Fast-tracking the energy transition

Invited Plenary Address to the "Reset: A Forum And Celebration Of Energy Transitions" Conference, Georgia Institute of Technology, Atlanta, United States, July 25, 2017

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Roadmap

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- Data sources
- Conceptualizing energy transitions
- Rethinking transitions (the case for “fast-tracked” transitions, or “deliberate diffusion” or “accelerated transformation”)
- Conclusion

Data sources

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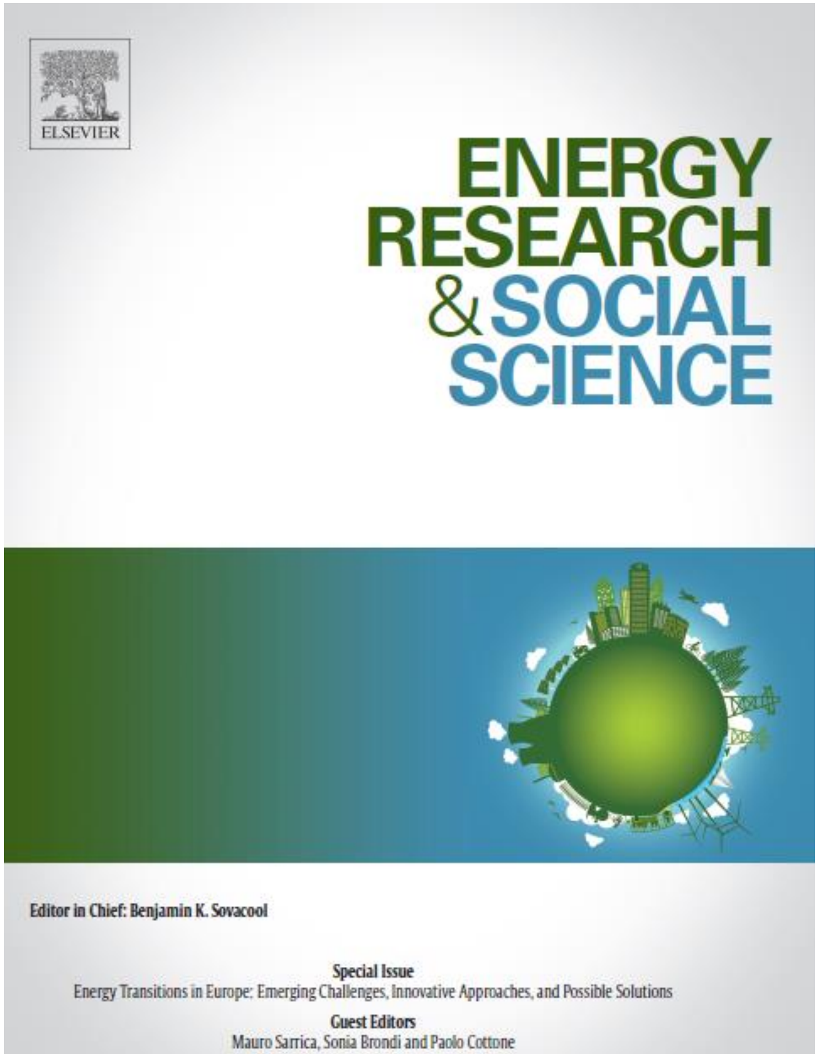

ELSEVIER

Volume 13, March 2016

CONTENTS

Special Issue
Energy Transitions in Europe: Emerging Challenges, Innovative Approaches, and Possible Solutions

Guest Editors
Mauro Sarrica, Sonia Brondi and Paolo Cottone

(Contents continued on inside back cover)

Data sources

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

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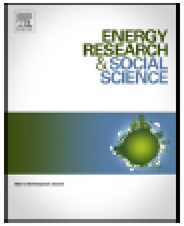

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Original research article

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

CrossMark

Benjamin K. Sovacool[a,b,*]

Conceptualizing energy transitions

- 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

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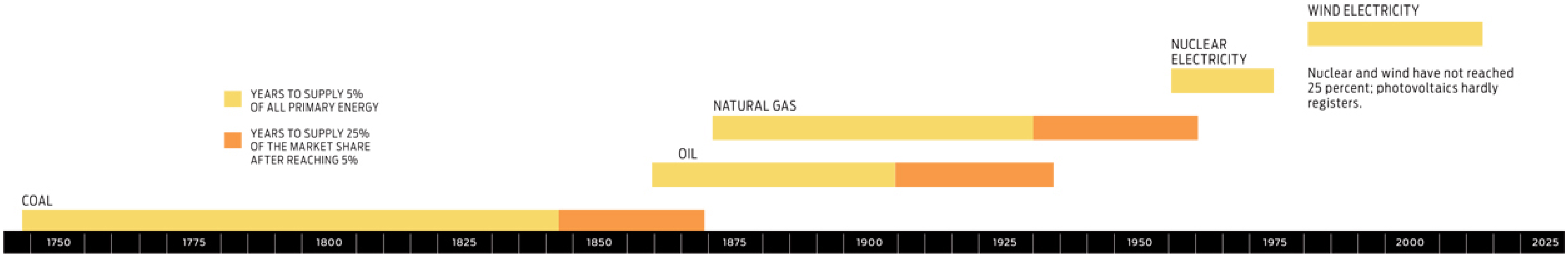
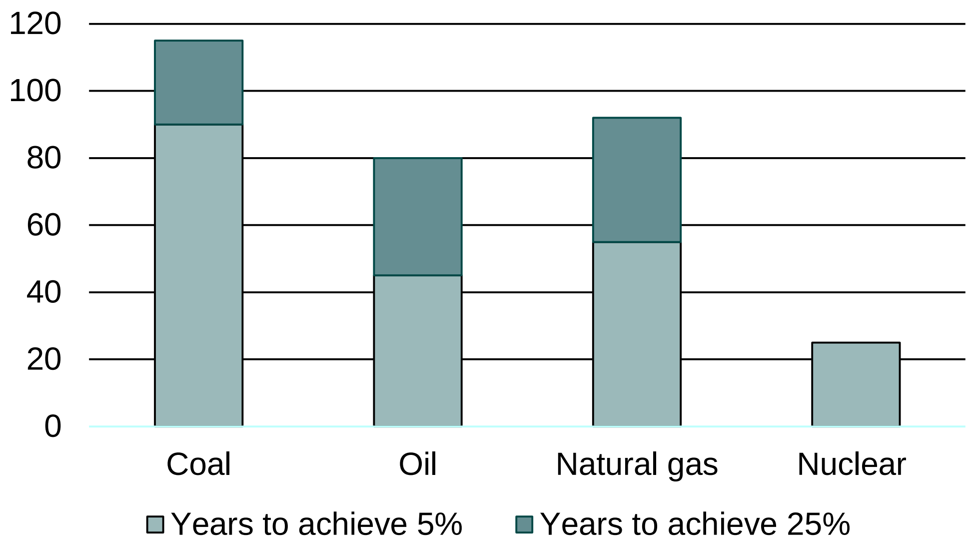
- What does the academic literature say?
- *"Energy transitions have been, and will continue to be, inherently prolonged affairs, particularly so in large nations whose high levels of per capita energy use and whose massive an expensive infrastructures make it impossible to great accelerate their progress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

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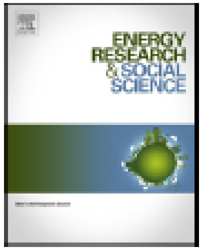

Short communication

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

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

Conceptualizing energy transitions

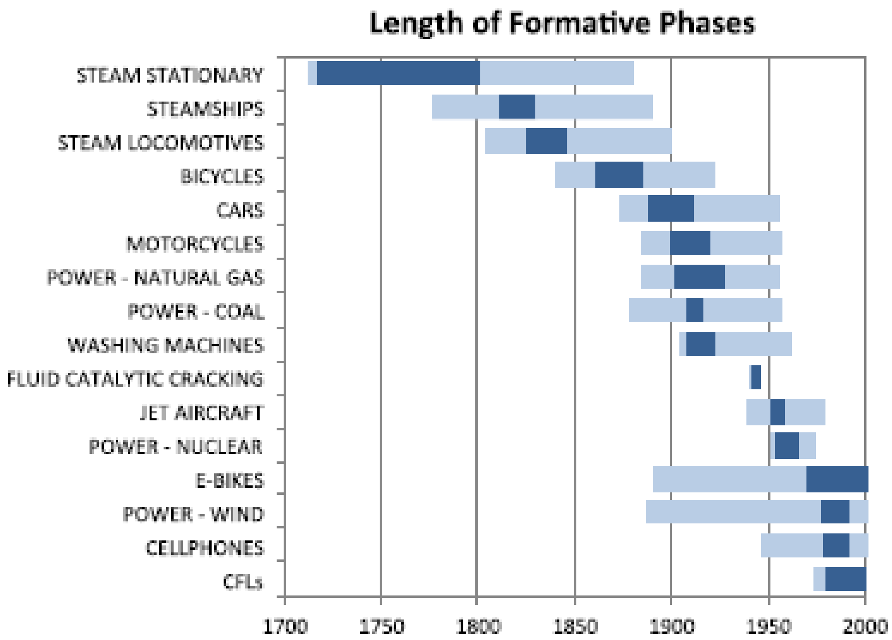

Fig. 1. Durations of formative phases for energy technologies are at a decadal scale [4]. Note: Ranges refer to alternative definitions for the start and end points of formative phases, and so capture measurement uncertainties.

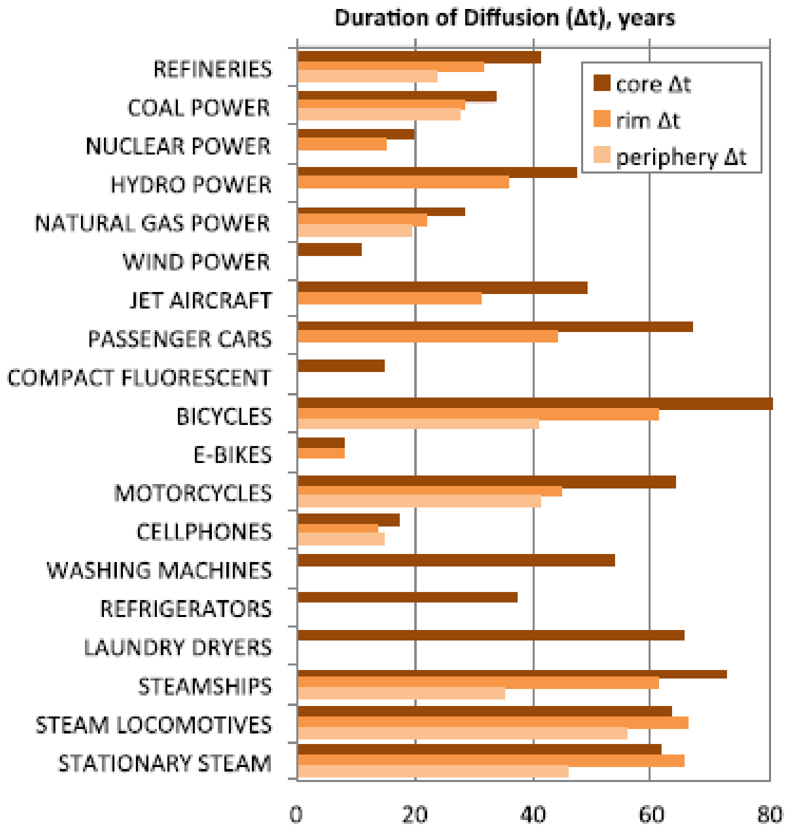

Fig. 2. Diffusion speeds accelerate as technologies diffuse spatially. Notes: Bars show durations of diffusion measured by cumulative total capacity installed, with historical data fitted via a logistic growth curve and the diffusion duration expressed as Δ t in years. 'Core' is typically within the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

Conceptualizing energy transitions

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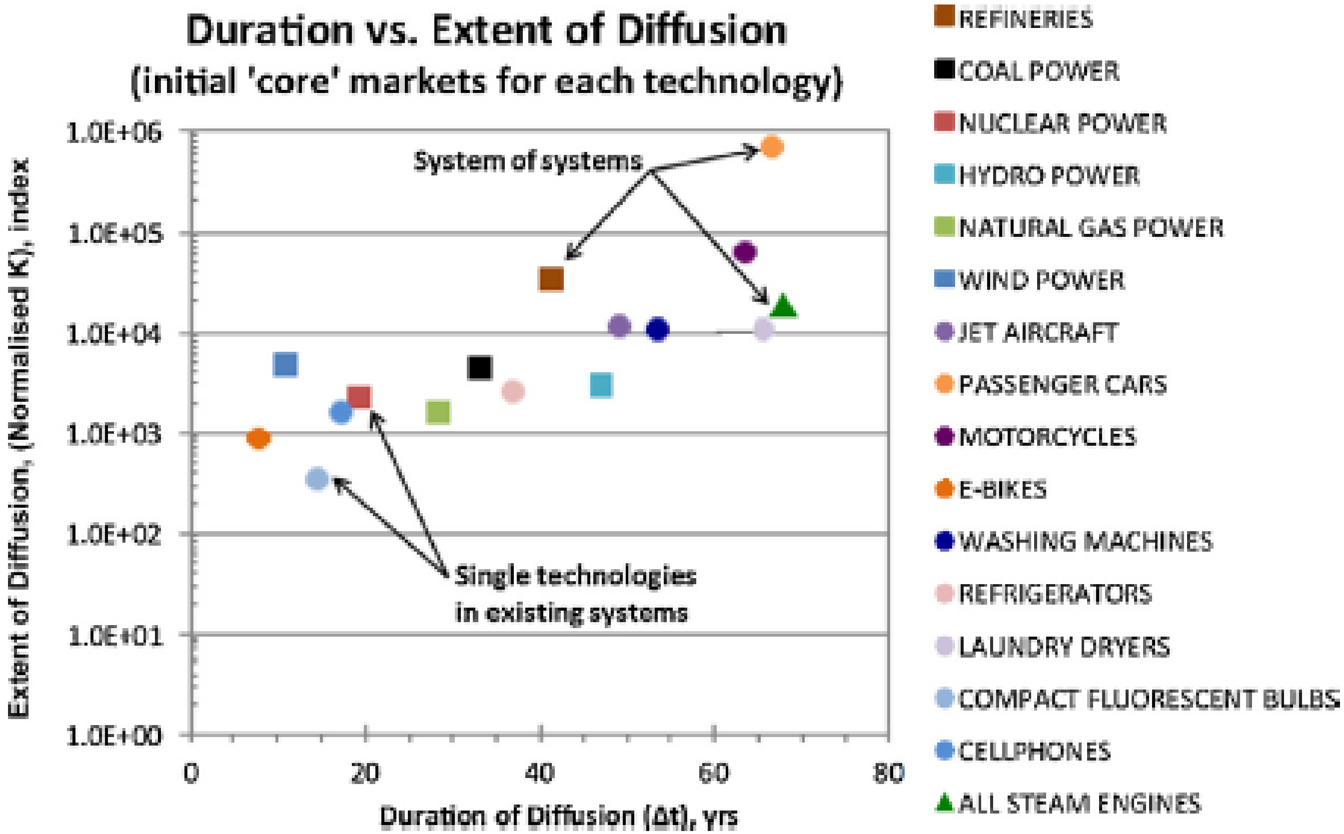

Diffusion durations scale with market size. Notes: X-axis shows duration of diffusion (t) measured in time to grow from 10% to 90% of cumulative total capacity; y-axis shows extent of diffusion normalized for growth in system size. All data are for ‘core’ innovator markets. Round symbols denote end-use 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).

Some peculiarities

- *Diffusion thresholds*: what % constitutes a transition (5%, 10%, 25%, 50%)?
- *Co-evolution*: one isolated technology or the seamless web (e.g. mimicry plus rail and telegraph and EVs)?

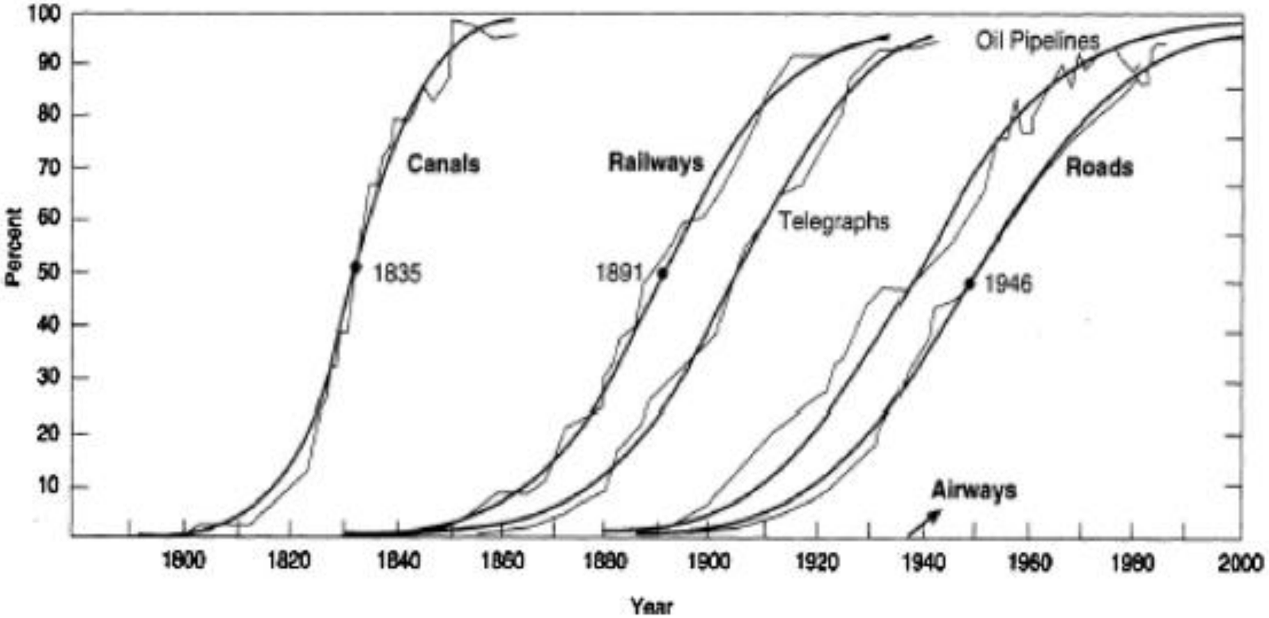

Fig. 1. Growth of Infrastructures in the United States as a Percentage of their Maximum Network Size.

- *Unit of analysis*: big oil or smaller changes in ICEs, steam engines on ships, oil lamps, oil heating boilers and furnaces?

Rethinking transitions: Can they be fast-tracked?

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- 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

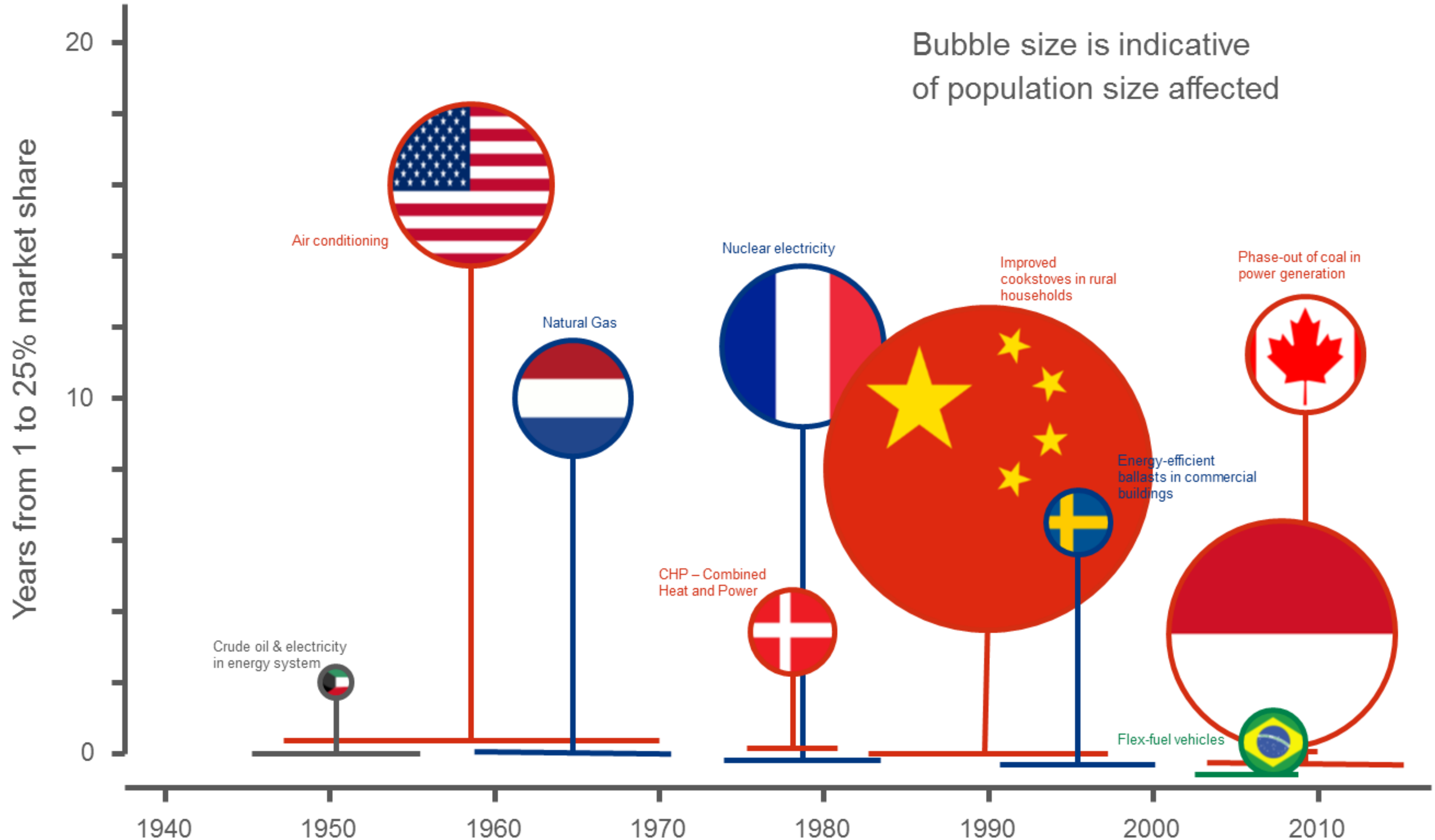

Figure designed by Gert Jan Kramer, used with permission

Rethinking transitions

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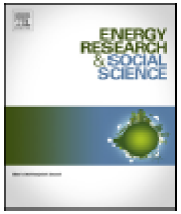


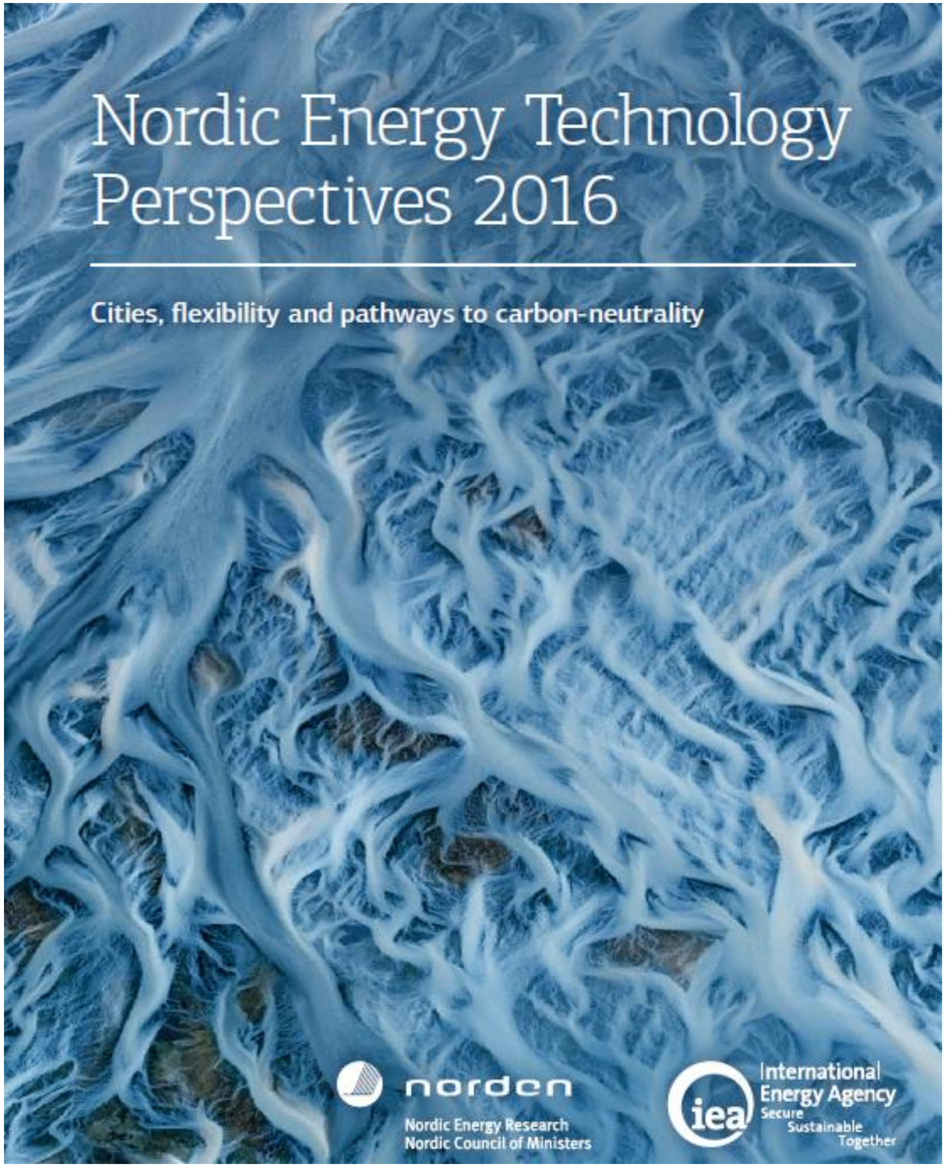
Short communication

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]

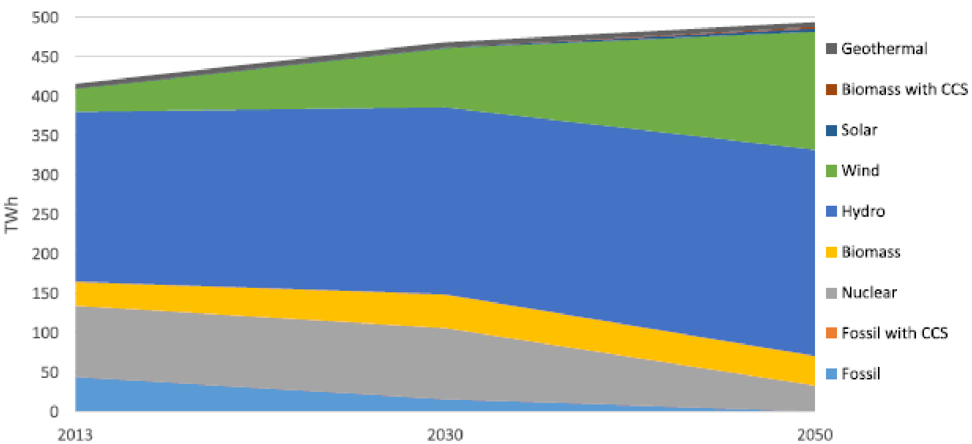
- Historic energy transitions have not been consciously governed, whereas today a wide variety of actors is engaged in active attempts to govern the transition towards low carbon energy systems
- International innovation dynamics can work in favor of speeding up the global low-carbon transition.
- The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

Rethinking transitions

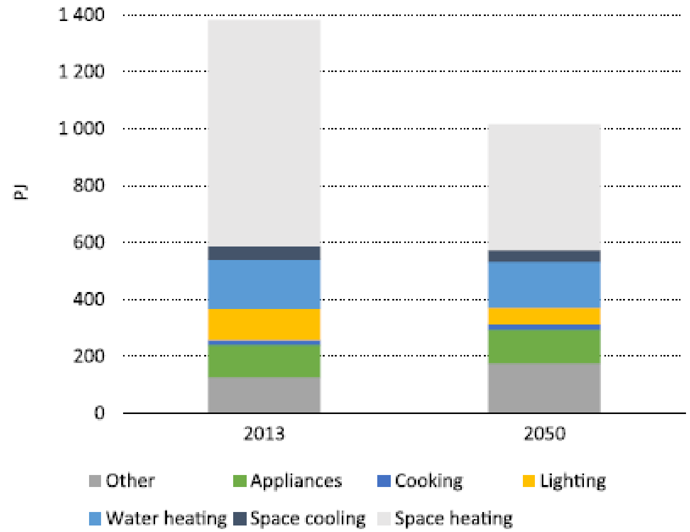


Rethinking transitions: electricity, heat, and buildings

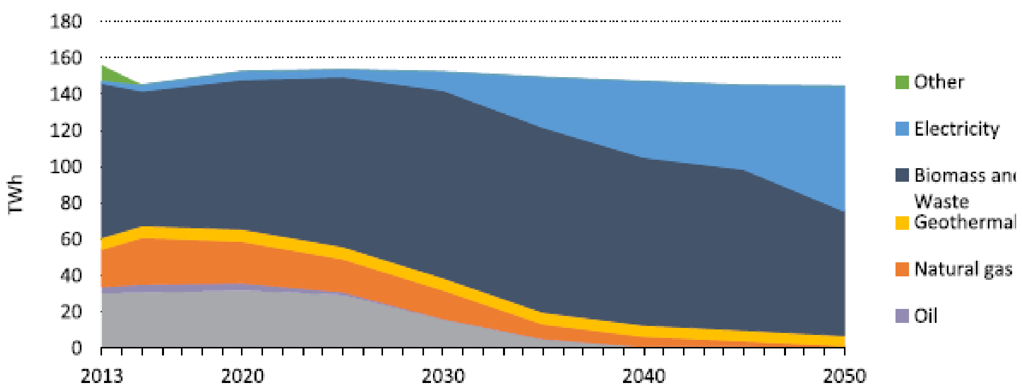
a. Top panel: Electricity generation



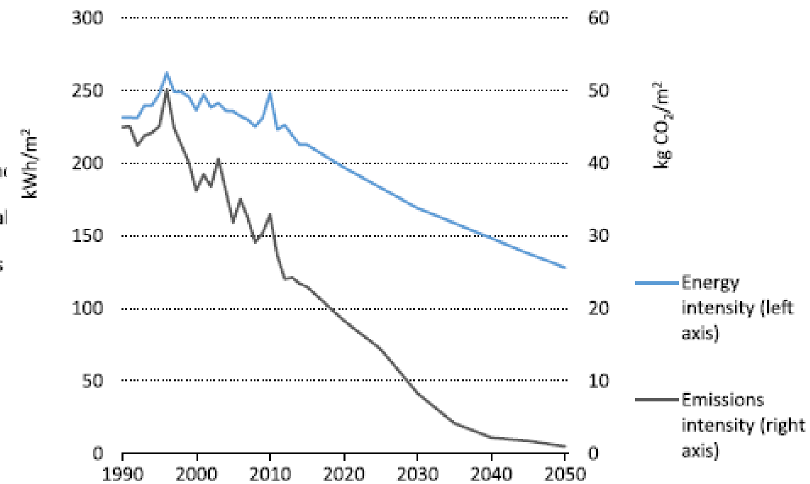
a. Top panel: Buildings energy consumption, 2013 and 2050



b. Bottom panel: heat supply

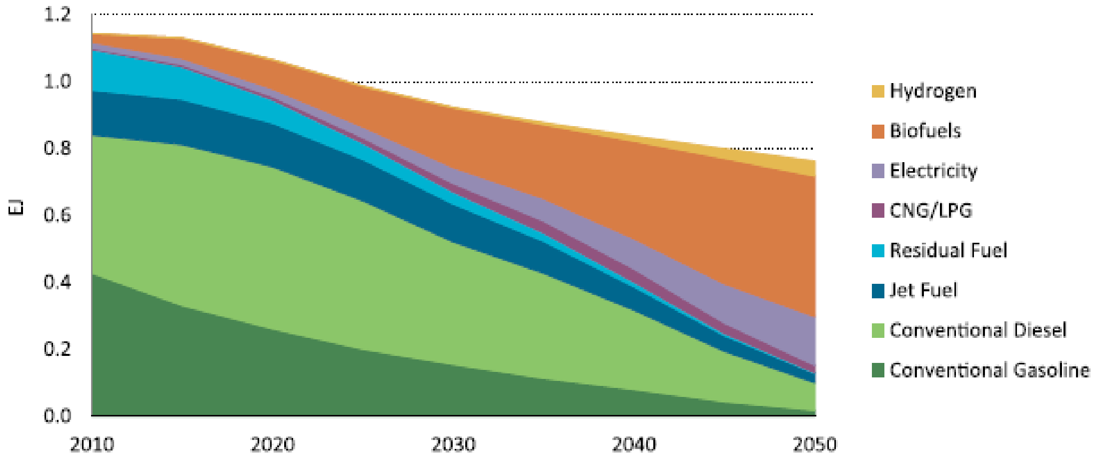


b. Bottom panel: Energy intensity and emission intensity, 1990 to 2050

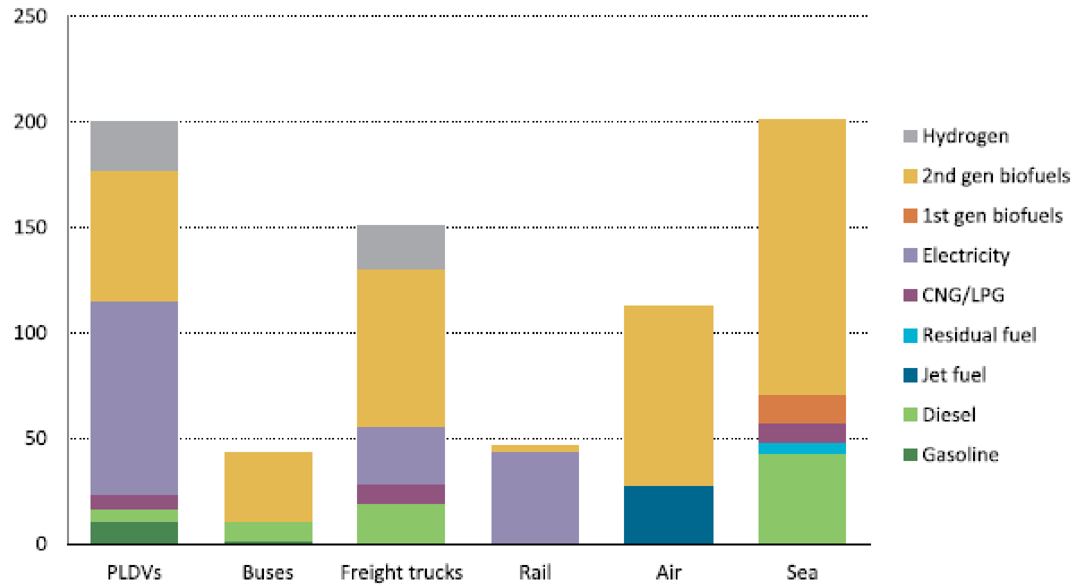


Rethinking transitions: transport fuel

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



b. Bottom panel: by transportation mode, 2050



Rethinking transitions: industrial emissions

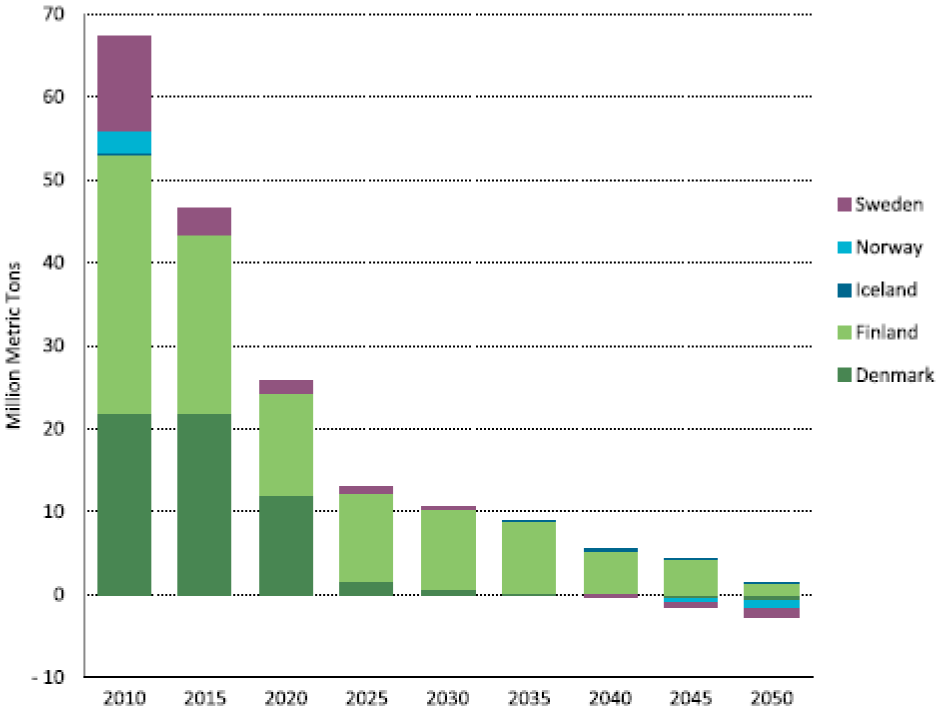
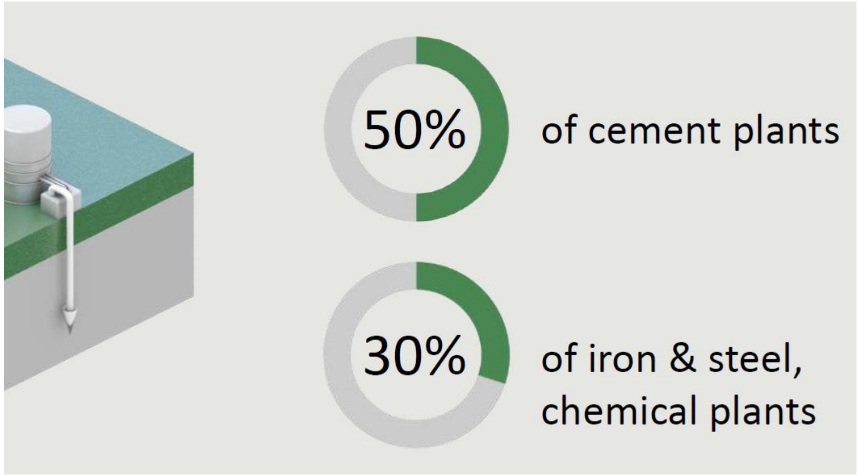


Fig. 11. Nordic Carbon Dioxide Emissions by Country, 2010–2050.

CCS utilization by 2050:



Rethinking transitions

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

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

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: Active phaseouts?

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Accelerating low-carbon innovation: the role for phase-out policies

Policy Briefing 05

March 2017

1. Control policies

This group of policy instruments aim to reduce carbon emissions from specific technologies or sectors. This is either through market mechanisms (in the UK, examples include the carbon floor price and EU Emissions Trading System (ETS)) or regulation (such as mandatory energy efficiency requirements for appliances, vehicle emission standards, zero carbon buildings, and a ban of incandescent light bulbs).

2. Changing market rules

These are rules that are applied at a broader level than control policies and typically address a whole market, sector or system, or even cross several systems. One example is the UK's 80% carbon reduction target, as set out in the Climate Change Act 2008.

3. Reduced support for dominant carbon intensive technologies or practises

High-carbon technologies and practises may receive support in a number of forms. These should be acknowledged and then reduced and removed over time. Examples include subsidies or tax exemptions.

4. Ensuring a balanced debate by developing actors or networks in emerging sectors

Incumbent industries can have a strong influence on policy decisions, whereas emerging innovations are unlikely to have well developed and influential networks. This imbalance can be addressed by creating new committees or networks involving actors mainly supporting low- and zero-carbon innovations in order to ensure incumbents are not given unfair weight in policy making processes.

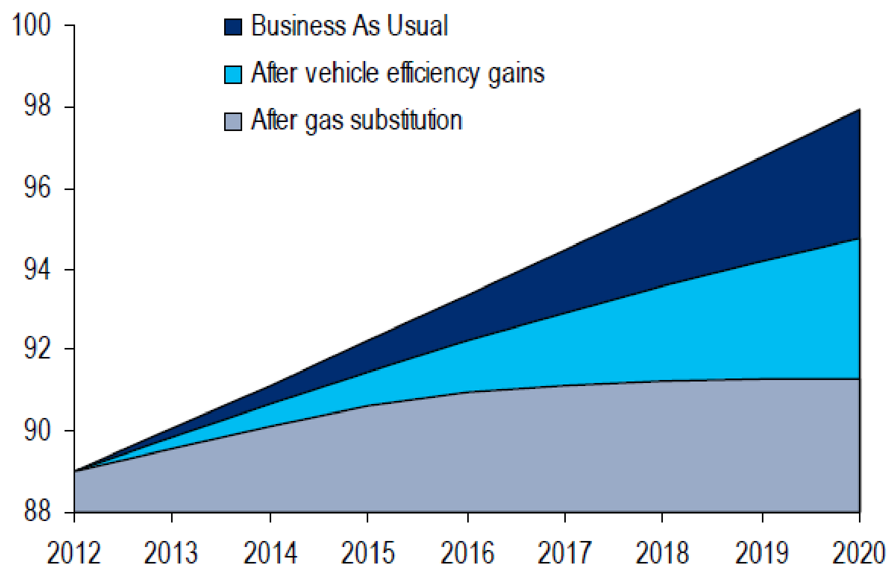
Changes in demand preferences, demand "peaks?"

Global Oil Demand Growth – The End Is Nigh
26 March 2013

Citi Research

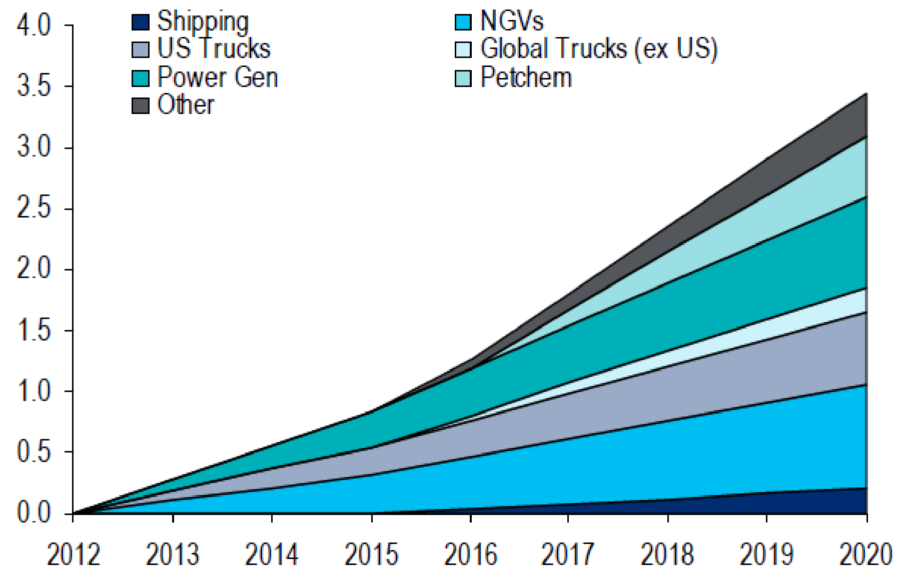
Global Oil Demand Growth – The End Is Nigh

Figure 1. Global Oil Demand Projections:-mb/d



Source: Citi Research

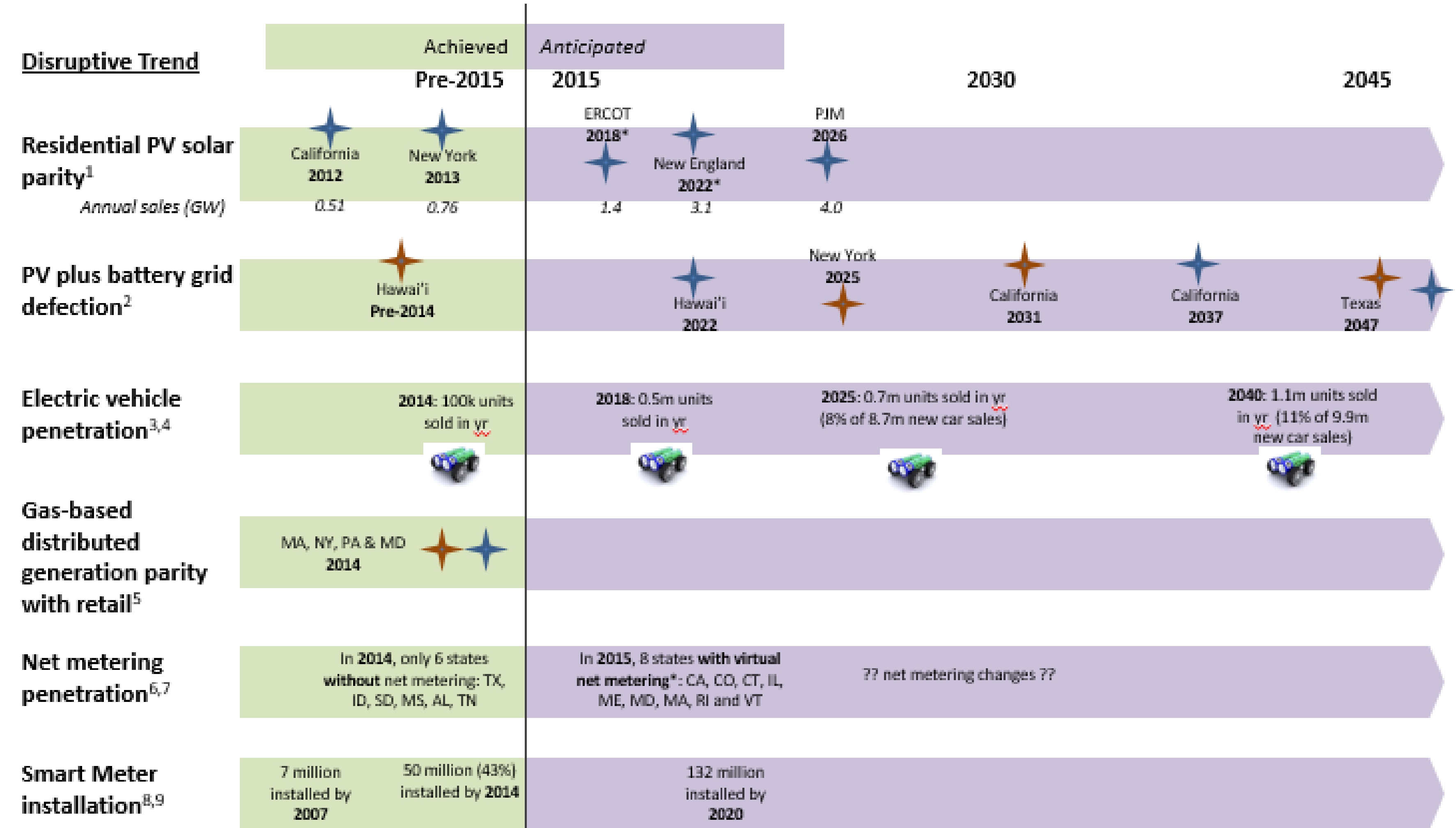
Figure 2. Potential Natural Gas Substitution For Oil:-mb/d



Source: Citi Research

A perspective from utilities and incumbents?

The energy transition is already happening?



[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

67 STARTUPS MAKING YOUR HOME SMARTER

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

APPLIANCES & AUDIO DEVICES
hiku, INDEPENDA, innit, SONOS, SECTORQUBE, KITU, 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

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

HEALTH & WELLNESS
eversmind, 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

- 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

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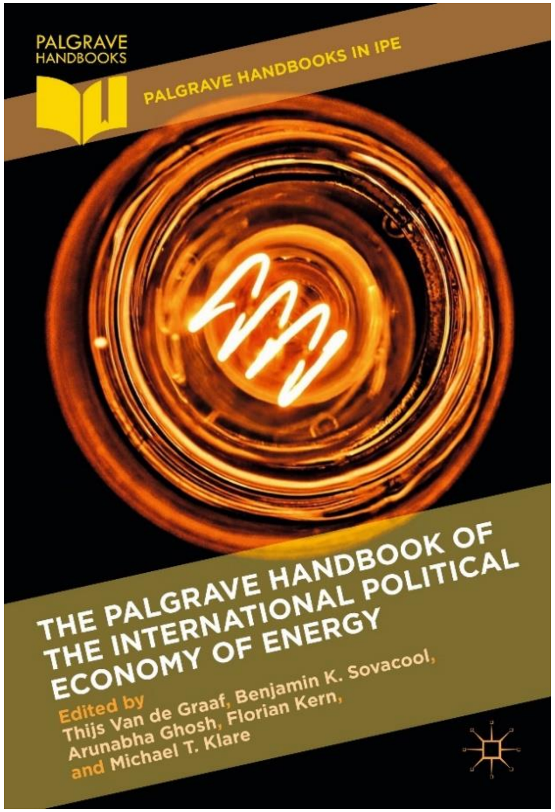

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