Rapid Switch Workshop

*Could availability of capital constrain low carbon energy transitions?*

FLASH PRESENTATION: BUSINESS / ECONOMIC RESEARCH IDEAS 12th June 2019

Prof Stephen Wilson | University of Queensland Centre for Energy Futures
The UQ Energy Initiative
Question

Could availability of capital constrain low carbon energy transitions?
Answer(s)

Short answer: **NO**

...from a narrow, purely financial sector perspective

Long answer: **YES**

...this is a crucial issue for decarbonization
it is subtle and complex
addressing it requires trans-disciplinary serious research
Capital investment — the big numbers (USD 2017)

Global **fixed capital** formation  20.1 Trillion

Global **energy** investment  1819 Billion

- upstream **fossil fuel** investment  790 Billion
- upstream **thermal coal** investment  80 Billion
- **all power sector** investment  750 Billion
- non-renewable generation  149 Billion
- transmission & distribution networks  303 Billion
- renewable generation  298 Billion
- **energy efficiency**  236 Billion
- electric vehicles  43 Billion


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Context

**Electricity systems** have a large and central role in the decarbonization challenge

All decarbonization measures and strategies involve **capital intensification**

Yet the **capital required** for deep decarbonization of electricity is very poorly understood

The **risks and return** on capital to be invested in electricity decarbonization are not well known

**Wind and solar** power are expected to play major roles in decarbonizing electricity globally

**System integration costs** of variable renewable energy (VRE) are subject to wide disagreement

The **system-level compatibility** of VRE with nuclear or thermal plants with CCS is controversial

The **roles of market forces and of the State** in directing capital investment is muddled
Proposal

Materially reduce the current extreme uncertainty range for system costs of VRE integration

Extend and broaden initial research underway at UQ starting with Australia and India, potentially extending to the US, China and Europe

Gain insights into the economic, financial, political and international ramifications

Bring together a diverse multi-university research team comprised of leading experts in:

• **power system engineering** for generation and storage, transmission and distribution
• **transport system engineering**, electric vehicles and energy storage
• **energy economics** and policy, for economic modelling and techno-economic simulations

with industry sponsors who are able to inform, engage, challenge and financially support the work
Questions and attempted answers

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Backup slides

if needed for discussion, questions and (attempted) answers
Q: Could availability of capital constrain low carbon energy transitions?

Discussion

Short answer: almost certainly, **NO**. However…

All decarbonisation measures entail **capital intensification**

The **electricity sector** is at the core of the decarbonisation challenge

**LCoE becomes increasingly misleading** the higher the shares of VRE on a system

Australia’s electricity sector is at the frontier of deploying **wind and solar** PV generation

General availability of capital is not likely to be an issue for continued wind and solar deployment

However **indirect constraints** on further deployment of capital are already becoming evident in Australia

**VRE system integration costs are severely non-linear**

…which drives up the capital required as risks rise and returns fall

System integration costs for high shares of VRE remain **very poorly understood by engineers** … but are

Essential for insight on capital flows, macro-economic effects, political and geostrategic ramifications

Australia’s recent market and political experience provide a relevant case study

**China, India and South-East Asia** are where deep decarbonisation globally will either succeed or fail
Global energy investment in 2017 (and percent change from 2016)

USD 1.8 Trillion

Electricity
- Networks (+1%) 303
- Renewable generation (-7%) 298
- Fossil fuel generation (-9%) 132
- Nuclear (-44%) 17

Oil & Gas Supply
- Upstream (+2%) 450
- Downstream (+4%) 266

Energy efficiency
- Buildings (+3%) 140
- TRN (+11%) 60
- IND (-8%) 35
- Coal Supply
- RT&H (-13%) 20

Global fixed capital formation to 2017 (current year USD)


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The Centre for Energy Futures in conjunction with the UQ Energy Initiative and the Dow Centre for Sustainable Engineering Innovation

Global fixed capital formation to 2017 (constant 2010 USD)


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Annual CO₂ emissions
Annual carbon dioxide (CO₂) emissions, measured in million tonnes (Mt) per year.

<table>
<thead>
<tr>
<th>Country</th>
<th>Emissions (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>10.1</td>
</tr>
<tr>
<td>United States</td>
<td>5.3</td>
</tr>
<tr>
<td>India</td>
<td>2.4</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.40</td>
</tr>
<tr>
<td>Australia</td>
<td>0.49</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.39</td>
</tr>
<tr>
<td>EU28</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Source: Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC)
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY-SA
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Share of global cumulative CO₂ emissions

Each country or region’s share of cumulative global carbon dioxide (CO₂) emissions. Cumulative emissions are calculated as the sum of annuals emissions from 1751 to a given year.

- **United States**: 26.1%
- **EU28**: 21.9%
- **China**: 12.9%
- **United Kingdom**: 5.1%
- **India**: 3.1%
- **Australia**: 1.1%
- **Brazil**: 0.9%

Source: Our World in Data based on Global Carbon Project (GCP)
https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

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### A framework for considering VRE system integration costs

<table>
<thead>
<tr>
<th>COST type</th>
<th>options</th>
<th>MODEL type</th>
</tr>
</thead>
<tbody>
<tr>
<td>macroeconomy</td>
<td>investment flows on to— → • electricity prices • demand, returns • wages/employ't • GDP, trade, … etc.</td>
<td>marginal, material, large, formidable</td>
</tr>
<tr>
<td>profile:</td>
<td>• interrupt /DR • curtail / spill • store → • backup</td>
<td>CGE model</td>
</tr>
<tr>
<td>overproduction</td>
<td>• months…seasons • days…weeks • minutes…hours</td>
<td>various power system models</td>
</tr>
<tr>
<td>reduced utilisation</td>
<td>• fast response • forecasting</td>
<td>simple energy and connection cost calculations</td>
</tr>
<tr>
<td>adequacy</td>
<td>• FCAS • inertia • system strength</td>
<td></td>
</tr>
<tr>
<td>balancing</td>
<td>• interconnectors • flow-on need for reinforcements</td>
<td></td>
</tr>
<tr>
<td>within the grid:</td>
<td>• plant-to-grid only</td>
<td></td>
</tr>
<tr>
<td>‘deep’ transmission costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONNECTION costs</td>
<td>to the grid: • energy only, undifferentiated</td>
<td></td>
</tr>
<tr>
<td>‘shallow’ generation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VRE share:</td>
<td>0% 25% 50% 75% 100%</td>
<td></td>
</tr>
</tbody>
</table>

**Author’s chart inspired by Ueckerdt et al (2013)**

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A framework for considering VRE system integration costs

**COST type**
- options
  - macroeconomy (investment flows on to →)
    - electricity prices
    - demand, returns
    - wages/employment
    - GDP, trade, ... etc.

**MODEL type**
- CGE model
- various power system models

**INTEGRATION costs**
- profile: overproduction, reduced utilization, adequacy
  - balancing: interrupt/DR, curtail/spill, store→ backup
  - within the grid: fast response, forecasting
  - connection costs: within the grid: ‘deep’, transmission costs
  - generation: ‘shallow’, plant-to-grid only
  - VRE share: energy only, undifferentiated

**INTERCONNECTION costs**
- transmission costs
  - interconnectors, flow-on need for reinforcements
  - simple energy and connection cost calculations

**CONNECTION costs**
- to the grid: ‘shallow’
  - plant-to-grid only
  - simple energy and connection cost calculations

**LCoE**
- here is almost irrelevant

**Author’s chart inspired by Ueckerdt et al (2013)**

1. Most of the recent good literature focuses in this zone
2. A few papers are looking here
3. But most of them don’t handle integration costs well or at all
4. Over here we actually have a serious order of magnitude problem
Snapshots from the literature show enormous uncertainty.

Very low integration costs for 100% VRE

VRE integration costs approach $\infty$ well before shares reach 100%

Source: Gabriel Rioseco (2019) How are VRE integration costs likely to affect the decarbonisation rate and the macro economy of India? Draft PhD confirmation report, University of Queensland (unpublished), June.
Rob Socolow’s ‘four world-views’ on climate change

Two simple questions:
1. Is climate change an URGENT matter?
2. Are fossil fuels HARD to displace?

From this we can map out what Rob calls ‘four world-views’ on climate change… …as well as indicating approximate, indicative future temperature scenarios, based on the IPCC’s estimates of climate sensitivity to CO₂
World views and policy dispositions tend to be related

We can identify ‘five policy dispositions’ as broad groupings of possible responses to the challenges of climate change.

The direction of influence is an open question: whether from world views to policy disposition or vice-versa.

The framework can be used by analysts and investors to help understand likely interactions between policy, prices and various physical systems.
It turns out that a remarkably elegant decision analysis on the effects of personal beliefs and scientific uncertainty about climate change was done at Carnegie Mellon in the early 1990s.


**TABLE 4**

<table>
<thead>
<tr>
<th>Perspective on abatement costs</th>
<th>Perspective on climate change damages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimist</td>
<td>(1) Dr. Pangloss</td>
</tr>
<tr>
<td>Moderate</td>
<td>(2) Environmentalists</td>
</tr>
<tr>
<td>(3) Dispassionate researchers</td>
<td></td>
</tr>
<tr>
<td>Pessimist</td>
<td>(4) Industrialists</td>
</tr>
<tr>
<td>Numbers in parentheses are scenario numbers.</td>
<td>(5) Dr. Doom</td>
</tr>
</tbody>
</table>
Using Lave and Dowlatabadi’s ‘perspectives’…

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