Annual Report 2021

Institute of Systems Sciences, Innovation and Sustainability Research

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Institute of Systems Sciences,
Innovation & Sustainability Research
University of Graz

Merangasse 18/I,
8010 Graz, AUSTRIA

EDITORIAL

In the editorial of the 2020 annual report, we highlighted the impact of the covid pandemic on our operational activities – teaching, research and administration. We were happy to conclude that the institute's performance was not significantly affected. In a similar manner, the 2021 statistics are indicating an impressive adaptive capacity of our institute and we can report even better results.

2021 IN A NUTSHELL

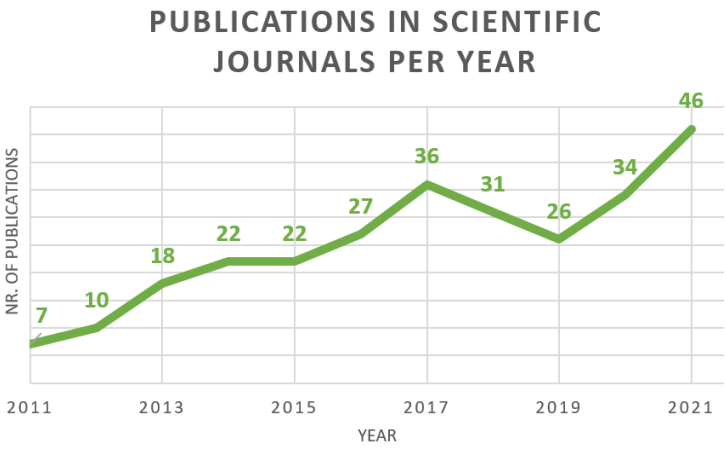
Since our institute is constantly evolving, we found the need to update our **Mission Statement** to better reflect the current goals and ambitions of the institute.

With the **Habilitation of Thomas Brudermann** the institute gained a new Associate Professor. We also welcome Theresa Boiger, Annechien Dirkje Hoeben, Paul Krassnitzer and Katharina Waniek as **new team members**.

In 2021 several new research projects were started:

- **Resonate** investigates resilient forest value chains
- **Biolib** looks at biobased laminates in battery housings for electric vehicles
- **SABATLE** is interested in the safety of flow battery electrolytes
- **Carpentier** explores wood-based hybrid structures and materials
- **Charging Rushhour** simulates the potential effects of electric cars on the power grid
- **METSET** studies adoption paths of smart energy technologies
- In a project funded by ALC Alpine Lions Cooperation **Regional and sustainable business models for the Alps region** are examined

In terms of scientific output, the institute broke its previous record of scientific publications by publishing **46 publications** in 2021.



2021 was also a successful year regarding **awards**. Among other achievements of the institute, Rupert Baumgartner was recognized as one of the top 2% scientists worldwide and Arijit Paul joined the governing council of Future Earth.

Regarding teaching, the institute is responsible for **1199 bachelor students as well 670 master students**. This year 25 students from 18 different countries were admitted to the **JD Sustainable development**. In 2021 **42 master theses and 3 doctoral theses** were finalized under the supervision of institute members.

In the light of these results, we are indeed looking forward to what we will be able to report next.

Contents

1 THE INSTITUTE

1.1 Mission statement

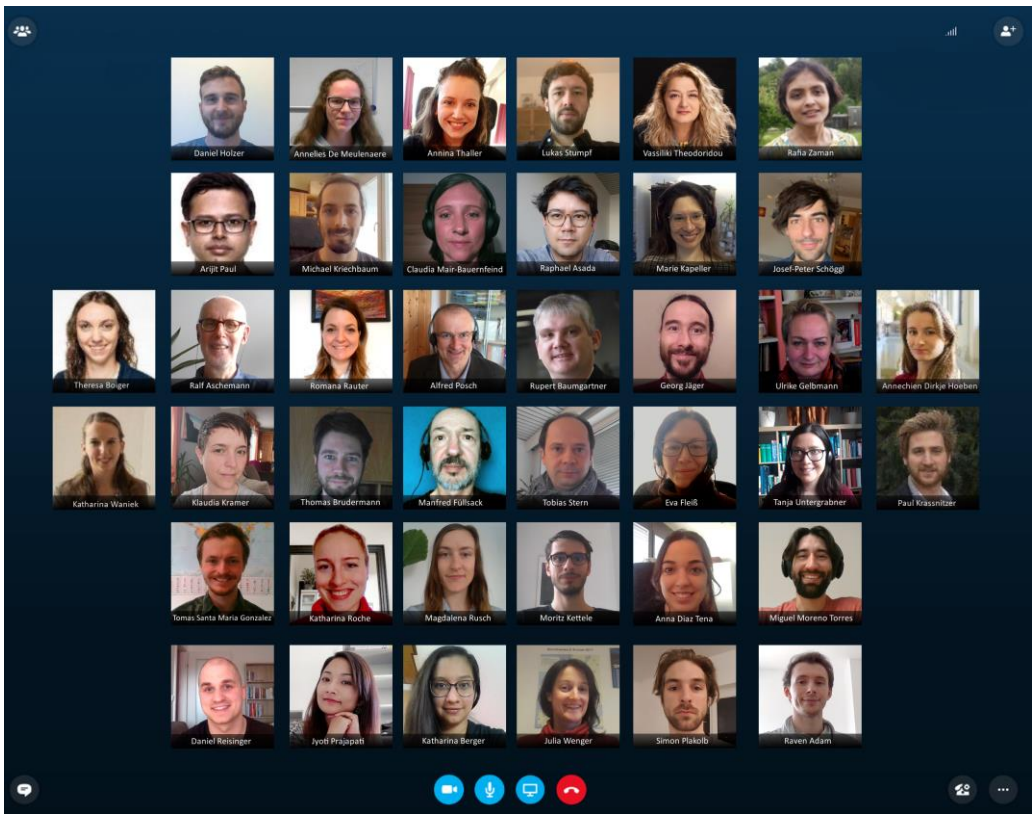
The Institute of Systems Sciences, Innovation and Sustainability Research investigates possibilities for the **transition towards a more sustainable future**. Therefore, we study transition, innovation, and adaptation processes within socio-technical and socio-ecological systems at various levels.

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 institute 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 Science, 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.



1.2 Faculty and Staff members

Professors:

Univ.-Prof. Dr. **Rupert Baumgartner**
Phone: 3237 Email: rupert.baumgartner@uni-graz.at

Vice Director of the Institute
Professor for Sustainability Management

Research Interests: Corporate Sustainability/CSR, Strategic Management, Life Cycle Assessment & Sustainability Assessment, Circular Economy, Management systems, Sustainable Supply Chain Management, Sustainable Business Models

Assoz. Prof. Dr. **Thomas Brudermann**
Phone: 7336 Email: thomas.brudermann@uni-graz.at

Academic coordinator Joint International Master's Programme in Sustainable Development

Research Interests: Human Decision Making, Choice Architecture and Nudges, Sustainable Development, Energy Transition, Complex Adaptive Systems, Diffusion of Green Technology, Collective Dynamics and Mass Psychology

Univ.-Prof. Dr. **Manfred Füllsack**
Phone: 3235 Email: manfred.fuellsack@uni-graz.at

Professor for Systems Sciences

Research Interests: Systems, Complexity, Networks, Games and Computational Theory, Work (History, Sociology, Economy, Philosophy), Computer-Based Modelling and Simulation

Univ.-Prof. Dr. **Alfred Posch**
Phone: 3234 Email: alfred.posch@uni-graz.at

Dean for studies at the URBi Faculty

Research Interests: Environmental and Innovation Management, Eco-Controlling, Industrial Ecology, Inter- and Transdisciplinary Learning for Sustainable Development

Assoz. Prof. Dr. **Romana Rauter**
Phone: 3236 Email: romana.rauter@uni-graz.at

Research Interests: Sustainability Innovation, Open Innovation, Innovation Management and Performance, New and Sustainable Business Models, Strategic Sustainability Management, Knowledge Transfer and Knowledge Management

Univ.-Prof. Dr. **Tobias Stern**
Phone: 7344 Email: tobias.stern@uni-graz.at

Director of the Institute
Professor for Innovation and Transition Research

Research Interests: Biobased innovation, Product development (biobased products), Technology assessment and forecasting (biorefineries), Bioeconomy (bio-based economy) transition, Innovation management, Market analyses, potentials and marketing

Research and Teaching Staff:

Raven Adam, BSc. MSc.
Phone: 3227 Email: raven.adam@uni-graz.at

Research Interests: Systems Modelling, Environmental Sciences, Natural Language Processing, Text Mining, Machine Learning

Raphael Asada, PhD Mag.
Phone: 7343 Email: raphael.asada@uni-graz.at

Research Interests: Transitions towards Bioeconomy, Social Metabolism, Integrated socio-ecological Modelling

Dr. **Ralf Aschemann**
Phone: 3232 Email: ralf.aschemann@uni-graz.at

Academic coordinator of the "Erasmus Mundus Master's Programme on Circular Economy"; coordinator of transdisciplinary case-study teaching; Erasmus advisor.
Research Interests: Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA), Env. Effects of Transport, Industrial Ecology, Circular Economy, Higher Education and Env. Assessment and Management, Health Impact Assessment (HIA)

Annelies De Meulenaere, MSc.
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Research Interests: Network Science, Traffic simulations, Urban last-mile delivery, Optimization algorithms and heuristics

Dr. **Ulrike Gelbmann**
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Chair of the Global Studies Curricula Commission

Research Interests: Strategic Sustainability Management, Corporate Social Responsibility, Stakeholder Management, Sustainability Reporting, Social Sustainability, Resilience, Waste Management

Ass.-Prof. Dr. **Georg Jäger**
Phone: 7348 Email: georg.jaeger@uni-graz.at

Research Interests: Computational Systems Science, Systems Modelling, Simulation of Complex Systems, Agent based Modelling, Data Science, Machine Learning, Network Science

Dr. **Marie Kapeller**, BSc. MSc.
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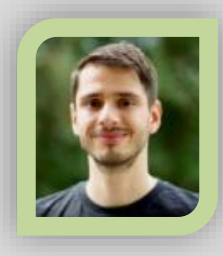
Research Interests: Computational Modelling (ABM, EBM), Social Network Analysis, Threat and Anxiety research (climate change), Early Warning Signals, Ecological Footprint modelling



Moritz Kettele, BSc. BSc. MSc.
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Research Interests: Sustainable supply chain management, Supply chain resilience and simulation, Risk and disruption management

Paul Krassnitzer, Dipl.Ing.
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Research Interests: Techno-economic and Environmental Assessment, Life Cycle Assessment, Lignocellulosic Biorefineries, Circular Economy

Michael Kriechbaum, PhD MSc.
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Research Interests: Environmental Innovation, Environmental Policy, Renewable Energy

Claudia Mair-Bauernfeind, PhD MSc.
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Research Interests: Life Cycle Assessment, Sustainability Assessment, Resource and Waste Management, Bioeconomic Innovations, Social Life Cycle Assessment

Miguel Moreno Torres, MSc.
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Research Interests: Climate Change Vulnerability, Resilience and Adaptive Capacity; Innovation Systems, Business Model Innovation; Sustainable Land and Natural Resource Management; Digitalization and Transition towards Industry 4.0

Arijit Paul, PhD MSc.
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Research Interests: Corporate sustainability, Corporate climate change strategy, Business Ethics, Sustainable Energy Strategies and Policies

Simon Plakolb, MSc. BSc.
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Research Interests: Traffic simulations, Computational Systems Science, Systems modelling, Functional programming

Daniel Reisinger, MSc. BSc.
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Research Interests: Systems Modelling, Artificial Societies, Cultural Dynamics, Behaviour Research, Network Science, Early Warning Signals

Katharina Roche, MSc.
Phone: 3230 Email: katharina.roche@uni-graz.at

Research Interests: Corporate Sustainability, Sustainable Operations Management, Strategic Management, Life Cycle Assessment, Sustainability Assessment

Katharina Waniek, Dr.techn. BSc MSc.
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Research Interests: Life Cycle Analysis, Sustainability Assessment of Chemical Processes, Sustainable Process Design

Martina Zimek, MSc. BSc. (maternity leave since July 2019)

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Research Interests: Corporate Social Responsibility, Sustainability Performance, Sustainability Assessment, Life Cycle Assessment, Sustainability, and Supply Chain Management, Waste Management, Strategic Management

Project Staff:

Katharina Berger, MSc. BSc.
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Research Interests: Circular Economy, Industrial Economy, Life Cycle Assessments, Sustainable Product Management

Anna Diaz Tena, MSc.
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Research Interests: Circular Economy, Product Lifecycle Management, Sustainable Product Design, Industry 4.0

Eva Fleiß, PhD MA
Phone: 1521 Email: eva.fleiss@uni-graz.at

Research Interests: Empirical Social Research, Validity of Survey Questions, Environmental Sociology/Sustainability, Renewable Energy, Photovoltaics

Mag. **Stefanie Hatzl**, PhD
Phone: 1521 Email: stefanie.hatzl@uni-graz.at

Research Interests: Energy Transition, Renewable Energy Technologies (PV), Empirical Social Research, Environmental Behaviour

Annechien Dirkje Hoeben, MSc. BSc.
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Research Interests: Nature-based solutions for climate-resilient sustainable growth, transitions towards the (forest) bioeconomy, non-wood forest products, forest ecology and business model innovation

Anita Lerch, BSc. (until February 2020)
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Research Interests: Digital Innovation, Sustainable Innovation, Green IT, Acceptance and Diffusion of Technology

Jyoti Prajapati, MSc.
Phone: 7427 Email: jyotil.prjapati@uni-graz.at

Research Interests: climate change mitigation strategies, low carbon sustainable mobility system and transitions, technological and non-technological innovations, business model innovations

Magdalena Rusch, MSc. BA.
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Research Interests: Circular Economy, Corporate Sustainability, Sustainable Product Lifecycle Management, (Social) Life Cycle Assessment, Digital Technologies, Industry 4.0

Tomas Santa Maria Gonzalez, MSc.
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Research Interests: Circular Economy, Circular Business Models, Sustainable Business Models, Business Model Innovation, Corporate Sustainability, Strategic Management

Josef-Peter Schöggl, PhD MSc. Bakk.
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Research Interests: Design for Sustainability, Life Cycle Assessment, Corporate Social Responsibility, Sustainable Supply Chain Management

Lukas Stumpf, BA
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Research Interests: Transition to a circular economy, operationalisation of sustainability in a circular economy, circular systems, design for sustainability and circularity

Annina Thaller, MSc. BSc.
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Research Interests: Climate Change Mitigation, Human Decision Making, and Behavior, Mobility Transitions, Carbon Lock-In

Vassiliki Theodoridou, Dipl. Ing.
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Research Interests: Corporate Sustainability/CSR, Strategic Management, Life Cycle Assessment & Sustainability Assessment, Circular Economy, Management systems, Sustainable Business Models

Julia Wenger, MSc. MSc. BSc.
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Research Interests: Transitions towards Bio-Economy, Lignocellulosic Biorefineries, Techno-economic and Environmental Assessment

Rafia Zaman, MBA
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Research Interests: Sustainable energy transition (climate change mitigation and energy access), Energy governance, Energy service security, Impact evaluation of energy programs

Administration:

Klaudia Kramer
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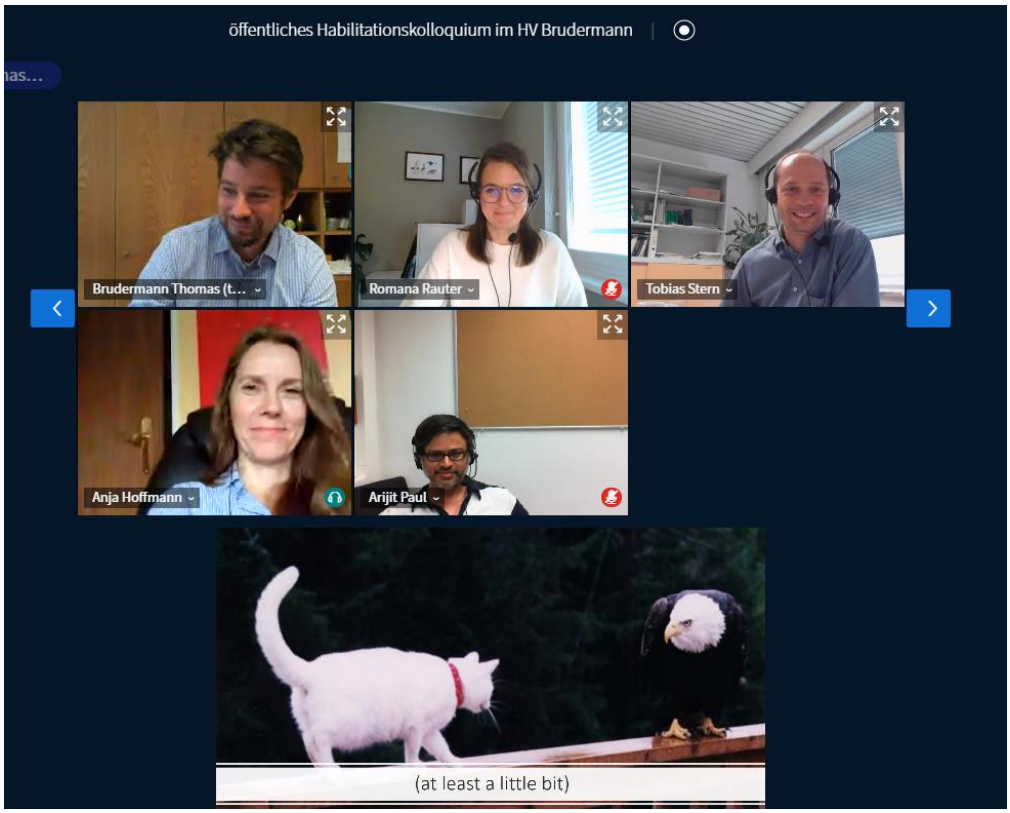
Tanja Untergrabner
Phone: 3238 Email: tanja.untergrabner@uni-graz.at

Student Assistants:

Gundula Allersdorfer	**Lisa Gruber**	**Jennifer Möhrke**	**Lukas Pertl**
Anna Dietl	**Tamara Janesch**	**Eva Nenninger**	**Verena Haas**
Lars Döringer	**Franziska Kirschen**	**Julius Ott**	**Alexandra Mayer**
Sophie Ebner	**Alexandra Lehner**	**Martin Popowicz**	**Leonie Sayer**
Iris Etzinger	**Angelika Meißl**	**Philip Röhr**	**Frederick Von Eickstedt**
Lisa Göberndorfer	**Tobias Micheli**	**Milica Savanovic**	**Katrin Winkler**

1.2.1 Habilitation of Thomas Brudermann

Thomas Brudermann earned the *venia docendi* in the field of Sustainability and Innovation Research. In the colloquium concluding the formal process on July 2nd 2021 he gave an inspiring presentation titled „Transitions to low-carbon energy: Challenges from a social science perspective“. Around 50 people attended the online event. Many say it was one of the best presentations ever seen at such an occasion. Following the completion of the habilitation rite, Thomas was promoted to associate professor at the institute.



The habilitation colloquium was not just for laughs, but also for science

1.3 Seminars and "SIS Science Talk"

For the "SIS Science Talk," the institute is inviting external experts to give a presentation on core research topics (i.e., systems sciences, innovation, 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 institute.

The following talks were held in 2020 and 2021:

- "How to Reduce or to Prevent Greenwashing in International Supply Chains" Dr. **Adolf Peter**, Shanghai University of Political Science and Law, 4 May 2021
- "The changing role of life cycle assessment (LCA) in the built environment" Dr. **Andreja Kutnar** and Dr. **Erwin M. Schau**, University of Primorska, Slovenia, October 6, 2020
- "The path towards sustainable e-mobility" Ass.-Prof. Dr. **Matevž Obrecht**, January 28, 2020
- "15 years proPellets Austria: Experiences with the introduction of a new energy carrier in Austria", Dr. **Christian Rakos**, January 21, 2020

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

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

- Webinar: Time- and Selfmanagement
- OSA - creation of the Online Self Assessments
- Evaluation of the mathematics
- Evaluation of the online system sciences
- Virtual Open House Day
- IP Experience Report
- Evaluation of the IPs
- Orientation Events USW Specials, Study Abroad, Masters Welcome
- How to write a bachelor thesis
- Job application check
- Master awards

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 Institute of Systems Sciences, Innovation and Sustainability Research:

- 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 institute (in alphabetical order):

2.1.1 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 institute's research activities.

2.1.2 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 institute'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 programme on CE. The institute'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.

2.1.3 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 institute 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.

2.1.4 Data Science & Artificial Intelligence

For most systems that are investigated by the institute, 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.

2.1.5 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.

2.1.6 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.

2.1.7 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.

2.1.8 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.

2.1.9 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.

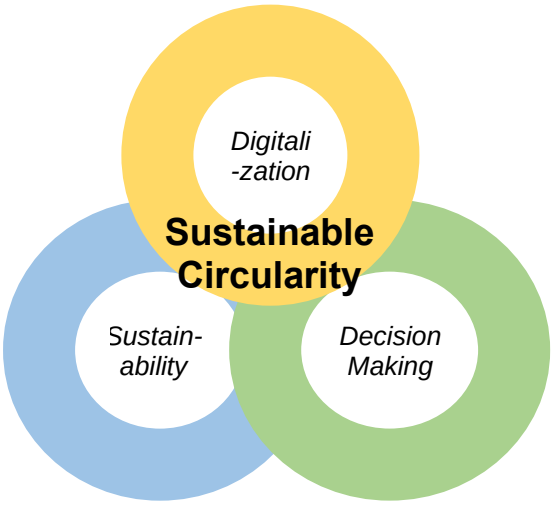
2.2 Research Projects

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

Head of the Laboratory: Prof. Dr. Rupert J. Baumgartner
Project team:
Magdalena Rusch, BA MSc,
Katharina Berger, BSc, MSc,
Moritz Kettele, BSc, BSc, MSc,
Dipl.-Ing. Vassiliki Theodoridou,
Lukas Stumpf, BA, MSc,
Katharina Roche, MSc,
Josef-Peter Schöggl, PhD,
Tanja Untergrabner

Duration: 2018 - 2025

Website: https://circular.uni-graz.at/en/



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 is aiming to conduct 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.

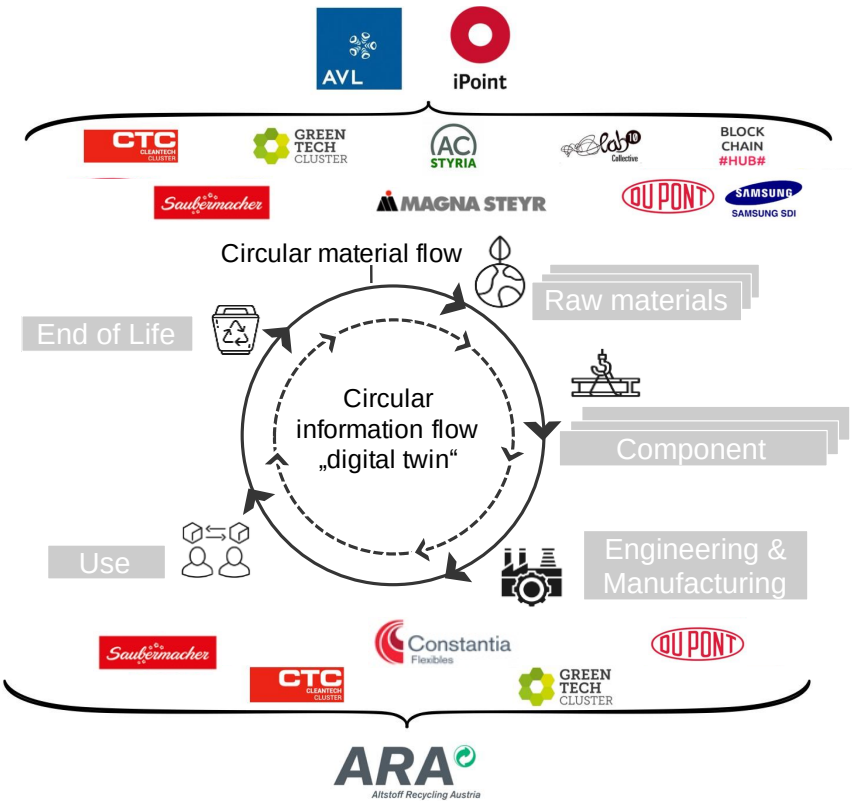
As a result of the research work, methods and concepts are developed for the collection of environmental and social data on products and services from the supply chain, the use phase and the end-of-life phase. This data will be used for the social and ecological evaluation and design of products and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

Unique project setting

In Christian Doppler Laboratories, application-oriented basic research is pursued at a high level, and expert 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 research within the CD-Laboratory focuses on sustainability management and assessment, circular economy, and digitalization. The recently produced research output concerned itself, for example, with exploring connections between sustainability and the circular economy based on the analysis of 3822 journal articles (Link), the identification of circular economy enablers and barriers and sectoral differences based on interviews and the analysis 131 circular economy business examples (Link), the illustration of the potentials of different digital technologies (IoT, AI, big data, blockchain) in terms of their useability along the product life cycle, their role as enablers for circular economy strategies and in specific product management activities (Link), an empirical study detailing the implementation of circular economy considerations into early stages of product design (Link). Furthermore, a concept of a digital product passport for electric vehicle traction batteries was developed (Link), a text mining-based investigation of 3000 circular economy projects was finished, and an empirical study detailing circular economy practices, strategies, and their effect on sustainability and firm performance in Austrian manufacturing firms based in 120 interviews was published (Link).

Project partners and funding

Austrian Federal Ministry for Digital and Economic Affairs, the National Foundation for Research, Technology and Development and the Christian Doppler Research Association; iPoint-systems GmbH, AVL List GmbH, ARA AG

2.2.2 CRESTING: CiRcular Economy-SusTainability implications and guidING progress

CRESTING is an Innovative Training Network (ITN) funded as part of the Marie Skłodowska-Curie Actions (MSCA) programme. The project has recruited 15 Early Stage Researchers (ESRs) to train in cutting-edge systematic analysis of Circular Economy (CE) activities in a wide range of geographic and economic settings: a total of 8 universities belonging to 6 different countries are involved. CRESTING has been divided into 5 Work Packages lead by multidisciplinary and international supervisory teams including non-academic partners:

- WP1: Assessing CE practices and discourse
- WP2: Corporate engagement with the CE
- WP3: Public sector engagement with the CE
- WP4: Capturing the benefits of circularity
- WP5: Measuring the impacts of circularity

The University of Graz leads WP2 and is also involved in WP4, acting as host institution of ESR 2.1 and ESR 2.2 under the main supervision of Prof. Rupert Baumgartner. The SIS will also be the institution of secondment for ESR 2.3, ESR 4.1 and ESR 4.3.

ESR 2.1 - Business strategies and practices for a circular economy (Tomas Santa Maria)
The key role of firms in the transition to a more sustainable and circular system has been widely acknowledged, though the potential contribution is far from being achieved. In order to realize CE aspirations, companies need to look beyond incremental improvements in products and processes into radical transformations found in business model innovation (BMI), which can be a source of competitive advantage by itself. However, BMI towards the CE has been low in the practice, and the literature on the topic is in its early days. The present research will contribute to a deeper understanding of BMI towards the CE, its process and the available frameworks that can support it, knowledge that is fundamental to foster the implementation of Circular Business Models and accelerate the transition to a CE.

ESR 2.2. - Sustainable product lifecycle management in a circular economy (Anna Diaz)
Strategies embedding circularity at the product level hold a lot of potentials: it is estimated that 80% of a product´s environmental impact is determined during its design phase. Circular product design can benefit from the growth of digital connectivity in manufacturing environments, making it possible to foster data-driven decision-making. Product Lifecycle Management (PLM) could be leveraged, which has consisted of the main companies' strategy to manage products' lifecycle information from the cradle to the grave. This research aims at bridging the gap between existing data sources in PLM and the data demanded by eco-design tools needed to embed circularity principles during the design phase of products.

Project team: Univ.-Prof. Dr. Rupert Baumgartner; Tomas Santa Maria, MSc; Anna Diaz, MSc.

Project partners: University of Hull/UK (Coordinator), University of Technology of Troyes/France, Utrecht University/Netherlands, Universidade Nova de Lisboa/Portugal, University of Messina/Italy, Universidade Aberta/Portugal, University "G. D'Annunzio" of Chieti-Pescara/Italy

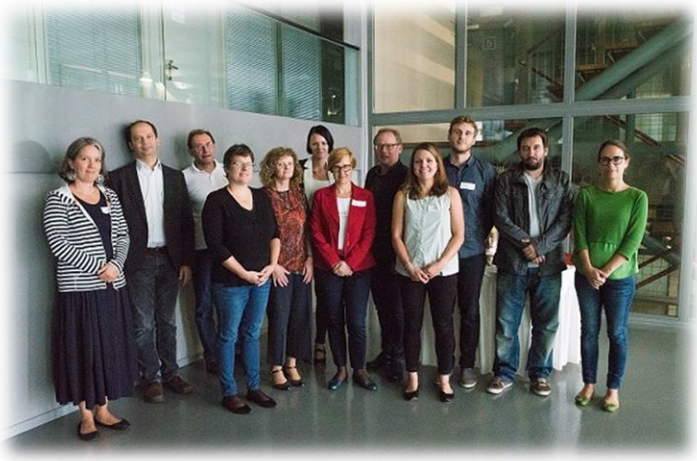
Duration: January 2018 - September 2021.

Funding: European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 765198.

2.2.3 START CIRCLES - Supporting TrAnsition from lineaR To CIRCuLar valuE chainS

The project objective is to increase sustainable innovation and resource efficiency in the program area, especially for SMEs. START CIRCLES is designed to enable SMEs better access to information, activities, as well as innovation partners in order to strengthen and support their cooperation with RTD partners.

The main project outcome is to integrate SMEs in cross-border innovation networks sustainably and circular economy oriented value chains to increase innovation and develop new products / materials. START CIRCLES has been developed from the perspective and needs of SMEs and RTD organizations. The project will monitor SMEs from innovation initiation to the launch of the new products while delivering new and sustainable support services for each phase.



The following approaches in the project are new/innovative:

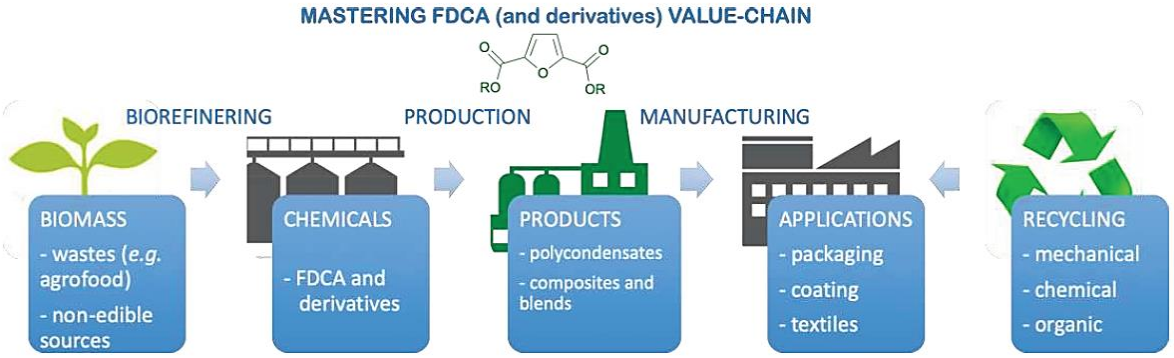
- documentation and utilization of RTD skills for the circular economy
- establishment of new cooperation models, especially regarding reuse-oriented value chains (training of mediators / facilitators)
- supporting SME in RTD networks
- support the launch of new products by developing new business models
- deliver a policy recommendation on a new theme: business models in the circular economy.

Further Information: http://www.si-at.eu/en2/start-circles/

Project team:	Univ.-Prof. Dr. Tobias Stern, Ass.-Prof. Priv.-Doz. Mag. Dr. Romana Rauter, Daniel Holzer, MA
Project partners:	Chamber of Commerce and Industry of Slovenia (Lead Partner), Wood Carinthian Competence Center, Limnos Ltd., asteenergy Ingenieurbüro, Faculty of Polymer Technology, University of Graz, Forschung Burgenland GmbH
Duration:	September 2018 – March 2022

2.2.4 "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

2.2.5 Wood for Automotive Applications – WoodC.A.R.

This COMET K-Project aims at gaining a more thorough and comprehensive understanding of wood as load-bearing and energy absorbing (crash and vibration) material in advanced applications is needed. WoodC.A.R. (Wood - **C**omputer **A**ided **R**esearch) will establish the knowledge and the requisites for integrating wood in virtual engineering and the industrial design process (e.g., vehicle design) in general. The Project will establish the needed knowledge base on the mechanical properties, the grading, the processing, the integration and the recycling of numerous wood species and wood composites in vehicle design. Moreover, WoodC.A.R. will evaluate and improve existing and develop advanced material models for use in computer-aided engineering (CAE). State-of-the-art production, joining and bonding technologies will be reviewed, analyzed, evaluated and integrated with the virtual engineering process. Application cases, not only from the automotive sector, will be selected. Based on meticulous specification sheets, the application cases will be developed by applying the initial virtual engineering process. In continuous feedback-loops, the process will be refined such that it is applicable in an industrial development process. Eventually, demonstrators will be built and tested, proofing the reliability of the virtual engineering process.

Photo: Mattro

Photo: MAGNA

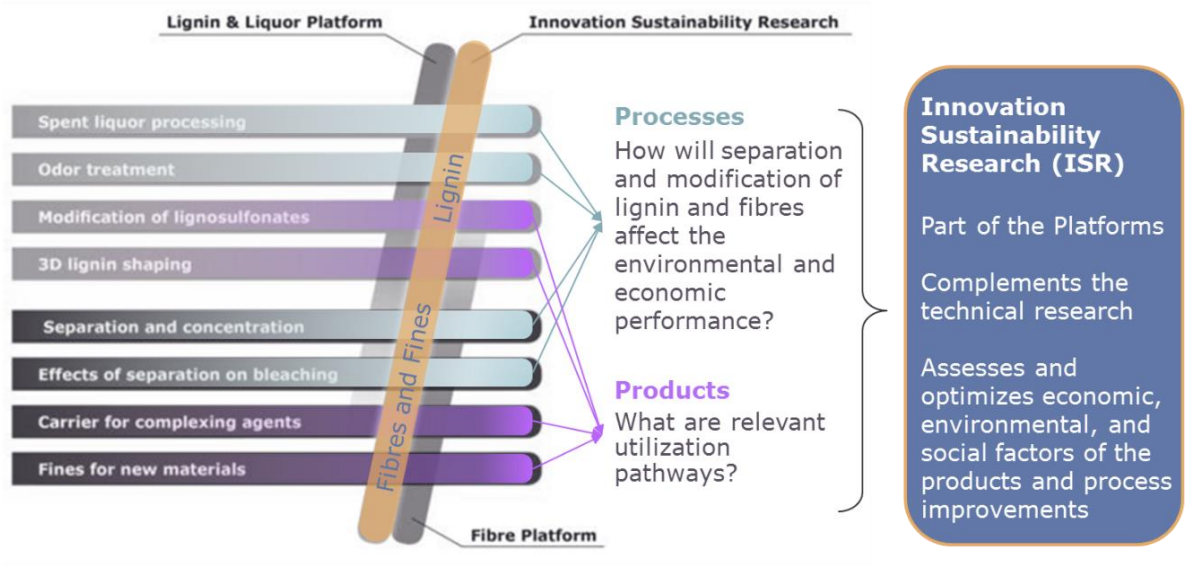
The Institute of Systems Sciences, Innovation and Sustainability Research is responsible for assessing the environmental and socio-economic impacts of wood in an automotive application. More precisely the institute will perform a Life Cycle Assessment (LCA) of the defined application cases in order to identify environmental and social substitution effects. Moreover, the socio-economic impacts of an increasing wood demand will be assessed by applying Input-Output analysis.
Further Information: http://www.woodcar.eu/index_de.html#

Project team:	Univ.-Prof. Dr. Tobias Stern, Claudia Mair-Bauernfeind, PhD, Univ.-Prof. Dr. Rupert Baumgartner
Lead Institution:	Innovationszentrum W.E.I.Z.
Company Partners:	MAGNA, MAN, MATTRO, Weitzer Parkett, DOKA, DYNAmore, EJOT, FHP – Forst Holz Papier, Holzcluster Steiermark, IB Steiner, LEAN MC, AC-Styria, Collano, Volkswagen,
Scientific Partners:	University of Natural Resources and Life Science, University of Graz (SIS), Graz University of Technology (VSI), Virtual Vehicle (Vif), University of Applied Science FH Joanneum, Innovationszentrum W.E.I.Z
Duration:	March 2016 - April 2021
Funding:	FFG, COMET K-Project

2.2.6 Flippr² - Future Lignin and Pulp Processing Research PROCESS INTEGRATION

This COMET K-Project is the follow-up project to FLIPPR⁰ (April 2013 – March 2017), where the University of Graz was already responsible for the area of sustainability research (e.g., LCA).

The efforts of the project are focused on integrated solutions to manufacture products from wood efficiently, specifically from spent liquor derived technical lignin and pulp derived specific short fibre fractions (fines). By tackling process integration issues associated with separation, fractionation and modification of bio-based materials in the pulp and paper industry, resulting products are expected to contribute towards a more sustainable knowledge-based bioeconomy, partly replacing fossil resources, and increasing value added.



Flippr² sub-projects and the innovation sustainability task

As illustrated in the figure above, SIS is responsible for the innovation and sustainability task. On the one hand, the respective technical sub-projects are complemented by (techno)-economic and environmental research: with a spectrum of methods at hand, tailor-made solutions are applied to support the decision-making process.
On the other hand, issues in a broader context such as bio-based innovations, (lignocellulosic) biorefinery developments and bioeconomy impacts are investigated.

Project Team:	Univ.-Prof. Dr. Tobias Stern, Univ.-Prof. Dr. Alfred Posch, Julia Wenger, MSc., Verena Haas, BSc., Mag.rer.nat. Raphael Asada PhD
Lead Institution:	Papierholz Austria GmbH
Company Partners:	Sappi Gratkorn-Produktions GmbH & Co KG, Mondi Frantschach GmbH, Zellstoff Pöls AG
Scientific Partners:	University of Natural Resources and Life Sciences Vienna, Graz University of Technology, University of Graz
Duration:	April 2017 - June 2021
Funding:	FFG COMET K-Project (6th Call): BMDW, BMVIT, KWF, SFG

2.2.7 Using Digital Media at Work: Impacts and Potentials from Employees' and Employers' Perspective in the Context of the Styrian Economy

Digitalization is transforming workplaces with unequal consequences for companies and their employees. Increasing deployment and use of digital technologies promise opportunities such as productivity gains, greater flexibility, and furtherance of employees' innovativeness. However, digitalization is accompanied by challenges in the corporate context as well such as additional burdens and stress on employers and their workforce alike.

For the Province of Styria, as the center of production and innovation, the digitalization of the work sphere is deemed to be of major importance. In this context, the aim of this research project is to shed light on this multifaceted process of restructuring and change caused by digital technologies and to make a step towards understanding the effects of the digital transformation on companies within the Styrian economy. This requires applied research on 1) the general use of digital media within the corporate context; 2) the individual user behaviour and digital literacy; 3) the organizational culture and its interaction with the business environment; and 4) on opportunities and challenges related to the use of digital technologies at the workplace.

The intended exploration of the current situation represents a crucial pre-condition for creating practical knowledge and deriving concrete recommendations for action, in order to reinforce the competitiveness of the Styrian economy.

Further Information: https://digital-at-work.uni-graz.at/

Project team:	Assoz. Prof. Mag. Dr. Romana Rauter, Anita Lerch, BSc
Project partners:	University of Graz (Institute of Educational Sciences), University of Applied Science FH Joanneum, Know-Center GmbH, Styrian Chamber of Labour, x-sample
Duration:	May 2018 – May 2020
Funding:	Land Steiermark (Province of Styria)

2.2.8 GEL ODP - Green Energy Lab Open Data Platform

The transition from a fossil fuel-based, unidirectional to a renewable, decentralized energy system requires the widespread adaptation of new technological innovations. Novel technologies require information exchange and data transfer among different stakeholders and may lack individuals' acceptance. Moreover, the implementation of technical innovations may foster end users' behavior change. Distribution System Operators typically have very little information about the load flows in their grids, and end users and energy suppliers could benefit from a better knowledge of disaggregated consumption profiles.

The main goal of the OpenData project is the development and implementation of an Open Data Platform (ODP) for the energy sector to provide an easy access and overview of relevant data and interdependencies of a current and future integrated energy system for different stakeholders, such as end-users, system operators, start-ups, or policymakers.

The ODP aims to provide all end users insight into their energy consumption or efficiency data, allowing a comparison with similar end-users (such as households), and tailor-made recommendations for energy relevant measures. This shall increase the understanding and acceptance among end-users. Therefore, disaggregated end-user data will be processed to identify most electricity consuming appliances and consumption patterns. This enables a better understanding of electricity cost and system impacts. Based on consumption patterns, predictive models will be developed providing a better understanding of load flows and enabling the identification of flexibility options in the energy system. In addition, data-driven persuasive strategies are envisaged for the ODP, helping to change the behavior and underlying attitudes of participants. User participation is critical for the widespread deployment of technological innovations. Hence, models of participation are developed for respective stakeholder groups, aiming to increase the rate of adoption.

The intended effect is decentralized demand-side management by incentivizing the consumer to participate in the energy system actively and provide flexibility. The GEL ODP will be integrated into the overall Green Energy Lab coordination to ensure the open data approach and monitoring key performance indicators of the Green Energy Lab.

The project is supported with the funds from the Climate and Energy Fund and implemented in the framework of the RTI-initiative "Flagship region Energy." For detailed information, see also: https://www.greenenergylab.at/projekt/open-data-platform/

Project team:	Univ.-Prof. Dr. Alfred Posch, Univ.-Prof. Dipl.-Ing. Dr. Tobias Stern, Eva Fleiß, MA PhD, Mag. Stefanie Hatzl, PhD
Project partners:	TU Vienna, University of Applied Sciences Burgenland, EVN AG, AIT Austrian Institute of Technology, AEE – Institute for Sustainable Technologies, twingz development GmbH, ms.GIS Informationssysteme GesmbH
Duration:	November 2018 - April 2022
Funding:	2nd Call - Energy Model Region (FFG)

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2.2.9 **Quality – Qualitative change to close Austria's Paris gap: Shaping the pathway**

Rapid and far-reaching changes are required in order to reach the 1.5° goal set in the Paris Agreement. Austria's total GHG emissions are again on the rise and above the 1990 level. The transport sector emissions in Austria have risen substantially since 1990, whereby passenger transport accounts for about 64% of transport GHG emissions.

Despite national plans to reduce Austria's total greenhouse gas emissions, those of personal transport did not seize to increase in the past years. QUALITY aims at counteracting this trend by considering not only incremental, but qualitative changes, i.e. substantial changes in the socioeconomic system for their potential to bring about substantial GHG emission reductions. Moreover, QUALITY identifies and evaluates policy packages and instruments to enable these qualitative changes and consequently aids a low-carbon transition.

Therefore, various aspects need to be considered and will consequently be addressed in course of the project, such as the potential for GHG emission reduction for respective qualitative change options for the passenger transport system in Austria. In order to find out how the behavioural shift must evolve to avoid carbon emissions, transportation modelling is applied. In addition, the total social costs for different modes of passenger transport are considered to elicit whether a reduction of GHG intensive modes of passenger transport could yield a reduction in total social costs.

These findings are considered together with legal aspects to develop effective and feasible policy instruments to achieve a low-carbon passenger transport system. Proposed policy packages that target a wide variety of possible measures, are discussed with stakeholders in order to ensure feasible policy design and to derive concrete policy recommendations for different levels, ranging from municipal to the European level.

Project team:	Univ.-Prof. Dr. Alfred Posch, Ass.-Prof. Dr. Georg Jäger, Simon Plakolb, BSc MSc, Thaller Annina, BSc, MSc, Eva Fleiß, MA PhD, Mag. Stefanie Hatzl, PhD, Raphaela Maier, BSc, MSc
Lead Institution:	University of Graz, Wegener Center for Climate and Global Change
Scientific partner:	University of Graz, Institute of Public Law and Political Science
Project partners:	TRAFFIX Verkehrsplanung GmbH, Environment Agency Austria
Duration:	November 2019 – October 2021
Funding:	ACRP, 11th Call

2.2.10 Challenges and Potentials of Distributed Working ('Digi@Homework')

This project was designed to investigate challenges and potentials of distributed and remote working under the specific COVID-19-circumstances. Being a follow-up-project of the 'Digi@Work'-project completed in spring 2020, a special emphasis has been put on older (55+) and female employees. While the prior group might have experienced challenges with technology usage itself, the latter one is supposed to encounter specific circumstances related to care work. Potentials and opportunities – also considered from a sustainability perspective – complemented the project's research agenda.

The empirical part of this research project included a representative online survey with 1,128 employees who worked from home for at least one week in 2020/2021. In addition, qualitative surveys were conducted with equal opportunities officers, works councils and HR managers from the university, automotive, IT and energy sectors.

Project member: Assoz. Prof. Mag. Dr. Romana Rauter
Project partners: FH Joanneum - University of Applied Sciences (Project lead), IGSF Interdisziplinäre Gesesllschaft für Sozialtechnologie und Forschung; University of Graz – Institute of Systems Sciences, Innovation and Sustainability Research
Duration: October 2020 – March 2021
Funding: Arbeiterkammer Steiermark – 2. Ausschreibung des Projektfonds Arbeit 4.0

2.2.11 Services and Digitalization in the Social Sector ('Digi@Socialwork')

This participatory and practice-oriented research project continues the research carried out in a previous project ('Digi@Work') and thereby puts focus on digitalization in the Austrian social sector. Digital media and technologies as well as different tools are widely used and open new possibilities as concerns communication, collaboration and care work. In such a setting, the research team aims to answer questions such as the following ones: How do employees perceive digitalization in their daily work? Or how can they actively shape the digital transformation in their companies? The results of an online survey (N=1246) and 9 group discussion (N=24) with employees show that acceptance of digitalization among employees is medium to rather high, with differences seen in gender and age. A large proportion of respondents wishes for more time and space to be able to try to learn new things in the area of digital technologies and employees want to be more involved in the selection of new digital technologies. Furthermore, the usage of private devices for professional purposes needs to be clearly defined. The central outcome of this project is going to be a toolbox to support shaping digital transformation processes in the social sector.

Project team: Eva Nenninger, BSc; Doris Prach, BSc; Assoz. Prof. Mag. Dr. Romana Rauter
Project partners: University of Graz – Institute of Educational Sciences (project lead)
Duration: June 2020 – May 2022
Funding: Arbeiterkammer Steiermark – 2. Ausschreibung des Projektfonds Arbeit 4.0

2.2.12 **1, 2, 3 – Verpackungsfrei (1, 2, 3 – Packaging Free)**

Food retail trade is eager to reduce packaging, and hence applies several concepts like returnable packaging with/without deposits or re-useable packaging filled by customers in the shop. These activities require the awareness and willingness to act of relevant stakeholders: Suppliers must adapt their production, employees and customers their ways of acting and habits. Exploring these contexts is the content of 1, 2, 3 - Packaging Free.
The project investigates respective approaches of conventional supermarkets, in our case SPAR Styria. We focus on how supermarkets support consumers in using more eco-friendly packaging and investigate how awareness and willingness to act of stakeholders are linked to their wish to avoid packaging material or to accept newly developed (low-packaging) alternatives. The results help us develop and test measures to increase awareness of and willingness to act for multiuse packaging of the stakeholders. 1, 2, 3 - Packaging-free aims to

- evaluate and improve the acceptance of established packaging reduction measures among relevant stakeholders,
- test new measures to conventional supermarkets and implement them,
- develop innovative measures and evaluate them for feasibility,
- evaluate awareness/readiness for action of relevant stakeholders for this three-step process and develop, test and implement measures to strengthen readiness for action,
- create the basis for roll-out in SPAR and become a role model for the industry,
- provide a solid science-driven basis for raising awareness for waste prevention.

Self-service filling station at a SPAR supermarket, © SPAR/Werner Krug.

Project Team: Dr. Ulrike Gelbmann
Company Partners: SPAR Austria, Christian Pirker KG
Scientific Partners: Austrian Institute of Ecology, Vienna
Duration: May 2020 – April 2022
Funding: VKS Verpackungskoordinierungsstelle

2.2.13 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.

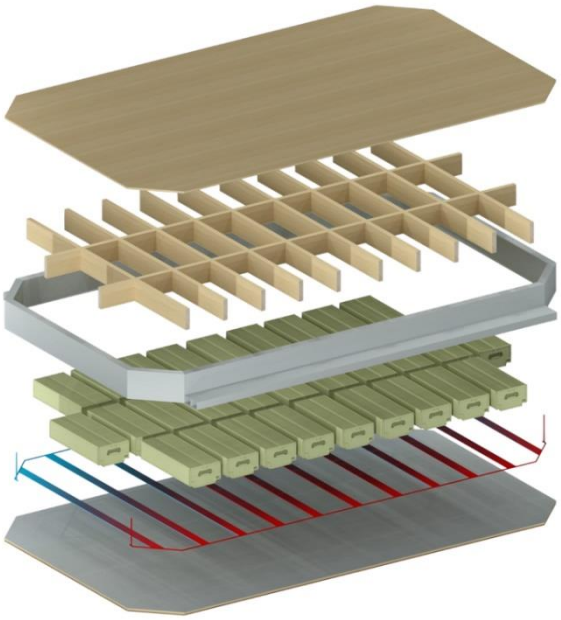
The Institute of Systems Sciences, Innovation and Sustainability Research is responsible for assessing the current resilience of European forest-based value chains to short-term and immediate stressors (e.g., disturbances) and more gradual effects over a longer term (e.g., climate change). More precisely, 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.

Further Information: https://resonateforest.org

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

2.2.14 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.

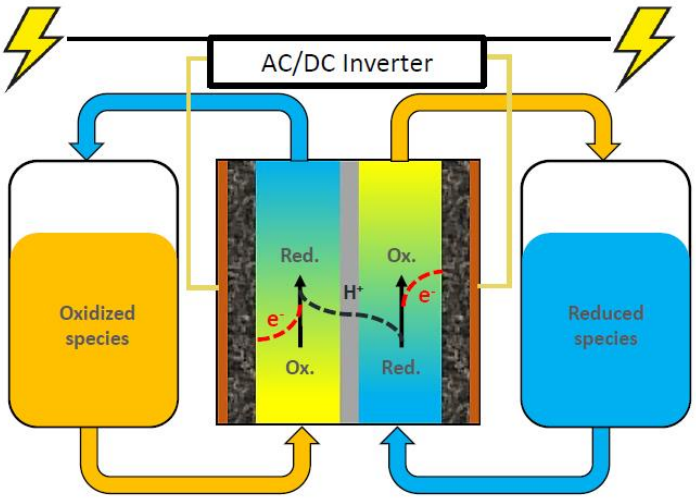


The project aims to develop a demonstrator of a segment manufactured from a steel-wood hybrid and verify its properties regarding thermo-management, vehicle safety and sustainability. To achieve this, the research focus lies on connection technology between wood and steel, wood modification to enhance 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 Institute of System Sciences, Innovation and Sustainability Research 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 (SIS), Graz University of Technology (VSI), Innovationszentrum W.E.I.Z
Duration:	April 2021 – March 2024
Funding:	FFG

2.2.15 SABATLE - Safety assessment of flow battery electrolytes

Redox flow batteries are an emerging technology for medium and large-scale stationary energy storage and are considered as a viable option to buffer fluctuations in the energy grid. These fluctuations are caused by the increasing share of renewable energy (e.g. solar and wind energy) whose production is dependent on weather and seasonal conditions.



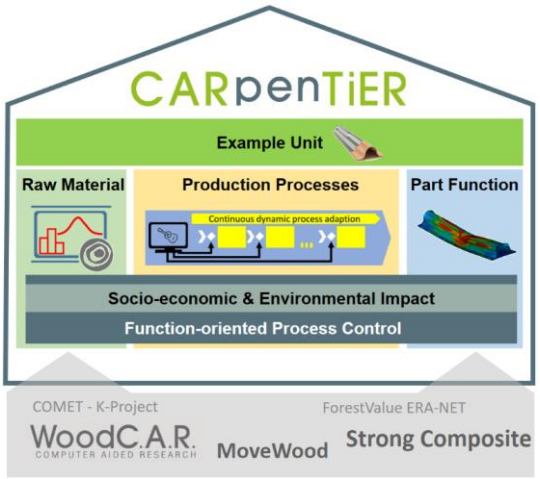
The core elements of a redox flow battery (RFB) are two tanks filled with the electrolytes. Currently used electrolytes feature several issues such as limited regional availability, stability, volatile price, lack of sustainability and – often neglected – significant toxicity. In SABATLE, we aim at investigating the safety and (nano)toxicity aspects of current and emerging electrolytes in redox flow batteries as well as the corresponding environmental impacts by performing a life cycle assessment of the whole life cycle from resource extraction to the end-of-life. We will investigate electrolytes from the following commercially available RFB technologies: vanadium, zinc-bromine/chlorine, iron, and compare them to emerging electrolytes based on organic compounds derived from lignins, so called quinones, currently being developed at one of the partners. The lignins as well as decomposition products of the electrolytes may contain also nanoparticles which may pose an additional risk for the environment. Human toxicity and ecotoxicity of electrolyte solutions will be assessed using algae, daphnia, and zebrafish biological models. Exposure scenarios upon accidents during operation of the battery and after end-of-life will be considered, and realistic doses for human exposure and ecotoxicity will be developed. Further, high impact will be generated by developing a tailored safe-and-sustainable-by-design (SaSbD) concept. Through the implementation of this concept a mitigation of potential hazards will be secured and more sustainable and inherently safe electrolytes will be provided. Public concerns, including risk assessment and stakeholder engagement will be covered in the project.

Project team: Univ.-Prof. Dr. Tobias Stern, Claudia Mair-Bauernfeind PhD, Julia Wenger M.Sc. MSc
Lead institution: Graz University of Technology, Institute of Bioproducts and Paper Technology
Company partners: Mondi AG, Biobide
Scientific Partners: BioNanoNet Forschungsgesellschaft;
Duration: January 2021 – December 2022
Funding: FFG

Graz University of Technology | University of Graz | BioNanoNet | Mondi AG | BioBide

2.2.16 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 fibres. 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.



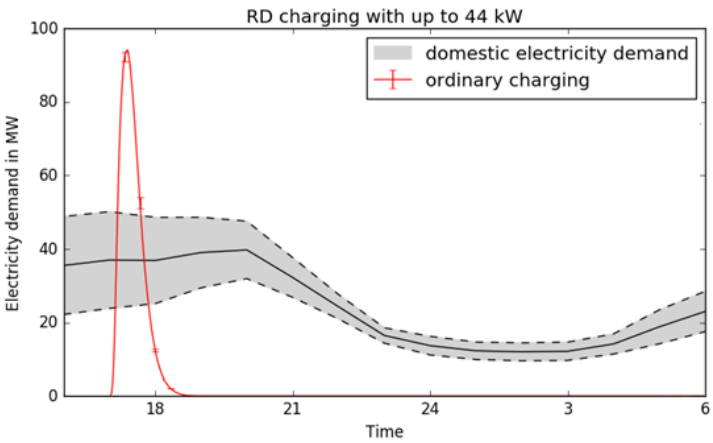
Although former research work has laid a solid basis in finite element modelling, there is a lack of suitable production technologies for industrial implementation. For this reason, the continuing research programme will focus primarily on process development and process control. Both, process and component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

The Institute of Systems Sciences, Innovation and Sustainability Research 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. Further information: http://www.carpentier.at/project.html

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, EJOT, FHP, FILL, Glanzstoff, HC-Styria, Klumpp, Lean MC, VW, Weitzer Parkett
Scientific Partners:	University of Natural Resources and Life Science, University of Graz (SIS), Graz University of Technology (IMAT), Virtual Vehicle (Vif), Innovationszentrum W.E.I.Z
Duration:	May 2021 – May 2025
Funding:	FFG, COMET-Projects

2.2.17 **Charging Rushhour**

The targeted decarbonization of passenger transport by 2040 will only be possible by operating passenger cars exclusively via electric motors in the future. This will not only lead to a drastically increased demand for electricity but will also create unprecedented demand peaks when many cars are being charged at the same time during rush hours. The Charging Rush Hour project uses an agent-based computer model to explore the extent of this problem, in which regions and at what times, and what counterstrategies are useful. In particular, the situation of at-risk regions in Styria is investigated.



Although it is not yet completely clear how the path to sustainable mobility will look like, we already know a lot about the goal to be achieved by 2040. One of the most important points here is the expansion of e-mobility. The declared goal of decarbonizing passenger transport can only be achieved when almost every passenger car is powered by an electric motor. This poses many new challenges for administration, companies, and individuals. The increased demand for electric power is one of these challenges. On the one hand, it must be ensured that this demand can be met from sustainable sources, and on the other hand, our energy network must be able to work with the demand peaks that will arise.

The aim of Charging Rushhour is to estimate the risk of such an overload. We investigate different regions, and those regions in which the greatest risk potential is suspected will be examined in greater detail. In addition, possible counterstrategies will be developed and evaluated.

Project team: Ass.-Prof. Dr. Georg Jäger; Lisa Göberndorfer, BSc; Milica Savanovic
Duration: November 2021 – October 2022
Funding: Land Steiermark (Province of Styria)

Das Land Steiermark
➔ Gesundheit, Pflege und Wissenschaft

2.2.18 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 digitalised 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 optimising, stabilising, and increasing resilience of the energy system, as they components, grids and actors to interact with each other. The contribution of digitalisation 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 digitalisation, 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:	Oktober 2021 – September 2021
Funding:	Land Steiermark, Green Transformation

2.2.19 **Strategic sustainability management for a logistics service provider**

The German CEP industry has gained considerable importance in recent years on its own. The CEP industry is considered systemically relevant, which has become particularly evident during the COVID-19 pandemic, and its sales and delivery volume have been steadily increasing over the last years alone. However, the CEP industry has come under increasing criticism and pressure to act more sustainably – whether from the public, politicians, employees, or competitors. In order to focus on sincere, long-term goals, it is particularly important to embed sustainability on a strategic level.

In this context, the cooperation project between DPD Germany and the Institute of Systems Sciences, Innovation and Sustainability Research (SIS) at the University of Graz was initiated to identify solutions and implementation options for strategic sustainability management. The project was divided into two sub-projects to focus on the company's 1) sustainability management and 2) packaging management. Due to the successful collaboration the project will be continued in 2021/22, with a focus on the implementation of the results identified within the project, especially concerning strategic recommendations for action.

The objective of the 1st sub-project "big picture sustainability" was to identify relevant sustainability issues and to derive strategic recommendations for action. The basis was a benchmarking study in which DPD was compared with its direct competitors within the CEP sector and selected companies outside the CEP sector that were considered to be particularly sustainable. In a further step, best practices and strategic recommendations for action were derived. The aim of the 2nd sub-project "Sustainable packaging management" was to provide scientific support for the development of solution approaches and implementation scenarios for sustainable packaging solutions. Promising solutions were identified with the help of design thinking workshops. As a starting point, literature research as well as research on previous packaging solutions were carried out. Consecutive design thinking workshops were conducted to identify packaging solutions. Finally, a detailed categorization of packaging solutions was conducted to identify current providers and packaging solutions most relevant for the logistics service provider.

Project team:	Univ.-Prof. Dr. Rupert Baumgartner; Josef-Peter Schöggl, PhD; Katharina Roche, MSc
Project partner:	DPD Germany
Duration:	December 2020 - December 2021.
Funding:	University of Graz

2.2.20 Regional and sustainable business models for the Alps region

In this project we aim to explore different types of business models that due to their characteristics can be aligned with the Sustainable Development Goals and are particularly suitable to be implemented in the Alps region. This geographical focus was chosen because of its relevance, the various challenges it is facing and in alignment with the funding body ALC Alpine Lions Cooperation. Existing conceptualizations of sustainable business models in literature are being applied to explore business models in two areas, namely tourism and coworking spaces in support of new forms of working and living. In this context, two master thesis projects are carried out and additional desk research and case analysis will complement their findings.

Project team: Assoz. Prof. Mag. Dr. Romana Rauter
Duration: October 2021 – July 2022
Funding: ALC Alpine Lions Cooperation

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, CO2 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 optimisation 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 ISDRS - International Sustainable Development Research Society

The International Sustainable Development Research Society (www.isdrs.org) was formally founded in 2006 and built upon a 20-year history of the International Sustainable Development Research Conferences. The vision is to establish a forum where diverse research communities can come together creating a transparent dialogue on key problems, issues, initiatives, policies and strategies needed to make sustainable development a reality. It aims to foster and communicate the importance of sustainable development in a global society, to promote high-quality dialogue and collaboration and to build bridges between different research communities and also between research and its applications in society. In 2020, the 26th annual International Sustainable Development Research Conference was held in Budapest, Hungary. Rupert Baumgartner is a board member of the ISDR-Society.

2.3.5 Early Career Researchers Network of Networks

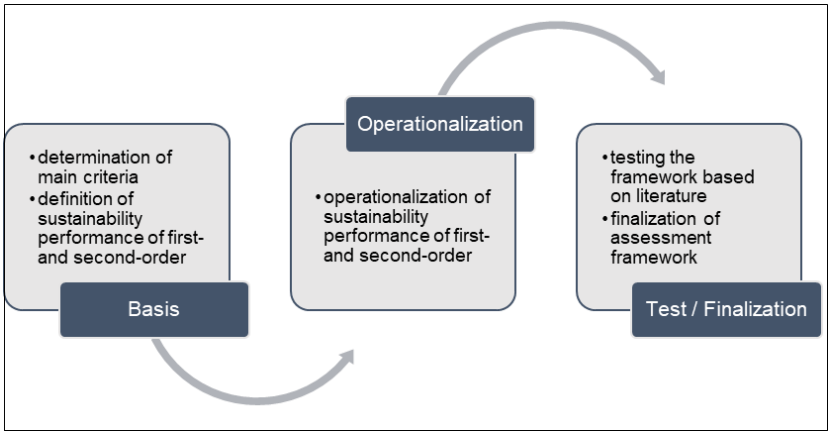
Early Career Researchers Network of Networks (ECR NoN) is uniting early career researcher organizations from all over the world to facilitate cooperation, to break silos across disciplinary backgrounds and engage with interdisciplinary issues. ECR NoN also addresses science-policy translation issues and provides early career researcher opinion in initiatives like Future Earth, the International Social Science Council (ISSC) and other relevant groups and organizations.
Institute of Systems Sciences, Innovation, and Sustainability Research (SIS) is part of this ECR NoN since mid-2016, with another 16 international networks involved. Each of the member organizations has the freedom to create working groups for certain topics of interest. SIS, represented by Arijit Paul and Anna Diaz Tena, together with 16 other networks/organizations have joined the Future Earth Working Group (FE WG), which concentrates specifically on sustainability and interdisciplinary research. Recently, Arijit Paul has been elected as the working group coordination committee chair at the executive committee of the ECR-NoN. Anna Diaz Tena has also joined the communication team of the executive committee of ECR-NoN.

2.4 Ph.D. projects (ongoing)

2.4.1 Operationalization of sustainability performance of first and second order

After the publication of the report "Our Common Future" by the World Commission on Environment and Development many milestones followed in defining sustainability. Most studies focus on sustainable development on a macro-level, rather than linking all affected levels (e.g., the company, market, society, and nature). It must be considered that sustainable development cannot be achieved by thinking within a firms' border. Everything is interconnected, and pollution doesn't stop at any (geographical or firms) boundary. A company is operating in a market system which is part of the society embedded in nature. The focus on the performance of a sub-system might potentially decrease the sustainability performance of society and nature in total. This means that whole system have to be studied, rather than focusing on single projects, processes, and activities. Thus, the dissertation focuses on the topic of sustainability performance in a systemic view. The goal is to operationalize sustainability performance of first- and second-order based on a definition of Baumgartner&Rauter (2017).

The first part of the dissertation is the development of a conceptual framework which includes essential dimensions to operationalize sustainability performance of first- and second-order. For testing the applicability of this framework, case studies will be conducted (e.g., sustainability performance of green chemistry processes). The figure below shows the methodological approach of the dissertation.



The methodological approach to operationalize first- and second-order sustainability performance

In the frame of the present dissertation the following main research questions will be studied:
Question 1: How can sustainability performance be operationalized if systemic impacts are integrated?
Question 2: Which dimensions are needed to operationalize sustainability performance of first- and second-order?

This dissertation is one of the first attempts to split sustainability performance into first- and second-order by identifying the degree of sustainability in a systemic way. This helps businesses to concentrate on major (sustainability management) activities to allow sustainable development, according to the Brundtland report 1987, to meet the needs for generations nowadays and in the future. Through this approach, companies can identify lack of sustainability performance. Based on this, improvements and targets can be set by implementing sustainable strategies. This is highly important as current situations show an urgent need to get companies to act in a more sustainable way.

PhD student: Martina Zimek
Duration: 2016 – 2022

2.4.2 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 – 2022

2.4.3 **Local Food Systems for Sustainable Development: Open, Connected and Circular**

My Ph.D. thesis is divided into three projects that deal with the sustainable transformation of the food system towards sustainable development (Caron et al. 2018).
Research project one and two state results of two inter- and transdisciplinary case studies. The first investigated how the urban and peri-urban food system of Graz including its surrounding districts can be changed such that more local food products are consumed within the target area. Research on urban food systems is increasingly concerned with assessing potentials for cities to "localize" their food supply through their surrounding areas (Cardoso et al. 2017). Therefore, the research process was guided by the question of how a resource-efficient local food supply may be enhanced in the target area. To support the research process with data, textual materials, including national and international reference projects on the local food supply in urban areas were analysed and semi-structured interviews with multiple local agri-food stakeholders were conducted. Furthermore, territorial food-carrying capacities by means of food self-sufficiency rates (FSSR) for seven food items were calculated. In a series of workshops, knowledge from scholars and practitioners were brought together, and summarized in a roadmap, showing how local agri-food stakeholder can contribute towards a resource-efficient and sustainable food provision.

The second case study represents a transdisciplinary case study (TCS, Scholz et al. 2006) on the development of sustainable food products. TCS is based on the idea of educating students in real-world settings. It combines three components, namely case studies, transdisciplinarity and sustainable development, and draws on PBL as a didactic framework. The research was carried out to determine how food technology and sustainability education could be promoted amongst secondary school students. The first objective of the research was to explore the students' food decisions by applying participatory research methods. The second objective, based on the initial findings, was to identify and produce sustainable food products by students for students. As such, the pull-concept for mutual learning was applied (Posch and Steiner 2006), which posits that learning occurs in a circular rather than a linear relationship among knowing, understanding, and applying. The students engineered sustainable food products from scratch and, as they went through their product development process, engaged in iterative learning steps.

The third project investigates how insects (i.e. *T. Molitor*) can contribute towards a sustainable protein supply in Austria. At first, a literature review on suitable substrates for the mass rearing of T. Molitor was conducted. Subsequently, agricultural and industrial by-products along the food supply chain were identified and quantified for Austria. Furthermore, the nutritional content of these feed sources was analysed (e.g. in terms of fat, carbohydrates, sugar) and feeding trials were conducted. The paper states the first findings of a five-year-long study. Furthermore, it highlights the role insects can have in a circular food system in Austria.

PhD student: Hartmut Derler
Duration: 2018 – 2022

2.4.4 SMEs in a circular economy: A management perspective on key factors influencing a transition towards a circular economy

In the course of the transition towards socially and economically more sustainable systems, the concept of the circular economy (CE) has emerged, which is intended to counteract a product-based linear economy with a "take-make-dispose" tradition. A circular economy aims to create an economic system that replaces the end-of-life concept through the reduction, alternative use, recycling and recovery of materials in production/distribution and consumption processes. In addition, it can promote new business opportunities, innovation and the creation of new jobs, while saving energy and raw materials and minimizing the impact of activities on nature.
However, it is unclear whether these stimulating factors act as enabling factor for all companies equally, in particular for small and medium-sized companies (SMEs). SMEs differ from larger organizations in terms of their available resources as well as their technology and R&D capacities, which affects several types of business activities. 99% of all enterprises in the EU are SMEs, responsible for 70% of total industrial pollution and 40-45% of industrial air emissions.
To explore this gap, my PhD thesis addresses the following questions:

- What are the barriers to and drivers for a CE in general?
- Which topical areas perceive Austrian SMEs as in important in the context of CE and how are they perceive to perform respectively? The purpose of this research is to identify key CE issues for Austrian SMEs.
- Furthermore, which contextual factors (e.g. company size, sector or external influences) influence the perceived importance and performance in these topical areas?
- Finally, due to the heterogeneous nature of SMEs, similarities between SMEs in different sectors are investigated in order to get a deeper understanding of the motivational factors for CE adaptation.

A further emphasis of the PhD thesis is the consumer perspective regarding CE. Moreover, consumer motivations for CE are investigated, with the aim of identifying overlaps between SMEs and consumers in the context of a CE in order to explore a unique business/consumer interaction.
For the research analyses I use both, primary empirical data based on conducted surveys and secondary data sources.
The doctoral thesis is embedded in the activities of the INTERREG project "Start Circles".

PhD student: Daniel Holzer
Duration: 2018 – 2022

2.4.5 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

2.4.6 Business Model Innovation for the Circular Economy: Understanding, Exploration and Guidance

Unsustainable patterns of production and consumption are pushing the economy beyond natural planetary boundaries, thus requiring an urgent shift towards a sustainable trajectory. In recent years, the Circular Economy (CE) paradigm has been promoted as an effective contributor to Sustainable Development and, even though there has been a broad interest on the concept, the business community has been slow in adopting its principles. Widespread adoption of circular business models is required to accelerate the transition, however, the literature supporting the process of business model innovation (BMI) for the CE -or Circular Business Model Innovation (CBMI)- is currently emerging. Though several publications on the topic have been published in the last five years, there is still a lack of understanding -and lack of guidelines- on the process of CBMI, particularly for incumbent firms; and, as the majority of the literature is theoretical, further empirical insights are required.

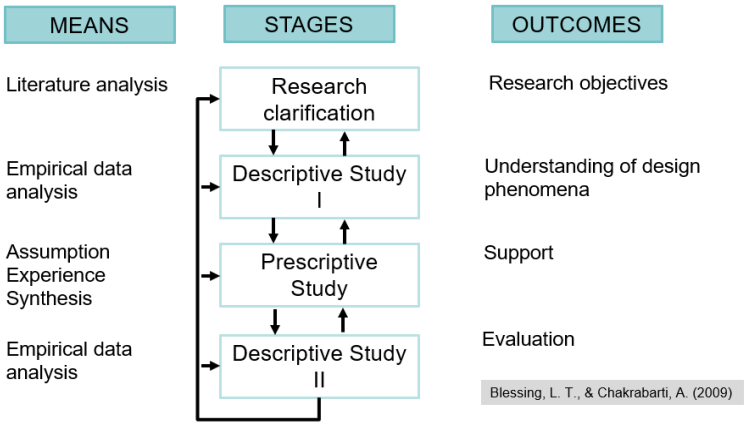
The goal of this thesis is to support the development of Business Models for the Circular Economy in incumbent firms, by compiling and assessing current knowledge on CBMI, exploring its occurrence in existing firms and providing guidelines to future innovation processes. This will be done through three interconnected research projects:

Research Question	Research Method	Expected Outcomes
RQ 1.1: What is known about Business Model Innovation for the Circular Economy (CBMI) and where should further research go?	Systematic literature review	(i) CBMI framework that summarizes the emergent field, built upon the structure of the BMI field; (ii) Identification of under and un-researched subtopics.
RQ 1.2: How can the emerging field of CBMI leverage on the maturing field of Business Model Innovation (BMI)?		
RQ 2: How does the process of CBMI happens in the practice in incumbent firms?	Multiple case study of CBMI on incumbent firms.	(i) Exploration of under-researched CBMI subtopics; (ii) Key elements and best practices of the CBMI process; (iii) Empirical review of drivers and barriers for CBMI
RQ 3: How could the process of CBMI be guided and facilitated using a Design Thinking approach?	Action research through specifically designed workshops and tools.	(i) Guidance through a CBMI process framework; (ii) Set of workshops and tools to facilitate specific stages of the CBMI process.

PhD student: Tomas Santa Maria Gonzalez
Duration: 2018 – 2022
Reference: CRESTING ITN MSCA Project

2.4.7 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
Reference: CRESTING ITN MSCA Project

2.4.8 **Consumer decisions: The case of sustainable mobility behavior**

Climate change is one of the greatest challenges of our time. A particularly problematic area in the context of mitigation is transport, where emissions are still rising. Although the magnitude of the task ahead is clear, action necessary to not exceed the 2-degree target is still lacking. But why? In this thesis, I argue that, while many of the efforts to date have focused heavily on technological improvements, behavior changes on the demand side must also occur to address this crisis. This requires the development and implementation of so-called "disruptive" policy packages that fundamentally change the current system. At the same time, there is a tension between the relevance of push measures that make driving less attractive, on the one hand, and the need for public acceptance for the implementation of such packages of measures, on the other. By applying quantitative and qualitative social science research in the Austrian context, I show that a balanced policy package is needed to effectively address climate change in passenger transport. Building on this, a quantitative analysis underlines the importance of policy packages for considering distributional aspects. Since the lack of public acceptance for such policy packages can hinder their implementation, I also examine the support for particularly restrictive policies. Finally, a case study of academic air travel sheds light on factors that influence people's willingness to reduce flying in the future. In the discussion, I address the importance of disruptive change and discuss its implications for policy by outlining current plans for transport policy, lessons learned from the pandemic, and critical factors for successful implementation. I also outline the content limitations of the thesis and propose several potential areas for future research.

Main research questions: How can rapid decarbonization in passenger transport be promoted through policy-driven behavior change? Which implications can be derived for policymaking?

Included papers:

Dugan, A., Mayer, J., **Thaller, A**., Bachner, G. & Steininger, K. (2022). Developing policy packages for sustainable passenger transport: A qualitative and CGE analysis of trade-offs and synergies, *Ecological Economics*, 193. doi:10.1016/j.ecolecon.2021.107304

Thaller, A., Schreuer, A., Posch, A. (2021). Flying high in academia – Willingness of university staff to perform low-carbon behavior change in business travel. *Frontiers in Sustainability – Sustainable Organizations*, 2, 790807. doi:10.3389/frsus.2021.790807

Thaller, A., Posch, A., Dugan, A. & Steininger, K. (2021). How to design policy packages for sustainable transport: balancing disruptiveness and implementability. *Transportation Research. Part D: Transport & Environment*, 91, 102714, doi:10.1016/j.trd.2021.102714.

Thaller, A., Wicki, M., Fleiß, E., Maier, R., Posch, A. Pushing low-carbon mobility: A survey experiment on the public acceptance of disruptive policy packages. *Climate Policy* (to be submitted/in preparation)

PhD student: Annina Thaller
Duration: 2018 – 2022

2.4.9 Transition towards a low-carbon electricity system: Analysing the contexts of emerging Asia from a system reconfiguration perspective

Fighting against energy poverty and upscaling sustainable energy access through low-carbon development in poor rural areas is considered a feasible climate change mitigation action. At present, 759 million people in developing Asia have no access to electricity, thus facing wealth and income constraints as well as human developmental deficits that make them vulnerable to the vicious cycle of poverty. Over the last 15 years, governments have promoted off-grid solar electricity in rural areas through a market-based system in association with donor agencies. However, a market system falls short in reaching out to rural households in the last mile, requiring governments to play a crucial role in electrifying over 600 million to achieve the sustainable development goal on energy (SDG 7) by 2030. Therefore, in electricity access deficit countries such as Bangladesh, India, Kenya, and Nigeria, national governments are adopting a quasi-market-based approach involving local political leaders to implement 'solar energy safety nets' and deliver clean energy services through rural energy markets. Nonetheless, off-grid solar energy endeavors raise distributional equity concerns.

My doctoral research is built on interdisciplinary theoretical insights, particularly trans(-)action (cost) theory in new institutional economics by J.R. Commons and Oliver Williamson, governance logic of transition studies by Timothy Foxon, and distributive justice principles, Jhon Rawls. In my research, I aim to investigate the effect of different institutional arrangements on the outcomes of the low-carbon off-grid electrification in the context of energy-poor regions of Bangladesh. In particular, I address the following research questions taking both the positivist and pragmatist approaches:

Firstly, what is the impact of market concentration on the installation of solar home systems in rural off-grid areas? Paper one is entitled, 'The impact of supply structure on solar home system installations in rural off-grid areas' (Environmental Innovations and Societal Transitions - https://doi.org/10.1016/j.eist.2021.10.015).

Secondly, whether a microcredit lending model distributes the financial cost of energy loans equitably across rural households facing borrowing constraints? Paper two is entitled, 'Distributional inequality in market-based solar home system programs: Evidence from rural Bangladesh' (Energy Economics - https://doi.org/10.1016/j.eneco.2021.105523).

Finally, does the geographical representation of local leaders affect the distribution of solar energy safety nets in Northern rural villages? Paper three is entitled, 'Spatially distributive benefits of solar energy safety nets: Local political representation matters!' (work-in-progress). Additionally, my research also comments on how solar energy safety nets improve pandemic-resilient livelihoods in rural areas? The research letter is entitled, 'Energy access and pandemic-resilient livelihoods: The role of solar energy safety nets' (Energy Research & Social Science - https://doi.org/10.1016/j.erss.2020.101805).

PhD student: Rafia Zaman
Duration: 2018 – 2022

2.4.10 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. Along with the increasing competitiveness at the global market and the pressure to reduce emissions from road vehicles, 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 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 the 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 investigate on the technological innovation through the lens of patents, more specifically through patent landscape analysis. While other aspects will be explored through innovation approaches and relevant models leading to enhanced understanding of innovation in low carbon and sustainable mobility system. Both qualitative and quantitative mixed method approach will be adopted for this purpose.

PhD student: Jyoti Prajapati
Duration: 2019 – 2022

2.4.11 Innovation in the forest-based sector in the light of climate change

Climate change is undoubtedly one of the main environmental challenges of the 21st century, its ripples disturbing natural and human-made systems alike. Institutions and organizations at all levels are establishing agreements (e.g., Paris Agreement), and participating in programs (e.g., Horizon 2020), strategies (e.g., Europe 2020) and joint initiatives (e.g., COST, EIP-AGRI) to foster a development model which counts on knowledge, innovation, sustainability and GHG reduction among its main pillars. The role that forestry and innovation are to play within the next decades has been widely identified as paramount in the action plans against climate change. Forests and the forest-based sector potentially offer one of the most efficient, economically feasible and socially beneficial options to capture and store CO2. However, this mitigation potential is threatened by the negative impacts that climate change is having on forest-based systems. Thus, innovation emerges as a necessary process that is of the essence to adapt them to the new scenarios generated under the effects of global warming.

With this background in mind, my PhD dissertation will be focused on the interrelations between climate change and innovation in the forest-based sector, mainly articulated around three research projects:

- The first project consists of a systematic literature review of the existing literature on the link between climate change and innovation in the forest-based sector in a global scale. Despite the considerable amount of literature on climate change mitigation and adaptation in forestry, and separately innovation and innovativeness in the sector, our study seems to be the first analyzing the important gap on how they relate to and influence each other and its outcomes.
- The second project studies the factors influencing the innovation (pre)disposition of companies in the forest-based sector towards climate change mitigation and/or adaptation. A survey designed in cooperation with colleagues from the InnoRenew CoE Institute in Slovenia, sent to companies in the forest-based sector, will allow us to collect data on the matter and establish a comparative analysis. It will initially be tested in Austria and Slovenia, and upon its success, the survey will be also used in Finland and Spain. This study is developed within the "Innovation activities of Austrian and Slovenian companies in the wood-value chain" project, funded by the Austrian Agency for International Cooperation in Education and Research.
- The third project will investigate the effect of climate change on collaborations among the different agents of the forest-based sector's quadruple helix (academia, industry, government, and civil society).

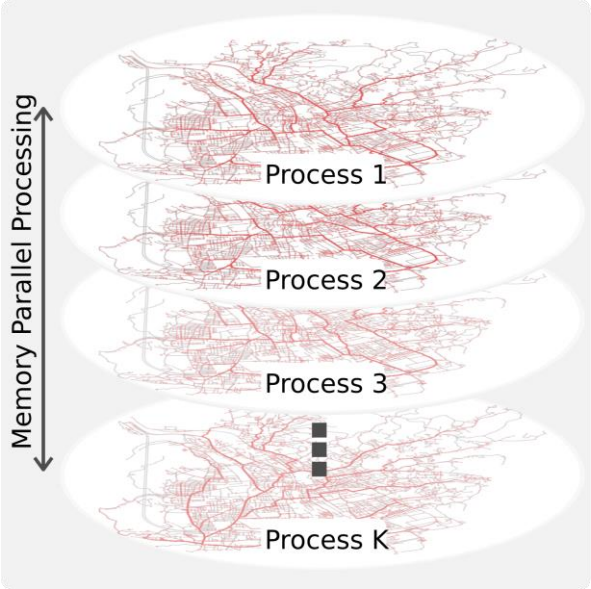
PhD student: Miguel Moreno
Duration: 2019 - 2023

2.4.12 Model based decision support for low carbon transport - Leveraging large sale network research with parallel computing

Current transportation and traffic models are vast and various. However, they fail to achieve a computational speed which would foster creative and interactive decision-making processes. The traffic model recently developed at the University of Graz already outperforms other models of similar scope in terms of speed. Nevertheless, the possibility of further acceleration and improvement is still given.

The first part of optimization regards the algorithmic expression for the already included Monte-Carlo like trip generation scheme. An alternative formalism could not only yield less computational demand, but furthermore still provide a qualitatively similar result. In the subsequent parallelization step, this algorithm is implemented upon a graphical processing unit (GPU). Such a highly parallel processing architecture may ultimately lead to almost instantaneous results. Therefore, a combined approach of a novel algorithm and parallel execution model is proposed to leverage such an implementation fostering interactive decision making.

Moreover, through the introduction of route choice based on the principle of future state maximization, also the realism of the model is aimed to be improved. On a microscopic level such a shift from a deterministic to a stochastic route planning model could yield a more human like driving behavior. Insights in the application of future state maximization may also help drive this novel field of research into new, prospering provinces.



Hence, the project encompasses a threefold approach of optimization, parallelization, and future state maximization. This trinity aims to overcome the struggle in between an accurate and a fast simulation adapting the scope form micro- to mesoscopic detail.

PhD student: Simon Plakolb
Duration: 2019 – 2023

2.4.13 Data Management for Sustainable Product Management in a Circular Economy

Sustainability and digitalization are two major driving forces and megatrends of today's markets and for organizations and impose major transitions on the world on various areas. These major transitions are urgently needed as the footprint of humankind on the global ecosystem has now become so active and big that it competes with some of the forces of nature in its impact on the functioning of the earth system. In 2018, over 89 billion tonnes of materials were extracted from the global economy and according to the circularity gap report only 9,1% of materials were being recirculated in the economy. That circularity gap even widened to a global resource circularity of only 8,6% in 2020. This resource overuse leads to environmental problems due to related emissions and waste flows and to societal problems caused by the current unsustainable production and consumption patterns. The linear consumption patterns of resources (by humans) result in a pressing state for the planetary resources and threatens the planet's carrying capacity and boundaries. To ease these pressures and decouple economic growth from resource consumption the concept of a circular economy (CE) gained attention in the last years. CE is described as an economic system that is restorative and regenerative by keeping materials at their highest value form in a closed-loop flow within the economic system. To implement a CE, the information and communication technology architecture of organizations and its dynamic adaptation to new technological developments can play a vital role.

Derived from the problem background described above, this thesis contributes to the literature by describing how sustainable product management, driven by environmental and social product data (partly from new digital technologies,) could underpin the transition towards a CE as a means to contribute to sustainable development. The overall research goal is to contribute to the operationalization of the generic meanings of sustainable development and CE on the corporate and product level and to show how to utilize the potential of digitalization for sustainable product management. Currently, it is not sufficiently clear which and how sustainability-related information, environmental and social product life cycle data, should be collected, managed, and shared along circular value chains of products.

Therefore, this thesis aims to understand the potential of data management to inform sustainable product management in a CE and to develop methods and/or concepts to collect, aggregate, manage and share sustainability-related information along a circular value chain of a product. In the field of data management for sustainable product management, a contribution shall be achieved by analysing (and utilizing) the potential that digitalization offers for sustainable product management and CE with sustainability and social scientific methods. The findings are ought to reflect and complement the technology-driven developments in these fields. Finally, the findings should facilitate the integration of relevant sustainability data into methods for a holistic and data-based sustainability assessment and sustainable product design in a CE.

PhD student: Magdalena Rusch
Duration: 2020 – 2023

2.4.14 Digital product declaration for a traction battery

The uptake of electric vehicles is projected to lead to an increase in demand for corresponding traction batteries, which often contain critical raw materials, such as lithium and cobalt. One could argue that the value chain of an electric vehicle traction battery might experience potential benefits (e.g. security of raw material supply) when transitioning from a linear to a circular one. However, a more circular value chain does not necessarily equate to a more sustainable one, and therefore calls for the investigation of possible positive and negative effects of a more circular value chain with respect to its sustainability. To achieve the transition to a sustainable circular value chain, respective value chain stakeholders need information, or rather data in order to (1) identify potential sustainable value chain loop-closing pathways, and (2) to decide on pathways that shall be pursued. However, a lack of quality data, as well as tools to assess the sustainable circularity performance at product level pose major challenges for value chain stakeholders when pursuing sustainable circularity product management endeavors. These challenges could be taken on by digitalization and its respective information technologies, such as the Digital Twin.

The objective of this PhD project is to develop a concept for a Digital Twin-driven digital product declaration (DPD) of an electric vehicle traction battery in the context of sustainable circular product management. A Digital Twin is initially described as a virtual real-time representation of a physical product, meaning that a Digital Twin is able to gather real-time data, and contain information based on such data with respect to its real-world counterpart. One of the core components of a Digital Twin is its underlying information model. To develop a concept for a Digital Twin-driven DPD of a traction battery the PhD project aims at developing the underlying information model with close cooperation of practitioners to generate a general understanding of (1) the traction battery value chain itself, (2) value chain stakeholder's decision-making problems in a context of sustainable circular product management, (3) as well as corresponding data needs and requirements.

The PhD project provides the following contributions to existing research:

- exploring the potential of Digital Twin in the context of sustainable circularity assessment at product level,
- a comprehensive identification of stakeholders along the value chain of an electric vehicle traction battery,
- identification of value chain stakeholders' data needs and requirements to support a sustainable circular product management,
- a valid and practical information model for a Digital Twin-driven DPD of an electric vehicle traction battery due to stakeholder engagement throughout the design and development process of the model,
- a building block for potential Digital Twin-driven DPD implementation regarding sustainable
- circularity assessment of electric vehicle traction batteries, as well as for other areas of application.

PhD student: Katharina Berger
Duration: 2020 – 2023

2.4.15 Carbon neutral transportation methods for urban last-mile delivery

In the past decade, an enormous growth of e-commerce has been observed, which can be expected to continue in the future. In 2019, business-to-consumer e-commerce accounted for approximately 11% of Austria's private household retail sales and 68% of the population used delivery services at least once that year. This enormous increase affects the delivery sector and challenges to look for innovative solutions. At the same time, more and more cities become aware of their big responsibility in climate change mitigation and seem to be willing to take policy measures on different levels. Due to incentives and big efforts, electric alternative transportation methods like e.g. electric vehicles, e-bikes or drones gain in popularity, which is a hopeful evolution.

In my PhD project, I examine and evaluate the usage of carbon neutral transportation methods for urban last-mile delivery. The usage of smaller delivery vehicles (bikes, scooters, drones, …) brings many advantages in dense urban areas. In small city centers, some streets may not be accessible for larger vehicles or are even completely car-free. Finding a parking place might even pose a bigger challenge in an urban context. A case study in London showed that delivery cars were parked for 62% of the time, while the drivers had to walk from the parking spot to several customers.

Apart from evaluating alternative transportation methods, my research also focusses on the urban network topology, in an attempt to determine properties of the customer network which play in the advantage of a certain transportation type. This should facilitate delivery companies to rethink their routes in order to make optimal use of carbon-neutral vehicles.

Because of their limited capacity, small vehicles need to be reloaded more often. Many solutions to this logistic issue are described in the literature or are put in practice already. In this project, I will compare existing strategies for Graz, including the distribution of parcel collection points in the city center or synchronization between large and small vehicles. When applying such solutions in a concrete situation, as is planned for the city of Graz, logistics have to be properly worked out to synchronize the timetables of different vehicles. Decisions have to be made about the clustering of customers, matching specific vehicles to certain customer sets, finding out where different vehicles could meet, and where to place parcel collection points. Providing a framework in which these decisions can be made and compared easily will be of advantage for both delivery optimization and city planning.

PhD student: Annelies De Meulenaere
Duration: 2020 – 2024

2.4.16 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
Duration: 2020 – 2024

2.4.17 Culture and Computation: How artificial societies contribute to the understanding of cultural dynamics

Literature on culture is vast and multi-faceted. Culture and its role in social life have been studied for many years now. Still, many of its dynamics, properties and mechanisms are not yet fully understood. This research aims to identify existing gaps and show how the study of culture may be approached from a complex systems and multi-agent perspective. We take into account the interplay between different cultural dynamics distinguishing between three levels of cultural analysis in particular: the macro level focusing on macroscopic phenomena, patterns and regularities, the micro level dealing with individuals and their interactions, and the nano level describing mental representations and underlying cognitive processes. Multi-agent models allow us to study a wide range of cultural phenomena. Our aim is to further contribute to the understanding of culture and culture related topics by modelling cultural dynamics with the use of artificial societies. In this endeavour, we will focus on two things: First, contribute to the understanding and modelling of the transmission process of cultural information, and second, connect the three levels of cultural analysis (nano, micro, and macro) to create a better understanding of the systemic relationships between them. To address these two areas of focus, we have formulated the following general research questions:

- Research Question 1: What theories exist on the transmission process of cultural information and how can they be translated into formal multi-agent models of cultural dynamics? This question specifically targets the study of micro level interactions and underlying nano level processes. It includes the identification of key properties and mechanism from an informal sociological and psychological point of view and, subsequently, from a formal modelling point of view.

- Research Question 2: How may the three levels of cultural analysis (nano, micro, and macro) be linked through multi-agent models and what kind of systemic properties can be identified in this process? This includes the identification of causal relationships and directional feedbacks between different levels. For example, micro level interactions might lead to certain cultural macro patterns. But as soon as these patterns have established themselves on the macro level, they can work back on the micro level, possibly shaping and reshaping future micro interactions.

- Research Question 3: How can the understanding about key mechanisms from Research Question 1 and the understanding about systemic interplay between the three levels of cultural analysis from Research Question 2 be used to provide decision support for dealing with real-life social groups and cultural dynamics. For example, targeted interventions of certain cultural dynamics might be formulated based on the identification of critical parameters that amplify certain dynamics, or on key types of social agents that hinder or promote certain dynamics, or on other systemic structures that amplify certain dynamics such as echo-chambers that promote polarization in social networks.

PhD student: Daniel Reisinger
Duration: 2020 – 2024

2.4.18 Information and Knowledge Retrieval with NLP in Environmental System 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 in 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 specialisations 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

2.4.19 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

2.4.20 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 type of policy 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 by means of sustainability assessment.

The main research questions that this research project addresses are:

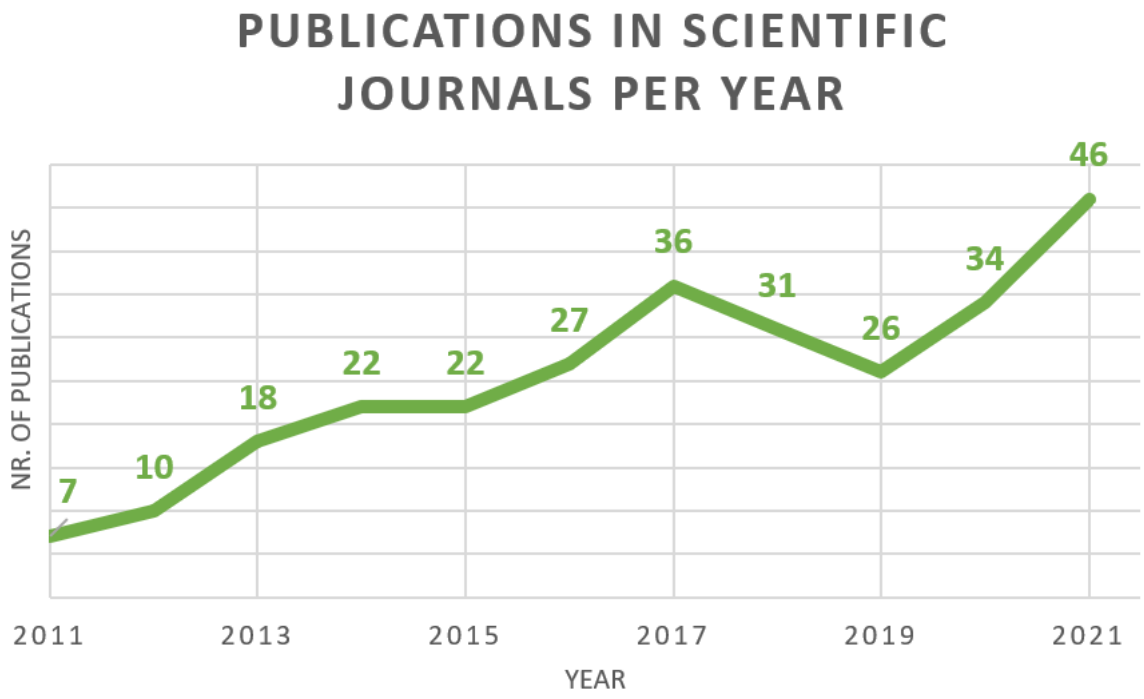
- How can a framework for linking Sustainability with Operational Excellence look like?
- Where and how can the framework be implemented towards Corporate Sustainability?
- What are the main benefits and challenges in applying the framework for Sustainability and Operational Excellence?

PhD student: Katharina Roche
Duration: 2020-2024

3 PUBLICATIONS AND OTHER RESEARCH OUTPUT

In this section, a detailed report on the institute's research output is presented. An overview is given in the following table:

Research activities and output	2017	2018	2019	2020	2021
Publications in scientific journals	36	31	26	34	46
Contributions to an edited book or proceedings	12	16	17	9	10
Posters and Presentations	51	28	61	39	66



Number of publications in scientific journals over the last years

3.1 Publications

3.1.1 Edited book series/journal

Gelbmann, Ulrike-Maria. Höflehner, Thomas; Pirker, Christian; Weichsler, Lisa (Ed.): *Afrika. Jenseits von Klischees und StereotypenBlog.* Grazonline : online 2021.

Gelbmann, Ulrike-Maria; Edlinger, Julia; Holzer, Christoph; Pirker, Christian (Ed.): *Bewusstseinsbildung für Abfallvermeidung.* Grazonline: online 2021.

Gelbmann, Ulrike-Maria; Ledersteger, Alfred, Pirker,Christian, Schalk, Sarah (Ed.): *Plastic Planet _ mei Plastik is net deppad.* Grazonline: online 2021.

3.1.2 Contribution to peer-reviewed journal

Altendorfer, Michael/Pomberger, Roland/Gelbmann, Ulrike-Maria: *Employment effects of different municipal waste treatment systems based on data from Austria,* in: Detritus 15, June 2021 (2021), 136-151. DOI: 10.31025/2611-4135/2021.15090

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Thaller, Annina: *Nudging und Co: Nachhaltige Mobilität und die Rolle der Psychologie,* for: Ich tu´s Webinar-Reihe Mobilitätswoche 2021, Klimabündnis Österreich, Online (Austria), 01.09.2021.

Thaller, Annina: *Pushing low-carbon mobility - A survey experiment on the public acceptance of disruptive policy packages,* for: Beyond Oil Conference, CET - University of Bergen, Bergen and online (hybrid) (Norway), 20.10.2021.

Thaller, Annina: *Pushing low-carbon mobility: Drivers affecting the level of public acceptance or regulatory and economic transport policies,* for: Conference on Environmental Psychology 2021, Norwegian Network for Environmental Psychology & Inland Norway University of Applied Sciences (INN University), Lillehammer, Norwegen (Norway), 18.11.2021.

Thaller, Annina: *Pushing sustainable mobility: A choice experiment on the public acceptance of disruptive policy packages,* for: ERSCP Conference 2021, (Austria), 09.09.2021.

Thaller, Annina: *The road towards sustainable mobility: Disruptive potential of urban transport policies,* for: Energy Futures - Emerging Pathways in an Uncertain World, Leibniz Research Alliance on Energy Transitions, Online (Germany), 25.02.2021.

Thaller, Annina: *The road towards sustainable mobility: Disruptive potential of urban transport policies,* for: Klimatag 2021, CCCA, Online (Austria), 2021.

Wenger, Julia; Haas, Verena; Plakolb, Simon; Mair-Bauernfeind, Claudia; Asada, Raphael; Stern, Tobias: *Developing future visions for products and applications based on FDCA & Selected topics of lignin sustainability and innovation research,* for: COST Fur4Sustain STSM Meetings, VTT Technical Research Centre of Finland, Espoo, Finland (Finland), 21.10.2021.

Wenger, Julia; Mair-Bauernfeind, Claudia; Asada, Raphael; Plakolb, Simon; Stern, Tobias: *Use of technical lignin for material applications – investigation of innovation-diffusion and sustainability issues,* for: JYU.Wisdom Lunch Colloquiums, University of Jyväskylä - School of Resource Wisdom (JYU.Wisdom), Jyväskylä, Finland (Finland), 17.11.2021.

Wenger, Julia; Plakolb, Simon; Asada, Raphael; Mair-Bauernfeind, Claudia; Stern, Tobias: *New biorefinery products from wood – Innovation-diffusion pathways and potential sustainability impacts,* for: CEM research meeting, University of Jyväskylä School of Business and Economics - Corporate Environmental Management, Jyväskylä, Finland (Finland), 29.11.2021.

3.1.6 **Science to Public**

Media article

Anna Díaz Tena, Tomás Santa-Maria, Estephania Delgadillo, Tatiana Reyes, Walter Vermeulen, Rupert J. Baumgartner: *Implementing sustainable circular economy innovations in privatesector organizations,* CRESTING Poliy Briefs, internet, 01.12.2021.

Gelbmann, Ulrike-Maria: *Einweg, Mehrweg, Pfand. Was ist ökologisch sinnvoller?,* Uni Graz News, social media, 02.12.2021.

Gelbmann, Ulrike-Maria: *Experiment. Interview durch David Steinwender (Transition Graz) zu den UN Global Development Goals,* Radio Helsinki, radio, internet, 01.09.2021.

Rauter, Romana: *Glokalisierung Das Beste aus beiden Welten.,* Kleine Zeitung, print, 10.12.2021.

Thaller, Annina; Dugan, Anna: *Verkehr und Klimakrise: Wie nachhaltige Mobilität gelingen kann,* Die Presse, internet, 18.01.2021.

Unterholzer, Antonia; Brudermann, Thomas: *Bitte alle einsteigen!,* Aircampus - Podcast der Grazer Universitäten, internet, other media type, 13.12.2021.

Mentioned in media

Aschemann, Ralf in: Mag.a. Eva Schlegl, *Helena Milchrahm trifft Dr. Ralf Aschemann,* Alumni Universität Graz, print , 20.10.2021.

Baumgartner, Rupert J. in: Bernhard Gaul, *Energiewende als Rohstoff-Fresser,* Kurier, print, 05.11.2021.

Baumgartner, Rupert J. in: Josef Puschitz, *Mehr als Recycling: Wie nachhaltig ist die Kreislaufwirtschaft?,* Business Monat: Das Magazin für Wirtschaft, Nachhaltigkeit und Genuss, print , 01.04.2021.

Baumgartner, Rupert J. in: Lukas Meissl, *Wie nachhaltig sind Kunststoffverpackungen?,* ORF Landesstudio Steiermark: Steiermark Heute, television, 02.03.2021.

Baumgartner, Rupert J. in: Sonja Bettel, *Sind wir bereit für die Kreislaufwirtschaft?,* Der Standard, print , 16.06.2021.

Brudermann, Thomas in: Jochen Stadler, *Forum Alpbach - Experten halten Plastik für besser als seinen Ruf ,* APA / Austria Presse Agentur, internet, 27.08.2021.

Brudermann, Thomas in: Michael Loibner, *Schöne Ausreden für Klimasünden,* Die Presse, print, 28.08.2021.

Brudermann, Thomas in: *Plastik laut Forschern besser als sein Ruf,* Wiener Zeitung, internet, 27.08.2021.

Brudermann, Thomas; Thaller, Annina in: Claus Reitan, *Das gefühlte Wissen zum Klimawandel ist deutlich größer als das tatsächliche,* Klimafakten.de, internet, 09.02.2021.

Jäger, Georg in: Roland Reischl, *Land Steiermark treibt Forschung zur grünen Transformation voran,* meinberizk.at, internet, 24.08.2021.

Rauter, Romana in: Hart, Patrick, *Erfolgs-Faktoren im Home Office,* botenstoff. Human Technology Styria, Ausgabe 4/4 2021, print , internet, 01.12.2021.

Rauter, Romana in: *So gerne arbeiten die Steirer zu Hause,* Kronen Zeitung, print, 05.12.2021.

3.2 External Scientific Functions

Reviews were undertaken for 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
- Technovation
- Urban Forestry and Urban Greening
- Utilities Policy

3.3 Institute of Systems Sciences, Innovation, and Sustainability Research Report

In 2012 the institute decided to issue a report series of its own, called "Institute of Systems Sciences, Innovation, and Sustainability Research Report." The series is dedicated to disseminating interesting scientific results from institute members and their colleagues as well as from excellent students. The aim is to provide a means of publication that works more quickly than journals would and an opportunity to publish excellent research work that has not been published in other ways. This includes research reports, excellent master's or Ph.D. theses as well as collections of papers from conferences (conference proceedings) or excellent reports from teaching projects. The series appears at irregular intervals. It bears an ISSN number and is available in the form of hard copies and especially as a pdf online on our website. The language of publication is German or English.

Published reports:

- SIS Report #1: Florian Hold, Informelle Abfallwirtschaft in Österreich – Chancen, Risiken und Praxis. Graz, October 2012 (in German).
- SIS Report #2: Maximilian Mrotzek, Andreas Kreuzeder, Walter Gössler (Eds): Phosphorus: Papers of an Interdisciplinary Practical Training at the University of Graz. Graz, January 2013 (in English).
- SIS Report #3: Manfred Füllsack (Ed.): Networking Networks. Graz, May 2013 (in English).
- SIS Report #4: Rauter, R., Gsodam, P., Nguyen, T. D., Stabauer, P., Baumgartner, R. J.: New Business Models in Austria -Forerunners in Sustainable Economics. Graz, October 2013 (in English).
- SIS Report #5: Gastinger, B.: Biologische Abfallbehandlung in der Steiermark und ihr Beitrag zum Klimaschutz. Graz, December 2013 (in German).
- SIS Report #6: Baumgartner, R.J., Gelbmann, U., Rauter, R. (eds.): Making the Number of Options Grow. Contributions to the Corporate Responsibility Research Conference 2013. Graz, January 2014 (in English).
- SIS Report #7: Rauter, R., Globocnik, D., Perl-Vorbach, E., Baumgartner, R. J.: Open Innovation und Nachhaltigkeit. Bedeutung von Kooperationen und formalen Managementpraktiken zur Steigerung des nachhaltigkeitsorientierten und wirtschaftlichen Innovationserfolgs. Graz, November 2015 (in German).
- SIS Report #8: Rauter, R., Zimek, M., Kiesnere, A. L., Baumgartner, R. J.: Exploring a changing view on organizing value creation: Developing New Business Models. Graz, June 2017.
- SIS Report #9: Baumgartner, R.J., Damert, M., Fritz, M.M.C., Schöggl, J.-P.: IP Sustainability in Global Supply Chains: A stakeholder perspective. Graz, September 2017.
- Report #10: Rauter, R., Stern, T.: Research Project Innovation Management: Die Digitalisierung der Arbeitswelt. Graz, September 2019.

3.4 Prices and Awards

3.4.1 World's Top 2% Scientists

World's Top 2% Scientists

The Standford University has released an update containing the World's 2% Top Scientists. This list takes into account standardized information on citations, h-index, co-authorship adjusted hm-index, citations to papers in different authorship positions and a composite indicator. We are proud to announce that Prof. **Rupert Baumgartner** is part of this list of the World's 2% Top Scientists.

Source: https://elsevier.digitalcommonsdata.com/datasets/btchxktzyw/

3.4.2 Future Earth Council Member

We would like to congratulate post-doc researcher **Arijit Paul** for being elected into the governing council of Future Earth. Future Earth is an international research program which aims to build knowledge about the environmental and human aspects of Global change, and to find solutions for sustainable development. It aims to increase the impact of scientific research on sustainable development. The project brings together natural and social sciences, as well as the humanities, engineering and law, and focused on designing and producing research together with stakeholders from outside the scientific community. Arijit will work at the interface between science and policy, supporting today's decision makers on major sustainability challenges of the world.

3.4.3 IIASA Outstanding Young Scientist – honorable mention

IIASA has announced the winners of the annual Peccei and Mikhalevich awards for Young Scientists Summer Program (YSSP) participants. The awards are given annually for exceptional papers from the previous year's YSSP cohort. Candidates are nominated by the program director of the relevant IIASA research program and assessed by a committee comprised of one member from each research program. Each candidate's paper is evaluated based on its quality, originality, and relevance. The final decision is made by IIASA Director General Albert van Jaarsveld. **Simon Plakolb** received an honorable mention for his study on: "Using the Future State Maximization paradigm to analyze the emergence of socially sub-optimal mobility behavior".

3.4.4 AGEO Award

The AGEO AWARD aims to support students by recognizing outstanding achievements in the field of spatial information sciences. In 2021 **Theresa Boiger** was awarded 5th place for her Master's thesis "The impacts of fear on cycling in cities - An agent-based model".

3.4.5 ERSCP – Best Student Paper Award

The European Roundtable on Sustainable Consumption and Production (ERSCP) took place in Graz from 8. till 10. September 2021. **Katharina Berger** was awarded the Best Student paper award for her study titled "Sustainable and circular battery management - Conceptualization of an information model".

3.4.6 Anton Schelnast Award

With the Anton Schelnast Award for Performance and Innovation, the University of Graz annually honors colleagues of the general university staff who implement creative ideas, cooperate particularly efficiently, and are exceedingly committed to their field of work. Supervisors as well as colleagues are eligible for nomination. Formerly known as the "Performance and Innovation Award", the award was renamed the "Anton Schelnast Award for Performance and Innovation" in 2017 to commemorate the dedication of Office Director Anton Schelnast (1958-2017) to the university and its staff. In 2021 **Tanja Untergrabner** was awarded this price in the category Commitment.

4 TEACHING

4.1 Study Programmes

4.1.1 Environmental Systems Sciences

In teaching, our institute is the focal institute for the bachelor and master study programmes 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 programme 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 focussing 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 programmes 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 programmes 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 programmes in October 2003 which are still unique in its conception in Europe. Now, about 1,300 students are enrolled in the bachelor and master programmes in Environmental Systems Sciences; the bachelor programmes comprise 180 ECTS credit points which equals a study period of six semesters, and the consecutive master programmes 120 ECTS credit points, or four semesters.

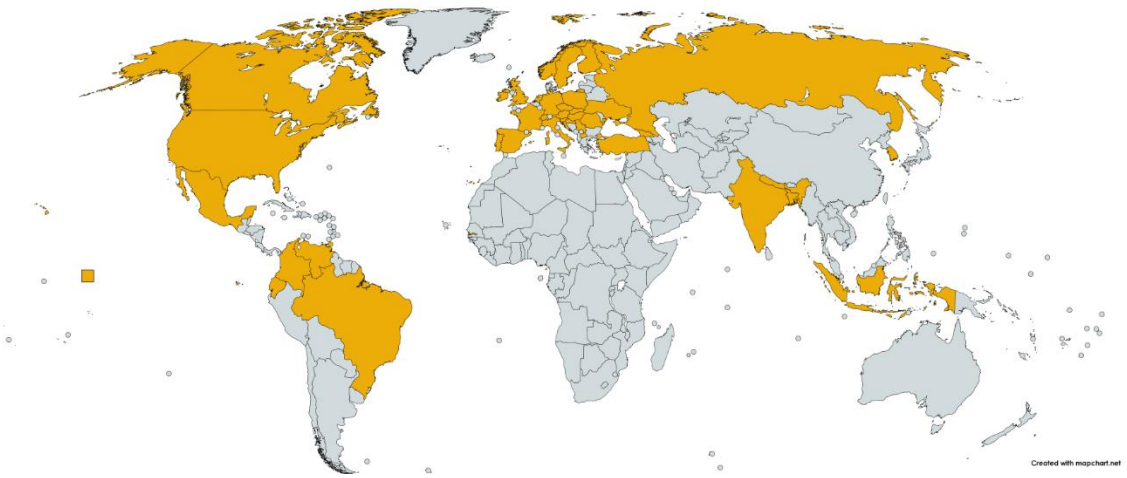
Our institute is responsible for the education in formal methods of systems sciences, mathematics and statistics, interdisciplinary education for basics in human-environment systems, for parts of the teaching subject business administration (bachelor level), for the teaching subject sustainability-oriented 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 transdisciplinarity 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 Programme in Sustainable Development

In this master's programme sustainability issues are approached from an international as well as inter- and transdisciplinary perspective. The focus is set on applying the competences to the question of sustainable development and the needs and possibilities of societal transformation. The programme combines the strengths of eight partner universities: Graz, Leipzig, Utrecht, Venice and Hiroshima are possible entrance universities and offer specialization tracks to students of the other entrance universities. Mobility semesters can also be spent at University of Basel, TERI University (India) and Stellenbosch University (South Africa). Students profit from a wide range of perspectives on sustainable development, and are prepared careers in in the private, public and semi-public sectors, or subsequent PhD studies.

2021 came with continued challenges due to the pandemics (online courses in the summer term, and restrictions regarding the mobility semesters). Nonetheless, 2021 also was a record year for the program in Graz: The number of applications increased significantly, and eventually 25 students from 18 different countries were admitted. We were happy to welcome our first students from Ecuador, Indonesia, Mexico, Ireland, Ukraine and Georgia. The highly active and diverse student community is definitely a big asset of the institute.



The map shows the nationalities of the students in the last 10 years.
Incoming students from the partner universities are not included in this map.

Admission to this Master's Programme 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 Master's Programme comprises 120 ECTS credits corresponding to a period of study of at least four semesters or two years. 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 institute offers courses for the first semester in basics in Sustainable Development, and for the integration module in the third semester. For students of our partner university 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 Programme in Sustainable Development can be found at www.jointdegree.eu/sd. The students of the program also operate a website – see https://sustainers-graz.weebly.com/.

4.1.3 Erasmus Mundus Master's Programme on Circular Economy

Beside the International Joint Master's Programme in Sustainable Development and the 2017 completed "Erasmus Mundus Master's Programme in Industrial Ecology", the Erasmus Mundus "International Master's Programme on Circular Economy (CIRCLE)" is already the third Joint Master Programme co-ordinated by our institute.

At first, the funding of the European Commission lasts until 2024 and consists of 62 scholarships for four intakes of students (which start 2019, 2020, 2021 or 2022, respectively), which have to be selected by the CIRCLE consortium.

The curriculum of CIRCLE is designed as "Erasmus Mundus Double Master Degree", thus 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 co-ordinating the CIRCLE programme and Ulrike Krawagna, Anja Hoffmann and Melanie Novak 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).

From 8 to 13 August 2021, two intakes of CIRCLE students met face-to-face for their summer school and the first CIRCLE graduation, both organized at Seggau Castle in Styria. Due to the pandemic, the newcomers' intake joined the event online for its orientation week. The fresh graduates and the CIRCLE team are pictured in the photo! For more information on CIRCLE, please browse to https://www.emcircle.eu!

4.1.4 **Global Studies**

SIS, together with the dean's office, has been in charge of managing the three master programs "Global Studies" at the University of Graz for nearly two years now. The program consists of three comprehensive and diverse curricula that source their courses from all six of theuniversity's faculties and an additional four interfaculty centers. Global Studies have developed since 2010 in a growth process supported by the commitment and interest of researchers, lecturers and students of our university in cooperation with external organizations. The KoBü Coordination Office for Environmental Systems Sciences and now Global Studies took care of about 350 master's students from the three programs contained in the Global Studies in 2021.

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 focal contents, which also corresponds to the "Sustainable Development Goals" of the United Nations. Global Studies prepare their students to think and act holistically in an increasingly complex, dynamic globalized world.

To this end, Global Studies are inter- and multidisciplinary. The know-how achieved enables graduates to professionally analyze the numerous international and intercultural challenges that society is currently facing due globalization. In their studies, students develop the sensitivity and integrated way of thinking required in a wide variety of multicultural settings.

A group of Global Studies students of the 2021 IP "Plastic Planet" at the Saubermacher plastic sorting plant in Graz

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. In each of the three programs students can choose from several disciplinary specializations and additionally from interdisciplinary modules designed to broaden mindsets and guarantee for an outside the box perception. 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, which was shaped in reference to the IPs in Environmental Systems Sciences.

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 programme 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 Programme DK Climate Change

In the winter semester 2014, the interdisciplinary doctoral programme **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 programme and Univ.-Prof. Dr. Gottfried Kirchengast (Wegener Center for Climate and Global Change) serves as co-speaker. Three of the eleven board members are affiliated with our institute: Univ.-Prof. Dr. Rupert Baumgartner, Ao.Univ.-Prof. Dr. Alfred Posch and Univ.-Prof. Dr. Wilfried Winiwarter. The programme is supported by Dr. Bettina Lackner and Mag. Regina Brunnhofer.

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 programme's partner universities.

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

4.2 Completed theses (master and doctoral)

In 2021 **42 master** students completed their thesis within one of the study programs Environmental Systems Sciences, Global Studies, Sustainable Development, and Industrial ecology. They are listed in alphabetical order.

Albers, Vivien Katharina (2021): Transition from below: Opportunities and Limits of Niche Actors in Promoting E-Cargo-Bike Sharing for an Urban Sustainable Mobility Transition
Supervisor: Posch Alfred

Andrade de Oliveira Alcantara, Luciana (2021): The circular transition of the fashion industry and its contributions towards sustainable development
Supervisor: Aschemann Ralf

Bauer, Bernadette Adele (2021): National Policies to Remedy and Prevent Human Rights Violation in Supply Chains: An Analysis of Selected National Policies on Human Rights with a Focus on Food Supply Chains
Supervisor: Aschemann Ralf

Bisko, Nina (2021): Development of sentiments towards artificial intelligence-based energy management optimization in buildings towards achieving Sustainable Development Goal 7
Supervisor: Jäger Georg

Boiger, Theresa (2021): The impacts of fear on cycling in cities - An agent-based model
Supervisor: Füllsack Manfred

Chakalova, Kalina (2021): Collaboration in the fuzzy front end of the innovation process in cluster focus groups
Supervisor: Rauter Romana

Chaudhary, Shamita (2021): Circular Economy in the Indian Construction Sector: Status Quo, Barriers, and Potential Solutions
Supervisor: Rauter Romana

Diem, Magdalena Sophie (2021): Sustainability in Industrial Enterprises - Relevance of the Sustainable Development Goals in Wood Processing
Supervisor: Stern Tobias

Dockhorn, Anna (2021): Sustainable Development of Alpine Summer Tourism in the Austrian Alps - Potential Climate Change Impacts, Challenges and Strategies for Sustainable Development
Supervisor: Aschemann Ralf

Figler, Diana (2021): Sustainability implications of reusable coffee-to-go-cups: Case study BackCup Graz
Supervisor: Aschemann Ralf

Gruber, Lukas Alexander (2021): After-sale marketing in the wood industry - Wood mobilization in small-scale forests through the use of after-sales activities
Supervisor: Stern Tobias

Harrer, Melanie (2021): Carbon Management for Climate Protection: Analysis of the Greenhouse Gas Emissions of the University of Graz Campus and Campus-related Gastronomy
Supervisor: Aschemann Ralf

Hauswiesner, Angelika (2021): Dynamics of Collective Expectations About Wind Power in Germany
Supervisor: Posch Alfred

Hilz, Xaver (2021): Assessing areas of concern in the commercialisation process of biorefineries – an Importance Performance Analysis
Supervisor: Stern Tobias

Hirsch, Devika (2021): Sustainable Business Models in the Digital Economy: An Analysis of Platform Cooperatives in the Service Sector
Supervisor: Rauter Romana

Hofer, Caroline (2021): A comparison of national circular economy strategies and roadmaps of EU countries and the resulting learning potential for Austria
Supervisor: Aschemann Ralf

Humaira, Nadya (2021): The challenges of circular business models in food delivery services in Indonesia: Reuse and return systems for food packaging
Supervisor: Rauter Romana

Kainz, Kristina Maria (2021): Implementation of measures to raise awareness in the area of sustainability - Qualitative analysis of the activities of three Styrian educational institutions in the years 2017-2020
Supervisor: Gelbmann Ulrike-Maria

Katholnig, Julia (2021): The acceptance of wood as a sustainable high-tech material in vehicles. An end-user perspective
Supervisor: Stern Tobias

Kienast, Pauline Elisabeth (2021): Sustainability at Farmers‘ Markets. Definition of criteria using the example of the farmers’ market on Lendplatz in Graz
Supervisor: Gelbmann Ulrike-Maria

Klöppner, Johannes (2021): Netnography in Theory and Practice
Supervisor: Stern Tobias

Kogler, Britta Elena (2021): Development of a sustainability assessment method for companies using the example of a battery cell manufacturer
Supervisor: Baumgartner Rupert

Kukies, Tatjana (2021): From laboratory to industrial scale: environmental upscaling effects in the production of automotive wood components
Supervisor: Aschemann Ralf

Kuppek, Selina (2021): Sustainability Communication in the Online Financing Sector
Supervisor: Rauter Romana

Lerch, Philipp (2021): Future economic potential of demand response for the chlor-alkali electrolysis industry
Supervisor: Posch Alfred

Meltzer, Andreas Christian (2021): Environmental Hot Spots of Covered Electrodes: A Life Cycle Assessment
Supervisor: Baumgartner Rupert

Moosbrugger, Lisa (2021): Sustainability aspects in e-commerce - with a special focus on small and micro enterprises
Supervisor: Rauter Romana

Neumayr, Julia (2021): The influence of sustainability reporting on strategic management decisions
Supervisor: Baumgartner Rupert

Oberreiter, Manuel Christian (2021): The sustainability work of the five largest breweries in Austria - implementation and public perception
Supervisor: Baumgartner Rupert

Oka, Putu Tasya Sanjivani (2021): Rethinking mobility: Economic and Environmental Analysis of Service-oriented Transportation for a Decarbonised Transportation System in Austria
Supervisor: Posch Alfred

Pertl, Lukas (2021): Circular Economy in the Construction Industry: Life Cycle Costs of a Wooden Prefabricated External House Wall
Supervisor: Stern Tobias

Popowicz, Martin (2021): Circular economy in the Austrian plastics sector: An exploratory study of the current state and possible future directions
Supervisor: Stern Tobias

Proß, Christoph (2021): Analysing the total social costs of public transport in Austria
Supervisor: Posch Alfred

Rezaie, Shogofa (2021): A Transition Towards Circular Cities - Exploring the Potential of Urban Symbiosis: A Case Study in Stockholm, Sweden
Supervisor: Aschemann Ralf

Rosic, Zeljka (2021): Biogenic waste management in Croatia considering the circular bioeconomy
Supervisor: Gelbmann Ulrike-Maria

Schmid, Johannes (2021): The Rs of Circular Economy: A text mining-based analysis
Supervisor: Baumgartner Rupert

Siegert, Anna Helena (2021): From cocoa pod husk to organic soap: Innovations in the African cocoa sector and their contribution to sustainable development
Supervisor: Posch Alfred

Silber, Susanna (2021): The relationship between corporate culture, sustainability and innovation and the importance of these factors for personnel search and personnel development
Supervisor: Rauter Romana

Silberschneider, Kilian (2021): Circular economy in the Austrian wood sector: An exploratory study of the current situation and possible future directions
Supervisor:: Rauter Romana

Spitalar, Gregor (2021): How do companies in wood processing innovate with regard to climate change avoidance or adaptation, examined using the theory of planned behavior?*Supervisor: Stern Tobias*

Verhnjak, Tina Joanna (2021): Social Collaboration Tools and their use at the workplace in Styrian companies
Supervisor: Rauter Romana

Zombori, Lilla (2021): Application of a sustainability balanced scorecard in the industrial packaging sector. A case study analysis on corporate sustainability management and performance measurement
Supervisor: Baumgartner Rupert

In addition, **three doctoral theses** have been completed within the doctoral school for Environmental System Sciences which was founded in October 2011.

Hofer, Christian (2021): Complex Networks and Sustainability: Modeling Mobility, Resilience and Cooperation
Supervisor: Füllsack Manfred

Schweiger, Gerald (2021): Smart Energy Systems: Analysis of key technologies that facilitate sector coupling
Supervisor: Posch Alfred

Zilian, Laura Samantha (2021): Technological change and employment dynamics - a complex system perspective
Supervisor: Füllsack Manfred

4.3 Course list

Legend			
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 2021			
Type	**Course**	**Contact hours**	**Lecturers**
SE	Annual Workshop DK Climate Change	2	Bednar-Friedl B, Birk S, Foelsche U, Kirchengast G, Maraun D, Meyer L, Posch A, Schulev-Steindl E, Steiner A, Steininger K
PS	Applied Systems Sciences 1	2	Lechner G, Mellacher P, Schober A
PS	Applied Systems Sciences 2	2	Henner D, Ringsmuth A
SE	ARQUS Winter School: Rethinking climate risk	2	Stelzer H
VU	Calculus for Systems and Environment Sciences	3	Adam R, Kapeller M
KS	Change Management and Learning for Sustainability	2	Gelbmann U, Pirker C
AG	CIRCLE Summer School	2	Aschemann R
SE	Colloquium DK Climate Change: Transition to low carbon and climate resilient society	2	Bednar-Friedl B, Birk S, Foelsche U, Kirchengast G, Maraun D, Meyer L, Posch A, Schulev-Steindl E, Steiner A, Steininger K
SE	Data in Systems Sciences	2	Füllsack M
PS	Economic Technology Assessment and Foresight	2	Stern T
KS	Environmental and Technology Assessment	2	Aschemann R
KS	Environmental Decision Making	2	Brudermann T
SE	How to write a Bachelor Thesis	2	Füllsack M, Posch A, Stern T
VO	Human Beings and Environment: Biosphere and Eco-Systems	2	Raspotnig G, Tschernatsch M

VO	Human Beings and Environment: Geosphere	2	Mergili M, Schöner W
DQ	Human Factor in Digital Transformation	2	Füllsack M, Kleinert J, Kubicek B, Otrel-Cass K, Staudegger E, Thalmann S, Vogeler G, Wessely C
VU	Inter- and Transdisciplinary Methods	2	Aschemann R, Höflehner T
AG	IP: Africa! Beyond clichés and stereotypes	4	Gelbmann U, Höflehner T, Pirker C, Weichsler L
AG	IP: Climate Heroes	4	Höflehner T, Steinwender D, Wrentschur M
AG	IP: E-mobility	4	Hasler A, Senger M, Vlk T
AG	IP: Greening the Gas	4	Kriechbaum M, Nabernegg S, Stern T, Stürmer B
AG	IP: Reducing Packaging in Supermarkets	4	Edlinger J, Gelbmann U, Holzer C, Pirker C
AG	IP: Societal responses to climate risk	6	Meyer L, Posch A, Schöner W, Sefc K, Steininger K, Stelzer H, Weber B
AG	IP: Sustainable Parties in Graz	4	Friesenbichler M, Höflehner T, Rusch M, Schöggl J
AG	IP: Sustainable Tourism	6	Osebik D, Pizzera J, Sattler T, Terler J
AG	IP: Sustainable water and forest management	4	Hubmann R, Regelsberger M, Weiss S
PS	Introductory Seminar - Elementary Statistical Concepts and Methods, Examples and Practice	1	Fleiß E
VU	Linear Algebra for USW	2	Adam R, Kapeller M, Lendl S, Roche K
PS	Management of Sustainable Development 2 Environmental Management	2	Kettele M, Ulz A
SE	Master Seminar	2	Füllsack M, Posch A, Stern T
SE	Master Seminar (Global Studies)	2	Höllinger F, Kleinert J
SE	Orientation Tutoring	0.5	Hummel S
DQ	PhD Doctoral Colloquium I	2	Füllsack M, Posch A, Stern T
UE	Practical Exercises: USW Computational Basics	1	Reisinger D
KS	Practise-Analysis	1	Hohenwarter M
KS	Product and Service Development	2	Globocnik D

KS	Quantitative Methods of Social Research	2	Fleiß E
SE	Realizing Scientific Contributions in Refereed Journals	2	Dentchev N
AG	Research Project Sustainability and Innovation Management	4	Brudermann T, Crockett S, Everall J, Otto I, Ringsmuth A
PS	Selected Topics of Sustainability and Innovation Management (Bachelor Seminar)	2	Mair-Bauernfeind C, Roche K
SE	Seminar for Postgraduates	2	Füllsack M, Posch A, Stern T
SE	Seminar in Research Methodology	2	Asada R, Stern T
KS	Strategic Sustainability Management	2	Gelbmann U, Paul A
SE	Sustainability and Environmental Management	2	Posch A
KS	Sustainability Controlling and Management	2	Kettele M, Mair-Bauernfeind C
KS	Sustainable Innovation	2	Rauter R
VO	Systems Sciences 2	2	Jäger G
VU	Systems Sciences 3	2	Fachbach I, Granigg W
VO	Systems-Modelling and Systems-Analysis	2	Propst G
SE	Systems-Modelling and Systems-Analysis (Agent based modelling)	2	Füllsack M, Jäger G
KS	Transition Management	2	Kriechbaum M, Stern T
KS	Value Chain Management	2	Aschemann R

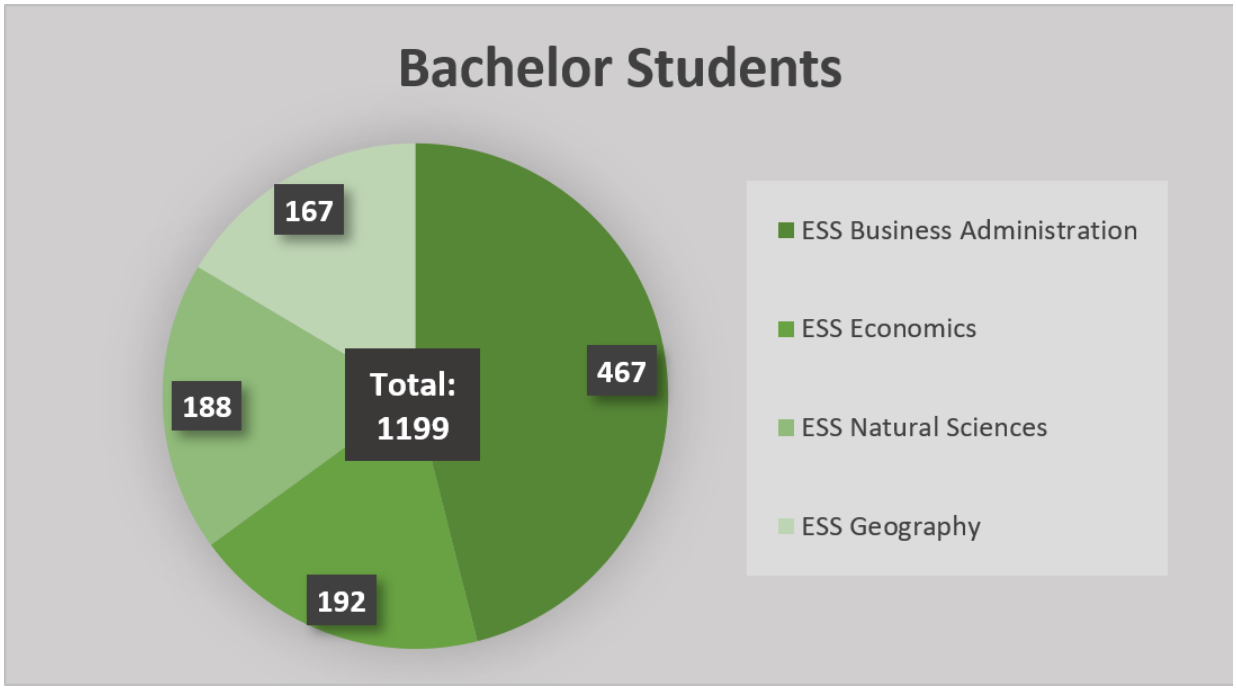
Winter Term 2021/2022			
Type	**Course**	**Contact hours**	**Lecturers**
PS	Applied Systems Sciences 1	2	Mellacher P, Schober A
PS	Applied Systems Sciences 2	2	Bachner G, Jury M, Ringsmuth A
VU	Calculus for Systems and Environment Sciences	3	Adam R, Dugan A, Kapeller M, Steiner E
KS	Change Management and Learning for Sustainability	2	Gelbmann U, Pirker C

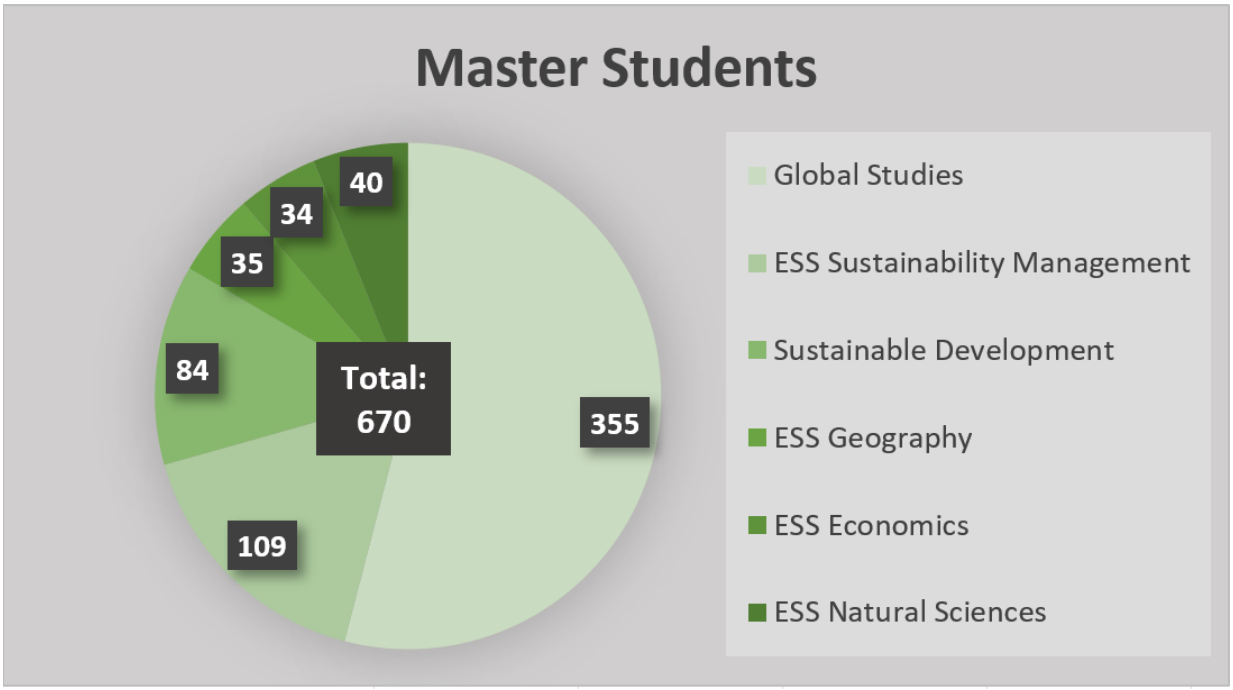
SE	Colloquium DK Climate Change	2	Baumgartner R, Bednar-Friedl B, Birk S, Foelsche U, Kirchengast G, Maraun D, Meyer L, Posch A, Schulev-Steindl E, Steiner A, Steininger K
AG	Cross-university collaboration: Sustainability Challenge	2	Rusch M, Tschuchnik M, Waniek K
SE	Data in Systems Sciences	2	Füllsack M
VO	Data in Systems Sciences	2	Füllsack M
KS	Environmental and Technology Assessment	2	Aschemann R
KS	Environmental Decision Making	2	Brudermann T
VO	Environmentally Oriented Innovation and Technology Management	2	Rauter R, Stern T
VO	Ethical and sociocultural dimensions of globalization	2	Höllinger F, Neuhold L
SE	Fundamentals of Circular Economy and Industrial Ecology	2	Aschemann R
SE	How to write a Bachelor Thesis	2	Brudermann T, Posch A, Stern T
VO	Human Beings and Environment: Anthroposphere	2	Posch A, Steininger K
AG	Inter- and Transdisciplinary Case Study on Sustainable Development	6	Brudermann T, Posch A, Santa Maria Gonzalez T, Wasserbaur R
VU	Inter- and Transdisciplinary Methods	2	Höflehner T, Lakitsch M
AG	IP: Designing decision support for pro-environmental organizational decision-making on sustainability topics	6	Baumgartner R, Fleiß J, Schöggl J
AG	IP: Digital Transformation of Packaging Management	4	Baumgartner R, Kettele M, Rusch M, Schiffleitner A, Schöggl J
AG	IP: Food Justice	4	Karner S, Raith D, Steinwender D
AG	IP: Plastic Planet	4	Gelbmann U, Ledersteger A, Pirker C, Schalk S
AG	IP: Social Entrepreneurship Lab	6	Mayer P, Paul A, Rauter R
AG	IP: Tipping elements in climate and socio-economic systems	4	Ladstädter F, Otto I, Ringsmuth A, Steiner A
AG	IP: Waterpower	4	Hammer A, Maier R, Weiss S

AG	Interdisciplinary Practice Reflection (for students shifted to W18 from W17)	3	Gelbmann U, Pirker C, Weichsler L
VO	Interdisciplinary Scientific Approaches at the URBI Faculty	2	Aschemann R, Breyer C, Kruse A, van Poppel M, Wlasak P
VO	Interdisciplinary Working Methods	2	Aschemann R
PS	Introductory Seminar - Elementary Statistical Concepts and Methods, Examples and Practice	1	Asada R, Fleiß E, Holzer D, Mitterbacher K, Schweighart M
VU	Introdution to Global Studies	1	Gelbmann U, Weichsler L
VO	Law and Economics of Globalization and Development	2	Rossi S, Werther-Pietsch U
VU	Linear Algebra for USW	2	Kapeller M
SE	Master Seminar	2	Baumgartner R, Brudermann T, Füllsack M, Posch A, Rauter R, Stern T
KS	Methods for inter- and transdisciplinary problem-solving	2	Aschemann R
PS	MSD 2 Corporate Social Responsibility	2	Ulz A
PS	MSD 2 (Reportage of Sustainability)	2	Resel K
SE	Orientation Tutoring	2	Hummel S
UE	Practical Exercises: USW Computational Basics	1	Jäger G, Plakolb S, Reisinger D
KS	Quantitative Methods of Social Research	2	Fleiß E
AG	Research Project Sustainability and Innovation Management	4	Crockett S, Mair-Bauernfeind C, Stern T, Waniek K
KS	Selected Topics of Innovation Management	2	Moreno Torres M
SE	Seminar for Postgraduates	2	Baumgartner R, Brudermann T, Füllsack M, Posch A, Rauter R, Stern T
SE	Seminar in Research Methodology	2	Asada R, Fleiß E, Stern T
SE	Social competences for managing sustainable development	2	Neuburger-Hillmayer B

SE	Social Competences for Working in Inter- and Transdisciplinary Teams	2	Neuburger-Hillmayer B
VO	Statistics	2	Fleiß E
KS	Strategic Sustainability Management	2	Gelbmann U, Paul A, Zimek M
VO	Sustainability and Environmental Management	2	Baumgartner R
KS	Sustainability Controlling and Management	2	Baumgartner R, Kettele M, Paul A
VO	Sustainability Dimensions in Globalization and Development	2	Rauter R, Steininger K
KS	Sustainable Business Models	2	Rauter R
AG	Sustainable Development - Integrating Perspectives	6	Brudermann T, Posch A, Steiner A, Wasserbaur R, Winkler T
KS	Sustainable Innovation	2	Rauter R
VO	Systems Sciences 1	2	Füllsack M
VU	Systems Sciences 3	2	Fachbach I, Granigg W
SE	Systems-Modelling and Systems-Analysis	2	Otto I
SE	The Sustainability Challenge	2	Crockett S, Posch A
KS	Transition Management	2	Kriechbaum M, Stern T
PV	Tutorial for Postgraduates	2	Baumgartner R, Brudermann T, Füllsack M, Posch A, Rauter R, Stern T
VO	USW Computational Basics	2	Jäger G
KS	Waste and Recycling	2	Gelbmann U, Schmidt G

4.4 Student Statistics





Number of registered students in 2021 (source: student statistics from UniGrazOnline)

Institute of Systems Sciences,
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