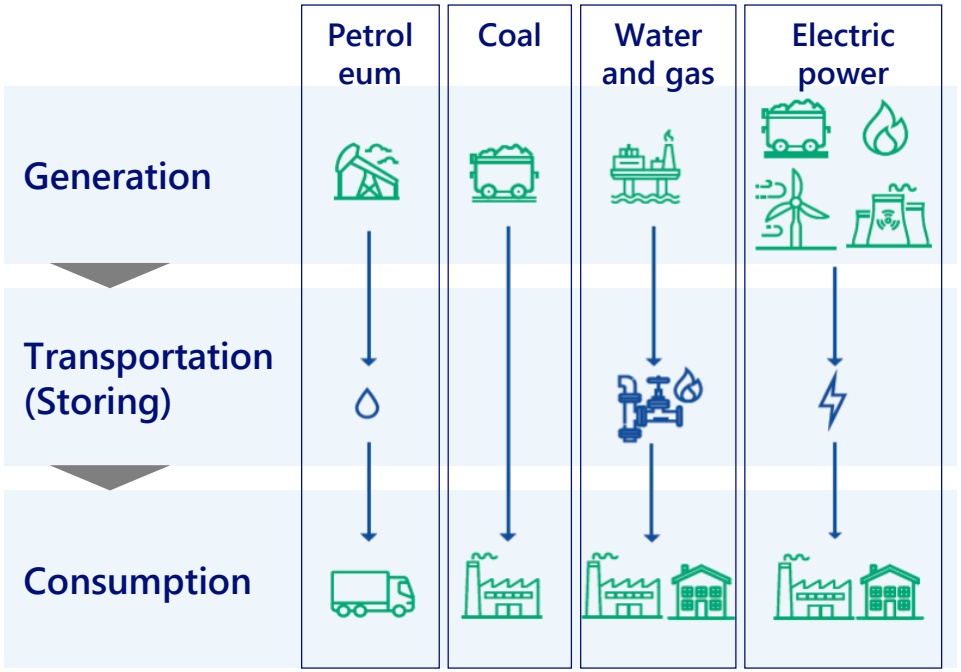
Industry trends in Energy System Integration

- With Sector Coupling, the Energy System will evolve from a conventional linear type to an efficient cyclical type, realizing integration across sectors and regions

Conventional Energy System



- Energy System is a linear system
- Energy flows in only one direction, and there is no coordination between sectors, so waste is likely to occur due to excess or shortage

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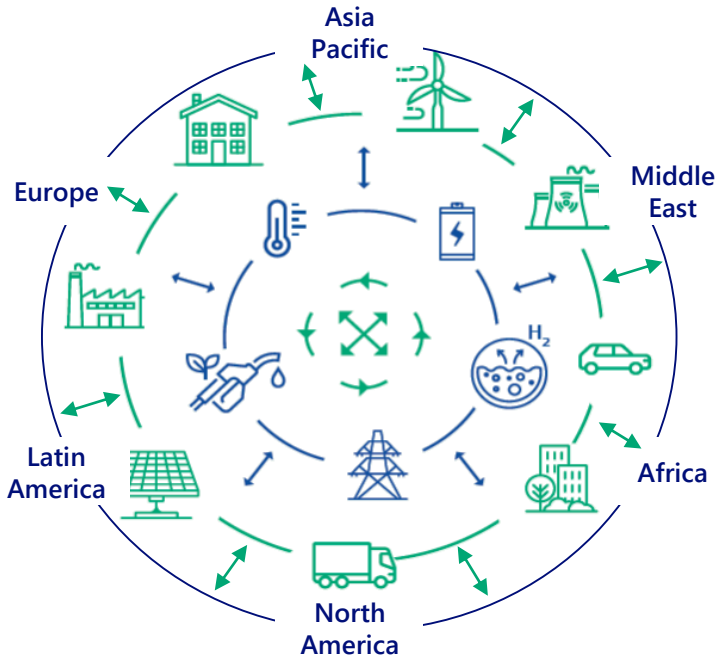
Future Energy System



- Energy System is an efficient cyclical system
- Sector couplings between the energy sector and the consumption sector will be realized, and cross-regional energy transportation will be promoted
- There is no waste because excess energy is captured and reused

Source: Based on European Commission's *EU Energy System Integration Strategy* and modified by NRI

Industry trends in Energy System Integration

- The approach to achieve carbon neutrality through Energy System Integration may differ depending on regional characteristics

Typical Approaches to Achieve Carbon Neutrality through Energy System Integration

	Type 1 "Renewable Rich"	Type 2 "Green Trading"	Type 3 "Storage Rich"
Overview	• Providing maximum primary energy supply with renewable energy within the area	• Energy produced in the region is consumed in the region, and the shortage is compensated by imports from overseas.	• Allow for some GHG emissions from fossil fuels and achieve net zero emissions through the use of NETs
Examples of Areas	• Europe • Australia • Middle East	• Japan • ASEAN • India	• United States • Russia • Middle East
Area Features	• Abundant supply of low-cost renewable energy	• Inadequate low-cost renewable energy • Have existing infrastructure and customer facilities	• Abundance of reservoirs
Key Technologies to Realize CN	• Large-scale renewable energy • Large-scale hydrogen production equipment + hydrogen infrastructure	• Methanation/catalyst • Distributed locations + on-site production of CO2 sources • Transportation from overseas	• Fossil fuels + CCS (including DACCS and BECCS)

Technology trends in Energy System Integration

- For Energy System integration, various efficiency and cost improvements, new technology development, and actual operation are being carried out, mainly in Power to Gas/Mobility/Heat and Optimizing supply and demand of electrical power.

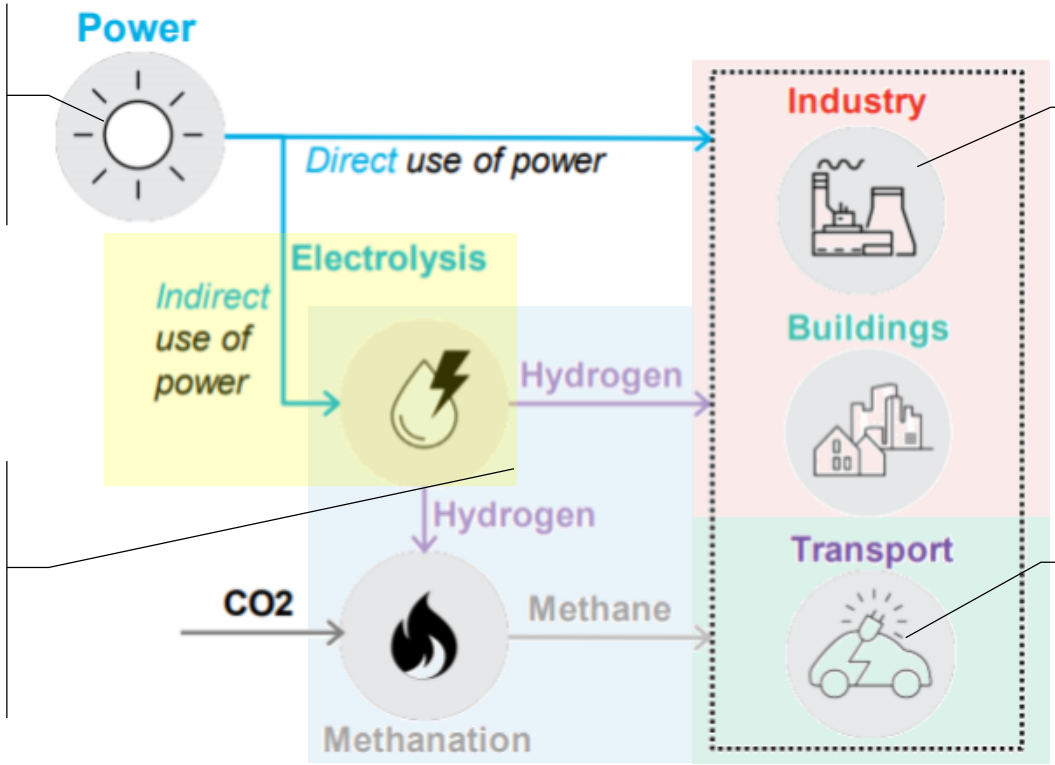
Technology Trends in Energy System Integration

Optimizing Supply and Demand of Electrical Power

- Challenges
  - Sustainability, stable supply, and economics
- Trends
  - Integration of distributed technologies, etc.

Power to Gas

- Challenges
  - Efficiency and technology development
- Trends
  - Improvement of hydrogen conversion and storage efficiency, development of technology for hydrogen fuel cells, and development of gas generation and conversion technology



Power to Heat

- Challenges
  - Efficiency and cost
- Trends
  - Heat storage facility that is more efficient and can reduce costs
  - Development of various software

Power to Mobility

- Challenges
  - Efficiency and cost
  - Actual operation
- Trends
  - Expanding capacity, improving efficiency, and reducing costs for in-vehicle storage batteries and fuel cells
  - Commercialization of hydrogen engines for automobiles, trains, ships, etc.

Source: Robinius, M.; Otto, A.; Heuser, P.; Welder, L.; Syranidis, K.; Ryberg, DOOH.; Grube, T.; Markewitz, P.; Peters, R.; Stolten, D. Linking the Power and Transport Sectors – Part 1: The Principle of Sector Coupling. Energies 2017, 10, 956.