MUSIC

Market Uptake Support for Intermediate Bioenergy Carriers

D2.1 Series of PowerPoint presentations on lessons learned from earlier projects WP2: State-of-the-art, framework conditions and growth potential for IBC

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857806.

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Task:	T2.1 Mapping biomass mobilisation and logistical lessons learned
Task leader:	BTG
Deliverable title:	D2.1 Series of PowerPoint presentations on lessons learned from earlier projects
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Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, restricted under conditions set out in Model Grant Agreement	

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EXECUTIVE SUMMARY

MUSIC aims to improve logistics and trade of biomass and intermediate bioenergy carriers (IBCs). Furthermore, MUSIC targets to inform, engage, train and support consortium partners as well as (industrial, regional and other) stakeholders on this topic.

One of the project tasks, setting the frame for MUSIC implementation activities, is to map the current state-of-the-art of the biomass mobilisation, logistics, trade centres and industrial IBC production technologies.

Results of the mapping tasks are presented in the form of a series of PowerPoint presentations, developed by various MUSIC beneficiaries. These PowerPoint presentations (a) synthesise relevant results and findings of earlier European and national projects and (b) describe recent experience and best-in-class examples of IBC deployment and associated logistics.

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1 Background and introduction

The MUSIC project

Intermediate bioenergy carriers (IBCs) are biomass that is processed to energetically denser materials, analogous to oil, coal and gaseous fossil energy carriers. This means they are easier to transport, store and use.

The MUSIC project will support market uptake of three types of Intermediate Bioenergy Carriers (IBCs) by developing feedstock mobilisation strategies, improved cost-effective logistics and trade centres. IBCs covered in MUSIC include pyrolysis oil, torrefied biomass and microbial oil.

IBCs are formed when biomass is processed to energetically denser, storable and transportable intermediary products analogous to coal, oil and gaseous fossil energy carriers. They can be used directly for heat or power generation or further refined to final bioenergy or bio-based products. IBCs contribute to energy security, reduce greenhouse gas emissions and provide a sustainable alternative to fossil fuels in Europe.

Mapping the state-of-the-art

The aim of WP2 is to sketch the current status and set the frame for MUSIC implementation activities. Among others, WP2 will map the current state-of-the-art of the biomass mobilisation, logistics, trade centres and industrial IBC production technologies, based on and integrating outcomes (results and findings) of recent projects.

Approach and intended use of the outcomes

In the mapping exercise (led by BTG), MUSIC beneficiaries developed a series of PowerPoint presentations (a) synthesising relevant results and findings of earlier European and national projects and (b) describing recent experience and best-in-class examples of intermediate bioenergy carriers deployment and associated logistics. These PowerPoint presentations are intended to help inform the consortium partners as well as stakeholders, especially from industry.

For internal training, the respective PowerPoint presentations will be presented and discussed at the March 2020 consortium meeting. To inform external (industrial and other) stakeholders, the PowerPoint presentations are firstly collected within the current public document. They will furthermore be made available online at the MUSIC project website and may also be used as training / dissemination material for further MUSIC project activities, including Task 7.4 Industry Working Groups.

2 Results

In total seven PowerPoint presentations were developed, four covering a case study region and three covering intermediate bioenergy carriers (IBC) technologies, markets, and experiences. Under the guidance of task leader BTG, each of these PowerPoint presentations were developed by up to three MUSIC partners, as shown below

Experience from earlier European and national projects

Title	Author(s)
Biomass mobilization and logistics experiences in EU	Kaisa Vikla and John Vos, BTG
Biomass mobilization and logistics experiences in Greece	Myrsini Christou, CRES
Biomass mobilization and logistics experiences in Italy	Marco Buffi / David Chiaramonti, RE-CORD
Biomass mobilization and logistics experiences in Sweden and Finland	Magnus Matisons, BFR / Vesa Kainulainen, GFN

IBC Technologies, markets, experiences

Title	Author(s)
Biomass Torrefaction - Recent experiences and best-in-class examples	Kyriakos Panopoulos / Giorgos Kardaras, CERTH and Cristina Calderón / Michael Wild, IBTC
Biomass Fast Pyrolysis - Recent experiences and best-in-class examples	Kaisa Vikla / Patrick Reumerman, BTG
Microbial oil - Recent experiences and best-in-class examples	Marco Buffi / David Chiaramonti, RE-CORD and Daniele Bianchi, ENI

The PDF versions of the PowerPoint presentations are attached as Annex 1.

Annex 1: Series of PPT presentations

Citation, Acknowledgement and Disclaimer

John Vos, Kaisa Vikla, Patrick Reumerman, Magnus Matisons, Myrsini Christou, Kyriakos Panopoulos, Giorgos Kardaras, Marco Buffi, David Chiaramonti, Cristina Calderón, Michael Wild, Daniele Bianchi, and Vesa Kainulainen, 2020
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www.music-h2020.eu

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Market Uptake Support for Intermediate Bioenergy Carriers

Biomass mobilization and logistics experiences in EU

Recent projects and best-in-class examples

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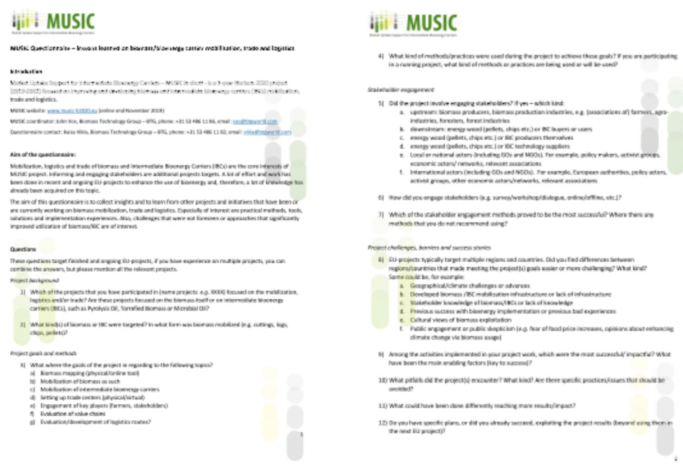
Task 2.1: Mapping biomass mobilisation and logistical lessons learned

- This task will yield a series of PowerPoint presentations (a) synthesising recent relevant results and findings of **(inter)national biomass mobilisation** and **logistics research projects** and (b) describing **recent experience** and **best-in class with examples**.
- Examples of **intermediate bioenergy carriers deployment** and associated **logistics**. The mapping exercise will help inform the consortium partners as well as stakeholders, especially from industry.
- Methods:
  - Search in CORDIS, Internet to find the relevant projects
  - Phone interviews with the relevant project's participants.



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Recent experiences

- The overview includes 18 projects, of different types:
  - Networking projects (CSAs) with a focus on Awareness raising, Engagement, Dialogue, Brokerage, et cetera
  - Research projects (RIAs) producing technological and logistic innovations for developing new harvesting, transport and storage technology
- All projects (will) offer valuable material including: fact sheets, handbooks, guidelines, best practices, tools, methodologies, databases, atlases, market oriented information, investor information
- The next slides show summaries of the key results and lessons with examples
- Project matrix shows targeted biomass, project's focus and target areas with links to further information
- The projects are each presented afterwards for those who are interested in further information (1-2 slides each)

Overview of best-in class examples and lessons learned

1. Tools developed
   - Biomass mapping, matching, assessment
   - Logistics tools
   - Example of biomass and IBC logistical tool
2. Information and trade platforms
3. Documents
   - Handbooks
   - Reports
   - Guidelines
4. Case studies relevant for MUSIC
5. Lessons learned
6. Stakeholder engagement
   - Methods
   - Lessons learned
7. Project matrix
8. Project summaries and further information

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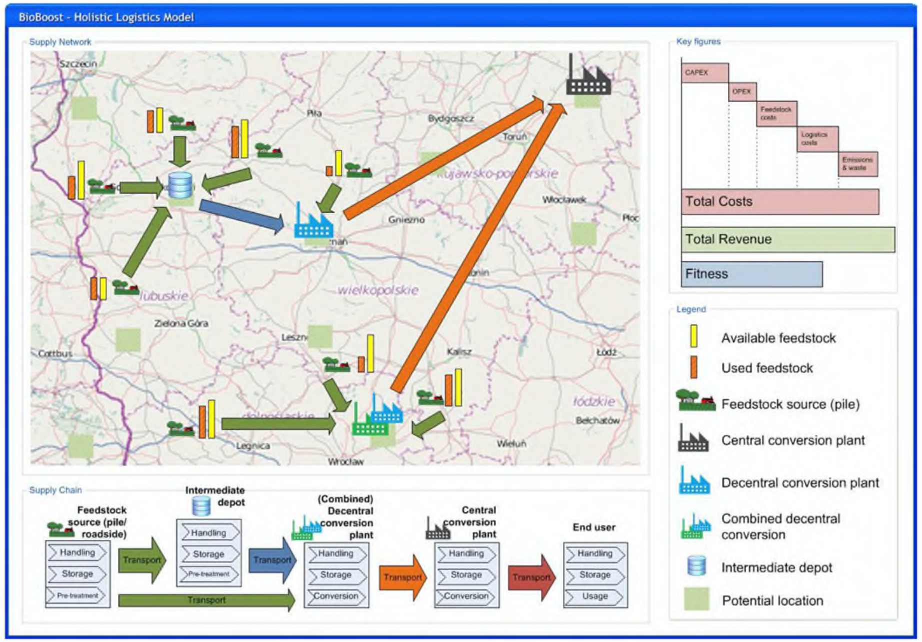
1. Tools developed for biomass and IBC mapping, conversion and logistics

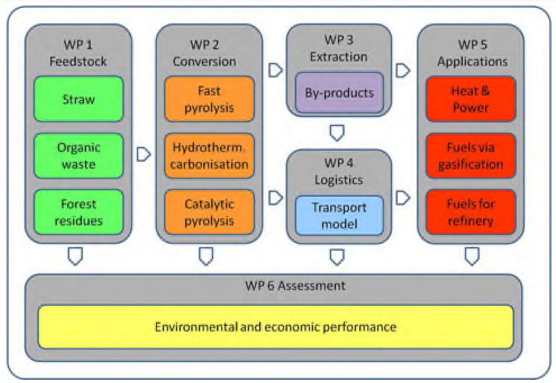
Tool	Description	Project	Tool type	Sector
Tools for biomass chains	Comprehensive web-based toolset for biomass supply data, conversion technologies, logistics. A good starting point for MUSIC interests. Unfortunately, logistics tool is not available.	S2BIOM	Online tool	Mixed
BioBoost Simulator	A customized algorithm optimizes locations and capacities of plants as well as biomass and energy carrier logistics.	BioBoost	Computer program based on modelling	Mixed
BioBoost Navigator	The aim of the BioBoost Navigator is to inform about modeled costs, sites and sizes of three pathways for the conversion of residue biomass to usable bioenergy products in the European Union.	BioBoost	Online tool	Mixed
BioRaise mapping tool	Biomass mapping tool in Mediterranean countries. Possibility of selecting a specific map point and performing a biomass availability assessment in an arbitrary radius around it.	BIOmasudplus	Online tool	Agro
Biomass mapping from agrarian prunnings	Observatory map of biomass from agrarian pruning and plantation removal. Online tool, enables to search, e.g. by crop, country, value chain. Mainly southern Europe in the database	uP_running	Online tool	Agro
Logistics Smart System	SmartBoxTool to look and order suitable biomass. Enables to look for certain biomass with specifics and amounts. Then order it to be transported to you and to be monitored the transport. (still online, but not used)	Europrunning	Online application	Agro

Example: BioBoost

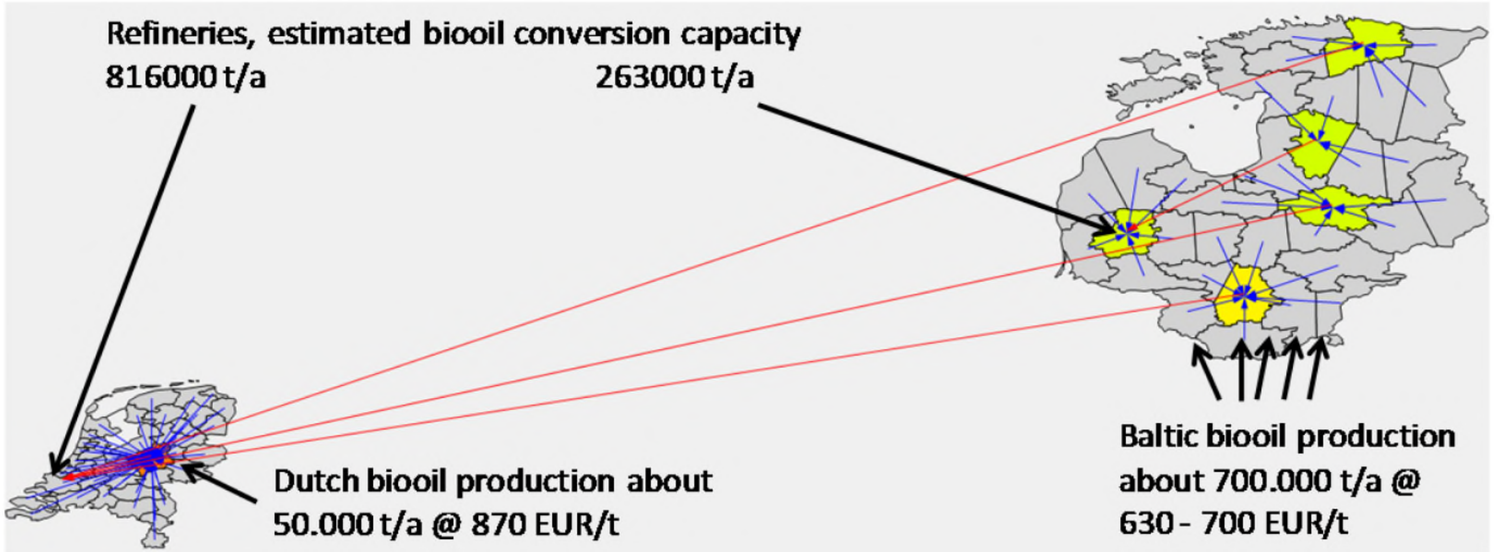
- **Project's Scope:** The project concentrated on dry and wet residual biomass and wastes as feedstock for de-central conversion by **fast pyrolysis** (straw), catalytic pyrolysis (forest residues) and hydrothermal carbonization (organic waste) to the **intermediate energy carriers** oil, coal or slurry.

- **BioBoost Simulator:**
- Heuristics logistics model
  - separate chain per feedstock;
  - uses process information and solution candidates;
  - storage sizes & routing can be determined;
  - a logistics process is transport, handling, storage or pre-treatment;
  - evaluation of costs & emissions for feedstock, transport & handling, storage, conversion & construction and revenue of intermediates;
  - optimization overall production costs by feedstock utilization (per region), plant size and transport network





Example: Heuristic model optimization of catalytic fast pyrolysis



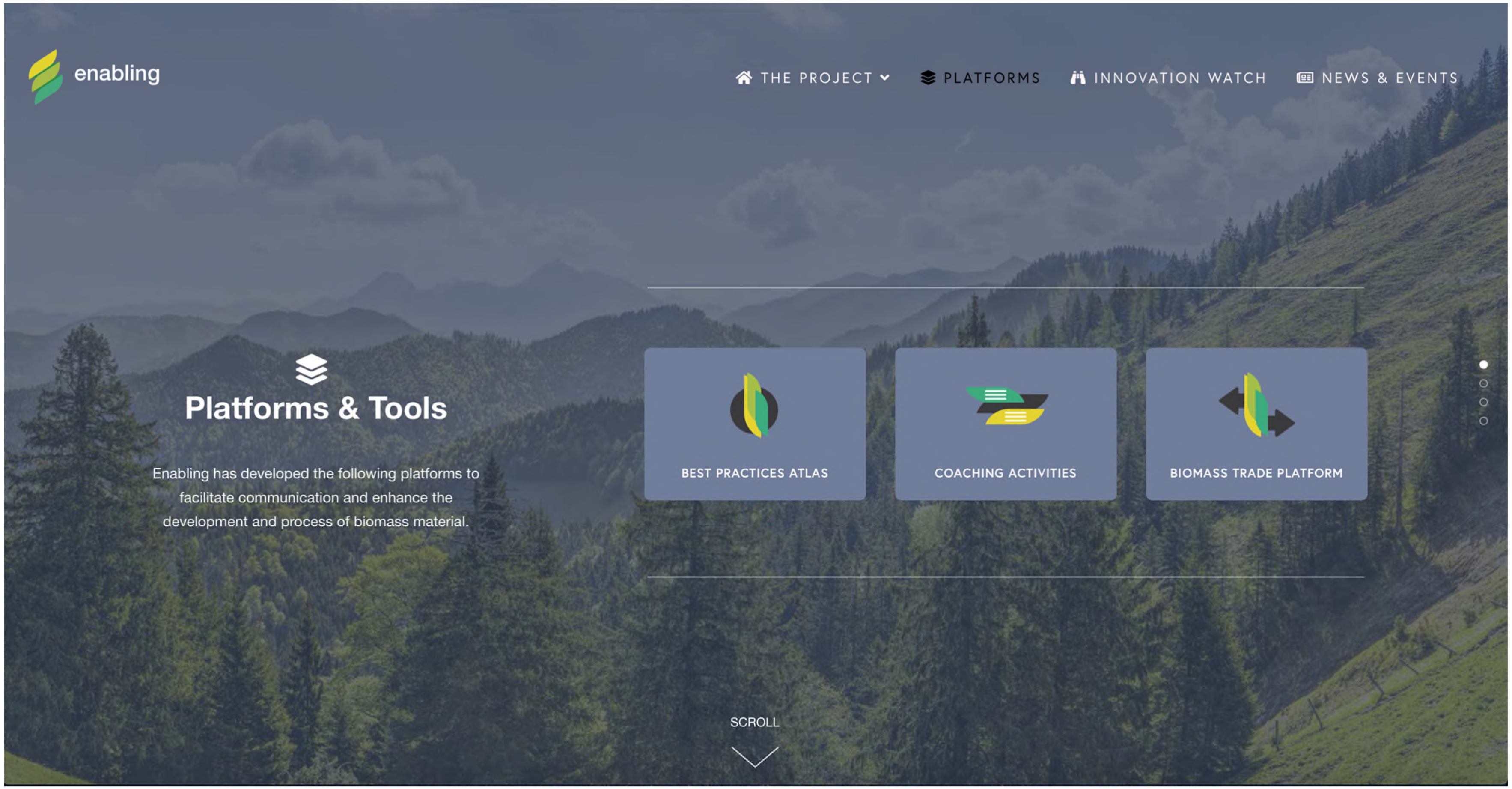
- Forest biomass is pyrolyzed in presence of a catalyst.
- Bio-oil yield 15-20% oxygen storable, compatible for crude oil transport.
- Production is near the biomass resources: Baltic States.
- Upgrading near established refineries: Dutch refineries.

- In the model assumption are made: All refineries nearer by the Baltic States have already saturated their surplus capacity with regional produced bio-oil -> CP-oil is transported to Rotterdam refineries (NL).
- In this model run, the Dutch CFP-plant had a bio-oil production of less than 50.000 t/a while the Baltic had about 150.000 t/a.
- The calculated bio-oil logistic costs vary between 1 €/t for the catalytic fast pyrolysis plant at the Lithuanian refinery to about 100 €/t for long distance railway transport to Rotterdam.
- The two refineries were calculated to have production costs of about 1,400 – 1,600 €/t.

2. Information and trade platforms developed

Platform	Description	Project	Sector
ENABLING Platform	Online information platform. Contains Best Practices Atlas: Collection of best BBP (Bio based Products and Processes) practices, from inside and outside Europe, that are wholly or partly transferable to other regions, or serve as an inspiration for partners in the value chain. Biomass Trade Platform, enabling trading of biomass without 3rd parties. Coaching Activities: available through an online simple questionnaire provided via the website, will support biomass producers or the BBP industry for the uptake of emerging best practices and help the applicants figure out more details about the bio-economy and its component.	ENABLING	Mixed
Information platform	The greenGain.eu Information Platform provides information on biomass from landscape conservation and maintenance work with a focus on the energy utilization of this feedstock.	GreenGain	Landscape management
Your way into a BLTC - Practitioners' Guidebook	Provides practical guidance on basic terminology and methodology on the biomass logistics, how to establish and operate a BLTC as regional hub in its different stages of business development	BioRES	Forest
Policy database	Instruments & Measures that foster the development of regional bioeconomies. (Can be outdated, from 2016)	S2BIOM	Mixed

Example: Biomass Trade Platform

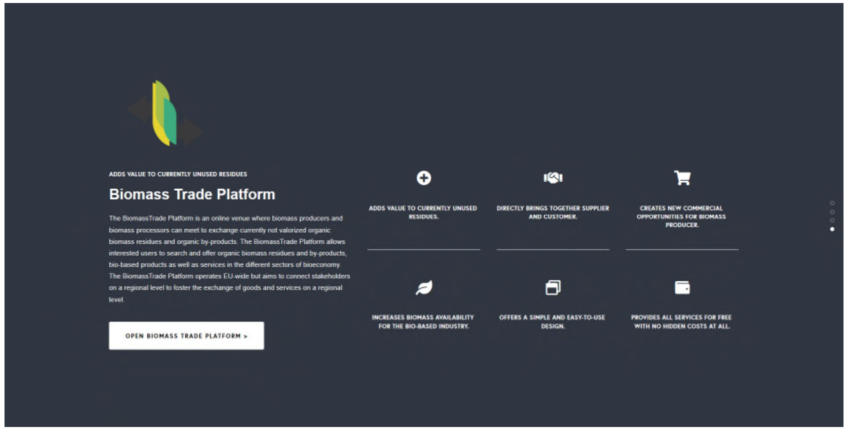


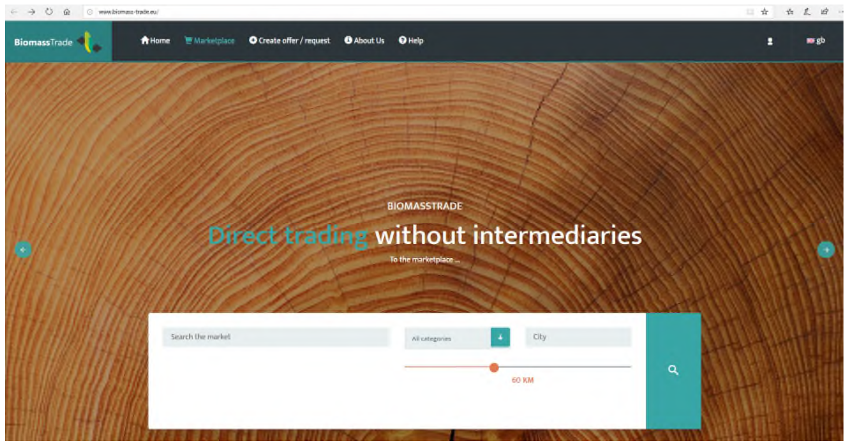
enabling platform

Example: Biomass Trade Platform

- The Biomass Trade Platform is an online venue where **biomass producers and biomass processors** can meet to exchange currently not valorized organic biomass residues and organic by-products.
  - Direct contact between supplier and customer, no intermediary
  - User- friendly (clear, simple and easy to use design)
  - No hidden costs, free to use
- The Biomass Trade Platform allows interested users to **search and offer** organic biomass residues and by-products, bio-based products as well as services in the different sectors of bioeconomy.
  - Very detailed categories for biomass types and products
  - Also possibility to offer services, such as advisory, analysis, logistics, jobs
- The Biomass Trade Platform operates EU-wide but aims to **connect stakeholders on a regional level** to foster the exchange of goods and services on a regional level

Biomass Trade Platform





3. Documents - Handbooks, reports and guidelines 1/3

Document	Description	Project	Sector
Handbook for wood mobilisation in Europe	The extensive booklet covers barriers that exists in certain countries for improved wood mobilization and also includes measures how to lift these barriers.	SIMWOOD	Forest
BioRES Lessons Learnt - PDF	Highlights some lessons learned while supporting Biomass Logistic and Trade Centres (BLTC) owners and operators. Useful for individuals and groups that wish to work on similar challenges.	BIOres	Forest
Book of the project results	Modeling and Optimization of Biomass Supply Chains, Top-Down and Bottom-up Assessment for Agricultural, Forest and Waste Feedstock. Not for free, can be purchased from Elsevier.	S2BIOM	Mixed
Final publication	Innovative, effective and sustainable technology and logistics for forest residual biomass	INFRES	Forest
Report on biomass mobilisation	Report on logistics processes for transport, handling and storage of biomass residues from feedstock sources to decentral conversion plants	BioBoost	Mixed
Report on biomass and IBC logistics	Report on logistics processes for transport, handling and storage of biomass residues as well as energy carrier from feedstock sources to central conversion plants. Includes evaluation of logistics assets for transportation of IBCs	BioBoost	Mixed
Generic guidelines for establishment of biomass trade centres	Includes guidelines for establishing physical biomass trade centers	BiomassTradeCenter II	Forest
Wood Fuels Handbook	Production, quality and trading of wood fuels	BiomassTradeCenter II	Forest
Directory Wood Fuel Producers	Directory of wood fuel producers in Italy, Poland, Austria and Slovenia	BiomassTradeCenter II	Forest

3. Documents - Handbooks, reports and guidelines 2/3

Document	Description	Project	Sector
Policy guidelines	Contains Key Messages with associated recommended actions	uP_running	Agro
Booklet	Analysis of the opportunities of implementing new businesses. Report focuses on the production of intermediates for bioenergy & biofuels and biocommodities for biobased products, and in a logistical integration, in the sectors selected as the most promising for implementing IBLCs in Europe.	AGROinLOG	Agro
Country report on opportunities in Sweden	Basic analysis of targeted agricultural sectors in Sweden	AGROinLOG	Agro
Country report on opportunities in Greece	Basic analysis of targeted agricultural sectors in Greece	AGROinLOG	Agro
Guideline for implementation	Guideline for implementing an agro-industry logistic centre into an agro-industry	sucellog	Agro
Handbook for agro-industries	Handbook for agro-industries interested in starting a new activity as biomass logistic centre: Lessons learned and good practice examples	sucellog	Agro
Biofuel characteristics and quality assessment	Selected biofuels characterization results and quality assessment report. Results of analysis of more than 300 samples of biomass for quality assessment	BIOmasudplus	Agro
Residential heating biofuels market report	Residential heating biofuels market state of the art. Report on market assessment on biofuels in target countries	BIOmasudplus	Agro

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3. Documents - Handbooks, reports and guidelines 3/3

Document	Description	Project	Sector
Handbook for know-how on LCMW chains	Overview of the steps to implement successfully an energy production chain based on biomass from landscape conservation and maintenance work (LCMW)	GreenGain	Landscape and maintenance
Information platform	The greenGain.eu Information Platform provides information on biomass from landscape conservation and maintenance work with a focus on the energy utilization of this feedstock.	GreenGain	Landscape and maintenance
Strategy paper for EU policy makers	Strategy paper for EU policy makers: Increasing market uptake of biomass from landscape conservation and maintenance work	GreenGain	Landscape and maintenance
Final report	Final report on the project Logist'EC developing new/improved logistics technologies for (multi-) annual crops, perennial grasses, and short rotation coppice	Logist'EC	Energy crops

4. Case studies relevant for MUSIC

Document	Description	Project	Sector
D3.4 + D3.6 : Annex 3 Logistical case study in Finland D3.4 + D3.6: Cover report Results logistical case studies	The logistical case study in Finland tried to find cost-efficient operation models in timber transport logistics by trucks in a preset case environment in Central Finland. (2015)	S2BIOM	Forest
D6.3-Flagship cases report v1	uP_running case study of power plant (FIUSIS) using olive tree prunings as fuel. Located near Taranto in Italy.	uP_running	Agro
Swedish case study	Demonstration of an Integrated Biomass Logistic Centre (IBLC) inside the grain-milling and feed industry for the production of straw-based bio-commodities for the transport sector (bioethanol and bio-oil)	AGROinLOG	Agro

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5. Lessons learned 1/2

- Projects with IBC logistics scare
- Lots of biomass mobilization activities, knowledge transfer, awareness rising has been done (still needed)
- Many tools developed for biomass mapping, only a few for logistics
  - Some tools not operational anymore
  - BioBoost tools the most relevant for use in the pyrolysis case, needs expertise to run simulations.
  - Important considerations for developing and offering tools for stakeholders:
    - Ask the end user what kind of tool they would use
    - Involve the end user in the development or testing stage
    - User friendliness is essential, but also appearance
    - Accessibility
    - Promotion, one eventually wants the tool to be used!?

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5. Lessons learned 2/2

- Knowledge transfer, awareness building
  - Local contacts essential
  - Social acceptance is a challenge
  - Cultural differences
  - Implementing knowledge from one country or region to another, time and effort needs to be spent to fully learn and understand the target environment
- Biomass mobilization
  - Demonstration of equipment or methods for biomass harvesting needs 2 seasons, one season is not enough.
  - Do not use equipment that is a prototype in demonstrations

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6. Stakeholder engagement

- Who is a stakeholder?
  - Someone who bares a risk in some sort after having invested some form of capital or value in a firm, for example:
    - Upstream producer, downstream producer, IBC producer
  - Someone who is at risk as a result of a firm's actions, for example:
    - Government official, non-government, local authority, activist groups
    - European authorities, international policy actors, other economic actors/networks

- Most common ways
  - Local contacts, such as associations, organizations (also the most important one!)
  - Events, such as workshops, information evenings, trainings

- Other ways to engage
  - Training of trainers, training of consultants (not always successful)
  - Open call to show case projects of the locals (depends on the project)
  - Competition with a price, e.g. consultancy for a SME
  - Communication after the project, questionnaires to evaluate the project in the eyes of the stakeholder
  - Combining events with other projects to reach larger audience

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Stakeholder engagement – lessons learned

- Connection and communication:
  - First bilateral communication or small groups to create a solid contact with the interested parties.
  - Motivation of the stakeholders by underlining the benefits for them, make sure **the why's** are understood.
  - Motivation of local contacts
- Financial:
  - Added value for the stakeholder
    - Financial compensation within the project is not enough if the stakeholders do not see long term benefits (financial, social).
  - Prove financial viability first (for establishing new value chains)

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Stakeholder engagement – lessons learned

- Practical
  - Offer working and user-friendly solutions/tools (in user's opinion!)
  - Combine event with events that stakeholders could normally join, higher chance of exposure
- Cultural
  - Think of the local culture and environment
    - How do people like to communicate when in business
  - Approach/engage them when they are not busy with their main business/activity
    - For example: farmers are busy during harvesting season, district heating operators in the winter
  - Take local events into account, such as religious holidays, important football matches

" The major driving force for achieving success are passionate local leaders who want to change the current situation. " –Lessons learned in BioRES project.

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7. Project matrix - navigating in this document

	Biomass type				Project focus					Target countries			
Project name	Forest biomass	Agro biomass	Landscape biomass	Marginal lands /energy crops	Biomass mapping	Mobilisation of biomass	Value chain development	Logistics development	Logistics and trade centers	SOUTH EU	NORTH EU	CENTRAL EU	EAST EU
AgroBioHeat		x		x			x			x			
AGROinLOG		x							x	x	x		
BioBoost	x	x	x		x	x		x		x	x	x	x
BIOMASSUD PLUS		x			x					x			
BIO4A				x			x			x			
BiomassTradeCenter II	x								x				x
BioPlat-EU				x			x			x	x	x	x
BioRES	x								x				x
Europruning		x				x		x		x		x	
ENABLING	x	x	x	x		x	x		x	x	x	x	x
FORBIO				x	x		x			x		x	x
GreenGain			x		x	x	x			x		x	
INFRES	x				x			x			x	x	
Logist'EC				x		x	x	x		x		x	
S2BIOM	x	x	x	x	x			x		x	x	x	x
SECURECHAIN	x						x			x		x	
SIMWOOD	x					x				x	x	x	x
sucellog		x							x	x		x	
uP_running		x	x		x	x	x			x		x	
Other projects													

Use the links to go to the project of your interest. Each slide contains a link back to this page.

Final remarks

- MUSIC interest are covered in many projects and a lot of knowledge is available
  - Important to check if the information is up to date
  - Many technological solutions exists and have been developed for biomass mobilization
  - Logistics solutions are scarce, no prior demonstrations of IBC logistics
  - Social acceptance and knowledge transfer important in engaging biomass producers
  - Policies and guidelines are needed to enhance the use of biomass
  - Stakeholder engagement is a general and well-known challenge. It requires resources; connections, communication, knowledge and understanding
- The most interesting results are combined in the first half of the presentation
  - More information about the projects and the results can be found on the project summaries after this slide
  - Navigating via project matrix

PPT contributors: Kaisa Vikla, John Vos and Patrick Reumerman from BTG.

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9. Project's summaries and further information

Market ready agrobiomass heating solutions: AgroBioHeat

- H2020 project between Jan 2019 - Dec 2021, GA 818369
- 13 partners: DEN, ES, BE, AT, GR, HR, RO, UA, FR, DE
- Market uptake support project.
- **Scope:** Focuses on using agricultural biomass (residues, energy crops, agro industrial byproducts) for small scale heating applications (indicatively 1MW in thermal). Project builds on the experience from uP_Running, Biomasud Plus and others.
- **Goals:** Helping to set up value chains for utilizing local biomass sources to improve use of bioenergy. Targets groups are local actors, such as communities, SMEs, municipalities, greenhouses, agroindustries or other instances that would like to use agricultural biomass for heating. To raise trust among stakeholders in agrobiomass heating solutions. To promote changes in the mind-set of the value chain actors and clusters as well as to empower them for the deployment of agrobiomass heating solutions.
- **Methods:** Open call will be created to invite stakeholders to present their case to the project. Possible collaboration with other projects.
- **Project's website:** https://agrobioheat.eu/

Logistic centres at agro-industries: AGROinLOG

- EU-supported project funded under the H2020 programme (GA 727961)
- Implemented between November 2016 and April 2020
- **Agro-industrial sectors/countries**:
  - animal feed sector (Spain)
  - olive oil production sector (Greece)
  - cereal processing sector (Sweden)
- **Scope:** demonstration of Integrated Biomass Logistic Centres (IBLC) for food and non-food products, evaluating their technical, environmental and economic feasibility. Help the companies involved to utilize residues to IBCs or exploitable biomass (pellets or other densified material) and bring new products to markets.
- IBLC = "a *business strategy for agro-industries to take advantage of unexploited synergies in terms of facilities, equipment, and staff capabilities to diversify regular activity both on the input (food and biomass feedstock) and output side (food, biocommodities and intermediate bio-based feedstock) thereby enhancing the strength of agro-industries and increasing the added value delivered*"
- Project website: www.agroinlog-h2020.eu

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Logistic centres at agro-industries: AGROinLOG

- Initial results
  - Updated conceptual description of an Integrated Biomass Logistics Centre
  - Basic analysis of targeted agricultural sectors – Full Report. In depth-description of selected agro-industrial sectors in Greece, Serbia, Spain, Sweden and Ukraine and a review of the sectors' potential as basis for IBLC activities and benefits. Also include a broad EU-28 review.
  - Opportunities for production of biomass, bioenergy intermediates & biocommodities with logistics integration. Potential and possibilities of establishing IBLC in selected agricultural sectors and industries: 1) vegetable oil extraction, 2) olive oil mills (chain), 3) feed and fodder, 4) wine sector (cellars & distilleries), 5) grain chain (incl. straw until final product biofuel) and 6) sugar industry. Theoretical and practical opportunities were integrated by combining desk studies of possibilities and the perspective or vision of economic stakeholders.
  - Swedish case study - Demonstration of an IBLC inside the grain-milling and feed industry for the production of straw-based bio-commodities for the transport sector (bioethanol and bio-oil).

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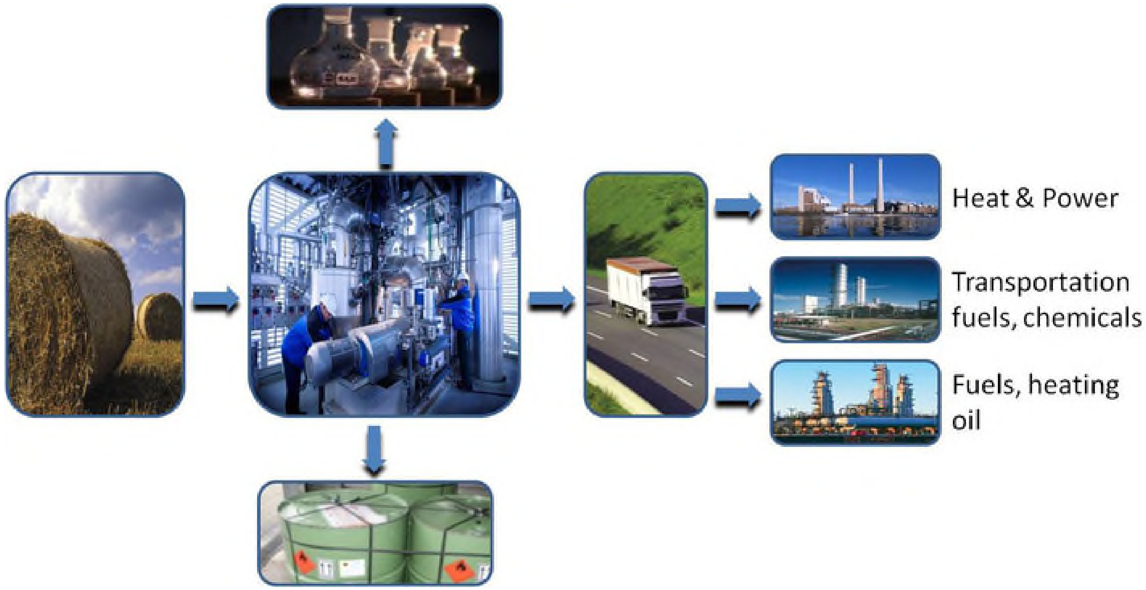
Biomass based energy intermediates boosting biofuel production - BioBoost

- FP7 supported project Jan 2012-Jan 2016, GA 282873
- Research project, 13 partners from 6 countries – DE, FI, AT, PL, NL, GR
- **Scope:** The project concentrated on dry and wet residual biomass and wastes as feedstock for de-central conversion by **fast pyrolysis**, catalytic pyrolysis and hydrothermal carbonization to the **intermediate energy carriers** oil, coal or slurry.
- Collaboration with GreenGain project
- Project's website: http://bioboost.eu/



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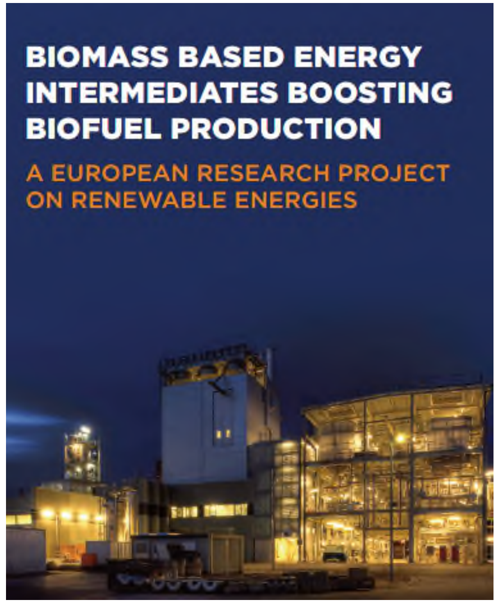
Biomass based energy intermediates boosting biofuel production - BioBoost

- **Goal:** Pave the way for de-central conversion of residual biomass to optimised, high energy density carriers, which can be utilised in large scale applications for the synthesis of transportation fuel and chemicals or directly in small-scale combined heat and power (CHP) plants.
- **Methods:** Major activities included the analysis of economic efficiency of the complete production pathways, the optimization of logistic chains and the investigation of environmental compatibility.
- **Key results:**
- BioBoost Simulator A customized algorithm optimizes locations and capacities of plants as well as biomass and energy carrier logistics.
- BioBoost Navigator is to inform about modeled costs, sites and sizes of three pathways for the conversion of residue biomass to usable bioenergy products
- Report on logistics processes for transport, handling and storage of biomass residues from feedstock sources to decentral conversion plants
- Transport & Logistics work package reports on biomass and IBC transport logistics, including equipment for material handling, cost analysis, etc.
- Executive summary of the project
- Public results: Lots of written material from the project's outcomes, ebook, all the deliverables and manuals for the tools developed.



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Sustainable markets for MED biofuels – BIOmasudplus

- Developing the sustainable market of residential Mediterranean solid biofuels
- January 2016 - December 2018, H2020, GA 691763
- 11 partners, from ES, IT, TR, PT, GR, SI, CZ, DE
- **Scope:** Developing and extending a quality and sustainability certification system for solid biomass. Assessing the existing barriers and identifying solutions with emphasis on the sustainability and quality control systems. Developing tools and databases with information about sustainable biomass resources to have a global vision and identifying sustainable solid biofuels supply chains.

- **Project's website:** http://biomasudplus.eu/

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Sustainable markets for MED biofuels – BIOmasudplus

- **Goals:** Develop markets for solid biofuels in MED countries and develop a fuel quality label for these markets.
- **Methods:** Assessing the existing barriers and identifying solutions with emphasis on the sustainability and quality control systems. Developing tools and databases with information about sustainable biomass resources to have a global vision and identifying sustainable solid biofuels supply chains.
- **Main results:**
- Selected biofuels characterization results and quality assessment report - Selected biofuels characterization results and quality assessment report. Results of analysis of more than 300 samples of biomass for quality assessment.
- Residential heating biofuels market report - Residential heating biofuels market state of the art. Report on market assessment on biofuels in target countries.
- BioRaise mapping tool - Biomass mapping tool in Mediterranean countries.

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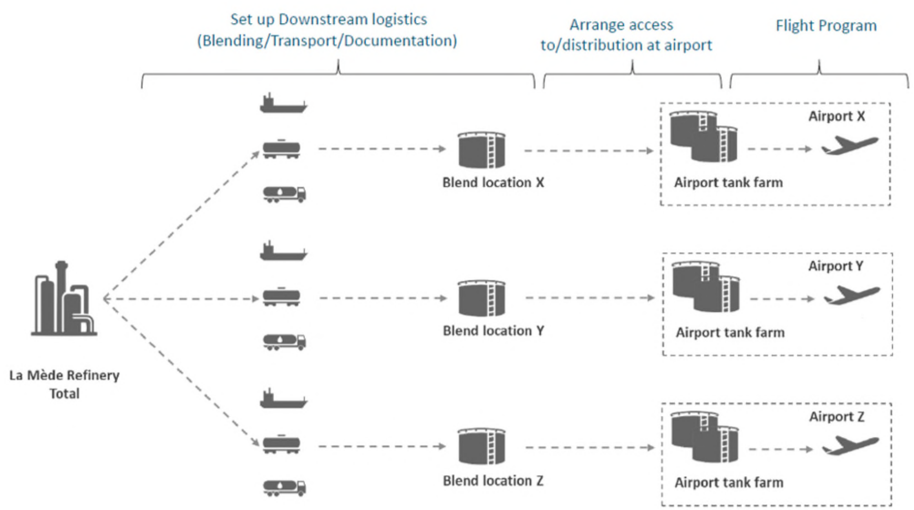
Advanced Sustainable Biofuels for Aviation – BIO4A

- H2020 project between 2019-2022, GA 789562
- 7 partners from IT, FR, NL, ES
- **Scope:** Focused on scale up of sustainable aviation fuels from residual and waste lipids, such as used cooking oils.
- **Goal:** Large-scale pre-commercial production of ASTM-certified sustainable aviation fuel in the EU.
- **Methods:** Research of drought resistant crops on marginal lands for production of alternative source of lipids for aviation fuel. Industrial demonstration pathway in which residual and waste lipids, such as used cooking oils, will be refined to the aviation fuel. The project will test the entire value chain and logistic at industrial scale and it will assess the environmental performance of the overall process.
- Project's website: https://www.bio4a.eu/



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Logistic and Trade Centres: BiomassTradeCentre II

- EU-supported project funded under the IEE programme
- Implemented between May 2011 and April 2014
- 9 MS: Austria, Croatia, Germany, Greece, Ireland, Italy, Romania, Slovenia and Spain
- **Scope:** to trigger investments in new bioenergy business, new biomass trade and logistic centres and promote new bioenergy supply contracts by bringing together interested key actors in workshops, one-to-one meetings, study visits and open days. Creation of a network of biomass quality laboratories and promoting the implementation of CEN quality standards. Demonstration of modern technologies for wood biomass production chains to forest owners, farmers, forest entrepreneurs and SMEs in rural areas.
- Further develops the idea of its predecessor - that apart from a concept of trade and logistics centres quality assurance and quality control (QA/QC) are decisive for a greater consumption of energy from biomass
- Project website: http://www.biomasstradecentre2.eu

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Logistic and Trade Centres: BiomassTradeCentre II

Biomass Trade Centre2

- Goal
  - Transfer existing good practices in biomass production, biomass trade centres and energy contracting to project countries – with a main focus on quality assurance and quality control.
- Results
  - 12 wood chip suppliers negotiated contracts with heating plants; 14 new biomass logistic and trade centres were built; 40 are in progress, receiving support from the project though feasibility studies, technical support, financial business plans etc.
  - A QA/QC system for wood fuels was developed, and tested in 26 companies. A network of 23 biomass laboratories that can help with QA/QC was created
  - Support was provided to 93 investment projects. These projects will mobilise one million tonnes of wood.
  - Relevant reports on wood biomass production, catalogues of forestry companies and biomass producers and technical information on advanced biomass technologies, fuel quality, energy contracting models, state of the art certification and necessary quality control assurance systems.
  - Monitoring of wood fuel prices in participating countries, providing useful information to potential investors.
  - Nearly 400 events (workshops, trainings, study tours, match-making events and open days), in which more than 16,500 of stakeholders participated
- Key outcomes
  - Generic guidelines for establishment of biomass trade centres
  - Wood Fuels Handbook, Energy Crops in Arable lands booklet, and Directory Wood Fuel Producers (available in multiple languages)
  - Overview on wood biomass production and biomass markets in Slovenia, Croatia, Austria, Italy, Greece, Romania, Catalonia, Spain, Germany and Ireland, http://www.biomasstradecentre2.eu/wood-biomass-production/state-of-the-art/
  - Establishment of wood biomass laboratories network, http://www.biomasstradecentre2.eu/quality-standards/network-of-wood-biom...
  - A technical paper on energy contracting model dealing with technical, economic and legal aspects
  - Catalogues of wood biomass producers and forestry companies Service provider application was lunched. Online available at http://www.biomasstradecentre2.eu/wood-biomass-production/service-providers/
  - Close to 8000 participants in 157 different events (workshops, study tours, trainings, match making events, trainings). As a result a dozen biomass trade centres were build or in progress.

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Promoting sustainable use of underutilized lands for bioenergy production through a web-based platform for Europe -BIOPLAT-EU

BIOPLAT-EU

- BIOPLAT-EU: H2020, Nov 2018 – Oct 2021, GA 818083
- 12 partners: DE, HU, AT, IT, UA, RO, NL, FI
- **Goal:** Promote the market uptake of sustainable bioenergy in Europe using marginal, underutilized, and contaminated (MUC) lands for non-food biomass production through the provision of a web-based platform that serves as decision support tool.
- **Methods:** An information platform will be created for the availability of underutilized lands in Europe. The project will be a reference for underutilized lands. Data produced can serve as a starting point for a value chain development. Financial feasibility studies will be carried out later in the project. Provision of technical and financial structuring support stakeholders on all aspects of biomass production and processing.
- Project's website: https://bioplat.eu/

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Logistic and Trade Centres: BioRES

- EU-supported project funded under H2020 programme (GA 645994)
- Implemented between January 2015 and June 2017
- 3 target countries: Serbia, Croatia, and Bulgaria
- **Scope:** introducing an innovative concept of Biomass Logistic and Trade Centres (BLTCs) to help increasing the demand for woody bioenergy products (processed fire wood, wood chips, wood pellets, and wood briquettes)
- BLTCs are local or regional centres with optimised logistics and trading organisation, where different woody bioenergy products (or heat) are marketed at standardised quality
- Builds on various projects, e.g. BiomassTradeCentre II, FOROPA, SolidStandards, BIOREGIONS
- Project website: http://bioresproject.eu

BioRES Sustainable Regional Supply Chains for Woody Bioenergy

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Logistic and Trade Centres: BioRES

BioRES
Sustainable Regional Supply
Chains for Woody Bioenergy

- **Goal:**
  - Establish and strengthen wood biomass supply chains in the 3 target countries
- **Methods:**
  - BioRES identified priority locations for new BLTCs, country level criteria for BLTCs created
  - Assessed regional potentials for the production/use of woody bioenergy products, feasibility studies of the BLTC operations in the target countries
  - Initiated local stakeholder dialogues involving producers and potential users
  - Involving stakeholders in the assessments of the BLTCs their future opportunities and threats
- **Key outcomes and results:**
  - Your way into a BLTC - Practitioners' Guidebook - Provides practical guidance on basic terminology and methodology on the biomass logistics, how to establish and operate a BLTC as regional hub in its different stages of business development
  - BioRES Lessons Learnt – PDF
  - Report about priority locations for new BLTCs in Bulgaria, Croatia and Serbia
  - Checklist for the selection of priority regions/priority locations of new BLTCs in Bulgaria, Croatia and Serbia
  - Potentials and limitations for the transfer of European good practices to Bulgaria, Croatia and Serbia

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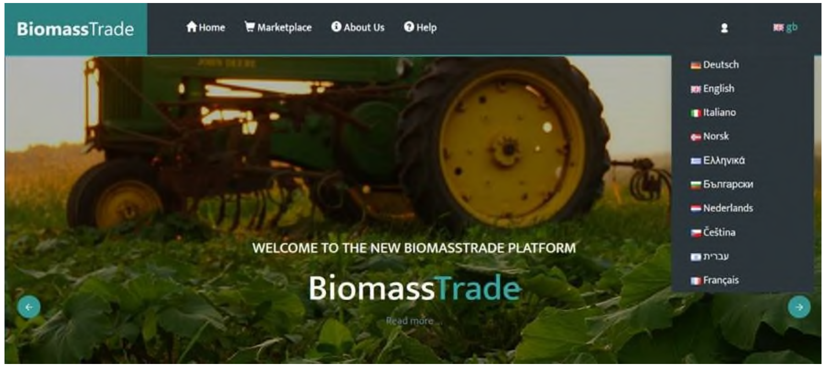
Biomass value chain development: Enabling

- EU-supported project funded under the H2020 programme (GA 774578)
- Implemented between December 2017 and November 2020
- **13 countries**: IT, BE, NO, IE, AT, BG, UK, NL, GR, CZE, IL, FR, DE
- **Scope:** encouraging the creation of efficient and structured biomass supply chains for the production of bio-based products
- Project website: www.enabling-project.com



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Biomass value chain development: Enabling

- **Goal:**
  - Support the spreading of best practices and innovation in the provision (production, pre-processing) of biomass for the Bio-Based Industry, in particular aiming at the creation of appropriate conditions for the development of efficient biomass to BBPs (Bio-Based Products and Processes) value chains.
- **Methods:**
  - **Best Practices Atlas** presents (wholly or partly transferable) practices, to serve as an inspiration for value chain partners.
  - The **Biomass Trade Platform** will allow biomass producers and processers to search and offer biomass residues and by-products, bio-based products as well as services.
  - The **Coaching Activities** will provide primary sector & BBI industry support for the uptake of emerging best practices.
  - The **Innovation Watch** presenting useful info (Articles, Projects, Scientific Reports, Videos, Products & Applications).
- **Key outcomes and results:**
  - **Handbook with Best Practice Sheets in the EIP-AGRI format** (D3.8) presents results achieved in the collection of the first 20 practices for the ENABLING project. Meant to be a useful and inspirational source of info for practitioners and potential stakeholders of the bioeconomy sector.

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Fostering Sustainable Feedstock Production for Advanced Biofuels on Underutilized Land in Europe - FORBIO

- H2020, 2016 -2018, GA 691846
- 12 partners: FR, DE, HU, IT, PL, RO, UA
- Target countries: DE, UA, IT
- Demonstrating viability of using land in EU Member States for sustainable bioenergy feedstock production that does not affect the supply of food and feed, in addition to not interfering with land currently used for recreational and/or conservation purposes.
- Project activities and outputs set the basis for building up and strengthening local bioenergy value chains that are competitive and that meet the highest sustainability standards, thus contributing to the market uptake of sustainable bioenergy in the EU.
- The project developed a methodology to assess the sustainable bioenergy production potential on available “underutilized lands” in Europe (contaminated, abandoned, marginal, fallow land etc.) at local, site-specific level. Based on this methodology, the project produced feasibility studies in selected case study locations in three countries.
- **Results:**
  - Report on best practices for bioenergy policy, regulations and support schemes which allow the most sustainable and energy efficient use of bio-resources
  - Roadmap for the removal of the main economic and non-economic barriers to the market uptake of advanced bioenergy
- Project’s website: https://forbio-project.eu/

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Biomass from maintaining public areas: greenGain

- EU-supported project funded under the H2020 programme (GA 646443)
- Implemented between January 2015 and December 2017
- Model regions in Spain, Italy, Czech Republic, Germany
- **Scope:** To strengthen the energy use of regional and local biomass from the maintenance of nature conservation areas and landscape elements, performed in the public interest.
- Project website: www.greengain.eu

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Biomass from maintaining public areas: greenGain

- **Goal:**
  - Collect relevant information related to the energy utilization of biomass originating in the maintenance of public areas, and provide this information in an easy and accessible way.
- **Methods:**
  - Development of the greenGain.eu information platform (greengain.eu/platform/) with info on biomass from landscape conservation and maintenance work with a focus on the energy utilization of this feedstock. BioBoost tools were used to match the biomass type with technology.
- **Key outcomes and results:**
  - Handbook for know-how on LCMW (Landscape Conservation and Maintenance Work) chains - provides an overview of the steps to implement successfully an energy production chain based on biomass from LCMW.
  - Summary good practice guidelines for regional players - discussed the main issues that need to be considered when promoting initiatives that use biomass coming from landscape conservation and maintenance work.
  - Business models of most economic conversion pathways - addresses business opportunities arising from landscape management activities. Includes cases on wood chips and grass.
  - Strategy paper for EU policy makers - demonstrates chances and perspectives of the biomass from LCMW and provides recommendations/measures for responsible policy makers on how to foster this type of biomass.

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Delivery of sustainable supply of non-food biomass to support a “resource-efficient” Bioeconomy in Europe - S2BIOM

S2Biom

- FP7 framework program Sept 2013 – Aug 2016, GA 608622
- **Scope:** The project supported the sustainable delivery of non-food lignocellulosic biomass feedstock at local, regional and pan European level through developing strategies, implementation plans and a R&D roadmap
- **Key results and outcomes:**
- Project tools are used in many activities
- Tools for biomass chains Assessment of non-food biomass resources, including energy crops and residues for EU commission to use as reference data for different aspects. More of a policy tool than actual tool for biomass mapping. Data from the project is used in many modelling exercises in EU level. Also includes a logistics aspect Bio2Match, BeWare and LogaGIStics (this one not working at the moment).
- Logistical case study in Finland - The logistical case study in Finland tried to find cost-efficient operation models in timber transport logistics by trucks in a preset case environment in Central Finland.
- Logistical case studies Aragon
- Logistical case study Burgundy
- Policy database - Instruments & Measures that foster the development of regional bioeconomies. (Can be outdated, from 2016)
- D6.1 Policy database - Deliverable on the policy database
- Book of the project results - Modeling and Optimization of Biomass Supply Chains, Top-Down and Bottom-up Assessment for Agricultural, Forest and Waste Feedstock

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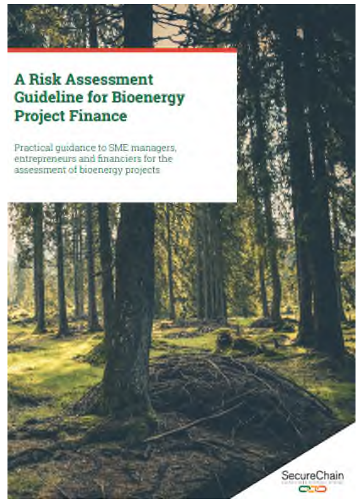
Sustainable Supply Chain Management (SSCM) practice for bioenergy - SECURECHAIN

- H2020, between 2015-2018, GA646457
- 10 partners: SE, NL, ES, GR, DE, EE
- **Goal:** promoting a Sustainable Supply Chain Management (SSCM) practice for bioenergy that meets highest environmental quality and financial viability standards and targets local biomass suppliers, energy producers and financial sector players.
- **Methods:** Focus on the whole value chain from the biomass (solid form) source to the end user. Setting up value chains. Evaluating sustainability of the value chains. Helping SMEs in different regions in Europe to improve their business. The whole value chain was involved, mainly upstream, downstream intermediary, technology owner, government official.
  - Case studies/Pilot projects were used. Project also used mentoring approach to assist SMEs in developing their bioenergy chains, in 6 regions in Europe.
  - Stakeholder consultation and learning labs were used. Regular meetings were held in which pilot projects presented their project to the stakeholders and they gave feedback on it. Mentoring approach.
  - LCA was made for the pilot projects.
  - Competition (Innovation Voucher Competition) was set up to invite SMEs to show their ideas for sustainable bioenergy solutions, price was 5000€ worth of consultancy.
- **Results:**
  - SecureChain Summary Report 2018 – including 15 fact sheets
  - A Risk Assessment Guideline for Bioenergy Project Finance - Practical guidance to SME managers, entrepreneurs and financiers for the assessment of bioenergy projects
  - The project triggered 10 million investment for future development of the pilot projects
- Project's website: http://www.securechain.eu/



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Forest wood mobilisation: SIMWOOD

SIMWOOD
Sustainable Innovative Mobilisation of Wood

- EU-supported project (GA 613762) funded under FP7 call KBBE.2013.1.2-07 - Novel practices and policies for sustainable wood mobilisation in European forests
- Implemented between November 2013 and October 2017
- EU contribution nearly 6 million euro
- Scope: How can we mobilise more wood from forests that belong to small owners?
- Project website: www.simwood-project.eu



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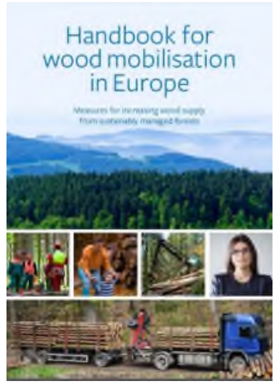
Forest wood mobilisation: SIMWOOD

- Goal
  - Promote collaborative wood mobilisation in the context of multifunctional forest management across European forest regions.
- Methods
  - The project proposed a novel integrated approach by addressing the five domains in wood mobilisation- at the same time -governance, ownership, management, harvesting and functions. 20 different pilot projects were developed around Europe. Learning labs were used to feedback the partners.
- Key outcomes and results
  - The **Handbook for wood mobilisation in Europe**. Based on a survey of initiatives and pilot projects across Europe main barriers impeding wood mobilisation are presented along with a set of corresponding measures and interventions that are considered capable of lifting these barriers. Aimed at practitioners and policy makers in the forest-based sector.
  - Stakeholder engagement: After the project, the stakeholders (pilot project participants) were interviewed with semi structured questionnaires about the project. Interestingly, the stakeholders viewed themselves as main contributions and actors instead of the project partners.



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Logistic centres for agro-industry: sucellog

sucellog

- EU-supported project funded under the IEE II programme
- Implemented between April 2014 and March 2017
- **Countries**: AT, FR, DE, IT, ES
- **Scope:** to increase the participation of the agrarian sector in the sustainable supply of solid biofuels in Europe. The project action focuses on the implementation of biomass logistic centres in the agro-industry, using the large synergy existing between the agro-food economy and the bio-economy.
    - These logistics centers have the equipment and facilities for handling organic material (food or feed). They often operate seasonally and therefore there is an opportunity to do seasonal operation. These centers also have handling and delivery capacity for biomass and also a network of clients.
- Project website: www.sucellog.eu

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Logistic centres for agro-industry: sucellog

- Goal
  - Widespread participation of the agrarian sector in the sustainable supply of solid biofuels.
- Methods
  - **Providing technical support** and helping decision-making to agro-industries willing to start operating as solid biofuel logistic centres.
  - **Creating capacity building** in regional and national agrarian associations to provide support service to their associates and so ensuring permanent capacity beyond the end of the project
- Key outcomes and results
  - Results and lessons learned
  - Handbook for agro-industries: the basic demand of information
  - Handbook for agro-industries: carrying out a feasibility study
  - Handbook for agro-industries: Lessons learned and good practice examples
  - Guideline for implementing an agro-industry logistic centre into an agro-industry
  - Guide on technical, commercial, legal and sustainability issues for the assessment of feasibility when creating new agro-industry logistic centres in agro-food industries
  - Special document explaining the organisation of SUCELLOG deliverables
  - Stakeholder engagement: More knowledge transfer required in this field to create positive awareness about biomass and bioenergy markets.

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Supply of APPR biomass: uP_running

- EU-supported project funded under the H2020 programme (GA 691748)
- Implemented between April 2016 and June 2019
- 11 partners: ES, GR, IT, UA, FR, CR, PT
- Target countries: ES, GR, IT, UA
- Builds on Europrunning (technical aspects and harvesting of biomass from pruning)
- APPR: woody biomass from Agrarian Pruning and Plantation Removal
- **Scope:** set the path for the development of bioenergy utilisation of APPR (in particular wood obtained from vineyards, olive groves and fruit tree plantations). Awareness building.
- Project website: www.up-running.eu

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Supply of APPR biomass: uP_running

- Goals:
  - Unlock the potential of woody biomass from APPR, especially those obtained from vineyards, olive groves and fruit tree plantations
  - Promote sustainable use of biomass as energy feedstock, reduce scepticism regarding technical as regard of the technical difficulties and the occurrence of non-successful experiences.
- Methods:
  - Sector analysis and Policy recommendations
  - Demonstrations of new chains
    - Mobilisation of biomass 5 demonstrations in 4 target countries (20 value chain demos)
  - Observatory of pruning potential and utilisation
  - Capacity building, consultancy, advocacy
- Key outcomes and results:
  - Main results (concise 1 page flyer)
  - Policy guidelines Contains Key Messages with associated recommended actions
  - Observatory map of biomass from APPR. Contains >500 (uP_running and other) experiences of field measurements; mechanised collection, and value chains
  - Demonstration case studies analysis
  - D6.3-Flagship cases report v1 uP_running case study of power plant (FIUSIS) using olive tree prunings as fuel. Located near the Italian demo site in Taranto.
  - D6.4: Flagship success cases update, report on case studies of fruit trees and olive tree pruning to produce wood chips and pellets for the markets.

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KBBE.2012.1.2-01 - Development of new or improved logistics for lignocellulosic biomass harvest, storage and transport

- Three FP7 sister projects: INFRES, Logist'EC & EuroPrunning
- Implemented between 2012 and 2016, with combined budget of ca. 10 million euro
- Joint scope: **field-demonstrated practical solutions** implemented in rural communities to harvest, store and transport lignocellulosic biomass for the production of bioenergy and biomaterials. Besides developing technologies and adapting machines, projects also assessed sustainability of the proposed supply chains and barriers to innovation.
- Project websites are offline, but some final reports are accessible trough CORDIS. Results on logistical concepts are also fed into S2BIOM D3.2 "Logistical Concepts" (August 2015) that surveyed logistical biomass value chains addressed in various European projects

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Forest residues logistics: INFRES

- Target countries: FI, SE, AT
- Goal
  - Accelerate the technological development of biomass mobilisation by producing research-based knowledge, technologi service innovations for forest residue feedstock supply to deliver heat, power and biorefining industries
- Methods
  - Improved technical solutions, modelling optimization of mobilization and logistics of forest biomass, market predictions for 2nd generation biofuel from wood chips were made. LCA emission calculations.
  - 9 demonstrations were carried out to improve the logistics and harvesting of forest biomass resulting in reduction of costs for the supply chian (10-20%) and reduction of emissions (10% for the value chains.
- Outcomes and Results
  - Development of technology and quality improvement of forest biomass
  - Adapting existing forestry practices for improved biomass production
  - From demonstrations to practice; Sustainability of forest biomass feedstocks
  - Technology foresight and barriers to innovation.
- Final publication summarises key results & findings, and gives insight into the current status and development trends of forest biomass sourcing for energy production.
- Journal article: Diana Tuomasjukka, Dimitris Athanassiadis & Martijn Vis (2017), *Threefold sustainability impact assessment method comparison for renewable energy value chains*, International Journal of Forest Engineering

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Agricultural residues logistics: Europruning

- First project to focus on mobilization of biomass from agrarian pruning
- Goal:
  - to implement a pruning-to-energy value chain by introducing new technology and by removing barriers to the use of agricultural residues as an energy resource. The technical barriers : scattered biomass, no collection methods, collection volumes and quality of biomass low.
- Methods:
  - Europruning developed specific equipment for pruning harvesting and an innovative logistics tool for optimising pruning handling along the value chain. Equipment was field demonstrated under real environmental conditions working with different species and climate and procurement situations in demos performed in FR, ES, DE
- Outcomes and Results:
  - Pruning harvesting equipment (chippers, bailers)
  - EuroPruning's Logistics Smart System (not used)
  - Pruning to energy logistics chains demonstration and monitoring
  - Changes in prunings quality specifications along the logistics chain
  - Pruning to energy logistics chains and soil management
  - Environmental and socioeconomic assessments
  - Awareness build and realization of the challenges in the field of pruning's mobilization (social challenges).
  - Business Models, Policy implications
- Final report summarises key results & findings.

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Energy crops logistics: Logist'EC

- Goal
  - Developing new/improved logistics technologies for (multi-)annual crops, perennial grasses, and short rotation coppice (SRC)
- Methods
  - Included pilot- to industrial-scale demonstrations, in particular around 2 existing bioenergy and biomaterials value-chains in Eastern France and Southern Spain
- Outcomes and Results
  - Benchmarks for currently-commercial and new technologies
  - Methods, models tools to integrate, design and assess supply chains
  - Data bases on logistic chains (relative to individual pieces of equipment, feedstock management, yields, and sustainability criteria),
  - Examples of whole-chain implementation
- Final report summarises key results & findings.

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Further projects of interest

- The project **BECOOL** (H2020) aims to strengthen EU-Brazil cooperation on advanced lignocellulosic biofuels. Information alignment, knowledge synchronization, and synergistic activities on lignocellulosic biomass production logistics and conversion technologies are key targets
- The project **Vineyards4Heat** (LIFE+) demonstrated the performance of the biomass circle with pilot tests in two wineries (Codorniu and Vilarnau) and in one area of public facilities in Vilafranca.
- **Baltic ForBio** (Interreg) aims to increase production of renewable energy by improving the capacity of public authorities, forest and energy agencies, organizations of forest owners and entrepreneurs and forest advisory organizations for promoting the harvest and use of logging residues and small trees cut in early thinning

BECOOL Brazil-EU Cooperation for Development of Advanced Lignocellulosic Biofuels

VINYES XCALOR

Interreg Baltic Sea Region
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

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Market Uptake Support for Intermediate Bioenergy Carriers

Biomass mobilization and logistics experiences in Greece

Recent projects and best-in-class examples

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EU H2020 grant no. 857806, 1/9/2019 – 31/8/2022

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Content

1. Bioenergy role in Greece
2. Biomass types, availability and logistics
3. Recent experiences
4. References and further information

1. Bioenergy role in Greece

1.1 Recent developments

- The new NATIONAL ENERGY AND CLIMATE PLAN was launched in 2019 for public consultation. It is characterised by the strategic decision announced by the Prime Minister for a faster transition to a de-fossilised economy, and includes the decision to cease the operation of lignite-fired power plants until 2028.

1.2 Main targets

- **0%, the percentage of lignite coal** (the reduction in the mining of lignite and its use for power generation purposes will have a direct and indirect impact on growth and employment in lignite-producing areas and will be felt by the local communities. Therefore, specific transition policies will have to be developed).
- **About 65%** of the gross final electricity consumption from RES, compared to previous target of 55%. In practice this means that from approximately 6 GW electricity consumption today, we will have to reach 14.5 GW- 8 new GW of installed RES.
- E-mobility: Maintain the target of 10% of all passenger cars in Greece in 2030 to be electrically driven.
- To promote bioenergy, thermal energy produced by **RES mainly in district heating networks** including biomethane injection into the natural gas network will be promoted, as well as **efficient supply chains for residual biomass/biodegradable matter** and for the support and implementation of optimal environmental and energy-efficient **bioenergy applications.**

Main targets (continued):

- National targets for RES until 2030: >30% RES gross final energy consumption
  - >55% in electricity, >30% in heating/cooling, >14% in transport)
- In the field of RES electricity generation, the main applications for the next period to achieve the targets are wind farms and photovoltaic parks, which are considered to be the most mature and competitive (Fig. 1). **Biomass/biogas is expected to contribute with 320 MW (2030) from 82 MW (2019).**

Fig 1: The thin green line represents biomass/biogas. Bioenergy, until 2016, shows small market penetration in comparison with the other forms of RES

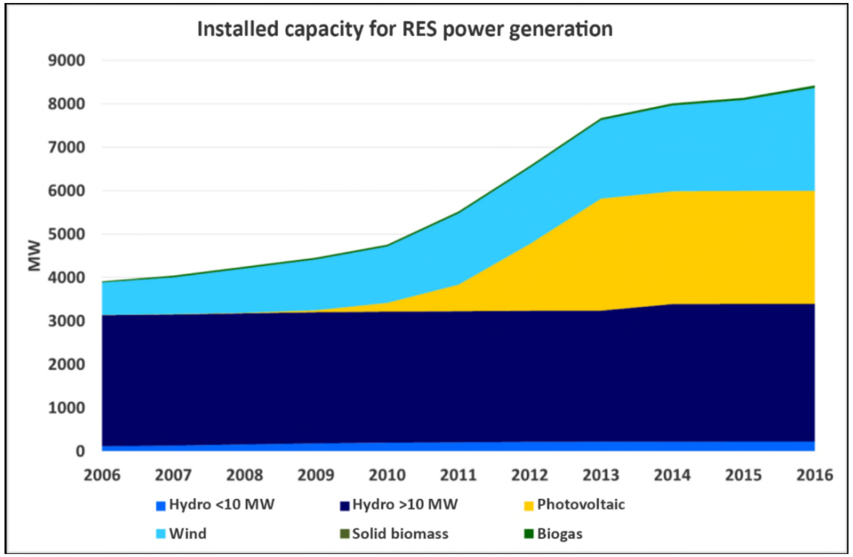
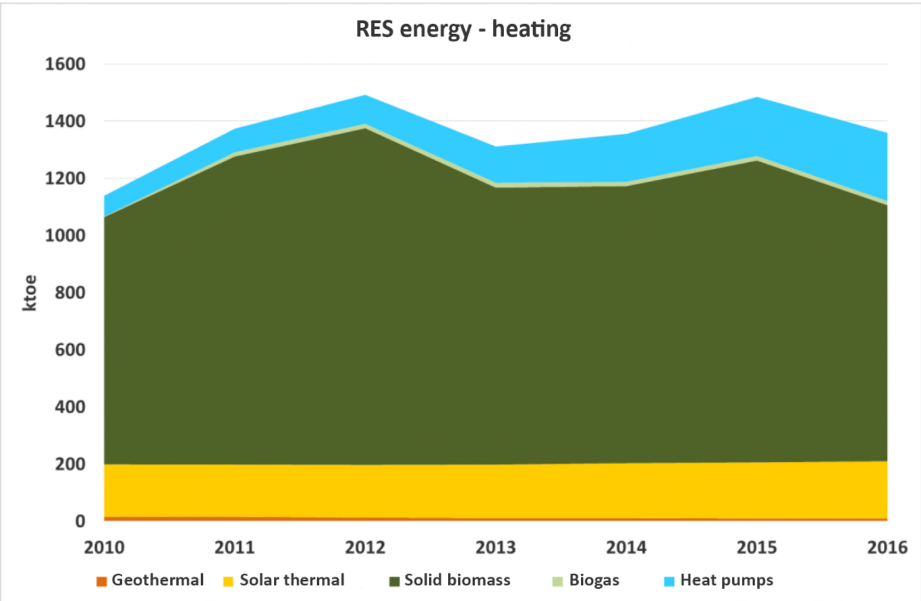


Fig.1: Installed capacity for RES electricity generation in the period 2006-2016. (Source: NATIONAL ENERGY AND CLIMATE PLAN)

Regarding the penetration and participation of RES to meet thermal needs in final consumption, the economic downturn of the previous years, in conjunction with the promotion of the use of solid biomass in urban areas have led to a historically high level of consumption of solid biomass, and in particular domestic firewood for heating. After 2020 it is expected that there will be a steady contribution of biomass (but relatively small increase) and a significant increase in the role of heat pumps thermal solar systems and geothermal energy..



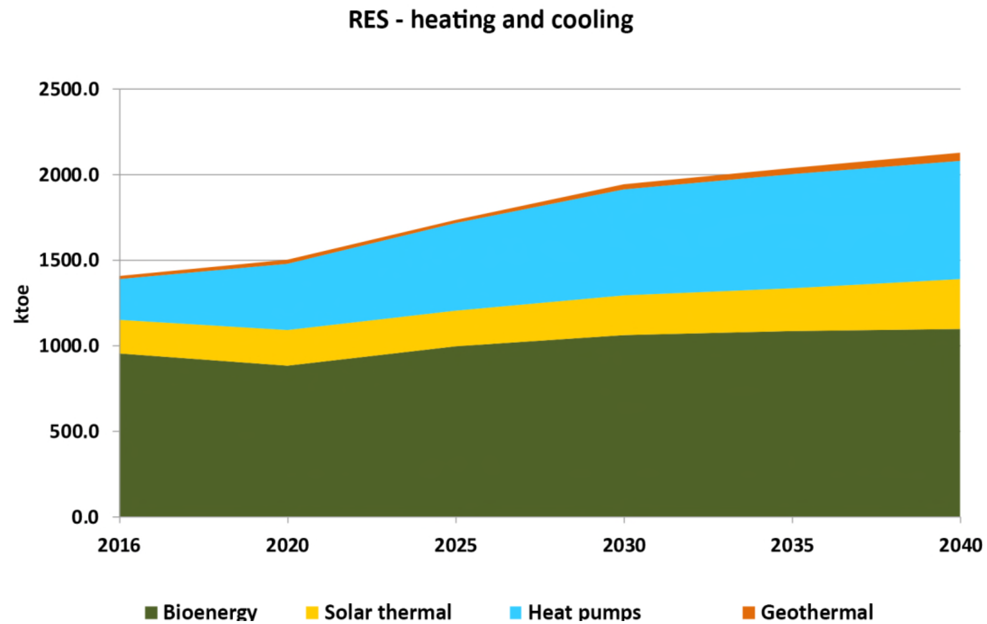


Fig. 2: RES thermal energy generation in the period 2010-2016 (left), and development of RES shares for heating and cooling in the final consumption of energy until 2040 for the scenario of existing policies and measures (right). (Source: NATIONAL ENERGY AND CLIMATE PLAN)

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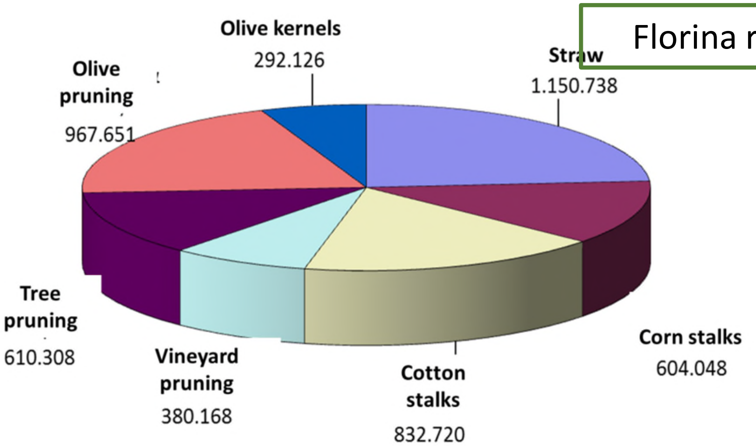
1.3 General indication of the type of biomass available (Case-study region)

- ✓ Biomass availability mainly refers to agricultural residues: straw, olive pruning, cotton and corn stalks and tree pruning. According to our estimates, technically available are ~4.9 MT dry matter/year, with energy potential of ~88 PJ/year (~ 24.4 TWh)
- ✓ Technically available firewood potential: ~410,000 t DM/year, energy potential: ~7.7 PJ/year (~ 2.1 TWh)
  - ➢ Biomass potential shows the possibility that there is room for further promotion of bioenergy



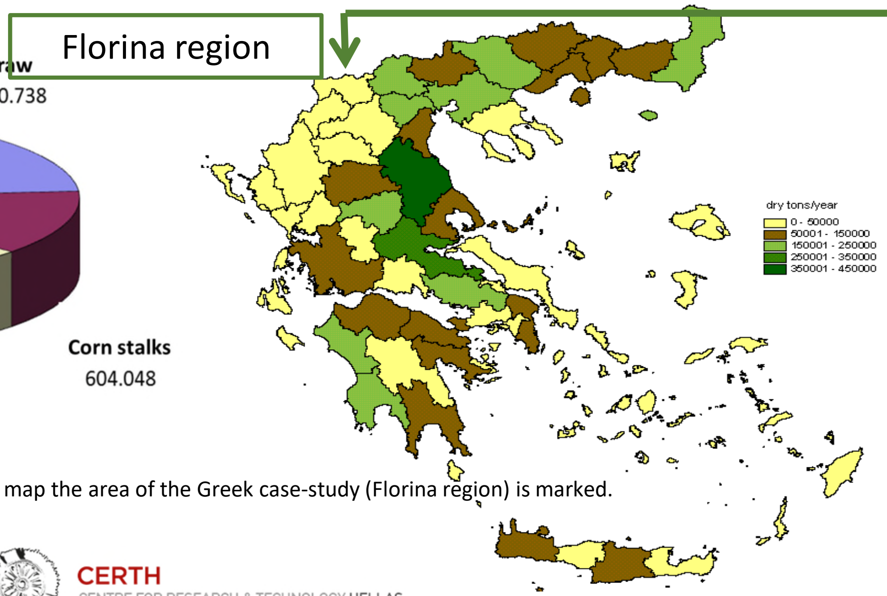


Fig. 3: Technically available agricultural residues . In the relevant map the area of the Greek case-study (Florina region) is marked.

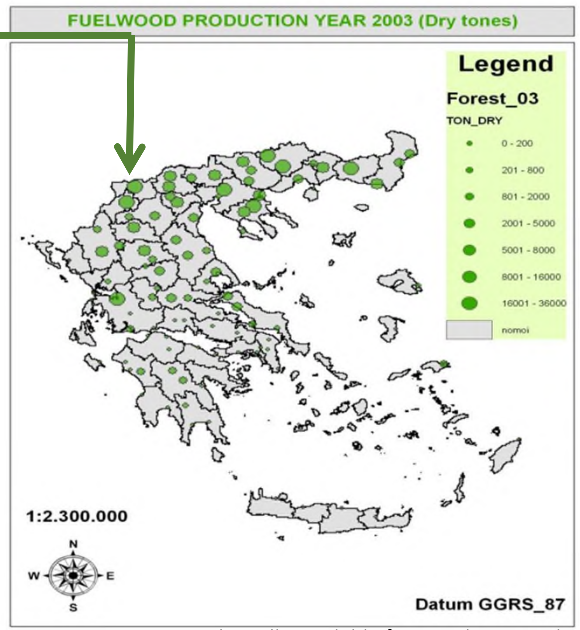


Fig. 4: Technically available firewood potential

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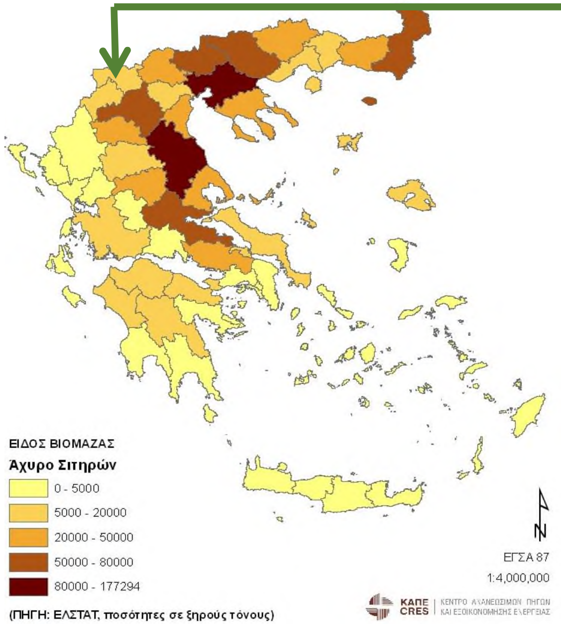
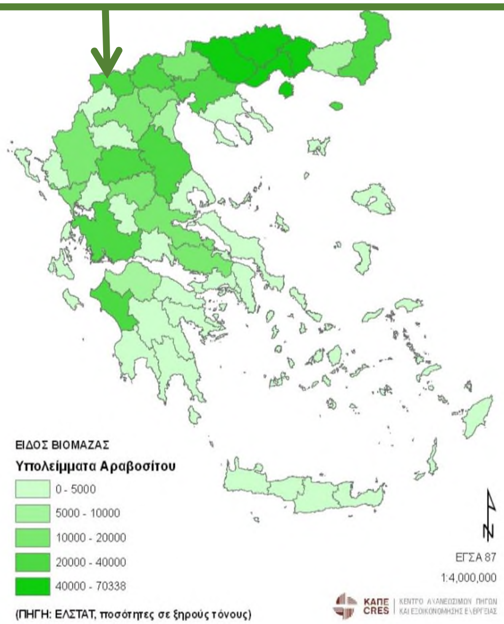
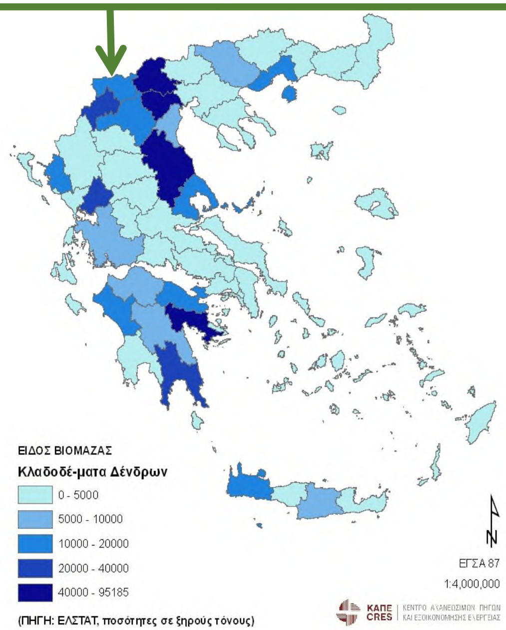
Biomass potential Florina region (MT dry matter/year)



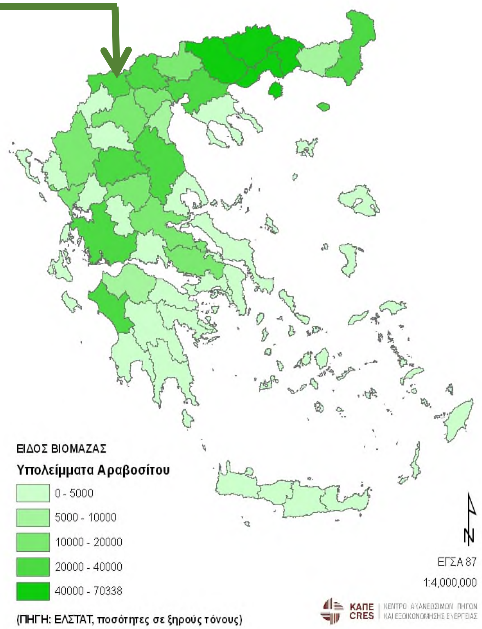
Straw availability



Corn residues availability



Pruning availability



Cotton stalks availability

Source: Hellenic Statistical Authority

1.3 Specifics on bioenergy needs and technologies in Greece

Biomass for heating (2018)

In the domestic sector (heating boilers, fireplaces etc.) consumption is about:

- 2,000,000 tons/year of firewood of forest or non-forest origin
- 61,500 tons/year of pellets

In the industrial sector (mainly small CHPs) consumption is about:

- 385,000 tons/year of oil kernels (olive-oil mills, olive kernel mills)
- 60,000 tons/year of agro-industrial residues (cotton ginning factories, fruit and nut industries, rice husks, etc.)
- 52,000 tons/year of wood residues (forest industrial residues)

In total around 2 500 000 tons/year of biomass were consumed in 2018 corresponding to 34,7 PJ.

➢ Industrial use of biomass is comparatively low due to mobilization difficulties and biomass product quality inconsistency

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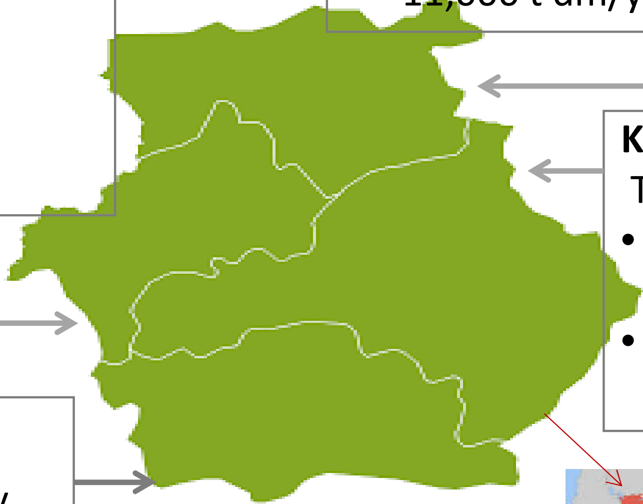
2. Biomass types availability, logistics in the Greek case-study

2.1 Availability of biomass types

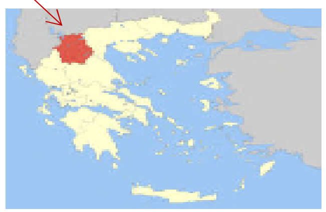
Florina region:
Total biomass:~ 120,000 t dm/y
- 104,000 t dm/y cereals (of which 55,600 t dm/y is corn residues)
- 11,000 t dm/y pruning (vineyards, fruit trees)

Kastoria region:
Total biomass:~ 47,000 t dm/y
- 41,000 t dm/y mainly straw
- 4,000 t dm/y pruning
- 1,800 t dm/y firewood



Kozani region:
Total biomass:~ 225,000 t dm/y
- 203,000 t dm/y cereals (of which 50,000 t dm/y is corn residues)
- 8,000 t dm/y pruning (vineyards, fruit trees)

Grevena region:
Total biomass:~ 91,000 t dm/y mainly straw



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2.2 How is this biomass available?

Straw is available in the form of bales, with average prices of 2 €/small bale and 10€/big square/cylinder bale(see the following two tables)

Pruning is collected loose within each field and it is mostly burnt on the field.

Bulk density of straw (kg/m³)	Type of bales	kg/bale	Volume of bales (m³)	Dimensions (m)		
				Length	Width	Height
95.83	Small square bale	23.00	0.24	1.20	0.50	0.40
154.32	Big square bale	300.00	1.94	2.40	0.90	0.90
124.66	Big cylindrical bale	215.00	1.72		1.30	1.30

Type of residues	Dry matter (t/ha)	Moisture after harvest (%)	Number of bales/ton	Number of bales/ha	Mean weight (t/bale)
Wheat straw	2,17	5,00	4,65	10,09	0,215
Barley straw	1,20	5,00	4,65	5,58	0,215
Cotton stalks	2,54	39,90	4,17	10,58	0,24
Corn stalks	10,10	14,70	3,45	34,83	0,29

2.3 When is this biomass available – Seasonal availability

Biomass harvesting window is shown in the table: For the rest of the year biomass has to be stored

Months	1	2	3	4	5	6	7	8	9	10	11	12
Wheat straw												
Corn stalks												
Tree pruning												
Forest harvesting												
Forest industries' residues												

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Logistics

- **Firewood (forest or non-forest origin)** → Extraction (chipping) → Transportation (truck) → Utilization (households-fireplaces)
- **Wood residues** → Conversion (pellets/briquettes/ wood chips) → Transportation (truck) → Utilization (households-heating boilers/SME-small CHP, small steam boilers)
- **Oil kernels** → Conditioning (drying) → Transportation (truck) → Utilization (SME-small steam boilers)
- **Agricultural residues** → Extraction (Harvesting) → Conditioning (drying) → Baling/chopping) → Conversion (pellets/briquettes/ chopped) → Transportation (truck) → Utilization (SME-small CHP, small steam boilers)
- **Agro-industrial residues** → Conditioning (drying) → Conversion (pellets/briquettes) → Transportation (truck) → Utilization (SME-small steam boilers)

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Potential value chain of straw/pruning of the Greek case study

Corn/straw residues/pruning

Truck

10-50 km

Residues transported directly to the DH plant

District Heating Plant of Detepa

or

Truck

10-50 km

Residues transported to the torrefaction unit

Torrefaction unit

Truck

~10 km

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aGROWchain (https://agrowchain.eu/)

- **Duration**: 29/05/2018-28/05/2020
- **Budget**: 669.084,90€
- Funded under 'Interreg IPA CBC Programme Greece- Republic of North Macedonia 2014-2020'
- **The scope** of this project is to design and implement a supply chain for green wastes, combined with the relevant business model, which will secure its sustainability.

The project is carried out in Municipality of Florina in Greece and Municipality of Lechovo in North Macedonia.

The supply chain will serve selected end users in each country, therefore its operability will be tested and possible problems and barriers will be resolved.

Partners: DETEPA, CRES, CLUBE, Municipality of Novaci, National Extension Agency

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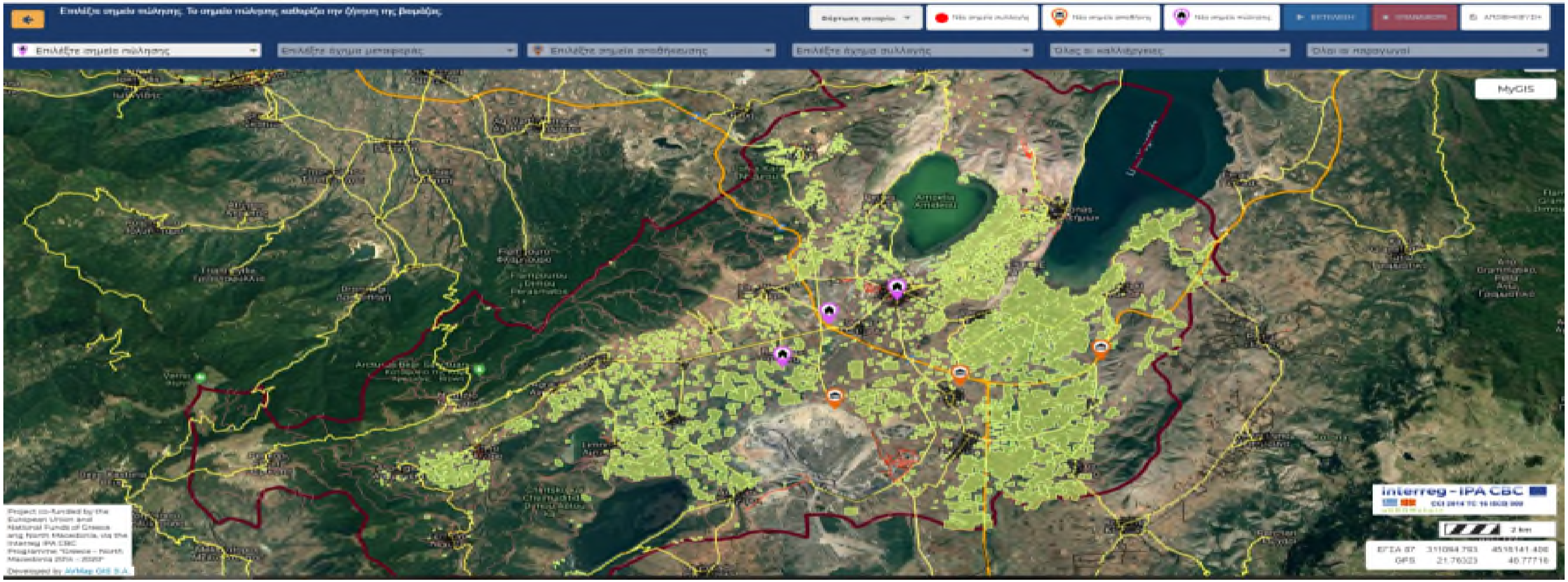
Screenshots from GIS of the aGROWchains project



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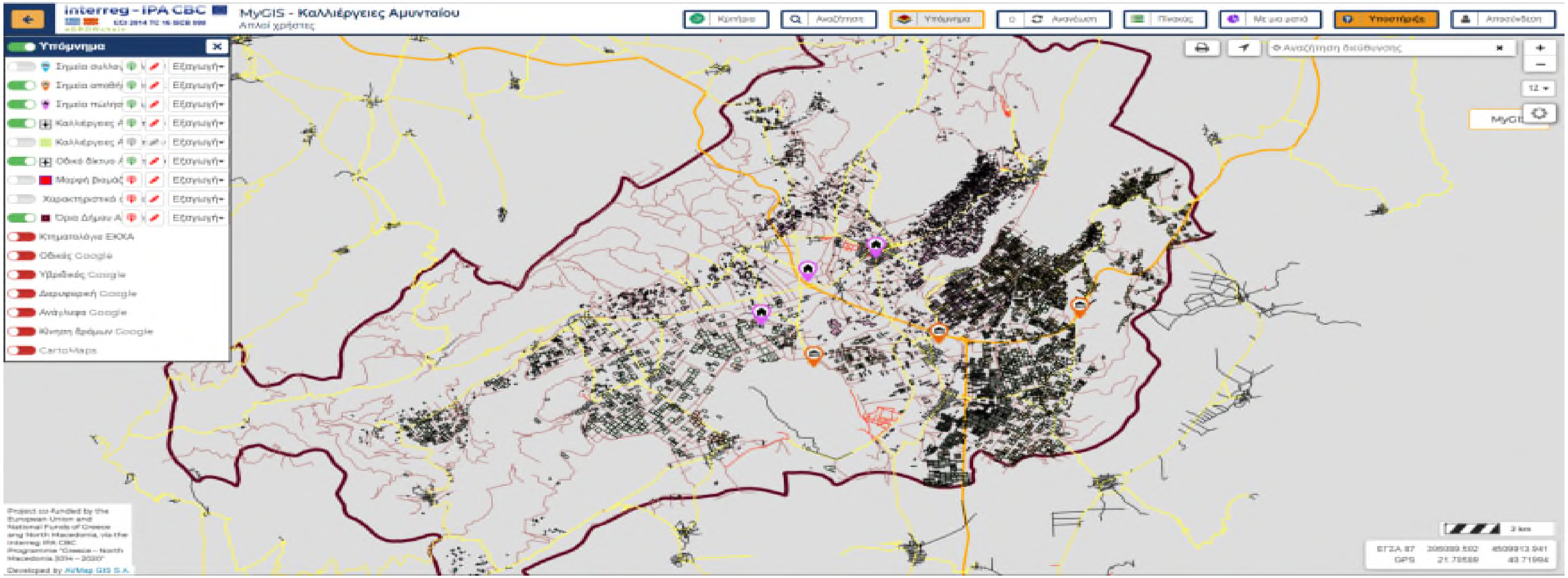
Screenshots from GIS of the aGROWchains project



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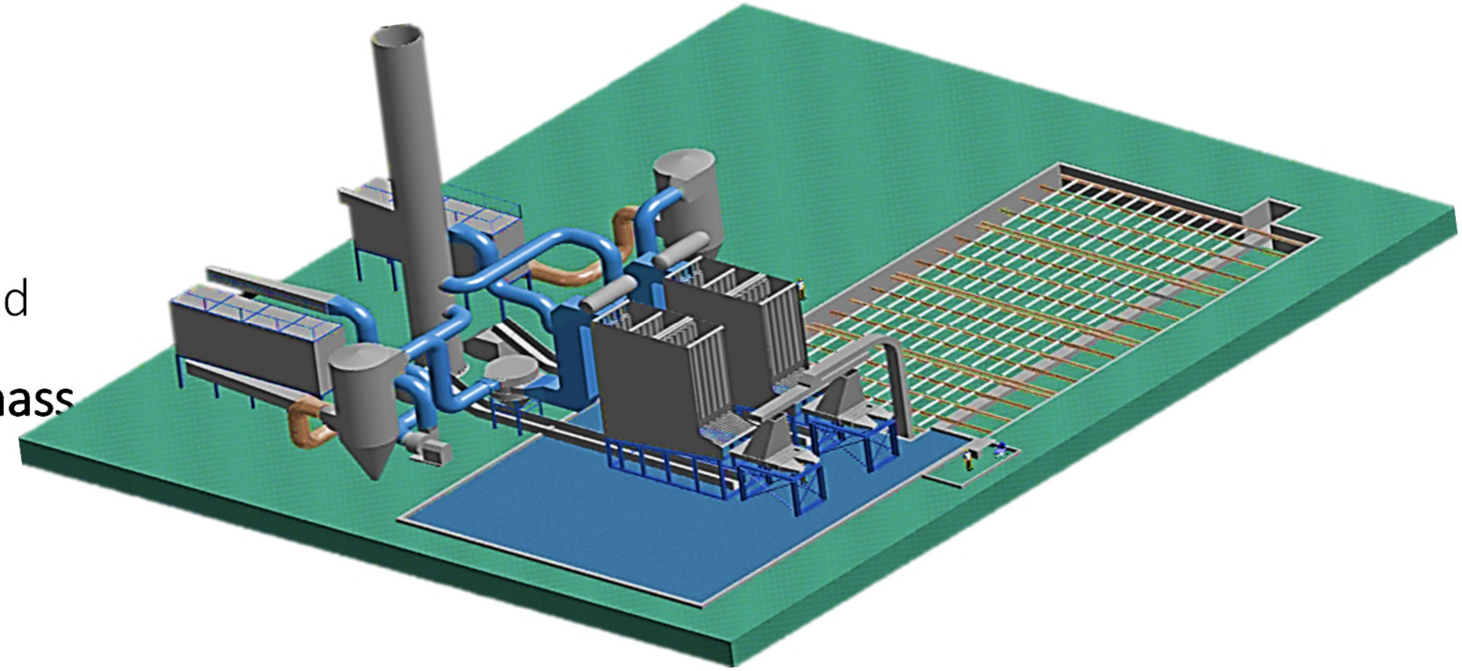
The DISHEAT project



The combustion unit is designed for mixtures of **lignite and biomass** with typical moisture rates **of 25% and 45%,** respectively.

ACKNOWLEDGEMENTS

The DISHEAT project is co-financing of the project by the European Regional Development Fund and Greek national resources. The Implementatio &

Innovation (OP Competitiveness, Entrepreneurship & Innovation).

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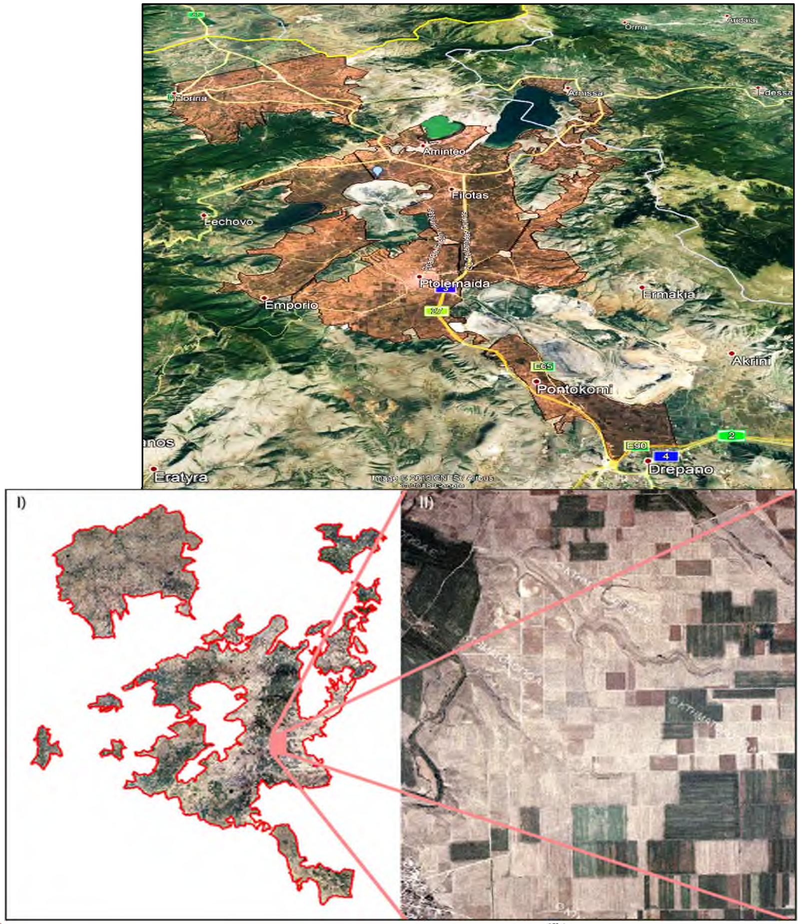
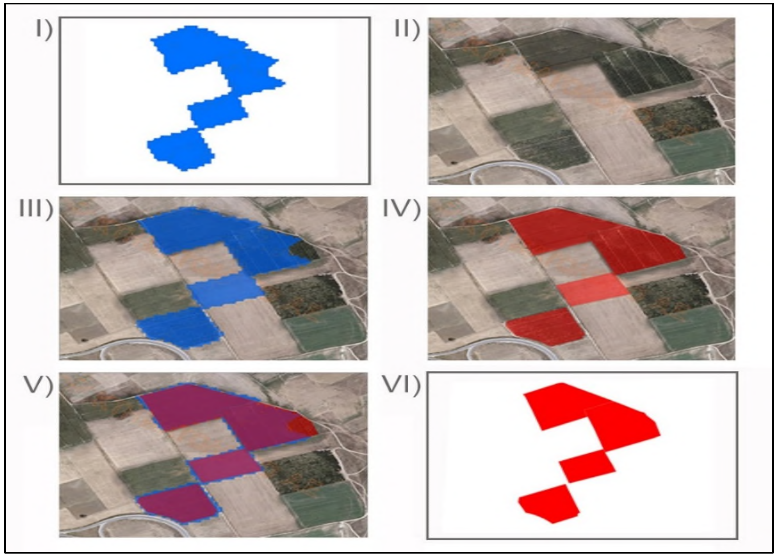
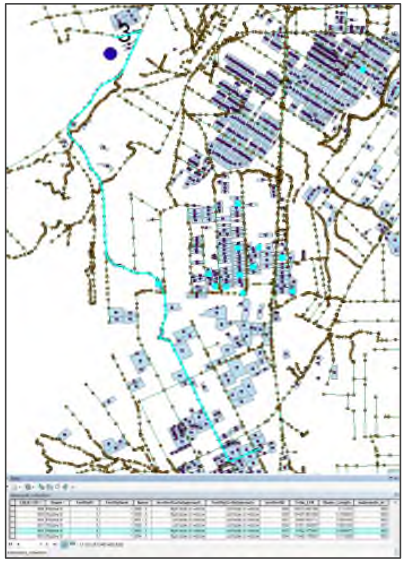
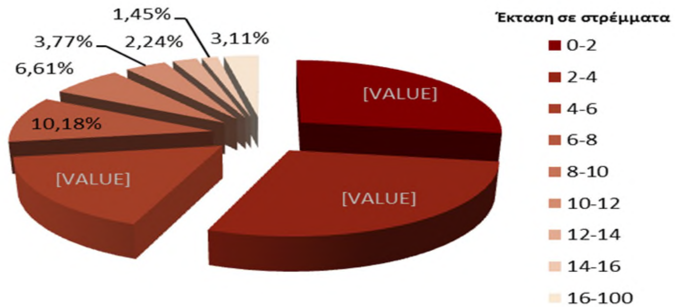
MUSIC Mapping of the area in DISheat project









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DISHEAT

The DISHEAT project is co-financing of the project by the European Regional Development Fund and Greek national resources. The Implementation is under the OP Competitiveness, Entrepreneurship & Innovation (OP Competitiveness, Entrepreneurship & Innovation).

AgroChains (http://agrochains.gr/)

- **Project info**: Supply chains of green residues for energy exploitation
- **Duration**: 31/07.2018 – 30.6.2021 (3 years)
- **Budget**: 822.256,52 €
- **The scope** of this project is:
  - to develop, implement and economically evaluate supply chains from agricultural residues (straw, corn stalks and combs), tree pruning and urban green
  - to produce bioenergy carriers (chips, pellets, briquettes) that will be subjected to combustion tests (chips, pellets) and gasification tests
  - to evaluate the acceptance of the produced solid biofuels and assess sustainability and local impacts of supply chains, both environmentally and economically,
- Funded by the European Regional Development Fund and Greek national resources. The Implementation is under the OP Competitiveness, Entrepreneurship & Innovation

Partners:

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

Potential bioenergy products/carriers

- Chips
- Bales
- Pellets
- Briquettes

- Pellet consumption in Greece (2016 data): 44,000 t/y, pellet production potential surpasses 130,000 t/y.
- Pellet prices: 220-280 €/t, which however concern AAA category of high quality wood.
- Pellets are mainly used in the residential (65%) and tertiary sector (25%), while a 10% is used in the industry.

Field trials

- Comparison of existing collection methods / equipment (time, costs, losses)
- Comparison of existing storage methods (losses, quality control)
- Transportation (time, costs, losses)
- Pellets (technology efficiency, quality control)
- Briquetes (technology efficiency, quality control)
- Combustion (technology efficiency, technical burdens)
- Gasification (technology efficiency, technical burdens)

КАПЕ CRES | CENTRE FOR RENEWABLE ENERGY SOURCES AND SAVING

CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

Final remarks

- Significant biomass potential at case study area
- Majority of biomass (80%) is consumed by households in the form of fire woods
- Significant opportunities rise from the announced shutting down of the lignite-fired power plants combined with the high demands of district heating plants for biomass
- But there is a lack of transition policies during the decarbonization era as well as lack of established heat prices
- Promotion of other forms of RES at the expense of biomass utilization
- The industrial sector is reluctant to use biomass (difficult mobilization, lack of established biomass supply chains, high logistics costs, lack of biomass trade centers, inconsistency of product quality)
- Greece presently falls behind on fulfilling its individual targets for biomass utilization.

References and further information

- aGROWchain (https://agrowchain.eu/)
- DisHeat (http://disheat.gr/)
- AgroChains (http://agrochains.gr/

Acknowledgements

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Market Uptake Support for Intermediate Bioenergy Carriers

Biomass mobilization and logistics experiences in Italy

Recent projects and best-in-class examples

RE-CORD

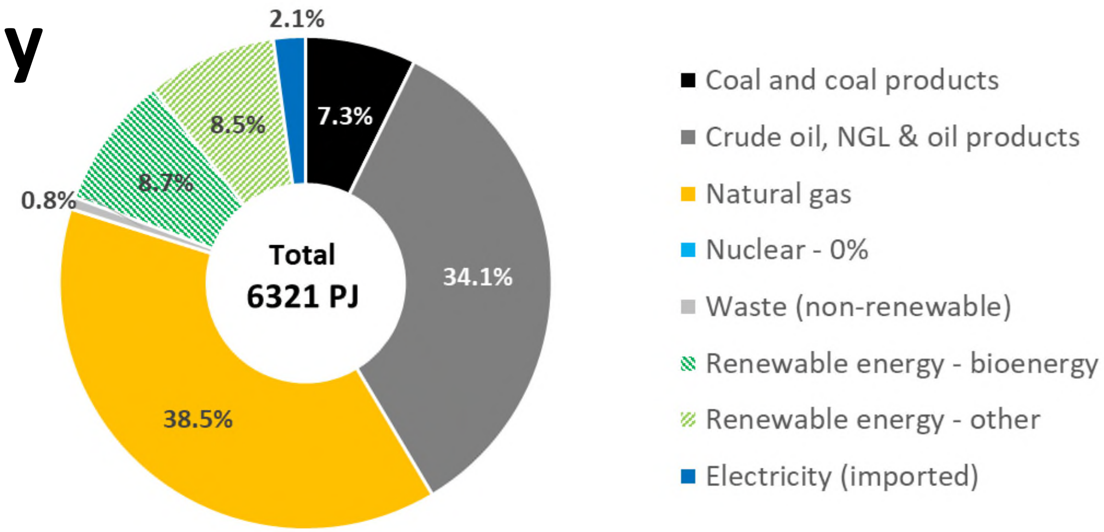
EU H2020 grant no. 857806, 1/9/2019 – 31/8/2022

Content

1. Bioenergy role in Italy
2. Biomass types, availability and logistics
3. Recent experiences
4. References and further information

1 - Bioenergy share in Italy

- In Italy, half of total primary energy supply of renewable energy sources is covered by bioenergy (552 PJ). In detail, share of bioenergy is divided as follows (source: ieabioenergy.com):



Sector	Share of bioenergy	Share of renewable energy	Overall production/ consumption
Electricity production	6.8%	37.5% *(14.7% hydro)*	288 TWh (1,037 PJ)
Transport energy (final consumption)	2.9%	3.9%	1,499 PJ
Overall fuel and heat consumption[4]	Direct biomass: 12.9% Biobased heat: 1.3%	14.8%	2,168 PJ

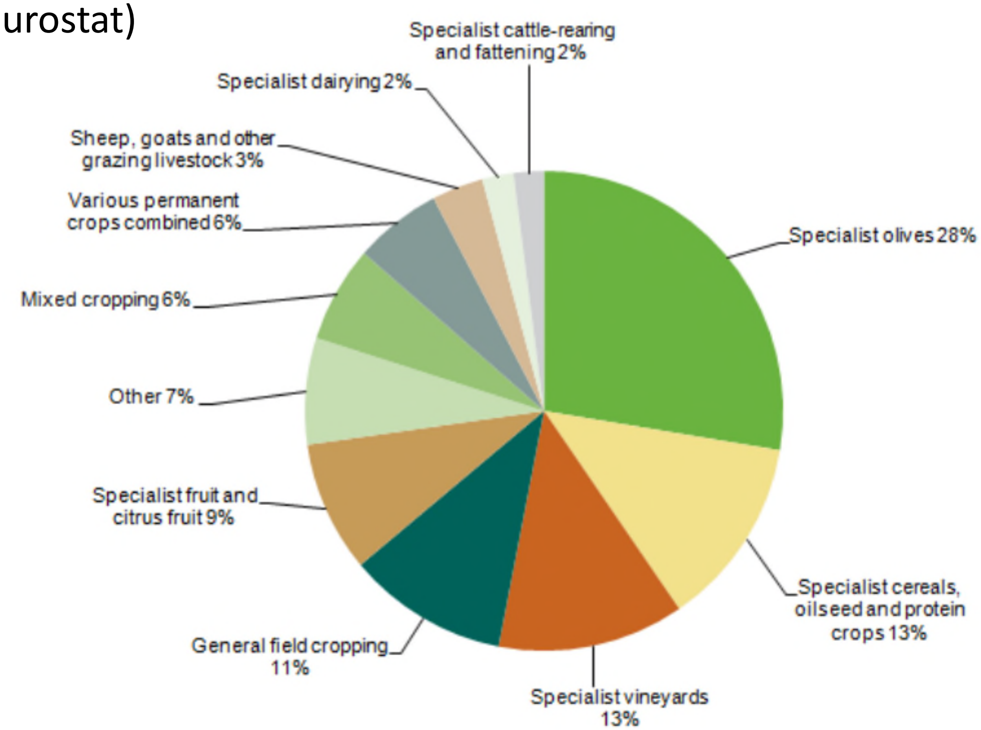
Source: World Energy Balances © OECD/IEA 2018

Goals and stimulating measures for bioenergy

- Electricity:
  - In Italy, electricity generated from renewable energy sources is promoted through VAT- and real estate tax deductions. Two mechanism are available: (1) sold to the grid; (2) net-metering (solar panels).
- Heat and cooling:
  - A price-based scheme (Conto Termico) is in place for small RES-H sources. Biomass technologies are eligible and the incentive is granted for 2 and 5 years. Furthermore, a tax regulation system is currently in place for the promotion of RES-H. Conto Termico and Tax detractions are not combinable.
- Transports:
  - The current goal foresees 8% of biofuels, of which 0.8% advanced biofuels in 2019. The competent authority is the GSE and the obligated parties are all those who feed gasoline or diesel in the system. To monitor the compliance with the biofuel quota certificates are released. One certificate corresponds to 10 Gcal of biofuel or 5 Gcal of advanced biofuel. Producers of advanced biomethane or advanced biofuels (no biomethane, which has a special regulation) are entitled to receive a premium of € 375 for every CIC that they would be entitled receive if the biofuel is released for consumption in the transport sector.

Land use in Italy

- Italy has 301,340 sq. Km of surface in 2018, where 127,170 sq. Km are cultivated land and 93,508 sq. Km are forest area (source: https://tradingeconomics.com/Italy). In general, crops distribution is the following (source: Eurostat)



2 - Biomass types, availability, logistics

- Biomass types available in Italy
  - Biomass available is mainly agro- and forest residues, dedicated crops and wood from infected trees of Xylella.
  - Biomass could be in form of pure biomass, bales, blocks pruning, pieces of wood – depending on biomass type.
  - Type of biomass are: olive, grape prunings - sorghum, corn, triticale, or also Arundo (if planted) – infected olive wood.
  - At least a kind of biomass is available all year long.
- Depending on the IBC' conversion pathway, biomass has to be pretreated (chipping, grinding, drying, …).

Agro-residues becomes the most important biomass source in a bio-economy concept!

Biomass volumes - estimations

- From VIGOR project, it has been estimated the following biomass potential production and costs (e.g. around ENI' biorefineries).
- The simulations assumes the biomass potential as «energy crops» and not as «agro-residues».

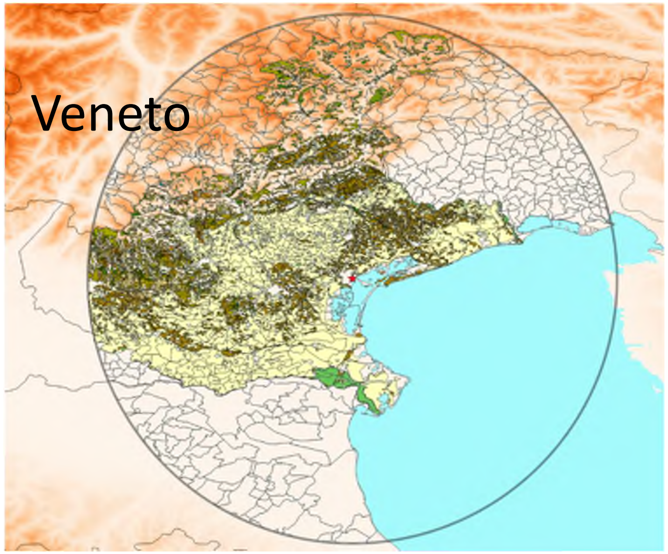
Site	Distance, radius [km]	Cost [Euro/tons]	Potential availability [tons]
Portomarghera (Veneto, Italy)	250	21	2,201,846
Gela (Sicily, Italy)	250	21	2,706,843
Portomarghera (Veneto, Italy)	100	15	1,769,533
Gela (Sicily, Italy)	100	15	1,384,785

Biomass supply - modelling

- In Italy, a GIS instrument (CropSys software) will be adopted to identify the biomass potential.
- Supply area
  - **Radius of 150km from the IBC site *(as the crown flies)***
    - → ***Porto Marghera*** *could gather biomass from* ***5 different Italian regions*** *(Veneto, Lombardy, Trentino Alto-Adige, Friuli Venezia-Giulia, Emilia-Romagna), and from* ***3 countries other than Italy*** *(Austria, Croatia, Slovenia)*
    - → ***Gela*** *could gather biomass from* ***its region only*** *(Sicily) and from* ***another country*** *(Malta)*
    - → ***Taranto*** *could gather biomass from* ***4 different Italian regions*** *(Apulia, Campania, Basilicata and Calabria)*
- **Important**: including different regions and/or countries in the study complicates the scenario building process, in particular as regards geographical data → accuracy loss might occur

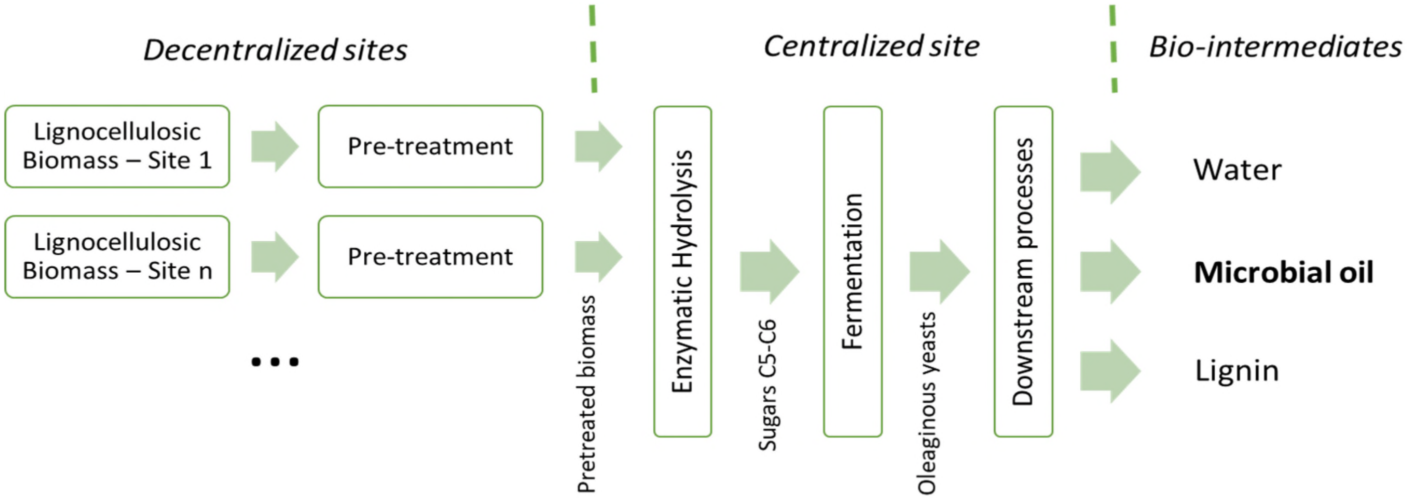
Biomass supply - modelling

- Maps from geographic model proposed (from VIGOR).
- Regional area in 100 km radius: in yellow the current cultivated lands are shown.



Biomass logistics – Strategic CS

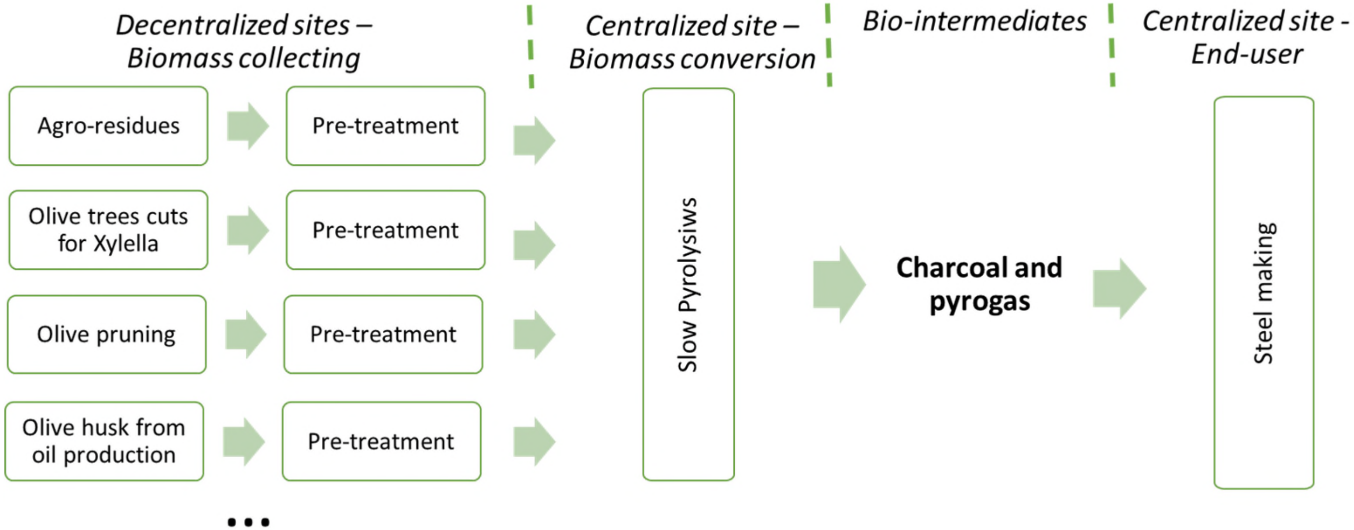
- The proposed approach is a network of decentralized physical pre-treatment sites to produce an energy-dense transportable feedstock to a centralized IBC plant (in proximity of the HVO plant).

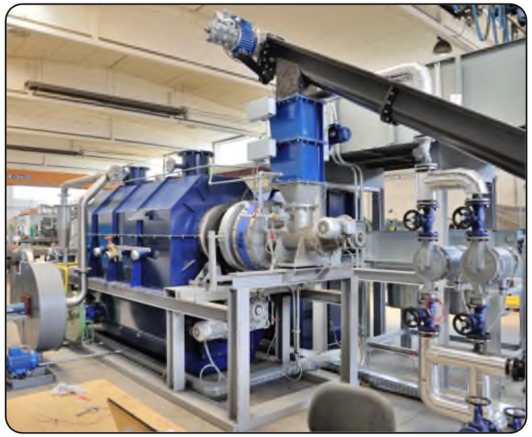


Oleaginous yeasts

Biomass logistics – Advanced CS (Only in Apulia)

- The proposed approach is a network of decentralized physical pre-treatment sites to produce an energy-dense transportable feedstock to a centralized IBC plant (in proximity of the steel making plant).





RE-CORD slow pyrolysis unit

An example of ENI biorefinery concept: From biomass to HVO

Ground biomass (sawdust) from regional producers

Truck

150 km

IBC plant (very similar configuration of Crescentino 2nd Gen Ethanol plant)

Forest- or agro- residues are converted to Microbial Oil

Pipes

< 1 km

ENI biorefinery in Portomarghera (Veneto, Italy)

3 - Recent experiences

- Microbial oil production is a technology at TRL 4-5, self-financed by ENI. No other projects supported the development of MO production yet.
- However, combining the pre-treatment technology developed by M&G/Biochemtex, now ENI, for producing sugars from lignocellulosic biomass (TRL 8) with the MO production pathway, a high triglycerides potential can be leveraged to supply the feedstock to the Italian bio-refineries (TRL 9).
- The following projects are named in the proposal:
  - Italy: **VIGOR, VISPO, BABEL, BioLYFE, and other (RE-CORD)**
- In the following slides, a brief recap of each project have been reported.

Project overview: VIGOR

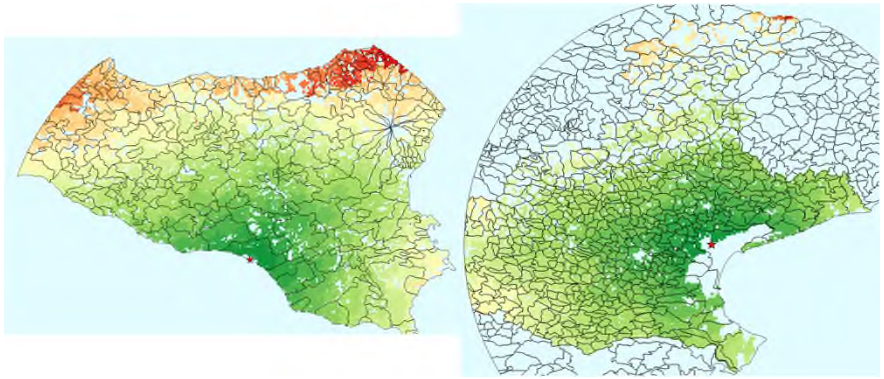
- National project, based on a contract between RE-CORD, UniFI and ENI
- Duration: 1 year, from Nov 2016 to Nov 2017.
- Budget: 100,000 Euros
- Contract Nr. 3500043092. No public data available since they are property of ENI.

PROGETTO **VIGOR**

Vegetable oil Initiative for Green Oil Refinery

VIGOR in brief

- Goal
  - The project aims to identify the potential supply of oleaginous and ligno-cellulosic biomass for green diesel: market analysis/biomass potential/agronomic aspects and barriers
- Methods
  - A GIS instruments, CROPSYS software, has been used to define biomass potential



- Results
  - The project demonstrated a potential integration of biomass supply for biorefineries from Italian soil (including used cooking oil) in substitution to palm oil.
  - The main outcome is the **biomass costs and productivity** in the mid- term scenario, as well as a **market analysis** of lipids market in 2017.

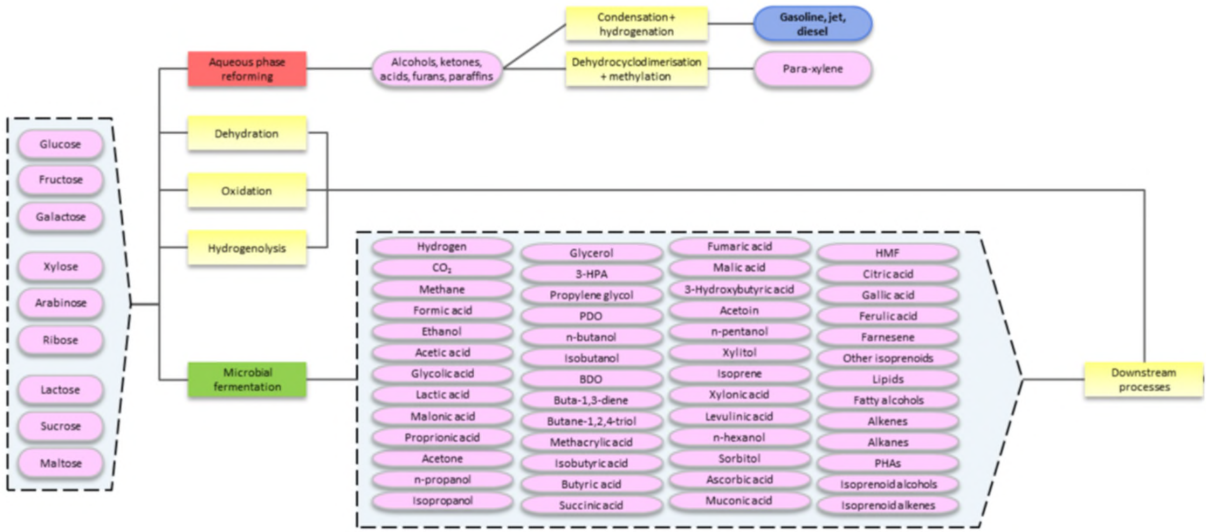
Project overview: Sugar platform

- A contract between EU Commission Directorate - General Energy and RE-CORD, E4Tech and WR under N° ENER/C2/423-2012/SI2.673791
- Duration: 1 year, from Nov 2015
- Budget: about 120,000 Euros

Full report available: https://ec.europa.eu/energy/sites/ener/files/documents/EC%20Sugar%20Platform%20final%20report.pdf

From the “Sugar Platform” to biofuels and biochemicals in brief

- Goals
  - Investigation on sugars conversion to biofuels and biochemicals via novel pathways with an emphasis on applied research and its commercialisation not basic research.
- Methods
  - This study used literature surveys, market data and stakeholder input to provide a comprehensive evidence base for policymakers and industry – identifying the key benefits and development needs for the sugar platform.
- Results
  - The study created a company database for 94 sugar-based products, with some already commercial, the majority at research/pilot stage, and only a few demonstration plants crossing the “valley of death”.



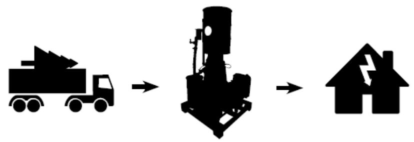
A scheme from the final report about the downstream process options from sugars (the majority of which are fermentation based)

MUSIC

VISPO in brief

- Goal
  - The project aims to develop an efficient value chain based on pruning wastes (olives and grapes) recovery from two farms in the Chianti area (Florence, Italy). The biomass is used to produce bioenergy and electricity on field by means of a plant prototype gasification.
- Methods
  - Biomass from prunings have been collected, analyzed and processed in the form of briquettes. Then, briquettes have been tested in a small scale gasification unit.

Power pallet specs	10 kW
Power output	3-10 kW
Biomass consumption	12 kg/h @ 10 kW
Fuel moisture content	Up to 30%
Dimensions	1.2 m x 1.2 m x 1.8 m
Weight	499 kg



- Results
  - The project demonstrated the electricity production in a small scale gasifier (GEK) from biomass in the form of briquettes .
  - Stable operation has been achieved. Barriers related to high ash content into biomass prunings should be evaluated in long-term tests.

RE·CORD

MUSIC

Project overview: VISPO

- Regional project of Tuscany Region (Italy) – Funded by Misura 124.
- Partners: UniFI, Farm Montepaldi, Farm Grassi, Chianti Classico foundation for soil protection.
- Duration: 3 year (2009 – 2012)
- Budget: 300,000 Euros
- Contract: REGIONE TOSCANA - Misura 124, Agronomic development programme (PSR), 2007-2013 - Reg. CE n. 1698/2005 GAL Start

Progetto V.I.S.P.O.

Valorizzazione Innovativa di Scarti di Potatura di Olivo

C.R.E.A.R. CENTRO RICERCA ENERGIE ALTERNATIVE E RINNOVABILI

FLORENTINA STUDIORUM UNIVERSITAS

RE·CORD

VISPO in brief

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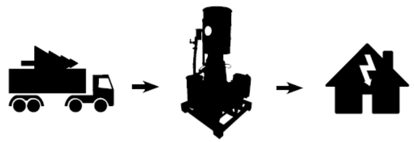


- Results
  - The project demonstrated the electricity production in a small scale gasifier (GEK) from biomass in the form of briquettes .
  - Stable operation has been achieved. Barriers related to high ash content into biomass prunings should be evaluated in long-term tests.

Project overview: BABEL

- Regional project of Tuscany Region (Italy) – Funded by Misura 124.
- Partners: RE-CORD, Ass. FUTA LE-ENER, Unione Comuni Valdarno, Rincine farm, Ballerini farm, CNR-IVALSA.
- Duration: 2 year (2013 – 2015)
- Budget: 120,500 Euros
- Contract: REGIONE TOSCANA - Misura 124, Agronomic development programme (PSR), 2007-2013 - Reg. CE n. 1698/2005 GAL Start – Act 16/124/2013

BABEL

Raffinazione dei biocombustibili legnosi: nuovi prodotti per il mercato

BABEL in brief

- Goal
  - The project aims to demonstrate the potential production of charcoal with an innovative slow pyrolysis unit, designed and constructed by RE-CORD. The project gives to farmers the possibility of becoming "the first converters" of a high value bio-product from their biomass.
- Methods
  - Woody biomass from Mugello area (Florence, Italy) have been collected, analyzed and used as feedstock for a carbonization pilot unit (50 kg/h capacity).

- Results
  - The project demonstrated a very high quality of the charcoal produced from local biomass.
  - Stable plant operation has been achieved and the unit was patented.
  - The additional production of heat from pyrogases could be considered for CHP.

Other activities: contract from BioLYFE project

- Contract to assist Biochemtex in the scientific coordination of BioLYFE project.
- Duration: 3 year, from Jan 2010 to Nov 2013
- Budget: 15.3 M€
- Funded by EU 7th Framework Programme (Project No. FP7-239204).

BioLYFE in brief

- Goal
  - The overall goal of the project was to developing and demonstrating the hydrolysis and fermentation steps at industrial scale of the lignocellulosic bioethanol process, considering the entire value chain: from raw biomass to the biofuel.
- Role of RE-CORD
  - Prof. Chiaramonti from RE-CORD assisted Biochemtex in the scientific coordination of the project.

- Outcomes
  - Construction of a significant industrial scale plant (20,000 tonsEtOH/y) of innovative 2nd generation ethanol technology.
  - In October 2013, the world’s first plant for the production of second generation biofuels was opened in Crescentino, Northern Italy.
  - The plant operated for years since Biochemtex went in bankrupt in 2017. Today the plant is operated by Versalis SpA (the chemicals arm of ENI).
  - Biochemtex was part of Mossi & Ghisolfi group (that was Italian plastics multinational), which pu its U.S. operations in bankruptcy after taking on more debt than it could handle to expand a Texas resin factory.
  - This failure was due to a series of wrong investments in the world of plastics, disconnected from the activities with biofuels.

Final remarks

- Italian industry seems to have suffered considerably from the recent economic crisis when biofuel production dropped significantly.
- The absence of policies together with the low crude oil price limited biofuels & bioenergy growth.
- Large companies (excluding few cases) did not invested in bioenergy promotion, and financial supporting from EU- or Italian government was limited at demo-scale projects or with low incentives.
- The knowledge acquired by previous project will be considered as the starting point for MUSIC.

References and further information

- *http://www.re-cord.org/*
- *https://www.eni.com/en-IT/home.html*
- *https://www.ieabioenergy.com/*
- *https://www.biolyfe.eu/*

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°857806. The content of the document reflects only the authors' views. The European Union is not liable for any use that may be made of the information contained therein.

MUSIC

Market Uptake Support for Intermediate Bioenergy Carriers

Biomass mobilization and logistics experiences in Sweden and Finland
Recent projects and best-in-class examples

BioFuel Region™

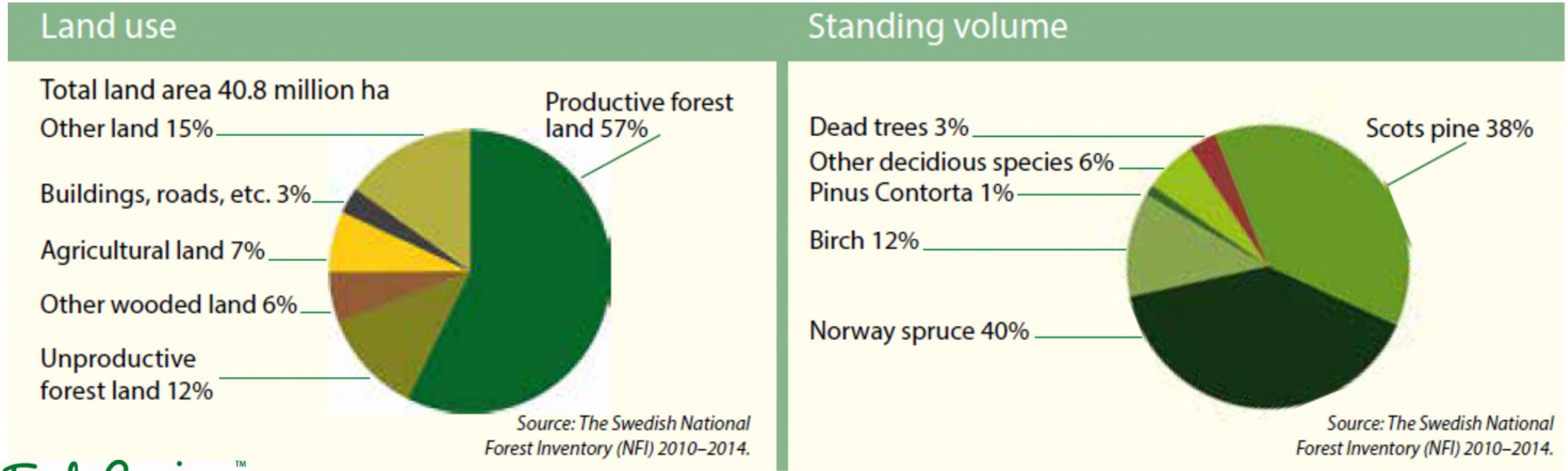
EU H2020 grant no. 857806, 1/9/2019 – 31/8/2022

Content

1. Bioenergy role in Sweden
2. Biomass types, availability and logistics
3. References and further information

Sweden is a country dominated by forests.

Sweden holds just under one percent of the world's commercial forest areas, but provides ten percent of the sawn timber, pulp and paper that is traded on the global market.



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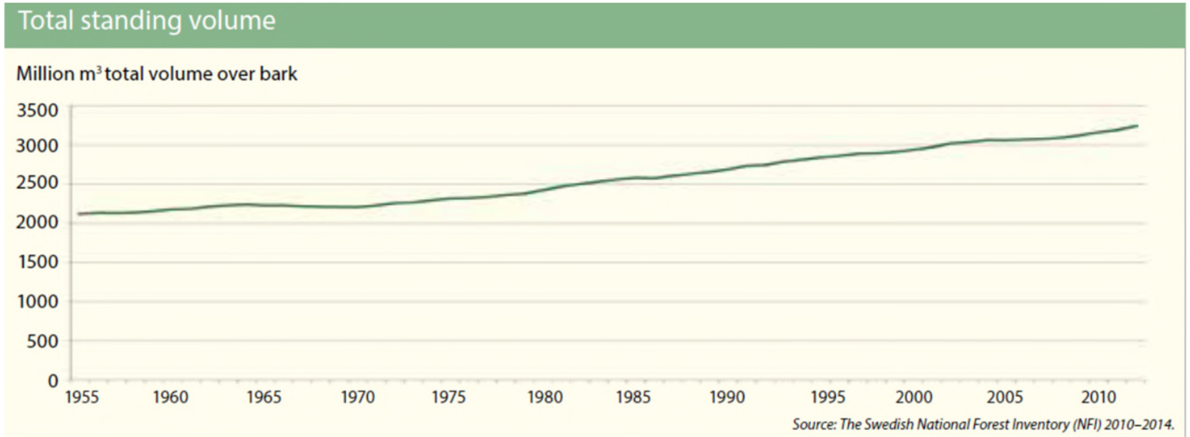

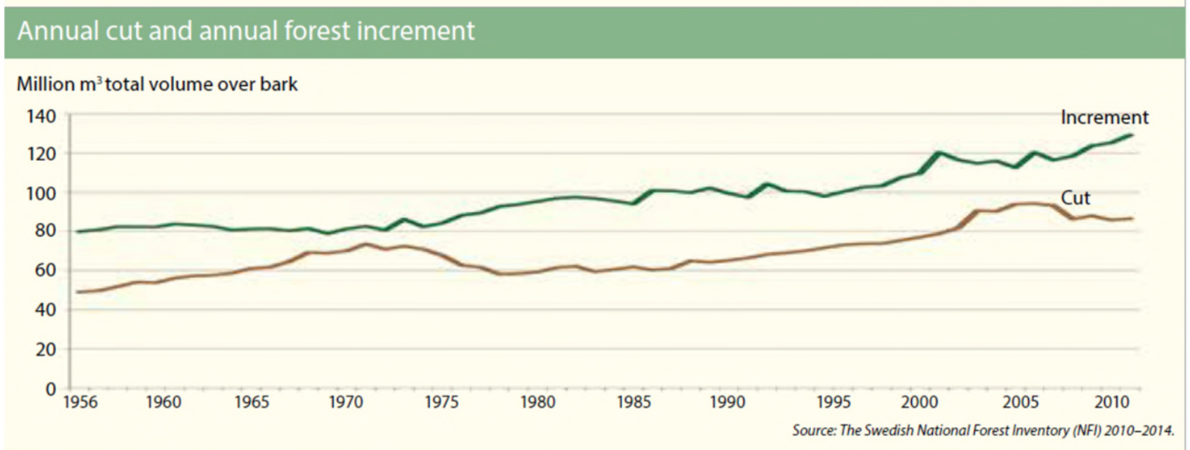

The total stock of wood in the Swedish forests, and stored carbon, has increased year by year, despite the rapidly increasing use of biomass by the forest industry and for energy. Swedish forests have high rates of productivity and low rates of natural disturbances, thus allowing for large transfers of biomass from forests through the avoidance of emissions from emission-intensive products such as steel and concrete, and from fossil fuel and products.

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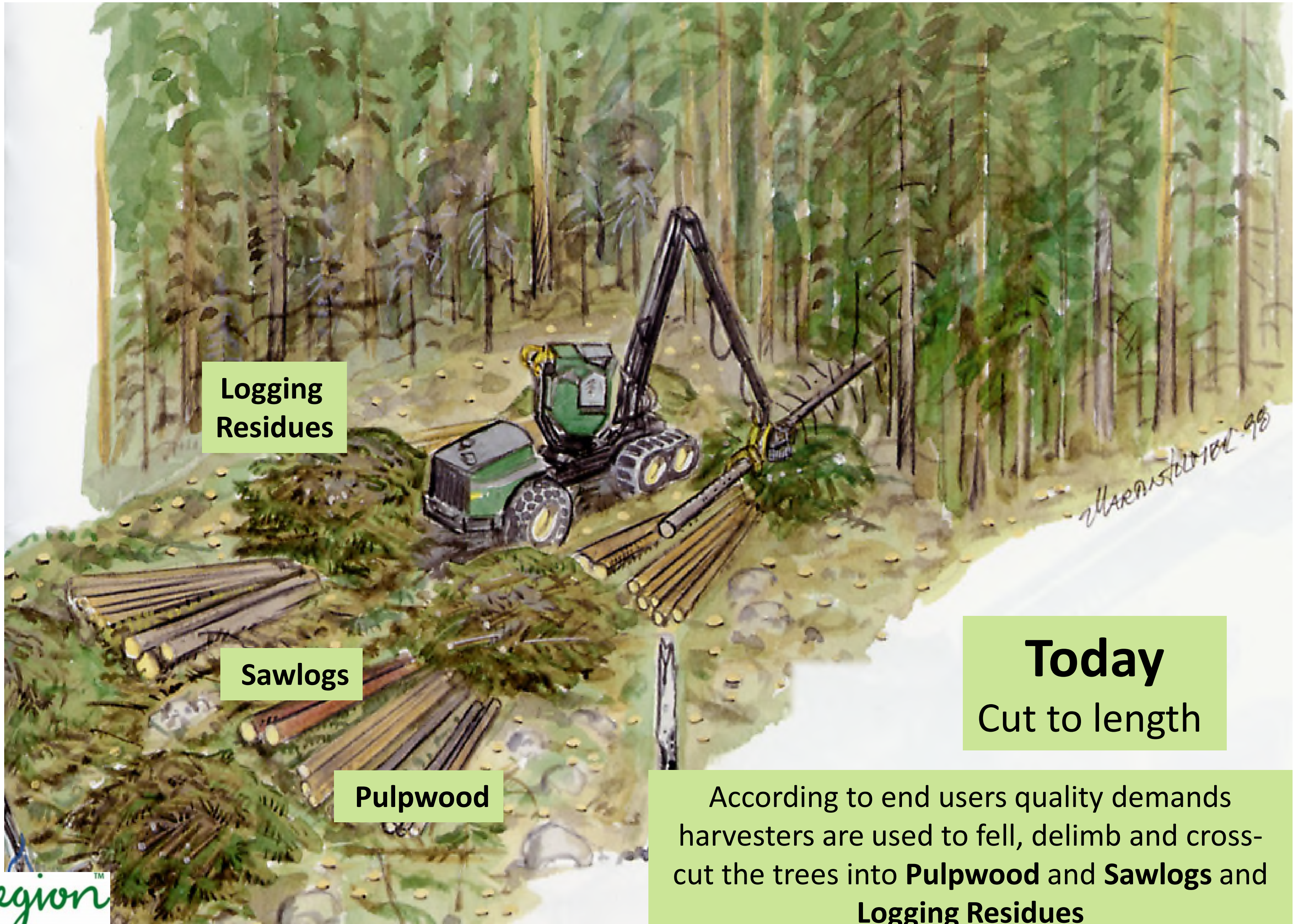

Today

Cut to length

According to end users quality demands harvesters are used to fell, delimb and cross-cut the trees into **Pulpwood** and **Sawlogs** and **Logging Residues**

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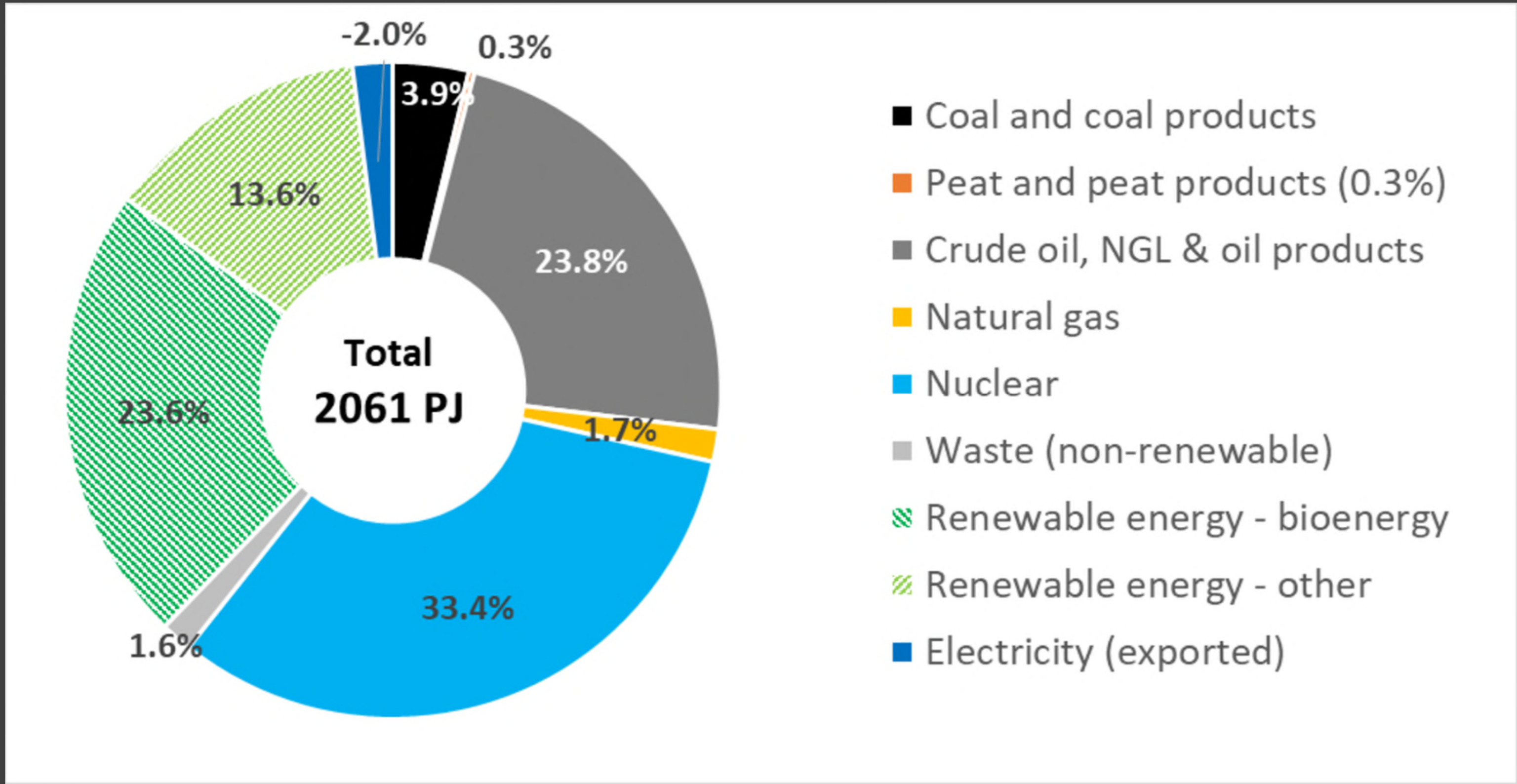
Bioenergy role in Sweden

- Bioenergy is the leading energy source in Sweden today. The Swedish energy system has gone through a major transformation. In the 1970s oil was totally dominating. Today, oil is almost entirely a transport fuel, whereas bioenergy has taken over in district heating, and plays a major role in industry and in electricity production.
- The primary reason for the growth of the bioenergy sector in Sweden is broad political support and the use of strong general incentives like the Swedish carbon dioxide tax (introduced in 1991) the green electricity certificates (introduced in 2003), and tax exemption for biofuels for transport, as well as direct investment supports.



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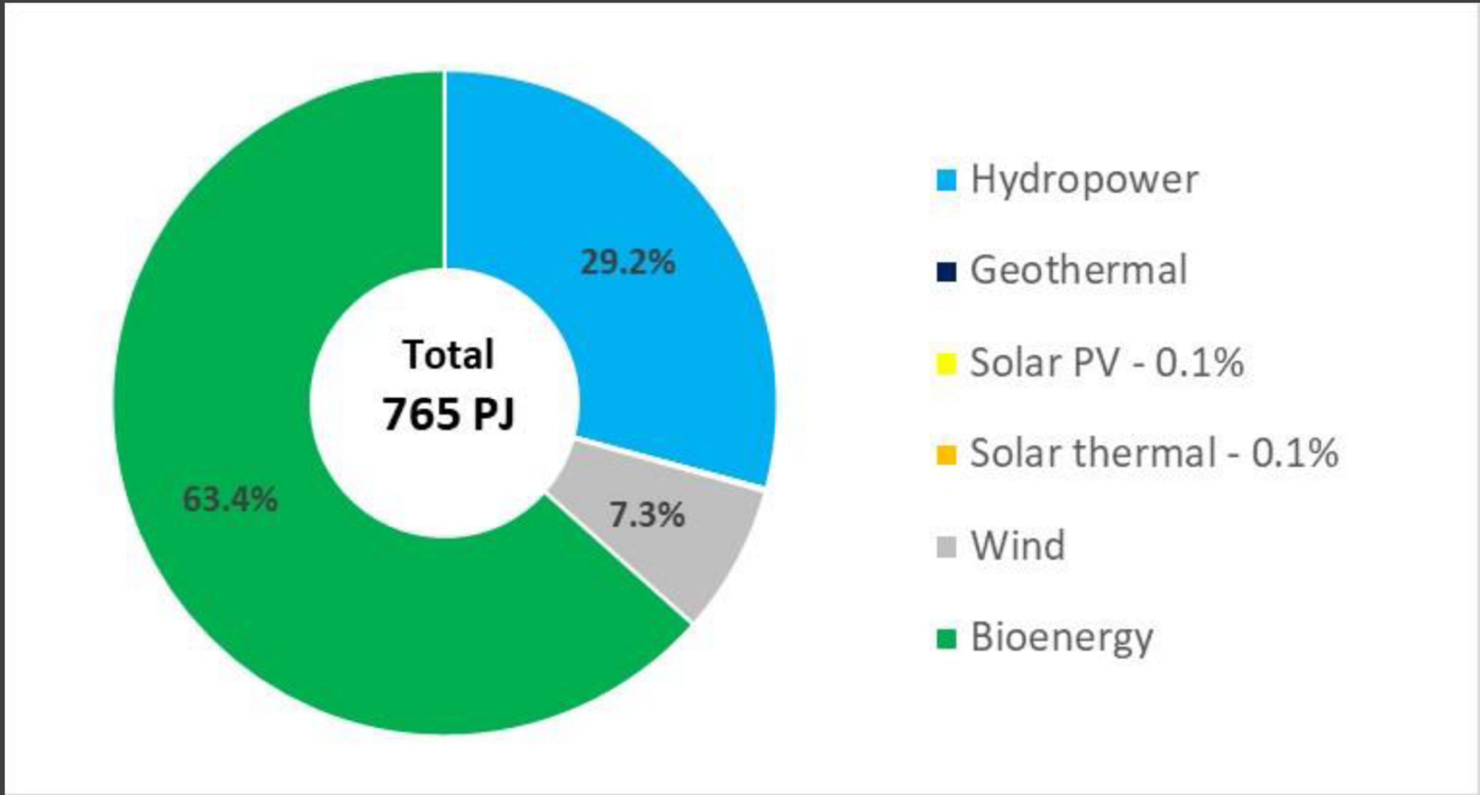
Total primary energy supply of Renewable Energy Sources in Sweden in 2016 (Source: World Energy Balances © OECD/IEA 2018)



Total primary energy supply6 in Sweden in 2016 (Source: World Energy Balances © OECD/IEA 2018)

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Bioenergy role in Finland

- Gross inland and energy consumption ➔ 2030 *)
  - Fossil Energy 247 TWh
  - Renewable Energy 171 TWh
  - Renewable Energy 40% of Total by 2030
    - 33,5% from biomass of which app. 50% in CHP energy production
    - 6,5 % from other renewable sources

Renewable energy

TWh	Statistics 2010	Statistics 2015p	Base scenario 2020	Base scenario 2030	Policy scenario 2020	Policy scenario 2030
Hydro power	13	17	14	15	14	15
Wind power	0,3	2	5	6	5	8
Solar energy	0	0	0,2	0,7	0,2	0,7
Small-scale combustion of wood, pellets	19	16	19	20	19	21
Black liquor and other concentrated liquors	38	39	44	48	44	48
Wood chips	14	16	22	29	22	31
Industrial wood residue	20	22	19	21	19	21
Heat pumps	3	4	6	7	6	7
Recovered fuel (bio-fraction)	3	4	5	5	5	5
Biofuels and bioliquids	2	6	6	5	6	12
Biogas	0,5	1	1	1	1	2
Total	**111**	**128**	**142**	**158**	**141**	**171**

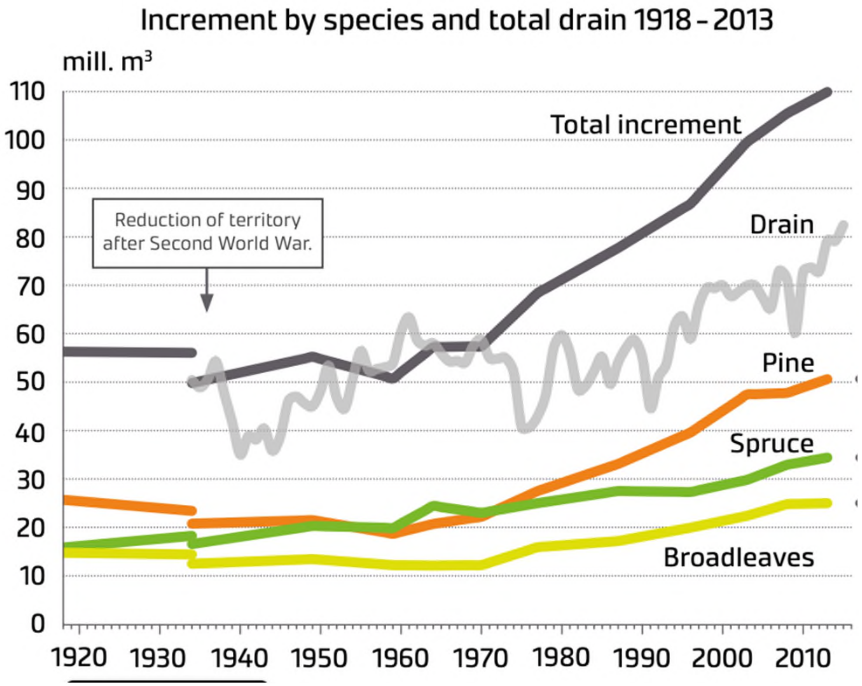
2015p = provisional data

Gross inland and final energy consumption

TWh	Statistics 2010	Statistics 2015p	Base scenario 2020	Base scenario 2030	Policy scenario 2020	Policy scenario 2030
Oil, incl. bio-fraction	97	87	81	77	79	73
Hard coal	40	17	15	7	15	3
Coke, blast furnace and coke oven gas	12	12	16	18	16	18
Natural gas	41	22	27	22	27	23
Nuclear energy	66	68	106	123	106	123
Net imports of electricity	11	16	3	2	3	1
Hydropower	13	17	14	15	14	15
Wind and solar power	0	2	5	7	5	9
Peat	27	15	20	15	20	15
Wood fuels	90	93	104	118	104	121
Others	10	14	16	18	16	18
Total energy consumption	**407**	**361**	**408**	**420**	**406**	**418**
Final energy consumption	318	*297 (2014)*	313	316	311	314

GREEN FUEL Nordic Oy

Biomass Available

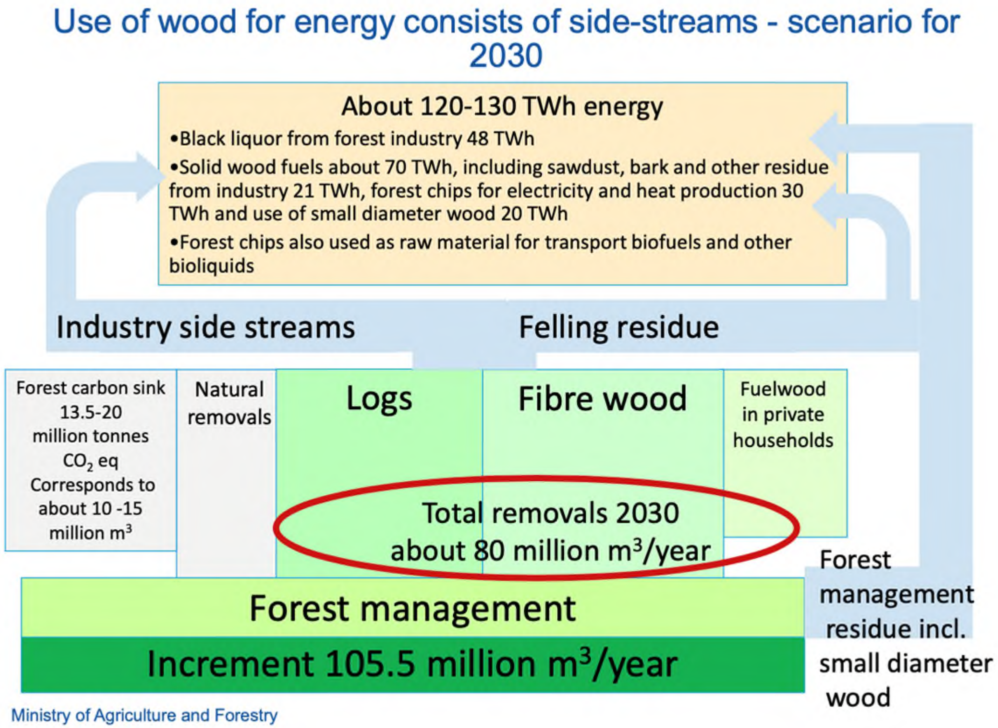


Source:
https://www.luke.fi/wp-content/uploads/2017/11/finland-forests-resources-2017-factsheet_www.pdf

- The need for wood-based energy calculated in Finland Energy and Climate Strategy would be met with removals determined by the industry's demand in 2030 at the level of 79 million m3/year
- This corresponds to the target of 80 million m3 set in the National Forest Strategy

GREEN FUEL Nordic Oy

Biomass sources in Finland



- About 120 – 130 TWh energy available annually
  - Black liquor from forest industry 48 TWh
  - Available Biomass 70 TWh

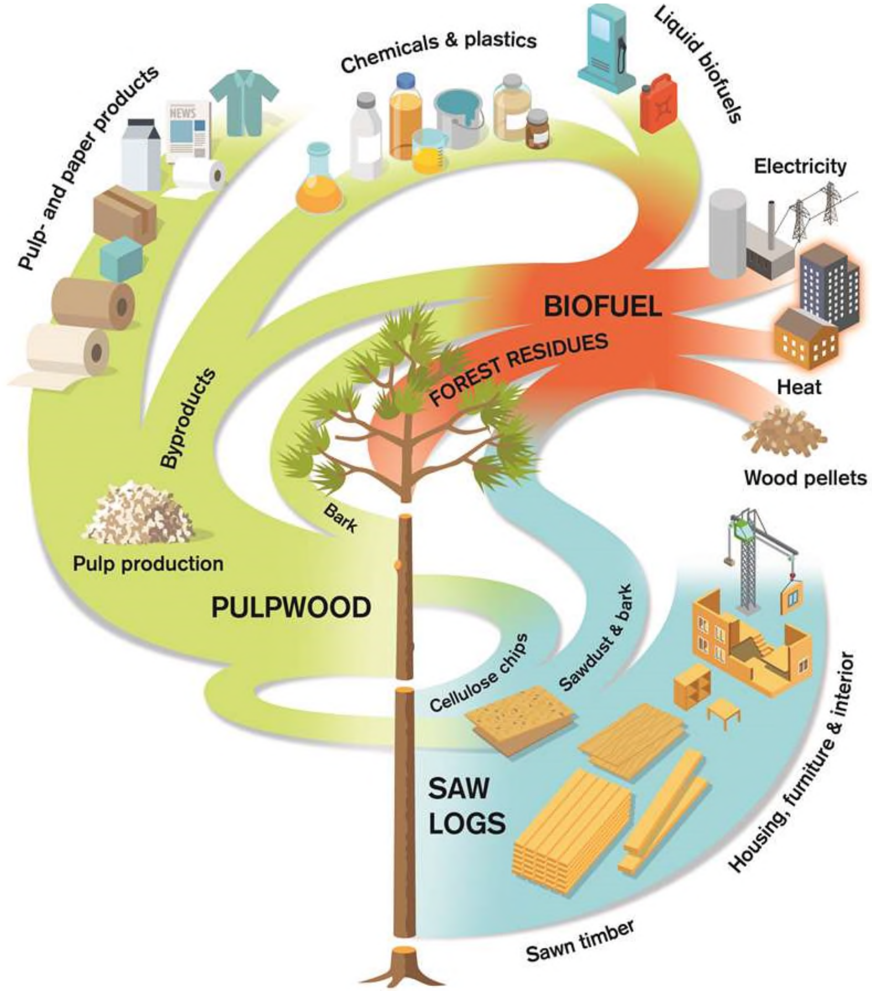
GREEN FUEL Nordic Oy

Mobilization of forest biomass

- In Sweden, readily accessible forest industry by-products such as bark, black liquor, sawdust and shavings are initially used as bioenergy feedstocks and there are few environmental concerns associated with this biomass use for energy.
- Logging residues, non-commercial roundwood and plantations represent complementary resources that can support ramping up to significantly larger scales if wood energy prices stimulate mobilisation.
- The impacts of utilising these resources are location specific and their availability across forest landscapes depends on both logistic factors and management/harvest guidelines safeguarding soils, water quality, biodiversity and other values.
- Mobilization calls for a high level of integration with those forest industries that generate the raw materials (usually by-products of timber harvesting and wood processing).

Biomass flows between different forest industry segments

As a result of forest industry activities, huge amounts of forest industry byproducts are available. Forestry is a co-production system, i.e. several products are produced simultaneously, such as saw logs, pulpwood and logging residues. Therefore, the potential amounts of the different assortments are not independent.



Sawmill by products are produced as a result of sawmill operation all the year around.

- **Sawdust -** 20% of the wood - Today used for pellet production and combustion
- **Woodchips -** 20% of the wood - Today used by the pulp and paper industry
- **Bark –** 10% of the wood – Today used for combustion

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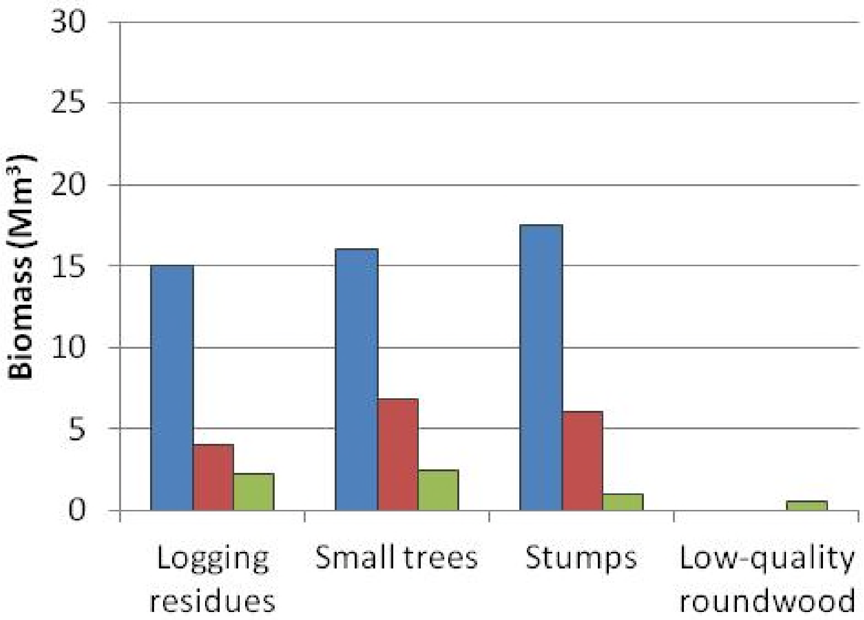
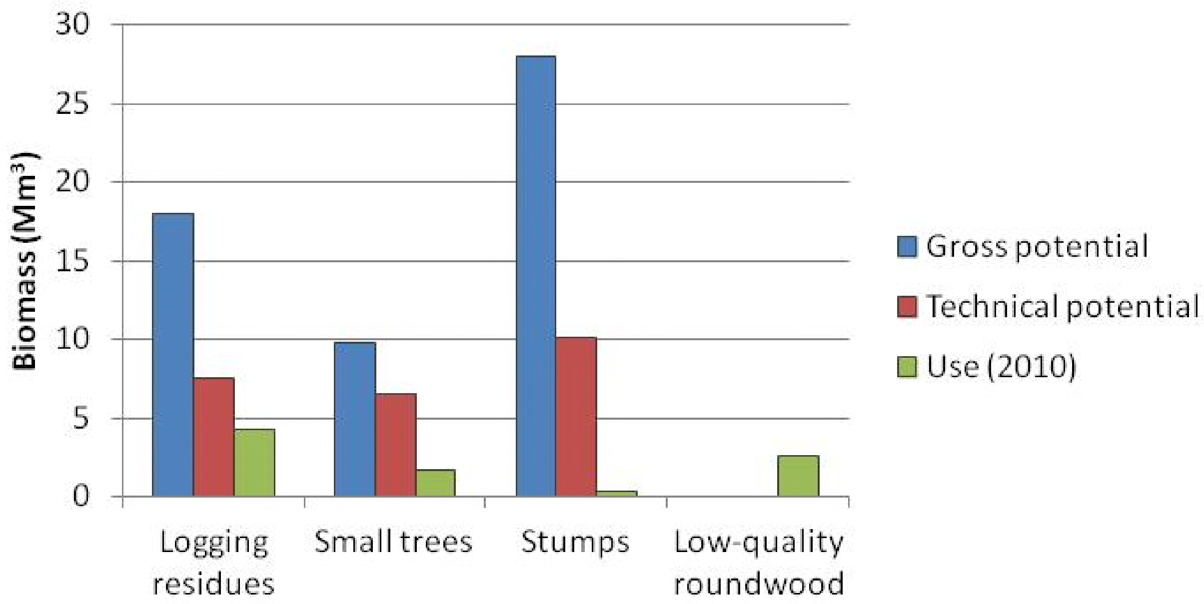
Forest fuels

Forest fuels are wood fuels which have had no previous use. Logging residues (tops and branches) of trees as well as low quality wood, inadequate for use in saw- or pulp mills, are examples of this.

They are produced as result of forest operations which goas on the year around. Operations can be intensified in a certain region during certain times of the year e.g. during winter on frozen ground.

Technical harvesting potentials, and gross potentials of forest chips Sweden and Finland in 2010.





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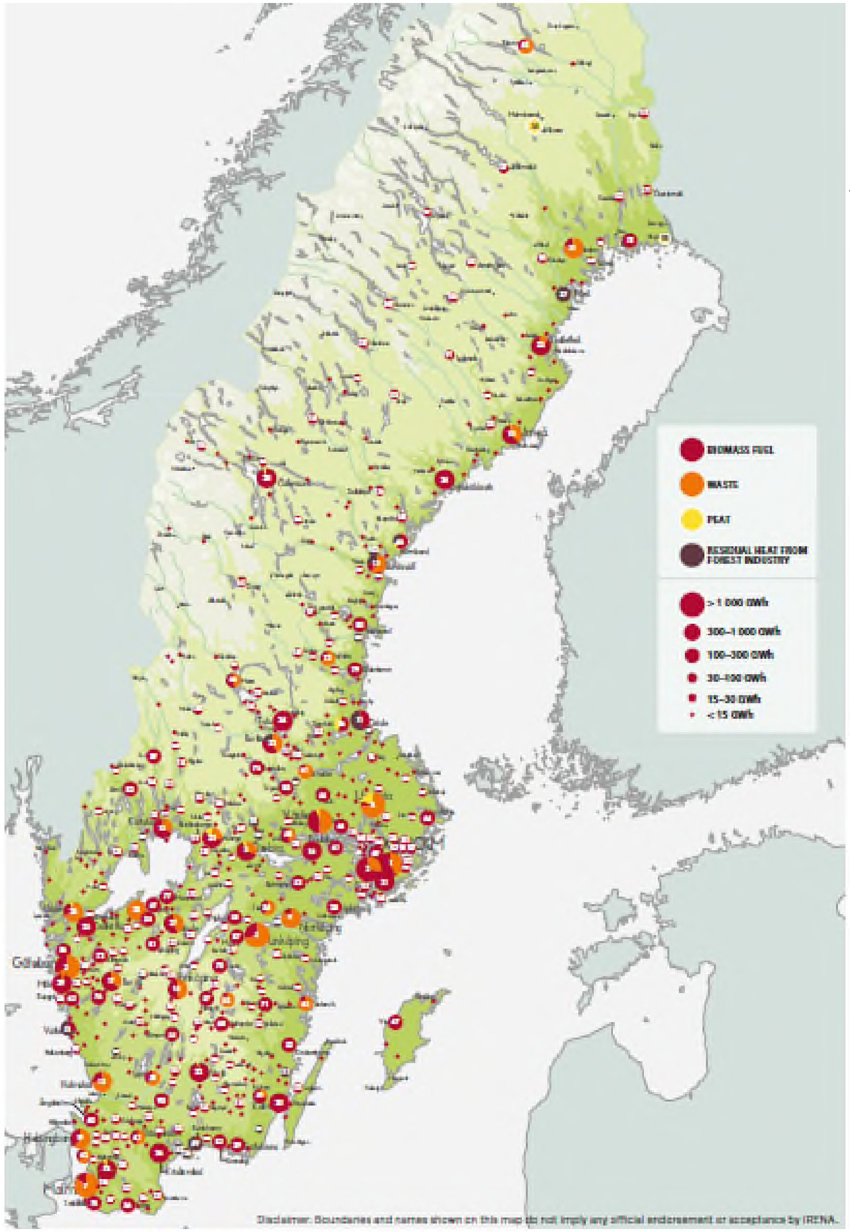
Recycled wood

Recycled wood fuel is wood fuels that have been used in other processes than energy generation, for example recycled pallets and construction wood.



Source: Bioenergi and Svebio (2018)

CHP plants in Sweden

- 214 CHP plants
- 510 district heating network
- 15 new planned 16 Billion SEK
- 15 TWh Green Electricity

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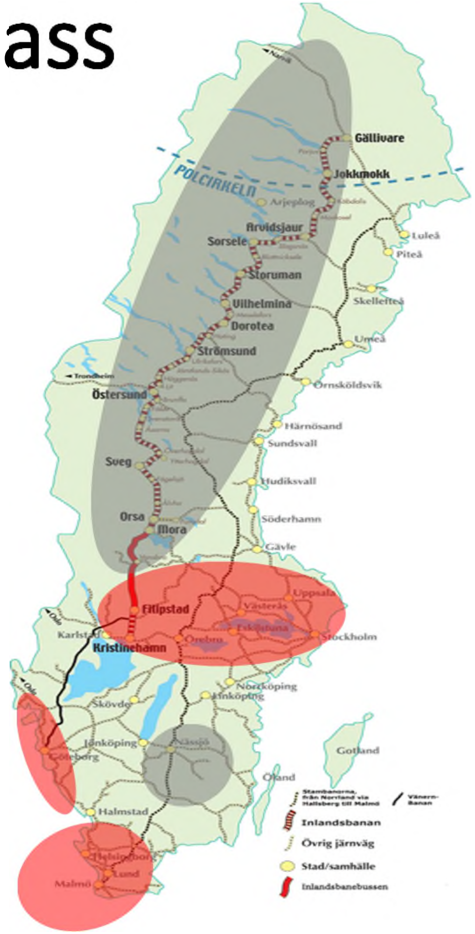
Logistical Challenge of forest biomass

- Raw material is distributed over large areas
- Demand in bigger cities (in red)
- Demand raises heavily during winter
- Logging residues truck < 100 km



Forest Biomass

The cost for harvest, transport, storing and handling of the biomass
is of prime importance when calculating the overall cost for biorefining

Seasonal variation in quality

50 km	100 km	120 km	200 km
15-20 %	35-40 %	40 %	60-70%

Solid volume content

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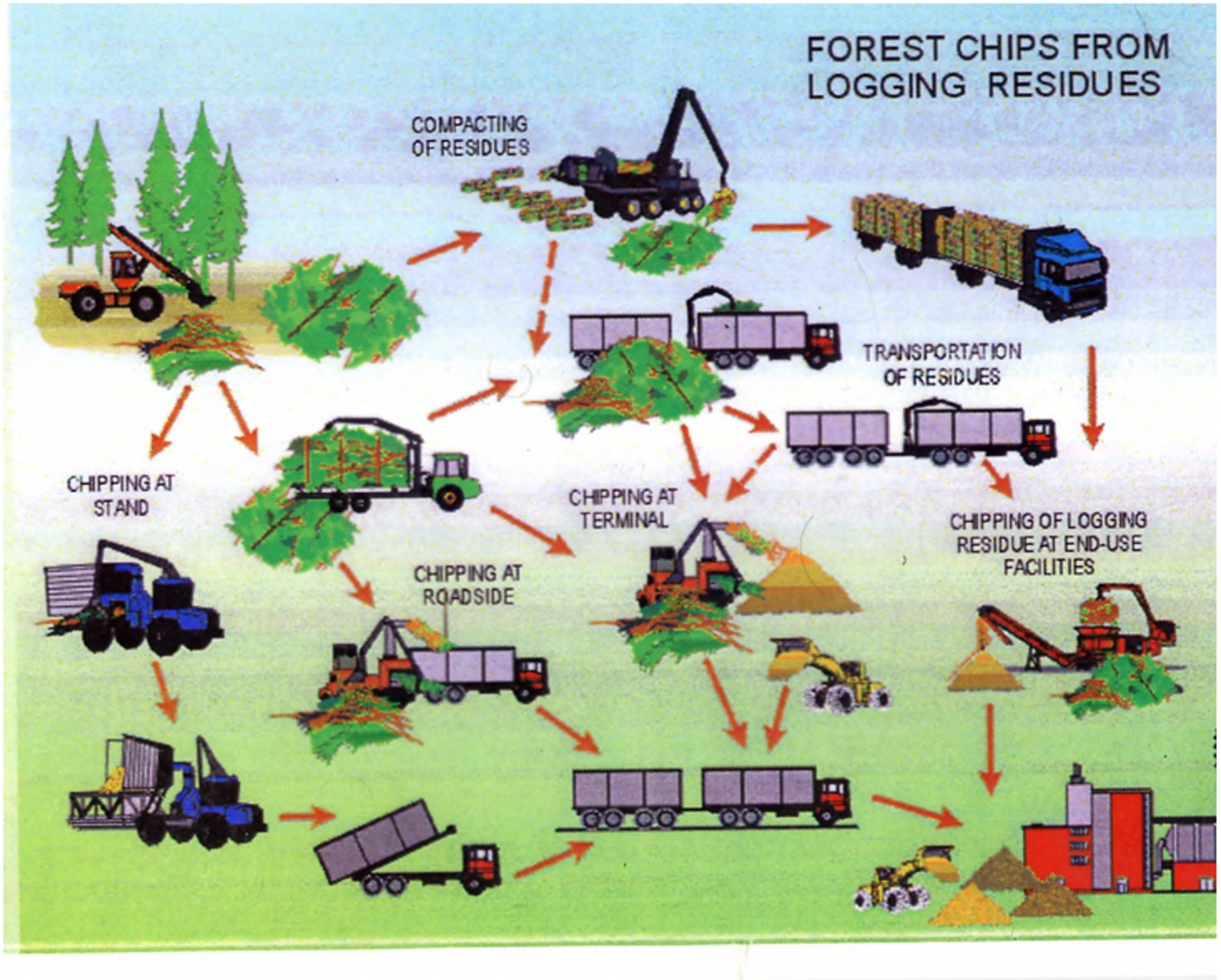
Overview of different Forest biomass supply chains for bioenergy production

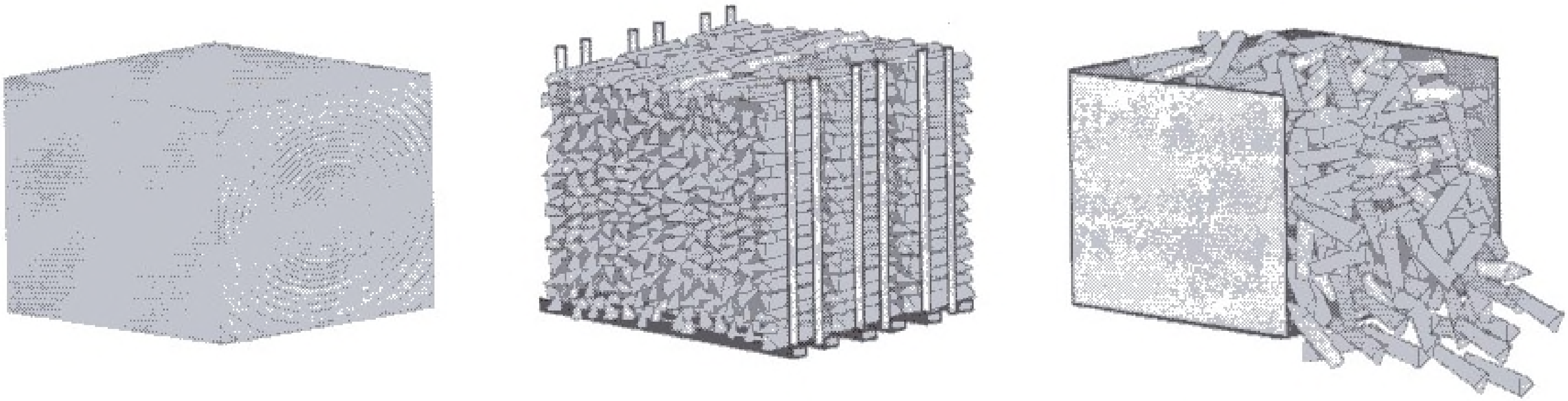


Bulk density of biomass is a major factor in determining the cost and logistics requirements of handling and moving biomass from farm to biorefinery.

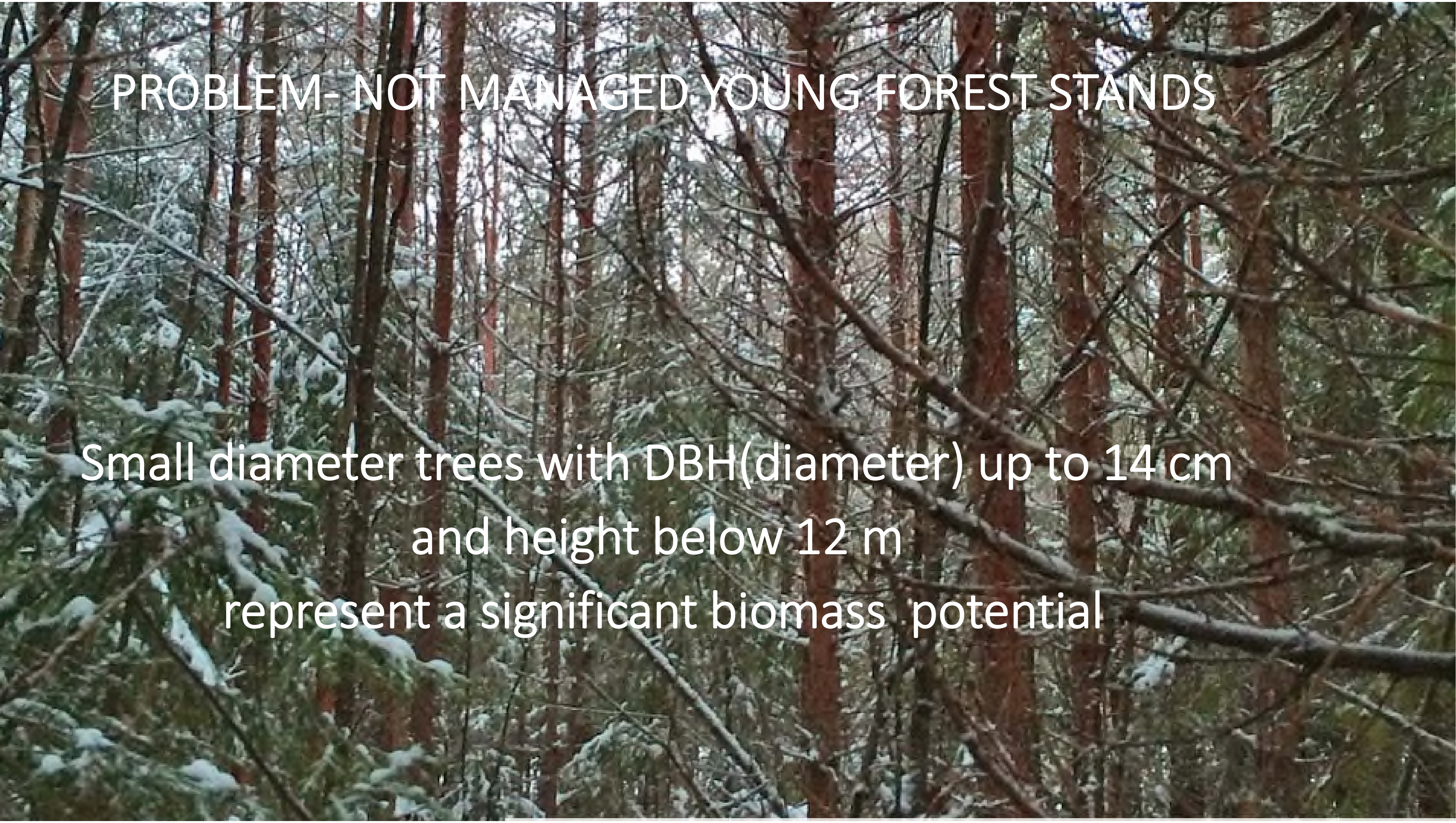
Bulk Density

110 - 150 kg/m3

Cubic meters matters

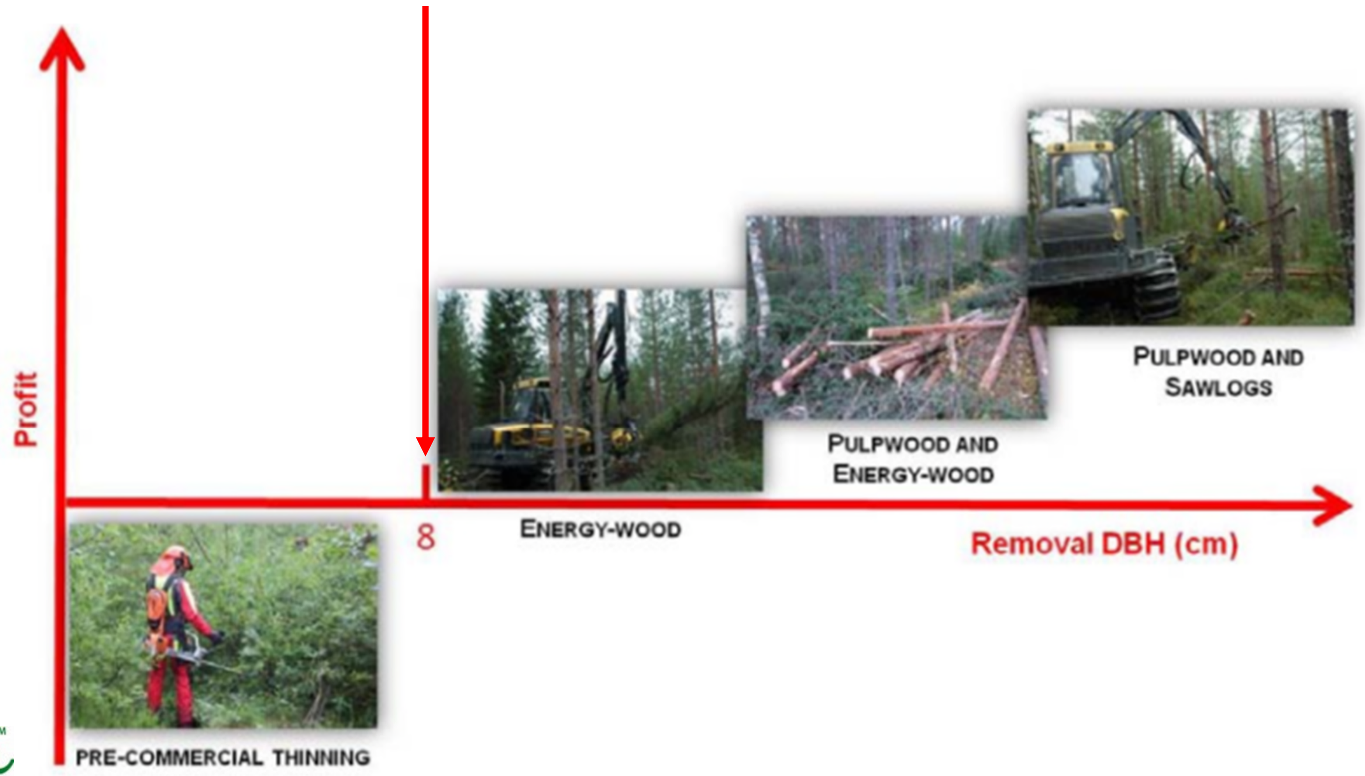


1 solid m^3 = 1.49 x stacked m^3 = 2.5 x bulk m^3


PROBLEM- NOT MANAGED YOUNG FOREST STANDS
Small diameter trees with DBH(diameter) up to 14 cm
and height below 12 m
represent a significant biomass potential

Currently used technology suffers from low productivity if the average tree size harvested falls below 8 cm DBH

Conventional harvesting systems are profitable in stands with average harvested tree sizes above approx. 8-9 cm DBH (35dm3)



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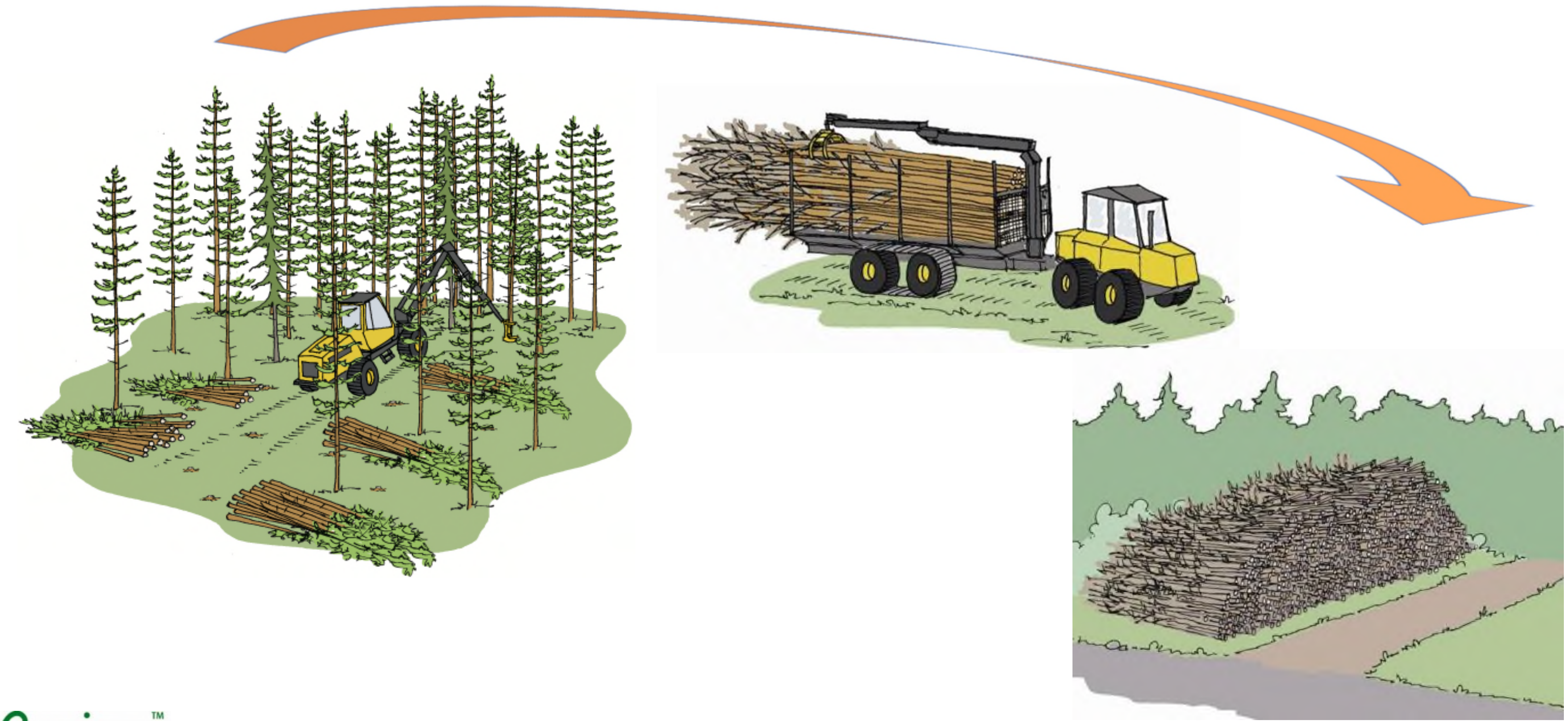
Harvesting of young trees by conventional harvesters



Drawings: Juha Varhi

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HARVEST

HANDOVER TO AUTOMATIC CRANE

DELIMBING AND FEEDING INTO BUNDLER

BUNDLING AND UNLOADING

Bundle of small diameter trees

BioFuel Region™

Wood fuel truck loaded by front loader

- Length 24 meters with total weight of 60 tonnes
- Load capacity 40 tonnes or 140 m^3 loose
- If material is wet transport is limited by weight, if material is dry transport is limited by volume
- Can unload itself to the side but has to be loaded by front loader

Self loading woodfuel truck

Capacity ~ 30 tonnes
Volume ~ 120 m^3 loose
Length 22 m

Bucket ~ 1,6 m^3 loose

Crane + bucket ~ 2,6 ton

- Biomass often have a bulky and troublesome nature making cost effective transport to end user difficult
- Fuel quality is determined by end users quality demand but important parameters are often moisture content, ash content, heating value, particle size distribution and bulk density
- The most important fuel quality factor is moisture content, since it affects the calorific value, storage properties and transport costs. It is taken into account in the pricing of the fuel.

Moisture Content

- Sesonal variration in moisture content in deliveries of chips produced from stumps that has been stored 1-2 years roadside

- Source *Källa: Jussi Larila and Risto Lauhanen Silva Fennica, 20*

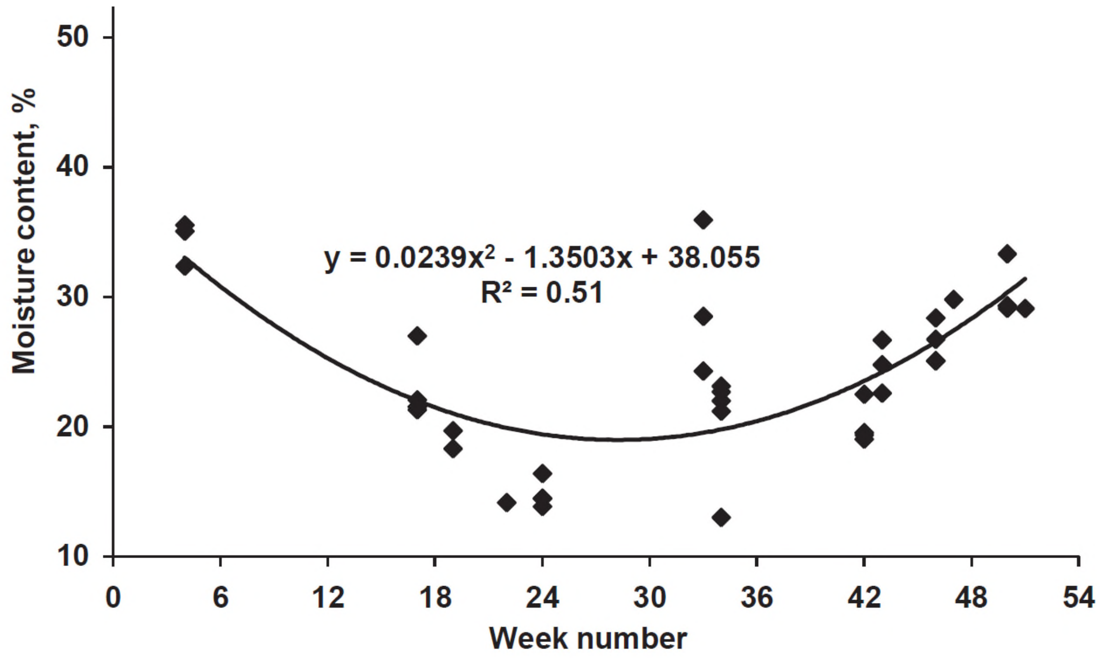
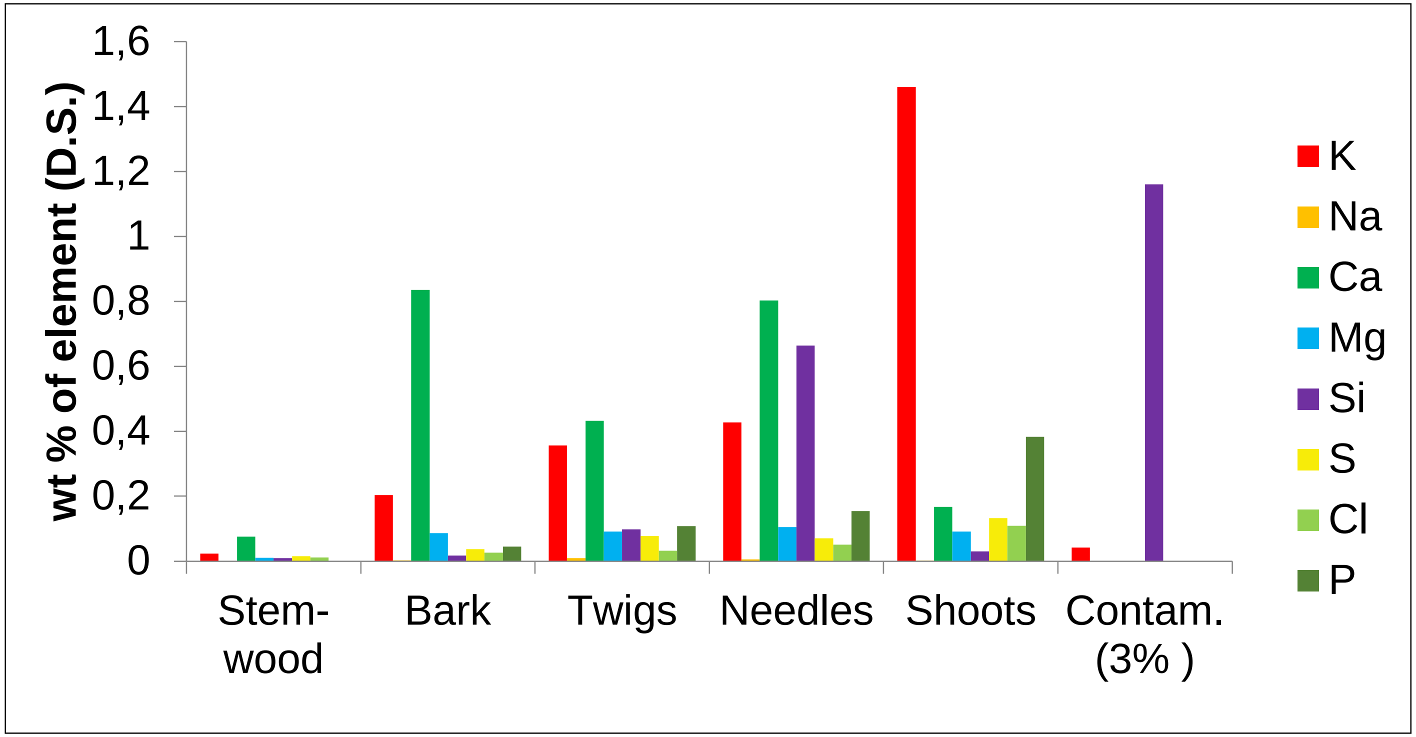


Fig. 5. The function between stump moisture content and time (calendar week number) based on the four year average.

Ash elements in different parts of spruce logging residues

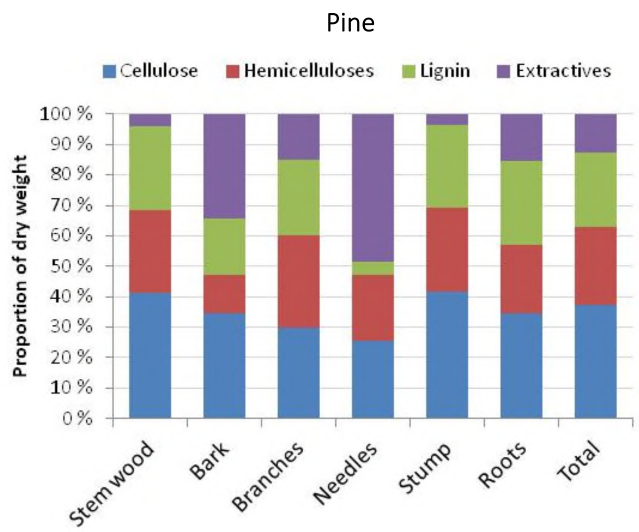


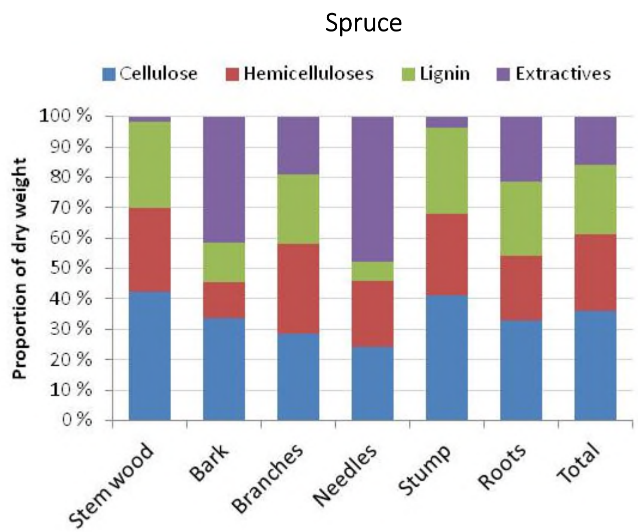
Source . Werkelin, Thesis, 2008, Åbo Akademi University

Chemical composition of biomass components

The chemical composition of forest biomass have to be known in order to describe the characteristics of raw material reserves in the point of view of biorefining

- The most important tree species
  - Pine
  - Spruce
  - Birches
- Biomass components
  - Stem wood
  - Bark
  - Branches
  - Needles/leaves
  - Stump and roots





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Biomass types, availability, logistics

- Biomass types available in a partner country
  - What is type of biomass (*e.g.* wood, straw)
  - In which form it is available
  - List 5-6 most important types of biomass
    - MUSIC is interested in solid biomass, but if there are other types that can be interesting, please list them as well.
    - Tip: combine type with how it becomes available, e.g. wood chips, pine tree bark, etc.
  - They can be listed in a table, for example:
    (cost data can be a challenge; use ranges if needed)

Biomass	Quantity	Cost

- How is this biomass available?
  - Seasonal variation?

Information about forest fuel supply chain

- History from 5 previous projects we have been involved in with the overall aim to improve and cut costs in the forest fuel supply chain.
- https://biofuelregion.se/en/projekt/biohub/history/

- BioHub - EU Intereg Botnia Atlantica 2017–2019 budget 2.3 M €
- https://biofuelregion.se/projekt/biohub/
- BioHub has worked towards the creation of the BioHub model – a new business and operational model for forest biomass terminals – in order to improve the terminals' ability to cater both traditional forest industries as well as emerging biorefining industries.

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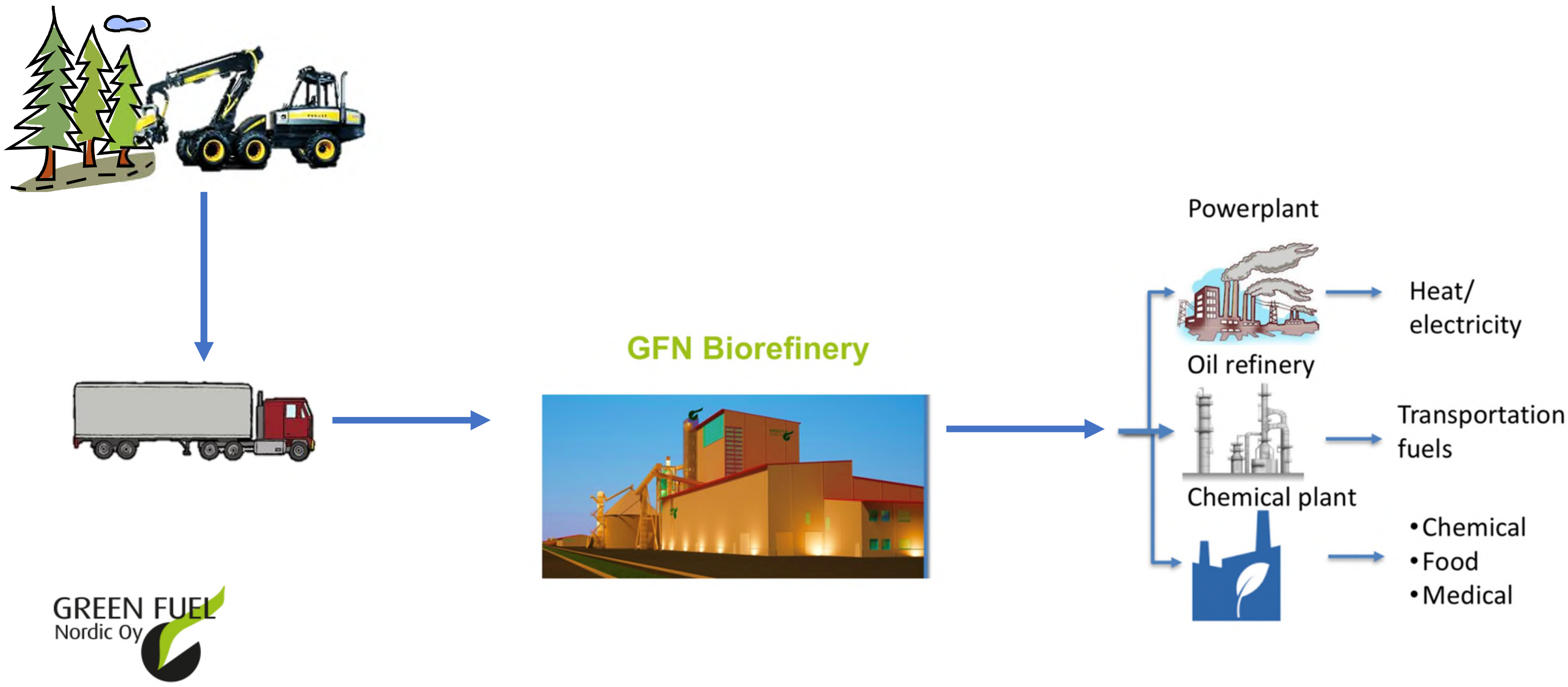
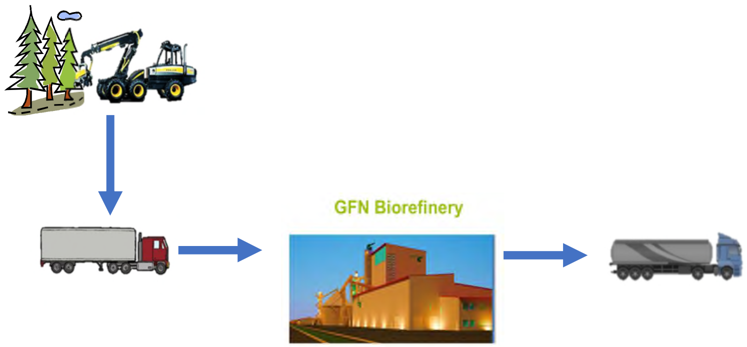
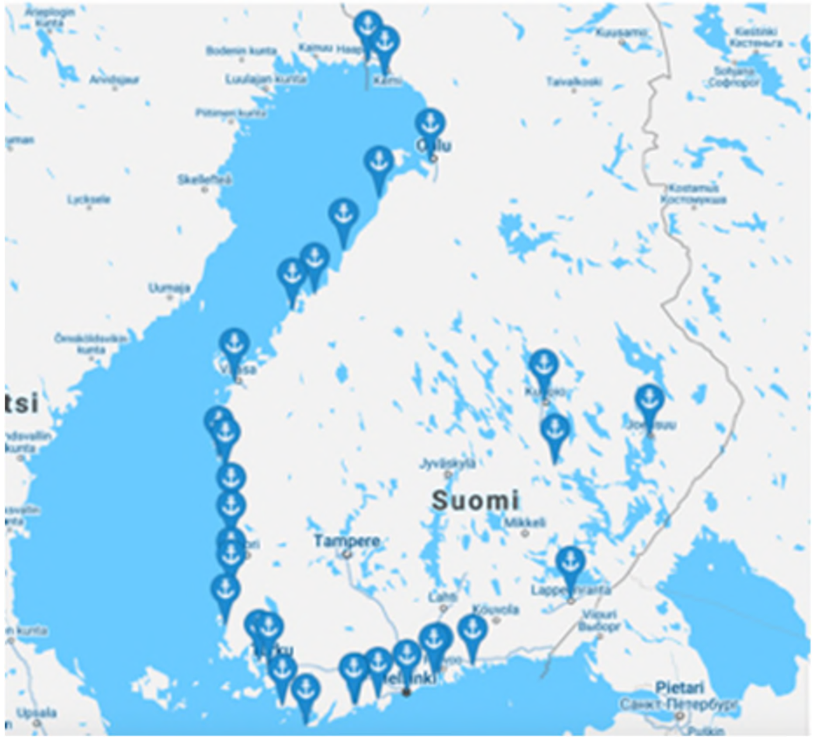
Biomass to pyrolysis oil to end-user logistics



Biomass to pyrolysis oil to end-user logistics



- Land transportation from GFN biorefineries to harbors
- Transportation by sea to Europe markets to end-users or upgrading to transportation fuels



- Forest Refine. EU Interreg Botnia Alantica 2012–2014 budget 2.5 M €
- https://biofuelregion.se/en/projekt/forest-refine/results/
- The overall objective was to acquire knowledge of ways to optimize biomass supplies for refineries in the Botnia-Atlantica Region from existing, planned or potential procurements areas. All the results are compiled into a final paper, ”Synthesis report: Forest Refine, 2012-2014”. The project has been unique in its aim and scope, and the results presented plays an important role for developing the coming biobased markets in the BA region.

- Forest Power EU Interreg Botnia Alantica 2009-2012 budget 4.4 M €
- A cross-border research project with the aim of increasing the utilisation of forest biomass in the Botnia-Atlantica area. The project had the goal of increasing the value and quality of products and services within the forest fuel supply, feed-stock conversion and combustion chains.

References

- Government report on the National Energy and Climate Strategy for 2030 (Unofficial translation). Publications of the Ministry of Economic Affairs and Employment 12/2017. http://urn.fi/URN:ISBN:978-952-327-199-9
- Natural Resources Institute Finland (luke.fi) 2017. https://www.luke.fi/wp-content/uploads/2017/11/finland-forests-resources-2017-factsheet_www.pdf

Acknowledgements

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Market Uptake Support for Intermediate Bioenergy Carriers

Biomass Torrefaction

Recent experiences and best-in-class examples

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Content

1. Process overview
    - Process
    - Reasons for torrefaction: Raw biomass vs torrefied
    - Phases and parameters
    - Technologies
    - Process flow sheet
2. Product characteristics
    - Torrefied biomass properties
    - Quality and standardization
    - Alternative process steps
    - Applications
3. Status and commercial use
    - Status
    - Torr-Coal B.V.
    - Clean Electricity Generation (CEG)
    - Advanced Fuel Solutions
    - Futerra Fuels
4. Challenges and opportunities for market implementation
    - Barriers to large scale deployment
    - Market opportunities
5. Estimated production costs

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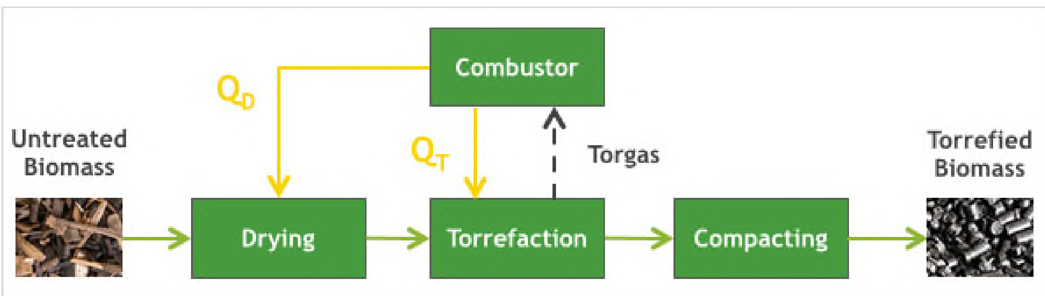
Torrefaction process

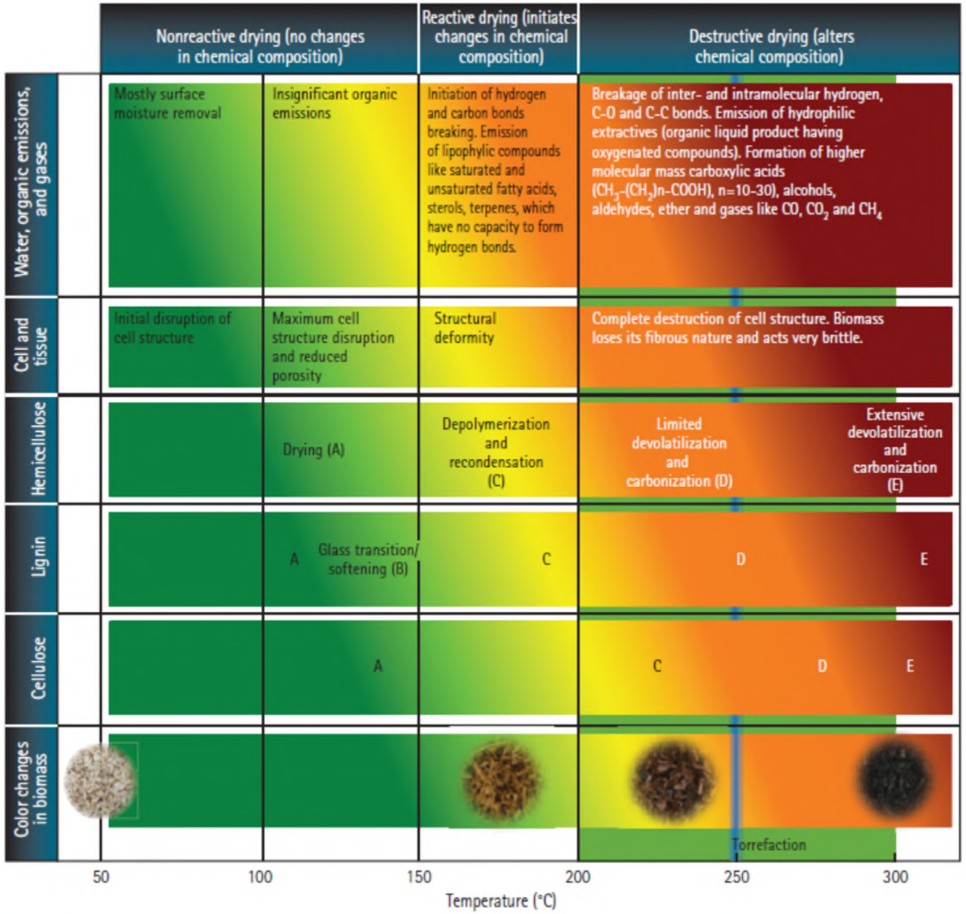
- Torrefaction refers to a thermal treatment of biomass where raw biomass is heated in an inert atmosphere at temperatures of 250–320* °C for the purpose of upgrading solid biomass fuel.
- During torrefaction, three different products are produced: (1) brown to black uniform solid biomass, which is used for bioenergy applications, (2) condensable volatile organic compounds comprising water, acetic acid, aldehydes, alcohols, and ketones, and (3) non-condensable gases like CO_2, CO, and small amounts of methane.

*Temperature depends on feedstock used and desired degree of torrefaction

BASIC TORREFACTION PRINCIPLE



Source: Blackwood Technology



Source: Tumuluru et al., 2011

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Raw biomass vs torrefied biomass

- Higher moisture (14-60 wt)%
- Lower heating value (6-13 MJ/kg)
- Lower energy density (0,7-1 MWh/m^3)
- Higher O/C (0,5-0,8) and H/C ratios (1,2-2)
- Hygroscopic
- Poorer grindability
- Non-uniform properties

Solid raw biomass

Wood (branches; bark)
Agricultural residues
Grass (various types)
Demolition wood
Solid Recovered Fuel

Torrefaction

- 250-320 °C
- Inert atmosphere

- Lower moisture (3-8 wt%)
- Higher heating value (19-24 MJ/kg)
- Higher energy density (1,3-2 MWh/m^3)
- Lower O/C (0,2-0,4) and H/C ratios (0,8-1,2)
- Hydrophobic
- Better grindability
- More uniform properties

Torrefied biomass

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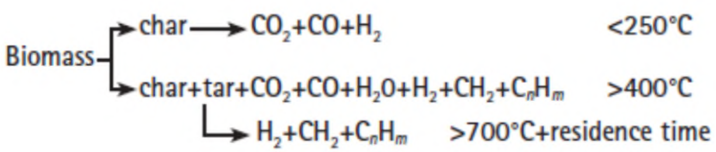
Torrefaction phases and parameters

- Temperature and residence time.
- Heating rate.
- Operating atmospheric composition.
- Controlling torrefaction process instability.
- Reactor type.



	Phases	Description
1.	Heating	Biomass is heated until the drying temperature is obtained and the biomass' humidity starts to evaporate.
2.	Pre-drying	Occurs at 100 ºC when the free water present on biomass evaporates at a stable temperature.
3.	Post-drying	The temperature is increased until it reaches 250 ºC. The remaining water present on biomass chemical bonds is completely evaporated. This phase is responsible for mass loss due to the evaporation of several biomass components.
4.	Torrefaction	Main phase of torrefaction process. It occurs at 250 ºC and is responsible for the main mass loss. The torrefaction temperature (TT) is given by the maximum stable temperature used during the process.
5.	Cooling	To avoid auto ignition the final product is cooled down below 50 ºC before it contacts the air

Source: Bergman et al., 2005

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Torrefaction technologies

Torrefaction technologies		Proven techn.	Heating integration	Heat transfer	heating rate	Temp. control	Particle size tol.	Mixing	Res. time control
Rotary drum reactor	Direct heating	+	+	+	+	0	+	+	+
	Indirect heating	+	+	0	0	+	+	+	+
Fluidized bed reactor	Direct heating	+	0	+	+	0	0	+	0
Moving bed reactor	Direct heating	0	+	0	0	0	+	0	+
Vibrating belt reactor	Direct heating	+	+	+	+	0	+	+	+
Screw conveyor reactor	Direct heating	+	+	+	+	0	+	+	+
	Indirect heating	+	+	0	0	+	+	+	+
Multiple hearth furnace	Direct heating	+	+	+	+	0	+	+	+

0 : less favorable, ideal or good
+ : favourable, ideal or good

Source: Torr-coal, 2020

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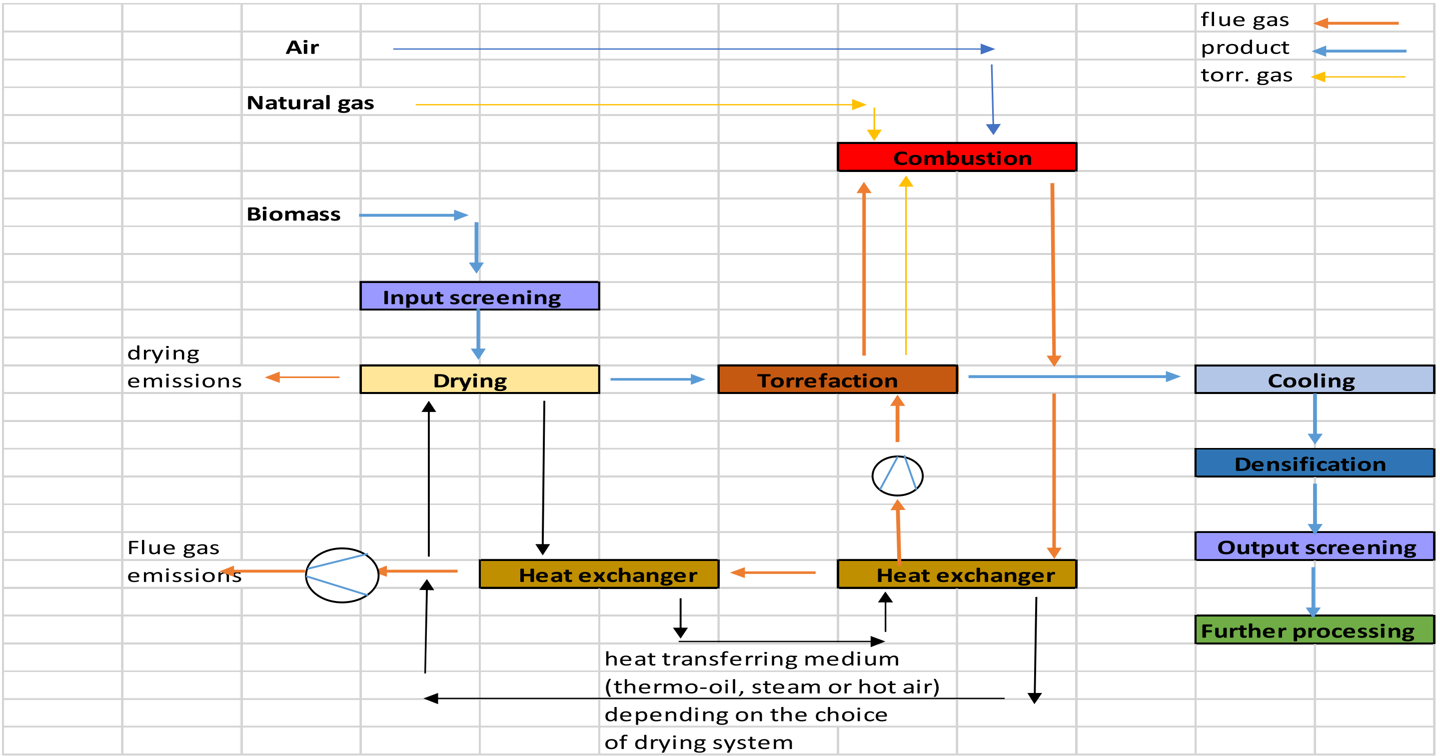
Torrefaction process flow sheet: Direct heating (flue gasses)



Source: Torr-coal, 2020

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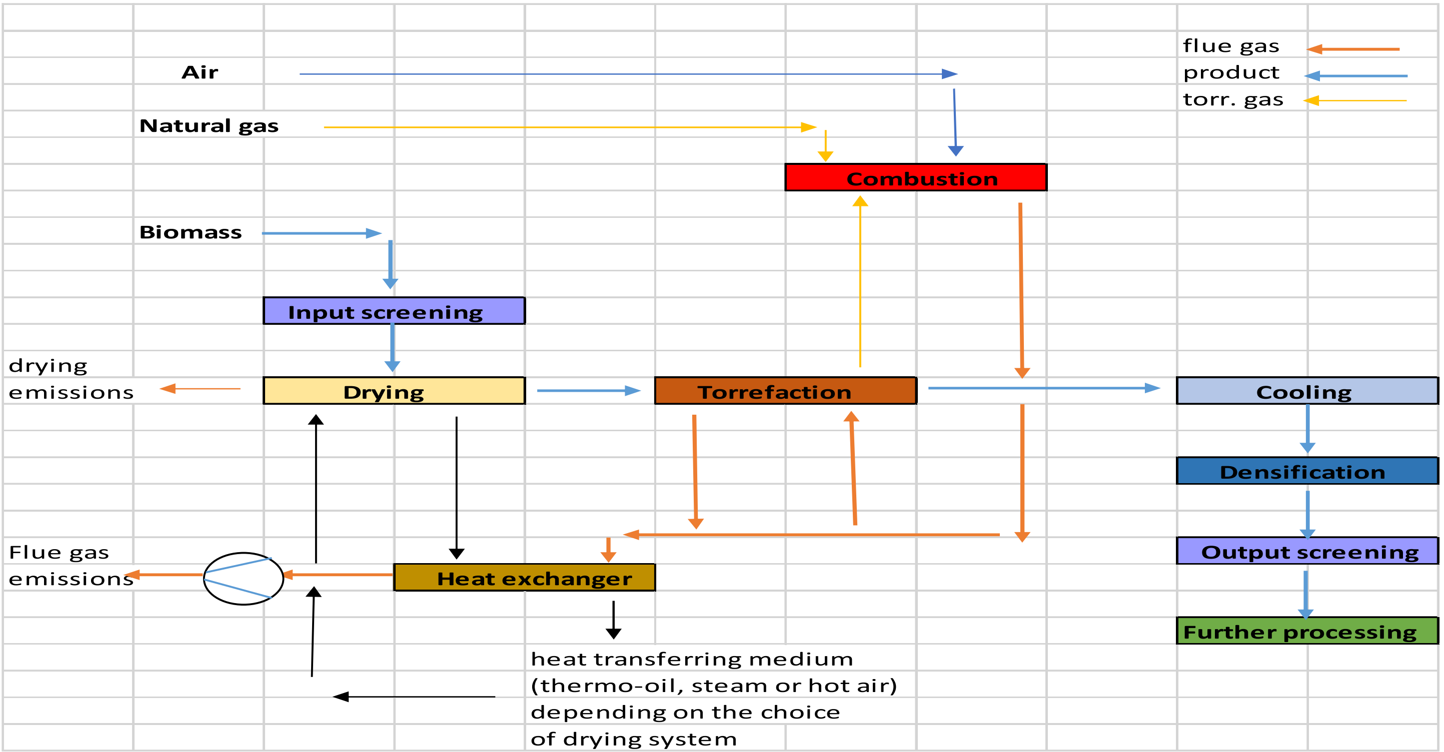
Torrefaction process flow sheet: In-direct heating (flue gasses)



Source: Torr-coal, 2020

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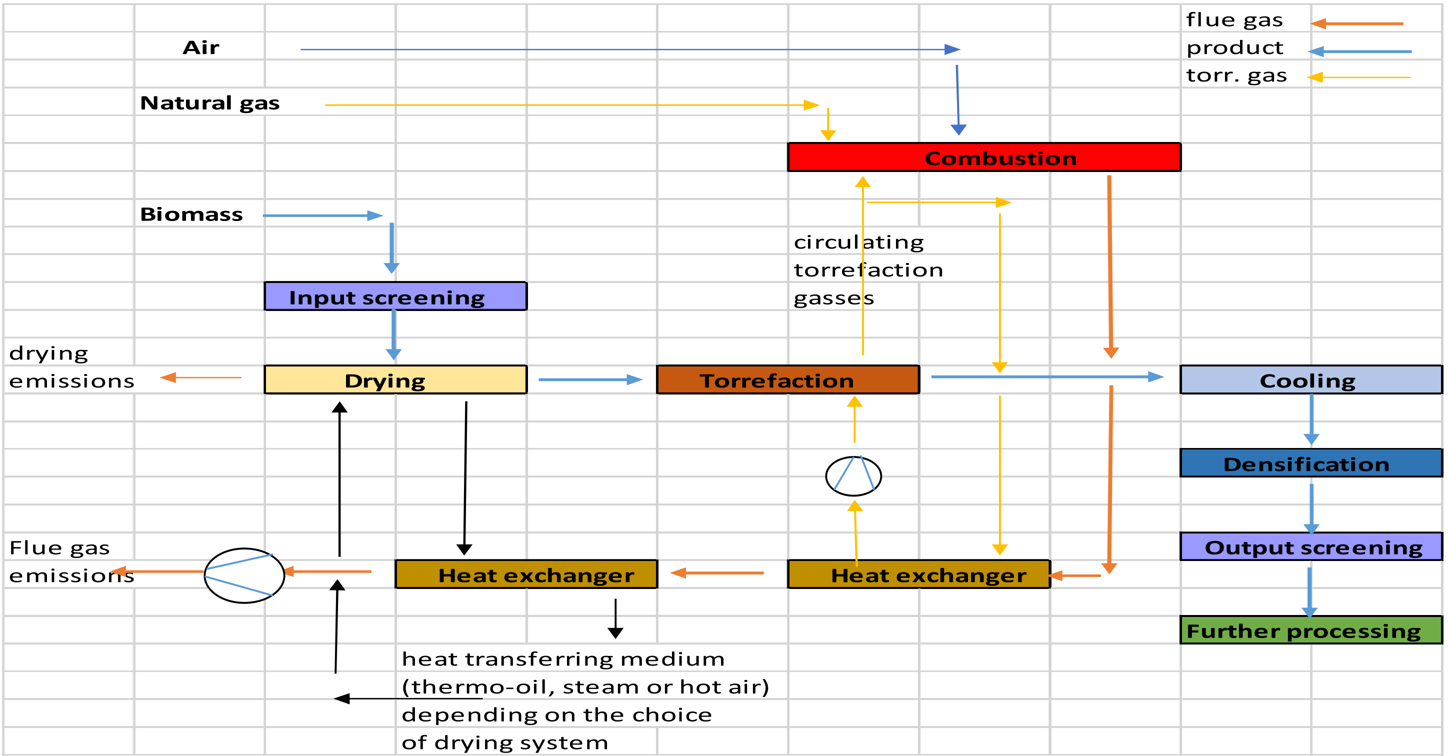
Torrefaction process flow sheet: Direct heating (Torr. process gasses)



Source: Torr-coal, 2020

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Torrefied biomass properties

Indicative properties of different biomass and coal-based fuels

	Wood	Wood pellets	Torrefied wood pellets	Charcoal	Coal
Moisture content (% wt)	30-45	7-10	3-8	1-5	10-15
Net Calorific value a.r. (MJ/kg)	9-12	15-16	19-24	30-32	23-28
Volatiles (% db)	70-75	70-75	55-65	10-12	15-30
Fixed carbon (% bd)	20-25	20-25	28-35	85-87	50-55
Bulk density (kg/l)	0,2-0,25	0,55-0,75	0,65-0,75	0,2	0,8-0,85
Energy density (GJ/m^3)	2-3	7,5-10,4	15-18,7	6-6,4	18,4-23,8
Dust	Average	Limited	Limited	high	Limited
Hygroscopic properties	Hydrofilic	Hydrophilic	Hydrophobic	Hydrophobic	Hydrophobic
Grindability	Worse	Worse	Better	Better	Better
Biological degradation	Yes	Yes	No	No	No
Handling requirements	Special	Easy	Classic	Classic	Classic
Product consistensy	Limited	High	High	High	High
Transport cost	High	Average	Low	Average	Low

Source: Nunes et al., 2014; Proskurina et al., 2016

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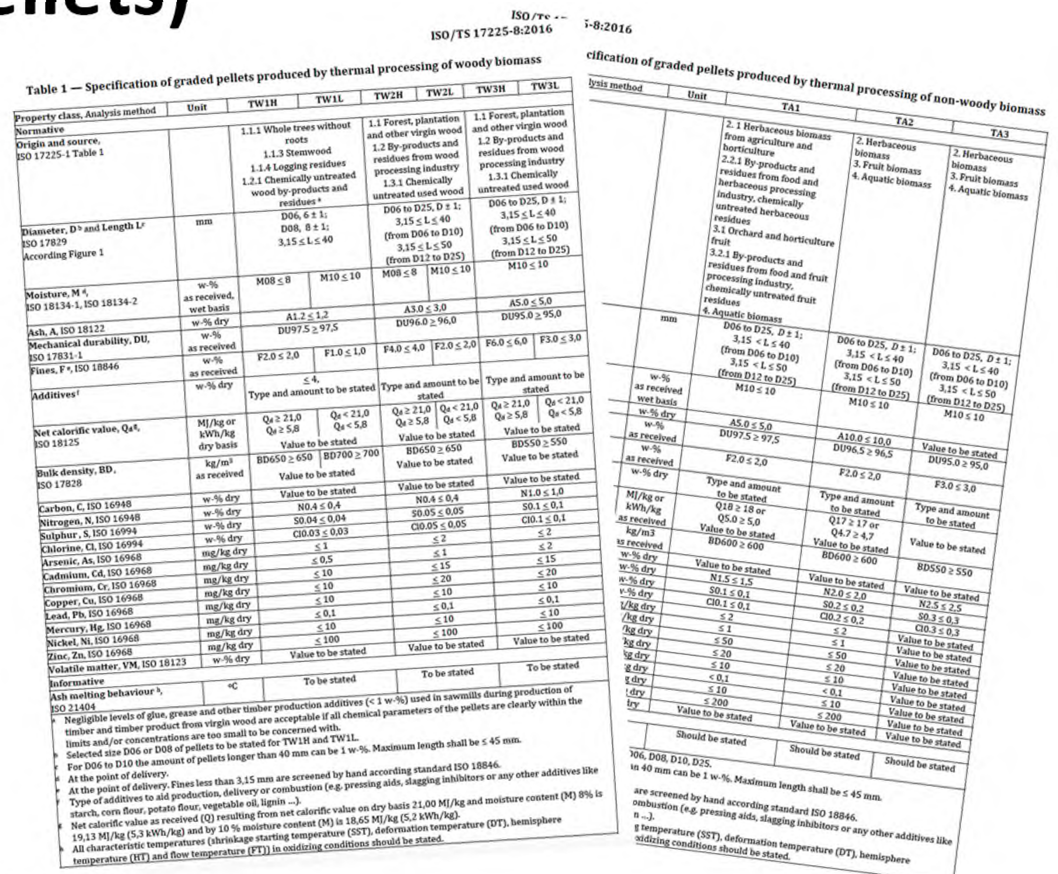
Quality and standardization (pellets)



ISO/TS 17225-8:2016

Table 1 — Specification of graded pellets produced by thermal processing of woody biomass

Property class, Analysis method	Unit	TW1H	TW1L	TW2H	TW2L	TW3H	TW3L
Normative							
Origin and source, ISO 17225-1 Table 1		1.1.1 Whole trees without roots 1.1.3 Stemwood 1.1.4 Logging residues 1.2.1 Chemically untreated wood by-products and residues [a]		1.1 Forest, plantation and other virgin wood 1.2 By-products and residues from wood processing industry 1.3.1 Chemically untreated used wood		1.1 Forest, plantation and other virgin wood 1.2 By-products and residues from wood processing industry 1.3.1 Chemically untreated used wood	
Diameter, D [b] and Length L [c] ISO 17829 According Figure 1	mm	D06, 6 ± 1; D08, 8 ± 1; 3,15 ≤ L ≤ 40		D06 to D25, D ± 1; 3,15 ≤ L ≤ 40 (from D06 to D10) 3,15 ≤ L ≤ 50 (from D12 to D25)		D06 to D25, D ± 1; 3,15 ≤ L ≤ 40 (from D06 to D10) 3,15 ≤ L ≤ 50 (from D12 to D25)	
Moisture, M [d], ISO 18134-1, ISO 18134-2	w-% as received, wet basis	M08 ≤ 8	M10 ≤ 10	M08 ≤ 8	M10 ≤ 10	M10 ≤ 10	
Ash, A, ISO 18122	w-% dry	A1.2 ≤ 1,2		A3.0 ≤ 3,0		A5.0 ≤ 5,0	
Mechanical durability, DU, ISO 17831-1	w-% as received	DU97.5 ≥ 97,5		DU96.0 ≥ 96,0		DU95.0 ≥ 95,0	
Fines, F [e], ISO 18846	w-% as received	F2.0 ≤ 2,0	F1.0 ≤ 1,0	F4.0 ≤ 4,0	F2.0 ≤ 2,0	F6.0 ≤ 6,0	F3.0 ≤ 3,0
Additives [f]	w-% dry	≤ 4, Type and amount to be stated		Type and amount to be stated		Type and amount to be stated	
Net calorific value, Q_d [g], ISO 18125	MJ/kg or kWh/kg dry basis	$Q_d \geq 21,0$ $Q_d \geq 5,8$	$Q_d < 21,0$ $Q_d < 5,8$	$Q_d \geq 21,0$ $Q_d \geq 5,8$	$Q_d < 21,0$ $Q_d < 5,8$	$Q_d \geq 21,0$ $Q_d \geq 5,8$	$Q_d < 21,0$ $Q_d < 5,8$
		Value to be stated		Value to be stated		Value to be stated	
Bulk density, BD, ISO 17828	kg/m³ as received	BD650 ≥ 650	BD700 ≥ 700	BD650 ≥ 650		BD550 ≥ 550	
		Value to be stated		Value to be stated		Value to be stated	
Carbon, C, ISO 16948	w-% dry	Value to be stated		Value to be stated		Value to be stated	
Nitrogen, N, ISO 16948	w-% dry	N0.4 ≤ 0,4		N0.4 ≤ 0,4		N1.0 ≤ 1,0	
Sulphur, S, ISO 16994	w-% dry	S0.04 ≤ 0,04		S0.05 ≤ 0,05		S0.1 ≤ 0,1	
Chlorine, Cl, ISO 16994	w-% dry	Cl0.03 ≤ 0,03		Cl0.05 ≤ 0,05		Cl0.1 ≤ 0,1	
Arsenic, As, ISO 16968	mg/kg dry	≤ 1		≤ 2		≤ 2	
Cadmium, Cd, ISO 16968	mg/kg dry	≤ 0,5		≤ 1		≤ 2	
Chromium, Cr, ISO 16968	mg/kg dry	≤ 10		≤ 15		≤ 15	
Copper, Cu, ISO 16968	mg/kg dry	≤ 10		≤ 20		≤ 20	
Lead, Pb, ISO 16968	mg/kg dry	≤ 10		≤ 10		≤ 10	
Mercury, Hg, ISO 16968	mg/kg dry	≤ 0,1		≤ 0,1		≤ 0,1	
Nickel, Ni, ISO 16968	mg/kg dry	≤ 10		≤ 10		≤ 10	
Zinc, Zn, ISO 16968	mg/kg dry	≤ 100		≤ 100		≤ 100	
Volatile matter, VM, ISO 18123	w-% dry	Value to be stated		Value to be stated		Value to be stated	
Informative							
Ash melting behaviour [h], ISO 21404	°C	To be stated		To be stated		To be stated	

[a] Negligible levels of glue, grease and other timber production additives (< 1 w-%) used in sawmills during production of timber and timber product from virgin wood are acceptable if all chemical parameters of the pellets are clearly within the limits and/or concentrations are too small to be concerned with.
[b] Selected size D06 or D08 of pellets to be stated for TW1H and TW1L.
[c] For D06 to D10 the amount of pellets longer than 40 mm can be 1 w-%. Maximum length shall be ≤ 45 mm.
[d] At the point of delivery.
[e] At the point of delivery. Fines less than 3,15 mm are screened by hand according standard ISO 18846.
[f] Type of additives to aid production, delivery or combustion (e.g. pressing aids, slagging inhibitors or any other additives like starch, corn flour, potato flour, vegetable oil, lignin ...).
[g] Net calorific value as received (Q) resulting from net calorific value on dry basis 21,00 MJ/kg and moisture content (M) 8% is 19,13 MJ/kg (5,3 kWh/kg) and by 10 % moisture content (M) is 18,65 MJ/kg (5,2 kWh/kg).
[h] All characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

-8:2016

cification of graded pellets produced by thermal processing of non-woody biomass

lysis method	Unit	TA1	TA2	TA3
		2. 1 Herbaceous biomass from agriculture and horticulture 2.2.1 By-products and residues from food and herbaceous processing industry, chemically untreated herbaceous residues 3.1 Orchard and horticulture fruit 3.2.1 By-products and residues from food and fruit processing industry, chemically untreated fruit residues 4. Aquatic biomass	2. Herbaceous biomass 3. Fruit biomass 4. Aquatic biomass	2. Herbaceous biomass 3. Fruit biomass 4. Aquatic biomass
	mm	D06 to D25, D ± 1; 3,15 < L ≤ 40 (from D06 to D10) 3,15 < L ≤ 50 (from D12 to D25)	D06 to D25, D ± 1; 3,15 < L ≤ 40 (from D06 to D10) 3,15 < L ≤ 50 (from D12 to D25)	D06 to D25, D ± 1; 3,15 < L ≤ 40 (from D06 to D10) 3,15 < L ≤ 50 (from D12 to D25)
	w-% as received wet basis	M10 ≤ 10	M10 ≤ 10	M10 ≤ 10
	w-% dry	A5.0 ≤ 5,0	A10.0 ≤ 10,0	Value to be stated
	w-% as received	DU97.5 ≥ 97,5	DU96.5 ≥ 96,5	DU95.0 ≥ 95,0
	w-% as received	F2.0 ≤ 2,0	F2.0 ≤ 2,0	F3.0 ≤ 3,0
	w-% dry	Type and amount to be stated	Type and amount to be stated	Type and amount to be stated
	MJ/kg or kWh/kg as received	Q18 ≥ 18 or Q5.0 ≥ 5,0	Q17 ≥ 17 or Q4.7 ≥ 4,7	Value to be stated
	kg/m3 as received	Value to be stated BD600 ≥ 600	Value to be stated BD600 ≥ 600	BD550 ≥ 550
	w-% dry	Value to be stated	Value to be stated	Value to be stated
	w-% dry	N1.5 ≤ 1,5	N2.0 ≤ 2,0	N2.5 ≤ 2,5
	w-% dry	S0.1 ≤ 0,1	S0.2 ≤ 0,2	S0.3 ≤ 0,3
	w-% dry	Cl0.1 ≤ 0,1	Cl0.2 ≤ 0,2	Cl0.3 ≤ 0,3
	/kg dry	≤ 2	≤ 2	Value to be stated
	/kg dry	≤ 1	≤ 1	Value to be stated
	/kg dry	≤ 50	≤ 50	Value to be stated
	kg dry	≤ 20	≤ 20	Value to be stated
	kg dry	≤ 10	≤ 10	Value to be stated
	g dry	< 0,1	< 0,1	Value to be stated
	g dry	≤ 10	≤ 10	Value to be stated
	dry	≤ 200	≤ 200	Value to be stated
		Value to be stated	Value to be stated	Value to be stated
		Should be stated	Should be stated	Should be stated

D06, D08, D10, D25.
in 40 mm can be 1 w-%. Maximum length shall be ≤ 45 mm.
are screened by hand according standard ISO 18846.
ombustion (e.g. pressing aids, slagging inhibitors or any other additives like
n ...).
g temperature (SST), deformation temperature (DT), hemisphere
xidizing conditions should be stated.

ISO 17225

- ➢ Solid biofuels – Fuel specifications and classes

ISO TS 17225 - 8:

- ➢ Part 8: Graded thermally treated and densified biomass fuels

Different Classes

- ➢ *Woody* and *Non Woody*
  - ✓ NCV, Durability, Bulk Density, Volatile Matter etc.

Additional parameters in ISO working group:

- Grindability
- Water resistance
- Energy balance

Source: ©Wild&Partner

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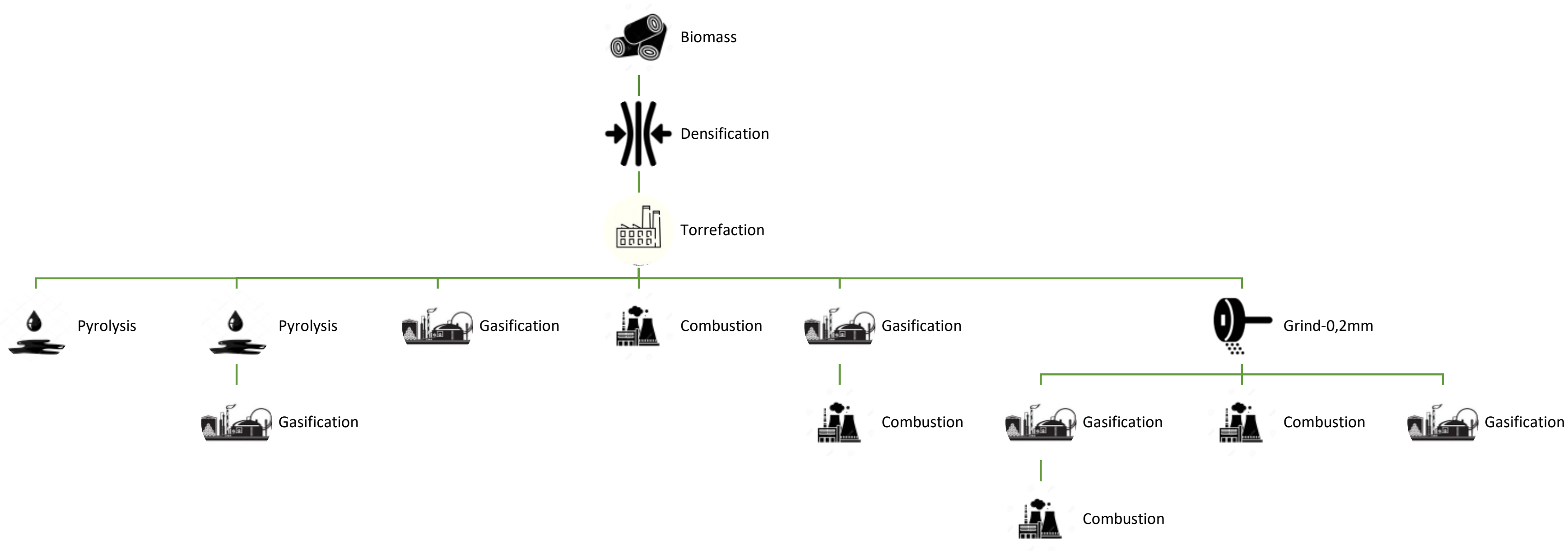
Alternative process steps for torrefied biomass utilization



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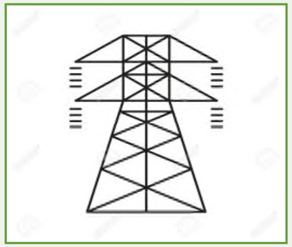
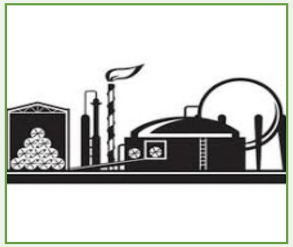
Applications

Steam

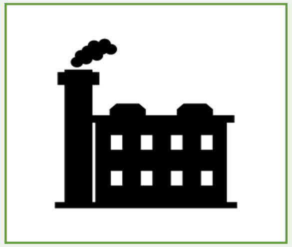


Electricity

Transportation fuels

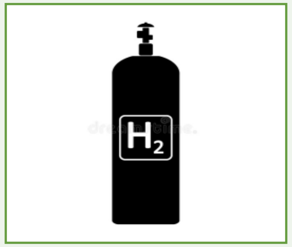


Syngas



Steel industry

Chemicals



Hydrogen

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Status

Country	Company	Technology	Feedstock	Output capacity (ton/h)	Operation
Austria	Next Fuel	Rotary drum	Woodchips	1	Yes
Belgium	Torr-Coal B.V.	Rotary drum	Woodchips; soft pellets (paper rejects; SRF)	5 powder ; 0,5 pellets	Yes
Belgium	CMI/NESA	Multiple hearth	Sawdust, woodchips; agricultural residues	Pilot scale	Only for development activities
Ireland	Arigna Fuels Ltd	Screw reactor	Sawdust, woodchips; agricultural residues	Unknown	Yes
Netherlands	Yilkins	Fluidised bed	Unknown	2,5	Only for development activities
Portugal	Advanced Fuel Solutions	Rotary drum	Eucalyptus wood	0,5	Under Construction
Portugal	Futerra Fuels	Swirling fluidised bed	Eucalyptus wood	0,6 black pellets ; 0,3 white pellets	Under Construction
Sweden	BioEndev	Screw reactor	Woodchips; sawdust	2	Closure of black pellet production and industrial demonstration plant (Feb 2020)
United Kingdom	CEG	Vibrating belt reactor	Woodchips	4	Yes

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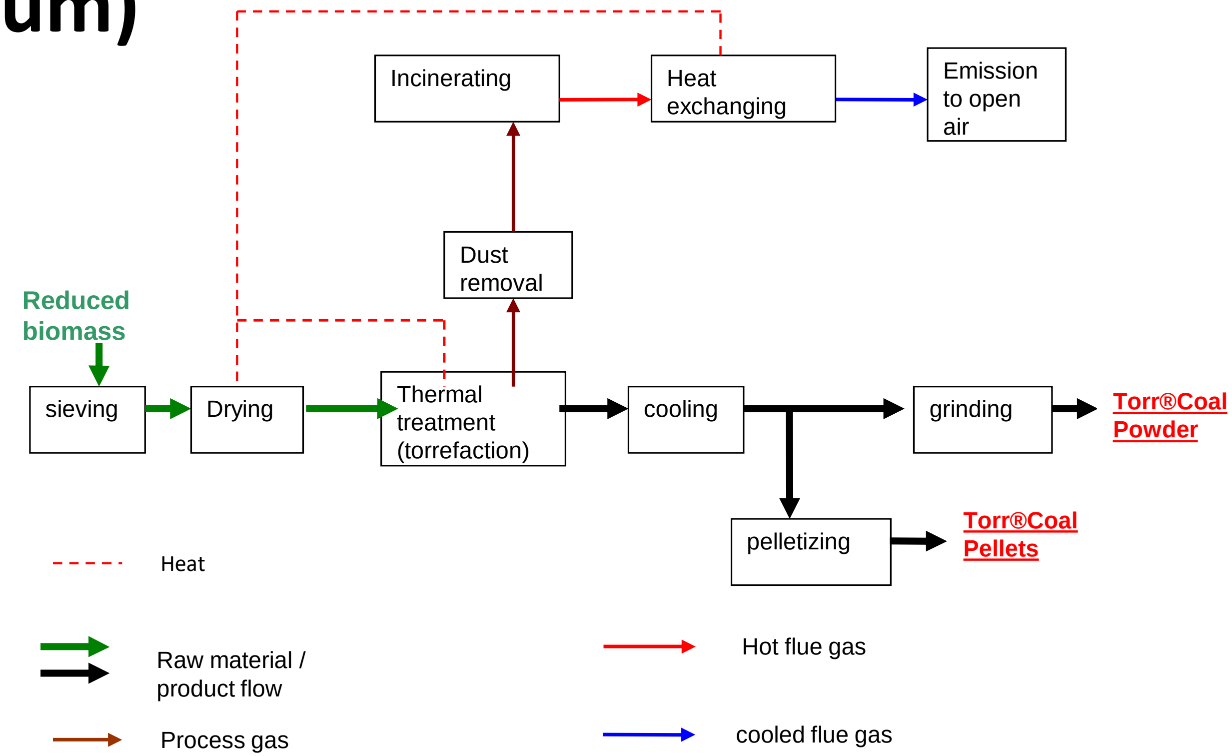
Torr-Coal B.V. (Belgium)

- Production start: 2010
- Output capacity: 40 kton/a (powder and pellets)
- Process technology: based on rotating drum reactor
- Feedstock: woody biomass



Source: Torr-Coal B.V.

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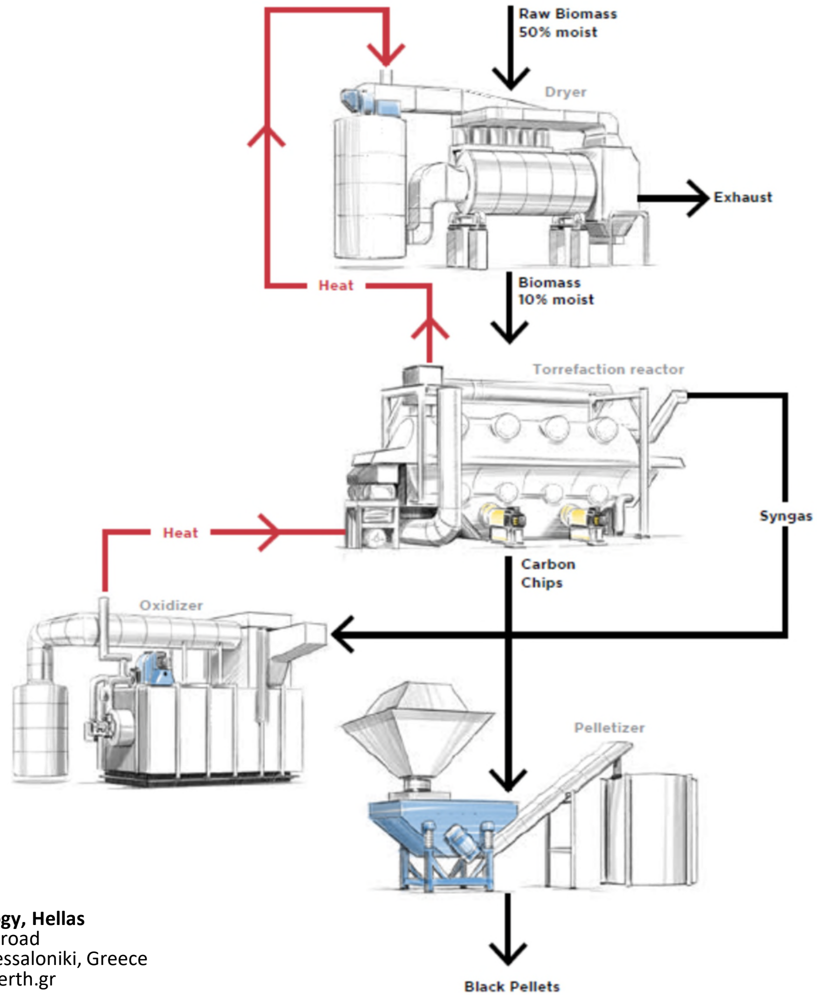
CEG (United Kingdom)

- Founded: 2013
- Reached maximum capacity: 2018
- Output capacity: 30 kton/a CEG bio-coal
- Process technology: based on vibrating belt reactor
- Feedstock: woodchips



Source: CEG

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Advanced Fuel Solutions (Portugal)

- Construction begun:2015
- Initially expected commissioning of production lines: mid 2016 (still under construction-final stages)
- Nominal output capacity: 96 kton/a
- Process technology: based on rotary drum (designed and supplied by Konza Renewable Fuels)
- Feedstock: Eucalyptus wood

Source: Advanced Fuel Solutions

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Futerra Fuels (Portugal)

- Established:2015
- Construction begun:2018
- Expected commissioning of production lines: mid 2020
- Nominal output capacity: 120 kton/a black pellets, 55 kton/a white pellets
- Process technology: based on swirling fluidized bed (designed and supplied by Yilkins B.V.)
- Calorific value: 20-24 MJ/kg
- Feedstock: Eucalyptus wood
- Total investment: 38 million EUR
- Long term supply contracts with European energy companies and industries
- Small scale tests in domestic and commercial boilers

Source: Futerra Fuels

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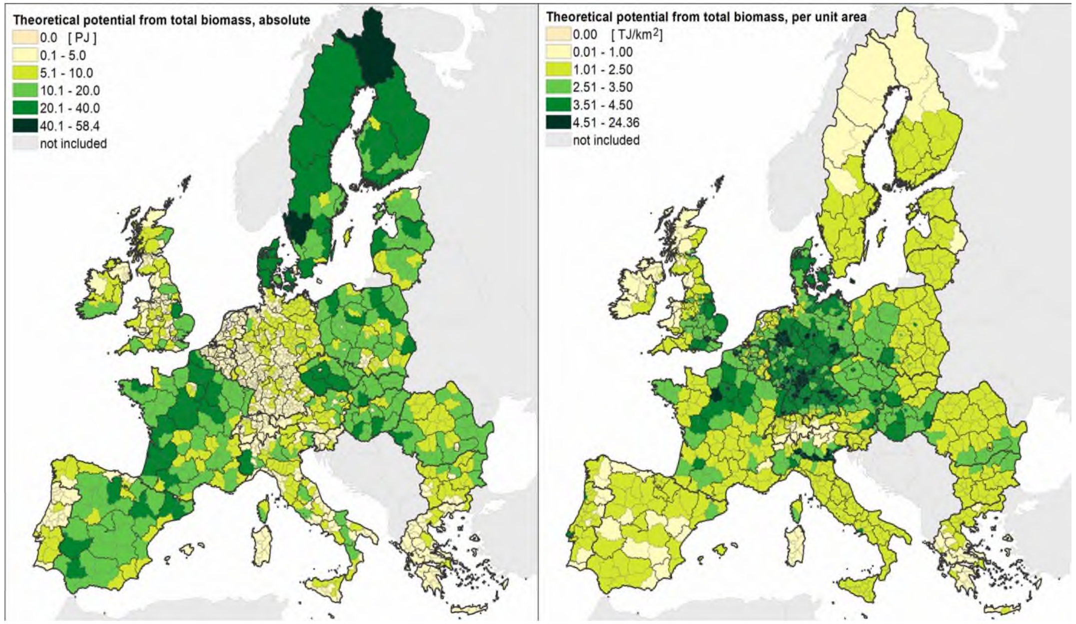
Barriers to large scale deployment

1. Biomass supply chains
   - Security of supply
   - Transport
   - Handling
   - Storage
2. Technological
   - Depending on the reactor type-challenge to scale up from pilot to commercial use
   - Product consistency-wide range biomass quality
   - Plethora of operational parameters-reactor temperature, residence time etc.
   - *Limited knowledge on volatiles composition (Some developers use these volatiles for heat generation)
   - Heavy tars might result in operational problems
3. Economical
   - Logistics cost
   - Biomass drying
   - Increased process cost compared to coal



Source: Hamelin et al. 2018

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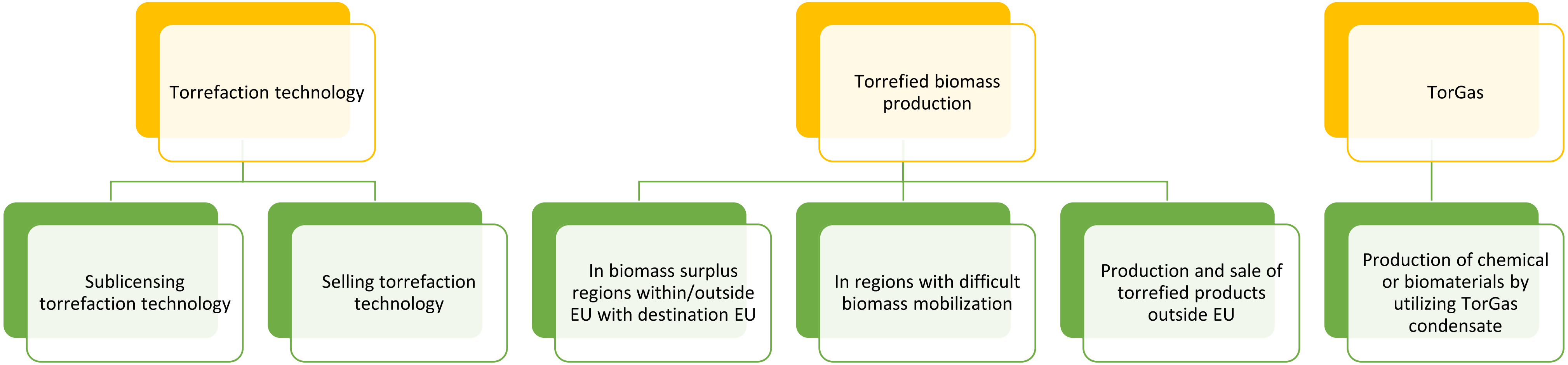
Market opportunities



Adapted from: Thran et al., 2016

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Estimated production costs*

Case	Stand-alone torr. plant (Europe)	New sawmill and torr. plant integrated	Existing sawmill and new torr. plant	Existing pulp mill and new torr. plant
Capacity (t/a)	72.800	231.600	101.100	407.200
Fixed operating costs (M€/a)	3,99	5,39	3,47	6,71
Variable operating costs (M€/a)	9,87	31,73	14	58,5
Annualized capital costs (M€/a)	5,44	11,68	6,84	17,34
Total costs (M€/a)	19,3	48,8	24,31	82,54
Production costs (€/MWh)	43	34	38	33
Market price of wood pellets (€/MWh)	30	30	30	30
Price compared to market price (%)	145	115	126	111

*Thran et al., 2016; Wilen, Arpiainen, Report on Optimisation Opportunities by Integrating Torrefaction into Existing Industries, SECTOR Deliverable D3.2, 2014

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Conclusions

- Slow technological maturation and market introduction
- Several companies gone bankrupt
  - Inability to produce consistent product
  - Lack of buyers
- Some developers consider smaller domestic or industrial markets more promising than large scale utilities
- Most important technical challenges
  - Achieving constant and well controlled product quality
  - Process scale-up
  - Product densification (pellet or briquette)
- Development on using agro-residues is limited due to the challenging physical and chemical characteristics
- For long transportation distances, the additional costs of the torrefaction process can be compensated by savings in transportation costs
- Similarity to coal can enable higher co-firing percentages (or even complete fuel switching), without significant modifications to a power plant
- With low prices for coal and CO_2 penalties and a high perceived risk, there is limited willingness to pay reasonable prices for torrefied pellets
  - Only if significant commercial production starts up and trade volumes increase, a true market value of torrefied pellets or briquettes will be established
- Pressure on fuel costs in the power industry is huge
  - For domestic or small industrial scale applications current fuel price levels may be more attractive to introduce torrefied biomass
- In RED II, the overall EU target for Renewable Energy Sources consumption by 2030 has been raised to 32%, 8 out of 28 EU member countries aim to phase out coal-powered electricity by 2030, enabling the commercial market introduction of torrefied biomass
  - Price parity with coal could accelerate large scale implementation
- It is important that CO_2 emission allowances are tightened in order to increase CO_2 prices
- Individual EU member countries should facilitate co-firing of torrefied biomass via additional support schemes
- Torrefied biomass needs to be accepted within regulatory frameworks

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Market Uptake Support for Intermediate Bioenergy Carriers

Biomass Fast Pyrolysis

Recent experiences and best-in-class examples

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EU H2020 grant no. 857806, 1/9/2019 – 31/8/2022

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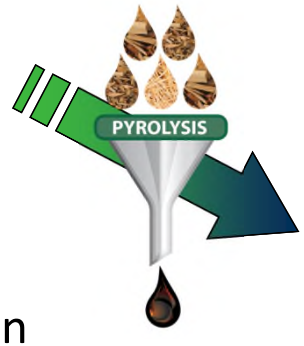
   - Fast pyrolysis – Why make oil from biomass?
2. Fast pyrolysis oil characteristics
   - Oil properties
   - Applications
   - Upgrading of the oil to fuels
   - Materials and chemicals from pyrolysis oil
3. Fast pyrolysis technology – Status and commercial production
   - Fortum, FIN
   - EMPYRO, NL
   - Ensyn/Honeywell UOP, North America
4. Pyrolysis oil logistics issues and examples
5. References and further reading



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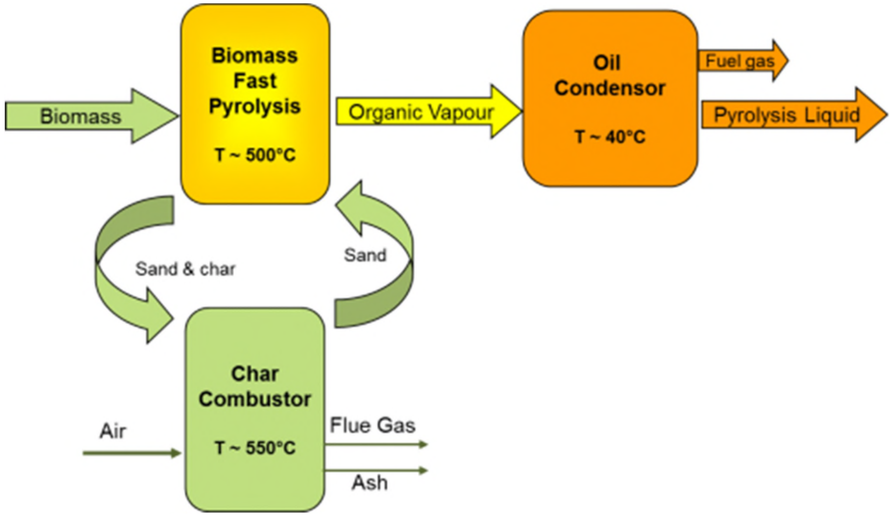
Fast pyrolysis – the pyrolysis oil technology

- Fast pyrolysis: lignocellulosic biomass is heated in the absence of air rapidly (≈2 sec) to 450 - 600°C at ambient pressure. The structure is broken down and vaporized. When this vapor is condensed, pyrolysis oil is formed.
- Char and gases are also formed during fast pyrolysis process.



More information: PyroWiki

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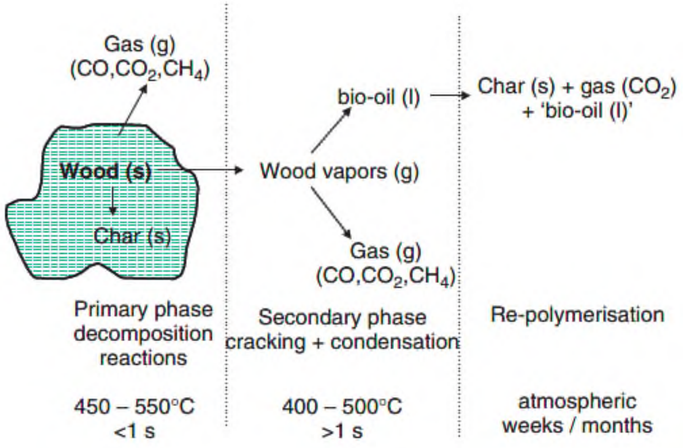
Fast pyrolysis – Important factors

- For achieving maximum yield and high quality of the oil rapid heat transfer is essential. This can be done by using small, homogeneous feedstock particles (typically 5mm) with a moisture content of less than 10 %.
- Technology developed by BTG-BTL uses a Rotating Cone Reactor which utilizes mechanical mixing of hot sand and the biomass particles. Sand acts as a heat carrier for enhancing the heat transfer during the fast pyrolysis.
- The sand is heated during combustion of char in a combustor (see previous slide). Combustion of the char provides energy that can be used to power the plant or to produce process heat for other applications.
- For a good oil quality quick condensation of the formed vapors is also important.
- Naturally, factors that also influence the product are the type of reactor used, operating conditions and other feedstock properties, like ash content.



Rotating cone reactor

Source: Venderbosch R.H., Prins W., Fast pyrolysis technology development

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Fast pyrolysis - Why make oil from biomass?

- Pyrolysis oil compared to raw biomass:
  - Pyrolysis oil is easier to store, transport and use than the biomass itself.
  - Biomass becomes available in many forms. With pyrolysis these can be converted to a homogeneous liquid.
  - Energy density of pyrolysis oil is 4-20 times higher than biomass.
  - Biomass contains minerals that are almost absent in the pyrolysis oil, this reduces the emissions during usage of the material.
  - Pyrolysis oil can be upgraded to transport fuels, chemicals and materials.

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Fast pyrolysis oil characteristics

- Pyrolysis oil is a mixture of cracked components originating from the biomass structure (cellulose, hemicellulose, lignin).
- Typical oil properties are shown in the table:
- Pyrolysis oil is brown/red liquid with distinguishable smoky odor.
- A wide variety of functional groups (such as acids, aldehydes, ketones, carbohydrates, furans, pyrans, aromatics, hydrocarbons) are present in the oil, and several of them can even be present in a single component.
- The higher heating value (HHV) of pyrolysis oil is 16-23 MJ/L. Fossil fuel is 37 MJ/L.
- Due to large amount of oxygenated components present, the oil has a polar nature and does not mix readily with hydrocarbons.
- The degradation products from the biomass components include organic acids (like formic and acetic acid), giving the oil its low pH. Due the low pH handling and storage needs to be arranged accordingly.
- Water is an integral part of the single-phase chemical solution. The (hydrophilic) bio-oil have water contents of typically 15 - 35 wt%. Typically, phase separation does occur when the water content is higher than about 30 to 45 %.

Pyrolysis oil properties

Property	Unit	Value
C	wt%	46
H	wt%	7
N	wt%	< 0.01
O (Balance)	wt%	47
Water content	wt%	25
Ash content	wt%	0.02
Solids content	wt%	0.04
Density	kg/Ltr	1,2
LHV	MJ/kg	16
LHV	MJ/Ltr	19
pH	-	2.9
Kinematic viscosity (40 °C)	cSt	13

Source: BTG-BTL

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Fast pyrolysis oil – direct combustion

- Biomass derived fast pyrolysis oil is a renewable fuel that can be used for the production of heat, steam and power.
  - After relatively small modifications, good quality pyrolysis oil can be used in traditional boilers, furnaces and turbines.
  - Redesign of the burner and its operation mode are usually required for small units. Corrosion resistant materials are also needed for the equipment that is contacted with the pyrolysis oil.
  - Co-combustion of pyrolysis oil in large power stations is well demonstrated:
    - In the US Ensyn oil reported in 1997 that a 370 hours (5 %) co-combustion test in the Manitowoc 20 MWe coal fired boiler in Wisconsin was completed.
    - In The Netherlands, BTG completed a 10 hour test with 15 ton pyrolysis oil in the natural gas fired power station in Harculo.
- Combustion of pyrolysis oil as such in an internal combustion engines remains a challenge due to e.g. particulates, acidity, poor lubrication, thermal instability, ignition, viscosity, water content
  - There are numerous research projects ongoing for making transport fuels from pyrolysis oil

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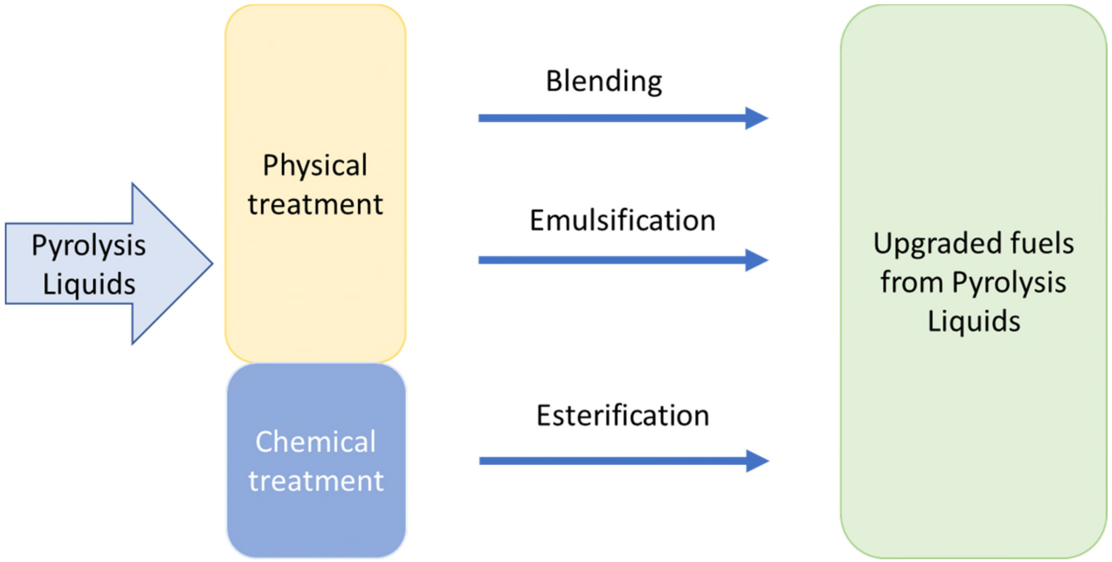
Fast pyrolysis oil – fuel for stationary engines and turbines



- To be able to use Pyrolysis Liquids as a fuel for stationary engines and turbines a mild physical or chemical treatment is needed.
- These modifications will improve specific properties like acidity, viscosity and stability. Examples of such treatments are blending emulsifying and esterification .
- However, these treatments will not enable the use in automotive applications.

Source: Pyrowiki

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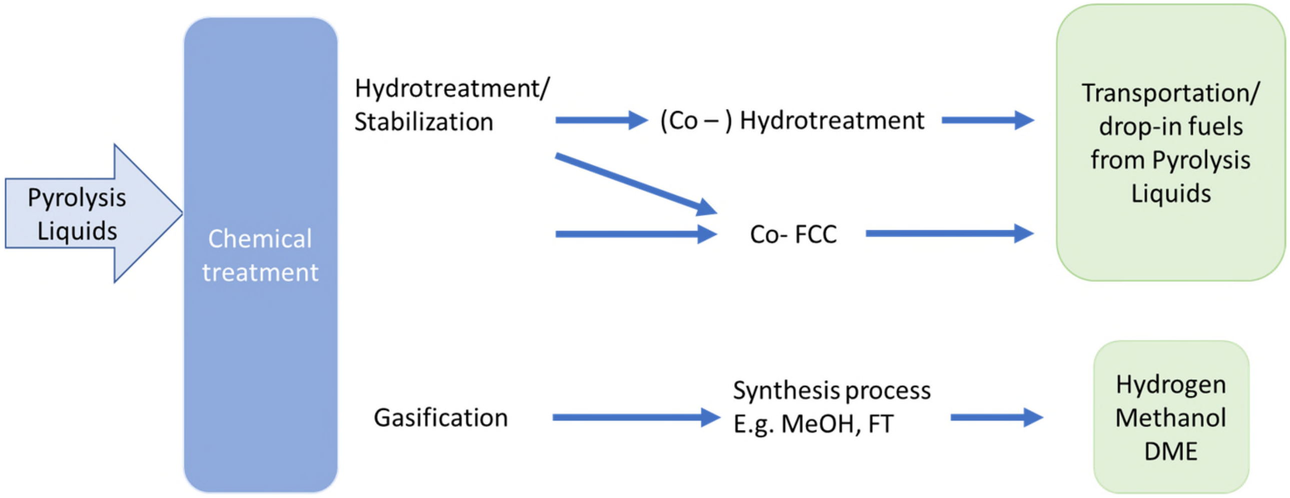
Fast pyrolysis oil – upgrading for a transport fuel

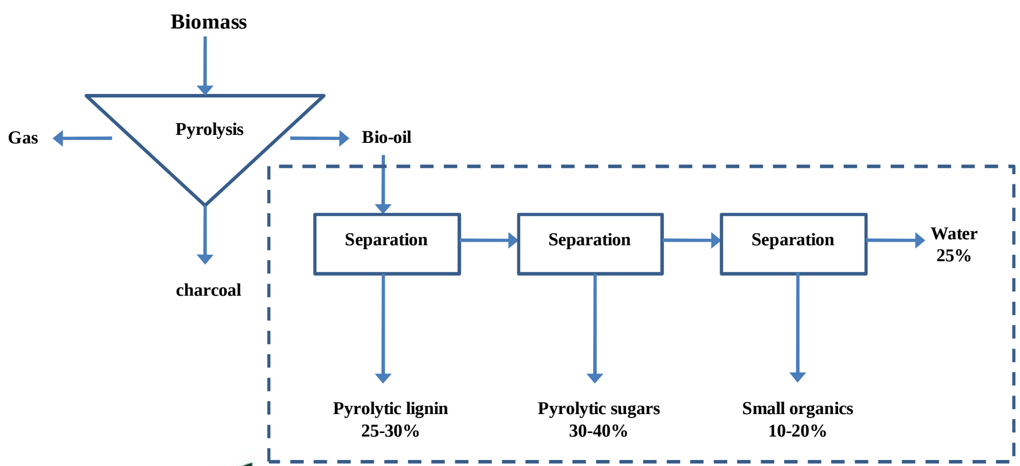


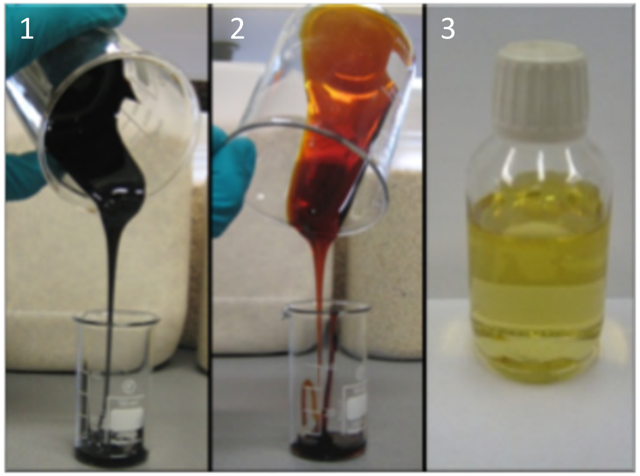
Source: [Pyrowiki]

- It is necessary to upgrade pyrolysis oil in order to use it as a transport fuel.
- For production of diesel, kerosene and gasoline thermochemical treatment of PO is necessary. Options are:
  - Deoxygenation of the oil in a catalytic hydrotreatment process. This requires large amount of hydrogen.
  - Partial deoxygenation followed by upgrading in a traditional crude oil refinery unit.
  - Fluid Catalytic Cracking of the pyrolysis oil.
- PO can also be gasified to syngas and further upgraded/synthesized to hydrogen, methanol or dimethyl ether.

Fast pyrolysis oil – towards chemicals and materials

- Pyrolysis oil can be separated by Fractionation into 3 main components:
    1. pyrolytic lignin
    2. pyrolytic sugars and an
    3. water fraction





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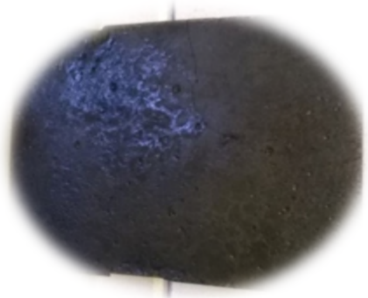
Fast pyrolysis oil – towards chemicals and materials

The Pyrolytic lignin, pyrolytic sugar and water phase can each be used as a renewable source of chemicals and materials

Modified wood, made more durable by pyrolysis sugars impregnation

Garden shed painted with pyrolysis lignin-based paint



Composite produced using a 'green' crosslink material based on pyrolysis lignin

Roofing material containing pyrolysis lignin to replace fossil bitumen

Glue, containing phenolic components from pyrolysis oil

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Fast pyrolysis technology – commercial use

- Fortum pyrolysis plant in Joensuu (FIN), combined with a CHP plant. The plant was commissioned in 2013.
  - The pyrolysis reactor is a Circulating Fluidized Bed, using local forest residues, wood chips and saw dust. Heat is provided to the CHP plant. The reactor was designed and delivered by Valmet.
  - Total investment costs were 38 million Euro for pyrolysis oil plant and for the link with the CHP plant.
  - The location for the plant was chosen based on the availability of the feedstock nearby and the high level of forestry knowledge in the region.
  - Combining the CHP plant and the PO plant allows for better use of lower-quality biomass fuel (residues and sawdust) that would otherwise be used at lower efficiency in conventional CHP. Furthermore, biomass in the region can be converted to more valuable fuel when demand for heat and power are limited.

Fortum	
Standard production capacity	
Feedstock	300 000 m3 wood
Pyrolysis Oil	50 million Liters
Electricity (from CHP)	56 MW
Heat (from CHP)	180 MW

Sources: Fortum CHP plant, Fortum press release 1 , Fortum press release 2, Fortum bio-oil brochure - pdf , Valmet press release, IRENA report : Bioenergy from Finnish forests

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Fast pyrolysis technology – commercial use

- EMPYRO pyrolysis plant built by BTG-BTL in Hengelo (NL), commissioned in 2015.
  - Owned since January 2019 by Twence, local waste management company and renewable energy supplier.
  - Uses local wood residues, like residues (crumbs) from a pellet factory.
  - Reactor type is Rotating Cone reactor. 70% of the biomass is converted to oil, the rest is char and gas.
  - Plant is producing electricity for its own use. Also steam is produced, which is supplied to Nouryon salt factory next door.
  - Funded by the private investors, the EU-FP7 program within EMPYRO-project and national and local funds. Total capital expenditure: 20 million Euro.

EMPYRO	
Standard production capacity	
Feedstock	120 ton wood/day
Pyrolysis Oil	20 million Liters/year
Electricity	4500 MWh/year
Steam	80,000 ton/year

Source: BTG-BTL EMPYRO leaflet - pdf

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Fast pyrolysis technology – commercial use

- The Ensyn/ Honeywell UOP technology is referred as Rapid Thermal Processing or RTP™. Ensyn is established 1984 based on research carried out by University of Ontario, Canada.
  - Uses circulating bed system with sand as heat carrier material. The technology has been in production for 25 years and has efficiency of 70-75%. Gas and char produced are used for running the facility and drying the woody biomass.
  - First commercial use in was in 1989 for production of liquid smoke for food industry. Currently, 30 different food ingredients produced from wood with RTP.
  - Several units have been commissioned over the years:
    - In 2007, Ensyn commissioned Renfrew Ontario, with a capacity of 75ton/day unit producing renewable fuel oil, RFO™.
    - Ensyn joined forces with UOP in 2008 and established Evergent Technologies LLC (55% UOP, 45% Ensyn). The Renfrew facility was upgraded to 200 ton/day in 2016. The facility produces RFO from forest slash, which is used by several end-users.
  - Ensyn and UOP are further targeting global petroleum markets with co-processing of bio-oil in refineries. They are collaborating with Petrobras (global petrochemical company) and Fibria (Brazilian pulp and paper company).

Ensyn - Port-Cartier, Quebec	
Standard production capacity	
Feedstock	65 000 ton dry biomass/year
Oil	40 million Liters/year

Source: Ensyn RTP, Venderbosch R.H. in Thermochemical Processing of Biomass, Ensyn presentation 1 - pdf file, Ensyn presentation 2 - pdf file

Fast pyrolysis technology – plans

- Two plants under construction: one in Finland and one in Sweden.
- Technology for both is developed by BTG-BTL and provided in cooperation with Technip BV. The construction is done in modules. The modules are assembled in NL, tested, disassembled again and then transported to the building site.
- Finland:
  - Green Fuel Nordic (GFN) pyrolysis plant in Lieksa, Finland:
    - Construction works have started in September 2019. Commissioning is expected in 2020. Annual production capacity 20 million liters of PO.
    - Will use forestry residues and sawdust as a feedstock from sawmill nearby.
    - GFN will provide oil for local/international consumers. Savon Voima in Iisalmi is one the customers for PO from GFN, and will use the PO in their district heating plant
    - The Lieksa plant will use the steam to provide energy for feedstock drying.

More information: Green Fuel Nordic Oy website, Savon Voima press release

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Fast pyrolysis technology – plans

- Sweden:
  - Setra Group pyrolysis plant Pyrocell in Kastet sawmill outside Gävle, Sweden:
    - Owned jointly with Preem, Sweden's largest refiner
    - Planned to be completed in 2021. Annual capacity 20 million liters of pyrolysis oil (PO).
    - Will use sawmill residues for PO production. The annual usage of sawdust is estimated at 80 000 ton.
    - Pyrocell aims to upgrade the PO to transportation fuel (for automotive applications) at Preem refinery in Lysekil. Transportation of PO will be by tanker.

More information: Pyrocell brochure – pdf, Setra Group information

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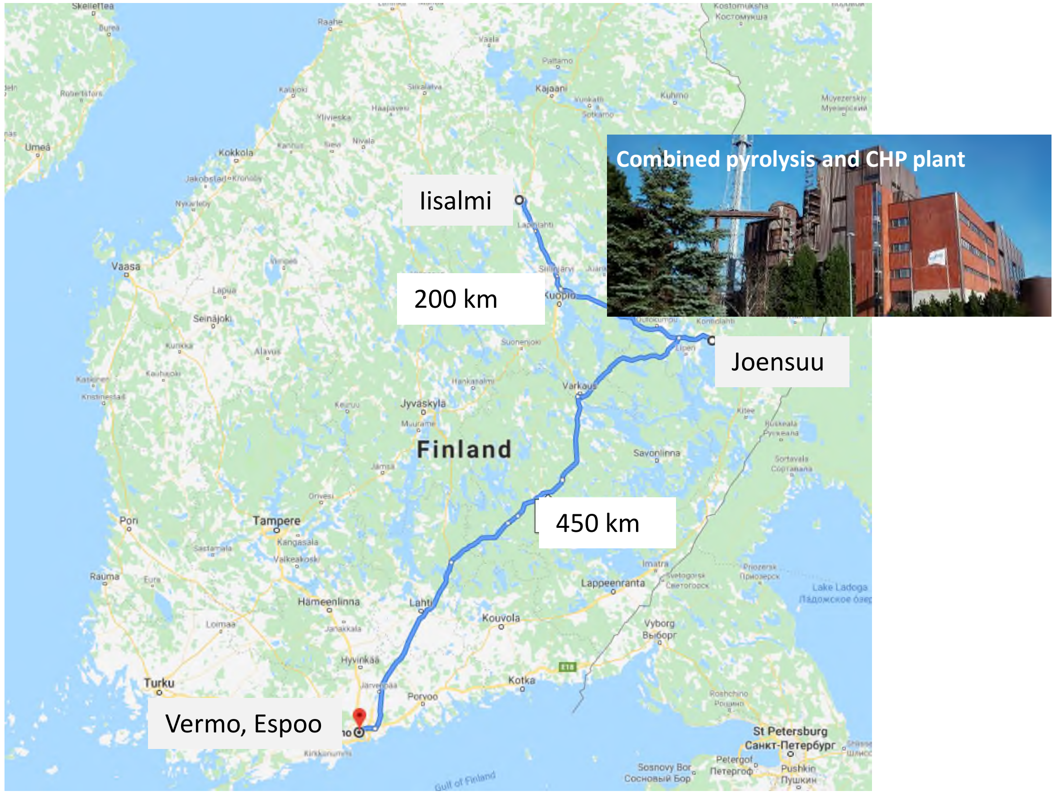
Pyrolysis oil logistics issues and examples – Feedstock to Fortum (FIN)

- Fortum uses small-size wood thinnings as a raw material for the pyrolysis plant
  - The wood is harvested using a harvester with single-stem or multi-stem harvesting head and haulage is done with a forwarder. The wood is chipped at the roadside and transported to the plant as chips or wood is transported as logs and chipped at the plant terminal.
- In Finland, it is possible to use large 76 ton trucks in transportation, which makes train transportation rare. Also, there is only one state owned train operator without competition. Train transportation is not competitive against truck transportation for short distances.
  - In the Joensuu region, wood can be transported to the large terminals using ferries. Ferry transportation can be used to provide sufficient amounts of raw materials for the long winter.
- On daily basis 46 trucks transport wood ships to the plant. In the winter time when the heating season is highest the number of truck can be can be up to 100.

Sources: BioPad Case Study: Fortum CHP , IRENA report : Bioenergy from Finnish forests

Pyrolysis oil logistics issues and examples – Pyrolysis oil from Fortum plant

- In 2015-2017 PO was supplied from Joensuu to Savon Voima power company in Iisalmi by truck (?):
  - Multiple test firings were done by using the PO in a district heating plant. In 2017 this was stopped due to problems with the oil quality, mainly due to inhomogeneity during storage. Fortum uses PO in its own district heating plants in Joensuu and in Vermo, Espoo.
  - It is expected that the transportation is by truck to Espoo.
- Fortum is providing solutions to customers for converting their existing fossil-based heating oil plants to PO fueled plants. They promise to do this for plants that have more than 35MW capacity. The success of this is not reported publicly.
- Fortum's PO is a branded as Otso®.



Sources: Fortum press release 1 , Fortum press release 2, Fortum press release 3, Fortum bio-oil brochure - pdf, Yle news article, Savon Voima press release

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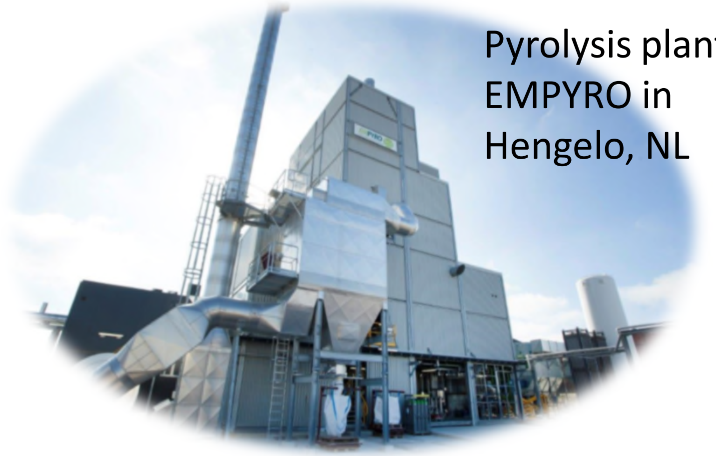
MUSIC

Pyrolysis oil logistics issues and examples – Feedstock to EMPYRO

- EMPYRO uses residues from wood pellet production. These are sieved crumbs and fines that are considered otherwise as a waste.
- EMPYRO has 2 feedstock suppliers:
  - One local about 35 km from the site.
  - The other in Moerdijk in the south west of the Netherlands 200km away.
  - The feedstock is delivered by a truck 4-5 times a day.
  - Having 2 suppliers will give more security to the plant operation.
  - In total EMPYRO has contracted 35 000 m^3 ton of wood per year for 10 years.
- The feedstock is brought to the plant with a pellet truck that pneumatically feeds the residues to the storage vessel.
  - This is a limitation for using different types of feedstock, like wood chips that are transported by other means.
  - EMPYRO is building a new storage silo that allows more flexibility with feedstocks.



Pyrolysis plant EMPYRO in Hengelo, NL

- It is important to realize that EMPYRO was built near the developers of the technology (BTG-BTL is ≈ 10 km away).
- a PO plant is more economically viable when build as near as possible to the feedstock in order to avoid costly transportation of a low value material. In case of EMPYRO the technology needed to be first demonstrated in a commercial scale and having the engineers and developers nearby the plant was crucial.
- BTG-BTL sought out for a local supplier for energy material and they came in contact with the pellet producer. To make the operation more robust a 2nd provider was contracted.

btg biomass technology group

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Pyrolysis oil logistics issues and examples – Products from EMPYRO

Plant is operational 24/7
Storage capacity: 250 m^3

EMPYRO products

- EMPYRO produces **3 products,** Pyrolysis oil, Steam and Electricity (from steam generator)
- Most of the oil is sold to Friesland Campina, a dairy company that uses the oil in their boiler to replace natural gas.
- Some oil is available for purchase for research purposes.
- Steam is provided to next door to Nouryon salt factory.
- Good to know: It is possible to provide the steam produced within 1km radius of a pyrolysis plant.
- 50 % of electricity produced is used by the plant itself and the rest is supplied to the grid.

Oil logistics and use at the customer:

- Truck transports the oil 3 times a day to the customer in Borculo. The contract is for 12 years.
- Distance is about 30km.
- The truck is selected for its ability to transport acidic material
- Oil is stored at the customer in 100m^3 tank
- The oil is partly co-fired to produce 40t/h of 20bar steam.

- For the customer it is essential that they are able to switch between natural gas and PO in case there are there is maintenance or production issues
- Both parties are aiming at simultaneous maintenance in order to keep production and delivery smooth. Especially, as EMPYRO does not have a large storage capacity. If the customer is not able to take the oil, they will have to shut down the plant.
- Friesland Campina has achieved above 90% GHG reduction by replacing natural gas with PO. This includes transport of biomass, production of PO and transportation to the client.

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Pyrolysis oil technology and logistics - Final remarks

- EMPYRO was not built specifically near the feedstock, the location was chosen close to location of technology developer.
  - It is important to define the sustainable perimeters for feedstock and IBC transportation.
- Customer engagement to Intermediate Bioenergy Carriers (IBCs): Product pricing need to be competitive to the fossil counter part. Or using a product that is slightly more expensive than fossil counter part should bring value in other ways to the customer, image, carbon credit etc.
- Industry engagement: Legislation or mandates (e.g. REDII) are needed to make industries relying on fossil energy and fuels committing to renewable choices, to bring changes to markets and support market uptake of IBCs.
  - REDII: Mandate for advance biofuels Annex IX. A dedicated target is set for advanced biofuels produced from sustainable feedstocks (listed in Annex IX). The contribution from these advanced biofuels is set to rise from 0.2 % in 2022 to 3.5 % in 2030.

Presentation contributors: Kaisa Vikla, Patrick Reumerman and John Vos from BTG, and Tijs Lammens, Marjolein Stuurman and Mark Richters from BTG-BTL.

Acknowledgements

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References and further reading:

- General information on fast pyrolysis technology:
  - PyroWiki
  - Website of BTG-BTL
  - Venderbosch R.H. Fast Pyrolysis chapter in Thermochemical Processing of Biomass: Conversion into Fuels, Chemicals and Power, Second Edition
  - IEA Task 34 - Direct Thermochemical Liquefaction: website

- Pyrolysis oil properties:
  - Website of BTG-BTL

- Commercial application of fast pyrolysis technology:
  - Fortum CHP plant
  - EMPYRO Plant
  - Ensyn RTP technology

- Future pyrolysis oil producers:
  - Green Fuel Nordic Oy
  - Setra Group/Pyrocell AB

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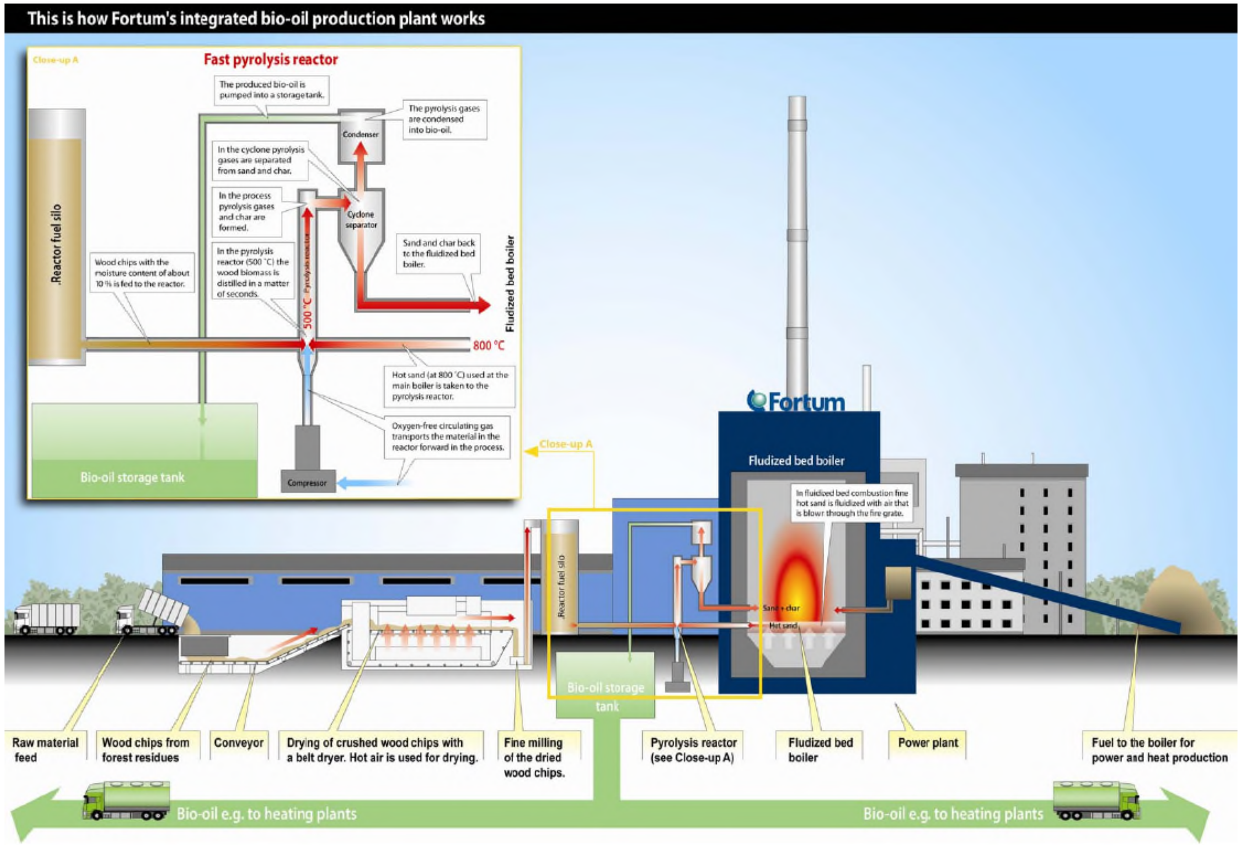
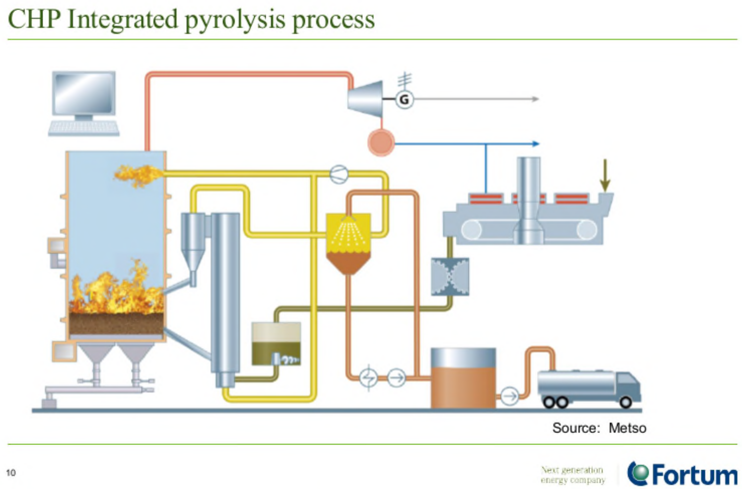
Attachment 1: Fortum process diagram





Source: http://www.etipbioenergy.eu/images/heiskanen.pdf

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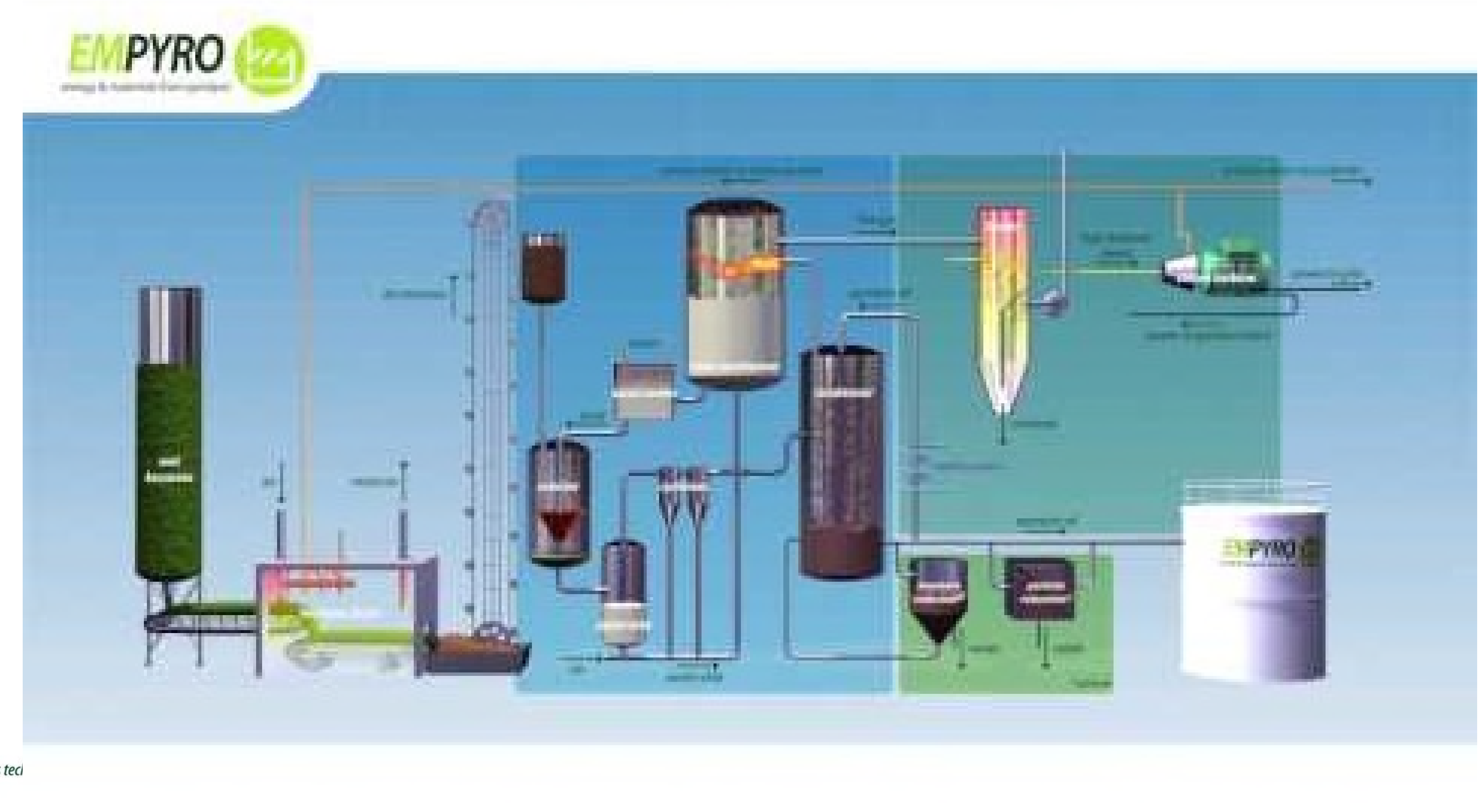
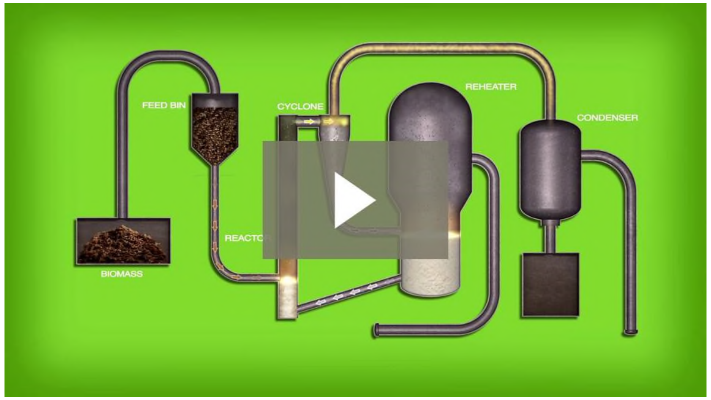
Attachment 2: EMPYRO process diagram



biomass tec

Attachment 3: Ensyn process diagram



RTP Applications - Ensyn - Renewable Fuels and Chemicals from Non-Food Biomass.

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Market Uptake Support for Intermediate Bioenergy Carriers

Microbial oil

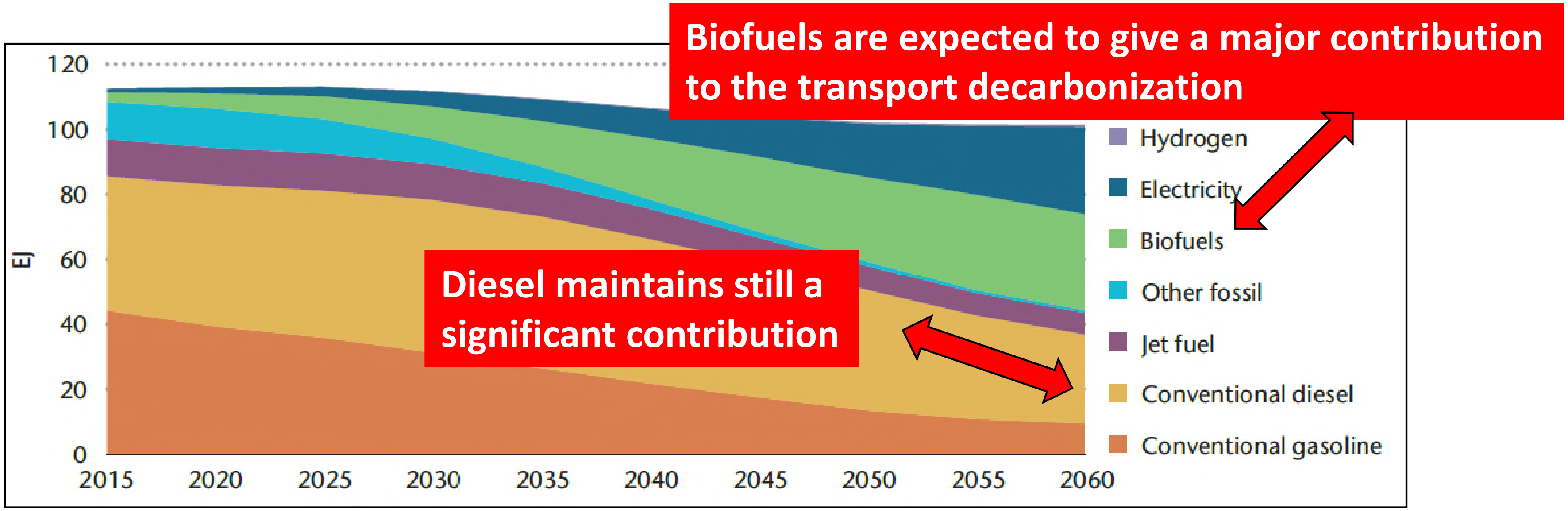
Recent experiences and best-in-class examples

EU H2020 grant no. 857806, 1/9/2019 – 31/8/2022

Content

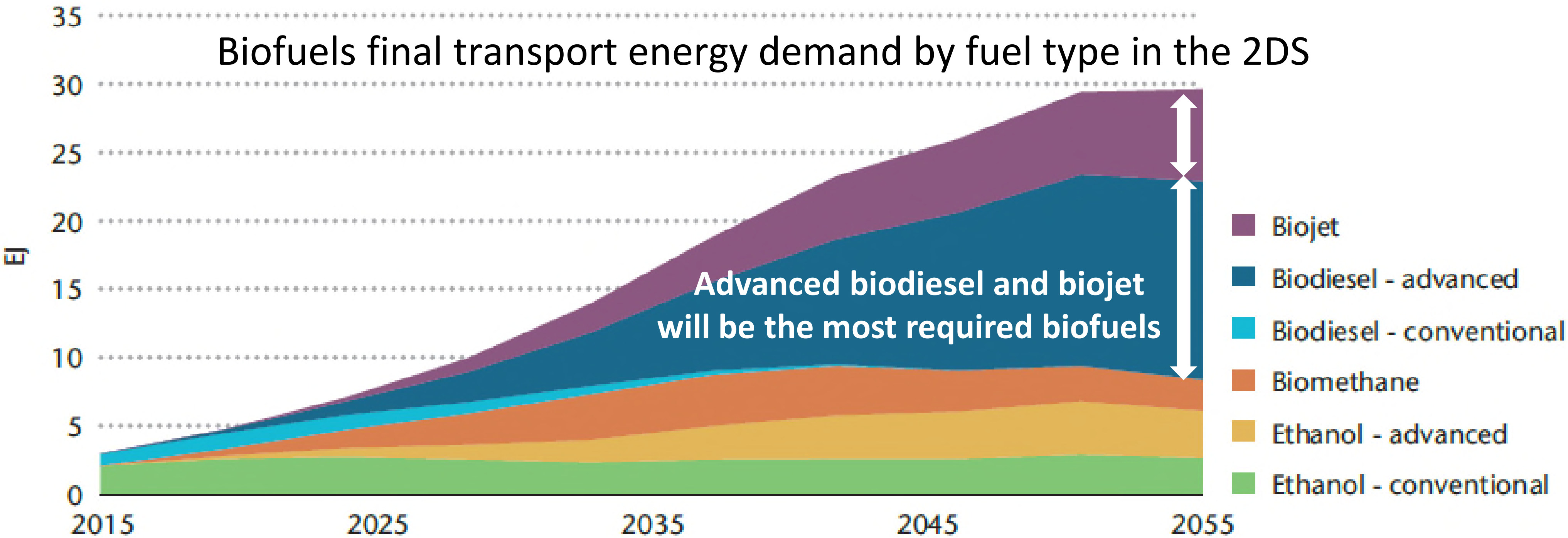
1. Expected biofuels demand by type
2. Biodiesel vs Greendiesel (HVO)
3. Microbial oils from cellulosic sugar
   - biomass saccharification
   - oleaginous yeasts fermentation
   - microbial oil extraction
   - microbial oil characterization
   - HVO processing
4. Status of technology

The fuel evolution requested to meet max 2°C global warming target



- Sharp reduction of fossil fuel consumption (gasoline, diesel and jet fuels) is forseen
- Major expansion in the role of biofuels forseen, reaching nearly **30 EJ in 2060** (**nearly 10 times 2016 levels**), and providing **29% of total transport final energy demand**.
- Sharp growth electricity.

Source: IEA -Technology Roadmap - Delivering Sustainable Bioenergy Report 2017



Biodiesel conventional = **crop-based** FAME biodiesel;
Biodiesel advanced = **residue-based** diesel biofuels (eg HVO, BtL)

The pattern of biofuel production also changes to meet the target, with growth concentrated on biofuels that have better overall GHG performance (diesel), and which have properties suitable for use in sectors where demand for liquid fuels will be concentrated (biojet).

Source: IEA -Technology Roadmap - Delivering Sustainable Bioenergy Report 2017

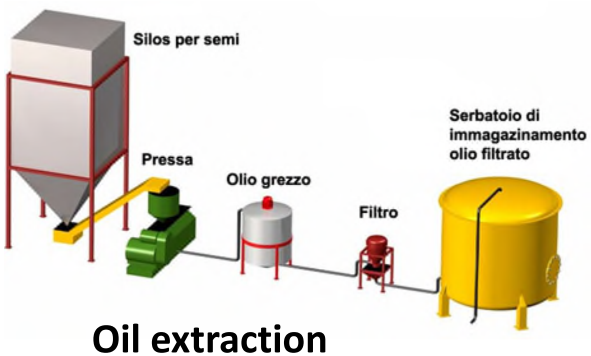
The biofuels policy (Europe)

2020 TARGETS (RED/ILUC Directive)	2030 TARGETS (RED II Directive)
20% Global renewable energy target	**32%** Global renewable energy target
10% Transport renewable energy target	**14%** Transport renewable energy target
0.5% sub-target on non-crop based “advanced” biofuels	**3.5%** sub-target on non-crop based “advanced” biofuels
7% Cap on food-based biofuels	Gradual decrease to **0% of HIGH-ILUC** food-based biofuels Certification required for **LOW-ILUC** food-based biofuels
60% GHG emission reduction from 2015	**70%** GHG emission reduction from 2021

In Europe the challenge is to produce advanced diesel biofuels starting from LOW ILUC raw material

Oleaginous crops

Biodiesel (FAME) process

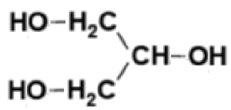


Oil extraction

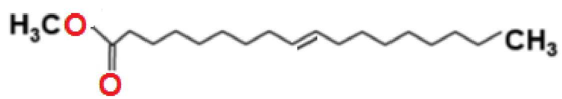
MeOH + cat (MeONa)

Transesterification

Purification

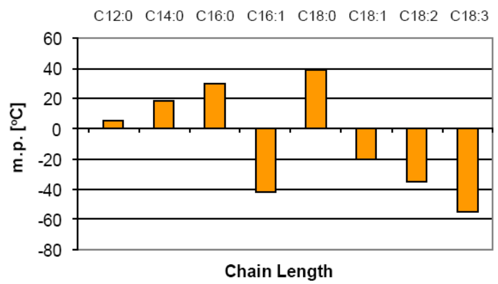


Glycerol



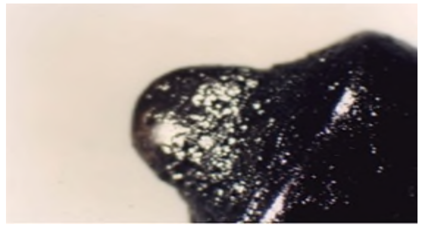
Fatty Acid Methyl Ester (FAME)

Conventional biodiesel drawbacks



- Poor oxidative stability due to the olefinic double bonds
- Poor cold weather properties (can gel)
- Solvent properties → degradation of rubber and elastomers
- It is biodegradable (i.e. can cause biofouling)

- Lower Heating Value than diesel (38 vs 43 MJ/kg)
- NOx emission is higher than that of conventional diesel
- Suffers for formation of deposits at injector tips

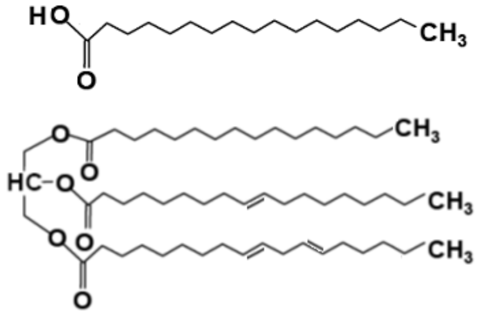


- **Cap at 7% (volume, corresponding to 6,3% on energy base) for blending with conventional diesel**

- **An improved fuel is required to meet the 10% (14%) target**

Hydrogenated Vegetable Oils (HVO)

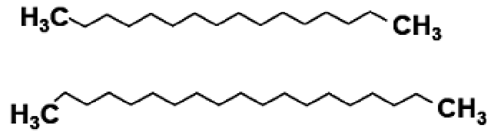
Triglicerides/ fatty acids



H_2

Hydro-deoxygenation

C14-C20 linear paraffins



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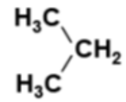
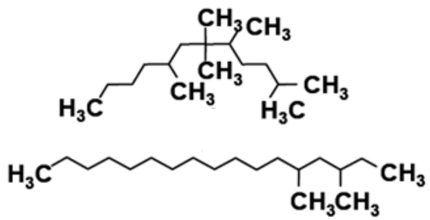


Green LPG

H_2

Hydro-isomerization

Distillation



C14-C20 iso-paraffins

Several companies have developed HVO technologies: **Neste Oil, BP, PetroBras, Syntroleum, ConocoPhilipps, Haldor Topsoe, Nippon Oil, Axens and eni/UOP**.

Neste Oil is the market leader with a total production capacity of 2 Mt/year

Oxygen-free product, equivalent to fossil diesel

Green diesel

or Green Jet

MUSIC

Conversion of a fossil refinery into a bio-refinery ➔ environmental and technological but also economic and social significance. It allows us to give new life to the plant and guarantees employment through innovation.

Eni Green Refinery projects: Ecofining Technology

- The facility is **on stream since April 2014** with a green diesel production capacity of **360 kt/year.**
- The final configuration target will be **560 kt/year**.

eni uop A Honeywell Company

- The conversion of Eni Gela refinery into an Ecofining based green refinery was **completed and operated form late 2019,** with a production capacity up to **670 kt/year.**

green 15% eni diesel+

15% renewable component

Available in over 3,500 fuel stations all over Italy from January 2016

RE·CORD

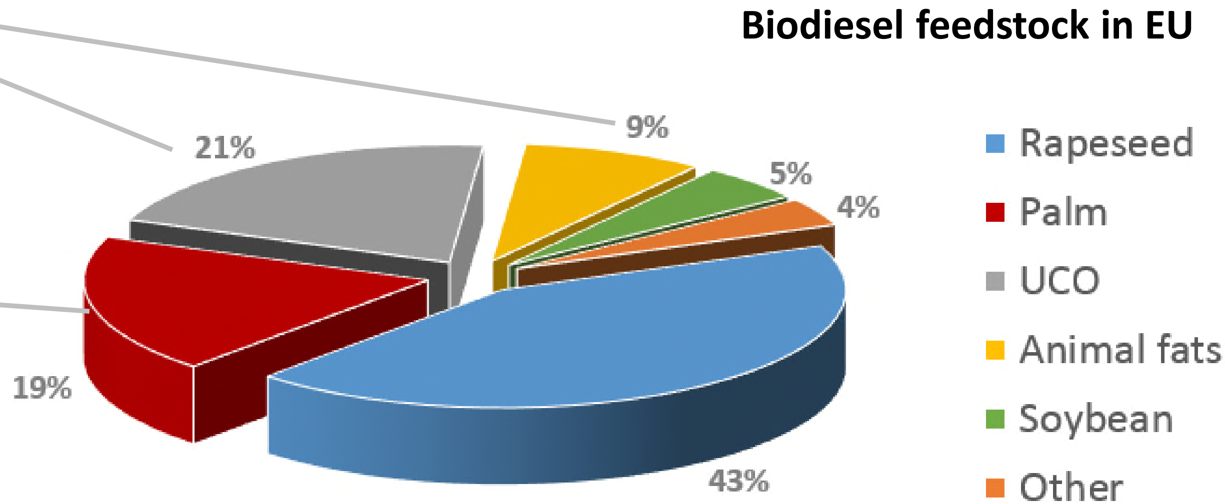
Biodiesel fuels feedstock

- At present, the main feedstocks for the production of biodiesel on the European market are **virgin vegetable oils:**

Used cooking oil and animal fats
- Limited availability (imported from Asia)

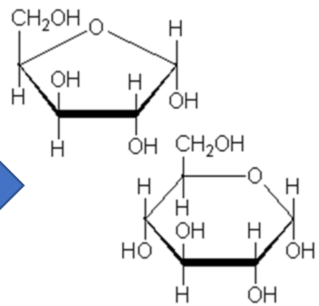
Palm oil
- Most abundant
- Lower cost
- Best feed for HVO (lower H_2 consumption)
- Competition with food
- Competition with rain forest

Phased out for fuel application by 2030



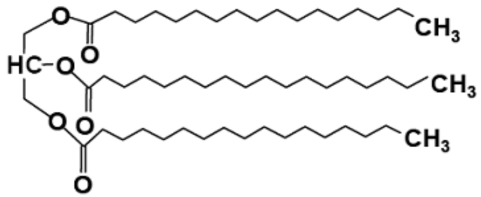
Microbial oils from lignocellulosic biomass

Agricultural wastes – energy crops



C5 and C6 sugars

Oleaginous Yeasts



Microbial oil

(triglycerides)

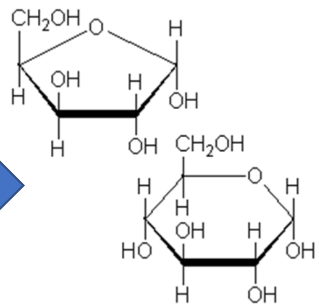
HVO Diesel

- Waste oils and animal fats, suffer from limited availability, compared to the size of the transportation fuels market.
- Lignocellulosic biomass are the most abundant renewable feedstock on the planet
- It is a complex transformation

RE·CORD

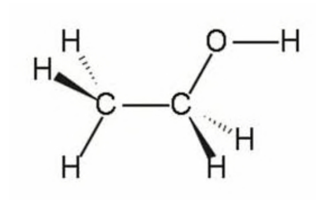
Ethanol from lignocellulosic biomass

Agricultural wastes – energy crops



C5 and C6 sugars

Yeasts



Cellulosic ethanol

- The current commercial process that converts sugars to biofuels, is the 2° Gen Ethanol pathway.
- Several companies across the world are using this technology from several years.

- The MUSIC concept for Microbial Oil biorefinery started from cellulosic ethanol production.
- From 2010 to 2013, Biochemtex (Mossi & Ghisolfi group) built a significant industrial scale plant (20,000 tonsEtOH/y) of innovative 2nd generation ethanol technology.
- EU FP7 BIOLYFE funded part of the plant (as reported in the other PPT “Country: Italy”).
- The plant was operated in 2013 but in 2018, after the financial failure of M&G group, the plant has been the acquired by ENI VERSALIS (ENI chemical branch).
- The concept of sugars production-to-oleaginous yeast is very similar to 2° Gen Ethanol production:

BIOMASS

Just minor hardware modifications in the last tanks «the fermenters» in terms of volumes and biological conversion times

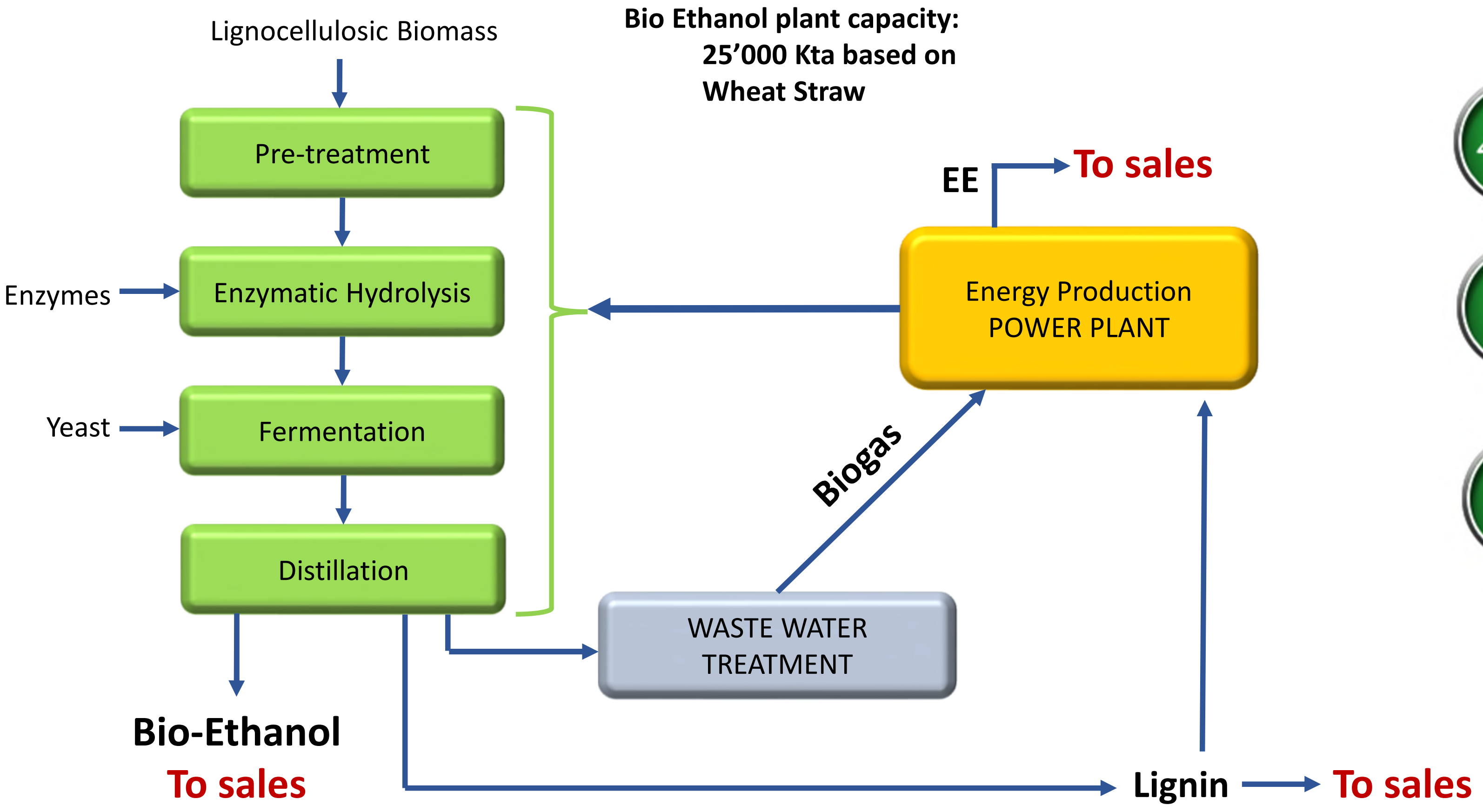
Microbial oil

GREEN DIESEL

- **Commercial plant for 2G sugars and Bio-ethanol production plants from biomasses** whit Proesa® technology
- Bio-ethanol classified as «Advanced Biofuel» by EU legislation
- Biomass avarage use about 200 kta/y
- **Biomass Thermoelectric power station serving the bio-ethanol plant,** fed with lignin *(co-product of the production process)*
- **Bio-gas production plant**

RE-CORD

MUSIC



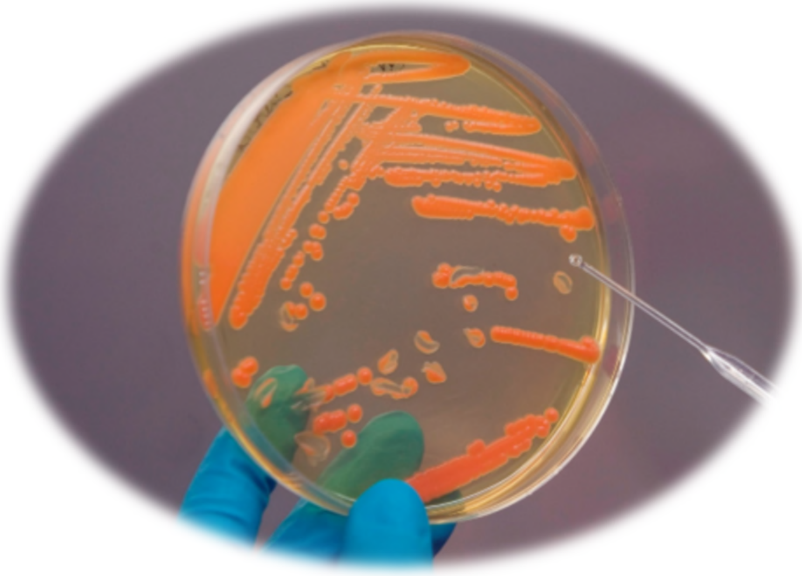
Biomass feedstocks flexibility from hardwood to softwood

Continuous process
No chemicals addition
Optimal sugar extraction with low enzymes dosage

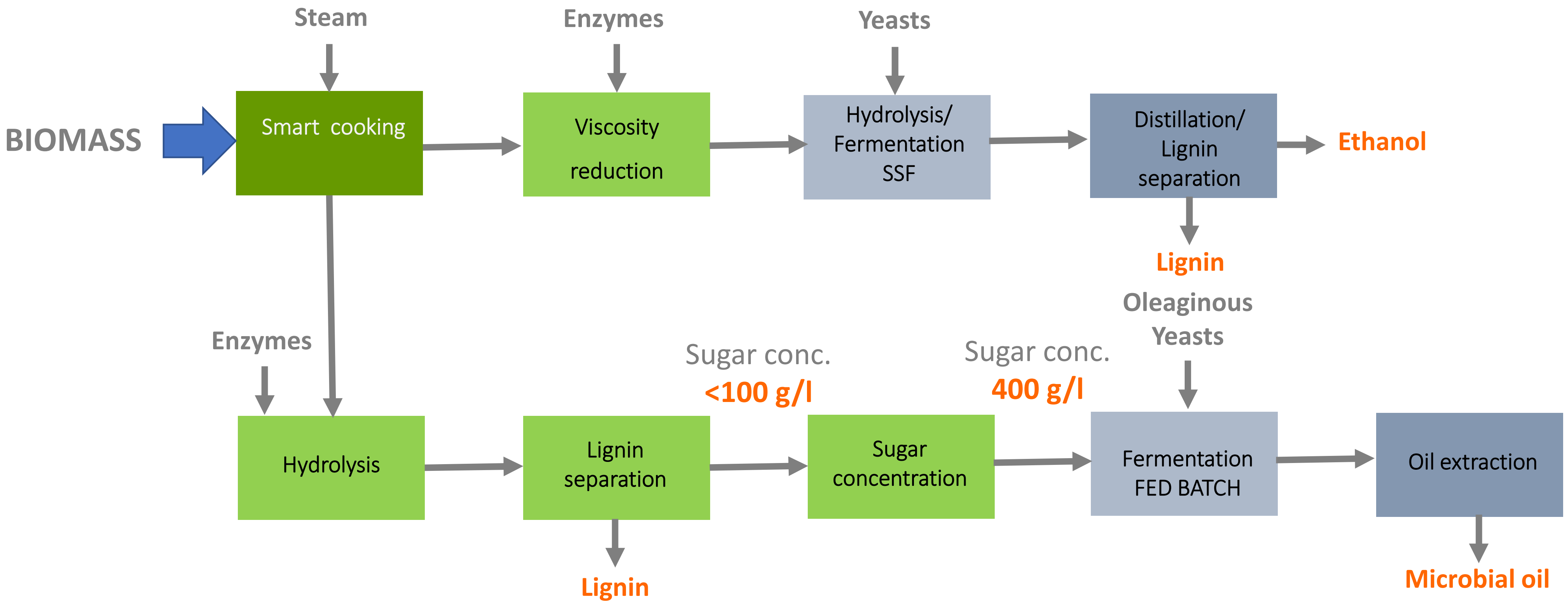
Fully integrated continuous process
for large scale production plants, with total water recycle, self electric energy production and bio methane export

RE-CORD

How **Microbial Oil** production is implemented in these technologies?

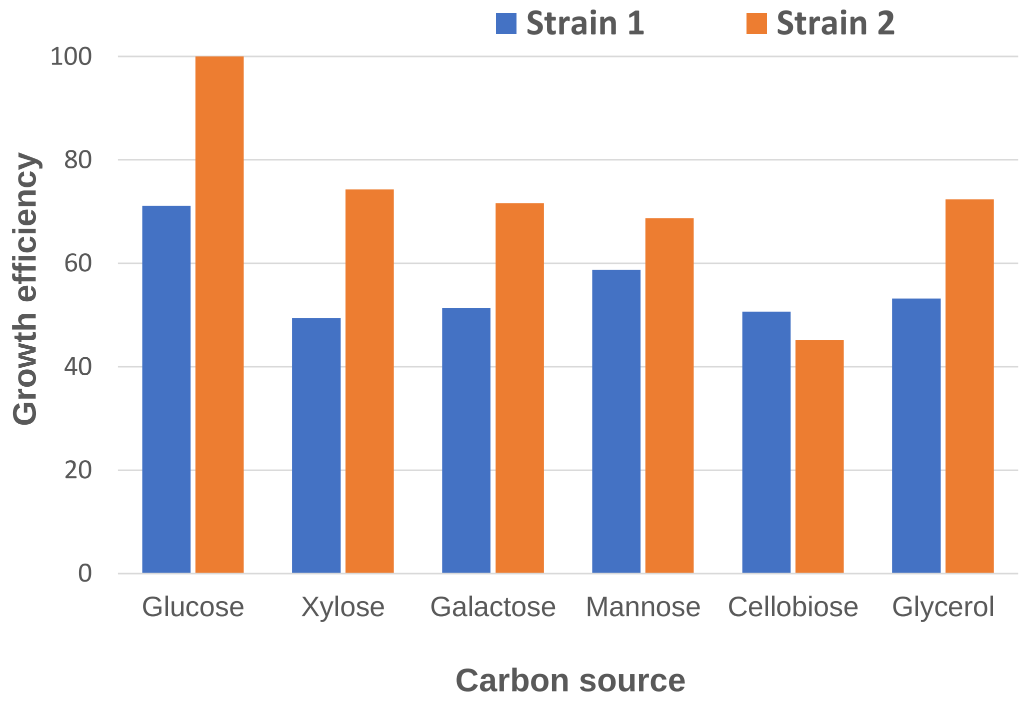


Microbial oil production in detail: Step 1 - biomass saccharification



- Oleaginous yeasts need different sugars feeding methods than ethanol yeasts to start the conversion process

Step 2: oleaginous yeasts fermentation



Flask cultivation tests
Carbon source: 50 g/l
Nitrogen source: NH_4SO_4
C/N ratio: 75

Oleaginous yeasts can grow on a wide range of sugars

Step 2: oleaginous yeasts fermentation

Fed-batch cultivation

Start-up

Volume: 6 l

Sugar: 50 g/l

Nitrogen source: (NH_4SO_4): 5 g/l

C/N ratio: 33

Feed

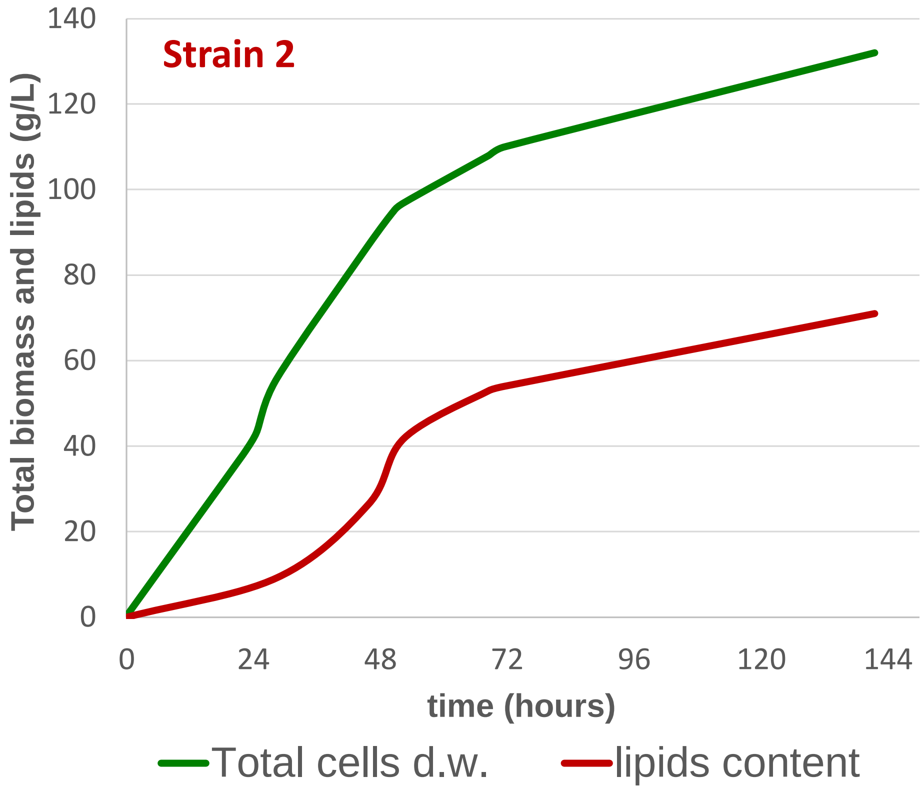
Fed volume: 12 l

Sugar: 400 g/l

Nitrogen source: (NH_4SO_4): 2.5 g/l

C/N ratio: 520

Lipid production (**lipogenic phase**) is activate under **nitrogen limitation**, but with a large amount of carbon source still present in the medium.
Thus, **low nutrients** to grow oleaginous yeasts are required!



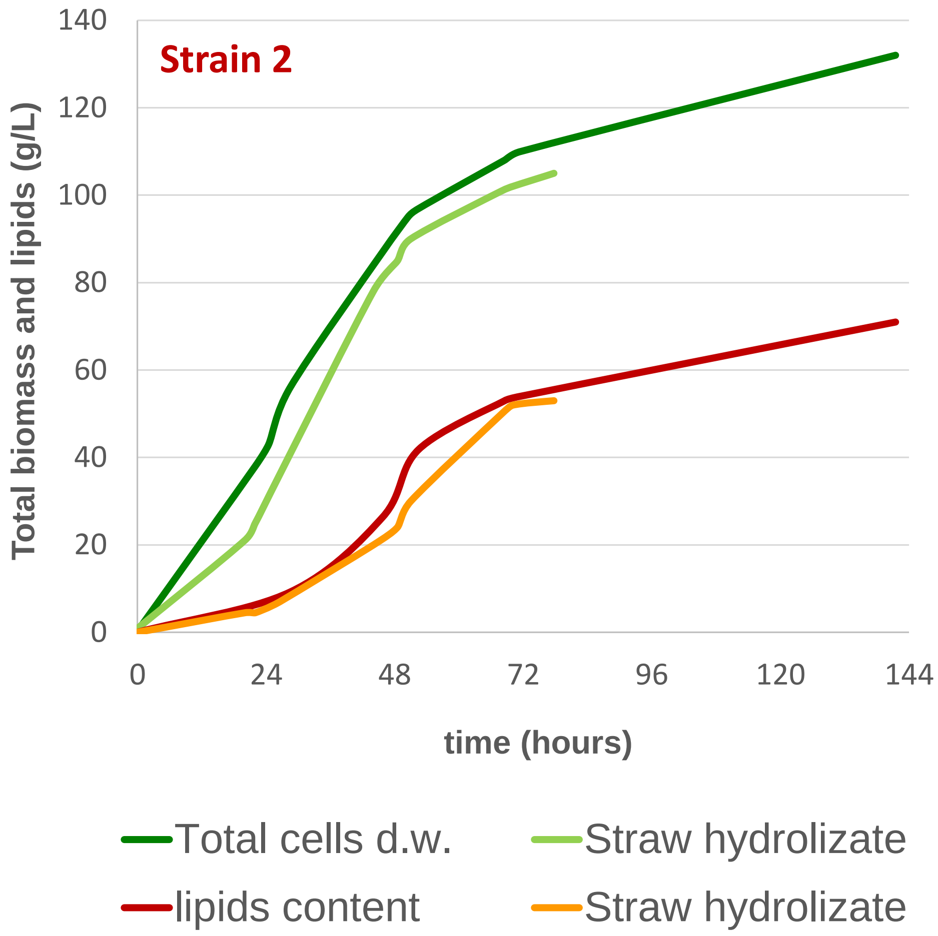
Carbon source: glucose

Step 2: oleaginous yeasts fermentation

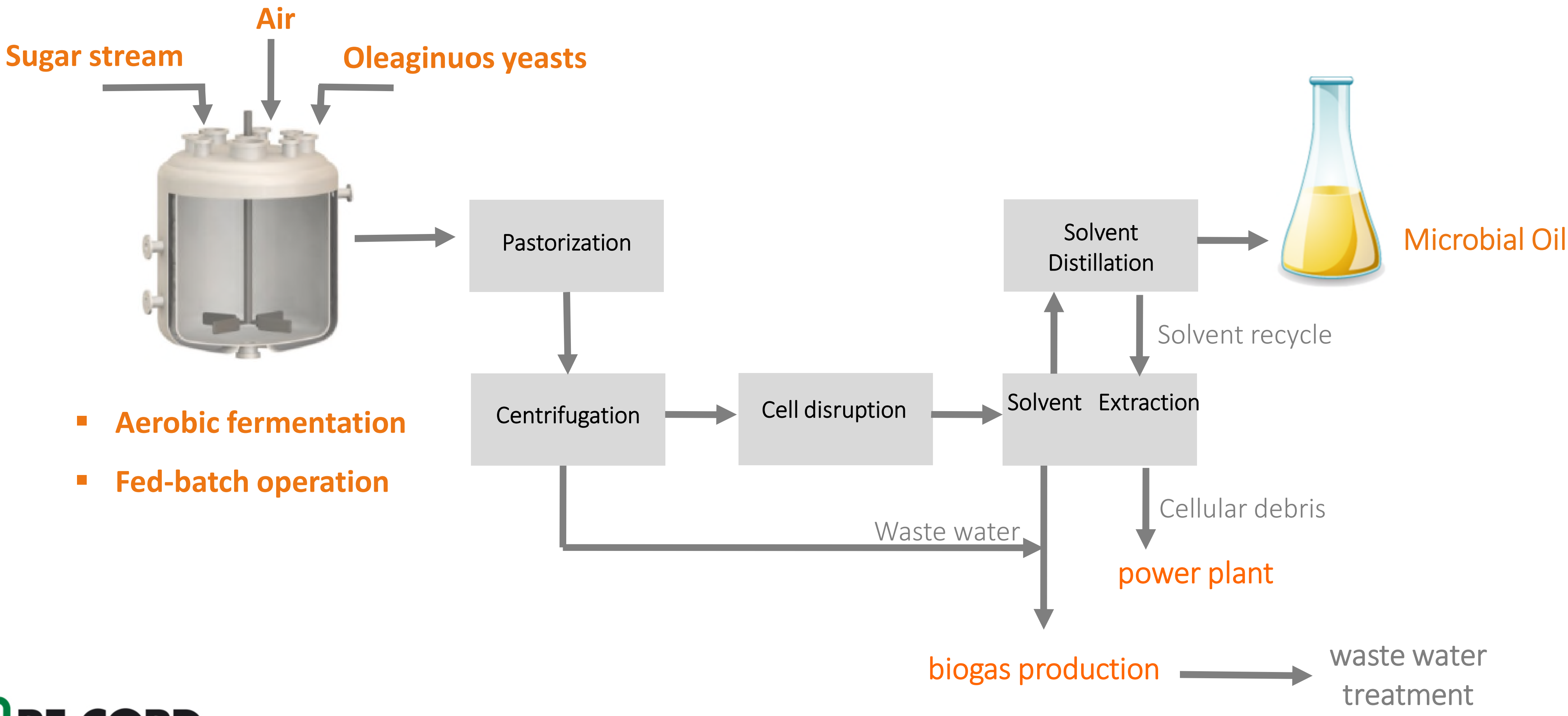
Fed-batch cultivation

Start-up
Volume: 6 l
Sugar: 50 g/l
Nitrogen source: (NH_4SO_4): 5 g/l
C/N ratio: 33
Feed
Fed volume: 12 l
Sugar: 400 g/l
Nitrogen source: (NH_4SO_4): 2.5 g/l
C/N ratio: 520

Lipid production (**lipogenic phase**) is activate under **nitrogen limitation**, but with a large amount of carbon source still present in the medium.



The microbial oil process



- **Aerobic fermentation**
- **Fed-batch operation**

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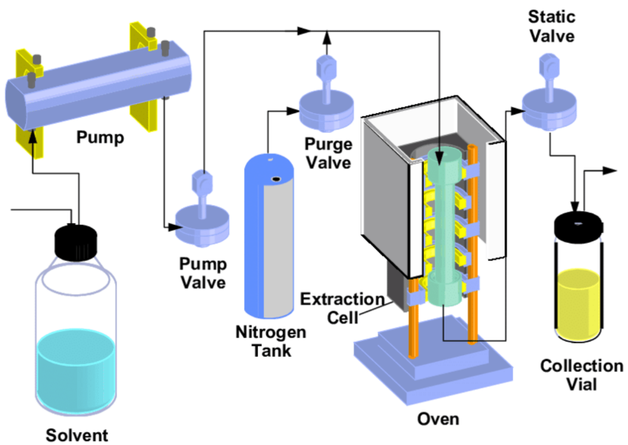
Microbial oil extraction

Cell density **100 g/l** → **Centrifugation** → Cell density **270 g/l** → **Cell disruption**

- Mechanical method (omogenizer)
- Phisical method (steam explosion)
- Thermal treatment



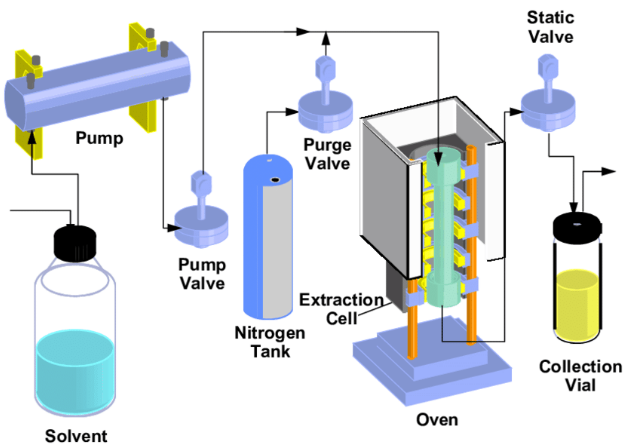
- Reference method: Accelerated Solvent Extraction (ASE) on dry cells; solvent: hexane/*iso*PrOH 3/2, 2 cycles; 120°C, 5 min

RE·CORD

Microbial oil extraction

→ **Cell disruption** → **Solvent extraction**

- Hexane/*iso*PrOH 3:2
- *iso*-octane/EtOH 9:1
- AcOEt
- ETBE
- MIBK
- Xylene
- *iso*-octane



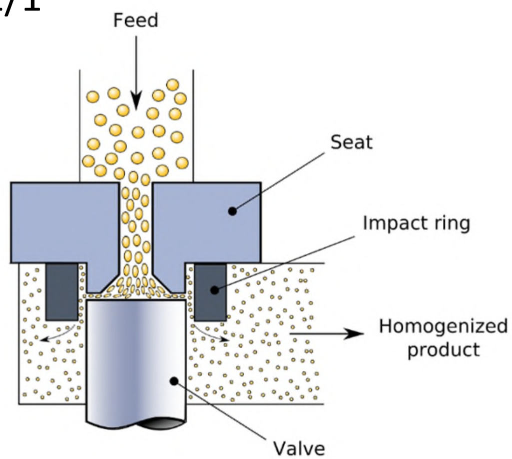
- Reference method: Accelerated Solvent Extraction (ASE) on dry cells; solvent: hexane/*iso*PrOH 3/2, 2 cycles; 120°C, 5 min

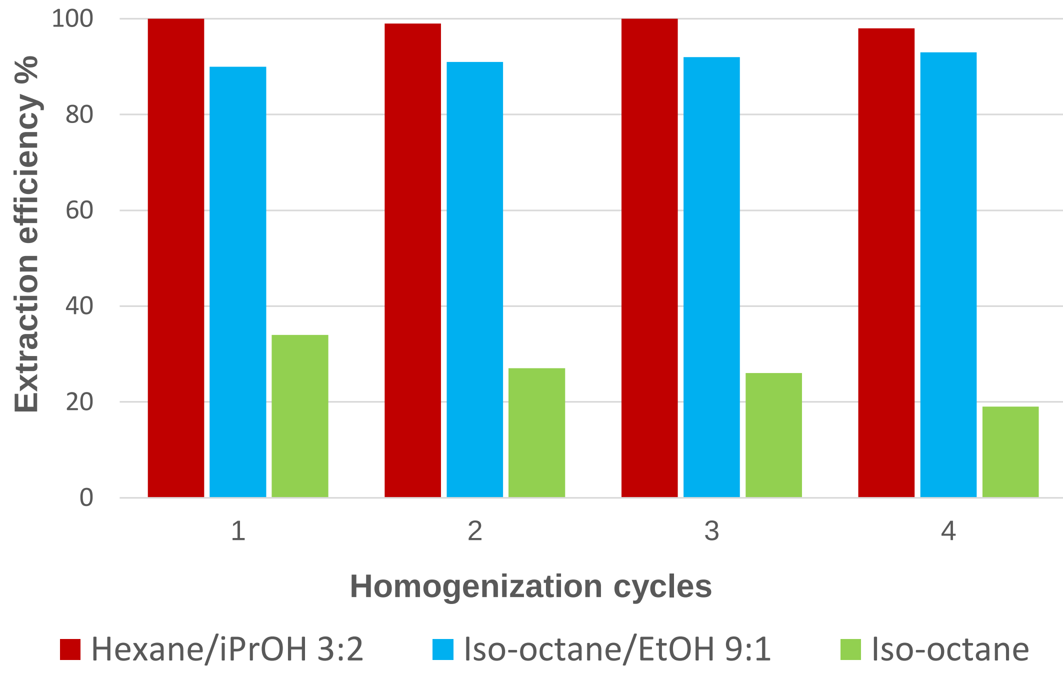
Microbial oil extraction

High pressure homogenization

Cell density: 270 g/l
Operating pressure: 1200 bar
Consecutive cycles

Solvent extraction:
two consecutive batches
Solvent/cell slurry: 1/1





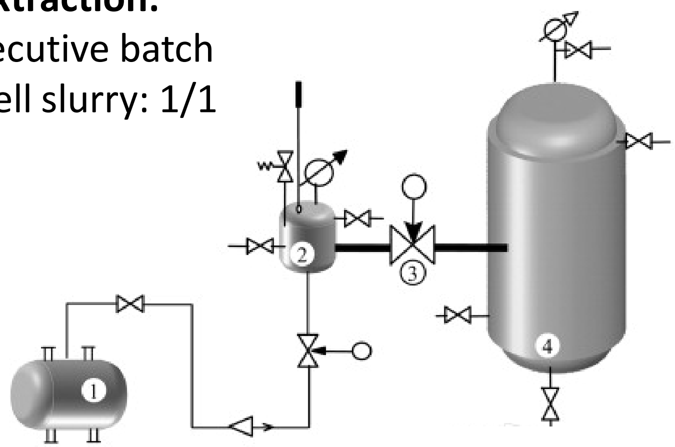
Method suitable only for polar solvents

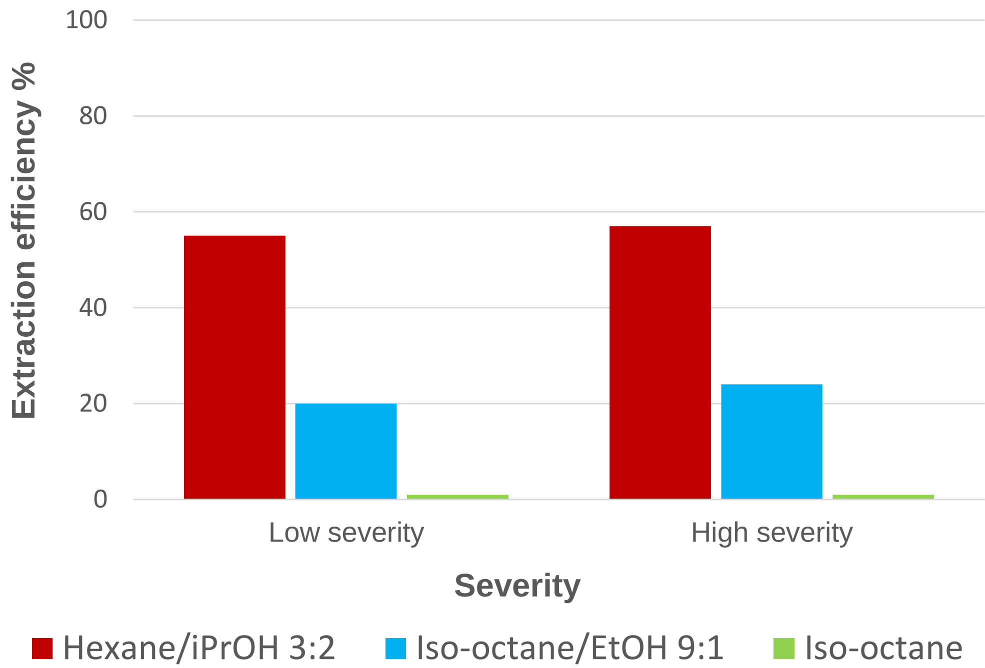
Microbial oil extraction

Steam explosion

Cell density: 270 g/l
Low severtity: 10 bar, 177 °C
High severity: 15 bar, 195 °C
Time: 10 min

Solvent extraction:
two consecutive batch
Solvent/cell slurry: 1/1





Method not suitable for yeast cell extraction

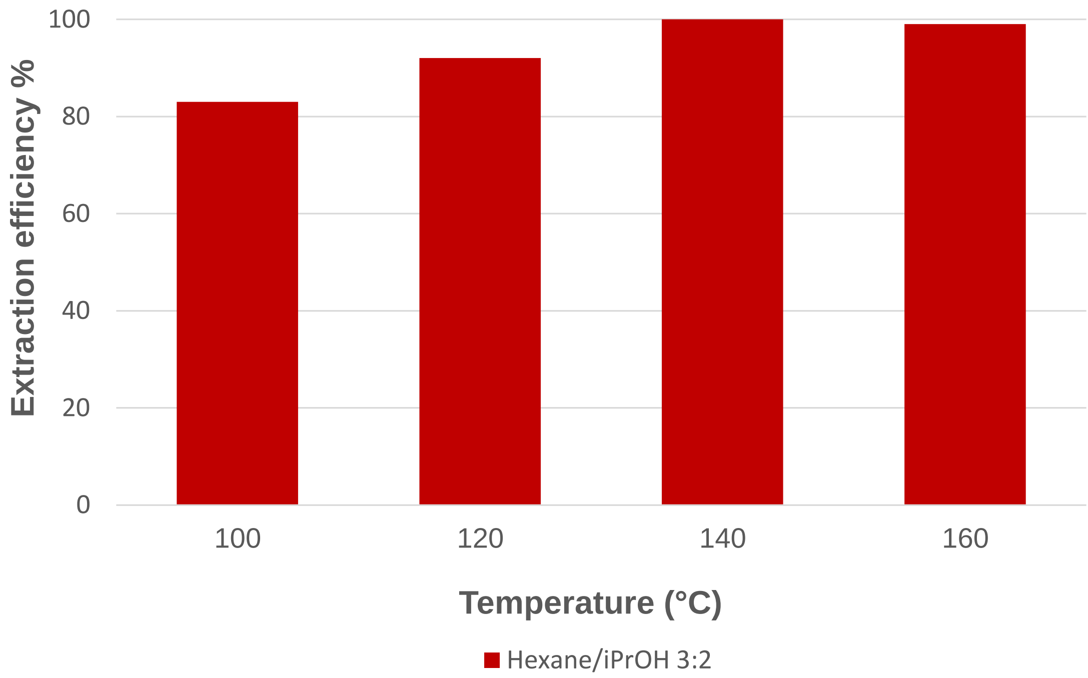
Microbial oil extraction

Thermal treatment

Cell density: 270 g/l
Temperature range: 100-160°C
Perrssure range: 1-6 bar
Time: 2 hrs

Solvent extraction:
two consecutive batch
Solvent/cell slurry: 1/1

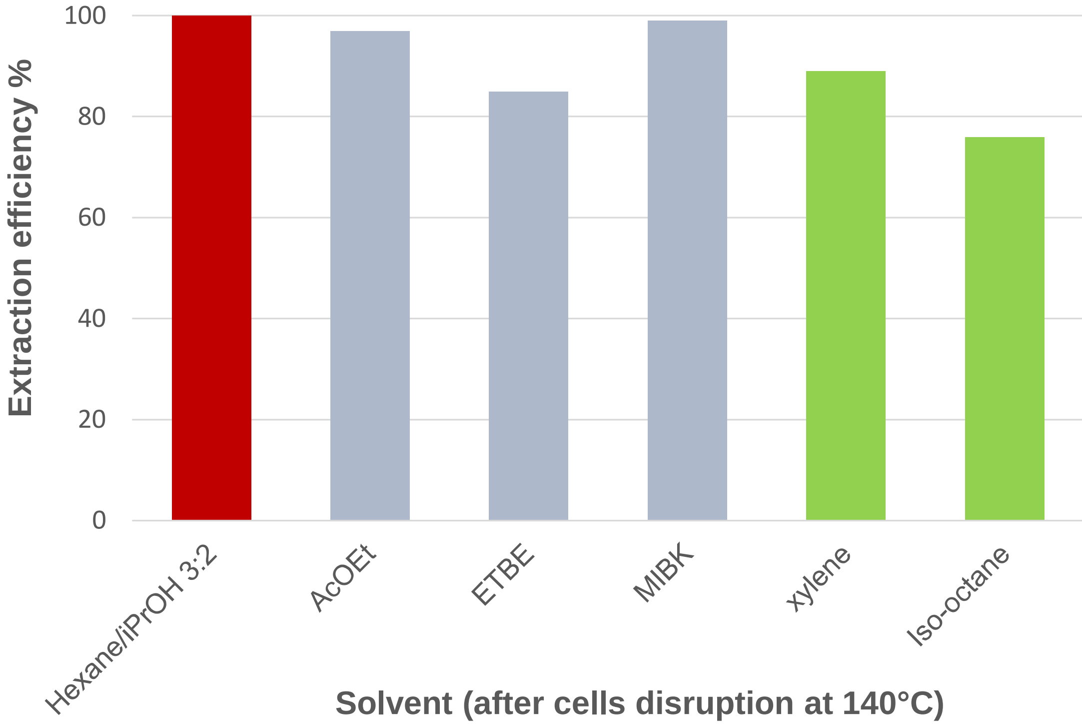
Stirred pressure vessel



High extraction efficiency starting from 140°C

Microbial oil extraction: solvent selection

Solvent extraction:
two consecutive batch
Solvent/cell slurry: 1/1



Method suitable for both polar and apolar solvents

MUSIC

Microbial oil extraction: solvent selection

Solvent extraction:
two consecutive batch
Solvent/cell slurry: 1/1

RE·CORD

Heteroatoms content in extracted microbial oil

	Hexane/ iPrOH 3:2	AcOEt	ETBE	MIBK	Xylene	Iso-octane
Extraction efficiency	100	97	85	99	89	76
N (ppm)	1207	1478	604	1183	695	426
S (ppm)	100					70
P (ppm)	20					10

High heteroatoms content

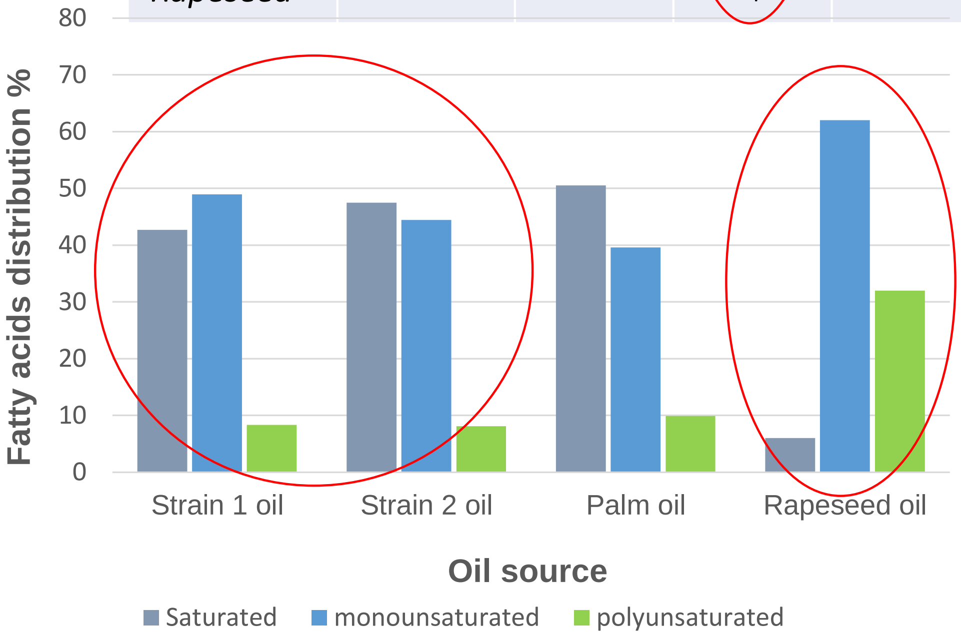
Low heteroatoms content

Heteroatoms can deactivate the catalysts used in HVO processes

MUSIC

Microbial oil charachterization

Oil source	Oil content (%w/w)	C_{14}	C_{16}	$C_{16:1}$	C_{18}	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Strain 1	60	Tracce	37	1	3	47	8	-
Strain 2	72	Tracce	32	-	15	44	8	-
Palm	-	1	45	1	4	40	10	-
Rapeseed	-	-	4	-	2	62	22	10



Low unsaturated fatty acids content

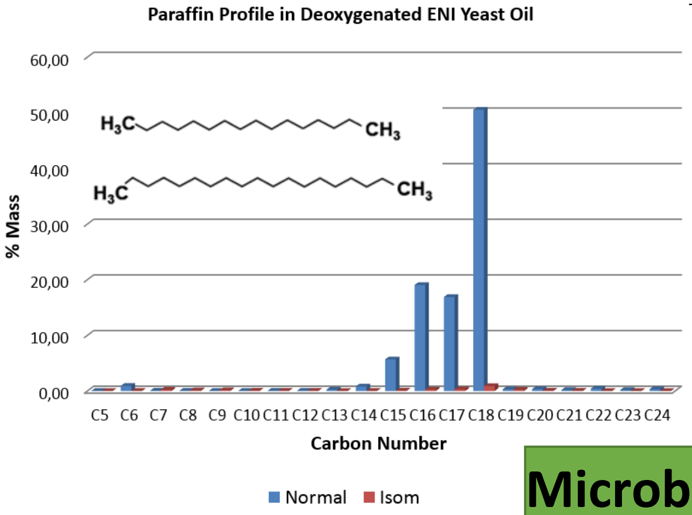
Suitable for HVO diesel production

High unsaturated fatty acids content

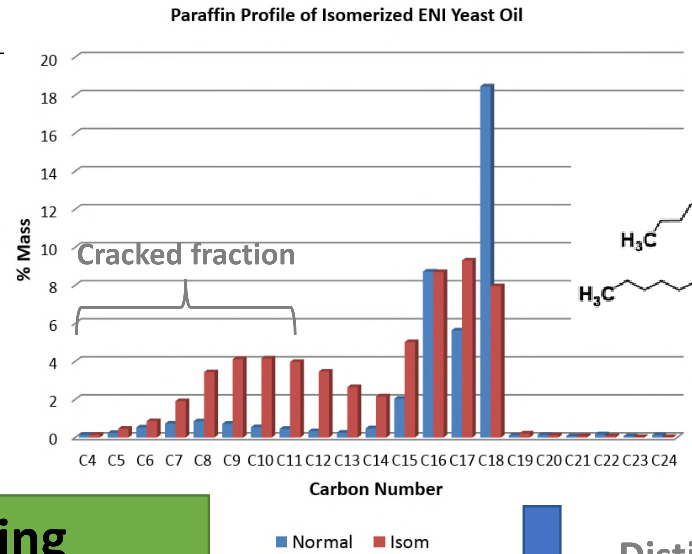
Suitable for biodiesel (FAME) production

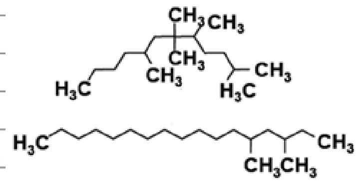
RE·CORD

Microbial oil processing (Ecofining HVO technology)

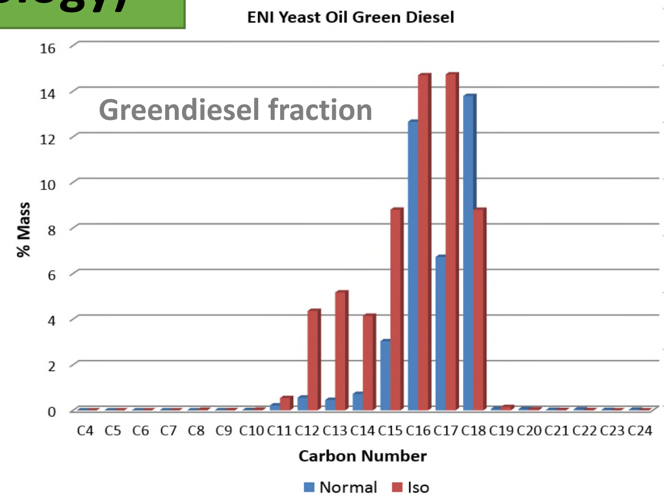


Isomerization





Distillation



HDO

Microbial oil

Microbial Oil technology potential – in brief

- Today the MO technology has a commercial level for both upstream and downstream process, and it has been validated at pilot scale.
  - The technology for upstream processing to sugar production to oleagionous yeast fermentation belongs to ENI VERSALIS (ENI chemical branch).
  - The technology for downstream processing to green diesel production from MO belongs to ENI.
- Expected CAPEX are 120 -150 M€ for a size of 200,000 biomass dry t/y IN (for 25 EtOH t/y) as Crescentino' site (source: https://ricerca.repubblica.it/repubblica/archivio/repubblica/2012/10/16/bioetanolo-carburante-made-in-crescentino.html https://www.liberoquotidiano.it/news/sostenibilita/1327418/a-crescentino-la-bioraffineria-da-75-milioni-di-litri-di-bioetanolo-l-anno.html)
- From Abengoa Hugoton plant in USA, a 2G ethanol capacity of 75 kton per year requires a CAPEX of 440 M$ (source: https://onlinelibrary.wiley.com/doi/full/10.1002/bbb.1663)
- Source of biomass for IBC are provided in the PPT Region: Italy

Final remarks

- In the middle between the two major advanced biofuels commercial technologies (2G EtOH & HVO), MO production has a very large potential.
- Due to REDII targets for palm oil phase out by 2030, MO production is taking a growing interest.
- Scaling up a biological process already commercial for similar scopes is very easy and quick.
- Short chain biorefinery feeded by lignocellulosic biomass instead of vegetable oils from distant origins can favor a local bioeconomy promotion.

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