

MSRE and the Thorium Fuel Cycle – Past, Present, and Future

Thorium Energy Alliance Conference – TEAC 10

Syd Ball

Reactor and Nuclear Systems Division (retired)

Oak Ridge, Tennessee

October 1, 2019

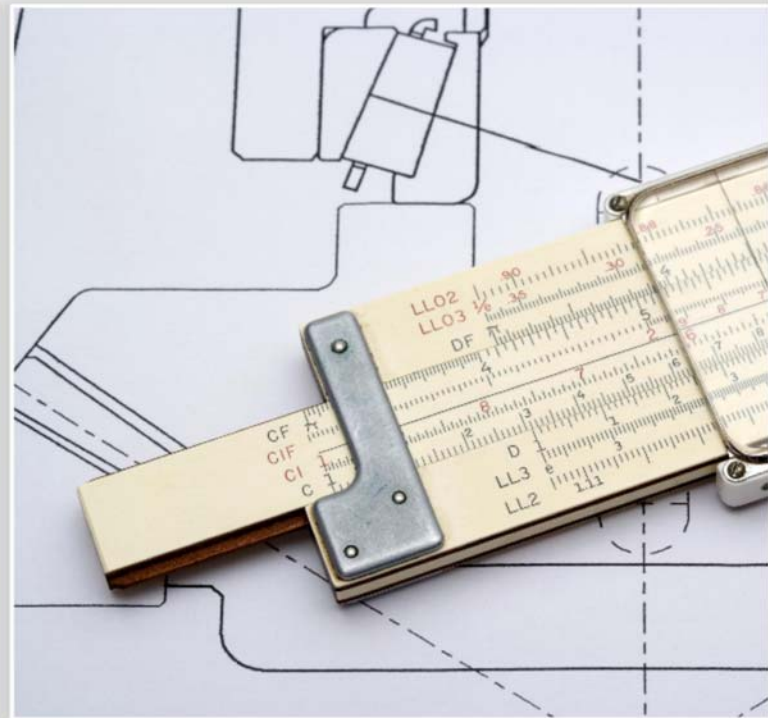
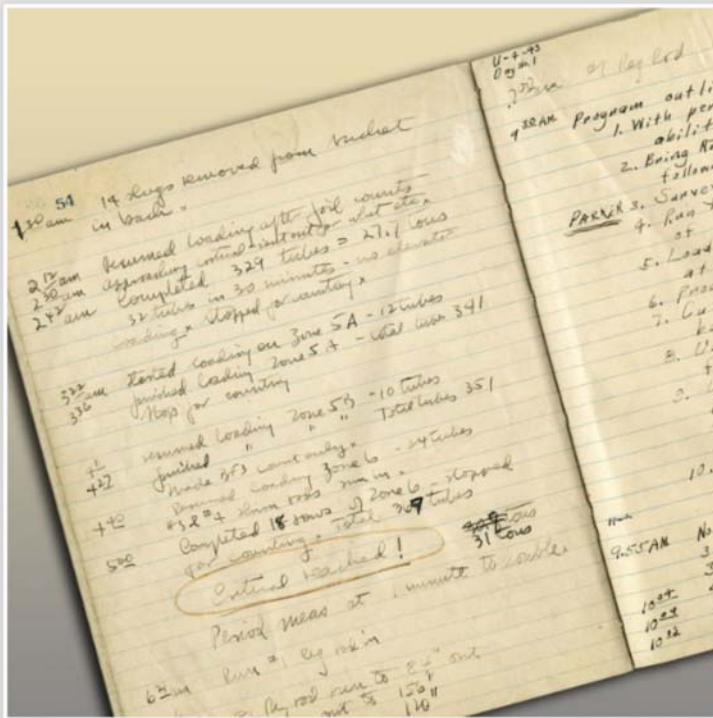
ORNL is managed by UT-Battelle, LLC for the US Department of Energy

Inspiration in 1957

- Alvin Weinberg's vision for peaceful uses of nuclear energy
- **Message:** If we could solve yesterday's problems with 1950s tools, we can handle bigger ones now!



1950s analytical capabilities were modest



ORNL Graphite Reactor “Data Logger”

ORNL's ORACLE digital computer: "State of the art"



2k word core memory (vacuum tubes) with speed ~14 kiloflops (40-ton a/c)



Speed of ORNL's current system
petaflops (>10¹⁵)

On a mission: Reduce fossil fuel use

- Resource depletion:
 - Competition (wars)
 - Fossil fuels: “gone forever”
 - Human costs of extraction
- Global air pollution:
 - “~6 million early deaths per year” (International Energy Agency IEA)

PLUS Economic impact:

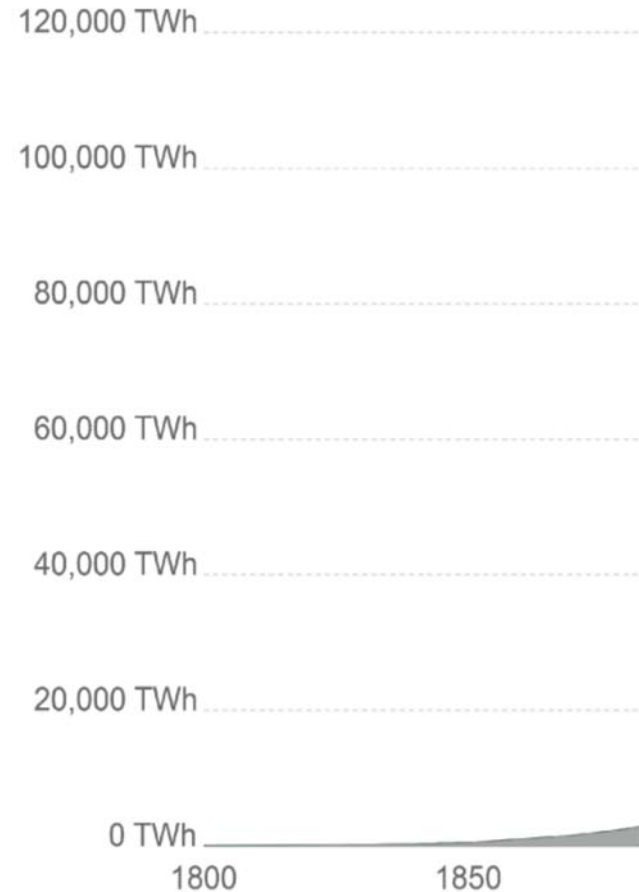
Trillions (\$) per year (World Bank)

& Oh, BTW: Climate Change!

[for later: think “external costs”]

Global fossil fuel consumption

Global primary energy consumption by fossil fuel sources



Source: Vaclav Smil (2017). Energy Transitions: Global and National. OurWorldInData.org/fossil-fuels/ • CC BY-SA

Tough job
handling
pollution* from
a coal-fired
plant!

*air AND solid
waste

* maybe clean
coal?



One day of a 1-gigawatt
coal-fired plant
uses 80 rail cars of coal

Each coal car
weighs 100 tons



Spent fuel
from one human lifetime's
worth of nuclear electricity



Alvin Weinberg's approach to solving our energy problems

Significant safety improvements (over LWRs): No core melt accidents!

Higher temperatures for greater efficiency:

Expand nuclear fuel resources: (Abundant) Thorium fuel cycle

With Glenn Seaborg



MSRE strip chart



His table



Renaissance man as well as scientist and Lab
Pianist, tennis player, and a terror at Division Inform

Early: ORNL's Homogeneous Reactor Test (HRT)

- Uranyl sulfate in heavy water: Demonstrate stability, reliability, and safety
- Precursor to a planned version with thorium in the blanket region for U-233 production

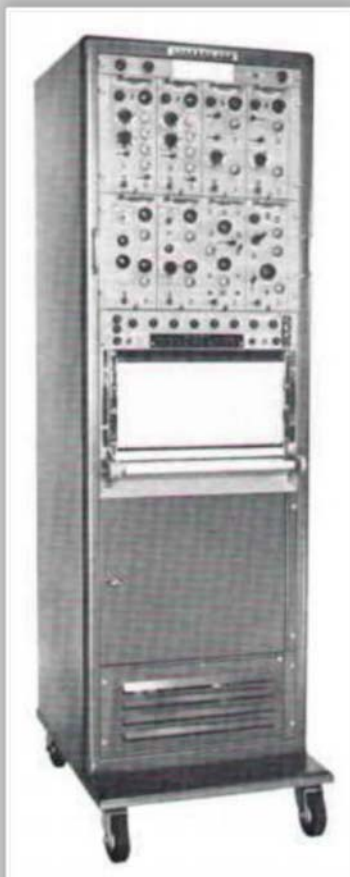


...before the hole in the HRT vessel....

HRT scale model in control room

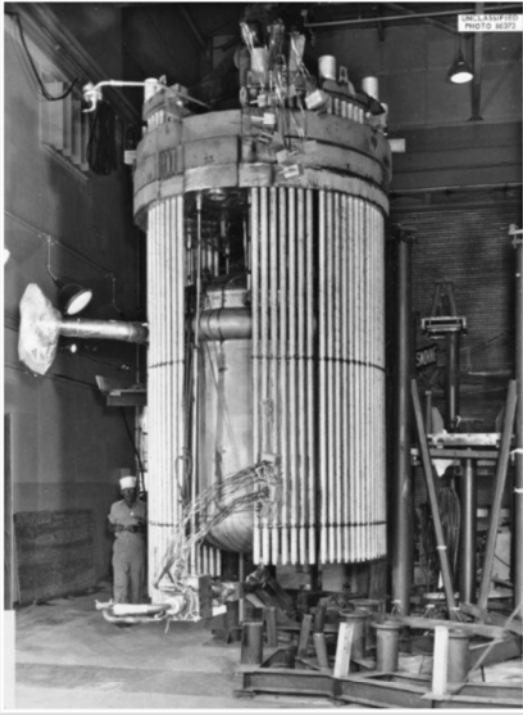


HRT's
Sanborn
recorder
with Syd
hiding in the
corner



JFK: "Which pipe did the

Shortly after HRT: The MSRE Project – - - - - with the great chemical stability of molten salt



Reactor vessel
(with heaters)



MSRE air-cooled radiator with its door open

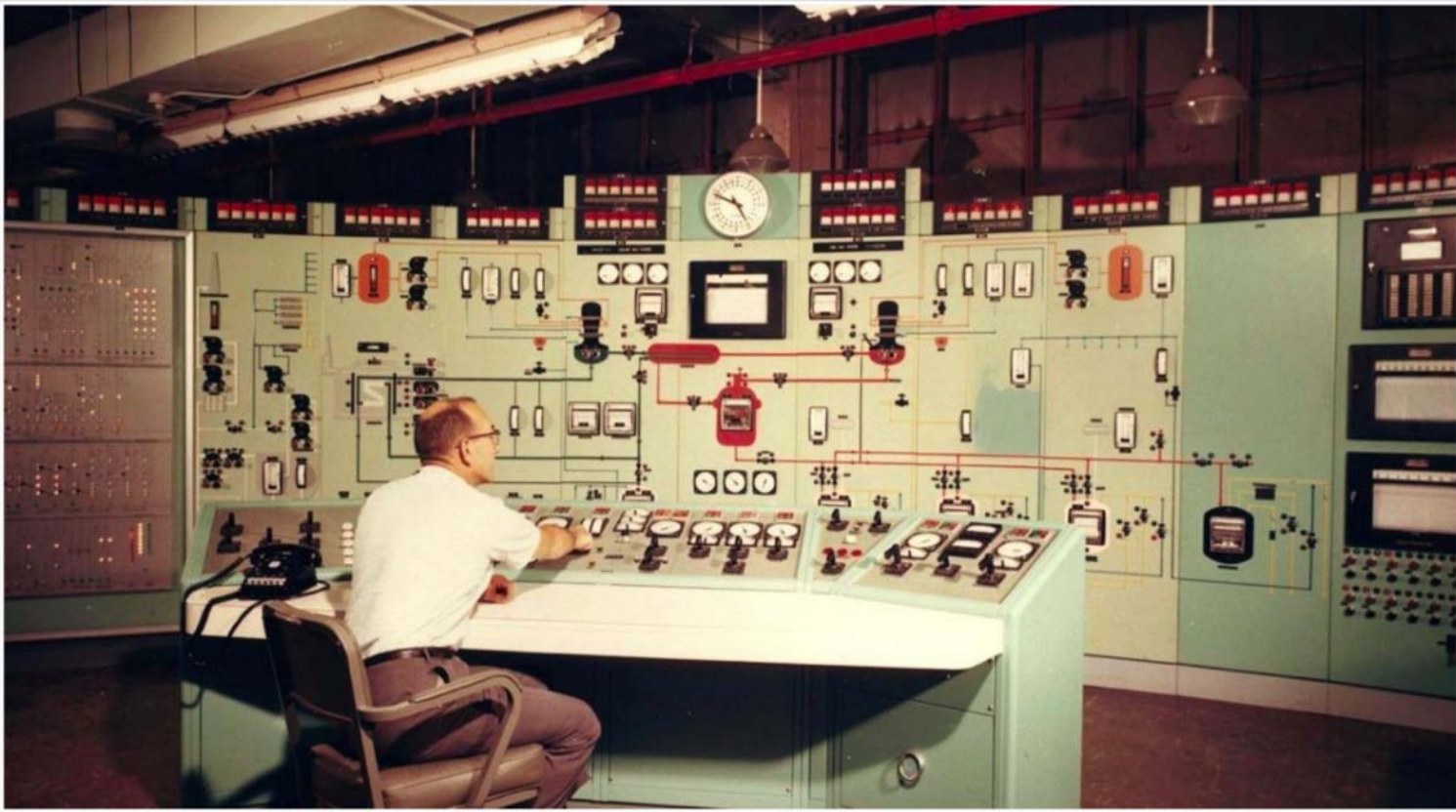
MSRE dynamics – Covered by Tom Kerlin

How well could MSRE dynamics be predicted over its full power range?

- Concern for Inherent safety, stability, controllability
- Results: Tests showed dynamics were well understood (and safe) – for all power levels

World's cheapest reactor training simulator

- pre-operation operator training



MSRE: Insights for current/future MSR dev

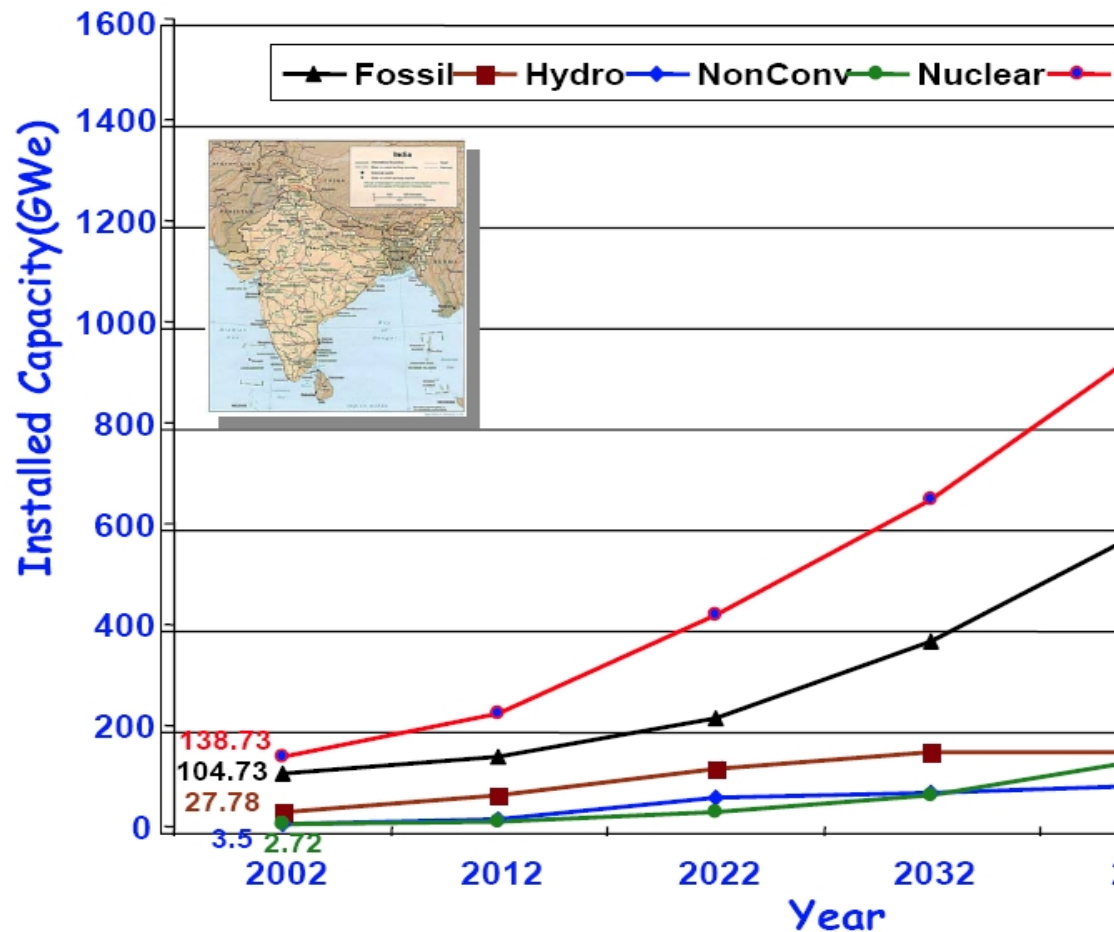
Lessons Learned - Contributors to success

- Project entirely at ORNL (not split between sister I
- Close collaboration between disciplines (teamwor
- Inspirational leadership and management with lim
- Exceptional nuclear-chemical and innovative main
- Operation and experiments confirmed predictions
- Everyone working on it ENJOYED it!

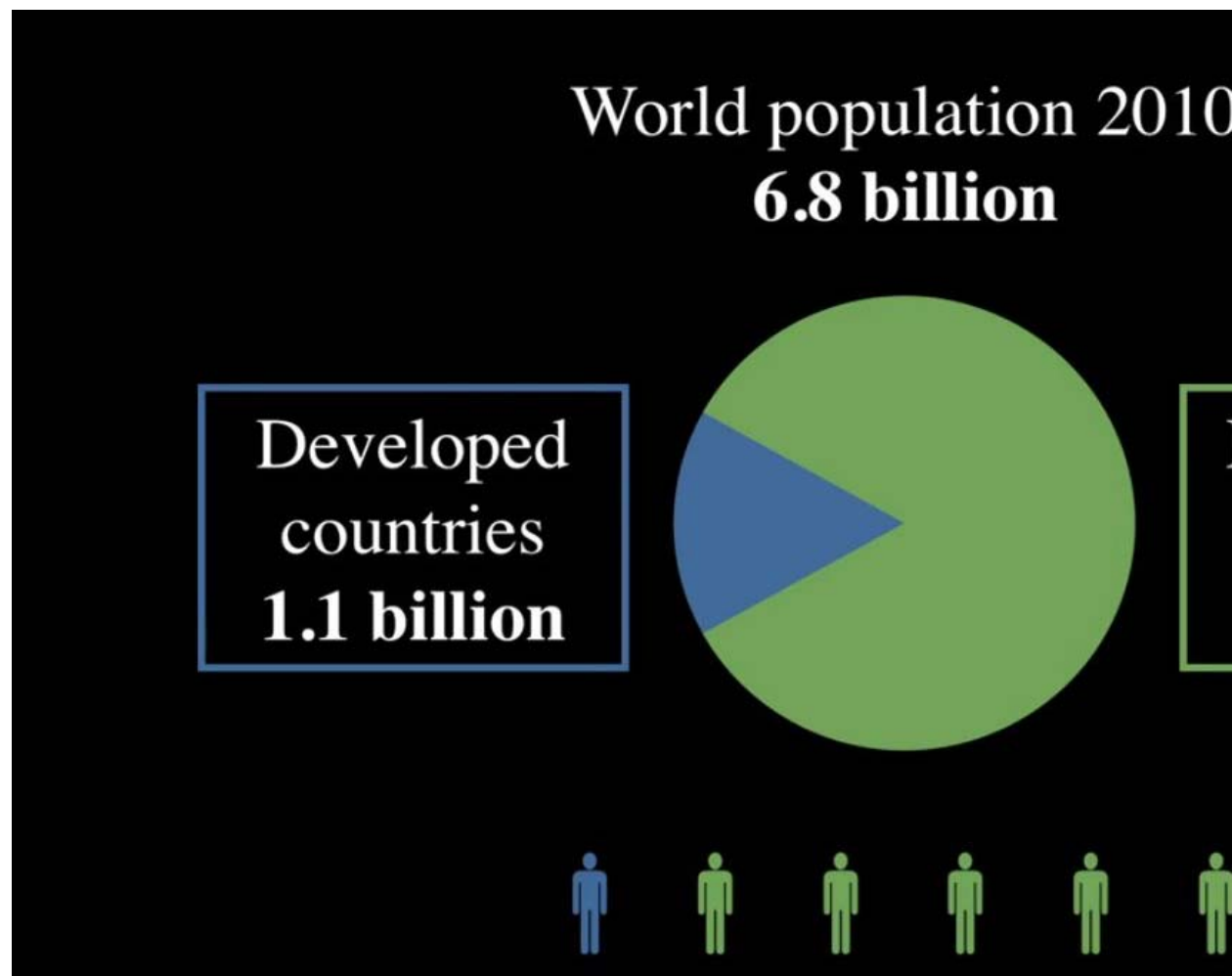
How do we fit into the planet's "Green Future" call
(...we're supposed to REDUCE fossil fuel use?!)

Example: India's fossil use: ~X4 by 2050 (&)

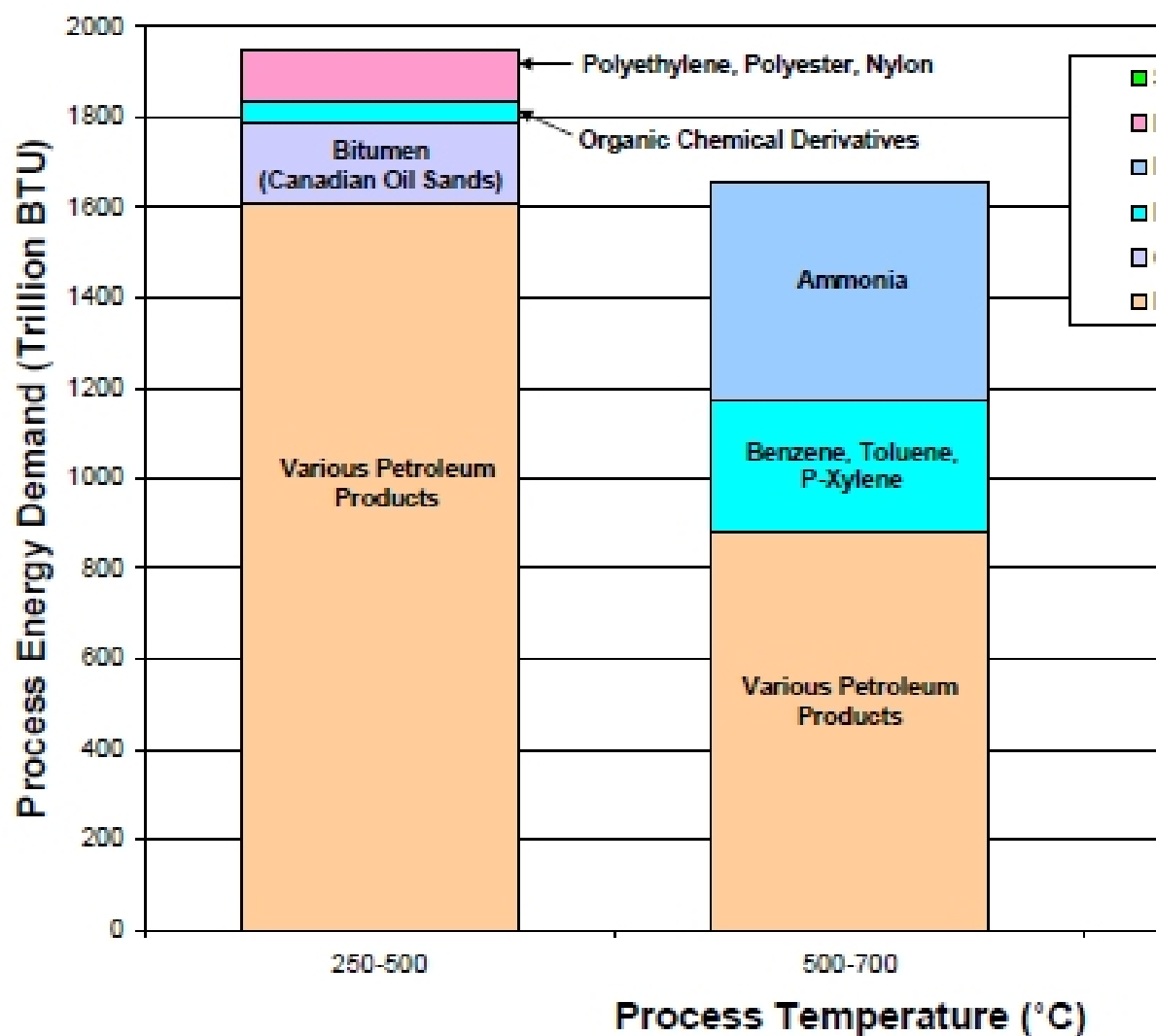
India's planned power capacity



Besides world population growth, developing countries want more electricity



MSRs (~700°C): for high-temperature process heat market
(U.S. Energy's "process heat" ~ electrical) P.S. & D



High-temperature with Thorium: KE

High-temperature Benefits

Efficiency: Less fuel & waste & required heat reject cooling.

Enables Gas Turbine (Brayton cycle) Balance Of Plant (BOP):

- Works well with solar/wind (fast response needed)

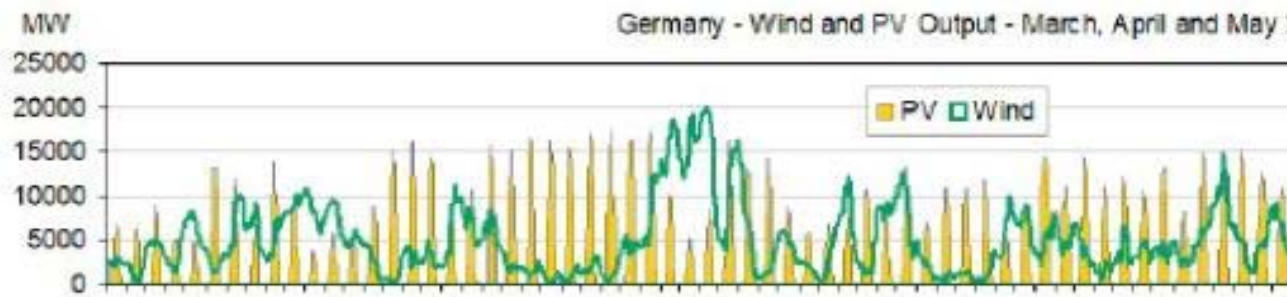
- Heat reject temperature: ideal for flash desalination (& district heating)

- Air**-cooled heat reject option > expand siting locations

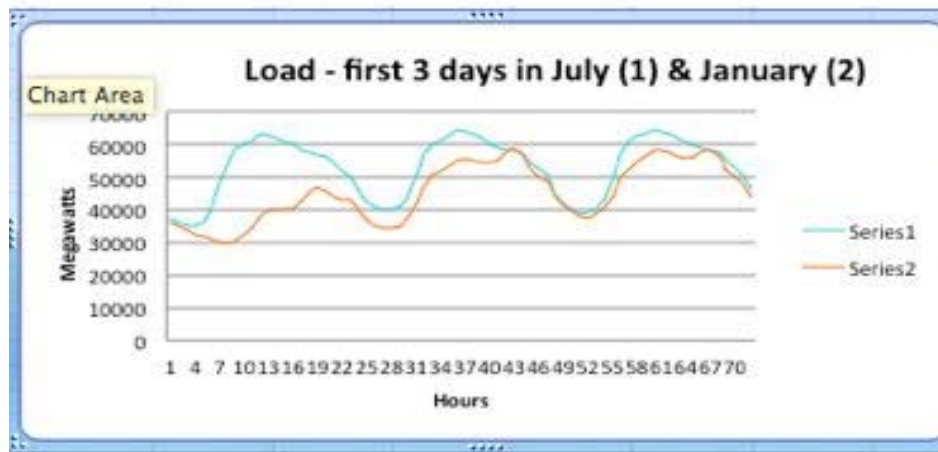
“Go Green” without Nukes Wo

Gas Turbine BOP can fill gaps (efficiently!) between “gr

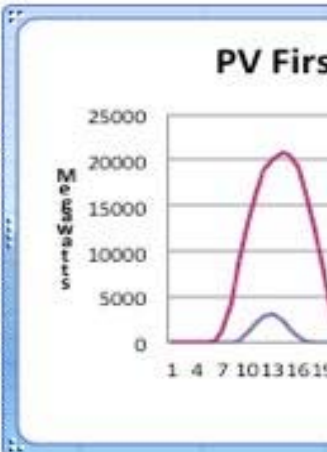
German Green Load factors (2012) PV: 0.14; Wind: 0.22. U



German grid load (3 days, Jan & July)



German P

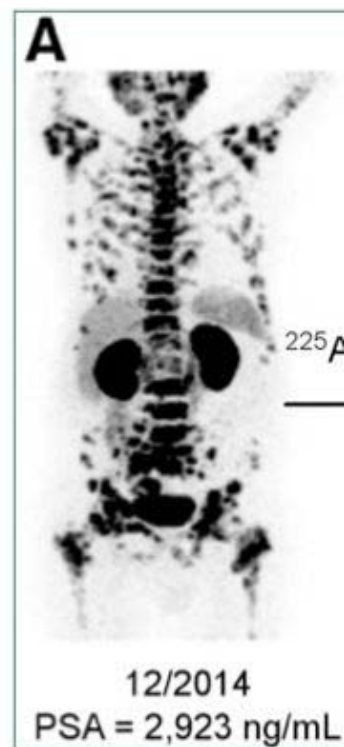


Spent fuel storage and Alpha Therapy: Excellent **negative** “external costs” for Th

Alpha therapy – 7
Ac-225 (from U-235)



Radiotoxicity of LFTR (thorium MSR) and PWR wastes over time



2 Impediments to MAJOR Ramp-Ups of

#1 Fear of Nukes

Safety: Demonstrate inherent (passive) safety of modern

Differences vs. 3-Mile Island, Fukushima, Chernobyl

Fear of Radiation: Overblown (“& encouraged”)

Linear No Threshold (LNT) theory – health impact ex

Price-Anderson Act: (Based on LNT) ~ \$13 Billion ins

Fukushima Health effects



- No radiation related deaths confirmed; those who died as a result of the earthquake and tsunami related to it, and approx 20,000 people were evacuated
- Unlikely to be any increase in cancer rates due to the doses received
- Psychological harm due to evacuation and radiophobia
- Huge economic effect on local area and a whole

Source: <http://www-pub.iaea.org/MTCD/Publications/PD>

#2 Impediment to MAJOR Ramp-Up

“Too Expensive!”

Modular designs can use in-factory mass production, automated assembly, etc. — MUCH cheaper when “External Costs” are considered (vs. traditional reactors).

Pollution (health), resource wars, global warming,...

[Thorium: negative external costs for spent fuel storage]

.... & Well, there are some technical challenges, including

Comprehensive accident analyses;

Licensing of “unfamiliar” reactor concepts;

Nuclear graphite availability;

Conversion of Thorium to U-233: dealing with Protactinium, U-232, etc.

Too late to do any good?

A few isolated demo plants: too little, too late

Check out the ThorCon story: MASS production!

There is hope!

Fossil, Military, & Green Lobbies

So where could funding come from?

Enlightened federal budget and/or billionaires of the fossil fuel industry & military complex

Example: The U.S. 2018 military budget is \$716 Billion. A small fraction of that could fund advanced reactor developments (hopefully).

What's Next?? “We must save the planet”

The two major threats: global warming and nuclear war
Thorium can help on both fronts:

GLOBAL WARMING

Replace fossil fuel
Clean, safe, “economical”
electricity

High-temperature
process heat

NUCLEAR WAR

Reduce resource consumption
avoid energy (& water)
Abundant Thorium

Reduce flooding, fire
failures,... that destabilize
displace populations

Avoid chaos... or so
the red button

Idea: Make “Prevent war” (Thorium) part of

So we have a problem! Here's some advice

“ Alvin Weinberg (1967) on tackling complex

In **BASIC** research the strength of labs like ORNL:

interdisciplinary composition of staffs... people in diverse fields make more scientific discoveries than geniuses working in isolation.

In **APPLIED** research:

Coherence is more important. Many of our large jobs at ORNL are in the agro-industrial complex developed for the world's hungry nations, in many different viewpoints, some from natural sciences, some from social sciences, some from humanities.

The key to successful attacks on these complex questions is the experts working together aggressively and with enthusiasm.

ORNL Review, Vol. 1, No. 1, 1967

Thanks for your attention!

Now get busy!



Xtra: 90K container ships; 15 (big ones) engines' dirty oil
60K deaths & \$300B health costs per year (Hey! ThorC

