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Considering different types of learning in low-carbon energy innovation policy

Abhishek Malhotra, Energy Politics Group, ETH Zurich
(with Prof. Tobias Schmidt, ETH, and Dr. Joern Huenteler, World Bank Group)

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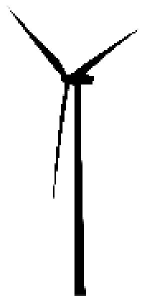
Many governments make use of deployment policies to induce cost reductions and industry formation

- Technological innovation is a key lever to address climate change and other societal issues
- Many governments introduced technology-push, coordination, and especially demand-pull policies to incentivize innovation (often driven by industry policy considerations), but with mixed results…
- We analyze the innovation patterns of three different technologies: Wind, Photovoltaics, and Li-Ion Batteries



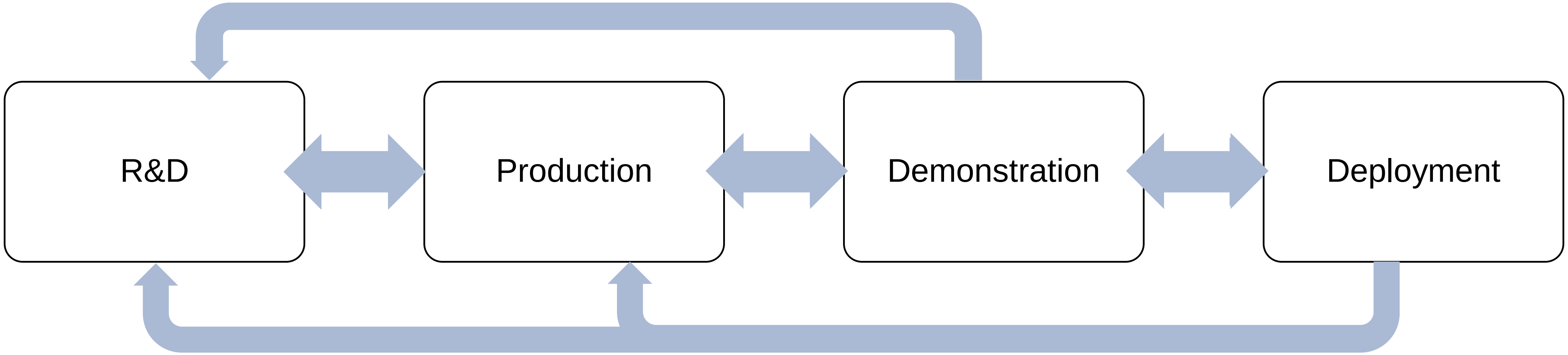
All three technologies…

- can play an important role in low-carbon electricity (and transport) systems
- have diffused to certain degree and experienced significant cost reductions

But there are interesting differences:

- Wind: complex product-system, Europe as industry leader China catching up very slowly
- PV: mass-produced good; for cSi-PV China caught up very quickly, now dominant
- Li-Ion: mass-produced good; China trying to catch up with Japan and South Korea

We analyze these technologies' differences regarding their innovation patterns



- Innovation as complex process involving knowledge feedbacks and iteration between research and experimentation
- Are innovation and feedback patterns technology specific? If so, what does it imply for policy?
  1. Where in the industry value chain does innovation occur and which type of innovation (product vs process) is most relevant?
  2. What role do interactive learning and knowledge feedbacks contribute to innovation?
  3. How are these patterns related to a technology's architecture?

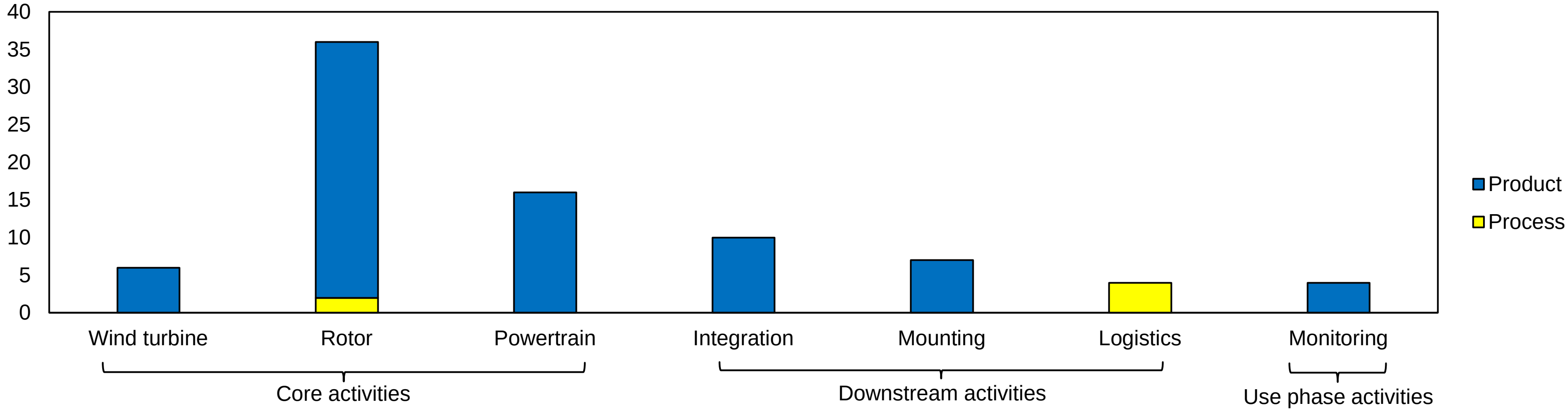
We apply a mixed method approach

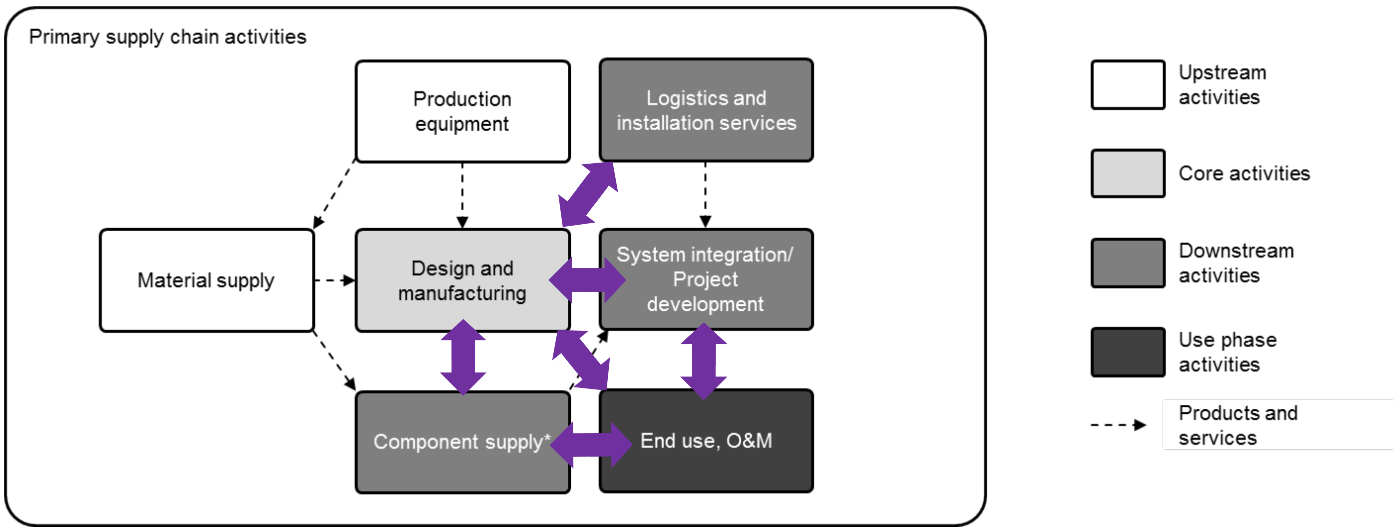
	Activity	Key outcomes

Patent analysis	▪ Extraction of patents from EPO Patstat (using combined search of patent classes and key word search)
	▪ Identification of key patents based on forward citations within 5 years
	▪ Qualitative analysis of key patents (coding based on abstract, claims, and inventor/applicant information)
		▪ 131,374 Li-ion, 230,246 solar PV, 92,990 wind patent families (1960-2013)
		▪ Understanding of:
		  ▪ Locus of innovation in the value chain
		  ▪ Type of innovation (product/process)

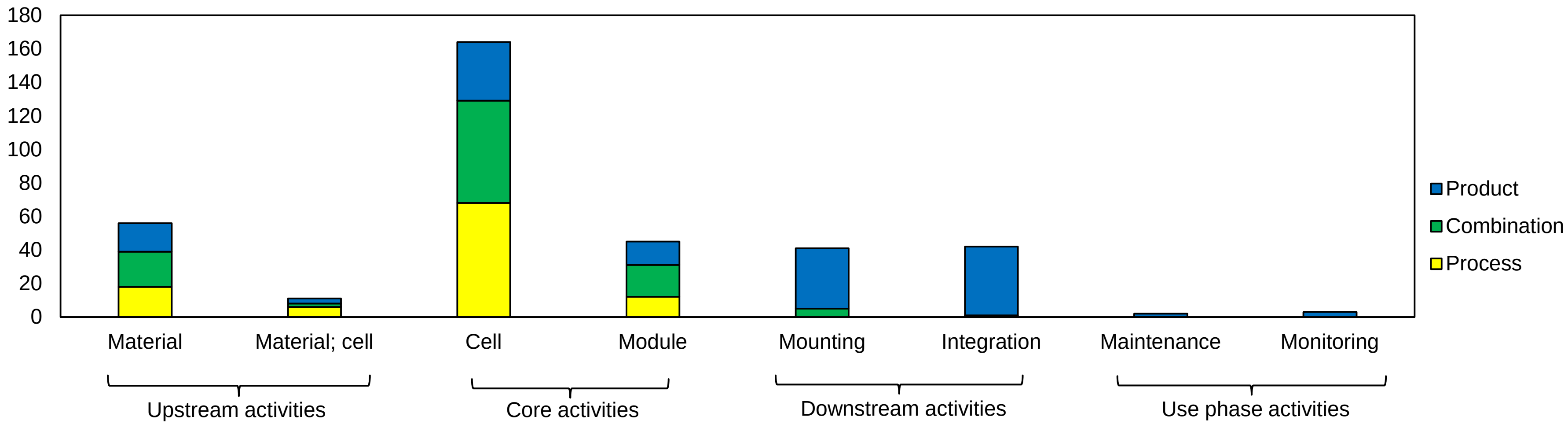
Semi-structured interviews	▪ 32 in-depth interviews with:
	  ▪ Research institutions
	  ▪ Manufacturers
	  ▪ Project developers
	  ▪ Industry experts
		▪ Understanding of:
		  ▪ Locus of innovation in the value chain
		  ▪ Type of innovation (process/product)
		  ▪ Interactive learning and knowledge feedbacks in the value chain

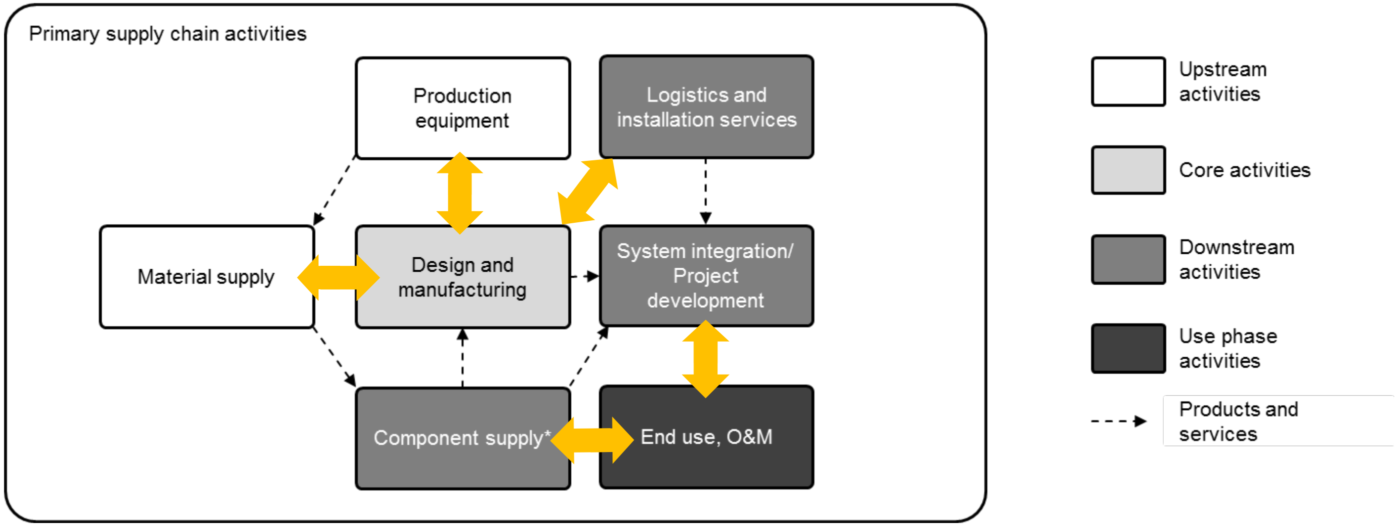
Wind power is dominated by product innovation, enabled by interactive learning and feedbacks among downstream activities



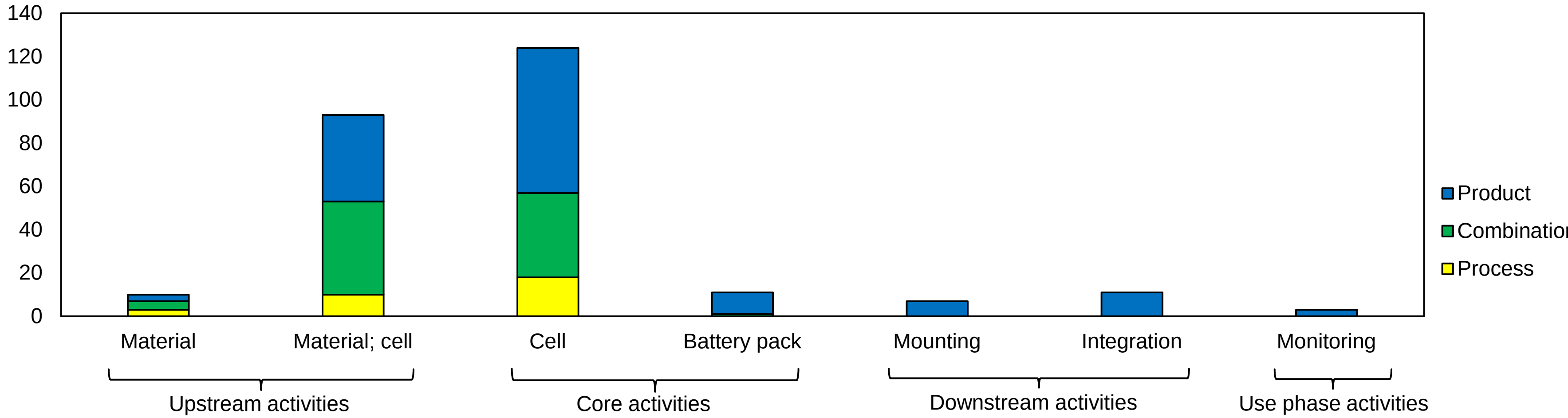


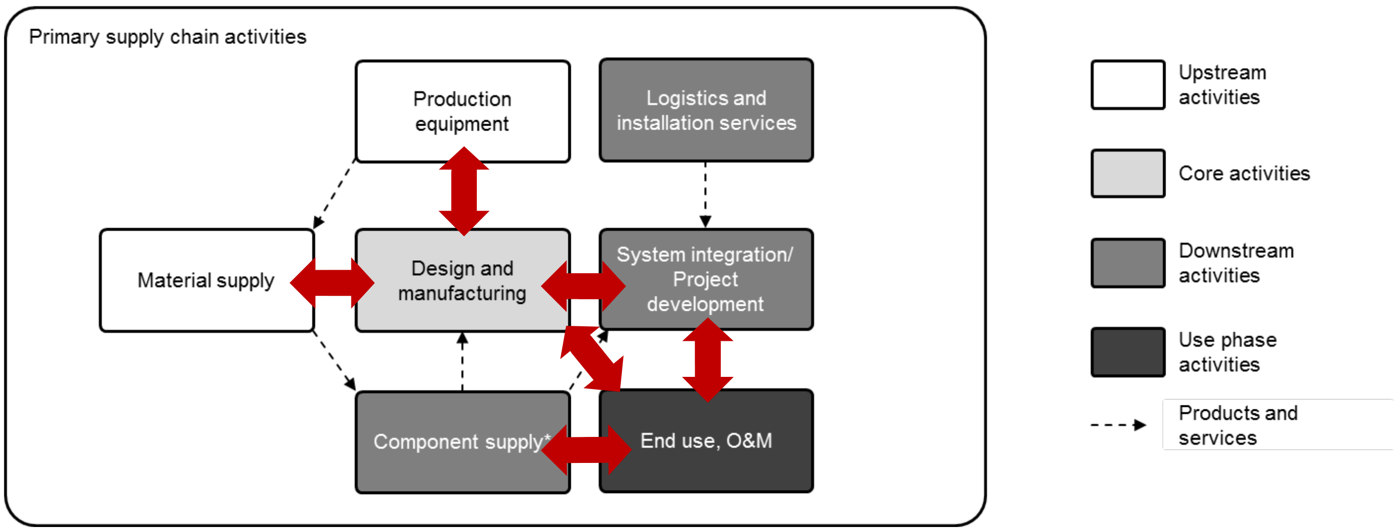
In solar PV process innovation is focused on core components, enabled by interactive learning and feedbacks in among upstream activities



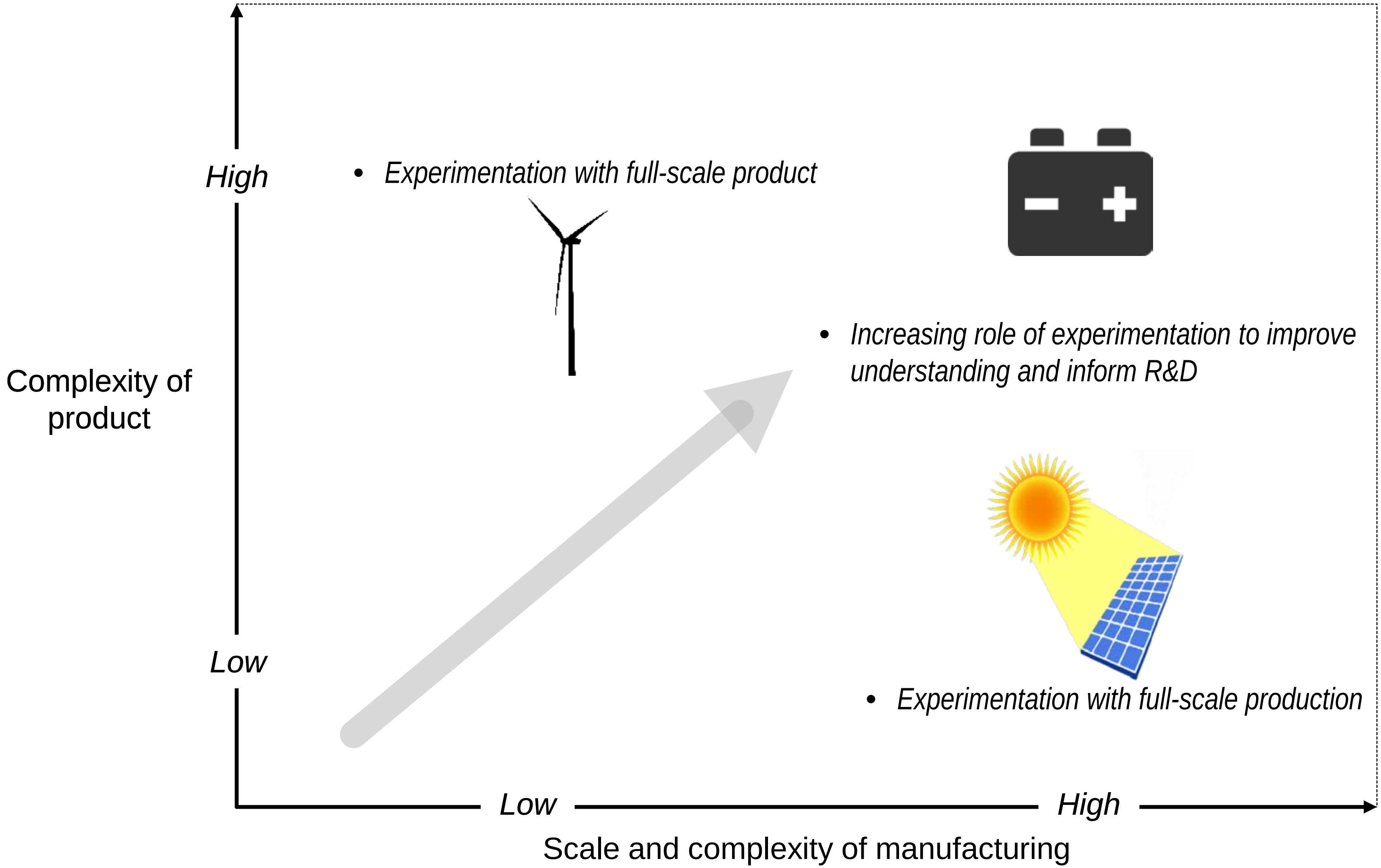


Li-ion focuses on core and upstream product and process innovation, and up- and down-stream feedbacks are important



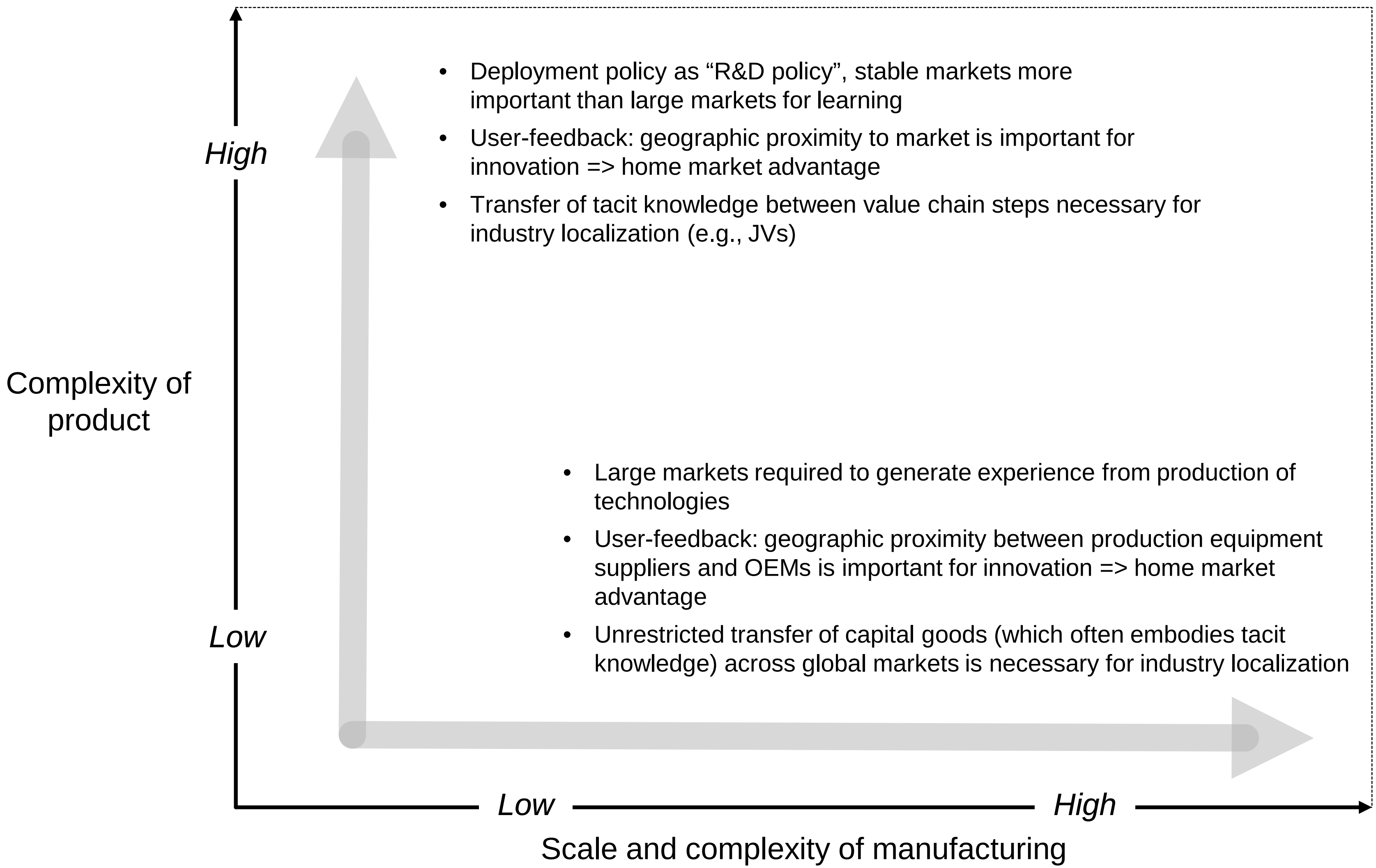


Policy implications



SOURCE: EPG/ETH Zurich; adapted from Schmidt, T. S., & Huenteler, J. (2016). Anticipating industry localization effects of clean technology deployment policies in developing countries. *Global Environmental Change*, *38*, 8-20; and: Huenteler, Schmidt, Ossenbrink, Hoffmann: Technology life-cycles in the energy sector — Technological characteristics and the role of deployment for innovation. *Technological Forecasting and Social Change*, 104 (2016) 102–121

Policy implications



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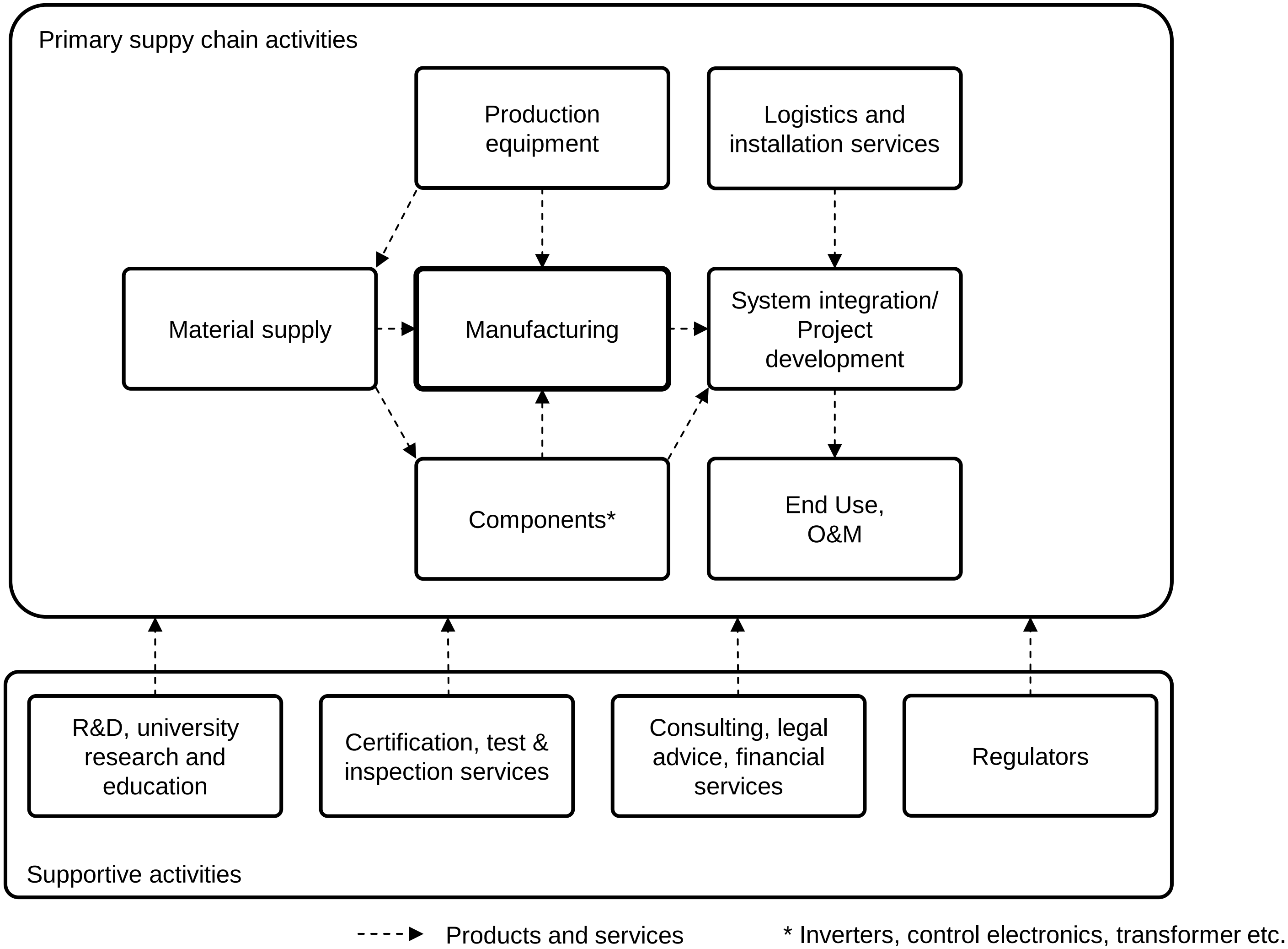
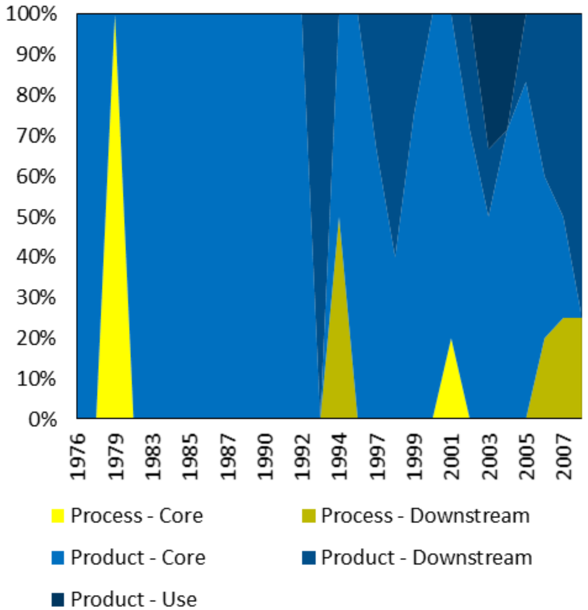
Industry value chain

"A collection of activities spanning across different firms that are performed to develop, produce, market, deliver and support a technology." (Porter, 1985*)

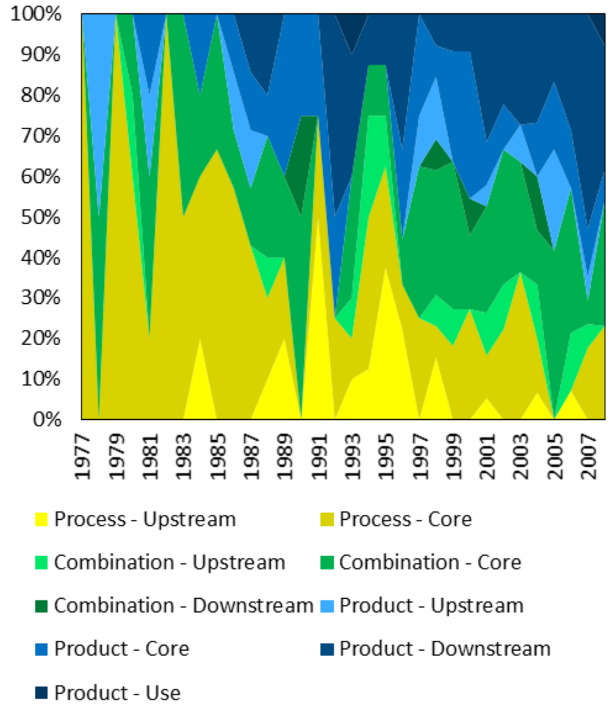


*Porter, M.E., 1985. Competitive advantage: creating and sustaining superior performance. 1985.

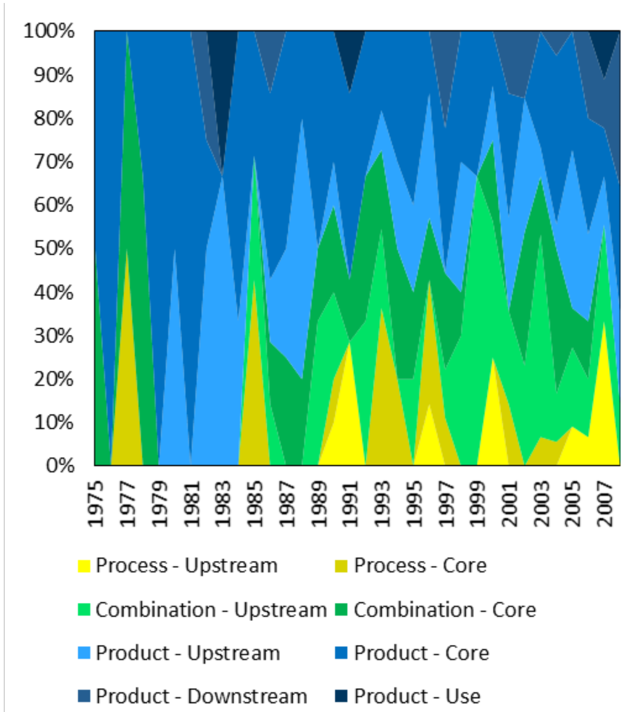
Wind



Solar PV

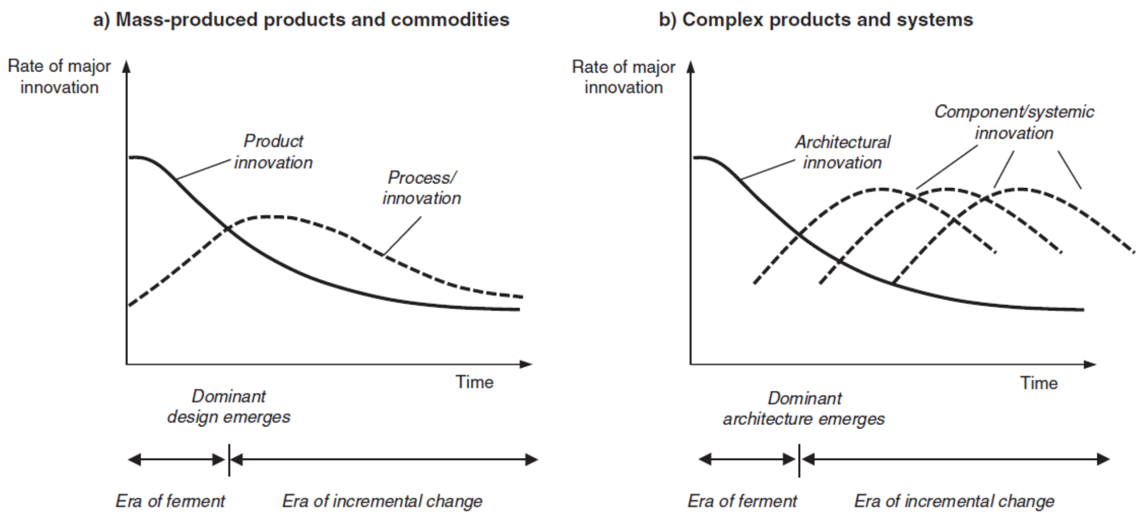


Lithium-ion



Theory

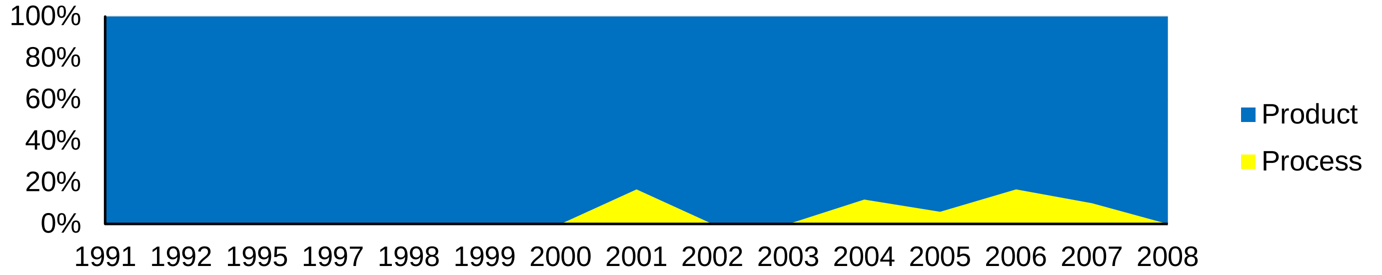
Literature on technology life-cycles	Literature on locus of learning
• Provides **technology-centered view** of innovation over the technology lifetime • Technological characteristics determine type and location of innovative activity in the technology architecture • Innovation activities differ between complex systems vs. mass produced products	• Provides **knowledge-centered view** of learning through interaction • Actors are located in industry value chains and exchange explicit and tacit knowledge • “Stickiness” of information (tacit knowledge) and locus of learning determine interactions required for technological innovation



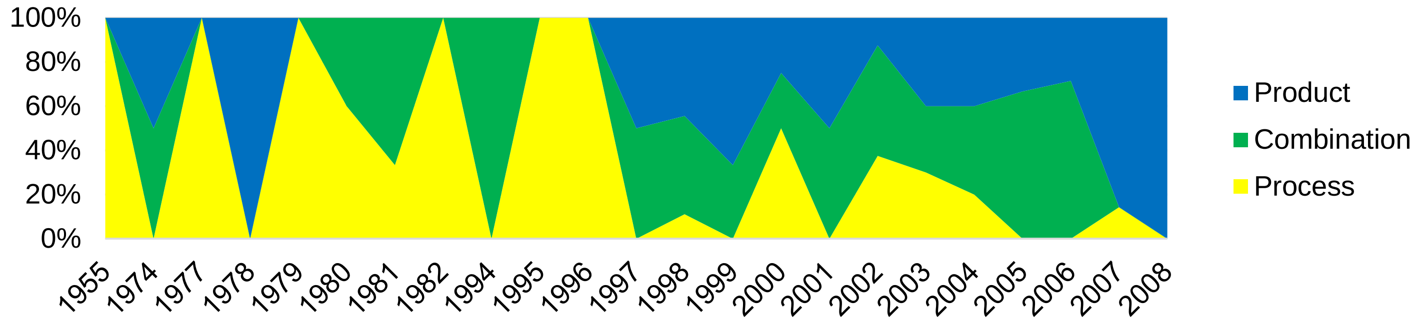
SOURCES: Huenteler, J., Schmidt, T.S., Ossenbrink, J. and Hoffmann, V.H., 2015. Technology life-cycles in the energy sector—Technological characteristics and the role of deployment for innovation. *Technological Forecasting and Social Change*; von Hippel, E. “Sticky Information” and the Locus of Problem Solving: Implications for Innovation. *Manage. Sci.* **1994**, *40* (4), 429–439.

RQ1 – The type of knowledge: product vs process knowledge (and beyond)

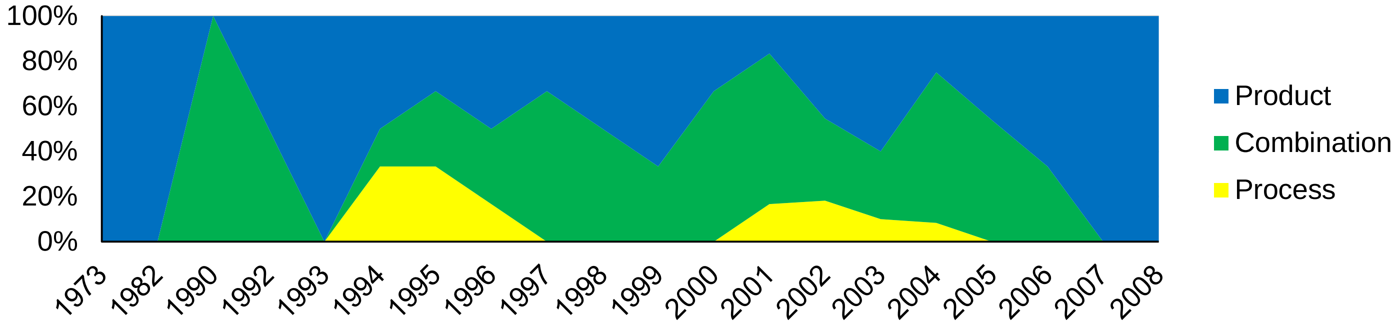
Wind



Solar PV

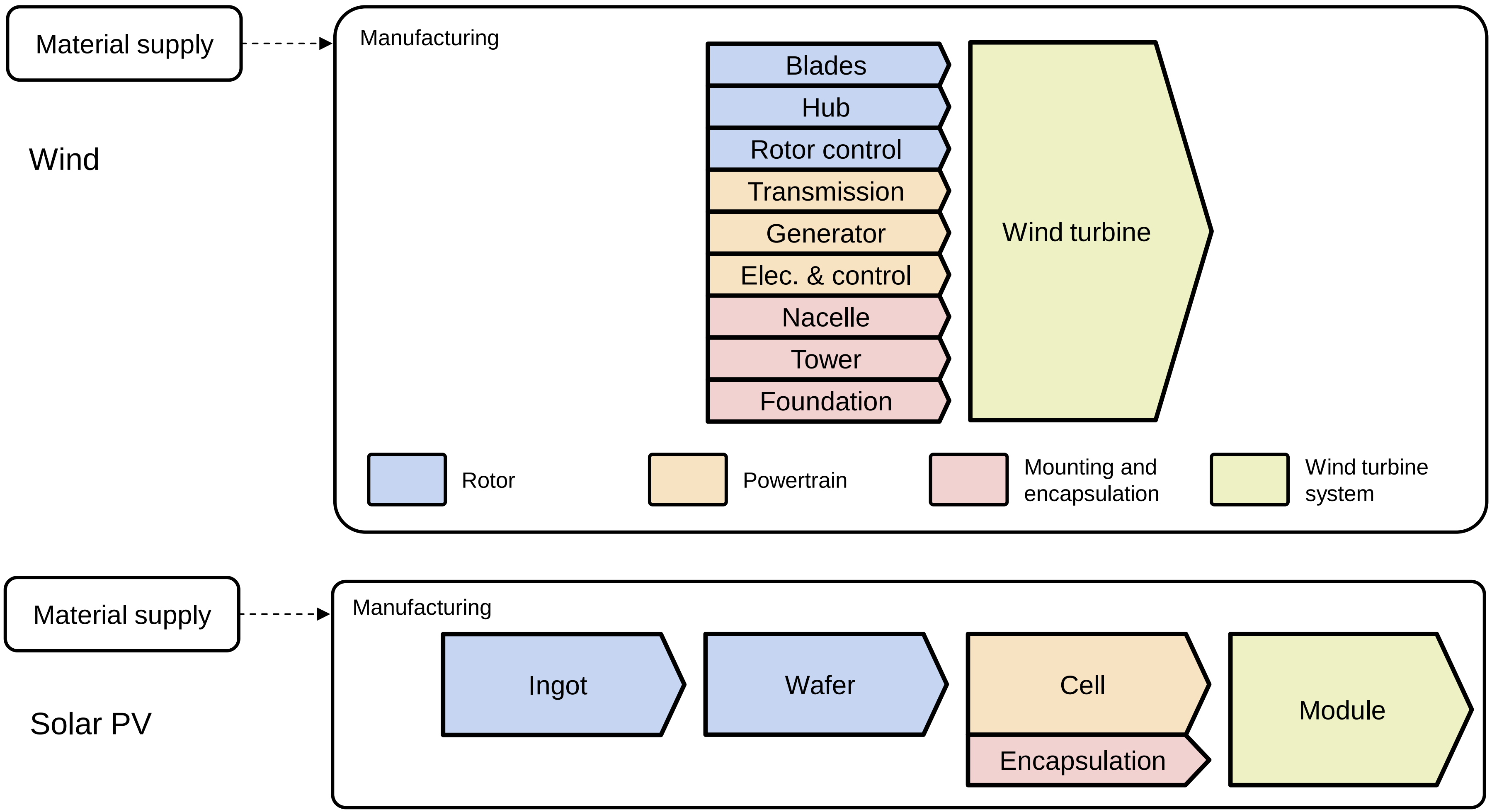


Lithium-ion



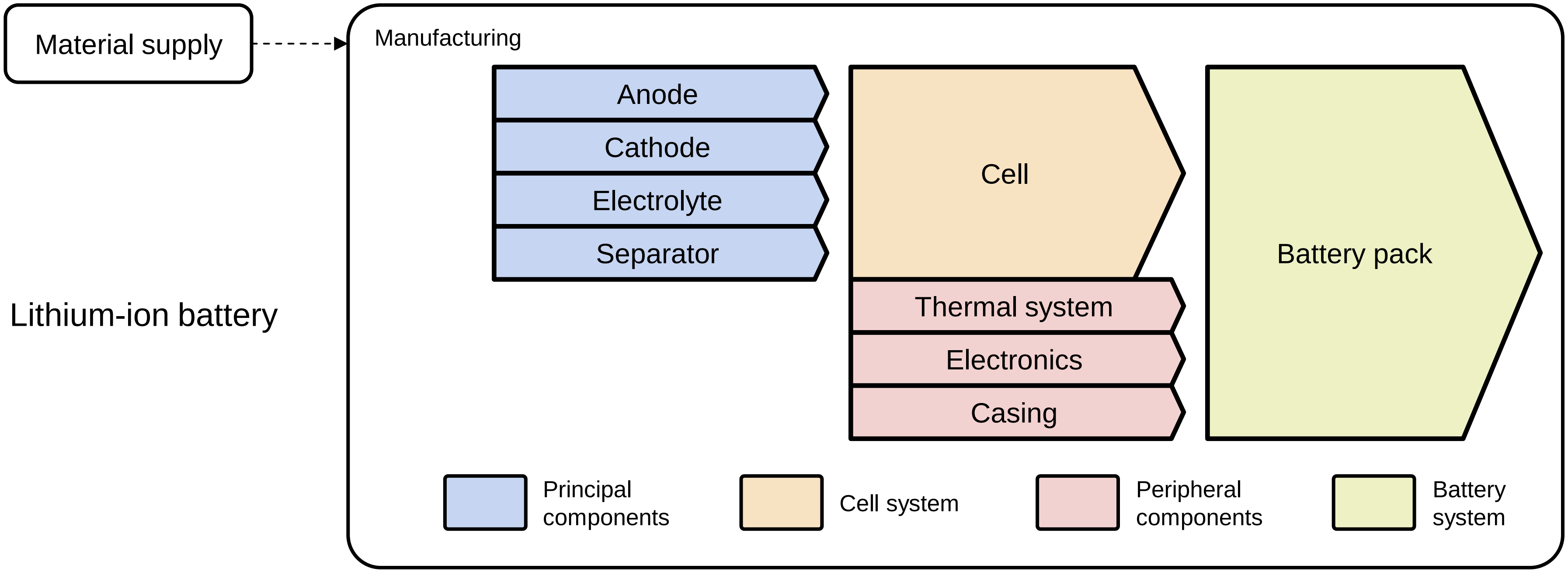
Source: EPG/ETH Zurich (ongoing study)

RQ2 – Zoom into Industry Value Chain: Solar PV and Wind



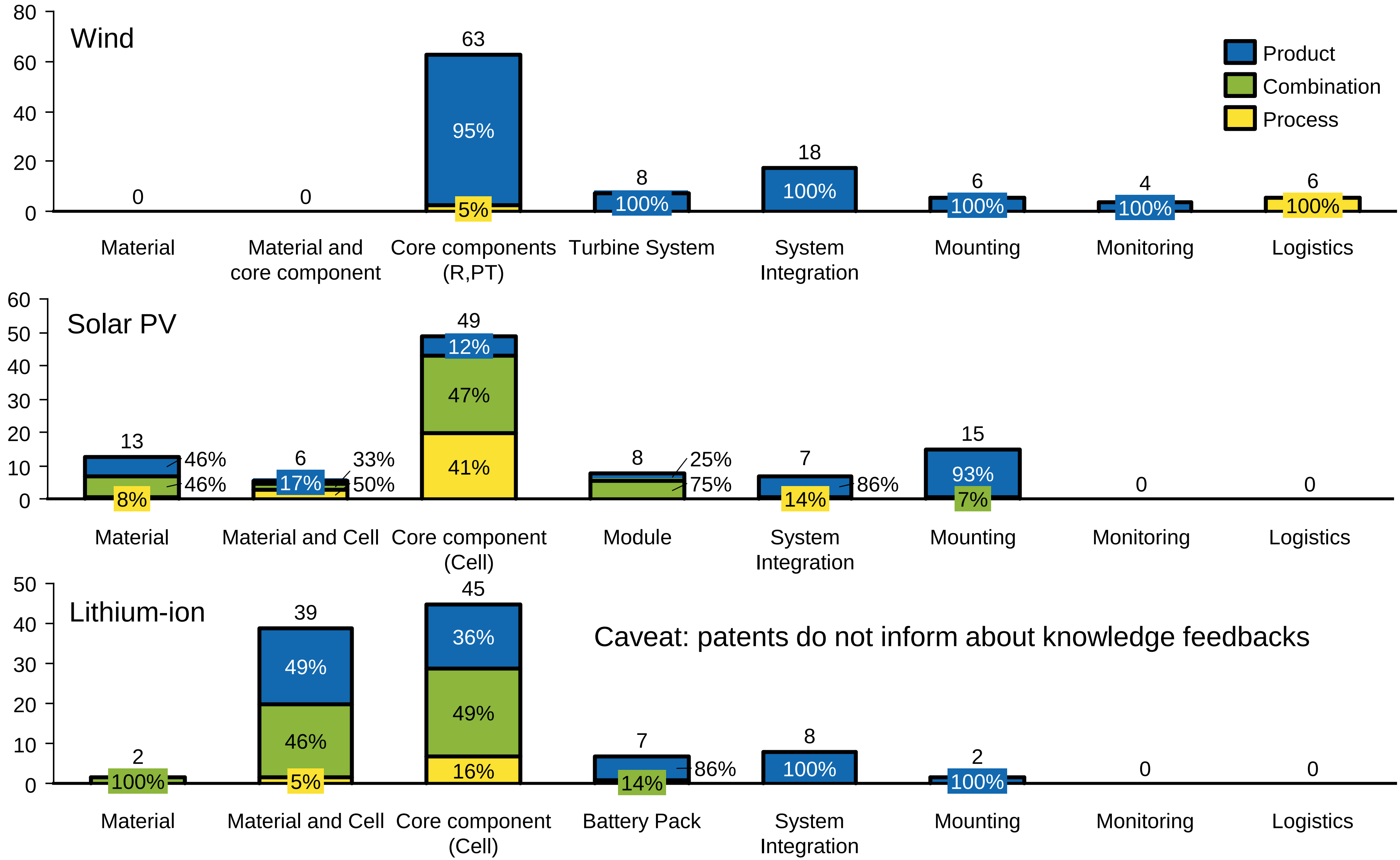
SOURCES: EPG/ETH Zurich (ongoing study) Adapted from: Zhang, F. and Gallagher, K.S., 2016. Innovation and technology transfer through global value chains: Evidence from China's PV industry. *Energy Policy*, *94*, pp.191-203; Huenteler, J., Ossenbrink, J., Schmidt, T.S. and Hoffmann, V.H., 2016. How a product's design hierarchy shapes the evolution of technological knowledge—Evidence from patent-citation networks in wind power. *Research Policy*, *45*(6), pp.1195-1217.

RQ2 – Zoom into Industry Value Chain: Li-ion batteries



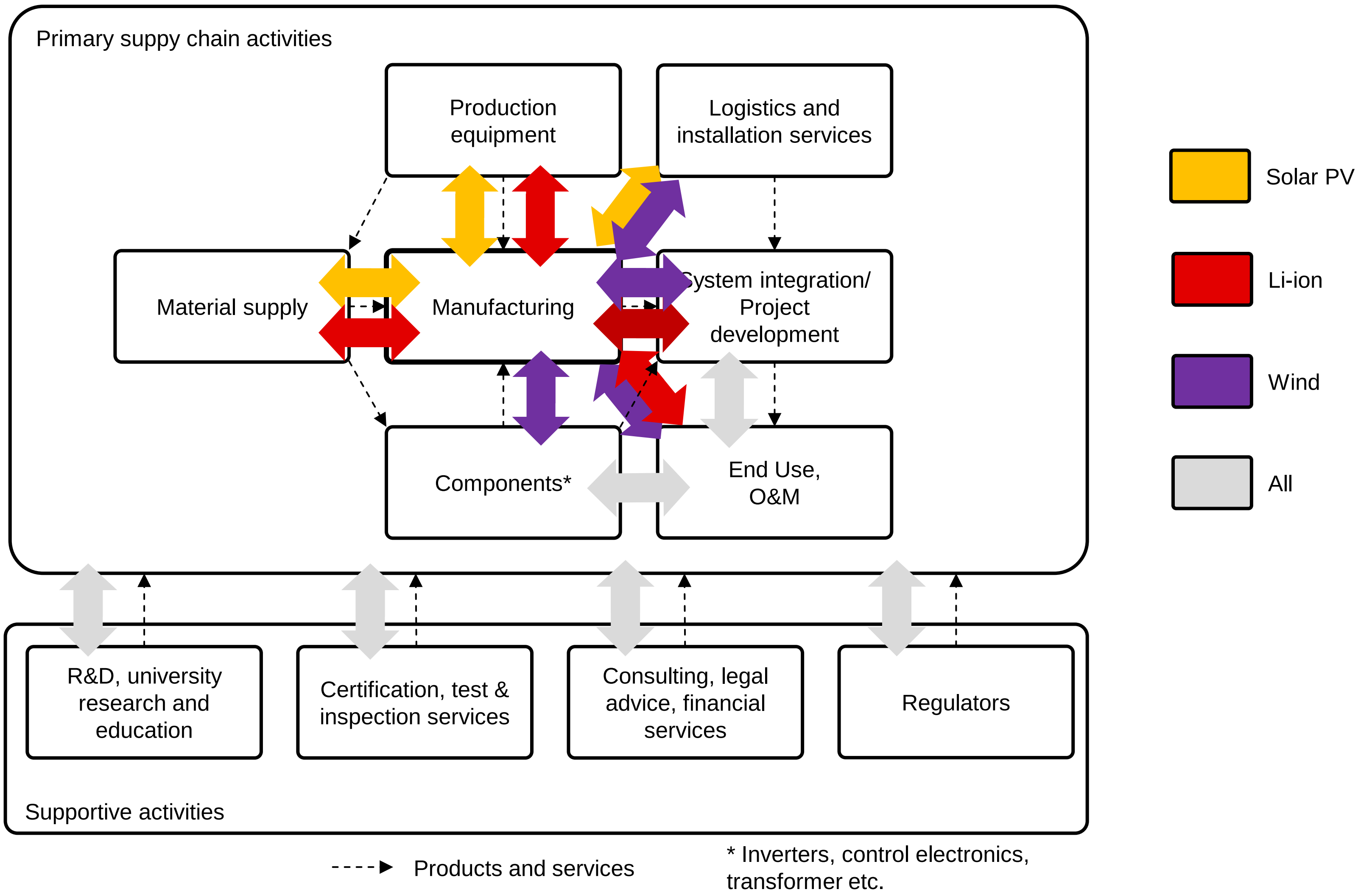
SOURCE: EPG/ETH Zurich (ongoing study)

RQ2 – Where in industry value chain does most important innovation occur?



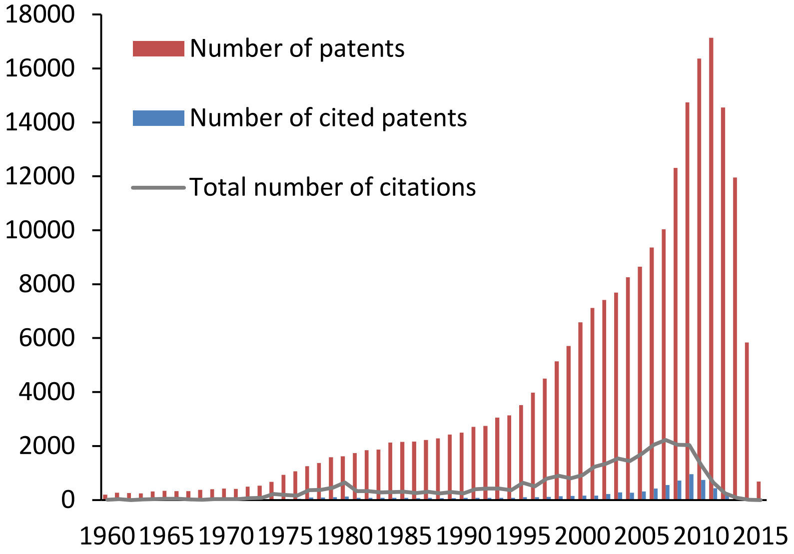
Source: EPG/ETH Zurich (ongoing study)

RQ2 – Knowledge feedbacks in industry value chain

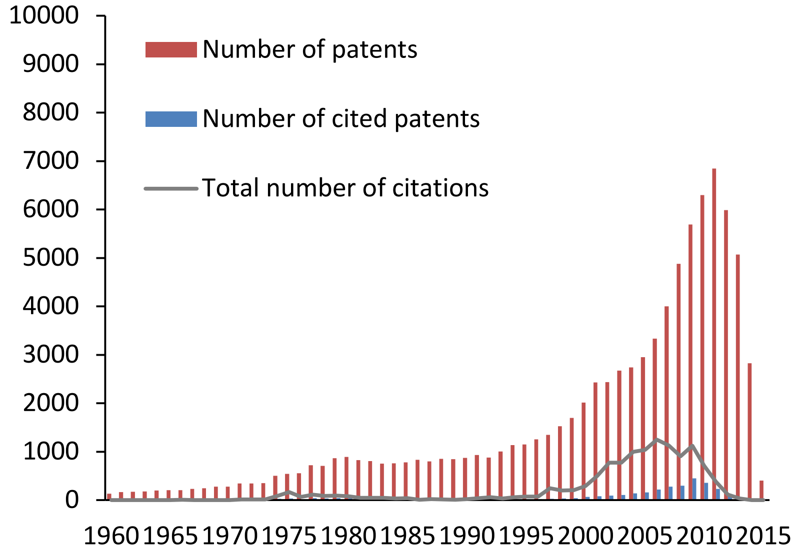


Source: EPG/ETH Zurich (ongoing study)

1. Solar PV



2. Wind



3. Lithium-ion