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BOKU

International Institute for Applied Systems Analysis
IIASA

FLEXIBILITY AND RESILIENCE IN ENERGY SYSTEM MODELS

EnInnov conference - 15.02.2024, Graz

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Background

Title: Integrative energy infrastructure planning tools for cross-sectoral resilience and flexibilisation concepts.
Sponsor/Call: Forschungsförderungsgesellschaft / ENERGIEFORSCHUNG 2022 - SCHWERPUNKT 3 & 4
Type/Runtime: Sondierungsprojekt / 12.2023 – 11.2024 (12 months) /
Acronym: FFG BioFlex Project

Consortium	Affiliation
Fabian Schipfer, Michael Harasek	TU Wien Institut für Verfahrenstechnik, Umwelttechnik und technische Biowissenschaften (ICEBE), Fachbereich Thermische Verfahrenstechnik und Simulation > Lead
Johannes Schmidt, Sebastian Wehrle	Universität für Bodenkultur (Boku), Institut für Nachhaltige Wirtschaftsentwicklung
Florian Kraxner, Shubham Tiwari	International Institute for Applied System Analysis (IIASA), Agriculture, Forestry, and Ecosystem Services Group

Input: IEA Bioenergy <> ETSAP (International Energy Agency - Energy Technology Systems Analysis Program)
Schipfer, F., E. Mäki, U. Schmieder, N. Lange, T. Schildhauer, C. Hennig, und D. Thrän. „Status of and Expectations for Flexible Bioenergy to Support Resource Efficiency and to Accelerate the Energy Transition“. Renewable and Sustainable Energy Reviews 158 (1. April 2022): 112094. https://doi.org/10.1016/j.rser.2022.112094.

Summary 1/2

Context:

Austrian energy system → climate neutrality in 16 (!) years
Energy system models → Engineering for economic and ecological sustainability
BUT are the resulting pathways also engineered for **reliability and flexibility**?

Project goals:

Risk management for the multi-faceted Austrian energy system

1. Review the capabilities of existing models
2. Test capabilities of selected
   power system (by Boku) and a
   bioenergy supply chain model (by IIASA)
3. Formulate a research and modeling agenda

Summary 2/2

Level of originality:

1. Focus not only on "physical" (i.e., feedstock-independent renewable power) but also "chemical energy" (incl. bioenergy) including its intricate metabolism, feedstocks, value chain networks, and waste products
2. Opening up vast uncertainty spaces including variabilities, trends, extremes and cascades
3. Consequences as positive & negative, direct and indirect effects on objectives
4. Multi-disciplinary jargon awareness fostering cross-disciplinary learning

Potential implications:

<u>More robust and coherent science-policy recommendations</u>

a) Strategies for the amplification of synergies and the mitigation of trade-offs inherent to system integration (also referred to as multi-sector coupling)
b) Moving multi-perspectivity into the spotlight, fostering responsible interdisciplinarity

Methodology 1/2

Risk management – Guidelines ISO31000:2018

- Terms and definitions
  Risk, consequences, likelihood …
- Iterative process → → →
- Risk treatment options including
  1. Avoiding or removing risks
  2. Taking or increasing risks

Critical reflection of scenario modelling, risk assessment techniques (ISO31010), resilience engineering, and dynamic adaptive planning

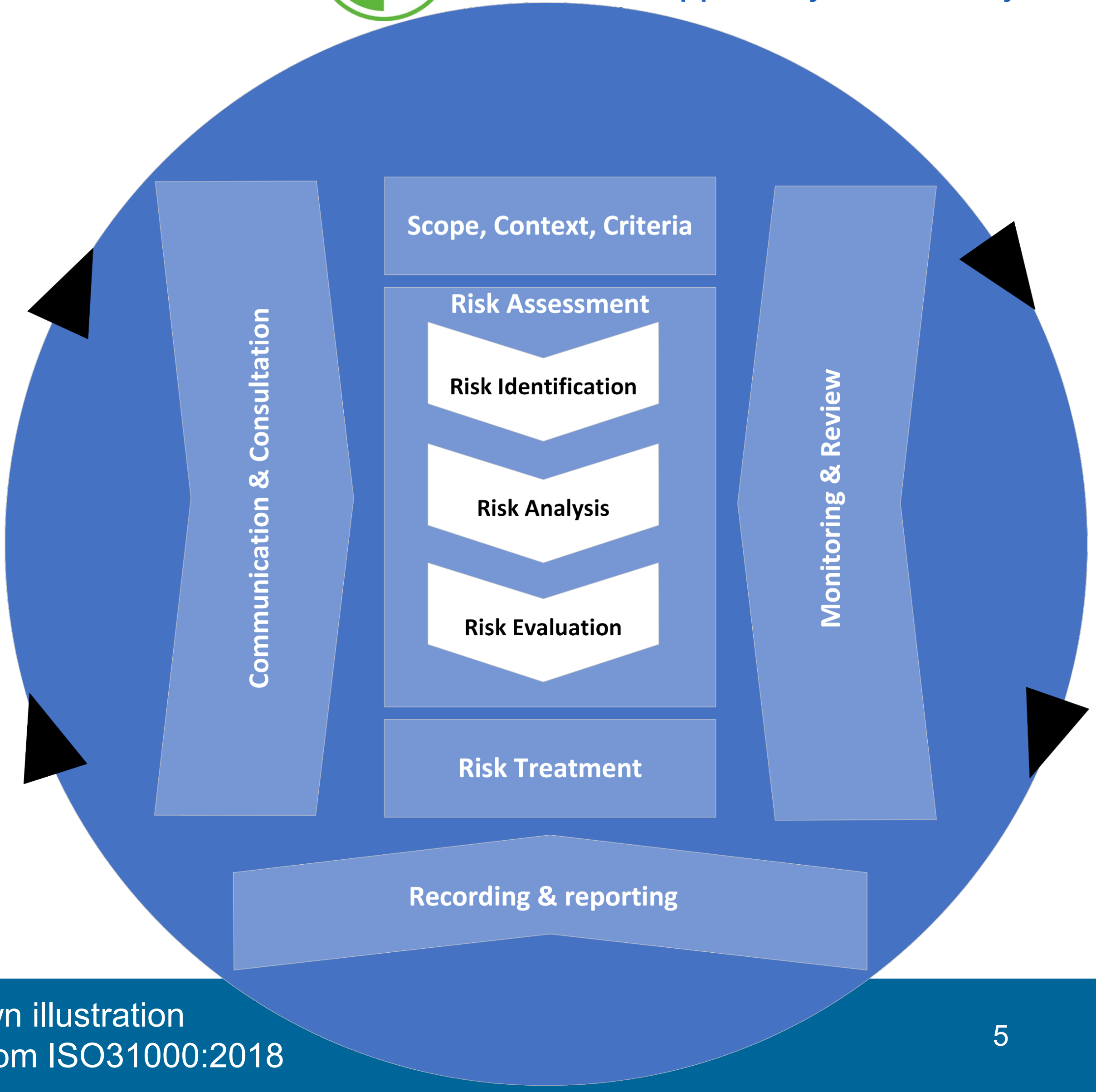

Figure: Own illustration adopted from ISO31000:2018

Methodology 2/2

Review and best practices of energy system models
despite large variations in relevant search terminologies

Information and documentation —Thesauri (for information retrieval) and interoperability with other vocabularies (ISO25964-1:2011)

No distinct discipline / scientific field is occupied with whole-energy system modeling
→ no joint controlled vocabulary is used for describing models, e.g., in

- Energy market design
- Power system modeling and dispatch models
- Transmission expansion and district heating network planning
- Bioenergy supply chain / value chain / value chain network design
- Circular Economy and Bioeconomy modelling
- Sector coupling and multi-sector coupling ….

Results – scope, context, criteria (Step 1/3)

“Physical energy”

- Power and heat from photovoltaic, wind, water, and geothermal, ambient heat
- Main infrastructure = power grids, partly heat networks
- Energy-water nexus
- “plug-in” technologies

“Chemical energy”

- Power, heat, fuels from fossil fuels, biomass, hydrogen, waste
- All infrastructures are relevant
- Food-Materials-Energy-Water nexus
- Metabolism character with inputs & outputs

Results – scope, context, criteria (Step 1/3)

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Multi-sector coupling

- = system integration
- Network of networks: power, heat, gas, oil, rail, road, water, hydrogen, CO2, …
- Conversion technologies as “connectors”
- Opportunity and threat (!!)

Results – risk identification (Step 2/3)

Earth system uncertainties categories:

Atmosphere

Biosphere

Hydro/ Cryosphere

Geosphere

Human system uncertainties categories:

Technosphere

Sociosphere

Cybersphere

Econosphere

Results – risk identification (Step 2/3)

Earth system uncertainties categories:

- Atmosphere
- Biosphere
- Hydro/ Cryosphere
- Geosphere

Human system uncertainties categories:

- Technosphere
- Sociosphere
- Cybersphere
- Econosphere

Uncertainty types:

- Variabilities
- Extremes
- Trends
- Cascades

Results – risk identification & evaluation (Step 2/3)

Definition by Risk Management – Guidelines ISO31000:2018
Risk = effect of uncertainty on objective

Objectives: Satisfying societal needs via a physical provisioning system
100% renewable power by 2030, Climate neutrality by 2040, Efficiency, Security
→ see e.g., Austrian national energy and climate plans (NECPs/NEKPs)

Events & consequences:

regarding nodes (also referred to as vertices, technologies, sources, users):
power, heat, fuel, metabolic waste treatment, food, and material (by-)production

regarding edges (also referred to as links, infrastructure, grids):
networks for power, heat, gas, oil, rail, road, water, hydrogen, CO_2, …

Results – risk identification & evaluation (Step 2/3)

Definition by Risk Management – Guidelines ISO31000:2018
Risk = effect of uncertainty on objective
can be positive, negative, or both, and can address, create, or result in opportunities and threats

Objectivity requirement in risk assessment

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Results – risk identification & evaluation (Step 2/3)

Definition by Risk Management – Guidelines ISO31000:2018

Risk = effect of uncertainty on objective

can be positive, negative, or both, and can address, create, or result in opportunities and threats ✓

Relevant definitions and implementations meeting this "objectivity requirement"	**Yes / No**
Definition by Knight, F.H. (1921)	✓
Implementation in most of the 31 risk assessment techniques of ISO31010	✗
Theoretical implementation in the 9 decision-making under uncertainty techniques (Marchau et al. 2019)	✓
Implementation in 9 resilience engineering techniques discussed in Patriarca et al. (2021)	✗
IPCCs continuously calibrated "uncertainty and confidence language" (Shukla et a., 2019)	✗
Traditional deterministic scenario modeling and current advancements in modelling "flexibility"	✗ ?

Results – risk treatment (Step 3/3)

Systems engineering and systems design for

Preferred term: **EFFICIENCY** → **The current focus of modeling disciplines**
Related terms: *sustainability, affordability, accessibility, acceptability, accuracy, precision, profitability, effectivity, rapidity, stiffness, resource conserving, …. sufficiency (!), appropriateness, adequacy*

Preferred term: **RELIABILITY** → **The current focus of risk assessment**
Related terms: *security, resilience, safety, robustness, rigidity, adaptability, redundancy, rebound*

Preferred term: **FLEXIBILITY** + → **Opportunity for a novel modeling paradigm**
Related terms: *plasticity, buoyancy, elasticity, agility, versatility, ductility, transformability, malleable to adaptation, interconnectivity, options, substitutability, responsiveness, resourcefulness*

Results – risk treatment (Step 3/3)

Broadening the definition of “flexibility”:

Ability to <u>shift resources</u>

- **through time,** ← short-, medium-, long-term storage
- **through space,** ← via networks & trade
- **between sectors &** ← via multi-sector coupling
- **between options** ← via portfolios

“Flexibilisiation” = increasing the ability …

Results – risk treatment (Step 3/3)

Broadening the definition of "flexibility":

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... to balance scarcities with surpluses

<u>Mitigating shortages</u>
system reliability/resilience

<u>Balancing</u>
via connectors

<u>Valorizing surpluses</u>
(broader) systems' efficiency

"Flexibilisiation" = increasing the ability ...

Preliminary conclusions – modeling requirements

<u>"all models are wrong" but which are useful to assess …?</u>

- The role of chemical energy, including bioenergy, hydrogen, and e-fuels, beyond 2040?
- What storage and infrastructure requirements are we facing in the next decades?
  Which (parts of) infrastructure to keep from phased-out traditional chemical energy (i.e. fossil fuels)?
- How to measure the opportunities (balancing) and threats (unbalancing) of system flexibilisation and system complexification via multi-sector coupling and system integration?
- Circular economy and circular bioeconomy system architectures?
- Effectiveness of existing controls regarding risk treatment? Tipping points (beneficial and harmful)?
- Consolidation of progressive, conservative, and regressive stances on system complexification?

Relevant publications

Schipfer, F., Mäki, E., Schmieder, U., Lange, N., Schildhauer, T., Hennig, C., Thrän, D., 2022. Status of and expectations for flexible bioenergy to support resource efficiency and to accelerate the energy transition. Renewable and Sustainable Energy Reviews 158, 112094. https://doi.org/10.1016/j.rser.2022.112094

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