



Towards Efficient Water Management in Nuclear Power Plants

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Department Nuclear Energy



Overview

- Introduction
- Water needs for NPPs
- Strategies for Water Management in NPPs
- IAEA Support





The Water Crisis

844 M | **2.3 B** | **2 min** |

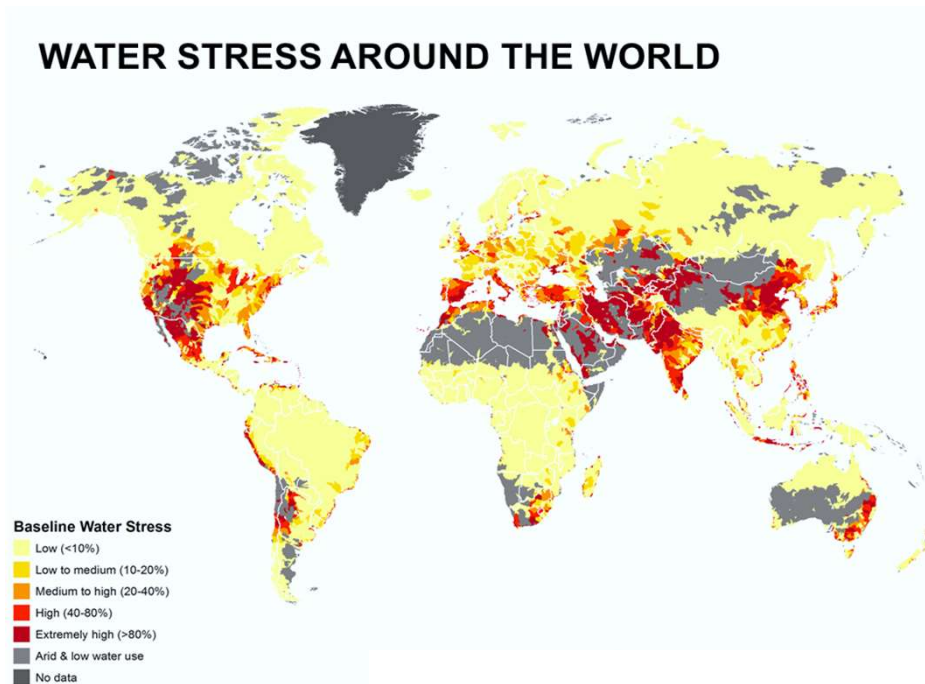
844 Million People living without access to safe water
(**1 in 9** people lack access to safe water)

2.3 Billion People living without access to improved sanitation
(**1 in 3** people lack access to a toilet)

2 min: every 2 minutes a child dies from a water-related disease

The Water Crisis

Middle East, which is already the least water-secured region in the world, would face exceptional water-related challenges for the foreseeable future



Top Water-Stressed Countries by 2040

Name	Score
Bahrain	5.00
Kuwait	5.00
Qatar	5.00
San Marino	5.00
Singapore	5.00
UAE	5.00
Palestine	5.00
Israel	5.00
Saudi Arabia	4.99
Oman	4.97
Lebanon	4.97
Kyrgyzstan	4.93
Iran	4.91
Jordan	4.86
Libya	4.77
Yemen	4.74
Macedonia	4.70
Azerbaijan	4.69
Morocco	4.68
Kazakhstan	4.66
Iraq	4.66
Armenia	4.60
Pakistan	4.48
Chile	4.45
Syria	4.44
Turkmenistan	4.30
Turkey	4.27
Greece	4.23
Uzbekistan	4.19
Algeria	4.17
Afghanistan	4.12
Spain	4.07
Tunisia	4.06

Bahrain

Kuwait

Qatar

UAE

Palestine

Saudi

Oman

Lebanon

Jordan

Libya

Yemen

Morocco

Iraq

Syria

Algeria

Tunisia

Countries already

operating/**constructing**/**considering**
nuclear power plants (NPPs)



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Water needs for NPPs

NPP with once-through cooling requires **water withdrawal** of **1.25 – 3.0** times that of a Fossil-based Power Plant*.

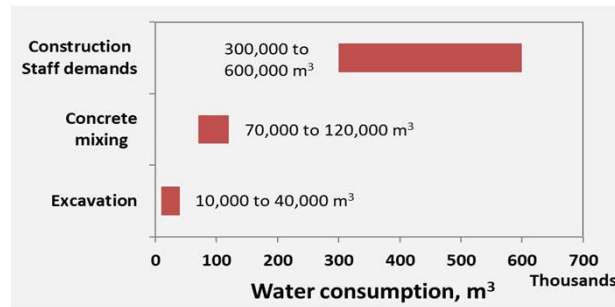
NPP with cooling tower or cooling pond **consumes** more than **Double** the water consumed by comparable fossil-based Power Plant*.

* of same capacity

Water needs for NPPs



Water consumption during 4- 5 years of NPP construction period



water consumption is mainly for cleaning and flushing and initial filling for the plants operating circuits. 20,000 to 30,000 m³ used during commissioning, in addition an average of 300 m³ per day for the staff use.



Reactor cooling is no longer required.

water is required for:

- spent fuel cooling,
- decommissioning of other industrial facilities,
- dust control.

Water needs for operating NPPs

WATER FLOW RATES IN CLOSED LOOP FOR A 1000 MW(e) NPP	Turbine condenser cooling (m ³ /s)	Supporting systems cooling (m ³ /s)
Recirculating cooling water	46	1.2
Evaporation losses	0.63	0.016
Blow-down losses	0.4	0.011
Make up water to compensate losses	1.03	0.027



More than 90 000 m³/d

Cover the needs of 150,000 – 1,500,000 people

Approximate Flow Requirements for NPPs

**For once-through cooling of typical
1000 MWe NPP:**

- **30 m³/sec or 476,500 gpm (for 30 ΔT)**
- **45 m³/sec or 714,750 gpm (for 20 ΔT)**

- **flow, gpm = 14,295 x MWe / ΔT**



Water needs for NPPs

Ultimate Heat Sink



- Range depends on design & Rated power: **4000 – 15000 m³**
- Provide all of the nuclear power reactor's cooling water and makeup water needs for the first 30 days of an accident as a minimum.

Strategies for Watering (NPPs)

Use of Desalination

Construction:

- (RO: potable water)

Operation:

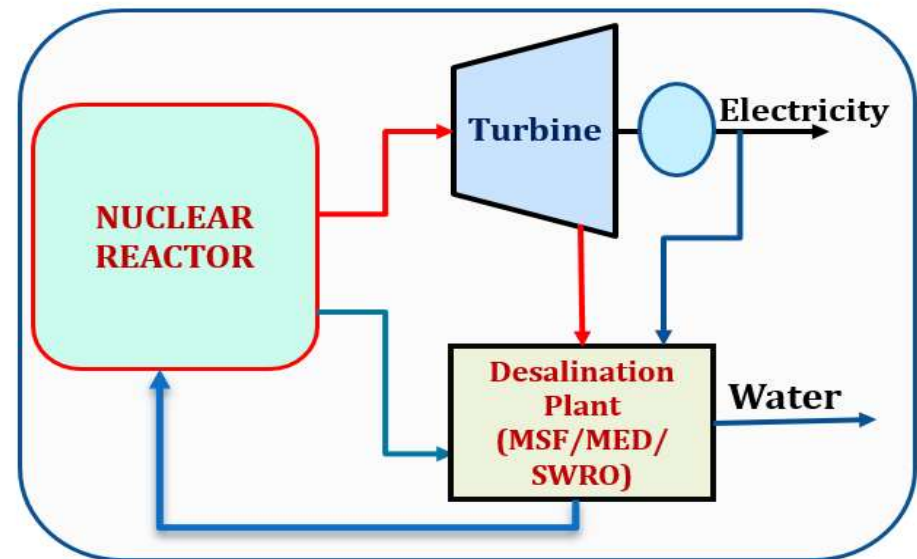
- (Hybrid: RO + MED/MSF:makeup)

Accident /Emergency:

- (RO: decontamination)

Shared Resources:

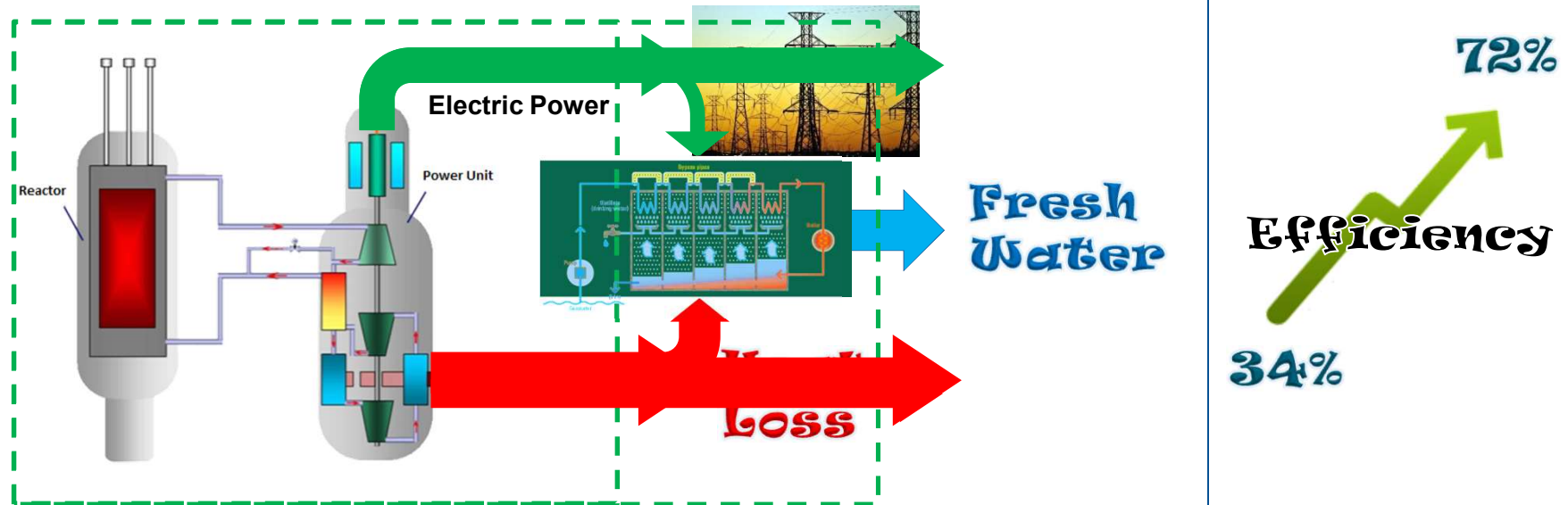
- (intake & outfall)



Strategies for Watering (NPPs)

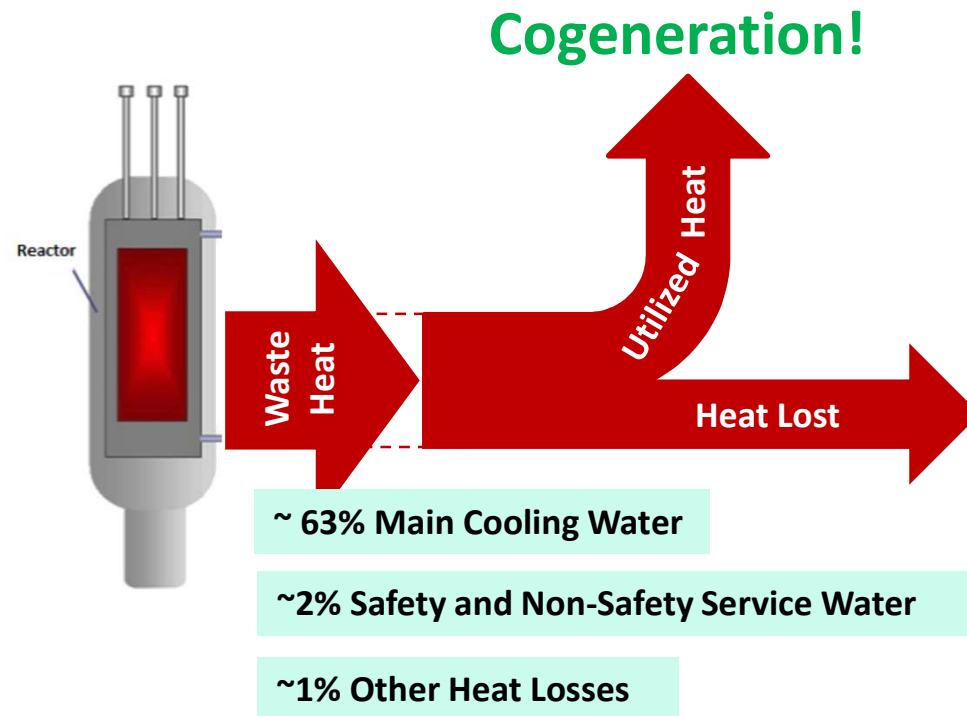
Use of Waste Heat from NPP: for Desalination

Waste heat: Heat extracted from NPP with no considerable penalty to the power production



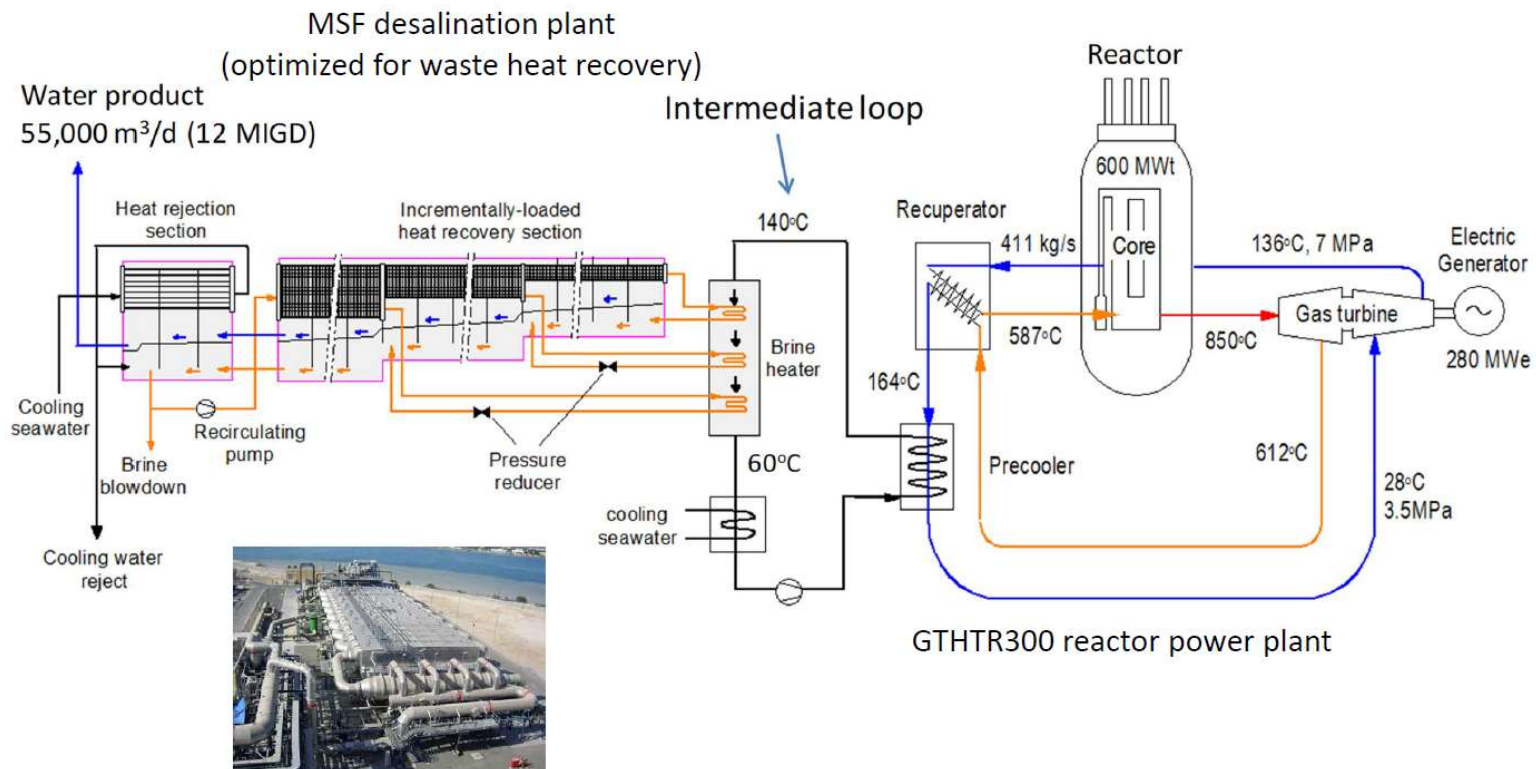
Strategies for Watering (NPPs)

Reduce Cooling Requirements: Harness the waste heat
(Think of zero-brine discharge)



Strategies for Watering (NPPs)

Use advanced technologies: High Temperature Reactors !!!



Strategies for Watering (NPPs)

Competitive cost for nuclear desalination using HTRs

Desalination costs between HTGR and fossil-fired CCGT

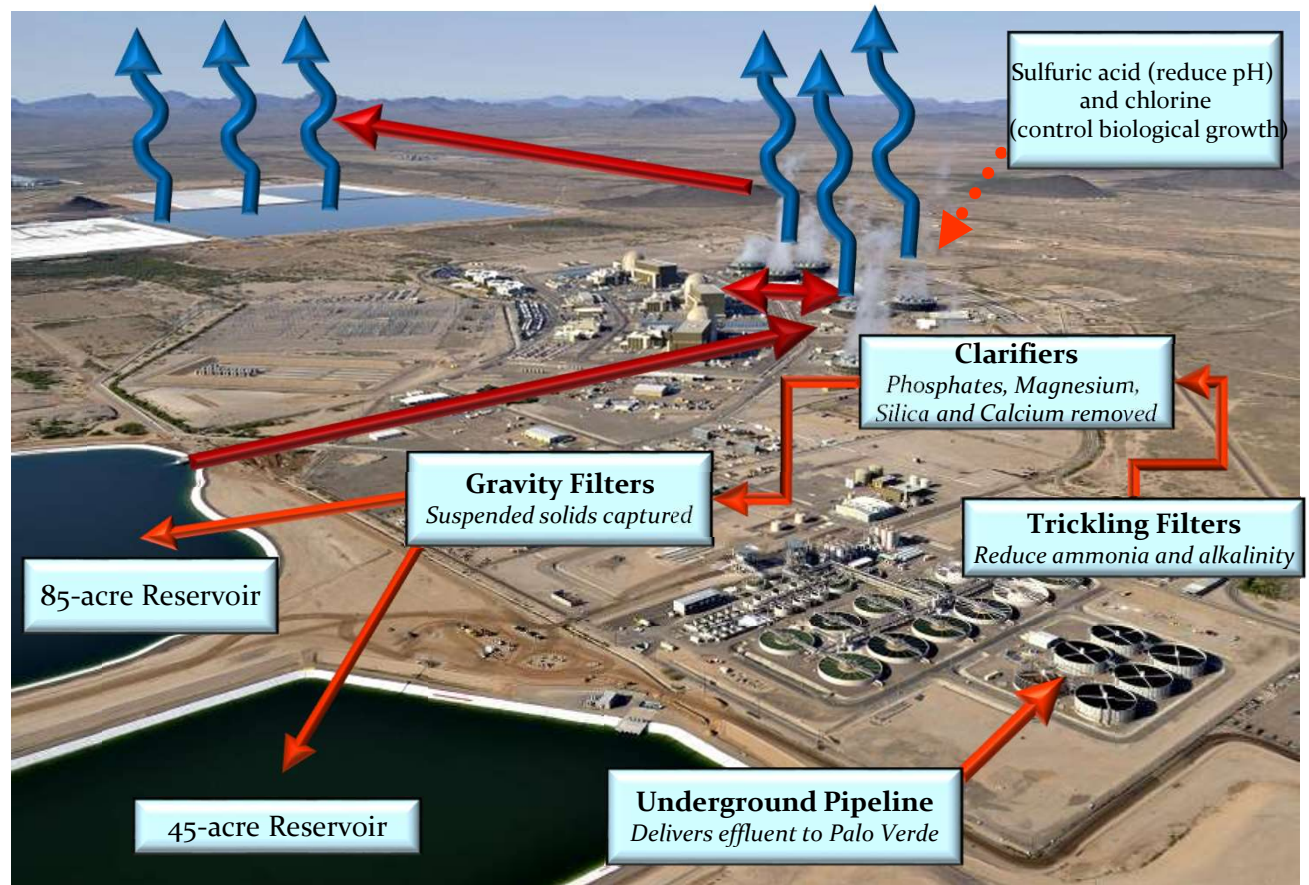
Plant ->	CCGT desalination plant		HTGR desalination plant
	Oil-fired**	Gas-fired**	
Capital (US\$/m ³)	0.29	0.29	0.39
Energy (US\$/m ³)			
Heat	1.65	0.67	0.04
Electricity	0.13	0.13	0.09
Operation (US\$/m ³)			
Consumables	0.02	0.02	0.02
O&M	0.03	0.03	0.03
Water cost (US\$/m³)	2.13	1.14	0.57

** Cost of fuel oil is 79.8 US\$/bbl, the minimum of the average of Brent, Dubai and WTI benchmarks during 2004.7 to 2014.7 and natural gas 5.6 US\$/MMBtu, the minimum of the average of US, Europe and Japan prices in the same period.

Strategies for Watering (NPPs)


Think of other Water Resources for NPPs!!!

WATER
RECLAMATION
FACILITY at Palo
Verde NPP (USA)



Upcoming IAEA Major event in 2019

International Conference on
**Climate Change and the
Role of Nuclear Power**
7–11 October 2019, Vienna, Austria



Organized by the
IAEA
International Atomic Energy Agency
Atoms for Peace and Development

#Atoms4Climate 08-275

iaea.org/Atoms4Climate



IAEA Nuclear Energy

Tweets	Following	Followers	Likes	Lists	Moments
5,280	313	5,130	258	1	0

Atoms4Climate@iaea.org



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Purpose/ scope:

To provide a forum on:

- ✓ the role of nuclear power,
- ✓ the opportunities and challenges of safe, secure and safeguarded nuclear technology development in supporting the low-carbon energy transformation needed to achieve the climate change goals.

The conference themes include a description of the mitigation challenge, implications for the power sector, environmental perspectives, and potential roles of existing, evolutionary and innovative nuclear power systems, including the integration of nuclear/renewable energy systems.

Email:

Atoms4Climate@iaea.org



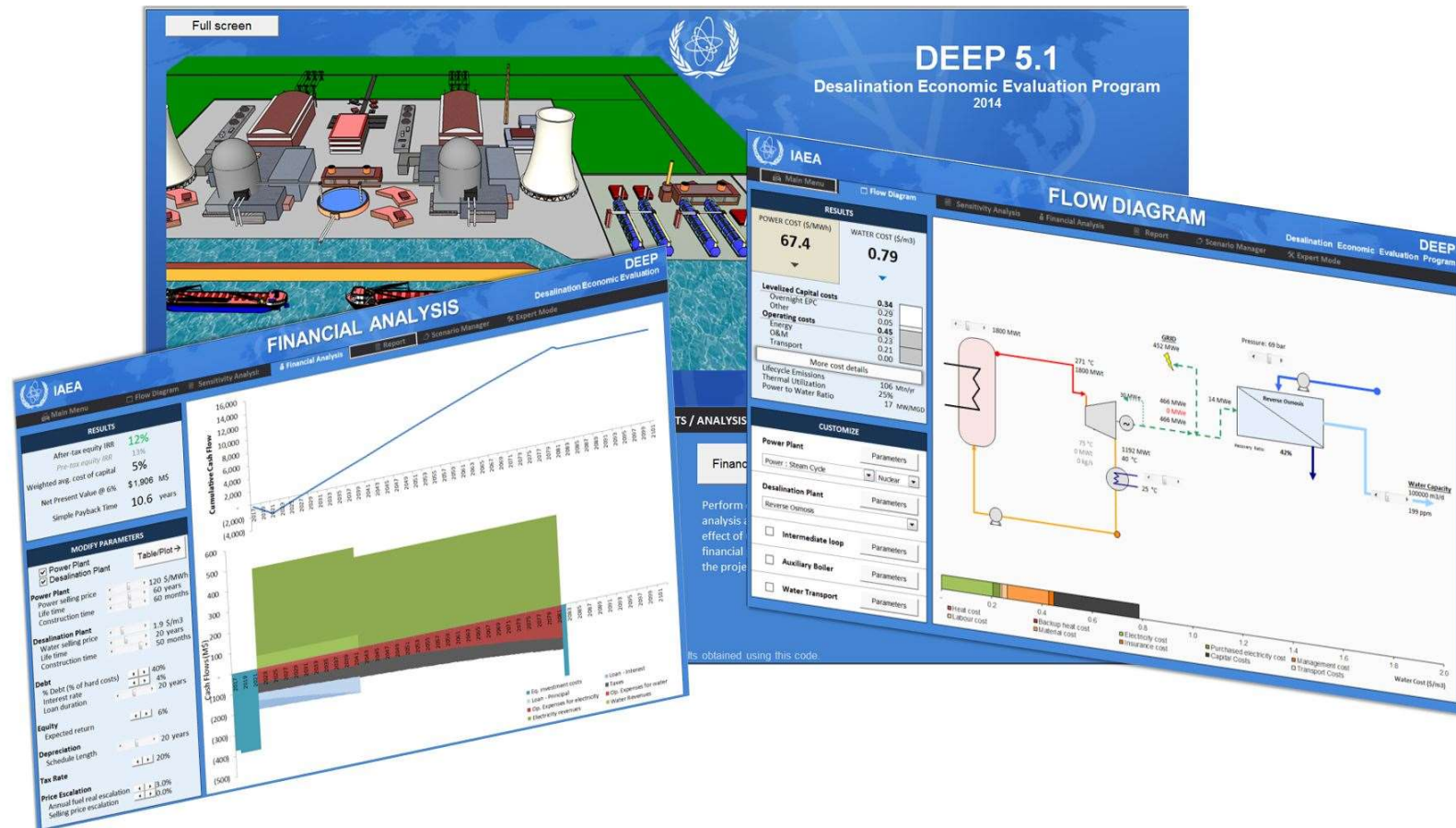
iaea.org/atoms4climate

Key deadlines:

- Submission of contributed papers, including Forms A and B, through official channels to the IAEA
28 April 2019
- Submission of Grant Application Form (Form C) through official channels
28 April 2019
- Deadline for exhibitor registration
31 May 2019
- Notification of acceptance of paper
26 June 2019

DEEP


performance and cost evaluation of various power and seawater desalination cogeneration configurations.



Desalination Economic Evaluation Programme

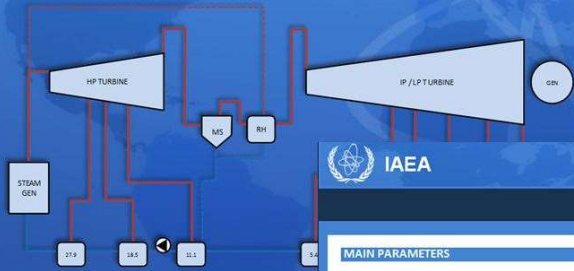
DE-TOP

models the steam power cycle of different WCRs coupled with nonelectrical applications



IAEA

DE-TOP
Desalination Thermodynamic Optimization Program



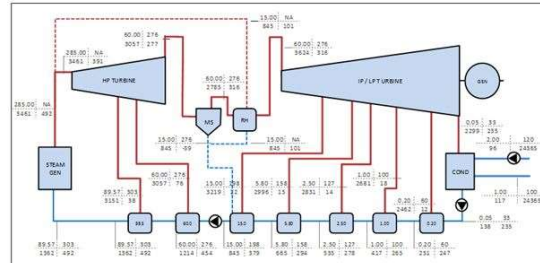
MAIN PARAMETERS	DUAL PURPOSE	SINGLE PURPOSE	
Gross Efficiency	49.9%	49.9%	%
Net Efficiency	47.4%	47.4%	%
THERMAL UTILIZATION	47.4%	47.4%	%
Heat rate	7,201	7,201	Btu/AWh
HEAT RATE	7,598	7,598	kJ/AWh

PLANT PERFORMANCE PARAMETERS	DUAL PURPOSE	SINGLE PURPOSE	
HEAT INPUT			
Heat input steam generator	1,032,750	1,032,750	MW(th)
Heat input reheater (Nuclear)	265	265	MW(th)
Heat input reheater (fossil)	-	-	MW(th)
GROSS POWER OUTPUT	515.1	515.1	MW(e)
High pressure turbine output	154.2	154.2	MW
Low pressure turbine output	371.4	371.4	MW
Total Mechanical Output	525.6	525.6	MW
AUXILIARY LOADS	25.8	25.8	MW(e)
Feedwater pump	12.1	12.1	
Condensate water pump	0.4	0.4	
Cooling water pump	2.9	2.9	
Other auxiliary loads	10.4	10.4	
NET OUTPUT	489.3	489.3	MW(e)
HEAT REJECTED CONDENSER	507	507	MW(th)

MASS BALANCE	DUAL PURPOSE	SINGLE PURPOSE	
LIVE STEAM FLOW	491.9	491.9	kg/s
Live steam to reheater	101.4	101.4	kg/s
Steam inlet to High Pressure Turbine	390.6	390.6	kg/s
High Pressure turbine exhaust	277.2	277.2	kg/s
Moisture separator condensate	(39.0)	(39.0)	kg/s
Steam inlet to Low Pressure turbine	316.2	316.2	kg/s
Low Pressure turbine exhaust	234.7	234.7	kg/s

DE-TOP
Non-Electric Applications

Power plant simulation Coupling configuration Home



DESALINATION TECHNOLOGY	MED TVC	WATER PRODUCTION
Max brine Temperature	115 °C	0 m³/day
TDS	20 ppm	
GOR	51.2 [-]	
Number of Stages	32 [-]	
Cooling water temperature	23 °C	TOTAL POWER REQUIREMENTS
DESALINATION PLANT CONSUMPTION		6.1 MW(e)
Heat to desalination	- MW(th)	POWER LOST RATIO
Power lost due to extraction	- MW(e)	
Desal. electric cons.	- MW(e)	
Total specific cons.	6.12 KWh(e)/m ³	
INTERMEDIATE LOOP		#DIV/0!
IL hot temperature	125.5 °C	
IL condenser return temp	117.5 °C	
IL mass flow	- kg/s	
IL pumping power	- MW(e)	

Step 1
POWER PLANT

Define the power plant (fossil fuel power plants or water cooled reactors) from user values or predefined cases.

Define power plant

Step 2
NON ELECTRIC APPLICATIONS

Define the non electric applications (desalination, etc.) from user values or predefined cases.

Define Non-Electric Applications

Desalination Thermodynamic Optimization

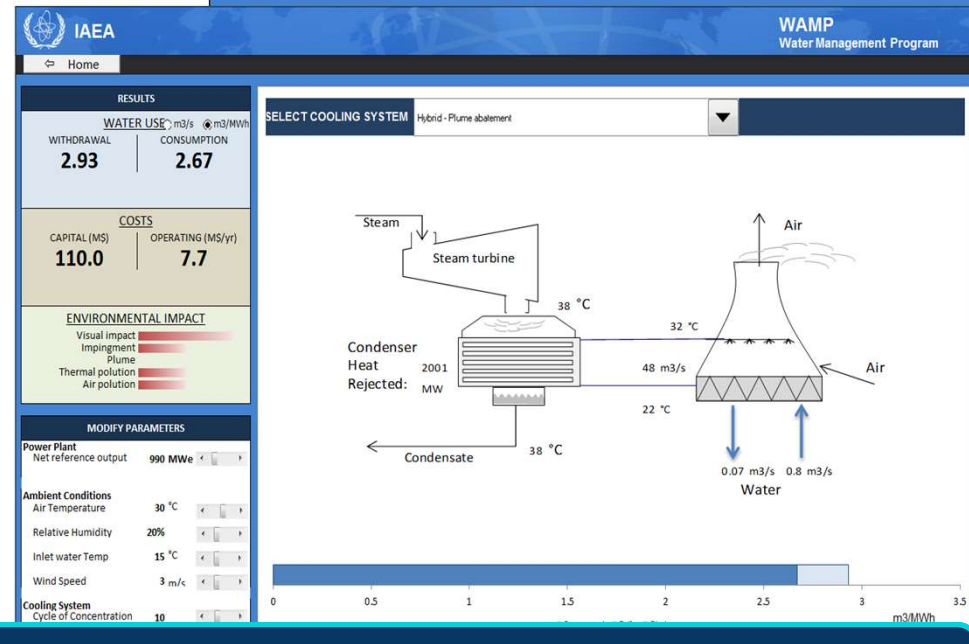
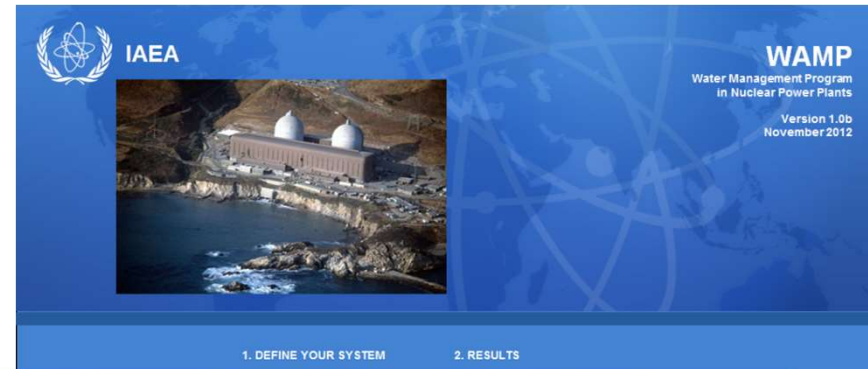
WAMP

Estimates water needs in NPPs especially for WCRs

WAMP helps in the selection of cooling systems by evaluating three different criteria: Water resources, environmental, economical.

WAMP estimates water needs in NPPs especially for water cooled nuclear power plants.

WAMP estimates both the needs for cooling water and other essential systems.



Water Management Program

IAEA

Guide

Generic Guidance on
Cogeneration Options

To be Published in 2019



NES

IAEA Nuclear Energy Series

Industrial
applications of
nuclear energy

Published in 2017



Publications

NES

IAEA Nuclear Energy Series

Opportunities for
cogeneration with
nuclear energy

Published in 2017

IAEA Nuclear Energy Series

No. NP-T-2.6

Efficient Water
Management in Water
Cooled Reactors

Published in 2012

International Atomic Energy Agency

TECDOC

Examining the Techno-
Economics of Nuclear
Hydrogen Production and
Benchmark Analysis of
the IAEA HEEP Software

Published in 2018

