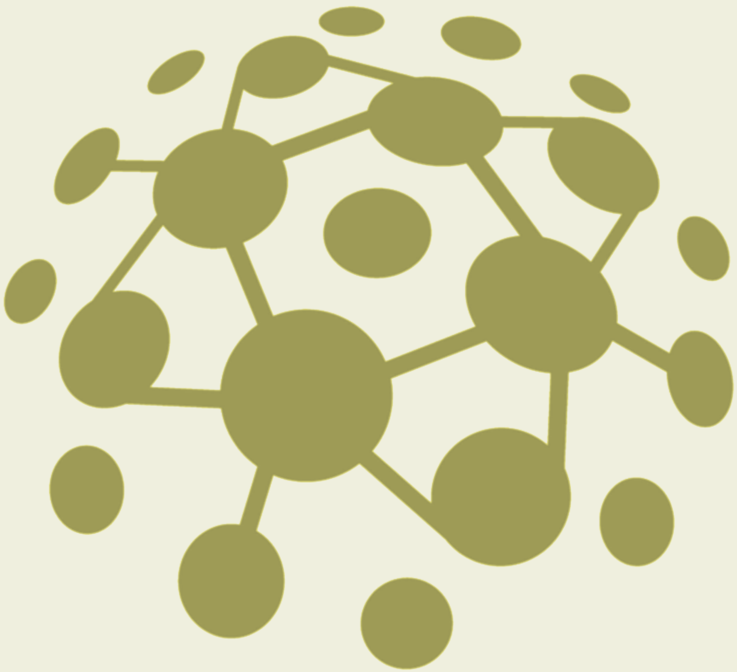

Greenhouse Gas Assessment and socio-technical analysis of advanced biofuels production

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Johannes Lindorfer

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Agenda

- The role of process assessment
- Current biofuel legislation in Europe
- Biofuel market in Europe
- Greenhouse gas performance of advanced biofuels
- Socio-technical performance of advanced biofuels
- Conclusion & Outlook

Process assessment in projects

What is it good for?

- **Support process development already at early design stages.**
  - Life Cycle Assessment for estimating the environmental performance
  - Techno-economic analysis for estimating the economic feasibility
  - Socio-technic analysis for estimating the overall sustainability performance
- **Early identification of strenghts and weaknesses – developing measures.**
  - e.g. bottlenecks, compliance issues, develop a basis for decision making
- **Support the development of sustainable processes for a future economy dominated by renewables.**

The „non-technical“ part of process development!

Process assessment in EU-H2020 funded projects

acronym	lead	duration	programme	logo
CHIBIO	Fraunhofer-Gesellschaft	2011 - 2014	FP7	ChiBio
CO2EXIDE	Fraunhofer-Gesellschaft	2018 - 2021	Horizon 2020	CO_2EXIDE
OPTISOCHEM	GLOBAL BIOENERGIES	2017 - 2021	Horizon 2020	Optisochem
LIGNOFLAG	Clariant Produkte (Deutschland) GmbH	2016 - 2021	Horizon 2020	lignoflag BBI JU
SUNLIQUID	Clariant Produkte (Deutschland) GmbH	2014 - 2020	FP7	sunliquid FP7
STORE&GO	DVGW Deutscher Verein des Gas- und Wasserfaches	2016 - 2019	Horizon 2020	STORE&GO
REWOFUEL	GLOBAL BIOENERGIES	2018 -2021	Horizon 2020	REWOFUEL
BAMBOO	CIRCE	2018 - 202	Horizon 2020	BAMBOO
GRASSFINERY	Biofabrik Technologies GmbH	2015 - 2018	Eco-innovation	GRASSfinery

EU legislative framework

Renewable Energy Directive II

- The EU-Parliament voted in January 2018 on the revision of the RED 2009/28/EC to basically endorse the so called EU RED II (Directive (EU) 2018/2001).
- RED (2009/28/EC) expires by the end of 2020.
- The new directive named **RED II** is going to **enter into effect on 1st January 2021.**
- **The RED defines**
  - mandatory blending targets for biofuels in the EU
  - sustainability criteria for the blending of biofuels
  - minimum greenhouse gas savings default values for renewable fuel compared to fossil fuels
- The standards defined in the RED are crucial for the biofuel market in the EU.

EU legislative framework

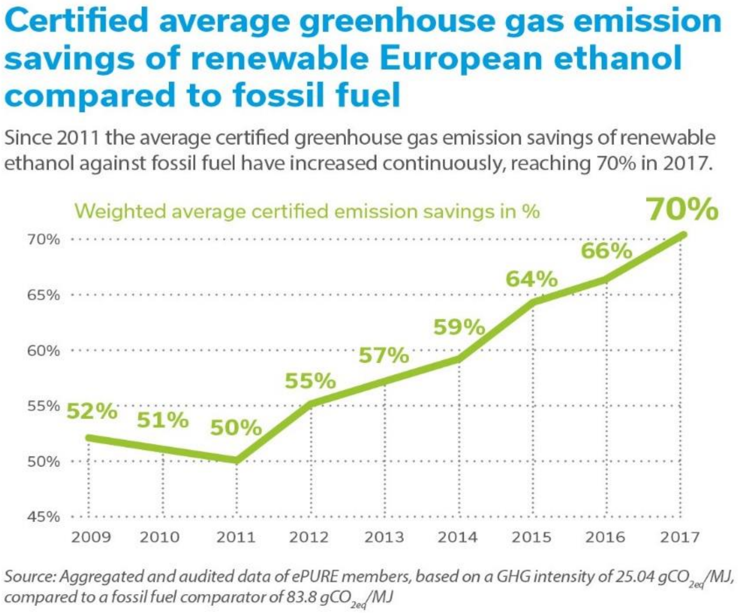
Renewable Energy Directive II

- Member states must ensure that **14 % of energy consumed in transport originates from renewable sources** until 2030.
  - advanced biofuel count double to this target
- 7 % max. share of biofuels from food and feed crops (first-generation biofuels)
- Each Member State has to introduce targets for the **minimum share of advanced biofuels.**
- The contribution of advanced biofuels as a share of final consumption of energy in the transport sector shall be
  - at least 0,2 % in 2022,
  - at least 1 % in 2025 and
  - at least 3,5 % in 2030.

EU legislative framework

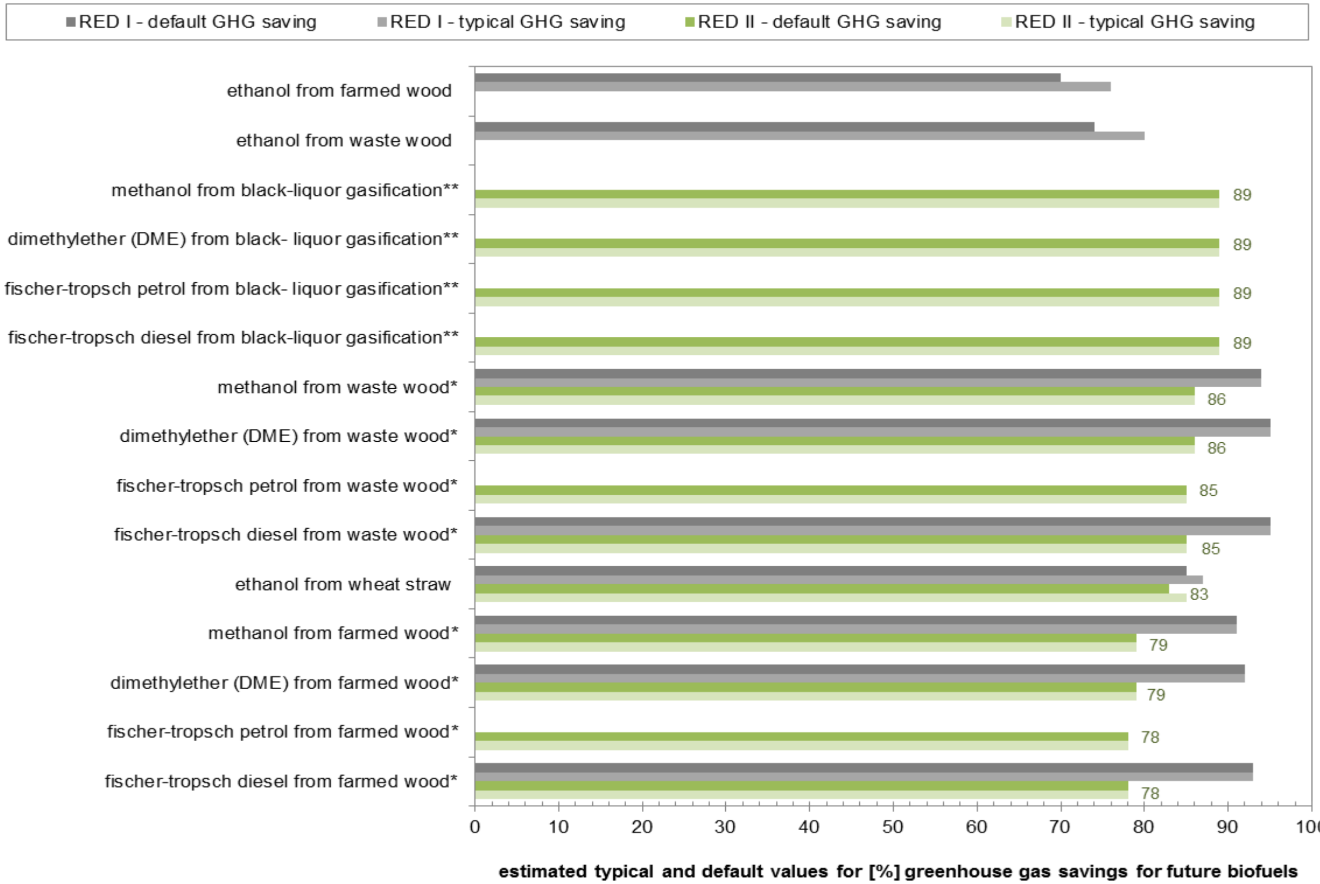
Renewable Energy Directive II

- The use of a biofuel have to prove GHG emission savings of at least 65 % compared to the fossil fuel if it is produced in a plant which starts operation after 1st January 2021.
  - Biofuels need to be certified considering their GHG saving in order to contribute to the EU´s blending targets.
  - Already today the average GHG emission saving of European ethanol exceeds the 65 % saving target.
  - According to RED II sugar cane ethanol show a default saving value of 70 %.



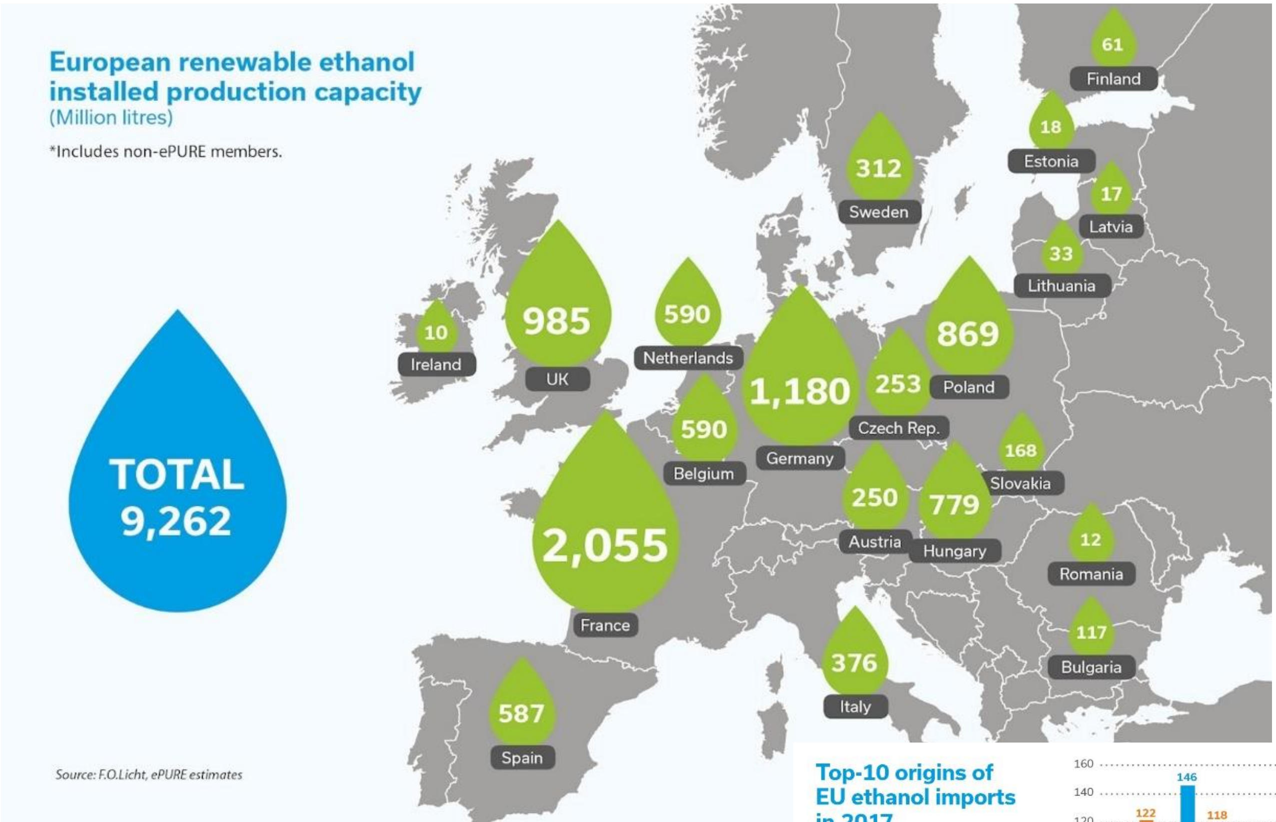
EU legislative framework

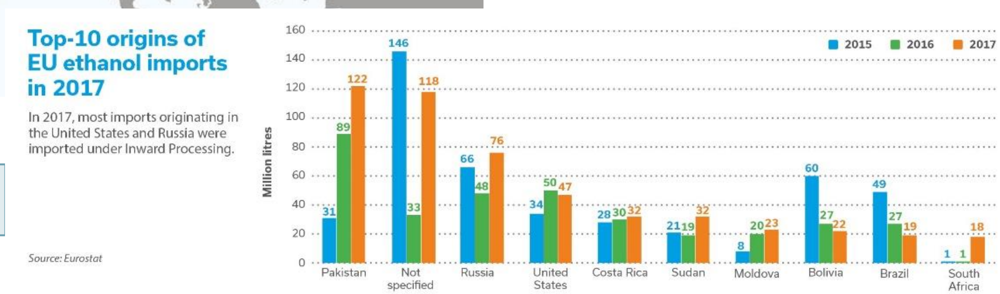
Renewable Energy Directive default saving values [%] of biofuels pathways compared to fossil fuels



Source: Energieinstitut an der Johannes Kepler Universität

European bioethanol market



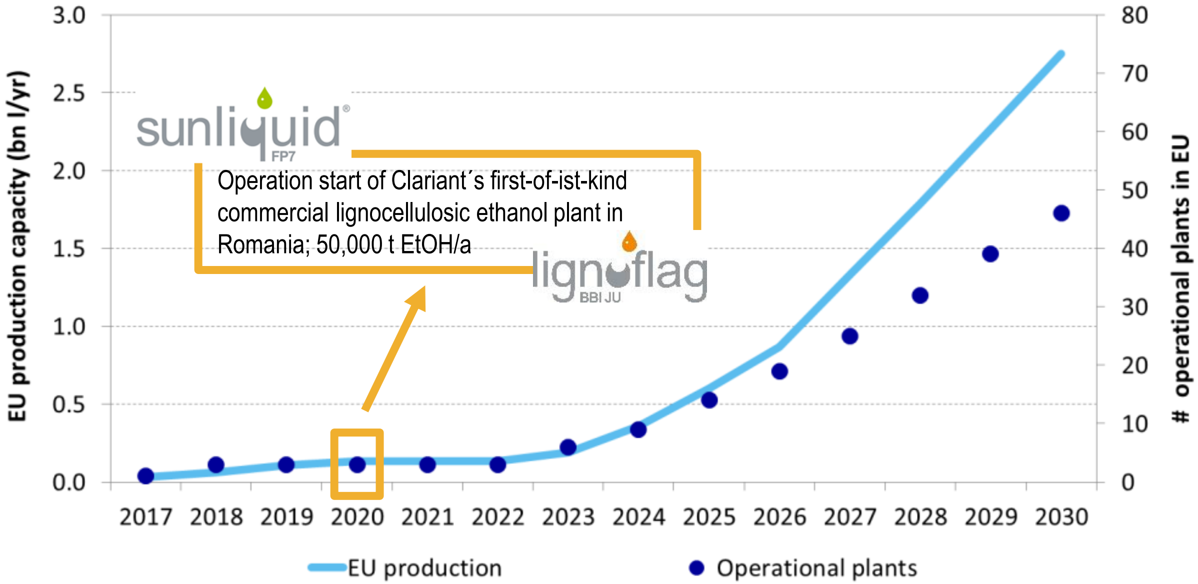


→ **Bioethanol consumption:** 5,250 million liters

European bioethanol market

2^{nd} generation bioethanol

Figure: Production capacity of cellulosic ethanol in the EU and number of plants



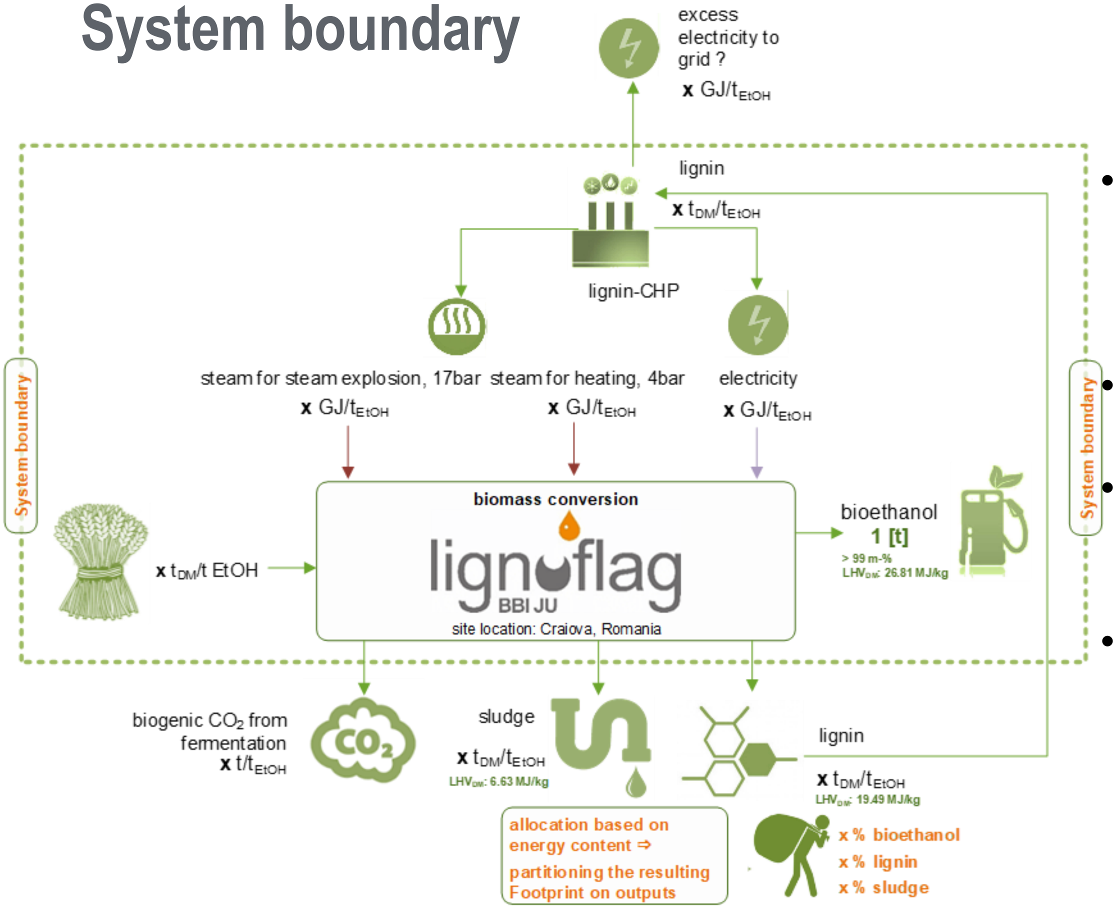
Source: Chudziak, C. et al (2017)

→ A boost in production capacity is expected by the year 2025 onwards

Source: Aggregated and audited data of ePURE members

Greenhouse gas assessment

System boundary



https://www.lignoflag-project.eu/

- First-of-its kind **flaship plant** planned in Romania – construction started in September 2018.
- Feedstock is **cereal straw**.
- Planned production capacity up to 60,000 tons of ethanol per year.
- Based on **sunliquid® technology** – lignocellulosic biomass to ethanol process developed by Clariant Produkte Deutschland GmbH.

Source: Energieinstitut an der Johannes Kepler Universität Linz

Greenhouse gas assessment

2nd generation bioethanol

- Greenhouse gas assessment according to RED II.
- RED II reduces the calculation of life cycle greenhouse gas emissions to a single formula:

$$E = eec + el + ep + \mathrm{e_{td}} + \mathrm{eu} - \mathrm{eccs} - \mathrm{eccr} - \mathrm{eee}$$

E=total emissions from the use of biofuel
e_{ec}= emissions from the extraction or cultivation of raw material (biomass in the framework of this scheme)

e_l=annualized emissions from carbon stock changes caused by land-use change

e_p=emissions from processing

e_{td}=emissions from transport and distribution
e_u=emissions from the fuel in use

e_{sca}=emission saving from soil carbon accumulation via improved agricultural management

e_{ccs}=emission saving from carbon capture and geological storage

e_{ccr}=emission saving from carbon capture and replacement

e_{ee}=emission saving from excess electricity from cogeneration

Greenhouse gas assessment

2nd generation bioethanol scenarios

Table 1: 2nd generation bioethanol production scenarios for greenhouse gas assessment

scenario	feedstock	allocation agricultural production	production location	enzyme production	process energy electricity	process energy thermal	sludge (slurries; distillers wash)	lignin utilisation
1	wheat straw	0 % → residue	Europe	on-site	natural gas-CHP	natural gas-CHP	fertilizer	off-site
2	wheat straw	0 % → residue	Europe	on-site	lignin-CHP	lignin-CHP	fertilizer	on-site
3	wheat straw	0 % ð residue	Europe	on-site	EU27-mix	lignin combustion	fertilizer	on-site

Source: Energieinstitut an der JKU

→ Scenario 1 additionally assumes a carbon capture and replacement of CO2 from fermentation for the use in the food and beverage industry.

Data sources for greenhouse gas assessment are:

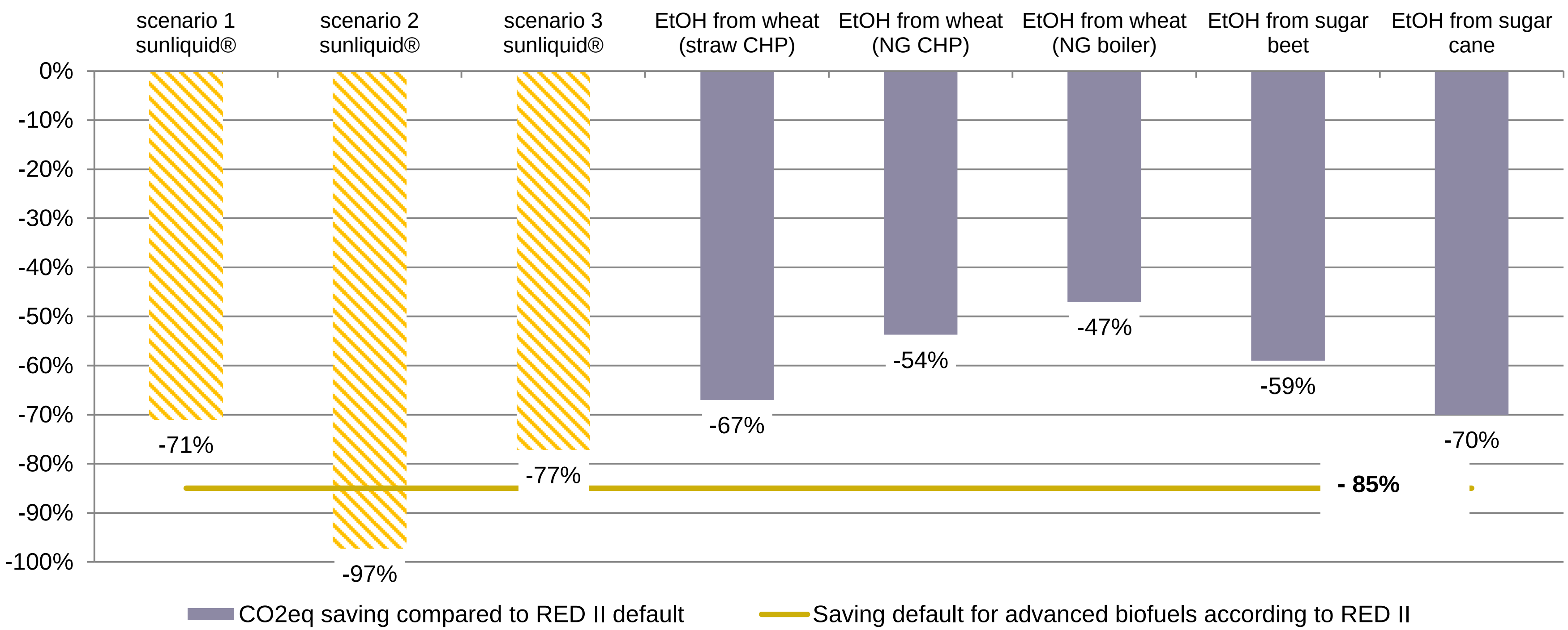
- Confidential (basic) engineering data from sunliquid® process developed by Clariant.
- RED II default values concerning the specific GHG emissions of for cultivation and transportation.
- BIOGRACE data for emission factors of energy carriers.

Greenhouse gas savings

2nd generation bioethanol

Gasoline default: 94 g CO_2eq/MJ

Figure 2: Greenhouse gas savings of bioethanol production pathways compared to gasoline default value



Source: Energieinstitut an der Johannes Kepler Universität

Greenhouse gas savings

2nd generation bioethanol

- Cereal straw based lignocellulosic ethanol achieves up to **97 % greenhouse gas savings** compared to fossil gasoline.

- **Pre-condition for achieving maximum greenhouse gas emission savings:**
  - ✓ use **100 % renewable** energy carriers for **process energy generation**
  - ✓ This implication found in the first round of GHG emission estimation according to RED is taken up in **first-of-its-kind plant design in Romania**
  - ✓ process energy generation with by-product **lignin CHP**, natural gas only as a back-up

Greenhouse gas assessment at an early plant design stage identifies the most „climate friendly“ production route and guarantees long term compliance with policy & best performance!

Socio-technical assessment

SAMBA Methodology

- The socio-technical assessment tool **SAMBA** (*Socio- and Multicriteria Model for reducing Barriers Analysis)* is an in-house instrument developed at the Energy Institute combining stakeholder analysis and STEEP* analysis in a comprehensive assessment
- **SAMBA** is able to assess the **sociological, technological, environmental, economical and political dimensions** of products, technologies, processes or projects.
- It provides **qualitative empirical based analysis** in order to find out more about the impacts of **the LIGNOFLAG value chain**.
- The SAMBA methodology consist of four modules.

*Sociological, Technological, Environmental, Economical and Political → **STEEP**

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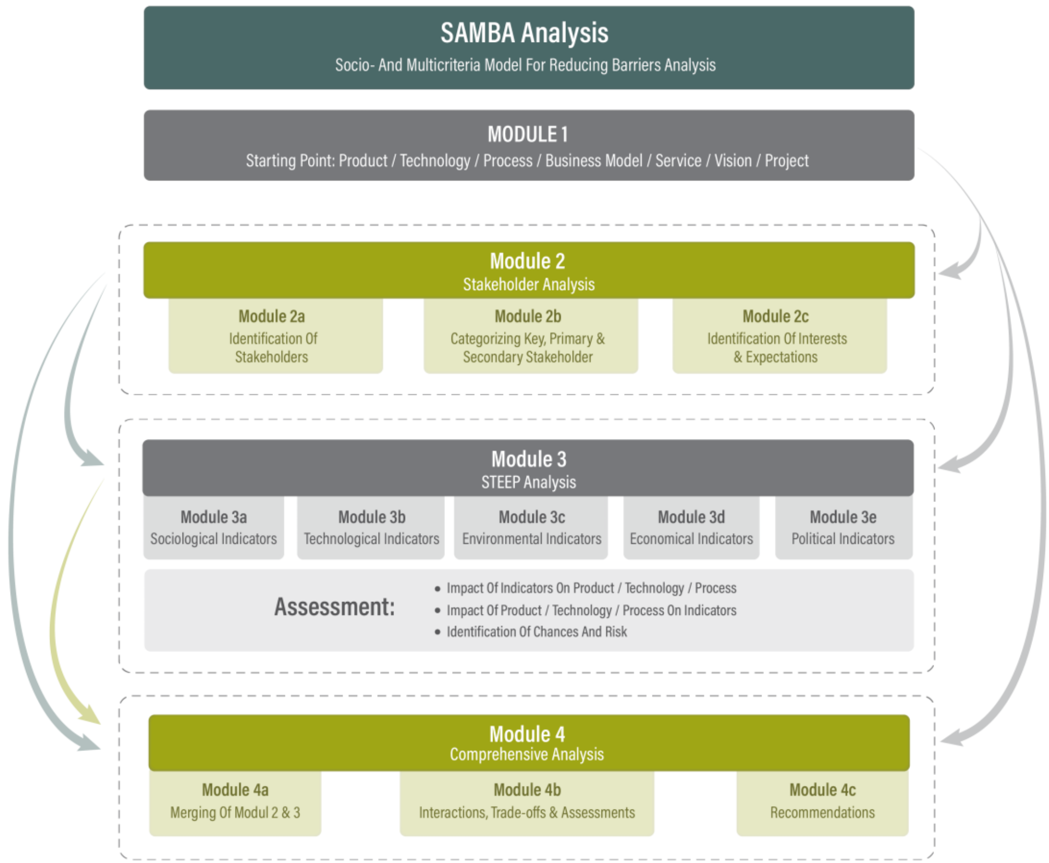
Socio-technical assessment

SAMBA Methodology & Procedure



Source: Energieinstitut an der Johannes Kepler Universität

Stakeholder Analysis - structure

Stakeholder cluster

administration, politics, associations, economy, press & media, civil society

Stakeholder ID

Ad….for administration
Po…for politics
As…for associations
Ec…for economy
Pr…for press/media
Cs…for civil society

Stakeholder

e.g. EU-government, national governments, industry & trade associations, agriculture, manufacturers, social media, society, etc...

Specific Stakeholder

e.g. EU-Commission, Romanian government, ePure, fuel trading companies, equipment manufacturers, Researchgate, neighbours, etc...

Role within the project

e.g. research granting, giving permissions, trading the product, supplying feedstock, working at plant, affected by traffic, etc...

Expectations/interest

e.g. achieve environmental goals, additional income, local work places, not being affected by plant, etc...

Estimated risk potential

25...for supporters
50...for neutrals
75... for criticals
100...for opponents

Type of stakeholder

supporters, neutrals, Criticals, opponents

estimated influence on process/technology/ product

1...very low
2...low
3...medium
4...high
5...very high

estimated importance for process/technology/ product

1...very low
2...low
3...medium
4...high
5...very high

discrepancies/conflicts of interest

qualitative description

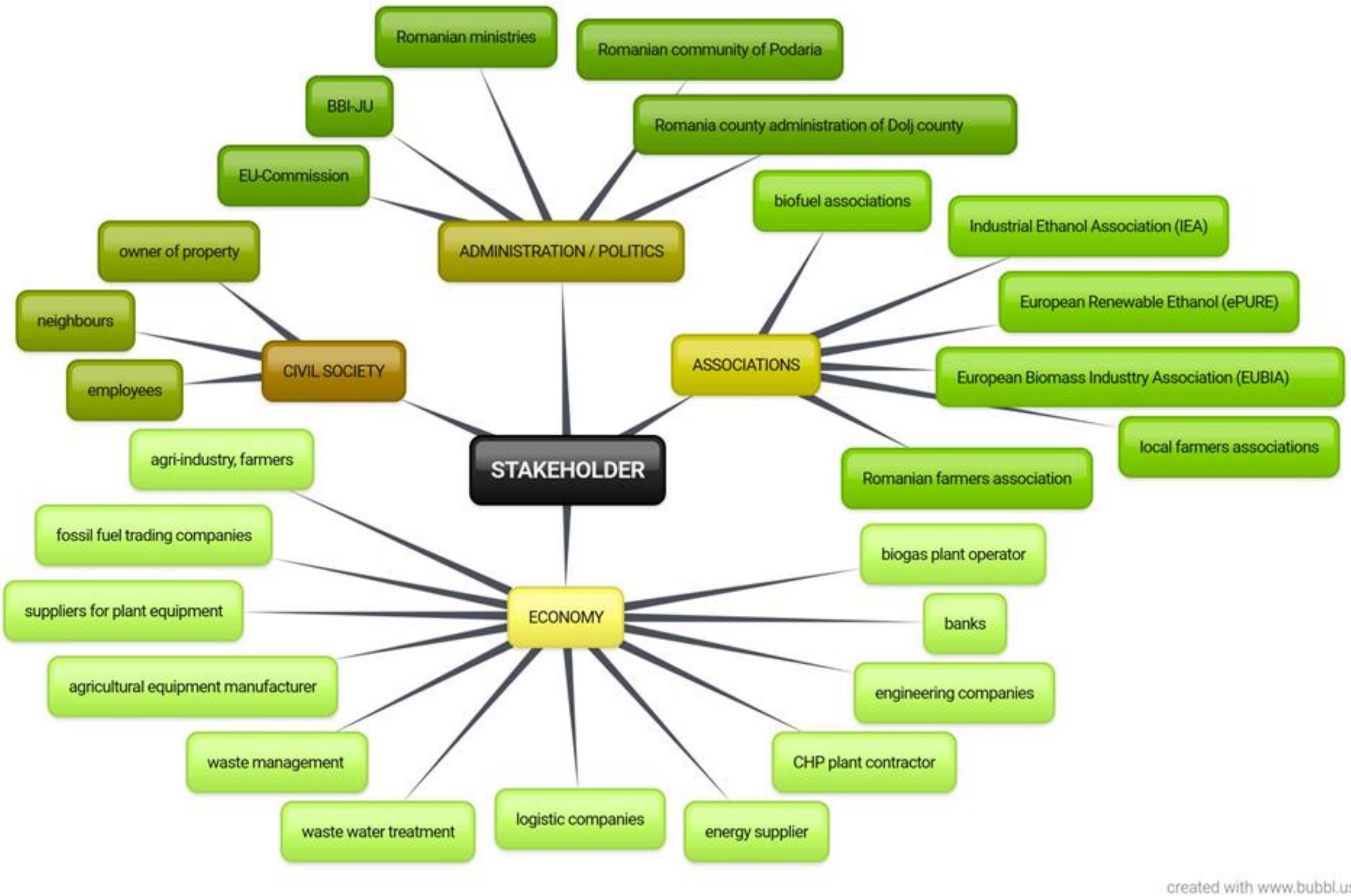
↓

Stakeholder Assessment

Source: Energieinstitut an der Johannes Kepler Universität

Stakeholder Analysis

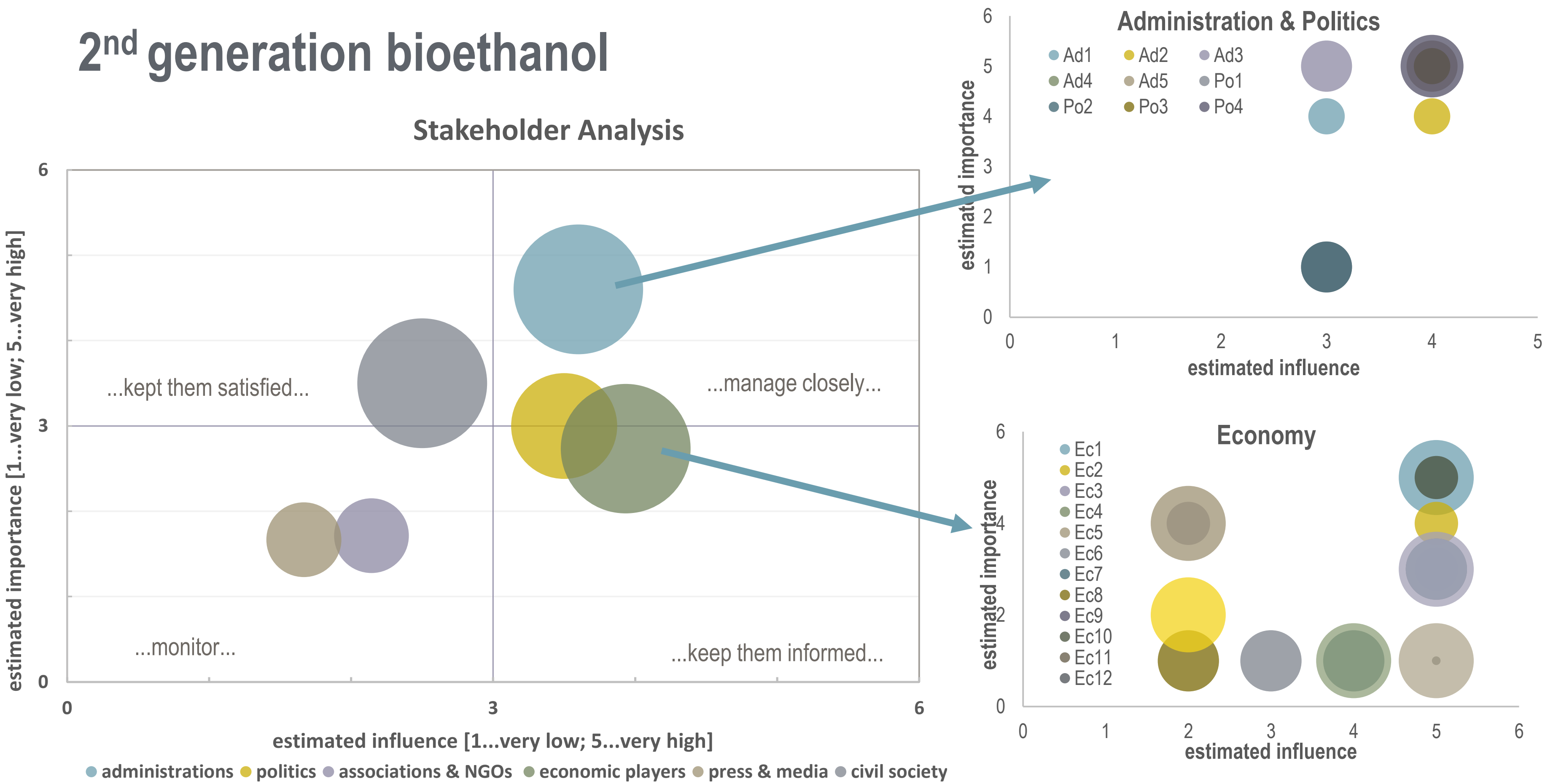
Key and primary Stakeholders



Source: Energieinstitut an der Johannes Kepler Universität

Stakeholder Assessment

2nd generation bioethanol



STEEP Analysis

Methodology

- STEEP covers the following dimensions:
  - Sociological
  - Technological
  - Environmental
  - Economical
  - Political

Each dimension encompasses a set of qualitative indicators for evaluation.

- The basis for evaluating the indicators is literature research, internal expert knowledge, expert judgement, questionnaires, workshops etc… – individual research design according to the project´s needs.
- It is an iterative, multi-stage process to finally come to a conclusion & derive recommendations.

STEEP Analysis

2nd generation bioethanol

- STEEP analysis is work in progress for the first-of-its kind lignocellulosic ethanol plant in RO.
- **Preliminary results** are based on literature research and internal expert knowledge from project team.
- **Surveyexperts is currently running:**
- The aim is to get a deeper knowledge of value chain design for STEEP indicator evaluation.
- The preliminary results are based on an overview of potential value chains.
- **Evaluation has to be refined throughout the value chain establishment period.**

STEEP Analysis

2nd generation bioethanol

System boundary:

I. RO- **focus on the regional effects** of the LIGNOFLAG value chain in Romania and the region (Sud-Vest Oltenia) where it is located.

II. EU – **focus on makro-level** for influencing factors concerning market & policy development which influences advanced bioethanol technology roll-out and market uptake.

III. The technical system boundary is similar to the LCA system boundary and encompasses the whole value chain from raw material sourcing to the market-ready product.

Benchmark – basis for comparison for indicator evaluation:

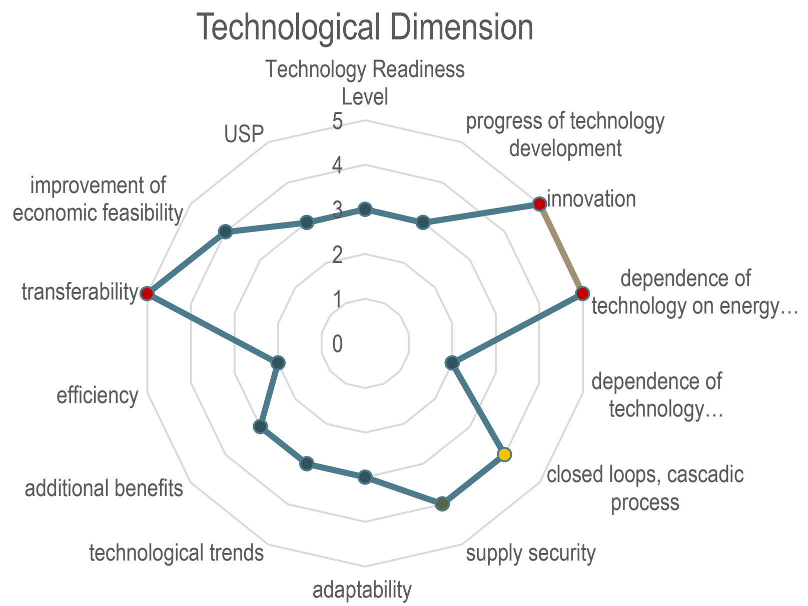
I. Social, political and economic dimension: situation without the LIGNOFLAG flagship plant (bussiness-as-usual)

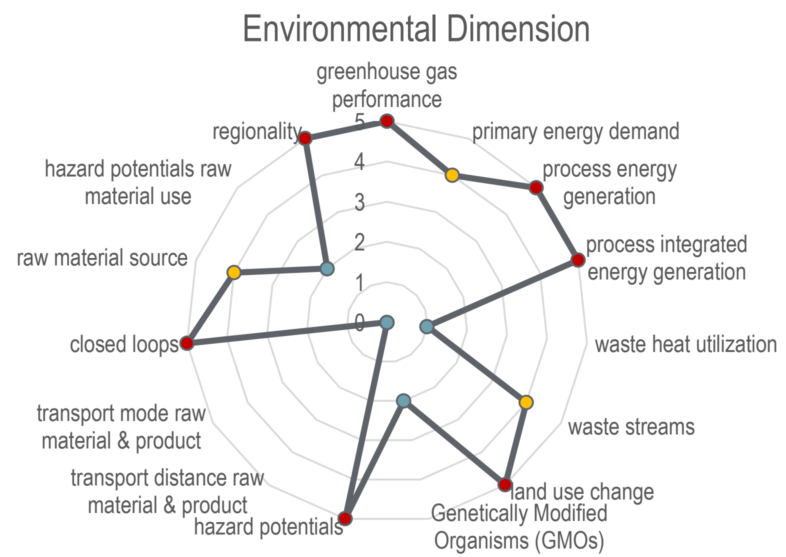
II. Environmental & technological dimension: 1st generation bioethanol production

STEEP Analysis – preliminary results

2nd generation bioethanol

Figure: Technological and environmental indicator evaluation





Source: Energieinstitut an der JKU

<u>Improvement compared to benchmark:</u> 0…none; 1…poor; 2…fair; 3…moderate; 4…good; 5…very good

STEEP Analysis – preliminary results

2nd generation bioethanol

Technological and Environmental Dimension

The most influencing aspects for evaluation:

- Greenhouse gas savings.
- Use of the non-food agricultural residue as feedstock which is currently burnt on the fields in RO.
  - Ensure sustainable straw removal and respecting regional competing uses
- No land-use change effects.
- Raw material flexibility of technology – e.g. bagasse, rice straw
- Integrated renewable based process energy generation (lignin CHP)
- Closed loops & by-product utilization– lignin CHP, sludge as fertilizer or biogas substrate.
- Hazard potentials (GMOs, EtOH leakage) are managed according to the state-of-the-art – the risks are at a minimum.

STEEP Analysis – preliminary results

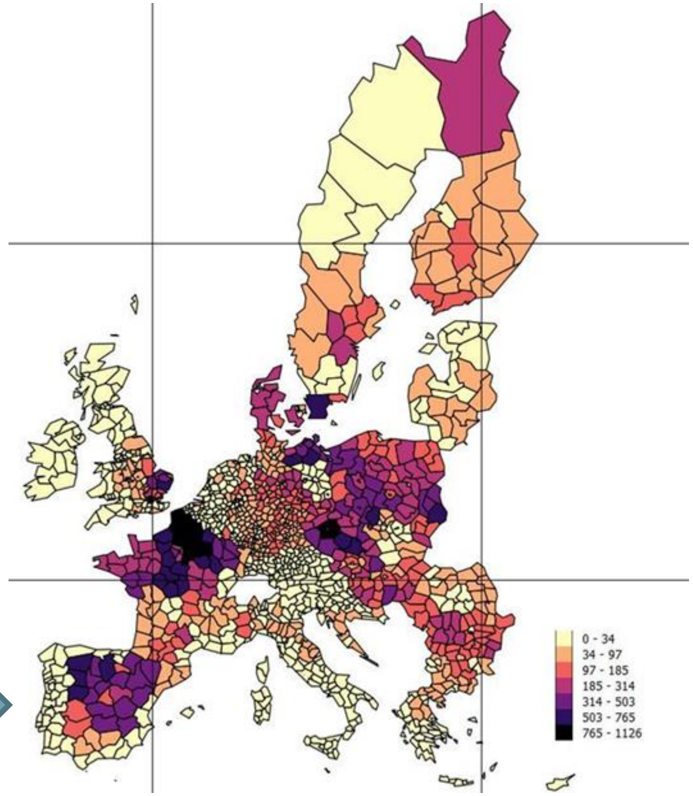
2nd generation bioethanol

Technological and Environmental Dimension

- Feedstock availability is crucial for a sustainable plant design.
- Keep transport distances as low as possible.
- Straw availability is an aspect for economic feasibility.
- Feedstock availability dependent on:
  - Agricultural structure
  - Share of animal husbandry
  - Soil & climatic conditions
  - Other competing uses

A regionally suitable plant desing is the first step to a sustainable advanced biofuel production.

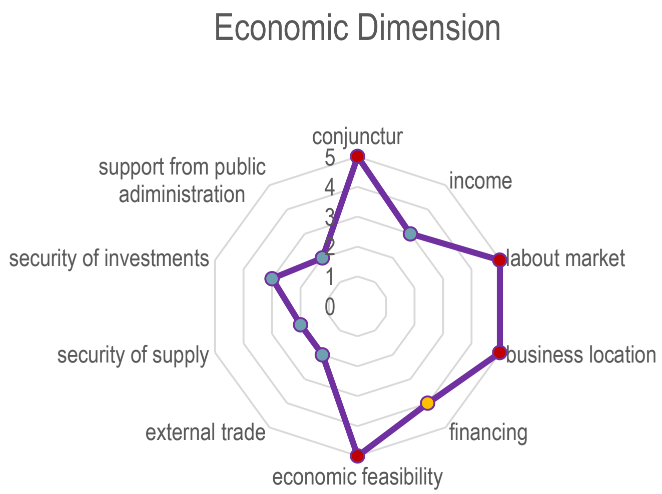
Availability of cereal straw in Europe [t/km²]



STEEP Analysis – preliminary results

2nd generation bioethanol

Figure: Economic indicator evaluation



Source: Energieinstitut an der JKU

Improvement compared to benchmark: 0…none; 1…poor; 2…fair; 3…moderate; 4…good; 5…very good

The most influencing aspects for evaluation:

- 100 million € investment for constructing the plant supported by EU funding programmes FP 7 and H2020 through the Bio-Based Industry Consortium Joint Undertaking (BBI)
- Construction phase will create approx. 800 jobs
- approx. 120 permanent jobs at the plant
- approx. 300 permanent jobs for side industries serving the plant
- Built in an economically weak region in RO.
- Revitalization of „old“ industry ground.

Conclusion

- Advanced bioethanol production shows maximised environmental advantages compared to fossil fuels or 1st generation biofuels under certain preconditions:
  - approx. 100 % renewable process energy generation.
  - Closed loops – by-product utilization.
  - Sustainable feedstock use – concern soil fertility.
- Advanced bioethanol production can boost a region´s economy under certain preconditions:
  - Regionally purchased feedstock.
  - Acquire local workforce
  - Engage local side industries.
- Involve local stakeholders (e.g.: farmers, local authorities, associations, etc…) at an early point of time.
- Engage locals in order to get to know the local business culture and official channels.

Outlook

- Conduct **full Life Cycle Assessment (LCA)** for lignocellulosic ethanol production in first-of-its-kind plant:
  - Based on „real-world" measured plant data.
  - Based on „real-world" transport modes and distances.
  - Account for detailed by-product utilization.

- Work-out **detailed socio-technical analysis** for the first-of-ist-kind plant:
  - Specify the impacts in the STEEP dimensions based on online-survey results
  - Discuss & verify indicator evaluation in a broader group of experts and scientific community.

This project receives funding from the Bio-based Industries Joint Undertaking under the European Union´s Horizon 2020 Research & Innovation Programme under Grant Agreement No. 709606

Life Cycle Assessment and socio-technical analysis of advanced biofuels production

Energieinstitut
at the Johannes Kepler University Linz