Large-scale Heat Pumps up to 200°C to Play a Crucial Role in the Path for Decarbonization of Heating Sector

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Large Heat Pumps (LHP) are utility-scale heating plants that allow to transfer large quantities of heat from a colder source, like environmental heat or industrial waste heat, to a higher temperature heat user, like a district heating network or an industrial process.

Heat Pump technology helps decarbonization path and provide the users with cheap heat generation thus reducing the energy bill.

Turboden, by providing innovative large scale heat pumps based on electrically driven turbo compressor technology with a high temperature output up to 200°C, has a target to help all those heat users that are willing to decarbonize their heating supply.

Considering the most commonly accepted net zero 2050 target, and given the current technological development in the decarbonization sector, it is necessary to identify CO2 reduction solutions that can be implemented quickly, in the short and medium terms, to achieve the intermediate results, while the future technologies (green hydrogen, CCUS, etc) to achieve the long-term targets are developed. Heat Pump for heat demand decarbonization is for sure a ready to use technology that can help in this.

Turboden, a Mitsubishi Heavy Industries group company, is an Italian firm and a global leader during more than 40 years in the design, manufacture, and maintenance of Organic Rankine Cycle (ORC) systems, highly suitable for distributed generation.

Ever since founded, Turboden has always acted as pioneer company in the energy efficiency sector.

Thanks to the consolidated know how and the strong synergy with MHI, Turboden has introduced new high performance Large Heat Pumps, suitable for high temperatures up to 200°C as well as tradition temperatures, in a range of size starting from 3 to 30 MW heat production.

1. Turboden company profile

Turboden, a Mitsubishi Heavy Industries group company, is an Italian firm and a global leader in the design, manufacture, and maintenance of Organic Rankine Cycle (ORC) systems, highly suitable for distributed generation. ORC systems can generate electric and thermal power exploiting multiple sources, such as renewables (biomass, geothermal energy, solar energy), traditional fuels and waste heat from industrial processes, waste incinerators, engines or gas turbines.

The company was founded in 1980 in Milan by Mario Gaia, Professor of Thermodynamics at the Politecnico di Milano and today Honorary Chairman of Turboden.

In 2013 Turboden became part of Mitsubishi Heavy Industries group that strongly supports Turboden in the development of innovative solutions and new markets by enlarging ORC size and introducing two new products to its portfolio: Large scale Heat Pumps and Gas Expanders.

As of today, Turboden counts more than 400 installations in 50 different countries, with more than 19 million cumulative hours operation time.

2. Turboden expertise applied to large heat pumps

During more than 40 years, Turboden developed a strong expertise in the rotating equipment manufacturing for energy efficiency solutions and gained a consolidated know how in different technology fields such as:

- HEAT TRANSFER: Expertise in design of custom equipment with different heat streams including but not limited to hot water, steam, thermal oil, geothermal resource and chemical mixtures. The majority of the nearly 400 ORC plants built by Turboden are cogenerative (CHP), which means that the heat rejected from the ORC condenser is used for heating purposes, exactly like is the case with heat pumps.
- HIGH TEMPERATURE: 40+ years' experience with operative temperatures up to 400°C
- INNOVATIVE DESIGN: Custom-made design with multiple possibilities of optimization. Custom units designed for brownfield project capable to integrate the technology into existing processes, facilities and sites.
- TURBOMACHINES: Own design for more than 60 different turbines frame. Compressor shares common technical features and solutions with Turboden turbine. Turboden has a strong support from MHI to develop new solutions such as larger turbines and compressors.
- WORKING FLUIDS: Experience with more than 10 different working fluids as refrigerants, hydrocarbons and siloxanes. Possibility to select the most proper working fluid depending on the specific working conditions. Capacity to handle and design rotating machines by selecting the most suitable fluid case by case. Use of low GWP, low ODP and not harmful fluids.

3. Turboden Large heat pumps: key features

Ever since founded, Turboden has always acted as pioneer company in the energy efficiency sector.

Heat pump technology represents a well-known technology that has been historically derived from refrigeration systems (chiller) which are based on the same working principle. Many suppliers are widely available in the market, proposing traditional solutions which are typically standard packages limited to a maximum supply temperature to 90 – 95°C. For this reason they are only capable to address to a limited portion of the market.

Thanks to the consolidated know how and the strong synergy with MHI – having the possibility to use MCO compressor for specific project features - Turboden has introduced new high performance Large Heat Pumps, suitable for high temperatures up to 200°C as well as tradition temperatures, in a range of size starting from 3 to 30+ MWth of heat production per single unit.

This represents a real game changer for the market, allowing the heat users to extend the efficient decarbonization potential via electrification to new borders.

Turboden can offer a custom-made solution where the heat pump system is designed on the specific requirement of the project in terms of heat source characteristics and thermal power needed at the heat sink.

Turboden Large heat pump main characteristics can be summarized as follows:

- High Efficiency: the system is based on electrically driven turbo compressor technology which allow to handle high temperature lift while having a high efficiency
- Large scale: thermal output from 3 to 30+ MWth for single unit. Cascade and parallel configuration are also available
- High lift: capacity to handle heat users and heat sources with up to more than 100°C temperature difference, possible thanks to custom design of the components.
- High temperature: based on the available heat source features, the system can deliver an high temperature output up to 200°C. Moreover, different heat carriers can be exploited, such as hot water, thermal oil or even steam up to 14 barg.
- Environment-friendly: experience and possibility to design the thermodynamic cycle with 10+ different working fluids with low GWP and low ODP **(Figure 1)** .

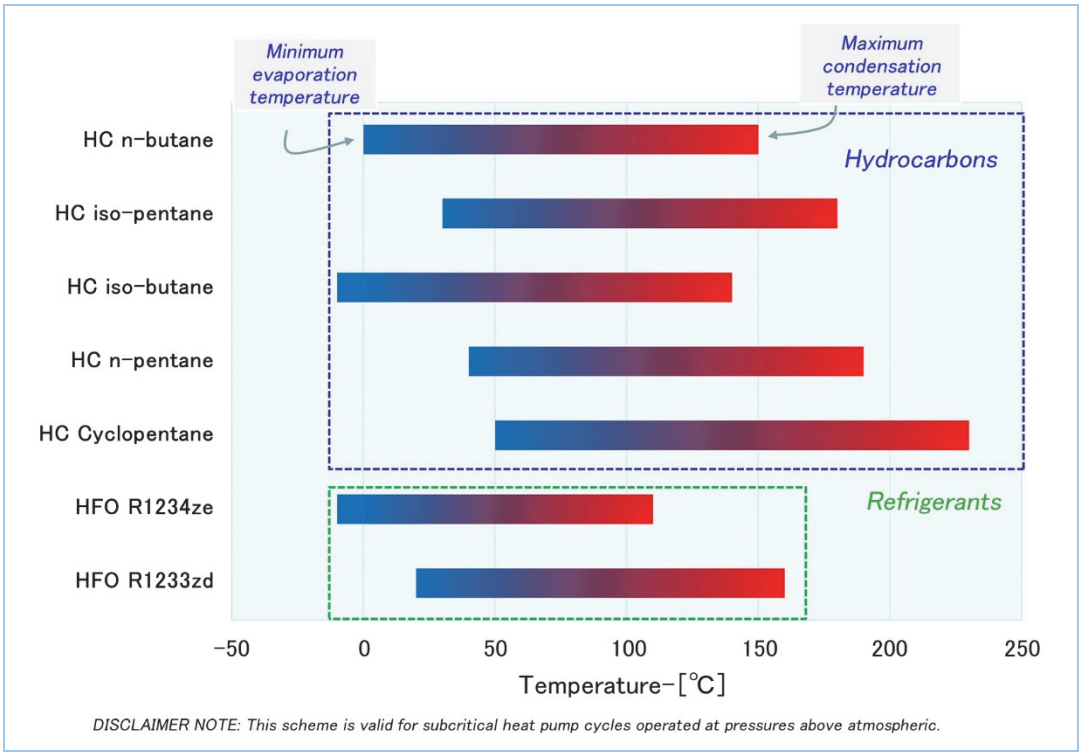

Figure 1 Most suitable organic fluids for heat pump application: operative range.

4. Reference case: ORI Martin steelworks

O.R.I. Martin S.p.A is a modern steelwork based on electric arc furnace that produces special steels for various applications, mainly in the automotive sector, mechanics, energy and construction. As all steelmaking process, ORI Martin has an energy intensive process which leads to many possibilities for heat recovery and energy efficiency solutions.

Turboden designed and installed an innovative Large Heat Pump system to elevate the waste heat, (by adding electrical energy) coming from the low-temperature thermal waste of the steel plant, from about 70°C up to 120°C, to transfer it to the local district heating network. Turboden Large Heat Pump has a thermal output of 6MWth and is capable to adapt its operation to specific process conditions, maximizing energy recovery from ORI Martin steel plant.

It will also be able to regulate the heat transfer temperature according to the specific needs of the district heating network, up to a maximum of 120°C, an important innovation compared to the maximum temperatures achievable by conventional heat pump technology.

Indeed, thanks to the installation of the large heat pump the heat from the cooling of the steelmaking process can be upgraded and then re-utilized instead of being wasted, i.e. dissipated through cooling towers (**Figure 2**)(**Figure 3**).

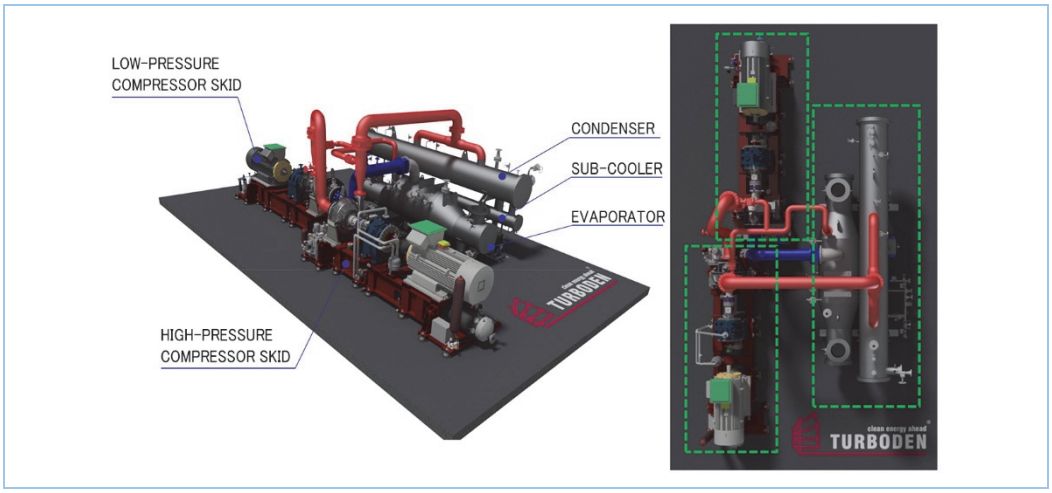

Figure 2 Layout of Turboden Large Heat Pump application for ORI Martin steelworks.

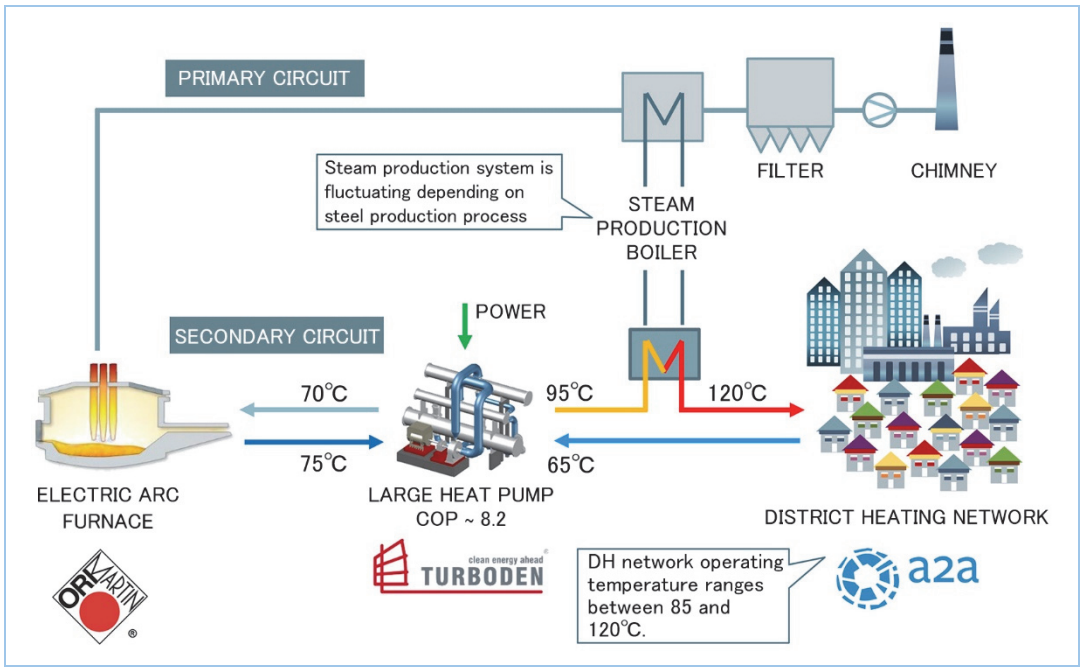

Figure 3 Schematic P&I of Turboden Large Heat Pump application for ORI Martin steelworks.

The steel facility has already installed a heat recovery system that exploit the thermal power within the exhaust gases stream of the Electric Arc Furnace (EAF) to produce hot water for the district heating network.

As a process optimization, in the basic configuration the heat pump produces hot water at 95°C which is then heated up to 120°C through the heat exchange with the existing heat recovery system, thus allowing to minimize the temperature lift and consequently consuming as less electricity as possible by optimizing its Coefficient Of Performance (COP).

Since the steel production in the EAF is a batch process, the EAF hot exhaust are not constant and therefore there are some time frames (during the furnace discharge) where heat recovery is not possible.

During the discharge operation the molten steel is sent to the continuous casting thus the heat recovery system does not work due to the absence of hot fumes from the EAF while the furnace cooling circuit is kept in operation. During this time frame the LHP receives the cooling water from furnace at 75°C (which is kept in operation to maintain a constant temperature in the EAF equipment which has to be ready for the next melting batch) and increases the outlet temperature from 95°C to 120°C in order to directly feed the district heating network replacing the primary circuit. When the EAF restart the process, the exhaust fumes comes back to the Primary Circuit and the LHP returns to deliver 95°C as shown in the scheme below.

This hybrid functioning is possible thanks to the high flexibility achieved with a custom design of the LHP equipment and with 2 high-speed compression stages with variable frequency driver which allow to follow the variable process and maximize the thermal output despite the heat source different conditions.

Furthermore, the system operates completely automatic and does not need any personnel during operation. The LHP can operate at partial load, the process and the generated electric power vary self-adapting automatically to the available thermal power.

5. Future developments

Cut down to zero greenhouses emission is a must to make our planet sustainable.

Heating sector represents one of the main sources of carbon emission since heat intensive users typically rely on fossil fuels to produce the required amounts.

According to Heat Roadmap Europe (https://heatroadmap.eu/project-reports/) - only in Europe - about 80% of the 2.740 TWh final energy demand for the heating sector, including heat for residential and industrial, is still generated by burning fossil fuels and only 20% is produced from renewable energy.

About half (1.100 TWh) of the fossil-based heat still generated can be decarbonized by using Turboden technology, which is suitable for either standard supply temperature and high supply temperature up to 200°C.

In fact, efficient electrification of heat via heat pump technology is widely seen as one of the most promising answers while targeting to reduce greenhouse gases emissions in the heating sector.

Turboden Large Heat Pumps – thanks to its innovative and competitive features - are considered at the forefront of the strategy for the electrification of heat in an increasingly decarbonized power grid. Turboden wants to take an active role in this process, by supplying District Heating sector and energy-intensive industries with its products.