The Influence of Severe Nuclear Accidents on National Nuclear Decommissioning Decisions

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Introduction

World NPPs operation status and life extension

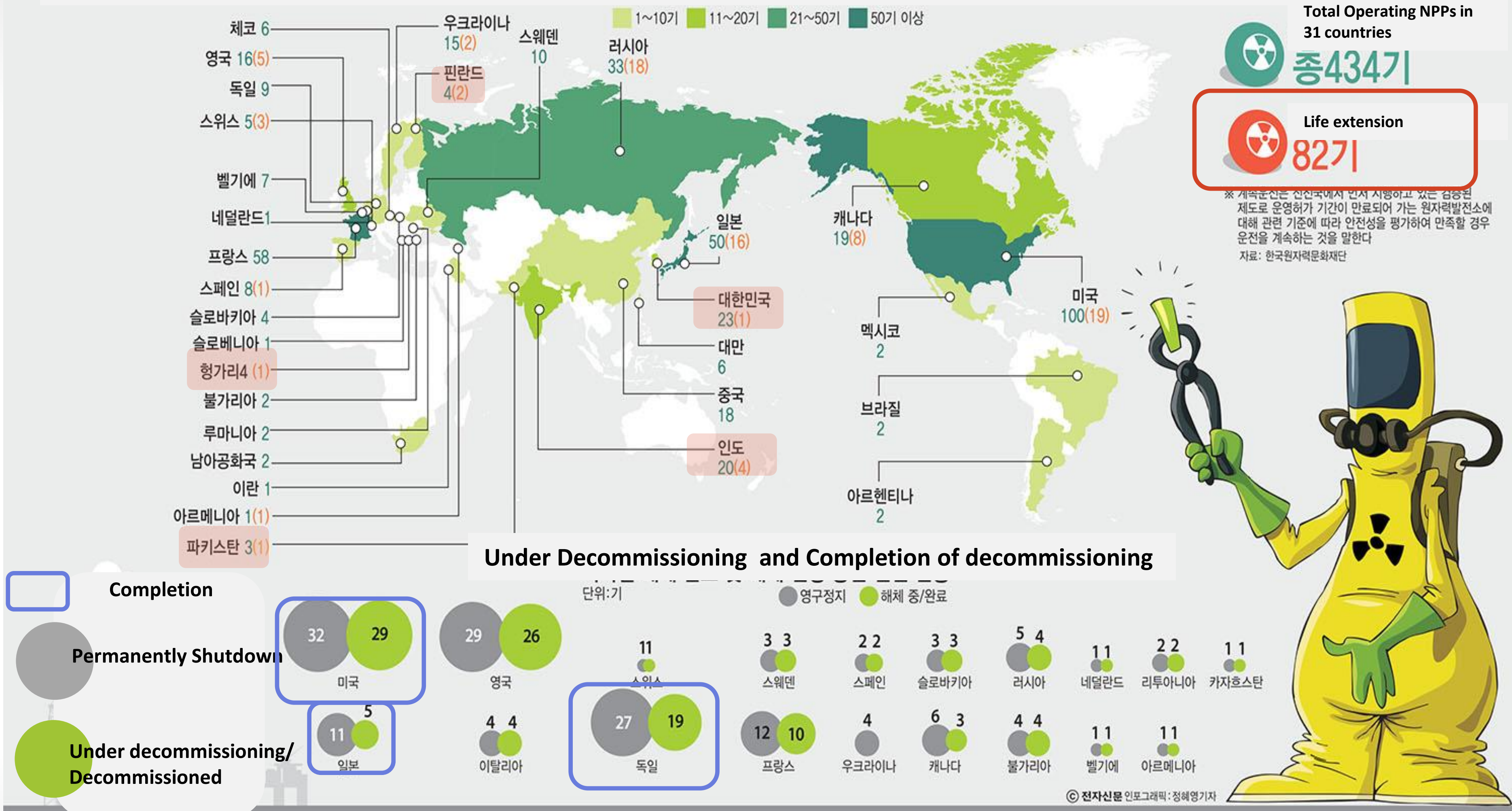


Figure 1. World NPP status and decommissioning status (http://www.etnews.com/)

- In case of commercial NPPs, only 18 countries have direct decommissioning experience.
- Only 3 of those countries completed some of their NPP decommissioning projects.

Imagine you are a policymaker

'A real necessity for early preparation for decommissioning'

- On the direct effect of ... unexpected premature ... of NPPs has intensifi...

- Increasing anti-nuclear movement

Your country situation

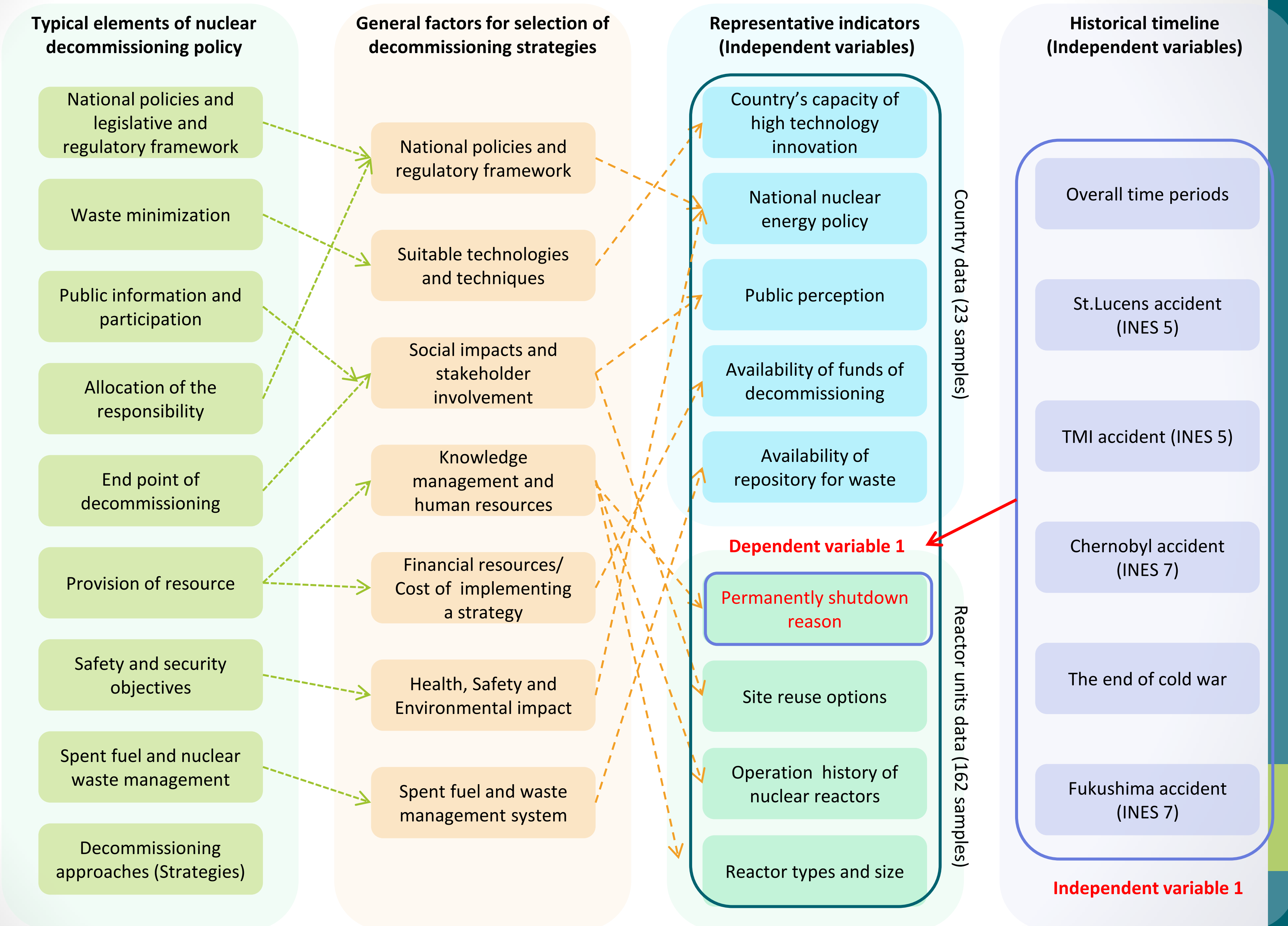
IAEA	OECD/NEA
Typical elements of nuclear decommissioning policy	General factors for selection of decommissioning strategies
National policies and legislative and regulatory framework	National policies and regulatory framework
Waste minimization	Suitable technologies and techniques
...nformation ...rticipation	Social impacts and stakeholder involvement
...tion of the ...onsibility	Knowledge management and human resources
...point of ...missioning	Financial resources/ Cost of implementing a strategy
...n of resource	Health, Safety and Environmental impact
Safety and security objectives	Spent fuel and waste management system
Spent fuel and nuclear waste management	
Decommissioning approaches (Strategies)	

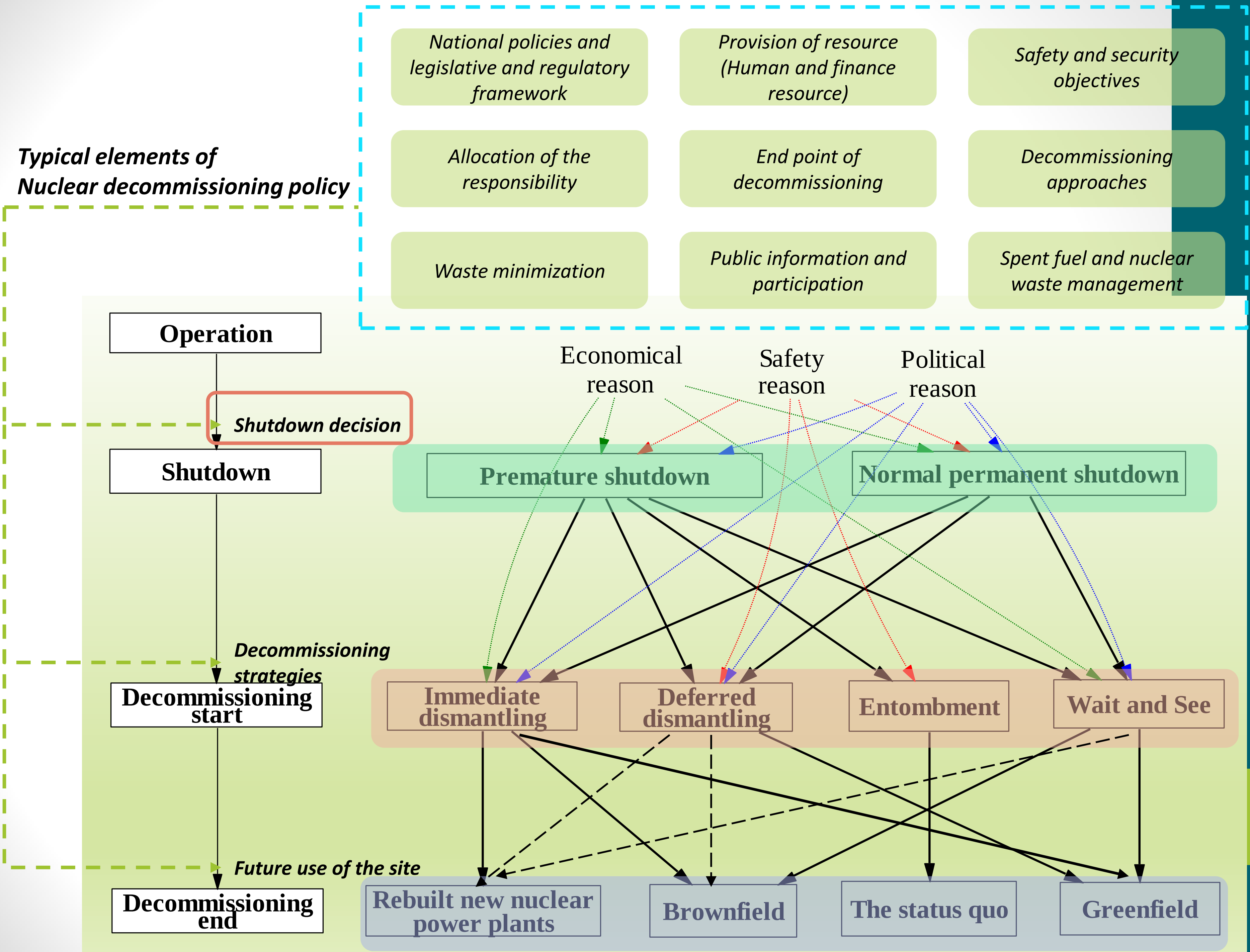
Recommended general factors for the decision of nuclear decommissioning policy

Example of 162 data set

A	B	C	D	E	F	G	H	I	J
#	Country	Unit reactor	Shut down [1]	Specific shutdown reason [2]	Shutdown reason in this paper	Decommissioning strategy	Current status on NPP site	Site reuse plan or already reused	Note
1	Armenia	Metsamor 1	1989	Political decision	Political decision	SAFESTOR	Undergoing Decommissioning	New NPP	Earthquake, Russian reactor
2	Belgium	BR-3	1987	Fulfilled their purpose	Economical decision	DECON	Decommissioned	Greenfield	-
3	Bulgaria	Kozloduy 1	2002	Political decision	Political decision	SAFESTOR	Decommissioned	Brownfield site	Gas dispute between Russia and Ukraine and resulting power shortages in the region
4	Bulgaria	Kozloduy 2	2002	Political decision	Political decision	SAFESTOR	Decommissioned	Brownfield site	1993 agreement between the European Commission and the Bulgarian government
5	Bulgaria	Kozloduy 3	2006	Political decision	Political decision	SAFESTOR	Undergoing Decommissioning	Brownfield site	-
6	Bulgaria	Kozloduy 4	2006	Political decision	Political decision	SAFESTOR	Undergoing Decommissioning	Brownfield site	-
7	Canada	Douglas Point	1984	Fulfilled their purpose & Economic reason	Economical decision	SAFESTOR	Partially Decommissioned	Restricted area	Storage with surveillance
8	Canada	Gentilly 1	1977	Fulfilled their purpose & Technical reason	Economical decision	SAFESTOR	Undergoing Decommissioning	Greenfield	-
9	Canada	Gentilly 2	2012	Fulfilled their purpose & Economic reason	Economical decision	SAFESTOR	Preceding Decommissioning	Unknown	A decommissioning process will proceed over a period of 50 years
10	Canada	PICKERING-2	2007	Economic & Technical reason	Economical decision	SAFESTOR	Preceding Decommissioning	Not Decided	"cold standby" Decommissioning to begin in 2020, Site reuse idea: production of isotopes with building a cyclotron
11	Canada	PICKERING-3	2008	Economic & Technical reason	Economical decision	SAFESTOR	Preceding Decommissioning	Not Decided	"cold standby" Decommissioning to begin in 2021, Site reuse idea: production of isotopes with building a cyclotron
12	Canada	Rolphton NPD	1987	Fulfilled their purpose	Economical decision	SAFESTOR	Partially Decommissioned	Schoolhouse Museum	-
13	France	Super Phenix	1997	Political decision	Political decision	SAFESTOR	Undergoing Decommissioning	Not Decided	-
14	France	Bugey 1	1994	Fulfilled their purpose	Economical decision	SAFESTOR	Undergoing Decommissioning	Not Decided	-
15	France	Chinon A1	1973	Fulfilled their purpose	Economical decision	SAFESTOR	Partially Decommissioned	Museum	-
16	France	Chinon A2	1985	Fulfilled their purpose	Economical decision	SAFESTOR	Undergoing Decommissioning	Not Decided	-
17	France	Chinon A3	1990	Ran approximately full-term	Economical decision	SAFESTOR	Undergoing Decommissioning	Not Decided	-
18	France	Chooz A	1991	Fulfilled their purpose	Economical decision	DECON	Decommissioned	Greenfield	-
19	France	Brennilis EL-4	1985	Fulfilled their purpose	Economical decision	SAFESTOR	Undergoing Decommissioning	Not decided	Site reuse optons: Industrial complex or greening, 12years(1967~1979)
20	France	Marcoule G-1	1968	Fulfilled their purpose	Economical decision	SAFESTOR	Undergoing Decommissioning	Science museum	-
21	France	Marcoule G-2	1980	Fulfilled their purpose	Economical decision	SAFESTOR	Undergoing Decommissioning	Science museum	-
22	France	Marcoule G-3	1984	Fulfilled their purpose	Economical decision	SAFESTOR	Undergoing Decommissioning	Science museum	-
23	France	Phenix	2010	Ran approximately full-term	Economical decision	DECON	Preceding Decommissioning	Unknown	-
24	France	St Laurent A1	1990	Fulfilled their purpose	Economical decision	SAFESTOR	Undergoing Decommissioning	Not decided	-

The range of this study





National policies and legislative and regulatory framework
Provision of resource (Human and finance resource)
Safety and security objectives
Typical elements of Nuclear decommissioning policy
Allocation of the responsibility
End point of decommissioning
Decommissioning approaches
Waste minimization
Public information and participation
Spent fuel and nuclear waste management
Operation
Economical reason
Safety reason
Political reason
Shutdown decision
Shutdown
Premature shutdown
Normal permanent shutdown
Decommissioning strategies
Decommissioning start
Immediate dismantling
Deferred dismantling
Entombment
Wait and See
Future use of the site
Decommissioning end
Rebuilt new nuclear power plants
Brownfield
The status quo
Greenfield

Purpose and Originality of this study

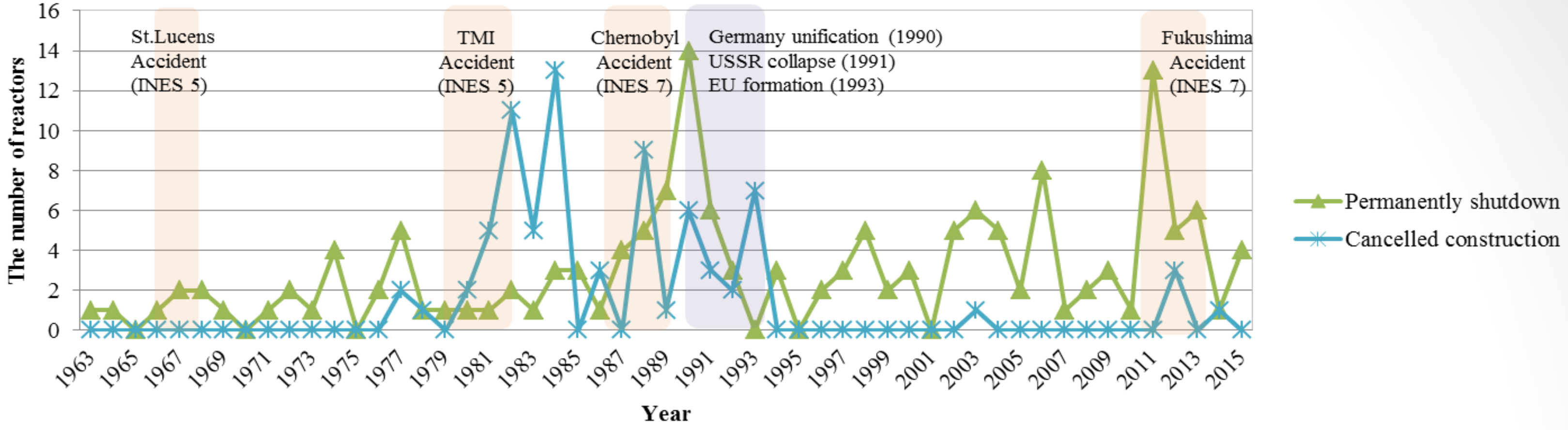
- **Objective of this study**
  - To examine the influence of severe nuclear accidents on national decisions for nuclear decommissioning
- **Limitation of previous studies**
  - No studies address the influence of severe nuclear accidents on national decisions on nuclear decommissioning options
    - Previous studies address: change of public acceptance, nuclear phase-out policy
  - No studies address the influence of major historical events on national decisions regarding nuclear decommissioning options.
- **Hypothesis**
  - *The number of NPPs relegated to permanent shutdown increase in response to historical incidents such as nuclear severe accidents and major historic events (i.e., end of cold war).*

Research approaches

- **Data collection**
  - The change in the number of World NPPs by year
    - Cancelled construction→ Nuclear phase-out policy
    - Permanently shutdown→ National decision on nuclear decommissioning
  - The empirical equation
    - $\text{Impact of Severe Accident} = e^{(-(the\ year - 1\ year\ after\ the\ accident\ occured)} \times e^{(-\frac{1}{INES})}$
    - Difficulties for measuring impact of severe accident
      - International nuclear event scale(INES)
      - Time
        - According to a human cognitive paper, the memory time of the public is generally 5-7 years.
    - Impact of historical event=1 , event happened in year 1.
- **Statistical analysis using STATA**
    - The Pearson's correlation coefficient (r) is a technique for investigating the relationship between two quantitative variables.

Results Statistical analysis

Figure 2.Permanently Shutdown and Cancelled Construction of Nuclear Power Reactors by Year



	Cancelled Construction		
	P-value (two side)	t value	R (Pearson coefficient)
St. Lucens	0.354	-0.934	-0.117
TMI	0.049	2.005	0.245
Chernobyl	0.093	1.706	0.210
The end of cold war	0.005	2.914	0.345
Fukushima	0.902	-0.124	-0.015
	The number of world NPPs (Shutdown)		
	P-value (two side)	t value	R (Pearson coefficient)
St. Lucens	0.425	-0.803	-0.100
TMI	0.342	-0.957	-0.119
Chernobyl	0.058	1.933	0.237
The end of cold war	0.007	2.781	0.331
Fukushima	2.83e-4	3.633	0.416

Table 2. Summary of Results of Pearson Coefficient Test

- Positive correlations with historical events and NPP construction cancellations or permanently shutdown NPPs were revealed.
- It means historical accidents can influence nuclear phase-out policy.
- Severe accidents and changes in the international political situation can result in the shutdown of NPPs and their eventual decommissioning.

Results

Case studies

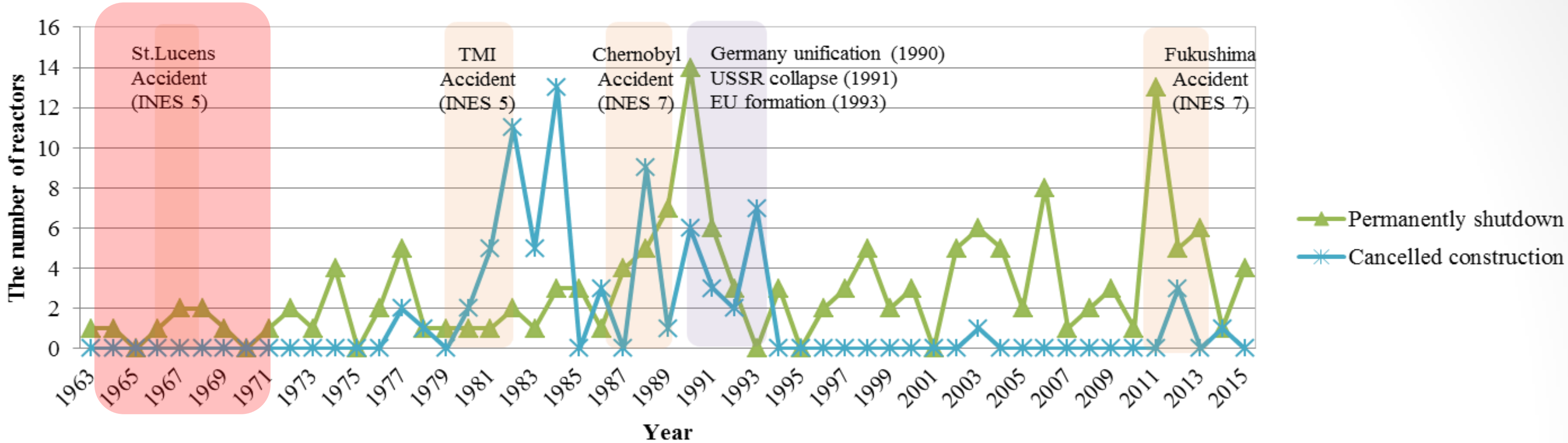


Figure 2-a). Permanently Shutdown and Cancelled Construction of Nuclear Power Reactors for the St. Lucens Accident

- **St. Lucens Accident**: little correlation
  - “localized phenomenon”
  - Lack of information exchange
    - No ‘Convention on Early Notification of a Nuclear Accident’
  - However, we still could not say ‘zero correlation’ with St. Lucens.
    - Switzerland decided on a nuclear phase out policy at that time.
    - Nearby Austria, halted construction of an almost completed NPP because of a public referendum.

Results

Case studies

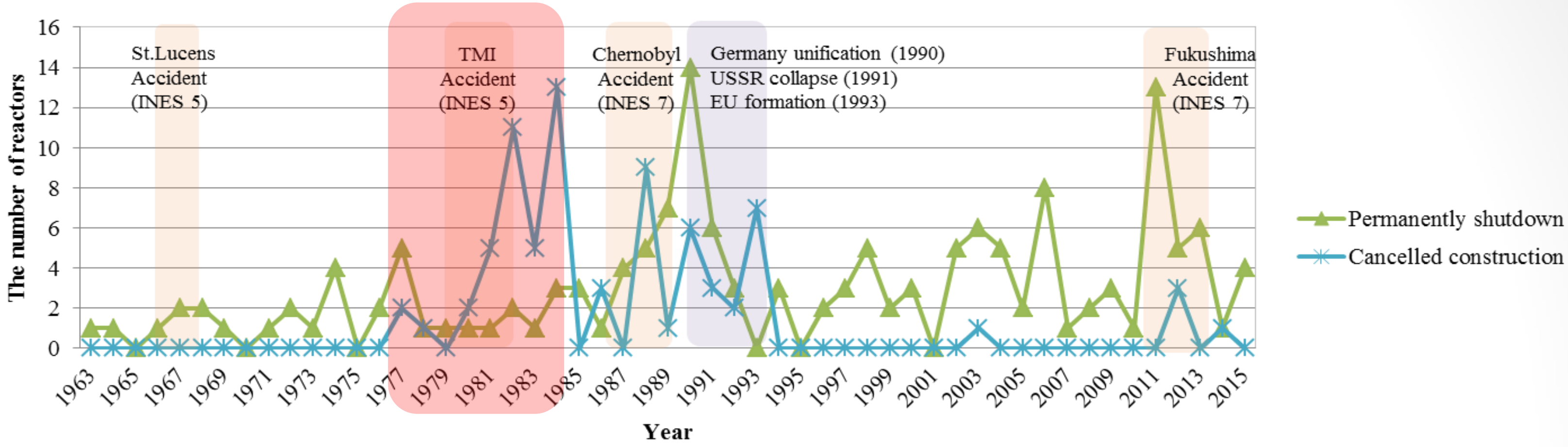


Figure 2-b). Permanently Shutdown and Cancelled Construction of Nuclear Power Reactors for the TMI Accident

- **TMI Accident:** little correlation with shutdown but direct correlation with cancelled construction
  - A local resident exodus phenomenon: increase in serious anti-nuclear activities
  - Former president Jimmy Carter's Anti-nuclear bomb policy
  - Increased power of environmentalists
  - Operating plants relatively new, no reactors in design obsolescence status

Results

Case studies

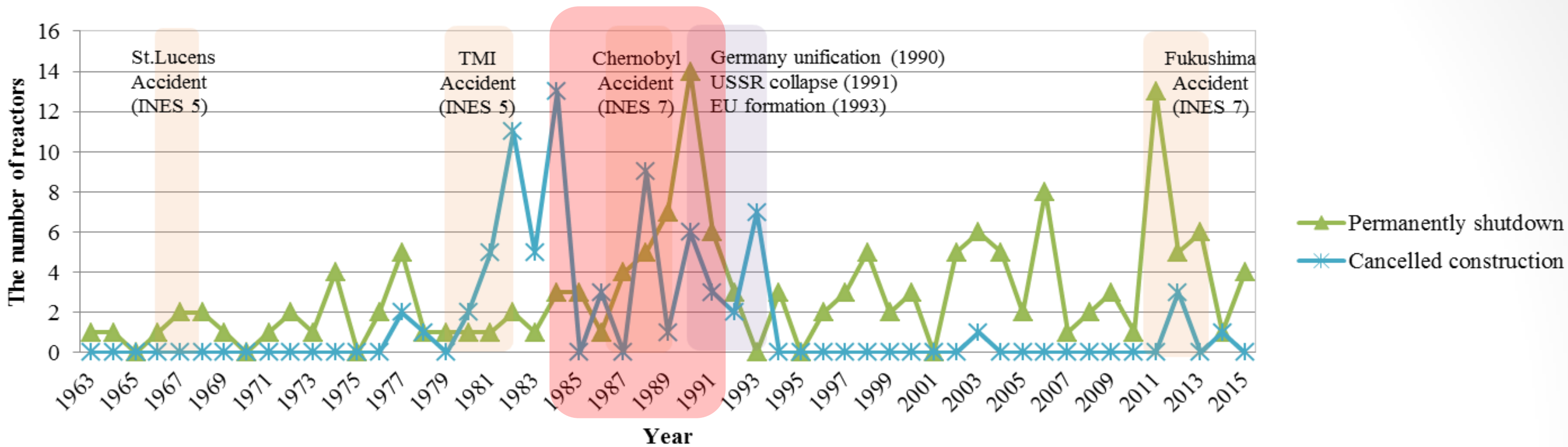


Figure 2-c). Permanently Shutdown and Cancelled Construction of Nuclear Power Reactors for the Chernobyl Accident

- **Chernobyl accident**: Positive correlation with both shutdown and cancelled construction
  - Several European countries (Italy, Finland, Switzerland and Sweden) decided to restrict the use of nuclear energy by halting construction and shutting down nuclear reactors.

Results

Case studies

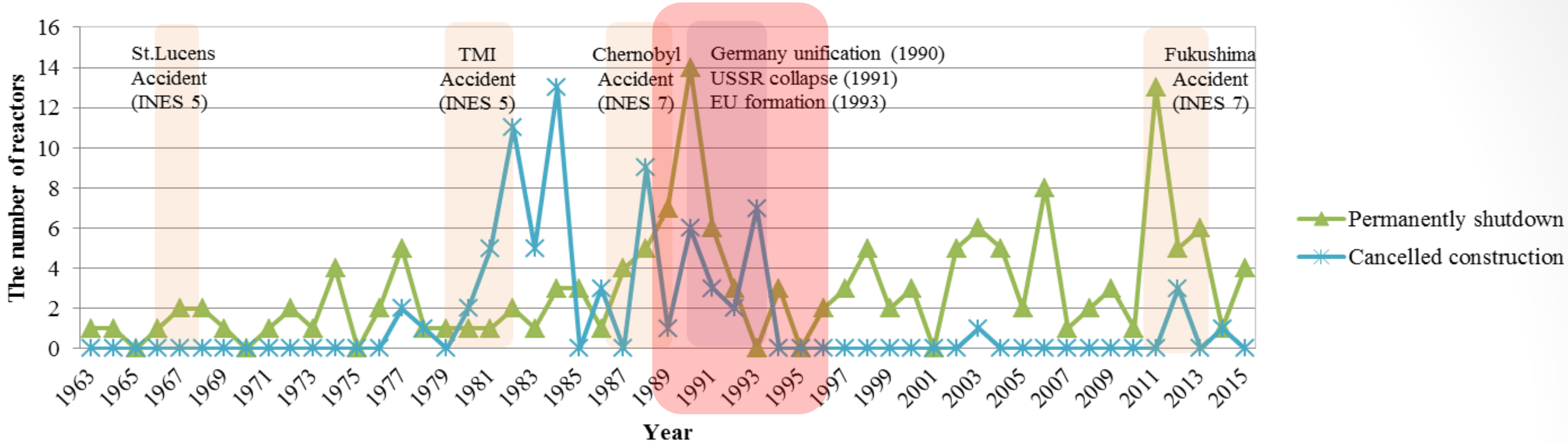


Figure 2-d). Permanently Shutdown and Cancelled Construction of Nuclear Power Reactors for the End of the Cold War

- **Historical events relating to the end of the cold war**
  - The anti-nuclear movement grew in Europe between 1990-1993, negative attitudes toward nuclear power plants was expanded.
  - German unification occurred in 1990 which led to the permanent shut down of East German reactors.
  - Several prototype reactors were approaching their lifetime limits.
  - With EU formation, the European Commission (EC) requested an agreement which contained a clause for premature shutdown of Russian types of reactors like VVER and RBMK.
    - Bulgaria, Lithuania and Ukraine

Results

Case studies

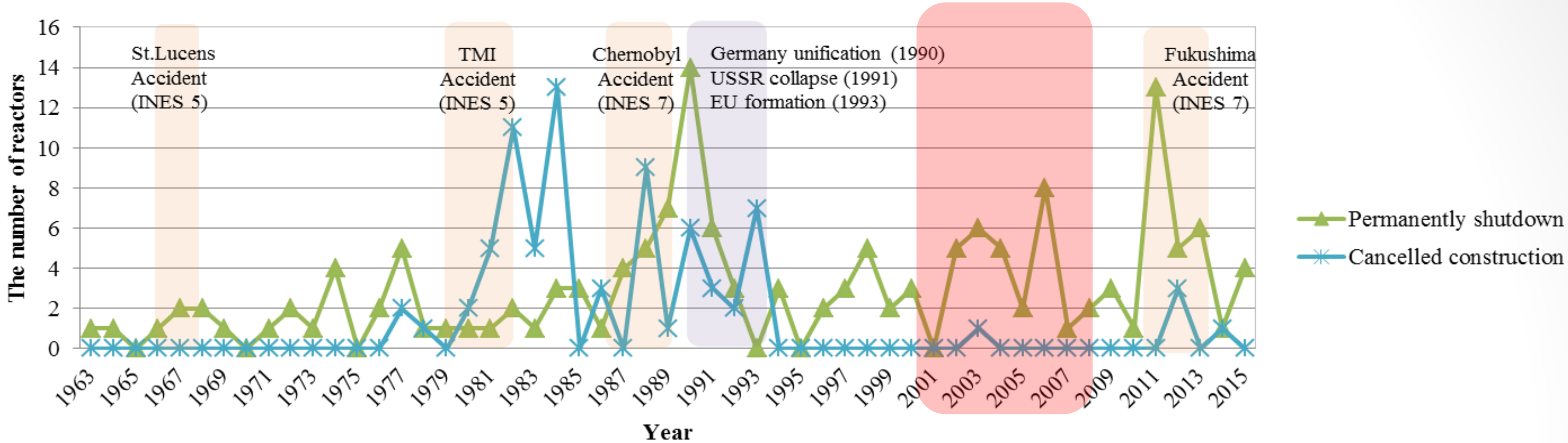


Figure 2-d). Permanently Shutdown and Cancelled Construction of Nuclear Power Reactors for Nuclear Renaissance

- **Nuclear renaissance:** In response to climate change
  - Only one cancellation of NPP construction plans : SINPO-1 at North Korea in 2004
    - To prevent the expansion of nuclear weapon capability
  - Several shutdowns of NPPs because of economic reasons
  - Many countries adopting phase-out nuclear energy policy, such as Italy, Belgium and Switzerland, changed their nuclear energy policy to re-start NPPs.

Results

Case studies

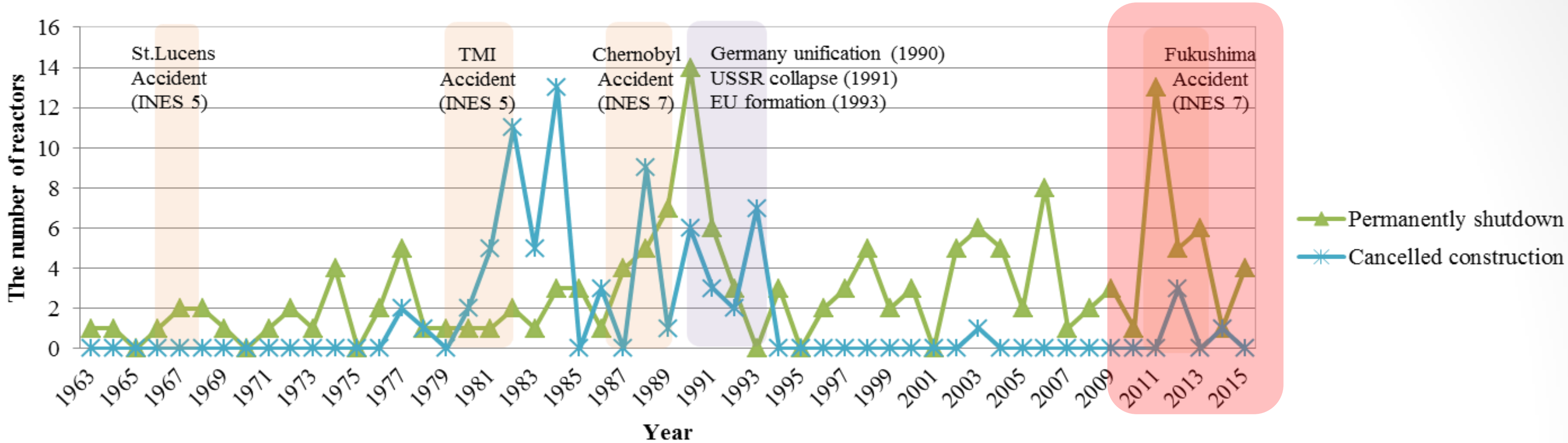


Figure 2-f). Permanently Shutdown and Cancelled Construction of Nuclear Power Reactors for the Fukushima Accident

- **Fukushima accident:** Positive correlation with the number of shutdown NPPs
  - Nuclear phase-out countries (Switzerland, Italy, Germany, and Belgium) and Japan decided to shutdown all of their NPPs.
  - However, it seems premature to make judgment on these results as the time period is still too short to correlate world trends with this event.

Conclusions

- Question: Did the nuclear accident(s) have an impact on nuclear decommissioning policy decisions?
  - ➢ **Answer: Historical event will have an Indirect impact on decommissioning policy decisions**

- *Hypothesis: The number of NPPs relegated to permanent shutdown increase in response to historical incidents such as nuclear severe accidents and major historic events (i.e., end of cold war).* ***"True"***
  - *National decision on shutdown might be depended on national circumstances*
    - *Nuclear phase-out policy*
    - *Anti movements*
    - *Their NPPs' design lifetime*
    - *Self reliance of energy*

- **Future studies** address the general factors for determining nuclear decommissioning policy and strategies such as a country's nuclear energy policy, reactor type and operation periods.



THANK YOU
FOR YOUR ATTENTION

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