GA no 282826

Production of Solid Sustainable Energy Carriers from Biomass by Means of Torrefaction

Deliverable No. D10.3

Proceedings of the Workshops

Annex 3

Bioenergy in the European Context

BioBoost and SECTOR Policy Workshop

Brussels 16-17 June 2015

Paul Verhoef
European Commission
Directorate-General for Research and Innovation
Renewable Energy Sources

European Commission

Outline

- Bioenergy potential and facts
- EU Energy Policy
- Energy Union
- EU R&I Policy
- Challenges and opportunities for Bioenergy

New realities in the global Energy market

Competitiveness
➔ Energy cost

Impact of the financial crisis

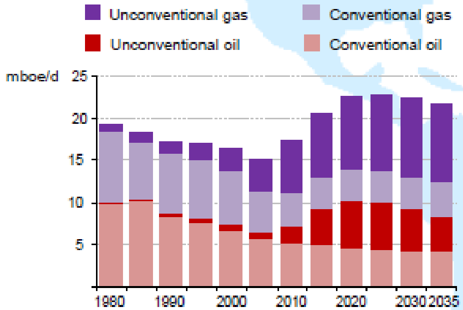
Fall in private investment, tight financing conditions

Fukushima

Some countries phase out nuclear power production

Shale gas

US oil and gas production



Source: IEA

Rising demand
➡ rising prices

By 2030, world economy set to double and energy demand to rise by 1/3

Bio-energy - an integral part of the low carbon economy...

"We need [..] a resilient energy union with a forward-looking climate change policy"

".. mobilise EUR 300 billion in public and above all private investments over the next three years [..] through the targeted use of the existing structural funds and of the EIB instruments .."

".. we need coordinated investment in infrastructure projects [..] in energy networks .."

"We need a reindustrialisation of Europe"

"Renewable energies and their development is a sine qua non if tomorrow's Europe really is going to create lasting, consistent and sustainable locational advantages which are directly comparable with those of other world players."

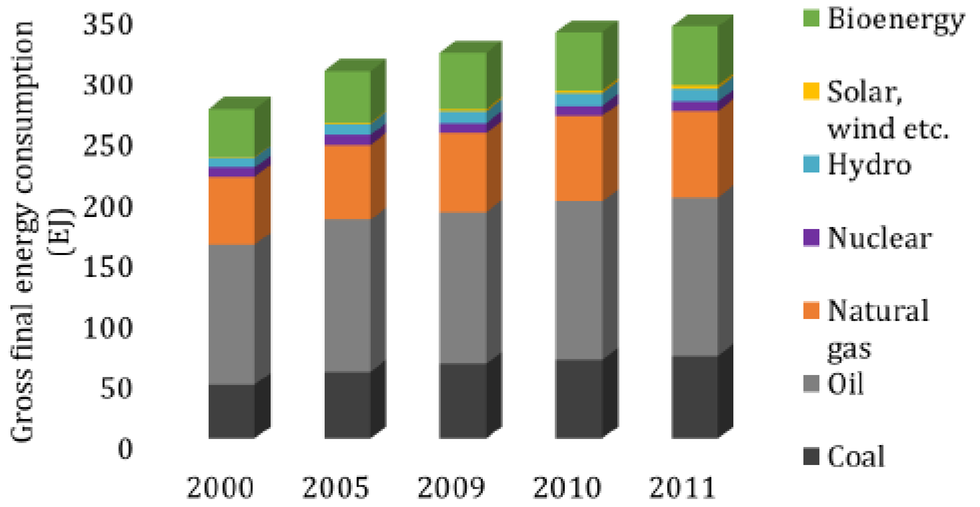
*"**I want the European Union to become the world number one in renewables**."*

Jean-Claude Juncker,
President-elect of the European Commission

Bioenergy Potential

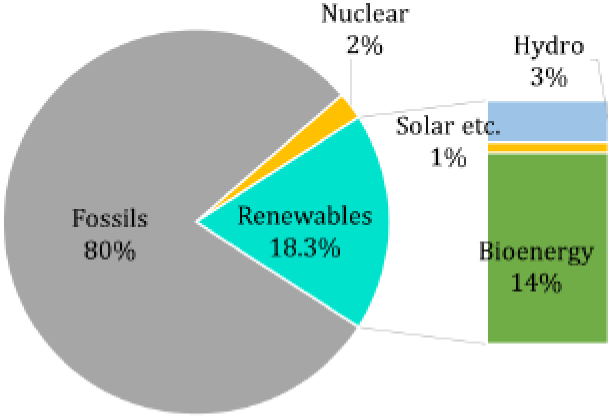
- Only renewable source that can replace fossil fuels in all energy markets – heat, electricity and fuels for transport
- Could sustainably contribute between 25% and 33% to the future global primary energy supply (up to 250 EJ) in 2050
- Development and deployment interconnected with growing demand for food, feed and fiber in addition to, the emerging bio-based economy
- Competition for land and for raw material with other biomass uses must be carefully managed
- Logistics and infrastructure must be managed
- Further technological innovation needed for more efficient and cleaner conversion of a more diverse range of feedstocks
- Expansion of bioenergy must be sustainable
- Bioenergy must compete with other energy sources and options!!

Role of bioenergy in global energy mix

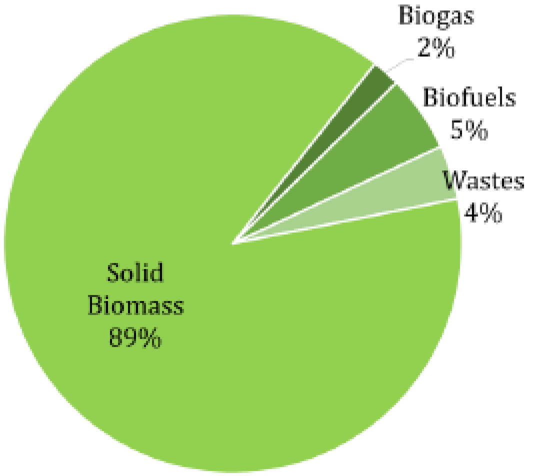


Source: IEA – 2014

Share of renewables and biomass



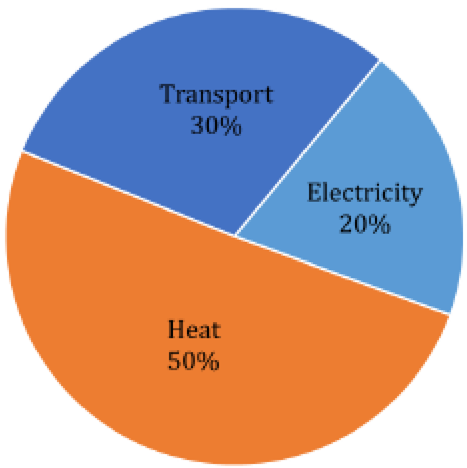
Final energy consumption



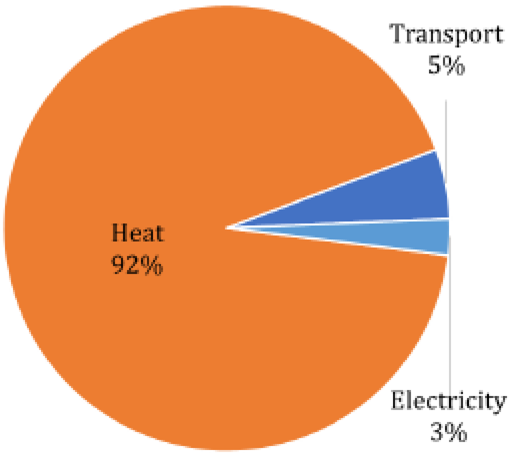
Supply of biomass

Source: IEA – 2014

Significance of bio – heat!



End use of energy

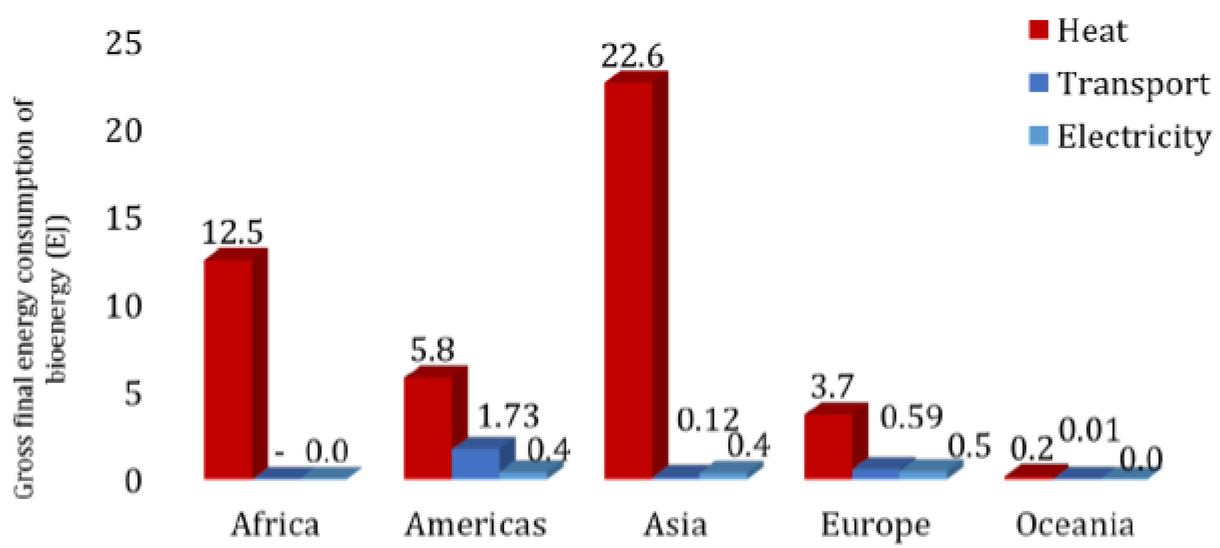


End use of bioenergy

Source: IEA – 2014

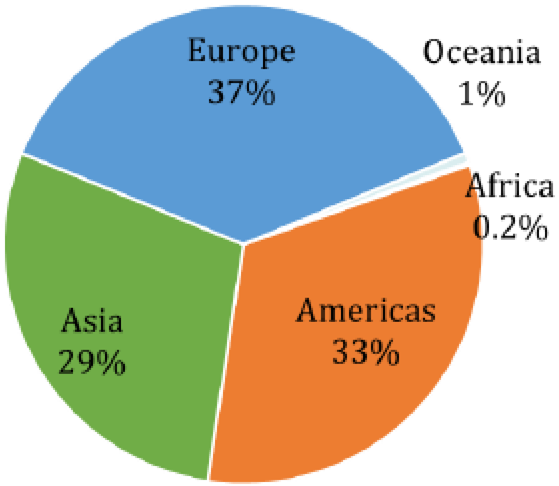
NOT LEGALLY BINDING

Continental distribution of bioenergy

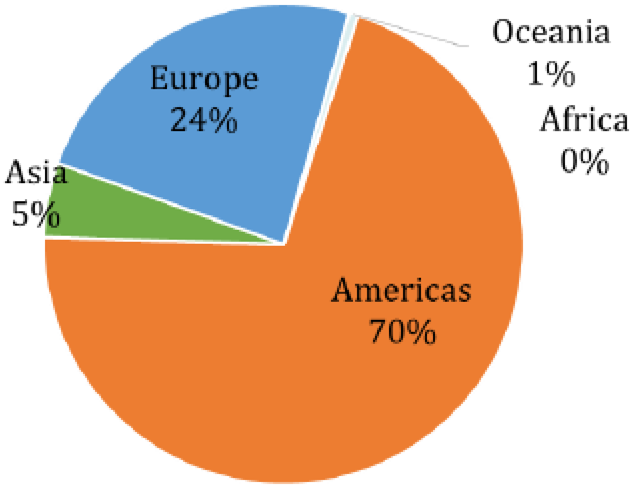


Source: IEA – 2014

Bioenergy in electricity and transport



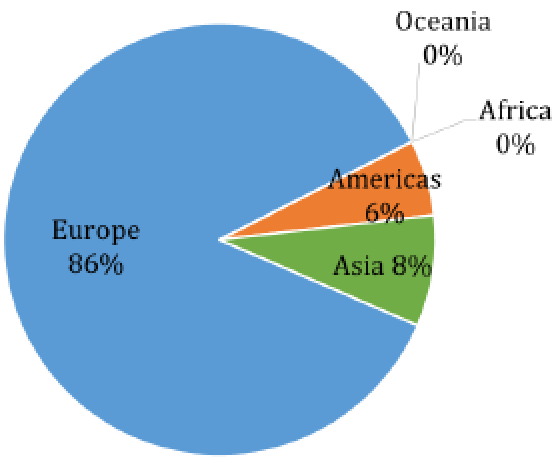
Electricity



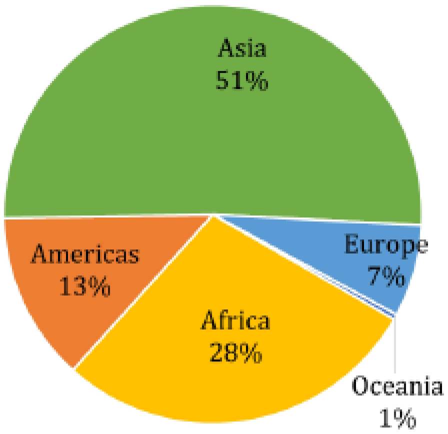
Transport

Source: IEA – 2014

Biomass for heating



Derived heat



Direct heat

Source: IEA – 2014

EU Energy policy priorities

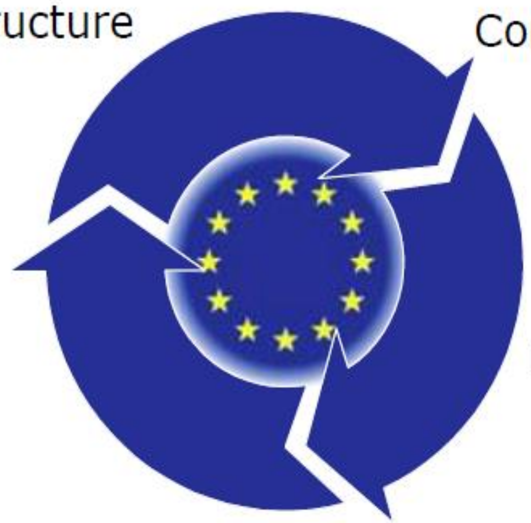
- Energy security strategy
- Energy efficiency goals
- Renewable energy targets
- Infrastructure renewal and interconnection
- Smart/intelligent networks
- New players with new roles/services/technology
- Focus on needs of users

European Commission

Competitiveness

Smart infrastructure

Competitive markets



Diversified supply

Energy efficiency

Renewable sources

Security of supply

Sustainability

European Commission

2020 targets and 2030 climate and energy Framework

2020	20 % GHG	20% RES (10 % RES in transport)	20 % EE	
2030	40 % GHG	27 % RES (No target in transport)	27 % EE	New Key Indicators

New governance system

NOT LEGALLY BINDING

European Commission

Opening speech of the Vice-President for Energy Union **Maroš Šefčovič** at the Energy Union Conference, **Riga 06/02/2015**

"Our commitment to becoming a low-carbon economy also means that we have to ***step up our efforts in the field of renewables****, so that we can honour the* ***promise made by President Juncker*** *when he became Commission President: that the Energy Union should be the* ***world number one in renewables*** *… We now have a unique opportunity to look beyond energy and climate policy and* ***link it up with other areas*** *such as* ***industrial policy, transport, competition, agriculture, foreign, trade and development policy, or research.*** *This is the only way to transcend the so-called contradiction between* ***'competitiveness' and 'decarbonisation'.*** *There is no such contradiction, we need both at the same time"*

NOT LEGALLY BINDING

ENERGY UNION – VISION
COM(2015) 80 final

- True **solidarity and trust**; speaking with **one voice** in global affairs
- An **integrated** continent-wide energy system
- Sustainable, low-carbon and climate-friendly **economy**
- Strong, innovative and **competitive** European economy
- **Citizens** taking ownership of the energy transition

TOWARDS A EUROPEAN ENERGY UNION

COM(2015) 80 final

- Energy security, solidarity and trust;
- A fully integrated European energy market;
- Energy efficiency contributing to moderation of demand;
- Decarbonising the economy
- **Research, Innovation and Competitiveness - Priorities**
  - **World leader in developing the next generation of renewable energy technologies,**
  - Participation of consumers
  - Efficient energy systems
  - Energy systems integration
  - A forward-looking approach to carbon capture and storage (CCS) and carbon capture and use (CCU)
  - Nuclear energy

ENERGY UNION PACKAGE – Action points

11. Speed up energy efficiency and decarbonisation in transport
✓ Action to create the right market conditions for alternative fuels deployment

12. Implement a climate and energy framework for 2030
✓ Legislation to achieve the 40% GHG reduction target in ETS and non-ETS sectors

13. Implement EU target of ≥27% for renewable energy by 2030
✓ New Renewable Energy Package including new policy for sustainable biomass and biofuels and legislation to meet cost-effectively the 2030 EU target

14. Develop forward-looking, energy and climate-related R&I strategy
✓ European energy R&I approach: upgraded SET Plan and strategic Transport R&I agenda

✓ Initiative on global technology and innovation leadership on energy and climate to boost jobs and growth

NOT LEGALLY BINDING

Bioenergy - Current situation in Europe

Investments include risks:

- The revision of the Renewable Energy Directive:
  - Capping of 1st generation biofuels due to ILUC (7%)
  - Optional sub-target for advanced biofuels (0,5%)
  - But measures for technology-neutral approach for promotion and expansion of advanced biofuels after 2020
- Post-2020 policy framework under development
  - Currently no sustainability for biomass to heat and power
  - Bioenergy sustainability under the new RES package
  - No specific RES target for the transport sector
- Most technologies still need to overcome "*valley of death*" including innovative heat and power from biomass

Current situation – RTD perspective

- Bioenergy and advanced biofuel investments are progressing
- European production technology is showing to be a critical component of new plants outside Europe
- EU technology providers are very present in these investments
- EU technology base continues to be very strong
- European production capacity planning and investments remain weak
- Regulatory uncertainties are being resolved
- Continued high level of bio-energy proposals under H2020 calls

The SET-Plan: coordinating research and innovation across Europe

The Strategic Energy Technology (SET) Plan is the technology pillar of the EU's energy and climate change policy

- **European Industrial Bioenergy Initiative (EIBI):** Update to the Implementation Plan for 2013-2015 (2013)
  + *European Biofuels Technology Platform (EBTP)*

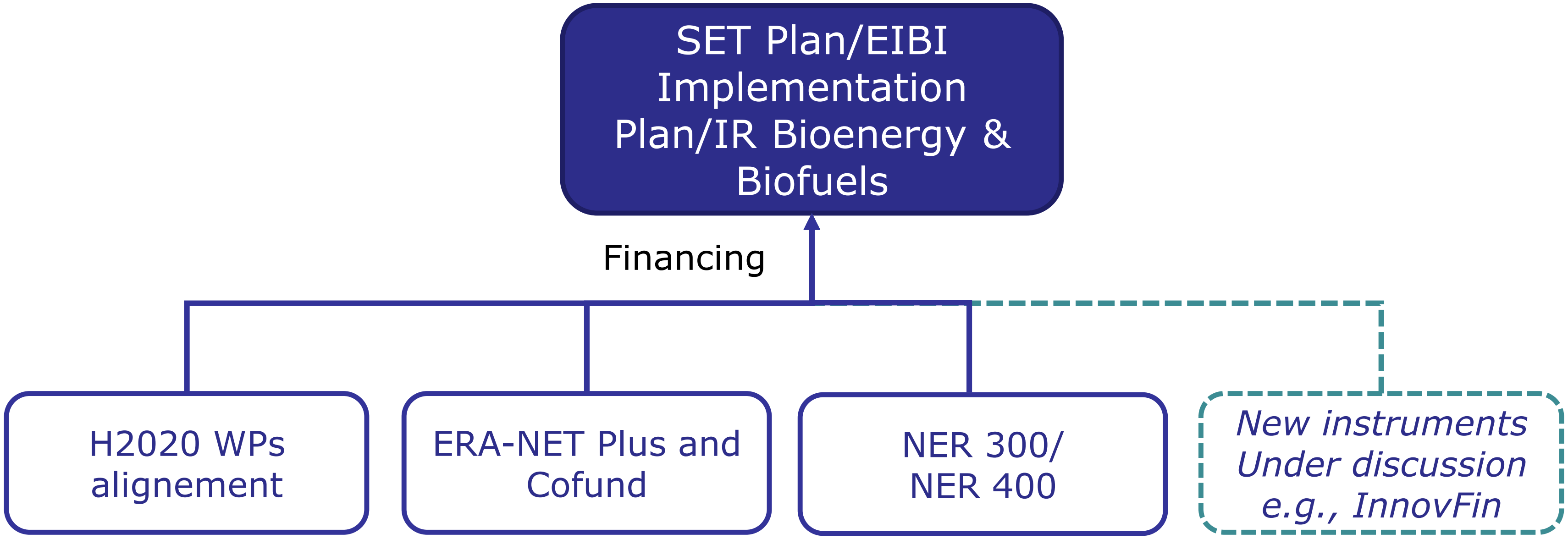
- ***Towards an Integrated Roadmap***
  updates SET Plan and puts forward key research and innovation actions

- *The Action Plan will* lay down **coordinated and/or joint investments** by individual Member States, between **Member States** and with the **EU** for the implementation of the ***Integrated Roadmap***.

  These investments should go **beyond grant programmes**

NOT LEGALLY BINDING

EC support to bioenergy



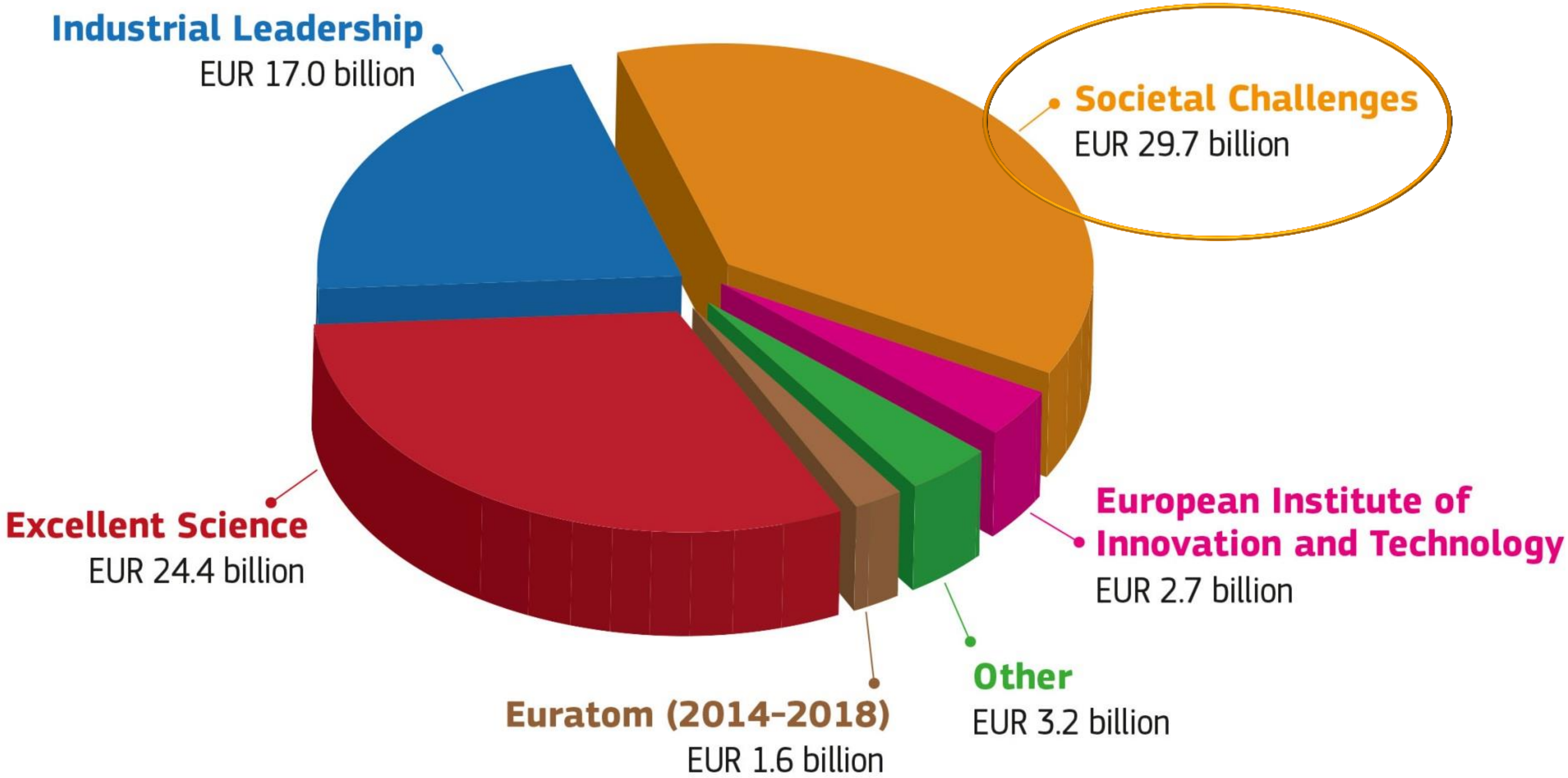
NOT LEGALLY BINDING

European
Commission

Horizon 2020: The new European Union Programme for Research and Innovation in 2014-2020

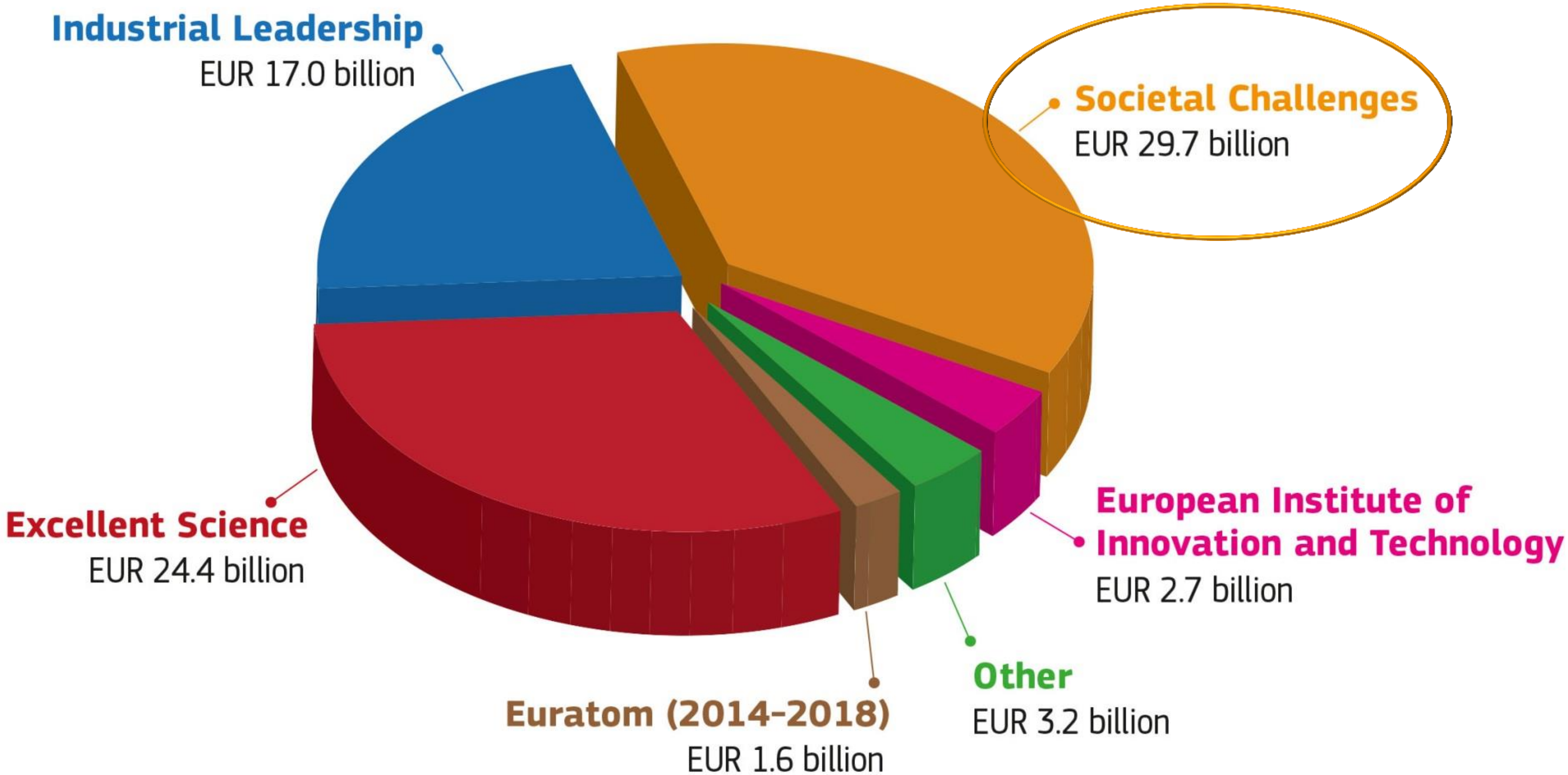
- An integrated programme coupling research to innovation
- Challenge based
- Strong focus on SMEs
- Major simplification
- EURATOM: same key priorities

Budget: 79 billion € from 2014 to 2020 (in current prices)



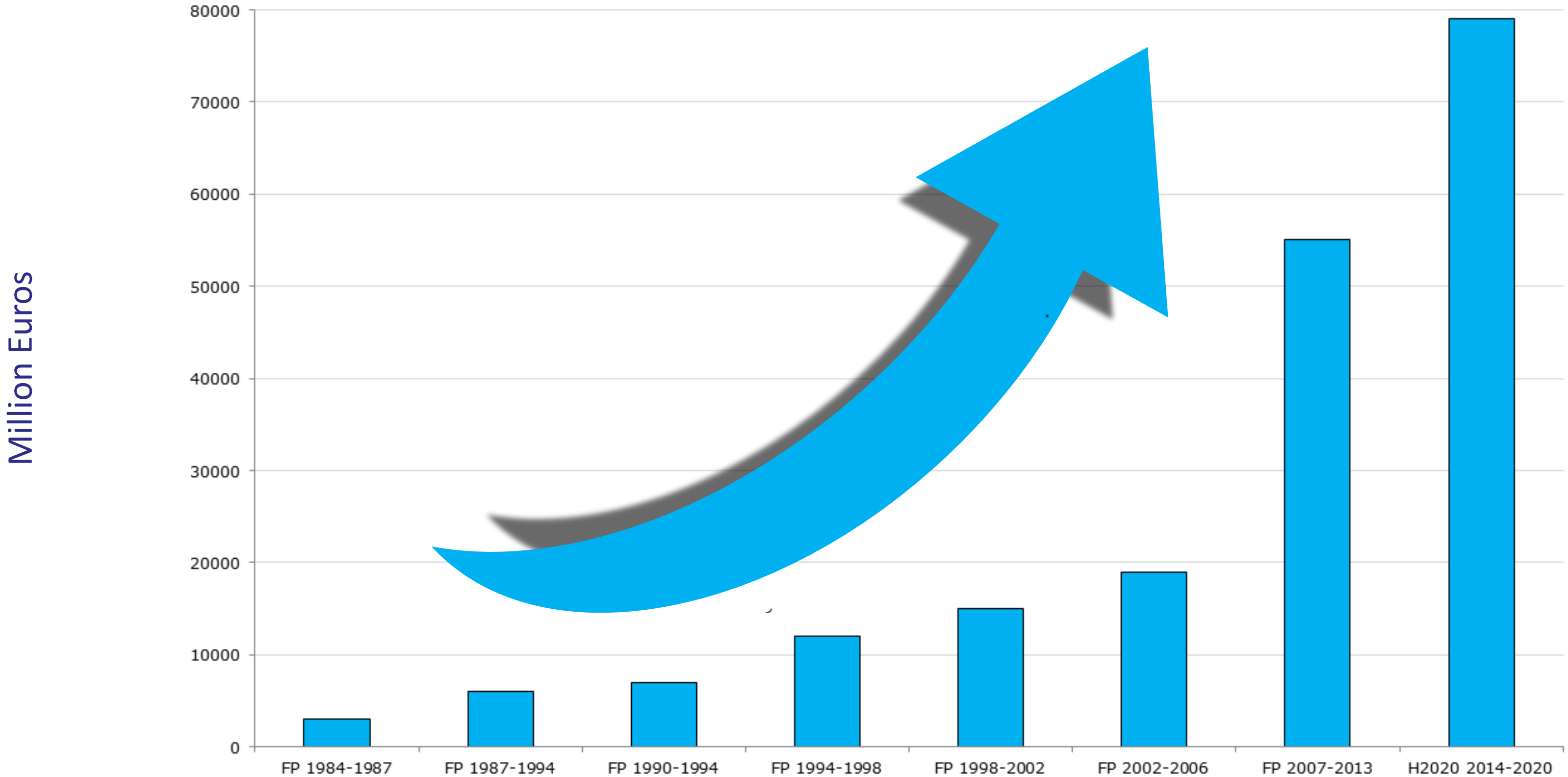
NOT LEGALLY BINDING

Budget: 79 billion € from 2014 to 2020 (in current prices)



NOT LEGALLY BINDING

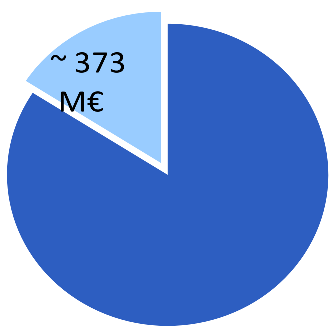
Growth of EU Framework Programme Funding



NOT LEGALLY BINDING

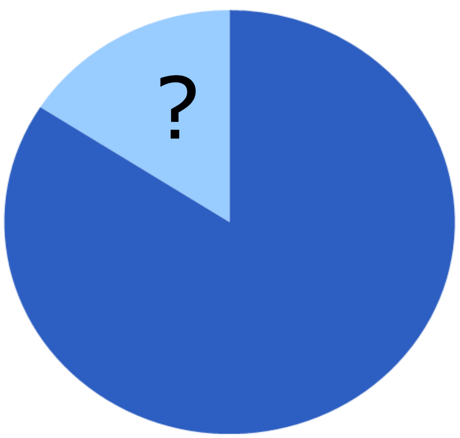
Energy Budget in FP7 and Horizon 2020

FP7: 2350 M €



Bioenergy
60 projects

H2020: 5931 M €



EU support so far for bioenergy R&I

- Grants for R&D and demonstration projects
  - **FP7**: 373 million for around 60 bioenergy project
    185 million for demonstration projects (55%)
  - **ERA-NET Plus** (EC and EU Member States) for EIBI demonstrations: 70 million for 2 projects (BESTF, BESTF2)
  - **NER-300**: EUR 933 million for 14 Bioenergy projects

NER300/NER400

- **Allowances** reserved in the new entrants reserve (NER) of ETS for financing commercial CCS and innovative RE demonstration projects
- **EIBI strategy was instrumental** in defining eligibility criteria for bioenergy projects
- **Large scale biofuel and bioenergy demonstration** projects were selected for funding
  - **First call: 8** bioenergy projects (max NER300 funding**: 629** M€)
    - **2** in **gasification** for grid and **1** in **pyrolysis** of biomass for CHP applications
  - **Second call**: **6** bioenergy projects (max NER300 funding: **304** M€)
    - **2** in **torrefaction** and **1** in **pyrolysis** of biomass for CHP applications
- **NER300 continues as NER400**

Bioenergy and advanced biofuels in Horizon 2020

WP 2014/2015

LCE 1: New knowledge and technologies (TRL 2 – TRL 3-4)

LCE 2: Developing next generation technologies of renewable electricity and heating/cooling (TRL 2 – TRL 3-4)

LCE 11: Developing next generation technologies for biofuels and sustainable alternative fuels (TRL 3-4 – TRL 4-5)

LCE 12: Demonstrating advanced biofuel technologies (TRL 5-6 – TRL 6-7)

LCE 14: Market uptake of existing and emerging sustainable bioenergy (TRL-7-9)

LCE 18: Supporting Joint Actions on demonstration and validation of innovative energy solutions - **ERA-NET Cofund**

WP 2014/2015

- Grants for R&D, demonstration and market-up take projects

  ~ **400** million euro available for RES including bioenergy/biofuels

  ~ **35%** of received proposals, ~ **35%** of successful proposals and ~ **30%** of budget allocated are to biofuels and bioenergy (2014)

WP 2016/2017

- Publication expected in fall 2015
- Grants for R&D, demonstration and market up-take projects; ERA-NETs

  ~ 400 million euro available for RES including bioenergy/biofuels
- Loans for investments for innovation actions (1st Kind), notably through Risk Sharing Finance Facility (RSFF) – **InnovFin**

WP 2016/2017

- **InnovFin: a pilot facility for first-of-a-kind demonstration projects**
  - H2020 budget to top-up for projects that can repay a loan, either by the promoter/ borrower or through project revenues
  - EC funds will up-take the risks of EIB loans for demonstration projects
  - Today, InnovFin products are demand-driven - No earmarking per sector, first come – first served)

InnovFin
Large Projects

European Commission

Bioenergy Opportunities and challenges

- The overall outlook for bioenergy and advanced biofuels up to 2050 is promising
- European leadership in bioenergy and advanced biofuels
- EU competitiveness will be linked to:
  - ✓ Bioenergy Policy (ILUC and post 2020)
  - ✓ Innovation-related policies
  - ✓ Biomass availability and cost
  - ✓ Financing
  - ✓ Sustainability certification
  - ✓ Demand-side management
- Technology empowerment needed through R&D&D
- Eventual feedstock constraints must be addressed horizontally
- Commercial availability of bioenergy and advanced biofuels should be enabled through achieving competitiveness

HORIZON 2020

Thank you for your attention!

Find out more:
http://ec.europa.eu/programmes/horizon2020/en/

Policy & Technology Workshop on improved bioenergy carriers

of the EU-projects BioBoost and SECTOR

Brussels, 16-17 June 2015

Perspectives for advanced bioenergy carriers

Daniela Thrän (DBFZ, UFZ),
Nicolaus Dahmen (KIT)

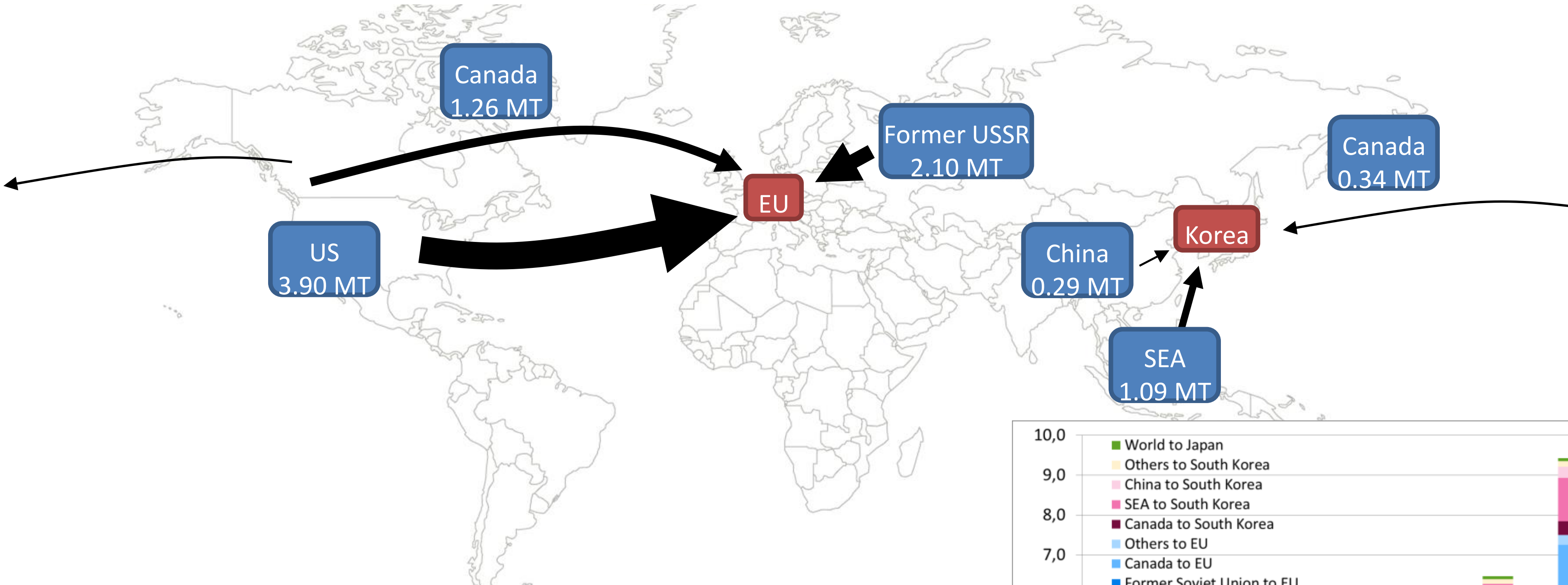


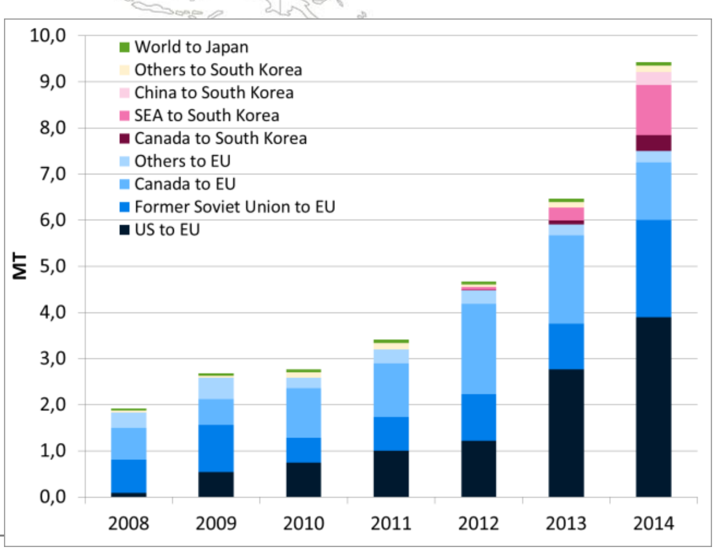



The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Global trade increase of bioenergy carriers

Wood pellets 2014



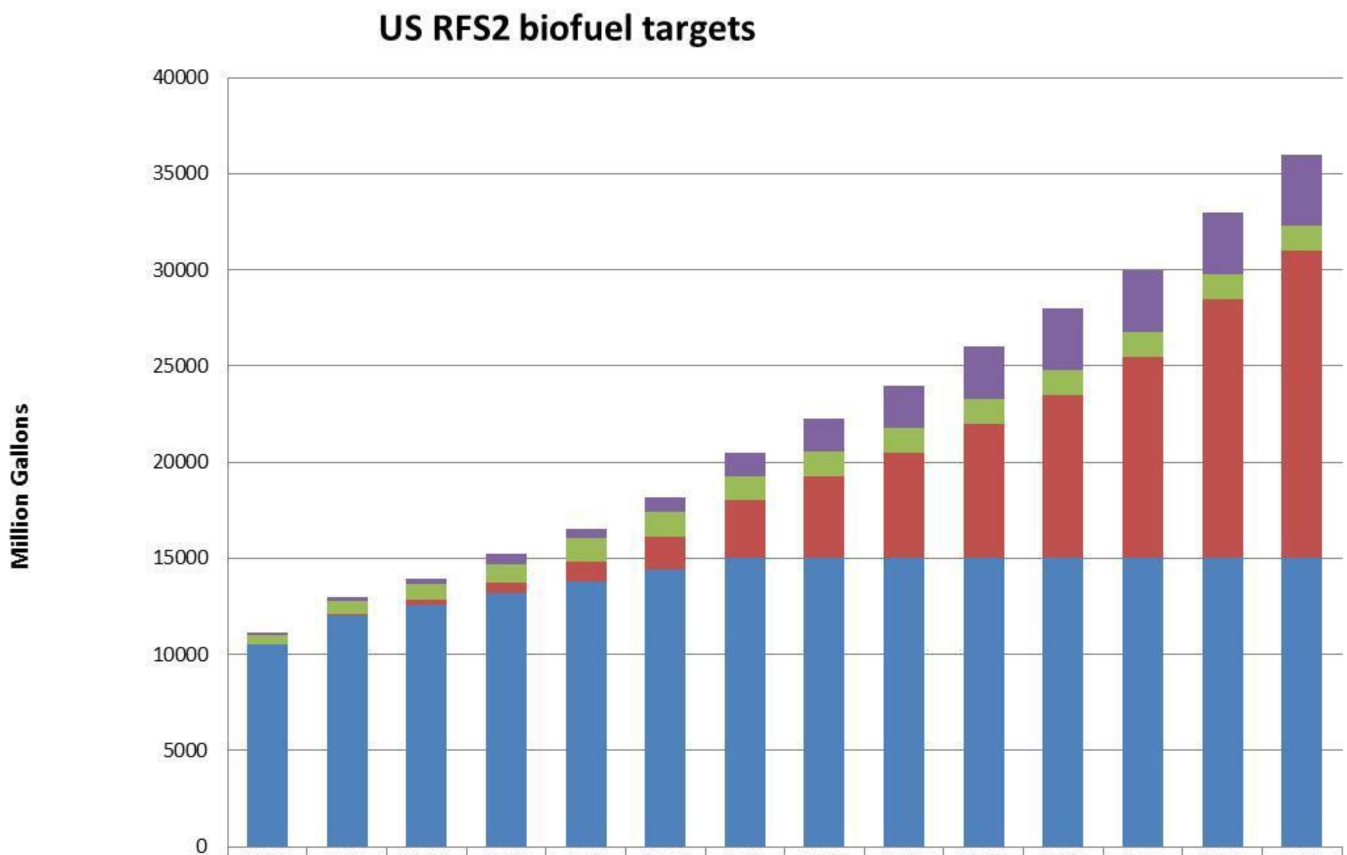


For 2008 - 2009 data is taken from UN Comtrade under "440130"
For 2010 - 2012 data is taken from Lamers et al. 2013, except for Japan and S. Korea from UN Comtrade under "440130".
For 2013 data is taken from UN Comtrade under "440131"
For 2014 data is taken/derived from Jessica Dell (Argus Media). For 'Others to EU', and 'World to Japan', both are assumed to be same as 2013.

Base reference:
Goh et al. (2014) Sustainable biomass and bioenergy in the Netherlands: Report 2013
http://english.rvo.nl/sites/default/files/2013/12/Sustainable%20biomass%20and%20bioenergy%20in%20the%20Netherlands%20-%20Report%202013.pdf

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Global trade increase of bioenergy carriers



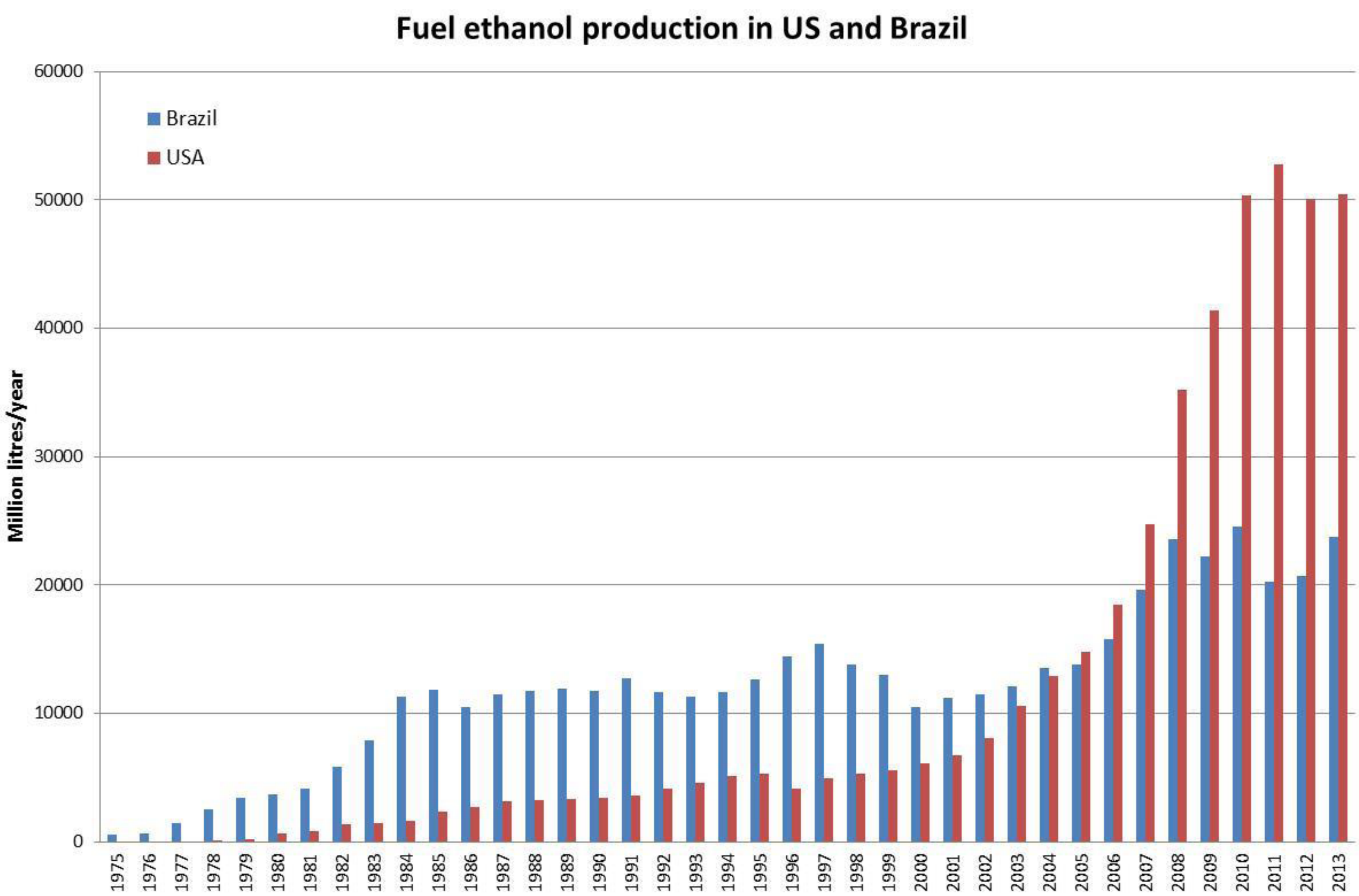
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
T	other advanced biofuels (A)	100	200	300	500	470	720	1220	1720	2220	2720	3220	3220	3220	3720
T	bio-based diesel (B) (A)	500	650	800	1000	1280	1280	1280	1280	1280	1280	1280	1280	1280	1280
T	cellulosic biofuels (S) (A)	0	100	250	500	1000	1750	3000	4250	5500	7000	8500	10500	13500	16000
T	implicit non-advanced biofuels (max)	10500	12000	12600	13200	13800	14400	15000	15000	15000	15000	15000	15000	15000	15000

Source: graph: IEA Bioenergy Task 40; data: EPA

SECTOR BioBoost

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Global trade increase of bioenergy carriers



Source: source: F.O.Licht's & EIA

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Why advanced bioenergy carriers?

- Activation of a broader range of feedstock
- Enabling of long distance transport
- Advantages for storage
- Homogenous and high quality -> needed for high value applications
- Tailored properties to user demand
- Thermochemical processes ideal to achieve these advantages

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Technology overview - process, products and TRL

	Torrefaction	Hydrothermal carbonization	Thermal fast pyrolysis	Catalytic fast pyrolysis
Conditions	200-320 °C ≈ 30 min	≈ 200 °C 10 bar, 6 h	500 °C sec.	500 °C sec.
Feedstock	Woody and non-woody biomass	„wet“ biomass and organic waste	Lignocellulosic biomass	Lignocellulosic biomass
Products	Pellets, briquettes	Biocoal dust, pellets and cakes	Catalytic pyrolysis oil (low O-content)	Biosyncrude (mix of pyrolysis oil and char)
Heating value		20-28 MJ/kg	≈ 30 MJ/kg	20-25 MJ/kg
TRL-level achieved		7	6-7	5

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Trend: Diversified and advanced demands

Fields of demand

In general: cost efficiency, low emissions, use of existing infrastructure, applicability small to large scale and varying end uses

Logistics & storage: small to big bags, bulks, tanks, grids, open storage, bunkers, pumps, belt conveyer

Pretreatment/milling: hammer mill, roller mill, fan beater mill

Conversion: pulverized fuel boiler, EF-gasifier, small/medium scale boilers, combustion engines, FLOX burner, refinery processes

Final products: heat, power, chemicals, transportation fuels, oil, coal, slurry

SECTOR BioBoost

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Requirements for advanced bioenergy carriers (examples)

End user demand

Energy content: as high as possible for transport and conversion efficiency

Durability: e.g. weather resistance, important for storage

Grindability: for optimal milling processes

Water resistance: optimisation for outdoor storage and handling

Particle size: optimal combustion efficiency

SECTOR BioBoost

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Promising advanced bioenergy carriers

BioBoost

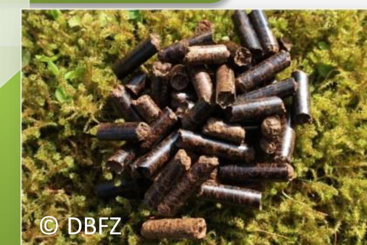
Potential and cost studies for residual biomass feedstocks (e.g. straw, forest residues, organic waste…)

Conversion by thermal and catalytic pyrolysis, hydrothermal carbonization to produce biosyncrude, catalytic pyrolysis oil, and HTC char

Application test for gasificatio (synthetic fuels), upgrading in refineries, CHP. Feasibility of by-product and nutrient separation.

SECTOR

22 feedstocks → e.g. st wood, logging residue, stra poplar, prunings from olive trees, willow, bagasse, eucalyptus, …



4 products → torrefied pellets, torrefied briquettes, torrefied chips, torgas

4 end use applications → cofiring, (co-)gasificatio pellet boilers, production c chemicals

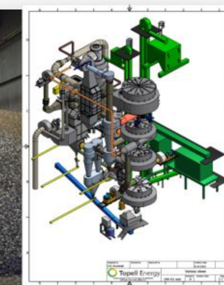
The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Key factors for market implementation

1. <u>End user demands identification and reliability of large scale production (confidence)</u>

Lab scale

Pilot scale



Demonstration scale

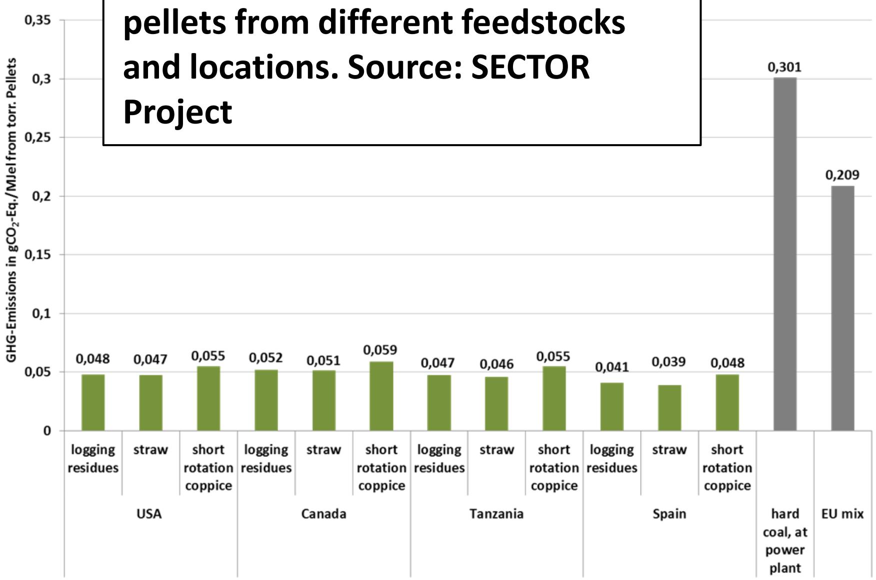
SECTOR BioBoost

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

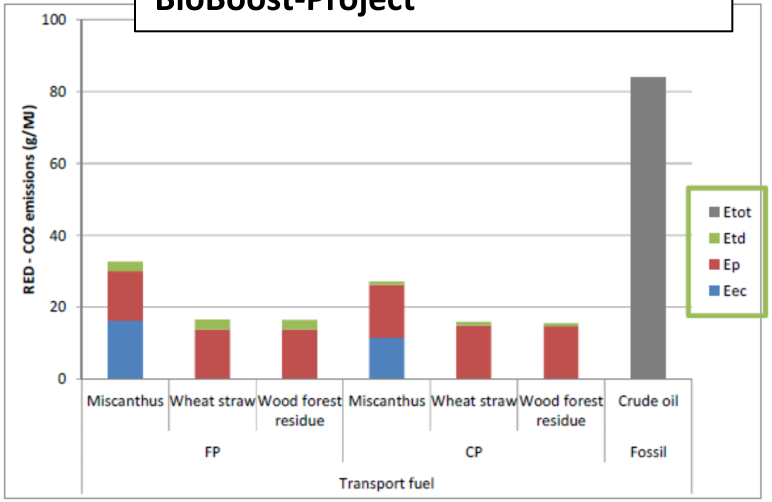
Key factors for market implementation

2. Proven sustainability

GHG-emissions from electricity production based on torrefied pellets from different feedstocks and locations. Source: SECTOR Project



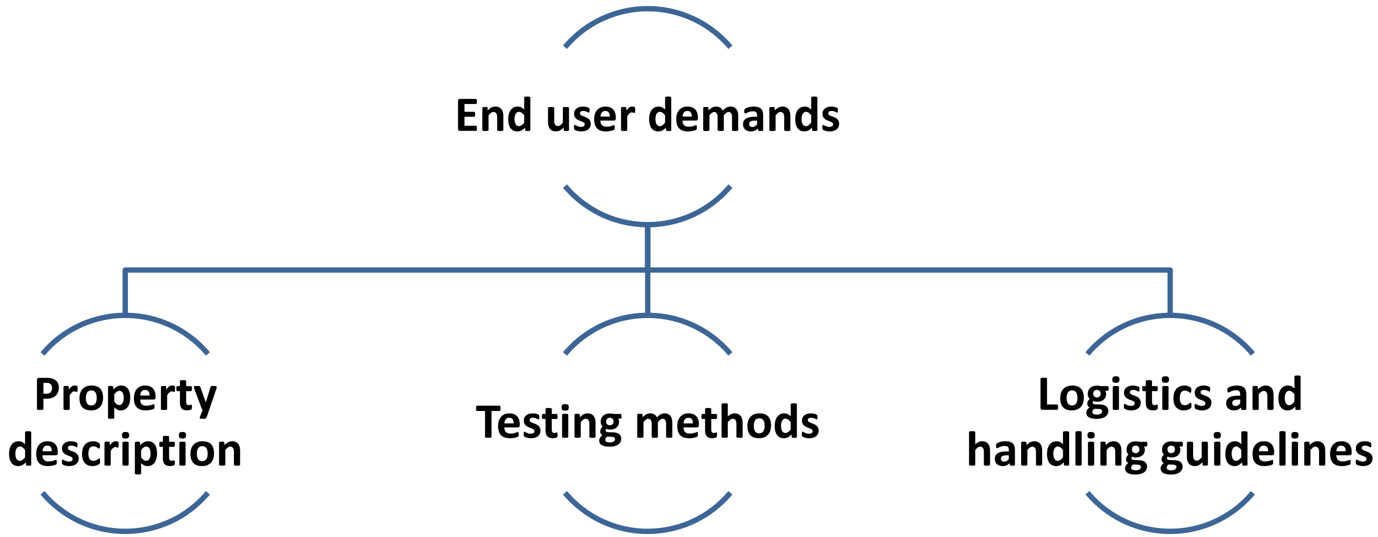
GHG-emissions accordng to RED for fuel production via thermal and catalytic pyrolysis pathway. Source: BioBoost-Project



The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Key factors for market implementation

3. describable, verifiable and tradable properties/quality



SECTOR: support of ISO 17225-8

BioBoost: identification of energy carrier properties and fuel requirements, application specific product optimization

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Main achievements in the last 3 years

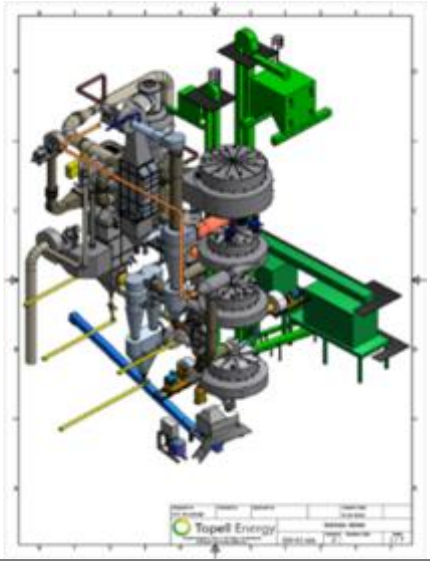
1. Up-scaling and increase of technology readiness level

SECTOR

→ Demonstration of torrefaction technology at commercial scale

→ Optimisation of torrefaction system and densification

→ Demo-Scale (Topell)
Toroidal bed reactor technology



Bioboost

→ Increase in TRL for thermal/ catalytic pyrolysis and HTC technologies

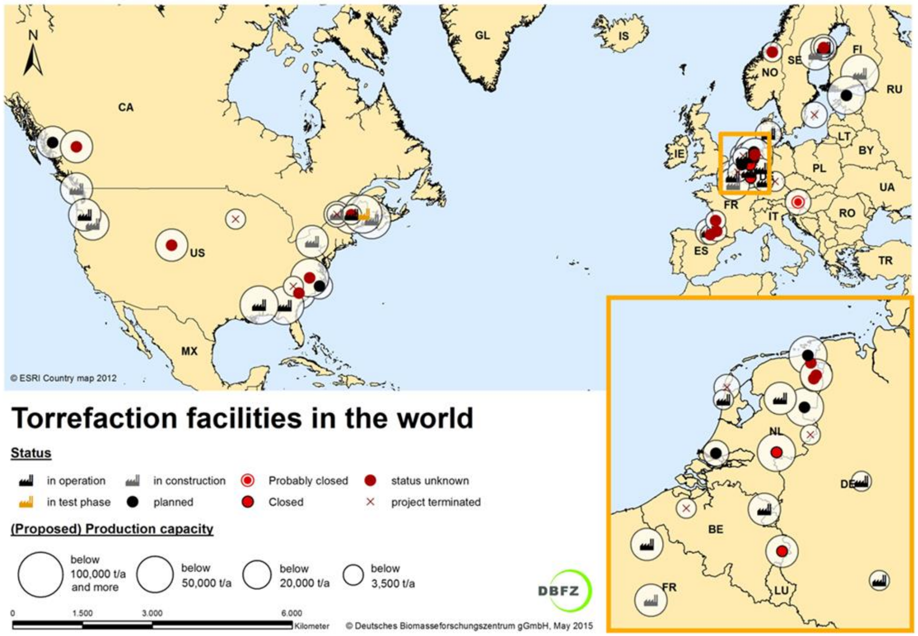
→ Customizing products towards CHP, gasification or upgrading for refinery integration

SECTOR BioBoost
The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Main achievements in the last 3 years

2. Intensified market activities

- **Torrefaction Plants:**



- **HTC Plants:**

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Main achievements in the last 3 years

3. Enhanced market strategies

- Approach of different sectors:
  - Small to medium scale appliances
  - Development of bioeconomy products
  - Designer fuels for transport sector

- Approach of different regions:
  - Supply: USA Southeast & Northwest Russia, Canada and Brazil with further biomass potential
  - Demand: Asia Pacific, South Africa, US, some parts of Europe, mostly in UK

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

The way ahead - pending issues

- **Research demand and market readiness**
  - Fast and catalytic pyrolysis as well as HTC have entered demonstration state
  - Torrefaction of woody biomass is ready to market – non woody biomass follows behind
- **Market Barriers to tackle:**
  - Low price for coal and CO_2-emission allowances – no biomass price parity
  - Competition to established technologies – confidence needs to be established
  - Lock-in into other solutions – once invested, change is unlikely
  - Sheer size of needed investment to supply relevant amount to potential customers
  - Policy coherence and stability for reliable European market conditions

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Basic considerations for market development

- Biomass only source of carbon in the long run
- Stepwise implementation of advanced utilisation of biomass from
  - Short term: heat and power via mainly combustion to
  - Mid term: Transportation fuels and chemicals
  - Long term: Added value by nutrient and by-product recovery

SECTOR BioBoost
The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

thank you very much!

Prof. Dr. Daniela Thrän
daniela.thraen@dbfz.de

DBFZ gemeinnützige GmbH
Torgauer Str. 116
04347 Leipzig
Germany
www.dbfz.de

e: info@sector-project.eu
w: www.sector-project.eu

Prof. Dr. Nicolaus Dahmen
nicolaus.dahmen@kit.edu

Karlsruher Institut für Technologie
Hermann-von-Helmholtz-Platz 1
z6344 Eggenstein-Leopoldshafen
Germany
www.kit.edu

e: nicolaus.dahmen@kit.edu
w: http://www.bioboost.eu

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Policy & Technology Workshop on improved bioenergy carriers

of the EU-projects BioBoost and SECTOR

Brussels, 16-17 June 2015

Session 2: Technology workshop
Introduction to Projects Background and FP7 goals

Jaap Kiel (ECN)






The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Main drivers of biomass upgrading

- Biomass is difficult energy source in view of:
  - Logistics (handling, transport, feeding)
  - End use (combustion, gasification, chemical processing)
- Difficult properties are:
  - Low energy density (LHV_{ar} = 10-17 MJ/kg)
  - Hydrophilic
  - Vulnerable to biodegradation
  - Tenacious and fibrous (grinding difficult)
  - Poor “flowability”
  - Heterogeneous composition (ash, chemical composition,…)

The projects have received funding from the European Union’s Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Main drivers of biomass upgrading

- Biomass upgrading enables decoupling of biomass production and use in:
  - Place
  - Time
  - Scale
- By converting biomass into high-quality bioenergy carriers (solid, liquid or gas), that:
  - Better fit in (existing) logistic infrastructures
  - Allow efficient, reliable and cost effective conversion into electricity and heat, transport fuels and chemicals

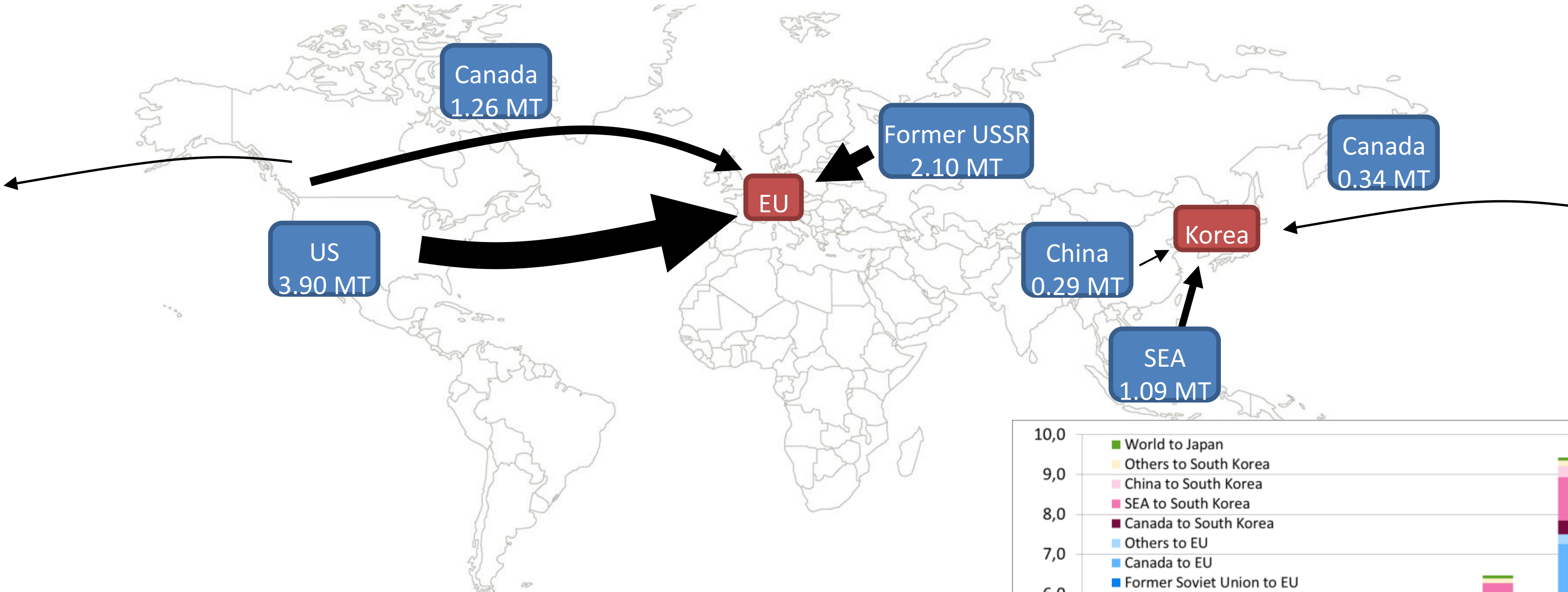
Solve biomass related problems at the source

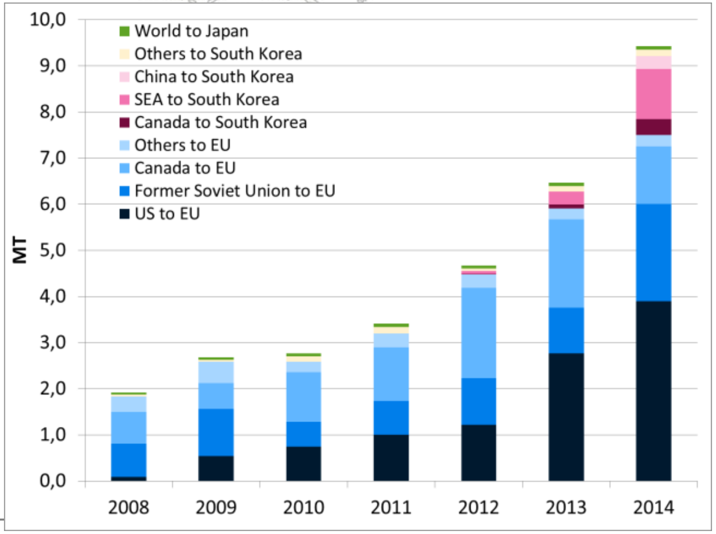
SECTOR BioBoost

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Global trade increase of bioenergy carriers

Wood pellets 2014





For 2008 - 2009 data is taken from UN Comtrade under "440130"
For 2010 - 2012 data is taken from Lamers et al. 2013, except for Japan and S. Korea from UN Comtrade under "440130".
For 2013 data is taken from UN Comtrade under "440131"
For 2014 data is taken/derived from Jessica Dell (Argus Media). For 'Others to EU', and 'World to Japan', both are assumed to be same as 2013.

Base reference:
Goh et al. (2014) Sustainable biomass and bioenergy in the Netherlands: Report 2013
http://english.rvo.nl/sites/default/files/2013/12/Sustainable%20biomass%20and%20bioenergy%20in%20the%20Netherlands%20-%20Report%202013.pdf

SECTOR BioBoost
The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Advantages of advanced bioenergy carriers

- Unlocking the potential of a broader range of feedstock
- Enabling long distance transport
- Advantages in storage
- Homogenous and specific products ready for treatment and trade
- Tailored properties to user demand -> electricity and heat, transport fuels and chemicals

→ Complementary thermochemical processes for different feedstock ideal to achieve these advantages

SECTOR BioBoost

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Dedicated FP7 call - main goals

Promote/support the market introduction of advanced bioenergy carriers as a sustainable commodity solid fuel

- **Further development of advanced biomass upgrading** technologies
- **Product characterisation, optimisation and standardisation**
- Development and standardisation of dedicated **analysis and testing methods** for assessment of transport, storage, handling logistics and end-use performance
- Assessment of the role of advanced bioenergy carriers in the bioenergy **value chains** and their contribution to the development of the **bioenergy market in Europe**
- Full **sustainability assessment** of the major torrefaction-based biomass-to-end-use value chains
- **Dissemination** of project results to industry and into international forums (e.g. CEN/ISO, IEA and sustainability round tables)

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

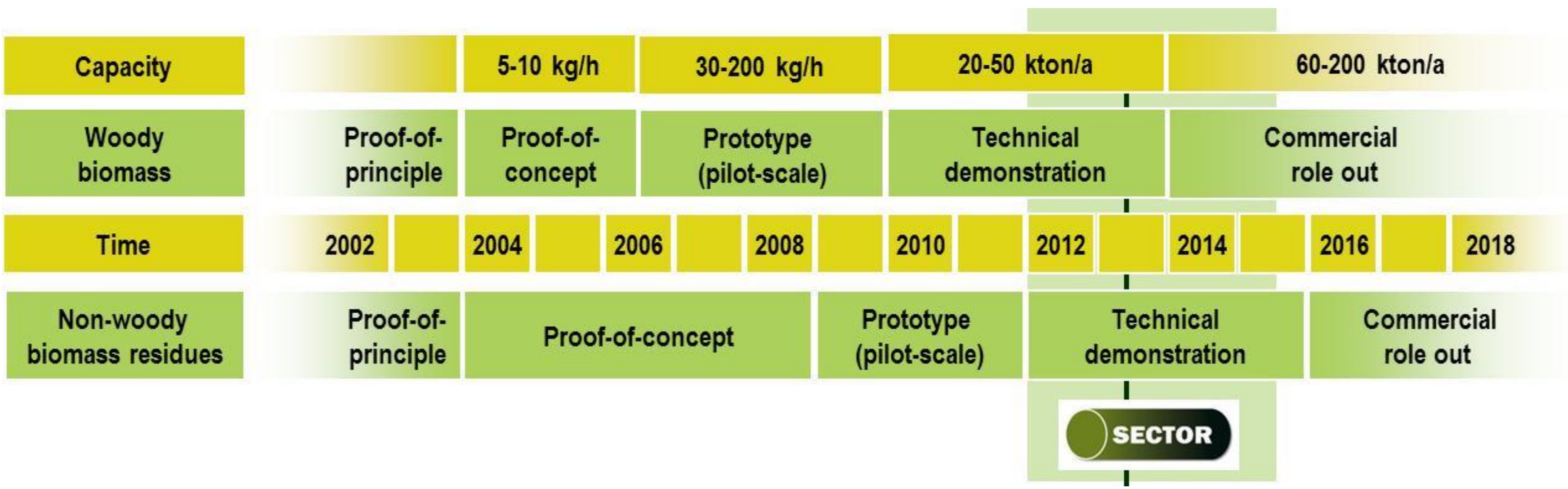
Two EU projects on advanced bioenergy carriers

- SECTOR
  - (Dry) Torrefaction
- BioBoost
  - Pyrolysis
  - Hydrothermal treatment (carbonisation and liquefaction)

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Torrefaction and densification technology roadmap

- …. As anticipated at the start of SECTOR
  - Rapid commercial role out for wood expected
  - Longer lead time for non-woody biomass residues



The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Very attractive properties, but based mainly on small-medium scale experimental work (at the start of SECTOR)

	Wood chips	Wood pellets	Torrefied wood pellets	Charcoal	Coal
Moisture content (wt%)	30 – 55	7 – 10	1 – 5	1 – 5	10 – 15
Calorific value (LHV, MJ/kg)	7 – 12	15 – 17	18 – 24	30 – 32	23 – 28
Volatile matter (wt% db)	75 – 85	75 – 85	55 – 80	10 – 12	15 – 30
Fixed carbon (wt% db)	16 – 25	16 – 25	20 – 40	85 – 87	50 – 55
Bulk density (kg/l)	0.20 – 0.30	0.55 – 0.65	0.65 – 0.80	0.18 – 0.24	0.80 – 0.85
Vol. energy density (GJ/m³)	1.4 – 3.6	8 – 11	12 – 19	5.4 – 7.7	18 – 24
Hygroscopic properties	Hydrophilic	Hydrophilic	(Moderately) Hydrophobic	Hydrophobic	Hydrophobic
Biological degradation	Fast	Moderate	Slow	None	None
Milling requirements	Special	Special	Standard	Standard	Standard
Product consistency	Limited	High	High	High	High
Transport cost	High	Medium	Low	Medium	Low

Abbreviations:
db = dry basis
LHV =Lower Heating Value

sources: ECN (table, fig.1, 3), Pixelio (fig. 2, 5), ofi (fig. 4)

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Technology status at the start of BioBoost

- Pyrolysis
  - Long development history
  - Questions/uncertainty concerning value chains and end-use options
  - Pilot-scale (+ some limited demo experience)

- Hydrothermal treatment
  - Main focus on HTC (hydrothermal carbonisation)
  - In general: high temperatures (up to 250 °C), long residence (up to 6 hours), limited attention to effluent treatment
  - Mainly batch-wise operation at bench-scale

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Thank you for your attention

Prof. Dr. Jaap Kiel
kiel@ecn.nl

ECN
P.O. Box 1
1755 ZG Petten
The Netherlands
www.ecn.nl

© ECN

The projects have received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826 (SECTOR) and 282873 (BioBoost).

Production of Solid Sustainable Energy Carriers from Biomass by Means of TORrefaction

SECTOR: Goals, Work Programme, Achievements

Policy & Technology Workshop on improved bioenergy carriers

of the EU-projects BioBoost and SECTOR

Brussels, 16-17 June 2015

Daniela Thrän (DBFZ/UFZ)
Kay Schaubach (DBFZ)
Jaap Kiel (ECN)
Michiel Carbo (ECN)

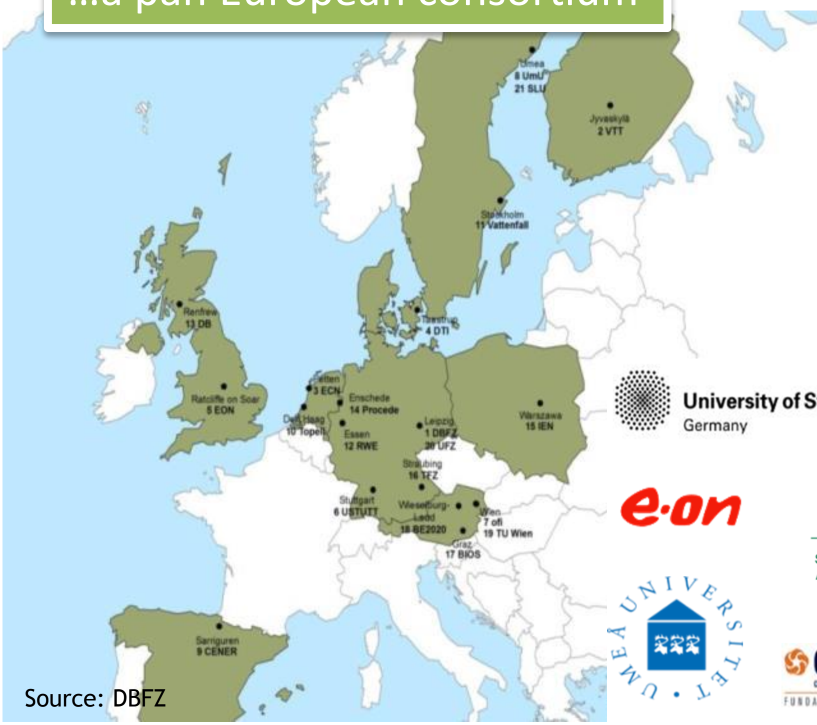





This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

The SECTOR project - Facts

...a pan European consortium

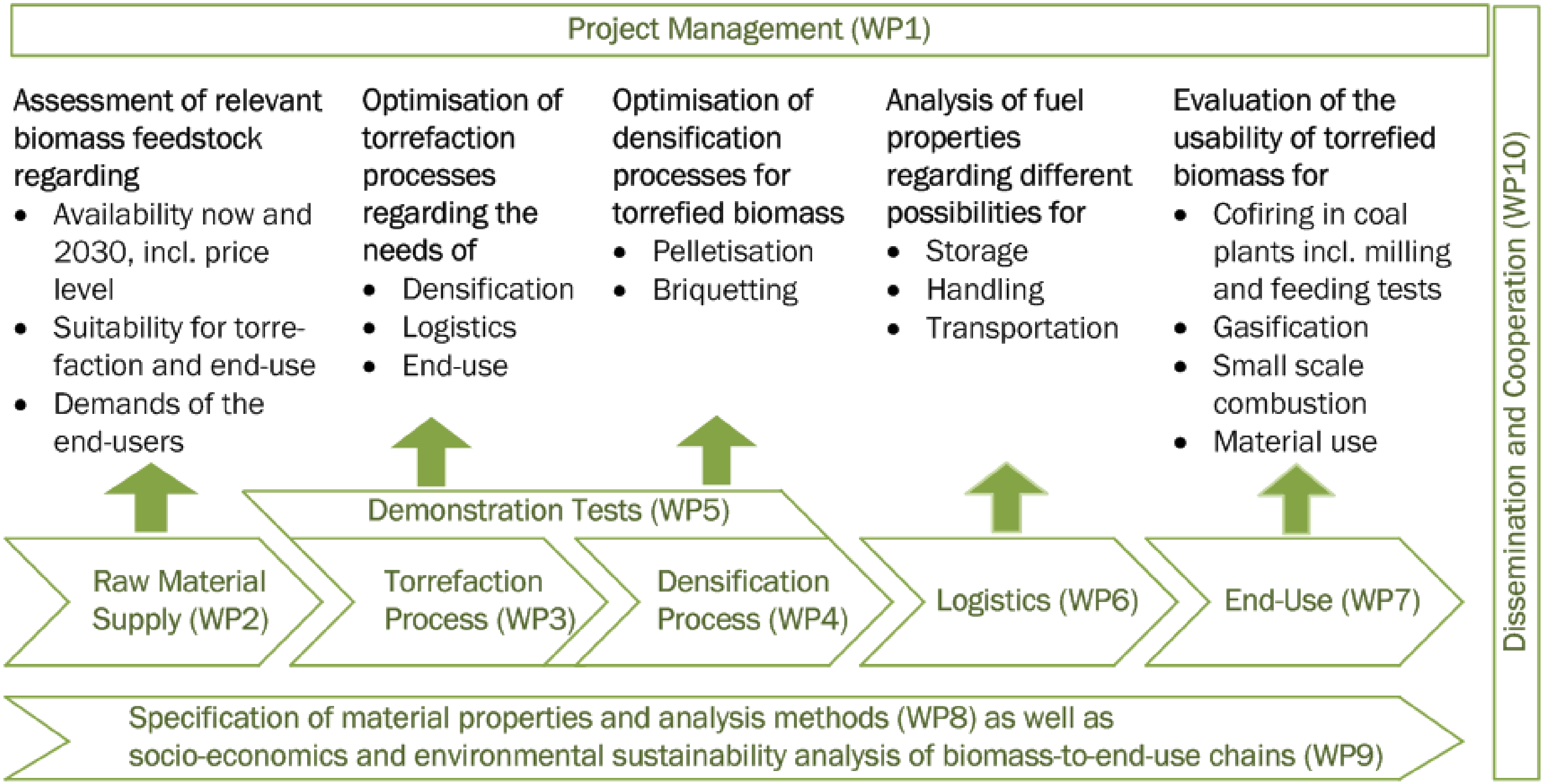


Source: DBFZ

Project start:	01.01.2012
Duration:	42 months (+6)
Total budget:	10 Mio. Euro
Participants:	21 from 9 EU-countries
Coordinator:	DBFZ

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Project structure



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

SECTOR Objectives I

- Further **development of torrefaction-based technologies** (up to pilot-plant scale and beyond) for production of solid bioenergy carriers from broad range of feedstock (domestic and imported biomass) including forestry residues and agro-residues
- Development of **specific production recipes**, validated through extensive lab-to-industrial-scale logistics and end-use performance testing
- Development and **standardisation** of dedicated analysis and testing methods for assessment of transport, storage, handling logistics and end-use performance

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

SECTOR Objectives II

- **Assessment** of the role of torrefaction-based solid bioenergy carriers in **bioenergy value chains** – including bio-products – and their contribution to the development of the bioenergy market in Europe, including the development of deployment strategies and scenarios
- Full **sustainability assessment** of the major torrefaction-based biomass-to-end-use value chains, including:
  - socio-economic assessment
  - life cycle assessment (energy and GHG balances)
  - full environmental assessment
- **Dissemination** of project results to industry and into international forums (e.g. EIBI, EERA, CEN/ISO, IEA and sustainability round tables)

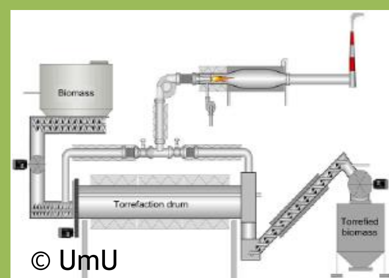
This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Achievements

22 Feedstocks

e.g. stemwood, logging residue, straw, poplar, prunings from olive trees, willow, bagasse, eucalyptus, …

4 Technologies

Moving Bed*	Rotary Drum	Rotary Drum	Toroidal Bed
			

Torrefied Chips (2 t)

Torrefied Pellets and Briquettes (<150 tons)

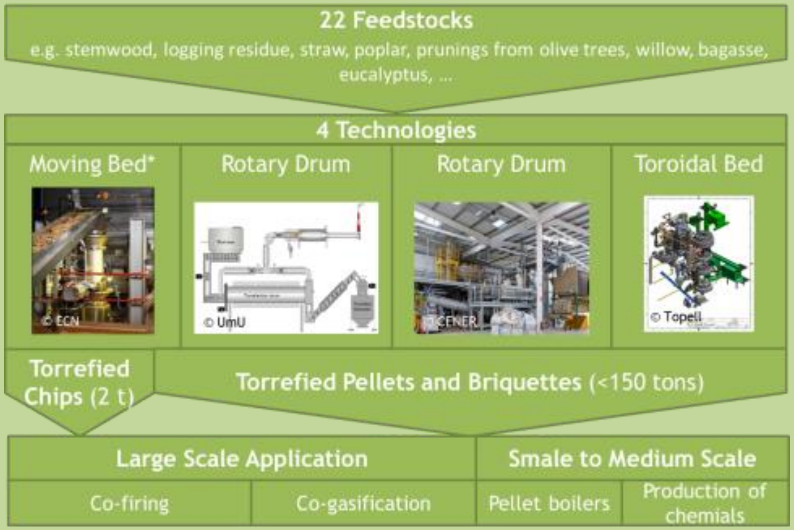
Large Scale Application		Smale to Medium Scale	
Co-firing	Co-gasification	Pellet boilers	Production of chemicals

** And the resulting Andritz/ECN technology, successfully demonstrated in Denmark at a scale of 1 ton/h*

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Value Chains, Sustainability and Standardisation

- Standardisation
- Sustainability
- Value Chains



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Standardisation - Highlights

Fuel specification and analysis

- Standardisation work – proposal for a product standard including fuel specifications for torrefied material - ISO 17225-8
- Validation of existing methods for applicability for torrefied material
- Development of new methods for a better description of torrefied material
- Development of general MSDS based on REACH
- Two international Round Robins organised (43 and 31 participants,17 parameters)

Methods developed / tested, e.g.

- Water absorption
- Grindability
- Degree of torrefaction
- Leaching behavior
- TGA
- NIR
- Flowability and size distribution

Standardisation - Validation of new test methods

- Round Robin II – Validation of new test methods
  - 31 Participants (12-29 participants per parameter)
  - 15 Countries
  - 6 Parameter

Test Series		Number of participants registered	Number of participants evaluated
Grinding energy	New method description	12	11
Water absorption	New method description	25	23/21
Carbon content	EN 15104	25	24
Gross calorific value	EN 14918	29	27
Ash melting behavior	CEN/TS 15370	15	10
Diameter and length	ISO/DIS 17829 or EN 16127	26	20/24

This project has received funding from the European Union’s Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Improved pellet quality

→ Optimisation of densification process

Date	Durability	Pine
October 2012	88.8	
January 2013	92.3	
June 2013	94.7	
November 2013	95.7	

Date	Durability	Straw
February 2013	84.2	
September 2013	94.3	
October 2013	96.6	
November 2013	97.6	

Parameters optimized:

- Particle size of feedstock
- Moisture content of feedstock
- Torrefaction degree of feedstock
- Die: diameter/length
- Die rotation speed

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Goals achieved

Support the market introduction of torrefaction-based bioenergy carriers as a commodity renewable solid fuel	All torrefaction-partners have **optimised their technologies** through extensive testing in SECTOR
	All torrefaction partners have developed **specific recipes** – more than 150t have been produced, quality demands are met
	New standard was proposed ISO 17225-8: "Solid biofuels - Fuel specifications and classes - Graded thermally treated densified biomass" and new analysis methods are being developed
	Assessment of torrefaction to activate more biomass potential and to enable international trade is ongoing
	Biomass to end use chains, storylines and scenarios were developed and calculated
	Project results were disseminated through more than 40 con-ferences, 2 workshops and through standardisation committees and platforms with membership of 13 SECTOR partners

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

thank you very much!

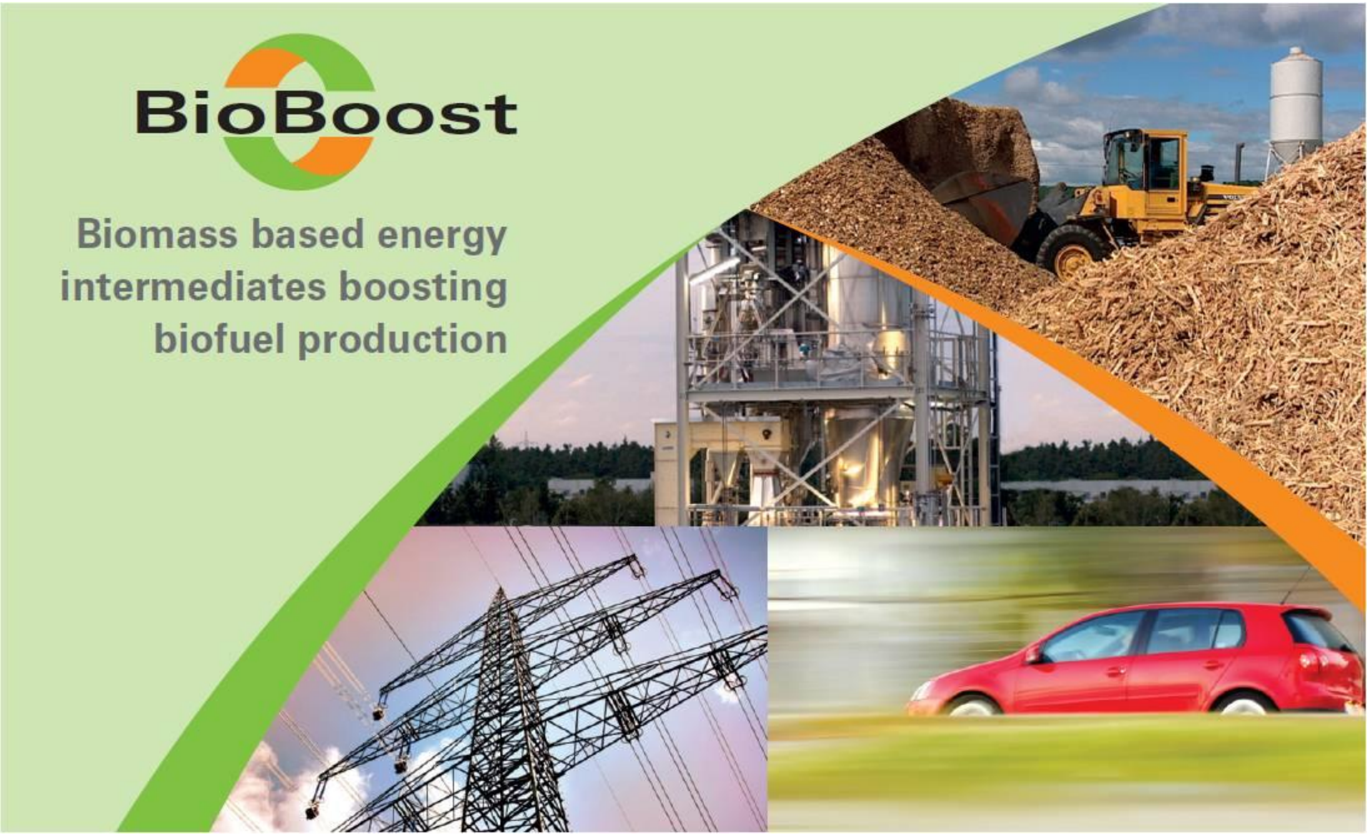
Prof. Dr. Daniela Thrän
daniela.thraen@dbfz.de

DBFZ gGmbH
Torgauer Str. 116
04347 Leipzig
Germany
www.dbfz.de

e: info@sector-project.eu
w: www.sector-project.eu

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

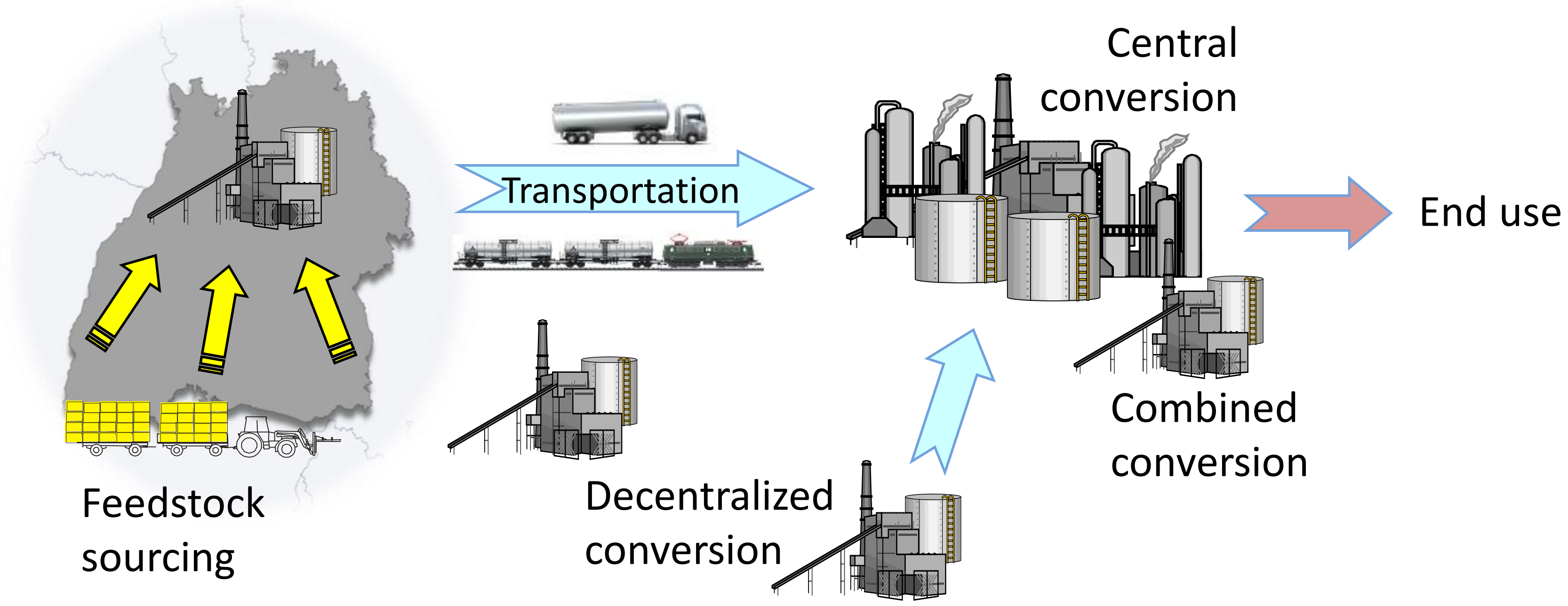
Goals, Work Programme, Achievements



A European R&D project co-funded under contract 282873 within the Seventh Framework Programme by the European Commission.

Main aim

Evaluate the techno-economic feasibility of bioenergy carrier production for heat&power and transportation fuel production in decentralized/central concepts!

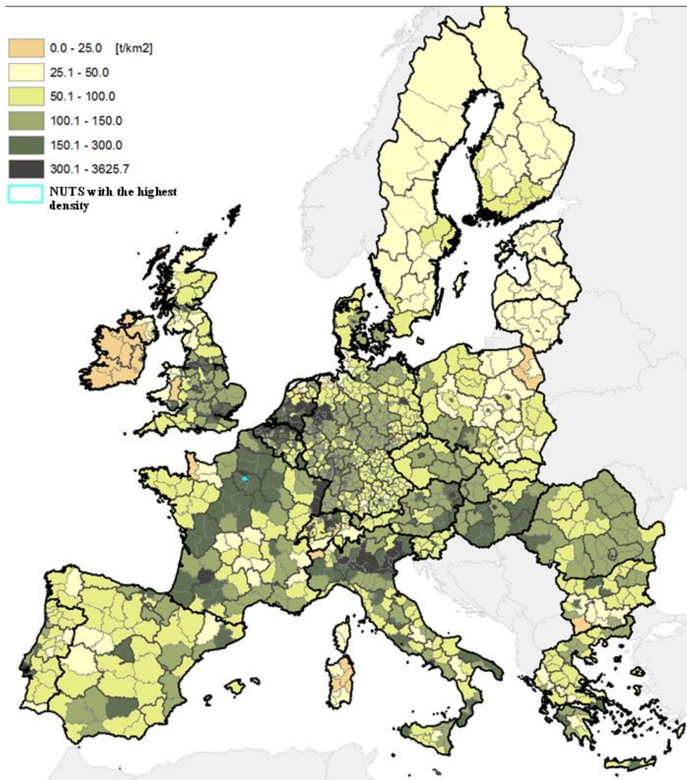


Tasks and Objectives

- To determine the available potential and costs of dry and wet residual feedstock
- To develop and improve thermal and catalytic pyrolysis and hydrothermal carbonisation as decentralized conversion technologies
- To optimize biomass and intermediate fuel transportation and logistic chains
- To explore the use of energy carriers and by-products
- To perform techno-economic and life cycle assessment

Project approach and structure

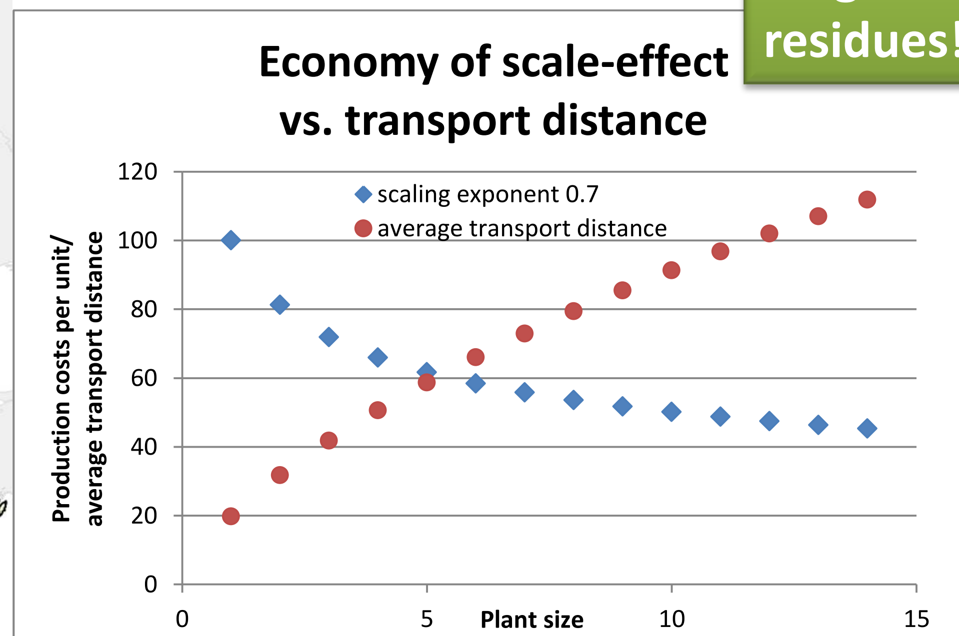
Identification of feedstock mass potential on NUTS3 level and costs in EU 28+CH

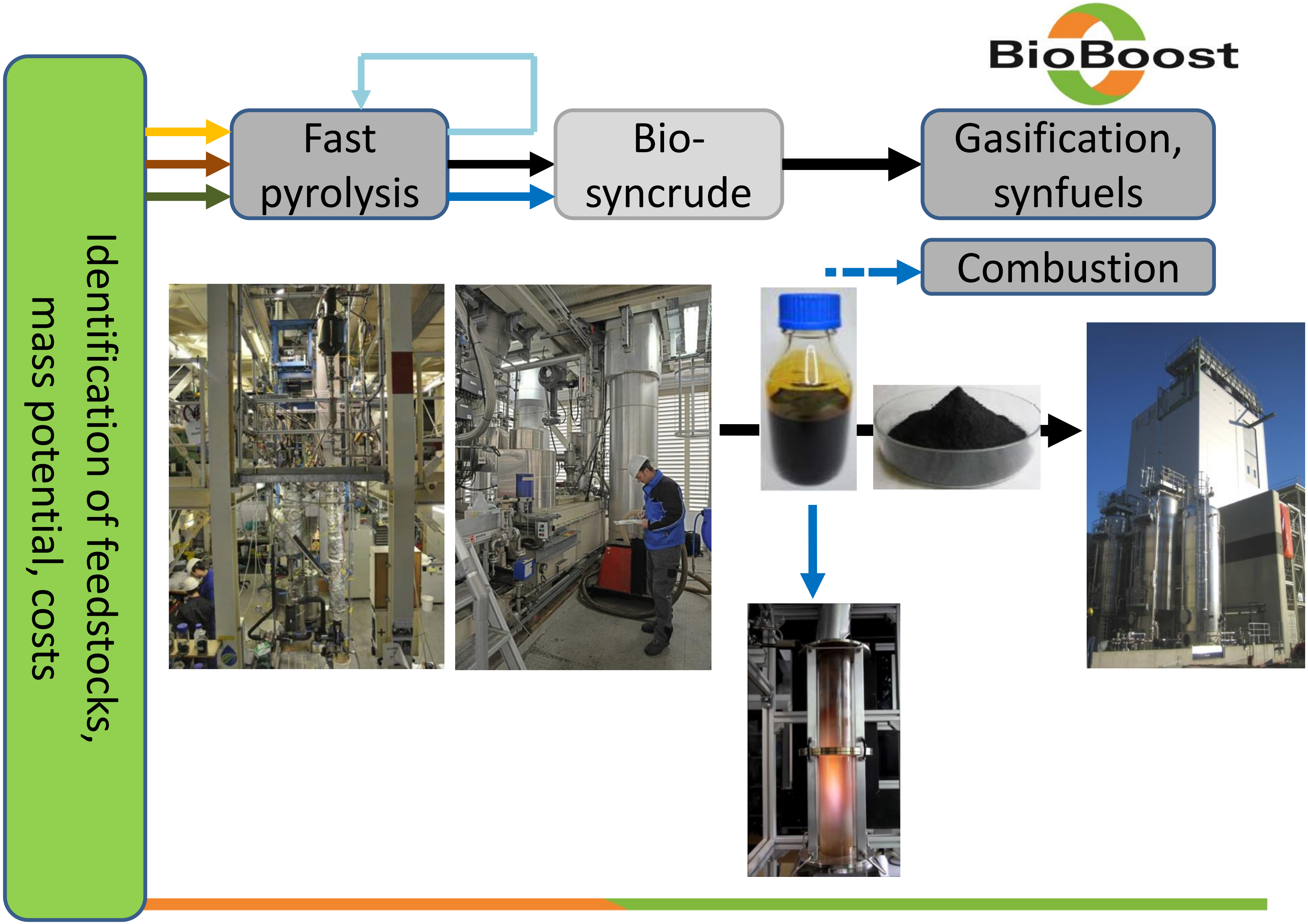


Low density of biomass residues

- Straw: < 250 t/km²
- Forestry res.: < 100 t/km²

Energy densification: a necessity for biogenic residues!





BioBoost
Identification of feedstocks, mass potential, costs
Fast pyrolysis
Bio-syncrude
Gasification, synfuels
Combustion

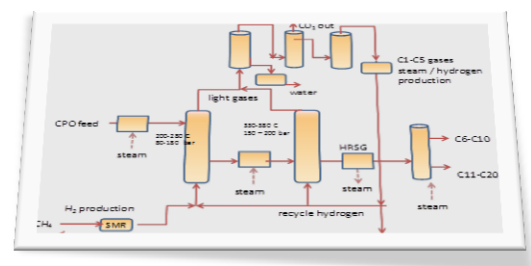
BioBoost

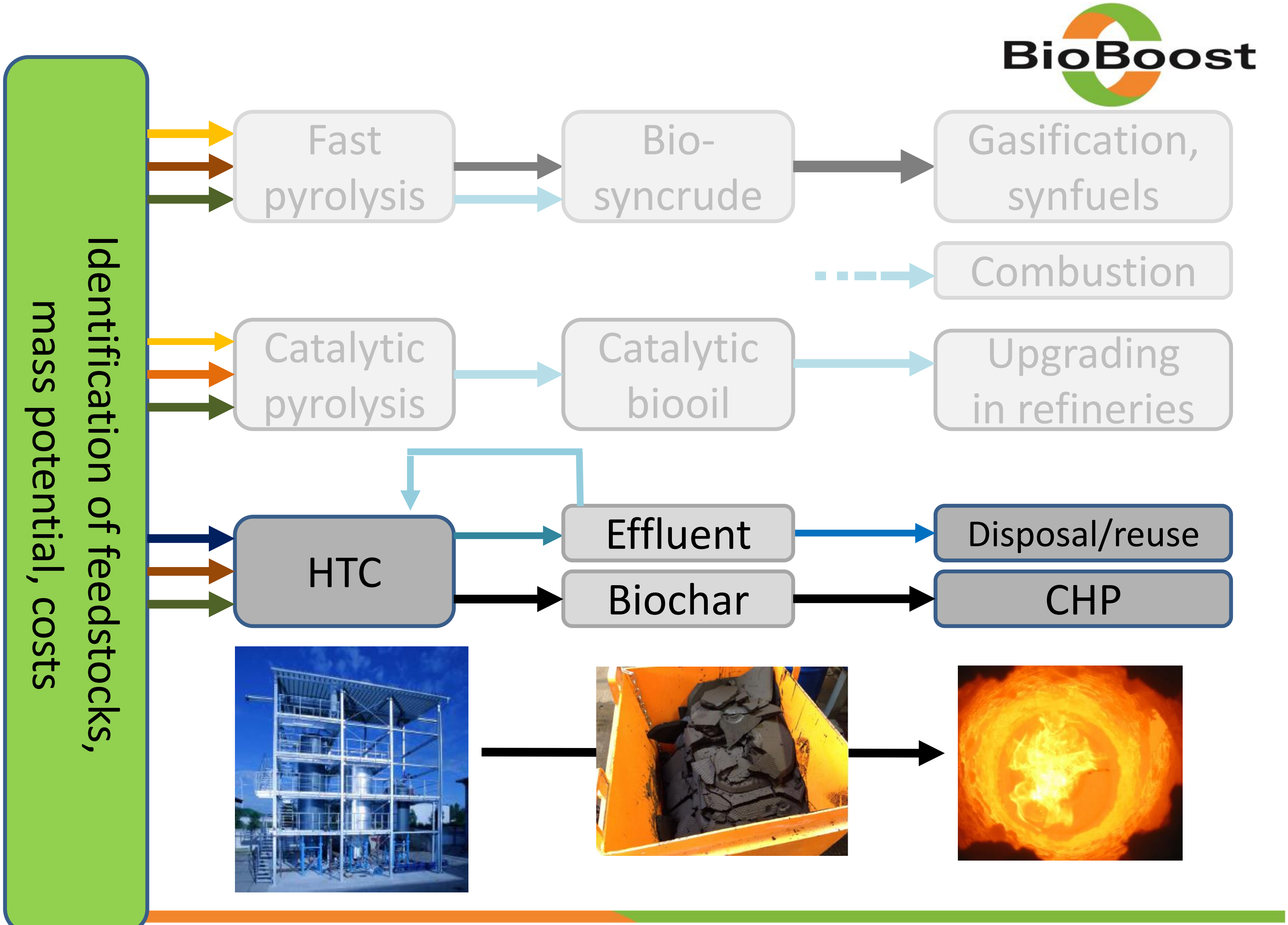
Identification of feedstocks, mass potential, costs

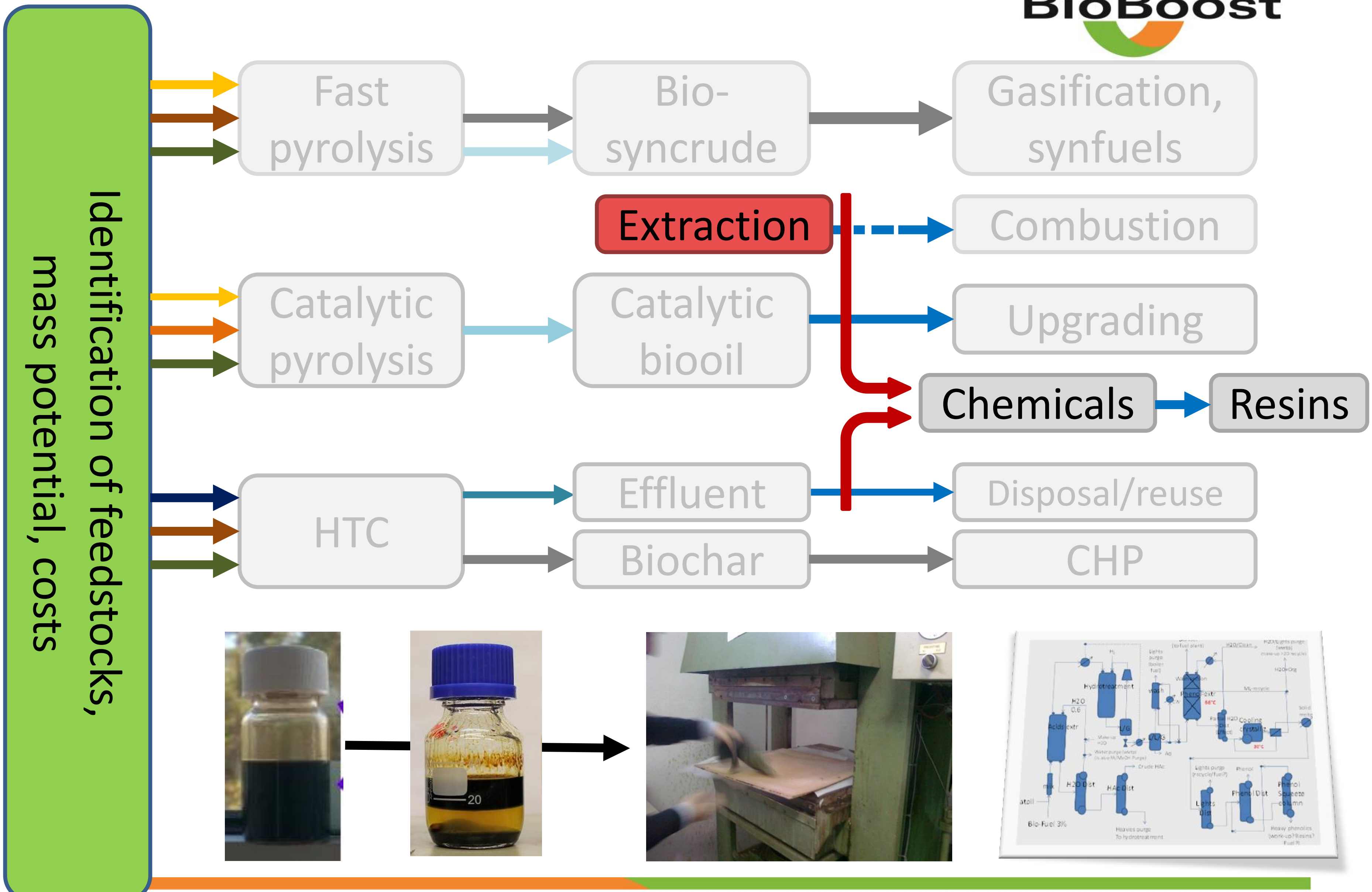
Fast pyrolysis → Bio-syncrude → Gasification, synfuels

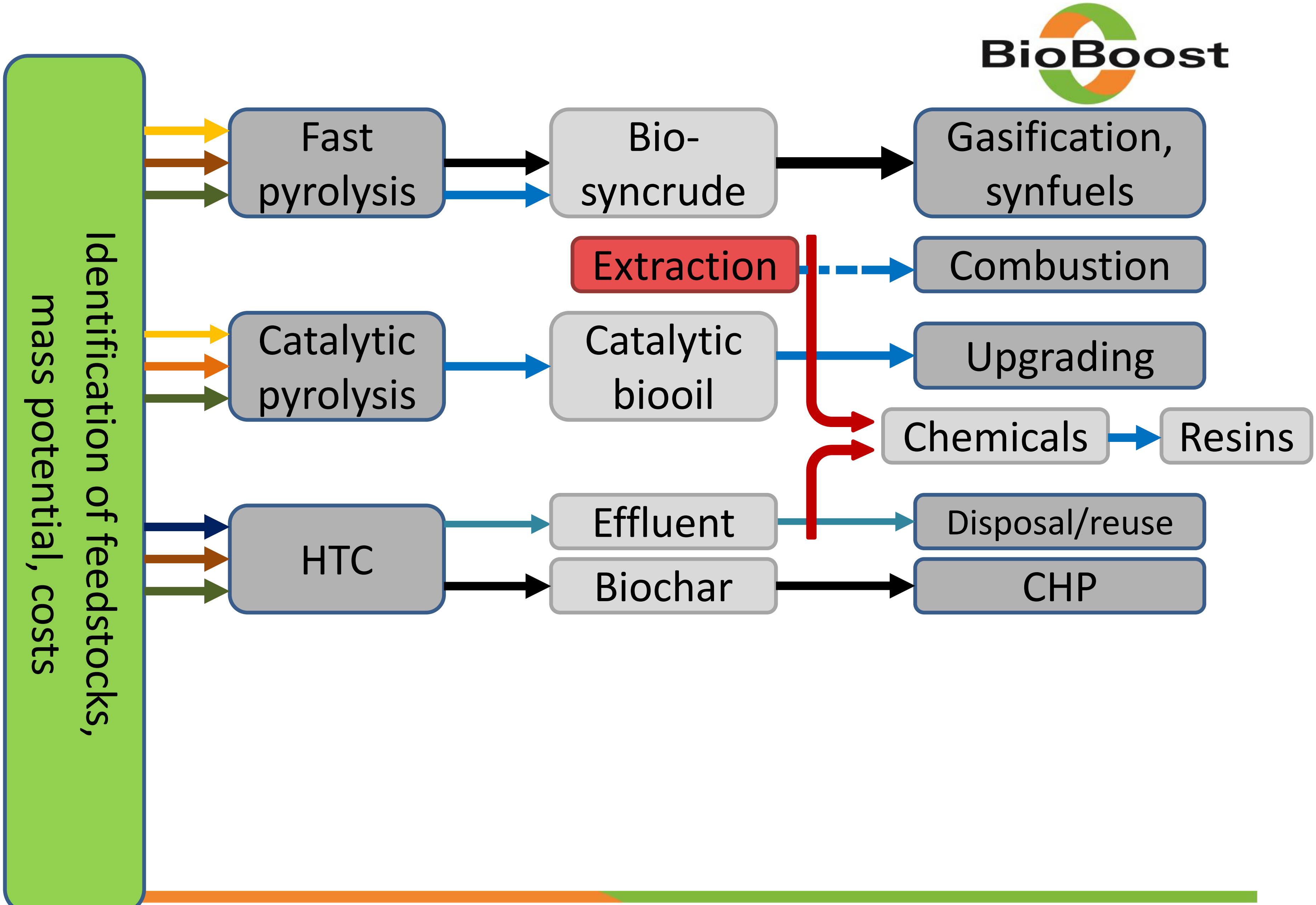
Combustion

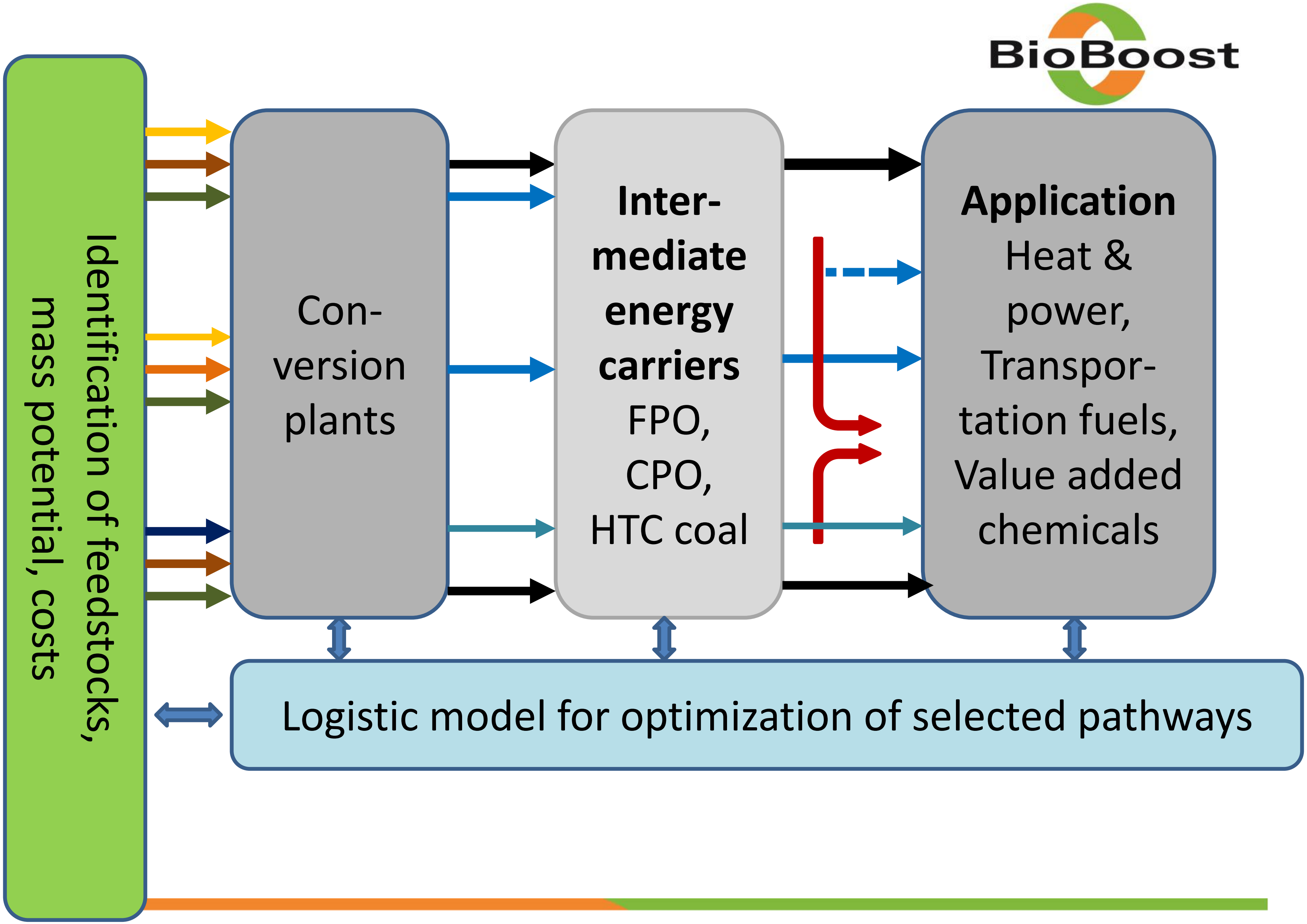
Catalytic pyrolysis → Catalytic biooil → Upgrading in refineries

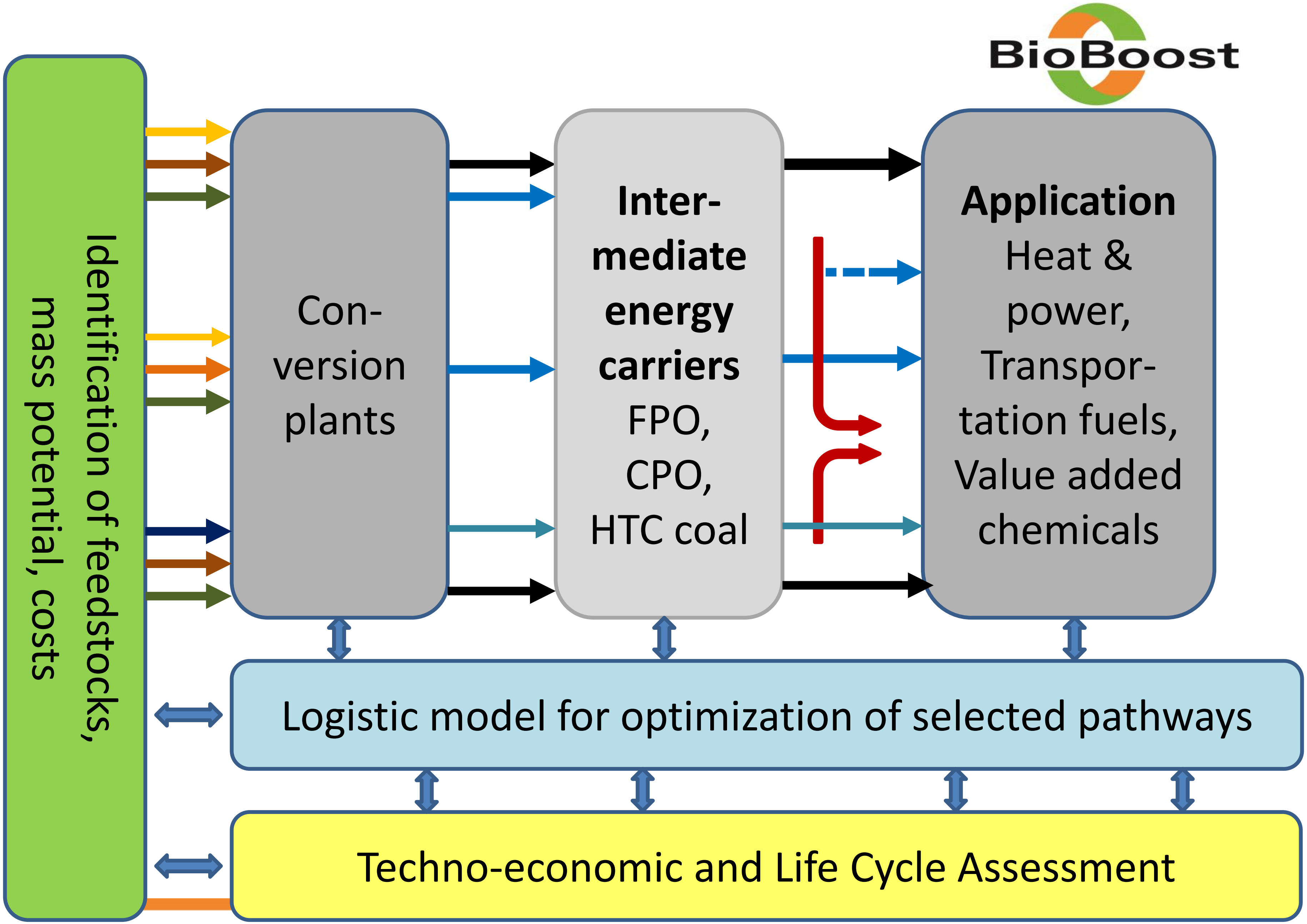



BioBoost
Identification of feedstocks, mass potential, costs
Fast pyrolysis
Bio-syncrude
Gasification, synfuels
Combustion
Catalytic pyrolysis
Catalytic biooil
Upgrading in refineries
HTC
Effluent
Biochar
Disposal/reuse
CHP


Identification of feedstocks, mass potential, costs
Fast pyrolysis
Bio-syncrude
Gasification, synfuels
Extraction
Combustion
Catalytic pyrolysis
Catalytic biooil
Upgrading
Chemicals
Resins
HTC
Effluent
Disposal/reuse
Biochar
CHP
20


BioBoost
Identification of feedstocks, mass potential, costs
Fast pyrolysis
Bio-syncrude
Gasification, synfuels
Extraction
Combustion
Catalytic pyrolysis
Catalytic biooil
Upgrading
Chemicals
Resins
HTC
Effluent
Disposal/reuse
Biochar
CHP


BioBoost
Identification of feedstocks, mass potential, costs
Con-version plants
Inter-mediate energy carriers
FPO, CPO, HTC coal
Application
Heat & power, Transpor-tation fuels, Value added chemicals
Logistic model for optimization of selected pathways


BioBoost
Identification of feedstocks, mass potential, costs
Con-version plants
Inter-mediate energy carriers
FPO, CPO, HTC coal
Application
Heat & power, Transpor-tation fuels, Value added chemicals
Logistic model for optimization of selected pathways
Techno-economic and Life Cycle Assessment

Partners

13 Partners from
6 European countries

7 Companies
2 Universities
4 Research Organisation

CERTH

Achievements

BioBoost

Technology

- Optimized process parameters and design
- Products characterized, specified and conditioned according to application
- Production of samples
- Flow scheme development

Methodology

- Potential studies
- Optimization tools
- Scenario evaluation
- Assessment tools
- Chemical analysis
- Application tests

Scenario Simulation

- Regional feedstock
- Optimized value chains
- Interaction between elements of network
- Market implementation plans

Dissemination

- Geoportal (public geo-information server)
- Logistic model (Web-navigator)
- 7 public workshops
- BioBoost film

Overarching outcomes

- Considerable Readiness Level and reliability improvement in process and product development
- Optimization of all conversion technologies and products towards specific applications
- Value chain of bioenergy carriers can be improved by co-producing chemicals
- Optimized transportation, conversion and logistic scenarios by simulation along the complete process chain, may later networks

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 282873

SECTOR

Production of Solid Sustainable Energy Carriers from Biomass by Means of TORrefaction

Technology Achievements in SECTOR

Speaker: Michiel Carbo, ECN

Place and Date: Brussels, SECTOR- Bioboost Workshop, 17th June 2015






This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Torrefaction: state-of-the-art

- Torrefaction technology in demonstration phase with >10 demo-units and first (semi-)commercial units in operation
- Successful co-firing trials aid to build-up end-user confidence and allow product quality optimisation, e.g.:
  - Buggenum IGCC (NUON, 2012)
    - 1200 ton pellets
    - Co-milling
    - Up to 70% co-firing (energy basis)
  - Amer 9 (Essent, end of 2013)
    - 2300 tonne Topell pellets
    - 5-25 wt% co-milling
    - 1-4 wt% co-firing
  - Studstrup 3 (DONG, March 2014)
    - 200 tonne Andritz pellets
    - Dedicated mill
    - 33 wt% co-firing
  - Helsingin Energia Hanasaaren (March 2014)
    - 140 tonne Torr-Coal pellets
    - 14 wt% co-firing

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

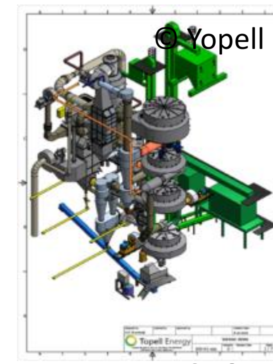
Torrefaction technologies

Different technologies

Moving bed
(ECN)
pilot

Rotary drum / Auger
(Umeå University)
pilot

Rotary drum
(CENER)
pilot



Toroidal
(Topell Energy)
demo

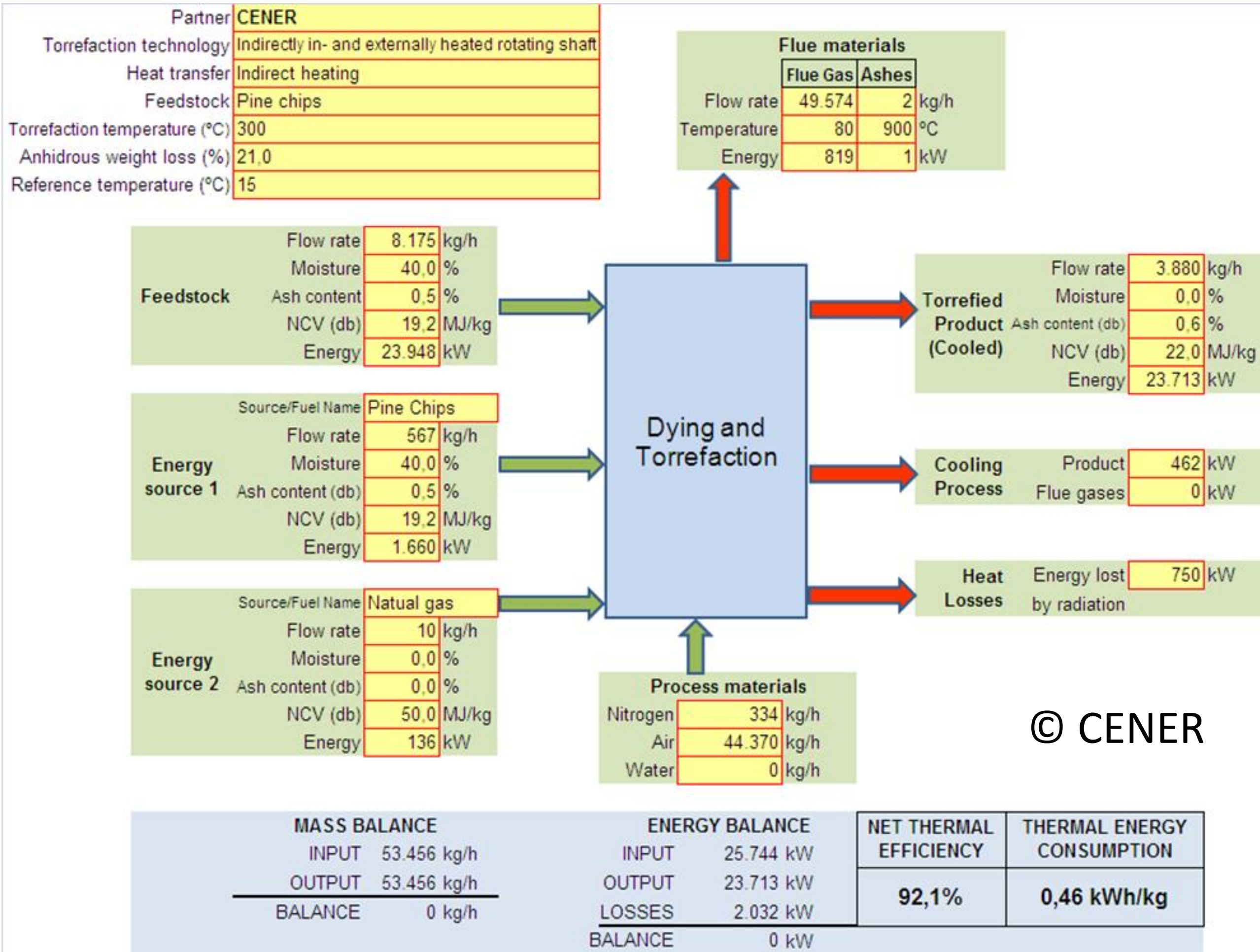
Production with available **pilot scale facilities**
Typical test runs 50-100 hours
Typical production per test few tonnes
3-6 different feedstocks

Production with available **demo plant**
Continuous operation
Production of 100-200 tonnes
Specific feedstock

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

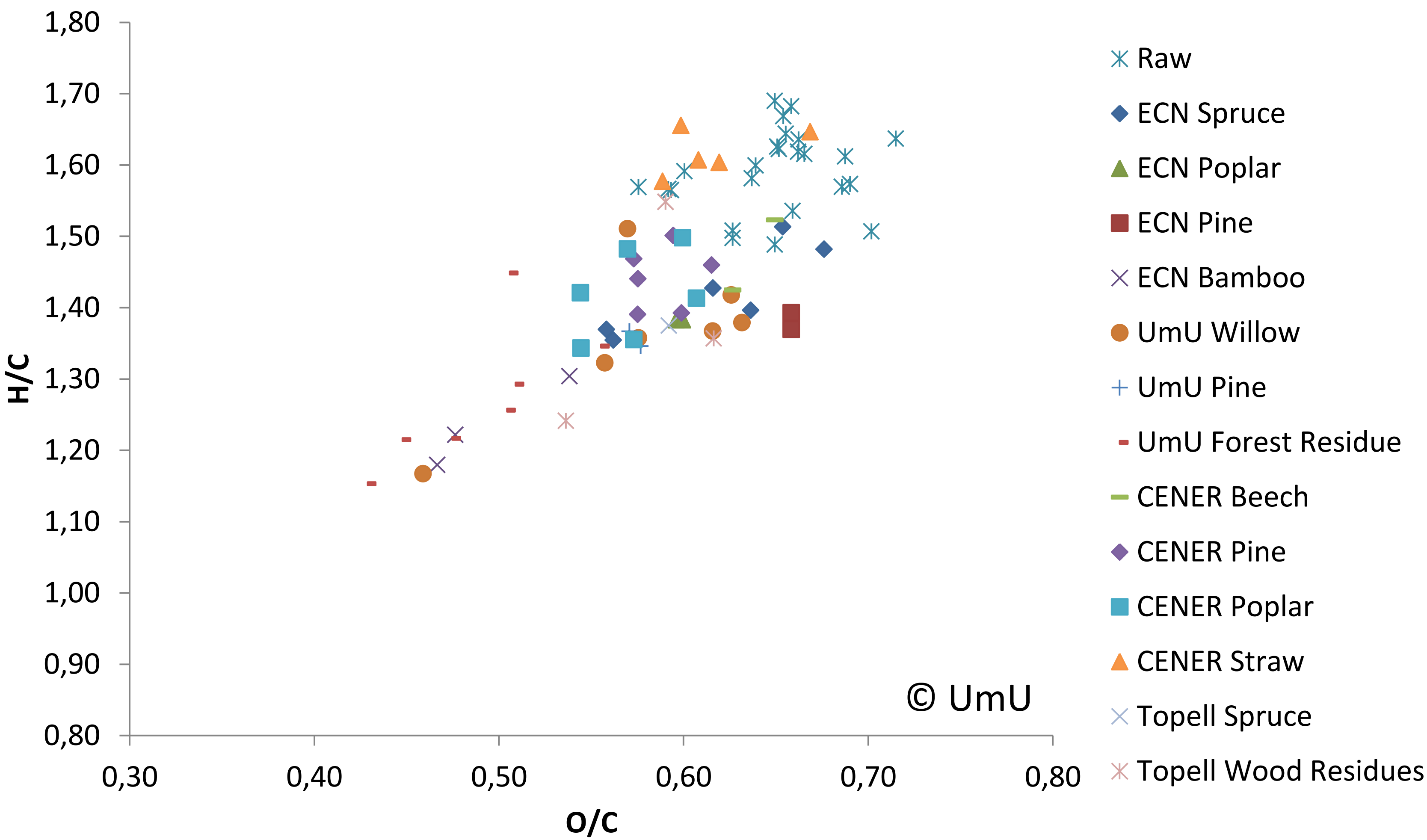
Torrefaction: Pilot-scale torrefaction tests (CENER)

- Mass and Energy balances prepared for pine by CENER, ECN & UmU



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Torrefaction: Feedstock and product analysis (UmU)



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Densification: Pilot-scale tests (CENER)

Optimised parameters:

- Particle size of feedstock
- Moisture content of feedstock
- Torrefaction degree of feedstock
- Die diameter/length ratio
- Die rotation speed

Date	Durabili	
October 2012	88.8	
January 2013	92.3	
June 2013	94.7	
November 2013	95.7	

Date	Durability	Straw
ebruary 2013	84.2	
ptember 2013	94.3	
October 2013	96.6	
November 2013	97.6	

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Demonstration (Topell)

<u>January 2012-November 2012</u>

- Production of large amounts of pellets, out of specifications of receivers
  - high ash content
  - low durability
  - high content in dust and fines

<u>November 2012-June 2013</u>

- Major overhaul plant
  - Change combustor
  - Heat integration
  - Densification process
  - Optimisation of product quality

<u>July 2013-December 2013</u>

- Production of several thousand tons torrefied forest residues pellets
  - Successful production runs 4-6 tons/h
  - Developed production recipies for different feedstocks
  - Optimisation of biomass pre-conditioning and product quality accomplished
  - Increased product quality met specifications of utilities

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Logistics: Small-scale tests

- Kilo-gram-scale uncovered open air storage tests

CENER

UmU

OFI

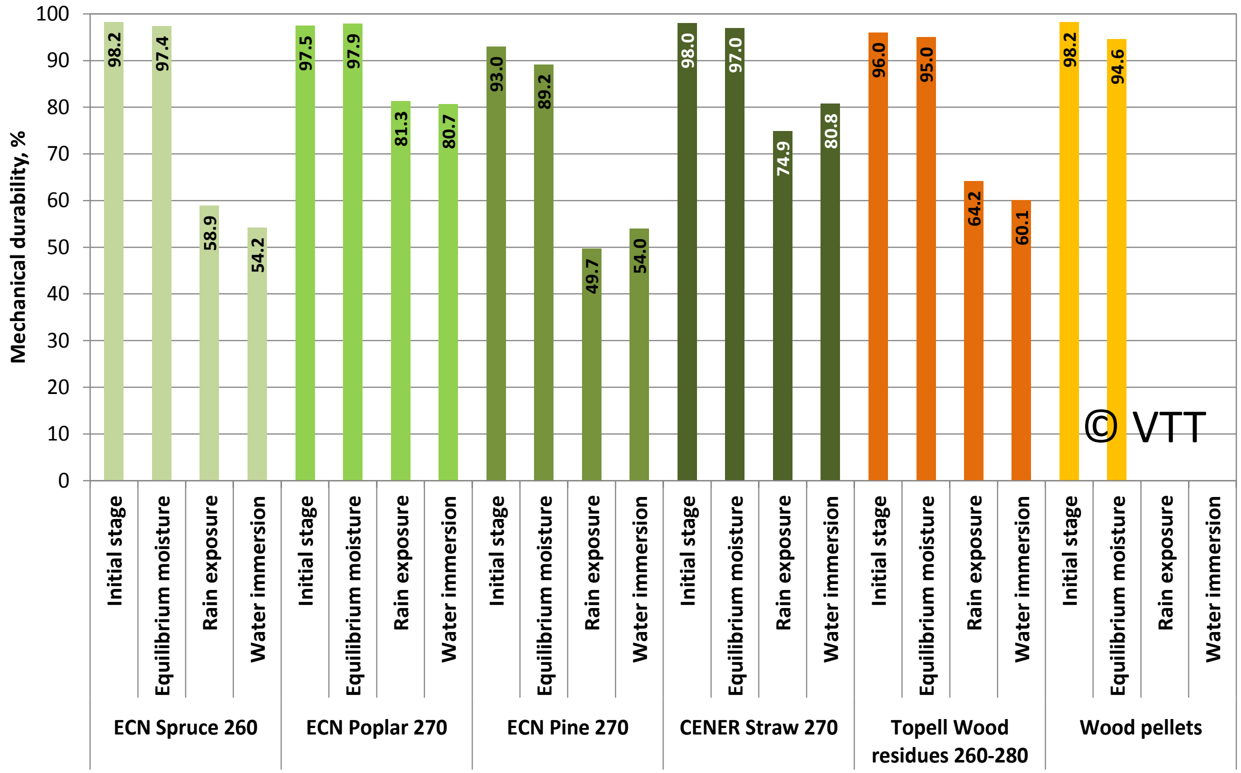
ECN

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

SECTOR Production of Solid Sustainable Energy Carriers from Biomass by Means of TORrefaction

Logistics: Small-scale tests (VTT)

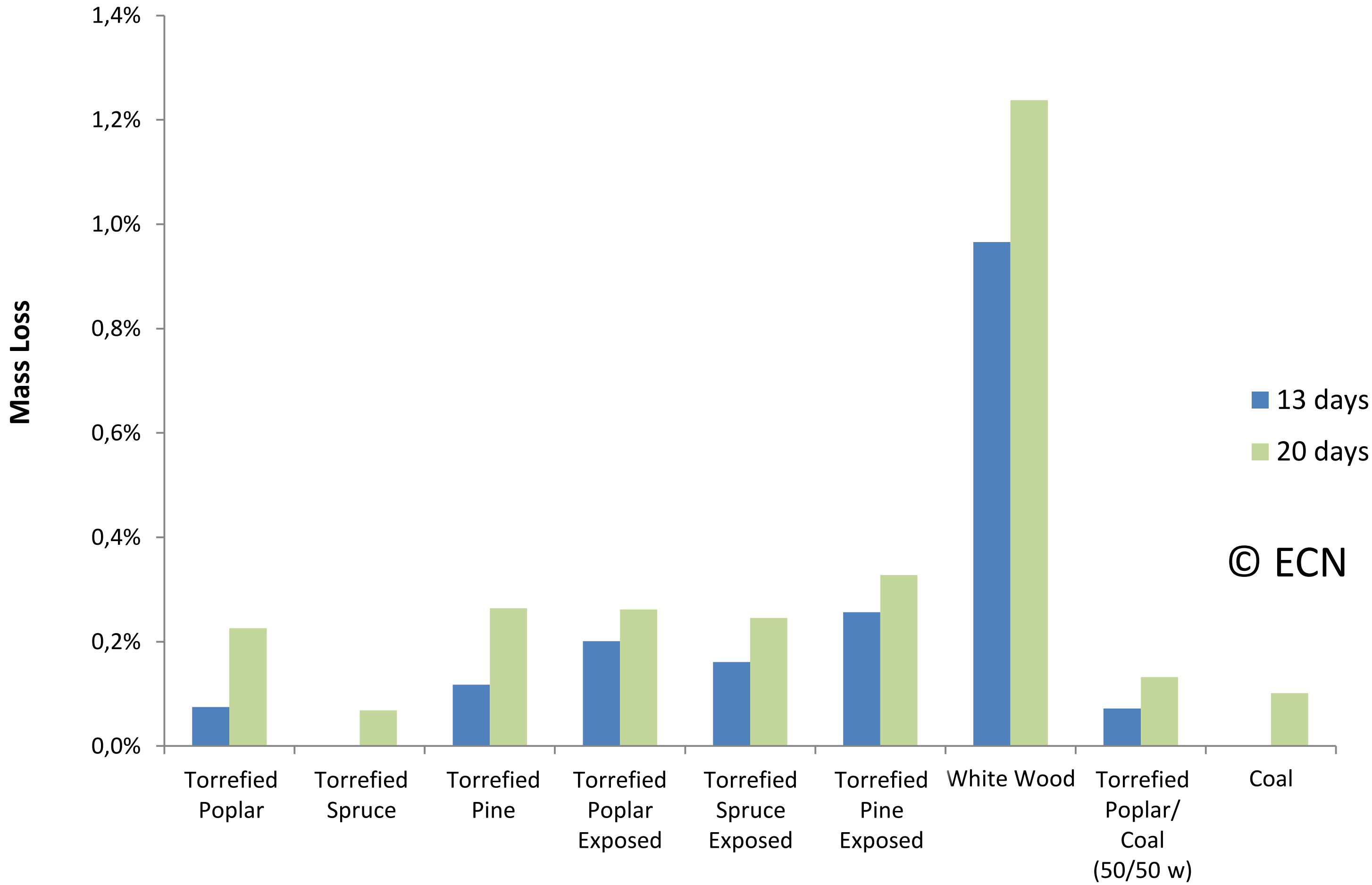
- Durability of pellets has been determined after exposure testing by:
  - ECN, VTT, CENER, UmU, OFI



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Logistics: Small-scale tests (ECN)

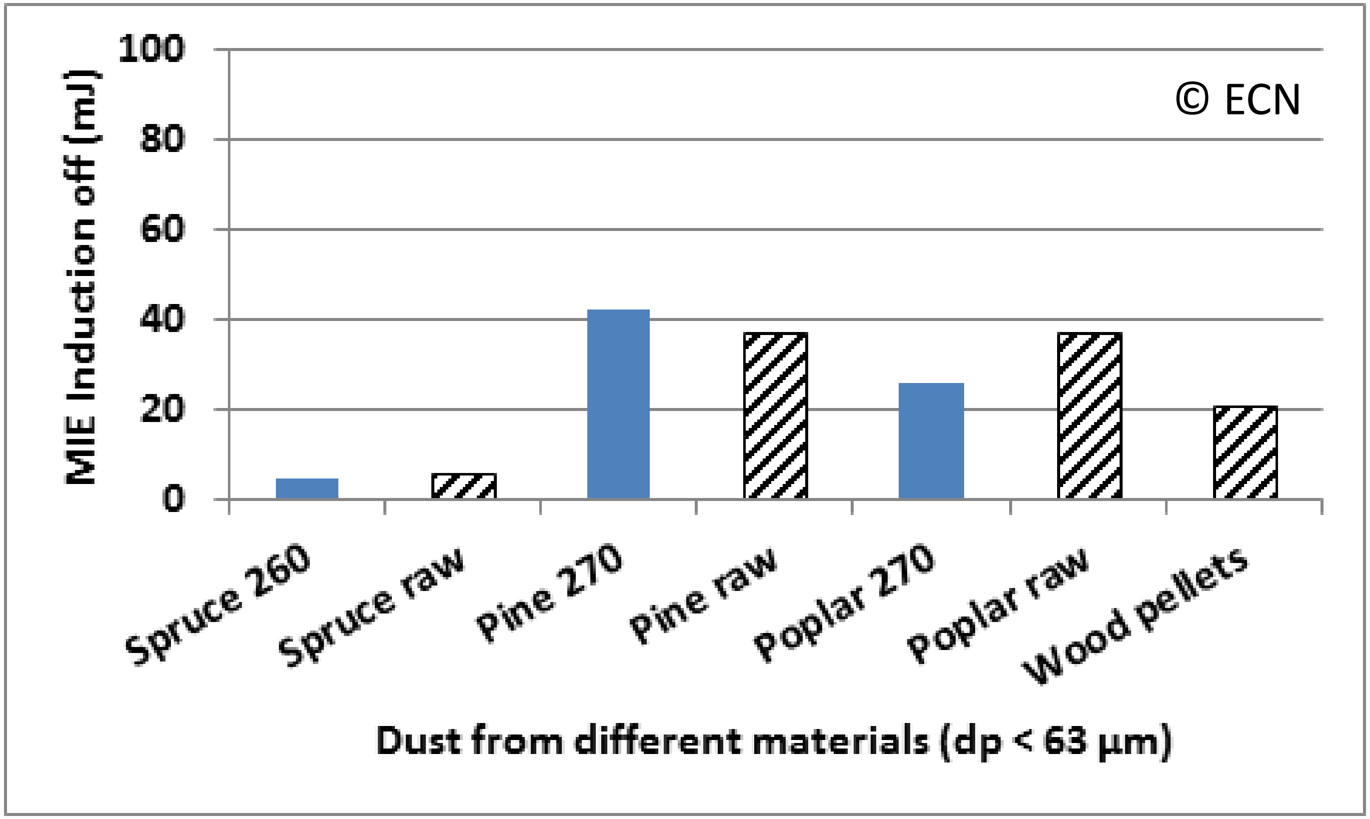
- Biological degradation (exposure at 20°C and RH 95%)



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Logistics: Small-scale tests (ECN)

- Explosivity characteristics before/after torrefaction (pulverised torrefied pellets vs. pulverised raw material)



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

SECTOR Production of Solid Sustainable Energy Carriers from Biomass by Means of TORrefaction

Logistics: Outdoor storage tests (EON)

Two outdoor storage piles built in June 2013

Peaked-topped pile

- Model the formation of piles after it has been delivered
- 4 tonnes
- 2.34 x 2.36 x 1.5 m^3

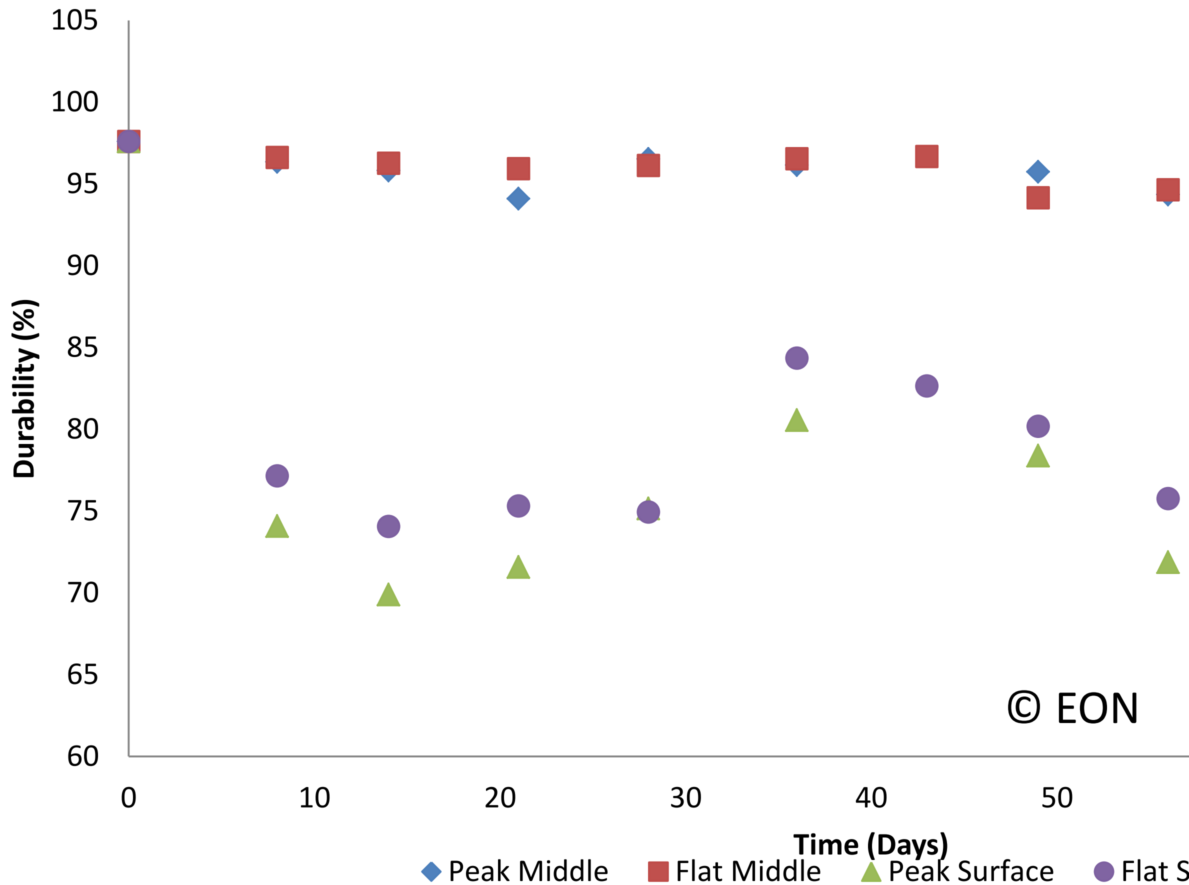
Flat-topped pile

- Model the formation of piles after compaction (though no compaction occurred)
- 3 tonnes
- 2.34 x 2.36 x 1.5 m^3

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Logistics: Outdoor storage tests (EON)

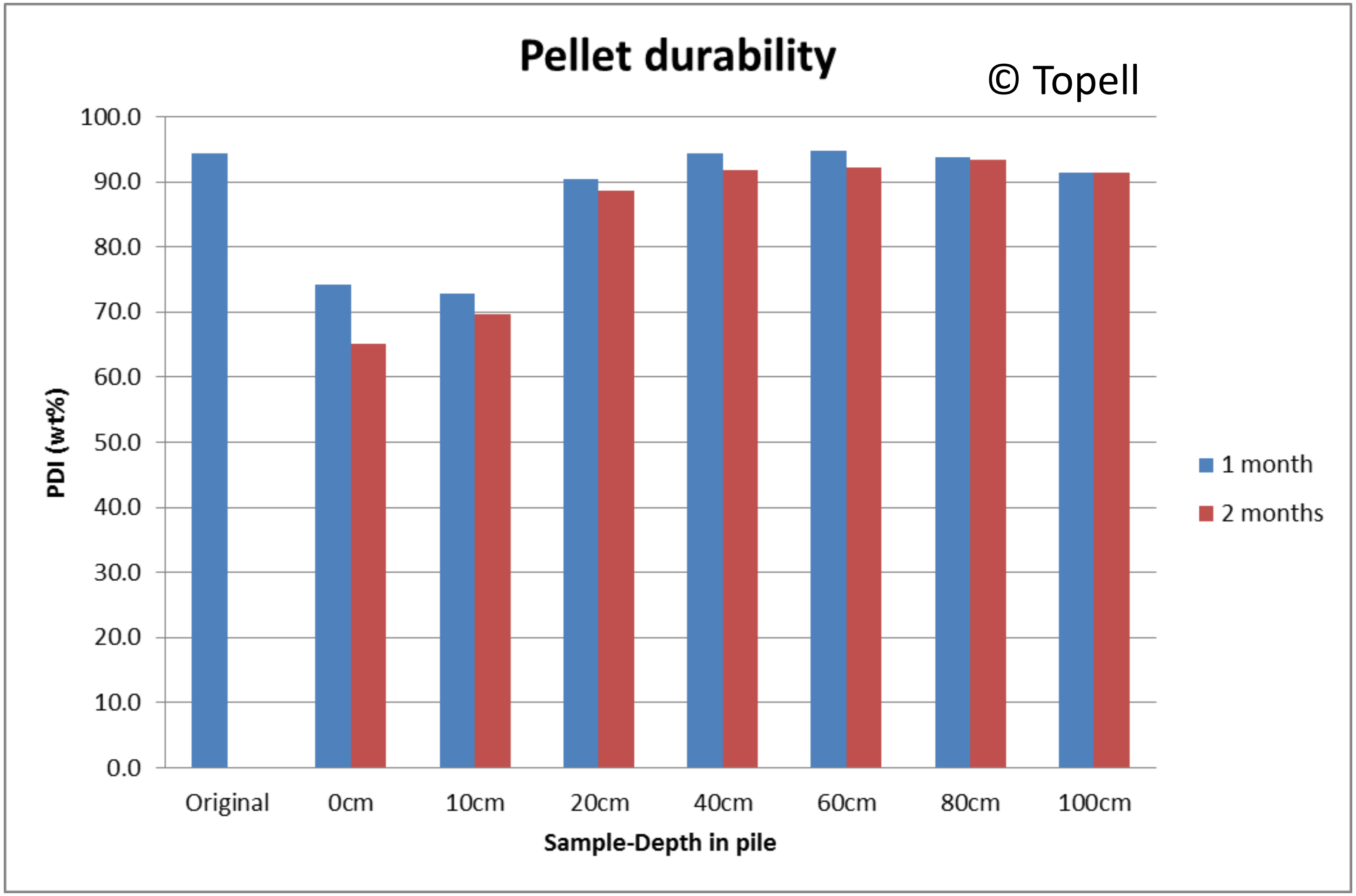
- Pellet durability as function of time



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

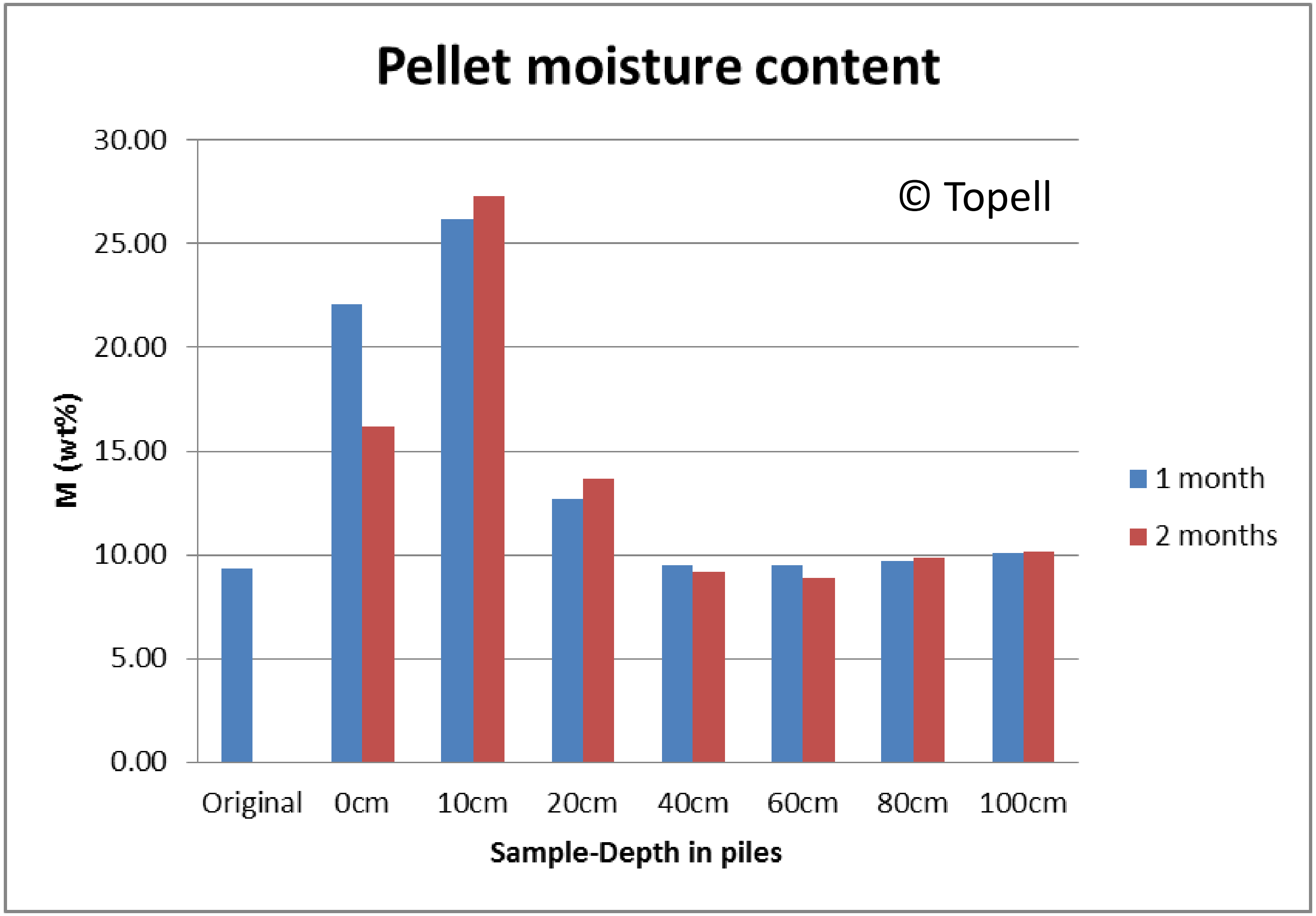
Logistics: Outdoor storage tests (Topell)

- Pellet durability as function of height in pile



Logistics: Outdoor storage tests (Topell)

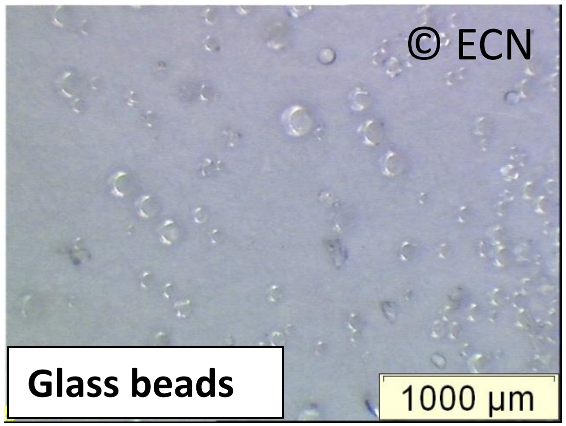
- Moisture content as function of height in pile

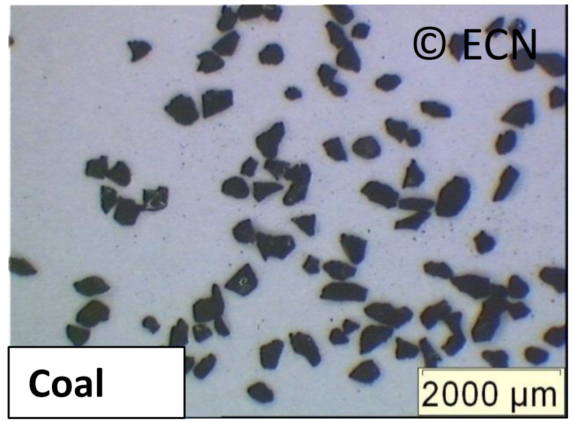


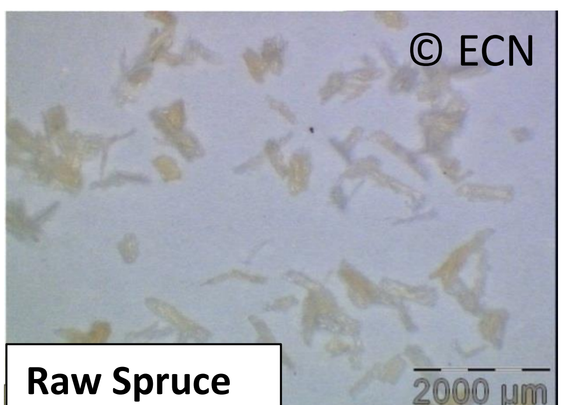
This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

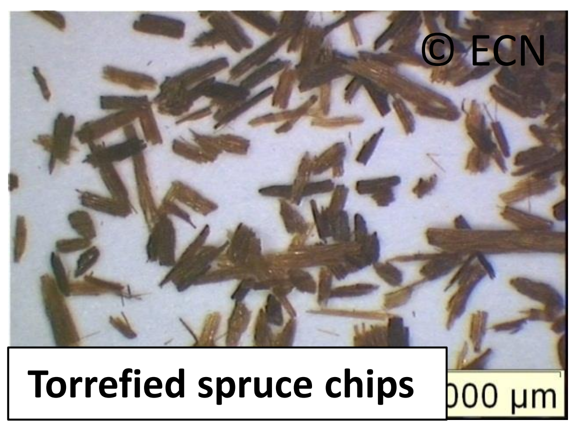
End use: Milling and feeding (ECN)

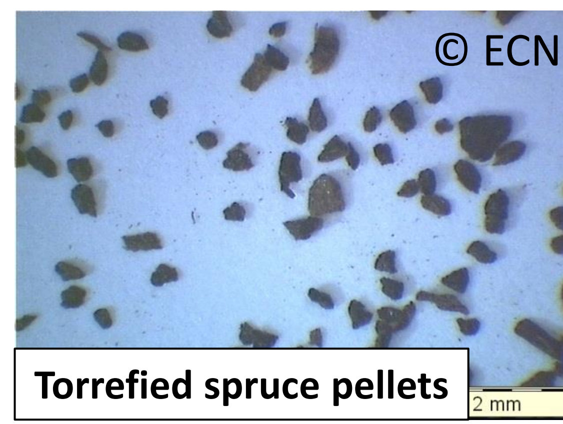
- Importance of particle morphology







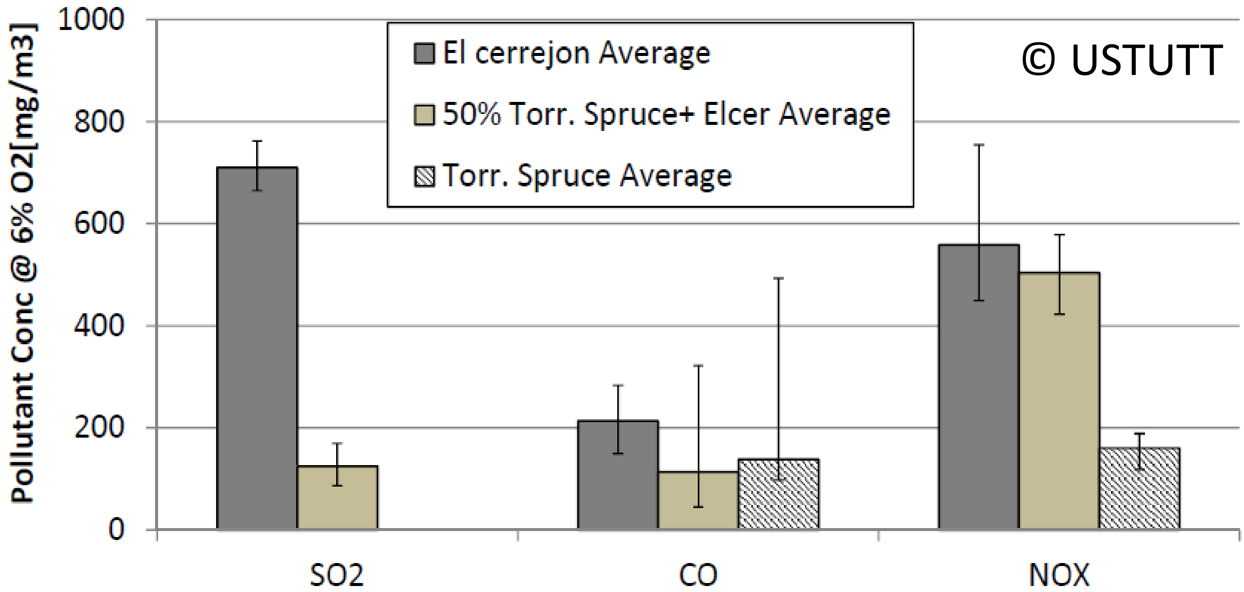




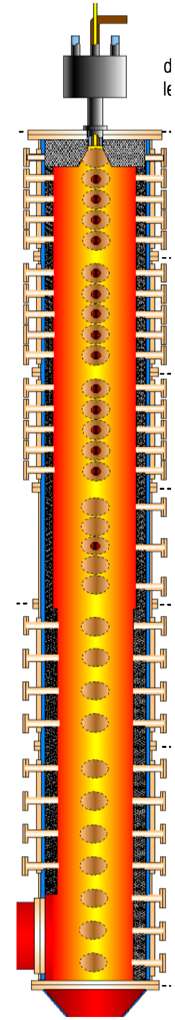
This project has received funding from the European Union’s Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

End use: Co-firing in PF boilers (USTUTT, Procede)

- Emission measurements during (co-)firing of torrefied pellets



Decrease in SO_2 and NO_x basically due to lower S and N fuel content. Staging will further reduce NO_x



- CFD predictions of CO, O_2, CO_2 and NO_x and temperature distribution (by PROCEDE) at furnace outlet match with experiments
- 11 types of torrefied biomass pellets were tested, with thermal firing share up to 100%

USTUTT's KSVA, 500 kW, 8 m length

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

End use: (Co-)gasification in EF gasifiers (Vattenfall)

NUON/Vattenfall Buggenum IGCC Plant:

- 253 MW_e power plant, entered service in 1993 as a coal gasification demonstration plant, closed in 2013
- Hard coal as main fuel with continuous co-gasification of saw dust up to 15 wt%
- Trial (outside SECTOR, but results brought in):
    - 1200 tonnes of torrefied biomass pellets co-gasified with hard coal during 24 hours trial
    - 70% torrefied biomass pellets on energy basis

Main observations during tests in 2012:

- No large technical challenges during conveying, sluicing and milling of torrefied biomass pellets/coal blend
- Estimated to be possible to achieve at least 90% of the plant nominal capacity without major modifications in the fuel feeding system
- Higher heating value in the pellets connected to better milling properties but less advantageous dust formation behaviour

This project has received funding from the European Union’s Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

End use: Commercial pellet boilers (TFZ, BIOS, BE2020)

- Torrefied pellets can be used in commercial small-scale wood pellet boilers and may provide the same or even higher combustion efficiency as obtained with wood pellets:
  - Slightly higher fixed carbon content in torrefied pellets vs. need for burnout time (adaptations of grate and burnout zone possibly required)
  - Air ratio and air-staging may require some adaptations
  - Pollutant emissions (CO, VOC, NOx and PM) depend on wood resources used, similar as for wood pellets. Higher expected fuel bed temperatures may lead to higher fine particle emissions
  - Ash and slag related problems may occur earlier due to higher ash content
- Fuels need to be certified by boiler manufacturers, therefore field tests over a full heating period are needed to obtain approval

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Standardisation: Round robin tests - standard methods (OFI)

- Round Robin I (RRI)– Validation of "standard" test methods for torrefied forest residue pellets
  - 43 Participants (19-41 participants per parameter)
  - 17 Countries
  - 11 Parameters

Parameter	Method/ Standard
Bulk density	acc. EN 15103
Mechanical durability	acc. EN 15210-1
Moisture content	acc. EN 14774-1 or 2
Ash content	acc. EN 14775
Calorific value	acc. EN 14918
Content of chlorine and sulphur	acc. EN 15289
Content of volatile matter	acc. EN 15148
Content of carbon, hydrogen, nitrogen	acc. EN 15104
Content of major elements	acc. EN 15290
Content of minor elements	acc. EN 15297
Ash melting behaviour	acc. CEN/TS 15370

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Standardisation: Results of Round Robin I (OFI)

- Comparison of results with solid biofuels performance from BIONORM II Round Robin test
  (project no. 038644 founded by European Commission)
  - **Ash**, **moisture content**, **chlorine** and **sulfur content**, **CHN** analysis – comparable
  - **Net calorific value** – reproducibility limit is higher than for solid biofuels
  - **Ash melting behavior** – reproducibility of deformation temperature is high; subjective method
  - **Minor elements** – low concentration/close to detection limits (as for solid biofuels)
  - **Mechanical durability** and **bulk density** no comparable validation available

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Fuel specification and classes, EN ISO 17225-8 (VTT)

- Thermal treatment includes processes, such as:
  - Torrefaction
  - Steam treatment (explosion pulping)
  - Hydrothermal carbonization and charing
- SECTOR project suppors drafting of standard and development test methods
- Drafting standard is carried out under WG2 of ISO/TC238
- 109 comments (data input) collected for 3 treatment processes
- Problem: some of the properties are based on raw material and some on technology

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Fuel specification and classes, EN ISO 17225-8 (VTT)

- TW classes for different net calorific values
  TWt Qd > 21 MJ/kg and TWs Qd < 21 MJ/kg

Property	TW1t	TW1s	TW2t	TW2s	TW3t	TW3s
Moisture, M, w-% wet basis	8	10	8	10	10	
Net calorific value as received, MJ/kg	21.0	16.9	20.0	16.9	18.7	16.0
Mechanical durability, DU, w-%	97.5		96		95	
Bulk density, BD kg/m^3	700		650		550	650
Ash, A, w-% dry	1.2		3.0		5.0	
Fines, F, w-%	1		4	2	6	3

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Fuel specification and classes, EN ISO 17225-8 (VTT)

Thermally treated woody biomass (TW) and non-woody (TA)

- For fines and moisture footnote to be added all tables
  - Moisture and fines to be stated at the point of delivery
- TW1 targeted for residential use
  - For TW1 maximum 4% additives (earlier 10%)
  - For TW1 Cd 0,5,Cr 10 and Cu 10 mg/kg dry as for wood pellets classes in ISO 17225-2
- TW2 S0.05 and TW3 S0.1 for pellets and briquettes
- TW2 Cd 1 and TW3 Cd 2.0 for pellets and briquettes
- Moisture for TW briquettes to M10
- S for TA1 to 0.1 and TA3 to 0.2 mg/kg dry

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Fuel specification and classes, EN ISO 17225-8 (VTT)

- Schedule for ISO 17225-8 standard

Action	Who	When
DIS draft to WG2 comments	WG2 secretariat	Mid of August 2015
Draft that modifications according the meeting have been taken care of	WG2 members	End of August 2015
DIS document to SIS	WG2 secretariat	Mid of September 2015
DIS ballot (2 translations+ 3 months ballot) (technical comments)	ISO	Until mid February 2016
WG2 meeting connected to ISO/TC 238 meeting, discussion of DIS comments	WG2 members	End of April 2016
FDIS document (if DIS approved)	WG2 secretariat	Early autumn 2016
FDIS ballot (only editorial comments)	ISO	Autumn 2016
International standard published	ISO	End of year 2016

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Market Readiness

- Torrefaction technology is ready for commercial market introduction and the basic drivers for torrefaction still hold
- But several factors slowed down this introduction, including:
  - European utility sector is facing difficult times – co-firing perhaps not the best launching end-user market (also in view of scale) – smaller-scale industrial or district heat perhaps a better option?
  - It takes time and effort to build end-user confidence
  - Instead of yielding immediately *the* ideal feedstock, torrefied biomass pellets development had to follow a learning curve, just as with white wood pellets
  - Biomass in general is under debate and opinions on biomass use are changing
- Many constructive and successful efforts have been made within this project to remove the barriers for market introduction
- Near-future torrefaction R&D should focus on:
  - Product quality characterisation, optimisation and standardisation (addressing torrefaction *and* densification)
  - Broadening feedstock base (including lower-quality biomass: agroresidues, SRF, etc.)
  - Torrefaction as part of co-production schemes for bioenergy carriers and high added value products
  - Separation/recycling of inorganic components

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

thank you very much!

Speaker: Michiel Carbo
e: michiel.carbo@ecn.nl

e: info@sector-project.eu
w: www.sector-project.eu

This project has received funding from the European Union’s Seventh Programme for research, technological development and demonstration under grant agreement No. 282826

Center for Research and Technology Hellas (CERTH)
Chemical Process & Energy Resources Institute (CPERI)

Policy Workshop on improved bioenergy carriers of the EC-projects BIOBOOST and SECTOR

Technology Achievements in BIOBOOST

Angelos A. Lappas
Research Director CPERI/CERTH

Brussels, 16^{th} – 17^{th} June, 2015

SEVENTH FRAMEWORK PROGRAMME

OUTLINE

- **Introduction-The BioBoost FP7 EU project**
- **Technology Achievements in Thermal Pyrolysis**
- **Technology Achievements in Catalytic Pyrolysis**
- **Technology Achievements in Hydrothermal Carbonization**
- **Conclusions**

THE BIOBOOST FP7 EU PROJECT

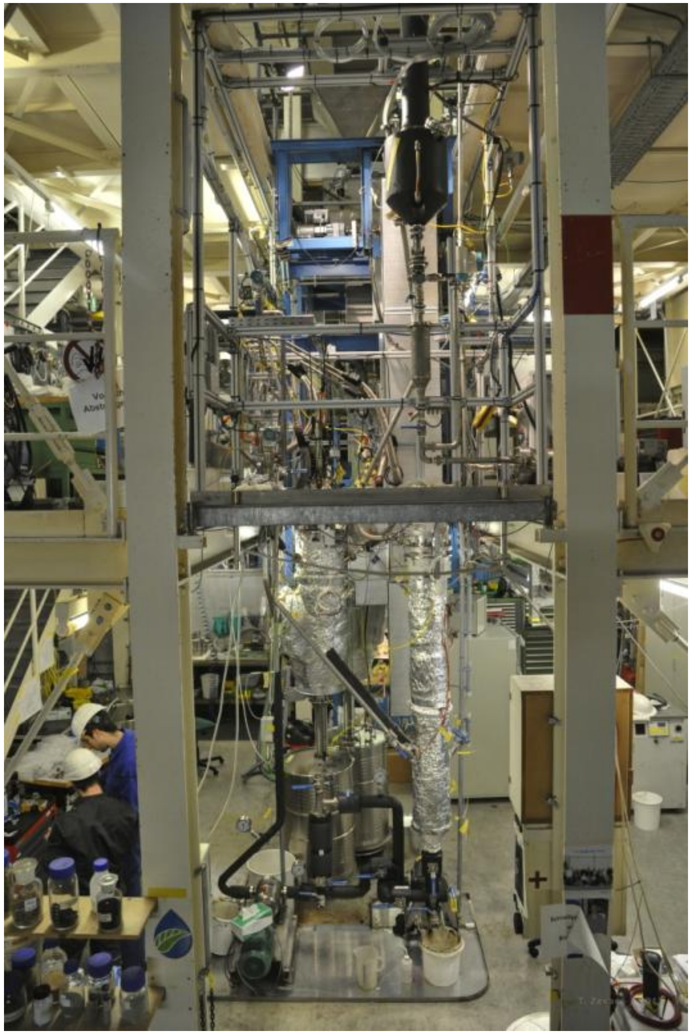
- BioBoost concentrates on dry and wet residual biomass and wastes as feedstock for de-central conversion by Fast Pyrolysis (FP), Catalytic Pyrolysis (CP) and Hydrothermal Carbonisation (HTC) to the intermediate energy carriers (EC) oil, coal or slurry.
- A logistic model for feedstock supply and techno/economic and environmental assessment of the value chain supports the optimization of the EC
- Application of EC is investigated for heat and power production, synthetic fuels & chemicals and as bio-crude for refineries.

THERMAL (FAST) PYROLYSIS

(KIT)

FAST PYROLYSIS (KIT)

Optimization at Process Demonstration Unit (PDU)



Retrofitted process demonstration plant (10 kg h^{-1}) at KIT referred to as **PDU Version II**

Optimization at Process Demonstration Unit (PDU)

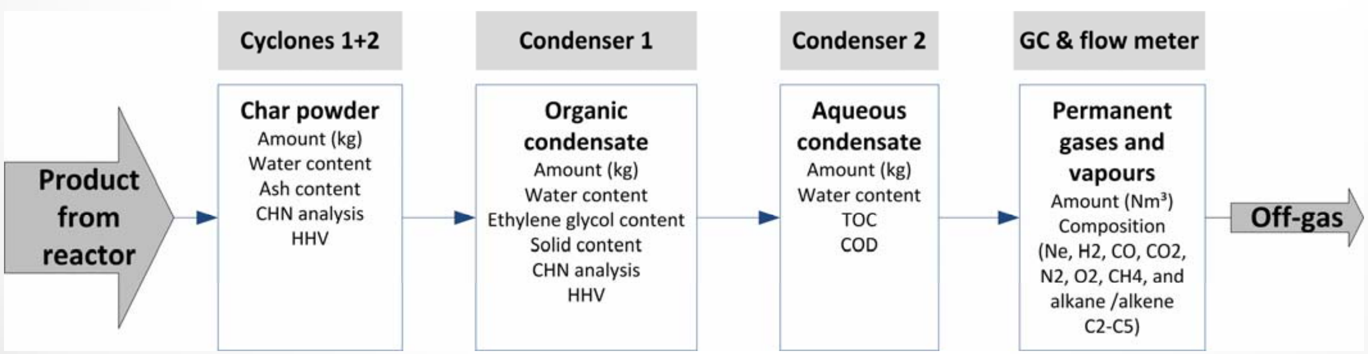
- **Testing of 3 feedstocks (properties in Del. 2.1):**
  - **Wheat straw**
  - **Miscanthus**
  - **Scrap wood**



- **5 test days for mass- and energy balances with wheat straw and 4 for each of miscanthus and scrap wood**

- **At steady-state, biomass fed to the reactor for about 3 to 4 hours with 6-10 kg/h (30 kg feedstock per test day pyrolyzed**

- **Analyses performed:**



Optimized Mass yields and Products in PDU V II

	Wheat straw	Miscanthus	Scrap Wood
Water content biomass (ar), %	*9.6*	*10.0*	*15.2*
Ash content biomass (ar), %	*9.2*	*2.3*	*1.4*
HHV (ar), MJ/kg	*16.8*	*17.4*	*16.7*
Char (ar), %	18.7	11.9	12.9
thereof ash, %	*39.8*	*16.4*	*11.4*
HHV (ar), MJ/kg	*19.6*	*27.3*	*29.1*
Condensate 1 (ar), %	42.8	48.5	50.1
thereof water, %	*33.6*	*24.6*	*32.8*
HHV (ar), MJ/kg	*13.4*	*17.5*	*15.3*
Condensate 2 (ar), %	10.5	16.1	11.3
thereof water, %	*74.9*	*74.5*	*73.6*
HHV (ar), MJ/kg	*5.5*	*5.2*	*5.4*
Gas (ar), %	28.0	23.6	25.8
thereof water, %	*6.0*	*4.4*	*5.0*
HHV (ar), MJ/kg	*6.0*	*9.3*	*9.5*

Mass yields of products as received in PDU Version II incl. ash respectively water content and high heating values, HHV

Products received with Version II of the PDU

Char

Organic and aqueous condensate

Assessment of the product recovery options investigated

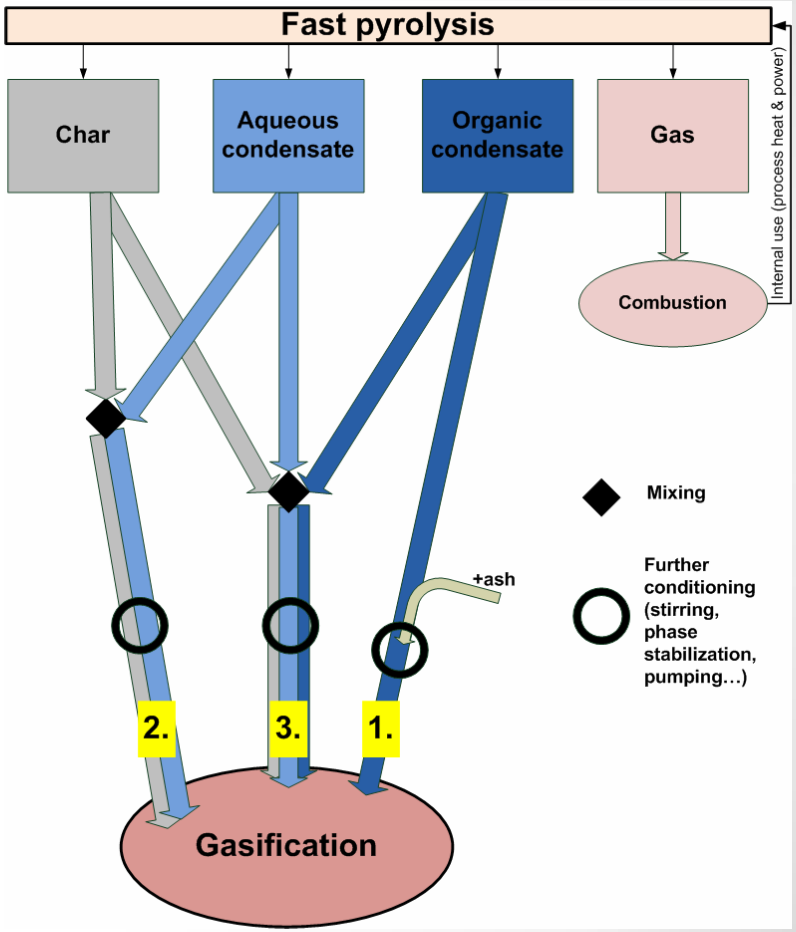
	Version I 'char crumbs'	Version II 'dry char and organic condensate'
Safety of product handling	+	-
Flexibility in the adjustment of condensation temperatures	+	o
Flowability of products	-	+
Product flexibility (respective processing/utilization)	--	++
Complexity of plant setup	o	-
Scale-Up	o	+

- **Both strategies of product recovery at PDU scale worked technically well**
- **Separation of wet char crumbs shows some advantages compared to the separation of dry char powder, especially in relation to safety aspects**
- **Higher flexibility for the utilization of the pyrolysis products in case of a separate recovery of the products**
- **Organic condensate as gained in the modified PDU and bioliq®-pilot plant is flowable and pumpable, i.e. to handle with standard equipment and less effort than the sticky char crumbs produced in the former setup**
- **Separate product recovery as utilized in the modified PDU and the pilot plant seems to be the better option**
- **Expected better scalability**
- **Product fractions can be mixed more flexibly to a slurry and thus can be adjusted to the needs and specifications of the gasifier**
- **Availability of separate product fractions as char, organic and aqueous condensates creates an additional value by alternative utilization**

FAST PYROLYSIS (KIT)

Energy carriers for entrained flow gasification

- For the use of the FP EC in gasification for the production of chemicals and fuels the following three forms of EC are the most promising:
  - Organic condensate (+ ash from biomass)
  - Slurry of aqueous condensate + char
  - "All-in-one"-slurry of the three product fractions: Aqueous condensate, organic condensate, char
- Option no.1 and no.2 can be produced and conditioned in a way that enables use in gasification
- Large gasifiers (several 100MW) will have independent feed lines – for safety reasons and flexibility – so it is possible to feed one line with organic condensate (+ ash) and another one with a slurry of aqueous condensate + char (+ash).
- Option no. 3 is not yet technically feasible due to stability problems (further research is necessary).



Energy carriers for entrained flow gasification

BioBoost

The timeline illustrates the advancement in the utilization of different feeds in the pilot gasifier of the bioliq® process.

2013
- Ethylene glycol + wheat straw ash

2014
- Ethylene glycol + milled beech-wood char + wheat straw ash

2014
- Ethylene glycol + milled wheat straw char

2014
- Tar conden-sate + beech-wood char + wheat straw ash
- Or + wheat straw char

2015
- Aqueous conden-sate + milled wheat straw char

2015
- Organic conden-sate from wheat straw + wheat straw ash

R&D
- Use of various bio-masses
- All-in-one-slurries: All condensates + chars

Further R&D:

- **Enhancements in pyrolysis process: Reduction of water content**
- **Other feeding forms: Pastes by extrusion ....**

FP CONCLUSIONS

- **BIOBOOST results obtained are very helpful for the progressions on applicability of pyrolysis products for gasification and the market implementation of pyrolysis products as energy carriers also beyond gasification.**

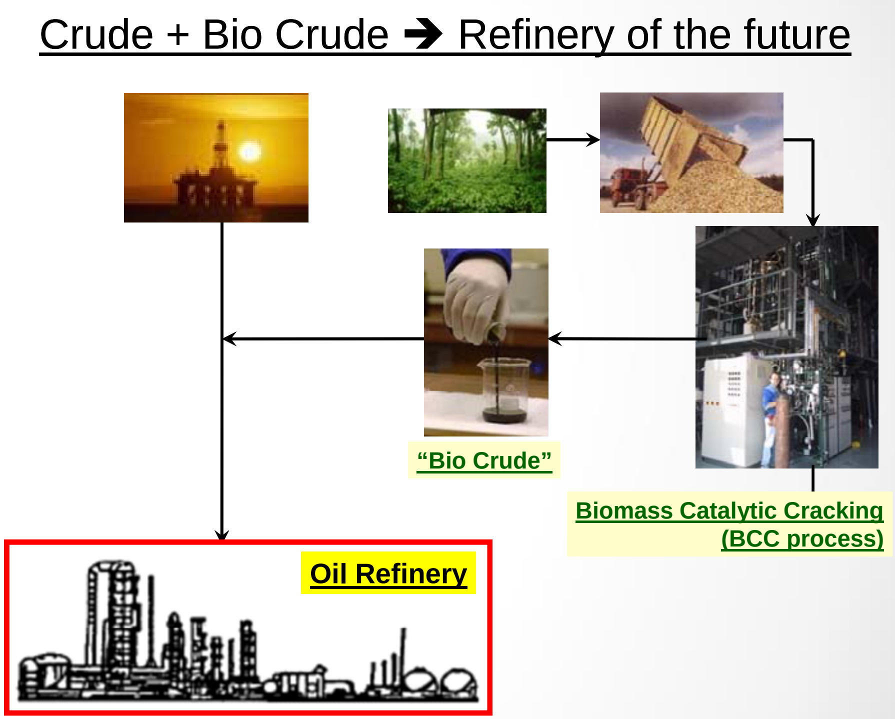
- **Biosyncrude – either as flowable slurry or non-flowable paste – can be customized according to the specifications for the following applications in a wide range.**

- **The knowledge gained during this project needs to be exploited in coming research activities, as there are still wide gaps in the understanding of processes during production and handling of the energy carriers.**

THE CATALYTIC FAST PYROLYSIS –CFP-PATHWAY (CERTH)

FAST PYROLYSIS (FP) vs. CATALYTIC FAST PYROLYSIS (CFP) OF BIOMASS

- **FP: thermo-chemical process for the production of liquids, solids and gaseous products**
  - **a solid heat carrier is used**
- **CFP: solid catalyst as heat carrier for in-situ upgrading of pyrolysis products aiming at the production of liquids (bio-oil) with better quality:**
  - **less O_2**
  - **improved stability and acidity**
  - **processing into existing refineries**
- **CFP oil can be a decentralized energy carrier (bio-crude) to be used in refineries**



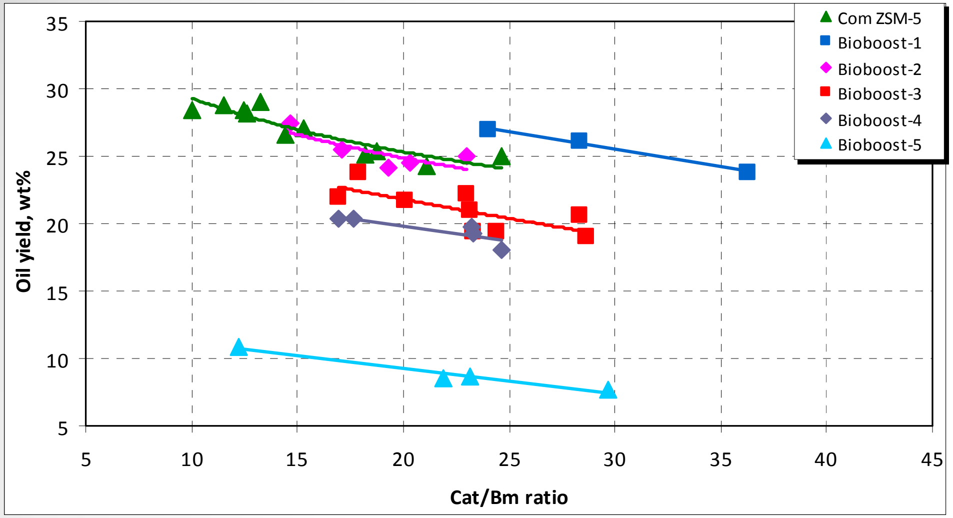
CATALYSTS USED IN BIOBOOST

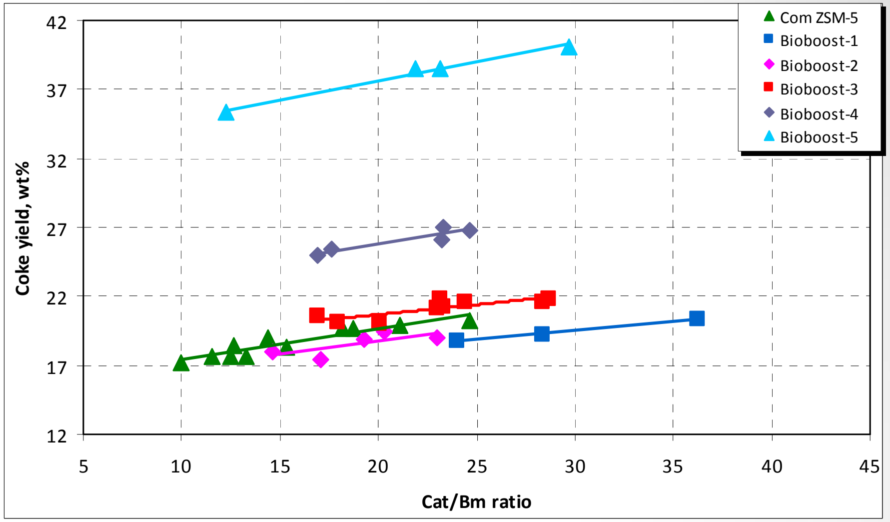
- **15 new catalysts (synthesized by Grace) and 5 commercially available fresh catalysts were pre-screened on a bench scale fixed bed pyrolysis reactor in CERTH.**

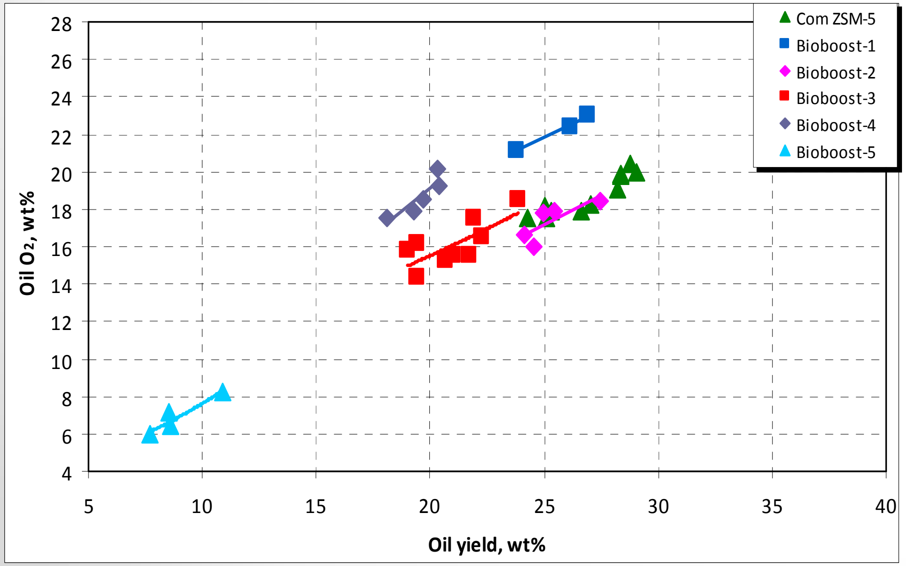
- **The five best catalysts were selected and scaled up in Grace at 20 kg level using spray-dried techniques.**

- **All these five catalysts as well as the best commercial catalyst were tested on pilot scale in CPERI.**

BIOBOOST Catalyst Evaluation on Pilot Scale with Woody Biomass

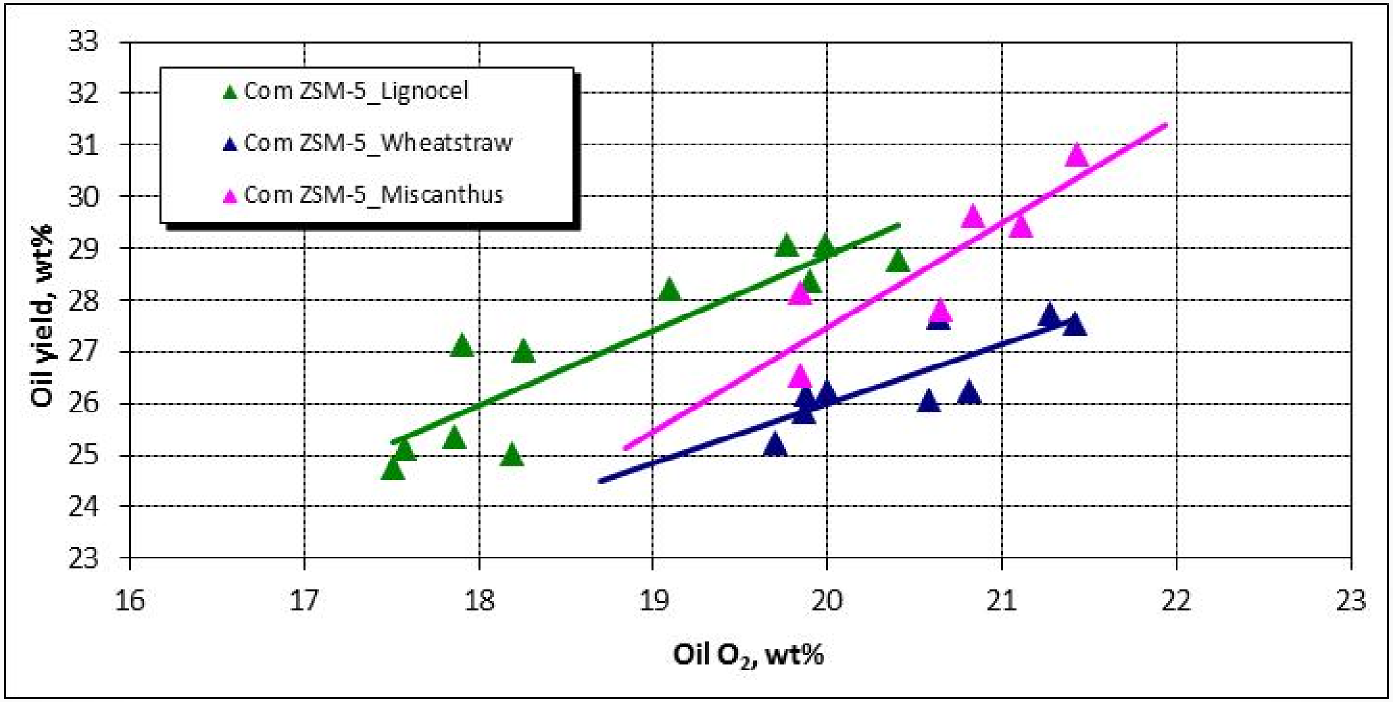






- Higher C/B ratios accelerate cracking reactions resulting in a lower oil yield
- Catalyst activities differ significantly
- Coke selectivity is crucial in CFP
- Cat-2 is the best catalyst and at the same Oil yield gives 1% less O2 compared with the state of the art commercial ZSM-5 catalyst

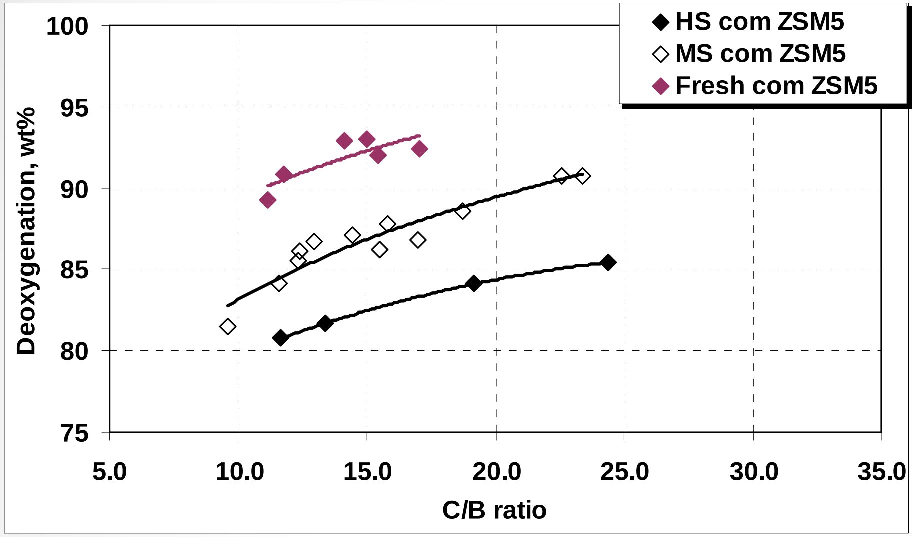
BIOBOOST Feed Effects: O_2 and Oil



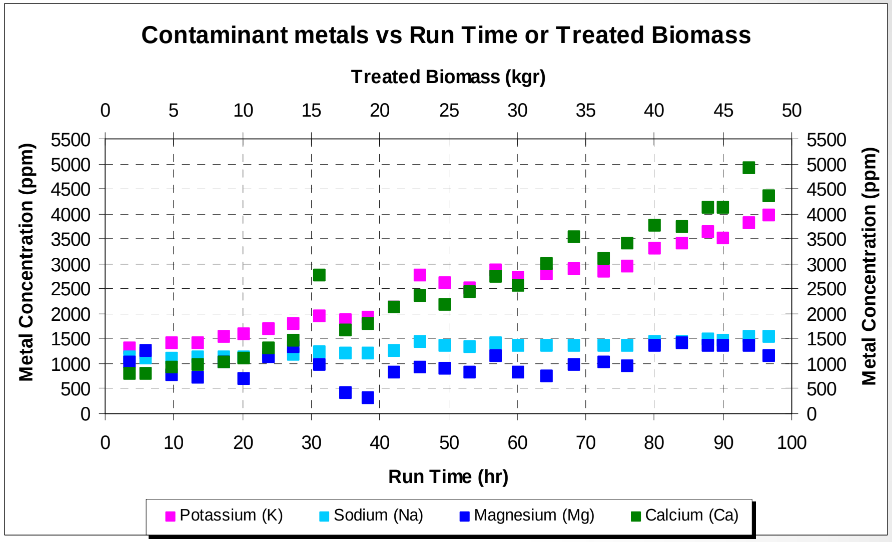
- **The woody biomass produces the highest oil yield with the same O_2 content followed by miscanthus and straw**

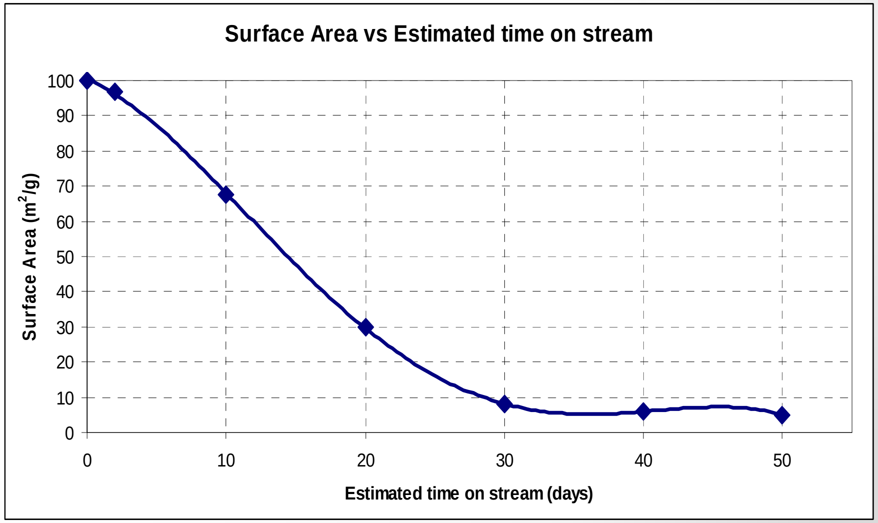
DEACTIVATION OF CFP CATALYSTS

Hydrothermal Deactivation



Metals Deactivation





- **Biomass metals are deposited on the catalyst with a deposition rate of at least 55%**
- **An ash metals spray-impregnated/steamed study in GRACE showed that CFP catalyst is stable up to about 10-20 days time on stream. Then zeolite is largely destroyed.**

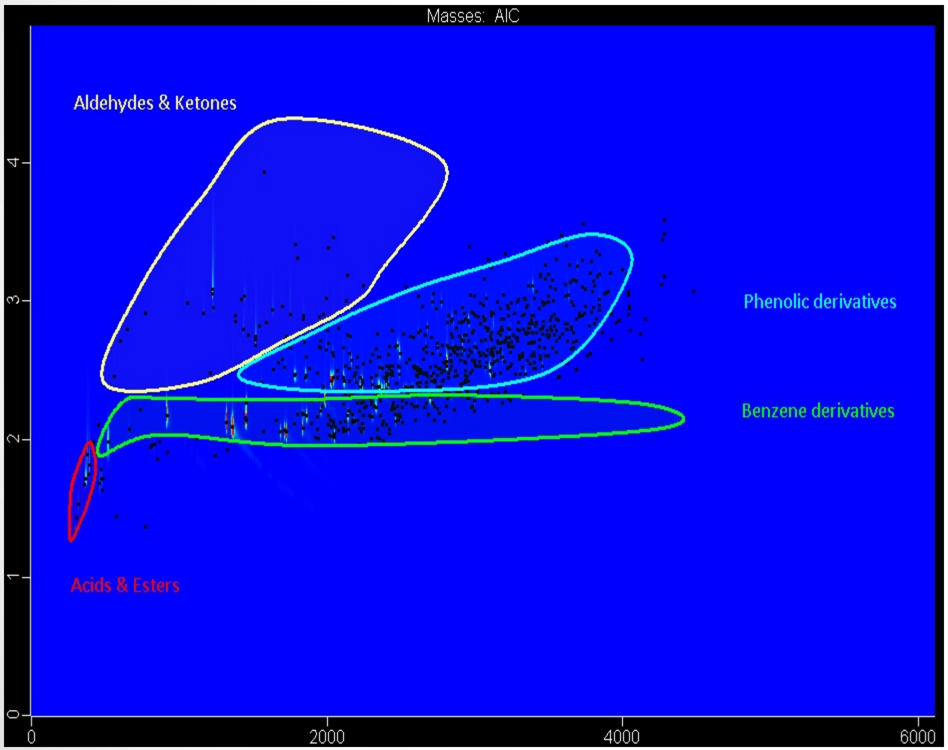
Characterization, handling and storage of CPO in CERTH

Storability of CP bio-oil

	0 months	stored in a cool room at 4°C, in dark for 6 months	stored in a cool room at 4°C, in dark for 12 months	stored in a cool room at 4°C, in dark for 18 months	stored in a cool room at 4°C, in dark for 22 months	stored in a cool room at 4°C, in dark for 27 months	accelerated ageing at 40°C for 7 days	accelerated ageing at 80°C for 24 hrs
C %	69.66	68.68	68.07	69.27	67.88	68.85	68.19	68.66
H %	7.8	7.17	7.27	5.7	6.12	7.53	7.00	7.04
O %	22.54	24.13	24.65	25.01	25.98	23.61	24.79	24.28
S (ppmwt)	n.a.	157	145.3	154.2	157.2	146.8	155.5	150.3
Density (g/mL)	1.1206	1.1237	1.1280	1.1317	1.1297	1.1308	1.1283	1.1269
Viscosity, 50°C (cSt)	13.6913	16.2569	-	25.8866	25.787	28.1242	23.9342	20.3159
HHV (MJ/kg)	29.5161	29.2492	29.6627	29.3934	29.3636	29.1754	29.5210	29.2832
TAN (mgKOH/g)	40.4036	41.5490	39.1287	40.9398	40.5965	41.0389	44.1220	41.4673
H2O (%wt)	6.5	6.4308	6.1026	5.8399	7.8162	7.5	6.8924	7.0882
Copper Corrosion	n.a.	1A	1A	1A	1A	1A	1A	1A

Excellent stability and storability of CPO

ORGANIC PHASE QUANTIFICATION OF CPO WITH 2DGC-TOFMS



Compound	% w/w	Group	Total %w/w
Benzene, 1,3-dimethyl-	4.77	**AR**	**16.35**
Benzaldehyde, 4-hydroxy-3,5-dimethoxy-	2.77	ALI	0.20
Phenol	2.47	**PH**	**20.55**
Toluene	2.11	FUR	2.07
Naphthalene, 2-methyl-	2.09	AC	0.00
Vanillin	2.08	EST	0.01
Phenol, 3-methyl-	1.93	AL	0.10
Phenol, 2,5-dimethyl-	1.80	ETH	0.08
Phenol, 2-methyl-	1.56	ALD	5.39
2-Cyclopenten-1-one	1.55	KET	5.18
Benzene, 1,2,3-trimethyl-	1.30	PAH	4.34
1,2-Benzenediol	1.22		
2-Propenal, 3-phenyl-	1.13		
Ethylbenzene	1.11		
Benzene, 1-ethyl-4-methyl-	1.10		
Benzaldehyde	1.02		
2-Methylindene	0.94		
Naphthalene, 1,7-dimethyl-	0.94		
2-Methylindene	0.89		
Indane	0.85		
Total $_{\textbf{Top 20 compounds}}$ **(% w/w)**	33.60		
Determined % w/w of total biooil	54.53		

- **Absence of levoglucosan**
- **Lower Acids concentration**
- **Increased peak number in the aromatic hydrocarbons area**

STATE OF THE ART ON CPO WITH ZSM-5

	CPO (BIOBOOST PROJECT)	TPO
H_2O content, %wt	5.0	25
C, %wt (dry basis)	77.5	53.0
H, %wt (dry basis)	6.5	7.5
O, %wt (dry basis)	16.0	39
TAN, mgKOH/g	25	80
HHV, MJ/Kg	31.5	20
Density, gr/cm^3	1.09	1.2
Stability	very good	medium

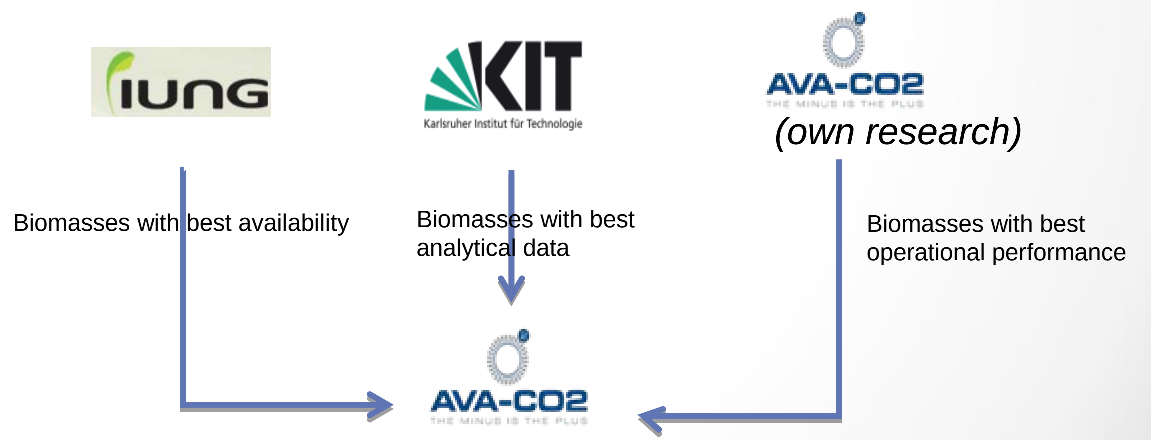
CFP CONCLUSIONS

- **CFB technology can be applied for CFP**
- **With new catalysts developed in BioBoost we can achieve state of the art CPO properties with 18% O_2 at 25% wt yield**
- **Catalyst deactivation in CFP is a challenge**
- **Woody biomass is the best for catalytic pyrolysis followed by the energy crop (Mischanthus) and the agricultural residue (wheat straw)**
- **CPO is a very promising bioenergy carrier**
  - **low O_2, high C, less TAN, good stability**
  - **source of useful chemicals like phenols**

HYDROTHERMAL CARBONIZATION (HTC) (AVA-CO2)

Hydrothermal Carbonization (AVA)

- Based on KIT lab results, AVA developed carbonization parameters for ist K3 (capacity 340 l) and industry sized plant (capacity 1,6 tons)
- First tests in K3 reactors in order to optimize parameters within limited economic and technical risks.
- Based on K3 results, most promising biomasses have been carbonized in the industry sized plant on AVA-CO2



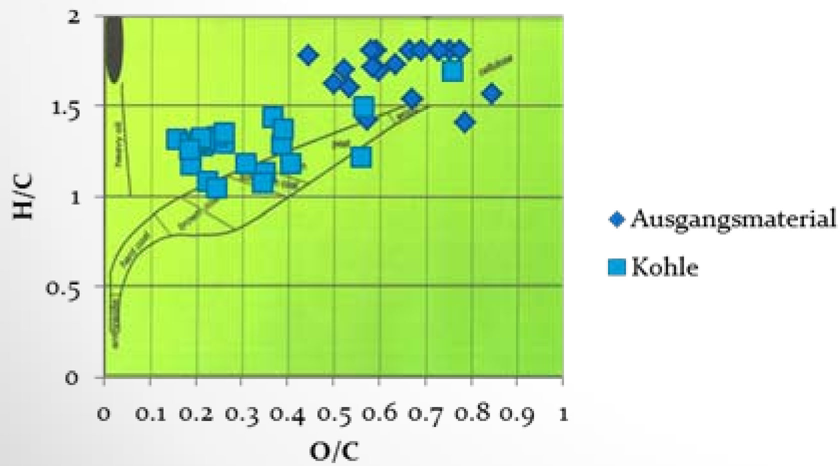
Hydrothermal Carbonization (AVA)
Scale-Up Tests at demo and industry scale batch reactors

Testing of 3 feedstocks:
- **Organic municipal waste**
- **Brewery spent grains**
- **Straw**

3-1: Organic Municipal Waste

-2: Spent Grains from Breweries.

: Straw.



Composition of ash for the mentioned feedstocks.

Ash composition at 550°C	BET	Spent grains	Straw
Cl (total) % DMC	0.36	0.001	n/a
P (total)% DMC	0.3	0.64	0.43
K_2O% DMC	1.5	0.046	0.93
Pb% DMC	0.0041	0.0003	<0.02
Cd% DMC	0.00003	0.00003	<0.004
Cr (total)% DMC	0.002	0.0005	n/a
Cu% DMC	0.0041	0.0017	<0.004
Ni% DMC	0.0014	0.0011	<0.008
Hg% DMC	0.00009	0.00001	n/a
Zn% DMC	0.014	0.021	0.036
Ca% DMC	7.1	0.43	0.043
Fe% DMC	0.64	0.057	0.011
Mg% DMC	0.52	0.25	0.93
Mn% DMC	0.091	0.0074	n/a
Na_2O% DMC	0.74	0.032	0.024
S% DMC	0.39	0.39	0.2
Sn% DMC	<0.0003	<0.0003	n/a
P_2O_5% DMC	0.79	1.4	0.98

Optimization at Industry Scale with BET (organic municipal waste)

	BET Feedstock	*BET Organic fraction*	Biocoal	*Biocoal Organic fraction*
Ash Content (% of DM)	54%	*ca. 5%*	19%	*ca. 6%*
Foreign materials (% of DM)	ca. 51.7%	*0%*	ca. 14% (suspended silt)	*0%*
Organic fraction (% of DM)	ca. 48.3%	*100%*	ca. 86%	*100%*
Higher Heating Value	**9.5 MJ/kg DM**	***19.7 MJ/kg DM***	**24.2 MJ/kg DM**	***ca. 28.1 MJ/kg DM***
Carbon (% of DM)	22.2%	*46.0%*	53.1%	*61.7%*
Oxygen*	18.6%	*38.5%*	19.0%	*22.1%*
Hydrogen	3.4%	*7.0%*	5.7%	*6.6%*
Nitrogen	1.1%	*2.3%*	3.3%	*3.8%*
Sulphur	0.39%	*0.81%*	0.055%	*0.06%*
Total phosphorus	0.3%	-	0.048%	-
Potassium (as K_2O)	1.5%	-	0.21%	-
Sodium (as Na_2O)	0.74%	-	0.12%	-
Total chlorine	0.36%	-	0.15%	-
O/C	**0.63**	**-**	**0.27**	**-**
H/C	**1.84**	**-**	**1.29**	**-**

Assessment of Organic Municipal Waste Treatment

- **Organic waste biomass feedstock was successfully processed into an above-average quality biocoal product via AVA-CO2's HTC**
- **Despite shredding and sieving of the biomass, there were still unacceptably high amounts of inorganic materials present in the process**
- **Silt material that remained in suspension in the slurry with the biocoal particles led to a slightly inferior higher heating value (HHV) of the biocoal than expected (24.2 MJ/kg DM)**
- **AVA-CO2 developed a new technology for the separation of up to 85% of the silt, thus raising the HHV to 27-28 MJ/kg DM**
- **Comprehensive pre-treatment (pre-sorting) of the biomass is the key for successfully processing**
- **Input quality of organic waste varies much more than more standardised biomasses like farm residues etc. Therefore individual tests are necessary to define the HTC process and outcomes**

Assessment of Separation, Drying, Handling and Storage

- **AVA tested 2 technologies for the separation of coal matter from liquid phase:**
  AVA recommends nano filtration instead of membrane bio reactor
- **AVA evaluated more than 10 technologies for the drying of the wet coal, and tested 4 out of them with coal out of brewery spent grains and organic municipal waste: AVA recommends mill drying**
- **AVA tested several storing technologies for biocoal dust, pellets and cakes short term and long term: for most cases big packs are a good option, but there is no final recommendation, esp. for large volume storage**
- **AVA evaluated transportation and security topics related to HTC for all three forms of coal for land transportation, inland waterway transportation, marine transportation and air transport.**

HTC CONCLUSIONS

AVA CO2 achieved breakthroughs:

- **Scale up tests showed that carbonization results in industry size reactors are up to 20% better than in micro autoclave; this has a direct impact to economic evaluation of HTC (causes for the increase are not yet analyzed in detail, there are only hypotheses to be worked on)**

- **A new resource (organic municipal waste) was tested, which implied a complete redesign of process parameters and modification of the plant (which resulted in a delay of sales and marketing)**

- **Based on these works, AVA CO2 shifted from classical feedstock as input to waste streams as primary source, which included a shift in marketing, sales and further development of HTC technology**

- **Market outlook improved drastically, because the strategic shift to waste resources leads to economic viability (due to gate fees)**

BIOBOOST CONCLUSIONS

- The following energy carriers were produced in Bioboost
  - Organic condensate (+ ash from biomass) from TP
  - Slurry of aqueous condensate + char from TP
  - CPO from CFP
  - Biocoal from HTC
- Technological achievements in TP
  - new product collection systems in PDU
  - technology in the creation of the slurries and pastes
  - technology in storage and transport
- Technology achievements in CFP
  - new catalytic materials
  - technology in catalyst deactivation
  - new methods for characterization of CPO
- Technology achievements in CFP
  - redesign of process parameters and plant modification for municipal wastes
  - technology for separation of biocoal from liquid and for drying the wet bio-coal
  - technology in storage and transport of biocoal

MORE DETAILS

Task 2.2: Optimization of energy carrier production technologies

Results documented in Deliverables 2.3, 2.4, 2.5, 2.6

Task 2.3: Energy carrier preparation, characterization, handling and storage

Results documented in Deliverables 2.9.1, 2.9.2, 2.9.3

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 282873

Modelling, Simulation and Optimization of a European-Wide Logistics Network

Erik Pitzer and Gabriel Kronberger

FH OÖ (University of Applied Sciences, Upper Austria)

Brussels, 17. June 2015

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 282873

Motivation

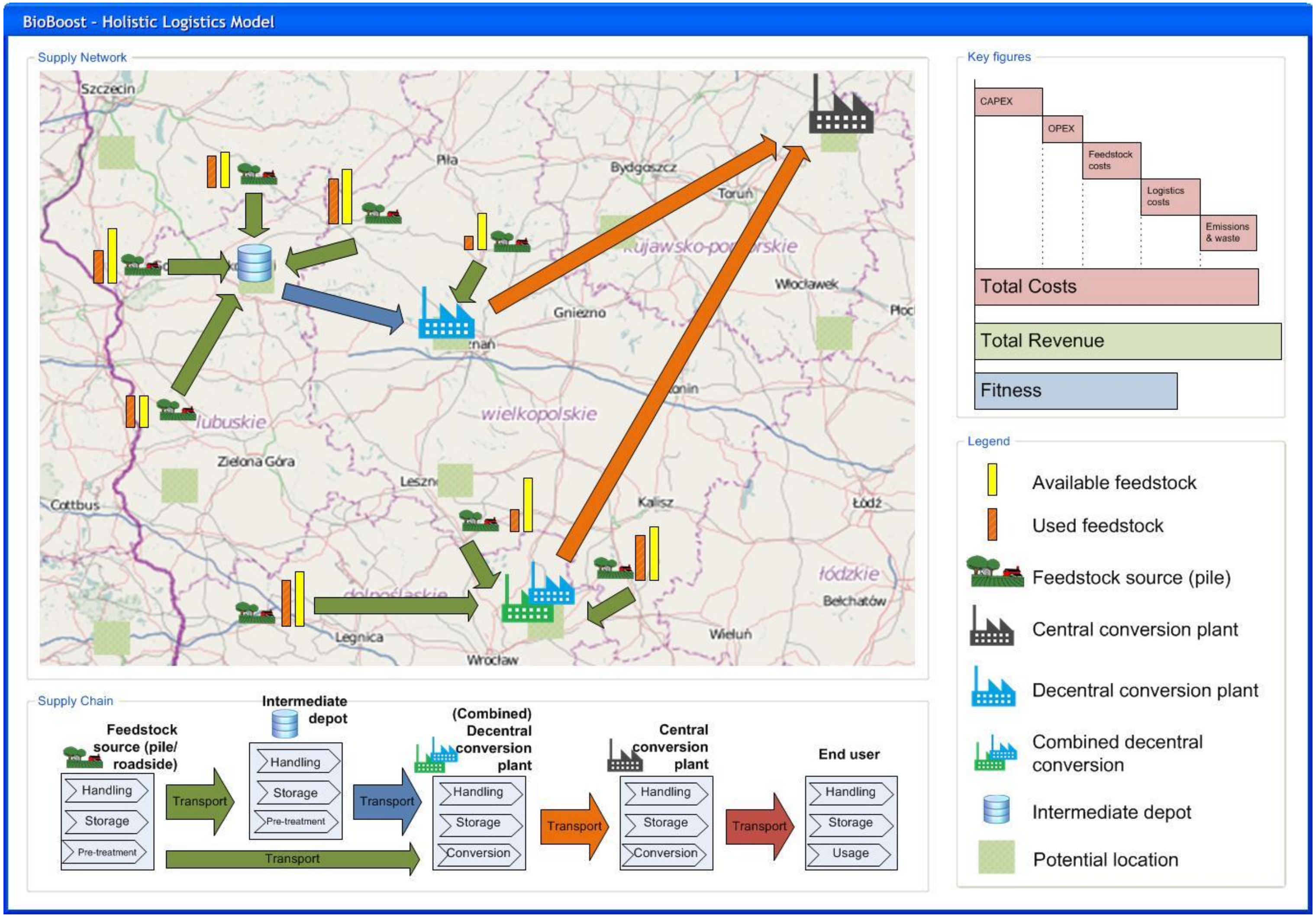
- Is decentral biofuel production economic?
  - different economies of scale (central/decentral)

- possible advantages
  - regional added value
  - mitigate transport volume
  - overcome
    low energy density

Vision

- optimal choice of
  - feedstock suppliers
  - logistic network
  - plant location
  - plant size
  - catchment area
- many factors
  to consider

Vision

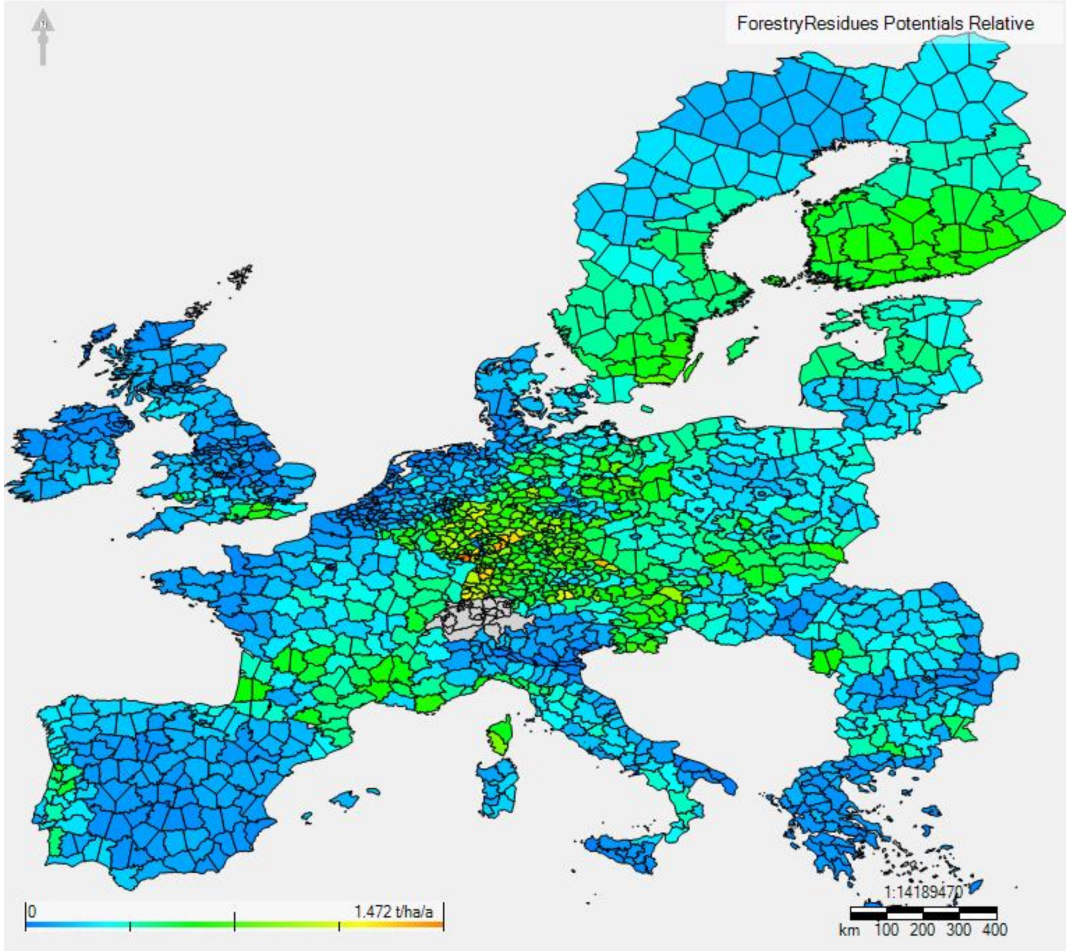


Source: FHOÖ

Required Data

- feedstock potentials (technical) **IUNG**
- market price (and development) **SYNCOM**
- transport modes & costs **FHOÖ**
- routes **FHOÖ**
- conversion possibilities (and scaling)
  KIT, **CERTH**, **AVACO2**, **USTUTT**
- product costs (feedstock, output, wastes)
  TNO, **NESTE**, **EnBW**, **CHIMAR**, **DSM**
- regional influences (labor, invest., infrastructure) **FHOÖ**

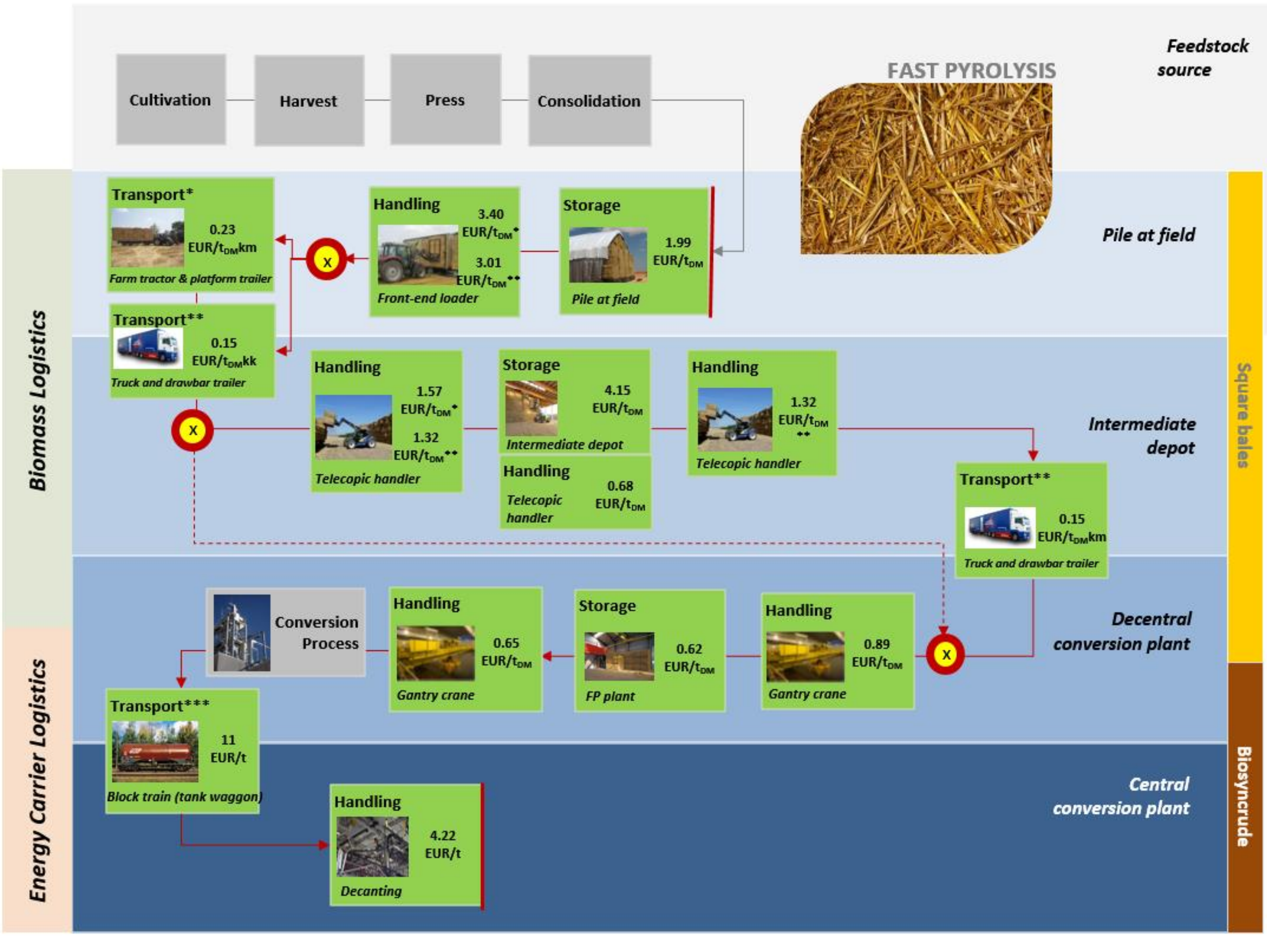
Feedstock Potentials



http://iung.neogis.pl/geoportal/

Source: FHOÖ & IUNG

Logistics Concept



Source: FHOÖ

Conversion Parameters

```yaml
conversions:
  - label: FastPyrolysis
    feedstock: Straw
    safety-stock: 365 # days
    dry-matter-loss: 0.08 # fraction
    storage:
      investment: 0.15
      labor: 0.35
      other: 2.1
    products: # [t/t]
      Biosyncrude: 0.675676
      CO2-green: 0.324324
      WaterVapor: 0.108108
      CoolingWater: -0.344595
      ElectricityIn: -0.087838
    main-product: Biosyncrude
    cost: 0 # [EUR/t]
    design-capacity: 219123.38028 # t/a
    construction: 11003716.52 # EUR/a
    maintenance: 7278442.59 # EUR/a
    construction-scaling-exponent: 0.7
    maintenance-scaling-exponent: 1 #factor
    utilization-factor: 0.913 # 8000 h/a
    available-maintenance-factor: 1
    max-capacities: { Default: 660000 } # 300%
    min-capacity: 125853 # 57%
```

Source: FHOÖ, KIT, TNO

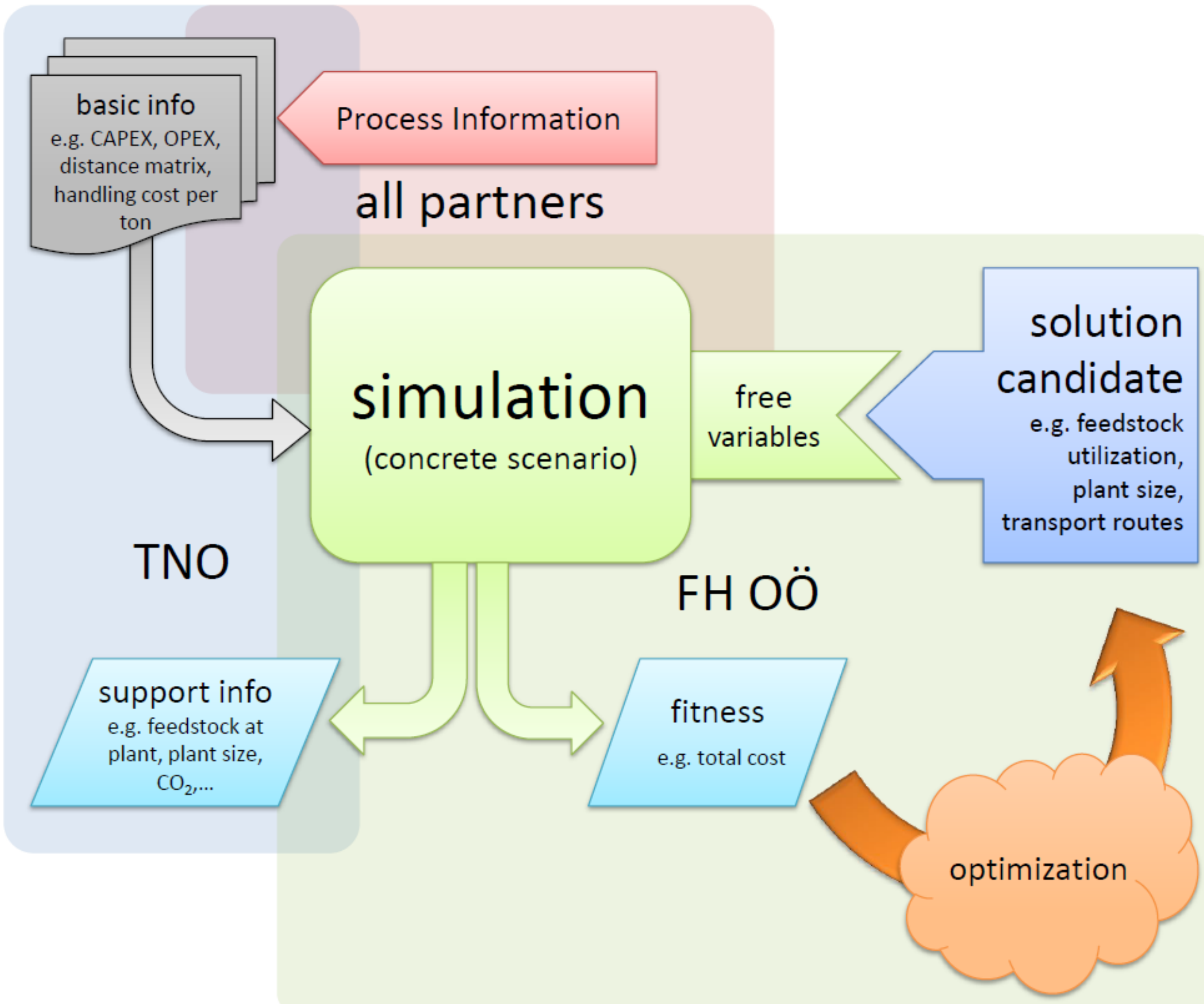
Scenario Simulation

- target values
  - return on investment
  - total amounts (ramping up)
- many free variables
- many more variations

Simulation Efficiency

- aggregations
  - yearly averages
  - NUTS3 regions
- route pre-calculation (distance matrix)

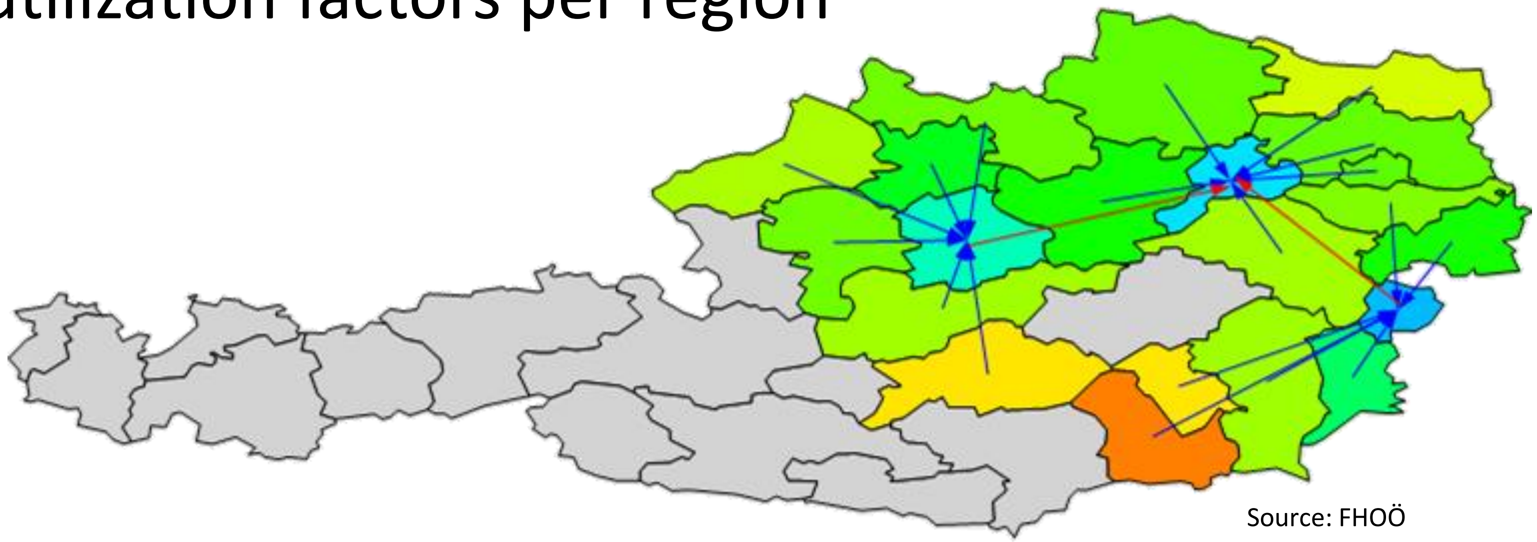
Simulation-based Optimization



Source: FHOÖ

Solution Space Reduction

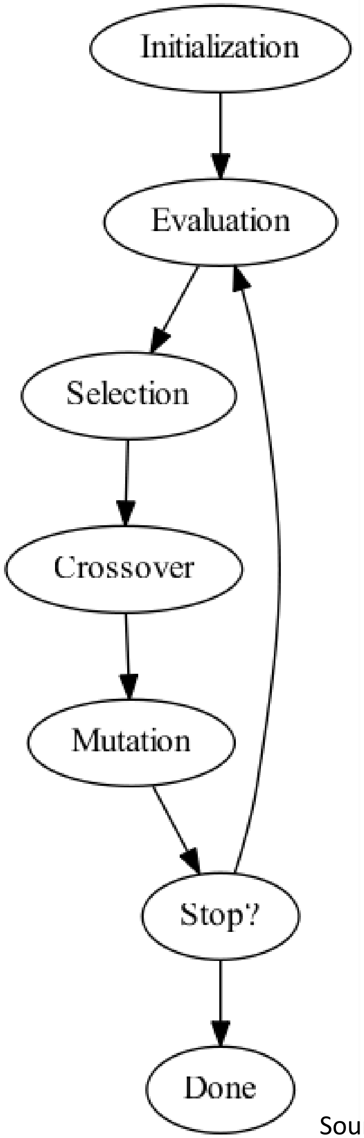
- implicit ("smart") choices for variables
- limits variables to
  - transport targets per product
  - utilization factors per region



Source: FHOÖ

Scenario Evolution

- evolution of scenarios
  - population based ("Evolution Strategy")
  - mutation i.e. moving/scaling plants
  - crossover



Source: FHOÖ

Results: Generic Model

- open-source software tool
  - plugin for HeuristicLab
  - http://dev.heuristiclab.com
- adaptable to other situations
  - e.g. raise transport tonnage allowance and reduce transport costs

Results: Generic Model

- open-source software tool
  - plugin for HeuristicLab
  - http://dev.heuristiclab.com
- adaptable to other situations
  - e.g. raise transport tonnage allowance and reduce transport costs

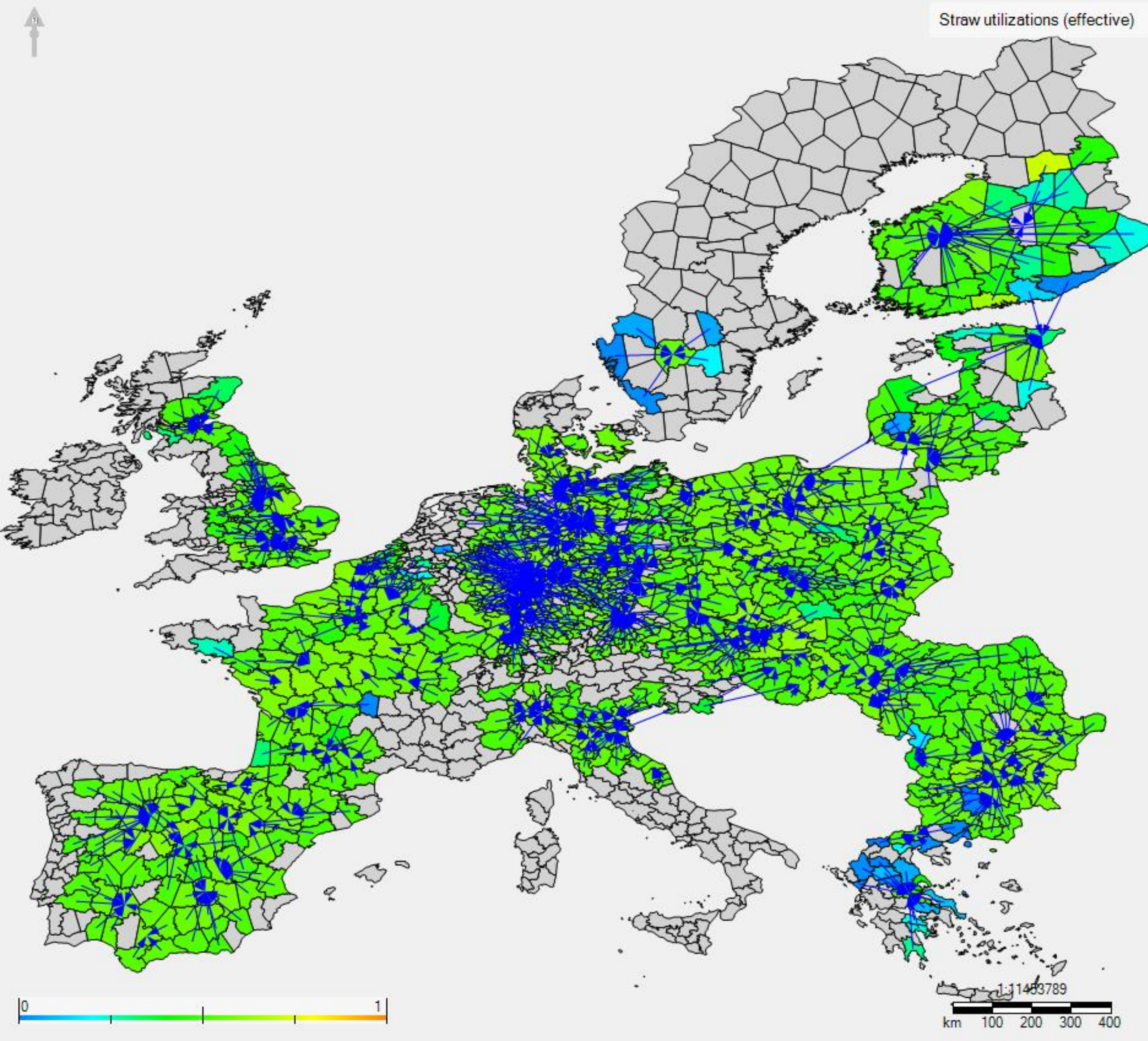
Results: Fast Evaluation

- several hundred scenarios per second
  - extended EU scenarios (1500 regions)
  - two echelons (decentral + central)
  - ROI and/or total amount
- 1-2 days per optimization (300-600 k generations)

Results: In Depth Analysis

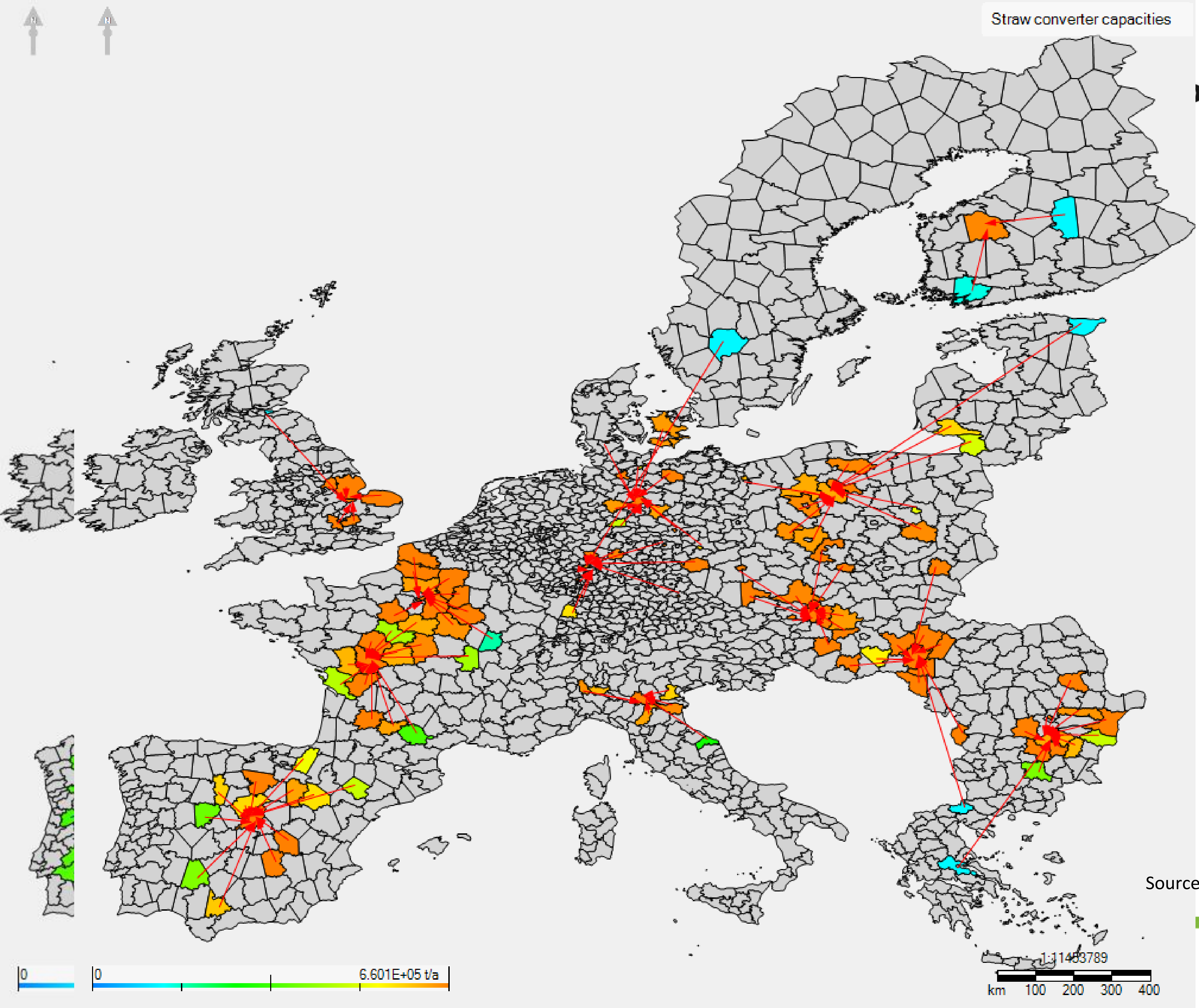
- more than 120 maps with different values e.g.
  - purchased amount in each region
  - conversion costs
  - logistic costs
- CSV export

Results:
Fast Pyrolysis on
European Scale

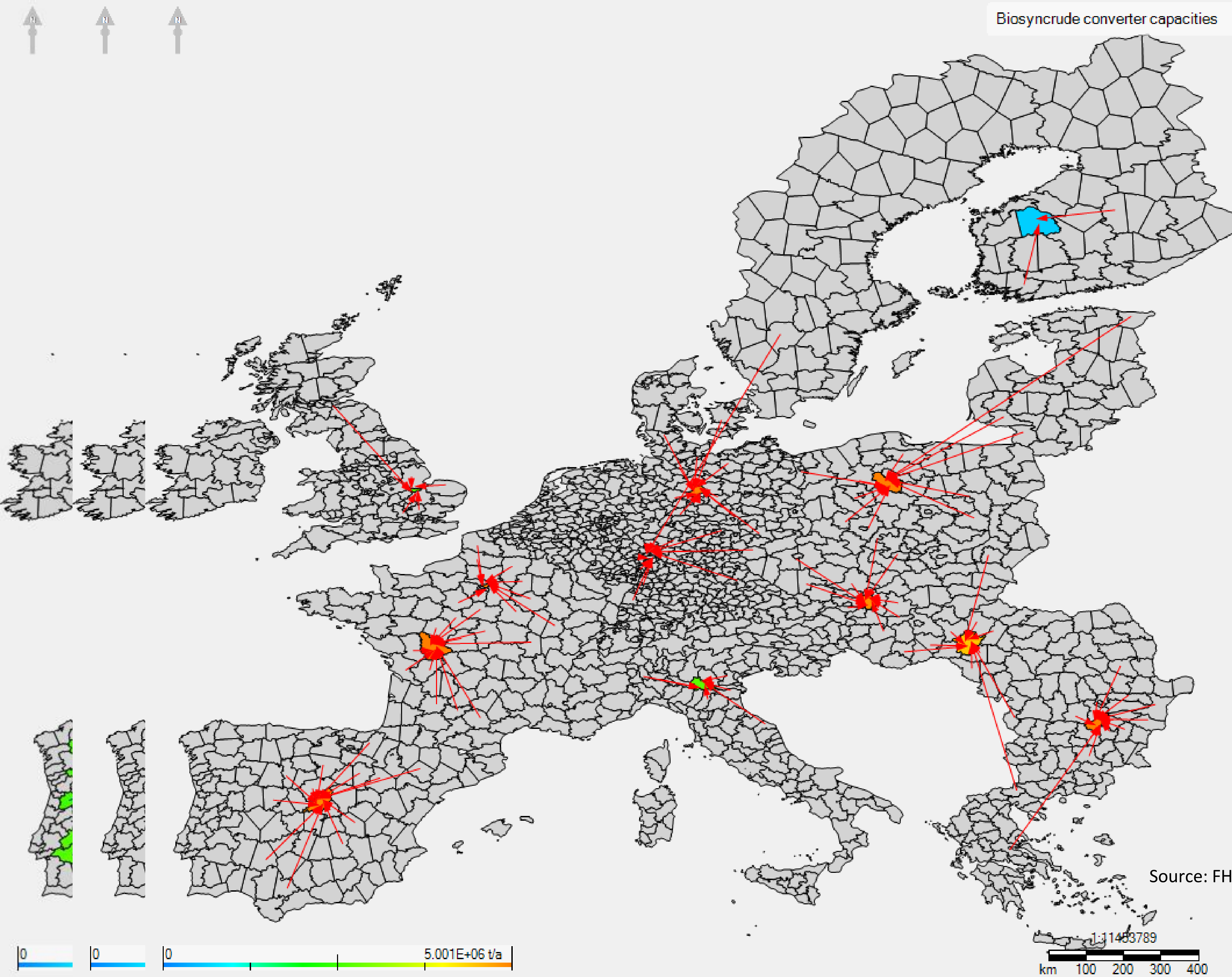

Straw utilizations (effective)
0
1
1:11433789
km 100 200 300 400

Source: FHOÖ

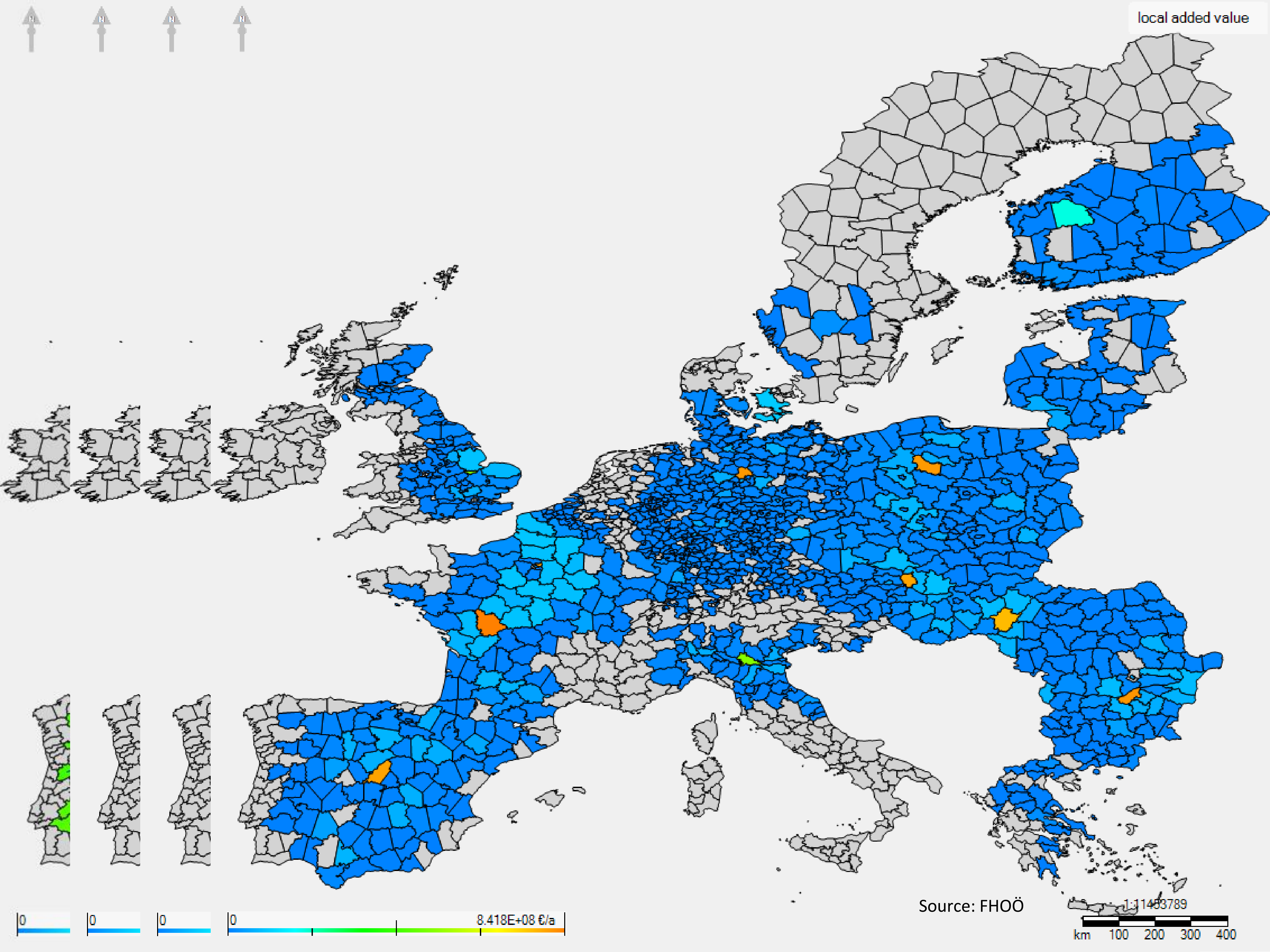
ost



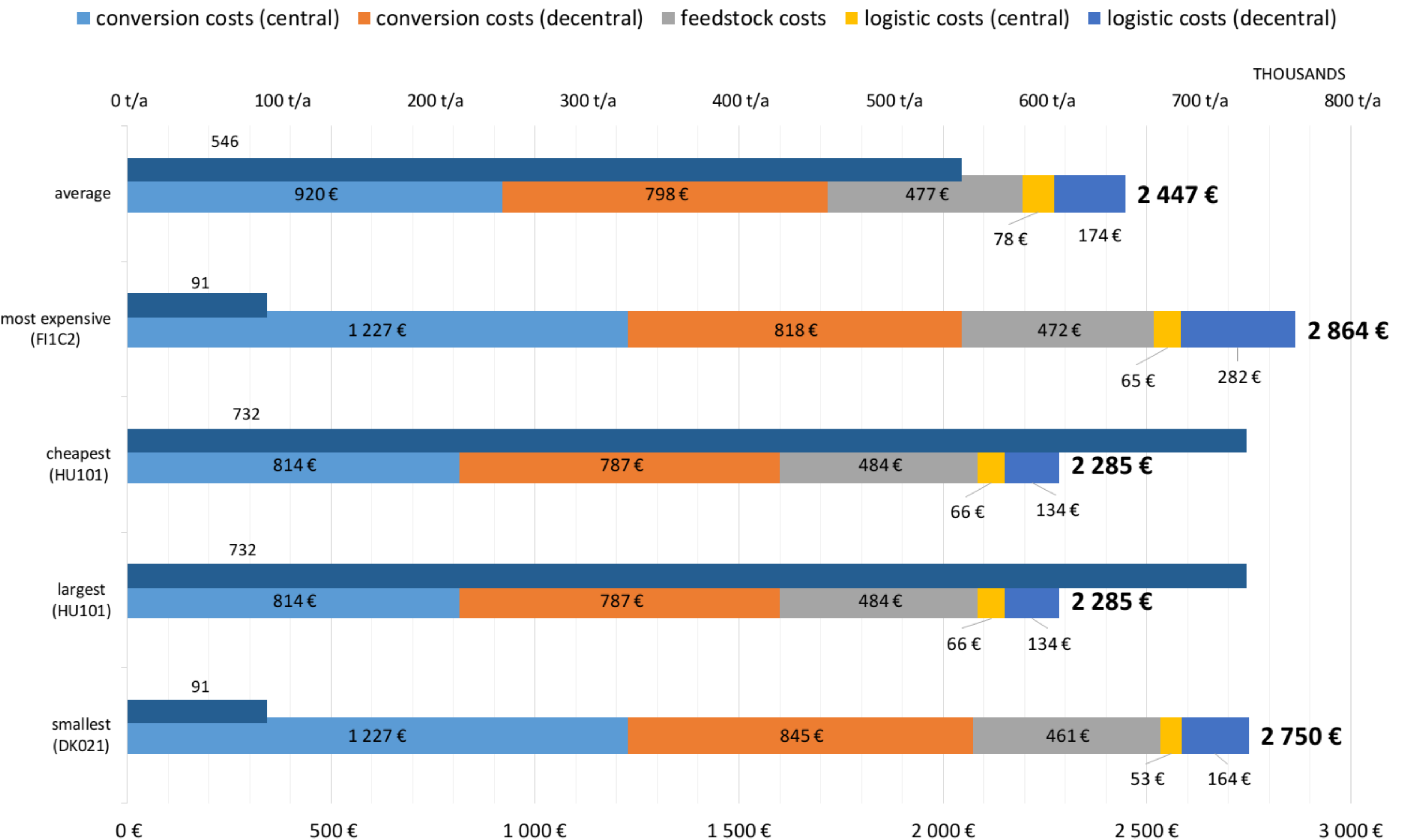
Source: FHOÖ


Biosyncrude converter capacities
0
0
0
5.001E+06 t/a
1:11433789
km
100
200
300
400

Source: FHOÖ

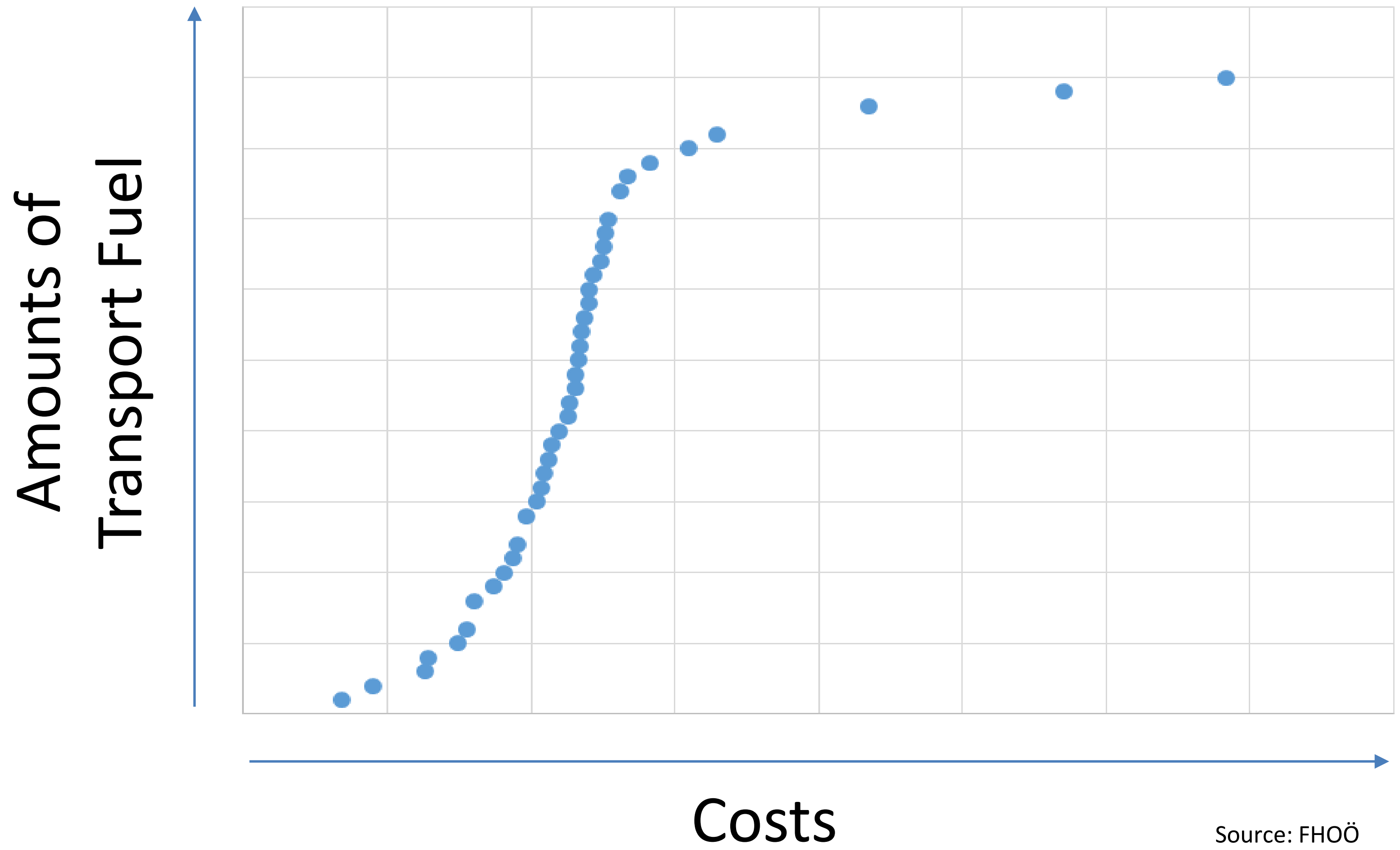

local added value
0
0
0
0
8.418E+08 €/a
Source: FHOÖ
1:11483789
km 100 200 300 400

Results: Fast Pyrolysis



Source: FHOÖ & BioBoost Consortium

Results: Ramp-Up Analysis



HeuristicLab

A Paradigm-Independent and Extensible Environment for Heuristic Optimization

http://dev.heuristiclab.com

UNIVERSITY OF APPLIED SCIENCES UPPER AUSTRIA

erik.pitzer@fh-hagenberg.at

SECTOR

Production of Solid Sustainable Energy Carriers from Biomass by Means of TORrefaction

SECTOR Specials: Value Chains, Economics and Sustainability

Michiel Carbo (ECN), Stefan Majer (DBFZ), Fabian Schipfer (TU Wien)

Brussels, 17th June

Bioboost – SECTOR Workshop






This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Main Questions

- What are the production costs of torrefied biomass pellets, and how can these be lowered by intregation in existing wood handling & conversion plants?
- What is the purchasing power of torrefied wood pellets versus white wood pellets?
- How could illustrative, possibly relevant biomass-to-end-use chains based on torrefaction look like?
- How could torrefaction deployment develop up to 2030 with regard to economic, social and environmental criteria?
- How big are the GHG emissions associated with the production, supply and use of torrefied biomass?
- What are the main drivers for GHG emissions?

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Torrefied wood pellets production costs

- Harmonised mass and energy balances (with belt dryer) presented in flow sheets of ECN, Topell and CENER processes
- Three main integration options: Saw mill, CHP, P&P mill
- Black box mass and energy balance data for calculations about integrated torrefaction
- Both feedstock and energy integration was explored
- The energy production of integrated torrefaction plants was based on biomass use (no energy use of natural gas or oil based products)
- The main advantages of integration:
  - front end: wood acquisition, logistics, wood handling and pretreatment
  - more efficient energy use compared to stand-alone plants
  - favorable power and heat prices
  - lower the production price of TOP-pellets (bigger boiler in integrated concepts, scale-up and efficiency benefits)

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Torrefied wood pellets production costs: alternatives

- Base Case: Stand-alone plant (50 MW_{th} torrefied wood pellets)
- Alternative 1:
  New sawmill and torrefaction integrated (158 MW_{th})
- Alternative 2:
  Existing sawmill and new torrefaction plant (72 MW_{th})
- Alternative 3:
  Existing CHP-plant (5 000 h/a) and new torrefaction plant (50 MW_{th})
- Alternative 4:
  Existing CHP-plant (3 500 h/a) and new torrefaction plant (50 MW_{th})
- Alternative 5:
  Existing pulp mill and new torrefaction plant (279 MW_{th})
- Alternative 6:
  Existing pulp and paper mill and new torrefaction plant (70 MW_{th})
- Alternative 7:
  Existing pulp and paper mill and new torrefaction plant (140 MW_{th})
- Alternative 8 & 9: Stand-alone plant in Nordic region and SE USA (343 MW_{th})

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

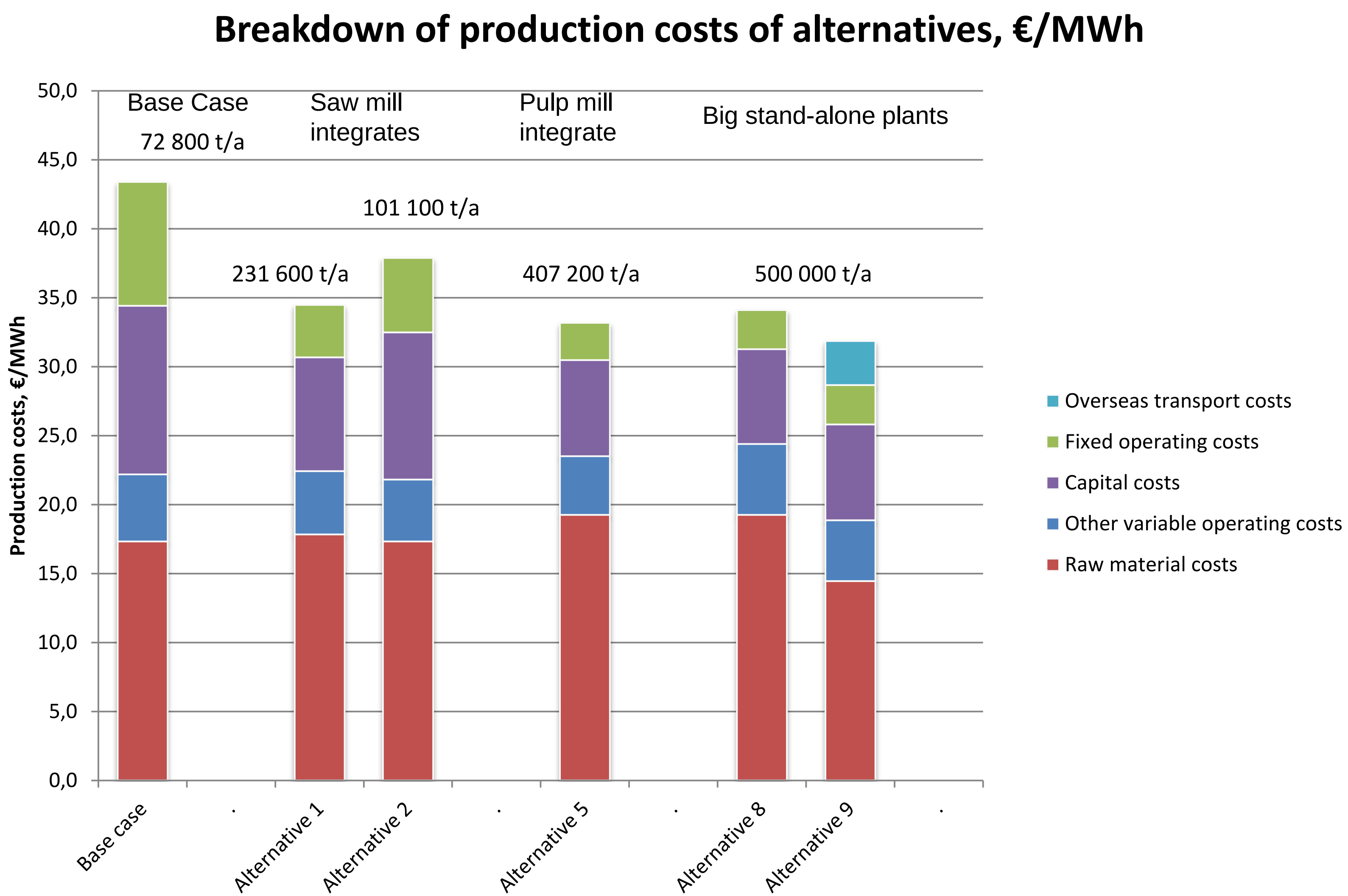
Torrefied wood pellets production costs: results

		New sawmill	Existing sawmill	Existing pulp mill	Standalone Nordic	Standalone USA
	Base Case	Alternative 1	Alternative 2	Alternative 5	Alternative 8	Alternative 9
Plant capacity, t torrefied pellets/a	72 800	231 600	101 100	407 200	500 000	500 000
Production costs of pellets, M€/a	19.3	48.8	24.3	82.5	104.2	87.6
Production costs of pellets, €/t	265	211	240	203	208	175
Production costs of pellets, €/MWh	43	34	38	33	34	29
Market price of wood pellets, €/MWh (PIX Pellet Nordic Index, 2012)	30	30	30	30	30	30
Price compared to base case, %	100	79	91	76	79	66
Price compared to market price, %	145	115	126	111	114	96

(orange)	Stand- alone plants
(blue)	Integrates

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

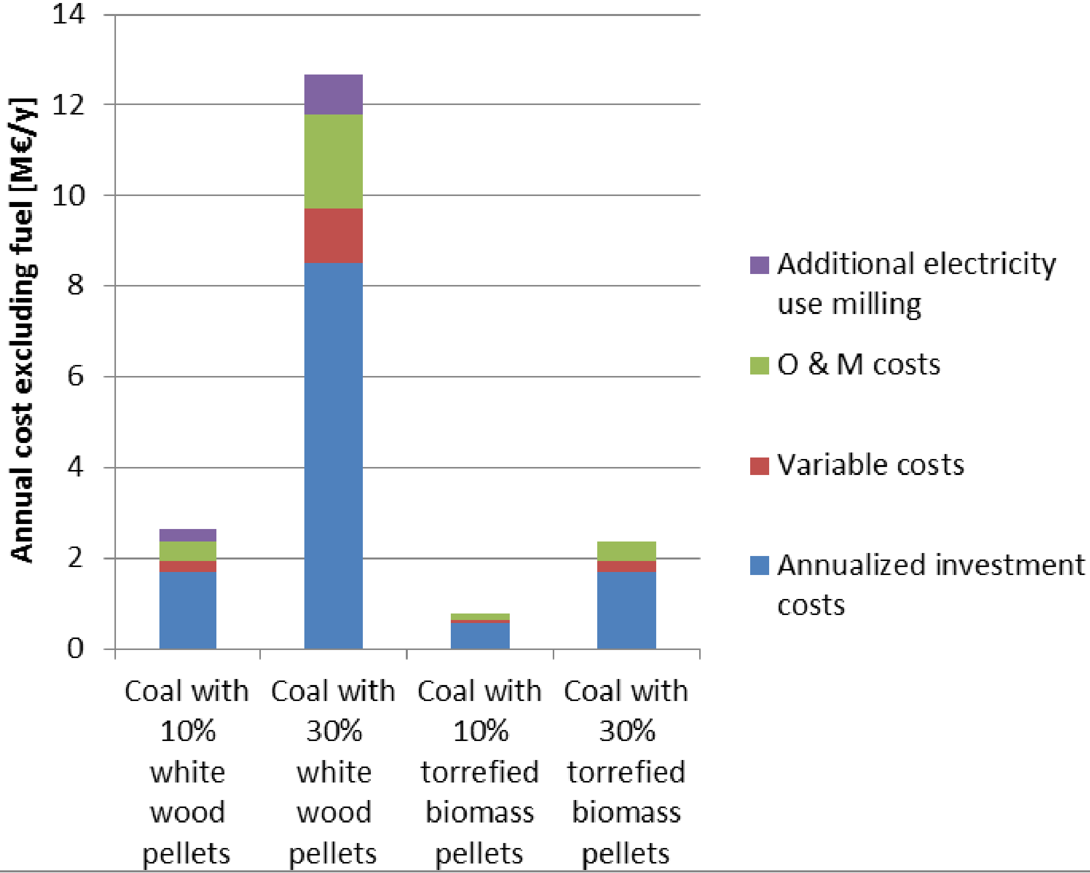
Torrefied wood pellets production costs: build-up



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Purchasing power white wood vs. torrefied wood pellets

- 10 and 30% co-firing in 400 MW_e coal-fired power station
- Efficiency kept at 40% for all cases (for simplicity's sake)



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Torrefaction process optimisation/integration

- Purchasing power white wood vs. torrefied wood pellets

		10% co-firing	30% co-firing
Cost difference between white wood and torrefied wood pellets	M€/y	1.86	10.31
Amount of biomass of pellets used	PJ	2.16	6.48
Price difference	**€/GJ** (€/MWh)	**0.86** (3.10)	**1.59** (5.72)
Case 1: price difference at higher rate of return (12% → 15%)	€/GJ (€/MWh)	1.08 (3.89)	2.02 (7.27)
Case 2: price difference at reduction of economic lifetime from 10 to 5 years	€/GJ (€/MWh)	1.24 (4.46)	2.34 (8.42)

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

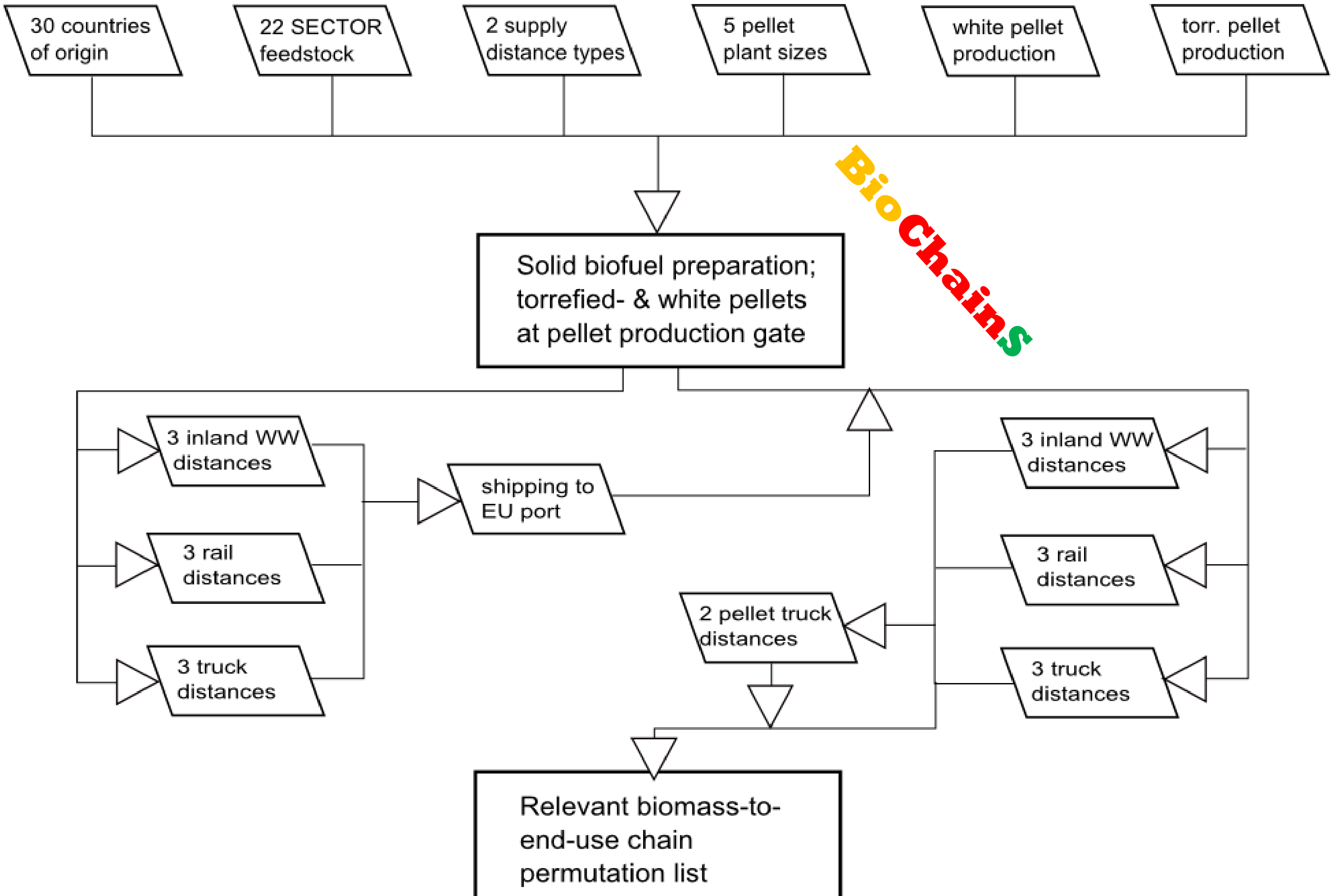
Main Questions

- What are the production costs of torrefied biomass pellets, and how can these be lowered by intregation in existing wood handling & conversion plants?
- What is the purchasing power of torrefied wood pellets versus white wood pellets?
- How could illustrative, possibly relevant biomass-to-end-use chains based on torrefaction look like?
- How could torrefaction deployment develop up to 2030 with regard to economic, social and environmental criteria?
- How big are the GHG emissions associated with the production, supply and use of torrefied biomass?
- What are the main drivers for GHG emissions?

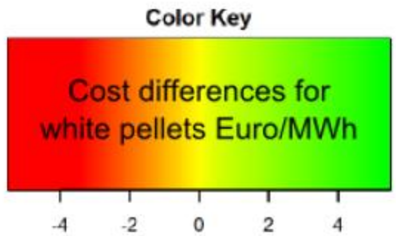
This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Value chain assessment - the BioChainS Tool

Tool **BioChainS** was adapted to research questions, feedstocks and pretreatment technologies to generate large set of probable relevant biomass-to-end-use chains.



Selected results – economic value chain assessment

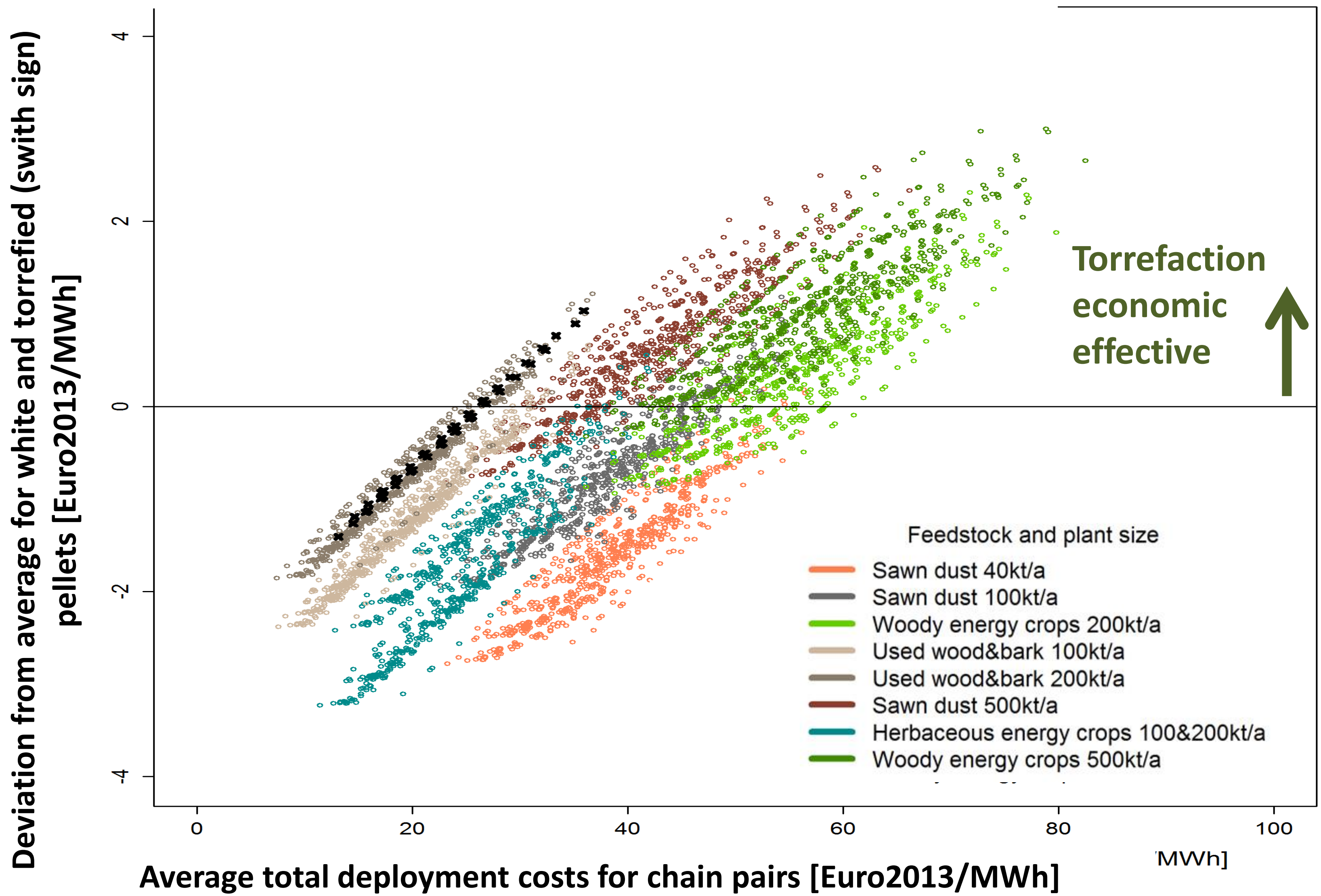


Average costs (number in the boxes, Euro2013/MWh) for torrefied pellets based on saw dust for selected biomass-to-end-use chain constellations

	100km EU-transport, large end use	400km EU-transport, large end use	800km EU-transport, large end use	100km EU-transport, small end use	400km EU-transport, small end use	800km EU-transport, small end use
US/CA,low supply dist., Pellet plant size <101kt	39.7	43.8	49.2	42.5	46.5	52
EU,low supply dist., Pellet plant size <101kt	35.8	39.8	45.3	38.5	42.6	48
US/CA,high supply dist., Pellet plant size <101kt	41.8	45.9	51.3	51.2	55.3	60.7
EU,high supply dist., Pellet plant size <101kt	38	42	47.5	47.4	51.4	56.9
US/CA,low supply dist., Pellet plant size >199kt	39.2	43.3	48.7	42	46	51.5
EU,low supply dist., Pellet plant size >199kt	35.4	39.5	44.9	38.1	42.2	47.7
US/CA,high supply dist., Pellet plant size >199kt	44	48	53.5	53.4	57.4	62.9
EU,high supply dist., Pellet plant size >199kt	40.3	44.4	49.8	49.7	53.8	59.2

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

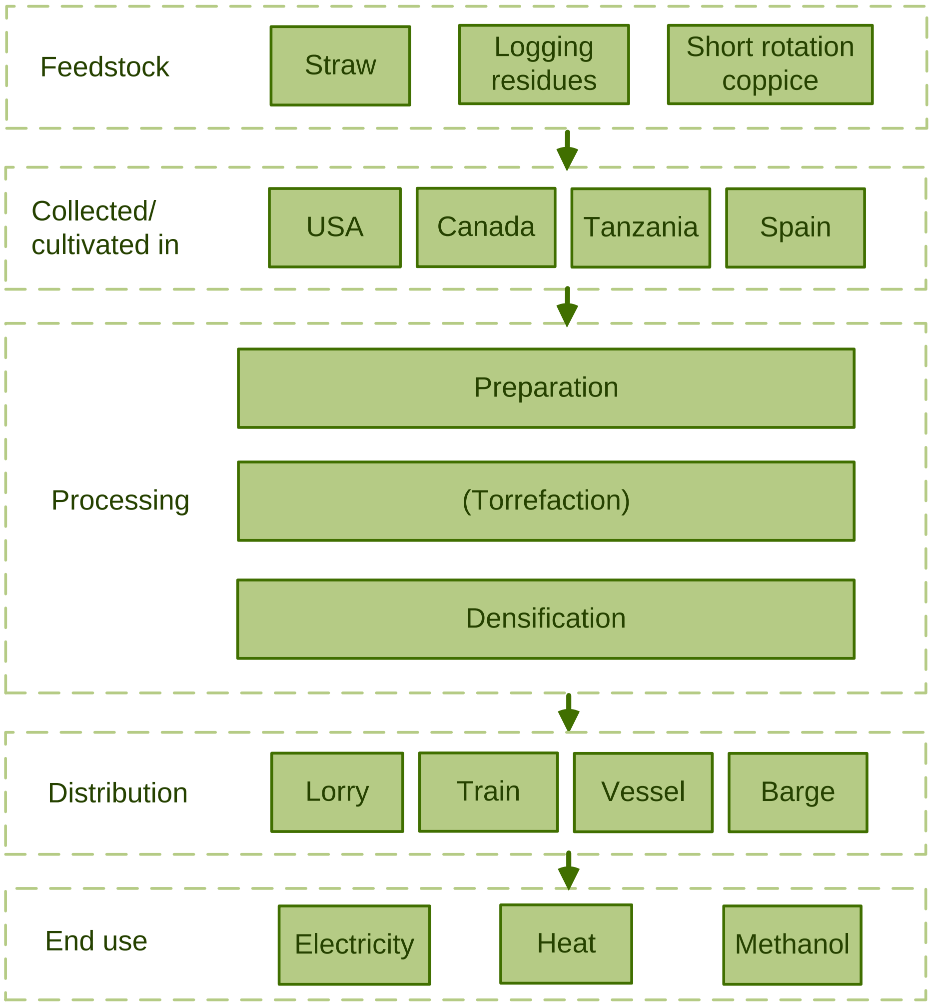
Differences between white and torrefied pellets for similar chains related to their avarage deployment costs



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

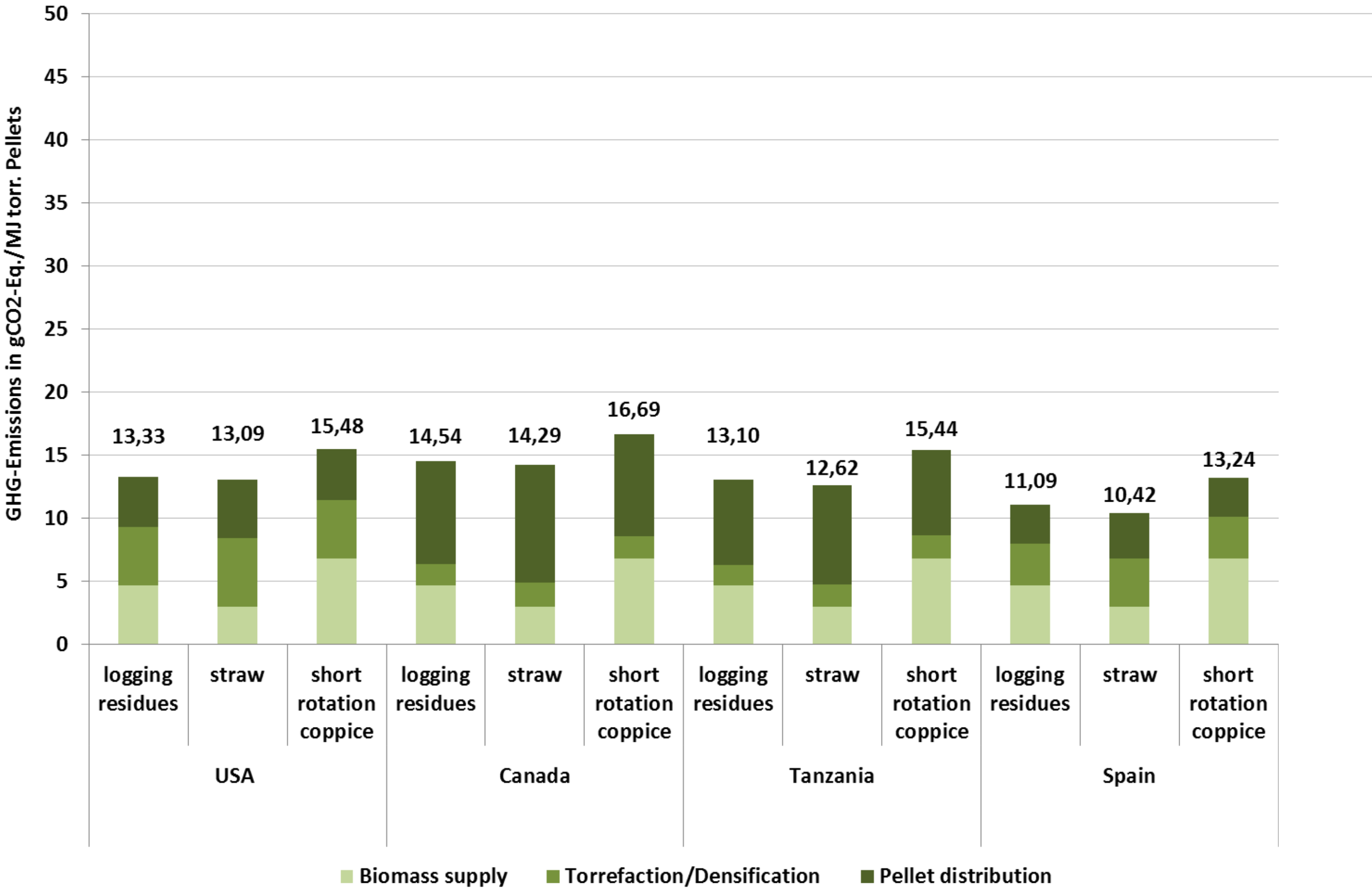
Selected results - GHG - pathways & system boundaries

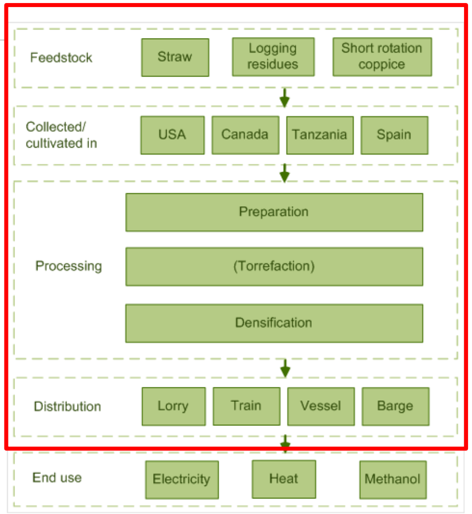
- 3 feedstocks and 4 different locations
- torrefied pellets and white pellets
- in each case transport to Europe (Rotterdam)
- different end uses



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Selected results - GHG - torrefied pellet production and distr.



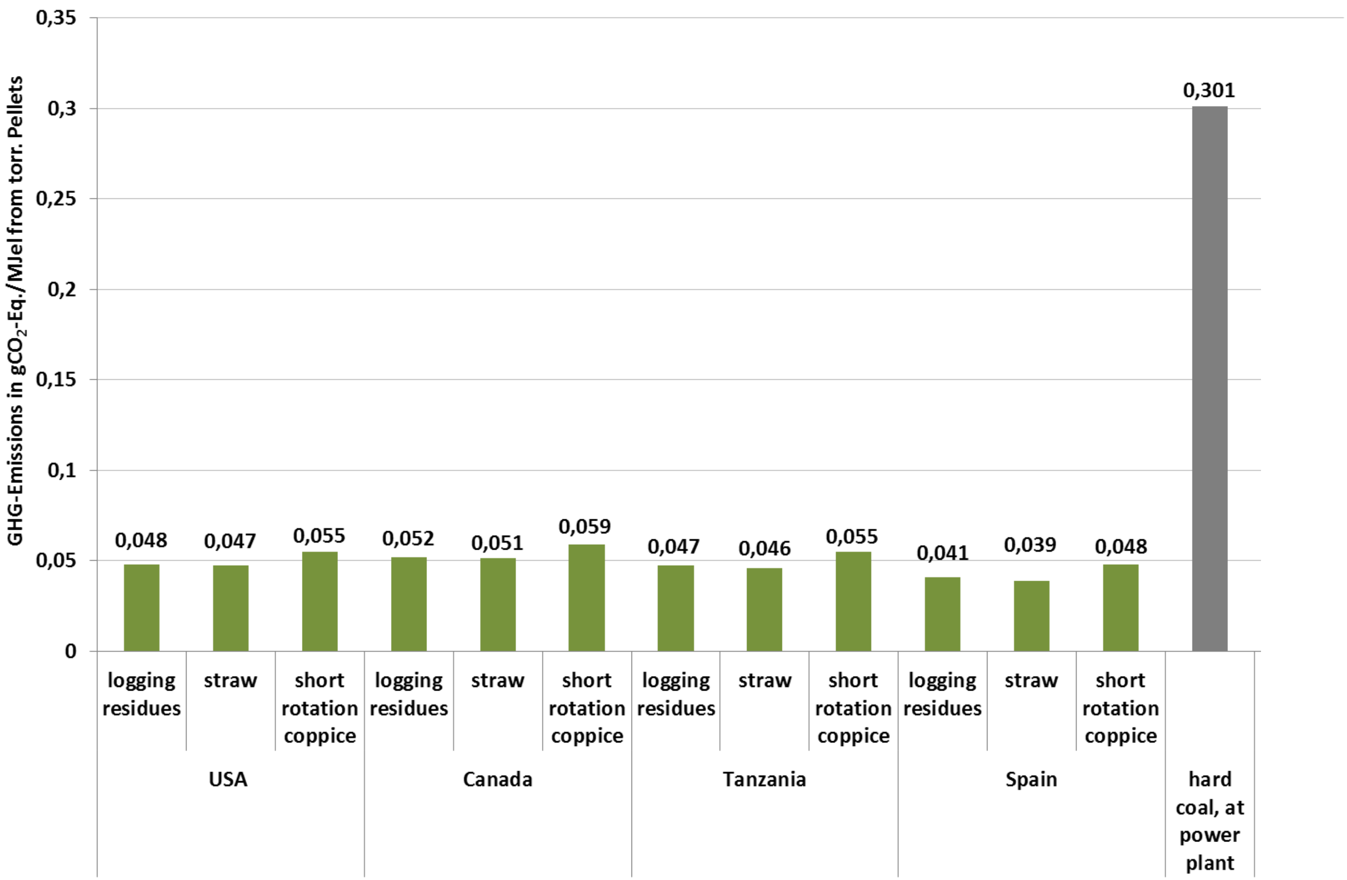


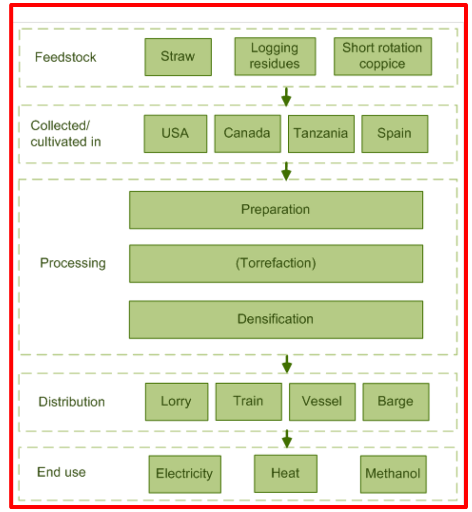
source: own Sector calculations & BioGrace II

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Selected results - GHG - results end use I

GHG-emissions from electricity production (co-firing)





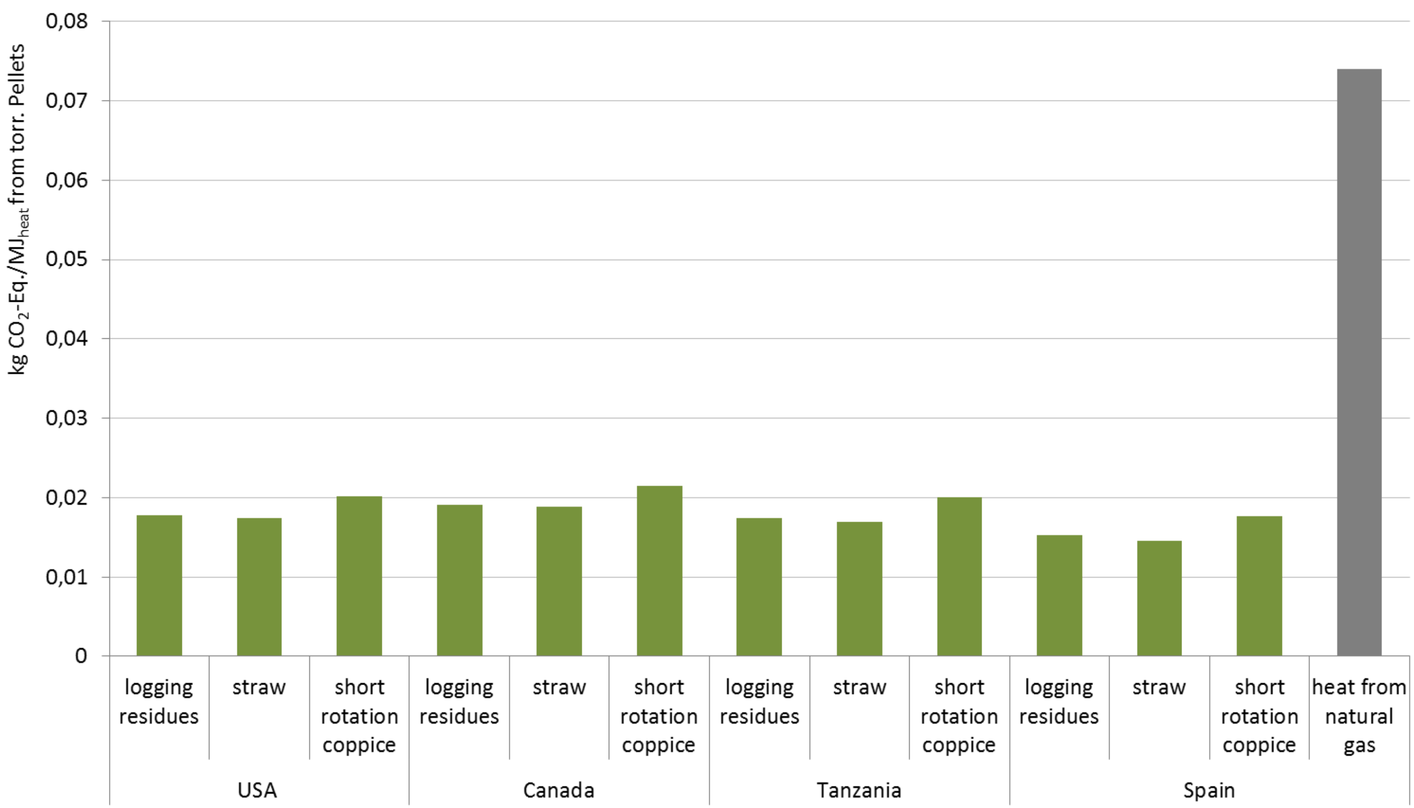
GHG-mitigation potential of 72% - 86%

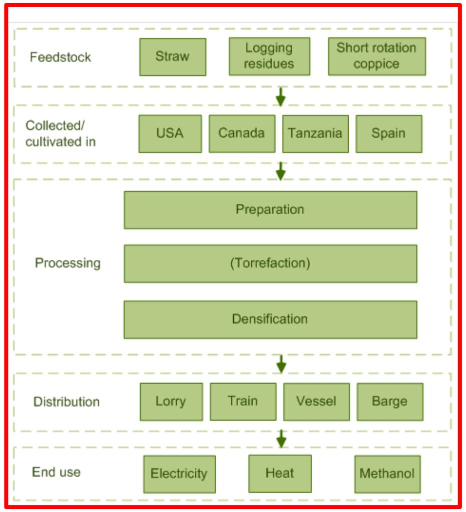
Source: own Sector calculations & Ecoinvent

This project has received funding from the European Union’s Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Selected results - GHG - results end use II

GHG-emissions from heat production





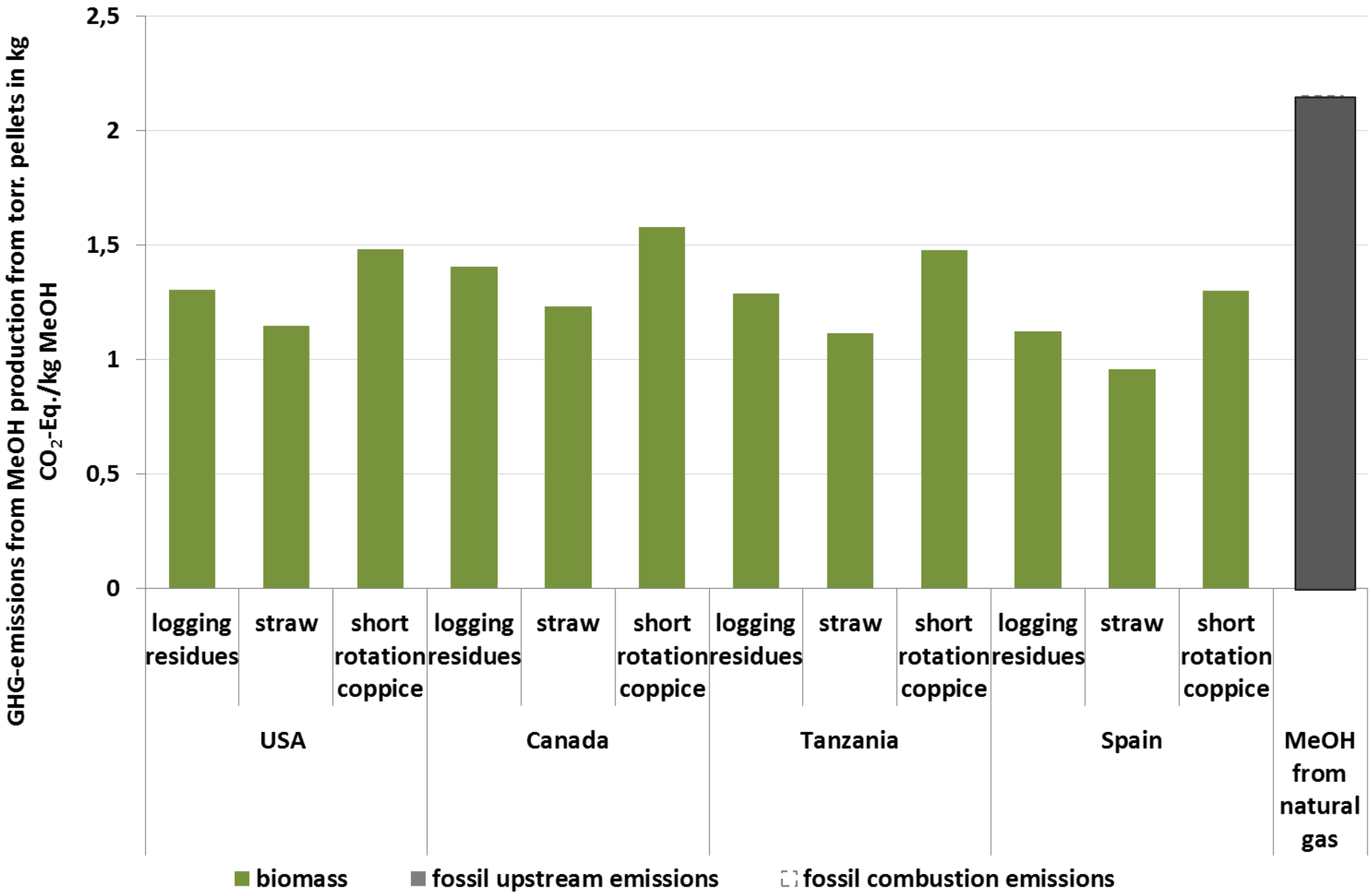
GHG-mitigation potential of 71% - 80%

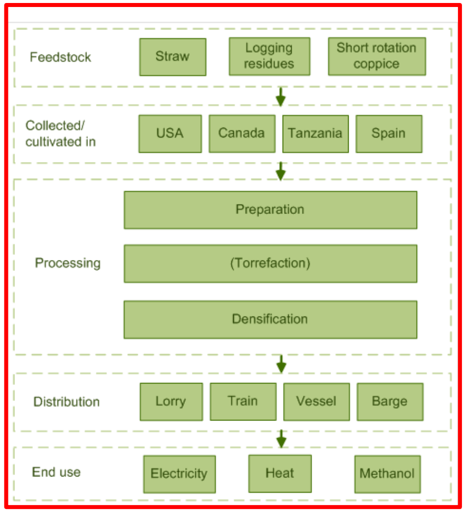
Source: own Sector calculations & Ecoinvent

This project has received funding from the European Union’s Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Selected results - GHG - results end use III

GHG-emissions from MeOH production





Source: own Sector calculations & Ecoinvent

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

Conclusions

- Considerable cost savings in scenarios with higher pellet deployment
- High GHG mitigation potential → type of feedstock, process energy carrier and emission factor for electricity are the main influencing factors
- Mass and energy balances from Sector WPs 3 & 4 might help to update and improve existing LCI & LCA datasets and calculators (e.g. BioGrace, Ecoinvent).

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826