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THE CENTER FOR INTERNATIONAL ENVIRONMENT & RESOURCE POLICY

Lessons Learned:

Empirical Studies of Innovation and Technology Transfer

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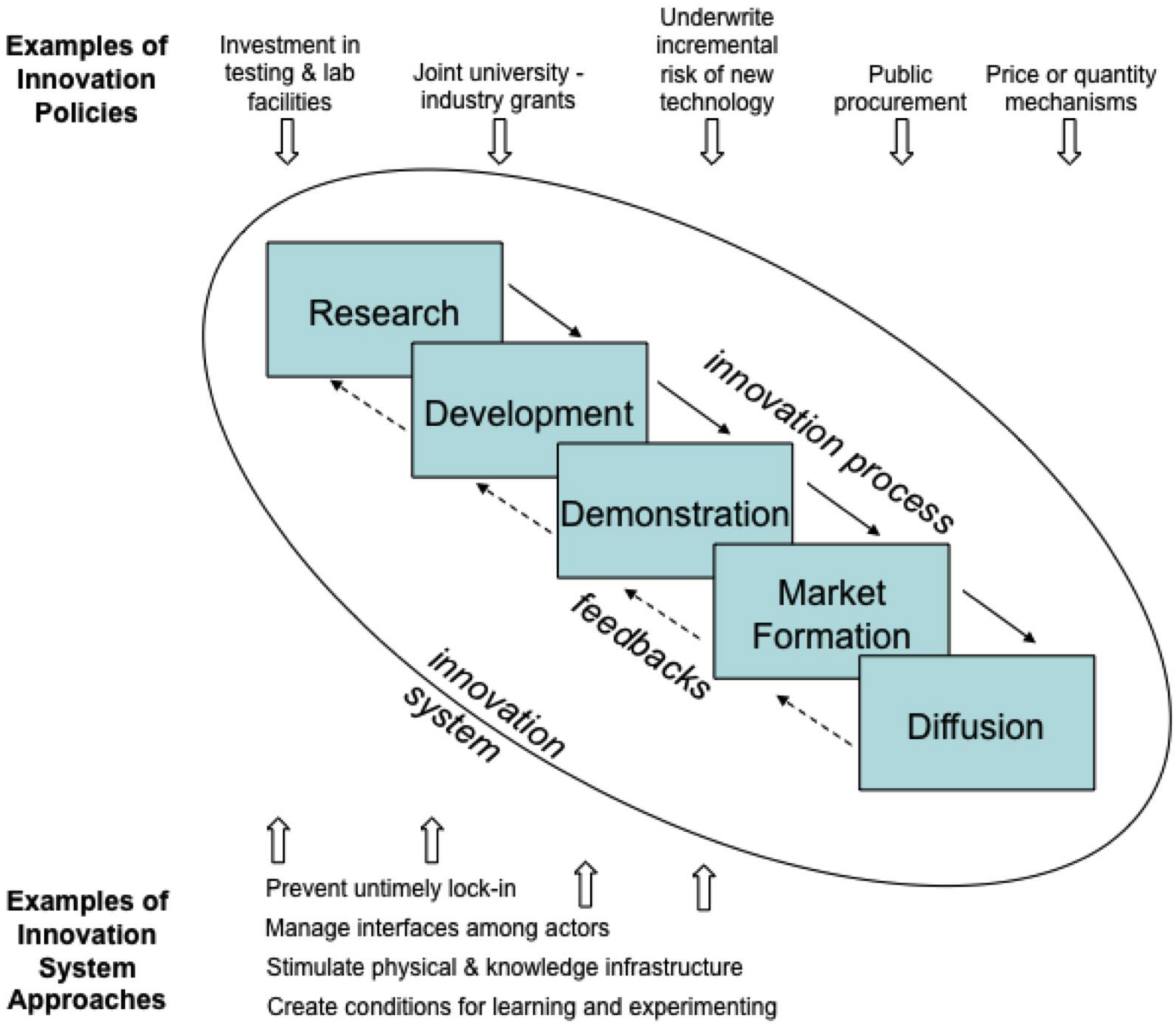
Myths and Realities about Innovation

- "No innovation is needed; all that's required is political will" *or*, "We can't take action now because the needed technologies are not available"
  - There are many technologies available to tackle environmental or social challenges that are underutilized due to insufficient market or policy incentives. But, the full suite of technologies to address climate change, at least, probably still do not exist. But that is no excuse for inaction.
- "The solution is a massive ramp-up in R&D expenditures" *or*, "If only the prices were right, innovation would take care of itself"
  - Government RD&D is a core element of the innovation system, but just one component of broader energy innovation system. A wide range of market failures exist that prevent the private sector from investing in ways consistent with social needs even when prices are "right". No single policy mechanism.
- "We need a balanced portfolio" *or*, "Technology X is the answer"
  - With scarce resources, you cannot avoid "picking winners". Still, there is no silver bullet. All technologies have some liability.

Innovation Theory

Photo of Building Integrated PV hotel in Baoding, China

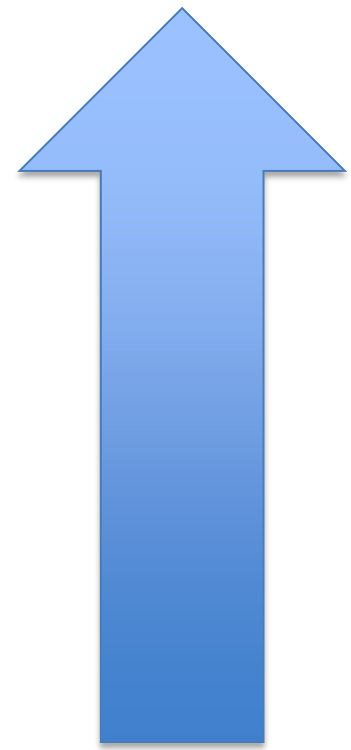
The Growth Model of Innovation



Source: Innovation Chapter, Global Energy Assessment, 2012

The Ladder of Capabilities

Invention
Demonstration
Technology modification
Technology manufacturing and export
Technology acquisition, absorption, and domestic diffusion



Make or buy decision?

Key Processes in Innovation Systems

- Entrepreneurial experimentation
- Knowledge development and exchange in networks
- Guidance of the search
- Market formation
- Resource mobilization and materialization
- Counteracting resistance to change

Empirical Point #1: Costs Don't Always Fall

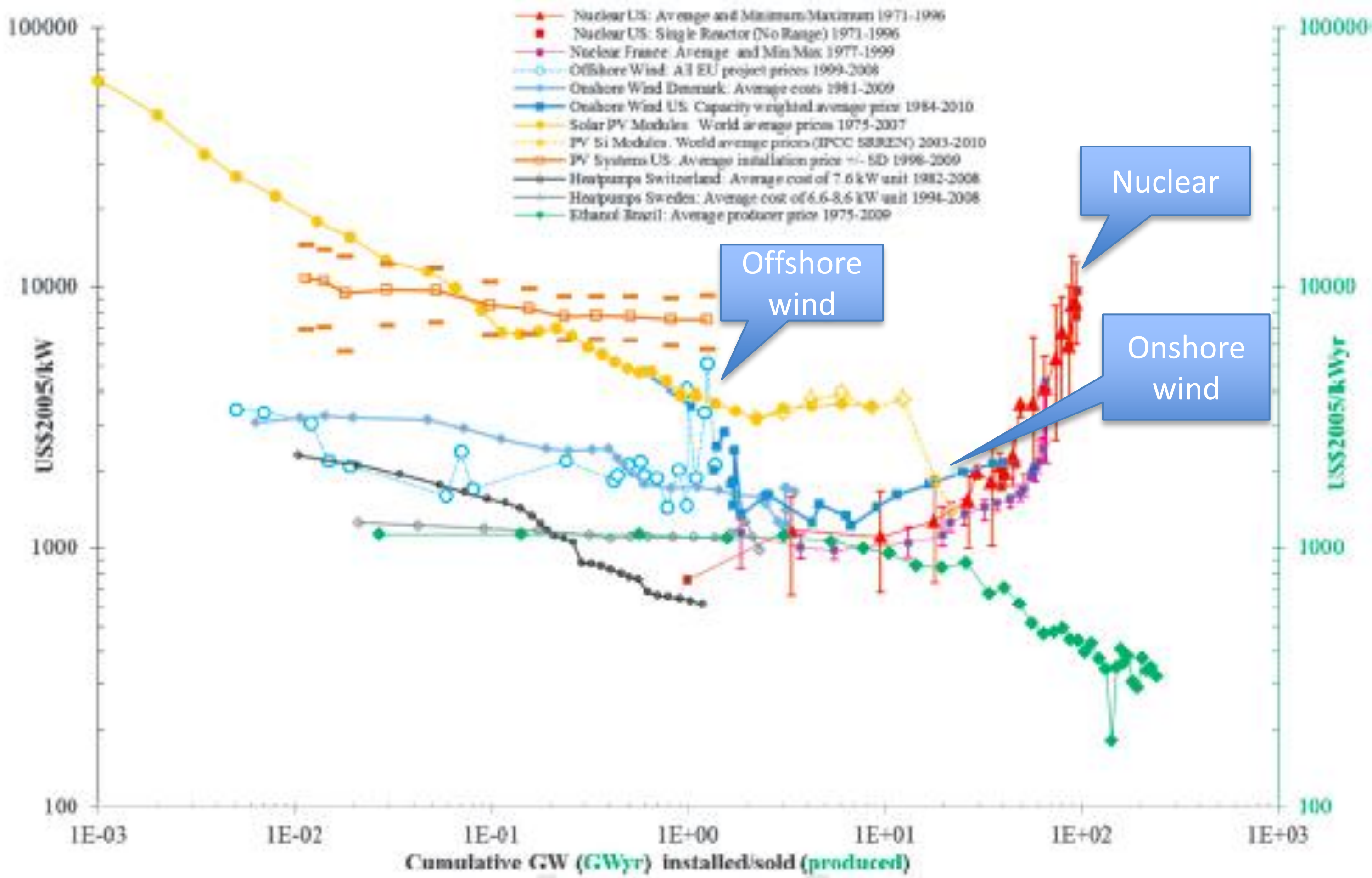
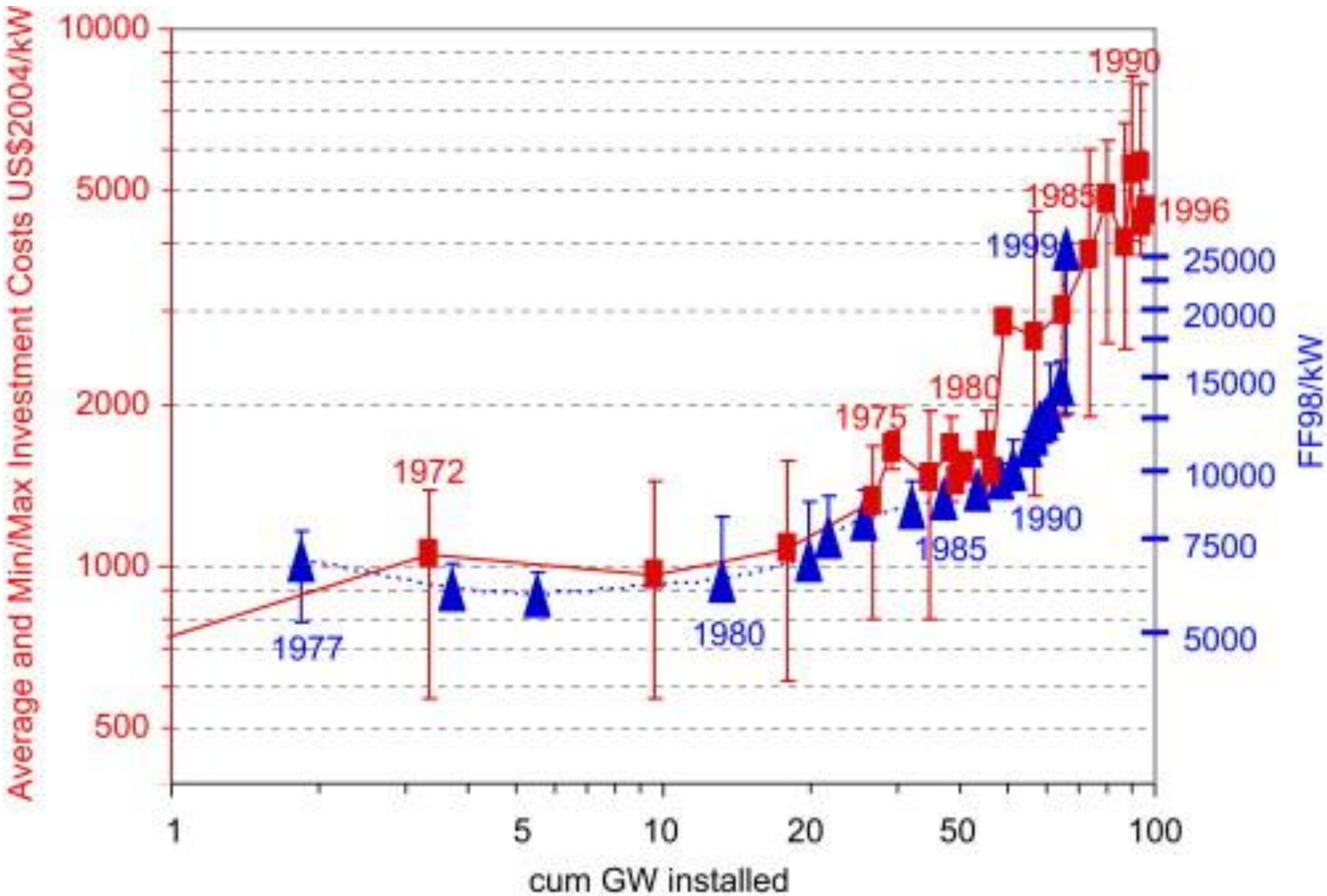


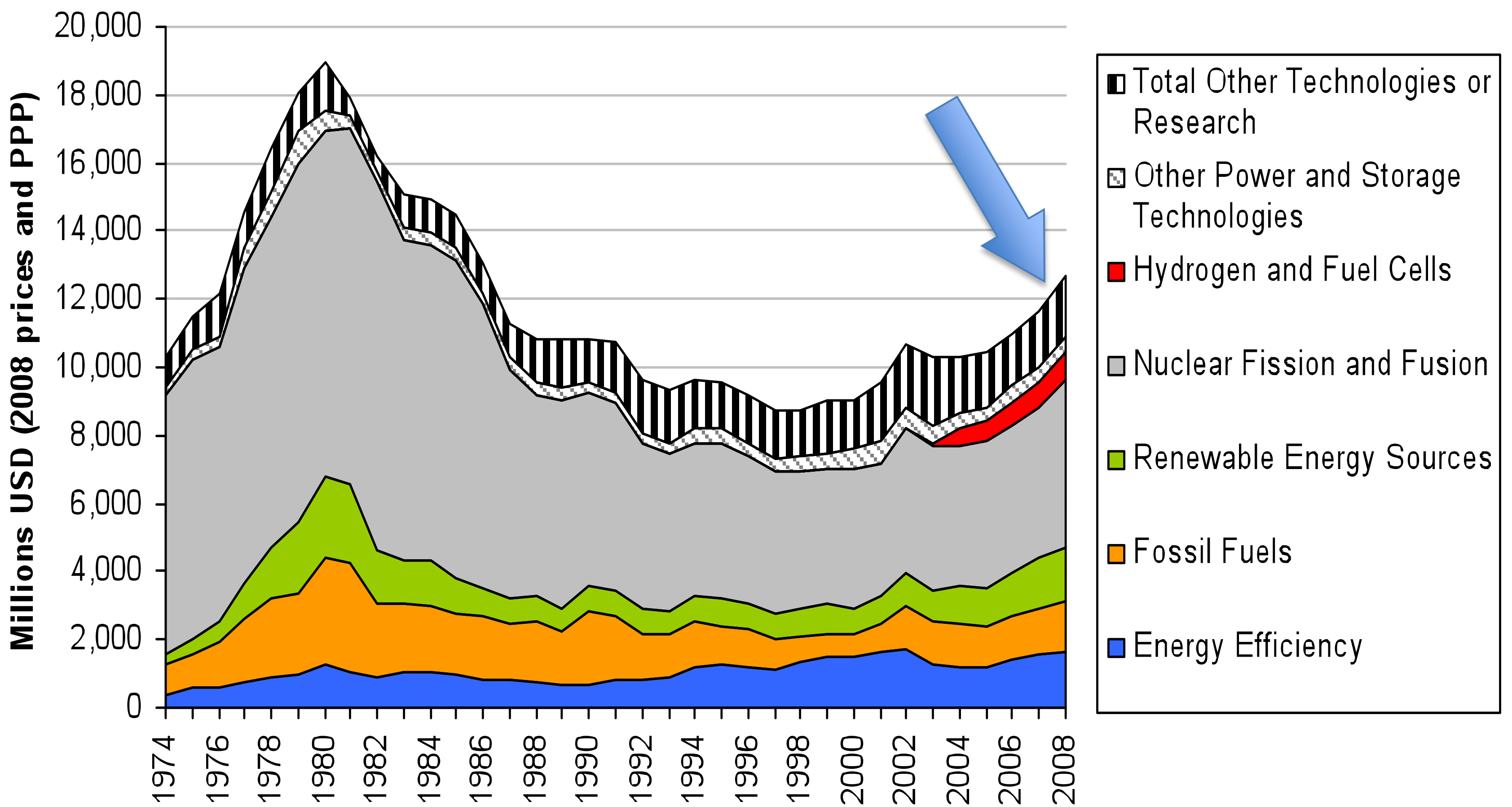
Figure 24.11 | Chapter 24 Case Studies summarized: Cost trends of selected non-fossil energy technologies (US$2005/kW installed capacity) versus cumulative deployment (cumulative GW installed). Source: Chapter 24 case studies.

Average and min/max reactor construction costs per year of completion date for US and France versus cumulative capacity completed



Grubler, Arnulf 2010, "The costs of the French nuclear scale-up: A case of negative learning by doing," Energy Policy, Vol. 38, Issue 9.

Empirical Point #2: Innovation is no longer OECD/national. It is global.



BRIMCS Public Energy RD&D

*in Million 2008 PPP $Int**	**Fossil (incl. CCS)**	**Nuclear (incl. fusion)**	**Electricity, transmission, distribution & storage**	**Renewable energy sources**	**Energy Efficiency**	**Energy technologies (not specified)**	***Total***
United States - Gov't	659	770	319	699	525	1160	*4132*
United States - Other ~	1162	*34*	*no data*	*no data*	*no data*	1350	*2545*
Brazil – Gov't	79	8	122	46	46	12	*313*
Brazil – Other	1167	*no data*	*no data*	*no data*	*no data*	184	*1351*
Russia – Gov't	20	*no data*	22	14	25	45	*126*
Russia – Other	411	*no data*	*no data*	*no data*	*no data*	*508*	*918*
India – Gov't	106	965	35	57	*no data*	*no data*	*1163*
India – Other	694	*no data*	*no data*	*no data*	*no data*	*no data*	*694*
Mexico – Gov't	140	32	79	*no data*	*no data*	*no data*	*252*
Mexico – Other	0.1[1]	*no data*	*no data*	*no data*	263[3]	19[4]	*282*
China – Gov't	6755	12	*no data*	*no data*	136	4900	*11803*
China – Other	289	7	*no data*	*no data*	26	985	*1307*
South Africa- Gov't	*no data*	133	*no data*	*no data*	*no data*	9	*142*
South Africa - Other	164	31[2]	26	7	*no data*	*no data*	*229*
BRIMCS - Gov't	**7100**	**1149**	**> 259**	**> 117**	**> 208**	**> 4966**	***> 13799***
BRIMCS - Other	**2724**	**>> 38**	**>> 26**	**>> 7**	**>> 289**	**> 1696**	***> 4781***
BRIMCS - GRAND TOTAL	**9824**	**> 1187**	**> 285**	**> 124**	**> 497**	**> 6662**	***> 18580***

* Data from United States, Brazil, Russia, India, China and South Africa based on 2008, Mexico on 2007.
'Other' includes (whenever available) funding from state and local governments, partially state-owned enterprises, NGOs, and industry.
~U.S. data on industry expenditure is from 2004 (NSF 2008).
[1]Based on PEMEX's fund for Scientific and Technological Research on Energy
[2]Based on total non-governmental investments into PBMR Ltd.
[3]Based on 2005 R&D expenditure in car manufacturing industry (CONACYT 2008)
[4]Based on 2005 R&D expenditure in utilities sector (CONACYT 2008)
> These cumulative values are based on data from only three to four BRIMCS countries, so actual expecteditures are likely to be higher.
>> These cumulative values are based on data from two BRIMCS countries or less, so actual expenditures are expected to be much higher.

Empirical Point #3: Global energy investments mostly supply-side, mostly fossil fuels

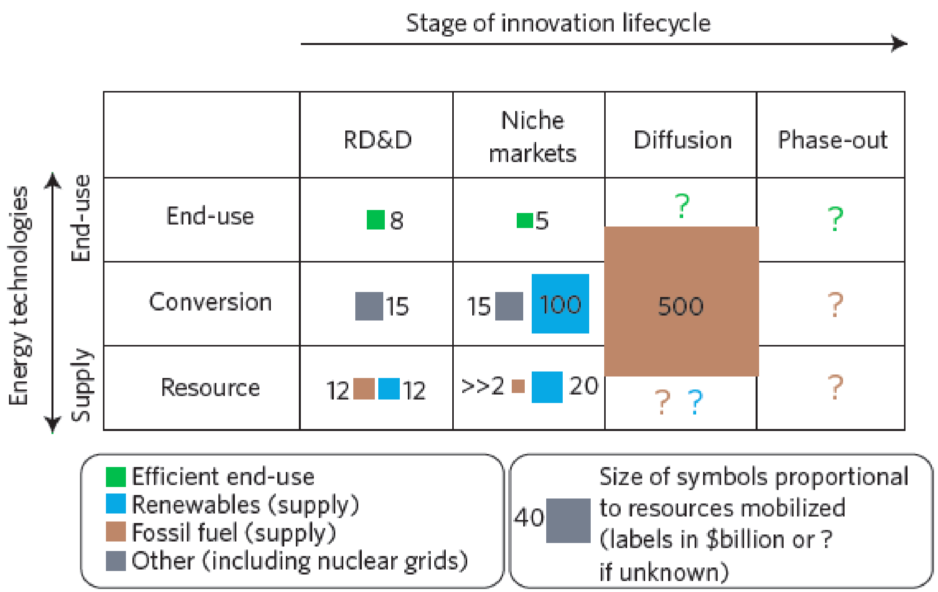
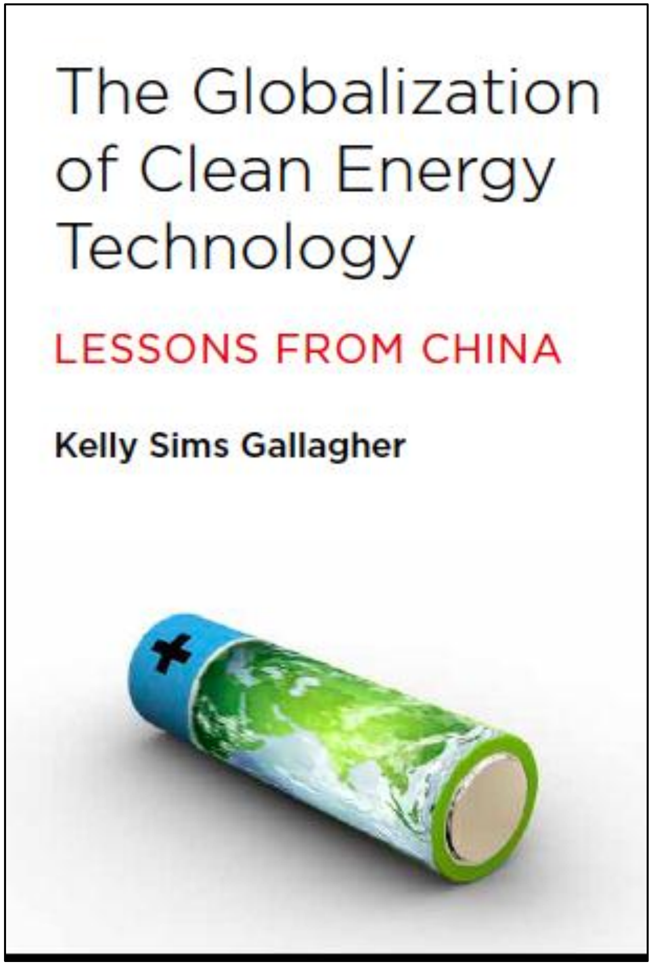


Figure 2 | Global mobilization of financial resources for energy technologies. Energy efficiency improvements in end-use technologies (green).Energy resource extraction and conversion disaggregated into fossil-fuel (brown), renewable (blue), and nuclear, network and storage (grey) technologies (see Supplementary Information for details). The phase-out stage of the innovation lifecycle is included to highlight its importance for capital stock retirement and replacement (that allows for growth of post-fossil-fuel alternatives); however, insufficient data exist to populate its cells.

Source: Wilson, C. et. al 2012, “Marginalization of end-use technologies in energy innovation for climate protection” Nature Climate Change

Technology Transfer



The MIT Press, 2014, currently available at Amazon.com

Assertions Policymakers Make

- We cannot cooperate with/transfer/sell/export technology to [China] because it will be stolen
- We do not have access to clean energy technologies due to patent protections and other restrictions [India]
- The costs of clean energy technologies are prohibitively high for developing countries [G-77]
- There are many barriers to the transfer of technology [UNFCCC]

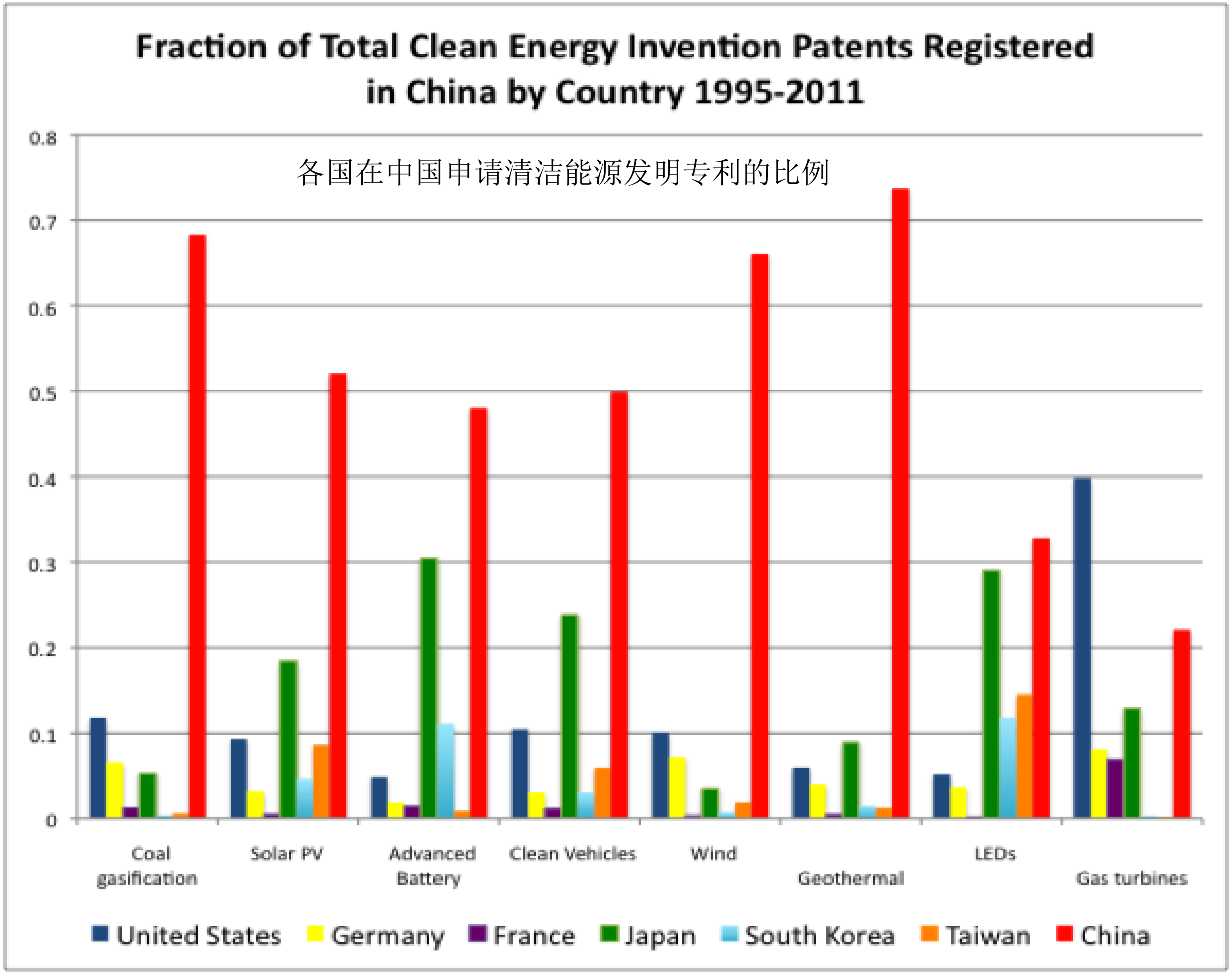
All hypotheses worth investigating. . . What is the empirical evidence?

Mechanisms for diffusion

Mechanism	Variation	Used by Chinese firms to acquire from foreigners	Used by foreign firms to acquire from China
Exports or imports of final goods	Equipment for manufacturing	✔	✔
Licenses		✔	✔
Purchase of foreign firm (M&A)	To acquire technology; merger	✔	✔
Strategic alliance or joint venture	Partial or 100%-owned	✔	✔
Migration of people for work or education	As entrepreneur, consultant, or employee recruited overseas	✔	✔
Contract with research entity	IP is negotiated with foreign university lab, research institute, firm	✔	✔
Collaborative RD&D		✔	✔
Open sources	Textbooks, conferences, journal articles, exhibitions	✔	✔
Bi-lateral or multi-lateral technology agreement	Research, development, demonstration	✔	✔
Sources: author, Lanjouw and Mody 1996, Mowrey and Oxley 1997, Gallagher 2006, Barton 2007, Lewis 2007, Odigiri et al. 2010, Lema and Lema 2010			

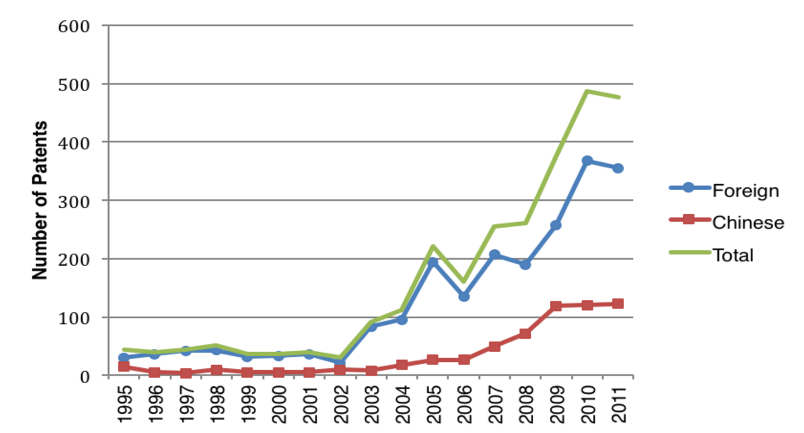
Intellectual Property: 3 Research Methods
知识产权：3种方法

- Case studies
  - Evidence of infringement from interviews
    - One notorious case (Sinovel vs. AMSC)
    - Several minor incidences, none life threatening to firm. Evidence of withholding from interviews
  - Limited evidence of withholding
    - Gas turbines
    - Hybrid electric vehicles
- Analysis of invention patents granted
- Analysis of court cases
  - No Chinese vs. foreign IP infringement court cases in case studies (except for Sinovel), not in the case selection

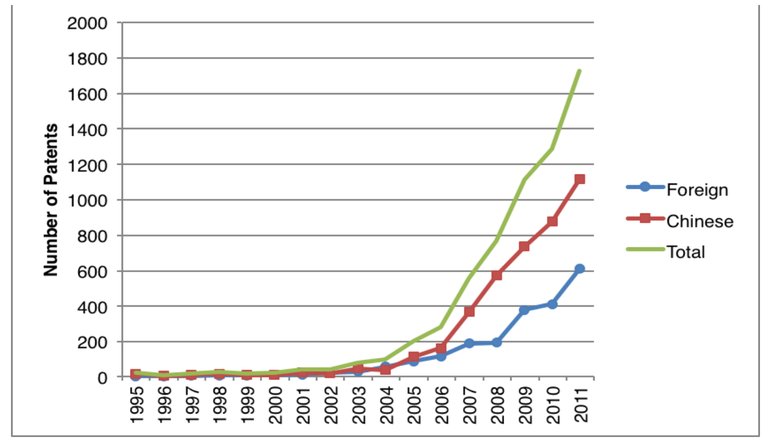


Gallagher, K.S. and A. Irwin, The Fletcher School. Raw data from the State Intellectual Property Organization, China – accessed 2012.

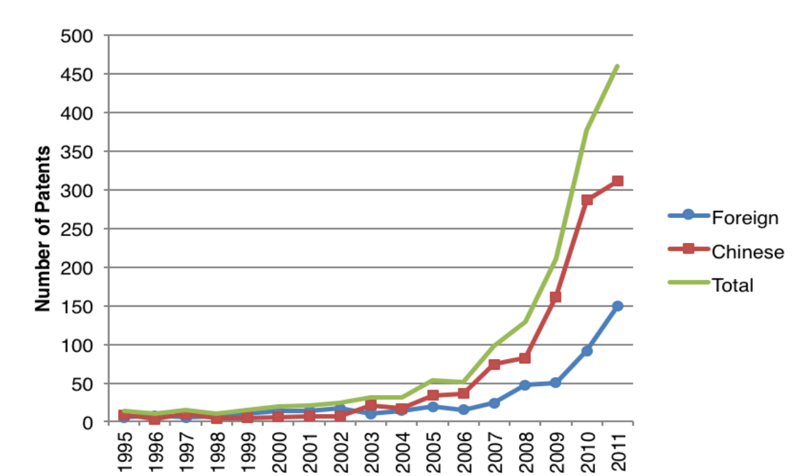
Gas Turbine Invention Patents
燃气轮机发明专利



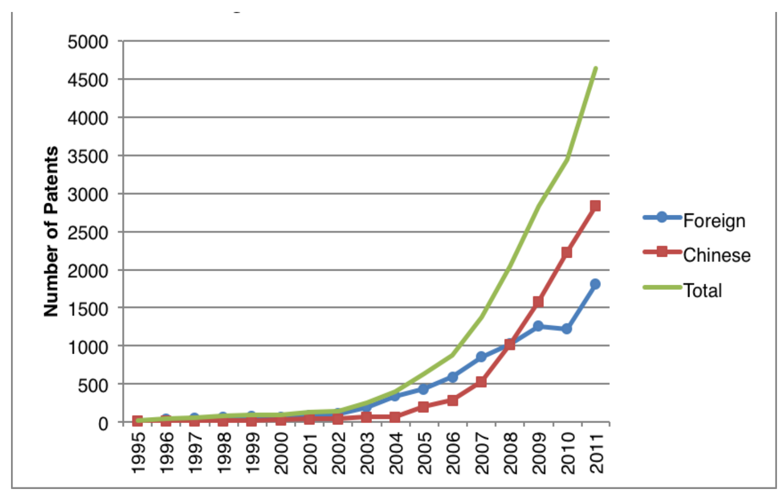
Wind Power Invention Patents
风电发明专利



Coal Gasification Invention Patents
煤气化发明专利



Solar PV Invention Patents
光伏发明专利



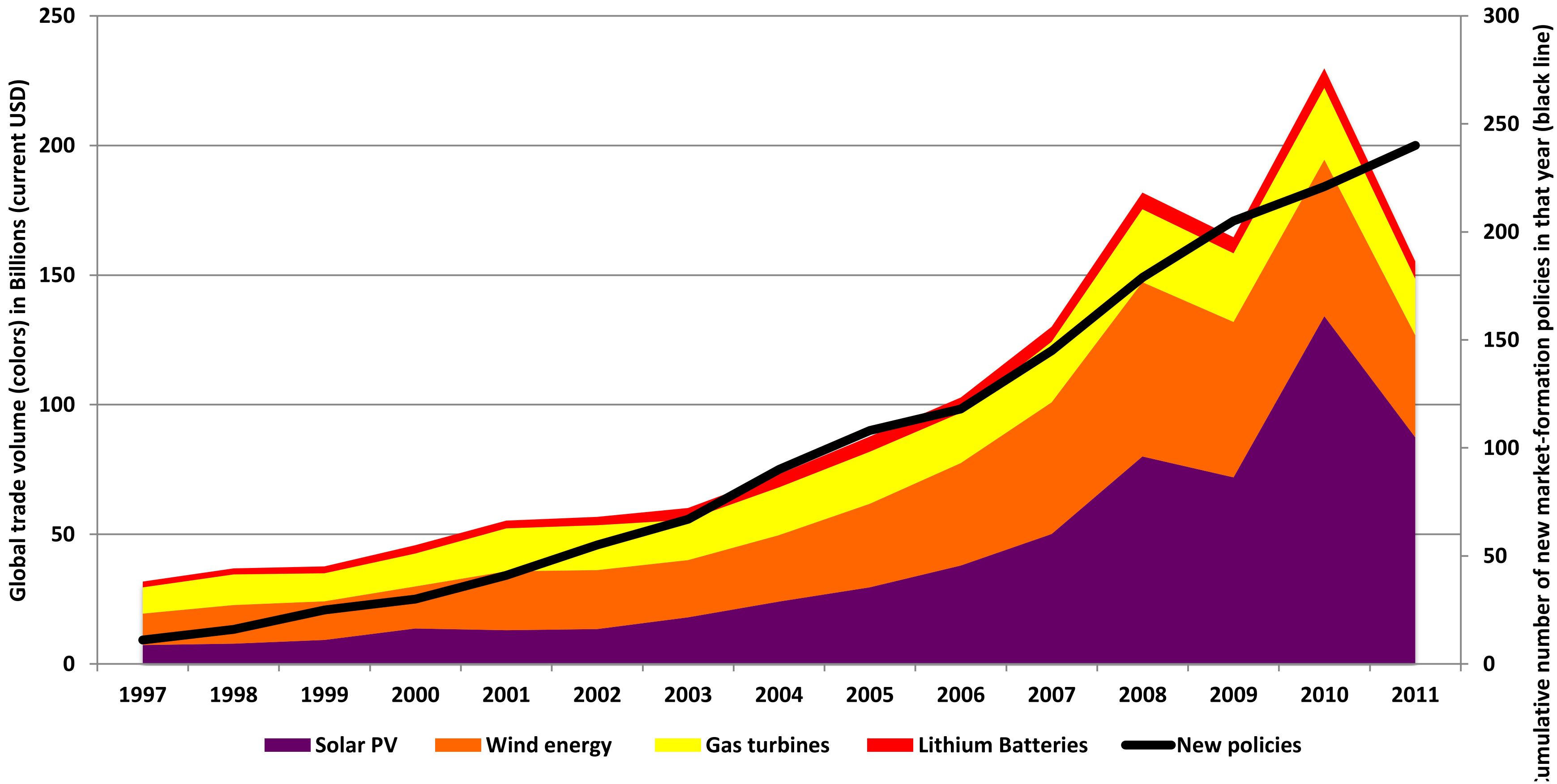
Charts by K.S. Gallagher (2013), data accessed from State Intellectual Property Organization (China) in 2012.

Market failures pervasive but policy can correct for them

- Energy markets are far from "perfect"
  - Asymmetric information (e.g. OPEC vs. consumers)
  - Highly subsidized in some countries
  - Highly regulated in some countries
- Externalities are pervasive and not valued by market
  - Energy security costs
  - Costs of conventional air pollution in terms of public health, premature death, damage to infrastructure
  - Costs of climate change (benefits of avoiding it, costs of adaptation)

National and Sub-National Market-Formation Policies and International Trade in Clean Energy Technologies

国家和次国家单元的市场形成政策与全球清洁能源技术贸易的关系



Trade data from COMTRADE (UN Statistics Division). Policy data compiled from various sources by Gallagher, K.S. 2013

Conclusions

1. Clean energy innovation is no longer a national process: it has globalized
2. Most important barriers are cost (due to market failures & distortions), lack of policy, insufficient access to finance
3. Best incentives are market-formation policies, provision of affordable finance

Updating an integrated theory

1. Diffusion is part of a *global* ETIS – a systemic approach required
   - Harmonization?
2. Most diffusion occurs through private markets
3. Diffusion caused by national and sub-national market formation
4. Market formation is wider than niche markets – structural change is needed (big is beautiful in market scale)
5. Anti-competitive behavior and monopolistic structures hinder diffusion
6. Core to periphery pattern true but international networks matter
7. Appropriateness, absorptive capacity indeed important
8. Technological leapfrogging is possible but not automatic

Thank you

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