The [redacted] family own [redacted] having 29 cheese production sites all over the world, decided in 2016 to construct a first [redacted] production site, located in [redacted]. The new plant has a gross floor building area of 74357 ft. sq. and 140 employees. The location choice of the new [redacted] cheese plant, near by an existing cheese and yogurt plant [redacted], offered a unique opportunity to join the mechanical infrastructure of cooling (chillers) and heating (heat pumps, hot water and steam boilers). The [redacted] plant had already an upgrading of its mechanical services and process heat exchangers, design and build by our company and leading to more than 50% reduction of the natural gas consumption. The [redacted], putting priority on the energy efficiency and GES reduction, mandate our company for predesign study (2016). Knowing the adjacent plant, allowed us to recommend the merging of cooling and heating capacities for the two plants, minimizing so the necessary investments in energy efficiency. Based on comparative design solutions and costs, the client took the decision to proceed with our solution of common infrastructure and retain our company to design the cooling, heating and hot water infrastructure included all processes supply and the plant ventilation. Besides the design we supply all necessary equipment (including prefab skids), instrumentation, control valves and dampers, the control (programming and operation interfaces) and participate all construction period with coordination, survey, tests, commissioning and start-up. The construction started in 2018 and finished in 2019 when the firsts production tests were performed.

Project Summary

The limits of the project were: the new [redacted] plant and the mechanical room necessary modifications to [redacted] existing plant. The adopted design (Figure 1) put in common:

- Existing [redacted] plant mechanical room with two R410A water cooled chillers of 200T, a R134a water-water heat pump of 500kW heating (up to 82ºC), a hot water boiler of 500kW and a 250HP steam boiler. A new steam-hot water heat exchanger of 1MW was added to increase the back-up capacity of the hot water. To minimize the instant heating and cooling capacity production we use buffer water tanks: 150 m3 for ice water (1 to 8ºC), 150 m3 for warm water (27 to 37ºC) and 200 m3 for hot water (77 to 85ºC)

- New [redacted] mechanical room with a R450A water-water heat pump of 500kW up to 87ºC and two VFD water cooled R134a chillers of 320T each. There is no natural gas supply to [redacted].

The utilities supplied (using a pipe rack) to the [redacted] plant are fluid loops:

- 30% Propylene glycol (PG30) of -3ºC, maximum flow 500 GPM used for +3ºC freezers, process cheese tunnel and 8ºC under-wax storage.
- Ice water of 1ºC, maximum flow 500 GPM used on production processes (HTST, VAT), process and control rooms cooling, laboratory and offices area cooling (using fan coils).
- Warm water of 27 to 37ºC, maximum flow 1200 GPM, used to cool the chillers and the compress air units, heat pump evaporator, preheat the wash water, cool the wax from 85ºC to 70ºC, preheat the milk in HTST, heat the offices and laboratory area. This loop is extremely important in energy efficiency because allow us to collect the residual heating (chillers, compressed air compressors, wax, etc) from both plants and reuse it as and when we need it, due to buffer tank. This energy is rejected by fluid coolers only if the tank temperature is above the supported limit by equipment cooled by this water (around 37ºC). Due to cold [redacted] climate and large amount of air make-up, in winter time, the fluid coolers are almost never used.
- 50% propylene glycol (PG50) of 5 to 10ºC in the summer and 28 to 34ºC in the winter, maximum flow 200 GPM used to cool/heat the air make-up units.
- Hot water of 77 to 85ºC, maximum flow 1200GPM used for processes heating (HTST, VAT, CIP, wax), wash water, washing machines, The return is reheated by the heat pump.
- Steam, 90 to 100 psig, maximum flow 1500 kg/h, used in a heat exchanger to heat a 105ºC water loop. This very hot water loop of max 500 GPM is used to thermal treating of the wax, daily sterilization of the HTST and washing machines, CIP.

All these utilities enter in a mezzanine mechanical room and the plant consumptions are measured by flowmeters and temperatures.

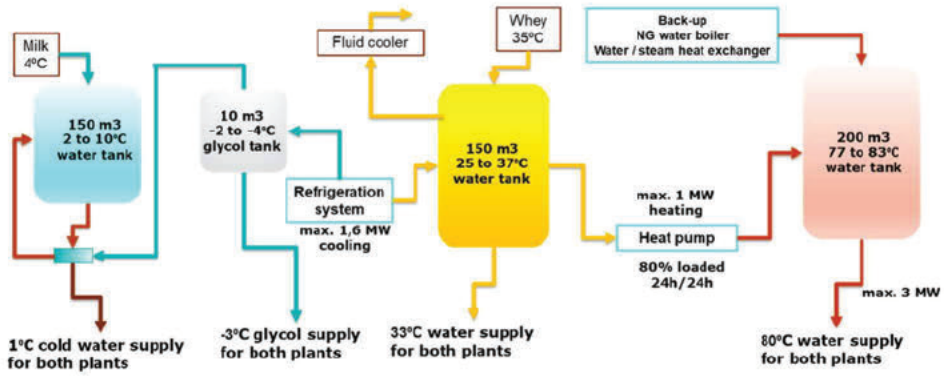


Figure 1 The principle of producing heating and cooling, using energy recovery and heat pumps

All is measured to be able to identify the energy consumptions for each plant. Each month, the overall consumed gas and electricity is automatically split between the two plants, based on their individual consumptions (Figure 2).

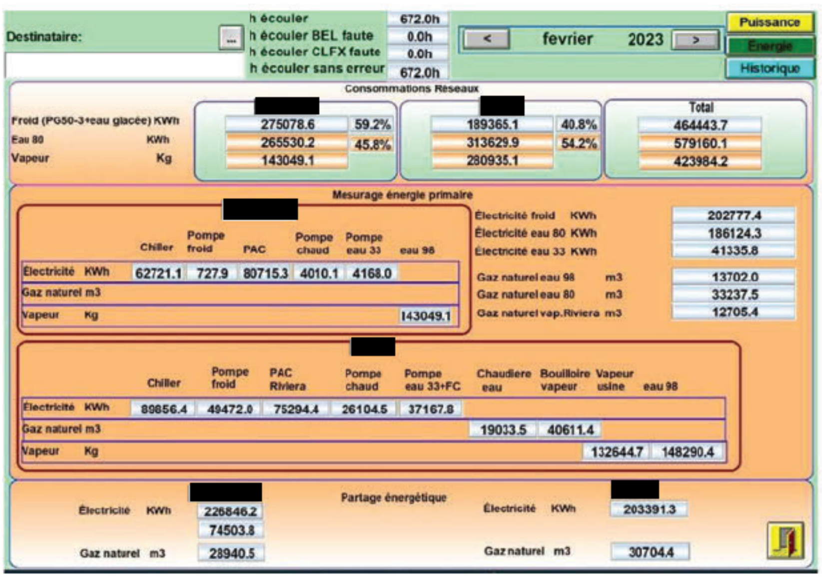


Figure 2 Monthly energy split between [redacted] and [redacted]

The cooling and heating supply to each type of process is done by dedicated prefabricated skids. The skids are installed in mechanical rooms or zones separated from the production areas with easy and non-restrictive access, using non sanitary valves and pumps so reducing costs and facilitating maintenance. The skids (Figure 3 as example), equipped with all necessary pumping, heat exchangers, control valves and instrumentation, needed on site only the piping, electricity and network control connections. This reduced worksite installation and allowed us to perform the FAT tests. The distribution of the skids in a limited places (three mechanical rooms and an over ceiling technical space) in the plant make an easier survey and maintenance.

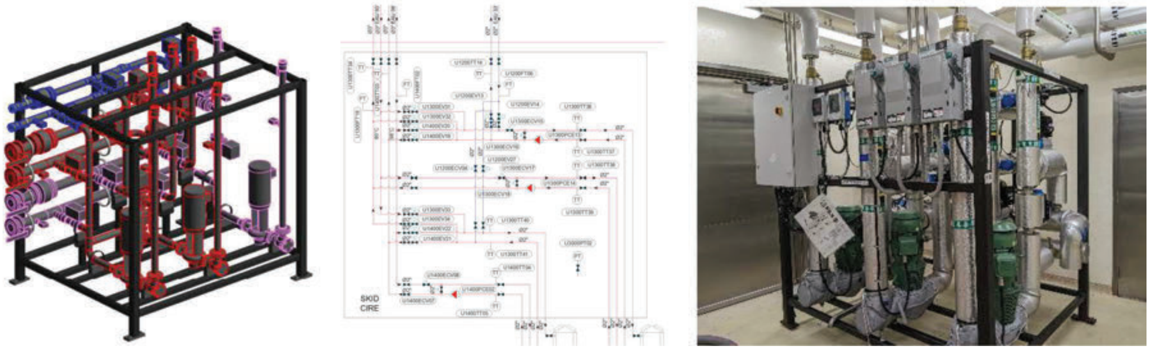


Figure 3 Skid wax. Supply in heating and cooling as requested by production

The plant ventilation took care of the production requirements and was different treated in the production area vs office and laboratory. The production requires a relative positive pressure between different zones (Figure 4) so a strict control between supply and evacuation of each room based on the requested direction of air migration from one room to another. The adopted solution was one air make-up unit HEPA filtered to supply in fresh air the production rooms having minimum air flow required by codes and pressure build-up. In the same time one unit to evacuate from production rooms the necessary air flow. Due to a positive pressure building and having direct evacuations from two washing machines, water treatment room and multiples access doors to outside, the requested fresh air flow supply in production period was 19500 CFM exceeding ASHRAE 62.1 and Regulation respecting the quality of the work environment S-2.1, r. 11 (local regulation). During the production, the washing machines and a pneumatical transport of braids from one room to another displacing 1500 CFM, are working upon request. All this makes conserving the pattern of relative pressure between production rooms more difficult and lead us to adopted solution. The make-up air unit combined with evacuation, both with air distribution passing on technical areas and having on each individual drop an electric actuated damper with flow measurement, assuring a dynamic balance conserving the relative pressures pattern based on production equipment functioning. All dampers are Modbus and receives from PLC the desired flow set point depending on what production evacuation is functioning. The supply and evacuation units have air flow measurement (by piezo-rings and ΔP) and the errors between the main (unit) and the sum of all dampers flows is less than 7% assuring us a proper control. (Figure 5).

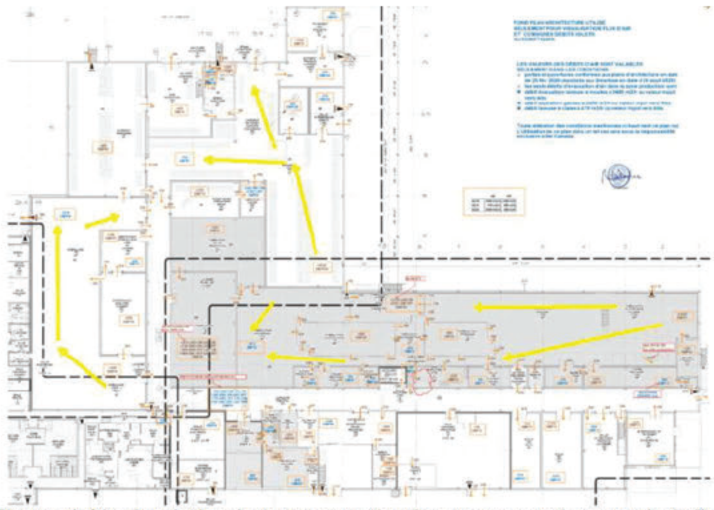


Figure 4 Air circulation between production rooms and general air flow

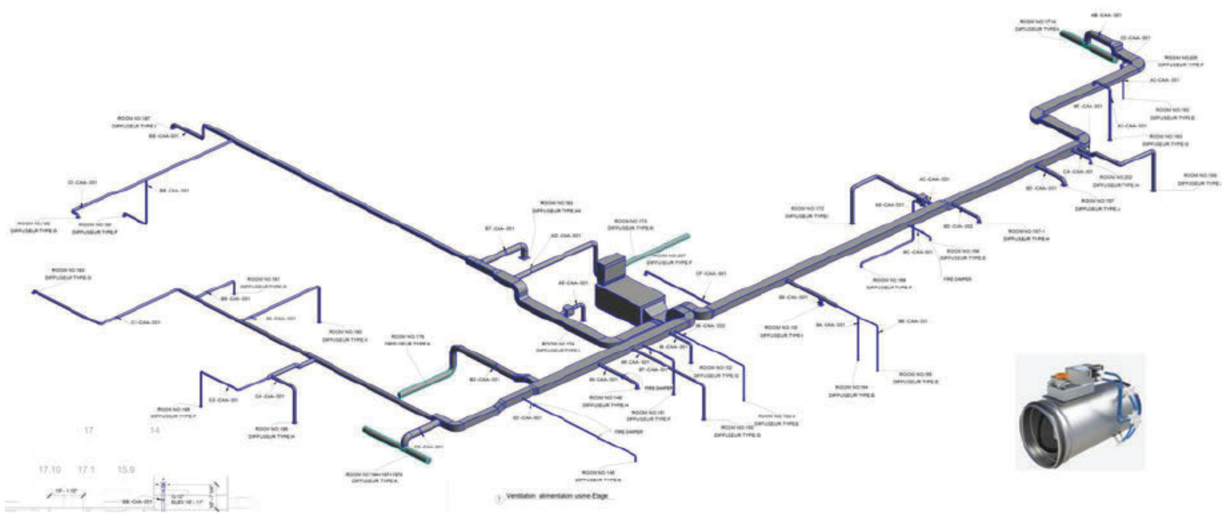


Figure 5 Air supply distribution

During the washing periods, the plant needs an increase volume of fresh air. We installed a 7000 CFM HEPA filtered air-make up unit coupled with 7000 CFM evacuation unit and air distribution to rooms where daily washing is necessary. Based on washing schedule we minimize the air capacity and, using the automatic dampers, we supply and evacuate the same air flow in each room to conserve the relative pressures and increase air circulation during washing period. The adopted solution to recover energy from exhaust air was a glycol loop assuring us no cross contamination (very important for production requirements). The control of the production rooms temperatures and humidities is supplemented with local sanitary fan coils (supporting CIP washing) since fresh air main purpose is to build-up necessary relative pressures between rooms. To maintain lower air velocities over production machines and occupied areas, we used microperforated sanitary textile ducts.

This ventilation solution was validated by the quality control of the client. Bacteriologic and air particles measurements were performed. For the relative pressure pattern a specialized company was hired to measure and validate. The client confirmed us passing all requirements.

For the office and laboratories area we used a supply air make up MERV 13 filtered, an evacuation unit and ceiling fan coils in each room. The supply fresh air is distributed to fans coils assuring more than ASHRAE 62.1 requirements using auto regulating dampers adjusted to necessary volume flow. The evacuation distribution is on ducts from toilets and locker room. Using transfer louvers, we ensure a general air flow from offices to toilets and vestiaries. The makeup air heating/cooling is done with the same PG50 loop used for plant units and the air exhaust energy recovery is by a glycol loop. Due to evacuation ducts (and not using ceilings) we were able to use the evacuation unit for two hoods occasionally used in laboratory area and avoid exhaust fans and stacks. In this case we used actuated dampers and, when hoods are used, we increase the fresh air supply to compensate the increase evacuation. Each room represent a temperature zone control. The fan coils of a zone might cool or heat independent on others. The fan coils use ice / warm water and the choice is based on the desired temperature set using control valves. To facilitate the maintenance and avoid undesired leaks in offices, a distribution skid able to control up to 40 zones was prefabricated and installed in a small mechanical room (Figure 6).

The heat generated by the cooling zones is recovered in the warm water which cool the chillers condensers so can be use in other purposes. There is no chiller or heat pump dedicated to offices. We use the same production heating and cooling infrastructure, based on a small consumption in office area. The water heating the ceiling fan coils, if needed (extreme cold), might increase the temperature by a hot water heat exchanger located on one prefabricated skid. In winter at -35ºC outside, warm water of 36ºC can heat the office area over 22ºC.

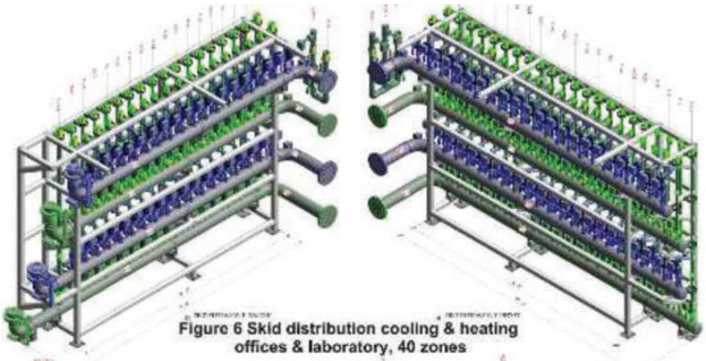
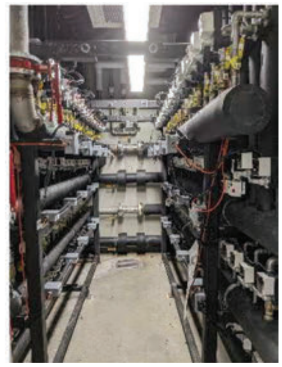


Figure 6 Skid distribution cooling & heating offices & laboratory, 40 zones



There are more than 1000 instruments (flowmeters, pressure, temperature, relative humidity transmitters), 90 automatic dampers, more than 250 control valves and all pumps and ventilators are on VFD. Everything is automatically controlled, no human intervention is needed, only periodic survey and eventual adjustment of set points. Alarms are routed on desired devices as phones. We prefabricated 18 skids enabling the client to measure and survey instant powers, energies (cooling, heating on each temperature level, electricity) on each production process. The fluid coolers installed on freezers are on VFD assuring a minimum electricity consumption and therefore minimum contributing to the freezers cooling charge.

Energy efficiency

In all 2013, before the energy efficiency project, the [redacted] plant was consuming 899549 m3 natural gas with a milk production of 30 833 000 liter. In 2022 both [redacted] and [redacted] plant consumed 565727 m3 natural gas and processed both 55 000 000 liters of milk. If in 2013 the specific gas consumption was 29.2 m3 NG/1000 L milk, after our project was 10,3 m3 NG/1000L milk, meaning a 65% natural gas reduction. The new plant natural gas and electricity (only for production and distribution of heating and cooling) consumption on last two years:

		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total Year
2021		13 575 m3NG	22 791 m3NG	25 625 m3NG	25 032 m3NG	26 812 m3NG	15 106 m3NG	12 326 m3NG	13 218 m3NG	14 670 m3NG	14 416 m3NG	16 120 m3NG	17 665 m3NG	**217 358 m3NG**
		177 786 kWh	169 922 kWh	143 691 kWh	147 023 kWh	167 729 kWh	221 465 kWh	287 495 kWh	286 206 kWh	337 411 kWh	258 637 kWh	256 133 kWh	227 867 kWh	**2 681 365 kWh**
2022		23 883 m3NG	31 546 m3NG	27 060 m3NG	26 097 m3NG	19 766 m3NG	17 332 m3NG	21 624 m3NG	22 644 m3NG	20 607 m3NG	23 084 m3NG	24 112 m3NG	25 115 m3NG	**282 870 m3NG**
		207 357 kWh	185 526 kWh	189 195 kWh	249 010 kWh	260 880 kWh	242 244 kWh	320 832 kWh	411 070 kWh	358 067 kWh	271 508 kWh	260 377 kWh	246 701 kWh	**3 202 769 kWh**

Since the beginning of plant production, the consuming of the heating was (Figure 7):

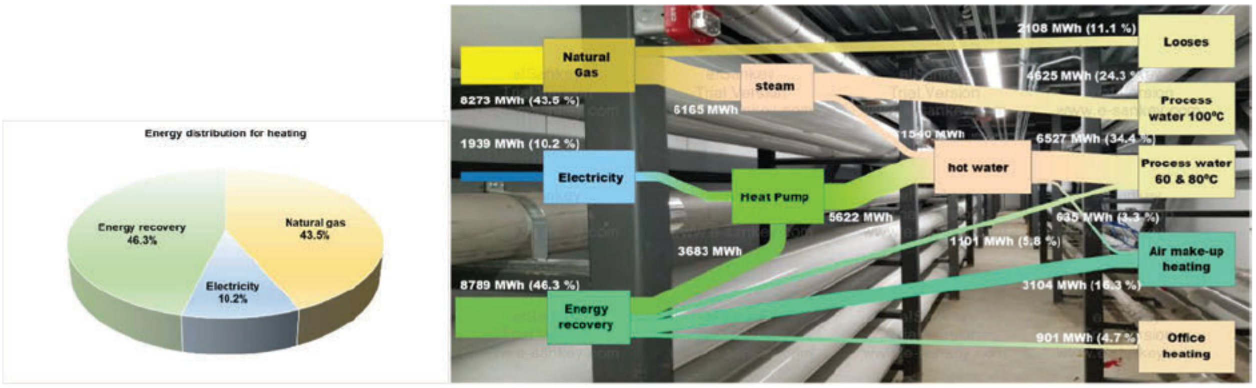


Figure 7 New cheese plant [redacted] heating energy consumption and processes using rate

Indoor air quality

In all plant occupied area, indoor air quality respect or overpass ASHRAE 55 and 62.1, Regulation respecting occupational health and safety, chapter S-2.1, r. 13 ([redacted] regulation). Independent air quality audit confirmed production area as ISO 8 (class 100000), temperatures of 23ºC with a variation of ±2ºC and RH less than 60%. For the offices and laboratories, the installed fan coils have adjustable (via BMS) air velocities, draft directions and room temperature set point. To increase the comfort and save energy, if room temperature is within set point the fans are stopped and only fresh air is entering the room. The BAS room temperature and humidity sensors has the ASHRAE 55 requirements (accuracy <0,5C, ±3%RH and history trends for more than 1 year at each minute). Due to supply 100% fresh air MERV13 filtered, local recirculation and minimum path evacuation, the probabilities of spreading contaminants from one occupied side to another due to building ventilation are at minimum. During the Covid pandemic period the plant did not have any sanitary issue forcing to temporary shutdown the activity.

Innovations

Using water buffer tanks and appropriate configuration of process heat exchangers allow us to do important energy savings in both cooling and heating (Figure 7). For a 220 000 milk liters daily production, the savings in heat and cooling are 5750 kWh/day, representing 24h/24h saving 68T cooling and 30 m3/h natural gas, added to less investment and maintenance in infrastructure. The dynamic balance of air flow in production area, unique for the [redacted] plants, corelate automatically production with necessary ventilation and is effective if production reconfiguration is needed. After two years a new cheese conditioning tunnel was added. This modification needed a new plant supply and evacuation configuration. Based on new production area pattern, new set points (supply and evacuations flows) were calculated and, by simply changing them in the control, the ventilation was adapted, saving time and money on manual rebalancing.

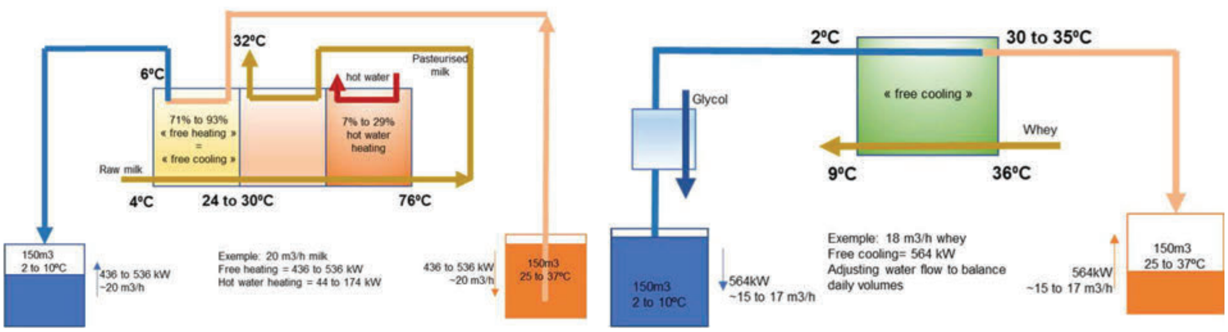


Figure 7 Preheating milk for pasteurization and generating "free" cooling

The new plant is the only in the [redacted] cooling wax without ice water (so without using chillers). In our project due to warm water loop we avoid using chillers for this process and, in the same time, recover the corresponding wax heating.

Operation and maintenance

The heating and cooling for production are operating automatically based on processes needs, known by appropriate communications protocols. All parameters are in historian data base allowing a documented quality control, fine tuning of processes control, troubleshooting, detail energy consumption survey. All equipment is located in mechanical rooms or technical areas, easily accessible, outside production area. All ventilation units for production are in a mechanical room, having all year possibility to be clean up. The distribution ducts are stainless steel made, with access doors for cleaning. All control valves for suppling cooling and heating to process are industrial quality, pneumatically actuated for fast positioning. Sharing the heating and cooling with existing [redacted] plant offered flexibility for start-up. We were able to supply and test process by process and heat office area before [redacted] plant construction end, saving valuable time.

Cost effectiveness

The client underlined the request for energy efficiency, making our proposal the less costly solution. Constructing a similar infrastructure only for [redacted] plant would significantly increase the mechanical rooms construction area and investment in equipment. The obtained grants for this project were accorded based on GES reductions compared with an industry standard solution. For our project, with the update energy prices (0,65$/m3NG and 0,075$/kWh):

Extra cost for energy efficiency	3 500 000 $
Grants	1 900 000 $
Natural gas savings	820 000 m3/y
Extra electricity consumption (heat pump)	1 100 000 kWh/y
Net extra cost of project	1 600 000 $
Energy bill savings	450 500 $/y
Simple payback	**3,6 years**

Environmental impact

Compared with an industry standard solution, by significant reduction of natural gas use, the new plant GES emissions are 1520 tCO_{2e}/y less. The refrigerant quantities are contained only inside four central chillers therefore the fugitive emissions are diminished. The air evacuation from water treatment room is activated carbon filtered to eliminate any undesirable odors.

Conclusion

Using thermal buffer energy, we were able to install heat pumps with heating capacity of 1MW and supply up to 3MW for limited periods of time, have a maximum recover energy rate and lower investment in power equipment. In 2013, existing [redacted] plant was consuming 900000 m3NG. In 2022, [redacted] and the new plant [redacted] used 565000 m3NG, reducing both 3260 tCO2e/y.