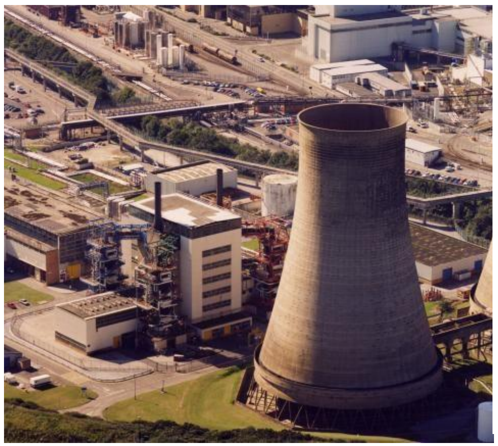
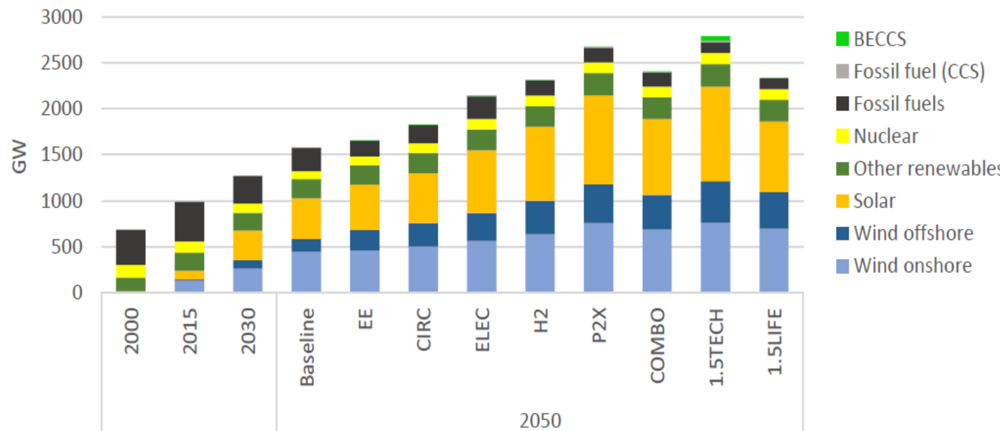
IAEE European, Ljubljana (Slovenia)

August, 28, 2019





Energy Scenarios, Projections, and Modeling ("Academic approach"):

Case of the "Clean European Energy Package"

Christian von Hirschhausen

based on joint research with colleagues mentioned …

TU berlin WIP

DIW BERLIN

Energiewende – the structure

Ch. 1: Introduction

Part I: The Origins of the „Energy Transformation"

- Ch. 2: German Energy and Climate Policies: An Historical Overview
- Ch. 3: The Transformation of the German Coal Sector from 1950 to 2017 – A Historical Overview

Part II: The Energy Transformation at Work in the Electricity Sector

- Ch. 4: Greenhouse Gas Emission Reductions and the Phasing-out of Coal in Germany
- Ch. 5: Nuclear power: Effects of plant closures on electricity markets and remaining challenges
- Ch. 6: Renewable energy sources as the cornerstone of the German energiewende
- Ch. 7: Energy efficiency: A key challenge of the energiewende
- Ch. 8: The role of electricity transmission infrastructure
- Ch. 9: Sector Coupling – A Techno-Economic Introduction and Application to Germany

Part III: The German Energywende in the Context of the European Low-carbon Tranformation

- Ch. 10: The European Context: Generation
- Ch. 11: The European Context: Infrastructure
- Ch. 12:Future International Coordination within Europe
- **Ch. 13: Modeling the Low-Carbon Transformation in Europe - Developing Paths for the European Energy System until 2050**

Ch. 14: Assessment, Perspectives, and Conclusions: 15 Theses

Agenda

1) Introduction: EEEP “Symposium on Scenarios and Modeling“

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

3) An example: The “Clean“ Energy Package

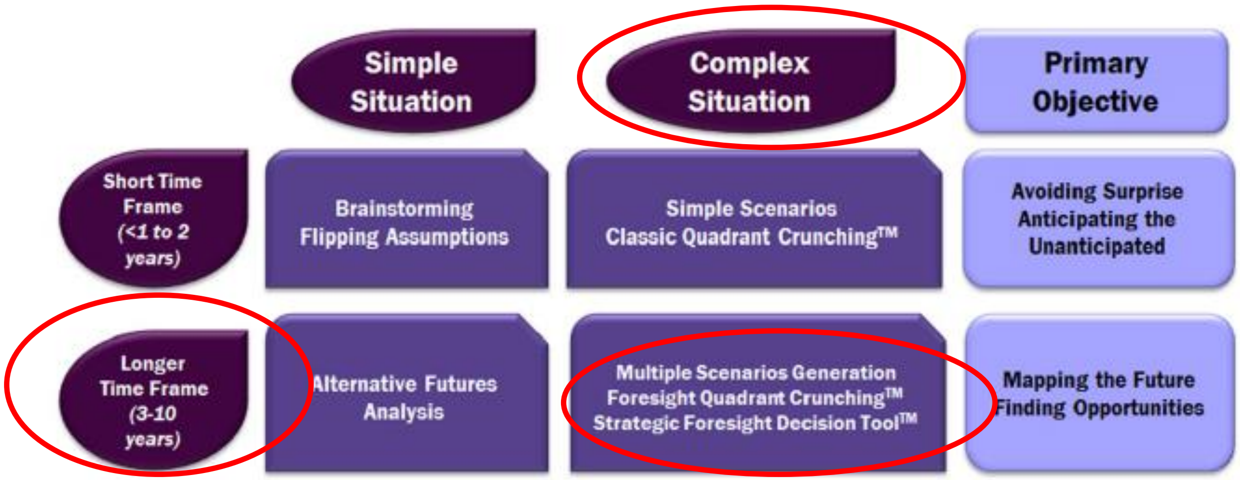
4) Conclusions

Forecast, foresight, and scenario development
(Ansari, Holz, and Tosun, 2018)

- Forecasting
  - Making a qualified statement or calculation of some future event or condition based on the results of study and analysis of data

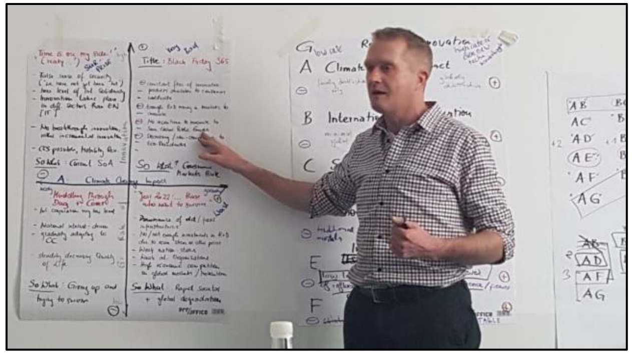
- Foresight
  - A reframing process that involves "the exploitation of insight(s) to create a state of being prepared for thinking, seeing, and acting in the future." (Peppler, 2015)

- Scenario development as an application of foresight analysis
  - "Bound the range of plausible alternative futures." Pherson (2015)



from Pherson (2015)

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."

Plenty of applications:

Industry: Shell, IEA, … scenario exercises

Academic organziations: MIT, Stanford Energy Modeling Forum, etc.

…

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.)

Scnearios can not be separated from models

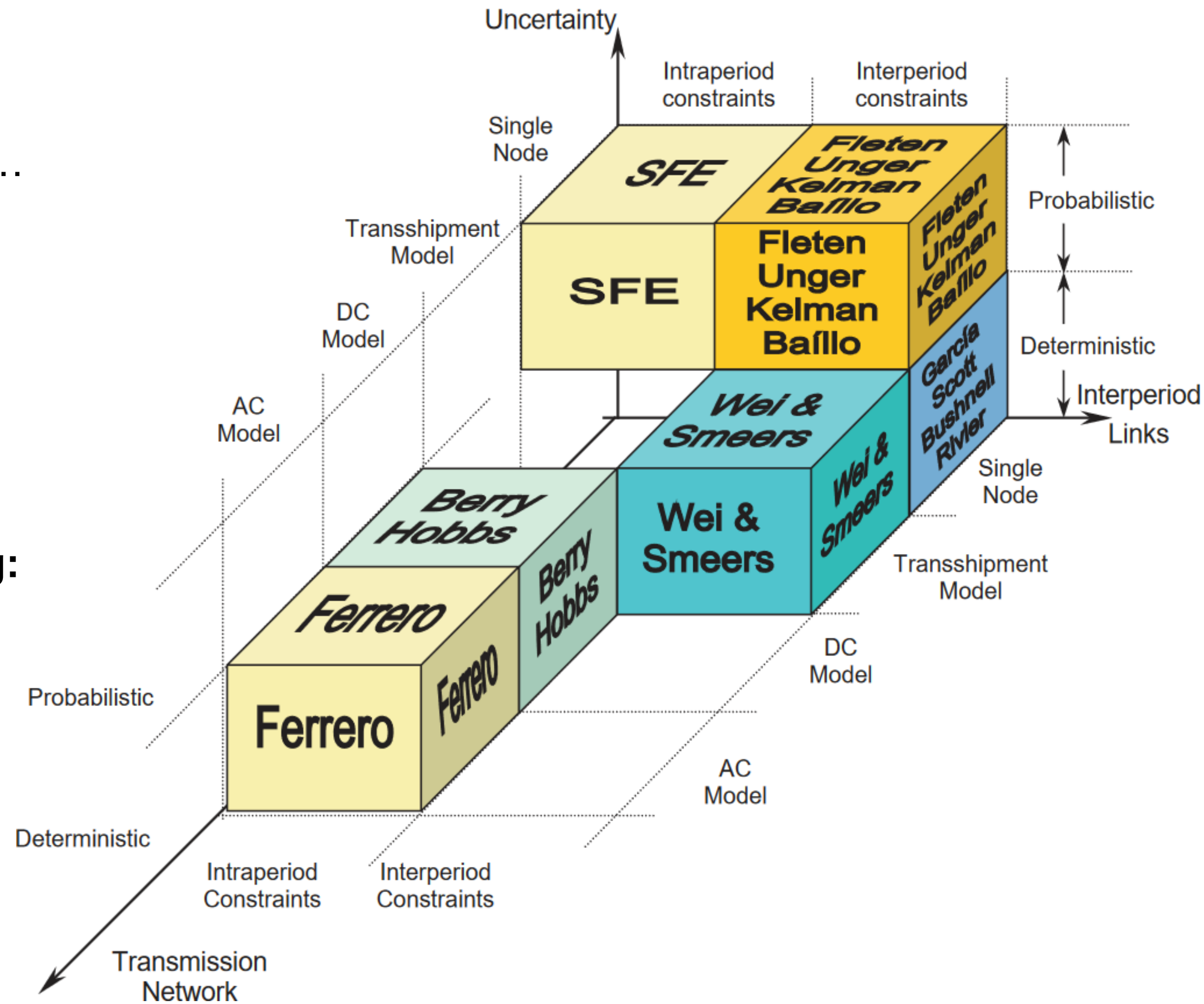
Assumptions on:

~ 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, carbon dioxide removal technologies (CDR), etc.**
- **~ "low-carbon-clean" technologies, e.g. nuclear power, renewables, etc.**
- **~ Auxiliary technologies, e.g. storage**

Call for Papers – Economics of Energy & Environmental Policy

Economics of Energy & Environmental Policy (EEEP), published by the International Association for Energy Economics (IAEE), focuses on policy issues involving energy and environmental economics. EEEP is a peer-reviewed, multidisciplinary publication which provides a scholarly and research-based, yet easily readable and accessible source of information on contemporary economic thinking and analysis of energy and environmental policy issues.

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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iaee@iaee.org

EEEP Symposium: “Energy and Climate Scenarios “

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Christian von Hirschhausen, Isabell Braunger, Chris Hauenstein, Pao-Yu Oei, Ben Wealer: Energy and Climate Scenarios – An Introduction

Sergeij Paltsev (MIT): Energy Scenarios: The Value and Limits of Scenario Analysis

Chandra Bushan (CSI India): Decarbonization in India – Current Status and Perspectives

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

Pedro Crespo del Granado, Gustav Resch: set-nav pathways Paper

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

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

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What model for scnenario-based scientific policy advice? Edenhofer and Korwasch (2012)

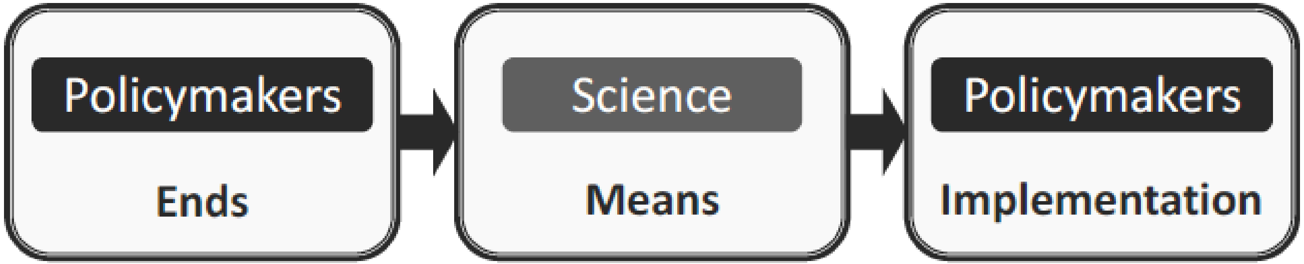


Figure 1: The decisionist

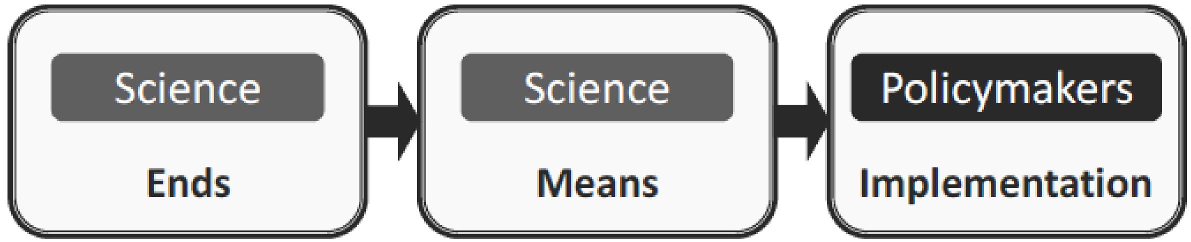


Figure 2: The technocratic model.

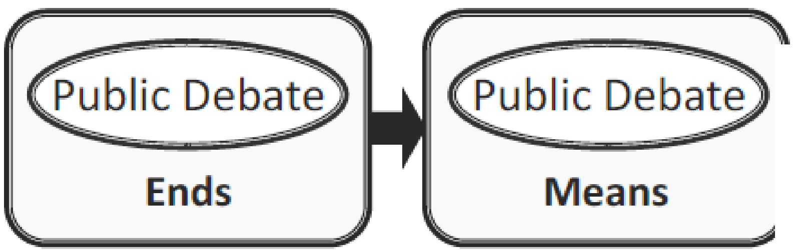


Figure 3: The pragmatic mo

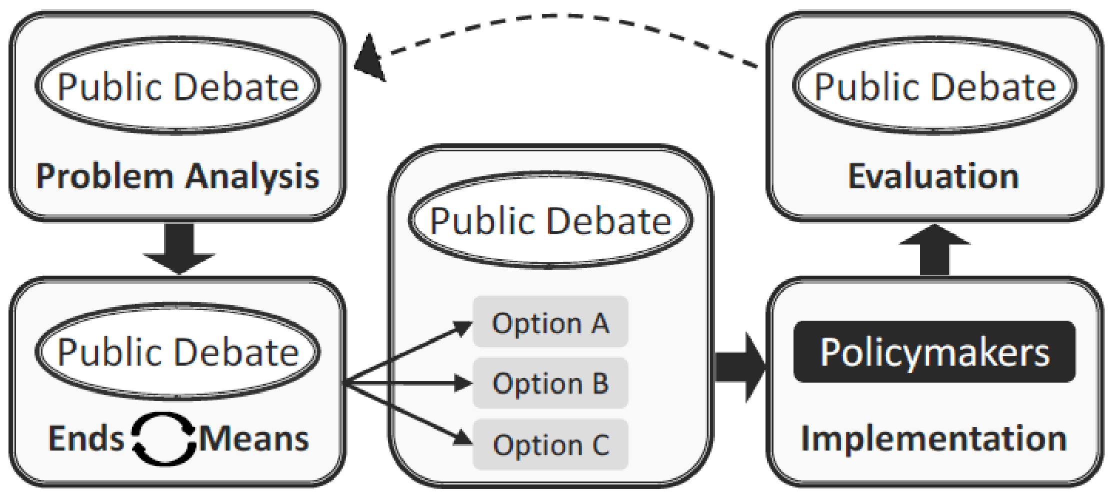


Figure 4: The process of the scientific policy advice as suggested by the pragmatic-enlightened model (PEM

In realtiy, the „scenariomakers and modelers“ are part of the policy process, not separated from it

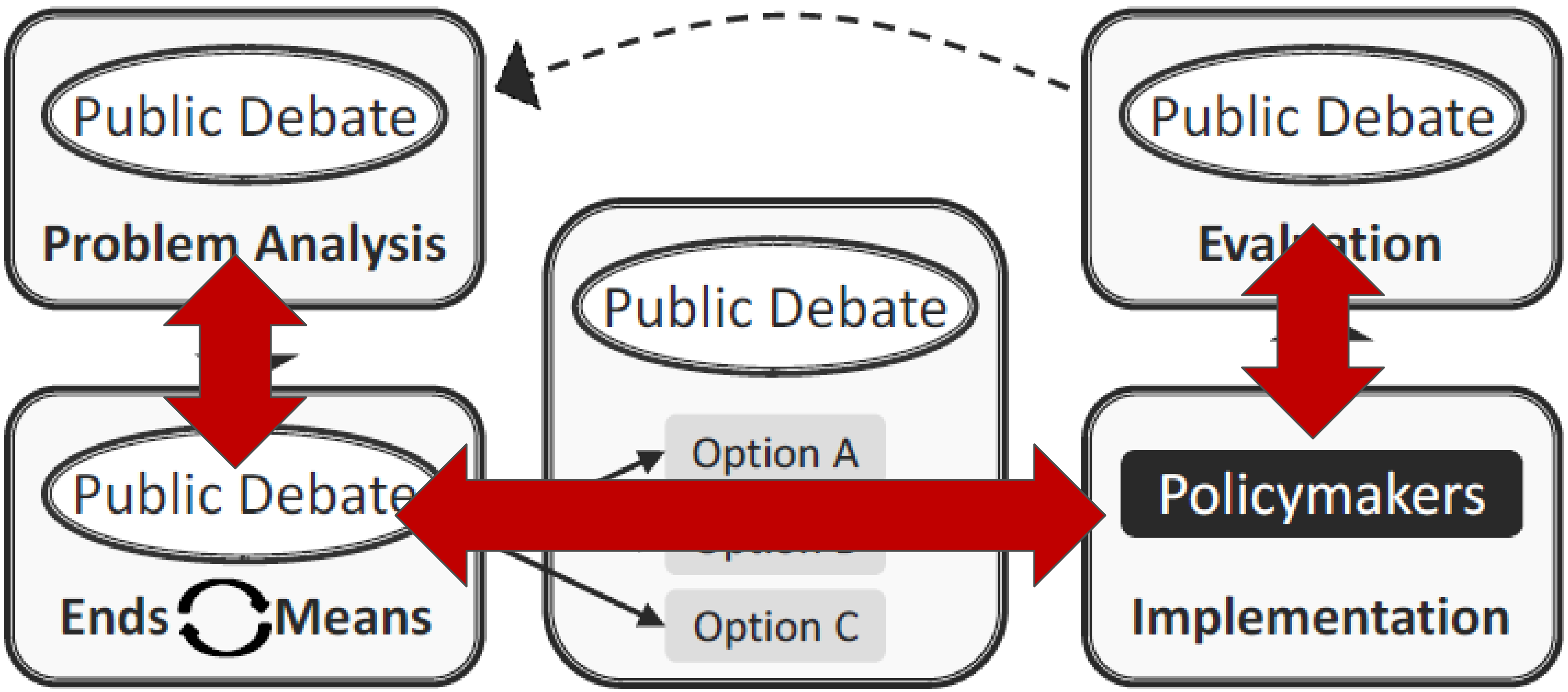


Figure 4: The process of the scientific policy advice as suggested by the pragmatic-enlightened model (PEM).

Yet another model: “Partisan model“ or “Iron triangle“ Midttun and Baumgartner (1986): “Negotiating energy futures“

~ In reality, thee is no strict separation between „scenario-model development“ and „politics/policy

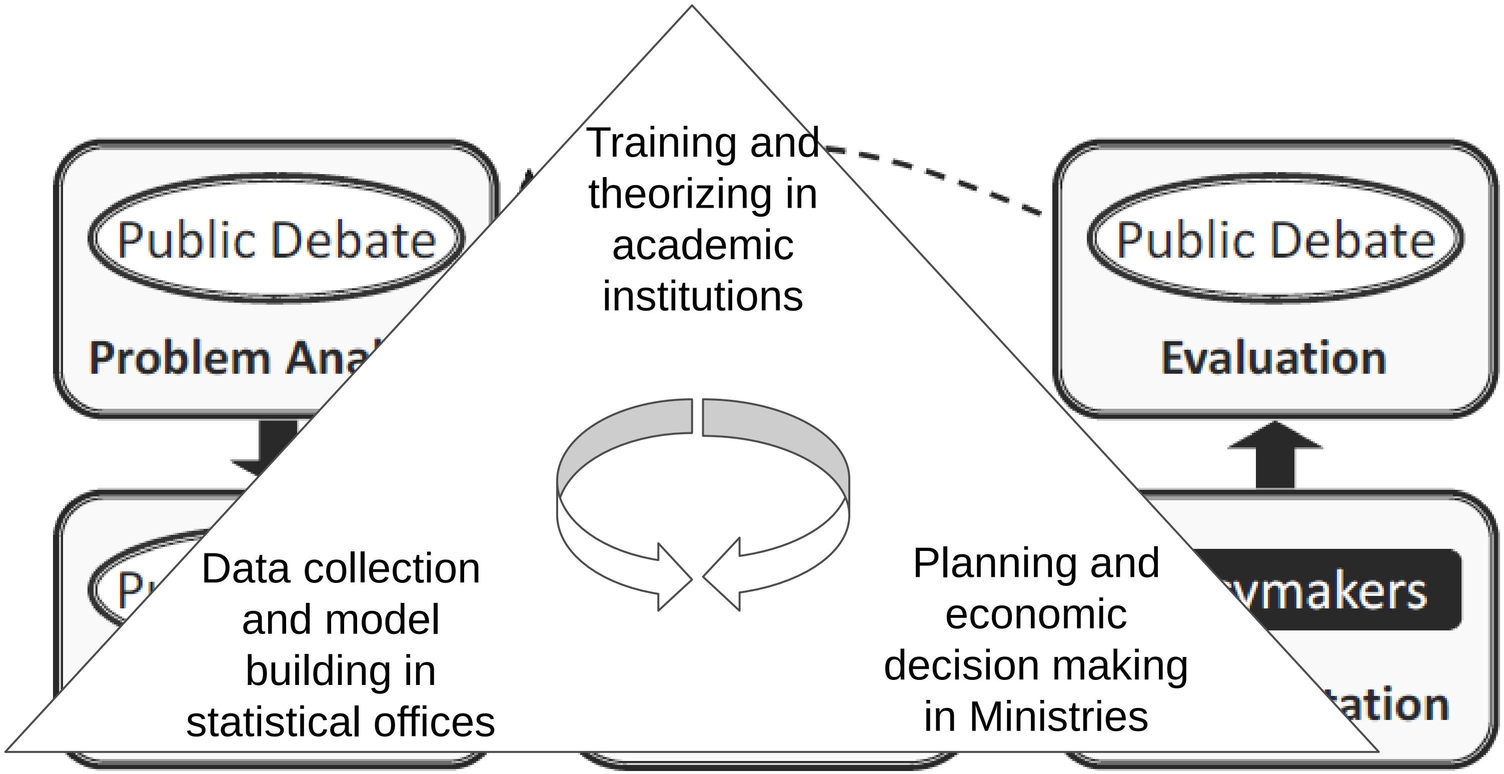
Refererring to discussion in the 1970s:

… 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”

The „“Iron Triangle“ in the PEM-Model



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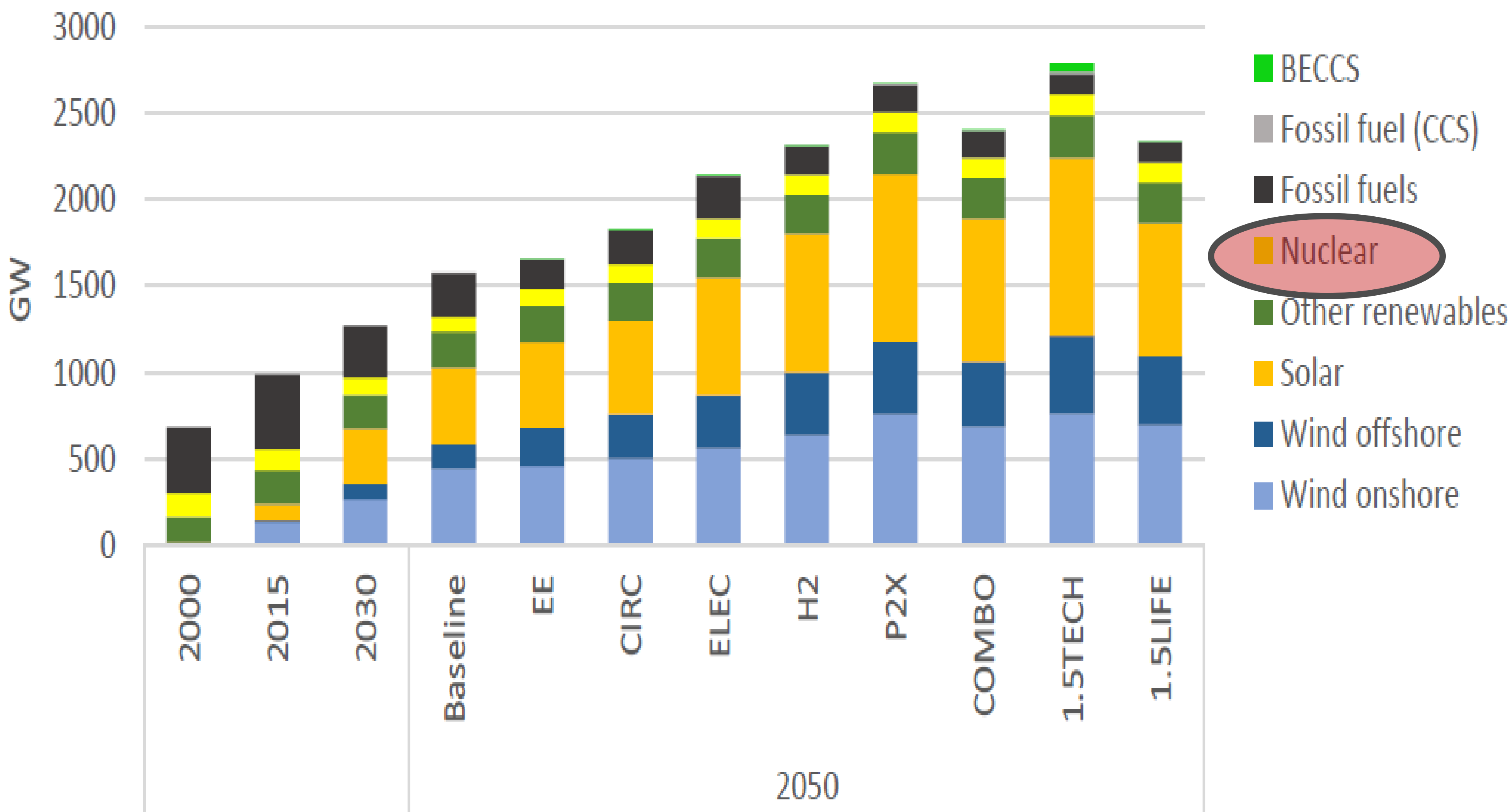
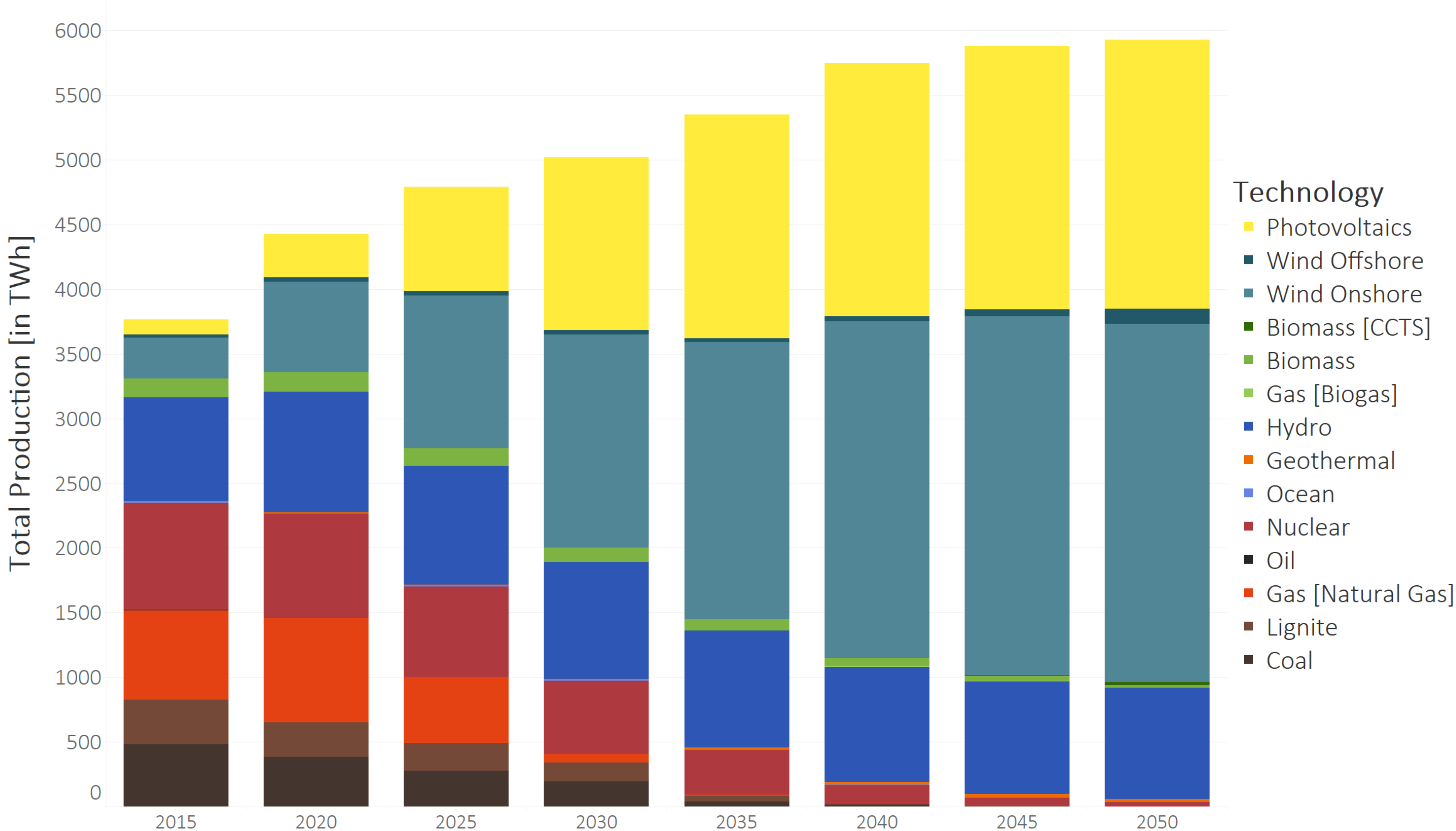
The “Clean“ Energy Package, focus on electricity



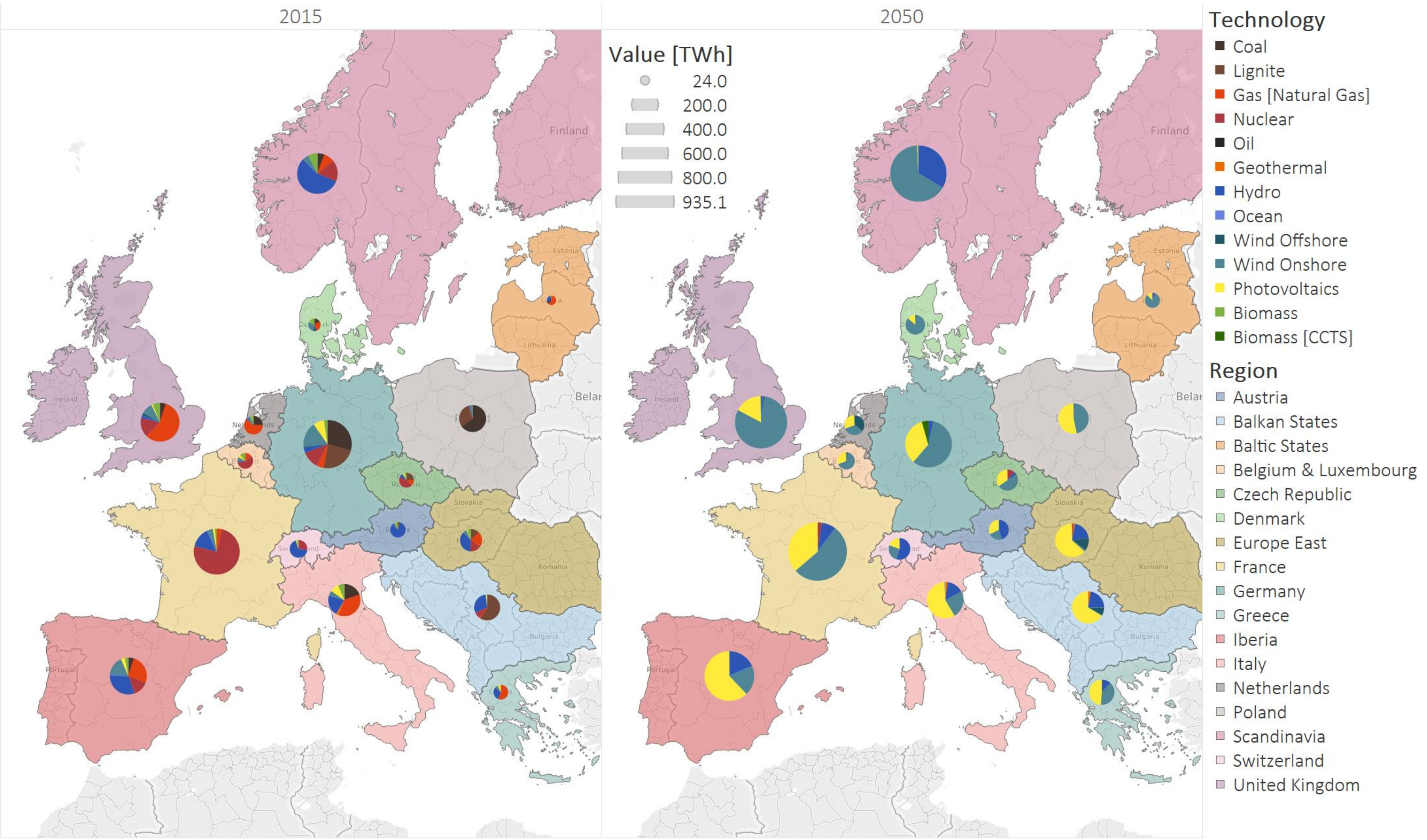
EC (2018)

Development of Power Generation



Source: Löffler, et al. (2018)

Regional Power Generation Profiles 2015 and 2050



Energy/climate change mitigation scenarios: Techno/supply-side bias

~ Nuclear not an option (see slides on nuclear).

~ Fossil/Natural gas not an option due to carbon dioxide emissions + methane leakage – not better than coal (e.g. Howarth 2019).

~ CCTS does not work and can economically not compete with RES (see slides below). (Gas + CCTS has further more the issue of methane leakages + no 100% CO_2-emission reduction possible with CCTS.)

~ Carbon dioxide removal (CDR): BECCTS, DACCTS, … (not to speak of Solar Radiation Management (SRM)) (i.a. Anderson and Peters 2016; Bednar, Obersteiner, and Wagner 2019; IPCC 2018; Lawrence et al. 2018; Minx et al. 2018; Shue 2017).

Technical feasibility not proven (individual technologies, as well as envisioned rapid scale-up), uncertainty about effective net CO2 removal and total CO2 removal potential.

High risk, uncertainty, and ignorance of possible adverse side-effects (possibly breaching other planetary boundaries and counteracting the achievement of SDGs).

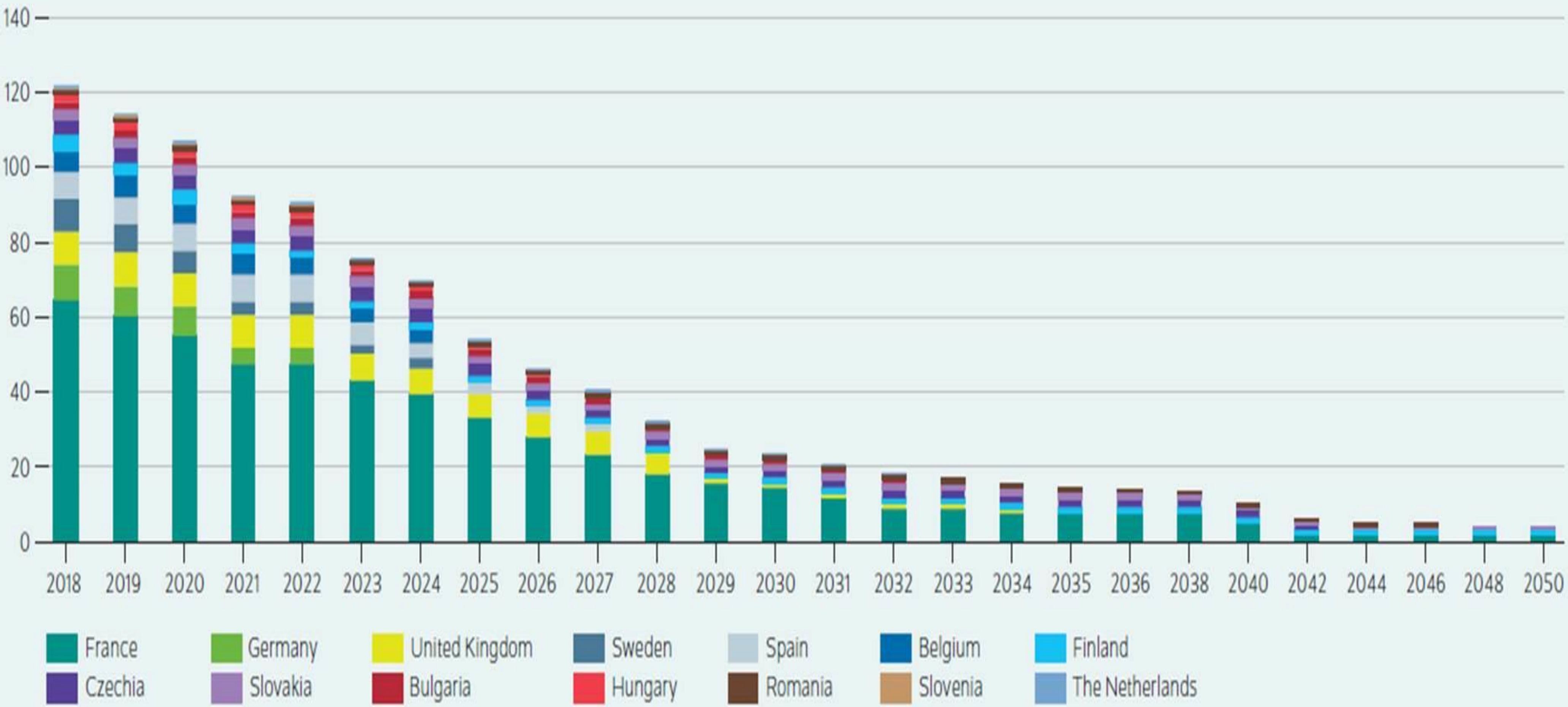
No business case / no policy enabling large-scale implementation.

~ RES: “clean”, but also issues (resources, land, social acceptance, availability, …).

➔ Considering demand-side mitigation

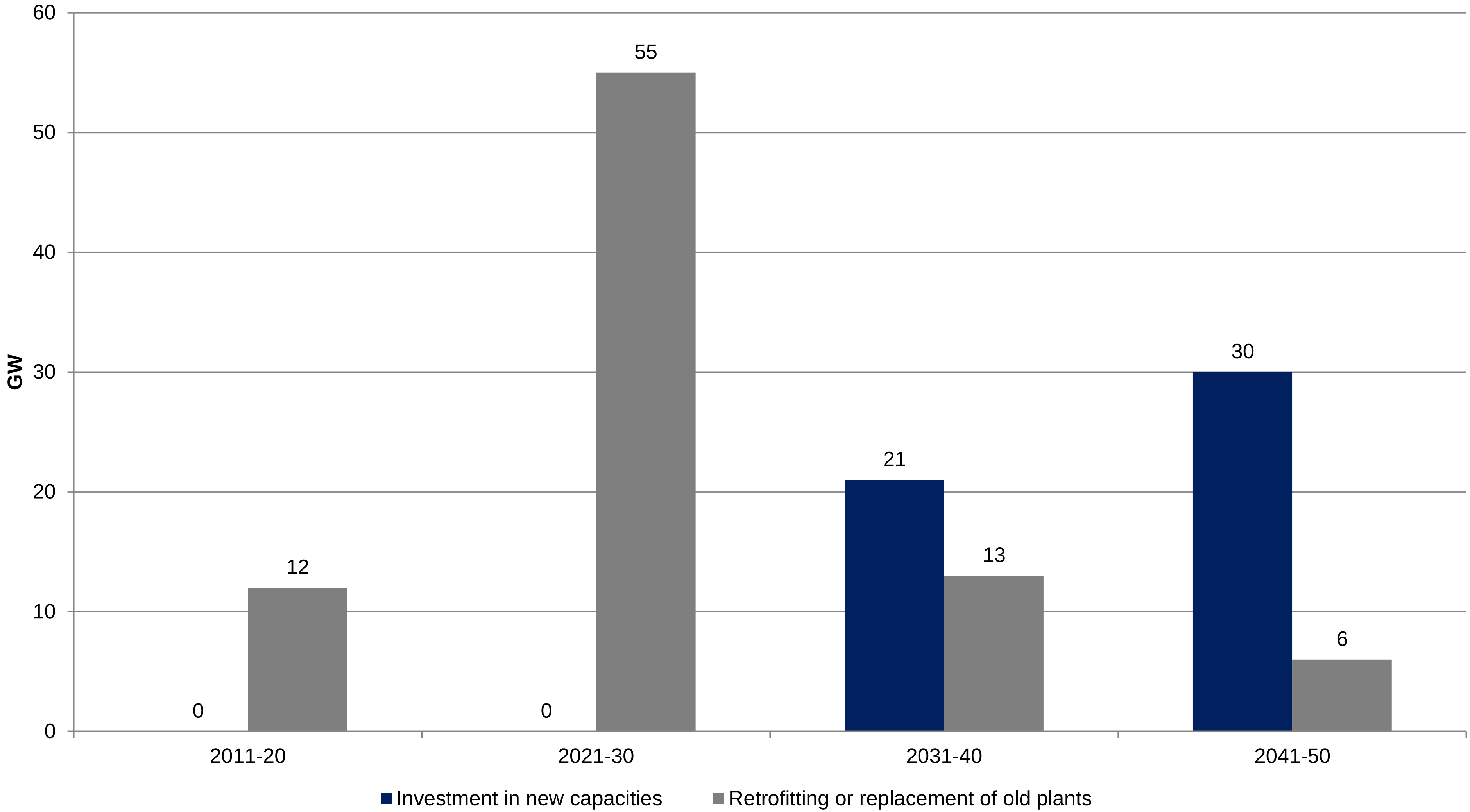
Installed capacity of nuclear plants in EU-28 given the scheduled shutdowns and end of life dates

In gigawatts



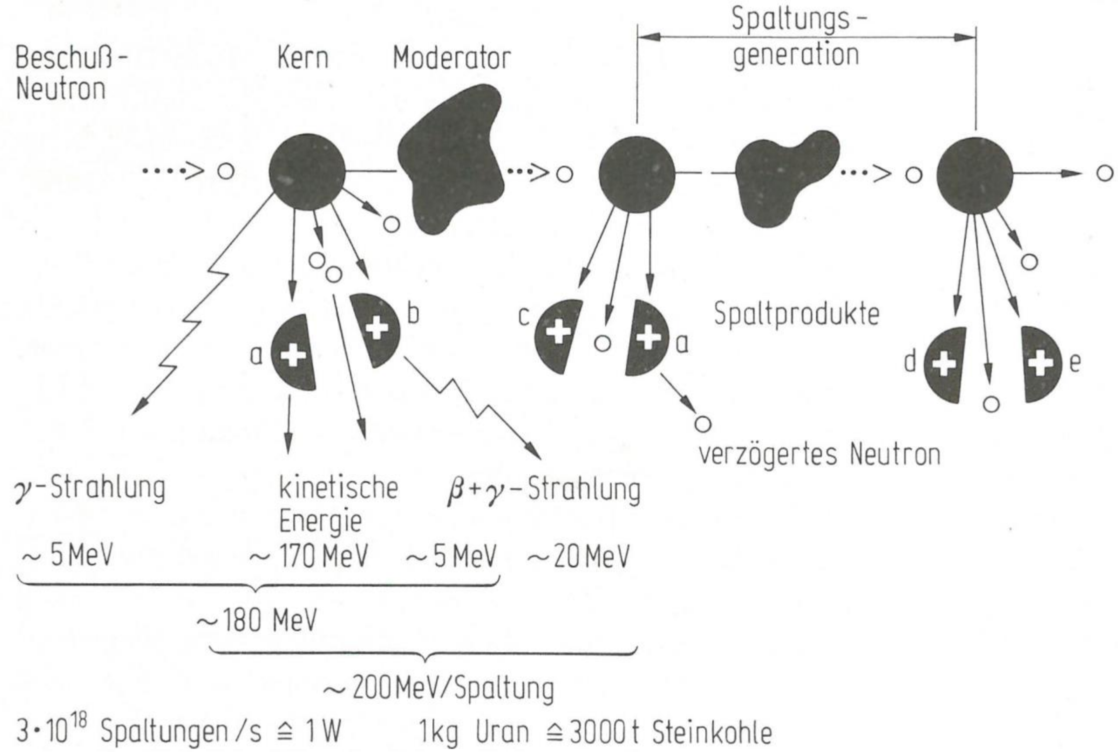
Source: own illustration based on Ben Wealer et al. (2018): Nuclear Power Reactors Worldwide - Technology Developments, Diffusion Patterns, and Country-by-Country Analysis of Implementation (1951–2017). DIW Berlin Data Documentation 93 (available online).

The “nuclear power paradox“: Newbuilt and retrofit of nuclear power plants in the EU 2016 Reference Scenario



Source: EC (2016)

Francois Lévêque (2012):
„The nuclear industry is the child of science and warfare“



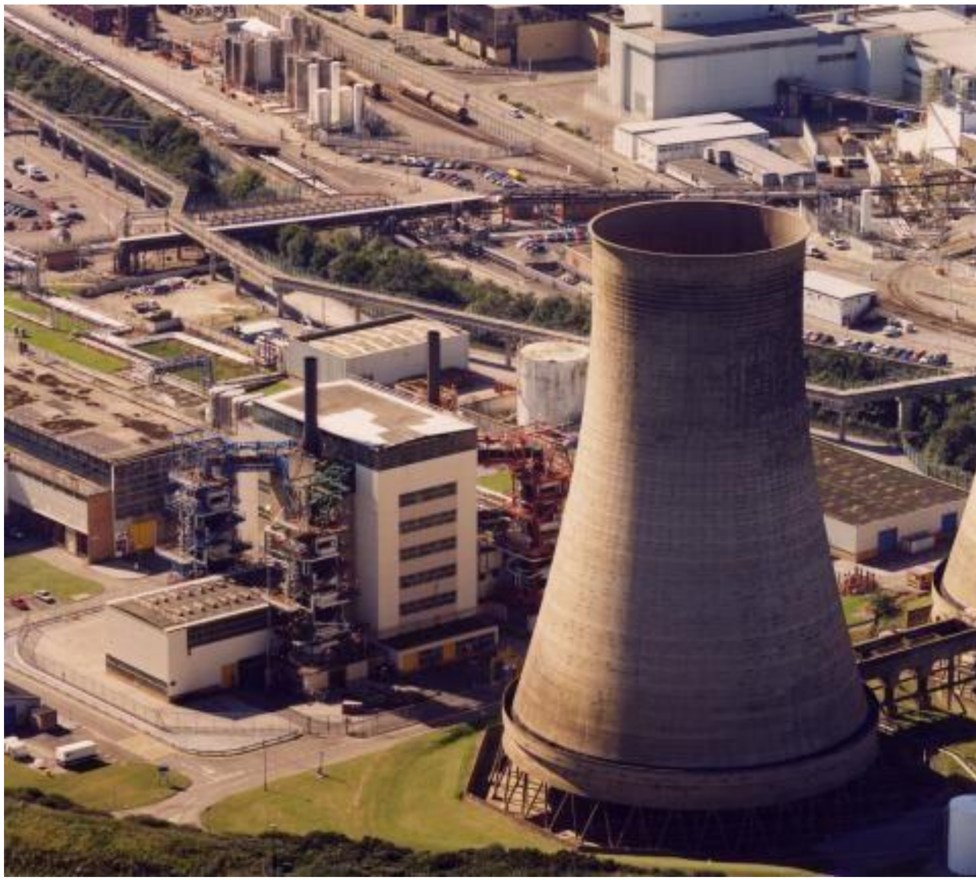
Durchschnittliche *Energieverteilung* für die Spaltung des U^{235}-Kerns in MeV:

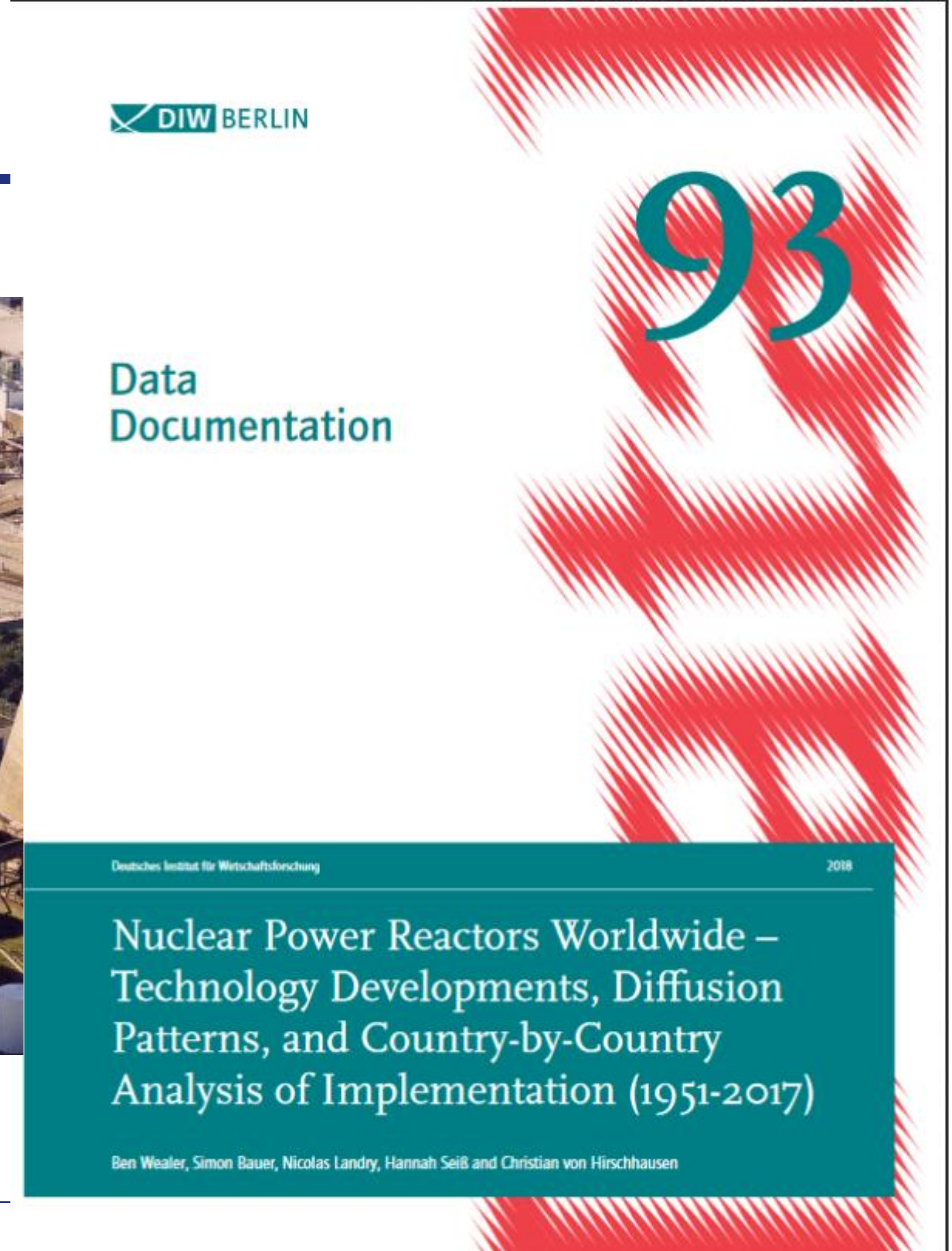
$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{236}_{92}U \rightarrow {}^{89}_{36}Kr + {}^{144}_{56}Ba + 3\,{}^{1}_{0}n$$

Ausgangskern (Spaltstoff)	thermisches Neutron 2000 m/s	kurzlebiges Zwischenprodukt	hier Krypton	hier Barium	3 Neutronen

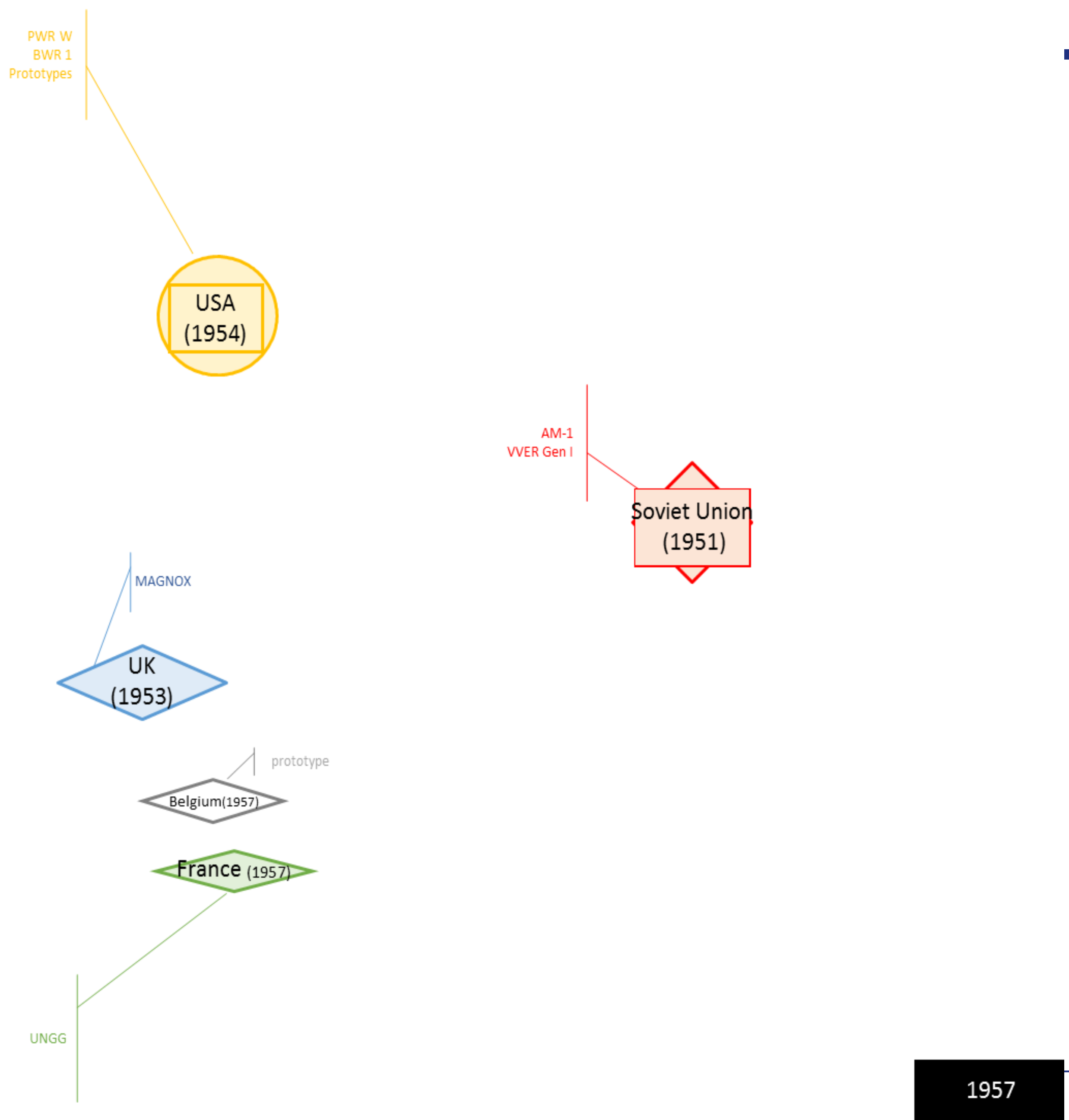
(als Beispiel häufiger Spaltprodukte)

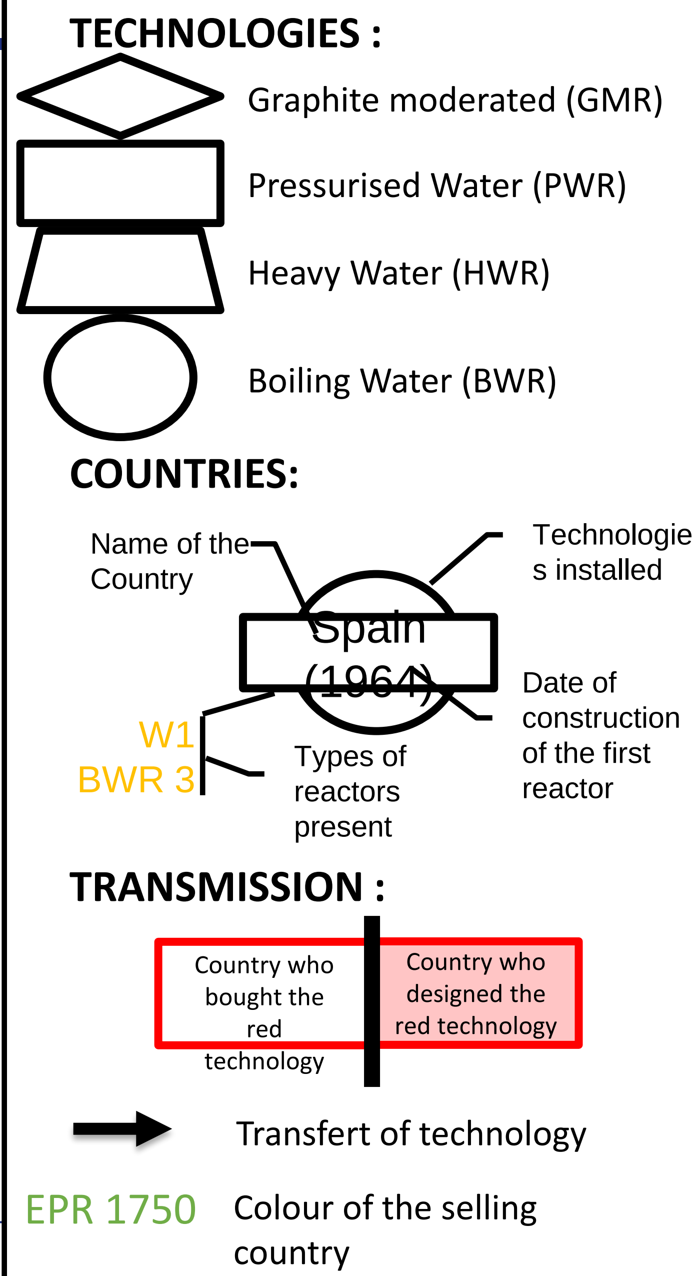
A Brief History of Nuclear Power





TRANSFERS OF NUCLEAR TECHNOLOGY





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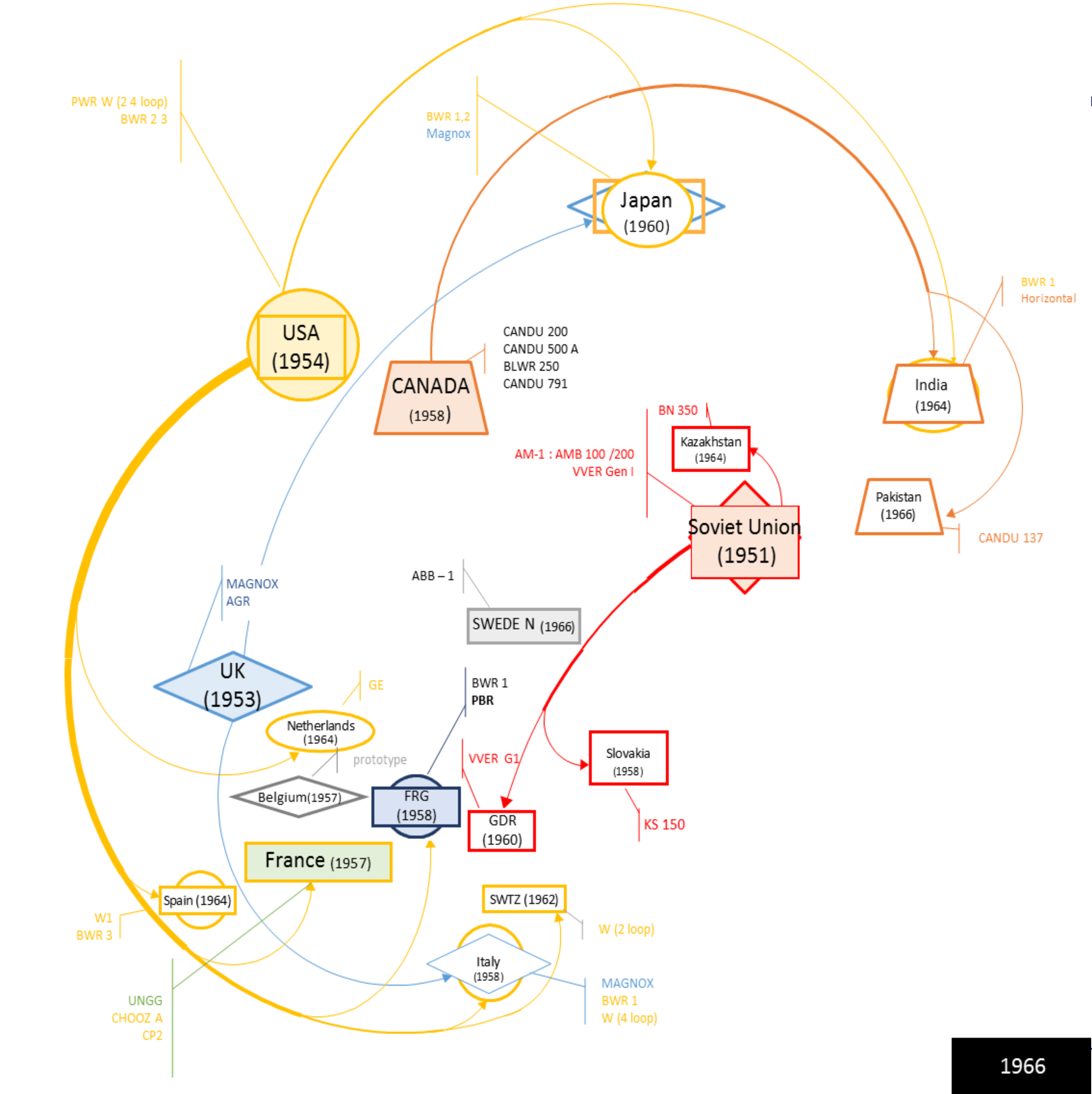

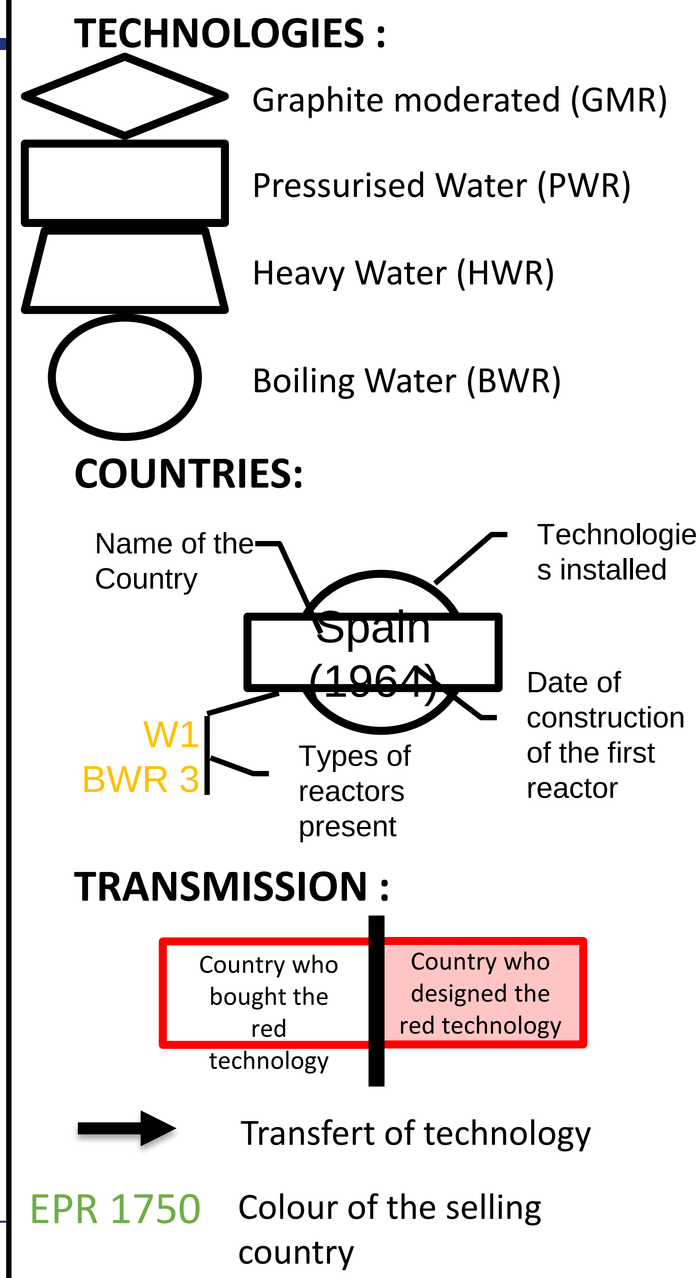

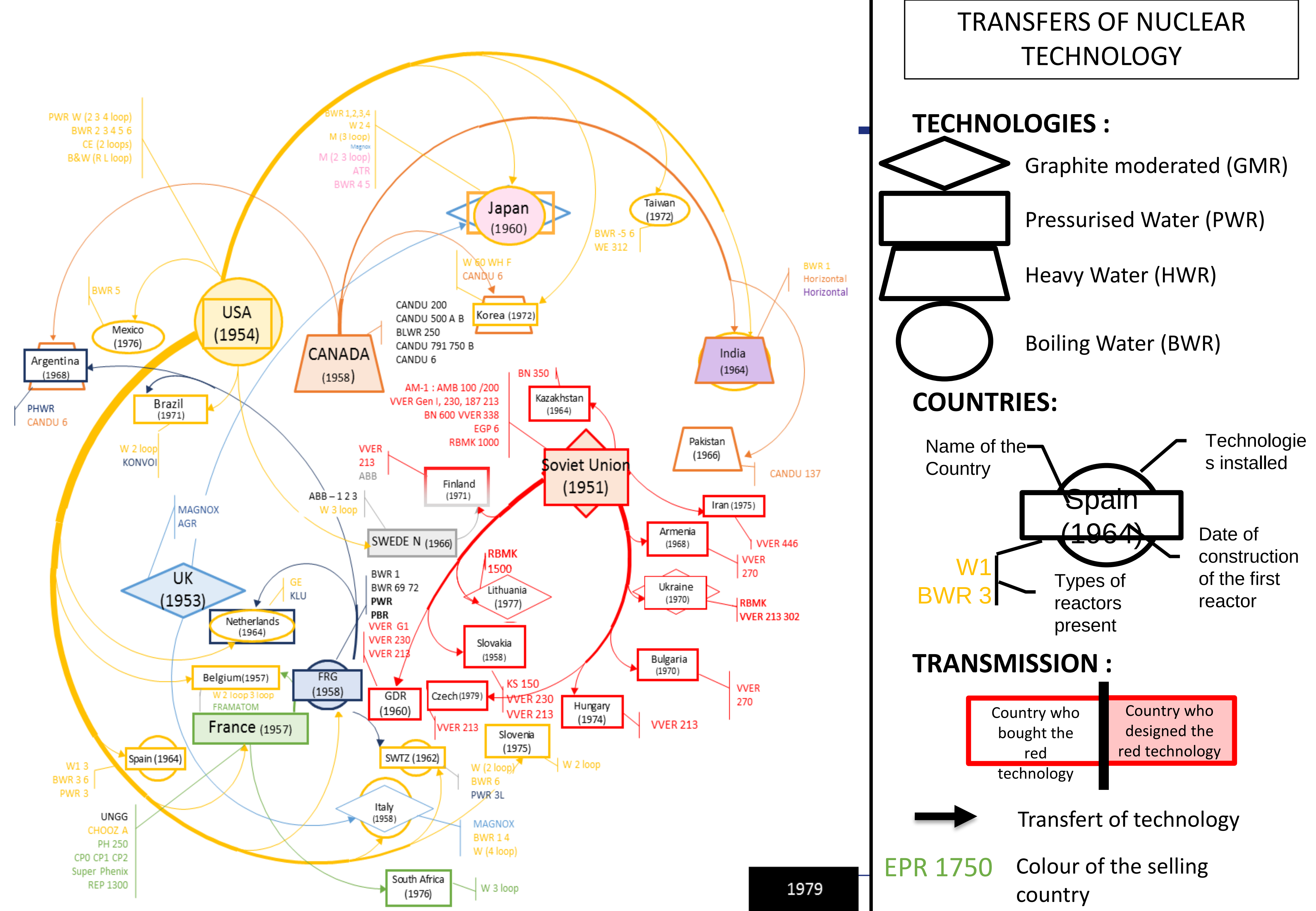
TRANSFERS OF NUCLEAR TECHNOLOGY
TECHNOLOGIES :
Graphite moderated (GMR)
Pressurised Water (PWR)
Heavy Water (HWR)
Boiling Water (BWR)
COUNTRIES:
Name of the Country
Technologies installed
Spain (1964)
Date of construction of the first reactor
W1 BWR 3
Types of reactors present
TRANSMISSION :
Country who bought the red technology
Country who designed the red technology
Transfert of technology
EPR 1750
Colour of the selling country
USA (1954)
CANADA (1958)
Japan (1960)
Taiwan (1972)
Korea (1972)
India (1964)
Pakistan (1966)
Mexico (1976)
Argentina (1968)
Brazil (1971)
UK (1953)
Netherlands (1964)
Belgium(1957)
FRG (1958)
France (1957)
Spain (1964)
SWTZ (1962)
Italy (1958)
South Africa (1976)
SWEDE N (1966)
Finland (1971)
Soviet Union (1951)
Kazakhstan (1964)
Iran (1975)
Armenia (1968)
Ukraine (1970)
Lithuania (1977)
Slovakia (1958)
Bulgaria (1970)
GDR (1960)
Czech (1979)
Hungary (1974)
Slovenia (1975)
PWR W (2 3 4 loop)
BWR 2 3 4 5 6
CE (2 loops)
B&W (R L loop)
BWR 1,2,3,4
W 2 4
M (3 loop)
Magnox
M (2 3 loop)
ATR
BWR 4 5
W 60 WH F
CANDU 6
BWR -5 6
WE 312
BWR 1
Horizontal
Horizontal
BWR 5
CANDU 200
CANDU 500 A B
BLWR 250
CANDU 791 750 B
CANDU 6
PHWR
CANDU 6
W 2 loop
KONVOI
AM-1 : AMB 100 /200
VVER Gen I, 230, 187 213
BN 600 VVER 338
EGP 6
RBMK 1000
BN 350
VVER
213
ABB
CANDU 137
MAGNOX
AGR
ABB – 1 2 3
W 3 loop
VVER 446
VVER
270
RBMK
1500
GE
KLU
BWR 1
BWR 69 72
PWR
PBR
VVER G1
VVER 230
VVER 213
RBMK
VVER 213 302
W 2 loop 3 loop
FRAMATOM
KS 150
VVER 230
VVER 213
VVER 213
VVER 213
VVER
270
W 2 loop
W (2 loop)
BWR 6
PWR 3L
W1 3
BWR 3 6
PWR 3
UNGG
CHOOZ A
PH 250
CP0 CP1 CP2
Super Phenix
REP 1300
MAGNOX
BWR 1 4
W (4 loop)
W 3 loop
1979

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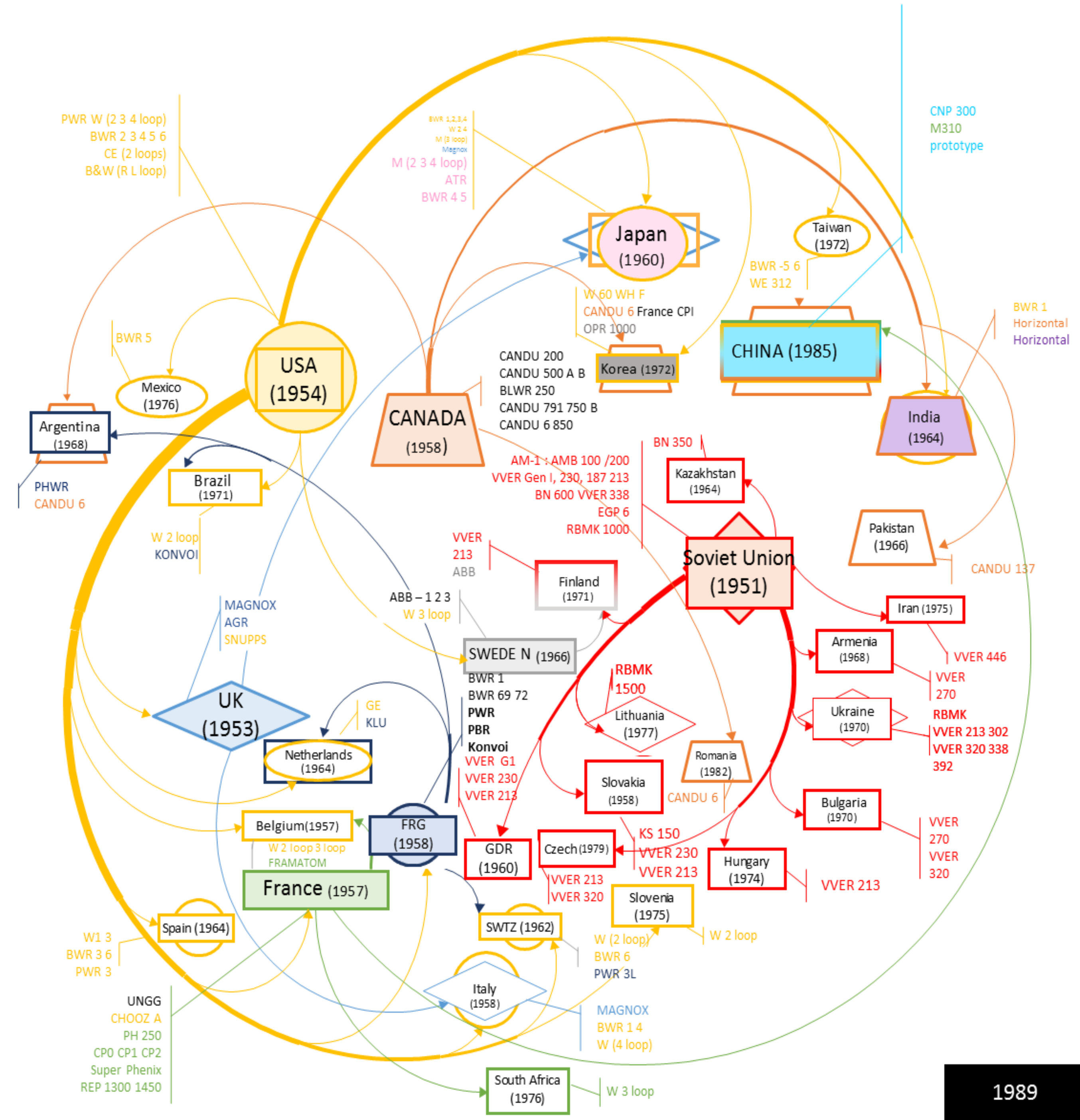

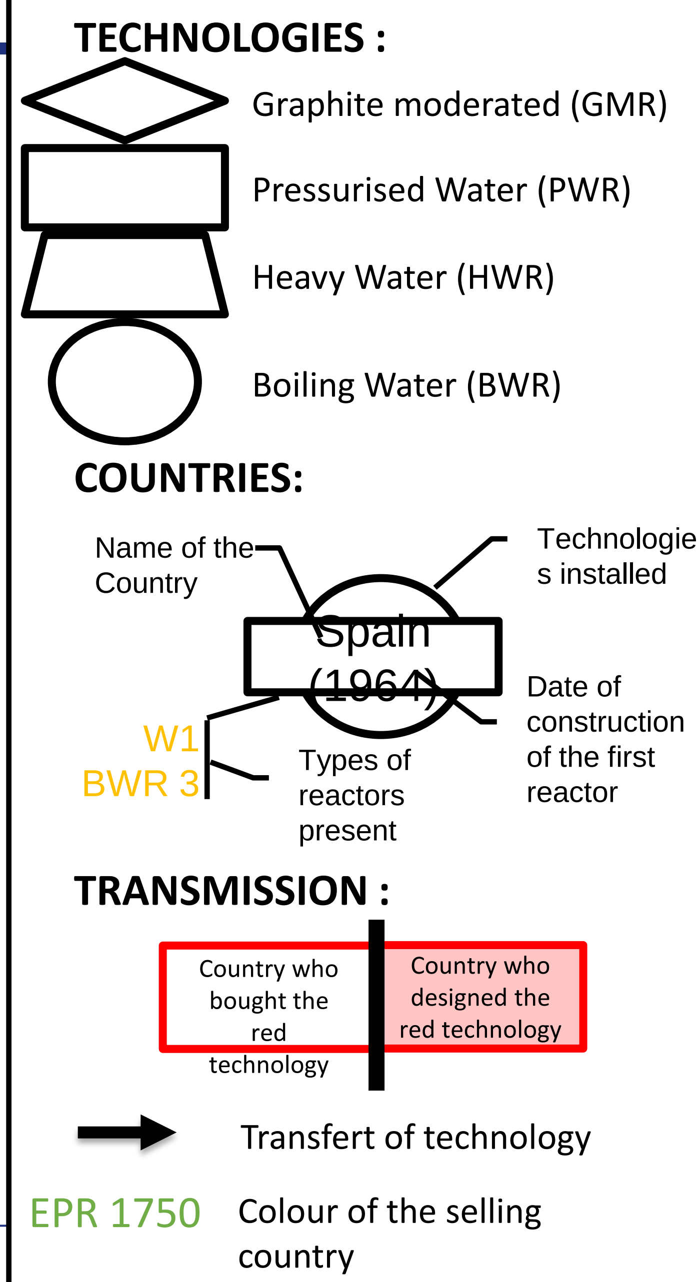

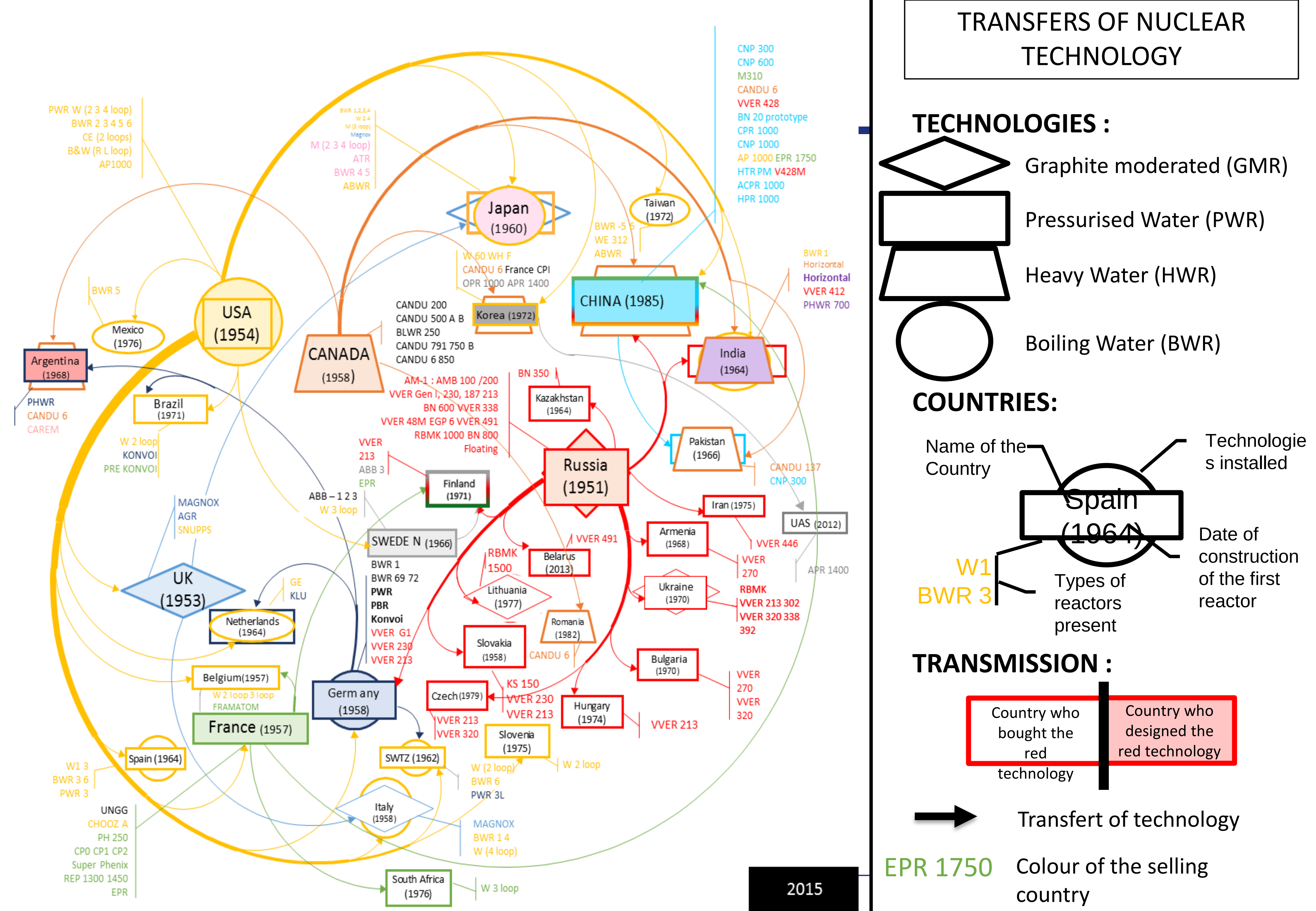
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PWR W (2 3 4 loop)
BWR 2 3 4 5 6
CE (2 loops)
B&W (R L loop)
AP1000
M (2 3 4 loop)
ATR
BWR 4 5
ABWR
Japan (1960)
Taiwan (1972)
BWR -5 6
WE 312
ABWR
W 60 WH F
CANDU 6 France CPI
OPR 1000 APR 1400
Korea (1972)
CANADA (1958)
CANDU 200
CANDU 500 A B
BLWR 250
CANDU 791 750 B
CANDU 6 850
CHINA (1985)
CNP 300
CNP 600
M310
CANDU 6
VVER 428
BN 20 prototype
CPR 1000
CNP 1000
AP 1000 EPR 1750
HTR PM V428M
ACPR 1000
HPR 1000
India (1964)
BWR 1
Horizontal
Horizontal
VVER 412
PHWR 700
Mexico (1976)
BWR 5
Argentina (1968)
PHWR
CANDU 6
CAREM
Brazil (1971)
W 2 loop
KONVOI
PRE KONVOI
AM-1 : AMB 100 /200
VVER Gen I, 230, 187 213
BN 600 VVER 338
VVER 48M EGP 6 VVER 491
RBMK 1000 BN 800
Floating
BN 350
Kazakhstan (1964)
Russia (1951)
Pakistan (1966)
CANDU 137
CNP 300
UAS (2012)
APR 1400
VVER 213
ABB 3
EPR
Finland (1971)
ABB – 1 2 3
W 3 loop
SWEDE N (1966)
BWR 1
BWR 69 72
PWR
PBR
Konvoi
VVER G1
VVER 230
VVER 213
MAGNOX
AGR
SNUPPS
UK (1953)
GE
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Netherlands (1964)
Belgium (1957)
W 2 loop 3 loop
FRAMATOM
France (1957)
Germany (1958)
RBMK 1500
Lithuania (1977)
VVER 491
Belarus (2013)
Iran (1975)
VVER 446
Armenia (1968)
VVER 270
Ukraine (1970)
RBMK
VVER 213 302
VVER 320 338
392
Romania (1982)
CANDU 6
Slovakia (1958)
Bulgaria (1970)
VVER 270
VVER 320
KS 150
VVER 230
VVER 213
Czech (1979)
VVER 213
VVER 320
Hungary (1974)
VVER 213
Slovenia (1975)
W 2 loop
SWTZ (1962)
W (2 loop)
BWR 6
PWR 3L
Spain (1964)
W1 3
BWR 3 6
PWR 3
Italy (1958)
MAGNOX
BWR 1 4
W (4 loop)
UNGG
CHOOZ A
PH 250
CP0 CP1 CP2
Super Phenix
REP 1300 1450
EPR
South Africa (1976)
W 3 loop

Davis (2012; JEP, p. 11): „70 years later …“

Table 3

Levelized Cost Comparison for Electricity Generation

	Levelized cost in cents per kWh		
Source	*Nuclear*	*Coal*	*Natural gas*
MIT (2009) baseline	8.7	6.5	6.7
Updated construction costs	10.4	7.0	6.9
Updated construction costs and fuel prices	10.5	7.4	5.2
With carbon tax of $25 per ton CO_2	10.5	9.6	6.2

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.

Looking back …
…no-one ever pretended nuclear was „economic“ …

MIT (2003): The Future of Nuclear Power

> **“In deregulated markets, nuclear power is not now cost competitive with coal and natural gas.” (p. 3)**

University of Chicago (2004):

> **“A case can be made that the nuclear industry will start near the bottom of its learning rate when new nuclear construction occurs. (p. 4-1) … “The nuclear LCOE for the most favorable case, $47 per MWh, is close but still above the highest coal cost of $41 per MWh and gas cost of $45 per MWh.” (p. 5-1)**

Parsons/Joskow (EEEP 2012)

> **“may be one day …”**

D’haeseleer (2013): Synthesis on the Economics of Nuclear Energy

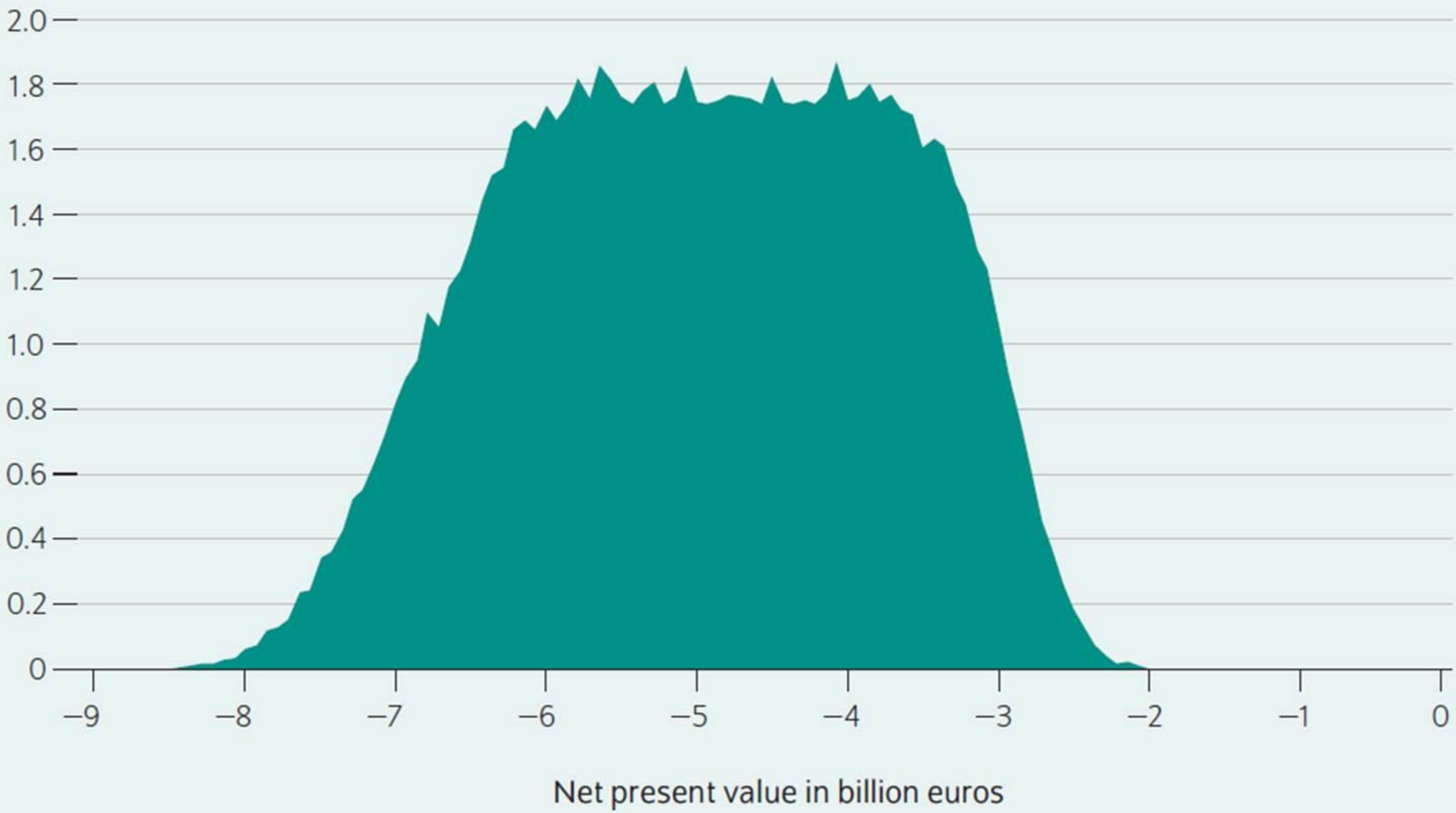
> **“Nuclear new build is highly capital intensive and currently not cheap, … it is up to the nuclear sector itself to demonstrate on the ground that cost-effective construction is possible.” (p. 3)**

Davis, L.W. (2012): Prospects for Nuclear Power. Journal of Economic Perspectives (26, 49–66))

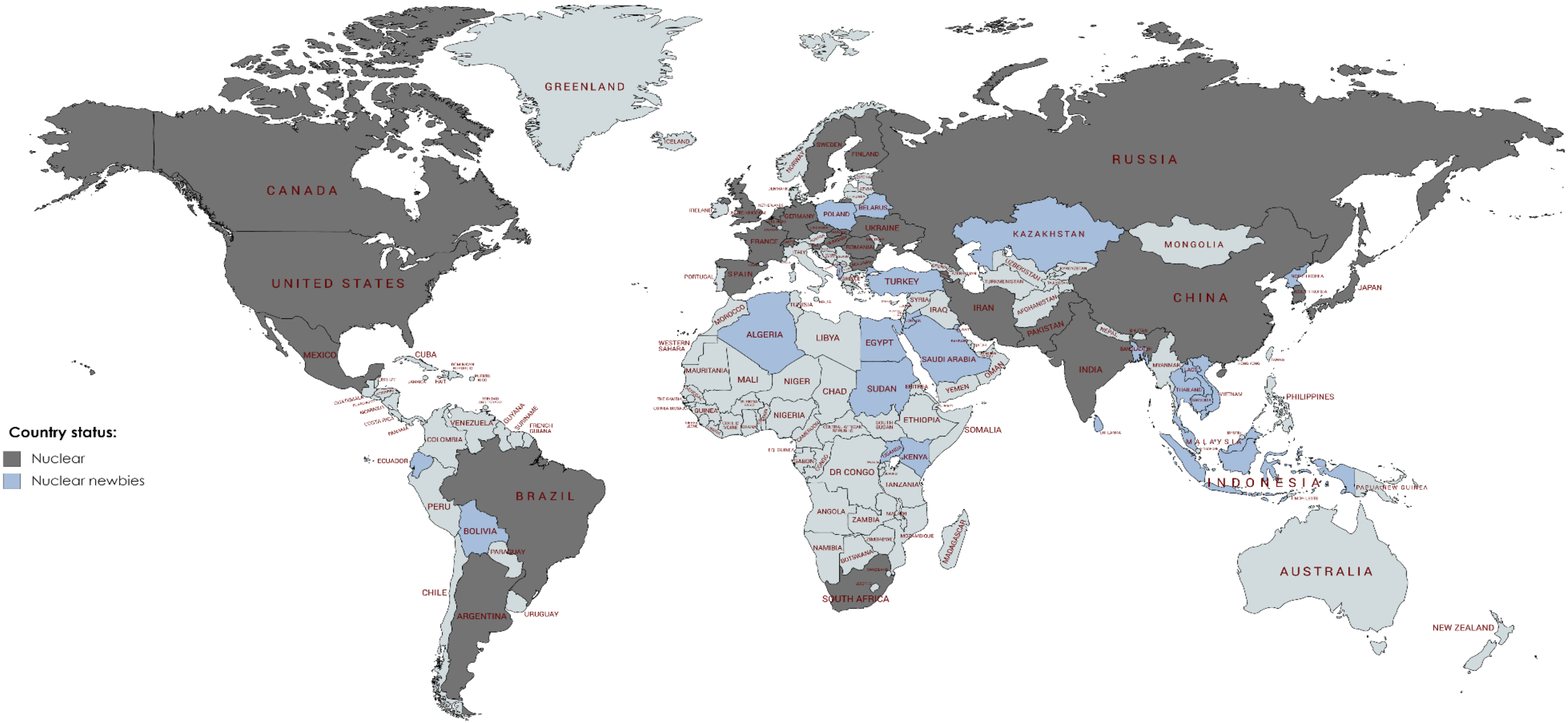
> **“These external costs are in addition to substantial private costs. In 1942, with a shoestring budget in an abandoned squash court at the University of Chicago, Enrico Fermi demonstrated that electricity could be generated using a self-sustaining nuclear reaction. <u>Seventy years later the industry is still trying to demonstrate how this can be scaled up cheaply enough to compete with coal and natural gas.“ (p. 63)</u>**

Results of the Monte Carlo simulation for the net present value of an exemplaric nuclear plant with 1000 megawatts

Probability density in percent



Global perspective on potential „nuclear newbies“ …



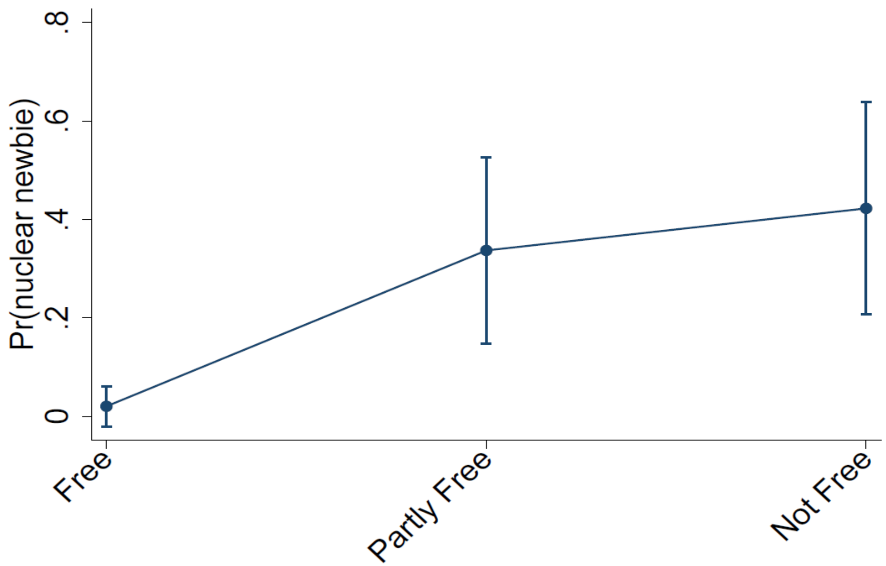
Notes: Countries not colored are considered as non-nuclear. ***Nuclear group:*** Argentina, Armenia, Belgium, Brazil, Bulgaria, Canada, China, Czech Republic, Finland, France, Germany, Hungary, India, Iran, Japan, Korea, Rep., Mexico, Netherlands, Pakistan, Romania, Russian Federation, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Ukraine, United Kingdom, and United States. ***Nuclear newbies group:*** Albania, Algeria, Bangladesh, Belarus, Bolivia, Cambodia, Ecuador, Egypt, Indonesia, Jordan, Kazakhstan, Kenya, Dem. People's Republic Of Korea, Kuwait, Lao PDR, Malaysia, Poland, Saudi Arabia, Sri Lanka, Sudan, Thailand, Turkey, Uganda, and Vietnam.

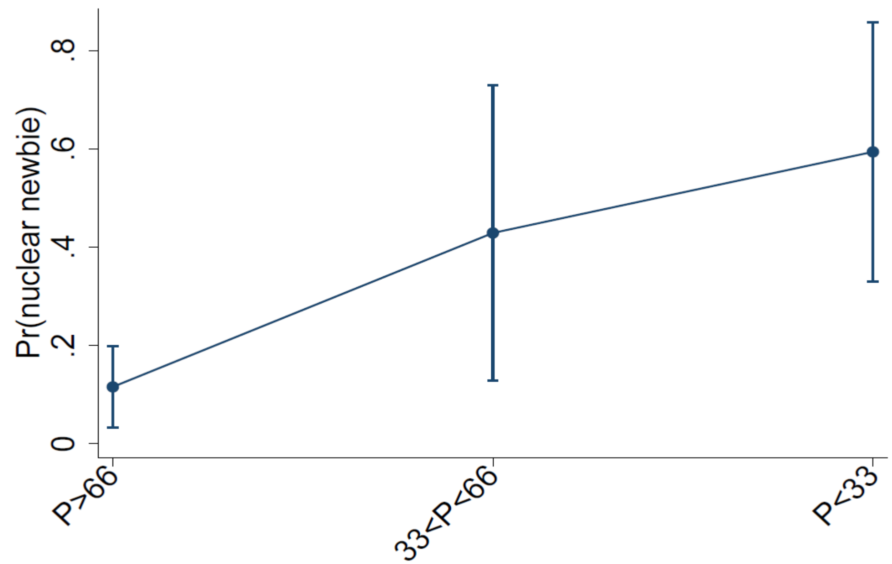
Sources: Wealer et al. (2018), World Nuclear Association (2018a), World Nuclear Association (2018b), and PRIS (2018).

… driven by everything but economics („nuclear diplomacy“)

Predicted probability of choosing the strategy “to go nuclear”, at each level of democratic freedom holding CO_2 and GDP at their means:

$$\hat{\pi}^{(\text{Nuclear Newbie})} = \frac{\exp(L^{(\text{Nuclear Newbie})})}{1+\exp(L^{(\text{Nuclear Newbie})})+\exp(L^{(\text{Nuclear Newbie})})}$$

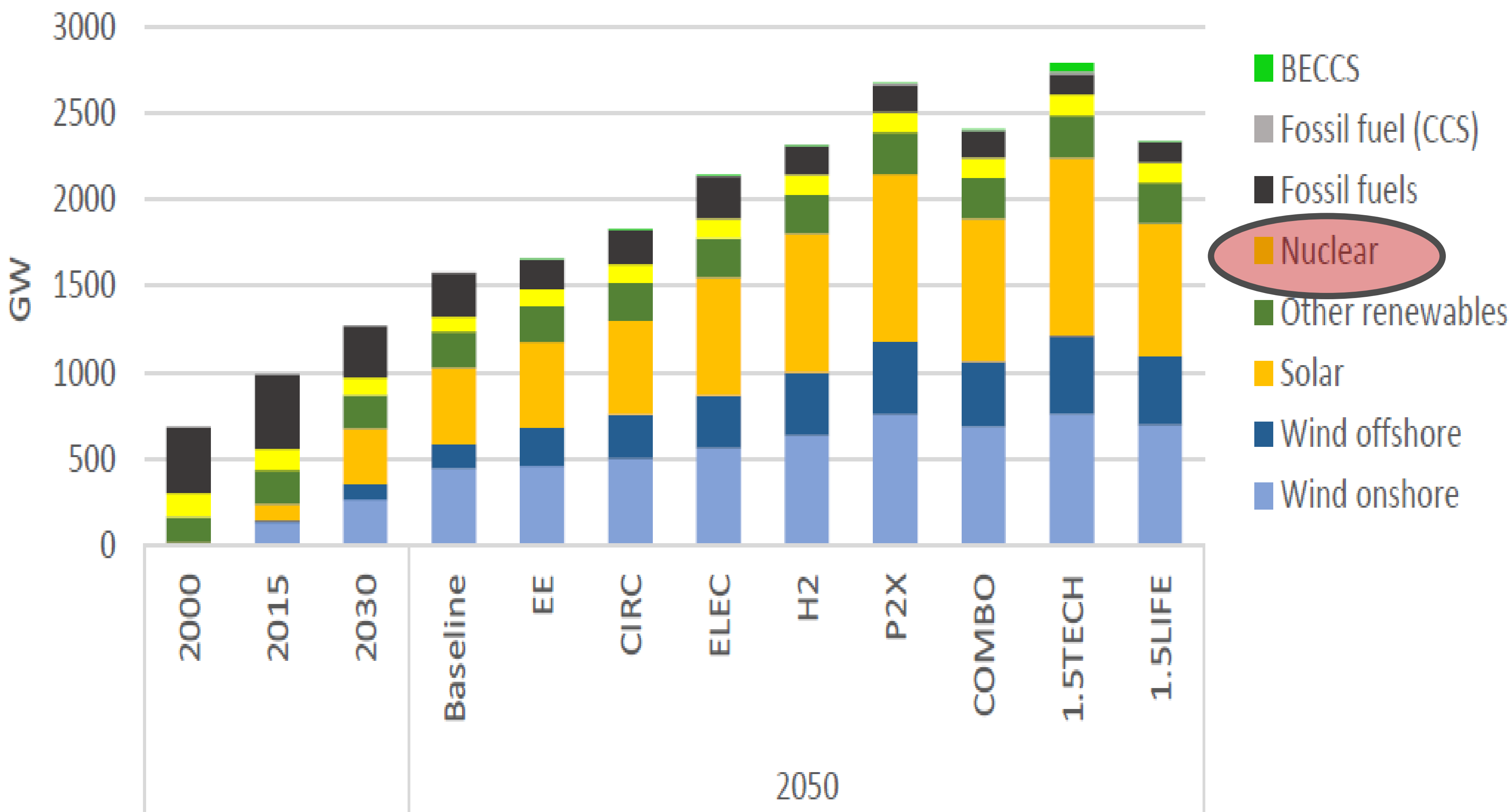




Notes: Left (right) plot indicates each level of the Freedom House (*POLITY™IV PROJECT*) indicator.

- The predicted probability of being in the Nuclear Newbies group (j=1) increases with decreasing levels of democratic freedom for both measures of democratic development.
- **Totalitarian countries tend to invest in future nuclear power development.**

The “Clean“ Energy Package, focus on electricity



EC (2018)

Agenda

1) Introduction: EEEP “Symposium on Scenarios and Modeling“

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

3) An example: The “Clean“ Energy Package

4) Conclusions

Conclusions

Climate and energy scenario are a controversial topic

Discussion currently focussing on the “technology-supply-side“

How to assess plausibility of behavioral changes etc.? (“singing and dancing”)

Considering demand-side mitigation

~ Demand-side measures not systematically represented in scenarios. Research focuses on supply-side (Creutzig et al. 2018).

~ Increasing energy efficiency is good, but not enough.

~ Have to start thinking of considering behavioral changes and societal transformations.

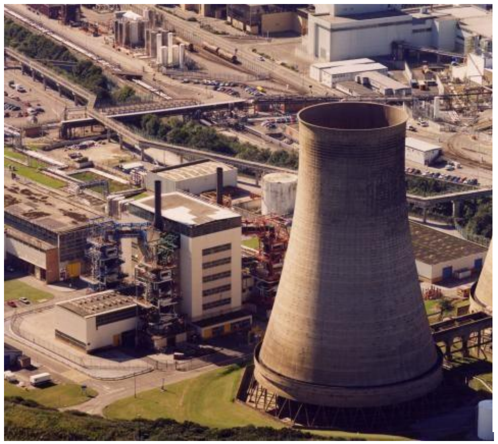
~ Need to engage in “messy business of socioeconomic scenario building” (Beck and Mahony 2018, 4).

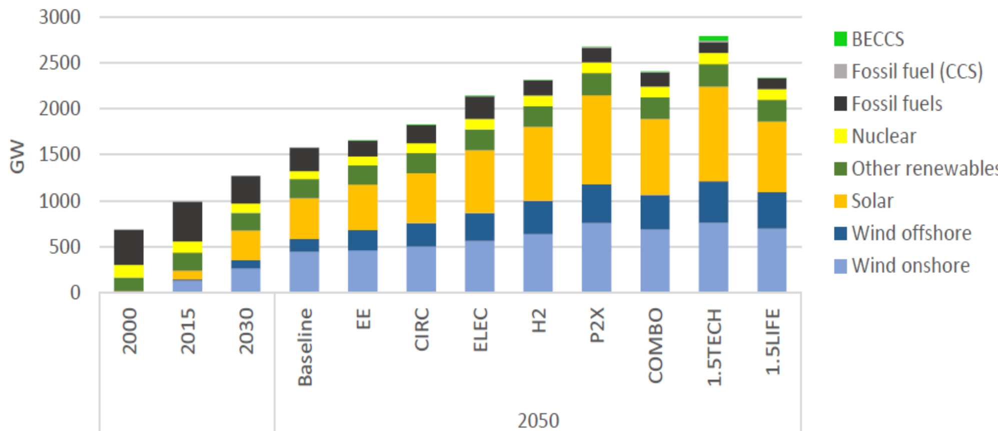
Transparency and open-data-open-code is important

… and lots of work to do…

IAEE European, Ljubljana (Slovenia)

August, 28, 2019





Energy Scenarios, Projections, and Modeling ("Academic approach"):

Case of the "Clean European Energy Package"

Christian von Hirschhausen

based on joint research with colleagues mentioned …

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