IDEA2022

Building Connections

June 6-9 | Sheraton Centre Toronto Hotel | Toronto, ON

INTERNATIONAL DISTRICT ENERGY ASSOCIATION

Hydrogen Solution

a Successful Co-Operation with Key Stakeholders

Juan Matson

Today's Agenda

01 **Hydrogen is becoming relevant**

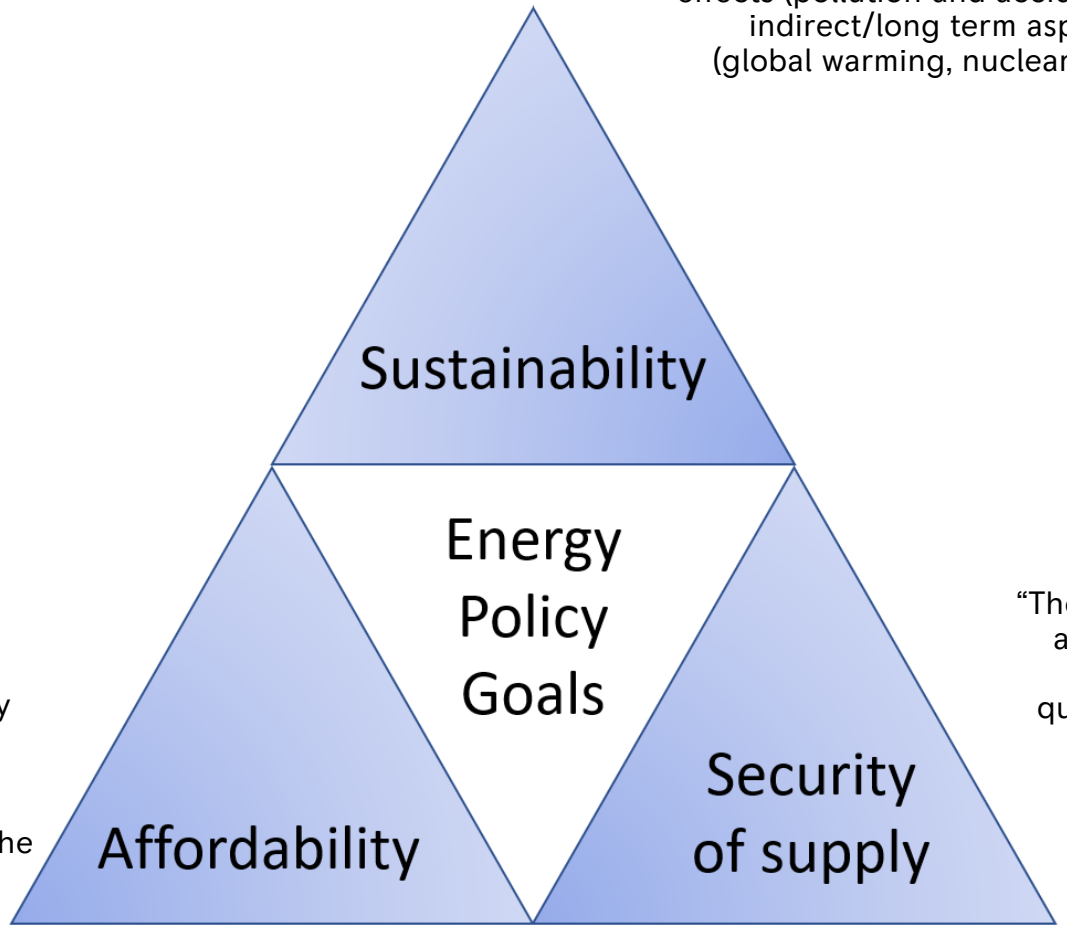
02 **The Energy Transition**

03 **Our latest Case**

01 Relevance of H_2

The Energy Policy Triangle (Trilemma)

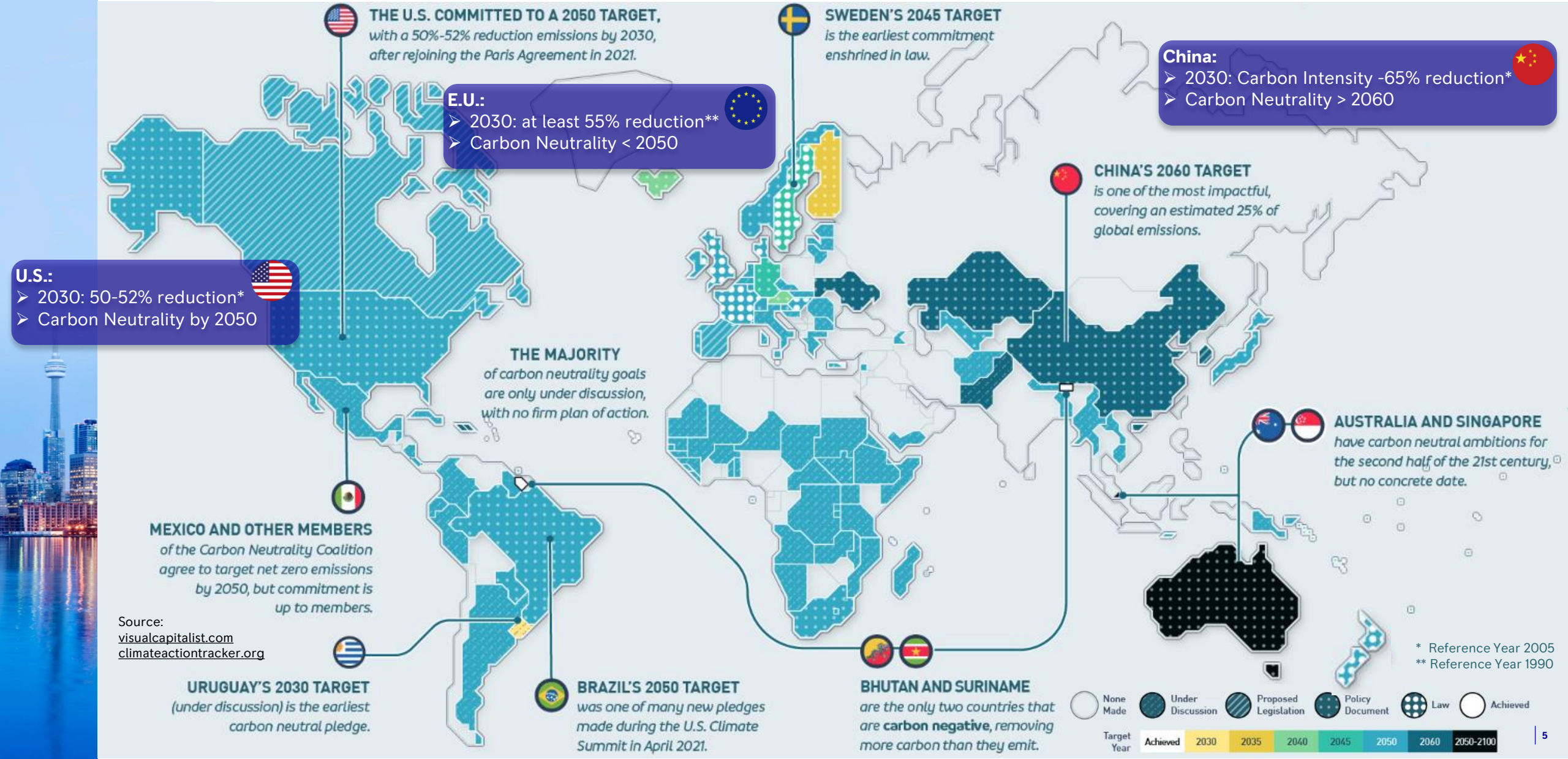
Environmental and Health concerns of direct effects (pollution and accidents) and indirect/long term aspects (global warming, nuclear waste)



Ensuring Energy Prices do not constitute a comparative disadvantage in the international market

"The availability of energy at all times in various forms, in sufficient quantities at affordable price"

01 The Race to NetZero … Carbon Neutral Goals Worldwide 06/2021



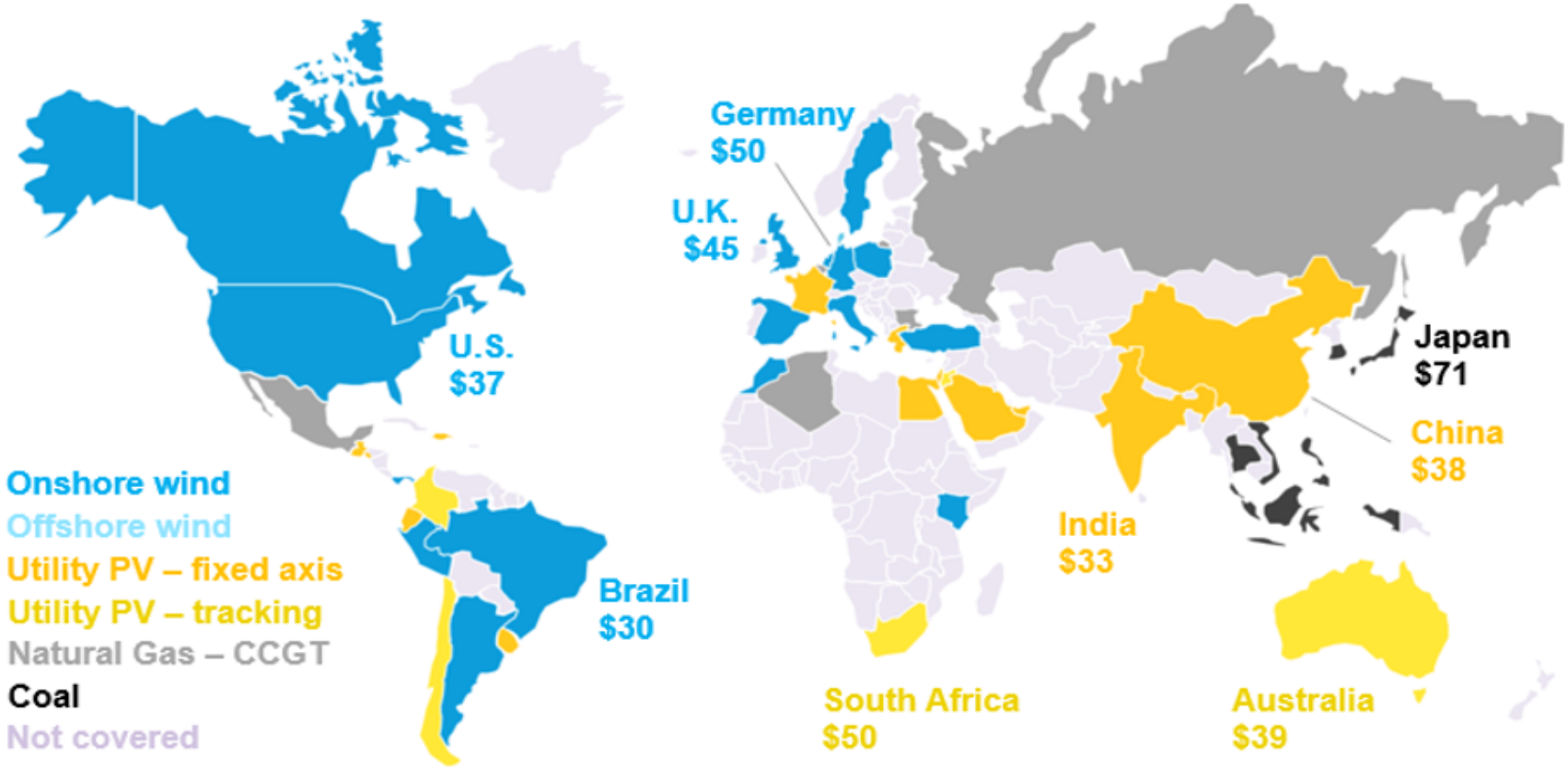
Source:
visualcapitalist.com
climateactiontracker.org

01

The Race to NetZero … Renewables

Facts and Challenges

Figure 1: Cheapest source of new bulk electricity generation by country, 1H 2020



Operating Reserve Challenge

more Variability in the System

Fast Response | BESS | FlyWheel

Transport Challenge

DG for from where it's used

Peak Shaving | BESS | Fuel Cells

Dispatch Challenge

Generation/Demand mismatch

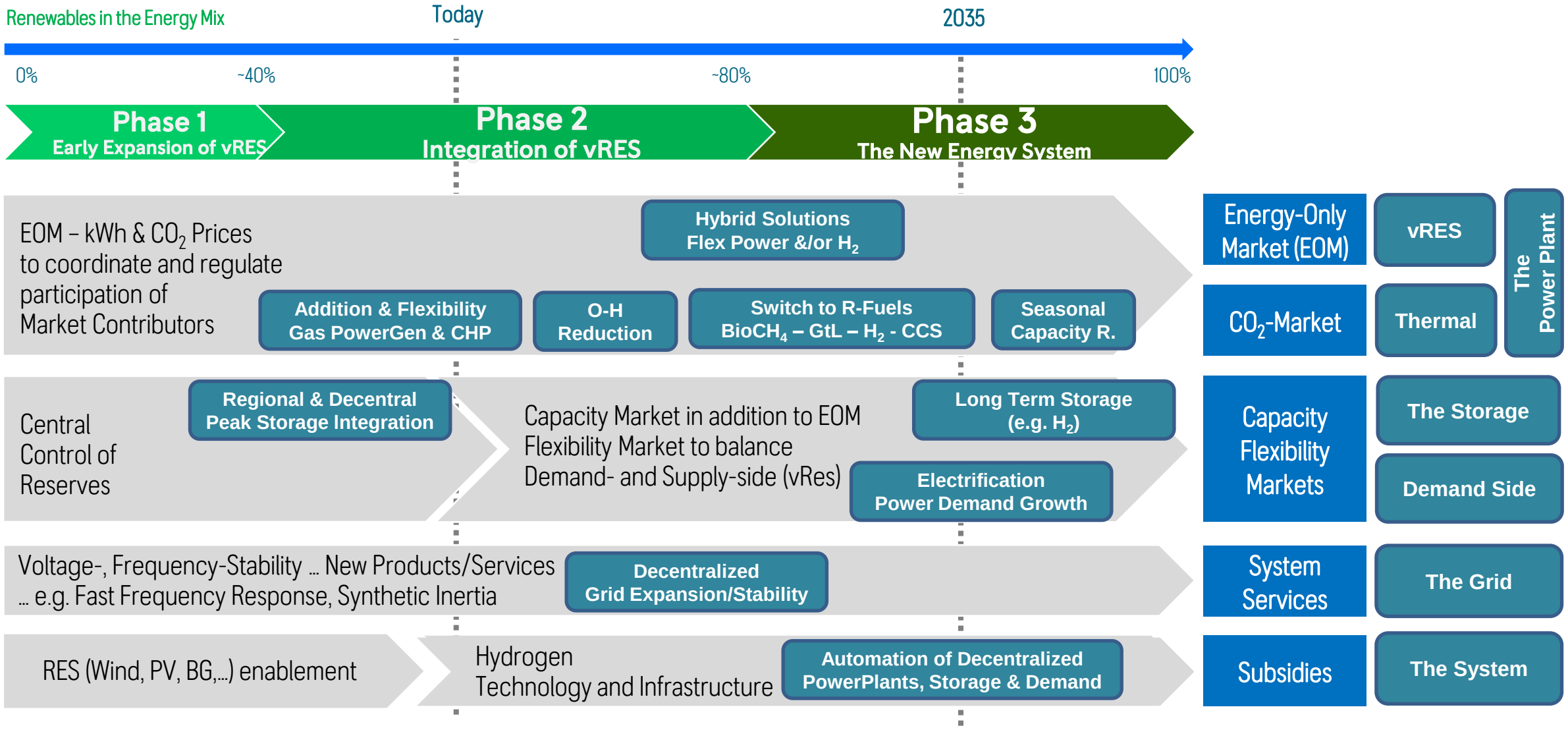
Energy Shifting | Power-to-X e.g. H_2 | Pumped Schemes

Source: Bloomberg NEF. Benchmark LCOE per Country in US$/MW-h. CCGT ▶ Gas Turbine
Note: LCOE Calculations exclude Subsidies or ITCs

01

Regulatory Mechanisms and Market Segments

reliable Framework to enable transformation to Net Zero

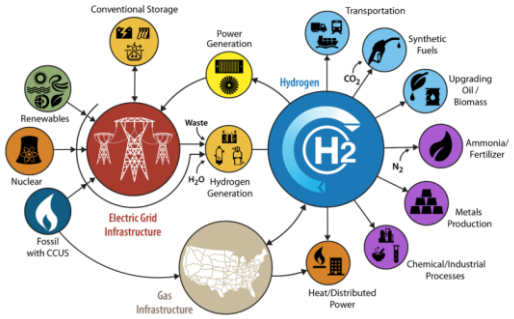


Source: VDMA Position Paper "Recommendation Electricity Market Design"

01

Relevance of H_2

DoE RFI # DE-FOA-0002664.002



Description (DoE H_2 Program RFI for Clean H_2 Hubs)

- RFI issued by the DoE for EERE's (Energy Efficiency & Renewable Energy), involves:
  - HFTO (H_2 & Fuel Cell Technologies Office).
  - FECM (Office of Fossil Energy & Carbon Management)
  - NE (Office of Nuclear Energy)
  - OCED (Office Clean Energy Demonstration)
- Intent: **Obtain input (@ no-Cost) for FOA** (Funding Opportunity Announcement)
- Seeks information through 5 Categories on:
  - **Regional Clean H_2 Hub Provisions and Requirements**
  - **Solicitation Process, FOA Structure, and Implementation Strategy**
  - **Equity, Environment and Energy Justice (EEEJ) Priorities**
  - **Market Adoption and Sustainability of the Hubs**
- Information collected will not be published

BackGround

- President Biden signed on 15-Nov-21 the Infrastructure Investment and Jobs Act
  - DoE **Appropriates 62+ BUS$ / 8 BUS$ (over 2022-2026)** for the H_2 Program
  - Program is to demonstrate Production, Processing, Delivery, Storage & End-Use
- To support Pres. Biden Goal to achieve:
  - Carbon-Free Electric Grid by 2035 & Net-Zero Emissions by 2050
- Technologies expected are Electrolizers, Fuel Cells, Turbines, etc.
- Aligned with Pres. Biden Executive Orders (EOs)
  - Workers Future EO 14005 // Climate Crisis EO 14008
  - Worker Organizing and Empowerment EO 14025
  - Promoting Competition in the American Economy EO 14036
- **Achieve Clean H_2 targets 2 US$/kg @ 2026 & the H_2Shot Goal of 1 US$/kg in 10 yrs**

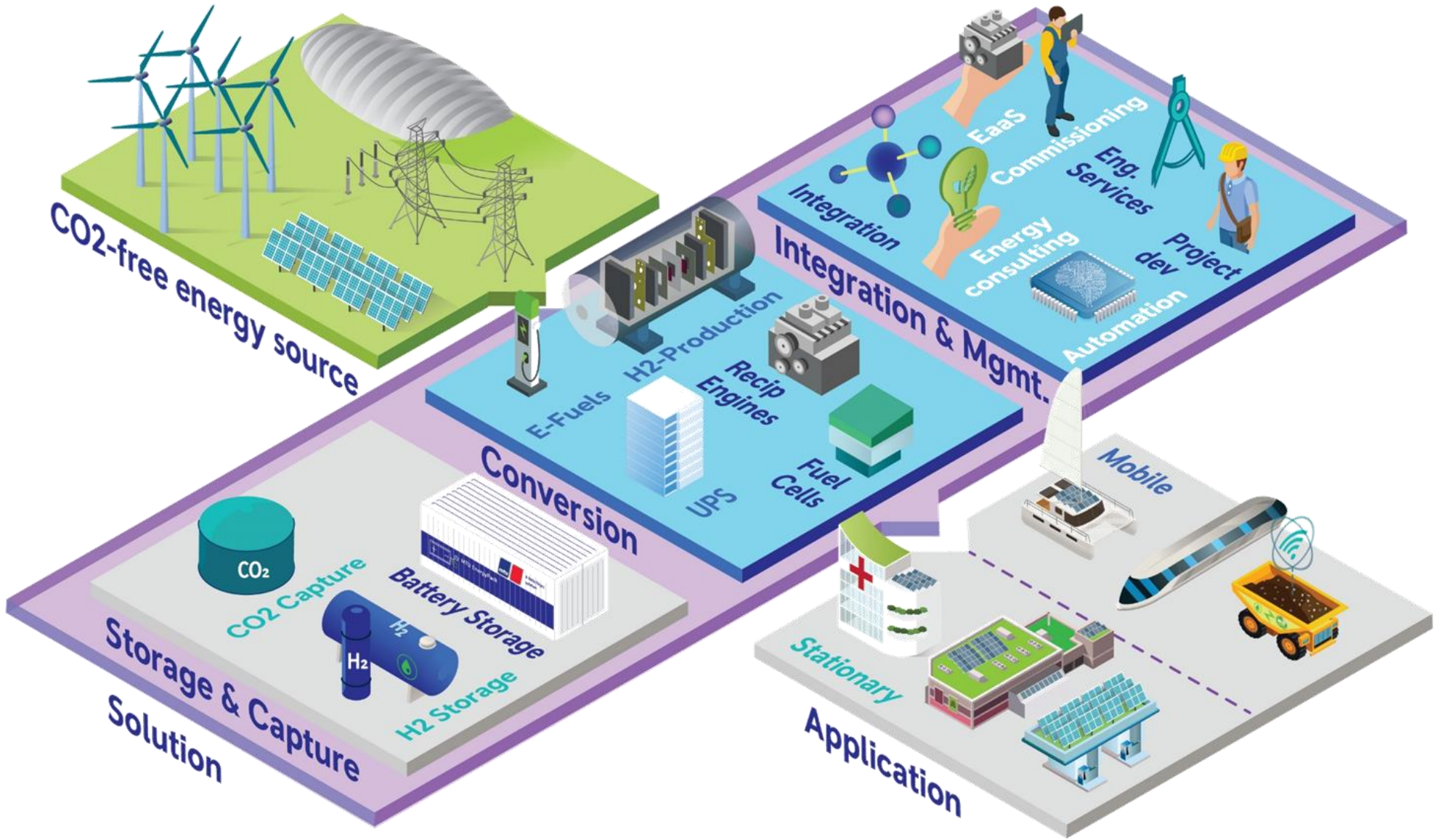
Clean H_2 Hubs

- H_2Hubs Road Map provisions are set in Section 40314 of the BIL adding:
  - Section 813 Regional Clean H_2 Hubs:
    - 813(a) Network of Producers, Consumers and Infrastructure
    - 813(b) Support Programs for least 4 Clean H_2Hubs that:
      - Aid the Achievement Production Standards
      - Demonstrate viability Value Chain & End-Use
      - Scalability to a National Clean H_2 Network and Economy
  - Section 813(c)(3) directs DoE to solicit within **180 days** of the BIL enactment:
    - **Feed-Stock Diversity** – at least 1 Hub in **Gn-H_2**, **Bl-H_2**, and **Pk-H_2**
    - **End-Use Diversity** – at least 1 Hub in PG, C&I, Res., and Transp.
    - **Geographic Diversity** – using abundant resources in different Regions
    - **Hubs in NatGas Production Regions** – at least 2 Hubs in major Areas
    - **Employment** – where Jobs are created
    - **Additional Criteria** – that are necessary or appropriate

Implementation Strategy

- DoE envisions that the Hubs solicitation be structured as a:
  - Single / Multi-Year FOA / w Open-Close Dates Different Launches (2022-2025)
  - Phases 1 & 2 would Solicit, Deploy the H_2Hubs
    - **4-5 BUS$ / Phase1-Planning (3-18 mos) / Phase2-Deployment (5+ yrs)**
    - **2-3 BUS$ / Phase1-Planning (3-18 mos) / Phase2-Deployment (5+ yrs)**
  - 3 & 4 would Solicit, Select & Deploy New-Technologies, Capabilities, End-Uses
    - Add supplemental Technologies for existing Hubs
  - DoE evaluate Applications based on detailed Plans, Activities, Partnerships
  - **Phase 1 –Initial Hub Planning and Analysis of Key Metrics. DoE expects:**
    - 1 to 4 Mio US$ per potential Hub plus Required Cost Share (TbD)
    - Key Partners, Community Engagement (Tribal, DisAdComm)
  - **Phase 2 –Go-no-Go of Development & Built-Out of Ph-1. DoE expects:**
    - Phase 2a - Development (Engineering, Permitting, Off-Taking)
    - Phase 2b/c – Hub Construction-Development / Operation

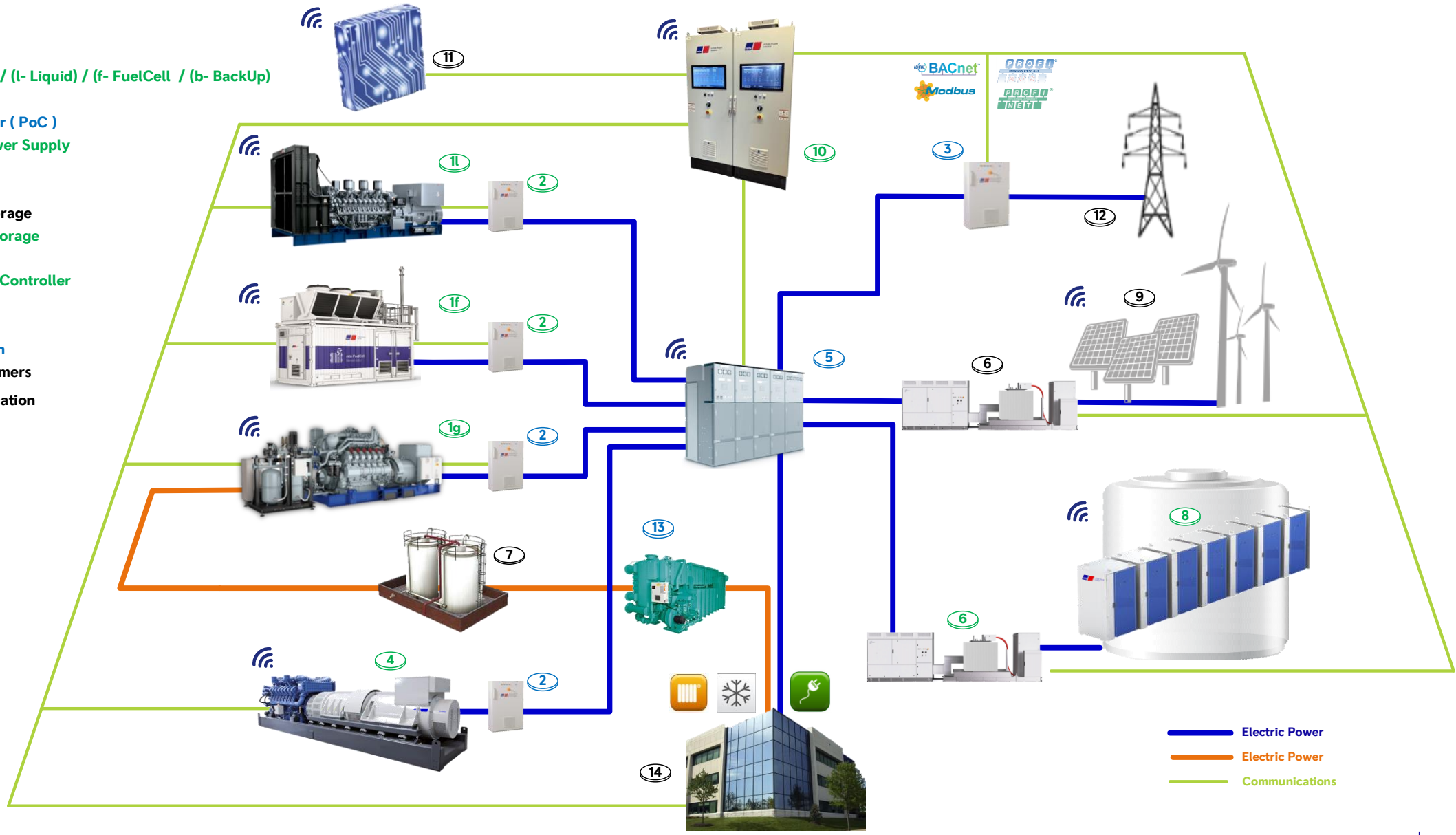
02 Our Vision of the Future Energy Value Chain



02 MicroGrids as a Foundation

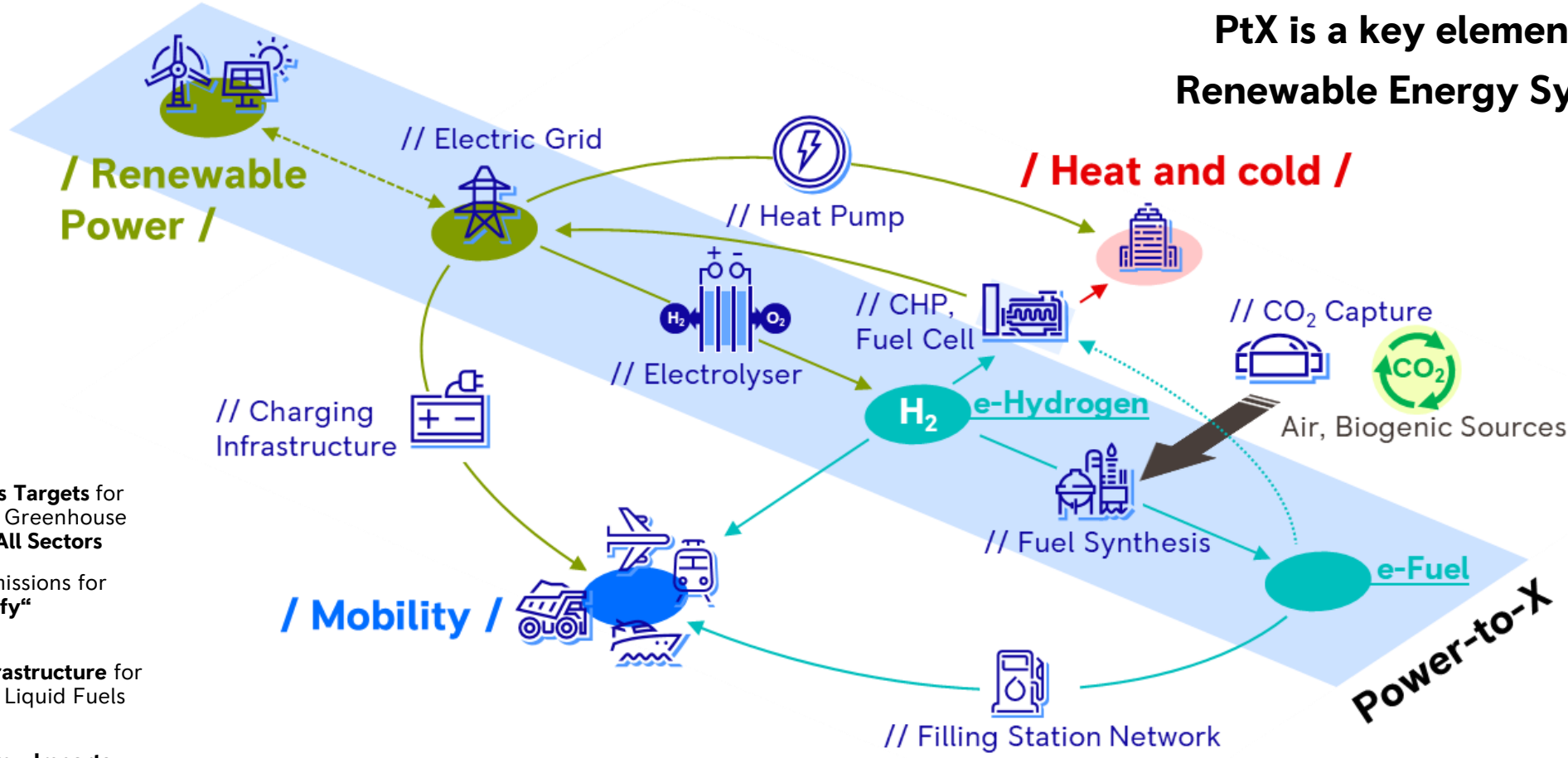
1. GenSets / (g – Gas) / (l- Liquid) / (f- FuelCell / (b- BackUp)
2. Circuit Breaker
3. Main Circuit Breaker (PoC)
4. Uninterruptible Power Supply
5. Switch Gear
6. PCS
7. Thermal Energy Storage
8. Electrical Energy Storage
9. Renewables
10. Master / MicroGrid Controller
11. Intelligent System
12. Main Supply
13. Thermal Conversion
14. Consumers / Prosumers

Wireless Communication



02 Power-to-X for Sector Coupling …. Green & CO_2 Neutral Fuel

PtX is a key element of a Renewable Energy System



Value Proposition:

- Reach **Ambitious Targets** for the reduction in Greenhouse Gases (GHG) in **All Sectors**
- Reduce GHG-emissions for **"Hard-to-Electrify" Applications**
- Use **Existing Infrastructure** for Natural Gas and Liquid Fuels
- Enable **Renewable Energy Imports**
- **Integrate Volatile Renewables** in the Energy System

02

Power-to-X for Sector Coupling …. from Electricity to Molecules ..

E-Fuels show lower Efficiency but enable a higher Energy Harvesting and Imports

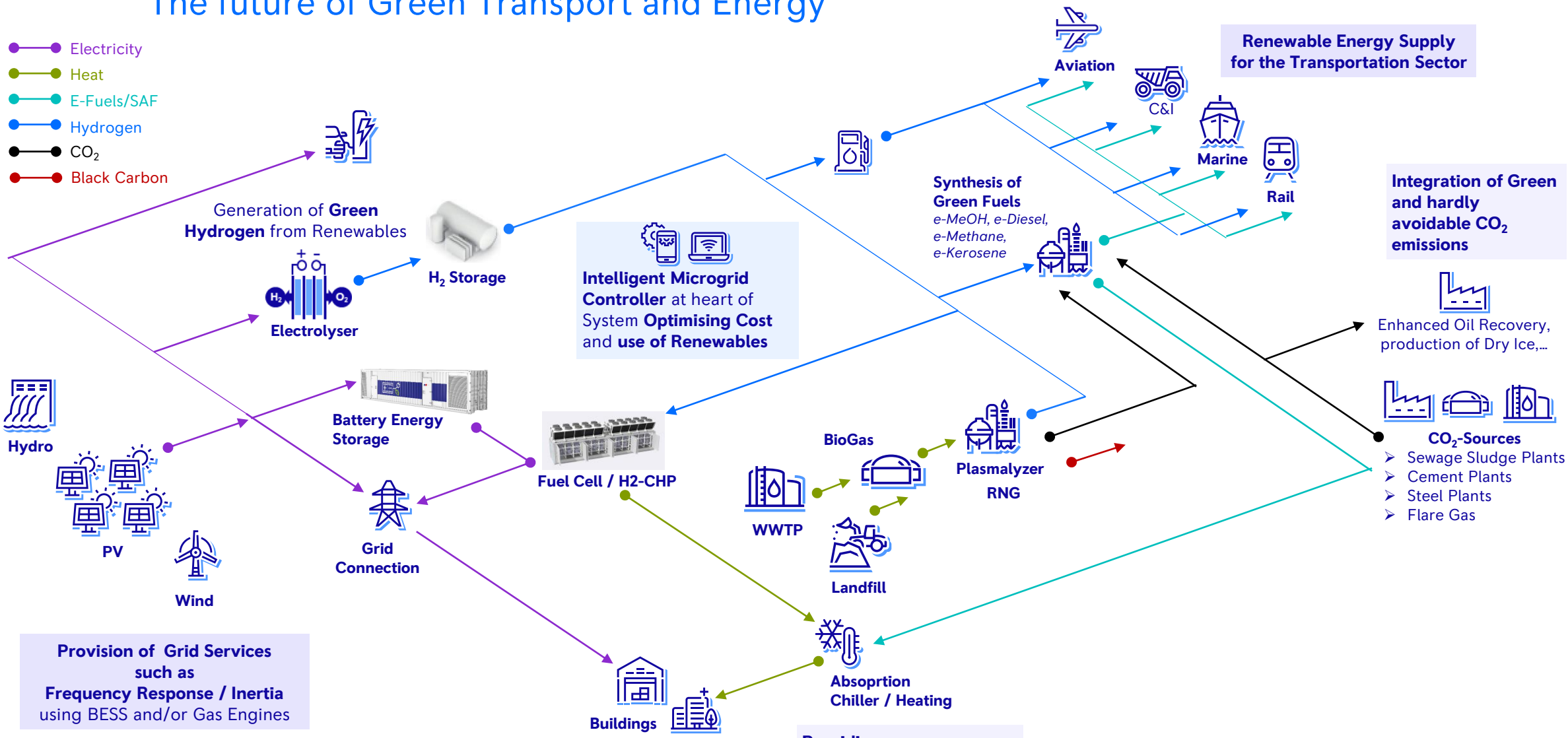
Mechanical Energy (10 MW Wind)
Efficiency η
Energy harvesting ratio ζ

Electric Propulsion Germany	18 GWh				17 GWh	15 GWh	**13.2 GWh** η=73 % ζ= 15 %
	20 % (1,800 h/a)	- %	- %	- %	96 %	90 %	85 %	
e-H_2 Germany	18 GWh	13-14 GWh			11-14 GWh	11-13 GWh	**4.3 – 6.6 GWh** η=24-37 % ζ= 5-8 %
	20 % (1,800 h/a)	65-80 %	- %	- %	97 % 125m CH_2 Truck	95 %	40/50 % ICE/PEMFC	
e-LH_2 Patagonia	60 GWh	39-48 GWh		32-39 GWh	29-36 GWh	28-34 GWh	**11.1-17.1 GWh** η=19-29 % ζ= 13-20 %
	68 % (6,000 h/a)	65-80 %	- %	82 %	91 % 7,500m Ship – 250mTruck	96 %	40/50 % ICE/PEMFC	
e-Diesel Patagonia	60 GWh	39-48 GWh	26-32 GWh		26-32 GWh	25-31 GWh	**10.2-12.6 GWh** η=17-21 % ζ= 12-14 %
	68 % (6,000 h/a)	65-80 %	67 %	- %	99 % 7,500m Ship – 250mTruck	99 %	40 % ICE	

02

Renewable Cross-Sectoral Energy Systems

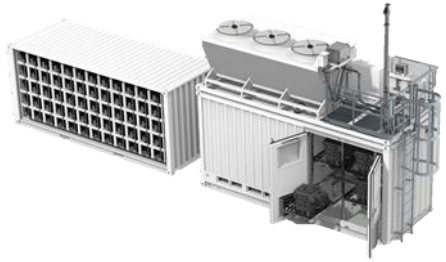
The future of Green Transport and Energy



02

Three Pillars of Hydrogen's Path to Power

- **H_2** is no more dangerous than NatGas or Liquid Fuels
  - ✓ of course its handling is different
- **H_2** is/does
  - ✓ lighter than Air
  - ✓ escapes quickly upwards
  - ✓ colorless & odorless
- **H_2 as a fuel …**
  - ✓ Ignites easier / burns faster
  - ✓ provides no unburnt HCs
  - ✓ provides no CO_2
  - ✓ provides NOx Emissions very low for high dilution ($\lambda > 2.5$)
- **H_2** has
  - ✓ a High Diffusion Coefficient (>4x CH_4) and quickly dilutes in air
  - ✓ Significantly narrower detonation limits than explosion limits
  - ✓ Lower Energy Content (vol)



Fuel Cells

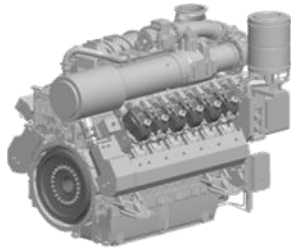
Scalability Approach

Grid Mixed

Lean Burn Fuel Flexible Engines

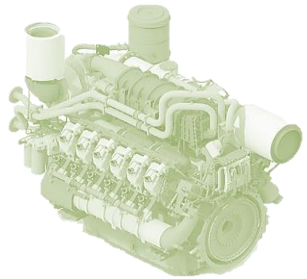
Active Blending

New Units



Legacy H_2 Ready Units Retrofit

100% H_2 Engine Port Injection

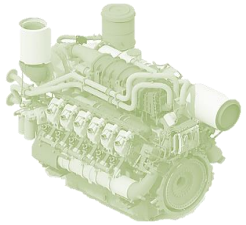


All Data from: Richard van Basshuysen,
Ottomotor mit Direkteinspritzung und Direkteinblasung

02

Hydrogen DG Concepts

RICE vs. Fuel Cell



Low/no-Bottleneck Resources

Specially precious / rare-earth metals

Low CapEx

Price comparable to existing RICE DGs

Exhaust Heat usage

Temperature level > 200 °F (100 °C)

Low Fuel Purity acceptable

<98% Vol. Hydrogen purity

Zero Emissions

No GHG, SOx, NOx

Low OpEx

Fewer Moving Parts

Fast Reaction Times

Response Times within secs.

High Electrical Efficiency

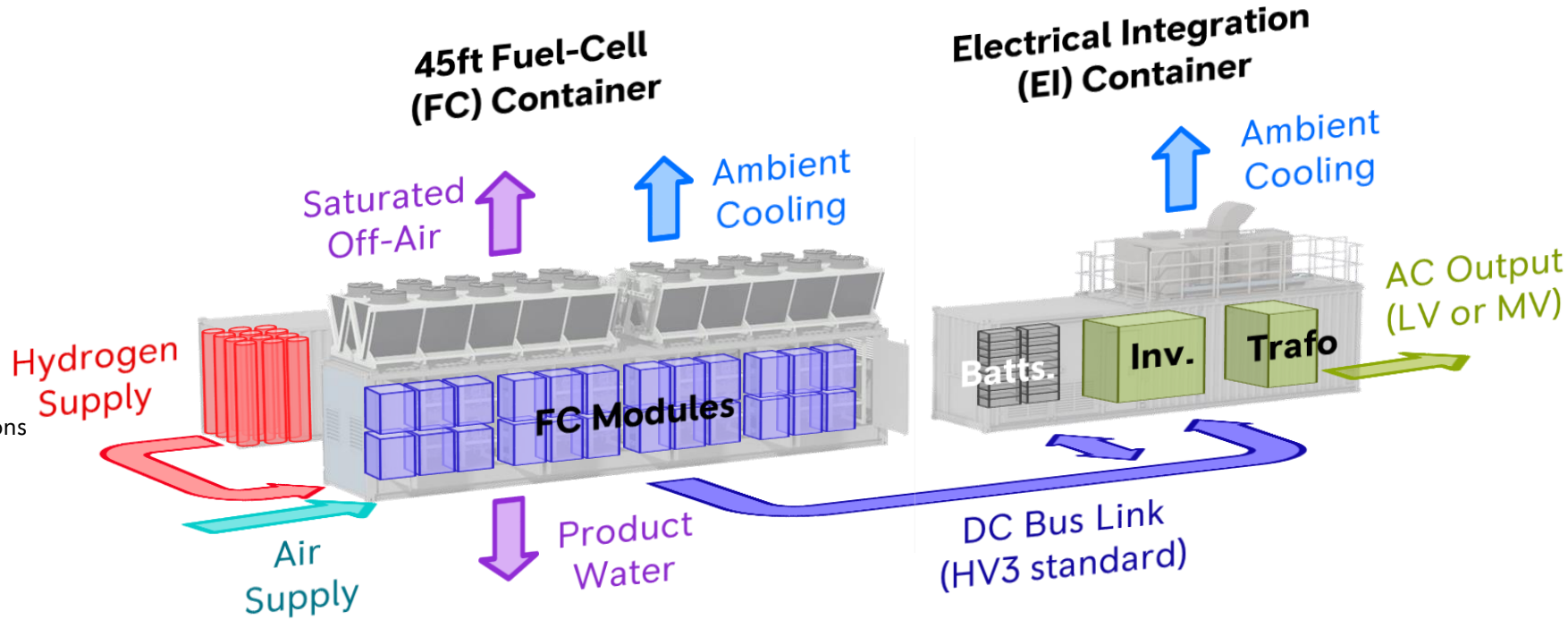
w/ optional use of thermal exhaust Energy

02 Hydrogen DG Concepts

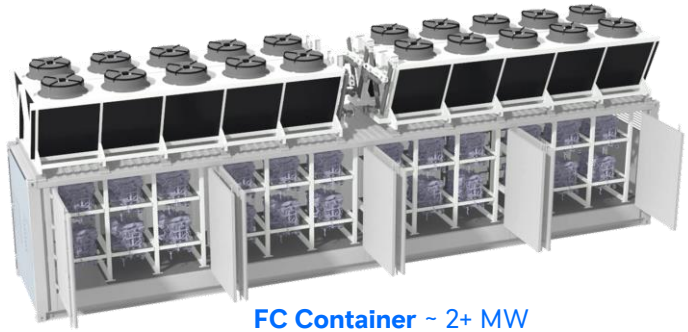
Fuel Cell

Value Proposition:

- PEM Technology (Mature)
  Proton-Exchange Membrane
  High Reliability/Availability
- Modular and Redundant Configurability
- Scalable / Flexible
- Holistic Safety
  Electric / Explosion
  Fire Detection & Extinguishing
- Fully Autonomous / Black start
- Operation in Wide range of Site Conditions
  5 °F to 104 °F @ $23g_{water}/kg_{air}$
- Fast Response (within seconds)
- Sustainable (only emits H_2O)
- Power Density and Compartmentalization
- Fully Integrated (FC / PCS / BESS)



FC Container 0.6 MW



FC Container ~ 2+ MW

Facts:

- Configurable Power Stacks
- 9-20 bar (130-290 psi) operating
- Waste Heat ~ 840 kWth @ 158 °F
  Condensate Water >> up to 5 l/min

- ~45% (42 kg/h @ 232-290 psi)

20' Storage @ 350 bar >> 6.8 h @ 100%

20' Storage @ 700 bar >> 10.9 h @ 100%

40' Storage @ 350 bar >> 13.7 h @ 100%

40' Storage @ 700 bar >> 21 h @ 100%

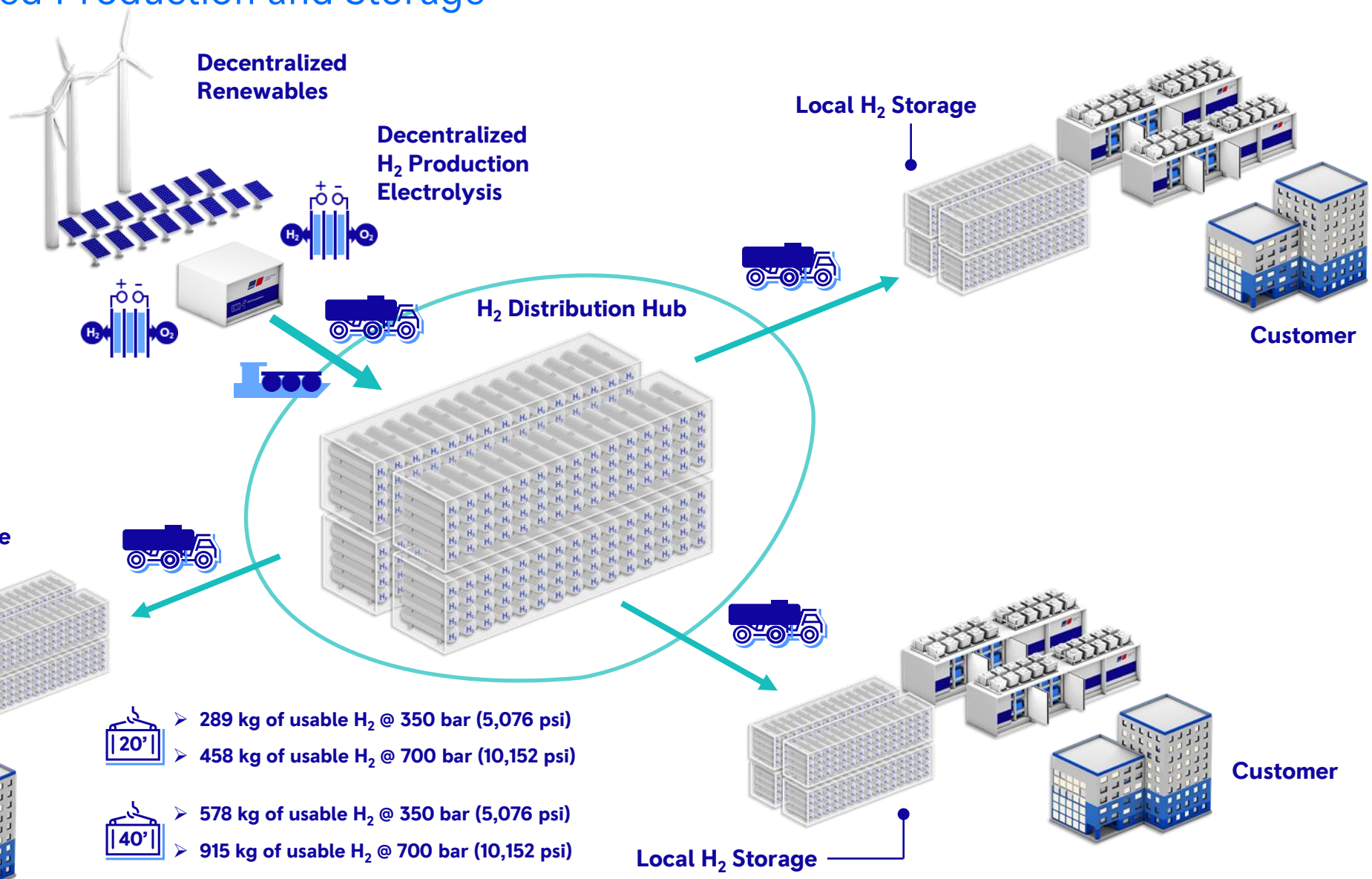
02

Hydrogen Supply Concepts

Decentralized Production and Storage

Value Proposition:

- Decentralized H_2 Production @ Wind/PV Parks
- Decentralized Storage with Integrated Storage Facility
- Use **Existing Infrastructure** for Natural Gas and Liquid Fuels
- Applicable for Vehicle Fleets and/or Stationary Power Applications
- **Direct On-Site H_2** Production also possible
- Containerized Solution



- 20': 289 kg of usable H_2 @ 350 bar (5,076 psi); 458 kg of usable H_2 @ 700 bar (10,152 psi)
- 40': 578 kg of usable H_2 @ 350 bar (5,076 psi); 915 kg of usable H_2 @ 700 bar (10,152 psi)

02

Hydrogen Production Concepts

Decentralized Production and Storage

Value Proposition:

- Decentralized H2 Production @ Wind/PV Parks
- Agile Operation
- **Direct On-Site H_2** Production also possible
- Containerized Solution

Performance

- To be above the 70% Efficiency threshold
- To reverse use the current PEM electrochemistry with flexible response time for RES combination.

Needed Technical Facts

Nominal power	70%+ Efficiency
H_2 production range	0 – 100 %
Output pressure	Usable within the 20 to 40 bar range
Output purity	Up to 5.0
Response time	0-100 % warm standby within secs. 0-100 % cold start within mins.
Water consumption	lowest water consumption possible

Needed Functionality

- **Fast Response** times minimizing need for energy buffering.
- **Dynamic Production** range between 0 and 100%.
- Fully **Autonomous.**
- **Purity** suitable for **Fuel Cell** and **H2-ICE** applications.

Needed Operation

- Power Supply to EL can be ramped up/down between 0 and 100%, **within seconds** from standby.
- Fully **Autonomous.**

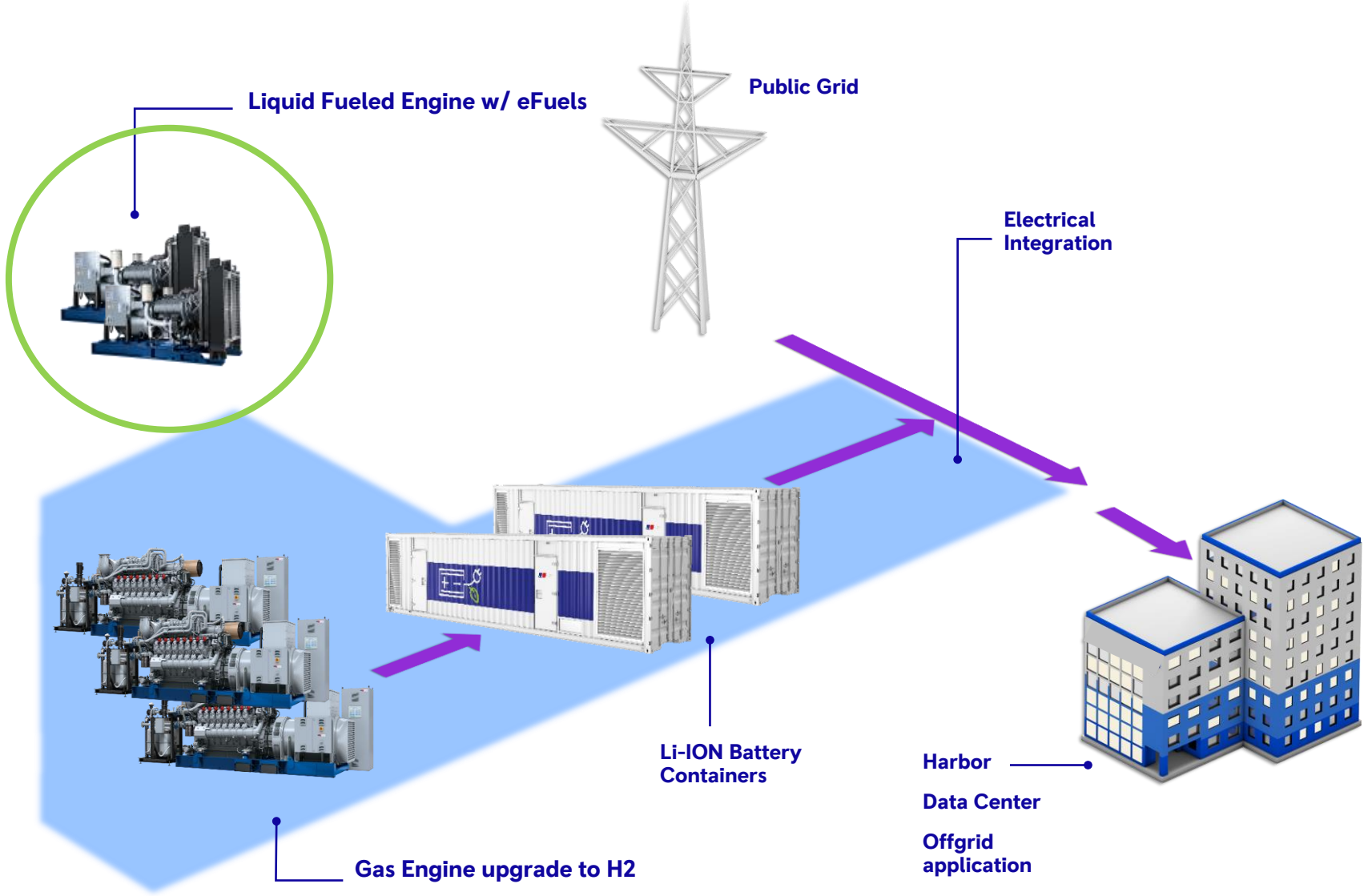
02

Hydrogen Ecosystem

End Use perspective

Hybrid BackUp Solutions based on Recip Engine and BESS

- Transition to 100% carbon free solution
- high flexibility
- Start with NG and shift to H2
- enables CO_2 free enhanced Grid Services
- provides backup and peaking capabilities

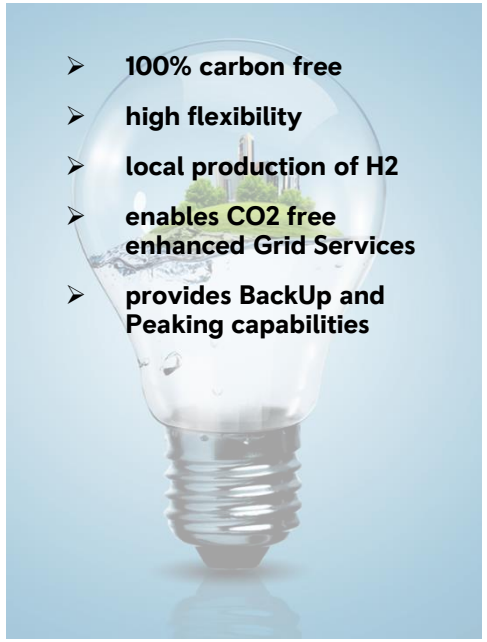


02

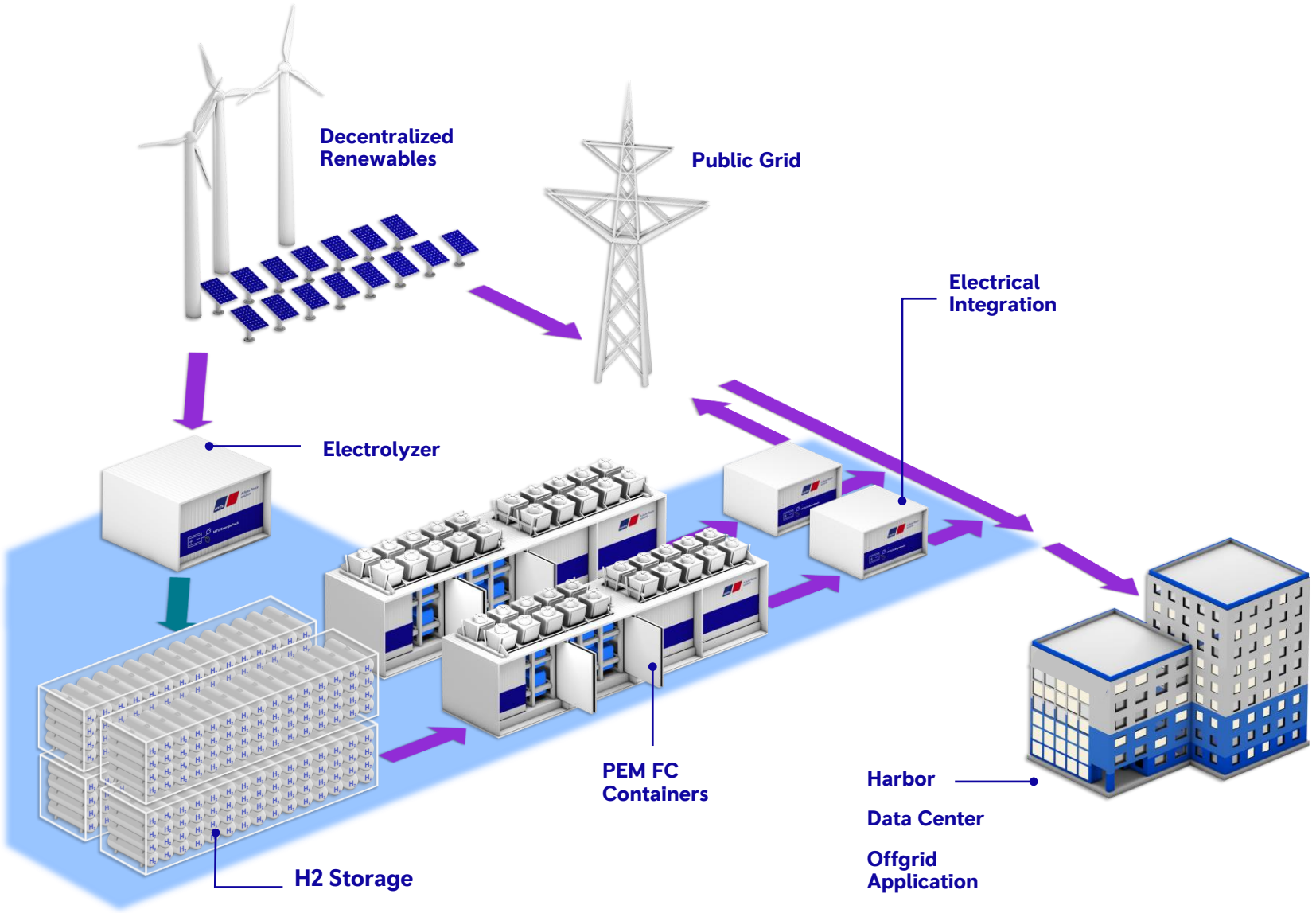
Hydrogen Ecosystem

End Use perspective

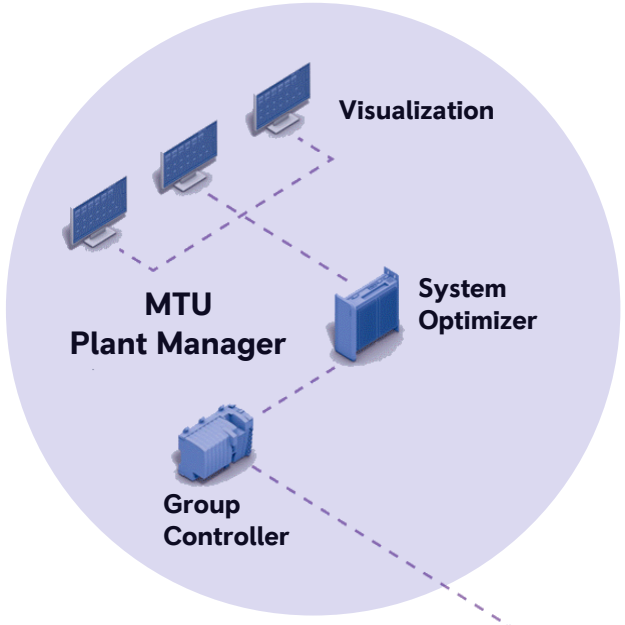
Triple-Use Energy System to provide CARBON FREE Uninterruptible BackUp Power and Grid Services

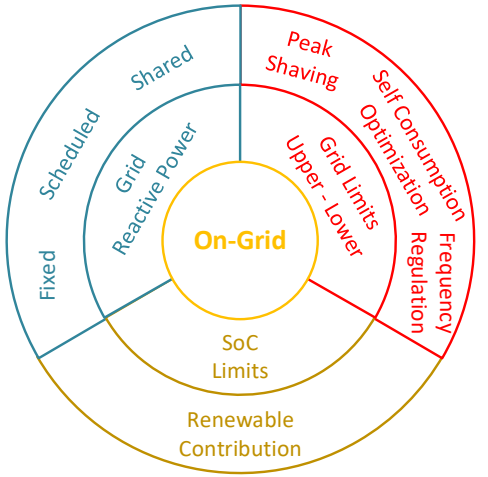


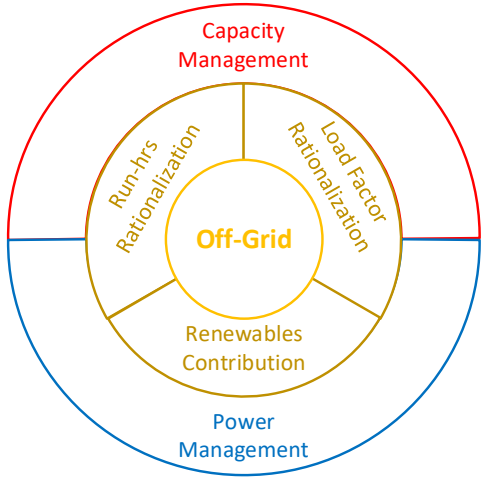
- 100% carbon free
- high flexibility
- local production of H2
- enables CO2 free enhanced Grid Services
- provides BackUp and Peaking capabilities

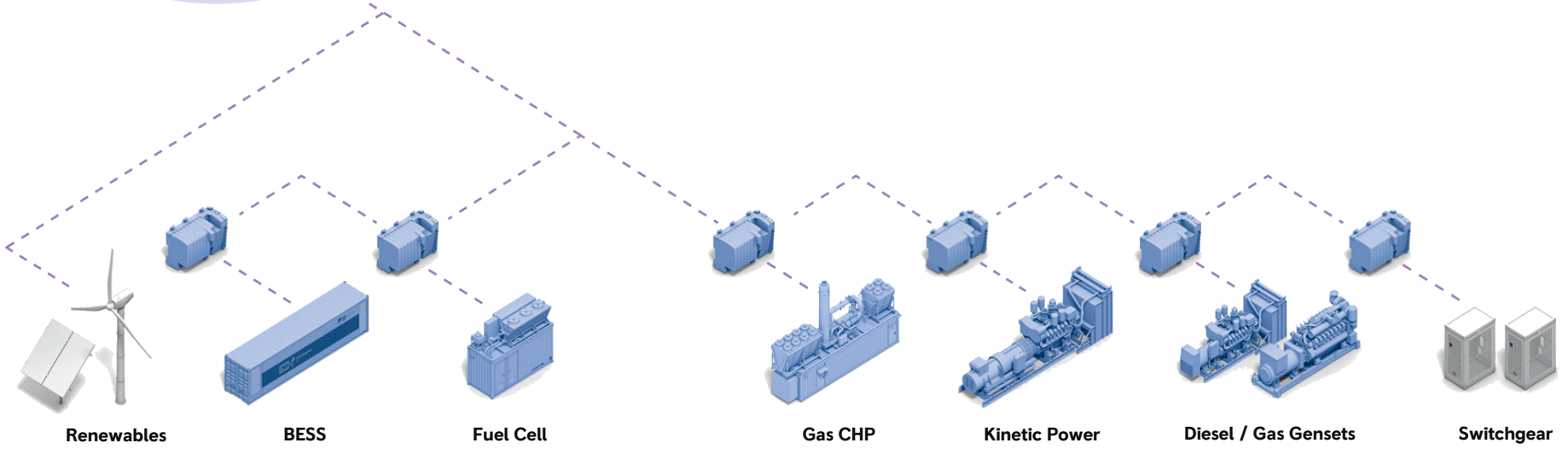


02 Controls and Connectivity will always play a fundamental Role





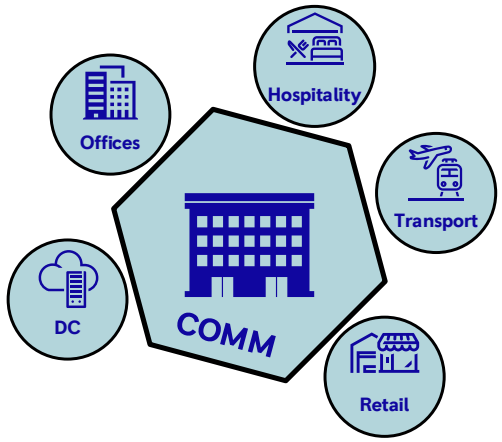




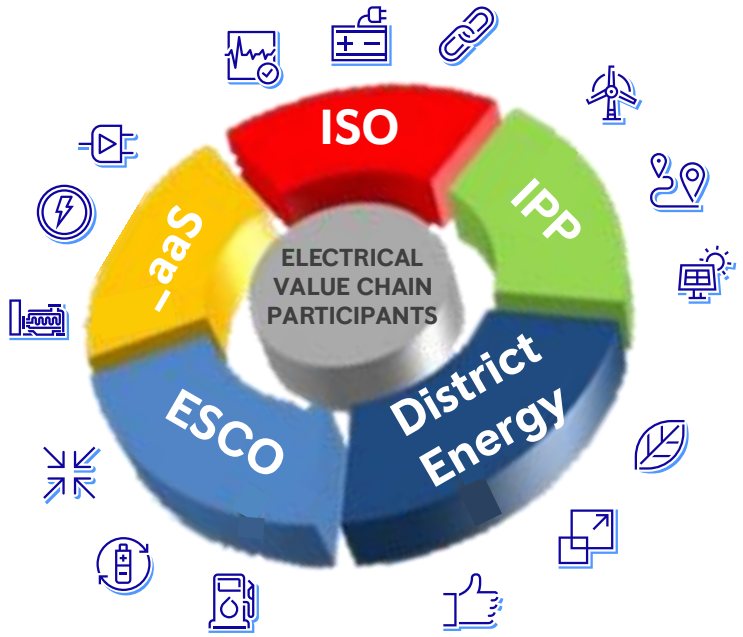
Value Proposition:

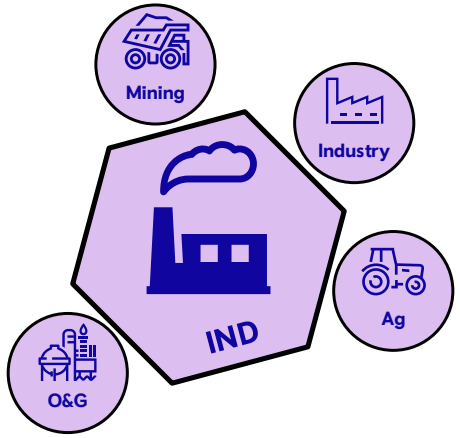
- Control of DG, BESS & Load
- Grid / Load Stability
- On-Grid / Off-Grid / Emergency Power and Peaking
- Mathematical Optimization Algorithms
- Scalable / Flexible
- Redundancy

02 Stakeholders in Project Development



U.S. DEPARTMENT OF ENERGY



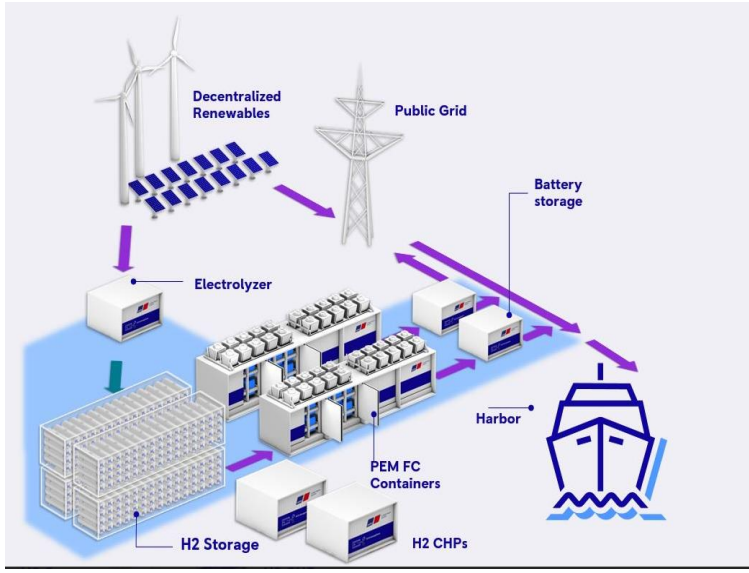


03 our most recent Success …. Duisburg Terminal

Duisburg Terminal Greenification

Customer:
Port of Duisburg

Location:
Germany



mtu Fuel Cell Solutions

mtu H_2 Gas CHP

mtu H_2 Storage Solution

Controls

- Duisport is one of the Largest Inland Port in the world.
- 1st Project of its kind with the Goal to bring it to a Scalable Ports Solution
- ***mtu*** H_2-Powered Fuel Cell Solution to provide for Peak Shaving
- ***mtu*** Gas GenSets either provide electricity to Terminal or feed it to the Grid, also provide Thermal Power for Heat Processes or Heating Buildings
- Photovoltaic and BESS are integrated into the local supply network by a combined effort between Duisburg, Research Enterprises and Local Utilities
- The Project is Funded by the German Federal Ministry of Economic Affairs
- Execution timeline 2021-2025 (H_2 Assets in 2023)

netzero @PowerSystems

Thank you very much for your attention!

A Rolls-Royce solution

Thank You!

Juan Matson