Forest-based Bioeconomy: research in RTU

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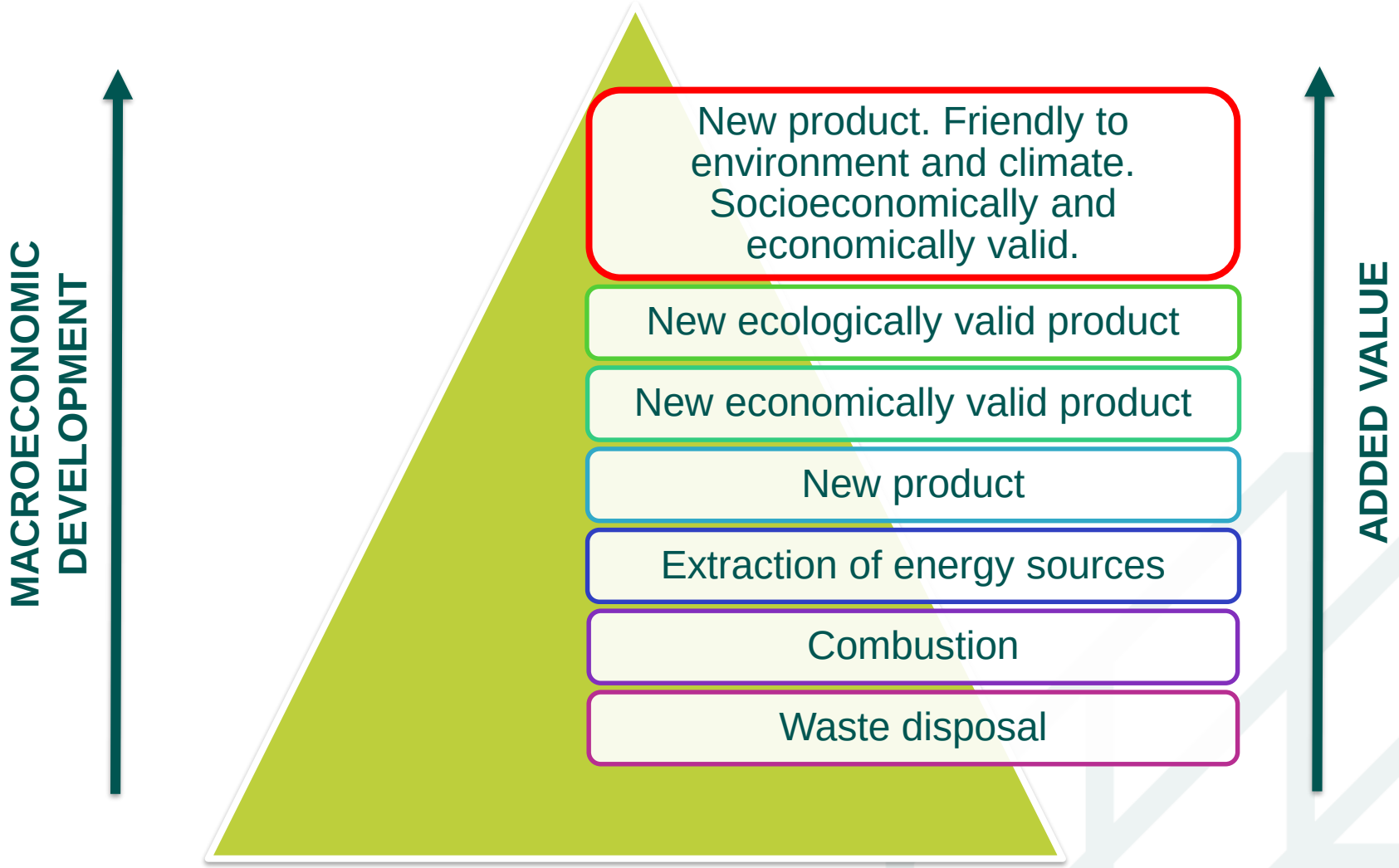
Bioresource use pyramid



Methods used in the study

Information collection and handling	• Scientific literature research • Surveys results
Innovative products multi-criteria analysis	• Criteria selection and determination of weights (importance) • Product selection
Market sales analysis	• Potential size of the market • Innovative product's price
Eco-design analysis of three innovative products	• Determination of product's effect on climate and environment
System dynamics model – economic analysis of three innovative products	• System dynamics model for determination of product's added value and determination of organizations profit in time
Recommendations and conclusions	• Challenges and possibilities • Questions for further research

Sources of information

- Information given by involved scientific institutions
- Scientific publications and studies
- Scientific literature
- Patent database (*Espacenet*)
- Organizations experience
- Statistical databases
- Other publically available, trustworthy information

Wood resources available for forestry (LSF data)

Forestry in Latvia

~11,5 mil. m³

Big dimension assortments for mechanical processing

~6.5 mil. m³

Paper wood

~3.5 mil. m³

2 mil.m³ SW

1.5 mil.m³ HW

Firewood

~1 mil. m³

0.8 mil. m³ SW

0.2mil. m³ HW

Forestry residues

~0.5 mil. m³

Unprocessed wood for <u>export</u>:

- paper wood 1,6 mil. m³;
- woodchips and firewood 1,4 mil. m³.

Multi-criteria analysis

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Products included in multi-criteria analysis

Power industry

1. Butanol
2. Biodiesel
3. Bioethanol
4. Bio-oil

Textile industry

5. *Ioncell-F*
6. Lyocell
7. Viscose

Food production industry

8. Vanillin, lignin, ethanol un cellulose
9. Fish food additive from microorganism proteins
10. Bird and animal food from pine and fir needles **(SILAVA / BIOLAT)**
11. Lignan

Biocomposite materials un building materials

12. Nanocellulose cement
13. Transparent wood
14. Cellulose cotton wool
15. Wood foam thermal insulation
16. ICLT - interlocking cross laminated timber panels
17. Wood fibre composite material floor
18. Glass fibre / wood flour thermoplastic composite material
19. Wood – plastic composites
20. *Dendrolight* cell material **(MeKA*)**
21. Thermal insulation material from needles **(RTU IESE)**

Other new products with high added value

22. Nanocrystallic cellulose
23. Suberin-acid salts
24. Suberin as cohesive substance **(LSIWC)**
25. Lignin polymers
26. Nanocellulose film
27. Activated coal as sorbent **(LSIWC)**
28. Xylan
29. Starch
30. Furfural **(LSIWC)**

*Forest and Wood Products Research and Development Institute (MeKA)

Multi-criteria analysis matrix. An example

No.	Criteria	Product A	Product B	Product C	Product D
		x_1	x_2	x_3	x_4
1	Production development stage	5	3	5	4
2	Wood resource consumption amounts	4	2	4	4
3	Product market	5	4	5	5
4	Complexity of technological process	3	2	4	5
5	Specific water consumption	2	3	5	3
6	Specific electricity consumption	2	3	1	4
7	Specific thermal energy consumption	2	4	1	2
8	Waste and residue amounts from production	2	5	5	3
9	By-products, that can be produced simultaneously from this material flow	3	5	2	4
10	CO_2 emission amounts from production	3	5	1	4
11	Product effects on natural environment (air, water, soil, climate, living organisms)	3	4	2	4
12	Product effects on human health	3	4	1	4
13	Product compliance to eco-design base principles	4	3	2	5
14	Necessary investments to start production	1	2	1	3

Results of multi-criteria analysis: TOP 10 products with highest commercialization potential

Product	Multi-criteria analysis result	Ranking
Biodiesel	0,829	1
Bio-oil	0,813	2
Lyocell (textyle)	0,767	3
Suberin as cohesive substance	0,710	4
ICLT – interlocking cross laminated timber panels	0,701	5
Xylan	0,689	6
Fish food additive from microorganism proteins	0,650	7
Suberin-acid salts	0,596	8
Transparent wood	0,587	9
Cellulose cotton wool	0,584	10

Products for further commercialization potential study

IESE recommendations	LSF selection
Biodiesel from bio-oil	Bio-oil
Lyocell (textile from wood) + fish food additive from microorganism proteins	Lyocell (textile from wood)
Suberin as cohesive substance	Xylan

TOP 3 products commercialization potential further study

- Products effects on climate policy goal achievement
- Available resources amount for production
- Eco-design analysis
- Potential market and price study
- Economic analysis

Product manufacturing technologies

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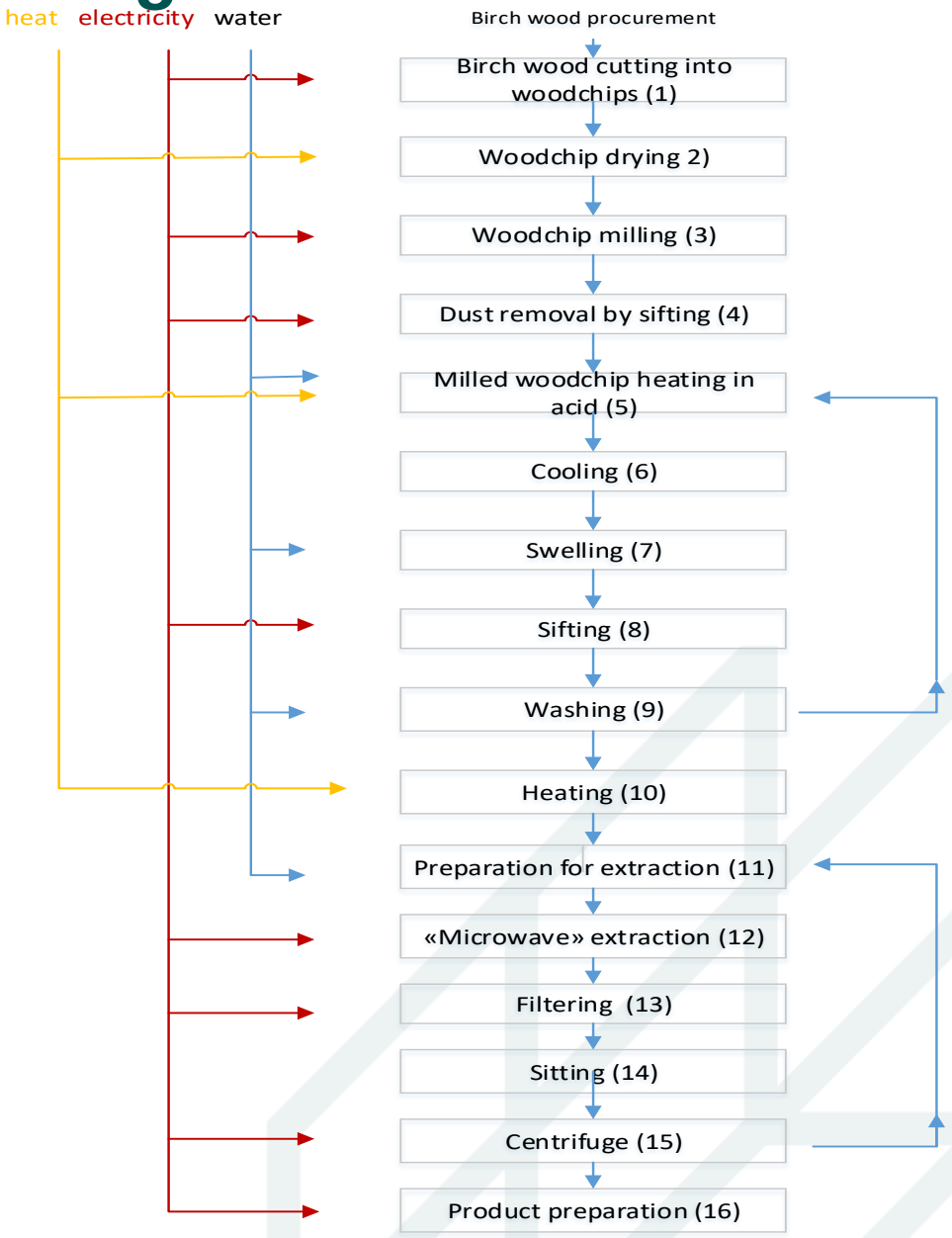
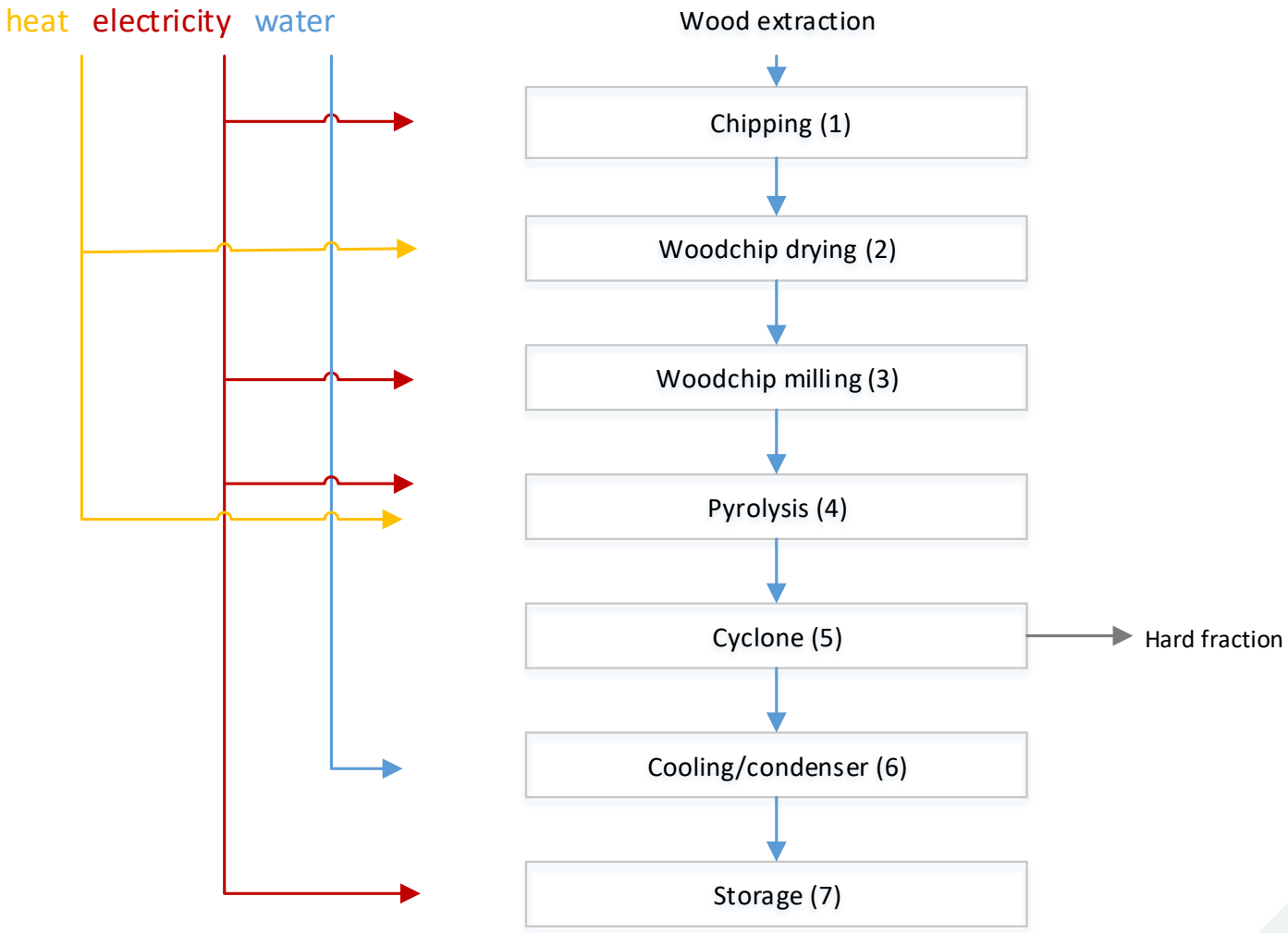
Xylan (xylite) production technologies

- Main raw materials:
  - woodchips;
  - hydrochloric acid;
  - ammonium hydroxide;
  - water;
  - sodium hydroxide.

- Biggest effects on environment:
  - electricity;
  - use of chemicals.

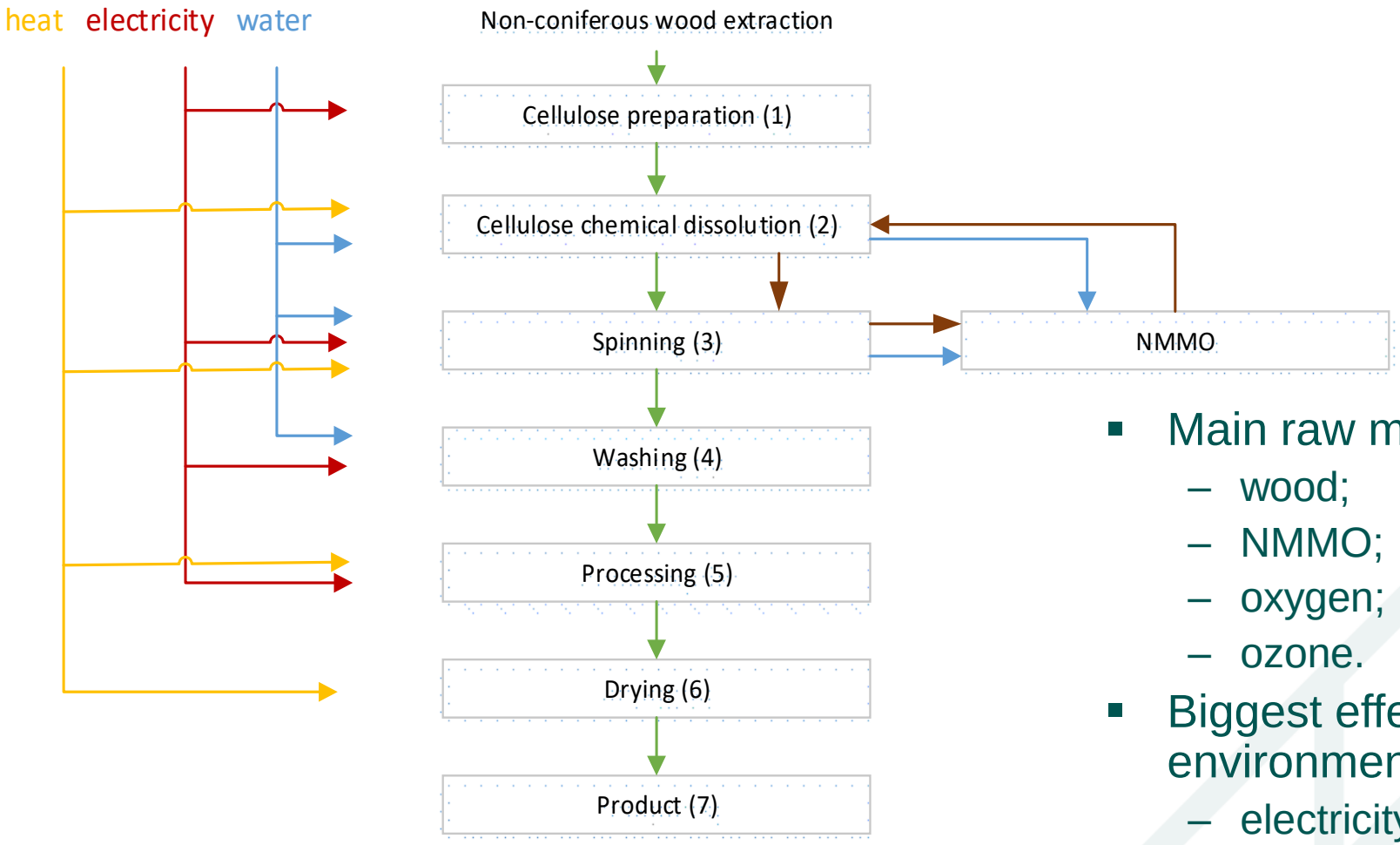


Bio-oil production technologies



- Main raw materials:
  - woodchips.
- Biggest effects on environment:
  - electricity;
  - heat;
  - woodchips.

Lyocell production technologies



- Main raw materials:
  - wood;
  - NMMO;
  - oxygen;
  - ozone.
- Biggest effects on environment:
  - electricity;
  - heat.

Eco-design analysis

Eco-design (I)

Eco-design is a systematic method to develop goods and services, that could improve **sustainability by decreasing products effects on environment in a whole life cycle.**

Selected products effects on environment modelling with program ECO-it

- ECO-it numerically evaluates effects on environment created by each material and process.
- Selected production amount for each products is 1 ton.
- To make productions mutually comparable, identical energy resources and transport were chosen:
  - transport (load >32 t), tkm – CO_2 eqv. 0,117 kg, mPt 14,0;
  - electricity (fossil), kWh – CO_2 eqv. 0,594 kg, mPt 59,9;
  - heat (firewood), MJ – CO_2 eeqv. 0,006 kg, mPt 3,61.

- ECO-it materials and process database is limited. For example, co-generation is not offered.

Results of eco-design analysis

	Xylan	Bio-oil	Lyocell
	CO_2 eqv./t	CO_2 eqv./t	CO_2 eqv./t
Electricity	3,00	0,05	3,10
Heat	0,10	0,05	0,17
Chemicals	0,73	0,00	0,02
Woodchips	0,19	0,04	0,04
Total	4,02	0,14	3,34

- Smallest effects on environments are created by bio-oil production.
- Electricity consumption dominates analysed products effects on environment, that can be explained by a fact that it is impossible to choose co-generation as electricity source.
- CO_2 eqv. method evaluates water effects as zero, therefore it is zero for all products independent of consumed water amounts.

Economic analysis

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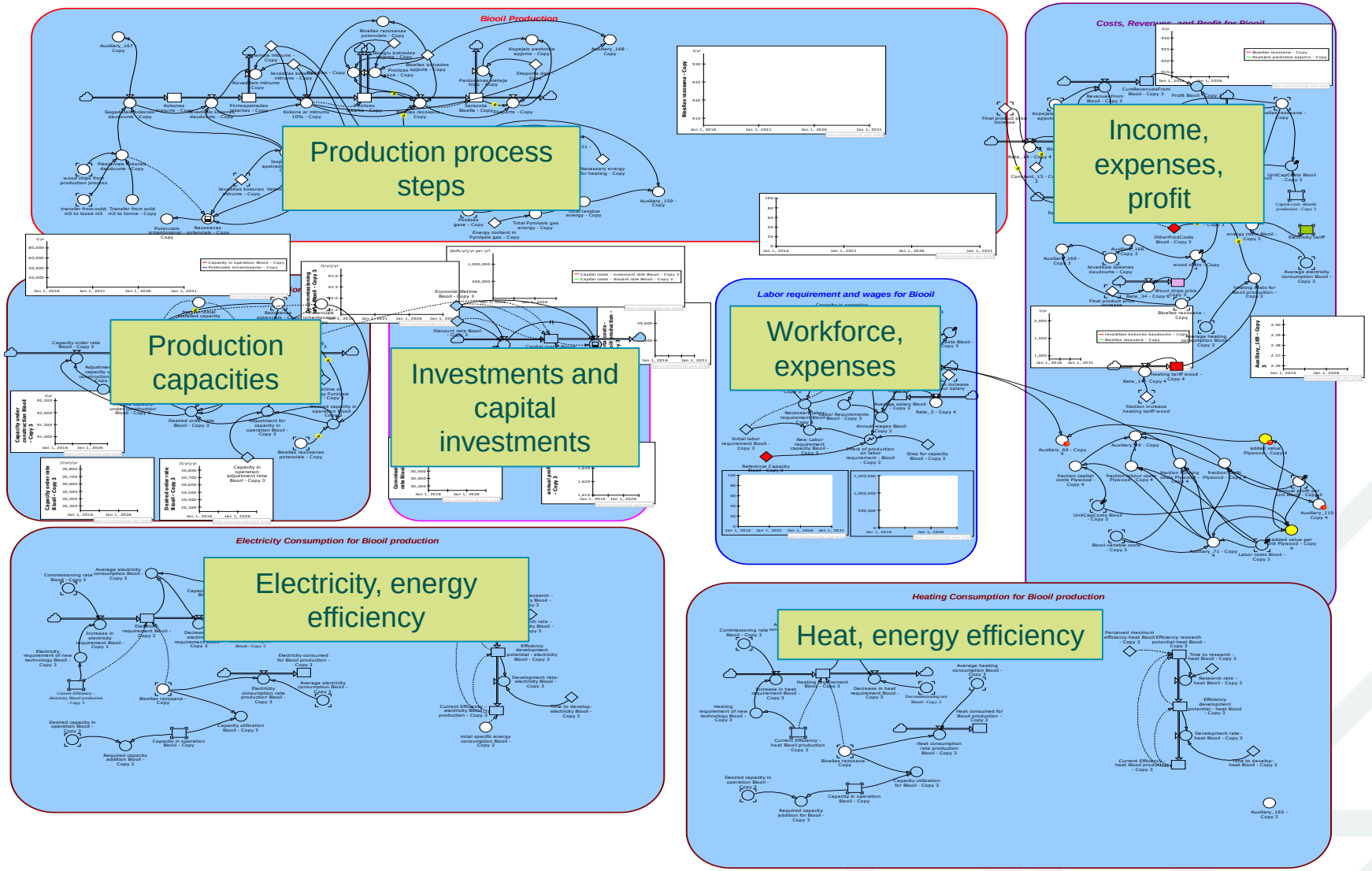
System dynamic model blocks



Input data for system dynamics model

Product	Selected production capacities, t/year	Product amount from used raw material, %	Product price, €/t	Capital investments, €/t
Lyocell	65 000	30,4 [1]	2 500	4 328
Bio-oil	30 000	70 [2]	190	600
Xylan derivatives	20 000	15 [1]	2 500	5 000

[1] – from input dry mass
[2] – from input raw material with 10% relative moisture content

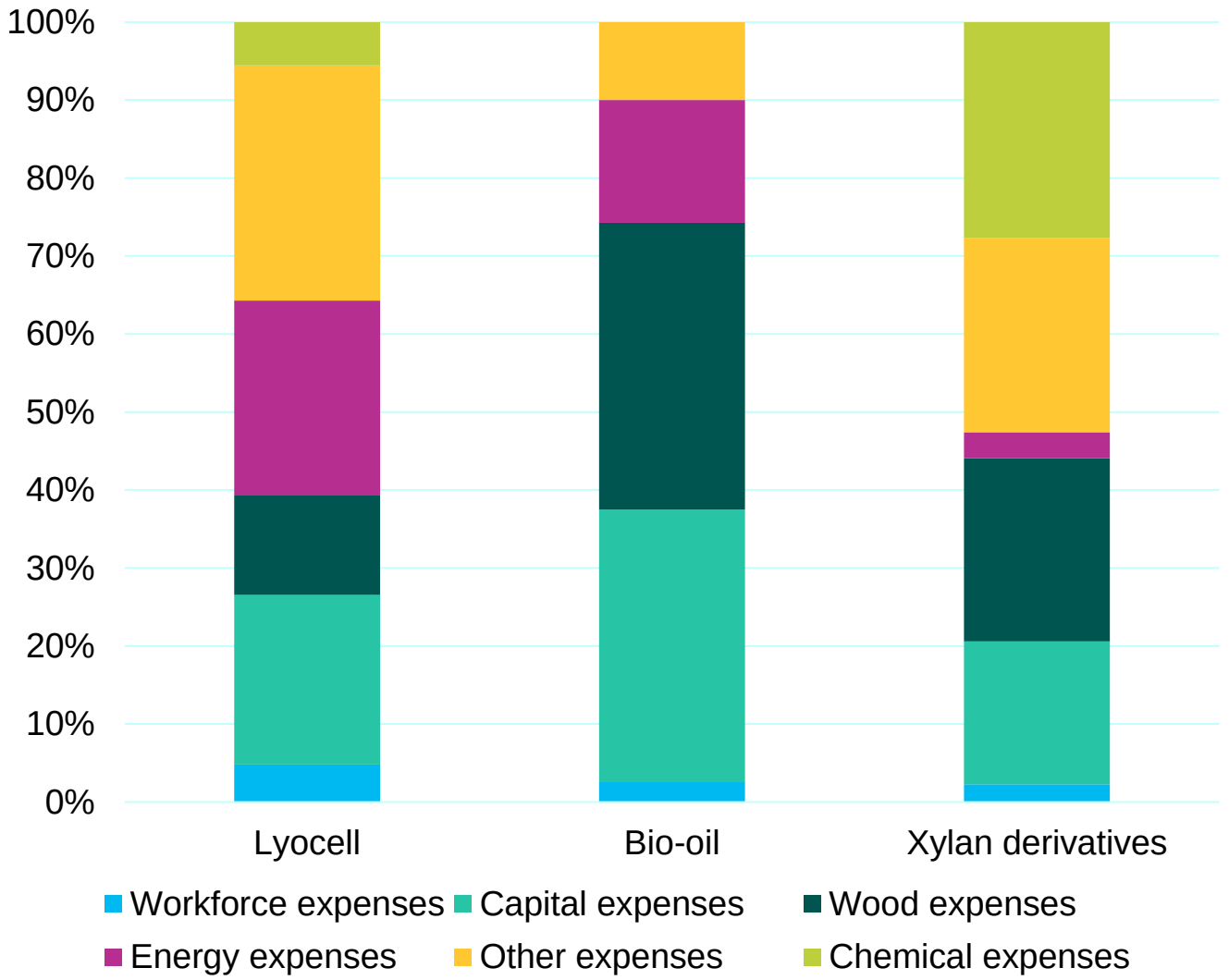
Input data, that are taken into account:

- electricity and heat consumptions and tariffs;
- chemical amounts and expenses;
- workforce and it's expenses.

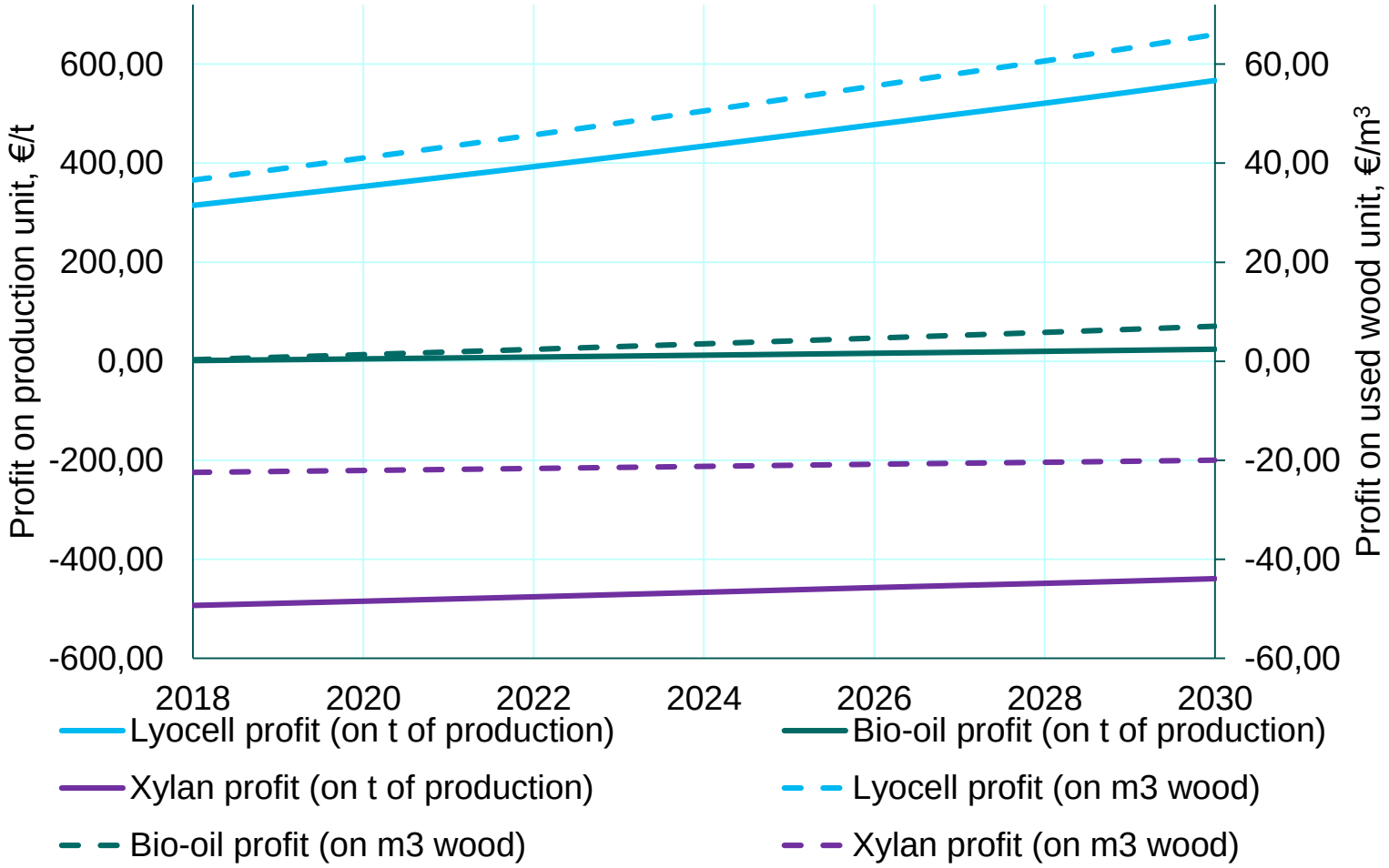
Assumptions in system dynamic modelling

- raw material and end products price increase is 2% per year;
- payment increase for workforce is 3% per year;
- heat tariff increase is 1,5% per year;
- electricity tariff increase is 1,5% per year;
- economic lifetime for technologies is 15 years;
- investments discount rate is 7%.

Products relative expenses comparison

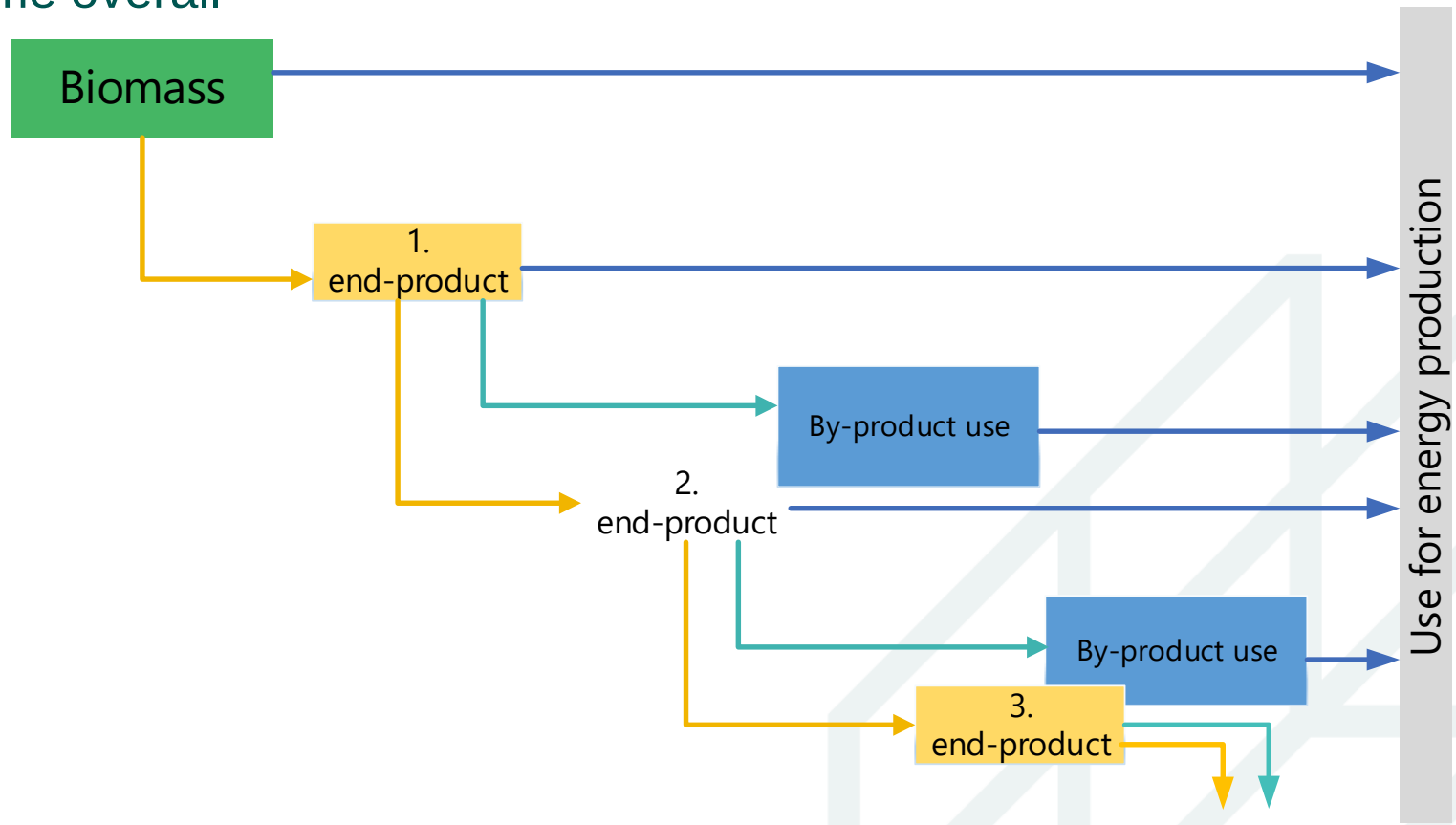


Profit showings comparison



Cascade type production unit

- Feasibilty study's economic and effects on environment evaluation shows that it is necessary to develop product groups not individual products, that matches up with bioeconomy principles and increase income overall



Potential market and price study

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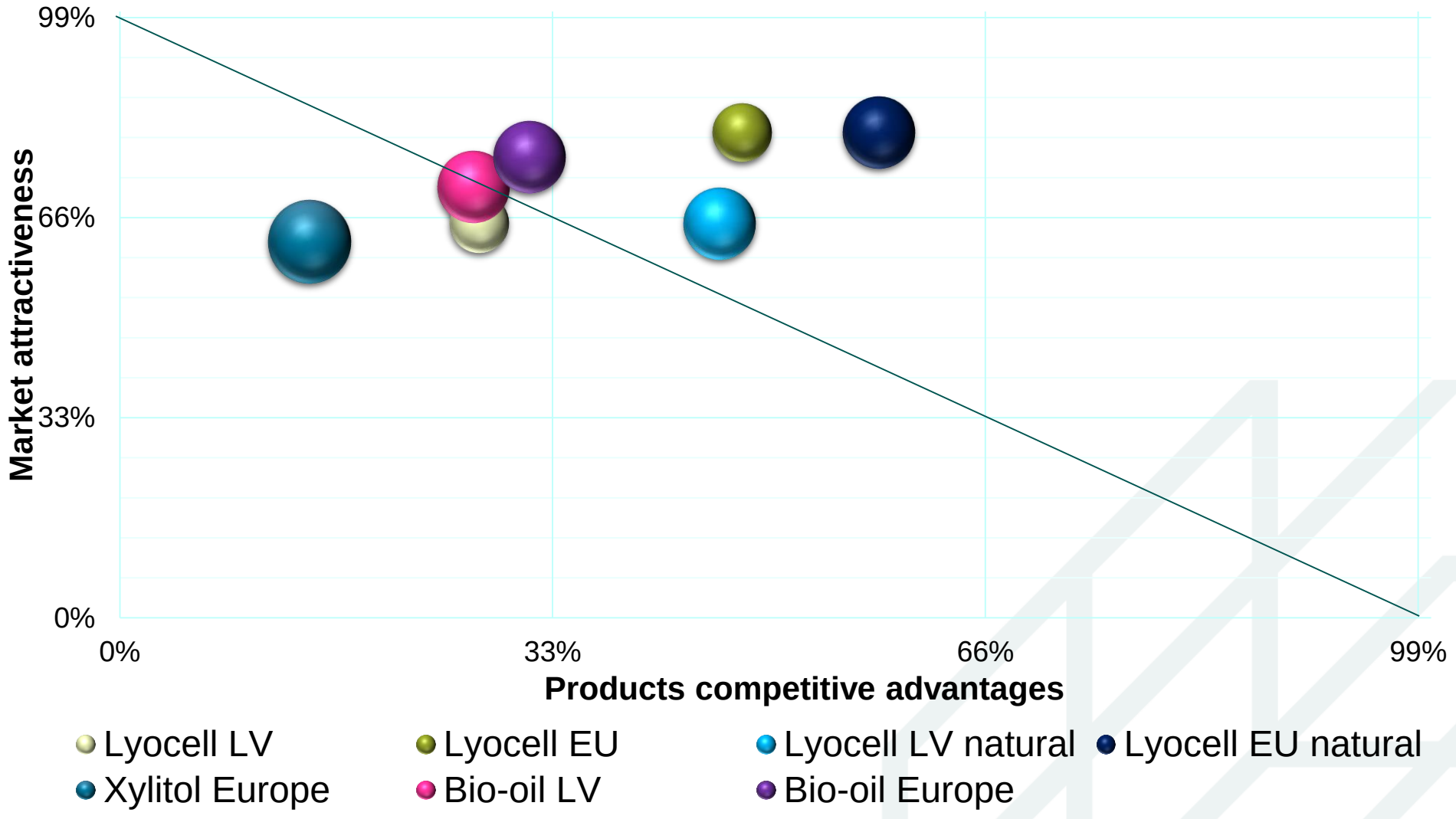
Potential market and price study

Product	Price	Market appeal		Competition advantages	
		Local market	International market	Local market	International market
Lyocell	2,54 €/kg	69 %	80 %	27 % 46 % (natural)	47 % 58 % (natural)
Bio-oil	9–15 €/GJ	67 %	73 %	27 %	31 %
Xylan (xylitol)	6 €/kg	-	67 %	-	14 %

Market outlook - GE/ McKinsey matrix



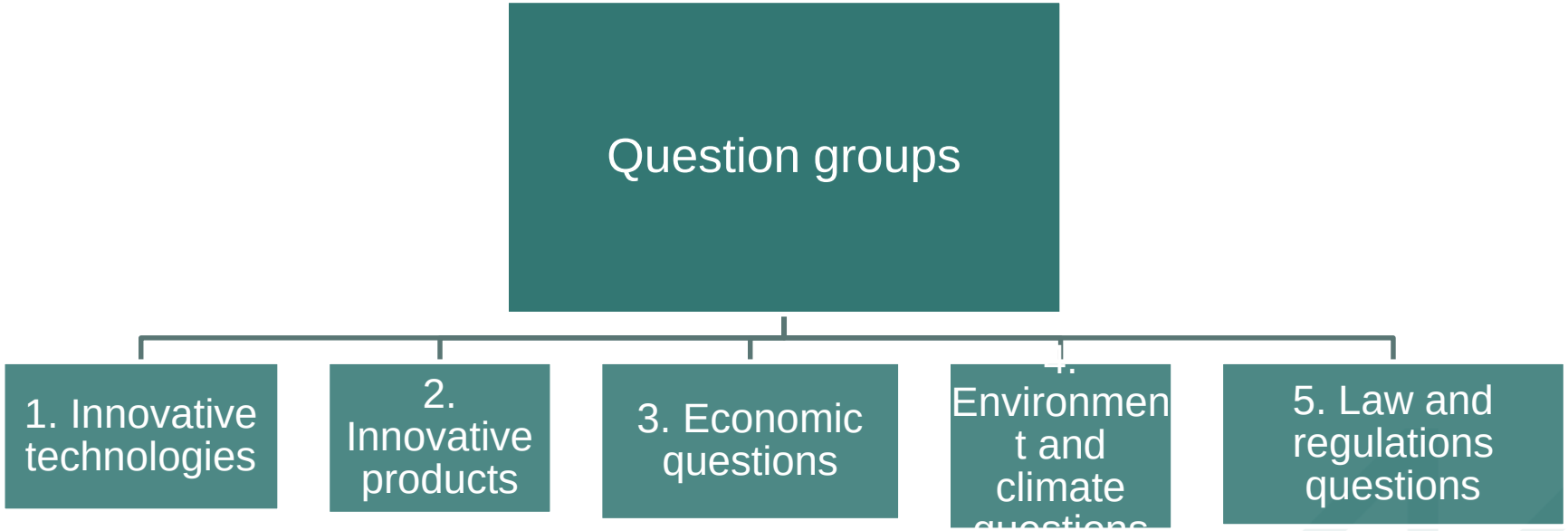
Market study results summary

- **Xylan** (xylitol) can be obtained as by-product in other production processes, xylitol as sweetener has big competition. Complex product manufacturing possibilities or manufacturing of xylan as by-product should be evaluated.
- **Bio-oil** as fuel is possible to realise, if competition advantages are improved, but it is advised to evaluate products from bio-oil with higher added value. Bio-oil use can be put to further processing in products with higher added value, for example, biodiesel (transport), phenol (rubber factories), volatile organic acids (ice-cover preclusion), additives for pharmacy and food factories, etc.
- **Lyocell** shows positive commercialization possibilities in a segment of natural fibres. Total textile fibre segment should concentrate on international market.

Before starting production and commercialization more detailed market study and analysis of business plan is necessary.

Additional research questions

Additional research questions



24 research questions are offered in a feasibility study

Conclusions

Conclusions (I)

- The golden string of LSF can be found in bioeconomy development of the forestry industry: there is a wide range of possibilities to increase price of forest resources in long term, by going step by step in exported forest resource processing in Latvia, by initializing (helping create) increased demand in local market and increased economic advantages of forest resource use.
- There are fields identified, where forestry industry organisations can work. It was done by evaluating three innovative products – textile from wood (lyocell), bio-oil and chemical products (xylan derivatives) commercialization possibilities. Separate manufacturing of one particular product, without using residues for manufacturing of other products with high added value, is not economically feasible in most cases and leave bigger effects on climate and environment. Therefore, it is suggested to evaluate manufacturing of these products in a complex system with other products (using by-products for manufacturing of other products) in detail.

Conclusions (II)

- Scientific institutions of Latvia are ready to carry out studies on manufacturing of innovative products from forest biomass, including development of new and effective technologies for globally known by-products, and their commercialization, but until now innovation development has been obstructed by:
  - lack of financial resources;
  - interdisciplinary cooperation nihility between different scientific institutions;
  - lack of studies that are oriented on results;
  - scientifically justified facts and trust, that there are adequate and suitable amounts of available bioresources in Latvia;
  - disregard of bioeconomy base principles.

- It should be continued to systematically develop innovative products and technologies commercialization possibilities by taking into account commercialization effecting factors (for example, not only economic and climate, but also political, resource and social, etc. factors) dynamic nature.

Recommendations

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Recommendations (I)

- To develop organisation (JSC «Latvia's State Forests») bioeconomy strategy, that would be a base for resource consolidation, research actions, product commercialization in short term and long term.
- Climate alignment. To help government institutions arrange climate politics questions, achieving support in carbon preservation innovative products methods acknowledgment and include these calculations in EU member states climate goals.
- Resource alignment. To make resource use study on non-coniferous wood, depending on species, use for products with high added value and on particular, incompletely used forest resource (for example, needles, barks) no residue use possibilities for manufacturing of different products with high added value.
- Manufacturing alignment. To make detailed studies on bio-oil, textile from wood and valuable chemical compound complex manufacturing possibilities in Latvia, including practical studies (development of technologies and prototypes) and business plan development for particular product manufacturing. To evaluate possibilities to establish biorefinery factory in Latvia, where forest biomass would be used as a main resource. To evaluate possibilities to renew cellulose production in Latvia for manufacturing of products with high added value, using innovative, environment and human health friendly technologies.

Recommendations (II)

- Environment alignment. To carry out a study on bioeconomy development effects on climate, environment and biodiversity, to define boundary conditions for different bioresources that can be collected from forest, without creating damages on climate, environment and biodiversity.
- To give an opportunity to representative of scientific institutions of Latvia to offer and for LSF to support local scientist created innovation development for forest biomass use to create product with high added value. To initialize scientists on result based research: for innovative products from forest biomass commercialization (from laboratory scale to product - TRL >7).

- Management alignment. Making of expert work group, including untraditionally thinking experts, for gradual and regular bioeconomy principles establishment in LSF.
- Development of information alignment, to (1) promote employer and forestry industry professional understanding and interest in sustainable forest resource use and (2) to advance society's education and involvement in forest resource eco-effective use.

Contract executors

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