Co-Production of Transportation Bio-Fuels - Current Finnish Focus

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VTT

Annual Meeting of the Finnish Recovery Boiler Committee
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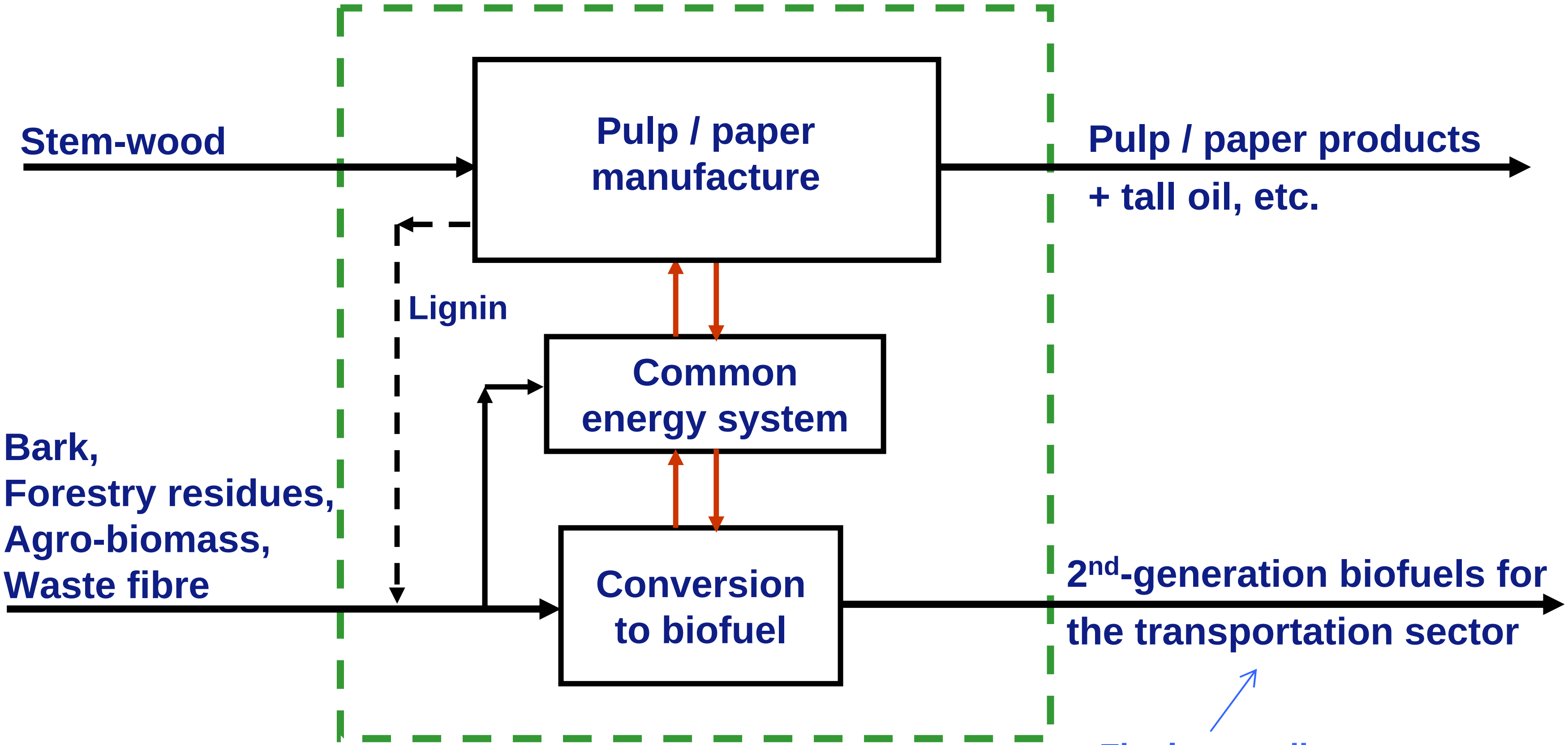
Co-Production of Transportation Fuels at Pulp and Paper Mills

The First Step Towards the Forest-Based Biorefinery



Final upgrading to transportation fuels may be carried out at a centralised facility elsewhere

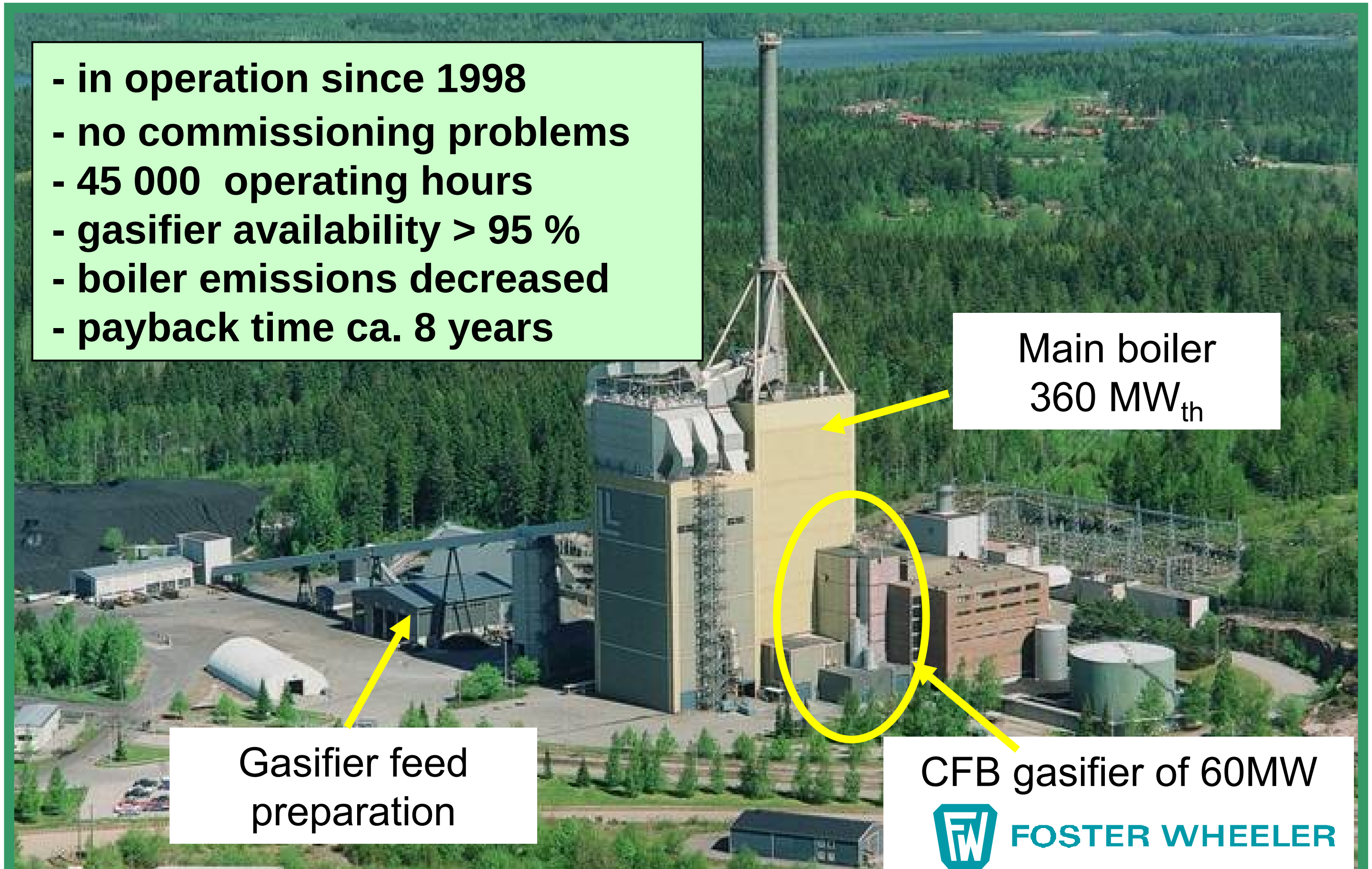
The Approach of the UCG R&D Project

- Development and commercialisation of technology for producing multi-purpose synthesis gas (syngas) from solid biofuels:
  - fluidised-bed gasification, applicable to a wide range of fuels:
    - woody biofuels, peat
    - straw and other agro-biomasses
    - waste-derived fuels
  - novel catalytic gas reforming and conditioning
- Finland (industrial companies, VTT) has strong track record in biomass gasification; recent gasifiers include Lahti and Corenso AFBs
- Envisaged commercial scale: 200 – 300 MW_{feed}; preferably integrated with energy-consuming paper mills
- The long-term objective is no less than to develop superior bio-syngas technology for export markets; e.g. a target cost of < 50 c/l has been set for Fischer-Tropsch diesel production based on this technology.

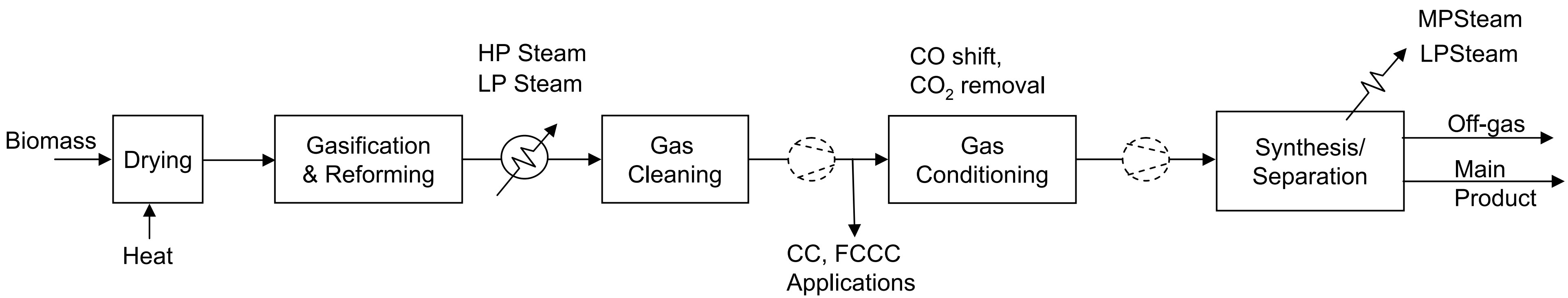
One of Several Successful Gasifiers Operating in Finland

Co-Firing Biomass Wastes, Lahden Lämpövoima Ltd, Lahti, Finland

- in operation since 1998
- no commissioning problems
- 45 000 operating hours
- gasifier availability > 95 %
- boiler emissions decreased
- payback time ca. 8 years



General Layout of Processes for Bio-Syngas Production and Conversion



1 – 30 bar	1 – 30 bar	30 bar	FT, SNG, H_2: 20 – 30 bar CH_3OH, DME: 100 bar
850 °C	40 - 280 °C (final) (IGCC: 500 °C)	40 - 350 °C (initial)	FT, CH_3OH, DME, SNG, H_2/trad: 200 – 300 °C H_2/PSA: 40 °C

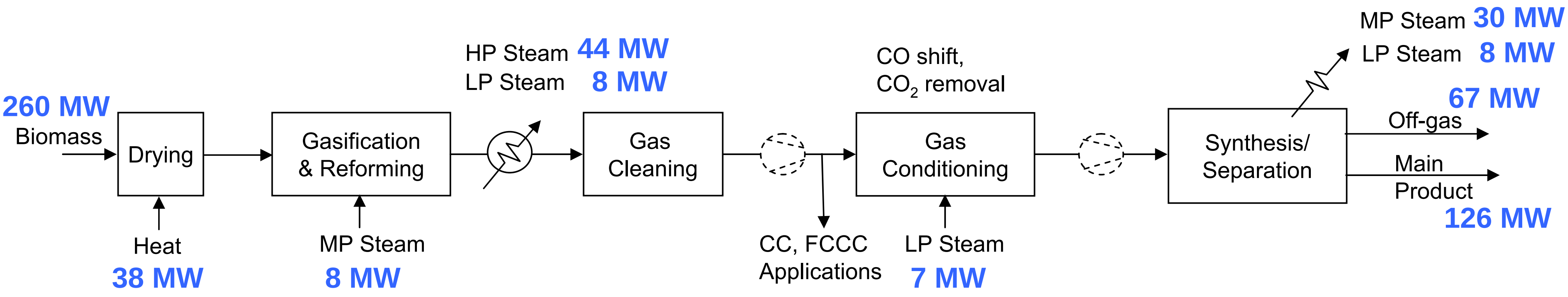
Abbreviations:

CC	Combined-Cycle energy production
FCCC	Fuel-Cell Combined-Cycle energy production
FT	Fischer-Tropsch liquid fuels
SNG	Synthetic Natural Gas (CH_4)
CH_3OH	Methanol
DME	Di-Methyl Ether
H_2/trad	Traditional process for H_2 production from syngas
H_2/PSA	H_2 production based on separation by Pressure Swing Absorption

General Layout of Processes for Bio-Syngas Production and Conversion

Fischer-Tropsch Liquids Example / Once-Through

Electricity consumption: 21 MW_e



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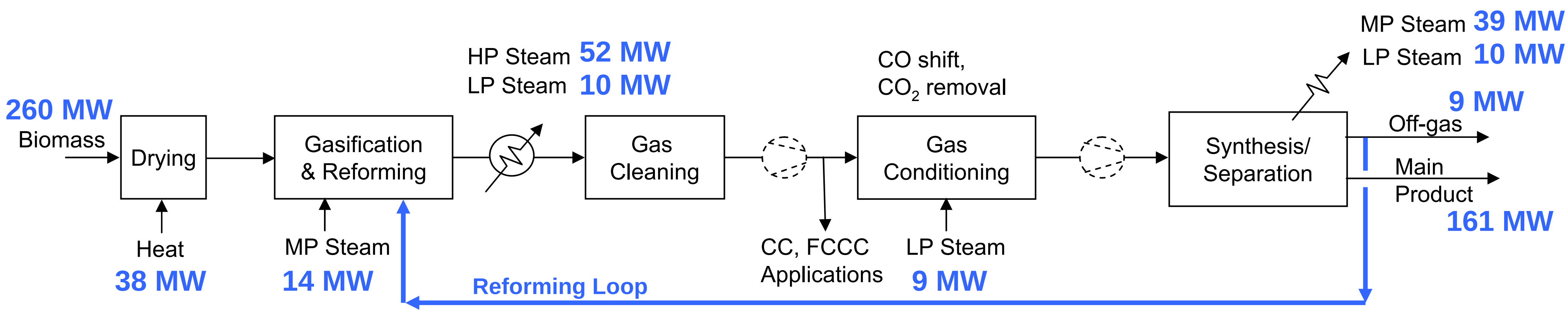
Fischer-Tropsch Liquids Example / Reforming Loop

Electricity consumption: 25 MW_e



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By-Product Energy of Synthesis-Gas Production and Conversion

A large amount of high-grade by-product energy

= significant potential benefit if integrated with a paper mill (or other energy-demanding industrial facility)

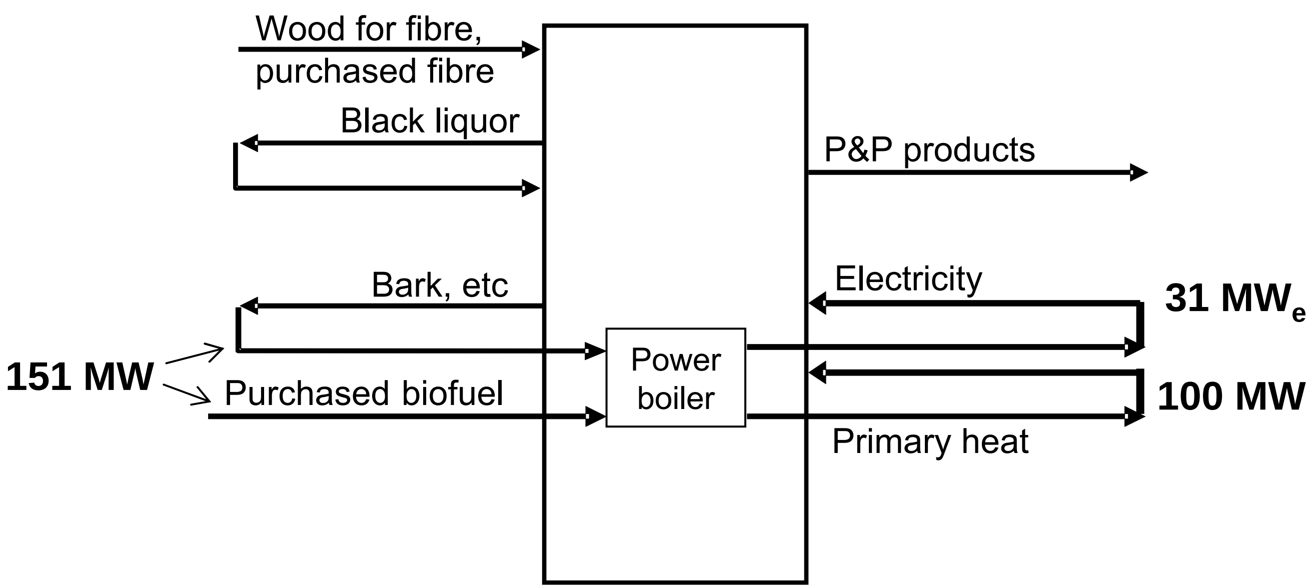
Example of Mill Energy Balances Before and After the Integration of a Plant Producing Fischer-Tropsch (FT) Liquids

- The next three slides (BEFORE, AFTER, NET CHANGES) show how the incremental energy balance is arrived at for one particular example of integration of an FT plant with a paper mill.
- For full integration benefit, the feed capacity of the original power-boiler process should be at least half that of the FT plant.

Co-Production of Syngas Derivatives at Pulp and Paper Mills

BEFORE INTRODUCTION OF FT PLANT

Power-Boiler Energy flows (LHV basis)



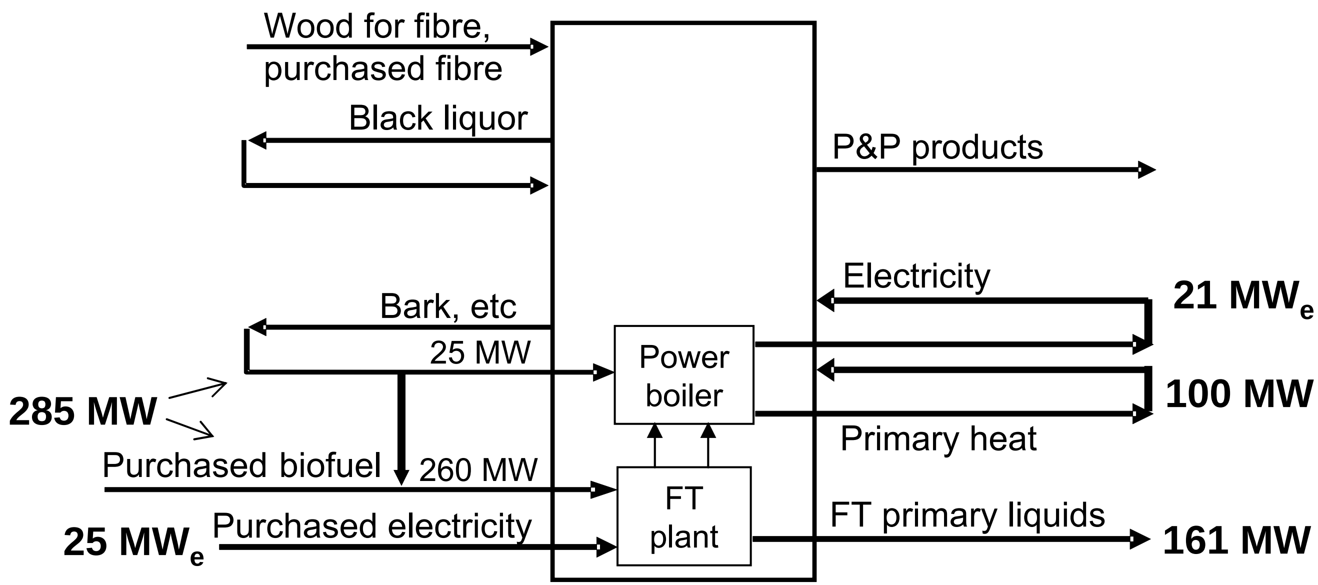
Co-Production of Syngas Derivatives at Pulp and Paper Mills

AFTER INTRODUCTION OF FT PLANT (260 MW_{feed})

Integration of steam system in conjunction with power boiler rebuild

Secondary heat used for biomass drying

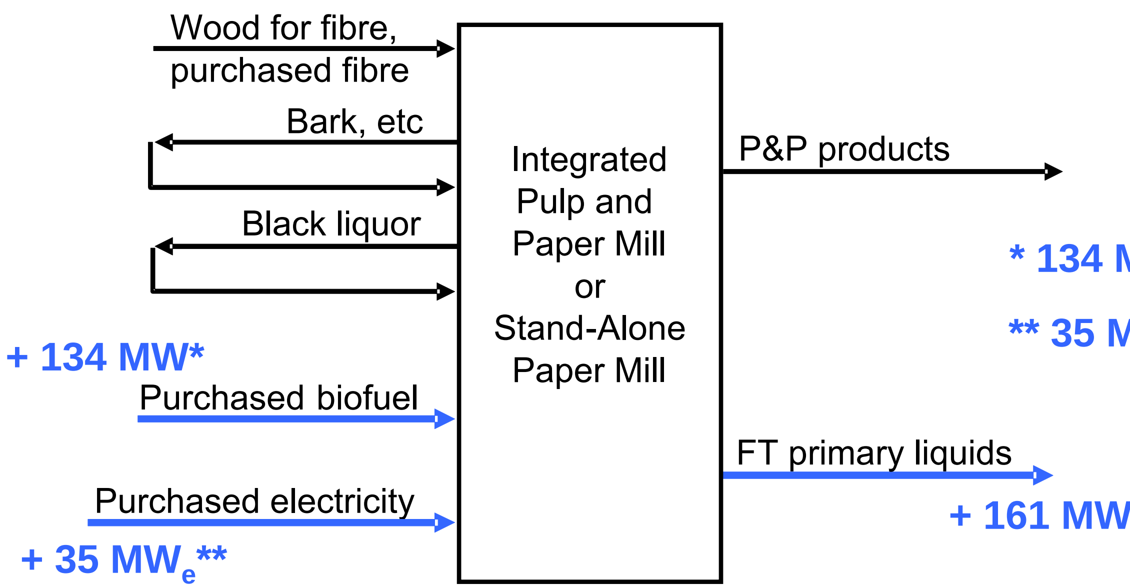
Energy flows (LHV basis)



Co-Production of Syngas Derivatives at Pulp and Paper Mills

NET CHANGES WITH INTRODUCTION OF FT PLANT (260 MW_{feed})

Integration of steam system in conjunction with power boiler rebuild
Secondary heat used for biomass drying
Incremental energy flows (LHV basis)



*** 134 MW = (285 – 151) MW**

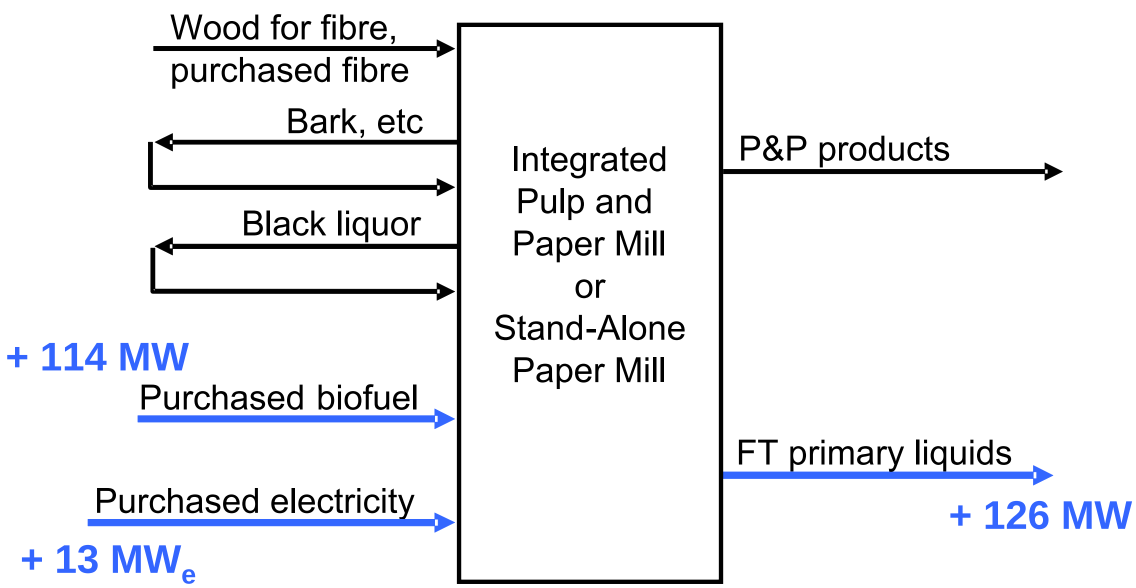
**** 35 MW = (31 – 21 + 25) MW**

Nominal overall efficiency = 100 x 161/(134 + 35/0.4) = 73 %
(purchased electricity generated from biomass at 40 % η)

Co-Production of Syngas Derivatives at Pulp and Paper Mills

FT ALTERNATIVE WITH LOWER ELECTRICITY INPUT

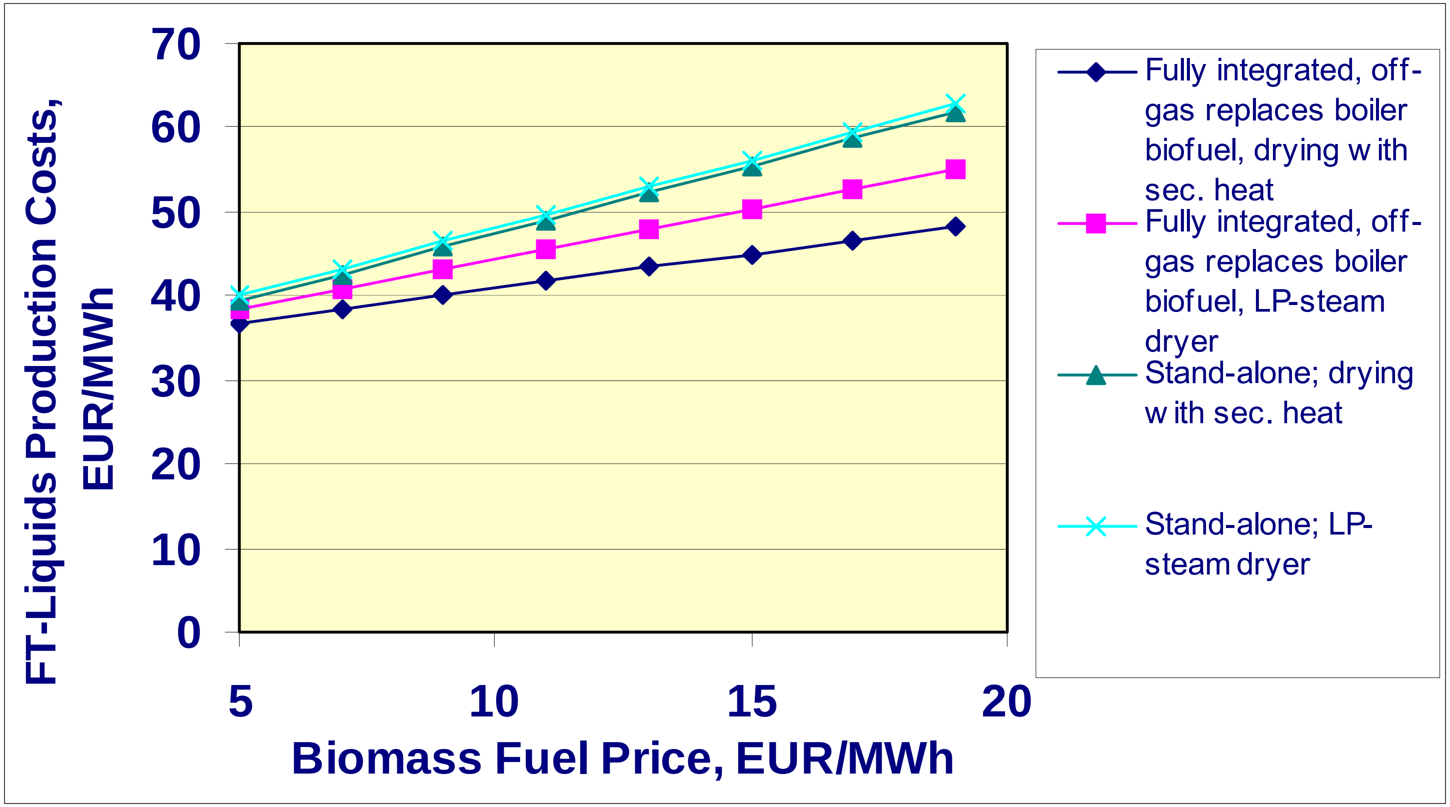
Power boiler replaced by combined-cycle plant fired by FT off-gas
Secondary heat used for biomass drying
Incremental energy flows (LHV basis)



Nominal overall efficiency = 100 x 126/(114 + 13/0.4) = 86 %
(purchased electricity generated from biomass at 40 % η)

Estimated Costs of Co-Produced FT Primary Liquids

260 MW_{feed}, Interest on capital: 10 %, 20 a



Investment requirement (mature technology): 220 MEUR

Cost of final upgrading to automotive fuels: 5 - 10 EUR/MWh

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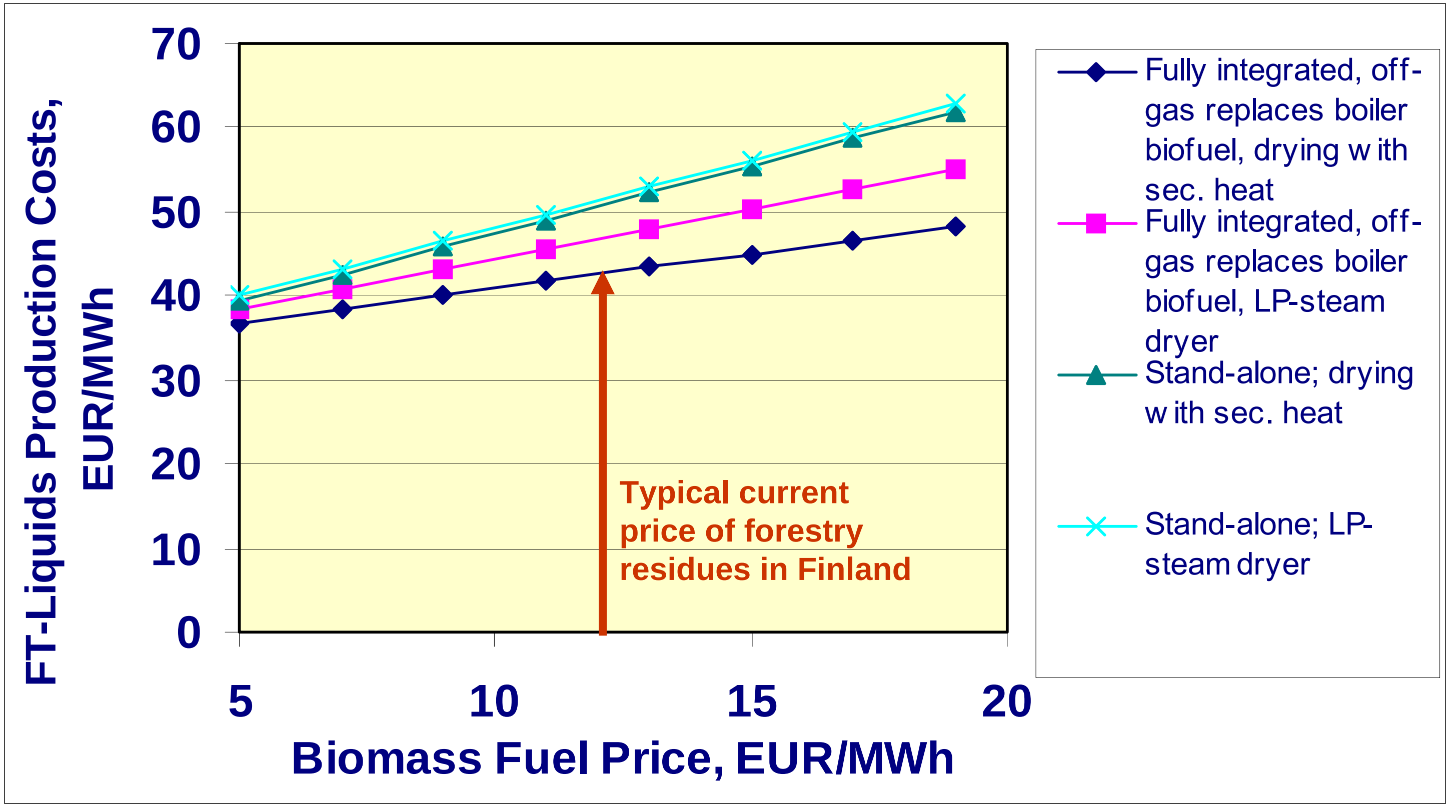

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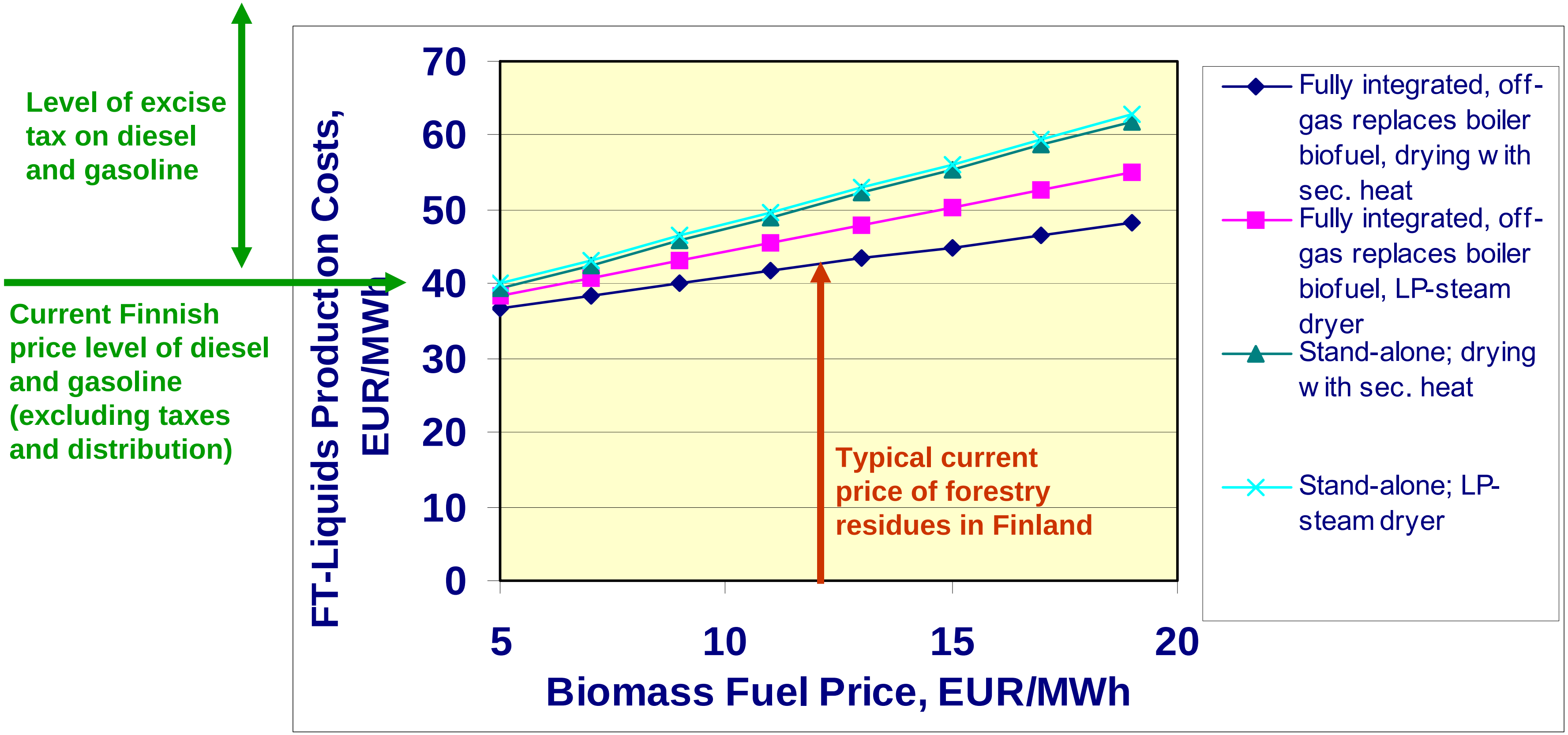

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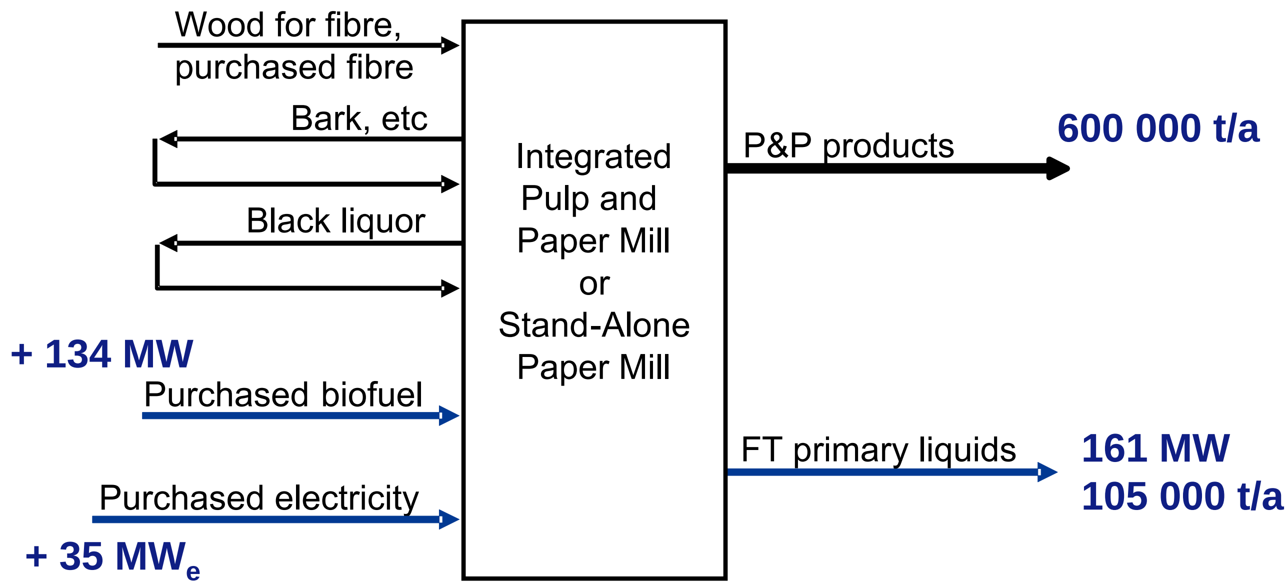
Potential Profitability of FT-Liquids Co-Production at Paper Mill

Paper production 600 000 t/a; FT-liquids production 105 000 t/a



Economic performance of paper-production process:
- Income: 420 MEUR/a (product value 700 EUR/t)
- Operating profit (@ 12.5 % of income): 52 MEUR/a
- Internal interest rate for greenfield plant (700 MEUR): 12 %

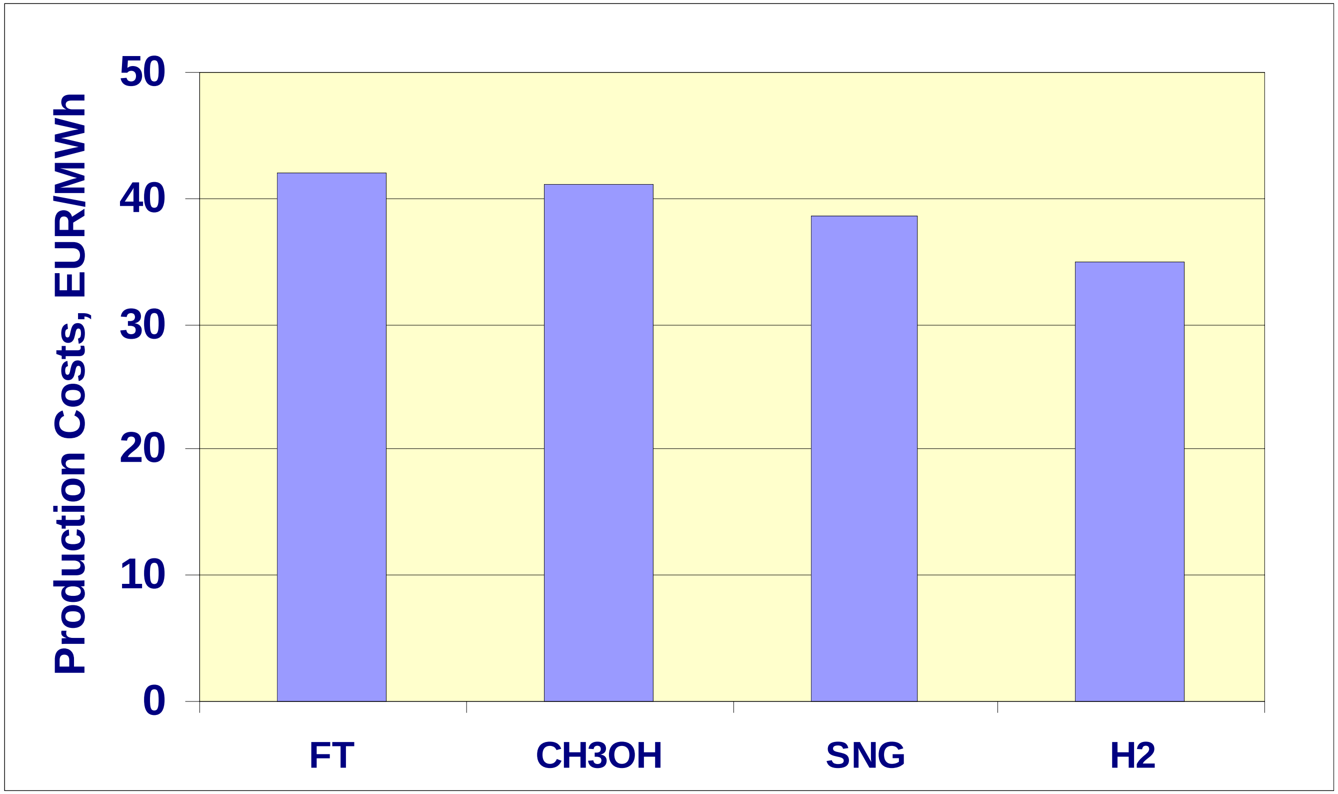
Economic performance of FT plant:
- Income: 79 MEUR/a (product value 750 EUR/t, 60 EUR/MWh*)
- Operating profit: 45 MEUR/a (purchased biofuel @ 12 EUR/MWh)
- Internal interest rate (incremental investment 220 MEUR): 27 %

Profit from co-production of FT liquids could be of similar magnitude to that from paper production.

* expected value once biofuel addition to automotive fuel is made obligatory in Finland

Estimated Production Costs for Alternative Syngas Products

260 MW_{feed}; Feedstock at 10 EUR/MWh; Interest on capital 10 %, 20 a



Notes: (1) Feedstock drying: from 50 % moisture to 30 % with secondary heat; from 30 % to 15 % with by-product steam. (2) FT: Fischer-Tropsch primary liquids; reforming loop included.

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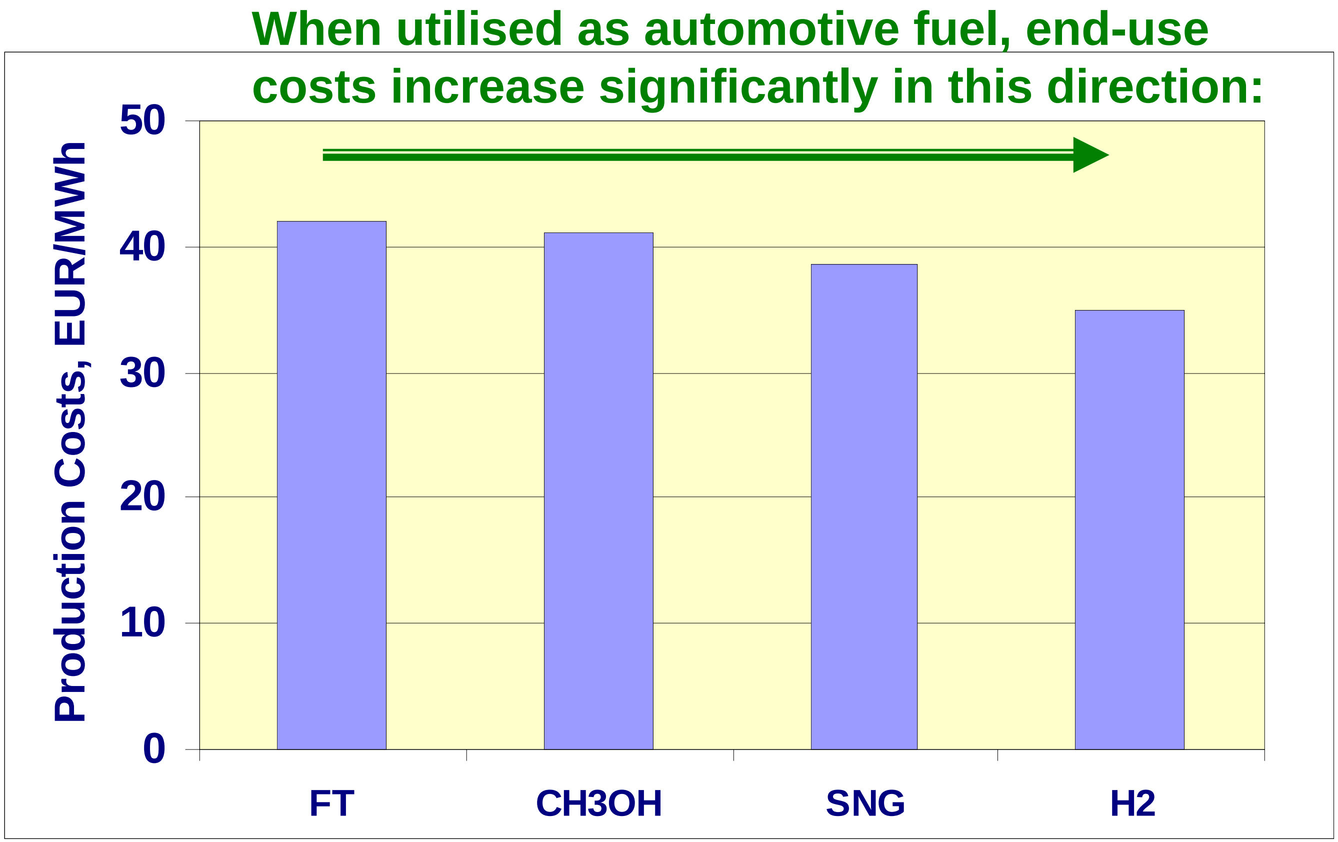
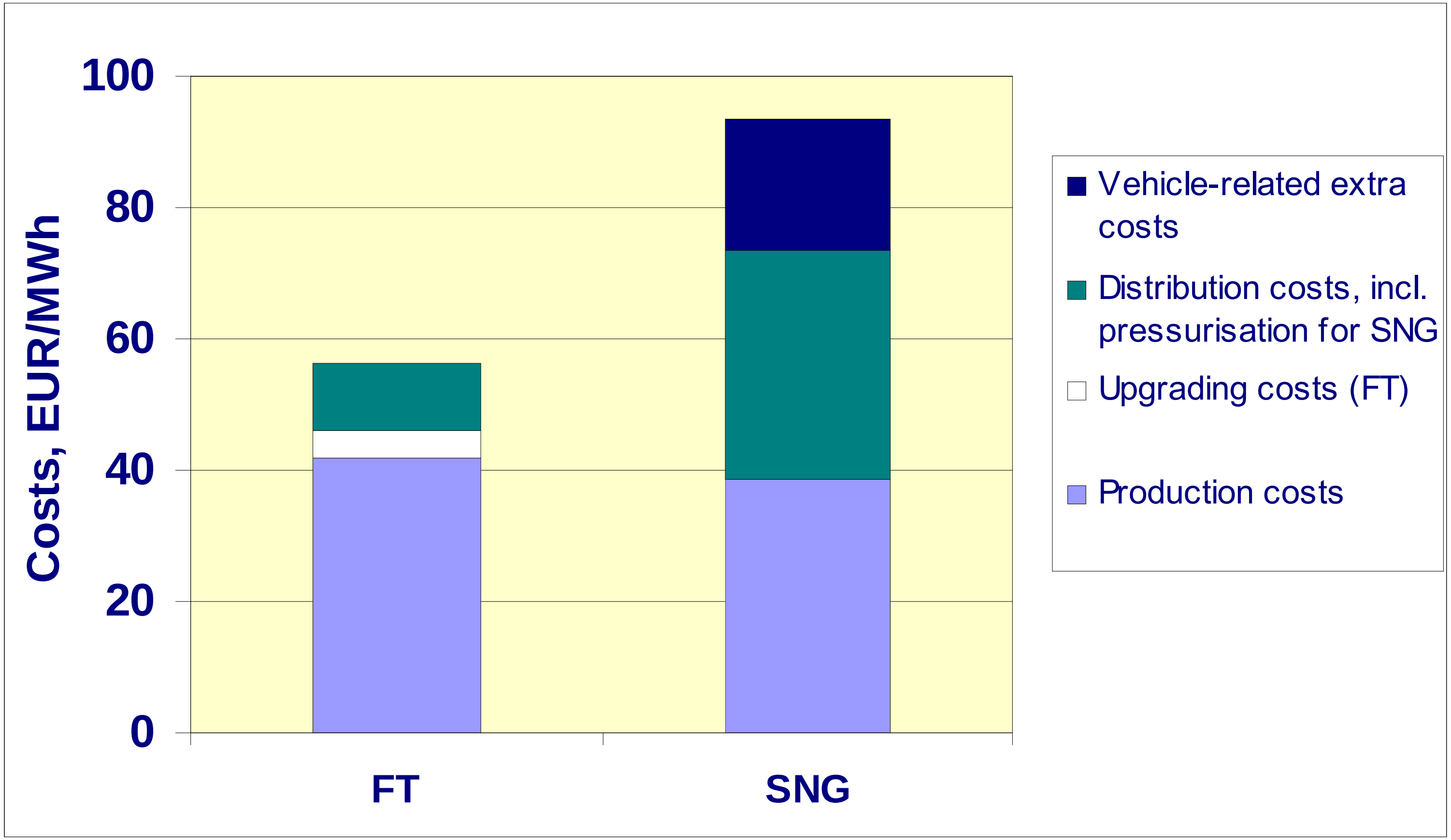


Notes: (1) Feedstock drying: from 50 % moisture to 30 % with secondary heat; from 30 % to 15 % with by-product steam. (2) FT: Fischer-Tropsch primary liquids; reforming loop included.

Estimated Forest-to-Wheel Costs

260 MW_{feed}; Feedstock at 10 EUR/MWh; Interest on capital 10 %, 20 a



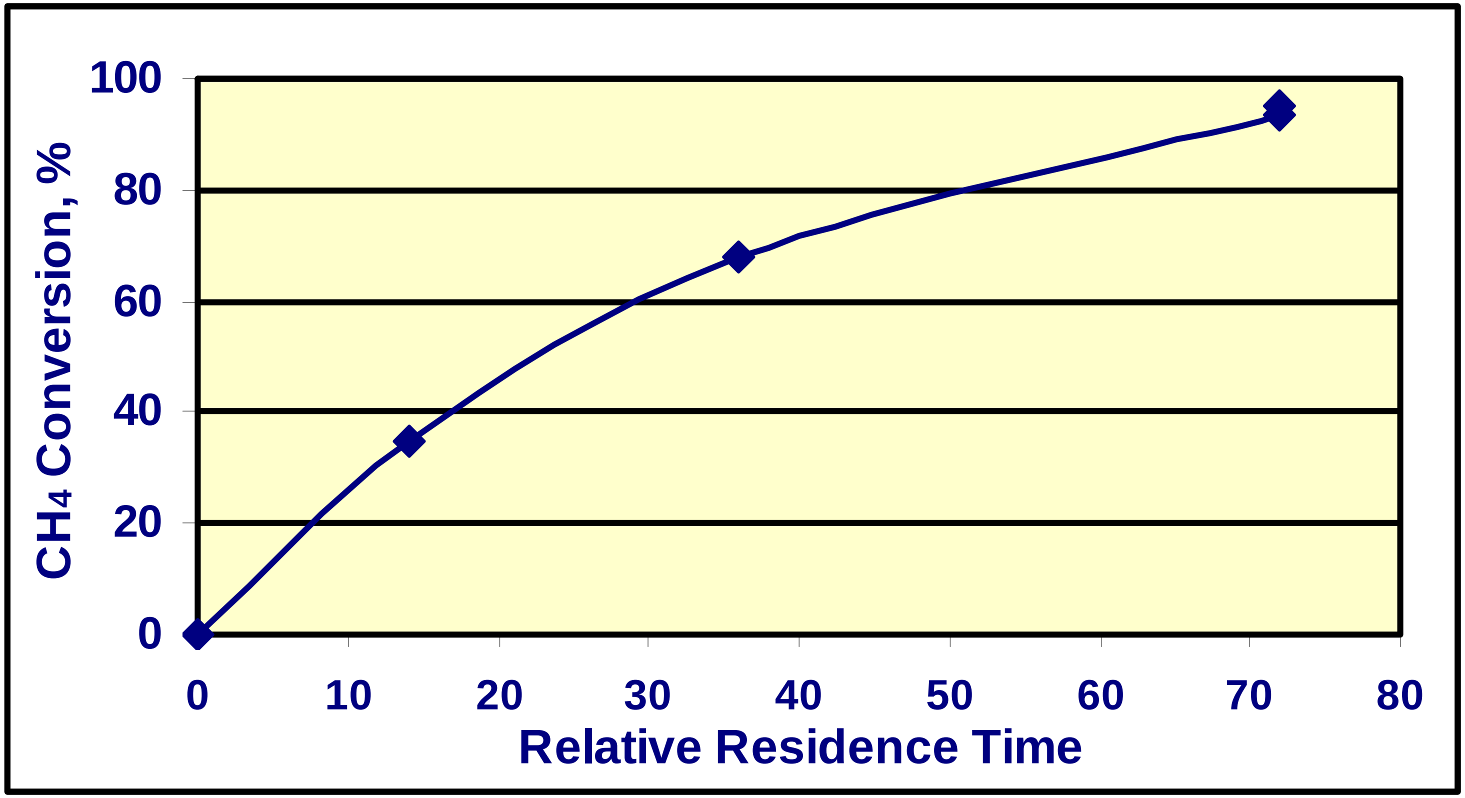
Forest-to-Wheel Costs: Biomass-FT < Biomass-SNG < Biomass-H_2-FC

Development Path Based on UCG Project

- Current development stage: 0.5 MW process development unit (PDU); designed and operated by VTT's Gasification Research Group
- UCG project: budget ca. 4 MEUR, duration 1.1.2004 – 31.5.2007
- UCG industrial consortium: Foster-Wheeler, Neste Oil, Andritz, Vapo, PVO, UPM, M-real, Metsä-Botnia, Stora-Enso
- Demonstration of bio-syngas process planned for the period 2008 – 2010
  - size of demonstration plant: 20 – 50 MW feedstock input
  - operation of plant to be economically profitable: replacement of natural gas or fuel oil; parallel experimental program on the flexible PDU unit
  - plant design studies already under way
- The subsequent step: pre-commercial plant; 200 MW; commissioning 2013

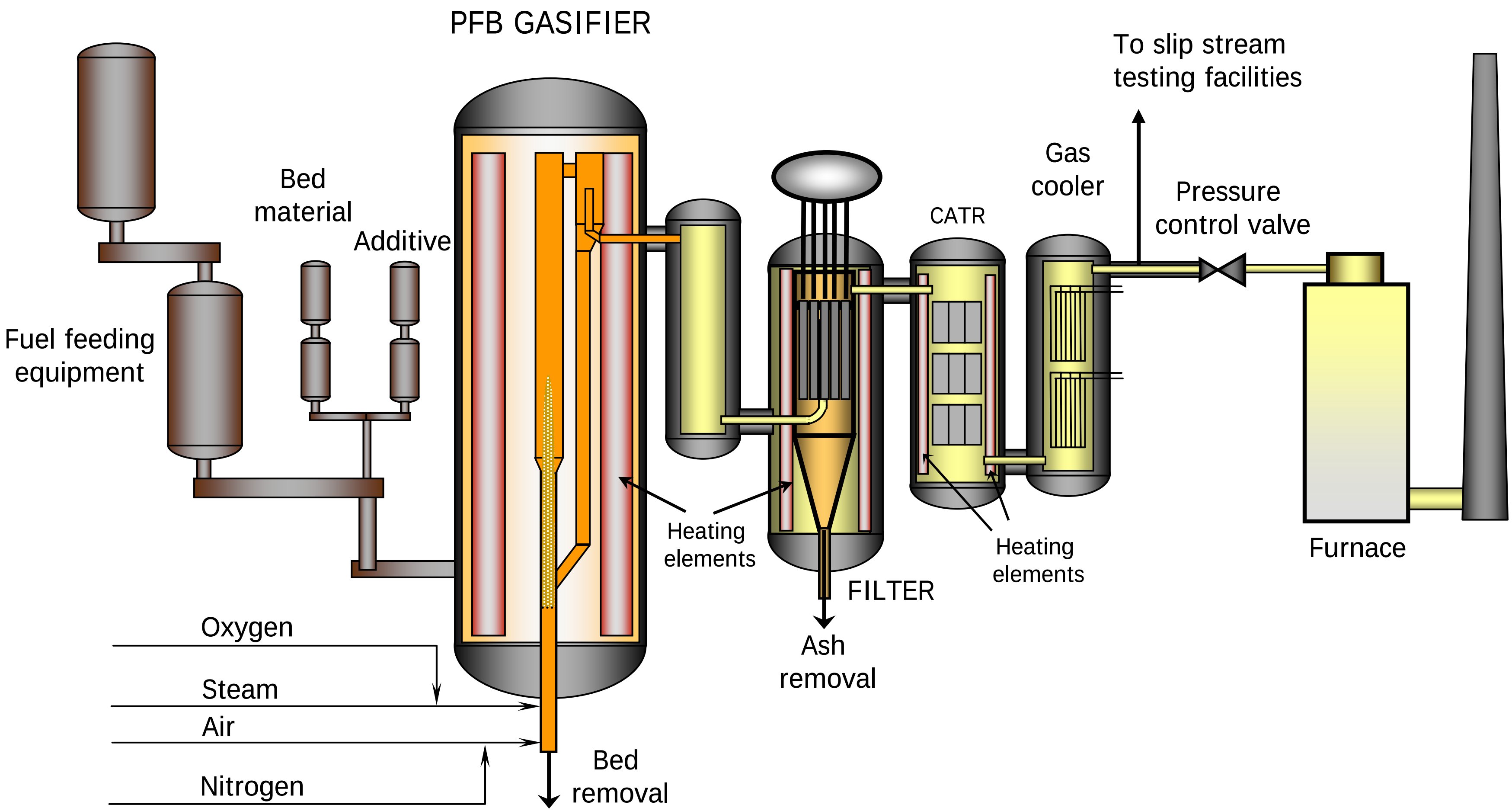
Catalytic Reforming / Bench-Scale Tests at VTT

CH_4 Conversion at 900 ºC



A near-term objective is to verify this promising result on the PDU unit (next slide)

0.5 MW Pressurized Fluidized Bed Gasifier (VTT PDU)



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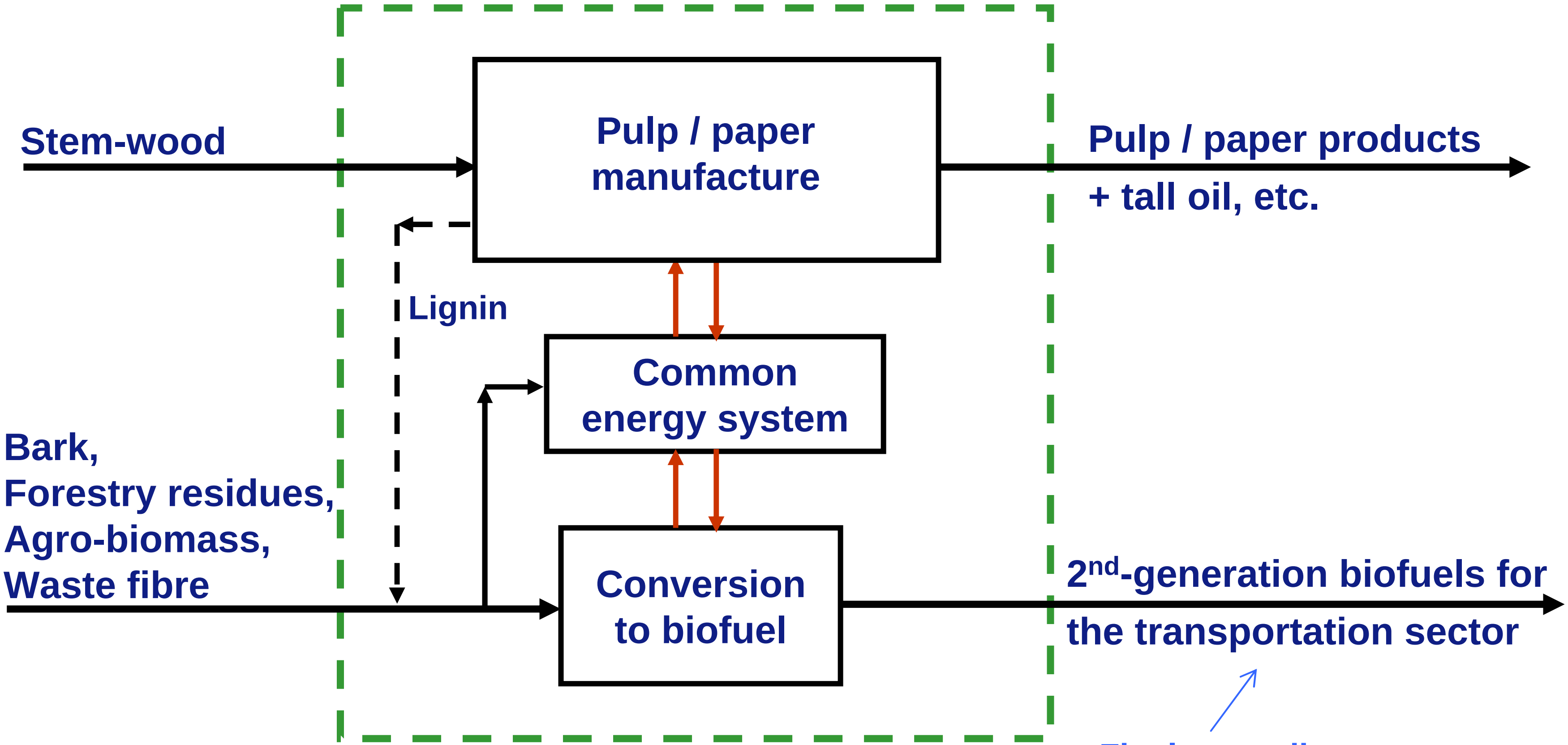
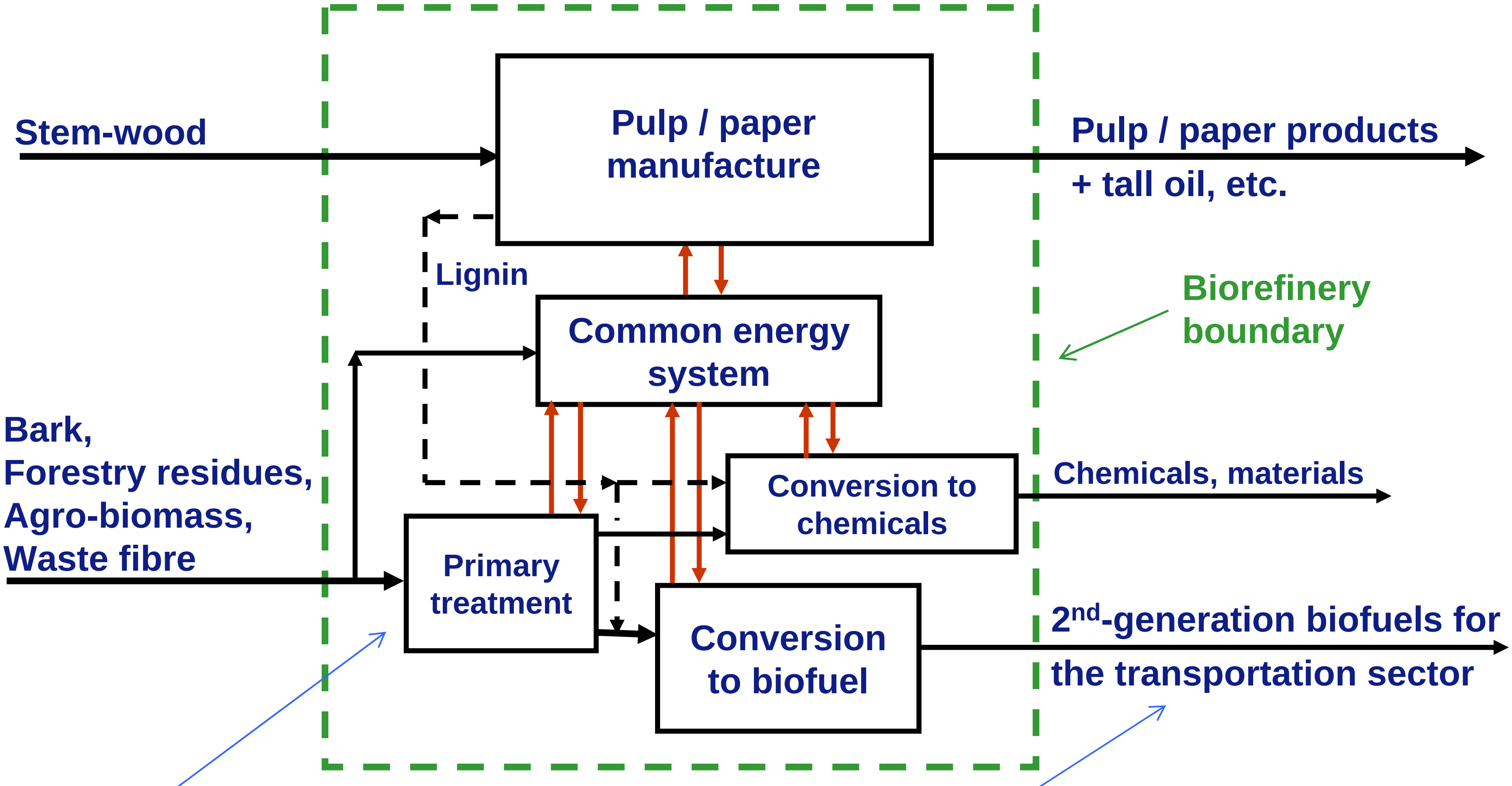


Final upgrading to transportation fuels may be carried out at a centralised facility elsewhere

Converting a Pulp and Paper Mill into a Biorefinery

A Long-Term Vision



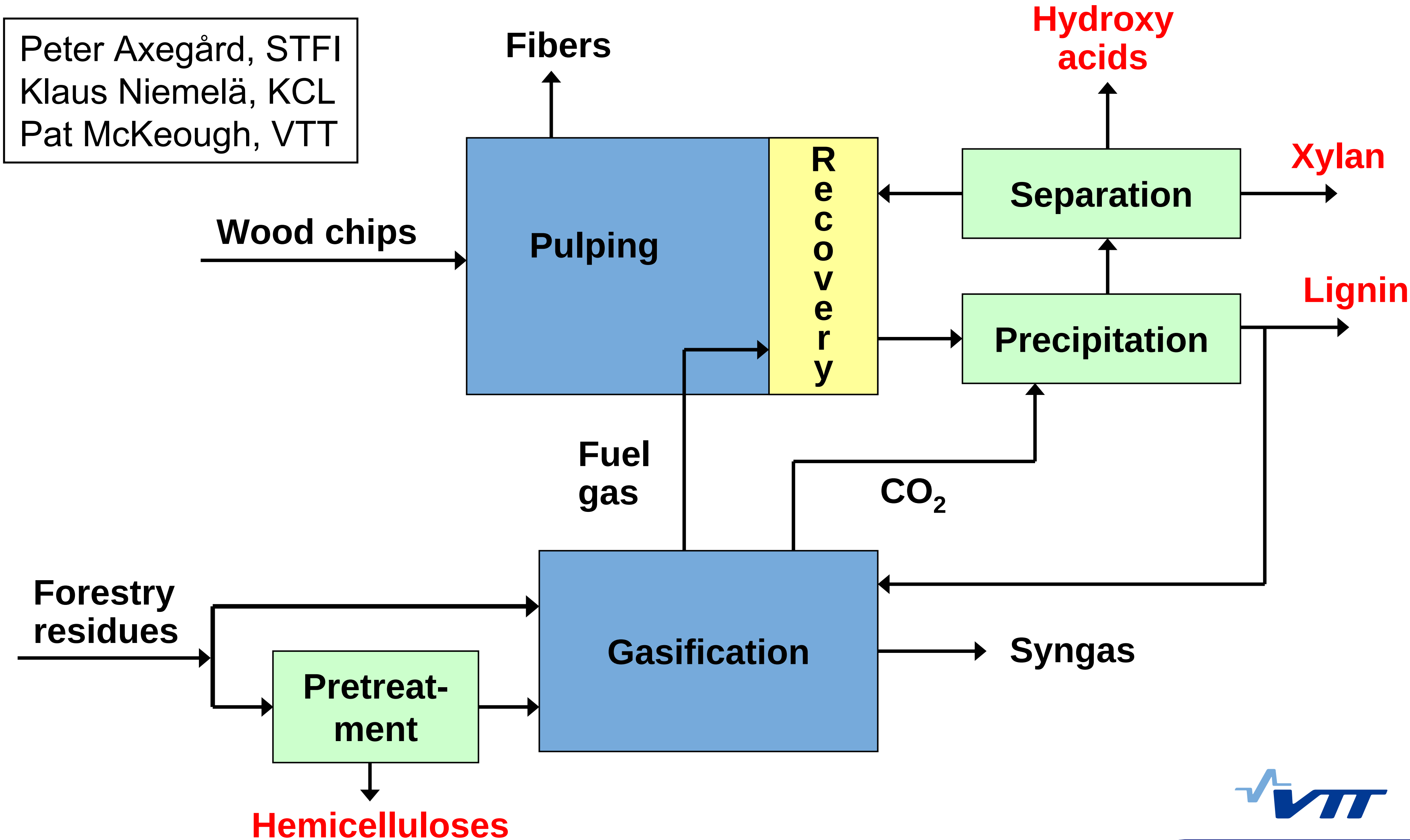
Primary treatment alternatives, e.g.:
- extraction
- pyrolysis
- hydrolysis

Final upgrading to transportation fuels may be carried out at a centralised facility elsewhere

One Example of Future Forest-based Biorefinery

Subject of Planned EU Project

Peter Axegård, STFI
Klaus Niemelä, KCL
Pat McKeough, VTT



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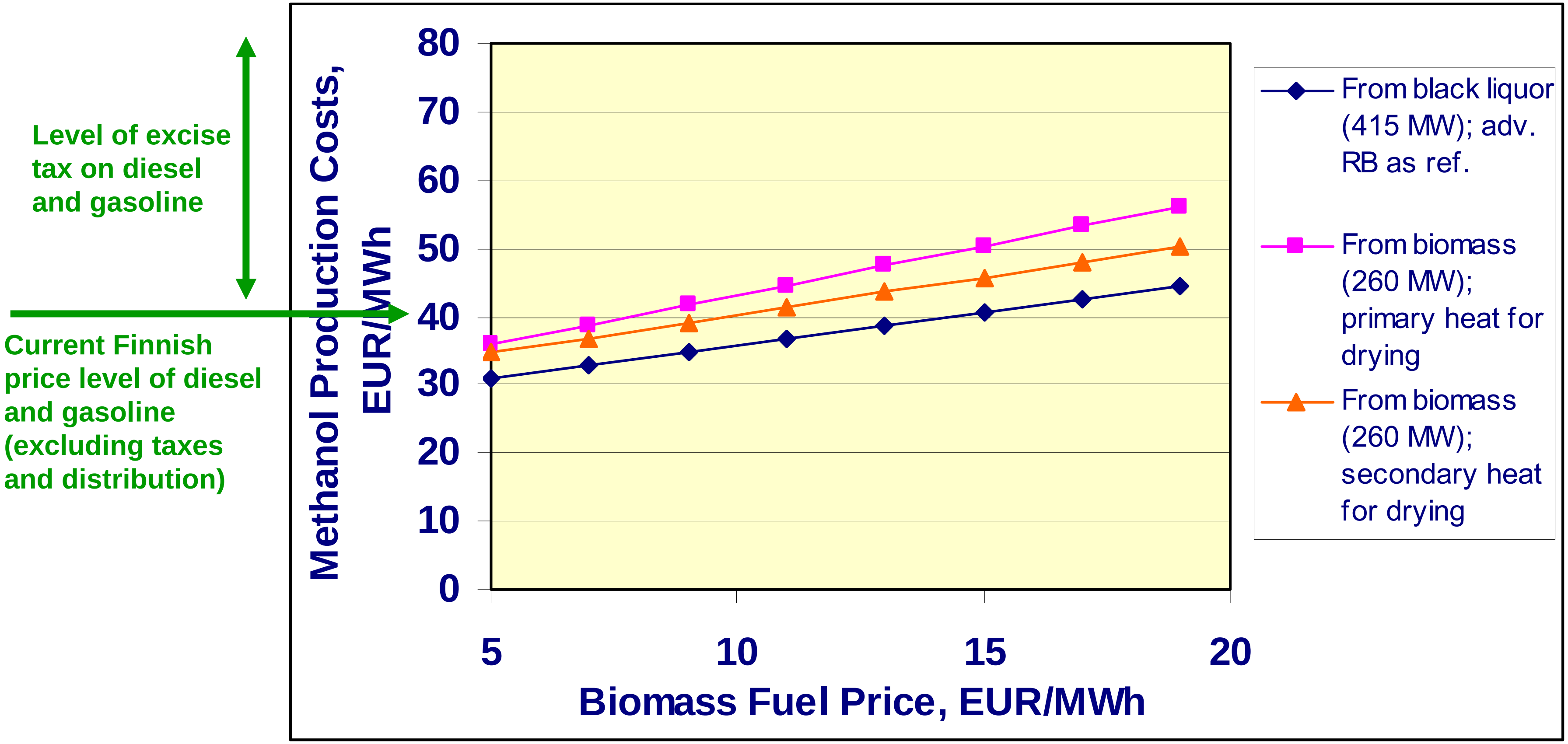
- The subsequent step: pre-commercial plant; 200 MW; commissioning 2013

Acknowledgement of funding sources: the National Technology Agency of Finland (Tekes), VTT and the companies of the consortium (above)

Estimated Costs of Methanol Production from Biomass or Black Liquor at a Large Integrated Pulp and Paper Mill



Note: methanol production from black liquor would typically be somewhat more economic at a stand-alone market pulp mill having the same black-liquor flow as the above case.

Biomass vs. Black Liquor for Producing Syngas Derivatives at Pulp and Paper Mills

- According to the present estimates, syngas derivatives could be co-produced somewhat more economically from black liquor than from solid biomass residues at integrated pulp and paper mills.
- The estimated ratio of incremental investment to co-product output is almost 50 % higher for the biomass-fired plant than for the black-liquor-fired plant. The economic advantages of the black-liquor-fired plant derive mainly from the following:
  - Compared to the boiler reference case, no additional pre-treatment is necessary for black liquor, whereas drying is required for biomass residues.
  - Feeding of black liquor to the pressurised gasifier is much simpler.
  - No separate gas-reforming step is required for the black-liquor plant (Chemrec entrained-flow gasifier).
  - The black-liquor plant has a (small) scale advantage (415 MW_{fuel} vs. 260 MW_{fuel}).
- Production of syngas derivatives from black liquor at a stand-alone market pulp mill would typically be somewhat more economic than at an integrated pulp and paper mill (same black-liquor flow). A limitation for the biomass-fired technology is that it cannot be effectively integrated with a stand-alone market pulp mill when all the black liquor is fired in the recovery boiler.
- On the other hand, **biomass-fired technology** has
  - a **greater market potential** (= a greater number of potential pulp and paper mill sites, wide range of potential feedstocks + stand-alone conversion plants in the longer term)
  - less interaction with the pulp-mill chemical-recovery cycle (= **smaller availability risk**)
  - considerably **less technical uncertainty** attached to it at the present time.

VTT-STFI Scheme for Efficient Integration of Biomass-Fired Syngas Plant with Stand-Alone Pulp Mill