Imperial College London

TSEC Biosys

TSEC-Biosys Theme 1 – Topic 1.1
Heat and power market segment analysis

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icept

Presentation outline

- Context and objectives
- Interfacing issues with other themes / topics
- Approach overview
- Key results and outputs

Introduction: context, objectives and fit with overall TSEC-BIOSYS

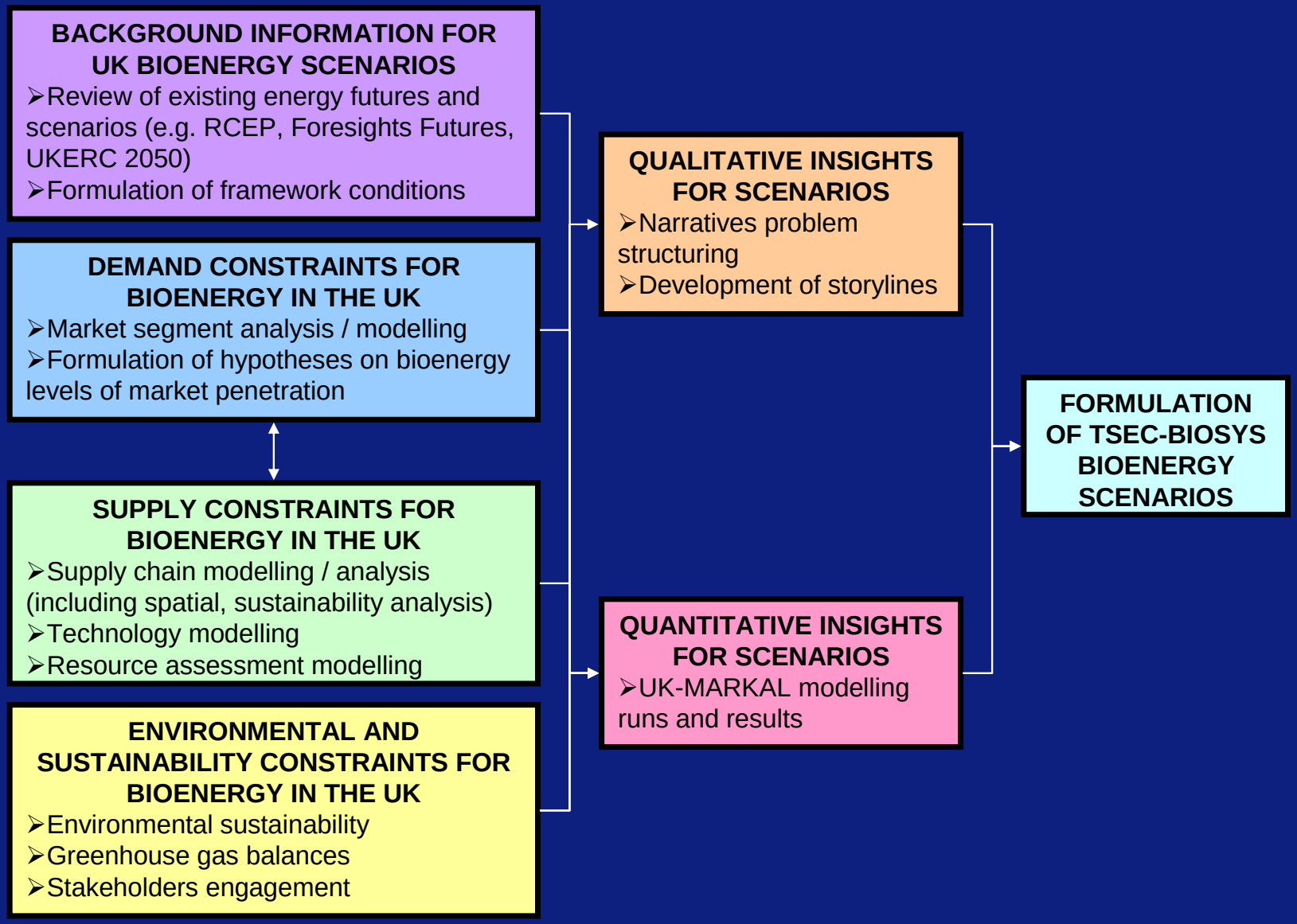
Context: why Market Segment Assessment

- Whole systems approach to take in account qualitative and quantitative factors in a systematic approach
- Comparison with outputs from Markal and aid for the development of bioenergy scenarios
- Address policy decisions (what are the “lost opportunities” for biomass, how to support it)
- Select the main barriers for biomass uptake

Objectives of the market segment analysis (heat and power)

- Define and characterise market segments in the UK heat and power markets
- Analyse which key factors influence the potential uptake of bioenergy heat and power technologies in the various market segments
- Identify which market segments appear the most promising for bioenergy heat and power
- Understand how bioenergy heat and power technologies could penetrate these segments further
- Quantify the potential demand for bioenergy heat and power (present and future)

Market Segment Analysis contribution to the formulation of UK bioenergy scenarios



Approach overview

Methodology for the market segmentation assessment

1. MARKET SEGMENTATION OF HEAT AND POWER

Segmentation of the heat-power markets based on:

- **User needs**
- **User types**
- **Geographical area**

1. MARKET SEGMENTATION OF BIOENERGY ROUTES FOR POWER GENERATION

Segmentation based on the characteristics of each bioenergy route (supply side assessment)

2. KEY FACTORS

Identification of the key factors which can affect the uptake of biomass for heat and power:

- **Technical factors**
- **Economic factors**
- **Strategic-organisational factors**
- **Regulatory-legislative factors**
- **Social factors**

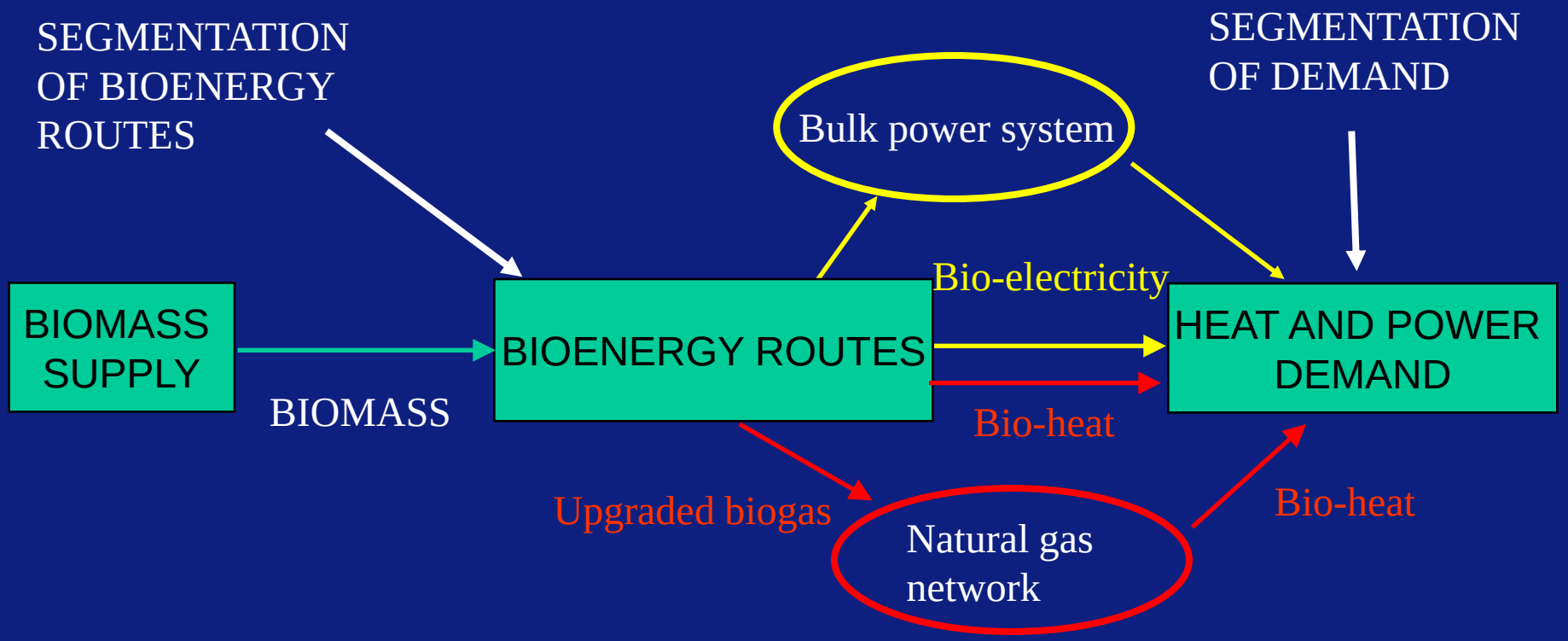
…
Factor **Y**
…

In the context of each sub-segment X, determination of whether each key factor Y provides an opportunity or a barrier for the use of a bioenergy system

3. PROMISING SUBSEGMENTS: qualitative and quantitative assessments

In comparing the results obtained for various market sub-segments it is possible to identify the subsegments that appear the most suitable for bioenergy applications

Market segmentation assessment for heat and power



Heat: segmentation of the heat demand

Power: segmentation of the electricity demand (for captive generation) and of the bioenergy routes (for grid delivered generation)

CHP: included in both the approaches

Application to the electricity sector

Market segmenting dimensions for power and CHP

BIOENERGY ROUTES

- Plant typology (Co-firing-Dedicated-Dual fuel)
- Conversion processes
- Generation technology
- Biomass typology (Solid-liquid-gas)
- Process integration (Only power-integrat into industrial facilities-biorefinery)
- De-coupling
- Biomass source (Domestic-by products - imported)
- Power plant size
- Supply chain length
- Plant operation – heat
- Plant operation-local demand
- Plant owner-operator

ELECTRICITY DEMAND

- Demand sector (Industrial-residential-tertiary-rural)
- Load size
- Yearly electricity load pattern (Seasonal-not seasonal)
- Yearly heat load pattern
- Heat load typology (low-high temperature)
- Biomass local availability
- Refurbishment (new-retrofit)
- Displaced fuel
- Plant owner

Key factors selection

Technical (T)

1.Technology reliability and maturity
2.Conversion efficiency
3.Biomass quality
4.Biomass quantity and logistics of supply
5.Space availability
6.Modularity and standardization
7.Load following option
8.Cofiring-dual fuel option
9.Amenity issues (noise, odours, emissions)

Strategic-organizational (So)

1.Biofuel security of supply
2.Biofuel price volatility
3.Organizational capability
4.Administrative issues and planning

Economic (E)

1. Electricity selling price
2.Cost of electricity (avoided cost)
3.Subsidies
4.Investment and development costs
5.Operating and maintenance costs
6.Biomass vs fossil fuel costs
7.Grid connection costs
8.Access to loans-cost of capital

Regulatory-legislative (R)

1.Reliability of incentives
2.Rules for bio-waste to energy
3.Biomass quality standards
4.Electricity market structure

Social (S)

1.Public perception
2.Awareness of real benefits
3.Employment

Other factors that influence the use of biomass for electricity

1. Alternative RES and nuclear power
2. Sustainability issues
3. Competition with other uses (food, biofuels for transport)
4. Competition among bioenergy routes

..and of course the evolution of both the energy demand and the energy supply

Key results and outputs

Selected branches for qualitative assessment– bioenergy routes

Segmenting dimension	Selected branches					
	a	*b*	*c*	*d*	*e*	*f*
Plant typology	Cofiring	Dedicated	Dedicated	Dedicated	Dedicated	Dedicated
Conversion processes	Thermal-combustion	Thermal-combustion	Thermal-gasification	Thermal-combustion	Thermal-gasification	Biological-AD
Generation technology	turbine	turbine	turbine	turbine	ICE	ICE
Biomass typology	solid	solid	solid	solid	solid	Solid-liquid
Process integration	Only power plant	Only power plant	Only power plant	Only power plant	Only power plant	Integrated industrrial facility
De-coupling	Single plant	Single plant	Single plant	Single plant	Single plant	Single plant
Biomass source	imported	Energy crops	Energy crops	Energy crops	Energy crops	By-products+energy crops
Power plant size	Extra large	large	large	medium	small	small
Supply chain length	Long	long	long	average	average	small
Plant operation - heat	Only electricity	Electricity driven CHP	Electricity driven CHP	Electricity driven CHP	Electricity driven CHP	Electricity driven CHP
Plant operation-local electricity demand	No on site electricity demand	No on site electricity demand	No on site electricity demand	Baseload high	Baseload high	Baseload high
Plant owner-operator	IPP	IPP	IPP	IPP	IPP	IPP

Selected branches for qualitative assessment – electricity demand segmentation

Segmenting dimension	Selected branches						
	a	*b*	*c*	*d*	*e*	*f*	*g*
Demand sector	industrial	industrial	tertiary	tertiary	resident	resident	rural
Load size	medium	medium	small	medium	micro	micro	micro
Yearly electricity load pattern	Not seasonal	Not seasonal	Not seasonal	Not seasonal	Not seasonal	Not seasonal	Seasonal
Yearly heat load pattern	low	medium	low	Medium	Medium	low	Medium
Heat load typology	High T	High T	Low T	Low T	Low T	Low T	Low T
Biomass local availability	No	Yes	No	No	No	No	Yes
Refurbishment	New	New	New	retrofit	Retrofit	New	New
Displaced fuel	Electr.	Electr.	Electr.	gas	Electr	Electr.	Electr.
Plant owner	Energy consumer	Energy consumer	Energy consumer	Municipality	ESCO	Consumer	Energy consumer

Results of qualitative assessment

Symbol	Meaning
o	neutral
++	strong opportunity
+	opportunity
-	barrier
- -	strong barrier
?	an advantage or a barrier case to case
empty	not pertinent for that market segment

		bioenergy routes						electricity demand						
Key factor	code	a	b	c	d	e	f	a	b	c	d	e	f	g
technology reliability	T1	++	+	+	o	-	+	+	+	-	o	--	--	--
conversion efficiency	T2	++	o	+	o	+	+	+	++	+	++	-	--	-
biomass quality	T3	+	o	o	-	-	-	o	++	-	-	-	-	o
logistics supply	T4	o	-	-	-	-	-	-	++	o	o	-	-	++
space availability	T5	o	-	-	o	o	-	+	+	-	-	--	-	++
modularity	T6									?	?	?	?	?
load following	T7													
dual fuel option	T8	o	o	o	+	+	+	+	+	+	+	+	+	+
amenity issues	T9	+	-	+	-	+	o	+	+	-	-	-	--	+
security supply	St1	-	?	?	?	?	++	?	++	?	?	?	?	++
volatility price	St2	-	?	?	?	?	++	?	++	?	?	?	?	++
organization	St3	+	-	-	-	-	-	+	+	-	o	-	-	+
permitting	St4	++	?	?	?	?	?	+	+	o	--	o	o	+
value electricity	E1	?	?	?	?	?	?	o	o	+	+	+	+	+
cost electricity	E2							?	?	?			?	?
subsidies	E3	+	+	+	+	+	+	+	+	+	+	+	+	+
investment	E4	++	-	-	-	--	-	o	o	-	-	--	--	-
O&M cost	E5	++	-	-	-	-	-	+	+	o	+	-	-	-
biomass cost vs fossil	E6	?	--	--	--	--	+	o	++	o	--	o	o	++
grid connection	E7	++	o	o	-	-	-	++	++	o	+	o	o	-
access loans	E8	++	o	o	-	-	-	+	+	o	o	o	--	--
subsidy reliability	R1	+	?	?	?	?	?	?	?	?	?	?	?	?
bio-wastes rules	R2	?					?	?	?					
biomass standards	R3	?	o	o	o	o	?	?	o	?	?	?	?	o
market structure	R4	?	?	?	?	?	?	?	?					
public perception	So1	o	-	-	+	+	+	o	o	+	+	+	+	o
awareness benefits	So2							o	o	+	+	+	+	o
employment	So3	-	++	++	+	+	+	o	o	+	+	o	o	o
TOT		++	-	-	+	-	+	+	++	+	-	-	--	+

Quantitative assessment

Bioenergy routes market segmentation:

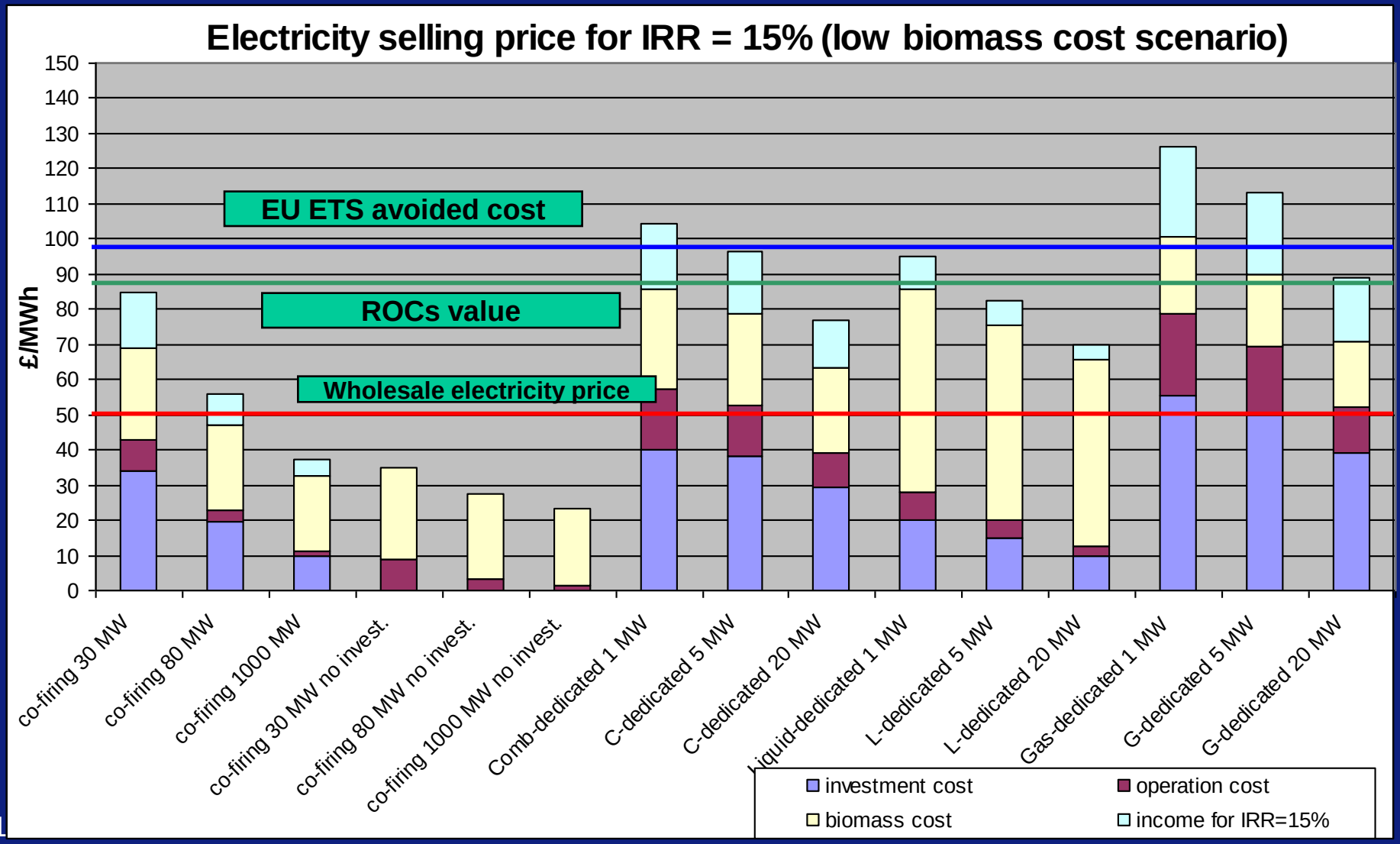
Assessment of levelized cost of electricity for different bioenergy routes for a comparison with other energy sources

Power and heat market segmentation:

Assessment of the economic profitability of heat and power generation from biomass in the different energy demand segments

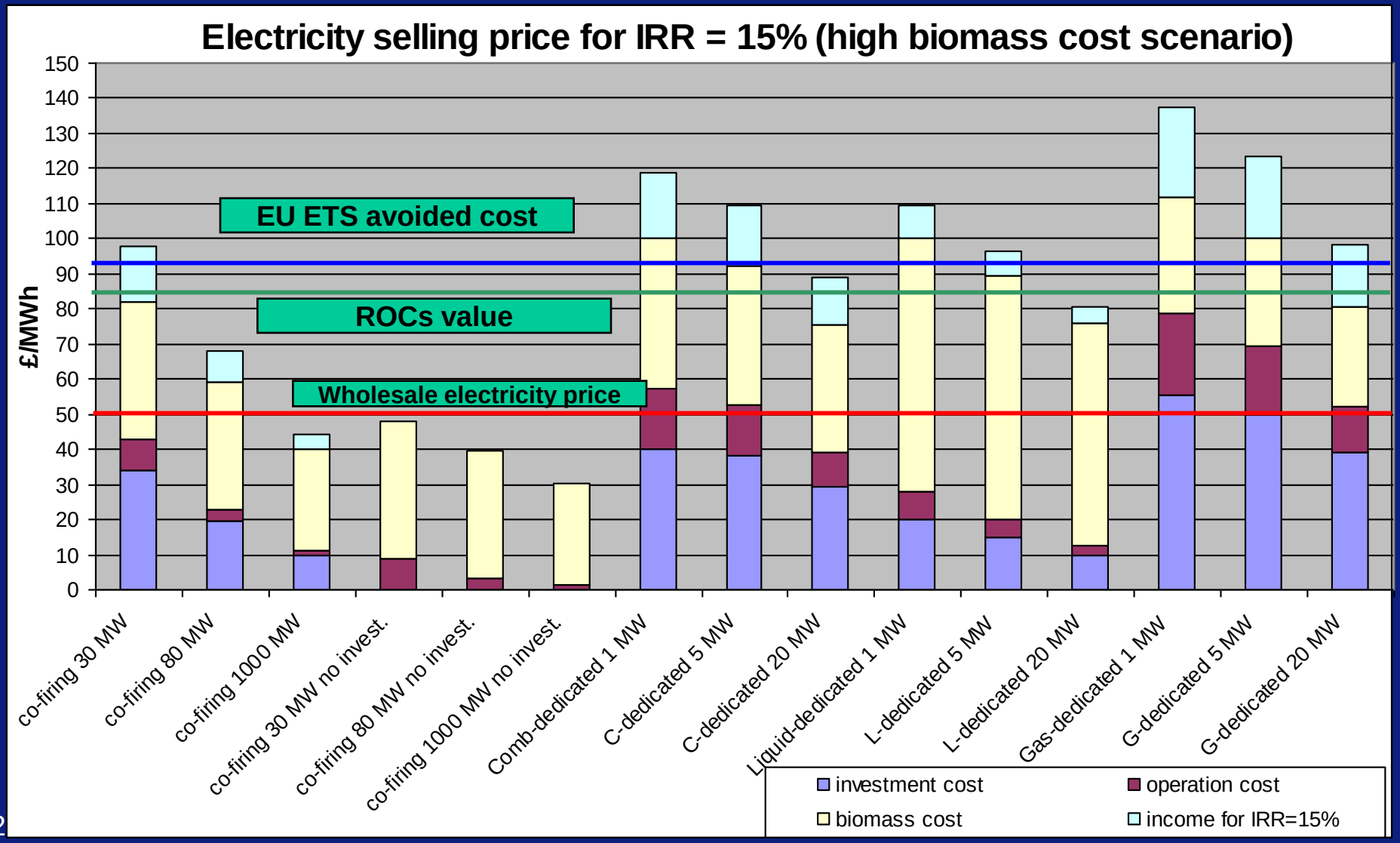
Competitiveness of biomass power plants (I)

Results of the quantitative assessment for grid delivered generation



Competitiveness of biomass power plants (II)

Results of the quantitative assessment for grid delivered generation



Most promising bioenergy routes

Brownfield plants – integrated into industrial processes – use of by-products – flexibility of supply – local heat demand – ROCs banding

Market segment	Positive KF	Negative KF
Cofiring	Technology reliability-Investment cost-efficiency-permitting-logistics	Subsidy (banding)
Biological-AD processes	Technology reliability-ROCs banding	Biomass quality
Large dedicated-combustion	Technology reliability- ROCs banding	Logistics-
Large-dedicated-gasification	Efficiency-ROCs banding	Reliability technology-biomass quality-logistics-
Large-dedicated-bio oil	Technology reliability, efficiency	Biomass price volatility-public perception (sustainability)
By-products fired plants	Biomass cost-security of supply	Bio-wastes rules amenity issues-public perception-planning
CHP	Efficiency, public perception	Investment, heat demand

Least promising bioenergy routes

Micro and small plants – high cost biomass (energy crops)

Market segment	Positive KF	Negative KF
Small-combustion (ORC, Stirling)	Heat demand, value of energy	efficiency-investment-O&M-amenity issues-
Small-gasification (ICE)	Heat demand, value of energy	Reliability technology-efficiency-investment-O&M-amenity issues
Small-biooil (ICE)	Heat demand, value of energy, reliability technology, efficiency	Amenity issues-biomass price volatility
Energy crops fired plants	Public perception-occupation-security supply-ROCs banding	Biomass costs

Most promising electricity demand segments

High and constant heat demand pattern – high cost of displaced fuel – on site biomass availability (rural-industrial sectors)– new facilities (for district heating)

Market segment	Positive KF	Negative KF
Industrial-large load	Efficiency (heat and power demand)-Amenity issues-	storage availability-
Industrial with biomass availability (food -beverage)	Security supply-biomass cost-amenity issues-efficiency	Bio-wastes rules-
Tertiary-large loads	Efficiency-high value of energy	logistics-storage availability-amenity issues-investment
Tertiary-new plants	Efficiency-high value of energy-investment	logistics-storage availability-amenity issues
Residential-high cost displaced fuel	High value of energy	Technology reliability - logistics-storage availability-amenity issues
Rural-biomass availability	Security supply-biomass cost-amenity issues-efficiency	Local heat and power demand - grid connection – access to loans
Rural-high cost displaced fuel	High value of energy-amenity issues	Local heat-power demand - grid connection – access to loans

Least promising electricity demand segments

No heat demand – micro and small applications – low cost of displaced fuel – refurbishment (district heating)

Market segment	Positive KF	Negative KF
Industrial-low heat demand	amenity issues	Efficiency-storage availability-
Tertiary-refurbishment	High value of energy-efficiency	Investment (district heating)
Tertiary-displaced gas	Public perception-subsidies	Cost of biomass-logistics-storage
Residential-micro	Heat demand, value of energy	Technology reliability-efficiency-investment-O&M-amenity issues

Thank you for your attention!

Comments – residential sector

- Main opportunities: high value of energy, heat and power demand
- Main obstacles: low efficiencies and high costs of conversion technologies, gas grid availability, logistics, storage, low energy density, environmental impact

Comments – tertiary and public sector

- Main advantages: high value of heat and electricity, aggregation of heat and power demand, heating and cooling systems (high electricity load factors); district heating and cooling mainly for new facilities
- Main disadvantages: space for storage, logistics and biomass handling-treatment, environmental inpact, high refurbishment costs

Comments – rural sector

- Main advantages: space availability, biomass availability, no access to gas network
- Main obstacles: no access to electricity grid, grid connection rules, low energy intensity

Most promising market segments – grid delivered

- Co-firing the most interesting option (great opportunity for the coal sector)
- Large scale dedicated biomass plants where low cost biofuels are available
- CHP plants near to: i) heat demand, ii) biomass production, iii) existing industrial plants, storage areas and biomass handling systems
- Alternative to other RES to reach the target of 20% RES with appropriate ROC value, after 2010

Preliminary findings about bioelectricity

- Very complex and multidisciplinar sector
- Biomass supply is one of the main issues, and there are a lot of biomass sources available, with very different supply costs and market scenarios
- There are a lot of technological options
- Legislative framework in UK not favourable to dedicated biomass plants, as the low ROC value does not balance the high costs of biomass (**banding**?)
- Social acceptance, financing systems, economic and logistic constraints hinder the development of dedicated plants

Segmenting dimensions – bioenergy routes

Segmenting dimensions	OPTIONS
Plant typology	Co-firing vs Dedicated vs Dual-fuel
Conversion processes	Thermal (combustion, gasification, pyrolysis) vs Biological (Anaerobic Digestion, esterification)
Generation technology	Turbine (steam, gas, EGT, ORC) vs Engine (gas, diesel, stirling) vs Fuel cells
Biomass typology	Solid vs liquid vs gas
Process integration	Only power plant vs Plant integrated into industrial facilities vs biorefinery
De-coupling	Single plant for biomass treatment and electricity generation vs large biomass treatment plant to supply biofuel to small generators
Biomass source	Domestic dedicated vs domestic by-product vs imported biomass
Power plant size	Small (< 1 MW) vs Medium (< 5 MW) vs Large (< 20 MW) vs Extra-large (> 20 MW)
Supply chain length	Small chain (biomass production and energy conversion within 5-10 km) vs Average chain (only 1 biomass transport from production to energy conversion in a collection radius up to 60-80 km) vs Long chain (several steps from biomass production to final energy conversion)
Plant operation - heat	Heat driven CHP vs electricity driven CHP vs only electricity
Plant operation-local demand	Peak load vs load following vs baseload low vs baseload medium vs baseload high vs no on site electricity demand
Plant owner-operator	IPP vs ESCO vs municipality vs biomass supply company

Segmenting dimensions – electricity demand

Segmenting dimensions	OPTIONS
Demand sector	Industrial vs residential vs tertiary vs rural
Load size	Micro (<50 kW) vs Small (< 500 kW) vs Medium (< 5 MW) vs large (> 5 MW)
Yearly electricity load pattern	Seasonal vs not seasonal
Yearly heat load pattern	None vs low (<20%) vs medium (<40%) vs high (>40%)
Heat load typology	Low temperature vs high temperature
Biomass local availability	Yes vs no
Refurbishment	New vs retrofit plant
Displaced fuel	Electricity (from the grid) vs on site generation from natural gas vs on site generation from coal or other fossil fuels
Plant owner	ESCO vs municipality vs energy consumer

Key factors – technical (code T)

1. *Technology reliability and maturity*
2. *Conversion efficiency*
3. *Fuel supply constraints: biomass quality*
4. *Fuel supply constraints: biomass quantity and logistics of supply*
5. *Space availability (storage, pre-treatments, etc)*
6. *Modularity and standardization*
7. *Load following option*
8. *Cofiring-dual fuel option*
9. *Amenity issues (noise, odours, particulate, emissions)*

Key factors – strategic-organizational (code St)

1. *Biofuel security of supply*
2. *Biofuel price volatility*
3. *Organizational capability*
4. *Administrative issues and planning*

Key factors – economic (code E)

1. *Wholesale electricity price or electricity buy-back tariffs (in case of decentralized generat.)*
2. *Cost of electricity (avoided cost for on site generation)*
3. *Subsidies (ROCs, ETS, LEC, CCL, net metering..)*
4. *Investment and development costs*
5. *Operating and maintenance costs*
6. *Biomass vs fossil fuel costs*
7. *Grid connection costs*
8. *Access to loans-cost of capital*

Key factors – regulatory-legislative(code R)

1.Reliability of incentives

2.Rules for bio-waste to energy

3.Biomass quality standards

4.Electricity market structure

Key factors – social (code So)

1.Public perception

2.Awareness of real benefits

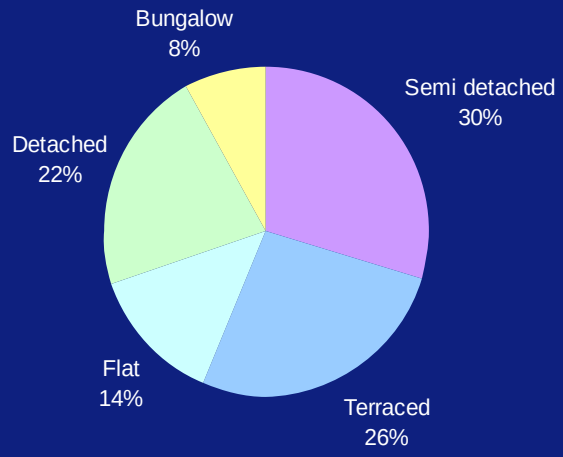
3.Employment

Examples of results of the analysis
Residential heat sector

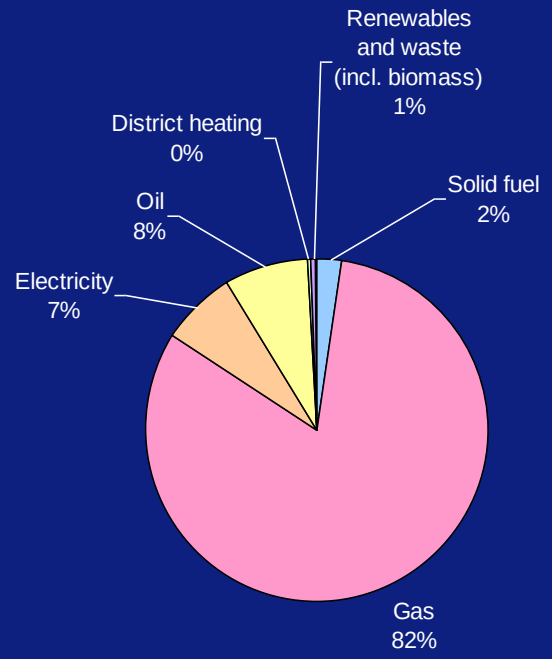
Starting with a macro-segmentation (sector level)…

The example of the residential heat market

1. Segmentation by dwelling types



2. Segmentation by fuel (for heat) supply option

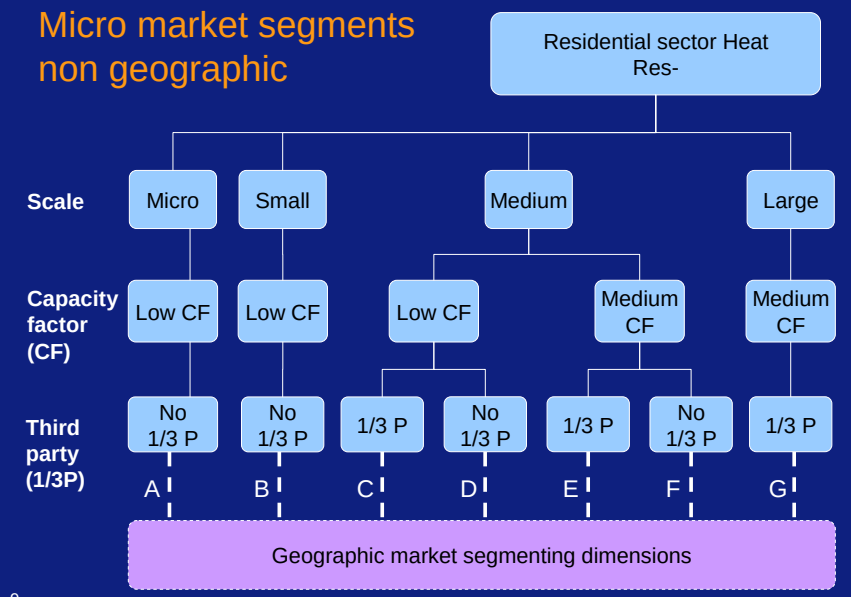


…then a micro-segmentation (application level)…

The example of the residential heat market

1. Non-geographic segmentation

2. Geographic



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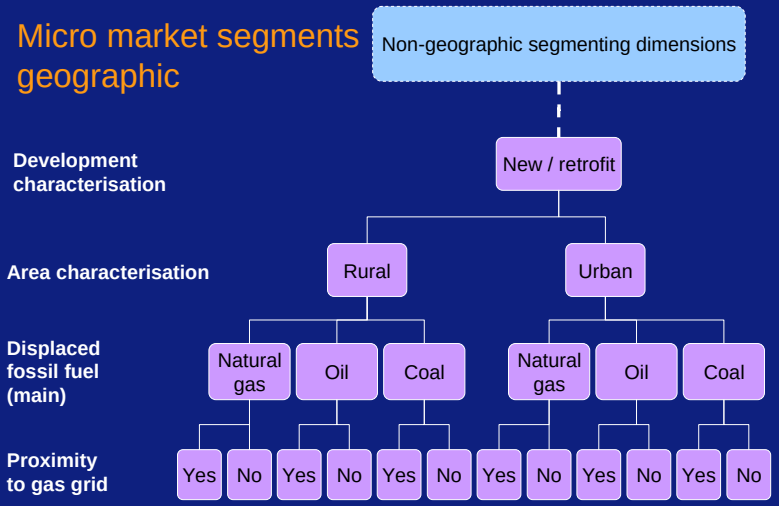

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…linking both macro and micro segmentations (residential heat example)…

A	55%	Individual house or flat
A*	< 0.1%	
B	34%	Big individual house / mansion, small apartment building, small private district heating with a few dwellings
B*	<0.1%	
C	0.1%	Medium apartment building , medium residential-only private district heating
C*	<0.1%	
D	7%	Big country estate or property (for residential purpose)
D*	<0.1%	
E	0.1%	Medium district heating system with mixed users (including commercial / service activities)
E*	<0.1%	
F	0.1%	Medium district heating system with mixed users (including commercial / service activities)
F*	<0.1%	
G	0.3%	Large district heating system with mixed users (including commercial / service activities)
G*	0.2%	

…we apply qualitative and quantitative tools to the market segments (residential heat)…

Key factors																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
o	o	o	o	- -	- - / - / o	o / +	o	+	o	-	- / - -	x	o	o	o	x	x
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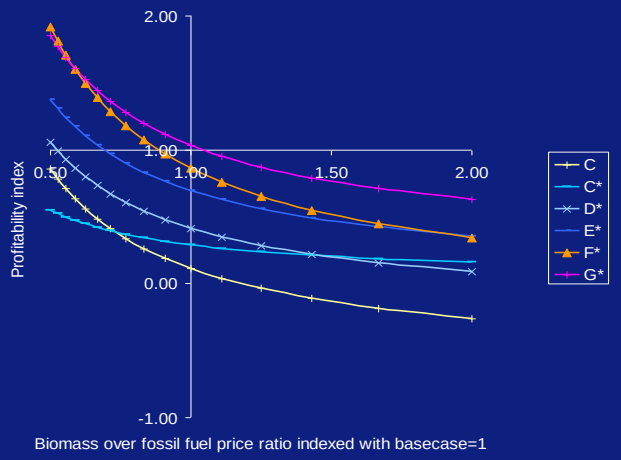


… and obtaining hypotheses of potential bio-energy demand via sensitivity analysis (example of residential bio-heat)…

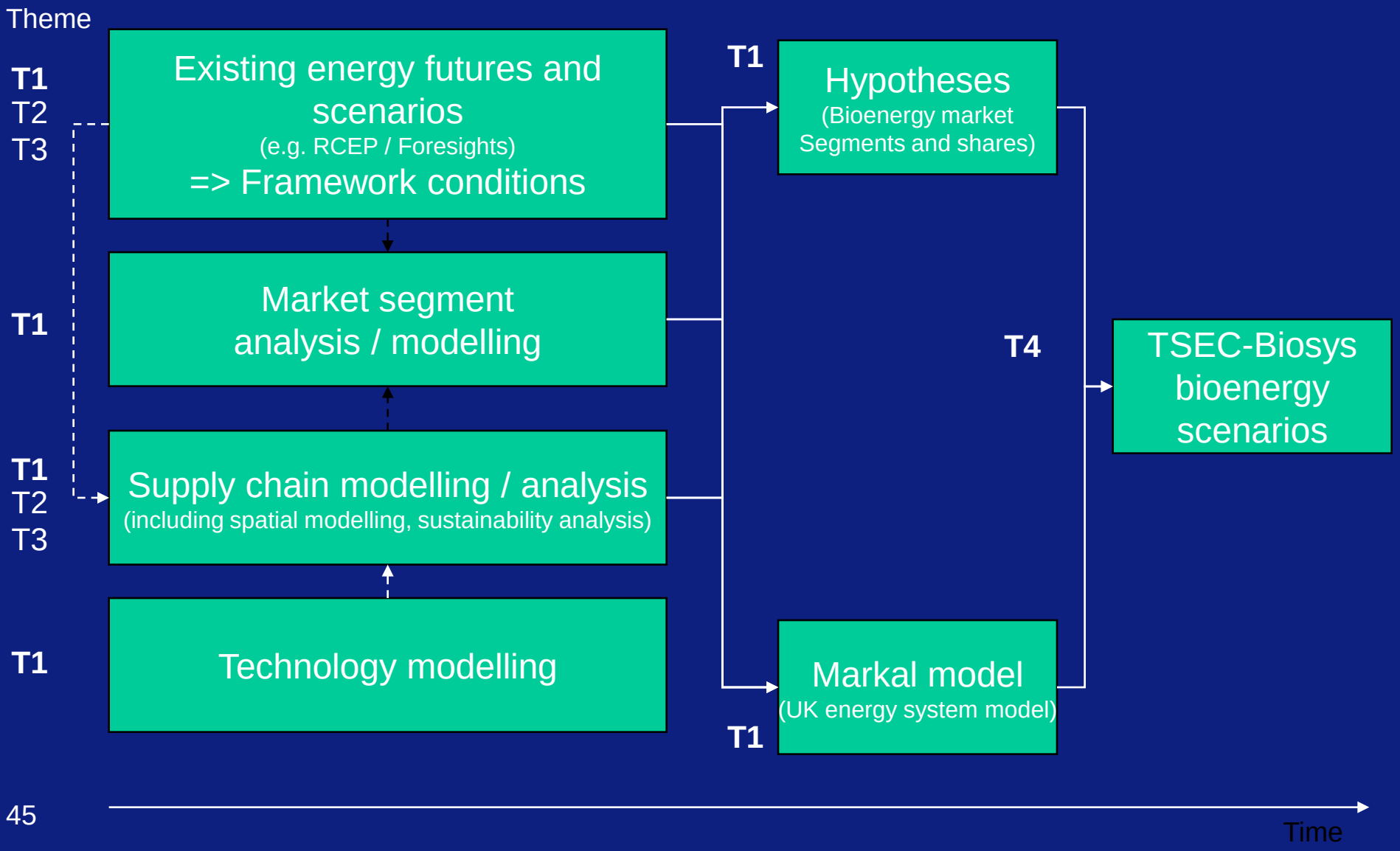
Hypotheses	Estimated potential (residential heat sector) – present penetration < 1%
Conservative	2.6 % (considering strong technical and economic constraints on the potential)
Middle-case	8.3% (allowing more flexibility on the technical and economic conditions for penetration)
Optimistic (very)	30.5% (considering technical and economic potentials less sensitive to barriers)

Next steps

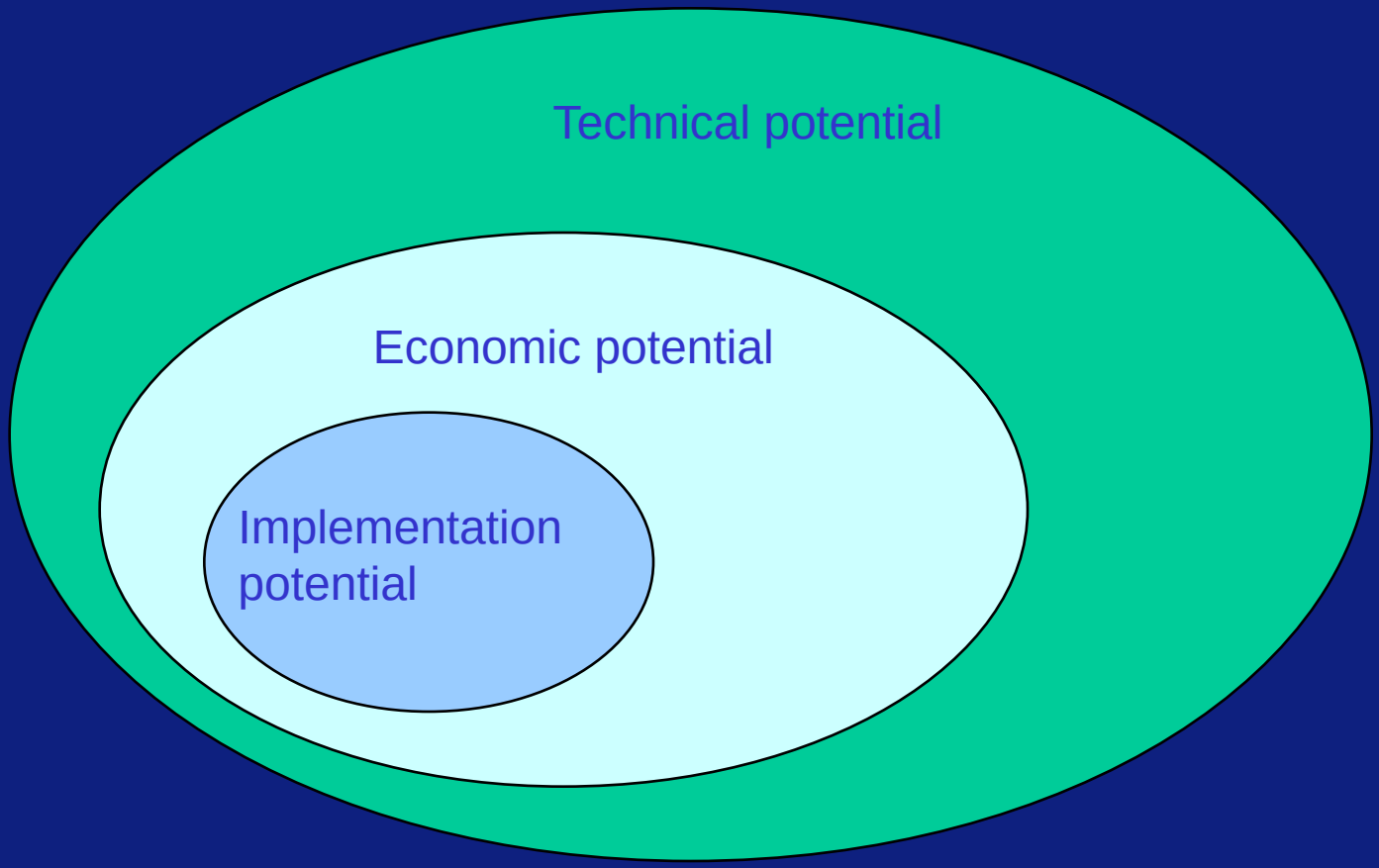
Next steps

- Refining and applying the quantitative tool: link with supply chain modelling, sensitivity analysis (to address uncertainties)
- Formulating hypotheses of potential demand for the industrial and commercial sector, based on similar approach
- Linkage with Markal analysis and scenario formulation for TSEC-BIOSYS

Defining bioenergy scenarios in TSEC-Biosys



Estimating the potential bioenergy demand



April-Nov 06

July-Dec 06

Jan-June 07

June-Dec 07

First half 08

Step I-1: Market segmentation
- Identification of heat users' needs and market segments
- Develop profiles of resulting market segments

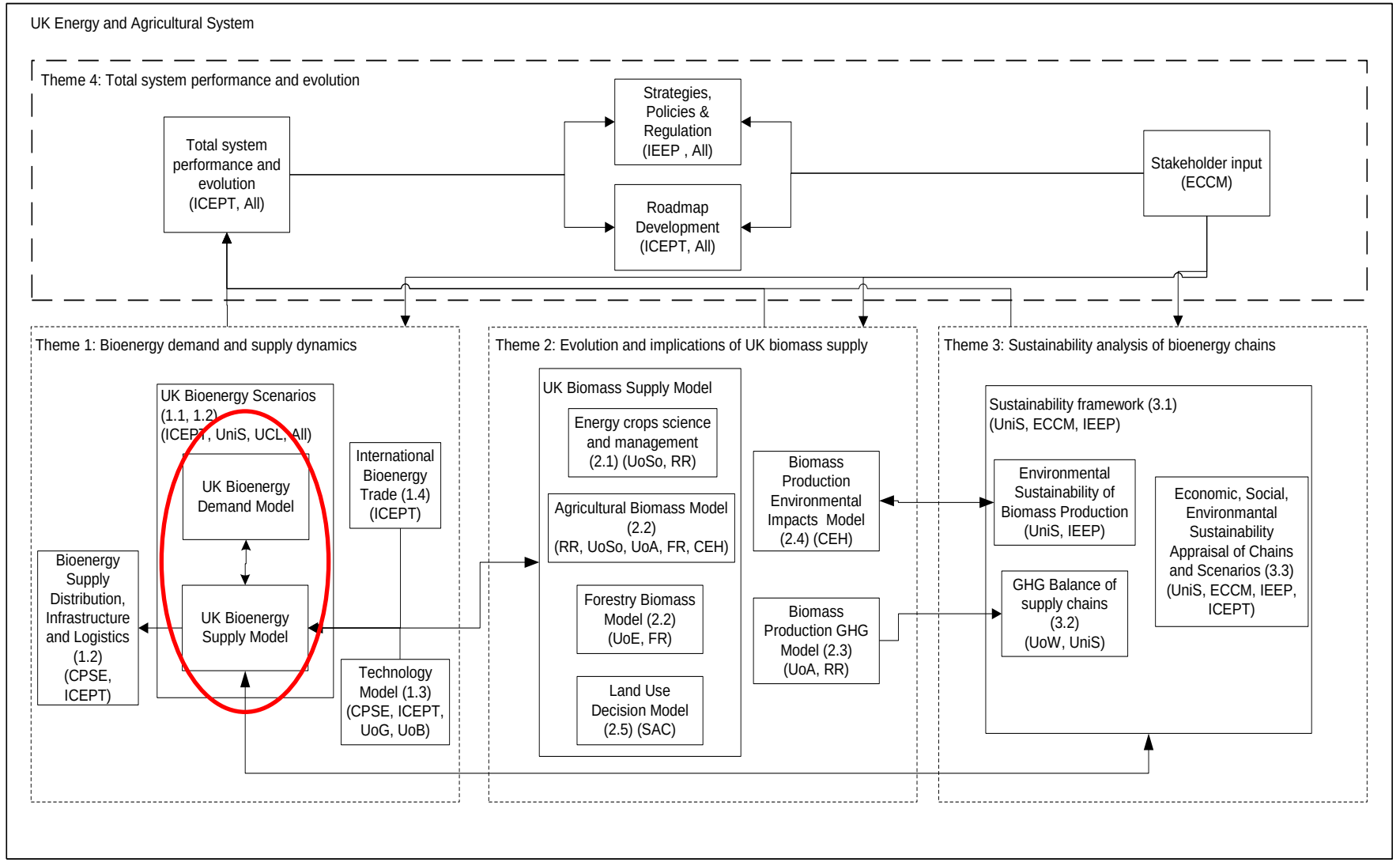
Step I-2: Key factors identification and classification
- Identification of differential advantages/disadvantages in each segment
- Classification of the data relevant with assessing potential market penetration

Step I-3: Interaction of key factors with market segments
- Evaluation of the attractiveness of each segment to bio-heat
- Ranking of the market segments with their sensitivity to key factors

Step I-4: Potential bio-heat demand (at present)
- Development of framework conditions for conservative and optimistic cases of potential demand
- Assessment of the potential demand in the various cases considered

Step I-5: Hypotheses on bio-heat demand in the future (2030 / 2050)
- Assessment of possible evolutions and related uncertainties with regards to market segments (structure, size, etc.), and key factors
- Formulation of explorative scenarios ("hypotheses") of potential bio-heat demand for the long-term future

Link with the TSEC BIOSYS whole system analysis <SJ: I think that this slide should be replaced by the slide included hereafter…>



SJ: I think that we should remove that slide as we have explained this linkage already in the section where we present the methodology…

Interface with other themes / topics

Link with other topics / themes

SJ: I think that we should remove that slide as we have a more updated one in the section where we present the methodology…