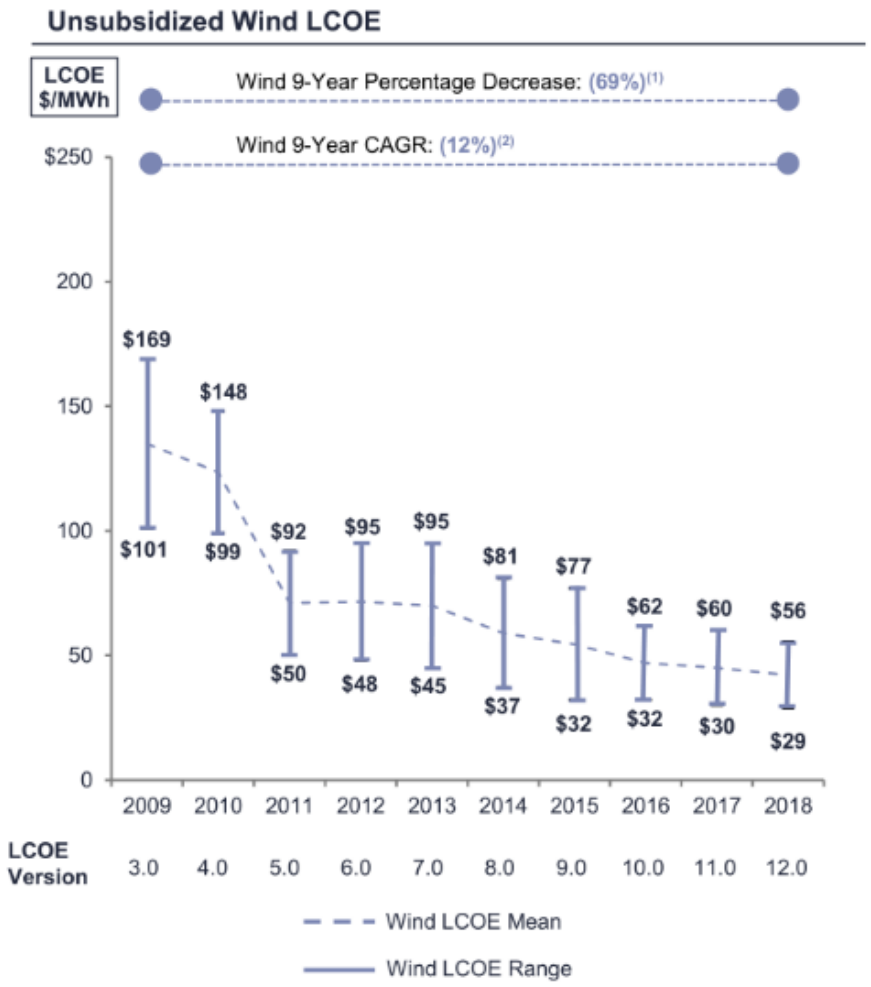
Value-optimised use of bioenergy in a flexible energy infrastructure - VaBiSys

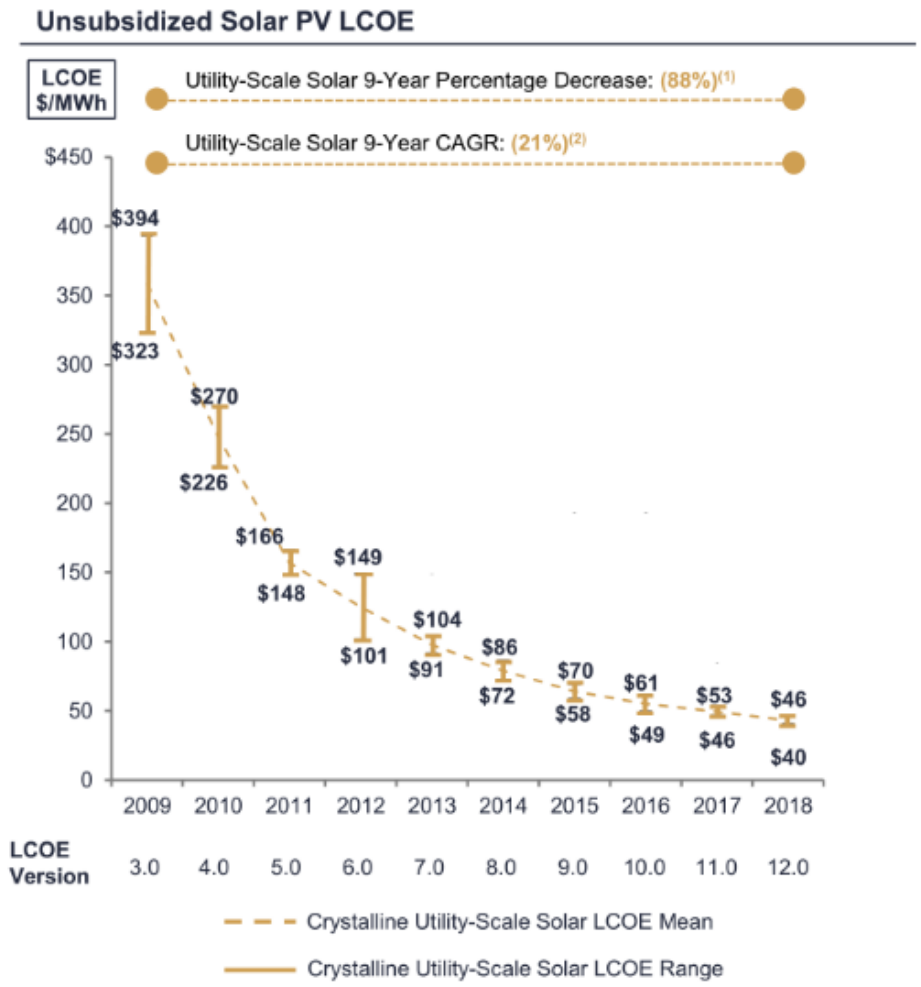
Highlights of Bioenergy Research 2020

CEBC 2020, Graz, Austria

Presented by: I. Hannula, VTT

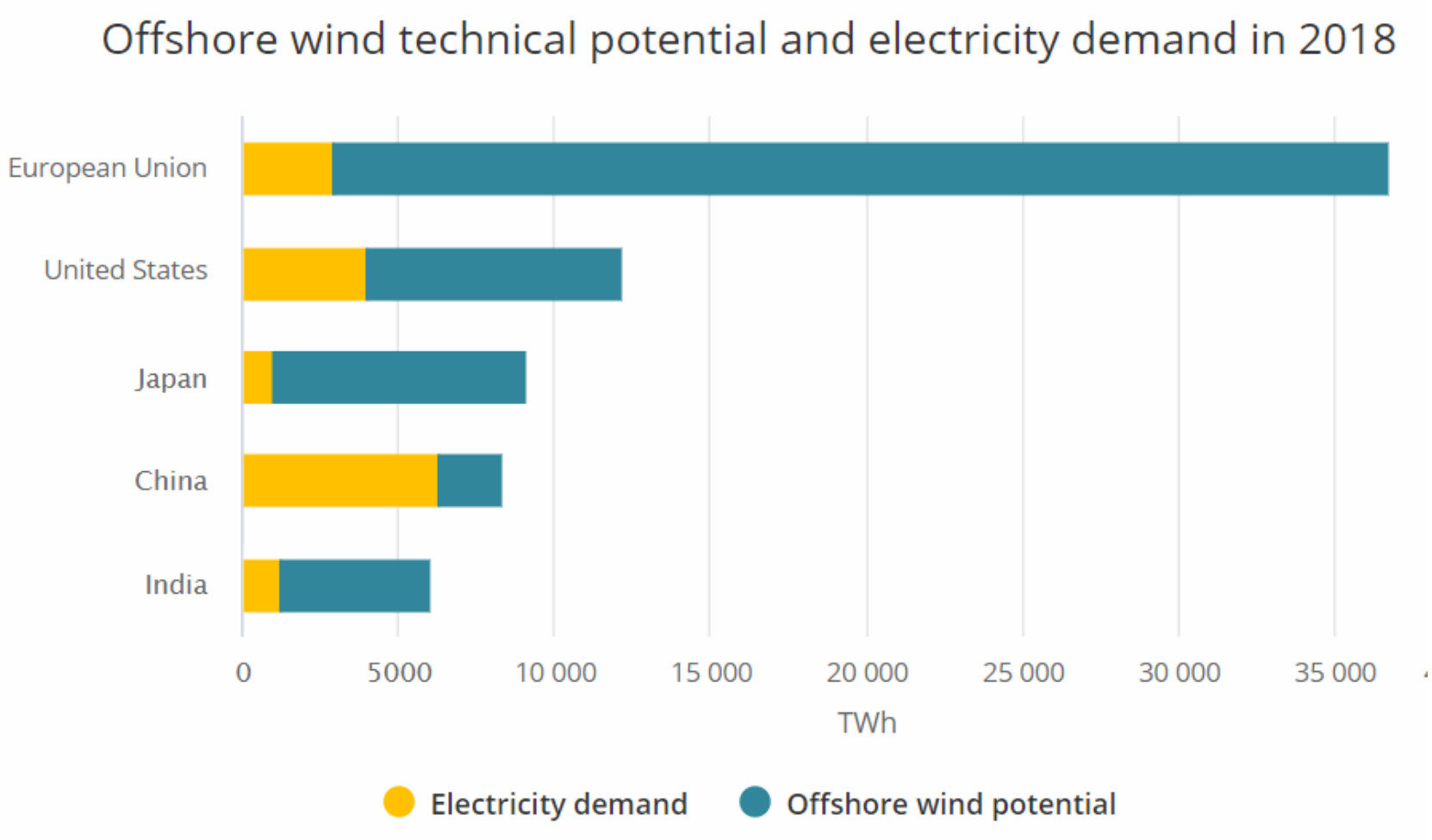
Cost of wind and solar has decreased drastically





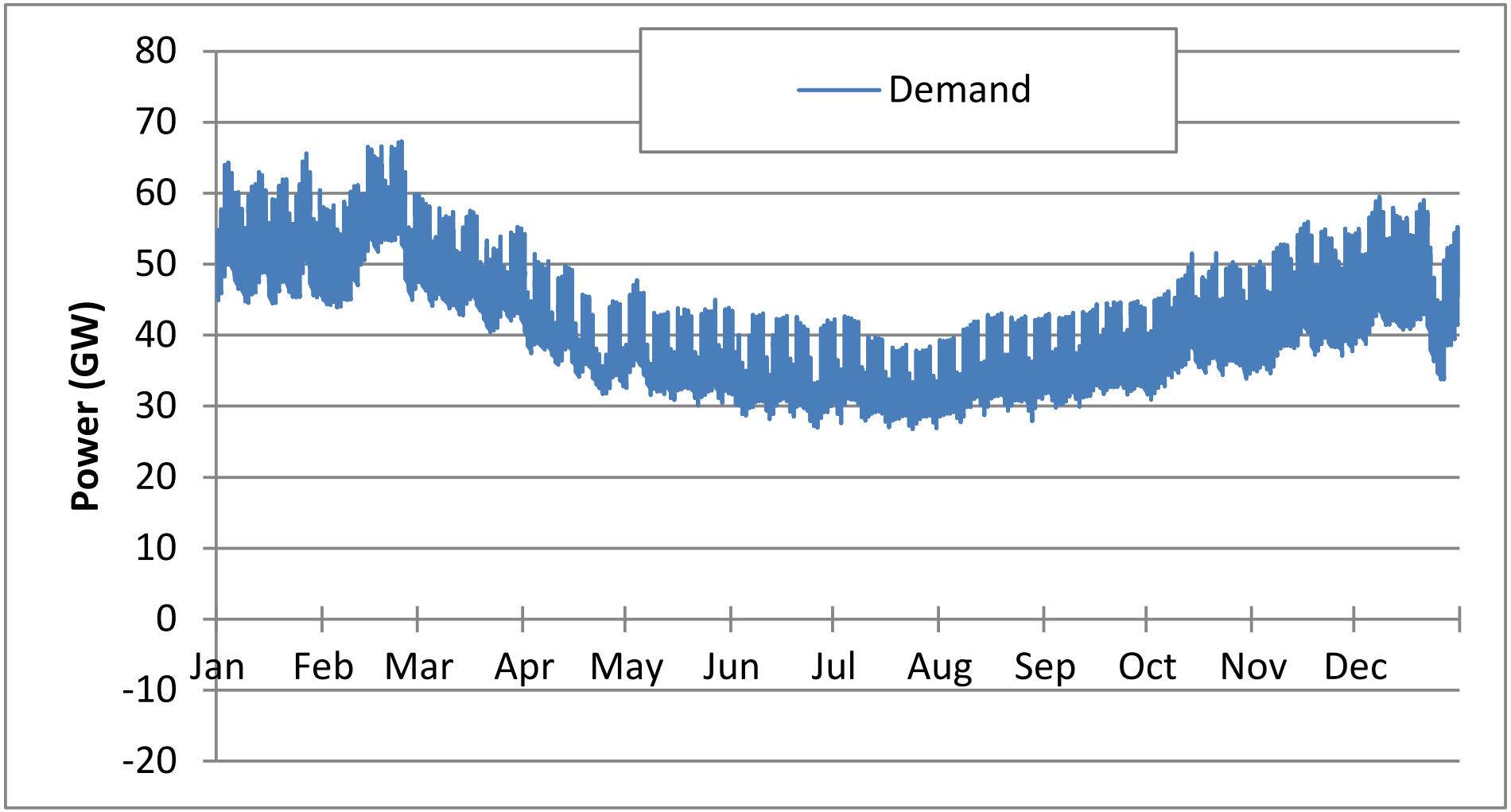
Source: Lazard's levelized cost of energy analysis – Version 12.0

Offshore wind has massive potential

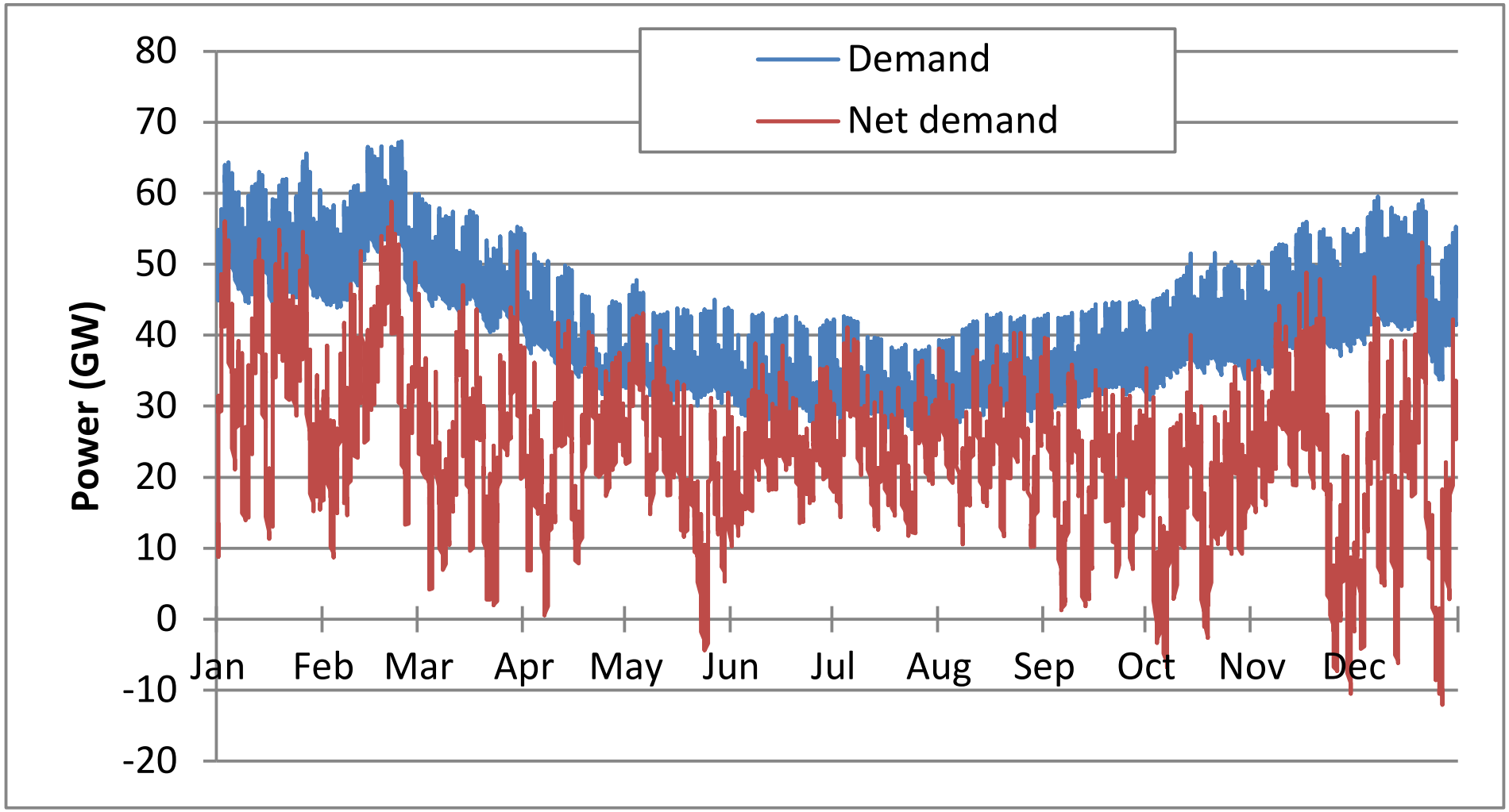


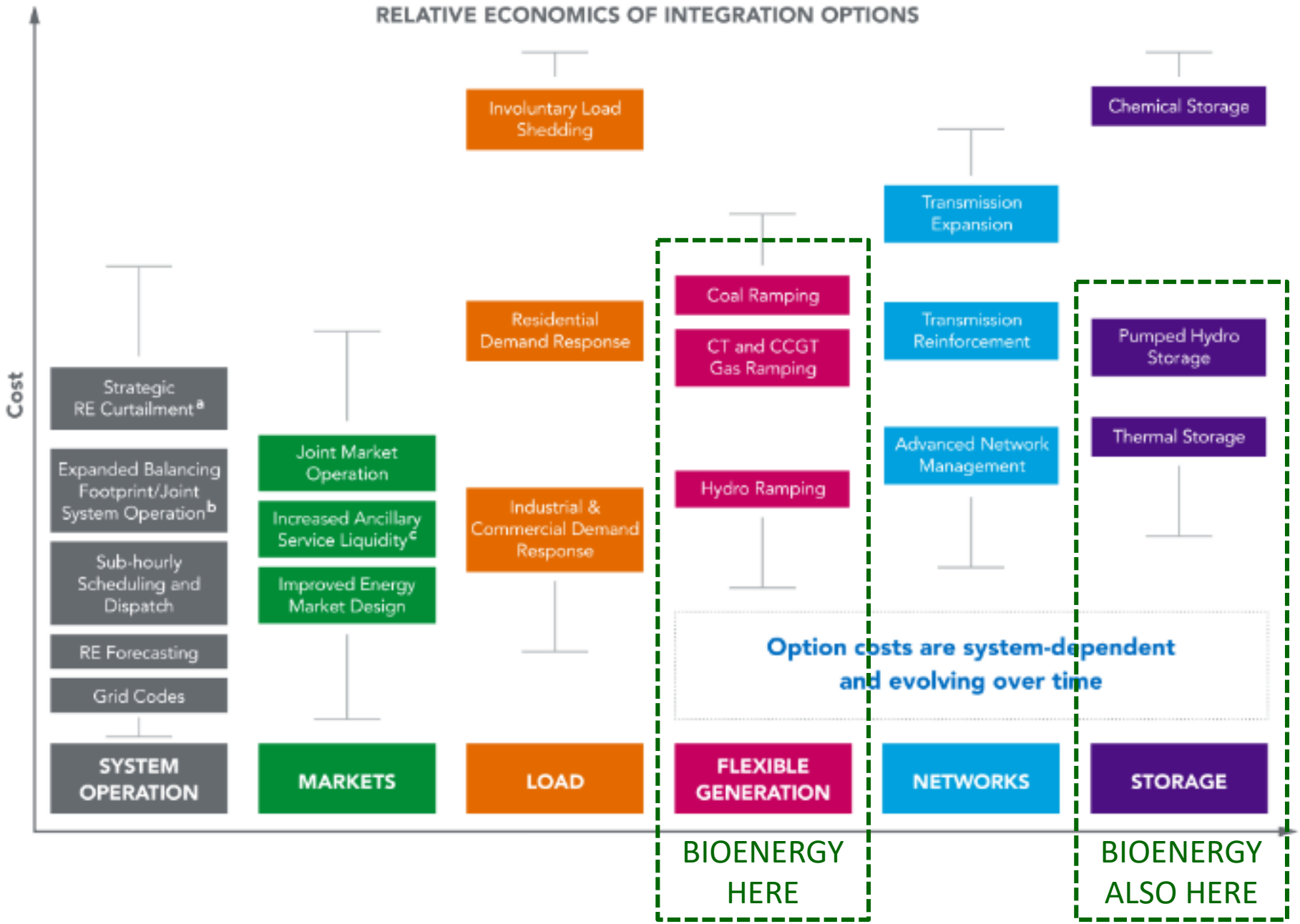
Source: IEA Offshore Wind Outlook 2019

Variability is normal



But variability increases with more wind




RELATIVE ECONOMICS OF INTEGRATION OPTIONS
Cost
Strategic RE Curtailment[a]
Expanded Balancing Footprint/Joint System Operation[b]
Sub-hourly Scheduling and Dispatch
RE Forecasting
Grid Codes
SYSTEM OPERATION
Joint Market Operation
Increased Ancillary Service Liquidity[c]
Improved Energy Market Design
MARKETS
Involuntary Load Shedding
Residential Demand Response
Industrial & Commercial Demand Response
LOAD
Coal Ramping
CT and CCGT Gas Ramping
Hydro Ramping
FLEXIBLE GENERATION
Transmission Expansion
Transmission Reinforcement
Advanced Network Management
NETWORKS
Chemical Storage
Pumped Hydro Storage
Thermal Storage
STORAGE
Option costs are system-dependent and evolving over time
BIOENERGY HERE
BIOENERGY ALSO HERE

ERA-Net project: Value-optimised use of biomass in a flexible energy infrastructure

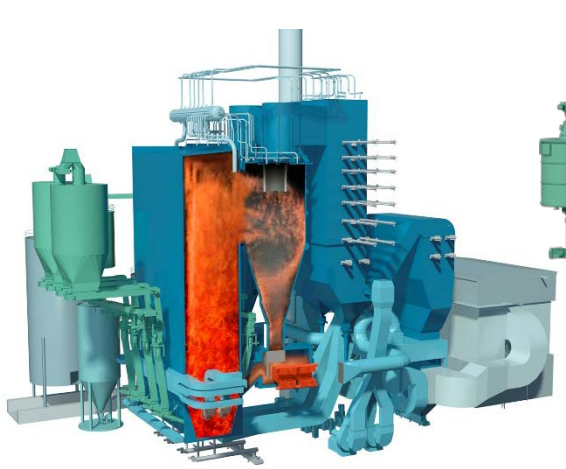
1. Development of **new bioenergy solutions** to serve energy markets with a high need for flexibility;
   - Solid-biomass boilers for back-up
   - Pyrolysis-based intermediates
   - Gasification plants co-producing heat, fuels and electricity
   - Biogas plants for back-up
2. Significantly **extending the flexibility of known** bioenergy technologies;
3. Identification of **costs, benefits and development needs** for potential bioenergy concepts in a VRE dominated energy system;
   A. Hour-based generation planning
   B. Production cost simulation for a full year (including forecasting errors)
4. Improved understanding about the economic, social and environmental **sustainability of biomass used in a flexible energy system**; and
5. Accelerating the deployment of flexible bioenergy technologies via market assessments and development of potential **business plans**.

Budget: 2 M€, Duration: 2018 - 2021

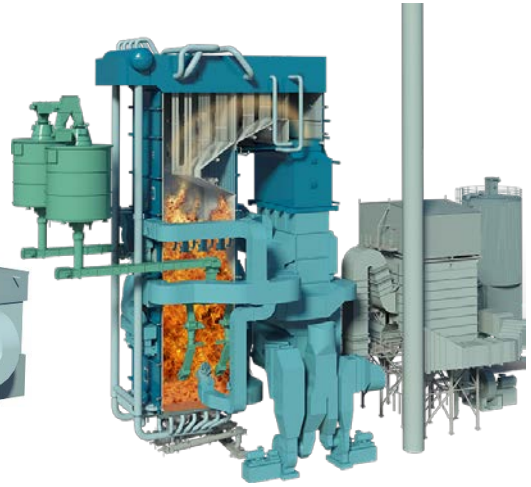
Low Carbon Flexibility with Renewable Solid Fuels

Performance of Circulating Fluidized Bed (CFB) & Bubbling Fluidized Bed (BFB) Boiler Technologies

Proven benefits
- Fuel flexibility
- Wide size range
- High efficiency
- High availability
- Low emissions
- Enables Bio Energy CCS

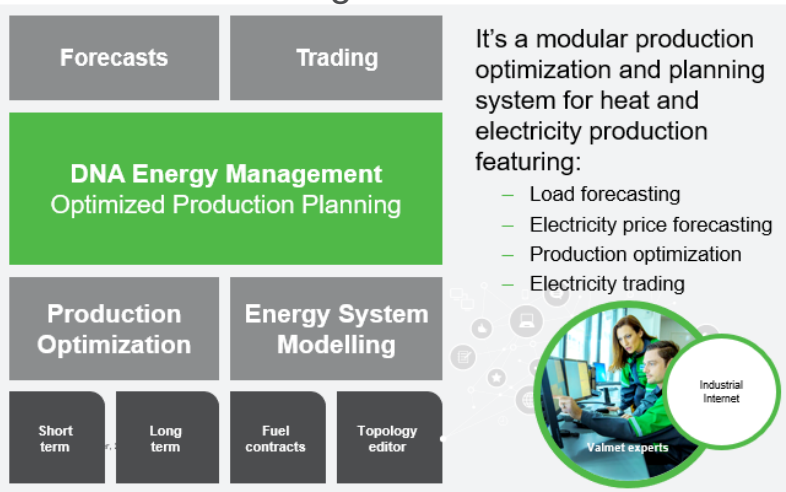


CFB Boiler Plant



BFB Boiler Plant

DNA Energy Management - Optimized Production Planning



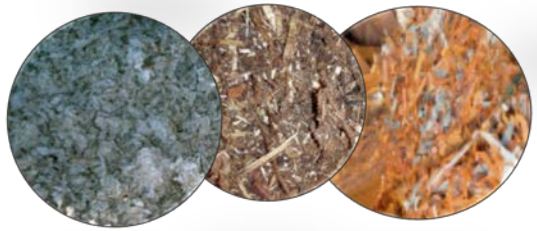
Current Indicative values	Size range	Max Steam Parameters*	Min load	Load change	Cold start up	Warm start up
	[MW_e]		[%]	[%/min]	[h]	[h]
Bio/Multifuel CFB plant	30 – 300	565 ºC 175 bar	30	5	10	4
BFB plant	5 – 130	540 ºC 160 bar	15	6	8	4

Recycled wood

Municipal solid waste

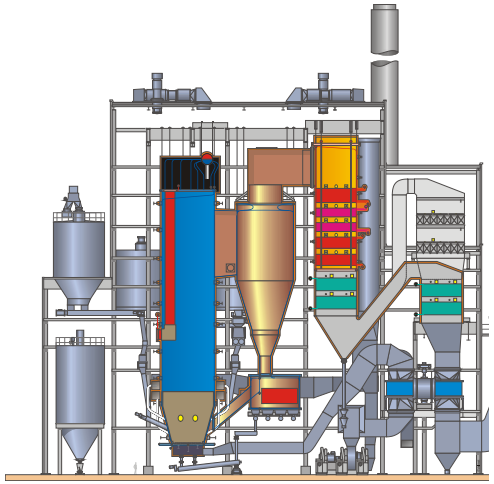
Agricultural residues

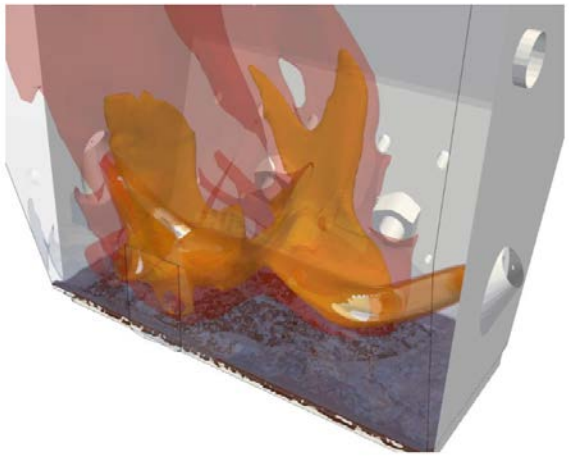
Industrial residues



Forest residue

Flexibility limits of biomass power plants





Minimum load

- Two min load measurement campaigns has been done
- Development of furnace designs using CFD modelling
  - Several scenarios simulated
  - Final evaluation ongoing

Ramp rates

- Start up CFD simulation with higher burner load is done
- Dynamic CFB model has been developed to enable start up simulations
  - Several fast start ups has been simulated
- Refractory lab tests and field studies has been done

Decentralized biomass-based cogeneration

Locally available residues

- wood chips
- low-quality wood chips
- mechanically pre-treated chipboard

flexible fuel change

Source: Spanner Re² (Renewable Energy Experts) GmbH

flexible operation

Local grid support

- operation in period with less VRE-electricity available
- offer local grid support and balancing

- emissions, efficiency
- mass- and energy balance

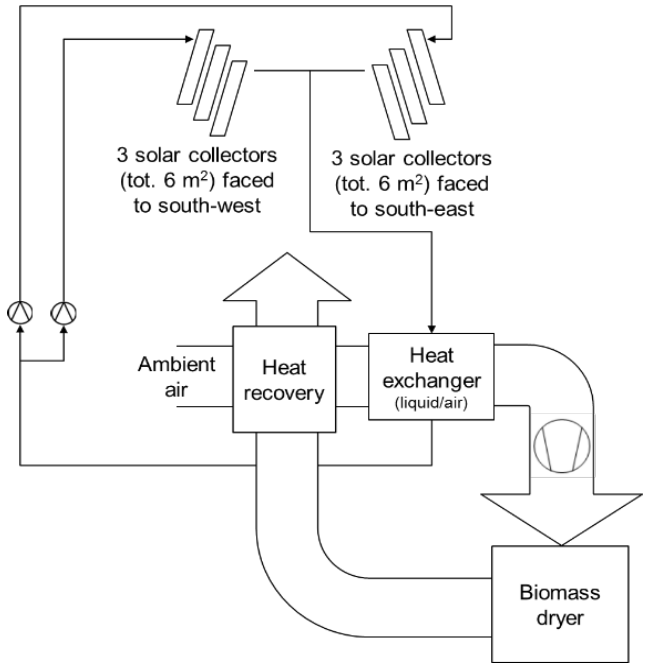
- fast load ramps
- short start duration
- improved engine control

Small-scale flexible CHP systems for local self-supply

- pre-treatment of different low-quality residues
  - standard wood chips, low-quality wood chips, chipboard
  - mechanical treatment, sieving, washing
- identification of optimum operating strategies for small-scale gasification unit
  - mixture ratio, water content, technical limitations
  - gas quality, efficiency, emissions, design and operation point
- further analysis and equipment
  - supported by FactSage, (Electrical) grid simulator, Hardware-in-the-loop Simulator
  - fuel and ash analysis

Solar enhanced biomass drying

- Scale up and system evolution – from lab scale to improved pilot scale
- Initial experiments done with VTT's convective solar enhanced biomass dryer:



Scaled-up dryer

Main changes and improvements:

- Increasing drying capacity by installing a heat pump (25 kW) to the system
  - Integrated into an air supply unit
  - Pump is used to dry the drying air
  - Dryer can be used also in cloudy days, possibly also in winter (depending on profitability)
- Increasing solar collector capacity to 24 m^2
- Building a new drying chamber
  - Possible to move and circulate raw material during drying – with vertical an vertical agitator and chain conveyor – resulting in even drying
  - Batch size up to 10 m^3

Testing in spring 2020
Experiments in summer 2020

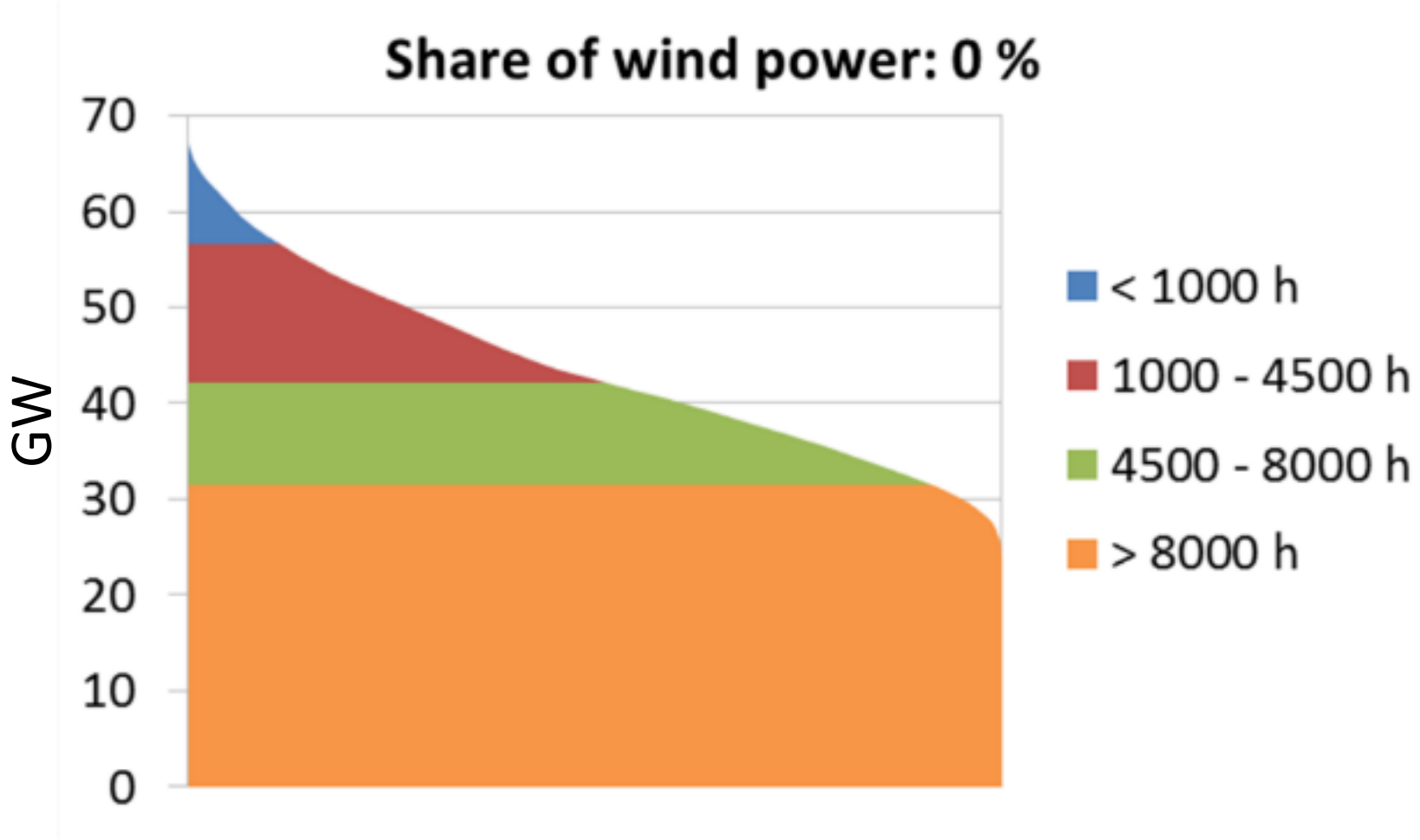
Techno-economic assessment

- In Finland, potential annual drying season is seven months, with great fluctuation
- Solar enhanced drying suits well for solid biomass drying
- Payback times less than 10 years with 30% investment support and cost of electricity below 50 €/MWh.

DRYER PAYBACK TIME IN YEARS	30% investment subsidy	
Collector surface area of the solar system	90m^2	5,000m^2
Seasoned wood, 6 m^2 system	21	14
Seasoned wood, 12 m^2 system	18	12
Fresh wood, 12 m^2 system	50	34
Seasoned wood, 70% solar energy enhancement	10	7
Fresh wood, 70% solar energy enhancement	20	14

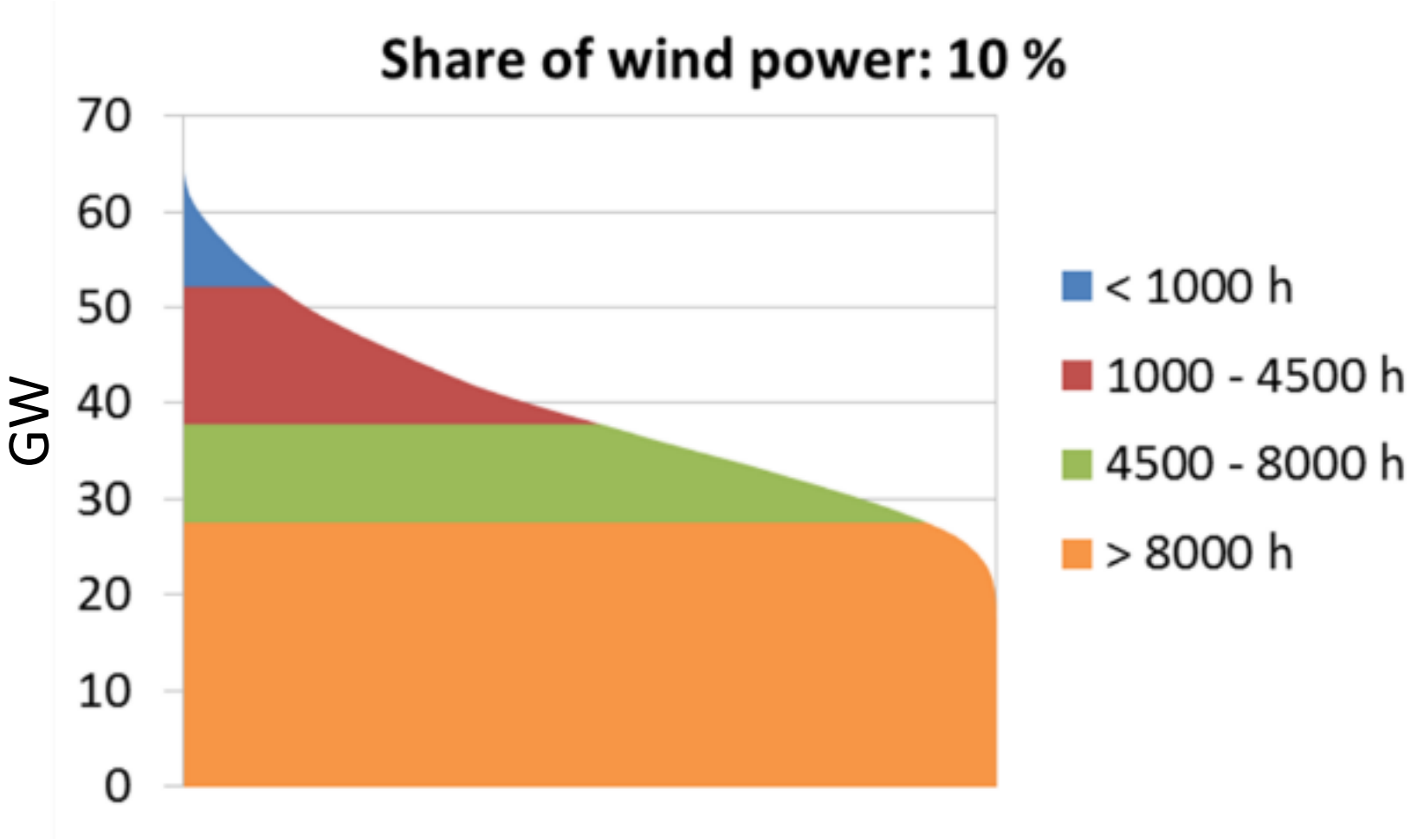
Raitila, J., Tsupari, E. Feasibility of Solar-Enhanced Drying of Woody Biomass. Bioenerg. Res. (2019) doi:10.1007/s12155-019-10048-z

Duration curve for power generation in the Nordics



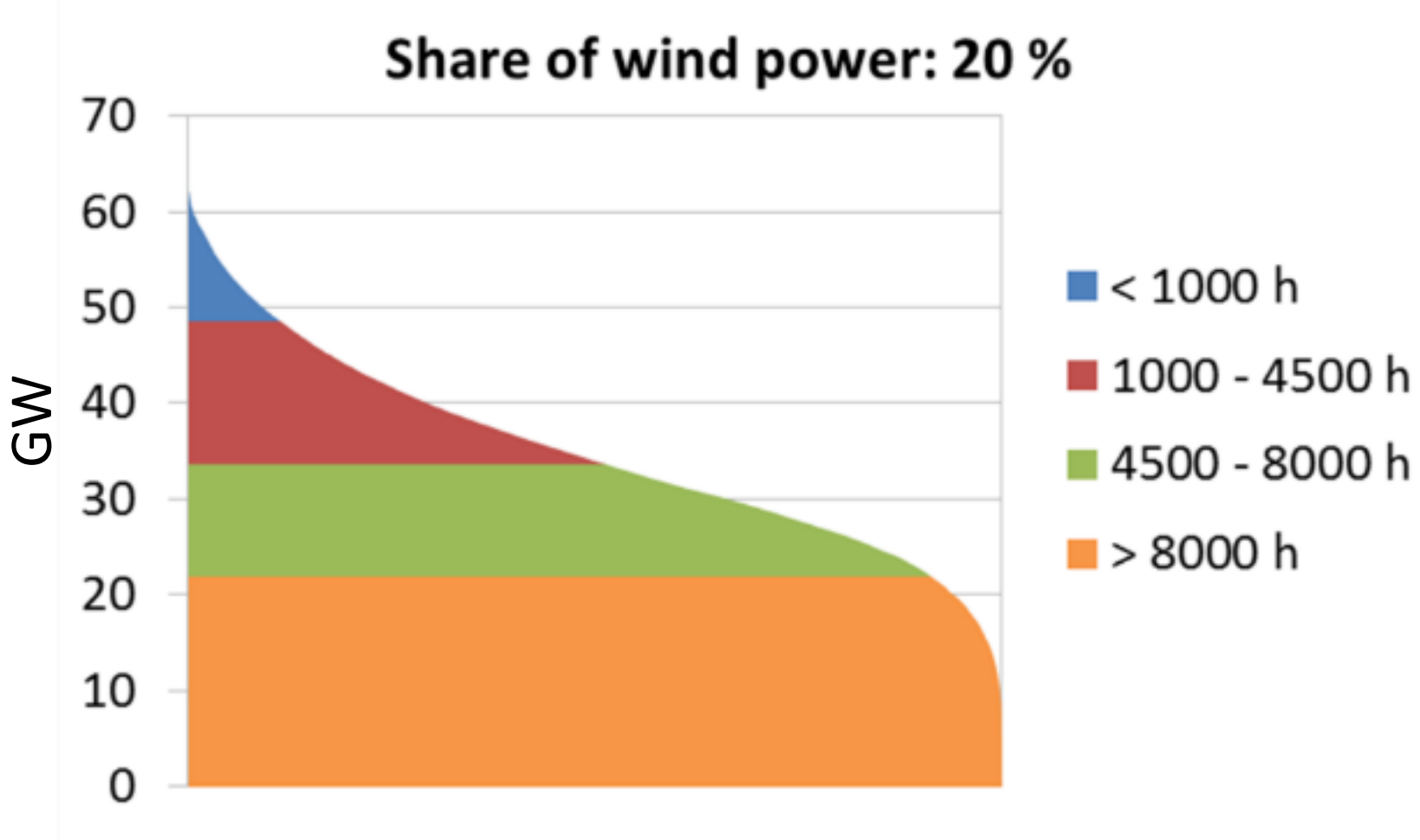
Source: Kiviluoma (2016). Balancing with Bioenergy (presentation for IEA Bioenergy report "Bioenergy in balancing the grid").

Duration curve for power generation in the Nordics



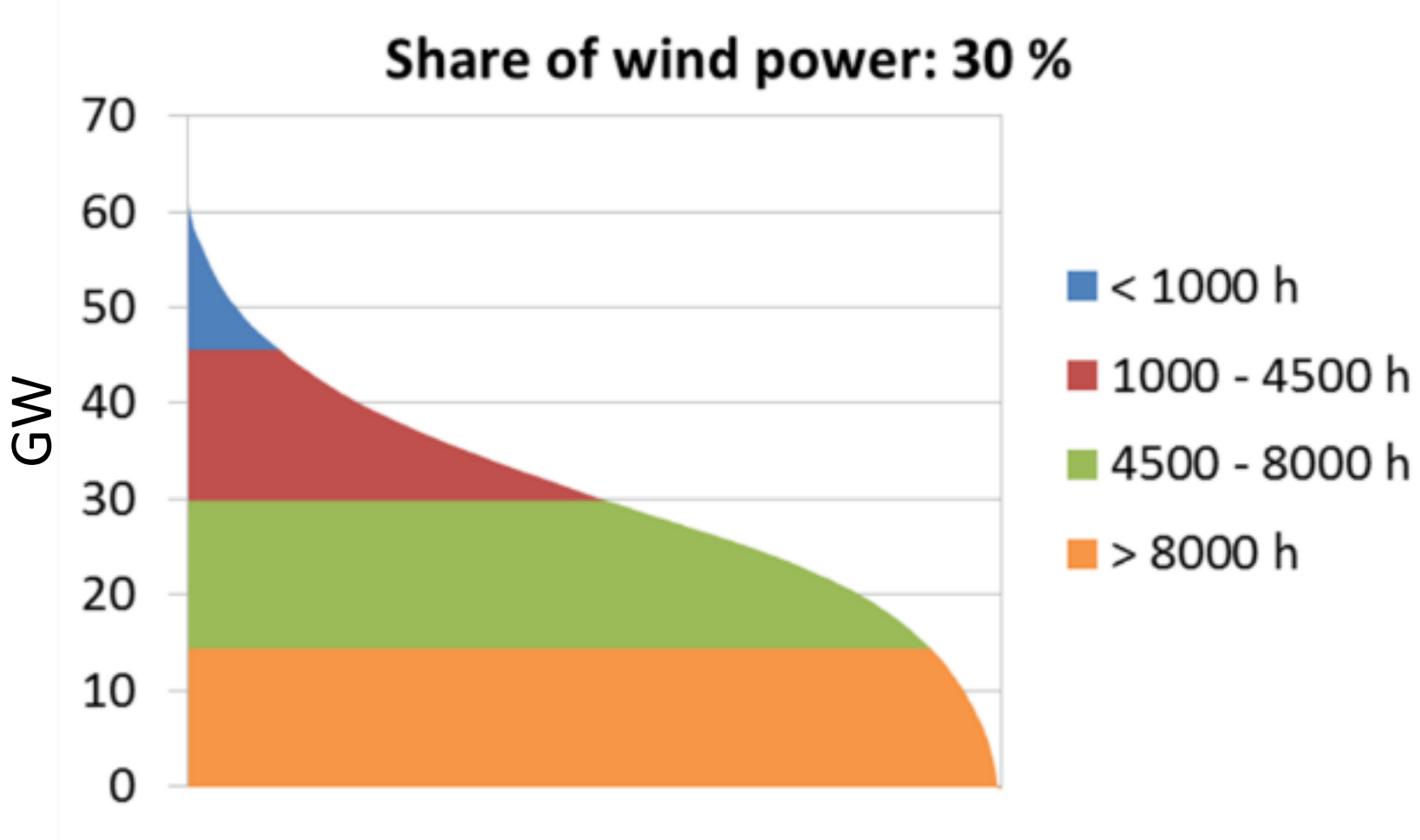
Source: Kiviluoma (2016). Balancing with Bioenergy (presentation for IEA Bioenergy report "Bioenergy in balancing the grid").

Duration curve for power generation in the Nordics



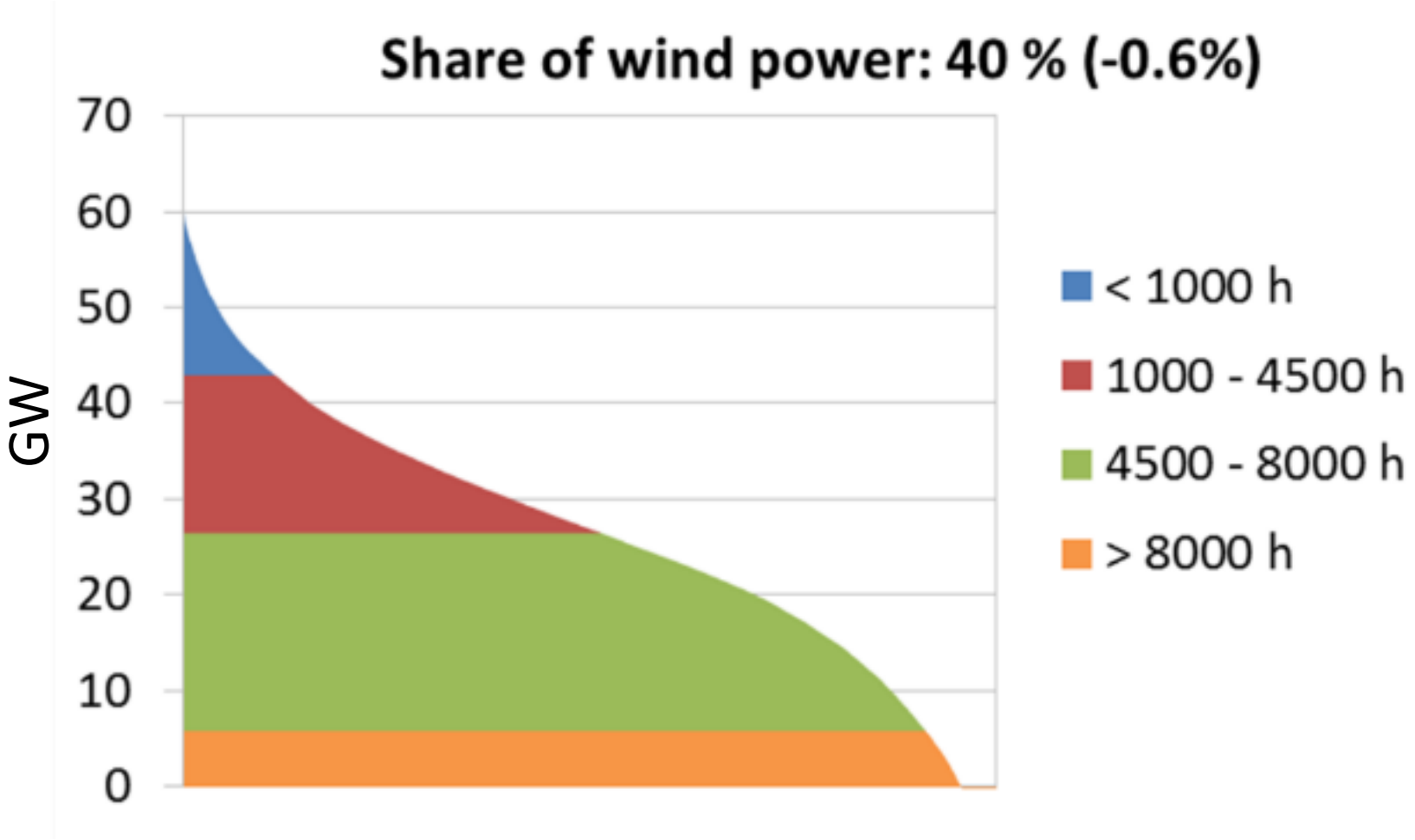
Source: Kiviluoma (2016). Balancing with Bioenergy (presentation for IEA Bioenergy report "Bioenergy in balancing the grid").

Duration curve for power generation in the Nordics



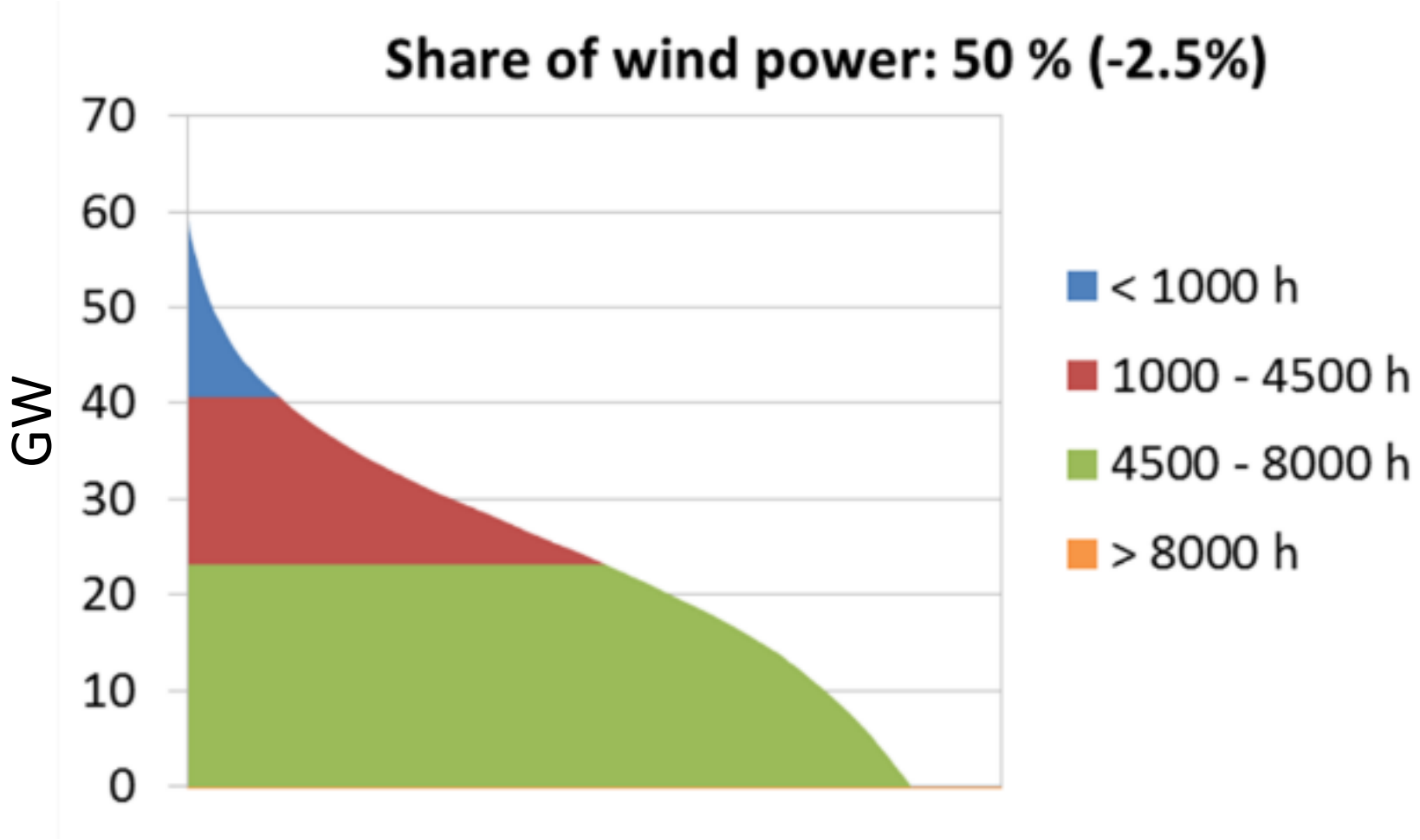
Source: Kiviluoma (2016). Balancing with Bioenergy (presentation for IEA Bioenergy report "Bioenergy in balancing the grid").

Duration curve for power generation in the Nordics



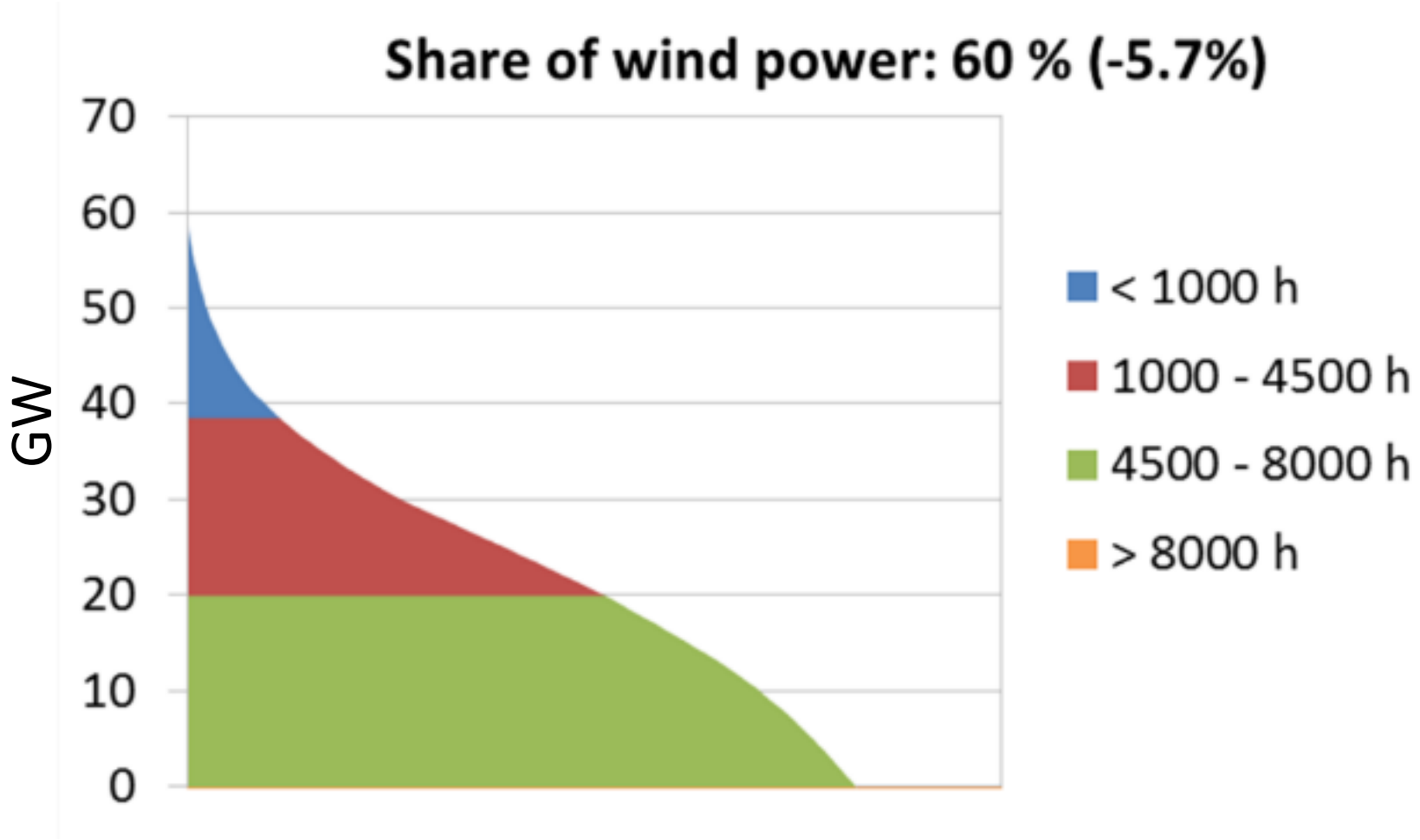
Source: Kiviluoma (2016). Balancing with Bioenergy (presentation for IEA Bioenergy report "Bioenergy in balancing the grid").

Duration curve for power generation in the Nordics



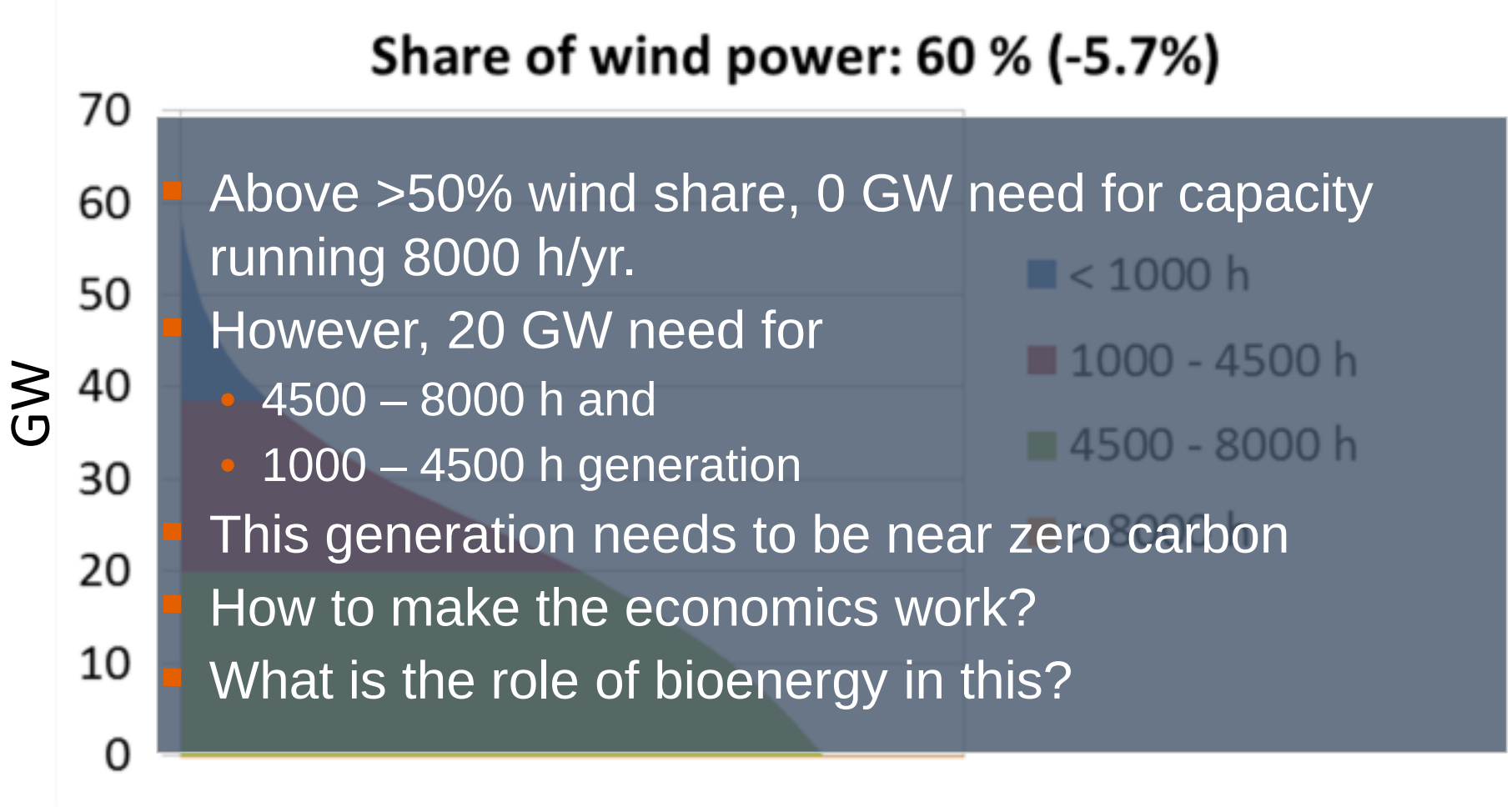
Source: Kiviluoma (2016). Balancing with Bioenergy (presentation for IEA Bioenergy report "Bioenergy in balancing the grid").

Duration curve for power generation in the Nordics



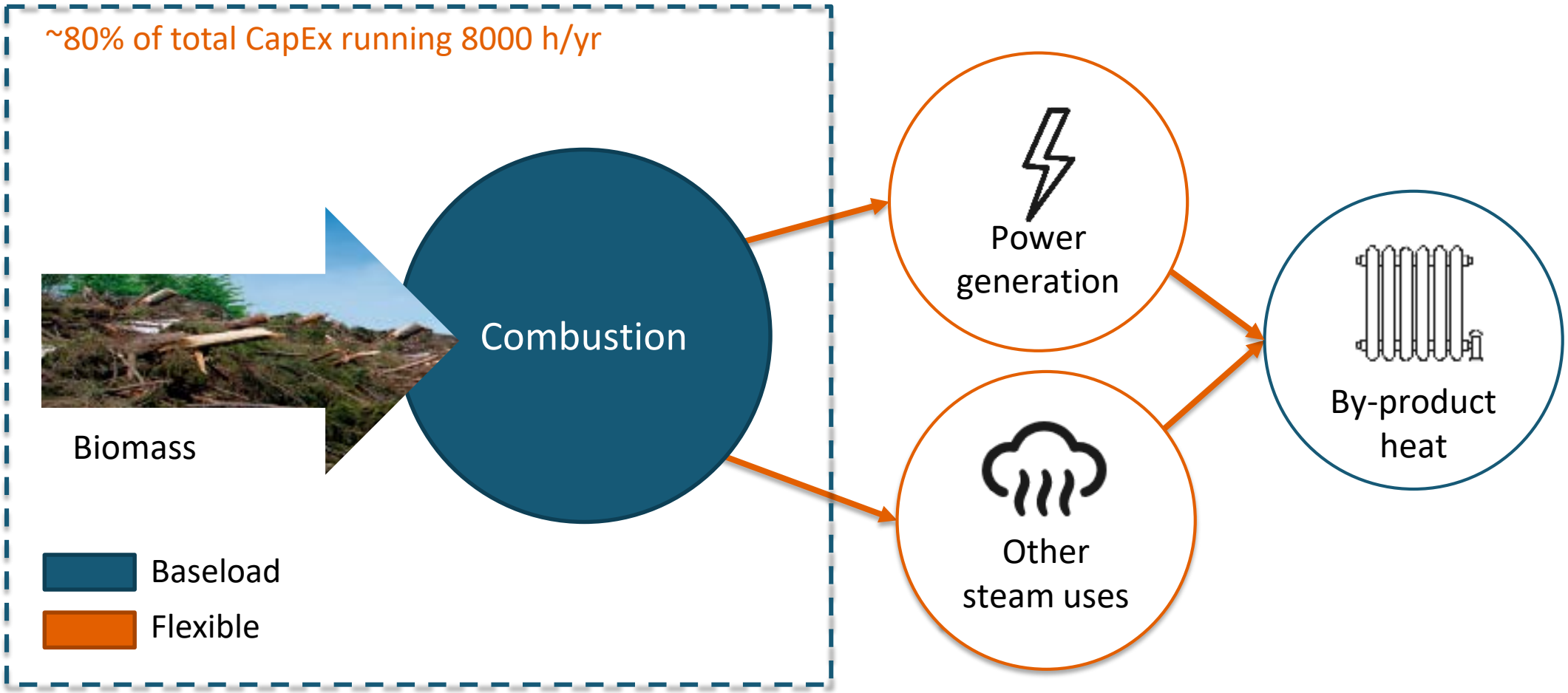
Source: Kiviluoma (2016). Balancing with Bioenergy (presentation for IEA Bioenergy report "Bioenergy in balancing the grid").

Duration curve for power generation in the Nordics

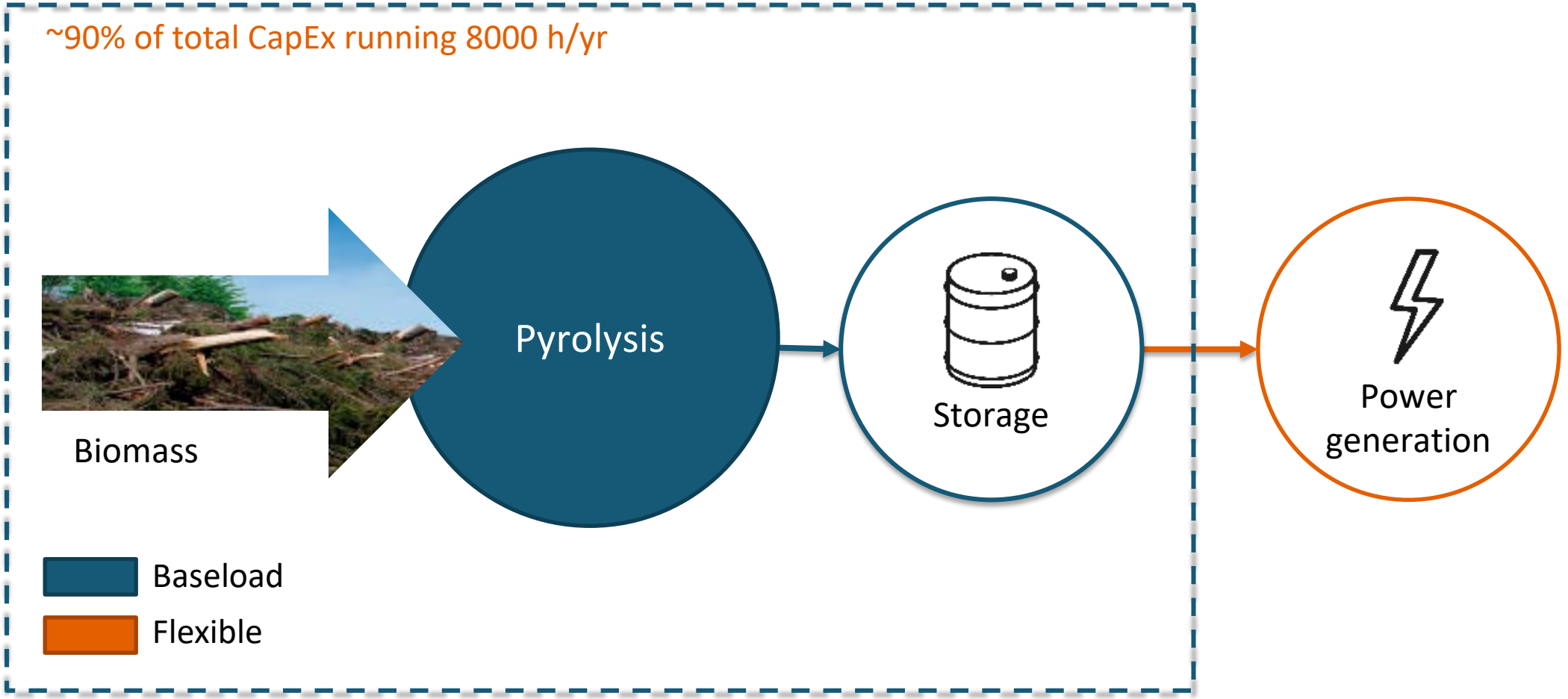


- Above >50% wind share, 0 GW need for capacity running 8000 h/yr.
- However, 20 GW need for
  - 4500 – 8000 h and
  - 1000 – 4500 h generation
- This generation needs to be near zero carbon
- How to make the economics work?
- What is the role of bioenergy in this?

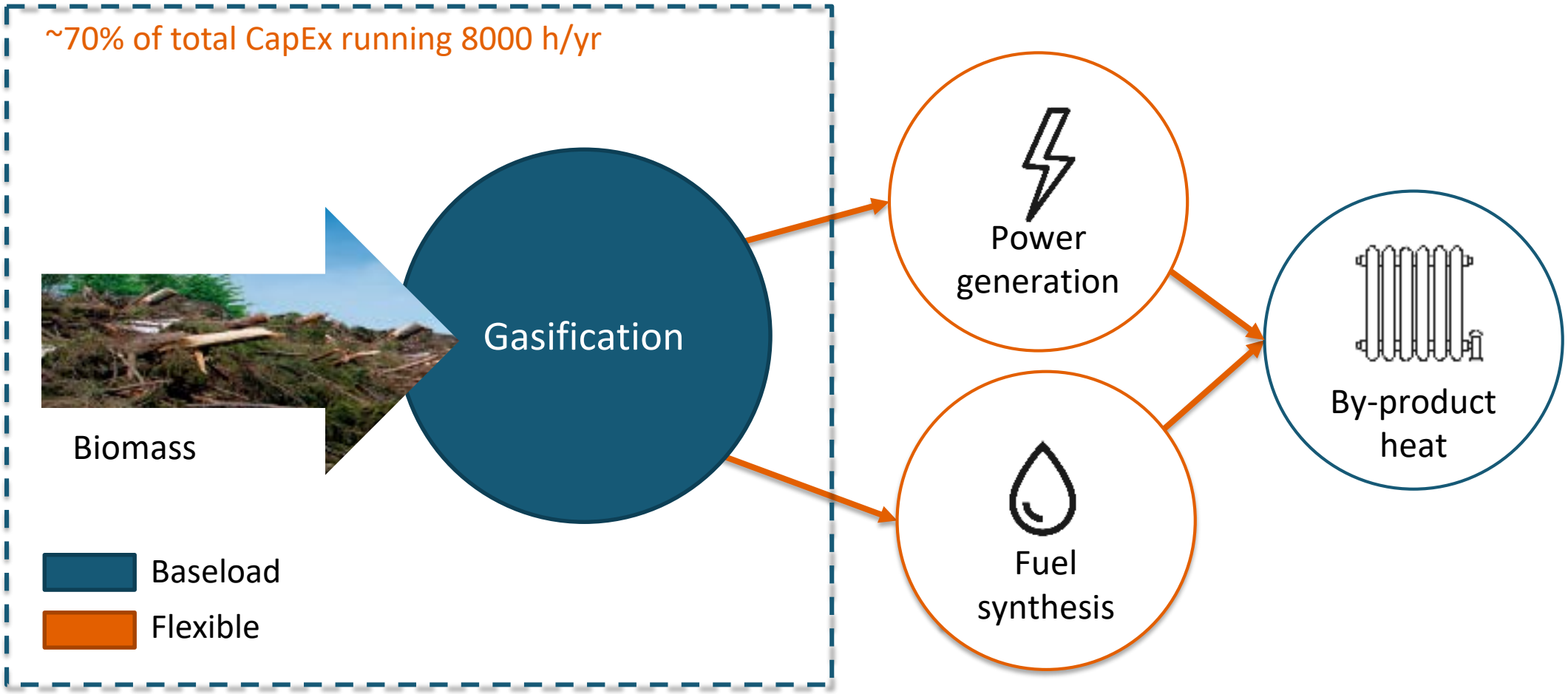
Co-production of power, steam and heat?



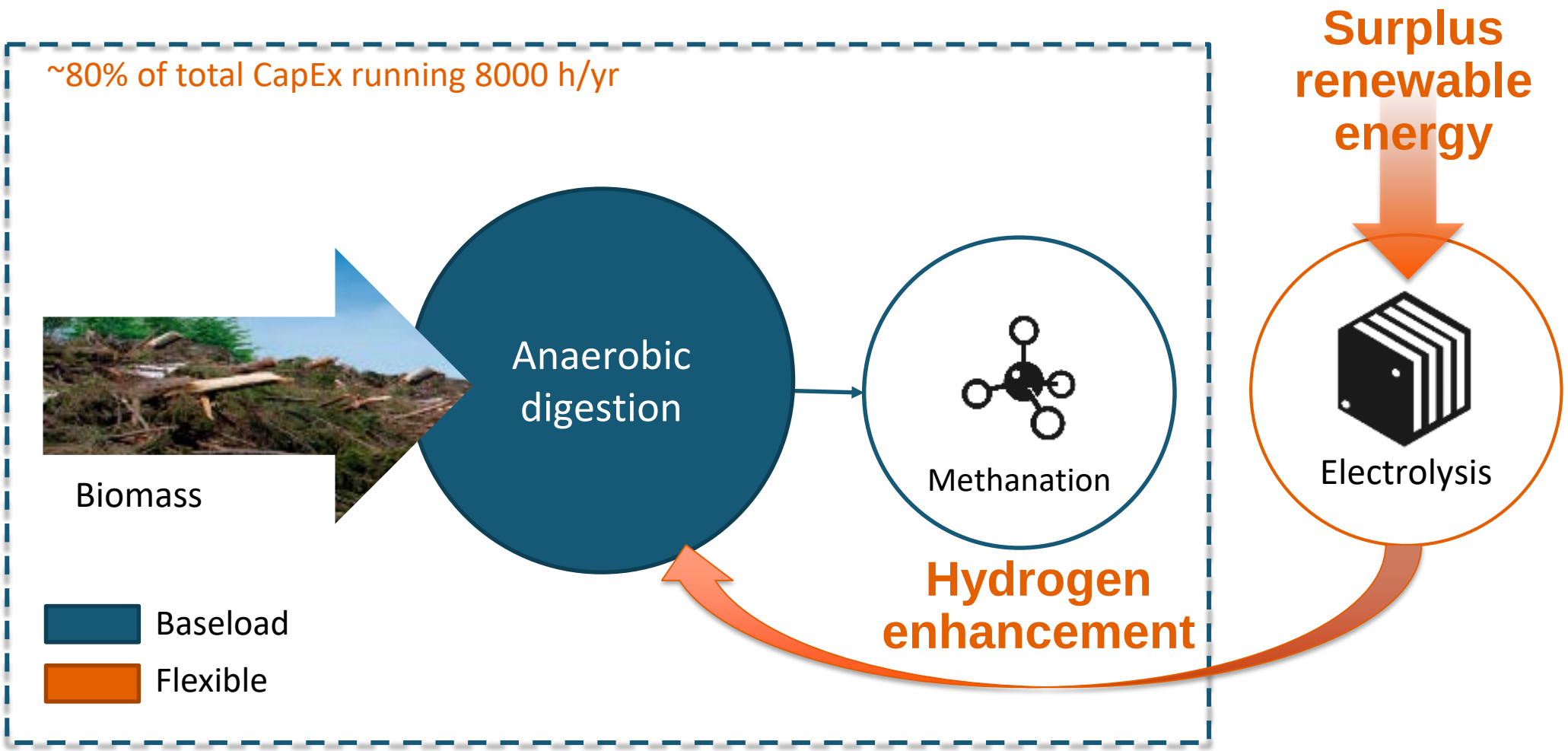
Liquid fuels for peaker plants?

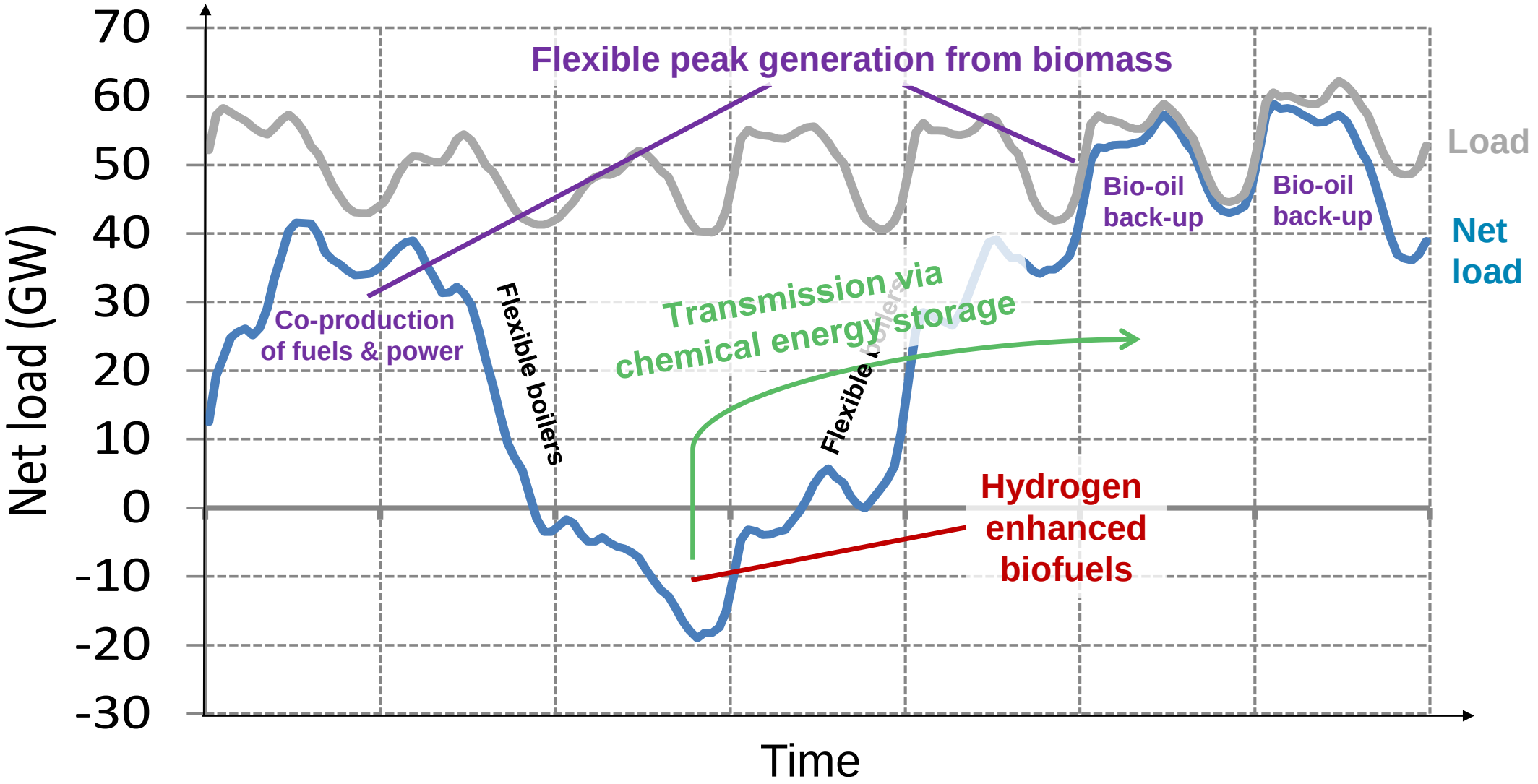


Co-production of fuels, power and heat?



Bioenergy with demand side flexibility?




70
60
50
40
30
20
10
0
-10
-20
-30
Net load (GW)
Time
Flexible peak generation from biomass
Load
Net load
Bio-oil back-up
Bio-oil back-up
Co-production of fuels & power
Flexible boilers
Transmission via chemical energy storage
Flexible boilers
Hydrogen enhanced biofuels