Technology policy for low-C technologies

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London
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Karsten Neuhoff

www.electricitypolicy.org.uk/tsec/2
• The challenge for low Carbon - cost and market size

• Incentives for innovation from strategic deployment

• How strategic deployment could address market needs
  – of project developers
  – of PV producers and equipment suppliers

• Conclusion
The Challenge of lower Carbon technologies – cost and market size

Price evolution for PV modules

Recent profit margins (based on solarworld annual reports)

<table>
<thead>
<tr>
<th>Year</th>
<th>Euro/W wafer</th>
<th>Euro/W cell</th>
<th>Euro/W module</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>0.286</td>
<td>0.079</td>
<td>0.063</td>
<td>0.427</td>
</tr>
<tr>
<td>2006</td>
<td>0.308</td>
<td>0.162</td>
<td>0.059</td>
<td>0.529</td>
</tr>
</tbody>
</table>

Source: IEA Implementing agreement solar PV, Maycock and News and Strategies Unlimited.
Where do we need to go?

- **Cost of PV electricity (2007)**
  - Module, cost/price 2200-3500 Euro/KWatt
  - Average output 900 h/a
  - Interest + depreciation = 10%
  - Levelised cost: 240-390 Euro/MWh

- **Fossil fuel**
  - Levelised cost: 40 Euro/MWh
  - Increase with 25 Euro/t CO2: 12-20 Euro/MWh

- **Can we reduce PV costs by factor 4?**
- **How long will it take?**
  - Learning rate 0.8 -> ¼ cost -> $2^6$ capacity
  - Growth rate 30% -> double in 2.5a -> 15 years
Incentives for innovation from strategic deployment?

The production line of PV cells

Cell producer

- Solar grade SI chunks
- Ingot manufacturing
- Wafer production
- Solar cell production
- Solar module production

Work with:

Katja Schumacher  Gregory Nemet  Misato Sato  Jan Lossen
DIW  University of Berkeley  University of Cambridge  Ersol
Berlin
Pv producers are horizontally integrated

<table>
<thead>
<tr>
<th>Solar grade Si chunks</th>
<th>Ingot manufacturin</th>
<th>Wafer product</th>
<th>Solar cell production</th>
<th>Solar module production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon preparation</td>
<td>Ingot manufacturin</td>
<td>Wafer slicing</td>
<td>Etching</td>
<td>Tabbing, stringing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wafer separation and cleaning</td>
<td>Diffusion</td>
<td>Arrangement, lamination</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Antireflective coating</td>
<td>Junction box, frame</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Metallization, screenprinting, G. firing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Edge isolation</td>
<td></td>
</tr>
</tbody>
</table>

Incentives for innovation from strategic deployment?
The modelling framework – what fraction of line to improve?

<table>
<thead>
<tr>
<th>Period 1</th>
<th>Period 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell Producer innovates on $0 &lt; \alpha &lt; 1$ of new line</td>
<td>Cost reduction $\gamma \alpha$</td>
</tr>
<tr>
<td>Production loss $(1 - \beta \alpha^2)$</td>
<td>Capacity expansion $I_2$</td>
</tr>
<tr>
<td>Innovation cost $\alpha c_d$</td>
<td></td>
</tr>
<tr>
<td>Capacity expansion $I_1$</td>
<td></td>
</tr>
</tbody>
</table>
Incentives for innovation from strategic deployment?

The role of the supply chain

**Cell producer**
- Solar grade SI chunks
- Ingot manufacturing
- Wafer production
- Solar cell production
- Solar module production

**Equipment supplier**
- Solar grade SI chunks
- Ingot manufacturing
- Wafer production
- Solar cell production
- Solar module production
Most equipment supplied for individual production steps

Ingot / Block production equipment:
Wafer production equipment:
Cell production equipment:
Panel production equipment:
Testers & Sorters for cell/panel production

Production process stage

Incentives for innovation from strategic deployment?
### Survey - How did the idea come about?

<table>
<thead>
<tr>
<th></th>
<th>Equipment supplier</th>
<th>Cell producer</th>
<th>University/Research Institute</th>
<th>Industry network</th>
<th>Call producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem identified in production process</td>
<td>0.50</td>
<td>0.16</td>
<td>0.00</td>
<td>0.09</td>
<td>0.82</td>
</tr>
<tr>
<td>Opportunity identified in production program</td>
<td>0.20</td>
<td>0.76</td>
<td>0.04</td>
<td>0.32</td>
<td>0.84</td>
</tr>
<tr>
<td>Transfer of idea from other industry sector</td>
<td>0.32</td>
<td>0.13</td>
<td>0.19</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Suggested by equipment supplier</td>
<td>0.16</td>
<td>0.04</td>
<td>0.28</td>
<td>0.19</td>
<td>0.00</td>
</tr>
<tr>
<td>Research project</td>
<td>0.09</td>
<td>0.32</td>
<td>0.20</td>
<td>0.04</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### Survey - Who initiated improvements?

Incentives for innovation from strategic deployment?

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<thead>
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<th>Call producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>n_{equip}=10</td>
<td>0.28</td>
<td>0.16</td>
<td>0.00</td>
<td>0.04</td>
<td>0.82</td>
</tr>
<tr>
<td>n_{cell}=17</td>
<td>0.19</td>
<td>0.76</td>
<td>0.04</td>
<td>0.13</td>
<td>0.84</td>
</tr>
<tr>
<td>Survey:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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The four models that we will look at

- **Model I**: Monopolistic supplier
- **Model II**: Monopolistic producer
- **Model III**: Competing suppliers
- **Model IV**: Competing producers

**Incentives for innovation from strategic deployment?**
Incentives for innovation from strategic deployment?

Model results

Competing innovations

One innovation per production step

Model III
Competing suppliers

Model IV
Competing producers

Model I
Monopolistic supplier

Model II
Monopolistic producer

Innovative suppliers

Innovative producers

Social optimum

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Results from PV model  (Preferred market structure?)

(1) Trade-off: Breadth versus Depth of innovation
   – Depth high if many equipment suppliers innovate for one segment of production line
   – Breadth high with monopoly suppliers

(2) Where equipment suppliers own innovation, successful innovation spreads faster
   – Also incentive for entry from other industry sectors
   – But challenge to coordinate along production line
Results PV model (Insights for support policy)

(3) Breadth of innovation always below social optimum
   – Provide subsidy for production innovation (Japan)
(4) Bigger future market increases today’s innovation
(5) Rapid (unexpected) current market growth
   – Creates profits for investment/innovation
   – High current margins are disincentive for experimenting (delays/downtimes)
How strategic deployment could address market needs?

Strategic deployment works via project developers

- Energy companies
- Project developers
- Technology companies
- Research Institutions

Demand, Exp. Focus, New ways

R&D - Strategic deployment
Expectation about Future market

Leveraging private Investment

Source: Neuhoff/Sellers EPRG 2006

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How to address needs of project developers?

Cost effectiveness of deployment instruments differs

Payment per KWh delivered, over project live

Source: Butler/Neuhoff, update August 2007
How to address needs of project developers?

ROC proponents might focus on wrong market

Competition among project developers and operators

Competition in Markets for input factors

Energy revenue
Balance, Network
Renewable obligation

Developer
Developer

pcomp
pcomp

Turbine producers
Construction services

20% Value added (VA)
80% Value added (VA)

Energy companies
Project developers
Technology companies
Research institutions

Demonstration
R&D
New ways
Exp. Focus
How to address needs of PV producers and equipment suppliers?

Can emission targets drive renewables innovation?


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How to address needs of PV producers and equipment suppliers?

Renewable targets more tangible for banks and technology companies

1. ‘Early’ role for renewables
2. Long-term position of technologies conditional on their performance

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How to address needs of PV producers and equipment suppliers?

International markets make demand more predictable

Installed wind power per year (MW)

Source: BTM consult, GWEC

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Conclusion

- The challenge for low Carbon - cost and market size
  - Learning by doing & R&D to get costs down
  - Scale up producers capabilities
- Incentives for innovation from strategic deployment?
  - 5 year expectations drive innovation
  - Unexpected demand surge might hamper innovation
  - Key role of manufacturing equipment suppliers
- How strategic deployment could address market needs
  - Facilitate financing for projects (feed in)
    - Allows focus on planning and implementation
    - Basis for large scale participation/policy success
  - Create growth perspective for technology developers
    - Renewables targets
    - International technology markets