding their sustainability in the early development stages since this is where the greatest potential lies hidden in accordance with the eco-design paradox (Chebaeva et al., 2021) – an overall propulsion system that has already been positioned on the market can only be optimized to a minor extent due to the fixed physical properties, supply chains, and use-cases. However, there is a lack of a holistic life cycle approach that helps developers and decision makers to consider and improve the sustainability of powertrain concepts from the beginning. First, research approaches exist that show the possible integration of such optimization into product development, but their results also display the enormous need for further research and methodological refinements (Chandrakumar et al., 2017; Hung et al., 2022; Wolff et al., 2021a, Bouchouireb, 2023).

Therefore, I focus in my PhD on the application of LCA as a key tool for evaluating the holistic sustainability of truck powertrain concepts over their entire lifecycle. The focus lies on the applicability of LCIA indicators during the different development phases of HDVs and the implementation of R-strategies in the LCA of conceptual designs of HDVs. Ultimately, a Life Cycle Sustainability Optimization (LCSO) framework is developed to assist developers and decision-makers in optimizing the sustainability of powertrains. By analyzing and discussing these aspects, the aim is to contribute to a more environmentally friendly and sustainable transportation sector.

PhD student	Nicolas J. Katzer
Duration	2023 – 2025
Supervisor	Rupert Baumgartner
Reference/Project	Christian Doppler Laboratory for Sustainable Product Management enabling a Circular Economy

2.4.19 An exploration of the Austrian Bioeconomy's growth limits

The bioeconomy has received increasing attention as a green growth concept involving the transforming production and consumption system to reduce anthropogenic environmental stress and increase economic activity. At least four paths are envisioned, focusing on fossil fuel substitution, primary sector productivity, novel and efficient uses of biomass and low-bulk, high-value applications. There remains room in the literature for systematically exploring these pathways' growth limits along physical, technological, economic and socio-political dimensions. The project attempts to fill this gap by assessing the potential anthropogenic environmental reductions and economic activity increases related to each pathway considering the mentioned limitation forms within Austria between 2020 and 2050. The project focus on anthropogenic greenhouse gas (GHG) emissions and land use as environmental stressors. The project is scenario-based, meaning quantified growth limits and other outcomes reflect clearly stated underlying assumptions. The scenarios will be based on the Shared Socioeconomic Pathways. In practical terms the project involves:

- A literature review to identify and technological, economic, and socio-political growth limiting factors.

- The construction of a systems dynamics model to simulate the price formation and displacement effects among mainly land-based sectors for the different scenarios. The model will build on the FOHOW model and extend it by incorporating non-forest related sectors such as agriculture.
- A multi-regional input-output (MRIO) model EXIOBASE3 will be used to represent the general economic environment and reflects future changes in GDP, population and energy mixes and can capture substitution effects.

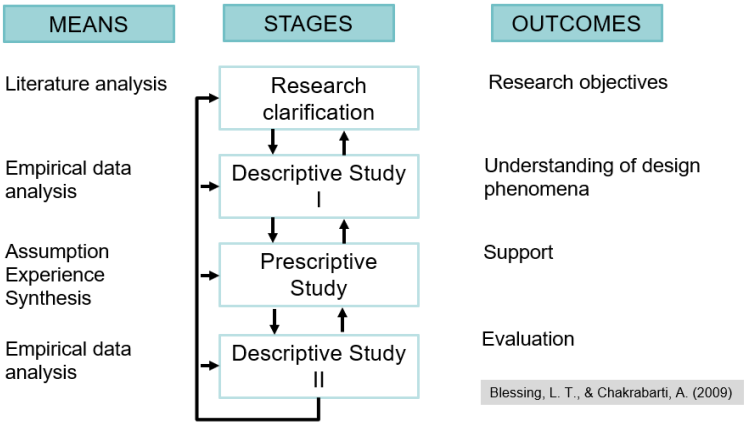
The project is embedded within the Below project.

PhD student	Edvard August Eggen Sveum
Duration	2023 – 2026
Supervisor	Tobias Stern

2.5 Ph.D. projects (completed or submitted)

2.5.1 Sustainable product lifecycle management in a circular economy

The accelerated population increase and the economic activity boost experienced within the second half of the 20th century has put human activities in the spotlight as principal agent of change for many biophysical indicators on the functioning of the planet. Circular economy (CE) has been proposed as an enabler of sustainable development, allowing humans to thrive economically without overshooting the planet's carrying capacity. For businesses, CE means adopting several value-retention options (Rs) along their operations. These aim at preserving and recovering the integrity of their assets and products for as long as possible. These strategies encompass long-established end-of-pipe interventions such as recycling or recovering the energy of products. Nevertheless, preferred options occur before that point – e.g., products' redistribution, refurbishing or reusing. The process by which products are made fit for these strategies is product design, in which around the 80% of the total environmental impact of a product is determined. The goal of this research project is to develop and evaluate the implementation decision-making support during the design process of products for a CE. The PhD research is structured according to the Design Research Methodology (DRM) (Blessing & Chakrabarti, 2009) and follows the research stages displayed in the figure below.



The research questions that this research project aims at answering are:

- Which product-related aspects relevant for its performance in a CE are decided upon in each phase of the design process and which criteria are used to guide the decisions?
- Which decision-making support, key actors and lifecycle information flows are involved at each phase of the design process of a product for a CE?
- How do product design alternatives score against circularity criteria?
- Does increased products' circularity lead to increased sustainability performance?

PhD student	Anna Diaz Tena
Duration	2018 – 2022
Supervisor	Rupert Baumgartner
Reference	CRESTING ITN MSCA Project

2.5.2 Organizational requirements for a more sustainable circular economy

The concept of a circular economy (CE) has gained considerable political and public attention in recent years, including growing scientific output and an ambitious CE agenda in two of the largest economic regions in the world, namely China and the EU. At the same time, CE is a highly dynamic field, driven by various stakeholders (think tanks, NGOs, science, politics, business), but without clear definition or framing. The promises of a transition of the economic system from a linear to a more circular one are – from the perspective of the European Commission – (i) more sustainable production and consumption patterns, (ii) job creation, as well as (iii) economic growth. Hence, CE is supposed to support all three pillars of sustainability and is consequently thought to contribute decisively to achieving the Sustainable Development Goals (SDGs). However, various obstacles have been identified in the transition towards a more circular economy.

- There appears to be a non-linear relationship between circular economy and sustainability due to manifold reasons: improvements in production patterns might be too incremental, too superficial organizational transformation disable deep transformation, inadequate and incomplete assessment leads to a lack of information and security, and CE seems present mainly on a process level while excluding social factors.
- Research interest around the CE is highly dynamic and exponentially growing in the past years. Due to its multi-stakeholder nature, various stakeholders drive the concept according to sometimes differing agendas. Consequently, confusion arises around the concept itself and what organizations need in order to be "circular economy ready"
- Circular economy is likely to require action and new paths in inter-organizational collaboration. Inter-organizational collaboration has the potential to push circular and sustainable practices forward: There is indication, that inter-organizational collaboration is helpful for effective eco-design and environmental improvements of products. Nevertheless, neither in the political sphere nor in the scientific community, this issue is yet to become a major focus of attention.

This research contributes to the definition of organizational requirements and obligations towards a more sustainable and circular economy on product level. This is achieved by a threefold approach: First, the relationship of sustainable development and circular economy is

revised and concretized through the definition of principles of a sustainable circular economy. Second, future developments and requirements for organizations for a transition towards a sustainable circular economy are investigated, taking into account the multi-stakeholder nature that forms CE, as well as emerging enabling technologies based on various forms of digitization. Based on the first two steps, a thorough analysis of inter-organizational collaboration delivers results regarding key actors and behavioral aspects that can enable sustainable circular practices. Thereby, this research also addresses complex interaction between actors that define sustainability and circularity aspects, as well as drivers for circular transition.

PhD student	Lukas Stumpf
Duration	2018 – 2022
Supervisor	Rupert Baumgartner
Reference/Project	Christian Doppler Laboratory for Sustainable Product Management enabling a Circular Economy

2.5.3 The Potential of Digital Technologies as Enablers for Sustainable Product Management in a Circular Economy

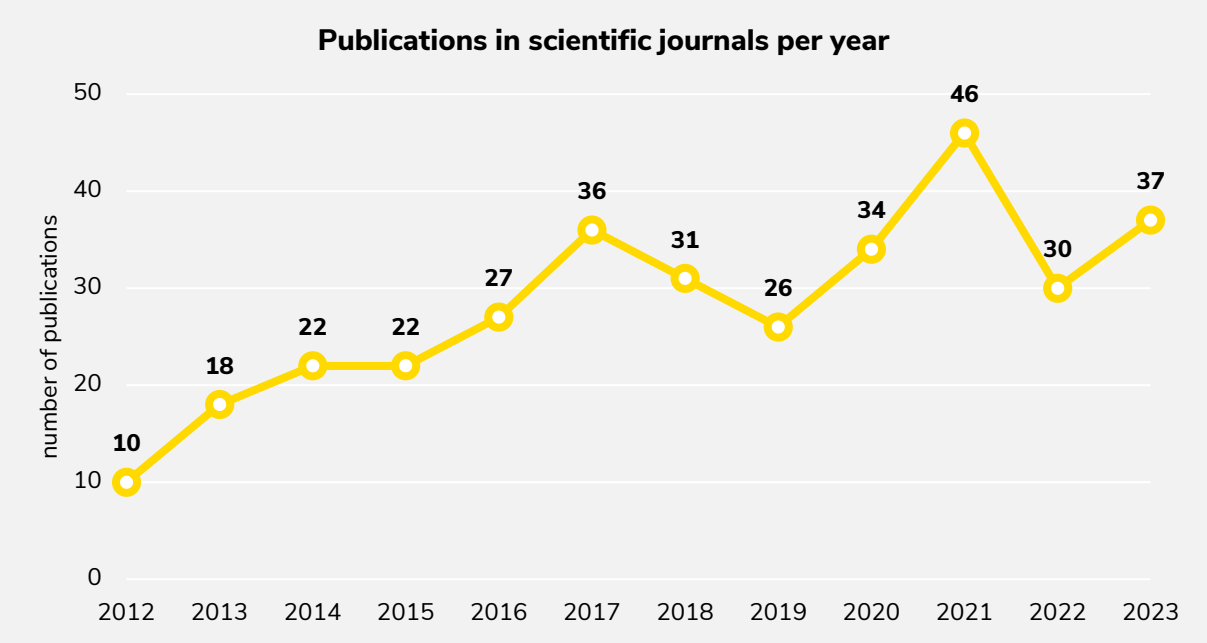
Unrestrained demand for natural resources is not possible in a finite world, and the current linear or "take-make-waste" approach as the predominant consumption and production model has devastating consequences on our planet. The urgency for a sustainability transformation increases as long as society continues to move in an unsustainable direction and companies uphold their "business as usual" approaches that contribute to the linear economy. However, in the last years, the circular economy concept gained attention for decoupling economic growth from linear resource consumption. It envisions a regenerative system that minimizes the use of natural resources and the creation of waste. But a widespread implementation of the circular economy is not yet taking place, and companies have difficulties operationalizing it. In the literature, digital technologies are described as potential facilitators for implementing corporate circular economy actions. They can be used to monitor products and parts in multiple lifecycles and ease the collection, management, aggregation, and exchange of product data. Thus, this thesis aims to explore how digital technologies can facilitate the implementation of a circular economy, especially on a product and company level. A design research methodology approach combining qualitative and quantitative methods was used to guide the research of this dissertation. As a result, a conceptual framework for sustainable product management is provided that should facilitate the implementation of a circular economy. Then, the role of digital technologies, particularly the internet of things, artificial intelligence, big data, and blockchain, for this implementation was further explored both in theory and practice. This resulted in a detailed description of the implementation level of digital technologies for sustainable product management in companies. Furthermore, the findings also reveal the status quo of the availability and quality of sustainability-related data in companies to support sustainable product management in a circular economy. In conclusion, in a circular economy, it is key that in addition to closing product and material

flows, the corresponding information flows also need to be circular. Further research should therefore explore how to ensure consistent information flows along circular product lifecycles. In addition, more research is needed on how to implement sustainable product management and operationalize circular economy in companies.

PhD student	Magdalena Rusch
Duration	2020 – 2023
Supervisor	Rupert Baumgartner
Reference/Project	Christian Doppler Laboratory for Sustainable Product Management enabling a Circular Economy

3 Publications and other research output

In this section, a detailed report on the department's research output is presented. An overview is given in the figure shown below, presenting the development of scientific contributions of members of the Department of Environmental Systems Sciences over the last years. In 2023, a milestone was reached with 37 contributions to journals, marking the second-highest result ever recorded. Moreover, posters and presentations reached an unprecedented level.



Contributions to edited books or proceedings	16	17	9	10	20	16
Posters and presentations	28	61	39	66	81	119

Number of publications in scientific journals over the last years

3.1 Publications

3.1.1 Monograph

Kogler, Marie L.; Adam, Raven: *Mathematische Grundlagen für Umweltsystemwissenschaften*, ISBN 978-3-540-95932-8. Heidelberg: Springer-Verlag Berlin 2023.

Pirker, Christian: *Fundraising: Grundlagen, Strategien*. Hamburg: Euro-FH 2023.

Pirker, Christian: *Grundlagen und Methoden der Transformationsforschung*. Hamburg: Euro-FH 2023.

3.1.2 Edited volume

Gelbmann, Ulrike-Maria; Karisch-Gierer, Dagmar; Pinter, Alexander; Pirker, Christian (Ed.): *Interdisziplinäres Praktikum Wald*. Grazonline: online 2023.

Görg, Christoph; Madner, Verena; Muhar, Andreas; Novy, Andreas; Posch, Alfred; Steininger, Karl W.; Aigner, Ernest (Ed.): *APCC Special Report: Strukturen für ein klimafreundliches Leben*. Berlin HeidelbergSpringer Berlin Heidelberg: Springer Berlin Heidelberg 2023. DOI: 10.1007/978-3-662-66497-1

3.1.3 Contribution to journal

Adam, Raven; Kogler, Marie Lisa; Scholger, Martina: *Aufwind in der Berichterstattung zum Klimaschutz. Langfristige Entwicklung von Themen und Stimmungsbildern in österreichischen Zeitungen*, in: Zeitschrift für digitale Geisteswissenschaften 8 (2023), online. DOI: 10.17175/2023_006

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3.2 Presentations

3.2.1 Oral presentation

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Asada, Raphael; Wenger, Julia; Mair-Bauernfeind, Claudia; Kriechbaum, Michael; Stern, Tobias: *Towards linking social metabolism with the behaviour of individual agents*, for: 11th International Conference on Industrial Ecology, Leiden University, Leiden (Netherlands), 03.07.2023.

Aschemann, Ralf: *Synergies of impact assessment and circular economy*, for: Resilience through impact assessment and leadership, Int. Association for Impact Assessment (IAIA), Kuching (Malaysia), 09.05.2023.

Baumgartner, Rupert J.: *Nachhaltiges Produktmanagement von Verpackungen*, for: Re-source 2023 – Fachtagung zur Ressourcenschonung und Kreislaufwirtschaft, Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, Salzburg (Austria), 04.05.2023.

Baumgartner, Rupert J.: *Sustainable Strategic Management in the era of the Anthropocene*, for: Liberec Economic Forum, Liberec University of Technology, Liberec (Czechia), 05.09.2023.

Baumgartner, Rupert J.; Schöggl, Josef-Peter: *Digital Battery Passports: Sustainability, Data Needs and Use Cases*, for: Legal-by-design digital disruption in the circular economy: High-level expert workshop on digital product passports and green hydrogen, University of Braga, Braga (Portugal), 10.10.2023.

Berger, Katharina: *Confidentiality-preserving data exchange to enable sustainable product management via digital product passports – a conceptualization*, for: 30th CIRP Life Cycle Engineering Conference, Rutgers School of Engineering, New Brunswick, New Jersey (United States (USA)), 15.05.2023.

Berger, Katharina: *Digital battery passport information content for end of (first) battery life management support*, for: 5th Product Lifetimes and the Environment Conference, Aalto University Finland, Espoo, Finnland (Finland), 31.05.2023.

Berger, Katharina: *Factors of digital product passport adoption to enable circular information flows along the battery value chain.*, for: 30th CIRP Life Cycle Engineering Conference, Rutgers School of Engineering, New Brunswick, New Jersey (United States (USA)), 16.05.2023.

Berger, Katharina: *From concept to information model: digital product passports for circular battery management*, for: 21st European Round Table on Sustainable Consumption and Production, Wageningen University, Wageningen, Online (Netherlands), 06.07.2023.

Brudermann, Thomas: *"Bruchlinien" aus psychologischer Sicht*, for: Fachtagung zur Energieautonomie+, Energieinstitut Vorarlberg, Bregenz (Austria), 11.10.2023.

Brudermann, Thomas: *"Ich hatte ja gute Absichten" – Einblicke in Umwelt und Klimapsychologie*, for: Sustainable Packaging Konferenz, IMH, Wien (Austria), 25.01.2023.

Brudermann, Thomas: *Ausreden gegen Klimaschutz – Was steckt dahinter, wie gehen wir darum?*, for: 4. steirischenKLIMASCHUTZGALA, Ich tu's, Graz (Austria), 08.11.2023.

Brudermann, Thomas: *Climate Hackathon*, for: Climate Hackathon mit Thomas Brudermann, ambuzzador, Climate Lab Wien (Austria), 10.11.2023.

Brudermann, Thomas: *Das 1 x 1 der Klimaausreden*, for: Green Buddy Event, Universität Graz, Graz (Austria), 06.12.2023.

Brudermann, Thomas: *Das 1x1 der Klimaausreden*, for: Stadtmahlzeit, Stadtlabor Graz, Graz (Austria), 14.06.2023.

Brudermann, Thomas: *Decision Making: Die Rolle von individuellen Entscheidungen für eine nachhaltige Zukunft*, for: Innovationscamp BIG Bio, Graz (Austria), 16.10.2023.

Brudermann, Thomas: *Die Klimakrise und wie wir damit umgehen: Sorgen, Ausreden, Handlungsmöglichkeiten*, for: Digitaler Klima-Club – Die Energiewende und wie wir damit umgehen, Museum für Kommunikation Frankfurt, Online/Zoom (Germany), 19.01.2023.

Brudermann, Thomas: *Die Kunst der Ausrede – Die Rolle von individuellen Entscheidungen für eine nachhaltige Zukunft*, for: Holzoberflächentag, Holzforschung Austria, Wien (Austria), 19.09.2023.

Brudermann, Thomas: *Die Kunst der Ausrede – Klimafreundlich Denken, klimaschädlich Handeln*, for: Systemic4Future 2023: Hoffen, Bangen und die Kunst der Ausrede – psychologische Aspekte des Klimawandels, Akademie der kulturellen Bildung, Remscheid (Germany), 10.03.2023.

Brudermann, Thomas: *Die Kunst der Ausrede – Selbsttäuschung statt Klimaschutz*, for: Volkshochschule Wangen, Rupert-Ness-Gymnasium, Wangen im Allgäu (Germany), 24.05.2023.

Brudermann, Thomas: *Die Kunst der Ausrede – Selbsttäuschung statt Klimaschutz*, for: Wissenschaft fürs Wohnzimmer, Alfred-Wegener-Instituts für Polar- und Meeresforschung, Online (Germany), 11.05.2023.

Brudermann, Thomas: *Die Kunst der Ausrede – Warum wir uns lieber selbst täuschen statt klimafreundlich zu leben*, for: leseumwelt-Fest, Land Niederösterreich, St. Pölten (Austria), 01.09.2023.

Brudermann, Thomas: *Die Kunst der Ausrede – Warum wir uns lieber selbst täuschen statt klimafreundlich zu leben*, for: Buchpräsentation und Vortrag, Fridays For Future Rohrbach, St. Martin im Mühlkreis (Austria), 20.06.2023.

Brudermann, Thomas: *Die Kunst der Ausrede – Was steckt hinter unserer Selbsttäuschung?*, for: Online Referat von Thomas Brudermann, IPU Schweiz – Verein für Umweltpsychologie, Online (Switzerland), 15.06.2023.

Brudermann, Thomas: *Die Kunst der Ausrede beim Klimaschutz*, for: Tag der Weiterbildung des EB Forum OÖ: Bildung für den Wandel – Was wir tun werden, um eine gute Zukunft zu bauen, EB Forum Oberösterreich, Linz (Austria), 09.11.2023.

Brudermann, Thomas: *Die Kunst der Ausrede*, for: Cusanische Fachtagung, Cusanuswerk, Online (Germany), 23.06.2023.

Brudermann, Thomas: *Die Kunst der Ausrede*, for: KEM & KLAR! Vernetzungstreffen, Energie Agentur Steiermark, Graz (Austria), 28.06.2023.

Brudermann, Thomas: *Die Kunst der Ausrede*, for: Lesung und Diskussion mit Thomas Brudermann, Stadtbücherei Korneuburg, Korneuburg (Austria), 10.11.2023.

Brudermann, Thomas: *Die Kunst der Ausrede*, for: Lesung, Buchhandlung Jakob in Kooperation mit Nürnberg Autofrei, Nürnberg (Germany), 06.02.2023.

Brudermann, Thomas: *Die Kunst der Ausrede*, for: Schöneicher Themenabend, Klimabeirat Schöneiche, Kapelle Fichtenau, Schöneiche (Germany), 10.02.2023.

Brudermann, Thomas: *Die Kunst der Ausrede*, for: Vortrag & Austausch mit Prof. Thomas Brudermann, Uni Graz, RCE Zürich, Kulturpark Zürich (Switzerland), 01.03.2023.

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Brudermann, Thomas: *Die Psychologie der Ausreden – Oder warumSelbsttäuschung so verlockend ist*, for: MedTech.Circle 2023 – Connect the MedTech, Business Upper Austria – OÖ Wirtschaftsagentur GmbH | Medizintechnik-Cluster, Linz (Austria), 20.06.2023.

Brudermann, Thomas: *Entscheidungsverhalten und die Kunst der Ausrede*, for: VGMS – 16. Wissenschaftliches Symposium, Verband der Getreide-, Mühlen- und Stärkewirtschaft, Würzburg / Online (Germany), 08.11.2023.

Brudermann, Thomas: *Excuses, excuses – And how to get rid of them*, for: Climate Action Day, Graz International Bilingual School, Graz (Austria), 23.06.2023.

Brudermann, Thomas: *Klimafreundlich denken, klimaschädlich handeln – Einblicke in Umwelt- und Klimapsychologie*, for: Stammtisch Webinar, Österreichs Wanderdörfer, online (Austria), 19.04.2023.

Brudermann, Thomas: *Klimapsychologie und Kommunikation – Ausreden beim Klimaschutz und Umgang damit*, for: Workshop mit Thomas Brudermann (hybrid), E7 – Energy Innovation Engineering, Wien (Austria), 19.06.2023.

Brudermann, Thomas: *Klimapsychologie:Schluss mit den Ausreden!*, for: Autorenabend, Stratum Consult, Berlin (Germany), 09.02.2023.

Brudermann, Thomas: *Klimaschutz nein, danke? Über den Umgang mit Klimaausreden*, for: Gemeindekonferenz, Land Steiermark & Energieagentur Steiermark, Leoben (Austria), 22.11.2023.

Brudermann, Thomas: *Klimaschutz: Wissen, Ausreden und Akzeptanz*, for: Grünes Forum Frechen, Forum Independent, Frechen, DE (Germany), 07.02.2023.

Brudermann, Thomas: *Klimawandel, so what? Über die Kunst der Ausrede beim Klimaschutz*, for: Forum Umweltbildung, Online (Austria), 24.10.2023.

Brudermann, Thomas: *Klimawandel: Psychologie und Kommunikation*, for: Wissen4Future Akademie, Scientists4Future Österreich, Online/Zoom (Austria), 27.01.2023.

Brudermann, Thomas: *Psychologische Aspekte von Nachhaltigkeitstransformationen*, for: Energie und Umwelt Gipfel, International Council of Energy & Environment (ICEE), Berlin (Germany), 27.11.2023.

Brudermann, Thomas: *Rethinking the role of individual decisions in sustainability transitions*, for: BrownBag Seminar, ETH Zürich – Transdisciplinarity Lab, ETH Zürich (Switzerland), 02.03.2023.

Brudermann, Thomas: *Stereotype der Selbsttäuschung und Verdrängung beim Klimaschutz*, for: Umweltpsychologie – psychologische Lösungen für die Klima- und Umweltkrise, Berufsverband österreichischer PsycholgInnen, St. Pölten (Austria), 06.10.2023.

Brudermann, Thomas: *The art of making excuses, or: The psychology of dealing with the climate crisis*, for: Excite Webinar, Austrian Energy Agency, Online (Austria), 12.10.2023.

Brudermann, Thomas: *Über Klimapsychologie und den Umgang mit Widerständen*, for: Kommunaler Klimaschutzlehrgang – Modul 3: Klimakommunikation und Klimapsychologie, Klimabündnis Steiermark, Zoom (Austria), 10.10.2023.

Brudermann, Thomas: *Umweltpsychologie: Nachhaltigkeit, Entscheidungen und Kommunikation*, for: Intensivausbildung Klimaschutz Coach, Das Gramm Akademie, Graz (Austria), 17.10.2023.

Brudermann, Thomas: *Umweltschutz ist ja super, aber …Was hinter den Ausreden bei Klimaschutz und Nachhaltigkeit steckt*, for: Grazer Eco Festival, GECO, Rathaus Graz (Austria), 03.06.2023.

Brudermann, Thomas: *Unbequeme Fakten oder bequeme Ausreden?*, for: GLOBART | Tage der Transformation, GLOBART Academy, Stift Melk (Austria), 01.09.2023.

Brudermann, Thomas: *Von Hans Solo zum Öko-Hans: Ausreden beim Klimaschutz*, for: "Sustained!"- Das erste große Nachhaltigkeits-Festls für Jugendliche und junge Erwachsene, Welthaus Graz, Stadtpark Graz (Austria), 14.10.2023.

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3.3.1 Media article

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Schöggl, Josef-Peter in: Veronika Teubl-Lafer, *Analyse der Uni Graz: "57 Prozent lesen die Gemeindezeitung regelmäßig"*, Kleine Zeitung, print, internet, social media, 28.01.2023.

3.4 Events

3.4.1 Organization of an academic event

Aschemann, Ralf; Berg Pettersen, Johan; Lundqvist, Ulrika: CIRCLE Summer School 2023, Selbu, Norway, 06.08.2023 – 11.08.2023.

Forstverein Steiermark; Global Studies Uni Graz, Mitveranstaltung: Waldfest Graz 2023 "Klima, Wald, Wandel", Graz, Austria, 14.06.2023.

Kogler, Marie: Text Mining & NLP COLIBRI Focus Workshop, Universität Graz, Austria, 27.02.2023.

Posch, Alfred: Buchpräsentation “APCC Special Report: Strukturen für ein klimafreundliches Leben” hrsg. von Christoph Görg, Verena Madner, Andreas Muhar, Andreas Novy, Alfred Posch, Karl W. Steininger, Ernest Aigner, Wien, Austria, 25.09.2023.

Posch, Alfred: Zukunftswerkstatt “Mobilität 2040”, Graz, Austria, 10.11.2023 – 11.11.2023.

Posch, Alfred; Thaller, Annina; Delitz, Alina; Hoff, Holger: Zukunftsbilder zur Verkehrsvermeidung, Online, Austria, 14.11.2023.

Stern, Tobias: 18. Waldökonomisches Seminar«Auswirkungen des Eigentums auf die Nutzung des Waldes im Körperschaftswald auf kommunaler Ebene», Münchenwieler, Switzerland, 06.11.2023 – 07.11.2023.

Thaller, Annina: TRANSFLIGHT Workshop Series – “Learning from frontrunners”, Online, Norway, 21.03.2023.

Thaller, Annina: TRANSFLIGHT Workshop Series – “Roadmaps”, Online, Norway, 28.03.2023.

Thaller, Annina: TRANSFLIGHT Workshop Series – “Scoping the challenge”, Online, Norway, 07.03.2023.

3.5 External Scientific Functions

Reviews were undertaken for the following journals.

- Applied Sciences
- Biomass and Bioenergy
- Business and Society
- Business Strategy and Development
- Business Strategy and the Environment
- California Management Review
- Computational and Mathematical Organization Theory
- Corporate Social Responsibility and Environmental Management
- Ecological Indicators
- Energies
- Energy Efficiency
- Energy Policy
- European Journal of Forest Research
- European Journal of Wood and Wood Products
- Forest Products Journal
- Gaia: oekologische Perspektiven in Natur-, Geistes- und Wirtschaftswissenschaften
- International Journal of Environmental Research and Public Health
- International Journal of Transitions and Innovation Systems
- International Wood Products Journal
- Journal of Business Ethics
- Journal of Cleaner Production
- Journal of Computational Methods in Sciences and Engineering
- Journal of Economic Psychology

- Journal of Industrial Ecology
- Longe Range Planning
- Scandinavian Journal of Management
- Science and Public Policy
- Sustainability
- Sustainable Development
- Sustainable Production and Consumption
- Systems Research and Behavioral Science
- Technological Forecasting and Social Change
- Technovation
- Urban Forestry and Urban Greening
- Utilities Policy

3.6 Department of Environmental Systems Sciences Reports

The ESS Reports was a series of reports published by the Department of Environmental Systems Sciences from 2012 to 2019. With the publication of the tenth report, this series concluded and will not be continued further.

3.7 Prizes and Awards

3.7.1 Eunice Foote Award

Thomas Brudermann and Annechien Hoeben received the prestigious Eunice Foote Award for climate change communication. The price is awarded to successful climate change communicators and is funded by institutions from Germany, Austria and Switzerland (including the Austrian ministry for climate and environment, Klimafakten.de and Meteo Suisse). Out of 140 submitted projects, eight were awarded in three categories, namely citizen participation, journalism and science communication. Thomas and Annechien, to the surprise of everybody, including themselves, won first prize in science communication with their project on “climate excuses” (“Projekt Klimaausreden”).

In this project, Thomas and Annechien de-construct popular discourses of delay against climate action with humor, behavioral expertise and illustration skills. The cornerstones of this endeavor are social media postings and colorful illustrations (sometimes with over 100,000 views) and the popular book “Die Kunst der Ausrede” (“The art of making excuses”, meanwhile in its 4th edition and already mistaken for a bestseller), Thomas and Annechien also generate workshop and presentation materials which are licensed as creative commons and therefore may be used free of charge. The international jury consisting of personalities from media, science and policy was impressed by this approach (we assume).

The award ceremony took place on 12th July in the Museum of Communication in Frankfurt, Germany. The laudation was given by famous actress Maria Furtwängler, known to the generation still watching TV as police detective in the German “Tatort” series. And although we appreciate the glory our two award-winning communicators brought to the department, we were disappointed that they missed the opportunity to also bring autographs from the TV star. The more senior colleagues at the department would have appreciated it.

https://www.uni-graz.at/de/neuigkeiten/keine-faulen-ausreden-thomas-brudermann-und-annechien-hoeben-erhielten-deutschen-preis-fuer-klimakommunikation/

3.7.2 Best Poster Award – Scientific Computing Conference

David Koch, MSc, received the "**Best Poster Award**" at the Scientific Computing Conference 2023 for presenting his master's thesis "Unlocking the potential of domestic solar energy storage – A low-hanging fruit for Austria's sustainable energy transition?", supervised by Georg Jäger. In his thesis, he developed an agent-based model to explore incentives and the role of the domestic sector in photovoltaics.

https://www.youtube.com/watch?v=ZQaY9YpfEY8

3.7.3 Master Thesis Awards of Excellence

The **Master Thesis Awards of Excellence** are awarded by the curriculum commission of the Environmental Systems Sciences study programs, in cooperation with the ESS coordination office. The following students received a price in 2023:

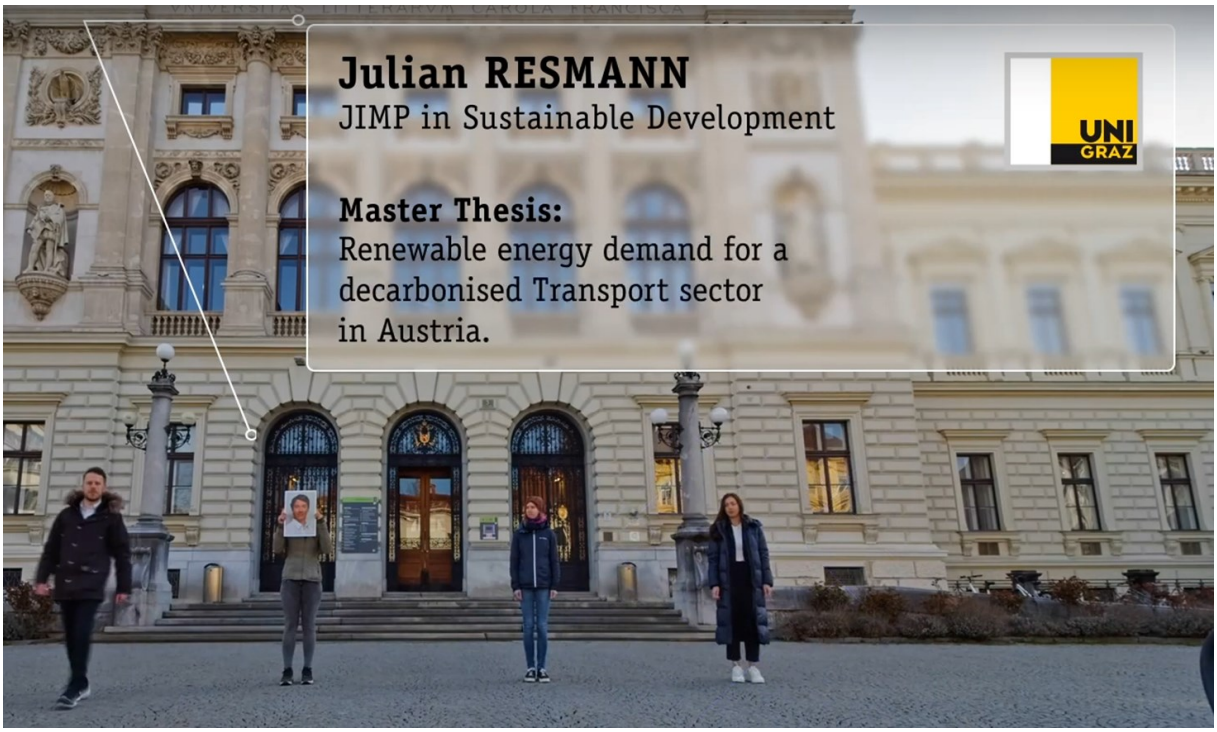
Name	Thesis	Supervisor
Florian Andreas Gollhammer	An Analysis of Austrian Mobility Behaviour to Support MaaS Policies in Austria	Georg Jäger
Melanie Harrer	Carbon Management for Climate Protection: Analysis of the Greenhouse Gas Emissions of the University of Graz Campus and Campus-Related Gastronomy	Ralf Aschemann
Christoph Matthias Kerner	Bioenergy with Carbon Capture and Storage and Direct Air Carbon Capture and Storage as climate solutions? An analysis of Carbon Dioxide Removal from the perspective of experts and the precautionary principle	Thomas Brudermann

Chiara Letter	Coping with Pandemics: How Different Governmental Measures Affect the Disease Spread as well as Greenhouse Gas Emissions	Georg Jäger
Antonia Pohlmann	Benchmarking sustainability aspects in the Courier, Express and Parcel (CEP) Industry to identify Best Practices and derive recommendations for action	Rupert Baumgartner
Theresa Pömmer	Der Klimawandel aus der Sicht der Landwirtinnen und Landwirte im Waldviertel	Martin Mergili
Laura Wallenko	The eco-social tax reform in Austria: Economy-wide and distributional effects of a CO2 tax under a region-specific revenue recycling scheme	Karl Steininger

https://umweltsystemwissenschaften.uni-graz.at/fileadmin/_files/_project_sites/_umweltsystemwissenschaften/2_Dokumente_ab_2023_USW_Seite/Bericht_Masterpraemierung_2023.pdf

3.7.4 WKO Research Fellowship

Julian Resmann, MSc received a "**WKO research fellowship**" in 2023 for his master thesis "Renewable energy demand for a decarbonised Transport sector in Austria", supervised by Georg Jäger. The Austrian Economics Chamber (WKO) gives this award to junior researchers, whose research is highly relevant for the economy.



https://www.uni-graz.at/en/news/vier-gewinnt-wko-steiermark-verlieh-an-vier-nachwuchswissenschaftlerinnen-der-uni-graz-stipendien/

3.7.5 WKO Forschungsstipendium

Kathrin Winkler, MSc (Environmental Systems Sciences / Sustainability and Innovation Management) received the "WKO Forschungsstipendium 2023" for her master thesis about "Business air travel: Analyzing drivers, barriers and future development". With her explorative study investigating these influencing factors for business air travel she also made a valuable contribution to the research project TRANSFLIGHT.

https://transflight.uni-graz.at/de/neuigkeiten/transflight-masterarbeit-von-kathrin-winkler-von-wko-praemiert/
https://www.youtube.com/watch?v=CysX6oRO46U&list=PLzhIx0dK-we1u_xc8EAUGR4u7fm0tQMVk&index=1

4 Teaching

4.1 Study Programs

4.1.1 Environmental Systems Sciences

In teaching, our department is the focal department for the bachelor and master study programs in Environmental Systems Sciences (USW – Umweltsystemwissenschaften) with its four subject foci: business administration (respectively sustainability oriented management), economics, geography, and NAWI-Tech.

NAWI-Tech is the newest of all subject foci and was established in 2012. This unique study program is provided by University Graz (KFUG) and Graz University of Technology (TUG) in their joint activity Natural Sciences. This study (USW Nawi-Tech) replaces the former subject foci physics and chemistry and is focusing predominantly on the aspects of natural sciences in the discussion of sustainability (for further information, please see: http://www.nawigraz.at/).

The main idea of these study programs is to generate interdisciplinary trained academics that are able to handle complex problems that are related to environmental protection and/or to the broader concept of sustainable development of different systems. Here, the capability to apply formal methods of systems sciences, in-depth knowledge in the respective subject focus and profound competencies for working in interdisciplinary teams are the most important cornerstones of the profile of graduates in Environmental Systems Sciences.

The roots of the study programs in Environmental Systems Sciences go back to 1991 when the first individual diploma studies were developed. Continuously increasing interests by students and high dedication of some professors finally led to the implementation of regular bachelor and master study programs in October 2003 which are still unique in its conception in Europe. Now, about 1,000 students are enrolled in the bachelor and master programs in Environmental Systems Sciences; the bachelor programs comprise 180 ECTS credit points which equals a study period of six semesters, and the consecutive master programs 120 ECTS credit points, or four semesters.

Our department is responsible for the education in formal methods of systems sciences, mathematics and statistics, interdisciplinary education for basics in human-environment systems, for parts of the teaching subject business administration (bachelor level), for the teaching subject sustainability-oriented management (master level), and last but not least for the interdisciplinary practical courses. The latter is a special and unique course type where an interdisciplinary team of teachers and students with different subject foci work together on a

complex real-world problem for sustainable development of a certain system. Interdisciplinarity and transdisciplinary are part of the teaching concept, aiming at the integration of stakeholders from outside the University in order to initiate a mutual learning process between academics and practitioners.

Comprehensive information on Environmental Systems Sciences can be found at http://umweltsystemwissenschaften.uni-graz.at or www.umweltsystemwissenschafen.at.

4.1.2 Joint International Master's Program in Sustainable Development

In this Master, sustainability issues are approached from an international as well as inter- and transdisciplinary perspective. The program combines the strengths of six partner universities: Graz, Leipzig, Venice and Hiroshima are possible entrance universities, University of Basel and Utrecht University are mobility partners.

One unique feature of the program is that one specialization track is completed during a mandatory mobility semester at one of the other entrance universities or one of the mobility partners. Students therefore profit from a wide range of perspectives on sustainable development and the specific focus offered by at least two universities. Alumni of the program usually work as sustainability experts in the private, public and semi-public sectors, or head for an academic career by pursuing a PhD related to sustainable development.

In 2023, 21 students from 12 different countries started the program in Graz.

Thomas Brudermann (SDG 16) and Jan Stalzer (SDG 12) with a few of the new Sustainers

Admission to this Master is granted to students who have completed at least the equivalent of a Bachelor's or Diploma degree, and can demonstrate their research skills, their basic knowledge of the natural and/or social sciences, and a general insight in the subject of

sustainable development and intervention strategies. The program comprises 120 ECTS credits corresponding to a period of study of at least four semesters or two years. At least 60 ECTS credits have to be earned at the home university. Students are required to complete at least 30 ECTS credits at one of the partner universities. Besides the consortium coordination, our department offers basic and advanced courses related to Sustainable Development, as well as courses related to corporate sustainability management and innovation research.

For students of our partner universities we provide two specialization tracks: *Corporate Sustainability Management*, and *Innovation and Transition Management*. Master theses are generally assessed by two professors of two different partner universities.

Comprehensive information on the Joint International Master's Program in Sustainable Development can be found at www.jointdegree.eu/sd.

4.1.3 Erasmus Mundus "International Master's Program on Circular Economy"

Beside the International Joint Master's Program in Sustainable Development and the 2017 completed "Erasmus Mundus Master's Program in Industrial Ecology", the Erasmus Mundus "International Master's Program on Circular Economy (CIRCLE)" is already the third Joint Master Program coordinated by our department. The funding of the European Commission lasts until 2024 and consists of 62 scholarships for four intakes of students (which have started 2019, 2020, 2021 or 2022, respectively), which have to be selected by the CIRCLE consortium. As the curriculum of CIRCLE is designed as "Erasmus Mundus Double Master Degree", its students have to study at two different European universities from the consortium and will then be awarded with a double degree from those.

Dr. Ralf Aschemann is coordinating the CIRCLE program, supported by Eva Fleiß PhD; Ulrike Krawagna and Anja Hoffmann from the Office for International Relations support all its administrative issues. Partners in the consortium are Leiden University and Delft University of Technology (Netherlands); Chalmers University of Technology Gothenburg (Sweden); and Norwegian University of Science and Technology (Norway). Moreover, three universities outside Europe are partners for an additional mobility, namely Curtin University (Australia); Waseda University (Japan) and Tsinghua University (China).

CIRCLE 3 alumni

From 6 to 11 August 2023, two intakes of CIRCLE students (the third and fourth generation) met face-to-face for their summer school and graduation ceremony, organized in Selbu in Norway. The fresh graduates of the third CIRCLE intake are pictured in the photo!

For more information on CIRCLE, please browse to https://www.emcircle.eu.

4.1.4 Global Studies

ESS, together with the dean's office, has overseen managing the three master programs "Global Studies" at the University of Graz since 2020. The program consists of three comprehensive and diverse curricula that source their courses from all six of the university's faculties and an additional six interfaculty centers. Global Studies have developed since 2010 in a growth process supported by the commitment and interest of researchers, lecturers, and students at our university in cooperation with external organizations. The KoBü Coordination Office for Environmental Systems Sciences and now Global Studies has been taking care of about 350 master's students from the three programs contained in the Global Studies 2023.

The programs bundle the professional expertise of the University of Graz in the fields of globalization and (sustainable) development. Fighting poverty, world hunger, education, environmental protection, human rights, worldwide production and working conditions, diversity and gender, peace, and justice etc. are central contents, which also corresponds to the "Sustainable Development Goals" of the United Nations. Global Studies prepare students to think and act holistically in an increasingly complex, dynamic globalized world.

To this end, Global Studies are inter- and multidisciplinary. The knowledge and competences achieved enable graduates to professionally analyze the numerous international and intercultural challenges that society is currently facing due to globalization. In their studies,

students develop the sensitivity and integrated way of thinking required in a wide variety of multicultural settings.

The three programs build on different preceding bachelor programs and offer a respective focus on either Economics, Business and Environment or Law and Politics or Society and Culture. The 2022 curricula have now been well-stablished and prove to allow for both a profound insight and for "out-of-the-disciplinary-box" thinking. In each of the three programs, students can choose from several disciplinary specializations and additionally from interdisciplinary modules designed to broaden mindsets. To this end, the "master modules plus" were fully integrated as another option. Furthermore, all students have a to organize a compulsory internship for themselves in Austria or abroad and they have to partake in a supervised Interdisciplinary Practical Training IP. The results of theses Ips can now be found on the website https://globalstudies.at/ and on social media (Facebook, Instagram, TikTok) under Globalstudies Graz.

Our alumni find their jobs in governmental and non-governmental organizations, enterprises, educational institutions or quite often make their own way in self-employment of founding companies themselves.

4.1.5 Doctoral School for Environmental Systems Sciences

In October 2011, the new Doctoral School for Environmental Systems Sciences was founded. The main goal is to provide high-quality education for our PhD-students in the field of Environmental Systems Sciences. The study program is based either on the curriculum for interdisciplinary Environmental Systems Sciences or on the curriculum for Environmental Systems Sciences focused on natural science. The thesis has to be cumulative based on three peer-reviewed journal publications instead of writing a monograph. This form of a dissertation complies with international scientific standards and ensures that the valuable results achieved by our PhD-students are presented to an international audience.

4.1.6 Doctoral Program DK Climate Change

In the winter semester 2014, the interdisciplinary doctoral program *DK Climate Change* has been launched. The program is a joint effort of researchers associated with the University of Graz's research core area "Environment and Global Change." Univ.-Prof. Lukas Meyer (Department of Philosophy) serves as a speaker for the program and Univ.-Prof. Dr. Gottfried Kirchengast (Wegener Center for Climate and Global Change) serves as co-speaker. Two faculty members are affiliated with our department: Univ.-Prof. Dr. Rupert Baumgartner and Univ.-Prof. Dr. Alfred Posch. The program is supported by Mag. Karin Osibow. The selected postgraduate students will be employed for 3 years in pre-doc research positions with the option to extend their employment by half a year if they choose to spend at least 6 months at one of the program's partner universities.

The program is funded by the Austrian Science Fund (FWF). Detailed information on the aims of the program, as well as information on all projects and involved researchers, can be found on the following website: http://dk-climate-change.uni-graz.at/en/.

4.2 Completed and submitted theses

4.2.1 Doctoral theses

In 2023, three doctoral theses have been completed within the doctoral school for Environmental Systems Sciences. They are listed in alphabetical order.

Diaz Tena, Anna (2023): Implementation of circular economy strategies during sustainable product development
Supervisor: Baumgartner Rupert

Rusch, Magdalena (2023): The Potential of Digital Technologies as Enablers for Sustainable Product Management in a Circular Economy
Supervisor: Baumgartner Rupert

Stumpf, Lukas (2023): The transition to a sustainable circular economy: Conceptualization, organizational requirements, and the company-supply chain relationship
Supervisor: Baumgartner Rupert

4.2.2 Master theses

In 2023, 49 master students completed or submitted their thesis within one of the study programs Environmental Systems Sciences, Global Studies, Sustainable Development, and Industrial ecology. They are listed in alphabetical order.

Agudelo Gaviria, Natalia (2023): Sustainability assessment and life cycle costing of Off-peak hours deliveries: A case study in Stockholm, Sweden
Supervisor: Posch, Alfred

Baldauf, David (2023): Sustainable travel policies and effects of Covid-19 on business travel within the German consulting sector
Supervisor: Rauter, Romana
Co-supervisor: Thaller, Annina

Boevink, Gijs Marijn (2023): Integrating biodiversity within business in the Netherlands: an overview of the latest measures, barriers and opportunities
Supervisor: Posch, Alfred

Brösel, Emma (2023): Car-free cities: An investigation of possibilities and stakeholders approaches in the case of Graz, Austria
Supervisor: Aschemann, Ralf

Cabrero Sinol, Aina (2023): Comparison of Two Supply Chain Alternatives for Ready-to-Eat Salad Bags: Life Cycle Assessment of a Case Study in Sweden
Supervisor: Posch, Alfred

Delitz, Alina (2023): Prioritizing public bus transport in urban traffic – a low hanging fruit as a policy measure for sustainable mobility?
Supervisor: Posch, Alfred
Co-supervisor: Jäger, Georg

Ebner, Corinna (2023): Nachhaltige Geschäftsmodellinnovation in Klein- und Mittelunternehmen im Dienstleistungssektor
Supervisor: Rauter, Romana

Egger, Clemens (2023): Assessing Nutrient Cycling and Resource Utilization in a Closed-Loop Aquaculture System: A Case Study of Fish Sludge Recycling for Aquafeed Fertilization
Supervisor: Stern, Tobias

Gollhammer, Florian Andreas (2023): An Explorative Cluster Analysis of Austrian Mobility Behaviour to Support MaaS Policies in Austria
Supervisor: Jäger, Georg

Grubelnik, Silke (2023): Ein Überblick über die Littering Problematik in Österreich
First evaluator: Gelbmann, Ulrike-Maria

Guevara Medina, Sara Fernanda (2023): Understanding the role of food forests in fostering regenerative mindsets: An exploratory study of participants of the National Monitoring Program for Food Forests in the Netherlands
First evaluator: Aschemann, Ralf
Co-supervisor: Exner, Andreas

Hassan, Syeda Erum (2023): Sustainability Assessment and Social Life Cycle Assessment – A case study of Off-peak Hours Deliveries (OPHD) in Stockholm City
First evaluator: Posch, Alfred

Häusel, Melanie (2023): Keeping up with ageing society: An equity-based assessment of mobility concepts of Austria and the Netherlands
Supervisor: Posch, Alfred
Co-supervisor: Thaller, Annina

Janesch, Tamara Sabrina (2023): Vermeidung und Verwertung von Lebensmittelabfällen entlang der Wertschöpfungskette von Brot und Gebäck in der Steiermark
Supervisor: Gelbmann, Ulrike-Maria

Kaltenegger, Sarah Lena (2023): Steering low-carbon Mobility into just Directions: Public Acceptance of restrictive Mobility Policies and its Determinants in Austria
First evaluator: Posch, Alfred
Co-supervisor: Thaller, Annina

Kammler, Lea (2023): Is it About Time? Intergenerational Justice in the Indonesian Energy Transition
Supervisor: Posch, Alfred

Klic, Rafaela (2023): Herausforderungen und Chancen Solidarischer Ökonomie am Beispiel des “Zeit-Hilfs-Netzes” der Landentwicklung Steiermark
Supervisor: Gelbmann, Ulrike-Maria

Koch, David (2023): Unlocking the potential of domestic solar energy storage – A low-hanging fruit for Austria’s sustainable energy transition? An agent-based modelling approach for exploring incentives and the role of the domestic sector
Supervisor: Jäger, Georg

Kornberger Rodriguez, Laura (2023): Waste Mobile Phones in Spain: Consumption and disposal, consumer behavior, and management
First evaluator: Aschemann, Ralf

Kroisleitner, Peter Josef (2023): Frauen als Opfer von Menschenhandel und die Auswirkungen auf den Aufenthaltsstatus in Österreich
First evaluator: Werther-Pietsch Ursula

Kunesch, Caroline (2023): The Relationship between Individual Motivation and Climate-Friendly Behavior within High-Impact Domains: An Application on the Self-Determination Theory
Supervisor: Brudermann, Thomas
Co-supervisor: Thaller, Annina

Langkau, Peter (2023): Evaluation of waste generation and saving potentials at the Division of Thoracic and Hyperbaric Surgery – Case Study at the University Hospital Graz
Supervisor: Aschemann, Ralf

Li, Belinda (2023): Incorporating Social Dynamics into Integrated Assessment Modelling: A Group Model Building Extension to the En-ROADS Climate Action Simulation
First evaluator: Brudermann, Thomas

Marcum, Charles Melvin (2023): Quantifying the Effects of Prioritizing Public Bus Transport in Urban Traffic – an Agent-based Approach
Supervisor: Jäger, Georg

Mishra, Adarsh (2023): Data Analysis of Trends in Air Travel: A Case Study of Austrian leisure travel in pre-pandemic and pandemic years
Supervisor: Posch, Alfred
Co-supervisor: Kogler, Marie

Misslinger, Johanna (2023): Environmental Sustainability Through Software Lifecycle and Sustainable Development Goals: Microsoft´s Reporting Explored
First evaluator: Aschemann, Ralf

Monroy Morera, Diana Carolina (2023): Leveraging Circularity: A Systems Perspective on Reframing Challenges for Early-Stage Circular Innovation
Supervisor: Aschemann, Ralf

Mora Espinosa, Irlanda Gabriela (2023): Circular Economy Strategies for Packed Beverages in the Netherlands
Supervisor: Stern, Tobias

Nenninger, Eva (2023): Environmental, Social, and Governance Ratings from a Business Model Perspective: A Qualitative Research Approach
Supervisor: Rauter, Romana

Obersteiner, Peter Claudius (2023): Social Perspectives in the Sustainable Mobility Transition: Environmental Discourse Analysis on the Re-Evaluation of the Lobau Highway Construction in Vienna
First evaluator: Brudermann, Thomas
Co-supervisor: Trimmel, Katharina

Omerovic, Medina (2023): Climate change (CC) impact on forest-based sector (FBS) companies' partnerships and collaborations
First evaluator: Stern, Tobias
Co-supervisor: Moreno Torres, Miguel

Pilz, Lydia (2023): Energie- und Klimapolitik in österreichischen Gemeinden: eine empirische Analyse über die Teilnahme am e5-Programm für energieeffiziente Gemeinden in Österreich
Supervisor: Posch, Alfred

Pölzl, Bernd (2023): Prioritising public bus transport in urban traffic – How effective are smart traffic lights, bus lanes and busways?
Supervisor: Jäger, Georg
Co-supervisor: Posch, Alfred

Pravato, Emily (2023): Development of a traffic-light sustainability index for packaging: a user-friendly approach
Supervisor: Aschemann, Ralf

Primus, Moritz Sebastian (2023): Assessing the properties of furan-based biopolymers for substituting petrochemical polymers in food packaging applications: An importance performance analysis
Supervisor: Stern, Tobias

Reichl, Tanja (2023): Status Quo of Sustainability Reporting in the Waste Management Sector: An Analysis in Austria
Supervisor: Gelbmann, Ulrike-Maria

Ribitsch, Clemens (2023): Untersuchung des ökonomischen Potenzials innovativer Technologien zur stofflichen Nutzung von Holz im regionalen Kontext
Supervisor: Stern, Tobias

Ritter, Sophia Luisa (2023): Barriers and Enablers in the Realization of Sustainable Transportation in Rural Areas – a Case Study on the Perception of Decision-Makers in the Austrian Rural Area Weiz-Gleisdorf
Supervisor: Posch, Alfred
Co-supervisor: Thaller, Annina

Roßa, Tim (2023): Transformative adaption to climate change of coffee farmers in Costa Rica
Supervisor: Stern, Tobias
Co-supervisor: Kriechbaum, Michael

Sadhu, Saumya (2023): Discrete Choice Analysis of Travel Behaviour: Case study of Styria, Austria
Supervisor: Jäger, Georg
Co-supervisor: Posch, Alfred

Sahin, Gizem (2023): Circular Economy Solutions and Onshore Wind Turbine Blade Waste Management: A Case Study in Germany
Supervisor: Baumgartner, Rupert

Schachner, Nathanael Frederic (2023): Wie ein Lebenszyklus nachhaltiger gestaltet werden kann – Anwendung der Kreislaufwirtschaft am Beispiel eines Fahrrades in der Stadt Graz
Supervisor: Gelbmann, Ulrike-Maria
Co-supervisor: Schöggl, Josef-Peter

Schmid, Felix (2023): The Styrian eco-innovation system from an SMEs perspective: A qualitative system analysis
Supervisor: Rauter, Romana

Thomsen, Imke Christina (2023): Downscaling the Planetary Boundary of Climate Change to City-Level: The Case of Carbon Emissions for Leipzig, Germany
Supervisor: Aschemann, Ralf

Trauner, Mathias (2023): Impacts of Socioeconomic Development on the Carbon Pool of Harvested Wood Products: An Empirical Analysis and Shared Socioeconomic Pathway-Based Scenarios
Supervisor: Stern, Tobias
Co-supervisor: Asada, Raphael

van den Hoven, Amra Estella (2023): Food miles and the avoidance of international transport: does producing locally lower the environmental impact of the horticultural sector? A comparative life cycle analysis on tomatoes, bell peppers and strawberries produced in the Netherlands and Spain.
First evaluator: Posch, Alfred

Waltenstorfer, Tobias (2023): Der Weg von einem Managementsystem nach der ISO 14001 zu einem Nachhaltigkeitsbericht in Konformität mit der Corporate Sustainability Reporting Directive
First evaluator: Rauter, Romana

Wetzlmaier, Viktoria (2023): Umweltbewertung von innovativen Fußbodenkonzepten unter der Berücksichtigung von mehreren Nutzungsphasen
Supervisor: Stern, Tobias
Co-supervisor: Mair-Bauernfeind, Claudia

Winkler, Kathrin (2023): Business air travel: Analyzing drivers, barriers and future development
First evaluator: Rauter, Romana
Co-supervisor: Thaller, Annina

4.3 Course list

AG	Work group	**PV**	Privatissimum
DQ	Doctoral Colloquium	**SE**	Seminar
KS	Course	**UE**	Exercises
OL	Orientation lecture	**VO**	Lecture
PS	Introductory seminar	**VU**	Lecture with exercises

Summer Term 2023

Type	Course	Duration	Lecturers
VO	Mensch und Umwelt: Geosphäre	2	Abermann J, Mergili M
VO	Mensch und Umwelt: Geosphäre	2	Abermann J, Mergili M
VO	Mensch und Umwelt: Biosphäre und Ökosysteme	2	Tschernatsch M
VO	Systemwissenschaften 2	2	Jäger G
VU	Systemwissenschaften 3	2	Granigg W, Güsser-Fachbach I
VU	Systemwissenschaften 3	2	Granigg W, Güsser-Fachbach I
PS	Angewandte Systemwissenschaften 1	2	Füllsack M, Lechner G, Tschofenig F
PS	Angewandte Systemwissenschaften 2	2	Bachner G, Ringsmuth A
UE	Übungen zu USW Computational Basics	1	Reisinger D
VU	Integral- und Differentialrechnungen für Umweltsystemwissenschaften	3	Adam R, Kogler M
VU	Integral- und Differentialrechnungen für Umweltsystemwissenschaften	3	Adam R, Kogler M
PS	Proseminar zu Statistik für Umweltsystemwissenschaften	1	Ott J
VU	Lineare Algebra für USW	2	Kogler M, Steiner E
AG	IP Circular Economy	4	Aschemann R, Baumgartner R, Klampfl-Pernold H
AG	IP Circular Economy	4	Aschemann R, Baumgartner R, Klampfl-Pernold H
AG	IP Ein elektrisierender Mobility-Mix – Bedürfnisorientiert, wegweisend und nachhaltig zum Ziel kommen	4	Hasler A, Höflehner T, Vlk T
AG	IP Ein elektrisierender Mobility-Mix – Bedürfnisorientiert, wegweisend und nachhaltig zum Ziel kommen	4	Hasler A, Höflehner T, Vlk T
AG	IP Design for Circularity – Am Beispiel von E-Fahrzeugen	4	Krassnitzer P, Mair-Bauernfeind C, Roche K, Schöggl J
AG	IP Leben frei von Wachstumszwängen – Degrowth in Wirtschaft und Gesellschaft	4	Möhrke J, Raith D, Wilfinger P, Wilhelm A
AG	IP Food Justice (Inwieweit kann sich Graz nachhaltig und sozial gerecht durch verschiedene Formen der urbanen Lebensmittelproduktion versorgen?)	4	Karner S, Steinwender D, Thaler A
AG	IP Food Justice (Inwieweit kann sich Graz nachhaltig und sozial gerecht durch verschiedene Formen der urbanen Lebensmittelproduktion versorgen?)	4	Karner S, Steinwender D, Thaler A
VO	Systems-Modelling and Systems-Analysis	2	Corominas Murtra B
SE	Data in Systems Sciences	2	Füllsack M
SE	Systems-Modelling and Systems-Analysis (Agent based modelling)	2	Jäger G

AG	IP Experimental analysis of sustainability-related decisions	6	Baumgartner R, Fleiß J, Schöggl J
AG	IP Understanding Social Entrepreneurship: Opportunities and Challenges	6	Paul A, Rauter R, Wetzl-Piewald R
AG	Cross-university collaboration: Sustainability Challenge	2	Egger G, Hoff H
KS	Herausforderungen und Chancen der nachhaltigen Entwicklung	2	Posch A, Steininger K
KS	Klimaethik und Klimapsychologie: Prinzipien, Erwartungen, Einstellungen, Verhalten	2	Brudermann T, Meyer L
PS	Umwelt- und Nachhaltigkeitsmanagementsysteme	2	Kettele M, Ulz A
PS	Ökonomische Technologiebewertung und -vorausschau	2	Boiger T, Stern T
PS	Ausgewählte Themen des Innovations- und Nachhaltigkeitsmanagement	2	Krassnitzer P, Mair-Bauernfeind C
PS	Management von Innovations- und Umweltprojekten	2	Posch A
SE	Seminar Bachelorarbeit	2	Baumgartner R, Füllsack M, Rauter R
SE	Seminar Bachelorarbeit	2	Baumgartner R, Füllsack M, Rauter R
KS	Strategic Sustainability Management	2	Gelbmann U, Paul A
KS	Change Management and Learning for Sustainability	2	Gelbmann U, Pirker C
KS	Sustainability Controlling and Management	2	Baumgartner R, Roche K
KS	Transition Management	2	Kriechbaum M, Stern T
KS	Product and Service Development	2	Globocnik D
KS	Sustainable Innovation	2	Rauter R
KS	Value Chain Management	2	Aschemann R
KS	Waste and Recycling	2	Gelbmann U, Schmidt G
KS	Sustainable Product Management	2	Baumgartner R, Diaz Tena A, Roche K
KS	Sustainable Product Management	2	Baumgartner R, Diaz Tena A, Roche K
KS	Decision Making for Sustainable Development	2	Brudermann T
KS	Human Factors in Transitions	2	Brudermann T
KS	Quantitative Methods of Social Research	2	Fleiß E
KS	Selected Topics – Low-carbon mobility behavior and policy options	2	Thaller A
AG	Research Project Sustainability and Innovation Management	4	Crockett S, Fleiß E, Posch A, Thaller A
SE	Fundamentals of Circular Economy and Industrial Ecology	2	Aschemann R
SE	Seminar in Research Methodology	2	Asada R, Fleiß E, Stern T
SE	Seminar in Research Methodology	2	Asada R, Fleiß E, Stern T
SE	Masterseminar	2	Baumgartner R, Brudermann T, Füllsack M, Posch A, Rauter R, Stern T
DQ	PhD Doktoratskolloquium I	2	Baumgartner R, Brudermann T, Füllsack M, Posch A, Rauter R, Stern T
DQ	PhD Doktoratskolloquium I	2	Baumgartner R, Brudermann T, Füllsack M, Posch A, Rauter R, Stern T
VU	Inter- und transdisziplinäre Arbeitsweise	2	Aschemann R, Höflehner T
AG	Interdisziplinäres Praktikum (Wald – De Sylvicultura Oeconomica)	4	Gelbmann U, Karisch-Gierer D, Pinter A, Pirker C

Winter Term 2023/2024

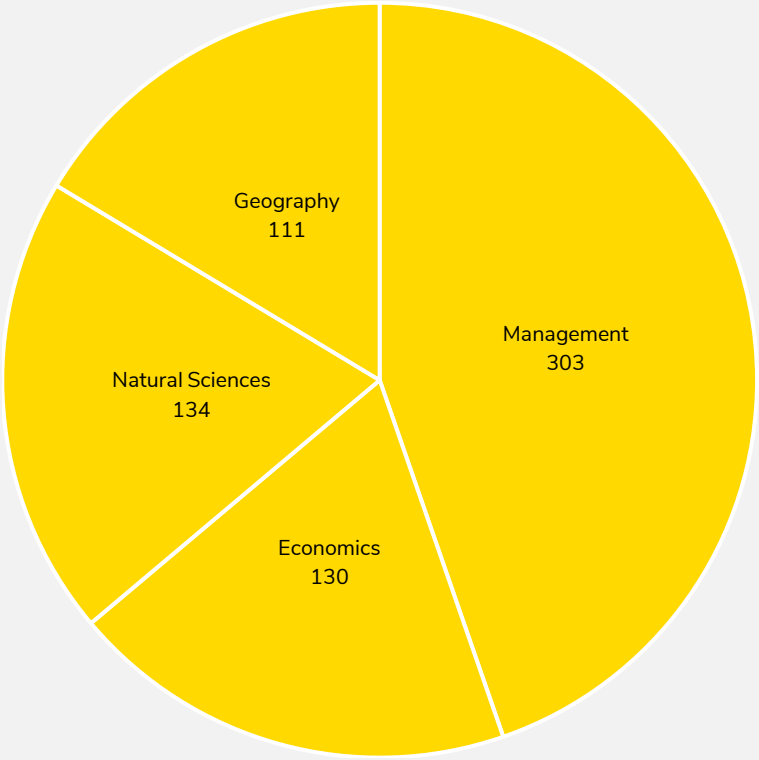
Type	Course	Duration	Lecturers
VO	Mensch und Umwelt: Anthroposphäre	2	Posch A, Steininger K
VO	Interdisziplinäre Arbeitsmethoden	2	Aschemann R
VO	Systemwissenschaften 1	2	Füllsack M
VU	Systemwissenschaften 3	2	Granigg W, Güsser-Fachbach I
VU	Systemwissenschaften 3	2	Granigg W, Güsser-Fachbach I
PS	Angewandte Systemwissenschaften 1	2	Jäger G
PS	Angewandte Systemwissenschaften 2	2	Bachner G, Truhetz H
VO	USW Computational Basics	2	Jäger G
UE	Übungen zu USW Computational Basics	1	Gupta M, Reisinger D, Rosenberger S
UE	Übungen zu USW Computational Basics	1	Gupta M, Reisinger D, Rosenberger S
VU	Integral- und Differentialrechnungen für Umweltsystemwissenschaften	3	Adam R, Kahr M
VU	Integral- und Differentialrechnungen für Umweltsystemwissenschaften	3	Adam R, Kahr M
VO	Statistik für USW	2	Fleiß E
PS	Proseminar zu Statistik für Umweltsystemwissenschaften	1	Schweighart M, Thaller A
PS	Proseminar zu Statistik für Umweltsystemwissenschaften	1	Schweighart M, Thaller A
VU	Lineare Algebra für USW	2	Adam R
VU	Lineare Algebra für USW	2	Adam R
AG	IP Nachhaltigkeitsziele der Agenda 2030 in steirischen Gemeinden	4	Schöggl J, Vötsch G, Wusser M
AG	IP Nachhaltigkeitsziele der Agenda 2030 in steirischen Gemeinden	4	Schöggl J, Vötsch G, Wusser M
AG	IP Weltklimaspiel – Can we change the game?	4	Braun L, Goger J, Strüver A
AG	IP Weltklimaspiel – Can we change the game?	4	Braun L, Goger J, Strüver A
AG	IP Datenanalysen zur Identifizierung von Greenwashing in Nachhaltigkeitsberichten	4	Baumgartner R, Kettele M, Reisinger D, Rusch M
AG	IP Green Campus Living Lab: Sustainable Food Systems	4	Bednar-Friedl B, Brudermann T, Hoff H, Preininger E, Seebacher U
AG	IP Green Campus Living Lab: Sustainable Food Systems	4	Bednar-Friedl B, Brudermann T, Hoff H, Preininger E, Seebacher U
VO	Data in Systems Sciences	2	Füllsack M
SE	Data in Systems Sciences	2	Füllsack M, Kvas A
SE	Systems-Modelling and Systems-Analysis	2	Everall J, Füllsack M, Otto I
SE	Systems-Modelling and Systems-Analysis	2	Everall J, Füllsack M, Otto I
AG	IP Fuel of the future? Regional hydrogen pathways in the context of international developments	6	Dayé C, Getzinger G, Kriechbaum M, Obersteiner P, Stern T
AG	IP Fuel of the future? Regional hydrogen pathways in the context of international developments	6	Dayé C, Getzinger G, Kriechbaum M, Obersteiner P, Stern T

AG	IP Food Security in a Changing Climate	6	Borsky S, Bruckner H, Jury M, Maraun D
AG	IP Food Security in a Changing Climate	6	Borsky S, Bruckner H, Jury M, Maraun D
VO	Interdisziplinäre wissenschaftliche Zugänge an der URBI-Fakultät	2	Aschemann R, Kruse A, Sattler M, Wächter N, Wlasak P
VO	Interdisziplinäre wissenschaftliche Zugänge an der URBI-Fakultät	2	Aschemann R, Kruse A, Sattler M, Wächter N, Wlasak P
AG	Cross-university collaboration: Sustainability Challenge	2	Egger G, Hoff H
KS	Methods for inter- and transdisciplinary problem-solving	2	Aschemann R
SE	Social competences for working in inter- and transdisciplinary teams	2	Dworzak V, Sposato R
SE	Social competences for managing sustainable development	2	Dworzak V, Sposato R
AG	Fallstudie zu Klimawandel und nachhaltiger Transformation	4	Meyer L, Posch A, Steiner A, Steininger K
VU	Einführung in das Studium USW / Management	1	Aschemann R, Brudermann T, Fleiß E, Füllsack M, Hampl N, Posch A, Stern T
VU	Einführung in das Studium USW / Management	1	Aschemann R, Brudermann T, Fleiß E, Füllsack M, Hampl N, Posch A, Stern T
VO	Nachhaltiger Konsum und Verhalten	2	Brudermann T
VO	Management nachhaltiger Entwicklung	2	Baumgartner R
PS	Nachhaltigkeitsberichterstattung	2	Resel K
PS	Stakeholdermanagement & Corporate Social Responsibility	2	Ulz A
PS	Ausgewählte Themen des Innovations- und Nachhaltigkeitsmanagement	2	Hampl N
AG	Praxislabor Nachhaltigkeitsmanagement	3	Baumgartner R, Zimek M
AG	Praxislabor Nachhaltigkeitsmanagement	3	Baumgartner R, Zimek M
SE	Seminar Bachelorarbeit	2	Rauter R, Stern T, Thaller A
SE	Seminar Bachelorarbeit	2	Rauter R, Stern T, Thaller A
KS	Strategic Sustainability Management	2	Gelbmann U, Paul A
KS	Change Management and Learning for Sustainability	2	Gelbmann U, Pirker C
KS	Sustainability Controlling and Management	2	Kettele M, Paul A, Roche K, Zimek M
KS	Transition Management	2	Kriechbaum M, Stern T
KS	Sustainable Innovation	2	Rauter R
KS	Waste and Recycling	2	Gelbmann U, Schmidt G
KS	Decision Making for Sustainable Development	2	Brudermann T
KS	Quantitative Methods of Social Research	2	Fleiß E
KS	Selected Topics – Low-carbon mobility behavior and policy options	2	Hampl N
AG	Research Project Sustainability and Innovation Management	4	Boiger T, Crockett S, Mair-Bauernfeind C, Stern T
AG	Research Project Sustainability and Innovation Management	4	Boiger T, Crockett S, Mair-Bauernfeind C, Stern T
AG	Research Project Sustainability and Innovation Management	4	Boiger T, Crockett S, Mair-Bauernfeind C, Stern T
KS	Sustainable Business Models	2	Rauter R

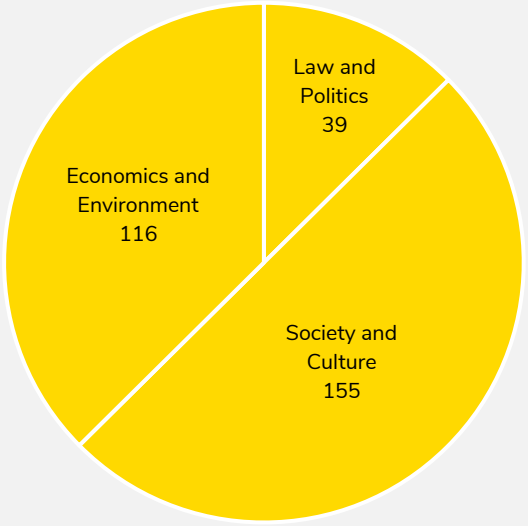
KS	Environmental and Technology Assessment	2	Aschemann R
SE	Fundamentals of Circular Economy and Industrial Ecology	2	Aschemann R
SE	The Sustainability Challenge	2	Crockett S, Posch A
AG	Sustainable Development – Integrating Perspectives	6	Brudermann T, Hampl N, Posch A, Steiner A, Winkler T
AG	Sustainable Development – Integrating Perspectives	6	Brudermann T, Hampl N, Posch A, Steiner A, Winkler T
SE	The Sustainability Challenge – reading and reflection	1	Posch A
SE	Seminar in Research Methodology	2	Asada R, Fleiß E, Stern T
SE	Seminar in Research Methodology	2	Asada R, Fleiß E, Stern T
SE	Masterseminar	2	Baumgartner R, Brudermann T, Füllsack M, Hampl N, Posch A, Rauter R, Stern T
SE	Masterseminar	2	Baumgartner R, Brudermann T, Füllsack M, Hampl N, Posch A, Rauter R, Stern T
AG	Inter- and transdisciplinary case study on Sustainable Development	6	Brudermann T, Hechenberger R, Posch A, Thaller A
AG	Inter- and transdisciplinary case study on Sustainable Development	6	Brudermann T, Hechenberger R, Posch A, Thaller A
PV	PhD Privatissimum	2	Baumgartner R, Brudermann T, Füllsack M, Hampl N, Posch A, Rauter R, Stern T
PV	PhD Privatissimum	2	Baumgartner R, Brudermann T, Füllsack M, Hampl N, Posch A, Rauter R, Stern T
SE	DissertantInnenseminar	2	Baumgartner R, Brudermann T, Füllsack M, Hampl N, Posch A, Rauter R, Stern T
SE	DissertantInnenseminar	2	Baumgartner R, Brudermann T, Füllsack M, Hampl N, Posch A, Rauter R, Stern T
VU	Einführung in die Global Studies	1	Gelbmann U, Weichsler L
VO	Globalisierung und Entwicklung: ökonomische und rechtliche Herausforderungen	2	Kleinert J, Werther-Pietsch U
VO	Globalisierung und Entwicklung: Nachhaltigkeitsherausforderungen	2	Rauter R, Steininger K
VO	Globalisierung und Entwicklung: ethische und soziokulturelle Herausforderungen	2	Ayata B, Ungericht B
VU	Inter- und transdisziplinäre Arbeitsweise	2	Höflehner T, Lakitsch M
AG	Interdisziplinäres Praktikum (Macht Milch müde Menschen munter?)	4	Gelbmann U, Höflehner T, Pirker C, Zimek M

4.4 Student statistics

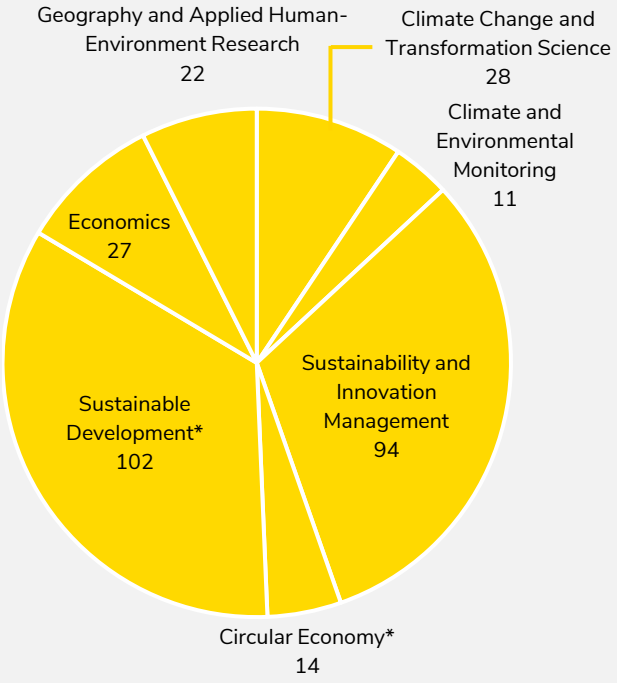
Bachelor Environmental Systems Sciences 678



Master Global Studies 310



Master Environmental Systems Sciences and International Master's Programmes 298



Number of registered students in summer term 2023 (source: student statistics from UniGrazOnline)
** International Master's Programme*

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