Task 41 - Special Project: Bioenergy RES hybrids

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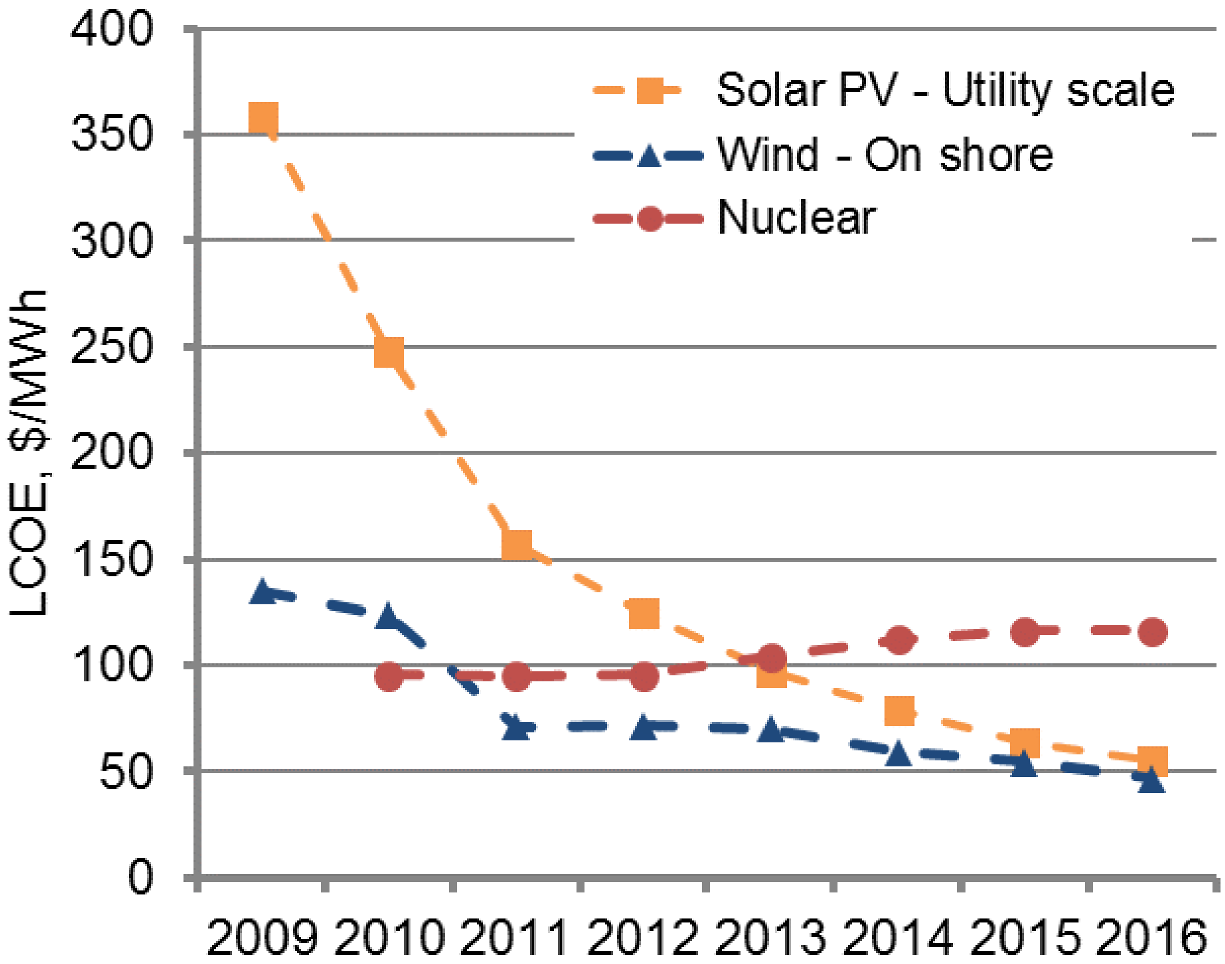
Driver: Cost of Variable Renewable Energy (VRE)

- VRE generation costs initially high, but have already reached or are approaching the cost of conventional generation options
- The trend is likely to continue, leading eventually to high shares of VRE in the energy system



Source: Lazard's Levelised Cost of Energy Analysis

Impact of VRE addition to the energy system

- Rapid VRE addition puts technical and **financial pressure** on existing generators and can trigger the **retirement** of pre-existing generation capacity
  - →How to best maintain the **stability and reliability** in a **VRE dominated** energy system?
- Fossil back-up strategy **incompatible with Paris agreement**
  - →Clear need for technologies that are **low-GHG, flexible and cost-effective**.
- What is the **role of bioenergy** in all of this?

Integrated bioenergy hybrids

“Process having at least two renewable energy inputs, of which one is bioenergy”

- Hybrid systems classification in our project report:
    1. Domestic applications
    2. Utility-scale applications and district heating and cooling networks
    3. Industrial applications
    4. Farm-scale applications

- Other classification could be used as well, e.g. the degree of dependency between components*
    - Light: Minimal shared equipment, no operational dependency; *bioenergy* + *wind*
    - Medium: Major shared equipment, some operational dependency; *bioenergy* + *solar thermal*
    - Strong: Major shared equipment, operational dependency; *bioenergy* + *geothermal*

*Source: Peterseim, J.H. et al., 2014, Concentrating solar power hybrid plants – Enabling cost effective synergies, Renewable Energy 67 (2014) 178-185

Domestic applications

- Today, hybrids are mainly found in the heating sector
- To replace oil and electric heating
- Flexible integration of different heat sources and robust operation
- In Germany, 60% of all pellet boilers and stoves combined with solar thermal
  - Growth expected also in Finland
- Investments market driven
- Household heating behavior
  1. Bioenergy for base demand
  2. Bioenergy for peak demand

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- The main challenge: Selection of technologies and their proper dimensioning

Utility-scale applications and district heating and cooling networks

- District heating is typical form of heating in studied countries
- DH and DC networks are good base for renewable energy adoption
  - Waste heat recovery, heat pumps and solar thermal growing trends
- In Germany and Austria several demonstration projects for renewable district and regional heat grids

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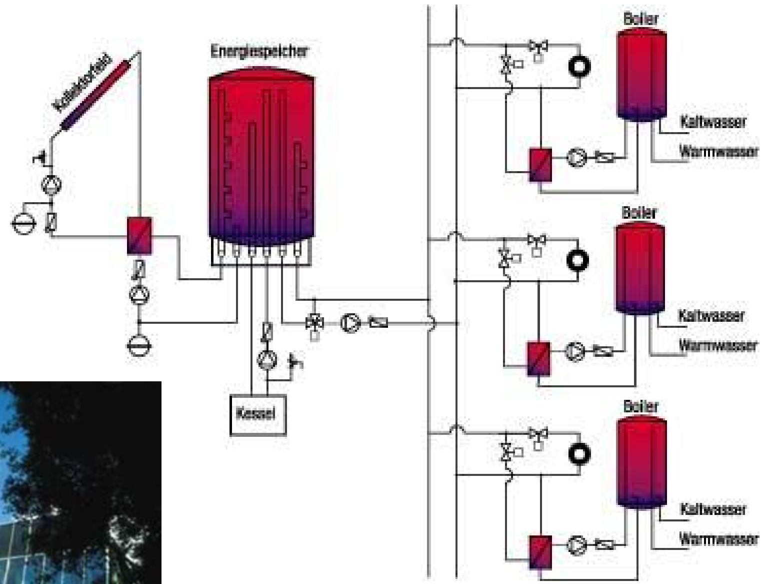
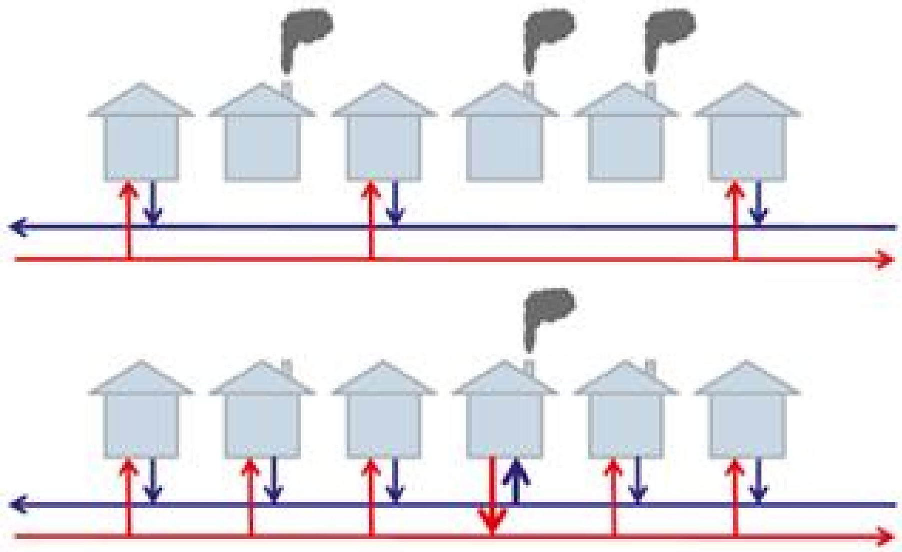


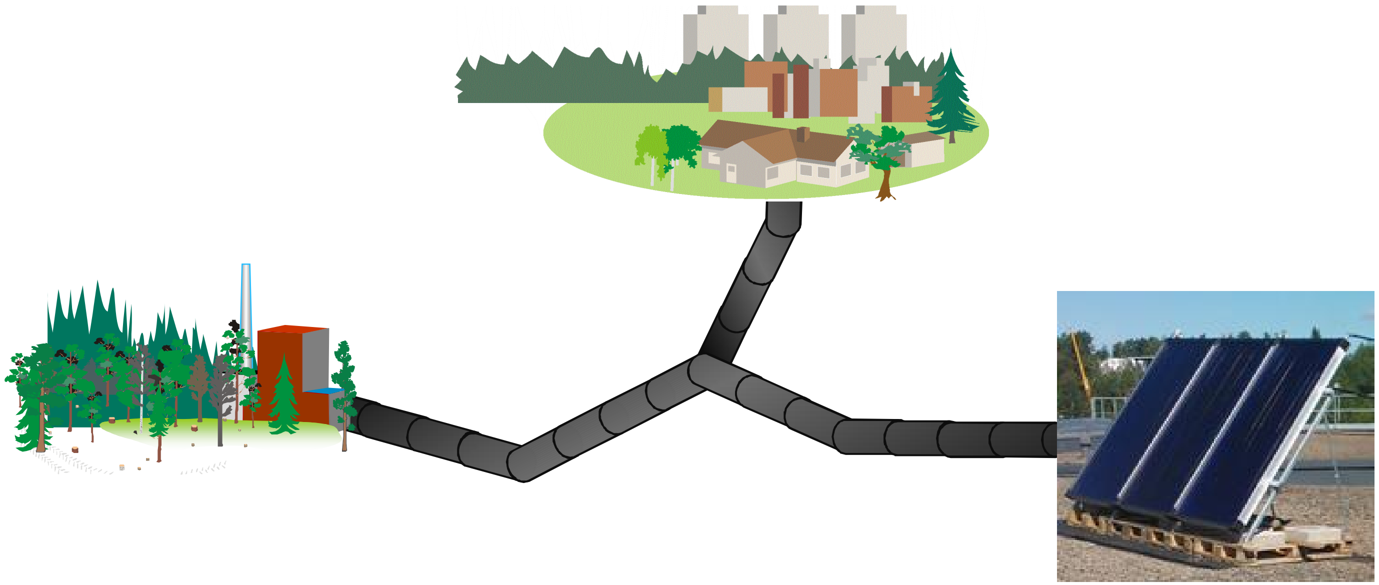
Large Scale Solar Heating Systems for Housing Developments, Austria

Bidirectional heating grid, BiNe2+ project, Austria



Ref. Lichtenegger, K. et al. 2016

Motivation for integrated RES hybrids



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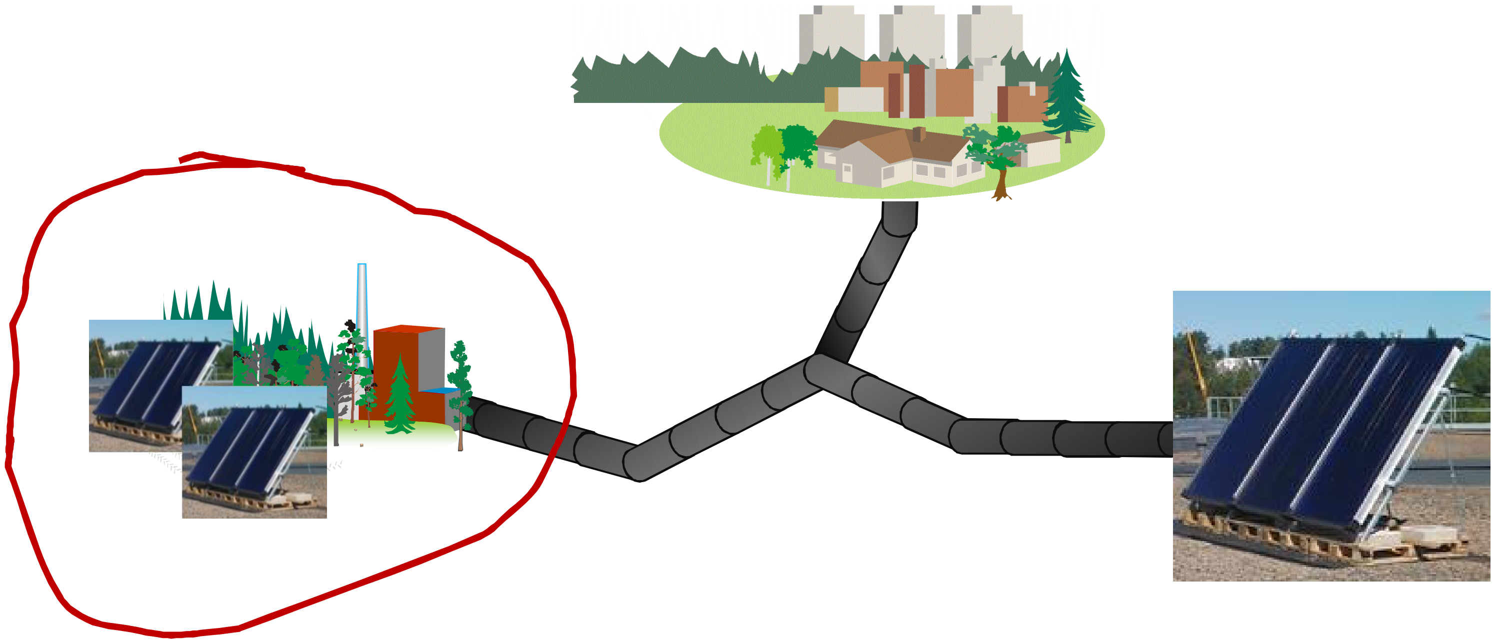


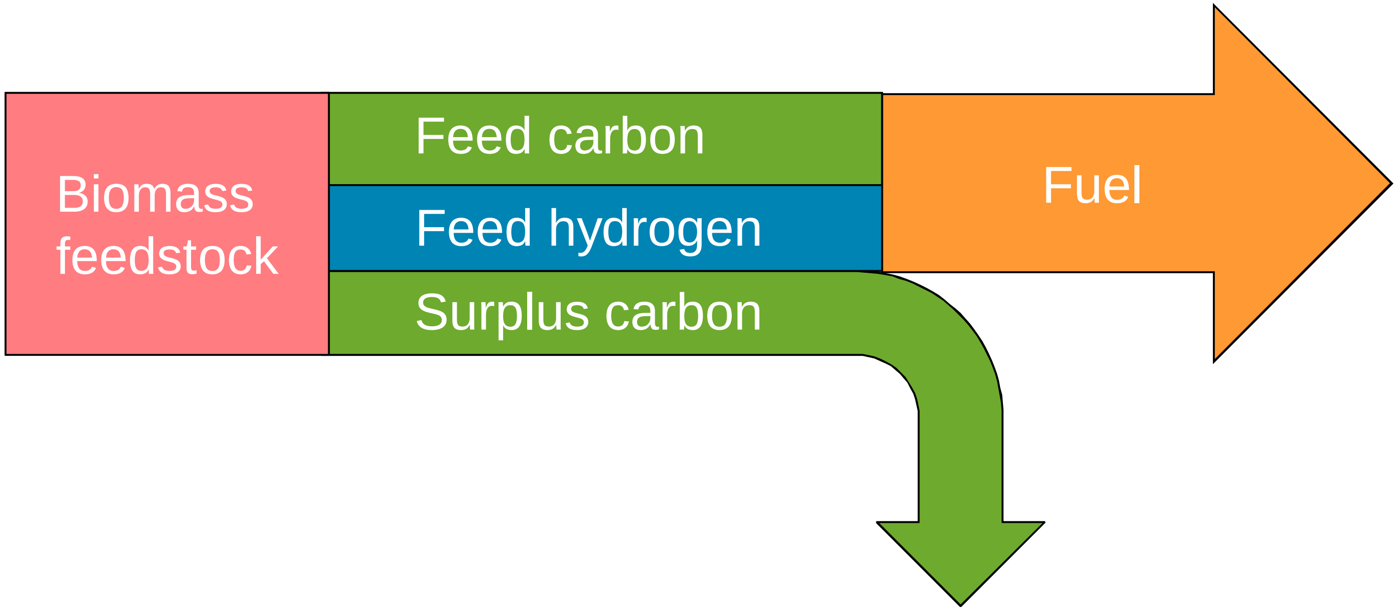
Integration benefits?

Motivation for integrated RES hybrids

- Efficiency improvements via heat integration.
  - Example: preheating of process feeds (water, air) with RES before combustion, gasification, pyrolysis etc.
- Lower cost via equipment sharing.
  - Example: common steam system.
- Improved resource efficiency (less biomass for the same job)
  - Example: RES integrated biorefineries

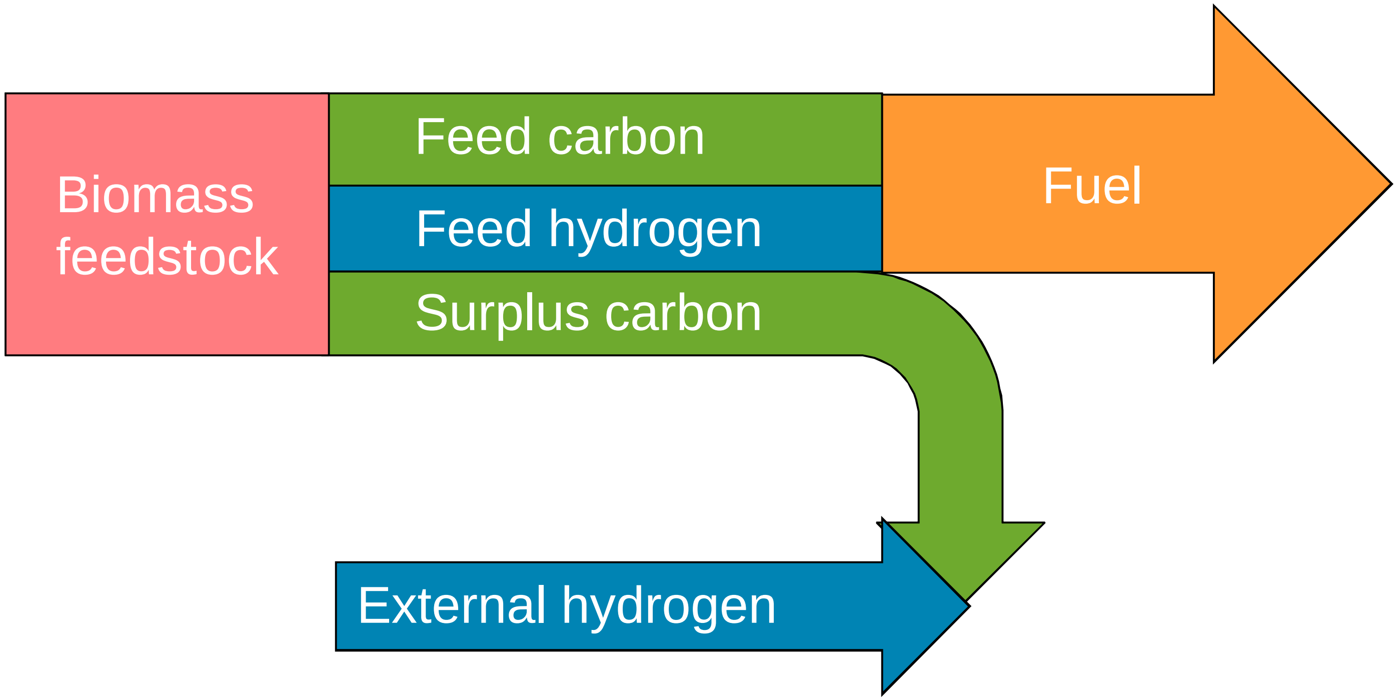
Increasing resource efficiency of biomass use

- Thermal biorefineries convert biomass **very efficiently** to fuels and saleable heat (~80 % overall efficiency, LHV)
- However, when biomass is the only feedstock, some carbon is unavoidably left unconverted, i.e. **resource efficiency not maximised**



Increasing resource efficiency of biomass use

By adding hydrogen from external source (enhancement), the **surplus carbon** could be hydrogenated to fuel as well.



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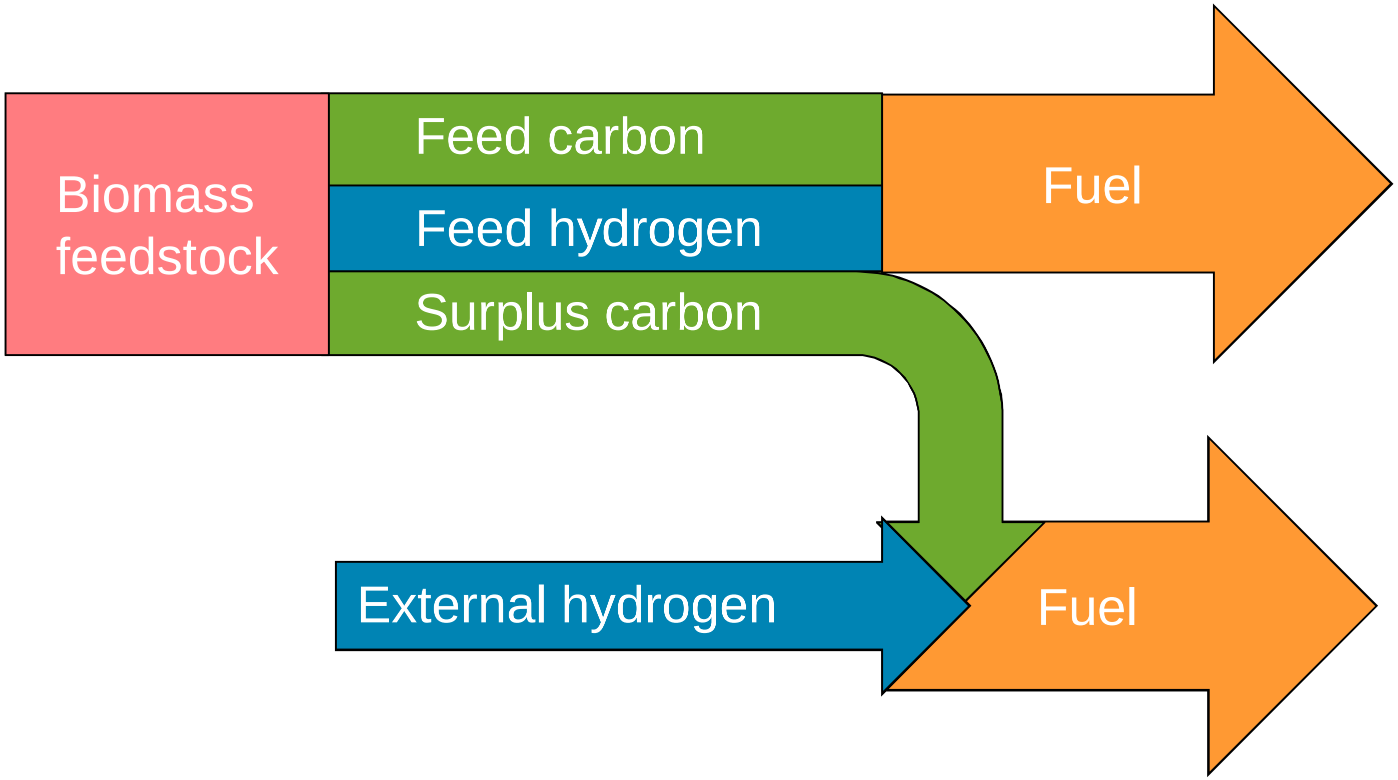
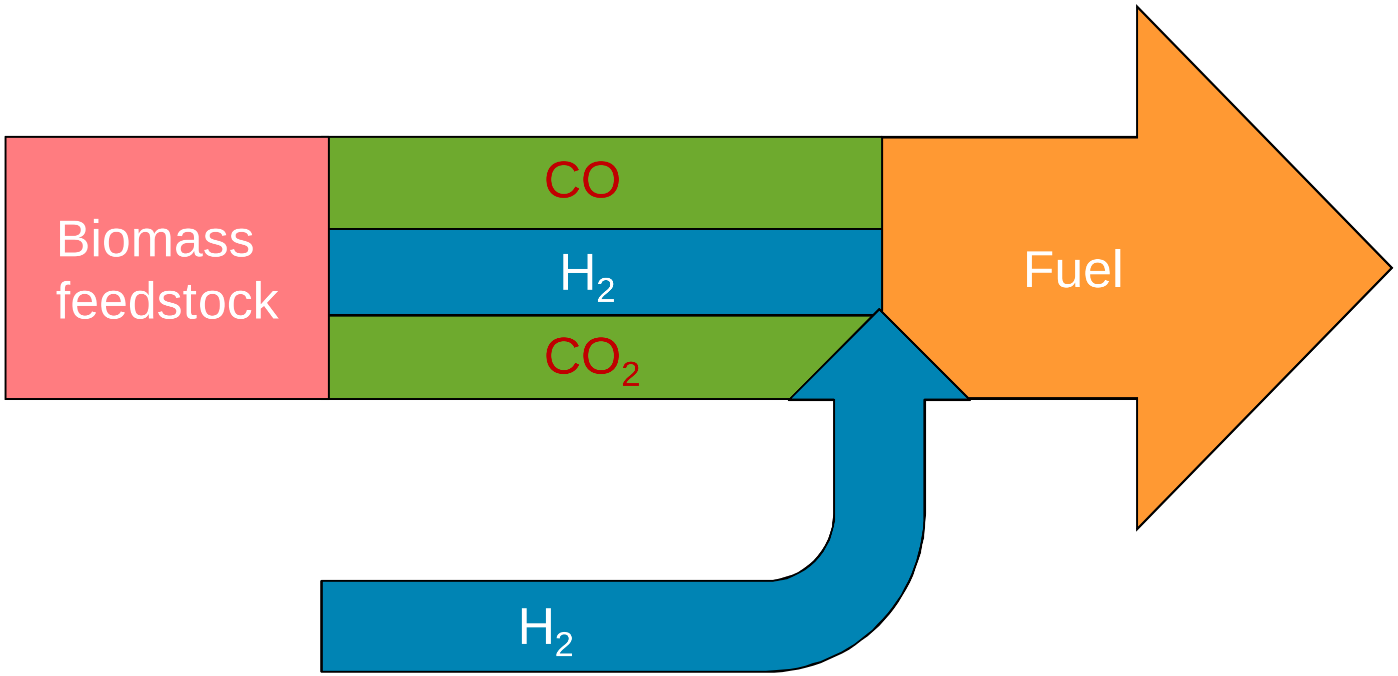


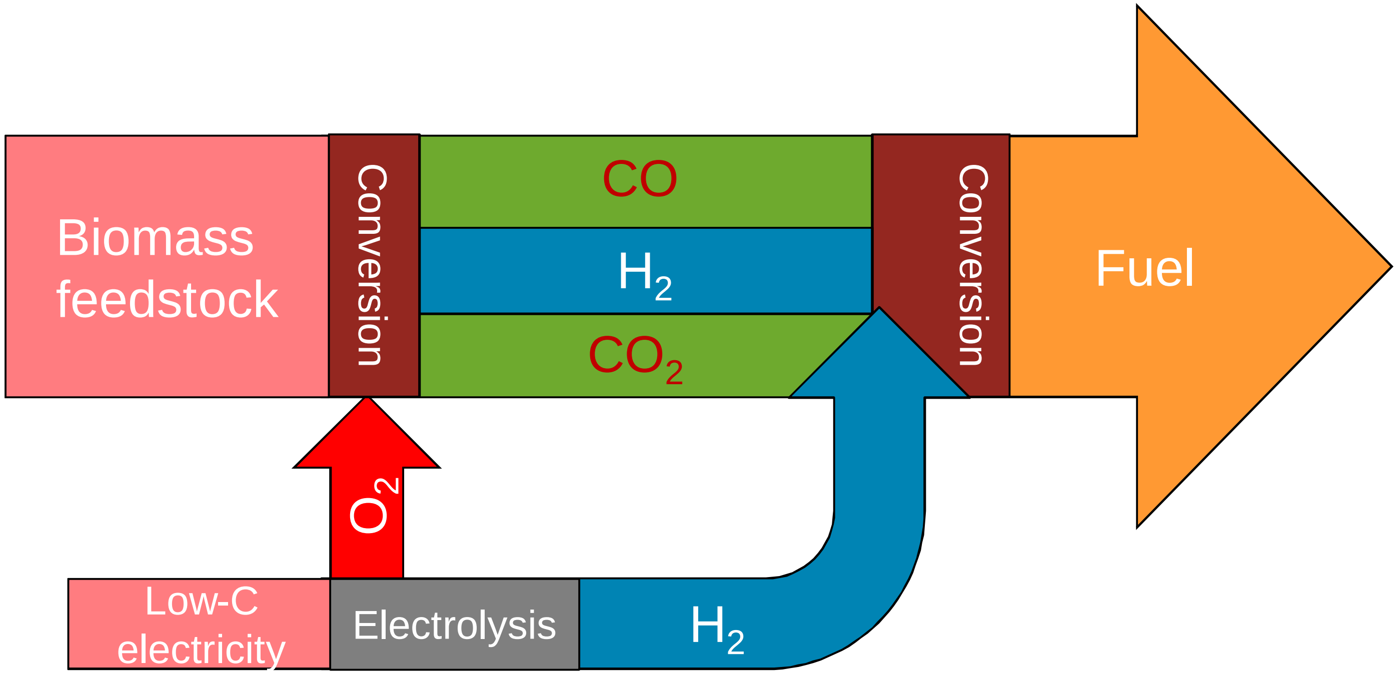
Increasing resource efficiency of biomass use

Despite challenges related to CO_2 hydrogenation, the potential increase in fuel output is significant.



Increasing resource efficiency of biomass use

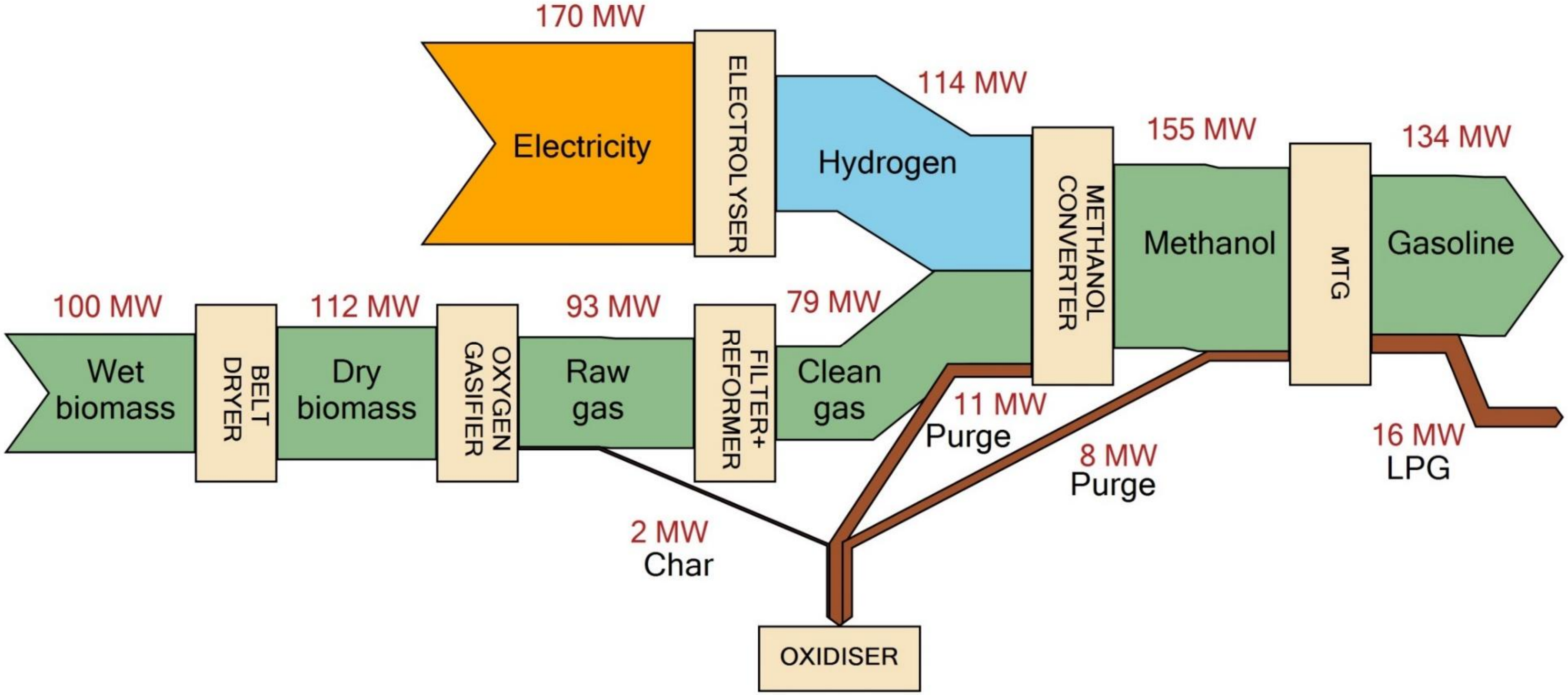
The process not sensitive to the source of hydrogen, but water electrolysis with low-carbon electricity a self-evident choice.



Increasing resource efficiency of biomass use

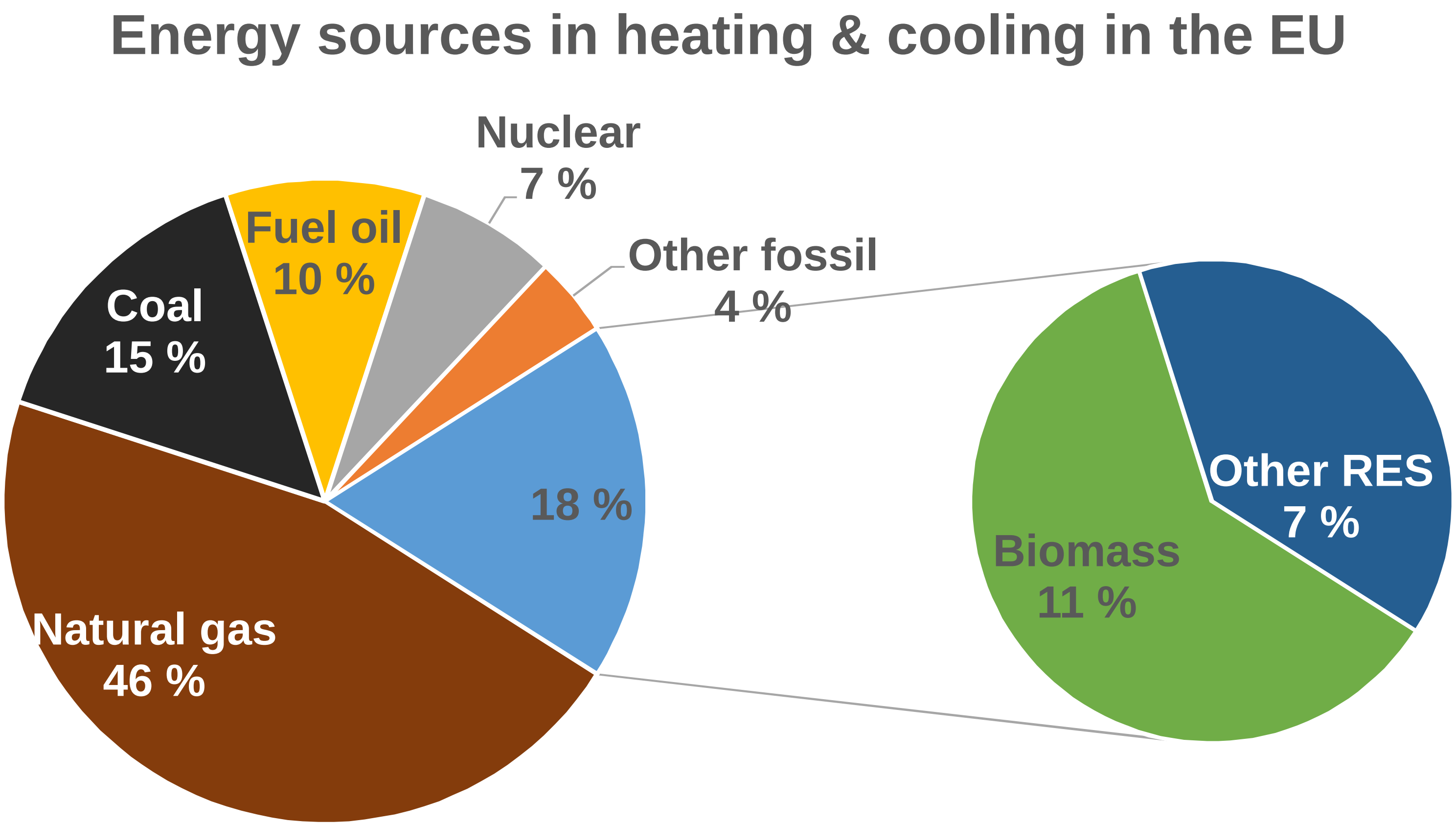
Process can be designed to operate either to

- **Flexibly store surplus** electric energy chemically
- Operate continuously to **maximise resource efficiency** from biomass.
  → Carbon efficiency from 30% to 80% to even 95%.*



*Source: Hannula, I. **2016**. Hydrogen enhancement potential of synthetic biofuels manufacture in the European context: A techno-economic assessment, Energy, Volume 104, Pages 199-212, ISSN 0360-5442, http://dx.doi.org/10.1016/j.energy.2016.03.119.*

Potential of RES hybrids in heating and cooling



Heating and cooling represent about half of EU's annual energy consumption

Potential of RES hybrids in biofuels supply

An Assessment of Advanced Biofuels
from Wastes & Residues

Key findings:

- If all the wastes and residues that are sustainably available in the European Union were converted only to biofuels, this could supply 16 per cent of road transport fuel in 2030. (Technical potential).
- If advanced biofuels from wastes and residues are sourced sustainably, they can deliver GHG savings well in excess of 60 per cent, even when taking a full lifecycle approach.
- Safeguards would be needed to ensure this resource is developed sustainably, including sustainable land management practices that maintain carbon balances and safeguard biodiversity, water resources and soil functionality.
- If this resource were utilized to its full technical potential, up to €15 billion of additional revenues would flow into the rural economy annually and up to 300,000 additional jobs would be created by 2030.

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With RES integration from 16% → 41% of demand*

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Key findings

- Technical potential for integrated bioenergy hybrids is considerable, as no significant limitations have been identified.
- Hybrids already available in the domestic energy sector
- Lack of standardised interfaces between technologies requires multiple control systems and thus adds costs.
- Biomass drying with VRE and chemical storage of electricity in fuels (hydrogen enhanced biofuels) potential seasonal storage concepts.
- A key advantage of a hybrid system is that it enables to use each energy source to its fullest potential (increased resource efficiency of a system)
- Integration benefits are key motivation for bioenergy RES hybrids
  - Economic: equipment sharing
  - Performance: efficiency improvements
- The costs and benefits of bioenergy hybrids not always captured by LCOE. System needs to be defined –> very complicated!

Key steps in the next five years

- Establish a “success stories database”, i.e. ~50 examples of best practises to accelerate technology transfer and reduce costs
- Standardisation of interfaces between technologies
- Improve tools for dimensioning of an integrated process with storage
- Increase understanding on the needs that a different VRE dominated energy systems have towards bioenergy technologies
- Develop bioenergy technologies with a focus on:
  - Stretching of operation limites while keeping efficiency high and emissions low
  - Fast and low-cost shutdown/start-up capabilities
  - Low-cost peaking concepts for biomass
  - Concepts for seasonal storages using biomass
    - RES integrated biorefineries with flexibility features
    - Drying of biomass with VRE

Thank you for your attention!

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- Learn about our project: http://task41project7.ieabioenergy.com/
- Download our Final report from Feb 2017 onwards!
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