An Overview of Global Activities in Nuclear Desalination

I. Khamis
International Atomic energy Agency (IAEA)
Vienna
Austria
&
P.K. Tewari
Head Desalination Division
BARC
Mumbai 400085
India

Percentage of World Energy Use

Fuel	Percentage (%)	Present trends
Oil	39	Short-term: Building of additional plants continues
Coal	25	Building of additional plants continues
Gas	22	Short-term – Building of additional plants continues; gas turbine combined cycle plants considered the cheapest of fossil fuelled plants.
Hydro	7	Building of dams continues, where possible
Nuclear	6	More or less stagnant in developed countries, with a hope for renewed interest; high rate of expansion in emerging countries.
Renew-able energies	1	Gradual expansion; continued efforts to reduce costs.

Reactor Types and Desalination Processes

Reactor Type	Location	Desalination Process	Status
LMFR	Kazakhstan (Aktau)	MED, MSF	In service till 1999
PWR	Japan (Ohi, Takahama, Ikata, Genkai)	MED, MSF, RO	In service with operating experience of over 150 reactor-years
	Rep. of Korea, Argentina etc	MED RO	Integral SMRs of the PWR type; under design or to be constructed
	Russia	MED, RO	Under consideration (Barge mounted floating unit with KLT-40)
	USA (Diabolo Canyon)	RO	Operating

Reactor Types and Desalination Processes (Contd.)

Reactor Type	Location	Desalination Process	Status
BWR	Japan (Kashiwazaki-Kariva)	MSF	Never in service following testing in 1980s, due to alternative freshwater sources; dismantled in 1999.
HWR	India (Kalpakkam) India (Trombay)	MSF/RO LT-MED	RO operating since 2002 In service since 2004
	Pakistan (KANUPP)	MED	Existing CANDU modified to be coupled to an MED plant (under construction)
NHR-200	China	MED	Dedicated heat only integral PWR; under design
HTRs	France, The Netherlands, South Africa	MED,RO	ANTARES, multipurpose reactor, GT-MHR and PBMR; under development and design.

Recent activities by Member States

- Argentina has identified a site (Puerto Deseado) for its small reactor (CAREM), which could be used for desalination.
- China has completed the feasibility study of nuclear desalination project using NHR type heating reactor at an identified coastal Chinese site (Shandong Peninsula).
- Egypt has completed a feasibility study for a nuclear co-generation plant (electricity and water) at El-Dabaa. NPPA has set up an experimental RO facility at El-Dabaa to validate the pre-heat RO concept.

Recent activities by Member States (contd.)

- France and Libya have agreed for nuclear desalination demonstration pilot plant (hybrid MED-RO) at Tjoura experimental reactor. Agreement with Morocco for techno-economic studies of specific sites is under consideration. Under a bilateral collaboration signed between India and France, the two partners will collaborate on the development of advanced calculation models, which will then be validated at Indian installations.
- Israel continues to regularly provide technical and economic information on low cost desalination technologies and their application to large-scale desalination plants.
- Japan continues with its operation of nuclear desalination facilities co-located inside nuclear power plants.

Recent activities by Member States (contd.)

- Morocco continues the process of establishing an adequate legal and regulatory nuclear framework while staying abreast of technical developments in nuclear desalination.

- Tunisia has been active in inter-regional study in the feasibility study of nuclear desalination.

Recent activities by Member States (contd.)

- USA includes in its Generation IV roadmap initiative a detailed discussion of potential nuclear energy products in recognition of the important role that future nuclear energy systems can play in producing fresh water.

- R&D activities are also underway in Indonesia and Saudi Arabia. In addition, interest has been expressed by Algeria, Brazil, Islamic Republic of Iran, Iraq, Italy, Jordan, Lebanon, Philippines, Syrian Arab Republic and UAE in the potential for nuclear desalination in their countries or regions.

Demonstration Projects in Member States

- India is building a demonstration plant at Kalpakkam using a 6300 m^3/day hybrid desalination system (MSF-RO) connected to an existing PHWR. The RO plant, with a production capacity of 1800 m^3/day, was set up in 2002 and is since operating. Already the CIRUS research reactor, providing waste-heat to a LT-MED plant, has been operating since 2004. It is also planned to couple the forthcoming AHWR with a desalination plant. Indo-French collaboration on integrated nuclear desalination system is progressing well.
- Libya and France have agreed for setting up a nuclear desalination demonstration pilot plant (hybrid MED-RO) at Tjoura experimental reactor. The MED plant, of about 1000 m^3/day production capacity, will be manufactured locally.

Demonstration Projects in Member States

- Pakistan is constructing a 4800 m^3/day MED thermal desalination plant coupled to a PHWR at Karachi.
- The Republic of Korea is proceeding with its SMART (System-integrated Modular Advanced Reactor) concept. The project is designed to produce 40,000 m^3/day of potable water and 90 MW electricity.
- Russia The Russian Federal Agency for Atomic Energy (ROSATOM) has started construction of a floating barge mounted heat and power co-generation.

Advances in Desalination Technologies

Desalination technologies have shown continued progress over the past decades with emphasis on cost reduction strategies through technological innovations.

Thermal Processes (Distilled quality water)

High Gain Output Ratio (GOR)

High heat transfer coefficient

Material of construction

Advances in Membrane Desalination

salt rejection efficiency

membrane flux

Enhanced chlorine tolerance

life membranes

Membrane based pretreatment

Efficient energy recovery devices

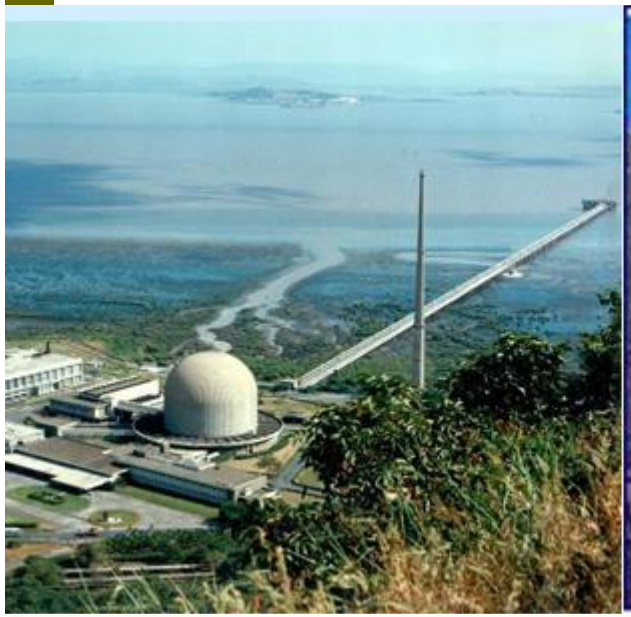
Cost Reduction Strategies

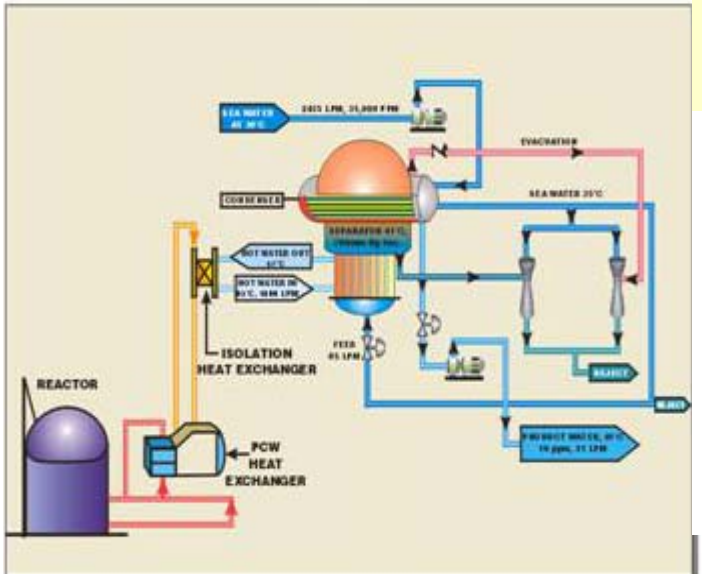
Utilisation of Nuclear Waste Heat

- High temperature Gas Cooled Reactor
- Condensers of PWR & CANDUs (ROph)
- Indian PHWRs
  - CIRUS
  - PHWR (500 MWe)

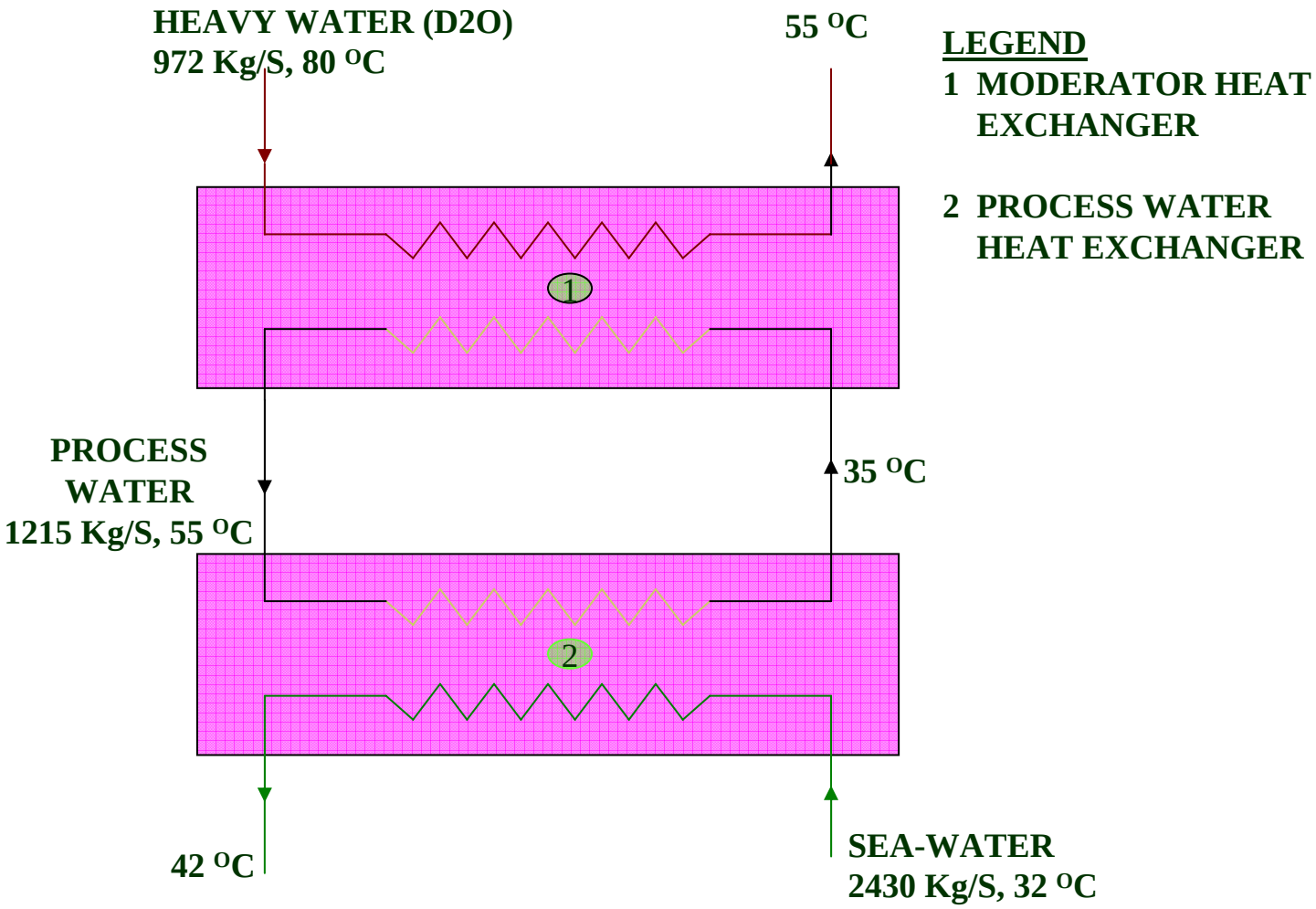
DAE (India) has nuclear power program of installed nuclear power capacity of 20,000 MW by 2020 implying high potential for dual purpose plants producing electricity & water in coastal areas including recovery of valuables from concentrated brine.

LTE Desalination Plant using Waste Heat of CIRUS Nuclear Reactor in BARC Mumbai (India) for Seawater Desalination

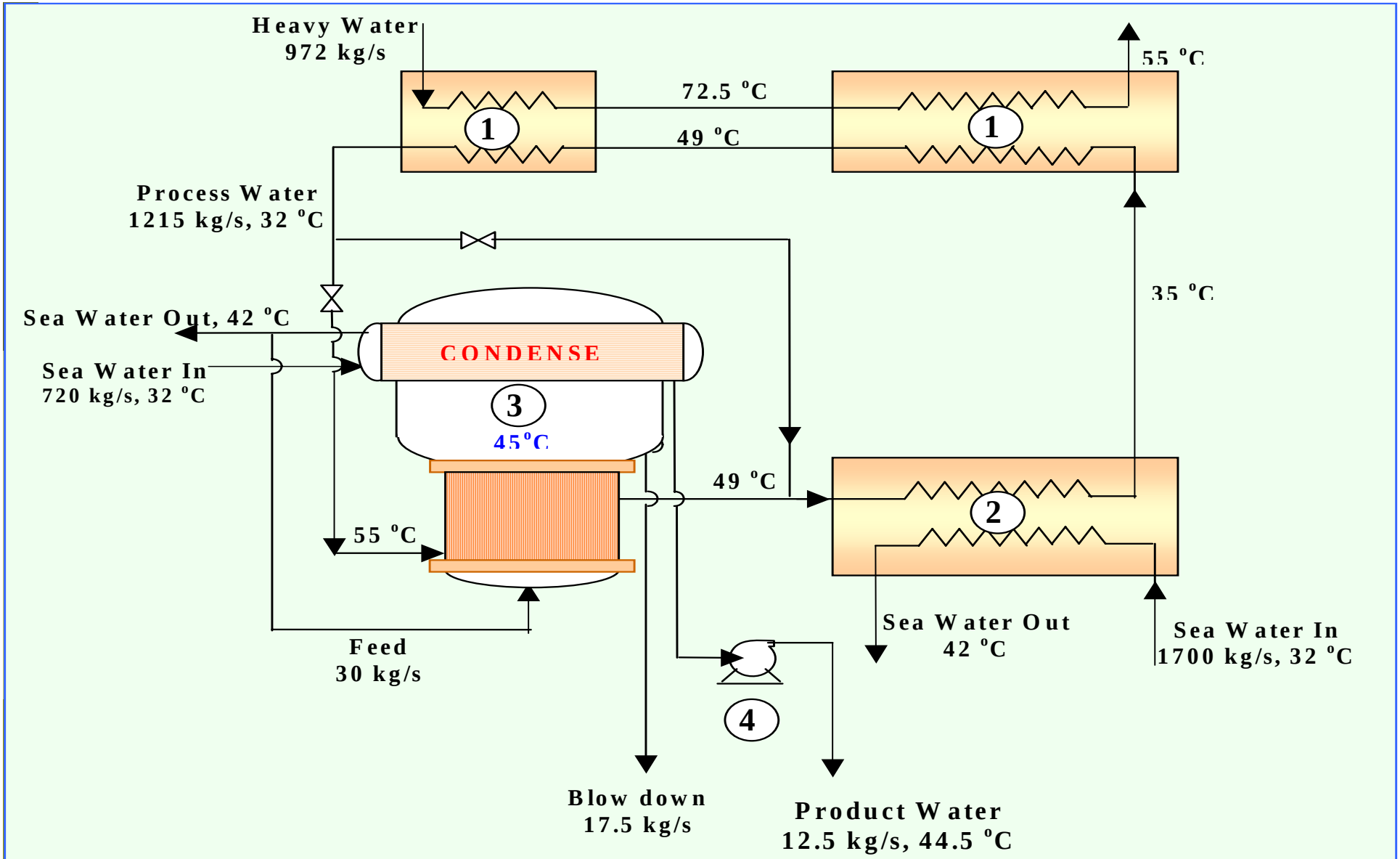




S. No	Power Rating (MW_{th})	PCW Temp (^oC)	Hot Water Temp (^oC)	Product rate (litres/d)	Product Water (µS/cm)
1	25	58	54	10,000	08-10
2	28	61	56	12,000	08-10
3	30	64	58	18,000	08-10
4	33	68	60	21,000	10-12
5	36	72	63	26,000	10-12
6	40	77	65	30,000	10-14



EXISTING SYSTEM FOR MODERATOR COOLING IN A COASTAL 500 MW(e) PHWR

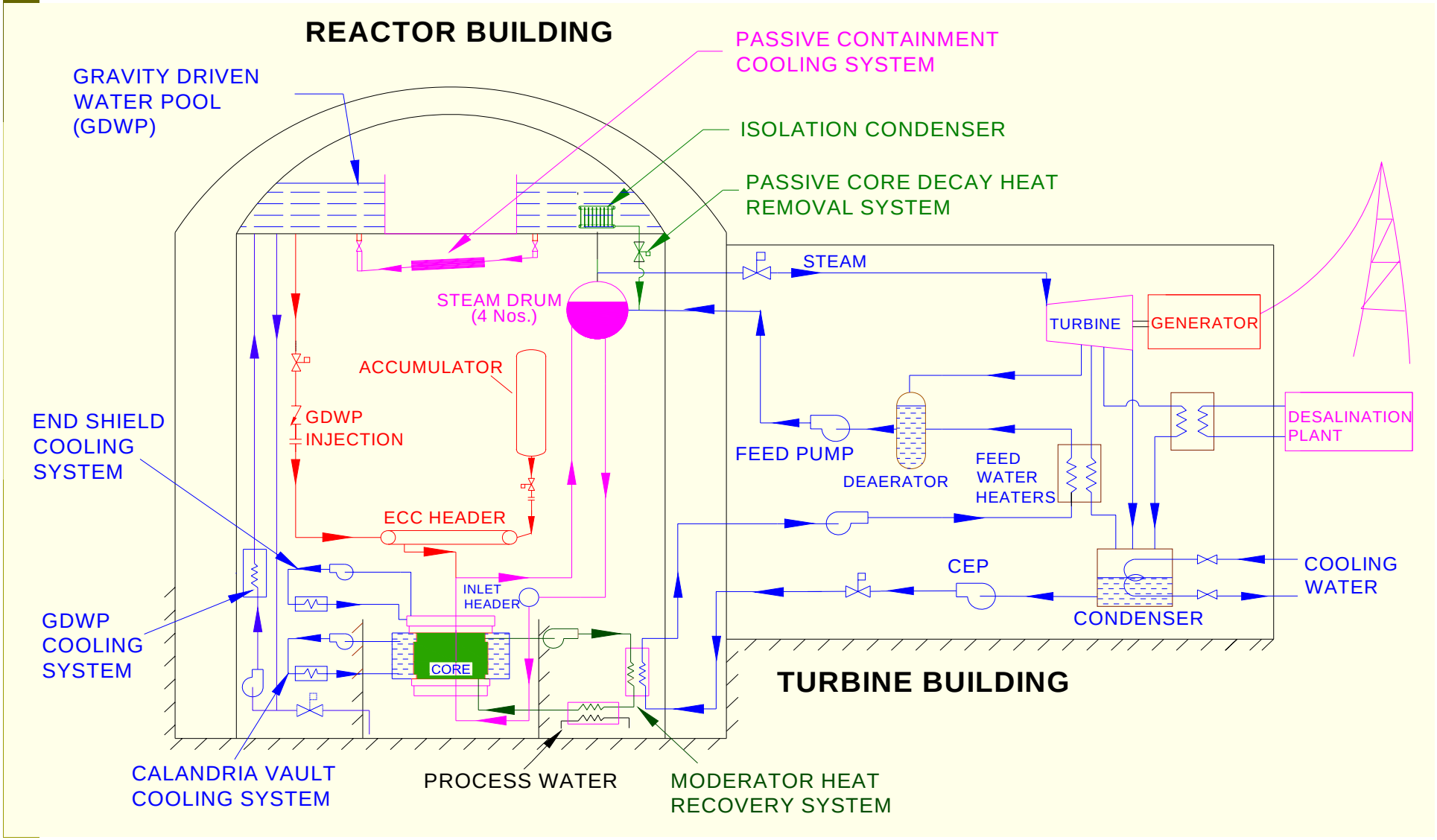


1. Moderator heat exchanger
2. Process water heat exchange
3. Desalination Unit
4. Product water pump

Note: When the desalination unit is shut down, the sea water required for the process water heat exchanger is 2430 kg/s at 32 °C

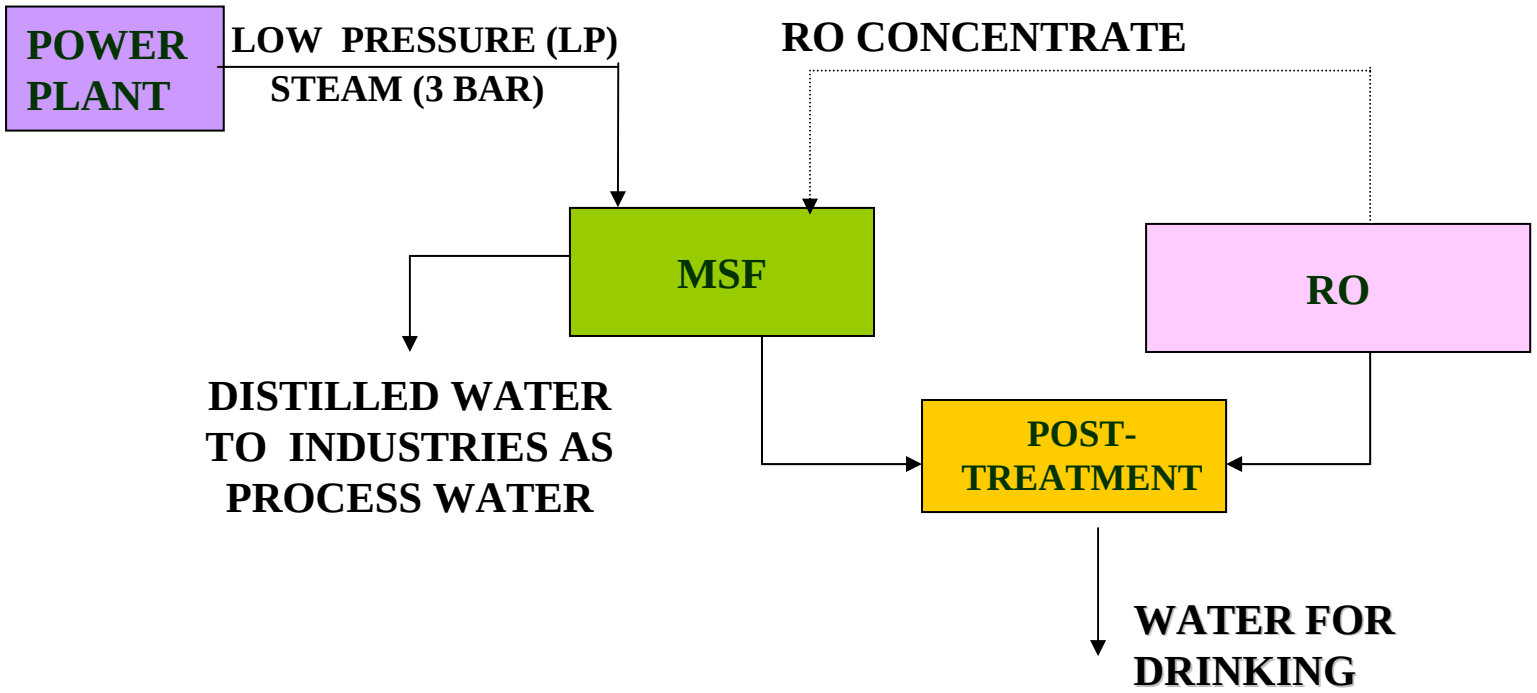
Seawater Desalination Plant (500 m3/day capacity) Coupled to Advanced Heavy Water Reactor (AHWR)

(Reactor power: 300 MWe, 920 MWth, Th fuel cycle, boiling light water cooled, D2O moderated)



Hybrid Systems

CASE I : POWER PLANT IS IN OPERATION ---



CASE II : POWER PLANT IS NOT IN OPERATION

Challenges

- Disparity
- Economics
  - Energy consumption
  - Potable water transport
  - Waste heat utilization
- Public Perception
- Socio-environmental aspects

Integrated Nuclear Desalination System

- Setting up nuclear desalination plant calls for an integrated approach considering various facets.
- These not only include the design aspects of nuclear reactors, desalination systems, and their optimum coupling but also safety & security, economics, infrastructure, socio-environmental issues and the public perception.
- Information exchange on these issues will be useful for future deployment of large-scale nuclear desalination in the Member States.

Conclusion

- **Nuclear desalination systems are technically feasible and economically attractive options.**
- **Cost Reduction Strategies:**

Utilisation of waste heat from nuclear reactors (PHWR, HTR, PWR etc.),

Hybrid Systems,

Recovery of valuables from brine

- **For nuclear desalination to be attractive in any given country, two factors must be in place simultaneously: i) lack of water and ii) the ability to use nuclear energy for desalination.**

Thanks