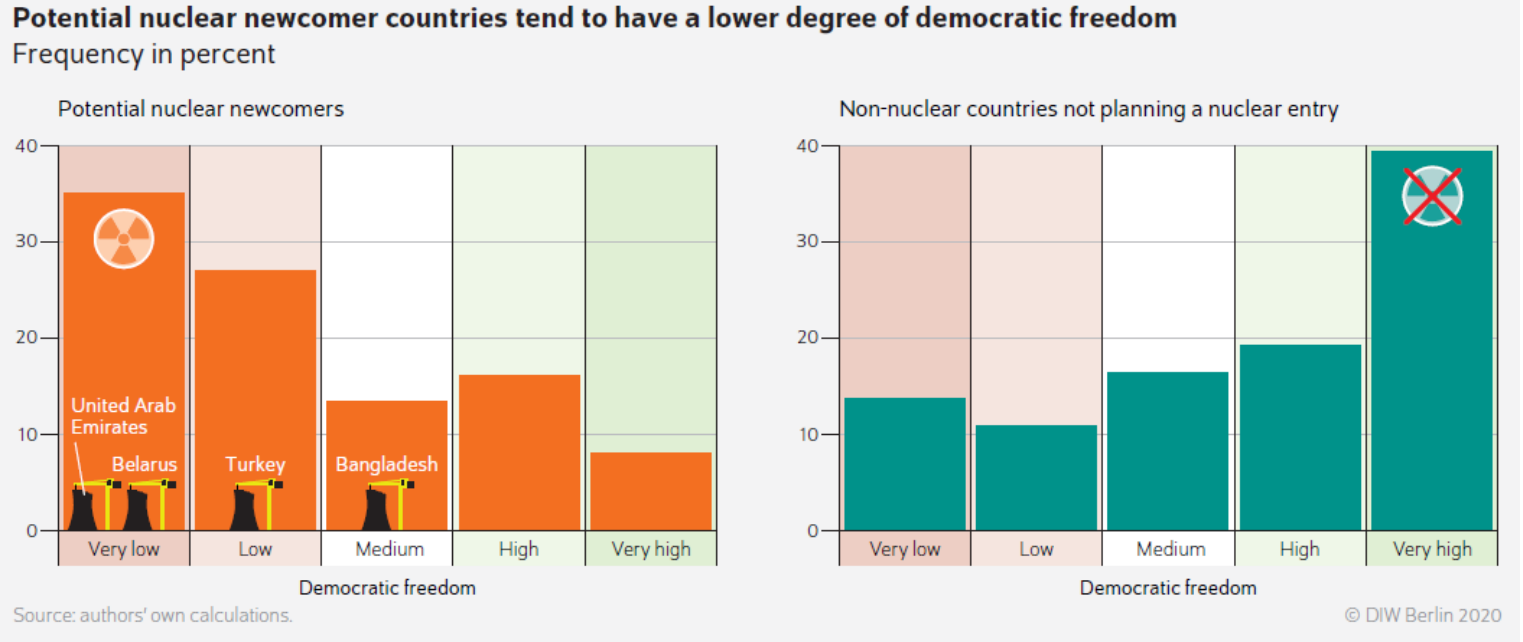
Reform Meeting, 25. August 2020

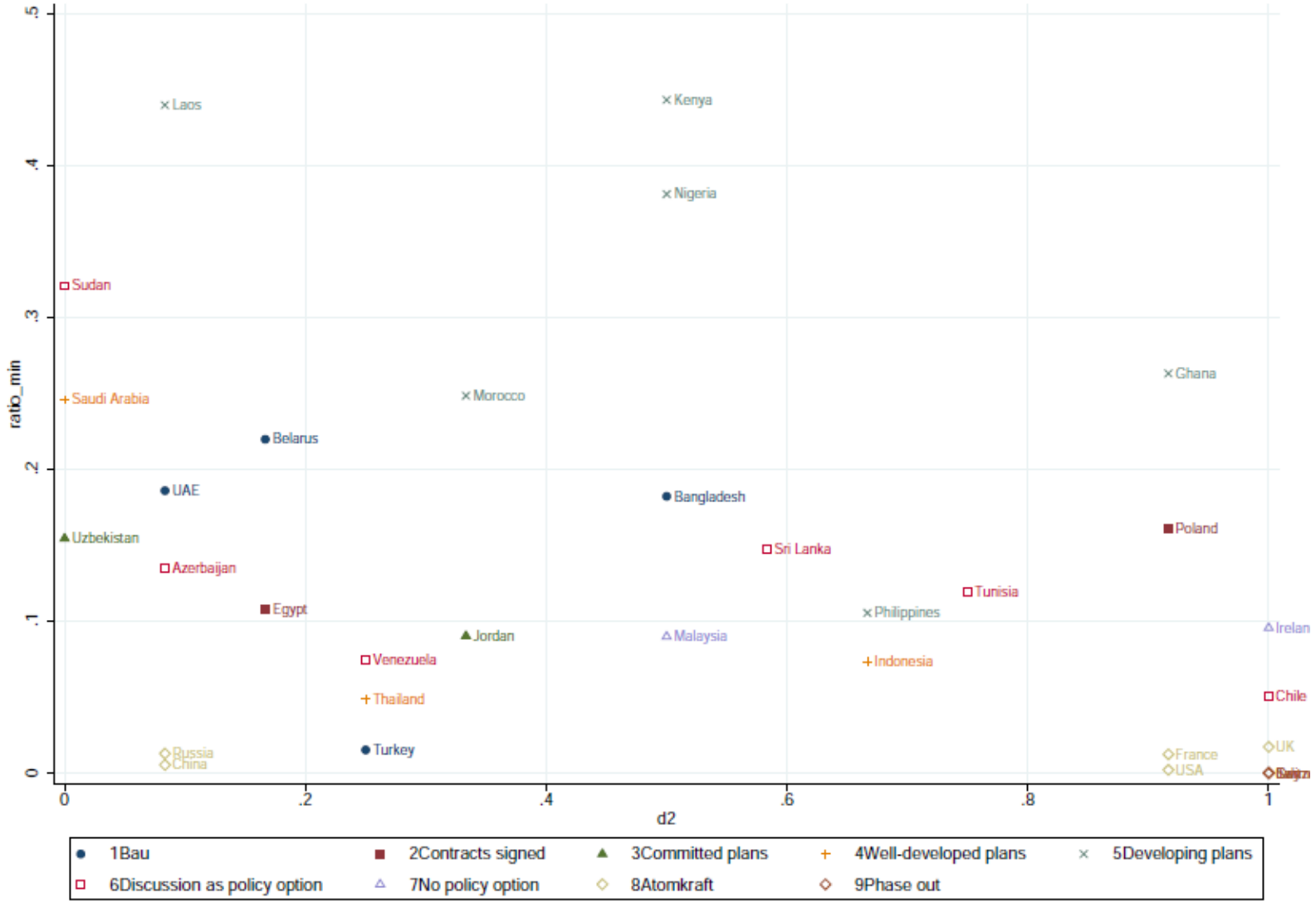


Nuclear power, democracy, and nuclear diplomacy

(or: “Who wants yesterday’s nuclear plants?)

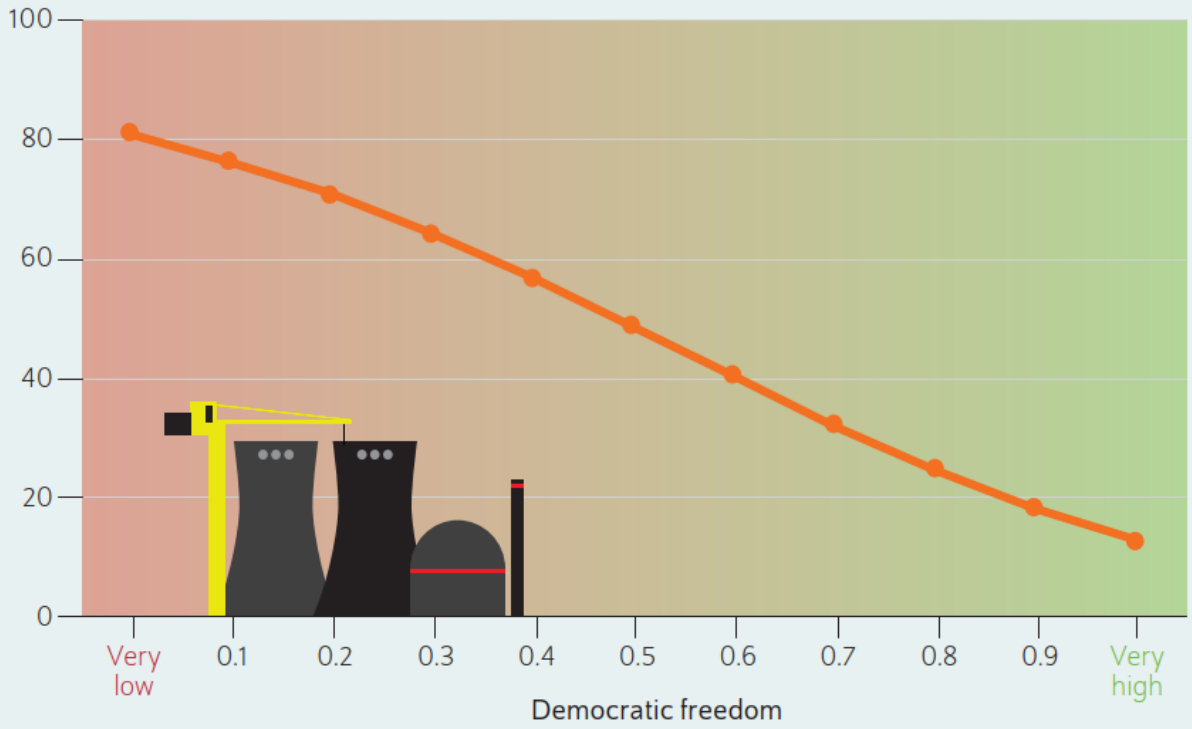
Christian von Hirschhausen, Claudia Kemfert, Lars Sorge, Ben Wealer

Democratic freedom and nuclear expansion – First sketch



Predicted probabilities for membership in the group of potential nuclear newcomers

In percent



Reading example: a value of zero for a country indicates the lowest level of democratic freedom; a value of one indicates the highest level. If the level of democratic freedom in a country is 0.5, the predicted probability of being classified as a potential newcomer to nuclear power is about 50 percent.

Source: authors' own calculations based on sources described in the box.

The extent of democratic freedom tends to be low in countries classified as nuclear newcomers.

Agenda

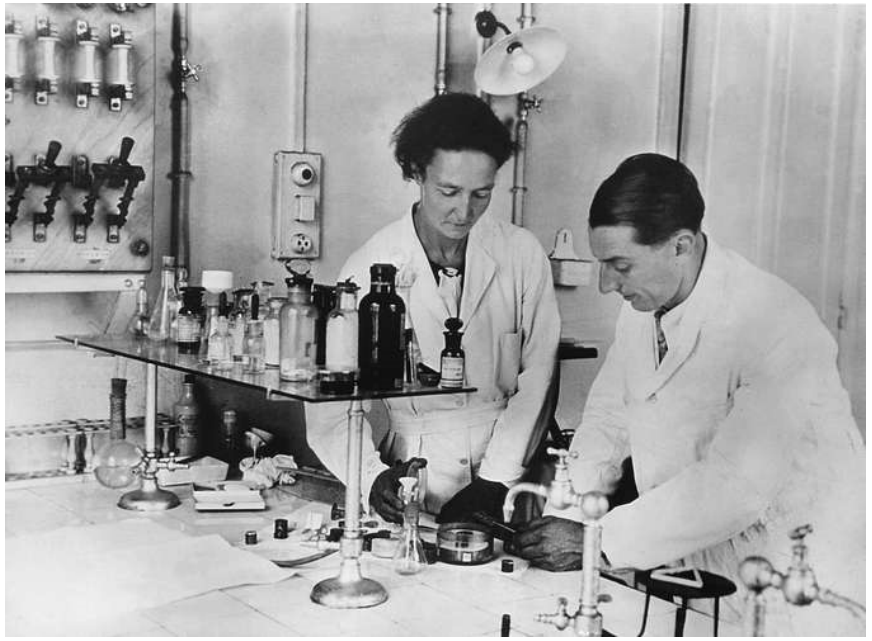
1) Introduction

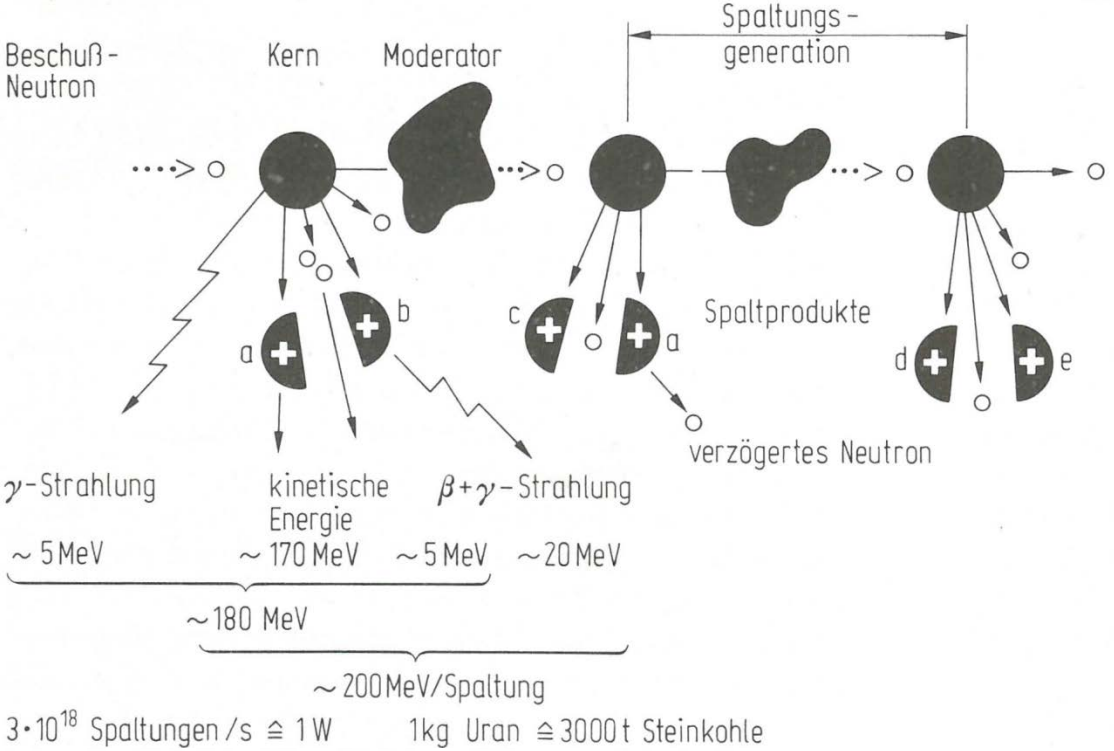
2) Demand and democracy

3) Supply and nuclear diplomacy

4) Conclusions

Francois Lévêque (2012): „Nuclear power is the child of science and warfare“





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

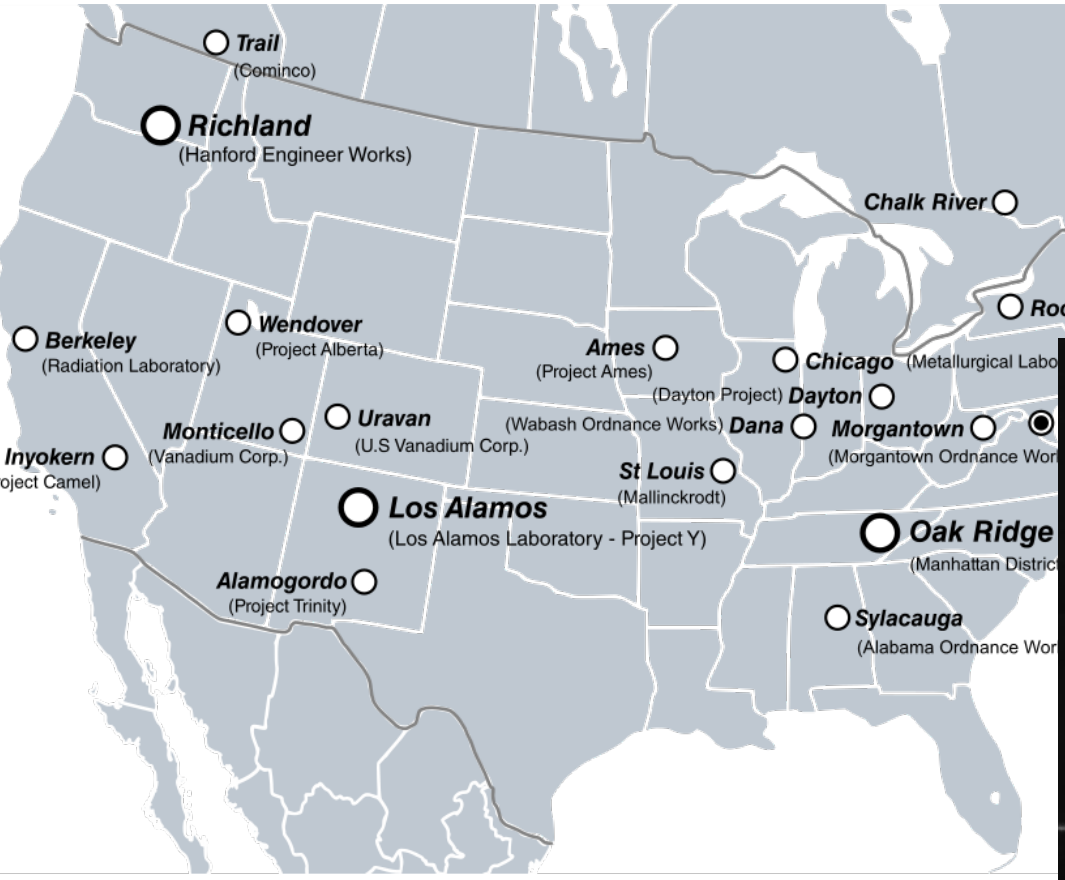
$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{236}_{92}U \rightarrow {}^{89}_{36}Kr + {}^{144}_{56}Ba + 3\,{}^{1}_{0}n$$

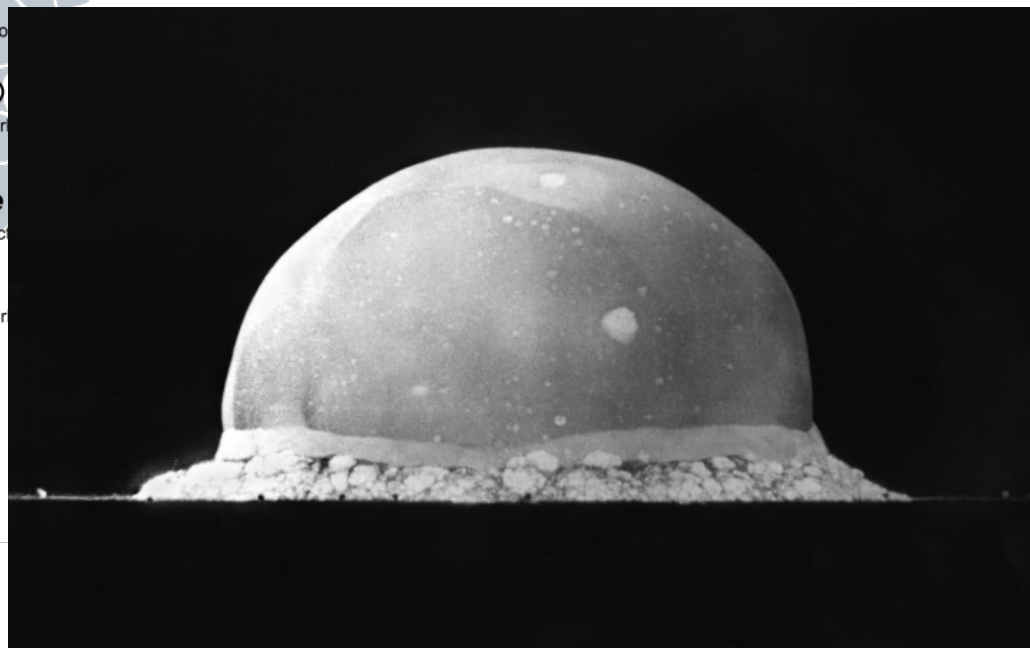
Ausgangskern (Spaltstoff)	thermisches Neutron 2000 m/s	kurzlebiges Zwischenprodukt	hier Krypton	hier Barium	3 Neutronen

(als Beispiel häufiger Spaltprodukte)

Manhattan Project (1942 – 1946): Science … and military warfare

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





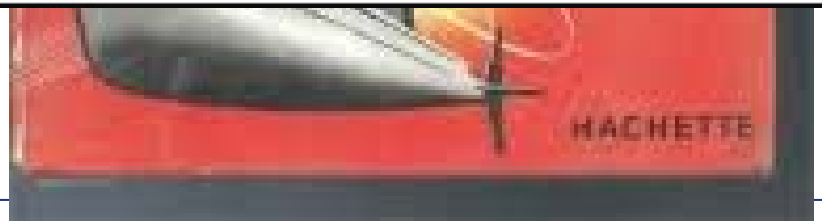
First nuclear bomb: Trinity-Test, July 16, 1945

The dream (1954) …

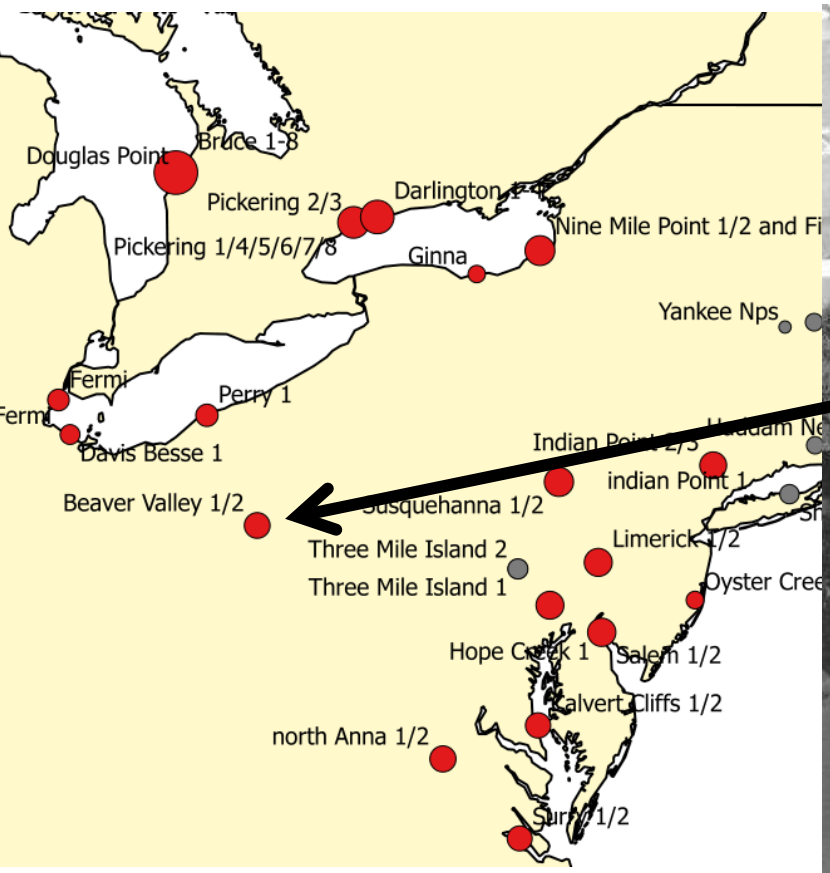
Our children will enjoy in their homes electrical energy too cheap to meter…will travel effortlessly over the seas and under them and through the air with a minimum of danger and at great speeds, and will experience a lifespan far longer than ours, as disease yields and man comes to understand what causes him to age.

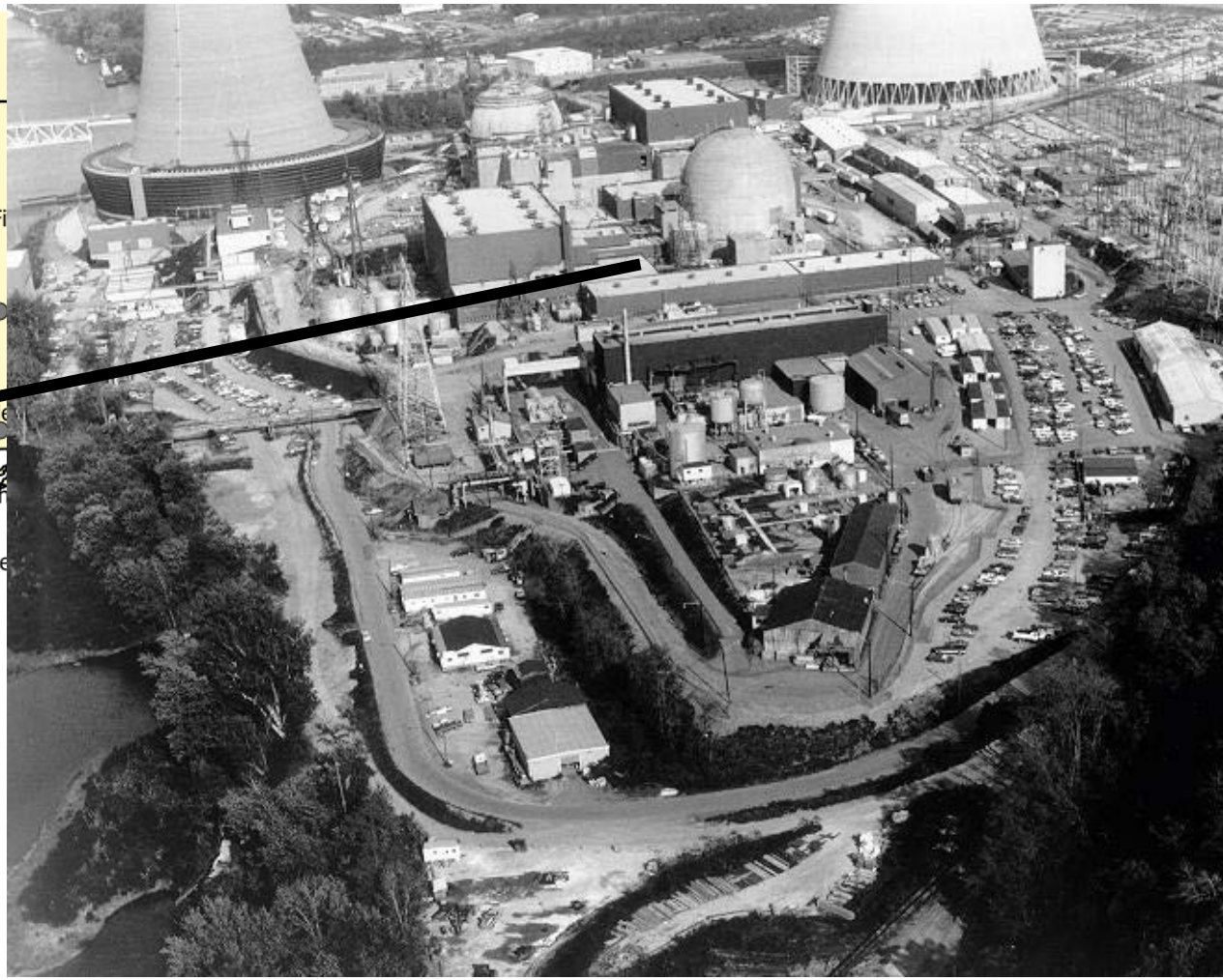
— Lewis Strauss —

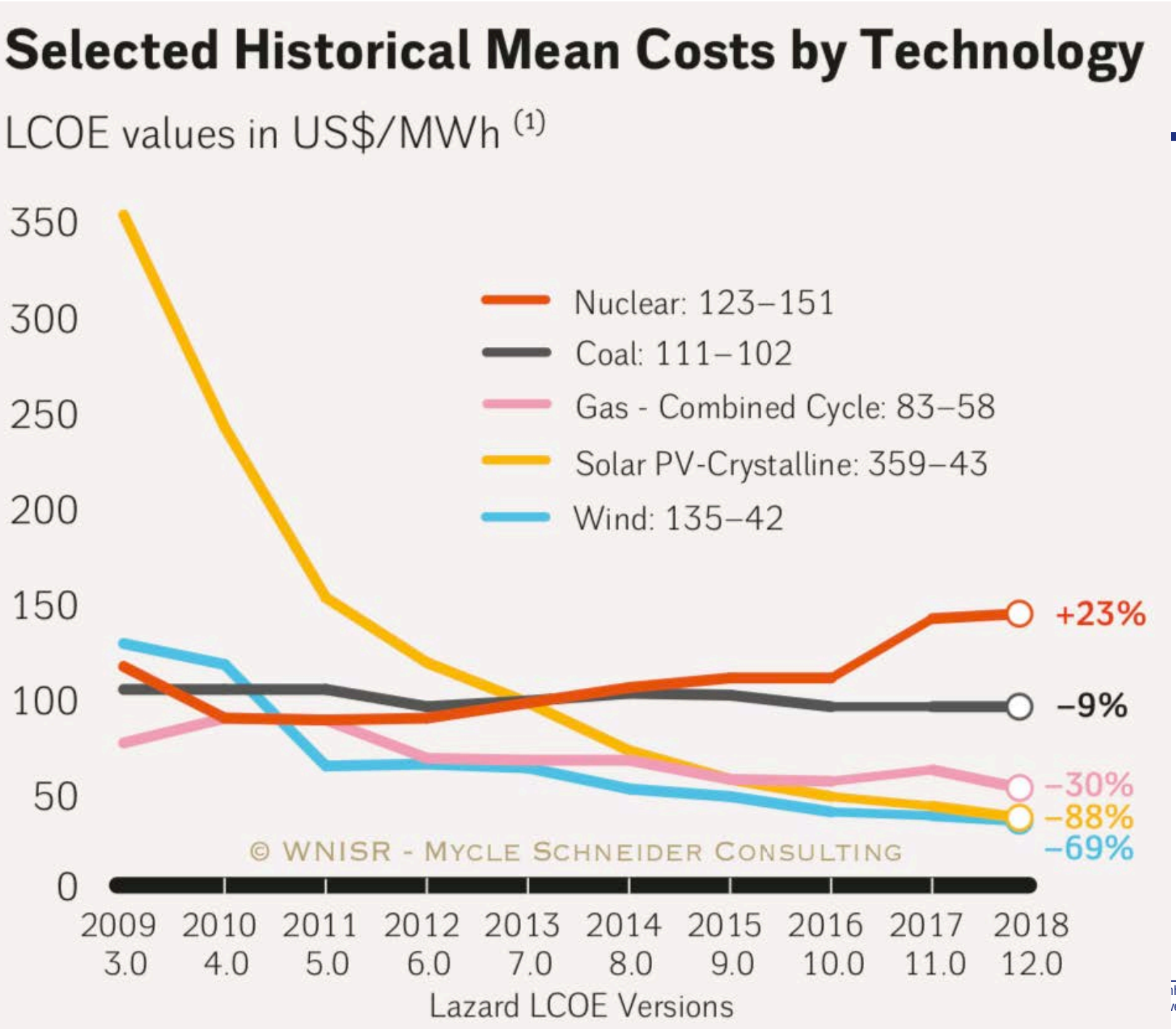
AZ QUOTES

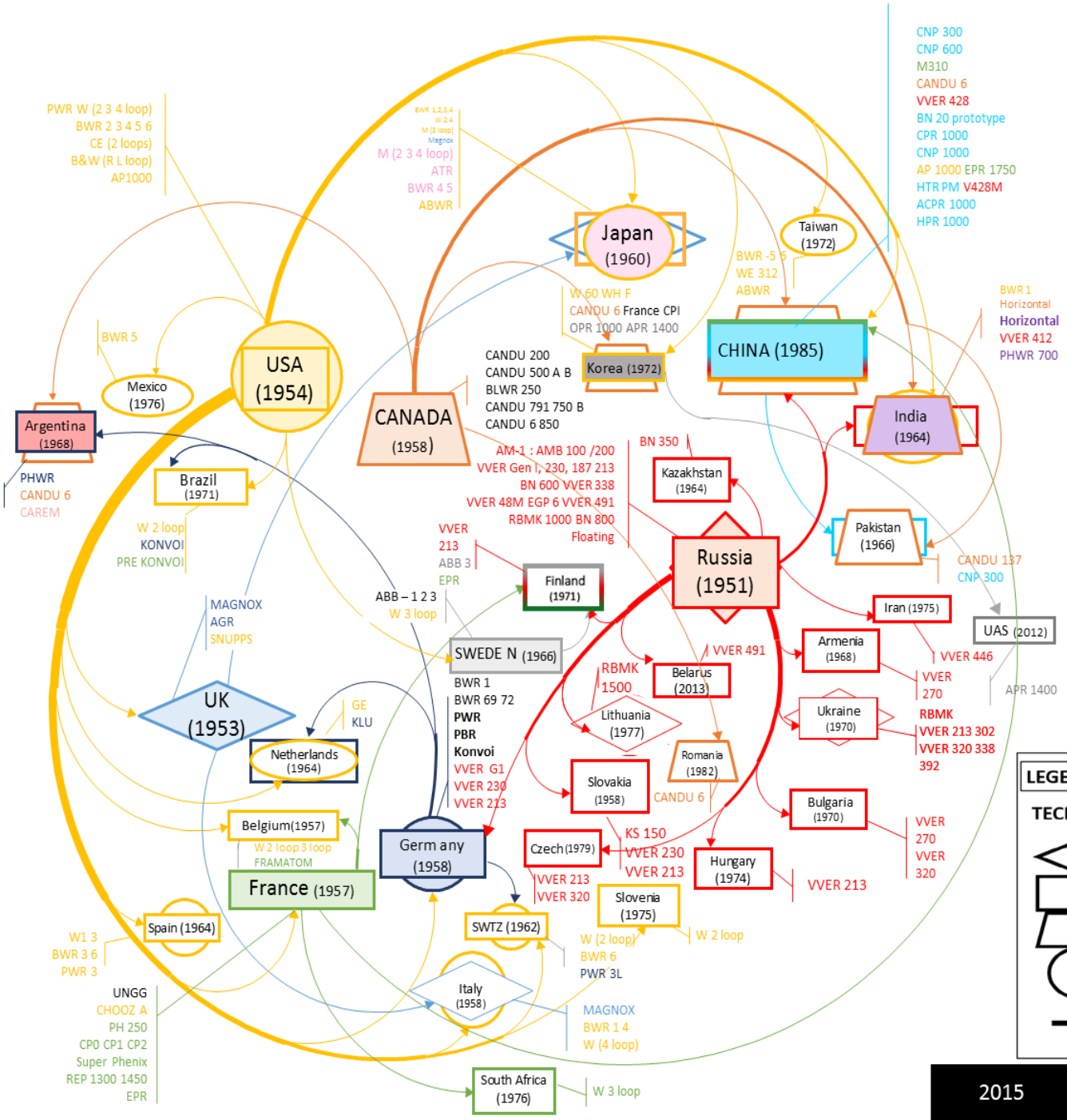


… destroyed in … 1957: Shippingport, first „commercial pilot reactor“: 8 times more expensive than the competitors (Radkau, 1983)






Selected Historical Mean Costs by Technology
LCOE values in US$/MWh (1)
350
300
250
200
150
100
50
0
Nuclear: 123–151
Coal: 111–102
Gas - Combined Cycle: 83–58
Solar PV-Crystalline: 359–43
Wind: 135–42
+23%
–9%
–30%
–88%
–69%
© WNISR - MYCLE SCHNEIDER CONSULTING
2009 3.0
2010 4.0
2011 5.0
2012 6.0
2013 7.0
2014 8.0
2015 9.0
2016 10.0
2017 11.0
2018 12.0
Lazard LCOE Versions



Period 4, post-Fukushima (2011) :

- Implosion of nuclear power in Wester economies (i.e. closure of reactors, abandonment of new build projects).
- This leaves the development of nuclear power to “other”, non-market systems, where countries hang on to nuclear development, for political, military-strategic, or other reasons.
- Increased use of “nuclear diplomacy”
- Major nuclear superpowers are China and Russia.

LEGEND:

TECHNOLOGIES :

- Graphite moderated (GMR)
- Pressurized Water (PWR)
- Heavy Water (HWR)
- Boiling Water (BWR)
- Transfer of technology

COUNTRIES:

Name of the Country — Spain (1964) — installed Technologies

W1
BWR 3
Types of reactors present

Construction start of the first reactor

TRANSMISSION :

Country who bought the red technology | Country who designed the red technology

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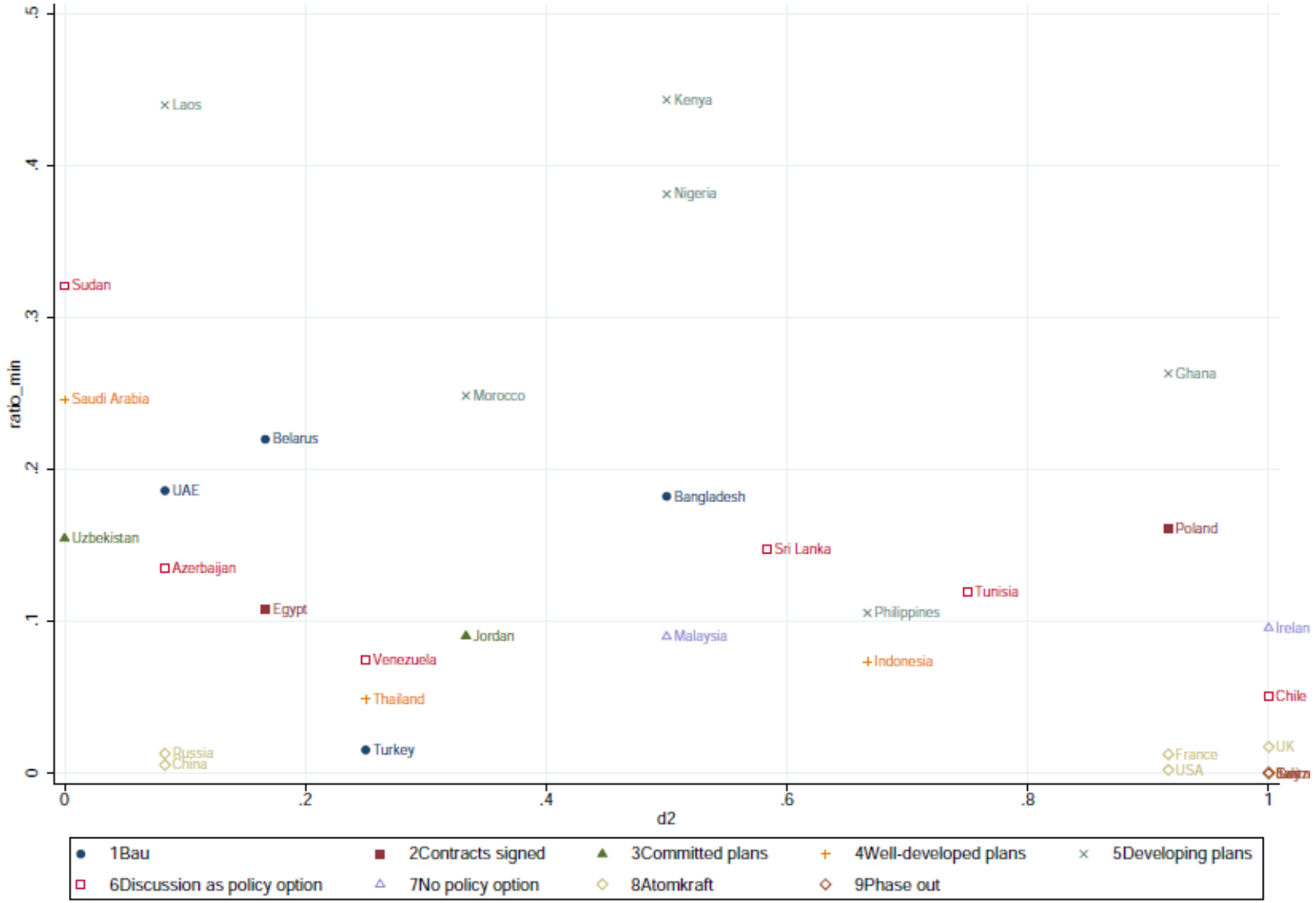
Motivation

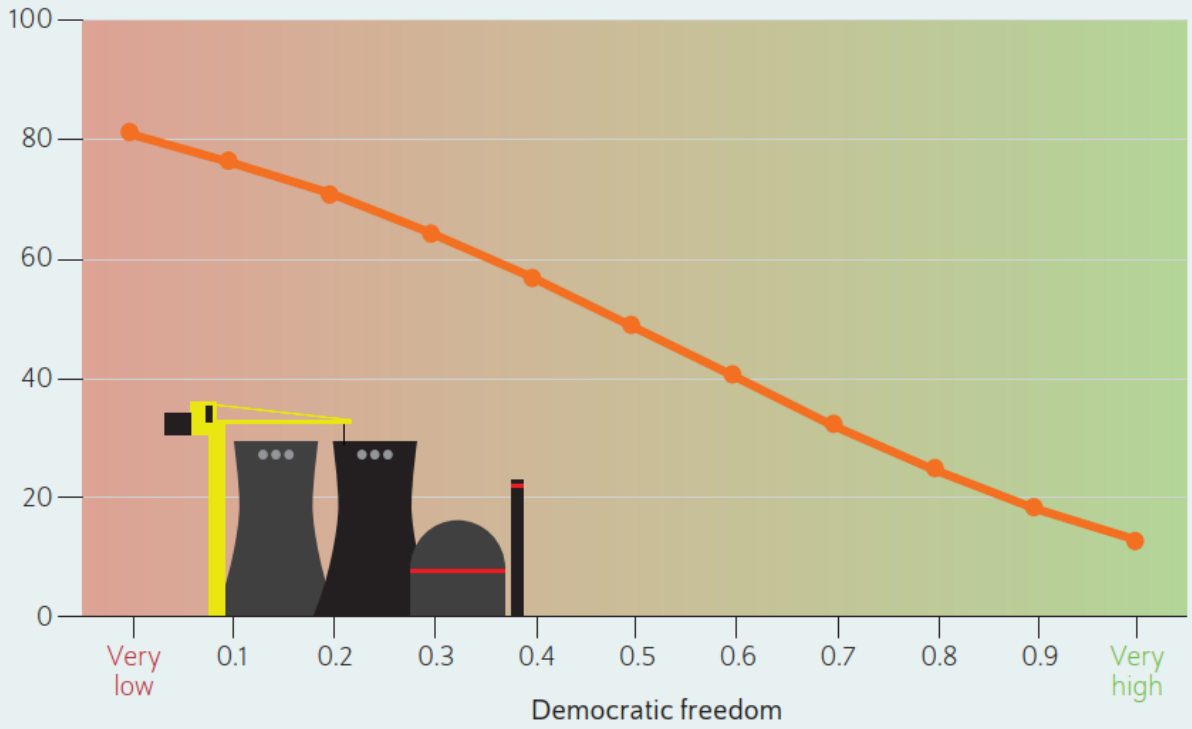
- About thirty countries are considering, planning or starting nuclear power (World Nuclear Association, 2019).
- The IAEA considers a high global potential for nuclear power up to the year 2050 (International Atomic Energy Agency, 2017).
- State-owned nuclear companies in Russia and China provide nuclear power plants to emerging countries at very favorable conditions including finance and fuel services (World Nuclear Association, 2019; Schneider et al., 2018).
- Identification of potential nuclear entrants: existence of civil nuclear cooperation agreements with with state-owned nuclear.

Democratic freedom and nuclear expansion – First sketch



Predicted probabilities for membership in the group of potential nuclear newcomers

In percent

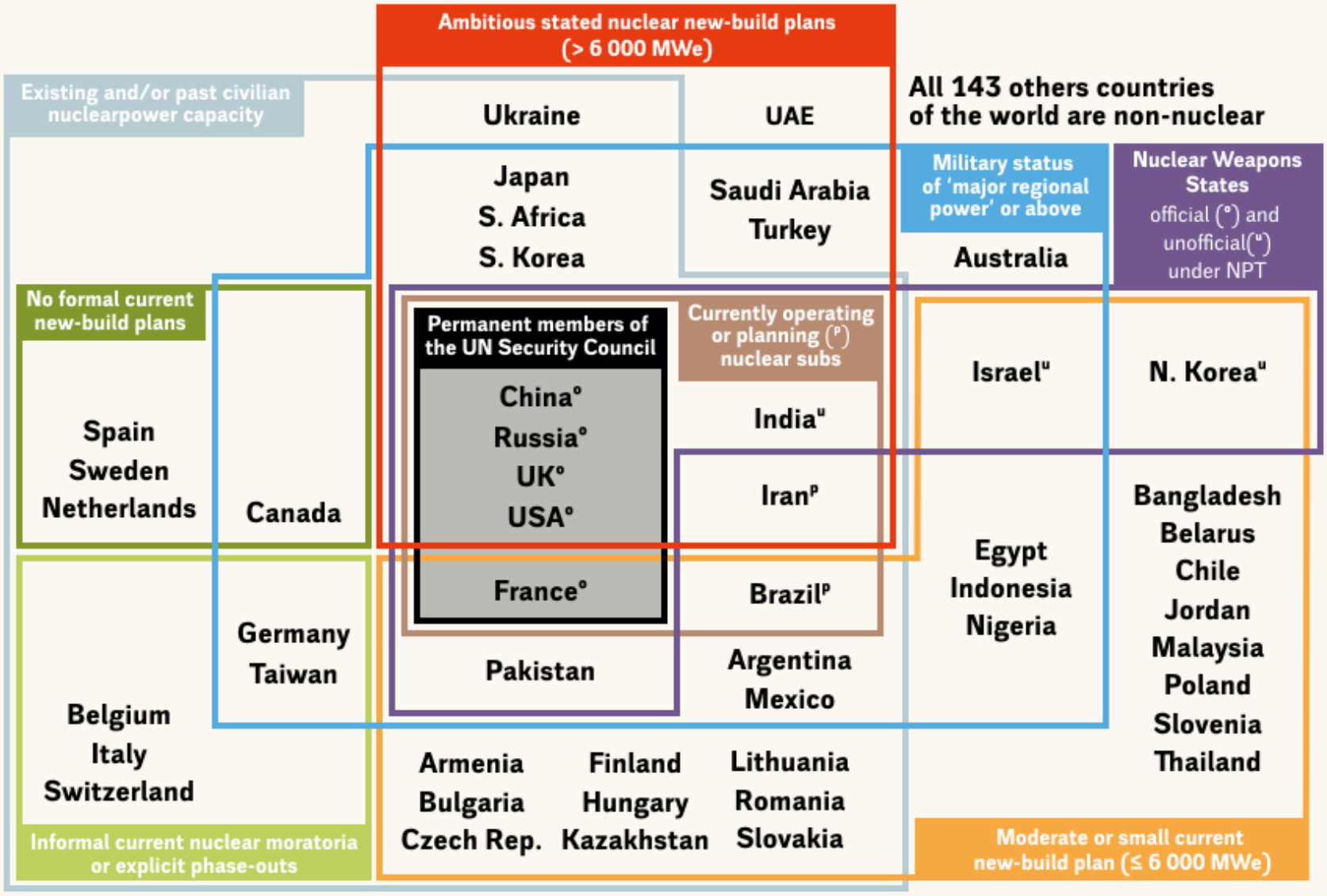


Reading example: a value of zero for a country indicates the lowest level of democratic freedom; a value of one indicates the highest level. If the level of democratic freedom in a country is 0.5, the predicted probability of being classified as a potential newcomer to nuclear power is about 50 percent.

Source: authors' own calculations based on sources described in the box.

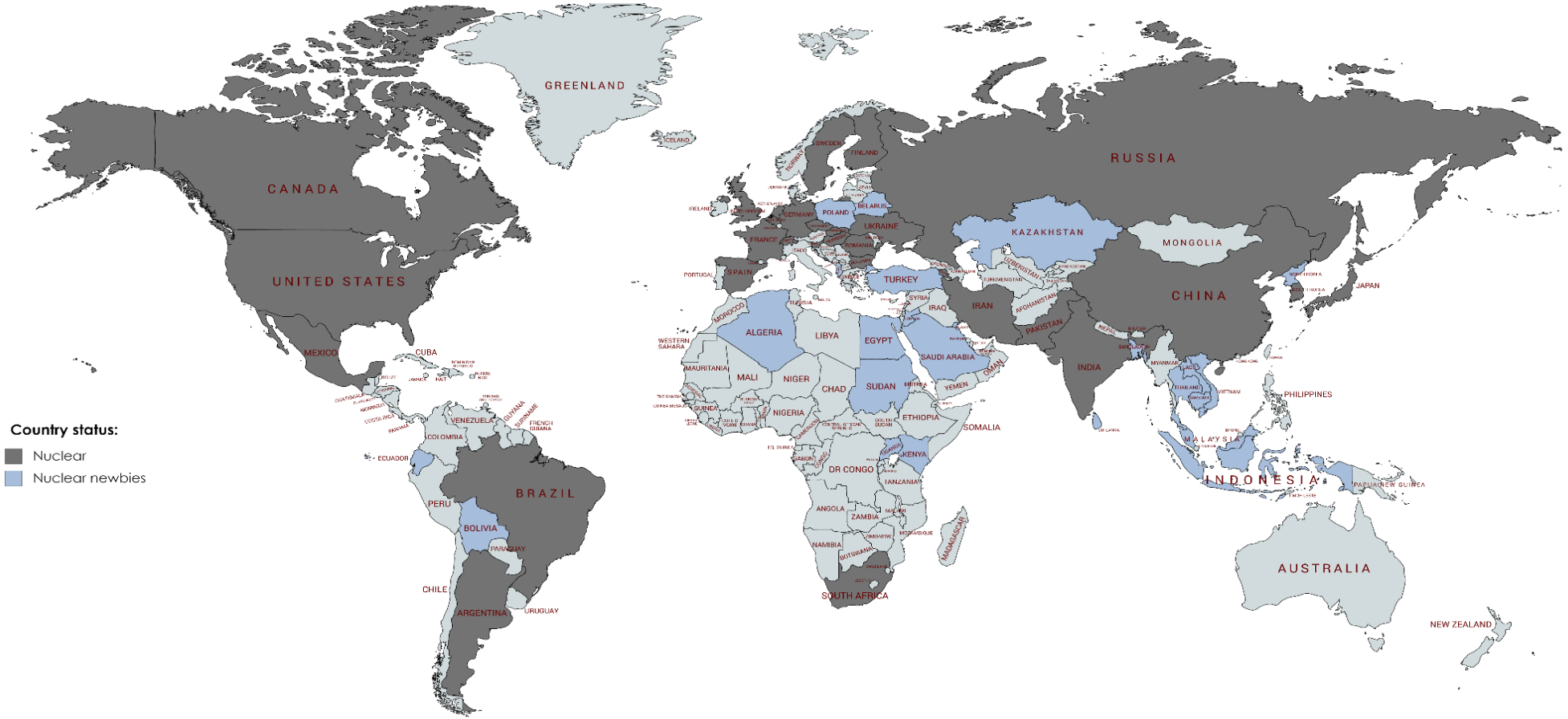
The extent of democratic freedom tends to be low in countries classified as nuclear newcomers.

Circumstantial Relationships Between WNA-Reported Civil Nuclear Ambitions and Different Categories of International Military and Geopolitical Status



Source: Andy Stirling, Phil Johnstone, WNISR 2018

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).

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journal homepage: www.elsevier.com/locate/erss

Democratic quality and nuclear power: Reviewing the global determinants for the introduction of nuclear energy in 166 countries☆

Anne Neumann[a,c], Lars Sorge[*,b,c], Christian von Hirschhausen[b,c], Ben Wealer[b,c]

[a] NTNU Trondheim, Norway
[b] DIW Berlin, Germany
[c] Berlin University of Technology, Germany

DIW Weekly Report 11 2010

AT A GLANCE

Nuclear Power Worldwide: Development Plans in Newcomer Countries Negligible

By Lars Berge, Claudia Kemfert, Christian von Hirschhausen, and Ben Wealer

- An analysis of current decommissioning and new construction projects reveals a downward trend in nuclear power worldwide
- Only four newcomer countries are currently constructing nuclear power plants and all are plagued by financial difficulties and delays
- An econometric analysis suggests that countries classified as potential newcomers tend to be less democratic
- On the supply side, the dominant driving force is the geopolitical interests of countries that export nuclear power

Literature Review

Analysis of potential nuclear entrants ("Nuclear-newbies")

- No clear consensus regarding defintion and amount of potential nuclear newcomers.
- Number of states potentially seeking initial nuclear power capabilities ranges from 14 to 52.
- Depending on the literature and publication date.

Literature Review II

- Gourley and Stulberg (2009): 40 countries.
- Adamantiades and Kessides (2009): more than 40 countries approached United Nations officials to express interest in starting nuclear power programs.
- Miller and Sagan (2009): 50 countries have requested technical assistance from the International Atomic Energy Agency (IAEA) to initialize nuclear energy programs.
- Jewell (2011): 52 countries which as of 2009 had an interest in building their first nuclear power plant.
- Gralla et al. (2017): 17 countries.

Literature Review III

World Nuclear Association (WNA):

- 55 countries as emerging nuclear energy countries.
- Seven categories which describe how far a countries' nuclear power programmes or plans have progressed:
  1. Power reactors under construction.
  2. Contracts signed, legal and regulatory infrastructure well-developed or developing.
  3. Committed plans, legal and regulartory infrastructure developing.
  4. Well developed plans but commitment pending.
  5. Developing plans; discussion as policy option.
  6. Discussion as policy option.
  7. Officially not a policy option at present.
- Identification of potential nuclear entrants: existence of civil nuclear cooperation agreements with with state-owned nuclear.

Classification of countries how far their nuclear power programs or plans have progressed according to the World Nuclear Association (WNA)

Category	WNA classification	Countries
1	*Power reactors under construction*	Bangladesh, Belarus, Turkey, United Arab Emirates (UAE)
2	*Contracts signed, legal and regulatory infrastructure well-developed or developing*	Egypt, Poland
3	*Committed plans, legal and regulatory infrastructure developing*	Jordan, Uzbekistan
4	*Well-developed plans but commitment pending/deferred*	Indonesia, Kazakhstan, Lithuania (deferred), Saudi Arabia, Thailand, Vietnam (deferred)
5	*Developing plans*	Algeria, Ethiopia, Ghana, Kenya, Laos, Marocco, Nigeria, Philippines, Rwanda
6	*Discussion as policy option*	Albania, Azerbaijan, Bolivia, Chile, Croatia, Cuba, Estonia, Israel, Latvia, Libya, Mongolia, Namibia, Paraguay, Peru, Qatar, Serbia, Singapore, Sri Lanka, Sudan, Syria, Tunesia, Venezuela
7	*Officially not a policy option at prsesent*	Albania, Australia, Cambodia, Ireland, Kuwait, Malaysia, Myanmar, New Zealand, Norway, Portugal, Qatar, Rwanda, Syria, Tanzania, Zambia

Note: Albania, Qatar, Rwanda, and Syria are listed in both the seventh and fifth or sixth category, respectively.

Source: World Nuclear Association, Emerging Nuclear Countries (2020) (available online).

Data

- Unbalanced cross-sectional data set covering 194 countries.
- Outcome ("nuclear energy strategy chosen") is based on observable characteristics from the WNA and contains three categories.

Specification of three categories which distinctively define a countries' nuclear energy strategy in 2019:

- Non-nuclear (0): countries with no nuclear power plant under construction or operational in 2019
- Nuclear (1): countries with at least one operational power plant in 2019
- Nuclear-newbie (2): countries which signed at least one civil nuclear cooperation agreement.

Predictor Variables

Democratic quality from Freedom House

- Independent organization which evaluates basic democratic rights considering political rights and civil liberties.
- Political rights and civil liberties measured on a one-to-seven scale (one is the highest degree of freedom and seven the lowest).
- Aggregated average of a country or territory's political rights and civil liberties ratings:
  - Free *F* (1.0 to 2.5).
  - Partly Free *PF* (3.0 to 5.0).
  - Not Free *NF* (5.5 to 7.0).
- Helliwell (1994): normalized index to run from 0 (no political rights and civil liberties) to 1 (complete set of political rights and civil liberties) *D*1.

Methodology I

- Multinomial logistic regression: predict categorical placement in or the probability of category membership based on independent variables.
- Response variable: nuclear energy strategy chosen.
  - not using nuclear at all ($j = 0$, "non-nuclear"), one nuclear power plant fully operational ($j = 1$, "nuclear"), and signed at least one civil nuclear cooperation agreement ($j = 2$, "nuclear-newbie").

Log-odds ratio that country i will fall in response category j relative to the reference category J is assumed to follow a linear model:

$$\eta_{ij} = \log\left(\frac{\pi_i^{(j)}}{\pi_i^{(J)}}\right) = \alpha^{(j)} + \beta_1^{(j)} X_{1i} + \ldots + \beta_k^{(j)} X_{ki}, \qquad (1)$$

where π_i is the probability for outcome j in the $i = 1, \ldots, n$ countries, $\alpha^{(j)}$ is a constant, and $\beta_1^{(j)}, \ldots, \beta_k^{(j)}$ are the k regression coefficients, for the $j = 1, \ldots, J-1$ outcomes. $X_{1i}, \ldots, X_{ki}$ are the k explanatory variables.

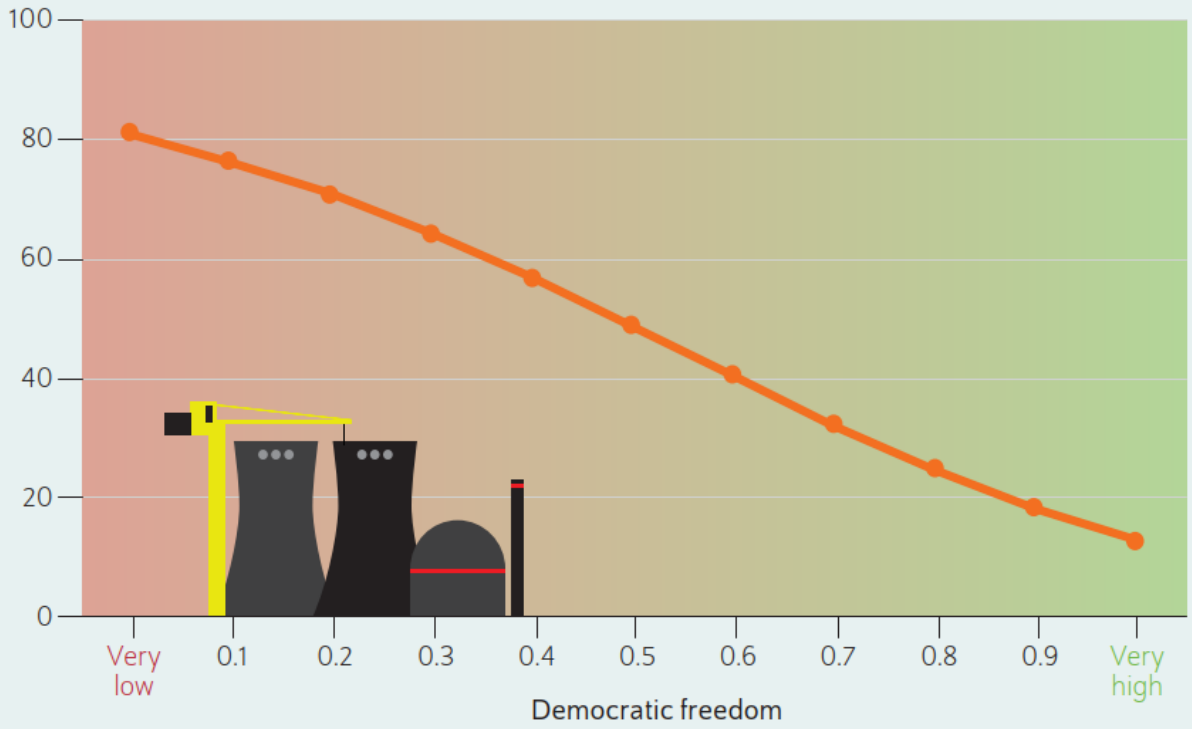
Results of the econometric estimation

Dependent variable: status of nuclear energy use

	Estimated coefficients (regression equation atomic states)		Estimated coefficients (regression equation potential nuclear newcomers)	
Variables	**Coefficient**	**Standard error**	**Coefficient**	**Standard error**
Democratic freedom	2.671	1.761	−2.512***	0.855
GDP per capita	−0.006	0.022	−0.014	0.022
Urbanization	0.006	0.023	0.002	0.014
Primary energy consumption	1.608**	0.742	0.347	0.685
Fossif fuel rents (percent of GDP)	−0.001	0.001	0.000	0.000
CO_2 emissions	−0.009	0.011	0.004	0.010
Share of renewables	−0.002	0.019	0.000	0.010
Soviet history	2.479***	0.783	0.198	0.710
Constant	−5.712***	1.951	−0.264	1.030
Observations	177			
Pseudo R^2	0.3927			

Predicted probabilities for membership in the group of potential nuclear newcomers

In percent



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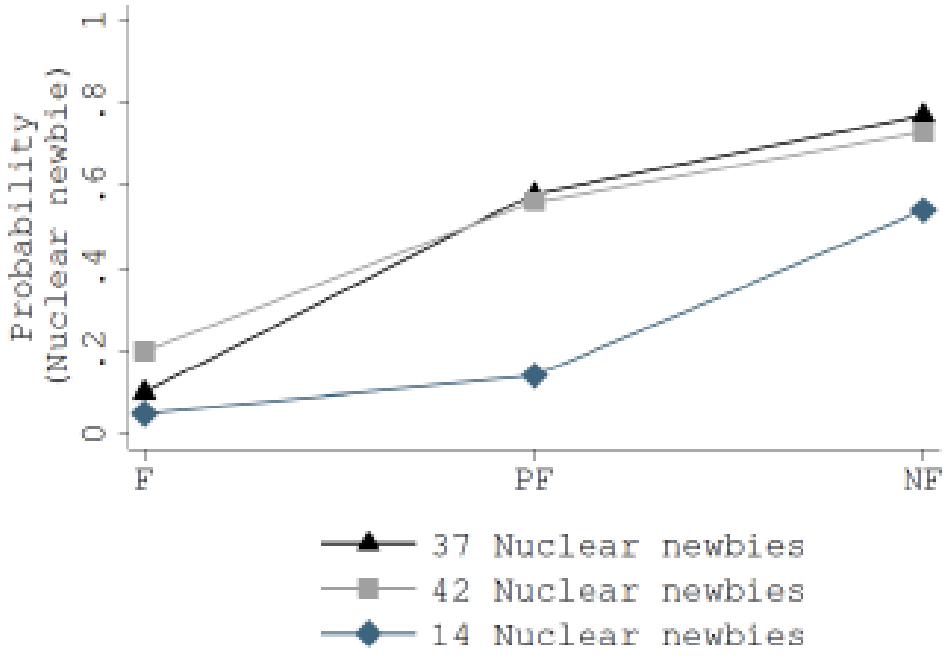
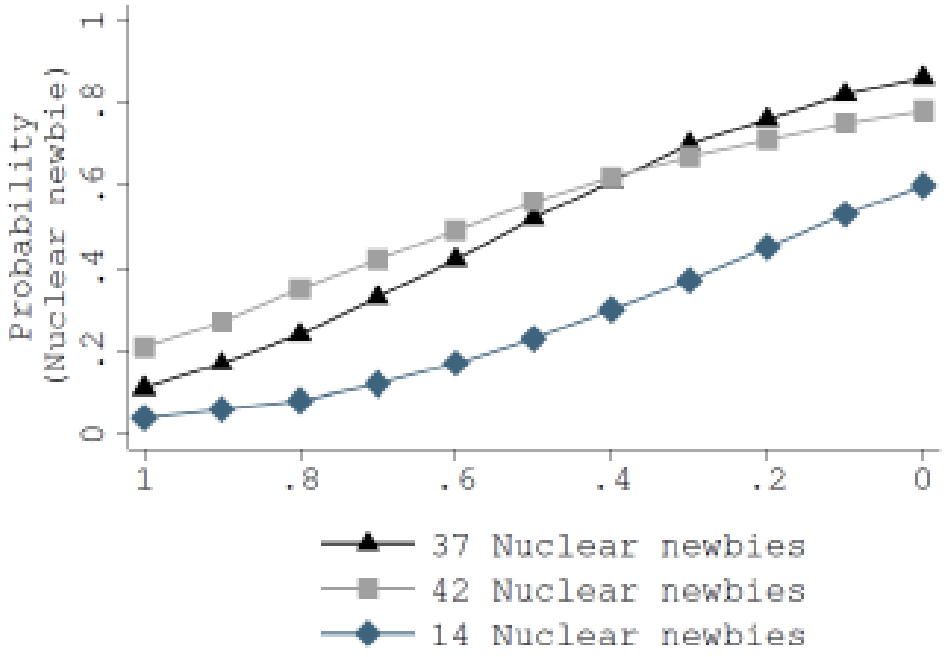
The extent of democratic freedom tends to be low in countries classified as nuclear newcomers.

Empirical Results IV

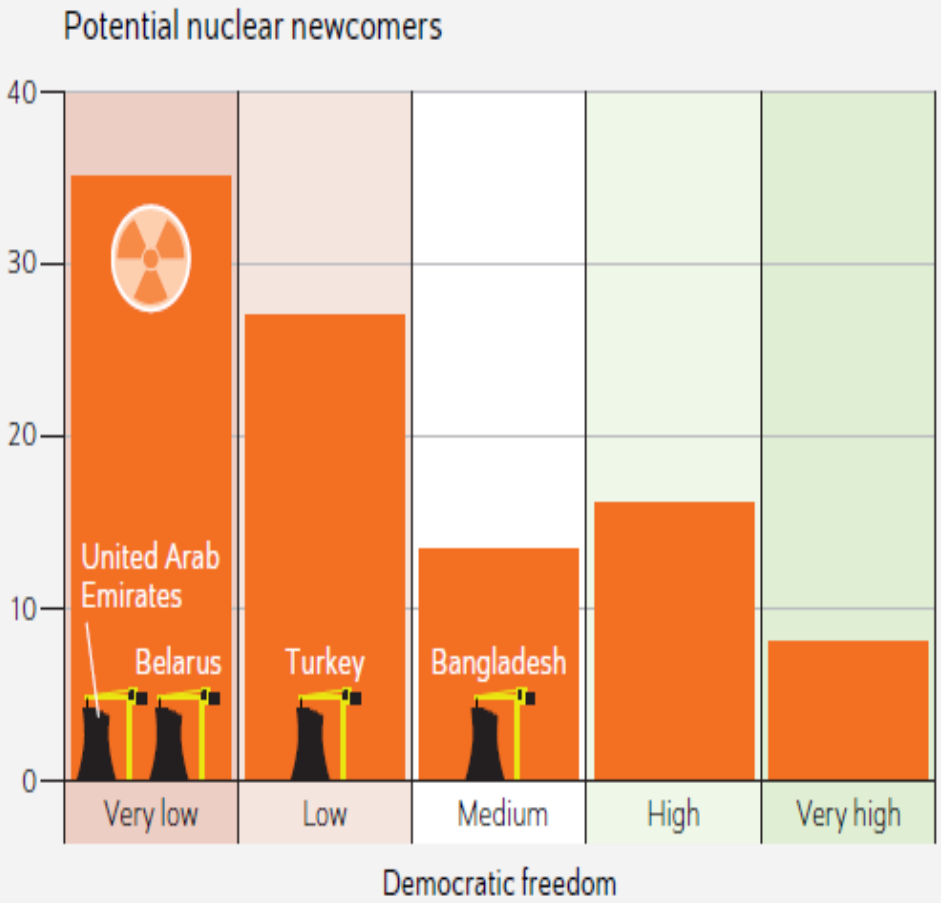
Figure 7: Adjusted predictions for group membership "nuclear newbie" by democratic quality

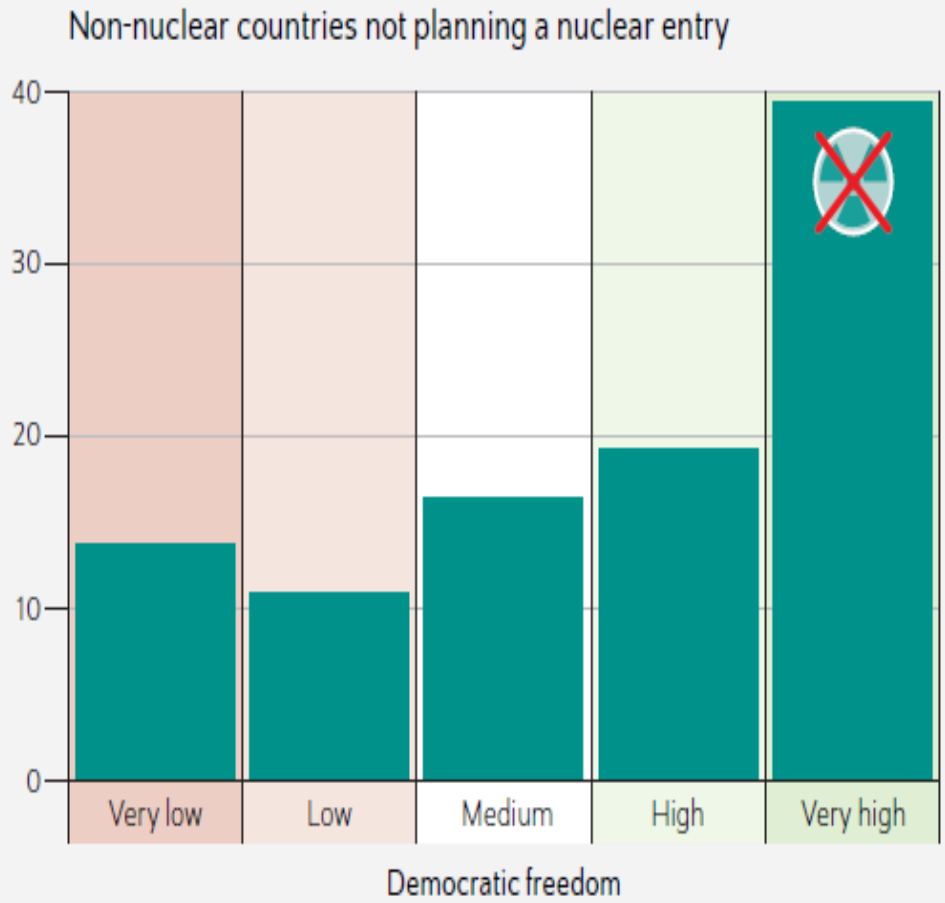




Potential nuclear newcomer countries tend to have a lower degree of democratic freedom

Frequency in percent





Source: authors' own calculations.

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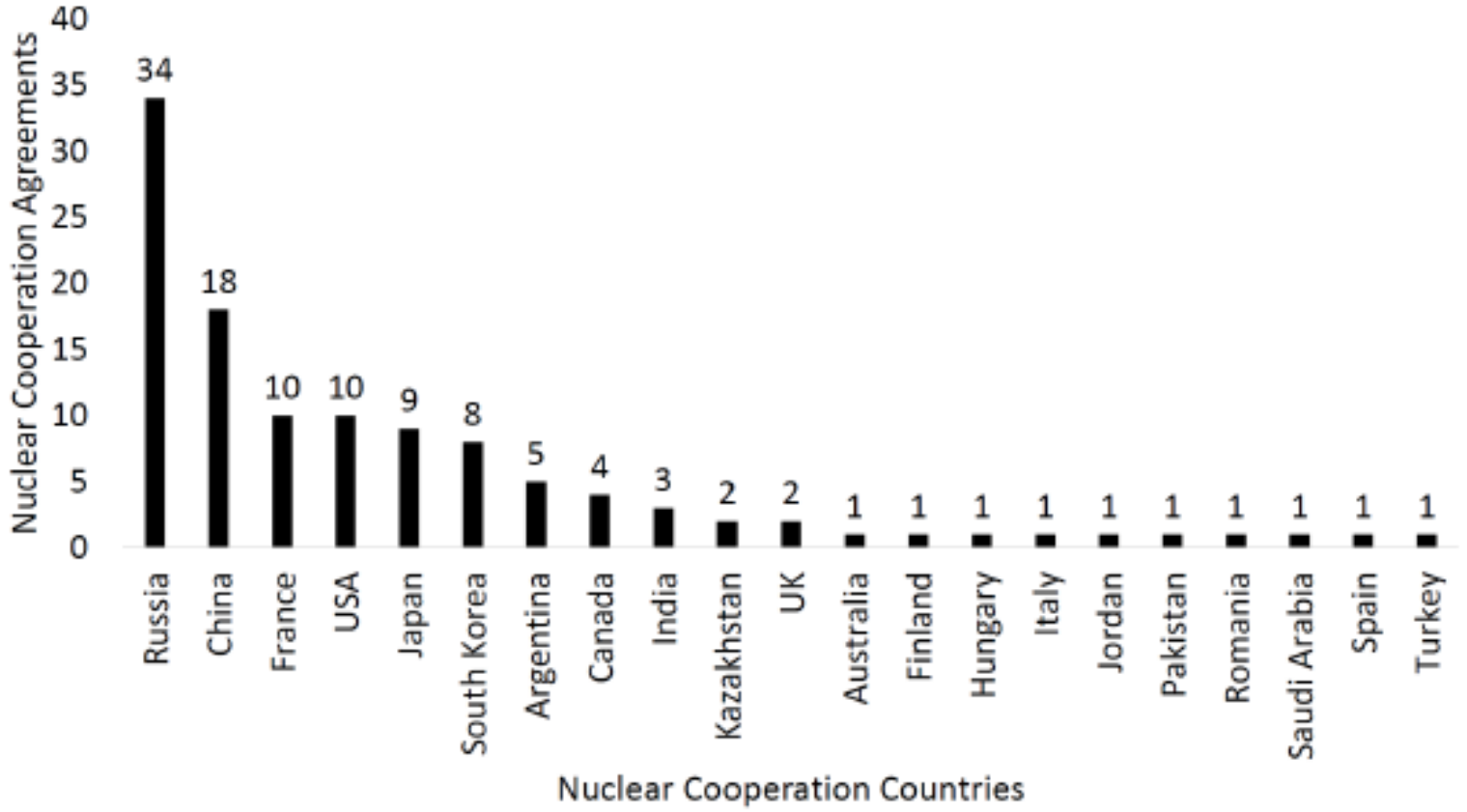
Supply Side of the Nuclear Market



- Russia, China, France, USA, Japan, and South Korea are main initiating nuclear cooperation countries accounting for more the 75% of the total of 115 civil nuclear cooperation agreements.

Overview over the current construction projects in four newcomer countries

Country (Site)	Capacity in Gigawatt (number of reactors)	Supplier (country)	Conclusion of contract	Construction start	Expected completion	Cost, financing, and particularities
UAE (Barakah)	5.4 (4)	Kepco (South Korea)	2009	2012	2021–2023	28.2 billion US dollars 16.2 billion US dollars from Abu Dhabi's Department of Finance 4.7 billion US dollars equity of Emirates Nuclear Energy Corp (ENEC) 2.5 billion US dollars from other sources
Belarus (Ostrovets)	2.2 (2)	Rosatom (Russia)	2012	2013	2021–2022	1.8 billion US dollars (2001) 90 percent financed by a Russian loan with a term of 25 years
Turkey (Akkuyu)	4.4 (4)	Rosatom (Russia)	2010	2018	2023–2025	20 billion US dollars supported by a project company (shares: 51 percent Rosatom, 49 percent others) 50 percent of the generated electricity will be renumerated with a high guaranteed price (123.50 US dollars per Megawatt hour)
Bangladesh (Rooppur)	2.2 (2)	Rosatom (Russia)	2015	2017	Mid-2020s	12.65 billion US dollars 90 percent financed by Russian loan on concessional terms with a term of 28 years

Source: authors' own depiction based on Mycle Schneider et al., *The World Nuclear Industry Status Report 2019* (Paris, Budapest: 2019) (available online).

… and China

~ China itself

~ Pakistan

~ UK (tomorrow France?)

~ Africa

~ why not: Germany???

USA (UK, France)???

...

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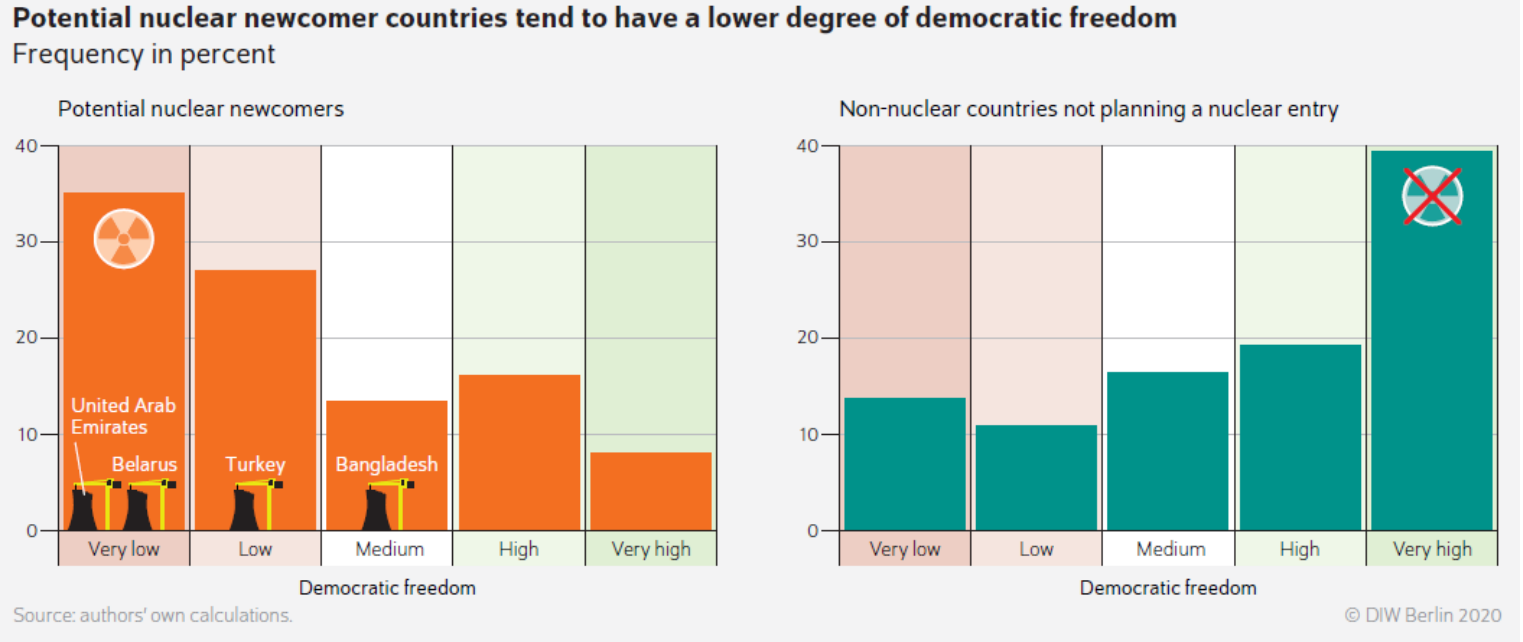
Conclusions

- An analysis of current decommissioning and new construction projects reveals a downward trend in nuclear power worldwide
- Only four newcomer countries are currently constructing nuclear power plants and all are plagued by financial difficulties and delays
- An econometric analysis suggests that countries classified as potential newcomers tend to be less democratic
- On the supply side, the dominant driving force is the geopolitical interests of countries that export nuclear power
- Within the relevant international organizations, Germany should work to ensure that no support is given to the construction of nuclear power plants in newcomer countries

Reform Meeting, 25. August 2020



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(or: “Who wants yesterday’s nuclear plants?)

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