

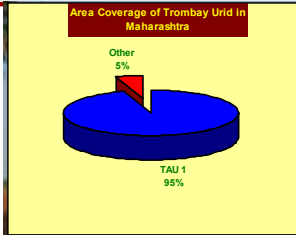
Evolving Indian Nuclear Programme: Rationale and Perspectives

A. Kakodkar,
Atomic Energy Commission

Public lecture at Indian Academy of Science, Bangalore
4th July, 2008

Available at <http://www.dae.gov.in/>

DAE at a glance



- An integrated system that translates nuclear and allied research into commercial/societal value
- Leading contributor to global effort in Heavy Water Reactors, Fast Breeder Reactors and Thorium related research



- GMRT discovered a new Pulsar in August 2004.



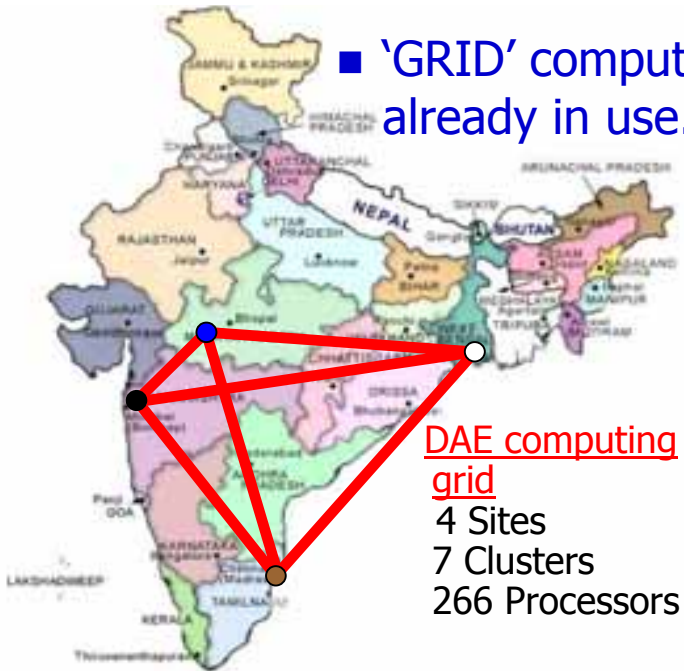
- Tata Memorial Centre recognised as the "Outstanding Cancer Organisation" for its excellence in Cancer control within and beyond India's borders by International Union for Cancer Control, Washington DC in 2006.



DAE at a glance...contd.

- India has an observer status at CERN along with USA, Japan, Russia, Turkey and Israel.

- 'GRID' computing Technology already in use.



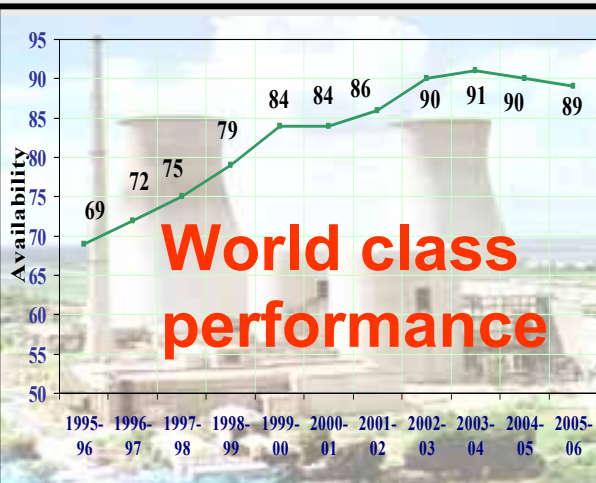
- Major contribution to national Groundnut ($\approx 25\%$) and Black Gram production ($\approx 22\%$)



"I found that whereas sanctions slowed progress in nuclear energy, they made India self-sufficient and world leaders in fast reactor technologies. While much of the world's approach to India has been to limit its access to nuclear technology, it may well be that today we limit ourselves by not having access to India's nuclear technology developments. Such technical views should help to advise the diplomatic efforts with India."

– Seigfried S. Hecker, Former Director of LANL – Testimony at US Senate committee on appropriations, Subcommittee on energy and water development, April 30 2008.

Three Stage Indian Nuclear Power Programme



Stage – I PHWRs

- **15 – Operating**
- **3 - Under construction**
- **Several others planned**
- **Scaling to 700 MWe**
- **Gestation period has been reduced**
- **POWER POTENTIAL \cong 10 GWe**

LWRs

- **2 BWRs Operating**
- **2 VVERs under construction**

Stage - II

Fast Breeder Reactors

- **40 MWth FBTR - Operating since 1985**
Technology Objectives realised
- **500 MWe PFBR- Under Construction**
- **TOTAL POWER POTENTIAL \cong 530 GWe (including \cong 300 GWe with Thorium)**

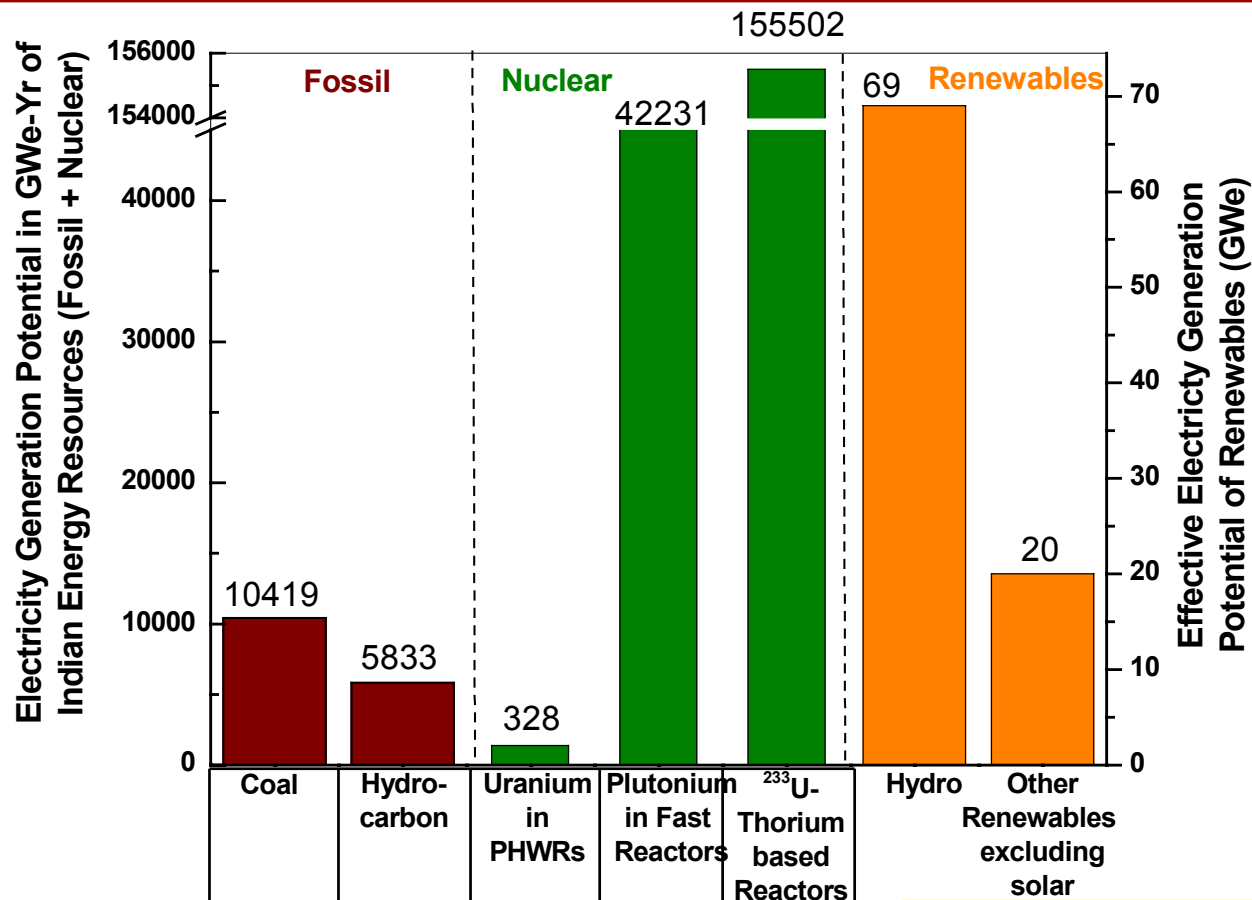
Stage - III

Thorium Based Reactors

- **30 kWth KAMINI- Operating**
- **300 MWe AHWR- Under Development**
- **POWER POTENTIAL IS VERY LARGE**
Availability of ADS can enable early introduction of Thorium on a large scale

Current Indian Energy Resources

(Ref: A Strategy for Growth of Electrical Energy in India, DAE, 2004; Coal data from Report of The Expert Committee on Road Map for Coal Sector Reforms)



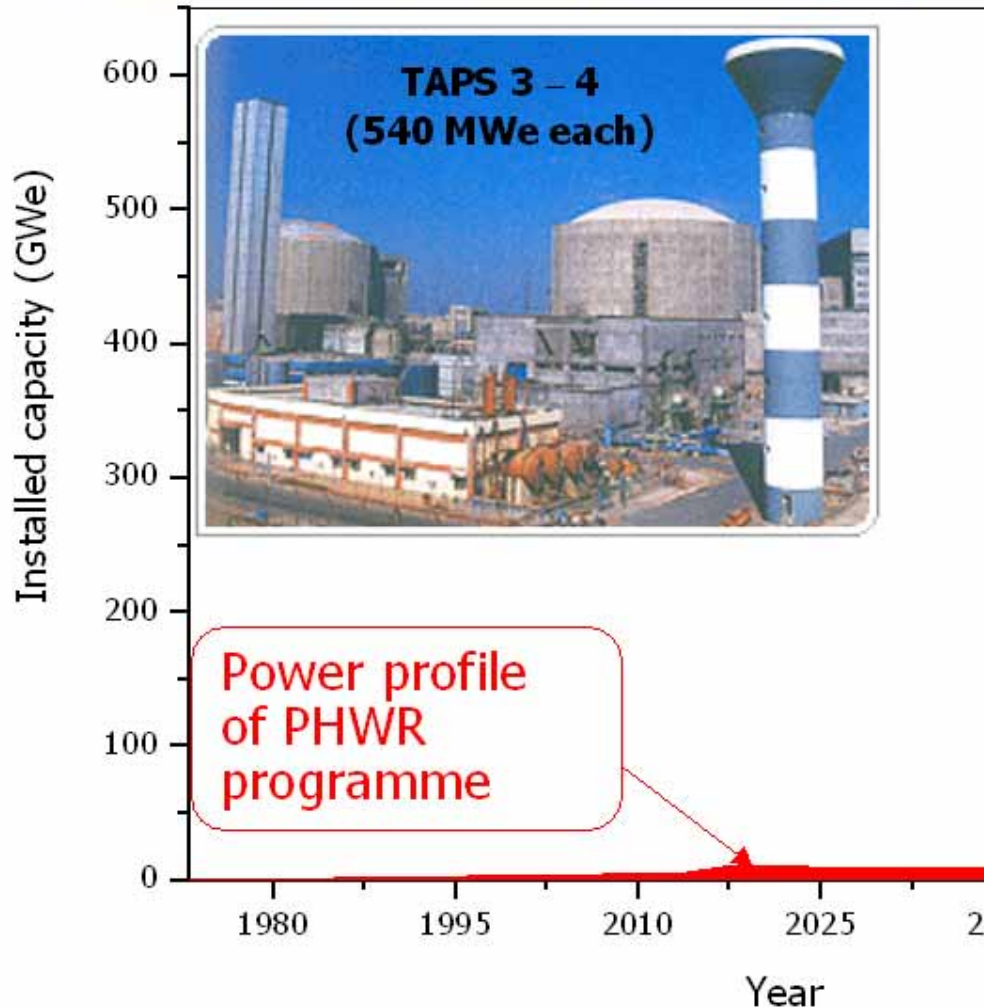
Years of depletion for electricity generation by single source	Current rate (697 TWh)	Coal	Hydro-carbon	Uranium in PHWRs	Plutonium in Fast Reactors	²³³ U-Thorium based Reactors
	2052 rate (7957 TWh)	11.5	130	*	4.12	211
		11.5	*	0.36	18.5	>170

Total Solar collection area required (based on MNES estimate 20 MW/km²):
 At current rate- >>3900 sq. km
 At 2052 rate- >>44650 sq. km

*: To be preferentially used in transport sector

Strategies for optimum use of domestic nuclear resources

NPCIL is a AAA (CRISIL) rated company for ten years in a row.



	Indian PWRs (700 MWe)	Global range
Capital Cost \$/kWe	1700	2000-2500
Construction period	5-6 years	5-6 years
UEC \$/MWh	60	60 - 70

* Completion cost

+ 2008 Prices

- KAPS – 1 adjudged the best performing PHWR in the world for the period October 2001 to September 2002.
- In 2003 and 2007, two senior Indian operators of Nuclear Power Stations, received the WANO excellence award.
- "At the end of 2002 average annual CANDU/PHWR performance continued to show a gradual improvement, led by the units of NPCIL (India)..." "The NPCIL PHWRs showed a major improvement in GCF in 2002, exceeding US light water reactor performance by almost 1%..." - Brian MacTavish, President, COG

Results for a scenario with current domestic Uranium resources and assuming short doubling time FBRs from 2021

Strategies for optimum use of domestic nuclear resources



Construction site with Safety Vessel under erection

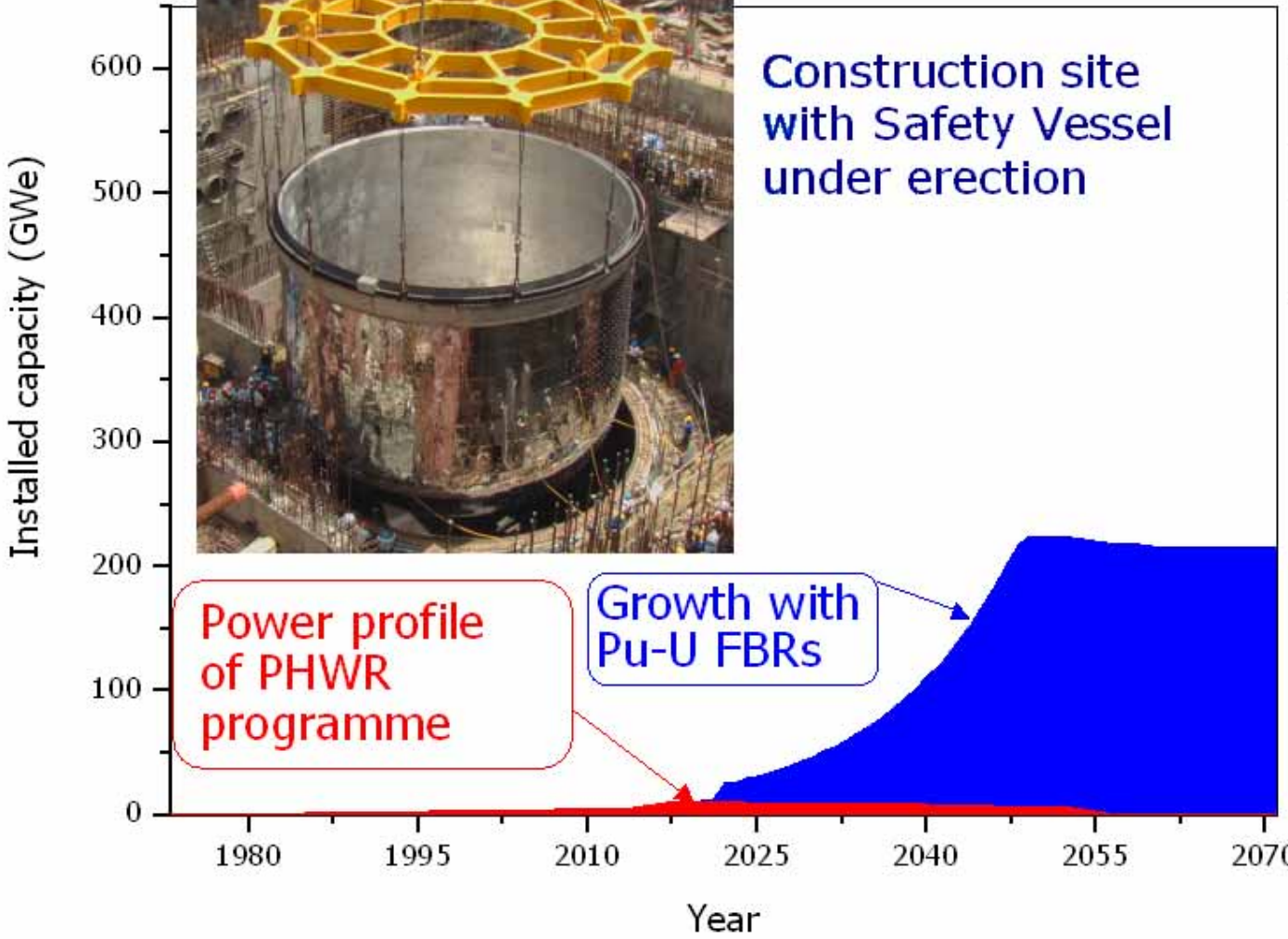
PFBR (500 MWe)

Capital cost (Rs/kWe)	69840
UEC (Rs/kWh)	3.22
Construction period	7 years

Project sanctioned in 2003

Further development being pursued to reduce doubling time and UEC

Russia is the only other country with a larger FBR under construction /operation

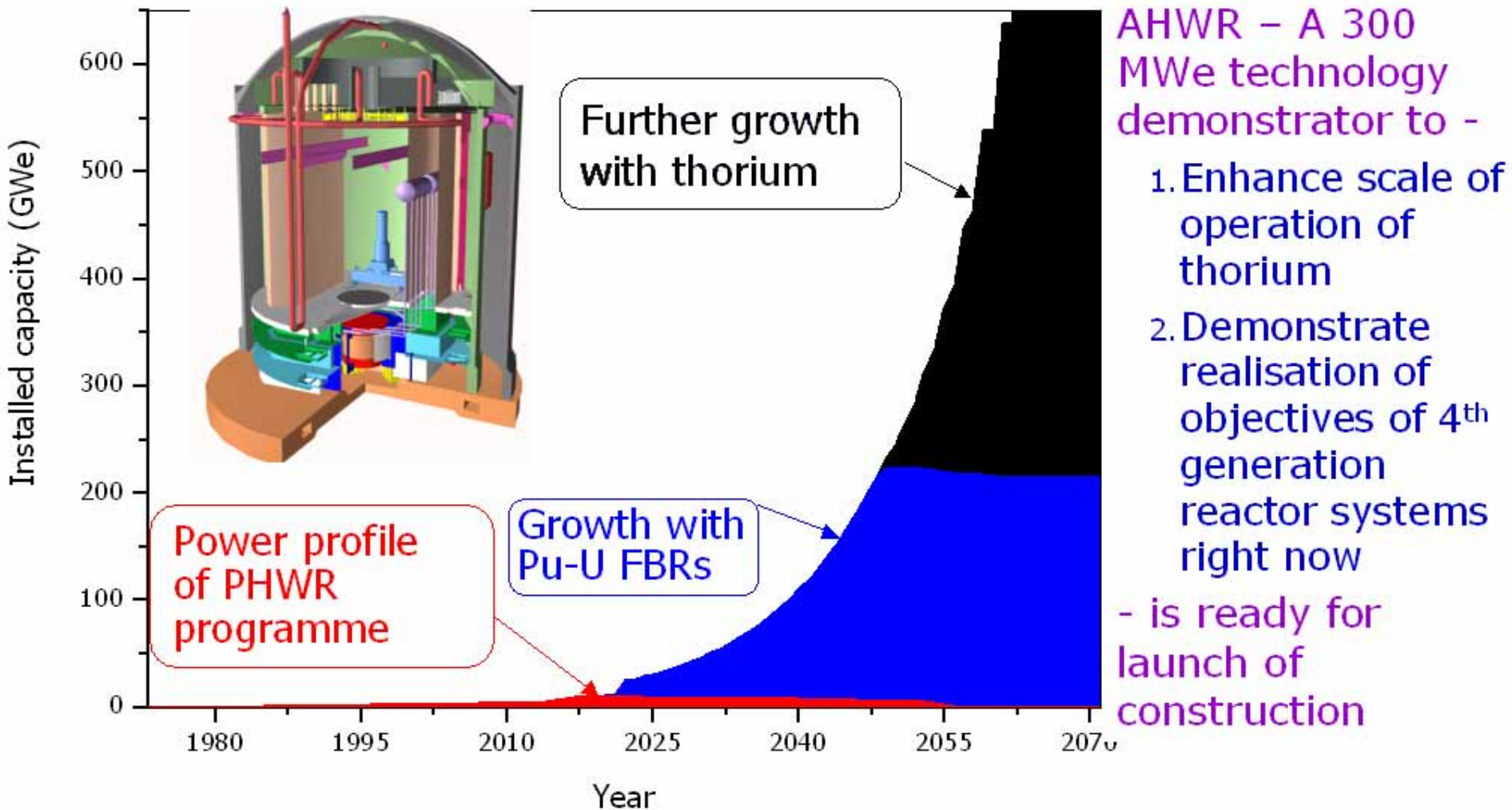


Power profile of PHWR programme

Growth with Pu-U FBRs

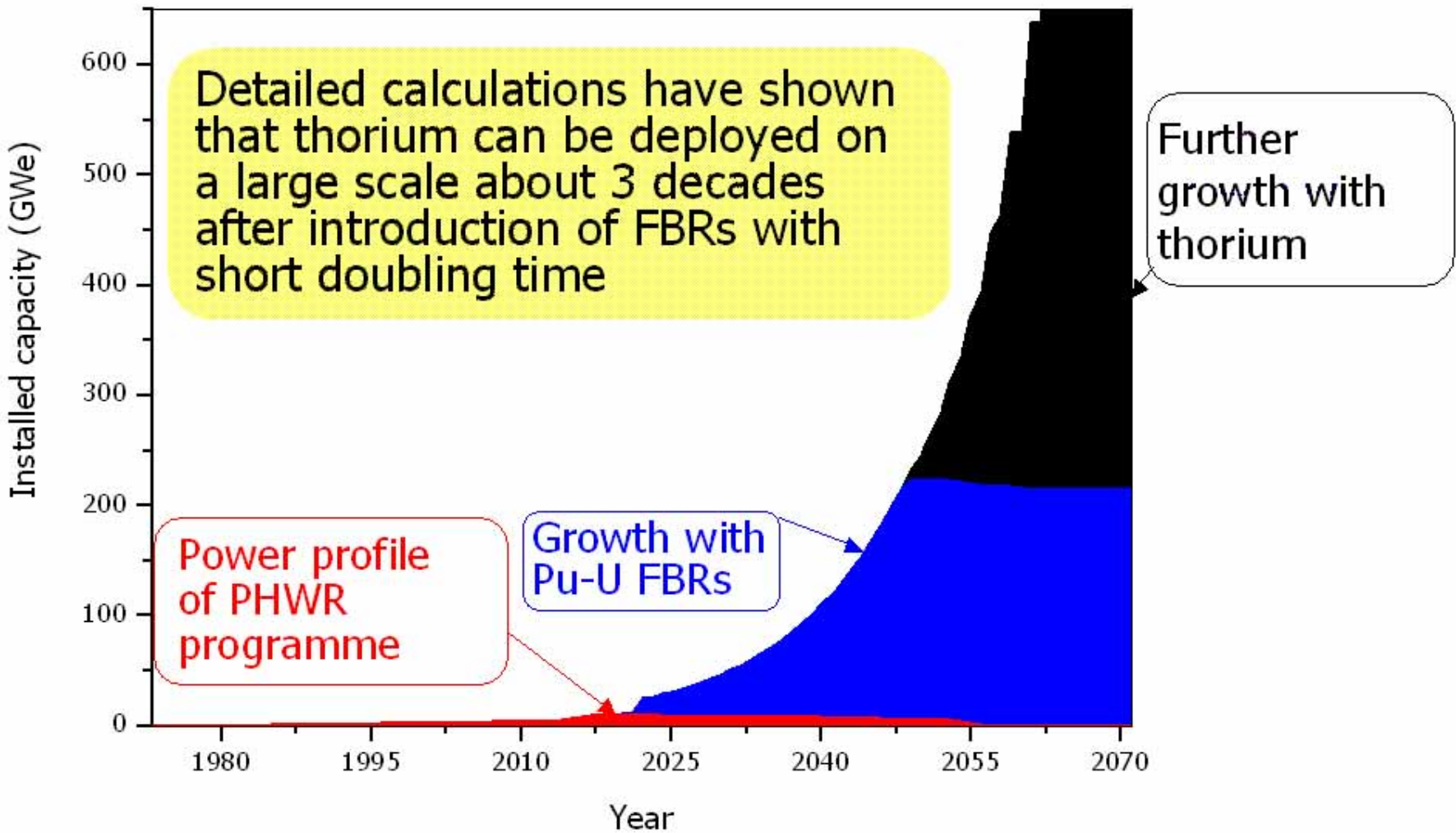
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Strategies for optimum use of domestic nuclear resources



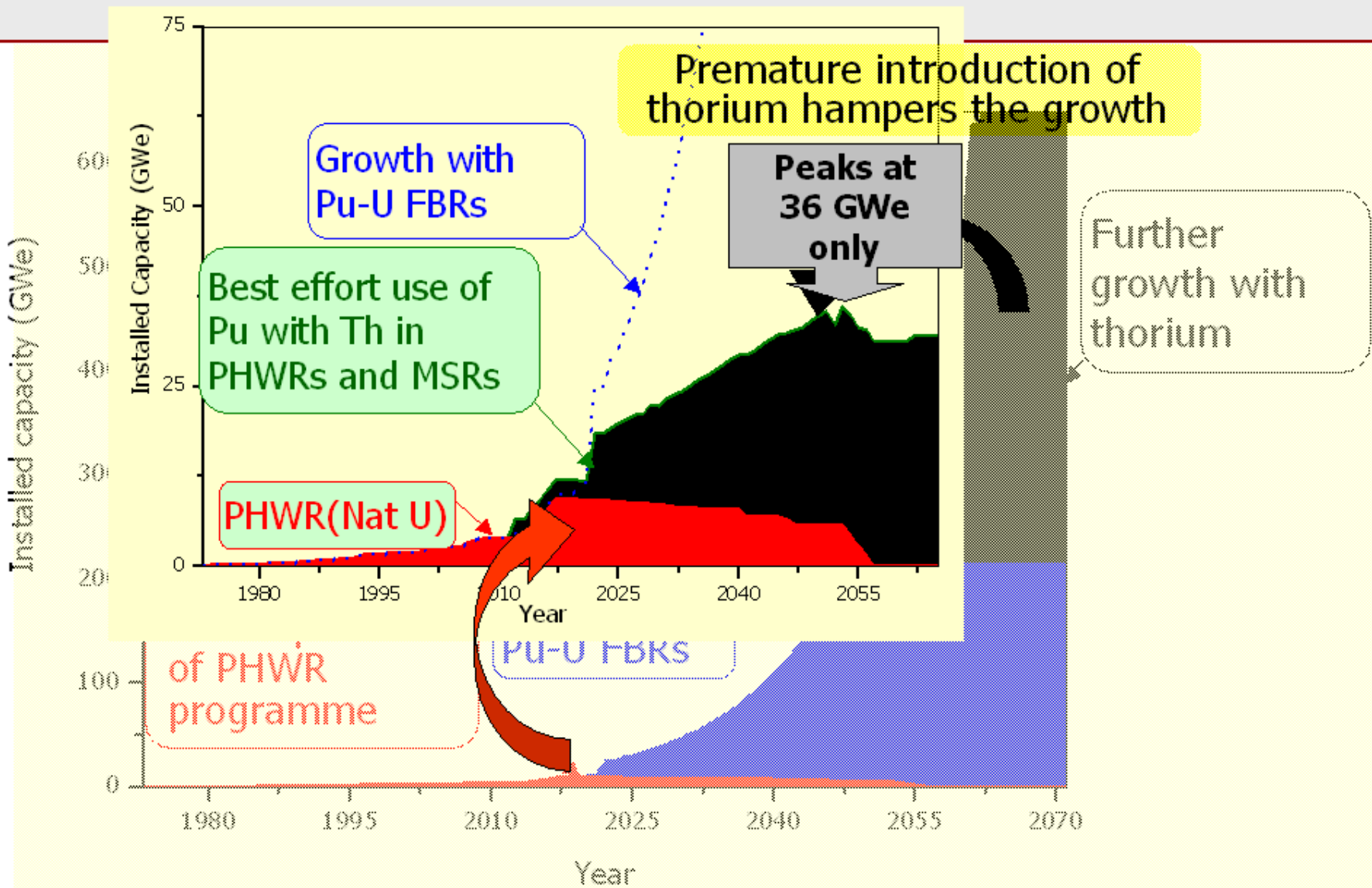
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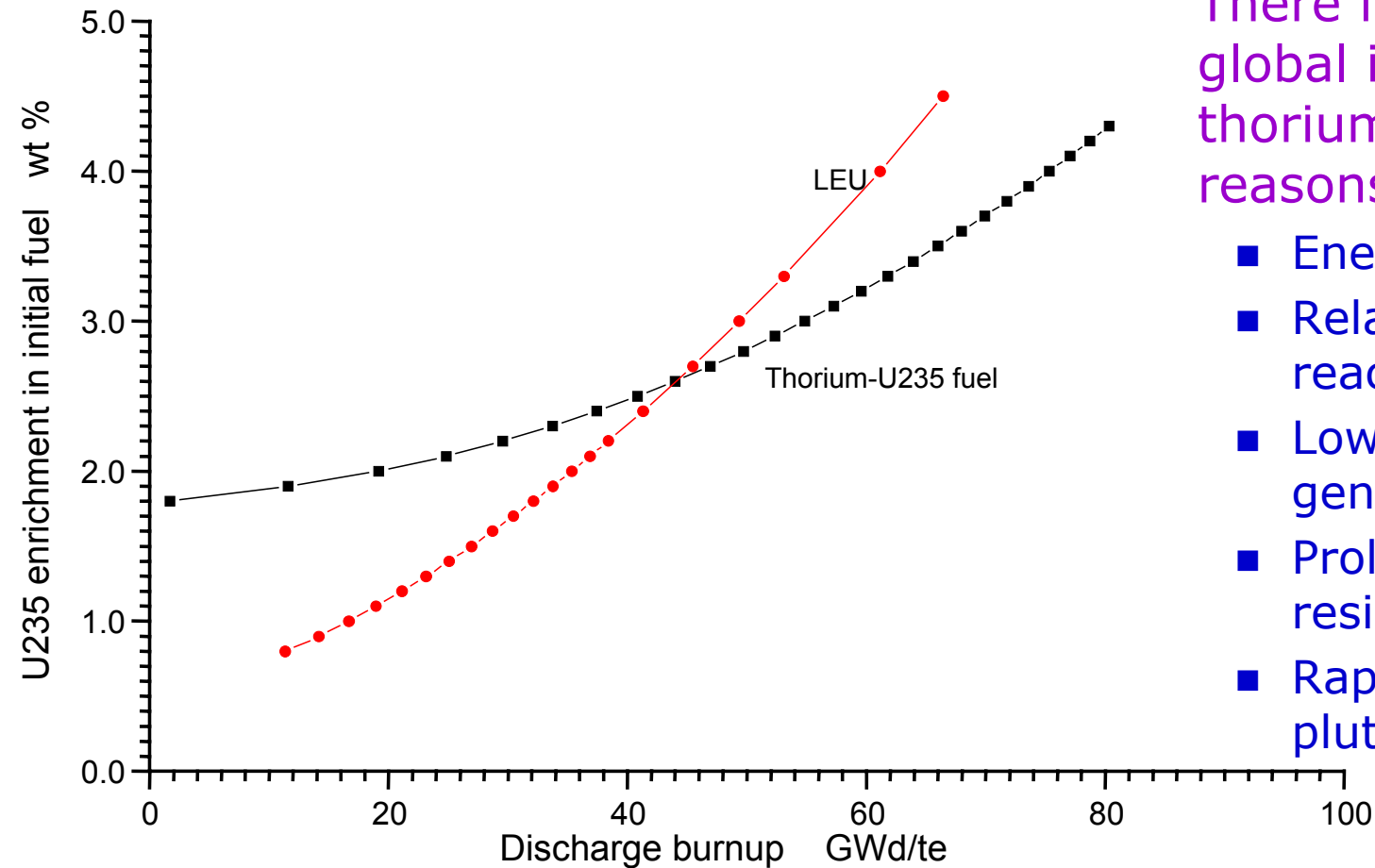
Results for a scenario with current domestic Uranium resources and assuming short doubling time FBRs from 2021

Strategies for optimum use of domestic nuclear resources



Results for a scenario with current domestic Uranium resources and assuming short doubling time FBRs from 2021

Advantage of thorium over uranium becomes evident if thorium based fuels are used at high burnups

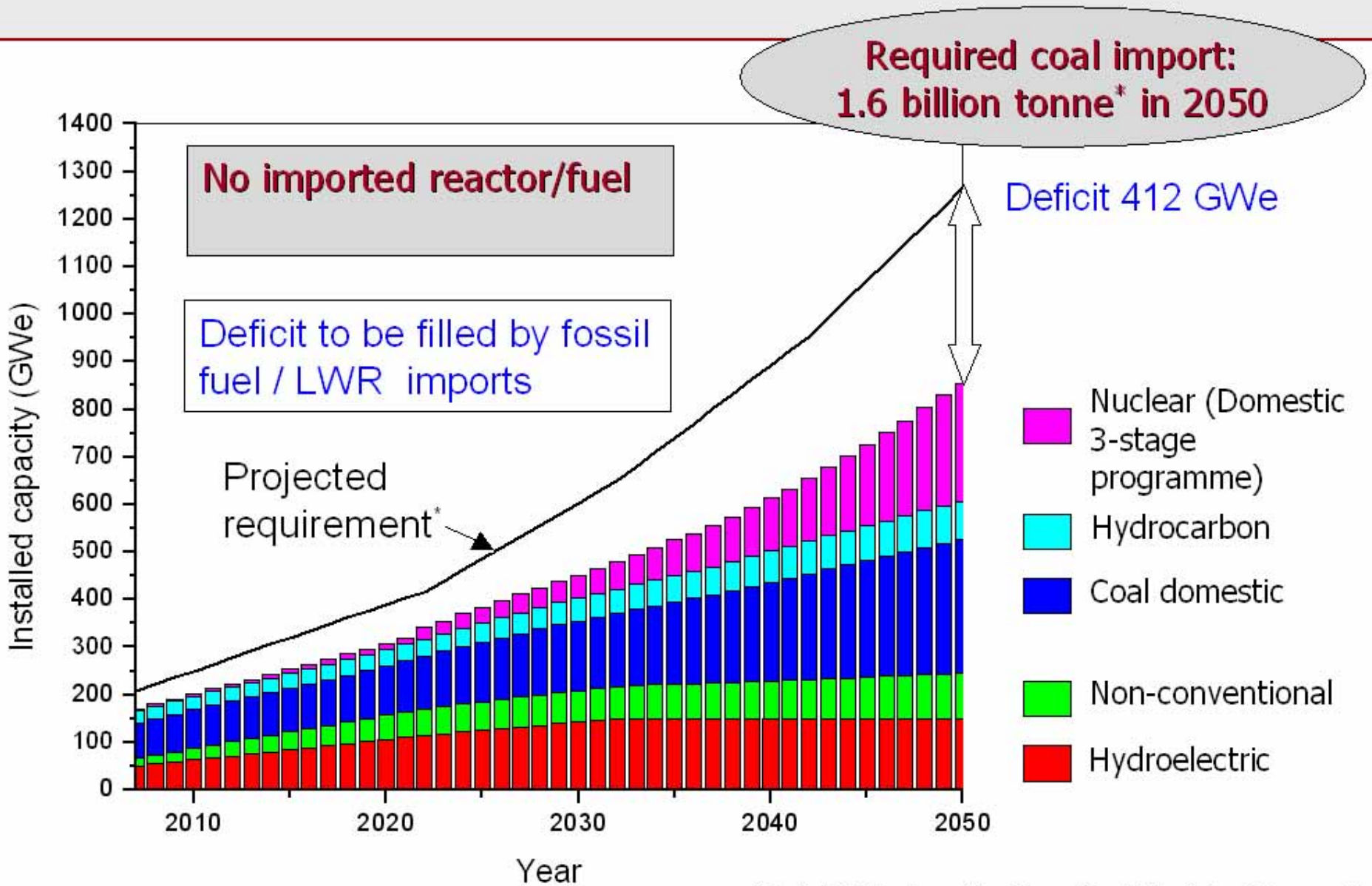


There is a growing global interest in thorium for various reasons such as

- Energy advantage
- Relatively stable core reactivity
- Low minor actinide generation
- Proliferation resistance
- Rapid disposition of plutonium

Performance potential of homogeneous mixture of fertile materials with U-235 in a PHWR

Strategies for long-term energy security

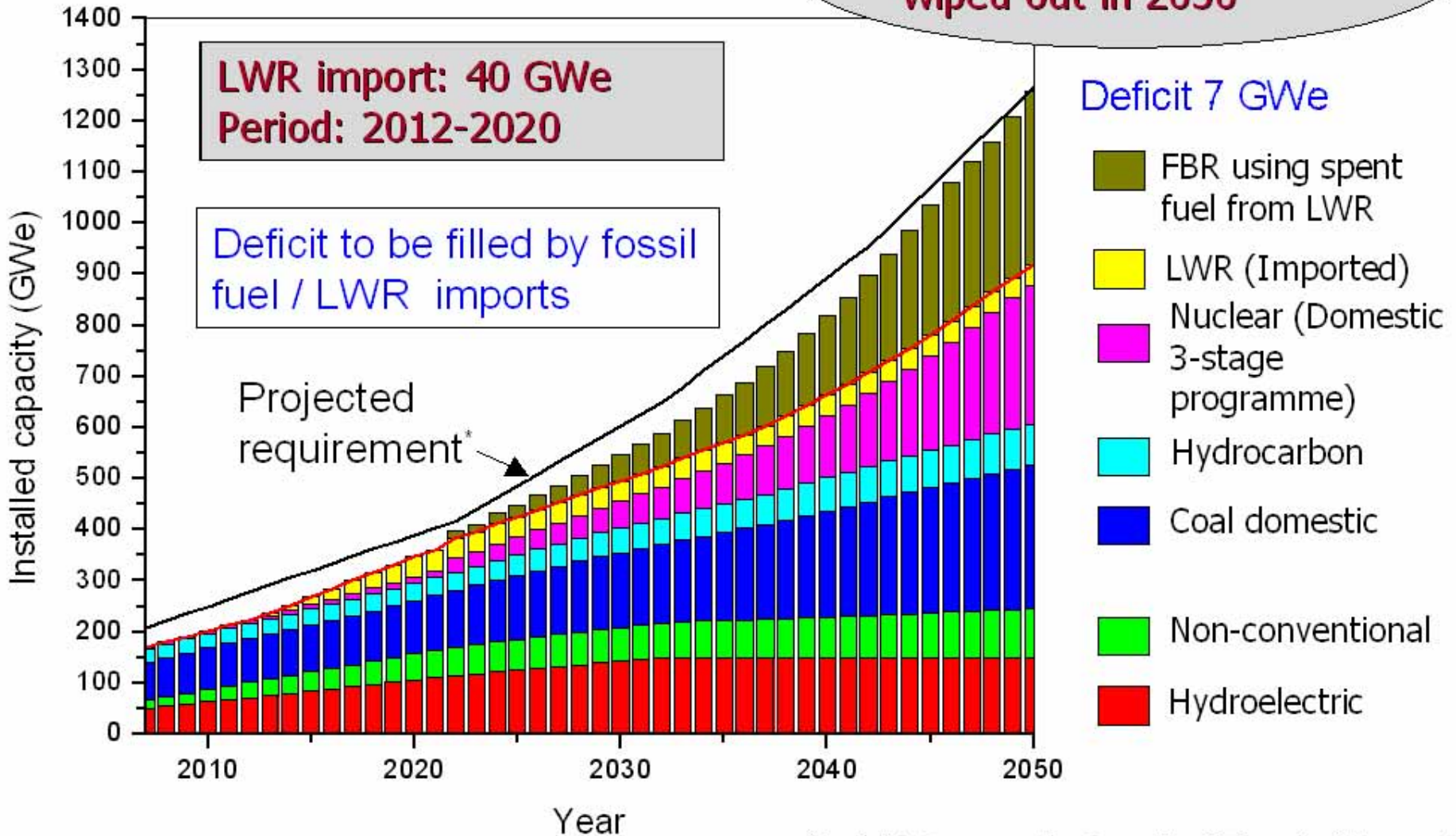


* - Assuming 4200 kcal/kg

*Ref: "A Strategy for Growth of Electrical Energy in India", document 10, August 2004, DAE

Strategies for long-term energy security

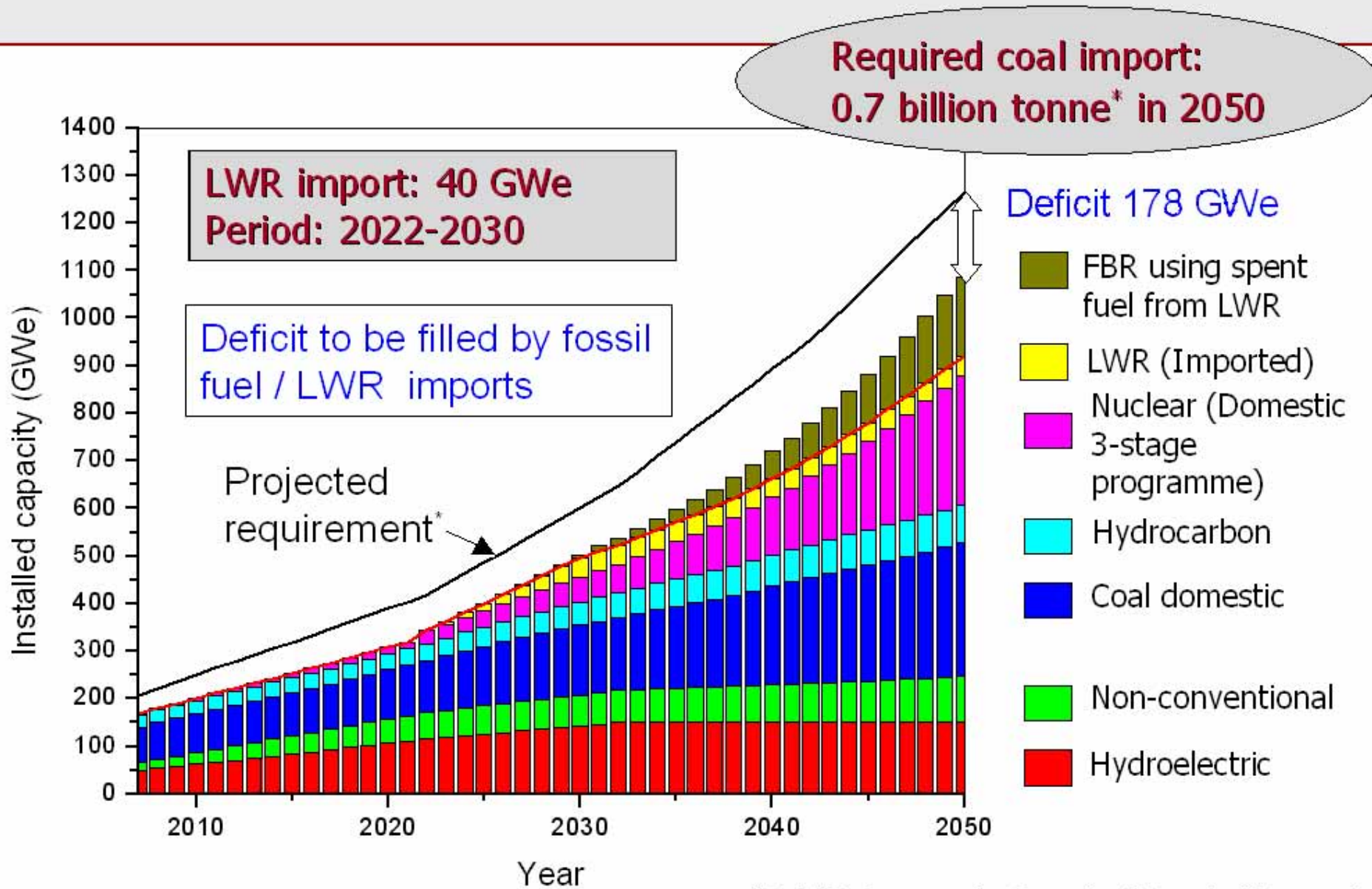
The deficit is practically wiped out in 2050



* - Assuming 4200 kcal/kg

*Ref: "A Strategy for Growth of Electrical Energy in India", document 10, August 2004, DAE

Strategies for long-term energy security



* - Assuming 4200 kcal/kg

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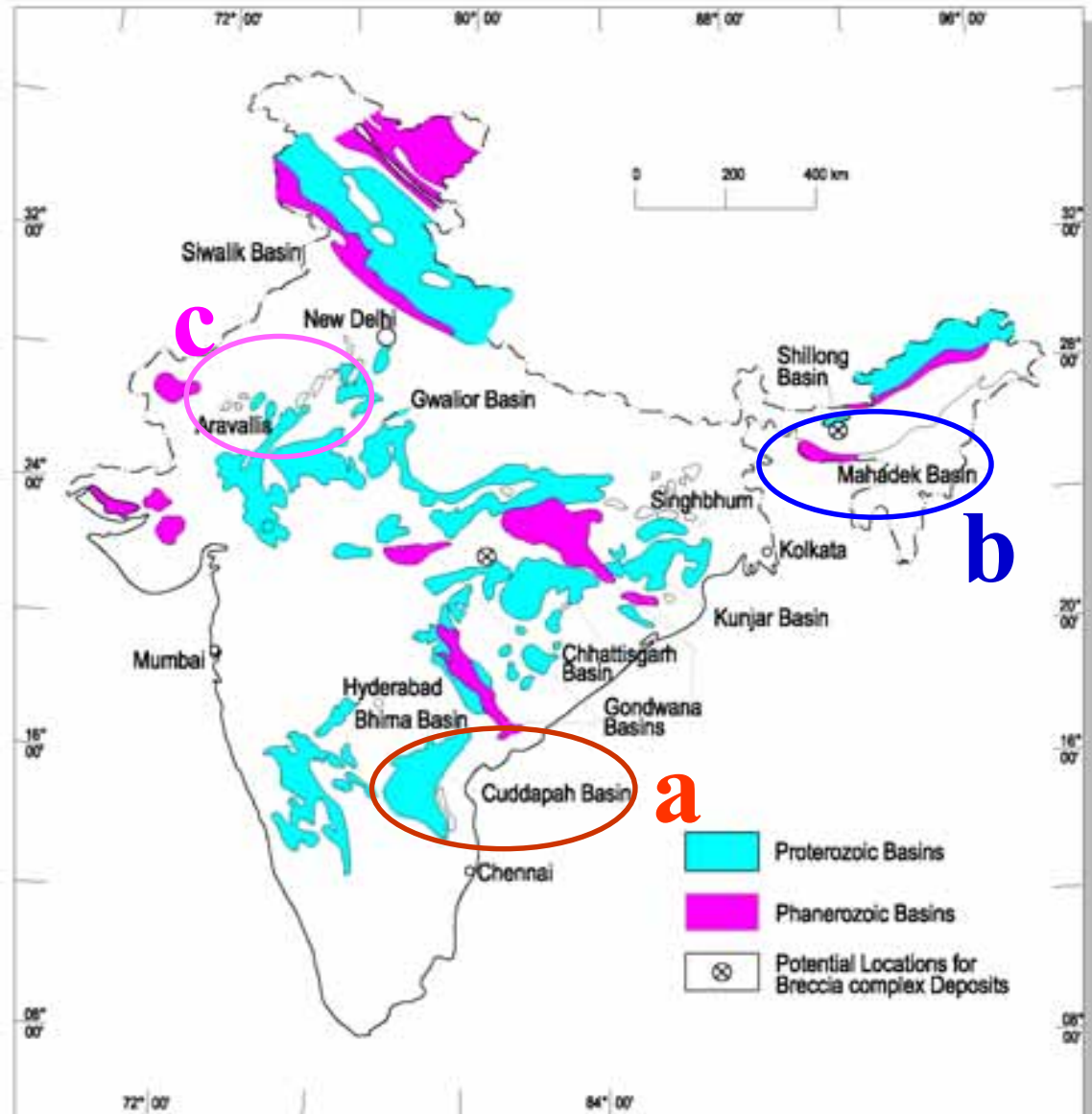
Augmentation of uranium resources : Thrust areas

THRUST AREAS

(a) Cuddapah basin,
Andhra Pradesh

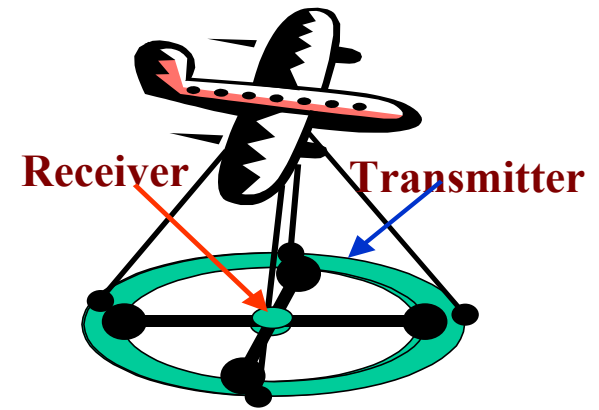
(b) Mahadek Basin
Meghalaya

(c) North Delhi Fold
belt, Rajasthan
and Haryana



Augmentation of uranium resources : Thrust areas

- Organisational restructuring
- Larger investment and deployment
- New Technology
 - Drilling
 - Time domain EM survey
- Broad base strategies for wider access to Uranium



Time Domain Electro Magnetic System being tested at Rohil, Rajasthan

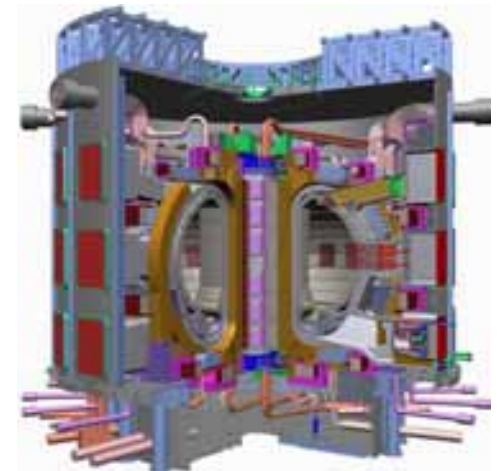
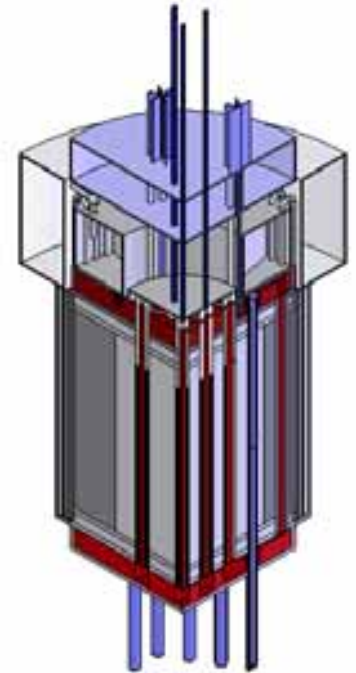
Advanced Energy Technologies: Thorium and beyond

New technology

- Metallic fuel
- Molten salt
- Liquid heavy metal
- High power accelerators
- High temperature materials
- Hydrogen production
- Hydrogen utilisation
- Fusion

Deliverables

- Short doubling time FBR
- ADS for isotope production
- ADS for power production
- Compact high temperature reactor
- IHTR (for commercial H₂ production)
- ITER



Spin-offs

Solar tower
Desalination
Fuel cells



Science – Energy Technologies Synergy

Large projects based on:

- Accelerators
- Super conductivity
- Cryogenics
- Radiofrequency (RF) / Microwave
- Plasma technology
- Lasers – photochemical process
 - Enrichment
 - Material processing



SST-1



FOTIA



KALI



Indus-1



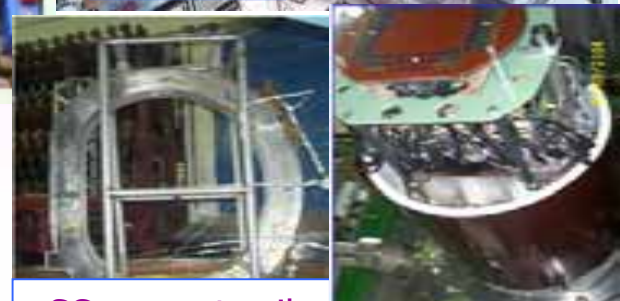
Aditya



Variable energy cyclotron



SCRFQ



SC magnet coil

Some features of DAE R&D environment

- Comprehensive approach to S&T and its delivery
- Strong emphasis on Translation:
Research – Technology – Deployment
- Value system that facilitates activities on and across interfaces
- Freedom of work and interaction duly tempered with the needs of sensitive programmes, programme priorities, overcoming embargo, security challenges etc.

Special challenges

- Continued emphasis on self reliance
(immunity from vulnerabilities, sustain and protect capabilities)
- New emphasis on education and training
(NIUS, UGC-DAE consortium, DGFS, DAE-MU CBS, NISER)
- Stronger bridges between basic research and technology development
(HBNI, BRNS, New Campus of BARC, Promote co-located institutions)

Summary

- Access to global energy sources would become increasingly difficult and expensive as time progresses.
- Early availability of domestic/imported uranium (imported reactors) is important for reducing dependence on import of energy resources in the future.
- We need to sustain the tempo of domestic R&D, focusing on issues and deliverables of a high priority for US.
- To address the range of the technological and scientific challenges, a holistic approach in the development of required human resource as well as in the management of science and technology is essential.