

One-page summary

Lusail City is strategically important because, as a planned 21st century city, it is the largest project undertaken in the State placing Qatar on the global map as a destination of choice for visitors, residents and businesses. Designed to local, regional and international standards and meeting the unique cultural and natural qualities of Qatar and the Gulf Region, the project has won critical acclaim for its innovative approach to real estate development. The progressive, self-contained city signifies the growth and development ambitions of the leadership of Qatar.

Lusail City is developed by Qatari Diar established in 2005 by the Qatar Investment Authority, the sovereign wealth fund of the State of Qatar. Headquartered northeast of capital Doha on the coast of the Arabian Gulf, Qatari Diar was entrusted to support Qatar's growing economy and to coordinate the country's real estate development priorities.

The Lusail City district cooling system will supply chilled water to end users through an integrated network with a connected cooling of 500,000 Tons of Refrigeration by utilizing multiple chiller plants of a total capacity of approximately 336, 000 TR. This will be one of the largest district cooling systems in the world. The Project envisions four district cooling plants to be built in multiple phases to provide the entire development of Lusail with chilled water for its cooling needs.

District Cooling is developed and supplied by Marafeq Qatar which was established in March 2009 and specialized in providing Comprehensive Utility Services and infrastructure for Real Estate Developers for commercial, residential, industrial and private organizations. The vision of Marafeq Qatar is applying world class resources to develop and operate utility services which are, environmentally responsible, economically competitive and of high quality and reliability.

The key innovation implemented by Marafeq Qatar was integrating the four system elements—building side, ETS, distribution network, and chilled water production. All four elements must function properly if the system is to meet customer expectations for reliability, comfort, and efficiency.

Lusail City is also the first development in the Middle East to implement pre-insulated piping that is designed and manufactured in accordance with the European standard for district heating and cooling—the EN 253 family of standards, and Marafeq Qatar was one of the primary drivers behind opening the eyes of engineers and contractors to the benefits of EN 253 piping systems.

Compared to conventional cooling approaches, district cooling will save 35% to 45% energy, and with less power being consumed, fewer pollutants will be emitted. Using projected customer demand in 2022, electric energy consumption will be reduced 500,000 to 700,000 MWh/year compared to conventional approaches. The avoided CO₂ emissions related to those savings would exceed 240,000 metric tons/year. At the full build out, these numbers change to 900,000 to 1,200 MWh/year and 520,000 metric tons/year avoided CO₂.

Introduction to the Lusail City District Cooling Project

Lusail City is strategically important because, as a planned 21st century city, it is the largest project undertaken in the State which is expected to place Qatar on the global map as a destination of choice for visitors, residents and businesses. Designed to local, regional and international standards and meeting the unique cultural and natural qualities of Qatar and the Gulf Region, the project has won critical acclaim for its innovative approach to real estate development. The progressive, self-contained city signifies the growth and development ambitions of the leadership of Qatar.

In order to appreciate the complexity of the overall project and the planning that went into Lusail City, one needs to understand the immensity of the project. Lusail City, located 15 km north of Doha, will be a mix of entertainment, residential, and commercial projects covering 19 districts and an area of 38 square km including 28 square km of waterfront. The Marina district alone will be home to 102 towers ranging from 15 to 40 stories tall. The Lusail City master plan specifies accommodation for 190,000 residents, a workforce of 170,000, and a capacity to welcome 90,000 visitors; an occupancy of almost 500,000 people!

The ultimate district cooling system will serve about 1,000 buildings, 1,000 Energy Transfer Stations (ETSs), through 173 km (supply and return) underground piping from four production plants (about 336,000 TR).

Qatari Diar

Qatari Diar Real Estate Company was established in 2005 by the Qatar Investment Authority, the sovereign wealth fund of the State of Qatar. Headquartered northeast of capital Doha on the coast of the Arabian Gulf, Qatari Diar was entrusted to support Qatar's growing economy and to coordinate the country's real estate development priorities.

The vision of Qatari Diar is to be a premier global real estate company, fully committed to its stakeholders, capturing the hearts and imaginations of communities while generating sustainable growth.

Lusail City, the company's first project, quickly went on to gain tremendous praise for its innovative approach to real estate. The progressive, self-contained city is the largest single development to be undertaken in the State of Qatar, and although it is currently under construction, Lusail already signifies Qatar's progress on a grand scale, reflecting the vision and quality that have become synonymous to Qatari Diar. The Lusail Real Estate Development Company was established in September 2008 with a dedication to the development, construction and ongoing operations of the visionary Lusail City development.

Parallel to its significant infrastructure developments within Qatar, the company has been committed since its founding to bringing the Qatari Diar vision, one for real estate that improves quality of life and contributes to the community, onto the international stage. Today, Qatari Diar has established itself as one of the world's most trusted and respected real estate companies because of its commitment to quality, local community, partnership and hallmark sustainability.

As of 2017, Qatari Diar has a shared capital of US\$7 billion and has more than 39 projects

under development and investment in Qatar and in 21 countries around the world with a combined value of over US\$35 billion.

Marafeq District Cooling

Marafeq Qatar was established in March 2009 and specialized in providing Comprehensive Utility Services and infrastructure for Real Estate Developers for commercial, residential, industrial and private organizations.

The vision of Marafeq Qatar is applying world class resources to develop and operate utility services which are, environmentally responsible, economically competitive and of high quality and reliability. The mission is adding a high standard value to our stakeholders through providing an integrated utility services in the local market.

Company Services include:

- District Cooling Services
- Gas Distribution Services
- Environmental Services

Marafeq Qatar is today a leading Utility Services Company, providing energy efficient and innovative sustainable solutions. It provides to Real Estate Developers a comprehensive package of Utility Management including Infrastructure designing, Construction Supervision and Operation, with Customer Services Support, which will give the spaces for Developers to focus on their business and be confident of Marafeq Qatar's experienced engineers and professional technical team to carry out the complete package of utility services.

Marafeq Qatar has succeeded in developing its mark in designing and developing pioneering technology to deliver energy efficient, cost effective and environment friendly utility solutions that support the growth of economy of the state of Qatar. Marafeq Qatar is owned by Qatari Diar Company, the leading company on developing and building cities in the Middle East.

Added values for clients:

- Comprehensive utility services for projects.
- Avoid Duplication and Additional Capital Expenditure.
- Achieving objectives by implementing world class technology standards.
- Applying "feedback system" to ensure services improvement and development.
- Preserve environment with less environmental impact and high standards of services for future generation.
- Best Risk Management Analysis to reach excellence on operation and maintenance.

Lusail City

Lusail City extends across an area of 38 square kilometres and includes four exclusive islands and 19 multi-purpose residential, mixed use, entertainment and commercial districts. It is a comprehensive arena with leisure spots, residential buildings, commercial towers, avenues and

public Marinas.

Created by Lusail Real Estate Development Company on behalf of Qatari Diar, Lusail City is the largest single sustainable development to be undertaken in the State of Qatar. It embodies Qatar's National Vision 2030 in the field of real estate development.

More than 200,000 residents will live in Lusail's scenic surroundings, with 170,000 people expected to work in the city's different districts, and 80,000 expected to visit its entertainment, recreation and retail and hospitality facilities. Lusail City's 19 districts will encompass not only new residential, commercial, hospitality, and retail opportunities, but a full array of community needs, complete with schools, mosques, medical facilities, sport, entertainment and shopping centers.

Lusail City is the first and largest sustainable city in Qatar with ambitious and ground breaking concepts that reinforce every facet of Qatar's National Vision. Lusail goes beyond the usual concept of a modern city by encompassing innovative ideas that take the sustainability principles into the core of the city masterplan. Lusail City is Qatari Diar's flagship project. More than just another development, it is a self-contained sustainable and comprehensively planned city signifying Qatar's progress on a grand scale.

The city of the future boasts a light rail network, a water taxi transportation system, cycle and pedestrian network, park and ride system and sophisticated intra mobility network. Construction work on the 38 square kilometer, progressive world-class sustainable development is well underway with 65% of the infrastructure completed and 67% private project under construction.

The smart, peaceful and inspirational environment combines artistic elements of architecture with various practical and versatile services to satisfy all the needs of its residents and visitors.

District Cooling Overview

The Lusail City district cooling system will supply chilled water to end users through an integrated network with a connected cooling of 500,000 Tons of Refrigeration by utilizing multiple chiller plants of a total capacity of approximately 336, 000 TR. This will be one of the largest district cooling systems in the world.

The Project envisions four district cooling plants to be built in multiple phases to provide the entire development of Lusail with chilled water for its cooling needs. Phase 1 of the Project will consist of a connected load of 69,000 TR.

The four district cooling plants will be located at the Marina, Wadi, West, and North.

An indicative version of the Lusail City District Cooling Master Plan



Overall System Design

One of the biggest challenges in district cooling projects is to integrate the entire cooling system design, operation, and maintenance efforts so issues in buildings don't adversely affect plant performance (or visa-versa). In Lusail City, Marafeq Qatar looked to eliminate industry common low delta T that has in the past led to availability, comfort, and energy performance issues.

In the plant, the chillers and thermal energy storage are designed for 5 / 14°C supply and return. Marafeq Qatar analyzed heat gain from ground and pumping and validated the expected supply temperature to the customer connections. On the building side, supply temperatures can be 6.2 / 15.2°C supply and return (9°C delta T) to account for the heat exchanger approach temperature.

To maintain adequate cooling to the buildings, the district cooling plant must deliver 6.2°C or lower on the building side of the ETS. The plant must also operate distribution pumps to supply the necessary differential pressure at the hydraulically most remote point(s) in the distribution system. For the plant to operate properly the buildings must be designed and operated to deliver an aggregate return of 14°C from the ETS to the plant. As buildings come on line, Marafeq Qatar will continuously monitor building performance and work with customers to solve problems that might arise.

Marafeq Qatar's planning made sure all four district cooling elements would work integrally so availability, comfort, and energy performance objectives can be met.

To help the building owner meet design delta T and reduce his operating cost while

maintaining building comfort, Marafiq Qatar guided them in basic principles need to make a building “district cooling ready”. However, since Marafiq Qatar has no direct control or responsibility over the building side design, the cooling service agreement assesses a penalty for low delta T which should be an incentive to correct deficiencies if they occur.

The ETS is the boundary between the district cooling system and the building or area served. This is the location where thermal energy consumption is metered and measured. The ETS can be either directly or indirectly connected, and the difference between them is indirect connections use plate and frame heat exchangers to separate the building water and pressure from the district. Separating the building from the district is necessary if the building is tall and the resulting static pressure is unacceptably high. In schemes where the district cooling provider serves many buildings, each with a different owner and operator, Marafiq Qatar recommended indirect connections to avoid problems that a poorly run building could impose on the entire system.

Network Design

Marafiq Qatar designed a distribution network with strategically placed loops and isolation valves. To assure high quality, Marafiq Qatar selected an all welded pre-insulated steel piping system with integrated leak detection system; all certified in accordance with the EN 253 family of standards. The key to EN 253 is the pipe is fixed in place by transmitting strain energy from thermal expansion / contraction to the ground through the insulation. If the bond between the insulation and the pipe or casing fails then the pipe slips and strain energy is transferred to pipe bends or valve bodies. Marafiq Qatar also discouraged flanged connections except in special cases. Extensive industry practice in Europe has demonstrated flanged valves installed in chambers are weak links in the distribution system and the European trend is to use an all welded system.

Plant Production Design

When planning the plant production, Marafiq Qatar assured the design was well thought out, incorporated redundant elements in order to maintain chilled water availability, and with design lives of 25 years for electrical and mechanical equipment and 50 to 60 years for civil works and pipelines.

To minimize the impact on the electrical system grid, the Lusail City district cooling system will use Thermal Energy Storage (TES) to shift demand from the peak period to off-peak periods. Although the primary benefit of TES is peak shaving, using TES benefits efficiency because chillers can operate more often near full load where the chillers are more efficient, and can operate more often in the evening (off-peak period) when wet bulb temperatures may be lower and thus the entering condenser water temperature can be lower and the chiller efficiency higher.

Other Technical Challenges

Marafiq Qatar developed a process to review sub-developer (customer building) progress. This process allows Marafiq Qatar to both monitor and influence the Energy Transfer Station

(ETS) and building-side designs.

Lusail City is developing across large areas (both north and south) which meant Marafeq Qatar had to closely communicate with the master developer about when and where utility services would be required. Power, water, and sewer—the main utilities—were updated so the master developer could plan supplying these utilities.

Coordinating the various segments of the distribution network also proved challenging since the network was divided into multiple construction packages and these were in various stages of development. Marafeq Qatar met with the master developer to communicate “missing distribution network pipes / links” that were necessary to supply customers across the city.

Since plot locations for distribution plants were somewhat limited, Marafeq Qatar had to carefully analyze network design and pumping to make sure all customers could be served and with some margins to allow for the inevitable changes that come with such an immense effort as Lusail City.

By tapping the knowledge base of our senior engineers, learning from the mistakes of others, and applying time-proven techniques, district cooling will be successful in Lusail City.

Climate Change Impact

Compared to conventional cooling approaches, district cooling will save 35% to 45% energy, and with less power being consumed, fewer pollutants will be emitted. Using projected customer demand in 2022, electric energy consumption will be reduced 500,000 to 700,000 MWh/year compared to conventional approaches. The avoided CO₂ emissions related to those savings would exceed 240,000 metric tons/year. At the full build out, these numbers change to 900,000 to 1,200 MWh/year and 520,000 metric tons/year avoided CO₂.

Innovation and Approach

The Lusail City project—a city eventually with up to an occupancy of 500,000 people—is so huge each of the 19 districts or each of the four district cooling plants is like a project in itself. And within the overall scheme, Marafeq Qatar prepared plans for temporary, modular, and permanent chiller plants to serve the various districts and mega-developers in addition to master developer (LREDC) developed districts.

The key innovation implemented by Marafeq Qatar was integrating the four system elements—building side, ETS, distribution network, and chilled water production. All four elements must function properly if the system is to meet customer expectations for reliability, comfort, and efficiency.

Lusail City is the first development in the Middle East to implement pre-insulated piping that is designed and manufactured in accordance with the European standard for district heating and cooling—the EN 253 family of standards, and Marafeq Qatar was one of the primary drivers behind opening the eyes of engineers and contractors to the benefits of EN 253 piping systems. Very recently European companies have created business alliances and are now producing pre-insulated piping in the GCC. Key features of EN 253 are:

1. Manufacturing is certified by an independent agency

2. Dependable bonding from pipe to jacket means thermal expansion is predictably controlled by the ground eliminating concerns about expansion forces.
3. Pre-insulated directly buried valves eliminated valve chambers which decades of history in Europe and Scandinavia has shown were prime causes of network failures.

Marafeq Qatar senior management were keenly aware of the past problems district cooling providers suffered when they built capacity ahead of customer commitment. Based on gross floor area and building occupancy type, Marafeq Qatar estimated customer demand using key figures time-tested in GCC district cooling schemes. From the beginning, Marafeq Qatar constantly communicated with the master developer and validated construction progress through site inspections and discussions with sub-developers. Marafeq Qatar understands they need to be flexible in meeting customer needs without building too much capacity ahead of demand. For this reason chiller plants will have the capability of expanding in phases to more closely follow growth in the development. Marafeq Qatar tracks changes in the development progress and adjusts how and where chiller production capacity should be added. Marafeq Qatar is also using other procurement approaches like temporary or rental chillers for early customers, package units for expedited implementation, and modular plants for similar reasons but with larger capacities.

Marafeq Qatar's district cooling plants will use efficient water cooled electric chillers, and compared to air-cooled chillers this will save 35% to 45% on power demand. Coupled with thermal energy storage, the water cooled plants will save around 55% power. And by using recycled treated sewage effluent for cooling tower make up, Marafeq Qatar will help Qatar conserve precious potable water while still embracing the highly efficient water-cooled chilling system. Integral with each chiller plant will be thermal energy storage. By producing and storing cooling energy off peak periods, Marafeq Qatar can run chillers nearly at full load where they are the most efficient and shave the peak that would otherwise be placed on the utility electric grid. This in turn reduces the electric infrastructure cost for generation, transmission, and distribution.

Marafeq Qatar invests significant time and interest in the sub-developer (customer) interface. We review the customers' designs and major materials used for the primary side of the Energy Transfer Stations (ETs). Additionally, to ensure high quality materials and construction practices are employed, we inspect the installation during construction and testing and commissioning. Marafeq Qatar is one of the few district cooling providers in the GCC region to use welded valves in primary side of ETS, along with Pressure Independent Control Valves (PICVs). The all welded piping system is robust, and the PICVs ensure good flow control independent of the network pressure fluctuations.

The leadership in Marafeq Qatar fostered a culture of open and transparent procurement. Favoritism is not allowed, and systems of checks and balances are put in place to make sure management objectives are followed. Marafeq Qatar is planning a business with a 25-year horizon and to assure the business remains sound all the time, Marafeq Qatar will carefully expand the system using efficient equipment, thermal energy storage to reduce power consumption and the demand put on the electric grid, recycled treated sewage effluent to reduce potable water consumption, and environmentally friendly refrigerants. Using the EN 253 piping system might cost more initially, but in the long run it will save money and thus benefit the district cooling customers. Employing welded isolation valves and PICVs in the ETS

ensures a robust and better controlled customer interface. In the end, the district cooling services offered by Marafeq Qatar will reduce air emissions by reducing power consumption, reduce power demand on the electric grid, reduce potable water consumption and all while providing extremely reliable, flexible, and efficient service from multiple plants connected to a single integrated distribution network.

Project Stakeholders

Lusail City is the largest district cooling undertaking in the country and for the region as a whole. Managing multiple stakeholders with often conflicting objectives was challenging but not insurmountable.

| # | Name | Role |
|----|--|---|
| 1 | Qatari government | Interest in the project since it positions Doha on the global map |
| 2 | Qatari Diar | Parent company of Marafeq Qatar and LREDC |
| 3 | Lusail Real Estate Development Company (LREDC) | Master developer |
| 4 | Marafeq Qatar | District cooling provider responsible for construction and operations and maintenance |
| 5 | Multiple mega-developers | Involved in the development of various districts |
| 6 | Individual building developers | Customers |
| 7 | Banks and financial advisors | Project finance |
| 8 | Insurance advisors | Placement of insurance |
| 9 | Legal advisors | Contracts |
| 10 | Construction contractors | Engineer, Procure and Construct (EPC) for plants, distribution network and ETS (Energy Transfer Stations) |

Market Environment

Starting in the latter part of 2008 the real estate market in the Gulf Cooperation Council (GCC) countries experienced a substantial downturn with Dubai being the worst hit. Although the impact was much less severe in other countries and Emirates, with prices in Dubai falling as much as 70%, there was a spillover effect on commercial real estate development which is intricately linked with district cooling.

The market has clearly been exposed to debt restructuring as headlined by some major, publicly traded district cooling companies. Other non-listed companies also suffered from similar problems. Marafeq Qatar had this extra roadblock to circumvent which presented challenges on two fronts:

1. Determining loads for the project based on market expectations in a downturn
2. Presenting the business case for financing to the lenders for project financing.

Market Load Estimation

In a difficult real estate market environment, developers have faced challenges in launching

projects, especially with the decline in the off-plan property sales. With off-plan sales having come down substantially, until recently, developers in the market have been finding it difficult to commit to real estate market penetration plans which determine the demand for district cooling. LREDC has, despite the difficult market environment, committed to market loads which have been translated into the district cooling market loads.

It would be fair to claim that the market loads for most real estate developments have been revised downwards relative to the first three quarters of 2008. However, the challenge in terms of market loads was to plan for the project in such a manner that it was economically viable and hence bankable. This was achieved through the gradual and phased development of the project; the details for which are provided later.

Phased Capacity Additions

Phased investments in capacity are based on the recognition of the fundamental principle that growth in the commissioning of installed district cooling capacities should match the growth in the development of the city. Based on the commercial experience of several district cooling projects, it is clearly evident that investing in capacity that may not be utilized results in low returns for shareholders. Having been through the downswing in the market, Marafeq Qatar proposed phased additions for the project. Given the space, power and water infrastructure and related constraints available from the developer, Marafeq's project development teams—technical and commercial—proposed capacity addition plans that would ensure that the diversity requirements against market loads were managed appropriately along with the goal to ensure the step-wise investments in phased capacity additions were economically viable. Essentially it was call for Marafeq Qatar to manage diversity, while ensuring the economic returns on all individual capacity additions were viable from a bank financing perspective.

Diversity

The implication for diversification in loads across different occupancy types, predominantly residential and commercial, is the installed capacity for district cooling providers is lower than the contracted loads at the customer level. The principle is that during office hours, for example, the load requirements in residential units are much lower versus non-office hours. The assumption for diversity however presents commercial risks, which represent a challenge in markets which have experienced slowdowns. If the diversity is higher than originally anticipated, production capacity might not satisfy the connected customer load and thus meeting supply temperature metrics may not be possible. Overinvestment however makes the project less economically viable. Marafeq therefore dedicated substantial time and resources to arrive at the best estimates for diversity.

Planning and Execution

From a planning and execution perspective, changes in market loads and estimates affect the delivery of district cooling service. Market loads based on diversity assumptions imply changes in installed loads which if resulting from downward revisions could possibly render an investment in a permanent plant unviable. Additionally, Marafeq Qatar was faced with issues related to the availability of power, water, and network which were the responsibility of the

master developer. Marafiq Qatar, therefore, proposed air-cooled temporary chillers and permanent water-cooled plants as the optimal solution. On a case by case basis, Marafiq Qatar made a complete plan for the delivery of chilled water to buildings based on the expectations of increase in market loads for the city for the next 15 years, and the corresponding availability or non-availability of the power, water and district cooling network infrastructures.