Approaches for Informing Public Preferences for CCS and Other Low-Carbon Technologies

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To evaluate CCS, people need to be properly informed about CCS and other low-carbon technologies

• People’s preferences are best elicited after they have been well-informed
  – Opinions are more stable and consistent with a person’s values (e.g., de-Best Waldhober 2009)

• People do not like to consider CCS in isolation. Instead, they want to
  – Compare it to other electricity technologies that reduce CO₂ (e.g., Ashworth et al. 2007, Sharp 2005)
  – Consider it as a part of a low-carbon portfolio (e.g., Palmgren et al. 2004, Fleishman et al. 2010)
People’s perceptions of CCS partly depend on their evaluation of other technologies.

However, people have many common misconceptions about a range of low-carbon electricity technologies:

- Low awareness and understanding of
  - CCS (e.g., Reiner et al. 2006, Huijts et al. 2007)
  - Biomass technologies (e.g., Plate and Monroe 2010)
- Misconceptions about
  - Nuclear, e.g. plants emit CO$_2$ (e.g., Reiner et al. 2006, Reynolds et al. 2010)
  - Renewables, e.g. inexpensive (e.g., Ansolabehere 2007) and reliable (e.g., Plate and Monroe 2010)
Misconceptions can be resistant to change, so education early on about low-carbon technologies is important

- Do science teachers have the knowledge to do so?
- 58 6th-12th grade science teachers answered surveys:
  - seven knowledge questions about common gaps and misconceptions of low-carbon technologies
  - measures of their environmental attitudes
- After testing teacher knowledge, teachers were
  - Presented with comprehensive information about ten electricity technologies
  - Asked to rank the technologies and low-carbon portfolios composed of the technologies following Fleishman et al. 2010
Knowledge Questions

1. Solar power costs less to make than coal power. (F)
2. The natural gas used in power plants to make electricity is not flammable. (F)
3. Electricity can be made by burning woody products such as farm crops, wood chips and paper mill products. (T)
4. Pennsylvania could make all of its electricity from wind power and solar power if we built enough wind and solar farms in the state. (F)
5. Engineers have developed equipment that can capture the carbon dioxide released by power plants, putting it underground instead of releasing it into the atmosphere. (T)
6. The carbon dioxide released by electric power plants is not flammable. (T)
7. Nuclear power plants release no carbon dioxide (CO₂) into the air. (T)
Teachers received information materials following Fleishman et al. (2010)

Materials corrected all tested misconceptions and:

- were technically accurate and understandable
- provided descriptions of the costs, risks, benefits and limitations of ten technologies
Teachers ranked the technologies and seven low-carbon portfolios

- Portfolios were designed to meet a specific CO$_2$ emissions limit
  - 3 diverse portfolios: 1) with CCS & nuclear, 2) with CCS, but no nuclear, 3) no CCS & no nuclear
  - 4 simple portfolios: 1) PC with CCS & PC, 2) IGCC with CCS & IGCC, 3) natural gas & wind, 4) nuclear & PC

- Costs and pollutant information for portfolios was also given to participants

Technology and portfolios rankings were elicited before and after a “group workshop” by asking participants to assume that the U.S. Congress had mandated a reduction in CO$_2$ emissions from power plants to be built in the future
Participants

- 58 6th-12th grade science teachers
- 23 to 64 years old (M=42.0)
- 58.6% female and 93.1% white
- All had a Bachelor’s degree, 76% had a Master’s degree or higher (most in an education discipline)
- Nearly 80% were high school teachers
## Knowledge Questions

<table>
<thead>
<tr>
<th>Statement (Correct Answer: T or F)</th>
<th>Participant Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correct</td>
</tr>
<tr>
<td>The natural gas used in power plants to make electricity is <em>not</em> flammable. (F)</td>
<td>87.9%</td>
</tr>
<tr>
<td>Electricity can be made by burning woody products such as farm crops, wood chips and paper mill products. (T)</td>
<td>86.2%</td>
</tr>
<tr>
<td>The carbon dioxide released by electric power plants is <em>not</em> flammable. (T)</td>
<td>81.0%</td>
</tr>
<tr>
<td>Engineers have developed equipment that can capture the carbon dioxide released by power plants, putting it underground instead of releasing it into the atmosphere. (T)</td>
<td>65.5%</td>
</tr>
<tr>
<td>Nuclear power plants release <em>no</em> carbon dioxide (CO₂) into the air. (T)</td>
<td>62.1%</td>
</tr>
<tr>
<td>Solar power costs <em>less</em> to make than coal power. (F)</td>
<td>56.9%</td>
</tr>
<tr>
<td>Pennsylvania could make <em>all</em> of its electricity from wind power and solar power if we built enough wind and solar farms in the state. (F)</td>
<td>52.6%</td>
</tr>
</tbody>
</table>
Knowledge Correlations

• Teachers environmental attitudes measured with New Ecological Paradigm (NEP) scale
  – More pro-environmental $\rightarrow$ more incorrect answers ($p<0.01$)

• Teachers rated their (1-7 Likert) agreement of whether: “government regulation should begin to significantly limit the amount of CO$_2$ that is released into the earth’s atmosphere”
  – More support for climate change policy $\rightarrow$ more incorrect answers ($p=0.02$)
Technology Rankings

• Ten technologies ranked from best (=1) to worst (=10)

• Concept: Nuclear-CO$_2$ emissions
  – Participants with correct answer ranked nuclear better ($M=3.4$) than those with ‘don’t know’ answers ($M=6.3$) ($p<0.01$)

• Concept: Solar and wind to make all of PA’s electricity
  – Participants with correct answer...
    • ranked wind worse ($M=5.1$) than those with incorrect answers ($M=3.4$) ($p=0.02$)
    • ranked wind marginally worse ($M=5.1$) than those with ‘don’t know’ answers ($M=3.7$) ($p=0.07$)
    • ranked solar marginally worse ($M=7.6$) than those with incorrect answers ($M=5.6$) ($p=0.06$)
Teacher Knowledge Discussion

Science teachers held gaps and misconceptions about:

- (1) the existence of CCS
- (2) CO₂ emissions from nuclear
- (3) solar cost relative to coal
- (4) wind and solar power's ability to meet all of PA's electricity needs

The teachers who most want to help the environment hold more misconceptions about low-carbon technologies:

- May be more likely to include environmental curriculum
- BUT less able to correct students’ misconceptions

Misconceptions and knowledge gaps may have biased participants relative rankings of nuclear, solar and wind:

- Despite receiving comprehensive information, correcting misconceptions

Results suggest that many science teachers hold an unrealistic view of the challenge of reaching a low-carbon energy future.
Science Teacher Ranking Results

Mean participant technology rankings (±SD), from 1 (best) to 10 (worst)

Participants
58 participants (6th-12th grade science)
Ages 23-64 (m=42.0)
59% Female; 93% White
All have Bach. Deg, 76% ≥ Mast. Deg.
Mean participant portfolio rankings (±SD), from 1 (best) to 7 (worst)

Portfolio with best mean ranking:
- 25% IGCC with CCS
- 21% Nuclear
- 20% NGCC Plants
- 17% PC Plants
- 10% Wind Power
- 7% Energy Efficiency
Public vs. Science Teachers

PUBLIC

N = 60 (general public)
Ages 18-73 (m=36.7)
63% Female
67% White
All graduated High School
67% ≥ Bach. Deg.
NEP scale = 4.7

Younger and more diverse
Slightly less pro-environmental

SCIENCE TEACHERS

N = 58 (6th-12th grade science)
Ages 23-64 (m=42.0)
59% Female
93% White
All have Bach. Deg,
76% ≥ Mast. Deg.
NEP scale = 5.0

Older and more educated
Slightly more pro-environmental

* NEP is on a 1-7 scale, where higher ratings denote more pro-environmental attitudes
Science teachers have very similar informed preferences to the public.
Science teachers have very similar informed preferences to the public.

Slight difference in rankings of portfolios E and B.

- **F** = Diverse, includes IGCC with CCS and nuclear
- **B** = Simple, IGCC with CCS and IGCC
- **E** = Diverse, includes IGCC with CCS, but no nuclear
- **D** = Diverse, includes NO CCS and NO nuclear
- **G** = Simple, natural gas and wind
- **C** = Simple, nuclear and PC
- **A** = Simple, PC with CCS and PC
Discussion & New Work

- **Similar results between science teachers and the public**
  - Suggests that once people are well informed, they are in agreement about their technology preferences
  - Interpret with caution: small convenience samples, unrepresentative populations, etc.

- **Limitations of the overall study**
  - Only given 7 discrete portfolios choices
  - While portfolios comply with technology limitations, participants may not explicitly understand them

- **New Work: develop a dynamic computer decision tool where participants can “learn-by-doing”**
  - Lay-users build their own portfolio
  - Observe how electricity prices and environmental impacts change along with the change in percentages of technologies
“…build a combination of new power plants [to meet increased demand] that you think is the best…[It] must make 60 TWh of electricity per year, but release 50% of the CO₂ that would have been released using the original plan [current PA energy mix].”
Thank You!

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[Logos of EPRI and CDMC]
References


# Low-Carbon Portfolios

All release 70% less CO₂ than a portfolio of 100% PC plants

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>Description</th>
<th>PC with CCS mix</th>
<th>IGCC with CCS mix</th>
<th>Nuclear mix</th>
<th>NGCC &amp; Wind mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>PC with CCS mix</td>
<td>81% PC with CCS 9% PC Plants</td>
<td>83% IGCC with CCS 17% IGCC Plants</td>
<td>70% Nuclear 30% PC Plants</td>
<td>66% NGCC Plants 34% Wind Power</td>
</tr>
<tr>
<td>B</td>
<td>IGCC with CCS mix</td>
<td>83% IGCC with CCS 17% IGCC Plants</td>
<td>70% Nuclear 30% PC Plants</td>
<td>66% NGCC Plants 34% Wind Power</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Nuclear mix</td>
<td>70% Nuclear 30% PC Plants</td>
<td>66% NGCC Plants 34% Wind Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>EPRI limited portfolio, no nuclear or CCS</td>
<td>66% NGCC Plants 13% Efficiency 10% Wind Power 6% BIGCC Plants 5% PV Solar</td>
<td>48% NGCC Plants 20% IGCC with CCS 13% Wind Power 13% Efficiency 5% PC Plants 1% PV Solar</td>
<td>25% IGCC with CCS 21% Nuclear 20% NGCC Plants 17% PC Plants 10% Wind Power 7% Efficiency</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>EPRI semi-limited portfolio, with CCS, no Nuclear</td>
<td>48% NGCC Plants 20% IGCC with CCS 13% Wind Power 13% Efficiency 5% PC Plants 1% PV Solar</td>
<td>25% IGCC with CCS 21% Nuclear 20% NGCC Plants 17% PC Plants 10% Wind Power 7% Efficiency</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Public Ranking Results

Mean participant technology rankings (±SD), from 1 (best) to 10 (worst)

Participants
60 participants in 9 workshops
Ages 18-73 (m=36.7)
63% Female; 67% White
All graduated HS, 67% ≥ Bach. Deg.
Public Portfolio Rankings

Portfolio with best mean ranking:  
- 25% IGCC with CCS  
- 21% Nuclear  
- 20% NGCC Plants  
- 17% PC Plants  
- 10% Wind Power  
- 7% Energy Efficiency

Mean participant portfolio rankings (±SD), from 1 (best) to 7 (worst)