CSP-DSW Workshop

WP4: Electricity generation

Steam turbine selection &
Interface conditions

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WP4: Electricity Generation

Objectives

EAC contribution to WP4

Work Package 4: Electricity Generation

Objectives :

To review the existing steam turbine technologies, select steam turbine size and type, identify steam turbine interfaces with other cycle components and determine power plant input and output conditions
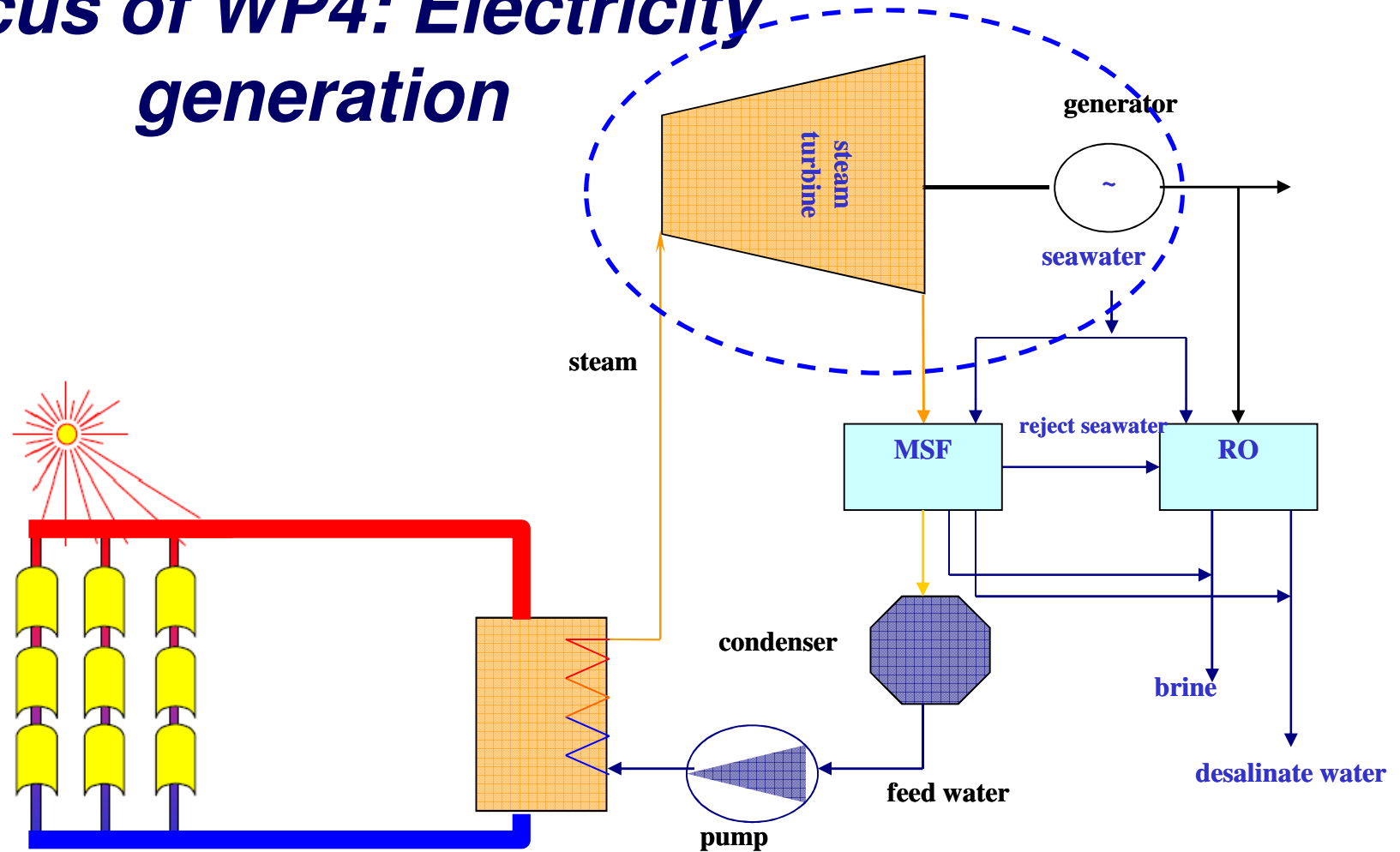
Tasks :

4.1 Review of existing steam turbine technologies

4.2 Selection and sizing of steam turbine

4.3 Power plant interfaces

4.4 Power plant input and output conditions
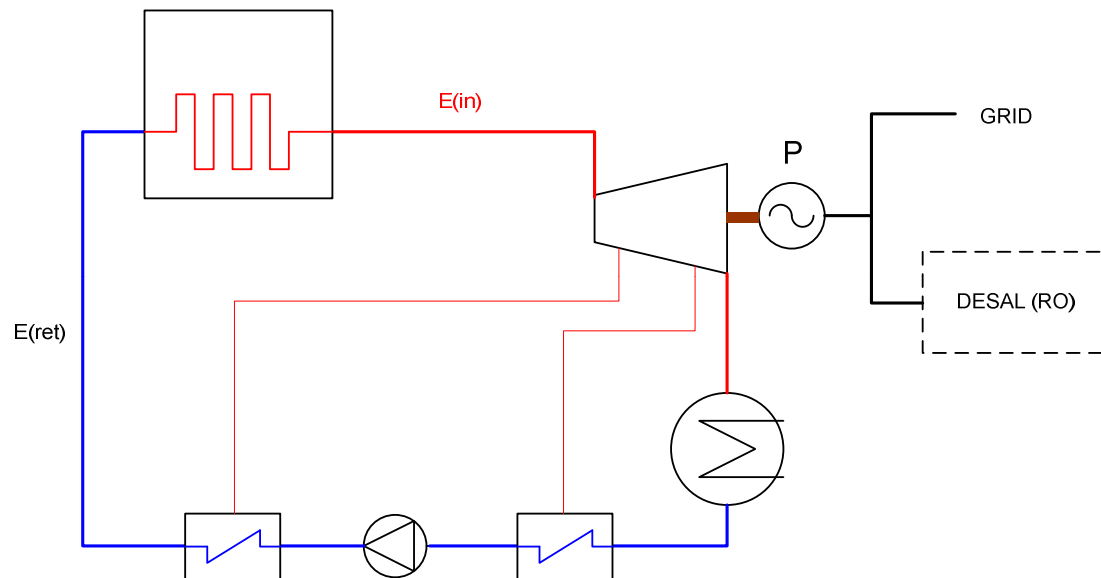
Focus of WP4: Electricity generation

Steam Turbine to Desalination Interface :

Configuration Options

1. Condensing turbine

Suitable for:

- *RO*

Interface conditions:

- *Solar field supply and return*

Power block output:

- *Power*
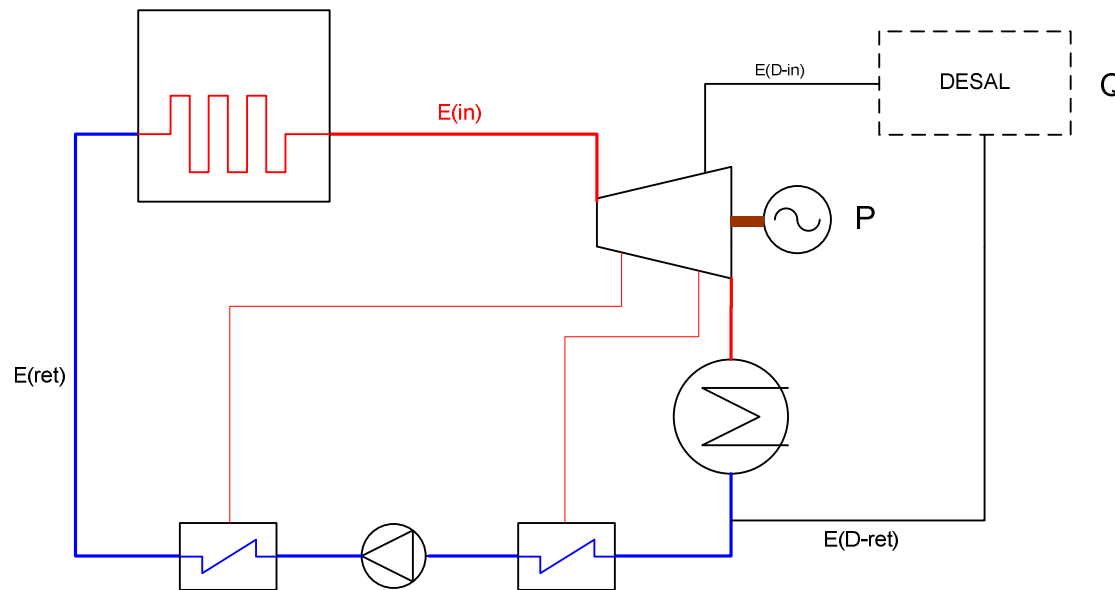
2. Extraction turbine

Suitable for:

- *Thermal desalination (MED, MSF)*

Interface conditions:

- *Solar field supply and return*
- *Desal. supply and return*

Power block output:

- *Power*
- *Heat to desalination*

E(D-in)

DESAL

Q

E(in)

P

E(ret)

E(D-ret)

3. Backpressure turbine

Suitable for:

- *Thermal desalination (MED, MSF)*

Interface conditions:

- *Solar field supply and return*
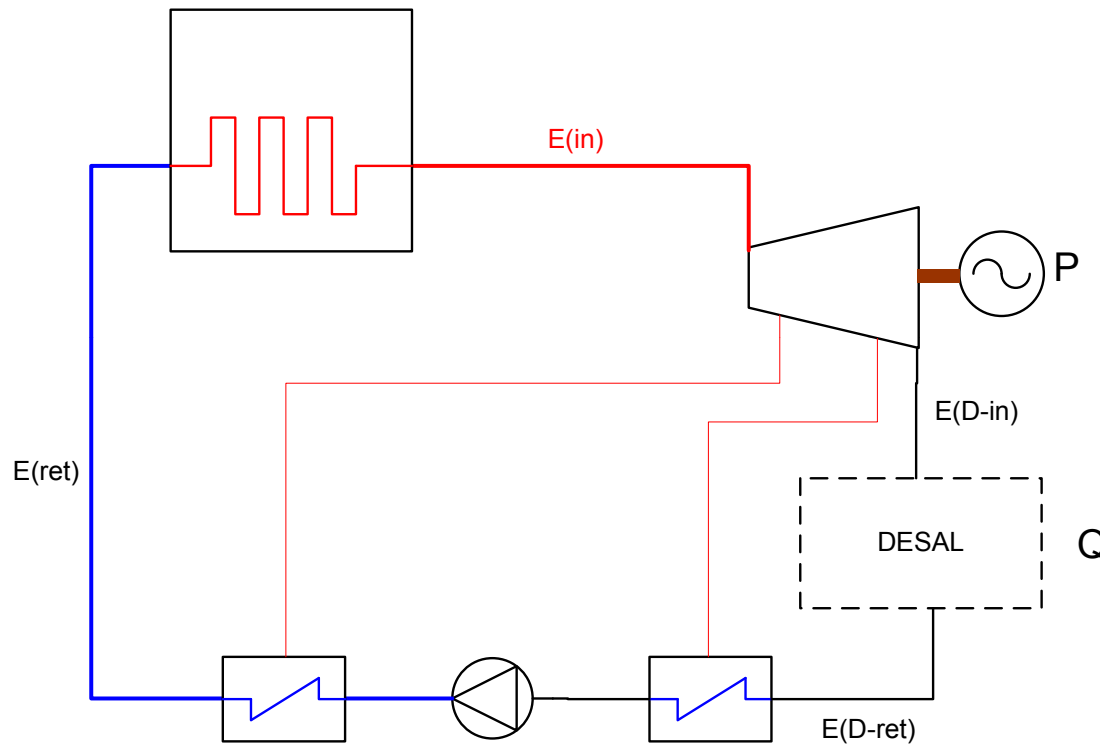- *Desal. supply and return*

Power block output:

- *Power*
- *Heat to desalination*

Parametric model

Overview

Parametric modeling structure

	4 MWe	**10 MWe**	**25 MWe**	**50 MWe**	**100 MWe**
Condensing turbine	✓	✓	✓	✓	✓
Extraction turbine	✓	✓	✓	✓	✓
Backpressure turbine	✓	✓	✓	✓	✓

A. For each plant size a base design is selected, according to industry practice.

B. Simulation of inlet condition range:

- 4 pressure levels

- Temperature range: saturation, up to max superheat

OBJECTIVE:

Improve steam turbine efficiency

Extraction & Backpressure turbine design

Fixed design parameters:

- *Turbine inlet conditions (P, T, m)*
- *Feed water return to solar field (boiler)*

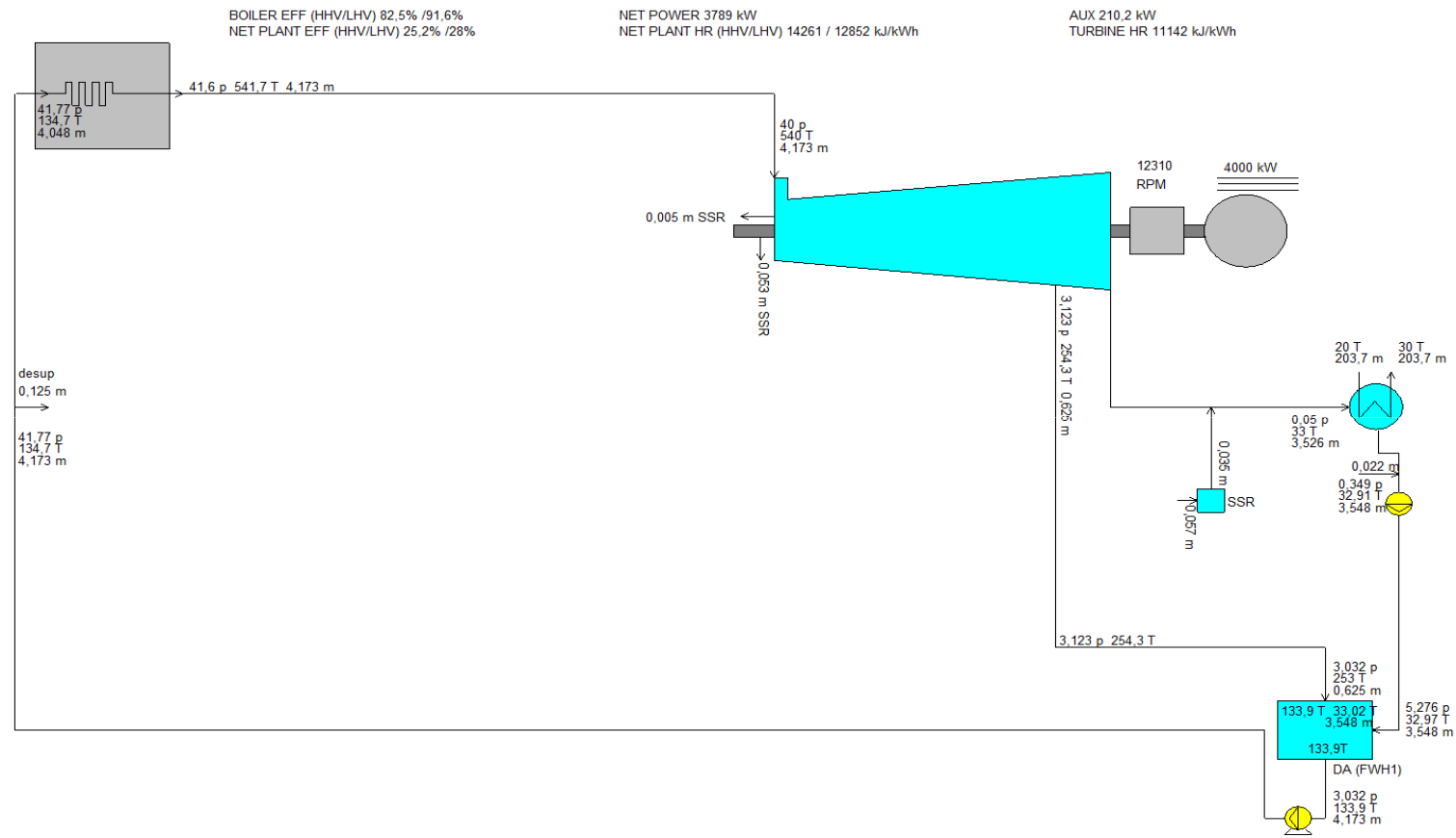➡ *Constant solar field output (for each plant size)*

Design variables:

- *Extraction pressure/turbine backpressure (1, 2, 6 bar)*
- *Extraction rate (extraction turbine only)*
- *Condensate return temperature ($80^0 C$)*

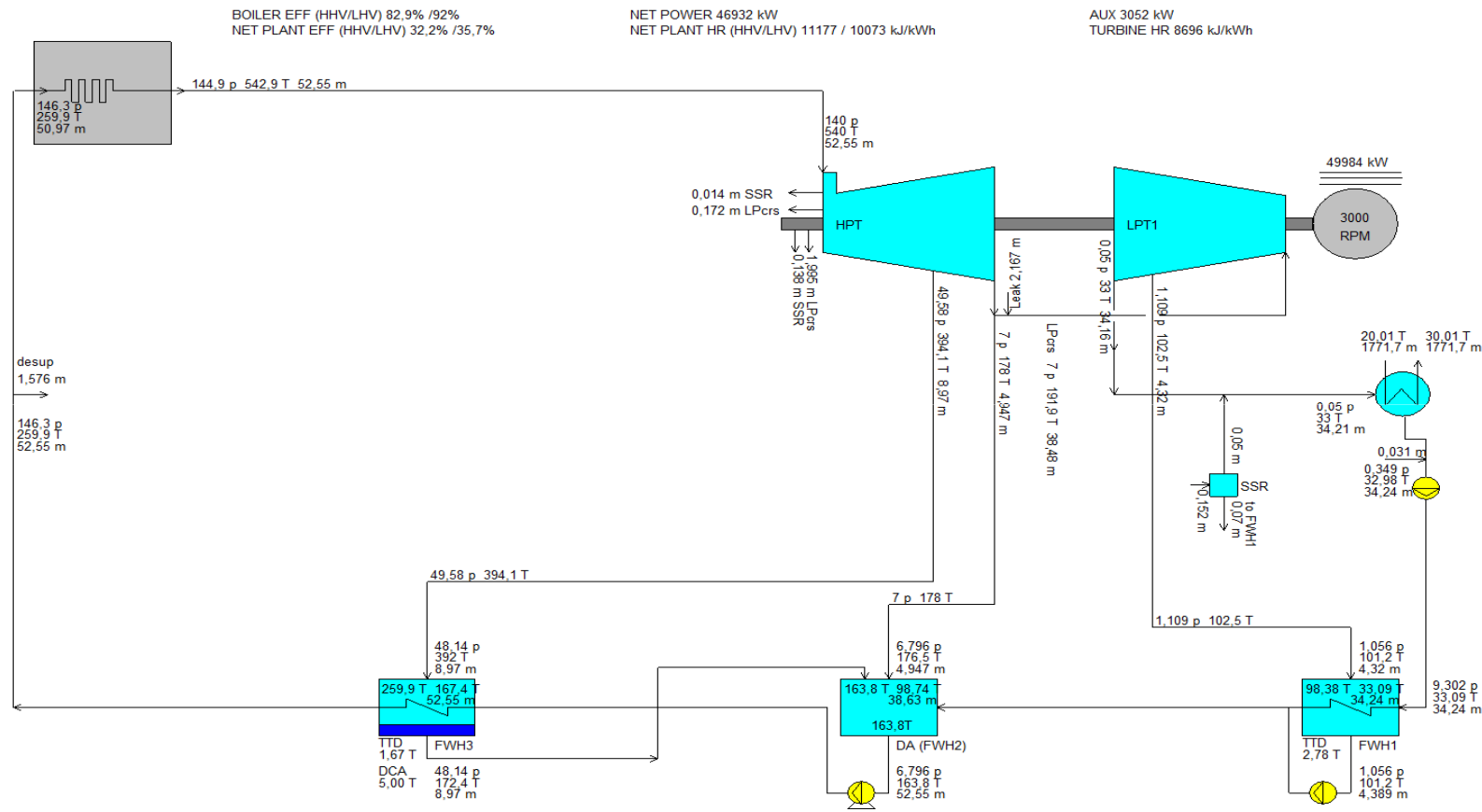➡ *Variable Power/Desal ratio*

Sample results

Condensing Turbine: 4MWe

BOILER EFF (HHV/LHV) 82,5% /91,6%
NET PLANT EFF (HHV/LHV) 25,2% /28%

NET POWER 3789 kW
NET PLANT HR (HHV/LHV) 14261 / 12852 kJ/kWh

AUX 210,2 kW
TURBINE HR 11142 kJ/kWh

41,6 p 541,7 T 4,173 m

41,77 p
134,7 T
4,048 m

40 p
540 T
4,173 m

12310
RPM

4000 kW

0,005 m SSR

0,053 m SSR

desup
0,125 m

41,77 p
134,7 T
4,173 m

3,123 p 254,3 T 0,625 m

20 T   30 T
203,7 m   203,7 m

0,05 p
33 T
3,526 m

0,022 m
0,349 p
32,91 T
3,548 m

0,035 m

SSR

0,057 m

3,123 p 254,3 T

3,032 p
253 T
0,625 m

133,9 T 33,02 T
3,548 m

5,276 p
32,97 T
3,548 m

133,9T

DA (FWH1)

3,032 p
133,9 T
4,173 m

pc STEAM PRO 18.00 1786 04-02-2009 06:33:36 Steam Properties: Thermoflow-STQUIK
FILE: C:\Documents and Settings\e46714\My Documents\Thermoflow 18\CONDENSING-4MW.stp   CYCLE SCHEMATIC
p[bar], T[C], h[kJ/kg], m[kg/s]

Condensing Turbine: 50MWe

BOILER EFF (HHV/LHV) 82,9% /92%
NET PLANT EFF (HHV/LHV) 32,2% /35,7%

NET POWER 46932 kW
NET PLANT HR (HHV/LHV) 11177 / 10073 kJ/kWh

AUX 3052 kW
TURBINE HR 8696 kJ/kWh

144,9 p 542,9 T 52,55 m

146,3 p
259,9 T
50,97 m

140 p
540 T
52,55 m

0,014 m SSR
0,172 m LPcrs

49984 kW

3000
RPM

HPT

LPT1

desup
1,576 m

146,3 p
259,9 T
52,55 m

49,58 p 394,1 T 8,97 m

1,995 m LPcrs
0,138 m SSR

Leak 2,167 m

7 p 178 T 4,947 m

LPcrs 7 p 191,9 T 38,48 m

0,05 p 33 T 34,16 m

1,109 p 102,5 T 4,32 m

0,05 p
33 T
34,21 m

20,01 T 30,01 T
1771,7 m 1771,7 m

0,031 m

0,349 p
32,98 T
34,24 m

0,05 p
0,152 m

SSR

to FWH1
0,07 m

49,58 p 394,1 T

7 p 178 T

1,109 p 102,5 T

1,056 p
101,2 T
4,32 m

48,14 p
392 T
8,97 m

6,796 p
176,5 T
4,947 m

9,302 p
33,09 T
34,24 m

259,9 T 167,4 T
52,55 m

163,8 T 98,74 T
38,63 m

98,38 T 33,09 T
34,24 m

163,8T

TTD
1,67 T

FWH3

DA (FWH2)

TTD
2,78 T

FWH1

DCA
5,00 T

48,14 p
172,4 T
8,97 m

6,796 p
163,8 T
52,55 m

1,056 p
101,2 T
4,389 m

pc STEAM PRO 18.00 1786 04-02-2009 06:24:04 Steam Properties: Thermoflow-STQUIK
FILE: C:\Documents and Settings\e46714\My Documents\Thermoflow 18\CONDENSING-50MW.stp CYCLE SCHEMATIC
p[bar], T[C], h[kJ/kg], m[kg/s]

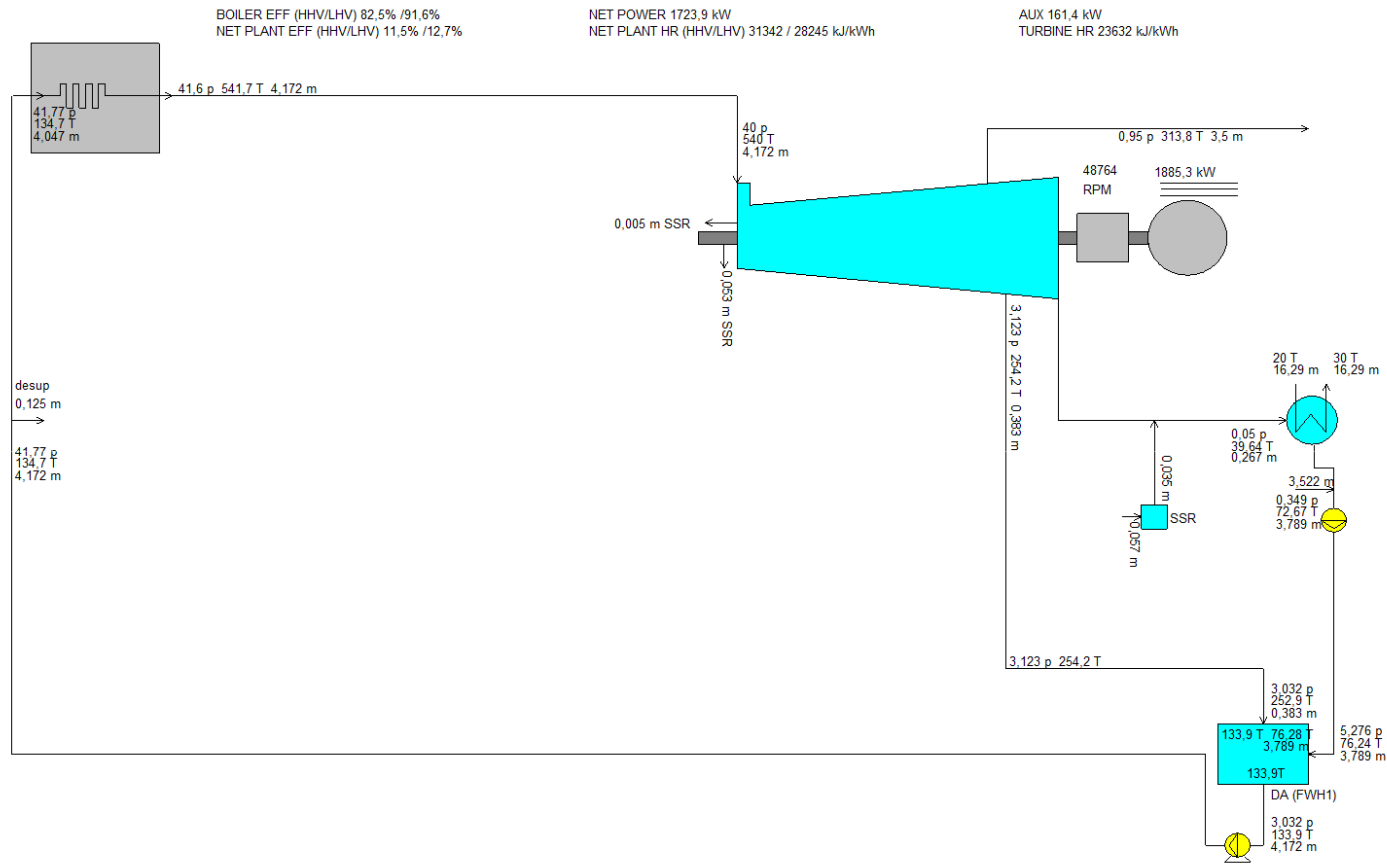# *Condensing turbine efficiency: 4 MWe*
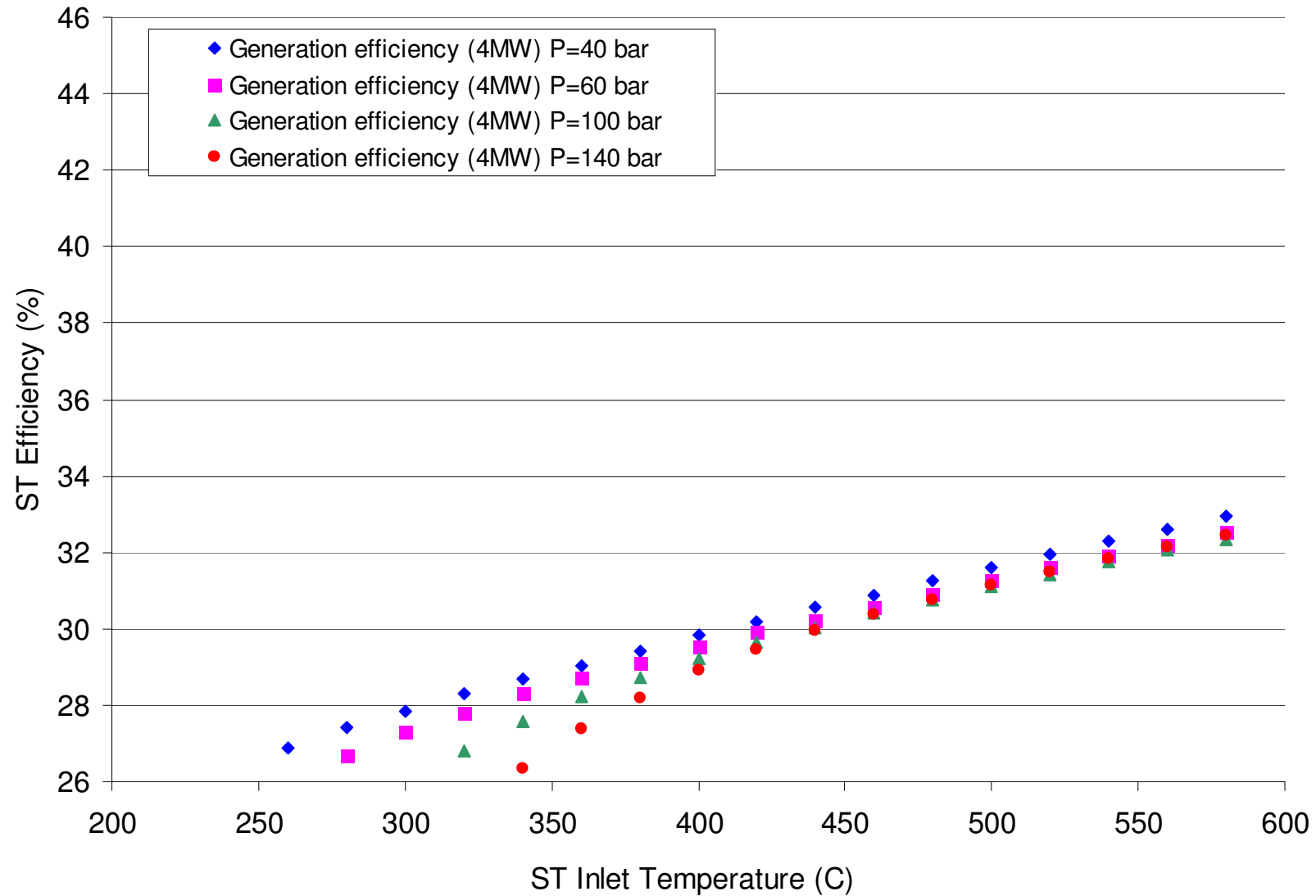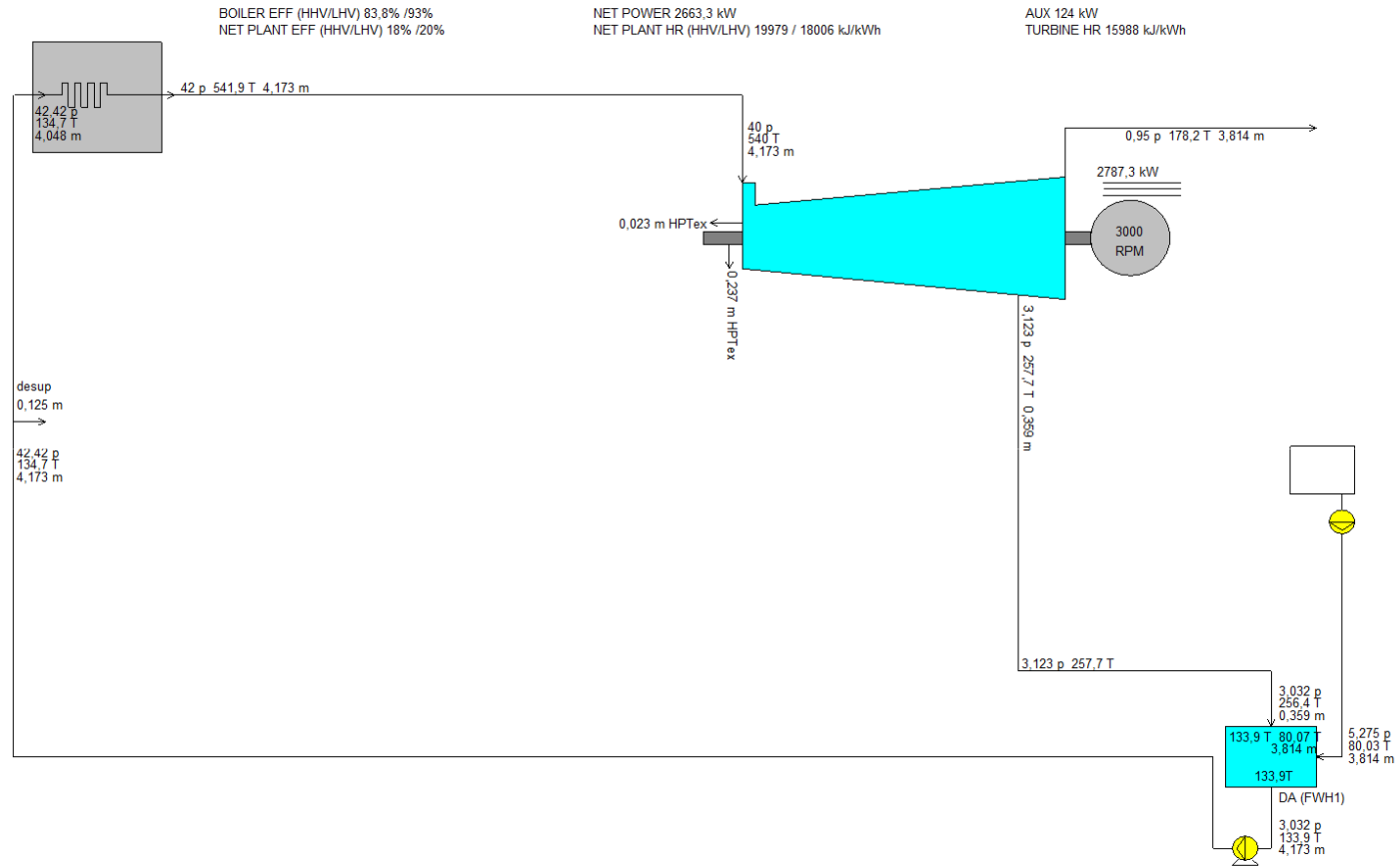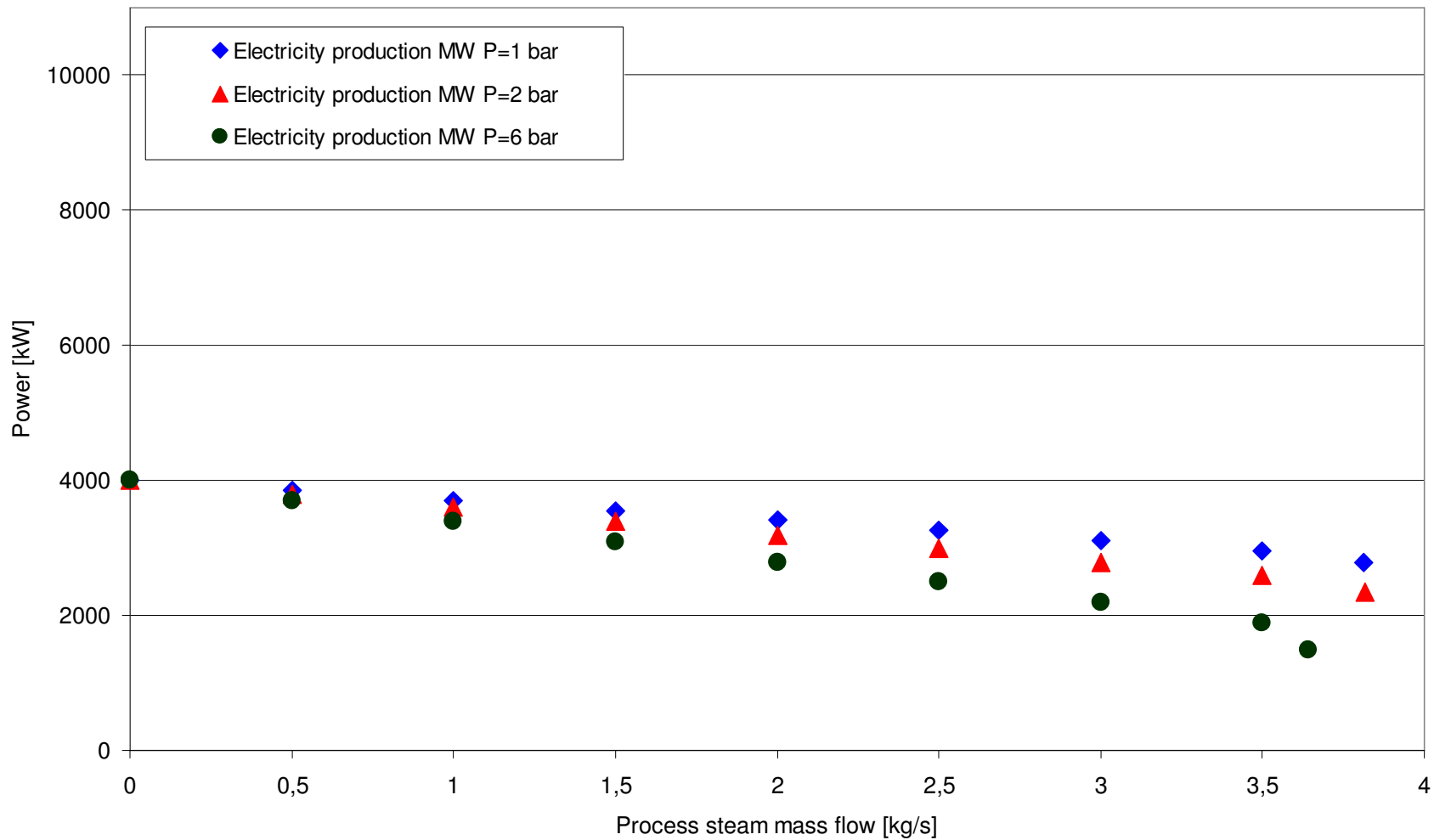
Condensing Turbine Result Summary

		4 MWe	10 MWe	25 MWe	50 MWe	100 MWe
Efficiency	*%*	*32,29*	*36,24*	*39,22*	*41,37*	*42,92*
Inlet pressure	bar	40	60	100	140	140
Inlet temperature	^{O}C	540	540	540	540	540
Inlet steam flow	kg/s	4.17	10,2	24,76	52,55	108
Return temperature	^{O}C	135	190	211	260	288
Net heat consumption	*MWth*	*12,4*	*27,6*	*63,6*	*120,7*	*233*

ExtractionTurbine: 4 MWe

Backpressure Turbine: 4 MWe

BOILER EFF (HHV/LHV) 83,8% /93%
NET PLANT EFF (HHV/LHV) 18% /20%

NET POWER 2663,3 kW
NET PLANT HR (HHV/LHV) 19979 / 18006 kJ/kWh

AUX 124 kW
TURBINE HR 15988 kJ/kWh

42 p 541,9 T 4,173 m

42,42 p
134,7 T
4,048 m

40 p
540 T
4,173 m

0,95 p 178,2 T 3,814 m

2787,3 kW

3000
RPM

0,023 m HPTex

0,237 m HPTex

3,123 p 257,7 T 0,359 m

desup
0,125 m

42,42 p
134,7 T
4,173 m

3,123 p 257,7 T

3,032 p
256,4 T
0,359 m

5,275 p
80,03 T
3,814 m

133,9 T 80,07 T
3,814 m

133,9T

DA (FWH1)

3,032 p
133,9 T
4,173 m

pc STEAM PRO 18.00 1786 04-26-2009 14:17:42 Steam Properties: Thermoflow-STQUIK
FILE: C:\Documents and Settings\e46714\My Documents\Thermoflow 18\ST Design\BACKPRESSURE 4MW.STP   CYCLE SCHEMATIC
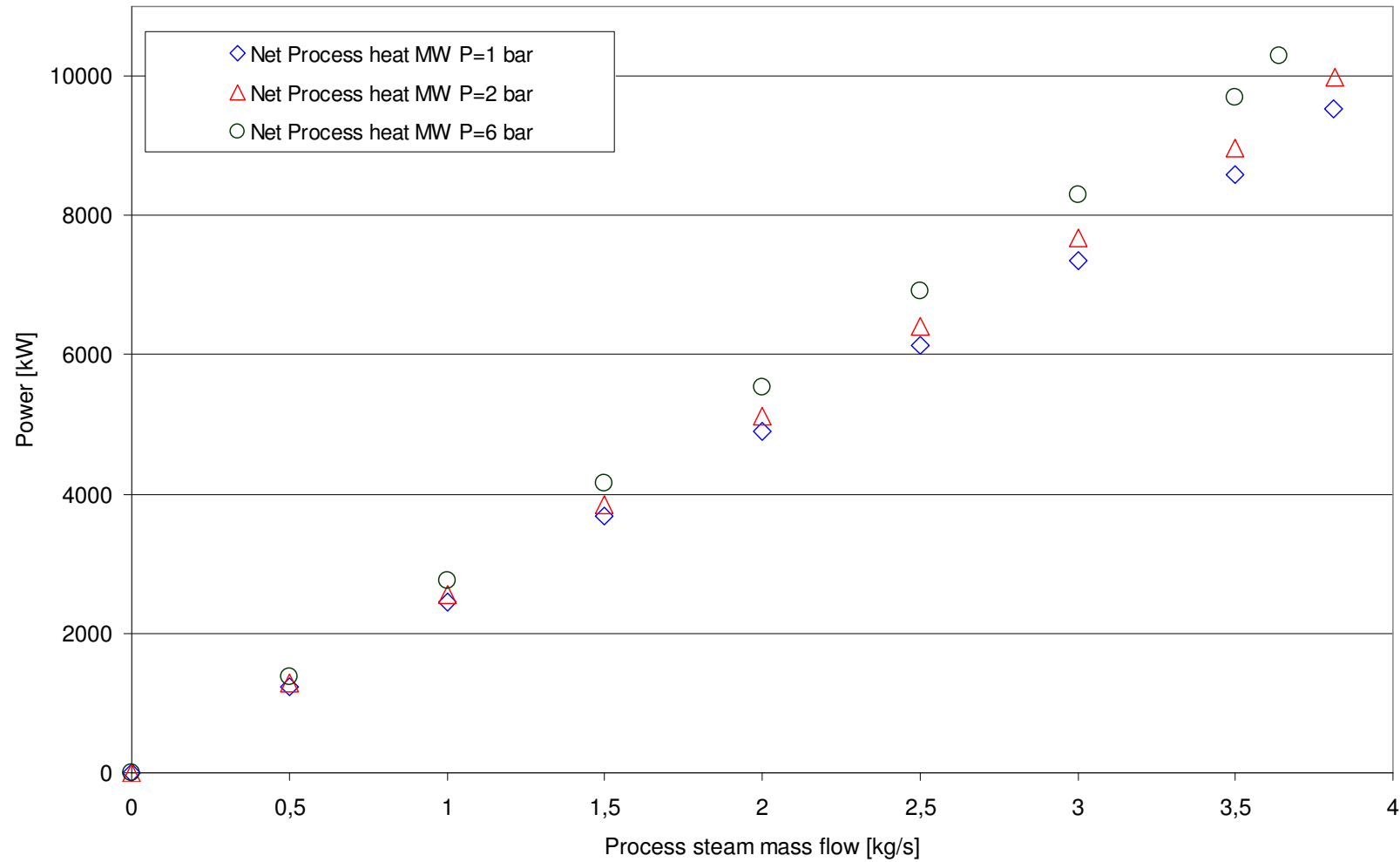p[bar], T[C], h[kJ/kg], m[kg/s]

4 MW Extraction & Backpressure turbine electrical power

4 MW Extraction & Backpressure turbine thermal power

Turbine Size		4 MWe (Equivalent)							
Process Pessure		—	1 bar			2 bar		6 bar	
Turbine Type		COND	EXTR		B/PR	EXTR		B/PR	EXTR		B/PR
Inlet pressure	bar	40	40			40			40		
Inlet temperature	^oC	540	540			540			540		
Inlet steam flow	kg/s	4,17	4,17			4,17			4,17		
Process steam flow	kg/s	—	0,5 - 3,5		3,8	0,5 - 3,5		3,8	0,5 - 3,5		3,6
Return temperature	^oC	134,8	134,7 - 134,7		134,7	134,7 - 134,7		134,7	134,7 - 134,7		165,8
Condenser CW flow	kg/s	203,7	176,9 - 16,29		—	176,9 - 16,29		—	176,9 - 16,29		—
Generation efficiency	%	32,29	31,09 - 23,87		22,50	30,67 - 20,87		18,91	29,86 - 15,22		12,60
Overall ST efficiency	%	—	41,70 - 93,58		99,33	41,71 - 93,67		99,38	41,74 - 93,85		99,45
Net ST heat consumption	MWth	12,4	12,4 - 12,4		12,4	12,4 - 12,4		12,4	12,4 - 12,4		11,8
Power	MWe	4,0	3,8 - 3,0		2,8	3,8 - 2,6		2,3	3,7 - 1,8		1,5
Net process (desal.) heat	MWth	—	1,2 - 8,6		9,5	1,3 - 9,0		10,0	1,4 - 9,7		10,3

Result Summary

Solar field interface

		4 MWe	10 MWe	25 MWe	50 MWe	100 MWe
Inlet pressure	bar	40	60	100	140	140
Inlet temperature	^{O}C	540	540	540	540	540
Net heat consumption	*MWth*	*12,4*	*27,6*	*63,6*	*120,7*	*233*

Interface conditions

Steam turbine outlet conditions to desalination

| Desalination technology	Supply pressure [bar$_a$]	Condensate return temperature [°C]
MSF	2	90-95
MED	1	70-75
ME-TVC	6	70-75

Interface conditions

Steam turbine outlet conditions to desalination with a backpressure steam turbine

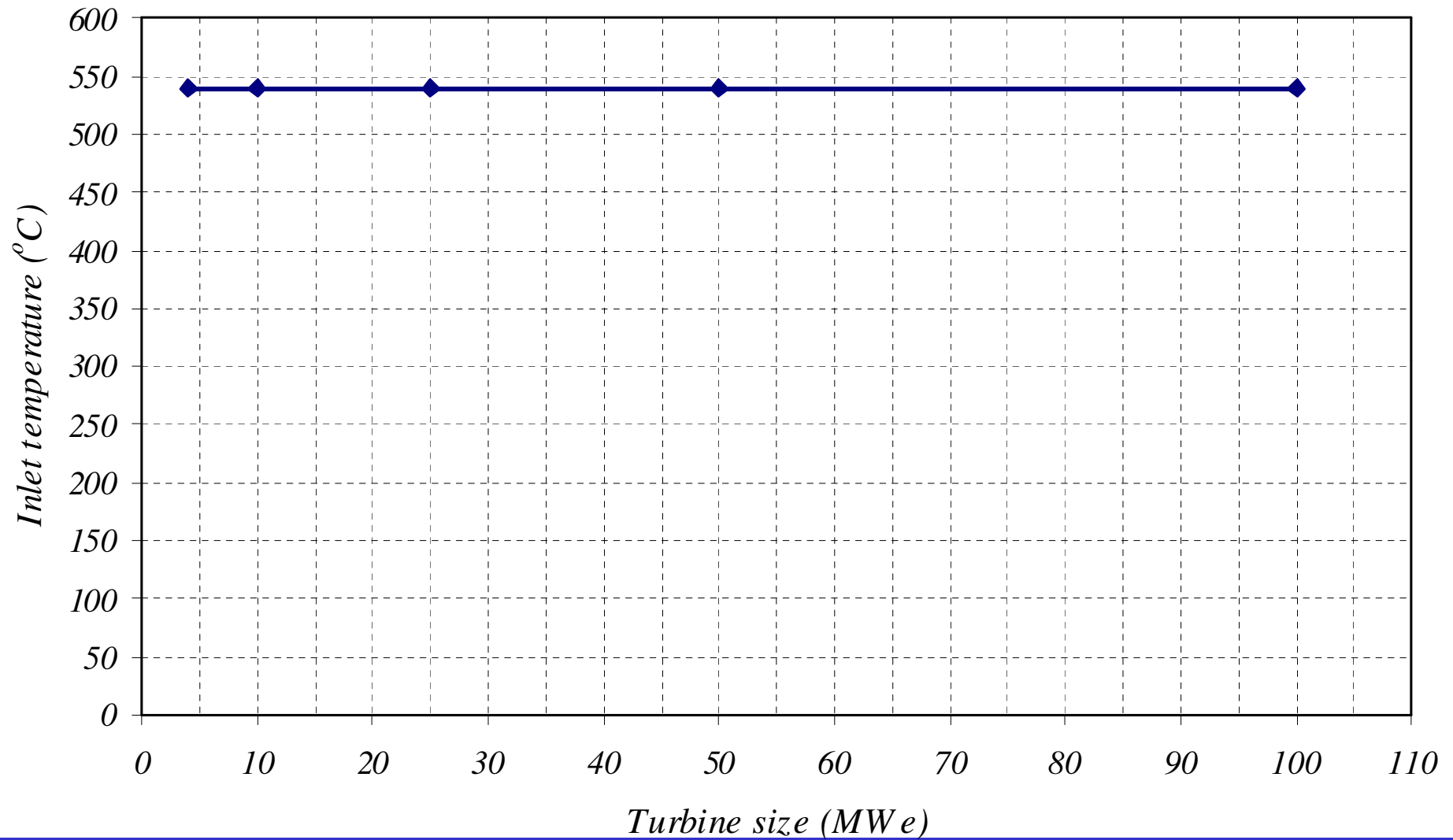| Power (MWe)	Supply pressure (bar$_a$)	Supply steam flowrate (kg/s)
4	1	3.8
10	1	8.4
25	1	19.4
50	1	37.1
100	1	71.0

Steam turbine input/output conditions
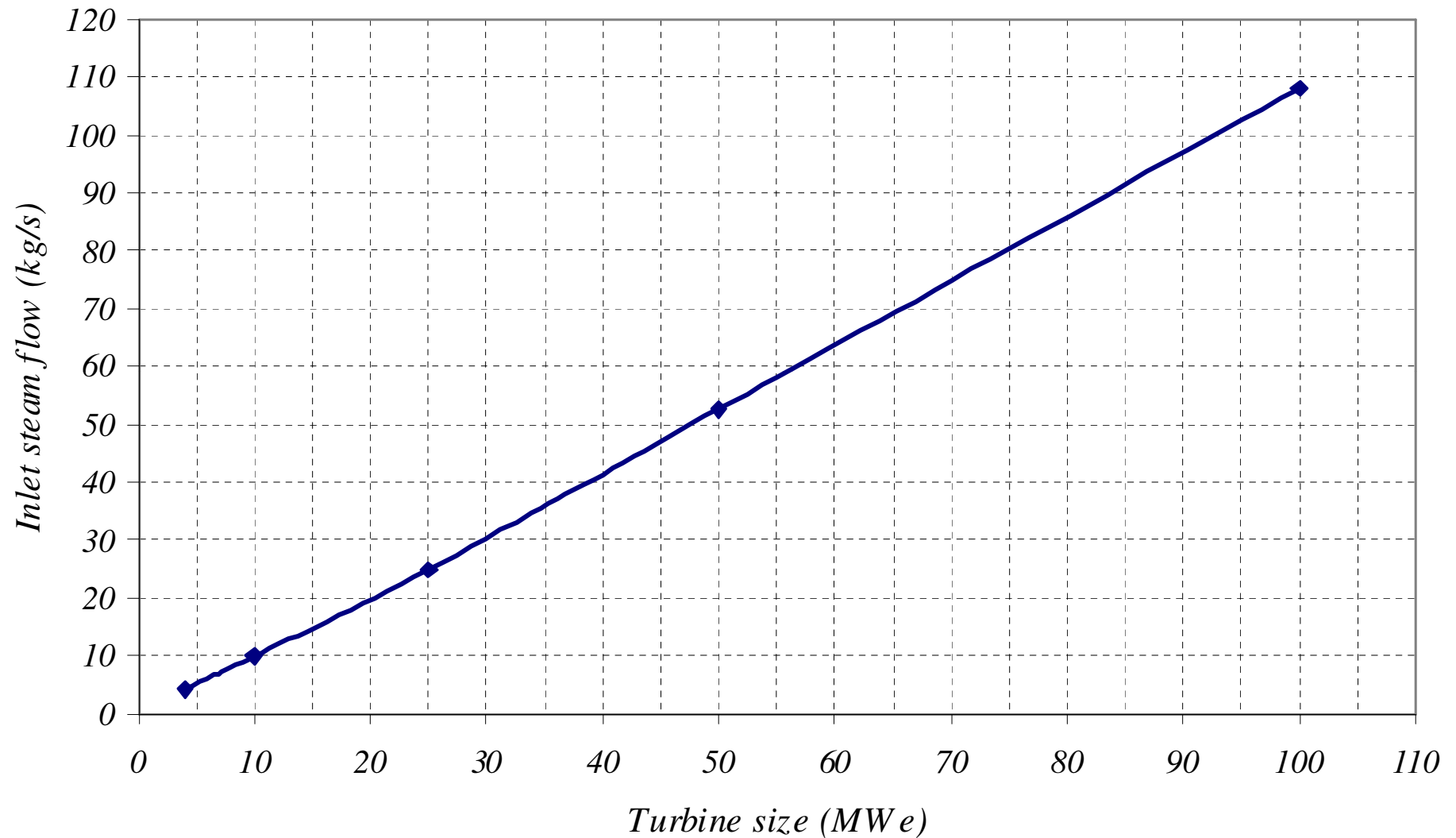
Steam turbine inlet pressure vs capacity
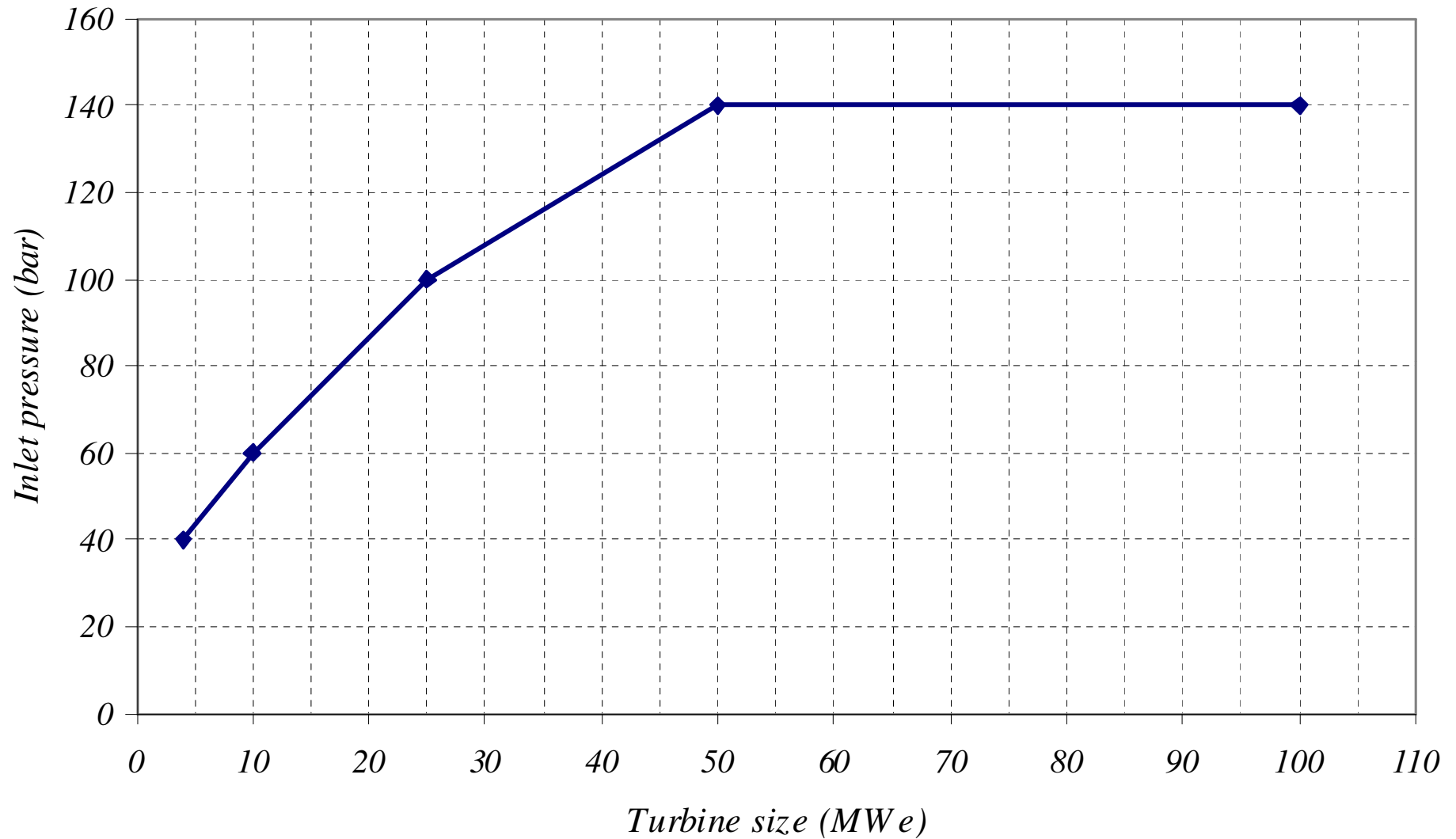
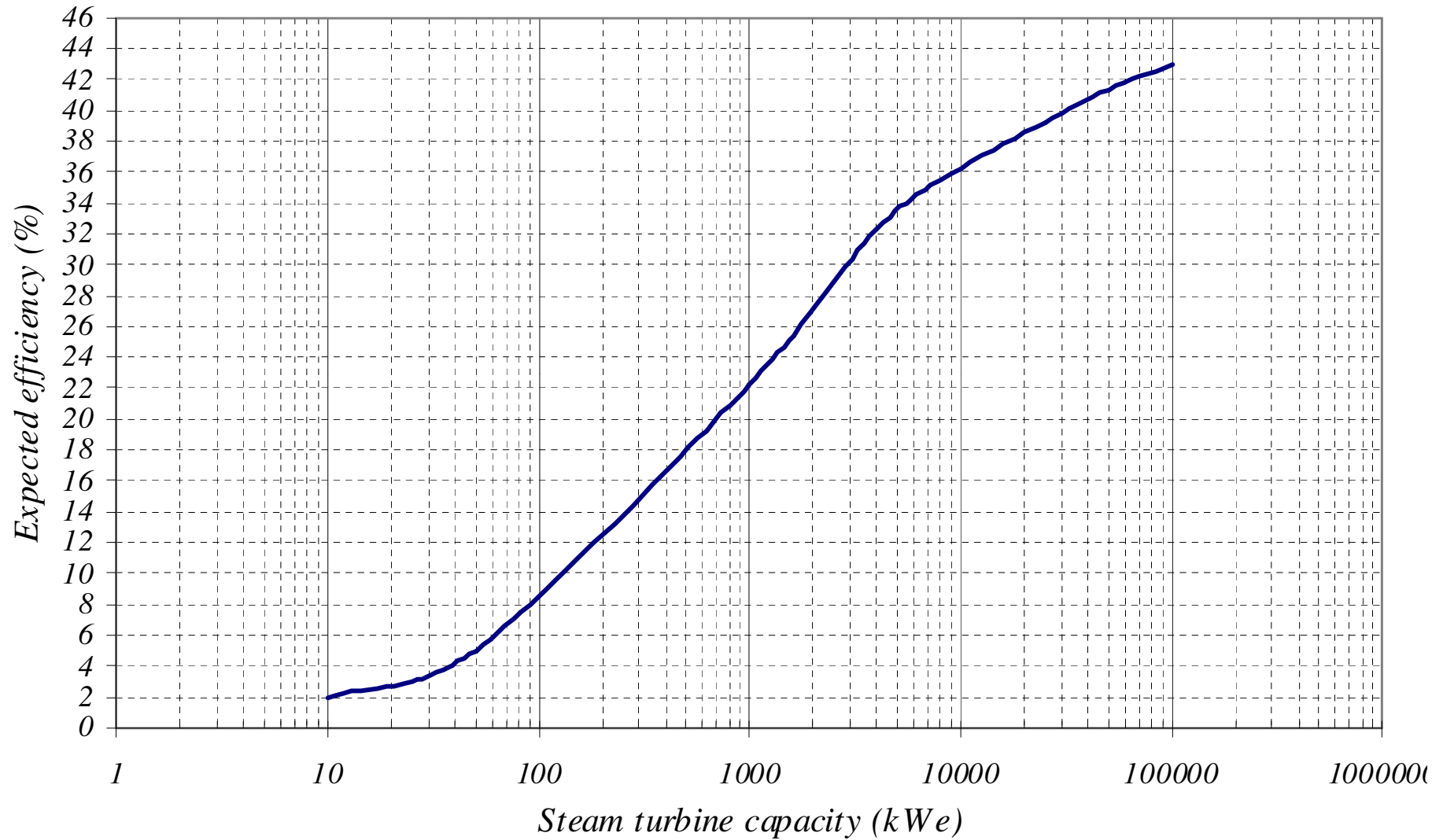# *Steam turbine inlet temperature vs capacity*
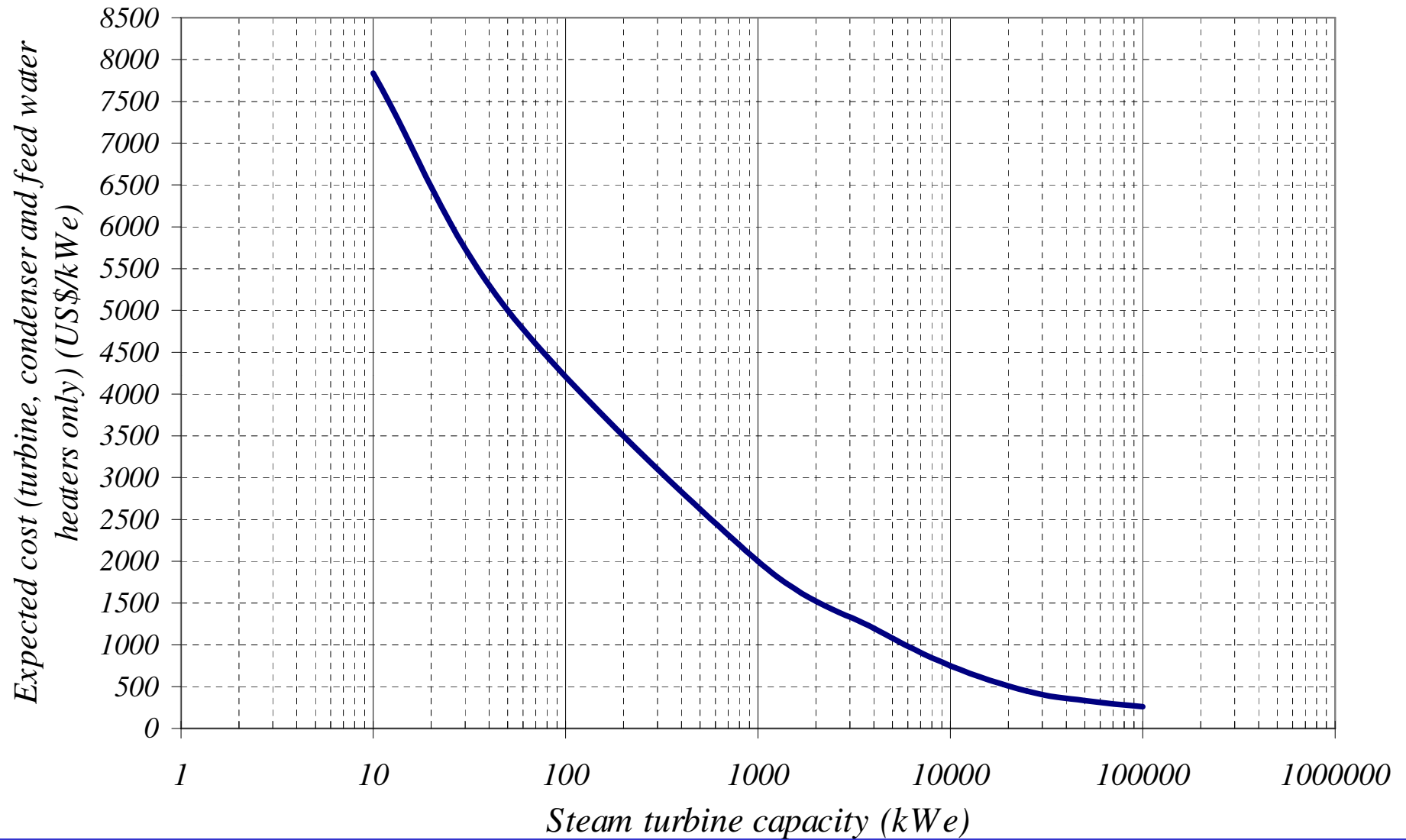
Steam turbine inlet steam flowrate vs capacity

Steam turbine efficiency and cost

vs capacity

Steam turbine efficiency vs capacity

Steam turbine cost vs capacity
(turbine, condenser and feed water heaters only)

Conclusions

Conclusions

Condensing turbine

– *Efficiency gains from*

- *Increased turbine size*
- *Increased inlet temperature*

Extraction turbine

– *increased thermal output to desalination results to:*

- *reduction in power output and generation efficiency*
- *improvement of overall efficiency*

– *Flexible Power/Desal ratio. Useful in satisfying varying needs*

Conclusions

Backpressure turbine

– *Lowest power output and generation efficiency*

– *Best overall efficiency*

– *Offers no flexibility in Power/Desal ratio*

Ευχαριστώ

Thank you