NUCLEAR ECONOMICS
CONSULTING GROUP
NECG

World experience with nuclear power and electricity reform

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JAPAN ATOMIC INDUSTRIAL FORUM,INC.

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World experience with nuclear power and electricity reform

- Nuclear power faces problems linked to electricity industry reform and organized electricity markets
  - Early retirement of existing units for economic reasons
  - Failure to invest in new units when approved
- My hope is that Japan's electricity industry reform is implemented in ways that avoid the negative impacts on nuclear power experienced in the United States and other countries

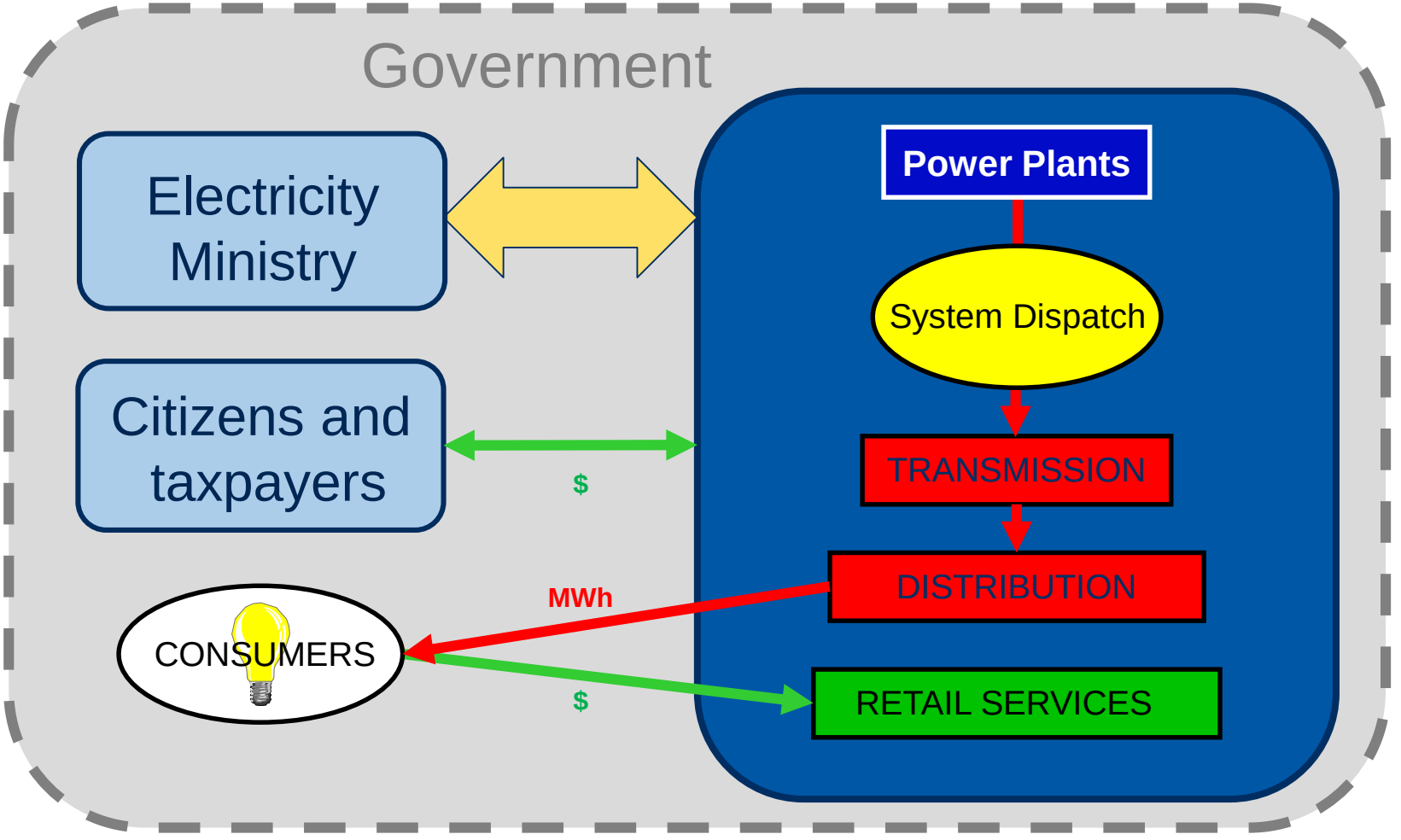
Agenda

- Industry structure
- Long-term vs short-term focus
- Revenue certainty & uncertainty
- Value for nuclear attributes and public benefits
- Market Failure and role of government
- Case Studies

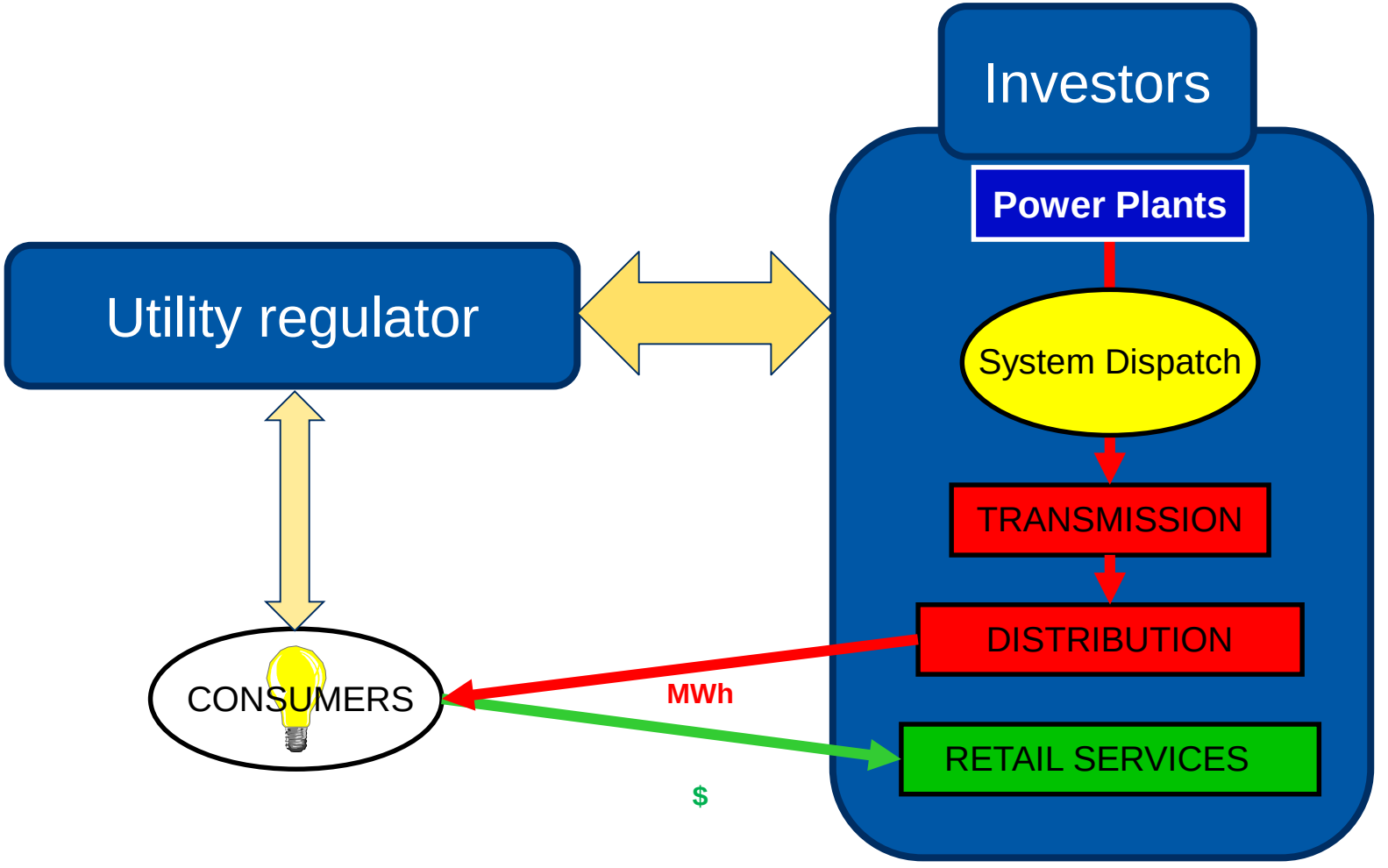
Industry structure important

- **Traditional electricity industry structure:** Strong link between nuclear generation and electricity system and customers
  - Facilitates investment
  - Long-term benefits flow to system and customers
- **Restructured electricity industry and markets:** Generation separate from system and customers
  - Investment difficult
  - Hard to reconcile long-term benefits

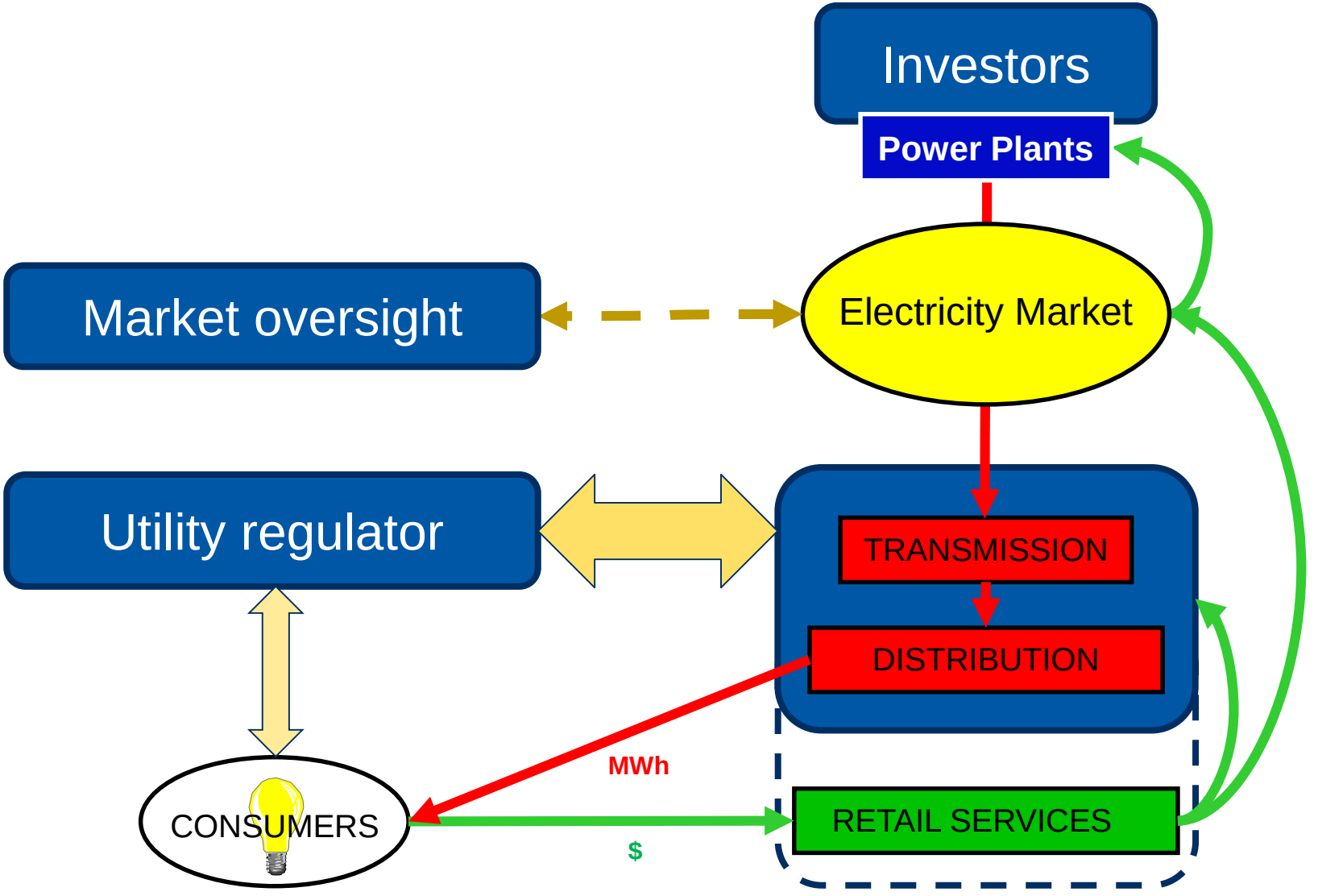
Government utility



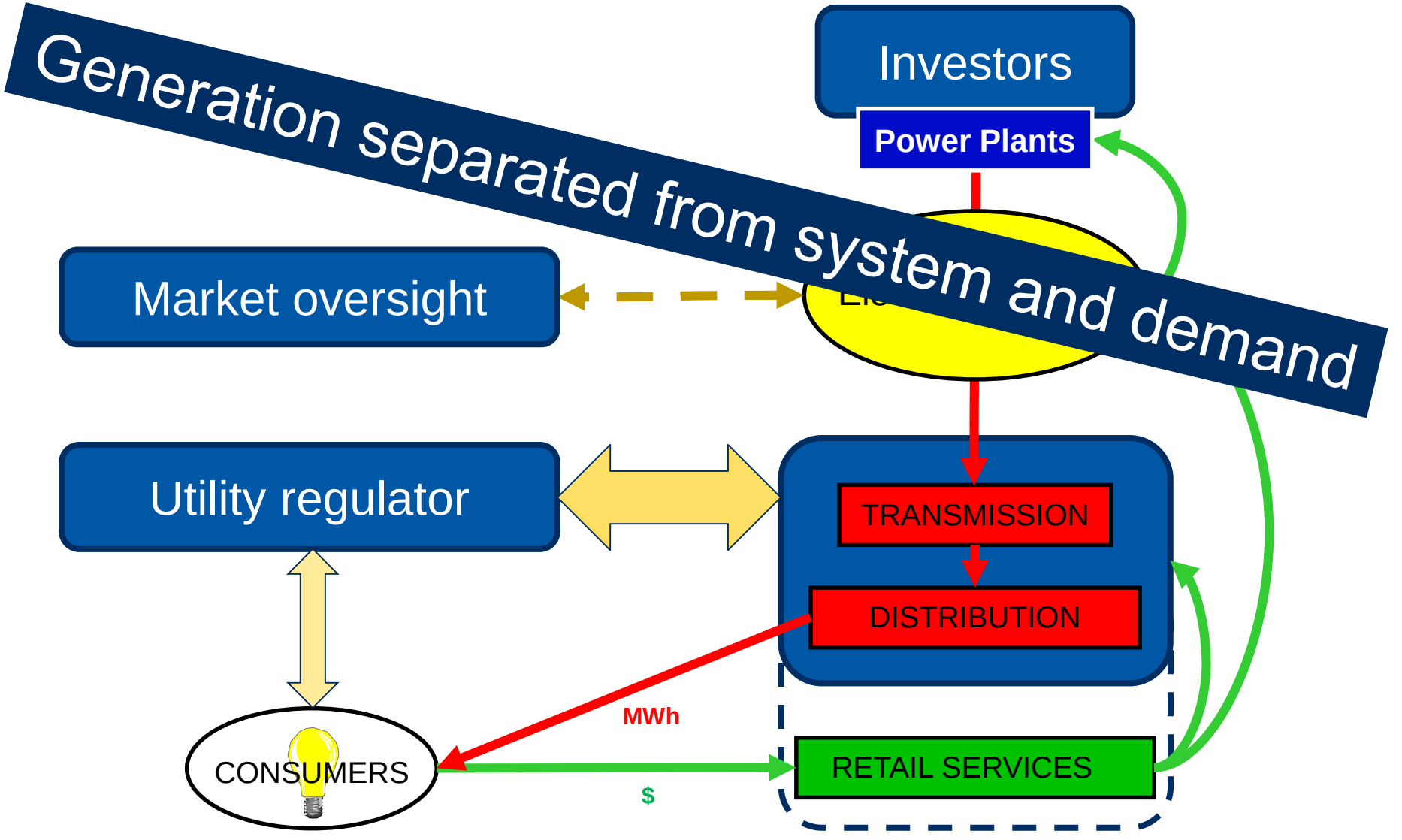
Regulated utility



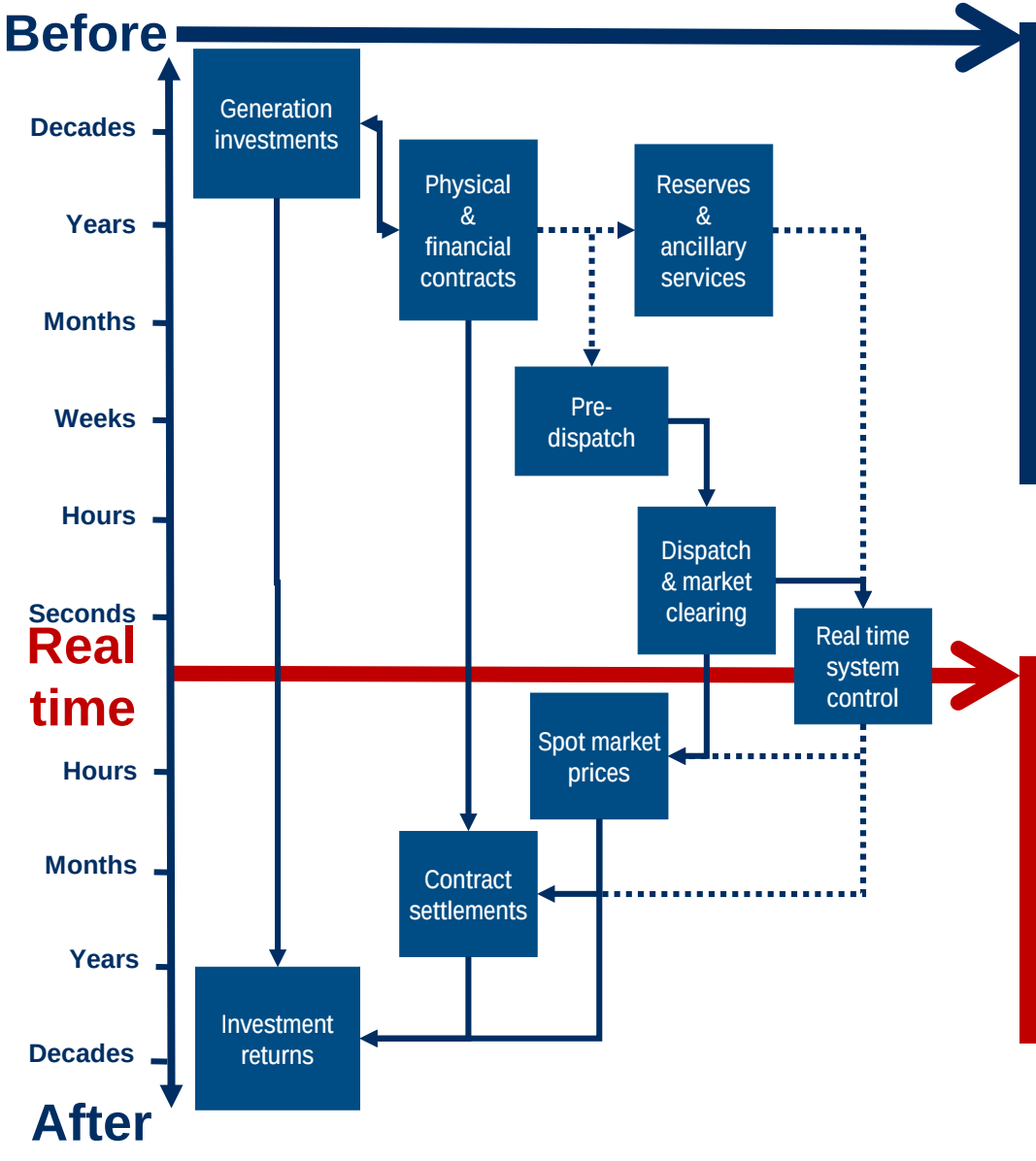
Electricity markets



Electricity markets



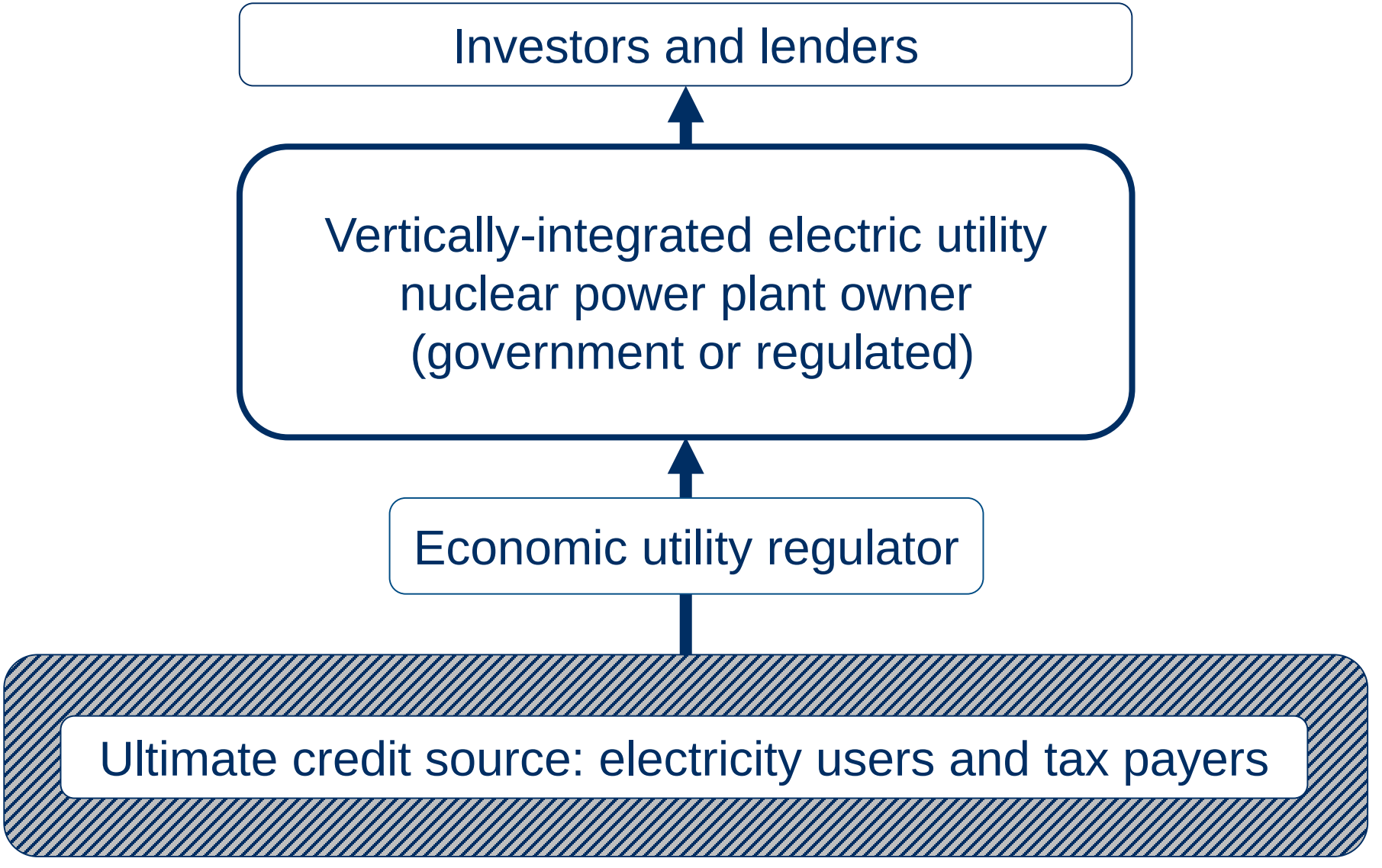
Long-term vs Short-term



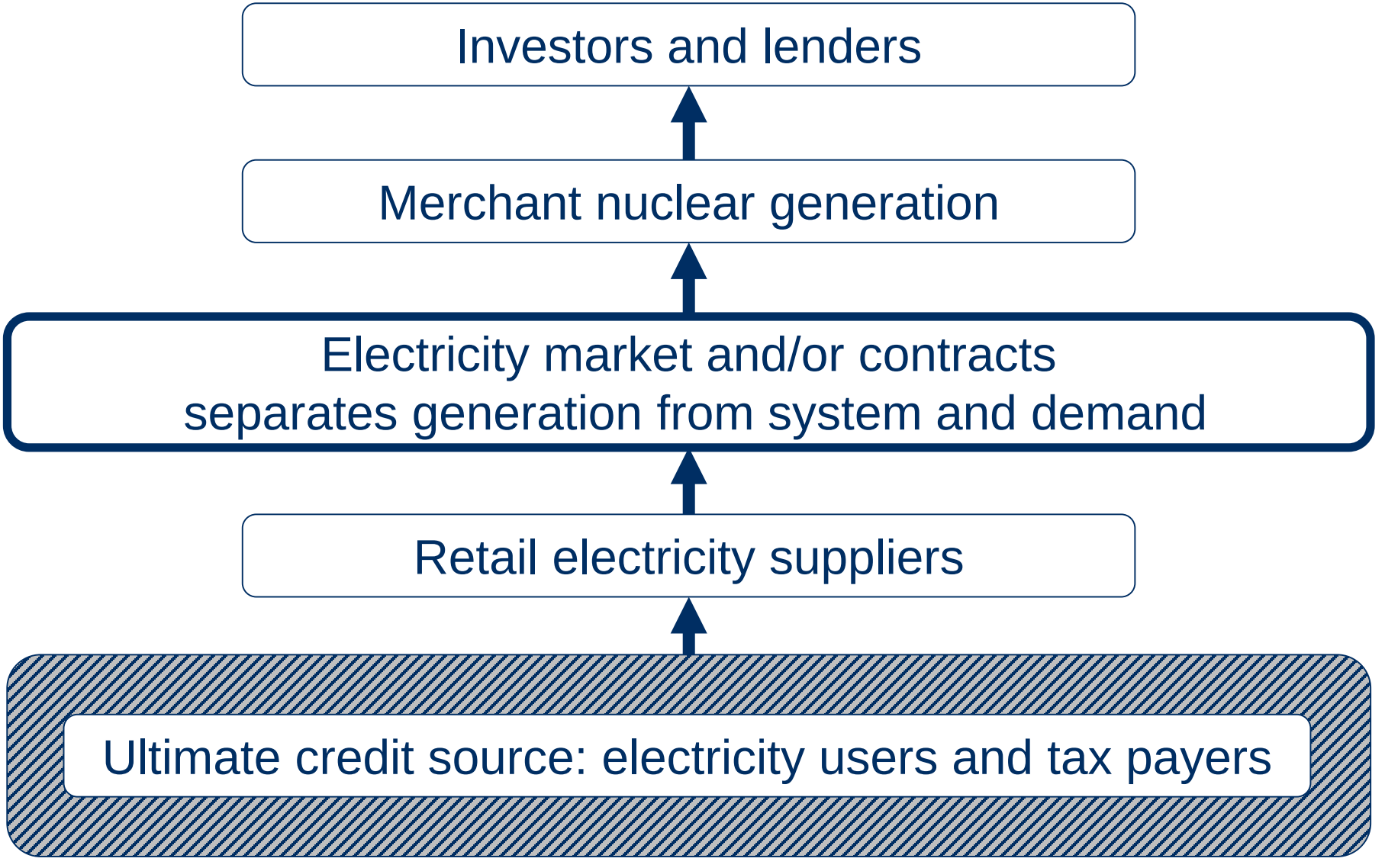
Long-term: Invest in generation portfolio to meet demand – focus on minimizing total system long-run cost

Real-time: Dispatch to meet demand – focus on minimizing system short-run marginal

Revenue Certainty



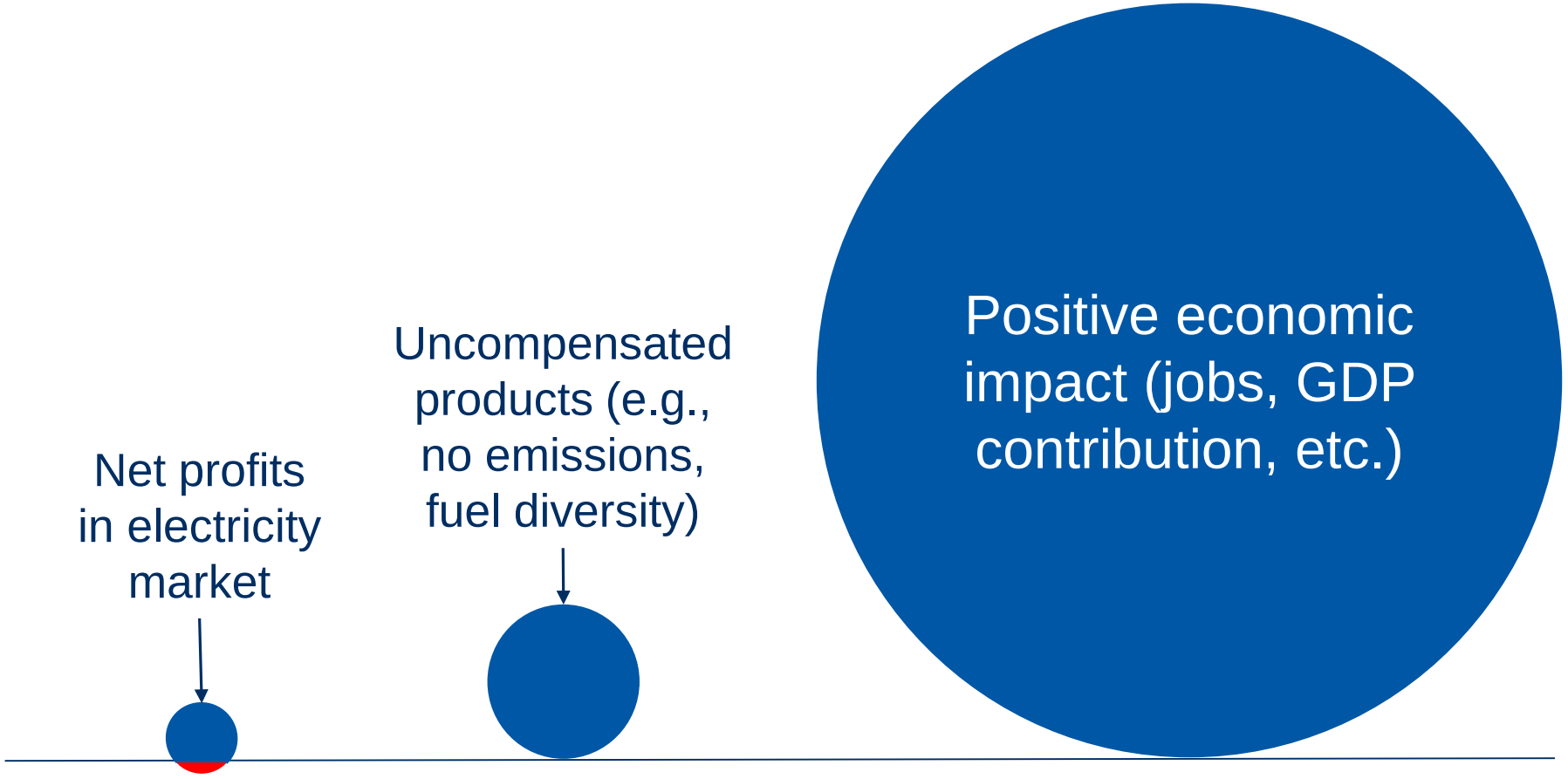
Revenue Uncertainty



Uncertain revenue in electricity markets

- Investment returns based on future revenues
- Hard to predict future electricity market revenue
  - Market simulations with range of assumptions and scenarios (new entry, fuel prices, demand, etc.)
- Power contracts may be out-of-market in future
- New nuclear time-lines make this really difficult
  - Revenue starts at COD (~10 years after project start)
  - Project operates for 60 years (or more)

No value for key nuclear attributes and public benefits in electricity markets



Market failure and role of government

- Electricity markets are failing to support existing or new nuclear (case studies follow)
  - Investment in assets requires a confluence of interests, tenor, and other factors between the asset owner and the ultimate user of the electricity produced
  - Electricity generation is long-term public good
- Only the government, or a pseudo-government body like an electricity economic regulator, can provide the appropriate link between nuclear power assets and electricity system/customers

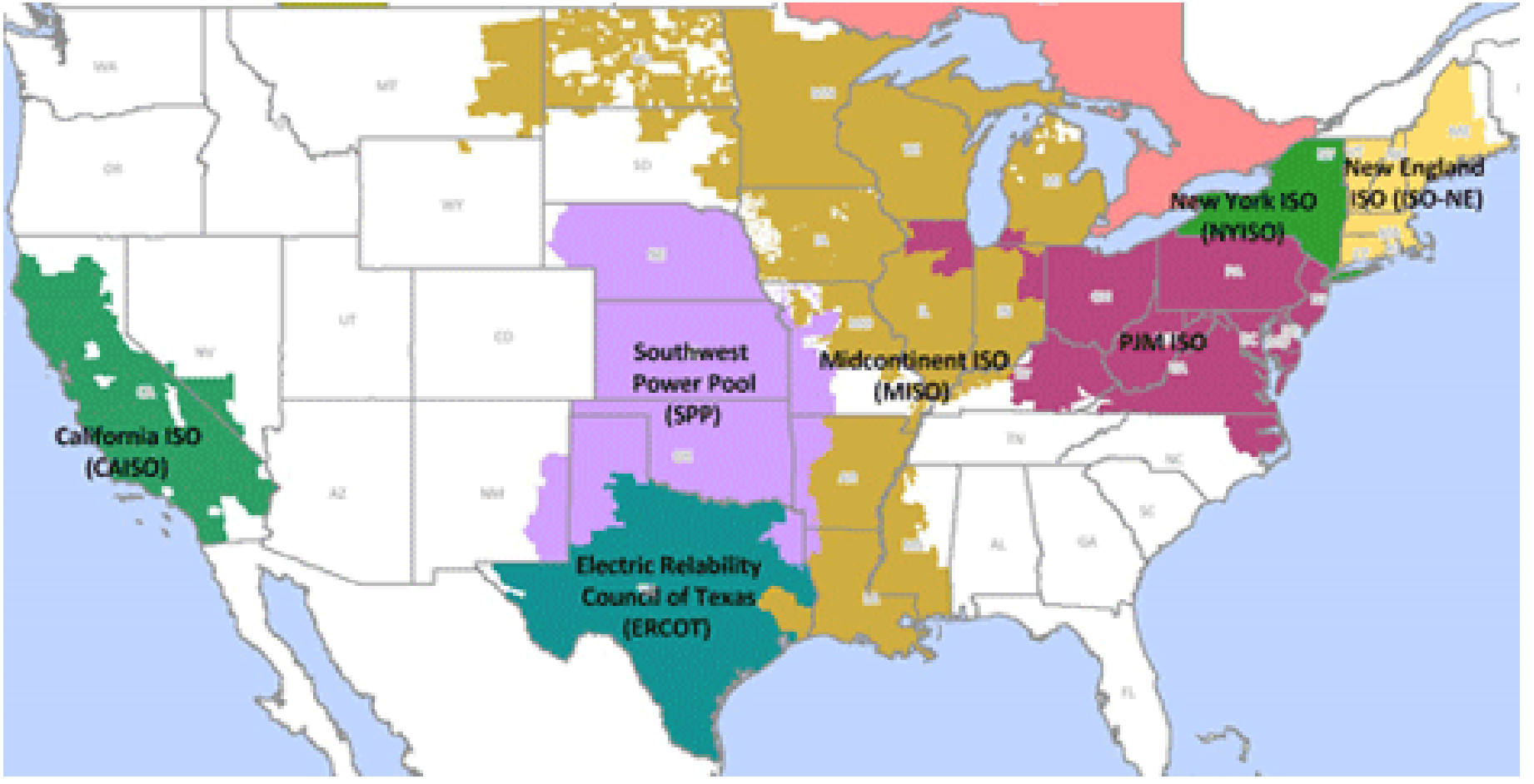
Case Studies

- US merchant nuclear plants
  - Kewaunee & Vermont Yankee
  - FitzPatrick & Pilgrim
  - Other units threatened with early retirement
  - New units
- UK
  - British Energy
  - Hinkley Point C

U.S. Electricity Reforms

- U.S. electricity industry was a mix of:
  - Vertically-integrated investor-owned utilities with a state economic regulator
  - Public power (e.g., municipal utilities, cooperatives, and federal power marketing agencies)
- Electricity reforms in some parts of the U.S.
  - Required divestiture of generation assets by investor-owned utilities
  - Implemented formal electricity markets
  - Created a new class of merchant generators

U.S. electricity markets



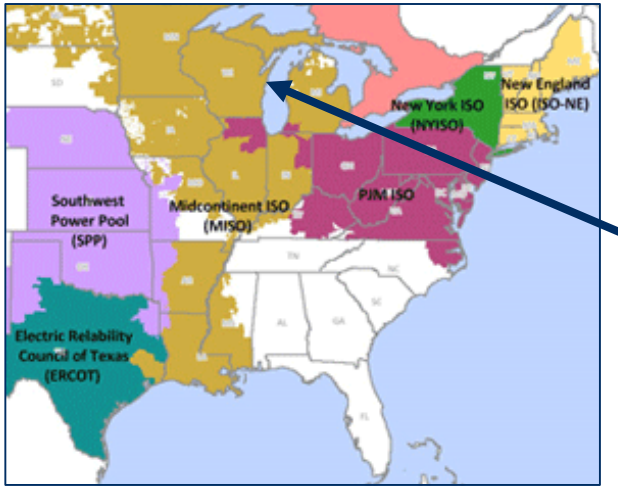
Kewaunee

556 MWe PWR

Original operating license expired in Dec 2013

License renewed in 2011; new expiry Dec 2033

Plant retired in May 2013



- Dominion Energy is owner
- Kewaunee earned market revenue in MISO that was less than cost of O&M and fuel
- Resulting financial losses led to early retirement, despite approval to operate to 2033

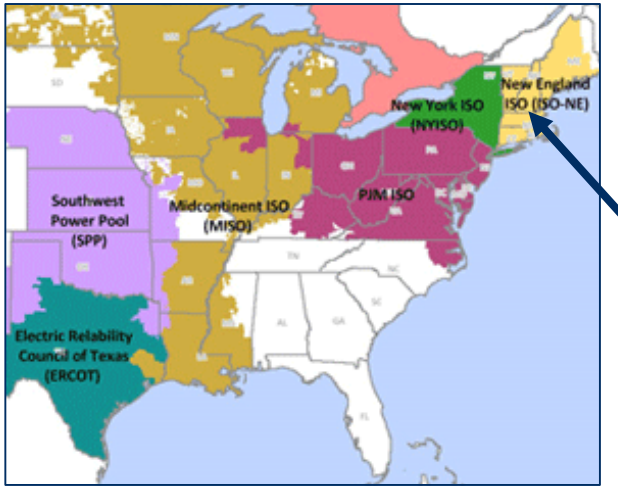
Vermont Yankee

605 MWe BWR

Original operating license expired in Mar 2012

License renewed in 2011; new expiry Mar 2032

Plant retired Dec 2014



- Entergy is the owner
- Vermont Yankee earned market revenue in NE ISO that was less than cost of O&M and fuel
- Resulting financial losses led to early retirement, despite approval to operate to 2032

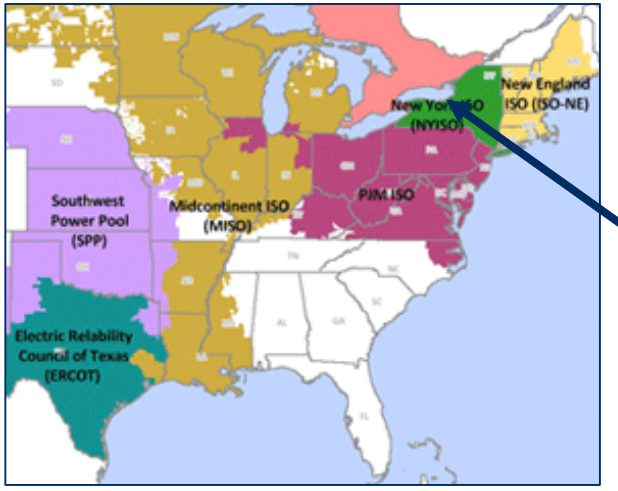
FitzPatrick

816 MWe BWR

Original operating license expired in Oct 2014

License renewed in 2008; new expiry Oct 2034

Plant operating; to be retired in 2017



- Entergy is the owner
- FitzPatrick unit owners estimated by UBS to be losing $29 million per year in NYISO market
- Plans to retire the plant in 2017
- New York state trying to save the plant (e.g., CES)

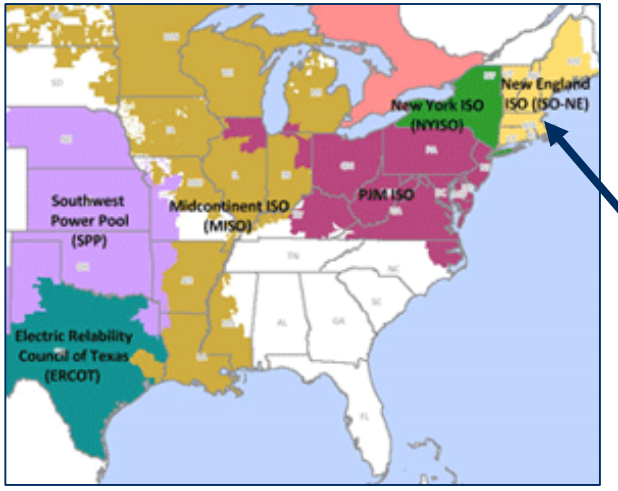
Pilgrim-1

690 MWe BWR

Original operating license expired in Jun 2012

License renewed in 2012; new expiry Jun 2032

Plant operating; to retire in 2017



- Entergy is the owner
- Pilgrim unit operating at loss in NE ISO electricity market
- Plans to retire the plant before Jun 2019

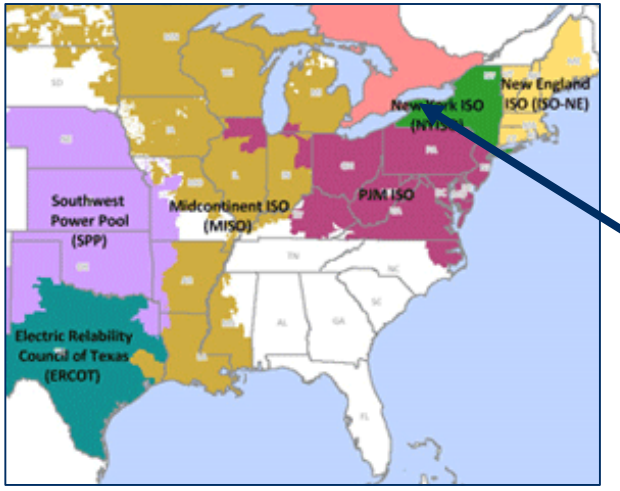
Ginna

556 MWe PWR

Original operating license expired in Sep 2009

License renewed in 2004; new expiry Sep 2029

Plant operating



- Exelon is the owner
- Ginna faced financial losses in NY ISO market
- A short-term reliability support agreement
- Potential for early retirement when reliability support contract ends

Exelon Illinois Units (PJM)

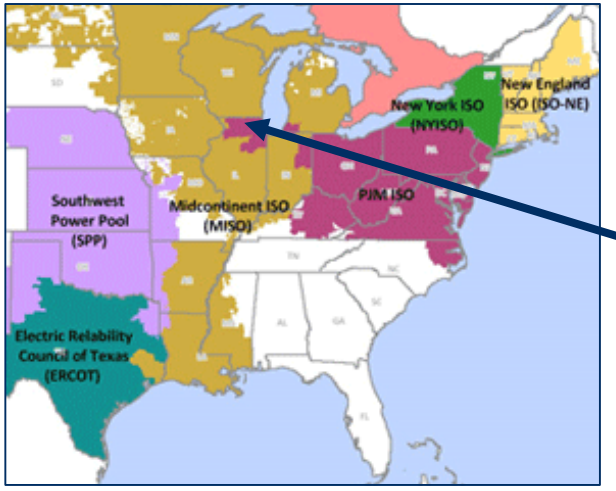
Braidwood 1&2, extended in 2016 to 2046/2047

Byron 1&2, extended in 2015 to 2044/2046

Dresden 2&3, extended in 2004 to 2029/2031

LaSalle 1&2, 2022/2023

Quad Cities 1&2, extended in 2004 to 2032/2032



10 units, 10,649 MWe

Braidwood 1&2, PWR, 2,360 MWe

Byron 1&2, PWR, 2,353 MWe

Dresden 2&3, BWR, 1,824 MWe

LaSalle 1&2, BWR, 2,288 MWe

Quad Cities 1&2, BWR, 1,824 MWe

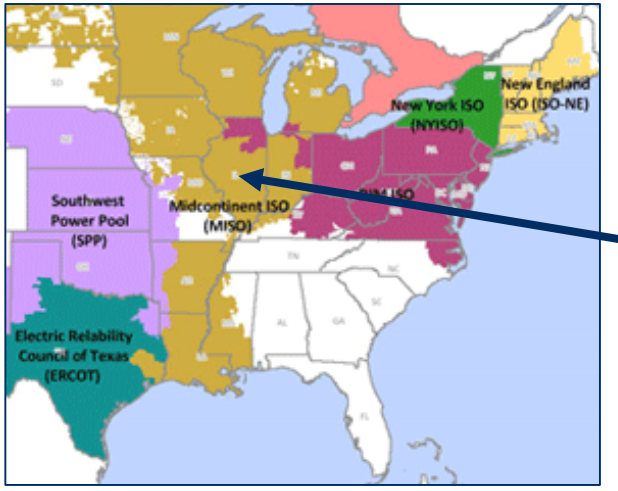
- Exelon's PJM units face electricity market losses, received additional revenue from capacity market
- Illinois considered a new Low Carbon Portfolio Standard in 2015, but was not approved
- These units are candidates for early retirement

Clinton-1

1.065 MWe BWR

Original operating license expires in Dec 2026

Plant operating



- Exelon unit in the MISO part of Illinois
- Some additional revenue in the recent capacity market
- Considered a candidate for early retirement

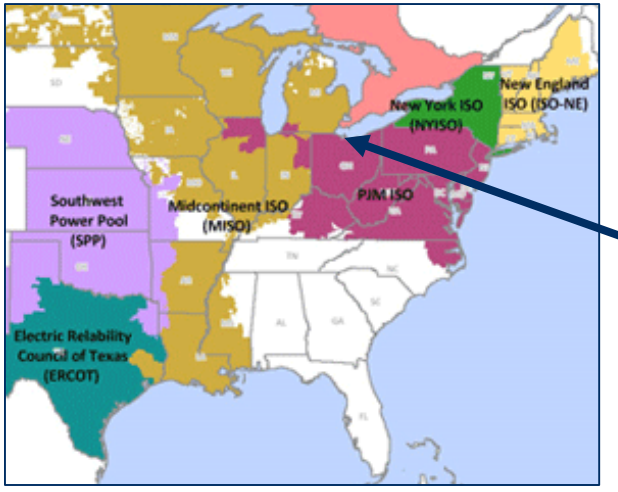
Davis Besse-1

894 MWe PWR

Original operating license expired in Apr 2017

License renewed in 2015; new expiry Apr 2037

Plant operating



- FirstEnergy is the owner
- Davis Besse faces market challenges
- Ohio utility commission put CfD arrangement in place on 31 Mar 2016 - some call this re-regulation
- Challenges expected at FERC and in courts

Fermi 3 COL

1,600 MWe ESBWR

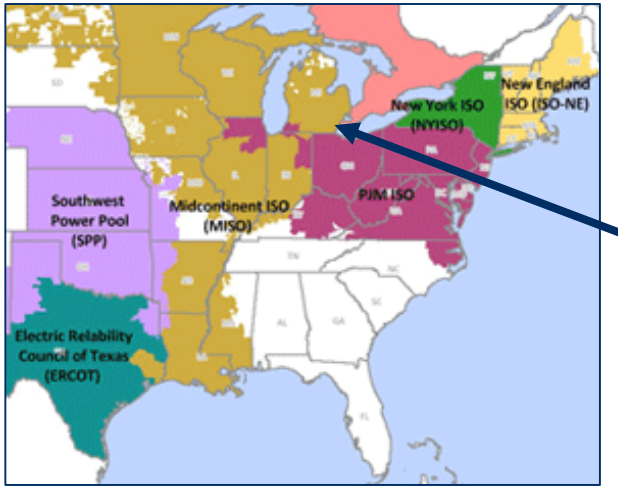
Located on existing site

2,700 MWe

COL application in 2008

COL approved Apr 2013

Project on hold



- Detroit Edison is the potential owner
- This is the first U.S. merchant nuclear unit to get NRC approval
- Project faces market challenges to profitability
- No plans to make investment in the project

South Texas Project 3&4

2 ABWR units

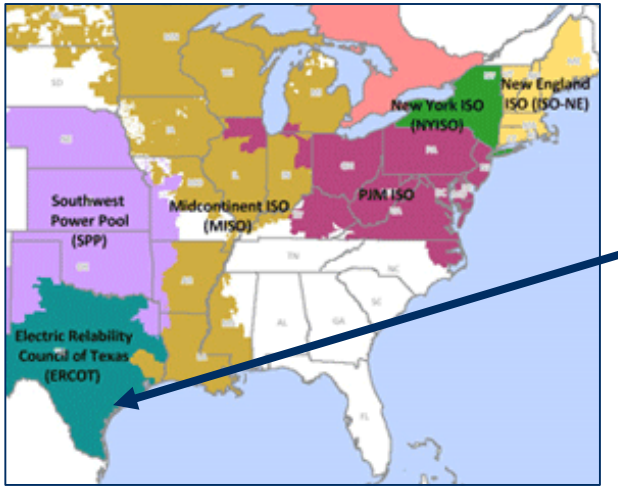
Located on existing site

2,700 MWe

COL application in 2007

COL approved Feb 2016

Project on hold



- NRG is owner, with involvement by Toshiba
- A merchant nuclear unit in the ERCOT market facing challenges to profitability
- NRC approval received in early 2016
- No plans to proceed with investment

Summer 2&3

2 AP1000 units

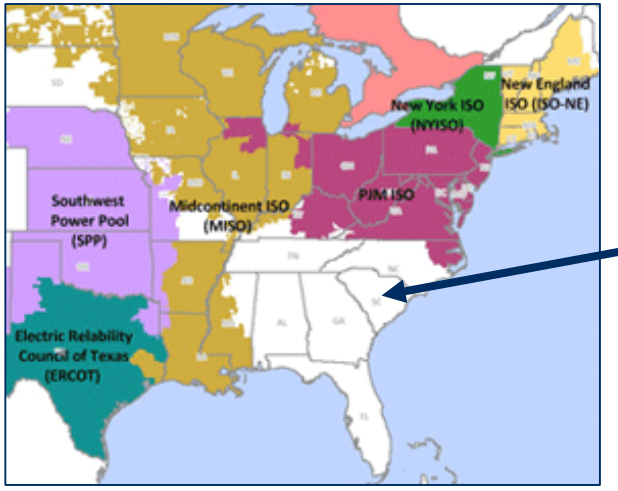
Located on existing site

2,034 MWe

COL application in 2008

COL approved Mar 2012

Construction start Mar 2013/Nov 2013



- SCE&G and Santee Cooper are owners
- A regulated utility project under construction
- South Carolina state laws and utility planning approach provides sufficient revenue certainty
- No U.S. loan guarantees

Vogtle 3&4

2 AP1000 units

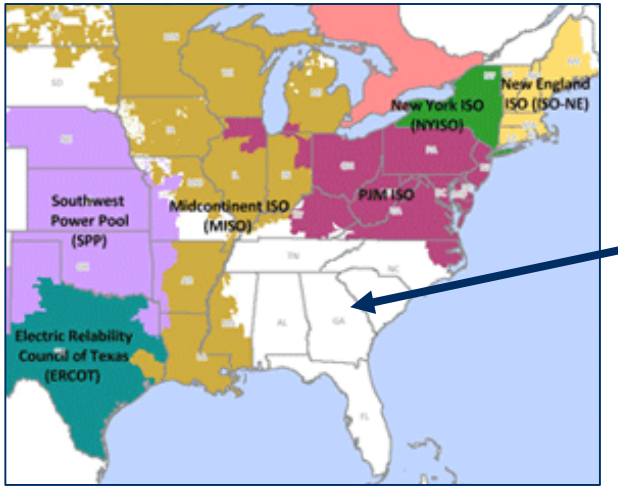
Located on existing site

2,034 MWe

COL application in 2008

COL approved Feb 2012

Construction start Mar 2013/Nov 2013



- Southern Company and public power are owners
- A regulated utility project that is under construction
- Georgia state laws and utility planning approach provided sufficient revenue certainty
- U.S. loan guarantee ***after*** construction start

UK Electricity reforms

- UK one of the first countries to reform the electricity sector in 1989/1990
- Primary drivers of reform were
  - Market focus of Thatcher government
  - Desire to privatize UK electricity industry
- Nuclear privatized later than other assets
  - British Energy formed as single UK nuclear company
  - British Energy operated eight UK nuclear plants

British Energy

- Privatized in 1996 by public offering
- British Energy faced financial trouble by 2002
  - Lower than expected wholesale energy prices
  - Issues and outages of some reactors
- Between 2003 and 2005, UK government restructured British Energy, returning it to government ownership and control
- In 2009, British Energy sold to EDF

EMR

- UK “Electricity Market Reform” process
  - Started with 2010 Ministerial Statement and papers
  - EMR allows UK government to provide incentives for new nuclear in the electricity market
  - Needed to meet binding carbon emission reductions
- EMR incentives include:
  - Contract for Differences (long-term)
  - Carbon floor prices
  - Capacity mechanisms
  - Loan guarantees

Hinkley Point C

- Hinkley Point is an existing nuclear power plant site acquired by EDF in the 2009 acquisition of British Energy
- EPR reactor received UK GDA approval in 2012
- First project under EMR nuclear programme
  - Approved by EU after year-long review
  - Still waiting for EDF Financial Investment Decision
- Shows difficulty for nuclear in electricity markets

Conclusions

- All existing nuclear power plants and all nuclear power plants under construction today built under traditional electricity industry structures
- Profound failure of nuclear in electricity markets
  - US early retirement of merchant nuclear
  - US COL approvals resulting in no investment
  - UK need to bail out British Energy
  - Hinkley Point C delays and difficulties
- Electricity markets not compatible with nuclear

NECG Commentaries

- I publish commentaries from time to time on the topics covered in this presentation:

  http://www.nuclear-economics.com/commentary

- JAIF translated the first 12 NECG Commentaries into Japanese:

  http://www.jaif.or.jp/necg-commentary-series/

American Nuclear Society Special Committee Toolkit

- I was involved in this effort and was the principal author of the Toolkit
- Policy and market tools to prevent further nuclear plant closures and promote new nuclear
  - Focused on U.S. market
  - Should provide ideas for any country
  - More information:

http://www.ans.org/pi/news/article-514/

http://nuclearconnect.org/wp-content/uploads/2016/02/ANS-NIS-Toolkit-download.pdf

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