Long-term Energy Scenarios and Energy Modeling – An Introduction

Christian von Hirschhausen
based on joint research with …
Agenda

1) Introduction
2) EEEP “Symposium on Scenarios and Modeling“
3) The role of scenarios and modeling in the policy process
4) An example: Nuclear power
5) A report from the engine room of scenario production@Berlin
Linking global and regional energy scenarios
Ex: SET-Nav Scenarios 2050 “translated” into regional ones

Scenario development as an application of foresight analysis
The object of scenario development is not to cover all possibilities, but to circumscribe them, or as Pherson (2015) puts it, to “bound the range of plausible alternative futures.”

How to develop scenarios: a step-by-step approach (based on Schoemaker, 1995)
1. Defining the scope (i.e. time-frame and subject)
2. Identifying major stakeholders
3. Identifying basic trends
4. Identifying key uncertainties (what events/trends whose outcomes are uncertain will significantly affect the issues we are concerned with)
5. Constructing initial scenario themes.
6. Developing learning scenarios (i.e. give more or less weight to some themes across scenarios depending on their relevance)
7. Clustering scenarios into four, rather extreme groups
8. Check internal cluster consistency and derive multiple-driver scenarios from them
9. Identifying Research Needs (do further research and inform ourselves about these uncertainties and trends)
10. Developing quantitative models (re-examine internal inconsistencies and assess whether certain interactions should be formalized via quantitative modelling.)
Scenarios and energy modeling

Forecasting is s.th. different from foresight, i.e. creating insights to think, see, and act in the future (Peppler, 2015)

Scenario development is an application of foresight analysis, to „bound the range of alternative futures“ (Pherson, 2015)

Scenarios are important … … and so is energy modeling

Plenty examples:
• Shell, IEA, … scenario exercises
• MIT, Standford, Energy Modeling Forum, etc.
• Individual research groups
Scenarios cannot be separated from models

Assumptions on:

~ competition:
  Cournot vs. perfect competition vs. …

~ trade:
  perfect competition vs. national perspective

~ sector linkage:
  partial vs. general equilibrium; macro-energy linkage

~ Different electricity sector modeling:
  Methodologies:
  ~ optimization vs. simulation,
  ~ different objective functions,
  ~ different time perspectives, etc.

Source: Ventosa (2005)
Policy choices are important …

~ **National** policies are diverse
  ~ US – NOPR on “grid stability” (capacity payments for coal and nuclear power)
  ~ OPEC-countries on fuel subsidies
  ~ Sweden on CO$_2$ pricing in transportation

~ **Regional** policies are transaction-cost intensive

~ **Cross-country** and “seams” issues” are complex
  ~ Legally binding
  ~ Politically consistent?

~ **Global** policies are important, but difficult to implement
  ~ Taxation, subsidies, etc.
  ~ Carbon pricing
  ~ Issue linking, e.g. with fiscal, social, other policies
... and technology is not different

Past: Emergence of technologies nationally specific, e.g. gas turbine, nuclear power, solar energy

Present: uncertainty about existing technologies and costs

Future: technical and economic availability
  ~ Fossil technologies, negative emission technologies (NET), etc.
  ~ “low-carbon” technologies, e.g. nuclear power, renewables, etc.
  ~ Auxiliary technologies, e.g. storage
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The publication encourages dialogue between business, government and academics and improves the knowledge base for energy and environmental policy formation and decision-making. EEEP produces original papers, policy notes, organized symposia on specific policy issues, feature articles, book reviews and commentaries on current energy and environmental policy issues and studies. The editors are Prof. Christian von Hirschhausen (Technical University Berlin, Germany), Prof. Valerie Karplus (MIT, Sloan School, US) and Prof. Juan Rosellón (CIDE, Mexico).

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ENERGY &
ENVIRONMENTAL POLICY

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Faith Birol and Pavel Ozierajmin

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A. Danny Ehrman

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Jean Tirole

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S. munic, Michael Brille and Ivan E. Tovilo

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Anna Orapova, Mohammad R. Hossain, and Thomas Torgerson

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Innovation and Disruption at the Grid’s Edge: How distributed energy resources are disrupting the utility business model
edited by Constantinos Efthymiou — review by Jean-Michel Clachart

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Subjects Covered
- Objectives and instruments in climate policy
- Energy market design
- Infrastructure regulation and regulatory policy
- Competition policy
- Emission trading
- Policy of international negotiations and agreements on environmental issues
- Energy, environment and developing countries
- Institutions for policy formation and enforcement
- Sustainability of energy systems
- Energy systems in city planning
- Demand response tools
- Energy security
- Renewable energy policy
- Technology and innovation policy
- Energy efficiency policy
- Natural resources policy for energy extractive industries
- Transportation policy
- Taxation and financial policy issues
- Private-public partnership in energy industries
This Panel Session: “Symposium on Scenarios and Modeling”


Christophe Bonnery (Enedis, France, Director, Economics & Prospectives): Role of Energy Prospectives

Ruud Egging (Norwegian Institute of Technology, Trondheim, Norway): Energy Scenarios and Methodological Developments

Laura Cozzi (IEA, WEO): Energy Scenarios in the World Energy Outlook

Klaus Mohn (University of Stavanger): A Review of IEA’s World Energy Outlook

Christian Breyer / Dmitri Bogdanov (Lappeenranta University, Finland): Scenarios for a Lower-Carbon World

Konstantin Löffler, Thorsten Burandt, Pao-Yu Oei, Claudia Kemfert: Scenarios using GENeSYS-MOD – An Overview

...
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1) Introduction

2) The role of scenarios and modeling in the policy process

3) An example: Nuclear power
What model for scientific policy advice?
Edenhofer and Korwasch (2012)
In reality, the „scenariomakers and modelers“ are part of the policy process, not separated from it.

Figure 4: The process of the scientific policy advice as suggested by the pragmatic-enlightened model (PEM).
Yet another model: „partisan model“
Midttun and Baumgartner (1986): “Negotiating energy futures“

~ In reality, there is no strict separation between „scenario-model development“ and „politics/policy“
Refererring to discussion in the 1970s:
... energy forecasts have been used for partisan purposes. ... industrial, political, and administrative interests compete for cognitive and methodological hegemony ...(p. 219) [“Iron triangle”]

“scientific negotiation of energy futures”

... “point to the filters of professional orientation that give every forecast an inherent cognitive bias”
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An example: Nuclear power in scenarios and models
François Lévêque (2012): "The nuclear industry is the child of science and warfare"

\[
\frac{235}{92}\text{U} + \frac{1}{0}\text{n} \rightarrow \frac{236}{92}\text{U} \rightarrow \frac{89}{36}\text{Kr} + \frac{144}{56}\text{Ba} + 3\frac{1}{0}\text{n}
\]

| Ausgangs- | thermisches | kurzlebiges | hier | hier | 3 Neutronen |
| kern | Neutron | Zwischenprodukt | Krypton | Barium | (als Beispiel häufiger Spaltprodukte) |
| 2000 m/s |
Manhattan Project (1942 – 1946): Science … and military warfare

Manhattan Project: 1942-1946: General Groves + Professor Oppenheimer (Jaensch and Herrmann, 2015)

First nuclear bomb: Trinity-Test, July 16, 1945
A Brief History of Nuclear Power


Ben Weate, Simon Bauer, Nicolas Landry, Hannah Seif and Christian von Hirschhausen
TRANSFERS OF NUCLEAR TECHNOLOGY

TECHNOLOGIES:
- Graphite moderated (GMR)
- Pressurised Water (PWR)
- Heavy Water (HWR)
- Boiling Water (BWR)

COUNTRIES:
Spain (1964)

TRANSMISSION:
- Name of the Country
- Technologies installed
- Date of construction of the first reactor
- Types of reactors present
- Country who bought the red technology
- Country who designed the red technology
- Transfert of technology
- Colour of the selling country
TRANSFERS OF NUCLEAR TECHNOLOGIES:

Countries: Spain

Technologies:
- Graphite Moderated (GMR)
- Boiling Water Reactor (BWR)
- Heavy Water Reactor (HWR)
- Pressurized Water Reactor (PWR)

Owner of the selling technology: France (1957)

Country who designed the red technology: France (1957)

Country who bought the red technology: Spain (1964)

Date of construction of the first reactor: 1964

Types of reactors present in Spain:
- BWR
- PWR

Transmission of technology:
- EPR 1750
- WS (1970)

Colour of the selling country: Red
TRANSFERS OF NUCLEAR TECHNOLOGY

TECHNOLOGIES:
- Graphite moderated (GMR)
- Pressurised Water (PWR)
- Heavy Water (HWR)
- Boiling Water (BWR)

COUNTRIES:

<table>
<thead>
<tr>
<th>Country</th>
<th>Design Country</th>
<th>Buyer Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spain</td>
<td>Germany</td>
<td>USA</td>
</tr>
<tr>
<td>(1964)</td>
<td>(1954)</td>
<td>(1964)</td>
</tr>
</tbody>
</table>

Date of construction of the first reactor: W1 (1964)

Types of reactors present: BWR 3

Country who designed the red technology: USA

Country who bought the red technology: Spain

Transfert of technology: EPR 1750

Colour of the selling country: Red
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Name of the Country
Technologies installed
Date of construction of the first reactor
Types of reactors present
Table 3
Levelized Cost Comparison for Electricity Generation

<table>
<thead>
<tr>
<th>Source</th>
<th>Nuclear</th>
<th>Coal</th>
<th>Natural gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIT (2009) baseline</td>
<td>8.7</td>
<td>6.5</td>
<td>6.7</td>
</tr>
<tr>
<td>Updated construction costs</td>
<td>10.4</td>
<td>7.0</td>
<td>6.9</td>
</tr>
<tr>
<td>Updated construction costs and fuel prices</td>
<td>10.5</td>
<td>7.4</td>
<td>5.2</td>
</tr>
<tr>
<td>With carbon tax of $25 per ton CO₂</td>
<td>10.5</td>
<td>9.6</td>
<td>6.2</td>
</tr>
</tbody>
</table>

Source: These calculations follow MIT (2009) except where indicated in the row headings.

Notes: All costs are reported in 2010 cents per kilowatt hour. Row 1 reports the base case estimates reported in MIT (2009), table 1. The cost estimates reported in row 2 incorporate updated construction cost estimates from U.S. Department of Energy (2010). Row 3, in addition, updates fuel prices to reflect the most recent available prices for uranium, coal, and natural gas reported in U.S. DOE (2011a). Finally, row 4 continues to incorporate updated construction costs and fuel prices and, in addition, adds a carbon tax of $25 per ton of carbon dioxide.
The global nuclear power paradox: Politization of forecasting at a fundamental, methodological level

IIASA World Energy Model:
- 8 years and $10 million modelling effort
- Used different complex submodels
- “Objective” results
- Transition to FBR by 2030 and 77% of overall nuclear contribution. Therefore, advice was given to build up expertise and capacity of relevant plants from now on.
- Coal Power 2030: 8%

- Models used are analytically simple
- No machine-processed iteration between the submodels
- No serious sensitivity analysis: A 16% increase of nuclear power costs leads to a capacity of FBR of 0% and a phase out of LWR.
- Coal Power 2030: 85%

Source: Midttun/Baumgartner (1986)
The IIASA model output fits in the a priori technological vision of the study assumptions

Assumption: “FBR is the future”

An uncertainty of 16% in nuclear power costs is marginal:
   e.g. costs for decommissioning not included in the original IIASA scenario

Transforming uncertainty into certainty: Scenarios are assumptions and therefore to be subjected to plausibility examinations and sensitivity analysis.

Normative modeling: Adapted scenarios to fit in the desired outcome. Modeling results verify the a priori expansionist and technological vision of the model maker.

Implications: Need for a transparent and coherent set of assumptions

Source: Midttun/Baumgartner (1986)
Looking forward…

…Gen IV as option for the foreseeable future (prototypes exist)?
„Small modular reactors“ (SMRs)
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1. Defining the scope (i.e. time-frame and subject)
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1.1 Long-Term Scenarios
Example: SET-Nav Scenarios 2050

- Business as usual
- Survival of the fittest
- Green Democracy
- ClimateTech
<table>
<thead>
<tr>
<th>Drivers</th>
<th>Indicators (selected)</th>
</tr>
</thead>
</table>
| • Continued geopolitical tensions  
• NDCs are issued by many polluting countries but without overshoot | • COP21 is respected but not succeeded by other major action before 2030  
• Various conflicts exist but do not escalate  
• Clean energy solutions fail to meet rising demand from developing countries |
**BUSINESS AS USUAL (CONT’D)**

**2020**
- Prolonged localised conflicts divert resource from climate change mitigation efforts
- Only modest improvements in NDCs, no major agreement

**2050**
- Growth in energy demand in the global south is mostly met with fossil fuels
- Coexistence of fossil fuels and renewables on global scale
- US catch up under a new, politically liberal administration
- Technological advances: Large-scale deployment of electric vehicles, efficiency gains in renewables, but no CCS or etc.
- Fading out of fossil fuels
- Still: Failure to achieve 2°C target leads to catastrophes
Survival of the Fittest

Drivers
- Escalation of geopolitical conflicts
- Growth of political isolationism and protectionist policies in major democracies

Indicators (selected)
- Security concerns trump sustainable development as populistic trends influence decision-making
- Wars in the Middle East and South-China sea
- UNFCCC loses its legitimacy
- Regionalisation of politics
Survival of the Fittest (Cont’d)

2020
- International governance is replaced by a multi-polar order.
- Expanding conflict in MENA, Crimea, and China South sea leads to diplomatic crises and a surge in oil production.
- A fragmented EU is still able to agree on a common European climate policy

2050
- Efforts towards energy transition mostly low and only on a regional scale, but with a growing role of India and China
- Private investment crowded out by protectionist policies
- Growing South built on cheap fossil fuels

- Carbon budget filled by 2030, leading to catastrophes
- International migrant crises further fuels isolationism
- Exploding adaptation costs, only affordable to rich nations
GREEN DEMOCRACY

Drivers
- Global return to appeasement leads to increased interconnectivity of economies and politics
- Bottom-up climate change mitigation

Indicators (selected)
- Re-emerging dialogue between the large regional powers after conflicts deescalate
- Achievement of an (informal) global carbon price
- Prosumers and smart-cities enable green growth
- Increased R&D investments
**GREEN DEMOCRACY (CONT’D)**

**2020**
- Rapid decrease of (armed) conflict in key regions
- Decreasing demand for fossil fuels

**2050**
- Tightening of COP21 in 2020 and 2025
- Dual objective: Poverty eradication and CC mitigation
- Empowered prosumers drive Indian energy transition
- Population growth and urbanization are met with clean city and transport approaches
- Leapfrogging with bottom-up solutions, e.g. clean microgrids
- Large R&D investments make CCS and others available

- Achievement of the 2°C target
„Translation“: BAU ➔ European Island

**Global Situation**
- Prolongation of Current Conflicts
- High Importance for Safety Issues
- Catch Up on Climate Policies (30s)
- Fulfilment of NDCs
- No Coordination of Climate Policy
- High Costs for Adaptation
- Rising FF Prices

**Increase in Temperature:**
- 2050 up to 2°C
- 2100 up to 3.2°C

**EU Climate Policy**
- Ban of Subsidies (30s)
- Phase Out: Coal (35) & Nat. Gas/Oil (45)
- ETS High CO2 Prices (35)
- Centralized RES
- National & Non-Coordinated Support Schemes for RES
- Huge Public Investments in R&D
- - 90% GHG Emissions
Survival of the Fittest

Global Situation

- Expansion of Conflicts
- Focus on Safety Issues
- Protectionism
- Paris Agreement is not met
- High Number of Refugees and Migrants
- RES to Foster National Energy Security
- Drastic CC Effects
- Enormous Costs for Adaptation
- Extreme Price Fluctuations for FF

Increase in Temperature: 2050 more than 2°C 2100 up till 4°C

EU Climate Policy

- Abolishment of FF Subsidies (40)
- Phase Out Coal (45)
- High CO2 Prices (35)
- Centralized RES
- Support Schemes for Low Carbon and Negative Emission Technologies
- Huge Public Investments in R&D
- Protectionism Slows Down Technical Innovation
- - 85% GHG Emissions
Green Democracy

Global Situation

• Quick De-escalation of Major Conflicts
• Security and Economic Concerns are Diminishing
• Climate Targets are Tightened and Become Binding in the 2020s
• International Coordination of CP
• Stable FF Prices
• Achievement of SDGs

Increase in Temperature: Achievement of 1.5°C target

EU Climate Policy

• Abolishment of Subsidies for FF (20s)
• Investments and Coordination of R&D
• Phase-Out: Lignite (2025) Hard Coal (2030) Oil/Natural Gas (2035)
• Integrated Energy Systems and Feed in Tariffs on EU Level
• Strong Bottom-Up Initiatives
• Decentralized RES and Regional Solutions
• - 100% GHG Emissions
## Set-up of quantitative scenarios

<table>
<thead>
<tr>
<th>CO2-Reduction ▪ 2030 and 2050</th>
<th>Survival of the fittest</th>
<th>European Island</th>
<th>Green Democracy</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>No global fulfilment of NDCs but 80% reduction in Europe by 2050 after failing 2030 target</td>
<td>Global fulfilment of NDCs and 85% reduction by 2050 in Europe and achieving 2030 target</td>
<td>Achievement of 1.5°C (?) target and enforced European efforts</td>
<td>IPCC (2015), …</td>
<td></td>
</tr>
<tr>
<td><strong>Energy consumption (sectoral)</strong></td>
<td>Moderate efficiency gains</td>
<td>Significant efficiency gains according to political objectives (40% by 2030), especially in the heating sector</td>
<td></td>
<td>E3M Lab (2016), Heat Roadmap Europe (2017)</td>
</tr>
<tr>
<td><strong>Expected potential of technologies</strong> ▪ Renewables ▪ Conventional</td>
<td>• RE costs at the upper end of todays expectations • No politically enforced phase outs</td>
<td>• Decrease of RE costs mainly triggered by subsidies • Phase-out of fossils until 2045</td>
<td>• Great effect of global learning effects on RE costs • Phase-out of fossils until 2035</td>
<td>Ram and Breyer (2017), Fraunhofer ISE (2018)</td>
</tr>
</tbody>
</table>