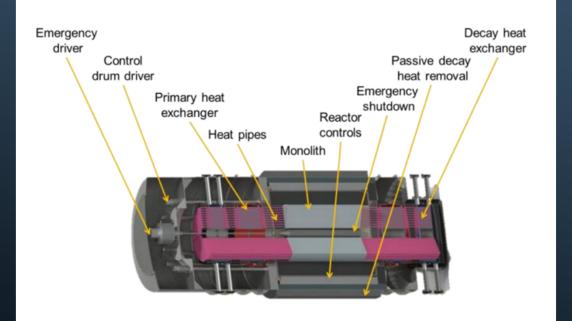
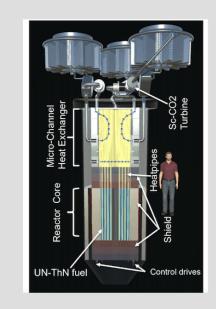


David Medich, Ph.D., CHP Associate Professor, Director of WPI NSE Program U.S. Nuclear Regulatory Commission 34th ANNUAL REGULATORY INFORMATION CONFERENCE



Evaluating Nuclear Microreactors as a Hybrid Next-Generation Source for University Research and Energy







Nuclear Research Reactors

Nuclear research reactors, also known as "non-power" reactors, are used for nuclear training and development programs and to advance research and knowledge in a broad range of fields.



https://engineering.purdue.edu/NE/research/facilities/reactor_html



Personal picture of the UMLRR Core (Please note that I believe Cherenkov makes everything look cool)



University Research Reactor Background

- U.S. University Research Reactors (URRs) operate between ~0 10 MW_{th}
- URRs were developed primarily to study reactor operations and provide greater insight into nuclear physics and engineering
- URRs also a great source for neutrons as a research tool in fields such as physics, chemistry, biology, mechanical engineering, electrical engineering, medicine, agriculture, forensics, and geology.
 - But... Many of these fields need high neutron intensities (about 5MW_{th} or more equivalent)...



https://www.uml.edu/Engineering/Chemical/Programs/Nuclear/default.aspx



Limits of URRs

The U.S. has built 59 Research Reactors – of which, only 25 remain in operation. Why?

- U.S. University Research Reactors (URR) are based on 1950's / 1960's designs,
- All URRs started operating in period between 1955 to 1975*
 - the first New England URR was at WPI (10 kW_{th}) in 1959
 - The last were UML (1MW_{th}) and University of Utah (100 kW_{th}) in 1975
 - Of US URRs, only two (MURR and MIT) can meet all current research needs!
- This limits scientific research! (e.g., SANS and root imaging)

 So, our Fleet of Research Reactors
 are about 50-65 years old and may be underpowered!

*https://en.wikipedia.org/wiki/List_of_nuclear_research_reactors#United_States



University Sustainability Push

Concurrent with the need for high intensity neutron sources, universities are strongly pushing to become more sustainable and reduce carbon emissions

https://www.bing.com/search?q=university+sustaina bility&first=6&FORM=PERE

What is Sustainability? | UCLA Sustainability

https://www.sustain.ucla.edu/what-is-sustainability + Sustainability is the balance between the environment, equity, and economy. The most often sounded definition comes from the LRI World Commission on Environment and Development.

Sustainability - Harvard University

https://www.harvard.edu/programs/sustainability = Sustainability. Sudercis enrolled is the Naster of Liseral Arts program in Sustainability will gain inside into ortical environmental factors affecting alt, water, climate, and eccessterns, ...

Sustainability | The University of Texas at Austin https://sustainability.utexas.edu +

Oct 29, 2021 - 1 month ago, reply2, retweet, star. Sustainability. Check us out on Facebook, Instagram, and Twitter for more information about sustainability initiatives on campus! ...

Sustainability - Boston University https://www.bu.edu/sustainability -

Sustainability. Homepage, We support the transformation of Boston University's planning, operations, and culture toward a sustainable and equitable future. We are guided by the ...

University sustainability rankings 2021 - Save the Student https://www.savethestudent.org/extra-guides/... -

Dec 09, 2021 · These university rankings reveal the best and worst places for sustainability. Credit: Tetiana Shumbasova (background) – Shutterstock The general UK university rankings ...

University Sustainability: 3 Innovative Schools Making a ... https://consteril.com/university-sustainability-projects -

In this article, we identify three innovative sustainability projects making an impact at universities around the country: 1. Plastic Water Bottle Bon at Washington University of St. Louis. In 2009, ...

University of Maryland Office of Sustainability - UMD https://sustainability.umd.edu -

The University of Maryland is committed to advance sustainability through the ways we impact the world: teaching, research, service, and operations. About SustainableUMD Our global fight ... USNEWS EDUCATION + Colleges Grad Schools Online Colleges Global Universities K-12 SkillBuilder Rankiegs

Home / Education / Best Colleges

Why College Campuses Are Going Green

University

SECURITY & SAFETY

Business

Colleges are embracing sustainability in their classrooms and communities.

By Alison Murtaph | Sept. 17, 2019, at 9.42 a.m.

https://www.usnews.com/education/best-colleges/articles/2019-09-17/why-college-campuses-are-going-green

https://universitybu

siness.com/college s-achieve-carbonneutral-net-zero-

sustainability/

By: Matt Zalaznick | January 24, 2020

sources while reducing consumption

ADMIN & MANAGEMENT ACCESS & ENROLLMENT



PROFESSIONAL CAMPUS JOBS EVENTS RANKINGS STUDENT

FACILITIES

How more colleges achieve carbon neutrality

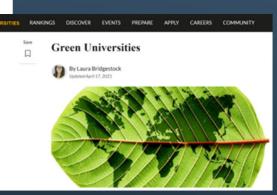
Campuses switch to solar and other renewable energy

How green is my university?

Academia has gone green in a big way in recent years, but some doubt whether it will make much difference to the planet. Nick Mayo speaks to scholars and students to assess the sector's environmental record

September 12, 2019

https://www.timeshighereducation.com/features/how-green-my-university



https://www.topuniversities.com/studentinfo/choosing-university/green-universities



Which Brings Us to Nuclear Microreactors

Nuclear Microreactors are a type of Generation IV (some can be Gen III+) nuclear reactor currently being developed. And they are SMALL...*

Generation IV Requirements**:

A Gen IV Reactor Must Demonstrate one or more of the following:

- increased efficiency,
- generation and capture of process heat for other thermal applications,
- increased safety and waste reduction.



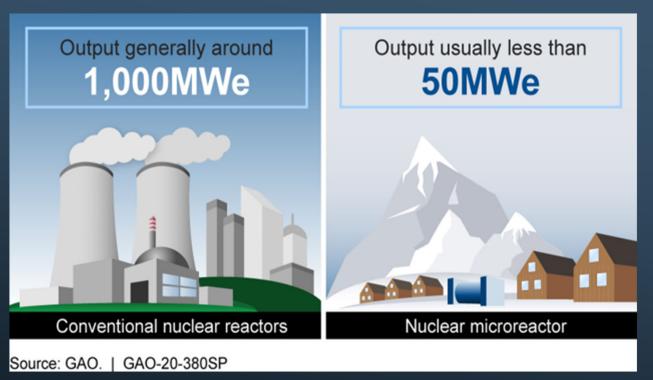
* (but not "micro" sized)

**Yıldız İlhami, Craig MacEachern, "Historic Aspects of Energy", in Comprehensive Energy Systems, vol(1), pp24-28, 2018



General Features:

- **1. Lower Power Output**
- 2. Factory Fabricated from Modular Components,
- 3. Transportable,
- Self-adjusting / Passive Safety Systems.

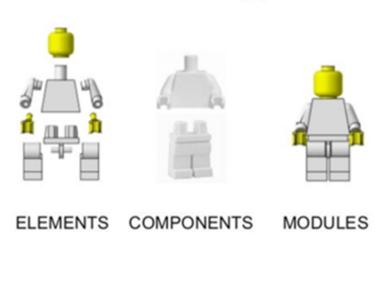




General Features:

- 1. Lower Power Output
- 2. Factory Fabricated from Modular Components,
- 3. Transportable,
- Self-adjusting / Passive Safety Systems.

Modular Design

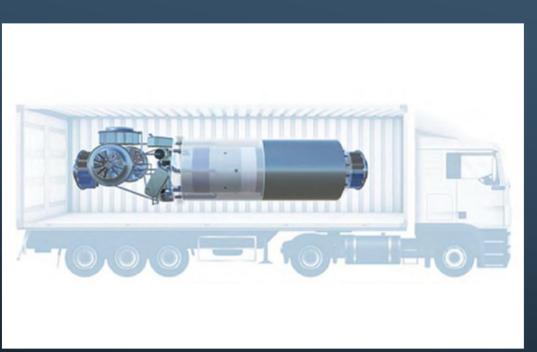


https://www.slideshare.net/Netlight/modular-design-58554891



General Features:

- 1. Lower Power Output
- 2. Factory Fabricated from Modular Components,
- 3. Transportable,
- Self-adjusting / Passive Safety
 Systems.



https://inl.gov/trending-topic/microreactors/



General Features:

- 1. Lower Power Output
- 2. Factory Fabricated from Modular Components,
- 3. Transportable,
- 4. Self-adjusting / Passive Safety Systems.



https://nenc.news/in-an-identical-simulator-pilgrim-operators-prep-for-shutdown/



A University Microreactor?

Therefore, a research/power microreactor can be advantageous because:

- a) They will operate at an equivalent thermal power to high-demand URRs
- b) They can meet most university power needs and have a *huge impact* on university carbon-reduction goals,
- c) They can be stationed at a university fairly easily and economically,
- d) They can be an excellent way to promote public support for next gen reactors given their enhanced safety and the safe operating history of current URRs...

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a + b + c + d = Graduate
Students
```



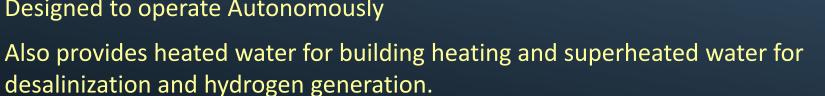


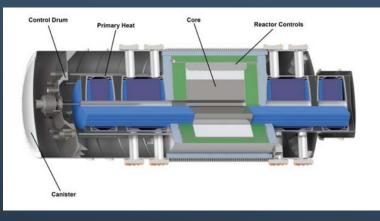
g.

Westinghouse eVinci Microreactor

We are using Westinghouse's eVinci Microreactor* as the basis for our research:

- It is a VHTR (designs finalized fall of 2021) а.
- Uses solid core and advanced heat-pipe technology b.
- Power output: up to 5MWe С.
- 40-year design life with 3+ year refueling interval d.
- Target less than 30 days onsite installation e.
- Designed to operate Autonomously f.





*https://www.westinghousenuclear.com/new-plants/evinci-micro-reactor



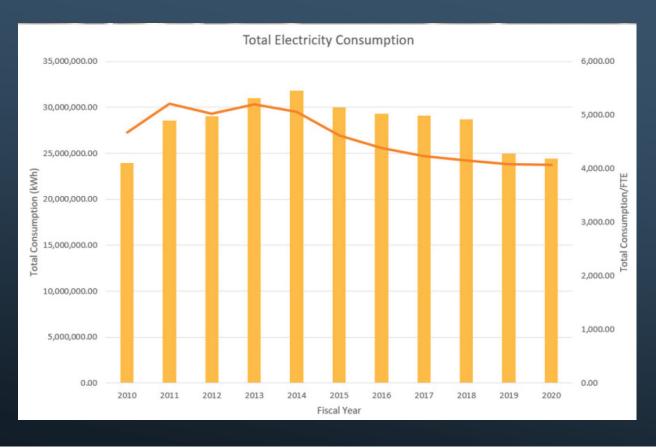
Can eVinci Meet WPI's Energy Needs

Sustainability Analysis: Energy Consumption

WPI <u>Average</u> Energy Use (2020): 2.8 MWe

WPI <u>Peak</u> Energy Need (2020): 4.1 MWe

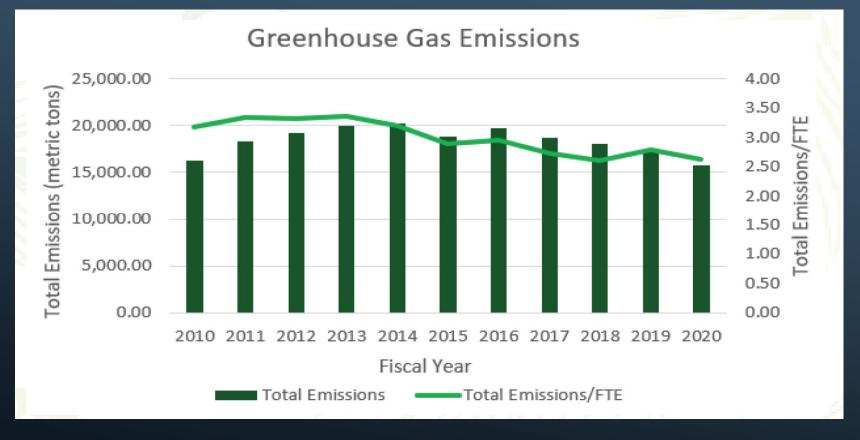
WPI <u>Average</u> Energy Use (2014): 3.5 MWe





Can eVinci Meet WPI's Energy Needs

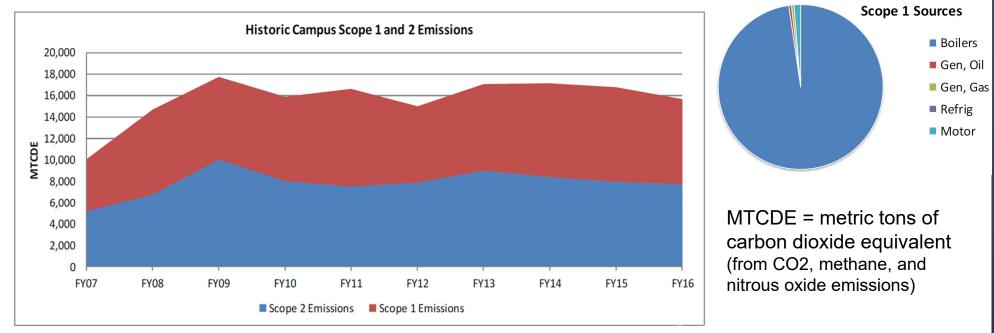
Sustainability Analysis: Carbon Net-Zero Emissions





Can eVinci Meet WPI's Energy Needs

Sustainability Analysis: Carbon Net-Zero Emissions



WPI Scope 1 and Scope 2 emissions. Scope 2 is due entirely to electricity use. Scope 1 is due primarily to natural gas for building heating with contributions from campus vehicles and power equipment.



eVinci as a Research Reactor

Much of our research efforts will be to Adapt eVinci as a Research Reactor:

- 1. Develop MCNP model of eVinci reactor,
- 2. Use MCNP to determine shielding needs of this reactor model (compare against Westinghouse's Scale model to validate model),
- 3. Develop research facilities to go with new reactor:
 - a) Thermal column: use microcollimator arrays for imaging at higher resolution/fluence rate,
 - b) NAA: use fast-scattering materials to enhance ex-core neutron activation ports(?),
 - c) Simulate designs for other research facilities (e.g. beamport, cold neutron source)
 - d) Structural and safety analysis of adding research facilities to shielding
 - e) Westinghouse wants to include a center flux-trap.



Preliminary Data

Too early for MCNP results, but here is some preliminarily data from a previous MQP* team (2017) for a homogeneous SMR core:

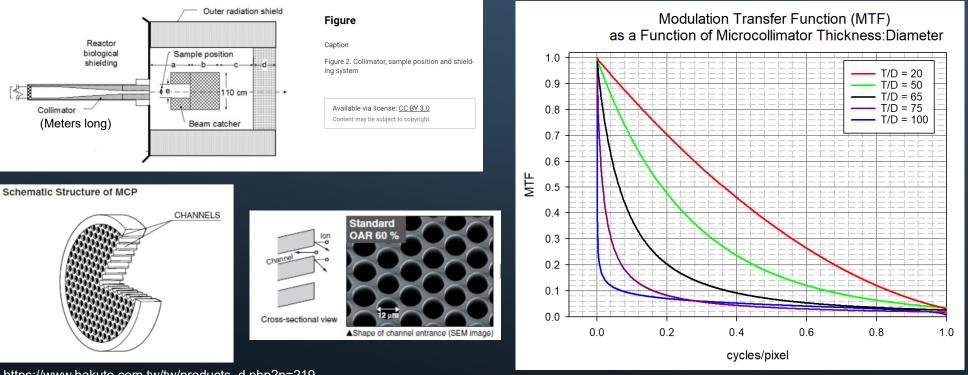
Table 6: Flux comparison			
Reactor	Average Flux (n/cm^2)	Maximum Flux (n/cm^2)	Beam Area (cm^2)
UMass Lowell FNI	$1.390 * 10^{11}$	$9.200 * 10^{12}$	900
Graphite Flask	$8.877 * 10^{12}$	$1.692 * 10^{13}$	900
GOFR Design	$1.963 * 10^{13}$	$5.048 * 10^{13}$	1963

*WPI is a project-based university. Students are required to perform an IQP (junior thesis) and MQP (senior thesis / capstone) to graduate. They can also participate as freshman in our Great Problems Seminar (GPS), where they learn how to perform scholarly research and work in groups.



Current Work: Microcollimator Array

New Results: Neutron Radiography: Replacing the Single (long) Collimator Design with an Ultra-Compact Array of Microcollimators



https://www.hakuto.com.tw/tw/products_d.php?p=219



Licensing Ideas

What about licensing a hybrid reactor? Although in the idea stage, we envision:

- 1. Initially license the reactor as a research reactor (no power),
- 2. Collect operations data on research reactor,
- 3. After a couple years and with sufficient operations data, we then could apply for a power reactor license.





Impact on Students

Current Student Work enabled by this NRC Award

- 1. Norbert Hugger, Ph.D. student: "Development of the Research Facilities to Support a Next Generation University Research Reactor"
- 2. Seamus Flanagan, senior MQP: "Modeling a Homogeneous Microreactor core in MCNP6 for First Order Fluence Rate Comparisons agains Current Research Reactors"
- 3. Matthew Jalbert, Ph.D. student. "Development of an Ultracompact Microcollimator Array For Neutron Fluence Enhancement"
- 4. Brock Jolicoeur, senior: "*Microcollimator array technology:* Determination of the L/D Needed to Achieve a 30um Resolution"











Impact on Students

Current Student Work enabled by this NRC Award

WPI 2021-2022 IQP Team: "Exploring the feasibility of nuclear microreactors for research and energy at WPI"

- 1. Derek Baker,
- 2. Leonardo Coelho
- 3. Maxwell Dargie
- 4. Patrick Hagearty
- 5. Declan Williams





Impact on Students

Previous student work (sorry, no pictures):

- 1. WPI MQP: "Geometry Optimized Flux Reactor (GOFR)", 2017
 - a) Sultan Jilani
 - b) Ivan Melnikov
- 2. WPI GPS Power the World project: "Campus Sustainability using an SMR" (2021)
 - a) Carlos Cueto
 - b) Samuel Darer
 - c) Jacob Ewen
 - d) Gabriel Garbes
 - e) Katee Harrington



I would like to thank:



NRC Research and Development Grant Award #31310021M0046 NRC Leadership Program: Fellowship Grant Award #31310018M0034



NRC R&D Award CoPI

Derren Rosbach, Ph.D. Associate Teaching Professor, Worcester Polytechnic Institute



NRC Fellowship Award CoPIs (cont)

Germano Iannacchione, Ph.D. Professor, Worcester Polytechnic Institute



NRC Fellowship Award CoPIs Izabela Stroe, Ph.D. Associate Professor, Worcester Polytechnic Institute



Snehalata Kadam, Ph.D. Associate Teaching Professor, Worcester Polytechnic Institute



Questions?

