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MATHEMATICAL MODELLING AND OPTIMIZATION OF CHP SYSTEMS FOR HOSPITALS IN TURKEY

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PRESENTATION TOPICS

- Basic Frame of Regulations for CHP Systems in Turkey.
- Outlines of Hospitals and CHP Potential in Turkish Hospitals.
- Mathematical Modelling Approach for CHP Systems' Optimization
- A Case Study (Hospital) In Turkey.

BASIC REGULATIONS FOR CHP SYSTEMS

Cogeneration and trigeneration projects have been developing based on the regulations by Energy Ministry and Energy Market Regulatory Authority (EMRA) in Turkey since 20 years.

All CHP facility had to get licence from EMRA until 2010, and all these facilities should be private company as well. This major rule was obstacle to establish CHP systems for state offices, public facilities, foundations and natural personalities.

However, According to regulation dated 03th December 2010 published by EMRA, legal and natural personalities get right to construct cogeneration systems without licence and without being a company if only to meet for own electrical consumption.

This regulation provides effortlessness for foundations, sites, state offices and small facilities to establish cogeneration systems.

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BASIC REGULATIONS FOR CHP SYSTEMS

Industrial facilities were pioneer for CHP system until 2010 and reached a certain maturity as potential by 7.000 MWe installed power. However, service facilities such as hospitals, hotels, shopping malls, universities and public buildings have been shining since 5 years.

When we consider that there are 1.500 hospitals, thousands of hotels and hundreds of shopping malls and universities in Turkey, it is clear that there is huge potential for CHP systems in near future.

BASIC REGULATIONS FOR CHP SYSTEMS

WITH LICENSE :

- No restriction for power output and efficiency.
- EMRA (Energy Market Regulatory Authority) is responsible for licenses.
- Legal Procedure is more detailed and long-term.
- Electricity Market Financial Settlement Center determines the Daily prices.
- Facilities has to pay some certain fee to distribution and transmission companies.

WITHOUT LICENSE :

- Restricton for power output and efficiency.
- * Micro CHP (<100 kWe)
- * Renewable Energy Sources (<1 MWe)
- * ***High Efficient CHP only for own consumption (Parallel to EU 2004/8/EC Directive)***
- Local Electricity Distribution Company is responsible for permissions.
- Legal Procedure is more simple and short-term.
- Facilities do not pay any fee to distribution and transmission companies.

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HOSPITALS IN NUMBERS (ELECTRICITY)

TYPE	STATE HOSPITALS	UNIVERSITY HOSPITALS	PRIVATE HOSPITALS	TOTAL
QUANTITY	860	65	555	**1.480**
NO. OF BEDS	129.000	38.000	34.000	**201.000**
AVG. NO. OF BEDS	150	585	61	
AVG. ELECTRICITY CONSUMPTION (kWh/m^2)	120	160	310	
TOTAL ELECTRICITY CONSUMPTION (GWh/year)	1.850	710	1.250	**3.810**

1,52 % of Turkey's total electricity consumption takes place at the hospitals.

Depending on the power need of hospitals instantaneous demand trends;
Winter** months at night (24: 00-05: 00) ranged between **260-290 MWe
***Summer** daylight hours (11: 00-16: 00) ranged between **630-680 MWe**.*
*The **average** annual **demand** is around **435 MW**.*

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HOSPITALS IN NUMBERS (HEAT)

TYPE	STATE HOSPITALS	UNIVERSITY HOSPITALS	PRIVATE HOSPITALS	TOTAL
QUANTITY	860	65	555	**1.480**
NO. OF BEDS	129.000	38.000	34.000	**201.000**
AVG. NO. OF BEDS	150	585	61	
AVG. HEAT DEMAND (kWh/m². year)	200-350	200-350	200-350	
TOTAL HEAT DEMAND (GWh/year)	3.200	1.230	2.170	**6.600**

When we consider the heat demand is provided by hot water boilers by natural gas with 90% efficiency;

Total natural gas consumption is 765 million m³/year.

1,47 % of Turkey's total natural gas consumption takes place at the hospitals.

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OPTIMIZATION OF CHP SYSTEM DESIGN

3 MAJOR PARAMETERS FOR MAXIMIZATION;

- Operation of CHP unit at maximum capacity
- Meeting electricity consumption at maximum rate
- Meeting heating & cooling demand at maximum rate

Cogeneration systems are produced in some certain nominal power steps and have to operate in some certain capacity range.

Hospitals' daily and seasonal consumption of electricity, heating and cooling demands vary in wide range. Because of such restrictions obligate to make optimization in aim of determining cogeneration nominal capacity.

There are three main parameters for determining capacity of a cogeneration system. These are; to meet electrical consumption in maximum rate, to meet cooling-heating demands in maximum rate, and to operate cogeneration system at maximum load. However, it is impossible to maximize these 3 parameters at the same time. Therefore, an optimization study has to be derived.

OPTIMIZATION to minimize payback period.

MISTAKES ON DETERMINING CHP CAPACITY

- Determination of CHP capacity according to Hospital's total transformer or total power demand.
- Ignoring consumption differences between Winter & Summer and Day & Night.
- Ignoring a minimum consumption from the grid.
- Determination of CHP capacity according to heat demand instead of electricity consumption.
- Ignoring CHP units' can not operate under 35-40% of nominal power output.

HOSPITAL CASE STUDY

Project Location	: İstanbul
Altitude (from sea level)	: 80 mt.
Max. Temperature (Summer)	: 35 °C
Min. Temperature (Winter)	: -3 °C
Total area	: 21.000 m²
Total Installed Transformer Power	: 2 x 1.600 kVA
Cogeneration Total Elec. Power	: 800 kWe
Cogeneration Total Heat Power	: 915 kWth.
Electricity Unit Price (EUR/ MWH)	: 97,50
Natural Gas Unit Price (EUR/ 1000 M3)	: 270,00

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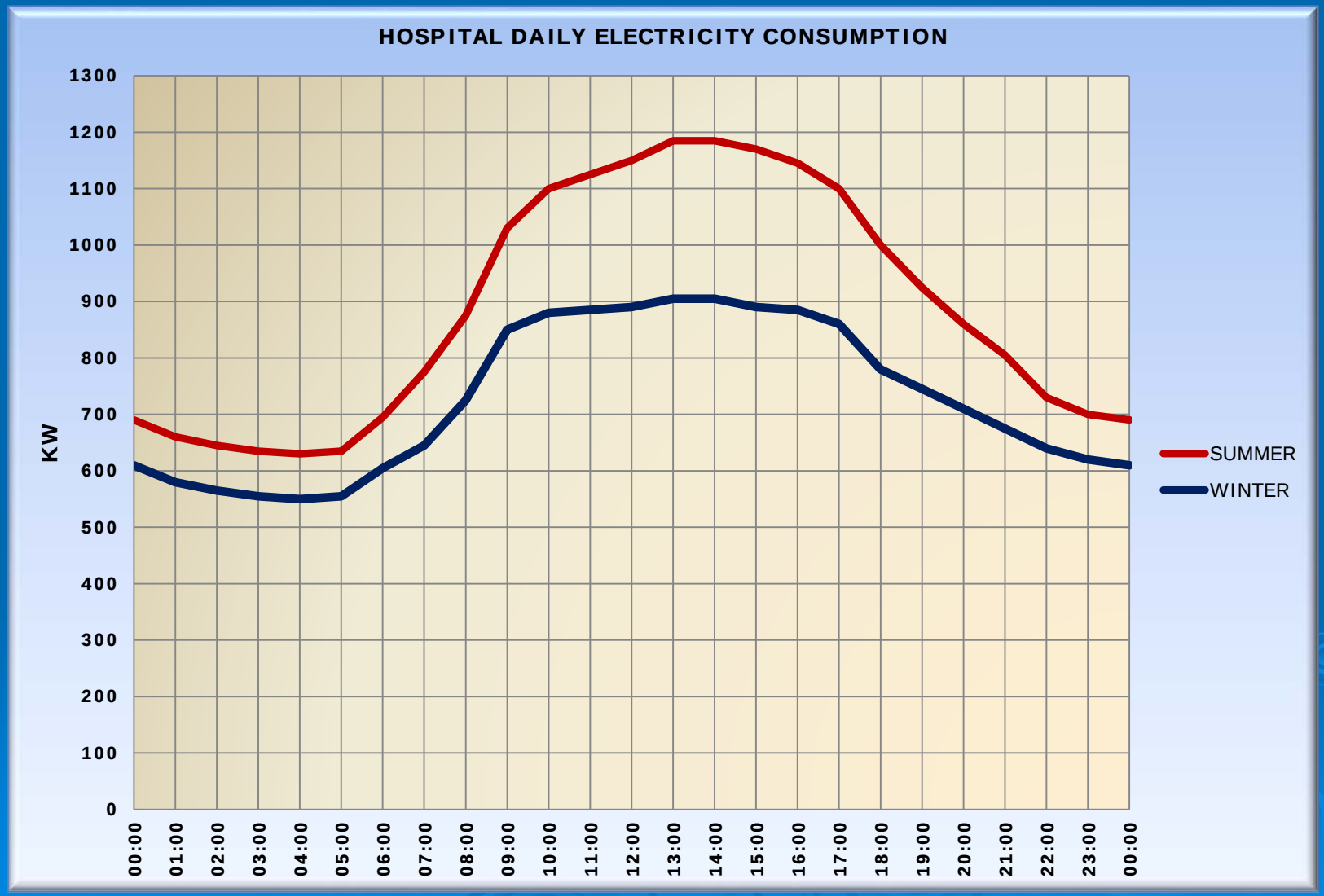
DAILY ELECTRICITY CONSUMPTION OF THE HOSPITAL



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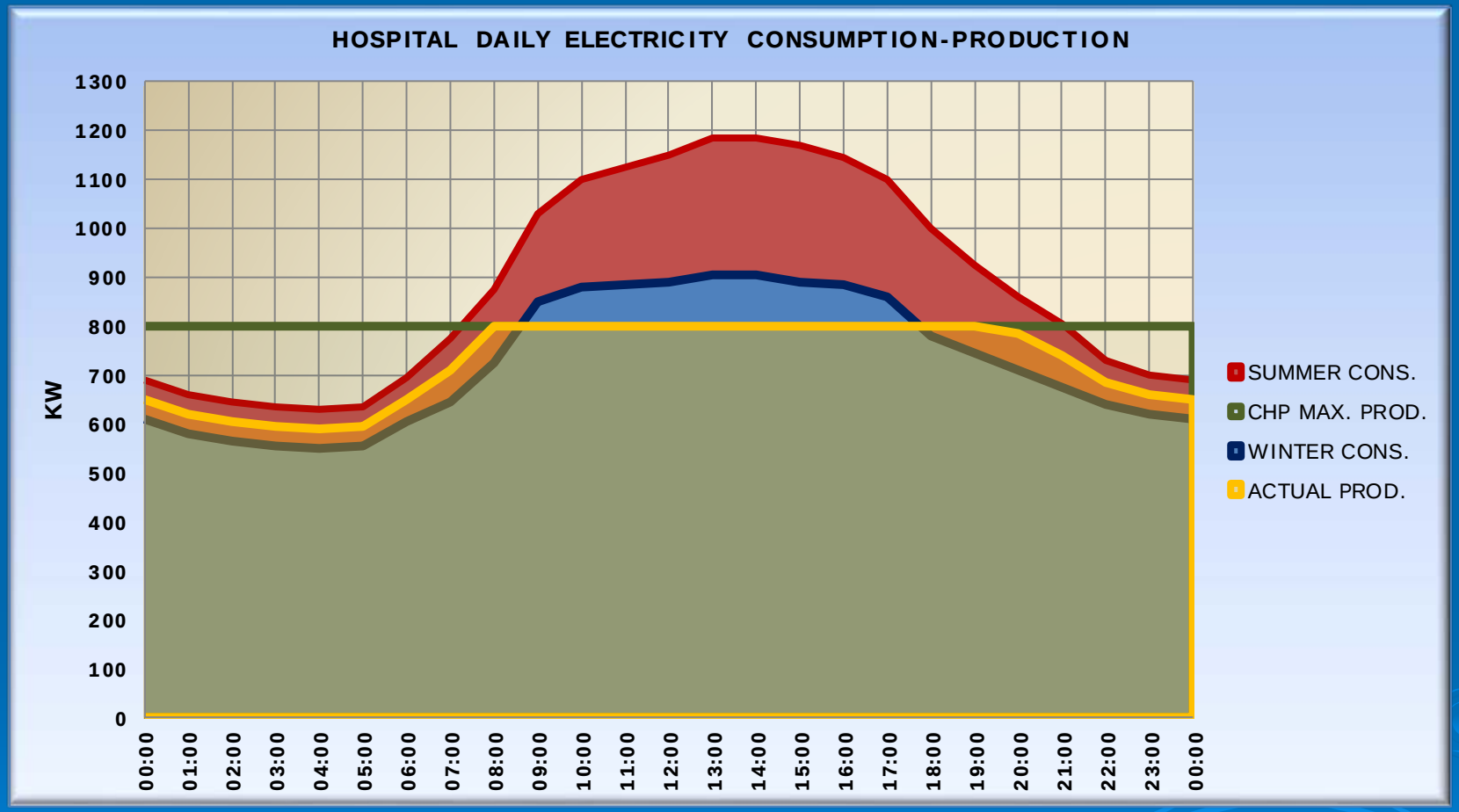
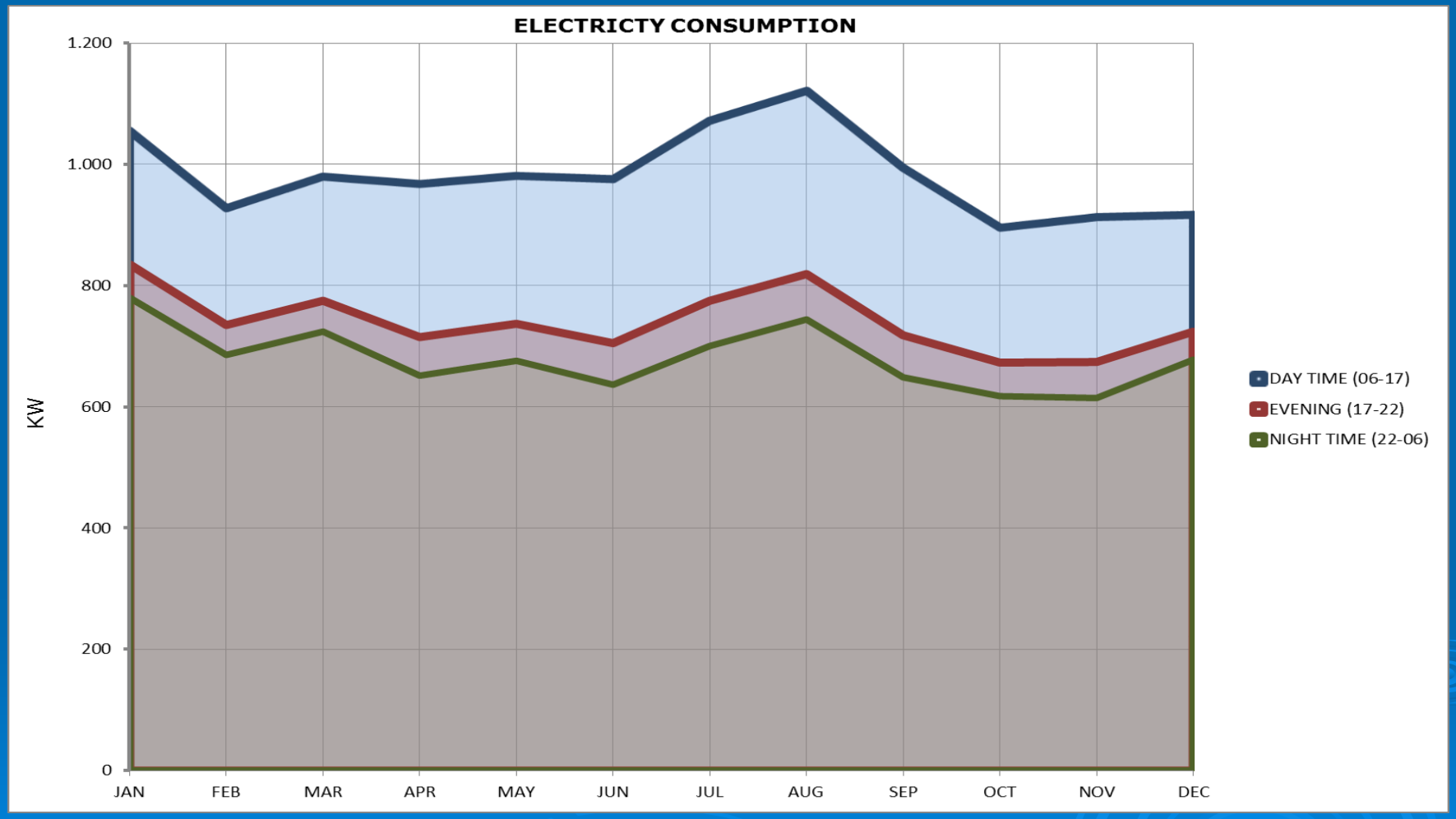
ELEC. CONSUMPTION & PRODUCTION GRAPH



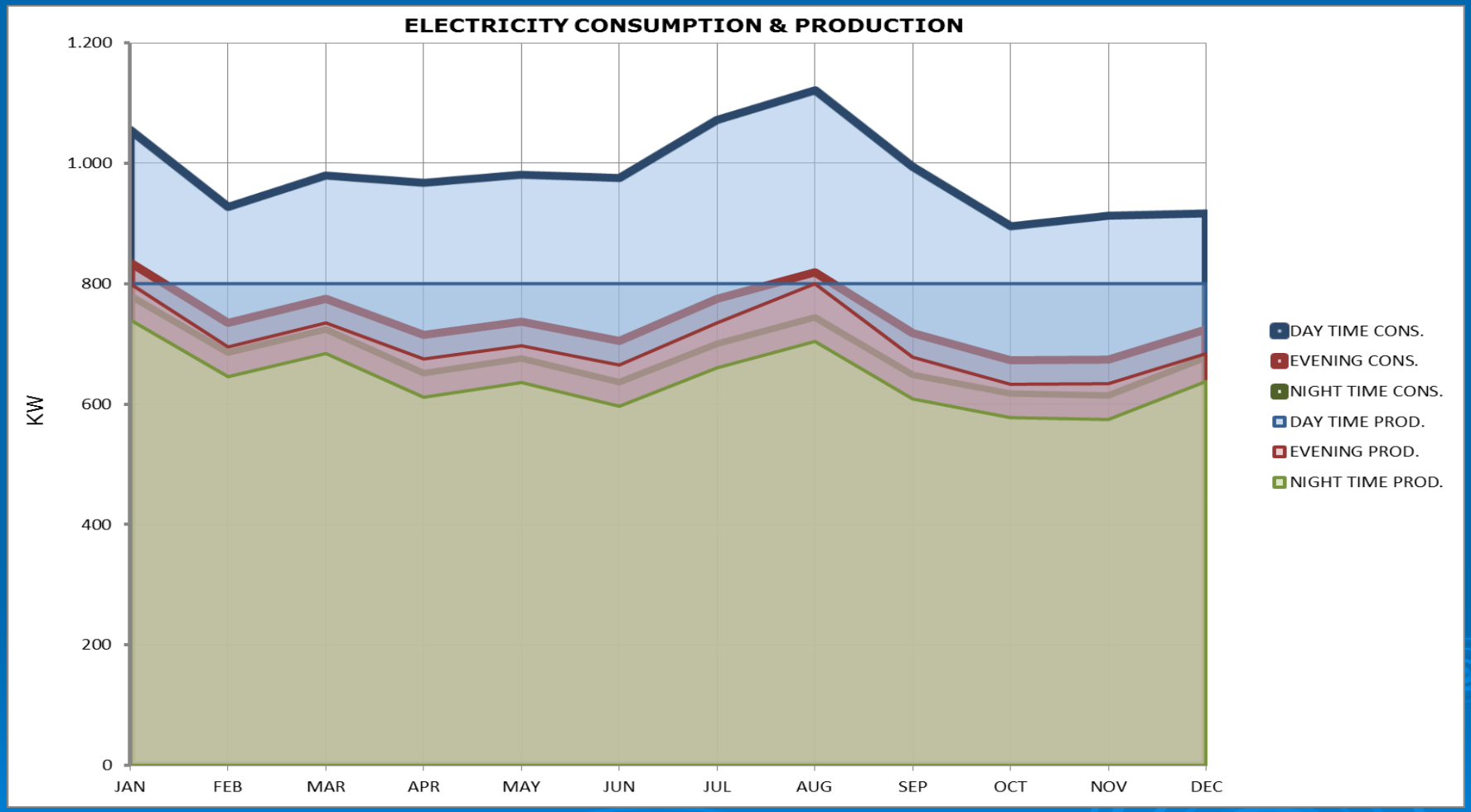
Power output of CHP system is determined to meet facility's base own electricity consumption.

System meets 84 % of consumption by running at 91 % load yearly cumulative.

SEASONAL
ELECTRICITY CONSUMPTION OF THE HOSPITAL



ELECTRICITY CONSUMPTION & PRODUCTION



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SEASONAL
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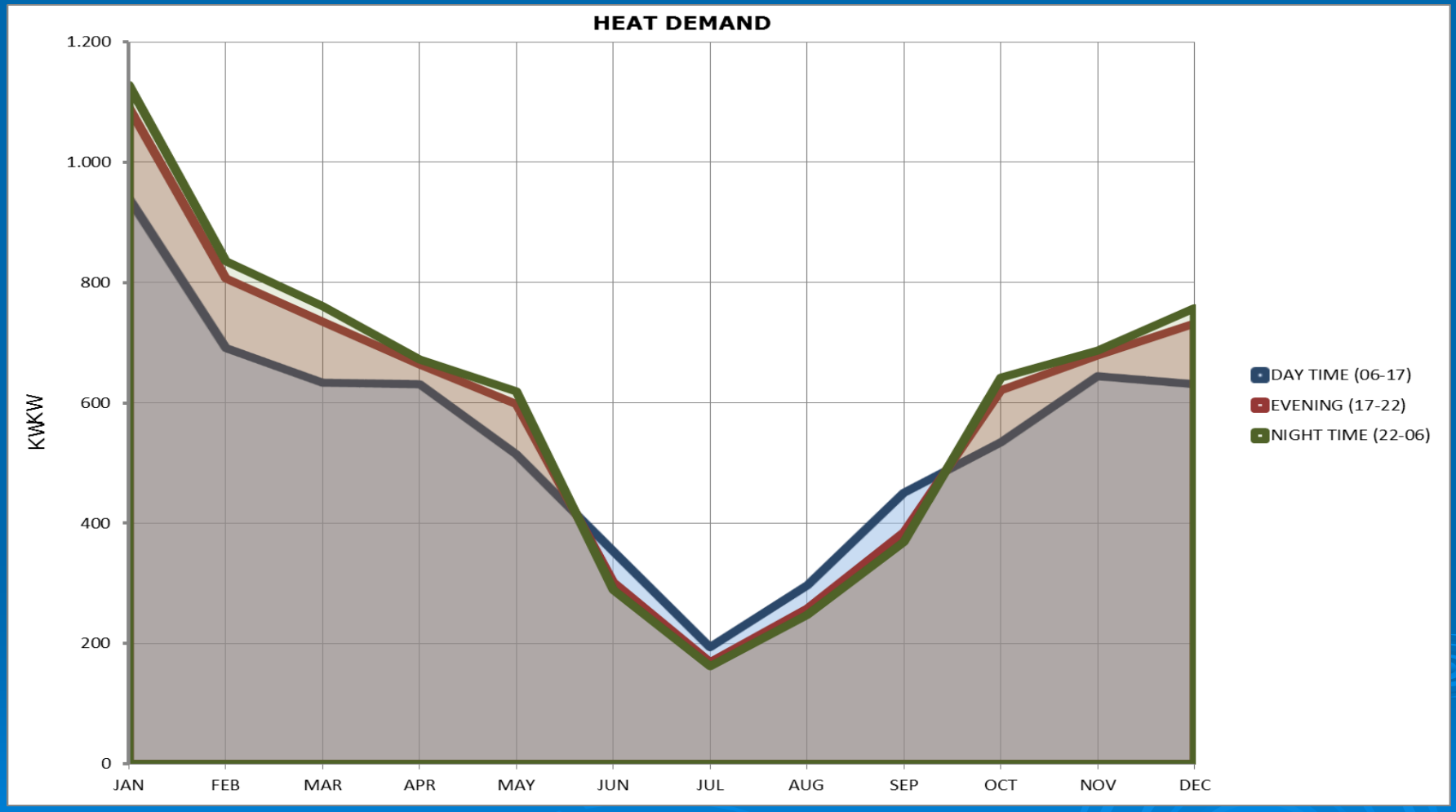
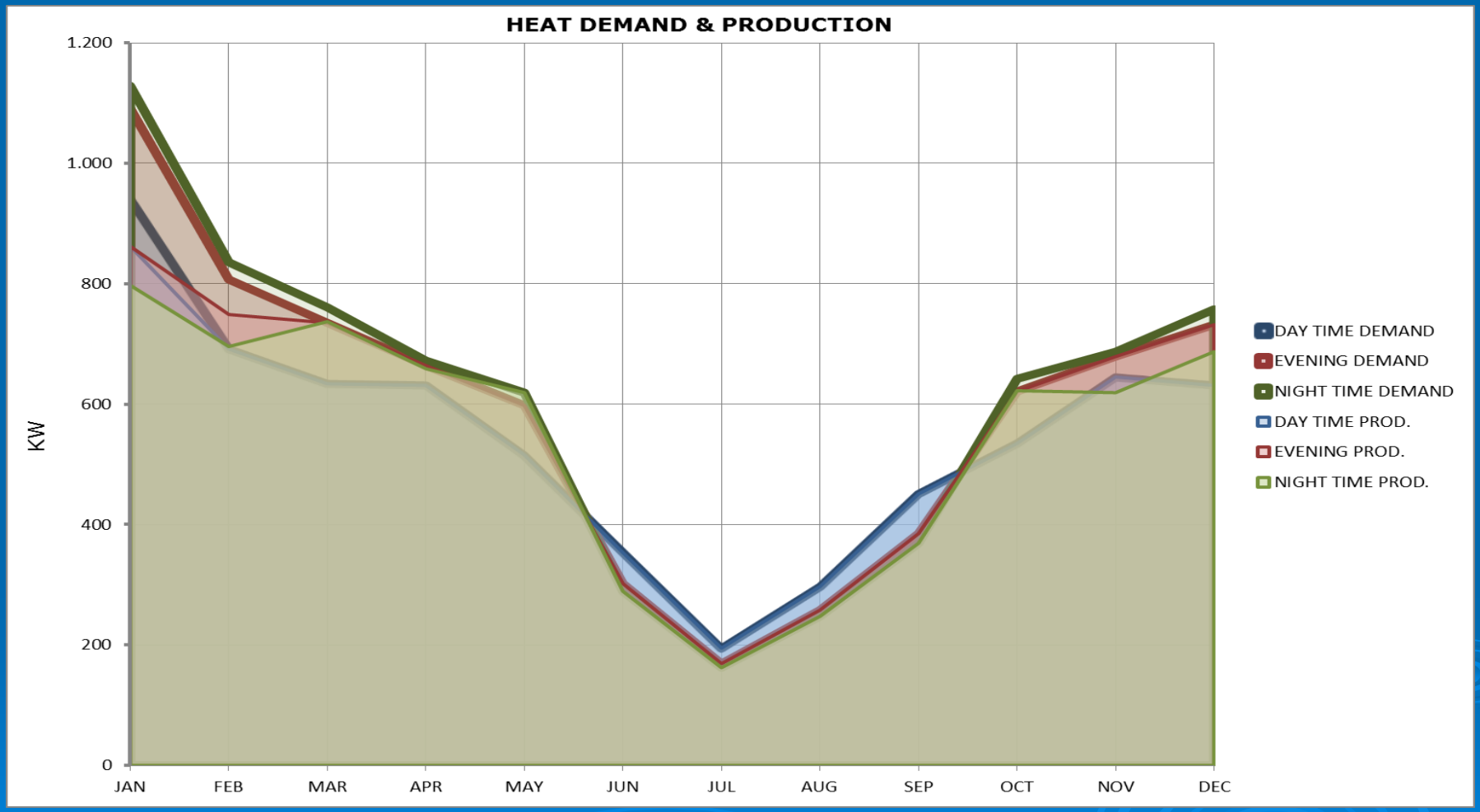


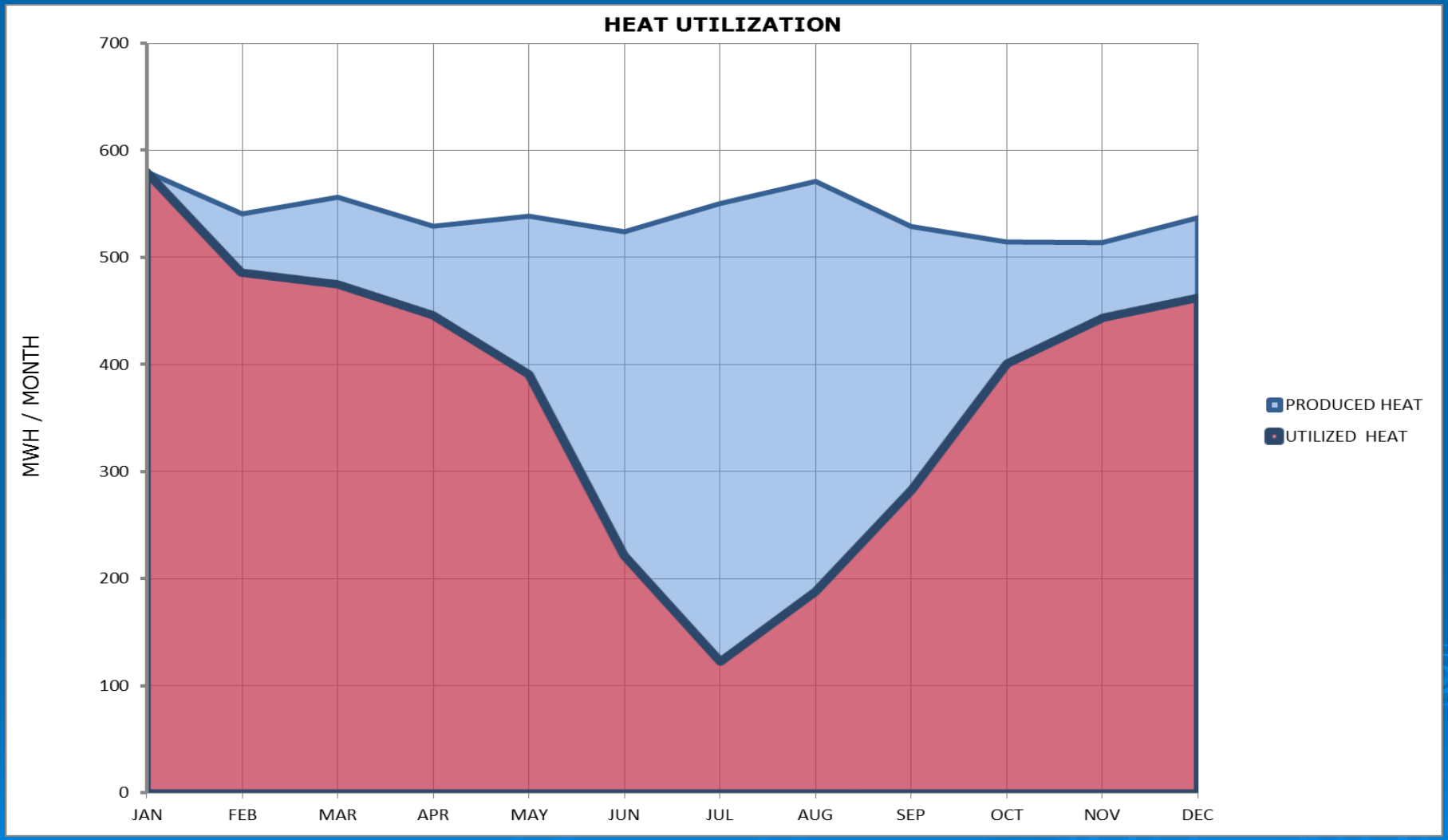
HEAT DEMAND & PRODUCTION



Heat from jacket water and exhaust circuits (in 90-70°C hot water form) meets 91% of annual heat demand of the hospital.

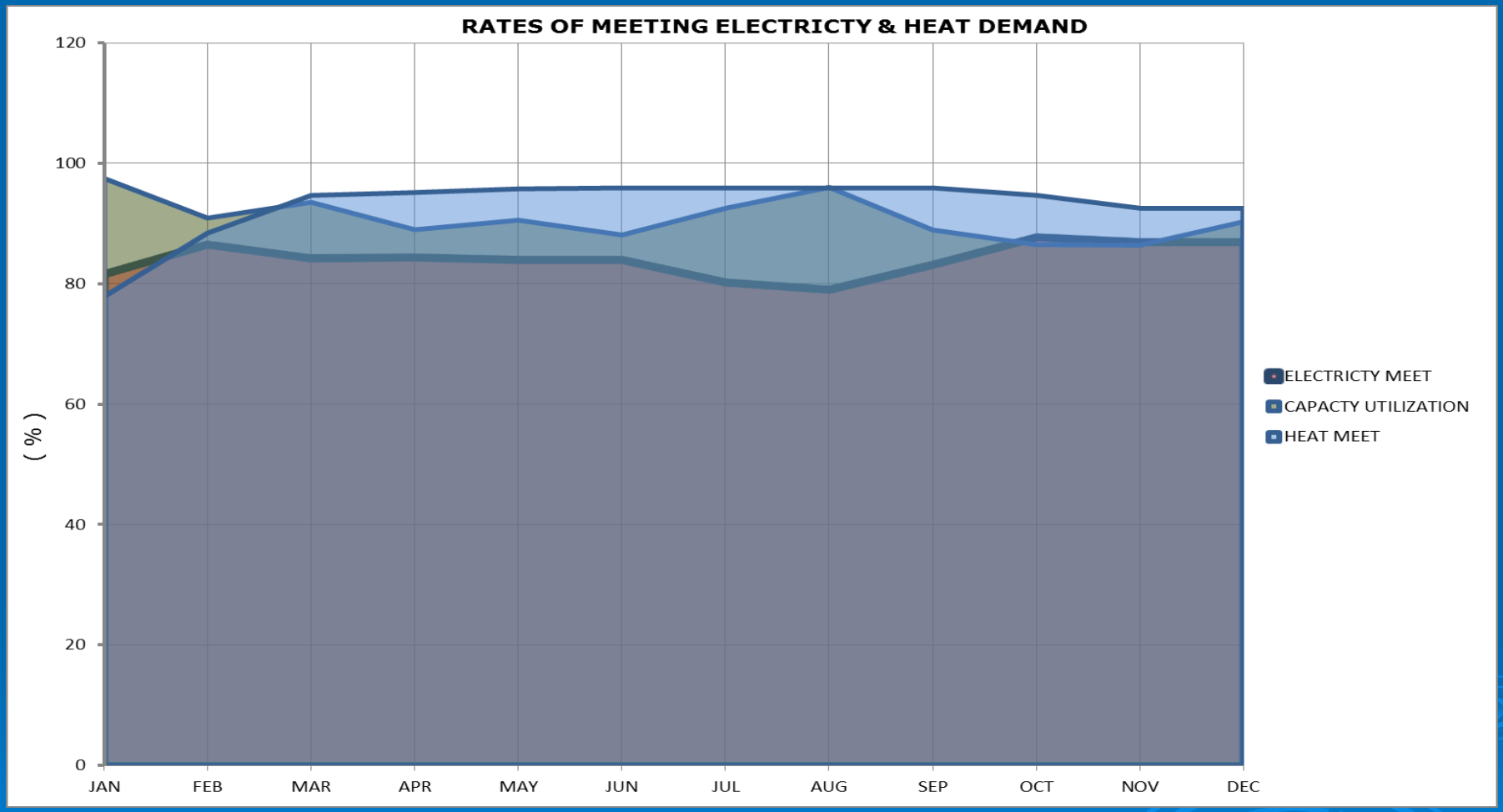
Rate of the utilized heat to total heat is 69%.

HEAT UTILIZATION



Rate of the utilized heat to total produced heat is 69%.

MEETING RATES

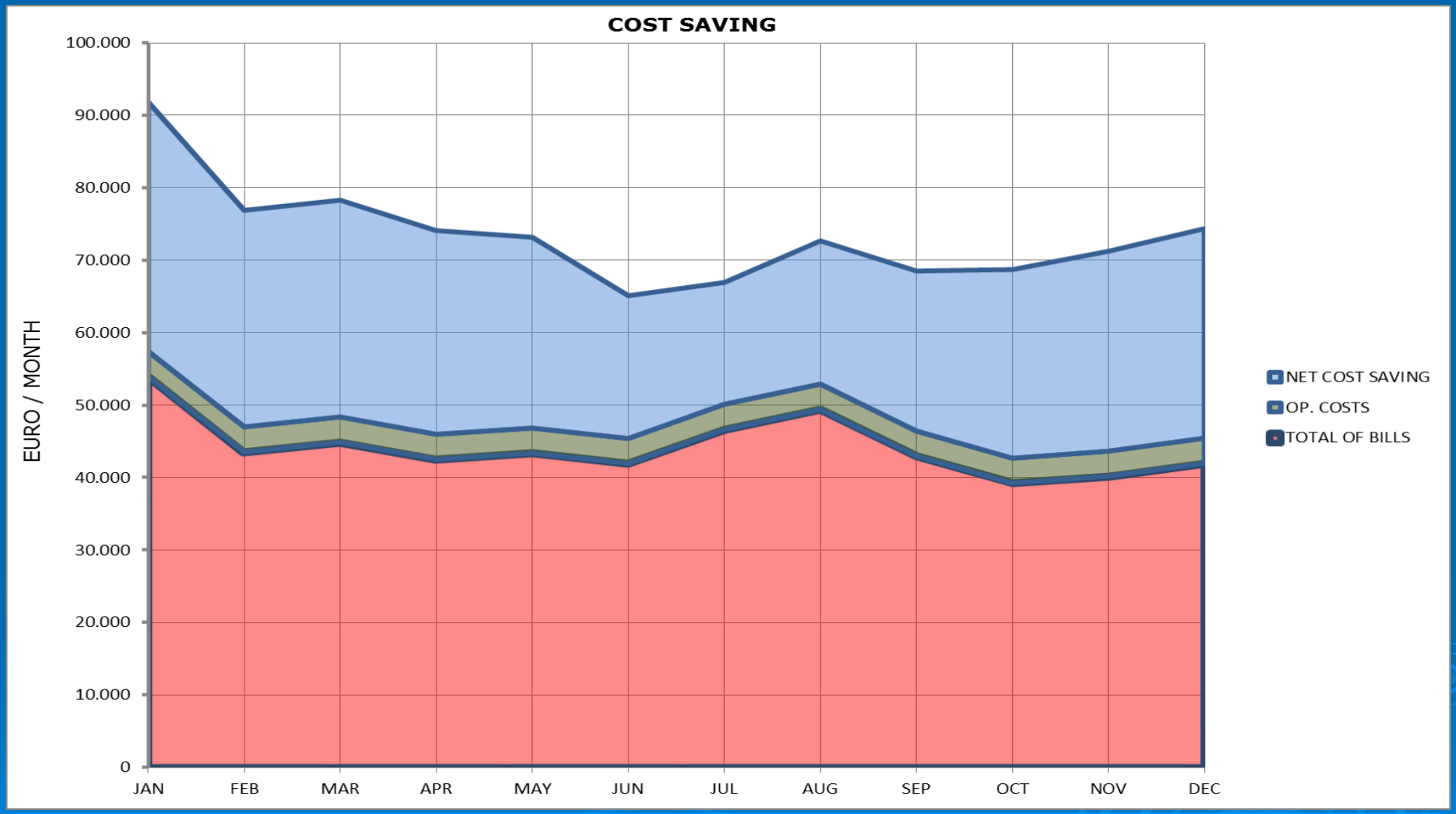


CHP System meets 84% of ELECTRICITY Consumption.

CHP System meets 91% of HEAT demand.

CHP System utilizes 91% of NOMINAL PRODUCTION CAPACITY.

COMPARISION OF ENERGY COSTS



The hospital's conventional energy cost was 882.000 Euro/year (Electricity: 700.500 Euro, Heat: 181.500 Euro). The total cost has been reduced to 572.000 Euro/year including maintenance costs. Thus, 35,1% (310.000 Euro/year) cost saving has been provided.
Total payback period of the project is 22 months (less than 2 years).

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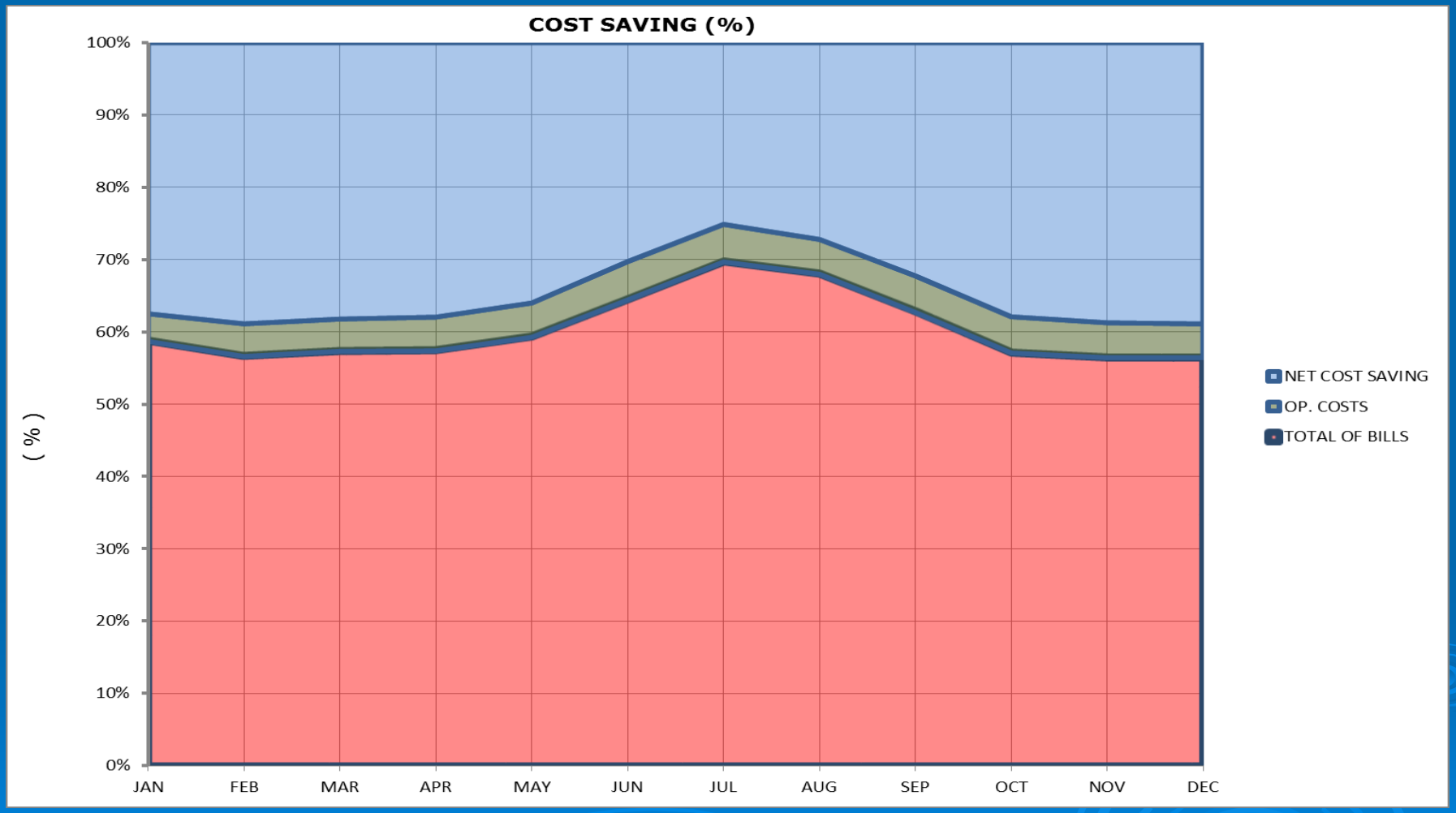

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PRIMARY ENERGY SAVINGS

$$PES = \{1 - \left[\frac{1}{\left(\frac{CHPHn}{REF\ Hn}\right) + \left(\frac{CHPEn}{REF\ En}\right)}\right]\} x 100\%$$

$$PES = \{1 - \left[\frac{1}{\left(\frac{48\ x\ 0{,}69}{90}\right) + \left(\frac{42{,}2}{52{,}5\ x\ 0{,}86}\right)}\right]\} x 100\%$$

$$\boldsymbol{PES = 23,2 > 10}$$

PES (Primary Energy Savings) value is 23,3% which is more than 10%.

Therefore, the practice is High Efficient Cogeneration.

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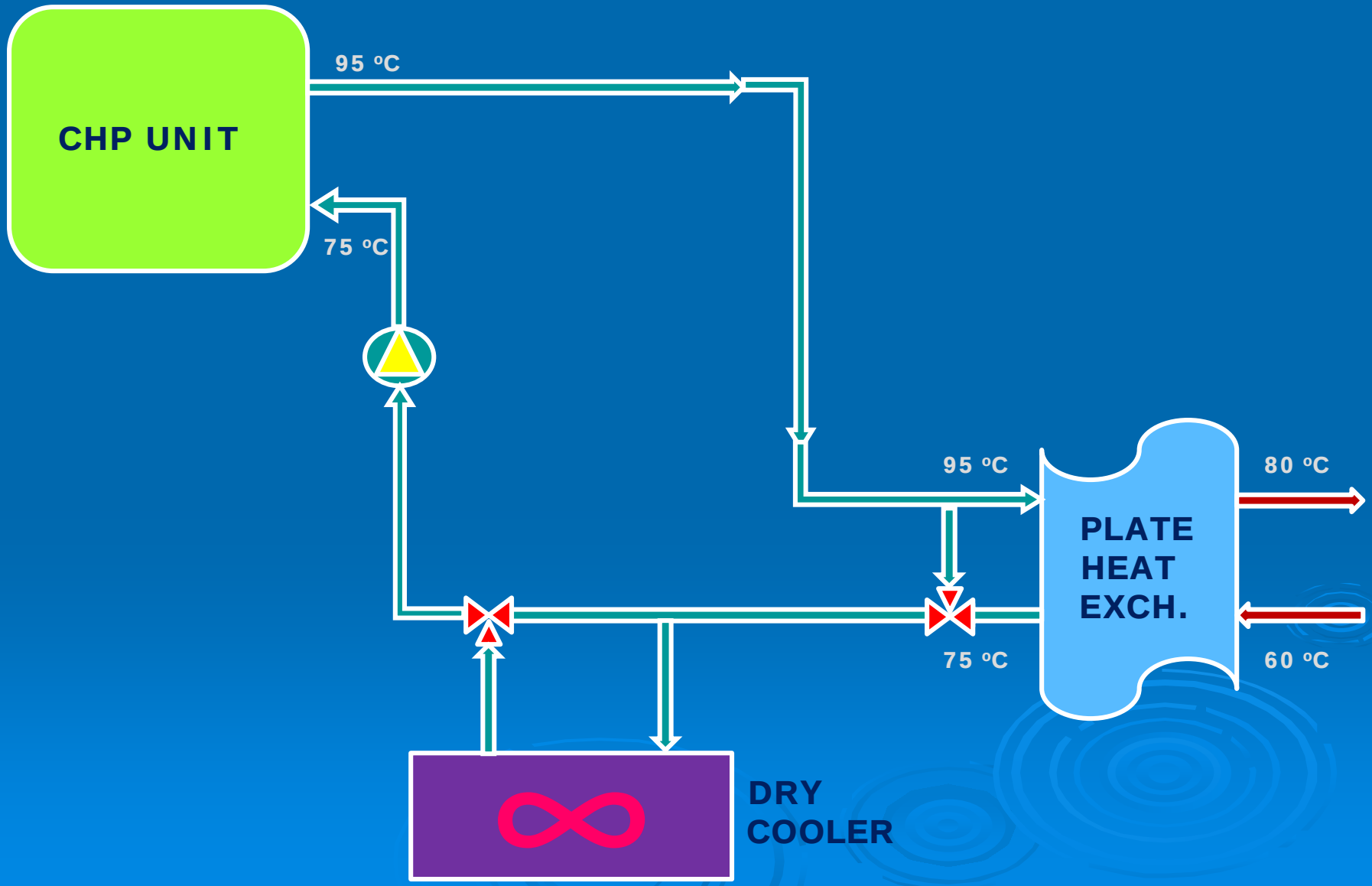
UNIVERSAL FLOW DIAGRAM FOR COGENERATION



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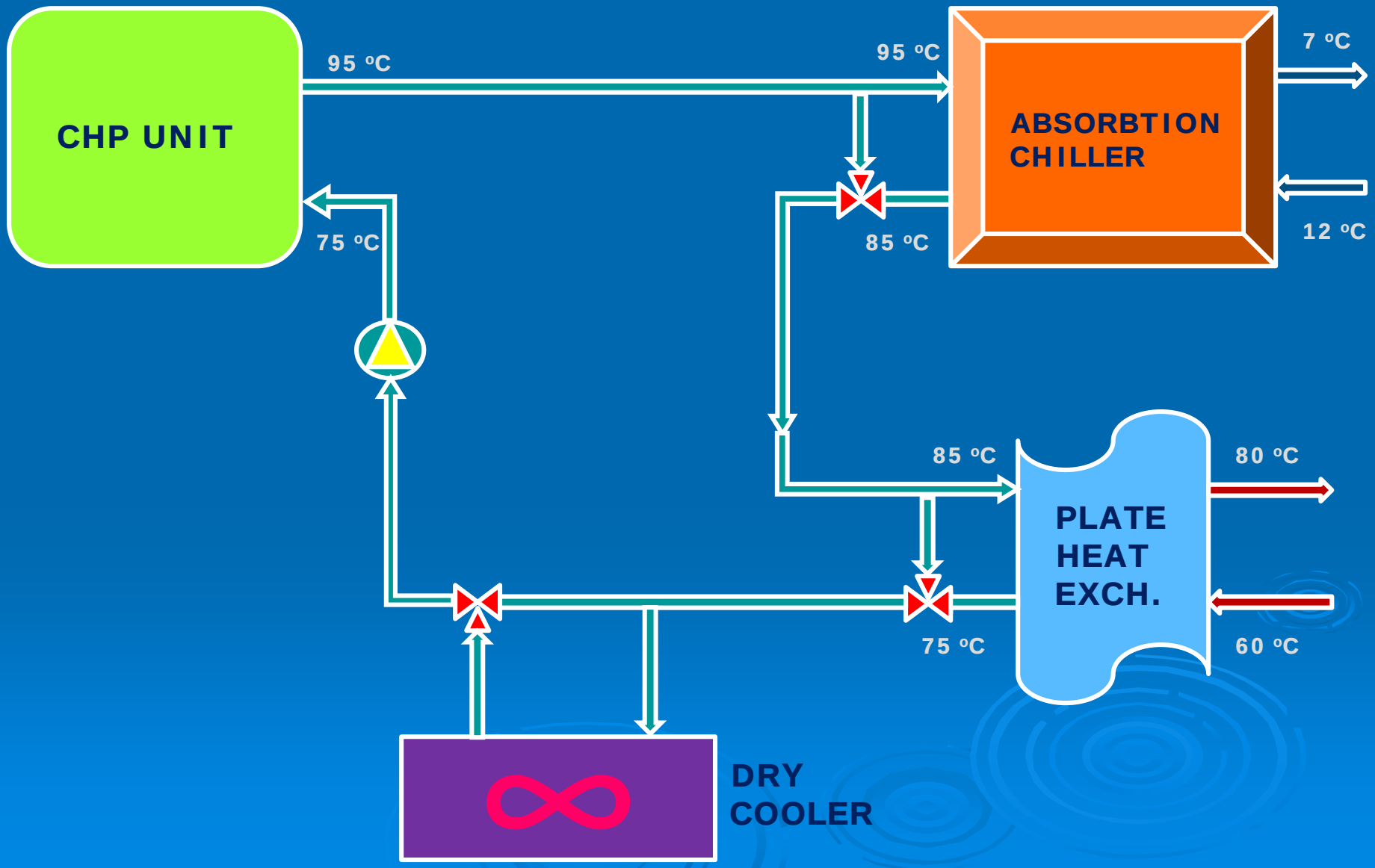
UNIVERSAL FLOW DIAGRAM FOR TRIGENERATION



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GENERAL APPROACH FOR TRIGENERATION PRACTICES

ADVANTAGES;

•Total cost saving is more than cogeneration system where all produced heat is not utilized for heating.

• More advantageous at regions those have warmer climate conditions.

DISADVANTAGES;

•It is unavoidable for hot boilers' operation and natural gas consumption during the heat from CHP unit utilized at absorption chiller.

• Payback period is longer than cogeneration system.

• Total area requirement for installation is more than cogeneration system.

CONCLUSION;

• Each Project shall be studied individually considering climate conditions.

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CONCLUSIONS

Main purpose of a cogeneration system is to provide cost saving. Capacity of these systems has to be determined accurately, to provide effective and efficient service. Otherwise, it will be unavoidable to create non-efficient and inactive facilities.

It is possible to make optimization accurately regarding to electrical and heating-cooling consumption datas of service facilities. Thus, it will be possible to avoid useless investments and minimize payback periods by accurately determining cogeneration system capacity which promises great economic savings.

THANK YOU FOR YOUR ATTENTION...