• Energy planning has a number of different meanings.
• One common meaning, that serves as reference in this course, is “the process of developing (long-range) policies/strategies to help guide the future of a local, national, regional or even the global energy system.(…)"
• Energy planning is often conducted using integrated approaches that consider both the provision of energy supplies and demand-side management strategies.

Essentially an exercise of finding the “best match” between the *supply* and the *demand* for the future
The “typical” practice

- Centered on the supply
- Demand-side approach much confined to a few measures on buildings and efficiency of appliances.
- Economic issues prevalent over Environmental ones / lack of internalization of the environmental costs.
- Liberalization devaluated the Energy planning exercise
- Meanwhile, climate-change and other challenges have recently made Energy planning “popular” again
Energy planning as a decision process

- Objectives: What we want to achieve
  - Different from “Targets”
  - Translated through “Attributes”
- Alternatives: What are the options
  - Often overlooked. Ensure that you identify / generate “enough and good” alternatives!
- Technical assessment of the alternatives
  - Producing the “attributes” for each alternative.
- Multi-Criteria evaluation of alternatives
  - Many methods possible
- Post-processing
  - Including implementation issues

Objectives

- Should be identified through discussion with the decision makers and/or stakeholders
- Necessary to pay attention to the difference between “ends” objectives and “means objectives”. E.g.: Is “reducing CO2 emissions and end-objective”?
- There are techniques to conduct an interview to identify objectives, e.g.
  - Value-Focused Thinking - A Path to Creative Decision making, Ralph L. Keeney
  - Causal mapping
Example 1: Objectives for E. E. plans

Table 2 – Fundamental objectives resulting from the interviews and bibliographic review

<table>
<thead>
<tr>
<th>Fundamental objectives</th>
<th>Relevant sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize the influence of energy use on climate change</td>
<td>1,2,4,5,6</td>
</tr>
<tr>
<td>Minimize the financial risk from the investment</td>
<td>2,3,4,5</td>
</tr>
<tr>
<td>Maximize the security of energy supply</td>
<td>1,2,3,4,5,6</td>
</tr>
<tr>
<td>Minimize investment costs</td>
<td>1,3,5</td>
</tr>
<tr>
<td>Minimize the impacts of building new power plants and transmission infrastructures</td>
<td>5</td>
</tr>
<tr>
<td>Maximize the local air quality</td>
<td>6</td>
</tr>
</tbody>
</table>

Example 2: Objectives for L. E. plans

Figure 18 – Group causal map resulting from the aggregation of the individual cognitive maps.
Alternatives (options)

• At some point in the process the DM will have to identify “what are the options”.

• In the decision-making language “options” are known as decision *Alternatives*.

*How many alternatives are there for the evolution of the PT E.S. until 2050?*

• Alternatives can be built/identified:
  – “Manually”, to a limited / low number;
  – “Automatically”, e.g. through combinations of measures, producing large numbers (potentially Millions)

• What can “alternatives” be in the frame of (broad) energy planning?

• How many alternatives are there to make .e.g. the GHG emissions become lower than 2 tpc by 2050?
T. Measures can be taken at the levels:

- Managing the demand (level of service)
- Options of the end-use technologies
- Options on natural/primary resources
- Options on the conversion technologies regarding the transformation of N. resources
- Options on energy transport & intermediary technologies.
→ Difference between technical measure and implementation mechanism.

Examples:

→ Technical measure:
  → Replacing lighting lamps;
  → Transforming a coal PP into a natural gas pp.
→ Implementation mechanisms:
  → Making mandatory | subsidies, tax rebate, …

• Considering the PM in the analysis increases significantly the number of alternatives and makes the analysis more complex.
• A possible (compromise) solution is a two-stage decision process:
  – First decide on the (combination of) technical measures;
  – Then decide the Promotion mechanisms.

Energy planning as a decision process

• Objectives
  – Translated through “Attributes”

• Alternatives
  – Often overlooked. Ensure that you generate “enough and good” alternatives!

• Technical assessment of the alternatives
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• Multi-Criteria evaluation of alternatives
  – Many methods possible

• Post-processing
  – Including implementation issues
1000’s of models possible, depending on:
- Intended outputs
- Available / Assumed inputs
- Level of detail and methods of calculation (precision)

Energy models compatible with concept & goal of EP as defined initially:

**INPUTS**
- Demand Disaggregated by energy service (good if useful energy)
- Characteristics of the energy transformation infrastructure (@ demand, @ supply, @ transport)
- Control Criteria (e.g., priorities on dispatch of electrical generation)

**OUTPUTS**
- Final energy demanded by energy carrier;
- Primary energy demanded by energy source;
- Investment and running costs;
- Midterm analysis possible;

Top-down vs. bottom-up approaches (1)

**Top-down:** “Evaluate the system from aggregate economic variables” (IPCC 2007).
- Top-down models aim at involving the entire macro economy and describing the interrelationship between labor, capital and natural resources such as energy.
- This interrelationship is modeled with elasticities of substitution, computed from past data.
- Thus, energy demand is a model result from that interrelationship. Top-down models try to capture endogenously the general economic development (income, price levels, unemployment etc.) due to changes on, for example, the energy markets, such as energy-price shocks and nuclear phaseouts (Erdmann 1995).
- Generally, top-down models are lacking in technology explicitness compared to bottom-up models and fail to some extent to capture technological development.

Sources:
- Unger et al, 2010: Coordinated use of energy system models in energy and climate policy analysis: - lessons learned from the Nordic Energy Perspectives project.
Top-down vs. bottom-up approaches (2)

**Bottom-up:** “bottom-up models consider technological options or project-specific climate change mitigation policies (IPCC 1996)”.

- Bottom-up models are traditionally technology-oriented and treat energy demand as either given, for example expressed as useful energy demand, or as a function of, for example, energy prices and national income.
- Energy demand is satisfied by a chain of supply and distribution technologies that, generally, are comprehensively described in the model.
- Technology change occurs through replacement of existing technology by new technologies if these have better cost performance under the circumstances given.
- Technology change is thus explicitly described technology-by-technology.

Sources:
**Accounting vs Optimization**

**Solution assessment methods**
- A “solution” is imagined and described.
- Inputs:
  - Demand by type
  - Supply sources
  - Conversion technologies
  - Economics
- The models produce results in terms of:
  - Environmental loads
  - Costs
  (i.e., the model computes the expected impacts of the preferred solution)

**Optimization methods**
- Only the boundary conditions are defined:
  - Demand by type
  - Supply sources
  - Conversion technologies available
  - Economics
- The models yield the “best” solution based on
  - Costs, etc.
- And results in terms of
  - Environmental loads (…)
- Results extremely dependent on the reliability of the economic information (care for long-term !)

**Tools & softwares**

<table>
<thead>
<tr>
<th>LEAP</th>
<th>Stockholm Environment Institute</th>
<th>Integrated Energy/Environment Analysis</th>
<th>Windows</th>
<th>Physical Accounting, Simulation</th>
<th>Free to qualified users from developing countries; click here for licensing for other institutions</th>
<th><a href="http://www.energycommunity.org">www.energycommunity.org</a></th>
<th><a href="mailto:leap@sei-ue.org">leap@sei-ue.org</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>MAED</td>
<td>International Atomic Energy Agency</td>
<td>Integrated Energy / Environment Analysis</td>
<td>Windows &amp; Linux</td>
<td>Optimization</td>
<td>Free to: public sector, non-profit and research organizations</td>
<td><a href="http://www.iaea.org">www.iaea.org</a></td>
<td></td>
</tr>
<tr>
<td>MESSAGE</td>
<td>International Atomic Energy Agency</td>
<td>Final and Useful Energy Demand Projections</td>
<td>Windows</td>
<td>Physical Accounting, Simulation</td>
<td>Free to: public sector, non-profit and research organizations</td>
<td><a href="http://www.iaea.org">www.iaea.org</a></td>
<td></td>
</tr>
<tr>
<td>RETSCREEN</td>
<td>Natural Resource Canada</td>
<td>Energy production, life-cycle costs and GHG emission reductions for various energy efficient and renewable energy technologies</td>
<td>Excel</td>
<td>Physical Accounting</td>
<td>Free</td>
<td><a href="http://www.retscreen.net">www.retscreen.net</a></td>
<td><a href="mailto:news@nrcan.gc.ca">news@nrcan.gc.ca</a></td>
</tr>
<tr>
<td>SUPER</td>
<td>OLADE</td>
<td>Energy Demand and Conservation, Hydrology, Planning under Uncertainty, Hydro-thermal Dispatch, Financial, and Environmental analysis</td>
<td>Windows</td>
<td>Optimization and Simulation</td>
<td>$4,000-$10,000 depending on institution</td>
<td><a href="http://www.ola.de.org">http://www.ola.de.org</a></td>
<td></td>
</tr>
<tr>
<td>TIMES/ SEAP</td>
<td>ETSAP</td>
<td>Integrated Energy/Environment Analysis</td>
<td>Windows</td>
<td>Optimization</td>
<td>$3,300-$15,000 depending on type of institution.</td>
<td><a href="http://www.etsap.org">www.etsap.org</a></td>
<td></td>
</tr>
</tbody>
</table>

More detailed descriptions at:

http://www.energycommunity.org/default.asp?action=71
Energy planning as a decision process

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  – Many methods possible

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  – Including implementation issues

Evaluation of the alternatives

• (1) Simple case with 2 attributes:
  MCDA application at the China Energy Technology program:
EXAMPLES

• 2013 - Ana Rita Neves: “Sustainable Energy Planning and Management at the Local Level” – PhD in Sustainable Energy Systems of the MIT Portugal program, Faculty of Engineering of the University of Porto. With co-supervising with Prof. João Lourenço from IST-UTL.

• 2012 - Gustavo Haydt: “A multi-objective decision support methodology for developing national energy efficiency plans” – PhD in Sustainable Energy Systems of the MIT Portugal program, Faculty of Engineering of the University of Porto. With co-supervision from Prof. Luís Dias from the Faculty of Economics of the University of Coimbra.
Objectives

Table 1 – Local sustainable energy planning objectives.

<table>
<thead>
<tr>
<th>Local Sustainable Energy Planning Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1 Reduce GHG emissions</td>
</tr>
<tr>
<td>O2 Reduce air pollution from road transport</td>
</tr>
<tr>
<td>O3 Maximise employment benefits</td>
</tr>
<tr>
<td>O4 Improve long-term energy independence</td>
</tr>
<tr>
<td>O5 Minimise the negative impacts on human health</td>
</tr>
<tr>
<td>O6 Reduce energy bill</td>
</tr>
</tbody>
</table>

Attributes

Table 1 – Fundamental objectives and respective attributes.

<table>
<thead>
<tr>
<th>Fundamental Objectives</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce GHG emissions</td>
<td>Tonnes of CO₂ equivalent emissions reduced</td>
</tr>
<tr>
<td>Reduce air pollution from road transport</td>
<td>Tonnes of NOₓ emissions reduced</td>
</tr>
<tr>
<td>Maximise employment benefits</td>
<td>Number of net jobs gained</td>
</tr>
<tr>
<td>Improve long-term energy independence</td>
<td>Tonnes of oil equivalent of imported fossil fuels reduced</td>
</tr>
<tr>
<td>Minimise the negative impacts on human health</td>
<td>Number of people who benefit from noise levels reduction</td>
</tr>
<tr>
<td></td>
<td>Tonnes of oil equivalent reduced for space heating and cooling of homes and offices</td>
</tr>
<tr>
<td></td>
<td>Number of passenger-km shifting from passenger cars to public transit, walking and cycling</td>
</tr>
<tr>
<td>Reduce energy bill</td>
<td>Euros saved per household per year</td>
</tr>
</tbody>
</table>
Construction of Alternatives:

Table 1 – Impact matrix for the six alternatives according to the selected attributes.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Alternative</th>
<th>Tonnes CO₂ eq. reduced</th>
<th>Tonnes NOₓ reduced</th>
<th>Number of net jobs gained</th>
<th>Toe of imported fossil fuels reduced</th>
<th>Toe reduced for space heating and cooling</th>
<th>Number of pkm (million) shifting from passenger cars to public transit, walking and cycling</th>
<th>Euros saved per household per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A1 Diversified</td>
<td>55975</td>
<td>87</td>
<td>52</td>
<td>20726</td>
<td>2786</td>
<td>360</td>
<td>331</td>
</tr>
<tr>
<td></td>
<td>A2 High diversified policies</td>
<td>61511</td>
<td>210</td>
<td>86</td>
<td>22311</td>
<td>3086</td>
<td>480</td>
<td>670</td>
</tr>
<tr>
<td></td>
<td>A3 Lifestyles changes</td>
<td>76356</td>
<td>259</td>
<td>112</td>
<td>27550</td>
<td>2836</td>
<td>600</td>
<td>958</td>
</tr>
<tr>
<td></td>
<td>A4 Great resilience</td>
<td>92546</td>
<td>205</td>
<td>112</td>
<td>34541</td>
<td>2607</td>
<td>600</td>
<td>887</td>
</tr>
<tr>
<td></td>
<td>A5 Business changes</td>
<td>55852</td>
<td>106</td>
<td>63</td>
<td>20982</td>
<td>2869</td>
<td>240</td>
<td>303</td>
</tr>
<tr>
<td></td>
<td>A6 Sustainable Barreiro</td>
<td>58658</td>
<td>111</td>
<td>76</td>
<td>21464</td>
<td>2095</td>
<td>480</td>
<td>777</td>
</tr>
</tbody>
</table>
Targets: From “A bit better” to “Enough better”

The climate and energy package is a set of binding legislation which aims to ensure the European Union meets its ambitious climate and energy targets for 2020. These targets, known as the “20-20-20” targets, set three key objectives for 2020:

- A 20% reduction in EU greenhouse gas emissions from 1990 levels;
- Raising the share of EU energy consumption produced from renewable resources to 20%;
- A 20% improvement in the EU’s energy efficiency.

Canada’s historical greenhouse gas emissions and projections to 2020

<table>
<thead>
<tr>
<th>Year</th>
<th>Without Measures</th>
<th>Red increase to Date = 198 Mt</th>
<th>Additional Reductions Required = 12 Mt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>50 Mt</td>
<td>51 Mt</td>
<td>1 Mt</td>
</tr>
<tr>
<td>2000</td>
<td>60 Mt</td>
<td>63 Mt</td>
<td>3 Mt</td>
</tr>
<tr>
<td>2010</td>
<td>70 Mt</td>
<td>74 Mt</td>
<td>4 Mt</td>
</tr>
<tr>
<td>2020</td>
<td>80 Mt</td>
<td>86 Mt</td>
<td>6 Mt</td>
</tr>
</tbody>
</table>

Canadian Target = 612 Mt

<table>
<thead>
<tr>
<th>Country</th>
<th>Target Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Francavilla</td>
<td>-26%</td>
</tr>
<tr>
<td>Pignola</td>
<td>-25%</td>
</tr>
<tr>
<td>Suria</td>
<td>-21%</td>
</tr>
<tr>
<td>Ceira</td>
<td>-21%</td>
</tr>
<tr>
<td>Paolo</td>
<td>-23%</td>
</tr>
</tbody>
</table>

Latest Benchmarks

- Aggregazione Dro-Roc-VII, Italy
- Creation of Environment Energy Office
• Are these targets “good”?
• Are these targets “good enough”?

Midterm target (~2050):
\[
\frac{18 \text{ GtCO}_2\text{eq}}{9 \text{Gpeople}} = 2 \text{ tCO}_2\text{eq/capita.year}
\]

From Forecasting to Backcasting

**Forecasting:**
- Predicting “how the world will change” and adopt changes in the energy system capable of coping with these changes.

**Backcasting:**
- Identifying where we want or need to be in the long/mid-term and planning changes in the energy system capable of taking us there.
• Readings:
  – (A. Neves): *Sustainable Energy Planning and Management at the Local Level*" (PhD thesis, FEUP)
THANK YOU