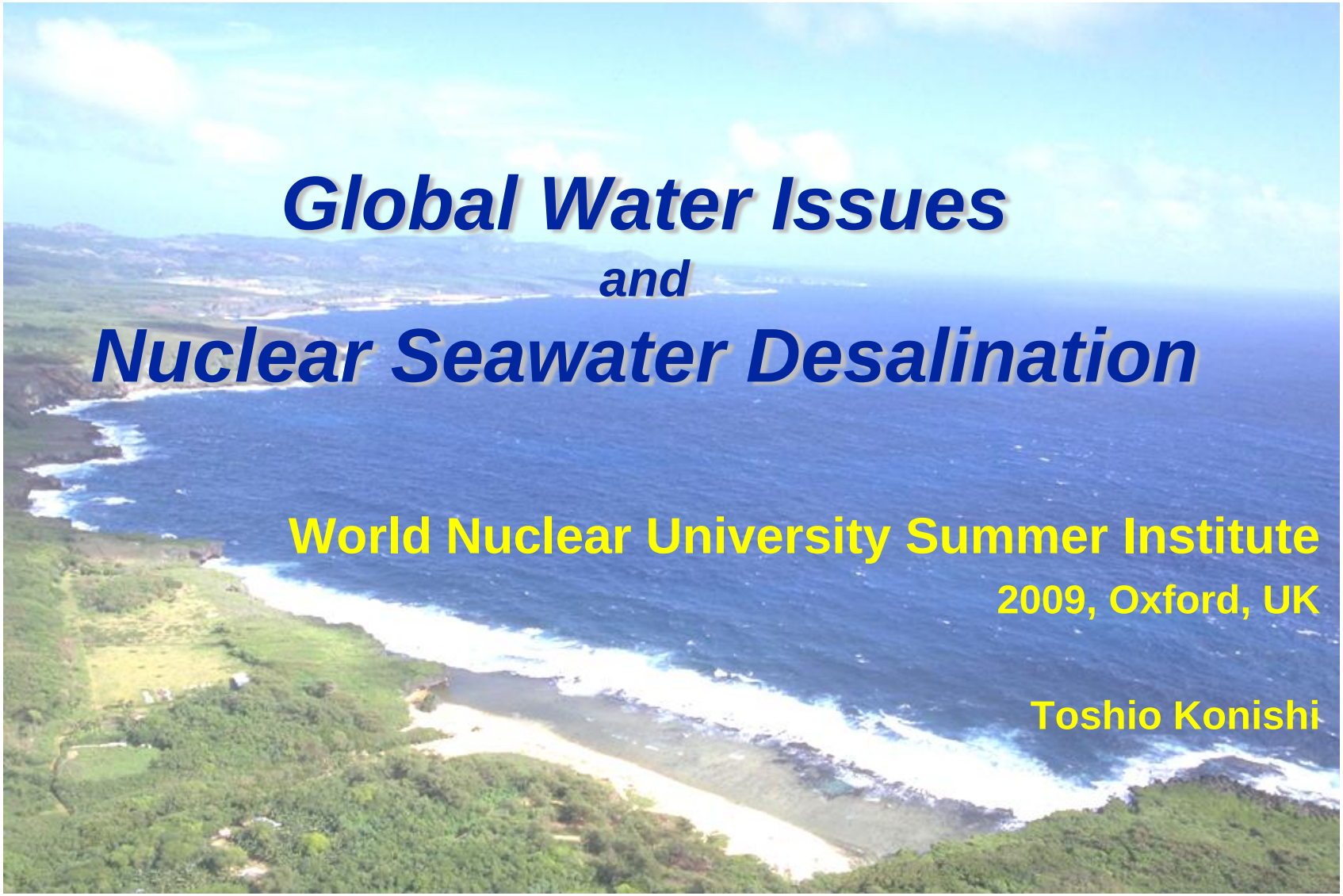


Global Water Issues
and
Nuclear Seawater Desalination

World Nuclear University Summer Institute

2009, Oxford, UK

Toshio Konishi

Content

- ***Three Questions***

1. ***Global water issues: what, why and where?***
2. ***Seawater desalination: A reality***
3. ***How can nuclear technology contribute?***
4. ***What is being done at the IAEA and worldwide?***
5. ***What issues do we have ahead?***

www.iaea.org/NuclearPower/Desalination/

You can contact IAEA at <*i.khamis@iaea.org*>.

If you want, you can contact me, too, at <*t-konishi@jaif.or.jp*>.

Three Questions to you

Q1: How many liters/day do you need/use for daily life?

Q2: Why is nuclear desalination not widely deployed?

Q3: What issues do we have ahead?

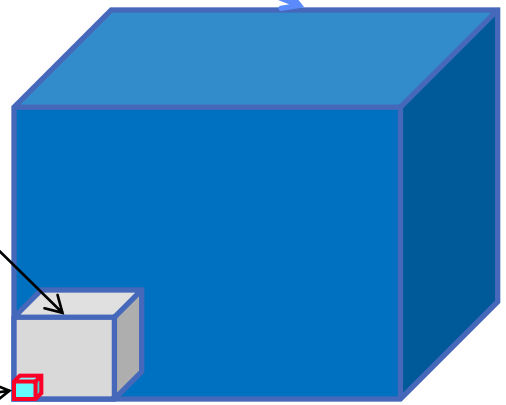
1. Global water issues: what, why, where?

Resources are abundant, but ---

World's water (1.4×10^{18} m^3)

Fresh water (non-renewable)

Renewable fresh water (rivers, lakes, ---) (10^6 ton/capita)

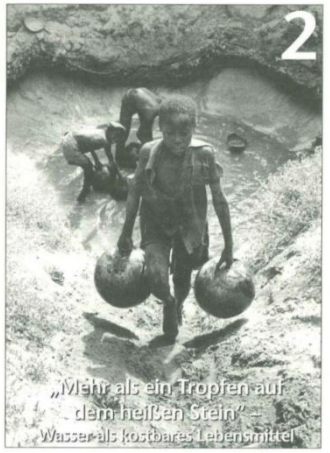


- ***Only 2.5% of world's water is freshwater.***
- ***It is mostly non-renewable in ice caps, aquifers, soil moisture ---***
- ***Only 1% or even less is accessible for use***
- ***Still abundant on the average***
- ***But ---***

Uneven distribution causes water issues

- ***Not evenly distributed (location, seasonal)***

(photos from UNDP report)



- ***Water collection by children and women***

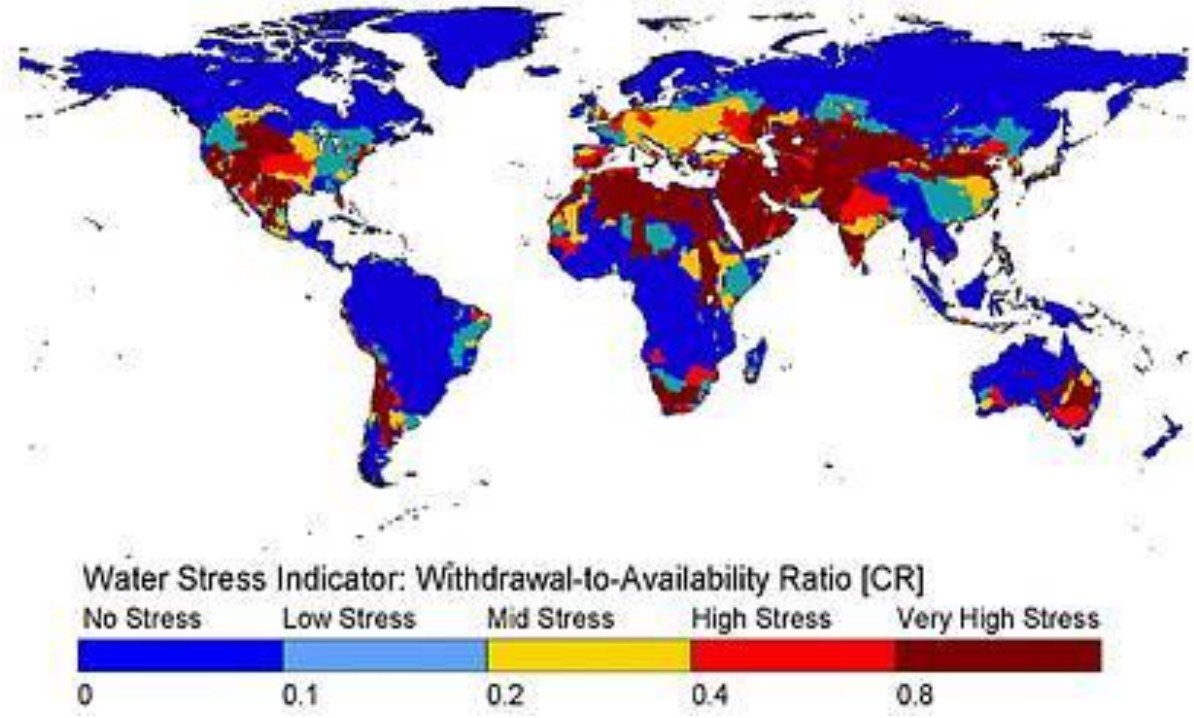
- ***Q1: How many liters/day do you need for daily life?***

Globally,

- ***2.3 billion people under water stress***
- ***1.1 billion people lack safe drinking water***
- ***3.3 billion related cases of illnesses***
- ***2 million related yearly deaths***

International Water Management Institute
and World Water Council

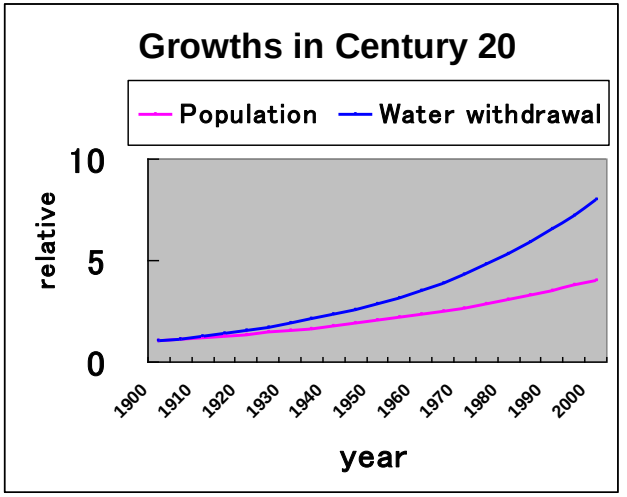
Water stress (Withdrawal to Availability)



World Water Council

Water crisis is expanding

- *In the 20th century, water withdrawal grew twice as fast as the global population.*
- *Global population increase continues.*
- *Population growth, industrialization and urbanization will expand the water crisis.*
- *Water resources are becoming scarce.*
- *Institutional issues complicates the crisis.*



World Water Council (http://www.worldwatercouncil.org/)

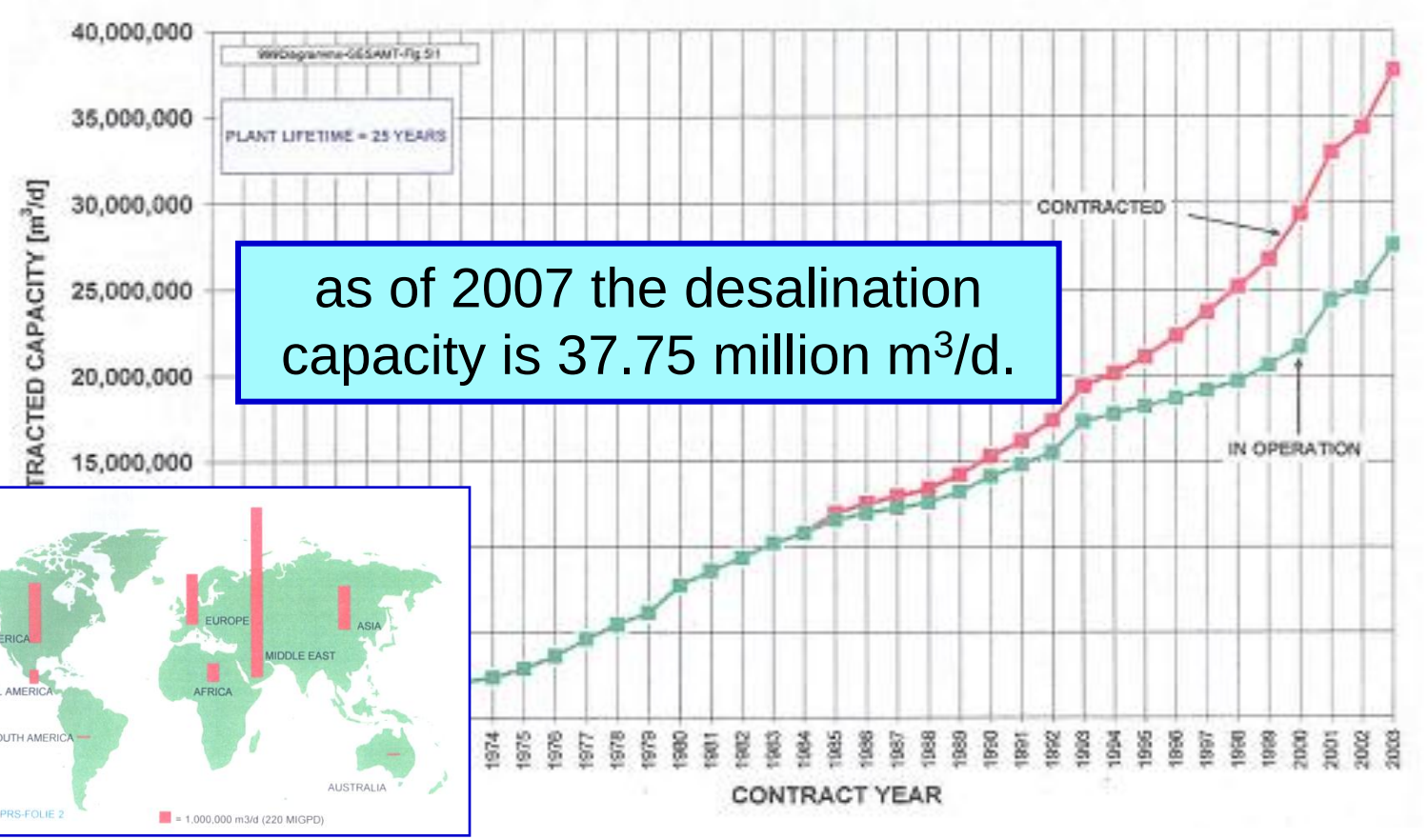
Useful URLs for information sources

- ***World Water Council*** www.worldwatercouncil.org/
- ***UNICEF/WHO JMP*** www.wssinfo.org/
- ***IRC International Water and Sanitation Centre*** www.irc.nl/
  International Desalination Association www.idadesal.org/
- ***Global Water Intelligence*** www.globalwaterintel.com/
- ***International Water Management Institute***
  www.iwmi.cgiar.org/

Water management first (saving, reuse, distribution), water production follows to meet water demands.

2. Seawater desalination: A reality

--- Existing Plant Capacities ---

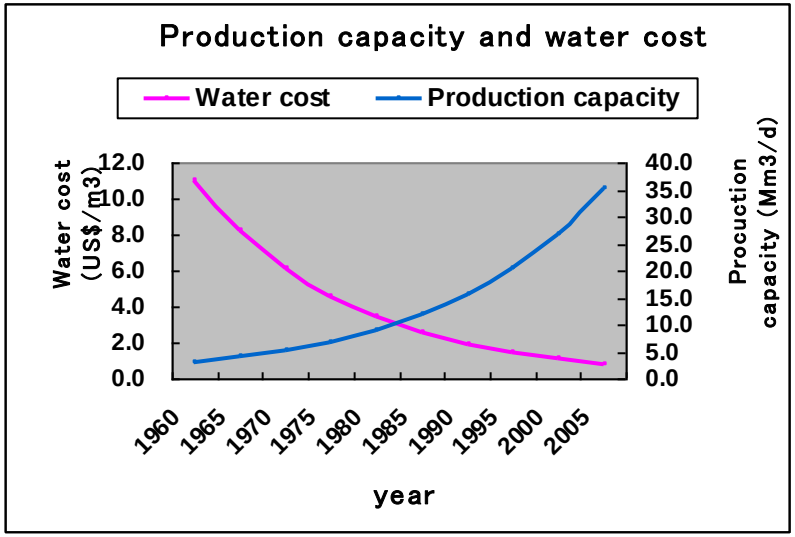


as of 2007 the desalination capacity is 37.75 million m^3/d.

Source: IDA Worldwide Desalting Plants Inventory Report, Wangnick Consulting GmBH and the International Desalination Association (IDA), May 2000

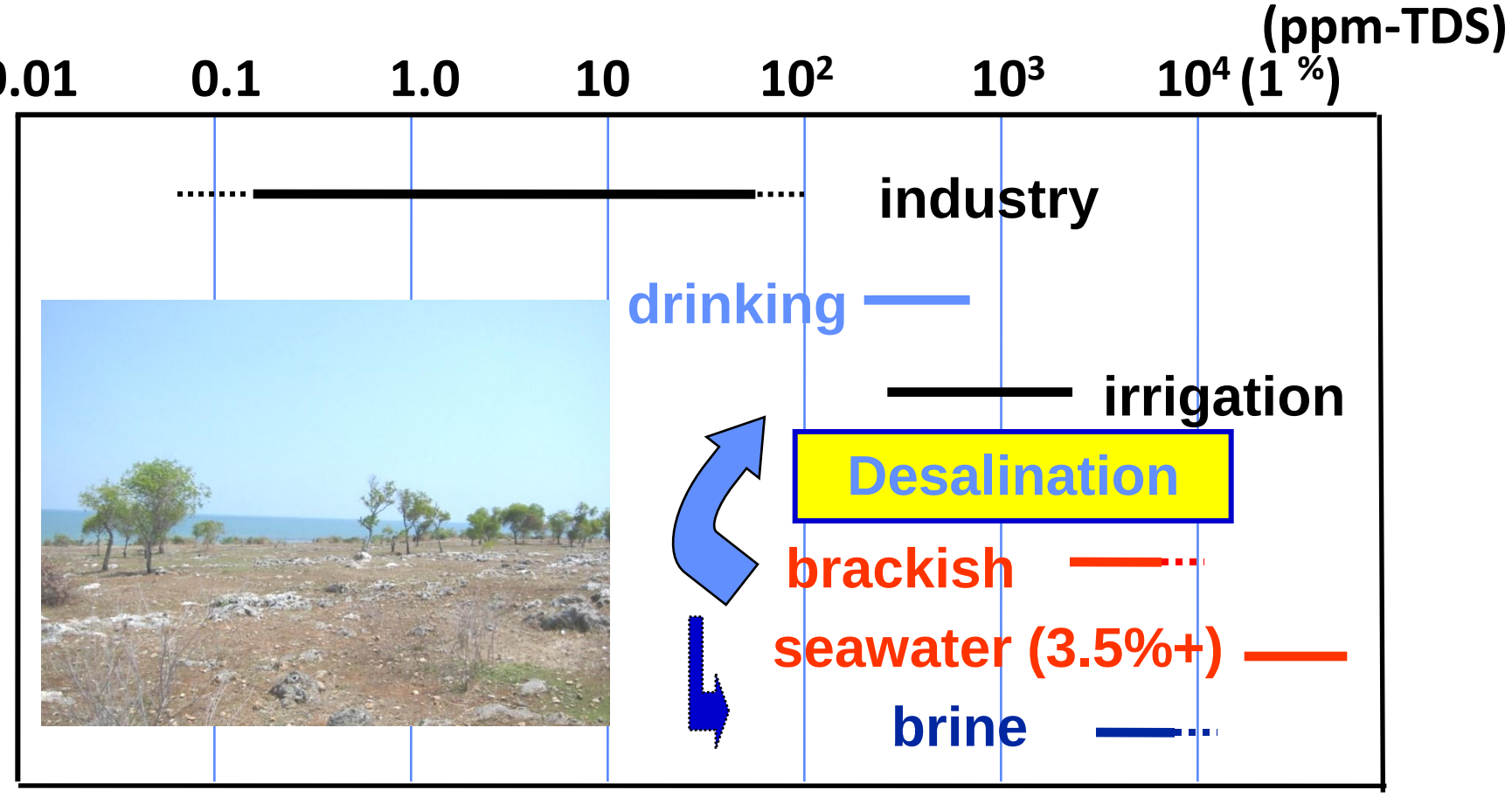
Why seawater desalination?

- *0.1 % of the Earth volume is seawater*
- *Proven technical and economical feasibility*
  - *Increasing installation capacities in arid and semi-arid zones*
- *Largest users: Saudi Arabia, USA, UAE*
- *Room for further improvement to reduce cost*



Water salinity and users

Indicator: TDS (Total Dissolved Solids)



Industrial desalination processes

- **Evaporation** for high purity
- Conventional since 17th Century
- Major existing capacities
- Multi-Effect Distillation (MED), Multi-stage Flash (MSF)

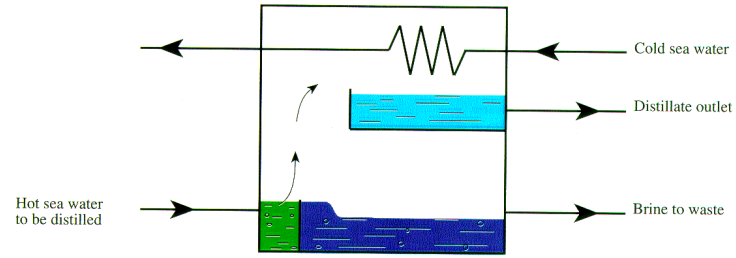
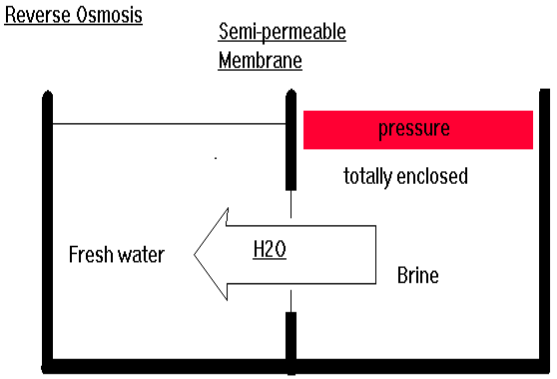


Figure N°1: Flash distillation principle

- **Mechanical** with no heat source
- Reverse osmosis (RO)
- Deployed since 1950s
- Penetrating the market, where electricity is available
- Energy efficient



Energy needs for desalination
(equivalent electricity consumption for producing 1 m^3)

- ***Evaporation***
  - ***MSF: (12-18) kW(e)·hr***
  - ***MED: (4.5-12.5) kW(e)·hr***
  - ***MED+VC: (7-9) kW(e)·hr***
- ***Mechanical***
  - ***RO: (4-6) kW(e)·hr***

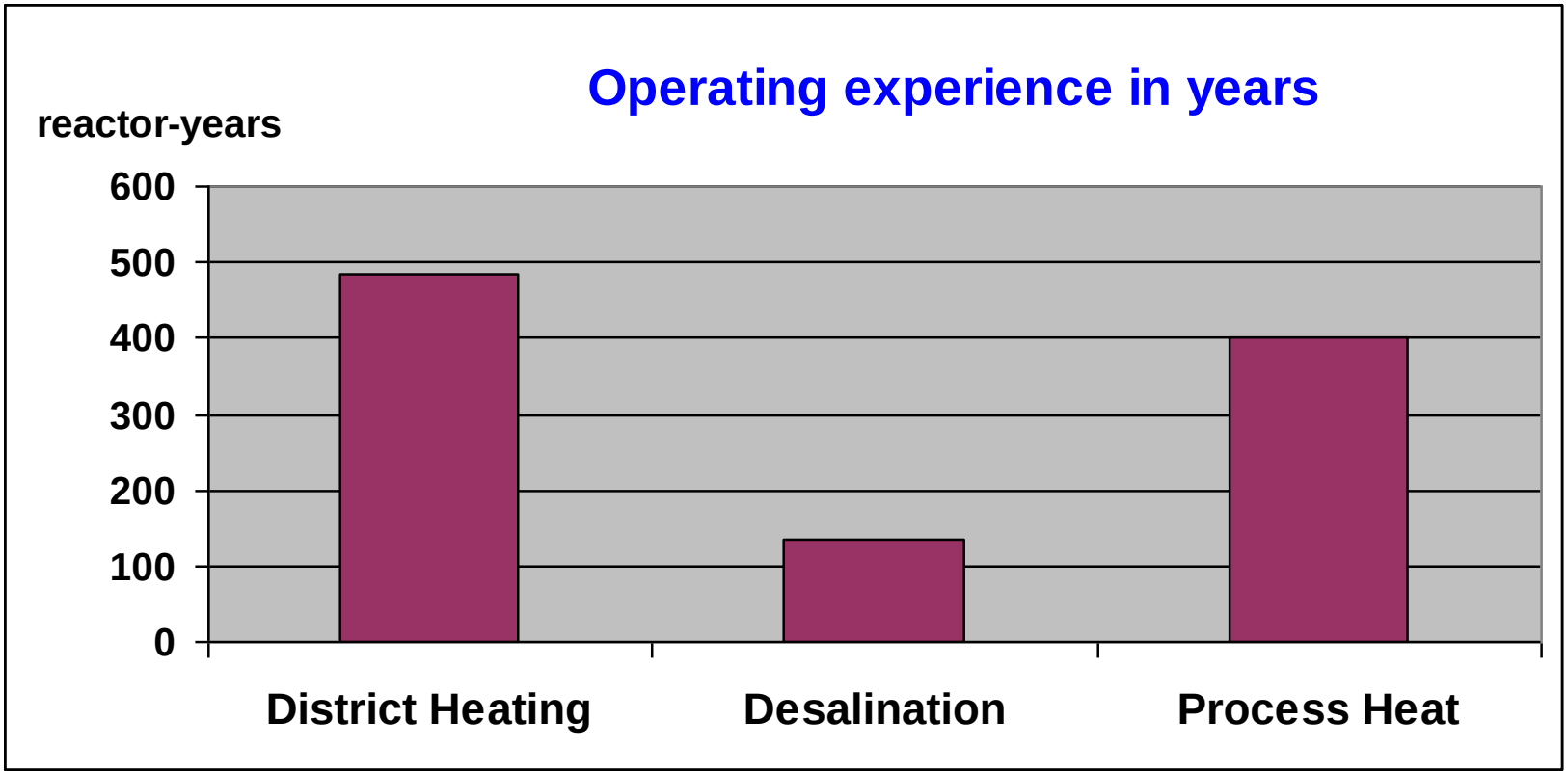
- ***Design example: 10 MW(th) for 8,000 m^3/d to 60,000 people***
- ***When connected to a co-generation plant, the energy needed for desalination is not a major component.***

3. How can nuclear technology contribute?
--- IAEA has two sub-programmes ---

- ***Isotope hydrology***
  - ***Traces the water movements in the hydrological cycle***
  - ***Investigates underground water resources (determine the sources, how recharged, risks of pollution, sustainability ---)***
  - ***More information found in <www-naweb.iaea.org/napc/ih/>***
- ***Nuclear desalination***
  - ***Produces freshwater from the seawater***
  - ***Uses nuclear heat/electricity for processing***
  - ***More information found in <www.iaea.org/NuclearPower/Desalination/>***

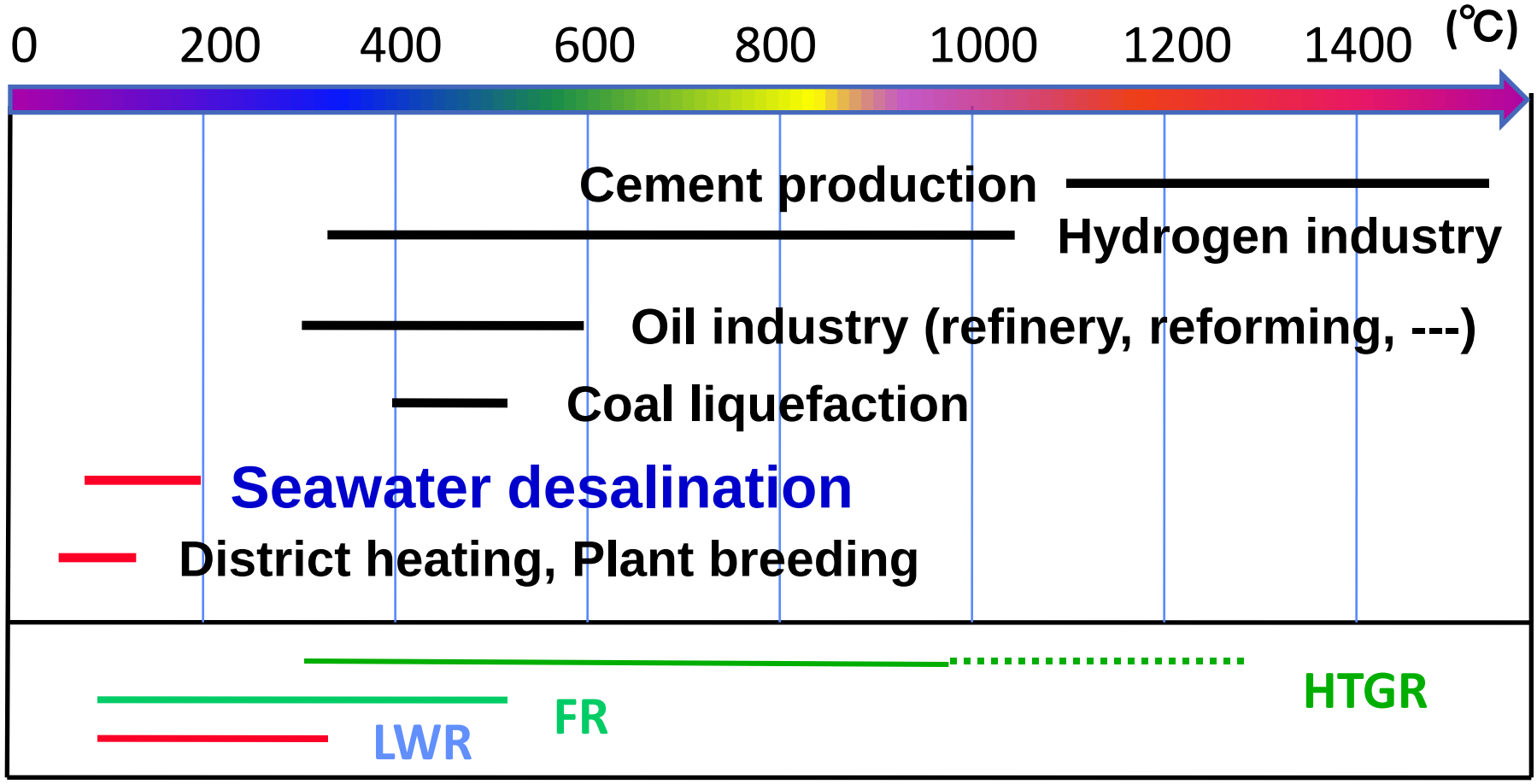
Nuclear heat for non-power products

--- Yes, we have experience.



(As of Spring 2009)

Nuclear heat temperatures and applications



Nuclear desalination at Aktau, Kazakhstan

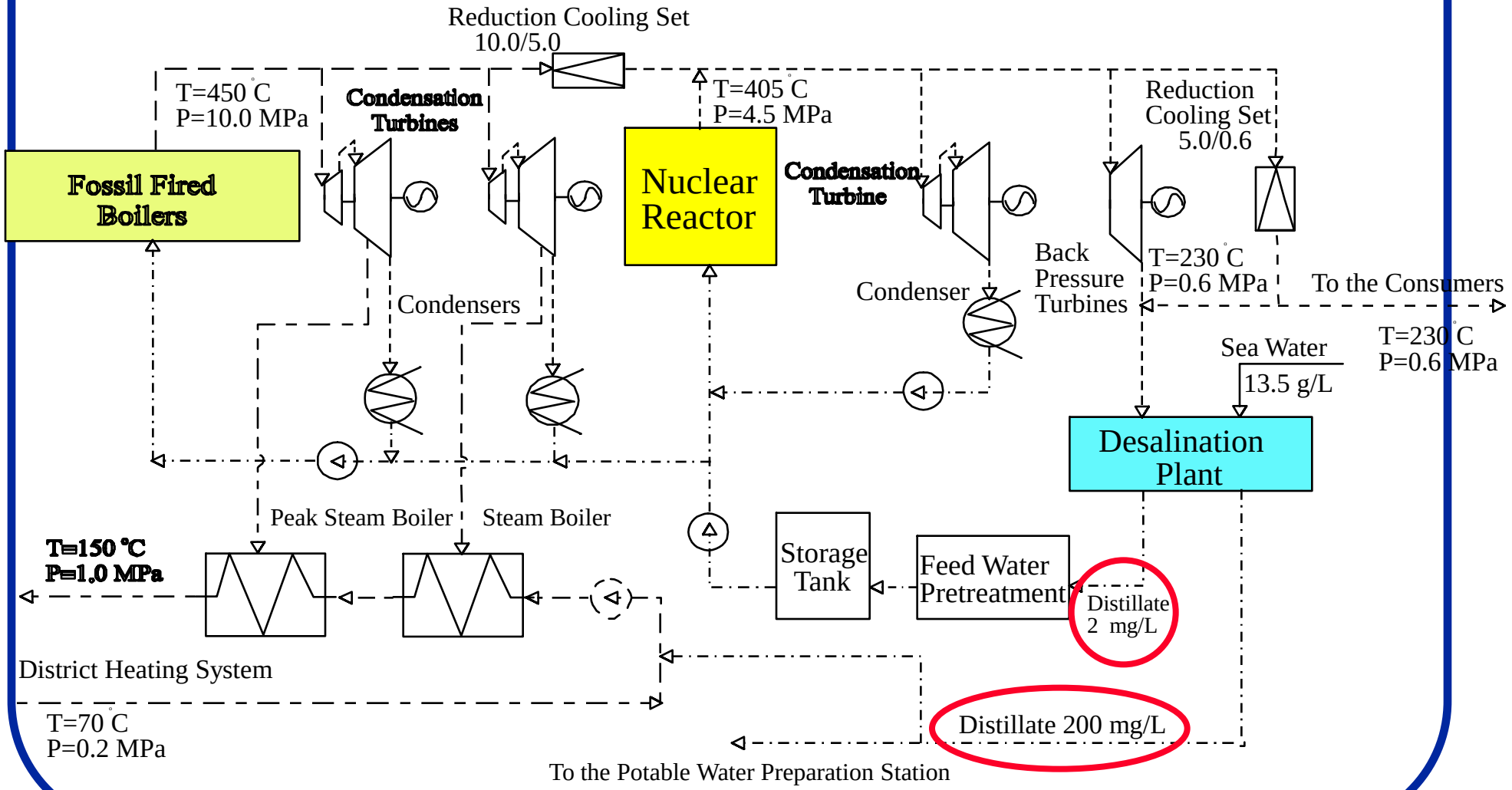
For in-plant water makeup, industries and citizens

Powered by BN350 (FBR) and a thermal boiler

Water source from the Caspian Sea

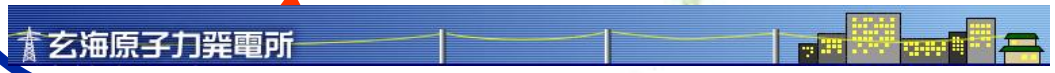
80,000 m^3/d MED

Flow diagram at Aktau

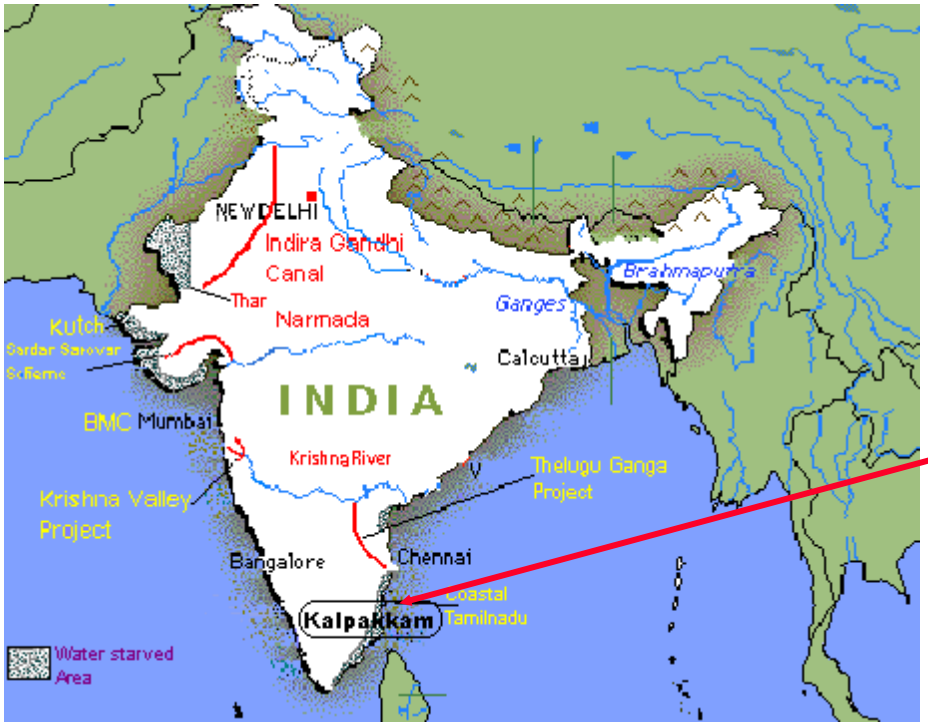


Nuclear Desalination in Japan

- *PWR: 8 units at Ohi, Takahama, Genkai and ikata in service*
- *BWR: K-K (dismantled)*
- *All for in-plant use (1000-2000m³/d/unit)*



Commissioning at Kalpakkam, India



PHWR(170MWe)

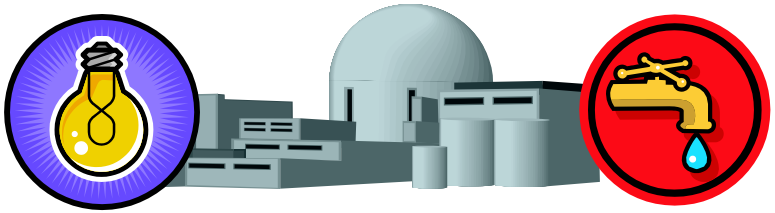
+ 1800 m³/d RO
+ 4500 m³/d MSF

Nuclear reactors for desalination

- *Experienced, Existing*
  - *FBR, PWR, BWR, PHWR*
- *Being planned/considered*
  - *Small PWR (Korea, Russia)*
  - *Heat-only (Russia, China)*
  - *HTGR (South Africa, France)*

→ ***Basically any type is technically feasible***

4. What is being done at the IAEA and worldwide?



Nuclear desalination is ---

Production of fresh water from seawater (or brackish water) in an integrated facility in which a nuclear reactor provides the energy source for the desalination process.

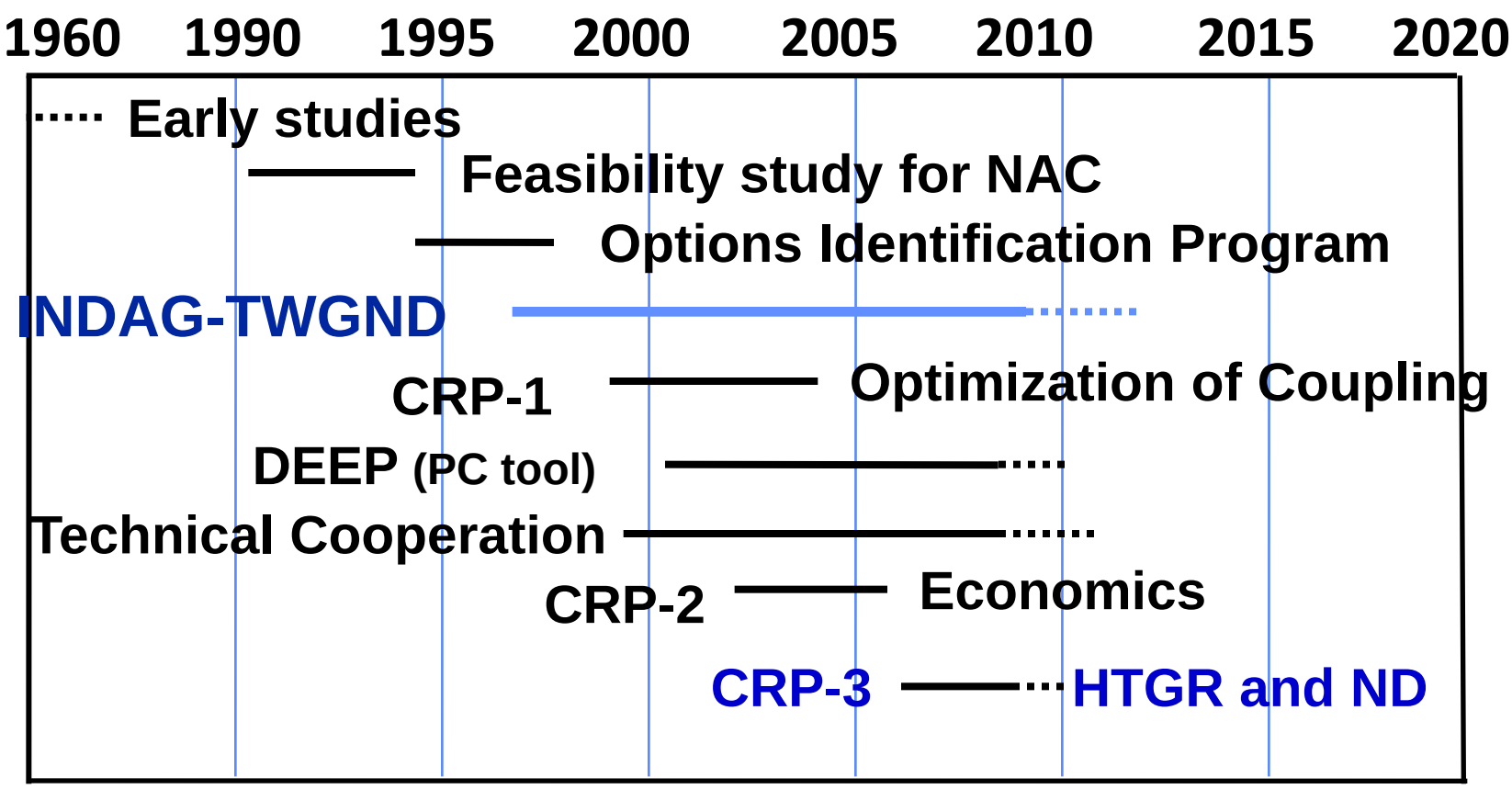
(*IAEA* Guidebook: TRS400)

Why nuclear desalination?

- ***Heat and electricity*** ***produced by nuclear plants are ideal for energy-intensive desalination processes.***
- ***"Clean"*** ***energy and minimal waste.***
- ***Successful operation*** ***has proved technical feasibility and reliability (Kazakhstan, Japan, now India).***
- ***Economically competitive*** ***with conventional co-production plants.***

(1) History and outcomes of IAEA activities

http://www.iaea.org/NuclearPower/Desalination/



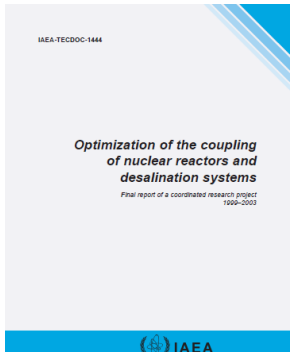
IAEA activities in brief …

- *FS for North African Countries, TecDoc-917*
  - Specific local conditions considered
  - Specific studies suggested
  - TecDoc 917 issued
- *Options Identification Programme*
  - TecDoc 898 issued
- *INDAG, now reformed to a TWG-ND*
  - Standing FORUM on nuclear desalination
  - Most Member States interested
  - Review and recommendation of IAEA and MS activities

IAEA (Scientific Secretary), i.khamis@iaea.org

… IAEA activities in brief

- ***CRP: Coordinated Research Projects***
  - ***CRP-1 "Optimization of Coupling"***
  - ***CRP-2 "Economics"***
  - ***CRP-3 "HTR and nuclear desalination"***
- ***Interregional/National TC Projects***
  - ***Country-specific feasibility evaluation***
- ***DEEP: Economic assessment, Manual No. 19***
  - ***A PC-based spreadsheet program***
  - ***Continually upgraded, users' group***



(2) Outcomes from IAEA activities …

Design requirements/considerations for Nuclear Desalination

- ***Basically any type is technically feasible***
- ***Practically PWR and PHWR in the SMR range are of higher interest, recent interest in HTGR***

- ***Design requirements of SMRs in general***
- ***Design requirements for coupling***
- ***Design considerations for water plants***

Design requirements of SMRs

- *Proven and standardized design*
- *Simplification and standardization (operation, maintenance, regulatory requirements, practices of construction, safeguarding)*
- *Factory-fabricated modular systems*
- *Proximity to the loads*

- *Operation flexibility in grids with limited capacity (frequency, voltage, load following, etc.)*
- *Longer grace period*

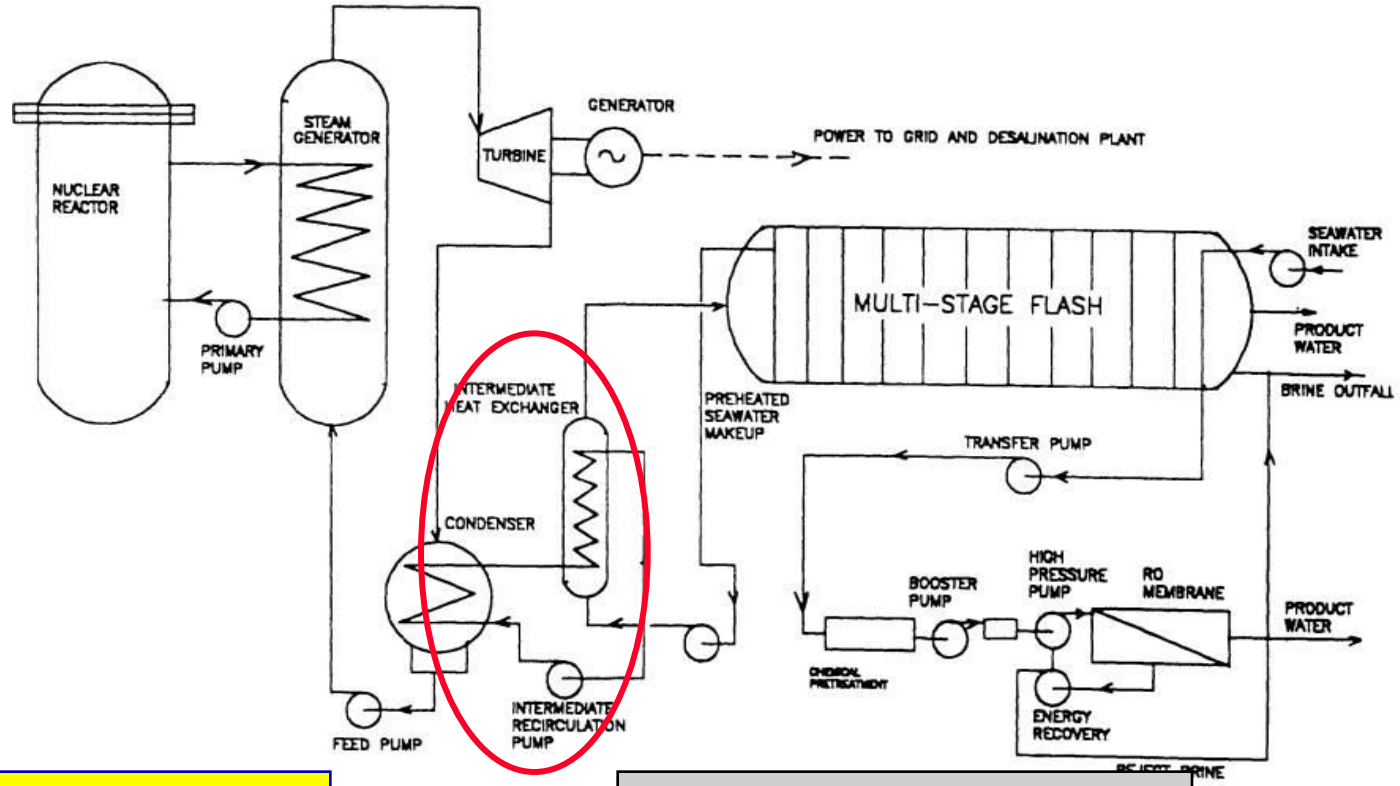
Design requirements for coupling

- *No carry-over of radioactivity to product water*
- *Distance between water intake/discharge lines*
- *Limited dynamic impacts due to water plant steam consumption variation (heat sink)*
- *Operational flexibility --- PWR variation of NPP, DP isolation for refurbishing/maintenance*

  (PWR: Power-to-Water Ratio, DP: Desalination Plant)
- *Construction flexibility --- shorter construction of DP*

Interface between NPP and DP (MSF+RO)

(intermediate loop as a barrier)



Nuclear grade

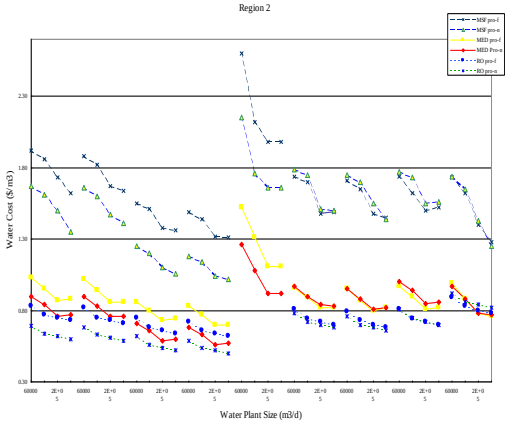
Non-nuclear grade

Design considerations for water plants

- *Proximity to consumers (residential areas)*
- *Topographical site conditions (limited undulation)*
- *Oceanographic conditions (salinity, turbidity)*
- *Waste heat utilization for higher RO efficiency*
- *Brine discharge (seabed topography)*
- *Back-up heat source for thermal processes*

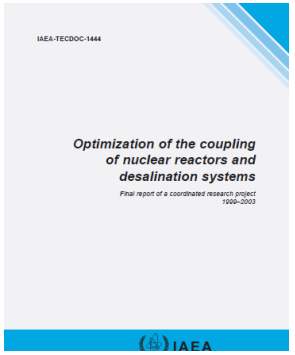
Main findings in economic study (DEEP)

- ***Nuclear power for desalination can be competitive with fossil-fueled energy sources***
- ***MSF costs higher than RO or MED***
- ***RO and MED costs are comparable***
  In genera US$0.5-0.9 /m3
- ***Costs higher with smaller reactors***
- ***Heat only reactors need special incentives***



Outreach of IAEA activities

- ***Symposium (1997), Conference (2007)***
- ***Technical Meetings***
- ***INDAG, now TWG-ND***
- ***Publications, mostly downloadable***
  - ***Guidebook (TRS400)***
  - ***TecDocs (Safety 1235, Status 1524…)***
  - ***Newsletters (NENP, INDAG)***



www.iaea.org/NuclearPower/Desalination/

Summarizing,

- ***Seawater desalination has been proven***
- ***Nuclear reactors can provide energy for desalination***
- ***We have technical experience in nuclear desalination***

Q2: Why, then, is nuclear desalination not widely deployed?

5. What issues do we have ahead?

On-going activities in Member States …

- ***China --- 4 projects foreseen, NPP/NHR connecting SWRO/LTMED, 15,000 to max.330,000m³/d***
- ***Egypt --- Planned for El-Dabaa, R&D on pre-heat RO***
- ***France --- FS with other countries***
- ***India --- Kalpakkam, CIRUS***
- ***Japan --- 8 units in good service***

… On-going activities in Member States

- ***ROK --- Co-generating SMART***
- ***Pakistan --- commissioning***

  1,600m³/d MED at KANUPP

- ***Russia --- A barge-mounted FNPP for co-generation being constructed, operation expected in 2010***
- ***Argentina, Indonesia, South Africa, Morocco, USA, Yemen, Libya, GCC countries, Tunisia --- country- specific studies***

(INDAG Newsletter, IAEA Conference in O-arai)

Q3: What issues do we have ahead?

- ***To demonstrate viability in user countries.***

What we have experienced are:

Where nuclear reactors are technically and institutionally feasible (competitive),

and

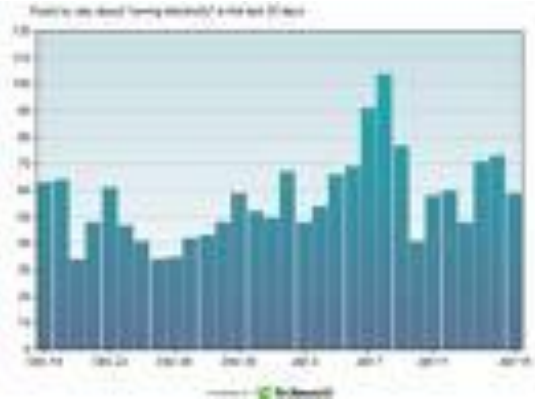
Where fresh water is needed on the coastal line.

Nuclear desalination can be an option.

Challenges to developing countries for demonstrating viability

- *Economic feasibility under local conditions*
- *Infrastructure and capacity building*
  - *Nuclear and conventional industry*
  - *Financing, Siting feasibility*
  - *Legislative and regulatory framework*
- *Firm energy policy and commitment*
- *Commitments to international nuclear conventions*
- *Public awareness of nuclear energy, not water*
- *Incentives for international assistance*

Energy, Water and Sustainability



Nuclear technologies can contribute to the solution of global water issues

Challenge for success, thank you, Konishi