Value of integrated hybrids and closing thoughts

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The rise of variable renewable energy supply

- Energy system in transition
- Cost of variable renewable energy (VRE)
  - Initially high, but significant cost reductions have taken place
  - VRE generation costs have already reached or are approaching the cost of conventional power and heat generation options
  - This trend is likely to continue, leading eventually to high shares of VRE in the energy sector

Impact of VRE to the energy system

- In OECD countries energy systems are typically characterised by
  - stagnating energy demand and
  - little need for replacing grid or generation infrastructure
- For such systems rapid addition of new VRE generation puts extreme technical and financial pressure on existing generators that were originally designed to operate as baseload units.

  → Low prices can trigger the retirement of pre-existing generation capacity
- How to best maintain the stability and reliability of a VRE dominant energy system?

Reliability under carbon constraints

- Reliability not a technical problem: Conventional and mature technologies can be used to maintain a reliable supply. (e.g. fast-response natural gas-fired boilers and turbines)
- Not an economic problem either as VRE dominated energy system with gas-fired backup constitutes a relatively low-cost scenario.
- Carbon constraints introduce a problem:
  - Ambitious long-term carbon-mitigation scenarios are not compatible with a fossil-based backup strategy.

  →There exists a clear need for technologies that are **low-GHG, flexible and cost-effective**.

  →For bioenergy both flexible generation and storage solutions are possible

Flexibility options

- Energy systems can have four different types of flexible resources:
  - system infrastructure,
  - flexible generation,
  - storage, and
  - demand side integration.
- In the context of bioenergy, applicable categories are
  - flexible generation, and
  - storage

Flexible generation from biomass

- Dimensions of flexible generation
  - ability to select the generation level (adjustability),
  - ability to select the speed of changing output level (ramping), and
  - start-up (lead) time of the plant.
- Benefits of flexible bioenergy technologies
  - fairly wide operational windows and
  - steep ramping gradients
- Costs of flexible bioenergy
  - premature component failures due to thermal and pressure stress
  - increased emissions and reduced fuel efficiency when operating outside name plate capacity range.

Flexible storage from biomass

- In the context of bioenergy, two main options have been identified:
  - biomass drying with VRE, and
  - chemical storage of VRE into biofuels
- Both approaches suitable for long charge-discharge intervals that allow bridging of seasonal energy imbalances.
- Chemical electricity storage one of the few large-scale options for seasonal storage (in addition to pumped hydro with large reservoirs)
- Unique among storage technologies because not constrained by its system stage = never fills up.

Bio-Dry – Solar enhanced drying

CHALLENGE

Several biomass using thermo-chemical concepts require rather dry biomass feedstock. Transportation of wet biomass with low energy density is expensive. On the other hand low-cost energy storage applications, especially related to solar energy, are urgently needed.

SOLUTION

- Through new solar enhanced biomass drying concepts energy content of limited sustainable biomass resources can be maximized
- Decentralized drying in biomass production sites enables distributed energy storage networks

BENEFIT

- By drying biomass fuels with solar energy:
  - Solar energy can be stored cost-efficiently
  - Dry-enough biomass for thermo-chemical processes can be produced
  - Logistic chain of biomass becomes more feasible (reduced water content in transportation)
  - Efficiency increases and emissions decrease in logistics and in use
  - Quality of feedstock remains better during storage

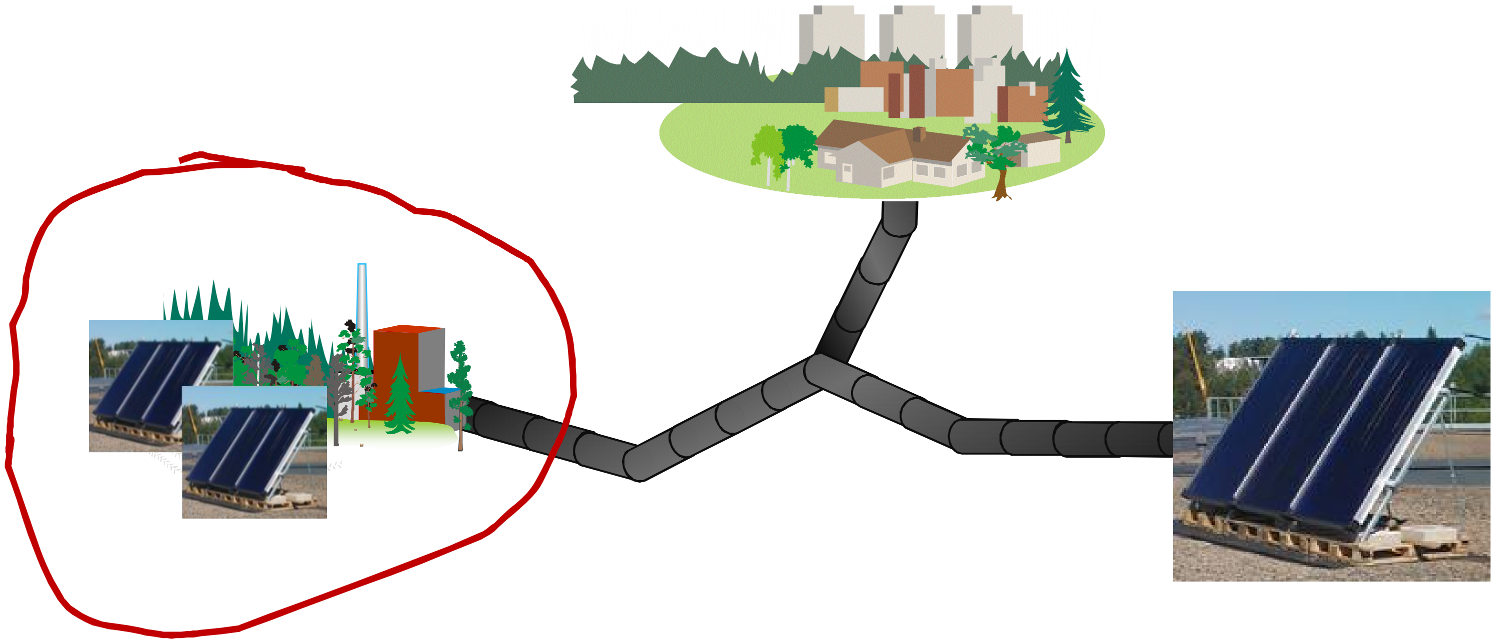
VTT’s solar collectors. 12 m2 area corresponds with 10 kW output.

The dryer can be used to dry a batch of
1-2 m3 of biomass using solar heat.

Value of flexibility

- Levellised cost of energy LCOE a standard metric
- LCOE does not capture effects of variable generation
  - What is the value of flexibility?
- Highly flexible generation, grid infrastructure and demand-side integration are capable of providing flexibility at very low cost
  - 1-5 $/MWh under favourable conditions, and
  - up to 20 $/MWh under less favourable conditions
- Electricity storage considerably costlier, ranging from
  - 20 $/MWh (pumped hydro storage in favourable locations)
  - above 500 $/MWh (distributed battery storage with low utilisation)

Motivation for integrated RES hybrids



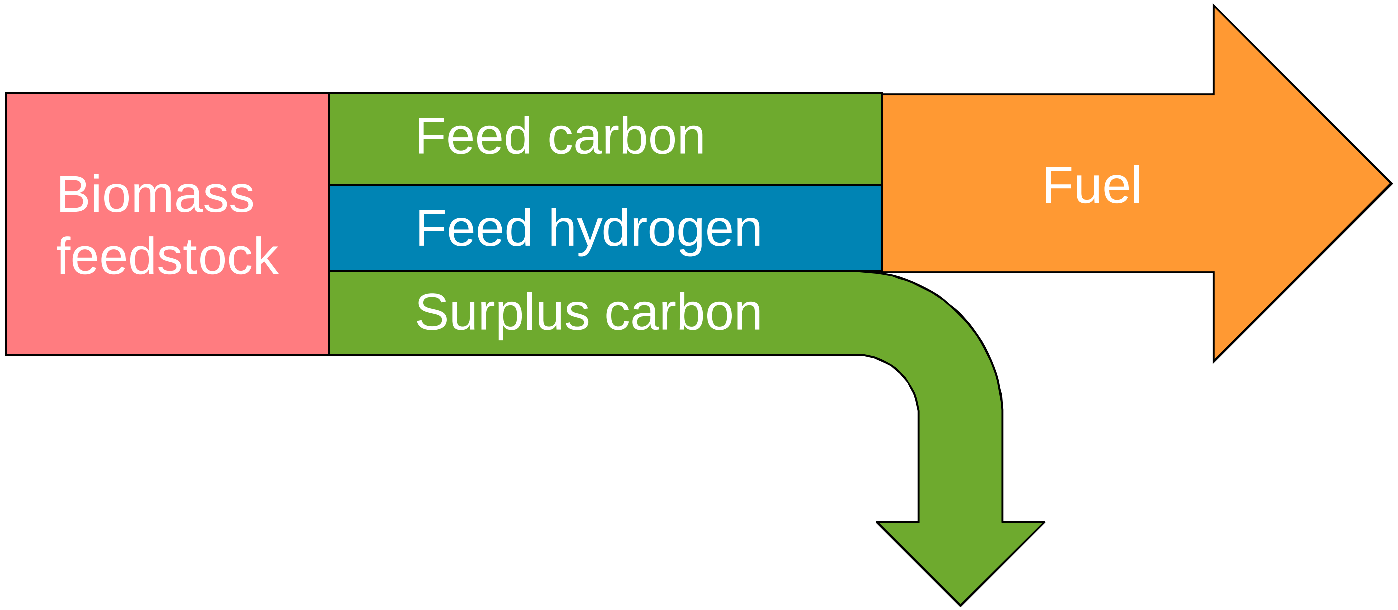
Integration benefits?

Motivation for integrated RES hybrids

- Efficiency improvements via heat integration.
  - e.g. preheating of process feeds (water, air) before combustion, gasification, etc.
- Lower cost via equipment sharing.
  - e.g. common steam system.
- Improve resource efficiency (reduced biomass use)
  - e.g. RES integrated biorefineries

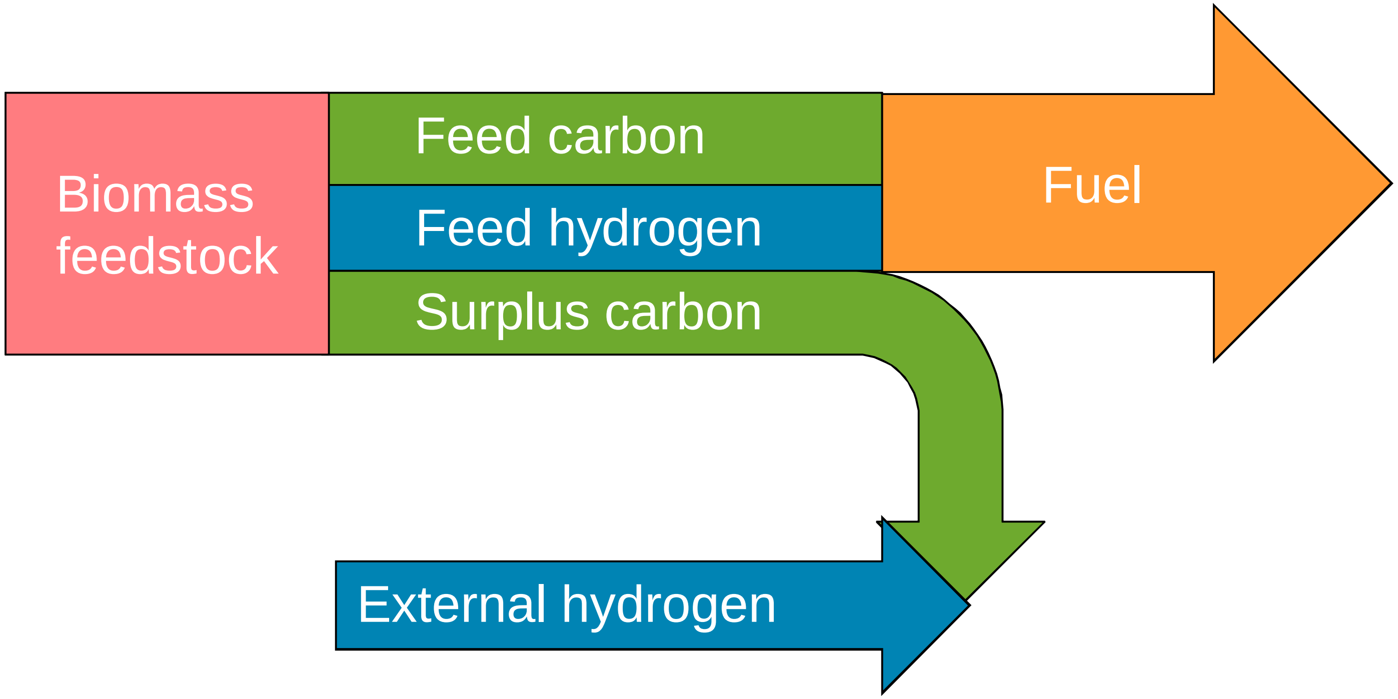
Increasing resource efficiency of biomass use

- 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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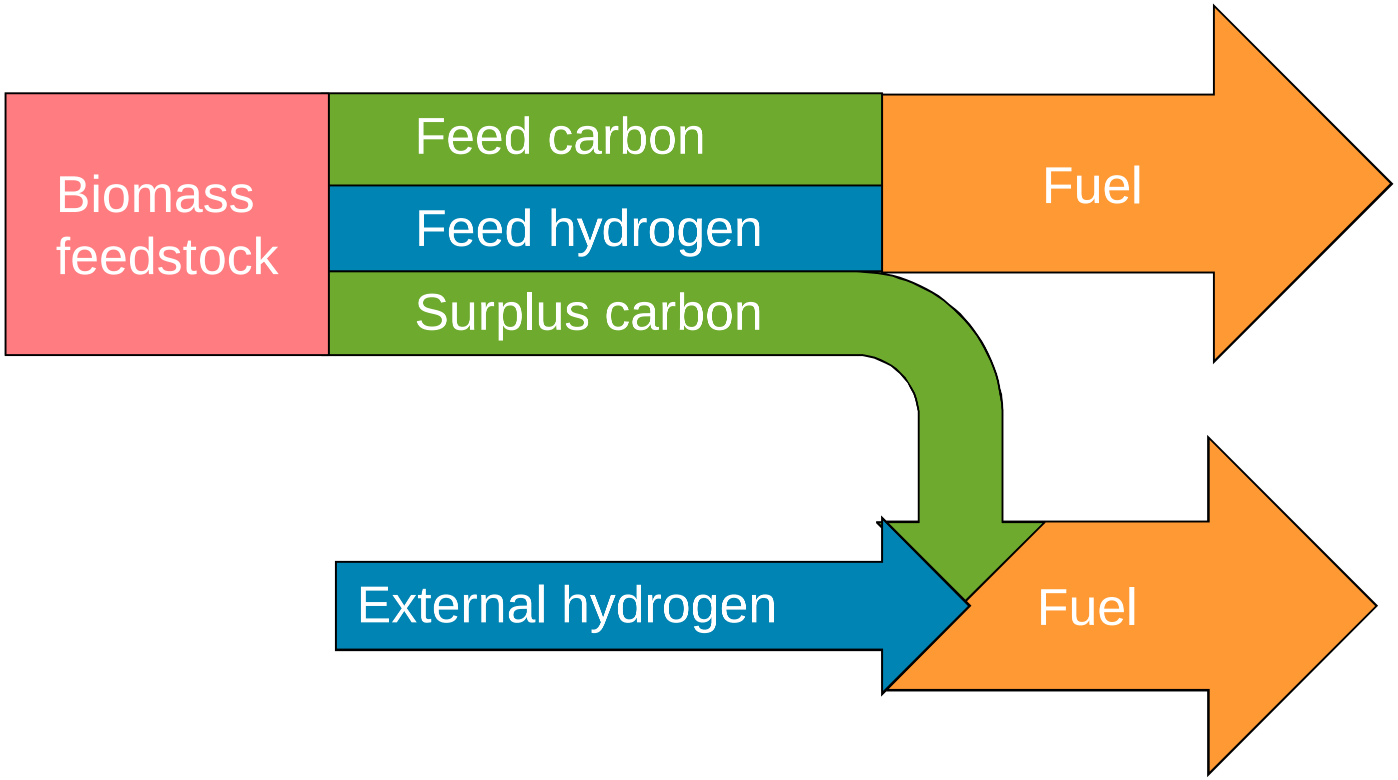
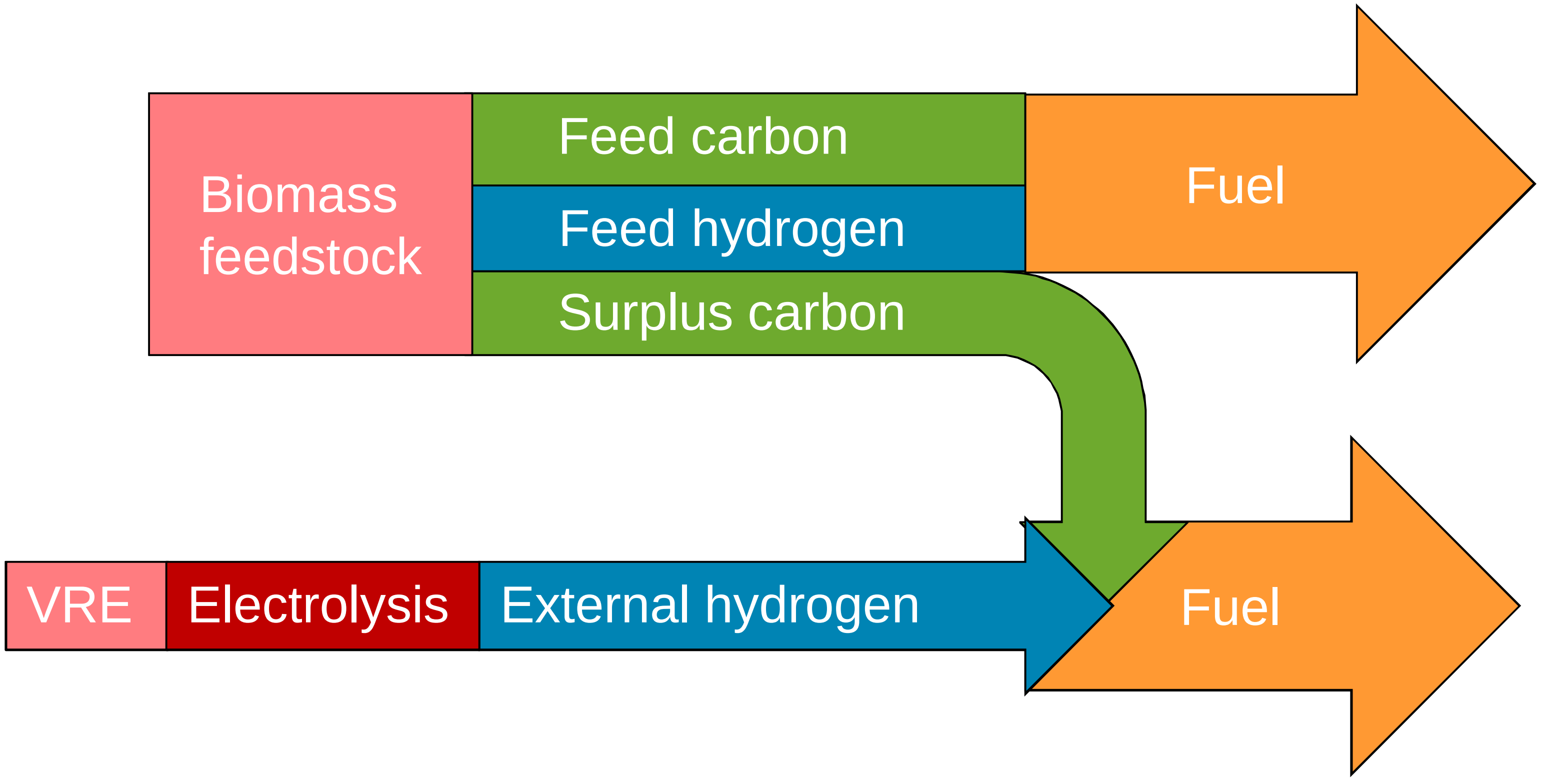


Increasing resource efficiency of biomass use

Process can be designed to operate either to

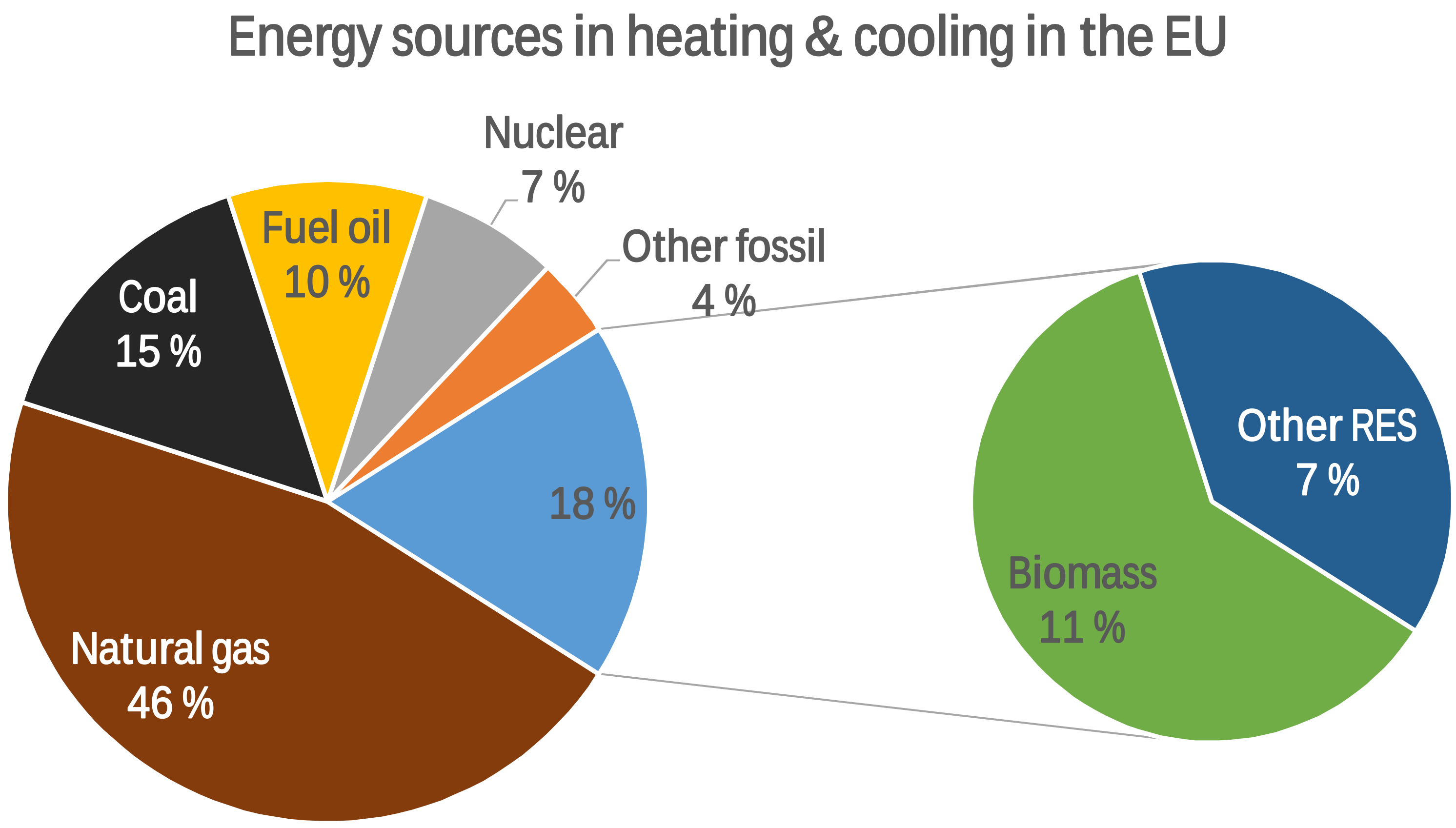
- **Flexibly store surplus** electric energy chemically
- Operate continuously to **maximise resource efficiency** from biomass (doubling of the biofuel output possible)



Current experience and challenges

- Currently hybrids commonly available in the heating sector
- Deployment outside domestic and medium scale not yet widespread
- Commercial success often depends on public incentives
- Solar thermal not yet widespread technology in DH production, but could contribute to production during summer periods.
- Long-term thermal storage sometimes in competition with biomass solutions
- Bioenergy as a natural energy source at farms creates good preconditions for hybrid systems in farm-scale, providing increased self-sufficiency through out the year.
- Optimal integrated hybrid solution depends on several issues, including:
  - Available resources
  - The cost of energy
  - Type of demand
  - Incentives and legal framework (national targets)

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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*I. Hannula, Hydrogen enhancement potential of synthetic biofuels manufacture in the European context: A techno-economic assessment, Energy, Volume 104, 1 June 2016, Pages 199-212, ISSN 0360-5442, http://dx.doi.org/10.1016/j.energy.2016.03.119.

State of Art summary

	Domestic scale	Utility-scale and DH / DC networks	Industry	Farm-scale
On market/ Implemented	• Biomass + solar thermal • Biomass + ground-source heat • Biomass + waste heat recovery • Biomass + electric heating • Biomass + DH • Biomass + PV	• Biomass + waste heat recovery • Biomass + passive solar energy • Co-combustion of biomass and coal	• Biomass + ground-source heat • Biomass + waste heat recovery • Biomass + PV	• Biomass + ground-source heat • Biomass drying • Biomass + PV • Biomass + wind • Biogas production
Ongoing developments	• Two-way DH connection • Optimized control algorithms	• Biomass + solar thermal • Biomass + geothermal • Hydrogen boosted biofuels • Waste heat utilization from new sources • Low temperature grids • Prosumer integration	• Biogas related networks • Hydrogen boosted biofuels	• Biomass solar thermal • Liquid biofuel production

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
- Operational optimisation through new controlling strategies
- Optimal dimensioning of integrated process with storage
- Better understanding on system needs for flexible generation and storage
- Cross-sectional questions between power & heating & transportation sectors and linkages between them.
- Develop technologies to better meet these needs:
  - Improved partial load operation and faster ramping/cycling while maintaining high efficiency and low emissions
  - Concepts for seasonal storages using biomass
    - RES integrated biorefineries with flexibility features
    - Drying of biomass with VRE

Thank you for your attention!

- Learn about IEA Bioenergy: http://www.ieabioenergy.com/
- Learn about our project: http://task41project7.ieabioenergy.com/
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Discussion

- What are the best selling arguments for RES hybrids?
- Mention some bottlenecks and how to solve them?
- Would you benefit from standardised interfaces between technologies?
- How do you see the future of RES hybrids?