Hegel

HIGH EFFICIENCY POLYGENERATION APPLICATIONS

The HEGEL project
a focus on trigeneration

Franco Anzioso
Paolo Chiantore
Centro Ricerche Fiat

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THE SCENARIO

The recently published **action plan for energy efficiency** underlines that the **European Union is facing a crucial challenge** in the energy field:

- Europe continues to **waste at least 20% of its energy** due to inefficiency
- the perspectives for the future is that **in 2050**:
  - ✓almost ¾ **of the world's energy supply will still come from fossil** fuels
  - ✓**energy demand as well as CO_2 emissions** will more than **double**

THE TARGET

Europe wants to **lead** the way **in reducing energy inefficiency,** using all available policy tools at all different levels of government and society.

THE CHALLENGE

European Union is facing a crucial challenge in the energy field and to complement centralised generation with distributed generation will be a winning strategy.

In this framework **HEGEL** will **test on the field some of** the **most promising technologies** for **distributed generation** without overlooking market and competitiveness aspects.

INTRODUCTION

HEGEL IS A PROJECT AIMED TO DEVELOP, DEMONSTRATE AND COMPARE HIGH EFFICIENCY APPLICATIONS OF MICRO-POLYGENERATION

Hegel

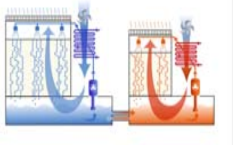
CRF COGENERATOR

Micro Turbine Capstone C65

Combined Cycle Application Installed in Turkey

CHP + Liquid Desiccant DuCool Installed in Italy

MT+Absorption Robur Hot Oil Driven Installed in Spain



Three demonstration plants will be constructed and tested:

- **"ICE-Desiccant"**

  a trigeneration plant that will be installed at Politecnico di Torino (Italy)

- **"Combi System"**

  a small-size combined-cycle that will be installed and tested at Middle Technical University, in Ankara (Turkey)

- **"MT-Absorption"**

  a trigeneration plant that will be installed in Spain.

HEGEL (high efficiency polygeneration applications) is a project financedby European commission in the 6th Framework Programme under priority 6.1.

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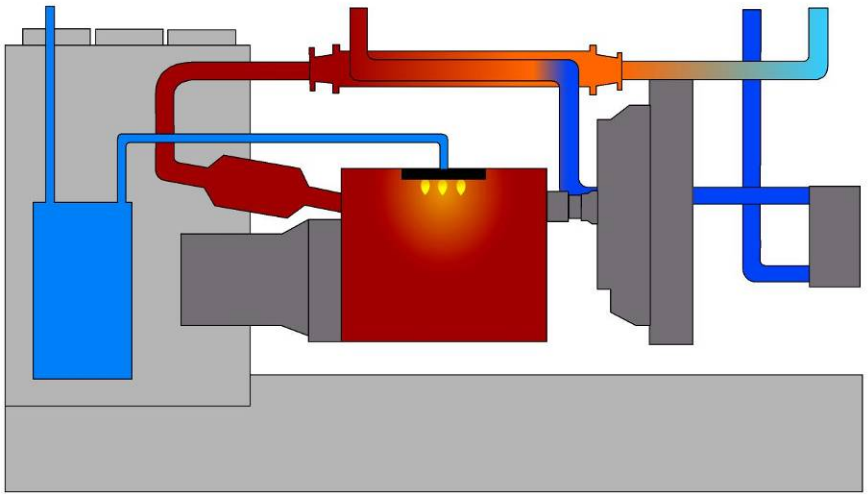
FIAT RESEARCH CENTER
CONTINUOUS COGENERATOR

CHARACTERISTIC OF THE CRF SYSTEM

Main Features:

- Automotive derived natural gas engine (stoichiometric, turbocharged, 3W catalyst)
- Power regulation at variable speed
- Constant efficiency @ partial load
- Telematic management
- Plug and Play



Technical features

Fuel:	natural gas/ biogas
Feeding:	multipoint injection

Performance

Nominal power:	~ 120 kW
Thermal power:	~ 188 kW
Electrical efficiency:	~ 33%
exhaust gas temperature:	~ 700°C
exhaust gas flow rate:	~ 0.13 kg/s

Function

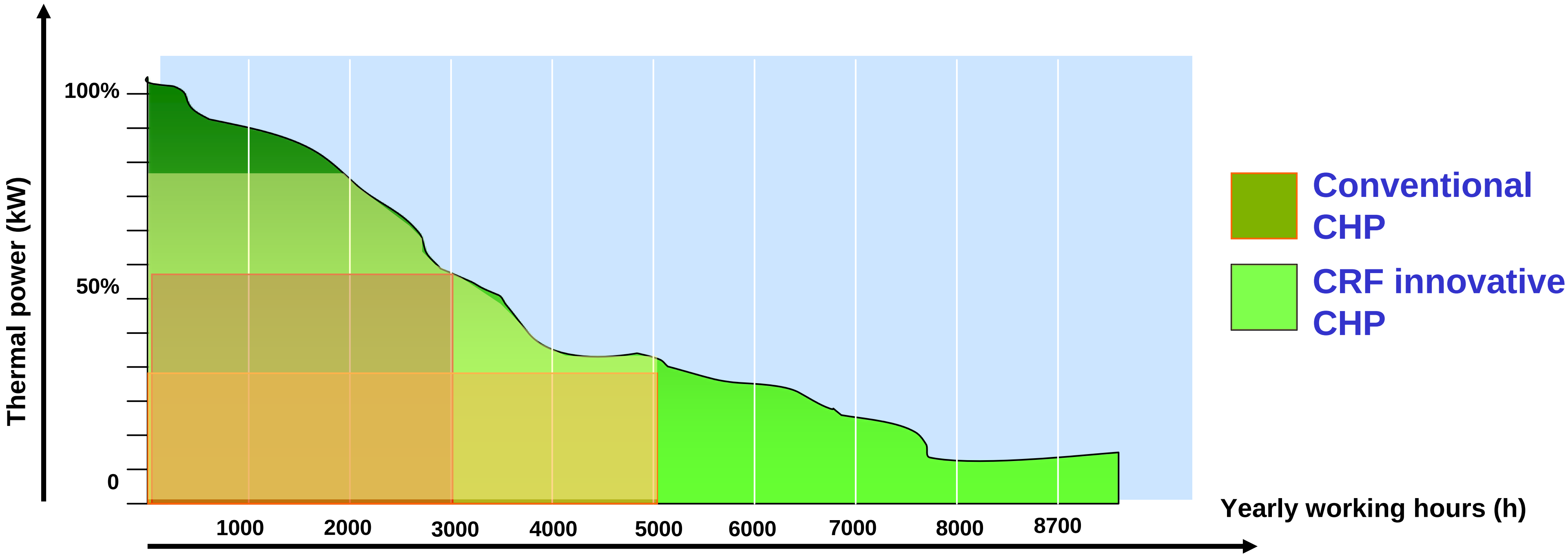
- **POWER RATE CONTROL**: acting on engine RPM and fuel injection (optimizing emissions and efficiency).
- **DUAL MODE**: automated switch between island and parallel mode.
- **UPS**: the continuity necessary before ICE startup is assured by a power buffer .
- **POWER QUALITY**: controlled through power electronics.
- **REMOTE MANAGEMENT**: via a telematic system.

Flexible output

A conventional cogeneration system is sized according to its nominal power capacity (best efficiency condition)

The <u>constant efficiency @ partial loads</u> of the CRF system make the power output <u>more flexible</u>:

→ capable of more yearly equivalent hours of operation ⇔ shorter payback
→ suitable to diverse final user load profiles.



CRF vs Microturbine: energy efficiency

Due to the application of advanced high efficiency engine, the CRF system shows higher efficiency at rated power (32,5% vs 28%).

Due to its unique variable RPM power control, CRF system efficiency remains almost constant at partial loads (30% vs nearly 17% @ 30% of rated power).

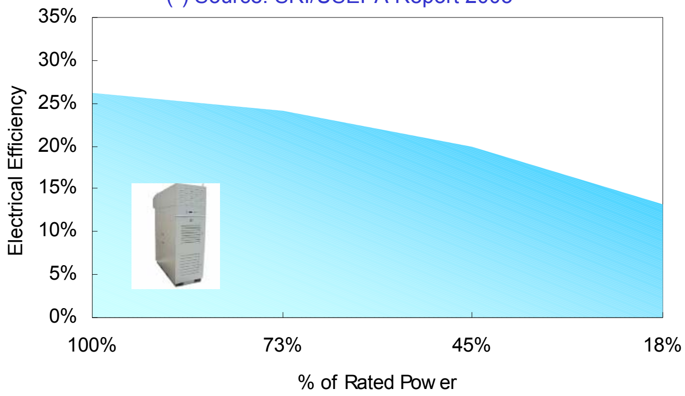
Application consequence

The higher the energy efficiency the lower the variable cost of the energy produced.

Nearly constant efficiency at partial loads provides the CRF system with a unique capability of following variable demand load profiles in a profitable way.

Electrical efficiency

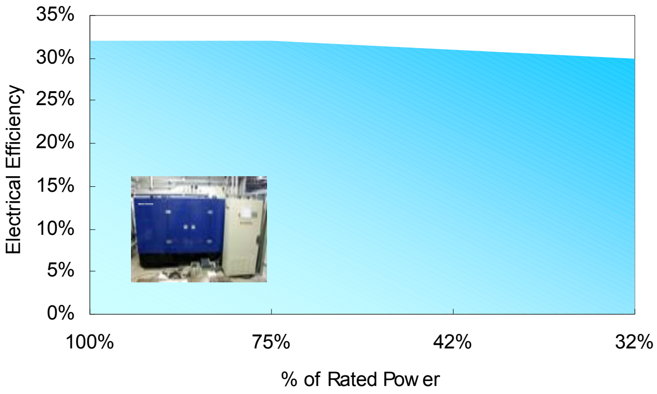
(*) Source: SRI/USEPA Report 2003



EL Energy cost [c€/kWh] (*)
15
17
21
26
35
52

(*) natural gas price @ 0,5 €/m^3

Electrical efficiency



ICED

Internal Combustion Engine + Desiccant Cooling
TRIGENERATION

What is it?

ICED stands for **I**nternal **C**ombustion **E**ngine and **D**esiccant cooling:

- it is a trigeneration plant
- based on the integration of:
  1. a natural gas Internal Combustion Engine cogenerator (ICE)
  2. a liquid Desiccant cooling system (TAC)
- its distinctive features will be:
  1. constant part load electrical efficiency
  2. UPS functions
  3. Thermally activated cooling
     (without post heating and with flexible humidity/temperature output ratio)
  4. Possibility of cooling storage

CRF cogenerator (features 1–2)

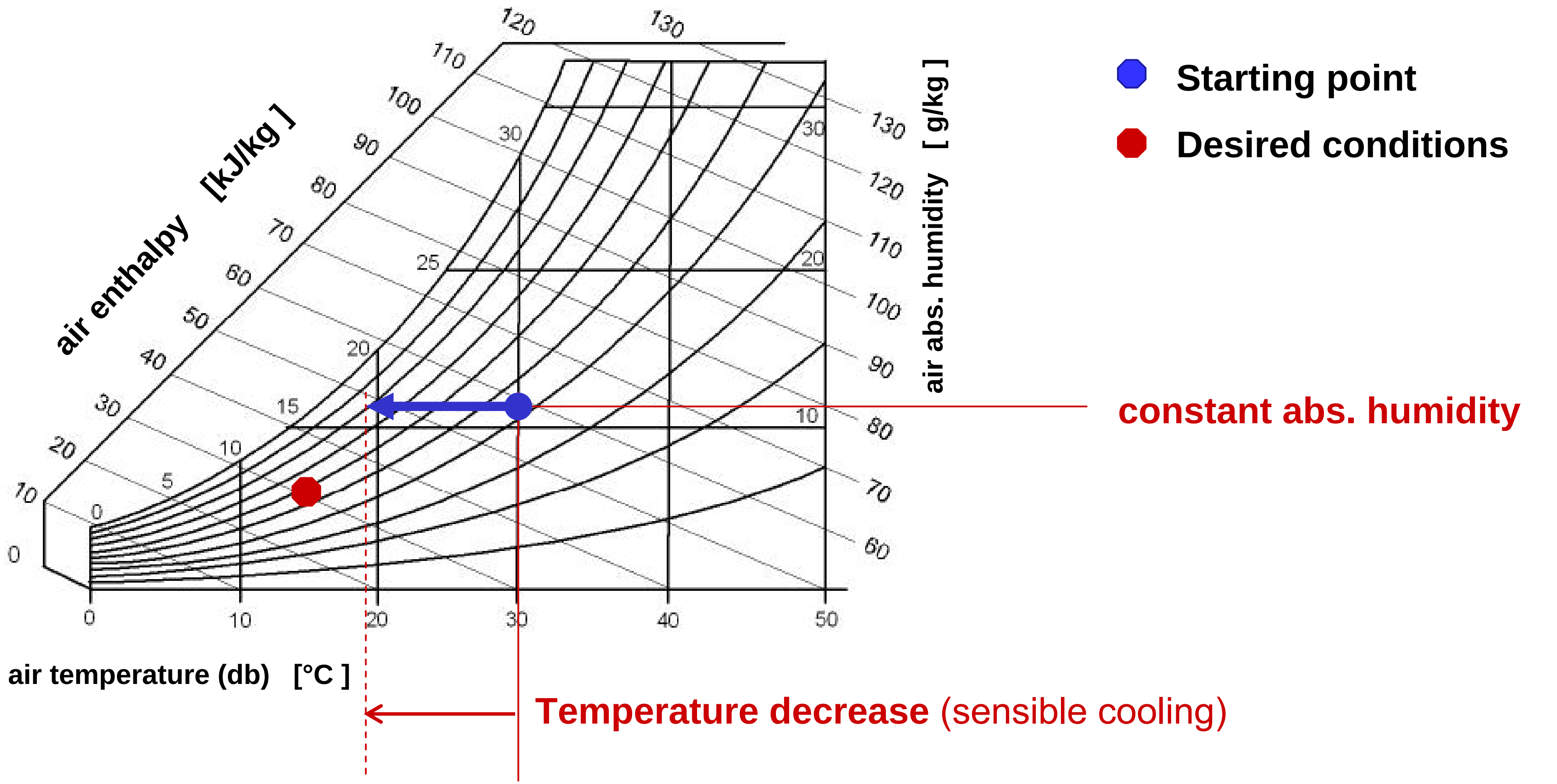
TAC system description

The TAC (Thermally Activated air Conditioner) desiccant cooling system is expected to have:

- **HIGH EFFICIENCY:** overall expected COP exceeding 1.
- **HUMIDITY CONTROL:** embedded in the desiccant control.
- **HIGH AIR QUALITY:** obtained trough humidity control and trough efficiency in latent loads handling.
- **HIGH FLEXIBILITY of HEAT INPUT:** operation will be possible at low inlet temperatures and even with fluctuating temperatures (a concentrated desiccants solution storage could add further flexibility to the required heat input).

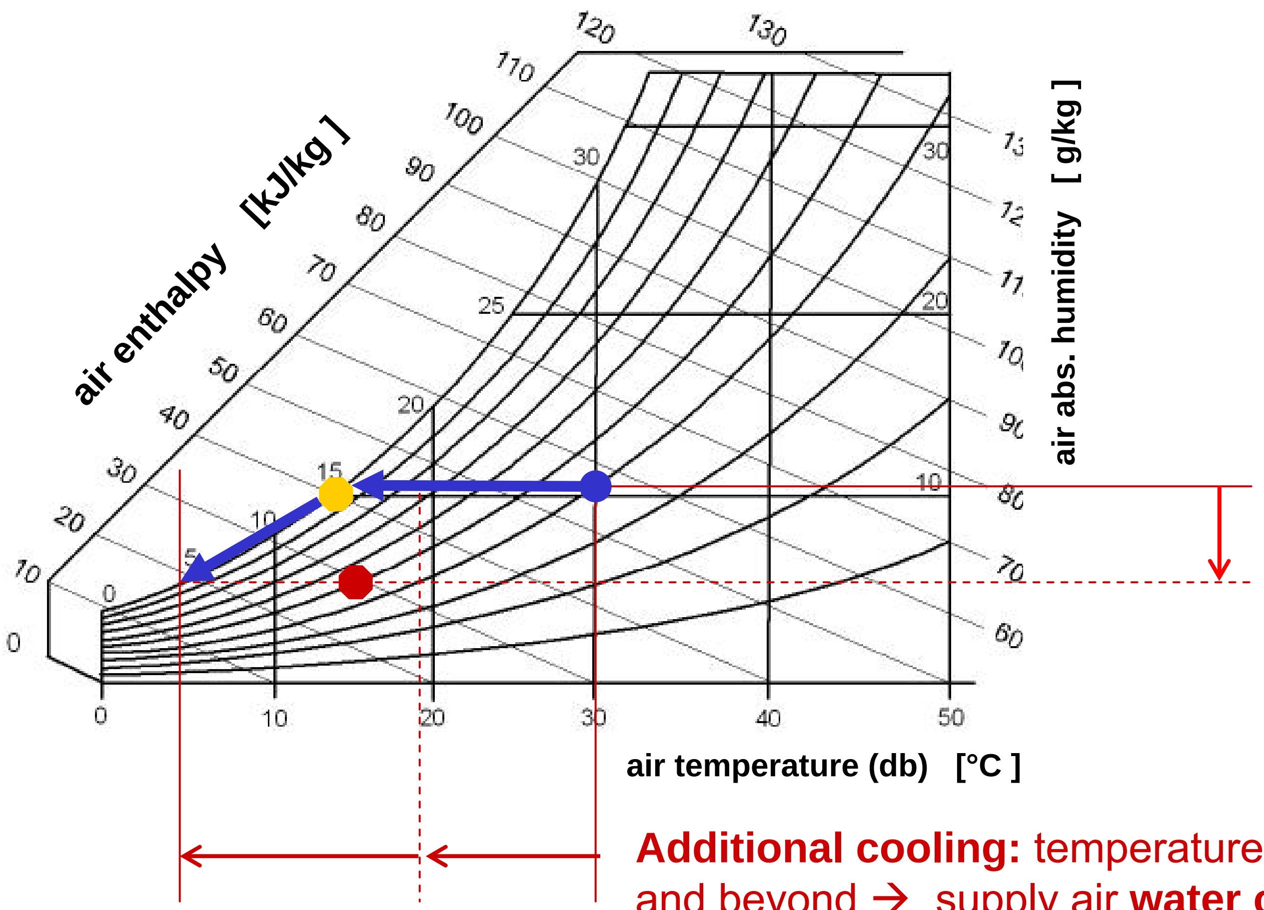
Conventional cooling concept

Traditional cooling systems allow to “move” only “horizzontally” on the psychrometric chart (i.e. air temperature decrease)



Conventional cooling concept

Traditional cooling systems have to reach the air **dew point** in order to lower humidity:



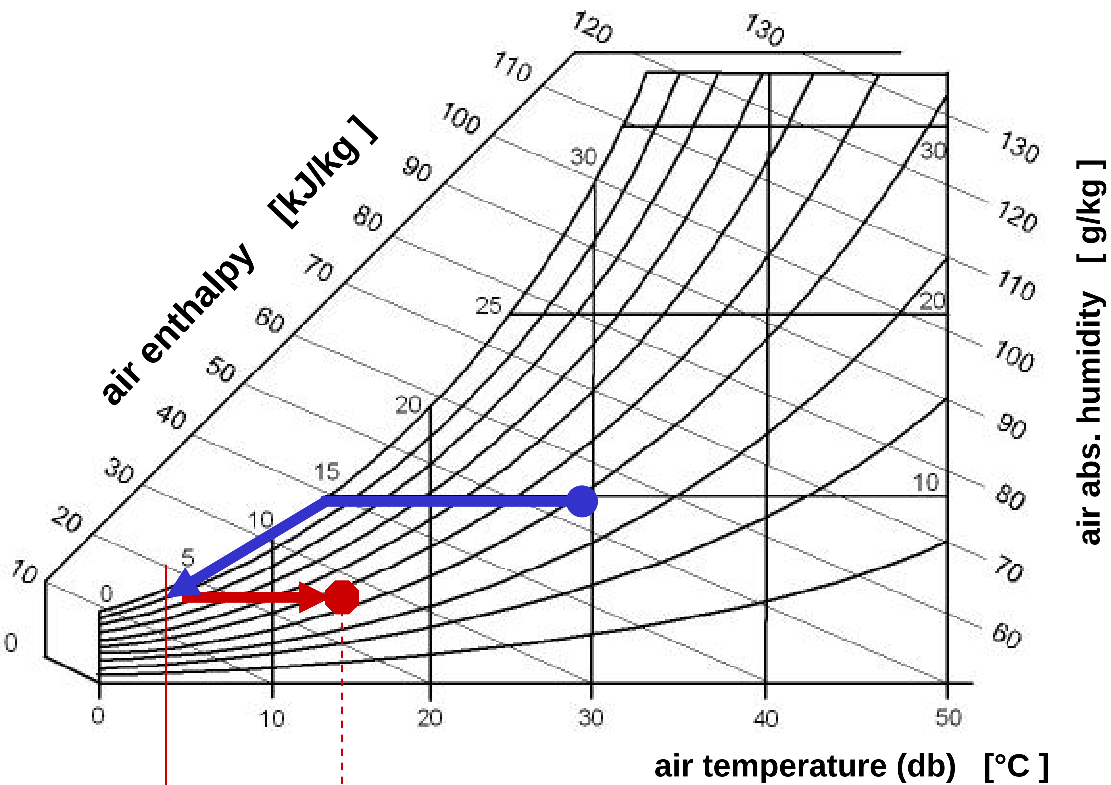
- Starting point
- Desired conditions
- Dew point

abs. humidity decrease
(latent cooling)

Additional cooling: temperature decreases to the dew point and beyond → supply air **water condensation** (diagonal line)

Conventional cooling concept

Traditional cooling systems need post heating, after reaching the desired humidity through condensation:



- **Starting point** (blue)
- **Desired conditions** (red)

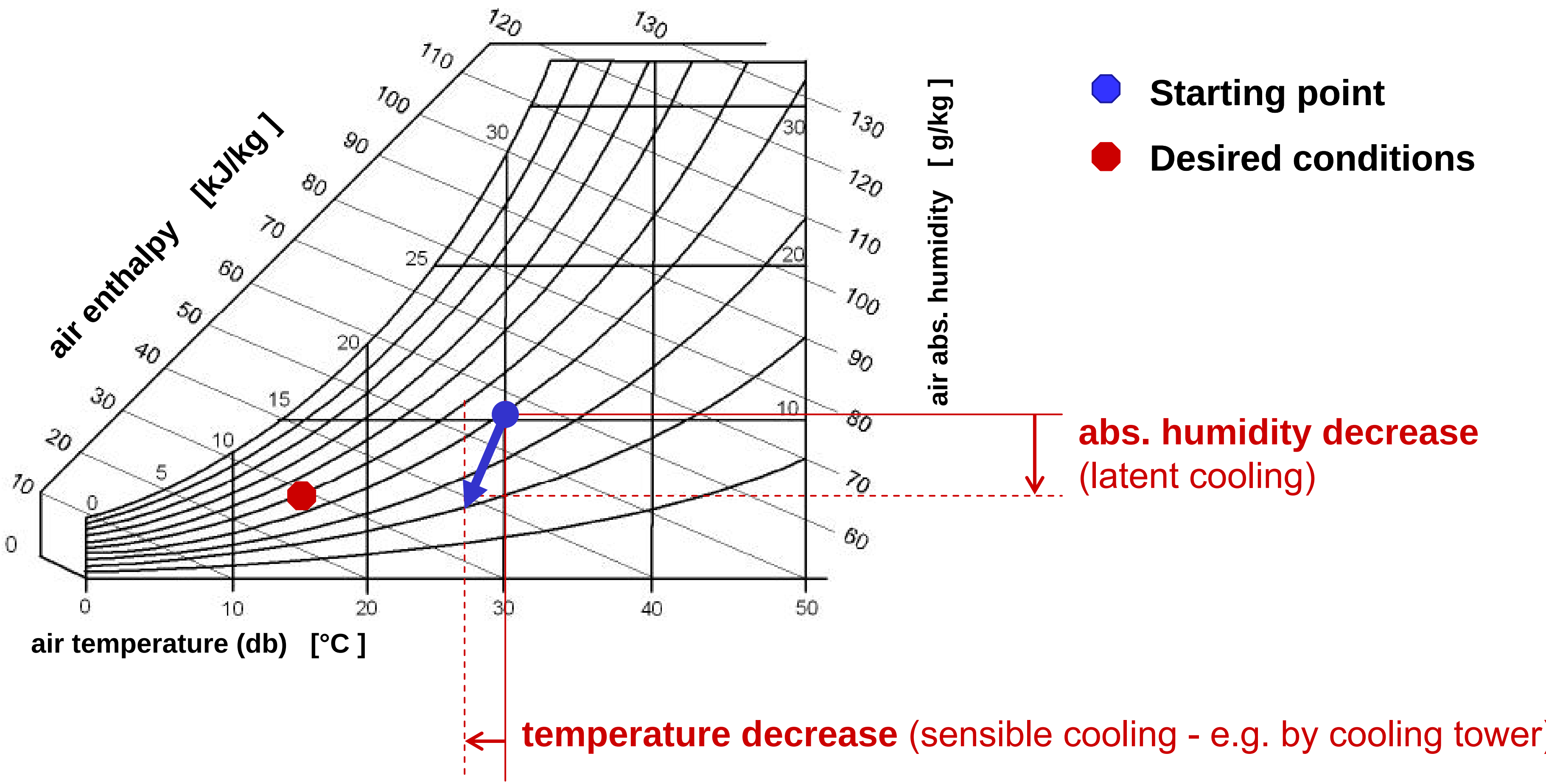
Example data

Starting point:	**30°C**	**11 g/kg**
Intermediate step:	**5°C**	**6 g/kg**
Arriving point:	**17°C**	**6 g/kg**

Post heating: temperature has to be increased to reach desired supply air temperature and r.h.

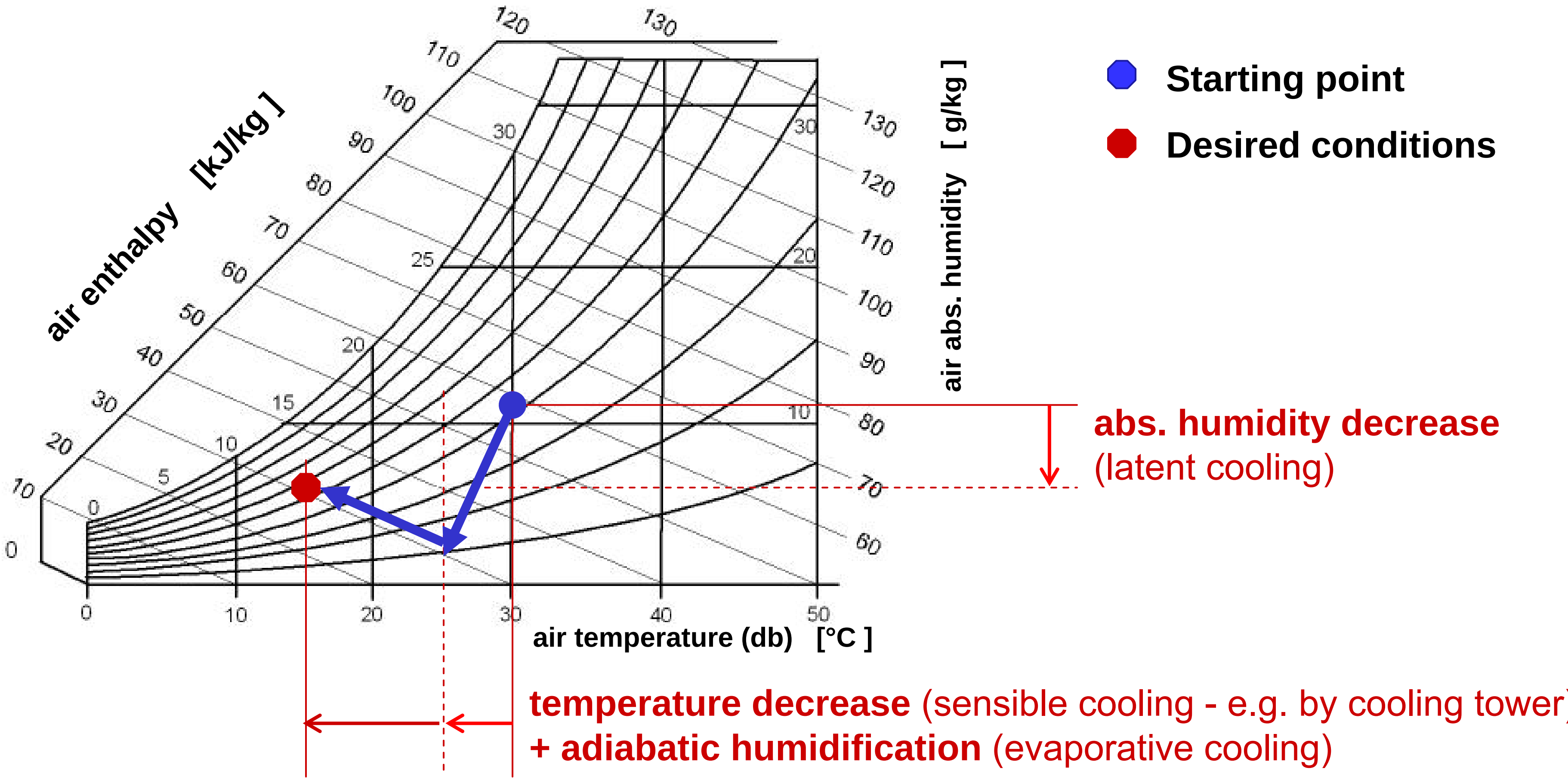
Desiccant cooling concept

Desiccant cooling systems allow to “move” in “diagonal” on the psychrometric chart (simoultaneous humidity and temperature decrease):



Desiccant cooling concept

Desiccant cooling systems need adiabatic humidification to adjust final supply air conditions (increase humidity @constant enthalpy):



Desiccant cooling pro/cons

Liquid Desiccant cooling systems advantages:

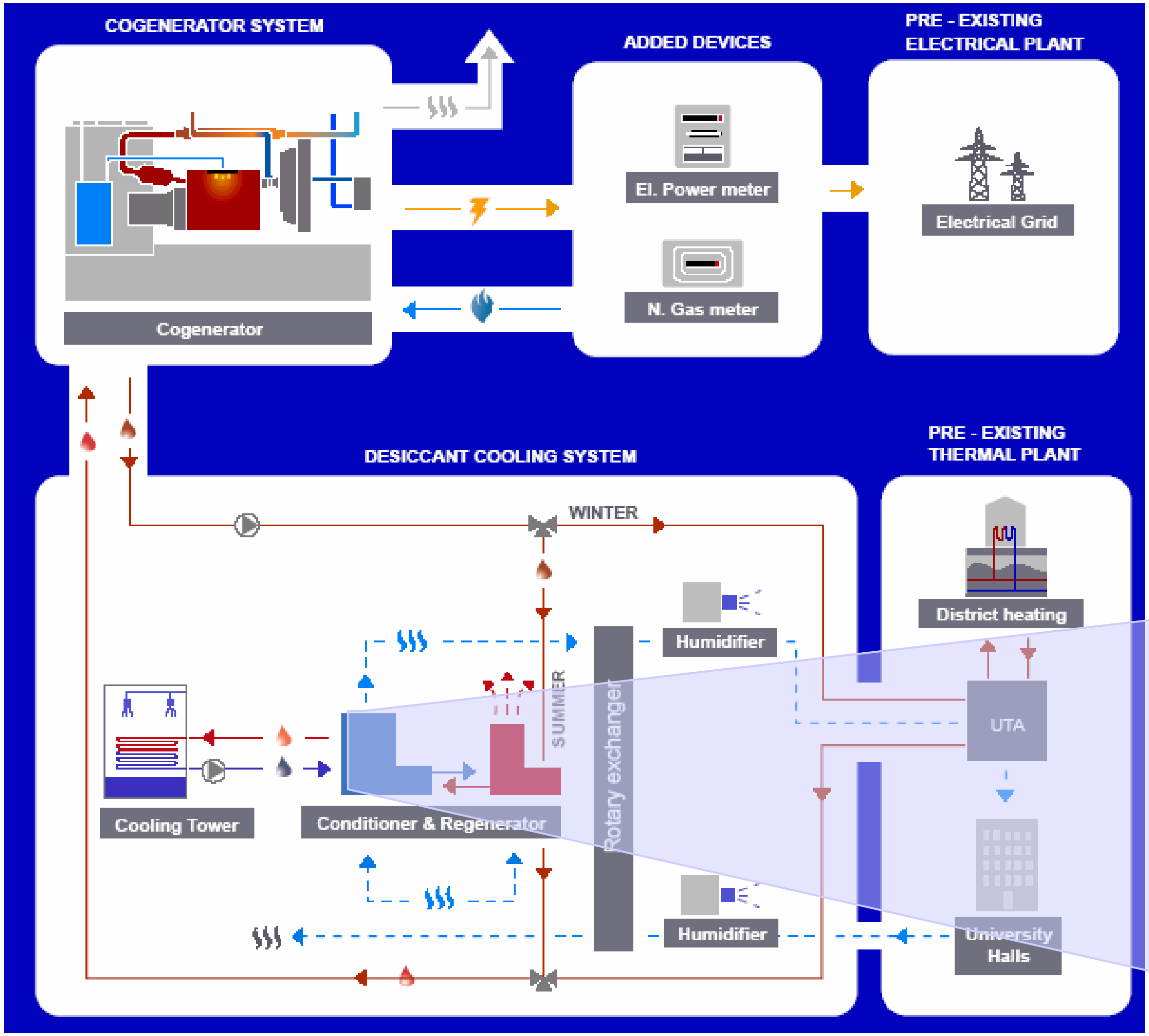
- Thermal activation (suitable for trigeneration)
- Precise control over humidity ratio
- No need for reaching the air dew point and then re-heat (cooling process intrinsically requiring less energy)
- Possibility of storing latent cooling capability at ambient temperature (through a concentrated desiccant solution storage) allowing flexibility over time of CHP heat output.

Liquid Desiccant cooling systems drawbacks:

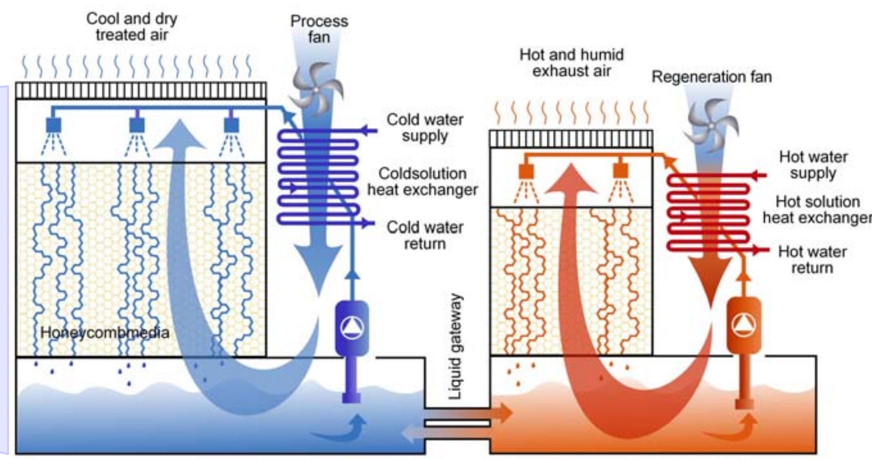
- Corrosion issues (when using LiCl desiccant solution)
- Need for cooling water (e.g. cooling tower)
- Operate on air stream (less flexible installation than hydronic systems)

THE INSTALLATION

FUNCTIONAL LAYOUT



The conditioned building is part of the Polytechnic of Turin (university lecture halls)



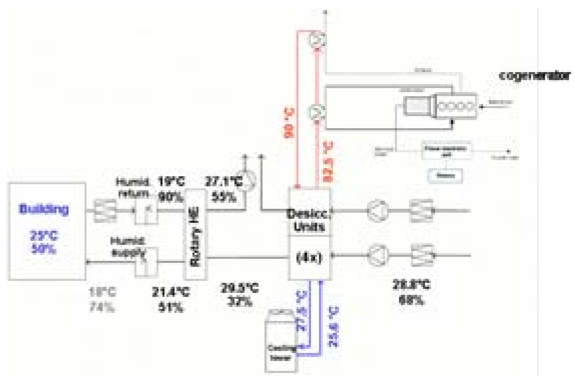
ICED quick glance

THIS SUBPROJECT IS AIMED AT INTEGRATING A LIQUID DESICCANT SYSTEM WITH THE COGENERATOR DEVELOPED AT CRF.

INSTALLATION SITE

The building, in the city of Torino – Italy, comprise seven University lecture halls within the Polytechnic of Turin premises.

The building is currently heated in winter through an all-air system integrated with hot water heaters (heat, both for AHU and heaters, is provided by district heating). No cooling is present in summer.



PERFORMANCE & BENEFITS (EXPECTED)

Electric	120 kW
Heating	188 kW
Cooling*	192 kW
Electrical efficiency (CHP)	33%
Total Efficiency (CHP)	85%
COP expected (Cooling)	1.3

Primary Energy Savings :

During Winter:	31 % (heat)
During Summer:	28 % (cool)

CO_2 Emission Savings

During Winter:	162 kg/h (heat)
During Summer:	32 kg/h (cool)

* external air @ 28.8°C 68% R.H.

MTA

Micro Turbine + Absorption chiller

TRIGENERATION

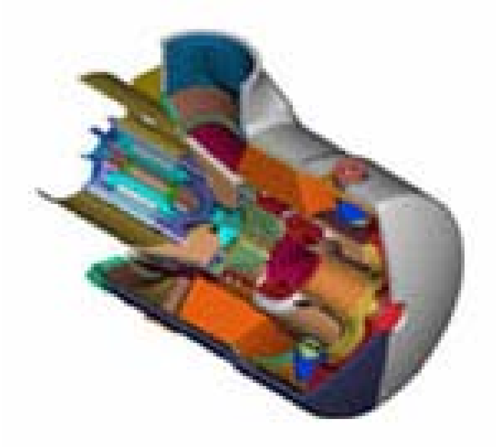
MTA

Micro-GasTurbines are excellent power generators for use in combined heat and power systems

Advantages over other competing technologies:

- **Lightweight and very compact systems**
- **Low noise levels and vibration free**
- **Lower exhaust gas emissions**
- **Less maintenance**
- **Fuel flexibility (natural gas, propane, bio-gas)**

A Micro Gas Turbine produces waste heat at very high temperatures that can be used to drive absorption chillers.

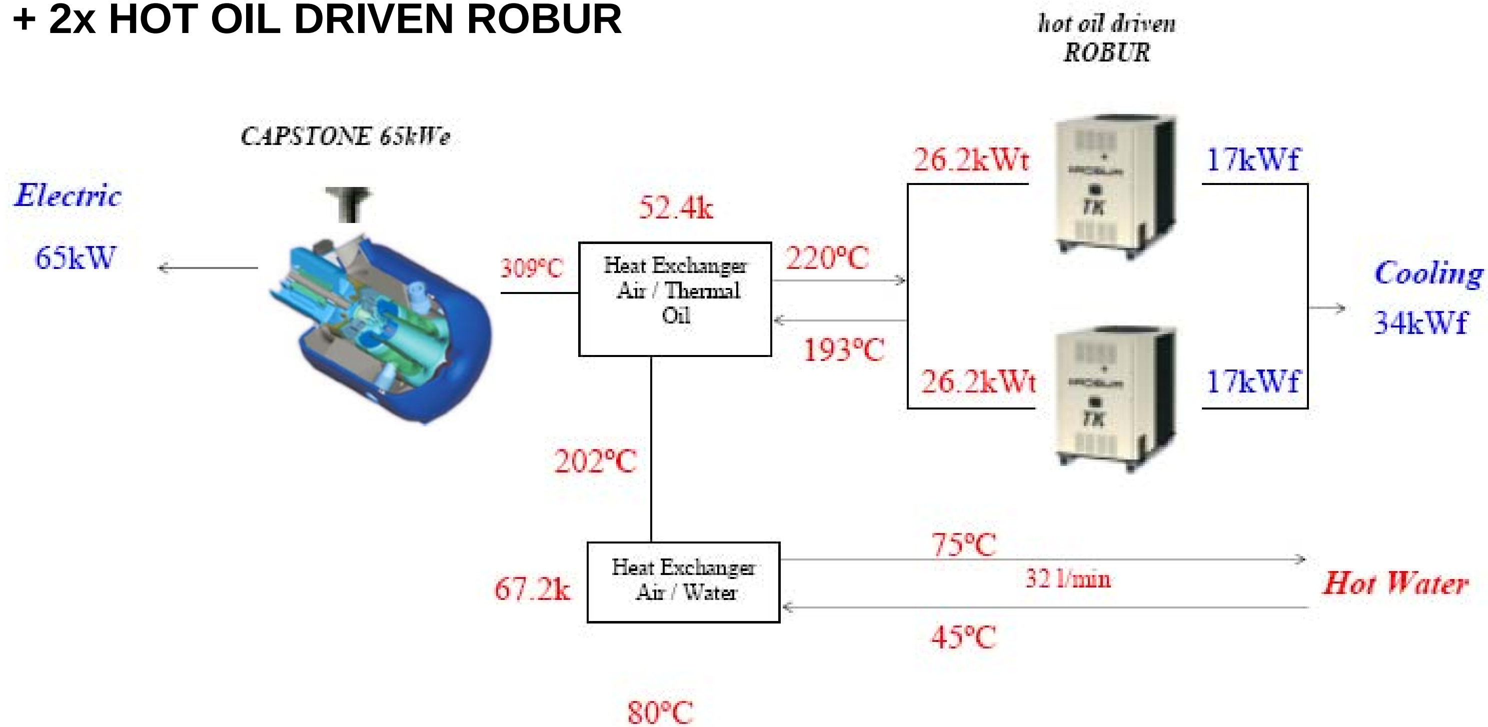


The **Capstone C65** :

- ✓Power 65 kWe
- ✓Natural gas pressure 4.5 bar
- ✓Fuel input: natural gas 224 kW
- ✓Electrical efficiency 29 %
- ✓Mass flow 0.49 kg/s
- ✓Exhaust Temperature 309ºC
- ✓Exhaust Energy 120kW

THE MTA PLANT

MGT C65 + 2x HOT OIL DRIVEN ROBUR



Main Features

- High production of electricity (65 kWe). The building consumes all the electricity produced.
- The system does not require cooling tower. Therefore the complete system is without a cooling tower.

Thank you.

ICED BALANCE OF PLANT: COGENERATION

The following are the **estimated values for cogeneration** (winter behaviour):

	Full load (100% nominal)	Part load (49% nominal)
Primary fuel [kW]	**361**	**177**
El. Power *(to the grid)* [kW_e]	**120**	**59**
Th. Power [kW_t]	**188**	**93.9**
Global efficiency	**85 %**	**86 %**
Electrical efficiency	**33 %**	**33 %**
Thermal efficiency	**52 %**	**53 %**

Energy Balance at full load:

Primary power needed with boiler 90% eff. + grid 38% eff.: $(188_{kWt}/0.9 + 120_{kWe}/0.38) = 525$ kW

Primary power needed with ICED: 361 kW

Estimated primary power saving

(with respect to conventional boiler 90% eff. + grid 38% eff.) = $(525 - 361)_{kW} \sim 164$ kW

Primary saving ratio: **164/525 = 31%**

ICED BALANCE OF PLANT: TRIGENERATION

The following are the estimated values for trigeneration (summer behaviour):

	Full load
External air	28.8°C 68% R.H.
Supply air	18°C 73.5% R.H.
Primary fuel [kW]	288
El. Power (*to the grid*) [kW_e]	95 – $(7.5 + (1.6+1.6+1.6)x4)_{auxiliary}$ = 68
Th. Power [kW_t]	152.5
Cooling power delivered [kW]	$54_{rot-exch}$ + $(34.4\ x4)_{DesUnits}$ = 192
COP (*regenerator*)	0.9
COP (*overall*)	192 / 152.5 = 1.26

Primary power needed with el. chiller COP=3 + grid 38% eff. (el. post heating needed 35 kWt) (electricity import = 68 kWe): $[\ (192-54_{rot-exch})_{kW} / 3_{COP} / 0.38 + 35_{kWt} / 0.38\ ] + [68_{kWe}/0.38]$ = **399 kW**

Primary power needed with ICED: 288 kW

Estimated primary power saving

(with respect to conventional el. chiller COP=3 + grid 38% eff.) = $(399 - 288)_{kW}$ ~ 111 kW

Primary saving ratio: **111/ 399 = 28%**

COMBY SYSTEM

Internal Combustion Engine + Steam engine

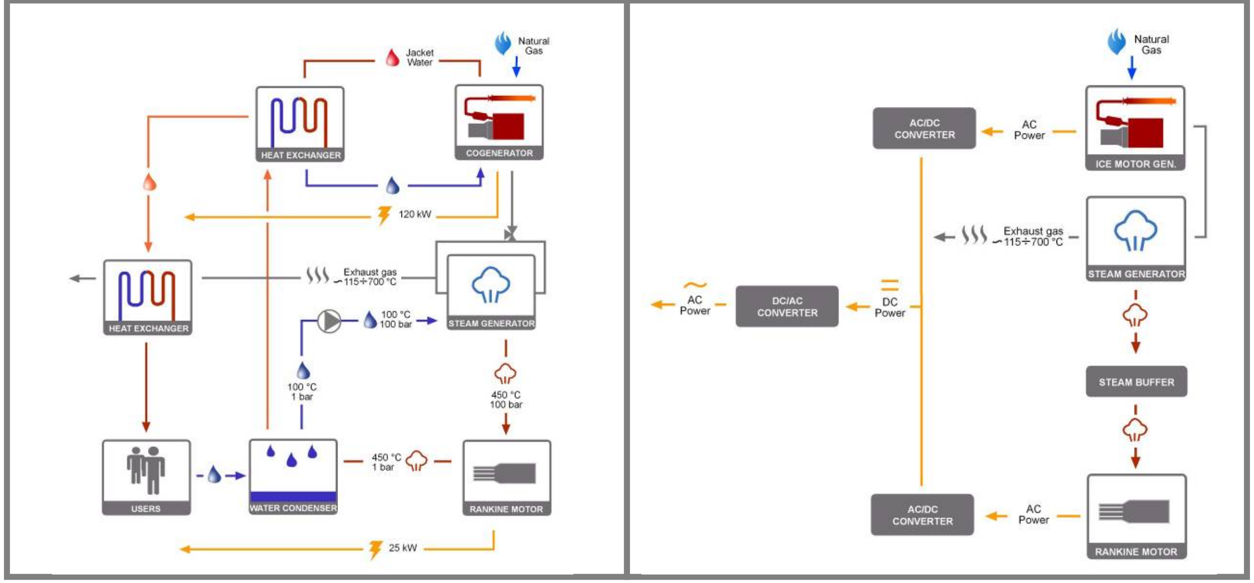
COGENERATION

CS QUICK GLANCE

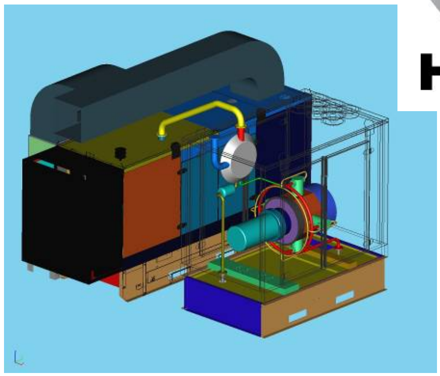
The system will have electrical efficiency about 40% and emissions of 539 gCO2/kWh$_e$ of electrical power produced, can conveniently substitute or complement centralised power generation, resulting in lower CO_2 emissions.

In fact the average *Italian* energy mix (i.e. the overall efficiency of the centralised power production) is 38%, resulting in average 618 gCO_2/kWh (fuel mix includes also “CO_2 intensive” fuels such as coal) at the power station. Such value does not account for transmission and distribution losses that on average determine additional 7% emissions

COMBI SYSTEM CONCEPT LAYOUT



PERFORMANCE & BENEFITS (EXPECTED)



Hegel

Electric	**~145 kW**
Heating	**~ 167 kW**
Electical efficiency	**~ 40%**
Total Efficiency	**~ 86%**
Primary Energy Savings :	**~ 39 %**
CO_2 Savings:	**~ 42%**
NO_x Savings:	**~ 73%**