The Global Diffusion of Clean Energy Technologies

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Multiple Motivations for Global Diffusion of CETs

Why clean energy?	*Why global diffusion?*
Global climate change	Emissions shifting to non-OECD
Jobs	Human development
Resource efficiency	Finite global resources
Energy insecurity	Global peace and stability
Air pollution (conventional)	Cleaner air and water (local and regional levels)
Economic competitiveness	Sustainable prosperity

Assertions Policymakers Make About Barriers

Technology transferred/sold/exported to [China] will be stolen

The costs of clean energy technologies are prohibitively high [G-77]

Many barriers exist to the transfer of technology [UNFCCC]

Access to clean energy is restricted due to patent protections and other restrictions [India]

What is the empirical evidence?

Research Questions

What are the main barriers and incentives to the cross-border movement of cleaner energy technologies?

- Does the diffusion of clean energy technologies differ from the diffusion of other kinds of technologies?
- Does the theory about international technology transfer hold up to the evidence for cleaner technologies?
- What do the conclusions imply for business practice and government policy?

Into the Dragon's Den: Why China?

- Largest energy consumer in world – paradoxically the largest clean energy economy too
- 2nd largest economy in the world
- Rapid evolution of policy for clean energy
- Chinese firms have used conceivable strategy for developing/acquiring/exporting technology
- China vs. industrialized countries (IP infringement)

Warming to Climate Change in China

If Chinese per-capita emissions of greenhouses gases reach U.S. levels, it would be “a disaster for the world.” China will not “follow the path of the United States. . . We want to reach the peak as soon as possible.”

– Xie Zhenhua, Vice Chair of the National Development and Reform Commission, October 2011

“The party committees and governments at all levels must consider energy conservation and emission reduction as the most important task for promoting scientific development, as the most important measure for transforming the economic development pattern, and as the most important index for evaluating cadres at all levels.”

-Wen Jiabao, Premier, September 2011 in teleconference with local officials

China's Clean Energy Policy Updates

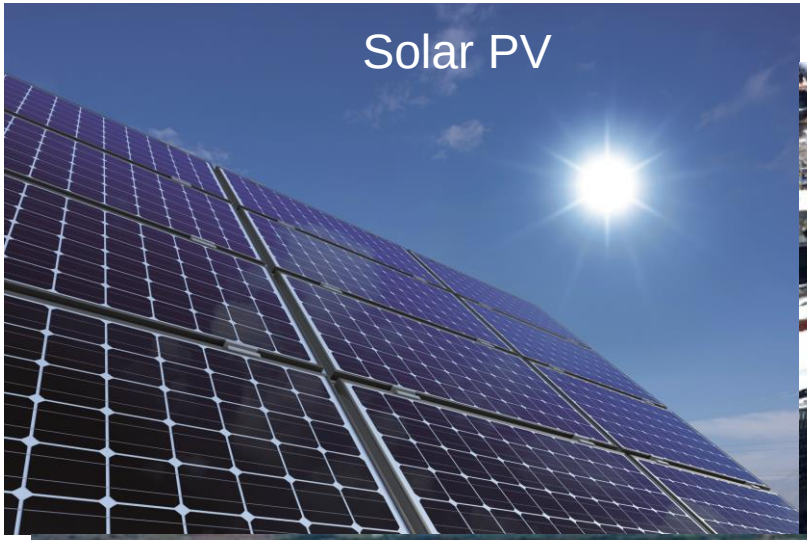
- Establishment of low-carbon development regions
- Piloting of cap-and-trade
- Public energy RD&D programs approx. 2.5 times as large as U.S. investments
- New coal caps (65% of TPE by 2017)
- Strong consideration of carbon tax
- RPS 15% or 500 GW by 2020 (300 GW hydro, 150 GW wind, 30 GW biomass, 20 GW solar)

Table 2.3. Key Targets in China's 12th Five Year Plan (2011-2015)

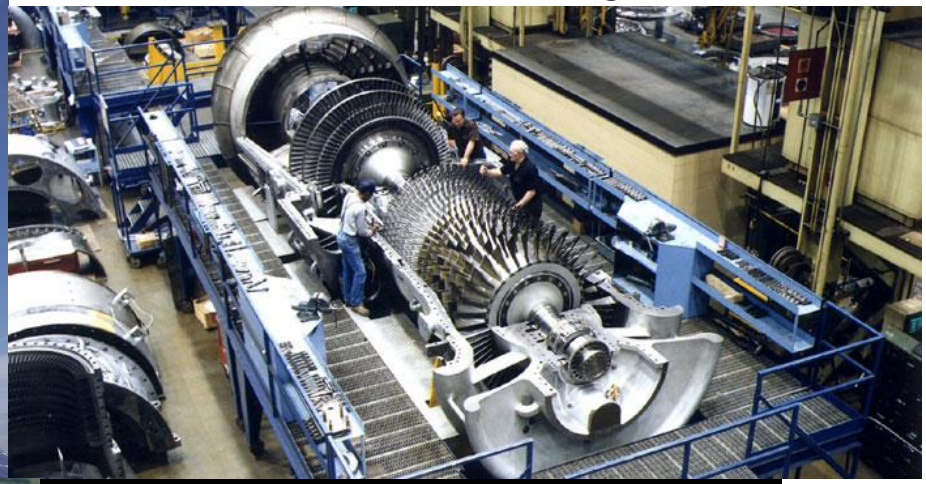
Percentage of non-fossil fuel in primary energy consumption	11.4% 13% by 2017
Carbon intensity (CO_2/GDP) reduction	17%
Energy intensity (energy/GDP) reduction	16%
Strategic emerging industries	Energy saving and environmental protection, new energy, new energy vehicles
Natural gas as % of energy supply	8%
Nuclear as % of energy supply	3%
Hydro, installed capacity	331 GW
Wind, installed capacity	105 GW onshore, 15 GW offshore
Solar, installed capacity	15 GW, including 4 GW rooftop solar PV and 1 GW concentrated solar
Nuclear installed capacity	40 GW new 50 GW by 2017
BEV and PHEV fleets	500,000 vehicles
New building efficiency	65% energy consumption reduction compared with 1980 building stock

Sources: *Various.*

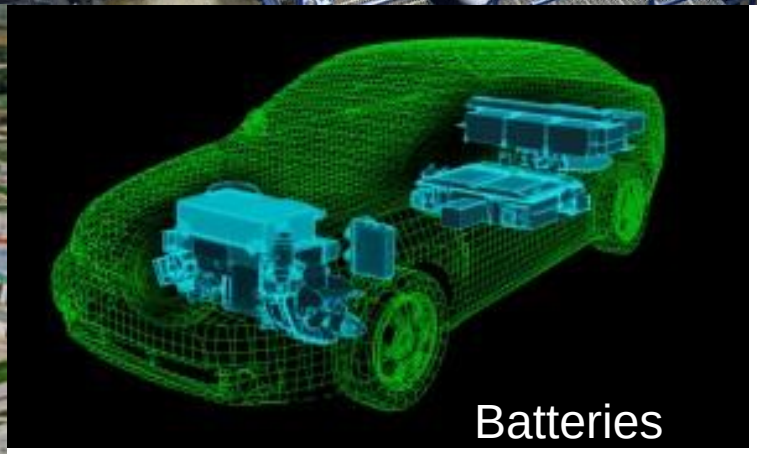
Four Telling Tales: Case Studies



Natural gas turbines



Coal gasification



for advanced vehicles

Mechanisms for energy technology 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

Barriers to the Transfer of Cleaner Energy to and from China

		Gas Turbines	Advanced Batteries	Solar PV	Coal Gasification
Policy factors	Export controls				
	Import tariffs				
	Restriction of access to domestic market				
	Weak innovation policy				
	Weak industrial policy				
	Weak market-formation policy		*	*	
	Weak export promotion policy				
Cost and finance factors	Access to finance/ability to invest		*		
	Lack of "natural" market				
	High cost of foreign technology				

Chinese point of view | Foreign point of view | Agreement Chinese-foreign perspectives

* Before new policies announced in the 12th Five Year Plan

Source: Author analysis, based on case study research

Barriers to the Transfer of Cleaner Energy to and from China (cont.)

		Gas Turbines	Advanced Batteries	Solar PV	Coal Gasification
Intellectual property factors	Export prohibitions in license agreements				
	Defensive, anti-competitive patenting				
	Fear of IP infringement				
	Refusal by foreign firms to license				
Business practice factors	Lack of experience in foreign markets				
	Weak IP management				
	High risk aversion				
	Poor after-sales service				

Chinese point of view

Foreign point of view

Agreement Chinese-foreign perspectives

* Before new policies announced in the 12th Five Year Plan

Source: Author analysis, based on case study research

Incentives for the Transfer of Cleaner Energy to and from China

		Gas Turbines	Advanced Batteries	Solar PV	Coal Gasification
Policy factors	Clear long term policy		*	*	
	Lack of trade barriers				
	Strong innovation policy				
	Strategic industrial policy		*	*	
	Stable market-formation policy		*	*	
	Strong export promotion policy				
	Alignment of policy				
Cost and finance factors	Good access to finance				?
	"Natural" market exists				
	Ability to buy tech if needed				
	Costs of foreign or Chinese technology reasonable				

Chinese point of view

Foreign point of view

Agreement Chinese-foreign perspectives

* Before new policies announced in the 12th Five Year Plan
(?) denotes a lack of data, where as lack of an entry means that the barrier does not clearly apply in this case

Source: Author analysis, based on case study research

Incentives for the Transfer of Cleaner Energy to and from China

		Gas Turbines	Advanced Batteries	Solar PV	Coal Gasification
Intellectual property factors	Strong or improving patent regime domestically				
	Confidence in domestic courts	some	some	some	some
	Willingness of foreign firms to license or cooperate in joint development				
	Strong domestic technological capabilities				
	Knowledge of technology needed/absorptive capacity				
Business practice factors	Experience in foreign markets				
	Flexibility, nimbleness of firms	some			
	Co-location with supply chain				
	Global perspective on markets				
	Good IP management				?
	Tolerance for risk-taking	some	some		
	Good after-sales service				

Chinese point of view

Foreign point of view

Agreement Chinese-foreign perspectives

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(?) denotes a lack of data, where as lack of an entry means that the barrier does not clearly apply in this case

Source: Author analysis, based on case study research

Summary of Main Barriers & Incentives

Most important **barriers** are cost, lack of **policy**, and, insufficient access to finance

Best incentives are market-formation policies and provision of affordable **finance**

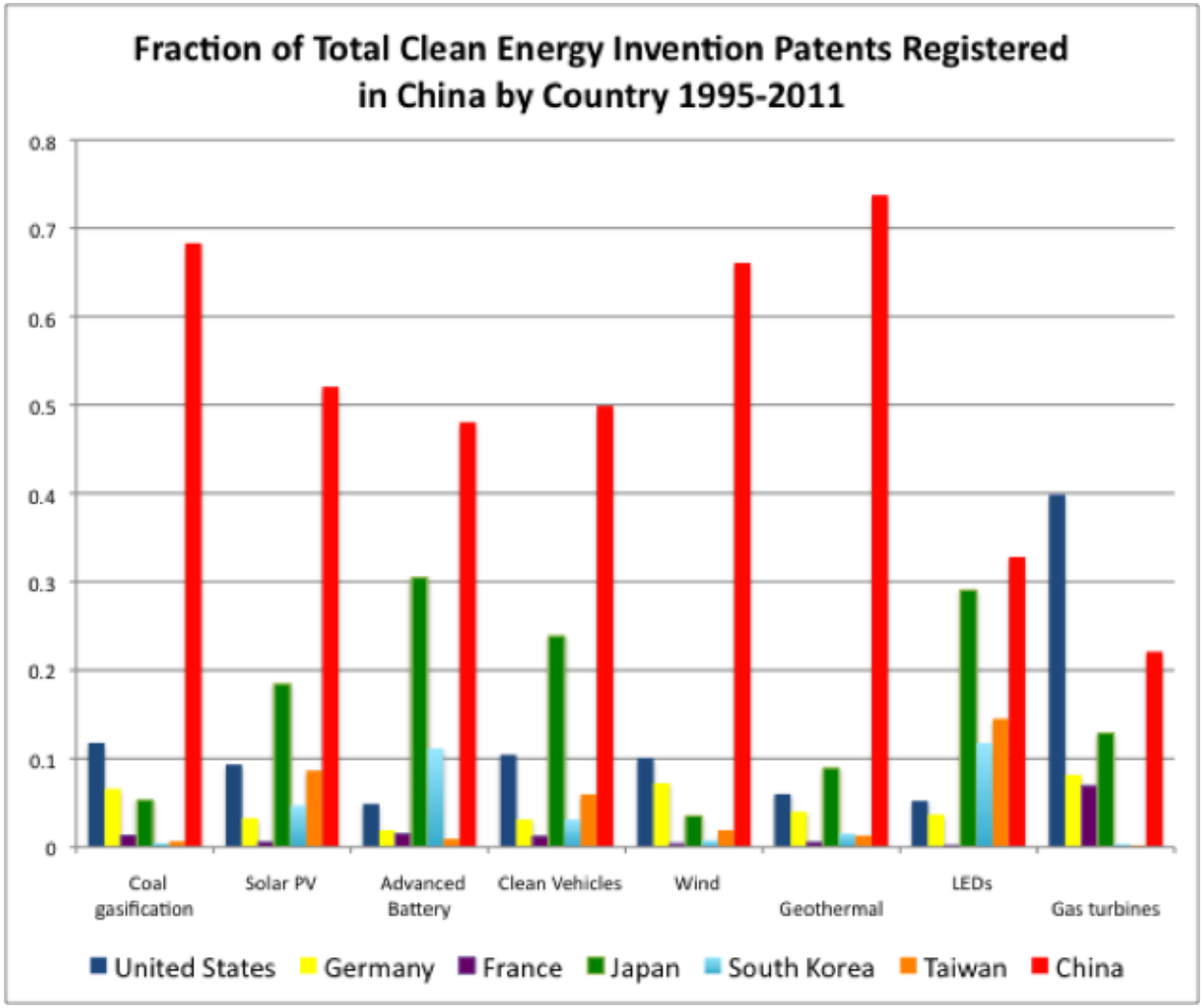
Intellectual Property

Intellectual Property: 3 Research Methods

- **Case studies**
  - Evidence of infringement
    - One notorious case (Sinovel vs. AMSC)
    - Several minor incidents
  - 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

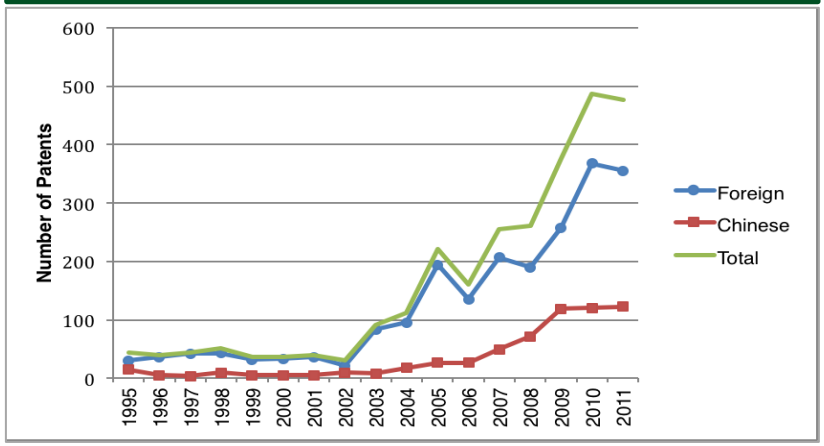
Annual Share of Foreign

My Case Studies

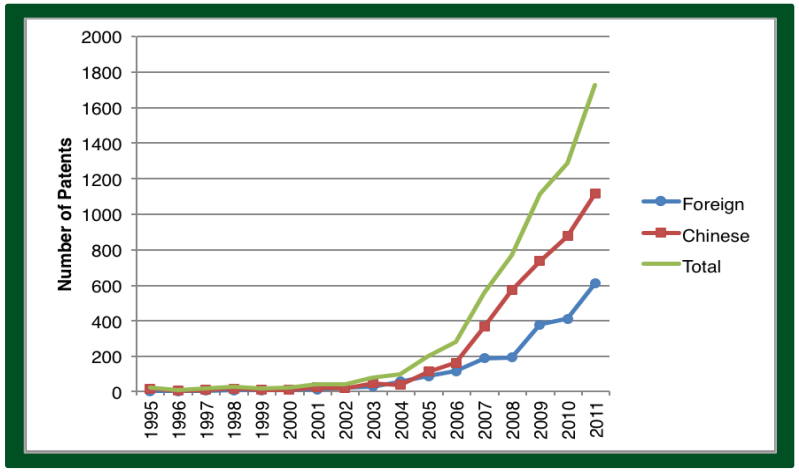


Gallagher, K.S. and A. Irwin, The Fletcher School. Raw data from the State Intellectual Property Organization, China – accessed 2012.

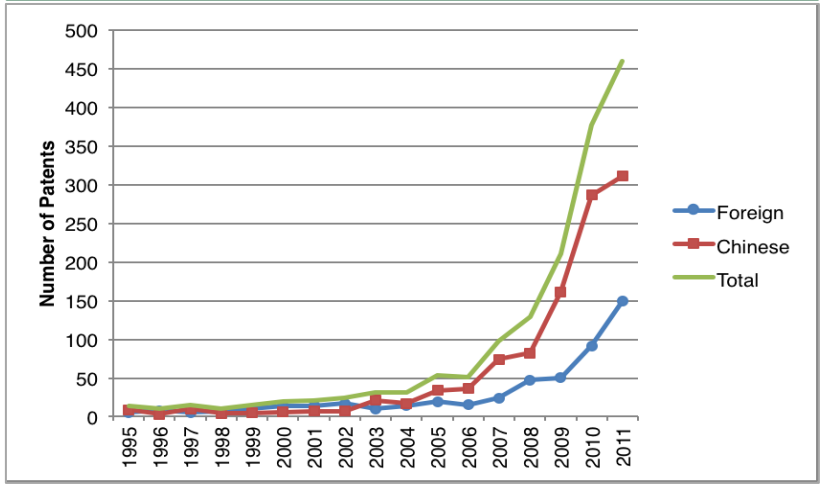
Gas Turbine Invention Patents



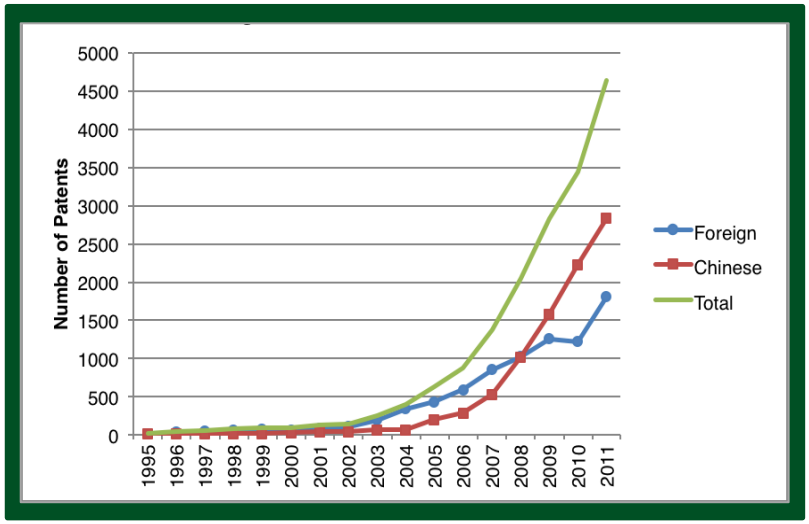
Wind Power Invention Patents



Coal Gasification Invention Patents



Solar PV Invention Patents



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

Clean Energy Invention Patents Granted by China's State Intellectual Property Office (1995-2011)

Cleaner Energy Technology	Foreign Percentage of Total	Chinese annual growth rate since 2005	Foreign annual growth rate since 2005	Year that number of new Chinese patents surpassed number of foreign patents
Gas turbines	78%	37%	28%	Not yet
LEDs	67%	72%	28%	Likely in 2012
Wind	34%	68%	44%	2005
Clean vehicles	50%	49%	39%	2009
Coal gasification	32%	58%	46%	2003
Advanced batteries for vehicles	52%	n/a[1]	n/a[1]	n/a[1]
Geothermal	26%	53%	23%	2002
Solar PV	48%	85%	28%	2008

Notes: All data from SIPO, calculations by author.
[1]The data series is too short

Reported Court Cases Related to Clean Energy Invention Patent Infringement in China

	Litigants	Nationality	Date Recorded[1]
Solar PV[2]	Grenadines Electronics (Xiamen) Co., Ltd. vs. Sulan Lou, Zhejiang China Commodities City Group Co., the second branch of the International Trade City	Chinese vs. Chinese	2010.12.15
	Yung-Wei Xu vs. Huatuo Solar Technology (Fenghua City) Co., Ltd.	Chinese vs. Chinese	2010.12.15
	Weihai Kehua Lighting Engineering Co., Ltd. vs. Jilin Chaoyu Industry and Trade Co., Ltd.	Chinese vs. Chinese	2007.12.15
Advanced Batteries for Vehicles[3]	Lanyi Chen vs. Jianbing Chen, Jianhua Chen, Liyan Chen	Chinese vs. Chinese	2007.12.15
	Inco Advanced Technology Materials (Dalian) Co., Ltd and Hunan Kaifengnew Co., Ltd vs. Hunan Corun New Energy Co., Ltd.	Chinese vs. Chinese	2009.12.15
Coal gasification[4]	Shanxi Institute of Coal Chemistry, Chinese Academy of Sciences vs. Shanxi Qinjin Coal Gas Gasification Equipment Co., Ltd	Chinese vs. Chinese	2007.12.15
	Beijing Jia Dei Xing Ye Science and Technology Co., Ltd, vs. Harbin Shiji Heat Energy Technological Development Co., Ltd, Sino Coal Dragon Harbin Gasification Co., Ltd	Chinese vs. Chinese	2010.12.15
Gas turbines[5]	None		

Notes: All data from Chinese government website: http:/ipr.court.gov.cn/, downloaded during April 1-10. 2012.

The IP Puzzle: Some Hypotheses

Hypothesis 1: Foreign firms are reluctant to pursue court cases because (1) not win in a Chinese court, or (2) not worth the trouble

Hypothesis 2: Clean energy techs are not sufficiently mature to warrant significant litigation

Hypothesis 3: Many cases are mediated or arbitrated

Hypothesis 4: Energy techs are complex systems, hard to copy

Hypothesis 5: Chinese capabilities are strong, they want to protect their own IP

Cost

Market Failure Pervasive

Energy markets are far from “perfect”

- Asymmetric information (e.g. OPEC vs. consumers)
- Highly subsidized
- Highly regulated

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

Cost and Finance

"The number one barrier is policy. Well, it is cost, and therefore you need to have policy to create the market."

-- Shi Zhengrong, CEO, Suntech

- Access to finance is not a barrier for the Chinese. Major competitive advantage.
- For smaller foreign firms, access to finance is their biggest problem
- The incremental costs of cleaner technologies are already being overcome with market-formation policies around the world

Policy

Universal agreement about importance of policy

"Government policy is extremely important to drive long-term sustainable development."

- Ed Lowe

"Without government regulation, you won't have a market for clean energy."

- Hans-Peter Bohm

"The policy environment is important – principally the stability and the predictability."

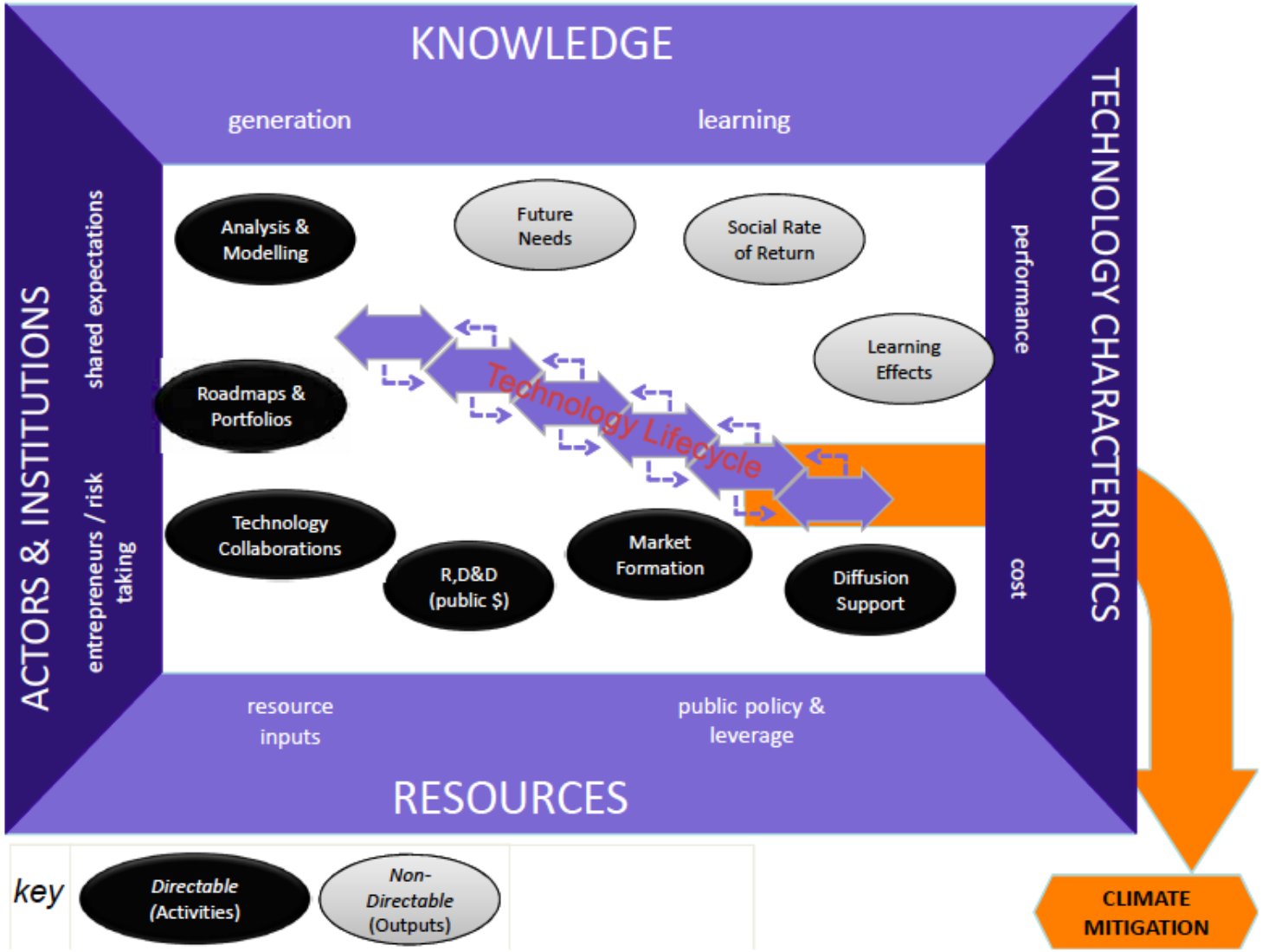
- Dick Wilder

Four types of policy affect global diffusion

1. Domestic manufacturing or industrial policy
2. Technology or innovation policy
3. Export promotion policy
4. Market-formation policy

Of course, policies can also inhibit diffusion as well

Innovation policy: a systemic approach



Chapter 24, Global Energy Assessment 2012

Snapshot of direct government support and related other sources of funding for energy RD&D in the BRIMCS in 2006

*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.

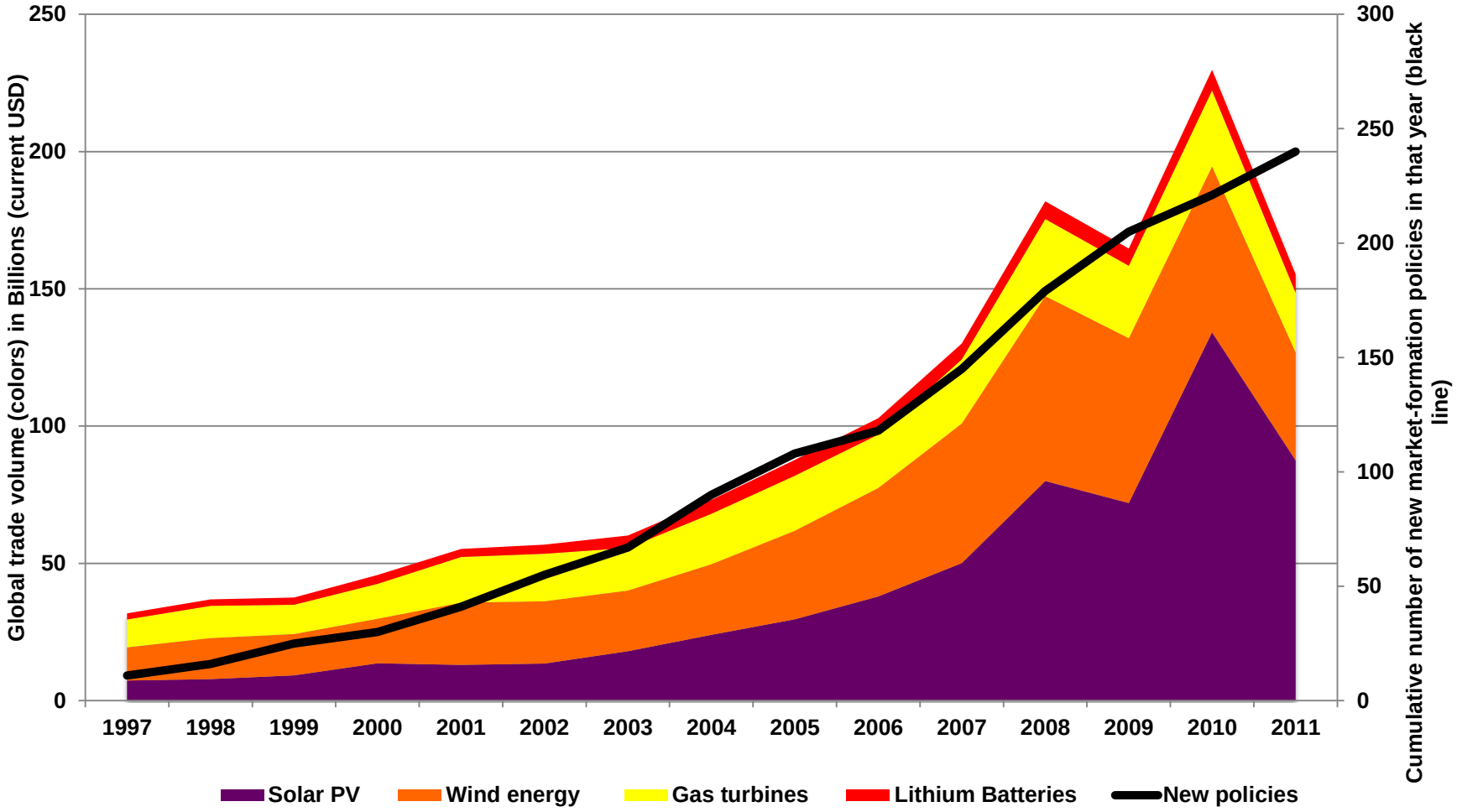
Domestic manufacturing or industrial policy

- *“You cannot export what you don’t manufacture”*
  - Forgiving domestic market required (scaling up, commercial demonstration, national branding)
- Availability of capital
  - “Like snowballs rolling down a hill”
- Standardization, agglomeration
- Innovation and technology policy
  - push and pull – systemic approach
- Export promotion

What is market-formation policy?

- *Not* the same thing as niche market formation
- More structural and broader in intent: compensate for market failures and overcome the “valley of death”
- Creates demand for certain types of technologies
  - 92 states, provinces or countries have established feed-in policies
  - 71 states, provinces or countries have either a RPS or a quota policy
- Evidence from the cases: solar PV vs. natural gas in China

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



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

The clean energy industry globalized around 2000: Why and how?

- Internalization of university education
- International collaboration
- Ease and increased normalcy of migration
- Globalization of energy RD&D
- Aggregated national market formation policies = global markets
- Trade liberalization and new int'l institutions
- Chinese willingness to finance the transition

Three Implications for Policy

1. Market-formation policy is essential

   Corrects the market failures. Creates investment certainty. Facilitates learning-by-doing. Usually leads to cost reductions.

   Harmonization to improve standardization?

2. Improve access to and availability of favorable finance

   U.S. at competitive disadvantage with China

3. Global perspective for technology acquisition and sales

   Innovation is no longer a national process

Conclusions

1. Clean energy innovation has **globalized**: it is no longer a national process

2. Most important barriers are cost, lack of **policy**, and insufficient access to finance

3. Best incentives are market-formation policies and provision of affordable **finance**

Updating technology transfer 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

Acknowledgements

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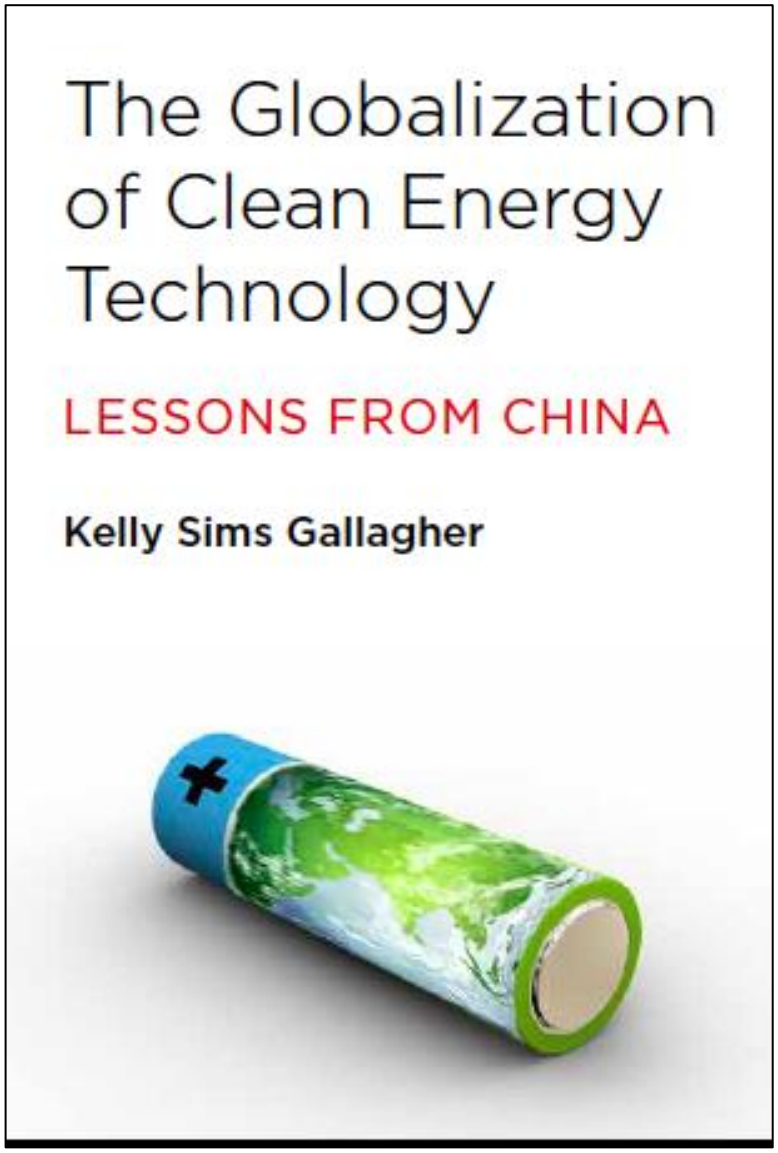

The MIT Press, 2014

Thank you