Twinning project Bulgaria

PROJECT TWINNING BULGARIA

Institutional Building at the Energy Efficiency Agency (EEA)

Seminar – Industrial Energy Audits

Energy efficiency case studies

Sofia February 20th 2007

Energy Efficiency Certificate (TEE)

- **Type I: energy saving in the field of electric energy;**
- **Type II: energy saving in the field of gas;**
- **Type III : energy for different fuels;**

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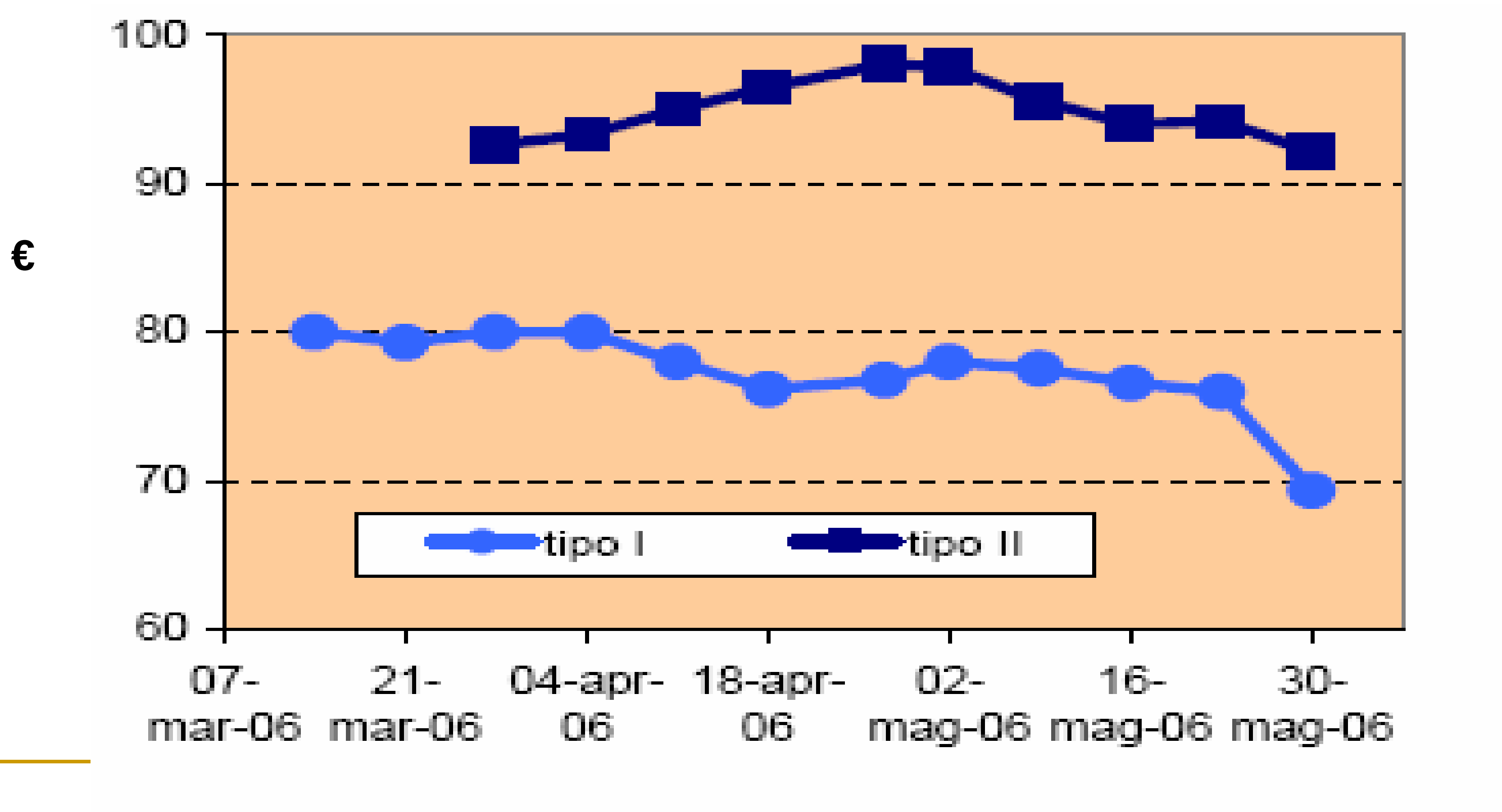
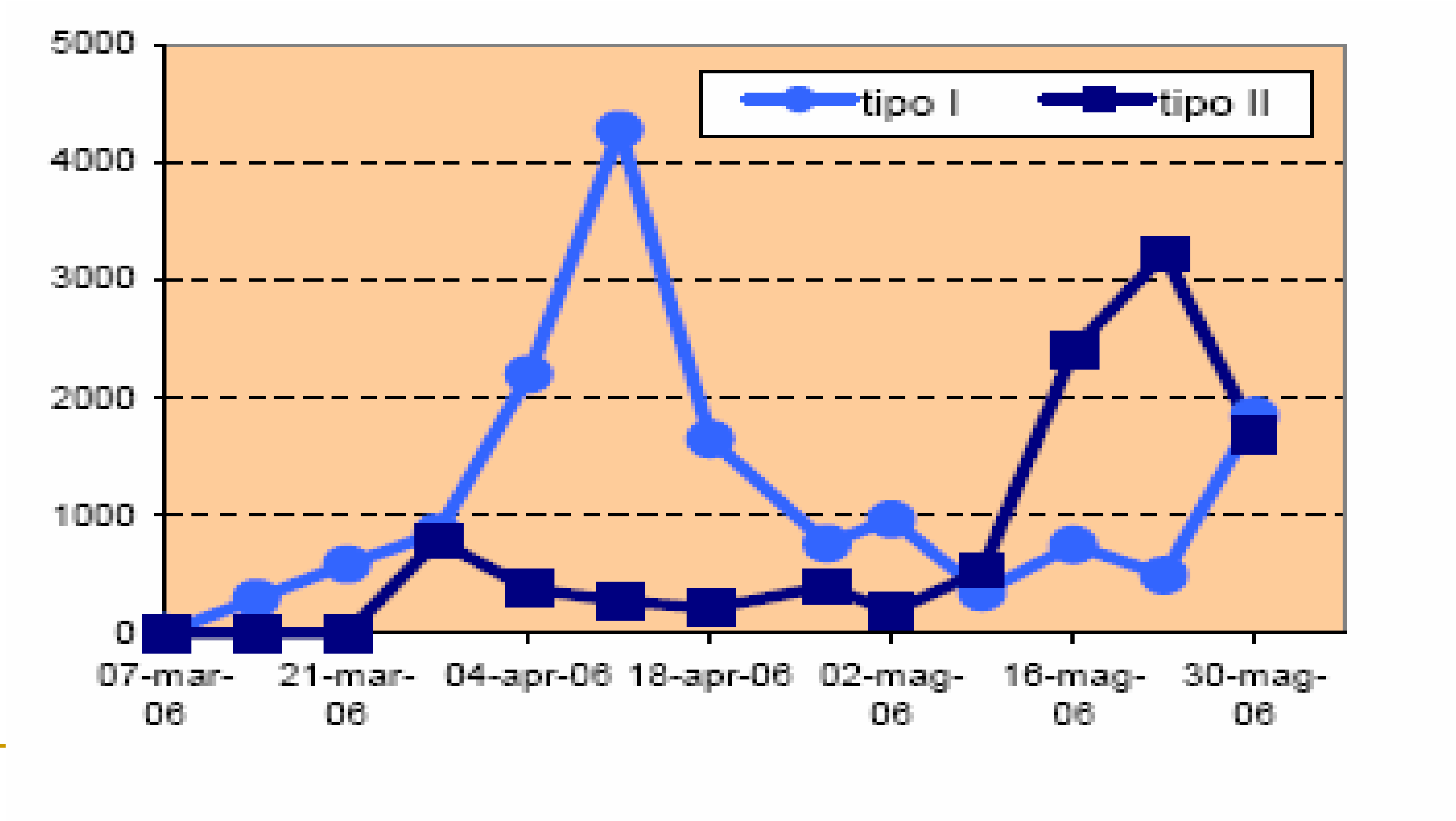
Average price for TEE Type I and Type II



Sales for TEE Type I and Type II



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Volume of sale for TEE in 2006

	Tipo I	Tipo II	Tipo III
Scambiati	15.024	10.086	76
Controvalore totale	€ 1.157.412,29	€ 948.060,73	€ 2.572,00
Prezzo minimo	€ 69,00	€ 90,00	€ 32,00
Prezzo massimo	€ 84,00	€ 98,00	€ 36,00
Prezzo medio	€ 77,04	€ 94,00	€ 33,84

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date	type	Min. price (€/tep)	Max price (€/tep)	Reference price (€/tep)	TEE sale
09-gen-07	I	49	50	49,83	600
09-gen-07	II	80	80	80	200
09-gen-07	III	-	-	-	0
16-gen-07	I	49,9	55	51,38	1450
16-gen-07	II	79	85	81,18	294
16-gen-07	III	-	-	-	0
23-gen-07	I	50	50	50	5025
23-gen-07	II	84	85	84,51	610
23-gen-07	III	-	-	-	0
30-gen-07	I	50	51	50,24	1439
30-gen-07	II	85,5	85,5	85,5	99
30-gen-07	III	-	-	-	0
06-feb-07	I	52	54,5	53	2500
06-feb-07	II	85	89	86,76	1156
06-feb-07	III	-	-	-	0
13-feb-07	I	50	51	50,22	798
13-feb-07	II	89,5	89,5	89,5	10
13-feb-07	III	-	-	-	0

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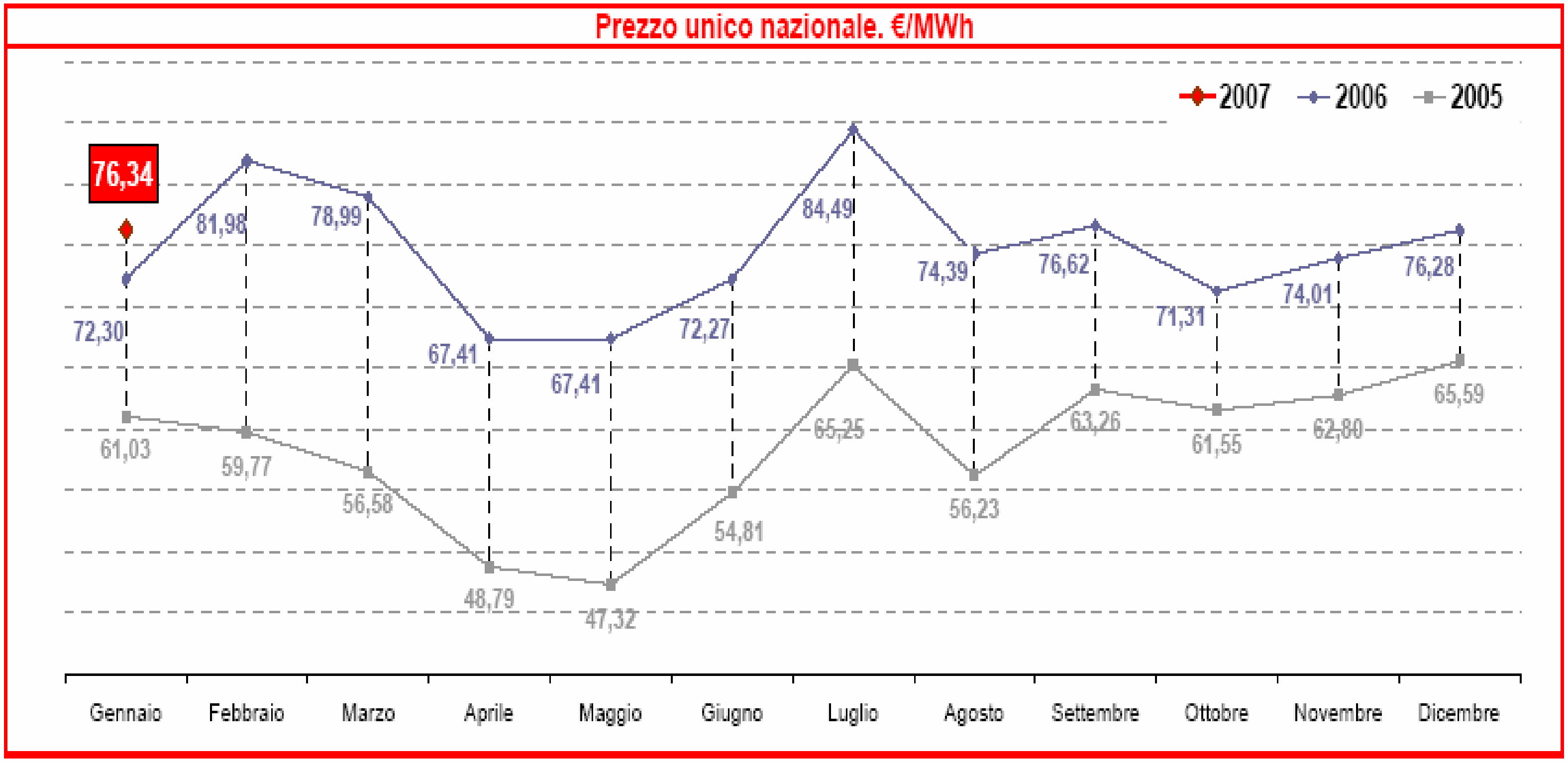
Average national price for Electric Energy 2005 – 2006 - 2007



Main items considered in case studies (1)

Italian situation

EE	80 - 100 €/MWh
Gas	30 € / NMc
TEE (Type I)	65 €/TEE
Discount rate	4,5 %
Inflation rate	2 %
Equity	30 %

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Main items considered in case studies (2)

Bulgarian situation

EE	40 €/MWh
Gas	18 €/NMc
TEE (Type I)	- €/TEE
Discount rate	8 %
Inflation rate	5 %
Equity	30 %

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CASE STUY 1

Application of an ORC (Organic Rankine Cycle) on flue gas from two heating furnaces in a steel making factory

ORC characteristics

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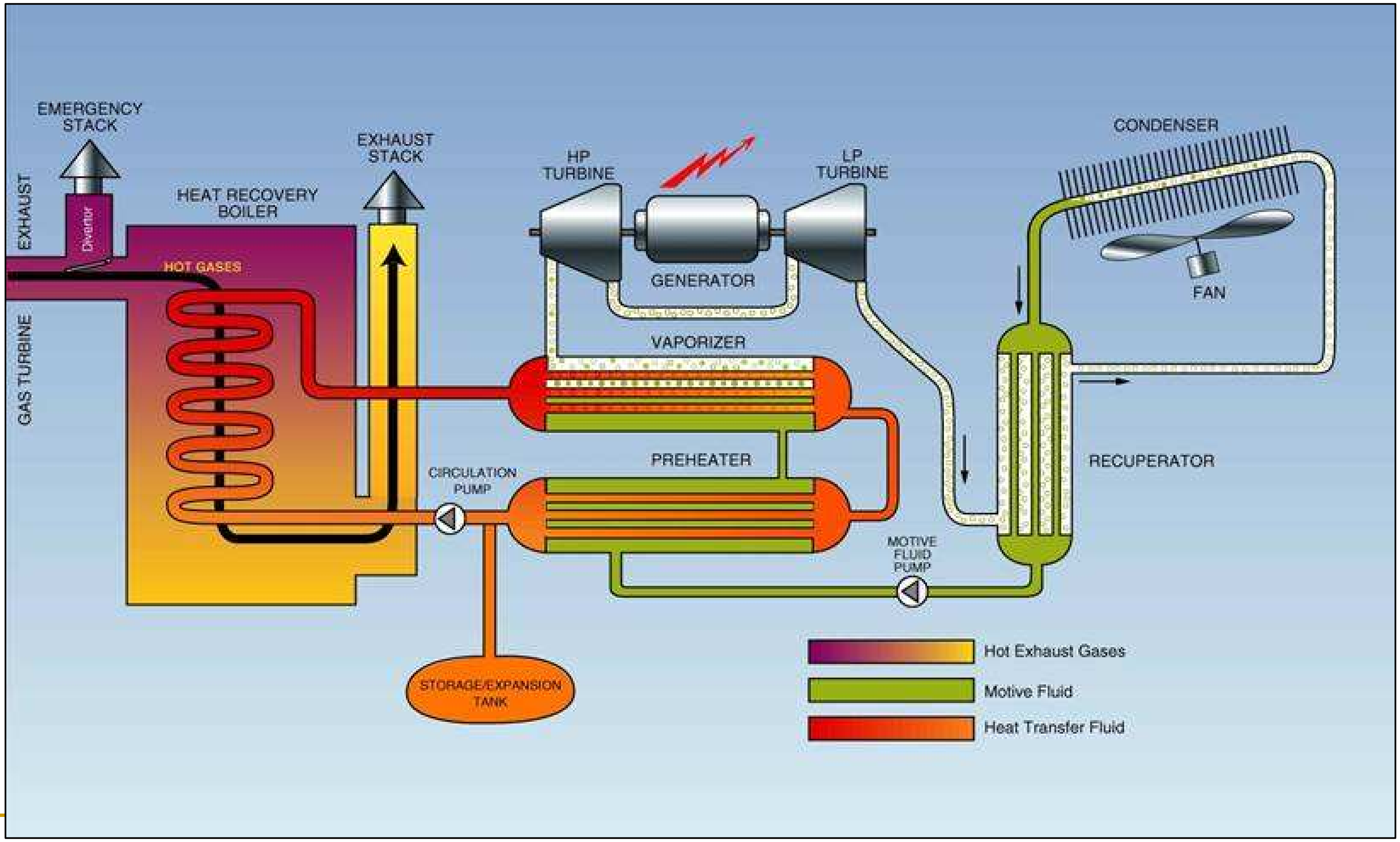
- Organic Rankine Cycle (ORC) is made by a closed turbo generator.

  Rankine cycle is that generally used for steam turbine;
- ORC, as for steam cycle, works according to a Rankine cycle, but:
  - the fluid is Hydrocarbon or, in general, a kind of organic fluid;
  - The cycle is completely closed

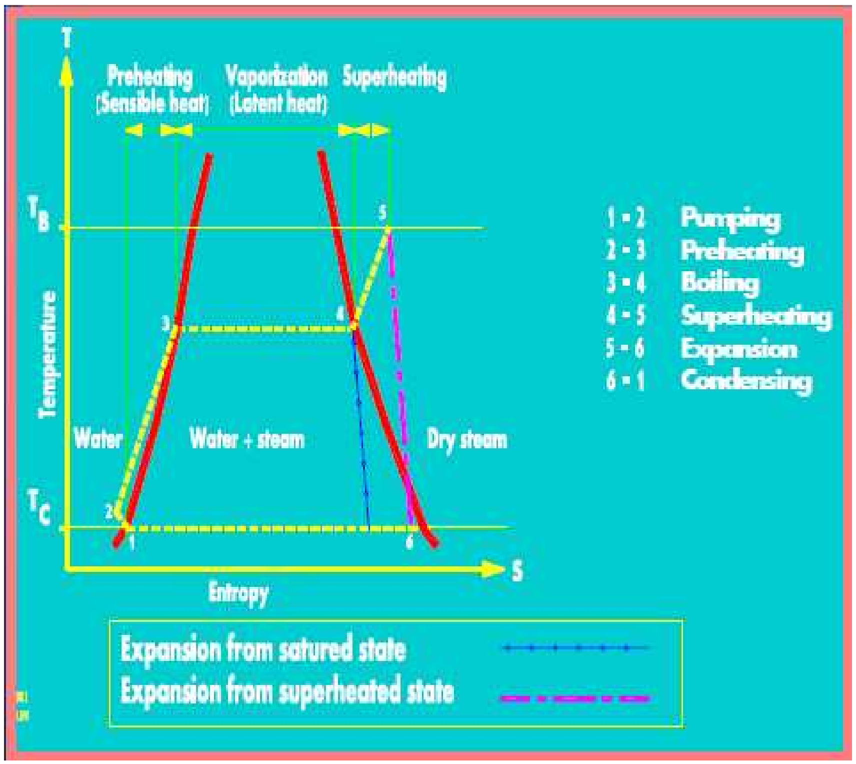
ORC characteristics

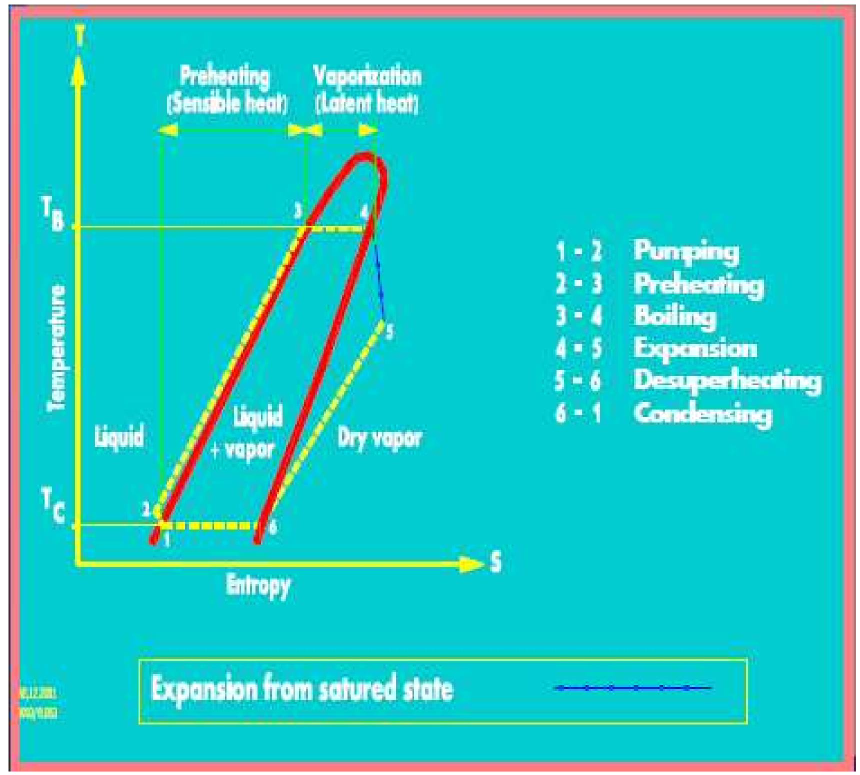
- Working fluid is an hydrocarbon, so there are not problems due to icing ;
- Turbine follows automatically variations due to flue gas flow rate or temperatures
- By ORC it is possible to use heat at a low entalpic level (not usable in common steam cycle)

ORC – Process scheme



Organic Rankine Cycles





ORC – Typical lay out

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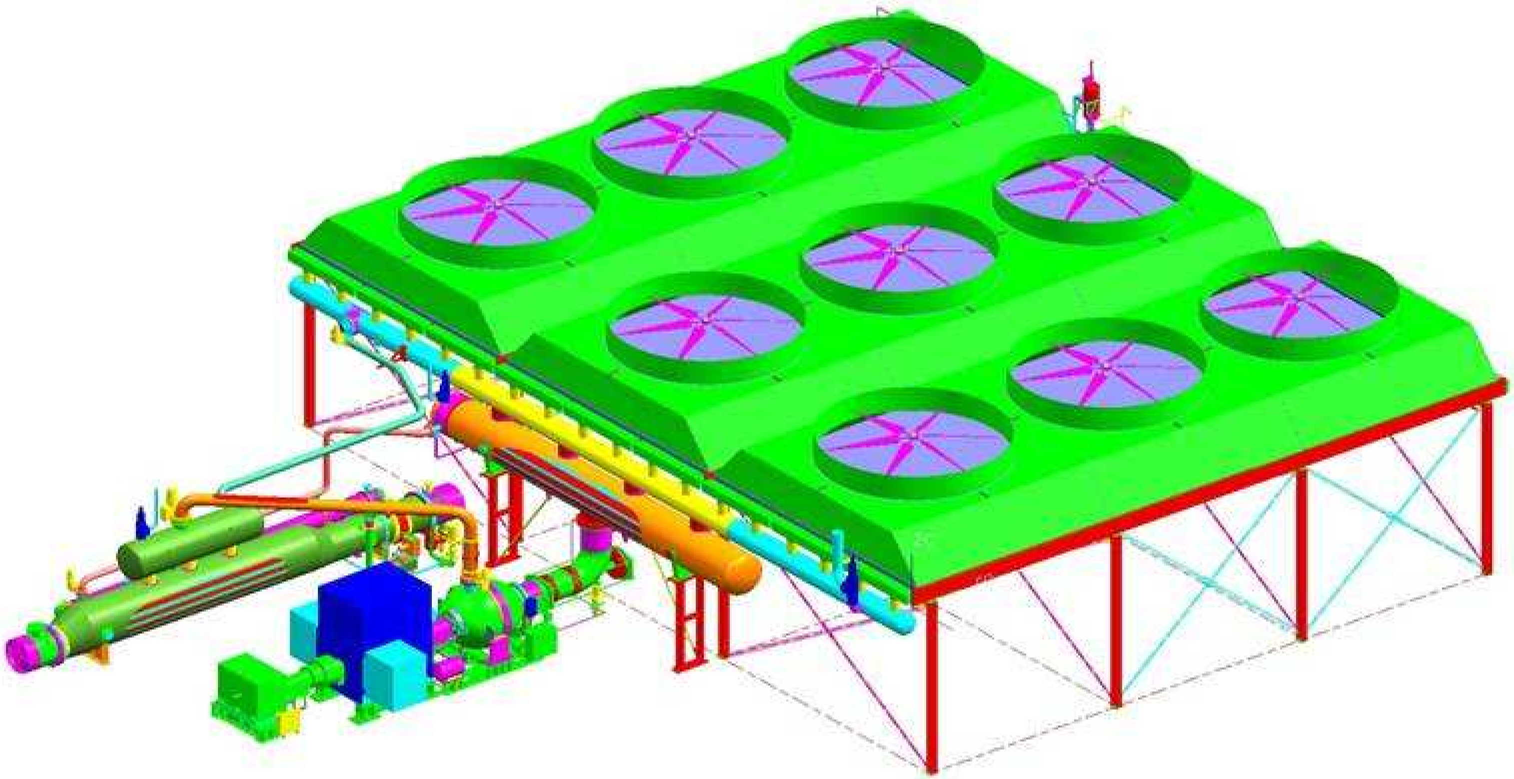

Heating furnaces

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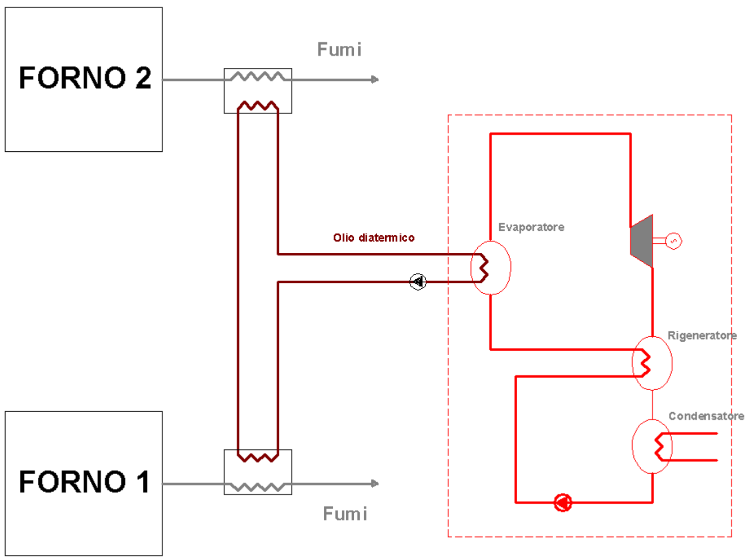

FURNACES		
h working	**8.000**	h/a
N° Furnaces	**2**	-
Flow rate (avg) Flue gas	**40**	kg/s
T_{avg} flue gas	**400**	℃
T_{out} After recovery	**160**	℃

Audit to define possible actions (1):

- Data collection on flue gas flow rate and temperature , for about 1 month;

- Implementation of collected data by historical data available on methane Flow rate , collected hourly ;

Heating furnaces

- **Audit to define possible actions (2)**

- Assessment of average flow rate and temperature (yearly base) ;
- Assessment of thermal energy that is possible to recover from flue gas;
- Assessment of technical aspects related to heat exchanger installation on flue gas from heating furnace (lay out, pressure drops, electrical connection)

Heating furnaces

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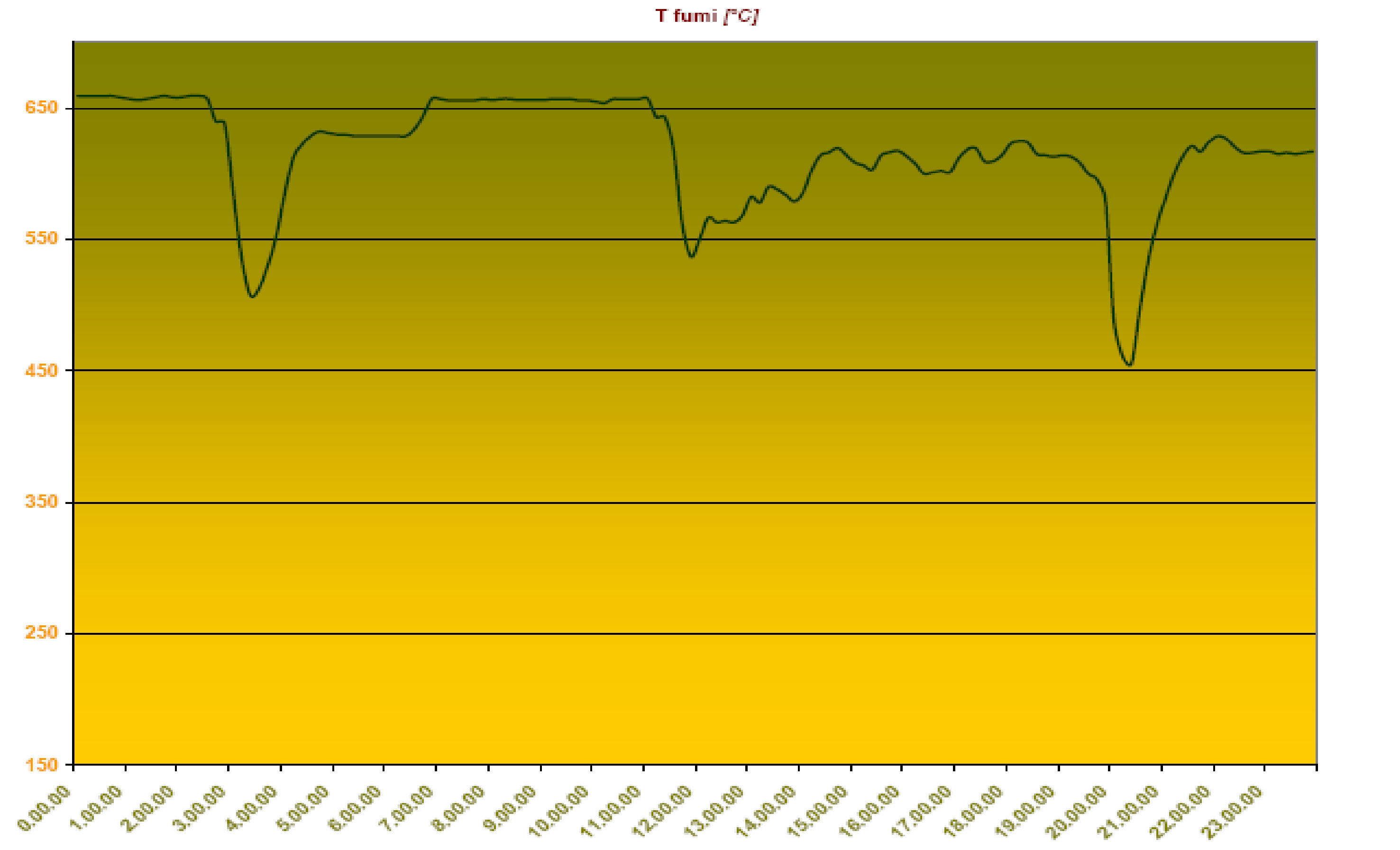
Temperature trend in furnace 1



Heating furnaces

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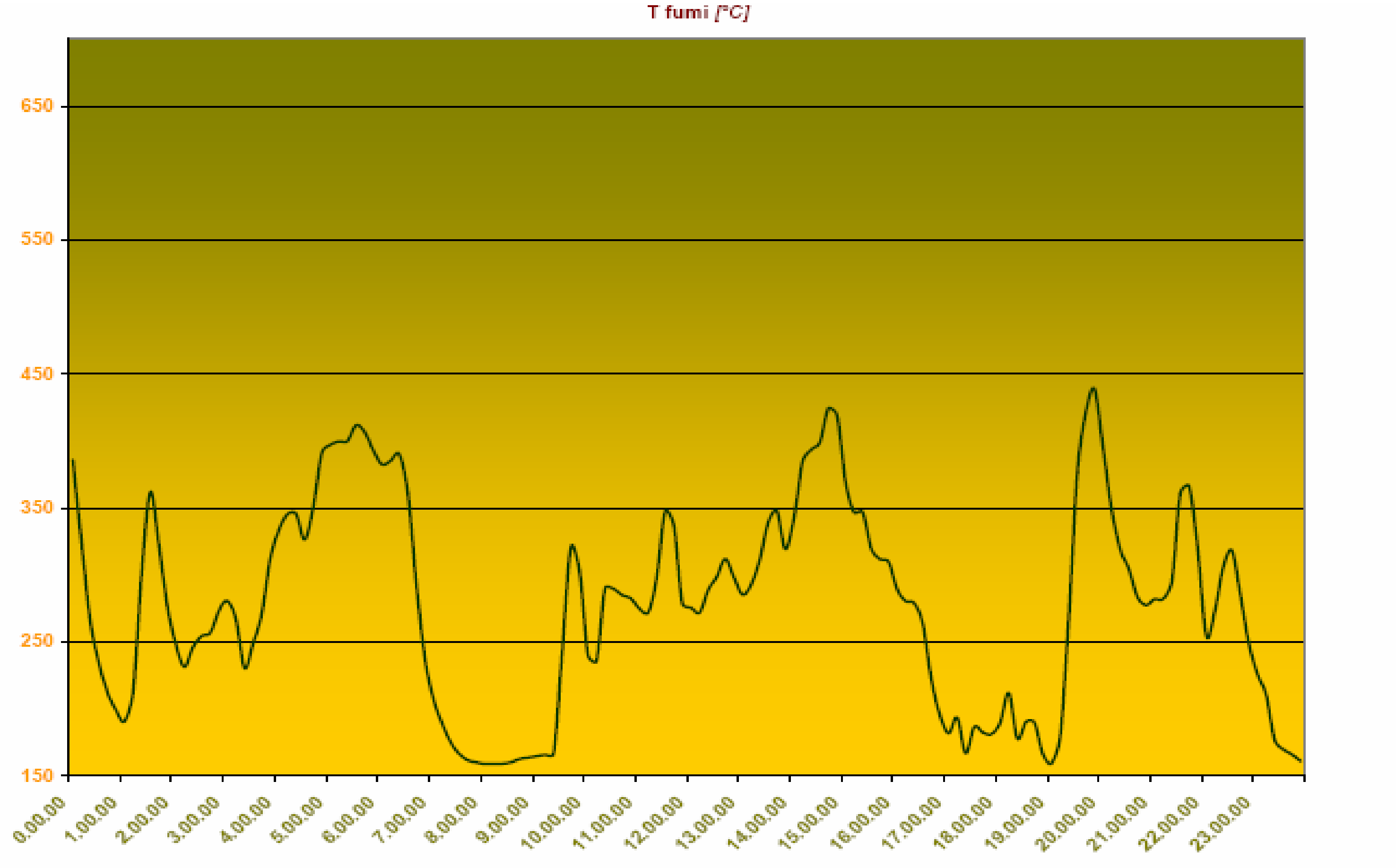
Temperature trend in furnace 2



Heating furnaces

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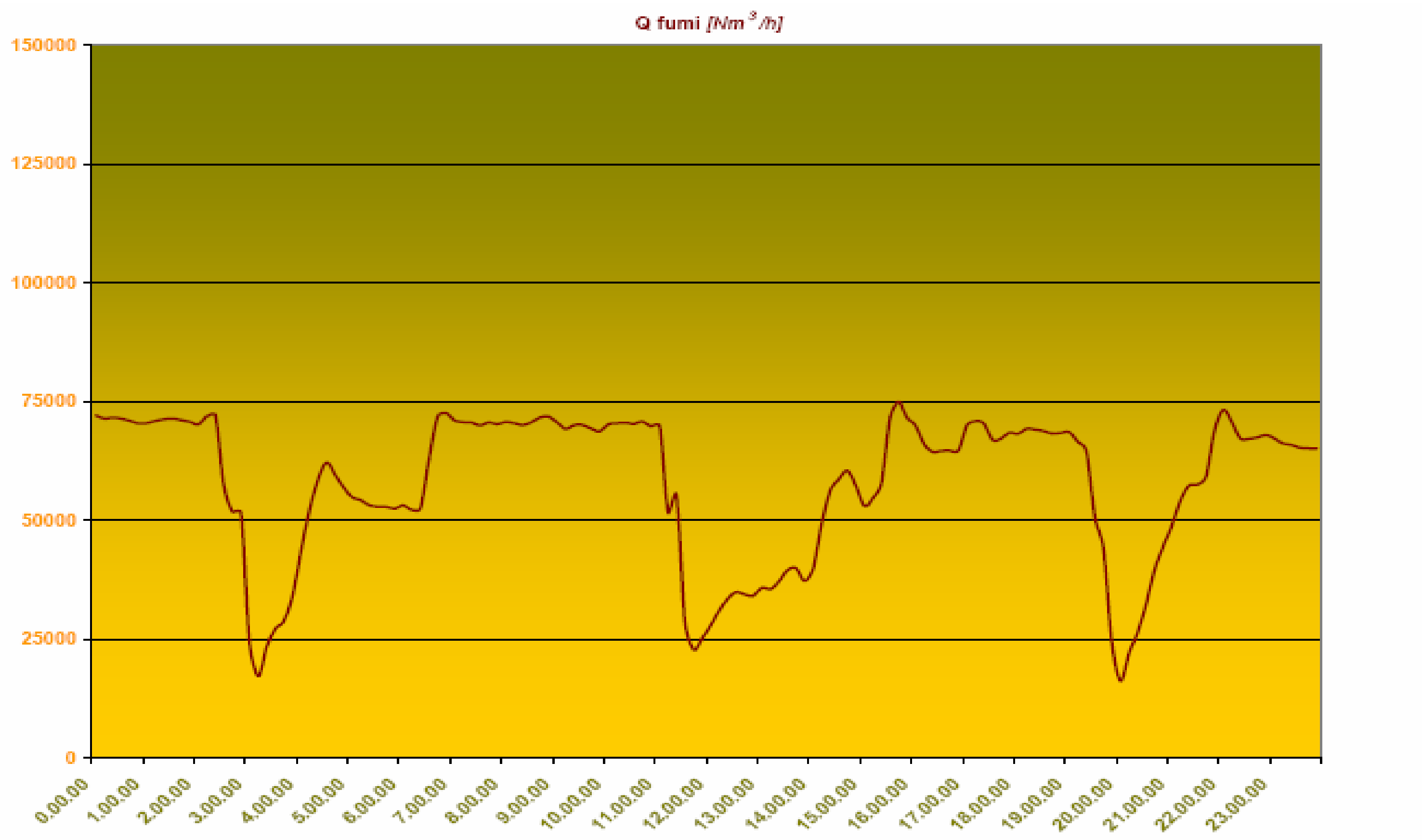
Flue gas flow rate trend in furnace 1



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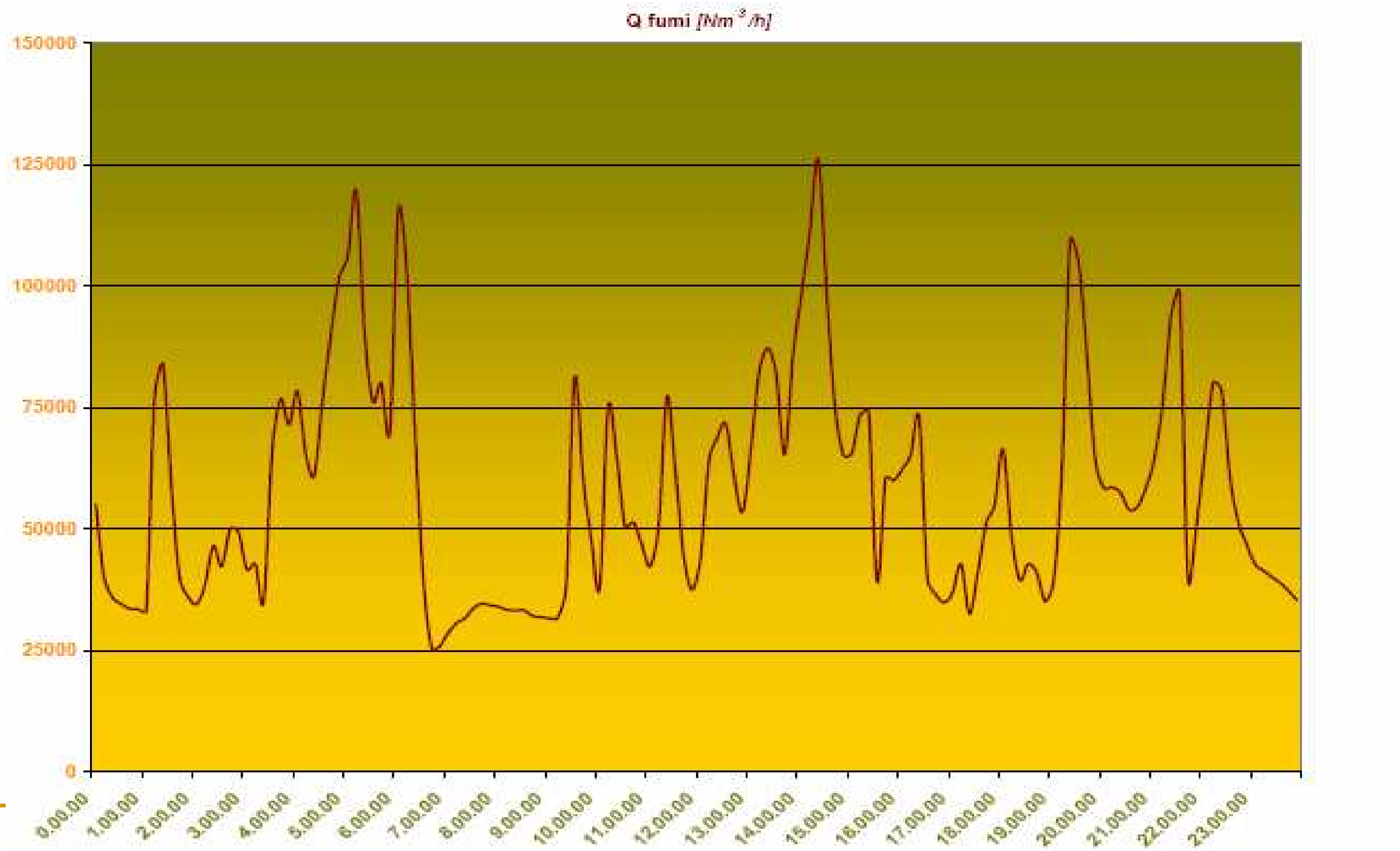
Flue gas flow rate trend in furnace 2



Heating furnaces

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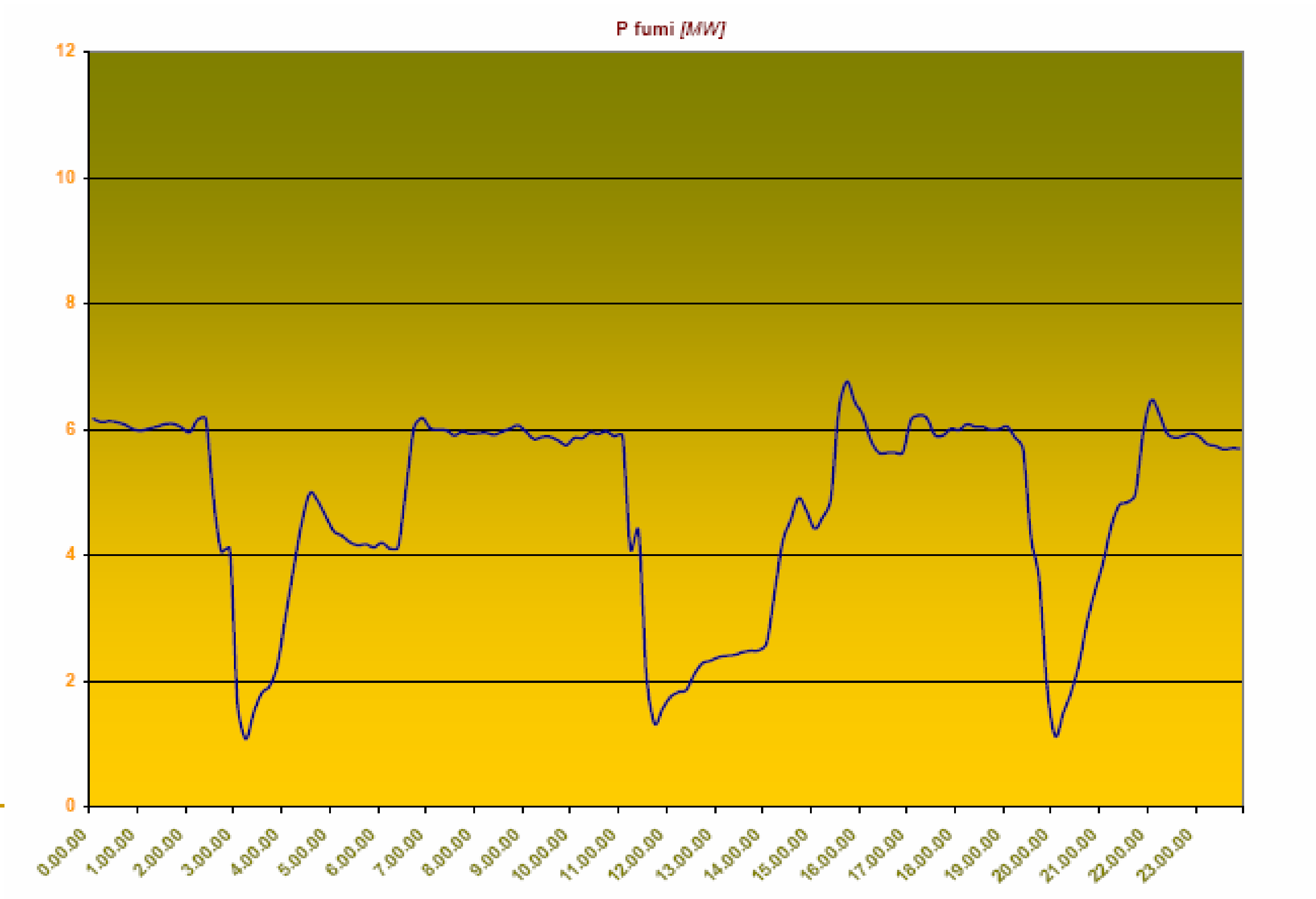
Thermal power in flue gas from furnace 1



Heating furnaces

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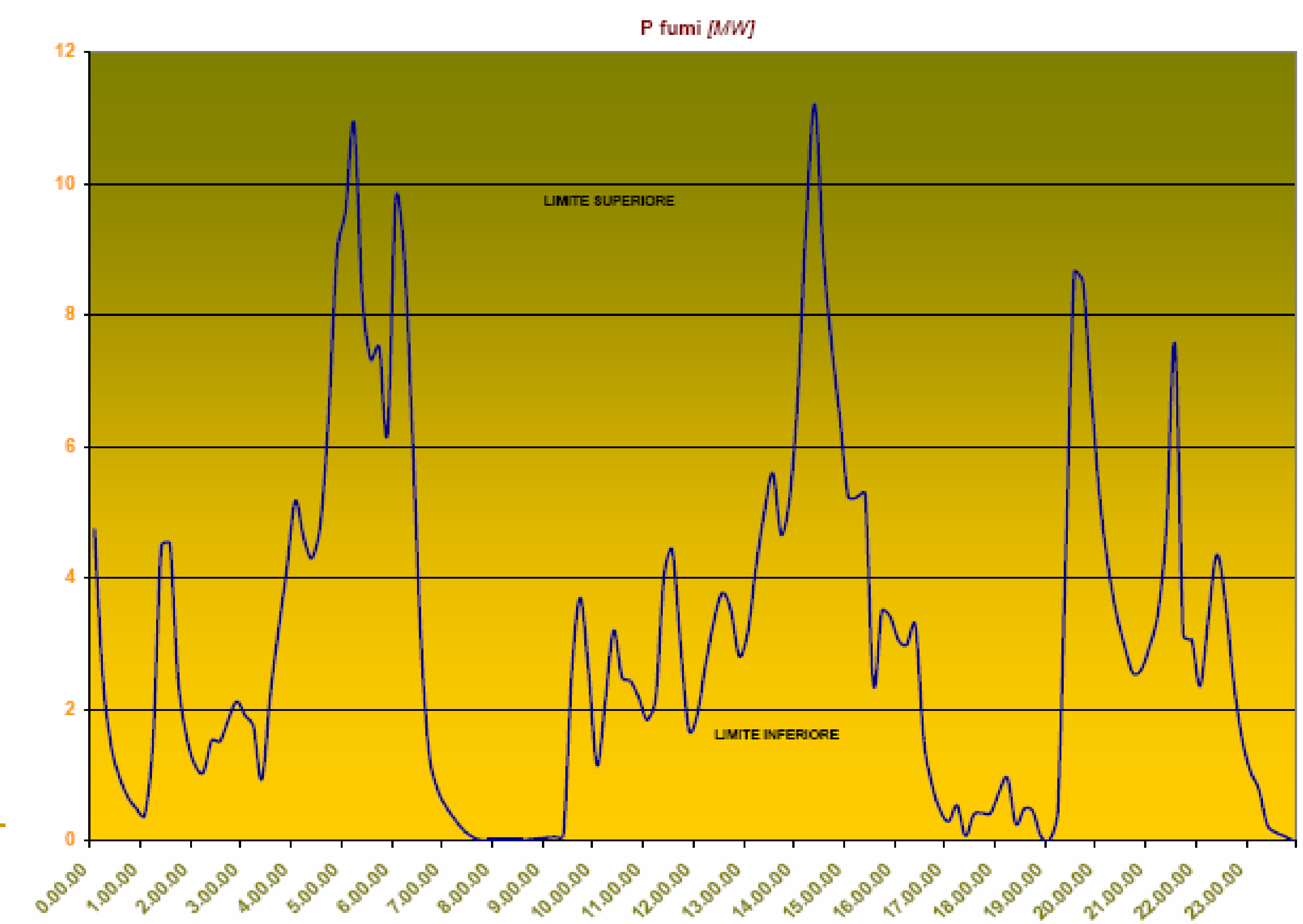
Thermal power in flue gas from furnace 2



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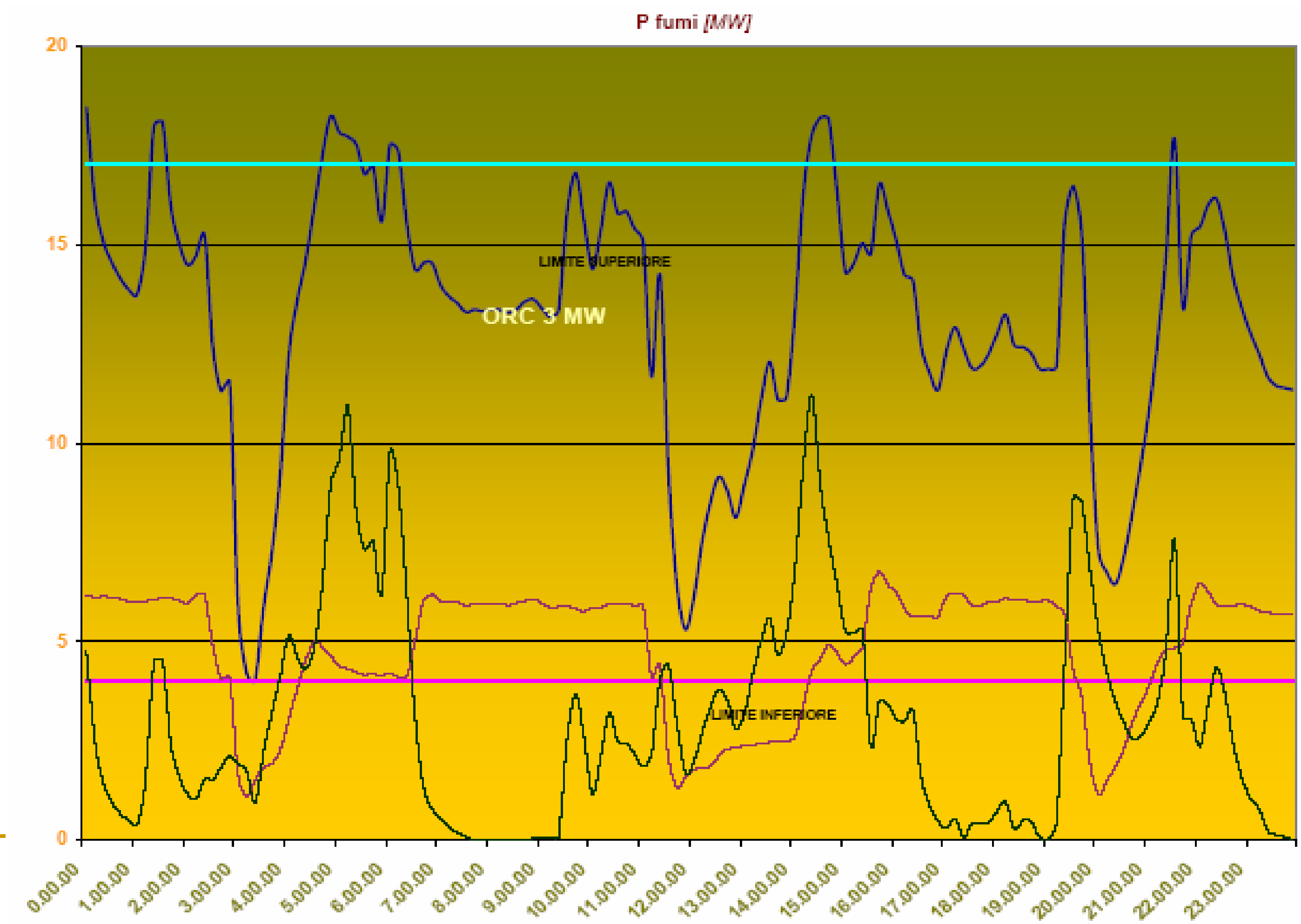
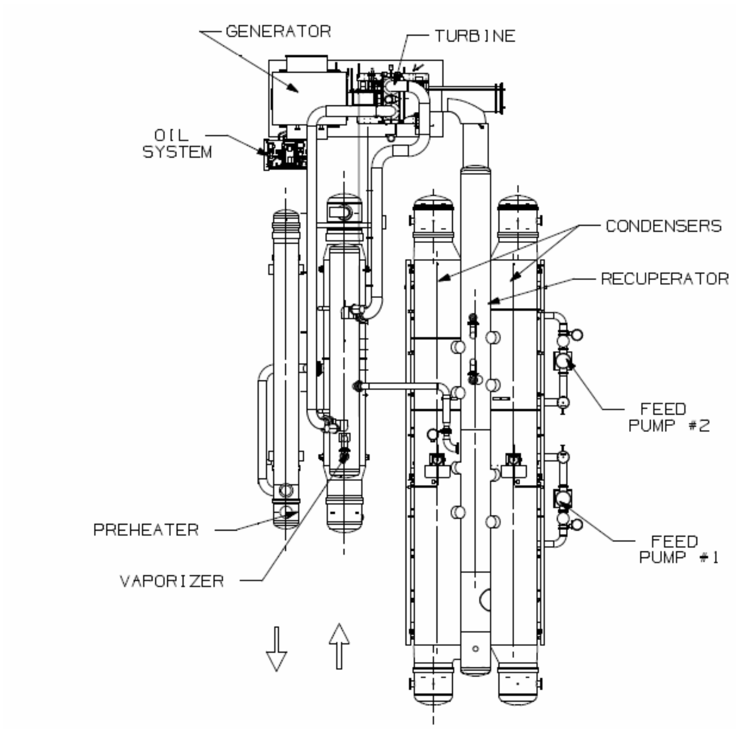
Total thermal power in flue gas



Heating furnaces



ORC		
Pe Installed	**3.000**	kW
Pe **media** Gross	**2.900**	kW
T diathermic oil IN	**270**	℃
T diathermic oil OUT	**120**	℃
Cooling water flow rate **(20 – 30 ℃)**	**1.000**	Mc/h
Diathermic oil flow rate	**150**	t/h
Pe **media** Net	**2.500**	kW
Ee Produced	**16.600**	MWh/year
TEE	**3.700**	-

Economical assessment (1)

Project data

- **Power installed** **3 MWh**
- **Internal consumption** **0,4 MWh**
- **Produced energy** **16.600**
  MWh/anno

Economical assessment (2)

Italian situation – ESCO

Project cost	4.000.000 €
Inflation rate	2 %
Discount rate (10 years)	4,5%
Equity	30%
EE price (BT)	80 €/MWh
EE applied price	60 €/MWh
TEE (5 years)	3700
TEE price	65 €/TEE
IRR (8 years)	25%
Pay Back	3,5 years
Cash flow for enterprise	> 300.000 €/y

Economical assessment (3)

Bulgarian situation

Project cost	3.500.000 €
Inflation rate	5%
Discount rate (10 anni)	8%
Equity	30%
EE price(BT)	40 €/MWh
TIR (8 years)	10%
Pay Back	8 years

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CASE STUY 2

Cogeneration in a tiles factory

COGENERATION

A cogeneration plant is a thermoelectrical plant in which a power source (the fuel) is used to produce mechanical energy (electrical energy) and heat in cascade, realizing more rational use of the contained energy in the fuel regarding processes that separately produce the two shapes of energy.

Application to tiles sector

It has been used an engine fuelled by natural gas. It produces: electric power through an alternator mounted on the drive shaft; warm air, to use in the dryer, through the recovery of thermal energy from the water of cooling, the lubricating oil and the engine supercharging air.

The convenience (1)

If, for absurdity, we thought to use the gas engine in order to produce exclusively electric power, we would notice that the electric efficiency would be too much low and the production cost of the kWh advanced to that one of purchase. Analogous, if we thought to use the gas engine to produce exclusively heat, we would notice that the thermal efficiency would be too much low regarding one normal boiler.

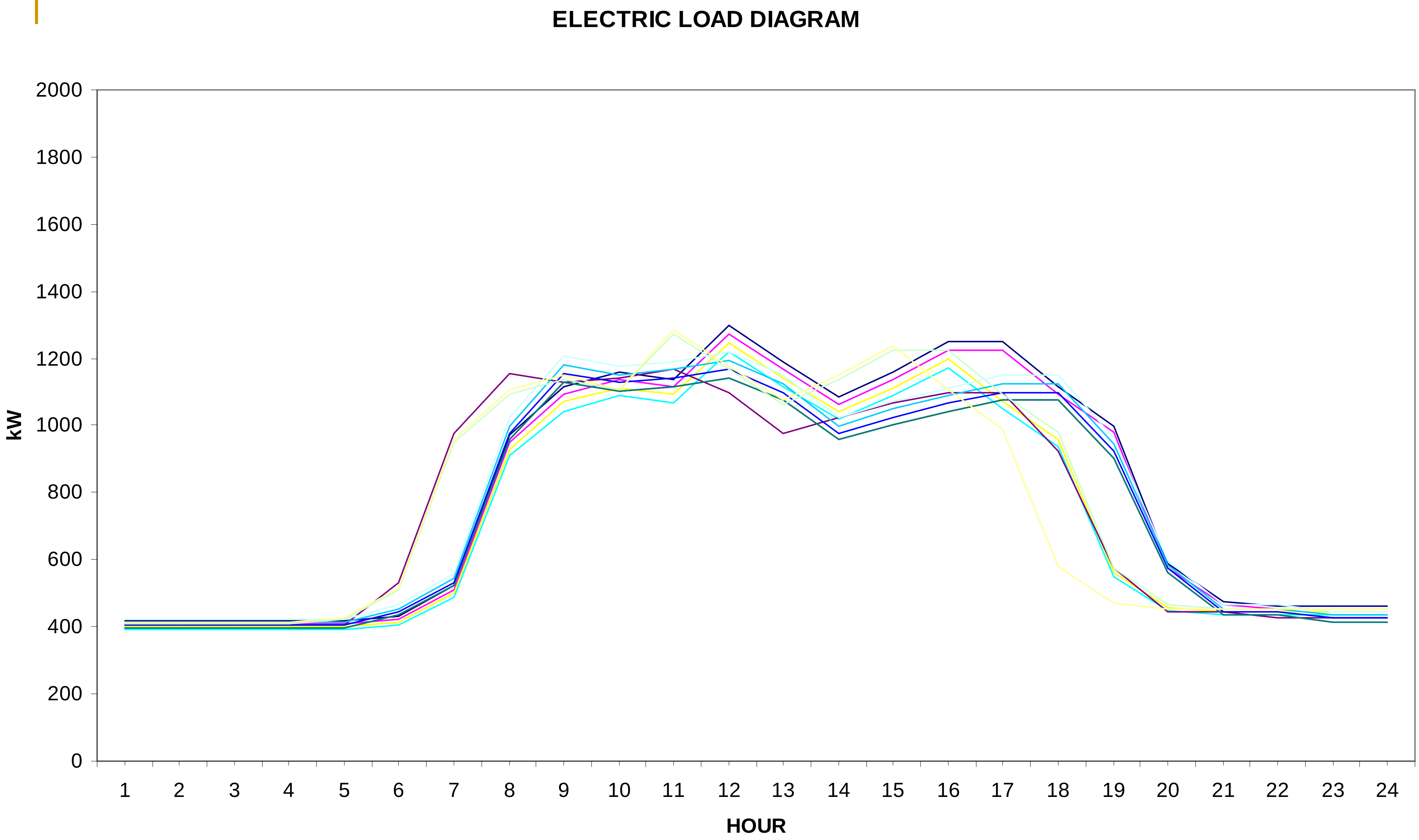
The convenience (2)

- Only taking advantage of both at the same time the produced shapes of energy, the convenience is obtained to use cogeneration.
- The convenience as well as more is high how much longest is the period in which at the same time the two shapes of energy are requested.

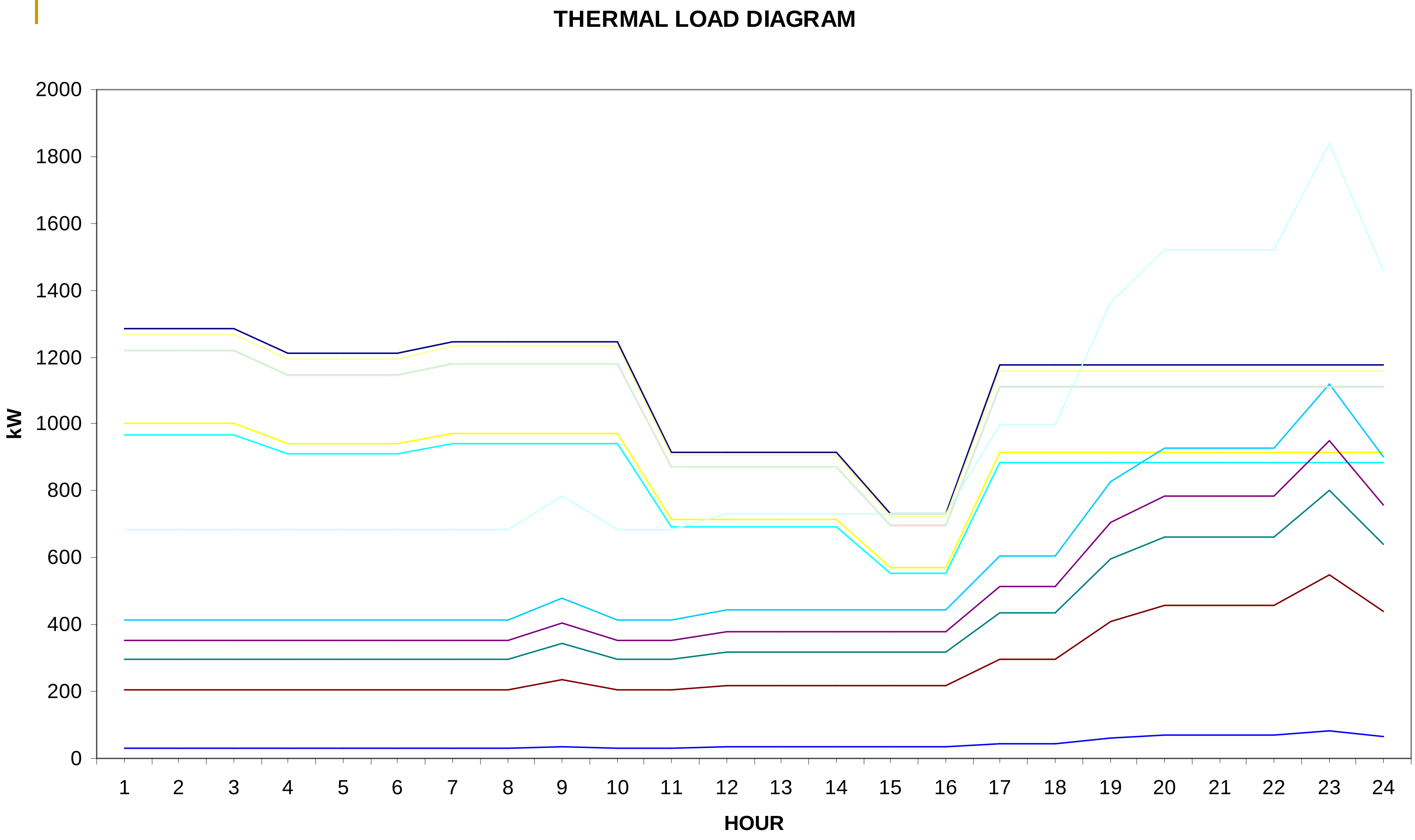
Main data

It is necessary, therefore, to know in detail the courses of loads (thermal and electric) of the process to estimate:

- the percentage of time in which electric and thermal energy are requested at the same time;
- the value of the aforesaid requirements;
- the duration of the same ones.

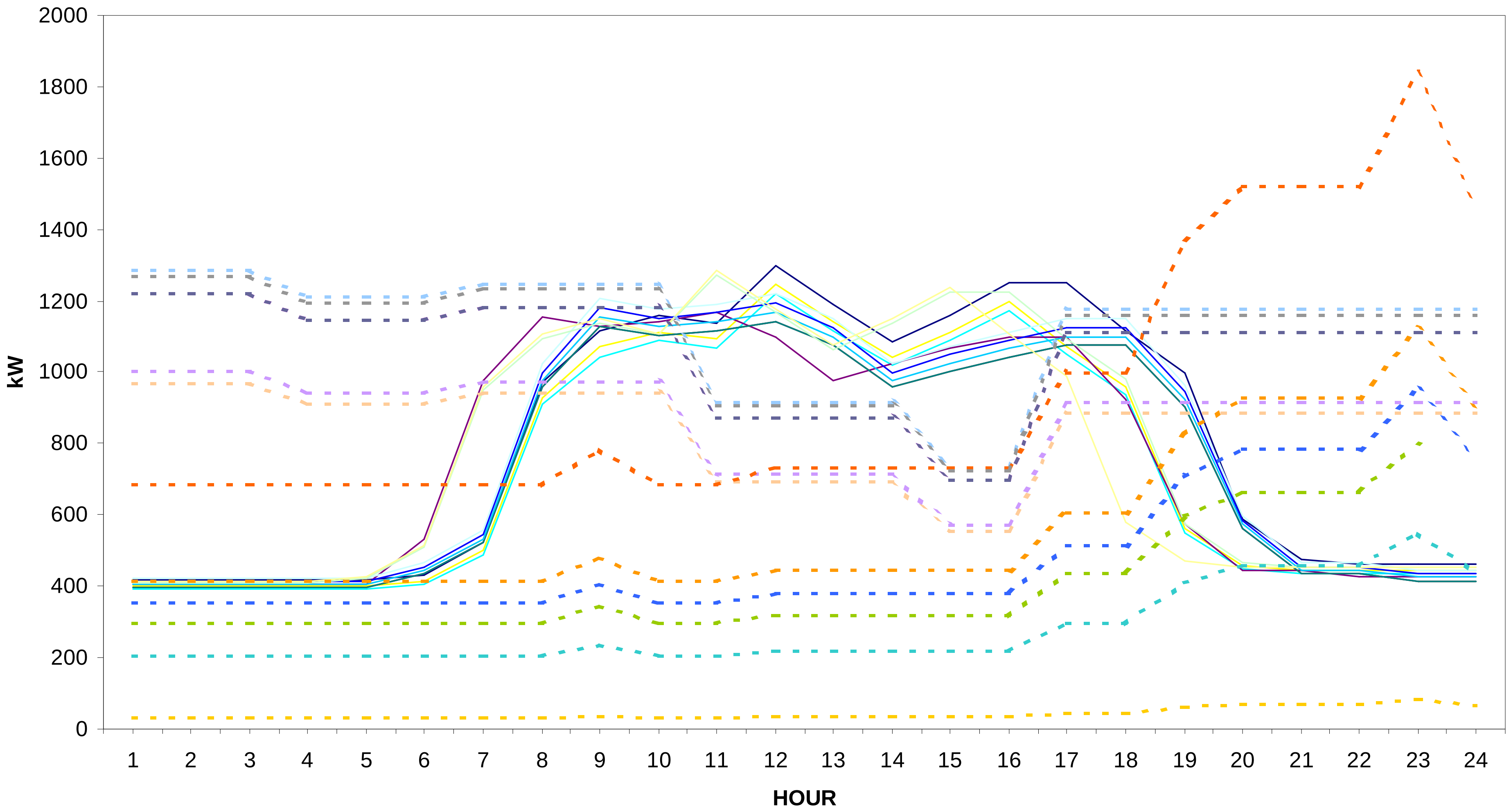


ELECTRIC LOAD DIAGRAM
kW
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
HOUR



THERMAL LOAD DIAGRAM
kW
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
HOUR

TOTAL LOAD DIAGRAM



ELECTRICAL AND THERMAL LOAD (kW)

hour	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
	el	th	el	th	el	th	el	th	el	th	el	th	el	th	el	th	el	th	el	th	el	th	el	th
1	418	1285	410	1219	401	1002	393	968	404	353	396	204	396	297	404	31	413	415	422	682	410	1219	414	1269
2	418	1285	410	1219	401	1002	393	968	404	353	396	204	396	297	404	31	413	415	422	682	410	1219	414	1269
3	418	1285	410	1219	401	1002	393	968	404	353	396	204	396	297	404	31	413	415	422	682	410	1219	414	1269
4	418	1211	410	1148	401	943	393	912	404	353	396	204	396	297	404	31	413	415	422	682	410	1148	414	1195
5	418	1211	410	1148	401	943	393	912	404	353	396	204	396	297	404	31	413	415	422	682	424	1148	429	1195
6	433	1211	424	1148	415	943	407	912	533	353	435	204	435	297	445	31	455	415	465	682	511	1148	516	1195
7	521	1248	511	1183	500	972	489	940	978	353	521	204	521	297	533	31	545	415	556	682	950	1183	960	1231
8	970	1248	950	1183	930	972	910	940	1154	353	957	204	957	297	978	31	1000	415	1022	682	1094	1183	1105	1231
9	1117	1248	1094	1183	1071	972	1043	940	1127	407	1129	235	1129	343	1154	35	1180	479	1206	786	1137	1183	1149	1231
10	1161	1248	1137	1183	1113	972	1090	940	1140	353	1102	204	1102	297	1127	31	1152	415	1177	682	1106	1183	1107	1231
11	1139	917	1116	870	1092	715	1069	691	1167	353	1115	204	1115	297	1140	31	1166	415	1191	682	1274	870	1287	905
12	1300	917	1274	870	1247	715	1221	691	1100	380	1141	220	1141	320	1167	33	1193	446	1219	733	1166	870	1178	905
13	1190	917	1166	870	1142	715	1117	691	978	380	1075	220	1075	320	1100	33	1124	446	1149	733	1065	870	1076	905
14	1087	917	1065	870	1043	715	1021	691	1025	380	957	220	957	320	978	33	1000	446	1022	733	1137	870	1149	905
15	1161	734	1137	696	1113	572	1090	553	1066	380	1003	220	1003	320	1025	33	1048	446	1071	733	1224	696	1236	725
16	1249	734	1224	696	1198	572	1172	553	1100	380	1042	220	1042	320	1066	33	1090	446	1113	733	1224	696	1105	725
17	1249	1175	1224	1113	1071	915	1048	885	1100	516	1075	298	1075	434	1100	45	1124	607	1149	996	1094	1113	989	1159
18	1117	1175	1094	1113	958	915	938	885	924	516	1075	298	1075	434	1100	45	1124	607	1149	996	979	1113	581	1159
19	999	1175	979	1113	563	915	551	885	573	706	904	409	904	595	924	62	945	830	965	1364	576	1113	472	1159
20	587	1175	576	1113	458	915	448	885	445	783	561	456	561	663	573	69	586	926	599	1521	468	1113	453	1159
21	477	1175	468	1113	444	915	434	885	445	783	435	456	435	663	445	69	455	926	465	1521	453	1113	453	1159
22	463	1175	453	1113	444	915	434	885	425	783	435	456	435	663	445	69	455	926	465	1521	453	1113	453	1159
23	463	1175	453	1113	444	915	434	885	425	951	415	551	415	801	425	83	434	1118	444	1837	453	1113	453	1159
24	463	1175	453	1113	444	915	434	885	425	760	415	440	415	640	425	66	434	904	444	1460	453	1113	453	1159

Plant dimensioning

From the load diagrams we can look at that requirements exist base of approximately 400 kW for the electric load and the thermal load too. A gas engine was has been chosen to cover only the base of the electric load diagram.

The gas engine provides an electrical power of 360 kW and a thermal energy of 735 kW under warm air shape send to the dryer directly.

The engine consumption is equal to 1125 kW.

Cost/benefits analysis (1)

For the economic analysis has been assumed various conditions on the base of economic data Italians and Bulgarians.

	Italy	Bulgaria
Electric energy price	10 c€/kWh	4 c€/kWh
Natural gas price	30 c€/Nm^3	18 c€/Nm^3
Interest real rate (%)	4,5	8
TEE Price (€)	65	0
Inflation (%)	2	5

Cost/benefits analysis(2)

The hour saving is:

360/0,36 + 735/0,97 – 1125 = 633 kW

In economic terms (€):

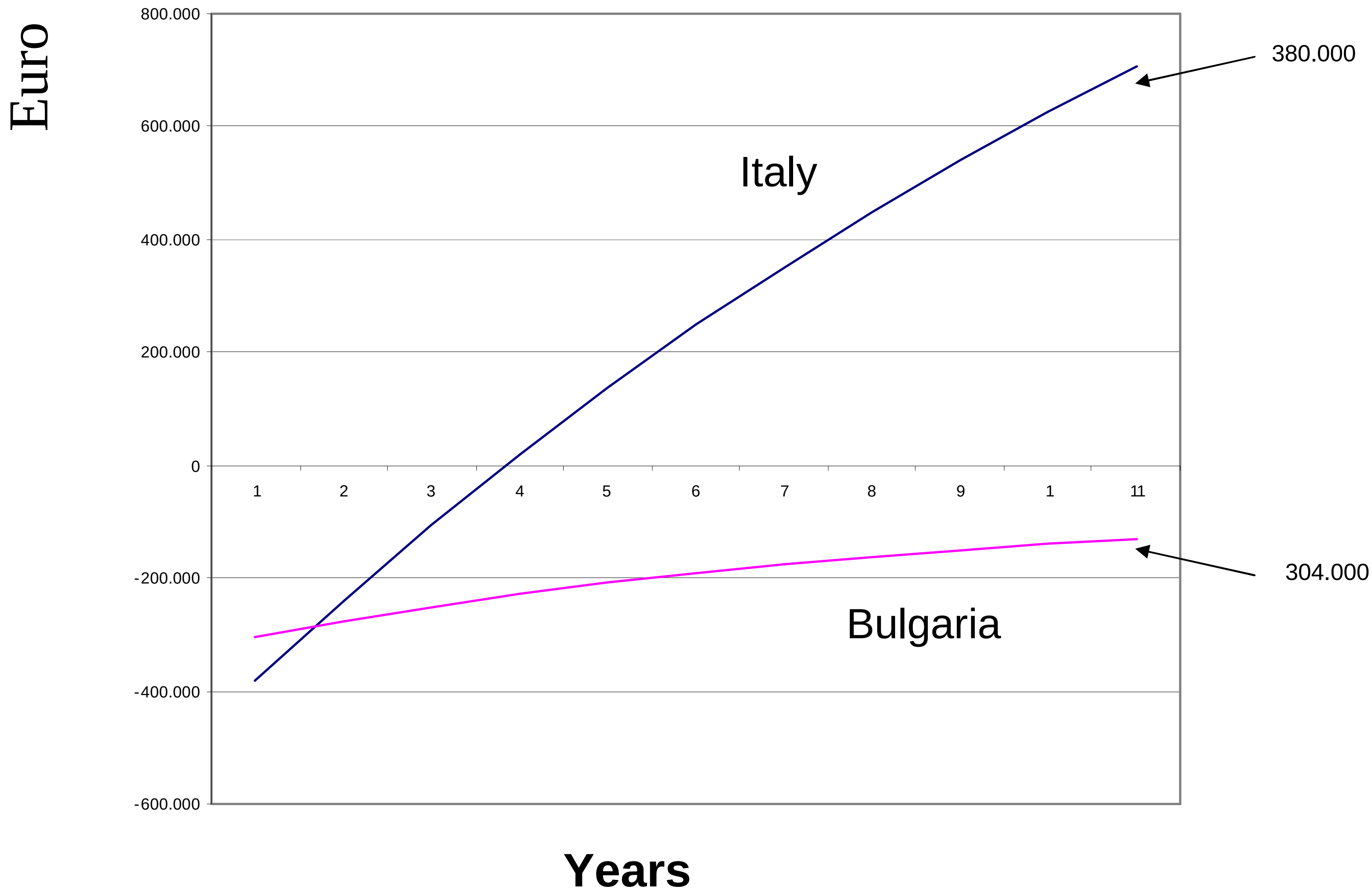
	Italy	Bulgaria
Electric energy	- 36,00	-14,40
Thermal energy	+11,55	+6,93
Manteinance	+1,48	+1,48
TEE	- 5,15	---
	------------	-----------
Total hour saving	- 28,12	- 5,99

Cost/benefits analysis(3)

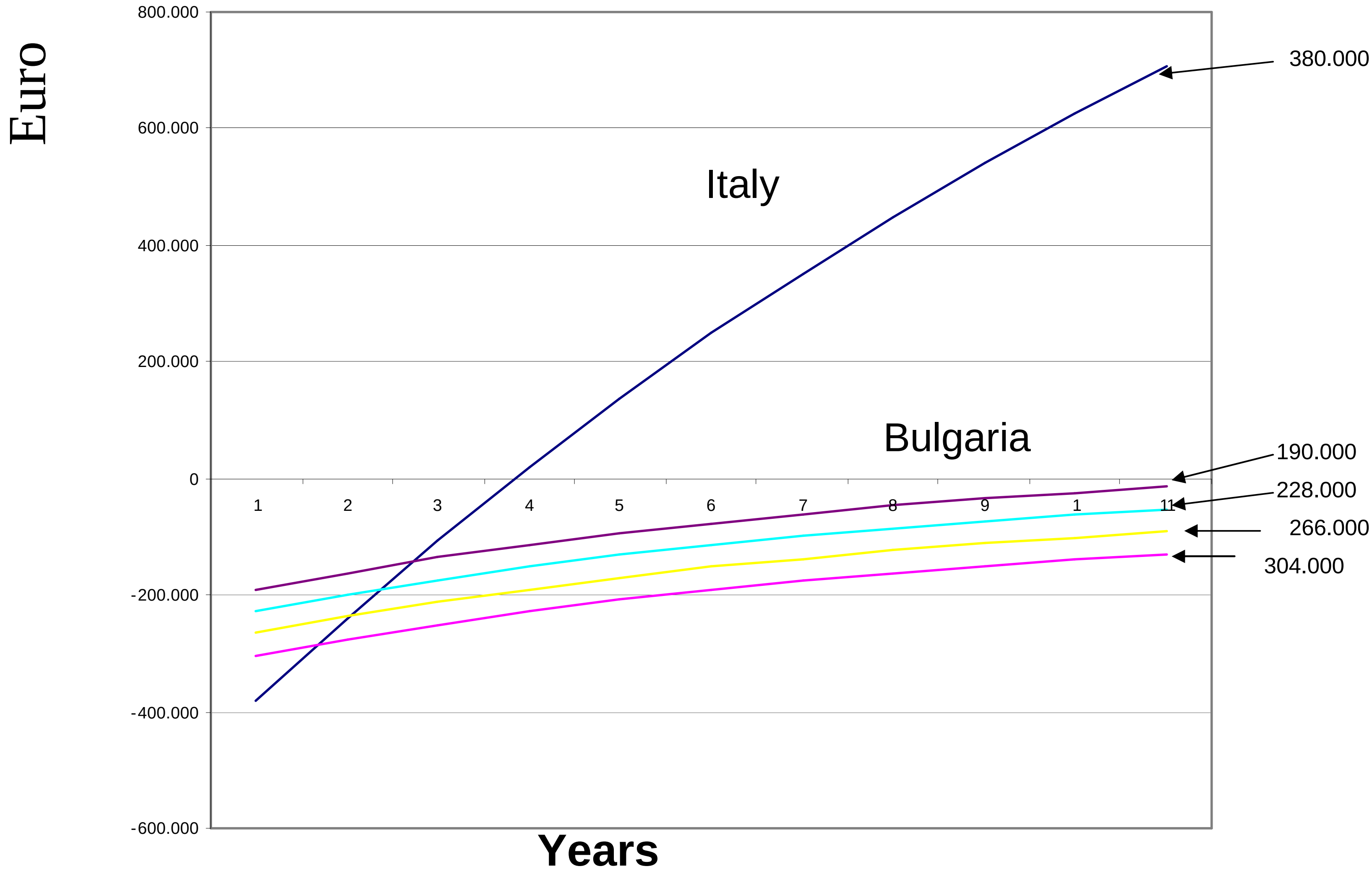
Assuming a load factor of 5376 h/year, a life of the engine of 55.000 hours and, therefore, a duration of the investment to approximately 10 years, it turns out how much follows:

	Italy	Bulgaria
Annual saving (€)	151.157	32.206
Investment (€)	380.000	304.000
Payback time (years)	2,51	9,44
DCF (€)	706.642	-129.243
TIR (%)	30	- 11

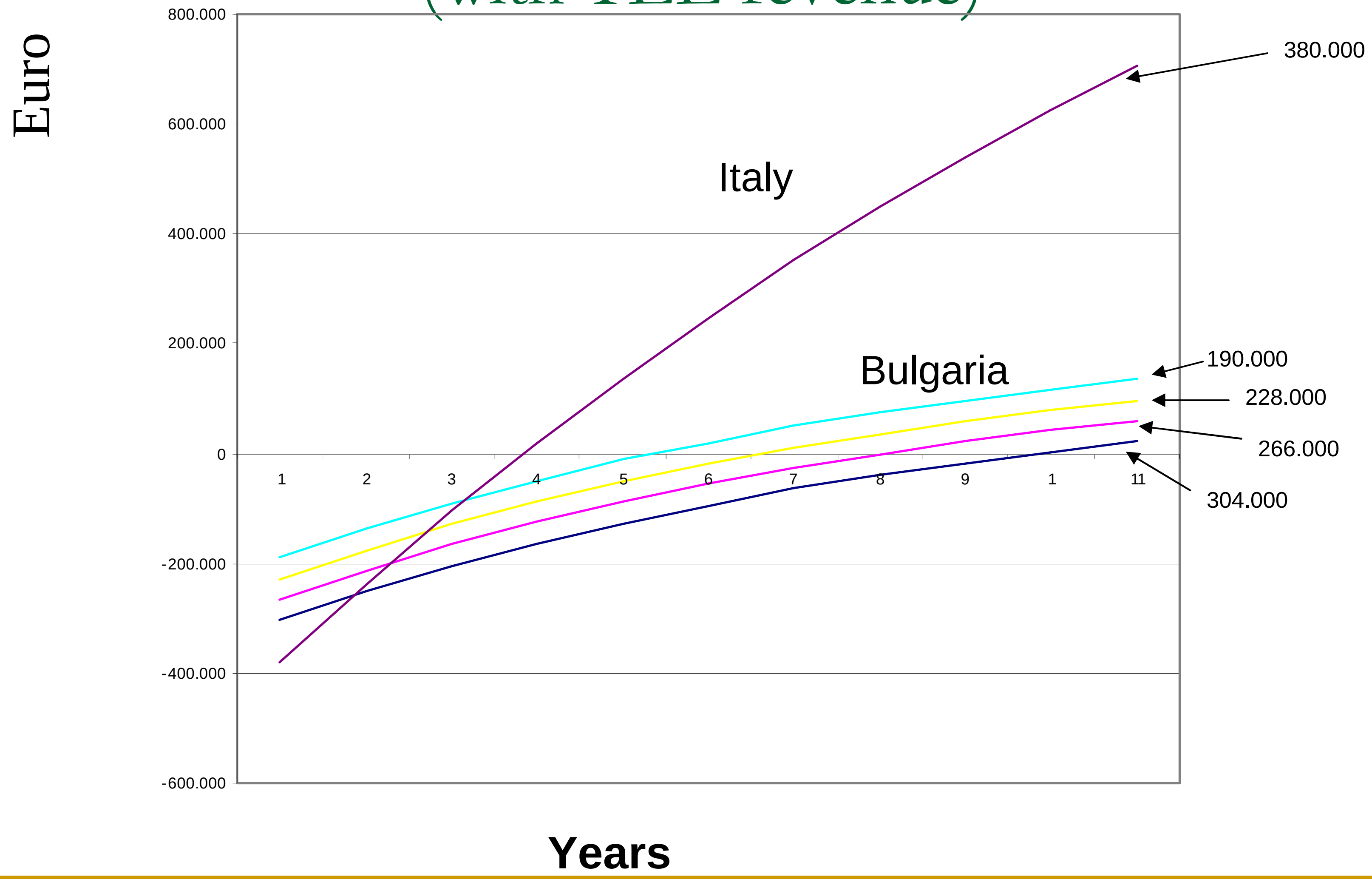
Discounted cash flow diagram



Discounted cash flow diagram



Discounted cash flow diagram (with TEE revenue)



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CASE STUY 3

Compressed air optimization

COMPRESSED AIR

Generally, the energy incidence is about 70 % in the costs of a compressed air system.

Power kW	Hours/year	full load (%)	no load (%)	standby (%)	Annual energy (kWh)	Annual cost (€)	
						Italy	Bulgaria
18	6.000	60	15	25	75.000	7.500	3.000
30	6.000	60	15	25	125.000	12.500	5.000

The power of compressors is generally oversized and this generates the necessity of a regulation that comes put into effect making it to work to empty in lack of demand for air (sees table).

Some interventions

The parameters that can influence on the operating costs of a compressed air system, are:

- Pressure and flow rate;
- compressed air quality;
- circuit losses;
- compressed air plant.

Pressure and flow rate

- Verify that it are fixed in order to the effective necessities and, if the plant demands two levels of pressure, estimate the convenience to install two compressors in such a way to produce the two requested levels.
  As an example, 1 bar of increase of the produced pressure consumes approximately 6 % in more than electric power. It is important also to try to organize the job of the several users in such a way to flatten the most possible demand.

Compressed air quality

It is tied to the presence of water and lubricating oil within the same air. For the water it would go estimated the technical-economic convenience of the use of centralized air dryers in alternative to the separators of condense.

For the oil it would go estimated the technical-economic convenience of the use of compressors without lubrication, more expensive, in alternative to those lubricates, less expensive, but demanding the adoption of opportune filters.

Circuit losses(1)

They are source of waste of considerable energy.

Hole diameter (mm)	Air flow rate at 7 bar (l/s)	Waste power (kW)
1	1,2	0,4
3	11,1	4,0
5	31	10,8
10	124	43

The previous table shows the air flow rate from a hole on a circuit to the pressure of 7 bars.

Circuit losses(2)

Therefore, as an example, if along the compressed air network there were zones of loss whose total surface is equivalent to a hole of 3 millimeter of diameter and our compressor works 100 hours the week for approximately 5200 hours/year, the economic loss, with a cost of the energy of 0,04 €/kWh, will be approximately 800 €/y.

It will be therefore opportune periodically to try the estate of the network detaching all uses of compressed air leaving the network in the exercise pressure. If the circuit does not have losses, the compressor will not be put in function.

Compressed air plant

The consumed energy in order to compress the air increases with the temperature of the same one.

It is therefore convenient to capture the air from outside and opportunely filter it before sending to the compressors.

High efficiency electric engines (1)

- Last, but not the least, to the scope of the energy saving, the adoption of high efficiency electric engines.
  - In the greater part of the cases the engines are oversized.
  - The electric engines are designed for having their maximum electric efficiency around 75 % of the nominal load.

High efficiency electric engines(2)

If the engine works between 50 % and 100 % of its nominal load, the electric efficiency decreases regarding its maximum, but not a lot. If instead the engine works under 50 % of its nominal load, the electric efficiency collapses to values many bottoms.

Contrarily to how much it can be thought, this case happens more frequently.

High efficiency electric engines(3)

It is to consider also that the power factor (cos φ) is as well as the more high how much the power which the engine works is next to its nominal load.

In synthesis, an engine oversized involve two disadvantage main, low electric efficiency and low power factor.

These disadvantages determine greater energetic consumptions.

High efficiency electric engines(4)

We suppose to have an engine of 11 kW that works 4,000 hours the year with a load factor of 40 %, an electric efficiency of 78 % and an annual consumption of 22.564 kWh.

It could be replaced with a high efficiency engine of 5,5 kW with load coefficient of 80 %, an electric efficiency of 91 %, a cost of purchase of approximately 300 € and an annual consumption, providing the same service, of 19.555 kWh.

High efficiency electric engines(5)

A smaller annual consumption of electric power of approximately 3.000 kWh could be obtained at the cost of 0,04 €/kWh. It involves an annual saving of approximately 120 € and a payback time more then two years.

An additional advantage is to improve the cos φ from 0,6 to 0,8.

That determines a further saving of approximately 50 € for the purchase of the condensers that deals to come down payback time less than two years.

…thank you for your attention!