TECHNISCHE UNIVERSITÄT WIEN

1st LCA–Symposium at TUW

16 June 2025

Application of life cycle assessment (LCA) and sustainability assessment (LCSA) in technology development – opportunities and challenges

Abstract Booklet

Dear researchers!

Life Cycle Assessment (LCA) is an increasingly integral component of sustainability research. As a standardised tool, it provides a framework for evaluating the environmental impacts of products or services through comprehensive and holistic investigations. It also forms the methodological foundation for a broader sustainability assessment that adds social and economic aspects.

In order to address future challenges, it is essential to adopt an interdisciplinary approach and to facilitate cooperation between a wide range of disciplines. The TU Wien is home to a number of researchers who have accumulated extensive expertise in life cycle assessment in their respective specialised fields over years. Our aim is to promote life cycle thinking and to increase knowledge about life cycle assessment and sustainability assessment among researchers and students at TU Wien.

The LCA–Symposium offers scientists at TU Wien a space to learn from each other, to network and to develop new projects and collaborations. The programme comprises a series of inspiring presentations and inputs from the various specialist areas.

We would like to thank all authors who submitted excellent abstracts for oral presentations and posters for the 1st LCA–Symposium at TU Wien on 16 June 2025. More than 30 research projects from seven faculties are presented, focusing on various aspects of Life Cycle Assessment within their respective disciplines.

The present abstract booklet provides a synopsis of the contributions presented at the LCA symposium. It is intended to serve as a review and anchor point for further discussion and networking.

For the Organising Committee:

Manuela Franz, Bettina Mihalyi-Schneider,
Bianca Köck, Rainer Pamminger

Proponents and organisation of the LCA–Symposium:

Dipl.-Ing.in Dr.in Manuela Franz
Dipl.-Ing.in Bianca Köck
Dipl.-Ing.in Dr.in Bettina Mihalyi-Schneider
Dipl.-Ing. Dr. Rainer Pamminger
Univ.Prof. MSc PhD Stavros Papadokonstantakis
Dipl.-Ing.in Dr.in Vanessa Parravicini
Dipl.-Ing. Dr. Daniel Cenk Rosenfeld
Ao.Univ.Prof. Dipl.-Ing. Dr. Wolfgang Wimmer

Symposium host:

TU Wien
Research Group for Process systems engineering for sustainable resources
Getreidemarkt 9/ E166-06-3
1060 Wien

LCA Symposium 2025 at TU Wien – 16 June 2025 – Programme Details

08:30-09:00 Registration, Get-Together

09:00-09:10 Opening: Rector Jens Schneider

09:10-09:30 Stavros Papadokonstantakis: Introduction to the LCA Symposium 2025

09:30-10:30 **Block I – Process Engineering**
Moderation: Stavros Papadokonstantakis
Safdar Abbas: From fingerprints to footprints: bridging lab-scale to industrial reality through prospective life cycle assessment
Stavroula Zervopoulou: Framework for LCA/LCC, Scalability and Modelling of the Biomass Waste Supply Chain for Sustainable Aviation Fuel (SAF) Production in the EU
Elias Nino Horn: Critical Aspects and Tools for Designing Circular Processes within the Chemical Industry
Trond Lehmann: Modernizing LCA Modelling for Wastewater Treatment: A Python-based Tool for Impact Assessment
Bianca Köck: Automated Life-Cycle Assessment Pipeline for Sustainable University – Procurement: Concept and Pilot at TU Wien
Diana Dimande: Membrane-based biogas upgrading to biomethane
Juan Diego Mora Fuentes: Life Cycle Assessment of coca leaf utilization in Cauca Region: Environmental Burden of Cocaine Production in Colombia
Mayuki Cabrera González: Economic and Environmental Assessment of Lactic Acid Production from Industrial Waste in Europe: Effects of Process Improvements, Scale-Up, Energy Source, and Market Condition (Poster only)

10:30-11:00 Coffee break + Poster Session

11:00-11:15 **Keynote I:** Oliver Cencic: Dealing with Uncertain Data
Moderation: Manuela Franz

11:15-12:15 **Block II – Civil Engineering / Architecture**
Moderation: Bianca Köck, Daniel C. Rosenfeld
Vanessa Parravicini: Life cycle assessment applications and challenges in the wastewater sector
Daniel C. Rosenfeld: Development of a method and presentation option for greenhouse gas savings at TU Wien
Karin Stieldorf: PV/BIPV represented in open BIM (IFC): Integration of environmental data
Kristina Orehounig: Renovate or replace – Finding the optimal decision for buildings considering cumulative CO_2 emissions
Michael Gruber: Greenhouse Gas Emissions in Hot Mix Asphalt Production: A Life Cycle Analysis for Sustainable Construction
Isidora Citic / Fabian Sprachowitz: Asphalt mixture without fresh bitumen? Findings from the NOBIT research project
Marius Valente: Circular Timber – Durability with Horizons
Ulrich Pont: Reuse-Woodhouses - Approaches to Circularity for prefabricated Timber-houses
Thomas Bednar: Life cycle greenhouse gas emissions from buildings - from information to requirements (Poster only)

12:15-13:15 Lunch break – Buffet

13:15-13:45 **Keynote II:** Michael Narodoslawsky:
Normative Basis of Impact Assessment Methods for LCA
Moderation: Manuela Franz

13:45-14:45 **Block III – Mechanical Engineering**
Moderation: Rainer Pamminger
Wolfgang Wimmer: Introduction to the Research Group for Ecodesign (15 min)
Kylian Keimel: Calculation of the Product Carbon Footprint for Informed Decision-Making in the Early Stages of Product Development Using the Web-Based Tool ECODESIGN+
Rainer Pamminger: LCA towards environmentally improved solutions applied on a powertrain for electric trucks
Niklas Marouschek: Life Cycle Assessment of a fuel cell electric tractor including hydrogen production
Gregor Lischka: Development of a Software tool for determining the holistic emissions in terms of an LCA approach for vehicle fleets in Europe
Thomas Trautner: Enabling Transparent and Verifiable Product Carbon Footprints through Digital Product and Process Passports
Josef Baumüller: From LCA to Activity-Based GHG-Management

14:45-15:15 Coffee break + Poster Session

15:15-15:45 **Block IV – Electrical Engineering / Computer Science / Other Universities**
Moderation: Gerhard Piringer
Manuela Franz: Land use of energy landscapes – Proposal for a multi–criteria assessment methodology for micro regions
Stefan Biffl: LCA value proposition with technical contributions and data analysis
Doris Rixrath: The Josef-Ressel Centre "Linked System Assessment to Support Sustainable Energy Supplies (LiSA)" (University of Applied Sciences Burgenland)
Iris Kral / Theresia Kern: The "BOKU-LCA Plattform" (BOKU University)

15:45-16:30 **Panel Discussion: The role of LCA in sustainability research at universities**
Moderation: Gudrun Weinwurm
Bettina Mihalyi-Schneider (TU-Wien), Doris Rixrath (HS Burgenland),
Iris Kral (BOKU University), Michael Narodoslawsky (TU-Graz),
Rainer Pamminger (TU-Wien), Stavros Papadokonstantakis (TU-Wien)

16:30-17:30 Networking, informal discussions with drinks and snacks

Block I – Process Engineering

From fingerprints to footprints: bridging lab-scale to industrial reality through prospective life cycle assessment

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Abstract: To build a sustainable chemical industry, it's essential to evaluate environmental impacts such as emissions and resource use through life cycle assessment (LCA). However, applying prospective LCA (pLCA) during the initial stages of process development remains a significant challenge, primarily due to the limited availability of detailed mass and energy balance data for both foreground and background systems. This study adopts an established and previously published framework for foreground system modelling, which originates at low technology readiness levels (TRLs) and offers a structured methodology to simulate industrial-scale production at higher TRLs using limited experimental data [1]. Notably, this framework does not rely on prior knowledge of large-scale process behaviour. Laboratory operations are typically composed of discrete, unconnected steps and involve equipment that differs substantially from that used in commercial-scale facilities. As such, directly extrapolating life cycle inventory (LCI) data from lab-scale to industrial-scale settings is generally inappropriate. Instead, the framework advocates for scaling up each individual process step independently by developing models that accurately represent realistic industrial plant configurations. To represent a prospective background system, this study utilizes future scenarios aligned with the Paris Agreement's climate targets for global energy system development. These scenarios are derived from an integrated assessment model (IAM), which plays a crucial role in shaping the outcomes of prospective life cycle assessment studies. Each scenario offers projections for key milestone years 2030, 2040, 2050 and extending to 2100 [2]. The pLCA is conducted using Activity Browser (AB), an open-source tool designed to implement LCA under evolving future conditions [3]. The goal of this pLCA is to address the gap in understanding how laboratory-scale chemical processes can be effectively scaled up, with the aim of enhancing the sustainability of emerging processes and materials. This approach enables the generation of results that more accurately reflect industrial-scale production.

Keywords: Prospective LCA, integrated assessment models, shared socio-economic pathways, technology readiness level.

References:

[1] F. Piccinno, R. Hischier, S. Seeger, and C. Som, "From laboratory to industrial scale: a scale-up framework for chemical processes in life cycle assessment studies," J Clean Prod, vol. 135, 1085–1097, 2016, doi: 10.1016/j.jclepro.2016.06.164.
[2] R. Sacchi et al., "PRospective EnvironMental Impact asSEment (premise): A streamlined approach to producing databases for prospective life cycle assessment using integrated assessment models," Renewable and Sustainable Energy Reviews, vol. 160, no. April 2021, p. 112311, 2022, doi: 10.1016/j.rser.2022.112311.
[3] L. C. A. A. Browser, "Activity Browser," 2024. [Online]. Available: https://github.com/LCAActivityBrowser/activity-brow

Framework for LCA/LCC, Scalability and Modelling of the Biomass Waste Supply Chain for Sustainable Aviation Fuel (SAF) Production in the EU

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Abstract: The aviation sector is under growing pressure to decarbonize in alignment with the EU Green Deal and the "Fit for 55" package, which sets ambitious targets for sustainable aviation fuel (SAF) integration, rising to 15% by 2035 and 38% by 2050 [1]. This research addresses the sustainability, scalability, and techno-economic modelling of a biomass waste-to-SAF supply chain, focusing on waste biomass as a key feedstock due to its limited environmental and land-use impact.

This research utilizes four lignocellulosic feedstocks as listed in the REDII (2018/2001), which are characterized as second-generation biomass

[2], processed through an innovative solar-assisted thermal fast pyrolysis technique. This method converts biowaste feedstocks into pyrolysis oil, a bio-based intermediate that requires further refinement before being used as aviation fuel. The analysis will focus from short (2030) to long-term (2050) availability of sustainable feedstock in the EU for small to large production capacities, and forecast SAF demand, considering the required minimum SAF blending targets of 6% by 2030 and 35% (with 70% of SAF, including at least 35% synthetic aviation fuels or e-fuels) by 2050, as outlined in Annex IX of the ReFuelEU Aviation regulation [3].

To support large-scale SAF deployment, a prospective Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) analysis will be conducted, covering the entire chain from resource supply and logistics to fuel conversion. The research emphasizes spatial and temporal dynamics, assessing how feedstock availability, logistics infrastructure, and conversion technologies align with future EU fuel demands. Particular attention is given to the integration of innovative technologies, such as the coupling of solar energy with fast pyrolysis, and their potential for reducing operational costs and GHG emissions. Furthermore, scenarios of centralized and decentralized supply chain structures will be examined. In both scenarios, the production of SAF is analyzed on a national scale, with additional consideration given to potential synergies. This study does not consider the co-processing of feedstocks; instead, separate feedstock batches are processed sequentially at the pyrolysis plant.

Multi-objective optimization will be applied to identify sustainable and cost-effective system configurations, considering environmental (LCA) and economic (LCC) trade-offs. Scalability analysis will draw on material and energy flows, technology requirements, and plant sizing to estimate capital (CAPEX) and operational expenditures (OPEX). The outcomes aim to highlight optimal deployment pathways that minimize import dependence while ensuring secure, domestic SAF production from carbon-based waste streams.

This work contributes to the broader understanding of how LCA/LCC tools can inform policy, investment, and innovation decisions, while navigating the challenges of prospective, system-scale sustainability assessment in the EU's evolving energy landscape.

Keywords: Sustainable Aviation Fuel, Supply Chain, LCA, EU ReFuelEU targets

References:
[1]. Circular Fuels, HORIZON-CL5-2022-D3-02-04 — Technological interfaces between solar fuel technologies and other renewables (https://circularfuels.eu/).
[2]. REDII. (2018/2001). Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) (Text with EEA relevance.). O. J. o. t. E. Union.
[3]. European Parliament and Council of the European Union. Regulation (EU) 2023/2405 of the European Parliament and of the Council of 18 October 2023 on ensuring a level playing field for sustainable air transport (ReFuelEU Aviation), Official Journal of the European Union, L202, 1–378 (2023).

Critical Aspects and Tools for Designing Circular Processes within the Chemical Industry

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Abstract: In addition to the principles of safety, the SSbD framework uses the life cycle assessment (LCA) method as a basis for ecological, economic, and social evaluation. Against this background, the circulation of substances and materials as well as the transformation of the economic system from the sale of goods to the sale of services is often seen as a desirable concept towards a sustainable society.

In the chemical industry, efforts are being made to make both products and processes sustainable right from the design phase through innovative approaches. Although LCA provides a good orientation, there is a lack of indicators to evaluate the circularity of products and production processes, especially in the early design phases. In addition, the technology readiness level (TRL) and the associated tools and possibilities for data generation and balancing for optimization and further technology assessment also play a major role in process development.

In this work, important aspects that are relevant to the development of closed-loop processes were identified on the basis of comparative liter-

ature. On the basis of these works, which have dealt with different groups of methods, individual tools have been assigned along the process development in the form of TRLs. This includes both "linear" methods such as LCA and their simplifications, such as different footprint calculations (PEF, ...), as well as "circular" metrics (Circular Economy Indicators, ...) that already consider a circular process. For the early stages of development (laboratory scale), some of which are still in the field of molecular modeling, various green metrics are also included.

A critical analysis of the identified aspects shows that there are gaps, particularly in the socio-economic field, which cannot yet be mapped in any of the technology-based indicators. Examples of this would be longevity (cost versus service life), user acceptance (e.g. status, convenience, etc.), missing or new technologies for closed loops (circular technology gap?) or the influence of subsidies and legal changes.

Economic and Environmental Assessment of Lactic Acid Production from Industrial Waste in Europe: Effects of Process Improvements, Scale-Up, Energy Source, and Market Condition

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Abstract: Lactic acid is a valuable product with applications in various industries, including food, pharmaceuticals, cosmetics, and chemicals. Its production yield depends on several factors, and improvements are typically first demonstrated at the laboratory scale. However, scaling up to industrial production requires modelling approaches that predict system performance under different optimisation strategies.

This study evaluates the economic and environmental sustainability of a conceptual lactic acid biorefinery by combining process modelling, techno-economic analysis, and life cycle assessment. The proposed biorefinery uses industrial candy waste and liquid digestate in Denmark as feedstocks, converting them into high-purity lactic acid through fermentation and membrane-based downstream processing.

A base case is first modelled to identify the system's economic and environmental hotspots. Several improvement scenarios are then explored, including reducing the consumption of energy, chemicals, and water, minimising waste generation, scaling up production, and integrating renewable energy. Additionally, a cost sensitivity analysis is performed to assess the impact of fluctuating energy, water, chemical, and labour costs in the European market.

Results show that by optimising the process, scaling up, and switching to renewable energy sources, the production cost and global warming potential of lactic acid can be reduced by up to 94% and 80%, respectively, compared to the base case. However, these optimisations do not occur simultaneously, highlighting a trade-off between economic and environmental performance. Even in the best scenario, production costs remain 141–232% higher than current market prices, suggesting that further process improvements or changes in market conditions are needed to achieve commercial viability.

Modernizing LCA Modelling for Wastewater Treatment: A Python-based Tool for Impact Assessment

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Abstract: In this project, a Python-based tool was developed for life cycle assessment (LCA) of wastewater treatment plants (WWTP). The tool is designed to be broadly applicable and supports the calculation of environmental impacts related to energy consumption (steam, electricity), auxiliary chemicals (e.g. NaOH, H_2SO_4), air and water

emissions, and sludge incineration - thus overcoming limitations of overly generic inventory data.

A major component is the automated migration from older Ecoinvent versions to the most recent version of the ecoinvent database (v3.11), ensuring up-to-date environmental factors (e.g. GWP, CED, ReCiPe). The model allows users to easily compare treatment scenarios with and without pH neutralization.

Structured Excel inputs and automated Excel outputs support efficient scenario analysis and interdisciplinary collaboration.

As a demonstrative case, the tool was applied to the evaluation of wastewater treatment linked to post-combustion carbon capture effluents, e.g., in the context of the HiRECORD project.

This implementation increases transparency, reduces manual errors, and enables reproducible assessments across different technology configurations. The modular setup allows for future extensions, such as High-Pressure Wet Air Oxidation or ammonia recovery.

Overall, the tool provides a practical, extensible solution for applying LCA in technology development, addressing challenges of outdated data and limited flexibility in traditional models.

Keywords: Life Cycle Assessment, Wastewater Treatment, Ecoinvent, ReCiPe, GWP, Carbon Capture, Python Automation

References:

[1] – Huijbregts, M.A.J., et al. (2017). ReCiPe2016: A harmonised life cycle impact assessment method at midpoint and endpoint level. The International Journal of Life Cycle Assessment, 22(2), 138–147. https://doi.org/10.1007/s11367-016-1246-y

[2] - Wernet, G., et al. (2016). The ecoinvent database version 3 (part I): Overview and methodology. The International Journal of Life Cycle Assessment, 21(9), 1218–1230. https://doi.org/10.1007/s11367-016-1087-8

[3] - Mutel, C. L. (2017). Brightway: An open source framework for Life Cycle Assessment. Journal of Open Source Software, 2(12), 236. https://doi.org/10.21105/joss.00236

[4] - Köhler, A., Hellweg, S., Recan, E., & Hungerbühler, K. (2007). Input-dependent life-cycle inventory model of industrial wastewater-treatment processes in the chemical sector. Environmental Science & Technology, 41(15), 5515–5522. https://pubs.acs.org/doi/10.1021/es0617284

Automated Life-Cycle Assessment Pipeline for Sustainable University Procurement: Concept and Pilot at TU Wien

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Abstract: The public procurement of large universities is a powerful yet under-utilised lever for climate-mitigation and broader environmental gains. Launching in May 2025, the LCA@TUW pilot will test the degree to which environmental assessment of purchased goods can be automated inside TU Wien's operational information landscape. Two contrasting product families—office supplies and laboratory chemicals—have been selected because they exhibit divergent material compositions, risk profiles and data availability. Together, they represent a substantial share of the university's annual purchasing footprint.

The proposed framework couples enterprise-resource-planning (SAP) and warehouse databases (SQL) with the commercial LCA platform Makersite via a four-stage pipeline: (i) establishment of an automated data extraction, cleaning and taxonomic harmonisation, including OCR of delivery notes; investigation and expansion with further TU databases (ii) AI-assisted product classification and life-cycle-inventory (LCI) proxy matching through Makersite's Intelligent BOM Importer and AI Mapping Engine; (iii) parametrised cradle-to-grave modelling with the Environmental Footprint 3.0 impact method and selected scenario analysis covering alternative suppliers, materials and end-of-life routes; (iv) bidirectional exchange of impact results and data-quality scores with the TU data warehouse to feed Power BI dashboards and enable continuous monitoring.

A mixed quantitative–qualitative evaluation will track reduction in analyst effort, LCI-coverage ratio, uncertainty envelopes and decision usefulness for procurement. The study will also cata-

logue systemic obstacles—including missing material declarations, heterogeneous nomenclatures, missing CAS numbers, and the inherent difficulty of gathering reliable data for the use and end-of-life phases of products—and propose mitigation pathways that balance automation with targeted manual review.

Expected outputs include a TU wide accessible process manual, a governance playbook for scaling to further product categories, and baseline impact metrics for TU Wien. By documenting both opportunities and pain points, LCA@TUW aims to provide a transferable blueprint for universities and other contracting authorities seeking to embed life-cycle thinking in routine purchasing while complying with Austrian naBe guidelines and EU Green Public Procurement criteria.

Keywords: Sustainable procurement; automation; Life Cycle Assessment; data pipeline; public sector

Membrane-based biogas upgrading to biomethane

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Abstract: With the rise of the concerning effects of climate change, and as we move towards the targets of the Paris agreement, several initiatives are being funded around the globe to put a hold on emissions. One of these initiatives is the European Green Deal, aiming to make Europe the first continent to reach carbon neutrality by 2050. Part of it includes developing new and improving existing technologies using renewable resources to cover partly the supply of high-demand fossil-based products, such as natural gas, supplied to Europe mainly through imports from Norway and the United States [1]. Biomethane is a promising candidate to cover some part of the supply for natural gas, as it can be produced from biogas upgrading using membrane technology, with the advantage of not using harsh chemicals, avoiding air pollution and wastewater [2].

An attributional life cycle assessment is performed in Simapro v9.5.0.1 (2023 PRé Sustainability B. V.) to evaluate the environmental performance of 1 MWh of biomethane produced via polyimide membrane upgrading of biogas. A set of relevant impact categories from the ReCiPe 2016 midpoint (H) V1.08 method is selected, allowing a more comprehensive evaluation and reducing the risk of problem-shifting. Therefore, key insights into process bottlenecks and environmental hotspots can be anticipated.

References:
[1] Council of the EU; European Council, “Fit for 55 - The EU’s plan for a green transition - Consilium,” https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/.
[2] M. Hiloidhari and S. Kumari, “Biogas upgrading and life cycle assessment of different biogas upgrading technologies,” Emerging Technologies and Biological Systems for Biogas Upgrading, pp. 413–445, Jan. 2021, doi: 10.1016/B978-0-12-822808-1.00015-5.

Life Cycle Assessment of coca leaf utilization in Cauca Region: Environmental Burden of Cocaine Production in Colombia

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Abstract: Cocaine production has reached critical levels in recent years in terms of volume, land use and trafficking, as shown by the UNODC (2025) Monitoring report on territories with coca crops. While public debate usually emphasizes socio-political or health aspects, the environmental burden remains comparatively less studied. Despite this, few efforts have been made to quantify the environmental impacts using standardized methodologies. To date, only one LCA has been conducted, which already recommends further research. This study aims to address some of the gaps identified in reports and other sources in the literature by evaluating the environmental impacts of cocaine production, relying on local data from the Cauca department in Colombia.
This study seeks to evaluate the life cycle of cocaine production in Cauca region of Colombia, due to its increasing concentration of coca cultivation and ecological and social vulnerability. The quantification of environmental pressures for

categories such as global warming potential, photochemical oxidation, human toxicity, ozone depletion and abiotic resource depletion aims to identify environmental burdens associated with the illicit supply chain.

The assessment applies an attributional approach with cradle-to-gate system boundary. The functional unit is defined as “The production of 1 kg of purified cocaine hydrochloride in powder form, ready for distribution, including agricultural cultivation and local chemical processing stages”. The data source is collected from SIMCI, UNODC, Ministry of Justice of Colombia and academic studies.

Environmental modeling will be conducted in GaBi through databases such as AGRIBALYSE, Environmental Footprints, and the Thinkstep education database.

Regional inventory includes inputs such as land use, agrochemicals, urea, gasoline, cement, sulfuric acid, and potassium permanganate, among others. Impact categories include climate change (GWP100), eutrophication, acidification, land use, and human toxicity.

The system includes all processes from field preparation, planting, and cultivation to chemical extraction and transformation into cocaine hydrochloride. Infrastructure and post-distribution processes are excluded. Data modelling will apply standard assumptions and sensitivity analysis for uncertain inputs.

Although results are not yet fully modelled, the ongoing construction of a regionalized life cycle inventory based on agrochemical and chemical substances will help identify environmental hotspots within the illicit cocaine production system. The expected outcome is clearer, science-based understanding of the environmental footprint of cocaine production in Cauca.

Keynote I

Dealing with Uncertain Data

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Abstract: Material Flow Analysis (MFA) is a tool that helps to model and quantify the flows and stocks of a system of interest. It is based on the law of mass conservation and should be the basis of any sound Life Cycle Assessment (LCA). In 2006, TU Wien released a free software, called STAN, which is especially designed to support this modelling approach and enables to consider data uncertainties. During his keynote, Oliver Cenčič will explain why it is vital to consider data uncertainties, how to get more reliable results by using uncertainty propagation, and how to resolve problems with contradicting data using a statistical tool called data reconciliation.

Block II – Civil Engineering / Architecture

Life cycle assessment applications and challenges in the wastewater sector

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Abstract: Life-cycle Assessment (LCA) is an established method to quantify the environmental impacts of a product or of an activity for its whole life cycle. LCA has found increasing application also in the context of municipal wastewater treatment as constrained by the intense publication activity of the past two decades. The goal of

LCA applied to wastewater treatment is a comprehensive consideration of the potential environmental effects arising from these installations in their whole life cycle. This represents an important step forward considering that assessments in the past focused exclusively on cost and energy consumption aspects.

Life cycle assessments can be used to assess the environmental impacts of a wastewater treatment plant construction, operation, and disposal as comprehensively as possible, to identify its environmentally relevant areas, and to compare different plant configurations and processes.

Especially as wastewater treatment undergoes a paradigm shift in which wastewater treatment plants become multifunctional and go beyond traditional wastewater quality objectives to include resource recovery and energy management, LCA play an important role because they can assess the environmental sustainability of new technologies and processes and capture trade-offs between impacts on different environmental categories (Corominas et al., 2020).

Examples of LCA applications in research projects conducted at the TU Wien, Institute for Water Quality and Resource Management, Research Unit Water Quality Management in the past decade are:

- Phosphorrückgewinnung aus dem Abwasser (BML, 2014)
- StraPhos – Zukunftsfähige Strategien für ein österreichisches Phosphormanagement (BML, 2021)
- ARA_Zukunft: Ein nachhaltiges Konzept für die kommunale Abwasserreinigung der Zukunft (Jubiläumsfonds OeNB, 2020)
- Feasibility study of electrodialysis to recover ammonia from sludge dewatering effluent at municipal wastewater treatment plants (2024, paper in preparation).

The goal of the current LCA activities in cooperation with the Department of Green Technology (IGT, Odense, Denmark), is to establish a LCA model for a general large-size municipal wastewater treatment plant (100,000 population equivalents) to be used as reference in different wastewaterrelated research projects. Due to its modular structure supplemental technologies of interest for resource recovery (e.g. phosphor, ammonia, water), for enhanced treatment performance (e.g. micropollutant removal) and for alternative approaches of biogas valorisation (e.g. hydrogen biomethanisation) can be implemented and compared. The application of a common model at research unit level not only enables more efficient use of project resources but also improves the comparability and transparency of project results.

Corominas et al. (2013) conducted a comprehensive review of LCA publications addressing wastewater treatment and highlighted the need for stricter adherence to ISO methodological standards to ensure quality and transparency of the results. In fact, although the international standards ISO 14040 and ISO 14044 provide a solid methodological framework for LCA, there is variability in how life cycle stages are carried out e.g. in the definition of the functional unit, in the selection of the system boundary and in the choice of the method for the environmental impact assessment.

The ARA_Zukunft (2020) project sought as one of its goals a critical approach to the selection and definition of methodological approaches. Methodological progress was made e.g. in the estimation of direct nitrous oxide emissions from the biological nitrogen removal stage and in the detailed consideration of the construction phase of the wastewater treatment plant. Furthermore, the critical analysis indicates that all the LCA stages are source of uncertainty. The defined functional unit (to which the assessment results are referred) needs be linked to the pollutant load treated in the plant (e.g. population equivalents/a) otherwise the use of a mere volume unit (1 m³ influent wastewater) of not defined composition will significantly reduce transparency and comparability of the results. Concerning the setting of the system boundary, the inclusion of indirect impacts from background processes is essential in several impact categories. The chemicals supply alone contribute up to 50% of the total net impact in the categories Cumulative Energy Demand, Terrestrial Acidification Potential and Depletion of Abiotic Resources. The construction phase contributes up to 10 % depending on the impact category, but the share can be higher at WWTPs that are operated almost energetically self-sufficient. It is pointed out, that there is urgent need to develop a solid methodology to estimate the impacts of the construction phase when real data are not available. Sludge disposal plays a significant role in several categories. Moving from sludge coincineration to application on agricultural soil changes dramatically the assessment results, decreasing the acidification potential by 20% and increasing the human toxicity by one order of magnitude. Direct emissions of nitrous oxide (N2O) and methane show a strong impact in the category global warming potential, accounting for more than the half of the CO2-equivalent emissions. Here, the assessment faces problems associated with data availability and data quality. Especially by the estimation of the temporally dynamic direct N2O emissions, the use of a variable emission factor linked to the operating conditions of the activated sludge tank would help caching the temporal fluctuation of these emissions.

In addition, the choice of the impact assessment method can significantly affect the outcome of the LCA, especially in the toxicity assessment. According to the authors, sensitivity analyses should become integral part of standardized guidelines for LCA application in order to improve the quality and transparency of the results, not only in the wastewater treatment field. Future challenges of LCA applied to WWTPs will be also addressed in the poster presentation.

Keywords: LCA, wastewater treatment, resource recovery, technologies comparison

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Development of a method and presentation option for greenhouse gas savings at TU Wien

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Abstract: Universities play a crucial role in advancing sustainability through their research and educational initiatives. The CO2 Dashboard @ TUW project aims to illustrate the sustainability impact of TU Wien by developing the methodological and operational framework to quantify potential

greenhouse gas (GHG) emission savings from the university's research projects.

The project will initially focus on the faculty of Civil and Environmental Engineering (CEE), with the intention of including a second pilot faculty that is yet to be determined. Ongoing or recently completed research projects within these faculties, which are expected to yield significant GHG emission savings, will be selected for analysis. The savings will be calculated through master's theses or directly by the project team. Based on the project work a robust methodology for estimating potential savings from diverse research developments will be developed.

The ultimate objective is to create a scalable approach that can be applied across all faculties, laying the groundwork for a comprehensive dashboard. This dashboard will aim to visualize the annual GHG emission savings achieved through TU Wien's research efforts, with the potential for integration into the university's website.

This project not only highlights the tangible impact of academic research on sustainability but also sets a precedent for other institutions to follow, fostering a culture of accountability and transparency in environmental stewardship.

PV/BIPV represented in open BIM (IFC): Integration of environmental data

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Abstract: The "BIM4BIPV" research project aims to represent photovoltaic elements and, in particular, building-integrated photovoltaics (BIPV) in multidisciplinary BIM planning. In Building Information Modeling (BIM), in addition to geometric data for the design of buildings and infrastructures in mostly three-dimensional models, a wide variety of data for various planning disciplines is integrated directly into the CAD model. Environmental data is playing an increasingly important role and must be brought into focus as a new planning object.

The following provides an overview of current legal changes and the associated issues affecting the assessment and planning of photovoltaic systems and their components:

- The "Green Deal," the "Fit for 55" initiative, and the "REPowerEU" package as triggers for solar energy and environmental data collection
- The new EU Building Directive (mandatory construction of zero-emission buildings, mandatory solar construction, and identification of "Global Warming Potential")
- The "New Circular Economy Action Plan" as an initiative to conserve resources and avoid waste
- The new "Ecodesign for Sustainable Products Regulation" (ESPR) provides for "Environmental Product Declarations" (EPDs) and "Digital Product Certificates" (DPPs), including the Recyclability Index and Repairability Index, as well as mandatory green procurement by public bodies
- The EU Energy Labeling for PV modules (from 500 MW production capacity)
- The revised "Construction Product Regulation" (CPR) for the integration of environmental friendliness Circularity and the verification of the "Global Warming Potential" of construction products. The central instrument is the "Environmental Product Declarations (EPDs)", which, published as "Delegated Acts", make calculation methods binding throughout the EU. Information about the construction product is documented in the "DPP - Digital Product Passport".

Photovoltaic modules are explicitly exempt from the CPR obligations because they are harmonized according to the "EU Low Voltage Directive". However, it may also be necessary to verify the environmental data of PV modules if they are part of, for example, prefabricated facade elements that are subject to the verification requirement. Further details of the European and respective national implementing regulations will have to be awaited.

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Renovate or replace – Finding the optimal decision for buildings considering cumulative CO_2 emissions

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Abstract: To reduce emissions from the building sector, a key question is which strategy is most effective for minimizing the CO_2 impact of the existing building stock. Is it better to renovate a building, or to rebuild it in a very energy efficient manner?

In a joint research effort we developed a framework to assess cumulative CO_2 emissions throughout the lifecycle of a building. The framework is based on a building energy simulation tool to assess operational emissions together with a lifecycle assessment framework to study environmental impacts and benefits associated with material and systems used during the construction or renovation process of buildings.

The approach was applied on various typical buildings in Germany, including single and multi-family houses, where we examined various scenarios of renovation and building replacement options. The aim of this analysis is to evaluate the trade-off between costs, emissions and energy consumption of the buildings during a time span of 25 years.

The approach consists of an analysis of relevant data sources, modelling of the geometry and constructions which are then used by both the building simulation and the life cycle assessment tool. A rigorous scenario analysis has been performed to evaluate life cycle costs, emissions and energy consumption for both retrofitting and replacement buildings.

Results show that the lowest CO_2 emissions during the lifetime of the analyzed single-family house can be achieved with a sustainable replacement building by using a heat pump coupled with PV under the condition of reusing the materials as much as possible, so that carbon remains stored in the wooden materials.

Interestingly, the application of small renovation measures, such as replacing the windows, doors and replacing the natural gas-based heating system by a heat pump is on the edge for achieving the 2°C CO_2 emissions target at much lower costs.

Greenhouse Gas Emissions in Hot Mix Asphalt Production: A Life Cycle Analysis for Sustainable Construction

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Abstract: The construction industry is a major contributor to greenhouse gas (GHG) emissions, playing a significant role in the acceleration of global climate change. In response to this growing environmental challenge, the European Union has updated the Construction Products Regulation (CPR), incorporating not only technical re-

quirements but also mandatory environmental assessments for construction materials. Life Cycle Assessment (LCA) has become a vital tool for evaluating the environmental performance of materials like hot mix asphalt, offering a holistic framework to assess their impacts from production through to end-of-life disposal. Despite its widespread use, current studies often struggle with comparability due to inconsistencies in the selection of functional units, making it difficult to draw reliable conclusions across different studies. This research aims to provide a detailed analysis of the GHG emissions associated with the life cycle of hot mix asphalt, covering the various stages defined in EN 15804. Particular emphasis is placed on the influence of factors such as the incorporation of additives (e.g., hydrated lime, regenerator), the use of reclaimed asphalt pavement (RAP), and the choice of energy sources in the production process. By providing insights into the life cycle impacts of asphalt production, this study contributes to the identification of optimization opportunities, ultimately supporting the transition towards more sustainable practices in the construction sector.

Asphalt mixture without fresh bitumen? Findings from the NOBIT research project

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Abstract: NOBIT (No Bitumen) is a research project, funded by the Volkswagen Foundation, aimed to develop a groundbreaking approach towards sustainable asphalt production by eliminating the need for virgin fossil-based bitumen. Asphalt, a critical material in global road infrastructure, traditionally relies on bitumen derived from petroleum refining, a process associated with significant environmental challenges, including high carbon emissions and resource depletion. NOBIT aims to address these issues by developing bioasphalt-mixtures – a circular material composed entirely of reclaimed asphalt pavement (RAP) enhanced with biological binders derived from renewable resources.

The project pursues two central objectives: maximizing the recycled RAP content within asphalt formulations and replacing conventional bitumen with environmentally sustainable biobinders. Raw materials which are considered promising to produce these bio-additives, such as lignins, resins, and vegetable oils — recycled from industrial waste or by-products — are systematically characterized through mechanical and chemical testing. In the final phase, a laboratory-validated bioasphalt mixture is produced at scale in an asphalt mixing plant and applied to a test section, marking a critical step towards real-world implementation.

In addition, a life cycle analysis (LCA) is conducted, integrating data from the chemical characterization and the provenance of the bio-additives, to critically assess the sustainability profile and quantify the desired economic and environmental benefits of this novel technological approach through a standardized impact assessment methodology.

Preliminary results indicate that bioasphalt-mixtures have a substantial potential to reduce waste streams and carbon emissions, while maintaining durability and performance levels comparable to those of conventional asphalt. The NOBIT project represents a pivotal step toward climate-friendly road construction practices, aligning with global sustainability goals.

Circular Timber – Durability with Horizons

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Abstract: The research project Circular Timber is dedicated to a holistic analysis of the circularity of load-bearing timber and timber-hybrid construction methods. The focus lies on both structural and material aspects as well as a critical examination of current sustainability assessment

systems and the legal framework in the building sector. Lifecycle Assessment (LCA) plays a central role and in new construction, the greatest impact from a planning perspective is often seen in the pre-construction (A0) and product stages (A1-A3), in accordance with ÖNORM EN 15978:2024_05_15.

Another key impact is the use stage B1-B8 of existing buildings. While dynamic LCA approaches often concentrate on the operational energy use (B6), the stages repair (B3) replacement (B4) and refurbishment (B5) are of greater relevance for architects and engineers. These involve material and product decisions that substantially influence the durability and circularity of building components.

Repair not only enables the functional preservation of components but can also legally maintain their status, provided the intervention occurs prior to dismantling. This opens up new design perspectives in the A0 stage as well as an expansion of its durability: load-bearing timber elements can, through targeted and architecturally integrated repair strategies, be transferred directly from the final replacement in the deconstruction stage (C1) back to the construction process stage (A4-A5).

The key criterion in this process is the highest possible preservation of material quality, regardless of whether the repair serves to maintain visual appearance or structural performance. This highlights the need for assessment systems that adequately account for these restorative measures within sustainable construction. The reuse of building components and the integration of source-separated secondary materials are still insufficiently considered in conventional LCAs, despite their considerable potential for resource conservation.

Through closing this LCA loop the linear end of life shared by the building and its components is replaced by a new horizon, where the demise of a building does not mean the end of its components.

Reuse-Woodhouses – Approaches to Circularity for prefabricated Timberhouses

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Abstract: This contribution focusses on recent efforts toward fundamental understanding about strengths, weaknesses, opportunities, and threats of the reuse of prefabricated components (walls, slabs) from existing prefabricated residential building. While the typical usage time of prefabricated timber detached houses can be observed to be 30 to 50 years, the Austrian standards that define rules for timber house construction stipulate 100 years of lifetime for such houses. As of today, such buildings are demolished rather than demontaged and reused. We believe that there is large potential for reusing of timber house components, given that such factory-made components follow an industrial production and mounting procedure, which could easily be extended toward deconstruction / demounting. However, to emphasize the circular use of these components, we observed the reuse of a detached house originally erected in a demonstration settlement for potential purchasers. This building was sold, deconstructed and 1:1 re-erected on the site of a client. This case alone, however, would not justify a in-depth implementation of circular economy approaches into production, construction and business procedures. Rather, the demounting and reassembling should happen with different components of different houses. Toward this end, the following aspects require attention: (i) Design for Deconstruction of Buildings and Components; (ii) a stringent data repository offering information about demounted and ready-for-reuse components; (iii) Know How of required (thermal, acoustical, fire safety) updates the components should be subjected to; (iv) Development of a business model that would clarify who should offer the reuse of prefab-components in future, (v) Clarification of potential legal liability issues, organizational aspects, and end-user acceptance, as well as approxi-

mation of the ecological and economic impact of the reuse of prefabricated timber components.

Life cycle greenhouse gas emissions from buildings – from information to requirements

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Abstract: In the May 2024 amendment to the revised Energy Performance of Buildings Directive (EPBD, EU 2024/1275), a new focus is placed on real energy consumption in the use phase and the holistic assessment of buildings, including life cycle greenhouse gas emissions (LCA calculation).

As of 2028, this requirement will apply to new buildings with a surface area exceeding 1,000 square metres, and as of 2030, it will be mandatory for all new buildings. The LCA calculation, to be conducted in accordance with the EN 15978 standard, must be submitted alongside the energy performance certificate. The legal focus will now extend beyond operational efficiency to encompass emissions from material production, construction processes, maintenance, and dismantling. This development signifies a pivotal step for Austria in its endeavour to transition towards a decarbonised building stock by the year 2050.

Consequently, in addition to the physical properties of the building products for the verification of structural safety, thermal/acoustic and visual comfort, electrical and thermal load profile, information on the life cycle assessment of the individual building products is also required during the planning stage. The initial step in this process is to ascertain representative data for the actual state, which will then be used to derive requirements.

How can a comprehensible declaration of the life cycle assessment of construction products be developed whose benefits justify the effort and develop the desired steering effect in the transformation of the construction industry?

Keynote II

Normative Basis of Impact Assessment Methods for LCA

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Abstract: Impact assessment is an integral part of any LCA. In this part of the analysis reports the (positive or negative) effect of the life cycle (and hence the product or service that is the object of the LCA) on the environment becomes evident. The results of this impact assessment are the fundament of the interpretation section and they are also the basis for comparisons between different ways to provide the product or service in question.

Assessment methods, regardless of their scientific methodology, are however inherently normative. The contribution discusses the reasons for this feature of assessment methods and explains what (implicit) decisions are made by the choice of a particular methodological approach to impact assessment. Following Narodoslawsky & Shahzad (2015) normative implications of choosing impact categories as well as aggregated assessment methods are explained. For a number of assessment methods their normative advantages, draw backs and blind spots are discussed. As normative decisions about assessment methods are in the responsibility of the authors of LCAs the contribution refrains from providing recommendations about "appropriate" choices for assessment methods for LCAs but intends to clarify the consequences of choosing a particular assessment approach.

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Block III – Mechanical Engineering

Calculation of the Product Carbon Footprint for Informed Decision-Making in the Early Stages of Product Development Using the Web-Based Tool ECODESIGN+

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Abstract: The development of technical products typically begins with the design of one or more conceptual variants, which are evaluated at an early stage to identify the most promising solution. Environmental considerations —particularly the assessment of the product carbon footprint (PCF) — are becoming increasingly relevant in this process.

To support this, fast and user-friendly access to reliable carbon footprint data can be of great value. The ECODESIGN+ tool, developed specifically for use in engineering design contexts, facilitates this process. It is web-based, leverages the ecoinvent database, and is tailored to the needs of product developers in early design phases.

This contribution illustrates the tool’s practical application using the case study of a spur gear unit.

LCA towards environmentally improved solutions applied on a powertrain for electric trucks

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Abstract: In the RHODaS (Horizon Europe project RHODaS, www.rhodas.eu) project Life Cycle Assessment (LCA) is applied beside other methodologies to optimize the environmental performance of an electric heavy-duty truck drivetrain, including its motor, power electronics, gearbox and heatsink.

Next to LCA and the environmental performance the products circularity should be improved and the use of critical resources minimized. By integrating Ecodesign criteria including circularity, criticality and climate aspects, the drivetrain is redesigned to minimize environmental impacts across all life cycle stages — from raw material to end-of-life. The drivetrain's most environmentally relevant components are designed for easy disassembly, ensuring efficient material recovery and component remanufacturing. Key strategies for the motor include e.g. the reuse of magnets to reduce reliance on critical raw materials or in the case of the inverter e.g., a modular power electronics system design, which facilitates repair, upgrading, and reuse during both the use and end-of-life phases.

Parallel to the technical optimization, a circular business model is developed for each component of the drivetrain to realize the remanufacturing and reuse processes. This comprehensive approach not only reduces GHG emissions but also contributes to a more resource efficient and circular electric mobility solution with a significant reduction in overall environmental impact, which will be highlighted by conducting an LCA on a system perspective, meaning the whole truck along its full life cycle. This includes the analysis of its use phase with electric charging and different end of life scenarios of the truck and its components.

Life Cycle Assessment of a fuel cell electric tractor including hydrogen production

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Abstract: Ambitious European climate goals demand sustainable and emission-free solutions in numerous areas, including agriculture. This work examines the environmental impact of a fuel cell electric tractor with renewable hydrogen supply from biomass throughout its lifecycle. In addition, measures for improving both systems are proposed, and a comparison of alternative vehicle and fuel-production configurations is presented.

FCTRAC and BioH2Modul, which were developed as part of the FCTRAC-project, serve as representative objects of investigation. For both systems, a Life Cycle Assessment in accordance with DIN ISO 14040 and 14044 is conducted. The life cycle is modelled following the stages Raw Materials & Supply Chains, Production, Use and End-of-Life. The functional unit is 1 kWh of energy released via the tractor powertrain. The environmental impact is determined along the impact categories Climate Change (GWP) and Cumulative Energy Demand (CED).

For FCTRAC, a global warming potential of 230 g CO2eq/kWh and a cumulative energy demand of 10,32 kWh/kWh can be reached by applying an optimized vehicle operation strategy, sustainable fuels for the wood chip logistics and renewable energy for the BioH2Modul auxiliary units. More than 85% of the environmental impact is caused by fuel production via BioH2Modul. Within hydrogen production, electricity consumption and wood chip production are the largest influencing factors.

Compared to a power equivalent diesel-tractor, the optimized FCTRAC shows a significantly lower GWP (-82%). This decline is primarily attributed to the hydrogen production within the use phase. When considering only the production stages, FCTRAC shows a higher GWP due to increased chassis weight, raw materials in HV-battery and fuel cell as well as carbon-fiber composites in the H2-tank. However, emissions from the production stages are nearly negligible over the entire life cycle. The total CED of FCTRAC is significantly higher than for a diesel-tractor (+108%) and is largely attributed to non-fossil energy sources.

Development of a Software tool for determining the holistic emissions in terms of an LCA approach for vehicle fleets in Europe

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Abstract: The aim of the project is to enable an emissions assessment of European road transport in terms of an LCA approach and to allow an impact evaluation of selected measures by means of future scenarios. This calculation is based on a completely newly developed methodological approach, which allows a much more detailed and realistic assessment compared to the existing literature. The methodology not only allows the entire European road traffic to be considered, but also enables country-specific analyses and the representation of larger cities such as Vienna or Salzburg.

Emissions are assessed on the basis of the entire real vehicle fleet, which is broken down according to emission-relevant factors such as vehicle classes, propulsion types, emission levels and year of first registration. A dynamic LCA is used to determine emissions, which allows for variable influencing parameters over the vehicle's lifetime so that, for example, the increasing share of renewable electricity generation can be taken into account.

The methodological development focussed on the determination of well-to-wheel emissions (WTW, energy supply + use phase), which were determined for the first time in an hourly time interval. Alternative propulsion types such as electric vehicles exhibit seasonal fluctuations that cannot be represented with an annual time interval, as is currently the case in the literature. A new approach was developed for energy supply, which enables the hourly country-specific emissions of electricity generation to be calculated, taking imports and exports into account.

A new methodological approach was developed to determine tank-to-wheel emissions (TTW, use phase), a sub-area of WTW emissions, which allows the hourly time interval to be linked to real vehicle movements and the real road network. A major advantage of this approach is that emissions can be determined much more realistically, which is subject to a large number of influencing parameters such as changes in ambient conditions, driving behaviour or traffic congestion. This makes it possible, for example, to consider that a vehicle of the same emission level and vehicle age in Vienna has different emissions than a vehicle travelling in the mountains in Tyrol.

Enabling Transparent and Verifiable Product Carbon Footprints through Digital Product and Process Passports

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Abstract: The upcoming implementation of the Digital Product Passport (DPP) under the EU's Ecodesign for Sustainable Products Regulation (ESPR) represents a transformative opportunity for enabling life cycle-based sustainability assessments across manufacturing value chains.

In response to the growing need of transparent, verifiable, and scalable sustainability information, this contribution introduces an auditable Product-Process-Resource (PPR) framework that integrates the DPP with Digital Process Passport (DPssP), built on the Asset Administration Shell (AAS) standard. A key strength of the approach is its compatibility with data space ecosystems and its focus on data sovereignty, allowing sensitive manufacturing data to be securely processed and verified without revealing confidential information.

The framework is validated through a case study in the injection moulding domain, in which a single inlay of an injection moulding tool undergoes band sawing and CNC milling. By capturing machine-level time series data and linking it to digital asset models the process level carbon footprints are calculated. Structured aggregation of energy and material data at the process level allows for dynamic Product Carbon Footprint (PCF) calculation and comprehensive traceability throughout the product's life cycle. By using AAS submodels, the proposed framework captures detailed information on products, processes, and manufacturing resources, ensuring interoperability and scalability. The AAS Carbon Footprint Submodel, in particular, enables real-time auditing and sets the stage for future integration into automated sustainability assessments.

The proposed approach addresses the need for auditability, transparency, and modularity in carbon accounting aligned with Life Cycle Assessment (LCA). It also helps bring the DPP to life as a practical tool for supporting circular economy and compliance within digitally connected manufacturing environments.

It demonstrates how the DPP, extended with the DPssP and grounded in the AAS, can serve as a critical enabler for comprehensive and verifiable LCAs, supporting digital transparency and sustainable manufacturing across sectors.

From LCA to Activity-Based GHG-Management

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The Clean Industrial Deal focuses on the decarbonisation of the European economy in order to create growth drivers and competitive advantages in international markets. The creation of climate-friendly production processes is thus (increasingly) moving to the centre of attention of politicians and companies, for whom considerable opportunities – not least in terms of financing – can open up. However, this requires the ability to measure and control the emissions caused by companies.

Consequently, the requirements for the future GHG reporting in Europe are specified in new laws that have to be applied since 2025. Most importantly, the Corporate Sustainability Reporting Directive (CSRD) and its associated European Sustainability Reporting Standard (ESRS) E1 on 'Climate Change' require companies to act on their GHG emissions. In turn, these requirements refer to the GHG Protocol for further guidance on how to fulfil the relevant requirements.

For calculating the product life cycle GHG emission the GHG Product Protocol specifies activity-based approaches, where financial as well as physical activity data are used. Based on these approaches, we have developed the '3-Levers-of-Emission-Control (3-LoEC)-model'. Different to tradition LCA approaches, cost and environmental accounting is integrated into one system and treated with the same logic. By adding external emissions related to materials consumed and equipment used, we extend the model to the '5-

Levers-of-Emission-Control (5-LoEC)-model', taking into account upstream indirect emissions as well.

As a result, our contributions give companies a framework to fulfil the requirements arising out of the Clean Industrial Deal in an effective and efficient manner. Further benefits are the seamless integration into the cost accounting that companies use in current ERP system applications and the employment of measurement methods that provide a fundament for external assurance. Beyond mere regulatory compliance, the implications of our contributions can be used for formulating and implementing strategies in order to reduce GHG emissions in the future.

Block IV – Electrical Engineering / Computer Science / Mathematics and Geoinformation / Other Universities

Land use of energy landscapes – Proposal for a multi–criteria assessment methodology for micro regions

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Abstract: The increasing expansion of renewable energy systems intensifies competition for land among agriculture, forestry, biodiversity conservation, and energy generation. Within the framework of Life Cycle Assessment (LCA), the environmental impact category "land use" remains insufficiently addressed, particularly during the use phase of energy systems. Current LCA approaches predominantly assess land use two-dimensionally, focusing solely on surface occupation and neglecting overlapping vertical and horizontal land use dynamics.

This research addresses the methodological challenges of land use allocation in multi-use energy landscapes, where activities affect not only the ground surface but also the vertical space above and below it across a more extensive geographical area. Consequently, a spatially limited two-dimensional perspective is inadequate for comprehensive and holistic environmental assessment.

A three-dimensional assessment model is proposed to improve allocation accuracy. Each land use activity is analysed according to a set of environmental impact sub-categories, with different factors influencing the location and extent of the spatial footprint in vertical and horizontal dimensions. The results are structured into a three-dimensional matrix, and weighting factors are applied to allocate land use impacts proportionally among activities in different vertical layers.

The methodology was exemplified through the assessment of a ground-mounted photovoltaic (PV) system combined with agriculture between the module rows (Agri-PV). The investigated subcategories were the land area required for structural PV-elements and the projected land area that would be fully irradiated by the sun. The results indicate that the allocated land use of the PV system ranges between 2% and 40%, contingent upon the specific impact category.

This approach reveals hidden ecological interdependencies and identifies additional synergy potentials in multi-functional land use systems. By expanding land use assessment into three dimensions and sub-categories, the proposed model enables a more accurate and comprehensive evaluation of environmental impacts of energy landscapes. It supports improved integration of renewable energy systems into regional land management and enhances the robustness of LCA studies.

LCA value proposition with technical contributions and data analysis

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Abstract: Life cycle assessment (LCA) concerns technical, economic, environmental. and social effects of processes in the life cycles of products and (flexible) production systems, as a foundation for improving these processes and systems. Therefore, improvement requires understanding

dependencies of LCA to technical contributions and data analysis concerns. However, model gaps between the effects of interest and contributions coming from processes, technical systems, and a variety of stakeholders in business, application technology, information architecture, IT/OT/software architecture, and regulation, make it difficult to evaluate the impact of planned changes. Our research concerns architecture services on how to connect added value to technology contributions, including data analysis and AI applications to improve production and data analysis capabilities, e.g., to reduce waste or scale up production. Our research results help to document, validate, and reuse knowledge across application domains. In the workshop, we want to discuss with colleagues opportunities for improving the added value coming from research and application of life cycle assessment applications.

Biogeophysics: non-invasive monitoring of environmental processes

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Abstract: The management of sensitive ecosystems, such as alpine permafrost, or natural resources like groundwater require detailed information about subsurface properties and processes. To date, such information is obtained through the analysis of soil and water samples, which may not be suited for continuous monitoring or the investigation of large areas. The necessity of real-time information on the negative impact of climate change in a variety of ecosystems demands the development of new diagnosis tools. Here I demonstrate that measurements of the physical properties of the subsurface, such as the electrical conductivity, can provide information about different biological and hydrological processes. Examples presented in this talk cover a wide range of ecosystems and processes: (1) understanding of the factors controlling the degradation of the soda lakes in the Neusiedlersee – Seewinkel National Park, (2) the quantification of surface water and groundwater interactions in landslides, (3) acceleration of rock glaciers due to the degradation of ground ice in alpine permafrost, (4) the identification of critical raw materials, such as graphite, (5) the mapping of biogeochemical hot-spots associated to the release of greenhouse gases in landslides, (6) the quantification of water and nutrient fluxes between soils and trees, and (7) the imaging of soil organic carbon and carbon pools.

The Josef-Ressel Centre "Linked System Assessment to Support Sustainable Energy Supplies (LiSA)"

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Abstract: The globally agreed climate targets as well as favourable economics are driving a global expansion of renewable energies. This expansion needs to be informed by a well-developed set of methods to assess technical, environmental, social, and economic impacts. These methods must cover the entire life cycle and should enable an efficient and target-oriented, quantitative assessment of energy technologies and systems.

The Josef-Ressel (JR) centre "LiSA" is designed to contribute to addressing this need. It was established at the University of Applied Sciences Burgenland on 1st January 2022, with a five-year funding period. The Centre focuses on thermal energy conversion systems embedded in a renewables-rich energy landscape. Three energy system levels are being targeted, 1) single technologies that generate and convert energy to heat/cold, and power, 2) district heating and cooling networks, 3) integrated energy systems that combine heating/cooling systems with renewable energy sources such as sector coupling technologies. The centre's objective is to adapt and apply methods to provide a dynamic sustainability assessment framework. The framework should be generally applicable to energy systems with a thermal component.

To model and assess different energy systems, the following sustainability assessment methods are part of the Centre's scope:

1) technical modelling/simulation
2) environmental life cycle assessment (LCA)
3) social life cycle assessment (SLCA)
4) economic evaluation of life cycle costs (LCC)

The presentation will focus on examples of LCA as applied to thermal energy systems. Specifically, the effects of time-resolved LCA as compared to the commonly used annual average energy balances will be shown, using a Viennese district-cooling plant with compression and absorption chillers as an example. The contribution will also provide some remarks on social LCA and how life-cycle based quantitative methods can be combined towards an LCSA (life cycle sustainability assessment) of multi-component energy systems. The presentation will conclude with a discussion of the Centre's current and remaining agenda.

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