

Upgrading of Existing Industrial Infrastructures to Biorefineries

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Introduction

- Challenge for many bioenergy routes: poor competitiveness compared with fossil energy
- An option for making them more cost competitive: co-production of high-value products from the same feedstocks, within biorefineries



BIOREF-INTEG

- A Coordination and Support Action project within the framework of the FP7 programme
- Funded by the European Commission
- June 2008 – May 2010



Objective

Development of advanced
BIOREFinery schemes to be
INTEGrated into existing
industrial (fuel producing)
complexes



Biomass processing sectors

- Evaluation of economical and ecological benefits of the integrated schemes in comparison to the reference case(s) of each sector

Bioethanol

Biodiesel

Pulp & paper

Conventional oil refinery

Power production

Food industry

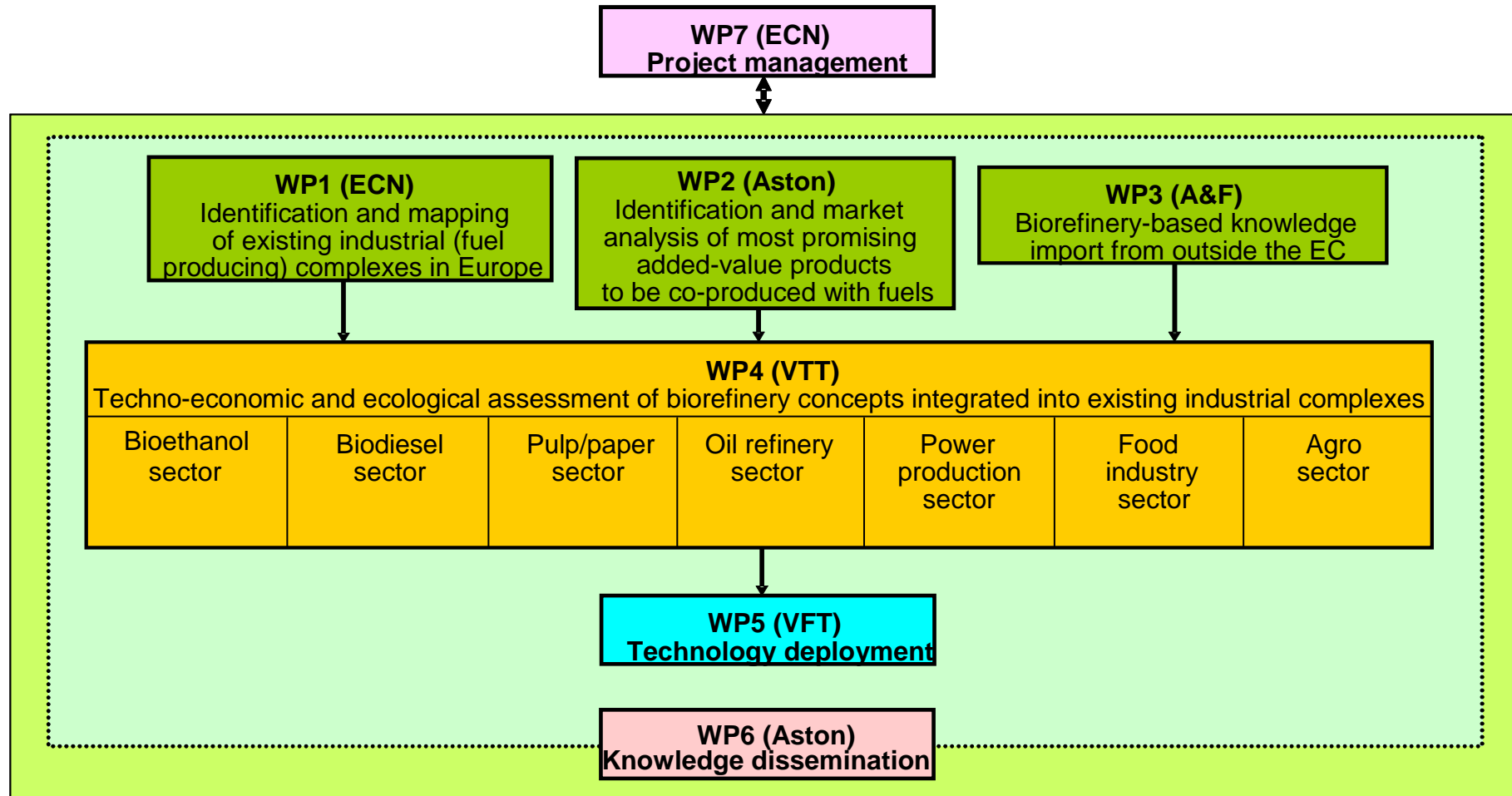
Agro sector

Partners

Industry	SME	University	RTD Institute
Abengoa Bioenergy New Technologies (ES) (Bioethanol)	ETC (SE) (Forest-based biorefinery / black liquor gasification)	Aston (UK)	VTT (FI)
Cehave (NL) (High quality animal feed)	Ten Kate (NL) (High quality animal fats & proteins)	UGent (BE)	WUR-FBR (NL)
Repsol (ES) (Conventional oil refinery)	VFT (BE) (Industrial marketing services with focus on renewable resource materials / coaching the innovation process)		Innventia (SE) (Pulp & paper industry)
	Fons Maes bvba (BE) (Biodiesel)		ECN (NL)



Work Packages



Methodology (1)

- Data collection regarding existing industrial (fuel producing) complexes in different biomass-related market sectors
- Survey mainly limited to partner-related countries (FI, SE, UK, BE, ES, NL), giving a sufficient overview of the existing complexes over the whole Europe
- 366 industrial (fuel producing) complexes identified



Methodology (2)

- Definition of the reference case(s) per market sector
- Reference case: a realistic representative (feedstock, scale, process) of the related sector
- Feedstocks reference case(s): cereals, oilseed crops, wood, milk, sugar beet, and grass
- Conversion technologies reference case(s): fermentation, transesterification, anaerobic digestion, combustion, gasification, fluid catalytic cracking, and hydrotreating

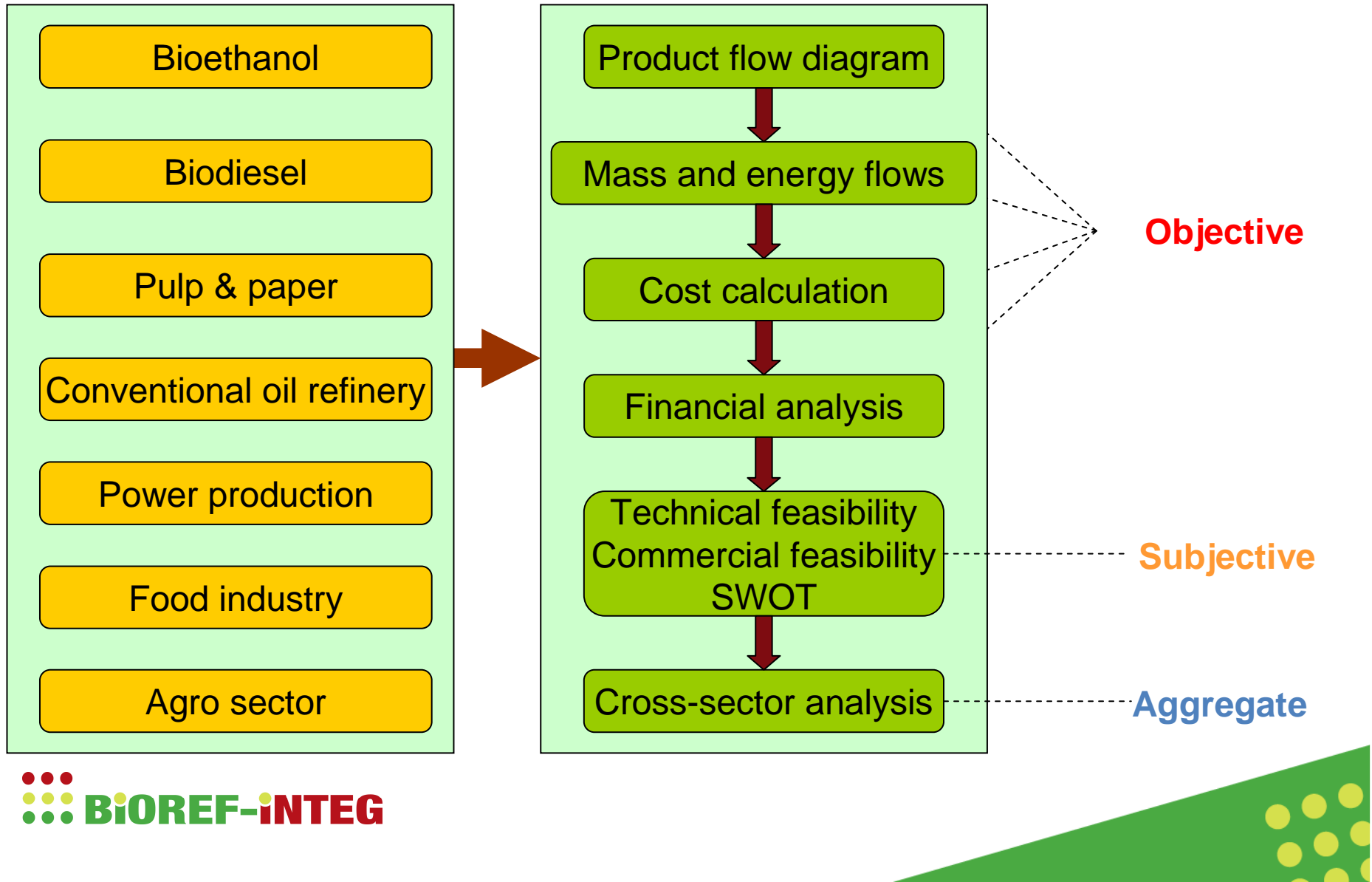


Methodology (3)

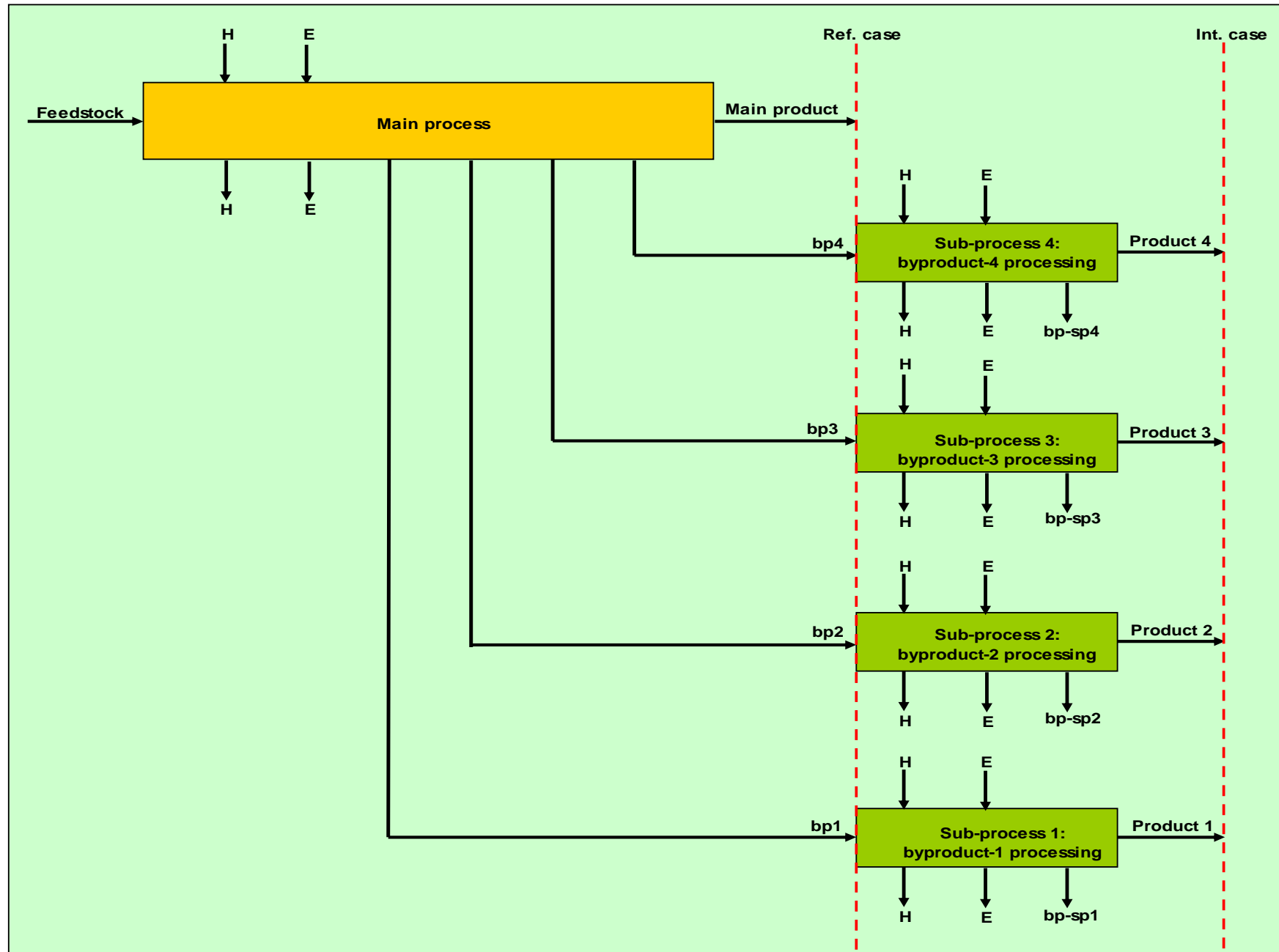
- Definition of the integrated biorefinery case(s) per market sector
- Technical, economic and (ecological) assessment
- Technology deployment



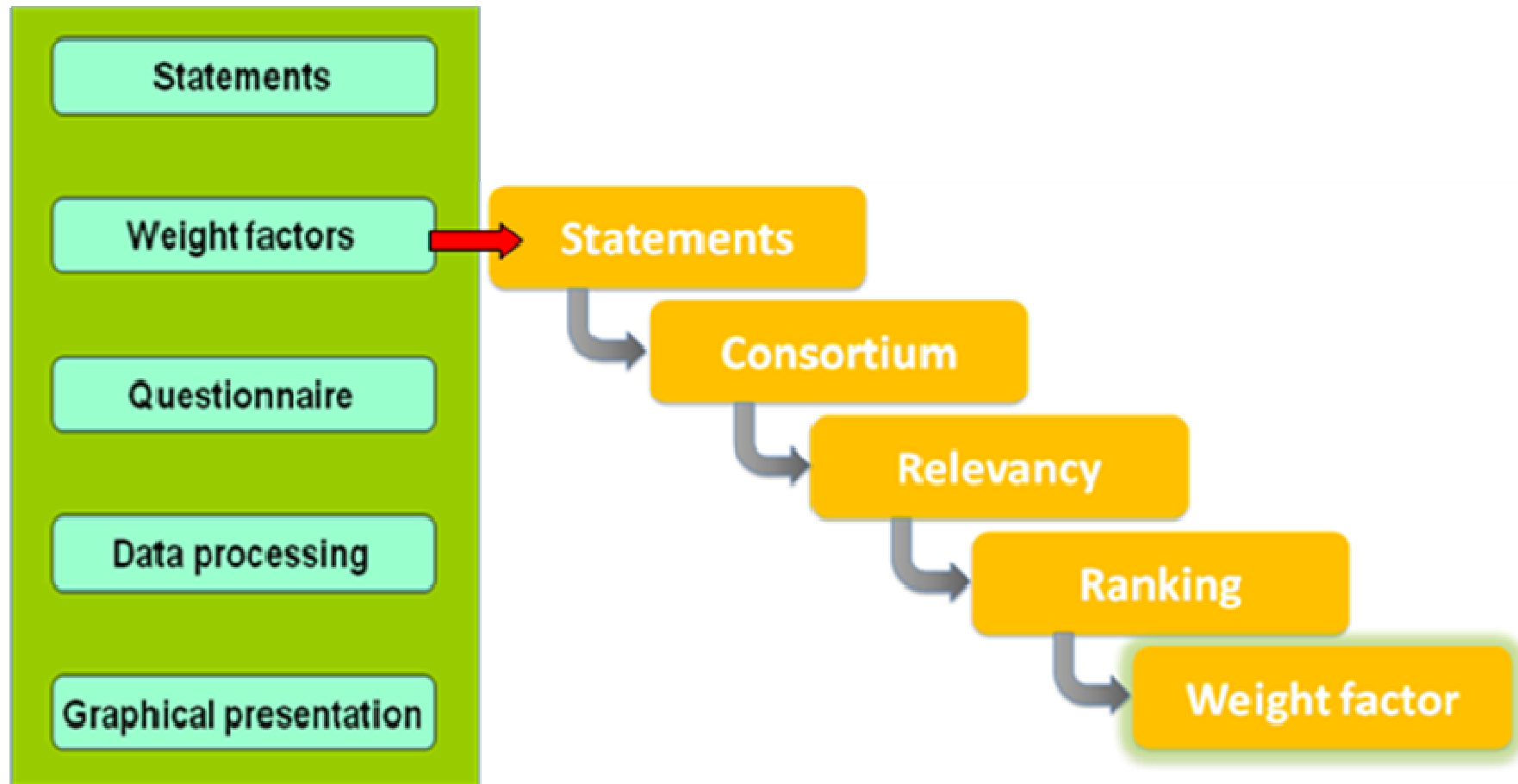
Bioref-Integ process flow



Biorefinery modeling tool



Questionnaire respondents



Statements and weight factors: TF

Statement	Weight factor
Process development	
The integrated concept does not require significant downstream processing	7
All steps of the integrated concept are well identified	7
Required technologies are already developed	6
Required technologies are proven on industrial scale	6
Process does not require toxic or hazardous auxiliaries	4
The integrated concept does not generate additional waste	4
Application development	
Most of the selected applications are already existing	6
Products can be used in most of the selected applications	3
Products are referenced in most of the selected applications	4
Secondary products are referenced in the applications	3
Technical feasibility	50



Statements and weight factors: CF

Statement	Weight factor
Project characteristics	
The integrated concept is leading to 1 new product	1
The product(s) can be used in several applications/markets	1
Market characteristics	
The integrated project addresses existing product/market combinations	4
The addressed markets are innovative (= open for new products/concepts)	2
The targeted markets are large enough to absorb the foreseen volumes	4
Competitive advantage	
Introduction of the new product(s) will lead to an economical benefit for the user	5
The new product(s) have functional benefits	5
There are specific benefits related to the integrated concept	4
Social & environmental impact	
The new product(s) is an alternative to fossil-based products	3
The integrated concept is not in competition with food supply	2
The integrated concept does not require large quantities of fresh water	2
The integrated concept is leading to additional renewable energy production	3
The integrated concept is 'LCA positive'	4
The integrated concept improves the European competitive position in a global market	3
Regulatory impact	
There are no regulatory barriers affecting the market introduction of the product(s)	3
There is a supporting EU directive promoting the integrated concept	4
Commercial feasibility	50



Questionnaire respondents

Bioethanol
Biodiesel
Pulp & paper
Conventional oil refinery
Power production
Food industry
Agro sector

6

5

4

3

5

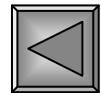
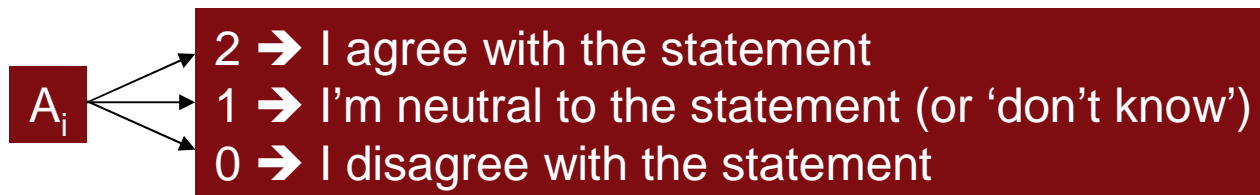
3

4



Data processing

$$\sum WF_i = 50$$



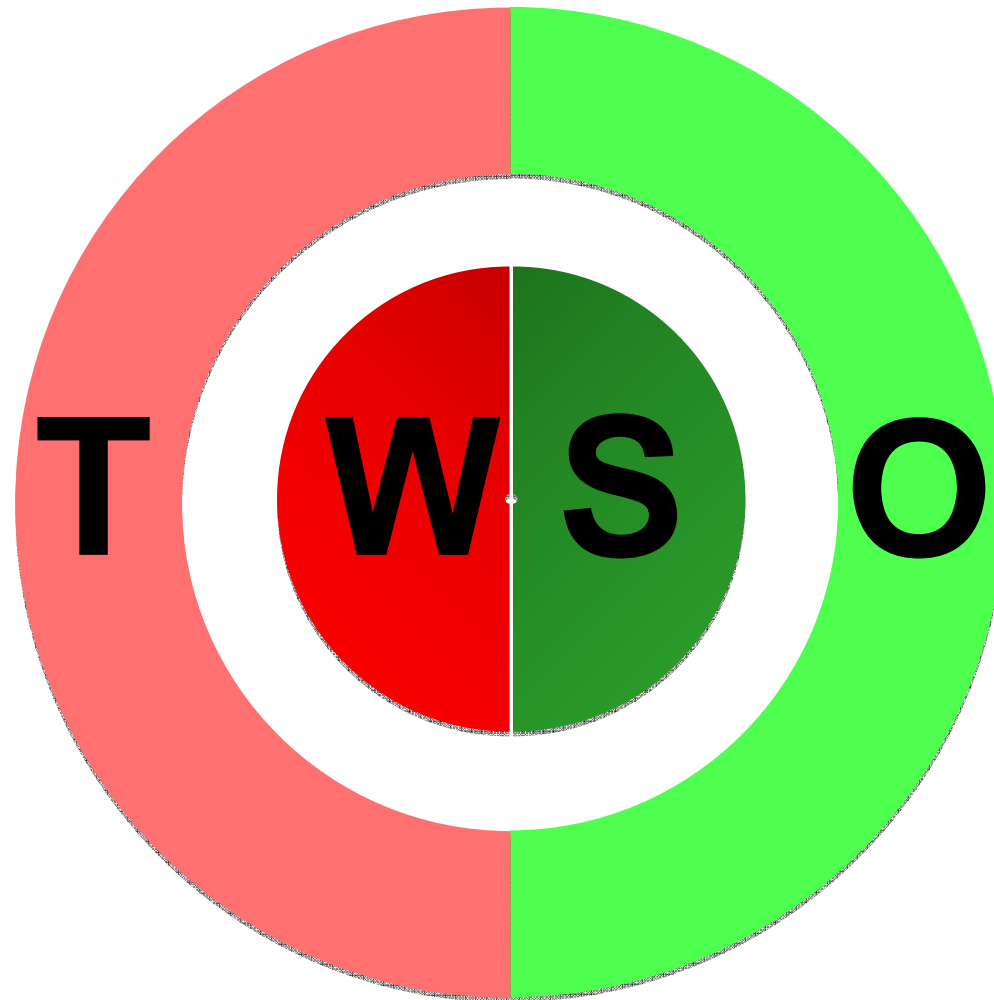
$$TF \text{ or } CF = \sum (WF_i \times A_i) \Rightarrow \text{Maximum score is 100}$$

$$TF_{\text{total}} \text{ or } CF_{\text{total}} = \sum_i (\sum_j (WF_{ij} \times A_{ij}) / \# \text{ respondents})$$

where i = a particular statement and corresponding weight factor
 j = a particular respondent



SWOT analysis



Questionnaire

Expert
committee

SWOT analysis

- **Strength:** internal; what features are improving the competitive position of the operator (compared to operators sticking to reference case)?
- **Weaknesses:** internal; what features are threatening the competitive position of the operator (compared to operators sticking to reference case)?
- **Opportunities:** external; general trends affecting the integrated concept positively
- **Threats:** external; general trends affecting the integrated concept negatively



Cross-sector analysis

- Impact level (low, medium, high)
- Required sales price to obtain an IRR of 20%
- Correlation analysis



Bioethanol sector

Reference case

- Conventional grain-to-ethanol plant

Integrated biorefinery cases

- Lactic acid production from C6 sugars
- Ethanol production from DDGS via AFEX (Ammonia Fiber EXpansion) pretreatment



Biodiesel sector

Reference case

- Rapeseed-based transesterification process

Integrated biorefinery cases

- Production of 1,3 propanediol from glycerol through fermentation
- Production of epichlorohydrin from glycerol according to the Solvay Process



Pulp & paper sector

Reference case

- Chemical pulp mill

Integrated biorefinery cases

- Lignin extraction from black liquor
- DME production via black liquor gasification
- Ethanol production from softwood pulp



Conventional oil refinery sector

Reference cases

- Sub processes of a conventional oil refinery:
Fluid Catalytic Cracking (FCC) /
Hydrosulfurisation process (HDS)

Integrated biorefinery cases

- Vegetable oil as partial feed of FCC unit
- Vegetable oil as partial feed of HDS unit
- Added-value products: gasoline, diesel, and kerosene



Power sector

Reference cases

- Medium scale: Conventional CHP power plant fueled with peat or biomass
- Large scale: IGCC power plant fueled with biomass

Integrated biorefinery cases

- Pyrolysis integrated in CHP
- Chemical recovery in gasification process



Food industry sector

Reference case

- Cheese manufacturing

Integrated biorefinery case

- Lactic acid production from whey



Agro sector

Reference cases

- Sugar beet refinery
- CHP system based on anaerobic co-digestion of grass and manure

Integrated biorefinery cases

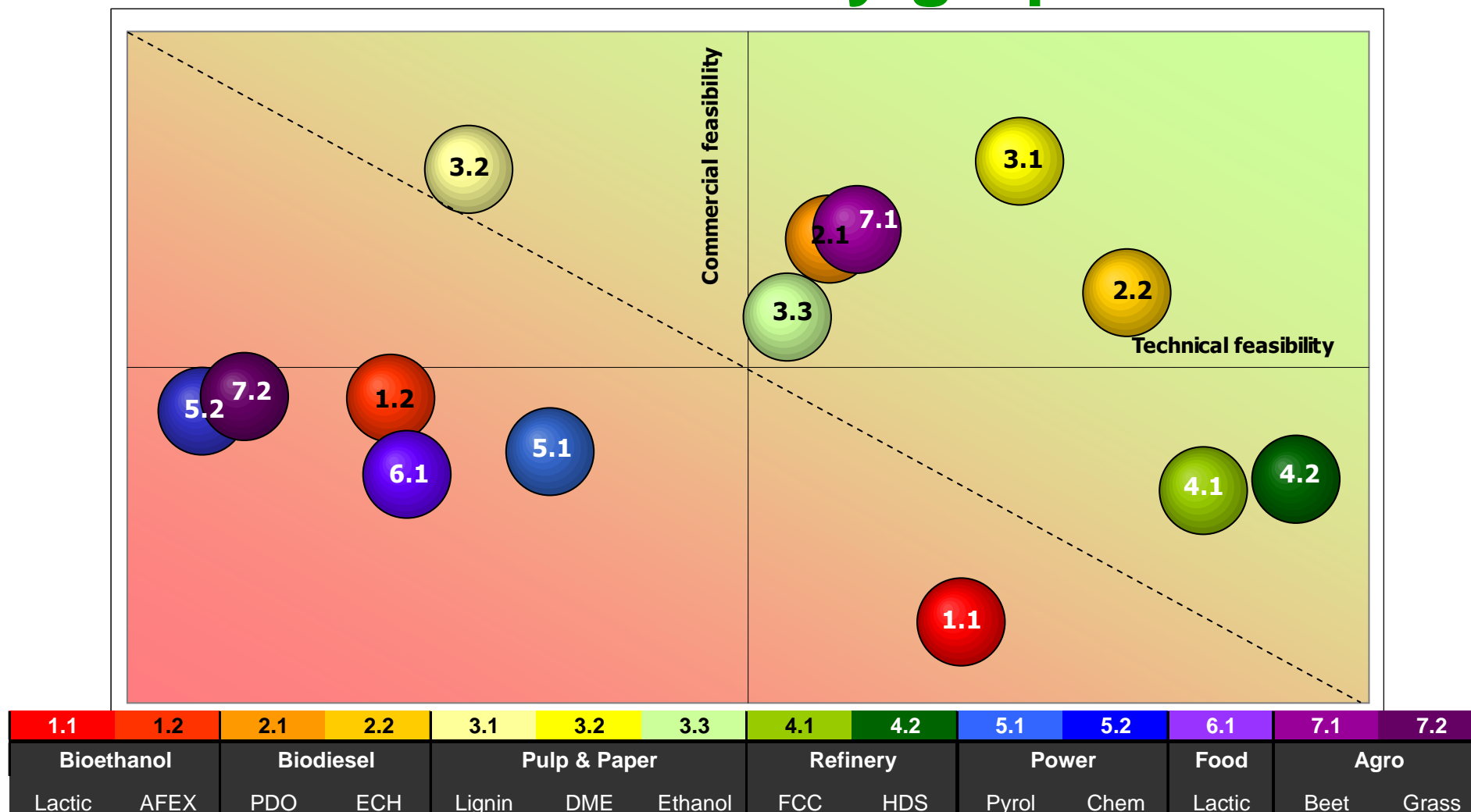
- Decentralised sugar beet biorefinery
- Grass biorefinery



Main product costs and related current market prices

	Case	Current market price	Main product cost
1	Bioethanol:reference	€800/T	€628//T
1.1	Bioethanol: lactic	€800/T	€368/T
1.2	Bioethanol: AFEX	€800/T	€577/T
2	Biodiesel: reference	€700/T	€726/T
2.1	Biodiesel: PDO	€700/T	€732/T
2.2	Biodiesel: ECH	€700/T	€668/T
3	Pulp & paper: reference	€500/T	€398/T
3.1	Pulp & paper: lignin	€500/T	€347/T
3.2	Pulp & paper: DME	€500/T	€367/T
3.3	Pulp & paper: ethanol	€500/T	€586/T
4a	Refinery: reference FCC	n.a.	n.a.
4.1	Refinery: vegetable oil FCC	n.a.	n.a.
4b	Refinery: reference HDS	n.a.	n.a.
4.2	Refinery: vegetable oil HDS	n.a.	n.a.
5a	Power: reference CHP	€50/MWh	€60/MWh
5.1	Power: CHP/pyrolysis	€50/MWh	€88/MWh
5b	Power: reference gasification	€50/MWh	€74/MWh
5.2	Power: gasification/chemicals	€50/MWh	€48/MWh
6	Food: reference	€2250/T	€1916/T
6.1	Food: lactic	€2250/T	€1441/T
7a	Agro: reference beet	€400/T	€329/T
7.1	Agro: decentralised beet	€400/T	€252/T
7b	Agro: reference grass	€50/MWh	€177/MWh
7.2	Agro: grass biorefinery	€50/MWh	€171/MWh

Cross sector feasibility graph



Subjective and objective criteria

	Subjective criteria			Objective criteria	
	Impact level	Technical feasibility	Commercial feasibility	New target sales price (for IRR 20%)	% change vs market price (for IRR 20%)
Bioethanol: reference				€775/T ethanol	-3%
Bioethanol: lactic	Low	78%	56%	€545/T ethanol	-32%
Bioethanol AFEX 80	Medium	60%	69%	€710/T ethanol	-11%
Biodiesel: reference				€765/T biodiesel	9%
Biodiesel: PDO	Low	74%	79%	€815/T biodiesel	16%
Biodiesel: ECH	Low	83%	75%	€735/T biodiesel	5%
Pulp & Paper: reference				€630/T pulp	26%
Pulp & Paper: lignin	Low	80%	83%	€550/T pulp	10%
Pulp & Paper: DME	Medium	62%	83%	€710/T pulp	42%
Pulp & Paper: ethanol	Medium	72%	74%	€990/T pulp	98%
Refinery: reference FCC				n.a.	n.a.
Refinery: veg. oil in FCC	High	86%	64%	n.a.	n.a.
Refinery: reference HDS				n.a.	n.a.
Refinery: veg. oil in HDS	High	89%	64%	n.a.	n.a.
Power: reference CHP				€150/MWh	200%
Power: CHP/pyrolyse	High	65%	66%	€185/MWh	270%
Power: reference gasification				€110/MWh	120%
Power: gasification/chemicals	High	53%	68%	€200/MWh	300%
Food: reference				€2.250/T cheese	0%
Food: lactic	Low	60%	65%	€2.050/T cheese	-9%
A gro: reference beet				€430/T sugar	8%
A gro: decentralised beet	High	75%	79%	€385/T sugar	-4%
A gro: reference grass				€280/MWh	460%
A gro: grass biorefinery	High	55%	69%	€330/MWh	560%

Cross-sector overview against average

Project type	Impact level	Technical feasibility	Commercial feasibility	Return on investment
Co-product valorisation	Low	Higher	Higher	Higher
Co-production	Low/Med/High	Higher	Average	Higher
Fermentation	Low/Med	Average	Average	Higher
Power generation	High	Lower	Average	Lower
Thermal treatment	Med/High	Lower	Lower	Lower
Legislation-driven	High	Higher	Lower	Lower



Summary /conclusions (1)

- 366 existing industrial (fuel producing) complexes in partner-related countries have been identified, and 10 market-specific reference cases have been defined.
- 14 integrated biorefinery cases for 7 considered biomass processing sectors have been defined.
- Integral technical and economic system assessments of defined biorefinery schemes have been performed.
- The Consortium tried to analyse the different biorefinery cases according to both objective (profitability measurement) and subjective (technical and commercial feasibility; SWOT analysis) criteria.



Summary /conclusions (2)

- Projects involving thermal treatment of biomass (CHP, pyrolysis, gasification) are clearly still immature and not yet industrially feasible. This appears clearly in a low technical feasibility and a negative economic value.
- Power generation (electricity from biomass) projects also have a negative evaluation (subsidies were not taken into account!). This is of course in line with the comments on thermal treatment, as frequently the same technology is used. The message to electricity-from-biomass projects is: find a value application for heat and ... keep it simple or ... change focus and produce products from biomass.



Summary /conclusions (3)

- Biorefinery projects that have the potential to improve the economics of reference cases are low impact projects (no significant impact on the reference process), fermentation projects and co-product valorisation projects. These projects frequently also have an above average technical and commercial feasibility score.
- Legislation is an important factor, driving the use of bio-based feedstock (see biofuel directive) or supporting directly biorefineries by several subsidy incentives.
- Final report: to be presented soon on the project website: <http://www.bioref-integ.eu>



**Thank you for your
attention!**

