Technological Innovation and the Future of Energy Value Chains

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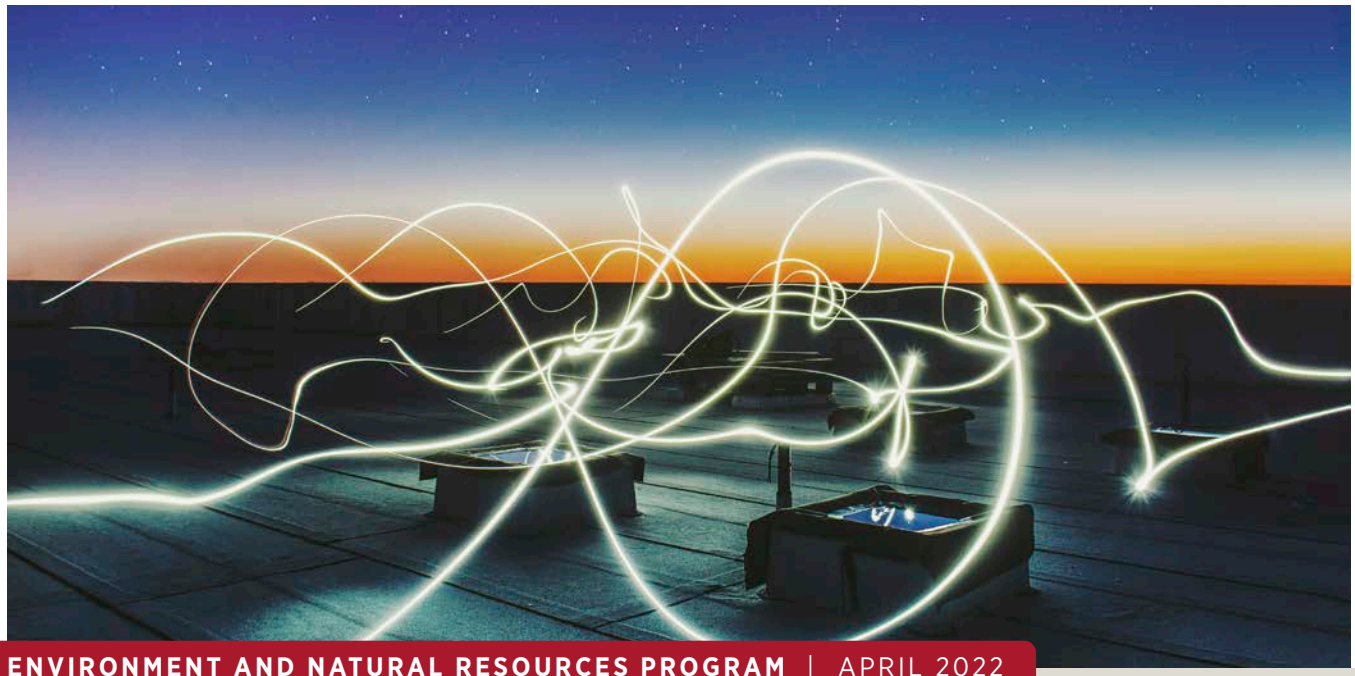

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Technological Innovation and the Future of Energy Value Chains

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The transition from energy systems dominated by fossil fuels[1] to ones based on renewable electricity and carbon-free molecules will significantly impact existing value chains[2] and forge new pathways and transformation steps from production to consumption. This transition will bring not only substantial cost challenges but also promises to dramatically alter stakeholders' interactions along value chains.

1 Today coal, oil, and natural gas still account for 80% of global energy demand.

2 We use the term value chain to define a more conceptual design of business relationships between stakeholders that support the development and adoption of a market or technology at scale. Unlike the term supply chain that is typically used to define a set of operational relationships designed to benefit a single stakeholder and deliver products or services.

Technological innovation is driving dynamics not seen in the energy sector since the Industrial Revolution, and it will be key to accelerating the transition to a low-carbon economy while sustaining growth and achieving prosperity for all. But as new technologies develop to meet growing energy needs, understanding how these technologies will impact existing energy value chains is crucial for navigating the energy transition successfully. To elucidate these dynamics, we must first identify the key technologies[3] driving disruptive change and then understand how their deployment at scale might impact existing value chains or cause new ones to emerge.

Value Chain Integration or Segmentation

An analysis of existing energy value chains highlights many reasons for how stakeholders position their offerings—including adopting sustainable business models, specializing in key technologies to gain a competitive advantage, or responding to regulatory constraints. However, these decisions generally result in two outcomes: integration or segmentation.

Integration is a process by which multiple stakeholders at different points along the value chain form sustained collaborations. Integrated scenarios generally occur when there is a need for intense coordination between stakeholders to develop and adopt a market or technology at scale. On the other hand, segmentation refers to activities that create unique markets or differentiation in services, where individual stakeholders realize a competitive advantage through specialization. In segmented areas of the value chain, competitors maximize profits by offering unique products or services to multiple clients.

But what does this mean in practice? Take renewable hydrogen (produced by splitting water with renewable electricity). Both integration and segmentation scenarios will emerge depending on the use case.

Due to its versatility, hydrogen is often described as the "missing link" in global decarbonization efforts and can be used in both stationary and mobility applications. As a readily dispatchable means of storing energy, hydrogen can help address growing intermittency and curtailment challenges associated with expanded renewable energy capacity. It can serve as a fuel in stationary systems for buildings, backup power, distributed generation, or high-temperature industrial heat. As a

3 Examples of disruptive technologies include renewable hydrogen; carbon capture, utilization and sequestration; blockchain; and nuclear fusion.

sustainable mobility energy carrier, hydrogen can power fuel-cell electric vehicles or be the base for synthetic fuels, thus complementing ongoing efforts to electrify road and rail transportation and provide a scalable option to decarbonize the shipping and aviation sectors. But this versatility also creates significant uncertainties that must not be overlooked. The infrastructure needed in an economy where hydrogen is used as a transport fuel is very different from one where its primary value is as a heating fuel for buildings.

On the one hand, stationary applications drive *integration scenarios* because the development and adoption of hydrogen at scale necessitate close coordination between all stakeholders from production to consumption. Similar to the emergence of liquefied natural gas markets where players along regional natural gas value chains had to work together to deploy the required infrastructure and drive adoption globally. On the other hand, hydrogen technologies will drive *segmentation scenarios* in the mobility sector. While the light-duty vehicle market will be dominated by lithium-ion battery-powered electric vehicles, the heavy-duty segment will be powered by hydrogen or hydrogen derivatives like ammonia.

Recommendations and Conclusions

As we move toward a more decarbonized and decentralized future spurred by technological innovation, the public and private sectors must work together to rethink their roles within value chains.

This will require a concerted approach to:

- Acknowledge and address the new geopolitical dynamics of a world less reliant on fossil fuels and the political push for self-sufficiency and strategic independence. For example, if renewable hydrogen were to be adopted at scale, future market dynamics will likely resemble today's regional natural gas markets—with the corresponding potential for geopolitical conflict. Countries will assume specific roles in global renewable hydrogen systems based on their renewable energy resources and water endowment levels, as well as their infrastructure potential. Therefore resource-rich countries will need to implement policies to trigger technology innovation and infrastructure investments. On the other hand, importing countries must prepare and embrace strategic long-term supply diversification to increase national energy security.
- Recognize key technologies driving disruptive change and examine how existing value chains will evolve or new ones emerge. This will require a concerted effort by all stakeholders to identify integration and segmentation scenarios and their impact on market dynamics along with any associated infrastructure needs.

- Define clear government policies and regulations based on the detailed analysis of value chain scenarios. Only a more profound understanding of these dynamics will allow policymakers and corporate investors to better navigate the opportunities that decarbonization will bring. In order to build the resilient energy systems of the future and tackle climate change, countries will need to develop industrial policies designed to leverage their comparative advantages while incentivizing internal competition in high-value-added sectors. Policymakers will need to facilitate the creation and growth of new markets, address capital misallocation across sectors, promote innovation to drive robust growth, and strengthen participation and integration in global value chains.

Success is possible, but only a cohesive and collective understanding of how energy value chains will evolve will enable each participant to take the best course of action to prepare for and succeed in the energy transition. Stakeholders who are able to embrace the new energy landscape will gain significant competitive advantages, while the others risk fading into obsolescence.

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