Development of the First Combined Heat and Power Plant in the Caribbean (CHP–District Energy)

Presented at the IDEA2016 107th Annual Conference & Trade Show

June 20 - 23, 2016 St. Paul, MN

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INTERNATIONAL DISTRICT ENERGY ASSOCIATION

Colombs Energy

EPS CAPITAL

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CEPM Consorcio Energético Punta Cana-Macao

CEPM's Facts

CONSORCIO ENERGETICO PUNTA CANA MACAO (CEPM),

- Is a privately owned electric utility company (InterEnergy subsidiary) engaged in generating, transmitting, and distributing electricity through two isolated integrated power systems serving the fast growing tourism-based Punta Cana-Bávaro and Bayahibe regions in the east of the Dominican Republic.

- Serves 60 hotels with approximately 35,000 rooms in these tourist destinations as well as approximately 20,000 commercial and residential customers.

- Company's installed capacity is 90 MWe with Wartsila and Hyundai diesel engines operated using HFO and purchases of 80 MWe.

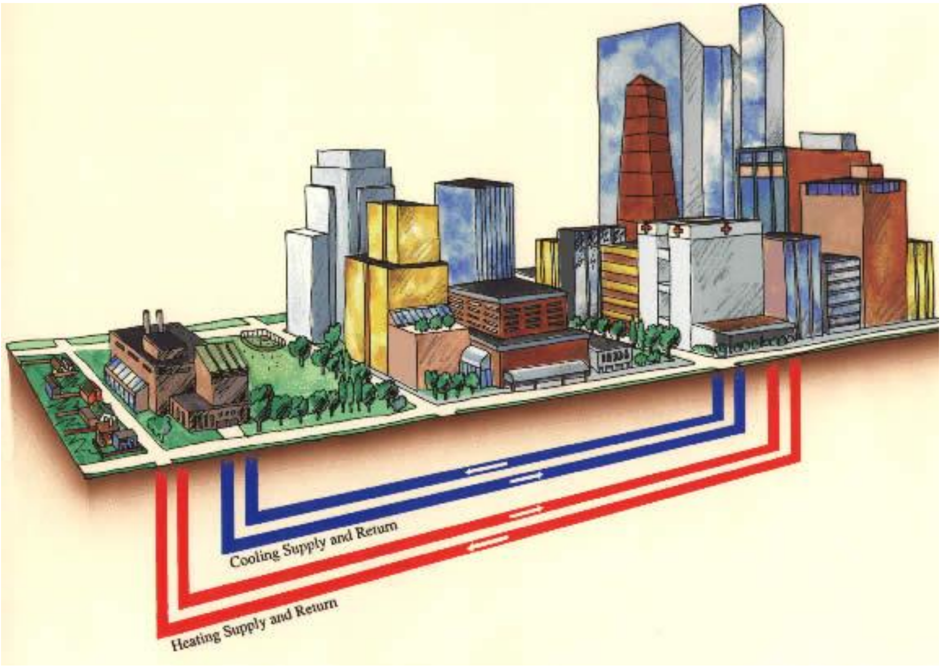
- CEPM also supplies thermal energies (10,000 TR chilled water, hot water and steam), with sales of:
  - 700 GWhe/year of electric energy,
  - 200 GWhcw/year of chilled water, (56,867,000 Ton-hour)
  - 65 GWhdhw/year of domestic hot water.

What is a District Energy ?

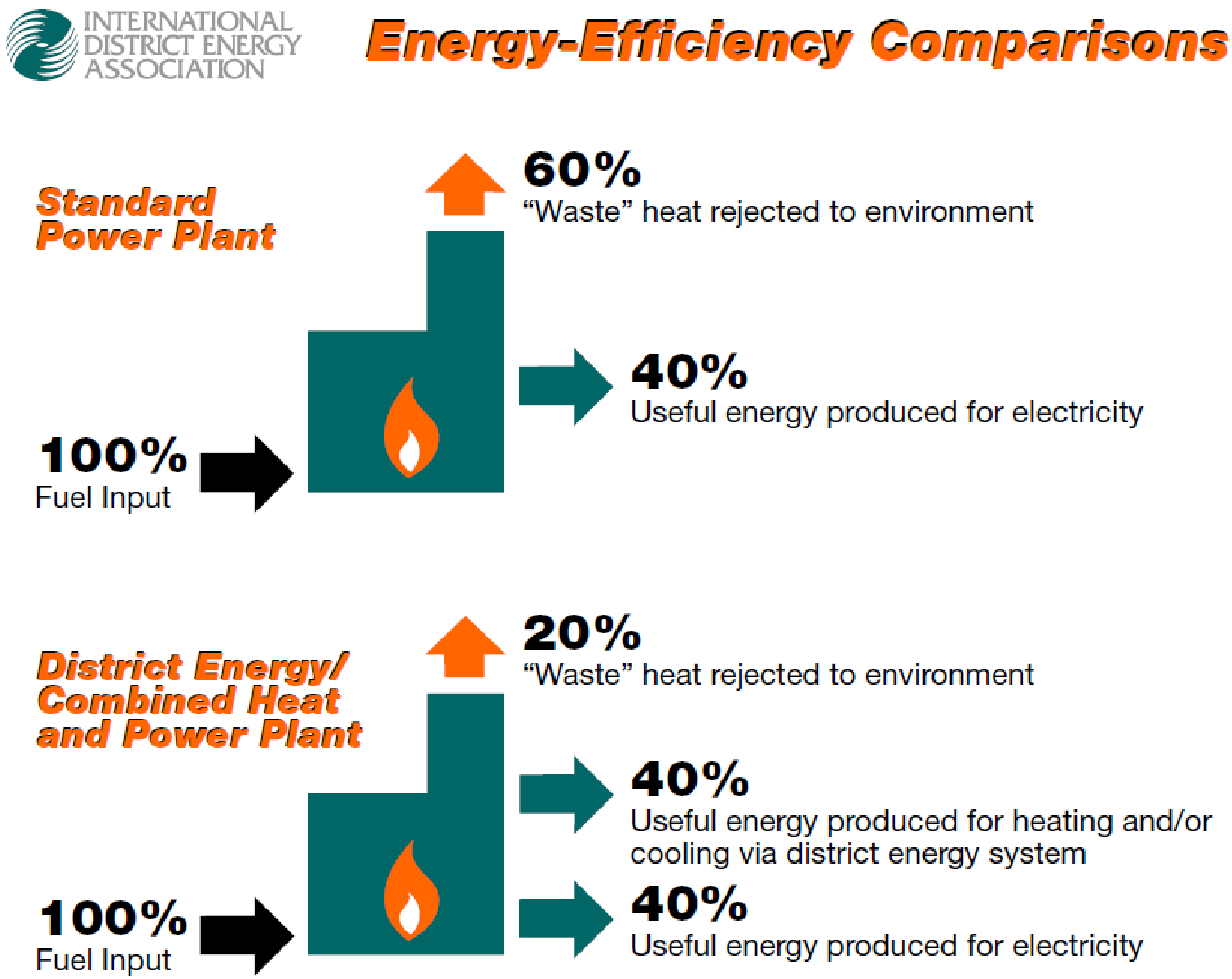
District energy systems produce steam, hot water or chilled water at a central plant. The steam, hot water or chilled water is then piped underground to individual buildings for space heating, domestic hot water heating and air conditioning.

As a result, individual buildings served by a district energy system don't need their own boilers or furnaces, chillers or air conditioners. The district energy system does that work for them, providing valuable benefits including:

- ✓ Improved energy efficiency
- ✓ Enhanced environmental protection
- ✓ Fuel flexibility
- ✓ Ease of operation and maintenance
- ✓ Reliability
- ✓ Comfort and convenience for customers
- ✓ Decreased life-cycle costs
- ✓ Decreased building capital costs
- ✓ Improved architectural design flexibility



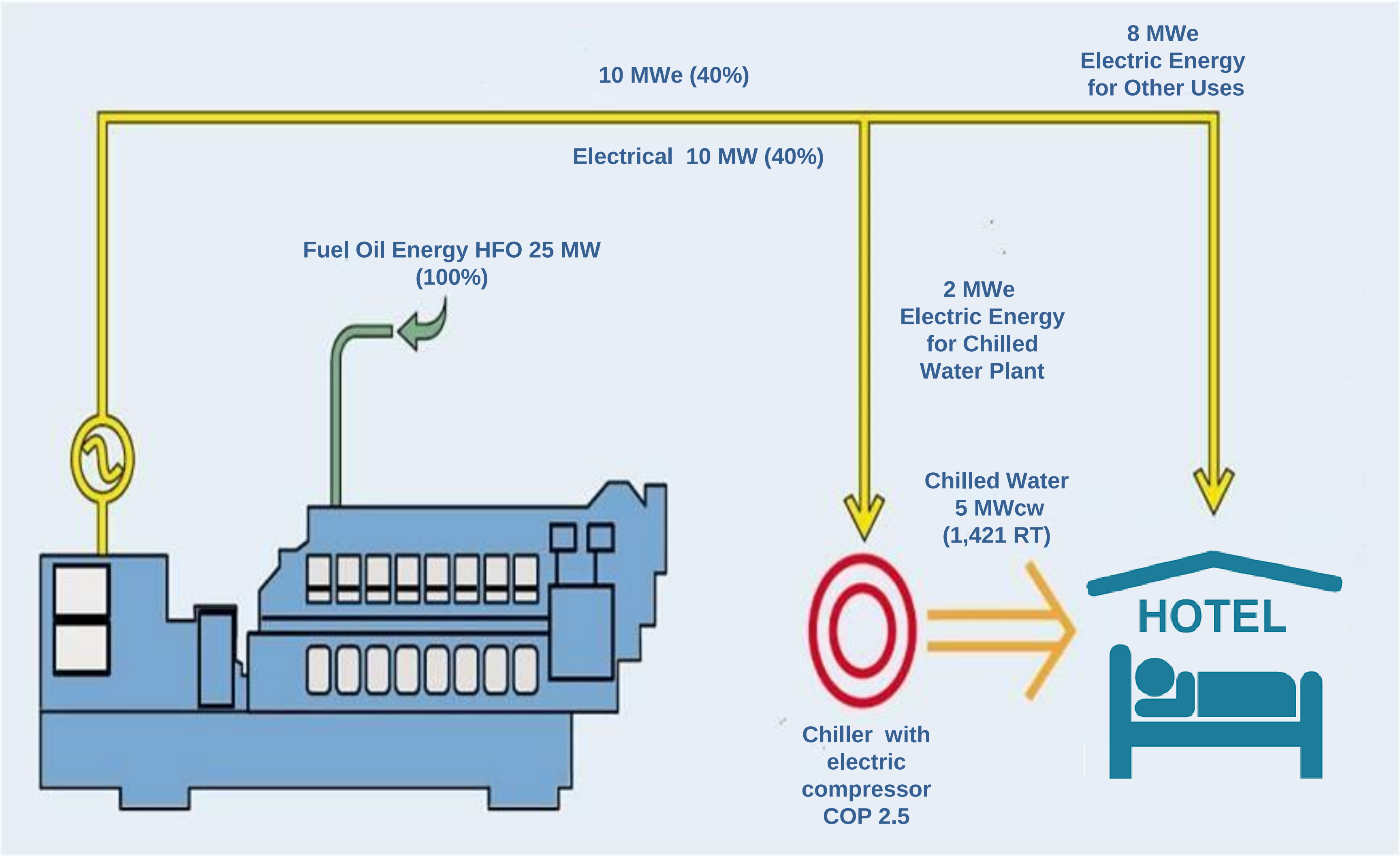
Energy - Efficiency Comparisons



From: International District Energy Association (IDEA)

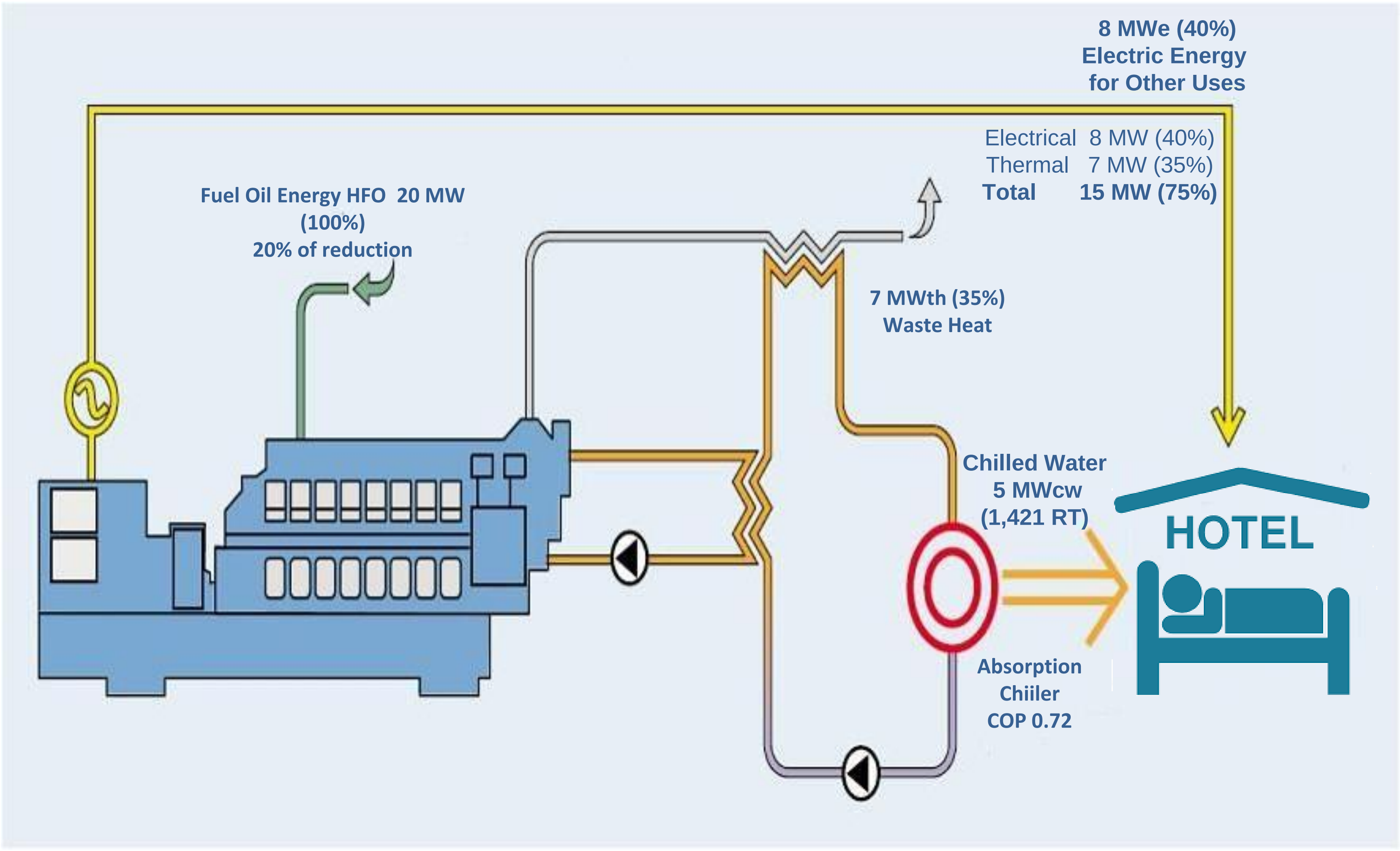
Chilled Water production with Electric Chiller (Without Cogeneration)

Indicative



Chilled Water Production with Absorption Chiller (With Cogeneration)

Indicative



CEPM's CHP-District Energy Project Overview

- As part of the expansion of CEPM's services to an Energy Services Company (ESCO), our team developed the First CHP-District Energy system in the Caribbean.

- This system provides 5,000 TR of chilled water (using Absorption Chillers) and Domestic Hot Water (DHW) to Hotels located near to CEPM's power plant.

- Waste heat comes from the exhaust gases and cooling water (Jacket water, Oil Cooler, Intercooler) of Six Wartsila Diesel Engines 18V32 Vasa (6 MWe each) that consume Heavy Fuel Oil (HFO).

- The distance from the power plant and the different Hotels group is about 2.5 miles (4 kilometers), making the new hot water loop a viable installation process.

Hotels included in the Project

CEPM's CHP-District Energy Project Overview (cont.)

- Chilled water is provided by locally based absorption chillers and the heat exchanger used to produce DHW (Domestic Hot Water) for both chilled and domestic hot water were installed inside the hotels.

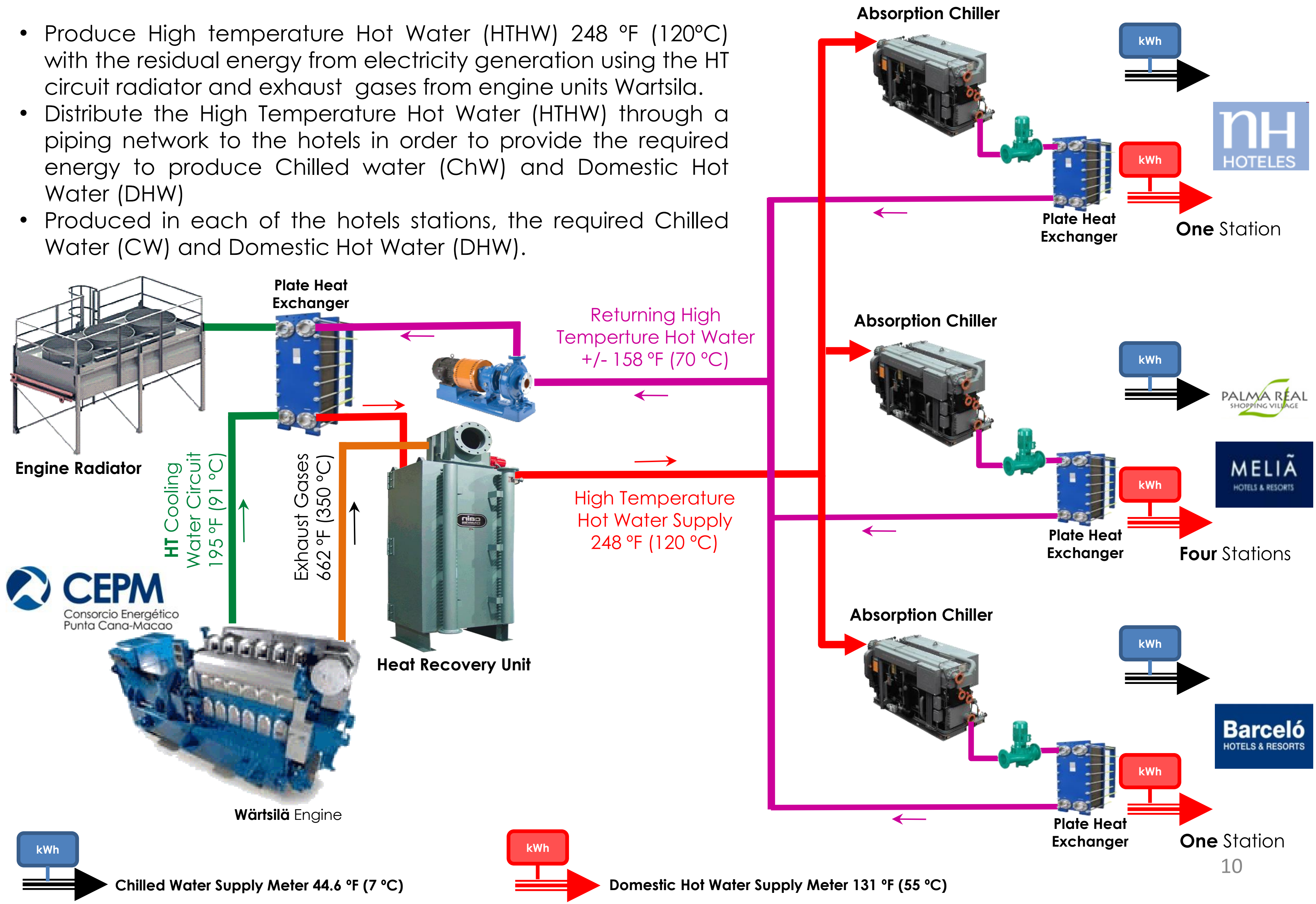
- The HTHW (High Temperature Hot Water) is produced in the power plant with a temperature of roughly 248 ºF (120 ºC).

- At the hotel this HTHW supplies the thermal energy to drive single stage absorption chiller units.

- The HTHW output after being used to provide chilled water via the absorption chillers is then connected to an additional set of heat exchangers to produce DHW, and the "spent" HTHW loop temp water is then sent back to the power plant with a temperature of +/- 158 ºF (70 ºC).

Operation Scheme of the Project

- Produce High temperature Hot Water (HTHW) 248 °F (120°C) with the residual energy from electricity generation using the HT circuit radiator and exhaust gases from engine units Wartsila.
- Distribute the High Temperature Hot Water (HTHW) through a piping network to the hotels in order to provide the required energy to produce Chilled water (ChW) and Domestic Hot Water (DHW)
- Produced in each of the hotels stations, the required Chilled Water (CW) and Domestic Hot Water (DHW).



CEPM's CHP-District Energy Project Overview (cont.)

- In this way a large delta T 90 ºF (50 ºC) can be effected by using the single loop to serve two purposes, first high quality heat to run the absorbers, and second the lower temperature resulting water out of the chillers used for all or part of domestic hot water generation.

- The key goal and advantage of this project is to recover waste heat from the operation of the existing diesel engines with an electric efficiency of 39.5%, and produce thermal energy which used to be wasted away and instead reuse part of it from the exhaust gases to create new economic value.

- Only about 16% of the heat is recoverable due to limitations imposed by the dew point of the exhaust gases when HFO with 2.5% Sulfur is used, about 25.2% on the cooling water which is only recoverable to the level of about 9.1% , and the remainder is low temperature water used via cooling water to dump heat, with roughly an additional 3% by radiation to the surrounding area.

- All of these are economically achieved, benefiting both the utility and large resorts, to say nothing of helping control costs to the other local customers (more and more local businesses and homes are connecting to this grid, some having had their own small generator systems, or connected to an adjacent power source).

CEPM's CHP-District Energy Project Overview (cont.)

- The sole reason the power company would consider this type of additional new investment is that their system MWe load has been growing about 5% per year, so redeploying some electrical load into thermal does not really hurt their business economically, and the lower resulting lower utility costs to the resort hotels provides an economic incentive to those resorts to continue dealing with the utility, which otherwise the resorts would not have to.

- The overall approach utilized as a business case was to "take over" the operation and maintenance responsibility at the resorts for the chiller plants, including compressors, chilled water pumps, condenser water pumps, and cooling towers, as needed, and install new absorption chiller systems, and thermal heat recovery systems, so that in the end "chilled water, and domestic hot water heat" are being sold.

- The heating system was similar in that the existing boilers and pumps were taken over by the utility, so that burden was removed from the resorts. The actual system results are sold as "thermal KWH" to the owners.

CEPM's CHP-District Energy Project Overview (cont.)

- The existing electric chillers are still used in summer peaking via electronic remote dispatch since there is insufficient heat through the loop for such peaks, but again, it is not relevant to the owner anymore since they buy delivered results. The paper will present the overall issues, and provide an overview of the results from this implementation process.

- This project entailed several years of planning and budgeting, securing written long term agreements from enough customers (resorts) to get the project rolling, with the rest of the customers assumed to come aboard as new loads once they could see the facility in long term operation, as has occurred in other district heating projects in Europe and the USA.

- The project was completed in 30 months and has been in operation now for 3 years.

CHP-District Energy Building Blocks

Diesel Engine or Heat Source

- Heat balance
- Waste Heat Quality (Combustion Gases & Cooling Water Temperatures)
- Type of Fuel

Waste Heat Recovery Systems

- WHRU Gas & Water side Corrosion Issues
- Combustion Gases Dew point
- Load and Temperature Control
- Water/Water Heat Exchanger

Waste Heat Transmission & Distribution Circuit

- High Temperature Hot Water Vs Steam
- Maximum pressures & Temperatures
- Circuit Pressurization
- Differential Temperature (Supply and Return)
- Variable Vs Constant Flow
- Electric Energy for Water Pumping
- Water Hammer & Pressure Surge
- Water Chemical Treatment

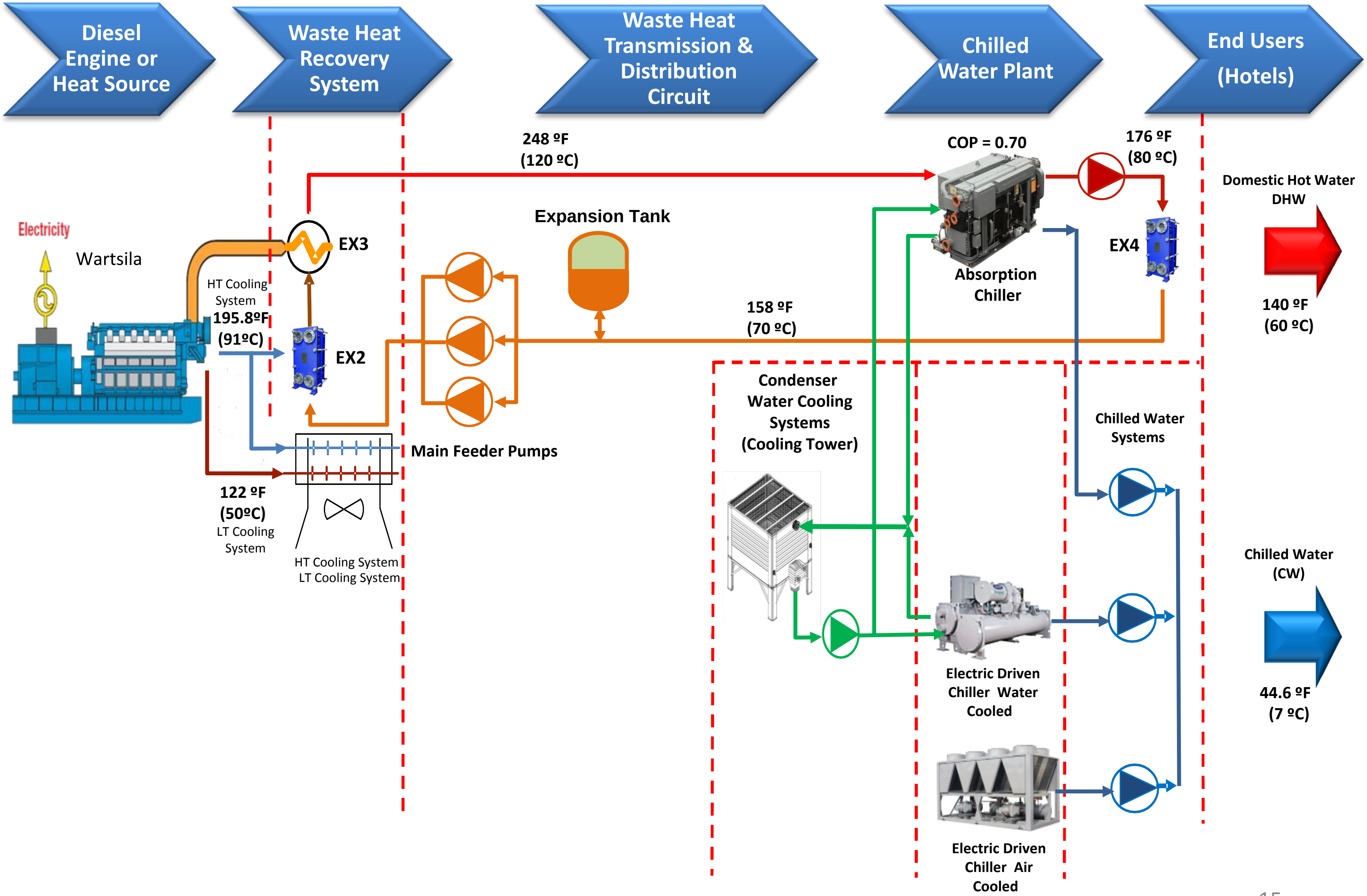
Chilled Water Plant

- Single –Stage Vs Double –Stage Absorption Chiller
- Electric Motor Driven Compressor Chiller
- Adsorption Chiller (future)

End Users (Hotels)

- Thermal Load Hourly Profile
- Electric Load Hourly Profile
- Thermal Base load Vs Peak Load
- Thermal Energy Storage?
- Thermal energy Billing meter

Schematic of CEPM CHP-District Energy (Cooling/DHW)



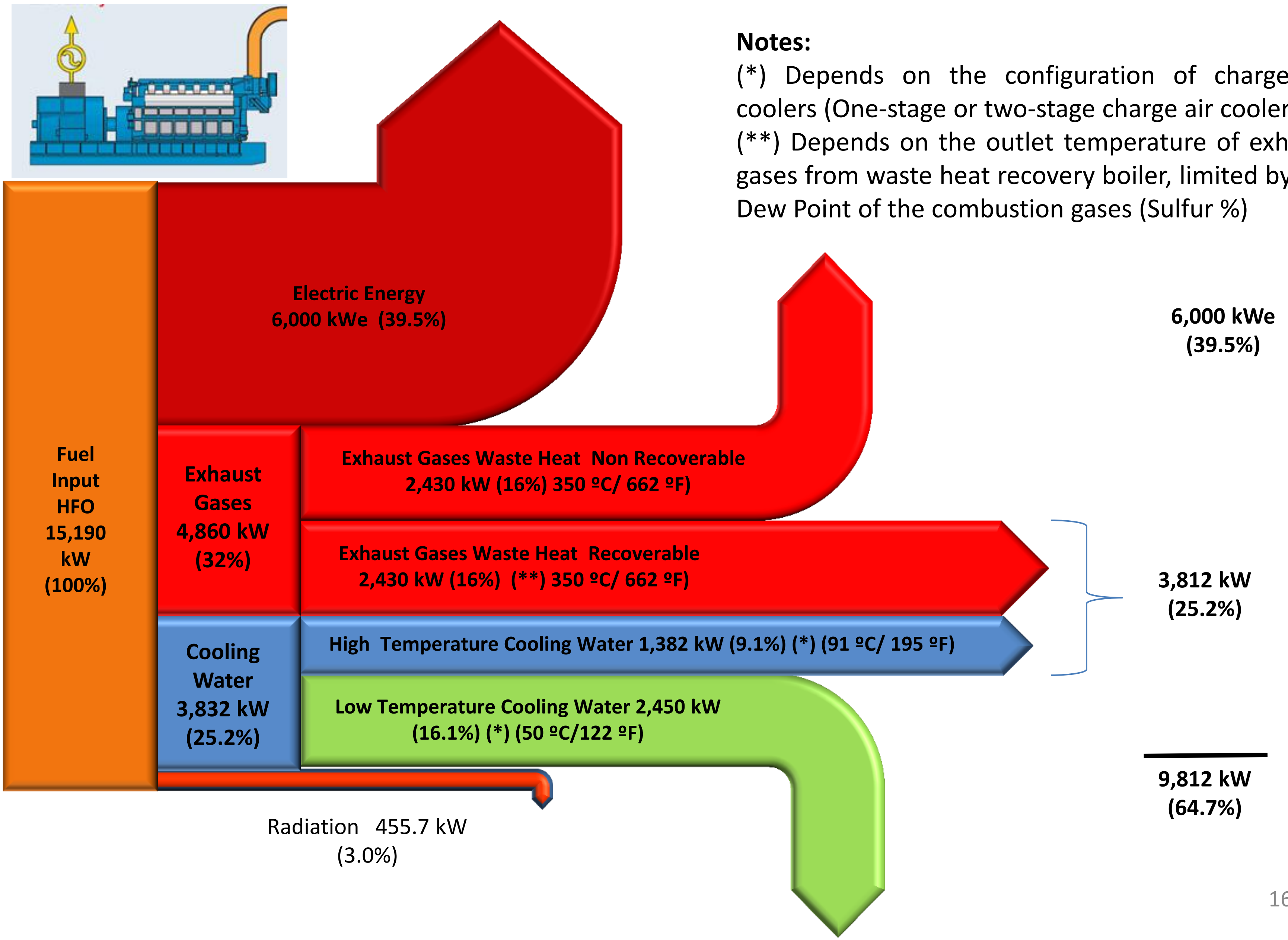
Diesel Engine Energy Balance (HFO)

Diesel Engine or Heat Source

Notes:

(*) Depends on the configuration of charge air coolers (One-stage or two-stage charge air cooler

(**) Depends on the outlet temperature of exhaust gases from waste heat recovery boiler, limited by the Dew Point of the combustion gases (Sulfur %)

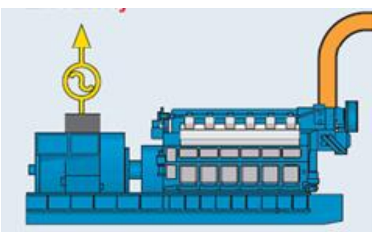


Business Model Option 1

Waste Heat Transmission & Distribution Circuit

- Produce High Temperature Hot Water (HTHW) 248 ºF (120ºC)
- Produce Chilled Water (CW) in power plant at CEPM 44.6 ºF (7ºC) 5,000 TR
- Distribute Chilled Water (CW) to the hotels

This option seems more expensive, because the temperature differential is only 9ºF (5ºC), which implies a large flow circulating (13,333 GPM) in the distribution net work and therefore larger pipe diameters (Diameters 24 to 30 inches)



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COP = 0.70

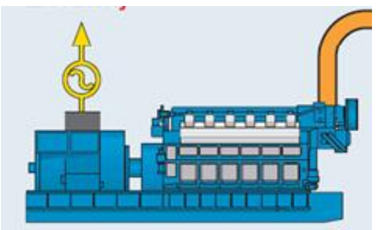
High Temperature Hot Water (HTHW)
248 - 176ºF
(120 - 80ºC)
25,121 kWte
2,381 GPM
Delta T = 72ºF (40ºC)

Chilled Water
44.6 -53.6ºF
(7 - 12ºC)
5,000 TR
17,585 kWr
13,333 GPM
Delta T = 9ºF (5ºC)

Business Model Option 2

- Produce High Temperature Hot Water (HTHW) 248ºF (120ºC)
- Distribute High Temperature Hot Water 248ºF (120ºC)
- Produce Chilled Water (CW) 44.6ºF (7ºC) in each hotel 5,000 TR
- Produce Domestic Hot Water (DHW) 140 ºF (60ºC) in each hotel

This option seems less expensive, because the temperature differential is 72ºF (40ºC), which implies a small flow circulating (2,198 GPM) in the distribution net work and smaller pipe diameters (Diameters 14 to 16 inches)



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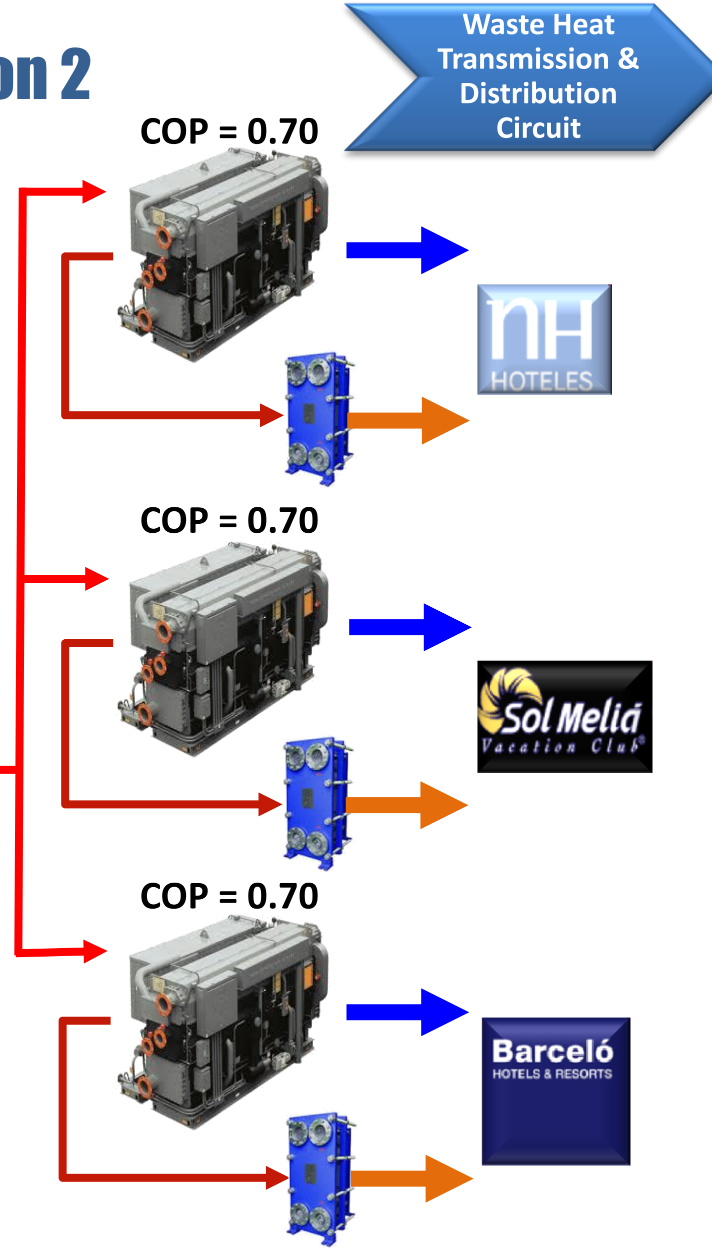
High Temperature
Hot Water (HTHW)
248 - 158ºF
(120 - 70ºC)
31,402 kWte (include
6,280 kWte for DHW)
2,381 GPM
Delta T = 90ºF (50ºC)



This option also allows to supply Domestic Hot Water to the hotels

Chilled Water
44.6 -53.6ºF
(7 - 12ºC)

High Temperature Hot Water (HTHW) System Vs Steam System:

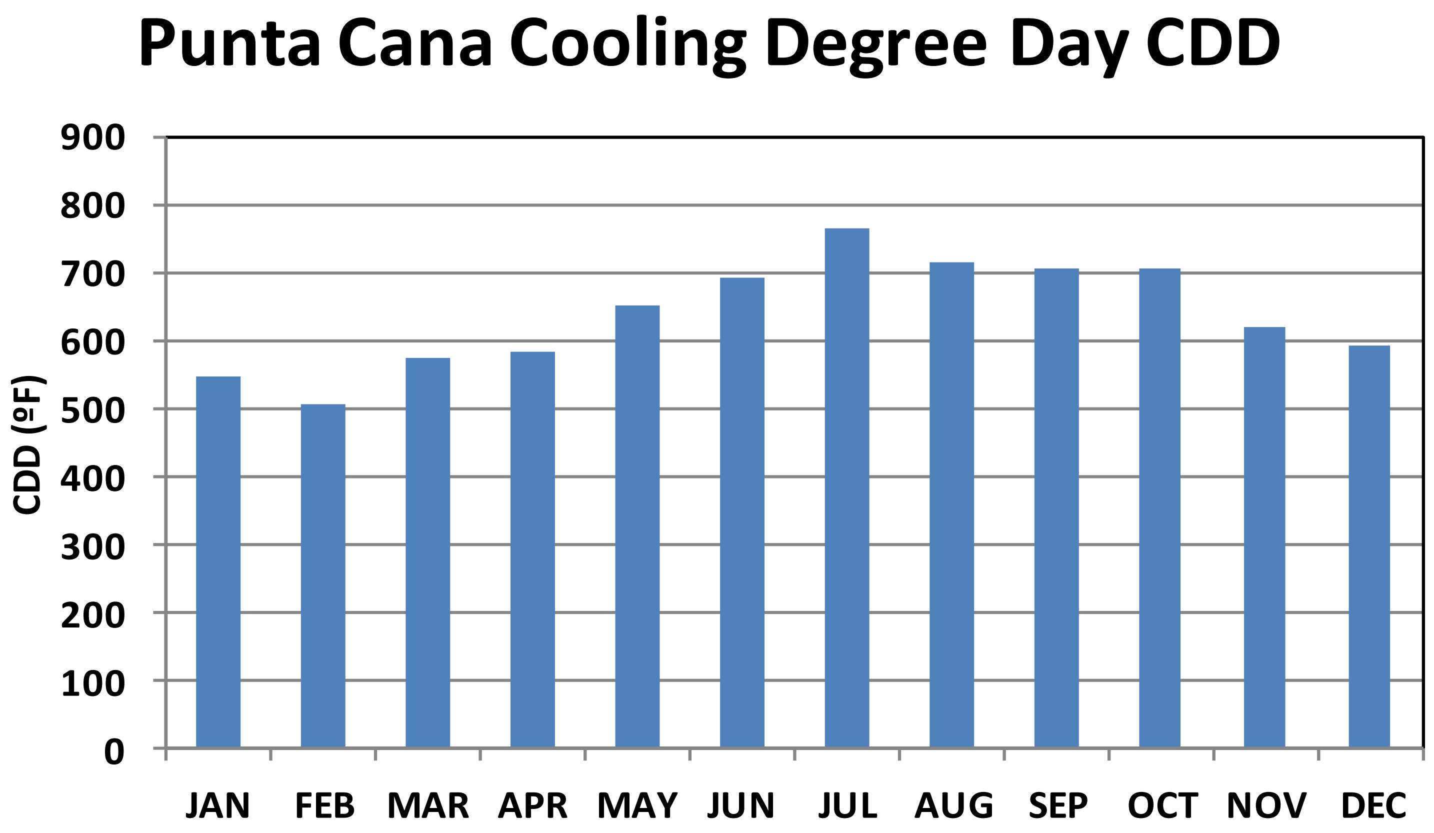
Advantages of HTHW over steam heat distribution systems:

- The amount of blow down required by a boiler depends on the amount and nature of the makeup water supplied. HTHW systems have closed circuits, require little makeup, therefore, practically never require blow down whereas steam systems commonly lose about 1% to 3 percent of the total boiler output because frequent blow downs are required. Operation within closed circuits permits reducing the size of water treating systems to a minimum
- Due to the heat storage capacity of HTHW systems (large mass of water), short peak loads may be absorbed from the accumulated heat in the system.
- The closed recirculation system reduces transmission and thermal losses to a minimum while practically eliminating corrosion and scaling of generators, heat transfer equipment, and piping.
- Both supply and return high temperature water piping can be run up or down and at various levels to suit the physical conditions of structures and contours of the ground between buildings without the problems of trapping and pumping condensate

Cooling Monthly Profile

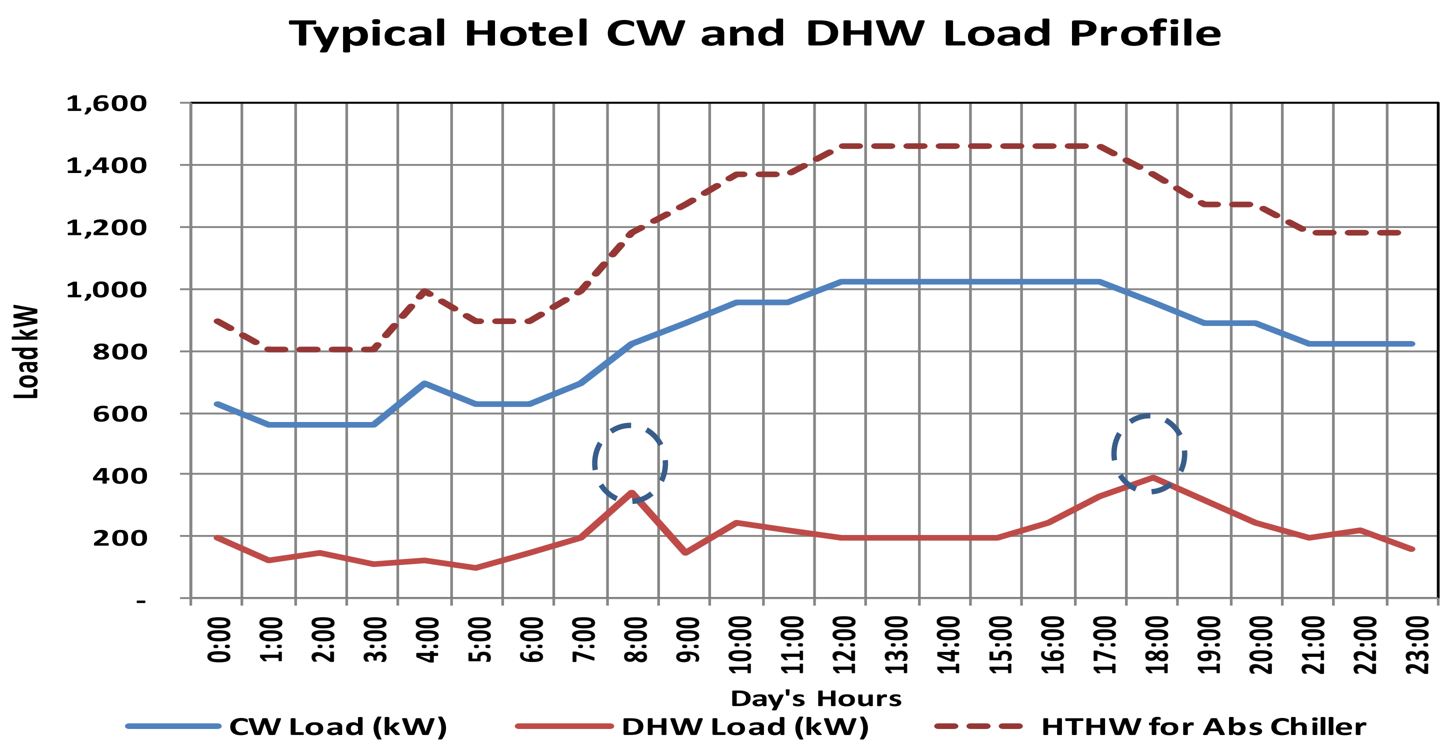
End Users
(Hotels)

The cooling load is highly correlated with the Cooling Degree Day CDD and in a hotel is also influenced by the room occupancy



Cooling Load Vs. DHW Load Hourly Profile

As shown there are two peaks in demand for DHW (red line) one at 8:00 and one at 18:00, these peaks do not coincide with the peak cooling demand therefore HTHW demand that drives the absorption chiller; in order to exploit the maximum of the thermal energy from HTHW circuit that leaves the absorption chillers to heat the DHW, tanks are used to store thermal energy during off peak hours.



The results of this project, from *inception to date* can be summarized as follows:

- ✓ Reduction of 25% of the electrical energy (kWh) consumed by the resorts versus the option of not doing cogeneration. This is primarily due to these group of customers consumed 34% of the electrical bill to produce chilled water ***before*** the district project energy was implemented. This implies that the utility company will consume ***25% less fuel*** to supply electric power to these group of customers and can thus ***delay*** the expansion of electrical transmission and distribution networks.

- ✓ The base demand for chilled water of the resorts was covered by the new absorption chillers plus reuse of limited amount of existing peak cooling with the current older electric chillers.

- ✓ All demand for domestic hot water was supplied to the resorts group by the district energy, therefore fuel consumption in the domestic hot water boilers was reduced to ***effectively zero***. This is very important given that all of these boilers were operated using Diesel or GLP, which is very expensive.

The results of this project, from *inception to date* can be summarized as follows (cont.):

- ✓ The overall COP of the systems with pumps, fans, compressors before was about 2.7, and the overall system after around COP=15 in winter, and about 7 or so for 365 days (due to the reuse of the older electric chillers for peaking purposes). The business case required that the resort owners sign long term contracts to insure the new cogen system loop and associated infrastructure could be appropriately amortized.

- ✓ This project demonstrated that you can use waste energy to produce thermal energies (chilled water and domestic hot water) required in the resorts for the comfort of its customers, in such a way that both the resorts benefit through ***total cost reduction*** as compared to the previous all electric load case, and the utility benefits as well through ***increasing overall company net revenues*** in a cost effective way which helps to cement a long term relationship with large key customers. This then becomes truly a win-win situation for all, which is one of the avowed goals of any third party cogeneration project.

Fuel Oil and Greenhouse Gas Emissions Reduction

With this cogeneration approach, about 25% of thermal energy is recovered to drive absorption chillers and DWH heat exchangers and reduce the Fuel consumption by 35,740 Bbl/year of HFO and 32,881 Bbl/year of LPG.

The Greenhouse gas emission is reduced by over 28,872 metric tons CO2/year.

Greenhouse Gas emission reduction effects		
Chilled Water Production		
Absorption Chillers	TR	5,000
Electric Chillers Displaced	TR	5,000
Electric Chillers Displaced	kWcw	17,585
Coefficient Of Performance (weighted)	COP	6.0
Electric Power for Chillers Displaced	kWe	2,931
Load Factor		0.95
Electric Energy for Chillers Displaced	MWhe/year	24,390
GHG emission factor for HFO Power Generation	tCO2/Mwhe	0.8084
Avoided CO2 emissions	**tCO2/year**	**19,716**
Avoided Fuel Oil (HFO)	**Bbl/year**	**35,740**
Domestic Hot Water Production		
Domestic Hot Water Production displaced from boiler	kWdhw	6,280
Load Factor		0.50
Domestic Hot Water Production displaced from boiler	MWhdhw/year	27,506
GHG emission factor for LPG	tCO2/MWhdhw	0.3329
Avoided CO2 emissions	**tCO2/year**	**9,158**
Avoided Fuel (LPG)	**Bbl/year**	**32,881**
Total Avoided CO2 emissions	**tCO2/year**	**28,874**

Questions?

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