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Energia da biomasse: possibili integrazioni in sistemi energetici urbani

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Sommario

- ***Esempi di integrazione bioenergia in aree urbane***
- ***Specifici problemi di ricerca***
- ***Metodologia di ottimizzazione e principali risultati***
- ***Potenzialità dell'integrazione con infrastrutture esistenti***
- ***Modelli di business innovativi per biomass-ESCOs***
- ***Conclusioni e potenzialità per bioenergia in aree urbane***

Bioenergia in aree urbane: alcuni esempi

GLA targets: *London Bioenergy Report - 100,000t/y of wood from arboricultural operations.. ≈12MWe, 1.3% electricity demand by CHP fired by urban lignocellulosic products*

National grid vision: AD and gasification by organic urban wastes, 1.5 Mt/y CO_2 avoided, 10 plants for 8 TWh/y biomethane

Biogas networks in rural communities Germany, Austria (20 km) - Bioethanol pipelines Brasil

Bio-oil chains: recovery of waste cooking oils for CHP (1 MWe for 500,000 inhab)

District heating systems fired by chips, pellets, torrefied biomass (Northern Europe)

Air pollutions in urban areas and biomass (old boilers-retrofit)

Room for optimization:
Transport biomass, biogas/bio-oil, biomethane or energy?
Distributed AD plants or centralized units? Coupling vs decoupling of processes
How urban areas should evolve to facilitate the integration of bioenergy?
What are the most suitable BeR for the various urban areas configurations?
Integration of BeR into existing infrastructures (cofiring-retrofit)

Examples – GLA targets

Combustion of wood for energy, AD organic wastes,

*"The "**London Bioenergy Report**" produced for the London Tree Officers Association by Econergy estimated that **100,000t/y** of wood from **arboricultural operations** could be recovered for energy generation within London. This wood will be dispersed across London and would be most suited to use in heat producing boilers or relatively small- scale CHP schemes.."*

*"We have estimated the quantity of potential clean wood fuel that could be recovered from **civic amenity sites** as 10% of the quantity of waste passing through the civic amenity site system. This gives about **50,000t/y** of suitable material across London…"*

"We have also estimated actual and prospective biomass arising from forestry and energy crop (coppice, SRC) sources, in and around the Greater London area..."

***Green Future:** Maximum attention is given to deployment of wood-to-energy schemes. Some wood from forestry sources around London is used to augment the sources outlined above. **Between 6-40 schemes (≈12MWe) could be deployed**.*

AND

Sustainable Waste Management Policies**: This scenario assumes that 50% of suitable MSW is treated through AD, leading to the deployment of between 10-30 plants with an installed capacity of around **13 MWe

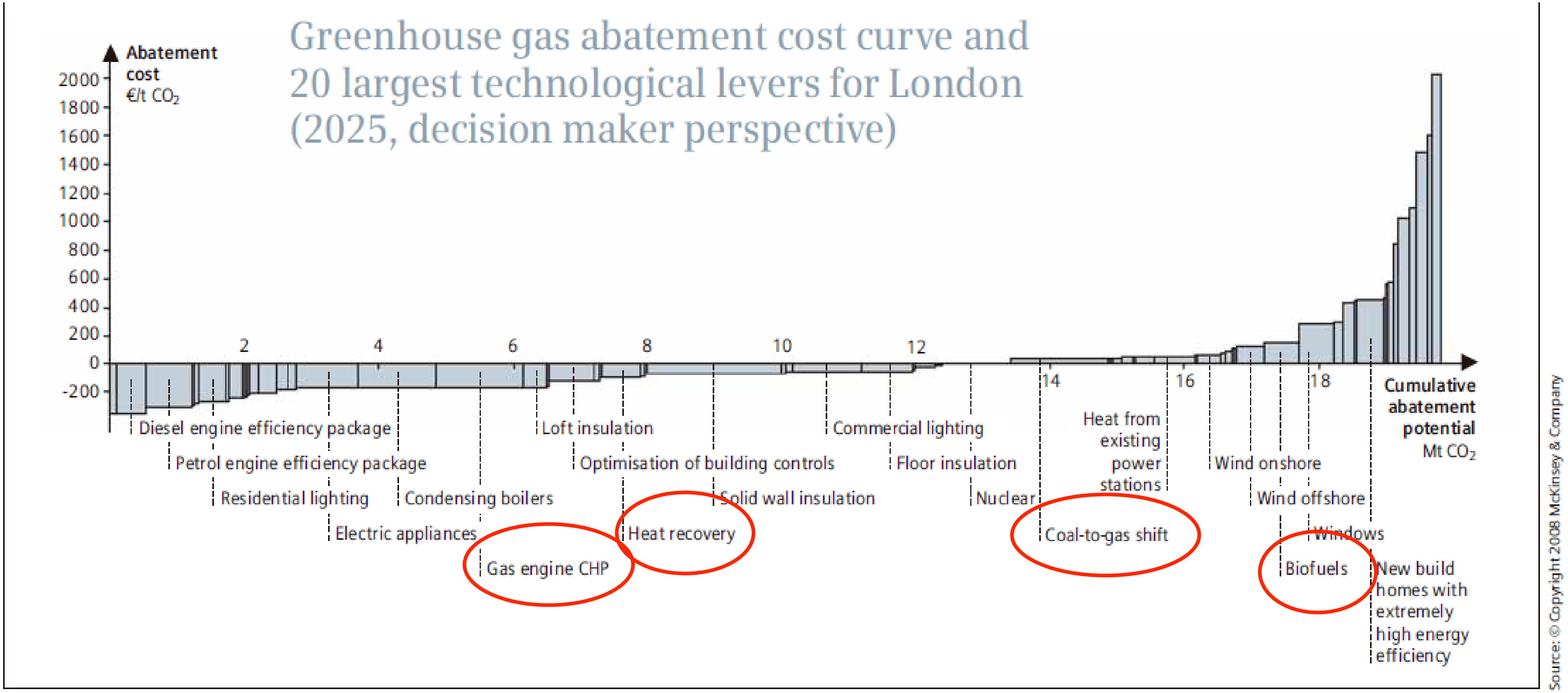
AND

***Energy from AD of sewage sludge**: an additional 5 AD schemes could be put in place London-wide, with an installed capacity of around **10 MWe**;*

Overall GLA electricity consumption **31 TWh/y** about **1.3% of electricity** demand satisfied by **biomass CHP** with urban lignocellulosic by-products

Examples – GLA targets

Combustion of wood for energy, AD organic wastes,



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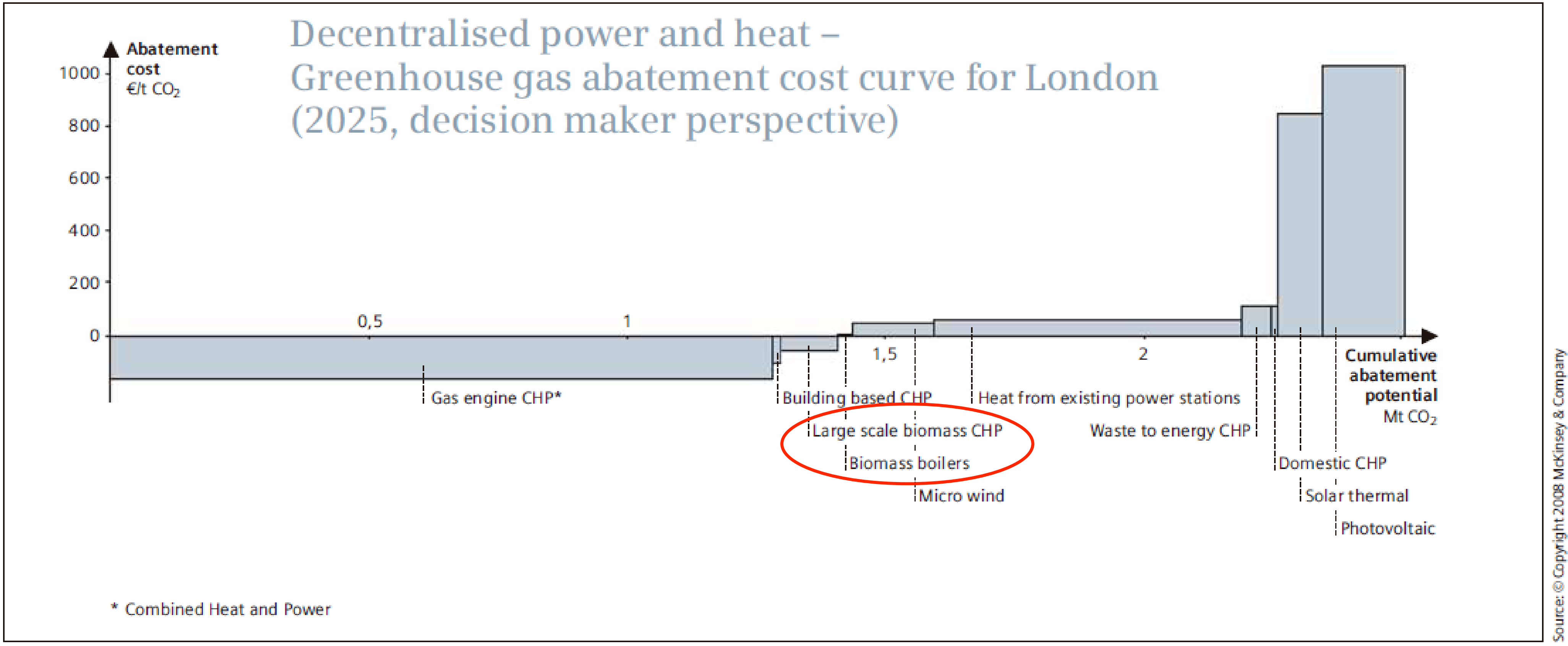
Examples – GLA targets

Combustion of wood for energy, AD organic wastes,



Overall GLA electricity consumption **31 TWh/y** about **1.3% of electricity** demand satisfied by **biomass CHP** with urban lignocellulosic by-products

Examples – rural municipalities

Decentralised AD plants and local biogas networks

The German city of Braunschweig (near Hannover) has built a large biogas complex with a dedicated, 20 kilometer pipeline since 2007. The unpurified biogas is pumped to a CHP plant to serve the local municipality, using both heat and power

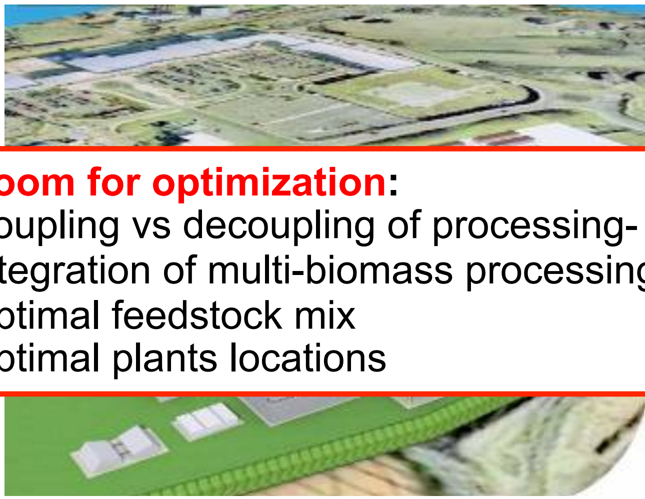
This proved to be more profitable than transporting heat or upgrading to biomethane

Replicated in Burgenland – Austria, with 15 municipalities

Served by a biogas grid with 4 Ad plants

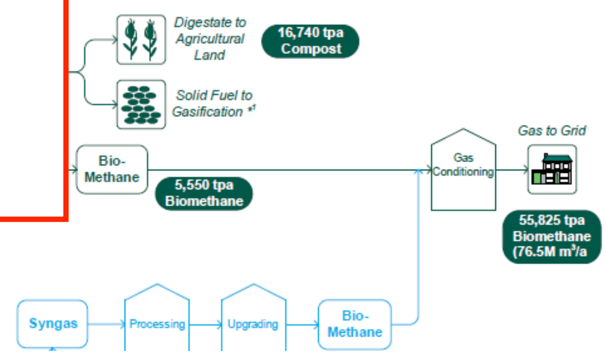
Room for optimization:
Transport biomass, biogas, biomethane or heat?
Several distributed AD plants or a centralized unit?
Several distributed CHP plants with biofuel transport
Biogas networks or centralized plant with DH network?
Some constraints:
low energy density of biomass-seasonality
Heat demand to increase global process efficiency

National Grid – the renewable gas urban energy centre concept



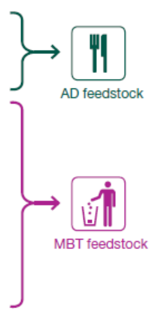
*Renewable gas produced from waste biomass or energy crops via **AD digestion** or **gasification** can be **injected into the gas network to deliver "green heat"** to urban areas*

Room for optimization:
Coupling vs decoupling of processing- energy conversion systems
Integration of multi-biomass processing technologies
Optimal feedstock mix
Optimal plants locations

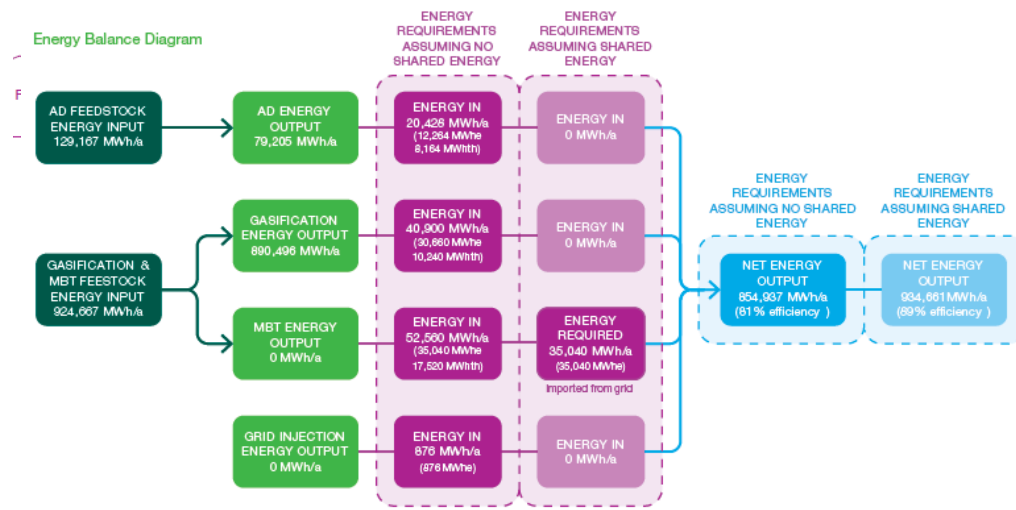


Energy Centre feedstock volumes

	Site Catchment		Greater London Area	
	Minimum (tonnes)	Maximum (tonnes)	Minimum (tonnes)	Maximum (tonnes)
Municipal Food Waste	4,317	64,310	37,859	493,763
C&I Food Waste	27,351	41,026	235,000	399,566
Municipal Green Waste	20,250	75,659	193,076	580,897
Municipal Separated & Co-Mingled	30,186	232,923	277,783	1,788,334
Municipal Black Bag[5]	444,337	71,445	3,228,411	365,418
C&I Separated & Co-Mingled	n/a	n/a	1,003,333	1,505,000
C&I Black Bag	511,355	767,032	4,211,000	5,398,573



[5] Minimum volumes exceed maximum volumes as the maximum scenario assumes that all local authorities implement source-segregated kerbside collections and achieve a 70% household participation, leading to less black bag (mixed unsorted waste) being generated.



Examples – bio-oil chains

Collection and refining of waste cooking oil

PROJECTS

OILPRODIESEL Life Project: 2005-09

ECOBUS Life Project 2002-04

Copacabana district vegetable cooking oil recovery

PLANTS IN OPERATION

Graz (AU): 15 kt biodiesel produced by urban waste cooking oil

ASM Rovigo (IT): 300 t/y collected from markets

POTENTIALS: 1.5-2.5 kg/ y per capita; 250-350 kg/y average restaurant

Consumption: 2,000 t/y for 1 MWe CHP plant (city of about 500.000 inhab.)

Room for optimization:
Biodiesel for transport vs refined bio-oil for CHP
Centralized refining vs cofefining vs decentralized upgrading near conversion plants
Heat vs CHP; engines vs turbines
Centralized generation vs decentralized plants and pipelines for biomass transport

Existing use of biomass and sustainability

Social perception of bioenergy

Impact of bioenergy on local air quality – regulatory issues

Air emission from biomass transport

Attention to environmental issues and incorporating them in modelling

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LCA of domestic and centralized bi
The case of Lombardy (Italy)

S. Caserini, S. Livio, M. Giugliano, M. Grosso, L. R...

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Planning for increased bioenergy use—Evaluating the impact on local air quality

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Room for optimization:
Retrofit opportunities of old boilers to pellet fired efficient systems

Specifici problemi di ricerca

Upgrading a biofuels: drying, storage, densification to stabilised biofuels

Logistica: storage (land use), transports (influence of biomass quality matters, supply chains dynamics and seasonality), connections with hinterland

Aspetti ambientali: air emission levels, transports

Domanda energetica: heat/cool/power, energy density, energy demand patterns and biomass seasonality

Integrazione con sistemi esistenti : existing networks and infrastructures, old biomass boilers retrofitting, cofiring and dual fuelling

The general research question

- How best integrate bioenergy in UES: holistic approach involving supply chains, energy demand, infrastructure, business models, thermo-economic studies
- Modelling: Optimize size, location, operation of processing and energy conversion plants
- Trade-offs: Decoupling vs coupling; centralized vs distributed; dedicated vs dual fuel; brownfield vs greenfield
- Specific issues: biomass quality, bioenergy processes, logistics, emissions, urban planning restrictions
- Capture the key factors of UES and bioenergy supply chains
- Assess limits of modelling approach that justify holistic approaches

Spatial modelling of bioenergy in UES: AIMMS based tool

AIMS

Whole systems modelling framework to capture key issues of BE in UES (storage, drying, processes decoupling, transport, air emission, baseline scenario)

Strategic and operational modelling assessment (what investment where, where DH competitive with sparse boilers, where biomass competitive with NG)

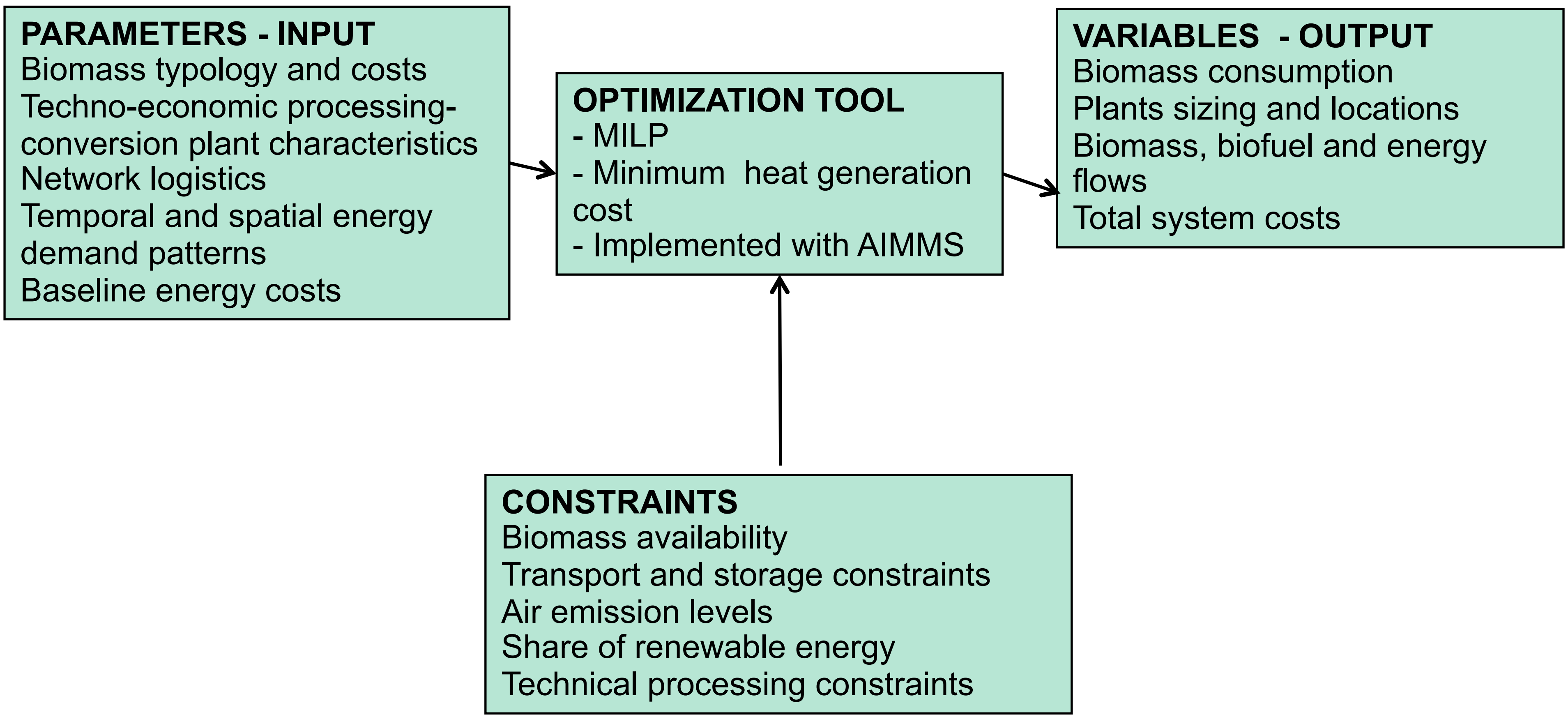
Spatially and temporally explicit multi-biomass multi-process optimization model

Influence of urban energy demand, city texture, existing infrastructures and energy systems

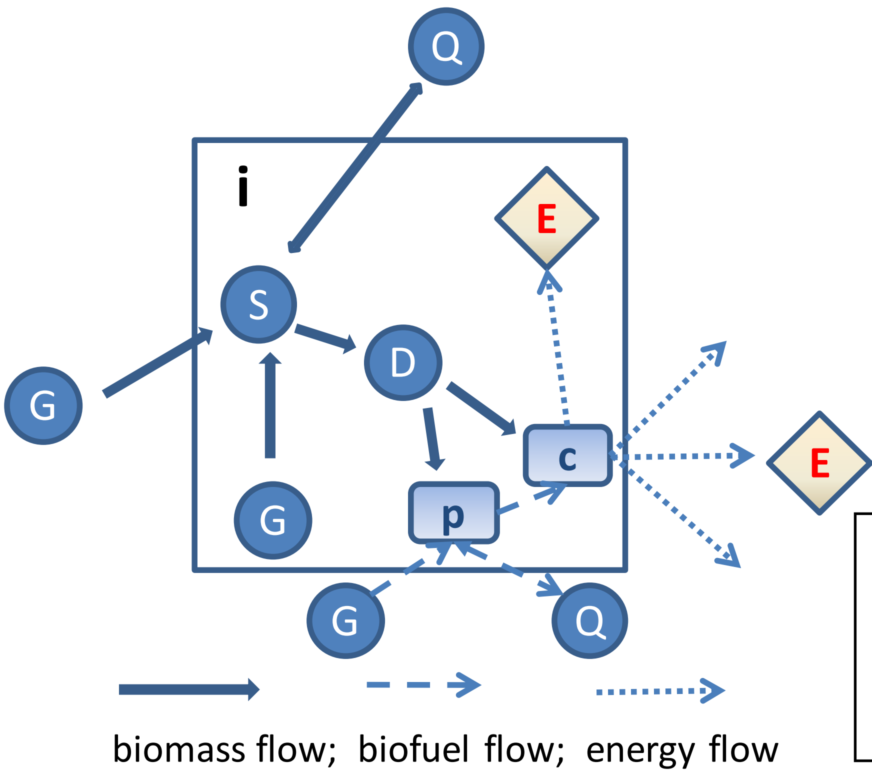
INNOVATION

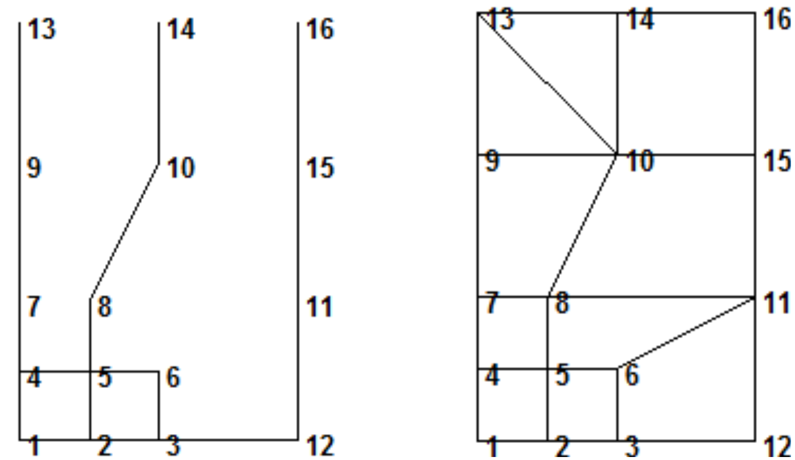
- No literature on bioenergy modelling for UES and specific trade-offs
- Strategic and operational planning are not addressed at the same time
- Model designed to be flexible to a broad range of processes and energy conversion
- Optimization of DH and NG networks based on specific length per load served
- Integration of biomass - natural gas; modelling biomass-biofuel process decoupling

Spatial modelling of bioenergy in UES: AIMMS based tool



Structure of the model and input data





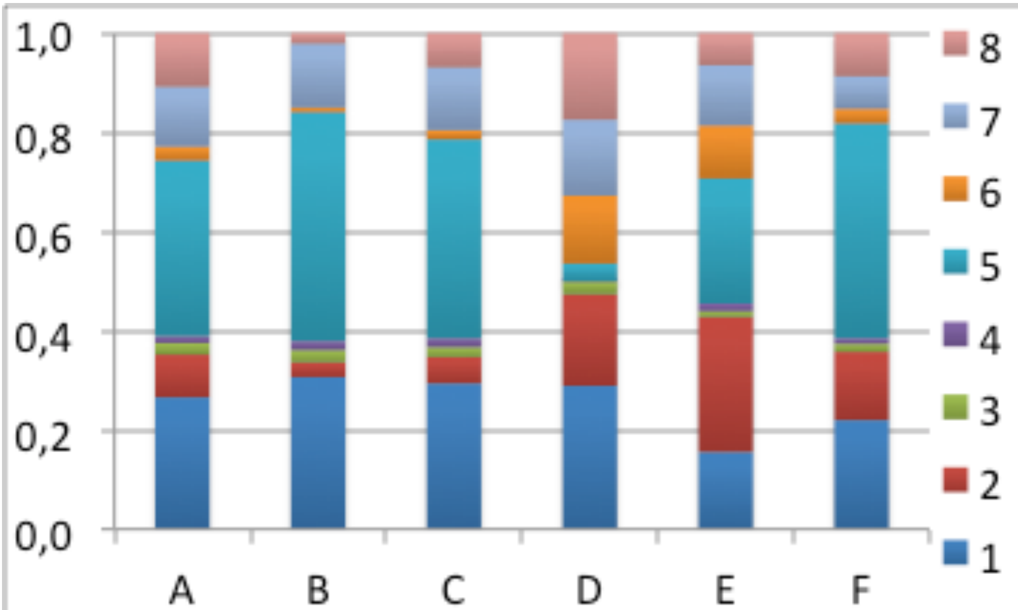
S: storage capacity (m^3);
G: biomass/biofuel produced in the cell or imported (t/month);
Q: biomass/biofue exchanged with other cells (t/month);
D: biomass/biofuel consumption for processing (p) or energy conversion(c) E: Energy delivered to the load (MWh/month);

	Type	Value
r	biomass	SRF wood, import chips, import pellets
f	biofuel	Chips and pellets (on site processing facilities)
i	cell	8 urban (500 x 500 m); 8 peri-urban (1 x 1 km)
j	Size of plant	Small-medium-large-extra large size
t	Time (month)	12 months - 3 seasons for energy demand
p	Processing technology	Storage, chipping, pelletization
c	Conversion technology	Heat, CHP

Spatial modelling of bioenergy in UES: key results (I)

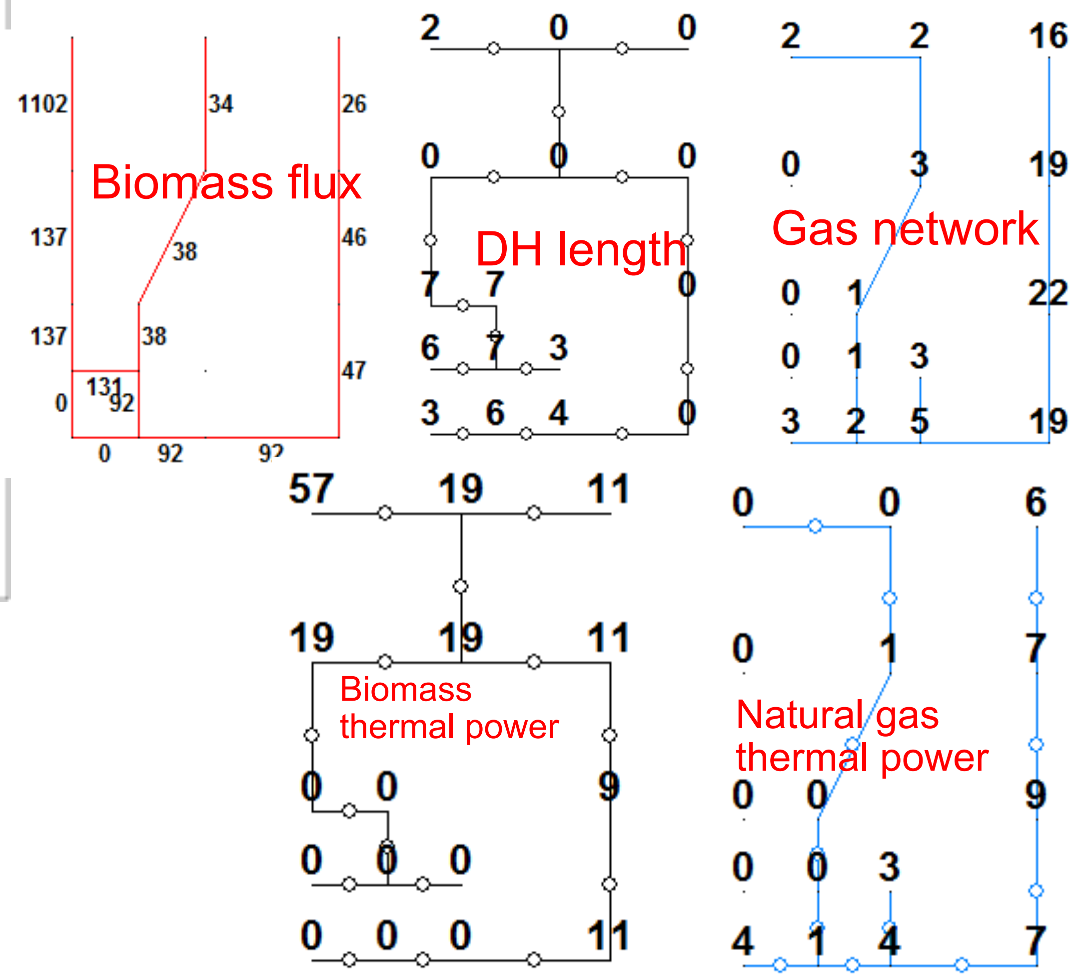
Scenarios

A: baseline; B: relaxed import constraints; C: relaxed PM and transport constraints;
D: existing gas network; E: high electricity price; F: bio-electricity incentive



Thermal energy generation cost share

1: biomass supply; 2: natural gas supply;
3: biomass processing; 4: biomass transport;
5: biomass conversion plants;
6: natural gas conversion plants;
7: DH network; 8: gas network



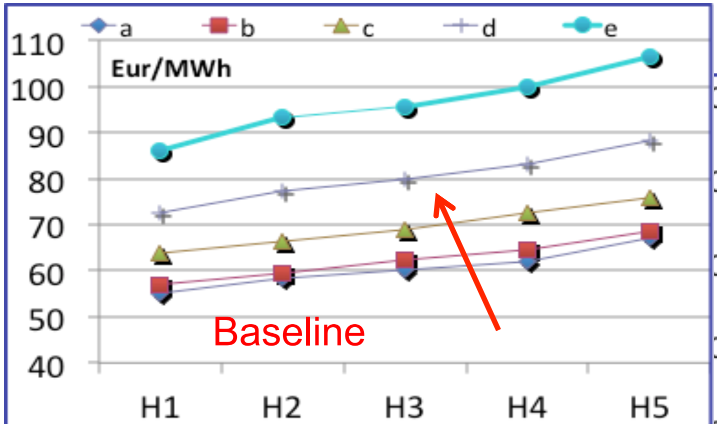
Sparse biomass boilers in periurban areas
DH and gas boilers to serve urban cells

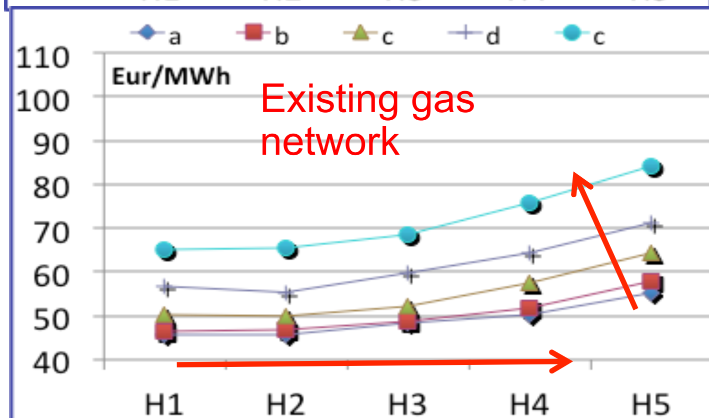
Spatial modelling of bioenergy in UES: key results (II)

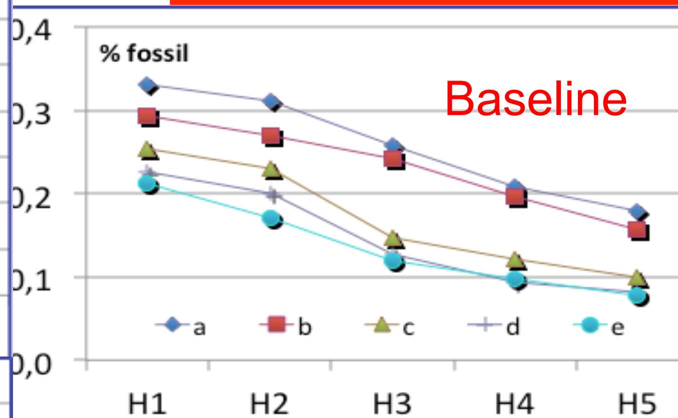
Sensitivity assessment

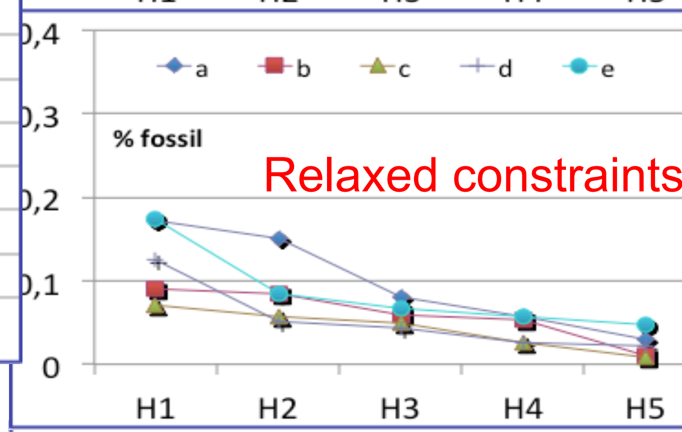
High efficiency levels and m climate increase bioenergy penetration (relative cost of f

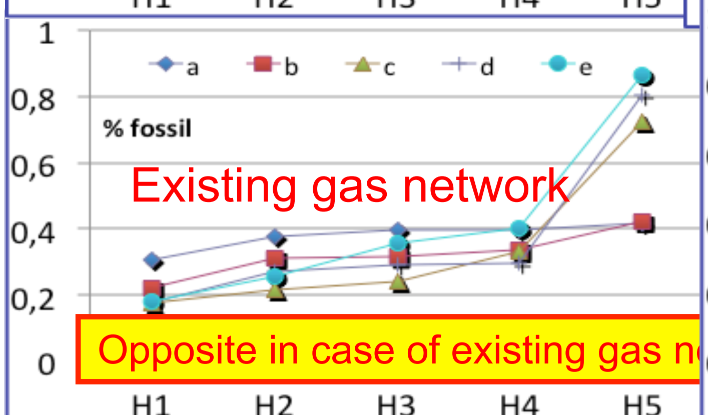
Reduction of DH at low energy density and relaxed biomass constraints



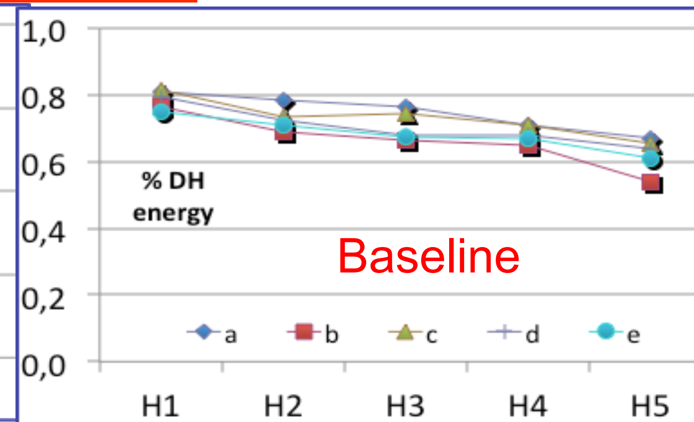


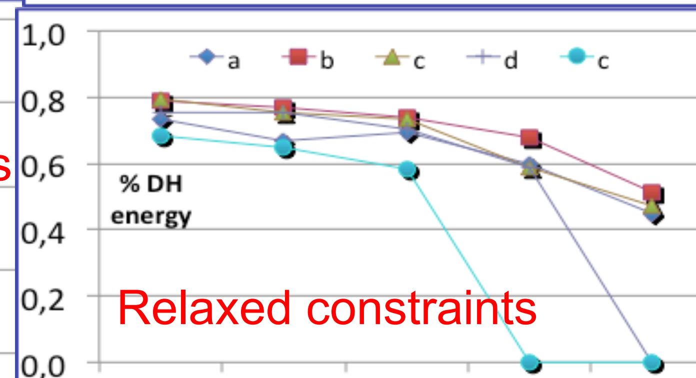


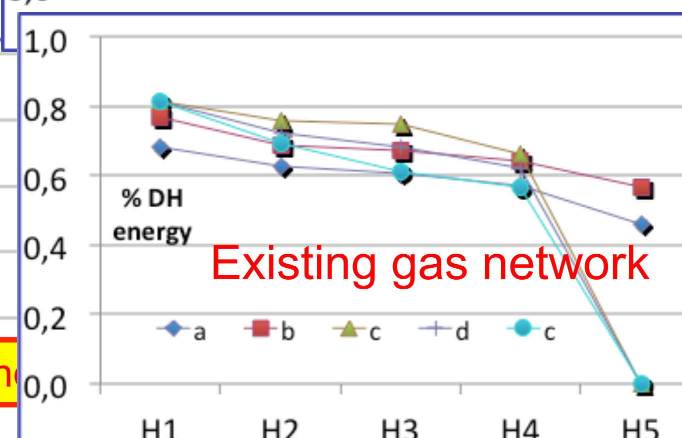




Opposite in case of existing gas ne



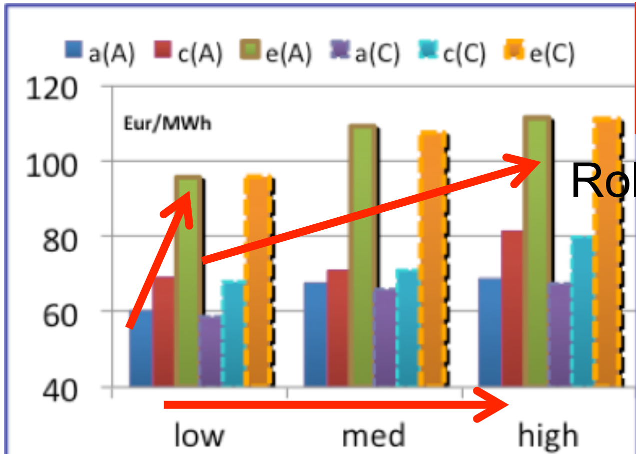


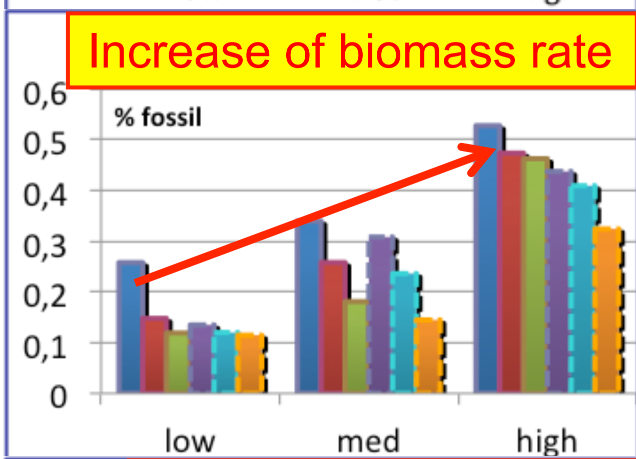


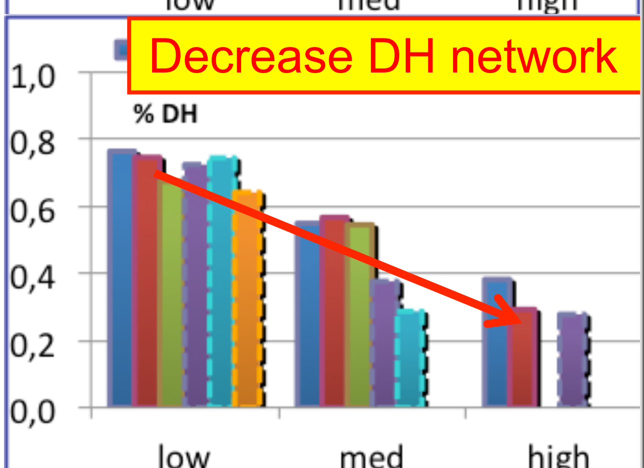
Increase of generation cost at higher energy efficiency level and colder climate conditions

Spatial modelling of bioenergy in UES: key results (III)

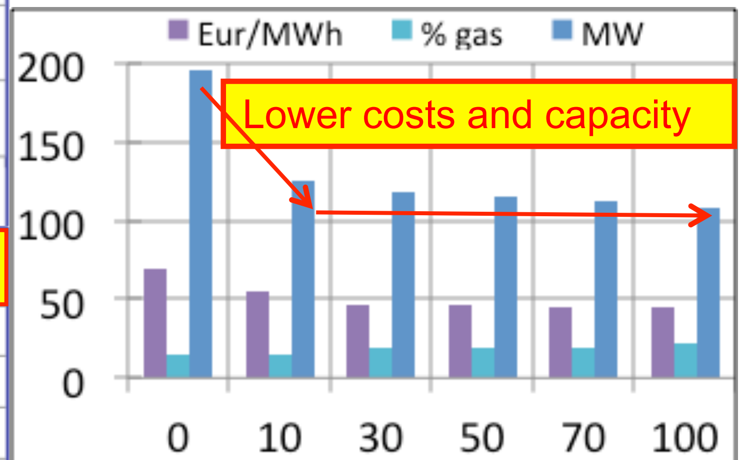
Decreasing linear thermal density (m network/ kW served)



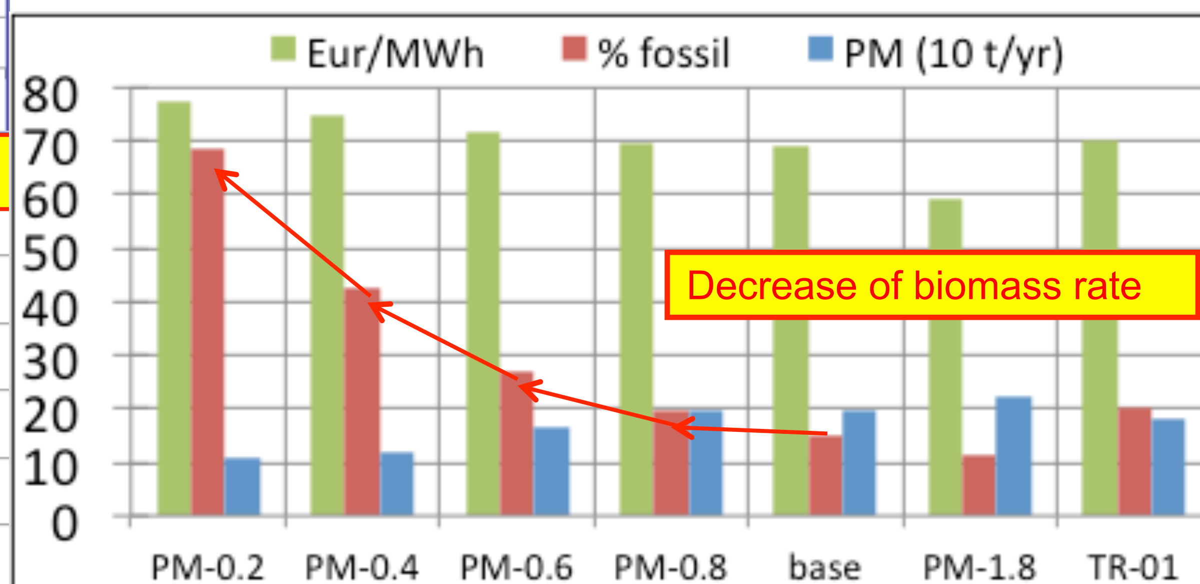




Role of thermal storage (% of peak demand)



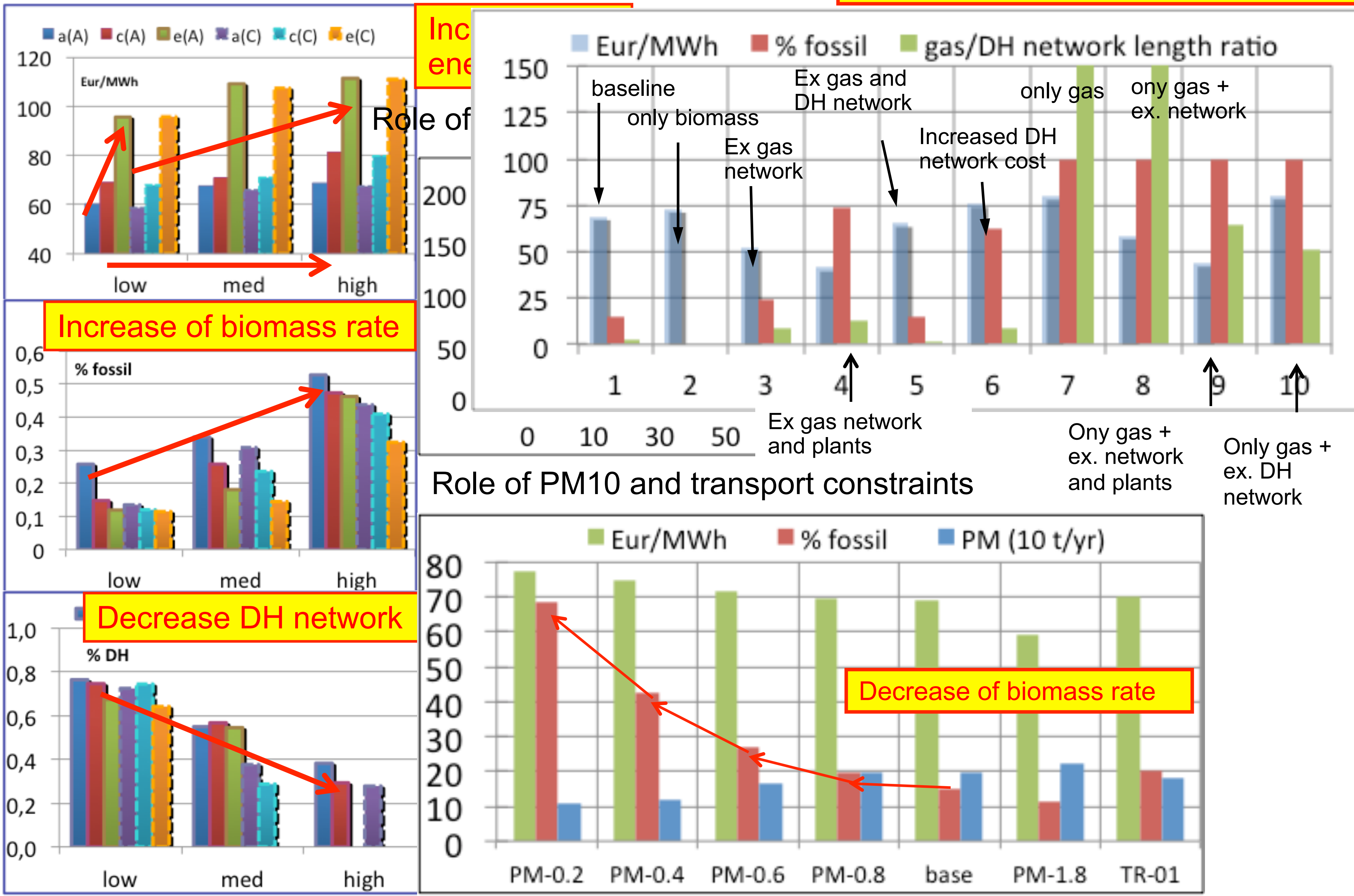
Role of PM10 and transport constraints



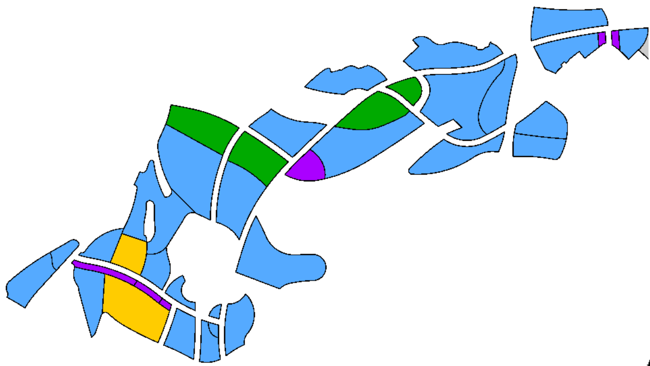
Spatial modelling of bioenergy in UES: key results (III)

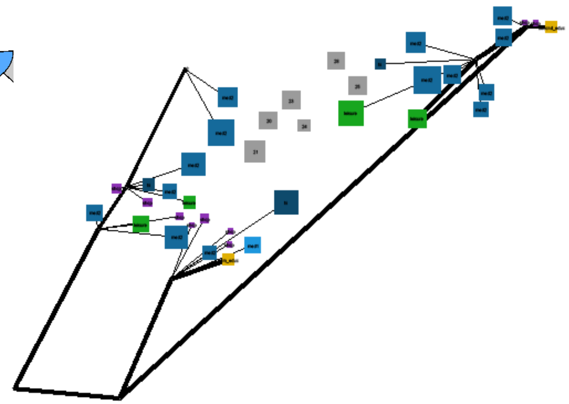
Decreasing linear thermal density (m network/ kW served)

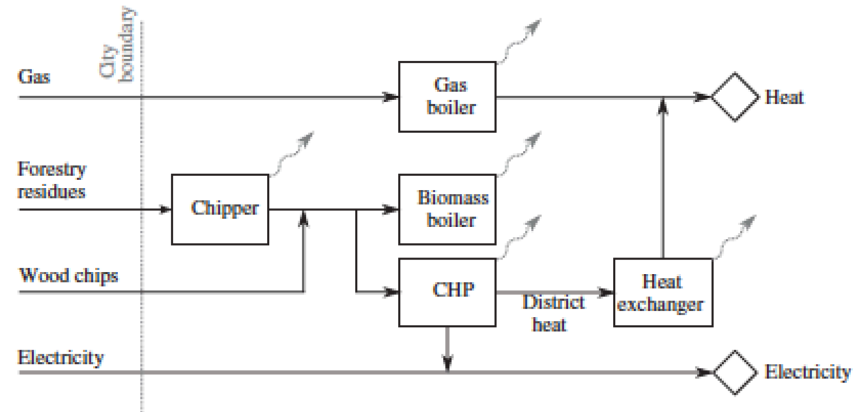
Existing infrastructures and fuel supply



Spatial modelling of bioenergy in UES: the RTN approach



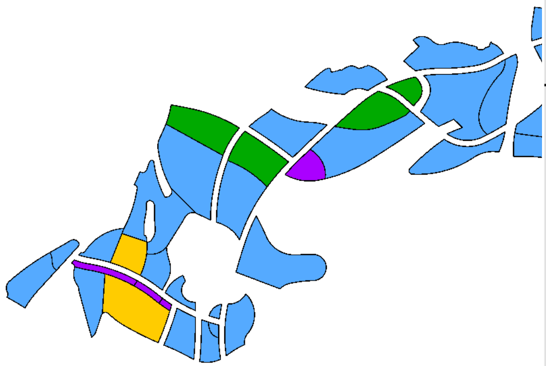




87 hectares, 6500 people

Technology	Size	η_e (%)	η_t (%)	TKC (k£)	O&M (k£/year)
Chipping plant	5 t/h			250	37.5
Domestic boiler	25 kW_t	–	82	6	0.5
ORC-small	500 kW_e	18	78	2000	80
ORC-medium	1000 kW_e	19.5	78	3400	120
ORC-large	2000 kW_e	20	78	6400	220
ICE-small	500 kW_e	24	50	1750	75
ICE-medium	1000 kW_e	25	50	3000	140
ICE-large	2000 kW_e	26	50	6000	260
Backup boiler	100–1000 kW_t	–	85	20–100	–

Spatial modelling of bioenergy in UES: the RTN approach



87 hectares, 6500 people

Technology	Size	(
Chipping plant	5 t/h	
Domestic boiler	25 kW_t	-
ORC-small	500 kW_e	1
ORC-medium	1000 kW_e	1
ORC-large	2000 kW_e	2
ICE-small	500 kW_e	2
ICE-medium	1000 kW_e	2
ICE-large	2000 kW_e	2
Backup boiler	100–1000 kW_t	-

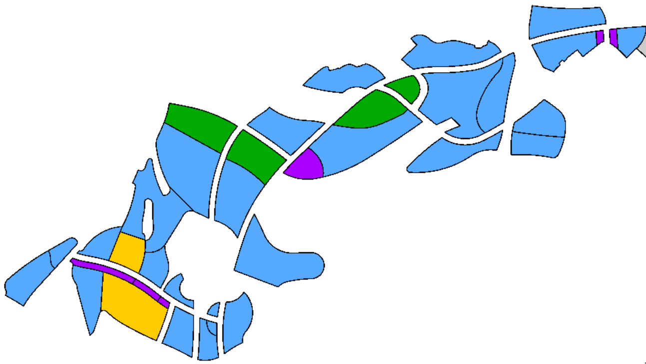
Table 7 – Summary of results. Scenarios 1 = grid fuels, 2 = biomass boilers, 3 = biomass CHP (ICE), 4 = biomass CHP (ORC), 5 = all-technologies.

Metric	Scenario				
	1	2	3	4	5
Headline metrics					
Energy consumption (delivered, GJ/cap)	28.6	30.7	34.1	27.4	34.6
Energy consumption (primary, GJ/cap)	40.3	42.4	34.2	32.7	35.9
Greenhouse gas emissions (tCO2/cap)	2.2	1.14–1.15	0.27–0.29	0.44–0.46	0.17–0.19
PM_{10} emissions (μg/Nm^3)	7.5	30–50	5.4–11.9	2.5–6.8	9.3–19.0
NO_x emissions (μg/Nm^3)	450–600	300–400	136–190	47–70	119–168
Total cost w/o ROCs (mil GBP)	6.7	9.0	6.6	6.4	6.0
Total cost w/ROCs (mil GBP)	6.7	9.0	6.2	6.3	5.7
Solution gap (% from relaxed)	1.6	0.2	12.3	9.0	5.8
Installed technologies – number					
Gas boiler	3132	–	59	3	1
Biomass boiler	–	3132	–	–	45
Heat exchangers	–	–	3073	3128	3086
Chip production	–	–	–	–	–
Chip storage	–	–	–	–	–
1 MW ICE CHP			–	–	1
3 MW ICE CHP			–	–	1
5 MW ICE CHP			1	–	–
1 MW ORC CHP			–	1	–
3 MW ORC CHP			–	1	–
5 MW ORC CHP	–	–	–	–	–
0.1 MW backup	–	–	–	2	–
0.5 MW backup	–	–	1	–	2
1 MW backup	–	–	–	–	–
Installed technologies – average rate (% of max capacity)					
Gas boiler	5.0	–	53.7	47.7	31.4
Biomass boiler	–	5.0	–	–	71.0
Heat exchangers	–	–	3.1	4.1	3.0
Chip production	–	–	–	–	–
Chip storage	–	–	–	–	–
1 MW ICE CHP	–	–	–	–	100
3 MW ICE CHP			–	–	86.0
5 MW ICE CHP			75.5	–	–
1 MW ORC CHP			–	8.4	–
3 MW ORC CHP			–	92.1	–
5 MW ORC CHP	–	–	–	–	–
0.1 MW backup	–	–	–	39.9	–
0.5 MW backup	–	–	55.0	–	39.7
1 MW backup	–	–	–	–	–

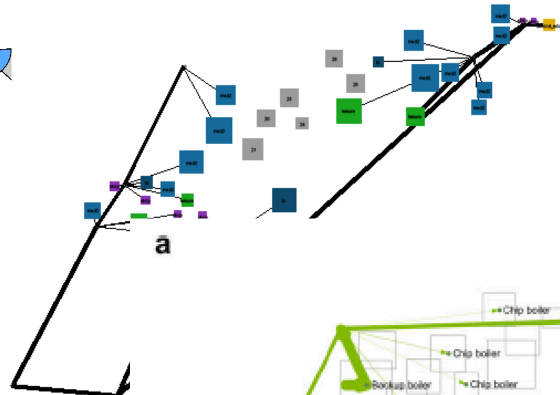
Biomass CHP preferred (higher electric efficiency)

Import wood chips preferred to forestry wood

Spatial modelling of bioenergy in UES: the RTN approach



87 hectares, 6500 people



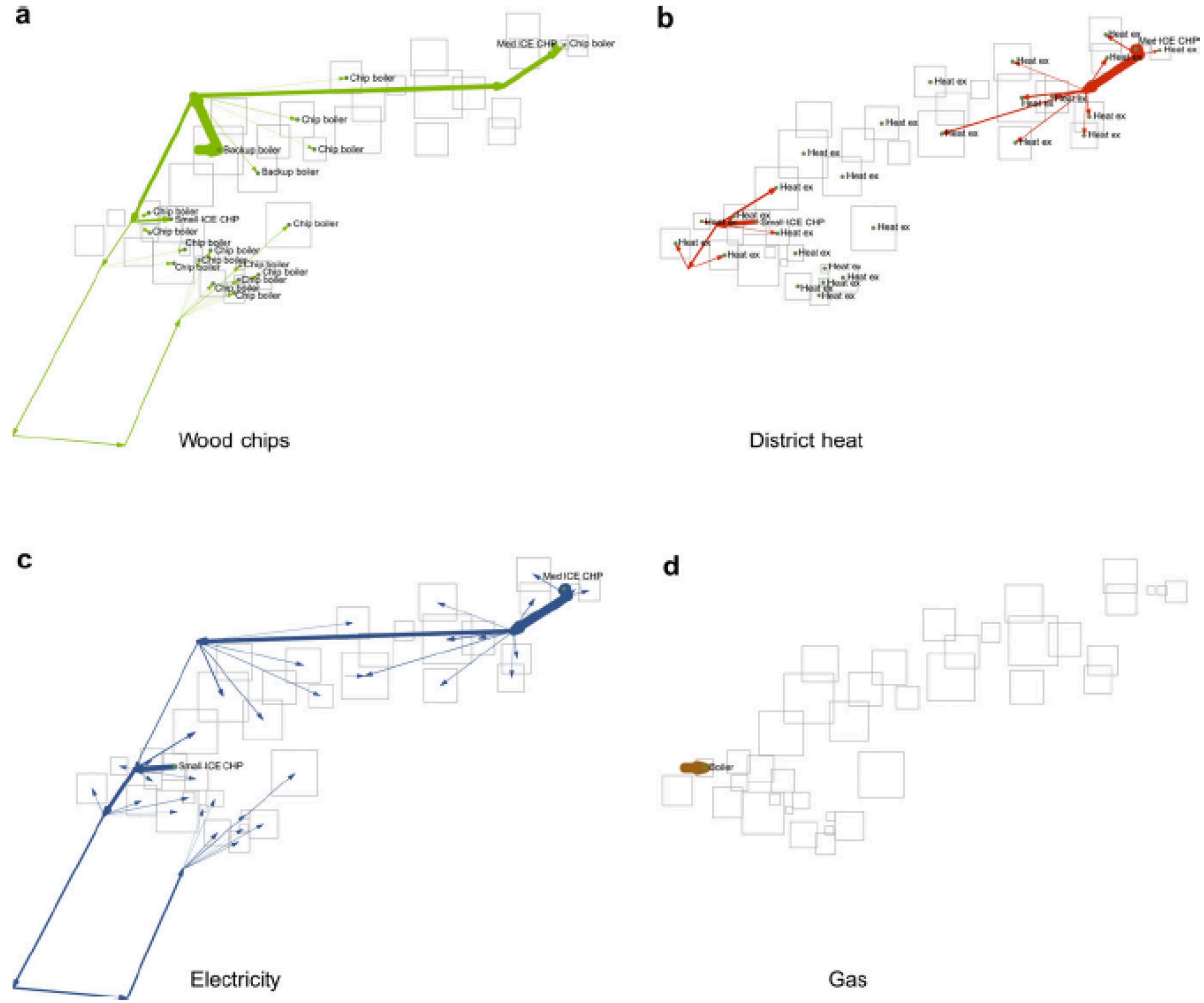
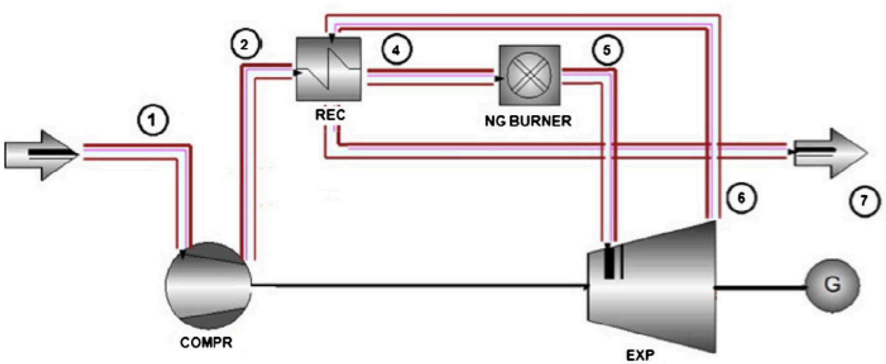


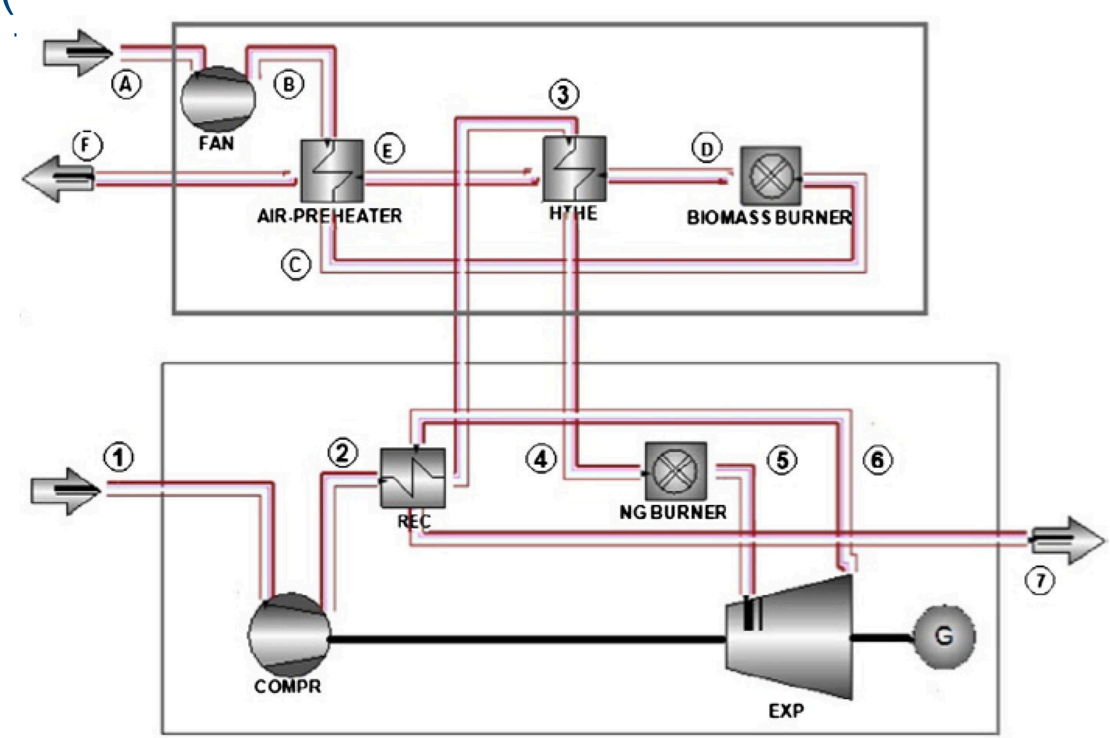
Fig. 3 – Distribution networks for the winter period of the all-technologies scenario (5). Arrow widths are proportional to resource flows.

Bioenergy in UES: thermo-economic assessment of dual-fuel MGT (I)

Rationale of the study: **CHP, small scale, dual-fuel**
CHP is essential in bioenergy and heat demand crucial
Small scale facilitates location at premises of heat demand
Dual fuel systems increase conversion efficiency (mostly at small size), flexibility of supply, plant operation and facilitates biomass supply chain (seasonality, storage, logistics) and **optimal integration** in UES

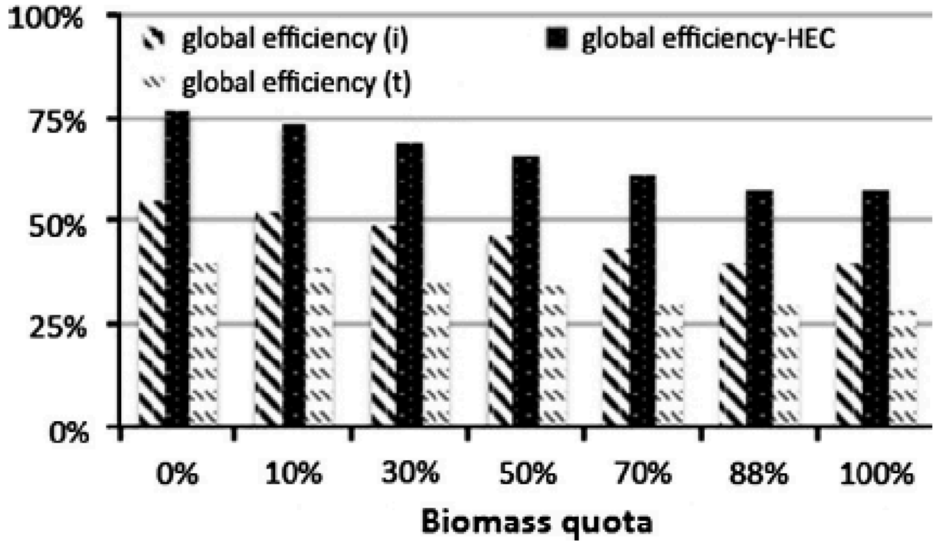
Gate-cycle modelling of Turbec 100 kWe microturbine
100-90-70-50-30-12-0% natural gas / biomass input
air T from HTHE 700-900 °C; TIT at 950 °C (900 °C only biomass)
Trade-offs: biomass furnace T (max 1000 °C

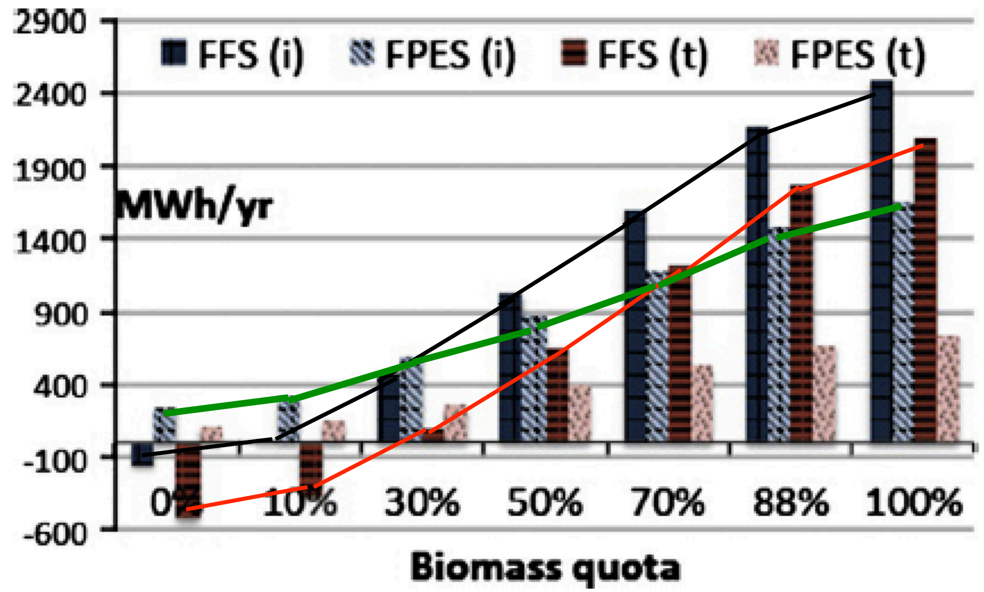




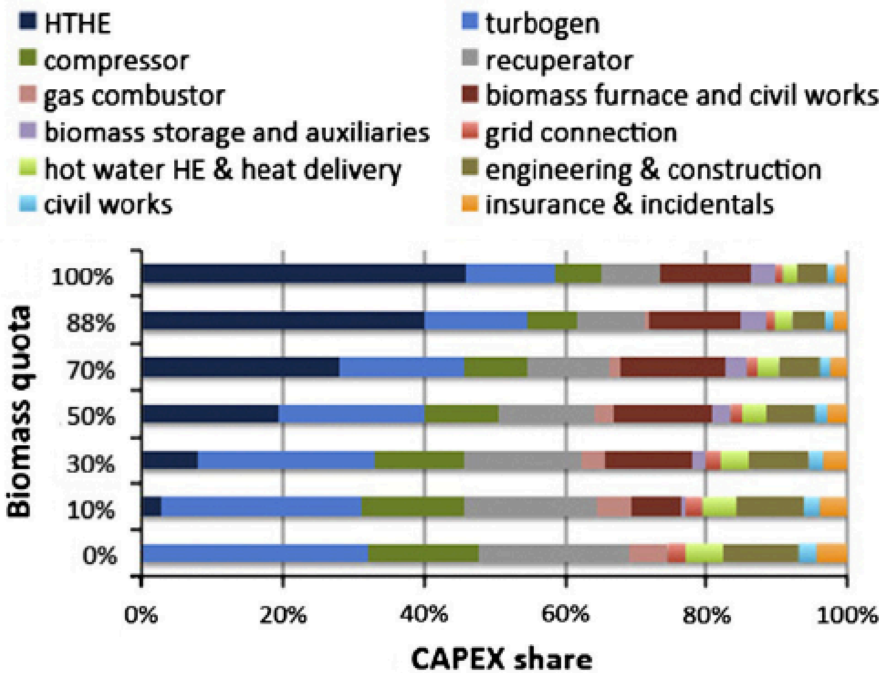
Bioenergy in UES: thermo-economic assessment of dual-fuel MGT (II)

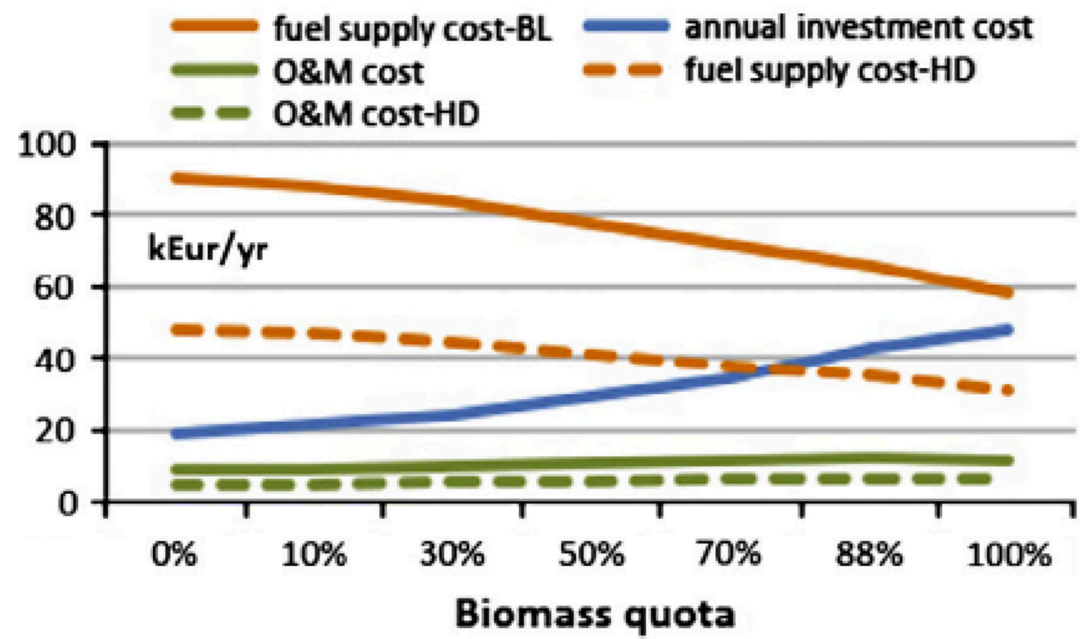
Efficiency: Electrical : 30.5-19.6%; Thermal : 46-37%
Fuel uptake: Biomass: 0 – 740 t/y; NG: 0 – 228 kNm^3/yr
PES index: 0.162 for case A, zero for other cases (Italian rules)
Energy demand: (i) high (industrial) 4,000 hr/yr; (t) tertiary 1,800 hr/yr
CHP baseload operation 7,500 hr/yr



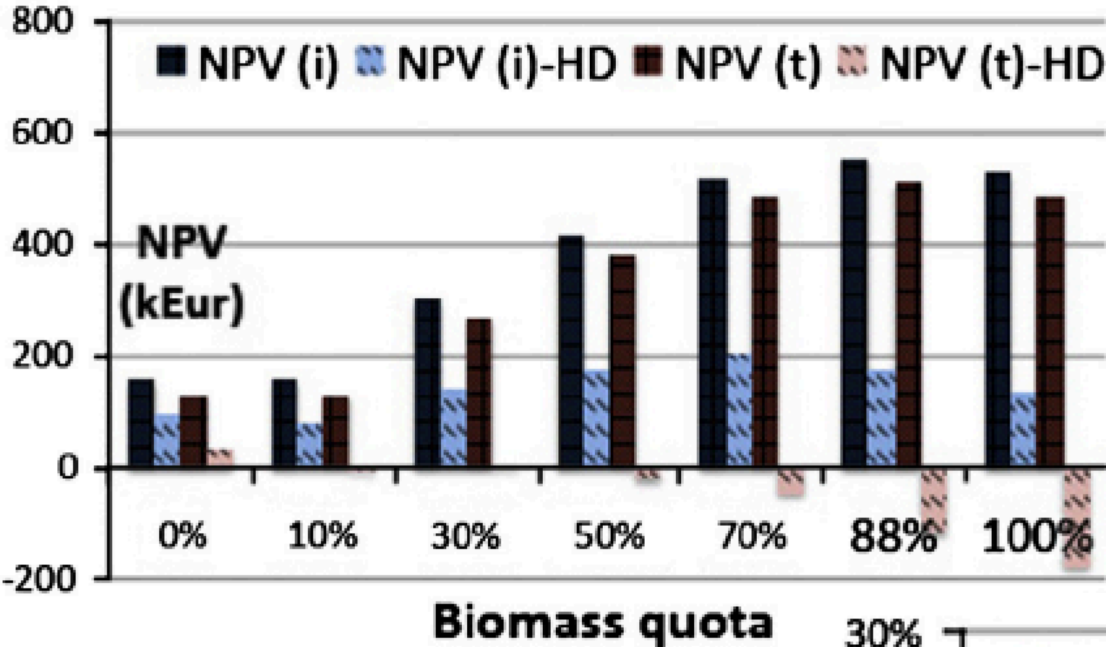


Bioenergy in UES: thermo-economic assessment of dual-fuel MGT (III)





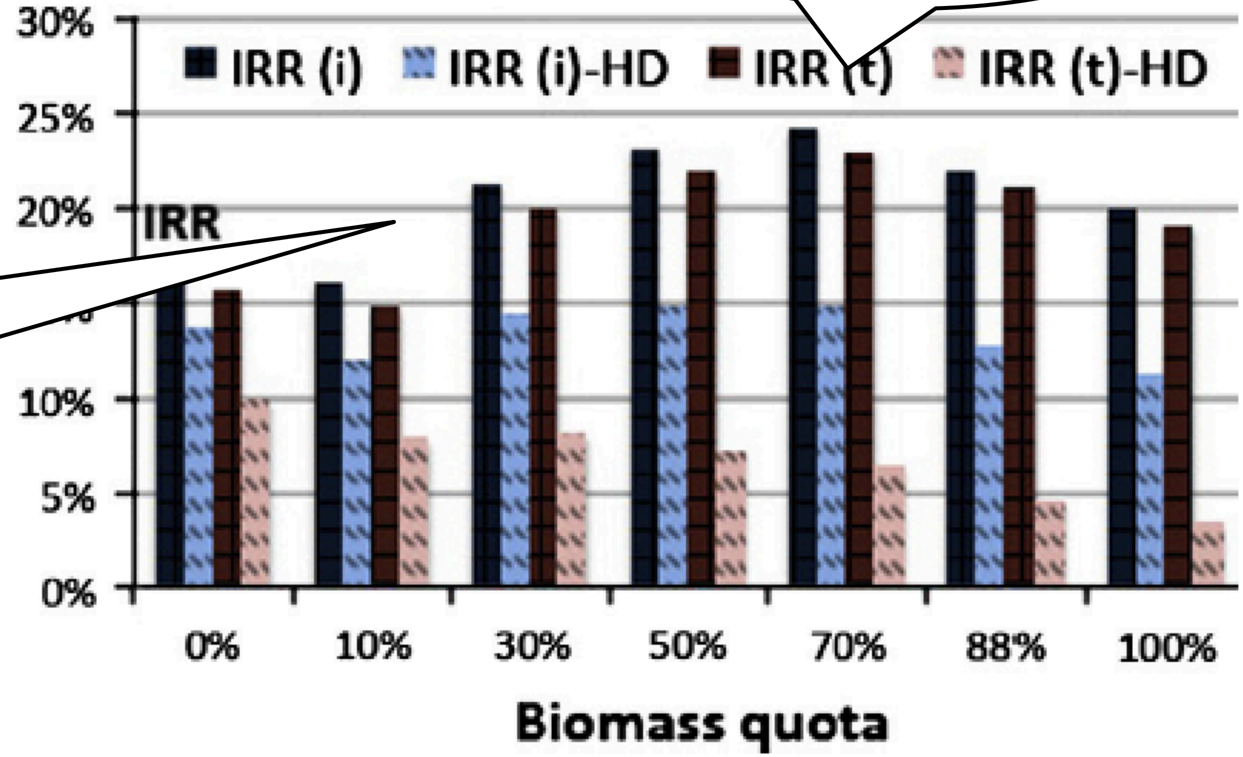
Bioenergy in UES: thermo-economic assessment of dual-fuel MGT (III)



High heat demand crucial

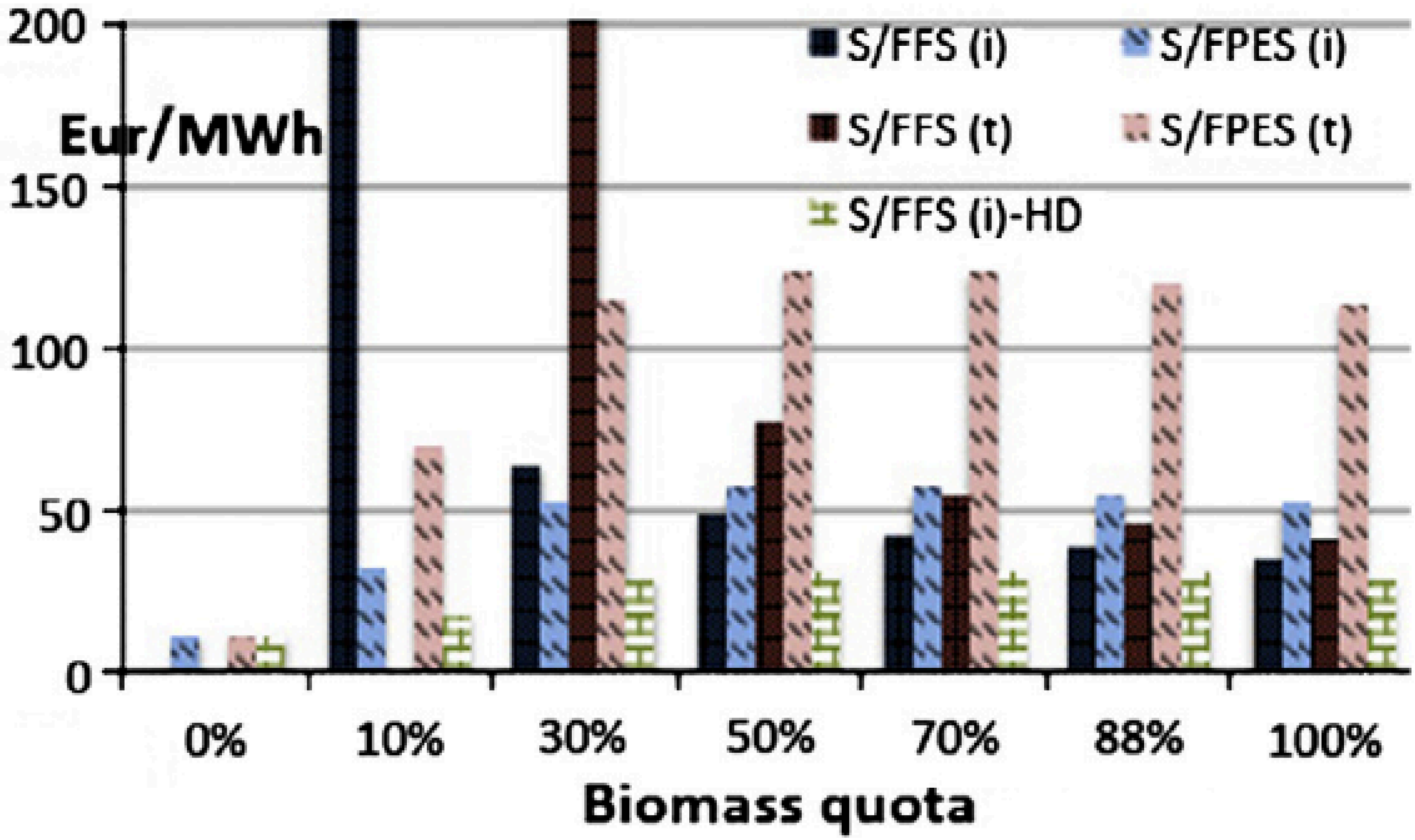
70% biomass most profitable (italian feed-in tariff)

Baseload most profitable than HD (but less efficient)



Bioenergy in UES: thermo-economic assessment of dual-fuel MGT (III)

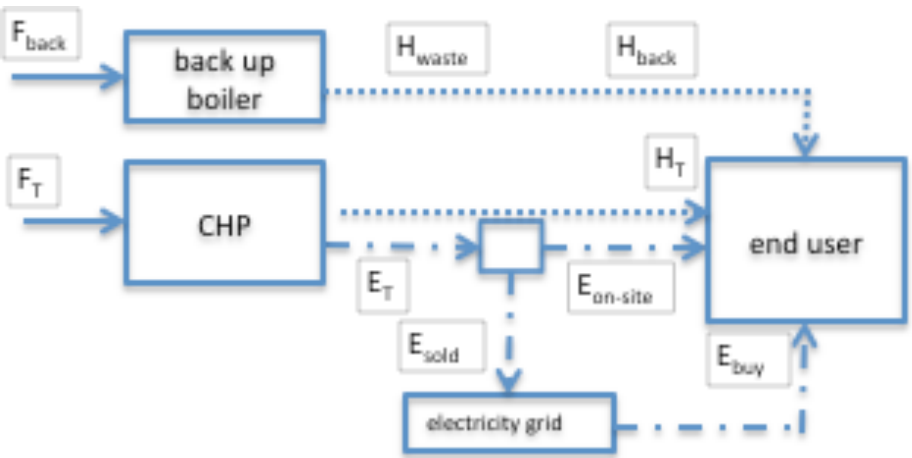
High cost for primary energy saving of these bioenergy routes

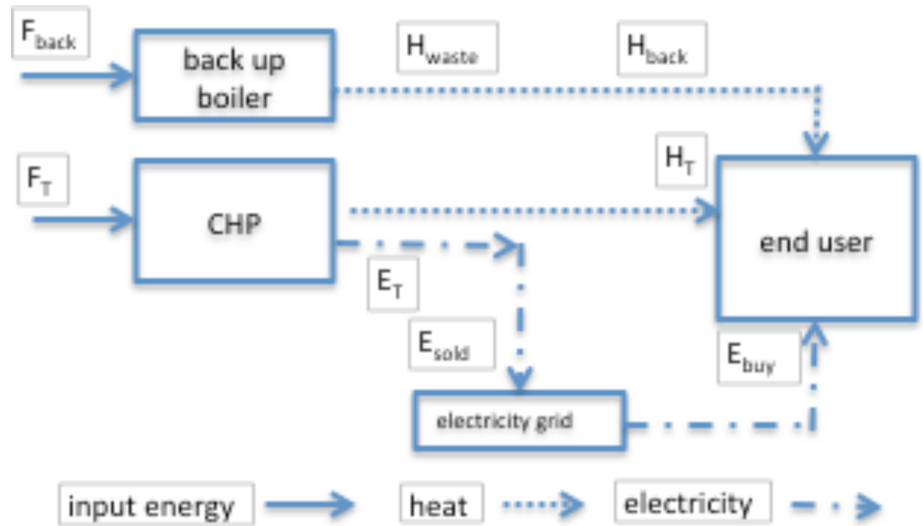


But different results at different energy demand intensity…

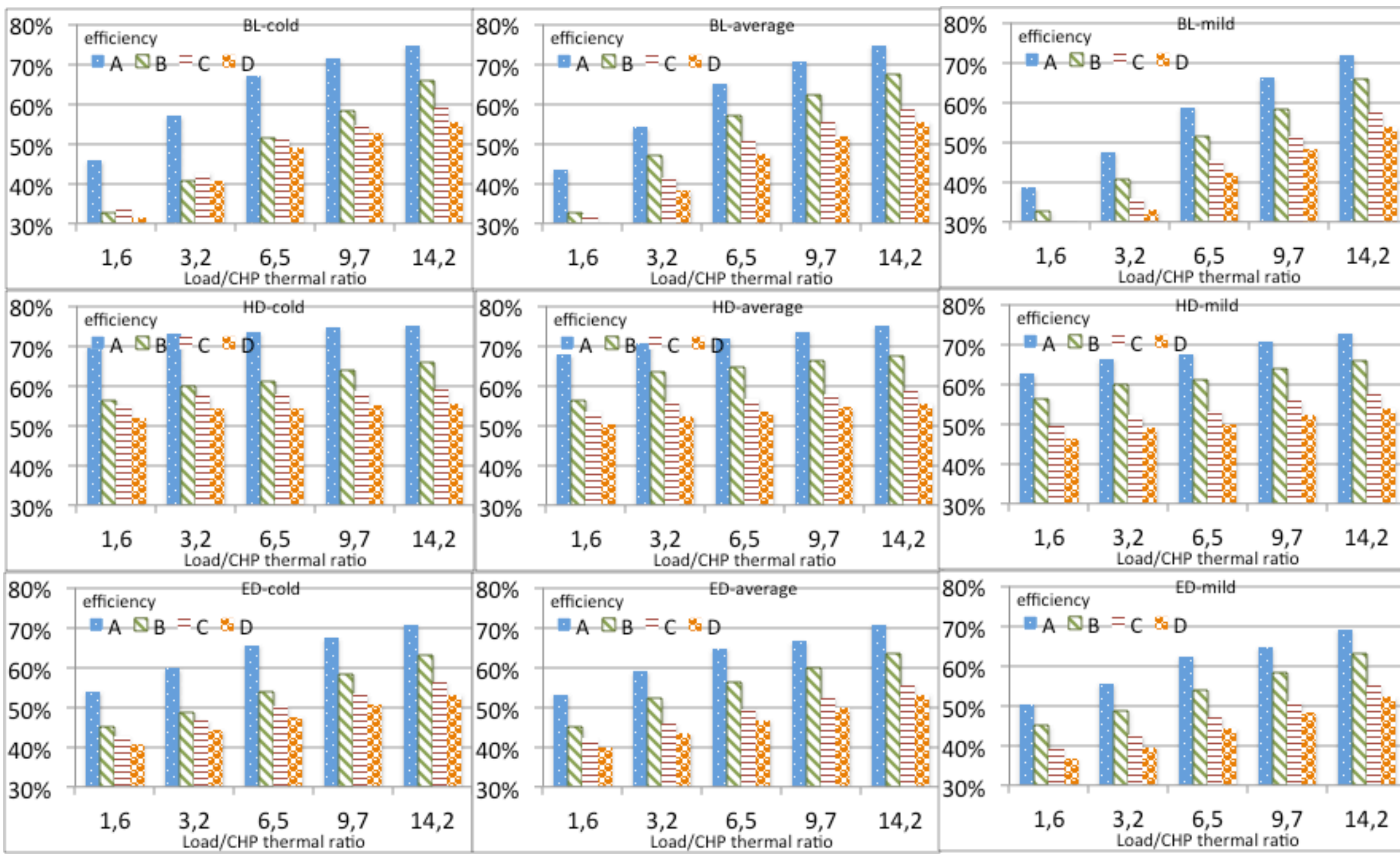
Bioenergy in UES: thermo-economic assessment of dual-fuel MGT (IV)

Operation strategies: BL, HD, ED; **Sizing**: range of load/CHP thermal power ratios
Part load operation: Gate-Cycle simulation; Energy demand: range of climate conditions
Energy price: heat-electricity costs for residential sector+subsidies (Italy)





Bioenergy in UES: thermo-economic assessment of dual-fuel MGT (IV)



Baseload
Sizing and heat demand relevant

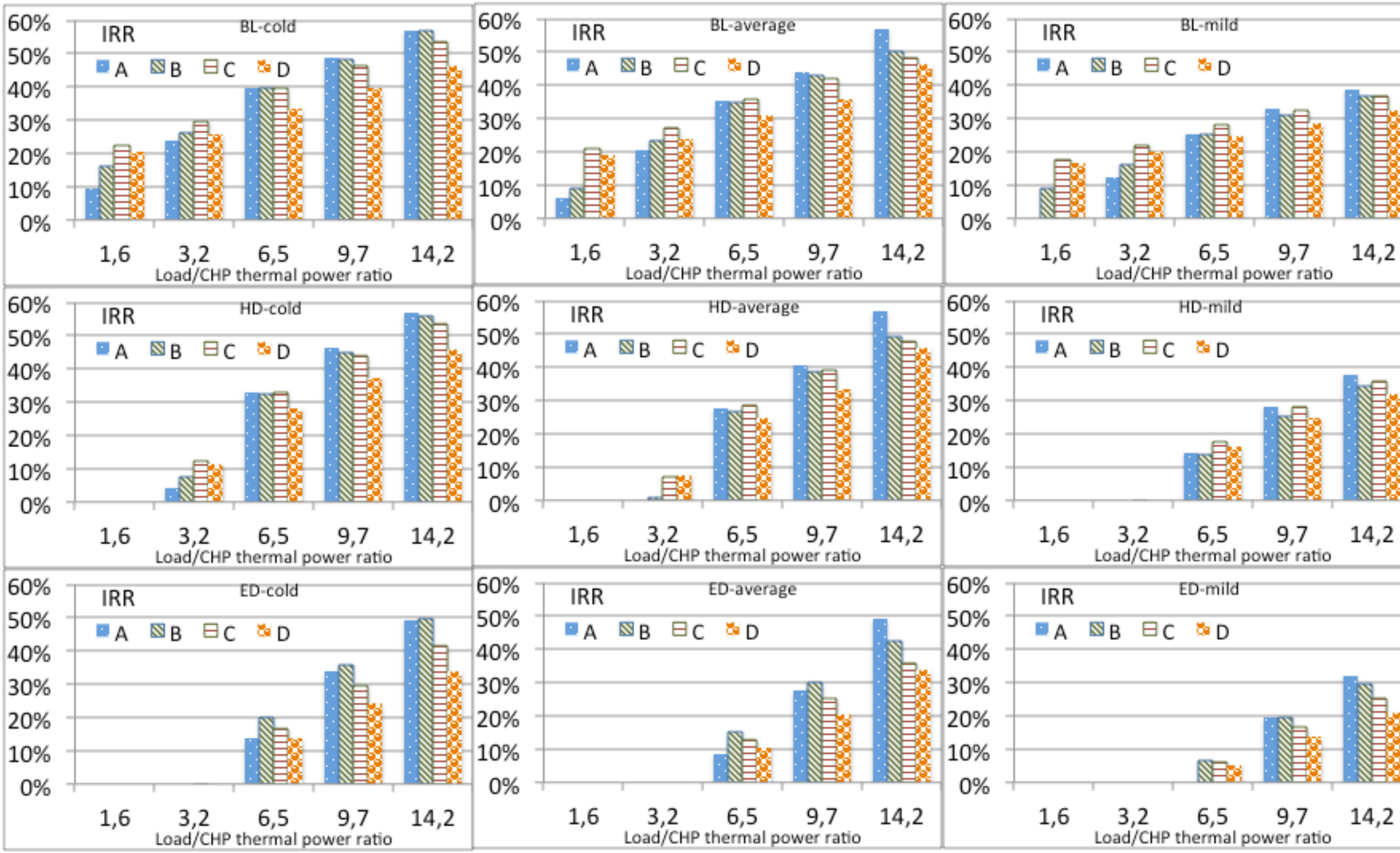
Heat driven
Best performance

Electricity driven
Lower performance
Sizing relevant

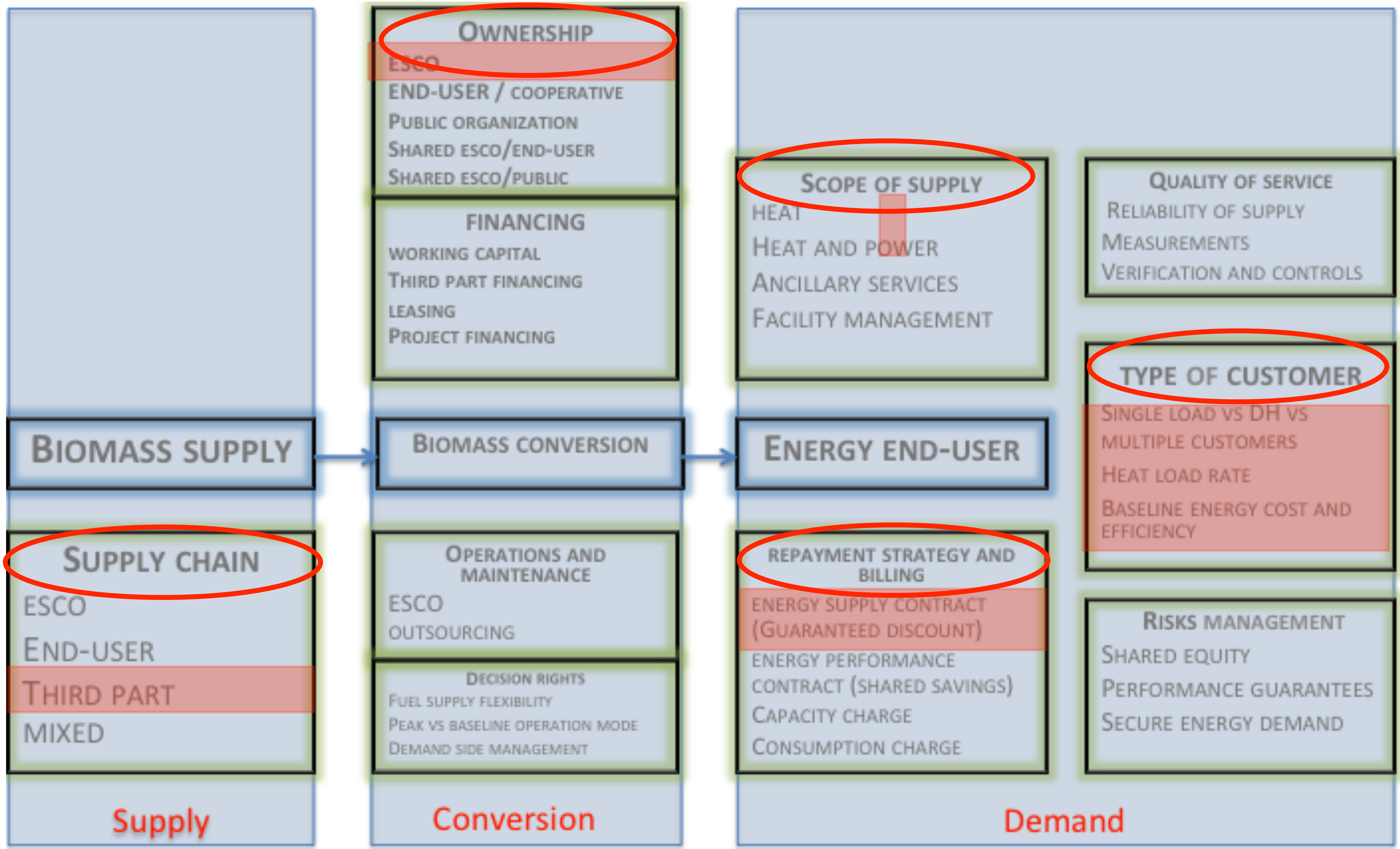
Bioenergy in UES: thermo-economic assessment of dual-fuel MGT (IV)

Optimal biomass rate influenced by CHP sizing

Profitability influenced by CHP sizing, mostly at ED mode



Biomass ESCO business models: classification



Selection of biomass ESCO operations

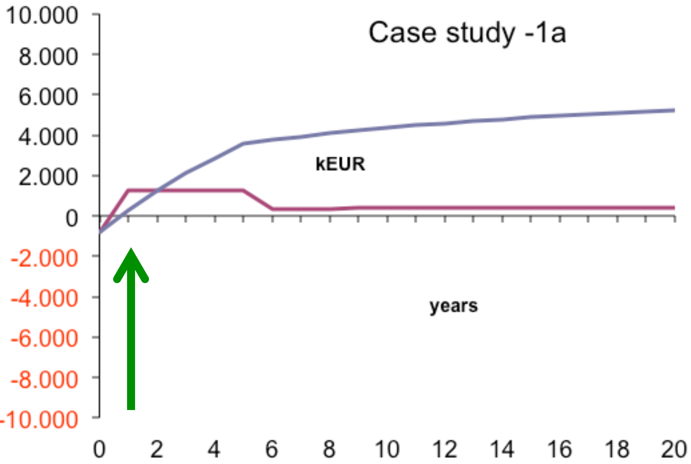
6 MWt (heat) and 1 MWe (CHP) size – ORC system

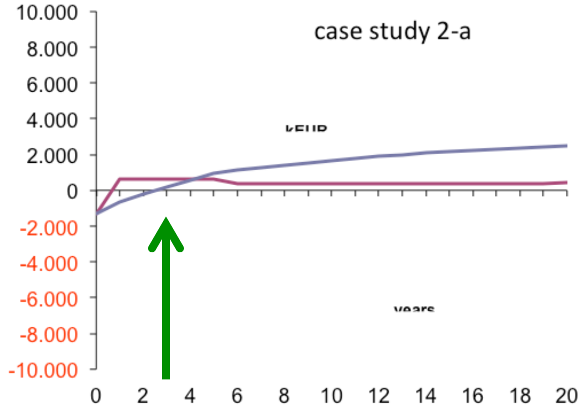
	1-a	1-b	2-a	2-b	3-a	3-b
Market segment	Agro-industrial (diary firm)		Tertiary (hospital)		Residential (borough)	
Investment cost for ESCO (kEur)	816	4,623	1,294	5,103	3,351	7,785
Duration of ESCO operation (yr)	5	20	5	20	10	20
O&M costs (kEur/yr) (1)	1,110	1,647	555	1,407	442	1,329
- of which Biomass supply cost (kEur/yr)	1,081	1,323	419	974	301	910
Baseline condition	Existing energy equipment owned by end-user (baseline efficiency in Annex I)					
Baseline heating cost (Eur/MWh) (2)	41.7		58.9		98.3	
Heat load rate (%)(3)	80%	80%	25%	25%	18%	18%

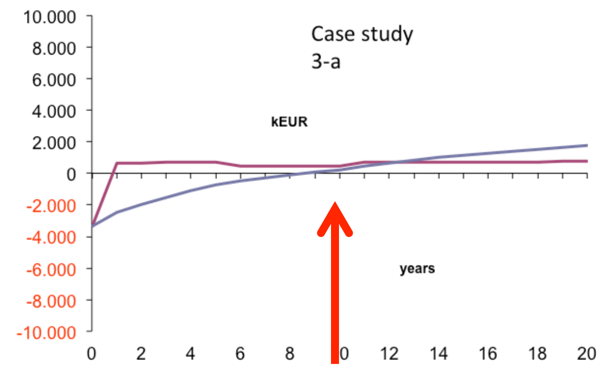
(1) details reported in Annex I, unitary biomass cost 70 Eur/t; (2) details reported in Annex I; (3) represents the equivalent annual plant operation at nominal power, and is dependent on the typology of heat demand;

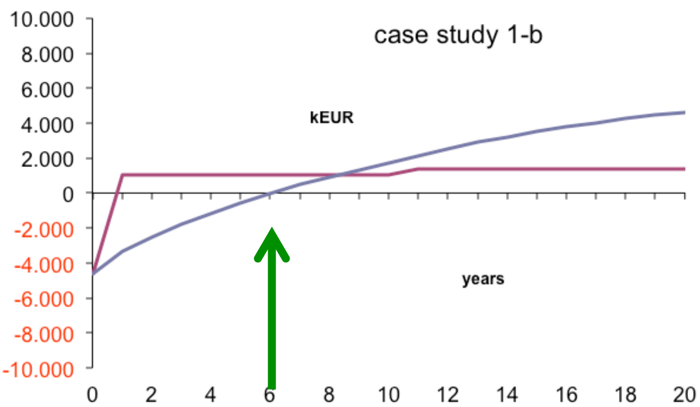
Selection of biomass ESCO operations

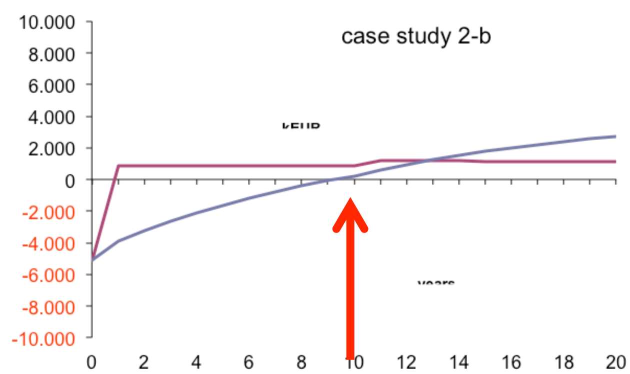
6 MWt (heat) and 1 MWe (CHP) size – ORC system

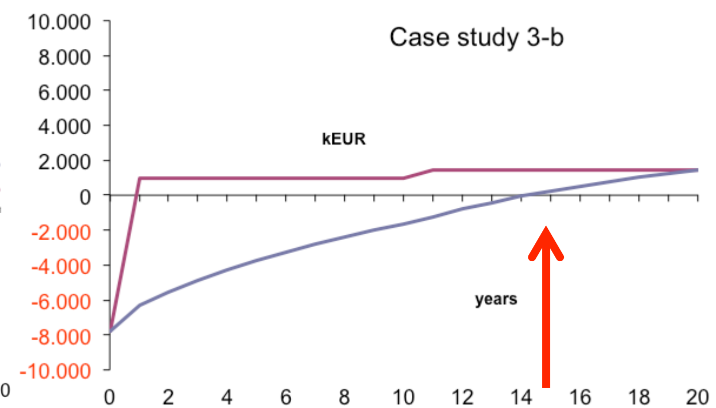












Key factors for profitability of ESCO

Supply-related factors

- **Biomass supply**
- Reliability of technology
- Flexibility of plant operation
- **Financing issues**

Energy demand factors

- **Heat load**
- Baseline cost of energy and taxation level
- Baseline conversion efficiency
- **Amenity issues**
- On site biomass availability
- Number of end-users
- Social acceptability

Policy framework

- **RES subsidies**
- Distributed generation policy
- Grid connection issues
- **Permitting and planning constraints**

Conclusions of modelling approach: key factors for bioenergy in UES

	Key factors	Promising market segments
Bio-energy	• Fossil vs biomass fuel costs • Baseline energy/environmental scenarios • Existing infrastructures (gas networks and gas boilers) • Environmental emission constraints • Logistic of transport-storage • Energy density and quality of biofuels	• Local boilers in low energy density areas • Centralized biomass heating systems (DH) in high energy density areas • Refurbishment of old biomass boilers (in rural areas)
DH networks	• Heat load rate (climate area) • Energy efficiency level of buildings • Thermal length of loads • Presence of gas network • Refurbishment costs for DH pipeline installation	• High energy density areas (climate and efficiency of buildings) • New urban areas (no presence of gas networks) • Low refurbishment costs (in case of existing areas) • Existing heating systems in dwellings suitable for DH (low T heat exchangers)
CHP	• Selling price / avoided cost electricity • Bio-electricity subsidies	• Presence of anchor loads • High and constant heat demand

Conclusions: promising bioenergy routes for UES

Promising bioenergy routes

Refined biofuels: chips vs pellets vs TOP; biogas vs biomethane; sustainab. bio-liquids

On site generation technologies: microturbines (EFGT), gasifiers coupled to Stirling or ICE, boilers coupled to ORC and steam turbine+ ads chillers, fuel cells, hybrid systems (heat pumps + solar thermal)

Systems integration: district heating (and cooling), integration with energy efficiency

Solid biomass: DH vs small boilers; **AD chains**: distributed vs centralized AD plants; biogas vs biomethane vs DH networks

Trends di ricerca

- Processi di upgrading a biofuels
- Dinamiche offerta biomasse – domanda energia
- Sparse district heating/cooling
- Localizzazione ottimale impianti, load aggregators, prosumers e demand side management
- Sistemi dual fuel – integrazione con sistemi energetici convenzionali
- Modelli di business per ESCO

Conclusioni

- Integrazione con sistemi energetici esistenti
- Disaccoppiamento condizionamento-conversione
- Integrare con efficienza energetica
- Incentivi per calore da rinnovabili
- Contabilizzazione benefici ambientali


GRAZIE PER L'ATTENZIONE
Perché? Perchè anche tu vivi qui!