Accelerating future energy transitions

Invited Presentation to the "Radical Innovation" Workshop of Energy Transition Week, NTNU, Trondheim, Norway, March 1, 2018

Benjamin K. Sovacool, Ph.D

Professor of Energy Policy

Director of the Sussex Energy Group

Director of the Center on Innovation and Energy Demand

Conceptualizing energy transitions

Energy Research & Social Science 13 (2016) 202–215

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

How long will it take? Conceptualizing the temporal dynamics of energy transitions☆

Benjamin K. Sovacool[a,b,*]

Conceptualizing energy transitions

Centre on Innovation and Energy Demand

- What is an energy transition?
  - Change in fuel supply?
  - Shift in technologies that exploit fuel, e.g. prime movers end use devices?
  - Switch from an economic or regulatory system (e.g. Cuba)?
  - Time taken for socio-technical diffusion?
  - At what scale?

Table 1
Five definitions of energy transitions.

Definition	Source
A change in fuels (e.g., from wood to coal or coal to oil) and their associated technologies (e.g., from steam engines to internal combustion engines)	Hirsh and Jones [22]
Shifts in the fuel source for energy production and the technologies used to exploit that fuel	Miller et al. [23]
A particularly significant set of changes to the patterns of energy use in a society, potentially affecting resources, carriers, converters, and services	O'Connor [24]
The switch from an economic system dependent on one or a series of energy sources and technologies to another	Fouquet and Pearson [25]
The time that elapses between the introduction of a new primary energy source, or prime mover, and its rise to claiming a substantial share of the overall market	Smil [26]

Conceptualizing energy transitions

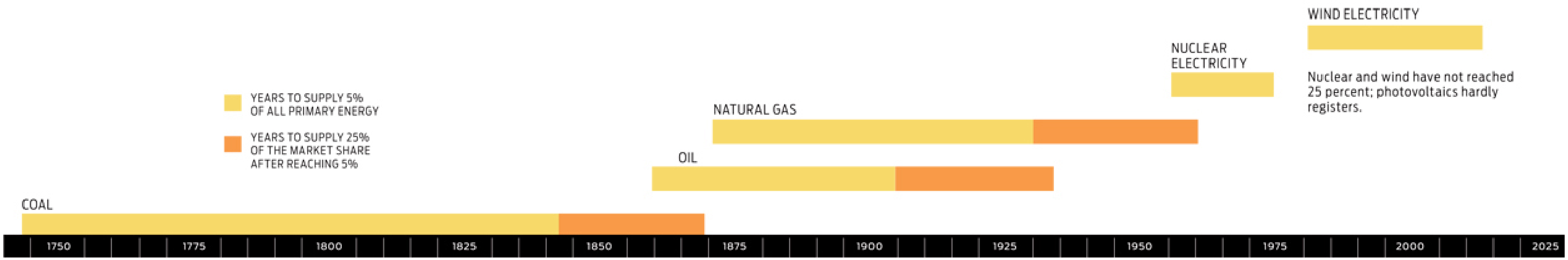
Centre on Innovation and Energy Demand

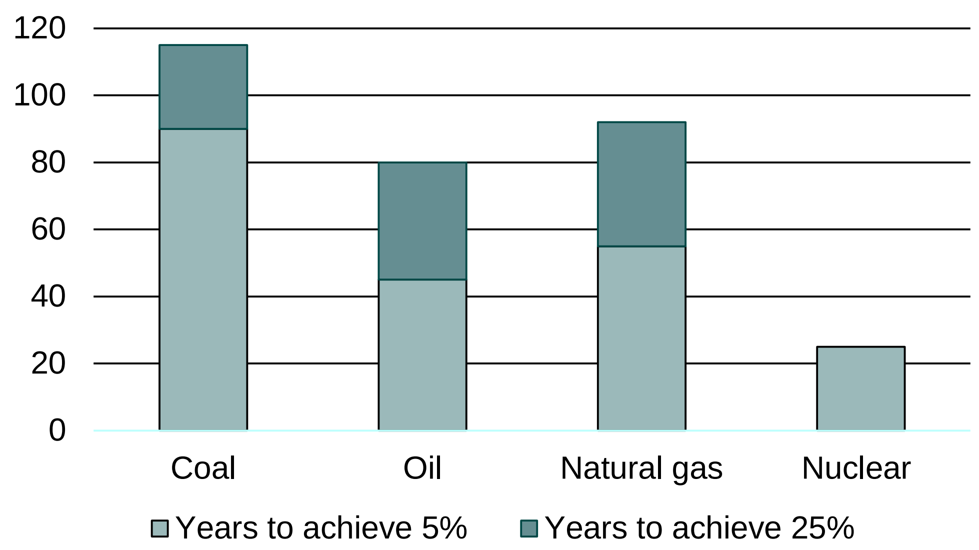
- What does the academic literature say?
- *"Energy transitions have been, and will continue to be, inherently prolonged affairs, particularly so in large nations whose high levels of per capita energy use and whose massive an expensive infrastructures make it impossible to great accelerate their progress even if we were to resort to some highly effective interventions …"*

Table 2
The differences in timing and speed of energy transitions in Europe.

Phase-out traditional renewables phase-in coal:		Diffusion midpoint	Diffusion speed
Core	England	1736	160
Rim	Germany	1857	102
	France	1870	107
	Netherlands	1873	105
Periphery	Spain	1919	111
	Sweden	1922	96
	Italy	1919	98
	Portugal	1949	135
Phase-out coal phase-in oil/gas/electricity:			
Core	Portugal	1966	47
	Italy	1960	65
	Sweden	1963	67
Rim	Spain	1975	69
	Netherlands	1962	62
	France	1972	65
Periphery	Germany	1984	50
	England	1979	67

Conceptualizing energy transitions





Conceptualizing energy transitions

Centre on Innovation and Energy Demand

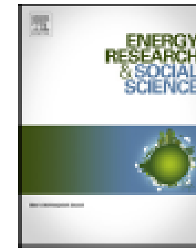
Energy Research & Social Science 22 (2016) 18–25

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

ELSEVIER



Short communication

Apples, oranges, and consistent comparisons of the temporal dynamics of energy transitions

CrossMark

Arnulf Grubler[a,b,*], Charlie Wilson[a,c], Gregory Nemet[d]

Conceptualizing energy transitions

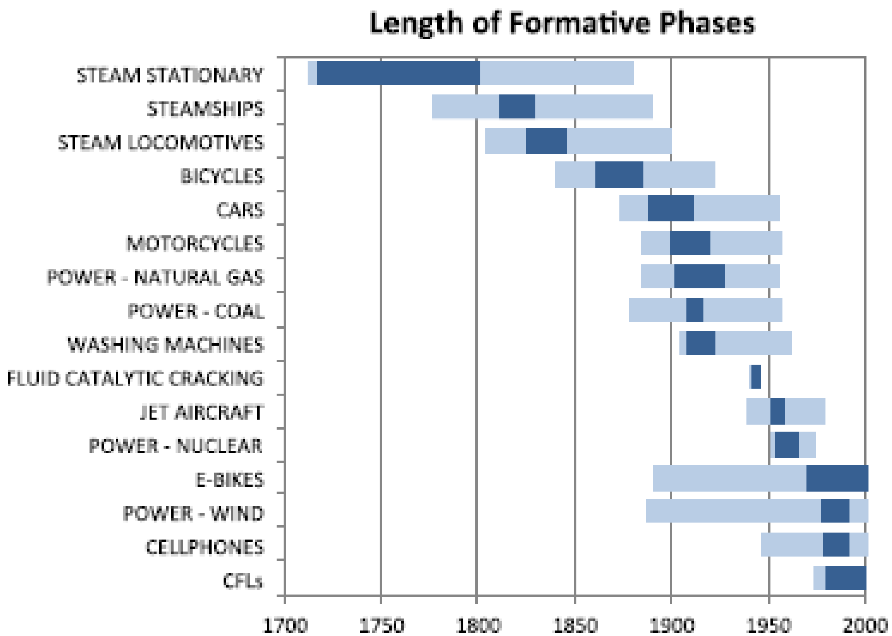


Fig. 1. Durations of formative phases for energy technologies are at a decadal scale [4]. Note: Ranges refer to alternative definitions for the start and end points of formative phases, and so capture measurement uncertainties.

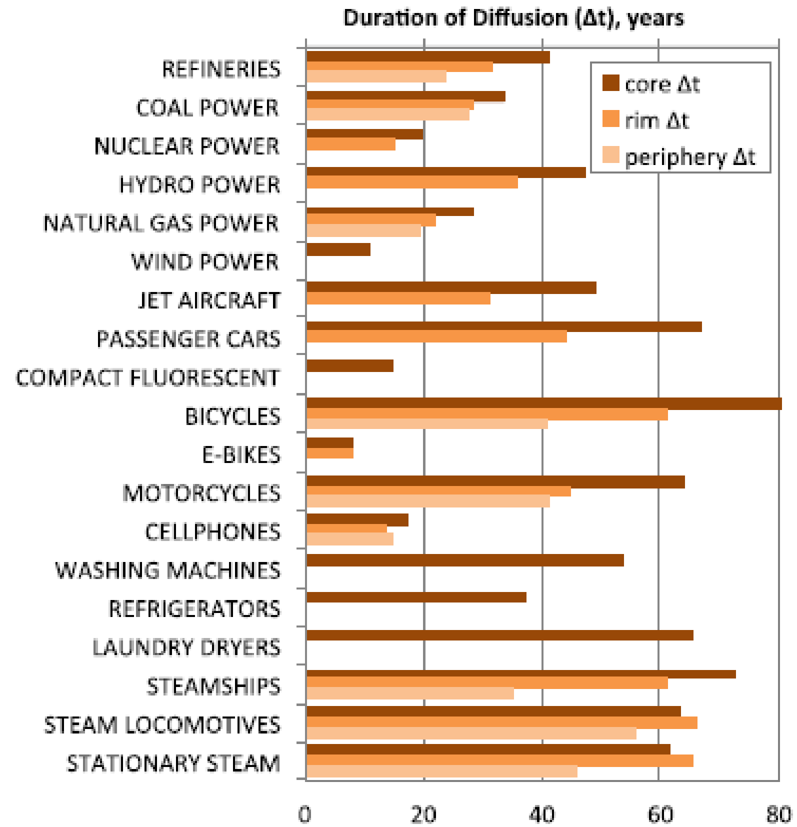
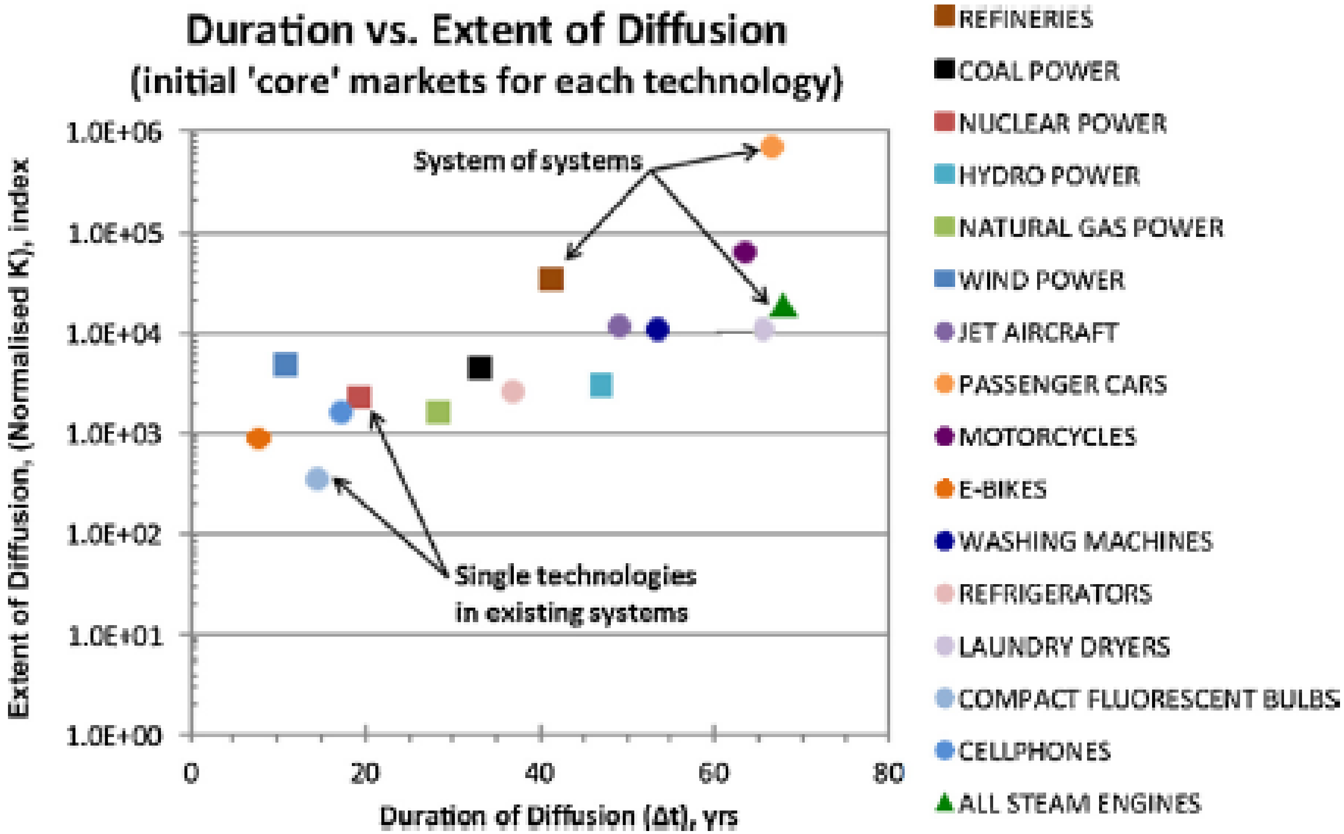


Fig. 2. Diffusion speeds accelerate as technologies diffuse spatially. Notes: Bars show durations of diffusion measured by cumulative total capacity installed, with historical data fitted via a logistic growth curve and the diffusion duration expressed as Δ t in years. 'Core' is typically within the OECD; 'Rim' is typically Asian countries; 'Periphery' is typically other world regions. For details and data, see: [42,3].

Conceptualizing energy transitions

Centre on Innovation and Energy Demand



Diffusion durations scale with market size. Notes: X-axis shows duration of diffusion (t) measured in time to grow from 10% to 90% of cumulative total capacity; y-axis shows extent of diffusion normalized for growth in system size. All data are for ‘core’ innovator markets. Round symbols denote end-use technologies; square technologies denote energy supply technologies; triangular symbol denotes general purpose technologies (steam engines). Arrows show illustrative examples of system of systems (refineries describing the rise of multiple oil uses across all sectors, cars describing the concurrent growth of passenger cars, roads, and suburbs, and steam engines are a proxy of the growth of all coal-related technologies in the 19th century). Arrows also highlight examples of single technologies diffusing into existing systems substituting existing technologies (nuclear power, compact fluorescent light bulbs).

Rethinking transitions

Centre on Innovation and Energy Demand

- We have seen at least five fast transitions in terms of energy end-use and prime movers
- Examples of many rapid national-scale transitions in energy supply also populate the historical record

Table 4
Overview of rapid energy transitions.

Country	Technology/fuel	Market or sector	Period of transition	Number of years from 1 to 25% market share	Approximate size (population affected in millions of people)
Sweden	Energy-efficient ballasts	Commercial buildings	1991–2000	7	2.3
China	Improved cookstoves	Rural households	1983–1998	8	592
Indonesia	Liquefied petroleum gas stoves	Urban and rural households	2007–2010	3	216
Brazil	Flex-fuel vehicles	New automobile sales	2004–2009	1	2
United States	Air conditioning	Urban and rural households	1947–1970	16	52.8
Kuwait	Crude oil and electricity	National energy supply	1946–1955	2	0.28
Netherlands	Natural gas	National energy supply	1959–1971	10	11.5
France	Nuclear electricity	Electricity	1974–1982	11	72.8
Denmark	Combined heat and power	Electricity and heating	1976–1981	3	5.1
Canada (Ontario)[a]	Coal	Electricity	2003–2014	11	13

[a] The Ontario case study is the inverse, showing how quickly a province went from 25% coal supply to zero.

Rethinking transitions

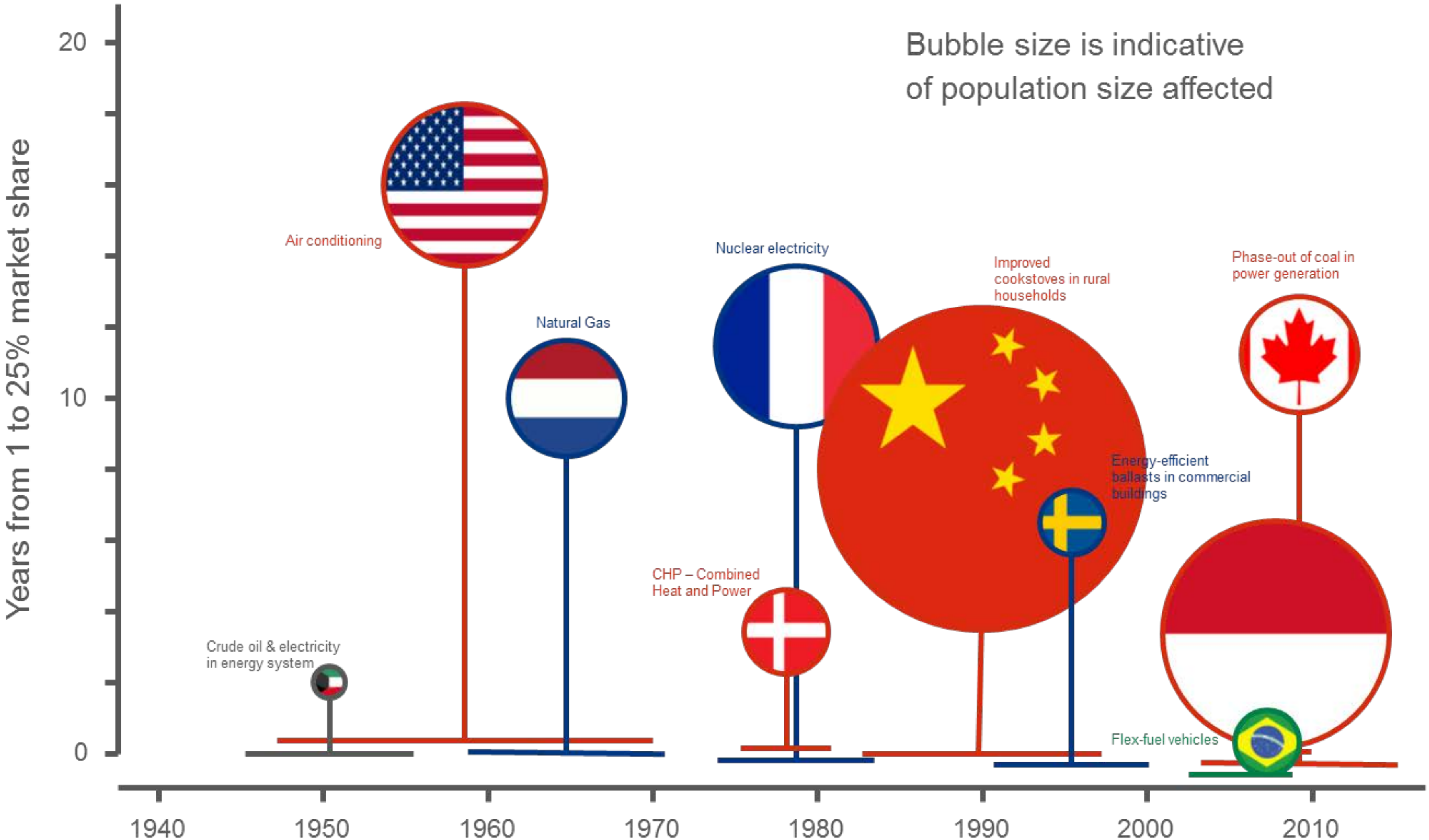


Figure designed by Gert Jan Kramer, used with permission

Rethinking transitions

Centre on Innovation and Energy Demand

Energy Research & Social Science 22 (2016) 13–17

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

ELSEVIER

Short communication

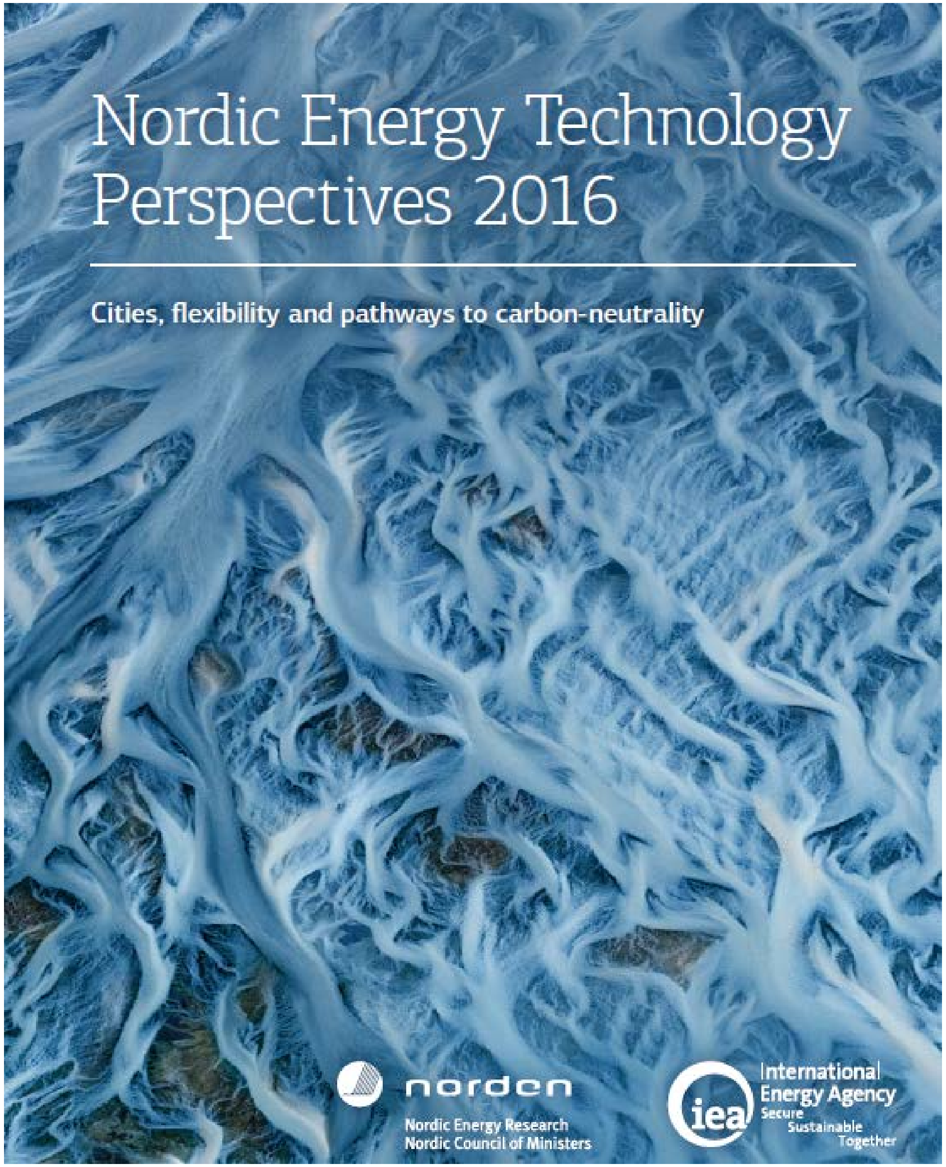
The pace of governed energy transitions: Agency, international dynamics and the global Paris agreement accelerating decarbonisation processes?

Florian Kern[a,*], Karoline S. Rogge[a,b]

- Historic energy transitions have not been consciously governed, whereas today a wide variety of actors is engaged in active attempts to govern the transition towards low carbon energy systems
- International innovation dynamics can work in favor of speeding up the global low-carbon transition.
- The 2015 Paris agreement demonstrates a global commitment to move towards a low carbon economy for the first time

Rethinking transitions

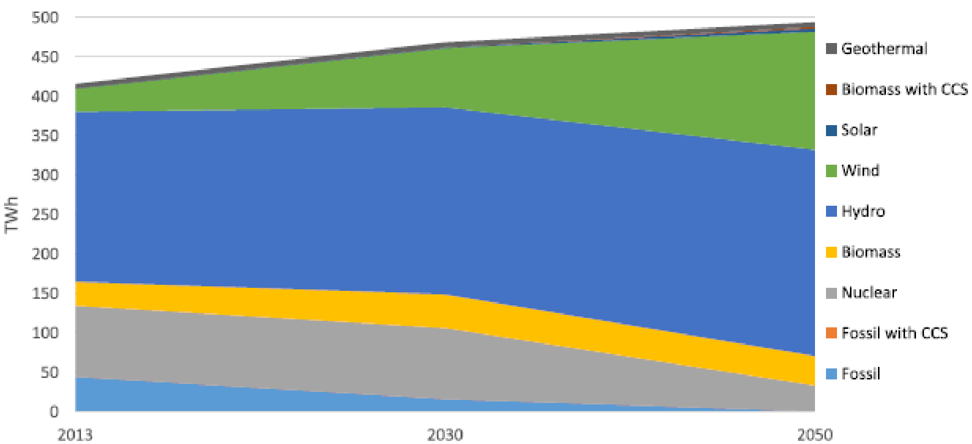
Centre on Innovation and Energy Demand



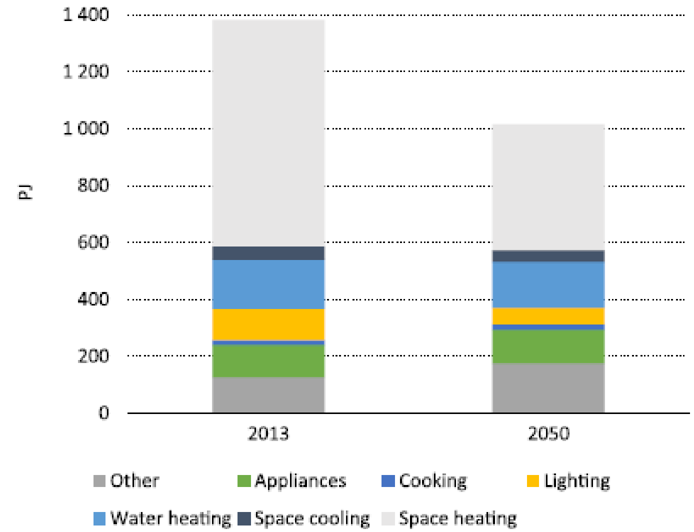
Rethinking transitions: electricity, heat, and buildings

Centre on Innovation and Energy Demand

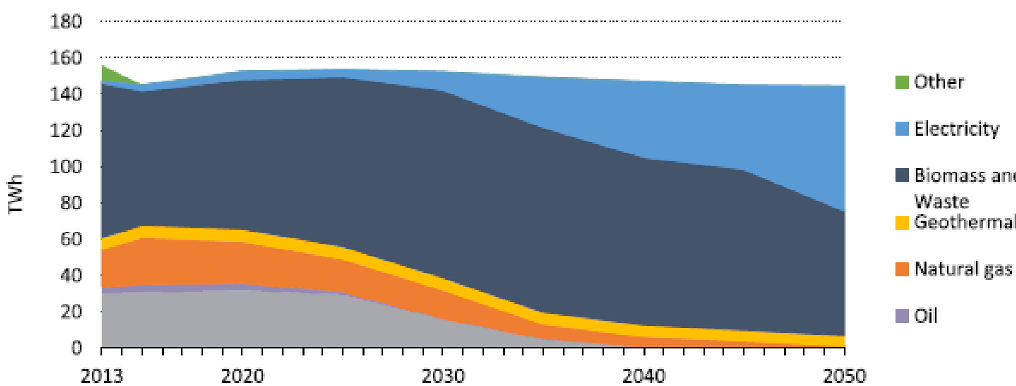
a. Top panel: Electricity generation



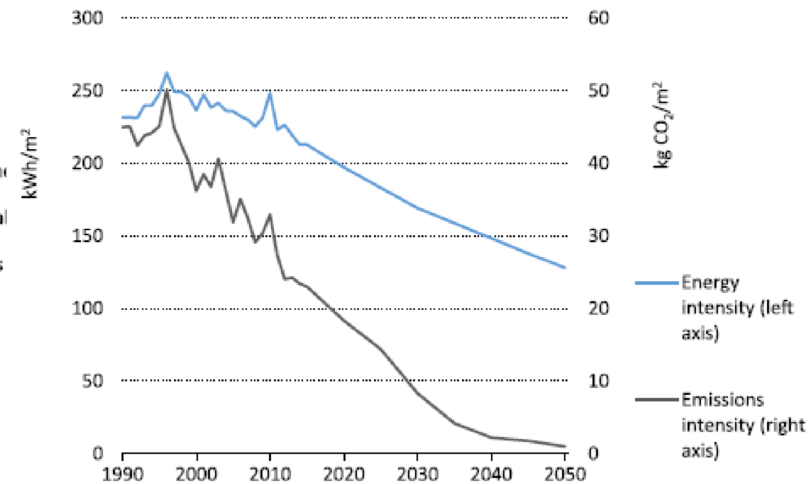
a. Top panel: Buildings energy consumption, 2013 and 2050



b. Bottom panel: heat supply



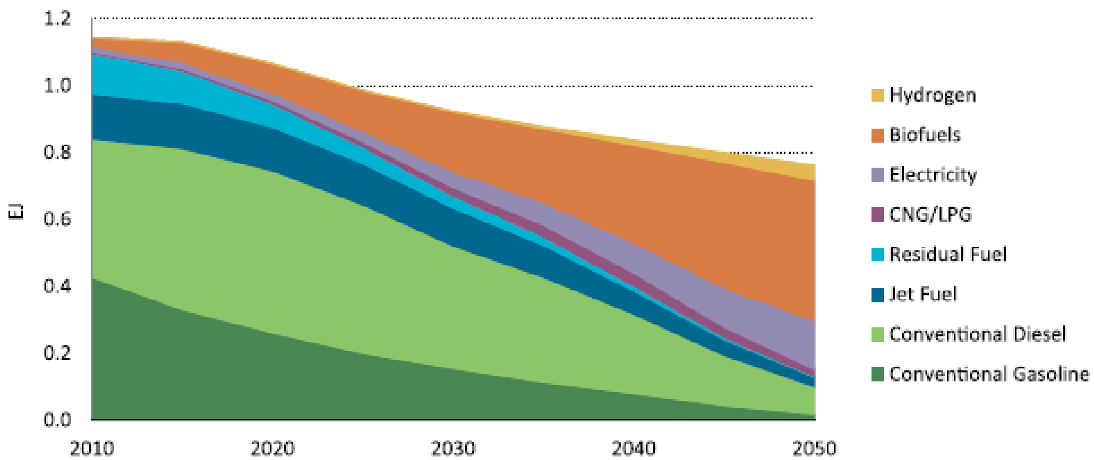
b. Bottom panel: Energy intensity and emission intensity, 1990 to 2050



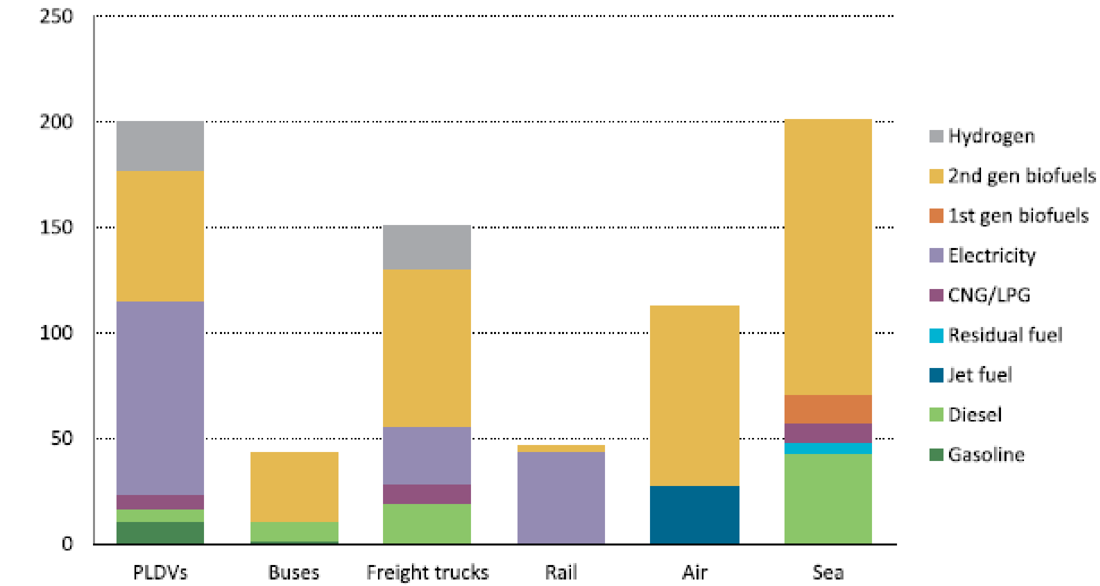
Rethinking transitions: transport fuel

Centre on Innovation and Energy Demand

a. *Top panel: by fuel source, 2010-2050*



b. *Bottom panel: by transportation mode, 2050*



Rethinking transitions: industrial emissions

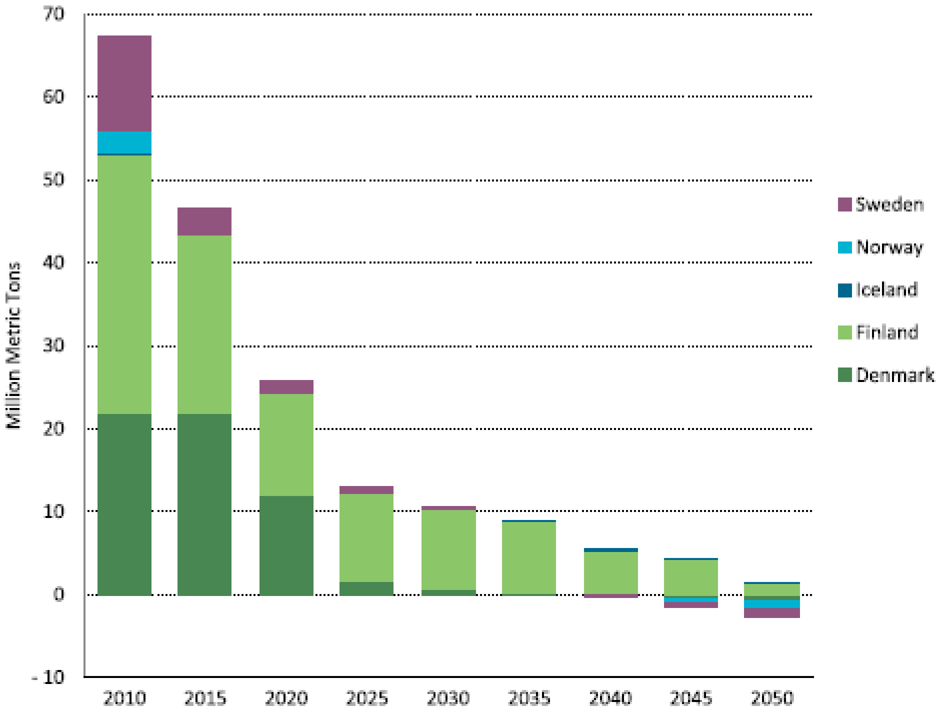
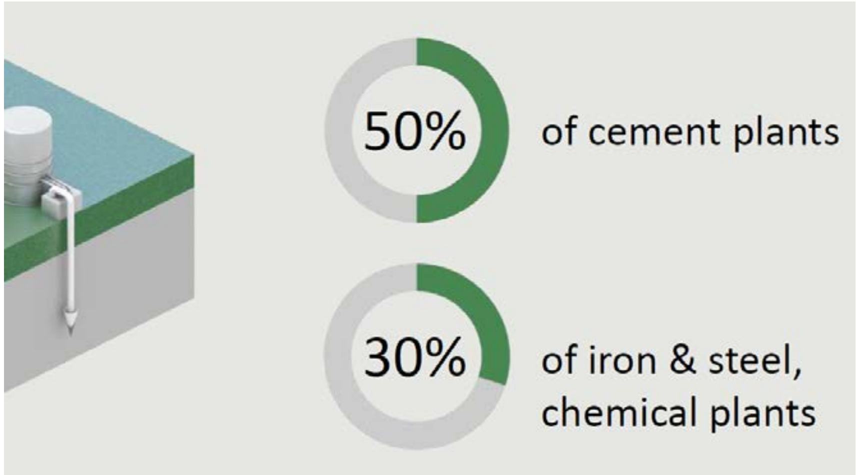


Fig. 11. Nordic Carbon Dioxide Emissions by Country, 2010–2050.

CCS utilization by 2050:



Rethinking transitions

Centre on Innovation and Energy Demand

Energy Policy 102 (2017) 569–582

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

ELSEVIER

ENERGY POLICY

Contestation, contingency, and justice in the Nordic low-carbon energy transition

CrossMark

Benjamin K. Sovacool[a,b,*]

Table 3

Cumulative Nordic Investments for Decarbonization by Sector, 2016–2050.

Source: Modified from International Energy Agency and Nordic Energy Research, Nordic Energy Technology Perspectives 2016 (Paris: OECD, 2016). Assumes the Carbon Neutral Scenario.

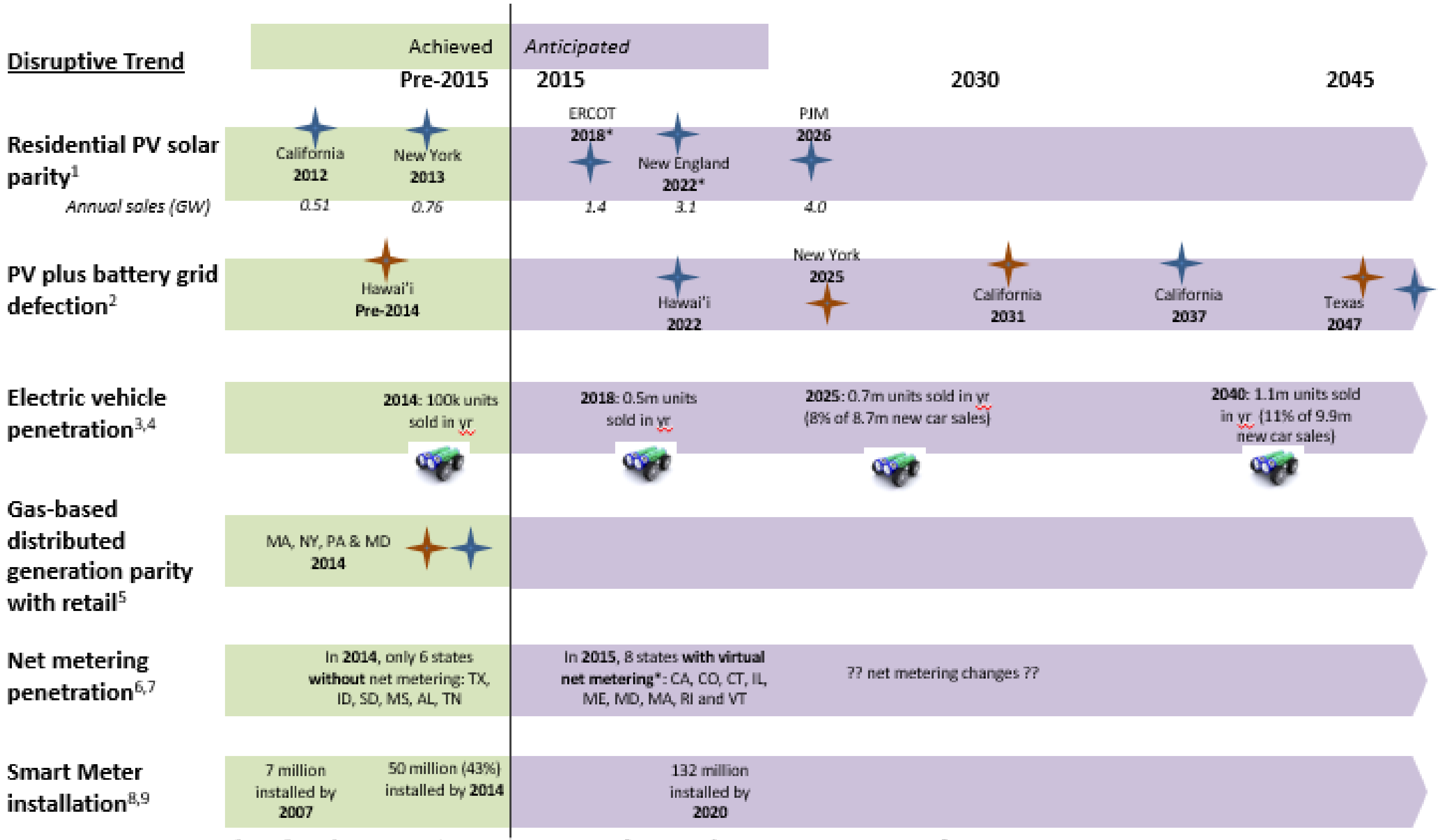
Sector	$ (USD Billion)
Energy-related investments in buildings	326
Industry	103
Transport: vehicles	1,674
Transport: infrastructure	1,121
Power: generation	197
Power: infrastructure	151
Total	3,572

- The total cost of the Nordic transition is roughly $3.57 trillion
- It requires an additional investment of only $333 billion
- This is less than 1% of cumulative GDP over the period
- If you monetize air pollution and fuel savings, it tips the economic equation firmly in favour of the transition

Rethinking transitions

The energy transition is already happening?

Centre on Innovation and Energy Demand



[1] Bloomberg New Energy Finance; [2] EPRI; [3] UBS; [4] U.S. Energy Information Administration; [5] GDF SUEZ; [6] Renewable Energy World.com; [7] Seia.org; [8] IIE; [9] Telefonica

* Enables multiple homeowners to participate in the same metering system and share the output from a single facility that is not physically connected to their property or meter

Residential

Commercial

67 STARTUPS MAKING YOUR HOME SMARTER

PET & BABY MONITOR
- Petnet
- iBaby
- Petcube
- nanit
- sevenhugs
- LULLY

APPLIANCES & AUDIO DEVICES
- hiku
- INDEPENDA
- innit
- SONOS
- SECTORQUBE
- KITU SYSTEMS
- MUSAIC

LIGHTING
- LUMETRIC LIGHTING
- plum
- switchmate
- emberlight
- LIFX

MISCELLANEOUS
- KAMARQ
- notion

SAFETY & SECURITY
- leeo
- BeONhome
- SimpliSafe
- roost
- MY ALARM CENTER
- myfox
- august
- Lockitron
- canary
- ring
- LATCH
- audio analytic
- cocoon
- Glue

ENERGY & UTILITIES
- Ecoisme
- sense.
- thinkeco
- rachio
- ecobee
- there.
- tado°

iStock.com/skypicsstudio

DEVICE CONTROLLERS
- SENTRI
- Fluent
- NINJA BLOCKS
- muzzley
- wigwag
- ivee
- peel
- avi-on
- iRule

HEALTH & WELLNESS
- evermind
- beddit
- hello
- MedMinder

GENERAL SMART HOME SOLUTIONS
- ecovent
- netatmo
- KEEN home
- vivint.SmartHome

HOME ROBOTS
- jibo
- Rokid
- 小鱼在家
- robart
- neato robotics

GARDENING
- grove
- NIWA
- EDYN

CBINSIGHTS

Shifts in business models and value creation alongside technology

Centre on Innovation and Energy Demand

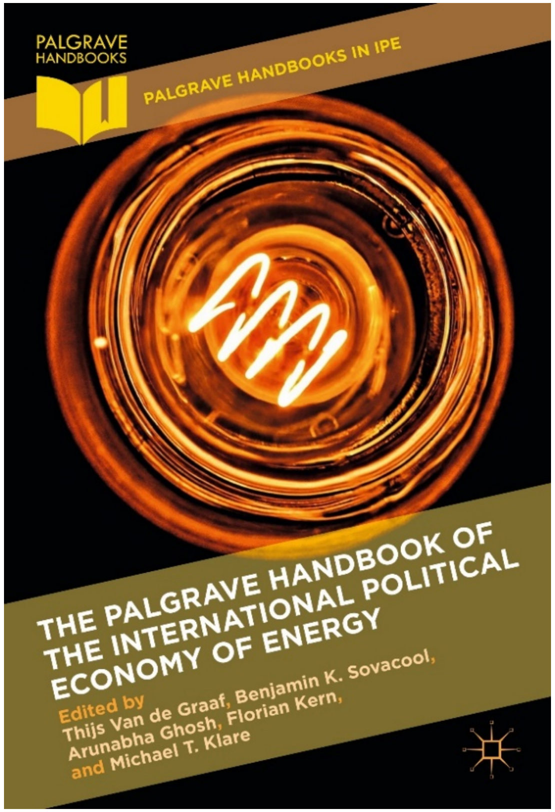
Trends pushing down the cost of solar, other renewables and energy efficiency	Examples
Increasing technical innovation	• New battery chemistries • New solar PV technologies
Synergistic solutions increasing the value of renewables	• Solar PV + battery storage • IT and storage for peak shaving
Data and internet of things increasing integration	• Sensors • Predictive software • Demand response automation
Innovative business models increasing customer bases	• No up front costs • Funnel analysis • Value beyond energy
Innovative financing reducing cost of capital	• Third-party financing • Green bonds • YieldCos

Concluding remarks

Centre on Innovation and Energy Demand

- Whether an energy transition can occur quickly or slowly can depend in great deal about how it is defined, so always check sources, data, assumptions etc.
- Causes are complex: WW2 (France and Kuwait), rural famine (China), 1970s oil crises (Denmark, Brazil), demand (AC in USA)
- Future transitions could be driven by active governance (phase-outs), scarcity, and demand pressures, rather than supply, markets, or abundance
- The past need not be prologue; history can be instructive but not necessarily predictive

Contact Information



Benjamin K. Sovacool, Ph.D
Professor of Energy Policy
University of Sussex
Jubilee Building, Room 367
Falmer, East Sussex, BN1 9SL
+44 1273 877128
B.Sovacool@sussex.ac.uk