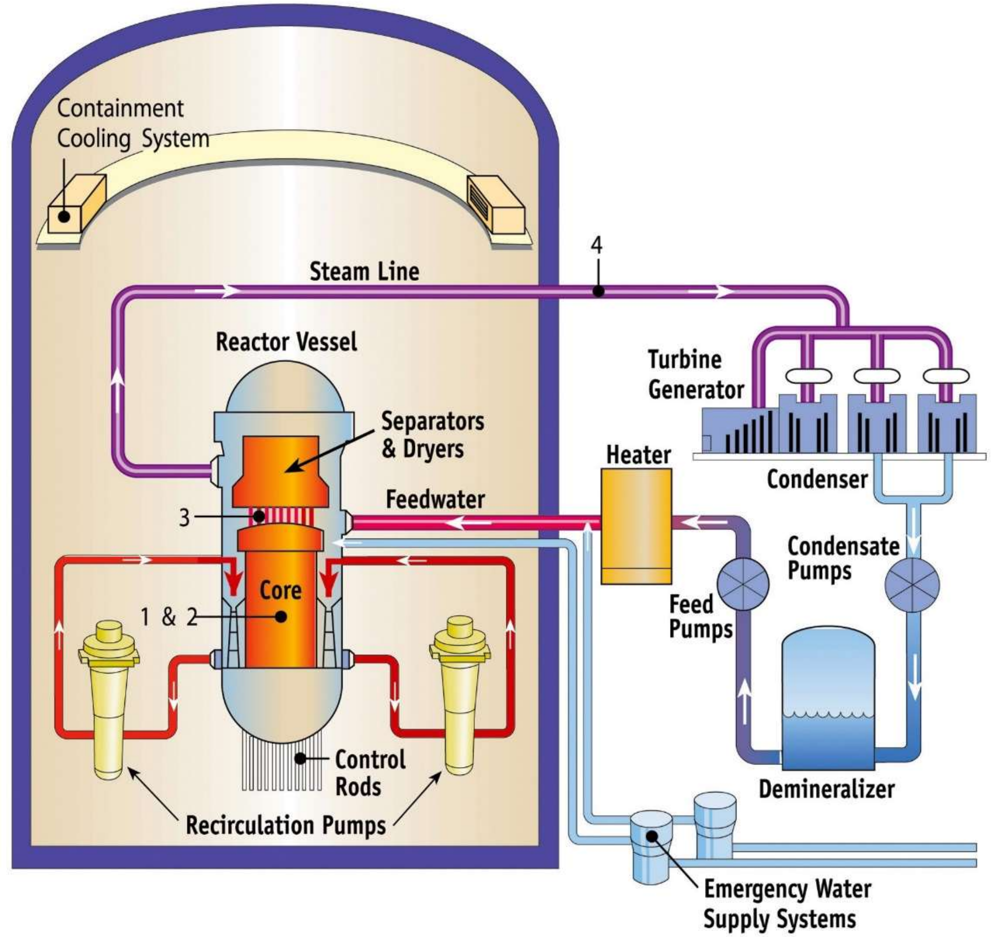
Nuclear Harvest

Beyond Nuclear seeks structured and mandated harvesting of materials from permanently closed reactors to narrow knowledge gaps about aging degradation and, hopefully, avoid accidents.

David Lochbaum
April 2019

BACKGROUND:
Nuclear Plant Aging

Nuclear power plants are not monolithic structures, but large, complex industrial facilities made of concrete, metal bars, wires, cables, motors, pumps, electrical relays, dampers, piping, sensors, and much more.

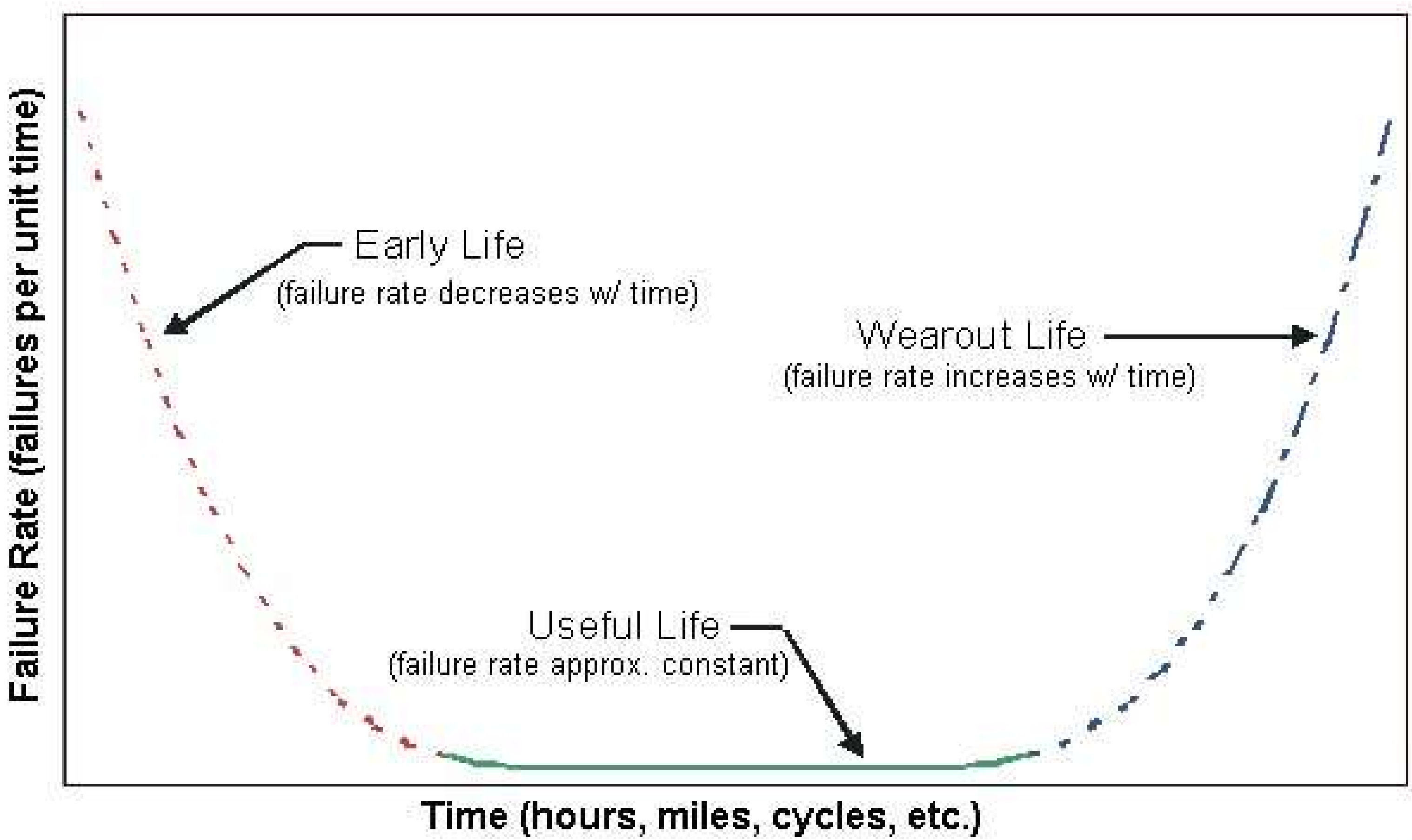


Source: U.S. Nuclear Regulatory Commission

A nuclear plant's materials degrade over time due to rusting, embrittlement, wear & tear, chemical interactions, and other factors.

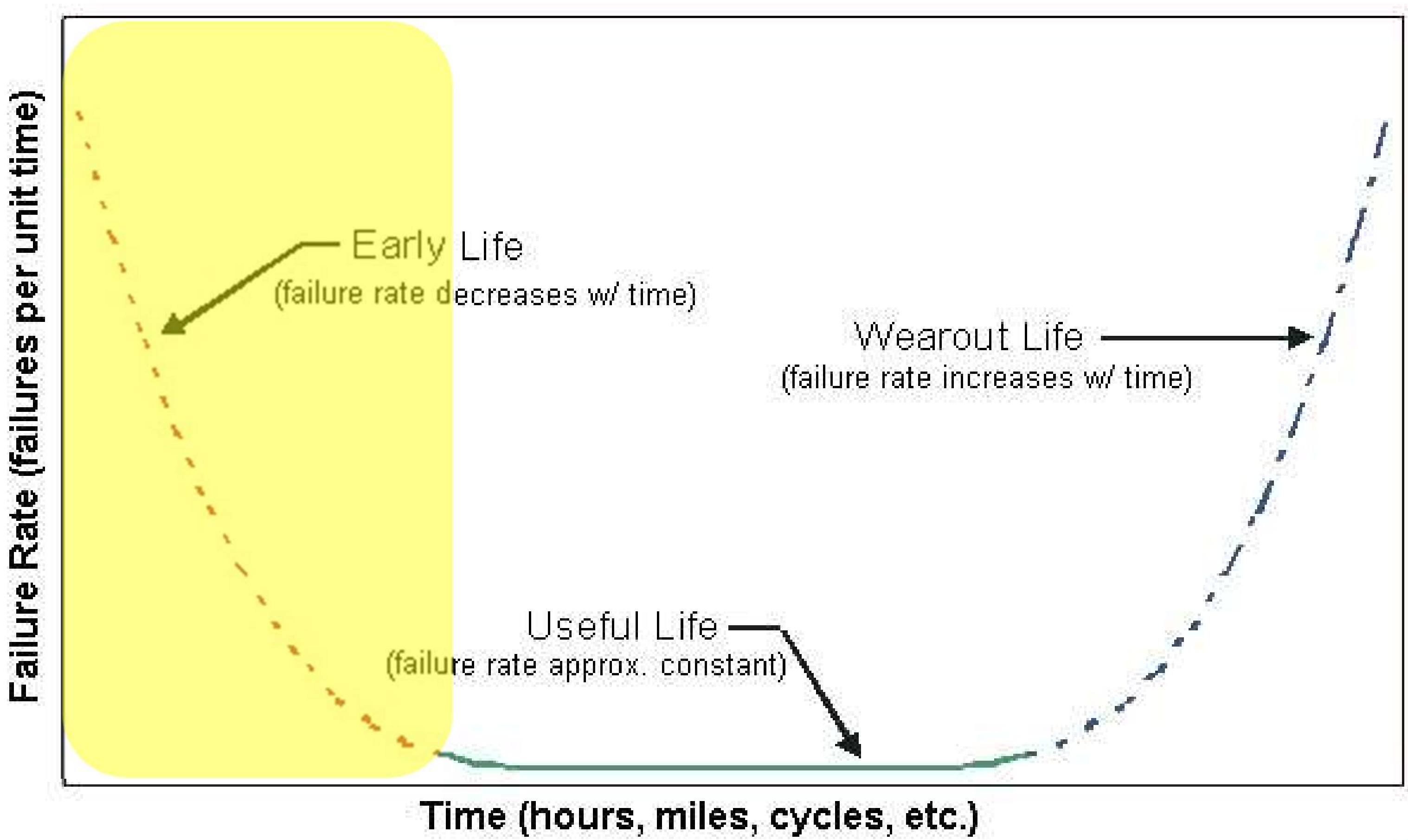
Degradation can compromise safety margins, increasing the likelihood of and/or consequences from failure.

BACKGROUND:
Aging Risk Over Time



A graph called the "Bathtub Curve" due to its shape illustrates the likelihood of component and structures failing over their lifetimes.

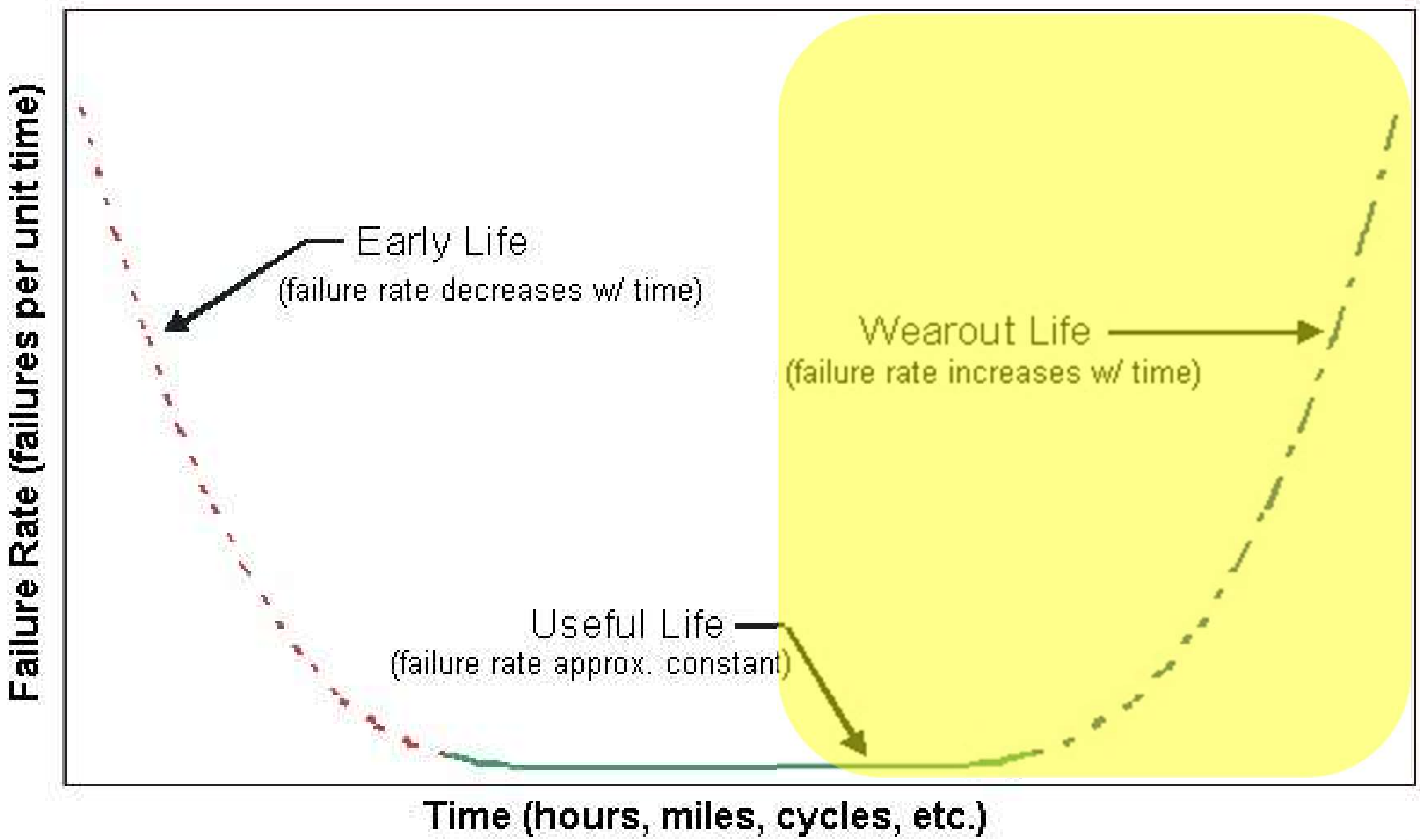
BACKGROUND:
Aging Risk Over Time



The failure rate is initially high due to factors such as material imperfections, assembly errors, and mis-use.

BACKGROUND:

Aging Risk Over Time



The failure rate rises later on due to aging factors that lessen the strength and reliability of materials.

To manage the risk of failures during the break-in and wear-out phases, and points in between, the U.S. Nuclear Regulatory Commission (NRC) requires periodic tests and inspections intended to ensure the necessary safety margins are maintained, or remedy them if found lacking before the vulnerabilities can be exploited.

With miles of cabling and piping, thousands of cubic yards of concrete, and thousands of relays, switches, gauges, sensors, and other widgets in each nuclear plant, everything simply cannot be tested and inspected every day. The key question becomes:

What gets inspected when?

OE

p x
e p
r e
a r
t i
i e
n n
g c
e

OE is a key factor when determining the testing and inspection regimes and in later adjusting them as understanding of aging mechanisms increases.

The primary sources of OE are:

1) **Results from laboratory analyses**
2) **Results from plant tests and inspections**
3) **Lessons learned from unexpected failures**
4) **Examinations of materials removed from operating facilities (e.g., replacement parts)**
5) **Examinations of materials harvested from permanently shut down facilities**

OE informs decisions about increasing inspections here and decreasing inspections there. Examples of the former include piping erosion/corrosion after the fatal accident at Surry in December 1986 and the reactor head corrosion at Davis-Besse in 2002. An example of the latter is the reduction in the testing frequency for emergency diesel generators.

BACKGROUND: Primary OE Sources

Results from laboratory analyses	
Medical researchers study animals for reactions to toxins and diseases and the effectiveness of various treatments	Nuclear researchers study materials for performance under extreme conditions up to their failure to define safety margins
Results from plant tests and inspections	
Medical professionals record pulse, white cell count, etc. for health insights	Nuclear professionals record vibration levels, pipe wall thicknesses, etc. for insights
Lessons learned from unexpected failures	
Medical professionals develop vaccines and treatments to prevent recurrences	Nuclear professionals identify root causes of problems and apply corrective actions
Examinations of materials removed from operating facilities	
Medical professionals biopsy tumors to better understand health	Nuclear professionals examine specimens and parts replaced for degradation insights
Examinations of materials harvested from retired facilities	
Medical professionals conduct autopsies to gain insights otherwise unattainable	Nuclear professionals can examine materials otherwise challenging to get

CONTEXT

Due to so many variables, improper context is primary weakness of aging management programs that OE seeks to remedy.

For example, Material X is well known to degrade at a predictable rate when exposed to a steady environment of 300°F.

But how does its degradation rate change if the material is exposed to radiation? Or if it is exposed to frequent fluctuations between 80°F and 300°F instead of a constant temperature?

And will Material Y degrade faster, slower, or at the same pace as Material X?

OE, and the aging management programs it serves, are journeys rather than destinations. Far more is known today about aging mechanisms than was known 20 years ago – but far less is known now than will be known in 20 years.

All nuclear reactors operating in the U.S. are heading towards, if not already in, the wear-out portion of the bathtub curve where the likelihood of failures increase.

Concurrently, OE is adding to the understanding of aging degradation and enabling adjustments to what gets inspected when to prevent failures that trigger accidents and/or make their consequences worse.

Since 2013, the Crystal River 3, Kewaunee, San Onofre Units 2 and 3, Vermont Yankee and Oyster Creek reactors have permanently closed while owners have announced plans to close several other reactors in near future. Very few new reactors are on the horizon.

How could the permanent closure of nuclear reactors affect OE and the adjustments to aging management programs needed to protect safety margins?

Recall that the primary sources of OE are:

1) **Results from laboratory analyses**
2) **Results from plant tests and inspections**
3) **Lessons learned from unexpected failures**
4) **Examinations of materials removed from operating facilities (e.g., replacement parts)**
5) **Examinations of materials harvested from permanently shut down facilities**

Fewer reactors operating means fewer test and inspection results from operating plants, fewer lessons learned, and fewer examinations of materials removed from operating reactors.

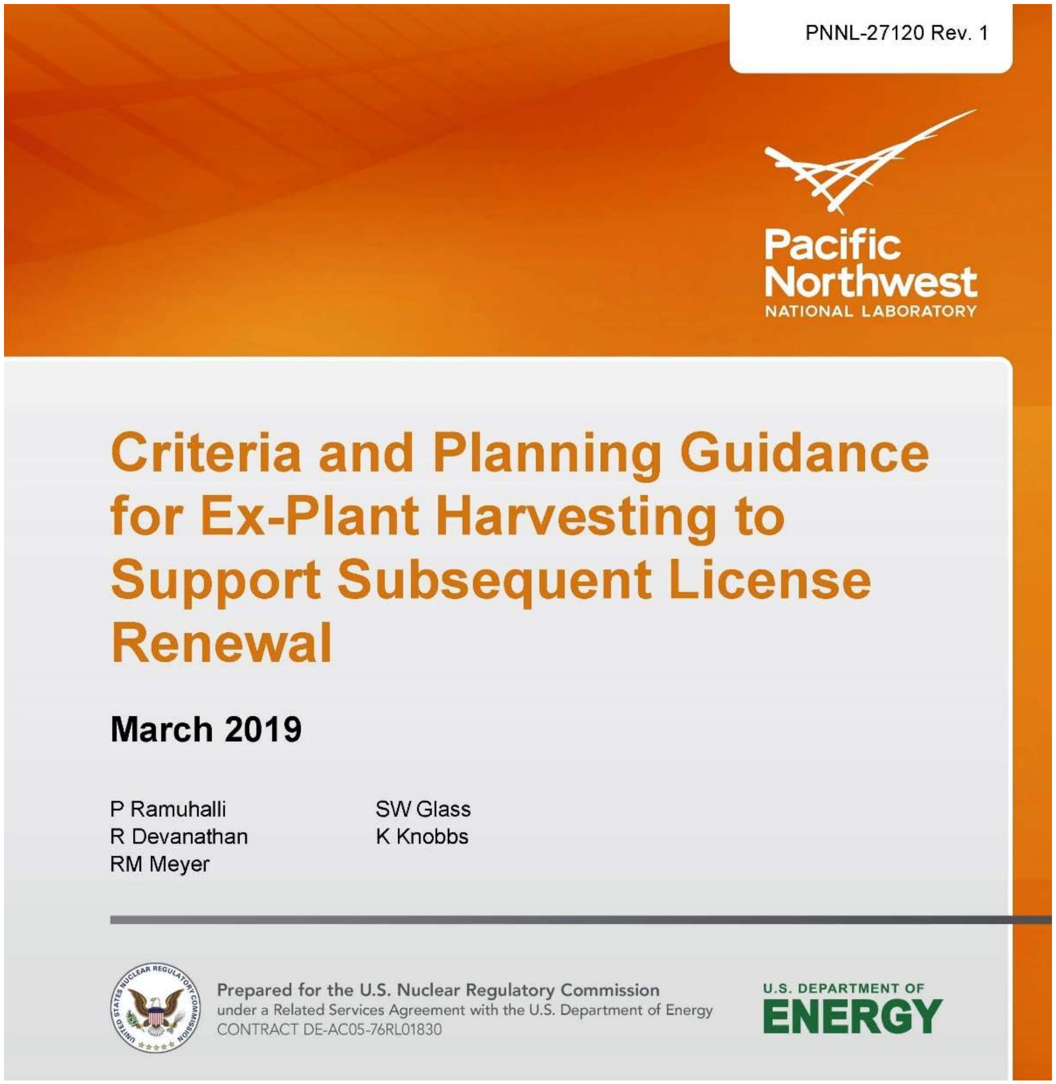
As OE from these sources shrinks, the expansion of the understanding of aging mechanism may not progress at the rate needed to preserve safety margins – unless OE from other sources increases in compensation for the losses.

Aging Catch-22

Unfortunately, the compensation for loss of OE from operating reactors is not linear – in other words, it's not a simple task of harvesting materials from N reactors after N reactors have permanently closed.

Fortunately, the NRC, the U.S. Department of Energy, and industry organizations like the Electric Power Research Institute have already identified gaps in the understanding of aging degradation. Their largest gaps include concrete degradation, electrical cable insulation aging, and irradiation-assisted stress corrosion cracking.

Aging Catch-22


PNNL-27120 Rev. 1

Pacific Northwest
NATIONAL LABORATORY

Criteria and Planning Guidance for Ex-Plant Harvesting to Support Subsequent License Renewal

March 2019

P Ramuhalli
R Devanathan
RM Meyer
SW Glass
K Knobbs

Prepared for the U.S. Nuclear Regulatory Commission
under a Related Services Agreement with the U.S. Department of Energy
CONTRACT DE-AC05-76RL01830

U.S. DEPARTMENT OF ENERGY

Fortunately, solid clues exist on where harvesting materials can narrow current knowledge gaps about aging degradation.

Unfortunately, harvesting materials takes time and costs money – unattractive incentives to owners of nuclear reactors no longer generating electricity and revenue.

Means must be provided to determine when harvesting provides information *nice* to know versus information *<u>necessary</u>* to know so the latter gets funded and done.

Harvest Time

In July 2018, the owner of the two operating reactors at the Peach Bottom nuclear plant in Pennsylvania applied to the NRC to renew their operating licenses for up to another 20 years (for a total of 80 years).

Beyond Nuclear formally intervened with the NRC, contending that the license renewal application failed to identify the sources of OE for the many aging management programs (AMPs) described in the application.

Beyond Nuclear contends that the dependency of AMPs on OE sources needs to be explicitly described to determine if closure of nuclear reactors diminishes the flow of OE such to require the analysis of aged materials strategically harvested from permanently closed reactors as necessary (i.e., justifies the investments needed to make it happen.)