Multi-Criteria Analysis of Nuclear Power in the Global Energy Systems:

Trade-Offs between Cost, Energy Security and Climate Impacts

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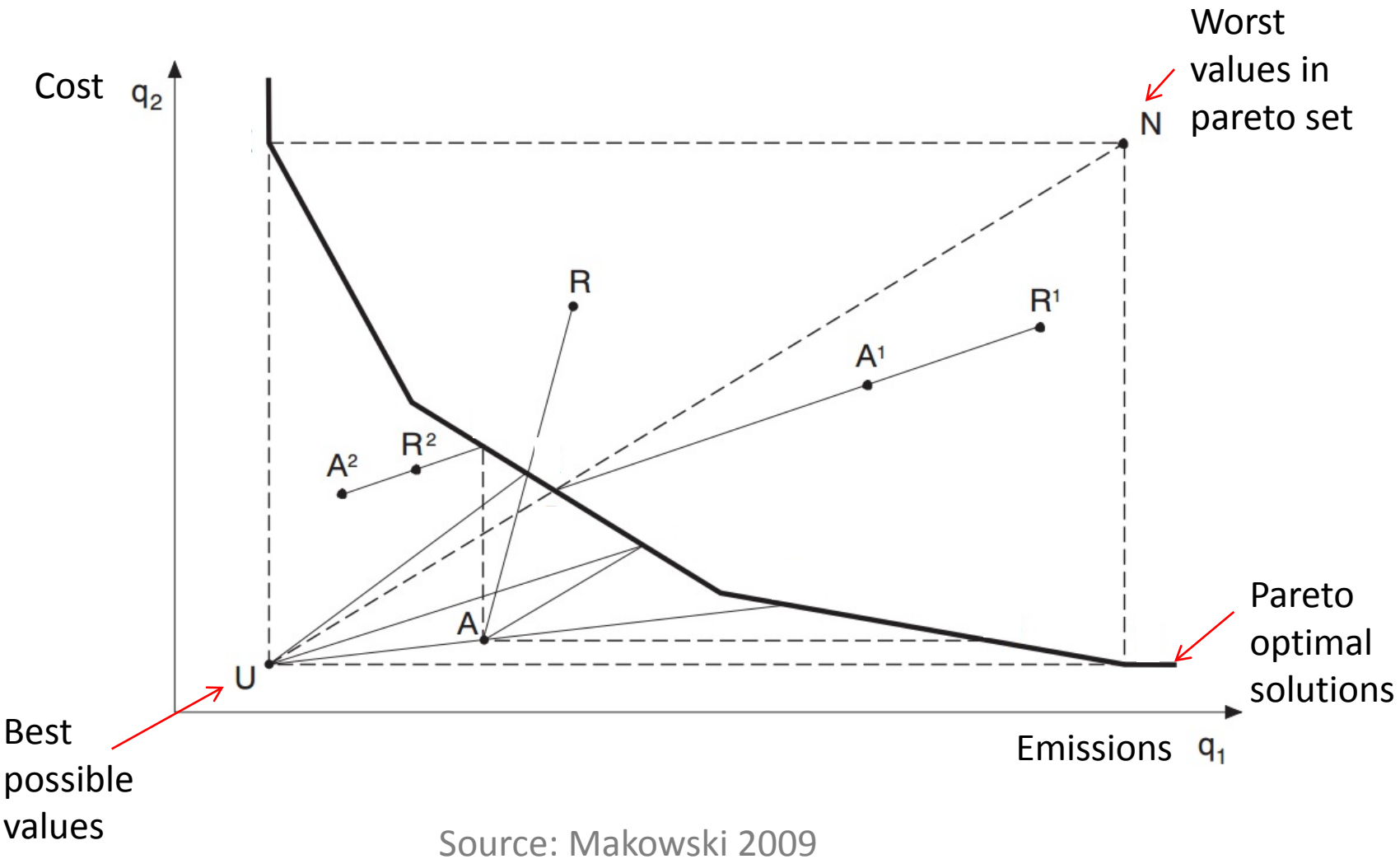
Motivation

- Many energy related challenges with no universal solution.
- Multi-criteria tools can be useful in the analysis of possible trade-offs and synergies.
- Nuclear energy is a technology with many risks and benefits.
- We combined global energy systems model MESSAGE with multi criteria analysis (MCA) tool transforming it from single objective optimisation model to multi-objective optimisation model with seven criteria.

Multi-Criteria Analysis

Reference point method – the aspiration–reservation based approach



Source: Makowski 2009

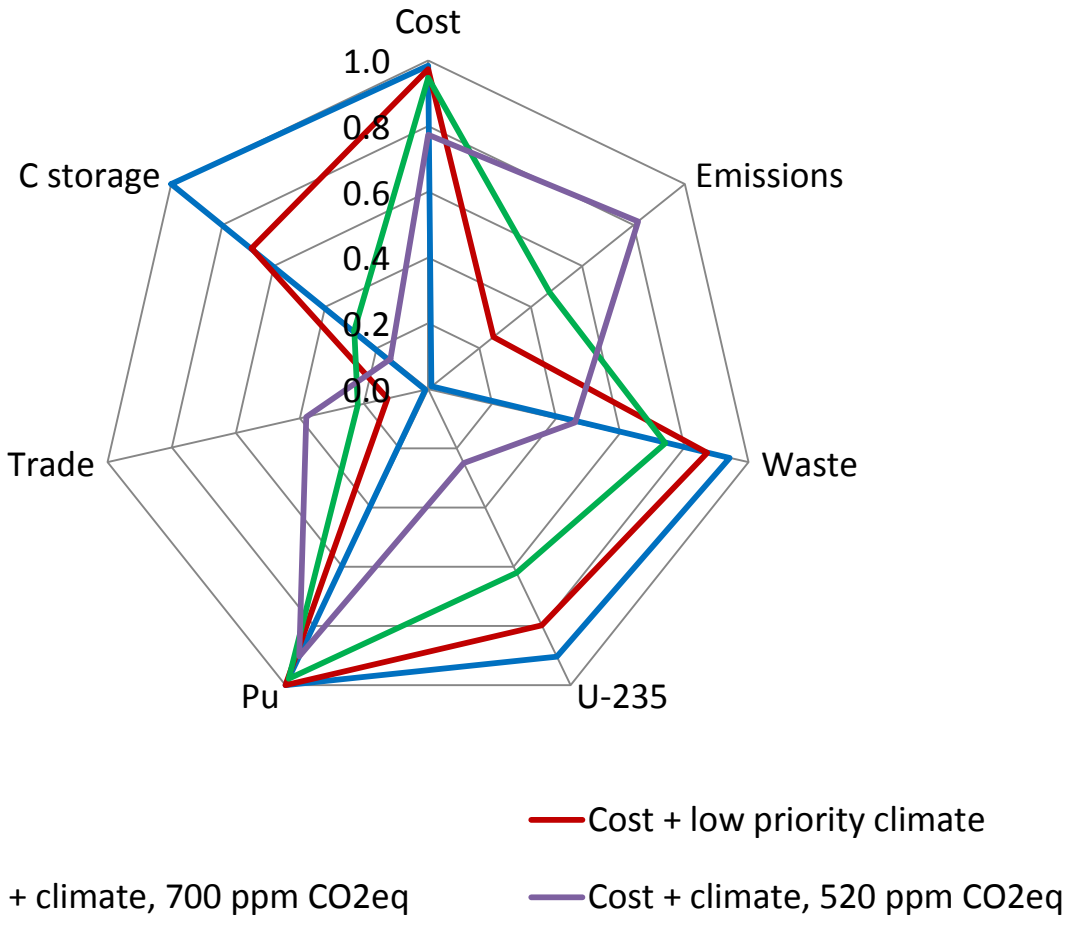
Criteria used in the study

Issue represented	Criterion	Short name	Unit
Affordability	Discounted cost of energy system including fuel cost	Cost	TUS$2005
Climate change mitigation	Cumulative GHG emissions	Emissions	$GtCO_2$-eq
Nuclear waste	Total excavation needed for HLW repository	Waste	Mm^3
Nuclear weapon proliferation (enrichment)	Cumulative production of uranium-235 enriched to 4%	U-235	kt of U-235
Nuclear weapon proliferation (reprocessing)	Cumulative production of plutonium	Pu	kt of Pu
Energy security	Cumulative global trade	Trade	ZJ
CCS failure risk	Carbon storage capacity required	C storage	Gt of CO2

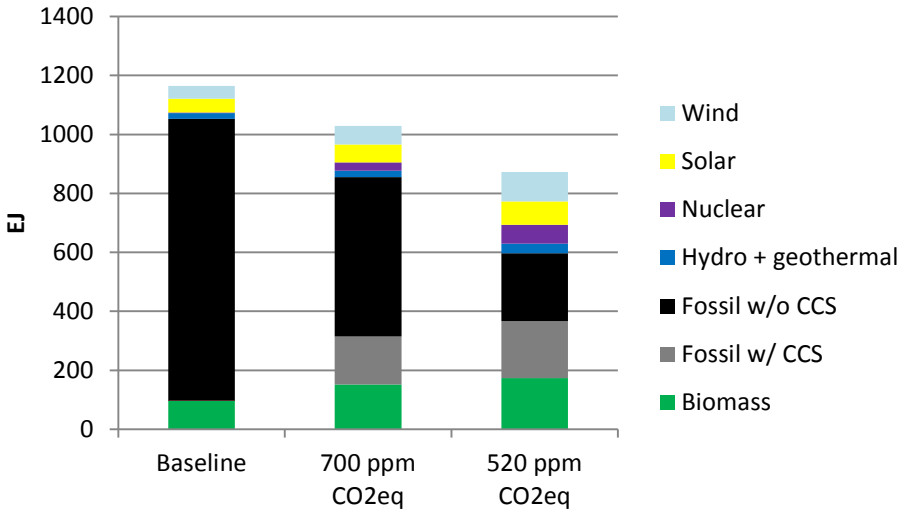
Utopia and nadir values for criteria

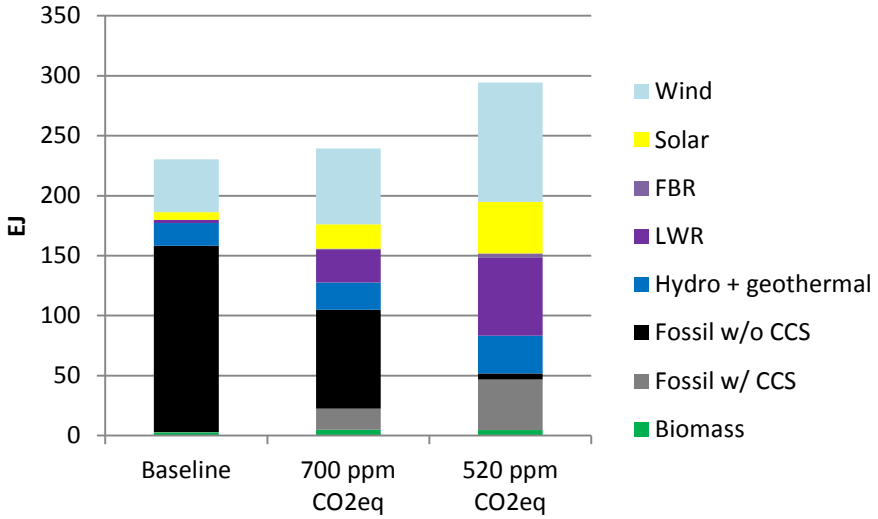
Criterion	Utopia	Nadir	Unit
Cost	47	66	TUS$2005
Emissions	1500	7600	$GtCO_2$-eq
Waste	0.13	25	km3
U-235	1.6	150	kt of U-235
Pu	0	65	kt of Pu
Trade	2.9	21	ZJ
C storage	0	1600	Gt of CO_2

Varying the importance on cost and climate criteria



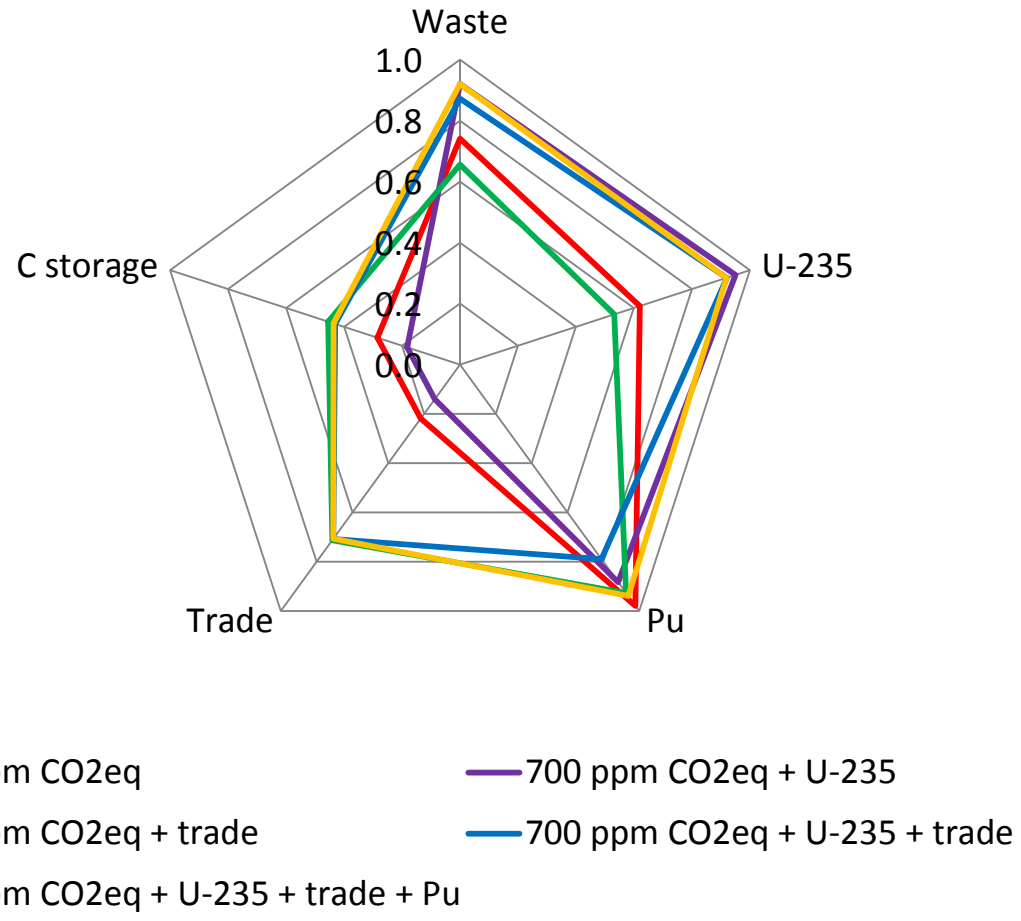
The composition of primary energy and electricity supply



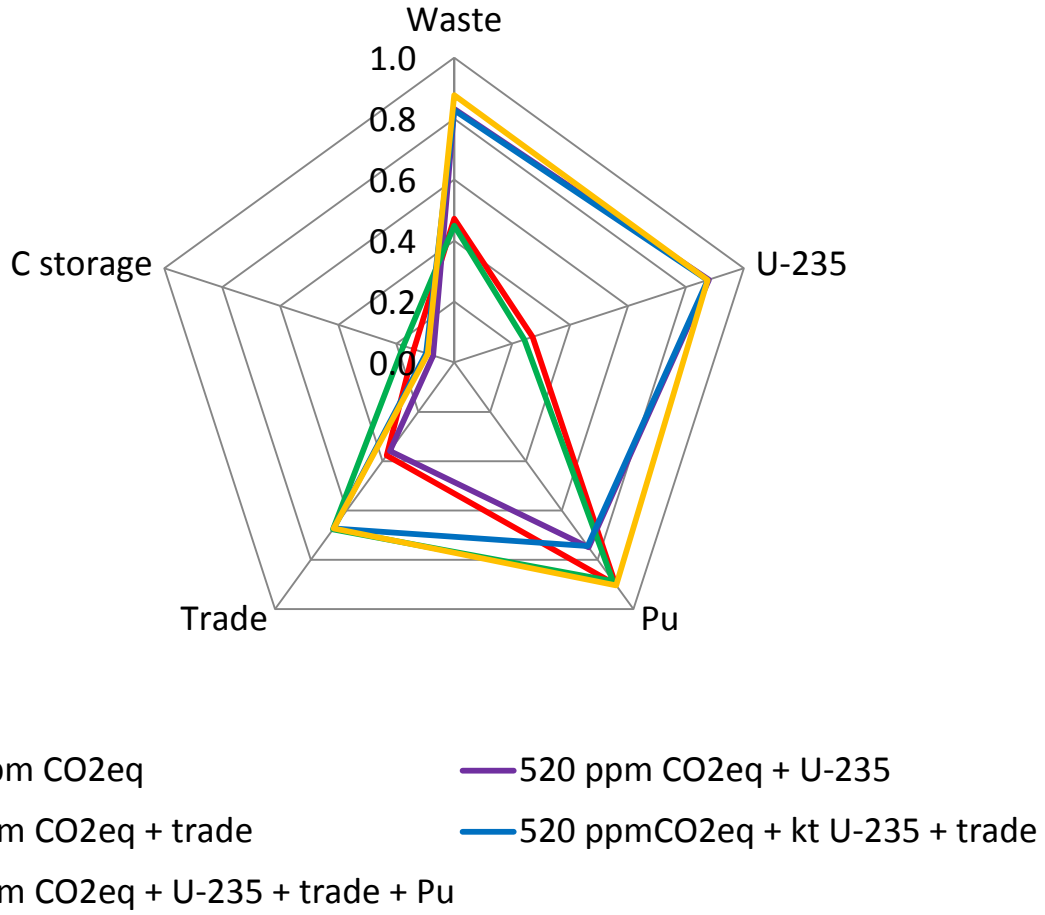


average of 2060–2080

Effect of prioritisations of criteria at 700 ppm CO_2-eq level



Effect of prioritisations of criteria at 520 ppm CO_2-eq level



Conclusions

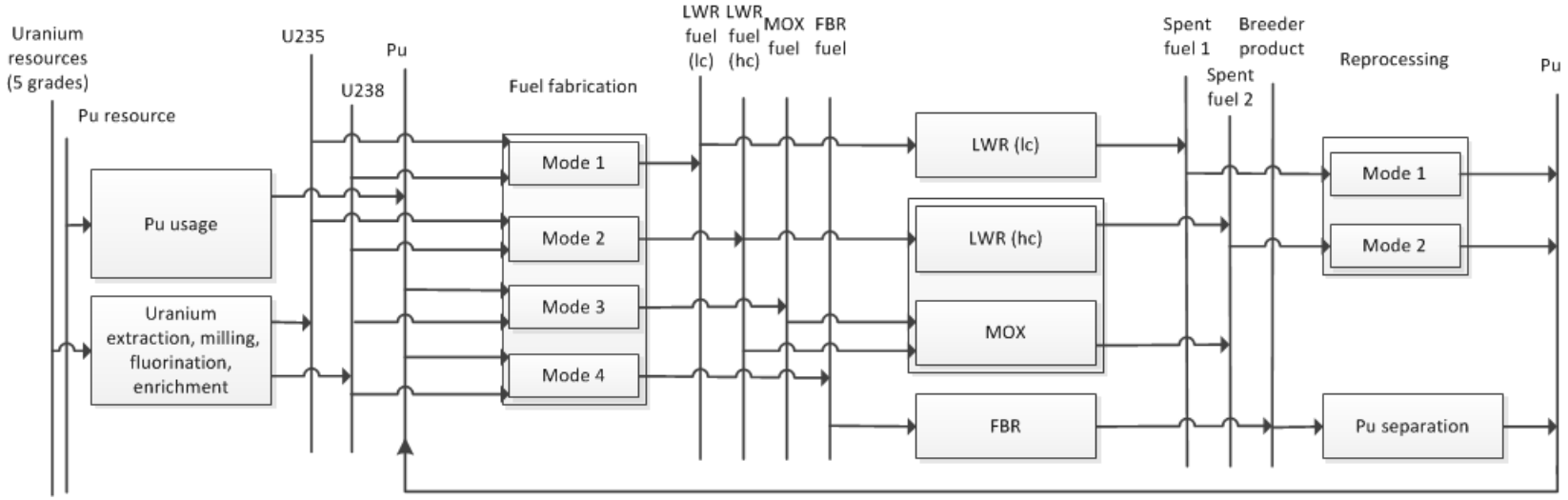
- About a 20% reduction in GHG emissions compared to baseline can be achieved by increasing the discounted energy system cost by 0.4%.
- Yet to reach the 520 ppm CO_2-eq target with relatively high certainty the cost for the energy system would increase by about 8%.
- Climate targets are needed to make nuclear power competitive.
- High priority of energy security in combination with climate targets enhances the role of nuclear power. The effect is stronger if climate targets are not very stringent.

Conclusions

- There is a significant synergy between climate mitigation and energy security goals related to reduced import.
- Focusing on both climate and energy security goals lessens the need for CCS and therefore also technology risk stemming from CCS.
- Taking the proliferation risk stemming from enrichment into account in combination with climate targets limits the total amount of nuclear power but enhances the use of FBRs.
- Assigning importance to limiting reprocessing as well reduces nuclear power without significant changes in other criteria values.

Extra slides

Nuclear cycles in MESSAGE



Varying the importance of cost and climate criteria

Criterion/Scenario	Cost	Cost + low priority climate	Cost + 700 ppm CO_2eq	Cost + 520 ppm CO_2eq	Unit
Cost	47.3	47.5	47.9	50.9	TUS$2005
Emissions	7630	6160	4910	2750	$GtCO_2$-eq
Waste	1.59	3.27	6.14	13.2	Mm^3
U-235	15.9	30.9	53.9	109	kt of U-235
Pu	0	0	1.39	6.65	kt of Pu
Trade	20.5	18.4	16.7	14.3	ZJ
C storage	0.1	498	1110	1430	Gt of CO_2