Growing Pains of Low-Carbon Technologies

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Disclaimer: this talk is based on an Opinion piece in Nature. Opinions expressed in this talk, e.g. on policy, are personal opinions of the author.

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- Back-up material
  - Why PV panels aren’t like Mobile Phones
  - Surprises? (If it has yet to be invented, it is too late.)

Context: Shell Energy Scenarios to 2050

Scramble

- National supply focus; reactive change

- People choose the easiest option for them
- Fear is not enough to change behaviors
- Climate change is too difficult
- Delegating action to the state
- Adapt rather than change

Blueprints

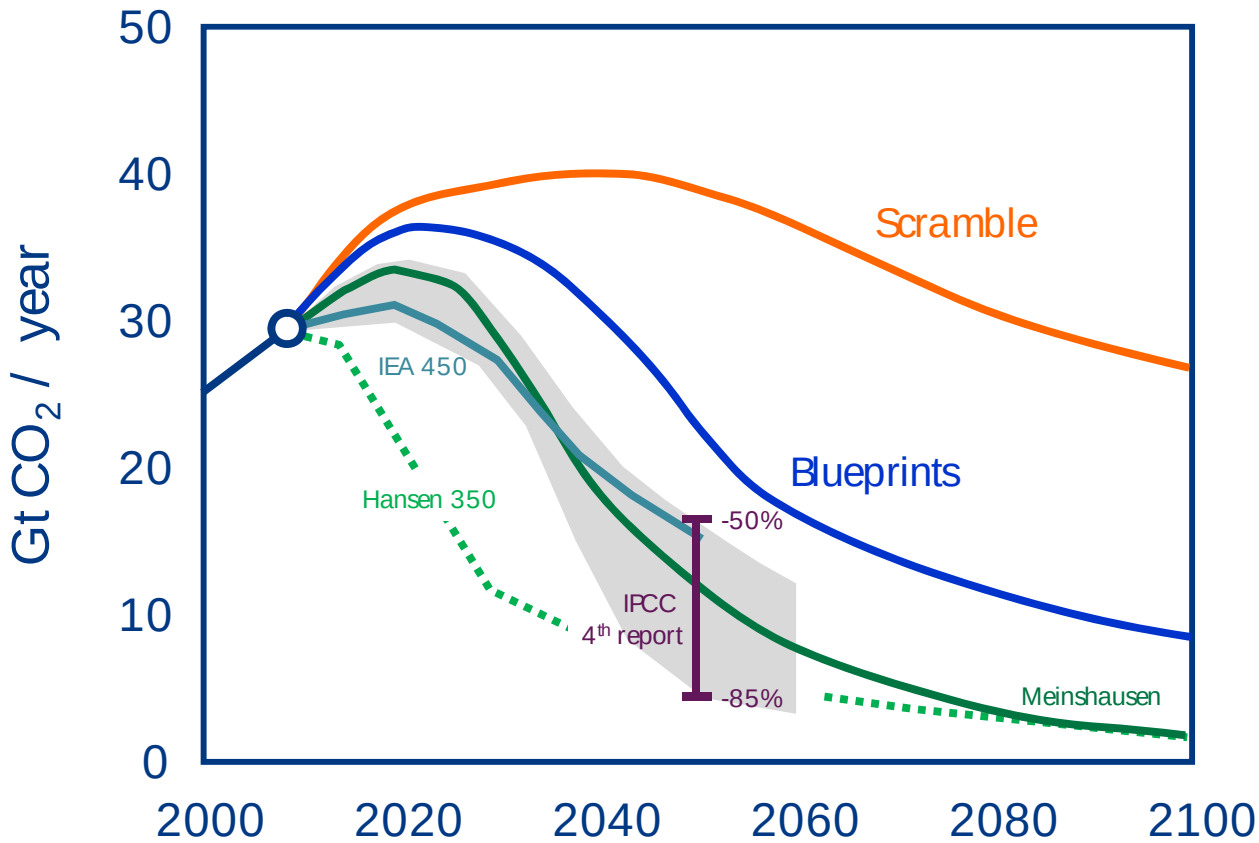
- Emerging coalitions; accelerated change

- Shared interest not altruism
- Adoption through “mainstreaming”
- Trial, error, collaboration and copying success
- Success is emergent, not centrally driven initially

Go to: www.shell.com/scenarios

What's Desirable? What's Doable?

Global direct CO_2 emissions from energy



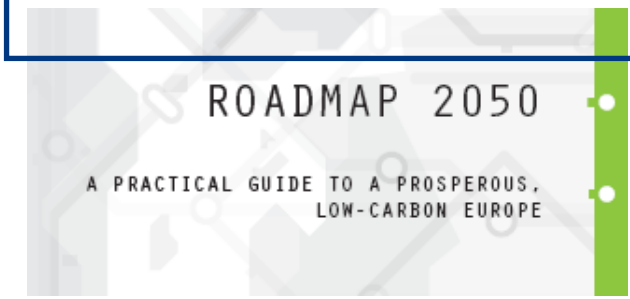
Sources: Shell International BV; IPCC 4th Assessment Report (2007); IEA WEO 2009; Meinshausen et al., *Nature* **458**, 1158–1162 (2009); Hansen et al., *The Open Atmospheric Science Journal*, **2**, 217-231

The Energy Transition: Done by ...

now 2020 2030 2050

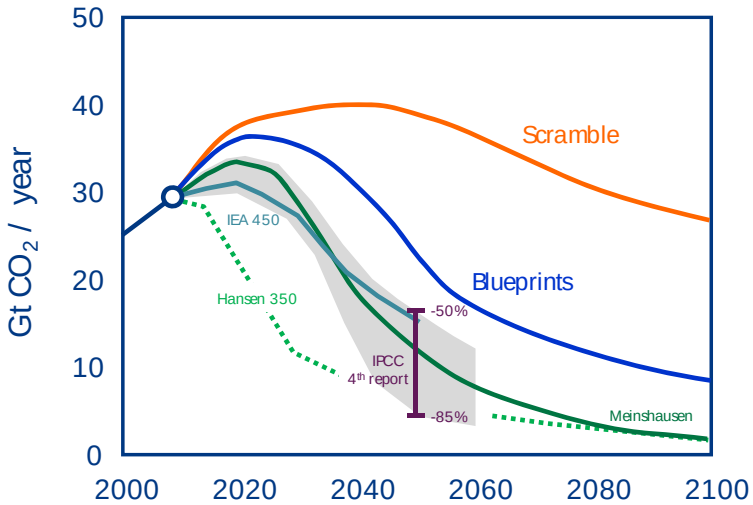
In July 2008 Al Gore announced a plan to “repower” America in ten years with Clean Electricity.

Mark Z. Jacobson and Mark A. Delucchi *Scientific American*, November 2009, p.38



In April 2010 the European Climate Foundation published a well-received roadmap to reach 80% carbon reduction in Europe by 2050.

What's Desirable? What's Doable?



Scramble versus Blueprints

In state affairs, by foreseeing problems at a distance, which is only done by men of talents, the evils which might arise from them are soon cured; but when, from want of foresight, they are suffered to increase to such a height that they are perceptible to everyone, there is no longer any remedy.

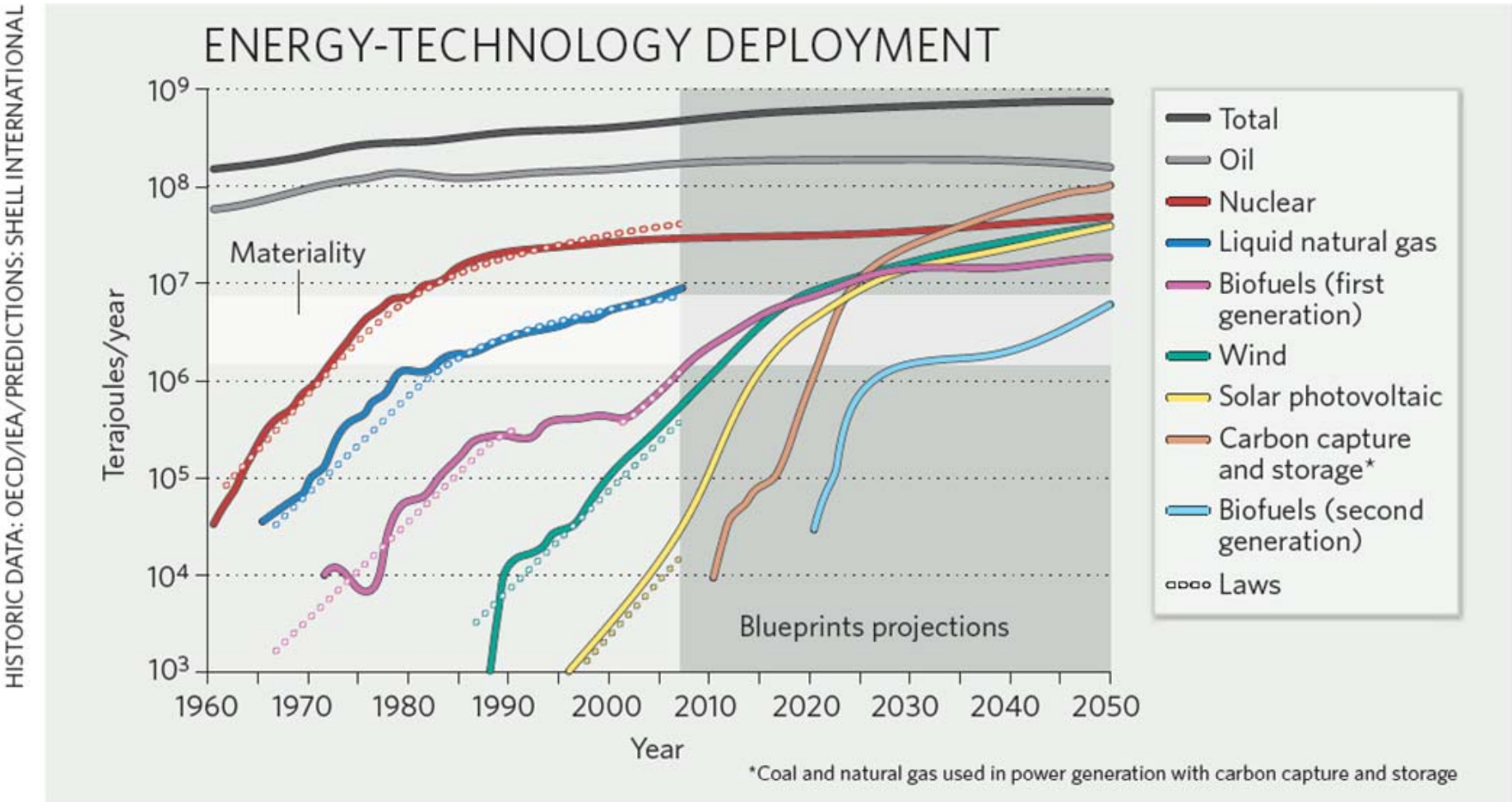
Machiavelli, *The Prince*

Blueprints versus 450 ppm Scenarios

[There] is little question that almost every one of the technical ideals of our experts can be realized within a comparatively short period of time if to achieve them were made the sole aim of humanity. There is an infinite number of good things, which we all agree are highly desirable as well as possible, but of which we cannot hope to achieve more than a few within our lifetime, or which we can hope to achieve only very imperfectly.

Friedrich von Hayek, *The Road to Serfdom*

Rates of Energy Technology Deployment



Source: Gert Jan Kramer and Martin Haigh, *Nature*, **462**, 568 (2009)

The “Laws” of Energy Technology Deployment

“Law 1”

When a technology is new, they go through a few decades of exponential growth, which in the twentieth century was characterized by scale-up at a rate of one order of magnitude per decade (corresponding to 26% annual growth).

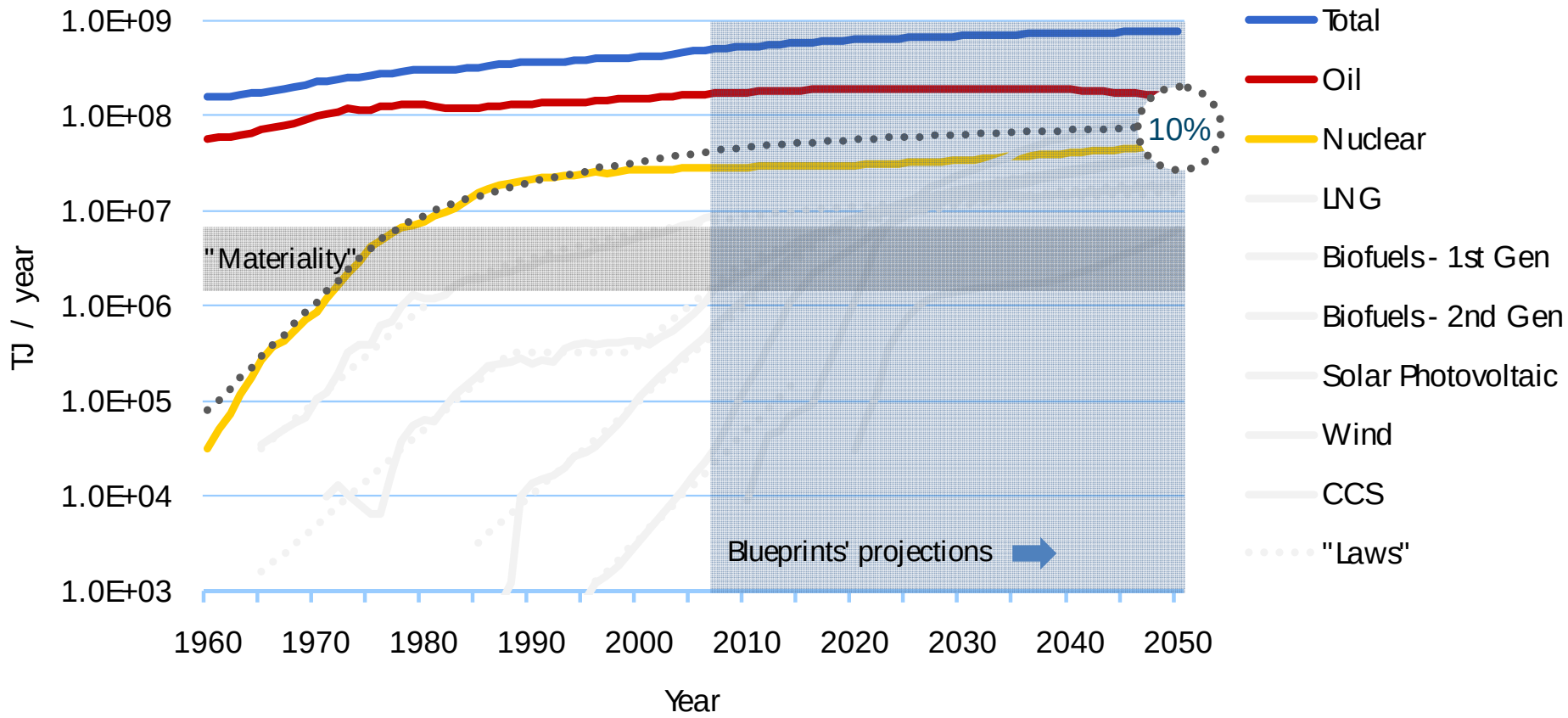
Exponential growth proceeds until the energy source becomes ‘material’ – typically around 1% of world energy.

“Law 2”

After ‘materiality’, growth changes to linear as the technology settles at a market share.

- Industry will avoid overcapacity
- Industry will be reluctant to retire old stock prematurely

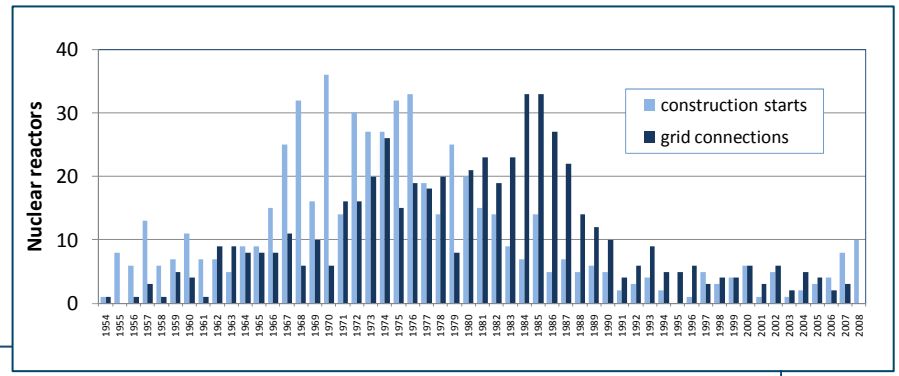
Empirical Evidence for “The Laws” Nuclear Energy

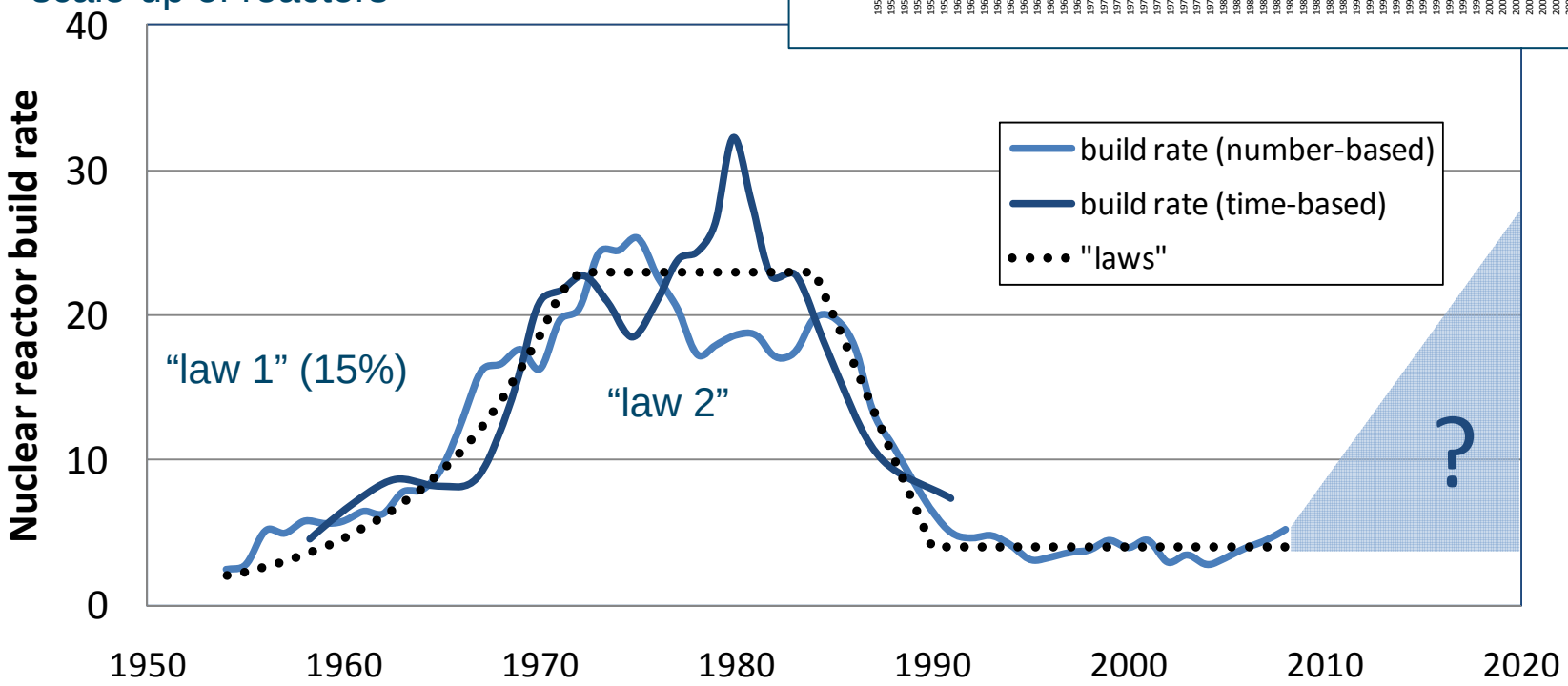


Nuclear grew at approximately 30% per year in the 1960s. Its levelling off in the 1970s and 1980s suggested it was on its way to capture a 10% market share (of total primary energy).

Historical Build Rates
Nuclear Energy

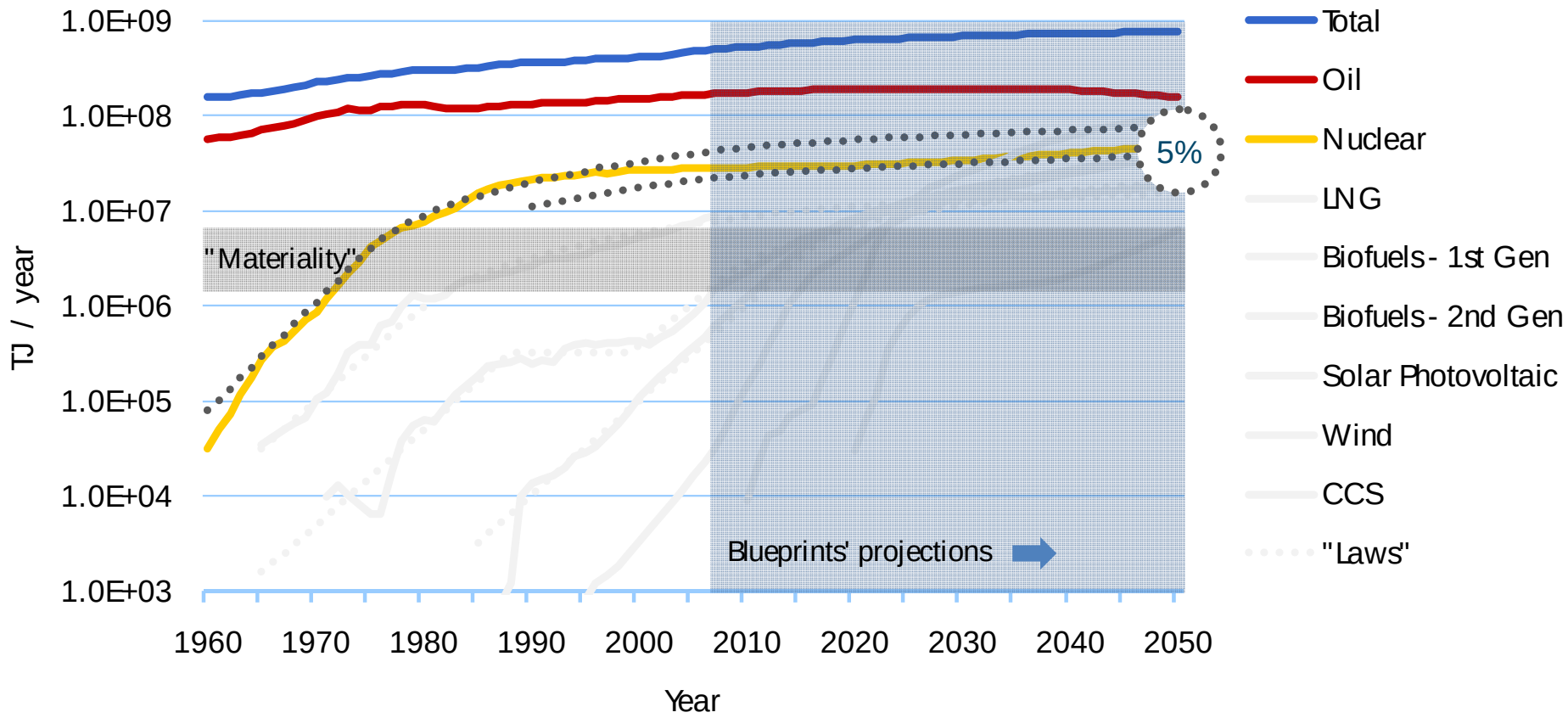
Industrial capacity is estimated on the basis of reactors under construction. Note that *numbers* grew only 15% per year while *energy delivery* at at 30%, reflecting scale-up of reactors





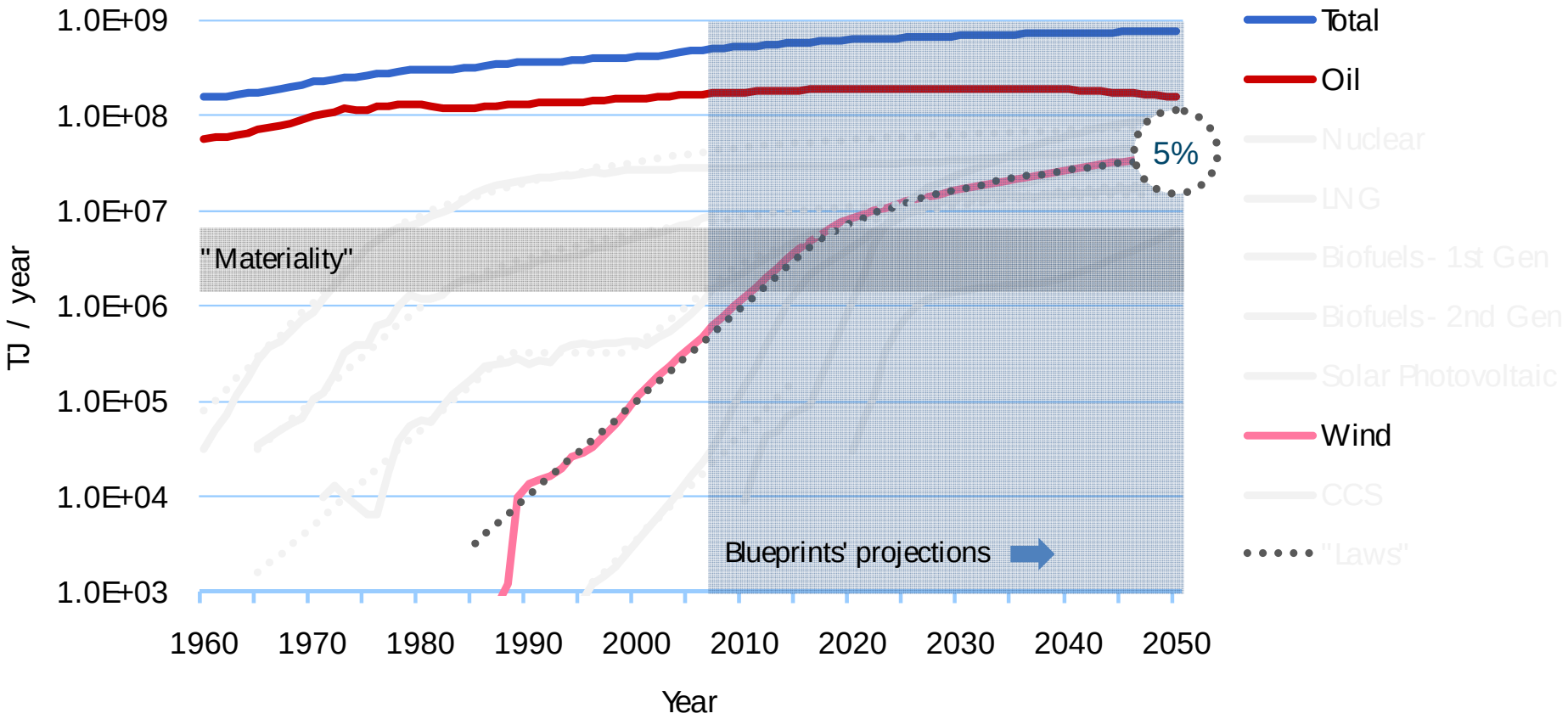
Source: Nuclear Power Reactors in the World (IAEA, 2009)

Empirical Evidence for “The Laws” Nuclear Energy



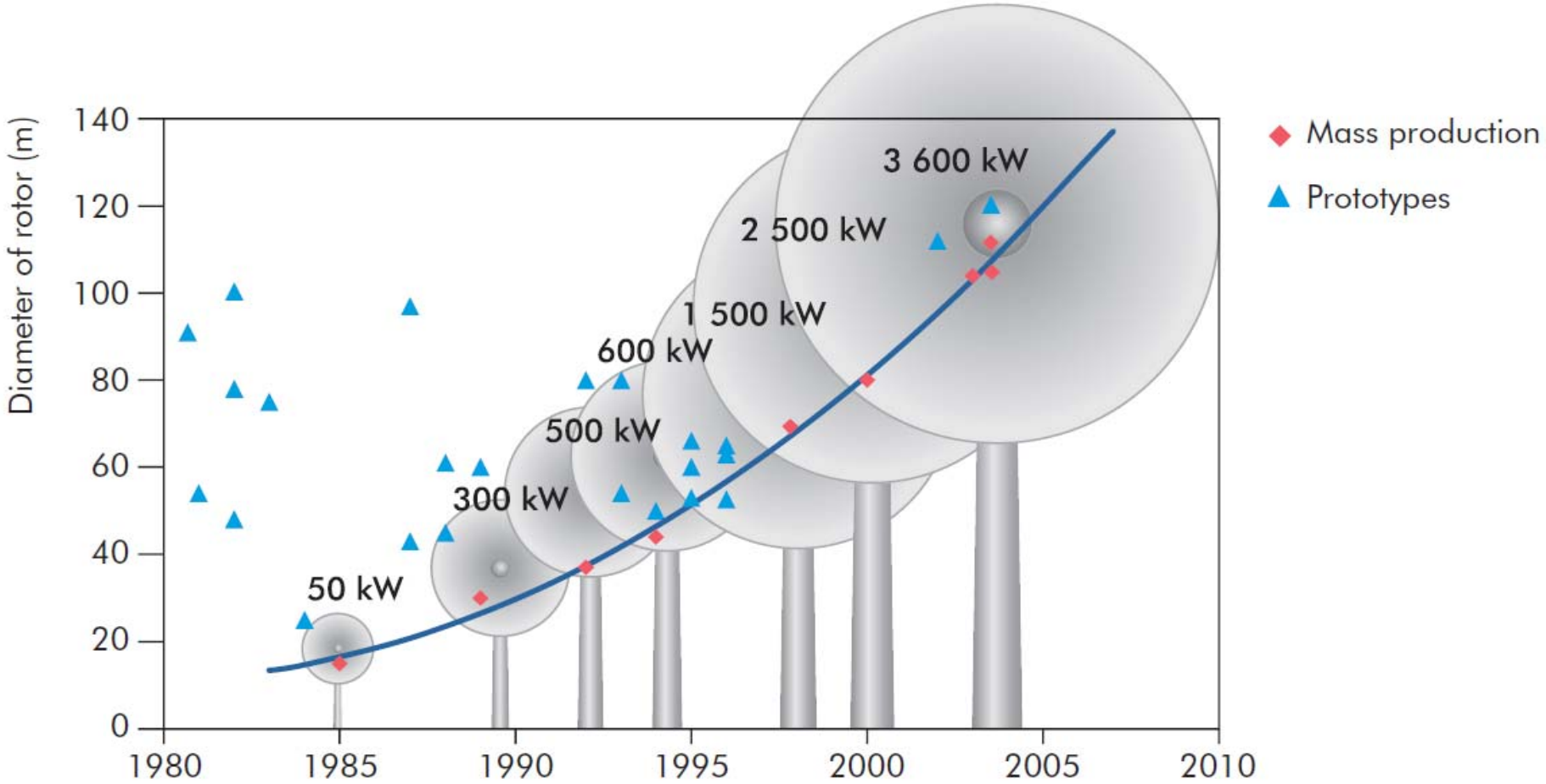
From the 1990s onward the appetite for nuclear stalled. It looks now set to deliver about 5% of Total Primary Energy.

Empirical Evidence for “The Laws”
Wind Energy



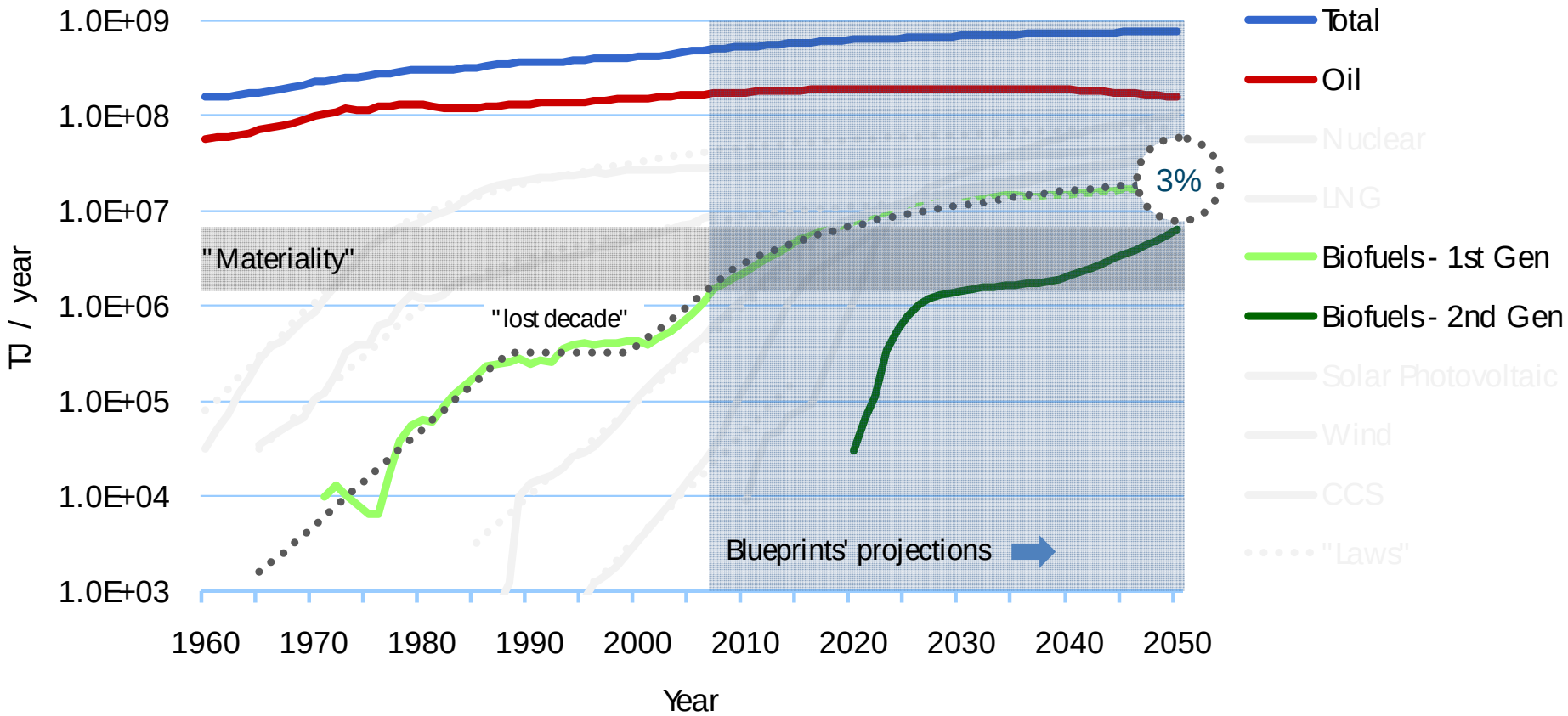
Wind Energy development has followed “law #1” faithfully since the mid 1980s and is now just about “material”.

Historical Progress
Wind Energy



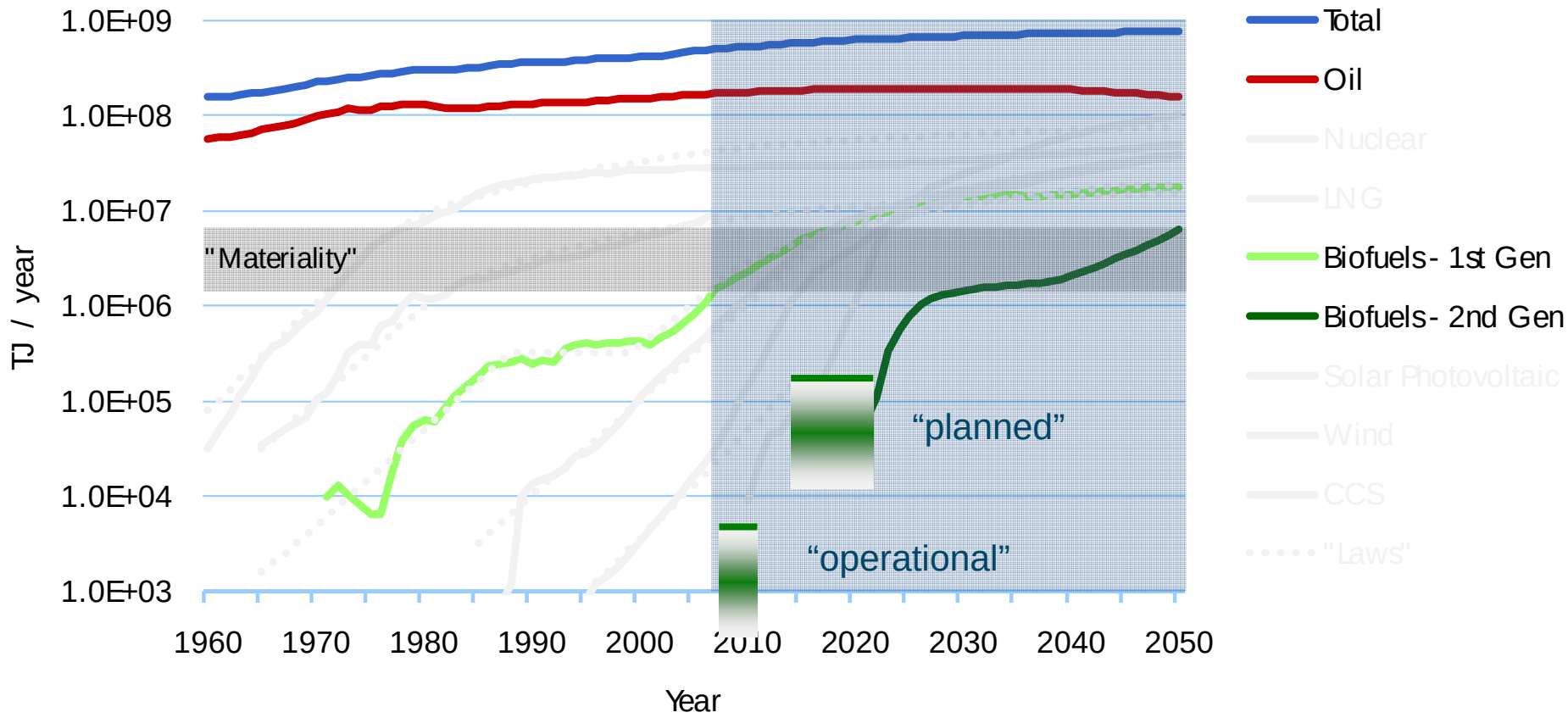
Source: German Wind Energy Institute (DEWI), 2006.

Empirical Evidence for “The Laws” Biofuels (1st and 2nd Gen)



1st Generation Biofuels grew according to “law 1” in the 1970s and 80s. From the late 80s to the late 90s progress stalled during a “lost decade”. Progress picked up again after 2000, towards saturation at 3 % of TPES,10% of Transport energy.

Expectations & Extrapolations
2nd Gen Biofuels

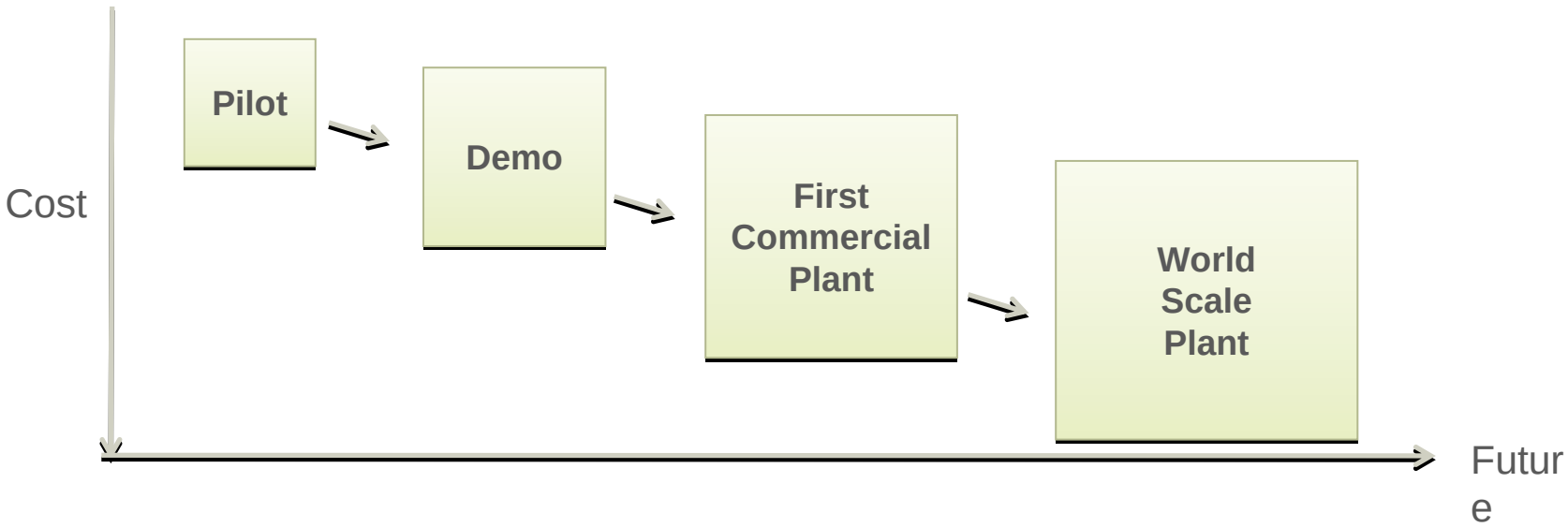


For quite some time to come, 2nd Gen Biofuels will not contribute significantly to the total biofuels pool.

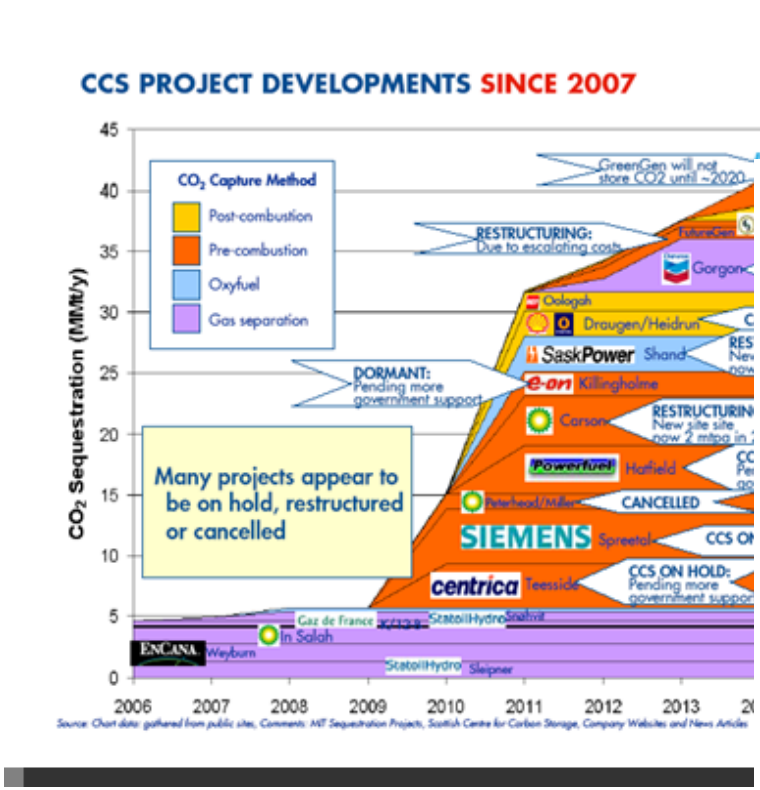
Source world totals for 2nd generation capacity: Accenture (2010)

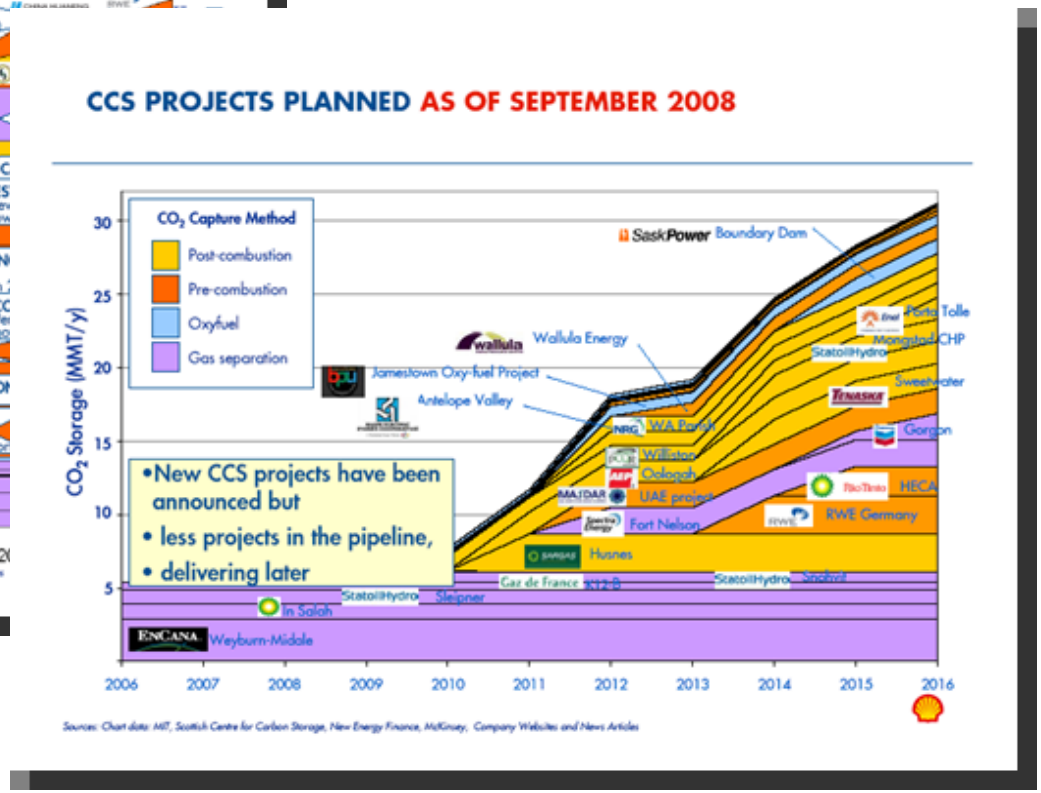
Advance Biofuels
Commercialisation and Economics

- Shell is successfully progressing new technologies from lab-based process to demonstration phase and towards commercial scale-up
- Shell aims to narrow down advanced biofuels technology options to a feasible set of commercial solutions
- In the long term all biofuels will need to be cost competitive with all road transport fuels
- In the short term, government policies, incentives and financial support accelerate development from lab to commercial deployment



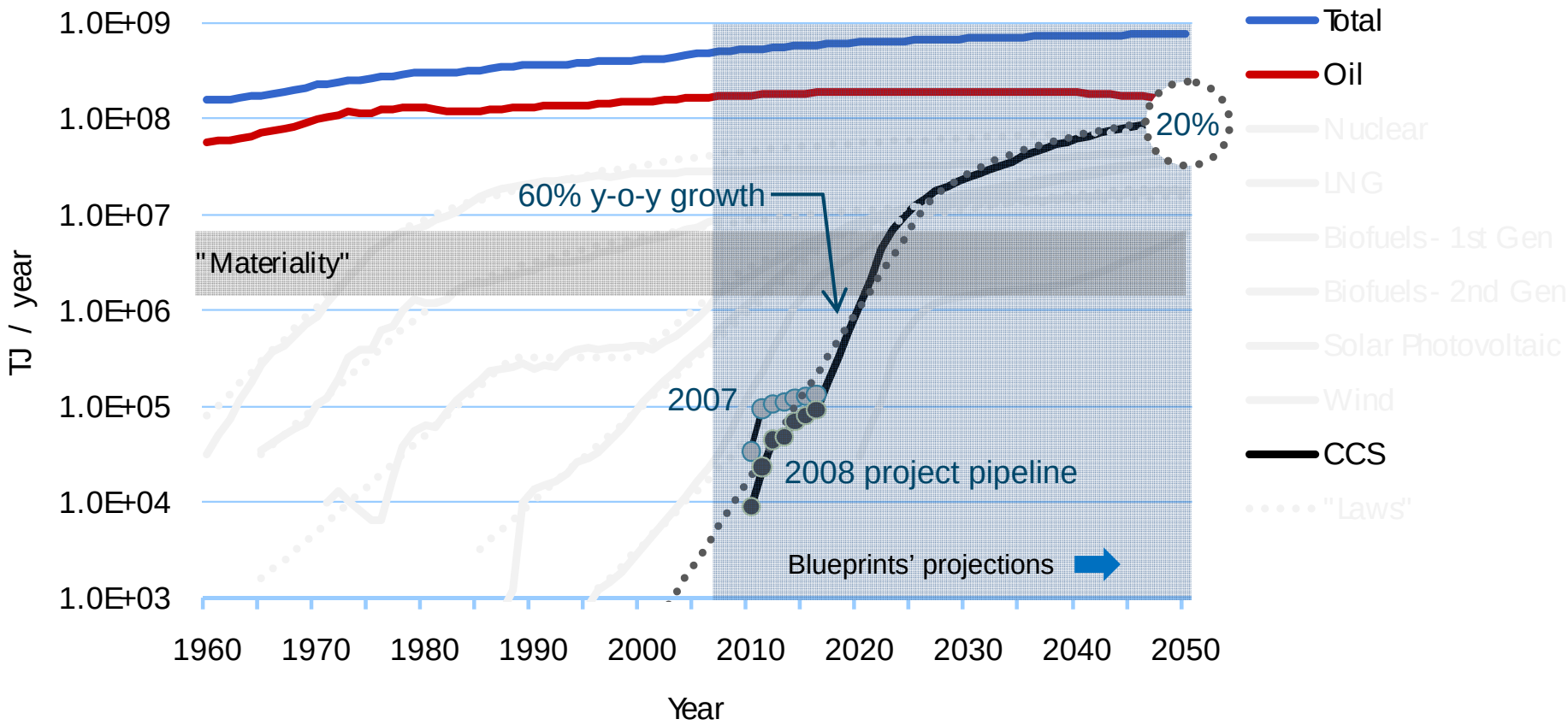
Great Expectations
Carbon Capture and Storage





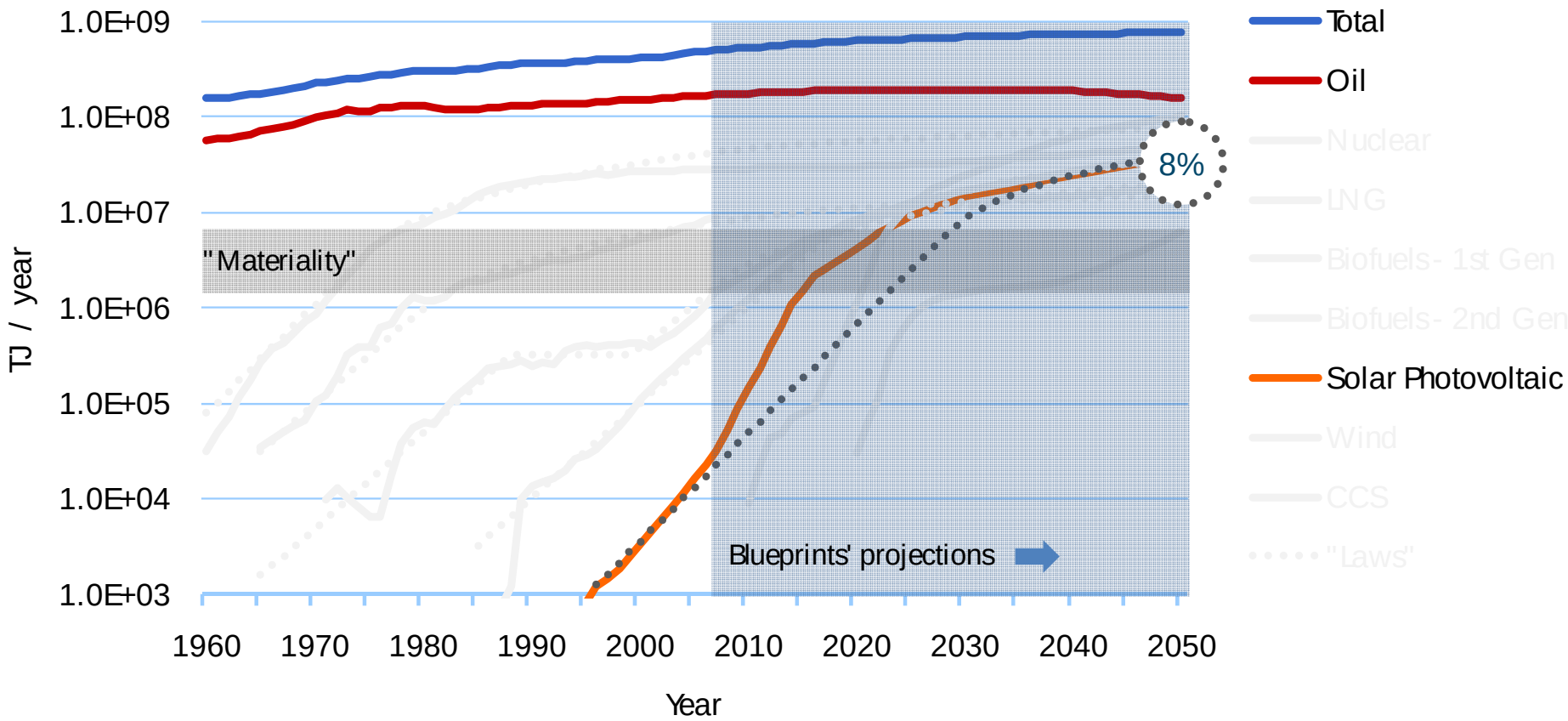
Source: Tim Bertels, Poznan, Dec 2008

Great Expectations
Carbon Capture and Storage



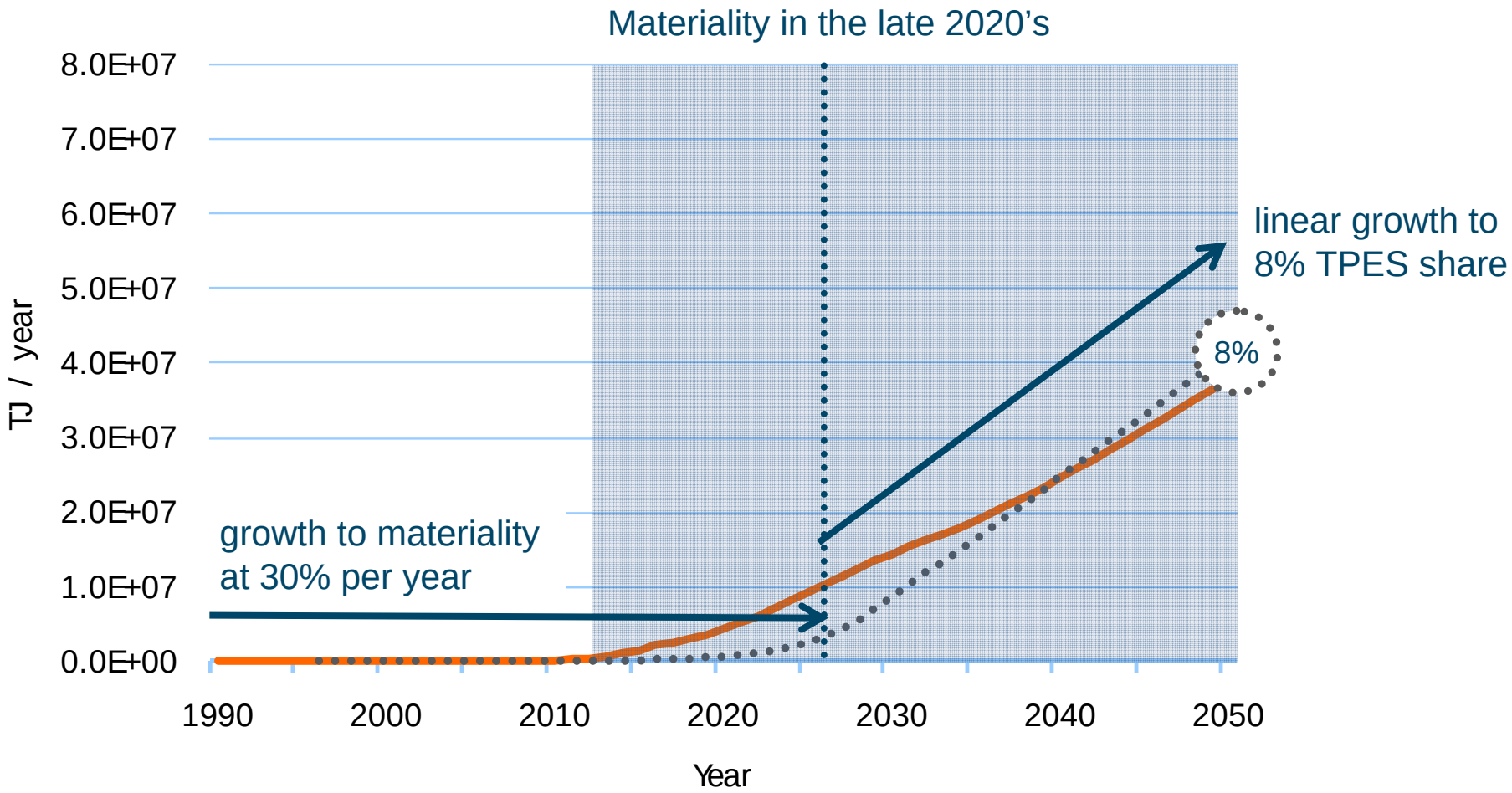
Carbon Capture *could potentially* take a spectacular 20 % market share (Blueprints), but that requires that all announced projects materialize and the project pipeline is rapidly filled with more projects, enabling an unprecedented 60 % year-on-year growth of the CCS industry.

Breaking the “Laws”?
Solar Photo Voltaics

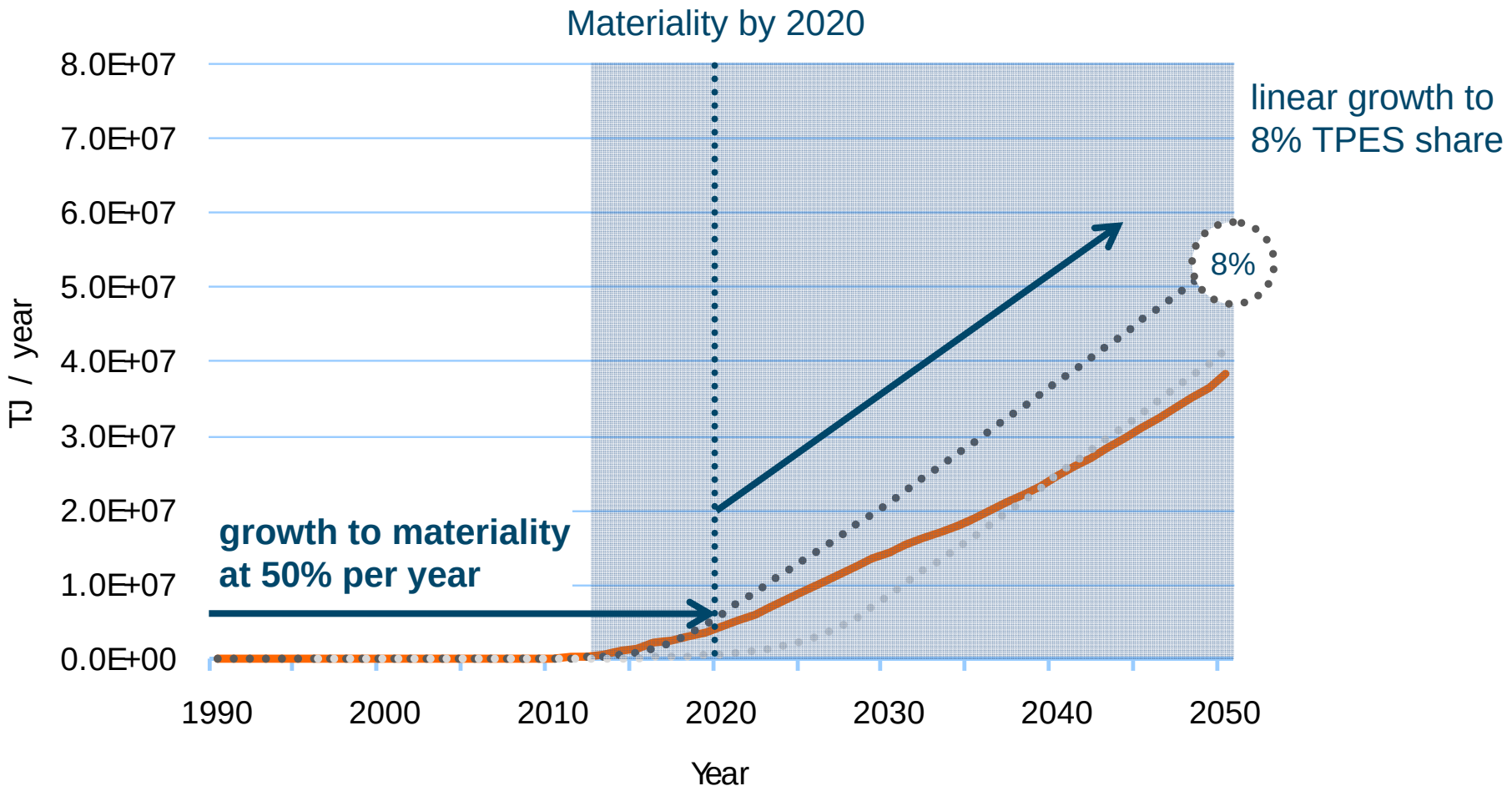


Growing at 40-50% for a number of consecutive years, PV seems to beat the “Law #1”. Will it last? And if so, how does it affect the overall picture? What about the “Law #2”?

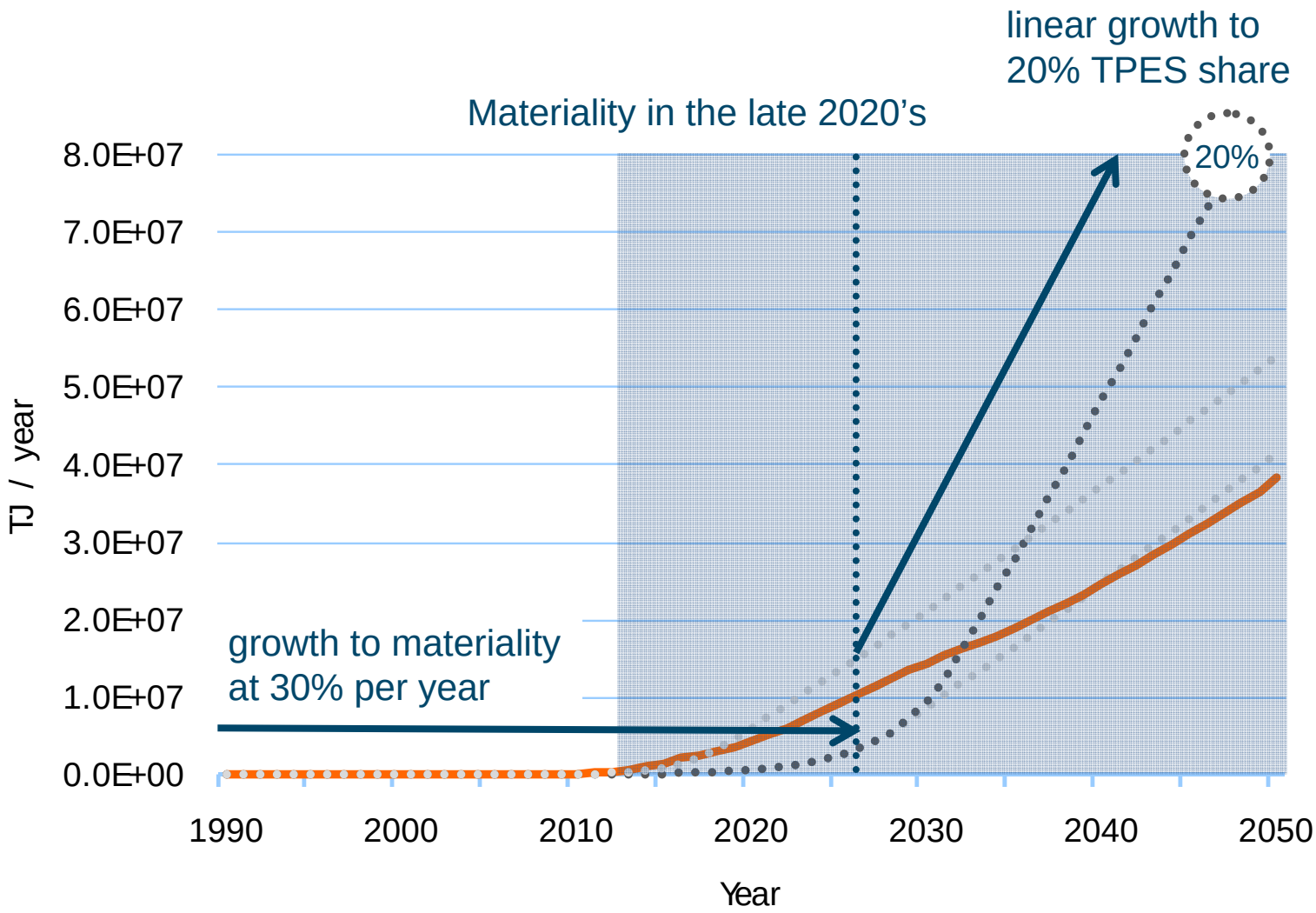
Beating “Law #1”
Solar Photo Voltaics



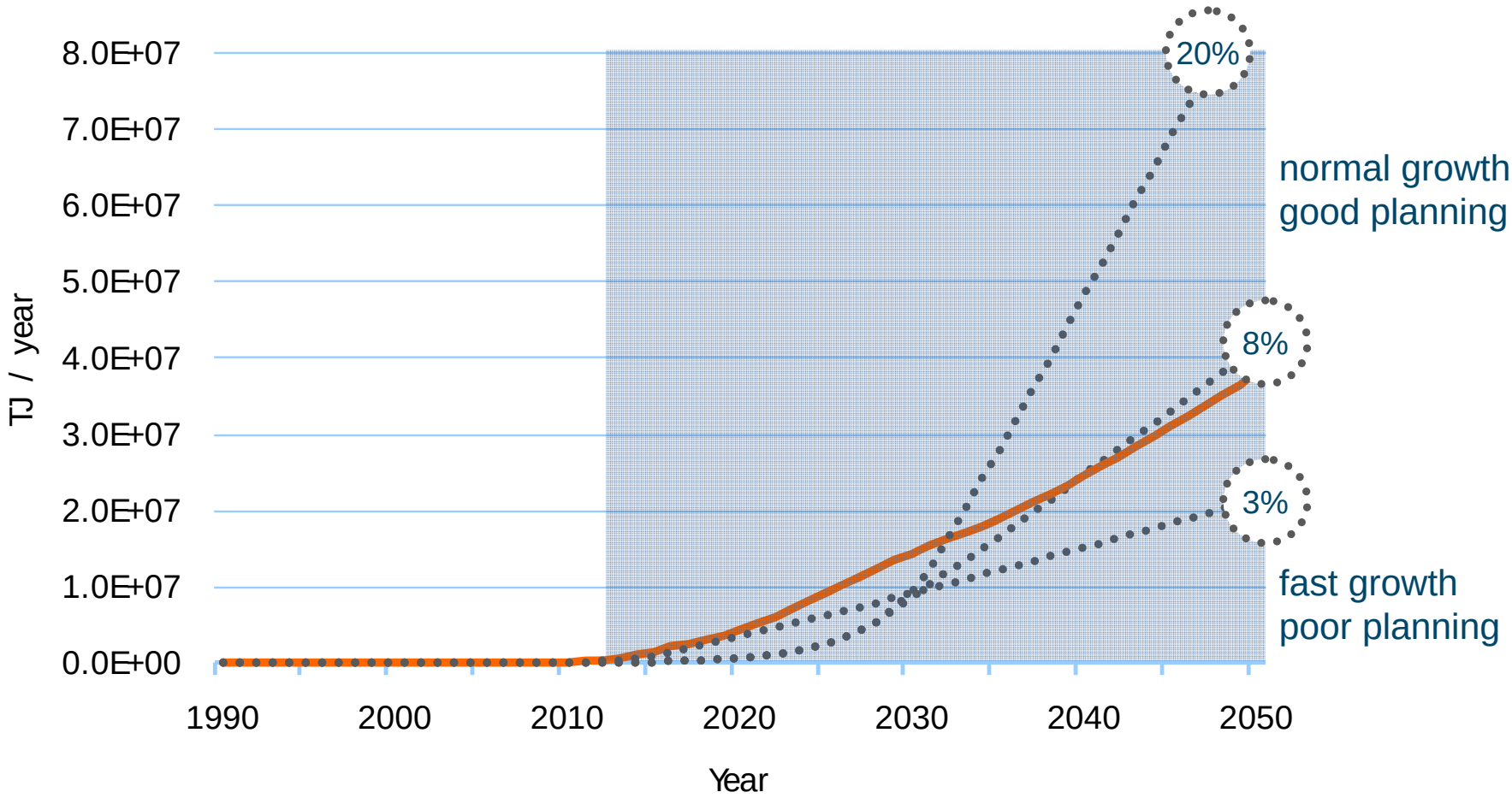
Beating “Law #1”
Solar Photo Voltaics



Beating “Law #2”
Solar Photo Voltaics

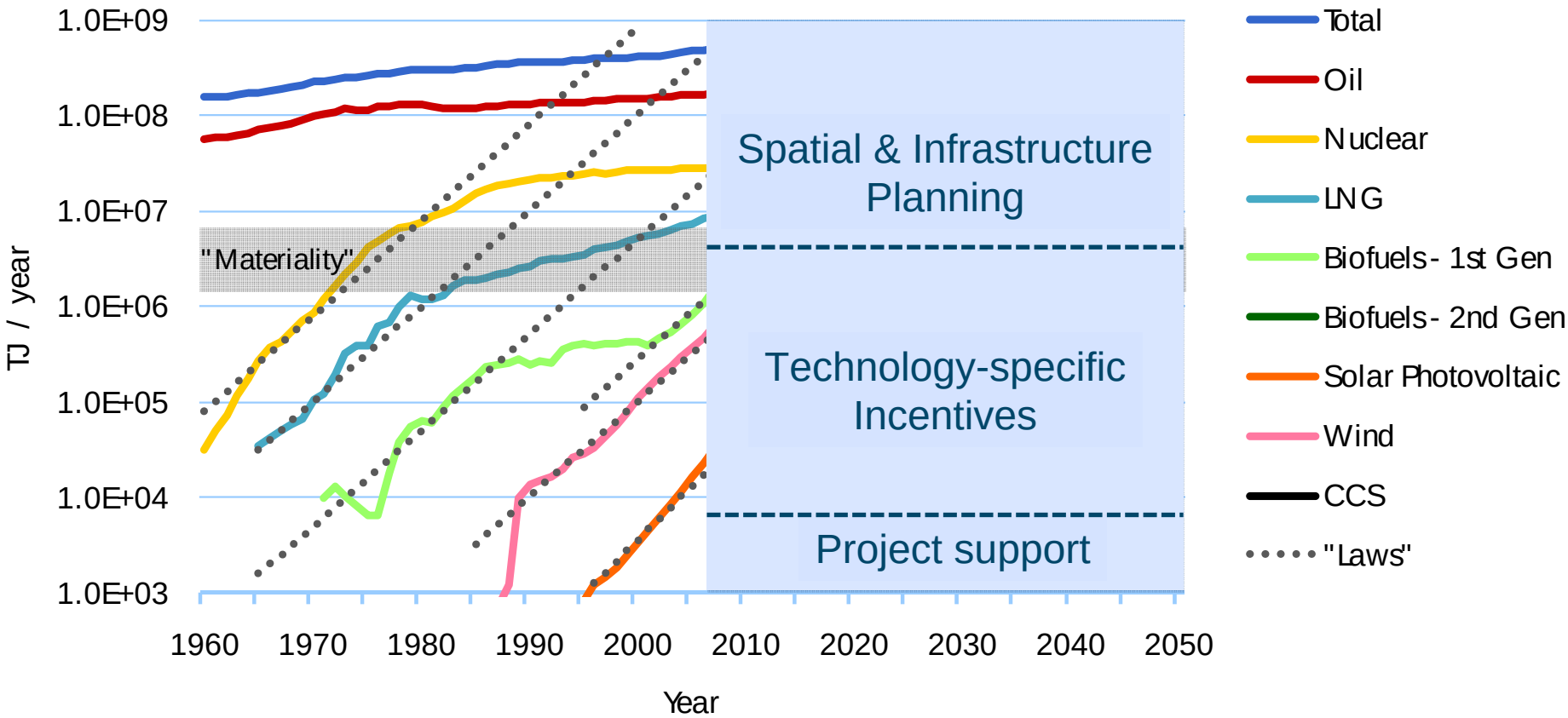


Soon Market Share will become more important than Annual Growth



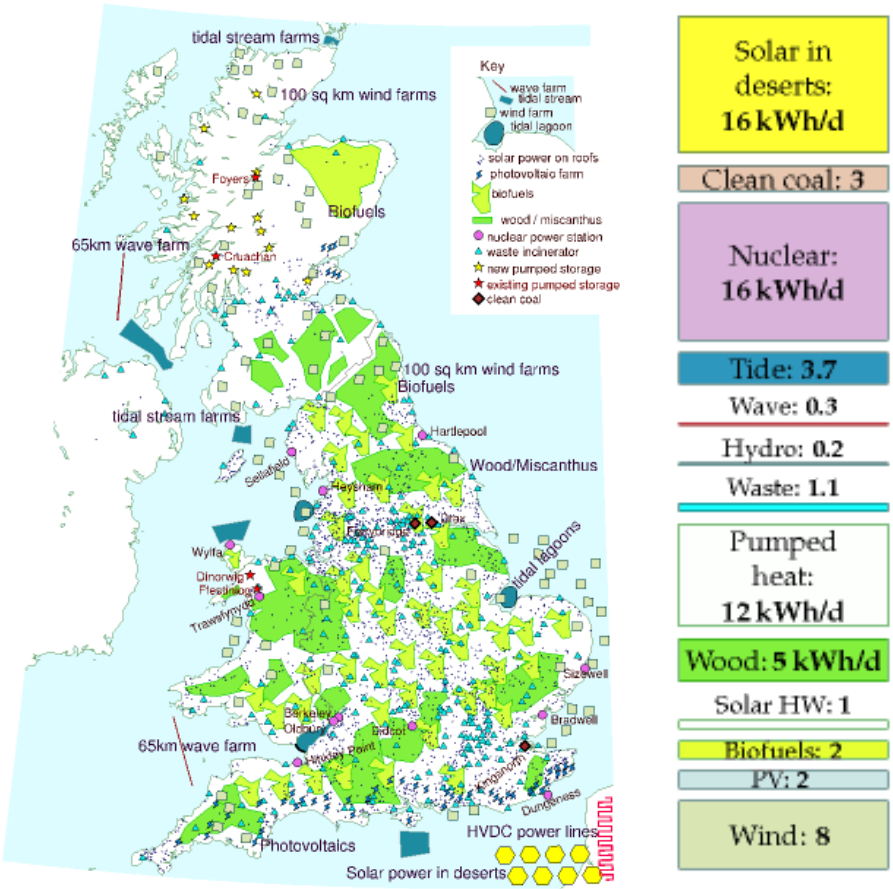
Note: capacity factor of PV varies from 7% (UK), 12-15 (US NE) to 19% (Arizona)

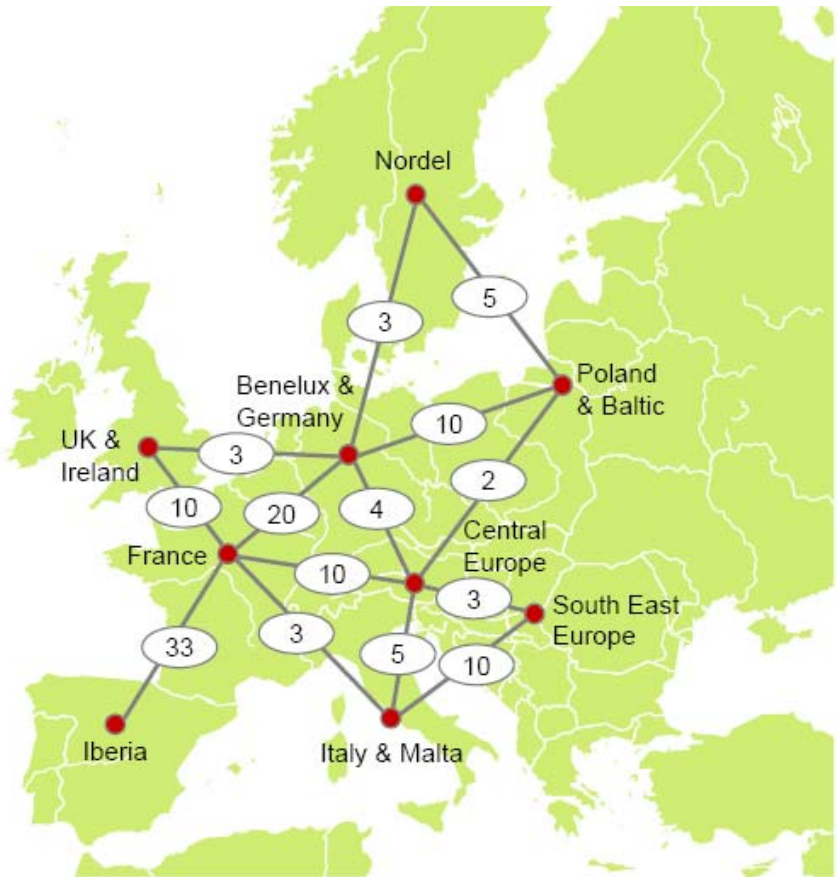
Implications for Policy



In order the “beat the laws” we have to recognize that the nature of the support that energy technologies require changes with their scale. Policy must recognize this and anticipate and prepare for the next stage.

Spatial and Infrastructure Planning



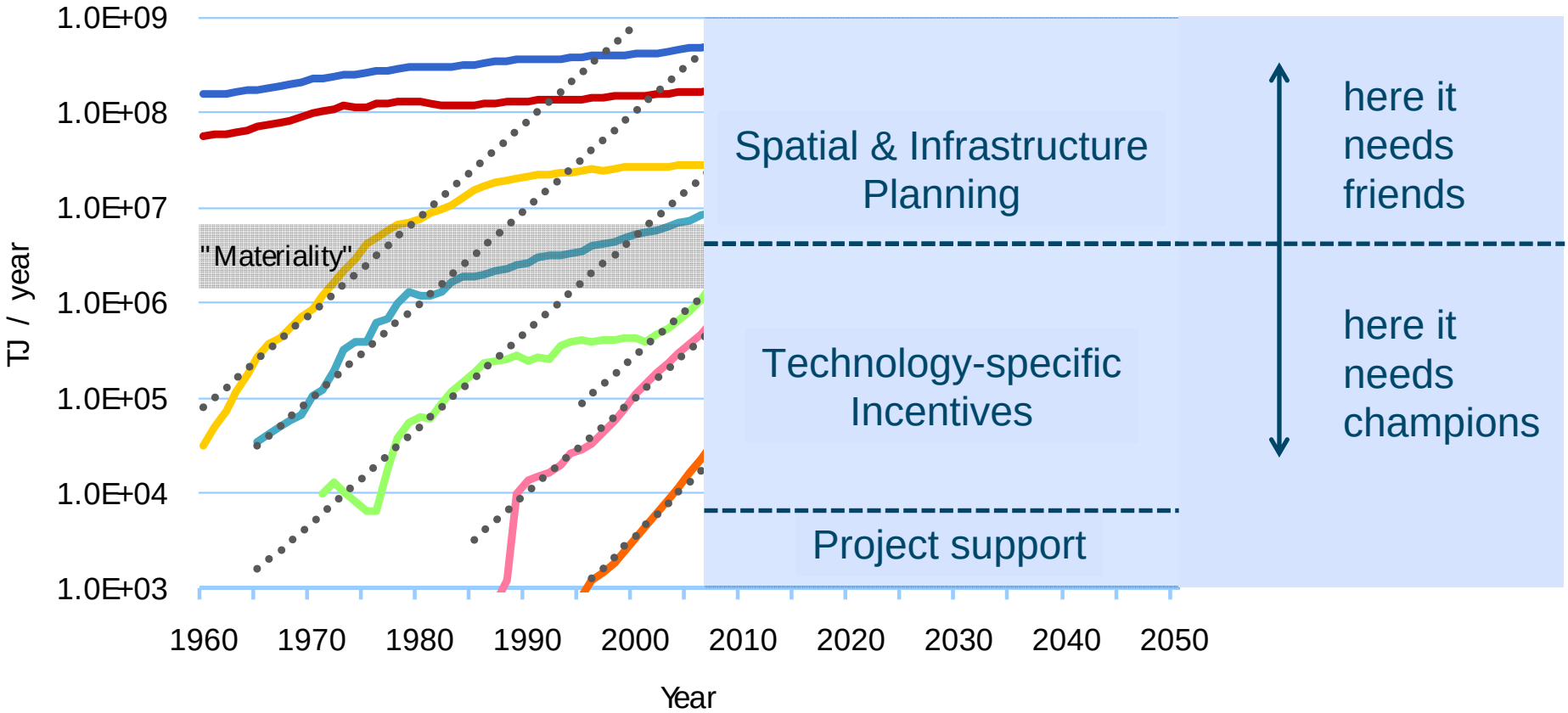


"Industrialization of the country side"

Massive grid expansion to allow 60% RES

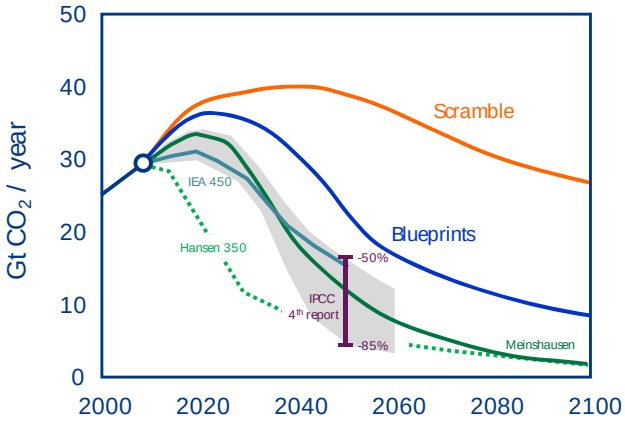
Sources: David MacKay, Sustainable Energy without the hot air (left); ECF Roadmap 2050 (right)

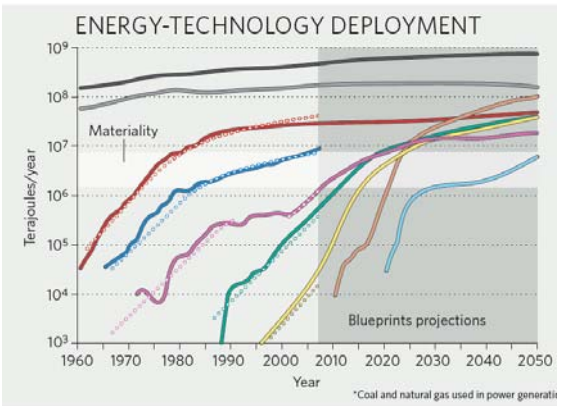
Implications for Society



In order the “beat the laws” we have to recognize that the nature of the support that energy technologies require changes with their scale. Policy must recognize this and anticipate and prepare for the next stage.

Beyond the “Laws”
Demand Side versus Supply Side





“One implication of the deployment laws is that more action is required on the demand side to increase efficiency and curtail consumption. The good news is that demand-side solutions are subject to different laws. In principle, everyone in the developed world could use less energy tomorrow. The bad news is that it has proven exceedingly difficult to restrain our appetite for more energy.”

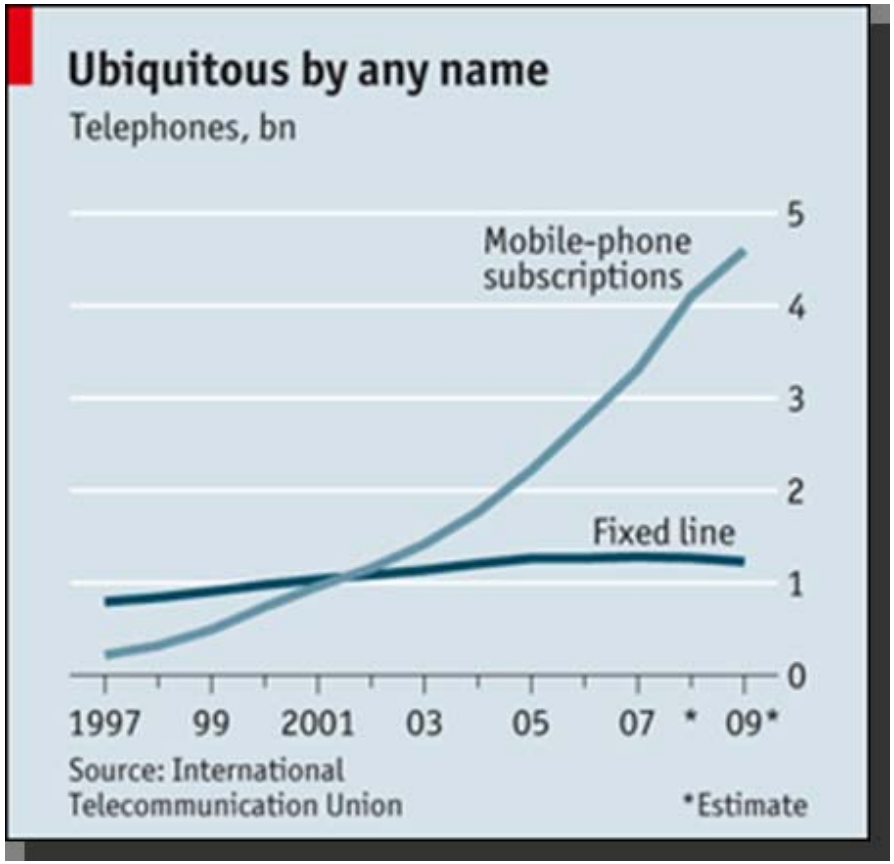
(final sentence of the *Nature* paper)

Source: Gert Jan Kramer and Martin Haigh, *Nature*, **462**, 568 (2009)

Acknowledgement: Martin Haigh

More information: www.shell.com/scenarios

Why not like Mobile Phones?

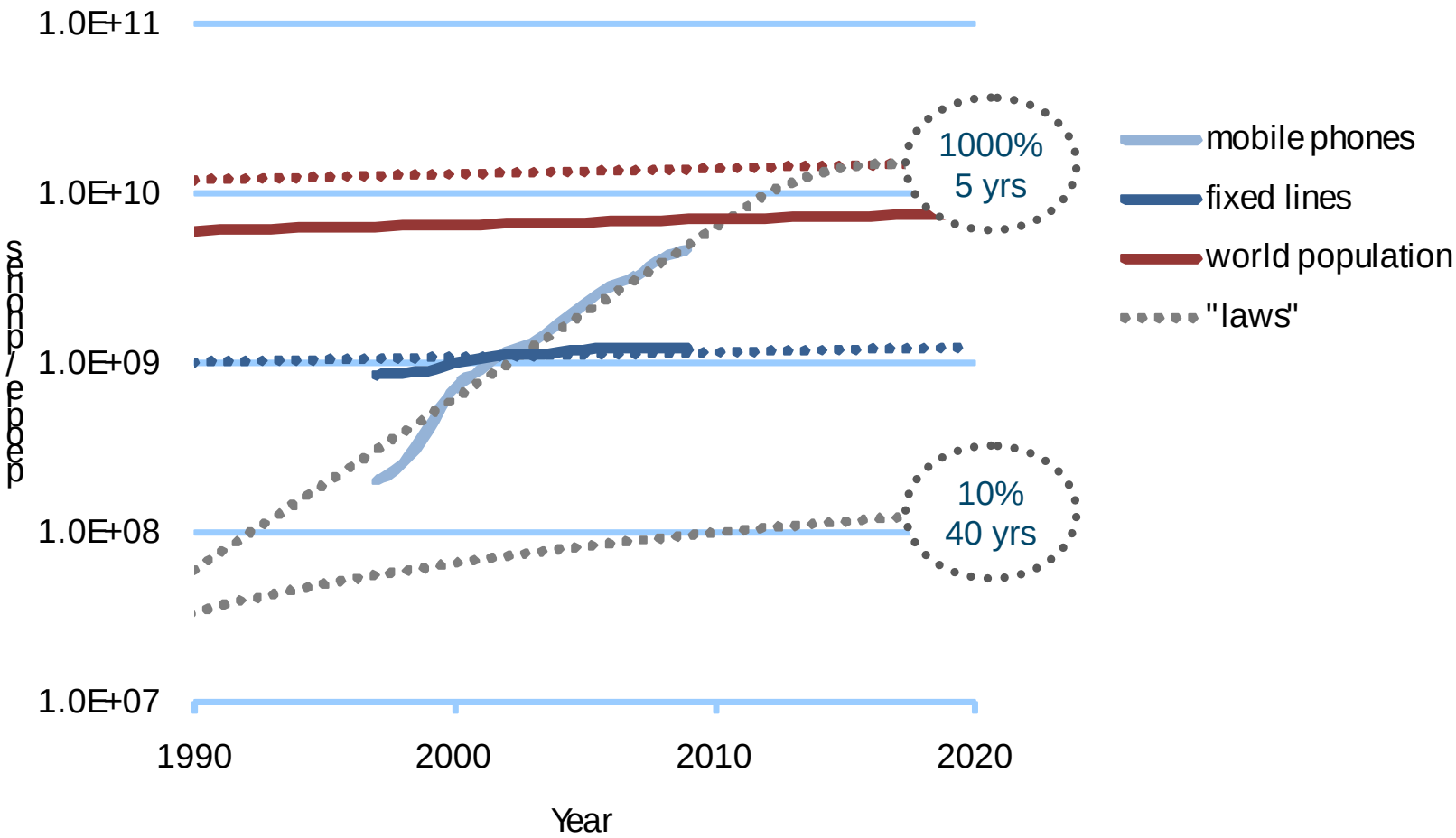


- In the last decade mobile phone subscriptions grew at a pace of about one order of magnitude per decade ("law 1").
- But apparently mobile phones didn't suffer from the slow-down post "materiality ("law 2").

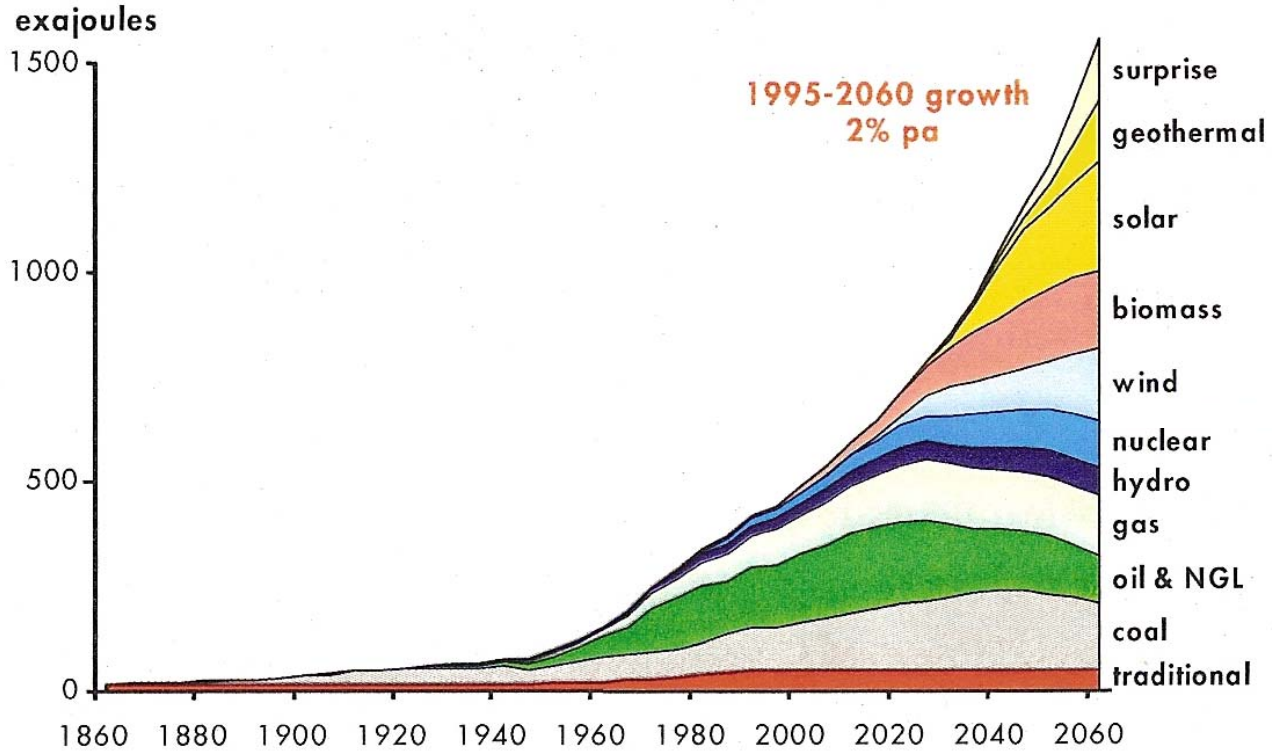
- The dynamics are different. Equipment life is years rather than decades.
- The demand for communication can expand more easily than for energy (mobile phones capture a 1000% market share).

Source: *The Economist* (January 2nd, 2010)

Why not like Mobile Phones?



Surprises?



One of the Shell Energy Scenario of the late 1990's featured a "Surprise." Should we still hope for one?

Energy Sources
Few recent surprises

- Coal — ancient
- Oil — ancient
- Gas — ancient
- Nuclear → "Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?“ *Analen der Physik* (1905)
- Hydroelectricity — ancient
- New Renewables:
  - Wind — ancient
  - Solar → "Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt.“ *Analen der Physik* (1905)
  - Tidal — ancient
  - Wave — ancient
  - Geothermal — ancient
  - Waste — ancient