ISO 50001 Energy Management System – Case Study

2022 UNITED ARAB EMIRATES

ADNOC LNG

Case Study Snapshot	
Industry	Oil and Gas (LNG)
Product/Service	LNG, LPG, PN, Sulfur and compressed NG
Location	Das Island, Abu Dhabi
Energy performance improvement percentage (over the improvement period)	21% improvement over 7 years
Total energy cost savings (over the improvement period)	USD$42 million over 7 years USD$55 million over 13 years
Cost to implement Energy Management System (EnMS)	USD$200,000
Total energy savings (over the improvement period)	14,131,246 GJ over 7 years 20,687,570 GJ over 13 years
Total CO_2-e emission reduction (over the improvement period)	202 kt

Organization Profile / Business Case

ADNOC LNG was established in 1973 at the direction of His Highness the late Sheikh Zayed Bin Sultan Al Nahyan, founder of the UAE, to enable offshore oil production while minimizing flaring and monetizing the associated gases. Ever since, ADNOC LNG has maintained its commitment to safeguarding the environment and to adding value to the UAE economy and the communities it works with. Delivering energy efficiency and operational optimization are critical focus areas for the company and the essence of the sustainability which, in turn, delivers cost efficiency.

ADNOC is significantly expanding its gas position to ensure it continues to meet growing customer demand for LNG, the cleanest-burning fossil fuel. To achieve this growth while meeting our long-term strategic goals for decarbonization is a challenge that will require the continuous monitoring of our energy management system and energy performance indicators.

ADNOC LNG has started the journey of energy optimization since 2006 following benchmarking exercise in 2005, number of major improvements took place through investment and operational changes. It was foreseen that to gain further improvement a centralized system is required. In 2014, ADNOC LNG established an Energy Management System (EnMS) aligned with the ISO 50001:2011 standard. This EnMS has been a central tool in improving our overall

energy performance and related practices across our value chain. Our procurement processes now consider energy performance as a key factor in selection; our project and design processes build in energy efficiency and optimization requirements; energy efficiency considerations have been incorporated into a wide range of our technical training modules; and for key personnel, a new priority category for Significant Energy Users (SEUs) was created in the company's ERP solution. In addition, more than 95 Energy Performance Indicators (EnPIs) have been created along with the corresponding baselines, which together bring monitoring and reporting to more than 98% of energy consumption within the organization.

ADNOC LNG consistently invests in training its people in energy management. Beyond general awareness training for HQ and project personnel, the core energy team received advanced internal auditor training. This training enables regular internal audits that check the level of understanding and awareness of the core teams; identify any gaps; and lead to actions. The external audits, held in parallel by independent expert third-party organizations, focus on performance and compliance. In these unbiased audits, based on the ISO50001:2018 standard, ADNOC LNG sees the efforts and progress and of its energy team. Related energy optimization workshops also show the progress and energy savings of ongoing initiatives, along with providing an update on the energy assets' performance.

Our people's awareness and commitment towards energy optimization has developed significantly over the years, contributing to a significant reduction in energy consumption. Dedicated platforms have allowed the energy team to capture many improvement ideas, either for immediate implementation or to contribute to the strategy process.

Our EnMS is an enabler in further improving our own energy usage and in educating our people around energy and energy management, creating a sense of ownership and building ever-greater commitment from all our stakeholders. Through this commitment, ADNOC LNG was able to achieve the followings since 2018 whereas the overall savings reported in overall case study snap shot table above :

- A reduction in fuel gas consumption by 6.8 MMSCFD.
- A reduction in emissions equivalent to 202kt CO_2
  This corresponds to an overall 4.6% reduction in emissions,.

To drive increasing operational excellence and long-term sustainability across our value chain, ADNOC LNG will further reduce its energy intensity and overall GHG emissions, by continuously monitoring 99 EnPIs, to achieve the below, in line with the ADNOC Group's 2030 vision:

- An additional 5% reduction in fuel gas consumption compared with the 2018 baseline
- A further 23-25%% reduction in ADNOC LNG's GHG intensity by 2030, as we work to support the UAE's net zero emissions target

"Our EnMS is a tool to enable energy optimization and plant the seed of responsibility, commitment and ownership in the employees who will drive improvement."

—Haitham Salmeen, Vice President Engineering Technical Services

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Business Benefits

ADNOC LNG's decision to pursue an EnMS was not driven by cost reduction. In fact, at the time of implementation, the company's energy costs were low. It was, rather, a choice driven by the company's commitment to the conservation of the UAE's natural resources and its responsibility for environmental stewardship.

Efforts from multiple disciplines in ADNOC LNG have combined to improve the operations' overall energy performance. This work has been underpinned by the commitment of the business' leadership, as evidenced by the release of ADNOC LNG's energy policy and their semiannual reviews of progress and outcomes. With these and a robust EnMS in place, the way forward would be to develop an energy transformation strategy, supported by internal and external audits.

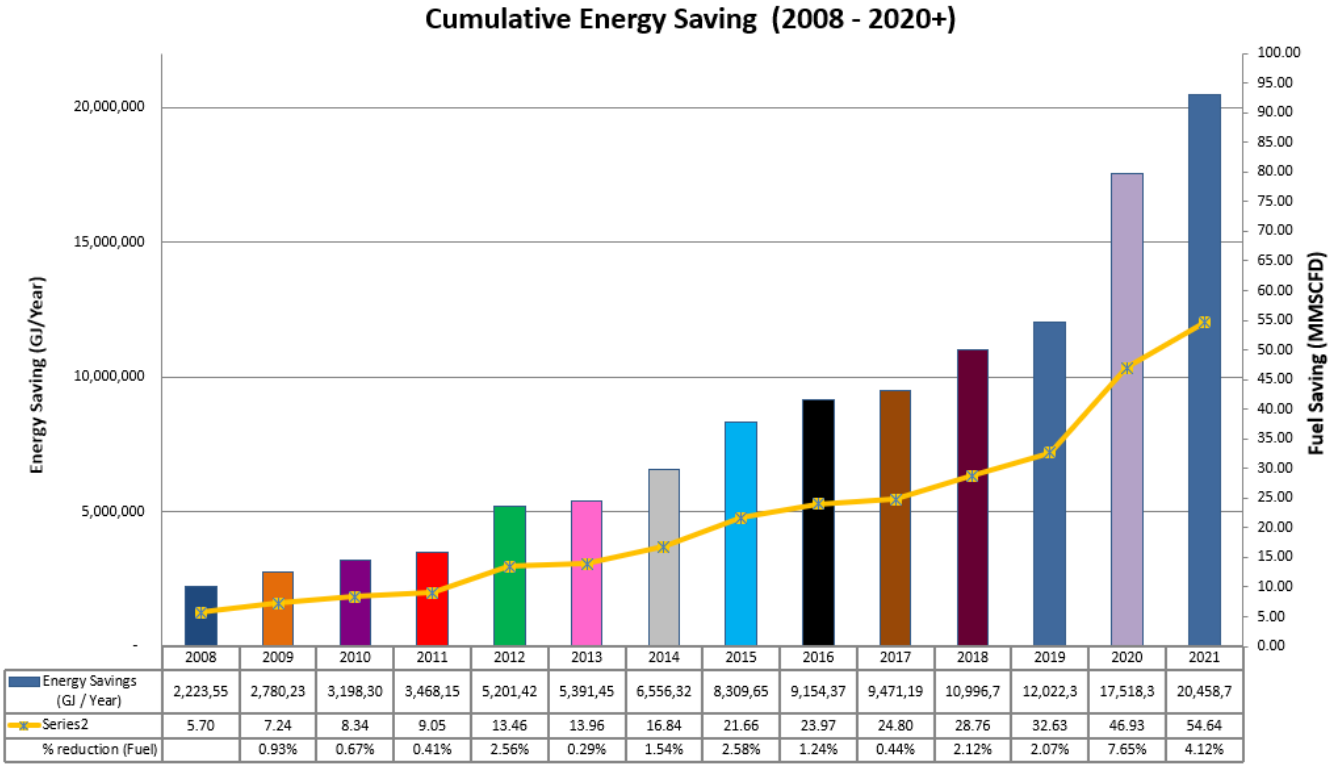
The EnMS performance indicators and continual monitoring enable ADNOC LNG to improve its environmental performance *and* profitability by optimizing overall fuel consumption and increasing energy efficiency. Achieving recertification to ISO 50001 in 2021, ADNOC LNG demonstrated it capacity to stretch the value of each of its molecules across the liquefaction process, via optimizations including:

- Energy Optimization – increasing the overall network energy efficiency and reducing fuel gas consumption
- Flaring Reduction – reducing overall emissions intensity of our assets

From the year of implementation , the value add from increased overall plant efficiency and operational improvements is equivalent to approximately USD$76.5 million; fuel gas consumption has been reduced by 6.8 MMSCFD and flaring emissions have been reduced by around 202kt of CO_2 equivalent. Some of the "quick wins" included:

- *Revising the operating philosophy of the Feed Gas Compressors (FGC):*
  Operating with only one FGC while maintaining the second on standby (e.g. during low gas supply periods from upstream sources). Savings in fuel gas consumption were 3.65 MMSCFD, equivalent to USD$4.06 million.
- *Replacement of the Boiler Feed Water Heaters (BFWHs):*
  The existing boilers operate relatively efficiently. However, ADNOC LNG made the decision to invest in a new design to improve the temperature outlet of the boiler feed water, thus increasing overall efficiency. This has led to a reduction of fuel gas consumption of 2.4 MMSCFD, which is equivalent to USD$1.64 million.
- *Change in Boil-Off Gas (BOG) operating philosophy:*
  Minimizing the number of BOG compressors in operation during non-shipping periods, which resulted in less BOG generation, in turn increasing overall LNG production and reducing power consumption. The equivalent added benefit is USD$3.1 million.
- *Increasing efficiency of power generators:*
  Integrating the N-1 operating philosophy in the power generation system resulted in an improvement in the overall efficiency of the power generators of 21.2%, equivalent to savings of USD$1.6 million.

The cumulative energy and fuel gas savings are reflected in the graph below. Where the yellow line represents the cumulative fuel gas saving in MMSCFD



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Energy Savings (GJ / Year)	2,223,55	2,780,23	3,198,30	3,468,15	5,201,42	5,391,45	6,556,32	8,309,65	9,154,37	9,471,19	10,996,7	12,022,3	17,518,3	20,458,7
Series2	5.70	7.24	8.34	9.05	13.46	13.96	16.84	21.66	23.97	24.80	28.76	32.63	46.93	54.64
% reduction (Fuel)		0.93%	0.67%	0.41%	2.56%	0.29%	1.54%	2.58%	1.24%	0.44%	2.12%	2.07%	7.65%	4.12%

Figure 1: Cumulative Energy Savings from total Initiatives 2008 - 2021

Overall, the VCO (Value chain Optimization) and EnMS have aided in the generation of around USD$77 million additional revenue, comprising 6.8 MMSCFD of fuel gas savings, 202kt of CO_2 emissions. The efforts will continue, pursuing defined plans with specific targets and actions, to realize tangible benefits and achieve challenging targets.

Case 1: Increasing efficiency of the power generators.

ADNOC LNG used in-house resources to improve the operational efficiency of ten existing gas turbine generators and two steam turbine generators. The challenge was that the Generator Management System (GMS) was configured to spread load to the generators equally, allowing the ISO-rated (leading) machine to vary its load to match the frequency required. ADNOC LNG saw an opportunity to improve its fuel gas consumption through distributing the power from machines to yield maximum possible overall efficiency.

Accordingly, the operational performance of the machines was examined, on a weekly basis, by Engineering, Operations and Maintenance teams, looking at aspects such as demand, on-line machines, plant conditions and operational constraints. The operating philosophy was guided using in-house built models and solvers which utilize the performance curves of the machines and actual plant data, taking into consideration operational constraints and power stability factors. The resulting proposal for pushing the machines to higher efficiency was guided to the operators by the engineers. This approach allowed the most efficient and cost-effective operation of the machines to be determined in real time in real-world conditions, resulting in significant fuel gas savings.

There are assigned EnPIs for each power generator as well as an overall EnPI for combined power generation system.

PDCA is summarized for this case study as:

- Plan: conduct weekly planning sessions with stakeholders to suggest the best configuration yielding highest overall efficiency
- Do: implement the suggestion on plant
- Check: daily review of performance of overall EnPI and overall weekly review
- Act: close the gaps based on the review

The calculation of savings is done through establishing a baseline based on the planned activities of the following week and compare to actual after implementing the actions. The internal efforts resulted in a notable improvement in the overall efficiency of the power generators, with fuel gas savings equivalent to USD$1.6 million, in only 6 months. Realizing the considerable merits, ADNOC LNG is pursuing the process of automating this tool through upgrading the Generator Management System (GMS) to allow distribution of power load based on efficiencies, rather than distributing the load equally.

Case 2: Replacement of the Boiler Feed Water Heaters (BFWH).

ADNOC LNG trains are steam driven. Today a total of six water tube boilers supply steam to the plant. These boilers are considered Significant Energy Users as they consume around 70% of the fuel gas used by the plant. An opportunity was seen to further reduce fuel gas consumption and emissions through investing into feed water heaters for four of the older design boilers. Boiler feed water (BFW) heaters are a heat integration medium, using waste steam to heat the water going into the boilers, reducing the energy demand on the boiler. It is to be noted that boilers can operate without the feed water heaters. Even with this heat integration in place, ADNOC LNG continued to pursue the deployment of ever-more efficient heaters in an attempt to secure the greatest possible energy recovery and emissions reduction. Their latest design delivers improved efficiency, reliability and availability, especially under their adverse operating conditions.

PDCA is summarized for this case study as:

- Plan: Review performance of boiler and all parameters impacting performance finding that there is potential of improvement by heating feed water
- Do: Design feed water heater which reduce fuel gas requirement
- Check: check the performance of boilers after implementation of heaters
- Act: close gaps/troubleshoot heaters to get the maximum potential

There was significant improvement in the boilers EnPIs following the installation and operation of the heaters. The estimation of savings was done based on difference of EnPIs performance before and after the improvement. All the heaters were upgraded, and fuel gas savings monitored, identifying estimated fuel gas savings of 2.4 MMSCFD, equivalent to USD$2.67 million.

Plan

ADNOC LNG's EnMS was established in 2014 to improve the company's energy performance across its value chain, including driving greater energy efficiency and reduced energy consumption. The system was created with the collaboration of departments and disciplines across the company. The respective stakeholders managed their respective roles and responsibilities while contributing ideas to the development program.

Following the standard requirement of PDCA, the first step was to issue the energy policy which shows the commitment from top management towards the activities of energy management and sets the expectations and objectives.

In order to translate the commitments from the policy, energy planning is essential step which identifies the energy sources, energy consumers and Significant Energy Use (SEU). Total number of 95 EnPIs covering plant energy consumers were established. For each EnPI a dynamic baseline compromising of past performance with normalization. In general, the normalization uses number of parameters such as plant load, ambient temperature, sea water temperature, etc. however, for each EnPIs different specific variables are incorporated based on their impact on overall performance. Accordingly, the EnPI has been developed at three categories;

- Level 1 - at asset level
- Level 2 - at unit/process level
- Level 3 - at equipment level

The energy consumption values, flow values production etc. have been extracted from historical data and trends and are reflected in the EnPI sheet, on monthly basis. They are sorted based on high energy consumption (SEUs) or if they offer/provide considerable potential for energy improvement. They are then compared against a dynamic baseline (typical three years of data) that allows users to automatically remove out-of-bounds values due to disruption or unusual working conditions.

Using these tools, actions are set with the aim of reducing consumption by SEUs and increasing overall efficiency. The energy team set objectives, targets and action plan for SEUs. These actions are closely followed up, prioritized and reported. All variable and equipment affecting SEUs are also monitored and prioritized for maintenance activities.

Energy team conducts energy planning forecast for each year based on the planned activities and production planning. This is done during the energy review meetings which is conducted at least twice a year. The energy review meeting is used as a platform to plan the improvement activities, follow up actions and prepare agenda for the management review meeting.

In addition, a value chain optimization (VCO) roadmap has been established to allow a refreshed and accelerated look at all our operating assets, to unlock further fuel and emissions reduction potentials, while sustaining or enhancing production. To date, several additional initiatives have identified on this roadmap, 13 of which pertain to energy savings, while six pertain to flare reduction. This demonstrates the drive for continual exploration for further savings opportunities.

Do, Check, and Act

“DO” Part is through implementing the initiatives either from action plans of SEUs, or improvements from daily monitoring.

The **“CHECK”** part of the PDCA cycle is done through daily and monthly reviews of EnPI, internal audits and external audits. Actual performance is retrieved and compared against the dynamic baseline, normalized, and the energy

performance is accordingly assessed. The Normalization process is performed, considering production loads, fuel gas consumption, operating philosophy and ambient conditions.

The following actions are taken accordingly:

- If the energy performance is satisfactory, the respective energy savings are calculated and reported.
- If the energy performance is not satisfactory, actions plans are put in place to review the root-cause and improve the performance.

Moreover, actions raised from daily monitoring, audits, energy review and management review meetings and monthly reports are captured in action register with target dates and priority. Attending these actions is considered as **"ACT".**

Finally, the business' leadership team has an annual energy management review to examine the actions and improvements planned and under way, and to look at additional suggestions for improvements.

Transparency

As part of its energy transparency practices, ADNOC LNG reports its energy performance and intensity KPIs to its parent company every month. The ADNOC Group monitors energy consumption throughout its supply chain at Company, Site, Unit, and Equipment levels.

Through networking and a series of initiatives and competitions, novel ideas and in-house innovations are shared with ADNOC LNG and other ADNOC Group companies, as well as with other companies and organizations in the region and across the energy sector, to promote energy management best practices and reinforce good energy management behaviors.

What We Can Do Differently

ADNOC LNG will continually work to evolve and progress towards greater energy optimization and more efficient support for the energy transition, meeting its commitment to reduce the company's impact on the environment. One tool in this progress may be an automated EnPI sheet with dynamic baselines that will show operators and engineers the real-time performance of end user equipment, allowing them to optimize the performance and efficiency of that equipment.

Further development will allow operators and engineers to see the impact of optimizing equipment in EnPIs that show the difference between their actual "dollar value" and the baseline, emphasizing the importance of the responsible operation of plant assets while maximizing opportunities and eliminating waste.