

# Renewables, energy security, learning curves and the greening of capitalism

School of Photovoltaic and Renewable Energy Engineering  
UNSW Sydney

16 October 2014

Professor John A. Mathews

Professor of Strategy, MGSM, Macquarie University, Sydney

## Industrial dynamics perspective: Why renewables provide the best form of 'energy security'

The green transition – in many ways, the biggest business transition there has ever been, the **biggest business opportunity of 21<sup>st</sup> century**

But what dominates debate is a mainstream economics perspective – carbon taxes; cap and trade; a cost-based perspective

Viewing green programmes solely as carbon emissions-reducing vehicles is self-defeating – places programmes outside evolutionary and entrepreneurial business dynamics, and sets up false dichotomy: development vs. zero-growth

**Instead**, can view green growth as part of a larger transition

\*China's pursuit of renewables (to complement its coal-based energy) is not a moral imperative, but an economic imperative

Renewables are manufactured devices, and can be utilized anywhere -- energy is harvested, and captures increasing returns

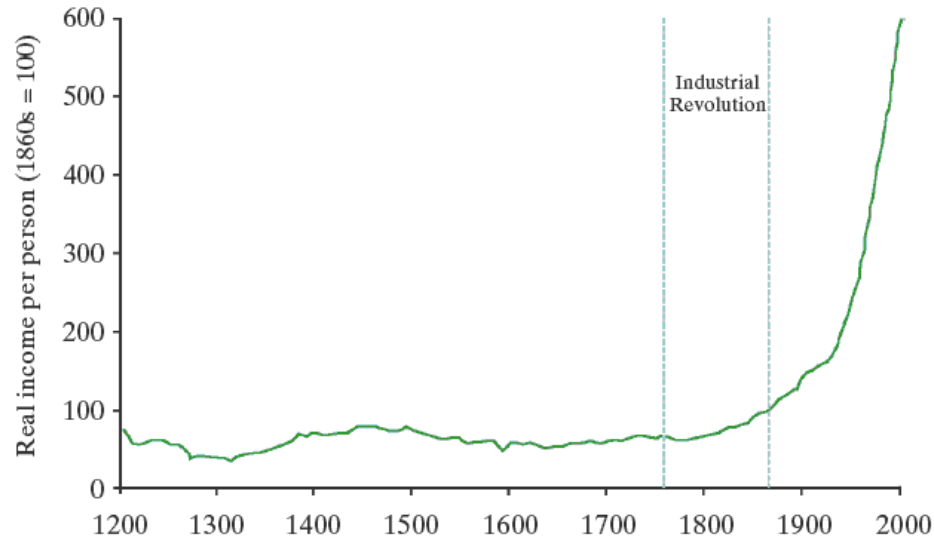
\*Renewable power viewed not as a carbon-reducing technology, but as based on manufacturing – thereby enhancing energy security

**A powerful source of energy security**



# Why China wants to industrialize: Growth of per capita income, England, 1260s – 2000s

REAL INCOME PER PERSON IN ENGLAND,  
1260s–2000s

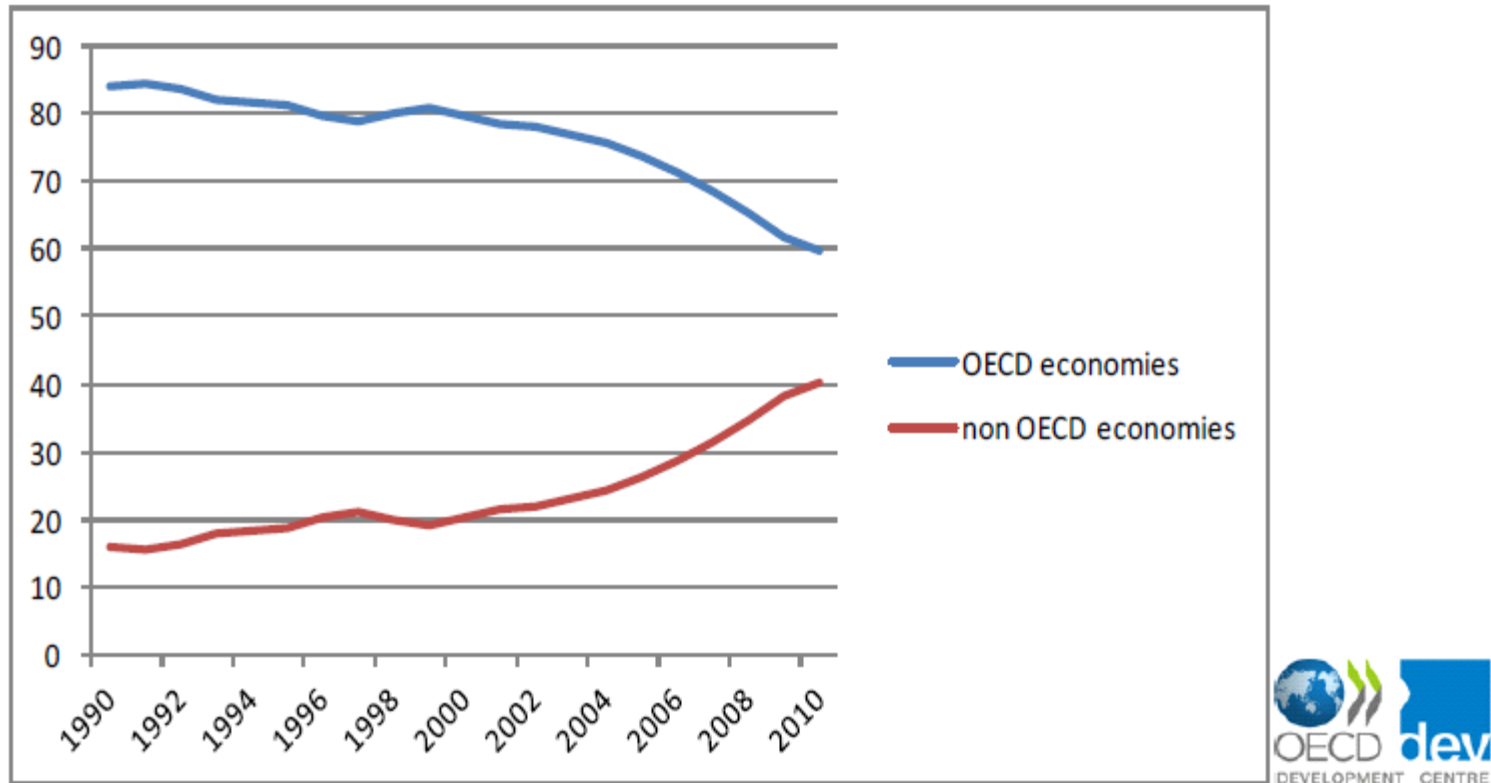


Source: Gregory Clark, *A Farewell to Alms: A Brief Economic History of the World*

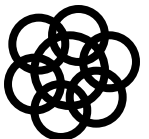
A view of the Industrial Revolution as escape from the ‘Malthusian trap’  
Agrarian economy: as income rises, so does population  
Industrial economy: can sustain endless rises in per capita income  
So long as resource barriers are not infringed  
Fortuitous role of fossil fuels: Created a ‘subterranean forest’ (Sieferle)

# Shifting Wealth: Manufacturing is shifting East

Share of manufacturing industry value added in total world manufacturing value added, 1990-2010

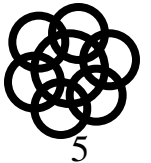
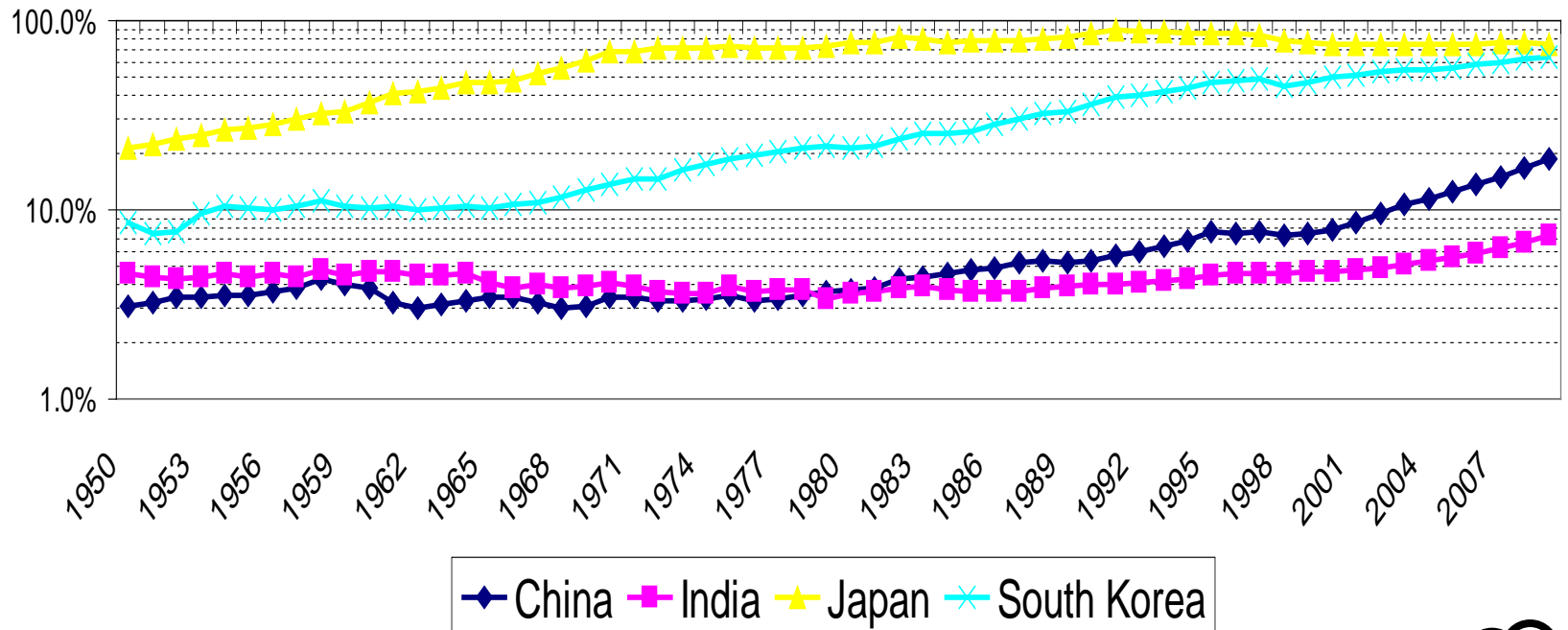


SOURCE: OECD Development Centre based on IHS Global Insight, special tabulations (2011) of World Industry Service database.  
Note: OECD: no data for Austria, Estonia, Greece, Hungary, Iceland, Luxembourg, Portugal, Slovak Republic, Slovenia.

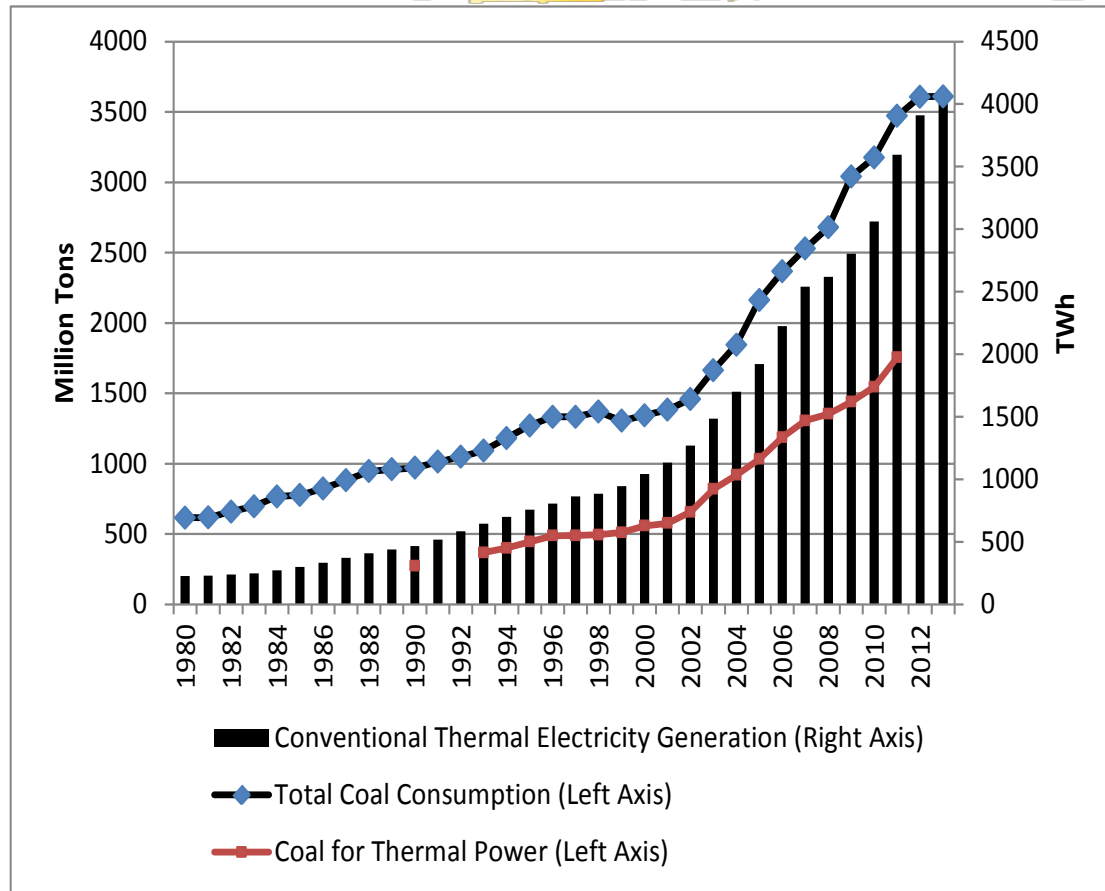


# The “great convergence” Asian convergence GDP per cap

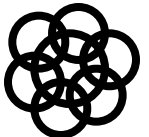
## ASIAN CONVERGENCE (relative to US GDP per head, at PPP)



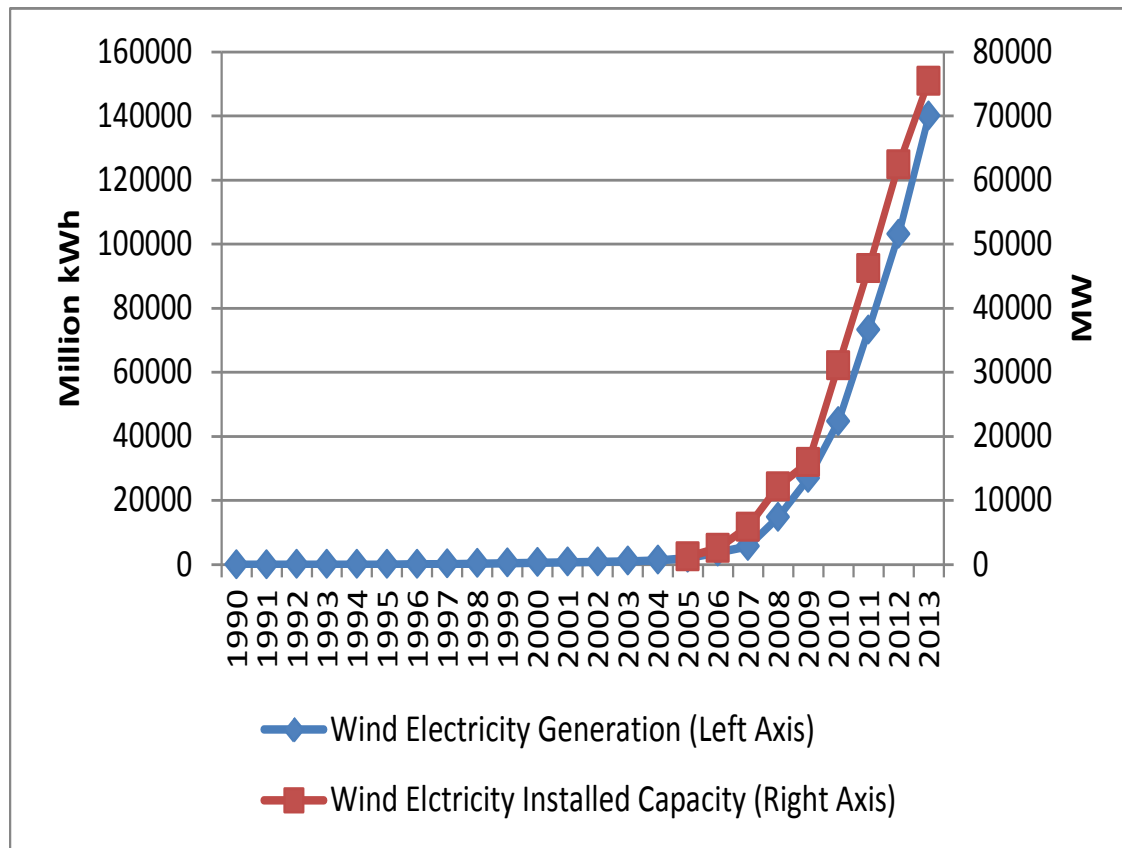
# One face of China: Chinese power generation and rising coal consumption



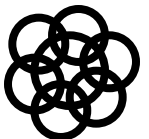
Source: Mathews & Tan; primary data: US EIA, China Electricity Council



# A different (green) face of China: China's build-up of wind power



Mathews & Tan: Source of primary data: US EIA;  
World Wind Energy Report



# The issues

Can China (and then India) scale an industrial production system that will lift not just 1 billion people out of poverty, but 5-6 billion?

What would be the implications of China following a BAU pathway – using coal, oil, gas in the way that Western countries did?

Can the ‘western’ industrial model scale in this way? Answer: No

But can an alternative be built, and in time?

Can China go beyond building the largest renewable energy system on the planet?

Or will ‘carbon lock-in’ doom us all?

Can carbon taxes and carbon markets make a sufficiently strong difference?

Can corporate and social responsibility save the system?

How can state intervention drive the transition?

## **Big questions, big issues**

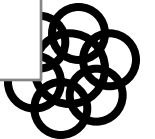
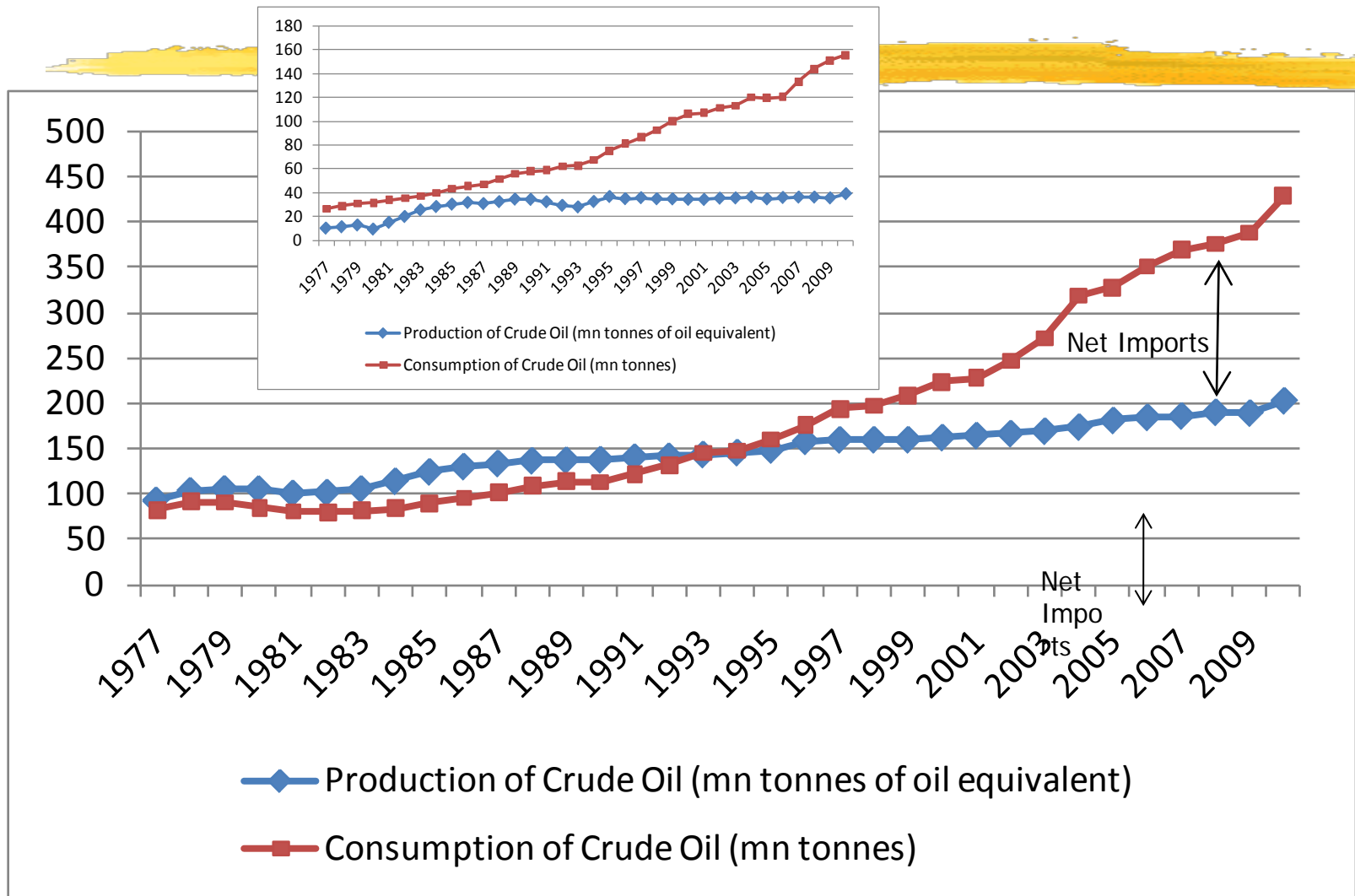
Need ‘big’ social science research, to illuminate the ‘next’ Great Transformation’

**First question: Is the fossil fuel era coming to an end?**

**How can China (and India) gain energy security?**



# The energy issue and development: China's (India's) looming oil/energy gap



# Financial Times: China now world's largest oil importer

October 9, 2013

## **The new gas guzzler**

By Ed Crooks and Lucy Hornby

China has overtaken the US as the world's top oil importer.

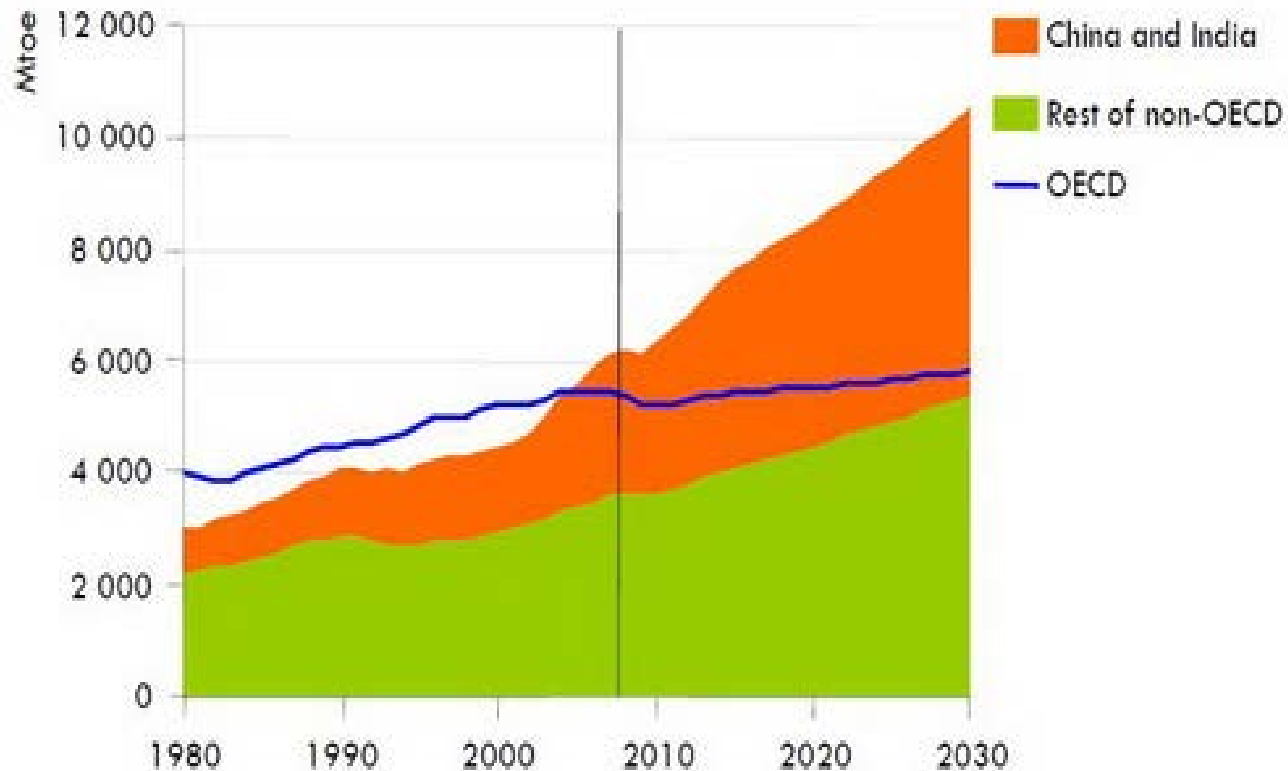
Therefore – China most vulnerable to rise and fall of oil prices ...

Energy security counts as most important issue in China

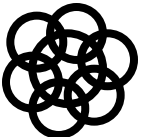


# Oil consumption shifting to China and India

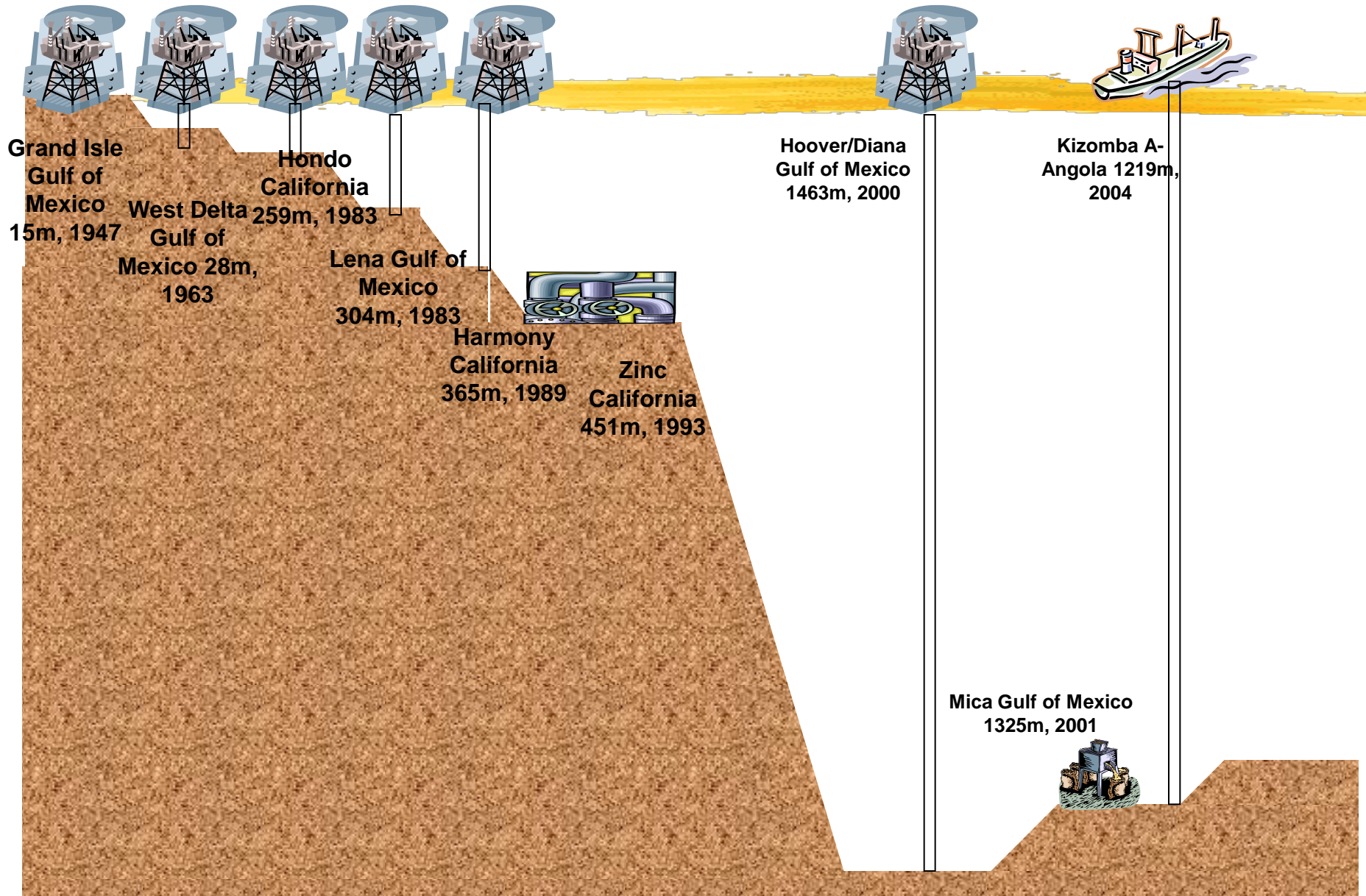
The IEA's 2009 report shows that China and India will continue to expand their oil consumption, but OECD countries are tailing off



Source: IEA 2009



# Extracting oil is increasingly difficult and expensive



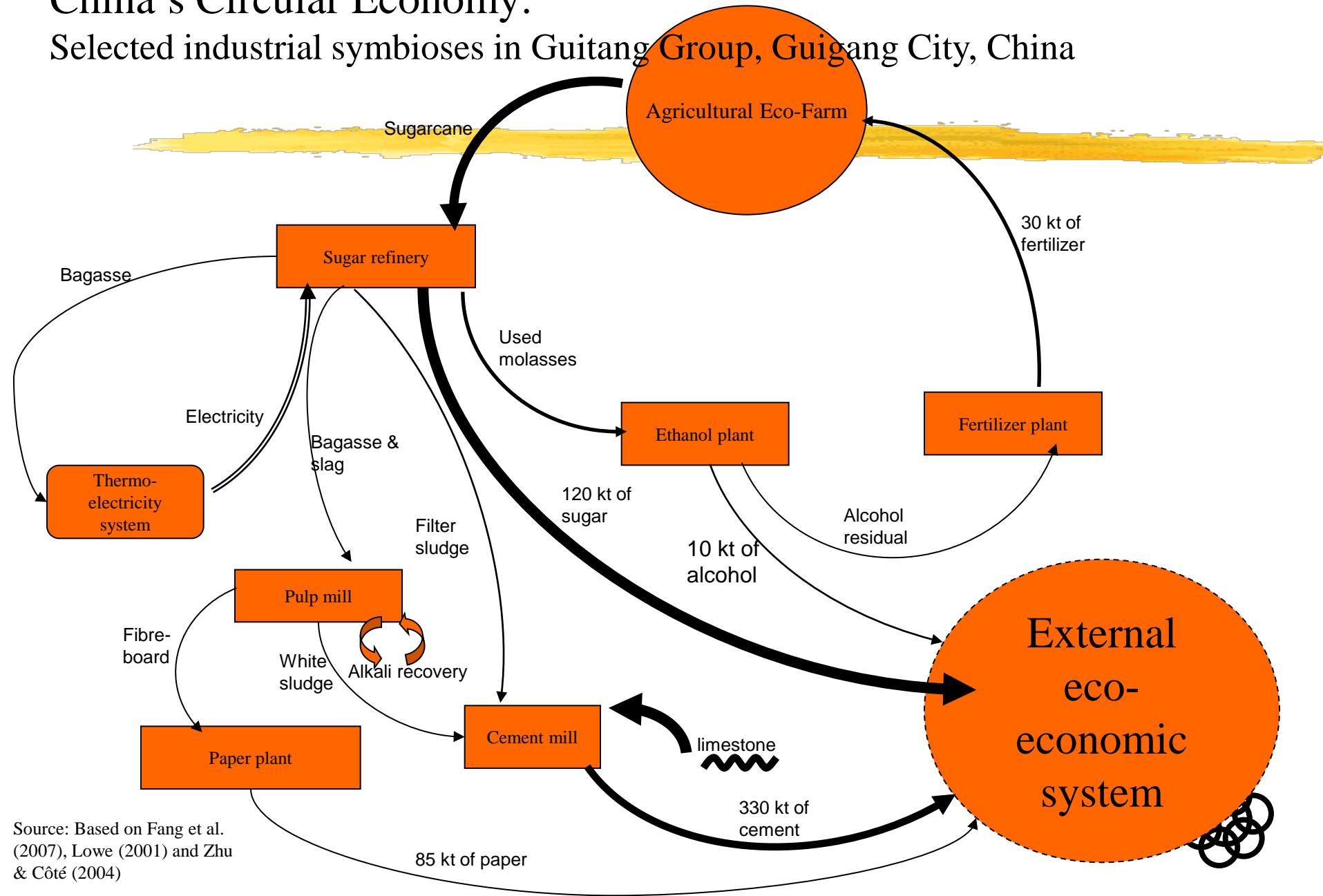
How we became dependent on the motor car – and oil

Ten years that changed the US



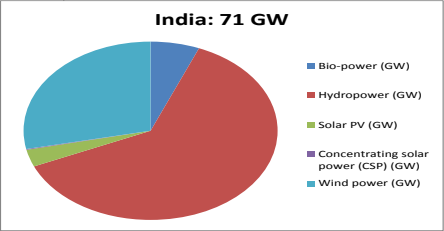
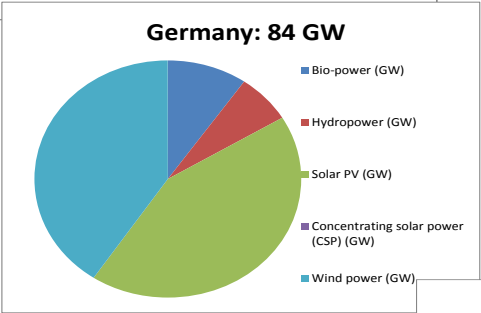
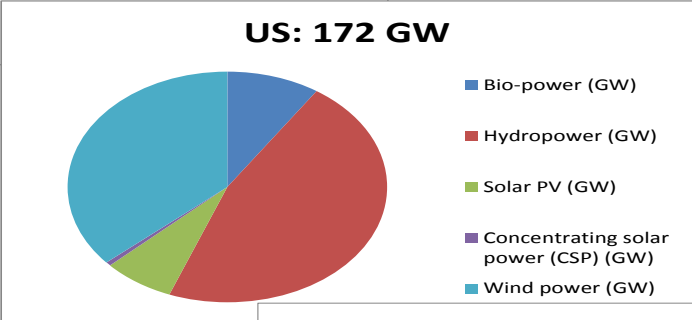
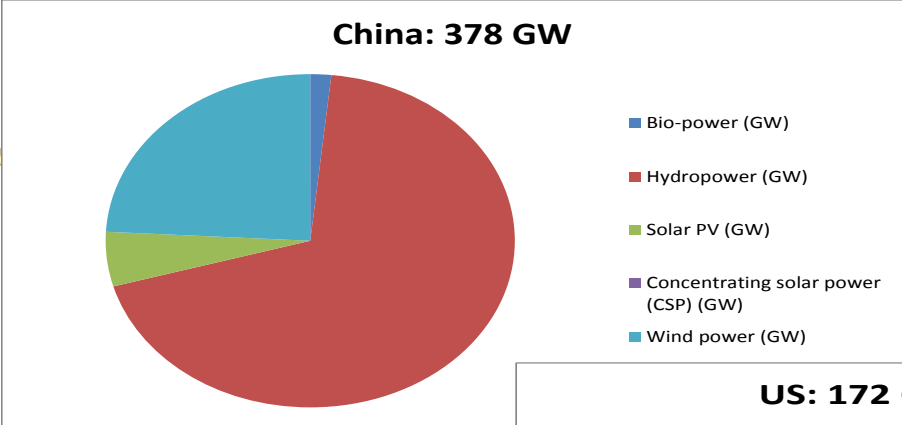
# China's Circular Economy:

## Selected industrial symbioses in Guitang Group, Guigang City, China

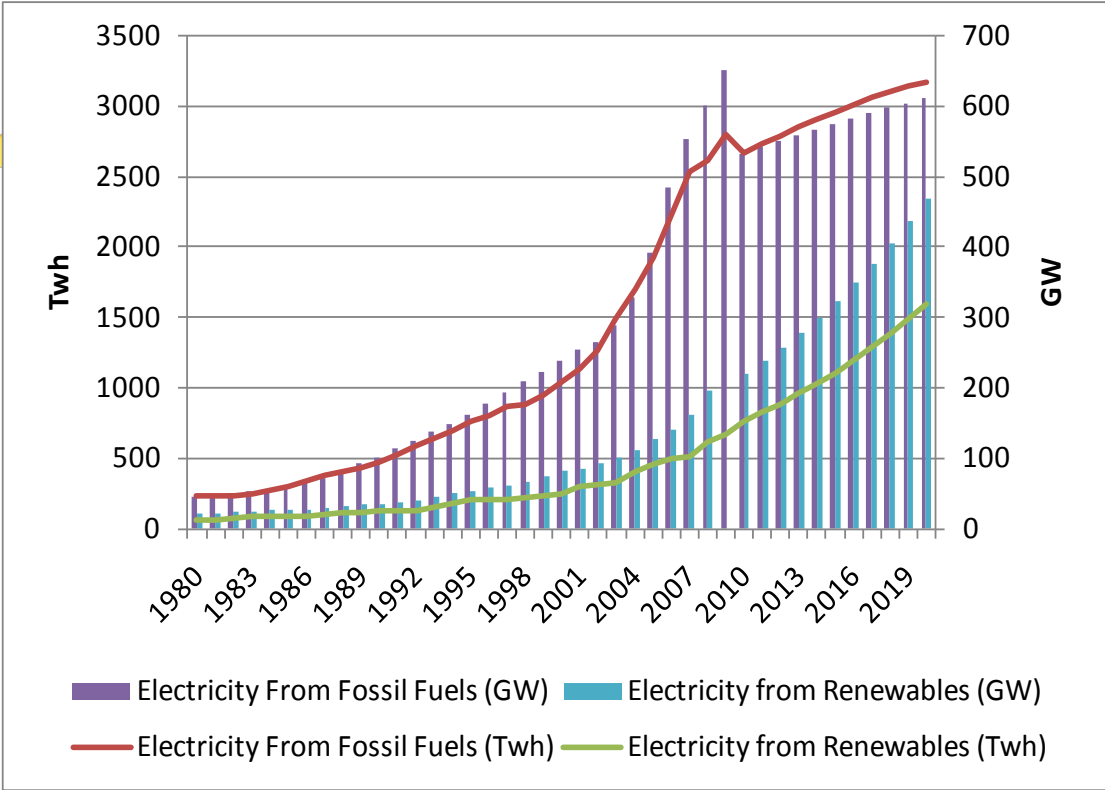


Source: Based on Fang et al. (2007), Lowe (2001) and Zhu & Côté (2004)

# China's renewable power system cf others

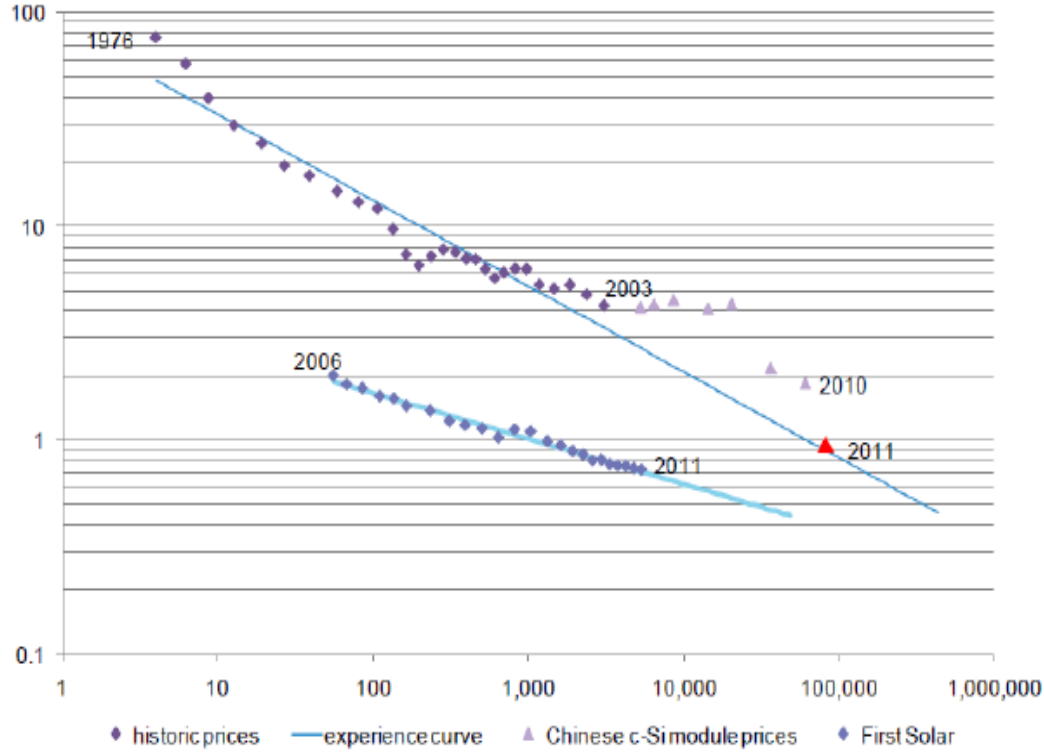


# China: electric power generation, up to 2020: Renewables 30%

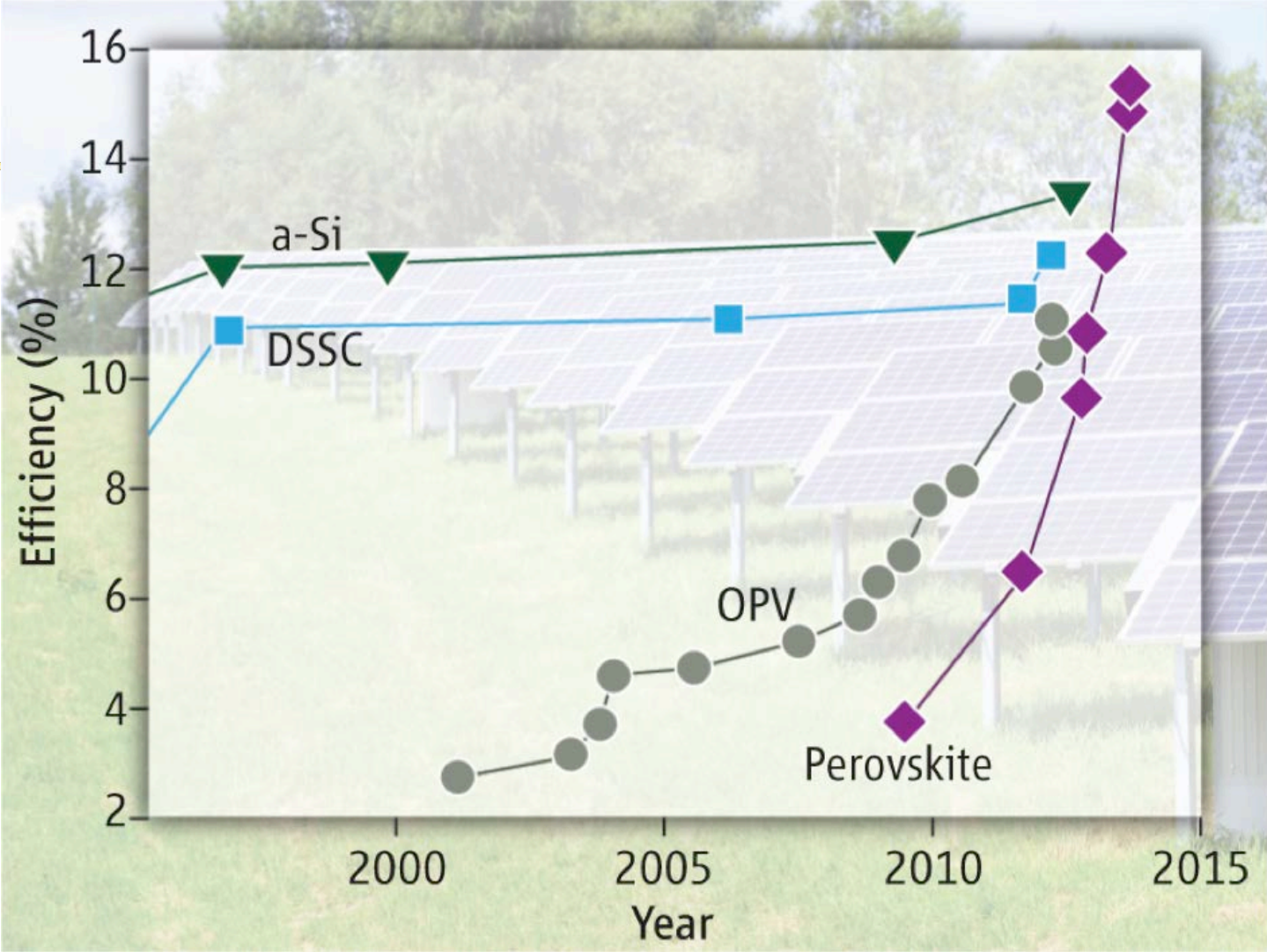




# Solar PV becoming universal: Learning curve (BNEF)



# Perovskites: The next phase of Solar PV

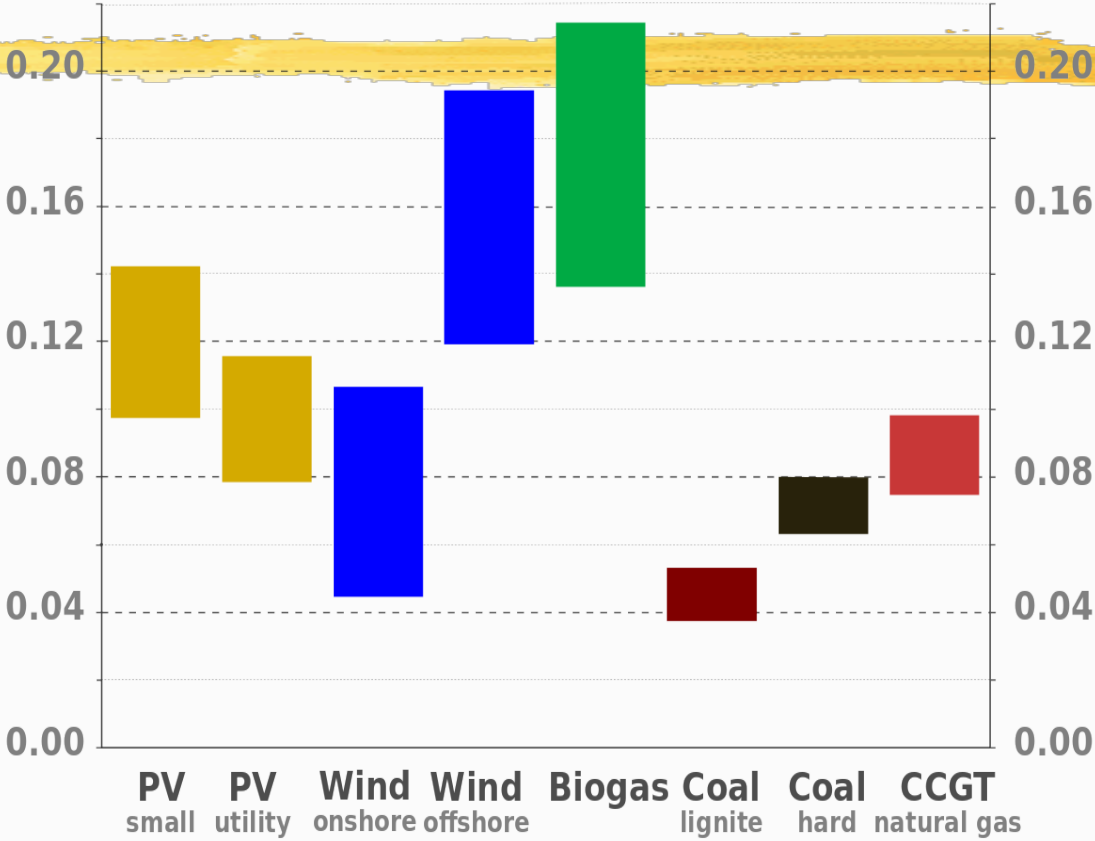


Source: Hodes 2013 *Science*

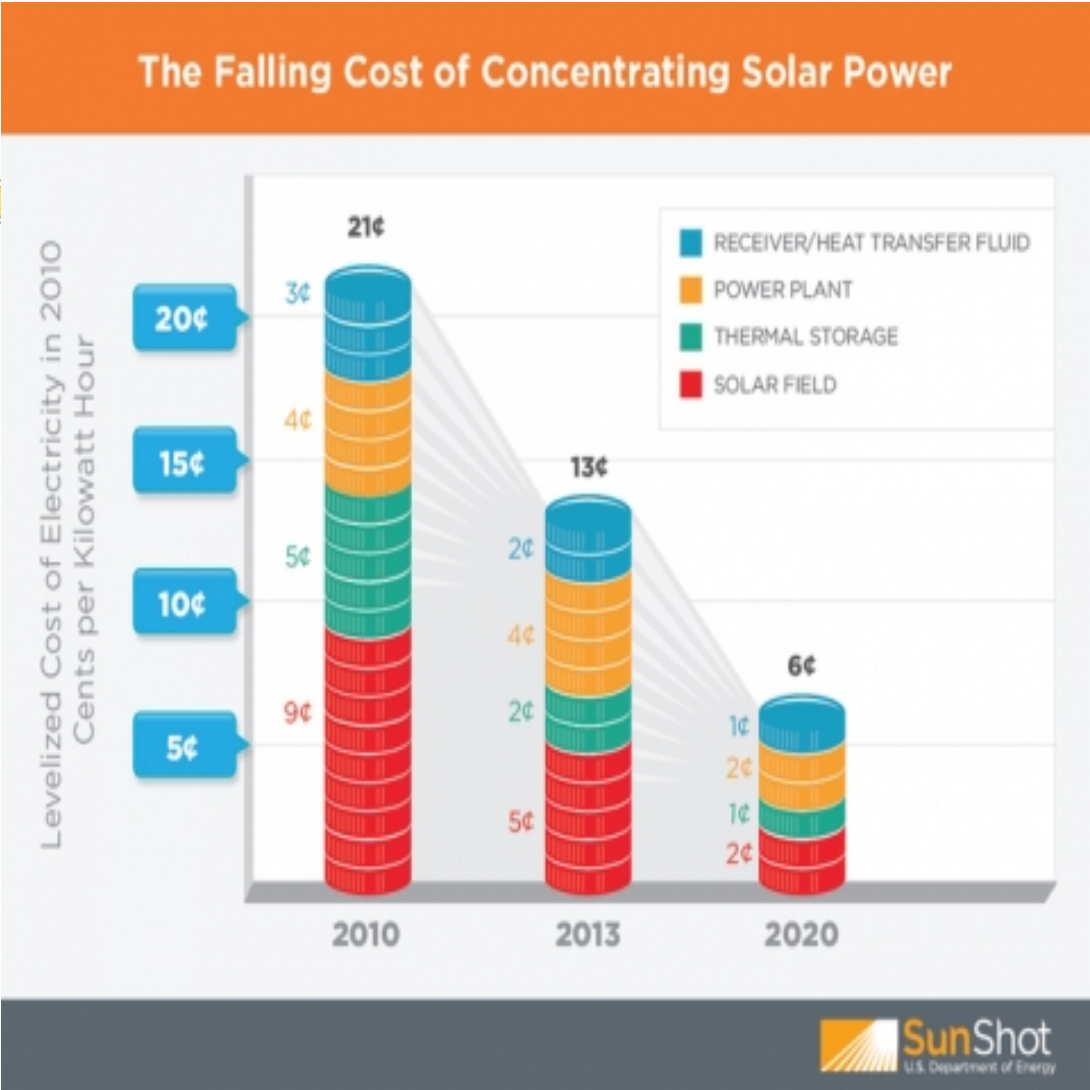
# Cost of solar PV electric energy compared with other sources

## Levelized Cost of Electricity in € per kWh

Source: Fraunhofer ISE, Germany November 2013



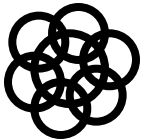
# Concentrating solar power (CSP) also riding learning curve



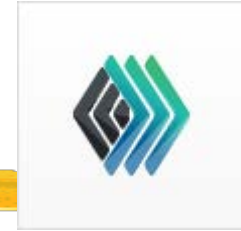
World's biggest business opportunity – investing in green industries  
Who will join these entrepreneurs?



Elon Musk (Tesla Motors);  
Wang Chuanfu (BYD);  
Masayoshi Son (Softbank



# Which companies will commercialize Perovskite Solar PV technology?



## **A huge industrial revolution getting under way**

Getting costs down is key – through market expansion

(Just as with X-Si solar cells: they undercut thin film solar cells)

(Recall Solyndra – and Konarka et al)

So the same must not be allowed to happen with Perovskite PV cells

One promising way forward: Tandem Si-Perovskite cells

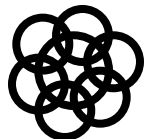
Hybrid forms are always best ways for new technology to enter an established market

Early movers, e.g. Oxford PV; UNSW/SPREE/TrinaSolar

Getting the Pb out of the picture; substitute with Sn

A vast market to be tapped – **Trillions of watts, trillions of dollars**

**And there's more!** Artificial leaf (artificial photosynthesis) utilizing Perovskite PV cells to provide energy to split water – VAST applications; scalable; non-toxic → solar hydrogen



# Solar PV: Market expansion drives down costs (adding to effect of cell efficiency improvements)

The expansion of the global market for solar PV cells, largely supplied from China, has been responsible for driving down costs by 80% since 2008.

A universal process: **as market expands, costs come down**

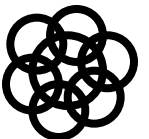
The learning curve

Nothing new here. The same principle of industrial expansion coupled with cost reduction established US supremacy in the automotive industry a century ago.

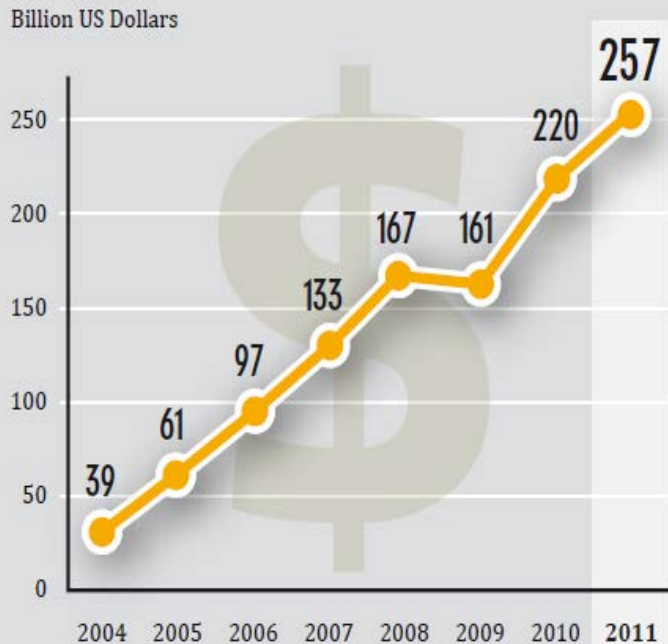
**Between 1909 and 1916, Henry Ford reduced the cost of his Model T Ford from \$950 to \$360, a 266% drop over seven years. Each year, sales doubled – from just below 6,000 in 1908 to over 800,000 in 1917.**

Same process is underway with solar PV cells – manufactured devices. Market expansion -> manufacturing efficiencies (division of labor) -> cost reduction -> further market expansion -> further efficiencies -> further cost reductions

**A chain reaction: Circular and cumulative causation**



# Investment Flows

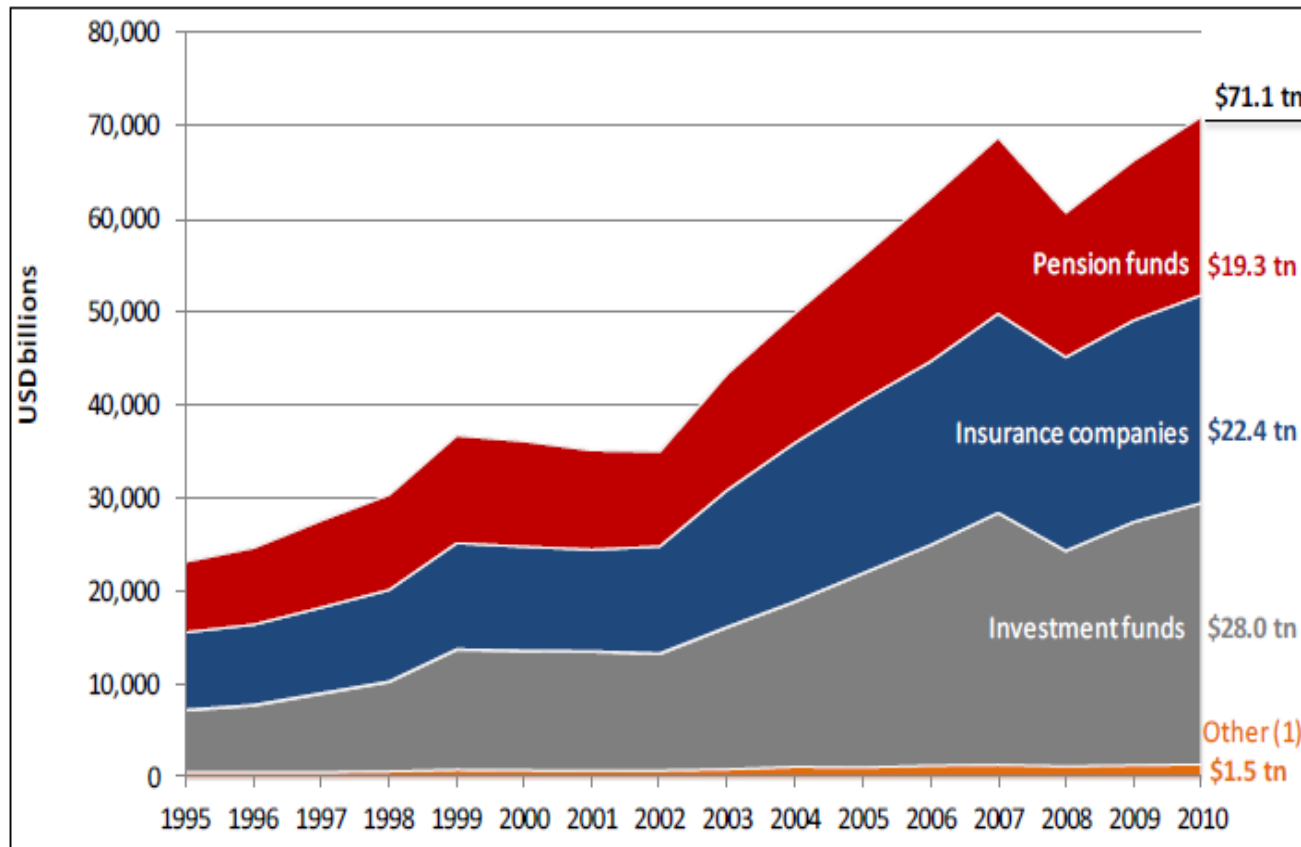


Source: UNEP/Bloomberg: Global Trends in Renewable Energy Investment 2011

- Total global investment in RE jumped in 2011 to a record of \$257 billion, up 17% from 2010
- This is 6 times the level of investment in 2004 and 94% more than the total investment in RE in 2007
- Total investment exceeds
  - \$267 billion including estimated \$10 billion (unreported) invested in solar hot water
  - ~\$282 billion including the \$25 billion invested in large hydropower (>50 MW)



## Funds available for investment (Institutional investors)

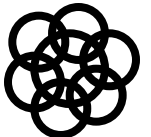


Source: OECD Global Pensions Statistics and Institutional Investors databases and OECD estimates<sup>15</sup>

Source: Andersen (2002) Fig. 1, based on Mitchell, B.R. (1988) *British Historical Statistics*. Cambridge: Cambridge University Press, p. 541. [Data for Ireland are not included. The data for 1868–70 are lacking or are problematic.]

# FINANCE: Investments needed for a renewable energy upsurge 2010-2030

- A 10 trillion watt expansion 2010-2030
- Doubling of present electric power levels
- To be driven by China and Germany (plus Japan?)
- At Euro 4 per Watt (\$5/W), investment of \$50 trillion needed
- Dwarfs current investment (\$200 billion in 2010)
- Dwarfs public tax-based resources, e.g. \$100 billion committed to Global Climate Fund (Cancun 2010)
- Private sector financial instruments needed on huge scale  
Climate bonds; Green banks (e.g. CEFC in Oz)  
Equity finance not yet helping – Stock Exchanges still promoting Fossil-fueled investments
- BUT: global pension fund system and institutional investors have \$71 trillion under management
- How to tap these funds????????????????????



## ‘Climate bond’-like financial instruments

### European Investment Bank (EIB) **Climate Awareness Bond 2007**

Euro 600m 5-year bond, issued by the EIB (financial arm of the EU) through the services of merchant bank Dresdner Kleinwort

EIB 2014 New \$1.5 billion bond

### World Bank **Green Bonds 2009**

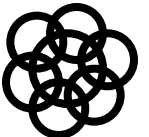
US\$350m 6-year bond issued by the World Bank

Second issue 2009: State of California purchased US\$300m

**African Development Bank 3-year US\$500 million Green Bond**  
(Oct 2013) – for funding green growth projects

Many kinds of financial instruments available!

The key to the greening of capitalism ...

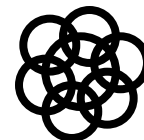


## 2013: Kexim Green Bond issue

- March 2013 Korean Export Import Bank
- Floats \$500 million 5-year bond designated for climate investments
- Targeted at institutional investors (pension funds, SWFs)
- Oversubscribed
- Funds to be channelled to green projects, audited by 3<sup>rd</sup> party CICERO (Centre for Int Climate and Env Research, Oslo)
- US investors took 47%; European 32%; Asian 21%
- Kexim has AA3 credit rating – bonds carry little risk
- Projects involving Korean firms around the world
- Coupon payments to be made from consolidated revenues

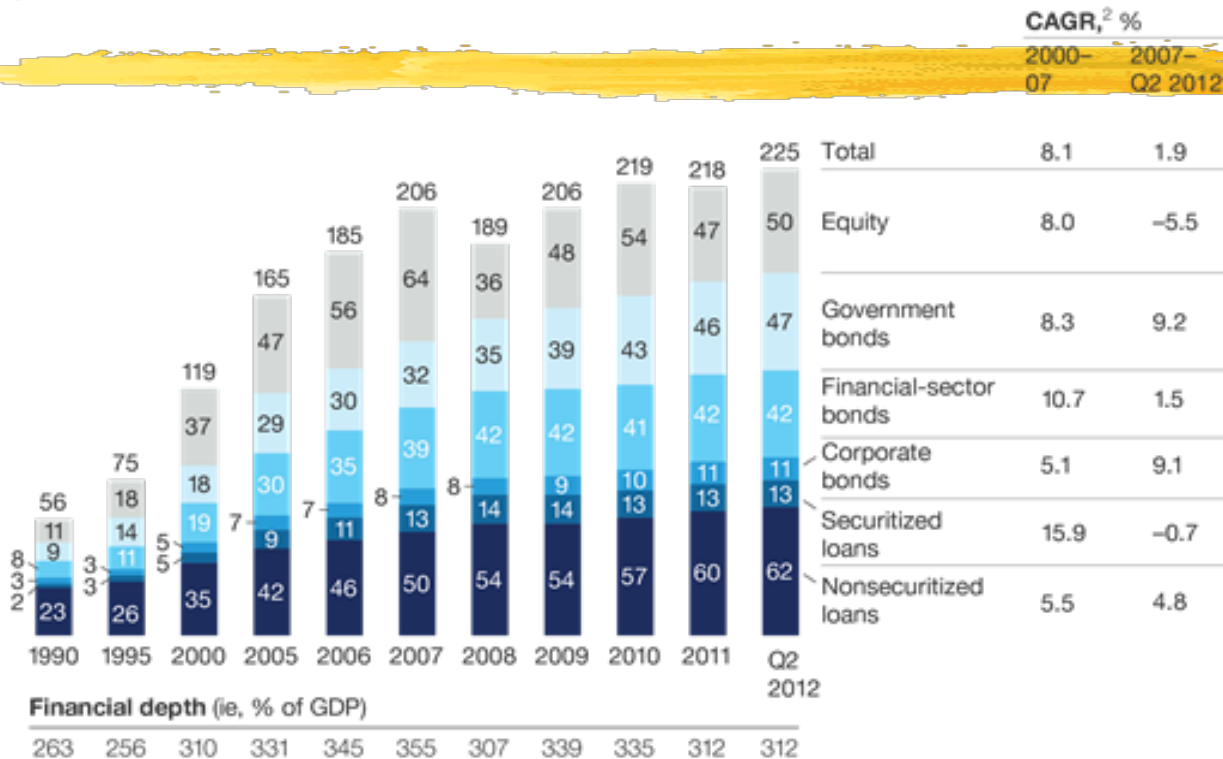
Bonds are serious business – if there is default, this would be counted as sovereign Korean default

Strong discipline for holding to green investment promises



# Global financial assets: \$225 trillion Bonds > equities

Global stock of debt and equity outstanding, \$ trillion<sup>1</sup>



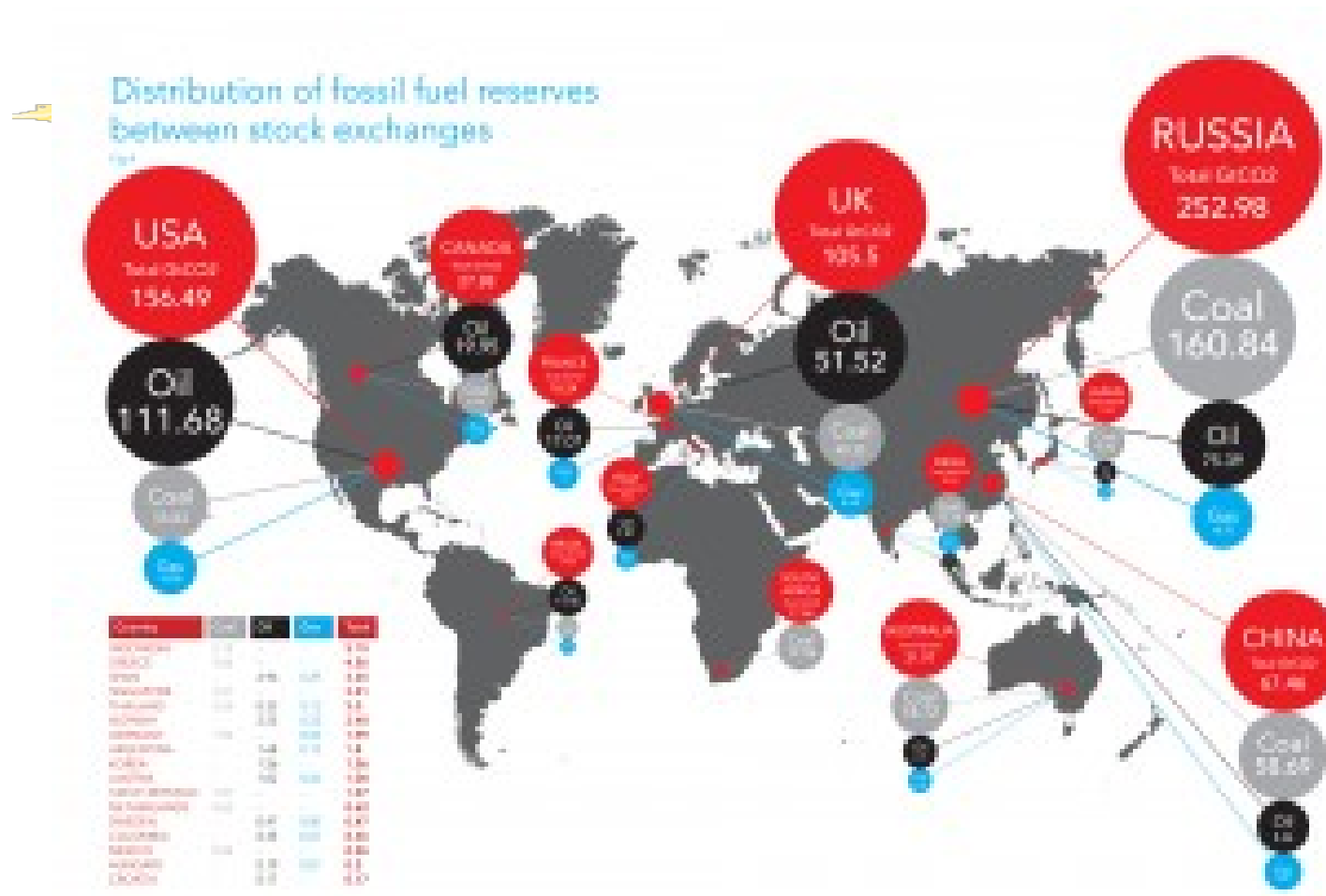
<sup>1</sup>End-of-year figures for a sample of 183 countries, based on constant 2011 exchange rates. Figures may not sum to totals, because of rounding.

<sup>2</sup>Compound annual growth rate.

Source: McKinsey Global Institute analysis

Source: McKinseys Global Institute, *Financial Globalization: Retreat or Reset?*  
March 2013

# The carbon budget: How stock exchanges are still funding the fossil fuel economy (Carbon Tracker Initiative)



## What are smart fossil fuel companies doing?

If coal seam gas is driving out coal from thermal power market –  
and if solar PV/wind is driving out gas

Then smart fossil fuel companies are looking to drive gas as prime  
petrochemical feedstock

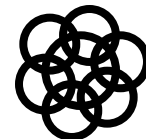
**Exxon-Mobil:** expanding its huge Baytown (Texas) refinery to include  
a gas-to-plastics operation [Baytown already largest integrated petro-  
chemicals plant in US]

**BASF:** Considering largest-ever single-site investment in shale gas-to-  
plastics facility on US Gulf coast

**BASF-Total:** Expansion of Texas ethylene facility (gas-fed)

**Braskem:** Rapidly diversifying into petrochemicals

Plus **Shell, Dow Chemical et al** – can all see a future for fossil fuels as  
petrochemical feedstocks



# What is driving China's energy revolution – and why can we expect India, Brazil et al to follow?

Climate change is probably least of China's concerns

-- after all, US and Eur created around 80% of the problem

More pressing as a driver is to clean the skies of smog: BIG problem

And to solve China's energy security problem

Oil, gas etc. – from Russia, Saudi Arabia, Venezuela, Nigeria

All geopolitical hotspots – threaten war, revolution and terrorism

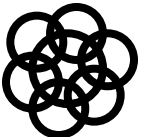
Better: Use **manufacturing industries** to build devices that tap into renewable energies and resource recirculation

Apply China's **latecomer catch-up strategy** to energy and resources problem

Building renewable energy industries creates export platforms of tomorrow (12<sup>th</sup> Five Year Plan) and drives industrial development

This relieves energy insecurity

And it clears skies      What is there to lose?





## Issues/debates

The “Age of Renewables” has arrived – China leading the transition

Germany and Japan following; US lagging

Investing in renewables and circular economy --

mitigating climate change – and enhancing energy security,  
creating new clean jobs, creating new industries and  
export platforms for tomorrow

Carbon credits are not the answer

Merely create “carbon bubbles” – and do nothing to  
address stranded assets of “unburnable carbon”

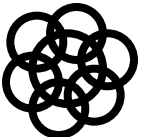
Finance is about to be mobilized at serious scale

Green bonds, climate bonds, green banks

Asian Infrastructure Investment Bank about to be launched

Debt drives Schumpeterian creative destruction

If capitalism created the problem, then it is capitalism that has  
to be used to find the solution



## Summary of argument: Why “green growth”?

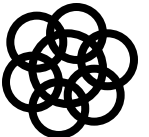
1. The current transition to green (clean) technologies is part of a wider transformation of the global business system
2. The first ‘great transformation’ – an unrepeatabe bonanza created by capitalist institutions and methods combined with fossil fuels
3. Now after 200 years spreading worldwide, driven by Chindia  
6 billion mid-income people by 2050, cf 1 billion in 2000
4. But the western model of industrial capitalism does not ‘scale’ to such an expansion; **need new model of green growth**
5. A new model IS being developed, particularly by China (+ Germany, Jpn)
6. ‘New model’ based on changes to:
  1. Energy markets: renewables the default option (manufactured devices)
  2. Resources/commodities: recirculation (Circular Economy)
  3. Finance: from generic to targeted eco-finance

Using financial system and banks to drive investment in green projects

7. This ‘new model’ is based on an **understanding of industrial dynamics, and transition from one technoeconomic paradigm to another**

An uncontrolled social experiment under way – could turn out very badly

Cautious grounds for optimism – industrial dynamics of transition





# Renewables: manufacturing, increasing returns, energy security



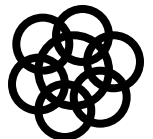
**Renewables, manufacturing and green growth:  
Energy strategies based on capturing increasing returns**

**John A. Mathews <sup>a,\*</sup>, Erik S. Reinert <sup>b</sup>**

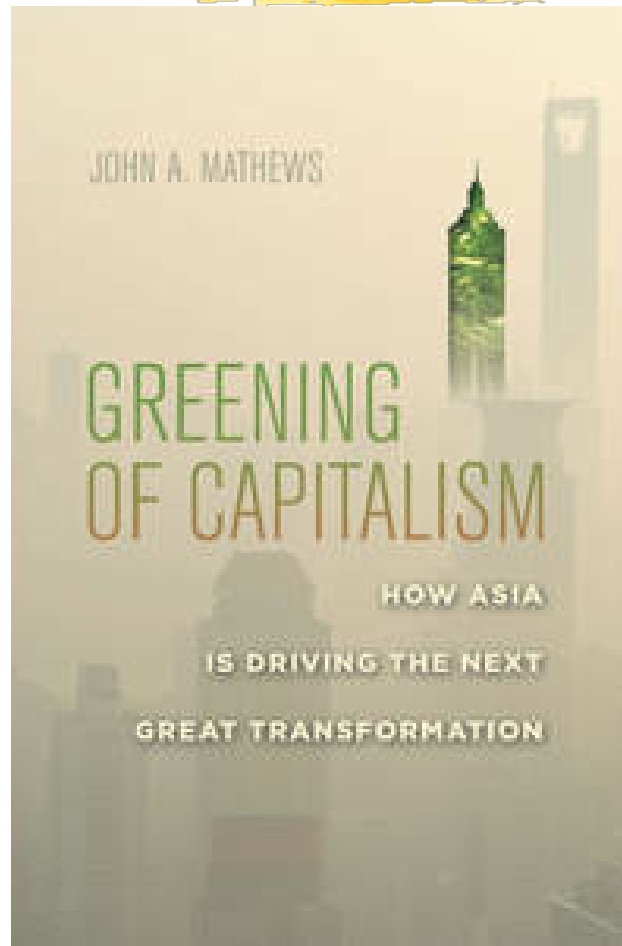
<sup>a</sup> Macquarie Graduate School of Management, Macquarie University, Sydney, NSW 2109, Australia

<sup>b</sup> Professor of Technology Governance and Development Strategies, Tallinn University of Technology

Dominant perspective frames energy futures and the case for renewables and cleantech in terms of their contribution to mitigation of climate change, as well as cleanliness and absence of carbon emissions. By contrast, energy security is generally discussed in terms of security of access to fossil fuels. In this paper we make a different case for renewables: we contrast the extraction of energy (fuels), which – in spite of technological change – takes place under diminishing returns, with the harvesting of nature’s renewable energy, which takes place in a process utilizing manufactured devices, where manufacturing generates increasing returns and costs decline along steep learning curves. This gives a fresh perspective on both renewables and energy security.



# *Greening of Capitalism: How Asia is Driving the Next Great Transformation*



Stanford University Press, November 2014

