# GEM*STAR, an Accelerator-driven Subcritical Reactor

**(Green Energy Multiplier Sub-critical Thermal-spectrum Accelerator-driven Recycling reactors)**


**Alireza Haghighat**

Professor and Director

Nuclear Science Engineering Lab (NSEL)

Arlington Campus

**Virginia Tech**

haghighat@vt.edu

http://nsel.ncr.vt.edu


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NSEL Nuclear Science and Engineering Laboratory Virginia Tech Research Center, Arlington, VA

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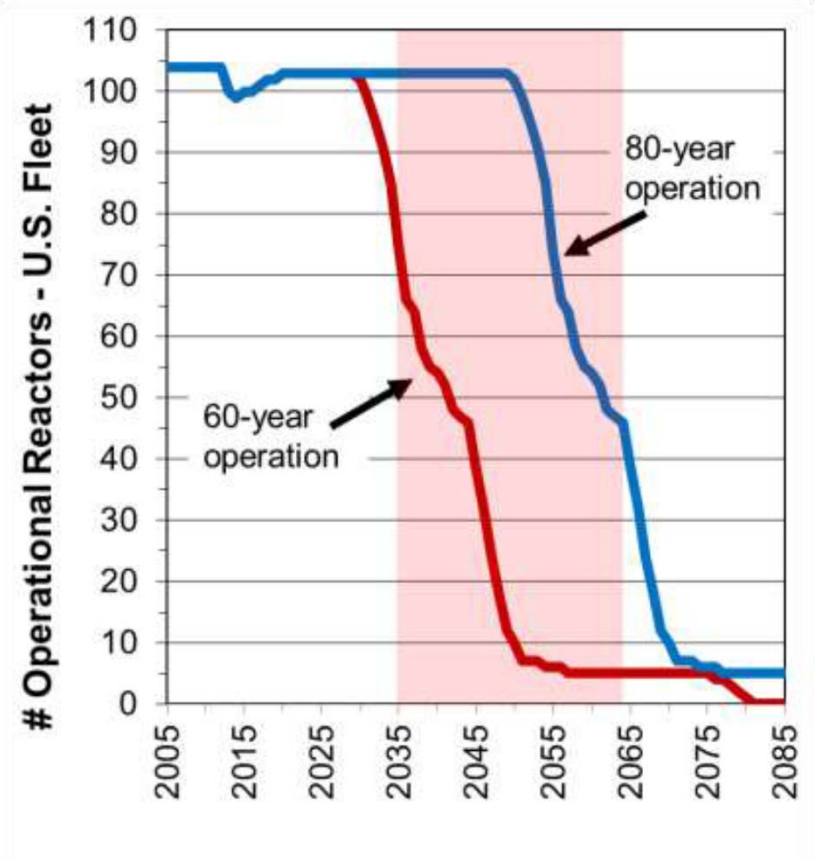
# US Nuclear Reactors – Operating Life

**US Reactors are approaching their 40-year life; majority have permission for 20 years of plant life extension (PLE).**

**Even with 20-year PLE, we have to START building NOW!**



# Introduction to GEM*STAR

**(Green Energy Multiplier Sub-critical Thermal-spectrum Accelerator-driven Recycling reactors)**

- Original design was developed by Charlie Bowman (ADNA) and Bruce Vogelaar (Virginia Tech) , and worked on a part-time basis between 2004-2013

- The GEM*STAR **is not an incremental approach**, but rather a strategy that addresses all the key issues raised about **current LWR technology** at once.

# Why GEMSTAR?

- To address key issues facing LWR technology:

  - **Used Nuclear Fuel**
  - **Proliferation (Enrichment, Reprocessing)**
  - **Safety (Fuel melting, beyond design accidents)**
  - **Cost**
  - **Timeline**

# Introduction to GEM*STAR

GEM*STAR is an accelerator-driven *subcritical* reactor (ADSR):

- *Subcritical*

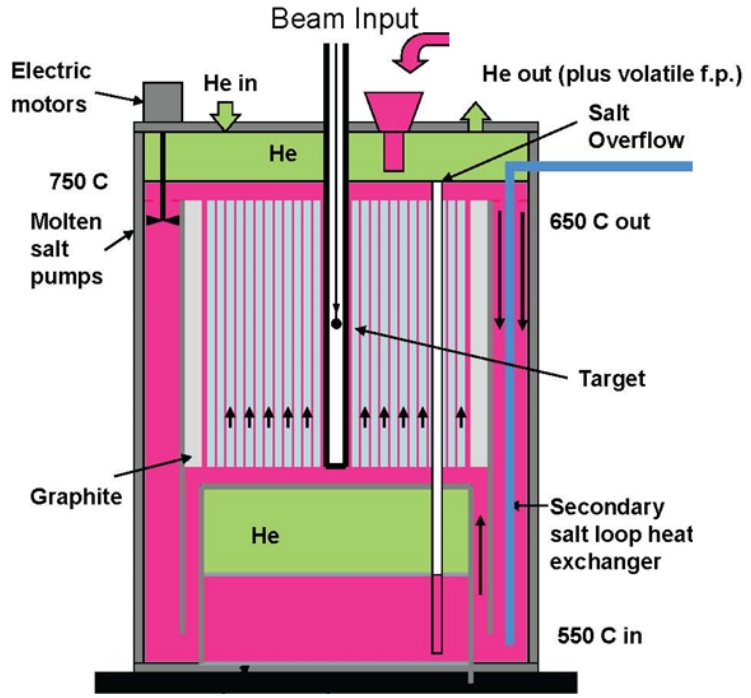
$$k = \frac{Neutron\ Production\ Rate}{Neutron\ Loss\ Rate} < 1$$

- *Compensate neutron deficiency*

*Accelerator (proton beam) – impinges on a target (e.g., uranium) – produce (neutrons)*

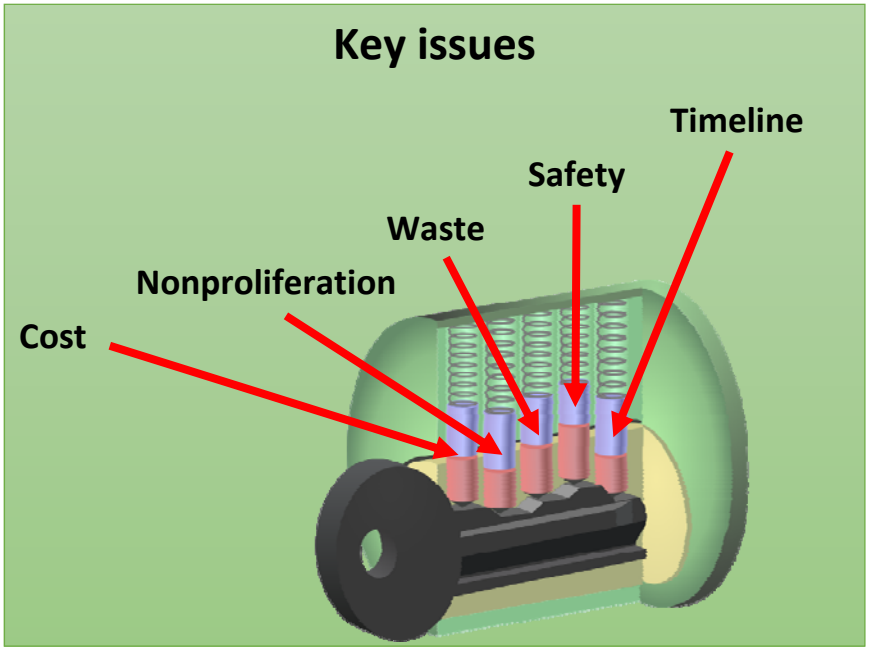
- *Fuel – Molten salt* $[(LiF)_2UF_4]$
- *Moderator - Graphite*

**GEM*STAR - Schematic**



# Why Subcritical?

- Flexible fuel cycle
  - Fueled with natural uranium (no need for enrichment)
  - Burn UNF
  - Convert WGPu
- Reduction of nuclear waste
- Simplified safety system
- Scalable



# Why molten salt fuel?

- No fuel melt under severe accidents
- High boiling point (>1,500 C), low-pressure systems
- High operating temperatures, higher efficiency
- High temperature, generation of syngas for liquid transport fuel

# Cost & timeline

- Lower construction cost (low pressure, simplified safety system, scalable, modular)
- Estimated electricity cost is competitive with coal
- Adequate technology is available today to demonstrate basic commercial viability.

Independent neutronics analysis by the Virginia Tech Transport Theory Group ($VT^3G$),

led by Prof. Haghighat

(Dec 2014 – June 2015)

# Use of GEM*STAR for:

- Electricity Generation
- Conversion of WGPu
- Burning of LWR UNF

# REMINDER
# Weapon Grade Pu (WGPu) versus LWR Pu

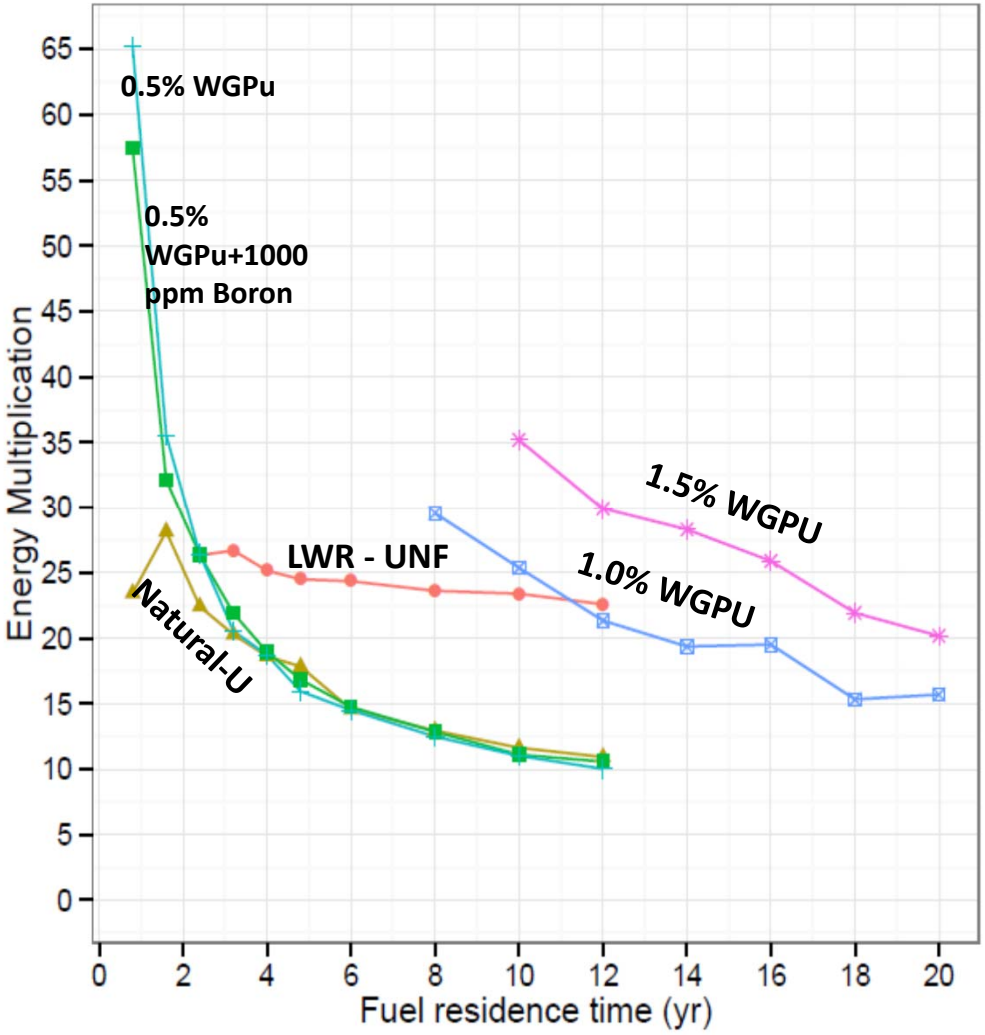
| Isotope | Half-life (yr) | WGPu Weight (%) | LWR [Weight (%)] |
|---|---|---|---|
| Pu-239 | 24k | 92.8% | 59.5% |
| Pu-240 | 6.6k | 6.1% | 10.3% |
| Pu-241 | 14 | 1% | 4% |
| Pu-242 | 373K | 0.1% | 6.1% |

# Examined feeds

| Fuel Material | Description |
|---|---|
| Natural Uranium | 0.711 w% U-235 |
| LWR UNF | 5.0 w% original enrichment<br>40 GWd/MT, 10 years cooling |
| 0.5% WGPu | Balance is depleted uranium |
| 0.5% WGPu + 1000 ppm Boron | Balance is depleted uranium |
| 1.0% WGPu | Balance is depleted uranium |
| 1.5% WGPu | Balance is depleted uranium |

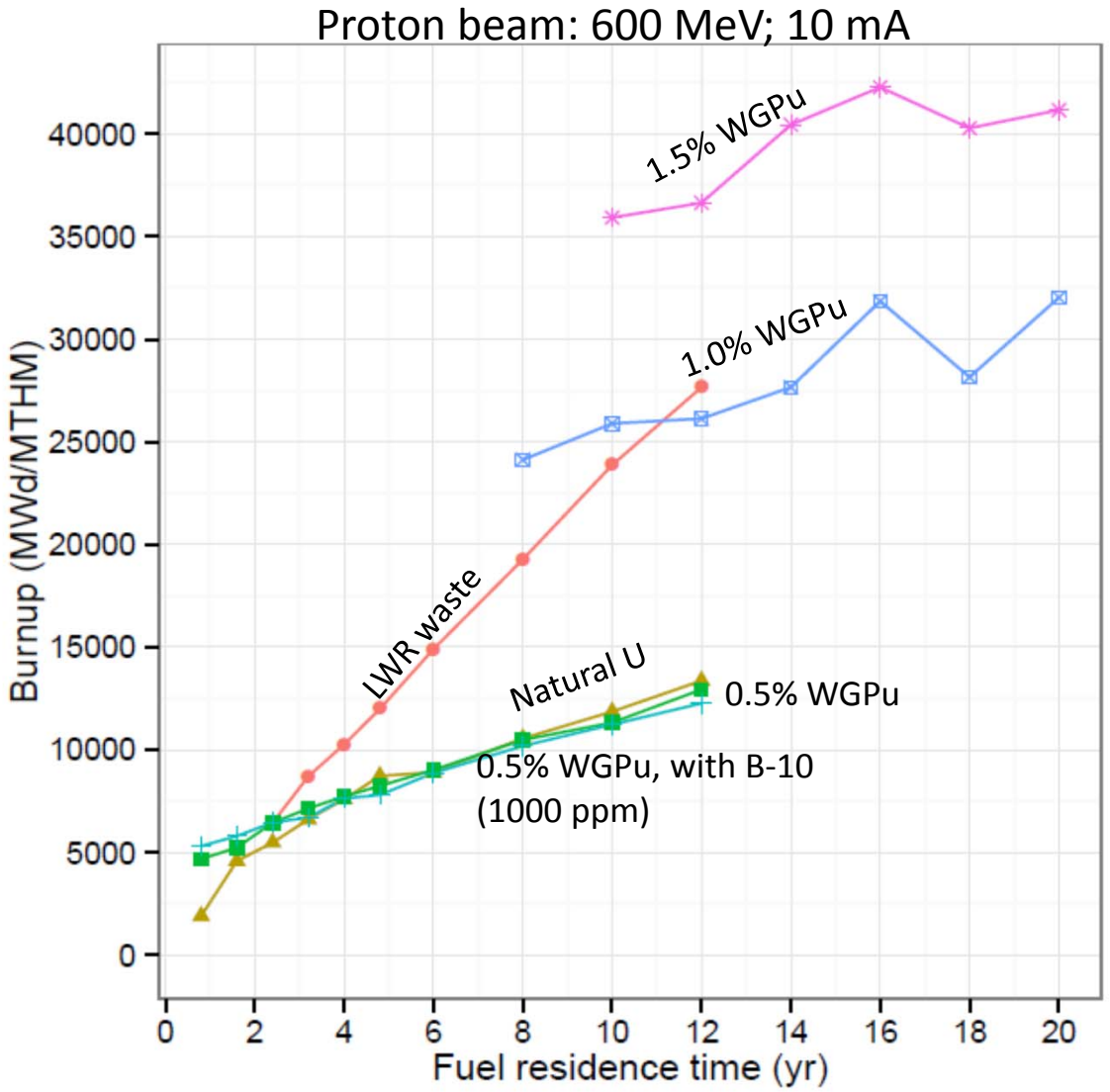
# Example - Electricity production

$$\textbf{Energy Multiplication } (M) = \frac{\textbf{Electric power out } (\textbf{thermal fission energy} * \textbf{efficiency})}{\textbf{Beam power on target}}$$




NOTE: Data is not presented for low-residence times for LWR-waste and WGPu, because the reactor becomes supercritical,

# Comparison of burnups vs. residence time for different feeds

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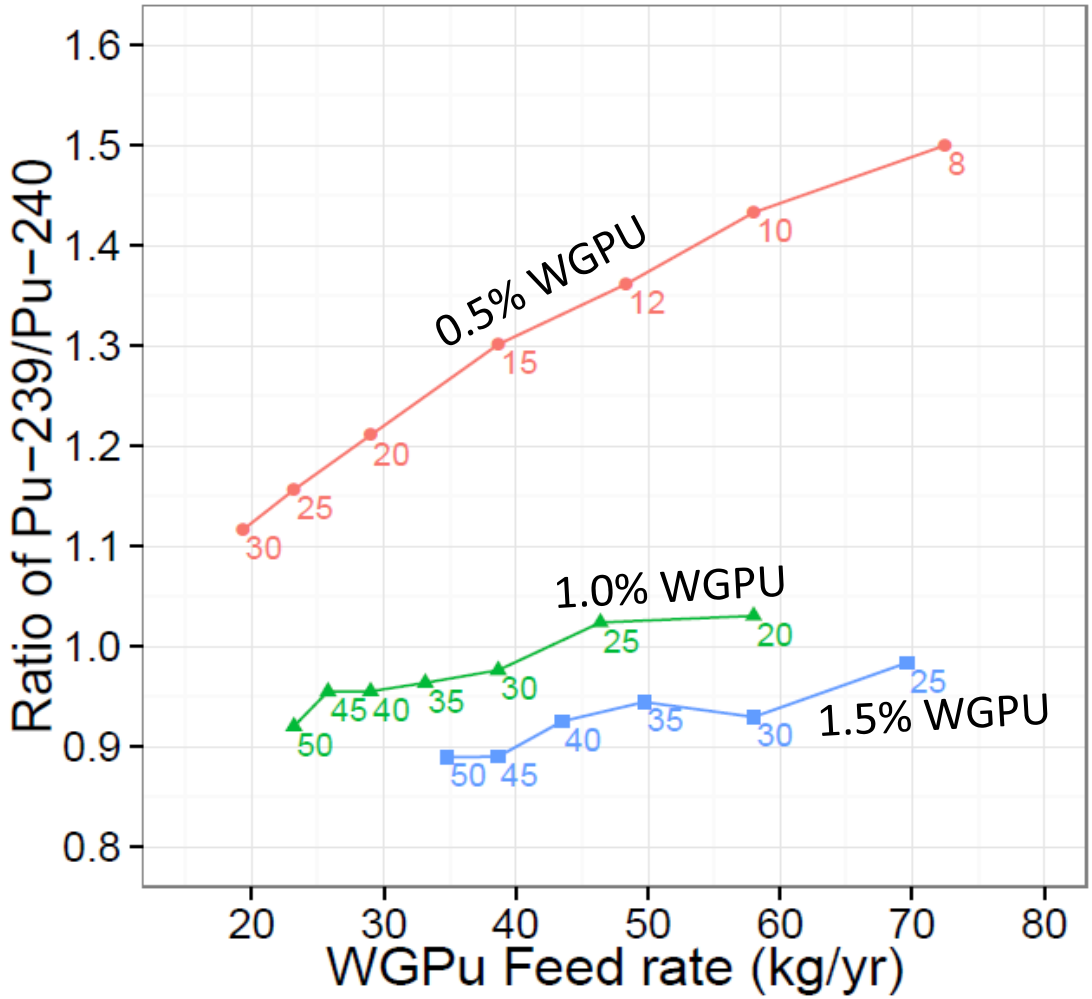
# Variation of Pu239/pu240 for different feed rates and residence times



# Conclusions & Future Work

- GEM*STAR is a promising advanced design with unique features addressing key issues facing the nuclear industry
- ORNL has expressed interest in working with us
- Talking with the VT leadership and other organizations, considering formation a small company
- Developed a 5-year plan (performing Target and molten salt studies, developed a financing plan for building a prototype, and initiating NRC licensing activities)
- Selected by the ICTAS' *Energy and Material Initiative (EMI)* for the establishment of *Safe, Secure, and Sustainable Nuclear Power (S3NPower)* Cluster (received initial funding and seeking members for an industry affiliates program)
  - Would the VNEC members be interested in participating in this initiative?
- Planning to submit proposals to the recent DOE opportunities (Advanced Reactor Design, *GAIN - Gateway for Accelerated Innovation in Nuclear*), and Bill Gates' recent initiative, i.e., *Breakthrough Energy Coalition.*
- Would the VNEC Board considers *S3NPower/GEM*STAR* as a new initiative for next year (2016-2017), and explore the potential for receiving funding from the State?

# Thanks!

Questions?