16th November 2018, BERLIN, Germany

H-DisNet workshop

Valorising low thermal residual heat through thermo-chemical networks

ING. FABIO FIDANZA

Acsm Agam
L'ENERGIA CHE UNISCE

Varese Risorse
Teleriscaldamento e Illuminazione Pubblica

Comocalor

Index

Valorising low temperature residual heat through thermochemical networks

1 GENERAL OVERVIEW

CHP VARESE
1992

CHCP VARESE HOSPITAL
2012

CHP MONZA
2009

WTE COMO
1990

SDH VARESE
2015

Acsm Agam L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

1 GENERAL OVERVIEW

- Electric energy produced in cogeneration asset: **72** GWh_e
- Heat produced as hot water, superheated water and steam : **225** GWh_t
- Cooling energy: **16** GWh_f
- DH Network extension: **62,6** km
- Avoided CO2 emissions : **5800** ton

Acsm Agam
L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

2 CHP Plants

VARESE HOSPITAL

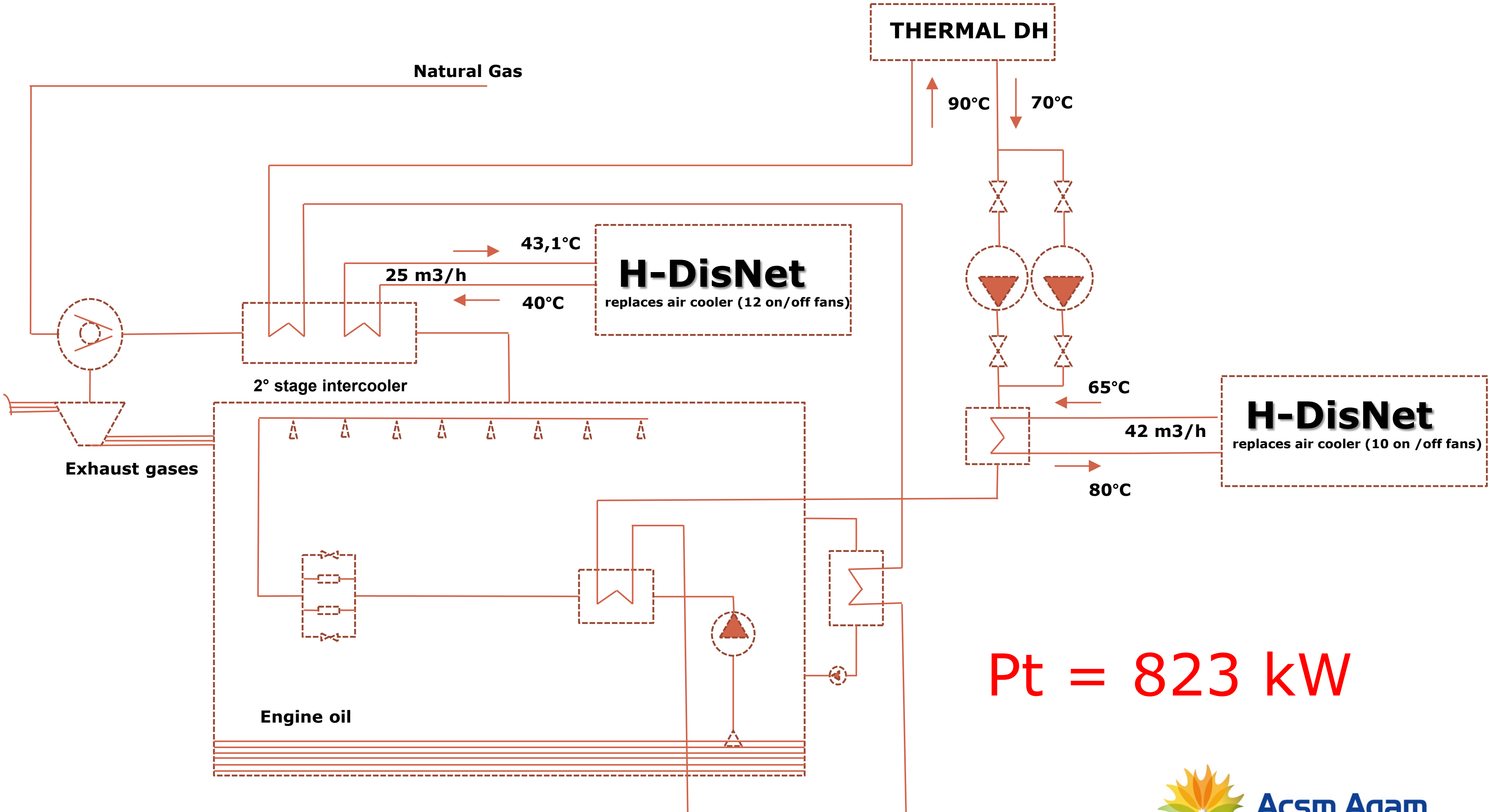
- Cogeneration engine inside the Hospital runs all the year to supply, electric energy, hot water, steam and cooling water

- Hospital distribution plants are not optimised so return temperature from the internal thermal network are often too high and some heat should be dissipated in the atmosphere in order to maintain design supply water temperature necessary to cool down engine oil without cogeneration engine efficiency losses.

- This dissipated heat could be as high as **823 kW_t** which is the design power of the air cooler

- H-DisNet could allow this *thermal* power to be used for new buildings to be projected and constructed inside the hospital area

Valorising low temperature residual heat through thermochemical networks



Pt = 823 kW

Acsm Agam L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

2 CHP Plants

VARESE HOSPITAL

- The plant has four absorption chillers and two compressor chillers for a total power of 13 MW_f, which needed four cooling towers to complete the cycle.
- As a necessary byproduct, refrigeration creates waste heat that is exhausted to ambience or could be recovered for heating purposes by means of H-DisNet
- Two cells cooling towers are dedicated to double stage absorption chiller or compressor chiller while three cells cooling towers are dedicated to single stage absorption chillers
- The total design dissipated heat is equal to 6000 kW for single stage absorption chillers and 4500 kW for double stage or alternatively compressor chillers
- Considering low temperature 33°C -35°C the H-DisNet integration seems more feasible during winter season where cooling power need goes down to about 1000 kW

Valorising low temperature residual heat through thermochemical networks

2 CHP Plants

CASSANO D’ADDA
(MI Italy)

- The plant, managed by ACSM AGAM shareholder A2A, has an overall design power of 760 MW_e

- The plant configuration comprehends two gas turbine (design power 250 MW_e each one) and one steam turbine (design power 260 MW_e)

- Bleed steam (30 MW_t) feeds Cassano water DH network

- Considering the goal to bring heat to Milan City, 35 Km far from Cassano D’Adda, a H-DisNet should be considered as a more efficient solution than traditional one to not disperse heat and to bleed steam from the turbine at a lower temperature

Valorising low temperature residual heat through thermochemical networks

2 CHP Plants

CHP VARESE

- The cogeneration section consists of a gas turbine GE Nuovo Pignone PGT5 with a design power of 5 MW_e and a heat recovery of about 10 MW_t at full load
- Turbogas operates only during winter season (4- 6 months/ year considering the climate conditions) at full load to maximise primary energy savings
- Oil is cooled by an air cooler always in operation when turbogas is running
- The total design dissipated heat is equal to 300 kW at a temperature around 70°C
- During thermal season should be necessary, especially during the night, to open shutters to convey exhaust gases to bypass chimney instead of heat recovery boiler or alternatively to reduce gas turbine load. In the first case heat is dissipated to atmosphere because return temperature from the network is too high and heat recovery exchanger size does not allow higher water flowrate

- H-DisNet integration could recover dissipated heat for oil cooling and also lower DH return temperature so maximising thermal recovery without throttling turbogas or worse opening exhaust gases shutters directly to the atmosphere

Valorising low temperature residual heat through thermochemical networks

3 Foundry

- Recently Varese Risorse has analysed the opportunity to install a cogeneration unit inside a foundry located not far from the municipal DH network

- The foundry registers great electric energy consumption due to the presence of induction furnaces in which the heat is applied by induction heating of metal avoiding in such a way dust and other pollutants emission.

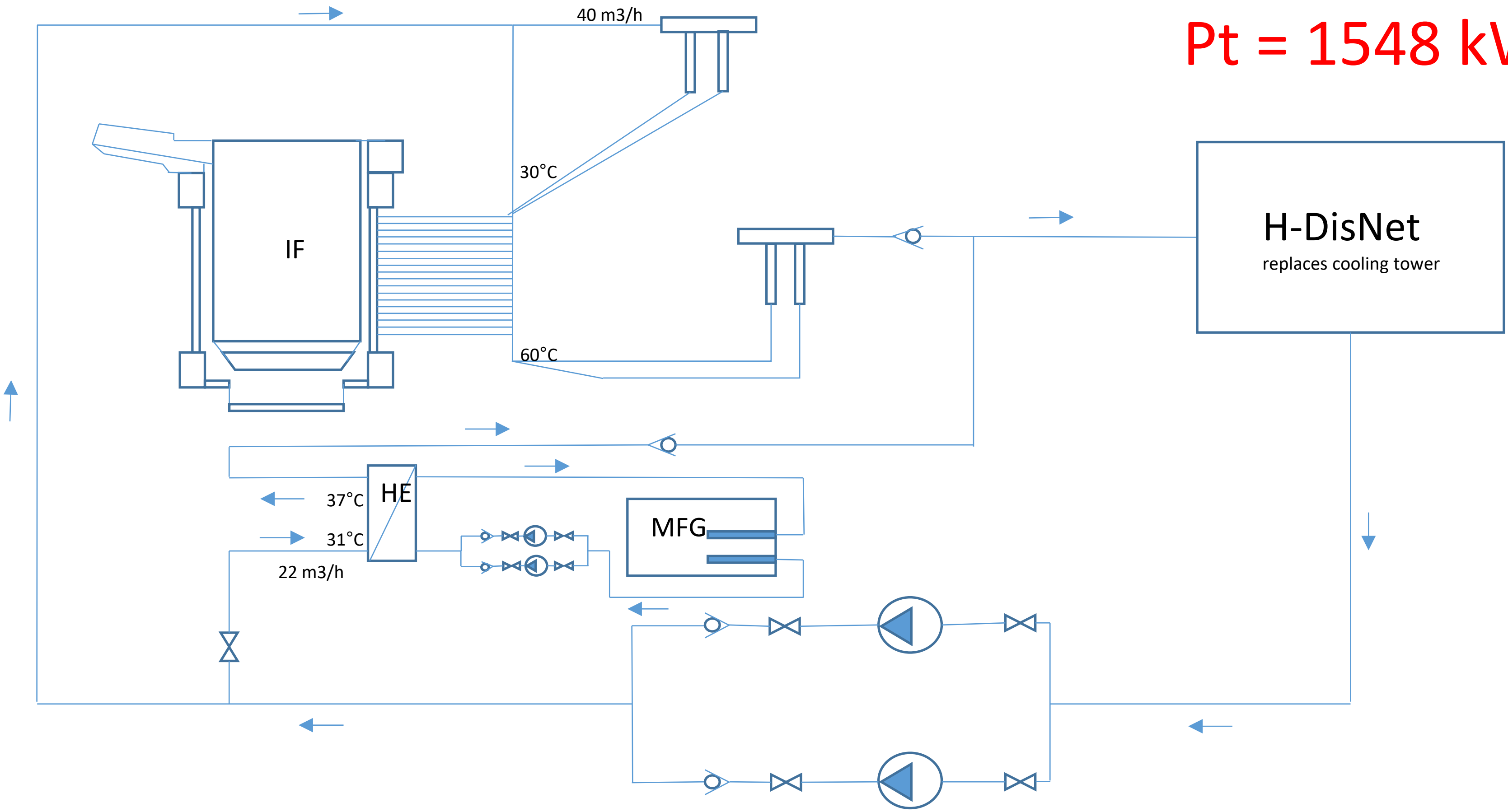
- The heat is generated within the furnace’s charge itself rather than applied by a burning fuel or other external heat source

- The eddy currents, flowing through the electrical resistance of the bulk metal, heat it by Joule heating

- Metal to be melted is placed in a non conductive crucible surrounded by a water cooled alternating current solenoid coil. The dissipated heat should be recovered by H-DisNet

Valorising low temperature residual heat through thermochemical networks

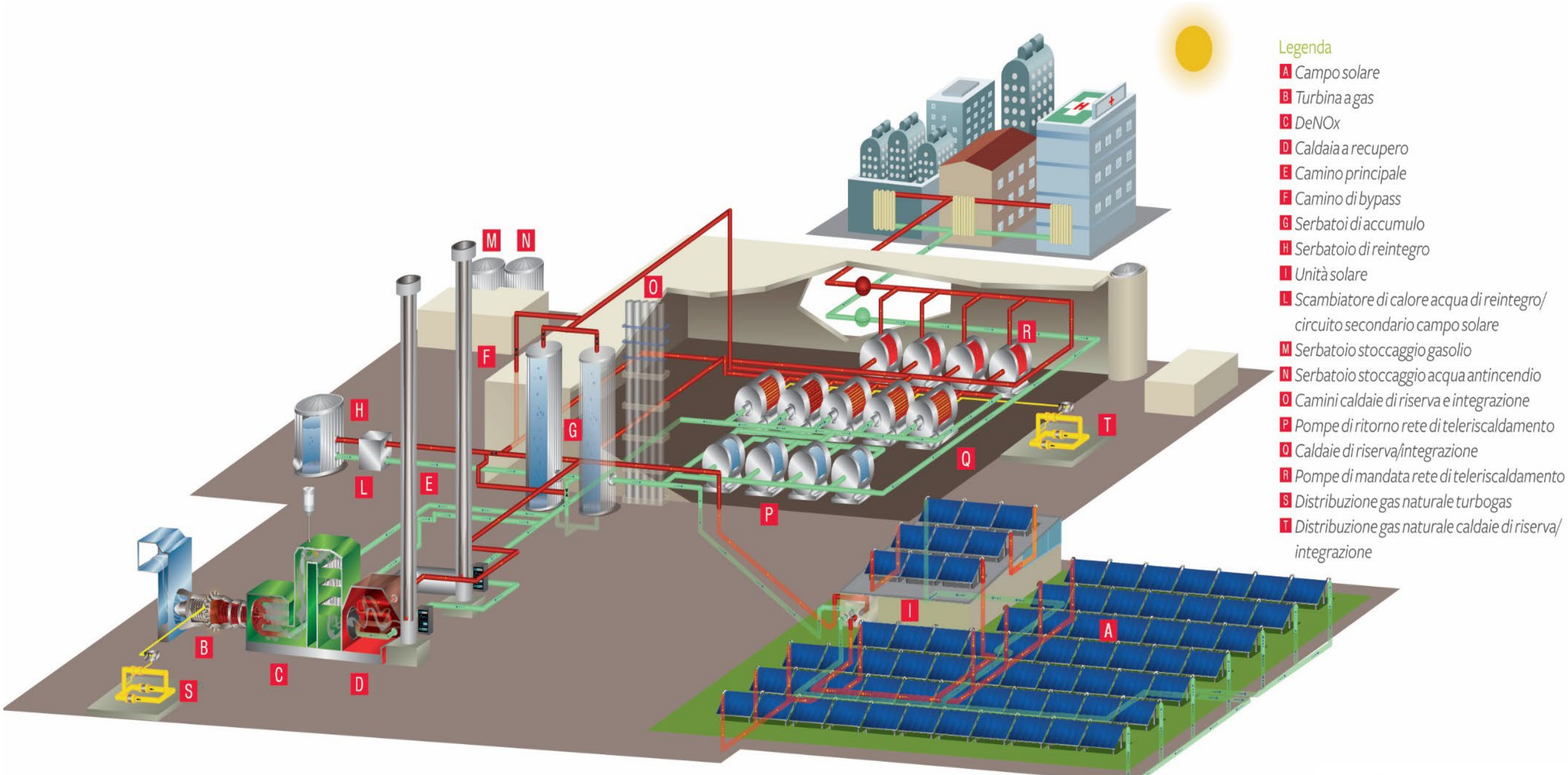
Pt = 1548 kW



Acsm Agam
L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

4 THERMAL SOLAR PLANT



Acsm Agam L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

4 THERMAL SOLAR PLANT

- Solar field gross area: 990 m^2 – Slope 35°
- Total available area : 2600 m^2
- Yearly make up DH water: 2708 m^3
- Yearly solar yield : 500 MWh_t
- Yearly solar fraction: 0,6% - summer: 3,3 %
- Yearly energy savings: 48 toe
- Yearly Avoided CO_2 emissions: 120 ton

Acsm Agam
L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

4 THERMAL SOLAR PLANT

Main Data

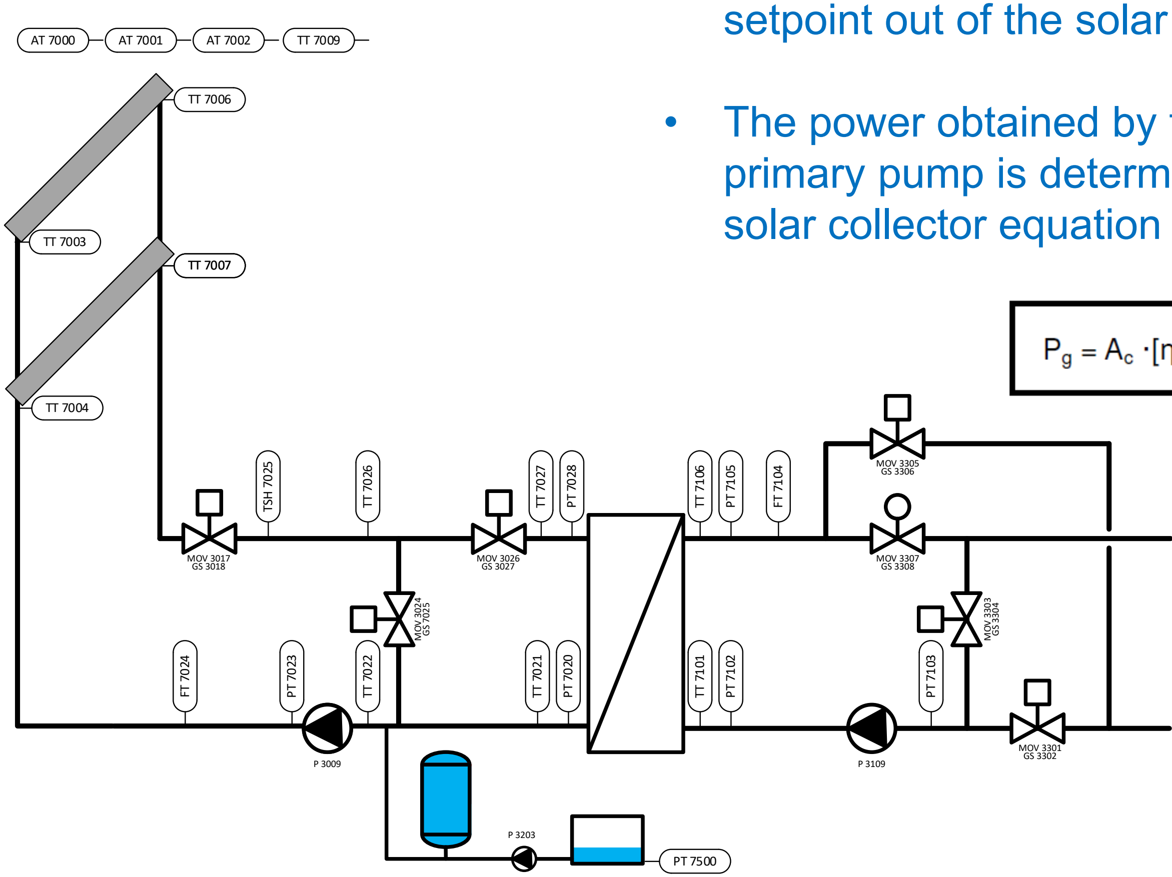
- Hot water storage: 430 m^3 available capacity
- DH heat load always higher than solar field maximum thermal power
- DH network nominal temperature (supply 90 °C, return 65°C) in compliance with thermal solar plant operation temperature range
- DH make up for an heating needs equal to around 15 MWh/month. The treated water is collected inside an insulated make up water tank for a capacity of 75 m^3
- Varese average registered solar radiation: on horizontal 1332 KWh/m^2 y; on tilted surface around 1600 kWh/m^2 y (data taken from Centro Geofisico Prealpino di Campo dei Fiori – Varese)

Acsm Agam
L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

4 THERMAL SOLAR PLANT

- The system is designed to reach a desired temperature setpoint out of the solar unit
- The power obtained by the field and thereby the flow of the primary pump is determined by the solar irradiation and the solar collector equation



ARCON standard unit

$$P_g = A_c \cdot [\eta_0 \cdot G - a_1 \cdot (T_m - T_a) - a_2 \cdot (T_m - T_a)^2] \cdot f_P \cdot f_U \cdot f_O$$

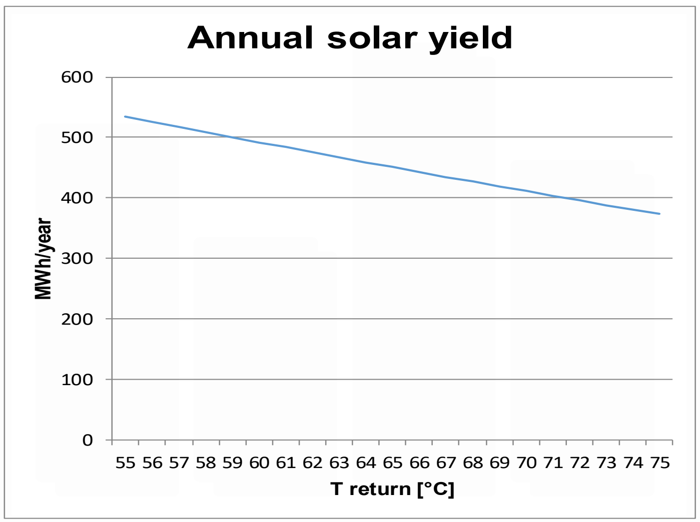
P_g:	Guaranteed performance (thermal power output)
A_c:	Collector area corresponding to the collector efficiency parameters: η_0, a_1 and a_2 (could be taken from collector test report) *Note: This will typically be the collector aperture area*
η_0:	Optical efficiency
a_1:	1st order heat loss coefficient
a_2:	2nd order heat loss coefficient
G:	Solar irradiance on collector plane
T_a:	Ambient air temperature
T_m	$= (T_{c,in} + T_{c,out}) / 2$
where:	
T_m:	Mean temperature of solar collector fluid
$T_{c,out}$:	Hot side of collector field (= collector outlet temperature)
$T_{c,in}$:	Cold side of collector field (= collector inlet temperature)

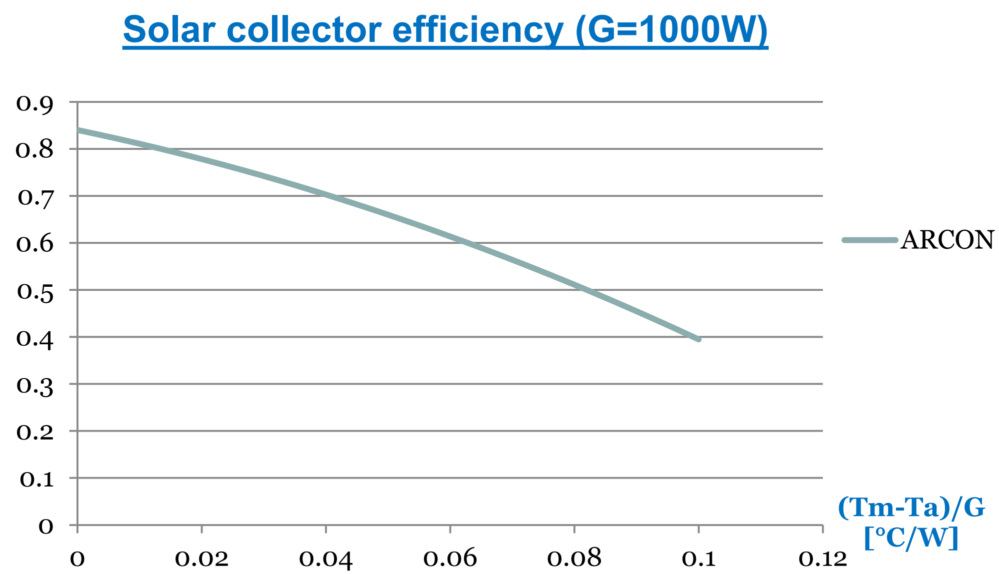
Acsm Agam L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

4 THERMAL SOLAR PLANT

- HT high efficiency plane solar collectors extended for 990 m^2 gross area. Yearly yield: 500 MWh_t



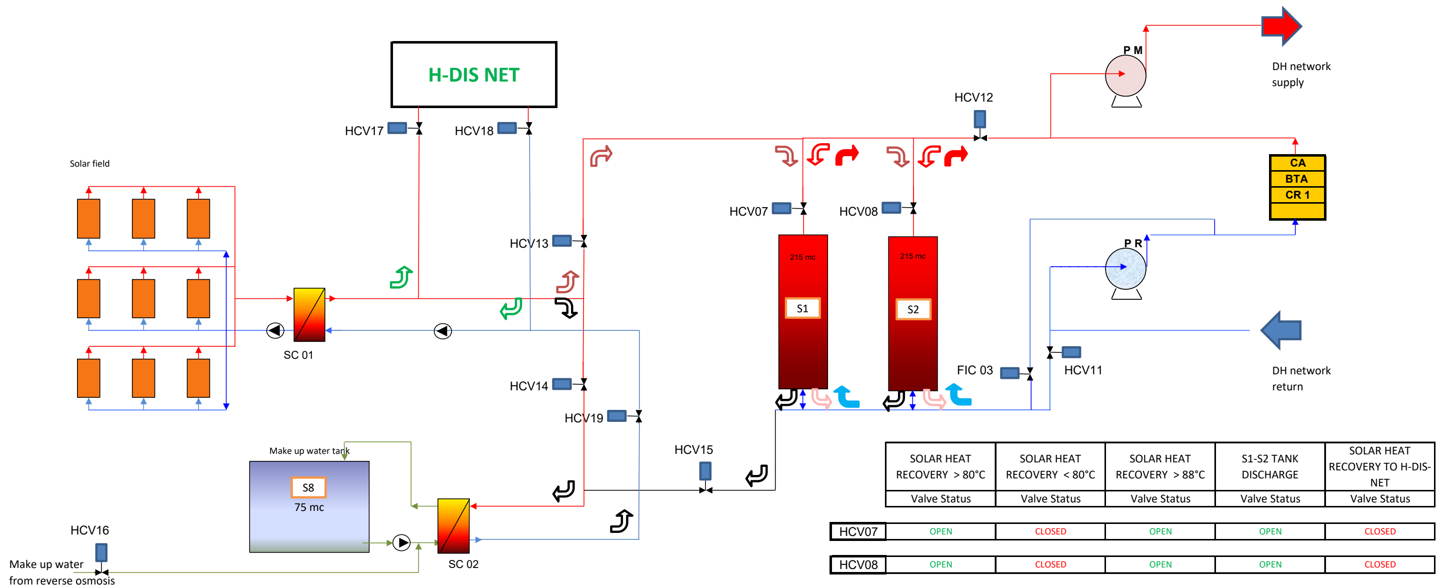


$\mu = 0,84 - 2,753(Tm-Ta)/G - 0,017[(Tm-Ta)/G]^2$

Acsm Agam L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

3 THERMAL SOLAR PLANT

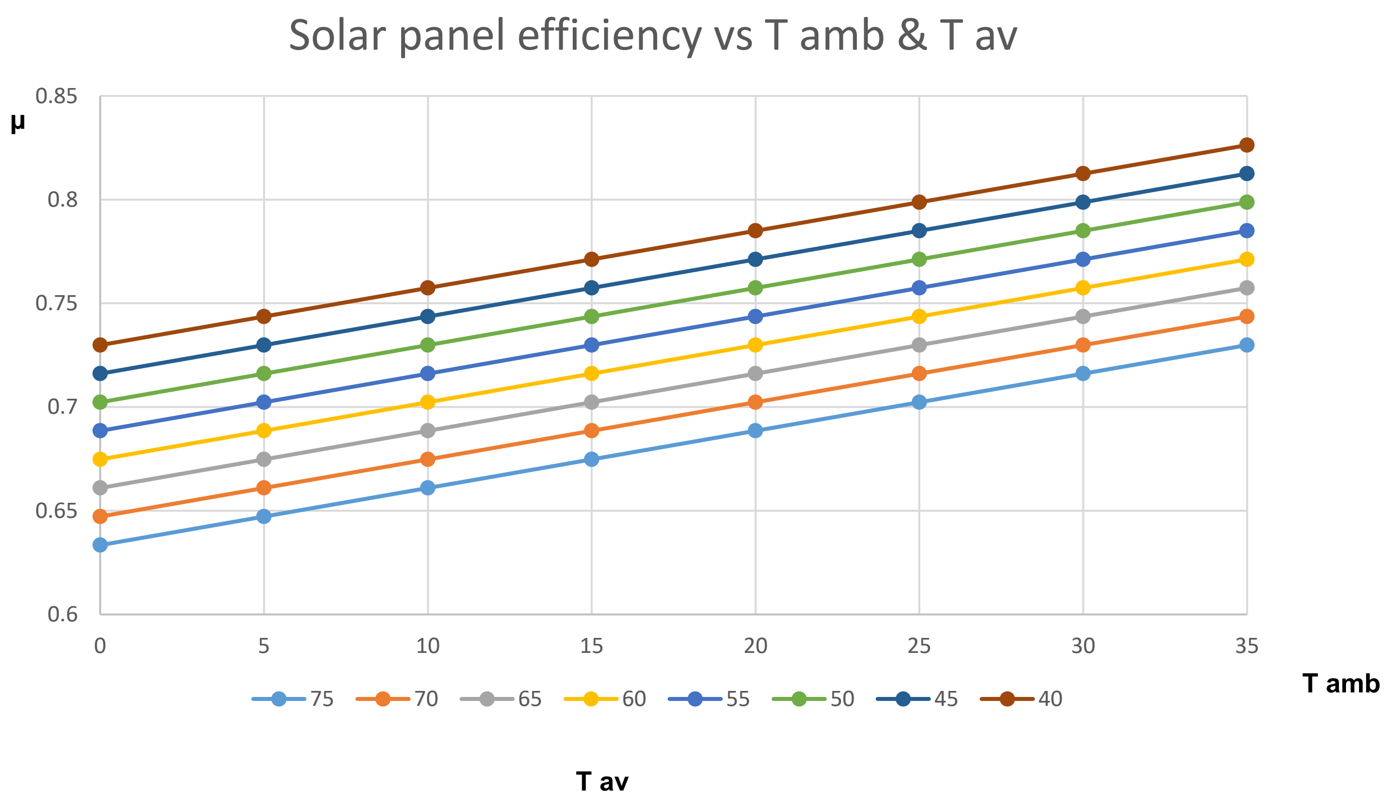


Flowrate	
	Solar heat recovery > 80 °C
	Solar heat recovery < 70 °C
	Cogeneration heat recovery > 88 °C
	Cogeneration heat recovery < 70 °C
	S1 -S2 tank discharge in DH network
	S1 -S2 tank discharge in DH network
	Solar heat recovery to H-DIS-NET

	SOLAR HEAT RECOVERY > 80°C	SOLAR HEAT RECOVERY < 80°C	SOLAR HEAT RECOVERY > 88°C	S1-S2 TANK DISCHARGE	SOLAR HEAT RECOVERY TO H-DIS-NET
	Valve Status	Valve Status	Valve Status	Valve Status	Valve Status
HCV07	OPEN	CLOSED	OPEN	OPEN	CLOSED
HCV08	OPEN	CLOSED	OPEN	OPEN	CLOSED
FIC03	CLOSED	CLOSED	CLOSED	OPEN	CLOSED
HCV11	CLOSED	CLOSED	OPEN	CLOSED	CLOSED
HCV12	CLOSED	CLOSED	OPEN	OPEN	CLOSED
HCV13	OPEN	CLOSED	CLOSED	CLOSED	CLOSED
HCV14	CLOSED	OPEN	CLOSED	CLOSED	CLOSED
HCV15	OPEN	CLOSED	CLOSED	CLOSED	CLOSED
HCV16	OPEN*	OPEN*	CLOSED	CLOSED	CLOSED
HCV17	CLOSED	CLOSED	CLOSED	CLOSED	OPEN
HCV18	CLOSED	CLOSED	CLOSED	CLOSED	OPEN
HCV19	OPEN	OPEN	OPEN	OPEN	CLOSED

Valorising low temperature residual heat through thermochemical networks

3 THERMAL SOLAR PLANT



H-DisNet increases solar field efficiency by almost 13% at ambient temperature 35°C and average collectors temperature of 40°C with respect to 75°C

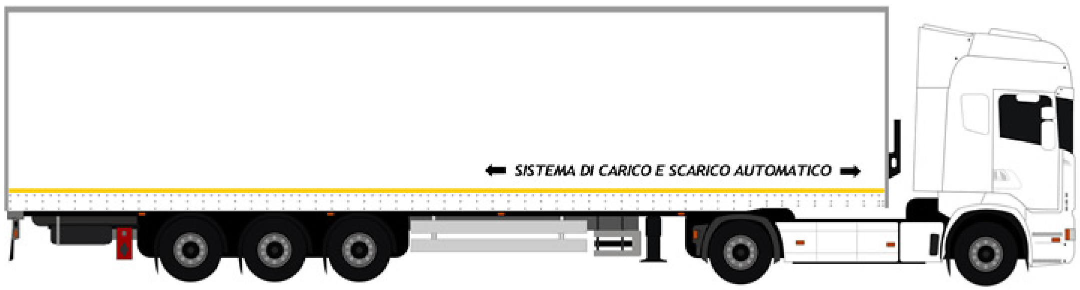
Acsm Agam L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

4 RMDHC

- **Renewable Movable District Heating and Cooling** is an idea to be applied to the transport refrigeration industry

- The refrigerated transport market is rapidly evolving and realise a turnover of up to five billions euro in the European Union alone where more than 650,000 refrigerated vehicles circulate



- Integrate photovoltaic cells and solar thermal collectors on the trucks roofs to produce the energy amount to control the compartment through compression and absorption chiller combined usage

Valorising low temperature residual heat through thermochemical networks

4 RMDHC

- Imagine trucks during sunlight hours still in parking areas properly equipped in contiguity with H-DisNet disposed in functional array to create a large temporary solar field transferring their surplus energy production directly to the network and the start for deliveries in the territory from sunset till dawn

- During the night, with the truck engine in operation, it should be also possible to use part of the flue gases heat discharged from the catalyst to supply heat to primary solar circuit connecting a dedicated heat exchanger downstream the catalyst in parallel with the solar panels

- A key role will be played by electric energy storage systems on which however there is already great technological excitement, while H-DisNet in itself already constitutes a natural excess heat storage tank

- Vacuum solar thermal collector choice, however, could also allow heat production with the trucks in movement during daylight hours considering that this type of panels do not have convective losses

Valorising low temperature residual heat through thermochemical networks

4 RMDHC

- The technological challenge is to construct a single integrated thermal and photovoltaic panel (hybrid (PVT) solar collector), designed using light materials (Al or plastic) to reduce the weight and thus the energy losses due to increased truck wheels friction

- An isothermal reinforced truck is characterised by walls thick at least 45 mm with a thermal coefficient k equal to or less than 0,40 W/ m^2 K. Taking into account a large truck (13,60 x 2,44 x 2,60) it can be assumed to dedicate the front area of the refrigerator compartment closest to the cabin to host the equipment necessary for the cold generation (absorption, compressor chillers, pumps, battery electricity storage, etc..) The cooling power required to remove the heat input from the six walls would amount to 1,816 kW with external temperature of 35°C and internal temperature equal to -5°C

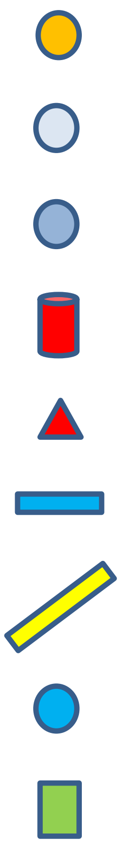
- The technical solution would consist of controlling the temperature in two stages of chilled water (added with 40% propylene glycol) in two separate circuits. A first “base stage” of absorption chiller would bring the temperature from 35°C to 10°C, a second “control stage” would adjust the compartment temperature between 10°C and -5°C through the compression chiller electrically or mechanically operated

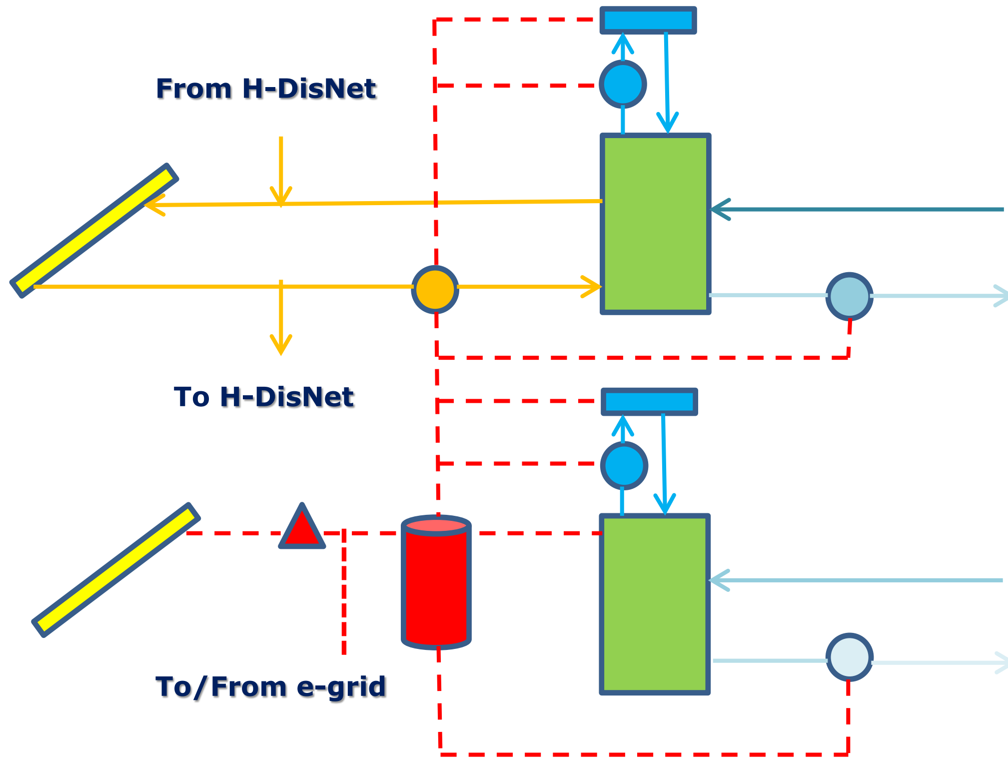
Acsm Agam
L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

4 RMDHC

Legend





Valorising low temperature residual heat through thermochemical networks

4 RMDHC

- The temperature control is delegated to two circuits that act in series to remove residual heat form the compartment. The external circuit is connected with the absorption chiller in “direct solar” mode. It means that the solar energy will be directly sent to the chiller without any accumulation after having ascertained the primary water temperature (at least 10 °C) than a technical minimum necessary to the operation of the chiller itself. In this operative conditions the adsorption chiller should always work at maximum load close to maximum achievable COP

- In case should be useless to refrigerate the compartment this primary circuit could be connected in suitably prepared parking areas to secondary circuit to enable H-DisNet allowing the delivery of solar heat via the series and parallel connection of solar panels as made in large solar fields in Northern Europe

- Similarly the electrical energy produced by photovoltaic panels could be fed directly to the power grid which the parking areas will be equipped with

Acsm Agam
L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

4 RMDHC

- The solar field would be so composed as a big puzzle where each truck represents the tile to compose the solar array whose connecting logistic with the H-DisNet will be agile and predefined

- The storage battery can also be powered by electric grid which the parking area will be equipped with. The advantage is that this electric energy may be drawn directly from high efficiency biomass cogeneration plants or waste to energy, CHP plants, wind farms electrically connected in parallel with the H-DisNet, thereby maximising the energy savings and the use of renewable energy

- Thinking of a vacuum solar panel 6 m^2 extended at Northern Italy latitudes it can be estimated a truck cooling production through single stage absorption chiller (COP 0,6) of about 2,880 kWh_f/year

- Considering a high performance photovoltaic panel 6 m^2 extended it can be estimated a truck cooling production of about 4,620 kWh_f/year by means of a compressor chiller (COP 4)

Acsm Agam L'ENERGIA CHE UNISCE

Valorising low temperature residual heat through thermochemical networks

4 RMDHC

- Limiting our analysis to 50,000 trucks we would have 300,000 m^2 of thermal solar collectors and 300,000 m^2 of photovoltaic solar panels with a total thermal power peak of 358 MW_t and electrical of 250 MW_e.
- The production of cooling energy would be equal to 393,000 MWh_t or alternatively the production of thermal energy by means of **H-DisNet** would be equal to **270,000 MWh_t** and the production of electricity would be equal to 57,750 MWh_e
- The primary energy savings, considering absolute references on the best benchmark for the combined production of electricity and heat (μt= 0,9 and μe= 0,525) would equal approximately **36,544 toe/year equivalent to 112,626 tons/year of CO_2 emissions** avoided in atmosphere data that **almost double in comparison with the actual situation**
- The above solution, adequately supported by governments and technologically developed with the best available techniques, could well provide an important contribution in the desired direction

Valorising low temperature residual heat through thermochemical networks

6 CONCLUSIONS

- Air conditioning demand continuously growing not only in the tertiary sector but also in residential applications
- Frequent crisis of the electrical network due to load peaks mainly satisfied recurring to fossil fuel thermoelectric plants
- Government future subsidies on demolition and reconstruction buildings in accordance with new building earthquake proof and energetic standards
- Worldwide target to reduce more and more greenhouse effect as stated in COP21 Paris agreement
- Civil and transport sector uncoupled to reach the efficiency, renewables, CO_2 emission European targets (for transport -30% by 2030)
- Parallel use of **H-DisNet** together with thermal DH network to valorise low temperature heat, waste heat or heat produced by renewables such as solar, biomass, waste to energy should be an effective way to get the goal as defined by Paris agreement even making a bridge between transport and civil sector by means of **RMDHC** solution allowing the distribution of waste thermal energy produced in plants or service stations located far from the cities where will be concentrated the major part of world population (nowadays 54%, trend 66% by 2030).

Valorising low temperature residual heat through thermochemical networks

6 CONCLUSIONS

"If a distinguished scientist says something is possible he is almost certainly right, but if he says that it is impossible he is very probably wrong"

Arthur C. Clarke (1917-2008)

Thank you for your kind attention!

[*fabio.fidanza@vareseririsorse.it*](mailto:fabio.fidanza@vareserisorse.it)

www.vareserisorse.it
www.acsm-agam.it

Acsm Agam
L'ENERGIA CHE UNISCE