IEA Task 11

Industry-based biorefineries towards sustainability

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IETS Task 11

Focus: Biorefineries integrated in industrial complexes – leading to decarbonization and energy efficiency

Interdisciplinary approach: industrial technologies, energy efficiency and biomass conversion

Picture: KI based image creation, https://huggingface.co/spaces/stabilityai/stable-diffusion

Examples:

- *integration of bio with oil refineries*
- *Bio-CCU options yielding hydrocarbons/hydrogen (e.g. EU DESIRED photocatalytic bio-CO2 conversion to C2+ molecules)*
- *Energy efficiency and Renewable energy for biorefineries and biobased industry*
- *Extending biorefinery pathways (e.g. new products, new energy usage) towards decarbonization*

→ *technology and systems aspects for a better use of energy*

Task 11 Vision

Industry and emissions

energy and resource efficient Biorefineries – new products, new pathways, possibly integrated to industrial complexes

Biorefinery concepts with net zero / negative emissions

Pictures: KI based image creation, https://huggingface.co/spaces/stabilityai/stable-diffusion

IEA IETS Task XI Industrial Biorefineries towards Sustainability

International Consortium: Finnland, Schweden, Canada and Portugal

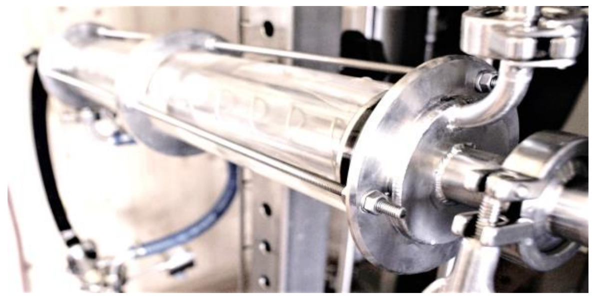
Austrian Consortium: AEE INTEC & Energieinstitut an der JKU Linz

TU WIEN, Institut für Verfahrenstechnik, Umwelttechnik und Technische Biowissenschaften

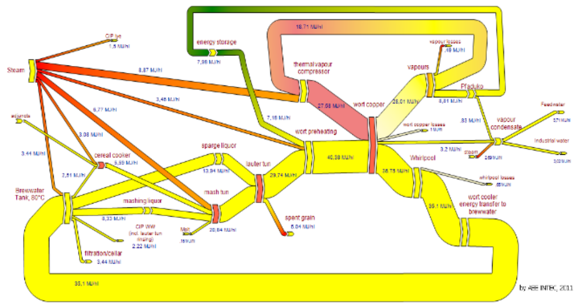
SUBTASK 1: Decision Support System and Ex-Ante Research – criteria to evaluate strategies

SUBTASK 2: Net-zero/Negative emission biorefineries - concepts for integrated biorefineries to reach net-zero/negative emissions

- High efficient (process) technologies; novel reactors enable resource and energy efficiency, new products
- Focus on impact on GHG emissions

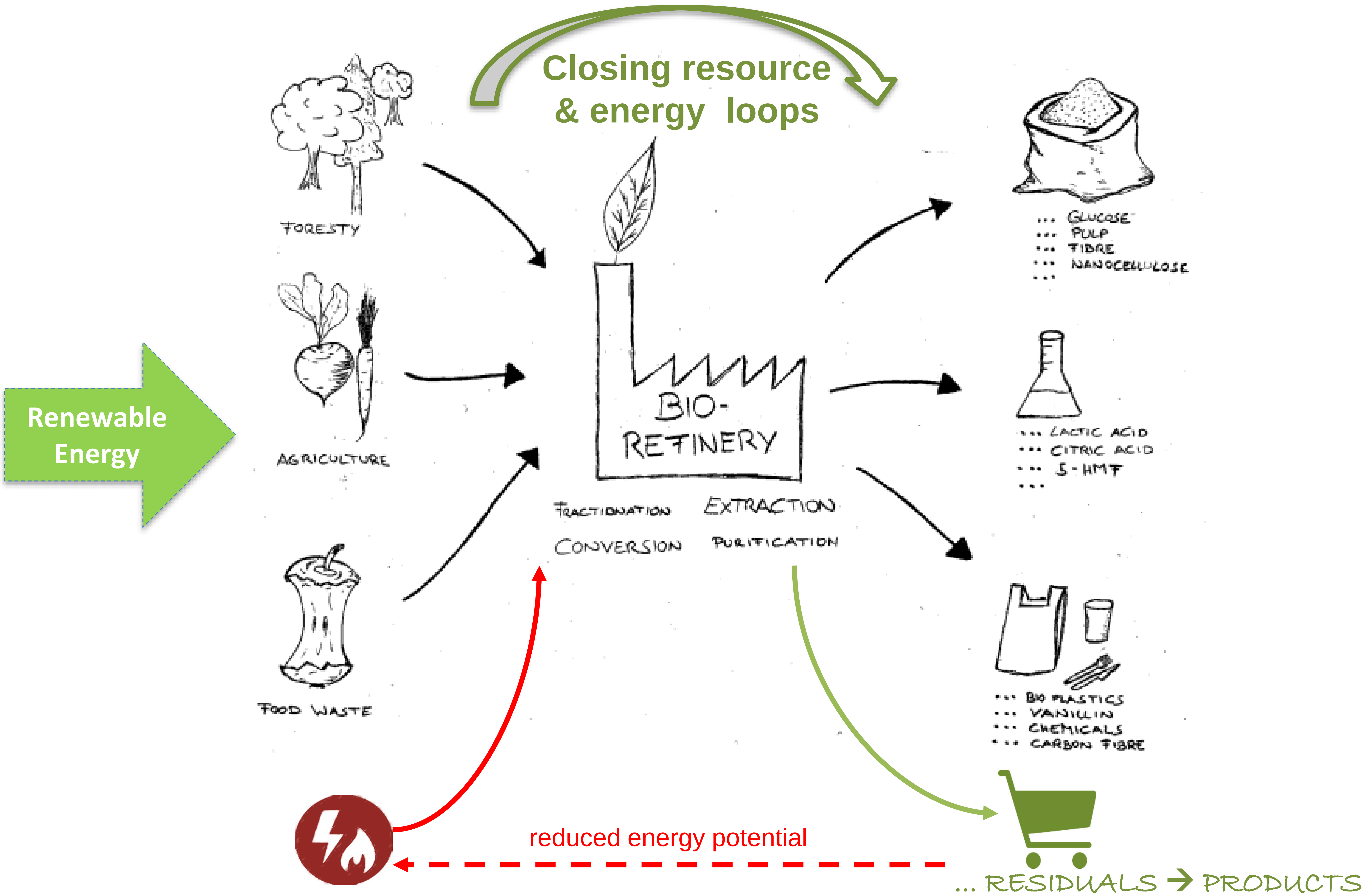


- Re-frame process integration tools for industry-based biorefineries, e.g.
- Site-analysis
- Pinch tools



- Database on best practices on negative/net-zero concepts

Optimized Biorefinery



Combined energy and ressource efficiency

Higher focus on resource use for material products, lower energy generation potential, can require energy in processing, utilities, chemicals etc.

Are resource and energy efficiency contradictory?

- Decision support systems (DSS) are available:
  - Advantages for integrating a biorefining technology
  - Technical impact
  - Scenarios of being economical and ecological

- **Weak points of DSS**: combined consideration of energy and resource efficiency

Key performance indicator set

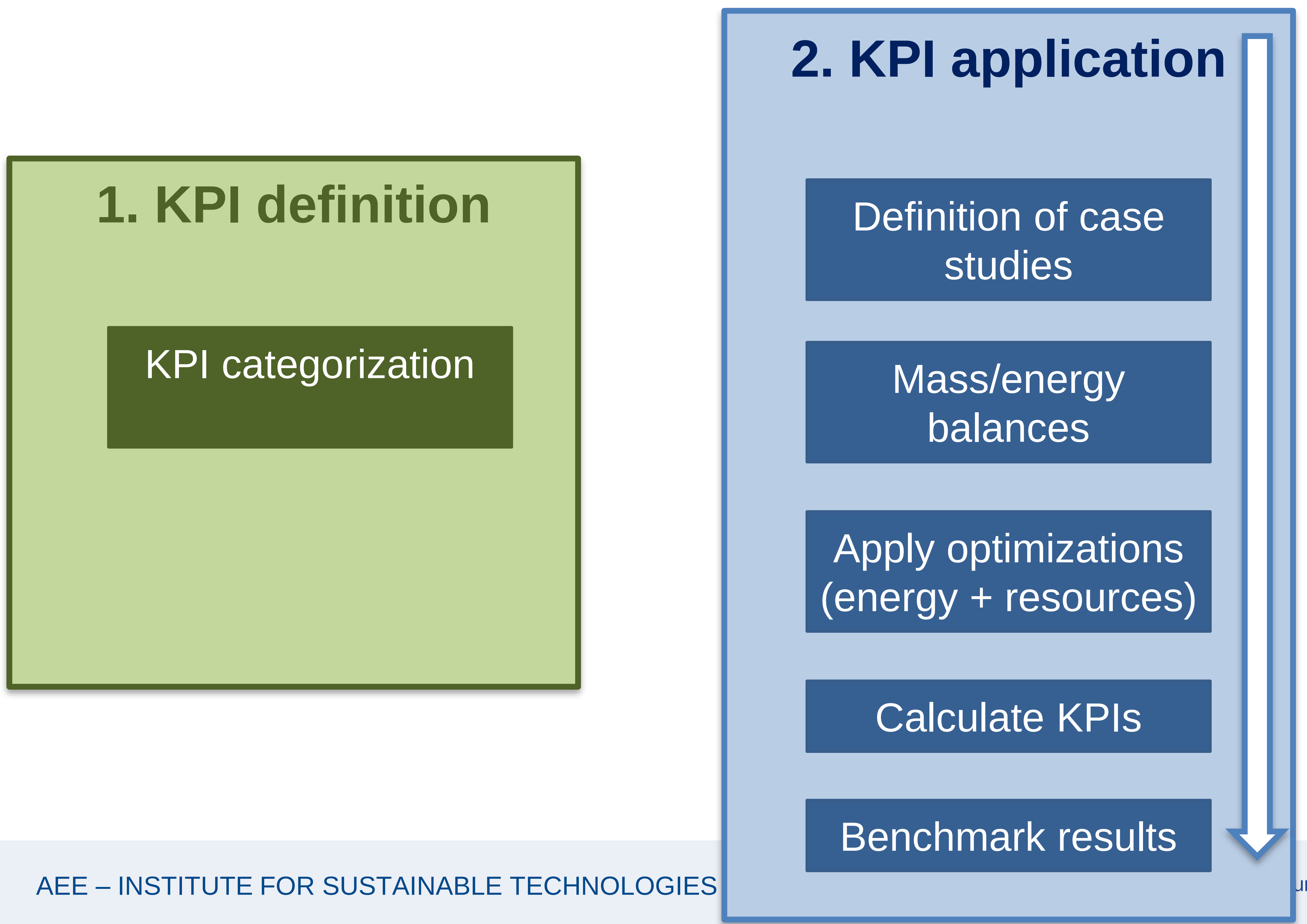
to evaluate energy and resource efficiency

Methodology

Holistic consideration of combined resource & energy efficiency based on **real case studies**

Elaborate **new (optimized) system concepts**

Define **key performance indicators (KPIs)** to analyze energy – and resource efficiency



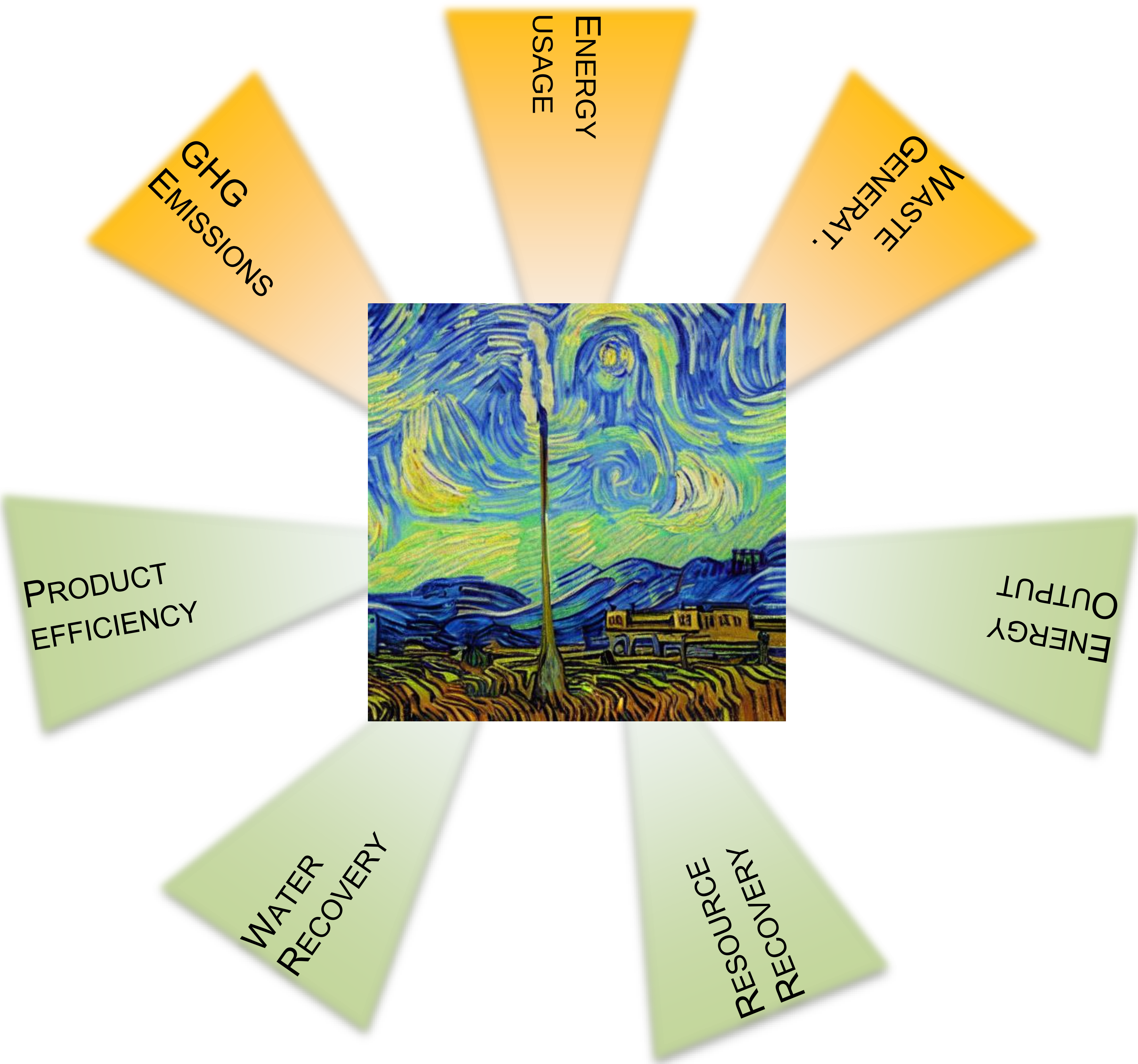
AEE INTEC

KPIs - Dimensions

Specific KPIs
for individual process steps

Global KPIs
for the entire system

Benchmark KPIs
to compare different scenarios and biorefineries with each other



KPI	Equation
Energy consumption	$\frac{kWh}{kg\ Biomass}$
Resource recovery	$\frac{kg_{Product}}{kg_{Biomass} + kg_{Additives}} * 100$
Chemical usage	$\frac{kg_{Additives}}{kg_{Product}}$
Water recovery	$\frac{m^3\ Water_{recycled}}{m^3\ Water_{fresh}} * 100$
Product efficiency	$\frac{kg_{Product}}{kg_{Biomass}} * 100$
Specific energy yield	$\frac{kWh_{Biogas}}{kg\ COD_{inlet}}$
GHG emission	$\frac{g\ CO_2\ Äq}{\mathrm{kWh}} * \frac{kW}{10^6} * operating\ hours$
Grade of waste	$\frac{kg_{Waste}}{kg_{Inlet}}$

CS1: WWTP - Scenarios of optimization

- **Scenario 1 & 2**
  - Integrating a **primary clarifier** with an additional **primary sludge thickener**
  - **Nutrient recovery (ammonia)** with a membrane distillation
- **Scenario 3**
  - Substitution of the primary clarifier with a **cellulose recovery system (product = wet cellulose pulp)**

178 Mt/a NH3
Haber Bosch = 1-2% of world final energy demand; 1,44% of CO2 emissions
energy losses: 50%

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75-90% of NH3 used for fertilizer production (e.g. urea, ammonia-sulfate solutions)
50% of world's food production relies on fertilizing

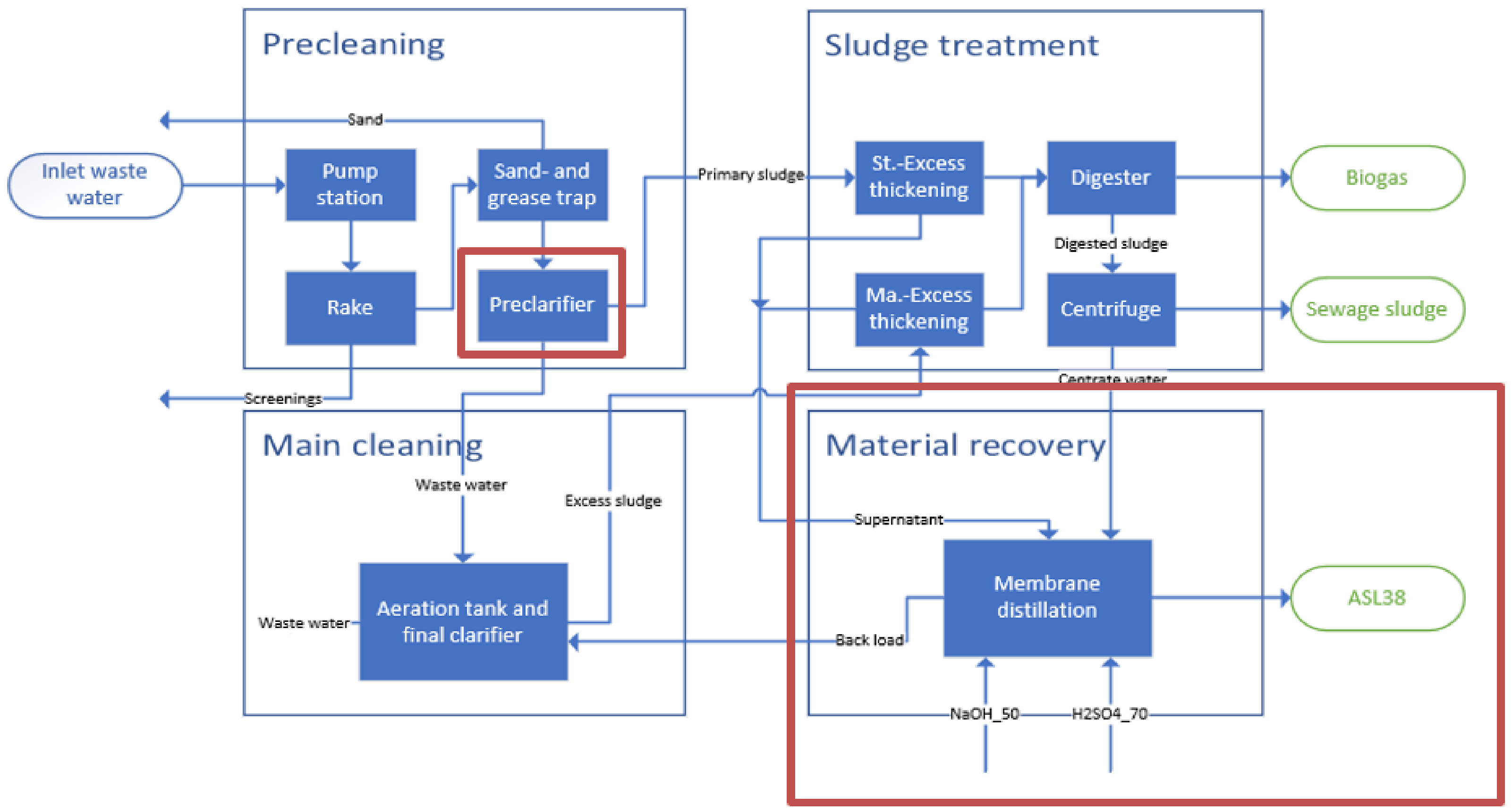


Fig.: Scenario 1 & 2

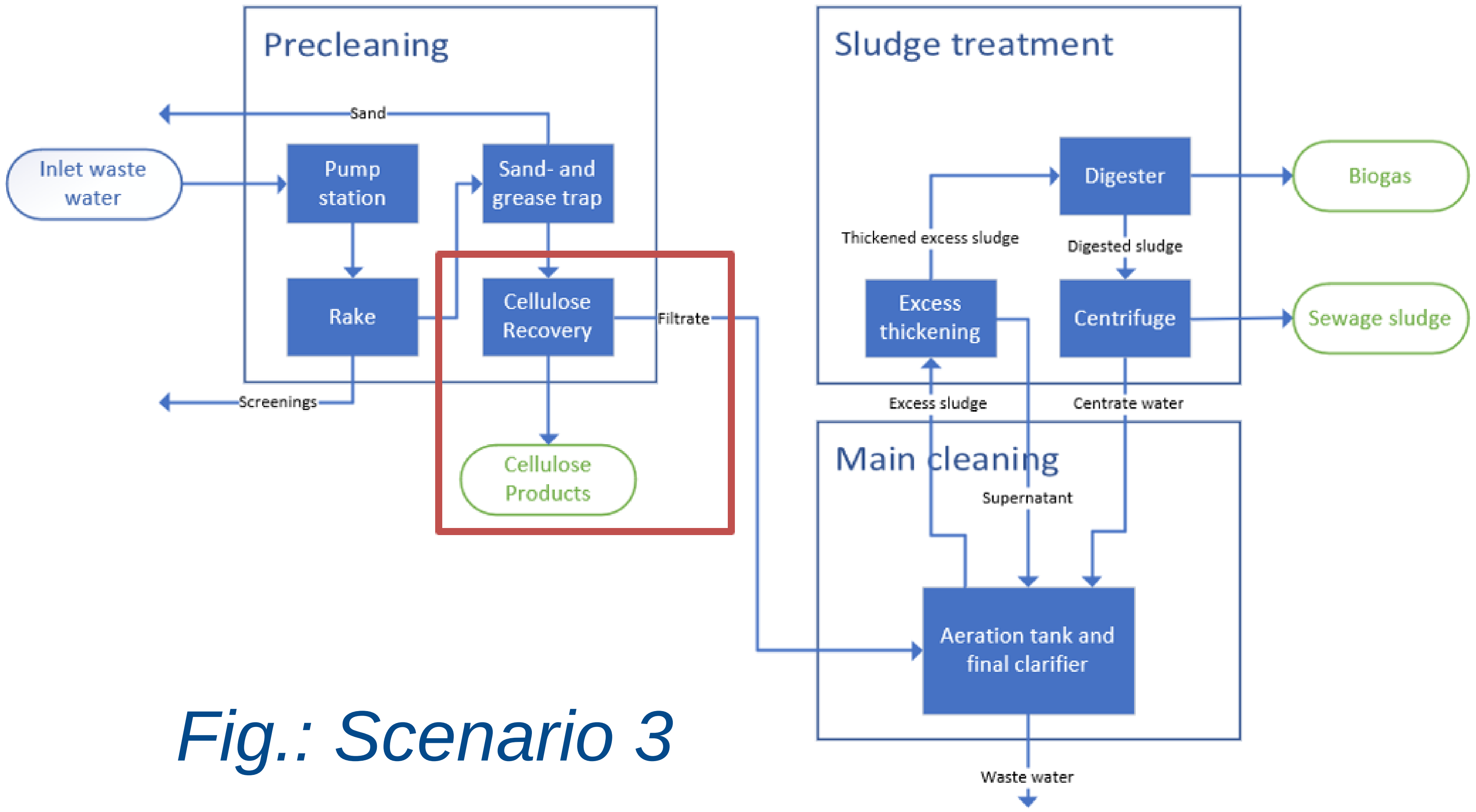
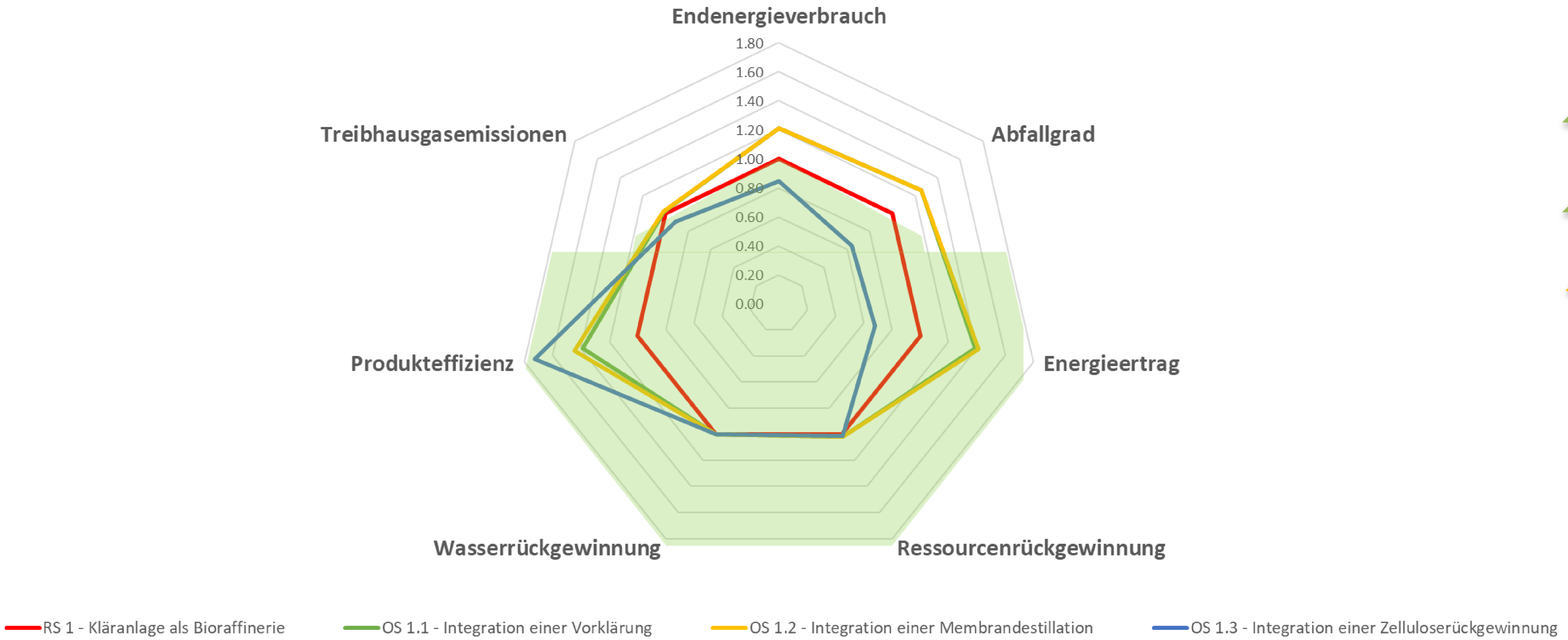


Fig.: Scenario 3

CS1: WWTP Results



Scenario 1&2:

- ↑ Biogas yield
- ↑ Product efficiency
- ↑ Energy demand (low grade)

Scenario 3:

- ↓ Energy demand
- ↓ Waste
- ↑ Product efficiency
- ↓ Biogas yield

Output = wet cellulose

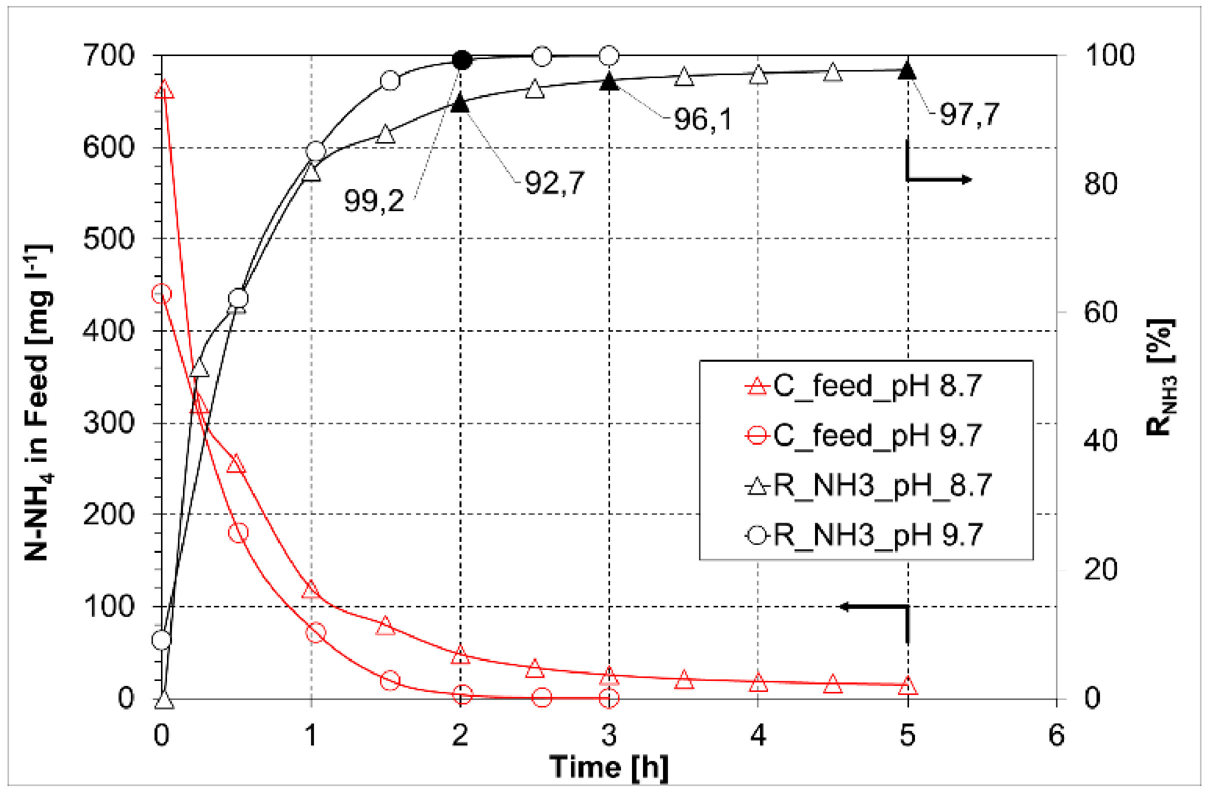
KPI	Reference [%]	Scenario 1 [%]	Scenario 2 [%]	Scenario 3 [%]
Energy consumption	100,00	121,39	149,53	84,80
Grade of waste	100,00	125,81	125,91	64,32
Resource recovery	100,00	102,59	102,01	101,22
Specific biogas yield	100,00	138,68	141,07	67,87
Water recovery	100,00	99,97	99,97	100,04
Product efficiency	100,00	138,68	144,88	227,50
GHG emission	100,00	101,76	114,13	90,95

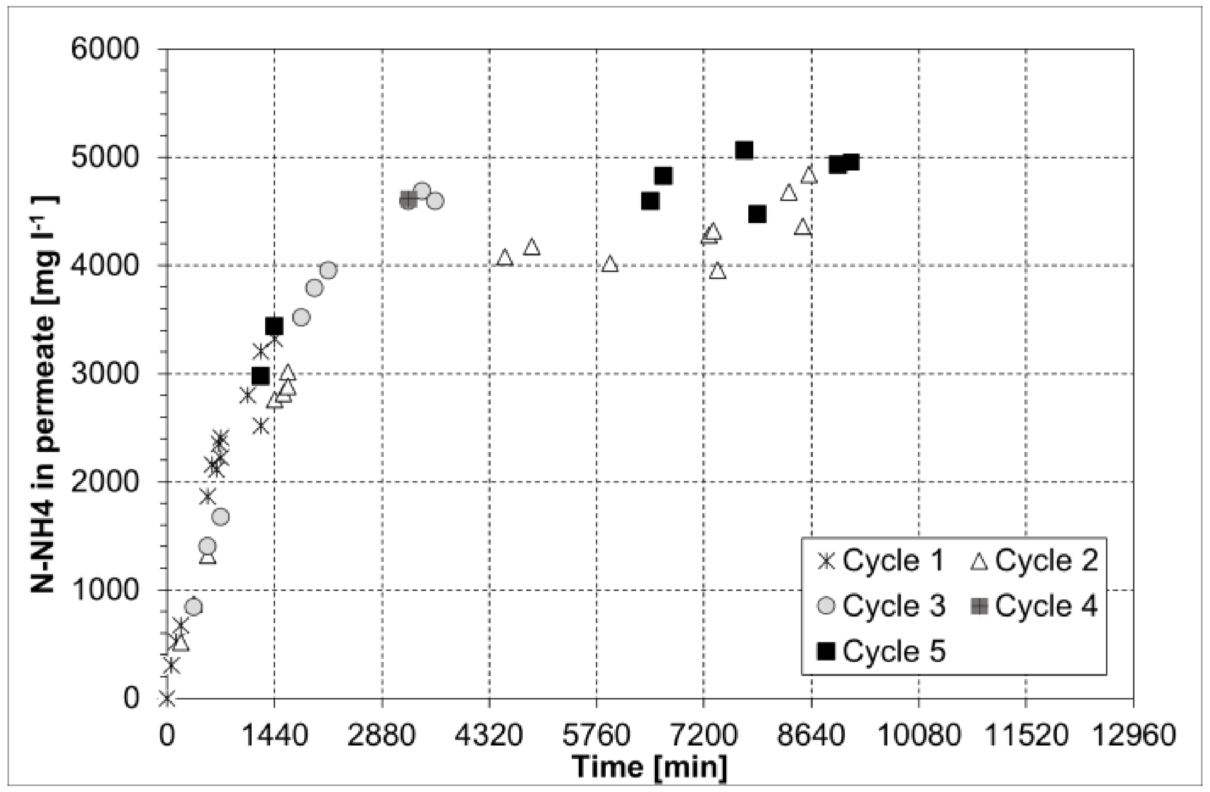
KPIs to trigger improvements

- Evaluation of combined energy- and resource recovery essential for biorefineries

- Key performance indicators give status quo / state of research → indicate further development options
  - E.g. energy demand increase with MD
  - → new research on ammonia removal < 38°C

- Next steps
  - integration of KPI dimensions in DSS tools like iBio-ref (NR Canada)
  - Socioeconomic evaluation (Johannes Lindorfer, JKU)





Guillen et al., 2022 under submission

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SUBTASK 2: Net-zero/Negative emission biorefineries - concepts for integrated biorefineries to reach net-zero/negative emissions – START 2022

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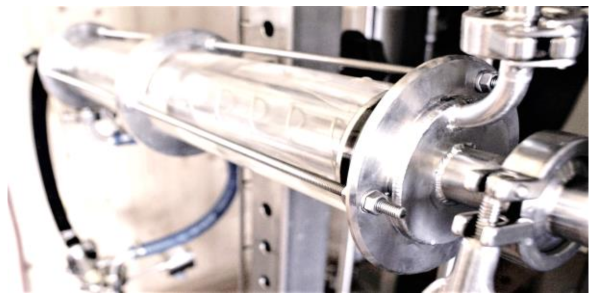

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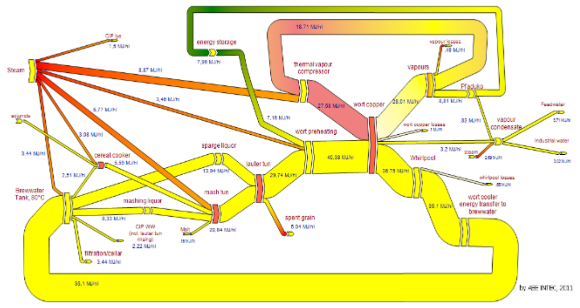
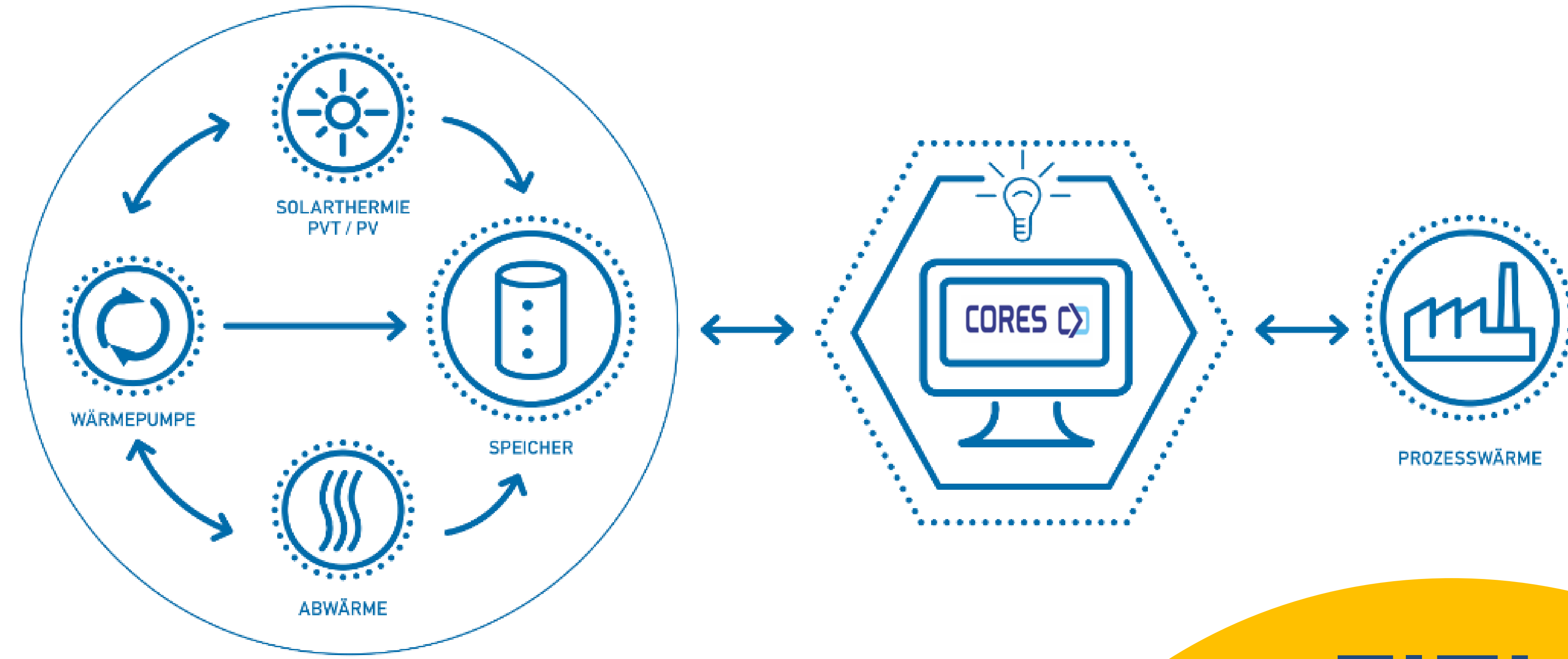


- Database on best practices on negative/net-zero concepts

CORES - Integration kombinierter, erneuerbarer Energiesysteme in die Industrie



ZIEL

Dekarbonisierung des industriellen Energiesystems durch optimierte Kombination erneuerbarer Technologien.

Ziel 1: Globale KPIs ♦ *technisch, ökonomisch und exergetisch*

Ziel 2: Systemsimulation ♦ *Kombionation ST/PVT/WP/PV/Speicher*

Ziel 3: Kontrollstrategien ♦ *optimierte Betriebsweise*

Bewertungskriterien (KPIs)

CORES

Technologie KPIs

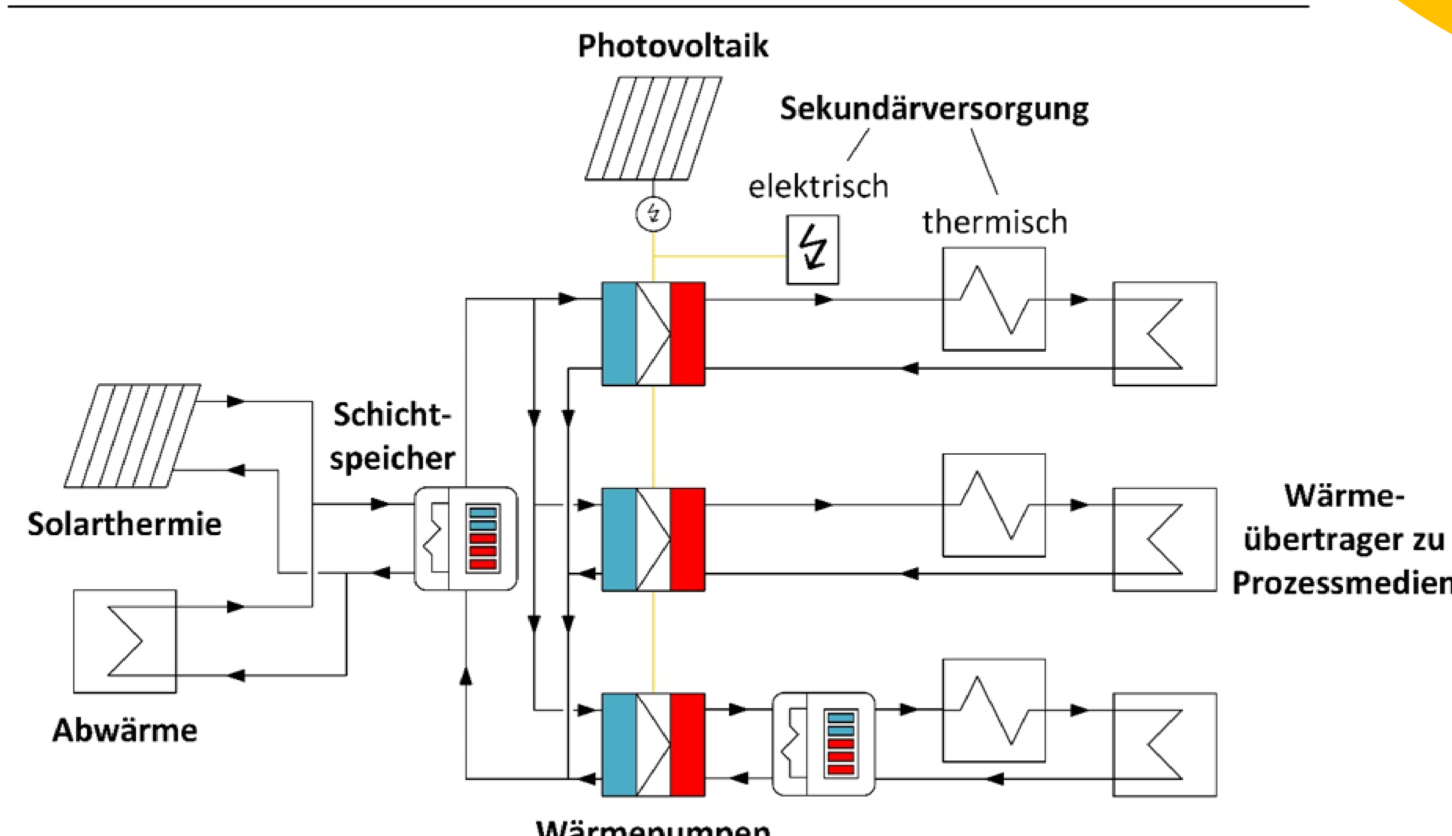
- Spez. Solarer Ertrag [kWh/m²]
- Solare Deckungsrate
- COP (Coefficient of Performance)
- Speicherzyklen und – effizienz
- Betriebsstunden

System KPIs

- Flächenbedarf
- Levelised Costs of Heat (LCOH)
- Payback time
- Ökonomische Bewertung
- CO_2 Emissionen
- Primär-/Endenergiebedarf
- Share of Renewables
- Flexibilität und Stabilität der Energieversorgung
- Grad der Autarkie

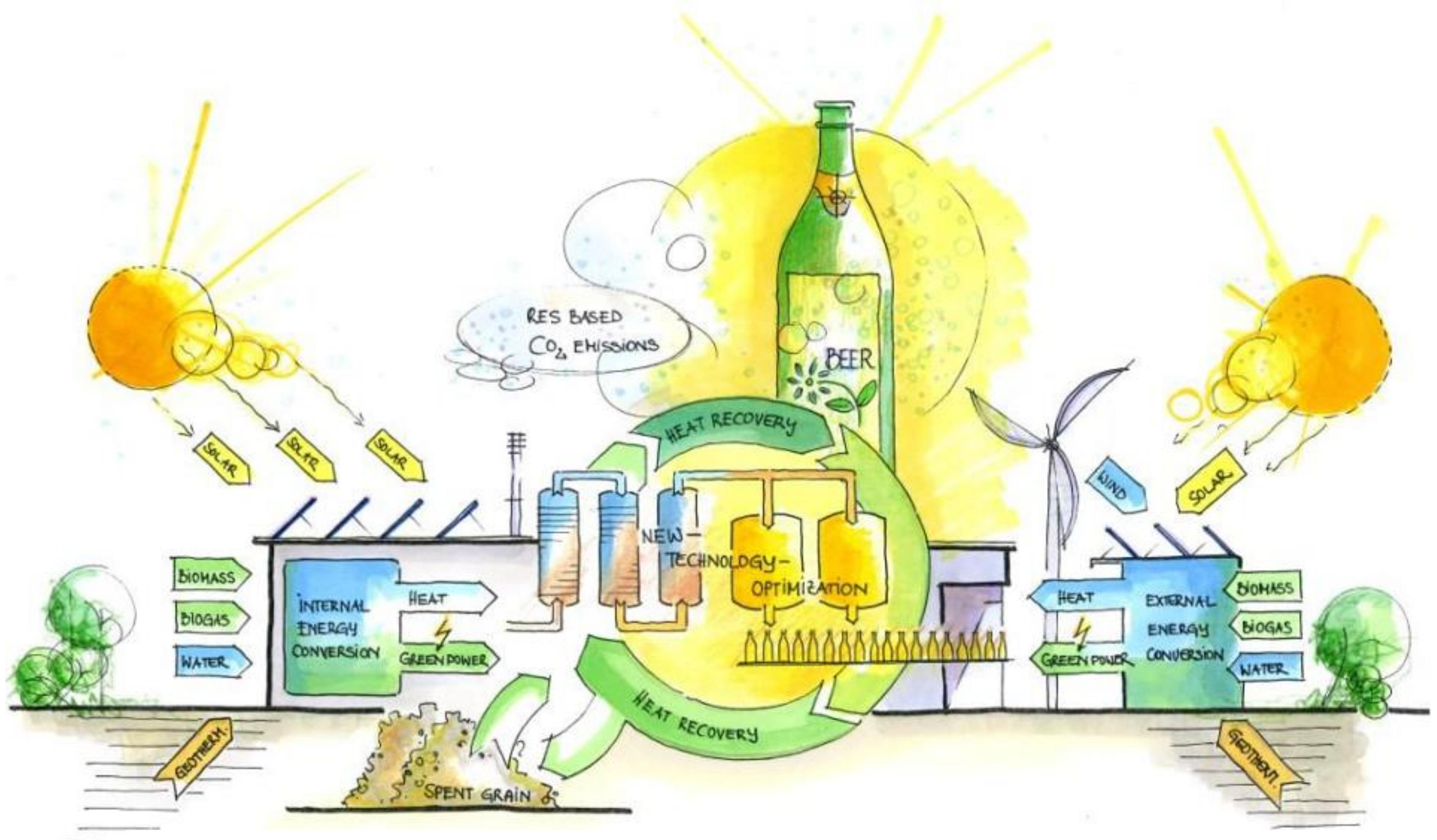
Beispielhaft Konfiguration Technologien

CORES



Example on research on negative emission concept

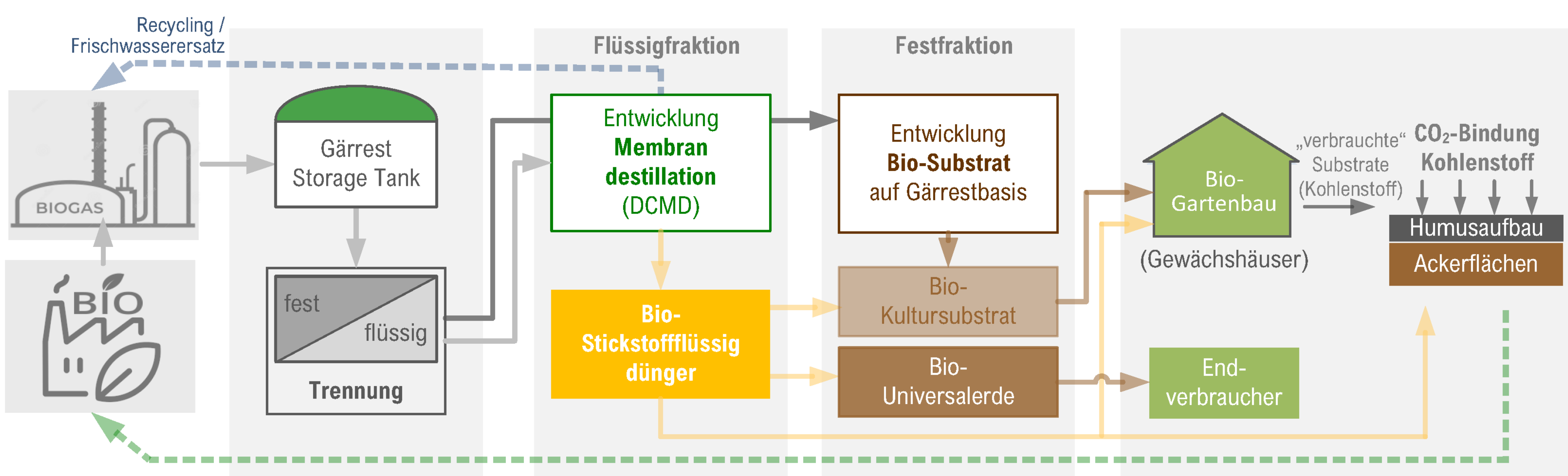
Climate-positive brewing



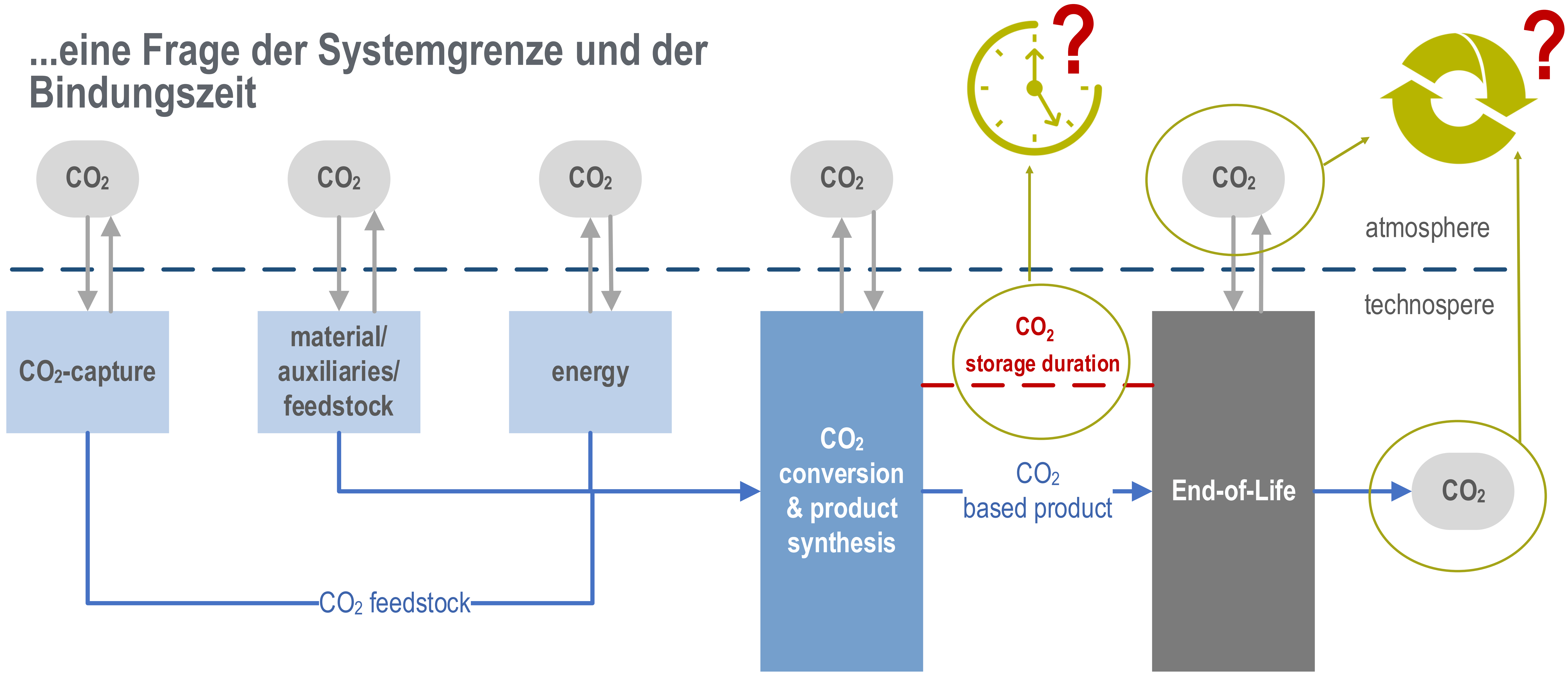
Abschätzung CO_2-Bindungspotential – Verwendung verbrauchtes Kultursubstrat zum Humusaufbau			
Jährlicher Gärrestanfall Brauerei Göss		20 000	to/a
Anteil Flüssigphase nach Separation	85%	17 000	to/a
Anteil Gärrest Festphase nach Separation	15%	3 000	to/a
Gärrest Festphase - verfügbar für Weiterverarbeitung		3 000	to/a
Anteil Gärrest im fertigen Kultursubstrat (Verhältnis Gärrest zu biogenen Zuschlagstoffen)[1]		1 : 5	
Erzeugungspotential Kultursubstrat auf Gärrestbasis		15 000	to/a
CO_2 gebunden im Dauerhumus je Tonne Ausgangssubstrat[2]		0,260	to_CO_2/to
Potential Jährliche CO_2-Bindung		3 895	to_CO_2/a

1) Bei Herstellung eines Kultursubstrates wird der Gärrest mit biogenen Zuschlagstoffen (z.B. Strohhäcksel, Bio-Fasern etc.) vermischt/gestreckt werden um einen optimalen Nährstoffgehalt bzw. Pflanzenverträglichkeit zu erzielen.

2) Quelle: Verband der Humus- und Erdenwirtschaft e.V



Kohlenstoffabscheidung und -verwertung



Quelle: Energieinstitut an der JKU basierend auf Zimmermann, A. et al. (2020)

- Der Energie- und Materialbedarf für die CO_2-Abtrennung muss berücksichtigt werden.
- Da CO_2 aus Punktquellen höchstwahrscheinlich ein "Nebenprodukt" ist, sind die Ergebnisse von der Allokation und der Expansion der Systemgrenze abhängig.

Workshop – Rückblick 20.9.2022

PROGRAMM

13:00 WELCOME (BioBASE / AEE INTEC)

Grußworte Theodor Zillner (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie)

13:15 Ressourcen & Energieeffizienz in Bioraffinerien

- IEA Task 11 – Industrial Biorefineries towards Sustainability – The Vision of Net-Zero Biorefineries (Bettina Muster-Slawitsch – AEE INTEC)
- Carbon Capture an Utilization: Assessment of novel Value Chains (Johannes Lindorfer – JKU/Energieinstitut)

13:45 Innovative Bioraffinerien – erfolgreiche StartUps

- Econutri: Sustainable Protein Production from Carbon Dioxide (Helmut Schwab)
- Ecolyte: Sustainable stationary Storage solutions inspired by Nature (Stefan Spirk)
- Lignovations: Natural functional Ingredients from Lignin (Martin Miltner)
- Agrobiogel: Saving Irrigation Water and protecting Crops from Droughts (Gibson Nyanhongo)
- Hycobility: Wood hybrid Materials for reduced CO_2 (Alexander Stadlmann)

14:25 PAUSE

15:00 Technologieentwicklung für Bioraffinerien & biobasierte Produkte

- Energy & Resource Efficiency of Protein Recovery from Food Residuals (AEE INTEC – Judith Buchmaier)
- Agricultural residues as Feedstocks for high value-oriented energy self-sufficient Biorefineries (TU Vienna ICEBE – Sebastian Serno Loaiza)
- Effective Isolation of Valuables from Process streams from the biobased Industry (TU Graz CEET – Marlene Kienberger)
- Biobased Barrier Coating Applications – Challenges and Opportunities (TU Graz BPTI – Daniel Mandlez)
- CO_2 to Products – Innovative CO_2 Refinery Concepts (TU Wien ICEBE – Michael Harasek)

16:15 RESÜMEE

16:30 MATCHMAKING

Conclusions

- New biorefinery pathways and products are highly important
- Material use of biomass can lead to requirement of energy supply: energy efficiency tools and renewable energy
- Holistic KPIs taking into account dimensions of energy, resource, waste, water, emissions, product….can trigger further (economic) optimization and circular economy
- Net-zero emission concepts in biorefineries will be elaborated and collected in the future – stay in touch with **IEA IETS Task 11**

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Thank you
for your Attention