Annual Report 2020

Institute of Systems Sciences, Innovation and Sustainability Research

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

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Editorial

Dear Reader!

When the first news came in late 2019 about a new virus found in China, we were not aware how fast this will have a serious global impact. Although we observed the rising number of cases in Asia and the first infections in Austria by the end of February, we didn´t perceive this as a challenge affecting our daily routines or our teaching and research activities. It was on Tuesday 10th of March 2020 when during our weekly jour fixe the first rumors were reported that teaching will be stopped in the following week. During the afternoon the rectorate decided to stop face to face teaching the next day. And we were not aware that the meeting of the professors of the Faculty for Environmental, Regional and Educational Sciences on March 11th was the last in-person meeting for the rest of the year. What followed was a full switch to home office, to distance learning and to a digitally supported decentralized working mode. Thanks to the motivation of all team members we management this switch successfully - students were provided with online lectures and didn´t lose any courses or exams and also the research processes continued successfully, which is confirmed for instance by the number of peer-reviewed publications.

The pandemic showed also the tremendous importance science has in dealing and coping with global challenges - starting from understanding the disease to finding vaccines in a remarkably fast way. But the last year revealed also the challenges scientists face during times of “fake everything”, where facts and scientific results are not debated in a serious way but systematically discredited and labelled as fake news. We can draw lessons from these experiences for our global sustainability crisis: on the one hand, science can play a crucial role in order to overcome this challenge and to support the transformation to a sustainable society. On the other hand, we have to cope with the resistance against this transformation which occurs as systematic delegitimization of sustainability research.

We can report about the results of the first international evaluation of the Christian Doppler Laboratory for Sustainable Product Management enabling a Circular Economy. Due to the pandemic this evaluation was conducted in a fully remote way and resulted in a positive outcome, i.e. the lab is funded further and even expanded. We are very happy to have AVL engineering as the third partner on board! We also showcased on how to successfully organize a training week in online modus as part of our Marie-Curie-project “Cresting”.

We congratulate Magdalena Rusch, Daniel Reisinger and Katharina Berger who finalized their master studies in 2020 and welcome them in our team as PhD-researchers. We also congratulate Claudia Mair-Bauernfeind, Raphael Asada, Marie Kapeller and Aisma Kiesnere for the successful finalization of their doctoral studies. Last but not least we can report that Romana Rauter finalized her habilitation work entitled “New Perspectives on Corporate Sustainability and Innovation: Strategic Management, Business Models, and Sustainability Innovations”.

All these results couldn’t be achieved without our excellent team members, our partners within the University of Graz and our national and international collaborators - thank you to all of you!

Prof. Dr. Rupert Baumgartner

Prof. Dr. Tobias Stern

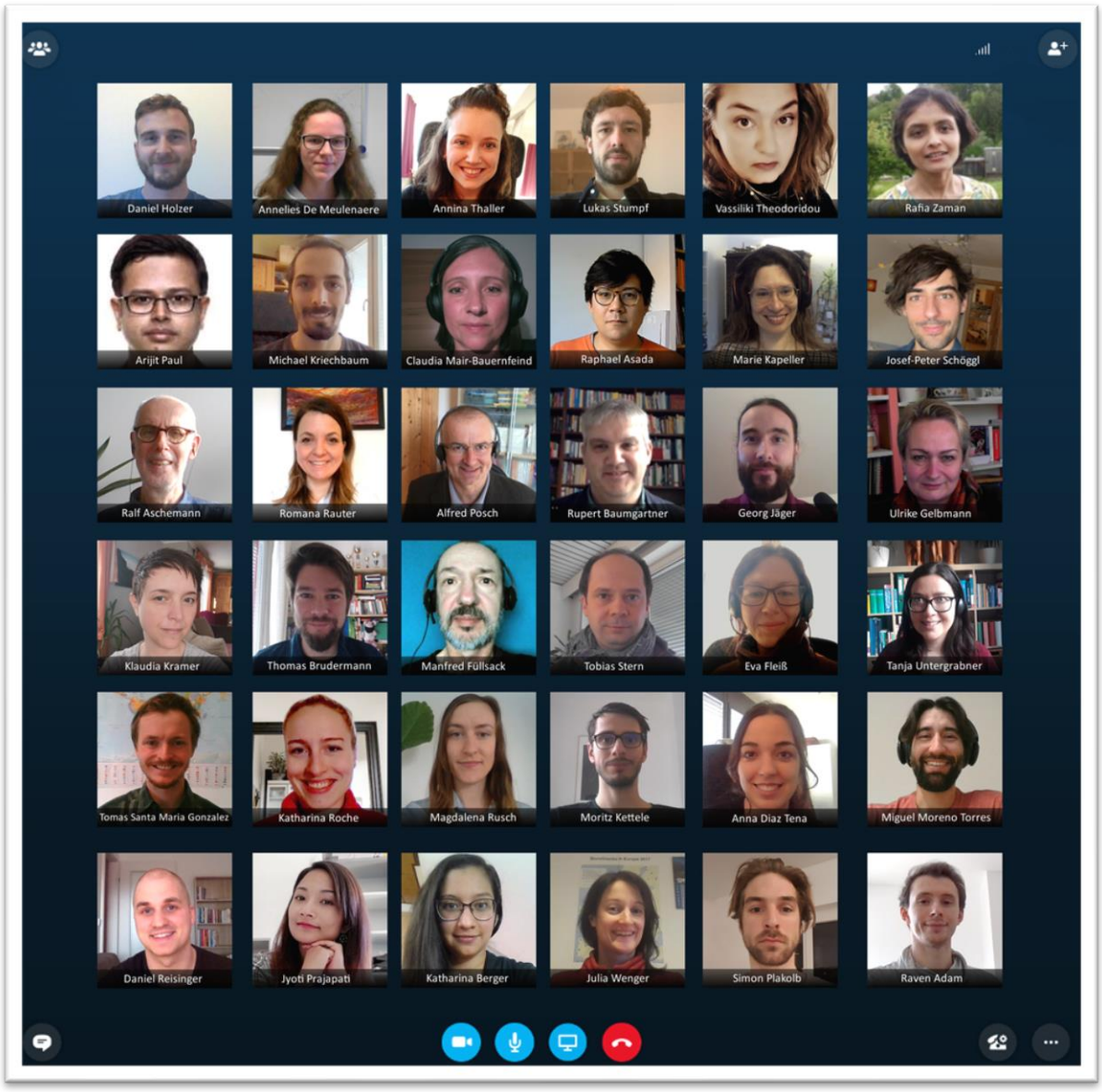
Contents

1 THE INSTITUTE

1.1 Mission statement

The Institute of Systems Sciences, Innovation and Sustainability Research is investigating possibilities for the transition towards a more sustainable world. Therefore, we study transition, innovation, and adaptation processes within human-environment systems, with a focus on firms and regions. We base our research on systems sciences, innovation, and transition sciences as well as on sustainability science, and develop inter- and transdisciplinary methods to analyse and model human-environment systems, develop scenarios and transition pathways, and assess regulatory strategies.

The institute is characterized by the disciplinary diversity of its members. Highly motivated researchers originating from diverse fields of natural, social and formal sciences collaborate along real-world problems.



Our team

The institute is unique in several ways:

- Scientific work focuses on three central topics: systems sciences, innovation, and transition sciences, as well as sustainability science and management.
- It is open to external collaboration with scientists from social as well as natural sciences.
- The transdisciplinary research focus facilitates high-quality research and leads to strong collaborative ties with regional stakeholders and with business and industry.
- Research projects apply a mix of both qualitative and quantitative approaches.
- Offering one of the few curricula on Environmental Systems Sciences, the institute grew into additionally coordinating two international joint master's programmes.
- The institute is well embedded in international networks in both teaching and research.

The institute is a part of the Faculty of Environmental, Regional and Educational Sciences and features a broad interface within the faculty as well as beyond. Together with the "Wegener Center" it plays a central role within the university's research core area "Environment and Global Change" and in the new field of excellence area "Climate Change and Sustainable Transformation."

1.2 The Institute's Website

The institute's website with an up-to-date news section and plenty of information can be accessed via http://sis.uni-graz.at/ (English version: http://sis.uni-graz.at/en/). While central information items like contact information, opening hours, news as well as important links can be found already on the start page, the rest of the website is organised in four categories:

- *Institute*: This category includes a mission statement, venue information including trip advisor and public transport planning tool, the annual reports since 2010 as well as further up-to-date information.
- *Studying*: This category involves information for both current and potential future students of our study programmes: Environmental Systems Sciences, Joint Degree Sustainable Development, CIRCLE and the recently founded doctoral school. A list of master theses and links to the alumni clubs can also be found there.
- *Research*: This section gives an overview of research aims and activities, ongoing projects, recent publications as well as existing cooperations with national and international partners. There is also a sub-category dedicated to the SIS science talk, which is a forum for invited (international) guests to present their research.
- *People*: Finally, one category is dedicated to introducing people who work (or worked) at the institute, including their research interests and publications. Open positions are also announced there.

1.3 Faculty and Staff members

Professors:

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

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

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

Ao. 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

Ass.-Prof. Priv.-Doz. 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

Vice 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)

Ass.-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

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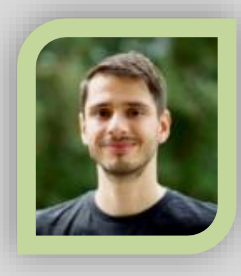
Research Interests: Computational Modelling (ABM, EBM), Social Network Analysis, Threat and Anxiety research (climate change), Early Warning Signals, Ecological Footprint modelling



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

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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Katharina Roche, MSc.
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Research Interests: Corporate Sustainability, Sustainability Management, Sustainable Operations Management, Life Cycle Assessment & Sustainability Assessment, Circular Economy

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

Mag. **Stefanie Hatzl**, PhD
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Research Interests: Energy Transition, Renewable Energy Technologies (PV), Empirical Social Research, Environmental Behaviour

Daniel Holzer, BA MA
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Research Interests: Transition towards Circular Economy, Circular Business Models, Empirical Social Research, Environmental Sociology

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Research Interests: Digital Innovation, Sustainable Innovation, Green IT, Acceptance and Diffusion of Technology

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

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Research Interests: Digital Innovation, Sustainable Innovation, Green IT, Acceptance and Diffusion of Technology

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	**Verena Haas**	**Alexandra Mayer**	**Lukas Pertl**
Iris Etzinger	**Tamara Janesch**	**Angelika Meißl**	**Martin Popowicz**
Gregor Fallmann	**Chiara Letter**	**Tobias Micheli**	**Katrin Winkler**

Habilitation of Romana Rauter

Romana Rauter successfully defended her habilitation thesis and was conferred the "Lehrbefugnis (venia docendi)" in the field of Sustainability and Innovation Management in December 2020.
The Habilitationskolloqium in which she presented "New Perspectives on Advancing Corporate Sustainability: Insights from Sustainable Strategic Management, Sustainable Business Model, and Sustainability Innovation Research" was held online. Thus, a large audience, including nearly the whole Institute, was able to attend digitally and virtually raise their glasses to celebrate the occasion.

1.4 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:

- "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):

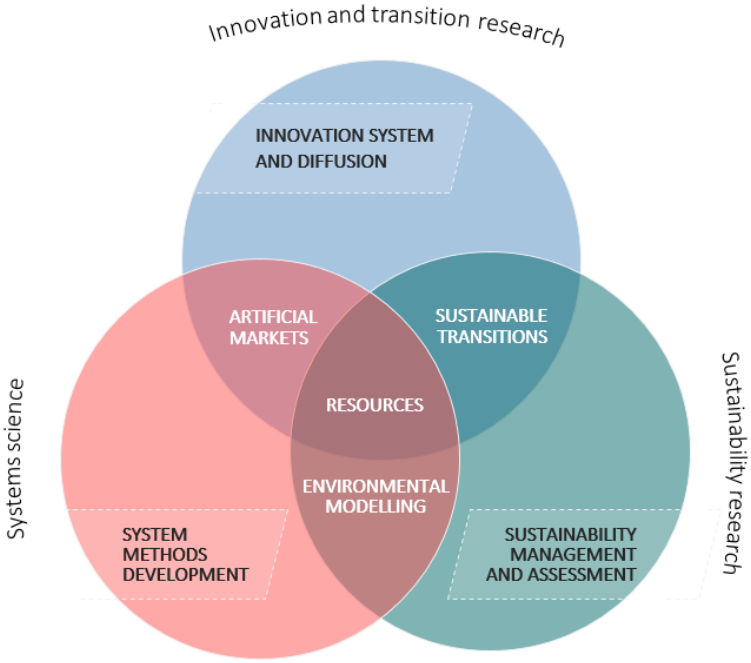
- Webinar: Time- and Selfmanagement
- Evaluation of Distance Learning
- Virtual Open House Day
- IP Experience Report
- Orientation Events in cooperation with student representatives
- Rework of the Global Studies and SIS webpage

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 (Füllsack), innovation- and transition research with a focus on innovation systems and diffusion (Posch, Stern), and finally sustainability research with a focus on sustainability management (Baumgartner).



Research areas and foci at the Institute of System Sciences, Innovation and Sustainability Research

Systems Sciences

Within the framework of the three-pillar concept at the SIS and in the ESS study, the research area of system sciences is primarily responsible for the development and provision of key methodological components required in research and teaching. Current focuses are on systems scientific and network-based resilience research, on equation- and agent-based modeling and simulation as well as on computer-based acquisition, processing, and evaluation of data. With the appointment of the current position holder of the Systems Science Professorship, the application and development of digital methods have been put into the forefront of attention. In terms of staff, this entailed the hiring of suitably qualified experts with a strong focus on IT skills.

In more details, system scientific research and methods development at SIS focuses on the following core areas. This includes the investigation and development of means for predicting critical phase transitions in social dilemmata situations (e.g., the loss of cooperation). It further includes research on network-theoretic aspects that could work as drivers for the enhancement of contribution to common pool resources. It also includes the development of tools for automated evaluation of large amounts of data relevant for sustainability questions (data and text mining). And an additional research focus is currently directed towards the development of a large scale simulation model for urban transport optimization and emission reduction. Furthermore, there is strong activity in the development of IT-based teaching methods and materials, such as interactive online repositories.

Innovation and Transition Research

The terms *bioeconomy* and *bio-based economy* refer to one of the recently most prominent political-economic concepts in Europe postulating the substitution for fossil resources by bio-based ones (e.g., Aguilar et al., 2017[1]). It thereby addresses ecological targets, i.e., climate change mitigation, and reduction of environmental impacts (European Commission, 2012[2]). Studies support — at least conditionally — that an intensified use of biomass can lead to greenhouse gas emission savings (e.g., Braun et al., 2016[3]). Apart from ecological challenges, bioeconomy is also intended to have socioeconomic benefits such as fostering economies' competitiveness, meeting rising demand and counteract resource depletion (European Commission, 2012).

According to OECD (2006[4]), the concept of bioeconomy can be defined as "transforming life science knowledge into new, sustainable, eco-efficient and competitive products." Therefore, innovation plays a crucial role when realizing the vision of a bioeconomy. Bio-economic innovations aim at replacing fossil resources for energy, chemicals, and materials with renewable and bio-based feedstocks.

The adherent causes, dynamics and consequences of bio-based innovation are in the focus of the research group around Tobias Stern, Professor for Innovation and Transition Research at the Institute of Systems Sciences, Innovation and Sustainability Research. The group consists of postdoc researchers (Raphael Asada, Michael Kriechbaum and Claudia Mair-Bauernfeind), as well as PhD candidates, whose research focus is in the field of bio-based innovation.

In particular, the working group focuses on questions like, how to overcome the gap between technical maturity and practical implementation, what broader economic, environmental or social implications might derive from an intensified use of bioprocessing technologies or which transition pathways are most feasible for sustainable use of bio-based materials. The research is underpinned by analyzing the transition, diffusion and innovation processes between the three key systems of sustainability. Only through a holistic approach to the manifold interrelations between environmental, societal and economic dimensions of bio-based economies, long-lasting and feasible solutions can be generated. With the institutes focus on innovation, environment and global change, this new chair features a promising link and extension to the already existing research activities.

The second focus area of this working group addresses energy innovation and transition for a decarbonisation of our economy. Obviously, the use of fossil feedstock for energy generation is the main cause for GHG emissions and thus for climate change. The energy transition can be understood as "… a change in the state of an energy system as opposed to a change in individual energy technology or fuel source"[5], or more precisely as a shift from a system dominated by fossil-based energy towards a system using primarily renewable energy sources, also increasing energy efficiency and better managing energy demand. For this, the working group addresses following aspects: Firstly, the energy generation side, where a shift towards renewable energies – energy sources such as solar energy, wind energy, hydroelectric power, biomass, and

[1] Aguilar, A., Wohlgemuth, R., Twardowski, T., 2017. Perspectives on bioeconomy. New biotechnology. 10.1016/j.nbt.2017.06.012.

[2] European Commission, 2012. Innovating for Sustainable Growth. A Bioeconomy for Europe. European Commission, Brussels, 64 pp.

[3] Braun, M., et al., 2016. A holistic assessment of greenhouse gas dynamics from forests to the effects of wood products use in Austria. Carbon Management 7 (5-6), 271–283.

[4] OECD, 2006. The Bioeconomy to 2030: Designing a Policy Agenda. OECD, Paris.

[5] Grubler, A., Wilson, C., and G. Nemet (2016): Apples, oranges, and consistent comparisons of the temporal dynamics of energy transitions, Energy Research & Social Science 22, 18-25.

geothermal energy, is needed. Here, the working group focuses primarily on the use of solar energy in different settings. The decentralization of the electricity generation with photovoltaics directly impacts the power distribution system. Additionally, there will be an increasing need for solutions regarding the short-term and also seasonal storage of renewable energies.[6] Secondly, the consumption side, which needs to be managed in a way, that demand profile become better adjusted to possible energy provision profiles of energy systems which are based to a greater extent on fluctuating renewable sources. Moreover, the consumption patterns might be an effective trigger to save energy, and/or to increase overall energy efficiency. The working group focused in recent years on energy efficient behaviour in public buildings.

Sustainability Management

The central interest in this research area is to improve the understanding 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.

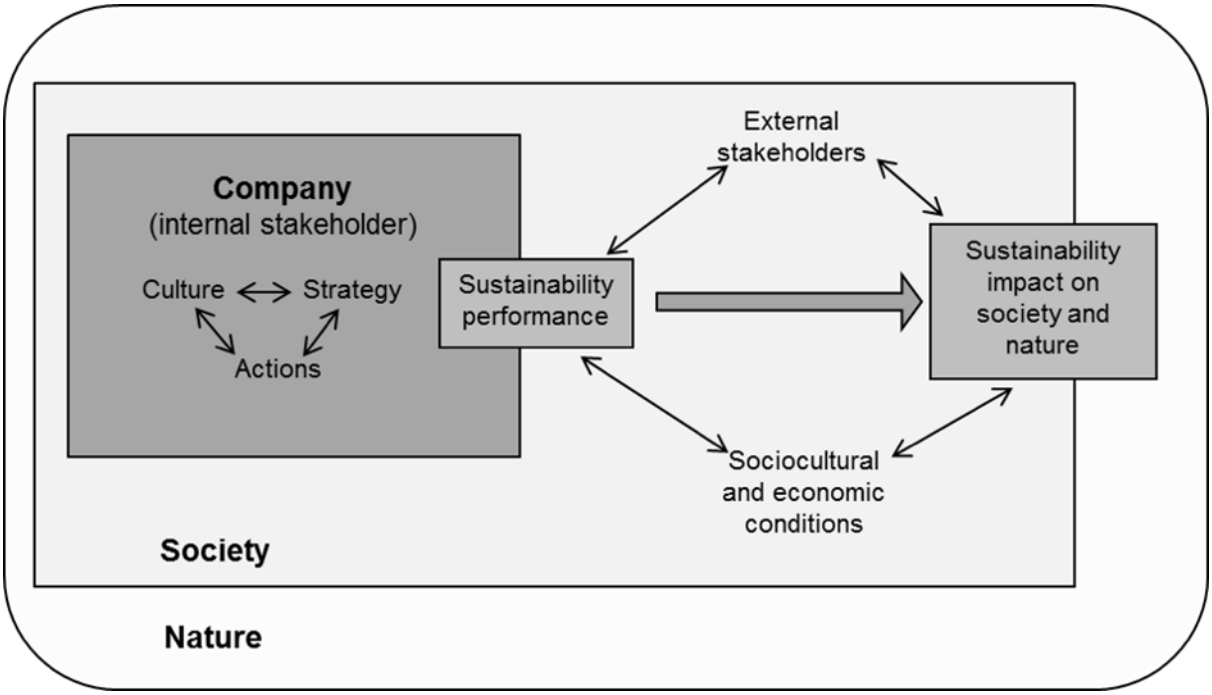
The figure below shows the basic research model, which combines factors within a company (i.e., relationships among organizational culture, strategy and actions) with the resulting sustainability performance of a company (and its products and services), as well as the final impact on society and the nature of this sustainability performance. Because a single company does not act alone within the economy and society, its relationships with other companies are also of interest.

Following topics characterize the research activities undertaken in this research area:

- **Corporate sustainability management:** Research in this field is conducted to determine the fundamental motivations of companies to act in more sustainable ways, examine organizational culture and corporate sustainability and develop frameworks for corporate sustainability management.
- **Corporate sustainability strategies and sustainable business models:** Research in this field is conducted to define and implement corporate sustainability strategies and identify the drivers, barriers, and impacts of sustainable business models.
- **Sustainability assessment**: Research in this field deals with environmental, economic and social impact assessments using qualitative and quantitative data (for example, by combining LCA with economic assessments).
- **Sustainable innovation:** Research in this field is conducted to identify innovation processes related to sustainability while placing a focus on open innovation.
- **Sustainability design:** Research is conducted to identify and develop frameworks and instruments that can be used to integrate sustainability issues into product design processes.

[6] Bruckner, T. et al. (2014): Energy Systems. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

- **Inter-organizational management, industrial ecology, and sustainable supply chain management:** Research in this field is conducted to examine how to coordinate actors in a network of companies with respect to sustainability issues (i.e., how to measure sustainability impacts in supply chains, coordinate industrial networks and supply chains and manage relevant data for inter-organizational management).



Sustainability impact chain,
from: Baumgartner, Rupert J.; Rauter, Romana (2017): Strategic perspectives of corporate sustainability management to develop a sustainable organization. In: Journal of Cleaner Production. Vol. 140, Part 1, pp. 81-92

2.2 Research Projects

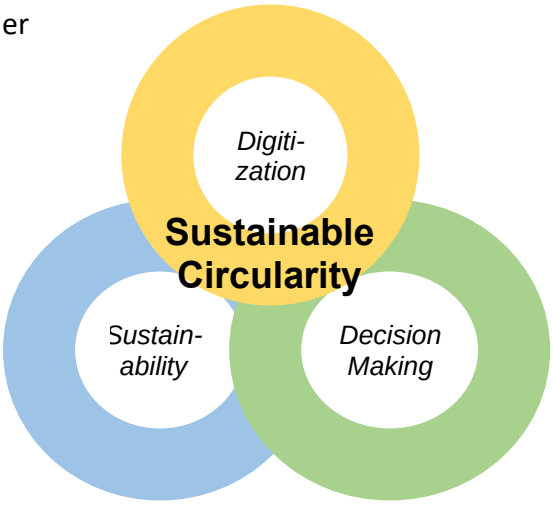
2.2.1 Christian Doppler Laboratory for Sustainable Product Management enabling a Circular Economy

Sustainable Circularity

Christian Doppler Laboratory for Sustainable Product Management enabling a Circular Economy

Head of the Laboratory: Prof. Dr. Rupert Baumgartner
Project team:
Magdalena Rusch, BA MSc,
Katharina Berger, BSc, MSc,
Dipl.-Ing. Vassiliki Theodoridou,
Lukas Stumpf, BA 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. The goal of this research laboratory is to support companies with new and improved methods and frameworks in order to maximise 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

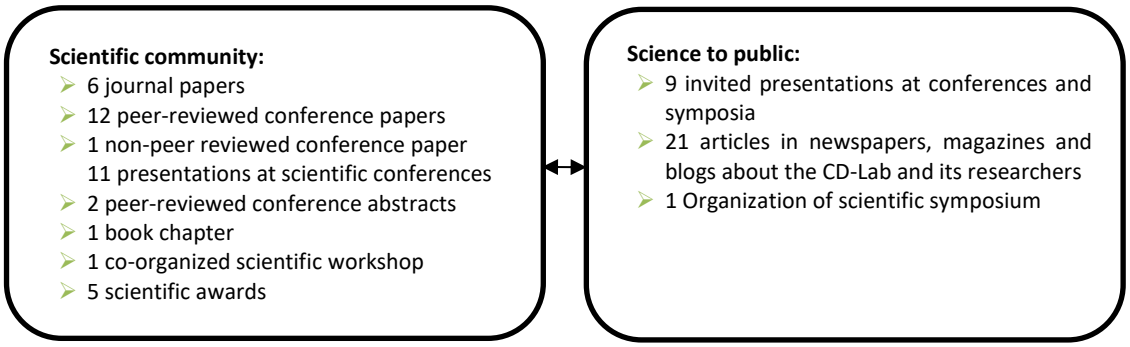
In Christian Doppler Laboratories, application-oriented basic research is pursued at a high level, and expert scientists cooperate with innovative companies. The Christian Doppler Research Association is an international best practice example for promoting this collaboration. Christian Doppler Laboratories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

AVL List GmbH as new industrial partner

The team of Prof. Rupert Baumgartner is successfully driving progress in their research endeavors which can be seen by, inter alia, their growing record of publications, the successful first project evaluation and a granted extension with the AVL List GmbH, who joined the CD-Laboratory as new industry partner in July 2020.
Together with AVL, the ongoing research will be expanded by two additional work packages which will complement the ongoing work. To tackle these newly added research endeavors, AVL List GmbH co-funded two new PhD positions. One position has been filled by Katharina Berger, whose research will focus on developing a concept for continuous product labelling of an automotive traction battery with a digital sustainable circularity twin. The other position was filled by Vassiliki Theodoridou, who will focus her work on determining a global sustainability optimum of alternative heavy-duty powertrain configurations in varying use cases.

Growing record of publications

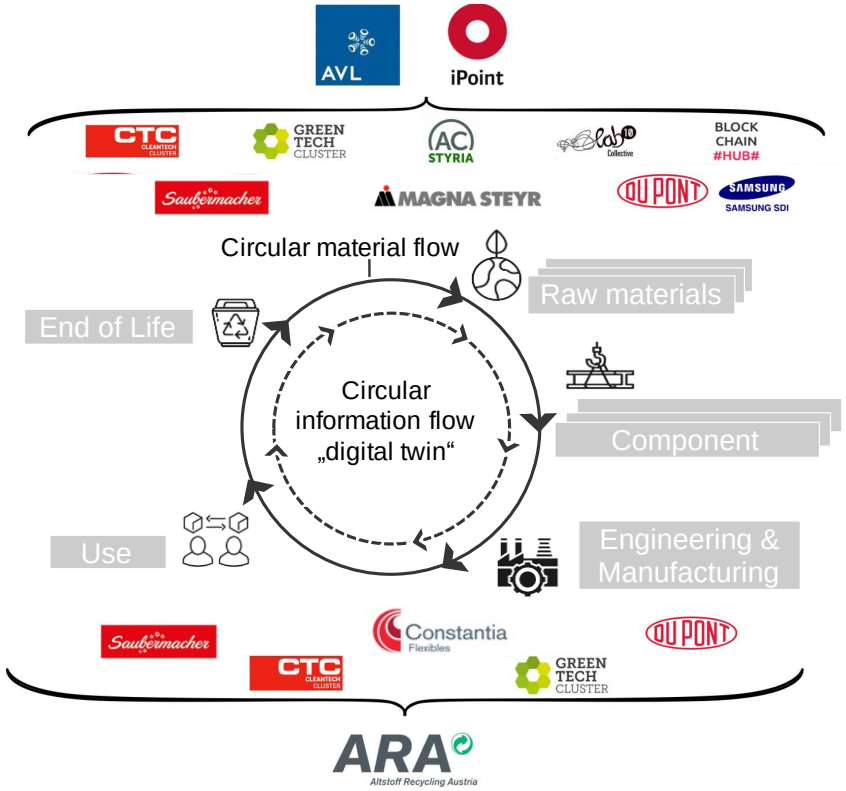
Since its foundation following output was achieved:



The conducted research of the CD-Laboratory is located in the areas of sustainability management and assessment, circular economy, and digitalization. The recently provided research output concerns itself, for example, with exploring connections between sustainability and circular economy, the analysis of circular economy business examples, data-driven sustainable product development, and data-driven decision-making instruments to support circular product design.

Use cases

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)

Scientific collaborations

The use-inspired basic research in the CD-Lab is highly interdisciplinary and it integrates aspects from sustainable product design and assessment, supply chain management and engineering, as well as from computational and systems sciences. To foster the exchange of knowledge and expertise between these field, the laboratory engages in several international research collaboration. Among these collaboration partners are the Center for ECO2 Vehicle Design at the Department for Engineering Mechanics of KTH - Royal Institute of Technology Stockholm/Sweden, the Institute for Interactive Systems and Data Science (ISDS) at Graz University of Technology (TU Graz), the Institute for Software Technology (IST) at TU Graz, the Department for Personnel Management, Work and Organizational Psychology at Ghent University/Belgium, LaRochelle Business School in France and the Technical University of Tampere, Finland.

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

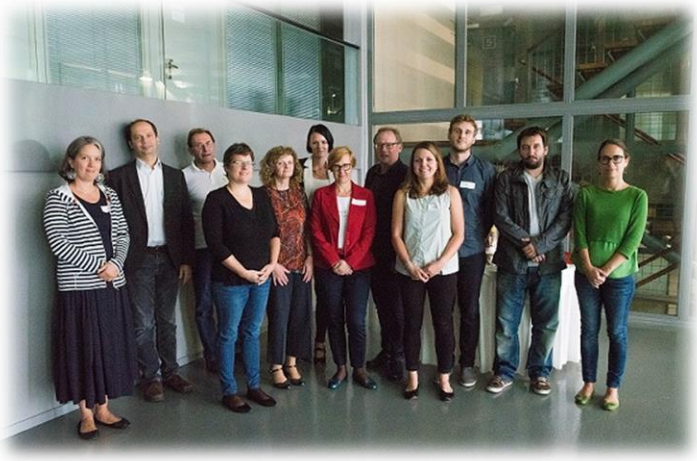
Duration: January 2018 - September 2021.

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:

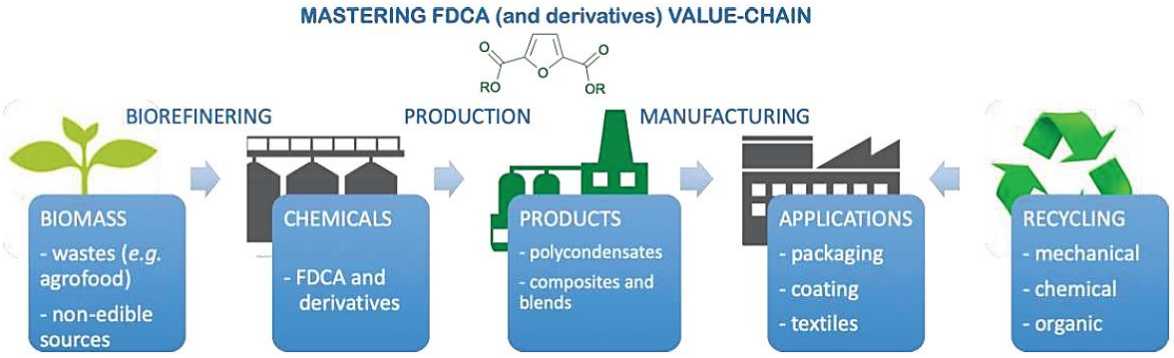
- documentation and utilization of RTD skills for the circular economy
- establishment of new cooperation models, especially regarding reuse-oriented value chains (training of mediators / facilitators)
- supporting SME in RTD networks
- support the launch of new products by developing new business models
- 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 – December 2021

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

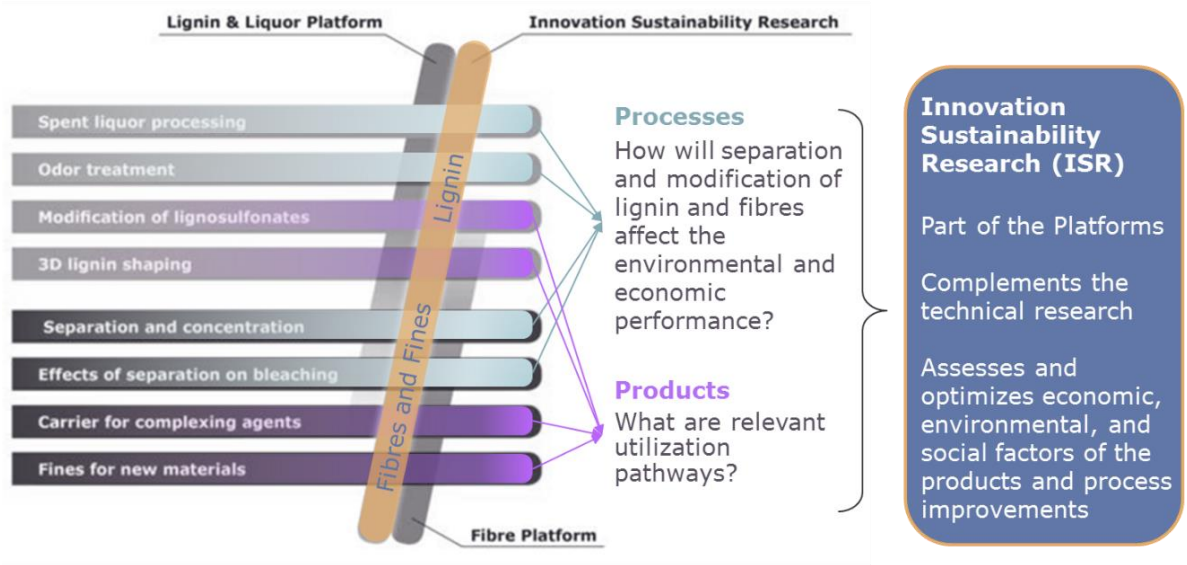
The Institute of Systems Sciences, Innovation and Sustainability Research is responsible for assessing the environmental and socio-economic impacts of wood in an automotive application. More precisely the institute will perform a Life Cycle Assessment (LCA) of the defined application cases in order to 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, Ao.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:	Ass.-Prof. Priv.-Doz. 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:	Ao. 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 - Oktober 2021
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:	A.o. 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 – complement the project's research agenda.

Project member: Ass.-Prof. Priv.-Doz. 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 put focus on servitization and 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? Thus, the central goals of this project are to determine the digital media experience of employees in the social sector as well as to collaboratively develop guidelines and procedures for this digital media use in practice.

Project team: Doris Prach, BSc; Ass.-Prof. Priv.-Doz. 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

2.3 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

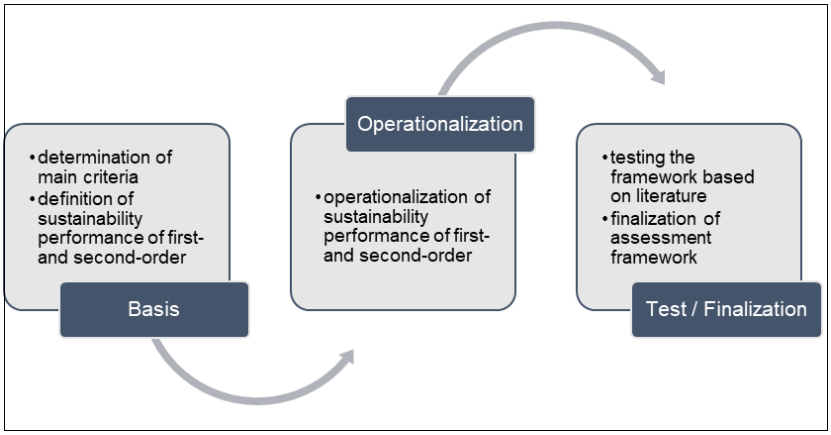
Early Career Researchers Network of Networks (ECR NoN) is uniting early career researcher organizations from all over the world to facilitate cooperation, to break silos across disciplinary backgrounds and engage with interdisciplinary issues. ECR NoN also addresses science-policy translation issues 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 – 2021

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 – 2021

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 – 2021

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 – 2021

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.

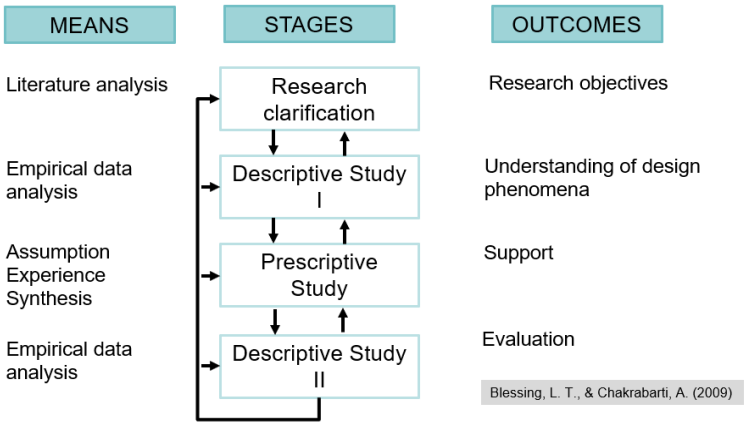
The goal of this thesis is to support the development of Business Models for the Circular Economy in incumbent firms, by compiling and assessing current knowledge on CBMI, exploring its occurrence in existing firms and providing guidelines to future innovation processes. This will be done through three 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 – 2021
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 – 2021
Reference: CRESTING ITN MSCA Project

2.4.8 Consumer decisions: The case of sustainable mobility behavior

The transport sector is one of the biggest contributors of greenhouse gas emissions, where a significant share of emissions is caused by passenger transport. Drastic reductions will be necessary to stay in line with climate goals, therefore alternative ways of being mobile have to be increased, implying the need for a modal shift. This shift will not be easy to attain, as the current system is fossil-fuel dependent and suffering from carbon lock-in, where other, more sustainable modes of transport are locked out. As incremental solutions will not be sufficient, not only is it necessary to focus on a modal shift within the system, but rather on system-wide changes of the current passenger transport system.

Based on the outline presented above, my dissertation on the one side deals with the investigation of so-called disruptive policy packages for passenger road transport, which have the potential to lead to a drastic decrease in transport-related emissions as well as a fundamental shift in the current system towards more sustainable and carbon-neutral mobility solutions. Additionally, I investigate the public acceptance of such policy packages with special focus on restrictive push measures. On the other side, my PhD project also incorporates research on academic air travel based on a case study design.

In my research I use both quantitative (such as surveys, statistical data analysis, hierarchical regression models, etc.) and qualitative methods (interviews, stakeholder workshops, etc.) from a social science perspective, where I am especially interested in individual decision making and sustainable behavior change.

Regarding the progress of my dissertation project, have a look on my current paper plans:

- "How to design policy packages for sustainable transport: Balancing disruptiveness and implementability "
  - Status: finalized
  - Methods: systematic literature review, qualitative expert interviews, stakeholder workshop
  - Accepted: January 2021, Transportation Research Part D: Transport and Environment; doi: 10.1016/j.trd.2021.102714
- "The role of public acceptance in the sustainable mobility transformation – Results of a choice experiment"
  - Status: survey in preparation
  - Methods: Quantitative survey, choice experiments, stakeholder workshop
  - Planned submission: Summer 2021
- "Reduction potential for academic air travel – Alternative developments at the University of Graz, Austria"
  - Status: survey completed, drafting manuscript
  - Methods: Case study, quantitative survey, OLS regression models
  - Planned submission: Spring 2021

PhD student: Annina Thaller
Duration: 2018 – 2021

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

My Ph.D. research is about the low-carbon electricity system transition in developing Asia, aiming to analyse the contexts of the market, political intervention, and technology governance. Transition in developing countries recently takes the scholarly attention due to its unique characteristics of the electricity regimes; for example, non-uniformity (co-existence of multiple technologies), supply-led generation system, spatially varied normative assumptions of energy-related sustainable development goals in urban and rural regime scales. The transition process while enhancing electricity access deficits in developing countries is a pressing socio-political agenda.

The first paper investigates the impact of market concentration on solar home system installations in rural off-grid energy markets. We use an extensive dataset that includes 4.11 million solar home systems installed in 503 markets over 15 years (2003-2017) under Bangladesh's market-based solar home system program. We show that an increase in the degree of market concentration reduces both the number and the total capacity of installed solar home systems after controlling for relevant demand and supply-side factors. The marginal effect is non-linear and is particularly strong at a higher degree of market concentration. Additionally, we find heterogeneous effects of market concentration depending on the size of the installed solar home system and customer group. It is particularly households buying small solar home systems, who are adversely affected by a lack of competition between the solar service providers. Our study implies that policymakers, program implementing authorities, and development donors of market-based solar home system programs should all take the supply structure of rural off-grid energy markets into account when designing rural electrification policies to achieve universal electricity access.

As a measure of a borrowing constraint in rural off-grid energy markets, the second paper investigates the effect of down payment on the pricing of solar home system loans. We use a unique cross-sectional dataset that includes a sample of 638,728 borrowers' loan. We estimate that a 10 percent increase in down payment per watt reduces the average total interest percentage by 2.83 percent. Our study also shows, on average, that highly constrained borrowers with low down payment per watt pay at least 19 percent higher total interest percentage than relatively unconstrained borrowers who make a larger down payment per watt. The borrowing constraint seems to generate distributional inequality in the pro-poor solar home system program, increasing the financial cost of market participation for these highly constrained borrowers. Poor people, therefore, pay a poverty penalty. We recommend that governments, policymakers, and development donors deploy targeted intervention mechanisms that update financial support for both lenders and borrowers to eradicate energy poverty persistent in developing countries.

Lack of energy access undermines the socio-economic conditions of households, reducing their resilience, particularly in the face of disruptive effects of the COVID-19 pandemic. Hundreds of millions of poor rural households, who live in remote and difficult-to-reach areas, are still without access to energy. Solar energy safety nets, in the form of targeted social assistance programs and off-grid technological solutions, do not only advance energy access but also develop capacities of households to prepare for, respond to, and recover from specific threats like pandemics. We discuss on-going solar energy safety net programs in the largest off-grid solar markets of Bangladesh, India, Kenya, and Nigeria, and how such programs are affected by the COVID-19 pandemic. We find that solar energy safety net programs should be maintained and updated to emphasize their potential for building pandemic-resilient livelihood. These programs can be supported with efforts to build local value chains and economies based on clean electricity. Well-designed solar energy safety net policies generate multiple co-benefits, including the resilience of households to pandemics.

PhD student: Rafia Zaman
Duration: 2018 – 2021

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 study 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 stablish 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 envision the digitalization development of the forest-based sector around blockchain technology under the influence of climate change. Some of the main topics to explore will be its use on value chain transparency and CO2 trading, and certification schemes.

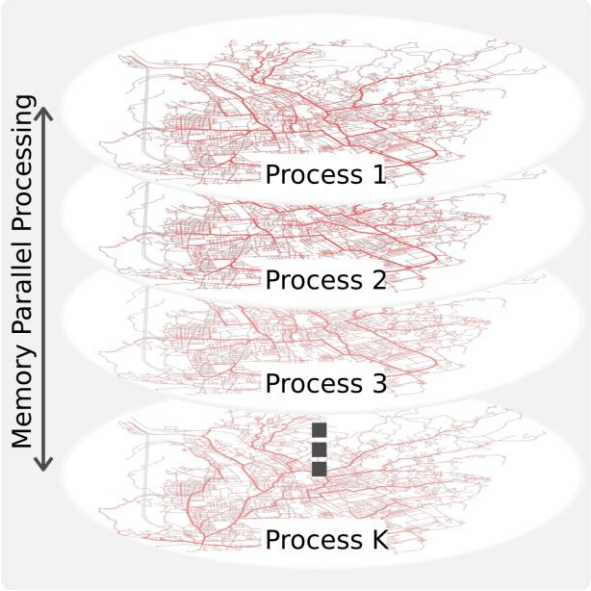
PhD student: Miguel Moreno
Duration: 2019 - 2022

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

2.5 Ph.D. Projects (finalized)

2.5.1 Sustainable development and companies: Actors and contextual factors promoting sustainability implementation and integration

Sustainable development at the societal level is rather unlikely without the sustainable development of organizations. Thus it is of interest to identify pathways that a company has to take to successfully integrate sustainability into the organization in general and to understand how decision-makers and other actors can successfully integrate sustainability throughout the organization. This main research question was approached from multiple angles and more detailed research questions have been formulated to specify the specific research scope for each research phase and the corresponding publication:

- Research Question 1: Who or what drives the integration of sustainability in the core business of the company?
- Research Question 2: How should top management be involved in sustainability management, and what roles does top management play in the sustainable development of the company?
- Research Question 3: How can organizational change processes for sustainability lead to sustainability integration on all levels of the company?

The research findings show that individuals (i.e., change agents) are likely to drive sustainability implementation without existing structures in place. In application of the promotor model, it is found that companies need power promoters (employees with influence) to enable the change for sustainability and emergence of more change agents. These change agents act as expert, process and relationship promoters, disseminating sustainability activities in the company. It could be seen that companies with different types of promoters were doing wider range of sustainability activities and had reached in parts better result in integrating sustainability in the organization. Most importantly, both top management support and organizational culture that is open to sustainability are required to enable the integration of sustainability throughout the company. This is the prerequisite to sustainability implementation and integration in the company.

This thesis contributes to the literature on corporate sustainability management in several ways. It is the first-time country-wide survey on sustainability implementation in large and smaller-sized companies, the effect of company size on sustainability management practices was investigated and it provides detailed insights which organizational units are involved in the integration of sustainability and the promoter model from innovation management was applied for the first time in sustainability management domain. Also insightful managerial implications can be drawn from the thesis. Managers interested to integrate sustainability into their organization should have authentic concerns and commitment about the sustainability challenge, should support with abundant resource, and based on their organizational context they should create multiple types of strategies for a successful integration of sustainability into their organization.

PhD student: Aisma Linda Kiesnere
Duration: 2016 – 2020

2.5.2 Exploring prospects of a bioeconomy based on input-output structures

The terms “bioeconomy” and “bio-based economy” are currently referring to one of the most prominent political-economic concepts in Europe focusing on ecological aspects, i.e., climate change mitigation and reducing environmental impacts. Furthermore, a bio-based economy is intended to have socioeconomic benefits such as fostering economies’ competitiveness, meeting rising demand and counteract resource depletion. Measuring and monitoring bioeconomic developments are important for future social, political and economic decisions.

Using the paradigm of socioeconomic metabolism (SEM) and drawing on the body of literature on the drivers of anthropogenic environmental stressors, prospects of a bioeconomy were explored. It has been shown that an effective bioeconomy policy would need to decouple economic growth and fossil resource consumption. Large-scale substitution of fossil resources for biomass could contribute to decoupling, but this would rely on economic, technological, and (geo)political developments in fossil markets. Besides, substitution is restricted due to finite land resources, which emphasizes the need for the efficient use of biomass. Various utilization paths of biomass exhibit large variation in terms of their potential to contribute to policy objectives. An effective bioeconomy policy is thus likely to internalize environmental externalities associated with the use of fossil resources and to be selective in terms of the biomass utilization paths promoted.

The thesis contributes to the body of literature with the findings of a longitudinal analysis of drivers for biomass and fossil raw material consumption and provides support for the relevance of competitiveness issues for SEM. An approach to investigate the effects of industrial input substitution was adapted and supplemented using a technique for uncertainty assessment. It is demonstrated that the methodologies and system delimitation provided by the SEM paradigm are useful for the empirical evaluation of the states and impacts of bioeconomies. In the thesis, some challenges are pointed out associated with a large time lag between release of input-output data and the period referenced, the tendency of top-down approaches to lack detail, and issues related to homogeneity and linearity assumptions.

PhD student: Raphael Asada
Duration: 2017 – 2020

2.5.3 The Sustainability of Bioeconomic Innovations: Tools and Indicators for a Substitution Assessment

The bioeconomy has been mainstreamed as an avenue of sustainability in which the basic components of materials and energy are made out of bio-based resources. Innovation is a vital part of the upcoming bioeconomy, since new applications and markets for bio-based materials have to be identified. The sustainability of these innovations, e.g., by substituting non-bio-based materials with bio-based ones, is not evident. Therefore, the overall aim of this thesis was to investigate the sustainability of bioeconomic innovations, including the appropriate tools and indicators for a holistic substitution assessment. More precisely, the thesis aimed out to answer the following research questions:

- What tools are available to assess the potential sustainability impacts of bioeconomic innovations? What role does Life Cycle Assessment play in holistic sustainability assessment?
- What needs to be considered when comparing bio-based with non-bio-based product systems?
- What are the potential sustainability impacts of introducing wood-based components into the automotive industry?
- What are the sustainability impacts of other bioeconomic innovations?

Life cycle approaches provide valuable support, enabling researchers to integrate sustainability into the design and evaluation of products. In this thesis, applying a prospective LCSA (analysis) to the case of substituting a steel component with a wood-based component in an automotive application showed that the wooden component has the potential to be environmentally, socially and economically beneficial in most indicators analyzed. An analysis of the net socioeconomic and environmental effects of the four analyzed sectoral innovations shows that negative impacts on climate change are likely to decrease. Most of the additional biomass needed is expected to come from EU-27 countries, which results in regional job creation and value added. Still, these results are a consequence of shifting production activity from one region to another. Attention should thus be paid to the potential trade-offs; e.g., shifting production and supply chains might reduce environmental impacts, but jobs might get lost at the same time. On a methodological level, this thesis work demonstrated the usefulness of applying a prospective LCSA (analysis) framework to a potential bioeconomic innovation, contributing to a better understanding of the sustainability implications of bioeconomic innovations. The results indicate that the applied approach is suitable to investigate the potential sustainability impacts, consequences and trade-offs of bioeconomic innovations.

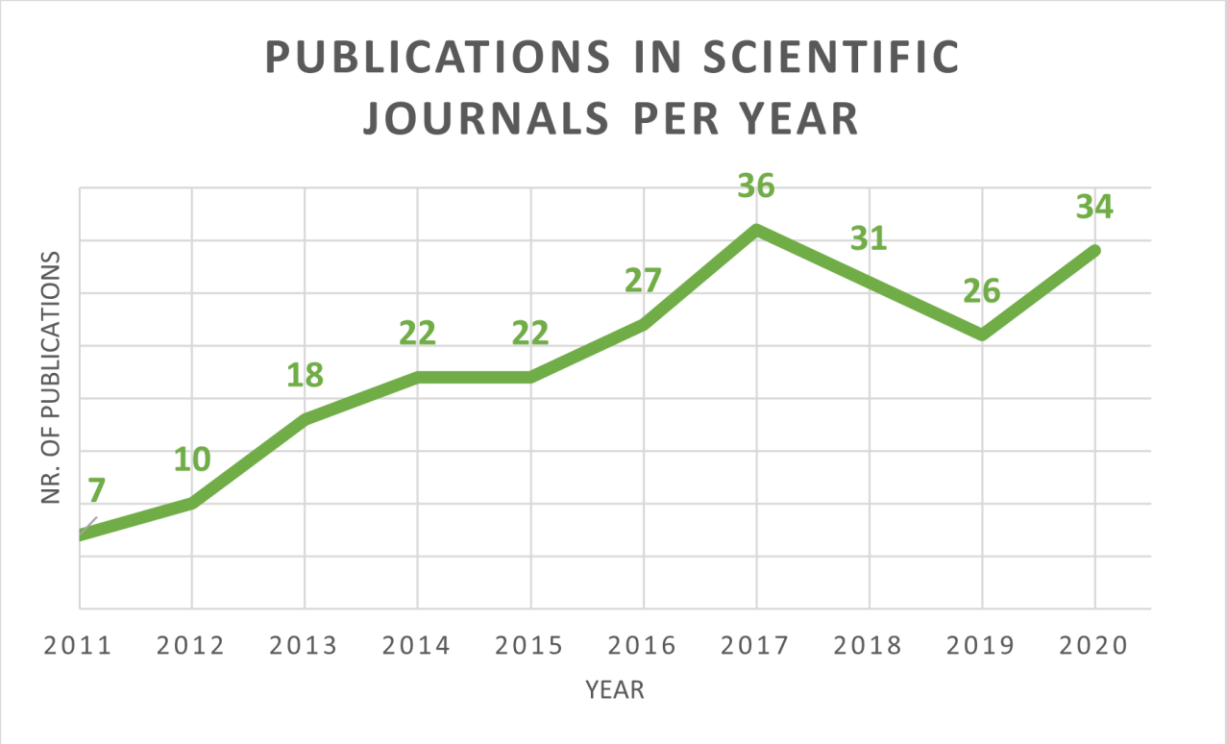
The PhD-project is partly embedded in the project WoodC.A.R.

PhD student: Claudia Mair-Bauernfeind
Duration: 2016 – 2020

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	2016	2017	2018	2019	2020
Publications in scientific journals	27	36	31	26	34
Contributions to an edited book or proceedings	22	12	16	17	9
Posters and Presentations	67	51	28	61	39



Number of publications in scientific journals over the last years

3.1 Publications

3.1.1 Edited book series/journal

Gelbmann, Ulrike-Maria, Kuhnel, Matthias, Pirker, Christian, Reindl, Sarah, Matthias (Ed.): Bewusstseinsbildung für Abfallvermeidung. Graz: Uni Graz 2020.

3.1.2 Contribution to peer-reviewed journal

Asada, Raphael; Cardellini, Giuseppe; Mair-Bauernfeind, Claudia; Wenger, Julia; Haas, Verena; Holzer, Daniel; Stern, Tobias: Effective bioeconomy? a MRIO-based socioeconomic and environmental impact assessment of generic sectoral innovations, in: Technological Forecasting and Social Change 153 (2020), 119946. DOI: 10.1016/j.techfore.2020.119946

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Hornischer, Hannes; Joshua Cherian Varughese; Ronald Thenius; Franz Wotawa; Manfred Füllsack; Thomas Schmickl: CIMAX: collective information maximization in robotic swarms using local communication, in: Adaptive Behavior: animals, animats, software agents, robots, adaptive systems May 4, 2020 (2020), 1-18. DOI: https://doi.org/10.1177/1059712320912021

Hornischer H., Plakolb S., Jäger G. & Füllsack M. : Authors' response: Fsx models and their building blocks, in: Constructivist Foundations 16,1 (2020), 066–068.

Hornischer H., Plakolb S., Jäger G. & Füllsack M.: Foresight rather than hindsight? Future state maximization as a computational interpretation of Heinz von Foerster's ethical imperative. in: Constructivist Foundations 16,1 (2020), 036–049.

Kapeller, Marie; Jäger, Georg: Threat and Anxiety in the Climate Debate—An Agent-Based Model to Investigate Climate Scepticism and Pro-Environmental Behaviour, in: Sustainability 12(5) (2020), 1823. DOI: 10.3390/su12051823

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Mair-Bauernfeind, Claudia; Zimek, Martina; Asada, Raphael; Bauernfeind, Daniel; Baumgartner, Rupert J.; Stern, Tobias: Prospective sustainability assessment: the case of wood in automotive applications, in: International Journal of Life Cycle Assessment 25,10 (2020), 2027-2049. DOI: 10.1007/s11367-020-01803-y

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3.1.3 Contribution to an edited book or proceedings

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3.1.4 **Other Publications**

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Pfeiffer, Christian; Hatzl, Stefanie; Fleiß, Eva; Maier, Claudia; Kremsner, Thomas Paul: A typology of end users' willingness to share energy data. Pinkafeld: enovaenova 2020.

Schreuer, Anna: Can the covid-19 crisis help us to reduce travel emissions in academia in the long term? https://climatefootnotes.com: Climate Footnotes (academic blog) Climate Footnotes (academic blog) 2020.

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3.1.5 **Presentations and Posters**

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Baumgartner, Rupert; Schöggl, Josef-Peter: Rethink & Digitize Forum, for: DIN-Innovationskonferenz 2020, Deutsches Institut für Normung, Berlin/online (Germany), 28.10.2020.

Brudermann, Thomas: Klimawandelkommunikation: Rahmenbedingungen und Ansätze, for: Workshop "Letzte Meile", Klimawandelanpassungsregion (KLAR!) Waldviertler Kernland, Krumbach (Austria), 15.07.2020.

Diaz Tena, Anna: Decision-making support to develop products for a circular economy: actors, tools and information flows, for: 26th International Sustainable Development Research Society Conference, International Sustainable Development Research Society, On-line (Hungary), 16.07.2020.

Gelbmann, Ulrike-Maria, Haberlandt, Stefan: Steigerung der Recyclingquoten von Kunststoffverpackungen als Beitrag zur Erreichung der EU-Abfallwirtschaftsziele und deren Auswirkungen auf Ersatzbrennstoffe, for: Recy- und Depotech 2020, Universität Leoben, Lehrstuhl für Abfallverwertungstechnik und Abfallwirtschaft, Leoben (Austria), 20.11.2020.

Gelbmann, Ulrike-Maria: How consumers perceive, manage and choose among different alternatives of single-use plastic packaging, for: Environmental Business Day Slovenian Chamber of Commerce, Slovenian Chamber of Commerce, online (Slovenia), 05.06.2020.

Gelbmann, Ulrike-Maria: Sinn und Unsinn von Einwegpfand, for: Österreichischer Gemeindebund, (Austria), 06.07.2020.

Jäger, Georg: Artificial Neural Networks for Agent-based Modelling, for: COLIBRI-Day, COLIBRI, Graz, Austria (Austria), 30.06.2020.

Kozina, Christian: Urban mobility as a sustainability challenge with a special focus on Graz, for: 5th CRESTING Workshop, Universität Graz, Institut für Systemwissenschaften, Graz (Austria), 22.09.2020.

Mair-Bauernfeind, Claudia: Holz im Fahrzeugbau – nachhaltig?, for: InnoRadar 2020 präsentiert „WoodC.A.R.“, Holzcluster Steiermark, Online Event (Austria), 01.12.2020.

Paul, Arijit: A theory of moral judgment on climate change, for: Oxford Business Ethics Discussion Group Seminar Talk, Saïd Business School, University of Oxford, Oxford (United Kingdom), 28.02.2020.

Plakolb, Simon: The GPU parallel passenger transport model - How to overtake on the fast lane, for: COLIBRI SAB Meeting, COLIBRI, University of Graz, University of Graz (Austria), 2020.

Plakolb, Simon; Annelies, DeMeulenaere: Creating a link in between vehicle routing and transport models, for: COLIBRI Day, COLIBRI, Uni Graz, Graz (Austria), 27.02.2020.

Posch, Alfred: Transformation zu einer nachhaltigen, klimaneutralen Wirtschafts- und Lebensweise, for: Zukunftsdialog, Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft, Wien (Austria), 14.01.2020.

Prajapati, Jyoti: Exploring the innovation process in low carbon sustainable mobility transition: A patent analysis, for: Postgraduate Seminar, Institute of Systems Sciences, Innovation and Sustainability Research, Online (Austria), 20.05.2020.

Prajapati, Jyoti: Innovation strategies of companies in the mobility sector to reduce GHGs emissions: An overview, for: PhD Doctoral Colloquium I, Institute of Systems Sciences, Innovation and Sustainability Research, Online (Austria), 05.06.2020.

Prajapati, Jyoti: Innovation strategies of companies in the mobility sector to reduce GHGs emissions., for: Science Policy Research Unit (SPRU) PhD Forum, University of Sussex, Online (United Kingdom), 15.05.2020.

Rauter, Romana: New Perspectives on Advancing Corporate Sustainability: Insights from Sustainable Strategic Management, Sustainable Business Model, and Sustainability Innovation Research, for: Habilitationskolloquium, Universität Graz, online (Austria), 27.11.2020.

Rusch, Magdalena: A classification of new data sources for sustainable product management in a circular economy, for: 26th ISDRS Conference “Sustainability in Transforming Societies”, Faculty of Economic and Social Sciences at the Budapest University of Technology and Economics, Budapest (online) (Hungary), 16.07.2020.

Rusch, Magdalena: Data management for sustainable product management in a circular economy, for: 26th Conference of the International Sustainable Development Research Society (ISDRS), Faculty of Economic and Social Sciences, Budapest University of Technology and Economics, Budapest (online) (Hungary), 14.07.2020.

Rusch, Magdalena: Data management for sustainable product management in acircular economy, for: 26th ISDRS Conference “Sustainability in Transforming Societies”, Faculty of Economic and Social Sciences at the Budapest University of Technology and Economics , Budapest (online) (Hungary), 14.07.2020.

Rusch, Magdalena: Social Life Cycle Assessment in a Circular Economy - A mixed-method analysis of 97 SLCApublications and its CE connections, for: 7th international social LCA conference, Chalmers University of Technology, Gothenburg Royal Institute of Technology (KTH), Stockholm The Swedish Life Cycle Center, Gothenburg (online) (Sweden), 17.06.2020.

Rusch, Magdalena: Students Call for Better Economics and Management Education: Kate Raworth in Conversation with Students, for: Students Call for Better Economics and Management Education: Kate Raworth in Conversation with Students, Partners for a New Economy, Netzwerk Plurale Ökonomik e.V., oikos International, Economists For Future, Rethinking Economics for Africa, online (Switzerland), 21.10.2020.

Santa-Maria, Tomas: Circular Economy Business Model Innovation through Design Thinking, for: The Indudstry Methods Shark Tank. ISPIM Conference, International Society for Professional Innovation Management (ISPIM), Berlin (Germany), 10.06.2020.

Santa-Maria, Tomas: Guest Lecture and Workshop: Busines Model Innovation for the Circular Economy & Design Thinking, for: HAN University of Applied Sciences. Master Circulaire Economie., Nijmegen (Netherlands), 01.12.2020.

Santa-Maria, Tomas: Masterclass: Innovación para una Economía Circular, for: Puentte, Santiago (Chile), 07.04.2020.

Santa-Maria, Tomas: Webinar: Business Model Innovation for a Circular Economy, for: Green Tech Cluster, Graz (Austria), 23.11.2020.

Santa-Maria, Tomas; Vermeulen, Walter J.V.; Baumgartner, Rupert J.: Framing and assessing the emergent field of Business Model Innovation for the Circular Economy: A combined literature review and multiple case study approach, for: 26th International Sustainable Development Research Society (ISDRS) annual Conference, International Sustainable Development Research Society (ISDRS), Budapest University of Technology and Economics (Hungary), 16.07.2020.

Santa-Maria, Tomas; Vermeulen, Walter J.V.; Baumgartner, Rupert J.: Business Model Innovation for the Circular Economy: an empirical exploration of best practices, for: ISPIM Innovation Conference, International Society for Professional Innovation Management (ISPIM), Berlin (Germany), 08.06.2020.

Schöggl, Josef-Peter: What to expect from data-driven sustainable product management? Insights from industry cases and PLM solution providers, for: Electronics Goes Green 2020+ Conference, Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration, Berlin/online (Germany), 01.09.2020.

Schreuer, Anna: [e]CLIFF - Escaping Carbon Lock-in of Frequent Flying at Universities?, for: IST2020 International Sustainability Transitions Conference, Austrian Institute of Technology & Vienna University of Economics and Business, Vienna (Austria), 2020.

Stern, Tobias: “Competing Goals Dilemma in forest-based Bio-economies”, for: The social and ecological value-added of small-scale forestry to the Bio-Economy, IUFRO/EURAC, Bolzano/Online (Italy), 07.10.2020.

Stern, Tobias: Perception of the forest-based sector, its innovations and future pathways, for: Midterm Seminar 17-18 Nov 2020, ForestValue, (Sweden), 18.11.2020.

Stumpf, Lukas: Circular Economy and Sustainability - A researcher's perspective, for: Circular Economy Roundtable and Ask me Anything, Factory Berlin, Berlin, Germany (Germany), 16.09.2020.

Stumpf, Lukas: Entrepreneurship, plastics and the Circular Economy: What does an incubator’s cohort tell?, for: Sustainability in Transforming Societies, Faculty of Economic and Social Sciences, Budapest University of Technology and Economics, Budapest / online (Hungary), 17.07.2020.

Thaller, Annina: Urban mobility and the sustainability challenge, for: V CRESTING Workshop - Stakeholder Event, Circular Economy: Sustainability Implications and Guiding Progress (CRESTING) - University of Graz, online (Austria), 22.09.2020.

Zaman, Rafia: Rural energy transition in-the-making: Assessing impact of market structure on solar home system diffusion, for: Governance in an Era of Change –Making Sustainability Transitions Happen, 11th Sustainability Transitions Conference (Austrian Institute of Technology and the Vienna University of Economics and Business), (Austria), 21.08.2020.

Zaman, Rafia: Solar home system prices are not what they seem: A cautionary tale for transition in practice!, for: Governance in an Era of Change –Making Sustainability Transitions Happen, 11th Sustainability Transitions Conference (Austrian Institute of Technology and the Vienna University of Economics and Business), (Austria), 19.08.2020.

3.1.6 **Science to Public**

Media article

Brudermann, Thomas: Menschen und Klima. Warum ist es so schwer, klimafreundlich zu handeln?, Wissenschaft fürs Wohnzimmer, internet, 08.10.2020.

Gelbmann, Ulrike-Maria, Christian Smetana: Responsible Consumption, The Free Lunch 02/20, print , 17.12.2020.

Gelbmann, Ulrike-Maria: 3 Fragen an Ulrike Gelbmann , ARA News 11/2020 | Abfallströme optimieren – Kreisläufe schließen, internet, 25.11.2020.

Gelbmann, Ulrike-Maria: Punkt 1 Radiolivesendung: Einweg, Mehrweg, Pfand, Recycling?, Ö1, radio, 04.06.2020.

Jäger, Georg; Jungwirth, Helmut: Wann werden wir alle ein Elektroauto haben?, Lets Dog about Science, internet, 27.11.2020.

Jäger, Georg; Jungwirth, Helmut: Wären Elektroautos die Lösung für eine nachhaltige Mobilität?, Lets Dog about Science, internet, 12.10.2020.

Melanie Köppel; Brudermann, Thomas: Nachhaltigkeit - Kann ich die Welt retten? Interview mit Thomas Brudermann, 360 Grad, print , internet, 15.01.2020.

Thaller, Annina: Klimawandelwissen (Publikation), Radio Soundportal, radio, 28.04.2020.

Thaller, Annina: Klimawandelwissen (Publikation), Radio Steiermark, print , 02.05.2020.

Mentioned in media

Baumgartner, Rupert; Schöggl, Josef; Stumpf, Lukas; Rusch, Magdalena in: Helmut Bast, Der „Drive“ zu Nachhaltigkeit, Steiermark Magazin, print , 25.05.2020.

Brudermann, Thomas; Thaller, Annina in: 60 Prozent halten Ozonloch für Hauptursache des Treibhauseffekts, Der Standard, internet, 30.04.2020.

Brudermann, Thomas; Thaller, Annina in: Das Wissen zum Klimawandel ist bescheiden, Die Presse, print , internet, 02.05.2020.

Brudermann, Thomas; Thaller, Annina in: Eigenes Klimawandel-Wissen wird überschätzt, Wiener Zeitung, internet, 28.04.2020.

Brudermann, Thomas; Thaller, Annina in: Klimawandelwissen oft überschätzt, orf.at, radio, internet, 28.04.2020.

Brudermann, Thomas; Thaller, Annina in: Martina Nothnagel, Wer weiß über die Fakten zum Klimawandel eigentlich wirklich Bescheid?, Falter Heureka, print , internet, 08.07.2020.

Rauter, Romana; Klingers, Sabine in: E-Mail regiert die Firmen.Untersuchung in Vor-Corona-Zeit zu Onlinetools, Kleine Zeitung, print , 08.05.2020.

Rusch, Magdalena in: Gerhild Leljak, Sozial nachhaltig, News.Uni-Graz.at, internet, 05.02.2020.
Santa-Maria, Tomas in: ¿Digitalización, un catalizador clave de la economía circular?, Diario Sustentable, internet, 23.07.2020.

Santa-Maria, Tomas in: Investigador estudia modelos europeos para aplicar a plataforma industria circular, Plataforma Industria Circular, internet, 02.06.2020.

Schöggl, Josef-Peter in: Helmut Bast, Der "Drive" zu Nachhaltigkeit, Steiermark Magazin, print, internet, 01.06.2020.

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 Award of Excellence

Marie Kapeller was awarded the Award of Excellence by Minister of Science Heinz Faßmann for her thesis titled “Emergence of collective behaviour on complex networks”.
The Award of Excellence is endowed with 3,000 euros. Due to the Corona pandemic, Minister Faßmann sent a digital message of greeting to the award winners. In addition to the work itself, he praised the "flexibility and resilience that the scientists have shown in completing their dissertations in these challenging times."
The Award of Excellence is a state award funded by student grants. Since 2008, the 40 best dissertations of the past academic year have been awarded. The proposals for this come from the universities.

3.4.2 Teaching Award – „Lehre: Ausgezeichnet!“

A recognition award, endowed with 500 euros, was awarded to **Georg Jäger** for his lecture “Systems Sciences 2”.
The lecture was nominated by student groups and chosen by a jury for exceptional dedication during the Covid semester 2020 for its successful application of digital methods for distance learning.

3.4.3 Best presentation - 7th International Conference on Social Life Cycle Assessment

Magdalena Rusch and **Rupert Baumgartner** were awarded the best digital appearance award at the 7th International Conference on Social Life Cycle Assessment for their presentation titled “Social life cycle assessment in a circular economy context — A mixed-method analysis of 97 SLCA publications and its CE connections”. The topic of the conference was “Social LCA: Impacts, Interests, Interactions” and it was held in Göteborg from 15. – 17. June 2020.

3.4.4 International Green Gown Award for the Sustainability Days

The Sustainability Days at the University of Graz were awarded the International Green Gown Award.

The International Green Gown Awards celebrate the exceptional sustainability initiatives being undertaken by universities and colleges across the world and are endorsed by United Nations Environment and supported by The Association of Commonwealth Universities (ACU), L'Agence universitaire de la Francophonie (AUF), The Higher Education Sustainability Initiative (HESI) and International Association of Universities (IAU).

Established as the most prestigious recognition of sustainability best practice within the education sector globally, the International Green Gown Awards provide benchmarks for excellence and are aligned with the UN Sustainable Development Goals.

According to the judges, the Sustainability Days at the University of Graz are a "great initiative that raises awareness amongst students and reaches a wide audience, with a very diverse programme involving arts, workshops, exhibitions and panel discussions. This initiative brings diverse community members together around sustainability and intensifies the learning component and creates links to the economy."

3.4.5 Sustainability Award 2020

The Green Mobility Design Thinking Challenge was awarded the Sustainability Award 2020 in the category Communication and Decision Making.

The Sustainability Awards are an Austria-wide competition for universities, universities of applied sciences and universities of teacher education. They are jointly awarded every two years by the Ministry of Education, Science and Research (BMBWF) and the Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology (BMK) for particularly innovative and sustainable university projects.

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.

Welcome meeting for the 2020 generation in September.

2020 came with a lot of challenges, especially for international students of the 2020 generation who faced travel and visa restrictions, and could only participate in the courses online. Nonetheless, 19 students from 12 countries could start the programme in Graz, and we were happy to welcome our first students from Bangladesh, The Gambia, and Trinidad and Tobago.

The Sustainable Development programme is also known for its highly active student community. The student community, among many other activities, organized an art exhibition on the topic of waste (*Kachara Vernissage*, hosted by the *Afro-Asian Institute* in Graz in February 2020), and produced a much-noticed year 2021 calendar titled "The Naked Truth of Sustainability". The calendar featured aesthetically appealing images and information on 12 selected topics related to sustainability, and the revenues were donated to *Nachhaltig in Graz*, a local association which aims to make Graz as sustainable as possible.

Title picture of the calendar "The Naked Truth of Sustainability 2021
Photographer: Andres Castiblanco, Instagram: @nadie.nobody.niemand
Editor: Nick Tweel, Instagram: @nicktweel
Further information: https://news.uni-graz.at/en/detail/article/hinschauen/

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 supervised by two teachers 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 blog with many interesting posts – see sustainersmagazine.wordpress.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 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 Vanja Novak, MA from the Office for International Relations is serving as its administrative co-ordinator. Partners in the consortium are Leiden University and Delft University of Technology (Netherlands); Chalmers University of Technology Gothenburg (Sweden); Norwegian University of Science and Technology (Norway); Curtin University (Australia); Waseda University (Japan) and Tsinghua University (China).

From 4 to 9 August 2019, CIRCLE has been kicked off with the orientation week for the first intake of selected students, organized on the island of Hönö/Sweden (see photo above). Due to the pandemic, both the orientation week 2020 for the second CIRCLE intake and the summer school 2020 for the first CIRCLE intake had to be delivered in an online format. Hopefully that can be changed to face to face meetings soon, as Seggau Castle in Styria is the intended venue for a joint CIRCLE event from 8 to 13 August 2021, where it is expecting three intakes of students!

For more information on CIRCLE please cf. https://www.emcircle.eu!

4.1.4 Global Studies: A New Addition in the Curricula Program offered at SIS

Since June 2020, SIS, together with the dean's office, has been assigned to manage the three master programs "Global Studies" at the University of Graz, which consists of three comprehensive and diverse curricula that source their courses from altogether five of the university's faculties and an additional four inter-faculty centers. The KoBü Coordination Office for Environmental Systems Sciences agreed to also take care of the about 400 master's students from the three programs contained in the Global Studies,

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, and were managed at the Faculty of Business, Economics and Social Sciences. 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 and 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 2019 IP "Music4Sustainability" talking with star conductor Gustavo Dudamel, © Johannes Steinbach/FairStyria)

The three programs build on different preceding bachelor programs and offer a respective focus on either Economics, Business and Environment, 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 Systems Sciences E-Textbook

The rise of tablet computers and smartphones is accompanied by new possibilities for students as well as professors. It allows providing eBooks and especially electronic textbooks with interactive elements. Besides the incorporation of audio and video material, educational examples like dynamic models and simulations can be made accessible out of the text, giving the students the possibility to understand better and comprehend the teaching subject.

Interactive E-Textbook

For these reasons, Manfred Füllsack, Professor for Systems Sciences, created an interactive electronic textbook for systems sciences based on software applications for tablet computers. This project is still in progress. A first version of the interactive textbook is available at http://systems-sciences.uni-graz.at/etextbook/.

The aims of the project are:

- To allow active learning with the help of significant examples where dynamics are not presented statically as graphics, but simulated directly via software applications.
- To give students the possibility to learn and try out the characteristic behaviour of specific impacts (for example the consequences of changing parameters) on their own, but at the same time under the guidance of the text.
- To test eBooks on their applicability for the special requirements of textbooks generally and to find a convenient, cross-platform and non-proprietary presentation method.

4.3 Completed theses (master and doctoral)

In 2020 **41 master** students completed their thesis within one of the study programs Environmental Systems Sciences, Global Studies, Sustainable Development, and Industrial ecology. The list is in alphabetical order.

Allerstorfer, Gundula Elisabeth (2020): Sustainability Assessment of Food Service Companies within their Supply Chains: A Case Study Applying the Sustainability Assessment of Food and Agriculture Systems to an Austrian Food Service Company
Supervisor: Baumgartner Rupert

Berger, Katharina (2020): Use of unconventional materials to achieve environmentally conscious vehicle designs. Influential factors of the environmental impact of a wood-based vehicle component
Supervisor: Stern Tobias

Bloder, Elisabeth (2020): The Green Wave - does it only reduce stress or emissions as well? An agent-based microperspective of a traffic model in Graz
Supervisor: Jäger Georg

Dorfegger, Iris Susanne (2020): Innovation Driver Climate Change? - Sustainable Entrepreneurs' Perception of Climate Change in a Business and Innovation Context
Supervisor: Stern Tobias

Fachbach, Ines (2020): Individual environmentally friendly actions. Model-based analysis of (in)action in Austria
Supervisor: Füllsack Manfred

Füßlberger, Lena (2020): The power of civil society for rapid decarbonization. An Analysis of the impact of environmental civil society movements.
Supervisor: Posch Alfred

Gansl, Alexander (2020): Nachhaltige Geschäftsmodelle für Living Labs - Entwicklung einer Taxonomie von Geschäftsmodellen Urbaner Mobilitätslabore
Supervisor: Rauter Romana

Gray, Maria Catalina (2020): An analysis of climate change mitigation programs: Identifying factors for success in Guatemala
Supervisor: Rauter Romana

Gruber, Patrick (2020): Kompensation von unternehmensbezogenen Emissionen als Beitrag zu einer nachhaltigen Entwicklung
Supervisor: Baumgartner Rupert

Haberlandt, Stefan (2020): Steigerung der Recyclingquoten von Kunststoffverpackungen als Beitrag zur Erreichung der EU-Abfallwirtschaftsziele und deren Auswirkungen auf die Ersatzbrennstoffe
Supervisor: Gelbmann Ulrike-Maria

Hirschenberger, Lena (2020): Tools and Methods for Sustainable Solutions
Supervisor: Stern Tobias

Hunjak, Tomo (2020): How can insights from behavioural economics tools help to improve the EU plastic waste management strategy
Supervisor: Brudermann Thomas

Järvinen, Joel (2020): Exploring the Influence of the Industrial Sector and the Raw Materials Base on Corporate Perceptions of the Bioeconomy - A Mixed-Method Study of Selected Industries in Finland
Supervisor: Stern Tobias

Kett, Tim (2020): Contribution of logistics facilities on decarbonizing supply chains: a case study
Supervisor: Baumgartner Rupert

Klug, Valentin (2020): Life Cycle Assessment and Comparison of Four Different Chemical Processes of Polyurethane Dispersion Production
Supervisor: Baumgartner Rupert

Koller, Manuel (2020): Identifizierung und Bewertung von Anwendungsmöglichkeiten für Faser-Feinstoffe aus der Papier- und Zellstoffindustrie
Supervisor: Stern Tobias

Krenn, Katrin (2020): Identifying substantial properties of technical lignin in selected application fields through user integrated development
Supervisor: Stern Tobias

Kusch, Jessica (2020): Waste management measures regarding plastics in Indonesia - Implications in the context of a Circular Economy
Supervisor: Aschemann Ralf

Lorenz, Karin (2020): Kontinuierliche Verbesserung des Qualitätsmanagements einer GmbH durch DIN EN ISO 9001:2015
Supervisor: Posch Alfred

Lunzer, Sabrina Juliana (2020): Circular City Graz: Ist-Analyse und Vision einer urbanen Kreislaufwirtschaft
Supervisor: Aschemann Ralf

Meixner, Andreas (2020): Industrie 4.0 - Herausforderungen und Potentiale der digitalen und vernetzten Zukunft für Wirtschaft, Umwelt und Gesellschaft
Supervisor: Baumgartner Rupert

Moder, Nadja (2020): Nachhaltige Unternehmensentwicklung - Eine Fallstudie zur Analyse der Transition in ein öko-effektives industrielles System
Supervisor: Aschemann Ralf

Muther, Hannah Roswitha (2020): Maßnahmenerhebung und Kategorisierung der Bewusstseinsbildungsaktivitäten im Bereich Abfallvermeidung im Großraum Graz zwischen 2017 und 2018
Supervisor: Gelbmann Ulrike-Maria

Plöbst, Lukas (2020): Möglichkeiten und Schwierigkeiten von E-Carsharing im ländlichen Raum am Beispiel der Steiermark
Supervisor: Posch Alfred

Probst, Peter (2020): Managementkompetenzen in der Corporate Social Responsibility
Supervisor: Gelbmann Ulrike-Maria

Rauscher, Jürgen (2020): Investigating customers' drivers and barriers related to adopting smart energy technologies
Supervisor: Posch Alfred

Reisinger, Daniel (2020): Predicting tipping points: A comparison of early-warning-signals when applied to data generated by equation-based versus agent-based models
Supervisor: Füllsack Manfred

Rücker, Manuel (2020): Development of an intercorporate Environmental Indicator System based on the Balanced Scorecard Concept
Supervisor: Baumgartner Rupert

Schnorr, Janick (2020): How can companies transform to sustainable businesses?
Supervisor: Baumgartner Rupert

Schweiger, Philipp Walter (2020): Einwegpfand im Europäischen Raum und Integrationsmöglichkeit im österreichischen Abfallwirtschaftssystem
Supervisor: Gelbmann Ulrike-Maria

Soto Bermudez, Samy Tatiana (2020): Organizational Requirements for implementing the Circular Economy in the European Plastic Packaging Industry
Supervisor: Baumgartner Rupert

Stefan, Lena (2020): Beitrag von Unternehmen zur Erreichung der Sustainable Development Goals - Analyse börsennotierter Unternehmen anhand ihrer Nachhaltigkeitsberichte
Supervisor: Gelbmann Ulrike-Maria

Steiner, Bianca (2020): Data supported circular product design. Can PLM Product Lifecycle Management systems assist a transition to circular products?
Supervisor: Baumgartner Rupert

Summerer, Simone (2020): End-of-Life of Vehicles - Investigation Regarding Current Second Use and Recycling Business Models in Austria and Germany and the Role of Authorized Treatment Facilities
Supervisor: Baumgartner Rupert

Tschuchnik, Martina (2020): Sustainable aviation: Passengers' single use plastic waste in the civil aviation industry
Supervisor: Aschemann Ralf

Venneman, Breana (2020): Environmental Sustainability Discourses Within Semi-Rural Communities of Alberta, Canada
Supervisor: Brudermann Thomas

Warren, Emma (2020): A Future for Coffee: Opportunities and Constraints for Emerging Origins - Evaluating Profitability Determinants for Smallholder Coffee Farmers
Supervisor: Baumgartner Rupert

Wiese, Elisabeth Gertrud Evelin (2020): Multifunctionality as enabler for sustainable urban development - environmental and economic assessment of integrated heat supply and stormwater retention technologies for the case study "Leipzig 416"
Supervisor: Posch Alfred

Yang, Lilia (2020): Die Entwicklung eines Intrapreneurship-Modells am Beispiel eines Energieunternehmens in Österreich
Supervisor: Rauter Romana

Zeberer, Zita (2020): Green Event Certification in Hungary: A Multi-Stakeholder Approach
Supervisor: Aschemann Ralf

Zieger, Jana (2020): Mobility Concepts in German Municipalities as an Instrument for Climate Protection. An analysis of potential, drivers and barriers in development and implementation.
Supervisor: Posch Alfred

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

Asada, Raphael Akira (2020): Exploring prospects of a bioeconomy based on input-output structures
Supervisor: Stern Tobias

Kapeller, Marie Lisa (2020): Emergence of collective behaviour on complex networks - Simulation of agents and artificial societies with application focus on environmental decision-making
Supervisor: Füllsack Manfred

Kiesnere, Aisma Linda (2020): Sustainable development and companies: Actors and contextual factors promoting sustainability implementation and integration
Supervisor: Baumgartner Rupert

Mair-Bauernfeind, Claudia (2020): The Sustainability of Bioeconomic Innovations: Tools and Indicators for a Substitution
Supervisor: Stern Tobias

Schröck, Andrea Maria (2020): Analyzing flows of nitrogen compounds within and between environmental compartments: benefits of budgeting approaches
Supervisor: Winiwarter Wilfried

4.4 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 2020			
Type	**Course**	**Contact hours**	**Lecturers**
PS	Applied Systems Sciences 1	2	Lechner G, Schmickl T, Schober A, Stefanec M, Vogrin M
PS	Applied Systems Sciences 2	2	Truhetz H
VU	Calculus for Systems and Environment Sciences	3	Hötzl E
AG	CIRCLE Summer School	2	Aschemann R
KS	Eco-Controlling	2	Paul A
PS	Economic Technology Assessment and Foresight	2	Asada R, Stern T
KS	Environmental Decision Making	2	Brudermann T
VO	Exogene and Endogene Processes in the Lithosphere	1.5	Fritz H
SE	How to write a Bachelor Thesis	2	Baumgartner R, 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	Fischer W, Kellerer-Pirklbauer-Eulenstein A, Schöner W
SE	Industrial ecology methods for a sustainable future	2	Van der Voet E
EX	Industrial Minerals	2	Klammer, D
VU	Inter- and Transdisciplinary Methods	2	Aschemann R, Höflehner T
AG	IP Alternative Packaging Concepts	4	Gelbmann U, Kuhnel M, Pirker C, Reindl S
AG	IP Bike Sharing	4	Kozina C, Kriechbaum M, Wieser B

AG	IP Palm Oil	4	Baumgartner R, Mittelbach M, Posch A
AG	IP Sustainability in Culture	4	Baumast A, Friedrich A, Muner-Sammer K
AG	IP Sustainable Journeys	4	Aschemann R, Maringer A, Osebik D
AG	IP Zero Waste	6	Baumgartner R, Kettele M, Kosnik E, Reindl S, Zimek M
PS	Introductory Seminar - Elementary Statistical Concepts and Methods, Examples and Practice	1	Fleiß E
AG	IP Focus on packaging-free shopping - ecological myth or really sustainable?	6	Baumgartner R, Mair-Bauernfeind C, Reindl S, Schlesinger A, Zimek M
SE	Kolloquium DK Climate Change: Transition to low carbon and climate resilient society	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
VU	Linear Algebra for USW	2	Batzel J, Fripertinger H, McMahon J, Prager W
PS	Management of Sustainable Development 2 Environmental Management	2	Ulz A
SE	Master Seminar	2	Baumgartner R, Füllsack M, Posch A, Stern T
SE	Master Seminar (Global Studies)	2	Höllinger F, Kleinert J
VO	Petrology for USW	1.25	Eichinger S, Klammer D
DQ	PhD Doctoral Colloquium I	2	Baumgartner R, Füllsack M, Posch A, Stern T
UE	Practical Exercises: USW Computational Basics	1	Kapeller M
KS	Practise-Analysis	1	Hohenwarter M
KS	Product and Service Development	2	Globocnik D
PS	Project Management	2	Posch A
AG	Research Project Sustainability Management	4	Crockett S, Kriechbaum M, Posch A
PS	Selected Topics of Sustainability and Innovation Management (Bachelor Seminar)	2	Kettele M, Stern T
SE	Seminar for Data in System Sciences	2	Füllsack M

SE	Seminar for Postgraduates	2	Baumgartner R, Füllsack M, Posch A, Stern T
SE	Seminar for Research Methods	2	Asada R, Stern T
SE	Seminar for System-Modelling and System-Analysis (Agent based modelling)	2	Füllsack M, Jäger G
KS	Strategic Sustainability Management	2	Gelbmann U
SE	Sustainability and Environmental Management	2	Posch A
KS	Sustainability Entrepreneurship	2	Paul A, Stern T
KS	Sustainable Innovation	2	Moreno Torres M, Stern T
VO	System-Modelling and System-Analysis	2	Propst G
VO	Systems Sciences 2	2	Jäger G
VU	Systems Sciences 3	2	Granigg W
TU	Tutorium Linear Algebra for USW	4	McMahon J
TU	Tutorium Systems Sciences 2	4	Fachbach, I
KS	Value Chain Management	2	Aschemann R
KS	Waste and Recycling	2	Gelbmann U, Schmidt G

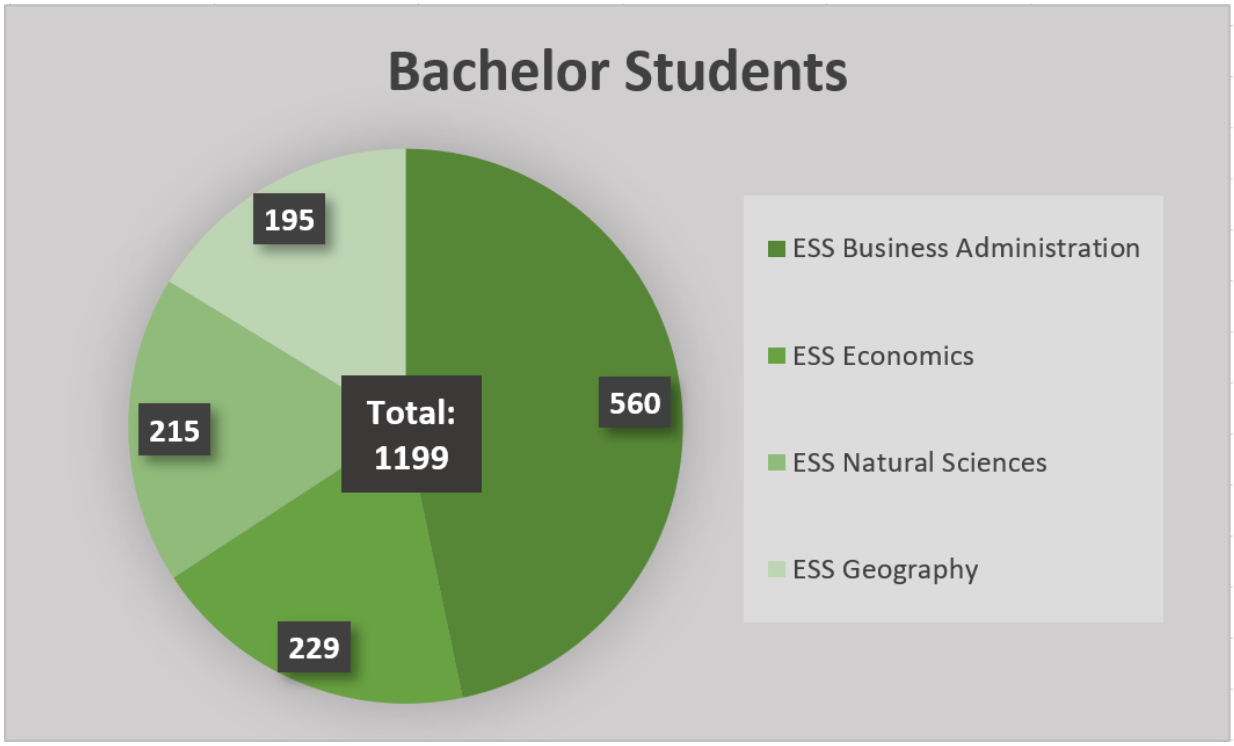
Winter Term 2020/2021			
Type	**Course**	**Contact hours**	**Lecturers**
SE	Annual Workshop DK Climate Change	2	Baumgartner R, Bednar-Friedl B, Birk S, Foelsche U, Kirchengast G, Maraun D, Meyer L, Posch A, Schulev-Steindl E, Steiner A, Steininger K
PS	Applied Systems Sciences 1	2	Plakolb S, Schober A
PS	Applied Systems Sciences 2	2	Bachner G, Osso Castillon A
VU	Calculus for Systems and Environment Sciences	3	Adam R, Kapeller M, Schiffer C, Steiner E, Thaler F
SE	Climate Policy	2	Crawford-Brown D

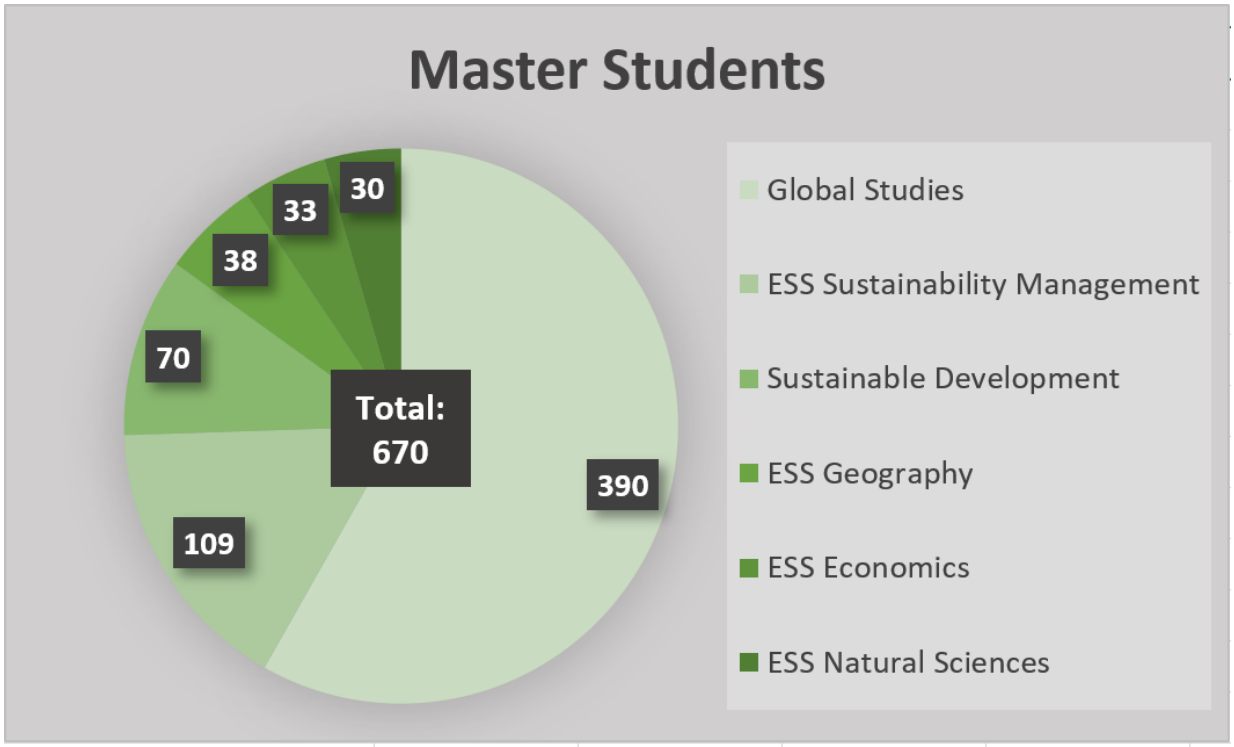
SE	Colloquium DK Climate Change	2	Baumgartner R, Bednar-Friedl B, Birk S, Foelsche U, Kirchengast G, Maraun D, Meyer L, Posch A, Schulev-Steindl E, Steiner A, Steininger K
VO	Data in Systems Sciences	2	Füllsack M
SE	Data in Systems Sciences	2	Füllsack M
KS	Design Thinking für nutzerzentrierte und nachhaltige Innovation	2	Rusch M, Zettl R
KS	Environmental Decision Making	2	Brudermann T, Paul A
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
VO	Human Beings and Environment: Anthroposphere	2	Posch A, Steininger K
DQ	Human Factor in Digital Transformation	2	Füllsack M, Kubicek B, Otrel-Cass K, Staudegger E, Thalmann S, Vogeler G, Wessely C
AG	Inter- and Transdisciplinary Case Study on Sustainable Development	6	Allmer V, Brudermann T, Crockett S, Kriechbaum M, Posch A
VU	Inter- and Transdisciplinary Methods	2	Höflehner T, Lakitsch M
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, Schöggl J, Schweighart M, Wenger J
VU	Introduction to Global Studies	1	Gelbmann U, Weichsler L
AG	IP Carbon removal technologies in the context of the European Green Deal	6	Aschemann R, Friedrich A, Schweitzer S
AG	IP Digital Sustainability Management	4	Baumgartner R, Kettele M, Rusch M, Schiffleitner A, Schöggl J

AG	IP Ethical decision-making on climate change: An experimental approach	6	Baumgartner R, Fleiß J, Paul A, Pölzler T
AG	IP Hard Facts of Hardware - Sustainability Impacts of Computers	4	Gelbmann U, Höflehner T, Mindler-Steiner J, Pirker C
AG	IP Integrative Urban Mobility	4	Aschemann R, Hammerl B, Seebauer S, Thaller A
AG	IP Natural Climate Solutions	4	Berg C, Holzinger W, Magnes M, Steiner A
AG	IP Value of Fashion	4	Friesenbichler M, Hatzl S, Winkler T, Zimek M
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, Füllsack M, Posch A, Stern T
SE	Master Seminar (Global Studies)	2	Bieber D, Schmidlechner-Lienhart K
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	Fuchsberger J, Jäger G, Reisinger D, Thaller A
KS	Practise-Analysis	1	Hohenwarter M
KS	Quantitative Methods of Social Research	2	Fleiß E
AG	Research Project Sustainability and Innovation Management	4	Asada R, Crockett S, Mair-Bauernfeind C, Moreno Torres M, Stern T
KS	Selected Topics of Innovation Management	2	Moreno Torres M, Stern T
SE	Seminar in Research Methodology	2	Asada R, Fleiß E
SE	Social competences for managing sustainable development	2	Seebacher U

SE	Social Competences for Working in Inter- and Transdisciplinary Teams	2	Hillmayer B
VO	Statistics	2	Fleiß E
KS	Strategic Sustainability Management	2	Gelbmann U
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, 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, Füllsack M, Posch A, Stern T
TU	Tutorium Calculus for USW	4	Bauer V, Kulmer D
VO	USW Computational Basics	2	Jäger G, Kapeller M
KS	Waste and Recycling	2	Gelbmann U, Schmidt G

4.5 Student Statistics





Number of registered students in 2020 (source: student statistics from UniGrazOnline)

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

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