



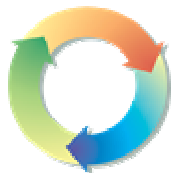
Development and pathways for competitive large-scale production of biomass based synfuels.

- SYNBIOS Conference, Stockholm - Sweden,

May 18-19, 2005 -

André Faaij

Copernicus Instituut – Universiteit Utrecht



Copernicus Institute

Sustainable Development and Innovation Management



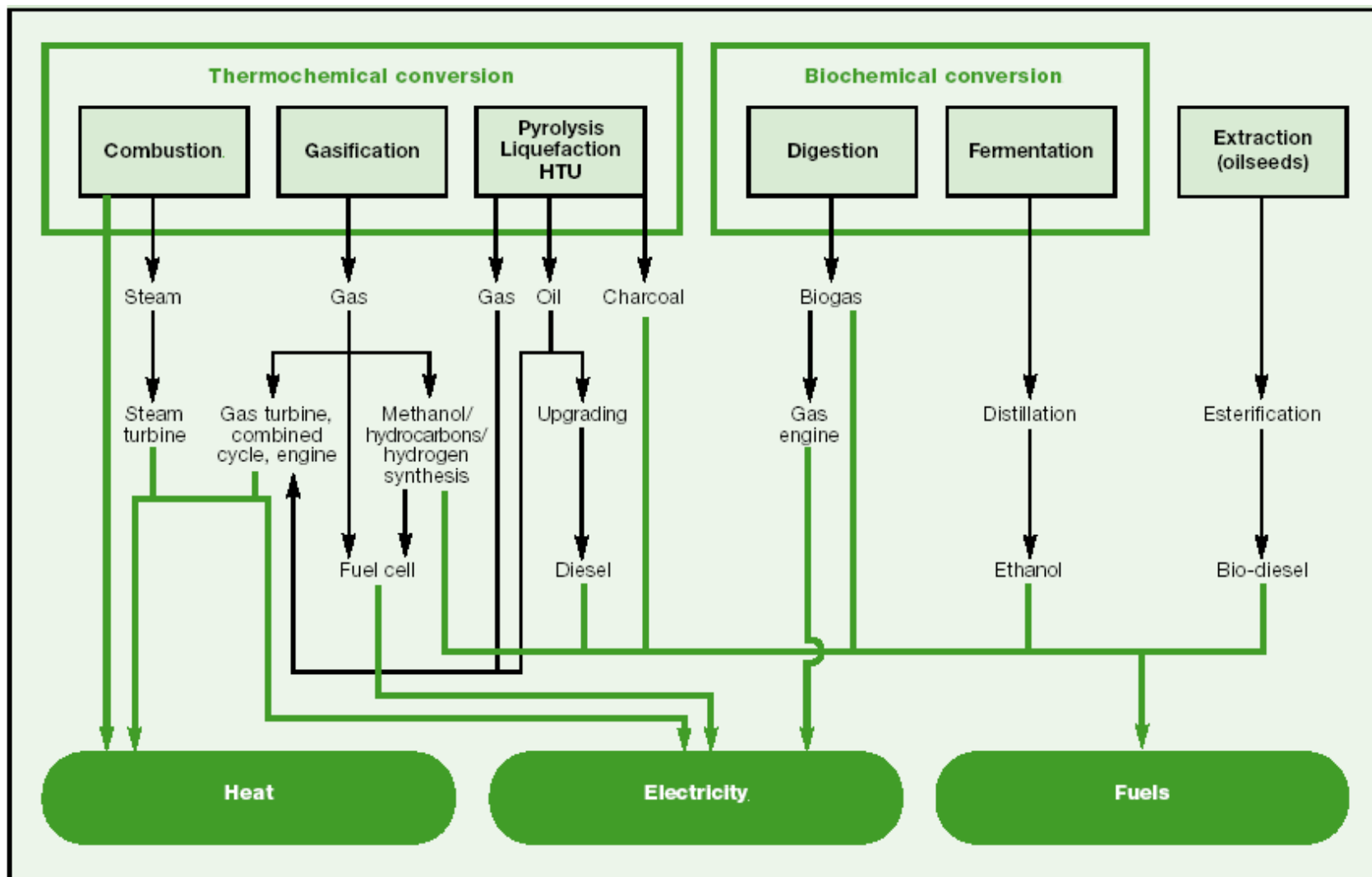
Elements:

- Context.
- Technological options and long term perspectives; WTW
- Development over time: learning, scaling up, co-feeding routes.
- Strategy...





Key bioenergy utilisation routes





Bio-energy use worldwide

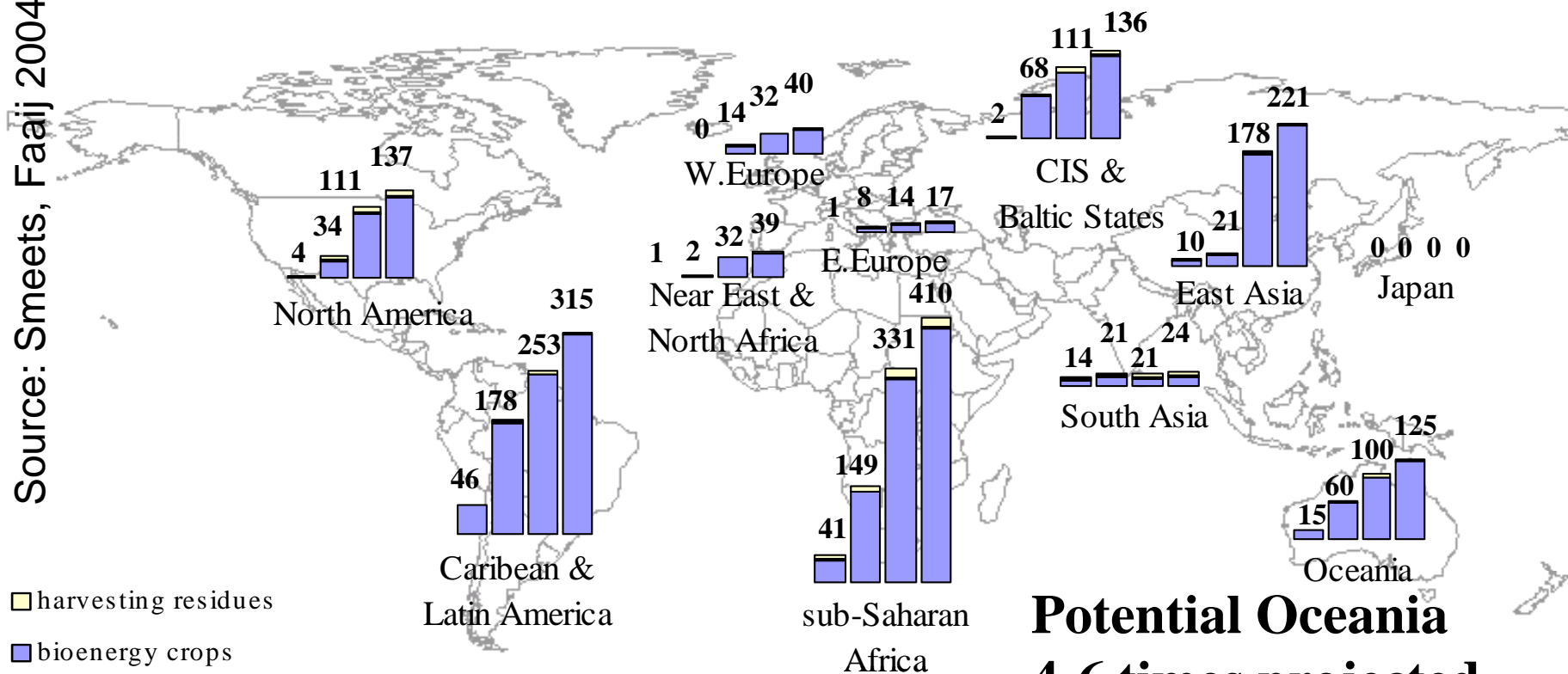
- Global Energy Demand: ~420 EJ
- About 10-15% (or 45 ± 10 EJ) of this demand is covered by biomass resources.
 - Traditional biomass: ~29
 - Commercial non-modern: 9 ± 6 EJ
 - Commercial: ~7 EJ
 - Liquid Biofuels ~0.5 EJ





Bioenergy production potential in 2050 for different scenario's

Source: Smeets, Faaij 2004



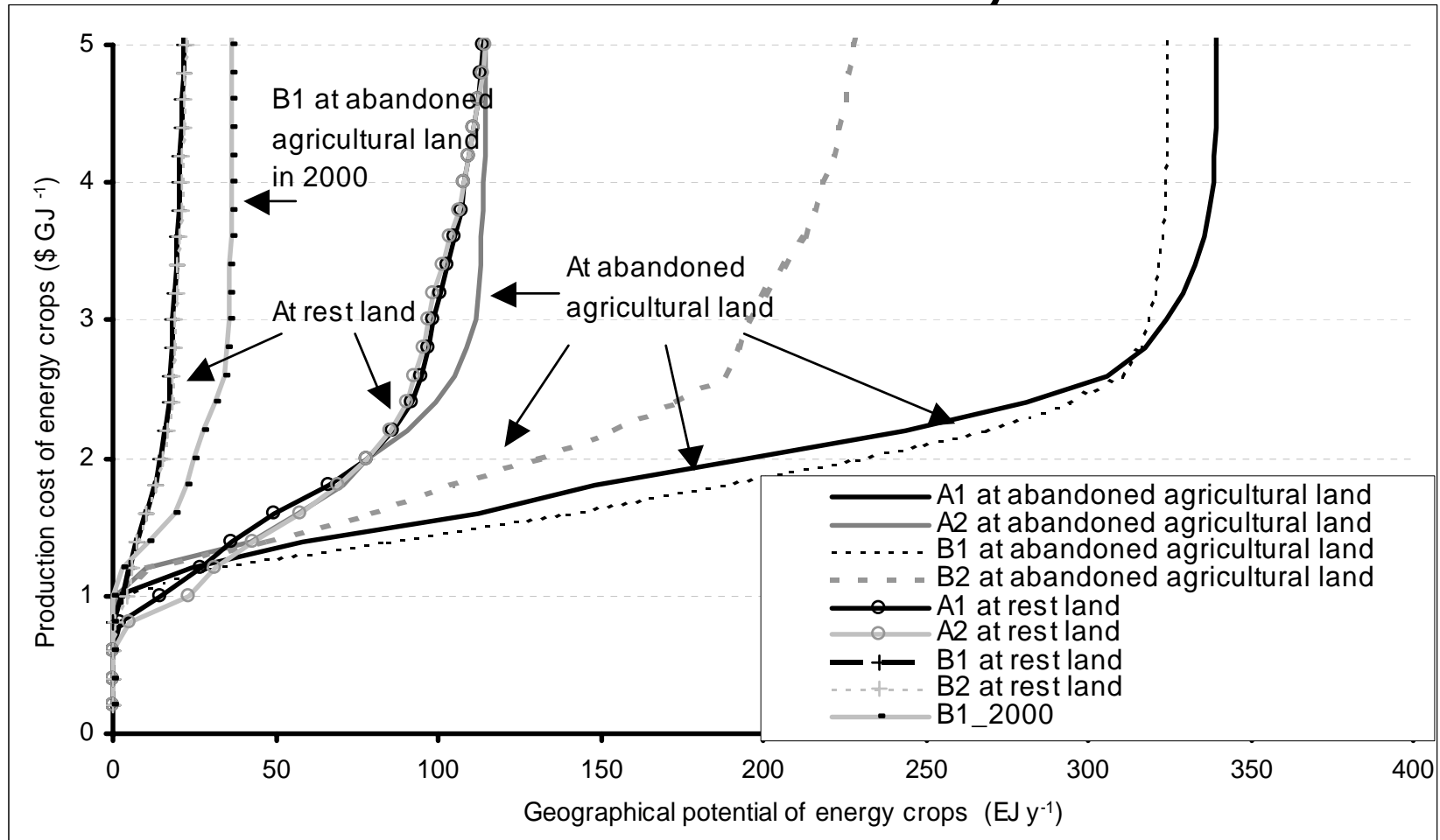
**Potential Oceania
4-6 times projected
primary energy use**





Global cost-supply curve for energy crops for four scenarios for the year 2050

Source: Hoogwijk, Faaij, 2004





Background

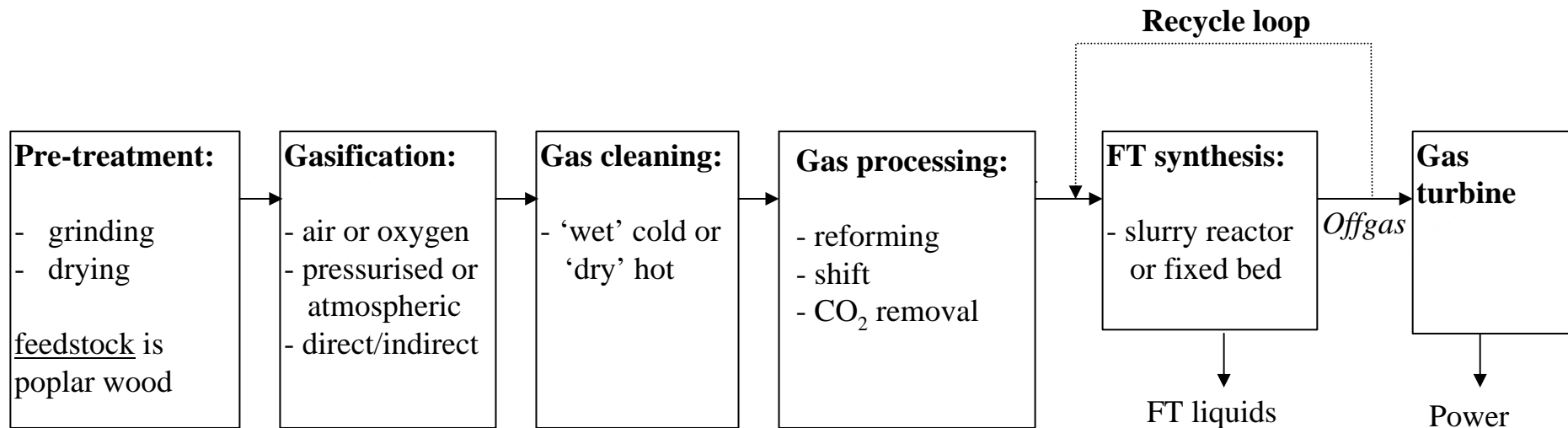
- Transport sector responsible for about a quarter of global CO₂ emissions + major contribution to (urban) air pollution.
- Energy use on global scale ~ 100 EJ and growing.
- Biofuels could offer an alternative
- Large variety of (possible) fuel-vehicle chains in differing stages of development.
- Biomass markets (resources and fuels) are developing towards international level and commodity trading.





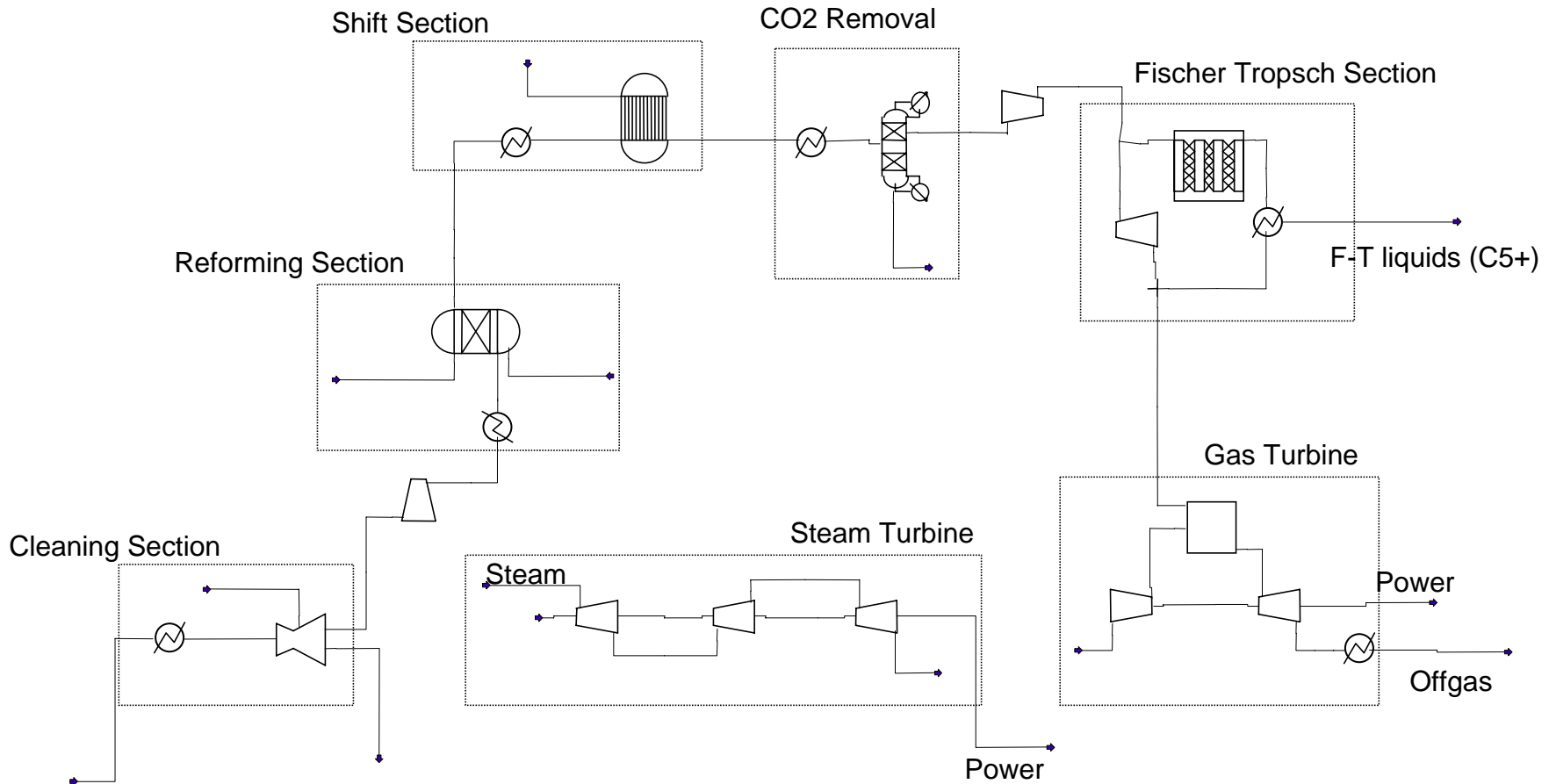
General process scheme

Biomass gasification to FT liquids - with gas turbine



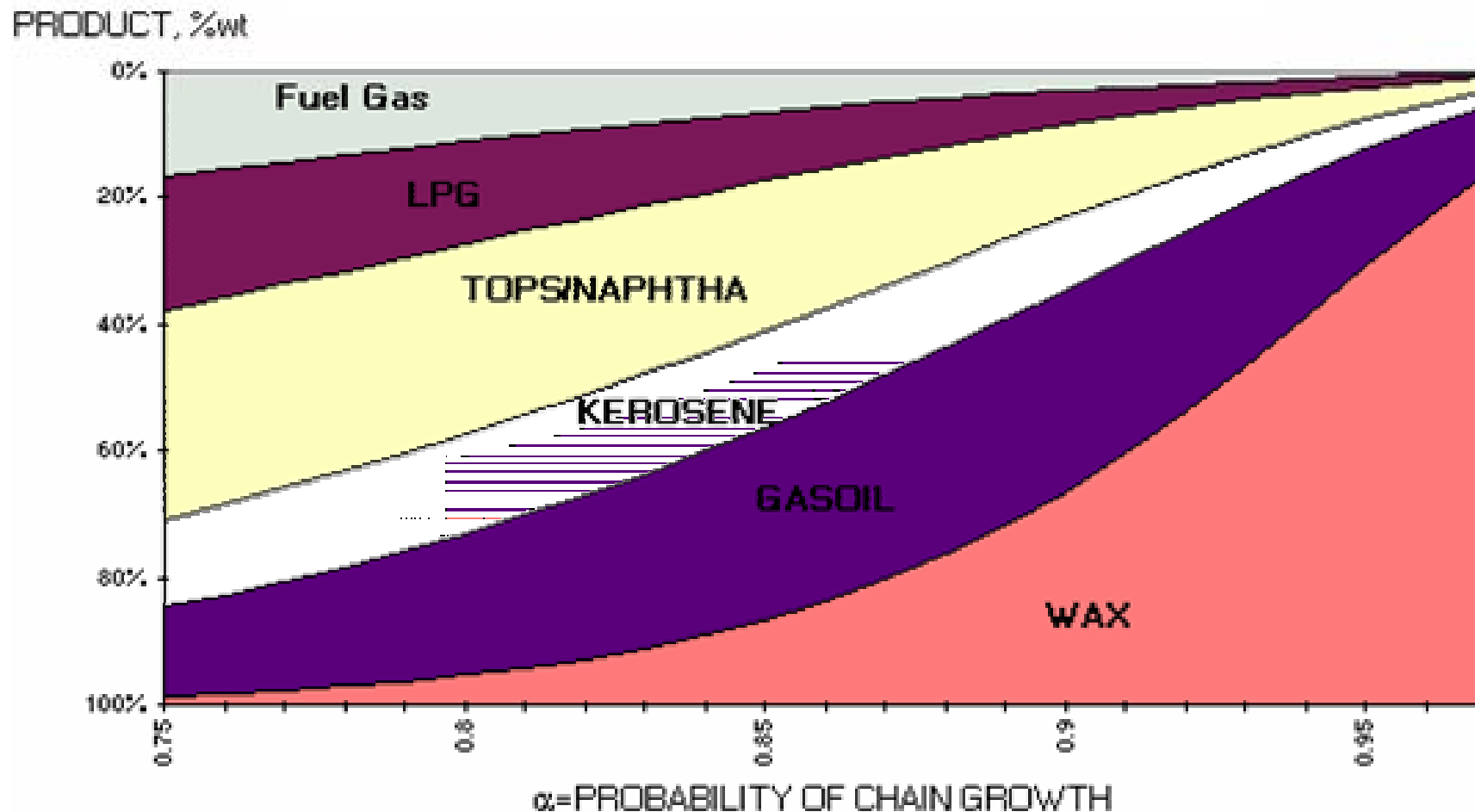


Typical flowsheet for the calculation of mass and energy balances





FT product distribution for different values of α



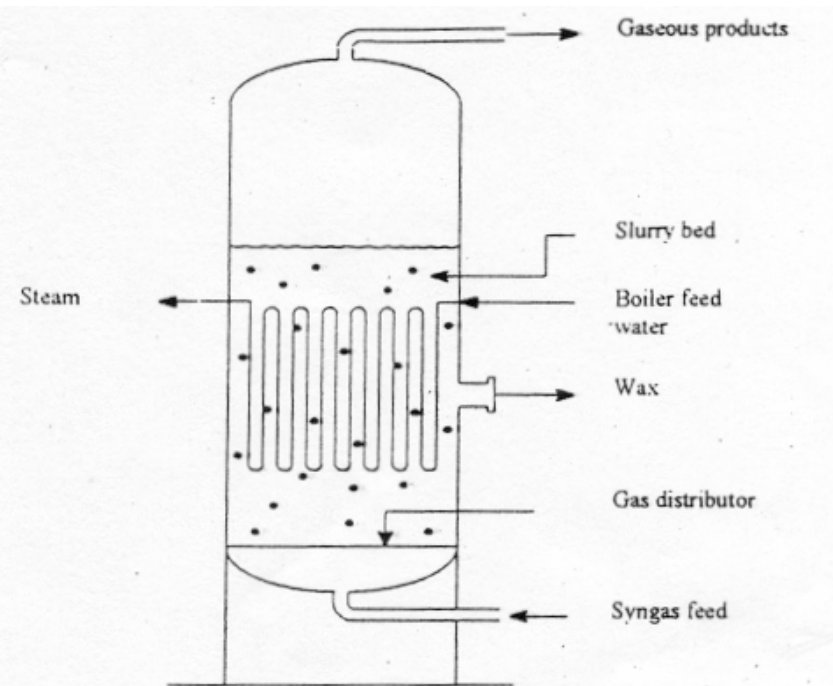
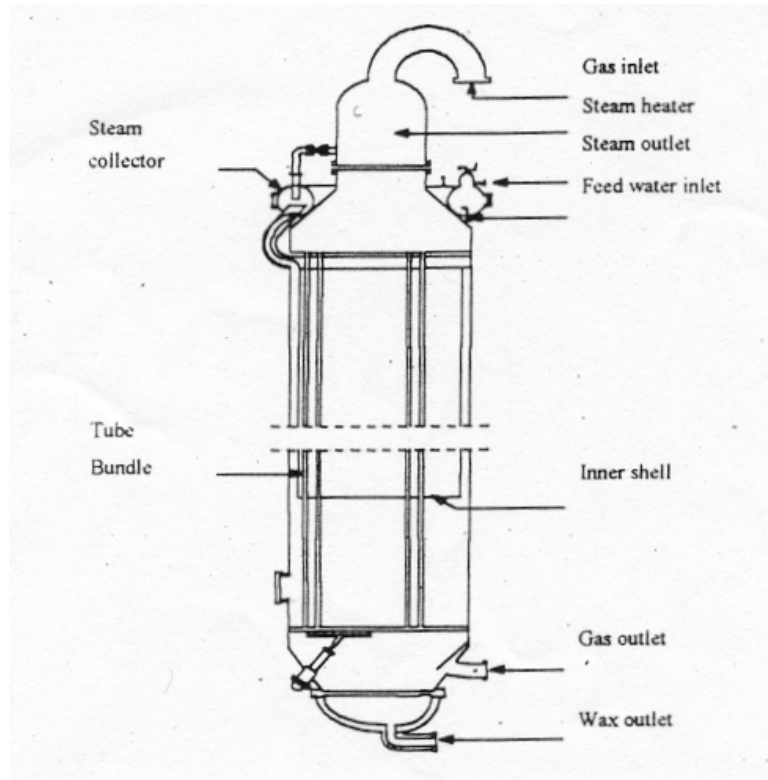


Gasifier characterisation

	BCL (Batelle Columbus gasifier)	IGT (Institute of Gas Technology)	IGT+ (IGT with process adjustment, based on estimates)	EP (Enviro Power with dolomite tar cracker)	TPS (Thermiska Processing with dolomite tar cracker)
Process type	Indirect, airblown, atmospheric	Direct, oxygen blown, pressurised	Direct, oxygen blown, pressurised	Direct, airblown, pressurised	Direct, airblown, atmospheric
Maximum size MW _{th} HHV	200	400	400	400	110
Gasifier efficiency in %	86.8	80.7	80.9	88.6	80.0
Composition in mol % [dry]					
H ₂ O	19.9 [0]	31.8 [0]	50.6[0]	13.55*[0]	13.55[0]
H ₂	16.7 [20.8]	20.8 [30.5]	15.68[31.7]	10.03[11.6]	13.25[15.3]
CO	37.1 [46.3]	15.0 [22.0]	7.83[15.85]	13.83[16.0]	17.22[19.9]
CO ₂	8.9 [11.1]	23.9 [35.0]	17.71[35.9]	15.4[17.8]	12.22[14.1]
CH ₄	12.6 [15.7]	8.2 [12.0]	5.73[11.6]	7.26[8.4]	2.82[3.26]
C ₂₊	4.8 [6.0]	0.3 [0.5]	0	0.48[0.62]	0.96[1.11]
C ₂ H ₄	4.2 [5.2]				0.94
C ₂ H ₆	0.6 [0.74]				0.02
N ₂ +Ar	0	0	0.40[0.8]	38.9[45.3]	39.20[45.3]
Others	<0.3	<0.3	<0.3	<0.3	<0.3
H ₂ /CO ratio	0.45	1.39	2.0	0.73	0.77

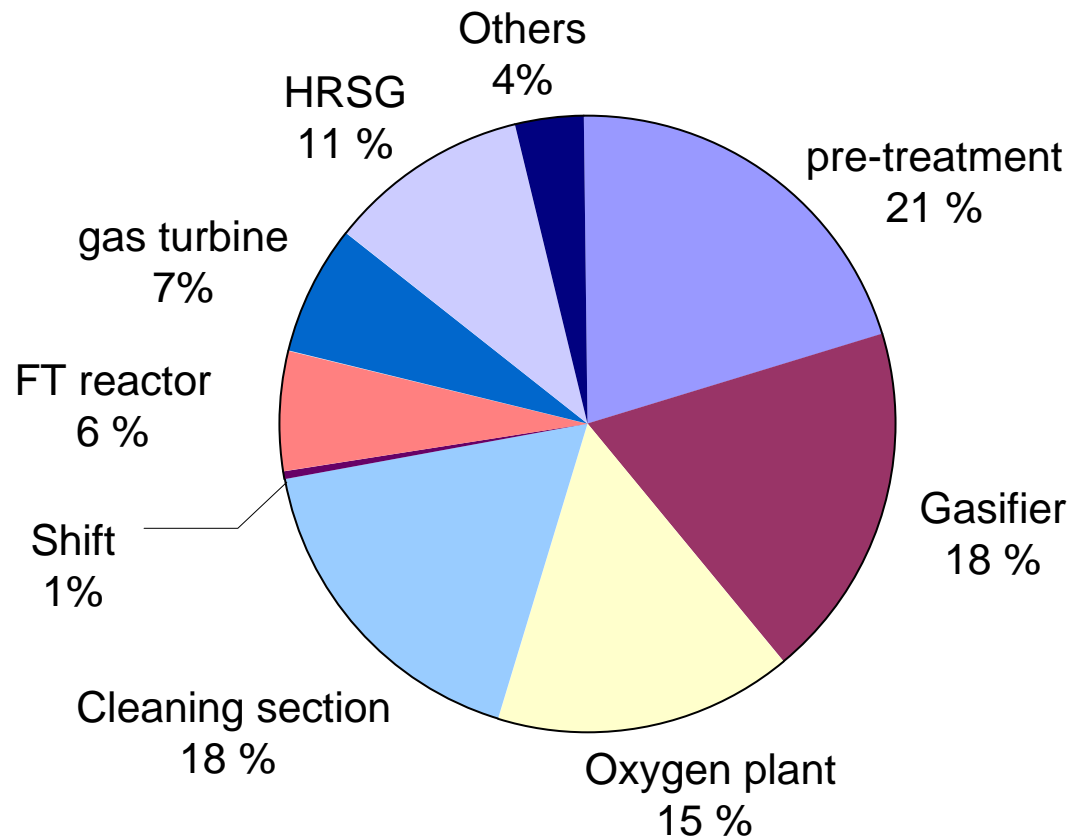


Fixed bed (L) and fluidised bed (R)



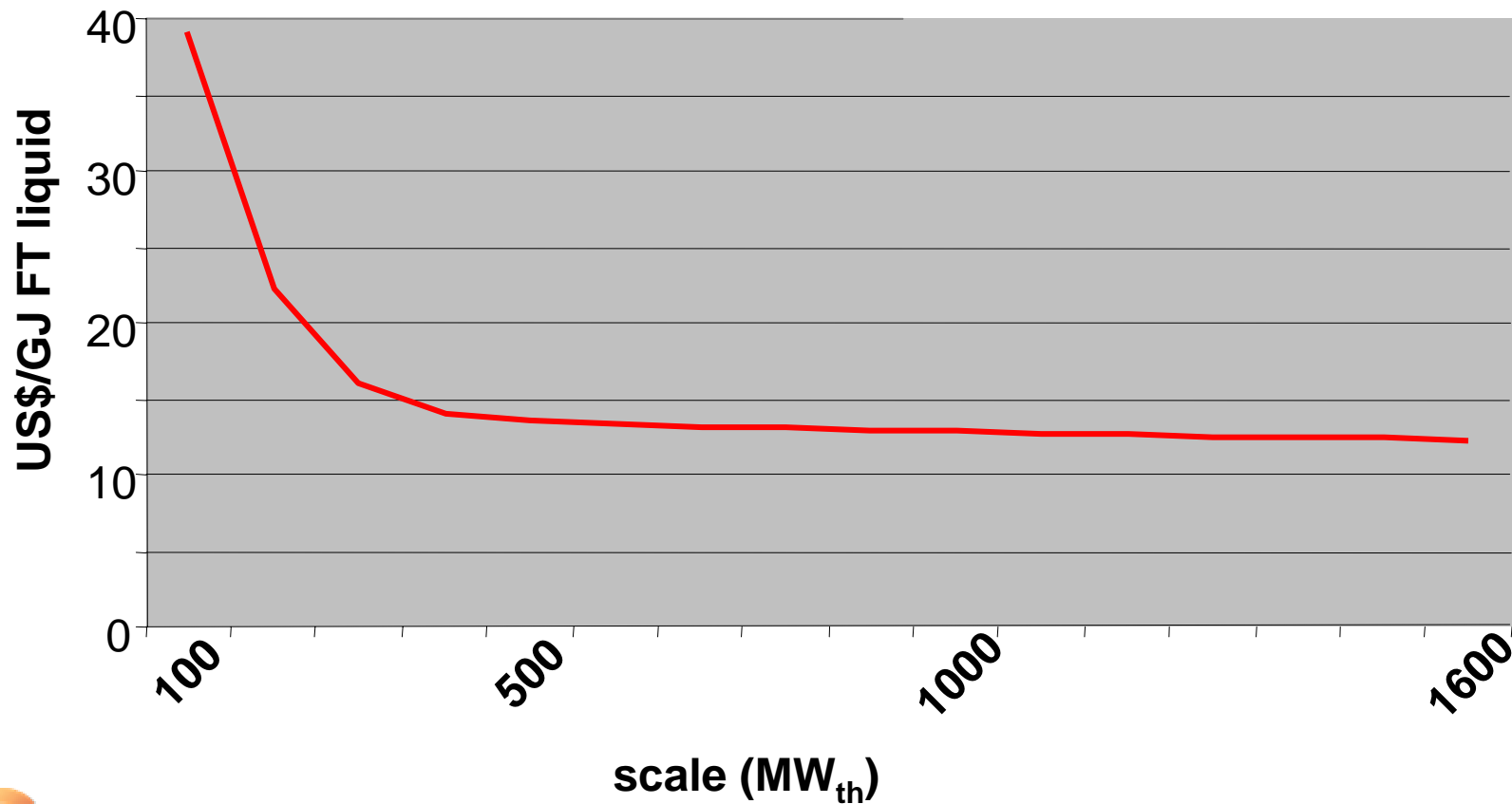


Breakdown installed costs for the IGT 80% conversion concept (400 MW_{th})





Effect of scale on production costs FT liquids





FT on short and long term

Short term (first commercial plant)

- IGT full conversion (40% once through, with CO₂ removal) is the best concept
- obtainable $\alpha=0.8$
- scale of the system is 400 MWth
- biomass costs are US \$2/GJ

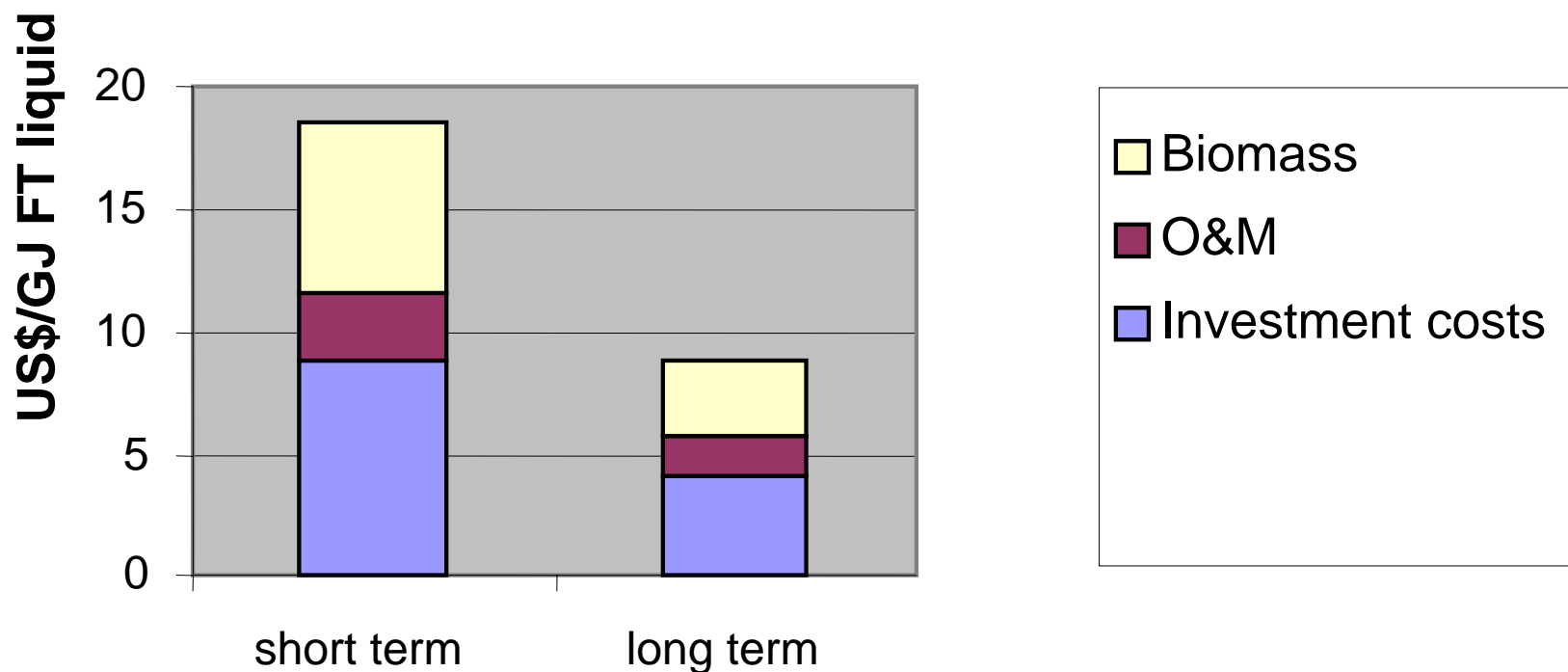
Long term (third generation)

- IGT once through 80% conversion (with high efficiency gas turbine) is the best concept
 - obtainable $\alpha=0.9$
 - scale of the system is 1600 MWth
 - biomass costs are US \$2/GJ
 - technological learning reduces capital costs with 15%
-





Costs breakdown FT crude (excluding hydrocracking)





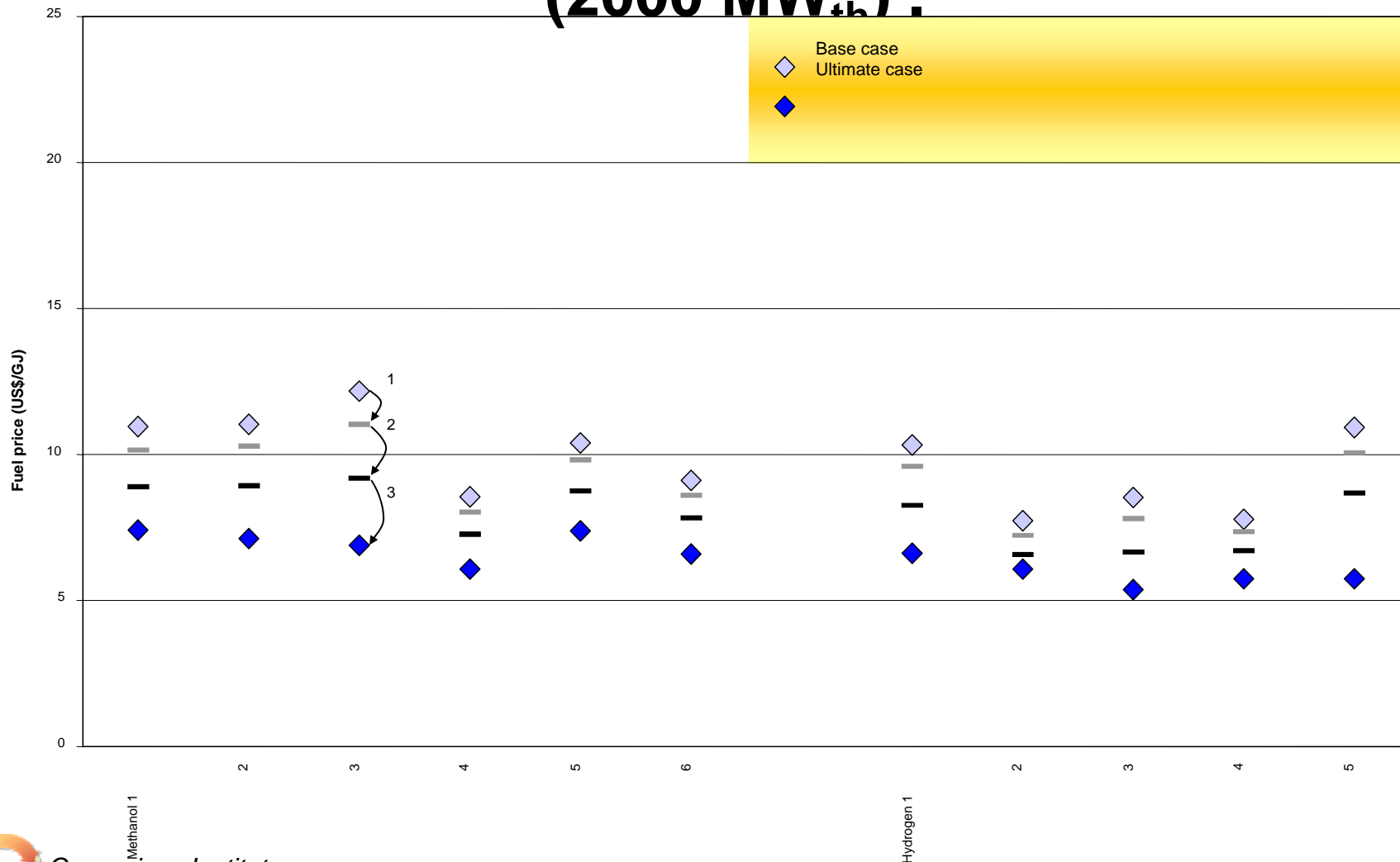
MeOH & H2 production configurations

		HHV Output (MW)		HHV Efficiency (%)	
		Fuel	Net electricity ¹⁾ (gross – internal)	Fuel + E	Fuel only ²⁾
Methanol					
1	IGT – max H2, Scrubber, Liquid Phase Methanol Reactor, Combined Cycle	161	53 (71 – 18)	50%	52%
2	IGT, Hot Gas Cleaning, Autothermal Reformer, Liquid Phase Methanol Reactor with Steam addition, Combined Cycle	173	62 (82 – 20)	55%	59%
3	IGT, Scrubber, Liquid Phase Methanol Reactor with Steam addition, Combined Cycle	113	105 (118 – 14)	51%	58%
4	BCL, Scrubber, Steam Reformer, Liquid Phase Methanol Reactor with Steam Addition and Recycle, Steam Cycle	246	0 (25 – 25)	57%	57%
5	IGT, Hot Gas Cleaning, Autothermal Reformer, Partial Shift, Conventional Methanol Reactor with Recycle, Steam Turbine	221	15 (38 – 23)	55%	56%
6	BCL, Scrubber, Steam Reforming, Partial Shift, Conventional Methanol Reactor with Recycle, Steam Turbine	255	-17 (10 – 27)	55%	54%
Hydrogen					
1	IGT, Hot Gas Cleaning, Dual Shift, Pressure Swing Adsorption, Combined Cycle	176	73 (93 – 21)	58%	66%
2	IGT – max H2, High Temperature Dust Filter, Ceramic Membrane (Internal Shift), Expansion Turbine	259	-1 (25 – 26)	60%	60%
3	IGT, Hot Gas Cleaning, Ceramic Membrane (Internal Shift), Combined Cycle	177	84 (103 – 19)	61%	74%
4	BCL, Scrubber, Steam Reformer, Dual Shift, Pressure Swing Adsorption	303	-22 (0 – 22)	65%	63%
5	BCL, Scrubber, Dual Shift, Pressure Swing Adsorption, Combined Cycle	149	72 (97 – 25)	52%	56%



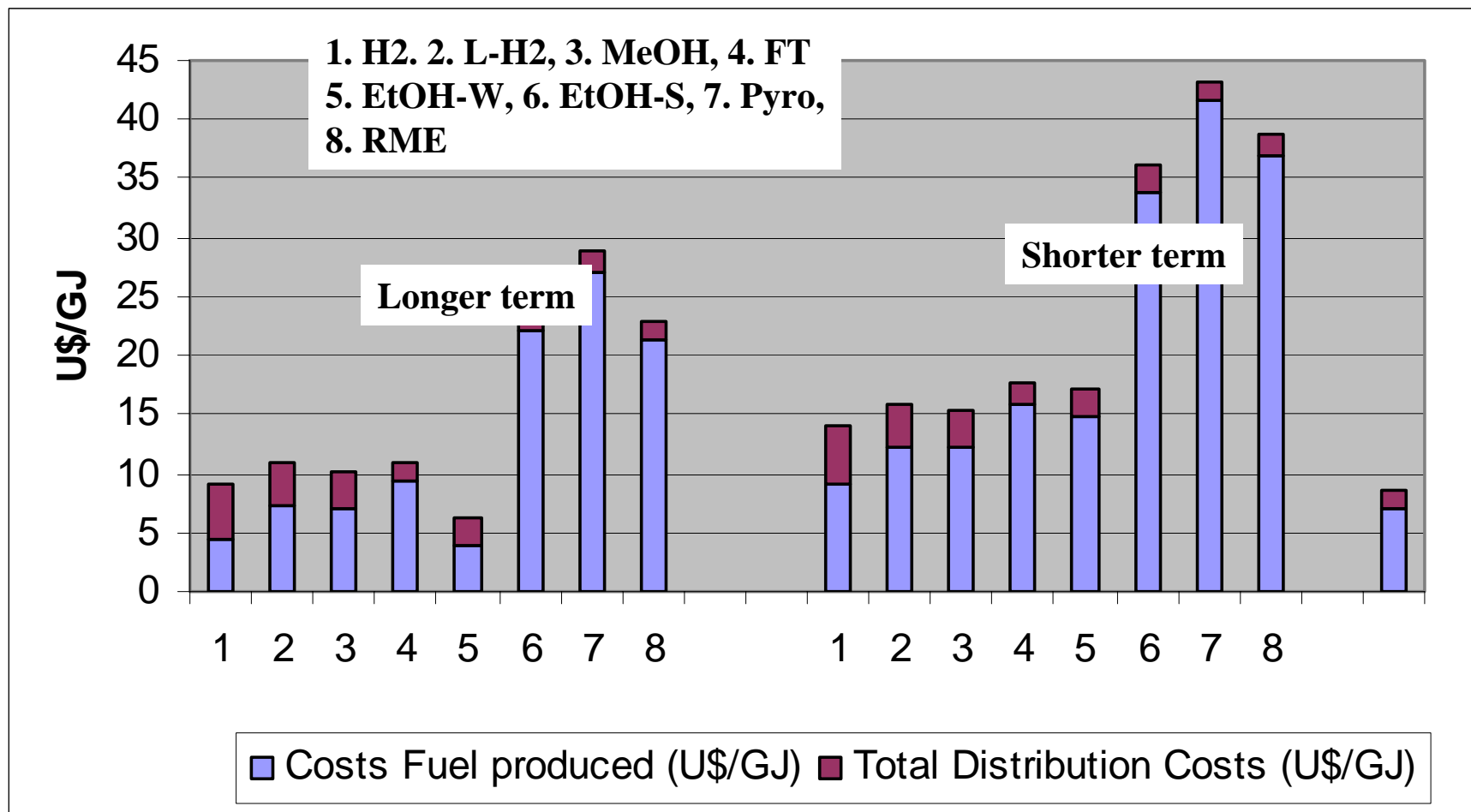


Costs & cost reductions: (1) biomass costs 15% lower, (2) technological learning (3) scale increase (2000 MW_{th}).



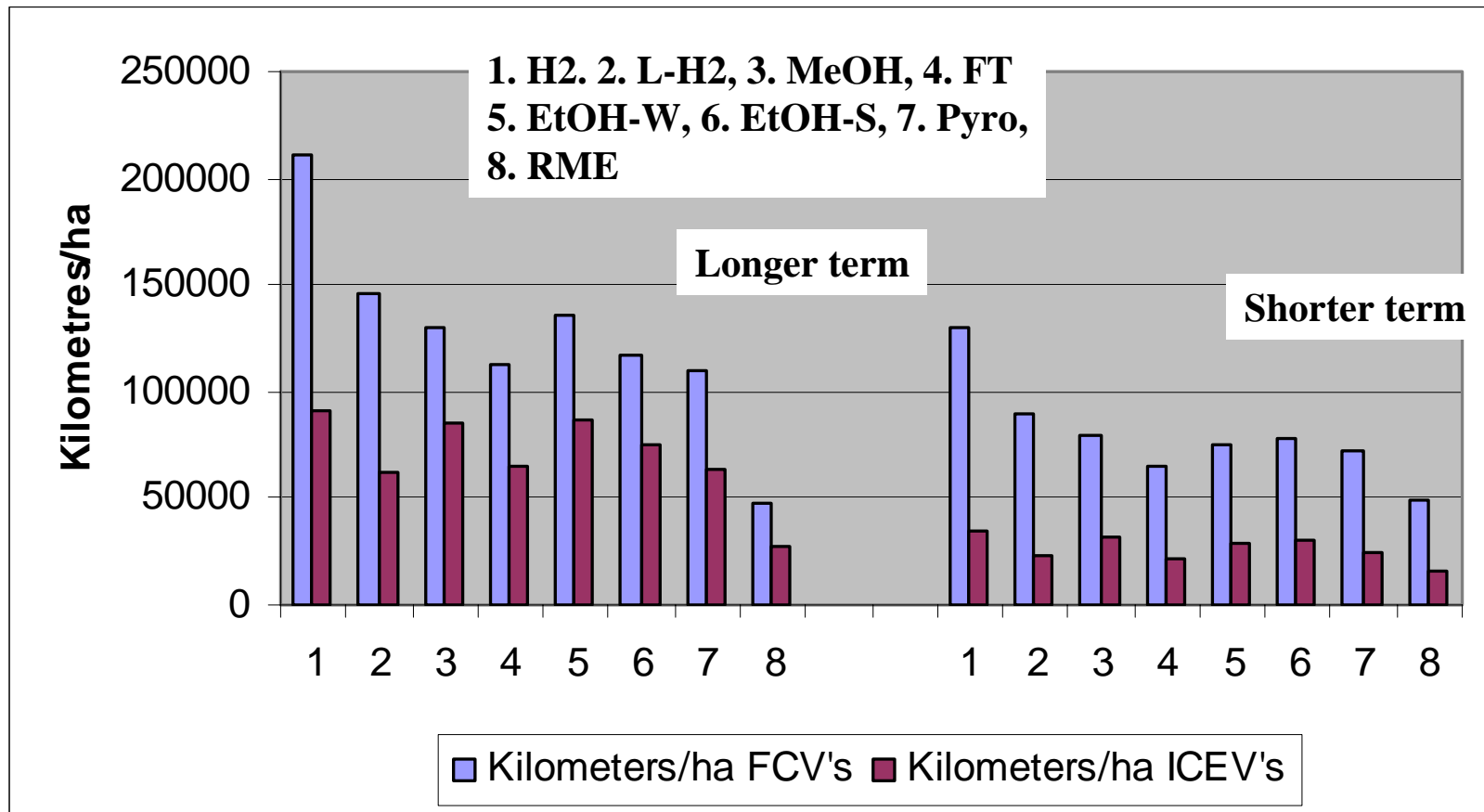


Costs per GJ fuel delivered at the car



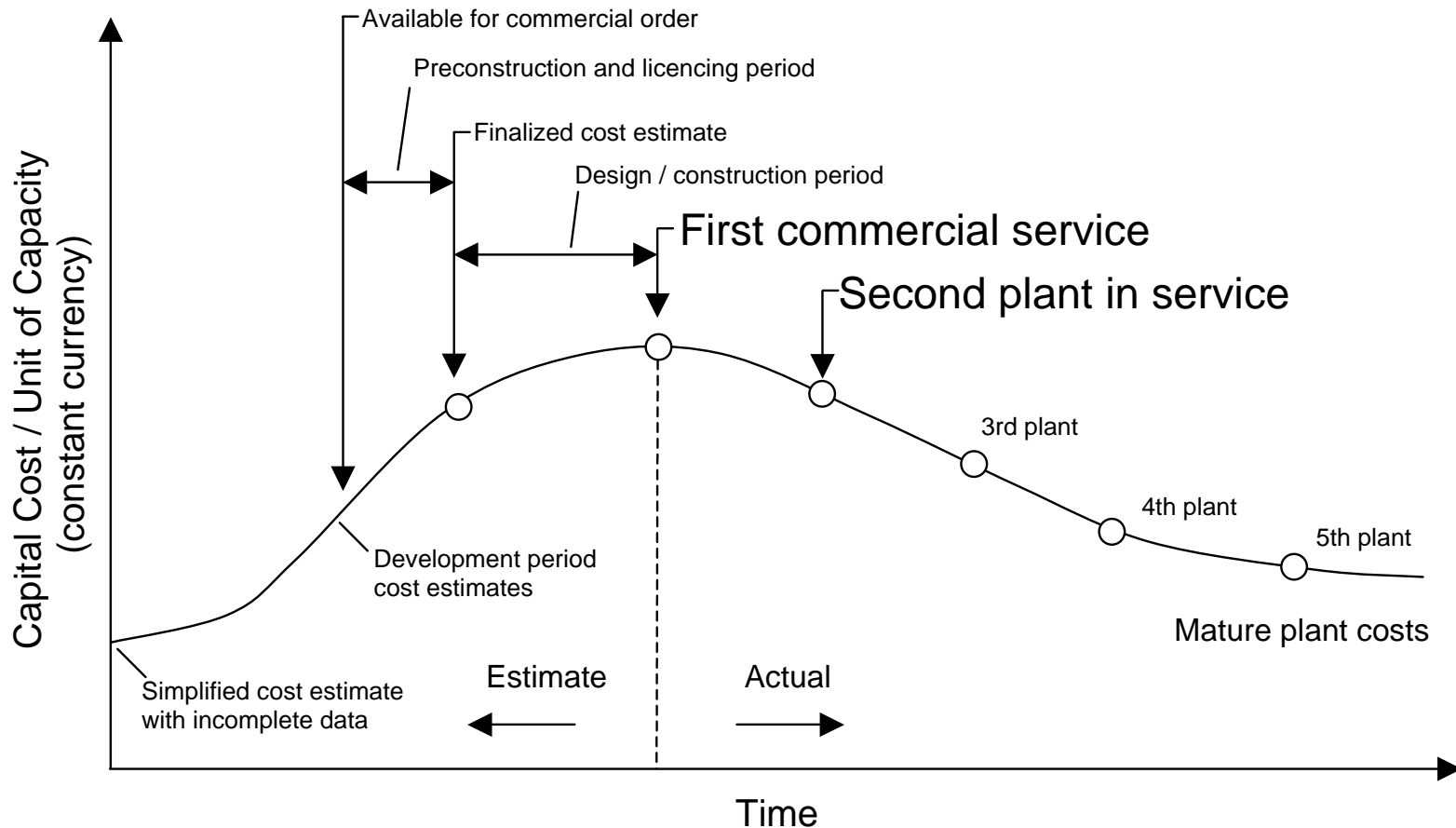


Biofuel chains; kilometres per hectare.





Generic learning curve for (e.g.) power plants; 'time' means decades





Ethanol from sugar cane...

J. Goldemberg et al. / Biomass and Bioenergy 26 (2004) 301–304

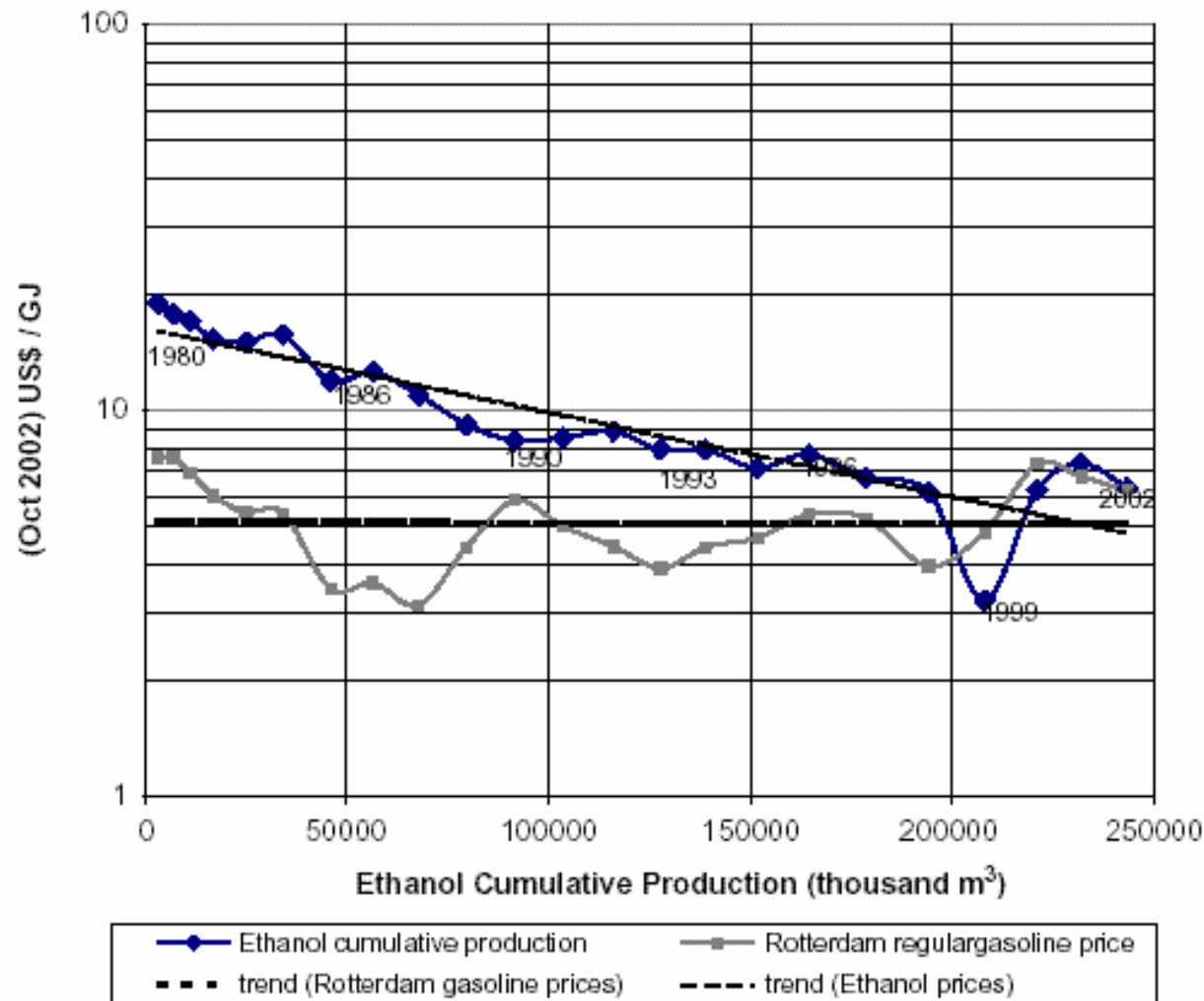
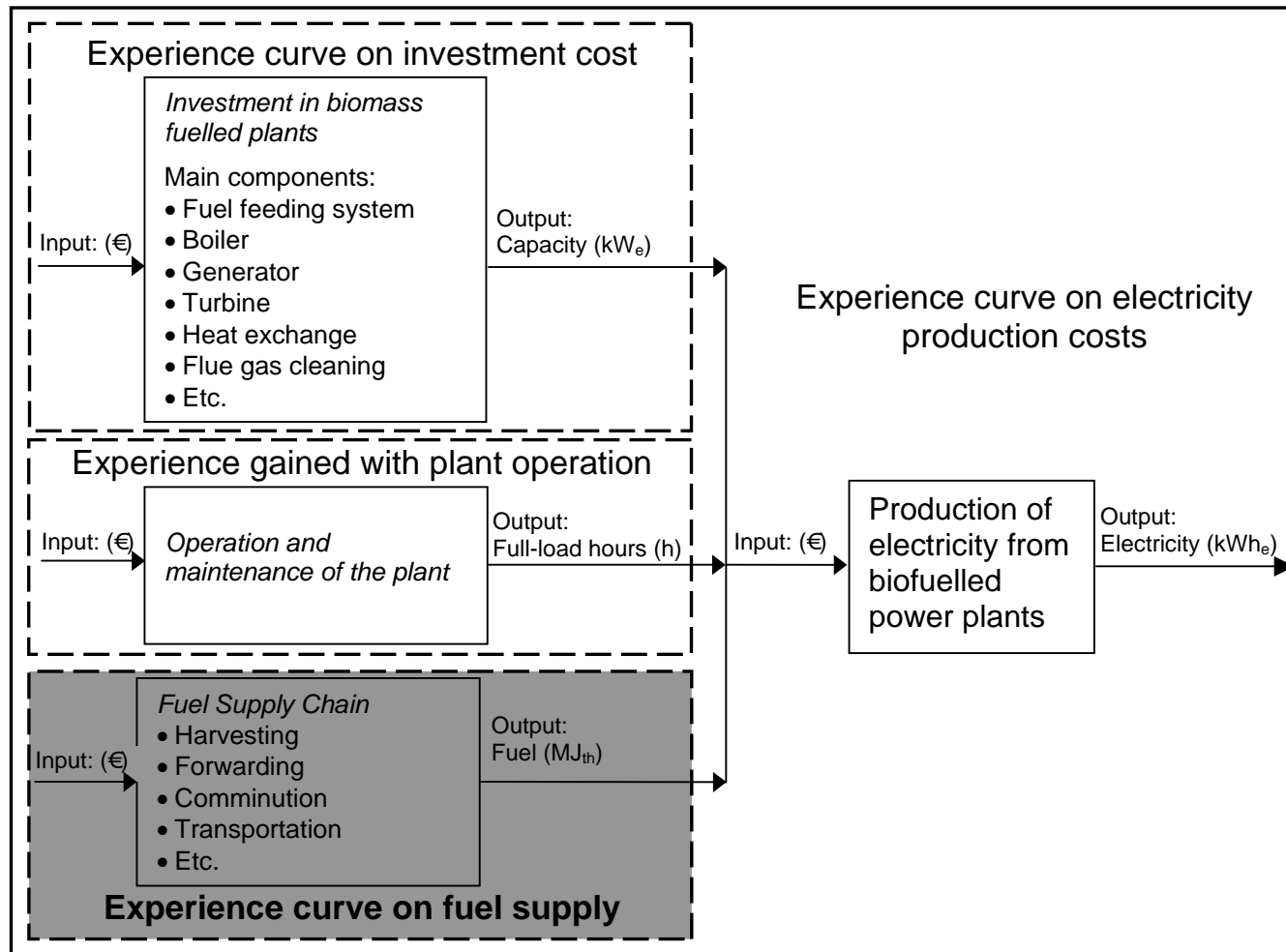


Fig. 2. Ethanol and gasoline prices.

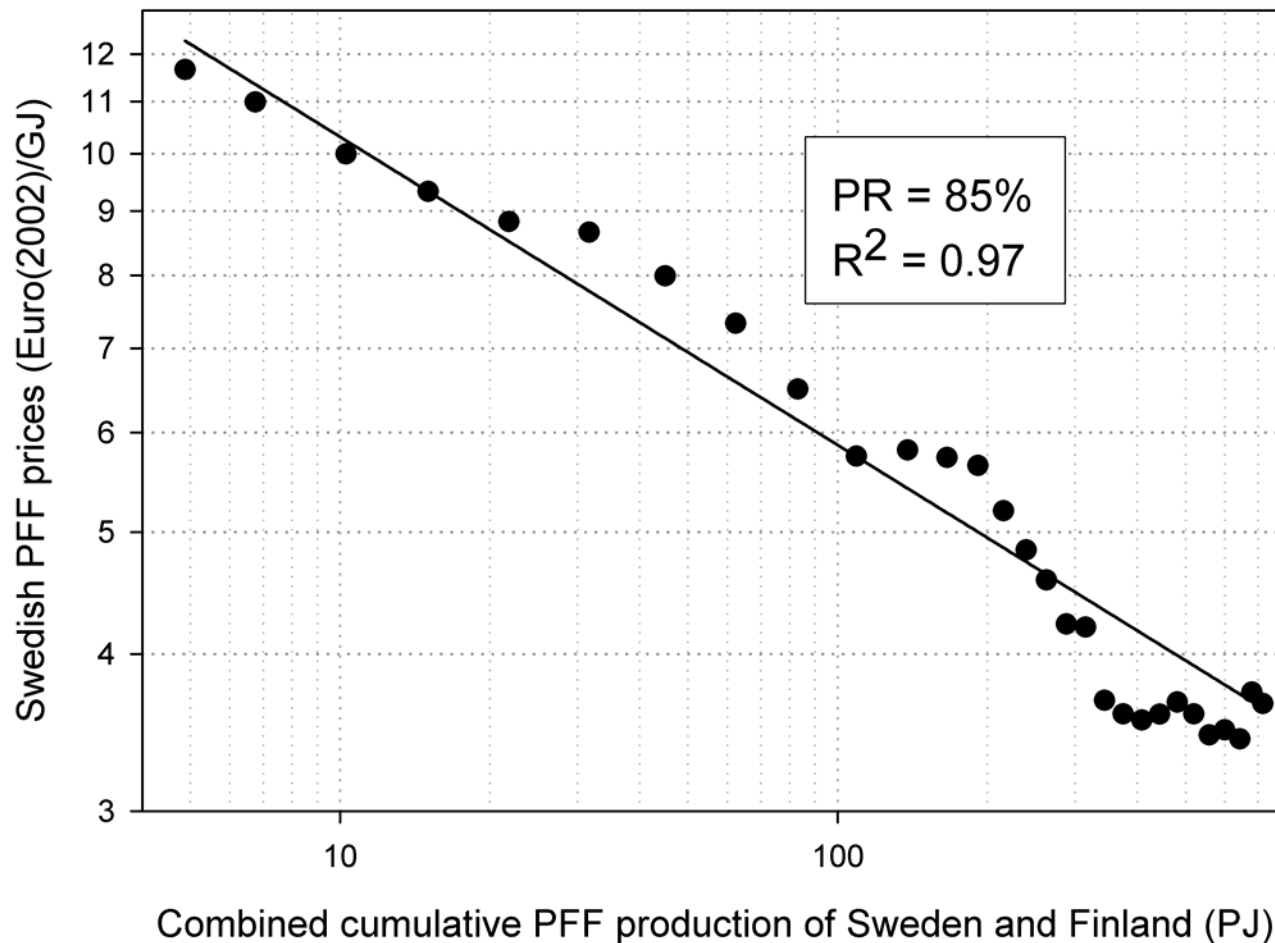


Total learning system for biomass-fuelled power plants producing electricity



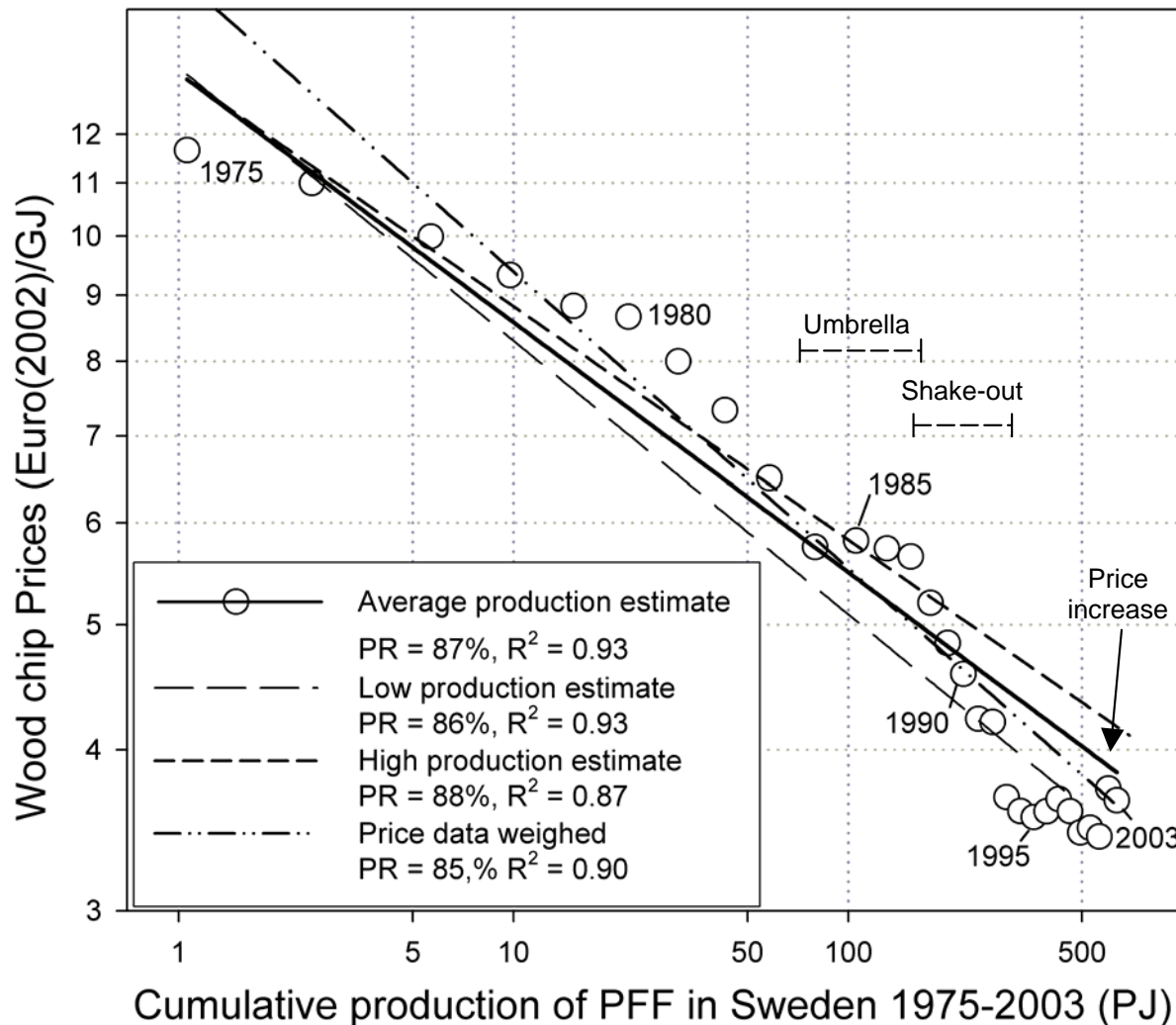


Experience curve for Sweden and Finland combined, between 1975 and 2003.



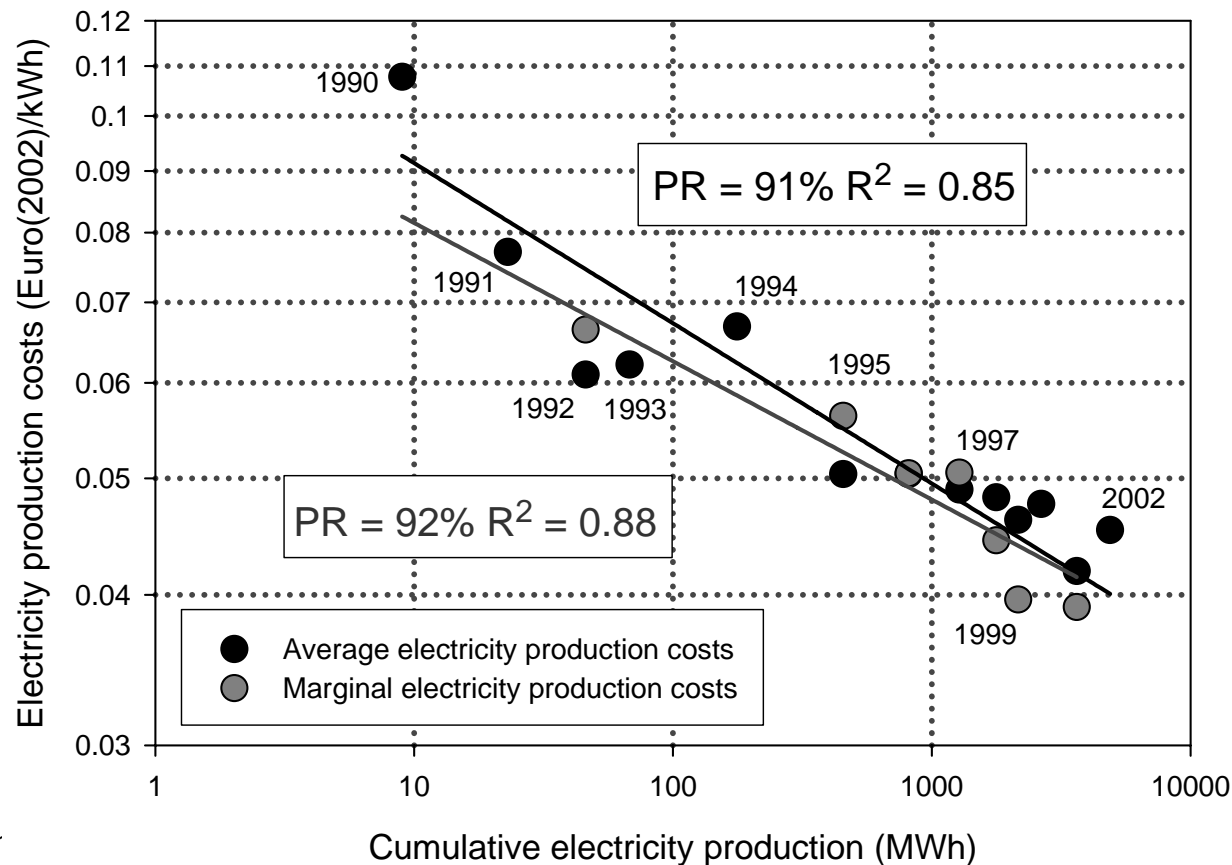


Experience Curve for Swedish PFF production from 1975-2003





Experience curve for the average and marginal production cost of electricity from Swedish biofuelled CHP plants from 1990-2002





Summary of energy related RD&D expenditures in IEA countries for the period 1983 – 1997. Both absolute and relative expenditures have dropped over time (WEA, 2000)

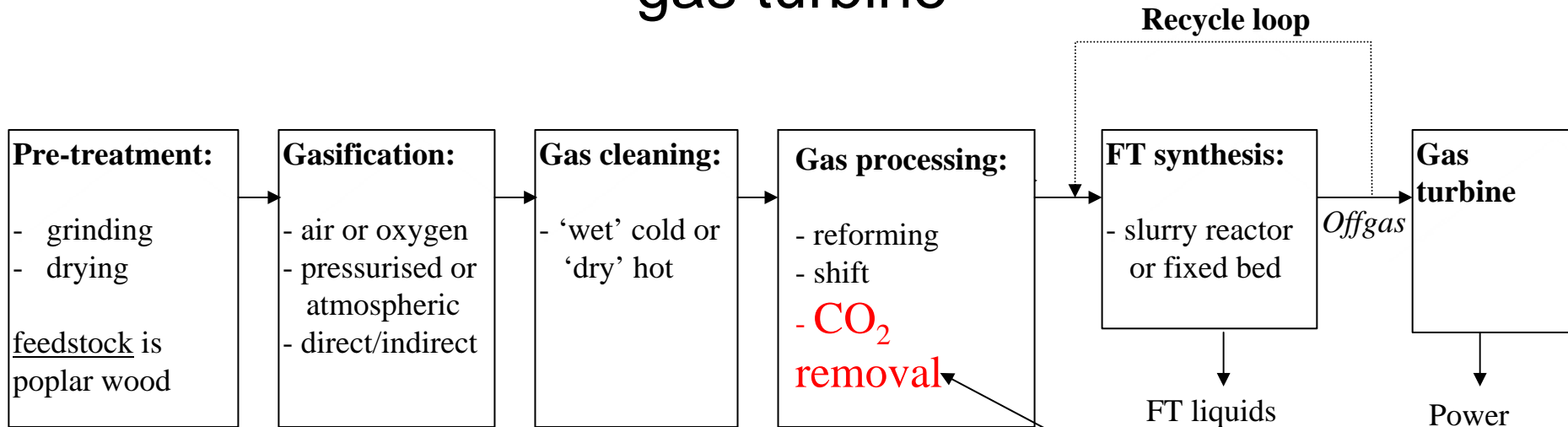
Year	Fossil	Nuclear (fission +fusion)	Energy conservation	Renewables	Other	Billion U\$	Percentage GDP	GDP (trillion 1998 U\$)
1983	1.61	7.52	0.82	1.03	1.09	12.07	0.158	7.64
1990	1.74	5.02	0.54	0.58	1.21	9.90	0.056	16.23
1995	0.90	4.20	1.05	0.68	1.39	8.22	0.037	22.44
1997	0.69	3.87	0.94	0.59	1.43	7.52	0.034	21.99





General process scheme

Biomass (& coal) gasification to FT liquids - with gas turbine



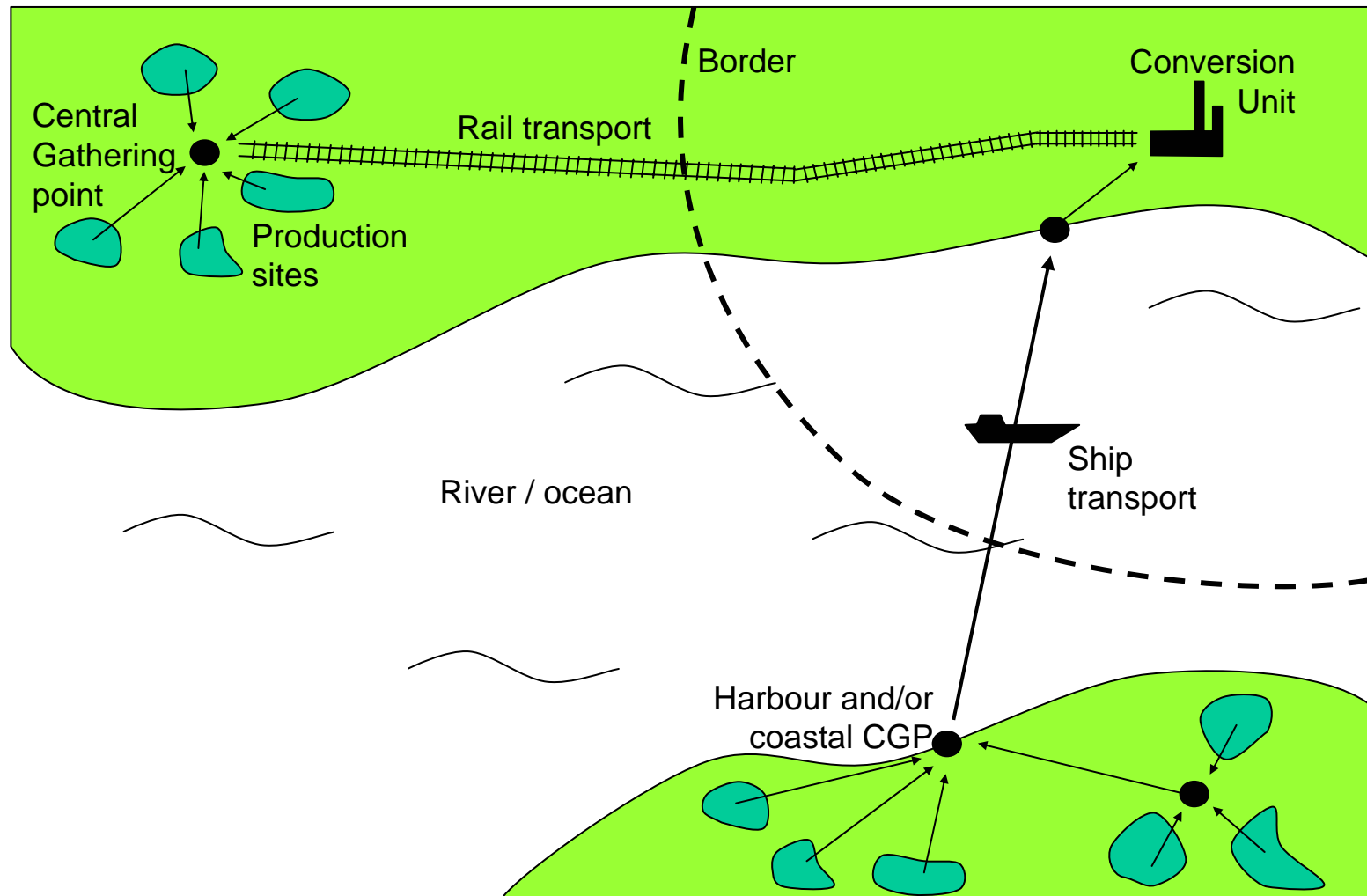
Major investments in IG-FT capacity ongoing in China **right now**:

- Reducing dependency on oil imports!
- Without capture strong increase in CO₂ emissions...

About 50% of carbon!



International bio-energy logistics



Source: Hamelinck, Faaij, 2003



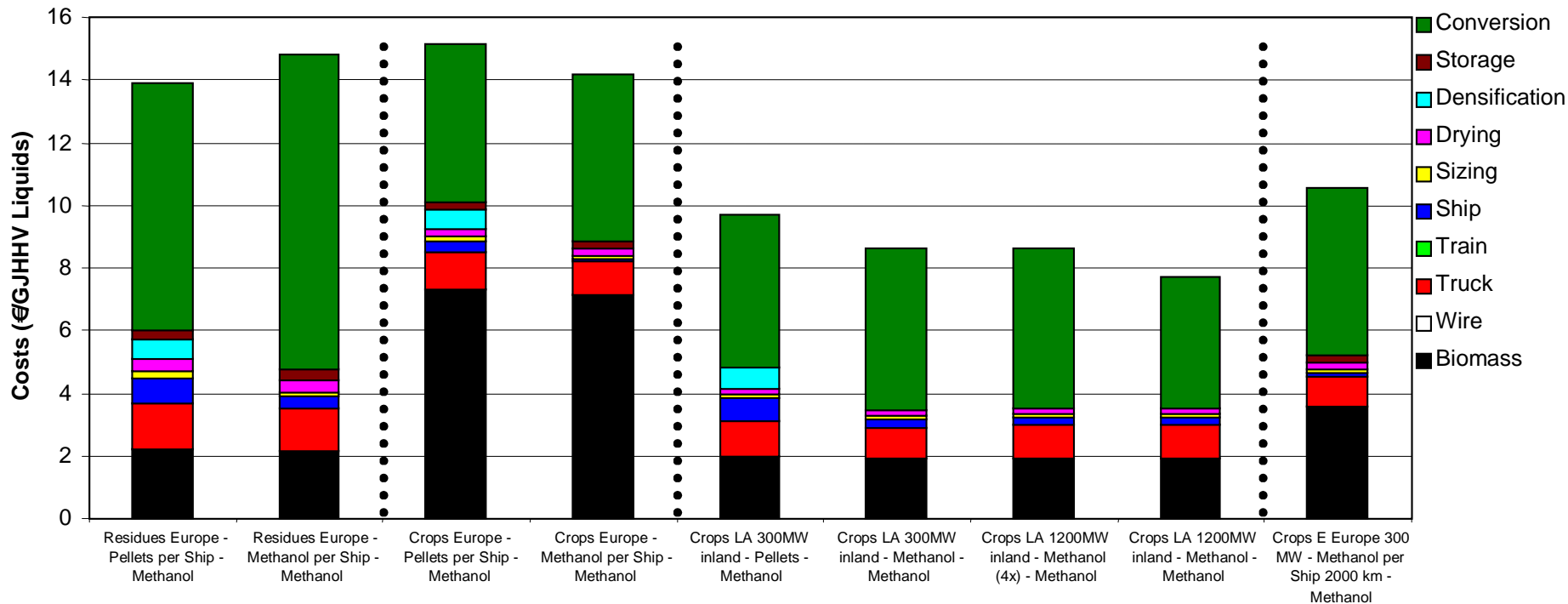
Many possible 'biotrade chains'

Exporter	Transport/transfer/storage	Importer
Biomass production	'raw' biomass	Full conversion
Biomass production & pre-treatment	Pre-treated (pellets, bales, bio-oil) biomass	(partial) conversion
Biomass production & conversion	Fuels (H ₂ , MeOH, EtOH, HC's)	End-use
Production and conversion	Electricity transport	End-use
Biomass production	'conversion along the way'	End-use





Bio-methanol produced from North & Eastern European and Latin American biomass supplied to Rotterdam Harbour.





Key RDD&D issues for bio-synfuels (I)

- Gasification: CFB, pressurized, large scale applications, cost reduction, scaling (single vessels), producing 'dedicated' (H₂/CH₄) syngas, minimizing tar formation (entrained...), fuel feeding.
- Gas cleaning: tar formation and removal, hot gas cleaning for stringent demands, cost reductions.
- Conceptual: fuel flexibility (co-fed and co-fired), multi-output systems, ceramic membrane technology, overall process integration.
- System-chain performance: optimisation including supply chain...





Key RDD&D issues for bio-synfuels (II)

- Coherent efforts over prolonged periods of time are essential for success.
- This will cost money.
- In liberalised energy markets national governments and supra-national bodies are key drivers.
- Market development essential component.
- Merge fundamental and applied (industrial) research in coherent programs.
- Set-up programs in international setting.





Final considerations (I)

- Biomass derived synfuels have potential to play a key role in the future worlds' energy supply; efficient & competitive.
- Development of several decades is needed to achieve wanted performance levels.
- Large scale production systems are a major factor in obtaining favorable economics; synergies with fossil fuels should be investigated further, in particular for shorter term.
- Conversion platforms (e.g. clustered around large entrained flow gasifiers) could be very flexible options.





Final considerations (II)

- Combination of biomass and fossil fuel fed conversion platforms offer flexibility, fuel security and thus low(er) risks, while combined with high quality output(s).
- Can be used for drastic GHG emission reductions (CCS) when needed (negative emission concept).
- Conversion platforms can respond to CO₂ price...





Final considerations (III)

- Costs on shorter term perhaps less important...
- Flexibility(!) low supply risks (versus oil).
- High quality fuels reduce non-GHG emissions as well.
- Fuel production costs minor share in driving costs.
- Combination of biofuels with hybrids or FCV's can obtain major breakthroughs in terms of efficiency (energy and land-use) and from environmental point of view.

