U.S. Nuclear Power Plant License Renewal and Long-Term Operation

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ANS President

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Presentation to the Japan Local Section of ANS

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ANS Vision

Nuclear technology is embraced for its vital contributions to improving peoples' lives and preserving our planet.

ANS Mission

Advance, foster, and spur the development and application of nuclear science, engineering, and technology to benefit society.

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ANS - Status

- Completing Change Plan 2020
- “New” Chief Executive Officer / Executive Director Craig Piercy
- Moving back to in-person meetings
- 2021-2022 president: Steven Arndt (retired Nuclear Regulatory Commission, now Oak Ridge National Laboratory)
- 2022-2023 president: Ken Petersen (retired Exelon)

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ANS 2022 Annual Meeting

- Anaheim, California – “The New Outlook”
- June 12-16, 2022
- Focus on innovation and the upcoming generation of nuclear technology professionals
- General Chair Dr. Per Peterson (co-founder of Kairos Power)
- Three embedded Topical Meetings:
  - Advances in Thermal Hydraulics
  - Nuclear Criticality Safety
  - Technology of Fusion Energy

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2021-22 President Focus Areas

- Enhance Society infrastructure for addressing advanced reactors
- Policy
  - Nuclear energy's role in the world's clean energy future
  - Alliances with environmental advocates
  - Action on nuclear waste
  - Diablo Canyon

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Outline of License Renewal and Long-Term Operation Discussion

- Nuclear Power in the U.S.
- U.S. License Renewal and Long-Term Operation
- U.S. Subsequent License Renewal
- International License Renewal and Long-Term Operation
- Conclusion

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Nuclear Power in the U.S.

- 92* nuclear power reactors generate about 20 percent of U.S. electricity
  - Nearly 55 percent of U.S. carbon emission-free electricity
  - All are large light water reactors
- Increasing recognition among policy makers and many environmental groups that nuclear energy is needed today and in the future
  - Reliable, around-the-clock electricity
  - Environmental benefits

* Palisades reactor permanently ceased operation May 20, 2022

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U.S. Energy Policy

- Difficult to Define
  - Each new administration pursues objectives which are constrained by congressional funding, laws, regulations, economics, etc.
  - Biden Administration is strongly focused on clean energy, including nuclear power but with a strong emphasis on renewable energy
- If there was a nuclear energy policy, it might be
  - Continued operation of existing power reactors
  - Development and deployment of new nuclear power plants, focusing on
    - Small modular reactors
    - Advanced non-light water reactors

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New Reactors

- No plans for new large light water reactors after Vogtle 3 and 4
- Small modular reactors
  - NuScale Power Module
  - General Electric Hitachi BWRX-300
  - Holtec SMR-160
- Advanced non-light water reactors
  - Developer companies with a variety of designs
    - Helium, liquid metal, molten salt coolants
    - Several fuel designs and concepts
  - Department of Energy (DOE) Advanced Reactor Demonstration Program
    - Two concepts to be deployed by 2027
      - X-energy Xe-100 (helium cooled, TRISO fuel)
      - TerraPower Natrium (sodium cooled, energy storage)
    - Additional cost-share support for other designs

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Existing Fleet of Reactors

Given the timescale for deployment of new reactors, the existing fleet will be the backbone of U.S. nuclear electricity production for years and probably decades to come

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However -

- The ability to expand electricity production from the existing fleet is very limited
- The U.S. nuclear fleet is aging and, barring license renewal and subsequent license renewal, units will have to shut down due to expiring operating licenses

Aging U.S. Reactor Fleet

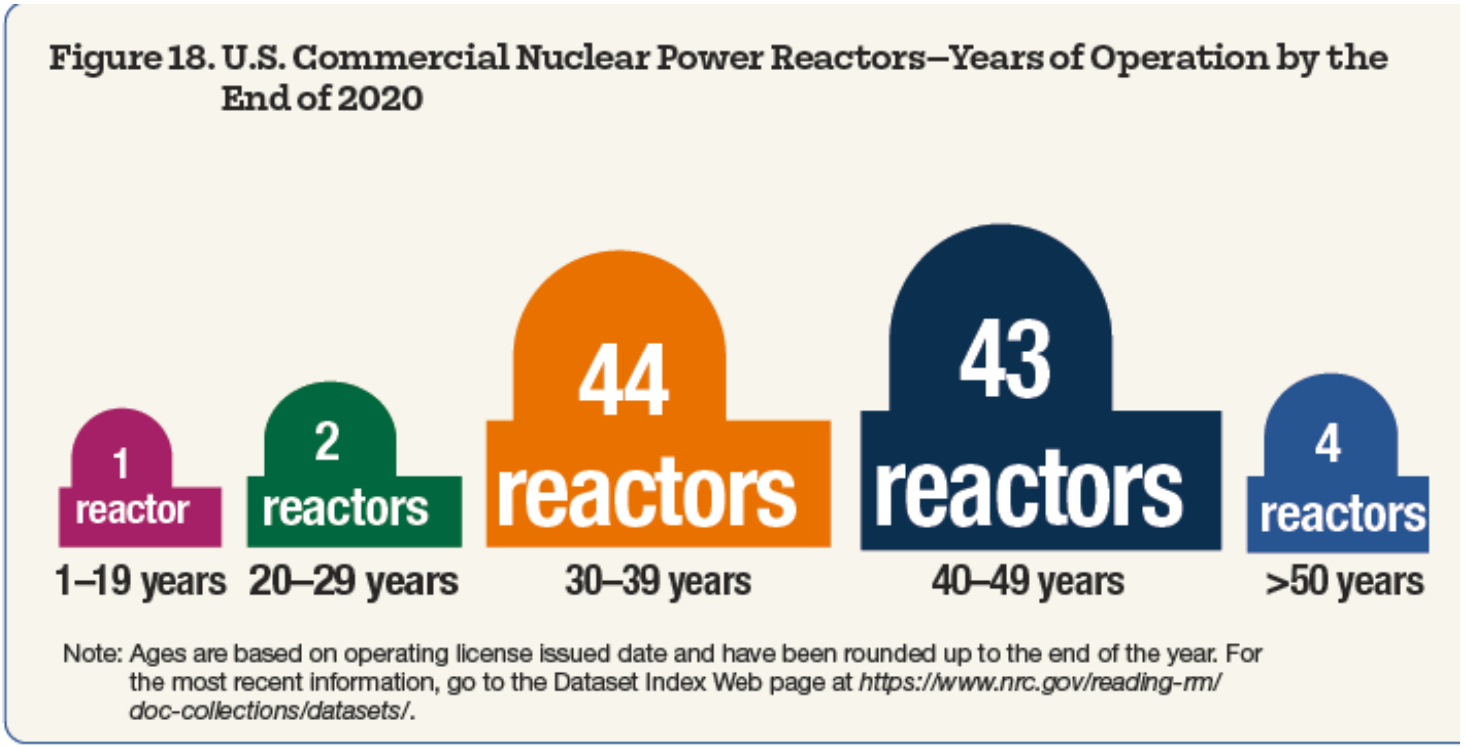

Figure from U.S. NRC 2020-2021 Information Digest (NUREG-1350, Vol. 32

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How Do You Get More Energy From an Existing Nuclear Reactor?

- Power uprate – increase the power level of the reactor
- Improve capacity factor – run the reactor a greater percentage of time
- Life extension – do not shut the reactor down at the end of its nominal “lifetime”

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Power Uprates

- First one in the U.S. was in 1977
- Since then, there have been 171 approved in the U.S. (some units uprated more than once)
- Total of 8,030 megawatt-electric
- No power uprate applications pending or expected by the Nuclear Regulatory Commission (NRC)
- Very limited potential remaining for existing reactor power uprates

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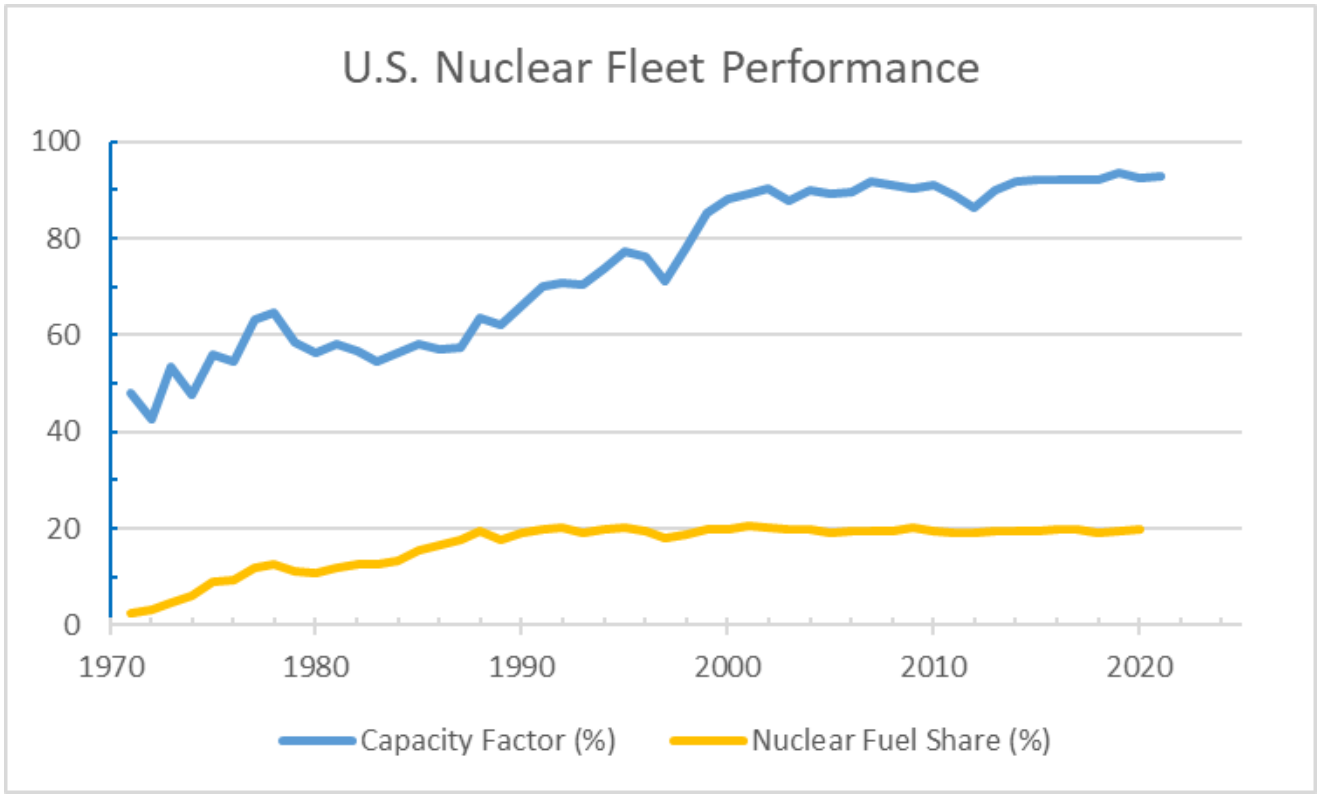
Capacity Factor



Based on data from the U.S. Department of Energy – Energy Information Agency and the Nuclear Energy Institute

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Long-Term Operation

- Requires
  - Demonstration of adequate safety and operating margin
  - Regulatory approval
  - Favorable economics for operation
- Already a success story in the U.S.
  - Initial 20-year license renewals (up to 60 years of operation) are straightforward in the U.S.
  - Subsequent license renewals (up to 80 years of operation) have been granted
  - Underpinned by
    - Aging management programs
    - Research
    - Analytical work

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Initial License Renewal

- The NRC licenses power reactors for 40 years in the U.S.
  - Length of license was not based on technological limitations, but on economics and accounting
  - However, analyses and engineering decisions were based on the projected 40-year life
- Discussions on license renewal began in earnest in the 1980s

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Situation in the 1990s

- Most nuclear plants had received initial licenses
- Construction costs had proven much higher than originally envisioned
- Operations were beginning to improve but well below current expectations
- The regulatory framework was challenging
- Environmental benefits of zero-emissions electricity production were not nearly as valued as today

It was not clear that long-term operation would be cost-effective

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Regulatory Framework

- The NRC, industry, and other stakeholders worked together in the 1990s to establish a workable framework for license renewal
- NRC issued 10 CFR Part 54, Requirements for Renewal of Operating Licenses for Nuclear Power Plants, in 1995

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Key Decision Point for License Renewal

- Would a license renewal be based on a plant's current licensing basis?
  - Alternatively, would a renewed license require upgrades to make a plant's licensing basis consistent with the latest NRC expectations?
- Ultimately, the NRC decided to stick with the plant's current licensing basis when considering an application for a renewed operating license

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Process for License Renewal

- Evaluation of safety impacts
  - Evaluation of licensee's plans for managing aging plant systems during the renewal period
  - Does not require absolute proof of no unacceptable degradation – just that monitoring will detect degradation before it reaches unacceptable levels
- Evaluation of environmental impacts
  - Generic evaluation in NUREG-1437, Rev. 1
  - Site-specific impacts
  - Includes impacts of continue storage of spent nuclear fuel
- Opportunities for public input

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Technical Challenges

- U.S. focus is on passive components
  - Active components are addressed on an ongoing basis by Maintenance Rule
- Technical issues
  - Reactor pressure vessel neutron embrittlement at high fluence
  - Irradiation-assisted stress corrosion cracking of reactor internals and primary system components
  - Concrete and containment degradation
  - Electrical cable qualification and condition assessment

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Addressing Technical Issues

- Research by DOE, NRC and industry to develop and refine aging management programs
- NRC Generic Aging Lessons Learned (GALL) report (NUREG-1801)

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First License Renewal Experience

- Calvert Cliffs Units 1 and 2 and Oconee Units 1, 2, and 3 submitted applications for license renewal in 1998
  - Lead plants for the industry
- The process went relatively smoothly and on schedule and the NRC issued renewed licenses to the plants in 2000
- Based on that favorable experience, many plants began the license renewal process
  - Three applications in 2000 and six in 2001

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First License Renewal Experience (cont.)

- Of the 92 operating reactors in the U.S.
  - Eight are operating under their original 40-year license
  - 78 are operating with renewed licenses (up to 60 years of licensed operation)
  - Six have had subsequent license renewals granted (up to 80 years of licensed operation)
- The NRC issued renewed licenses to eight other reactors which subsequently shut down permanently for economic or other reasons
- License renewal applications for three reactors were withdrawn
  - None have been rejected

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Subsequent License Renewal (SLR)

- In the 2000s license renewal became a fairly routine matter
- Industry interest was focused on building large light water reactors to add additional nuclear capacity (“nuclear renaissance”)
- Interest in construction of new reactors cooled in the 2010s
- There was still an incentive to add another 20 years of operation (up to 80 years total) for operating nuclear power reactors

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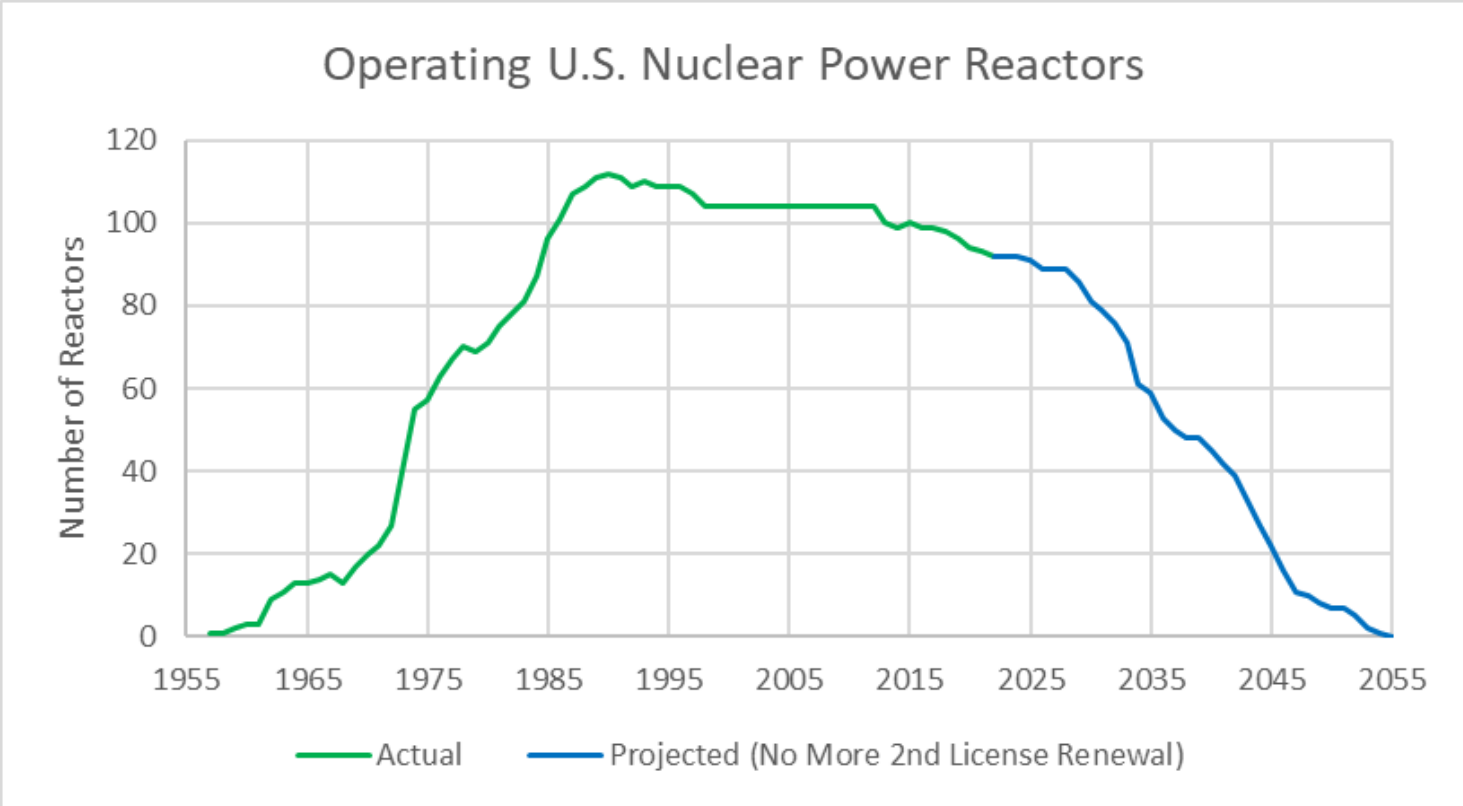
Case for SLR



Based on Data from U.S. NRC 2020-21 Information Digest (NUREG-1350, Vol. 32), assuming no additional subsequent license renewal

SLR Development

- After some consideration and stakeholder feedback, the NRC decided the license renewal framework is adequate for SLR, but additional guidance would be needed
- In 2017 the NRC issued
  - The Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) (NUREG-2191)
  - The Standard Review Plan for Review of Subsequent License Renewal Applications (NUREG-2192)
- Documents were developed with input from the Nuclear Energy Institute, interested utilities, and other stakeholders

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SLR Actions

- Three applications for SLR in 2018
  - Turkey Point 3&4, Peach Bottom 2&3, and Surry 1&2
  - NRC issued renewed licenses in 2019, 2020, and 2021, respectively
- Four applications currently under NRC review
  - Point Beach 1&2, submitted in 2020
  - North Anna 1&2, submitted in 2020
  - Oconee 1-3 submitted in 2021
  - St. Lucie 1&2, submitted in 2021

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New SLR Legal Issue

- The Nuclear Regulatory Commission issued a decision on February 24, 2022 negating subsequent licenses that had been granted
  - Issue relates to wording in one of the NRC's regulations (10 CFR Part 51) that is specific to the initial license renewal
  - NRC had applied the regulation to subsequent license renewal as well
  - Current Commission overruled previous ruling
- Revision the regulation to address issue will likely take years

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How Many U.S. Reactors Will Apply for SLR?

- Three applications are in the official NRC pipeline
- Some U.S. utilities have made ambitious statements of intent about reducing or eliminating greenhouse gas emissions over the next few decades
- Difficult to see how they can meet those commitments while shutting down nuclear power plants
  - Example - Duke Energy announced it would seek SLR for all 11 units it operates in support of its goal of net-zero carbon emissions by 2050

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Economics

- For plants that continue to operate, SLR is a relatively cheap way to keep future electricity generation options open
  - Even so, some plants may require major refurbishments (e.g., buried piping replacement, electrical cable replacement) that make plant life extension uneconomical
- Broader U.S. policy developments such as state and/or federal incentives for clean energy would make SLR more attractive
  - Department of Energy $6 billion Civilian Nuclear Credit Program
  - Limits on emissions from fossil fuels
- Higher natural gas prices incentivize nuclear generation

International License Renewal Situation

- Regulatory requirements and practices differ from country to country
- The International Atomic Energy Agency (IAEA) has been coordinating international cooperation and sharing of best practices since 2010
- International Generic Ageing Lessons Learned (IGALL) Safety Report Series No. 82 published in 2015 and revised in 2017

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International License Renewal Situation (cont.)

- IGALL is largely based on U.S. experience but goes beyond GALL and GALL-SLR
  - U.S. license renewal programs are focused on passive components because active components are addressed by the Maintenance Rule
  - IGALL includes programs for active components (other countries don't have the Maintenance Rule)
- Countries with a small number of reactors can benefit from cooperation afforded through the IAEA programs

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Conclusions

- Life extension of currently operating nuclear power plants is an important means of providing clean, reliable electricity in the coming decades
- There is a well-established and workable system for nuclear power reactor license renewals in the United States
- Current SLR issue should be resolved
- License renewal lessons-learned are being shared internationally through the IGALL program
- Ultimate decisions on life extension are based on economic and other considerations

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