

# Green windows of opportunity? Latecomer development in the age of transformations towards sustainability

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Eurolics Workshop 2019  
Tampere, Finland

# Background Summary

- Special issue project - Industrial and Corporate Change (with Xiaolan Fu and Roberta Rabellotti)
- Key questions:
  - Do windows of opportunities for latecomer development arise with the green transformation?
  - Can they be exploited in different types of green sectors with different characteristics and related institutional support requirements?
  - What are the circumstances?
- Focus on renewables and emerging economies, China in particular
- Eight papers submitted for review in June. Next workshop November.
- This is work in progress!!!

# Overview of papers

1. Introduction to SI by the editors  
*Rasmus Lema, Xiaolan Fu & Roberta Rabellotti*

## Sectoral Studies

2. Catch up, innovation and technological leadership under sectoral change: evidence from emerging market **wind turbine industries** – *Yixin Dai, Stine Haakonsson & Lars Oehler*
3. Windows of opportunity for catching-up in formative sectoral systems: the rise of China in the **Concentrated Solar Power sector** – *Jorrit Gosens, Alina Gilmanova, Ping Huang & Johan Lilliestam*
4. China's leadership in **hydropower** technology: comparing global knowledge positions for a green economy – *Zhou Yuan & Frauke Urban*
5. Is the window of technology opportunity a major factor for innovation in **solar PV industry** of China? – *Xielin Liu & Yutian Liu*
6. Windows of opportunity and changes in industrial leadership: the role of market demand location for latecomer catch-up in the **biomass industry** – *Ulrich*

*Elmer Hansen & Teis Hansen*

## Cross cutting studies

7. When the “red dragon” turns into green: Towards a **history-friendly model** of Chinese catch-up in global green industries – *Fabio Landini, Rasmus Lema & Franco Malerba*
8. Green Windows of Opportunity: Insights from new **patent quality analysis** – *Daniel Hain and Roman Jurowetzki*
9. Catching-up in **global innovation systems** – A comparison of four Chinese cleantech industries – *Christian Binz, Jorrit Gosens, Xiaoshan Yap & Zhen Yu*

### **Comparative elements:**

- Sector specific patterns: differences among mature and nascent technologies;
- China specific patterns in comparison with other emerging and incumbent countries.

# Outline

1. Transformation and Green Windows of Opportunity
2. Conceptual framing and operationalisation
3. Preliminary insights and implications

# 1. Transformation and Green Windows of Opportunity

# The green transformation

- Climate change and transgression of other planetary boundaries raise concerns about catastrophic and irreversible changes to global ecosystems
- The need to create a 'green economy' which drastically reduces the resources consumed in economic activities is becoming widely accepted
- Political will is mounting and is translating into institutional change
- Parts of our energy systems (power generation) are already transforming relatively fast – best example: Denmark raising the share of renewables from 22% to 63% in ten years (2006 to 2016)

# A techno-economic paradigm shift

- Underlying hypothesis: the green transformation constitutes a set of significant regime changes in the techno-economic paradigm which includes changes in and across institutional, market and technological domains
- It will be a major disruption in the capitalist world economy, comparable with the changes involved in the industrial revolution of the nineteenth century (Perez 2015)
- These changes could open up opportunities for new models of latecomer development, where synergy can be created between environment-related and economic development strategies (?)
- Aim of this work: To show the *significance* of this proposition as well as the *limitations*

# Green windows of opportunity

- GWOs are favourable but time-bound conditions for latecomer development arising from changes/disruptions in institutions, markets or technologies associated with the green transformation
- Idea is building theoretically on Perez and Soete (1988) who suggested that latecomers may find opportunities for leapfrogging in times of techno-economic paradigm transition.
- Lee and Malerba (2017) emphasised the distinction between windows based on technologies, markets and institutions – mainly evidenced catch-up facilitated by tech-disruptions (and new export opportunities)



# The specificity of green technology sectors

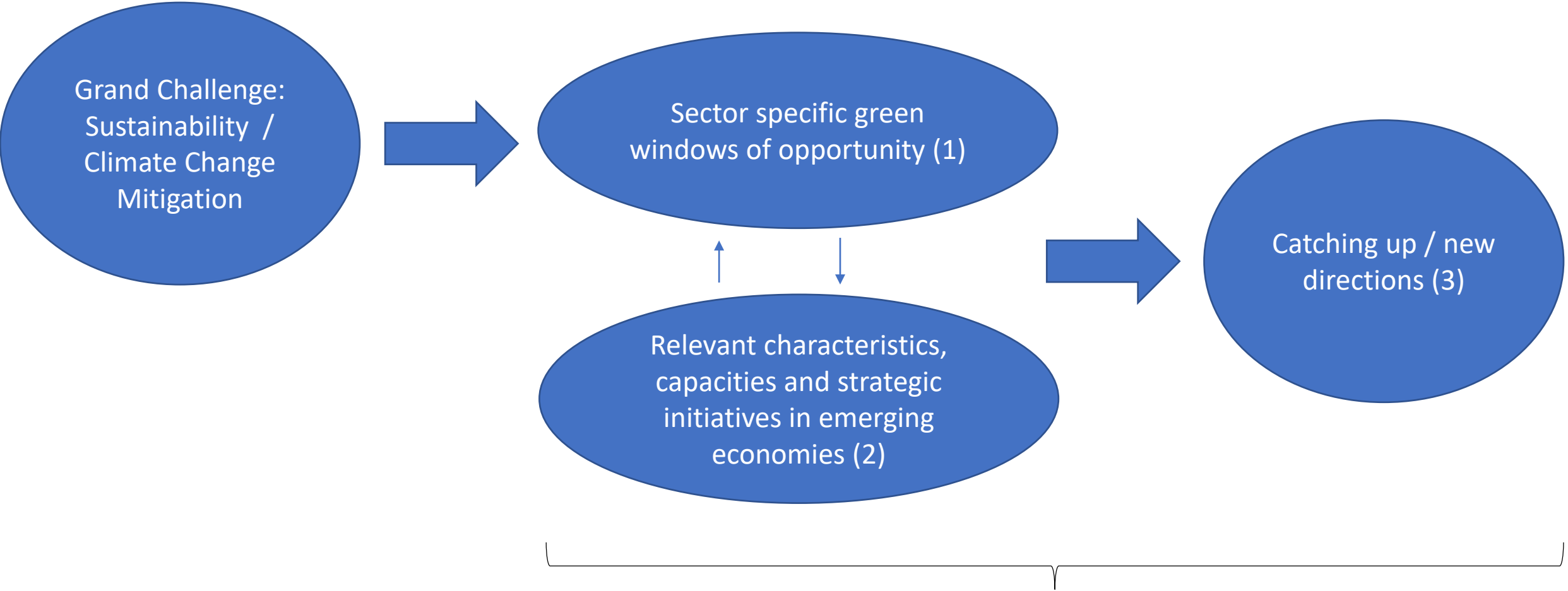
- Green technologies have a fundamental nature as public goods
- Environmental pressures and externalities means that there are local and global interests involved in their creation and diffusion
- Diverse set of technologies (transport, energy efficiency land-use etc) => Focus here is on (renewable) electricity generation:
  - Strong global agenda (e.g. Paris Agreement)
  - Nationally subject to energy and environment policy (highly regulated)
  - Public procurement, subsidies, quotas are accepted policy measures
  - Feed into value chains with professional users (intense user-producer interactions), highly systemic features and project modes of organisation
  - High degree of public R&D

# Catching up and 'directionality'

- Catch-up is not a race along a fixed track, where only relative speed matters. Running in a new direction may be important.
- 'Directionality' may be particularly important when it comes to latecomer development in green technologies (the energy sector):
  - Limited scope for imitation (following the stylised pathways may end up in lock-in, asset stranding, irreversible damage)
  - Unlike prior techno-economic paradigms, development is not only driven by economic utility functions, but also by social ones (directed development / public choice)
  - Latecomer development led by green transformation is different by definition

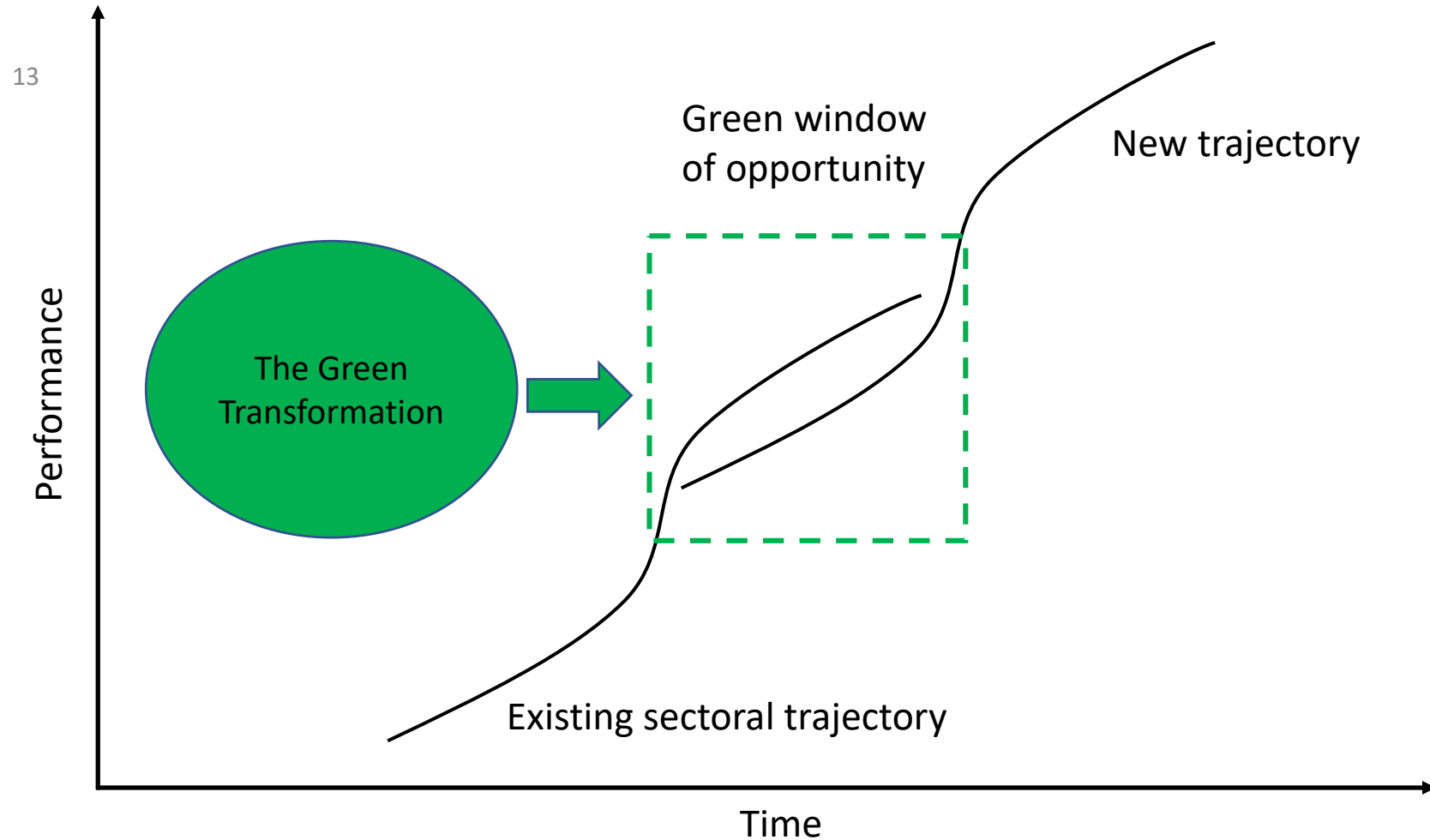
## 2. Conceptual framing and operationalisation

# Conceptual Framework: The main building blocks

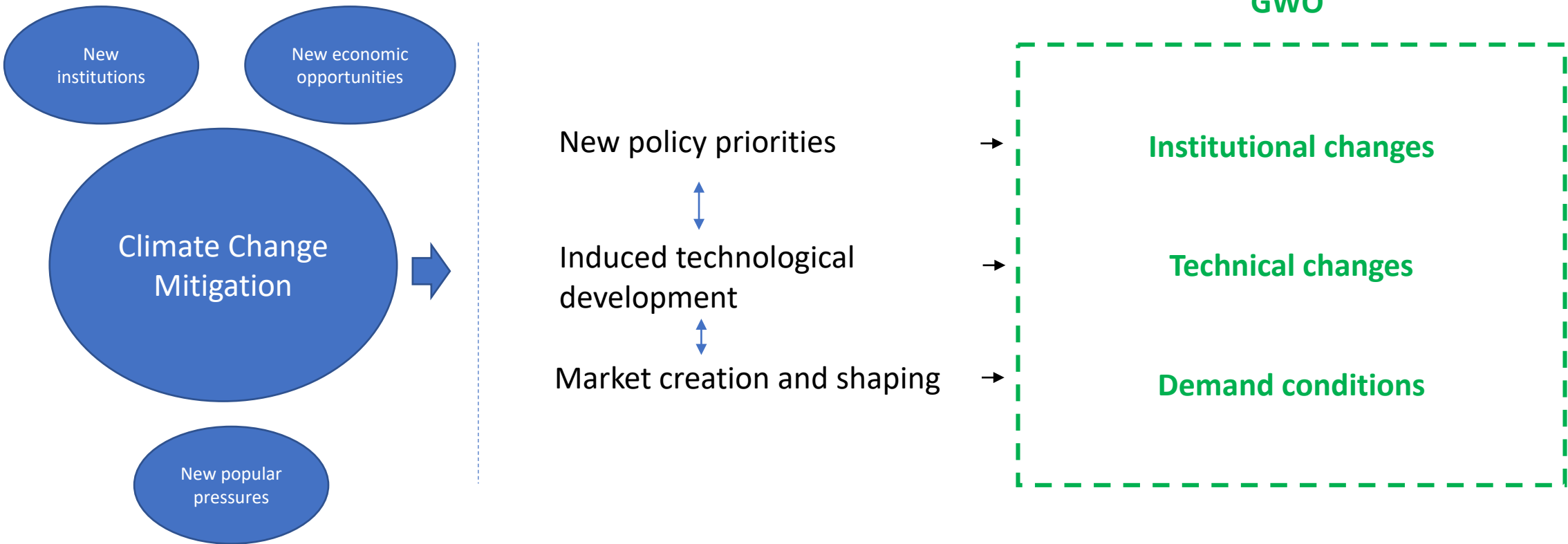


Empirical and analytical focus of the SI

# (1) Green Windows of Opportunity (GWO)



# Sector-specific GWOs: Creation and Shaping



### ***Institutions:***

- Major institutional changes at global or domestic level, e.g. climate change agreements by international organisations.
- Global initiatives such as the Technology Mechanism or other (UNFCCC) technology transfer mechanisms
- Local environmental standards or emission targets
- Technological standards and certification
- Renewable energy/sectoral deployment targets
- Demand side policies such as feed in tariffs in different forms in different sectors structuring the window.

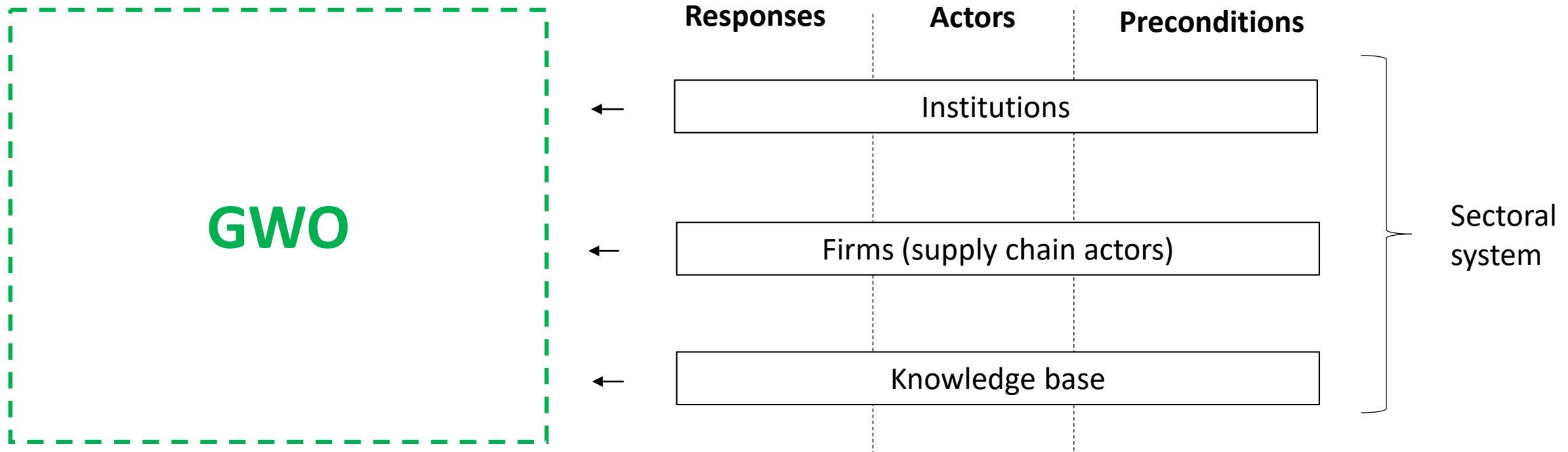
### ***Markets***

- Market opportunity in domestic markets or foreign markets.
- Opening of new markets, e.g. electrification initiatives low income countries
- Demand characteristics, e.g. quality and certification requirements in advanced markets, creating entry-barriers and limiting the scope of the window.
- Demand shifting to bigger or smaller solutions, e.g. small hydro or large wind.
- Demand shifting to more advanced or more simple solutions, depending on current needs or complementarities.

### ***Technology:***

- Generational shifts, e.g., comparable to quick succession of capacities in memory chips
- Breakthroughs in key basic research or engineering challenges
- Technological and logistic changes enabling shift new or more effective forms of deployment
- Knowledge base changes driving emergence of new dominant design
- New production methods leading to more effective mass production

## (2) Relevant sectoral characteristics, capacities and strategic initiatives





## 2. 'Indicators' for sectoral system responses

Building Block	Who?	Types of responses (Indicators)
Enterprises (Supply chain 'actors')	<ul style="list-style-type: none"> <li>- Electricity distributors</li> <li>- Professional users (utilities)</li> <li>- Independent power producers</li> <li>- Equipment manufacturers</li> <li>- Component supplier</li> <li>- R&amp;D enterprises</li> <li>- Technology suppliers</li> </ul>	<ul style="list-style-type: none"> <li>- Market entry and exit</li> <li>- Market re-orientation</li> <li>- Foreign direct investments</li> <li>- New product development</li> <li>- Supply chain creation or restructuring</li> <li>- Specialisation</li> </ul>
Institutions	<ul style="list-style-type: none"> <li>- Governments, national provincial</li> <li>- Energy regulators</li> <li>- Non-government organisations</li> <li>- Trade associations</li> <li>- Standard setting organisations</li> <li>- Banks and financial institutions</li> </ul>	<ul style="list-style-type: none"> <li>- Local content rules</li> <li>- Trade associations lobbying for export promotion initiatives or reduction of component import duties</li> <li>- Investment incentives</li> <li>- FDI &amp; OFDI policies</li> </ul>
Knowledge base	<ul style="list-style-type: none"> <li>- Universities</li> <li>- Research institutes</li> <li>- Training institutions</li> </ul>	<ul style="list-style-type: none"> <li>- Research programs and projects</li> <li>- R&amp;D Initiatives</li> <li>- Acquisition of technology (greenfield OFDI, brownfield OFDI, licenses, machinery imports)</li> <li>- Human capital acquisition and training</li> </ul>

## Sectoral systems compared: similarities and differences - TBD

	Wind	Solar PV	Hydro	Biomass	CSP
<b>Maturity</b>	<ul style="list-style-type: none"> <li>High</li> </ul>	<ul style="list-style-type: none"> <li>High</li> </ul>	<ul style="list-style-type: none"> <li>Very high</li> </ul>	<ul style="list-style-type: none"> <li>High</li> </ul>	<ul style="list-style-type: none"> <li>Low</li> </ul>
<b>Industry structure</b>	<ul style="list-style-type: none"> <li>Large firms</li> <li>Low entry rates / relative stability in top segment</li> </ul>	<ul style="list-style-type: none"> <li>High entry-rates</li> </ul>	<ul style="list-style-type: none"> <li>Large firms</li> <li>Low entry rates</li> </ul>	<ul style="list-style-type: none"> <li>One undisputed lead firm</li> <li>20-30 followers</li> </ul>	<ul style="list-style-type: none"> <li>Many small &amp; few large firms</li> <li>Many entry/exits</li> </ul>
<b>Users</b>	<ul style="list-style-type: none"> <li>Professional (Utilities/IPPs)</li> </ul>	<ul style="list-style-type: none"> <li>Professional</li> <li>Household</li> </ul>	<ul style="list-style-type: none"> <li>Professional</li> </ul>	<ul style="list-style-type: none"> <li>Professional</li> </ul>	<ul style="list-style-type: none"> <li>Professional</li> </ul>
<b>Lead firms</b>	<ul style="list-style-type: none"> <li>Manufactures</li> <li>Power producers</li> </ul>	<ul style="list-style-type: none"> <li>Manufactures</li> </ul>	<ul style="list-style-type: none"> <li>Large EPC (system integrators)</li> </ul>	<ul style="list-style-type: none"> <li>EPC</li> <li>Key component suppliers</li> </ul>	<ul style="list-style-type: none"> <li>EPC</li> <li>Key component suppliers</li> </ul>
<b>Type of learning</b>	<ul style="list-style-type: none"> <li>Licensing</li> <li>Learning from (global) suppliers</li> <li>R&amp;D</li> </ul>	<ul style="list-style-type: none"> <li>Learning from exporting</li> <li>Machinery imports</li> </ul>	<ul style="list-style-type: none"> <li>Project organised learning</li> </ul>	<ul style="list-style-type: none"> <li>Licensing</li> <li>JV</li> <li>Suppliers learning from lead firms</li> </ul>	<ul style="list-style-type: none"> <li>Learning by doing</li> <li>Machinery &amp; complex component imports</li> </ul>
<b>Role of foreign knowledge</b>	<ul style="list-style-type: none"> <li>High but decreasing over time</li> </ul>	<ul style="list-style-type: none"> <li>High but decreasing over time</li> </ul>	<ul style="list-style-type: none"> <li>Only at vert early stages</li> </ul>	<ul style="list-style-type: none"> <li>Mix of firms with high and low dependency</li> </ul>	<ul style="list-style-type: none"> <li>Low</li> </ul>
<b>Universities and research</b>	<ul style="list-style-type: none"> <li>Limited demand for domestic R&amp;D</li> </ul>	<ul style="list-style-type: none"> <li>Important connections with foreign universities</li> </ul>	<ul style="list-style-type: none"> <li>Limited but increasing, China moving to center</li> </ul>	<ul style="list-style-type: none"> <li>Important connections with domestic universities</li> </ul>	<ul style="list-style-type: none"> <li>Clear role for domestic R&amp;D</li> <li>Spin-offs &amp; cooperative development</li> </ul>
<b>Finance</b>	<ul style="list-style-type: none"> <li>SOE developer investment</li> </ul>	<ul style="list-style-type: none"> <li>Stock listing abroad, other private funding</li> </ul>	<ul style="list-style-type: none"> <li>China export-important bank</li> </ul>	<ul style="list-style-type: none"> <li>SOE developer investment</li> </ul>	<ul style="list-style-type: none"> <li>Mix of private &amp; SOE, institutional lending</li> </ul>
<b>Standards</b>	<ul style="list-style-type: none"> <li>Technical an standards</li> <li>Safety standards</li> </ul>	<ul style="list-style-type: none"> <li>GRID codes</li> <li>Monitoring</li> </ul>	<ul style="list-style-type: none"> <li>Environmental an social sustainability measures</li> </ul>		<ul style="list-style-type: none"> <li>Tower standards</li> <li>Participation in global IEC standard setting</li> </ul>
<b>Government Policy</b>	<ul style="list-style-type: none"> <li>FIT</li> <li>Local content</li> </ul>	<ul style="list-style-type: none"> <li>FIT</li> <li>Supply-side support for technology</li> </ul>	<ul style="list-style-type: none"> <li>FIT (below coal-fired price)</li> </ul>	<ul style="list-style-type: none"> <li>FIT</li> </ul>	<ul style="list-style-type: none"> <li>FIT</li> </ul>

# (3) Catching up patterns and cycles

- Catch up (production capacity and innovation capacity)
  - Measured as MW sold in the global (and domestic) market;
  - Technological capabilities (capability indicators), including creation of intangible assets
  - Position in global value chain
- Change in global leadership or closing the gap (... or failed attempts)
- Different catch up trajectories depending on GWO and responses
  - Path following
  - Path creating – new directions (new technologies, deployment models etc.)

# 3. Preliminary Insights and Implications

# To what extent are we seeing catch-up / leadership?

- Some sector cases with very high global market shares, undisputed market leadership and global champions (hydro, solar PV).
- Some cases with rapidly developing sectors (catching up), but with some gap in capabilities and more focused on domestic market (wind and biomass).
- Questions arise about the connection between technology leadership and market leadership.
- In CSP, a newly emerging technology, China is leading a global scramble for defining the dominant design based on indigenous technology.

# Are we seeing new pathways?

- Yes, at overall energy system level, to some extent, but not really detectible with a sub-sector lens
- No strong evidence of entirely new sector pathways – more path-following trajectories.
- Some evidence of ‘sub-stream trajectories’ (small wind, small hydro).
- Some differentiation in the organisation of production and role of financing power in external markets
- More novel pathways-in-the-making in India, SSA (distributed deployment – e.g. mini-grids; but less economic development potential).

# What is the scope and nature of green windows of opportunity? (1)

- *Markets:*
  - Strong role of endogenous window creation. Domestic demand creation very strong in all cases (feed-in tariffs, commissioning)
  - Investment in demonstration projects (earlier in more mature technologies, now in CSP)
  - Differentiated role of external market (different patterns of sequencing, e.g. solar and wind)
- *Technologies:*
  - Only little evidence of technological windows (relatively stable/incremental technologies), except for Concentrated Solar Power (CSP).
  - New process-technologies more important than product innovations.
- *Institutions:*
  - Overall goals and targets
  - Mandatory purchasing arrangements
  - R&D programmes

# What is the scope and nature of green windows of opportunity? (2)

- Green windows of opportunity different from those involved in catch-up in manufacturing industries (outsourcing)
- Green windows are much more dependent on *institutional disruptions* than on technological disruptions (contrast with Lee and Malerba 2017)
- They depend on endogenous window creation (not least markets)
- Multiple (co-occurring) and successive windows arise (e.g. solar PV industry)



# Important determinants:

- Creation of synergy between environmental and industrial policy + massive government investments
- Policy fine-tuning: demand window sequencing, temporary protectionism e.g. local content requirements, raising of quality standards
- Markets for technologies (licenses, KIBS, acquisitions – e.g. biomass, solar PW)
- Entrepreneurial and business development action, e.g. making acquisition at the right moment.
- Experimentation and fine tuning of direction of search (investment in offshore and ‘post turbine technology’)

# Implications

- For the green transformation:
  - Rapidly falling prices of renewables worldwide
  - New contenders and segmentations in the green economy
  - Formation of south-south linkages
  - East west-collaboration
- For catching-up
  - Latecomer-friendly models of 'green growth' are possible
  - But China's model may be difficult/impossible to replicate elsewhere (role of government, size of market, financing power).

Thank you!

	Wind	CSP	Hydro	Solar PV	Biomass
<u>GWO</u>  M  T  I	<b>M:</b> Yes, domestic market creation.  <b>T:</b> Located along three technology regimes.  Two or three windows? Technology windows (R2: offshore + R3 :??)	<b>I/M:</b> In the form of demonstration projects. First window: R1?  <b>T:</b> Era of ferment – a window in the making. Which design (standard) will win? Government role in standard facilitation?	<b>M:</b> First domestic market windows, then external market.  <b>T:</b> Emerging specifications such as social sustainability, environmental sustainability. Reservoir management.  Small hydro as GWO?	<b>M:</b> First, external market window (M1). Then internal window (M2).  <b>T:</b> Production/process technology improving. Markets for process technology. Thin film regime?  <b>I:</b> Supply side support (M1). Internal window creation for M2.	<b>M:</b> Domestic market creation. Mandatory purchase agreements (state).  <b>T:</b> ??? Markets for technology  <b>I:</b> Demand side initiatives. Co-emergence
<u>Responses / characteristics</u>  F  I  K	<b>F:</b> ??? Role of SOEs?  <b>I:</b> Government response to second regime (offshore)  <b>K:</b> Experimentation with R3 technologies?	<b>F:</b> Different firms backing different designs.  Limited role of external knowledge.  <b>K:</b> Domestic knowledge sourcing?  Related variability – integration of existing technologies components?	<b>F:</b> Chinese advantages in mature technology? What are they? E.g. Finance?  Consortia formation.  How do Chinese firm responses compare and differ with lead firms from Europe and N-S America.	<b>M:</b> Acquisitions  Value chain development	<b>M:</b> Firm responses to policy.  Acquisitions  Spillovers.  Flying geese model.
<u>Catch-up</u>  P (MW sold)  I (patents/indicator)	<b>P:</b> Yes, but only midsized turbines sold domestically. Very few exports Catch-up in capabilities?  <b>I:</b> Yes, to a degree, A ‘mid-quality trap’?	<b>P:</b> ??? <b>I:</b> Yes, at par with ROW	<b>P:</b> Global market shares – high.  <b>I:</b> Moving to the centre of of citation networks.	<b>P:</b> Yes, global market shares. <b>I:</b> ??? (exploration/exploitation)	<b>P:</b> Yes, market shares.  <b>I:</b> ??? Sector-specific indicators (heat, pressers).  VC: Yes, EPC

	Four cleantech industries	History models	FDI	Patent explorer
GWO	<p>Typology of windows? How does it differ from M-T-I?</p> <p>Finding patterns and typologising</p>	Demand window sequencing		<p>Method to identify the technological windows of opportunity</p> <p>Method to measure relative shortness of technology cycles.</p>
Respons	Firm strategies /govt respons (qualitative accounts)		FDI as key vehicle of of developing capabilities and catching up	Can show which geographies are strong.
Catch-up	<p>PI/I</p> <p>Yes, depends on techno-economic characteristics (learning mode and degree of customisation)</p>	Different performance I production and innovation catch-up		<p>Timing of catch-up in relation to WO</p> <p>Similarity to future / past</p>