MUSIC:
THE ITALIAN STRATEGIC CASE STUDY

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OUTLINE

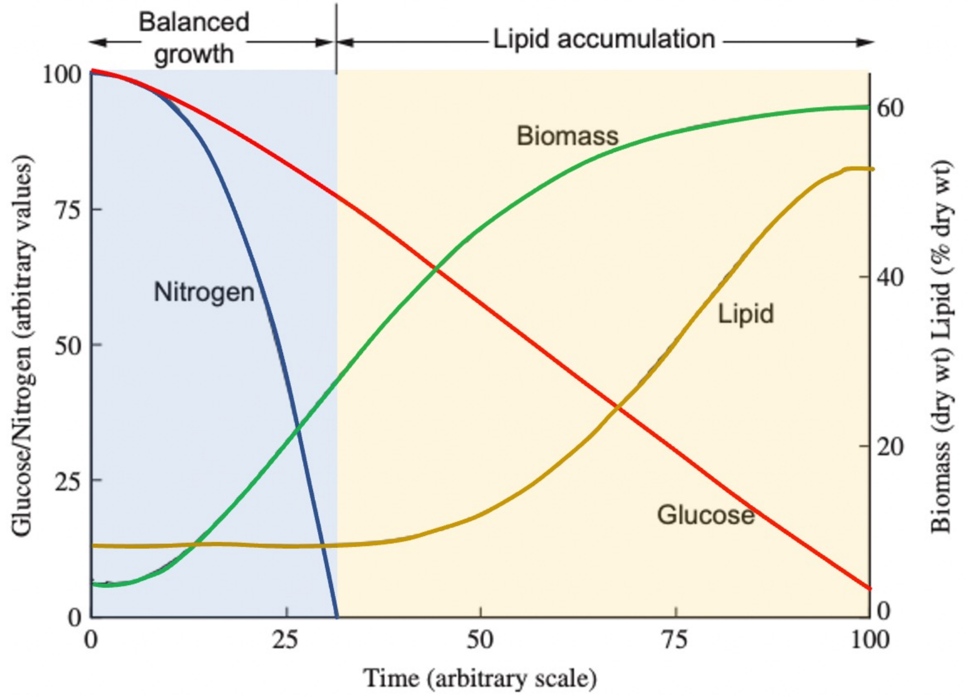
- Microbial Oil: properties, production, markets
- CS: General Info & high-level description
- IBC plant model
- Biomass Availability and Logistics
- Optimal IBC plants location
- Results
- Conclusions

OLEAGINOUS MICROORGANISMS

- **Archaea, bacteria, yeast, fungi,** and **microalgae** can produce a significant amount of lipids, mainly in the form of **triacylglycerides** (TAGs) and **fatty acids** (FAs).
- The **FA profile of microbial oil** is similar to that of vegetable oils (i.e. soybean, sunflower, palm oils, …)
- **Genetic engineering** is used to enhance microorganisms in terms of lipid accumulation, resistance to inhibitors and FA composition.
- **Yeasts** can accumulate oil contents ranging between **58% to 72%** of cell dry weight.

BASICS OF LIPIDS ACCUMULATION

- A two-phase process:
  - **Balanced growth:** all nutrients available, cell multiplication ongoing
  - **Lipids accumulation:** depletion of the growth-limiting nutrient (i.e. Nitrogen) → stop of cells multiplication
- Several metabolic pathways available, with **different theoretical yields**, i.e.:
  - **TAG:** 25g to 35g from 100g of glucose
  - **FA:** similar to TAG
  - **Farnesene:** 25g to 29g from 100g of glucose



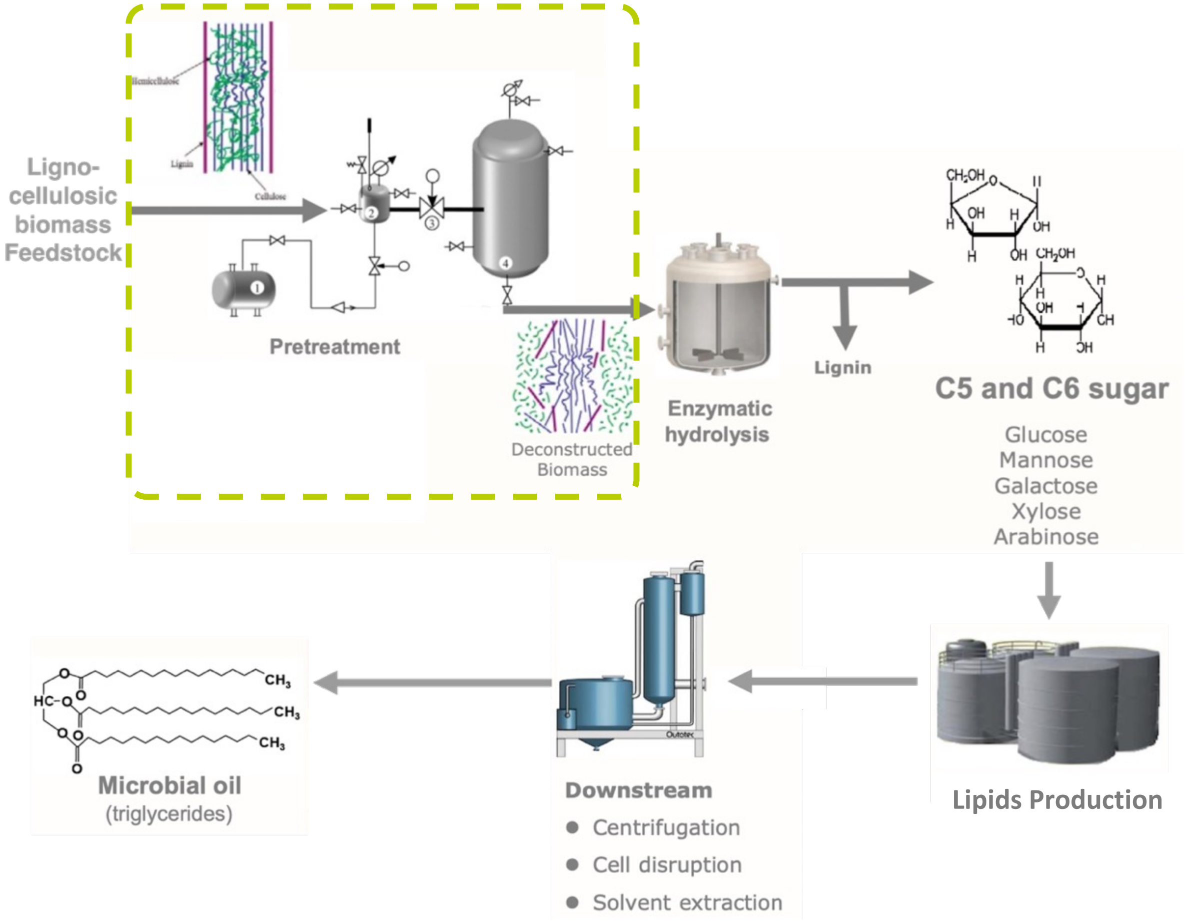
Ethanol yields are around 50g from 100g of glucose

M.O. PRODUCTION PROCESS

Focusing on a **lignocellulosic feedstock**, 4 different steps:

1. **L-C biomass pre-treatment:**

objective is to break the lignocellulosic matrix into cellouloses, hemicelluloses and lignin

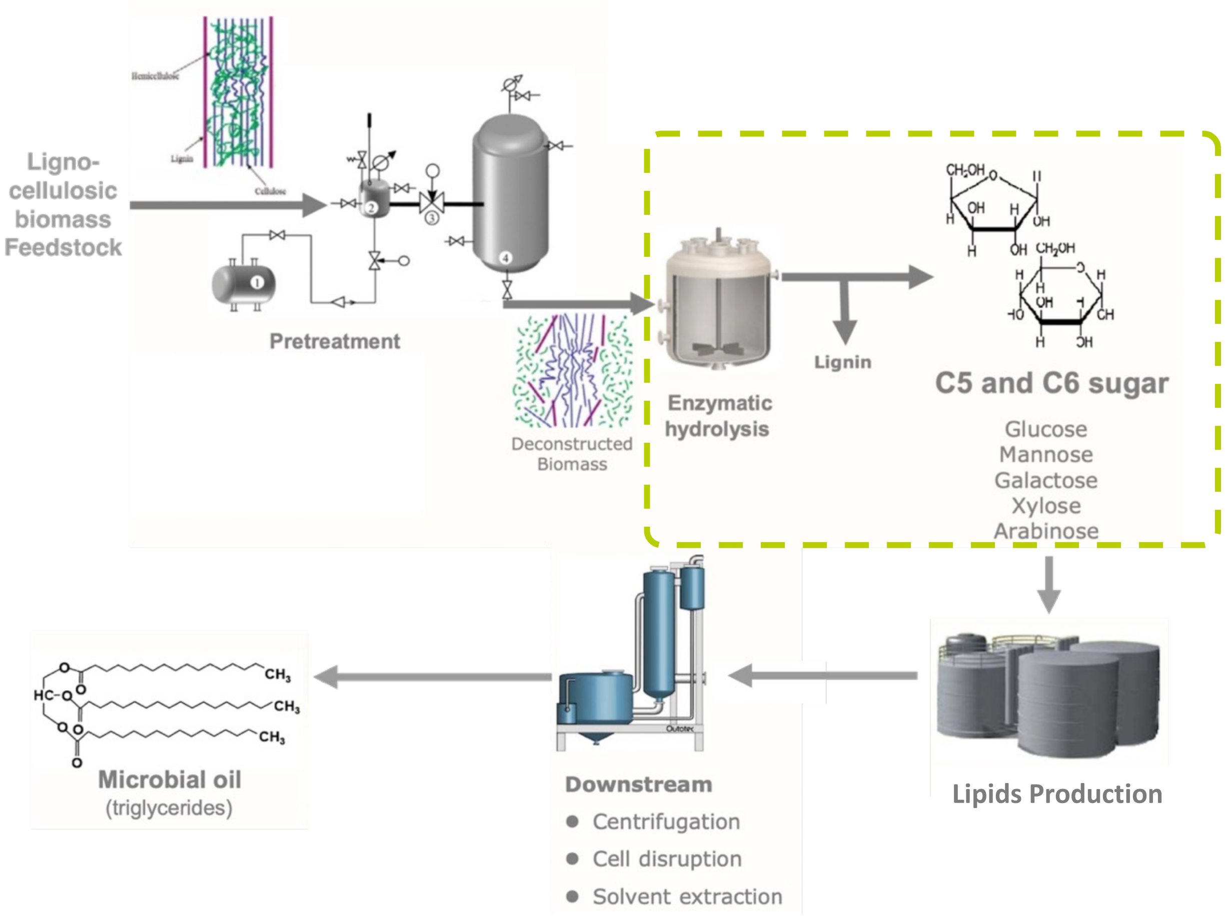


M.O. PRODUCTION PROCESS

Focusing on a **lignocellulosic feedstock**, 4 different steps:

2. **Hydrolysis of structural carbohydrates to sugars:**

objective is to produce sugar monomers (e.g. glucose and xylose) from cellulose and hemicellulose

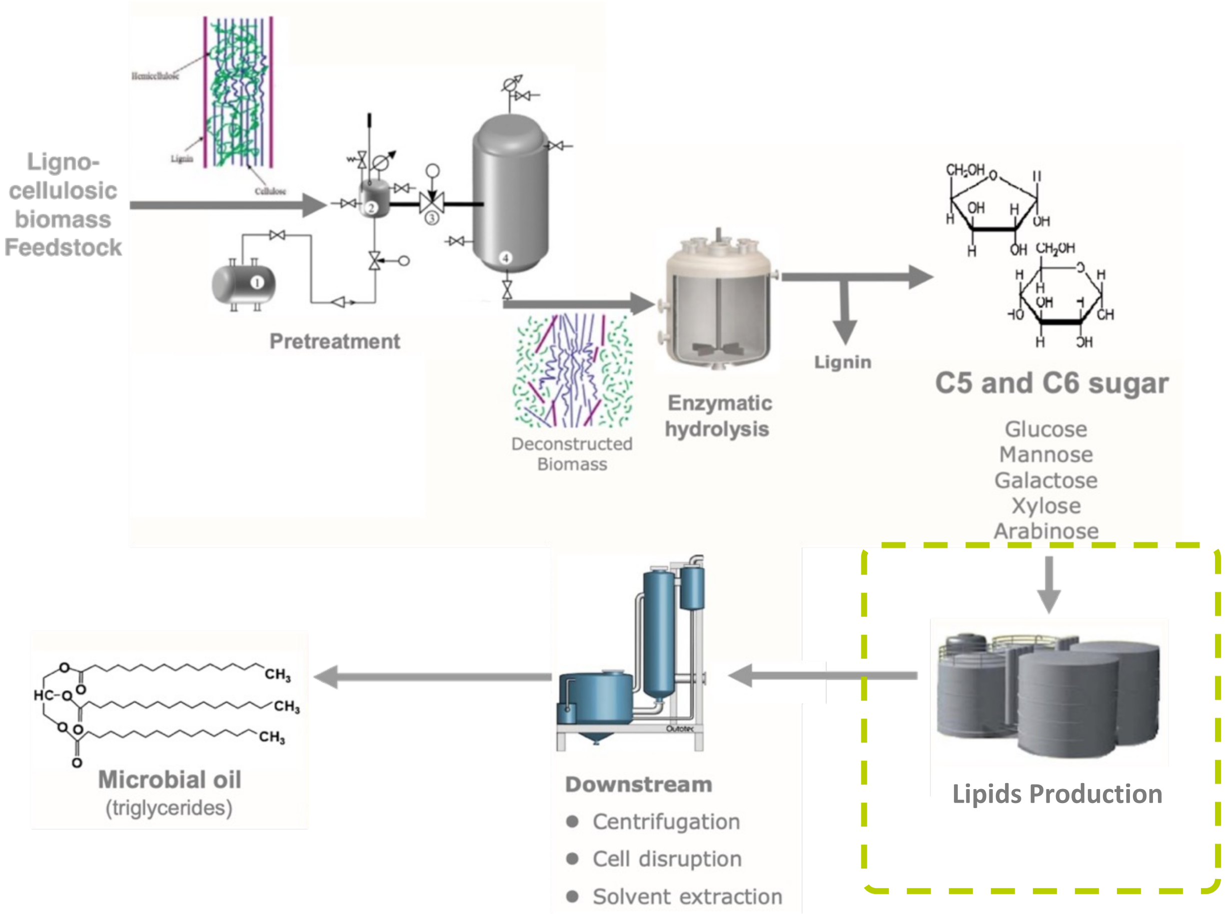


M.O. PRODUCTION PROCESS

Focusing on a **lignocellulosic feedstock**, 4 different steps:

3. **Microbial production of lipids:**

lipid accumulation is an anabolic biochemical process, that occurs putting microorganisms under stress conditions.

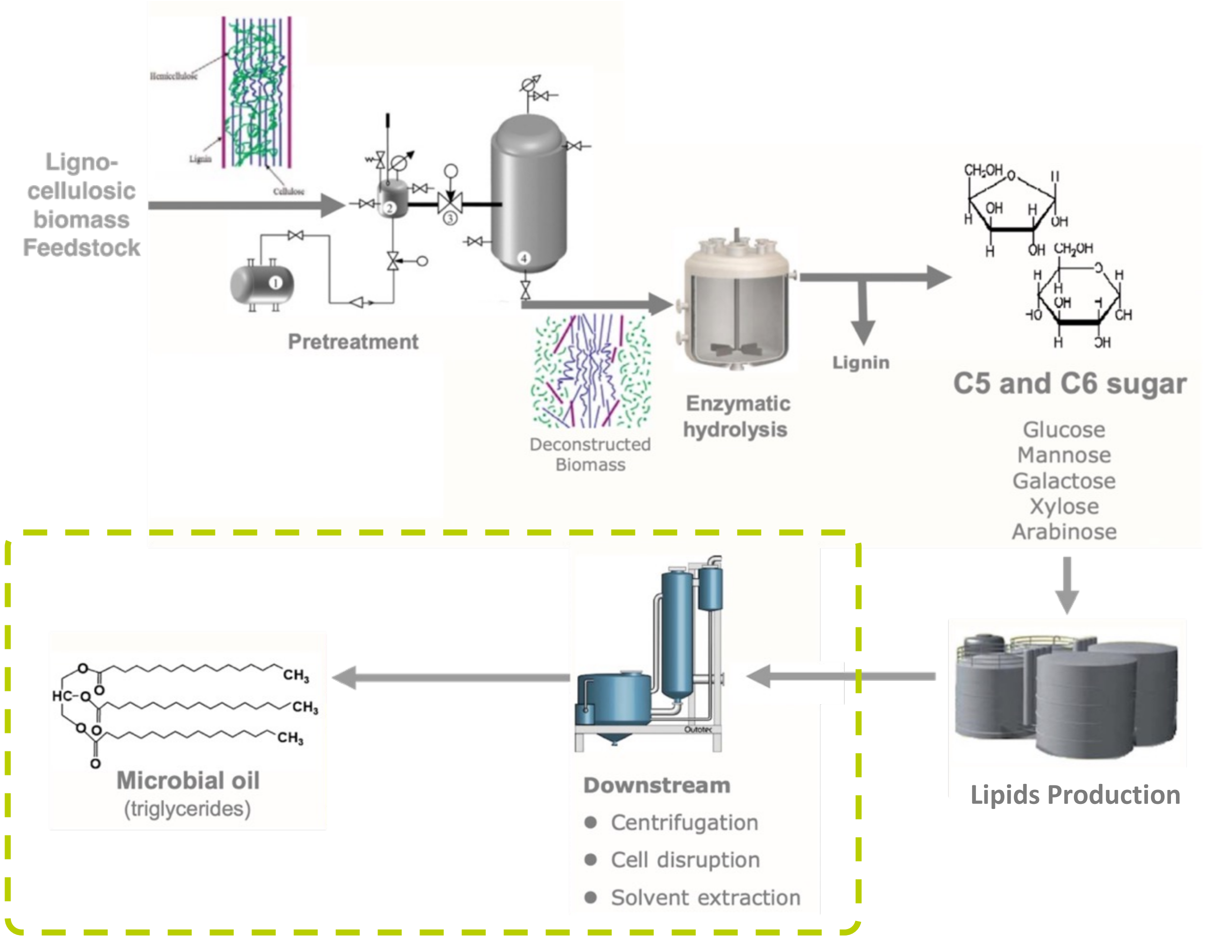


M.O. PRODUCTION PROCESS

Focusing on a **lignocellulosic feedstock**, 4 different steps:

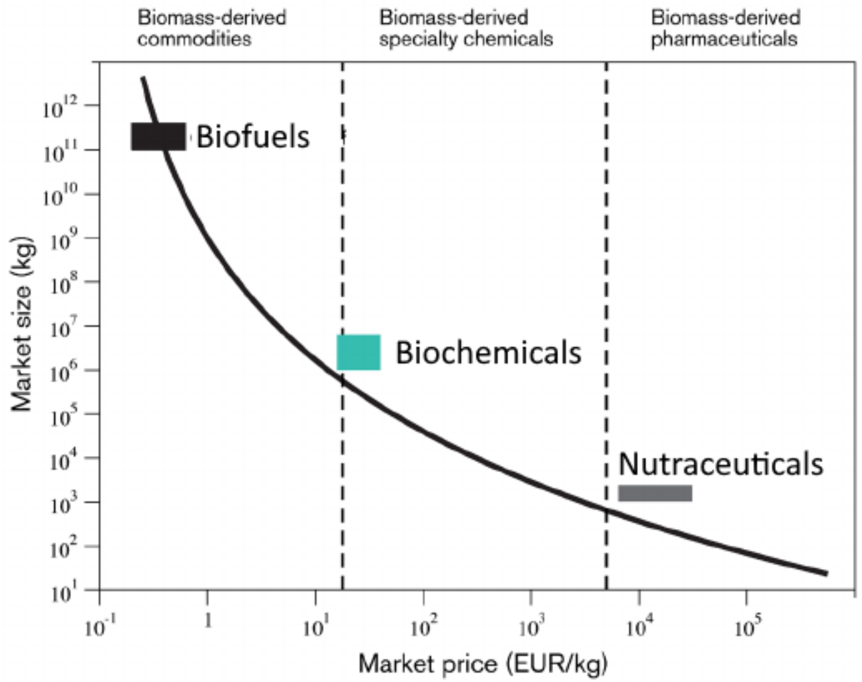
4. **Isolation and purification of the product:**

MO is accumulated intracellularly → need to disrupt the cell walls for efficient oil extraction



EXAMPLES OF M.O. APPLICATIONS

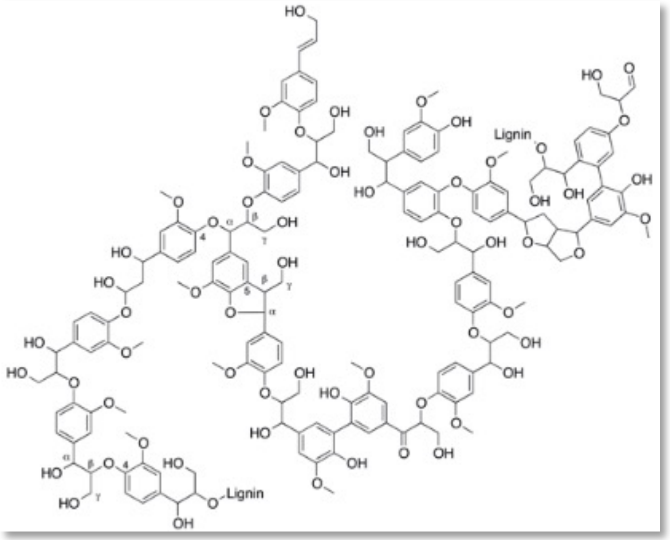
- Three possible applications have been analyzed:
  - **Biofuels:** biodiesel production via trans-esterification or hydrotreatment, and biojet (SAF) production (also) via the farnesene route
  - **Nutraceuticals:** using M.O. rich in essential FAs (EFAs, PUFAs) → **food-grade biomass feedstock**
  - **Biochemicals:** several uses can be found in the oleochemical industry



Applications → Markets → Economics

M.O. CO-PRODUCTS VALORIZATION

- Needed to lower overall production costs
- If available for sale, **microbial meal** could have a price of 400 – 800 USD/ton
- **Lignin** is is usually reported as the most abundant output product in a ligno-cellulosic biorefinery
  - ➢ Valorization strategies offer significant opportunities
  - ➢ Separation and conversion are primary challenges
- **Benzene, toluene, and xylene** (BTX) and **phenols** could be produced from lignin:
  - ➢ BTX market price around 1.200 USD/t
  - ➢ Phenols market price around 1.500 USD/t



M.O. INDUSTRIAL STAKEHOLDERS SURVEY

- MO has a low TRL → still at Lab-Pilot scale

- Several interviews, invited Stakeholders represented:
  - Academic research institutes, entities doing R&D on MO production process, producers of suitable feedstock for M.O., possible MO users

- Interviews followed a questionnaire inquiring about:
  - opportunities and driver,
  - challenges and barriers
  - ideal situation for MO

SURVEY RESULTS

- **Business** is seen as the first development priority
  - Economic sustainability of project is key
  - Cost-efficiency remains to be improved

- **Technical area** is following:
  - Still R&D work to be done
  - When close to optimization, the upscaling can be quite fast (proximity to downstream users)
  - Possible use of Adv. Feedstocks (as per RED II) seen as an advantage

- **Policy and Regulation** are immediately next:
  - As a low-TRL process, incentives could be of great help
  - Need for policy and regulatory framework stability
  - MO could contribute to the RED II 2030 Adv. Biofuels target

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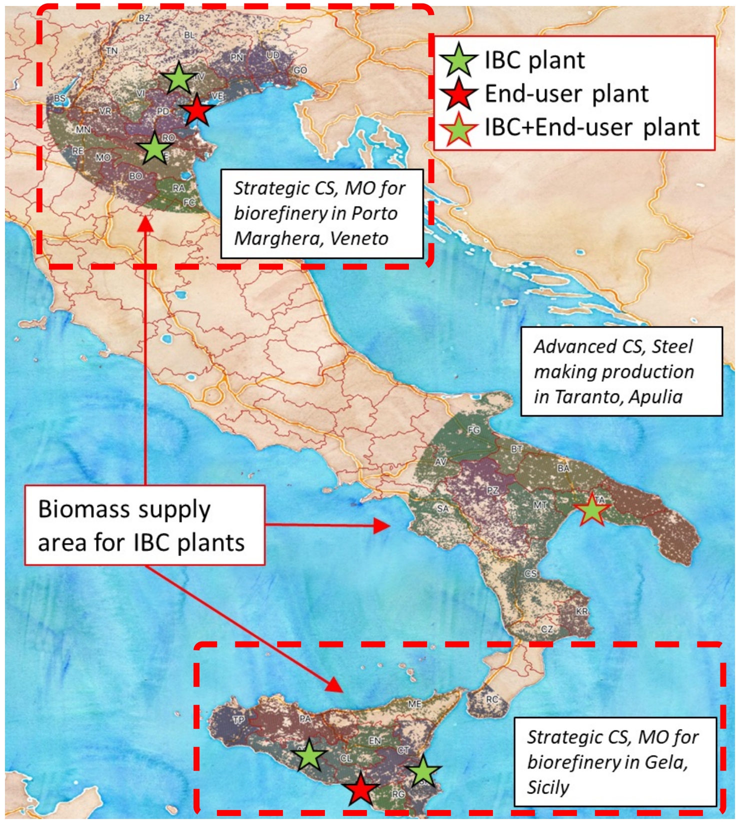
GENERAL INFO

Case Study leader: **RE-CORD**, supported by **UNIFI** and **ENI.**



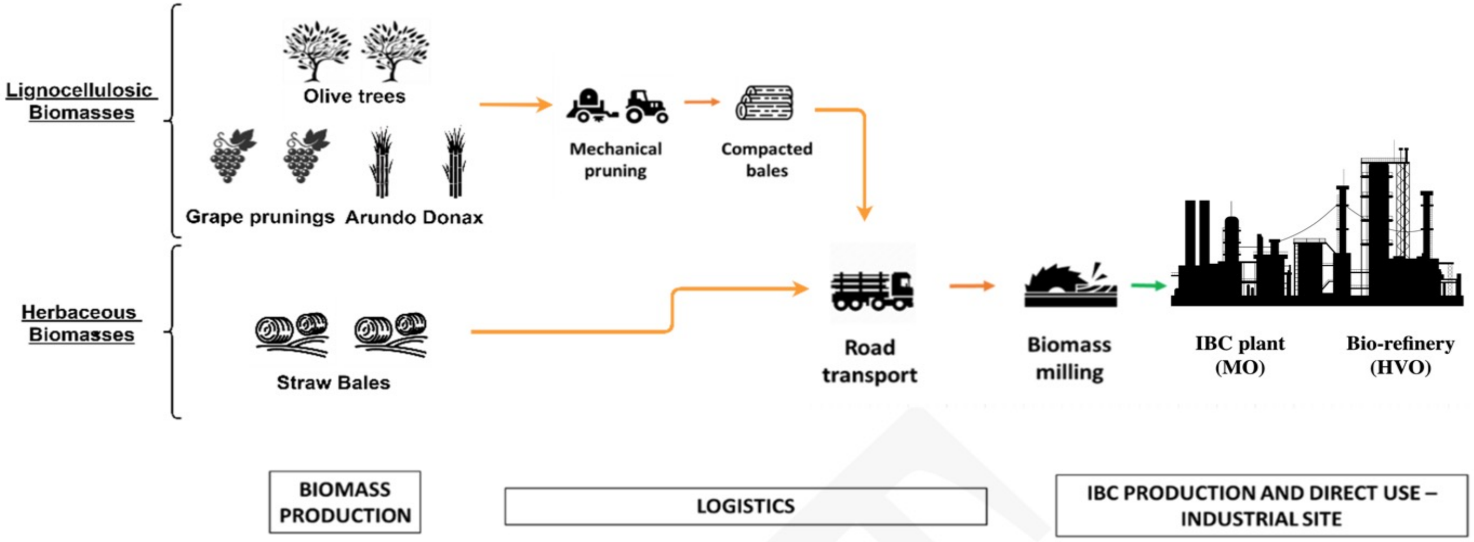
STRATEGIC Case Study:

Lignocellulosic biomass residues → Sugars → **Microbial Oil** → HVO fuels

Locations - ENI biorefineries: Porto Marghera (Venice, Veneto) and Gela (Caltanissetta, Sicily)

STRATEGIC CASE STUDY

- Target production of **100 kt/y MO,** roughly equivalent to **715 kt/yr dry biomass**
- The case study takes place in **two different Italian regions**
- **Two different scenarios** (complete V.C.) are evaluated **for each region**:
  - ➢ **Centralized:** the IBC plant is placed within the bio-refinery area
    - ▪ Takes advantage of existing infrastructures
  - ➢ **Decentralized:** two IBC plants are located in the region to optimize logistics.
    - ▪ Takes advantage of IBC densification process
    - ▪ Developed a methodology for IBC plant optimal location



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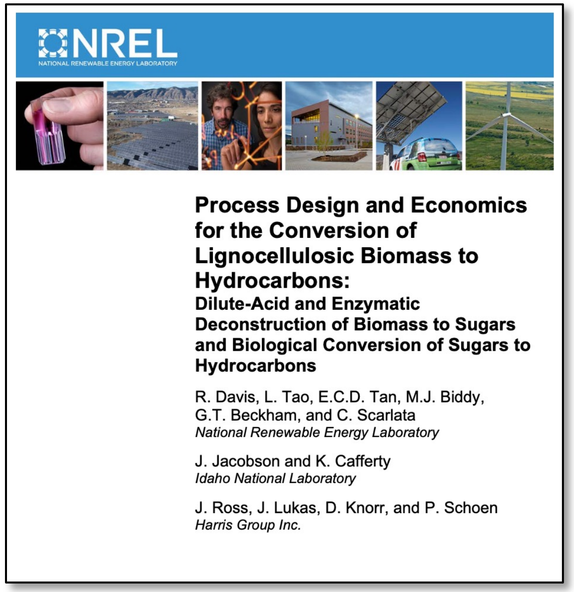
IBC PLANT MODEL

- Based on data from existing NREL model
- Also based on available information from Crescentino ethanol plant
- Comparable sizing
- Mass & energy flows available
- Detailed CAPEX & OPEX available
- Need to define CS-specific input costs
  - ➢ Biomass → from GIS biomass & logistics
  - ➢ Electricity
  - ➢ Others


NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Process Design and Economics for the Conversion of Lignocellulosic Biomass to Hydrocarbons:
Dilute-Acid and Enzymatic Deconstruction of Biomass to Sugars and Biological Conversion of Sugars to Hydrocarbons

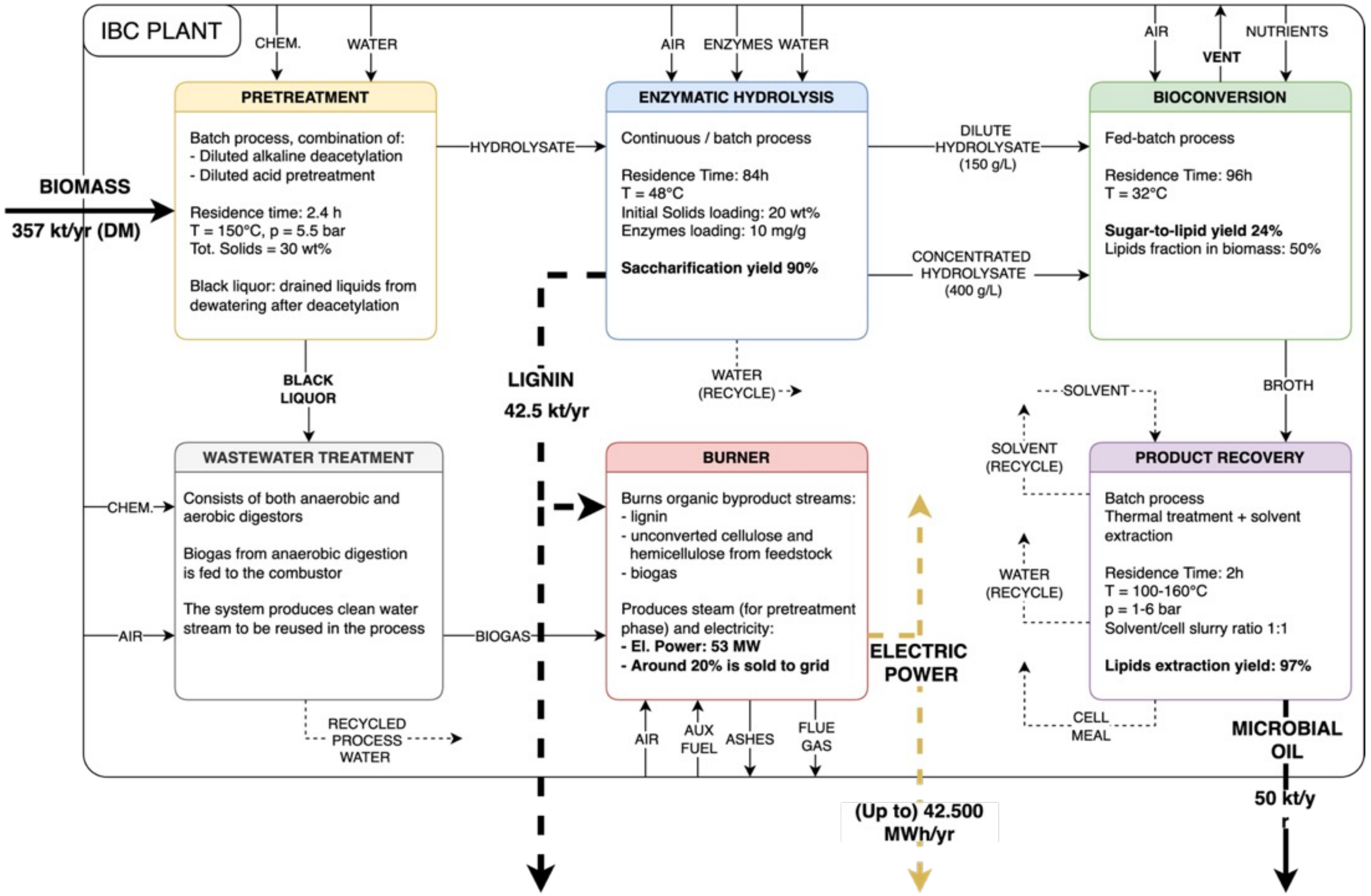
R. Davis, L. Tao, E.C.D. Tan, M.J. Biddy, G.T. Beckham, and C. Scarlata
National Renewable Energy Laboratory

J. Jacobson and K. Cafferty
Idaho National Laboratory

J. Ross, J. Lukas, D. Knorr, and P. Schoen
Harris Group Inc.

IBC PLANT MODEL

- **Overall process yield**: around **14-15%** (M.O./dry biomass)
- For a **50 kt/yr** M.O. output we have:
- **Dry biomass input: 357 kt/yr**
- **Lignin: 42.5 kt/yr**
- **Cell meal: 50 kt/yr**
- **Black liquor: 90 kt/yr**



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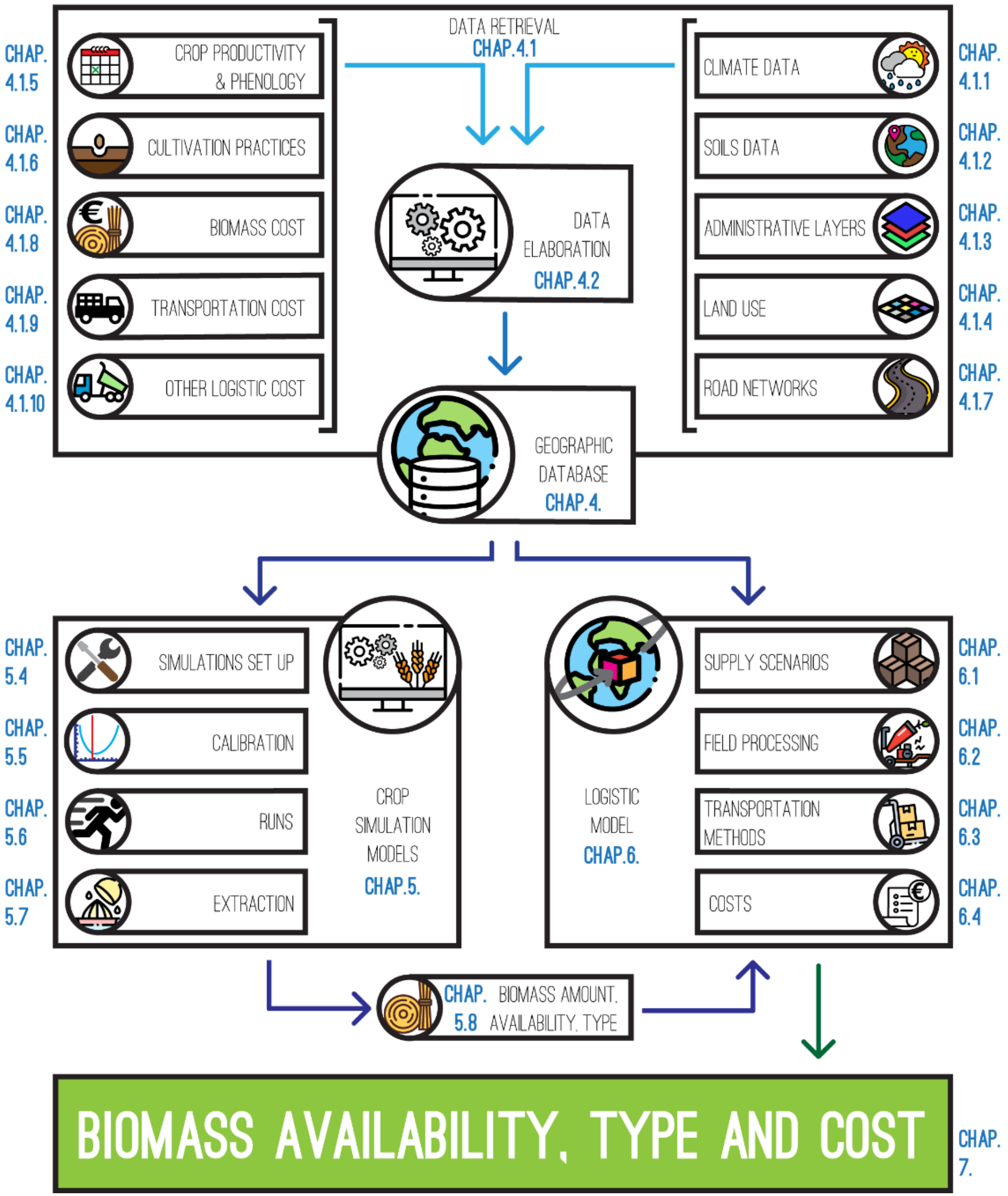
Market Uptake Support for Intermediate Bioenergy Carriers

THE INFER-NRG MODEL

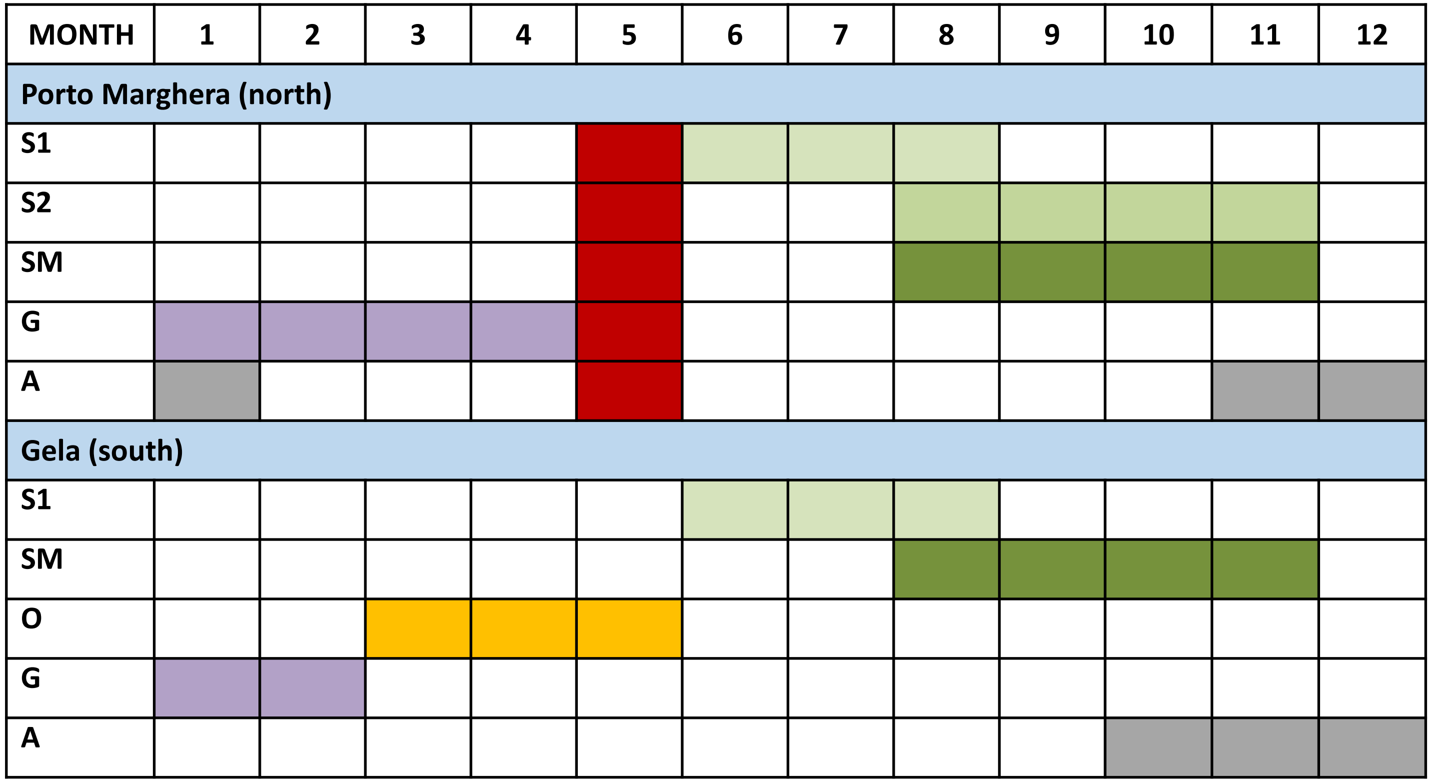
An integrated system for the simulation of biomass flows from field to energy:

1. Geographical Database
2. Data elaboration
3. Crop models
4. Logistics model
5. Biomass availability and costs assessment (biomass, transport)



4. LOGISTICS MODEL

Supply scenarios



#	Crop residues	Type	Moisture Content
G	Grapevine	Wood chips	40%
O	Olive		10%
S1	Wheat, triticale and barley	Straw (bales)	20%
S2	Rice		30%
SM	Sorghum and maize	Wood chips	66%
A	Arundo Donax		50%

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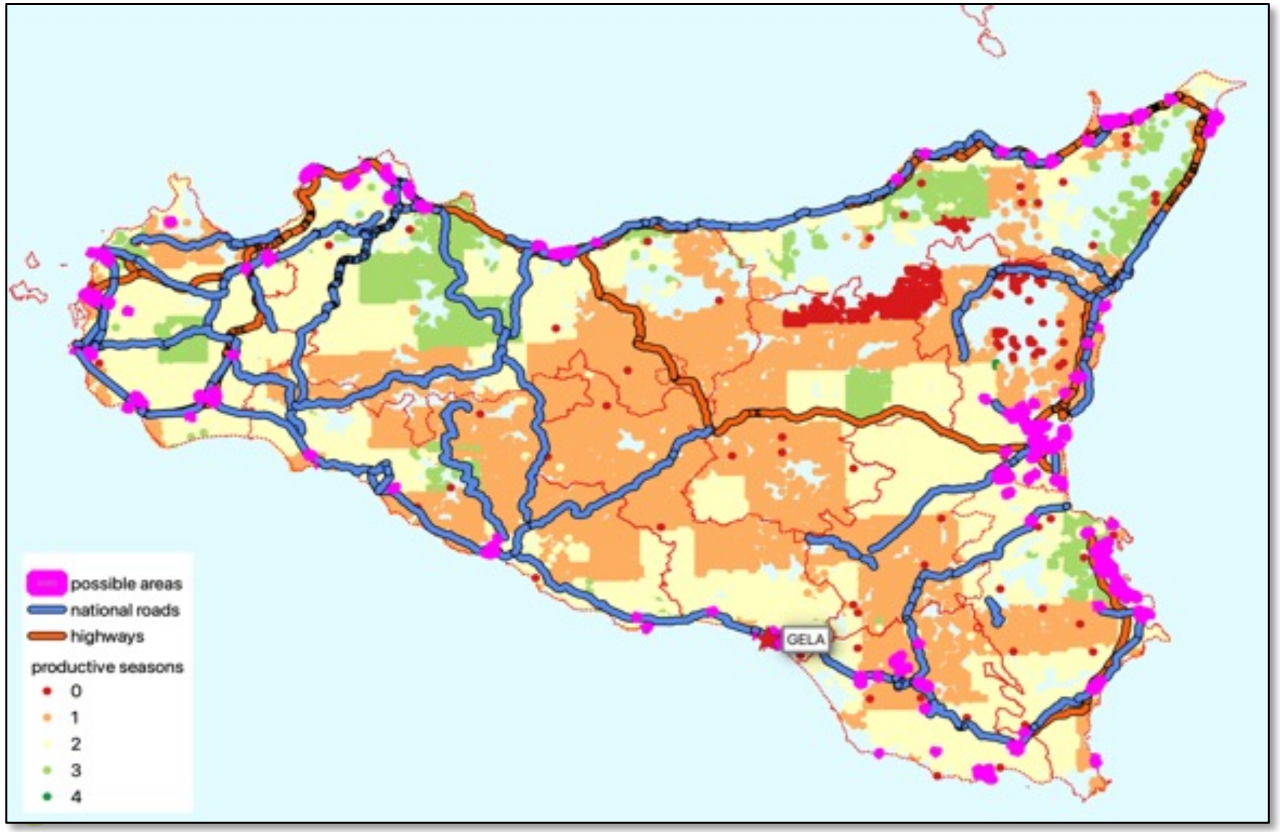
4. LOGISTICS MODEL

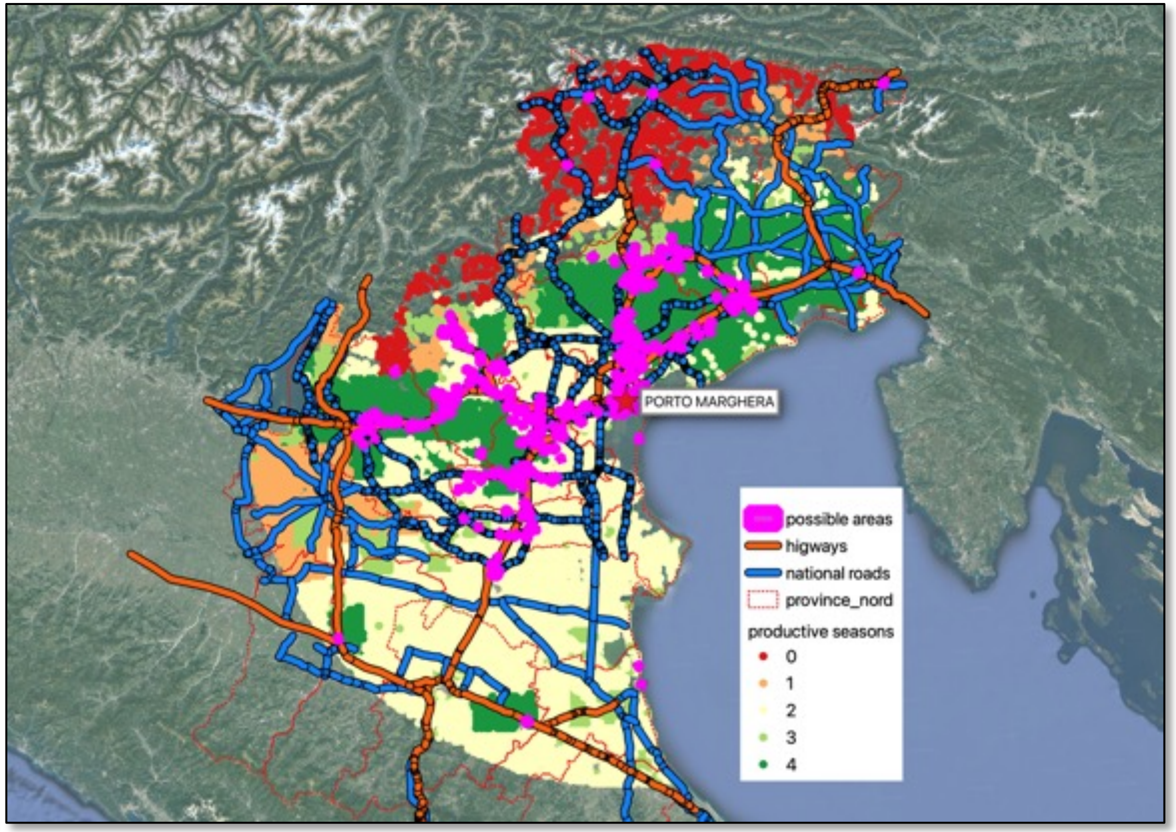
Decentralized scenario

- The IBC plants should be near to the biomass production areas (months)
- Extracted from the Corine Land Cover only the polygons (within both subcases) classified as industrial areas or other not-agricultural/not-urban/not-protected areas
- Selected only the polygons within a 5km radius from either highway exits or national roads
- Filtered out all polygons within a buffer of 5km from urban areas (the social acceptancy of the intermediate plant could be considered higher).

4. LOGISTICS MODEL



Gela (south)



Porto Marghera (north)

4. LOGISTICS MODEL

Gela (south): 6 intermediate plants

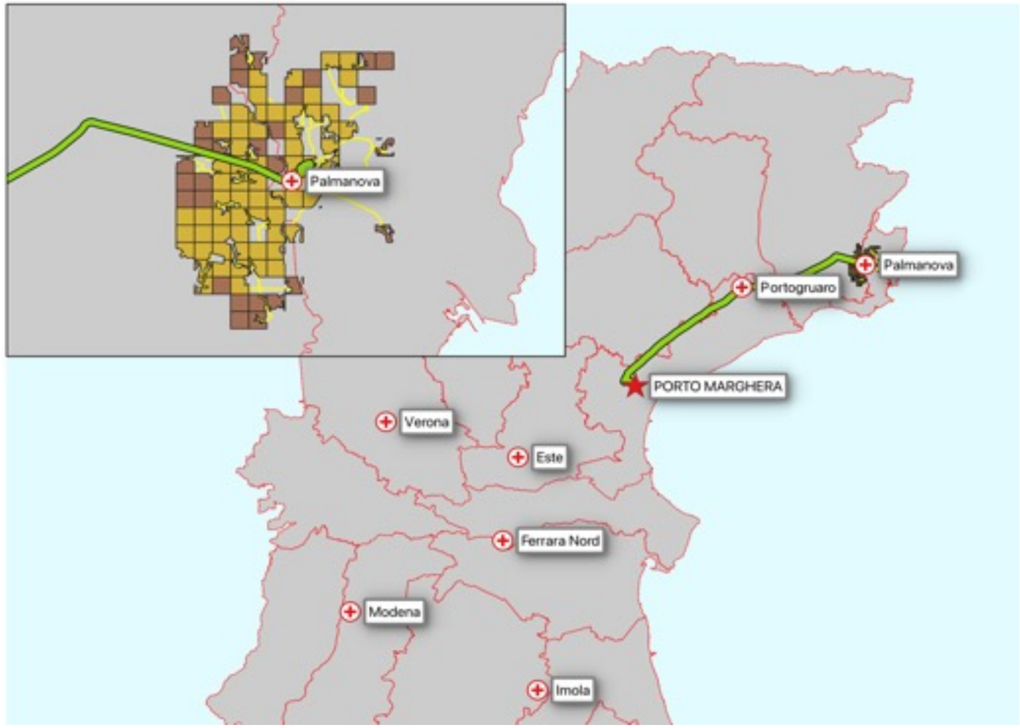
Porto Marghera (north): 7 intermediate plants

4. LOGISTICS MODEL

For each intermediate plant (and main IBC)

- Minimum area (30kt*[1] / 15kt*[2])
- Safety zone (45kt* [1] / 22.5kt* [2])

Following a time/distance spiral from the plant



* Sum of minimum production dry matter
[1] centralized scenario
[2] decentralized scenario

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BIOMASS FEEDSTOCK COSTS

- Sum of three cost components:
  - **Biomass feedstock cost**
  - **Collection** and **upstream logistics** costs (from the field to the IBC plant)
  - **Downstream logistics** costs (transport of MO from the IBC plant to the biorefinery)

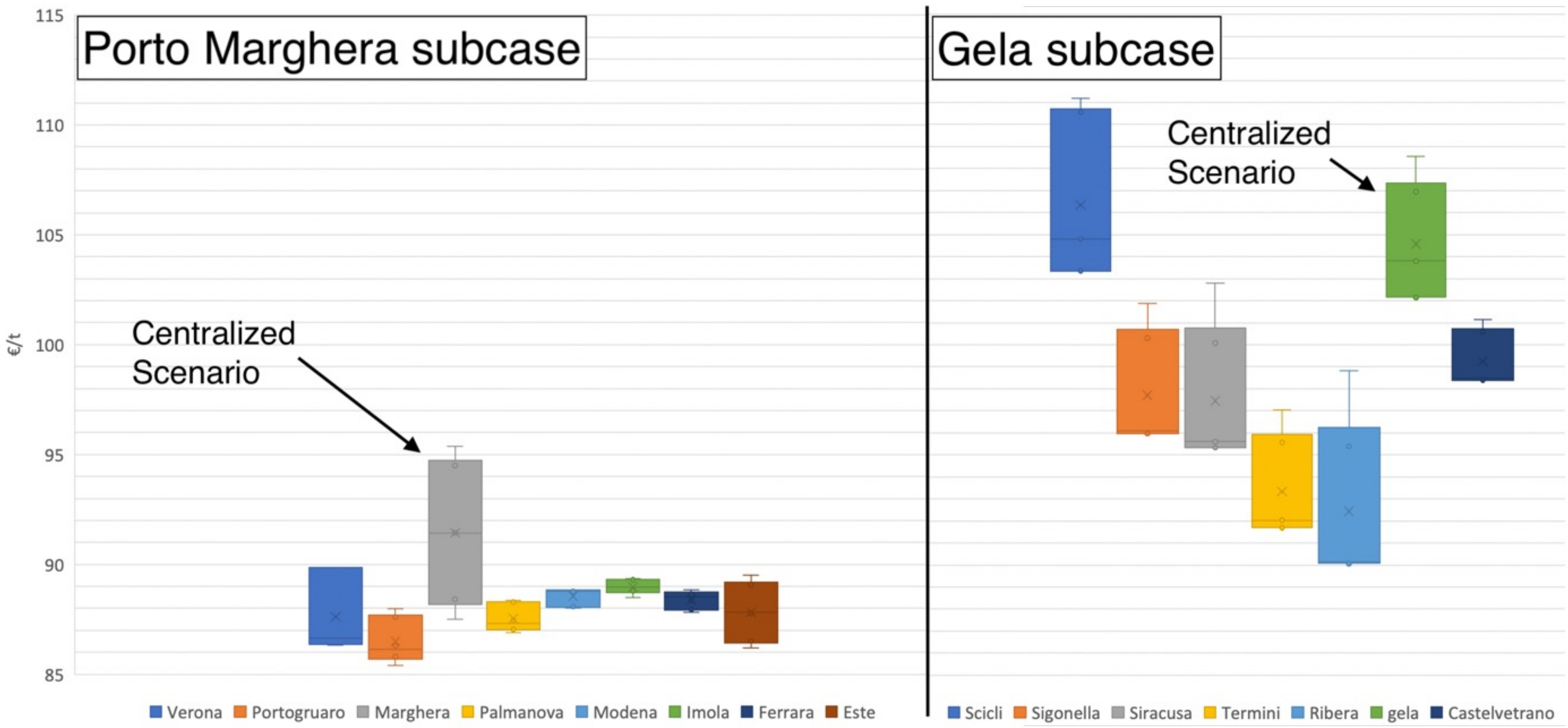
- Evaluated for different climate and use scenario, impact on biomass availability:
  - Impact on geographical location → transport duration → price

- Strongly influenced by **lack of transport infrastructures** in Southern Italy

- The downstream logistics costs impact for **less than 2%** on the total cost (0.54 - 1.84 €/t)

BIOMASS FEEDSTOCK COSTS

- Veneto subcase proves more robust (i.e. transport infrastructure)
- Centralized scenarios always have higher price variability (reach further for biomass)



TECHNO-ECONOMIC ANALYSIS

- A set of two subcases with four scenarios each has been developed:
  - **Subcases:** Porto Marghera and Gela
  - **Location scenario:** one centralized plant or two decentralized plants
  - **Lignin use scenario:** all lignin is burnt for internal IBC plant energy uses VS lignin sold on the market for further uses.

- The main costs and revenues components are:
  - **Plant CAPEX and OPEX**
  - **Biomass feedstock costs**
  - **Electricity incomes or costs** (depending on lignin use – for energy or sold on the market)
  - **Lignin price on the market**
  - **MO price on the market → palm oil used as a proxy (avoided cost)**
  - **Biofuels incentives → Italian CIC**

TECHNO-ECONOMIC ANALYSIS

- The main output parameter evaluated is **Minimum Fuel Selling Price** (**MFSP**)
  - Cost break-even selling fuel price at which the future sales of transportation liquids and byproducts are equal to the present value of CAPEX and OPEX

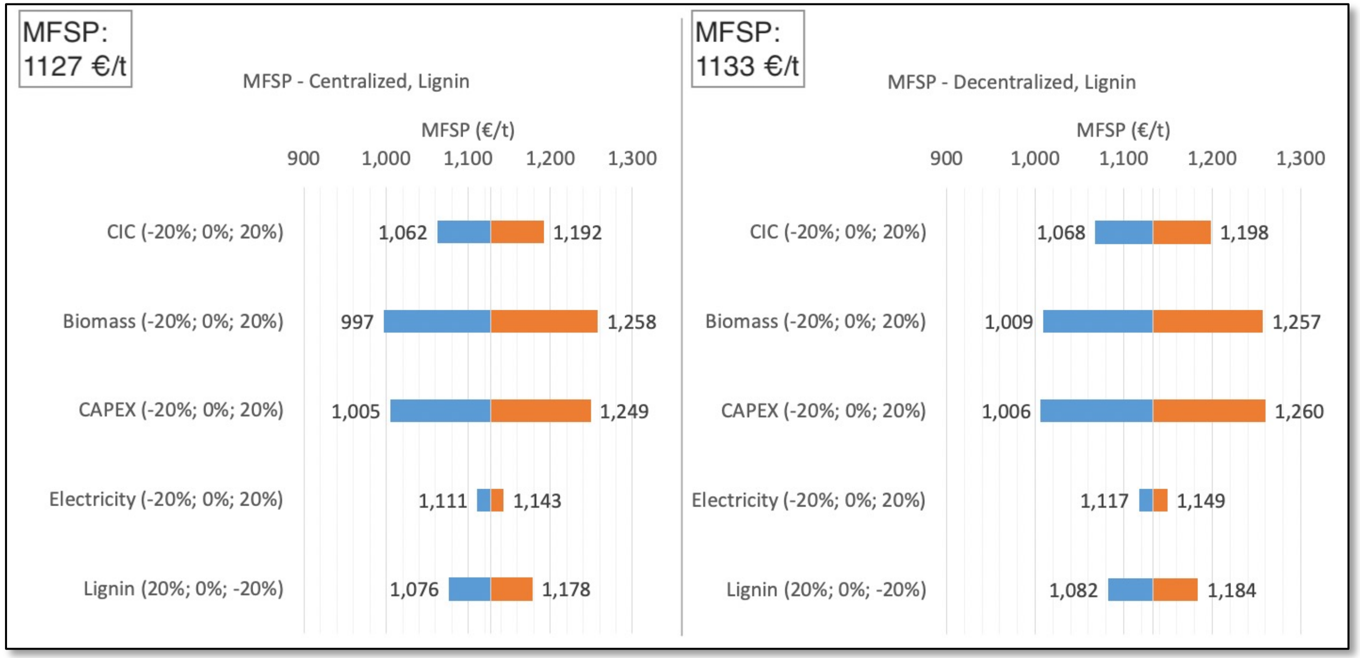
- Best result is obtained in the **Centralized, Sold Lignin** scenario for the **northern sub-case**
  - Combination of lower CAPEX and not-so-high biomass costs

Subcase	**Centralized**		**Decentralized**	
	Baseline	**Lignin**	**Baseline**	**Lignin**
Porto Marghera	1269 €/t	**1127 €/t**	1275 €/t	1133 €/t
Gela	1363 €/t	1221 €/t	1318 €/t	1176 €/t

TECHNO-ECONOMIC ANALYSIS

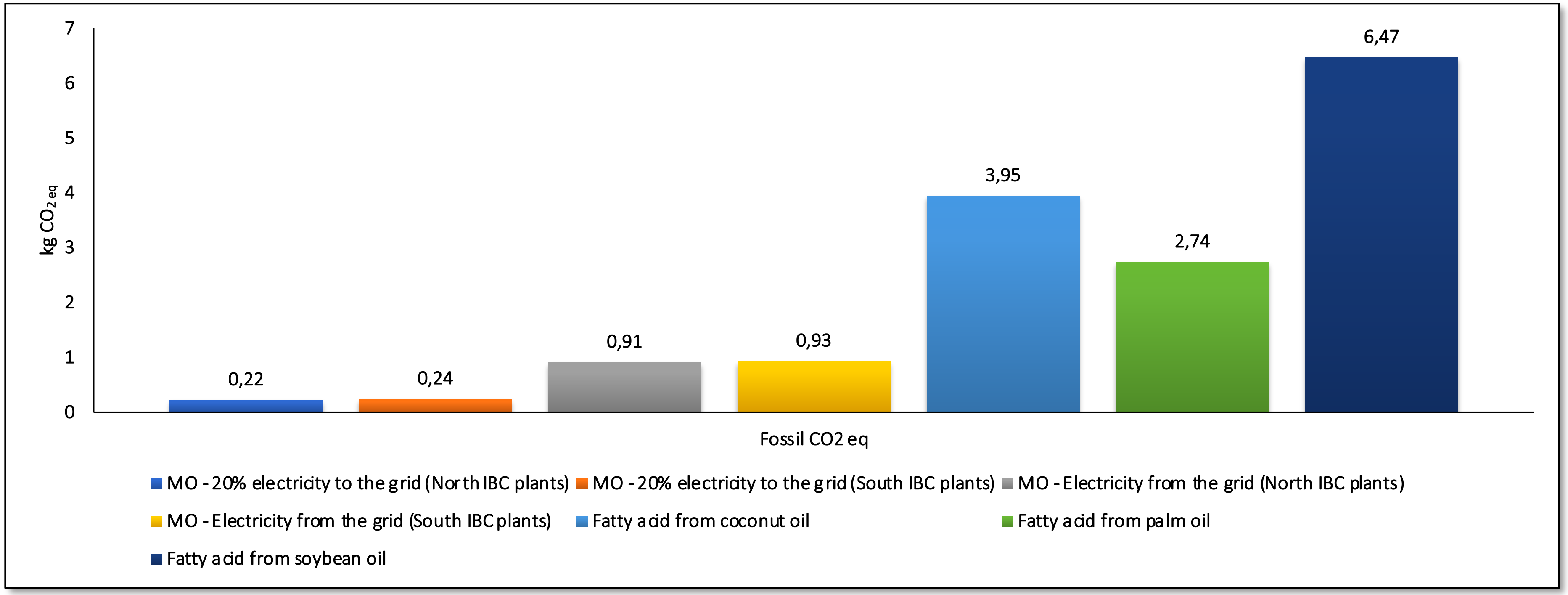
Sensitivity analysis

- Variation range +/- 20%
- CAPEX and biomass cost components are the most impacting
- Followed by incentives and lignin sale price



GHG EMISSION EVALUATION

- MO production process confronted with:
  - Fatty acids from palm oil
  - Fatty acids from soybean oil
  - Fatty acids from coconut oil
- Lignin sale on market is reported to lead to higher specific (kg_{CO2eq}/kg_{MO}) GHG emissions
  - Due to related reduction in renewable electricity production and need to compensate with grid electricity



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CONCLUSIONS

- **Biomass feedstock price evaluated at 86.9 €/t to 104.6 €/t**
  - **Lower price in northern Italy**
  - **High impact of transport costs**

- **MFSP ranging between 1127 €/t (Centralized, Sold Lignin, North) and 1363 €/t (Centralized, Baseline, South)**

- **Higher lignin sale price improve financial viability**
  - **Higher purity grade required → higher CAPEX, R&D**

- **GHG emissions reduction from around 3 to 10 times when compared with fatty acids production from palm oil feedstock.**

THANK YOU FOR YOUR ATTENTION!

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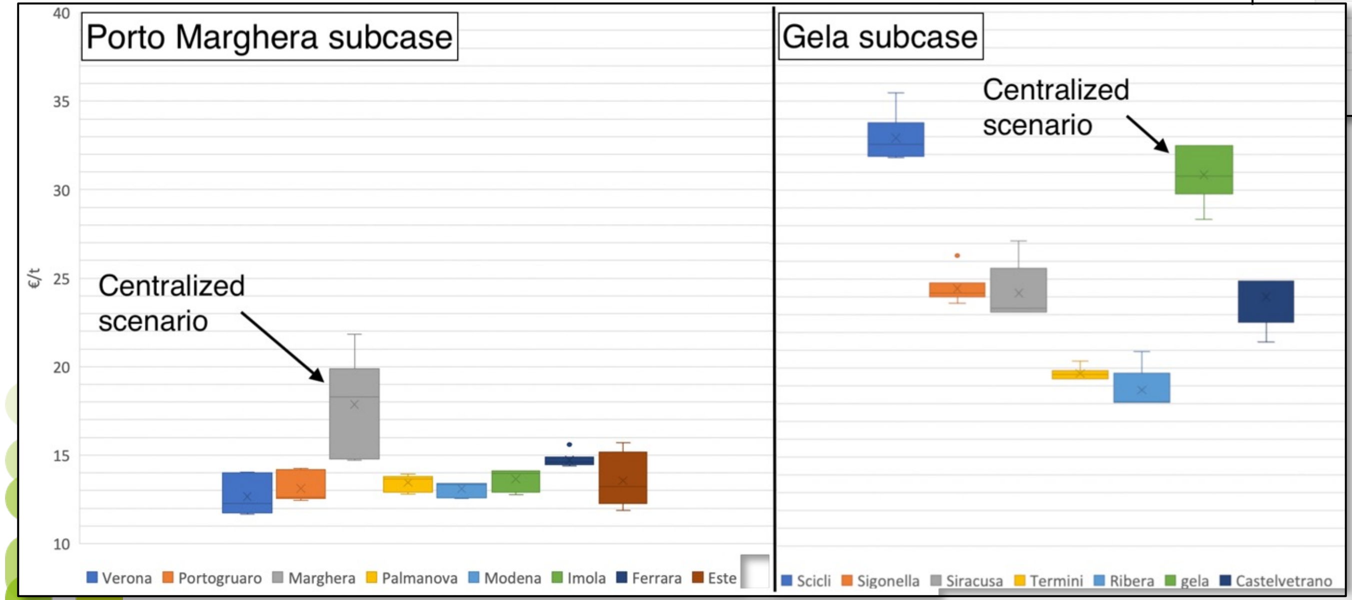
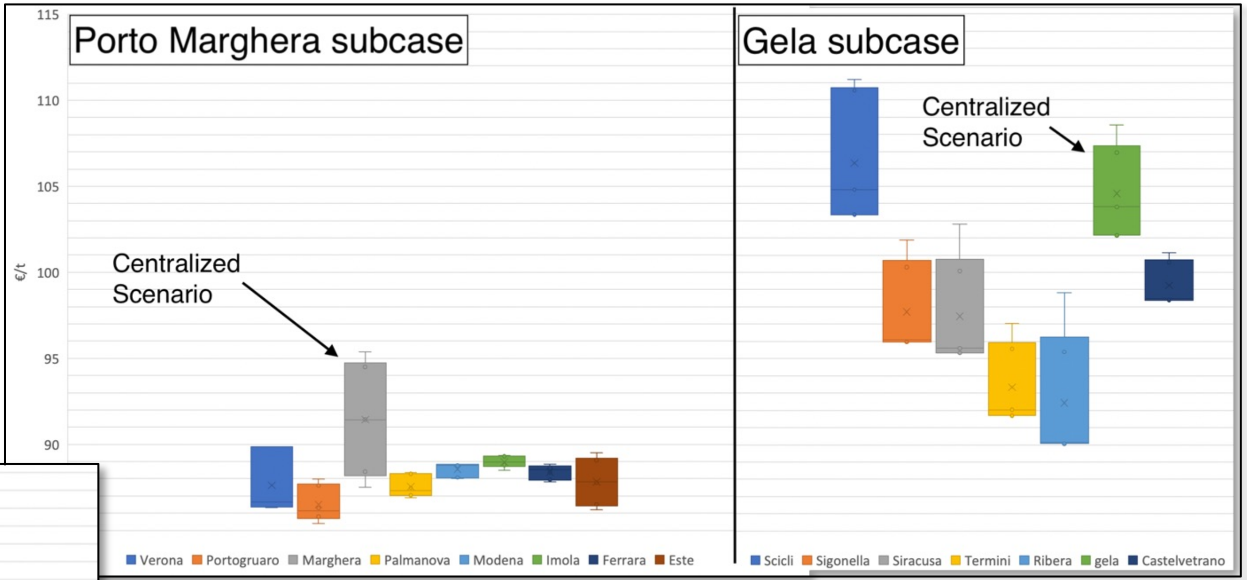
BIOMASS FEEDSTOCK COSTS

- Impact from transport infrastructure

Upstream Logistics Costs





Total Costs

TECHNO-ECONOMIC ANALYSIS

- Summary of the values of the parameters involved in the techno-economic analysis:

	Centralized		Decentralized	
	Base	**Lignin**	**Base**	**Lignin**
Biomass price (dry)	91.4 (PM) / 104.6 (G) €/t[1]		86.9 (PM) / 92.9 (G) €/t[1]	
Electricity price	50 €/MWh (sold) – 108 €/MWh (purchased)			
Lignin price	300 €/t			
Incentives value	375 €/10 Gcal (646 €/t MO or 779 €/t HVO)			
Palm oil price	700 €/t			
CAPEX (single plant)	335,151,077 €	327,972,466 €	174,982,678 €	171,328,112 €
OPEX (single plant)	52,320,075 €	58,374,512 €	24,944,245 €	27,971,463 €

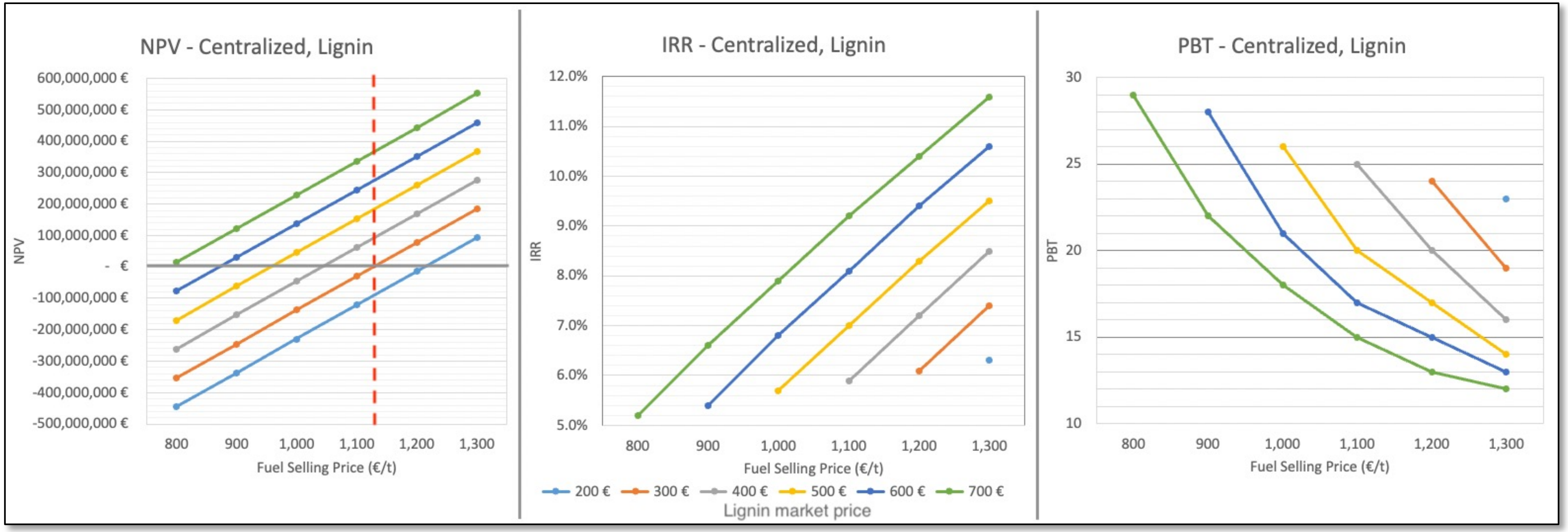
Depreciation	yr	10
Lifespan	yr	30
Discount Rate	%	5.0
Tax Rate	%	30

TECHNO-ECONOMIC ANALYSIS

Fuel Selling Price VS Lignin Market Price

- Red dashed line → MFSP with lignin @ 300 €/t

- Lignin price greatly affects financial viability
  - Higher CAPEX required to unlock higher lignin value (purity)
  - More R&D as well



Centralized, Lignin Sold, Northern Scenario