Semiconductors to Smart Devices

Capturing the System-Wide Impacts of a Growing Internet of Things Infrastructure

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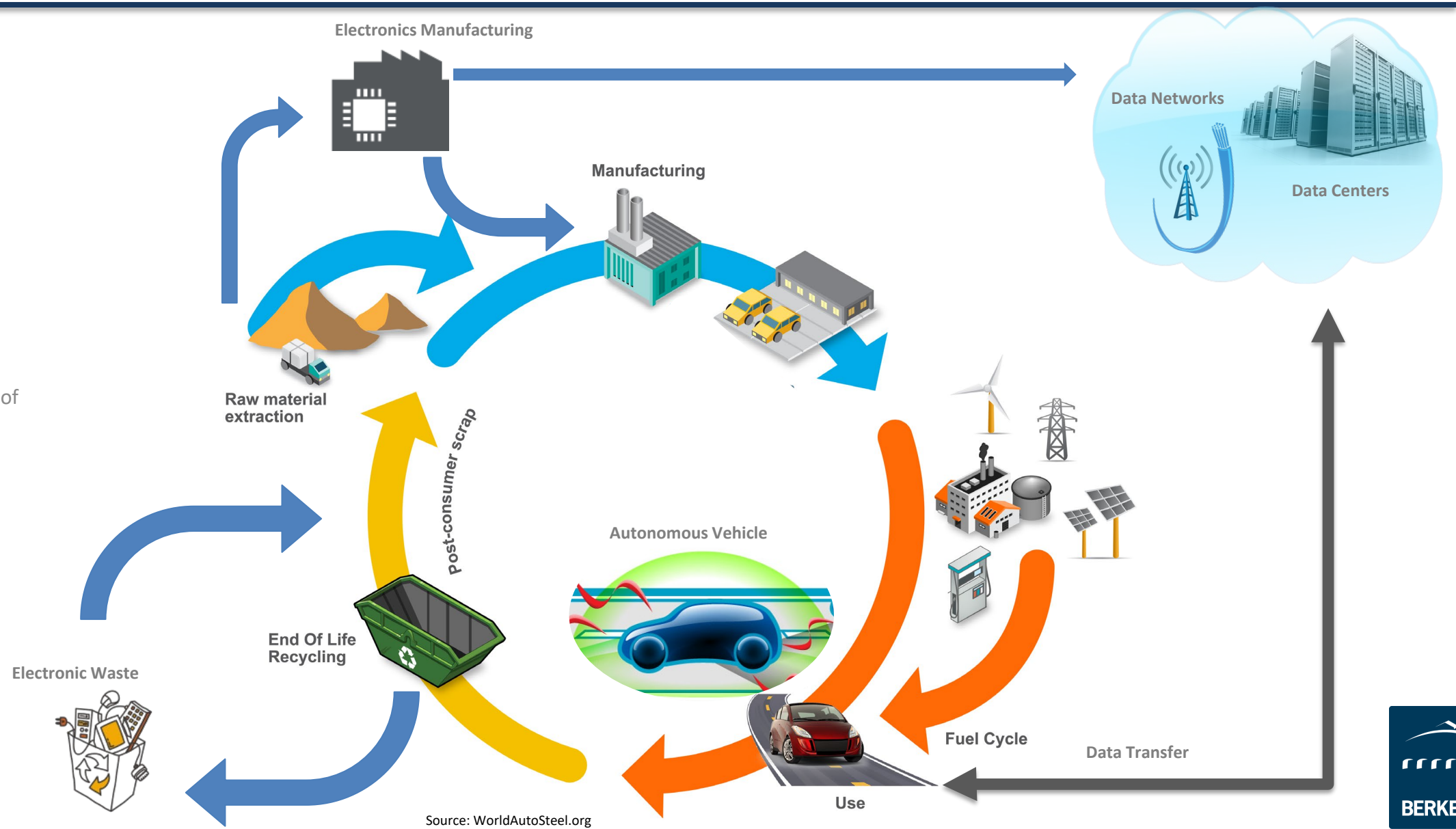
Systems-wide approach to IoT assessment

Example:
Analysis phases of
a vehicle LCA:



Source: WorldAutoSteel.org

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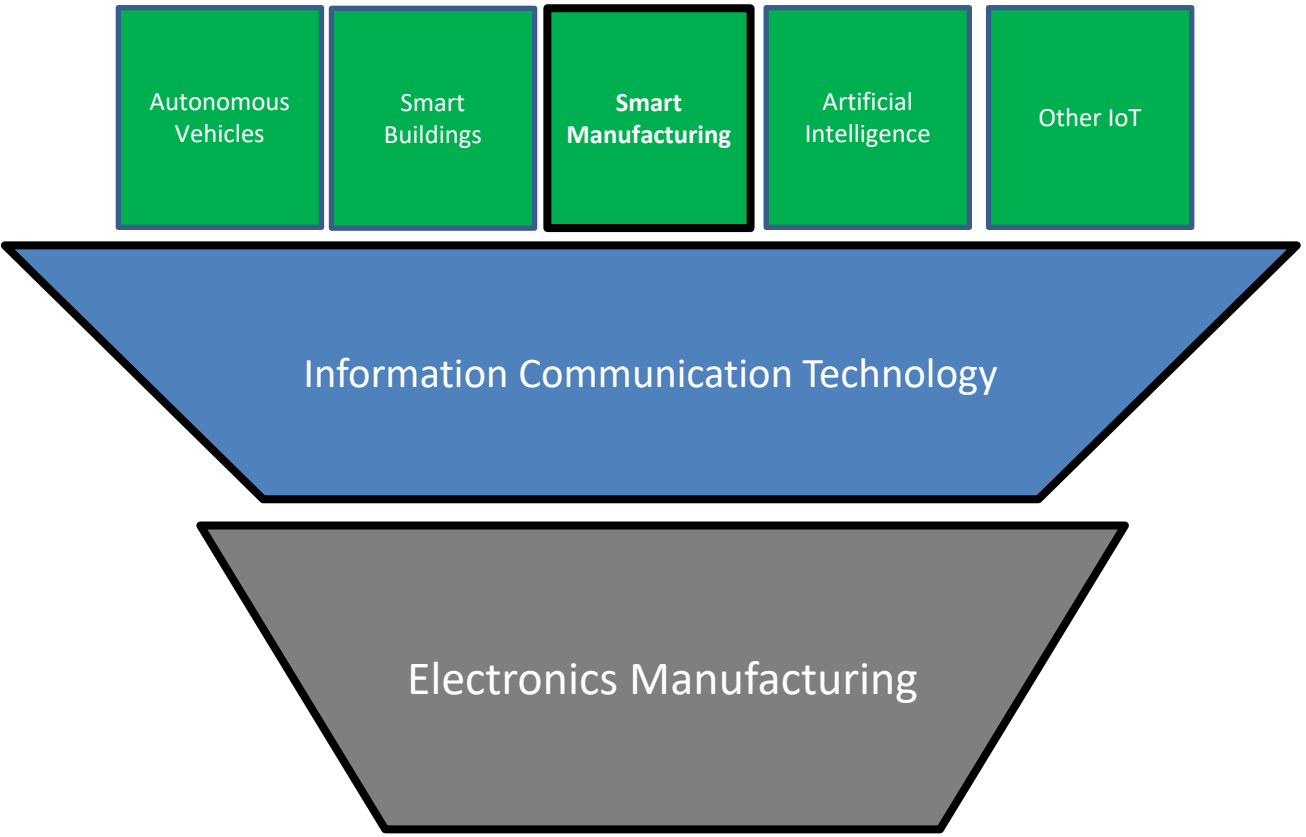
Department of Energy Report (forthcoming in 2023)

The Implications of Advanced Manufacturing in a Connected Economy
Moving Towards a Smart, Sustainable, and Productive Economy



- Chapter 1: ICT Infrastructure
  - Data center infrastructure
  - Data network infrastructure
  - Connected devices
  - Advance computational devices
- Chapter 2: Electronic Device Manufacturing
  - Life-Cycle Energy and Cost of IC Manufacturing
  - Global IC Manufacturing Supply Chain Trends and Competitiveness
  - Embodied Carbon in the U.S. computer and electronics manufacturing sector
  - EoL Management and Manufacturing Potentials of eWaste
- Chapter 3: Data Characterization Framework
- Chapter 4 Smart Manufacturing
  - Smart Manufacturing and the Internet of Things in Industry
  - Cost to Conserve Energy Framework
  - SM and IoT Tech in the Iron and Steel Industry
  - SM and IoT Tech in the Automotive Industry
  - SM Energy Savings Estimates for Other Industries

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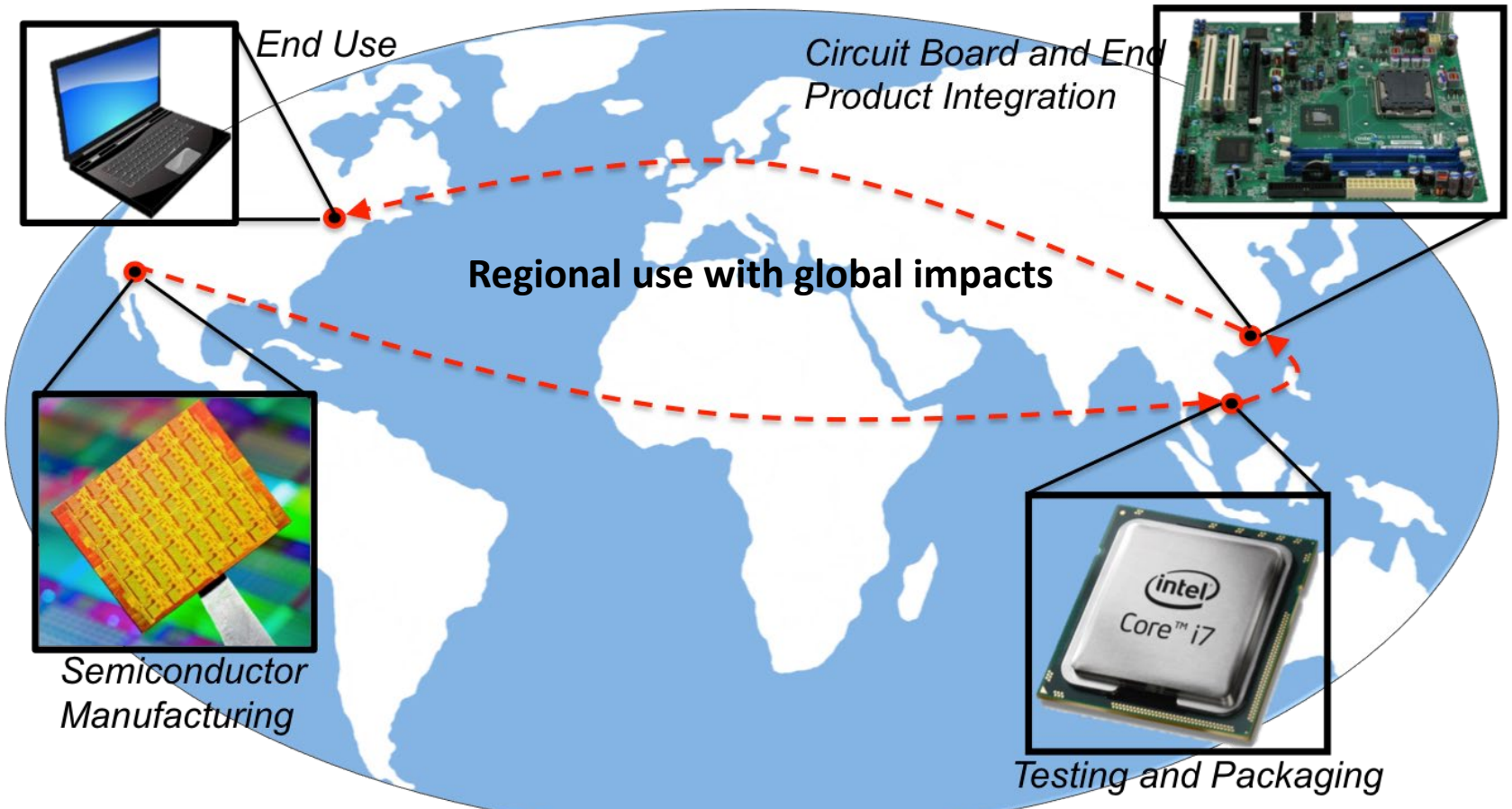
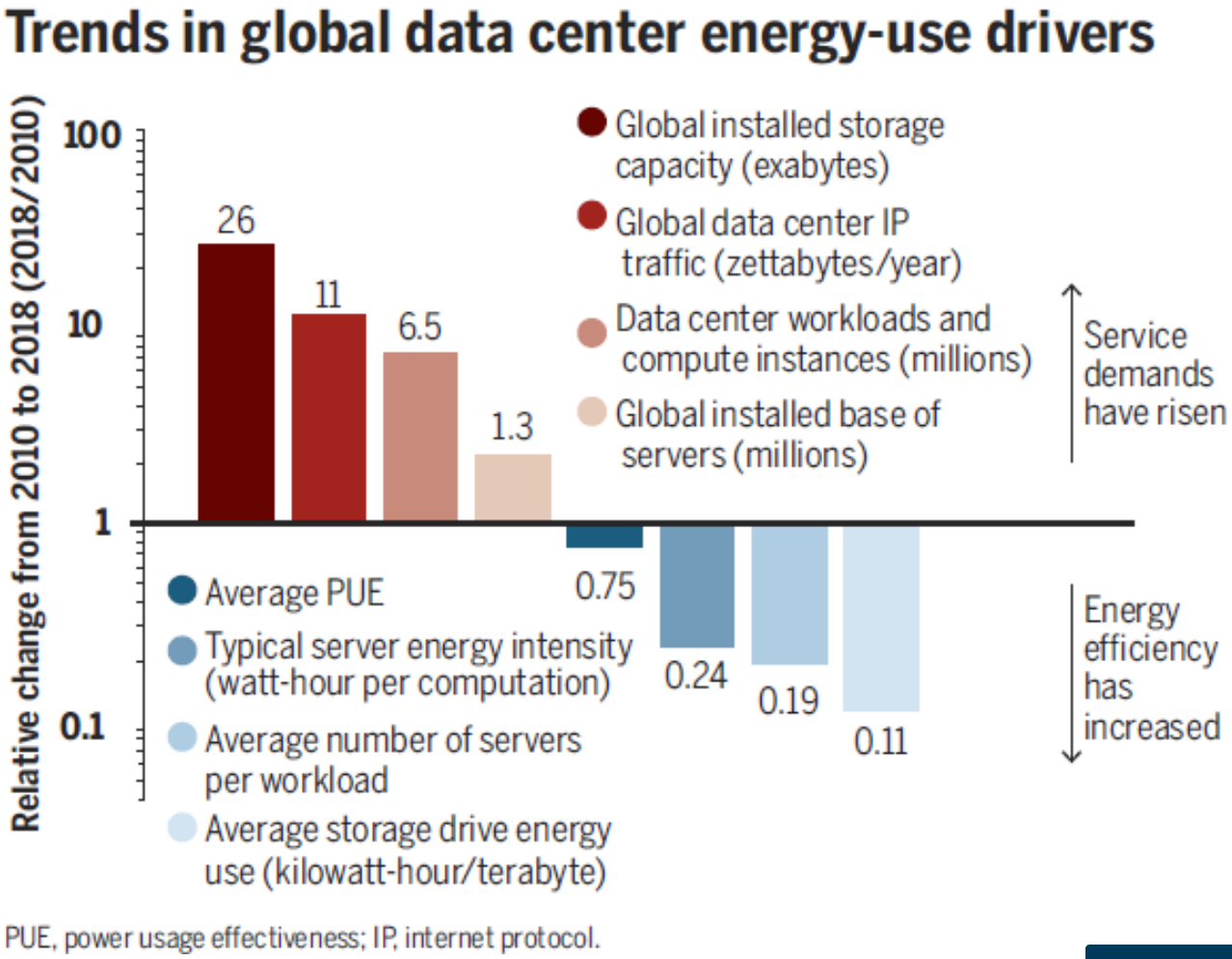
Challenge of global supply chains

- Manufacturing of electronic components crosses multiple boarders
- Limited data on manufacturing energy/material use
- Proprietary manufacturing practices



Challenge of a rapidly evolving technology

- **Computer processor efficiency**
  - Peak output efficiency doubled energy 1.5 years since 1950s[1]
  - More recently efficiency doubling takes 2.7 years[2]
- **Electricity intensity of data transmission**
  - Observed kWh/GB transfer has decreased by half every 2 years[3]
- **Data center workloads and energy**
  - From 2010 to 2018 power demands rose just **six percent** in the time it took for compute instances to jump **550 percent**[4]



Sources:

[1]Koomey et al 2011. *Implications of historical trends in the electrical efficiency of computing*. IEEE Annals of the History of Computing

[2]Koomey & Naffziger 2015. *Moore's Law might be slowing down, but not energy efficiency*. IEEE Spectrum.

[3]Aslan et al, 2018. *Electricity intensity of Internet data transmission: Untangling the estimates*. Journal of Industrial Ecology

[4]Masanet, E., Shehabi, A., Lei, N., Smith, S. and Koomey, J., 2020. Recalibrating global data center energy-use estimates. *Science*

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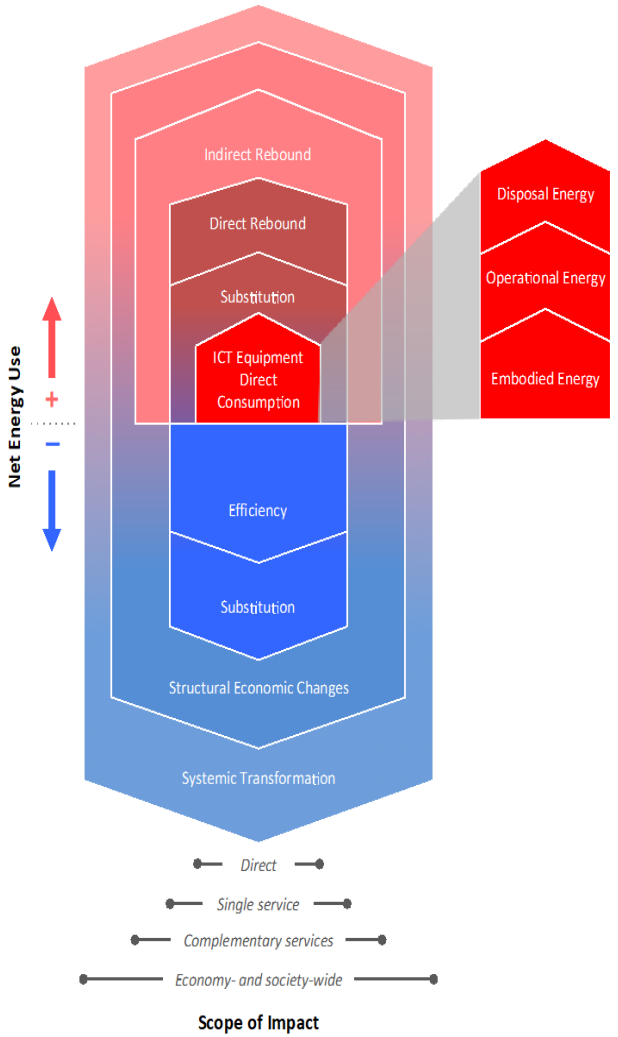
Challenge of consequential implications

- **Direct ICT equipment impacts**
  - Operation energy
  - Embodied resource
  - Disposal
- **Direct ICT application impacts**
  - Efficiency
  - Substitution
  - Direct rebound
- **Indirect ICT application impacts**
  - Indirect rebound
- **Structural economic changes**
- **Systematics transformation**

Taxonomy of ICT energy effects

Red effects increase energy use, blue effects decrease energy use, and shading intensity decreases as effect scope increases



Horner et al., 2016, *Known unknowns: Indirect energy effects of information and communication technology*. Environ. Res. Lett

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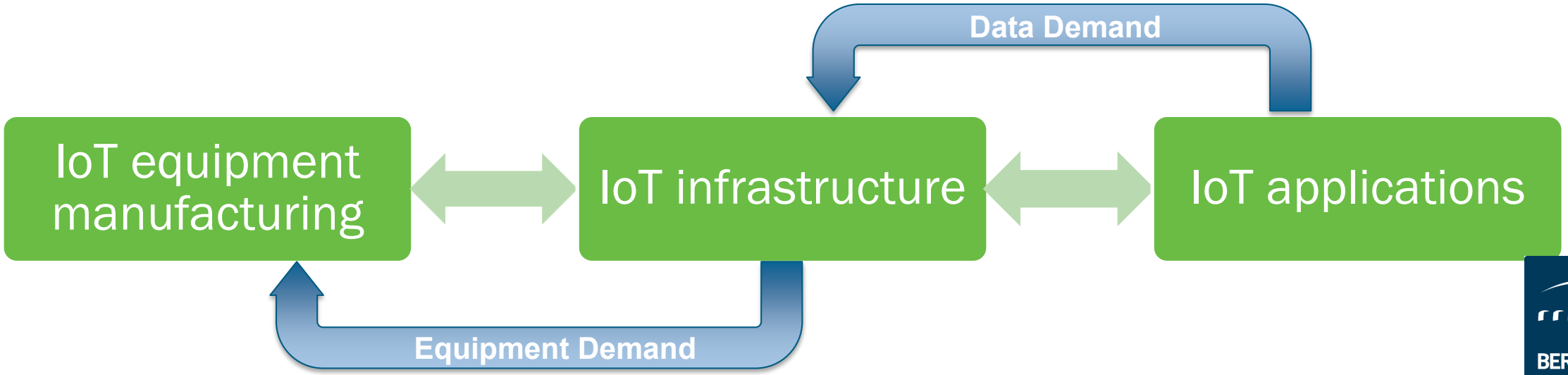
Initial questions around of IoT assessment

- **Sector level IoT applications, growth, and effects**
  - –Smart Cities, Smart Manufacturing, Smart Buildings, etc.
- **Equipment & infrastructure needs to meet IoT applications**
- **Manufacturing requirements to meet equipment & infrastructure needs**



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