Low-Carbon Technologies for Electricity Production: Environmental benefits, risks, and trade-offs

Edgar Hertwich
Norwegian University of Science & Technology

Brussels, 5 June 2013
Massive investments in new energy technologies are required to achieve climate technology objectives.

Technologies interact – especially supply and demand. Technologies may have unforeseen consequences on the ecosystems, human health or resources.

Fast decisions are required.

The chosen technologies may not be optimal for achieving their objective.
Objectives

• Understand the resource requirements and potential ecological impacts of low-carbon electricity supply technologies
• Identify potential show-stoppers, pitfalls, opportunities to avoid impacts
• Identify potential co-benefits
• “Due diligence”
Resource Panel Study

• Experts recruited to cover
  – Coal and gas with and w/o CCS
  – Hydro, wind, geothermal power
  – Solar power (PV and Concentrating thermal)

• Review, assessment and data provision

• Integrated, comparative life cycle modeling and assessment
Contributors

• Photovoltaics
  – Joe Bergerson
  – Shi Lei
  – Garvin Heath
  – Patrick O’Donoughue
• Concentrating solar power
  – Mathieu Saurat
  – Pallav Purohit
  – Peter Viebahn
  – Garvin Heath
• Hydropower
  – Edgar Hertwich
  – Cássia Maria Lie Ugaya
  – Claudia Peña
  – Haiying Li
  – Atle Harby
• Geothermal
  – Peter Bayer
  – Ladislaus Rybach
• Fossil fuels and CCS
  – Andrea Ramírez
  – Bhavik Bakshi
  – Takeshi Kuramochi
  – Joule Bergerson
  – Heather McLean
  – Yu Qian
  – Evert Bouman
  – Mike Griffin
• Wind
  – Anders Arvesen
  – Wang Zhongying
• Grid
  – Jan Weinzettel
  – Edgar Hertwich
  – Evert Bouman
Example Windpower: LCA review

Studies published since 2000 were reviewed and compared in terms of systems analysed, approach, and results.

Important variables identified: size, capacity factor, system boundary.

Source: Arvesen, A.; Hertwich, E. G., 2012
Small plants $S$ (<100kW) have higher energy requirements and GHG emissions than bigger plants; offshore has slightly higher than large onshore. Differences in cases and LCA methods.
Example Wind power: Own Inventory Assessed in Different Region & Times

Regional comparison: impact of the production of electricity for an onshore conventional windfarm on climate change, in g CO₂ eq./kWh

<table>
<thead>
<tr>
<th>Region</th>
<th>2010</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>14,5</td>
<td>8,0</td>
<td>5,7</td>
</tr>
<tr>
<td>IN</td>
<td>13,4</td>
<td>7,0</td>
<td>4,8</td>
</tr>
<tr>
<td>EU</td>
<td>9,0</td>
<td>5,0</td>
<td>4,5</td>
</tr>
<tr>
<td>NA</td>
<td>12,1</td>
<td>6,1</td>
<td>5,1</td>
</tr>
<tr>
<td>PAC</td>
<td>11,8</td>
<td>5,5</td>
<td>4,6</td>
</tr>
<tr>
<td>EIT</td>
<td>11,3</td>
<td>6,0</td>
<td>4,9</td>
</tr>
<tr>
<td>LA</td>
<td>10,4</td>
<td>5,7</td>
<td>4,8</td>
</tr>
<tr>
<td>AS</td>
<td>12,2</td>
<td>6,9</td>
<td>4,8</td>
</tr>
<tr>
<td>AME</td>
<td>12,2</td>
<td>6,2</td>
<td>4,9</td>
</tr>
</tbody>
</table>

- China
- India
- Europe
- North America
- Pacific
- Economies in Transition
- Latin America
- Other Asia
- Africa + MidEast
Example Wind Power:
Site-specific ecological impacts

Collision fatalities for birds and bats

• Observed fatality rates (IPCC 2011)
  – Birds: 1-12 deaths per MW per year
  – Bats: 0-53 deaths per MW per year

• Fatality varies
  – species type, site characteristics, turbine design, weather, season, ...

Raptors

• Bats
  – Attracted by wind turbines (birds are not)
  – May be susceptible to depressurization injuries (birds are not)
  – May be worth ~20 billion dollars annually to North American agriculture (Boyles et al. 2011)

Sources: Boyles et al. 2011, IPCC 2011, Arnett et al. 2008 , Willis et al. 2010
Case Study Wind Power: White-tailed eagles at Smøla

- Smøla wind farm, Norway
  - 68 turbines, 150 MW

- Recorded death rate
  - 7.8 eagles annually on average
  - > 50% total (detectable) mortality

- But: population size stable

*Source:* May et al. 2012 [NINA report]

*Photo:* Espen Lie Dahl
Technology Comparison

RE: very low GHG; challenge of variable production
NG: problems with fugitive emissions
CCS: substantial emission reduction especially for coal

Feedback of the penetration of clean technologies: lower emissions for the production of clean technologies.

Effect on materials, other pollution categories will be presented in the report.
Heavy Air Pollution Reductions

Emissions per kWh
Wind << Gas < Coal

But higher demand for steel, cement and copper.

Throughput replaced by stock of materials.