Integrated assessment methodologies for sustainability evaluations
Social Multi-Criteria Evaluation

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Sustainability appraisal context

Evaluating sustainability impaired by polemics and ambiguities with commercial and political interests in sustainable development

Proliferation of evaluation techniques

Sustainability often regarded as if it were an objective determinate quantity
Cost-benefit analysis

Environmental economics:
- Externalities
- Natural resources and environmental goods management

Cost-benefit analysis:
- Rationality
- Prices reflect preferences and needs
- Optimization, Internalizations and Compensation

\[
\max \sum_{t}^{T} \frac{B_t - C_t}{(1+r)^t}
\]
The Nauru island (Micronesia)
The Nauru island

• Phosphates discovered at the beginning of the ‘900
• Phosphate extraction has become the only economic activity
• In 1980 Nauru trust fund value amounted 1 billion US$
Nauru during the ’90s

- Trust fund value: 1.5 billion US$
- Population: 5000 inhabitants
- Free education (University in Australia)
- Free health system (including in Australia)
- Highest per-capita income in the world
- Nobody had to work
- Natural capital transformed into financial capital
- Phosphate mining almost the only economic activity
Nauru today

- Trust fund completely disappeared because of wrong investments, corruption, 97-98 financial crisis
- No environmental resources to exploit
- Emigration banned
- Population: 10,000 inhabitants
Nauru
Nauru: the paradise lost

- http://www.youtube.com/watch?v=pRl5ctx-S1M
- http://www.youtube.com/watch?v=a5MPcNiwS6M
From environmental valuation to sustainability appraisal

CBA criticized for/by:

- **Political philosophy arguments:** “if CBA is inappropriate for political decisions concerning say, abortion policy, than it is inappropriate for much environmental polity too” (Aldred 2006)

- **Lack of robustness:** “both altering the appearance of an interviewer and changing the degree of information provided can have significant impact upon stated WTP” (Bateman and Mawby, 2004)

<table>
<thead>
<tr>
<th></th>
<th>Casual</th>
<th>Formal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>£13.66</td>
<td>£24.47</td>
</tr>
<tr>
<td>High</td>
<td>£19.36</td>
<td>£32.29</td>
</tr>
</tbody>
</table>
From environmental valuation to sustainability appraisal

CBA criticized for/by (2)

• Behavioral assumptions, empirical evidence and moderns psychology. *Losses matter much more than gains*

• Distributional and ethical implications. “Externalities as cost-shifting success rather than a case of market failure”

Inter-generational inequality
  – *Discount rate*
  – *Those who are not yet born cannot bid in real or artificial markets*

Intra-generational inequality
  – *The poors sell cheap!*

• Protest bids as examples of **incommensurability**
The issue is not whether it is only the marketplace that can determine value, for economists have long debated other means of valuation; our concern is with the assumption that in any dialogue, or valuations or “numeraire” should be reducible to a single one-dimension standard.

Funtowicz and Ravetz (1994, p.199)
Incommensurability

Strong vs weak comparability

Technical incommensurability

Social incommensurability

How much is your god?
Social incommensurability

Terrotists or freedom-fighters?
One of the many definitions of sustainable development

Sustainable development implies:
“to maximize simultaneously the biological system, economic system goals and social system goals”,

Barbier 1987
Allen’s Sustainability issues

Sustainability of:

• What?
• For whom?
• For how long?
• At what cost?
Complexity

complex system as one “for which we have at our disposal a large number of subsets of measuring instruments, each of which gives rise to a different mode of description of the system. Another way of saying this is that a complex system is one which allows us to discern many subsystems..., depending entirely on how we choose to interact with the system”

Rosen (1977, p.229)

“all models are wrong but some are useful” (Box, 1979)

“Analytical work begins with material provided by our vision of things, and this vision is ideological almost by definition” (Shumpeter, 1954)
Non-Equivalent descriptive domains
= Non-reducible Models
Multiple identities of complex systems are a consequence of 
Epistemological plurality (non-equivalent observers) 
& 
Ontological characteristics of the observed system (non equivalent observations)
Complex adaptive systems (CAS)

- Co-evolutionary dynamics
- Self-organization and large macroscopic patterns emerging out of small scale and local interactions
- Cross-scale interactions and feedback loops
- Non linear patterns and high degree of complexity

In dealing with CAS, future scenarios and evolutionary trends
- risk
- uncertainly
- genuine ignorance
Reductionism

- Uncertainty can be managed
- What is good and bad for society can be known and defined in substantive way
- Different indicators related to different dimensions can be made commensurable

... the descriptive side and normative side are fused together

... uncontested agreement on the normative and descriptive side of Decision Making process
Integrated assessment

Should:

• Keep normative side separated from descriptive side
• Take into account incommensurable dimensions from different scientific languages, scales, legitimate representations
• Handle social and technical incommensurability in a consistent and transparent way

Possible tools:

• Social Multi-Criteria Evaluation (SMCE)
Multi-criteria analysis: the Lexicographic model
Lessons learned:

- MCA reflects human behavior with a very high degree of descriptive content
- The order of criteria determines relative weights
- What really matters is the learning process not the final result
- Compensability is the real issue in sustainability problems
From Arrow’s impossibility theorem to multi-criteria algorithms

Arrow’s impossibility theorem

• **Axiom 1: unrestricted domain**: The values that can be taken by the criteria are unrestricted and the mathematical aggregation convention must respect unanimity

• **Axiom 2: Independence of irrelevant alternatives**: the introduction of a new alternative or the deletion of an existing option should not cause changes in the ordering of preferences in other alternatives

• **Axiom 3: Positive responsiveness**: The degree of preference between two alternatives a and b is a strictly increasing function of the number of criteria (or weights) that rank a before b.
A less ambitious voting structures in social choice

- **Anonymity**: all criteria must be treated equally.
- **Neutrality**: all alternatives must be treated equally.
- **Monotonicity**: more support for an alternative cannot jeopardize its success.
Borda vs. Condorcet

Jean-Charles de Borda

Marquis de Condorcet
The condorcet tradition is chosen for four main reasons

1. **no-compensability** is implied, since intensities of preference are never used;
2. manipulation rules of weights guarantee they are **importance coefficients**;
3. it is the most consistent approach for generating a **complete ranking**;
4. there is a low probability of obtaining **rank reversals**.
Borda vs. Condorcet

Jean-Charles de Borda

Marquis de Condorcet
Social Multi-Criteria Evaluation of Alternative Geothermal Power Scenario: the Case of Mt. Amiata
Research outline

Objective: 1) to show the potential use of SMCE in managing problems related with conflicts arising around geothermal power 2) to explore the specific conflict of Mt. Amiata

Method: Social Multi-Criteria Evaluation (SMCE)

Case: Mt. Amiata
Traditional geothermal area (Larderello)

Mt. Amiata (Piancastagnaio, Bagnore)
Adapted from: Barelli et al.
Phases

• Problem structuring
  – Historical & institutional analysis (newspapers, press releases, technical documents, laws … and in-depth interviews)
  – Identification of social actors
  – Elicitation of preferences and aspirations

• Identification of alternatives

• Identification and estimation of criteria

• Selection and application of ranking algorithm

• Analysis of results and sensitivity analysis
Amiata: Historical context

1900: Beginning of mining activity

End of 50s: first geothermal power plants

1970s: closing down of mines

1990s: new geothermal plan for 200 Mw (geotermia 2000)
  : installation of 3 new plants (20MW each)
  : publication of an edited book sponsored by Piancastagnaio municipality

2000: explosions and fluid escapes near Piancas.

2001-2010: exceptions to As conc. law

2000s: Arpat reports on air emissions

2007: general agreement on exploitation of geoth. energ.
Amiata: geological configuration

Source: Barrelli et al. 2010
Potable aquifer

Reduction on spring flows

1970: first cartographic reconstruction set water table at 950 m.a.s.l (Calamai et al)

2003-2005 CNR geophysical survey identifies two important depressions

2010-2011: Piezometer reveals water level at 780 m.a.s.l
Scientific debate: impact on potable aquifer

ENEL – University of Siena position:
• Spring flow reduction due to rainfall, waterworks condition, tunnels of old mines, continuous drawing from wells
• Calamai et al. reconstruction and CNR survey subjected to errors

Borgia/EDRA – Hydraulic risk prevention office of reg. gov.:
• Geothermal exploitation provokes depression in geothermal reservoir. This recalls water from potable aquifer
• CNR depressions indicates refilling of geothermal reservoir from potable aquifer
• Ascent of gaseous contaminants facilitated by reduced water table pressure
• Reduction in spring flow causes increases in poisoning contaminants conc.
Scientific debate: impact on human health

Statistic epidemiological study (ARS, 2010):

• Significant excess mortality (+13%), excess of cancer (+19%) and excess mortality for breathing illness, all among males, small excess mortality for acute breath illnesses among females

• In all likelihood excesses not due geothermal exploitation but to life stiles and past employments
Social actors

Explicitly included
Regional government:
  • Tuscany reg. gov
Local authorities:
  • Piancastagnaio municipality
  • Abbadia S. Salvatore municipality
  • Arcidosso municipality
  • Santa Fiora municipality
Resident associations
  • Prospettiva Comune Piancastagnaio
  • Comitato Abbadia
Political parties
  • Rifondazione comunista (local branch)
NGOs:
  • WWF
  • Rete dei Comitati Difesa del Territorio

Others not included
NGOs
  • Amici della Terra
  • Italia Nostra
Associations
  • Merigar
Industrial associations and unions
  • Confartigianato
  • Coldiretti
  • Confesercenti
Technical and research organizations
  • CNR
  • University of Siena
  • University of Florence
  • Cegl
Criteria

1) Electricity produced
2) Profitability (NPV, 10% d.r.)
3) Municipalities revenues
4) Direct heat uses (qualitative)
5) GHGs emissions avoided
6) H$_2$S emissions
7) Hg emissions
8) NH$_3$ emissions
9) As emissions
10) Impact on aquifer
11) Visual impact (qualitative)
Alternatives - Scenarios

1) Business as Usual (Bau)
2) Reorganization plan in Piancastagnaio (Reorg)
3) Closing down PC2 (ClosingPC2)
4) Reorganization plan in Piancastagnaio + new 40MW plant in Bagnore (Reorg+BG4)
5) Reorganization plan in Piancastagnaio + new 40 MW closed cycle plant in Bagnore (Reorg+40CC)
6) Closing down PC2 + new 20Mw closed cycle plant in Bagnore (ClosingPC2+20CC)
7) Reorganization plan in Piancastagnaio + new 20MW closed cycle plant in Bagnore
## Multi-Criteria Impact Matrix

**Table 4.14: multi-criteria impact matrix**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Dir.</th>
<th>BaU</th>
<th>Reorg</th>
<th>ClosingPC2</th>
<th>Reorg +BG4</th>
<th>Reorg +40CC</th>
<th>ClosingPC2 +20CC</th>
<th>Reorg +20CC</th>
<th>Threshold value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity prod.</td>
<td>↑</td>
<td>531,670</td>
<td>620,800</td>
<td>302,713</td>
<td>504,670</td>
<td>924,800</td>
<td>867,200</td>
<td>577,350</td>
<td>100,000</td>
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<tr>
<td>Profitability</td>
<td>↑</td>
<td>153,148</td>
<td>196,155</td>
<td>148,517</td>
<td>232,372</td>
<td>184,249</td>
<td>130,164</td>
<td>183,463</td>
<td>15,000</td>
</tr>
<tr>
<td>Municipalities rev.</td>
<td>↑</td>
<td>20,056</td>
<td>25,761</td>
<td>17,749</td>
<td>51,806</td>
<td>47,445</td>
<td>32,554</td>
<td>37,242</td>
<td>5,000</td>
</tr>
<tr>
<td>Direct heat uses</td>
<td>↓</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Avoided GHGs em.</td>
<td>↑</td>
<td>296,187</td>
<td>345,840</td>
<td>281,145</td>
<td>515,194</td>
<td>483,106</td>
<td>281,145</td>
<td>414,473</td>
<td>150,000</td>
</tr>
<tr>
<td>H₂S emissions</td>
<td>↓</td>
<td>1,825</td>
<td>1,070</td>
<td>1,015</td>
<td>1,727</td>
<td>1,119</td>
<td>966</td>
<td>1,021</td>
<td>250</td>
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<tr>
<td>Hg emissions</td>
<td>↓</td>
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<td>309</td>
<td>251</td>
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<td>NH₃ emissions</td>
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<td>3,392</td>
<td>2,929</td>
<td>7,827</td>
<td>3,530</td>
<td>2,792</td>
<td>3,255</td>
<td>500</td>
</tr>
<tr>
<td>As emissions</td>
<td>↓</td>
<td>16</td>
<td>19</td>
<td>15</td>
<td>26</td>
<td>19</td>
<td>15</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>Impact on aquifer</td>
<td>↓</td>
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<td>280</td>
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Preference model

True criterion model

\[ j \, P \, k \Leftrightarrow g_m(j) > g_m(k) \]
\[ j \, I \, k \Leftrightarrow g_m(j) = g_m(k) \]

Quasi-criterion model

\[ j \, P \, k \Leftrightarrow g_m(j) > g_m(k) + q \]
\[ j \, I \, k \Leftrightarrow |g_m(j) - g_m(k)| \leq q \]
Important characteristics:

• Ranked results and not unique results
• Non compensatory
  – Weights as importance coefficients and not trade-offs
  – Intensity of preference not accounted for
• Condorcet consistent (and not Borda)
• Simple and transparent
Ranking alternatives

**Maximum ranking** supported by the maximum number of criteria for each pair-wise comparison summed over pairs of alternatives.

A $N \times N$ matrix is built respecting the axioms of:
- Diversity
- Symmetry
- Positive responsiveness

For any element $E: e_{jk} (j \neq k)$

$$e_{jk} = \sum_{m=1}^{M} \left( w_m(P_{jk}) + \frac{1}{2} w_m(I_{jk}) \right)$$

The final ranking $\tau^*$ is the one which maximizes $\varphi_s$

$$\tau^* \iff \varphi_* = \max \sum e_{jk}$$

with $N'$ possible ranking
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<td>7</td>
<td>5</td>
<td>6</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 4.15: outranking matrix**

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<thead>
<tr>
<th></th>
<th>BaU</th>
<th>Reorg</th>
<th>ClosingPC2</th>
<th>Reorg +BG4</th>
<th>Reorg +40CC</th>
<th>ClosingPC2 +20CC</th>
<th>Reorg +20CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaU</td>
<td>0</td>
<td>0.2727</td>
<td>0.4545</td>
<td>0.3636</td>
<td>0.1818</td>
<td>0.3636</td>
<td>0.2273</td>
</tr>
<tr>
<td>Reorg</td>
<td>0.7273</td>
<td>0</td>
<td>0.5455</td>
<td>0.5455</td>
<td>0.4091</td>
<td>0.4545</td>
<td>0.4091</td>
</tr>
<tr>
<td>ClosingPC2</td>
<td>0.7273</td>
<td>0.4545</td>
<td>0.4545</td>
<td>0</td>
<td>0.5455</td>
<td>0.4545</td>
<td>0.5000</td>
</tr>
<tr>
<td>Reorg +BG4</td>
<td>0.6364</td>
<td>0.4545</td>
<td>0.4545</td>
<td>0</td>
<td>0.3182</td>
<td>0.4545</td>
<td>0.5000</td>
</tr>
<tr>
<td>Reorg +40CC</td>
<td>0.8182</td>
<td>0.5909</td>
<td>0.5455</td>
<td>0.6818</td>
<td>0</td>
<td>0.5455</td>
<td>0.5909</td>
</tr>
<tr>
<td>ClosingPC2 +20CC</td>
<td>0.6364</td>
<td>0.6364</td>
<td>0.5000</td>
<td>0.5455</td>
<td>0.4545</td>
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<td>0</td>
</tr>
</tbody>
</table>

\[ e_{jk} = \sum_{m=1}^{M} \left( w_m (P_{jk}) + \frac{1}{2} w_m (I_{jk}) \right) \]
Results

Table 16: ranking for equal weights among all criteria

<table>
<thead>
<tr>
<th>1°</th>
<th>2°</th>
<th>3°</th>
<th>4°</th>
<th>5°</th>
<th>6°</th>
<th>7°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
<td>Bin20</td>
<td>Reorg</td>
<td>ClosingPC2</td>
<td>Reorg+BG4</td>
<td>BaU</td>
</tr>
</tbody>
</table>

Sensitivity analysis: Profitability

<table>
<thead>
<tr>
<th>N of times higher than other weights</th>
<th>Reorg+BG4</th>
<th>Reorg+Bin40</th>
<th>Reorg+Bin20</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Reorg+BG4</td>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
</tr>
<tr>
<td>5</td>
<td>Reorg+BG4</td>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
</tr>
<tr>
<td>4</td>
<td>Reorg+BG4</td>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
</tr>
<tr>
<td>3</td>
<td>Reorg+Bin40</td>
<td>Reorg+BG4</td>
<td>Reorg+Bin20</td>
</tr>
<tr>
<td>2</td>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
<td>Bin20</td>
</tr>
<tr>
<td>1</td>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
<td>Bin20</td>
</tr>
</tbody>
</table>

Electricity production

<table>
<thead>
<tr>
<th>N of times higher than other weights</th>
<th>Reorg+BG4</th>
<th>Reorg+Bin40</th>
<th>Reorg+Bin20</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
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<td>Reorg+BG4</td>
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<tr>
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<td>Reorg+Bin40</td>
<td>Reorg+BG4</td>
<td>Reorg+Bin20</td>
</tr>
<tr>
<td>3</td>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
<td>Reorg+BG4</td>
</tr>
<tr>
<td>2</td>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
<td>Bin20</td>
</tr>
<tr>
<td>1</td>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
<td>Bin20</td>
</tr>
</tbody>
</table>
## Results

Sensitivity & robustness analysis: $\text{H}_2\text{S} & \text{Hg}$ emissions

### Fig. 6: Sensitivity analysis of $\text{H}_2\text{S}$ emissions

<table>
<thead>
<tr>
<th>No. times higher than other weights</th>
<th>Reorg+Bin40</th>
<th>Reorg+Bin20</th>
<th>Bin20</th>
<th>Reorg+Bin40</th>
<th>Reorg+Bin20</th>
<th>Bin20</th>
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</thead>
<tbody>
<tr>
<td>20</td>
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<td>3</td>
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**Ranking**

<table>
<thead>
<tr>
<th>1°</th>
<th>2°</th>
<th>3°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bin20</td>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
</tr>
</tbody>
</table>

### Fig. 7: Sensitivity analysis of $\text{Hg}$ emissions

<table>
<thead>
<tr>
<th>No. times higher than other weights</th>
<th>ClosingPC2</th>
<th>Bin20</th>
<th>ClosingPC2</th>
<th>Reorg+Bin40</th>
<th>Reorg+Bin40</th>
<th>Reorg+Bin40</th>
<th>Reorg+Bin20</th>
<th>Bin20</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
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</tbody>
</table>

**Ranking**

<table>
<thead>
<tr>
<th>1°</th>
<th>2°</th>
<th>3°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bin20</td>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
</tr>
</tbody>
</table>

**Threshold:** reduced by 50%
Results

Sensitivity & robustness analysis: Impact on the aquifer
## Social analysis

<table>
<thead>
<tr>
<th>Groups</th>
<th>BaU</th>
<th>Reorgan</th>
<th>PC2 shuts down</th>
<th>Reorg+BG4</th>
<th>Reorg+Bin40</th>
<th>Bin20</th>
<th>Reorg+Bin20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuscan Region</td>
<td>Moderate</td>
<td>Good</td>
<td>More or Less Good</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Plancastagnaio Municipality</td>
<td>Bad</td>
<td>Very Good</td>
<td>Moderate</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Moderate</td>
<td>Very Good</td>
</tr>
<tr>
<td>Abbadia S. Salvatore Municipality</td>
<td>Bad</td>
<td>Good</td>
<td>Very Good</td>
<td>More or Less Good</td>
<td>More or Less Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Santa Flora Municipality</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Perfect</td>
<td>Perfect</td>
<td>Very Good</td>
<td>Very Good</td>
</tr>
<tr>
<td>Arcidosso municipality</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>More or Less Bad</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Citizens ass. Abbadia S.S.</td>
<td>Bad</td>
<td>Extremely Bad</td>
<td>Moderate</td>
<td>Extremely Bad</td>
<td>Extremely Bad</td>
<td>Moderate</td>
<td>Extremely Bad</td>
</tr>
<tr>
<td>Nuova Prospettiva</td>
<td>Bad</td>
<td>Bad</td>
<td>Good</td>
<td>Bad</td>
<td>Bad</td>
<td>Good</td>
<td>Bad</td>
</tr>
<tr>
<td>RC Santa Flora</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Very Bad</td>
<td>Bad</td>
<td>More or Less Bad</td>
<td>More or Less Bad</td>
</tr>
<tr>
<td>WWF</td>
<td>More or Less Bad</td>
<td>More or Less Bad</td>
<td>Moderate</td>
<td>Very Bad</td>
<td>More or Less Bad</td>
<td>More or Less Bad</td>
<td>More or Less Bad</td>
</tr>
<tr>
<td>Comitati Difesa del Territorio</td>
<td>Bad</td>
<td>Bad</td>
<td>More or Less Good</td>
<td>Very Bad</td>
<td>Very Bad</td>
<td>Moderate</td>
<td>Bad</td>
</tr>
<tr>
<td>ENEL</td>
<td>Moderate</td>
<td>Very Good</td>
<td>More or Less Bad</td>
<td>Perfect</td>
<td>Good</td>
<td>More or Less Bad</td>
<td>Good</td>
</tr>
</tbody>
</table>
Example of conflict analysis

G1: Tuscany Reg. Government
G2: Piancastagnaio Municipality
G3: Abbadia S. Salvatore Municipality
G4: Santa Fiora Municipality
G5: Arcidosso Municipality
G6: Citizens Association of Abbadia S.
G7: Nuova Prospettiva
G8: RC Santa Fiora
G9: WWF
G10: Comitati di Difesa del Territorio
G11: ENEL
# Ranking for coalitions

<table>
<thead>
<tr>
<th>Coalition / Social actors</th>
<th>1°</th>
<th>2°</th>
<th>3°</th>
<th>4°</th>
<th>5°</th>
<th>6°</th>
<th>7°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuscany Regional government Santa Fiora Municipality</td>
<td>Reorg+BG4</td>
<td>Reorg+Bin40</td>
<td>Bin20</td>
<td>Reorg+Bin20</td>
<td>Reorg</td>
<td>Reorg</td>
<td>ClosingPC2</td>
</tr>
<tr>
<td>Planestagnaio Municipality</td>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
<td>Bin20</td>
<td>Bau</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENEL</td>
<td>Reorg+BG4</td>
<td>Reorg</td>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
<td>Bau</td>
<td>ClosingPC2</td>
<td>Bin20</td>
</tr>
<tr>
<td>Abbadia S. Salvatore municipality</td>
<td>ClosingPC2</td>
<td>Bin20</td>
<td>Reorg+Bin20</td>
<td>Reorg+BG4</td>
<td>BaU</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 16: ranking for equal weights among all criteria

<table>
<thead>
<tr>
<th>1°</th>
<th>2°</th>
<th>3°</th>
<th>4°</th>
<th>5°</th>
<th>6°</th>
<th>7°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reorg+Bin40</td>
<td>Reorg+Bin20</td>
<td>Bin20</td>
<td>Reorg</td>
<td>ClosingPC2</td>
<td>Reorg+BG4</td>
<td>BaU</td>
</tr>
</tbody>
</table>
Amiata case: Conclusions

• Post-Normal Science case: *facts are uncertain, values in dispute, stakes high and decisions urgent*
• Possible alternatives explored in light of different points of view (*political sensitive maps*)
• ENEL projects rank first when profitability importance is at least 5 more than the others
• Binary cycle moves alternatives among highest positions
• Scenarios reflecting residents’ association points of view rank first with Hg emissions are at least three times more important than the others
• BaU always perform worst
• ClosingPC2+20CC possible compromise
Social-multi criteria evaluation: Conclusions

- It facilitates dealing with conflicts
- It facilitates decision making in presence of multiple criteria
- It tackles problems characterized by irreducible valuations and multiple perspectives
- It is transparent
- It facilitates multi/interdisciplinary approaches (i.e. Orchestration of sciences) and it is participative
- It identifies a technical ranking of solutions and checks it against their social acceptance
- It facilitates the identification of compromise solutions
- It complements cost benefit analysis
Thank You!
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