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Bioenergy and Sustainable Technologies

BEST Centre‘s Day 2024

26. September 2024

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GreenCarbon Lab, Lab-scale Pyrolysis

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Green Carbon Liquids:
Staged Condensation from Lab-Scale Pyrolysis

BEST – Center’s Day
Graz, 26.09.2024

Goxhabelli Ana
Area 1.1 Termochemical Technologies

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Pyrolysis Plant – Lab Scale

Feedstock: Poplar Wood Pellets

Staged Condensation Unit

Staged Condensation

Setup Parameters

1st Condenser	2nd Condenser	3rd Condenser
80°C	*R.T.*	*-20°C*

- Condensable Gases from the pyrolysis process are separated based on their *boiling points*
- As the vapors are gradually cooled, *different compound* will condense at *different T*
- Improved efficiency of separation

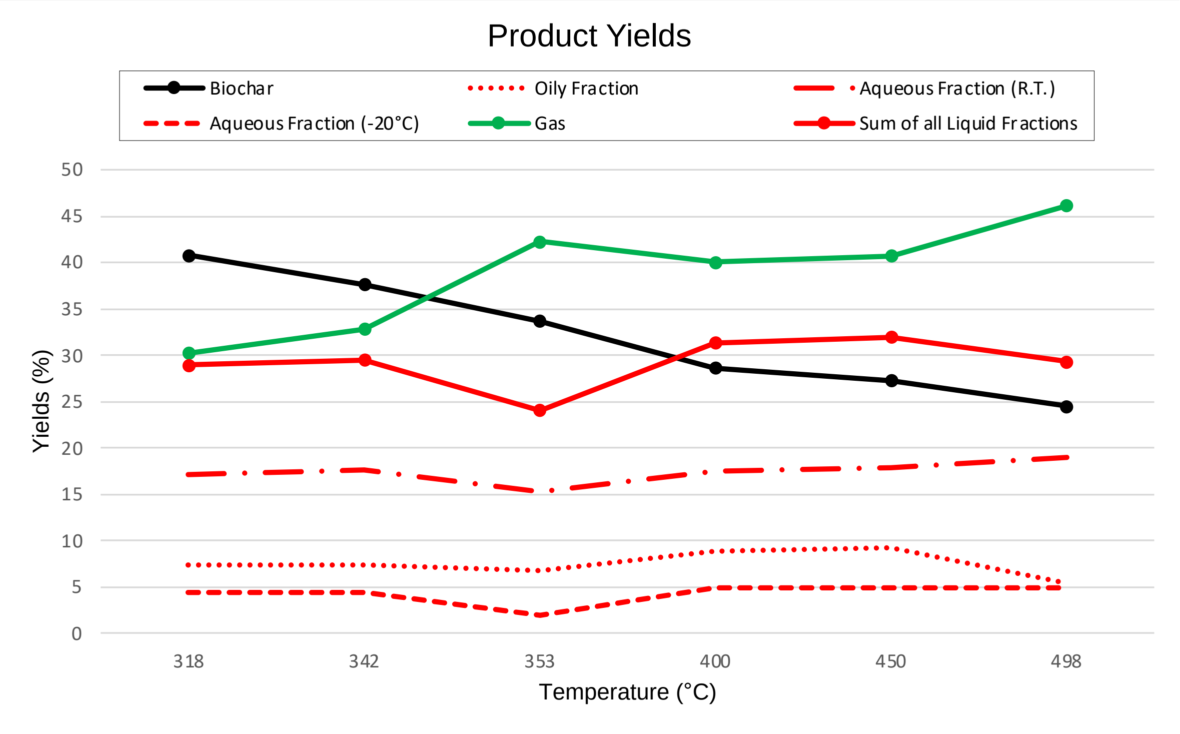
Products from Staged Condensation

Oily Fraction (80°C)

Aqueous Fraction (R.T)

Aqueous Fraction (-20°C)

Products from Staged Condensation



GAS FRACTION → Increases with T

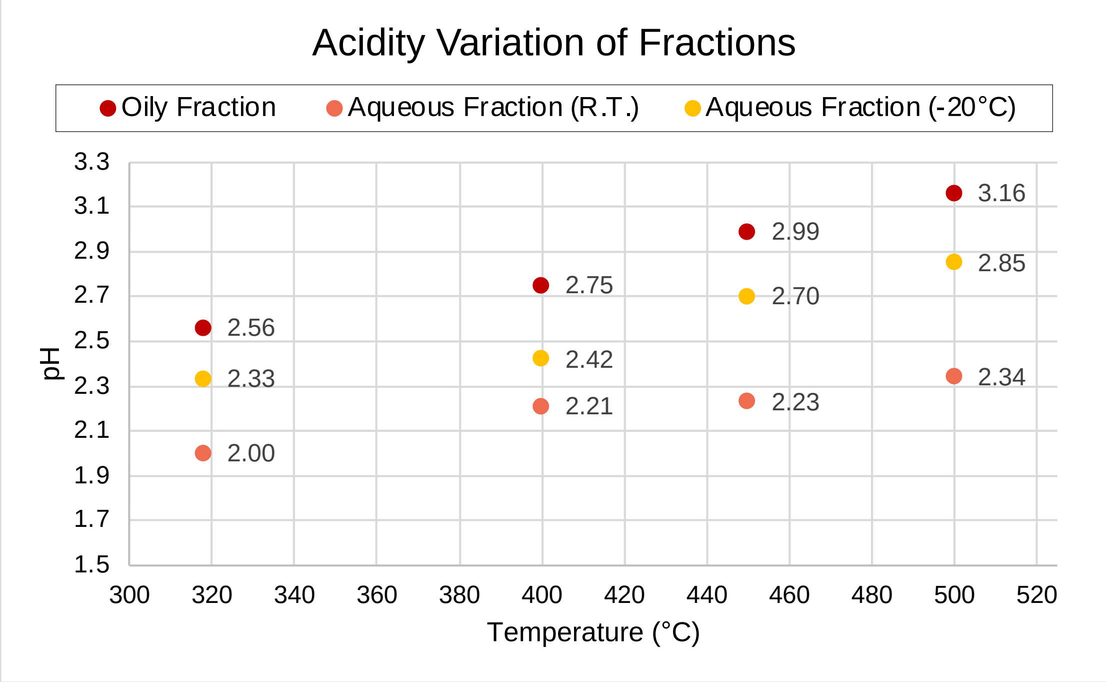
LIQUID FRACTIONS → Increase with T

BIOCHAR → Decreases with T

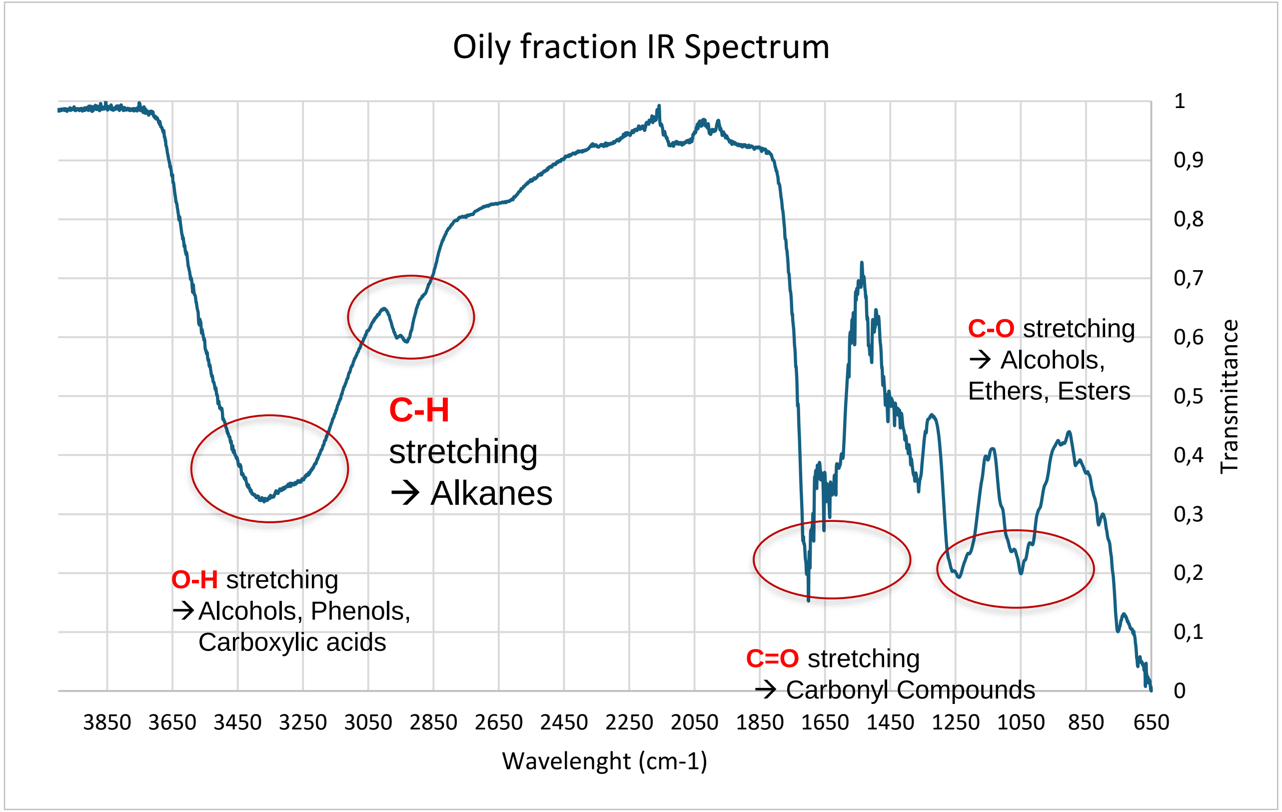
Products Properties - Acidity

- At lower T → higher yields of oxygenated compounds, like carboxylic acids, which lower the bio-oil's pH

- Higher T → reduced acidic components and higher bio-oil's pH



Spectral Analysis of Oily Fraction



Main components from literature:

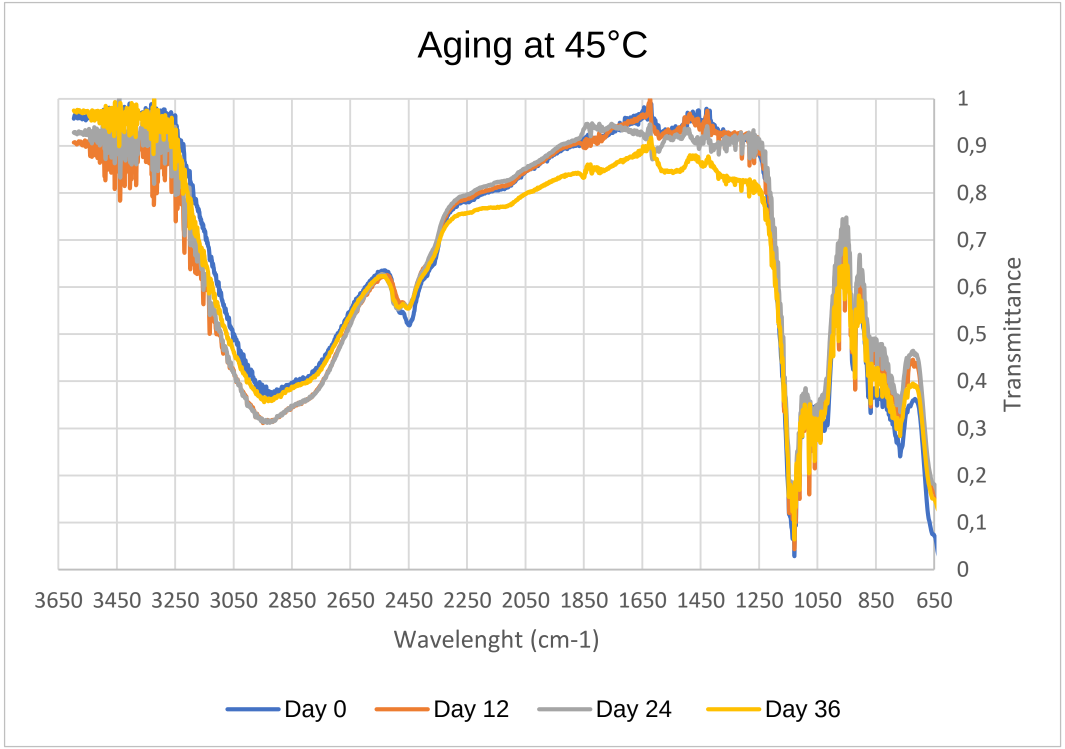
- ORGANIC ACIDS
- KETONES
- ESTERS
- ALDEHYDES
- ALKANES COMPOUNDS
- PHENOLS and DERIVATES

Aging Effect: FT-IR investigation

FT-IR analysis has been explored as a method to assess the Aging Effect of Bio-oil

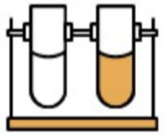
Over time a decrease in transmittance is observed…

… ONGOING INVESTIGATION



Conclusions and Future Work

Increased efficiency in fraction separation



Enhanced Production of different condensate liquids for specifi
pplication

Improving of Temperature Control to achieve purer
fra

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Green Gas – Green Heat for Industry from Biogenic Waste

Graz, 26.09.2024

Jascha Keifenheim

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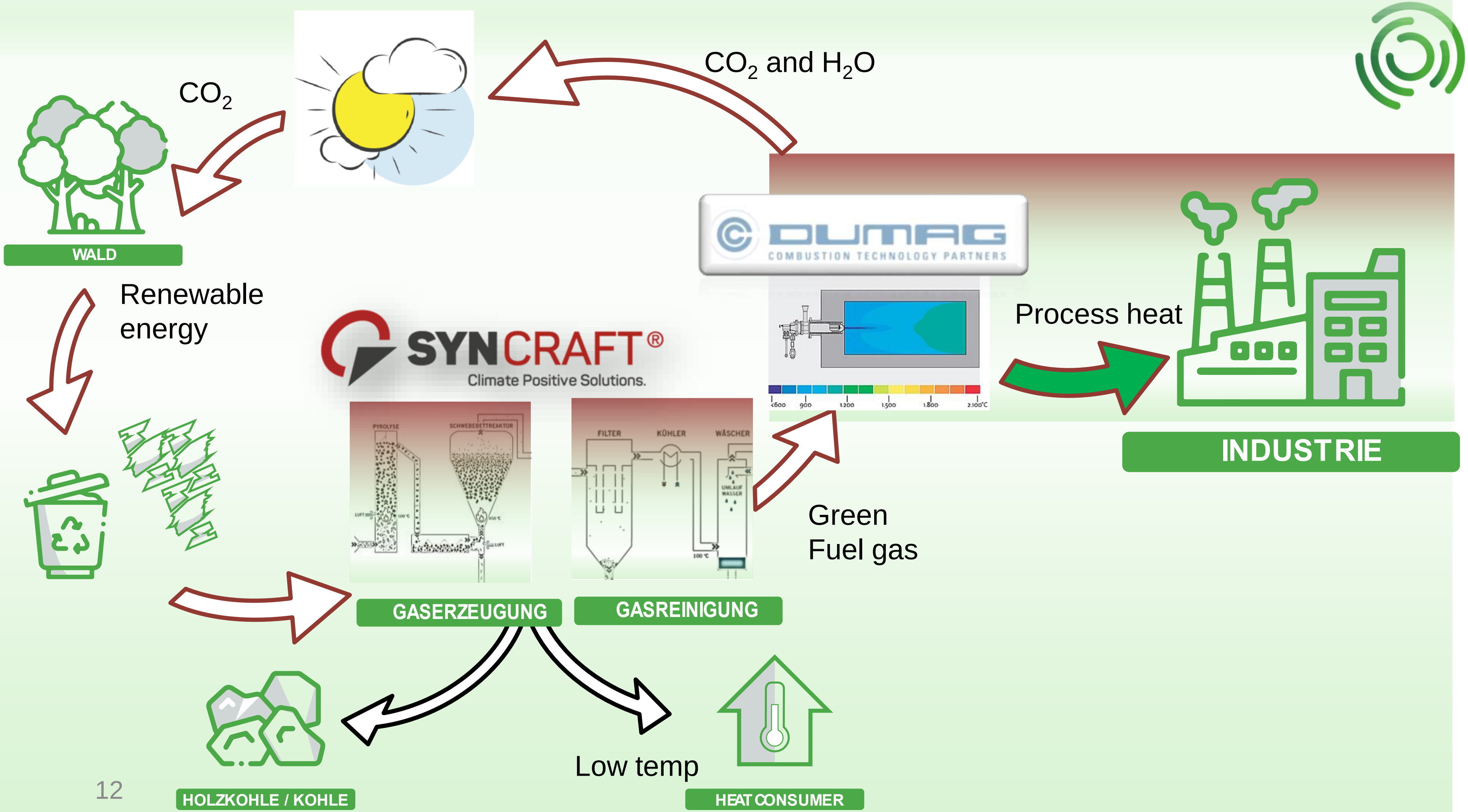


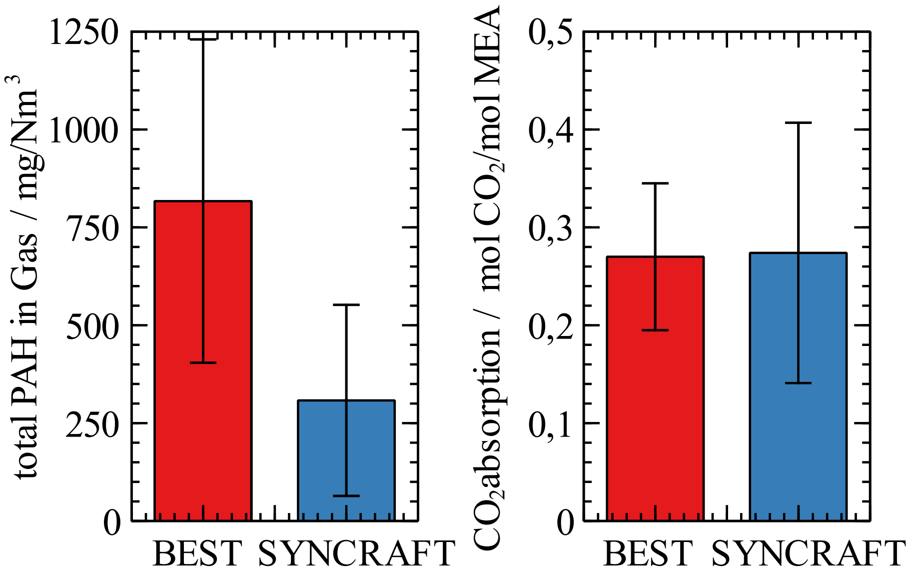
CO_2
CO_2 and H_2O
WALD
Renewable energy
SYNCRAFT®
Climate Positive Solutions.
DUMAG
COMBUSTION TECHNOLOGY PARTNERS
Process heat
INDUSTRIE
PYROLYSE
SCHWEBEBETTREAKTOR
FILTER
KÜHLER
WÄSCHER
Green Fuel gas
GASERZEUGUNG
GASREINIGUNG
Low temp
HOLZKOHLE / KOHLE
HEAT CONSUMER

Gas Cleaning

CO_2 and PAH Removal for Enhanced Gas Usability and Heating Value

PAH-Dependency on CO_2 Absorption

- More PAHs in the BEST gasifier
- Average absorption in BEST and SYNCRAFT gasifiers similar
- CO_2 absorption not PAH-dependent
- Proven concept of pre combustion CO_2 removal from the syngas

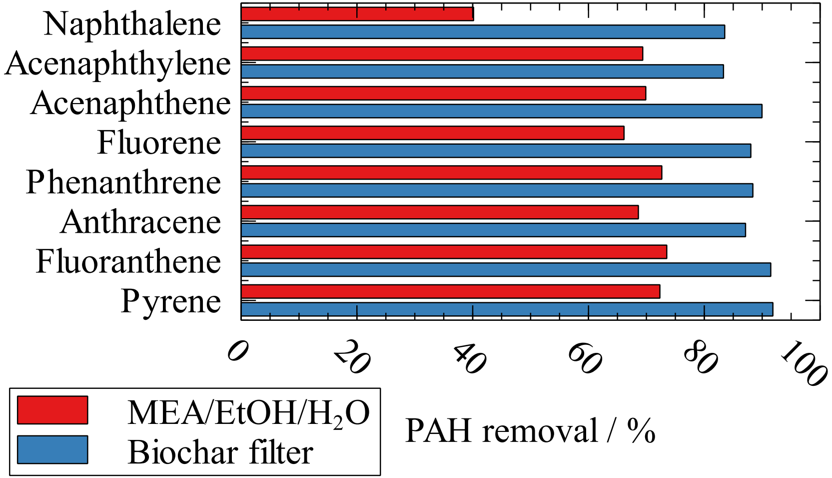


PAH Removal with MEA/EtOH/H_2O and Biochar

Two attempts for PAH removal:

1. Combined CO_2 and PAH removal
   - MEA/EtOH/H_2O mixture
   - Good removal of larger PAHs
   - Only 40 % Naphthalene

2. Biochar filter
   - Biochar directly from the process
   - > 80 % removal

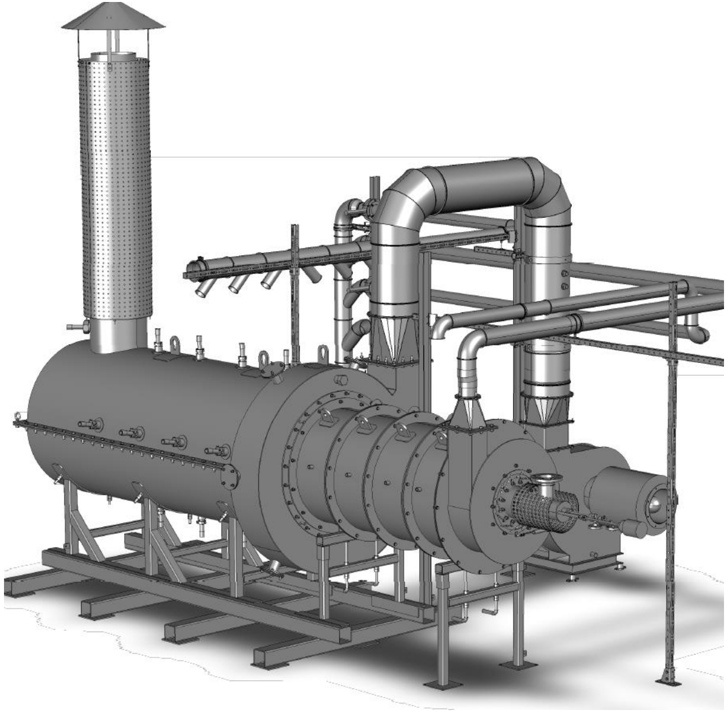


Pilot Scale Scrubber (Re-)Activation

- Adaption of existing NH_3 scrubber for CO_2-removal ~120 Nm³/h Syngas
    - Batch operation
    - Continuous operation later possible
- Extended sump vessel to circulate 1 m³ solvent
- Stripper to remove CO_2 from solvent

Gas Utilization

Valorization of Low Heating Value Gas for High-Temperature Heat in Industry

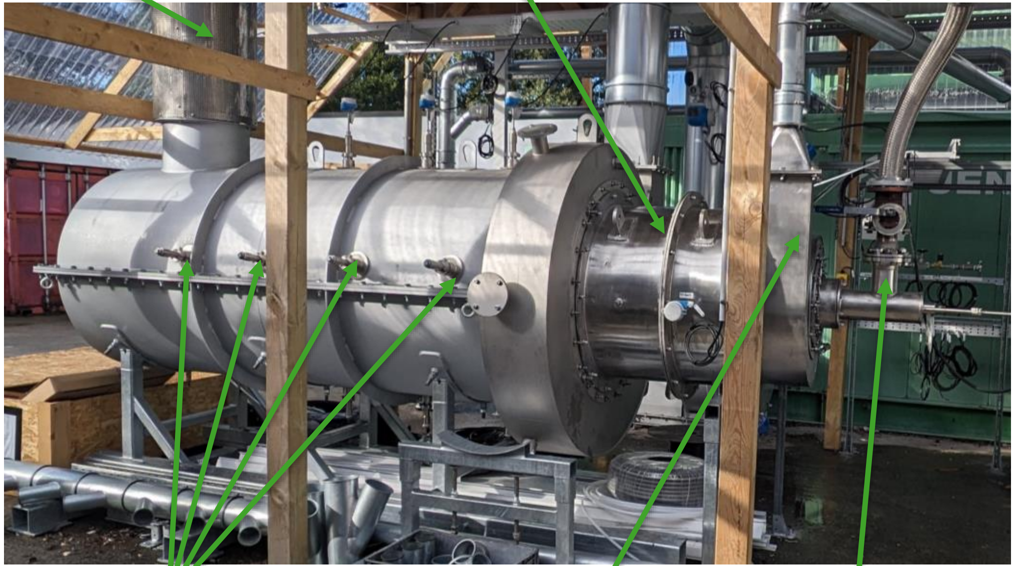


Mobile standard container sized burner test rig

Cooling air

Exhaust gas cooler

Variable length of the
pre-combustion zone



Sight glasses

Air-cooled double-jacket
combustion chamber to simulate
different operating conditions

Measurements of the
temperature profile

Primary air
(adjustable swirl
intensity)

Gas intake
150 – 750 kW

Outlook

- Further testing of biochar filter in labscale in october
- Launch of burner test rig in beginning of october
- First measurement campaign end of october
- Launch of scrubber in end of october
- First measurements in november

Biohydrogen – Implementation of Dark Fermentation for Industrial Wastewater Treatment

Graz, September 26th, 2024

Mario Preidelt, Matthias Neubauer, Richard Pummer, Wilfried Neuhauser, Bernhard Drosg

Introduction

- Project “Wastewater to Hydrogen”
- Partners:
  - Agrana Starch (Aschach, Upper Austria)
  - Agrana Research and Inovation Center (ARIC)
- Goal: Implement a treatment for organic wastewaters

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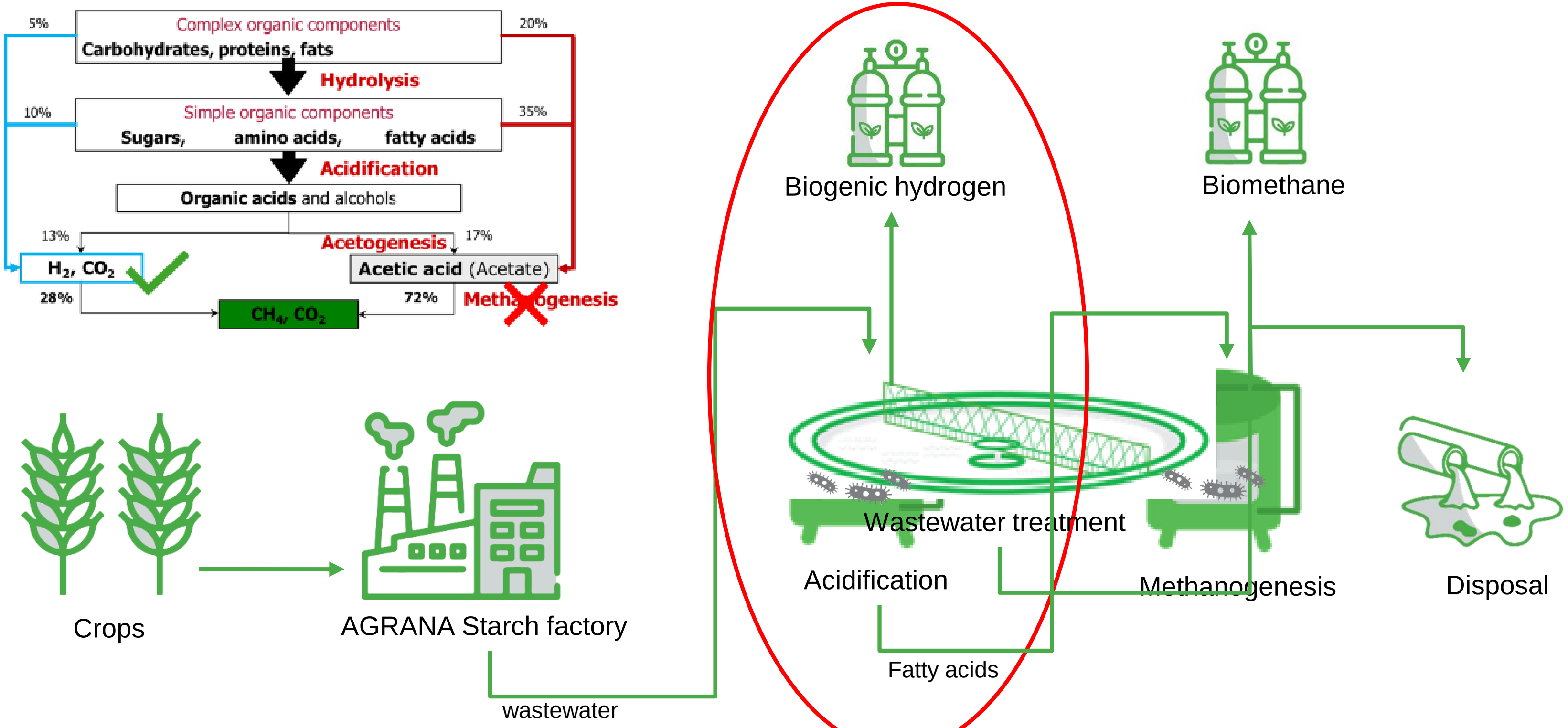
Aims and objectives



Experimental Setup

Pre-trials in serum bottles (**A**)
- Testing of media
- Complex nutrient sources tested
- Wastewaters screening (**B**)

Scale up – Pilot plant (**C**)
- Start with synthetic media
- Wastewater as carbon source (glucose)
- Complex nutrients sources (corn steep liqour, urea) + commercial trace element solution

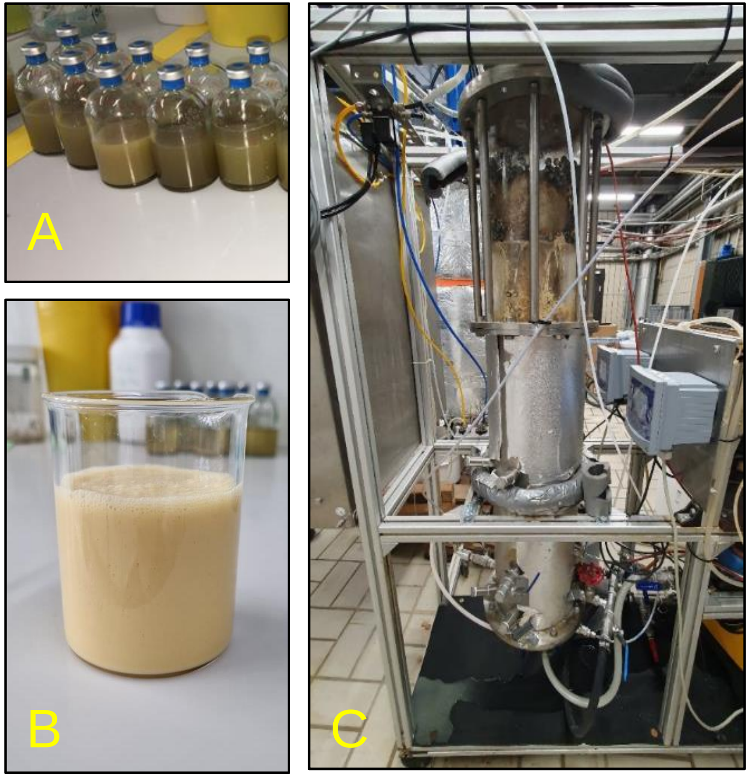


Figure 1: Serum bottles for pre-trials (A), the selected wastewater (B) and the operated pilot plant (C)

Experimental Setup – Pilot Plant

Cultivation parameters

- Temp.= 55 °C
- pH = 5.5 (2 M NaOH)
- Filling level = 13 L
- mixed consortium
- N_2 stripping
- Circulation pump

Analysis parameters

- Fatty acids and glucose
- pH
- N + P content
- Next generation sequencing
- AWITE - gas composition

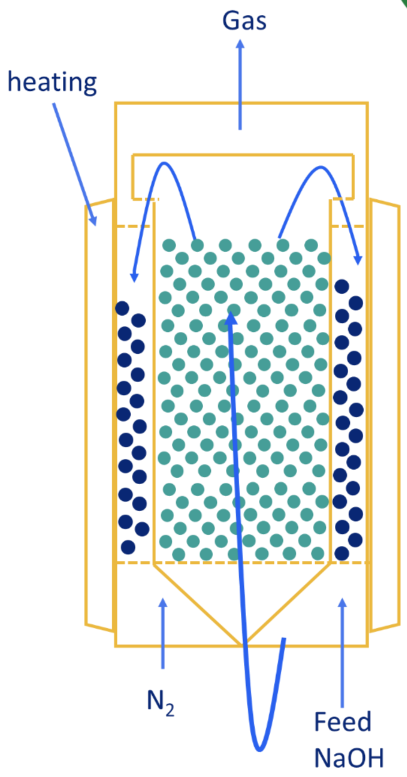


Figure 2: Sketch of the trickle bed pilot plant reactor

Problems

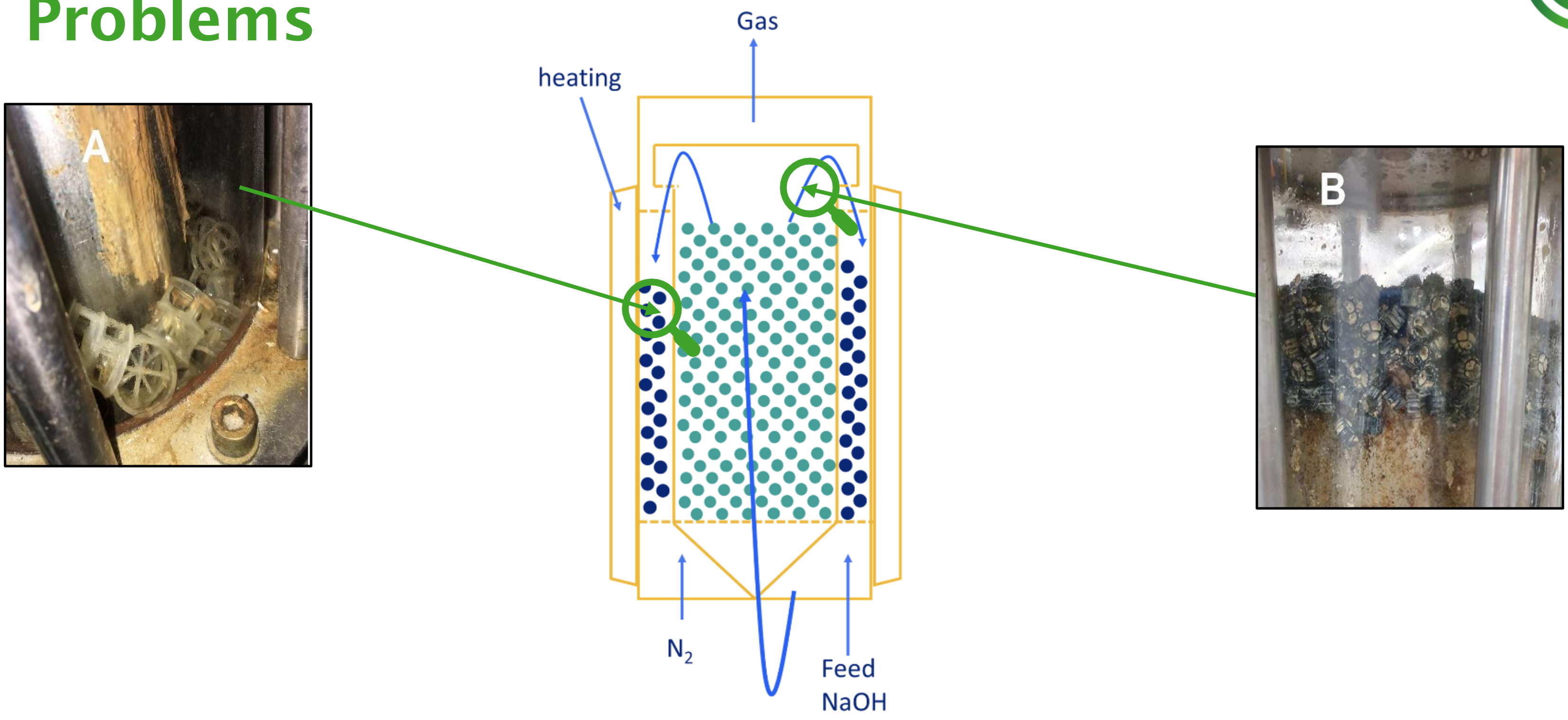


Figure 3: Filling bodies with accumulated wastewater solids. (A outer cyclinder, B center tube/top)

Results

- Stable operation at a maximum substrate flow of 200 mL/h.
- For a duration of 2 weeks:
  - Wastewater diluted (~ 15 g/L glucose) and acidified to prevent degradation
  - Nutrient solution (CSL, urea, trace elements) supplied

- 4.8 L media/day → HRT 2.7 days
- Observed blockage from solids
- Glucose degradation ~95 %

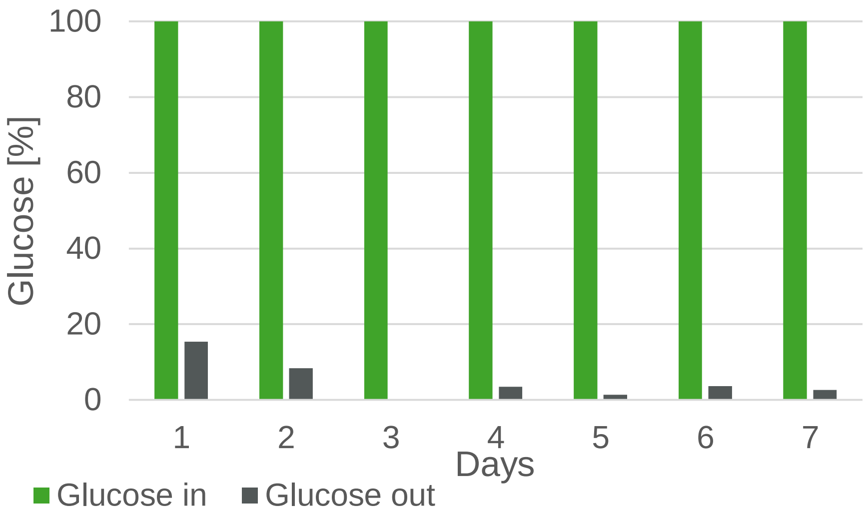


Figure 4: Glucose degradation

Results

Acetic acid ø 2 g/L
Butyric acid ø 4 g/L

Acids available for methanogenesis

- 9.5 g/d acetic acid
- 19.3 g/d butyric acid

Average = 20 Nl H_2/d

total Nl H_2: 280 Nl

total glucose input: 976 g

Productivity of 2.34 mol H_2/mol glucose

„Thauer limit“ of 4 mol H_2/mol glucose[2]

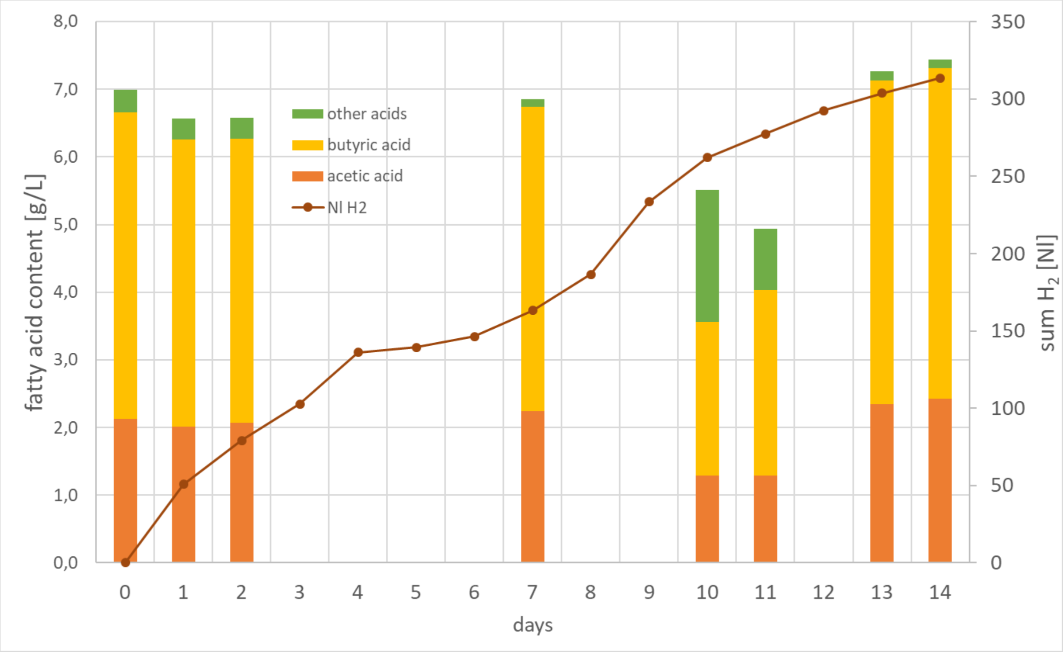


Figure 5: Fatty acid content and sum of Nl H_2 produced during stable operation of 2 weeks at 200 mL/h media flow.

Outlook

Often acidification prior to methanogenesis in an industrial setting

- Possibility to provide Fatty acids for methanogenesis

However no collection of H_2

- Released to environment
- Fully converted to CH_4 during hydrogenotrophic methanogenesis

Benefits of H_2 collection in an 2-stage biogas process:

- Possible energy carrier[3]
- Sustainable H_2 source → Reduce dependency on fossil fuels for H_2 production[3]
- Contribute to global H_2 demand – ammonia, electronics[4]
- More sustainable process for AGRANA → reduce use of fossil fuels[5]

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Effects of the climate crisis and pesticide use on fatty acids in the food web

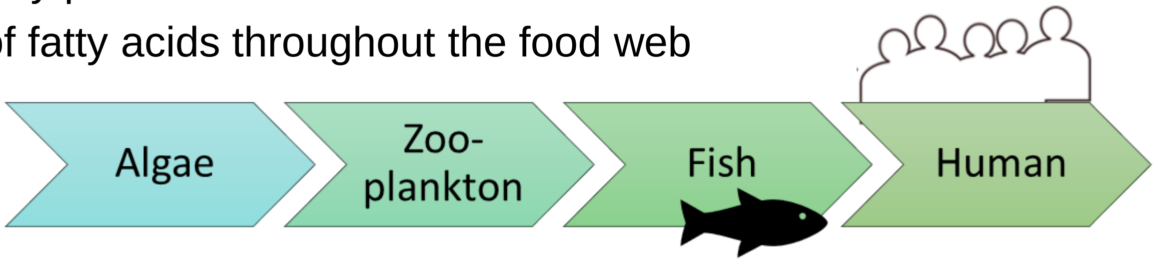
FUNDED AS PART OF THE RTI-STRATEGY LOWER AUSTRA 2027

Graz, September 26th, 2024

Katharina Ludwig, Lisa Bauer, Mario Preidelt, Emily Ruttner, Musa Elesad, Martin Kainz, Lidija Kenjeric, Michael Sulyok, Wolfgang Kandler, Ines Fritz, Bernhard Drosg

Fatty acids in the food web

- Phytoplankton – primary producers
  - Dietary transfer of fatty acids throughout the food web



- Essential functions in living organisms
  - e.g. energy storage, cell membrane, brain development
- Polyunsaturated fatty acids (PUFA) in food/feed important for consumers
  - Limited possibilities to adapt the fatty acid pattern through bioconversion

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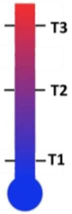
Influence of environmental factors

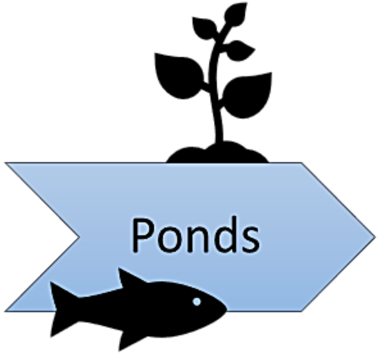
- **Fatty acid pattern in whole food web depends on environmental conditions**

- **Temperature** increase of 2-5 °C until 2100 predicted
  → increased water temperature
  - Changes in fatty acid pattern of phytoplankton
  - Heat → less long-chain and unsaturated fatty acids



- **Contamination** of freshwater ecosystems by xenobiotics, e.g. pesticides
  - Water soluble → surface run-off to ponds after heavy rains
  - Potentially harmful for aquatic organisms
  - Pesticides target metabolism of plants
    → similar effect on phytoplankton expected

Aims & first results



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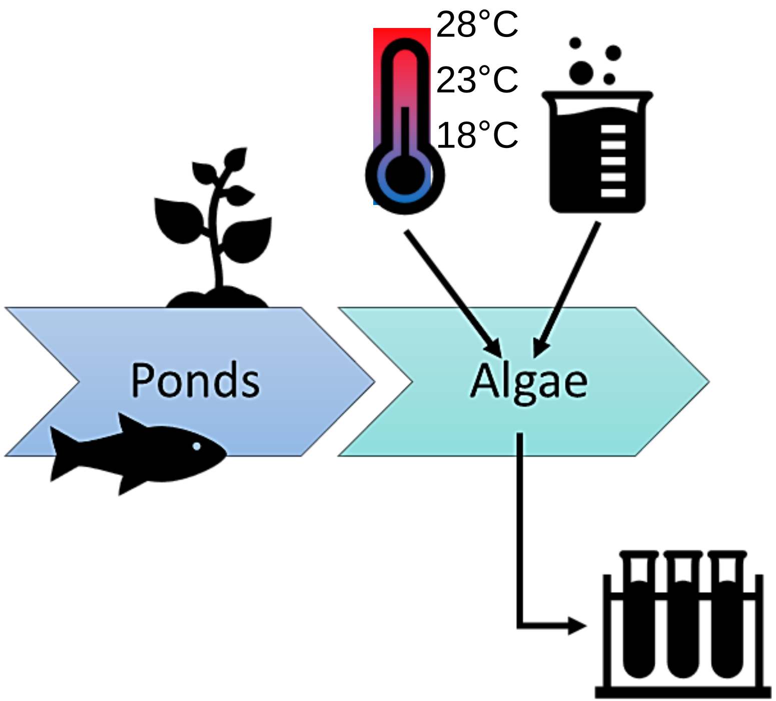

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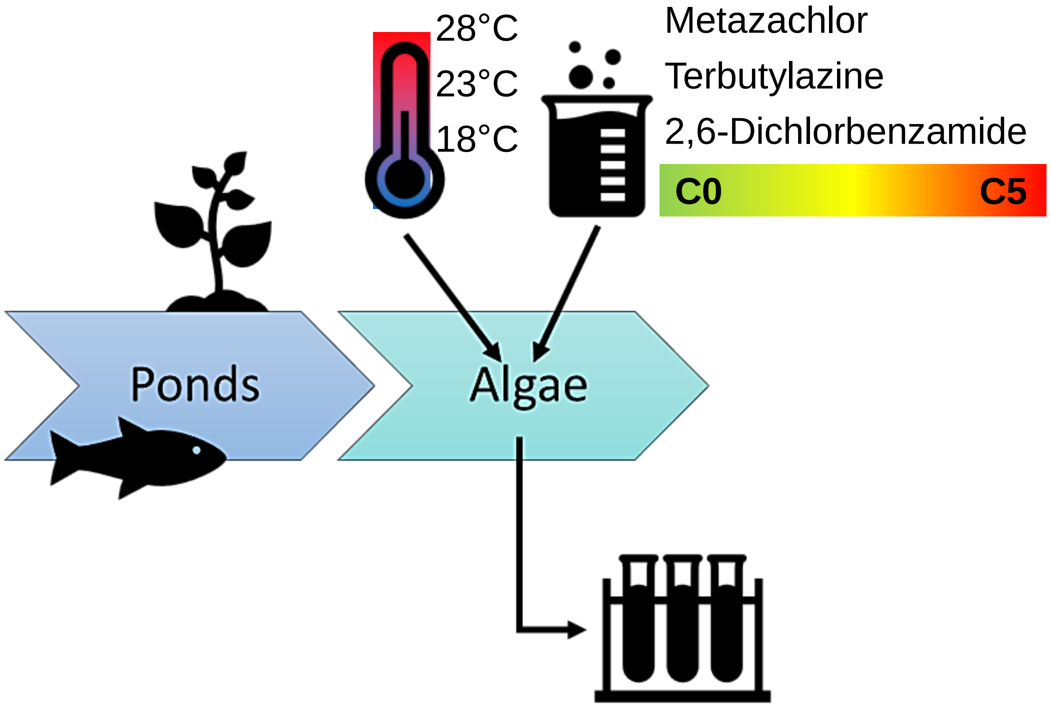

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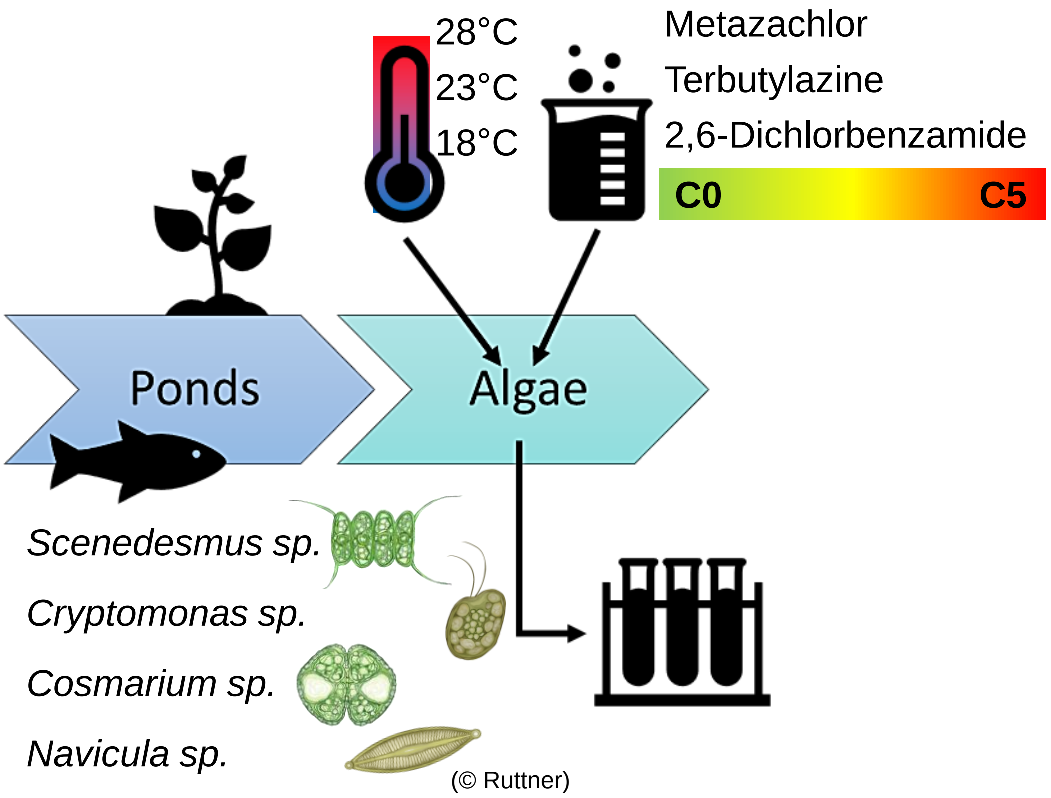

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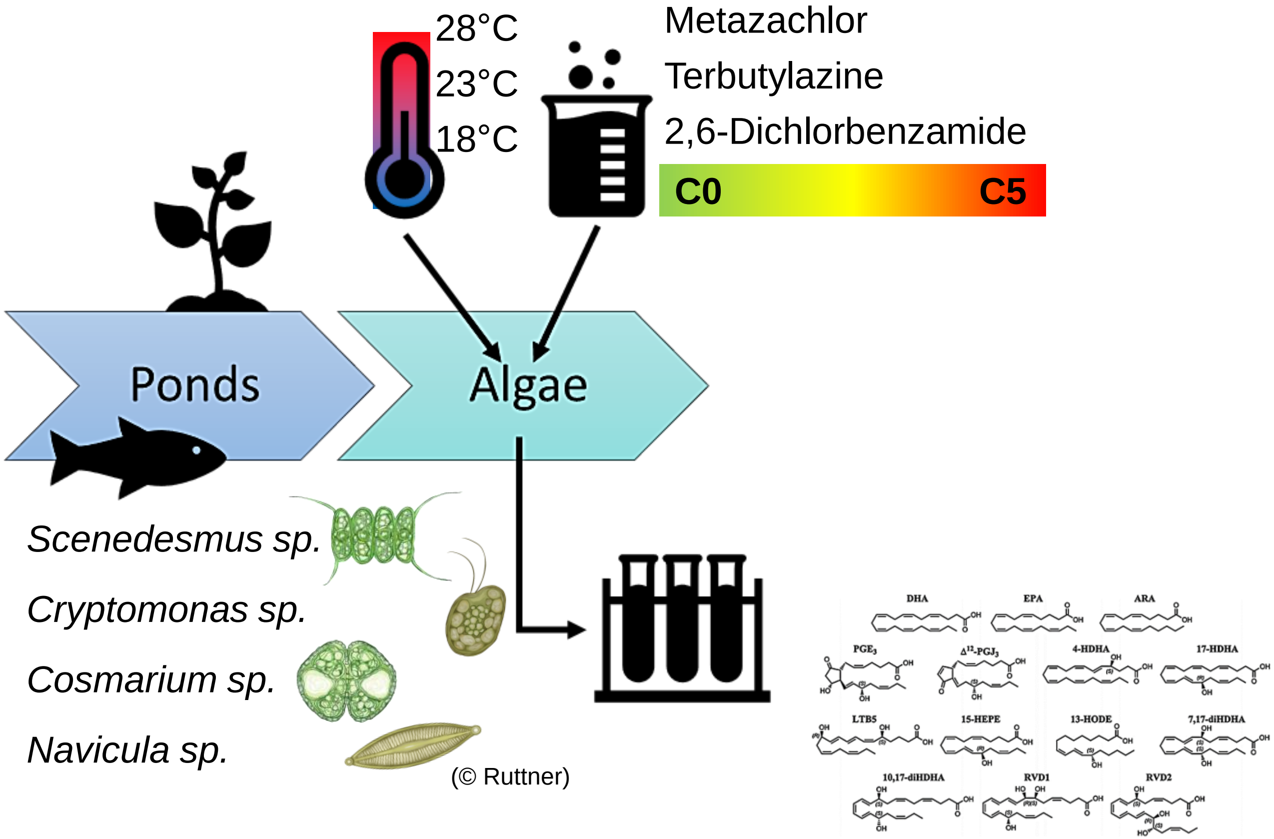

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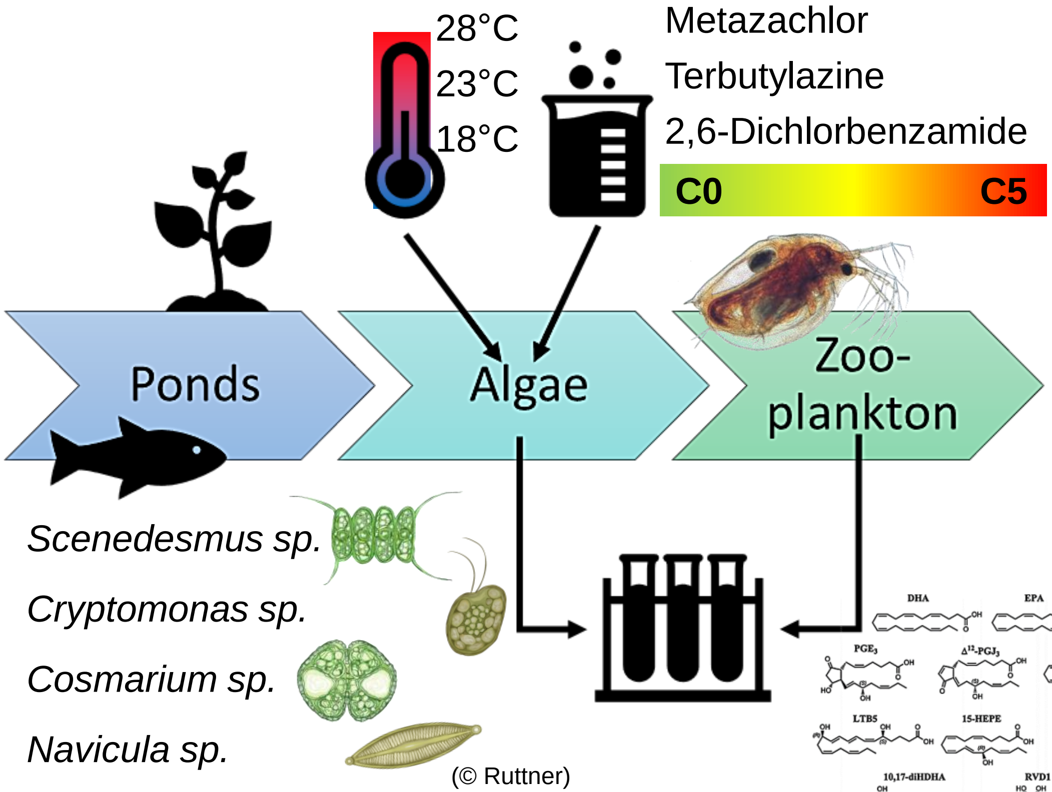

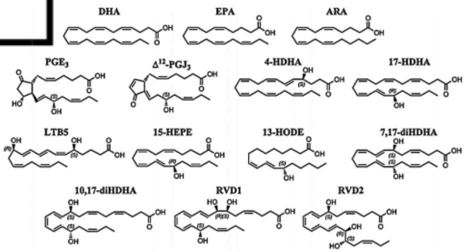

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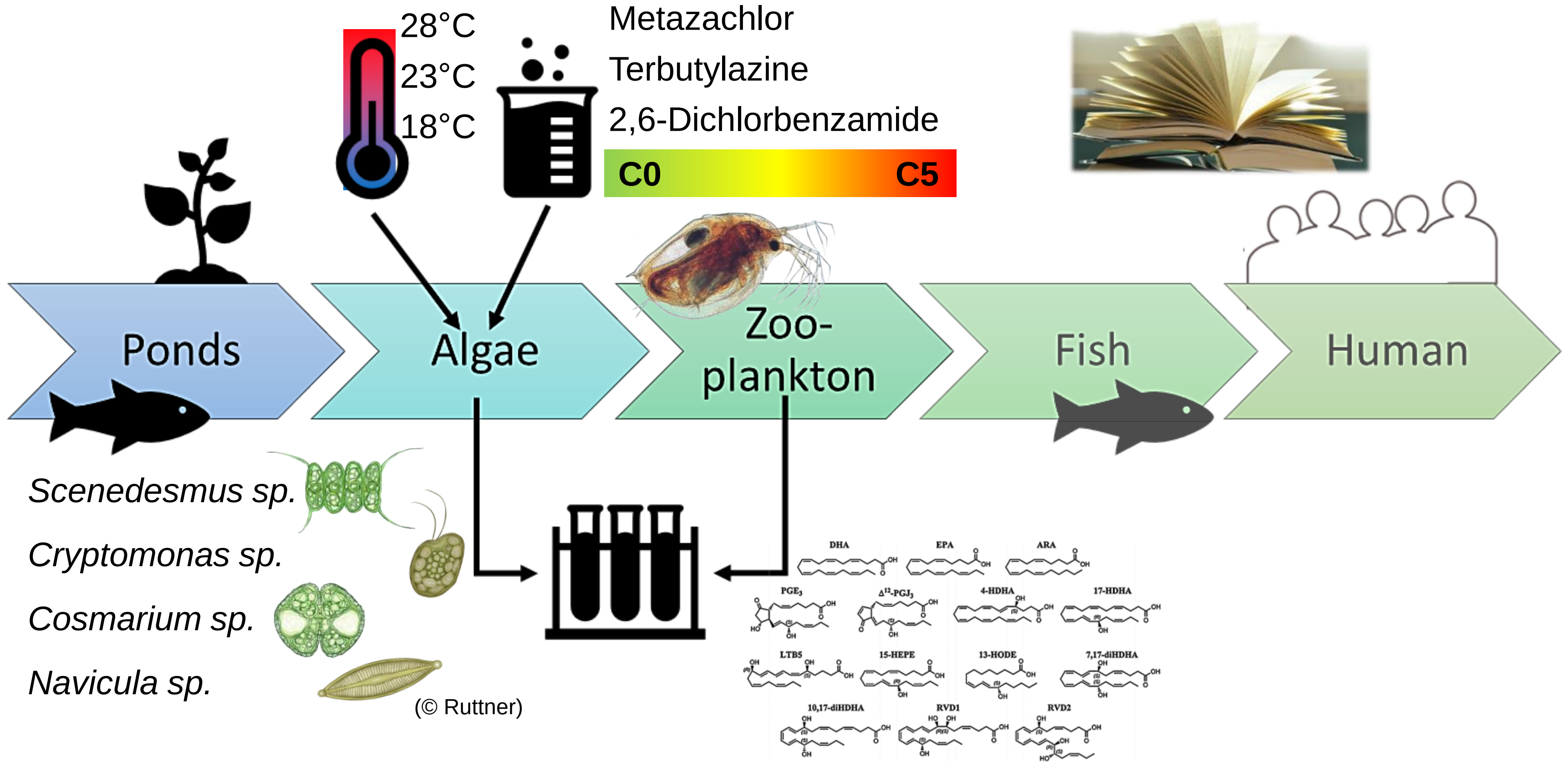
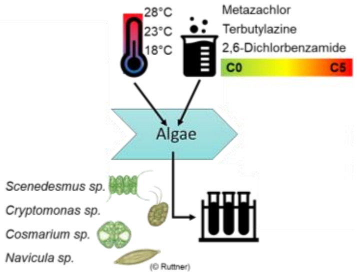
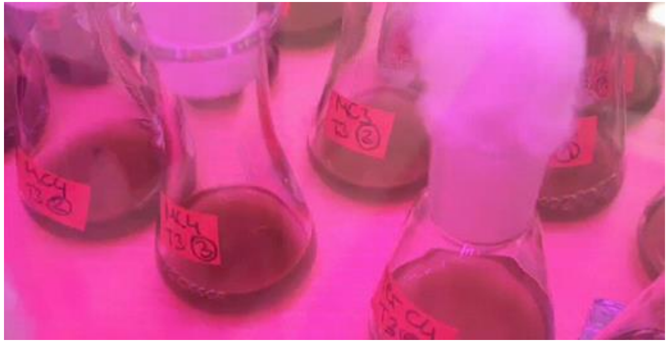


Current experiments – algae screening

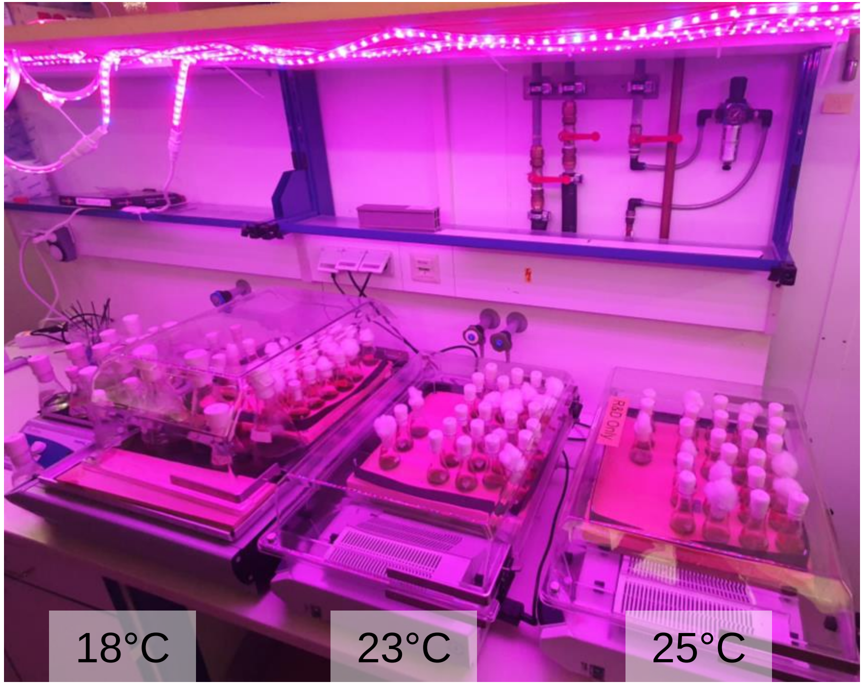




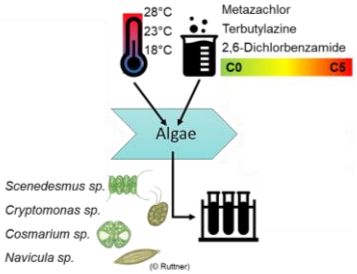
Cultivation in 25 mL shaking flasks (triplets)

Measurement of OD_{435}, OD_{680} in 96-well plates via plate reader

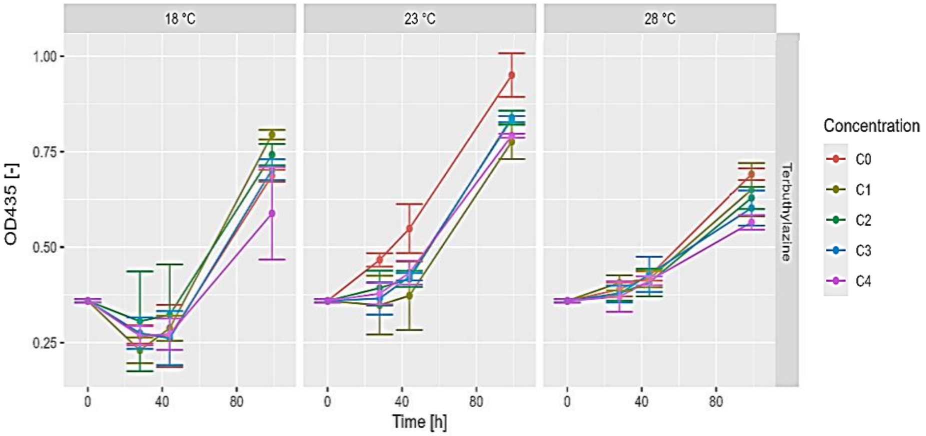
Data analysis in RStudio



Results – algae screening

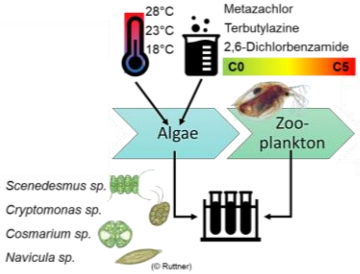


- Algae: *Scenedesmus*
- Pesticide: Terbuthylazine



- The growth rate of each algae strain is different
- Temperatures >23°C affect algae growth more than
  - increasing pesticide-concentrations
  - type of pesticide

Next steps



- Finalising algae screening and
- Data analysis

- Biomass production for
  - Lipid analysis and
  - Zooplankton cultivation

Thank you for your attention

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FTI-STRATEGIE NIEDERÖSTERREICH 2021–2027

GESELLSCHAFT FÜR FORSCHUNGSFÖRDERUNG NIEDERÖSTERREICH

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Bioenergy and Sustainable Technologies

Syngas production from biogenic residues and waste via advanced dual fluidized bed gasification

BEST Zentrumstag, Graz
September 29th, 2024

Miriam Huber

FFG Forschung wirkt.
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wirtschafts agentur wien
Für die Stadt Wien
Das Land Steiermark
Wirtschaft, Tourismus, Regionen, Wissenschaft und Forschung
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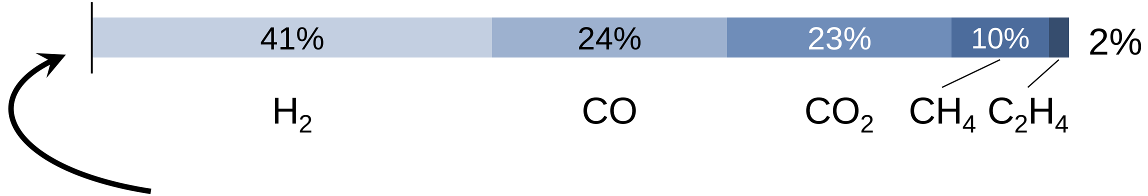
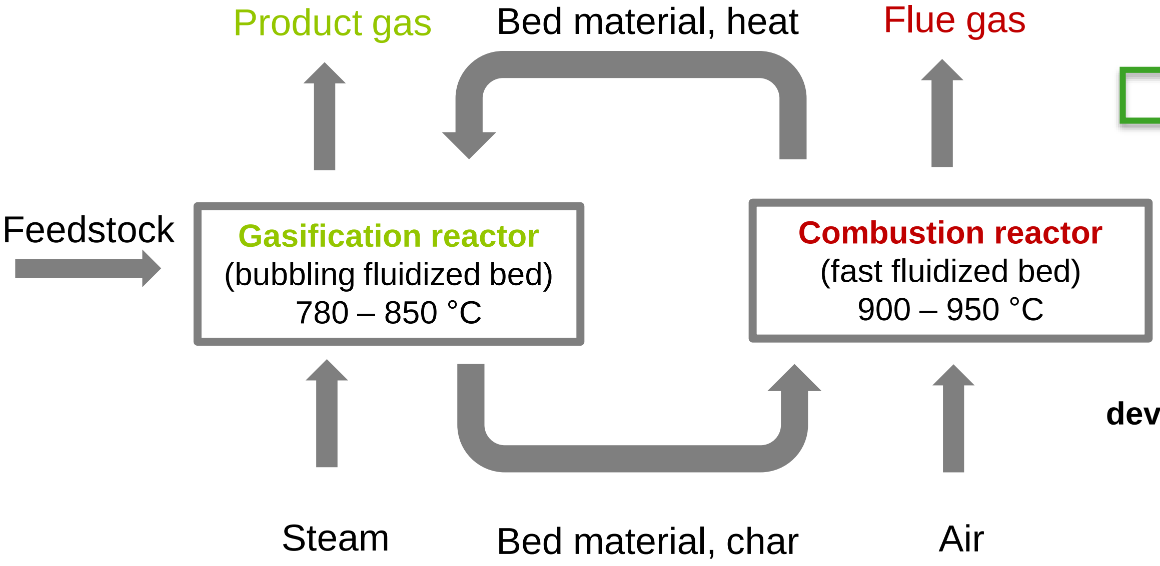
SYNGAS PLATFORM VIENNA

A **research hub** featuring a Waste2Value process chain: 1 MW **aDFB gasification** **+** 250 kW **Fischer-Tropsch** synthesis demo

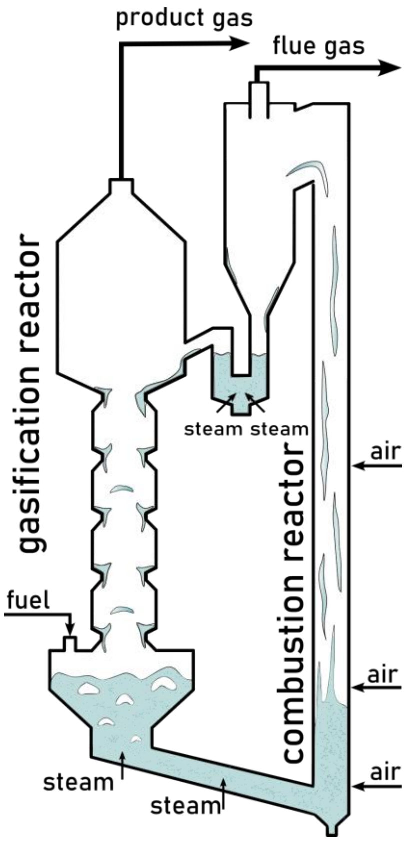
A connected **laboratory** supplied **with real syngas** for gas cleaning and upgrading

Advanced Dual Fluidized Bed Steam Gasification

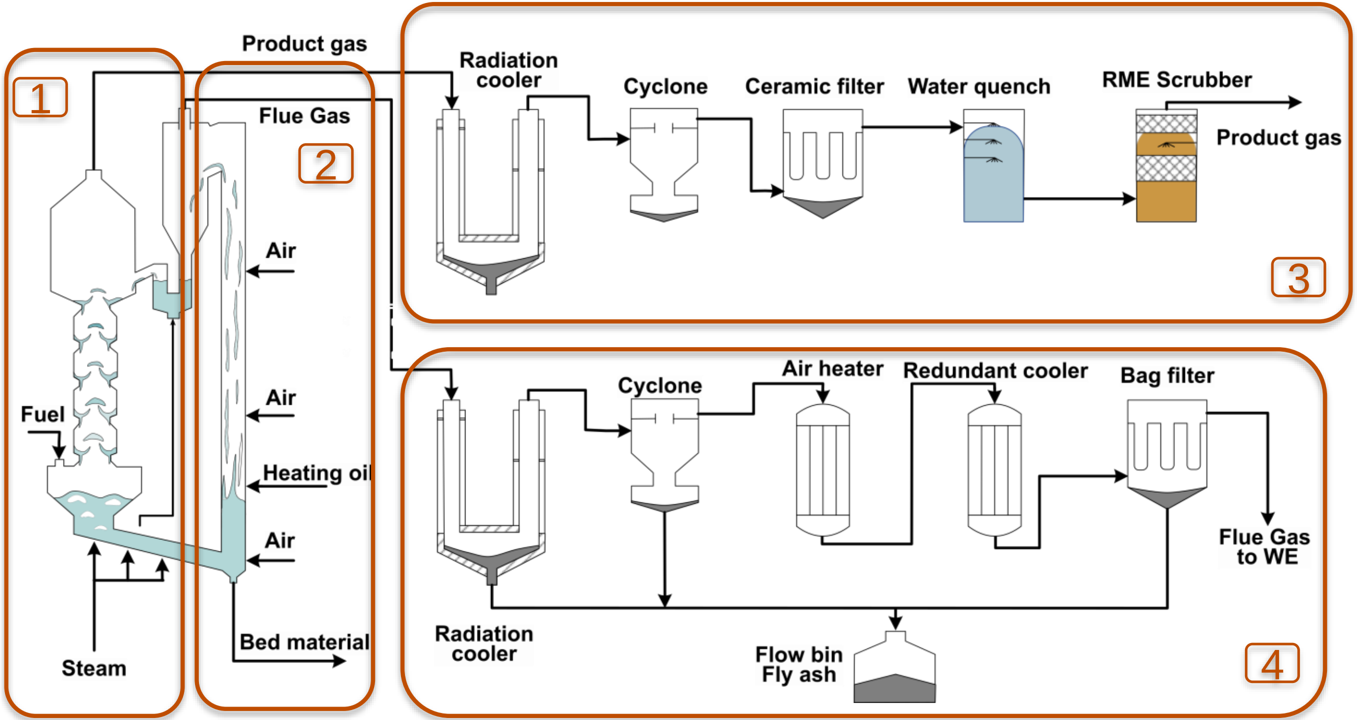




developed at



Process Scheme - Gasifier



1 Gasifier

2 Combustor

3 Product Gas Cleaning

4 Flue Gas Cleaning

Feedstock Variety

wood chips

plastic rejects

sewage sludge

Decreasing LHV

Increasing ash content

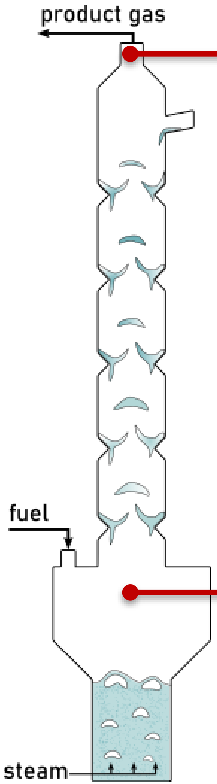
cashew husks

forestry residues

bark

paper sludge

Countercurrent Flow Column



Measurement Point
After Countercurrent Column

Gravimetric tar 8.9 g/Nm³
GCMS tar 11.0 g/Nm³

Measurement Point
Freeboard

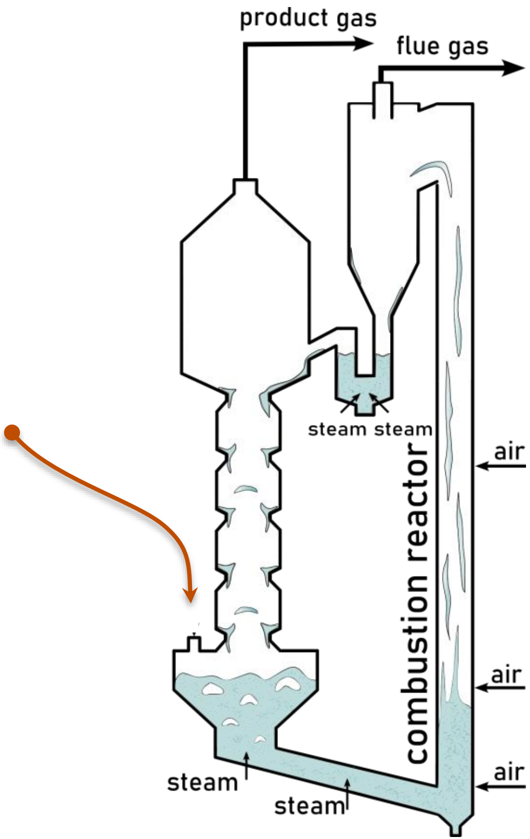
Gravimetric tar 11.5 g/Nm³
GCMS tar 16.9 g/Nm³

Plastic Rejects Blend

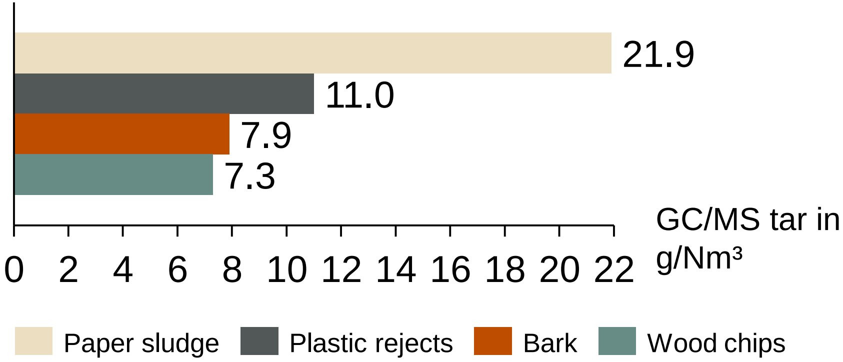
Countercurrent column
Increased contact of upstreaming product gas and downstreaming catalytically active bed material

Gravimetric tar -23 %
GCMS tar -35 %
for plastic-rich rejects blend as exemplary feedstock

Pulp and Paper Residues



Gas Impurities Before Cleaning



Below < 1.5 g/Nm³ after coarse gas cleaning

Research Areas

Extensive demonstration campaigns with challenging waste feedstocks

Optimization of product gas composition for i.e. FT synthesis

Upscaling of countercurrent column

Cold flow model investigations on fluid dynamics

Thank You For Your Attention!

BEST
Bioenergy and Sustainable Technologies

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Für die Stadt Wien
Das Land Steiermark
Wirtschaft, Tourismus, Regionen, Wissenschaft und Forschung
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Area 1.3 – Syngas Platform Technologies

New developments in gas cleaning for the production of C-based products and fuels via gasification

BEST – Zentrumstag, Graz, 26.9.2024

Anna Egger

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Why product gas cleaning?

Fouling reduction

- Reduction of blockages of heat exchangers, filters, blowers and other plant parts

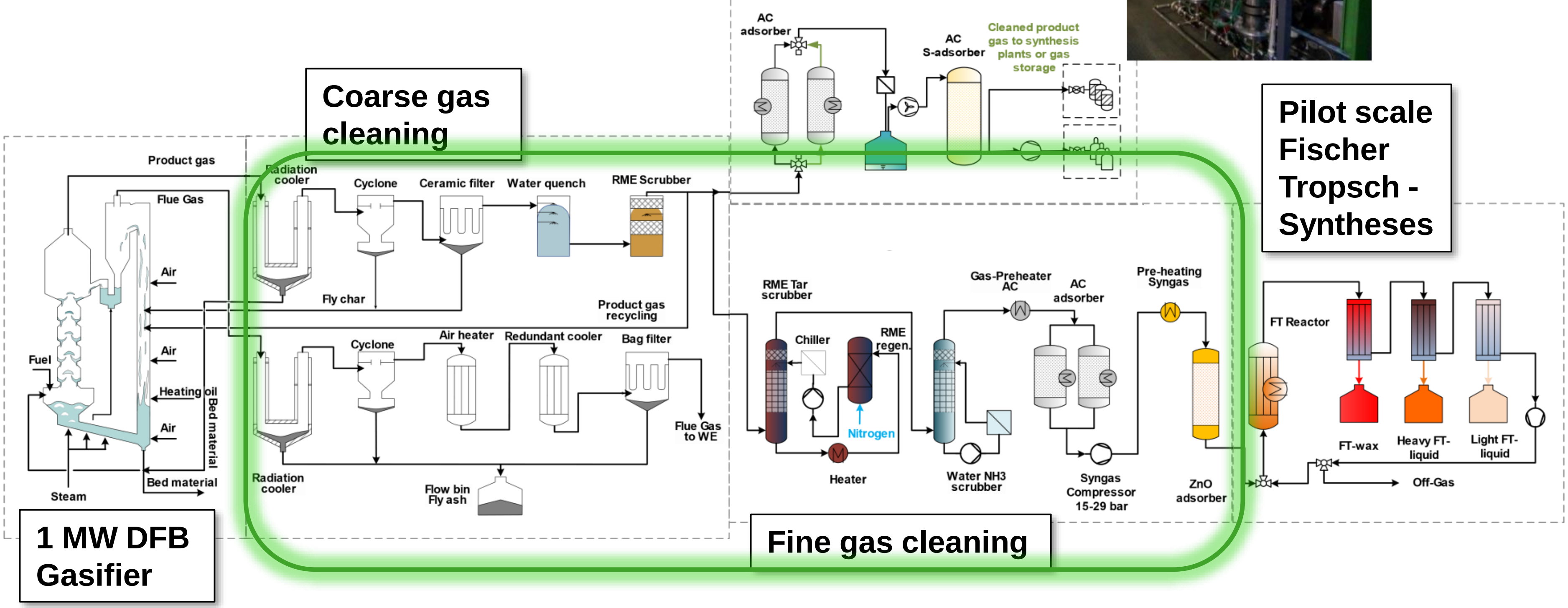
  ➔ Necessary reduction of: particles, tar compounds
- Result: decreased maintenance effort

Reaching requirements for down stream processes

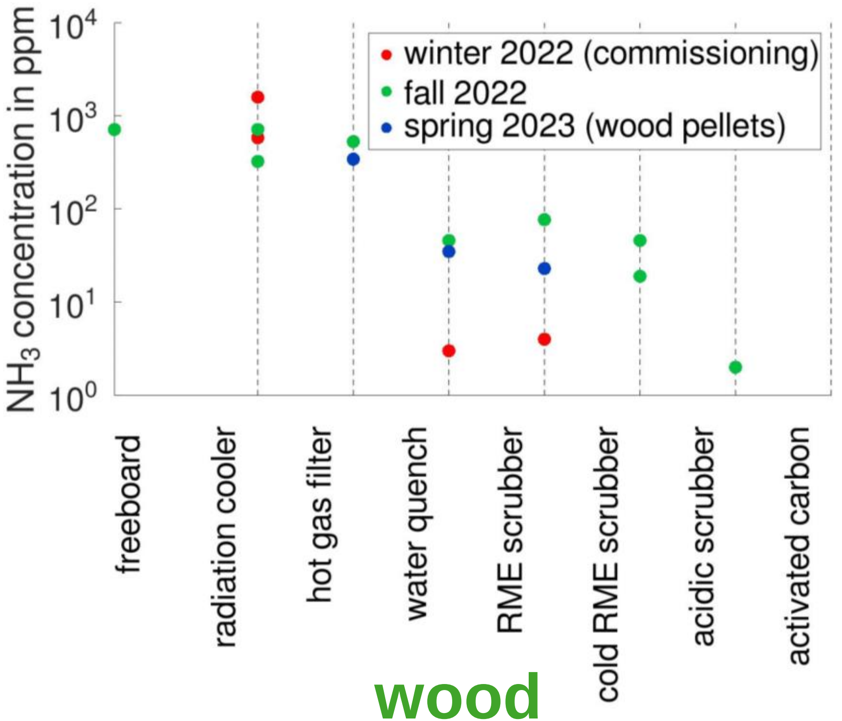
- Removal of components with negative effects on downstream processes

  ➔ Catalyst poisons: sulfur-, nitrogen- and halogen compounds
- Removal of reaction inhibiting components
- Particles, tar components and benzene

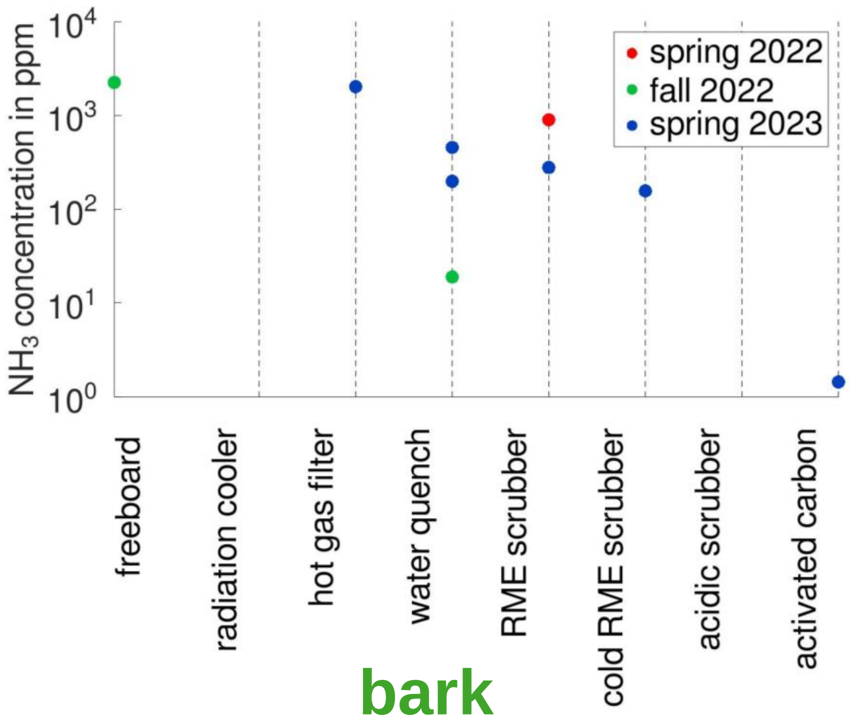
Process chain at the Syngas Platform Vienna



NH_3 concentrations observed during woody biomass gasification



wood



bark

Focused research areas

Effect on increased impurity contents on classic gas cleaning

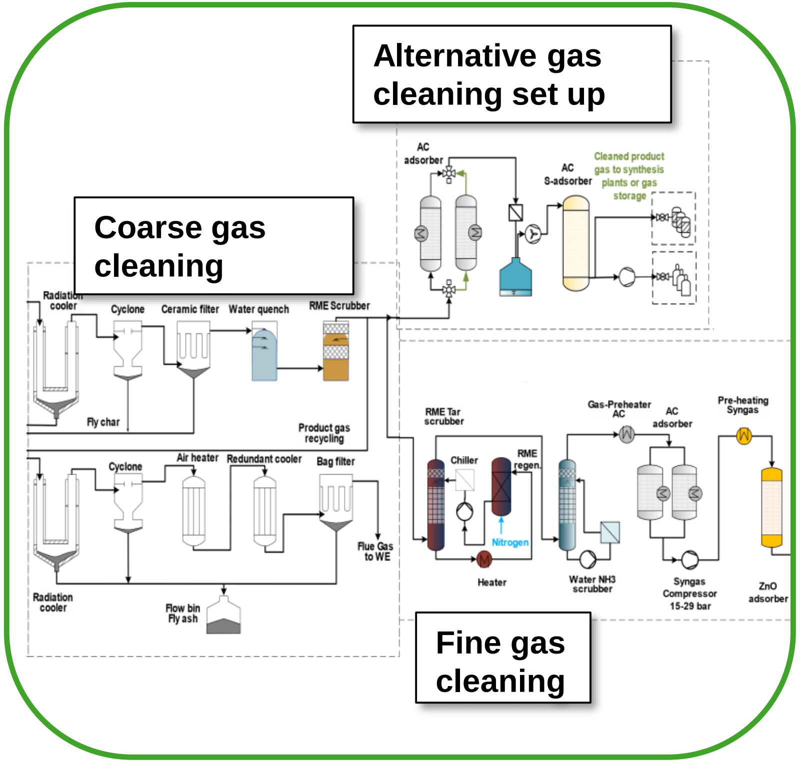
- Quench
- RME-Srubbers
- Activated carbon (RME-alternatives)

Impurities as value added products

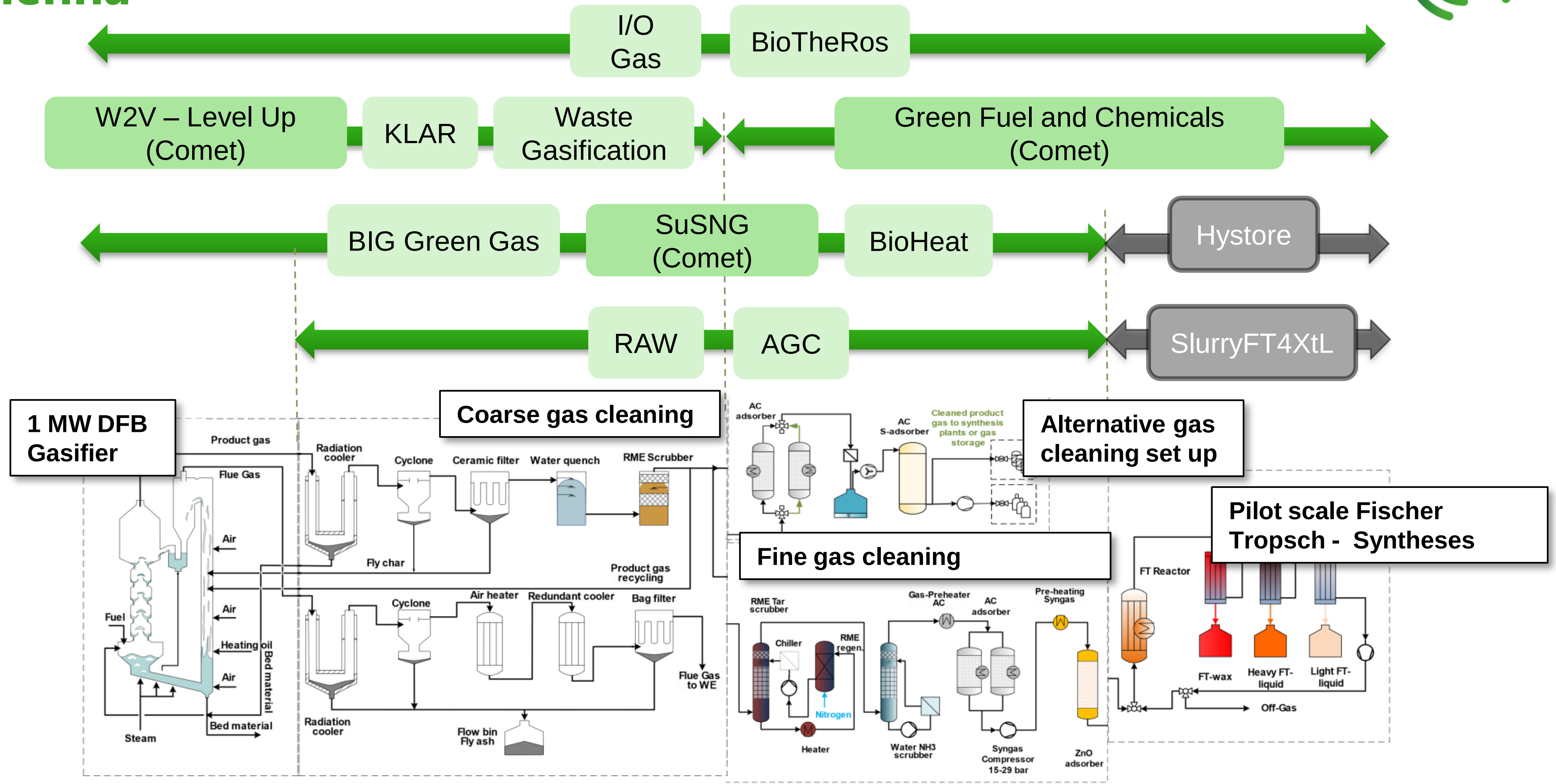
- Ashes
- Tar components
- Waste water

Evaluation of closed loops within the process and substance accumulation

- Loaded RME
- Waste water handling
- Fly char



Projects investigating gas cleaning at the Syngas Platform Vienna



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Bioenergy and Sustainable Technologies

Area 1.3 – Syngas Platform Technologies

Advancements in Fischer-Tropsch synthesis using a slurry bubble column reactor

BEST Zentrumstag, Graz 26.09.2024

Theresa Köffler

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Für die Stadt Wien
Das Land Steiermark
Wirtschaft, Tourismus, Regionen, Wissenschaft und Forschung
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FT Synthesis: Pathway to Green Fuels and Chemicals

Gasification → Cleaning → FT Synthesis

Raw syngas

Pure syngas

Green Chemicals

- α-Olefins
- Naphtha
- Wax

FT-Diesel

Hydroprocessing

Green Fuels

**woody biomass,
residues, cashew husks, …**

i/n- paraffins

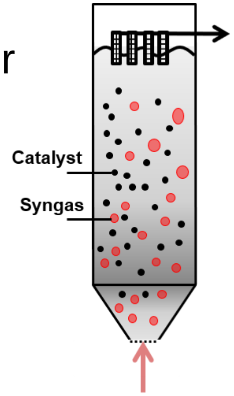
FT wax

Fischer-Tropsch Synthesis (FTS)

- Catalytic process to convert syngas ($CO + H_2$) into hydrocarbons

- Process conditions:
  - Temperature: 200 - 230°C
  - Pressure: 20 - 22 bar(g)
  - Catalyst: Co/γ-Al_2O_3 (commercial)

- Slurry Bubble Column Reactor
  - ✓ Heat and mass transfer
  - ✓ Simple reactor design
  - ✓ Load flexibility



Lab scale FTS

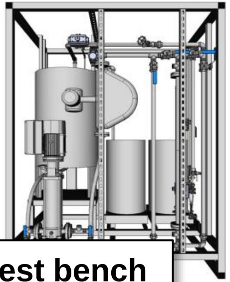
Pilot scale FTS

Research area - Process optimizations

- Reactor design
  - Different reactor configurations
  - Testing of different gas distribution systems

SBCR cold model

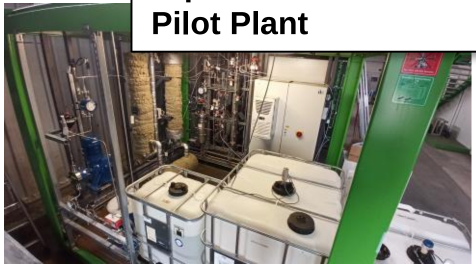
- Product separation
  - Thermal product separation
  - Fine separation of catalyst particles



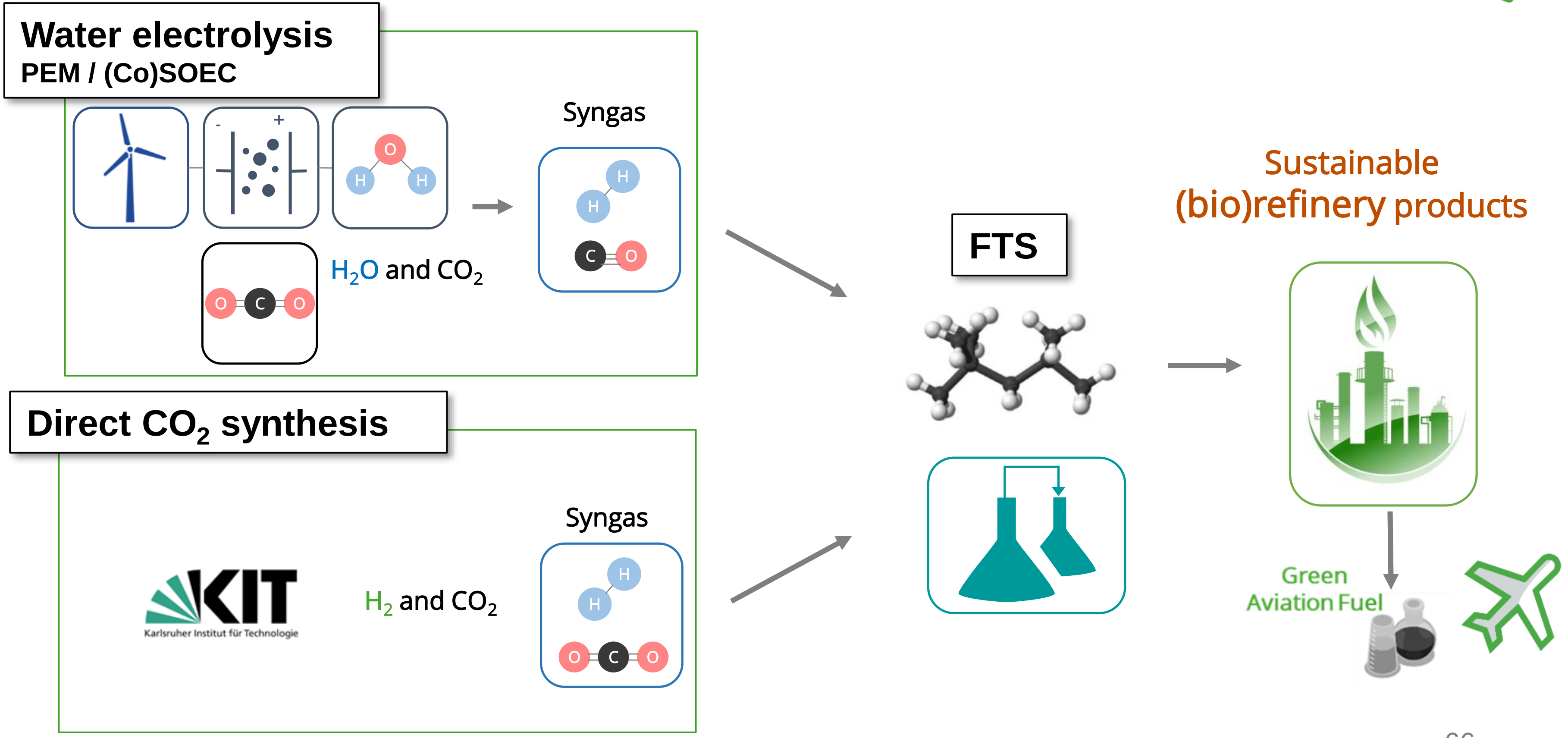
Filtration test bench

- Usage of FT water
- Tailgas Loop
- Effect of contaminations on FT synthesis

Aqueous Phase Reforming Pilot Plant



Research area – XtL Syngas pathways



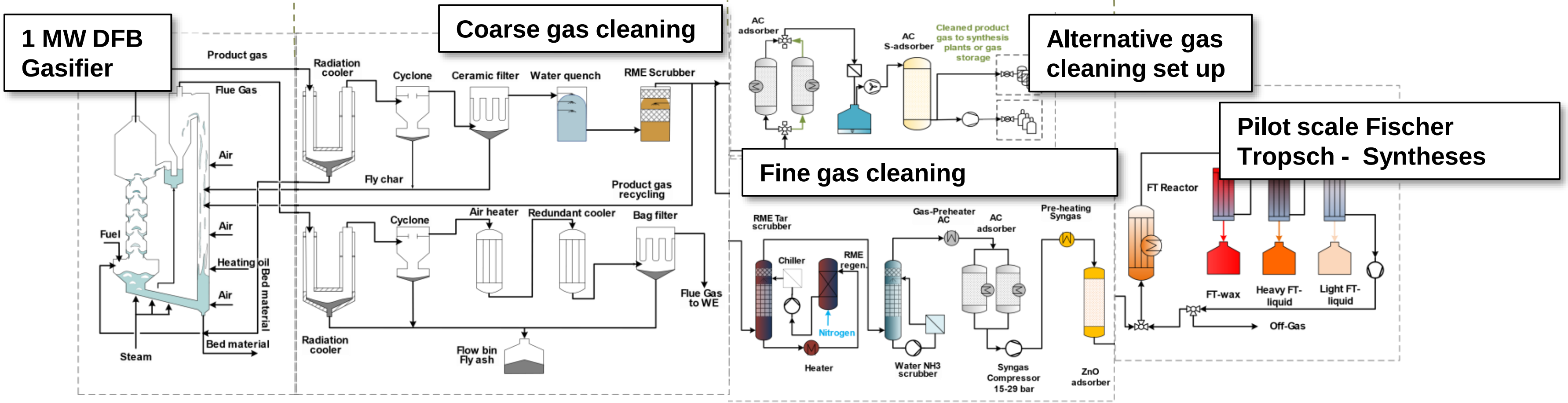
Projects investigating gas cleaning at the Syngas Platform Vienna

I/O Gas
BioTheRos

W2V – Level Up (Comet)
KLAR
Waste Gasification
Green Fuel and Chemicals (Comet)

BIG Green Gas
SuSNG (Comet)
BioHeat
Hystore

RAW
AGC
SlurryFT4XtL



Our industrial and scientific partners

BEST Bioenergy and Sustainable Technologies

WIEN ENERGIE

repotec renewable power technologies

DIEFFENBACHER

YOSEMITE CLEAN ENERGY

CAPHENIA

solarbelt fairfuel

BASF We create chemistry

ÖSTERREICHISCHE BUNDESFORSTE

BOKU UNIVERSITY

TU WIEN TECHNISCHE UNIVERSITÄT WIEN

LULEÅ UNIVERSITY OF TECHNOLOGY

UMEÅ UNIVERSITY

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KIT Karlsruher Institut für Technologie

Center for Future Energy Technologies

COMET

H&R Group

BEST Bioenergy and Sustainable Technologies

Biofuels – a crucial part of decarbonisation?

BEST Centre´s Day,
26^{th} September 2024, Graz

Dina Bacovsky, Doris Matschegg, Andrea Sonnleitner

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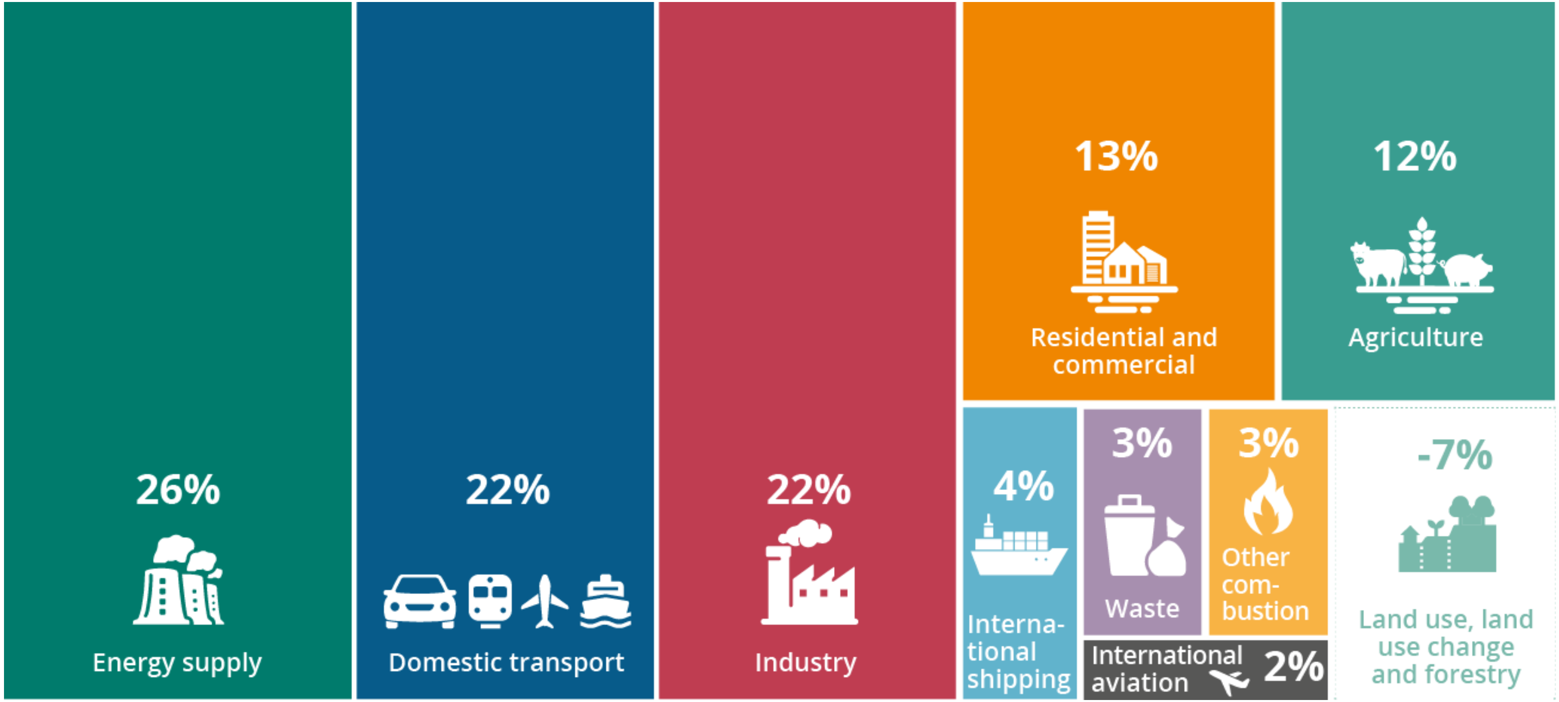
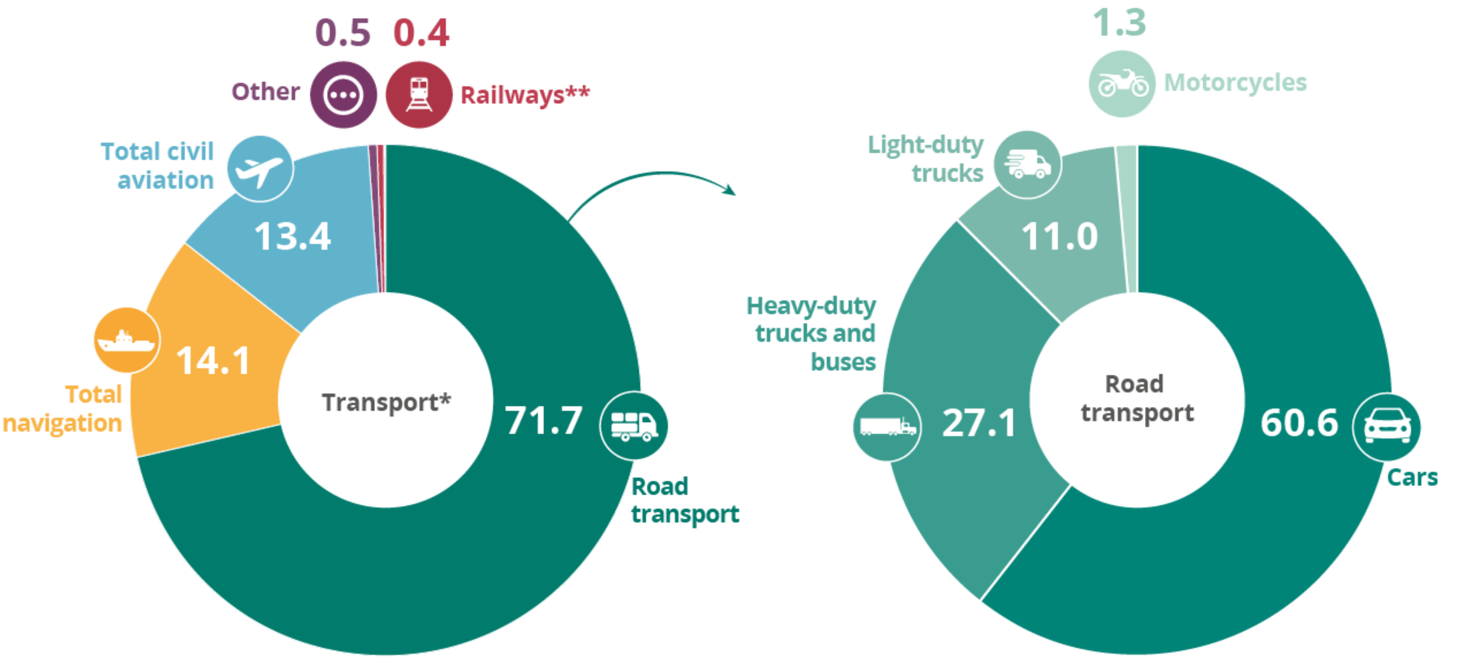
European GHG emissions per sector (2022)



https://www.eea.europa.eu/signals-archived/signals-2022/infographics/what-are-the-sources-of

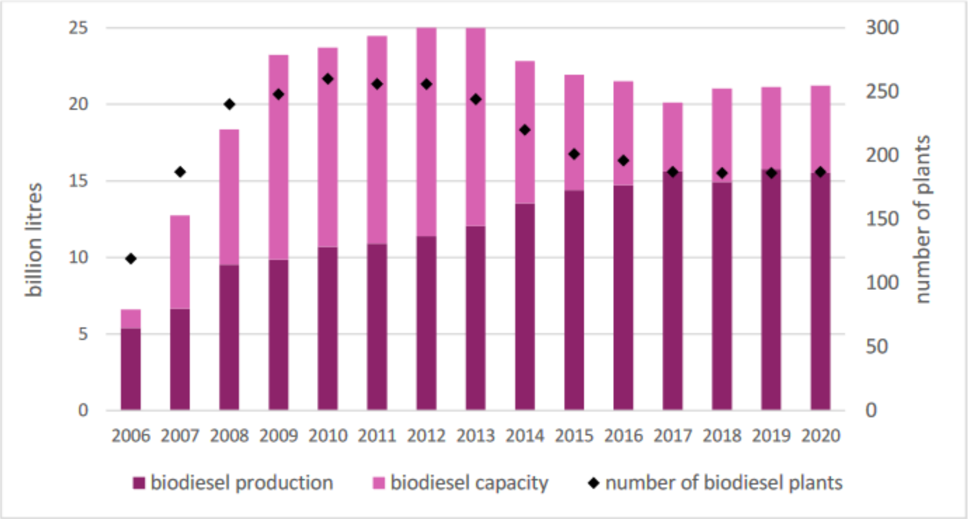
European GHG emissions in the transport sector (2022)



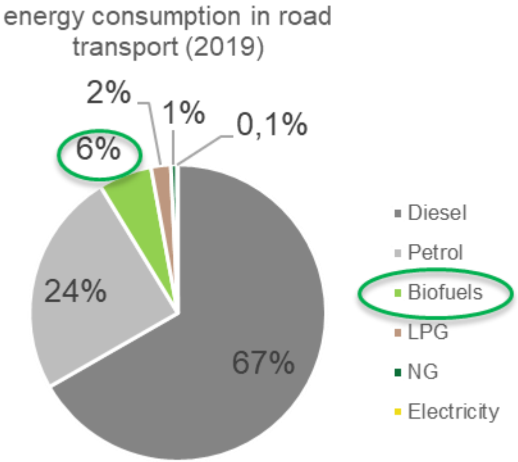
https://www.eea.europa.eu/en/analysis/maps-and-charts/greenhouse-gas-emissions-from-transport?activeTab=8a280073-bf94-4717-b3e2-1374b57ca99d

EU biodiesel production and capacity

Figure 6. Evolution of biodiesel production and capacity in the EU



Source: (USDA Foreign Agricultural Service et al., 2021)



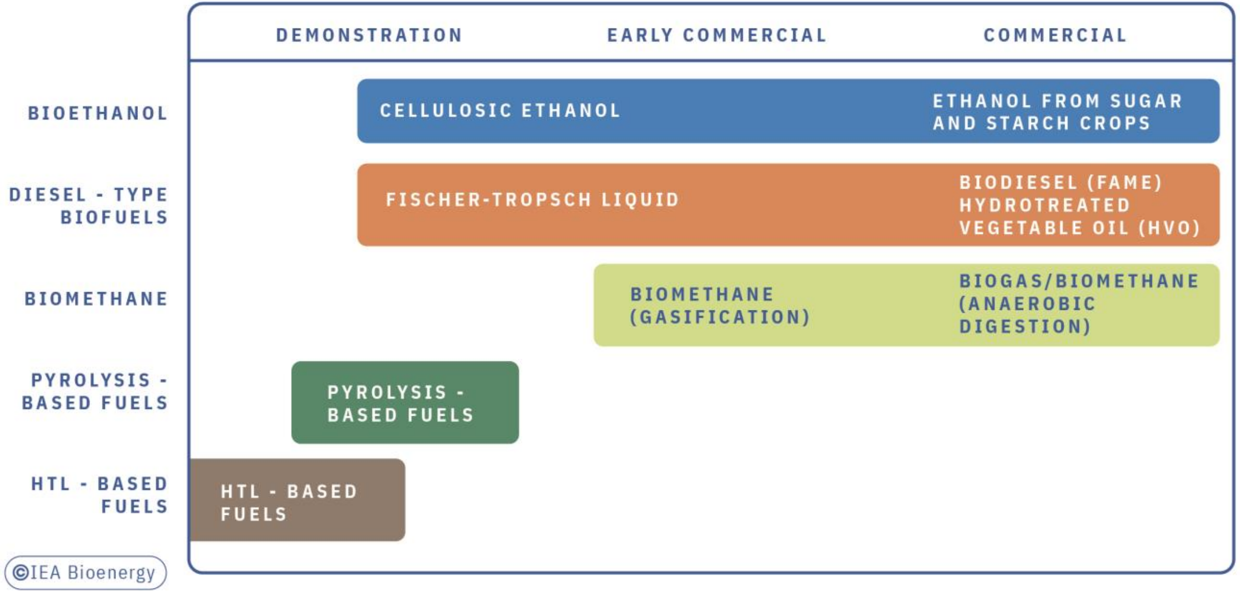
EEA Report No 02/2022. Transport and environment report 2021. **Decarbonising road transport — the role of vehicles, fuels and transport demand**

Hurtig O., Buffi M., Scarlat N., Motola V., Georgakaki A., Letout S., Mountraki A., Joanny G, **Clean Energy Technology Observatory: Advanced biofuels in the European Union** – 2022 Status Report on Technology Development, Trends, Value Chains and Markets, Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/938743, JRC130727

Technology pathways and TRLs

residues



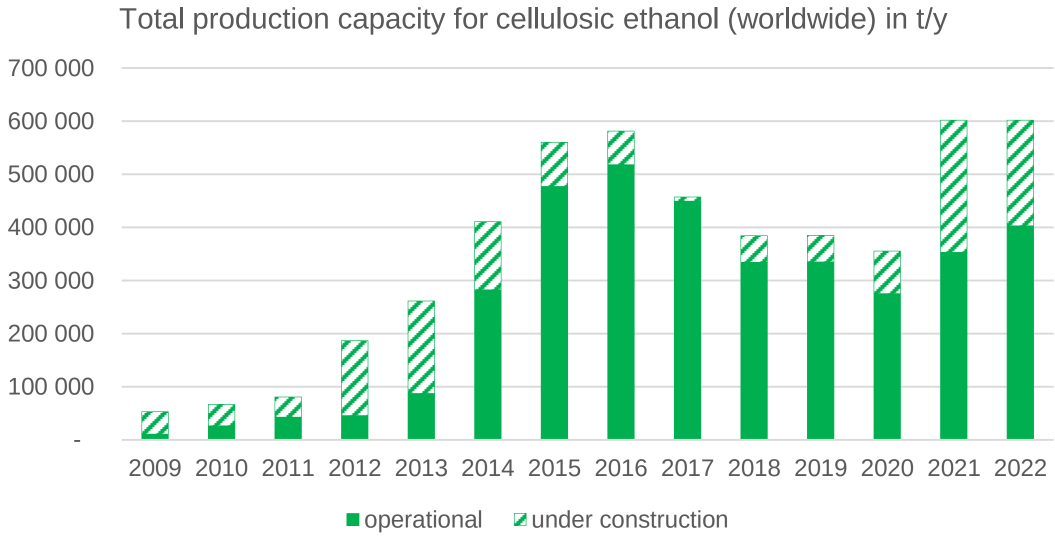


crops



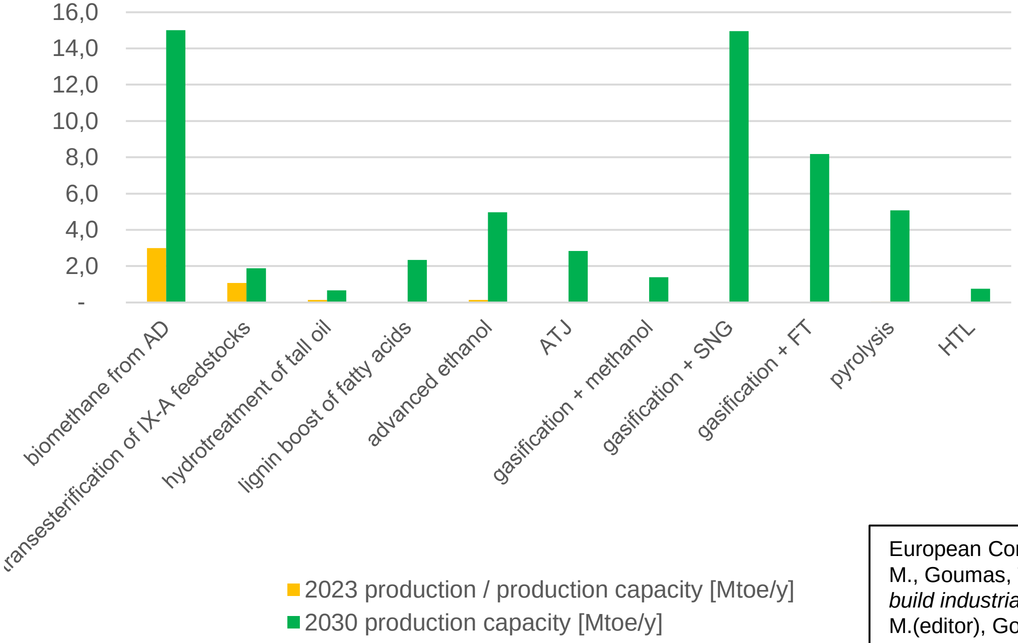
IEA Bioenergy, Bioenergy Review 2023, https://www.ieabioenergyreview.org/transport-biofuels/

Deployment of advanced biofuel technologies



https://demoplants.best-research.eu/

Possible evolution of advanced biofuel production capacities [Mtoe/y]



2030 target for adv. Biofuels	15 – 19 Mtoe
Total possible 2030 production incl. all biomethane	58 Mtoe
Biomethane to other sectors	- 28 Mtoe
Total possible 2030 production with limited biomethane	30 Mtoe

European Commission, Directorate-General for Research and Innovation, Georgiadou, M., Goumas, T., Chiaramonti, D., *Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels – Final report*, Georgiadou, M.(editor), Goumas, T.(editor), Chiaramonti, D.(editor), Publications Office of the European Union, 2024, https://data.europa.eu/doi/10.2777/679307

Implementation barriers / opportunities

- High production **costs** of fuel
- **Financial risks** of demonstration and First-of-its-kind facility
- Uncertainty of regulatory framework and **policies**
- Availability and sustainability of **Feedstock**
- **Policy focus** on other options

- Based on broad variety of biomass feedstocks – **diversification of energy supply**
- Biomass production provides **regional income**
- Applicable in current vehicles now – offer **immediate GHG emission reductions**
- **High energy density** – alternative solution for sectors that are **hard-to-electrify**
- Passenger cars → trucks, ships, planes

Biofuels – a crucial part of decarbonisation

Unit Biofuels

BIOFIT
Bioenergy Retrofits for Europe's Industry

Market uptake support

Inter-national R&D

IEA Bioenergy
Technology Collaboration Programme

Consulting

Net-working

BioTheRoS

Infor-mation Exchange

ETIP Bioenergy
European Technology and Innovation Platform

ADVANCED MOTOR FUELS
IEA-AMF

Modelling of biofuels impact

BEST
Bioenergy and Sustainable Technologies

Lunch

12:00 – 13:00

FFG Forschung wirkt.
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BEST
Bioenergy and
Sustainable Technologies

SPEED-UP ALGORITHMS for advanced simulations

Graz, 26.September.2024

Michael Eßl

FFG Forschung wirkt.
Bundesministerium Arbeit und Wirtschaft
Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie
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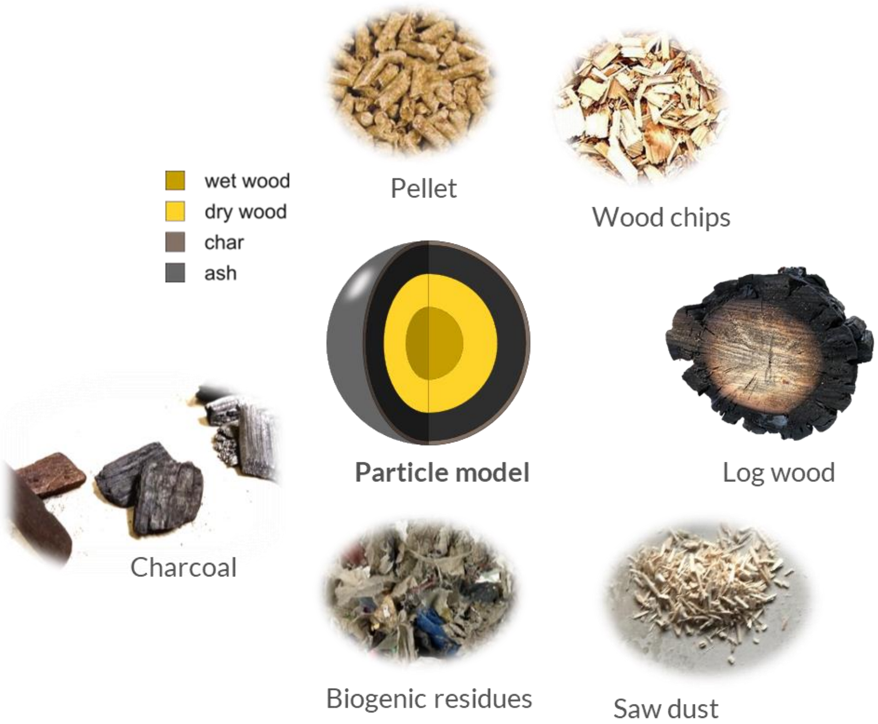
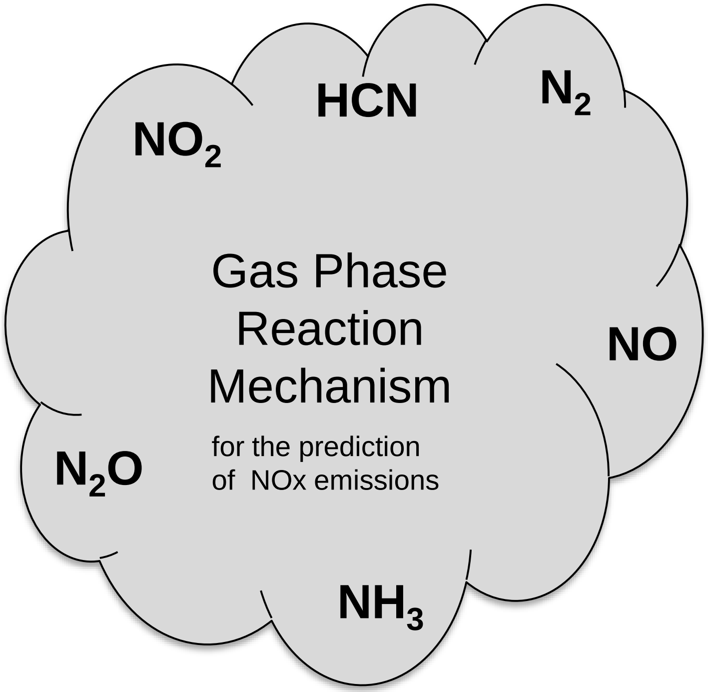
Areas in need of speed up

solid phase and gas phase

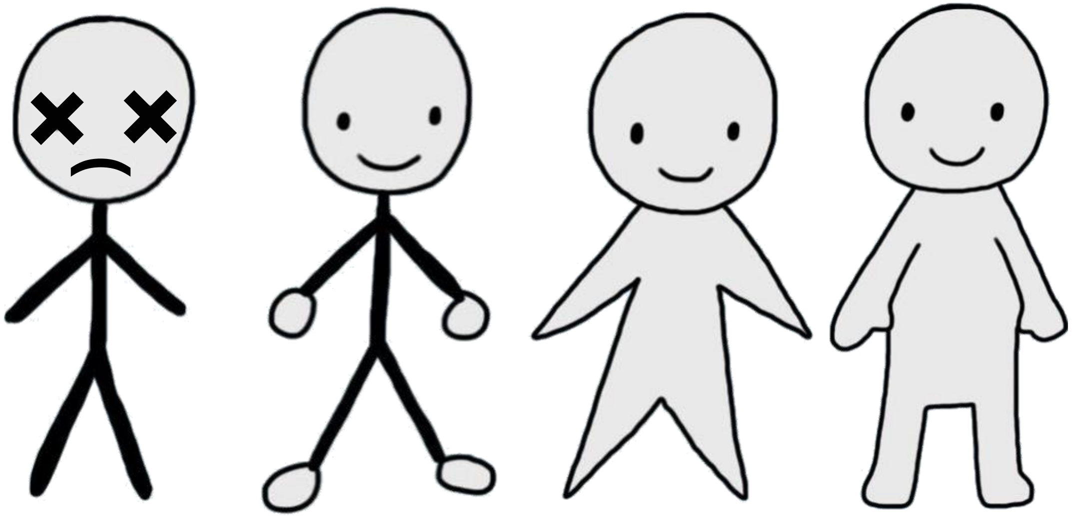




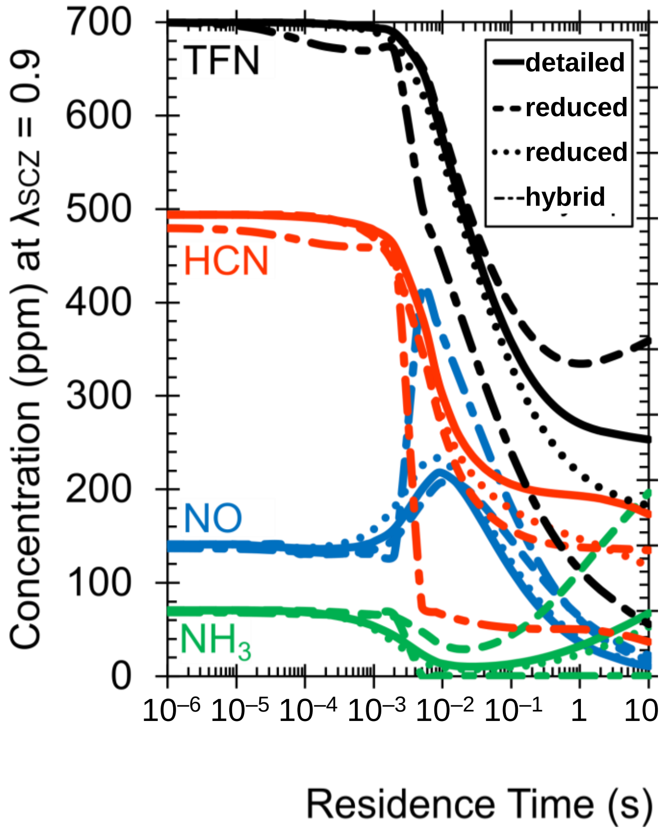
Speed-up of gas phase

complexity of reaction mechanisms for NOx in biomass combustion

global	hybrid	reduced	detailed
< 10 species < 10 reactions	10-20 species < 100 reactions	20-50 species 100-400 reactions	> 100 species > 1000 reactions



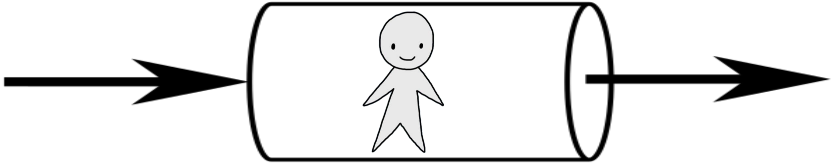
Speed-up Factor: 2.04 | 1.58 | 1.00



Speed-up of gas phase

speed up methods for gas phase reactions

Plug Flow Reactor (PFR)

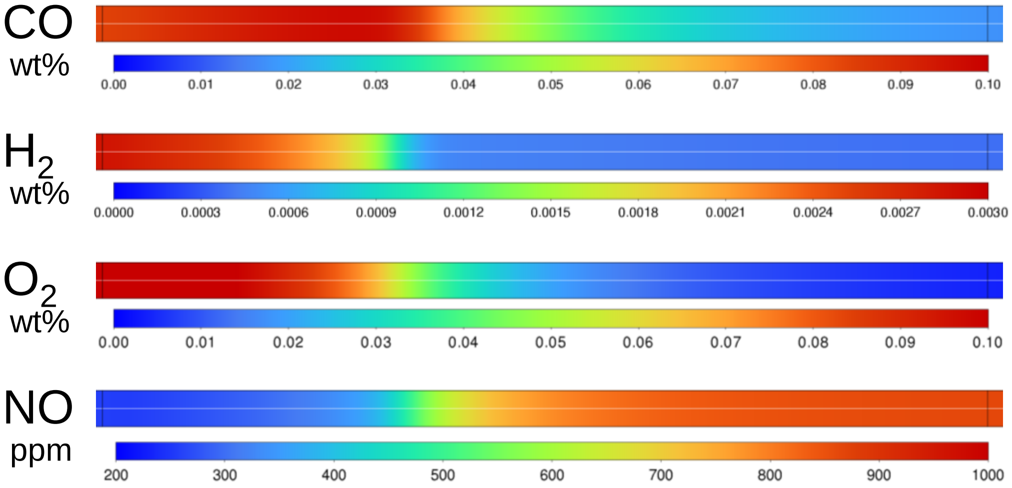


Test of different models and methods for the speed-up of gas phase chemistry calculation

Temperature: 1000°C
Residence time: 0.01 s

Methode	**Speed up Factor**
Base case	1.00
Chemkin solver	1.66
Dynamic Reduction	1.05
ISAT	5.00

Result of CFD TestCase

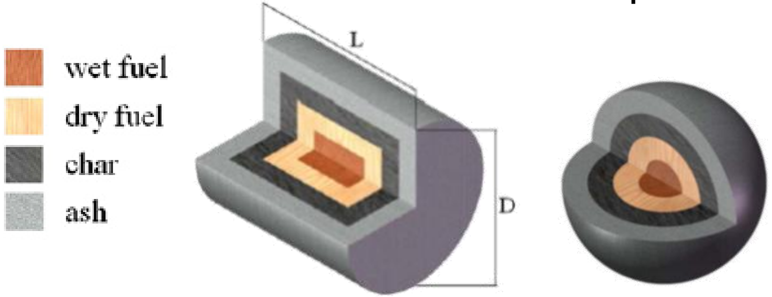


Speed-up of particle models

thermally thick vs. thermally thin

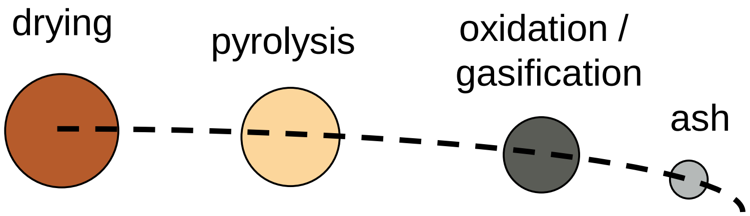
Thermally thick model (Layer model)

- Resolved temperature gradient in particle
- Parallel decomposition reactions
- Three component pyrolysis model
- Volumetric gasification reactions
- More accurate description
- Simulation time: 1 – 20 min / particle



Thermally thin model

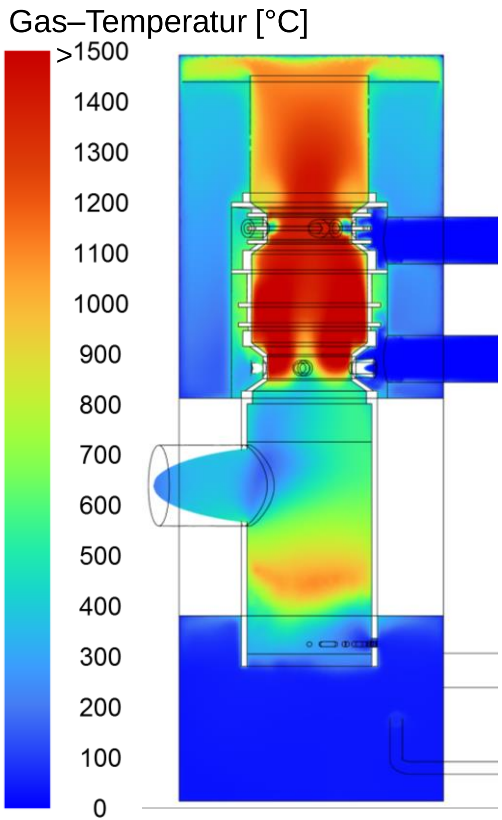
- Equal temperature throughout the particle
- Serial decomposition reactions
- Single rate pyrolysis model
- Surface char reactions
- Simple models
- Simulation time: < 1 sec / particle

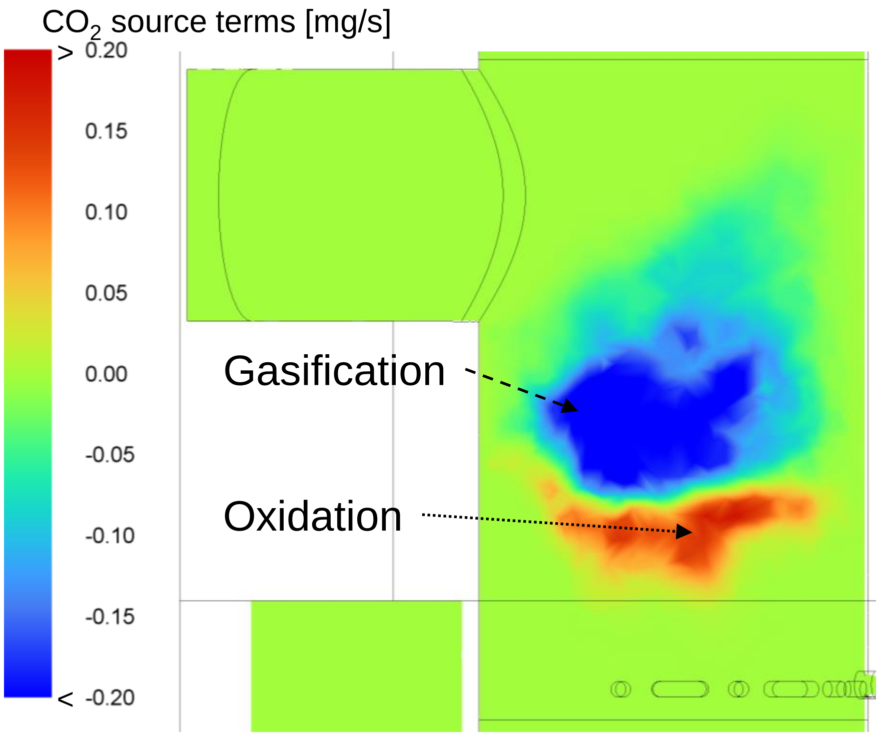


Speed-up of particle models

application of models to a small scale gasifier

- Example of a 30 kW gasifier
- for gasification applications an accurate description of char reactions is especially important
- Combination of thermally thin and thermally thick model





Speed-up Factor: ~ 5.0

Outlook

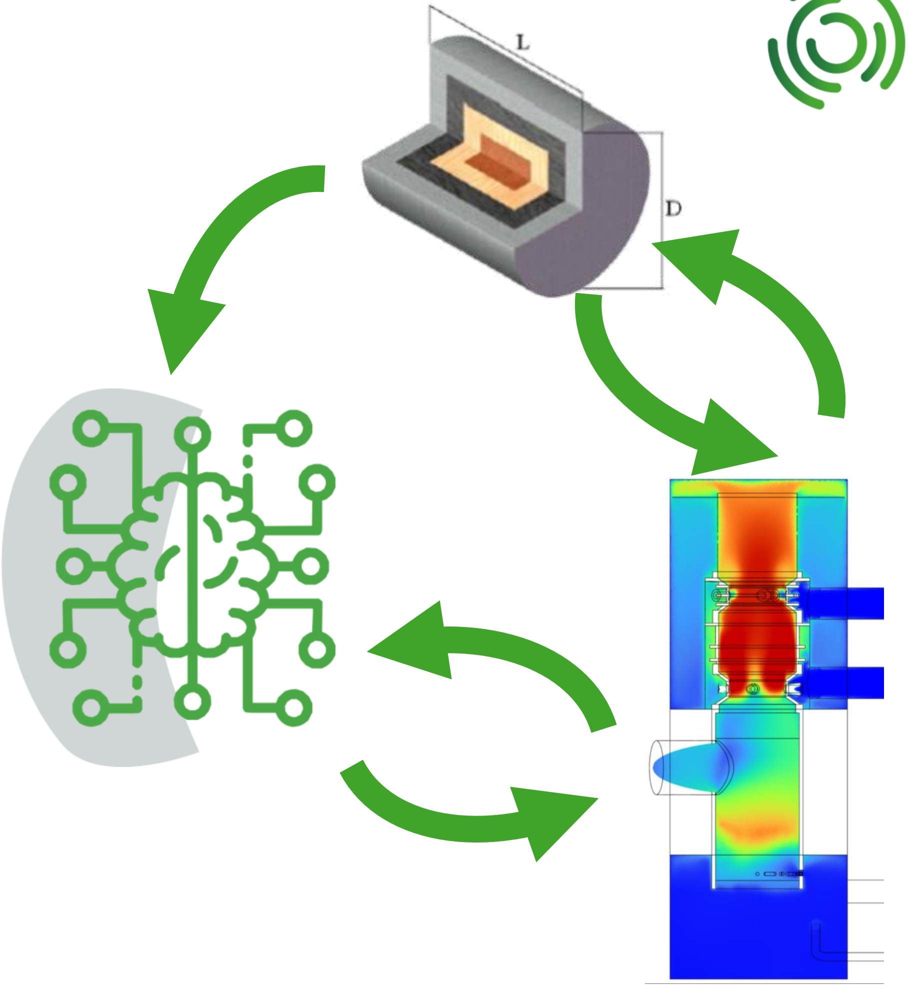
further development and current work

Gas phase reactions

- Derivation of reactor networks via cell clustering → see poster of “Modular simulation framework”

Particle model

- Relocate the layer model to an external solver (Julia) that can use several computing cores in parallel and also allows fast switching between models
- Implementation of a neural network that mimics the layer model



Multiscale modeling of metal oxide and biomass conversion for chemical looping processes

BEST – Zentrumstag, Graz, 26.9.2024

Thomas Steiner, Andrés Anca-Couce, Kai Schulze

Agenda

1. What are
   - chemical looping
   - multiscale modeling

2. Model development & validation

3. Model application

energy&fuels

pubs.acs.org/EF

Article

On the Applicability of Iron-Based Oxygen Carriers and Biomass-Based Syngas for Chemical Looping Hydrogen Production

Published as part of Energy & Fuels special issue "2024 Pioneers in Energy Research: Juan Adanez".

Thomas Steiner,* Lukas von Berg, Andrés Anca-Couce, and Kai Schulze

Cite This: https://doi.org/10.1021/acs.energyfuels.4c03137 Read Online

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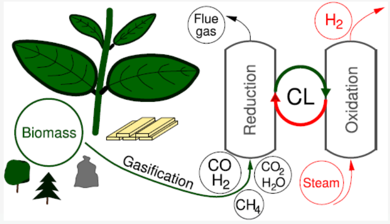
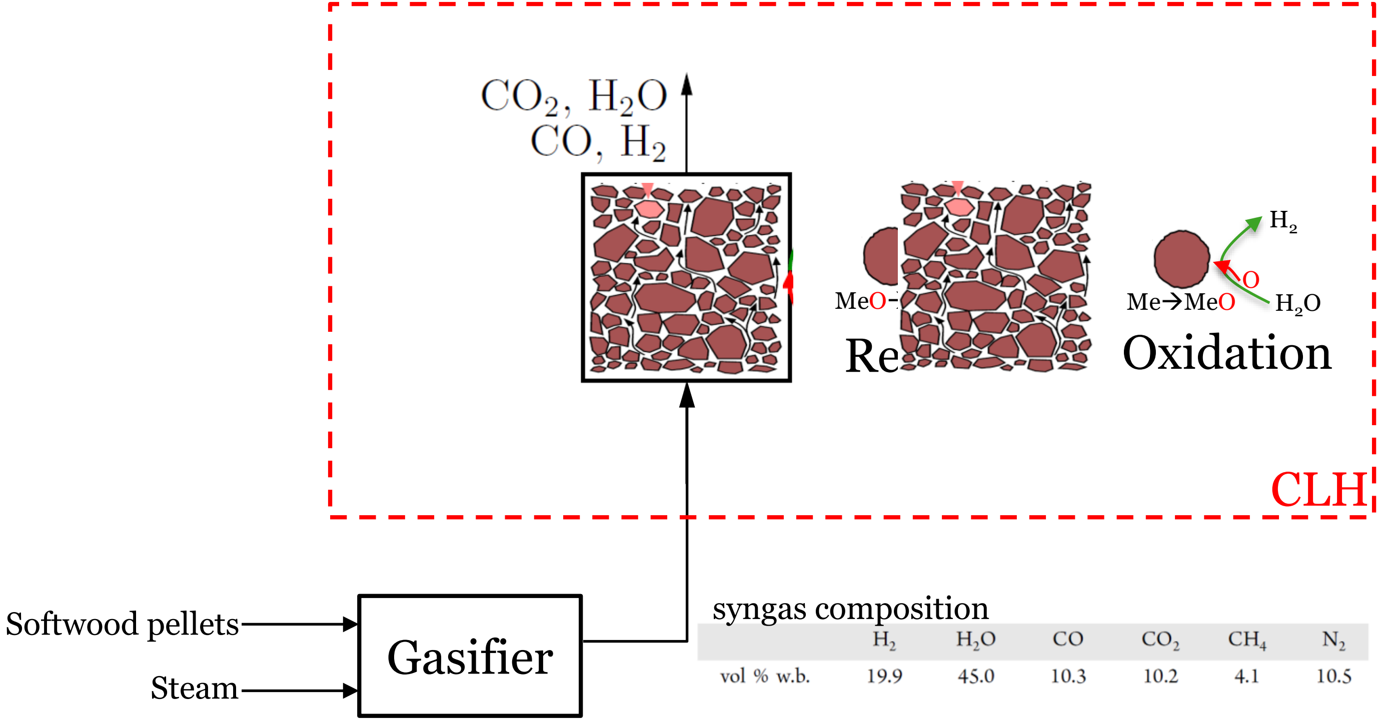
ABSTRACT: The chemical looping hydrogen (CLH) production process typically uses iron-based oxygen carrier materials and can provide hydrogen with high purity. Chemical looping is particularly attractive when renewable fuels like syngas from biomass gasifiers are used. This work provides a novel assessment of the possible thermodynamic and kinetic limitations for iron-based oxygen carriers in CLH fueled by biomass-based syngas, with a detailed study employing synthetic ilmenite (Fe_2O_3 + TiO_2). Its phase diagram with H_2/H_2O- or CO/CO_2-mixtures was compared to the typical Baur–Glaessner diagram for iron oxides. Thermogravimetric analyses underlined the necessity to consider TiO_2 as a chemically active component for this material, in contrast to the common



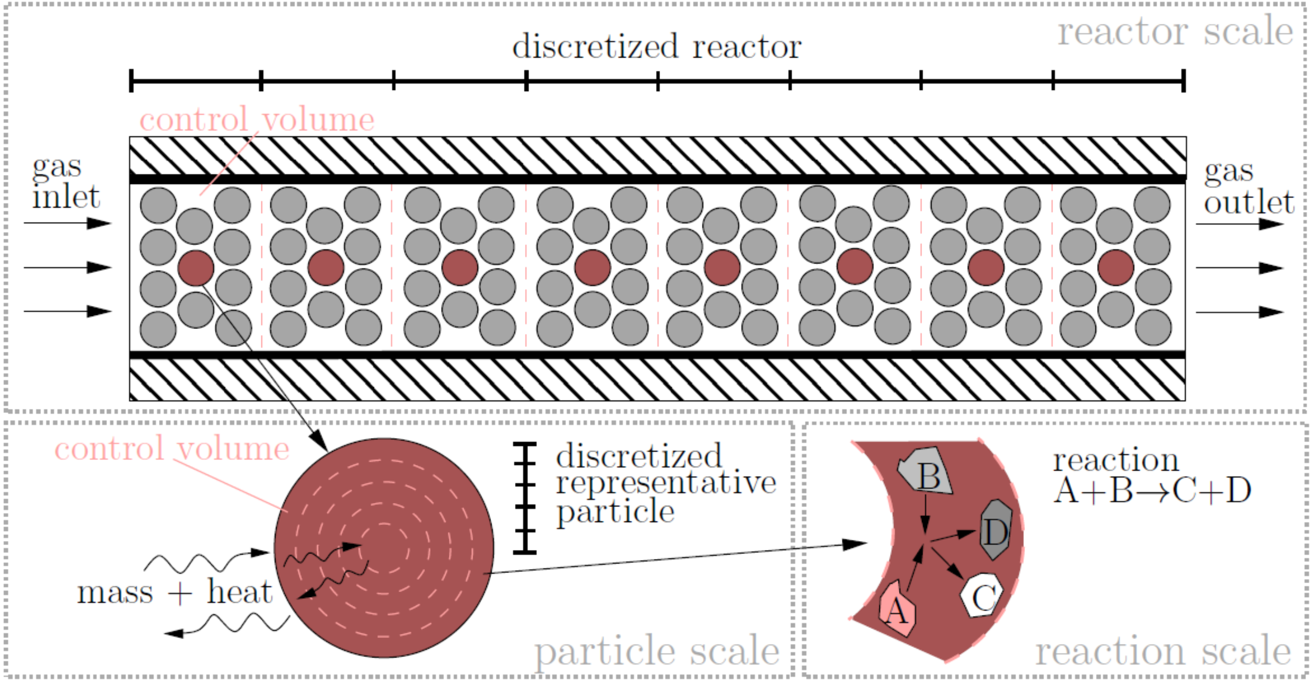
Chemical looping hydrogen (CLH)



syngas composition

	H_2	H_2O	CO	CO_2	CH_4	N_2
vol % w.b.	19.9	45.0	10.3	10.2	4.1	10.5

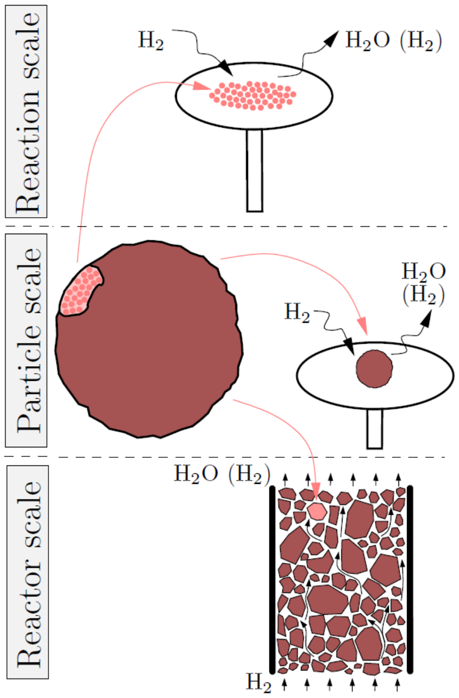
Multiscale model development



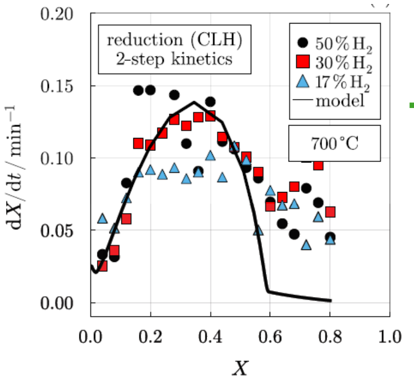
Multiscale model validation

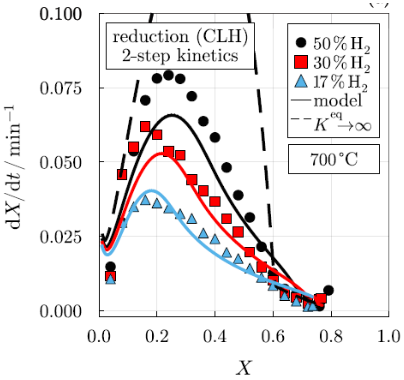
- OC: synthetc ilmenite (Fe_2O_3 + TiO_2)
- Fuel: syngas, H_2 / H_2O

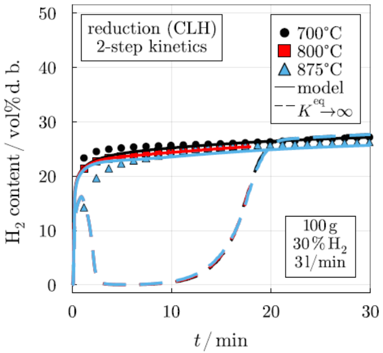
- Measurements at all three scales
  - reaction – thermogravimetry of powders
  - particle – thermogravimetry of pellets
  - reactor – fixed bed reactor (many pellets)

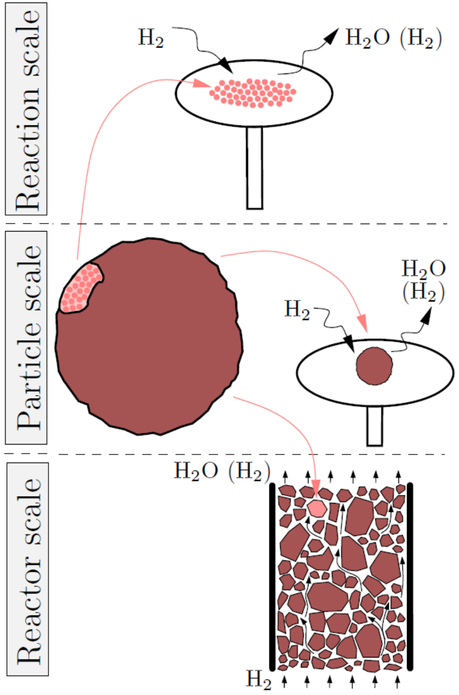


Multiscale model validation (2)









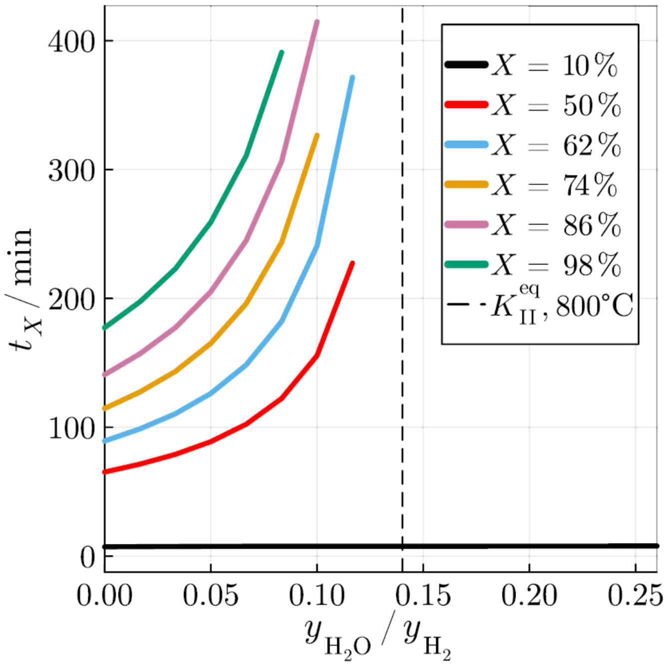
dX/dt … conversion rate

X … conversion

K^{eq} … equilibrium constant

Model application – Does fuel cleaning pay off?

reduction prohibited by equilibrium (X_{max} = 10%)

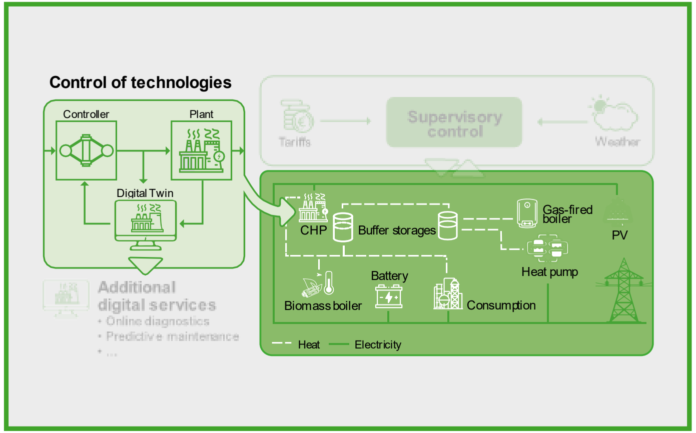


- t_X … bed reduction time
- X … conversion (100% = reduced)
- y_{H2O}/y_{H2} … molar feed ratio
- K_{II}^{eq} … equilibrium constant

Acknowledgement

- *The COMET Module is funded within COMET – Competence Centers for Excellent Technologies – by BMK, BMDW as well as the co-financing federal province Styria. The COMET programme is managed by FFG. www.ffg.at/comet*

Model-Based Control of the Generated Steam Mass Flow in a Fluidized-Bed Waste Incineration Plant



Graz, September 26th, 2024

Area 2.2

Helmut Niederwieser, Markus Gölles, Florian Jäger, Friedrich Kirnbauer

Bundesministerium Arbeit und Wirtschaft

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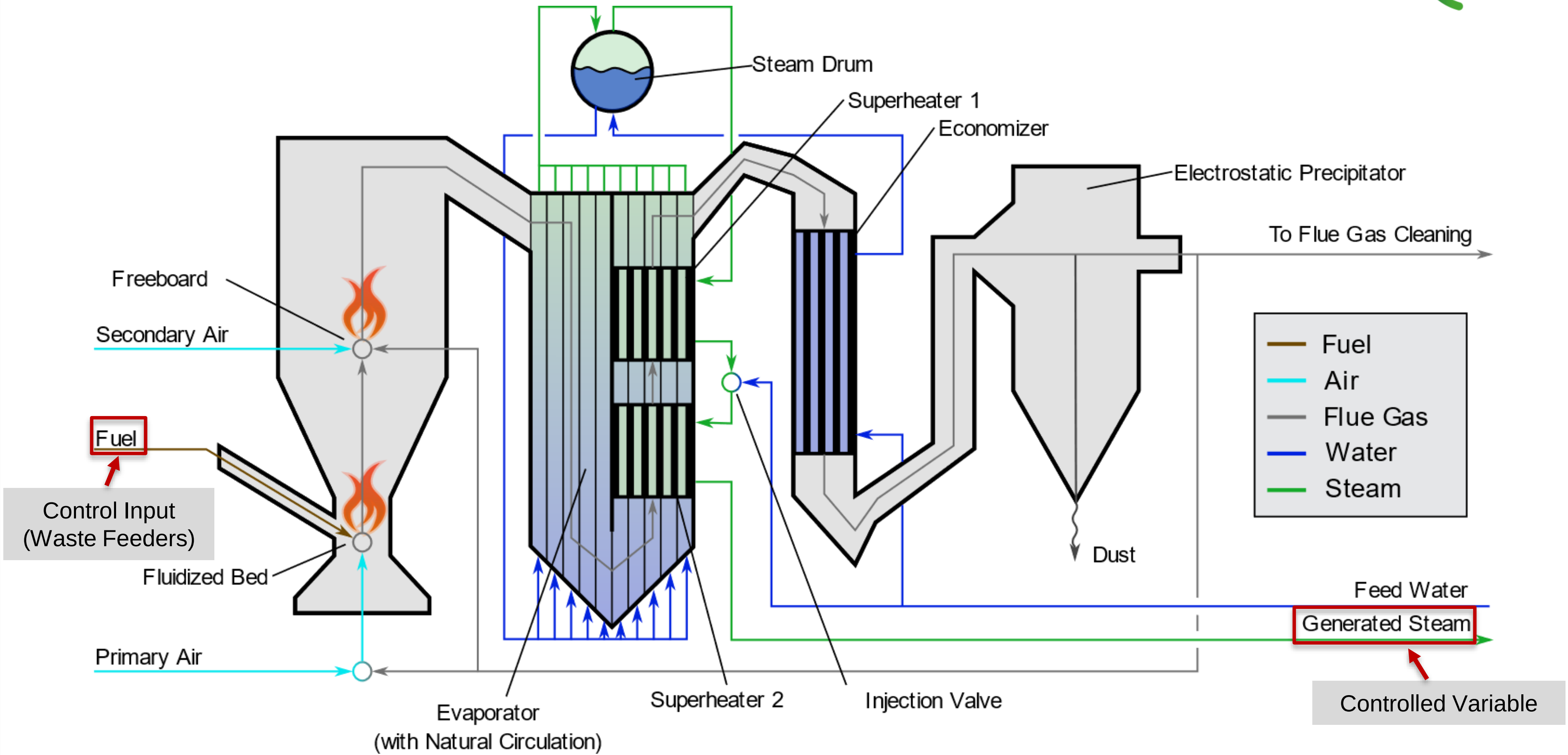
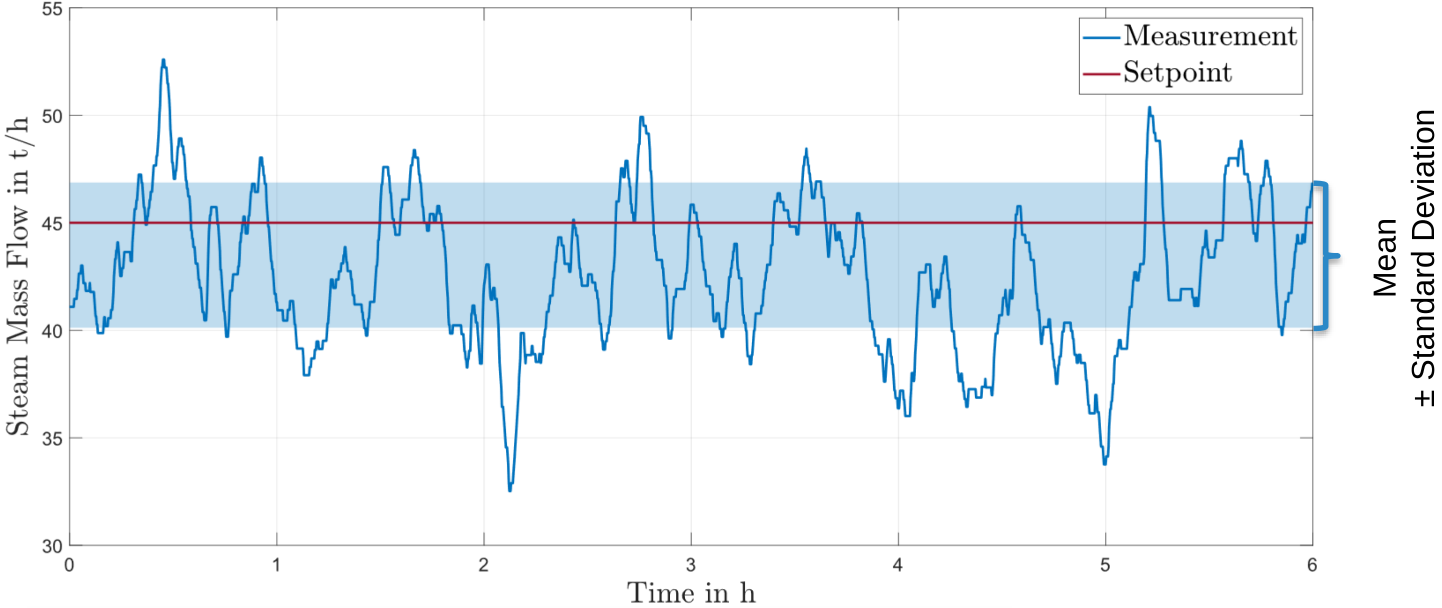
Für die Stadt Wien

Wirtschaft, Tourismus, Regionen, Wissenschaft und Forschung

Considered Waste Incineration Plant



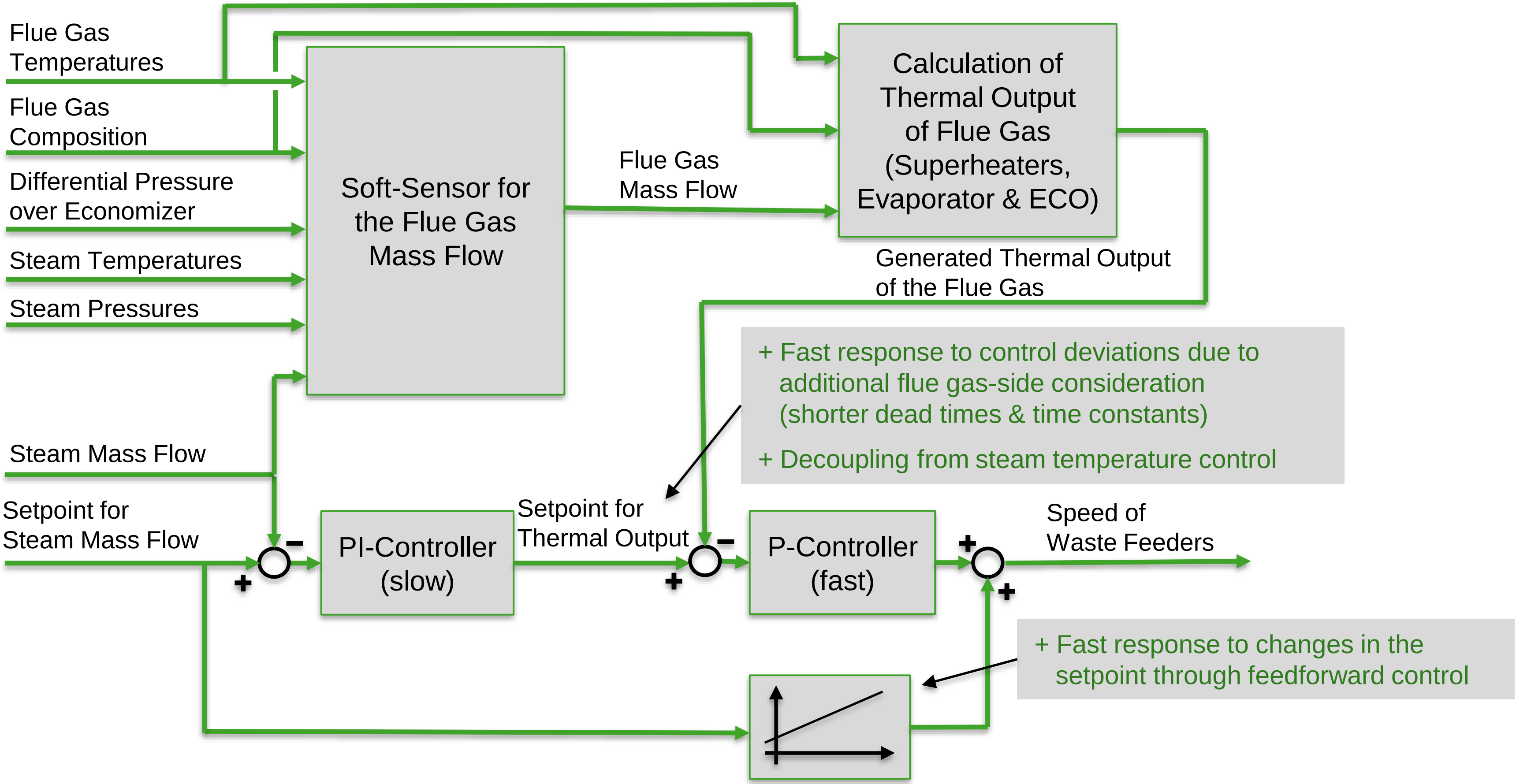
Motivation – Strong Fluctuations of the Generated Steam Mass Flow



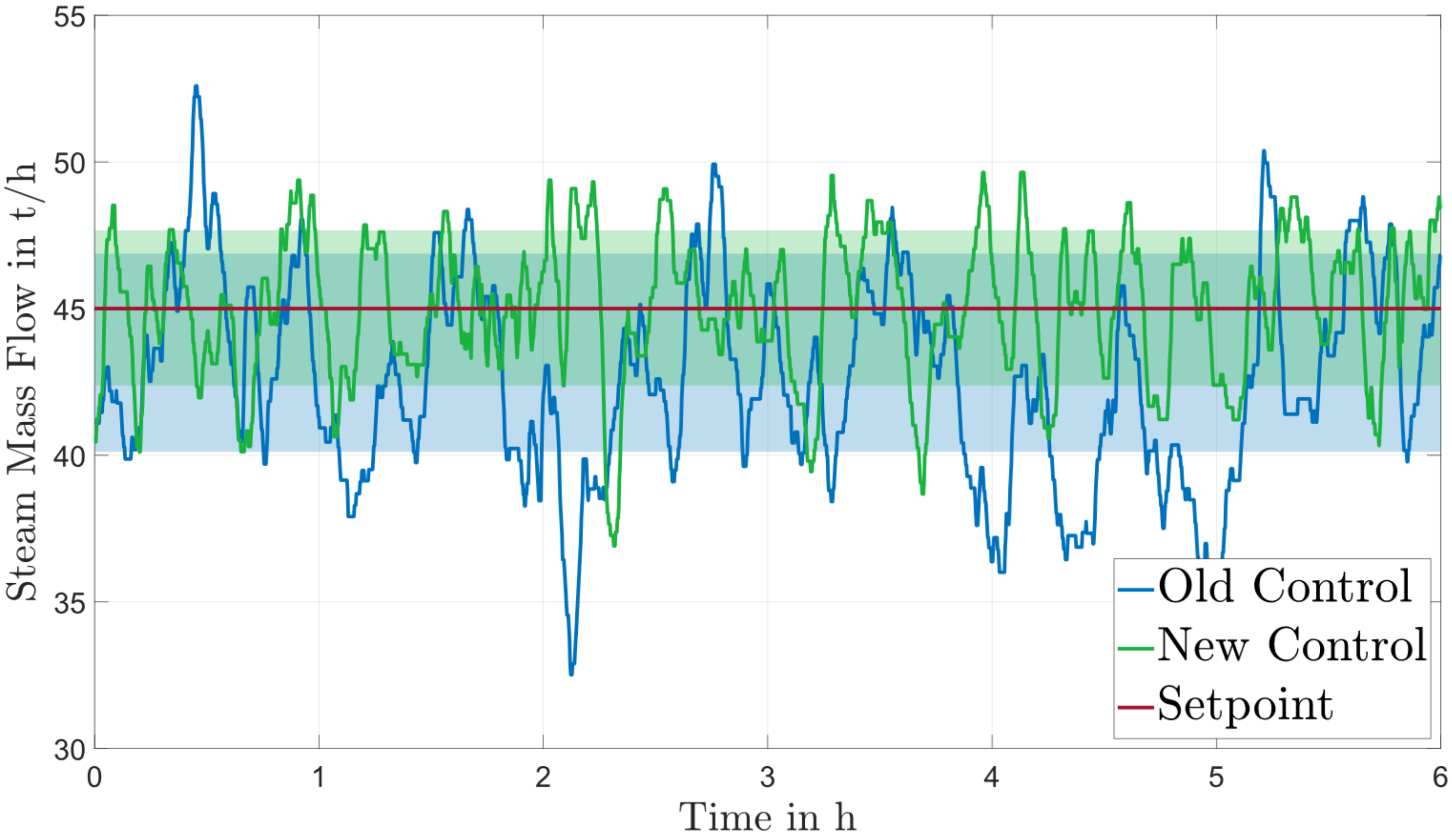
- Process fluctuations lead to…
  - increased wear
  - high failure rates
  - poor efficiency
- **Goal**: stable plant operation that is as constant as possible

→ **model-based control**

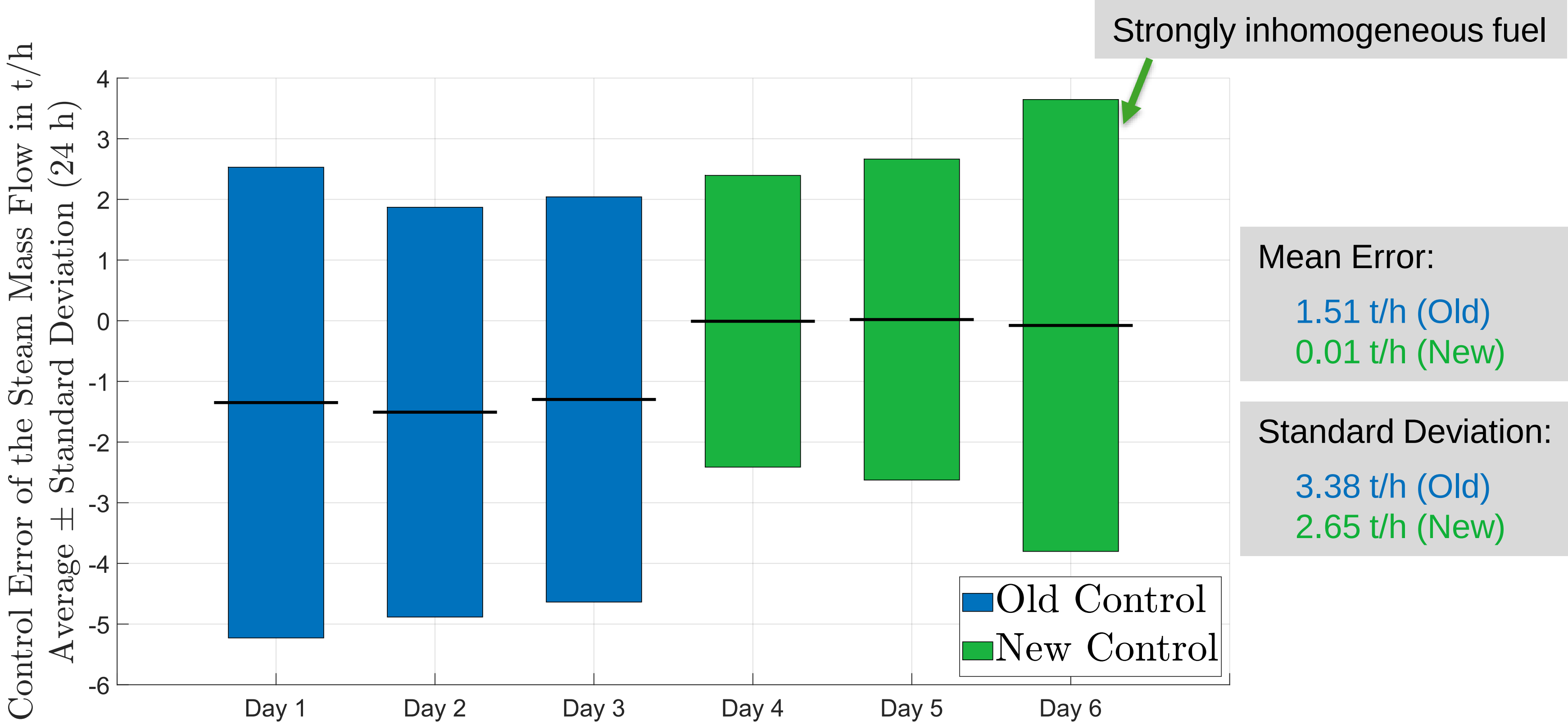
Model-Based Control Design



Exemplary Results – Generated Steam Mass Flow



Statistics of the Control Error



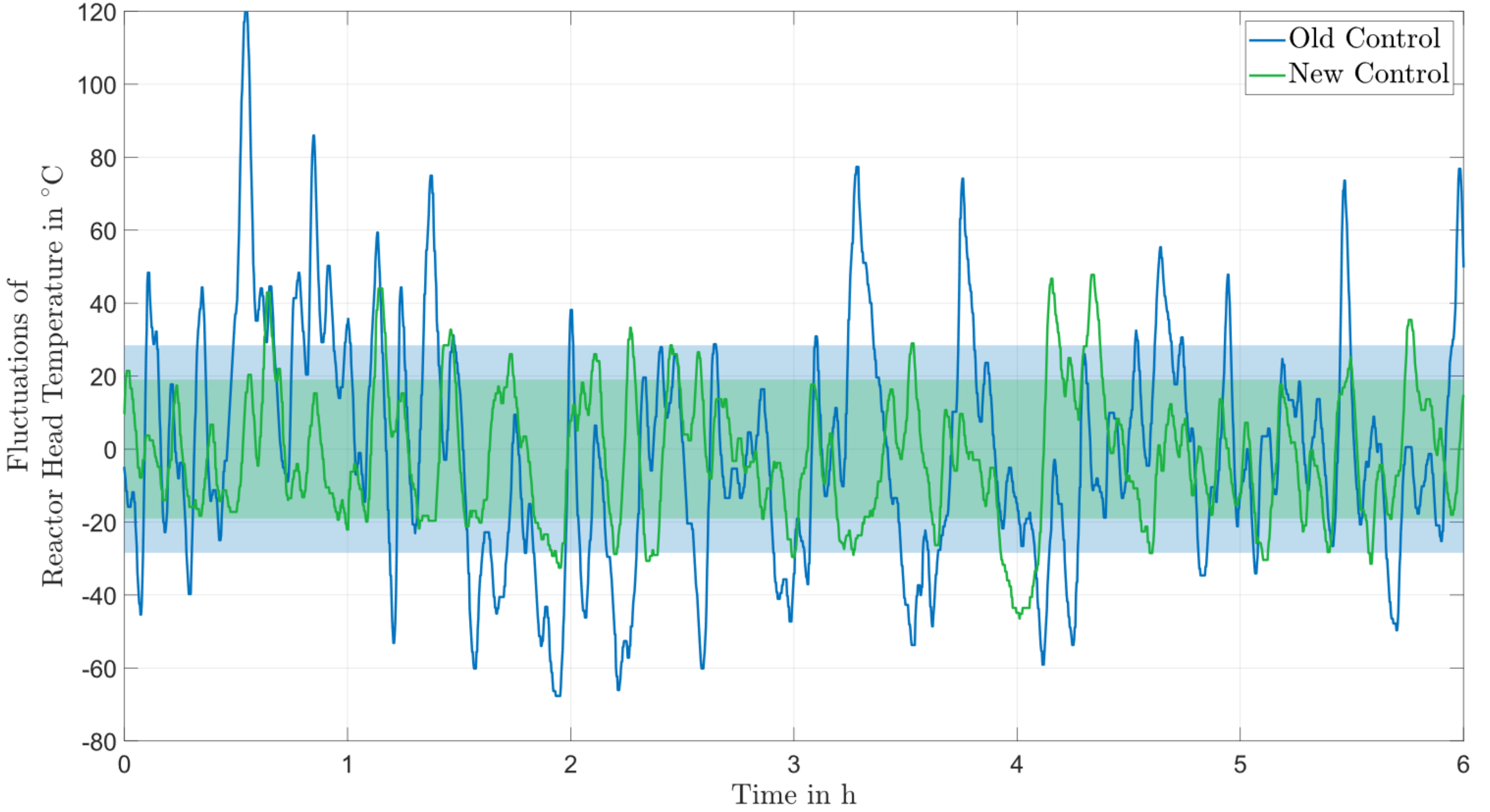
Mean Error:

1.51 t/h (Old)
0.01 t/h (New)

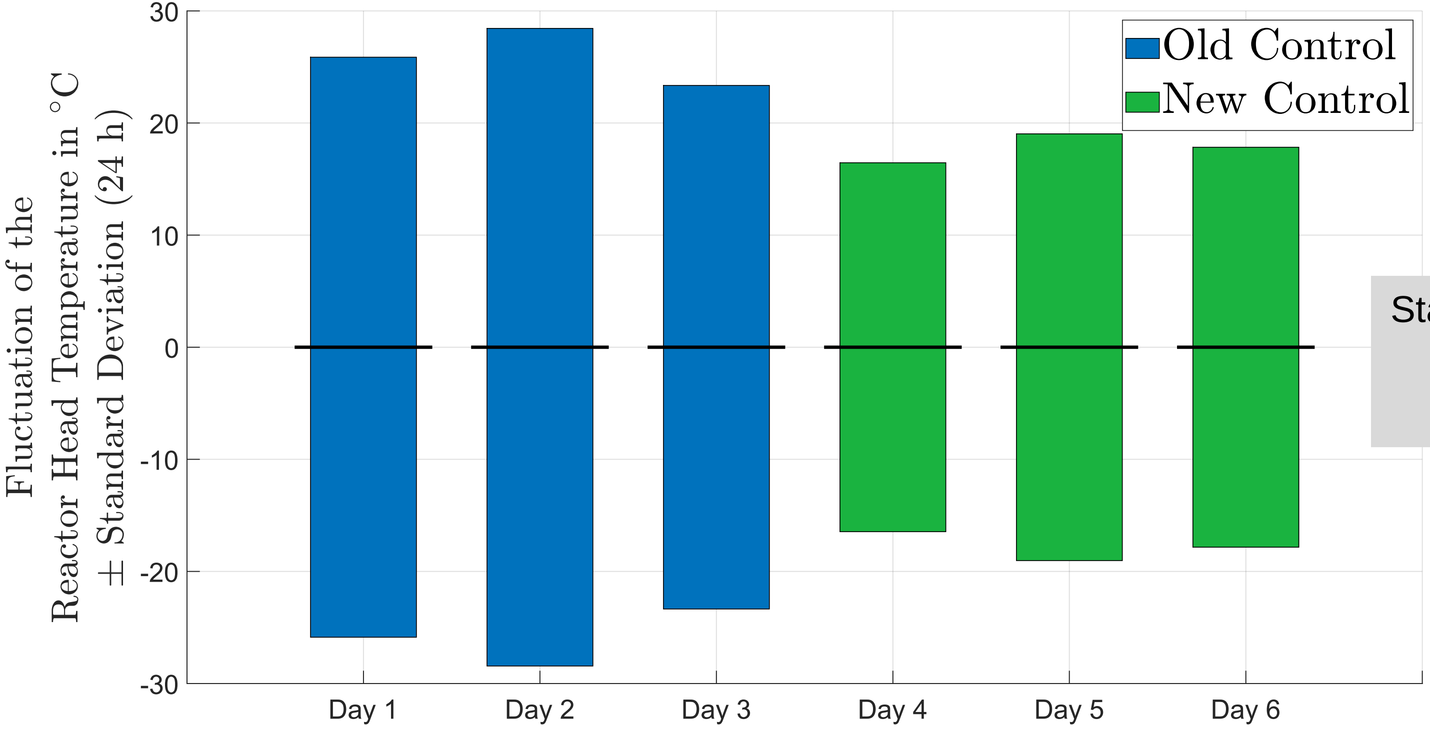
Standard Deviation:

3.38 t/h (Old)
2.65 t/h (New)

Exemplary Results – Reactor Head Temperature



Statistics of the Fluctuations of the Reactor Head Temperature



Standard Deviation:

28,4 °C (Old)
19.0 °C (New)

Conclusion

- Model-based control for generated steam mass flow:
  - Realizable through **soft sensor for flue gas mass flow**[1),2)]
  - Implementation requires **software update** only

- Statistical evaluation (in terms of standard deviation):
  - Reduction of **generated steam mass flow** fluctuations by **23 %**
  - Reduction of **reactor head temperature** fluctuations by **34 %**
- Outlook:
  - Algorithm for systematic premixing of the fuel
  - Model-base control of the oxygen content in the flue gas

[1)] Niederwieser, H., Zemann, C., Goelles, M., & Reichhartinger, M. (2020). Model-Based Estimation of the Flue Gas Mass Flow in Biomass Boilers. *IEEE Transactions on Control Systems Technology*, *29*(4), 1609-1622.

[2)] Niederwieser, H., Zemann, C., Gölles, M., & Reichhartinger, M. (2020, July). Soft-Sensor for the On-Line Estimation of the Flue Gas Mass Flow in Biomass Boilers with Additional Monitoring of the Heat Exchanger Fouling. In *28th European Biomass Conference & Exhibition* (pp. 280-284).

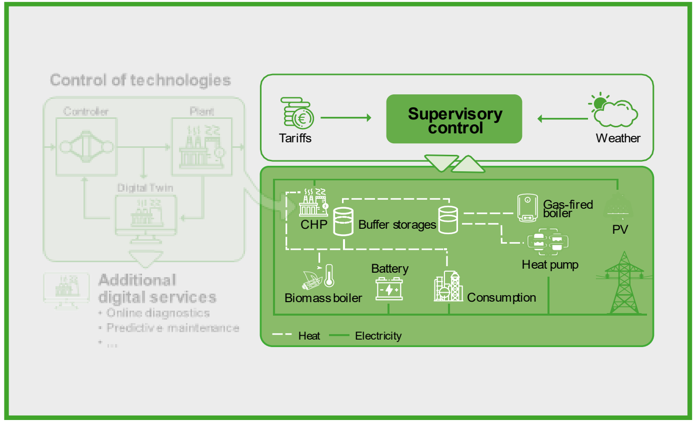
BEST
Bioenergy and Sustainable Technologies

Modular, predictive, optimization-based supervisory control of multi-energy systems:

General introduction and practical application for the energy management in single-family homes

Graz, September 26th, 2024

Area 2.2
Astrid Leitner, Daniel Muschick, Valentin Kaisermayer, Andreas Moser, Bernd Riederer, Mathias Schwendt Markus Gölles, Uwe Poms



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Für die Stadt Wien
Das Land Steiermark
Wirtschaft, Tourismus, Regionen, Wissenschaft und Forschung
SFG NEUES DENKEN. NEUES FÖRDERN.

Requirements for controlling multi-energy systems

optimal operation
(efficiency, CO_2 emissions, …)

→ **optimization-based**
ensures optimal operation of the system
by targeted utilization of the different technologies

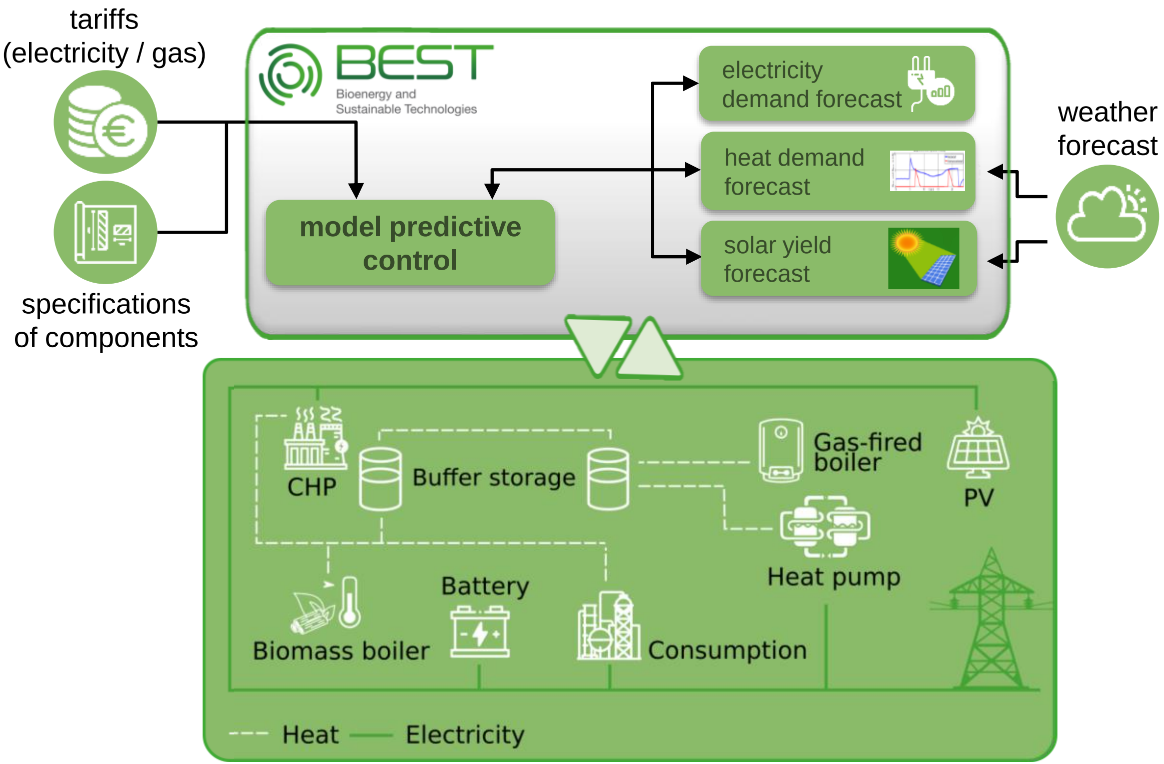
volatility
of production and consumption

→ **predictive**
integration of weather and price forecasts
calculation of forecasts for yields and consumptions

variation range
of the configurations

→ **modular**
automatic (re)formulation of the optimization problem
based on the specifications of the components

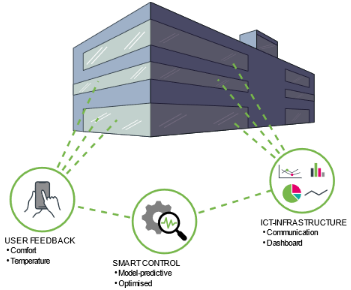
Modular, predictive, optimization-based supervisory control of multi-energy systems

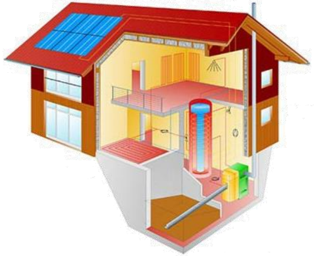


Applications and commercial products

- **One software framework for various applications**
  - Single-family homes
  - Commercial buildings
  - District heating networks
  - Industrial applications

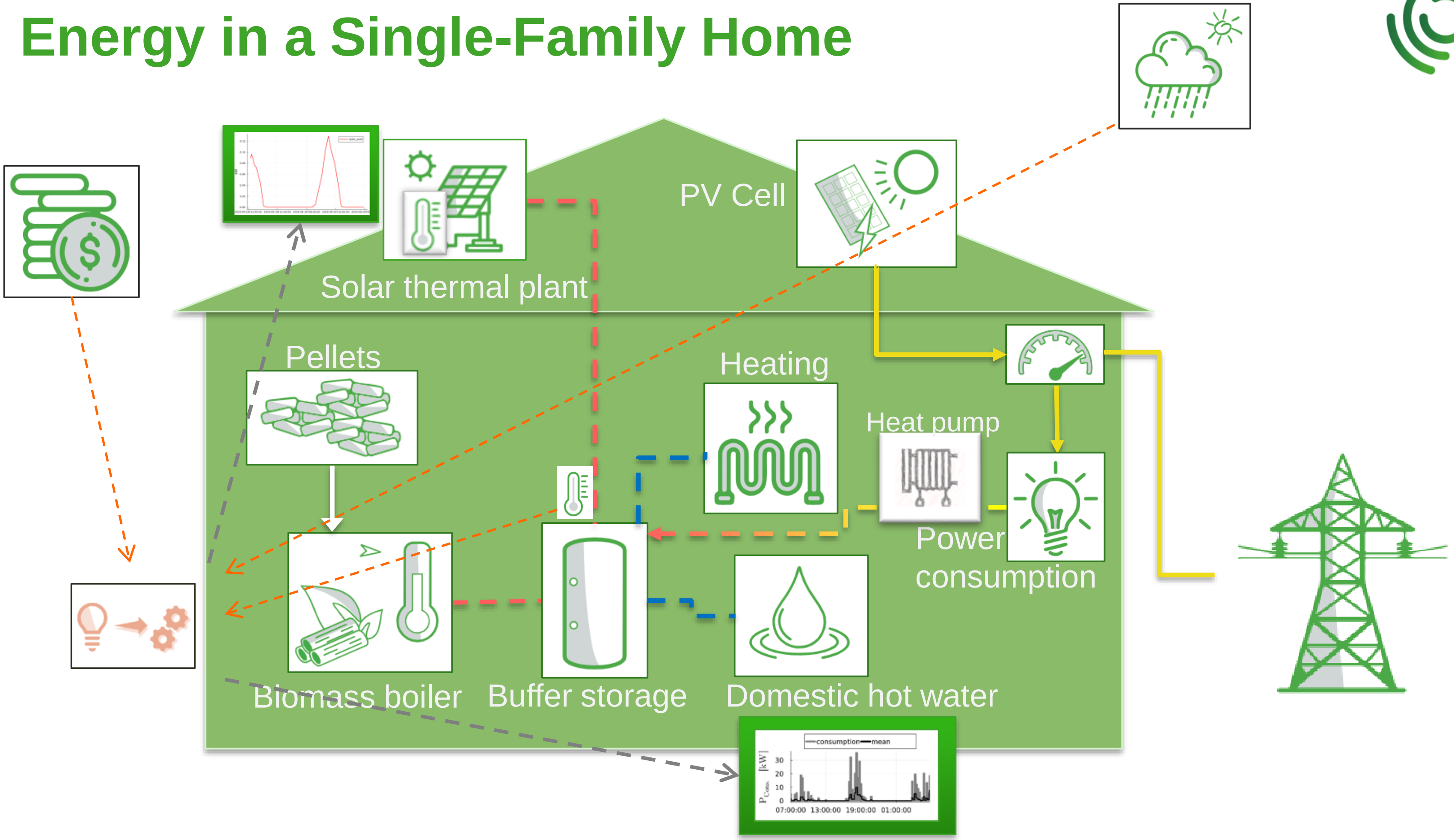
Workshop



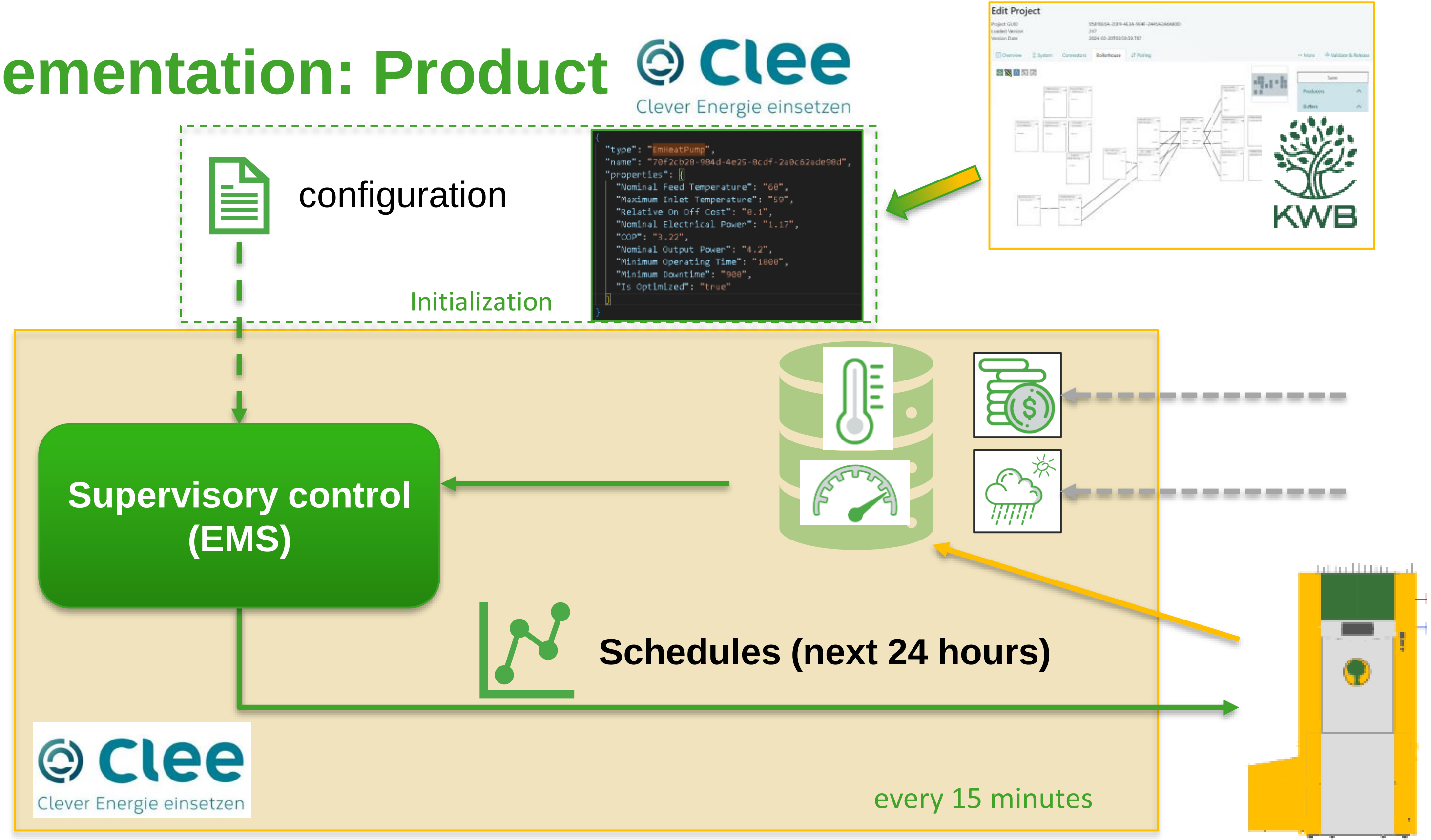


Achievable improvements (efficiency, CO_2 emissions, …): **~ 5-10%**

Energy in a Single-Family Home

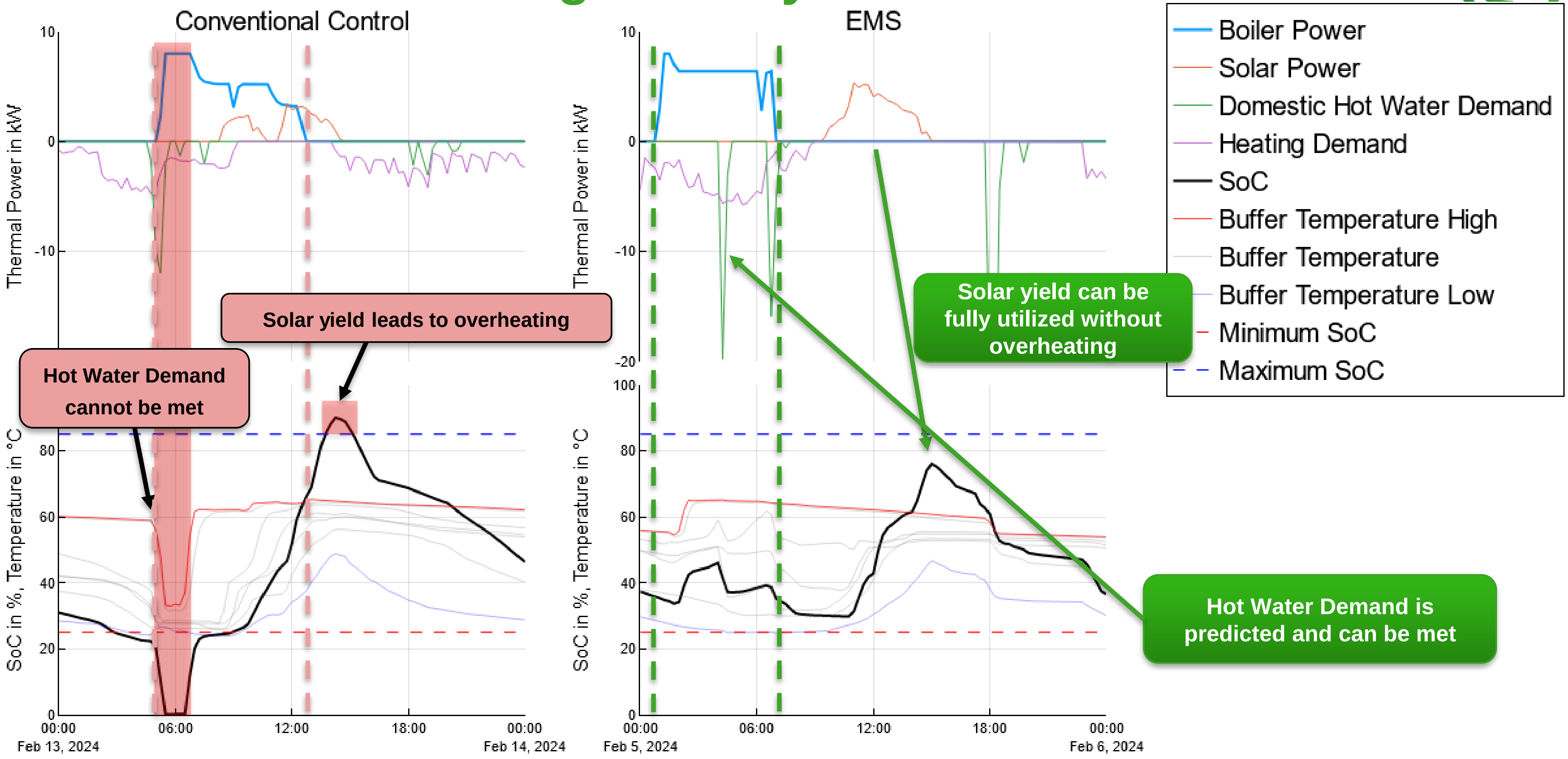


Implementation: Product



Runs in more than 100 single-family homes

Results from a single-family home in Graz



Conclusion

- Multiple producers, storages and consumers with different constraints
  → modular, predictive, optimization-based supervisory control
- Product for single-family homes

Outlook

- Combining heat and electricity
- Dealing with faulty components

Modular, predictive, optimization-based supervisory control of multi-energy systems:

General introduction and practical application for the energy management in single-family homes

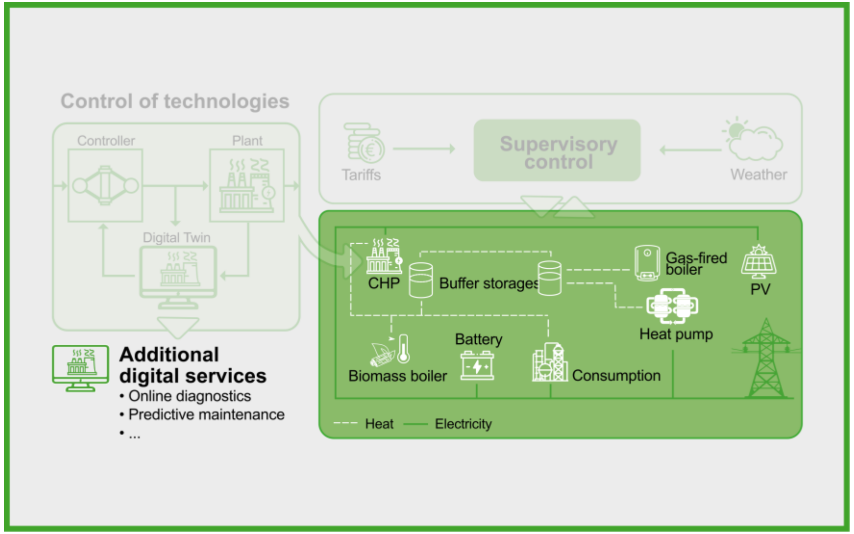
Graz, September 26th, 2024

Area 2.2
Astrid Leitner, Daniel Muschick,
Valentin Kaisermayer, Andreas Moser,
Bernd Riederer, Mathias Schwendt
Markus Gölles, Uwe Poms

Monitoring of a Renewable Flow Battery

Graz, 26.09.2024

Thomas Reiter-Nigitz
Johannes Niederwieser
Uwe Poms
Dominik Wickenhauser
Stefan Spirk
Markus Gölles



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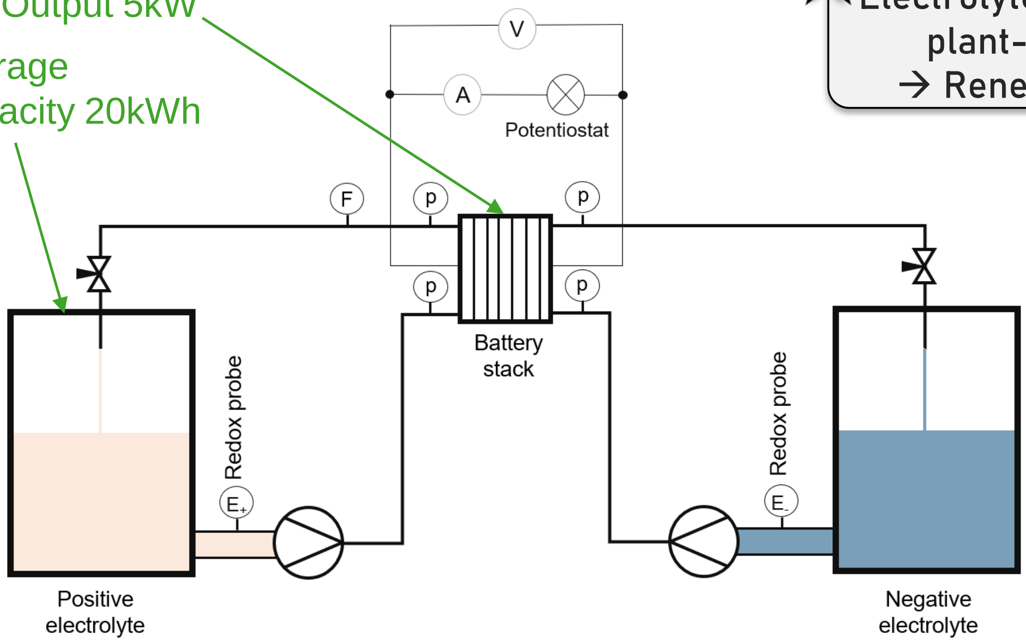
wirtschafts agentur wien
Für die Stadt Wien
Das Land Steiermark
Wirtschaft, Tourismus, Regionen, Wissenschaft und Forschung

Research demonstrator of a renewable flow battery

Output 5kW

Storage capacity 20kWh



Electrolyte is synthesized from plant-based resources
→ Renewable flow battery

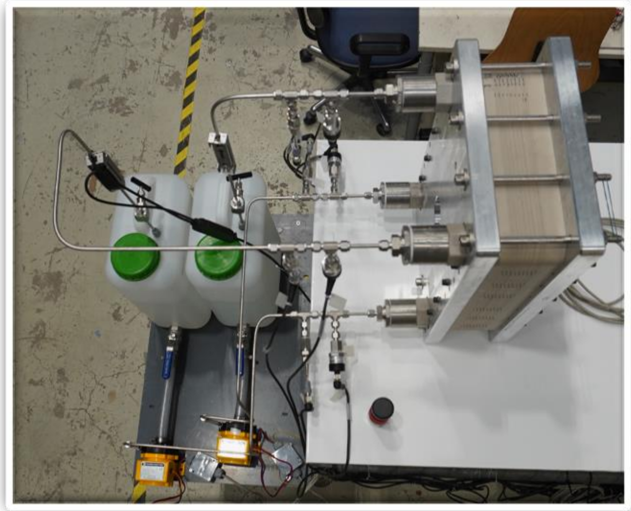
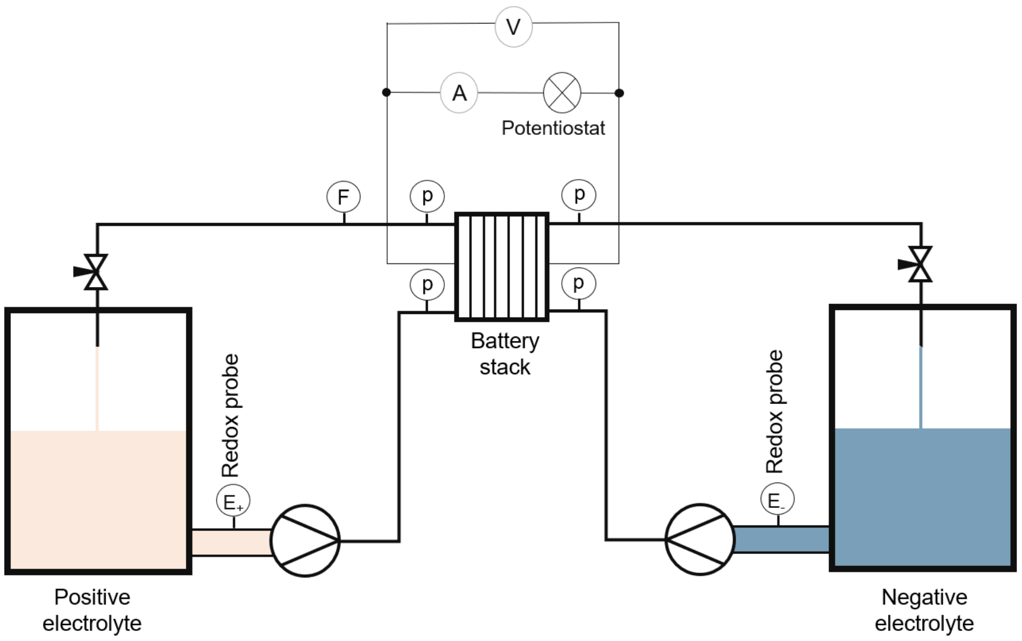
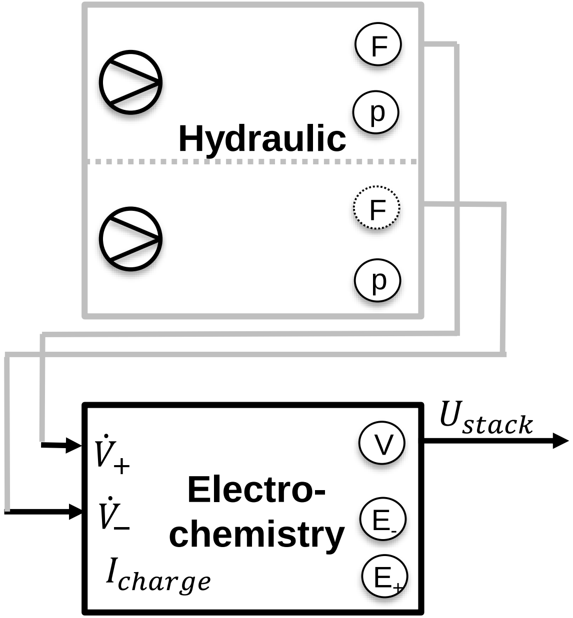


Photo © BEST

Redraw the research demonstrator with block diagrams





Monitoring task

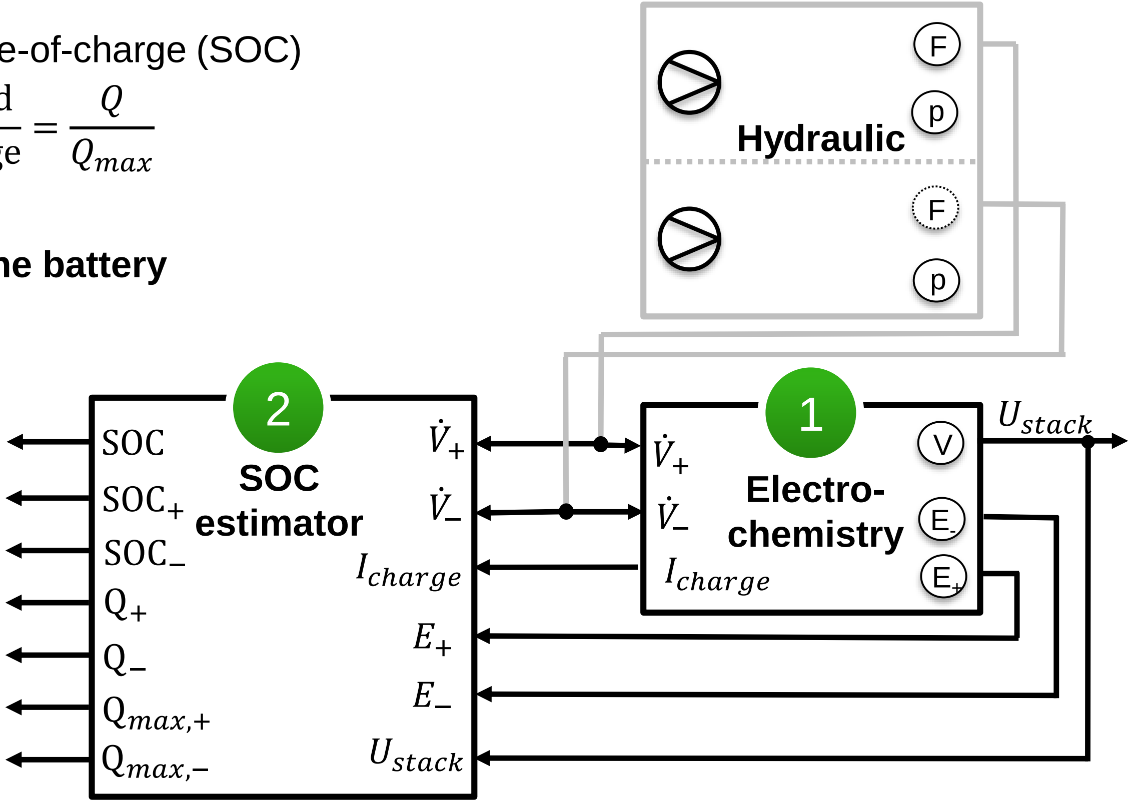
- Main monitoring variable is the state-of-charge (SOC)

$$\text{SOC} := \frac{\text{charge currently stored}}{\text{maximal storable charge}} = \frac{Q}{Q_{max}}$$

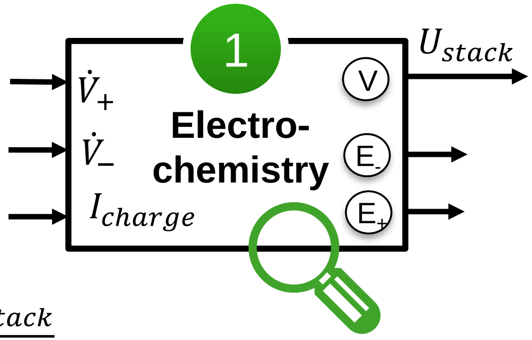
- SOC is NOT directly measurable
- **Estimate the state-of-charge of the battery**

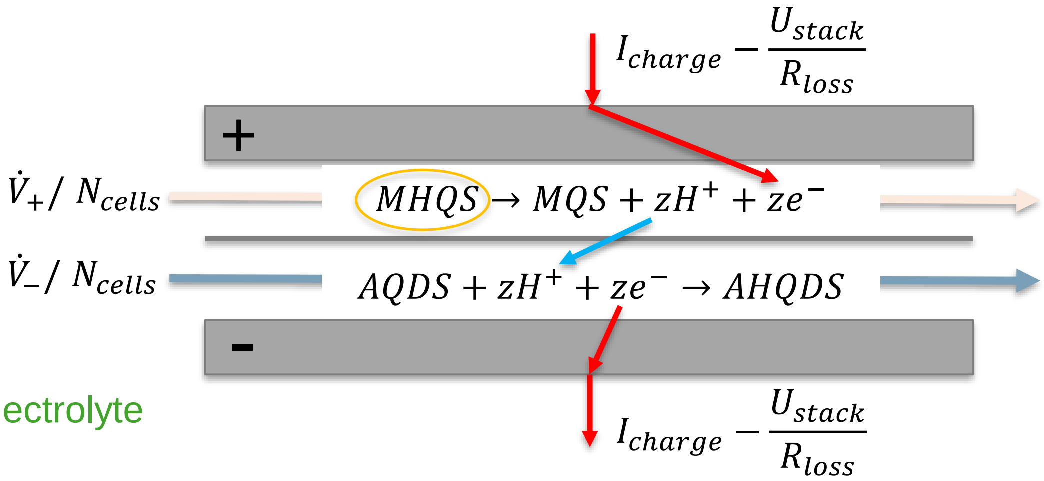
1 Model the electrochemistry

2 Develop SOC estimator



Detail: Model concentration of single species in one cell





Volume of one electrolyte in one cell

$$\frac{V_{stack}}{N_{cells}} \frac{dc_{MHQS\,stack}}{dt} = \frac{\dot V_+}{N_{cells}} \left(c_{MHQS\,tank} - c_{MHQS\,stack}\right) - \frac{\left(I_{charge} - \frac{U_{stack}}{R_{loss}}\right)}{zF}$$

Change of concentration due to volume flow

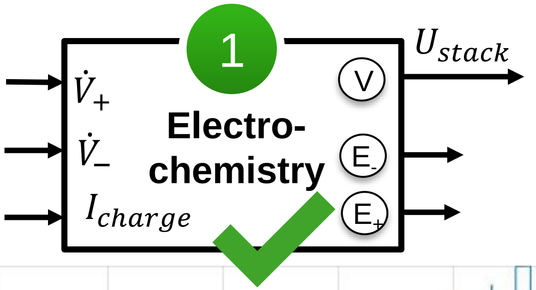
Change of concentration due to electric current

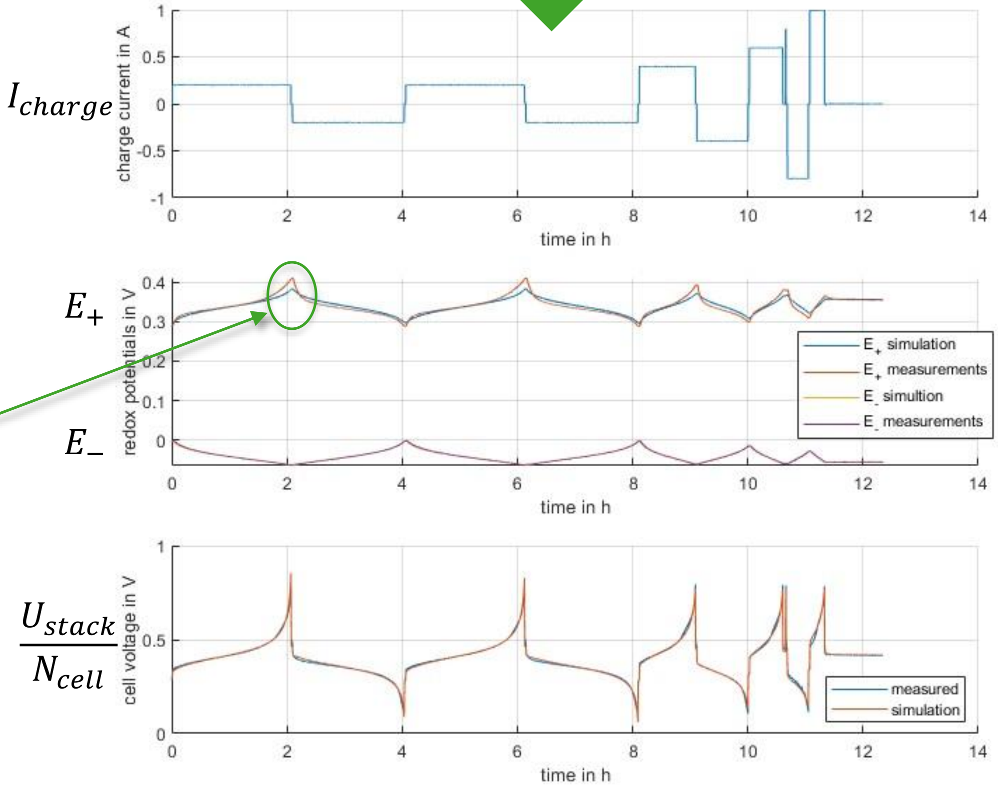
Electrochemistry model: Validation

- Volume flows are kept constant
- Electric current alternates between charging and discharging
- Redox potentials and stack voltage can be described by the electrochemistry model

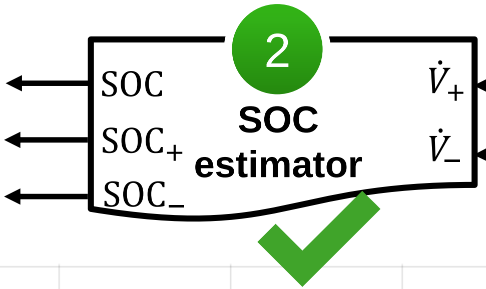
Model error at high SOCs

The developed electrochemistry model can be used for SOC estimation





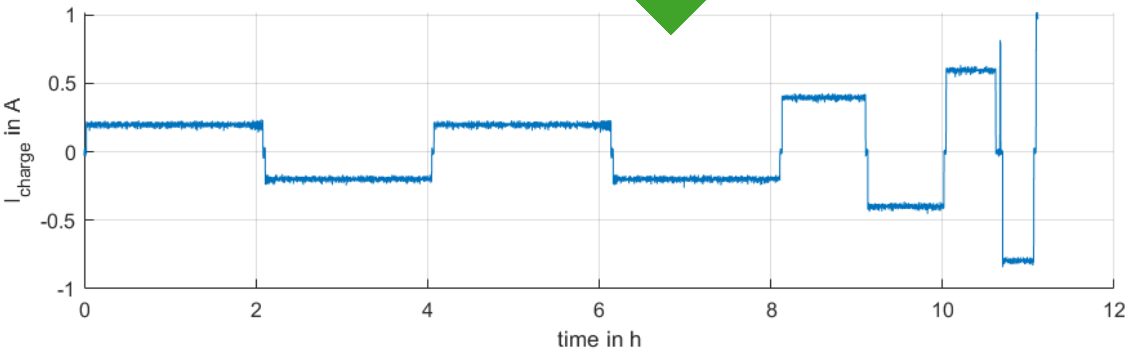
SOC estimator: Validation

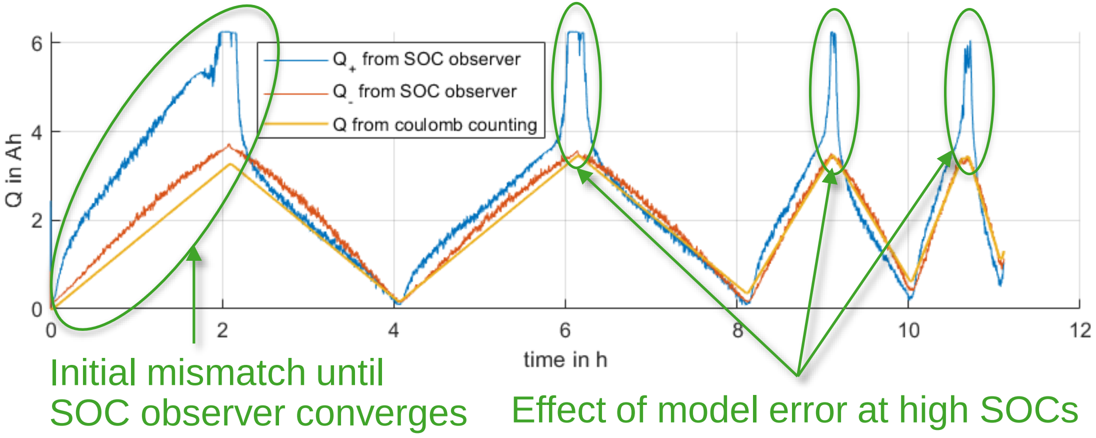


- Comparison
  - of charge Q from SOC estimator
  - with charge Q from coulomb counting

$$Q(t) = N_{cells} \int_0^t I_{charge}(\tau)\, d\tau$$

  - Measurement data is chosen such that $Q(0) = 0$ is a valid initial condition for the coulomb counting.
- Electric current alternates between charging and discharging





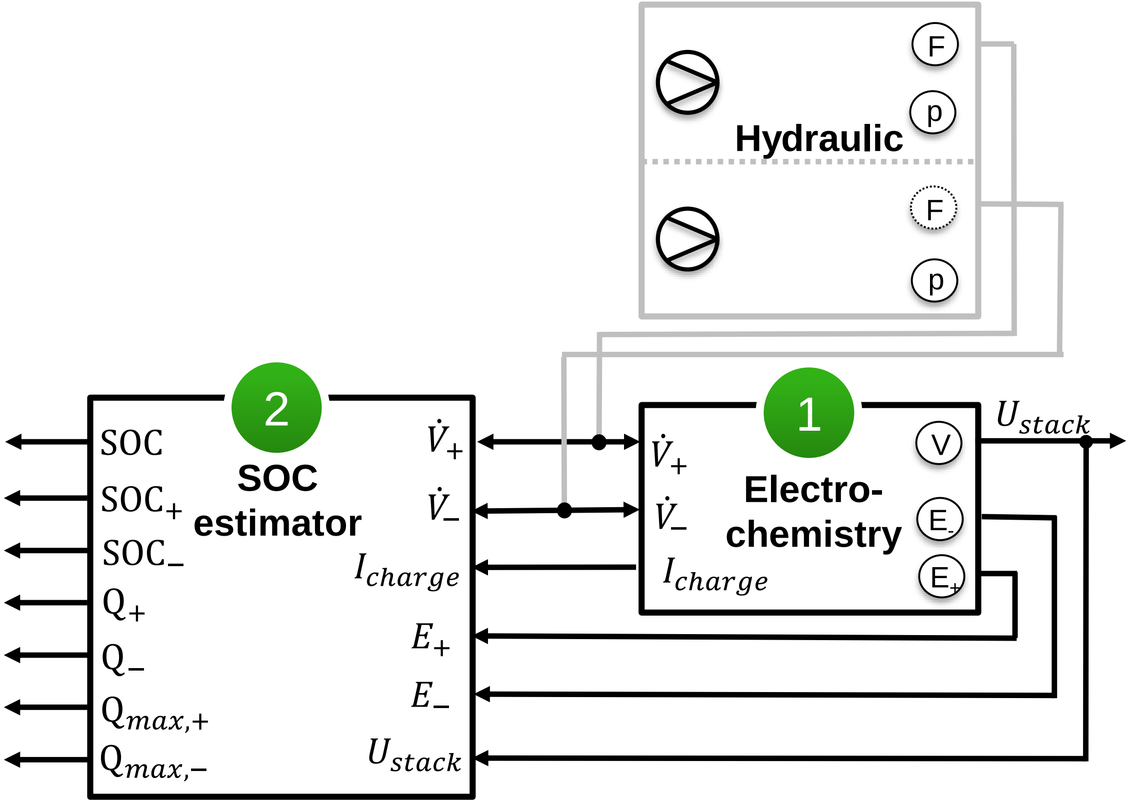
SOC estimator provides information about both electrolytes

Conclusion

Electrolyte is synthesized from plant-based resources
→ Renewable flow battery

1 The developed electro-chemistry model can be used for SOC estimation

2 SOC estimator provides information about both electrolytes



BEST
Bioenergy and Sustainable Technologies

Use cases of optimally planned multi-energy systems with OptEnGrid: hotel resort and renewable energy communities

26.09.2024, Graz

Laurin Zillner
Area 2.3 Microgrids and Smart Energy Communities

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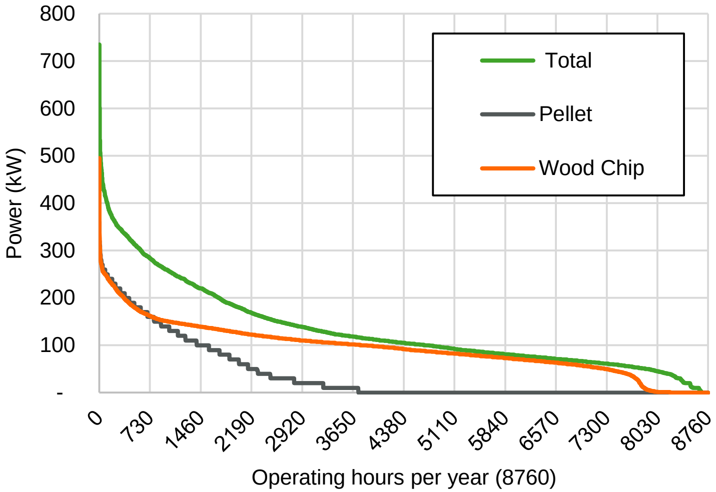
Wirtschaft, Tourismus, Regionen, Wissenschaft und Forschung
SFG NEUES DENKEN. NEUES FÖRDERN.

Hotel Resort Kothmühle

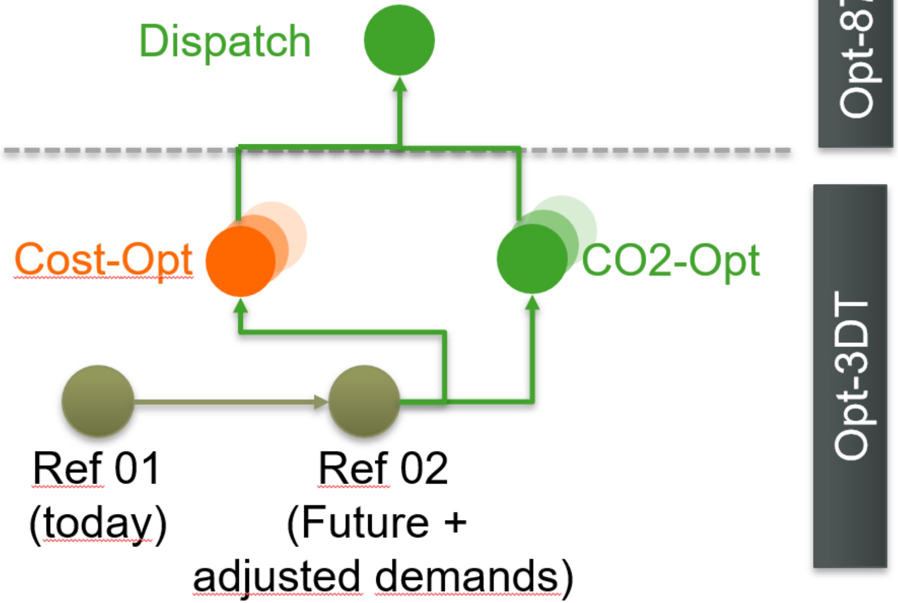
- 4 Star wellness and seminar hotel
- Planned:
  - Wellness area to be expanded
  - Laundry in house
  - Thermal insultation
  - E-charging stations to be expanded
- The goal is to be as self-sufficient as possible, through renewable energies



Hotel Resort Kothmühle

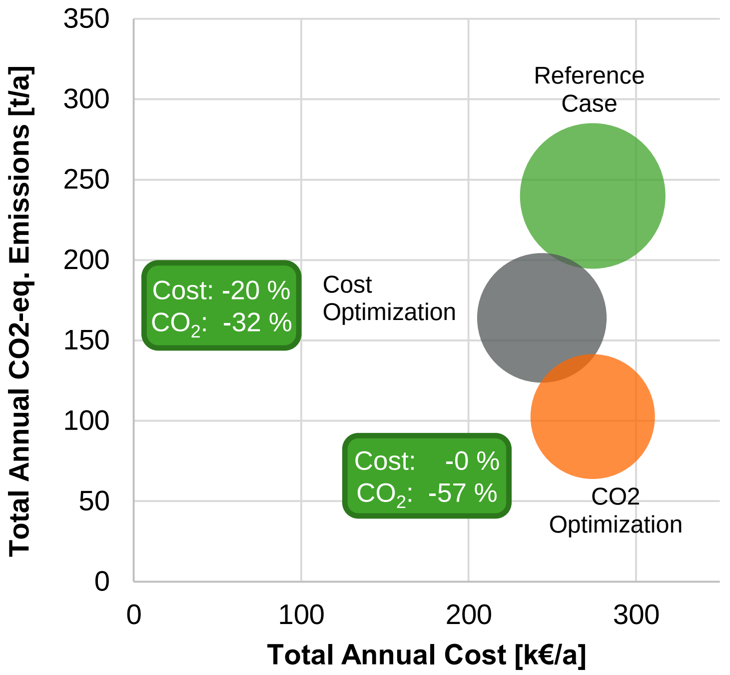
Holistic optimized planning in OptEnGrid:

- PV-planning
- Modernisation of old systems
- Complex use case
  - 5 energy profiles used
  - Various technologies



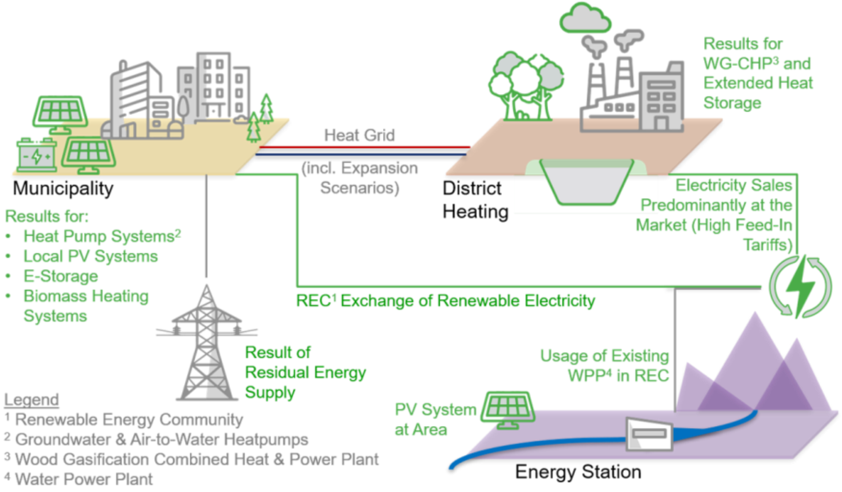
First Results Kothmühle

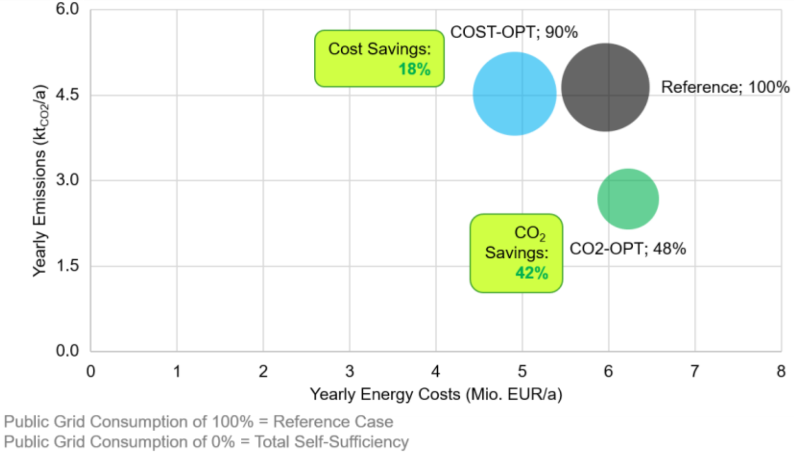
- Maximum PV installation 261kWp
- Battery storage system 65 kWh
- Expansion of heat storage +50 kWh
- Integration of cold storage 40 kWh
- Wood chip CHP 250kW$_e$ & 500kW$_{th}$



Optimized Planning of Energy Systems in more than 10 Austrian Communities

- **Increasing the share of renewable energy technologies**
- **Increasing local energy self-sufficiency**
- **Achieving cost and CO_2 reductions**





Adnet, Grödig, Hinterglemm, + 9 Ski Resorts

Maria Rain, Mallnitz

Perchtoldsdorf, Wieselburg, Wieselburg-Land

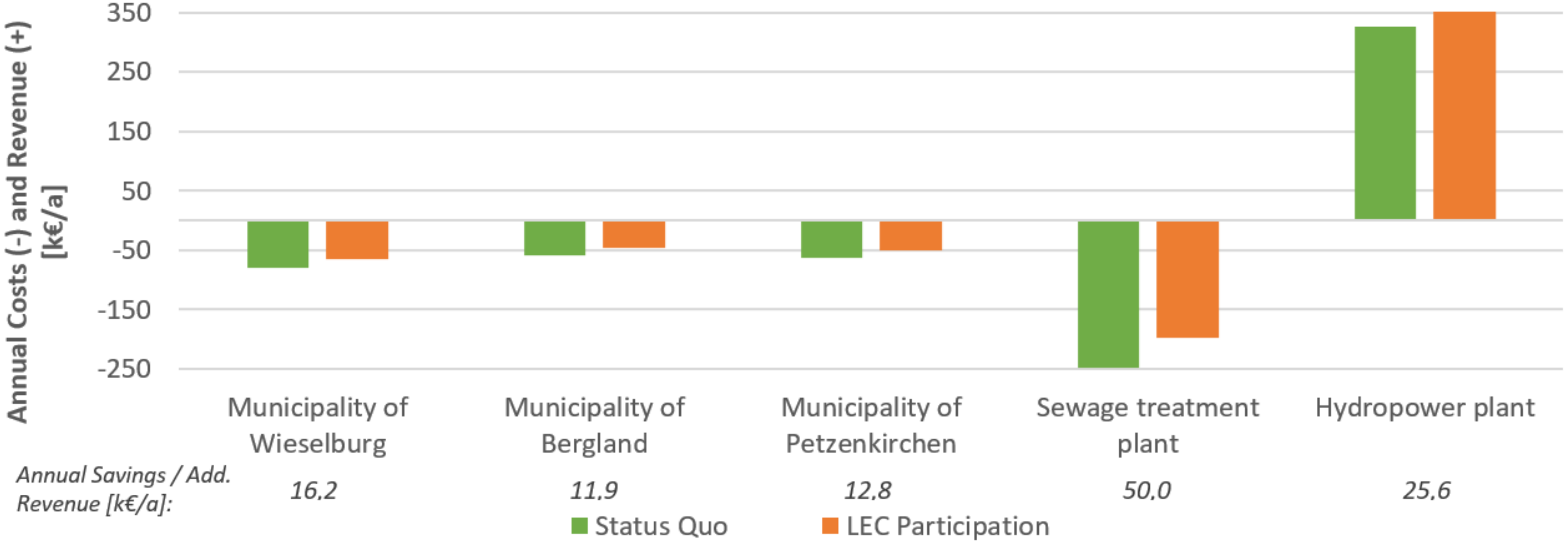
Ötztal, + 1 Ski Resort

Möllersdorf, Mureck

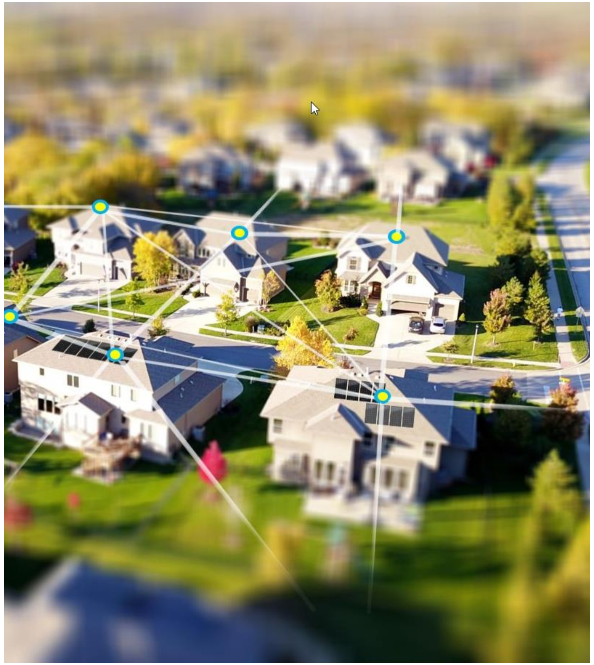
Renewable Energy Communities: InRegion South & InRegion North

- 4 participating municipalities
- The goals of the project were to
  - Use most of the local generated electricity locally
  - Save money on energy purchases
- Division into 2 LECs due to grid levels
- Involved metering points were mostly municipality owned
  - South 111 metering points
  - North 48 metering points

Renewable Energy Communities: InRegion North economic results



Conclusion



- Complex data & data procurement
- Significant cost & emission reduction possible
- 2 Different time-resolution models
  - 8760 model: Precise operating schedules
  - 3D model: Fast calculations
- Challenge: no Standard use case → every project is unique
- Advantage: Because of the high flexibility a wide variety of projects are possible

BEST
Bioenergy and Sustainable Technologies

Optimal Design of Multi-Energy Systems using OptEnGrid

26.09.2024, Graz

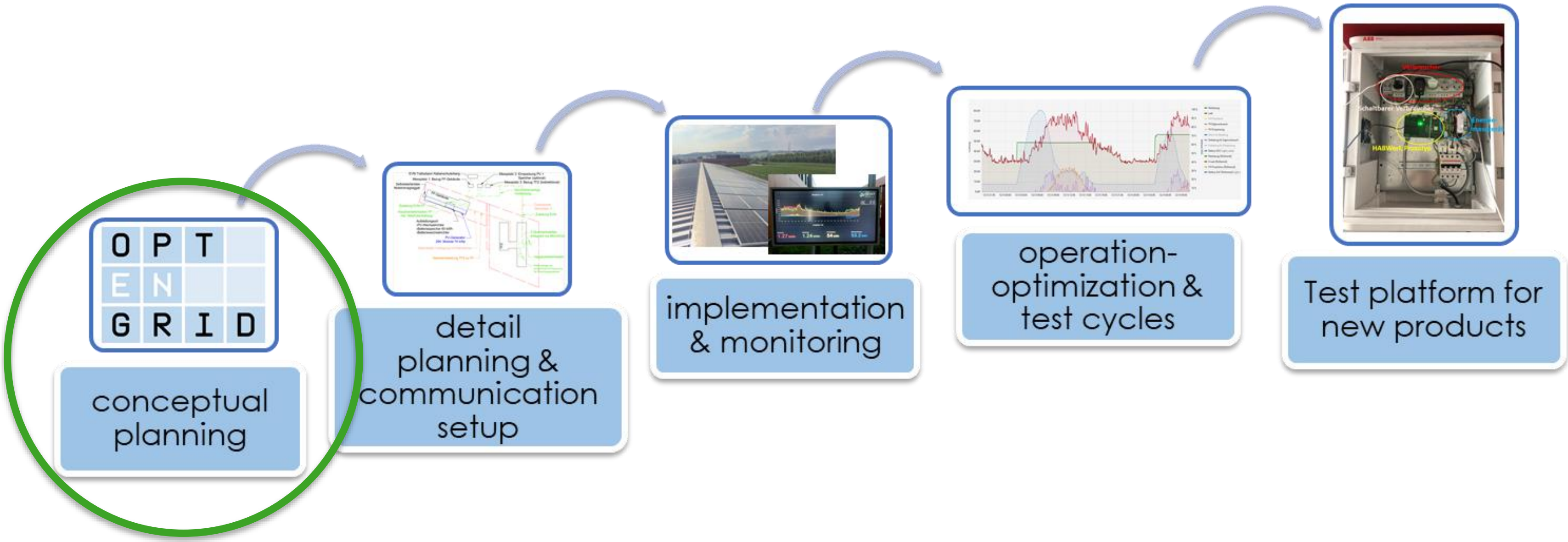
OPT EN GRID

Christian Oberbauer
Area 2.3 Microgrids and Smart Energy Communities

FFG Forschung wirkt.
Bundesministerium Arbeit und Wirtschaft
Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie
wirtschafts agentur wien
Für die Stadt Wien
Das Land Steiermark
Wirtschaft, Tourismus, Regionen, Wissenschaft und Forschung
SFG NEUES DENKEN. NEUES FÖRDERN.

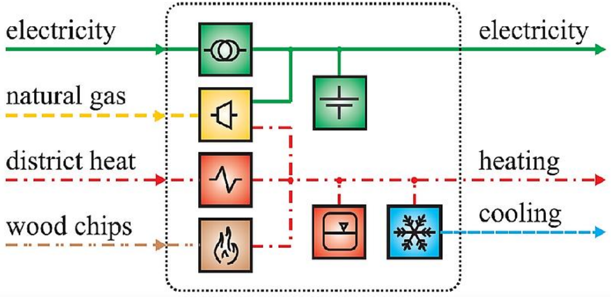
Implementation Process of Decentralized (Multi-) Energy Systems

- Optimal planning of decentralized energy systems → OptEnGrid
- Testing and optimization of hard- and software in real use cases → Microgrid Lab



Holistic Design of Multi-Energy Systems

- **Challenges**:
  - **High complexity** related to the diversity of:
    - Sectors (electricity, heating, cooling, mobility, …)
    - Energy sources (fossil and renewable fuels, etc.)
    - Technologies (generation, conversion, storage)



  - Conventional planning methods **do not provide an "optimal" result** in terms of
    - Costs and emissions – due to oversizing
    - Calculation effort → high implementation costs

- **Solution = mathematical optimization with OptEnGrid**
  - Simultaneous determination of optimal design in terms of
    - Capacities and operating schedule (hourly)
    - Costs (investment, O&M, fixed costs, energy tariffs)
    - and $CO_{2\text{-eq.}}$ emissions

image source: DOI: https://doi.org/10.1063/1.4993046

OptEnGrid: History & Validation

- 2000-2018: Development of DER-CAM[1] at LBNL[2] in Berkeley, California a.o. by Michael Stadler (founder of Area 2.3 at BEST); >1.500 users/institutions in >24 countries

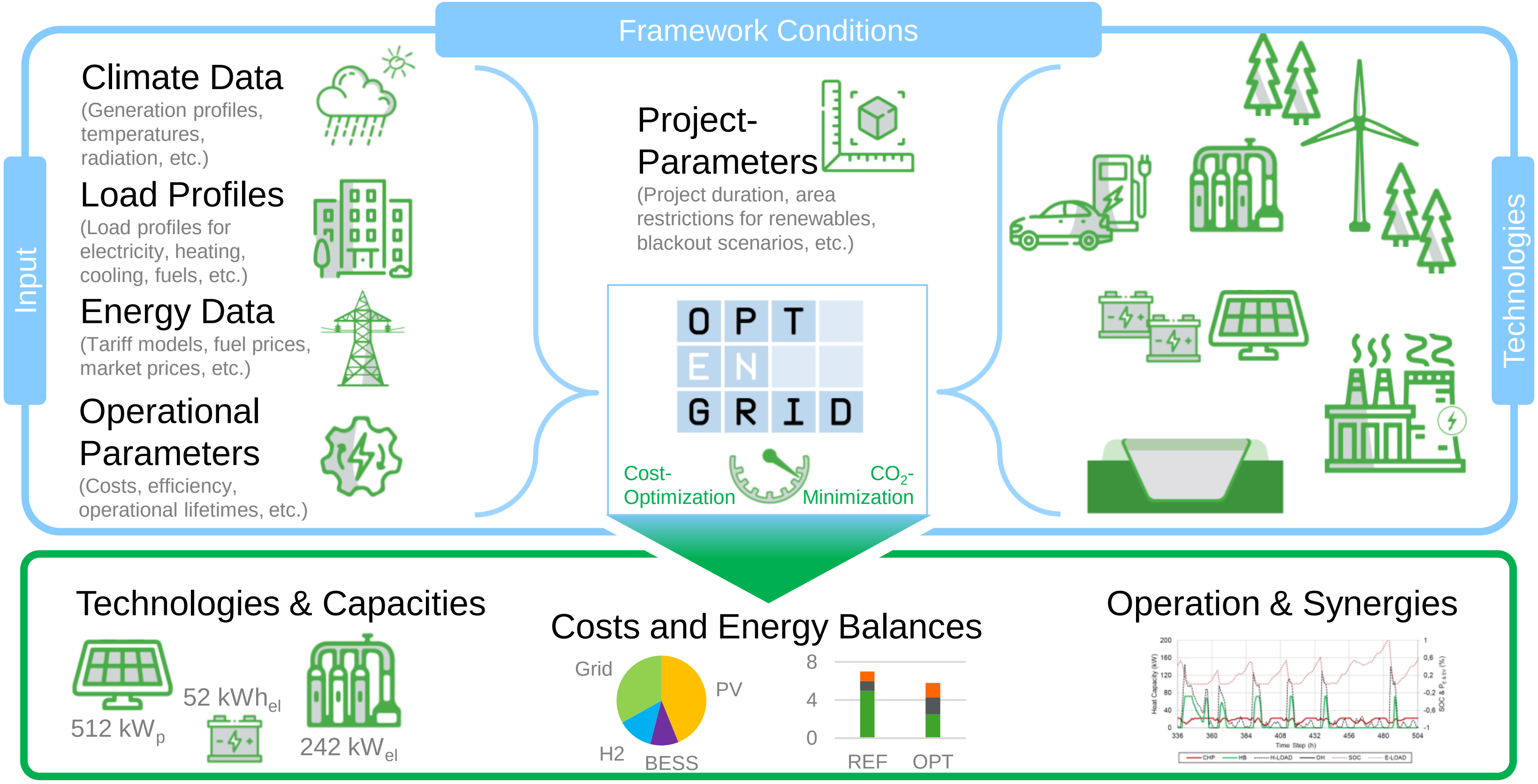
- 2017- today: **advanced development** & renaming to **OptEnGrid**[3] at BEST as part of research projects:

  → **Extension of the optimization model**

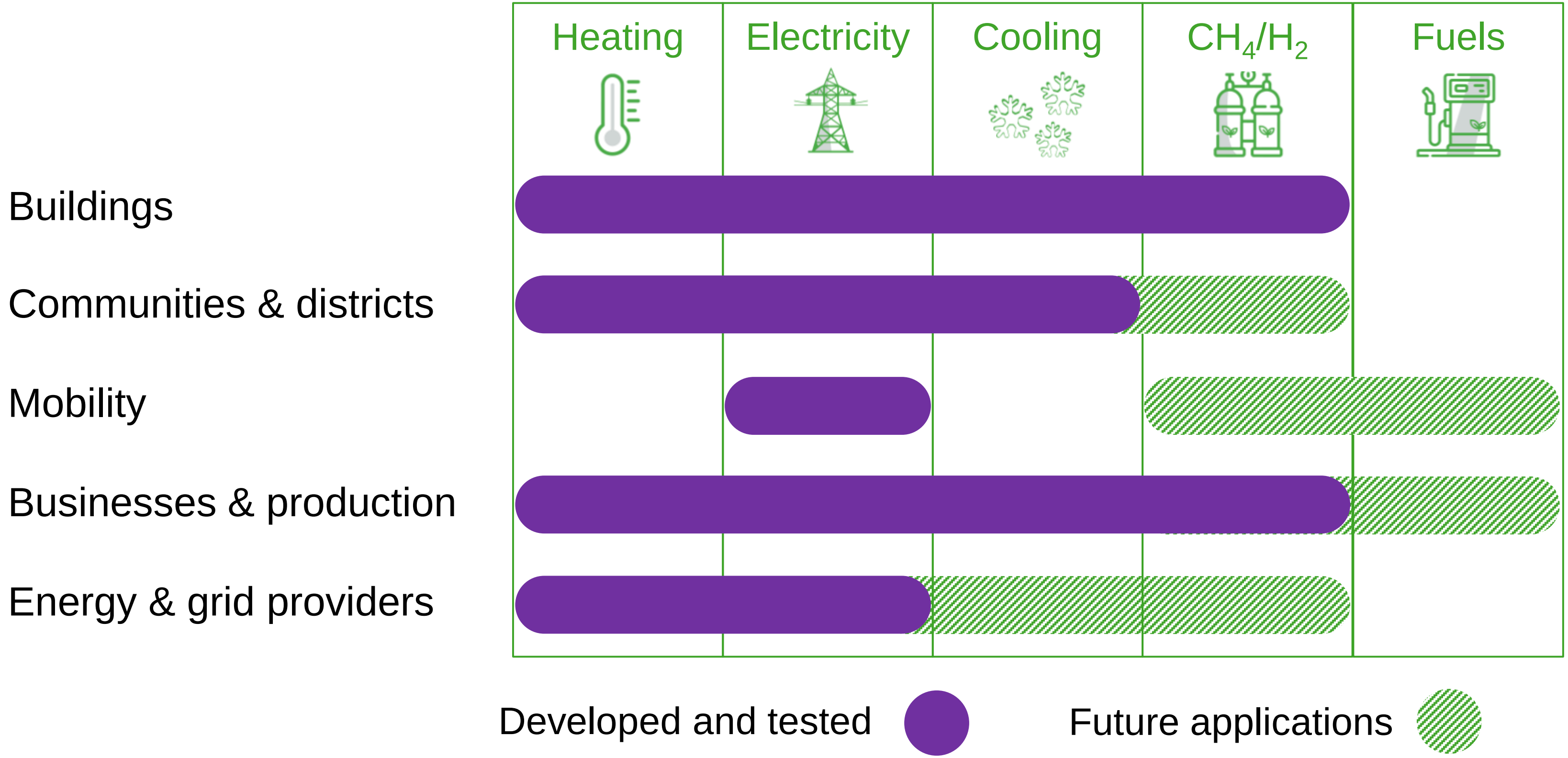
- 2019 – 2022: **Validation** of OptEnGrid based on a **real use case**:
  - **Microgrid Lab** at the Technical Research Centre Wieselburg-Land, Lower Austria
  - Planning → implementation→ monitoring → operation with the Microgrid Controller

[1] Distributed Energy Resources – Customer Adoption Model
[2] Lawrence Berkeley National Laboratory
3 Optimized Energy Grid

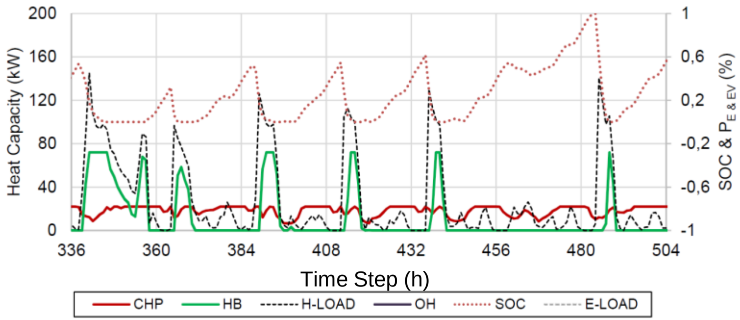
Big Picture - Workflow



Application Fields of OptEnGrid



Benefits, Potentials of OptEnGrid & Comparison of similar Tools



Benefits:

- Determination of the optimal **technology-mix** with rated capacities & **operational dispatch**
- **Average savings[1]:**
  - **~ 15 to 27% cost savings**
  - **~ 8 to 87% emission savings**

Potentials in Austria:

- 2.093 municipalities
- > 2.400 heating grids[2]
- ~ 5.000 energy communities[3]

	Model Type		Modelling Scope		No. of nodes	Resolution			Objective Function			Utilized Technologies							Performance	Availability
Tool	Simulation	Optimization	Residential	District	Multiple Nodes	Day Types	Hourly	< hourly (30/15min)	Cost-Minimization	CO_2-Minimization	Other Objectives	Electricity	Heating	Cooling	Hydrogen	Mobility	Fuels	Energy Communities	Quick Results	Open Source
OptEnGrid	0	1	1	1	1	1	1	0	1	1	0	1	1	1	1	0,5	1	1	1	0
HOMER	1	1	0	1	1	1	1	0	1	0,5	0	1	1	1	1	1	1	0	1	0
Reopt®	1	1	0	1	1	0	1	1	1	1	1	1	1	1	0	0	1	0	0	1
nPRO	0	1	1	1	0	0	1	0	1	0,5	0	1	1	1	0	0,5	1	0	1	0
urbs	0	1	0	1	1	0	1	0,5	1	1	0	1	0	0	0	0	0	0	0	1
ESYOPT®	0	1	1	1	?	0	0	1	1	1	1	1	1	0	0	0	1	0	?	0,5
KomMod	0	1	1	1	1	0	1	1	0,5	0	1	1	1	0	0	0,5	1	0	0,5	1
plan4energy	0	1	?	1	1	?	?	?	?	?	?	1	?	?	?	0,5	?	1	?	0
ENDOPT	0	1	0	1	1	?	?	?	1	1	0	1	0	0	0	0	0	0	?	0
Planungstool-EEG	0	1	0	1	1	?	?	?	1	1	0	1	1	1	?	0,5	?	1	?	0

Advantages:

- ✓ Flexible Application
- ✓ Multi-Energy-Systems
- ✓ Energy Communities
- ✓ Fast Results

[1] https://doi.org/10.1016/j.apenergy.2023.12091; https://doi.org/10.1016/j.energy.2021.121559; https://www.best-research.eu/files/publications/pdf/Liedtke_Ganzheitliche_Planung_DER.pdf
[2] https://www.klimafonds.gv.at/wp-content/uploads/sites/16/FEFahrplan-FernwaermeFernkaelte.pdf
[3] https://www.eda.at/fakten

Summary and Outlook – Future Developments

- **Advanced web-based graphical user interface** for ease of use and broad application (from private individuals to planners and energy consultants)
- **Automated data collection** for simplified and scalable planning processes (e.g. linked to GIS-databases)
- **Commercial planning tool** for utilities, industry, municipal planners and policy makers

BEST Bioenergy and Sustainable Technologies

Sustainability assessment: mere obligation or a key to success?

Graz, 26.09.2024

Christa Dißauer, Monika Enigl, Marilene Fuhrmann, Doris Matschegg, Christoph Strasser

FFG Forschung wirkt.
Bundesministerium Arbeit und Wirtschaft
Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie
wirtschafts agentur wien | Für die Stadt Wien
Das Land Steiermark – Wirtschaft, Tourismus, Regionen, Wissenschaft und Forschung
SFG NEUES DENKEN. NEUES FÖRDERN.

What does „sustainability“ mean?

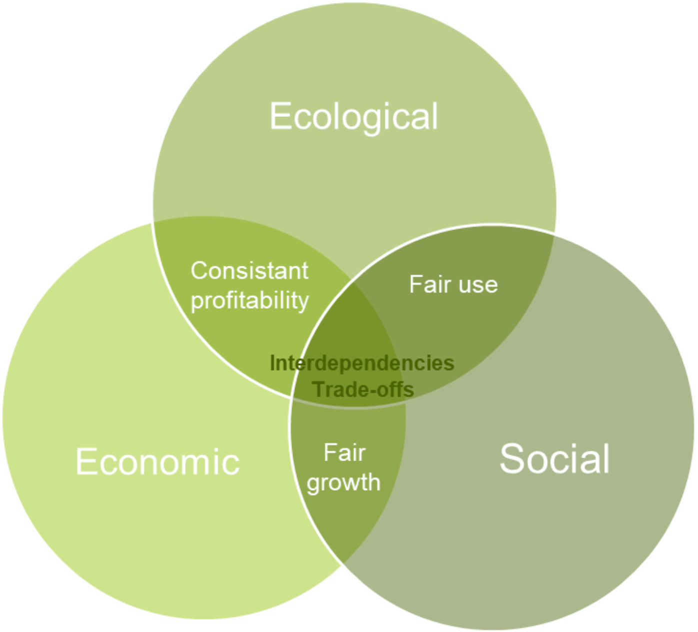
- United Nations Brundtland Commission 1987:

„meeting the needs of the present without compromising the ability of future generations to meet their own needs”

- The Environmental Protection Agency:

„sustainable development and environmental factors relate to just about everything - including the ability to generate social sustainability, promote economic prosperity, and reach economic objectives“

The 3 dimensions of sustainability



- Ecological pillar
  - Protect the environment by reducing risks of organizations' activities
  - Saving and preserving natural energy or agricultural resources
  - Prevent water scarcity and reduce overall waste for current and future generations
- Social pillar
  - Promote equality and respect for individual rights, combat social exclusion and discrimination
  - Promote solidarity – e.g., prioritizing fair trade products
  - Contribute to the well-being of stakeholders – e.g., encouraging the exchange of information and transparency
- Economic pillar
  - Fostering Innovation and Adaptation
  - Promoting resource efficiency and minimizing waste throughout the production and consumption processs
  - Ensuring Financial Stability and resilience to external shocks and crises

New rules on corporate sustainability reporting: The Corporate Sustainability Reporting Directive

On 5 January 2023, the Corporate Sustainability Reporting Directive (CSRD) entered into force

- What? modernises and strengthens the rules concerning the social and environmental information that companies have to report
- Who? Large companies, as well as listed SMEs and some non-EU companies if they generate over EUR 150 million on the EU market
- Why? To ensure that investors and other stakeholders have access to the information they need to assess the impact of companies on people and the environment and for investors to assess financial risks and opportunities arising from climate change and other sustainability issues
- When? The first companies will have to apply the new rules for the first time in the 2024 financial year, for reports published in 2025

European Sustainability Reporting Standards

- Companies subject to the CSRD will have to report according to European Sustainability Reporting Standards (ESRS)
- The directive also requires verification of the sustainability information reported by companies and provides for a digital taxonomy for the electronic submission of sustainability information to the company register (Firmenbuch)
- The responsible department of the Federal Ministry of Justice has prepared an initial draft of a federal law **(Nachhaltigkeitsberichtsgesetz – NaBeG)** for implementation - the draft is currently undergoing political consultation

European Sustainability Reporting Standards

- Companies subject to the CSRD will have to report according to European Sustainability Reporting Standards (ESRS)
- The directive ... ion reported by companies ar... ıbmission of sustainability

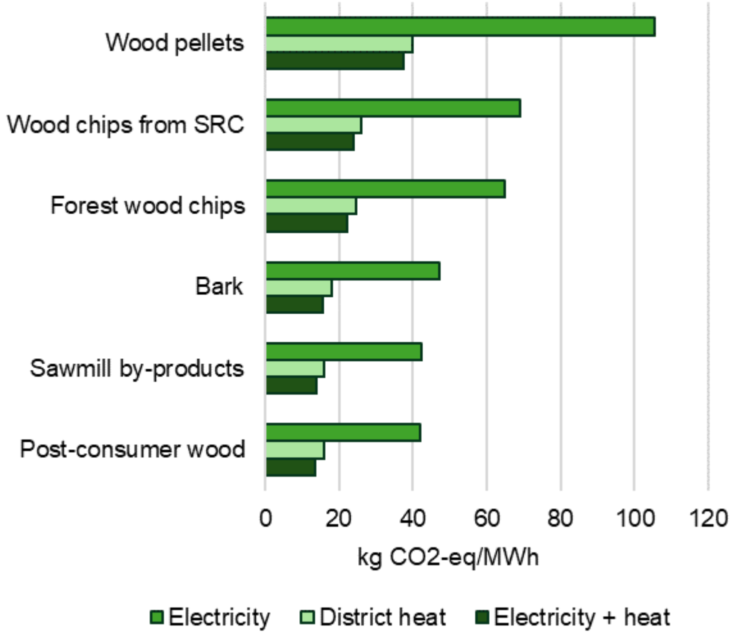
How to obtain scientifically based data required for reporting?

- The responsible department of the Federal Ministry of Justice has prepared an initial draft of a federal law **(Nachhaltigkeitsberichtsgesetz – NaBeG)** for implementation - the draft is currently undergoing political consultation

Sustainability assessment & science-based reporting support @BEST

- **BEST sustainability Quick-Check**
  - A quick check for the biobased systems and processes to identify "sustainability hot spots"
- **Life Cycle Assessment (LCA)**
  - LCA is a technique for assessing the environmental aspects associated with a product over its life cycle
- **Techno-Economic Assessment and Life Cycle Costing (LCC)**
  - Life cycle cost assessment is an economic evaluation of a product or an engineering project across its lifetime
- **The Bio-Value-Tool** (first developed in the BioEcon project as **"Wood-Value-Tool"**)
  - The calculation tool enables a techno-economic assessment of selected biomass value cycles; integrating the sustainability criteria facilitates to derive recommendations regarding sustainable supply and distribution strategies as well as to increase the resilience of bio-based systems
- **Social-Risk Matrix**

Example: Global Warming Potential



	kg CO_2-eq/MWh
Heating oil	344
Natural gas	249
AT electricity mix	226
AT district heat	179

BIOSTRAT
Strategies for the optimal bioenergy use in Austria from societies point-of-view – Scenarios up to 2050

Partners: BEST GmbH
Austrian Research Centre for Forests (BFW)
Energy Economics Group, TU Wien
Subcontractor: Göran Berndes (IEA Task 45, TU Chalmers)

Funding: Austrian Climate Research Programme (ACRP)

Sustainability assessment: a key to success

Sustainability assessment helps with

- identifing sustainability hotspots
- supporting the decision making process
- evaluating tradeoffs
- evaluating the effectiveness of actions taken
- tracking progress
- meeting new requirements
- establishing reward mechanisms and
- communicating goals and achievements

Top 3 reasons that organizations address sustainability*

1. **Alignment**
   Align with company's business goals, mission or values
2. **Reputation**
   Build, maintain, or improve corporate reputation
3. **Cost cutting**
   Improve operational efficiency and lower costs

*McKinsey Global survey results „Sustainability's strategic worth"
2010-2018

Sustainable as well as resilient biomass supply and technologies are key factors for the success and competitiveness of bio-based businesses