The Non-Electric Application of Nuclear Energy through the utilization of waste heat from existing NPPs by Heat Pumps on Carbon Dioxide

INPRO Dialogue Forum on Opportunities and Issues in Non-Electric Applications of Nuclear Energy (16th INPRO Dialogue Forum)

IAEA, Melia Vienna Hotel (DC Tower)

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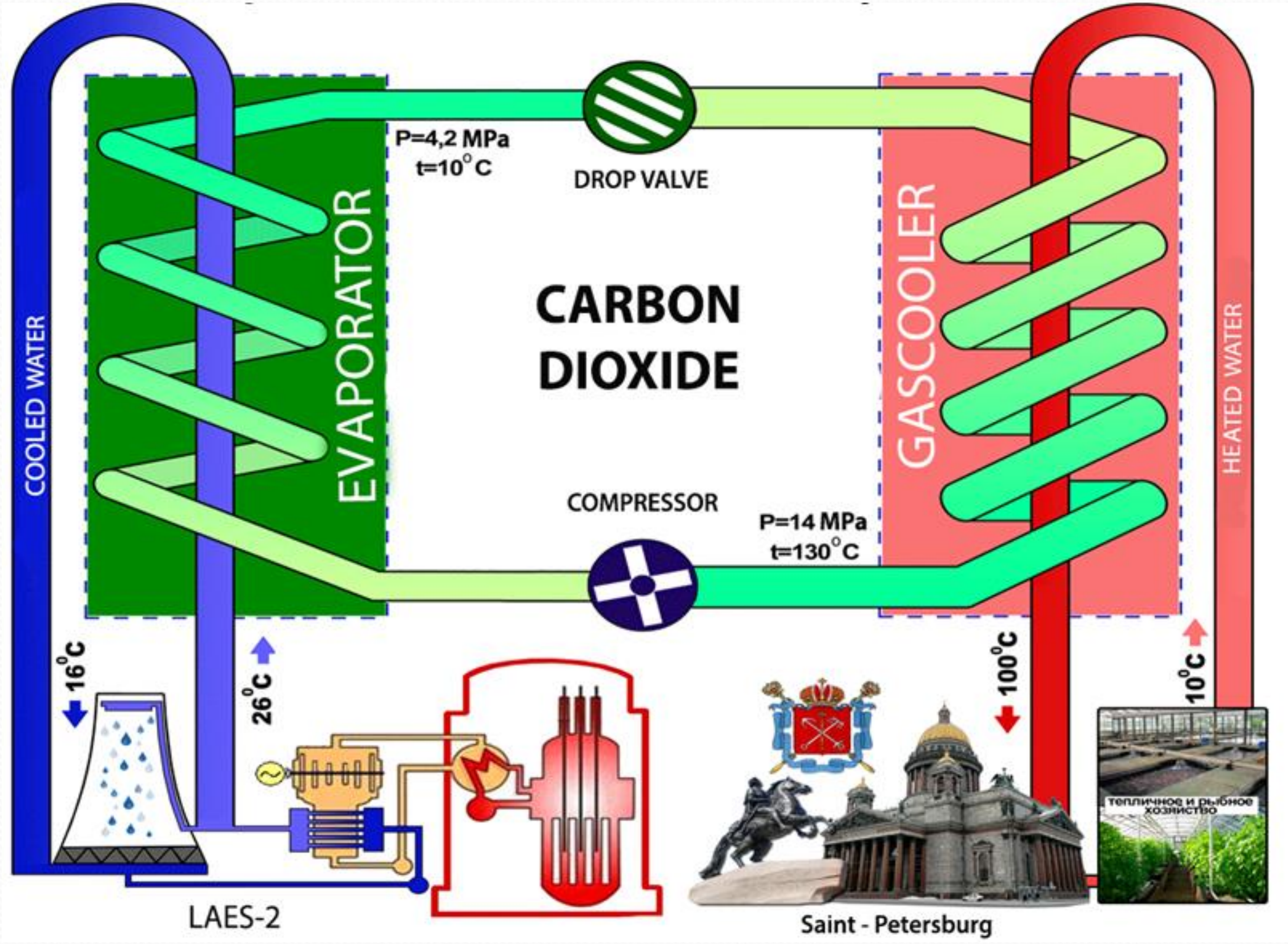
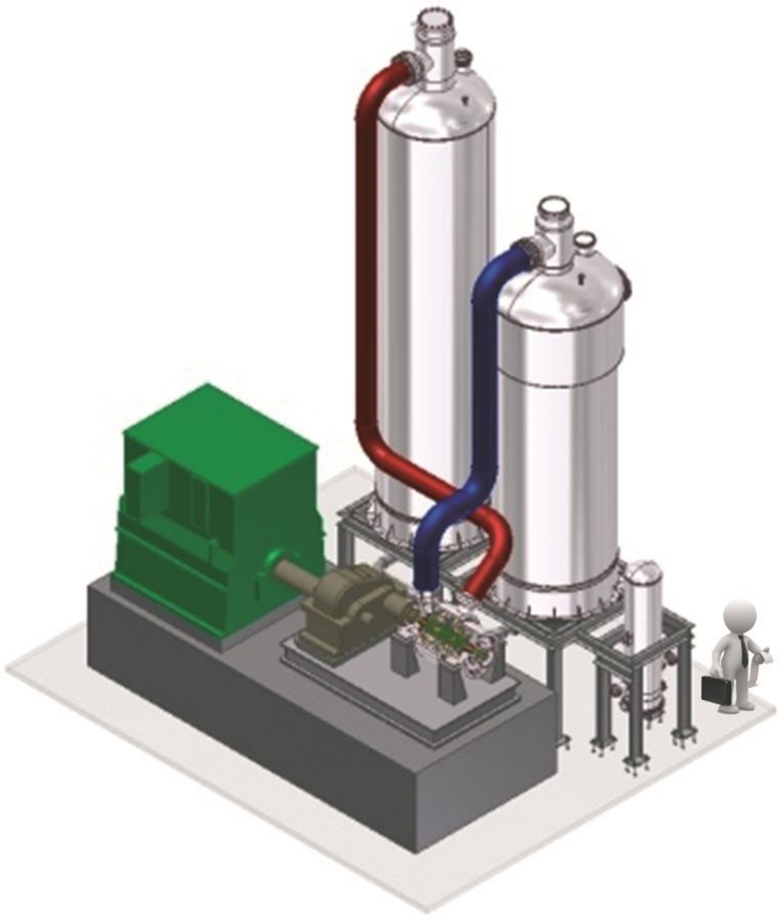
NPP-HPS Technology

Technology of Heat Pump Systems & Nuclear Power Plants (NPP-HPS) is based on the transformation from low-grade waste heat from operating NPP (20 … 40˚C) to the high-grade heat (80 … 100˚C and more) with the help of heat pumps on carbon dioxide and transporting heat to the distance up to 100 km.

Principle scheme NPP-HPS for example LAES-2 & SPB



HP CO2 100 MW



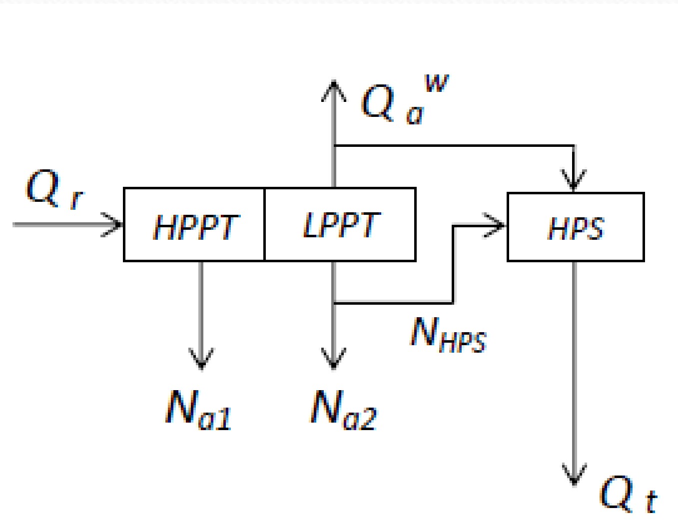
Heating Capacity	MW	100
Power Consumption	MW	25
Heating water temperatures (in/outlet)	°C	10/100
Cooling water temperatures (in/outlet)	°C	26/16
Dimensions L*W*H	meters	18.5x14x17.5
Weight	tons	270
Unit cost	$/kW	250

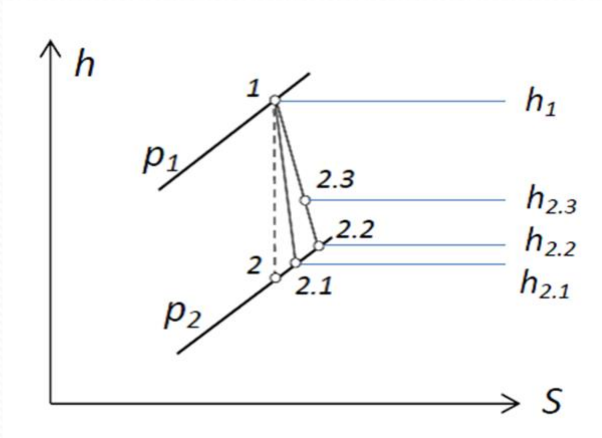
Heat Pumps Parameters

Parameters	Freon	CO_2
Thermodynamic cycle	vapor-liquid	gas-liquid
Maximum heating water temperatures, °C	not more 80	80-100 and more
Maximum heating capacity, MW	not more 30	20-100 and more
Coefficient of performance (COP)	3-4	4-5

Schemes of Low-temperature Nuclear Power Cogeneration

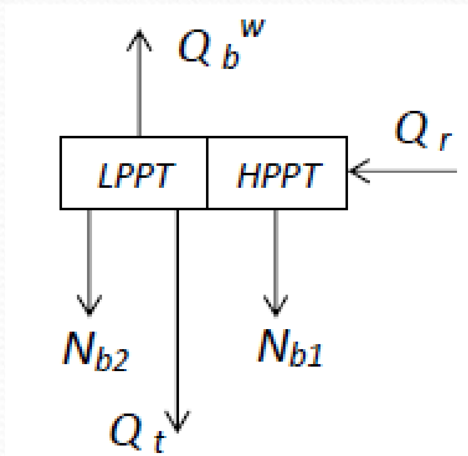
NPP-HPS





LPPT processes

CNPP



$$N_{a1} = N_{b1}$$

$$N_{a2} = (h_1 - h_{2.1}) \cdot G - N_{HPS}$$

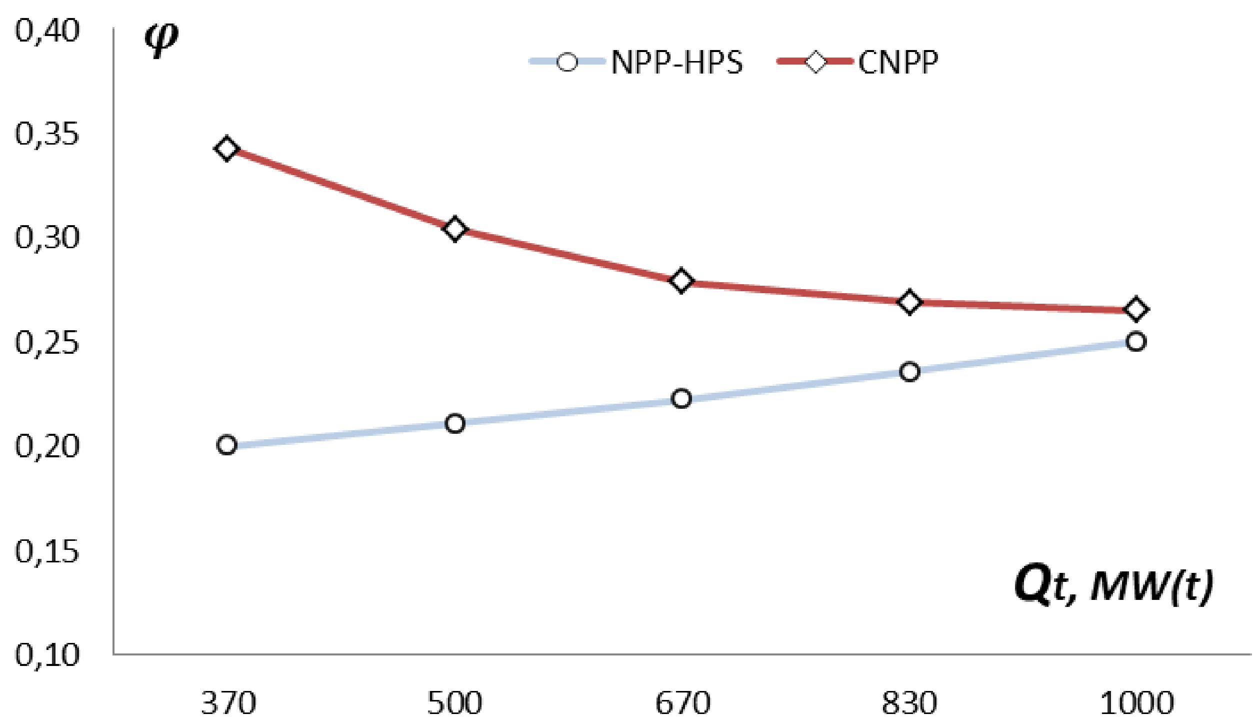
$$N_{HPS} = \frac{Q_t}{COP}$$

$$N_{b2} = (h_1 - h_{2.2}) \cdot G - \Delta N_2$$

$$\Delta N_1 = (h_{2.2} - h_{2.1}) \cdot G$$

$$\Delta N_2 = (h_{2.3} - h_{2.2}) \cdot G_t$$

Efficiency of Low-temperature Nuclear Power Cogeneration



$$\varphi_{NPP-HPS} = \frac{N_{HPS}}{Q_t}$$

$$\varphi_{CNPP} = \frac{\Delta N_1 + \Delta N_2}{Q_t}$$

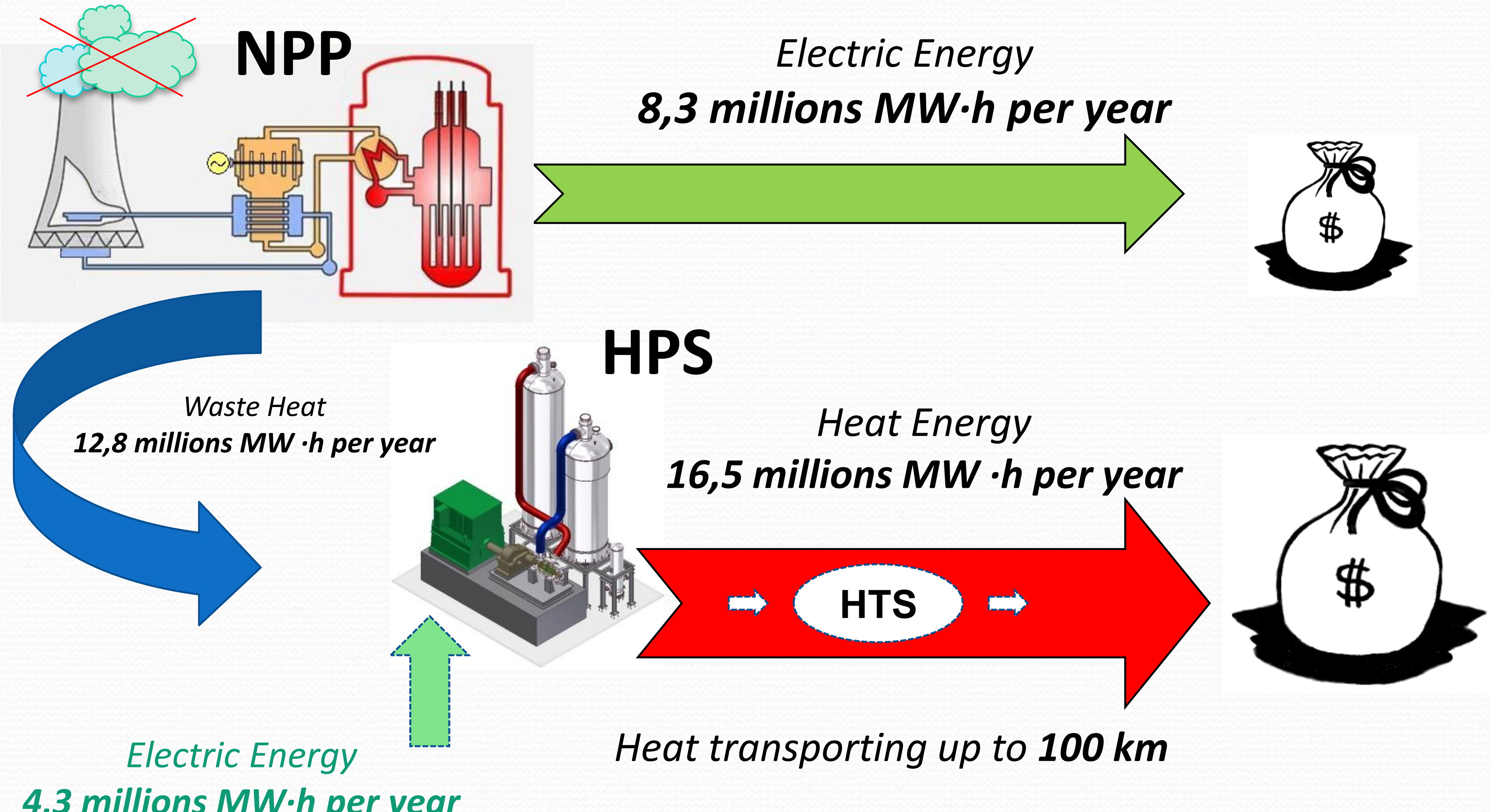
Nuclear Power Cogeneration on PWR-1200

Parameters	NPP-HPS	CNPP
NPP	operating	new project
Reactor plant power, MW(t)	3212	3212
Turbine	conventional	special
Installed electric capacity, MW(e)	1198,7	1130
Installed heating supply capacity, MW(t)	2500 (3200)	1000
Step-by-step introduction of heating supply capacity, MW(t)	100…2500 (3200)	1000

CNPP – cogeneration nuclear power plant
(…) – heat pump with gas drive of compressor

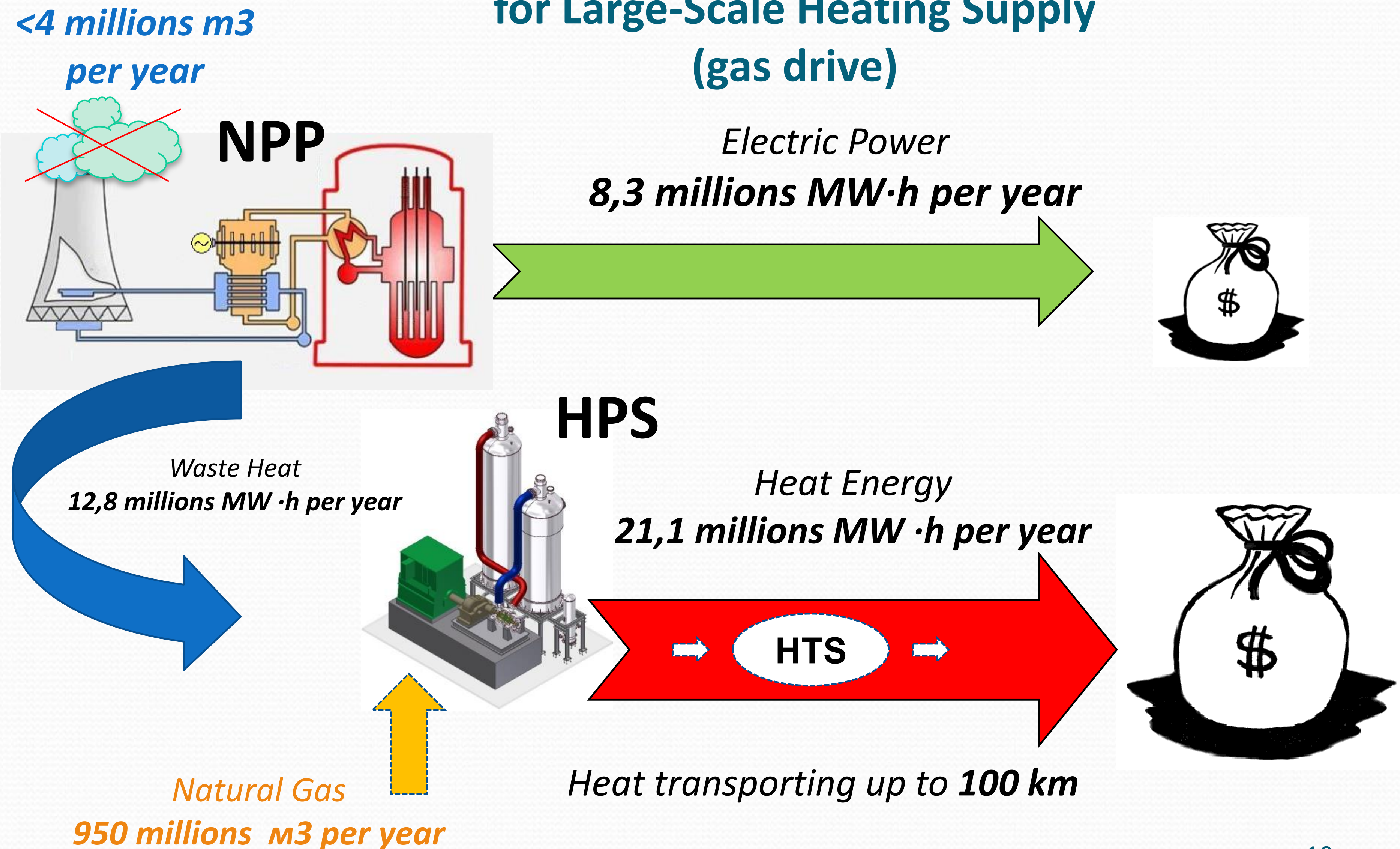
NPP-HPS on PWR-1200

for Large-Scale Heating Supply (electrically drive)



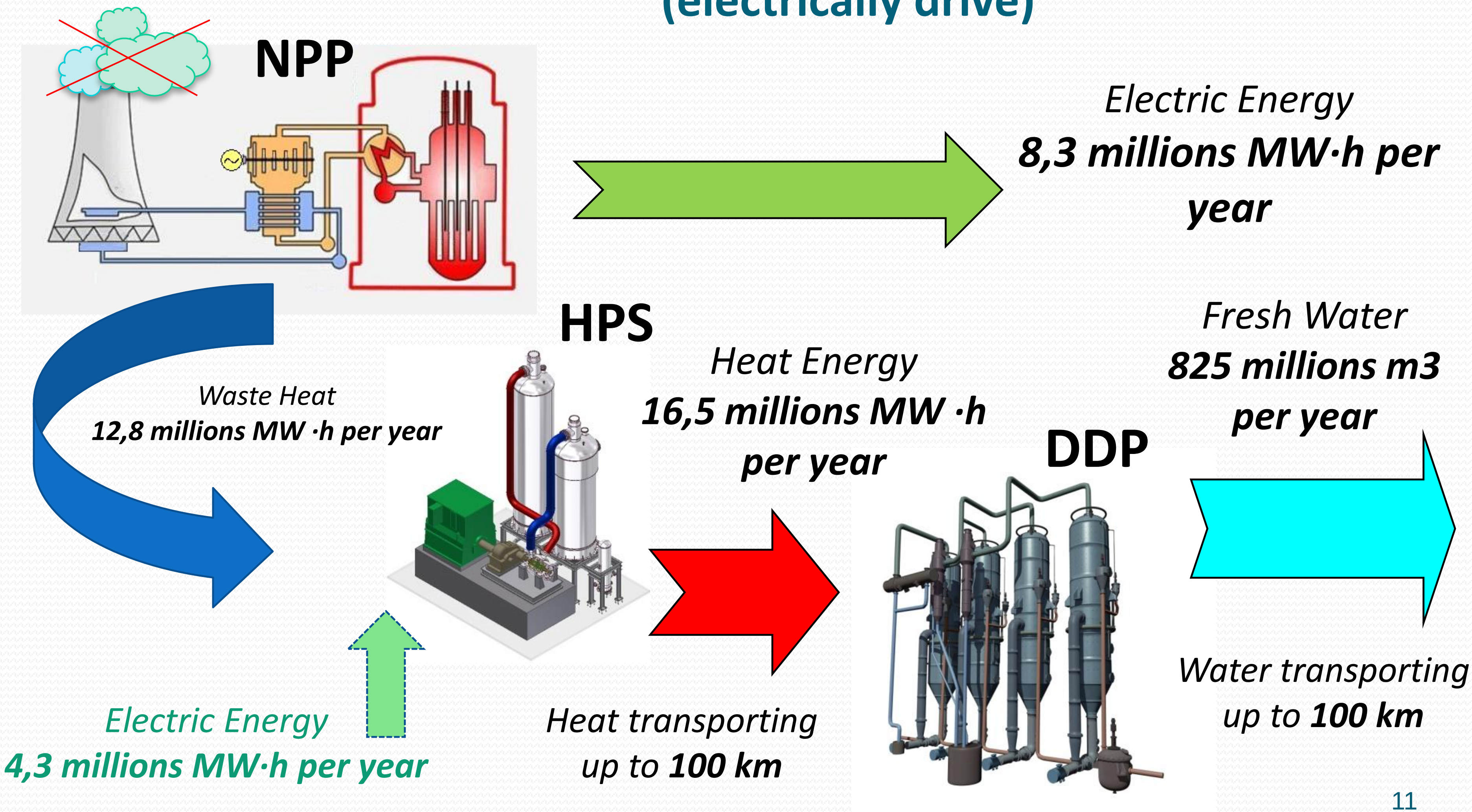
NPP-HPS on PWR-1200

for Large-Scale Heating Supply (gas drive)



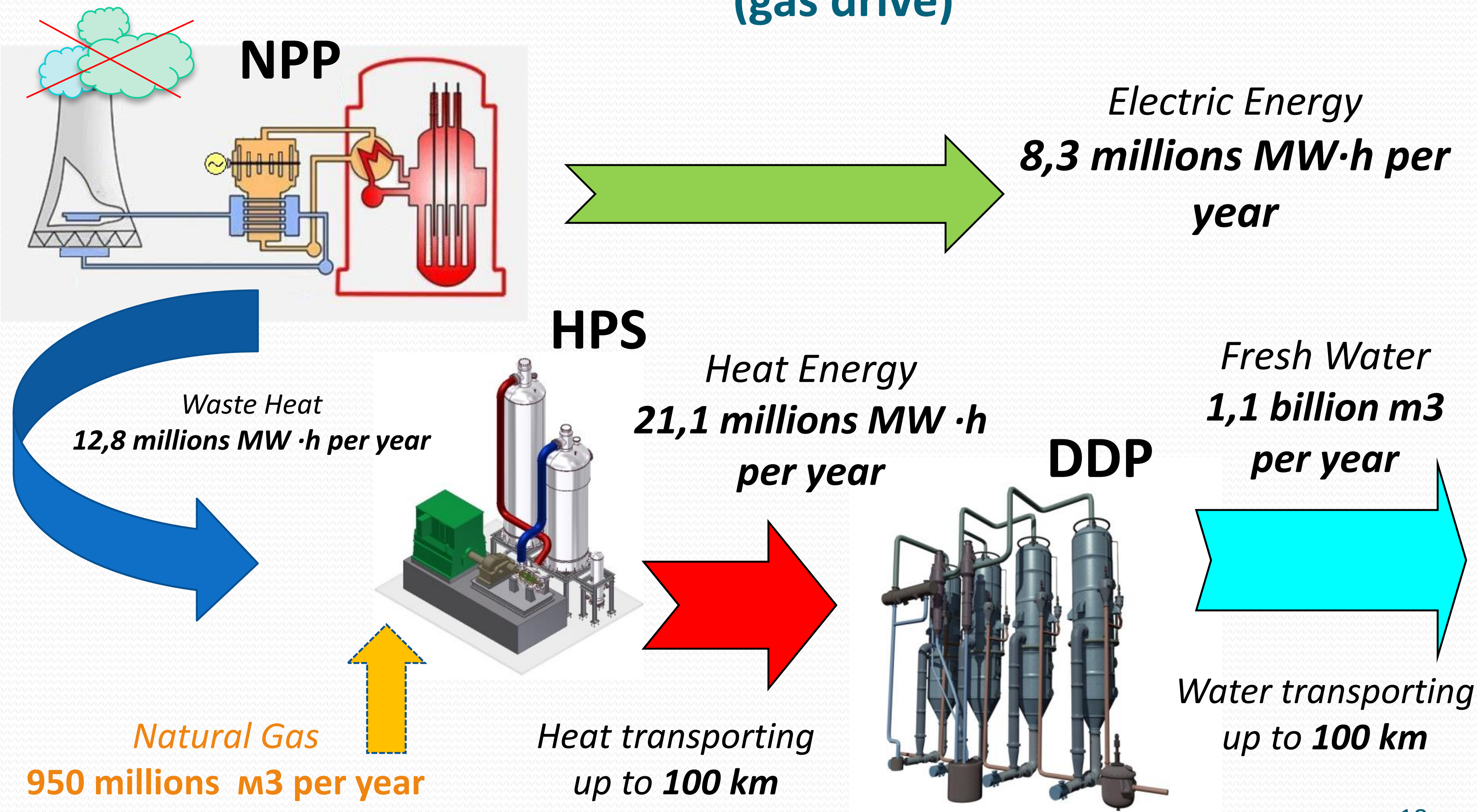
NPP-HPS on PWR-1200

for Distillation Desalination Plant (electrically drive)



NPP-HPS on PWR-1200

for Distillation Desalination Plant (gas drive)



Opportunities of Nuclear Power Cogeneration on PWR-1200

Applications	Measure unit	ED HP	GD HP
Large-scale Heating Supply	MW(t)	2500	3200
Distillation Desalination Plant	Billions tons of fresh water per year	0,8	1,1
Biocomplexes of closed ground	Millions tons of bioproducts per year	0,9	1,2

ED HP – heat pump with electrically drive of compressor;
GD HP – heat pump with gas drive of compressor

Conclusion

1. The NPP-HPS technology was supported in the framework of IAEA Technical meetings on non-electric applications of nuclear energy.
2. The introduction of NPP-HPS technology will increase the share of global nuclear energy from 5% to 10%, without taking into account the introduction of new NPP units, which corresponds to the basic provisions of INPRO.
3. The NPP-HPS technology allows to reduce greenhouse gas emissions, with a corresponding reduction in the consumption of atmospheric oxygen, which is consistent with international agreements of climate change mitigation.

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