Energy System Integration vs. Sector Coupling
Are they the same concept or different?

The ambition of achieving emission reductions and delivering a climate-neutral energy system of the future has given way to the development of many new concepts and creative problem-solving. However, some new adjoining terms are often misunderstood, with stakeholders perceiving them very differently, leading to communication misalignments, longer discussions, and, in some cases, "wrong" conclusions. This one-pager looks at the two similar terms and defines them as well as their importance in the energy system of the future.

According to the European Climate Law (2021), climate neutrality by 2050 is the underlying objective of EU and domestic energy policy. This is where the two discussed concepts of this paper come into play: energy efficiency and increased interlinkages within the energy system integration can help achieve the needed carbon reduction by 2050. Sector coupling can give the balance needed between the phasing out of fossil gases and increased integration of renewable and low-carbon gases as well as electrification across the energy carrier mix to reach the 2030 and 2040 decarbonization targets. They are different terms and concepts within the energy sector that complement each other.

Energy System Integration

The *Energy System Integration Strategy (ESI)* report by the European Commission defines the term as the **coordinated planning and operation of the energy system as a whole, across multiple energy carriers, infrastructures and consumption sectors** (European Commission, 2020). It encompasses three concepts:

1) A more circular energy system, with energy efficiency at its core (least energy intensive choice prioritized, and unavoidable waste streams reused).
2) A greater direct electrification of end-use sectors (using heat pumps for space heating or low-temperature industrial processes, electric vehicles for transport or electric furnaces).
3) The use of renewable and low-carbon fuels, including H2 for end-use applications where direct electrification is not feasible and for hard to abate sectors. (European Commission, 2020).

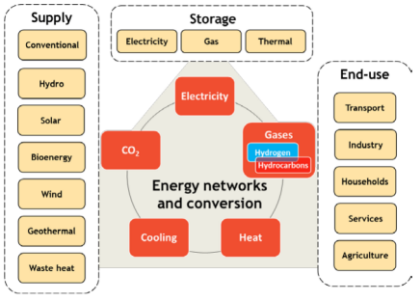
Adapted from EU integrated energy system (European Commission, 2024)

Sector Coupling

Sector Coupling (SC) can be defined as "**the process of progressively and increasingly inter-linking the electricity and gas sectors**, by optimizing the existing synergies in the generation, transport, and distribution of electricity and gas, **with the ultimate scope of a decarbonized and hybrid EU energy system** (Florence School of Regulation, 2020).

The European University Institute/FSR identifies four main building blocks of sector coupling (Olczak & Andris, 2018) :

1. Supply- Infrastructure planning
2. Storage- Research, development, and deployment
3. End-use- System operation and market rules
4. Tangent to all- Regulatory framework



Based on (Energy Future Lab - an institute of Imperial College London, 2018)

The decarbonization objective will not be achieved overnight, since large energy infrastructure takes decades to build (starting from R&D, technology readiness, business case profitability, scaling up, permitting and actual construction). With today's energy infrastructure handling 2/3 molecules and 1/3 electrons (Florence School of Regulation, 2020), the decarbonization of the energy sector will occur with progressively decarbonized molecules and electrification where it is deemed possible. But this time-intensive process needs to always follow the principles of efficiency, affordability, and security of supply, as well as meeting the energy demand of the hard-to-decarbonize sectors of e.g. transport (aviation and maritime).

There is a need for complementarity within an ecosystem of current and upcoming energy carriers. Energy flows between users and producers will no longer be linear (as it was in the past when energy production was local and dedicated to local end-users). While sector coupling indicates the integration of electricity and gas, energy system integration handles the interlinking of more sectors (e.g. heating, transport).

Henceforth, both system integration and sector coupling are key concepts/tools which will allow for flexibility between resources and optimization of the path towards the most carbon-neutral and lowest-footprint energy end products.

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