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Comparative evaluation of various energy options using qualitative multi-attribute models

Introductory note

The interest of reconsidering national energy development policy appears regularly every 20-30 years; it may be triggered by special events, like Tschernobyl 1986; political orientation on environmental protection and climate change: Rio 1992, Johannesburg 2002, Copenhagen 2012, IPCC 2014; Fukushima 2011; etc.

Interrelations and perception about

Strategic evaluation  Sustainability appraisal

Uncertainty of long-term predictions

Common expressions on sustainability

- Brutland's definition
- Balance between social, economic and environmental components
- Protection of resources (prudent use) – care for future generations
- Sustainable development

However, there is little (no) practical guidance on, e.g.,

- **When the balance is acheved (1/3 + 1/3 + 1/3)?**
- **Which are the measurable indicators of each of the components?**
- **How much use of a particular resource is "prudent"?**
- **How far are we from sustainable development? How do we know we are already there?**

Therefore

- There is a continuous development of the understanding of sustainability **– new and specific definitions appear in each and specific context**
- Participation is open for all interested parties **– inclusive and creative approach is desired and required**
- Interests and goals are the leading and prevailing components of the perception of sustainability **– agreement is difficult to achieve due to controversial standpoints**

Having such “undefined” situation – is sustainability appraisal feasible and beneficial anyway? Isn’t it better to stick to “strategic assessment”?

Energy options – Sustainability – Decision Making

Electric energy production options:

- Needs assessment (timeframes)
- Present capacities (lifetime)
- Technology alternatives (present, future)
- Energy mix: shares of production capacity (technology)

Sustainability:

- Goals (interests, value judgments, preferences)
- Indicators (effectiveness, measurability)
- Participation

Decision-making; ethics and democracy:

- Wisdom (Is it wise?...timeframes, uncertainty)
- Fairness (Is it fair?...equity, justice)
- Benefit (Is it good?...measurement and perception)

Complexity of sustainability appraisal – participation!

What is a decision about?

vision➔ strategy➔ policy➔ plan➔ program➔ project

Sustainability indicators – common list

Climate change
Ecology (flora in faun, biodiversity)
Fuel and raw materials
Economy, reliability, affordability
Water Quality
Waste
Air Quality
Transport
Noise
Landscape
Cultural heritage
Soil protection
Health and welfare
Sustainable community

Sustainability indicators – our approach

Main (aggregated) indicators	Note on sustainable development
Cost/Value	Sustainable development *does not mean* having less economic growth. On the contrary, a healthy economy is better able to generate the resources for environmental improvement and protection, as well as social welfare. It also does not mean that every aspect of the present environment should be preserved at all cost (*extremism, fundamentalism*). What it requires is that decisions throughout society are taken with proper regard to their environmental impact and implications for wide social interests. Sustainable development *does mean* taking responsibility for policies and actions.
Supply Reliability	
Economic/Technological Advancement	
Risk/Uncertainty Management	
Environmental and Health Impacts	
Welfare of local and regional communities	

Main (aggregated) indicators	Goals/objectives as a basis for specification of sub-indicators and development of the evaluation criteria
Cost/Value Supply Reliability Economic/Technological Advancement Risk/Uncertainty Management Environmental and Health Impacts Welfare of local and regional communities	Development of competitive (least cost) electricity production The energy payback ratio Development of an electricity system expansion plan that minimises greenhouse gas emission Enhancement of the welfare of local communities; growth of social capital across region Protection and improvement of the health of all residents and workers (good access to health care, reduced health inequalities, affordability of safe and quality nutrition, availability of recreation zones/infrastructure, nursing/work/social inclusion for elderly people, clean and healthy environment, safe urban areas, etc.) Changes/improvements in regional and local employment Improvement of economic benefit to the community (to reduce disparities in income; access to jobs, housing, and services between areas within the region and between segments of the population; access to better and effective education; energy efficiency; etc.) Maintenance of high and stable levels of economic growth (good accessibility to business within the region, stronger linkages between firms and the development of specialism within area, local strengths and economic value locally, emergence of new and high technology sectors and innovations, etc.). Effective protection of the environment (maintenance and enhancement of the quality and distinctiveness of the landscape; making towns more attractive places to live in; maintenance and improvement of the quality of air, ground and river water; reduced contribution to climate change (greenhouse gases); moving up through the waste management hierarchy; to apply reasonable, long-term land-use planning considering open space; improvement of resource efficiency; etc.)

Note on sustainable development: Sustainable development *does not mean* having less economic growth. On the contrary, a healthy economy is better able to generate the resources for environmental improvement and protection, as well as social welfare. It also does not mean that every aspect of the present environment should be preserved at all cost (*extremism, fundamentalism*). What it requires is that decisions throughout society are taken with proper regard to their environmental impact and implications for wide social interests. Sustainable development *does mean* taking responsibility for policies and actions.

Sustainability indicators

Issue: Measurability without site specification?!

Common indicators		Our approach	
Topic	***Specification; unit of measurement***	***Understanding***	***Specification; unit of measurement***
Climate change	GHG emission; CO_2 emission; t/MWh	Global issue; not possible to "see" impacts of concrete power plant on a specific site	Compliance with global policy; "good", "in progress"
Health and welfare	Pollution related; environmental epidemiological studies; YOLL, YPLL, DALY, etc.	Pollution is preventable (by development level); access to health care to all citizens, vital economy – no poverty; it is crucial to have a job!	Contribution of the energy system to societal development; revenue share of energy production returned to national budget
Waste	Amount; t/MWh	Isolation; safety culture	Proper land-use

Level of evaluation

Local/Project

ISSUE

National/Strategic

There is no clear disctinction between local and national level

NPP

Bio

Wind

Coal

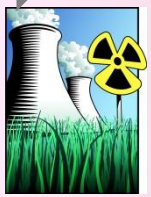
Hydro

PV

Gas

Mix 1: NPP+Coal+Hydro

Mix 2: Gas+Coal+Hydro



Mix 3: Wind+Gas+Hydro+Bio

Mix k: only RES

Mix n: all (?); shares?

e.g., noise, cooling towers, access roads, specific fish species, etc.

e.g., total installed capacity, spatial availability and land-use, reliability, financing, etc.

Sustainability indicators – our approach

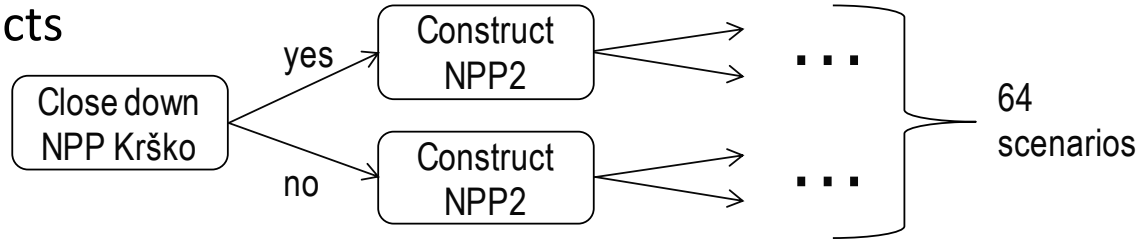
Agreement about top level indicators:

Feasibility, Rationality, Uncertainty of the energy options

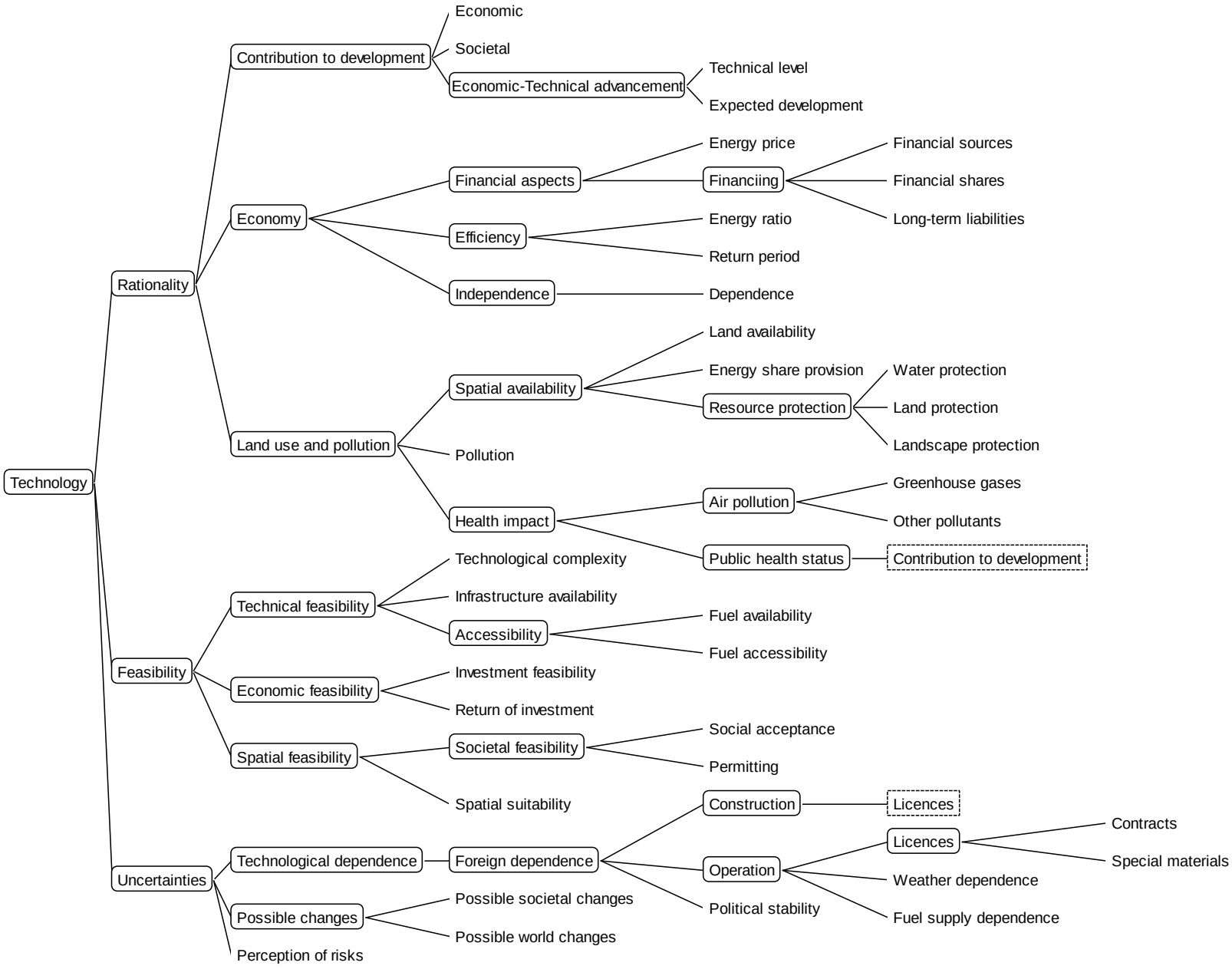
Multi-attribute modelling

Models

1. **Model for comparative evaluation of technology options**
   - Multi-attribute DEX model
   - Technologies: *hydro, coal, oil, gas, nuclear, bio, PV, wind,* (*import*)
2. **Model for comparative evaluation of technology mix options**
   - Multi-attribute DEX model
   - Technological share in technology mix: installed capacity
   - Technological share in annual energy production – reliability and availability (annual operational hours).
3. **Evaluation of the scenarios**
   - Evaluation of the technology mix options in the period 2013–2050
   - Decisions about objects



Model for comparative evaluation of technology options

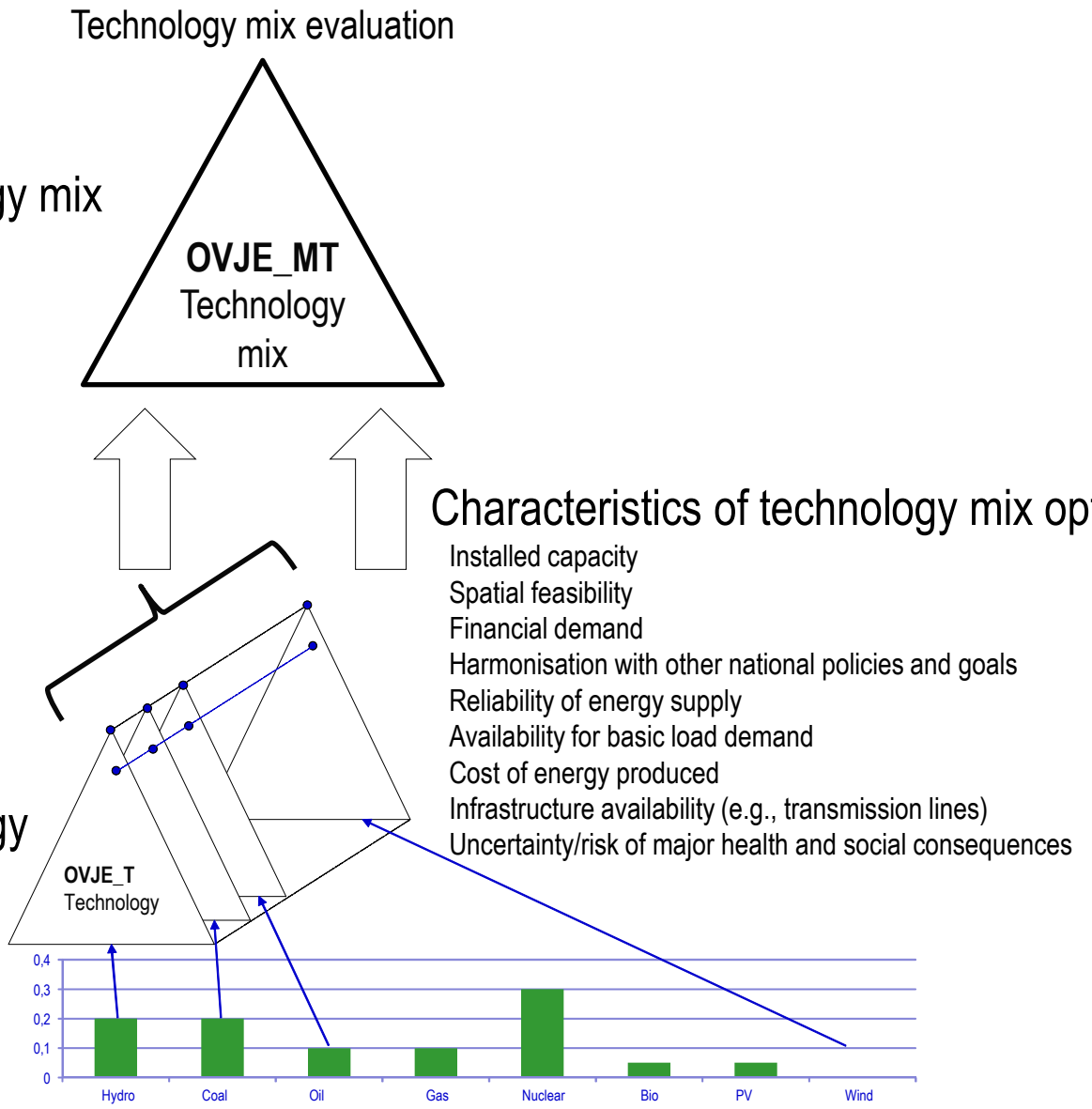


Model for comparative evaluation of technology mix options

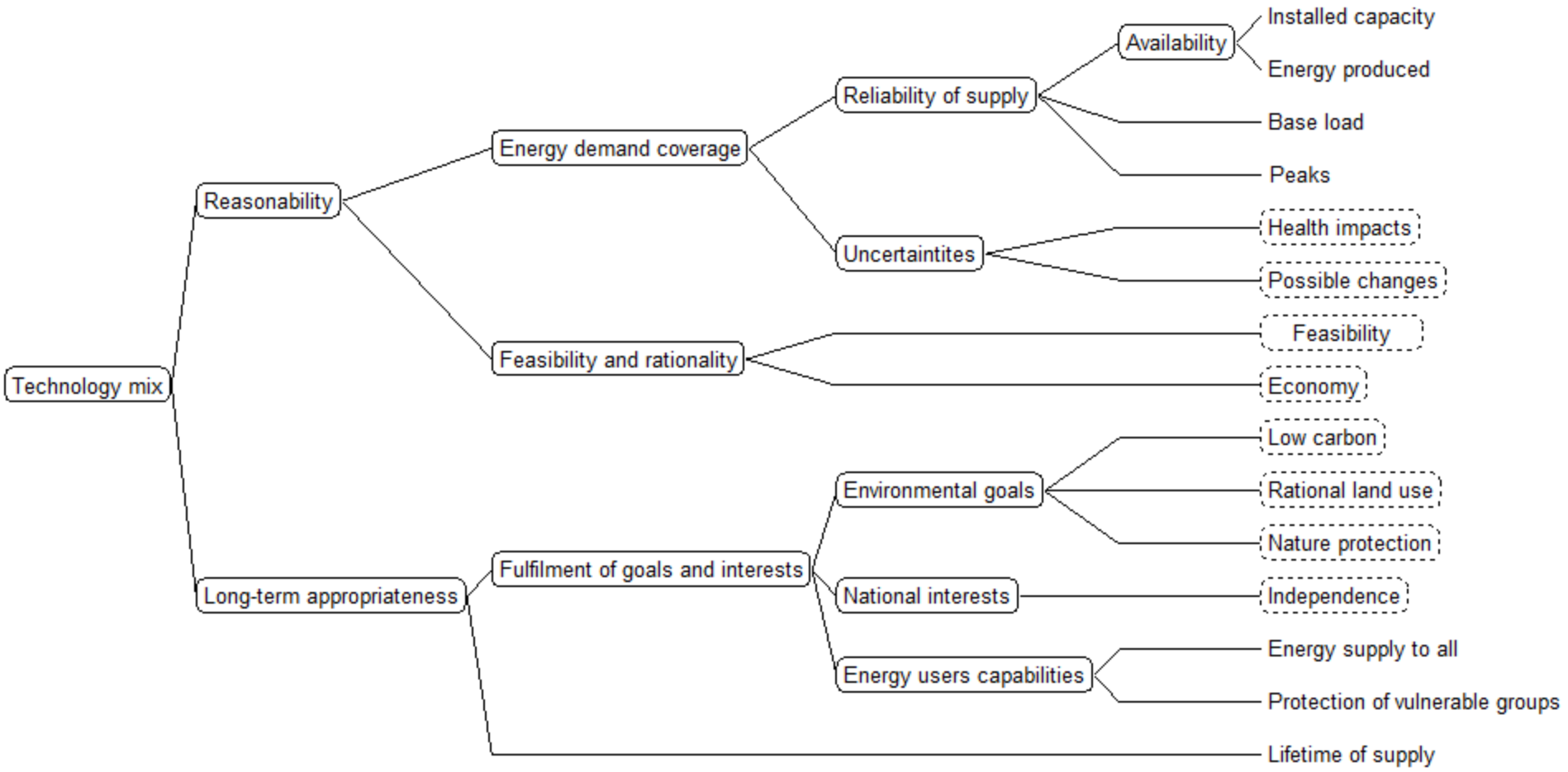
3. Evaluation of technology mix options

2. Aggregation

1. Evaluation of technology options



Model for comparative evaluation of technology mix options



Evaluation of the scenarios

Technology mix evaluation considering specific decisions about closing-down existing objects and construction of the new ones

Evaluation through time 2013-2050

3. Evaluation of technology mix options

OVJE_MT
Technology mix

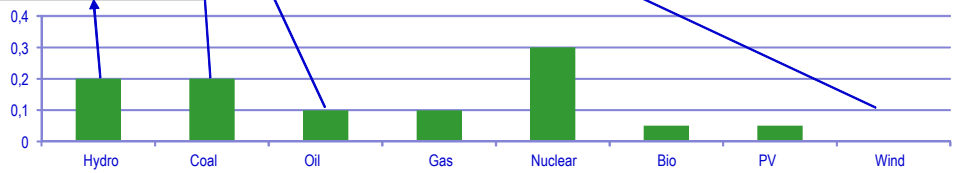
2. Aggregation

Characteristics of technology mix options

Installed capacity
Spatial feasibility
Financial demand
Harmonisation with other national policies and goals
Reliability of energy supply
Availability for basic load demand
Cost of energy produced
Infrastructure availability (e.g., transmission lines)
Uncertainty/risk of major health and social consequences

1. Evaluation of technology options

OVJE_T
Technology



Scenario decisions

Event	Year
Close-down of the NPP Krško Unit 1	2023
Construction of the NPP Krško Unit 2	2025
Construction of HPP Spodnja Sava	2025
Construction of gas fired PP	2025
Close-down of TPP Šoštanj 5	2027
Construction of HPP Srednja Sava	2035

64 scenarios in total considered

Implication of scenario decisions

	Year	2023	2025	2025	2025	2027	2035
	Explanation	Close-down of the NPP Krško Unit 1	Construction of the NPP Krško Unit 2	Construction of HPP Spodnja Sava	Construction of gas fired PP	Close-down of TPP Šoštanj 5	Construction of HPP Srednja Sava
POWER	**Hydro**	0	0	74	0	0	330
ENERGY		0	0	252	0	0	1122
POWER	**Coal**	0	0	0	0	-345	0
ENERGY		0	0	0	0	-1656	0
POWER	**Oil**	0	0	0	0	0	0
ENERGY		0	0	0	0	0	0
POWER	**Gas**	0	0	0	600	0	0
ENERGY		0	0	0	3000	0	0
POWER	**Nuclear**	-700	1600	0	0	0	0
ENERGY		-2520	11520	0	0	0	0
POWER	**Bio**	0	0	0	0	0	0
ENERGY		0	0	0	0	0	0
POWER	**PV**	0	0	0	0	0	0
ENERGY		0	0	0	0	0	0
POWER	**Wind**	0	0	0	0	0	0
ENERGY		0	0	0	0	0	0

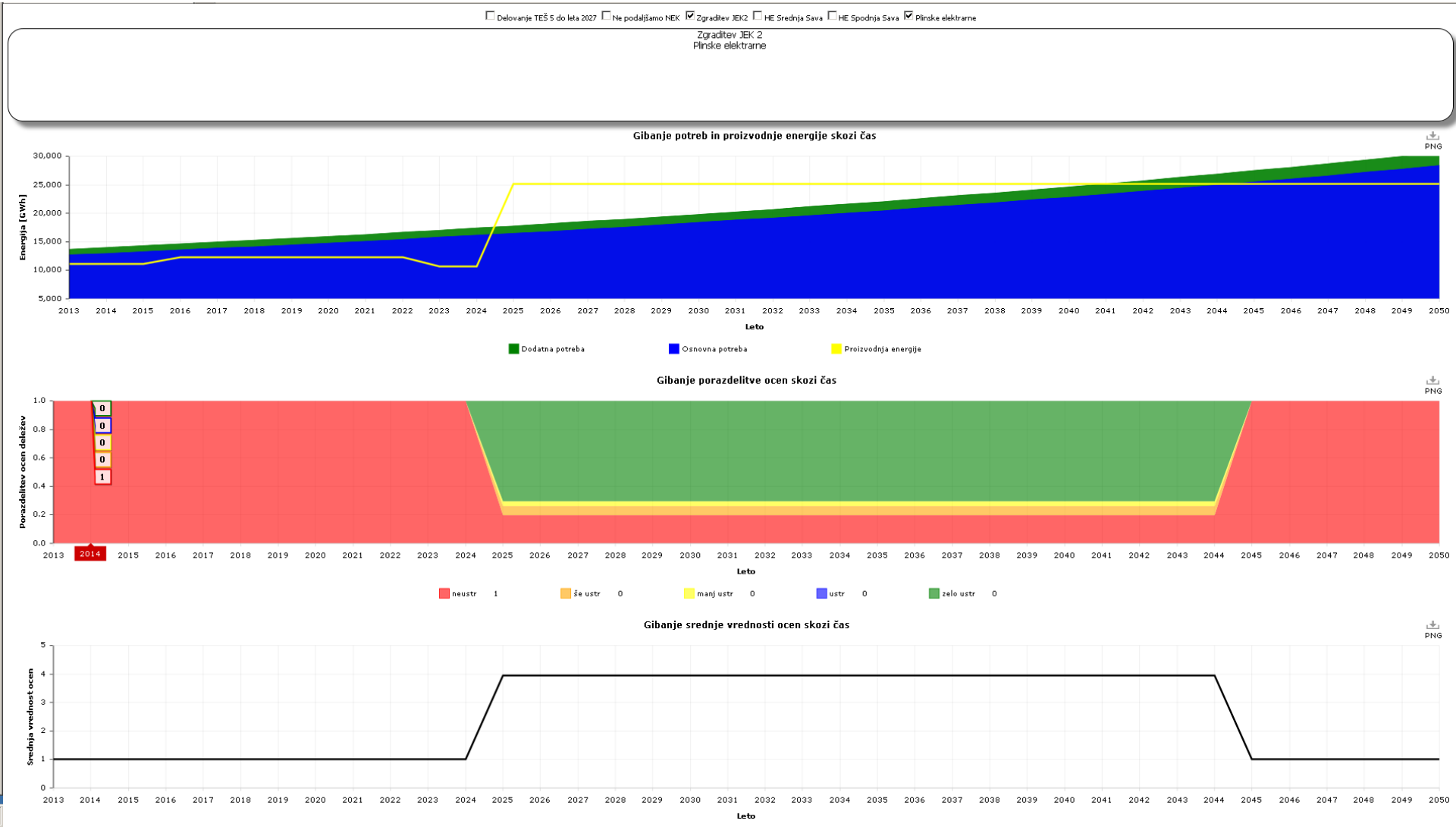
Units: POWER in MW; ENERGY in GWh

Results of the evaluation of technology options

Hydro:	less suitable – very suitable
Coal:	not suitable
Oil:	not suitable
Gas:	poor – suitable
Nuclear:	poor – very suitable
Bio:	not suitable
PV:	not suitable
Wind:	not suitable
Import:	not suitable

Results of the dynamic evaluation of scenarios

http://nejctrdin.com/ovjeGEN/



Results regarding efficiency of sustainability appraisal

Our approach to defining sustainability indicators for DEX modeling purposes better than other approaches deals with attribute definition, transparency of the evaluation, and treatment of options' uncertainty. It also includes a solution for spatial availability/feasibility of the technology mix options. In addition, the approach avoids ineffectiveness of the overall evaluation due to site uncertainty of concrete energy infrastructure objects, since the evaluation is performed on high strategic level instead of treating concrete objects on concrete locations - project level.

Input to decision-making

Base load supply:
nuclear, coal, hydro (continuation of present policy)

Total supply:
nuclear, coal, hydro; reasonable other RES introduction

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Looking forward to all your questions and comments!