MAXIMISING THE EFFICIENCY OF GW SCALE HYDROGEN PRODUCTION AS A MICROGRID

Crondall energy

Net Zero Technology Centre

Technology Driving Transition

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At a glance: Who we are

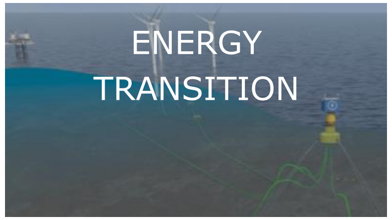
An independent multidisciplinary energy consultancy with special skills in process, pipelines, flow assurance, floating structures and subsea infrastructure.

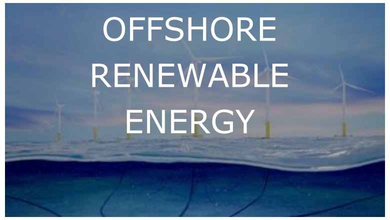
20+ years of energy projects from 6 offices covering the UK, Houston and Singapore.

Now deploying this expertise across a range of conventional energy, renewables, transition & abatement activities.

An established reputation for full project life cycle engineering support and technical and commercial advisory services.

Long term client relationships with energy companies and the investment & professional services communities.





Agenda

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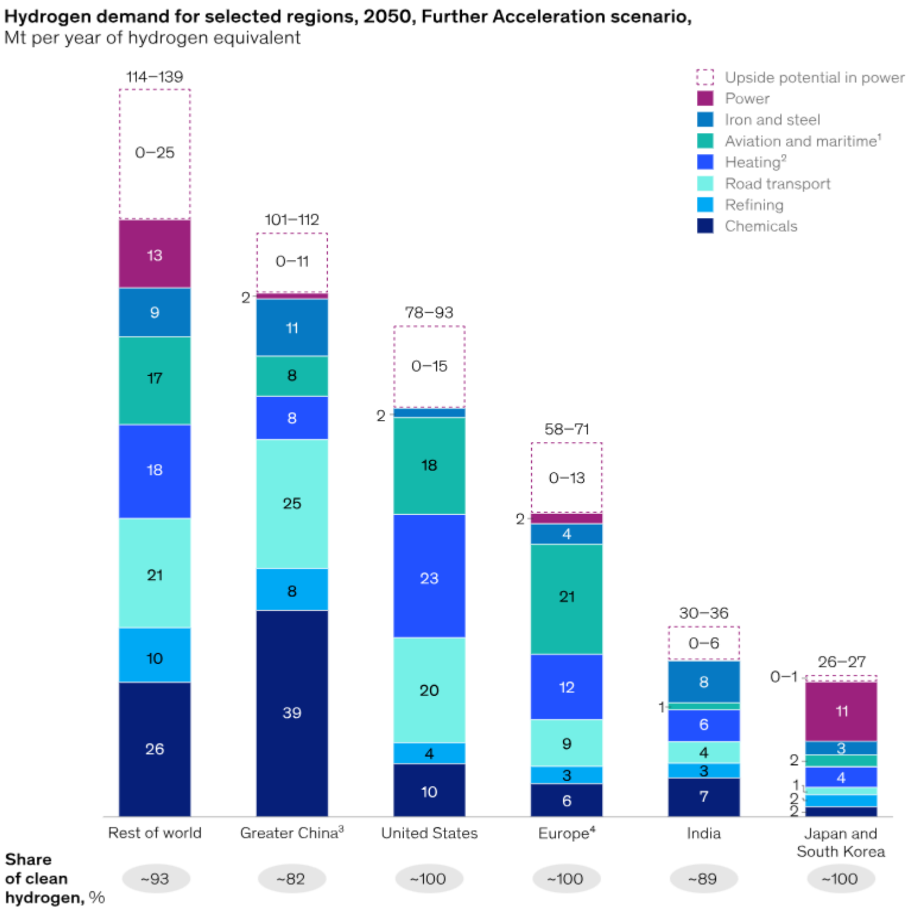
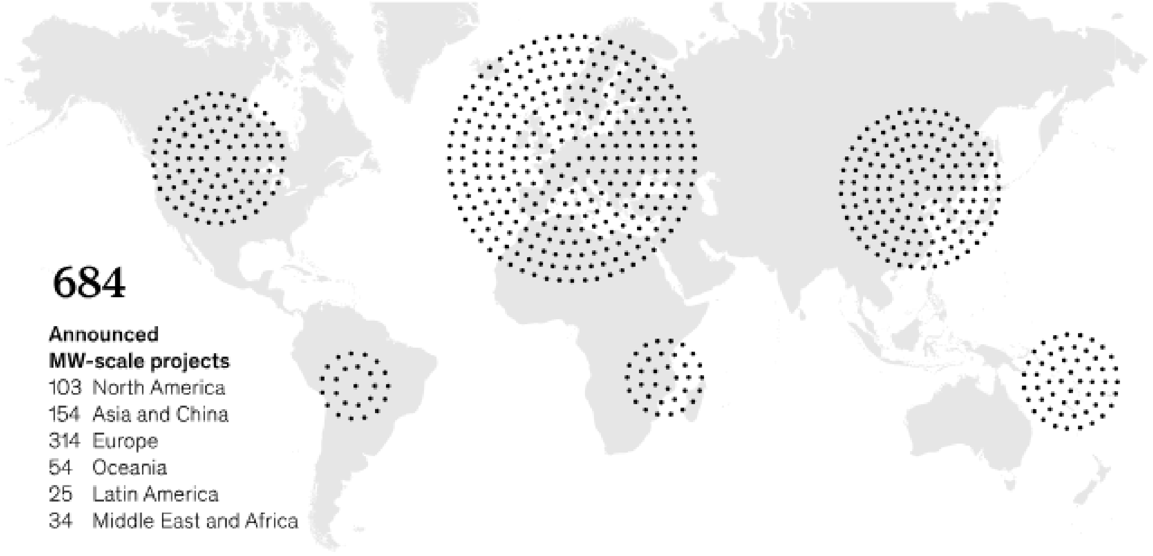
- Hydrogen Growth & opportunity
- Study objectives and boundary
- Energy hub components
- Scenarios studied
- Conclusions from the study

Growth of Hydrogen



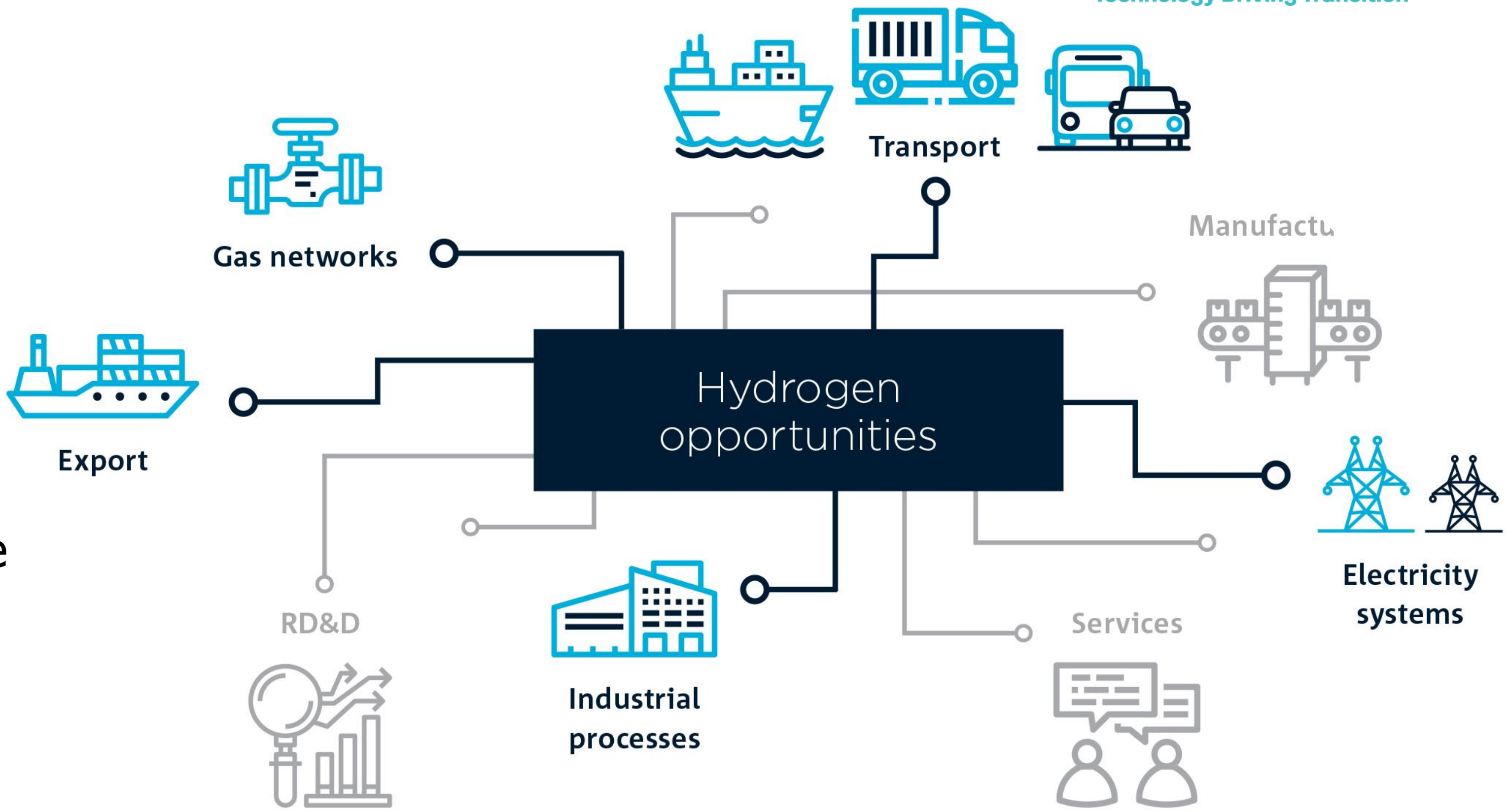


Current announced large scale hydrogen projects worldwide

- Natural gas is currently the main source of hydrogen production (approximately 94 Mtpa consumed)
- Clean hydrogen demand is projected to increase to between 125 and 585 Mtpa by 2050

Opportunities

- Scotland has potential to become a low-cost producer of green hydrogen
- Renewable hydrogen potential of 25 GW by 2045
- Abundance of offshore and onshore renewables and coastal water resource for electrolysis
- Opportunity for local consumption and export



STUDY OBJECTIVES & BOUNDARY

NZTC Energy Hub Technology Program

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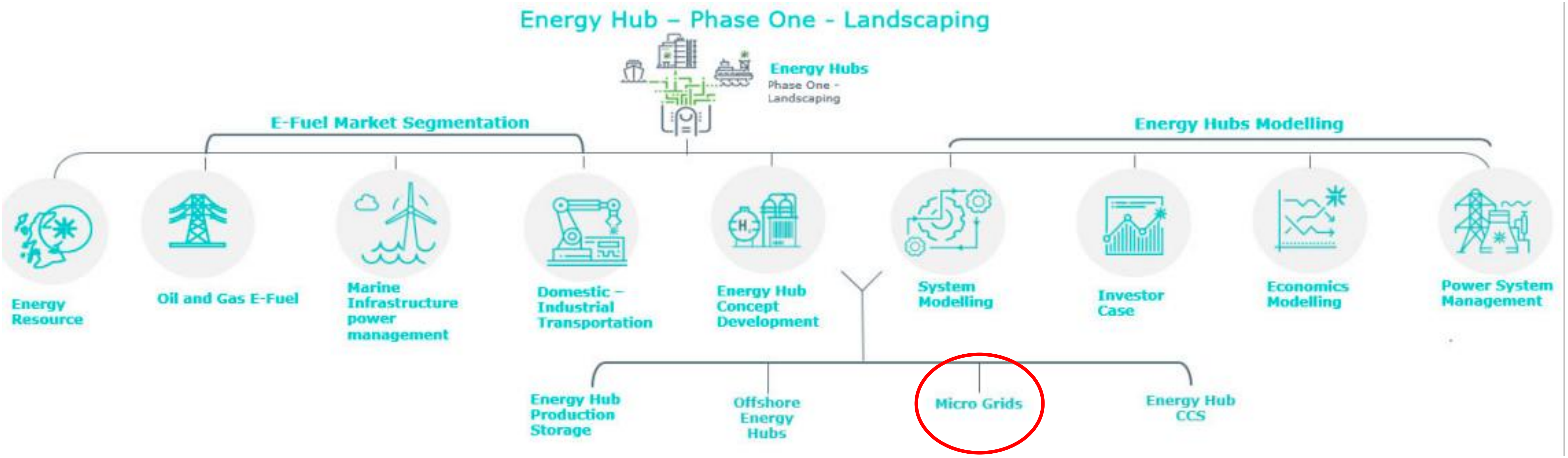
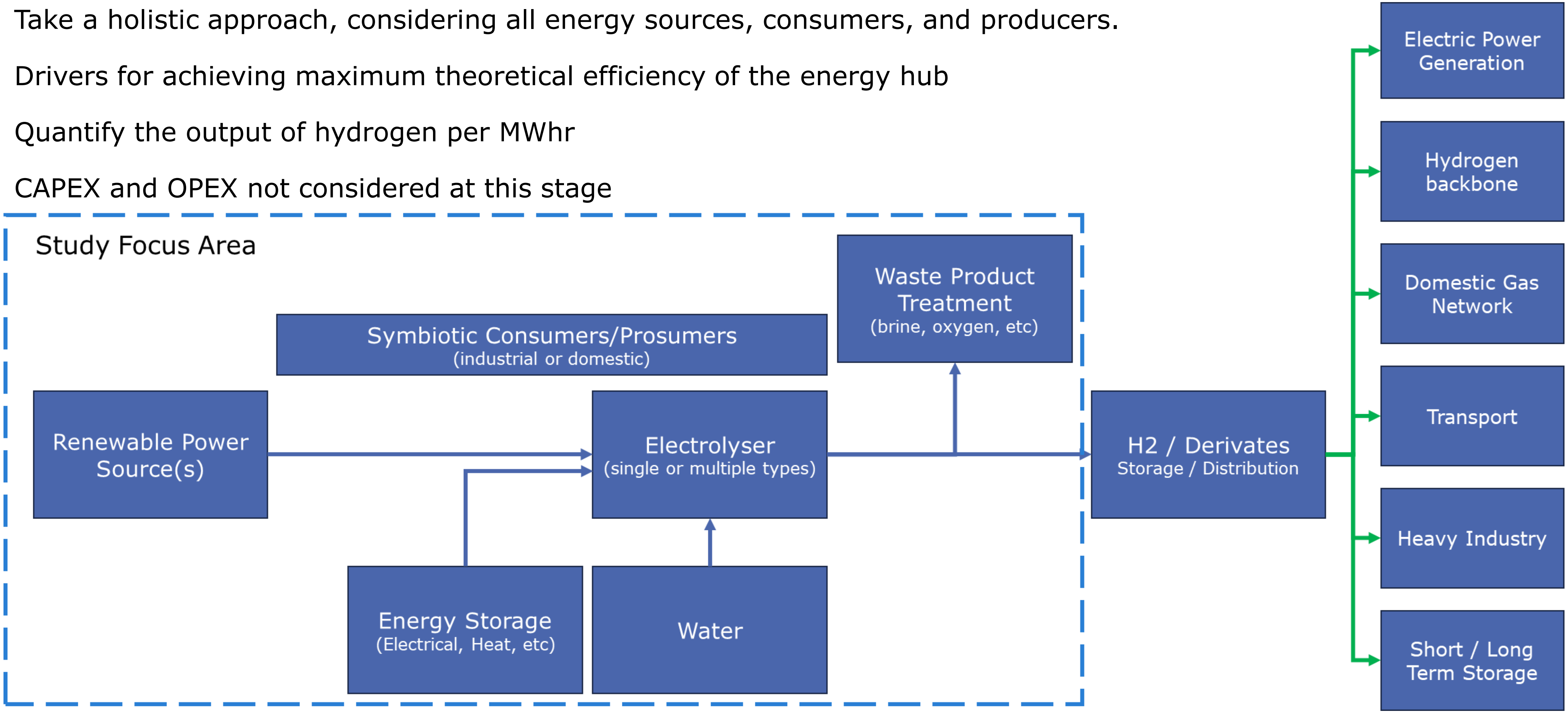


Study Objective

- Develop Microgrid Energy Hub concepts, i.e. without a grid connection
- Take a holistic approach, considering all energy sources, consumers, and producers.
- Drivers for achieving maximum theoretical efficiency of the energy hub
- Quantify the output of hydrogen per MWhr
- CAPEX and OPEX not considered at this stage



Capacity Requirements

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10GW of hydrogen generation capacity

INPUTS

High Purity Water	Salt Water	Electricity	Thermal Energy
1,500 m^3 /hr	9,000 m^3 /hr	10GW	Dependent upon electrolyser

Hydrogen

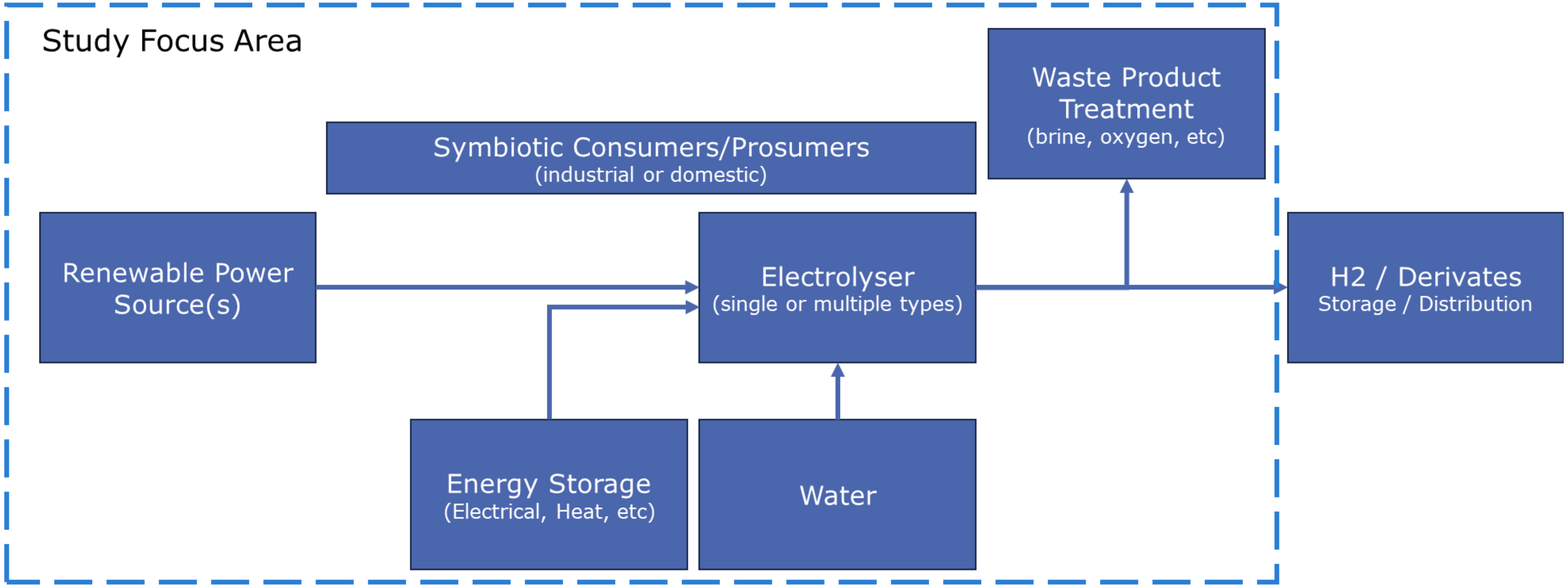
150,000 kg/hr

By Products

Oxygen	Thermal Energy	Brine
1,200,000 kg/hr	2-4GW	3,750 m^3/hr

ENERGY HUB COMPONENTS

Components & Efficiency



SCENARIOS STUDIED

Microgrid Study Scenarios:

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	1	2	3	4	5
Renewable Source	Offshore Wind	Offshore Wind + Tidal + Wave	Offshore Wind	Offshore Wind + Tidal + Solar	Offshore Wind + Geothermal
Transmission	HVDC	HVDC	HVAC	HVDC + HVAC	HVDC
Microgrid Dist.	AC	DC	AC	DC	AC
Energy Storage	Pumped Hydro	Hydrogen	Compressed Air	BESS	Sand Battery
Electrolyser Type	PEM	SOE	SOE + PEM	AEM + CFEC	PEM + sHYp
Heat Sources	N/A	External supply	PEM waste heat + external supply	N/A	N/A
Heat Consumers	District Heating	CCS + DACC	Compressed Air Energy Storage + Industrial / Manufacturing Plants	Industrial / Manufacturing Plants	Sand Battery
Other Symbiotic Interfaces	Salt Production Plant	Hydrogen Derivatives & Ammonia Production	Salt Production Plant	Hydrogen Derivatives & Ammonia Production	Aquaculture

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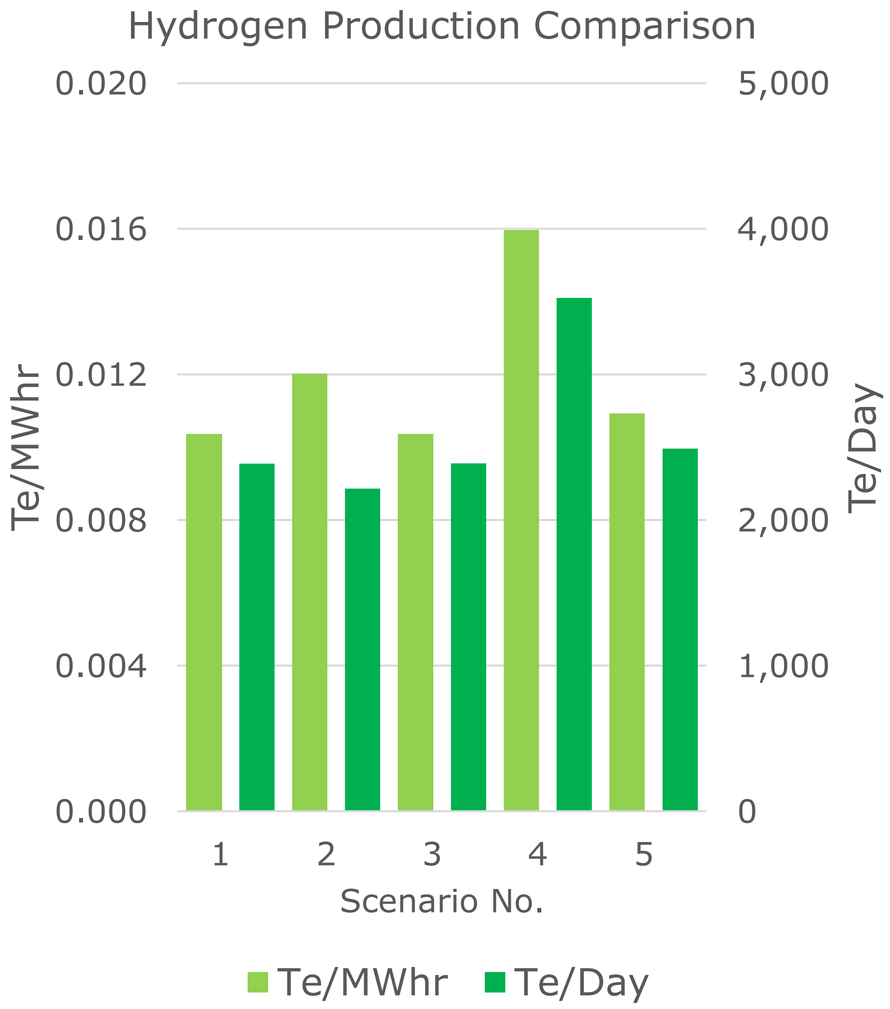
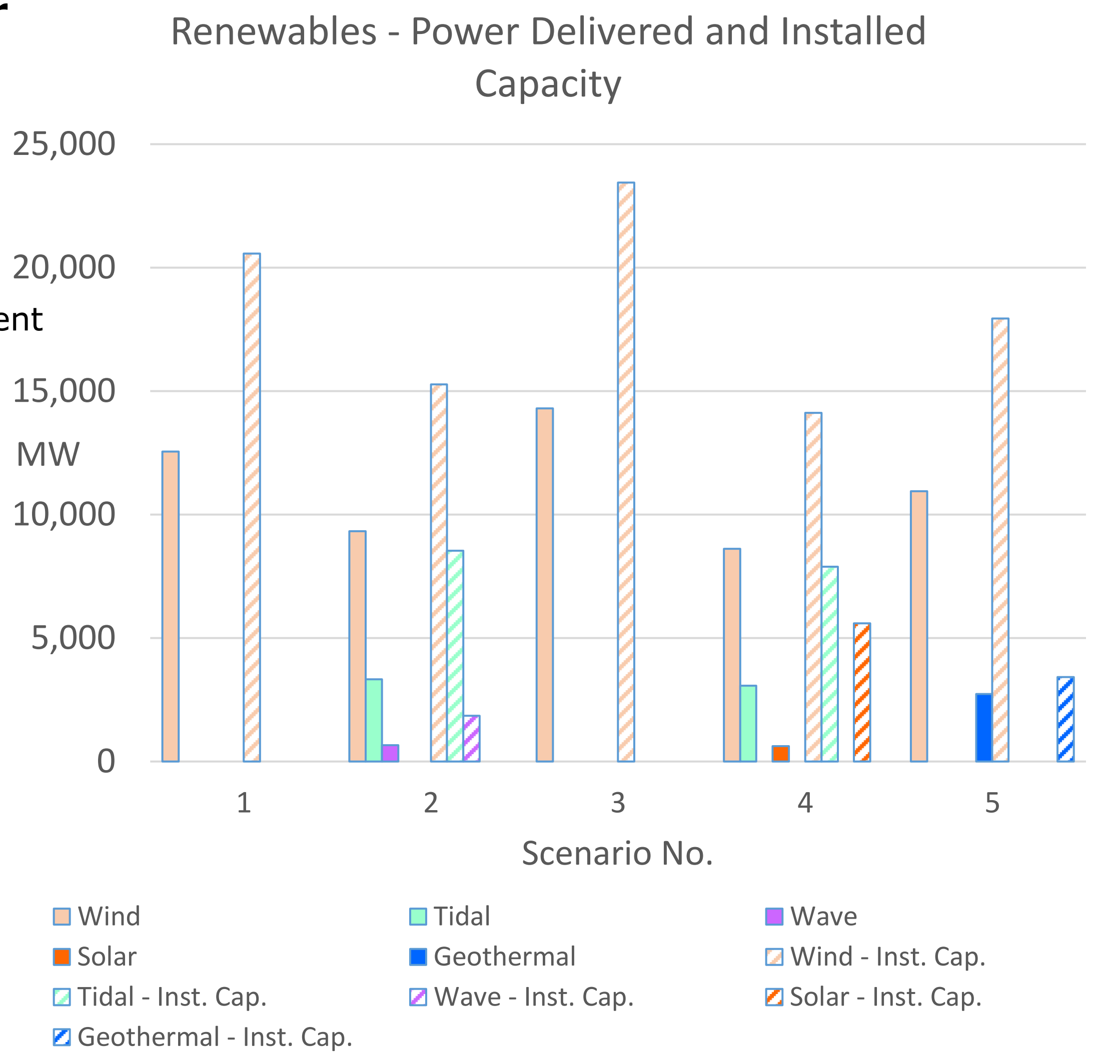
Key findings – Scenario specific

- **Scenario 4 - Highest hydrogen efficiency – 0.016 Te/MWhr**
  - Driven by; high efficiency electrolyser, BESS, HVDC transmission
  - Combining electrolysers types to accommodate intermittency and heat demands provides most efficient solution



Key findings – Scenario specific

- **Scenario 4 - Highest hydrogen efficiency – 0.016 Te/MWhr**
  - Driven by; high efficiency electrolyser, BESS, HVDC transmission
- **Power demand ranges from 12.3 – 14.3GW**
  - Driven by efficiency of energy hub
  - HV DC transmission for renewable sources >70km, most efficient
  - HV AC transmission for local renewables sources <70km, most efficient
  - Capacity of the transmission network will be significantly >10 GW
  - AC Distribution within the microgrid was the most efficient
- **Renewable installed capacity ranges from 20.6 – 27.6GW**
  - Considered; Wind, tidal, wave, solar, geothermal, hydro
  - High capacity factors are favoured to reduce install capacity
  - Combining intermittent source reduces energy storage requirements
  - Driven by the capacity factor (i.e. intermittency of generation)



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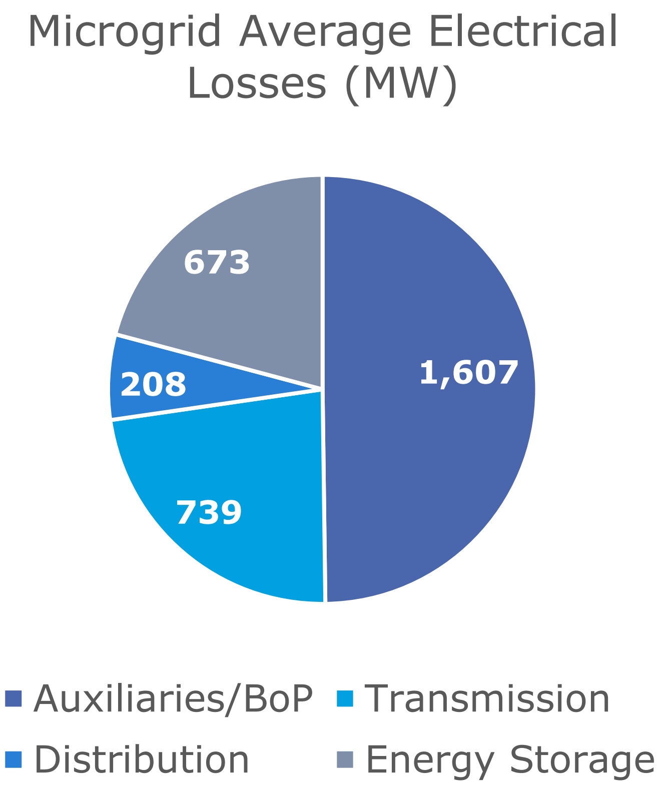
- **Balance of Plant/Auxiliary systems make up largest proportion of losses**
  - 43 – 67% of energy hub losses
  - Systems include; pumps, water treatment, H2 export compressors, etc



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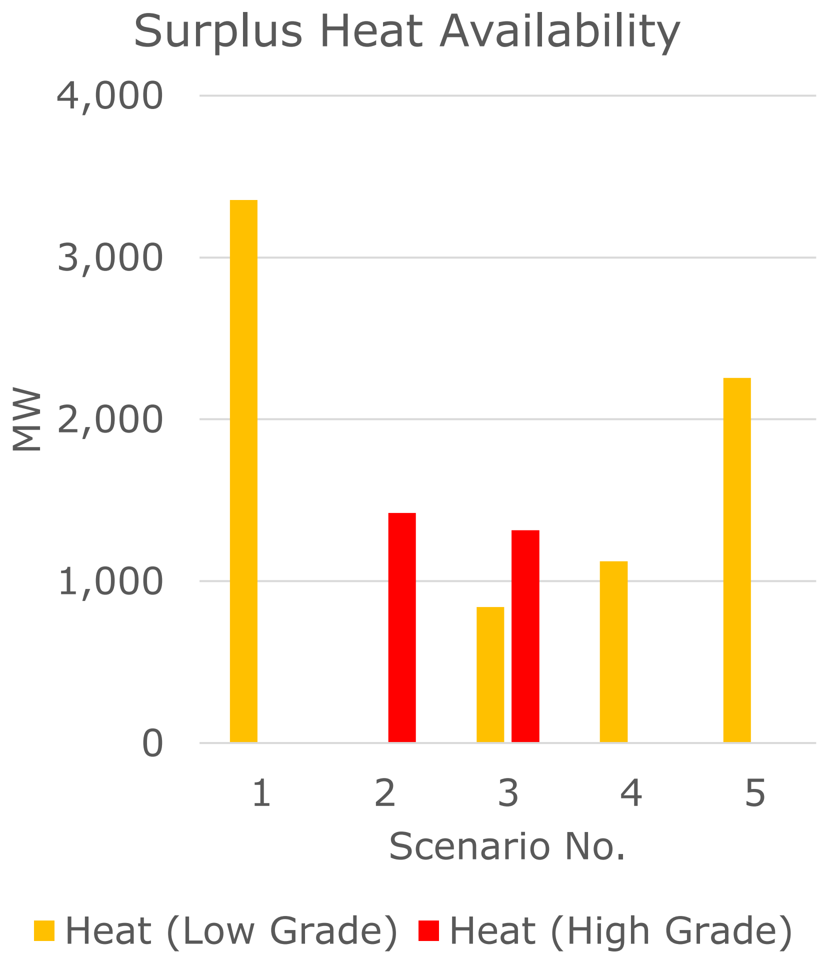
- **Surplus heat available 1.1 – 3.3GW**
  - Several uses for high grade waste heat identified; CCUS, steam turbine, industry, etc
  - Low grade heat has potential industrial and domestic consumers
  - Heat integration within the microgrid is critical to maximising energy hub efficiency



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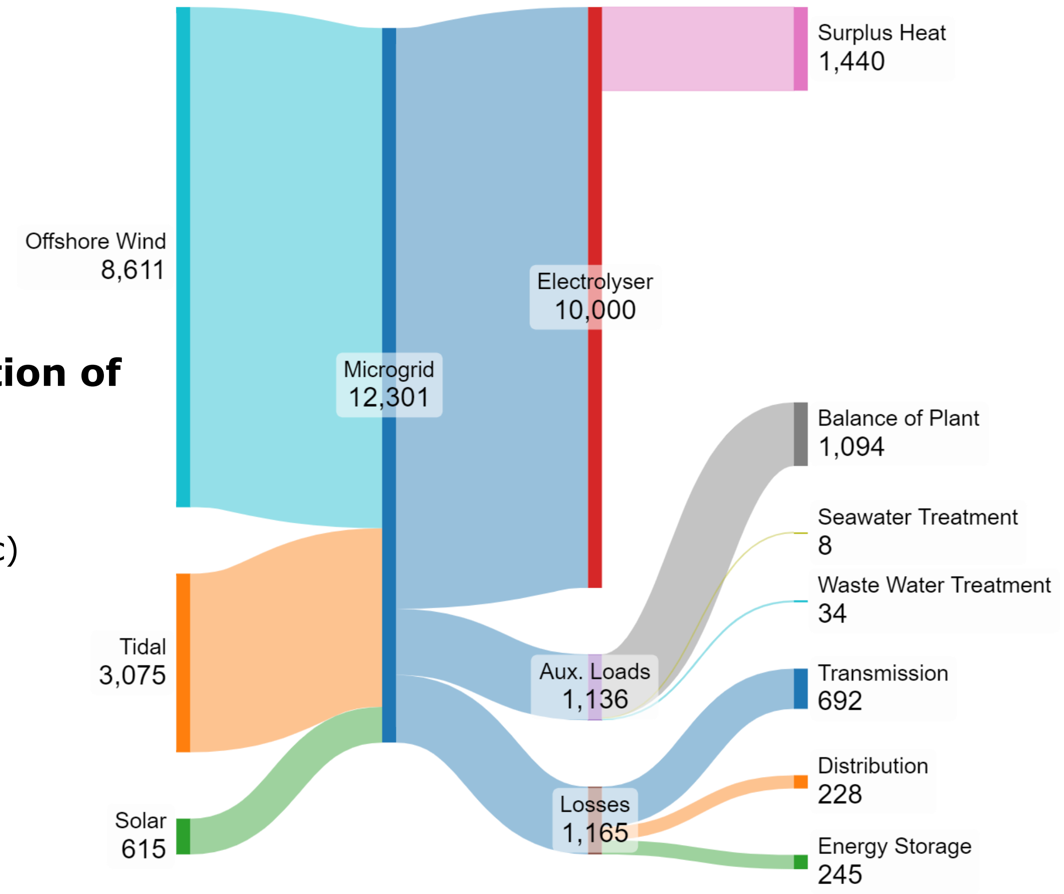
- **Surplus heat available 1.1 – 3.3GW**
- **By products are significant and require consideration**
  - >1,000 Te/hr of Oxygen
  - >400m^3/hr of Brine (without salt production plant)



Electrical Energy Flows (MW) (Scenario 4)

Key findings - General

- **Renewables**
  - High capacity factors are favoured to reduce install capacity
  - Combing intermittent source reduces energy storage requirements
- **Transmission and Distribution**
  - HV DC transmission to the microgrid was the most efficient
  - AC Distribution within the microgrid was the most efficient
- **Electrolysis**
  - Emerging technologies have potential for step change in efficiency
  - Emerging solutions that use saline water further improve efficiency
  - Combining electrolysers types to accommodate intermittency and heat demands provides most efficient solution
- **Energy storage**
  - Maximises hydrogen production rate, avoids curtailment, extends electrolyser life
  - Pumped hydro and CAES have most potential to make a meaningful impact on electrolyser uptime
  - BESS less viable due to the current practical limits
- **Symbiotic Industries**
  - Several uses for high grade waste heat identified; CCUS, steam turbine, industry, etc
  - Volume of oxygen generated exceeds demand
- **Location**
  - Costal location critical for access to seawater, offshore wind energy, and potential export route
- **Integration**
  - Holistic approach ensure maximum efficiency for the energy hub, must go beyond purely electrolyser efficiency

Next steps

- **Concept Selection**
  - Develop a concept that takes the building block opportunities from this study
- **Location identification**
  - Assess the impact of location on the energy hub concept
- **Further Technology investigation**
  - Electrolyser
  - Energy Storage
  - High grade heat
- **Economic analysis**
  - CAPEX and OPEX estimates

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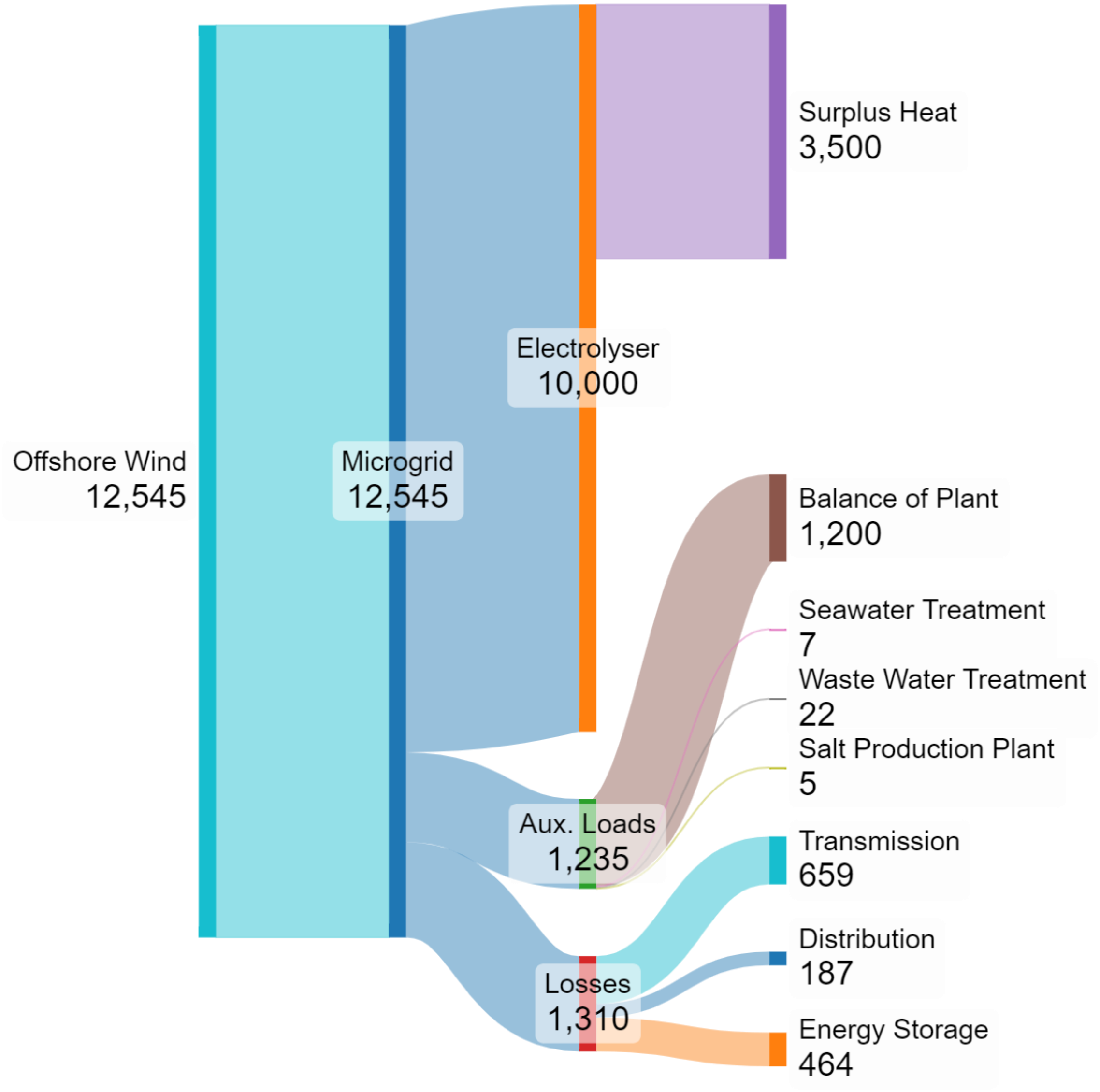
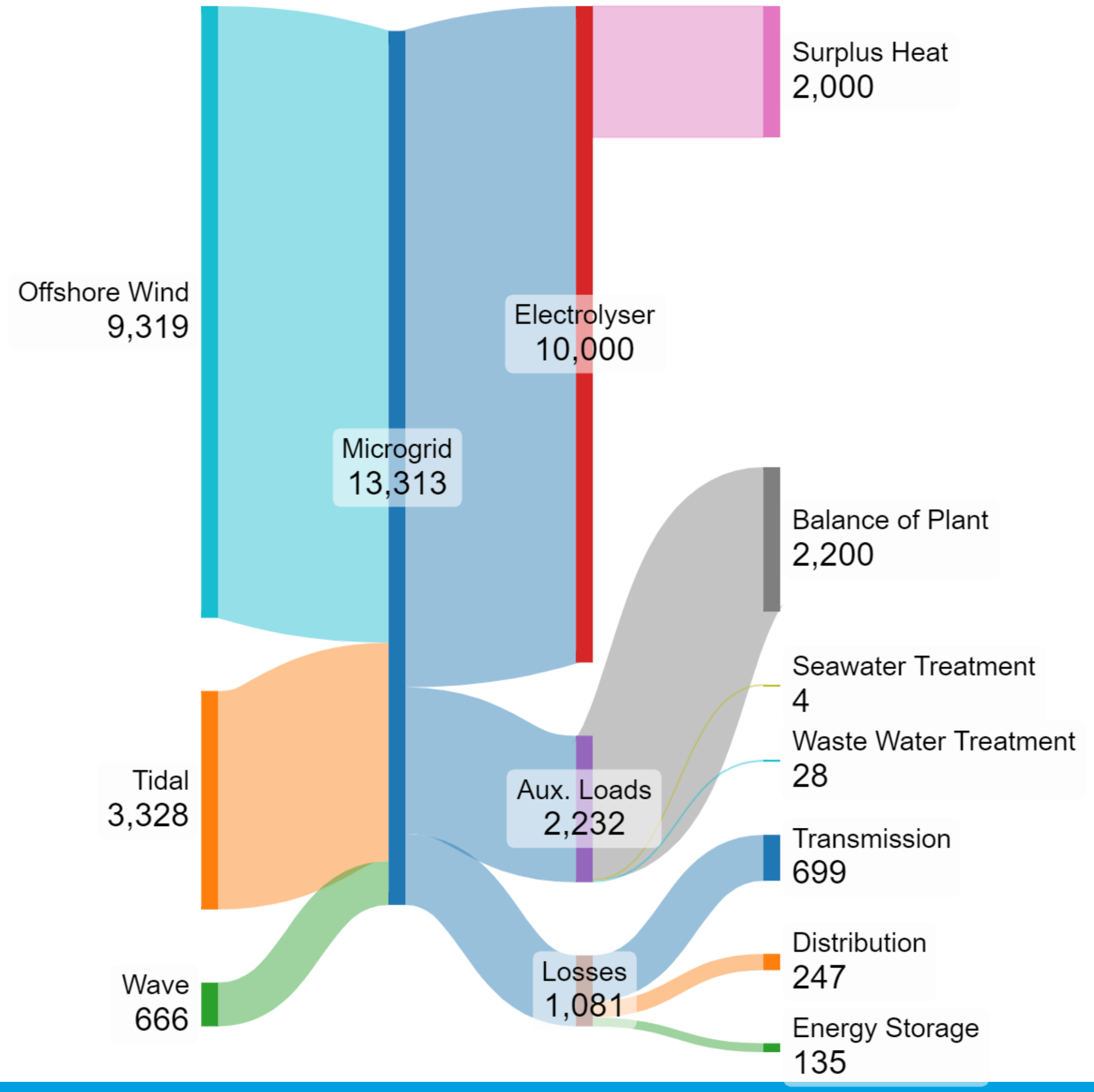
Scenario 1

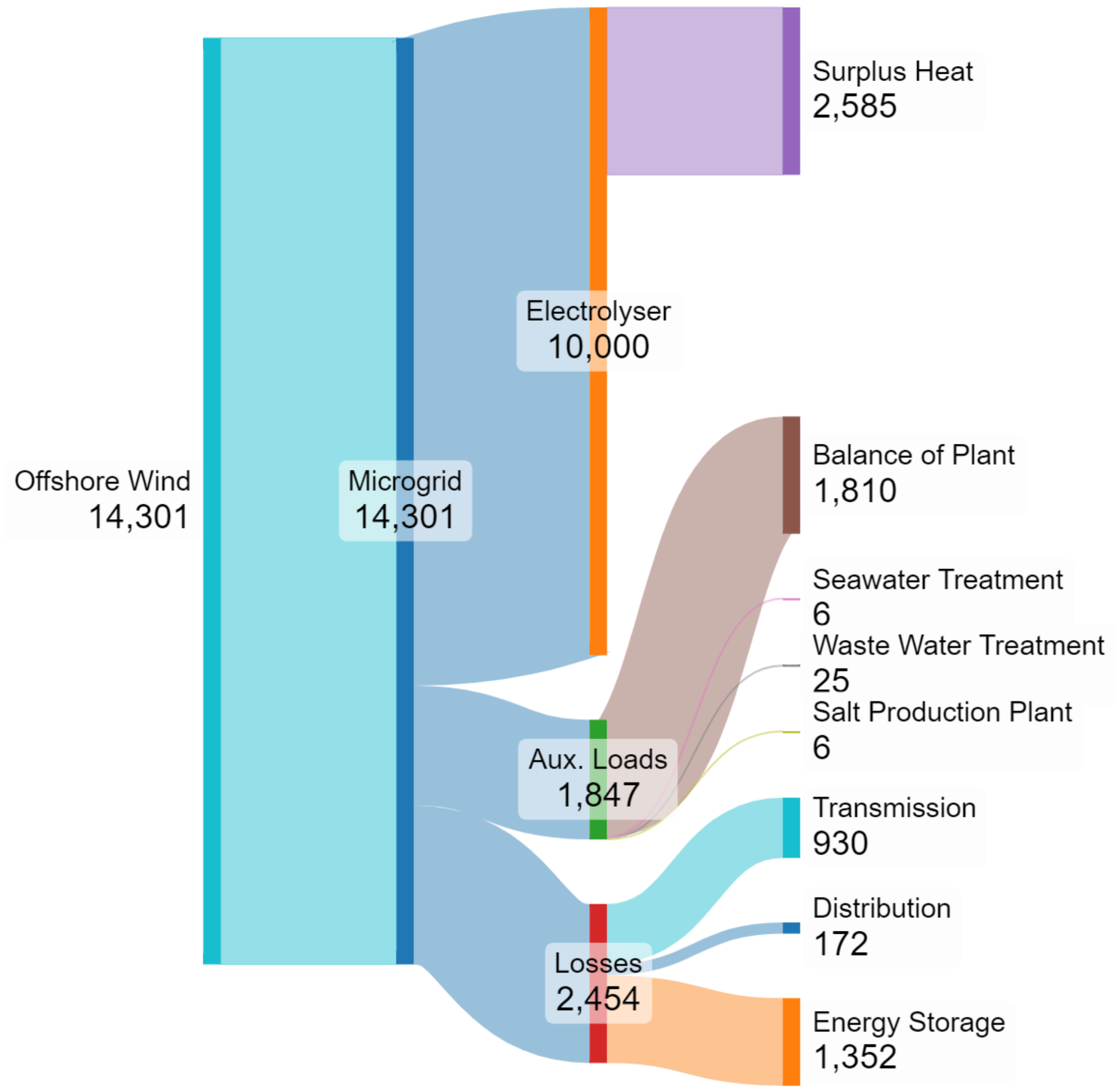


Offshore Wind
12,545
Microgrid
12,545
Electrolyser
10,000
Aux. Loads
1,235
Losses
1,310
Surplus Heat
3,500
Balance of Plant
1,200
Seawater Treatment
7
Waste Water Treatment
22
Salt Production Plant
5
Transmission
659
Distribution
187
Energy Storage
464

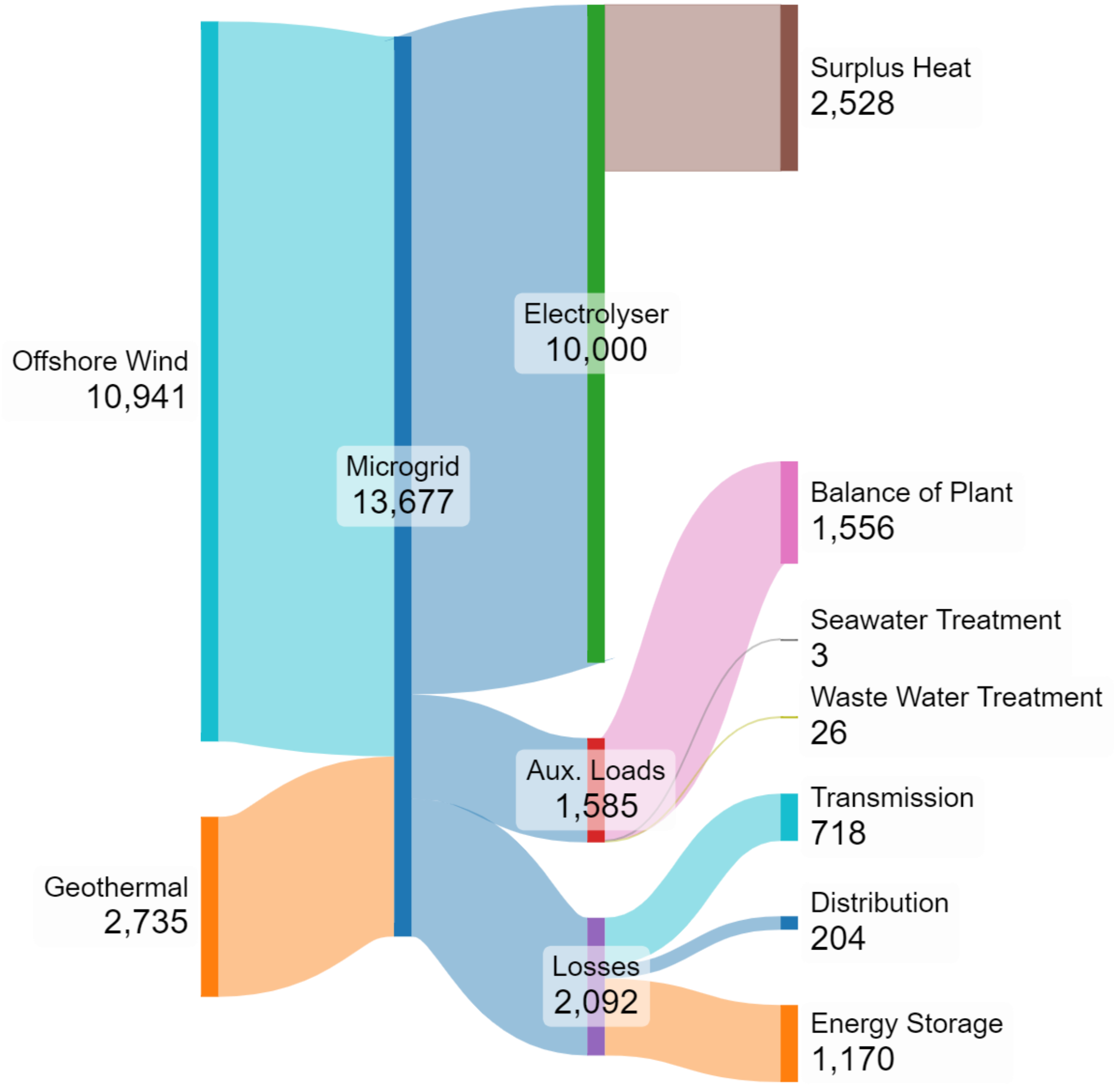
Scenario 2


Offshore Wind
9,319
Tidal
3,328
Wave
666
Microgrid
13,313
Electrolyser
10,000
Aux. Loads
2,232
Losses
1,081
Surplus Heat
2,000
Balance of Plant
2,200
Seawater Treatment
4
Waste Water Treatment
28
Transmission
699
Distribution
247
Energy Storage
135

Scenario 3


Offshore Wind
14,301
Microgrid
14,301
Electrolyser
10,000
Aux. Loads
1,847
Losses
2,454
Surplus Heat
2,585
Balance of Plant
1,810
Seawater Treatment
6
Waste Water Treatment
25
Salt Production Plant
6
Transmission
930
Distribution
172
Energy Storage
1,352

Scenario 5



Offshore Wind
10,941
Geothermal
2,735
Microgrid
13,677
Electrolyser
10,000
Aux. Loads
1,585
Losses
2,092
Surplus Heat
2,528
Balance of Plant
1,556
Seawater Treatment
3
Waste Water Treatment
26
Transmission
718
Distribution
204
Energy Storage
1,170