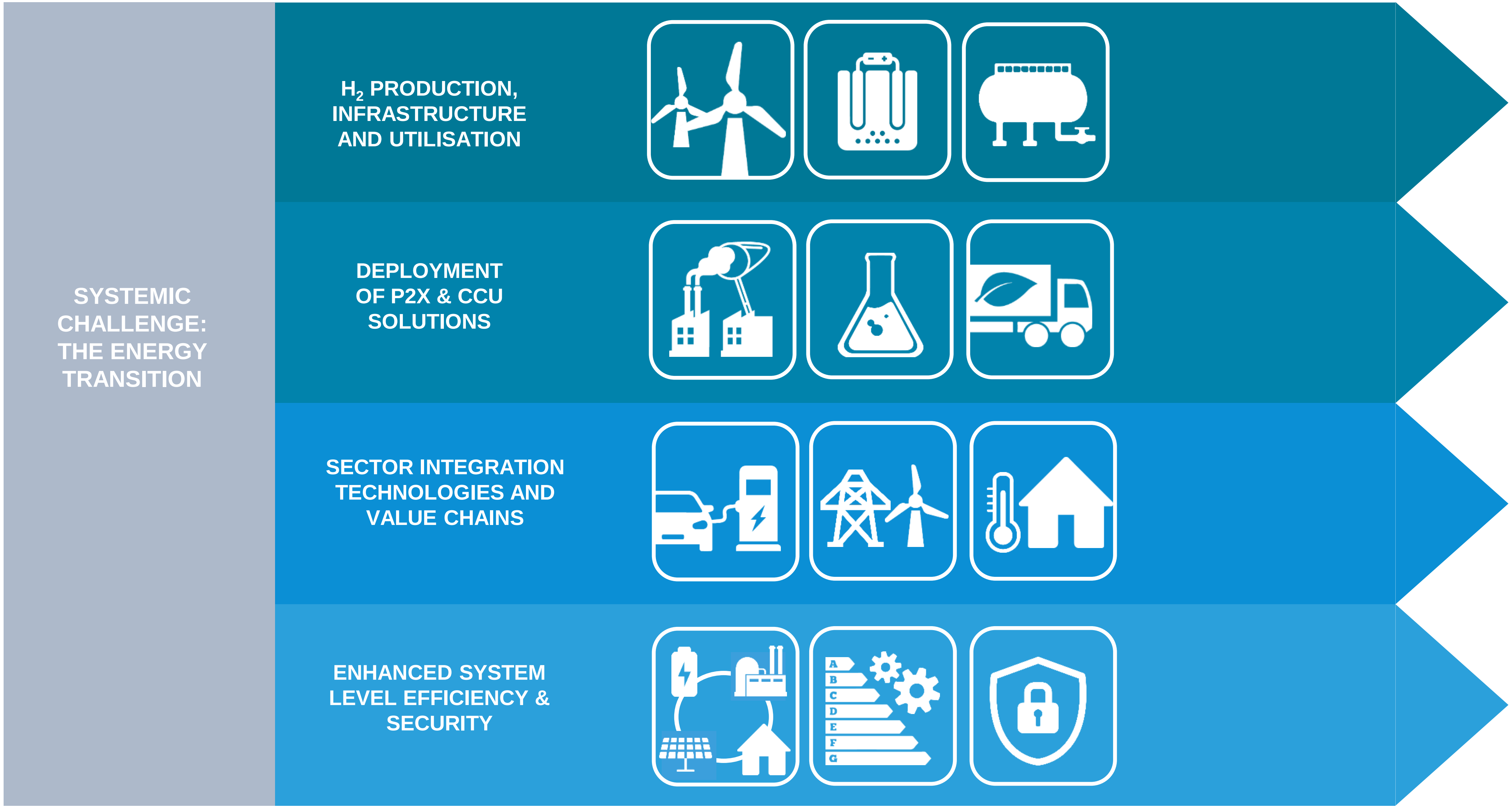
SYSTEMIC CHALLENGE: THE ENERGY TRANSITION
H_2 PRODUCTION, INFRASTRUCTURE AND UTILISATION
DEPLOYMENT OF P2X & CCU SOLUTIONS
SECTOR INTEGRATION TECHNOLOGIES AND VALUE CHAINS
ENHANCED SYSTEM LEVEL EFFICIENCY & SECURITY
A
B
C
D
E
F
G

Green H_2 PRODUCTION, INFRASTRUCTURE AND UTILISATION

GOALS

2025
- Properties of green H2 production technologies defined
- First green H2 production plants in use
- The role and most effective source streams of H2 defined and clearly presented in Finland
- Electrolyzer production started in Finland

2030
- Commercial engagement of the whole H2 value chain
- Sidestreams and H2 production from waste in use

2035
- Safe H2 logistics solutions in use, with connection to European gas grids.

Green H2 production processes and utilization

2025
- Studies on the role and system-efficiency of hydrogen in transport, energy and industry sectors in Finland
- System modelling to integrate power-to-x technologies
- Large scale electrolysers tested and optimized
- Process engineering know-how and experience in the steel, chemical and refinery sector
- Integrated concepts for hydrogen production and mobility infrastructure

2030
- Competitive H_2 price
- First commercial large scale production and utilization plants in the operation

2035
- The whole value chain in the operation

Cost-effective H2 production technologies

2025
- Improvement of electrolysis technology to lower capital costs, to enhance lifetime and durability and to increase system efficiency
- Off grid hydrogen production optimized and tested
- Purification of side stream H2
- Hydrogen production even from small side streams
- Circularity

2030
- Production mix of large-scale centralized and smaller de-centralized plants possible
- Photocatalytic production technology under development
- Thermochemical and biological methods tested

2035
- New production technologies tested and some of them already operating,
- Thermochemical water splitting pilots

Reliable safety solutions for production, logistics and storage of H2

2025
- Liquid organic hydrogen carriers (LOHC) solutions
- System requirements from materials and safety perspective
- Security development ongoing

2030
- Logistics operating.
- Material challenges of storages solutions solved.
- H_2 pipelines under construction

2035
- Fully commercial based solutions in use for production, logistics, storage and utilization.

DEPLOYMENT OF P2X & CCU SOLUTIONS

GOALS

2025

- Clear national strategy for P2X & CCU
- Proof-of-concept P2X2P (e-fuels, gas or liquid, energy storage) pilot(s) with customers.
- Most effective source streams of carbon defined. Properties of CC technologies defined.
- Legal and regulatory directions in different markets.

2030

- P2X2P, e-fuels and energy storage, commercial solutions.
- Business export (companies) and knowledge export (university research).
- Commercial-scale CCU demo - First Commercial Investment.

2035

- First P2X2P export project delivered and in use. CCU and P2X -solutions are part of industry and gas infrastructure.
- Established Research and Knowledge Centers around CCU&P2X solutions.

P2X processes, economic feasibility and energy efficiency

2025

- State-of-the-art survey on available and emerging technologies.
- Photo-electro-chemical (PEC) water splitting. Scalable demo reactor.
- Sustainability assessment of alternative routes from different carbon and hydrogen sources to different synthetic products.
- Flexible plants with multiple outputs (industrial transformation & integration).
- Modular plant solutions.

2030

- Industrial demonstration of catalytic processes for examined synthesis routes to produce a wider variety of synthetic products (polymers, chemicals etc.).
- Catalyst development for new, less researched synthesis routes.

2035

- Demonstration of new catalytic processes on industrial scale.

CCU (both CO2 and CH4) processes, cost and energy efficiency

2025

- Study on different available sources of carbon for carbon capture
- Development of CCU road map for Finland and related regulatory framework to support CCU demonstration activities.
- Optimization models for different CCU end products taking lifecycle into consideration.
- Establishment of CCU ecosystem for Finland for utilizing the strengths of Universities, RI and companies.

2030

- Commercial technologies to reduce CO2 content from the atmosphere.
- Solutions for direct air capture (DAC) of CO2.

2035

- Development of material and cost efficiency of processes for solid carbon applications.

Infrastructure for integrated energy networks, incl. conversion and storage

2025

- Process development to make e.g., H2 production a flexibility factor.
- Include storages and increase the flexibility of industrial processes.
- Combination of different types of storages: hybrid storages, batteries & compressed air, heat and electricity, bioenergy and synthetic fuels.
- Infrastructure for EV charging and V2G storage solutions.

2030

- E-fuels in transport and power generation.
- Low-carbon concrete production
- CO2 hardening of concrete.
- Low-carbon steel production
- Hydrogen-enabled Direct Reduced Iron.

2035

- Heat pumps and thermal energy storage dominate heating and cooling generation.
- Deployment of electro-mechanical storage in power grids with high share of renewables (RES).

CLIC

SECTOR INTEGRATION TECHNOLOGIES AND VALUE CHAINS

GreenE[2]

GOALS

2025

- Sustainability criteria for all energy forms defined on EU level
- Systemic planning tools and mechanisms
- Pilots for system integration use cases
- New actors enter district heating value chains
- Energy communities and microgrids

2030

- Platforms and platform economy
- Regulatory sandboxes for experimenting, scaling solutions for future smart energy systems
- Piloting new market structures

2035

- System of systems management
- Flexible and integrated networks ready to be utilized in transportation, energy, industry and agriculture

System integrating value chains

- **Interfaces and system architectures for sector integration aligned with global markets.**
- **P2X2P value chain.**
- **Assets for power grid flexibility (P2X, heat pumps, storage, waste heat utilization).**
- **Multi-object optimization to support emerging decentralized decision making (AI)**

- **Smart integration of electricity system and electric traffic**
- **Integration of electricity and heating systems (DH + heating of buildings).**
- **Integration of different markets (energy, transport, chemicals, heat, gas, hydrogen).**

- **Building H2 production and consumption near each other**
- **Side stream O2 and waste heat utilization nearby.**
- **Development of control strategies for different energy systems and business models.**

- **Efficiency and further operation improvements of sector integration value chains.**

Energy communities

- **Citizen engagement and consumer preferences.**
- **Methods for considering storage already in the planning phase of the energy system.**
- **Sale of electricity by prosumers.**
- **Distributed systems for trading.**

- **Smart home, smart heating**
- **Role of aggregators.**
- **Logistics and business models of EV charging points and V2G solutions.**
- **EV battery as a storage.**

- **Digital platforms for energy trading between prosumers.**
- **Micrograds and RES integration.**
- **AI applications optimizing prosumer operations**
- **Combining modern decentralized solution architecture and old centralized systems**

- **Decentralized energy solutions.**
- **Integral DHC networks powered by heat pumps.**

Flexibility services

- **Business models for industrial flexibility with new actors.**
- **Design of the new services and business models for sustainable living that covers sector integration.**

- **New services for integration of transport, heating, industrial processes and biofuels.**
- **Energy and mobility as a flexibility service, e.g., V2G.**

- **Aggregators to include even smaller loads to provide flexibility in smaller scales.**
- **Innovative business models for energy systems integrated with digital solutions.**

- **Digitalization and AI for management of flexibility assets (storage, heat pumps, EV charging).**

ENHANCED SYSTEM LEVEL EFFICIENCY, RESILIENCE & SECURITY

GreenE2

GOALS

2025

- Adoption of 6G and AI capabilities
- Communication infrastructure enabling big data applications
- Energy data space standards and framework
- Business models for emerging ICT solutions in energy systems
- Online energy cost used in production optimization: predictability, flexibility

2030

- Genuine alternatives exist in the energy system: different carriers to use in different markets
- Optimization pilots with different types of energy "communities"
- Cross-sectoral knowhow

2035

- Considerable efficiency improvements made in industrial processes
- Societal impacts of energy transitions are addressed

System modelling, optimization, monitoring forecasting & control

2025

- APIs to existing electricity simulations model to enable digital twins
- Dynamic multi-energy system models
- Block chain to trace data on energy value chains
- Vertical integration to enable use of real time IoT-data and modelling
- 6G technical and practical use cases for energy Network level slicing and edge computing adaption
- Role of AI in demand prediction and optimized energy management

2030

- Modelling overall efficiency of value chains
- Real time visualization of information
- AI for autonomous energy sub-systems, systems and system of systems.

2035

- Optimization of resource use for different energy needs
- Local optimization in a system of systems
- Dynamic optimization of production and consumption

System-level resilience and sustainability, cyber security and data safety

2025

- Theoretical and practical cyber security and use of war rooms for testing mechanisms
- Energy data spaces and data sovereignty
- Managing security of mixed energy system consisting of legacy systems and 6G systems

2030

- Cyber security as part of process design
- Cyber physical systems and resilience

2035

- Nearly carbon neutral energy systems, ensuring reliability and security of supply

Societal impact of energy transitions

2025

- Difference in population density and effects of sector integration on population
- Access to affordable energy prices & addressing energ y poverty in EU

2030

- Societal impacts of energy transition in terms of lost jobs and reskilling.
- Role of humans and AI when systems are automated

2035

- Balancing urban / rural dichotomy in terms of access to energy, mobility and employment possibilities.