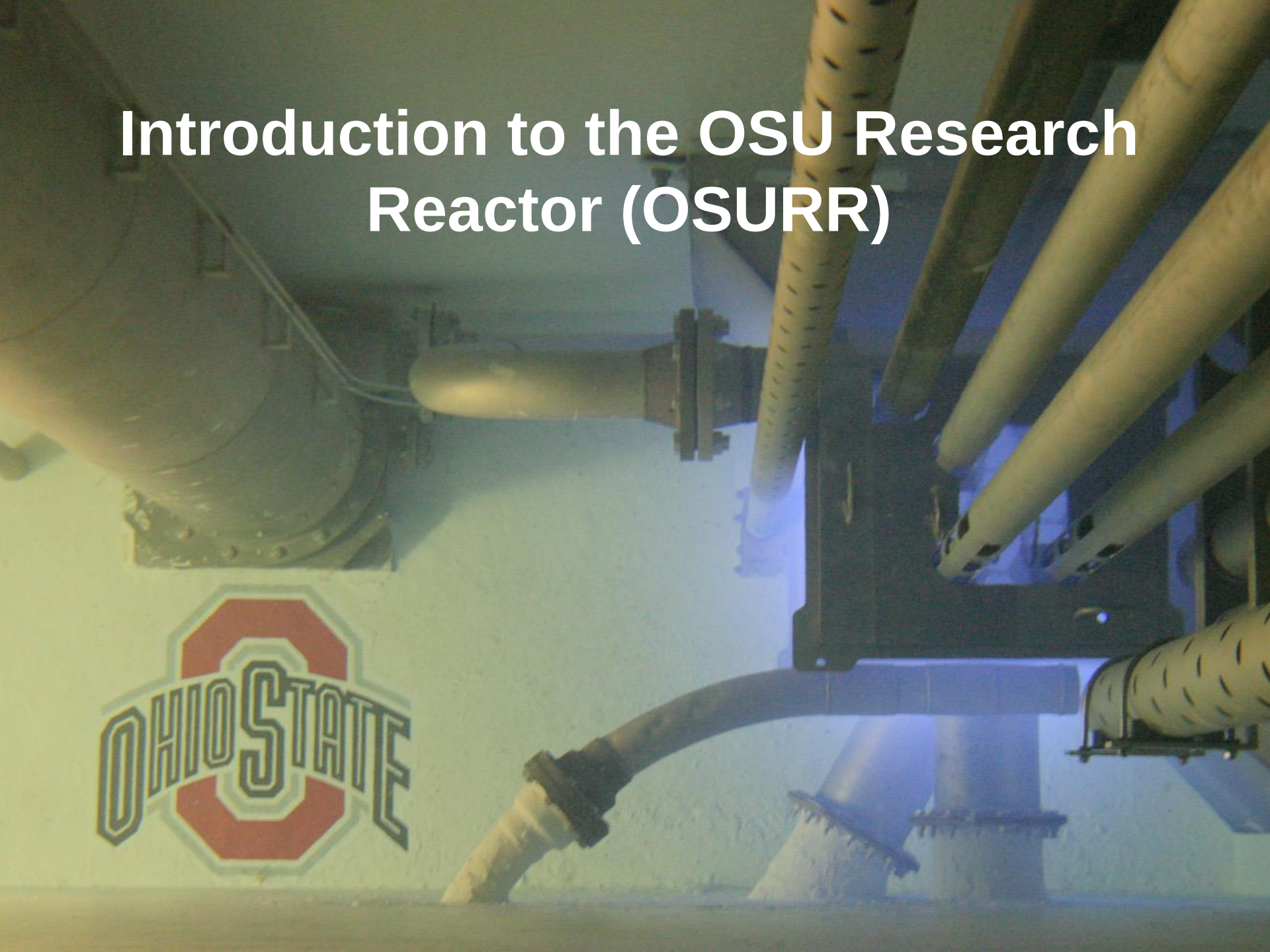
Introduction to the OSU Research Reactor (OSURR)



OSURR Tour

- Introduction in foyer
- Rotation in reactor bay
  - Reactor pool top
  - Control room
  - Rabbit workbench (activation demo)
- Please ask questions!

OSURR History

- Origin
  - Facility built in 1960; reactor first critical in 1961
  - 10 kW training reactor with HEU MTR-type fuel
- Conversion
  - Analysis for LEU fuel at 500 kW in 1980s
  - Fuel conversion to LEU in 1988
  - Power uprate in 1992
- Present
  - 500 kW reactor with multiple vertical dry-tubes
    - fluxes ~ 10^{12} – 10^{13} nv
    - Beam facility (flux ~ 10^{6} nv)
  - Gamma irradiators
    - In-pool, benchtop, spot
  - Gamma counting lab

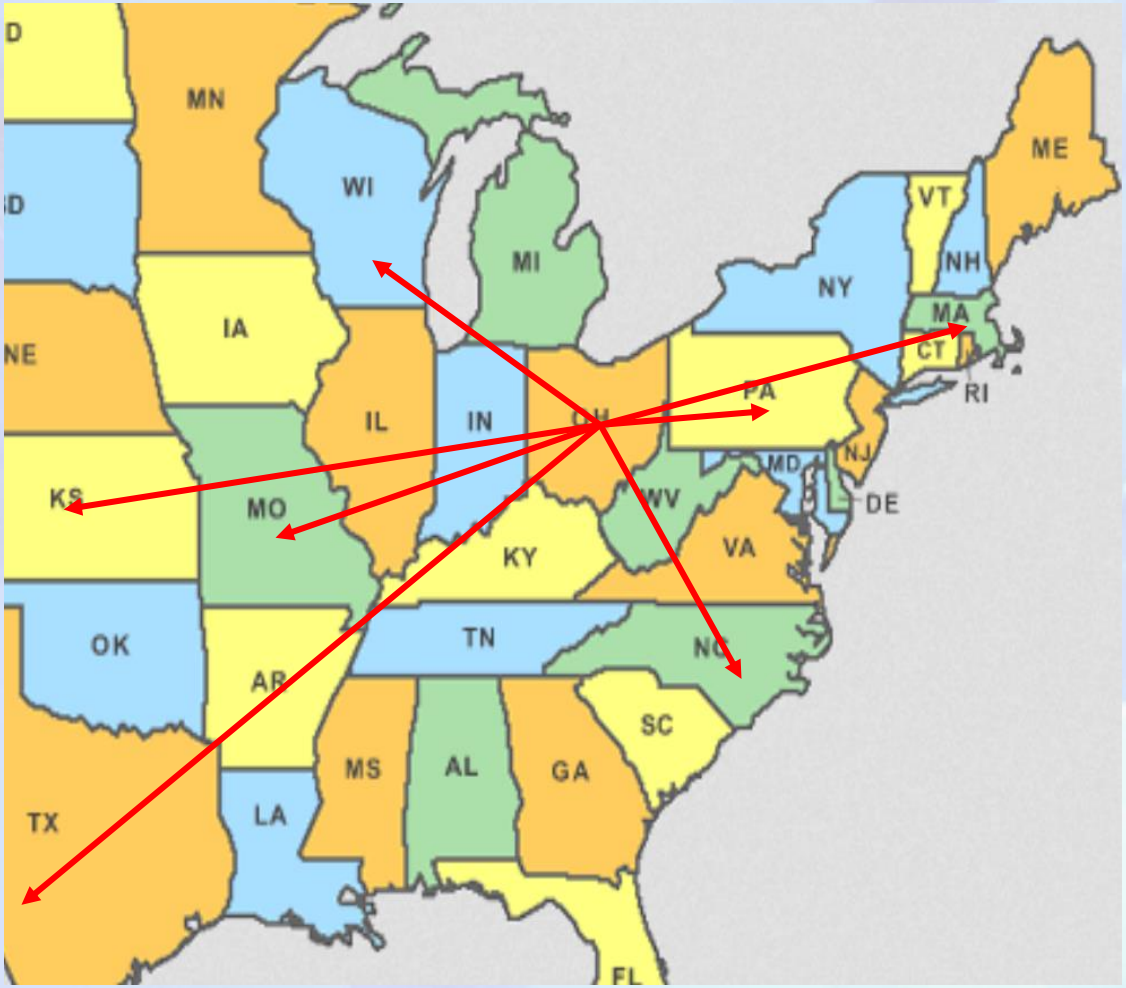
OSURR Power Level

- Only about 2 dozen university-based research reactors remaining in the U.S.
- U.S. research reactors cover large power range
  - Lowest power: 1 W_{th}
  - Most in US in range 100 kW – 2 MW
  - OSU-NRL: 0.5 MW_{th} (500 kW_{th})
  - Highest power at university: 10 MW_{th}
  - Highest power: 250 MW_{th}
- Power reactors ~ 3000 MW_{th}
  - About 1000 MW_{elec}

OSURR Purpose

- No electricity produced
  - No capability to produce electricity
    - Low power, low exit temperatures
    - No steam generators, turbines, generators, etc.
  - Not our mission
- Produce neutrons and radiation
  - Support research
  - Industry service
  - Education: reactor dynamics experiments and demos; educational tours

OSURR Purpose

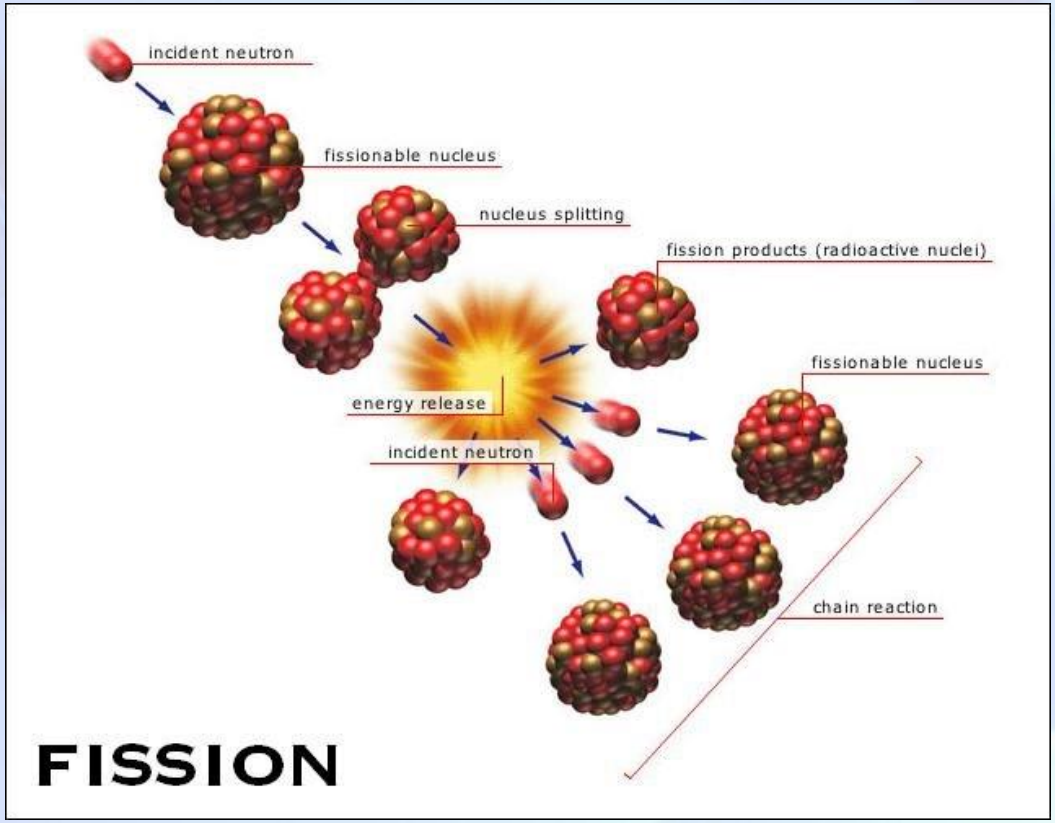


- Largely serve State of Ohio and the surrounding area
- Only research reactor in Ohio and within a 6-hr drive from Columbus
- Serve nuclear industry in Cleveland area
- Serve customers outside area too

(distance to nearest research reactors shown)

Fission Reaction

Same U-235 fission process used in all US power and research reactors



- U_{235} absorbs neutron → becomes unstable and splits into 2 smaller atoms (fission fragments)
- 2 or 3 neutrons are released (avg = 2.5)
- After slowing down, these neutrons can then cause more fissions → fission chain reaction
- In nuclear power plants, thermal energy used to make steam → electricity

$$ {}_{0}^{1}n + {}_{92}^{235}U \rightarrow FF_1 + FF_2 + 2.5n + \beta + \gamma + \bar{\nu} + 220\,MeV $$

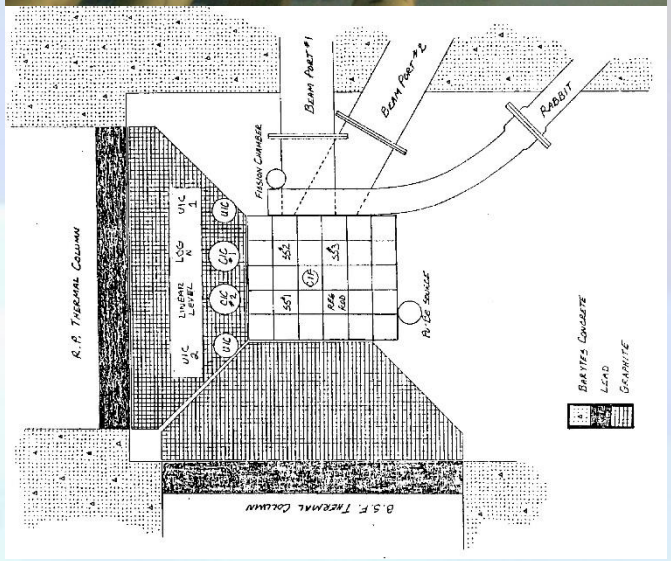
fission fragments *radiation* *energy*

Fission Reaction Control

- To control fission chain reaction, must absorb some of the neutrons that would otherwise cause fissions
- Neutron absorbers
  - Can use solid absorber rods called control rods
  - Can use absorbers dissolved in the coolant called chemical shim (power plants use boric acid dissolved in the water)
- OSURR
  - Stainless steel control rods; 3 with 1.5% natural boron
  - No chemical shim

OSU Research Reactor

- Fuel: elements composed of thin plates with Al cladding
  - Fuel elements sit in 5 x 6 grid plate
  - 4 elements have slots for control rods
- Dry tubes: used for irradiating experiments and samples
  - 3 vertical dry tubes in core; multiple moveable large dry tubes that can be positioned next to core
    - Capability for instrumented experiments for in-situ monitoring
    - *Unique capability of high-temp expts*
  - 2 beam ports
    - BP1 used as horizontal dry tube
    - BP2 used to bring thermal beam out of the reactor
  - 1 pneumatic “rabbit” tube

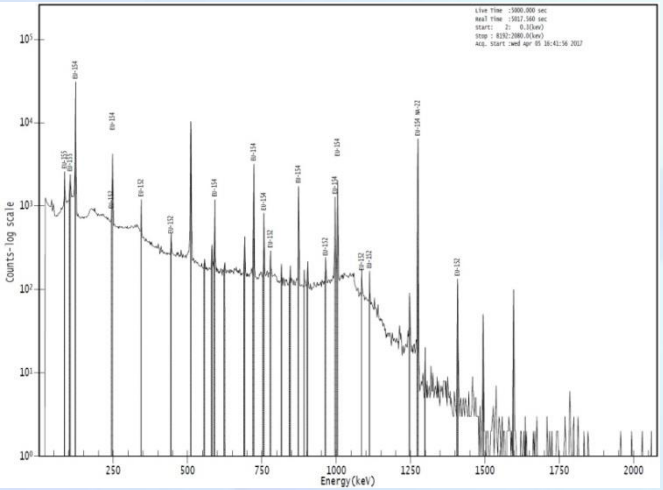


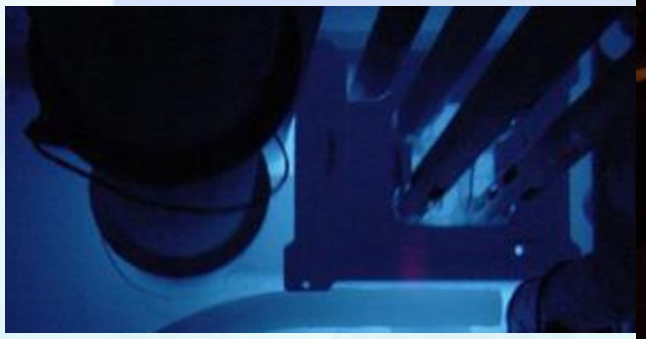
Reactor Monitoring

- Reactor power not directly measured
- Signals from neutron-sensitive chambers used to monitor reactor power
  - Some neutrons escape from the core, making the core a source of neutrons
  - of neutron emission is proportional to power
  - Chambers placed in pool near core
  - Different designs to cover full range of operation
  - Electric signal proportional to reactor power from ion chambers
  - Redundant channels for safety

OSURR Research, Testing

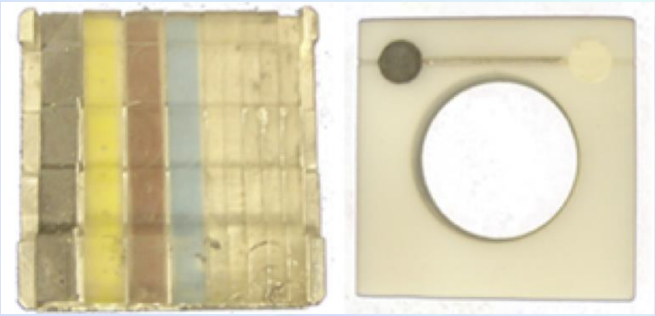
- Radiation sensor studies, radiation sensor testing
  - Test prototypes for next-gen reactors (fiber-based)
  - Test fission chambers for use in existing power reactors
  - Unique capability for high-temperature testing
- Neutron activation analysis (NAA)
  - Very sensitive means to determine elemental analysis
  - Measure energy of γs from reactor-activated samples
  - Trace element studies (ppb sensitivity for some)

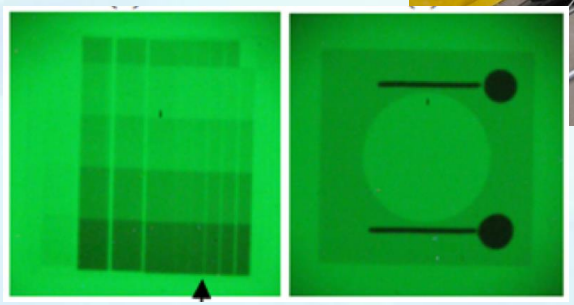




OSURR Research, Testing

- Neutron depth profiling
  - Measure distribution of certain elements
  - Useful for optimizing batteries by studying Li distribution
- Neutron imaging
  - Like taking X-ray images, but sensitive to different elements
- Neutron transmission testing
  - Test neutron absorbing capability of material by measuring percentage of neutrons that pass through





OSURR Research, Testing

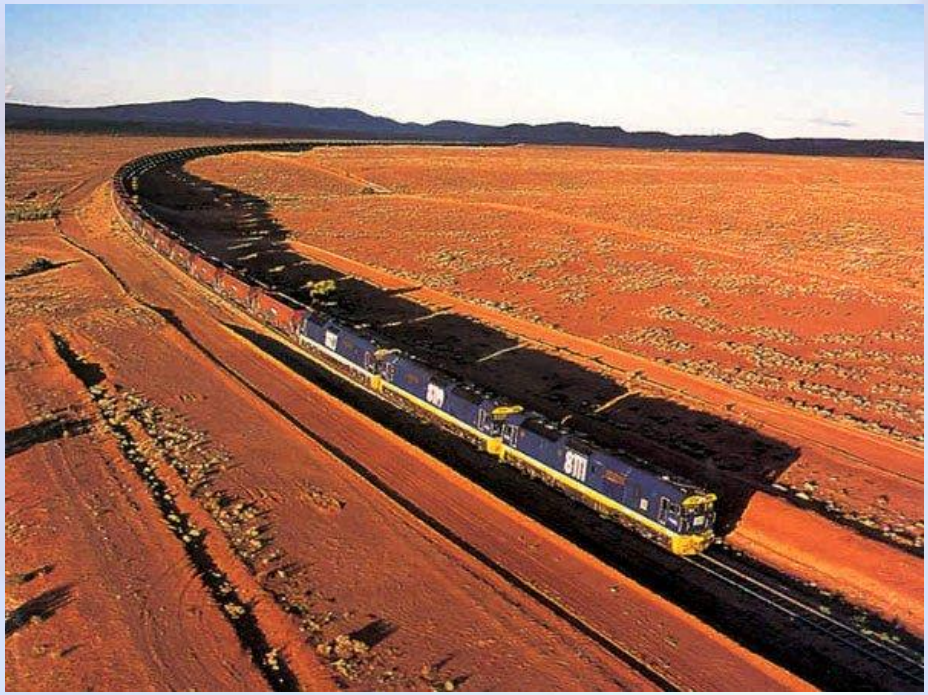
- Electronics damage studies
  - Characterize response of electronics to radiation to determine usefulness for use in nuclear industry, spacecraft
- Source production
  - Effluent monitor testing
  - Radioactive tracers
  - Medical studies (not humans for OSURR)
  - Physics studies

Supporting Ohio Industry

- GE (Measurement & Control Solutions, OH): fission-chamber testing
- Holtec (Orvillon division, OH): Testing neutron absorbing materials
- Fluke Biomedical (Victoreen division, OH)
- UDRI (OH): components for NASA spacecraft missions
- L3 Cincinnati Electronics (OH)
- University of Cincinnati
- Saint Gobain (world largest radiation scintillation detection manufacturer, Ohio)
- Lithium Innovations Company (SBIR, Ohio)

Why do we use nuclear power for generating electricity?

Energy density



Energy density of U-235 is about a million times greater than coal, so significantly less must be mined and used.

Lifecycle Emissions

Coal: 820 g CO_2/kW·hr

Natural gas: 490 g CO_2/kW·hr

Median values for lifecycle emissions data for various sources are from *2014 IPCC, Global warming potential of selected electricity sources*

Lifecycle Emissions

Biomass (dedicated): 230 g CO_2/kW·hr

Solar: 48 g CO_2/kW·hr

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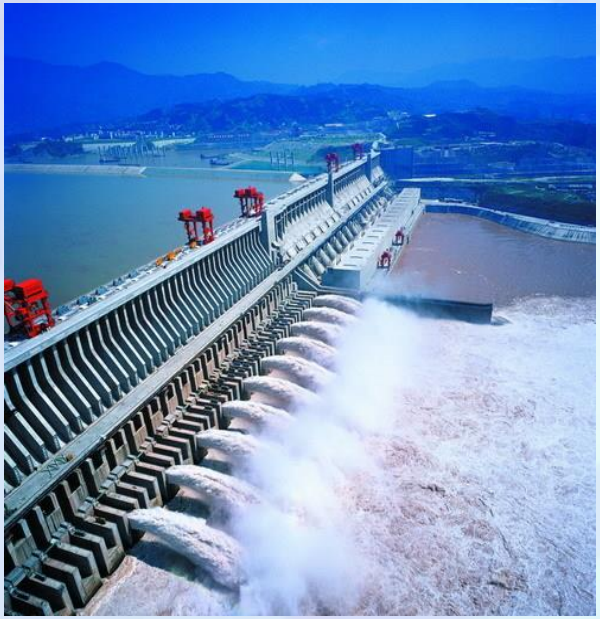
Lifecycle Emissions

Hydroelectric:
24 g CO_2/kW·hr



Wind: 11 g
CO_2/kW·hr

Median values for lifecycle emissions data for various sources are from *2014 IPCC, Global warming potential of selected electricity sources*

Lifecycle Emissions

Nuclear:
12 g CO_2/kW·hr

Median values for lifecycle emissions data for various sources are from *2014 IPCC, Global warming potential of selected electricity sources*

Emissions

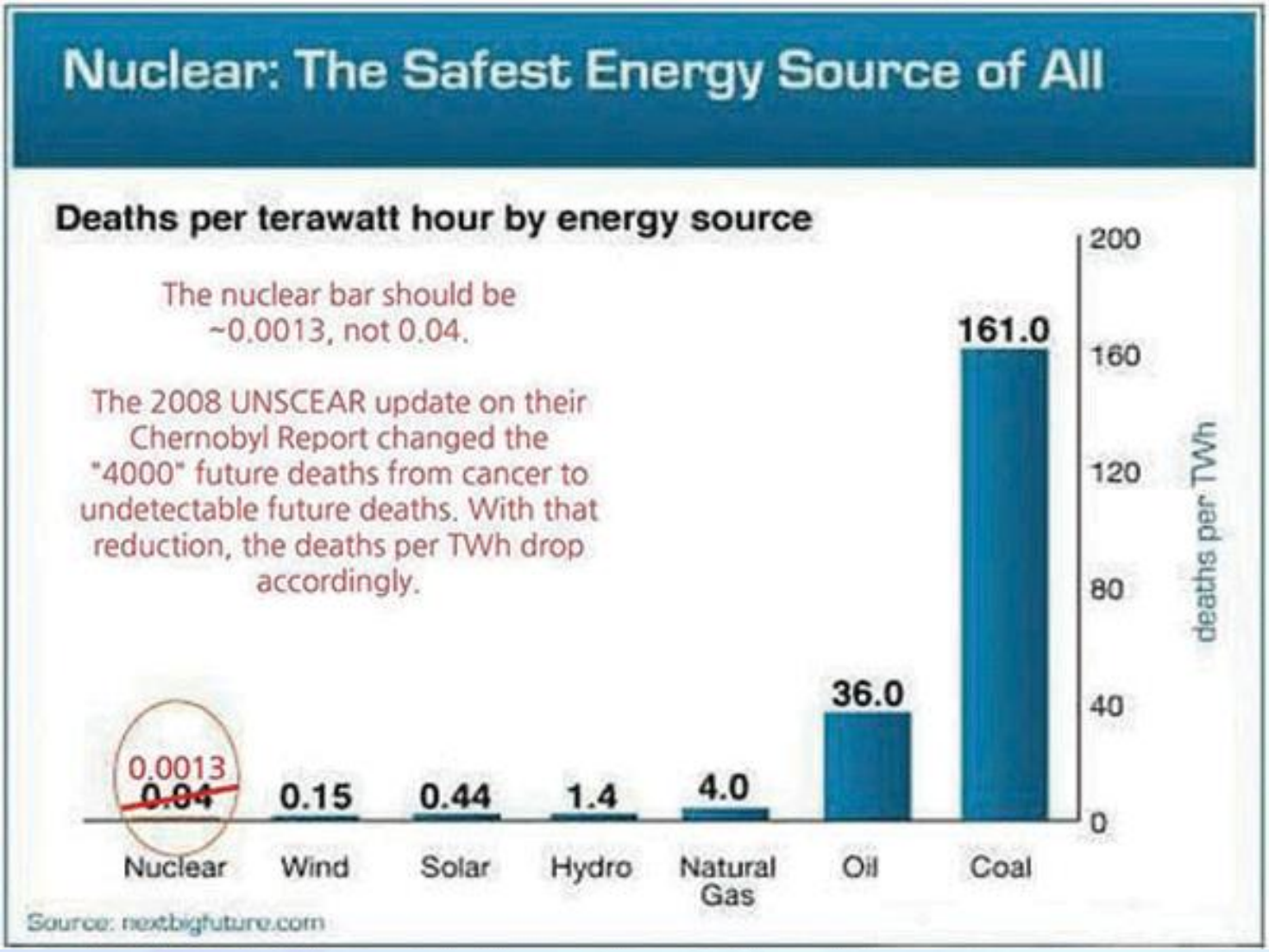
- In 2017, the average annual electricity consumption for a U.S. residential utility customer was **10,399** kilowatt-hours (kWh); therefore average tons of CO_2 per year per household per type is:
  - Coal: 9.4 tons
  - Gas: 5.6 tons; biomass: 2.6 tons
  - Solar: 0.5 tons; hydro: 0.3 tons
  - Nuclear, wind: ~ 0.1 tons

Emissions: pollution

- Forbes - How Deadly Is Your Kilowatt?
  - **Energy Source Mortality Rate (deaths/trillionkWhr)**
  - Coal – global average 170,000 (50% global electricity)
  - Coal – China 280,000 (75% China's electricity)
  - Coal – U.S. 15,000 (44% U.S. electricity)
  - Oil 36,000 (36% of energy, 8% elec)
  - Natural Gas 4,000 (20% global electricity)
  - Biofuel/Biomass 24,000 (21% global energy)
  - Solar (rooftop) 440 (< 1% global electricity)
  - Wind 150 (~ 1% global electricity)
  - Hydro – global avg 1,400 (15% global electricity)
  - Nuclear – global avg 90 (17% global electricity

    (w/Chern&Fukush worst-case predictions; LNT assumed)

Impact of Different Energy Sources



NRL Rules for Touring Visitors

- ***Backpacks and bags must be left in the classroom.*** The Nuclear Reactor Lab takes no responsibility for items lost or stolen at the facility, but the classroom door will be locked during the tour.
- ***Photography is not allowed*** in the Reactor Building; cameras must be left in the classroom. In addition, cell phones, pagers, and two-way radios should be left in the classroom.
- ***Consumption of food, beverages or gum is not permitted*** while in the Reactor Building.