The Danish Energy Agency

Anonymous Audit Report
from a chemical company

ECCBK, 18.04.2025

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Introduction to the context

On March 13, 2019, the Decision No. 280/QD-TTg on approval of the National Energy Efficiency Programme (VNEEP) for the period of 2019-2030 was issued by the Prime Minister.

The VNEEP implements synchronously activities in the field of economical and efficient use of energy, showing commitments of all levels of government, associations, businesses, organizations, individuals to energy efficiency in particular and to climate change resilience and environmental protection in general.

The Vietnam-Denmark Energy Partnership Program Phase 3 (DEPP3) for the period 2020-2025 implement a number of activities, making substantial and effective contributions to help Vietnam's energy sector transition towards green growth, reduce carbon emissions through the development of a green energy system, operate a flexible power system, efficiently enforce policies and measures promoting energy efficiency and conservation.

One of the very important activities of promoting energy efficiency through Energy Audit in a broad variety of industrial sectors in Vietnam.

This document contains an anonymised summery of a specific energy audit report conducted as a part of the DEPP3 program. The audit has been conducted on a chemical production plant, by ECCBK, in collaboration with an international expert from Viegand Maagøe.

Summary

1 About the enterprise

1.1 Description of the company

- Sector: Chemical
- Main products:
  - Product 1: 949,130 (ton/year)
  - Product 2: 150,092 (ton/year)
  - Product 3: 541,517 (ton/year)
- Annual energy total consumption
  - Electricity:
    - Grid: 170,122,888 (kWh), equivalent to 26,249 (TOE),
  - NG: 20,750,348 (GJ), equivalent to 529,225 (TOE).

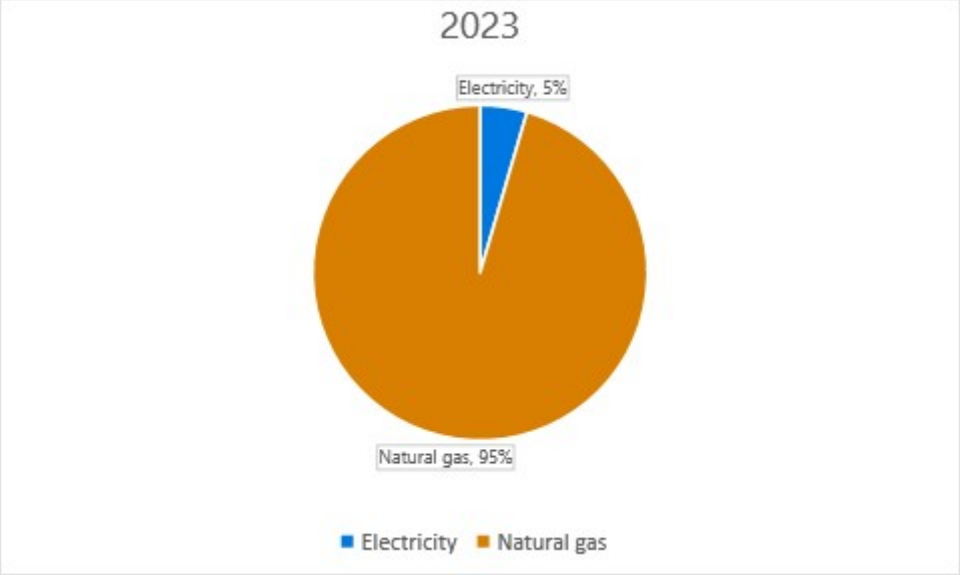


Fig 1.1 Break downs of the energy consumption

1.2 Description of the process

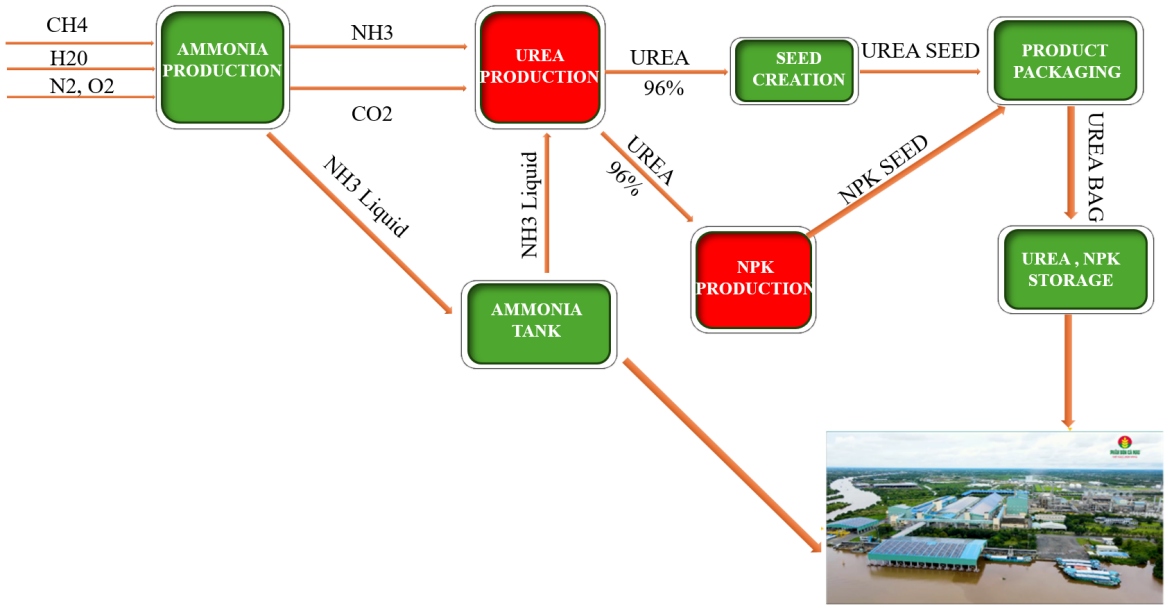


Fig 1.2 Process overview

The raw material source is natural gas. Natural gas after entering the Plant is used for the boiler of the Auxiliary workshop. The Auxiliary boiler produces high pressure steam, mixed with steam produced from the excess heat steam boiler to provide steam for consumers in the whole Plant.
In addition, natural gas is supplied to the Ammonia plant to be used as fuel in the primary Reforming furnace and as raw material to synthesize NH3 (the main raw material for Urea production).

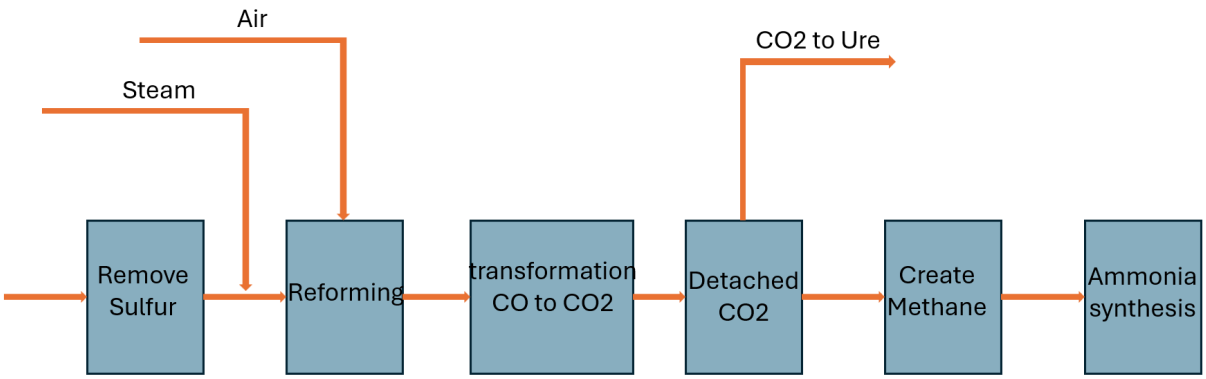


Fig 1.3 Amonia production process

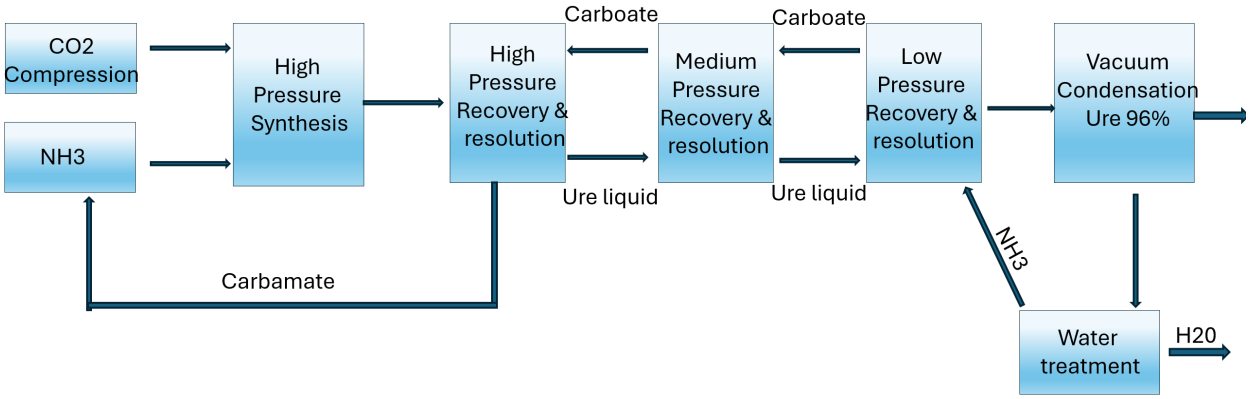


Fig 1.4 Ure production process

1.3 Description of the utility systems

- Boiler:

No	Boiler type	Fuel type	Design capacity (ton/hour)	Working pressure (barg)	Exhaust temperature (oC)	Average operating hours (hours/day)
1	Auxiliary boiler	NG	200	39	120	24
2	Waste heat boiler	Waste heat	250	110	-	24

- Refrigeration and Chillers:

No	Brand	Cooling capacity (Hp)	Quantity	Average operating time (hours/day)
1	Midea	3	19	8
		5	16	8
		1.5	7	8
		5.5	2	8
2	Samikura	3	1	24
		5	3	24
		2.5	1	24
3	Gree	2	1	24
		3	6	24
		4	2	24
		1.5	6	24
4	Yatai	5	6	12
5	Bartec	2.5	2	8
6	Daikin	1.5	11	8
		2	16	8
		3	11	8
		4	2	8
		5	14	8
		13	1	24

No	Brand	Cooling capacity (Hp)	Quantity	Average operating time (hours/day)
		5.5	11	8
7	Rittal	1.5	8	24
8	Hitachi	1.5	1	24
9	Kangning	12	3	24
10	LG	2	2	24
11	Mitsubishi	1.5	4	8
12	Reteech	1.5	8	8
13	X60001A/B	268	2	24
14	X54001	77.8	1	24
15	X55003	310	1	24

- Air compressors:

No	Device Name	Quantity	Rated power (kW)	Working compression pressure (bar)	Operating time (hours/day)
Workshop 1					
1	Air Compressor	6	200	9	-
2	Ammonia Compressor	2	141.5	18.01	24
Workshop 2					
1	Air Compressor	1	9,738	32.6	24
2	Synthetic Air Compressor	1	16,629	130.7 - 138.3	24
3	Ammonia Compressor	1	6,176	18	24
4	Ammonia Booster Compressor	1	500	200	-
5	Compressor	1	75	40	-
6	CO2 recovery compressor	1	630	29	-
Workshop 3					
1	CO2 Compressor	1	11.04	157	24
2	Air Compressor	2	37	160	24

2 Methodology used to identify EE projects

2.1 How EE projects have been identified and developed

- Conduct energy audit and prepare an energy audit report with potential energy-saving solutions based on circular 25/2020/TT, MOIT energy audit guideline and Energy Mapping User guide from DEPP3 project.
- Based on overall energy mapping result, major energy consuming processes are identifed. Because over 95% of the energy consumption related to heating and cooling, intensive investigations of the cooling system, main heat exchangers, and waste heat sources are realized. Heat exchangers are grouped in terms of

location and functions to reduce the number of heat exchangers involved while can still be representative for the specific heat exchanger network.

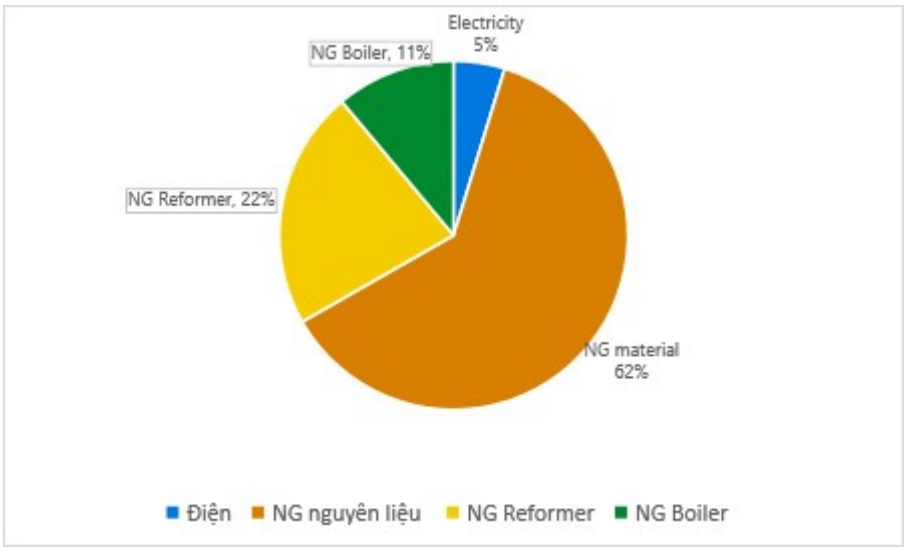


Fig 2.1 Overal energy mapping

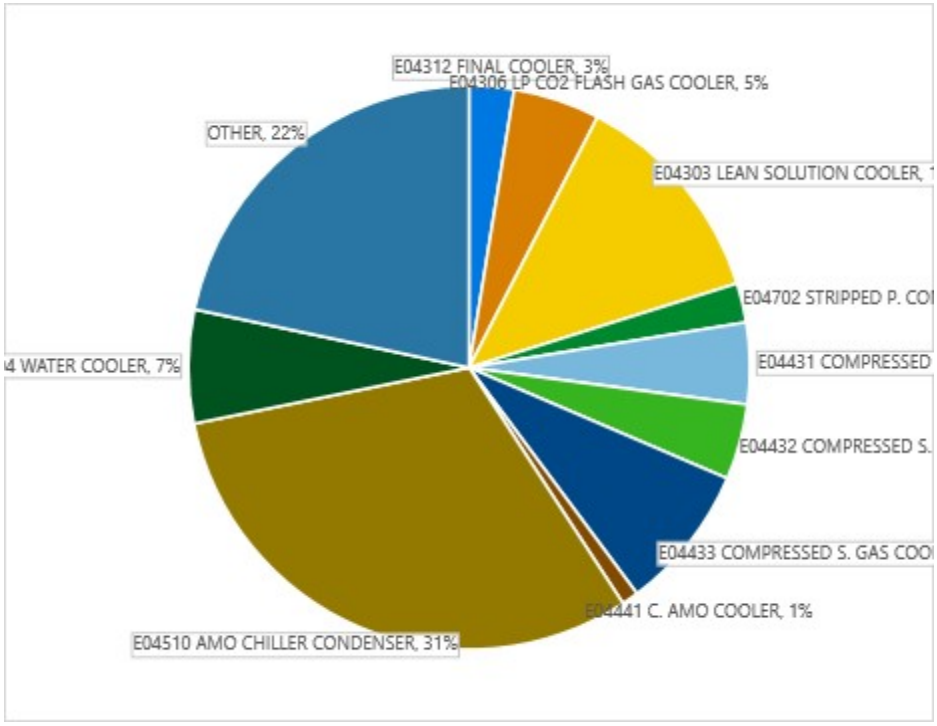


Fig 2.2 Detail energy mapping

- Intensive Temperature analysis is realized by level-2 mapping where any thermal energy demand (heating and cooling) is mapped by energy demand and temperatures. The purpose of this is to identify potential energy savings potentials through modification of processes or the energy supply systems. Based on the temperature analysis, energy saving opportunities are identified including potential for heat recovery.

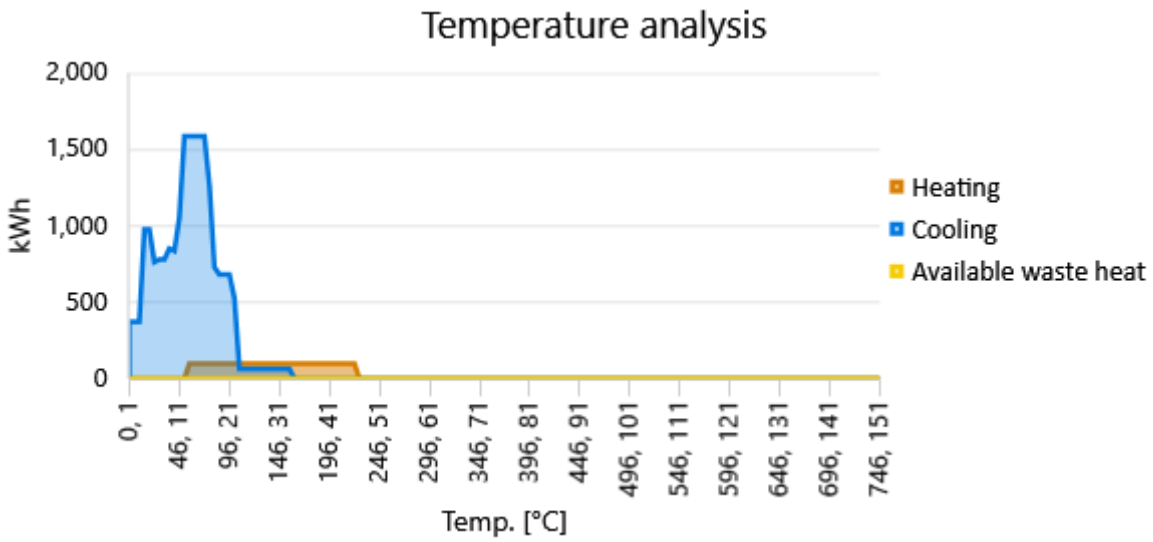


Fig 2.3 Temperature analysis based on Level 2 mapping

- Energy saving opportunities will be presented in two types of projects at Level A and B. During the energy audit process, many observations will be made which could have potential energy savings through a large screening list can be created. This list of observation could be referred to as level B projects, where the potential energy savings and investment are evaluated based on estimates if possible. The screening list of level B opportunities should be evaluated and should be selected for further development. These projects will be called level A projects and should be developed enough for making a decision of whether to carry out a pre-feasibility study.

2.2 EE Project evaluation

Basically the following values are determined to evaluate energy saving measures:

- Energy savings in thermal or electrical units (kJ or kWh)
- Energy savings by unit of mass, volume (ton, liter, m^3)
- Annual energy cost savings (VND/year)
- Capital costs to implement energy saving measures (VND, million VND)
- Payback period (months, years)

Non energy benfits such as water saving, capacity expansion capability are also considered.

2.3 EE Project prioritisation

During the energy audit, a wide range of observations regarding potential energy savings were noted. Given the volume of these observations, it was not feasible to perform a detailed analysis on each one. Instead, all observations have been initially categorized as level B projects. Following in-depth discussions with facility staff, the most promising opportunities considering company priority were identified and selected for further development into level A projects.

Enterprises feedback

The Enterprise offers valuable feedback on the benefits and technical feasibility of the proposed energy-saving projects. They are considering including level A projects in their implementation plan. Additionally, the Enterprise has requested support for the evaluation and implementation of these proposed projects.

3 EE Projects identified

The company consumes approx. 500 mills. m3 natural gas per year, counted for 95% of the total energy consumption. The high consumption of natural gas is caused by the fact that the gas partly (65%) used as raw material, partly (35%) used as fuel to heat the processes at the facility. So that the heating and cooling process will be the main focus of the audit.

During the site visit, a number of focus areas for further energy audit activities were identified and discussed with key-staff at the facility:

1. Rehabilitation of cooling systems
2. Use of VSDs to control the capacity of large fans and pumps
3. Increased power production with ORC
4. Rehabilitation of boiler feedwater preheating system
5. Delta-T-hunting and improved heat recovery
6. Assessment of potential for use of biomass, CO2-capture and green hydrogen
7. Rehabilitation of condensers in ammonia chiller system to improve COP
8. Optimization of compressed air systems operation
9. New KPIs to monitor operation of instrument air systems and cooling tower systems

After discussions, the following areas were concluded to be most important:

- Rehabilitation of cooling water systems
- Utilization of waste heat and delta-T-hunting

Table 1: Groos list (level B mapping)

No.	Solutions	Detail
1	Rehabilitation of cooling systems	There are opportunities to apply cooling tower water directly for process cooling in some areas in stead of using fresh water cooling (5^{o}C higher temperature)

		- This will make cooling more efficient due to lower feed temperature of cooling tower water - This will also increase the capacity on E21201H-T (eventually reducing delta-T) Promissing locations are: - Syn Gas compressor intercooler E04431, E04432, E04433 (16,629 kW). - Air compressor intercooler E04221, E04222, E04223, E04224 (9,738 kW) - CO2 compressor intercooler E06119, E06120, E06121 (11,040 kW)
2	Optimization of Plate Heat exchangers E21201H-T	A delta-T of 5 degrees for E21201H-T is relatively high compared to other water-to-water plate heat ex-changers of similar size. The current construction of the heat exchanger E21201H-T leaves a place for extra plates to increase size minimizing delta-T. Fresh cooling water temperature can ben reduced by about 1.1 oC after increasing E21201H-T size by 50%.
3	Use of VSDs to control the capacity of large fans and pumps	It has been observed that large manual valves are installed in multiple locations within the utility systems to regulate flow capacity. Specifically, the following dampers are partially closed: B07602 and B07603 (70%), B07605 (60%), and B07601 (50%). The plant has already planned to install a Variable Speed Drive (VSD) for B07602 to reduce energy consumption. It is recommended that VSDs also be considered for B07602, B07603 and B07605 to enhance energy efficiency.
4	Delta-T-hunting and improved heat recovery	E04503 (~195 GJ/h) has high delta-T that can be improved to recover heat and reduce cooling load at E04504.
5	Increased power production with ORC	After a comprehensive mapping of the heat exchangers and cooling system, the following waste heat sources have been identified as candidates for power production using an Organic Rankine Cycle (ORC) or for chilled water production using an absorption chiller: - E04510 AMO Chiller Condenser: Capacity: 28,650 kW; Operating Temperature: 102.4°C

		- E04433 Compressed S. Gas Cooler 3: Capacity: 7,719 kW; Operating Temperature: 157.6°C - E04221-E04224 C. Air Cooler: Operating Temperature: 124.8°C - E06119 CO2 compressor first intercooler: Capacity 3,217 kW, temperature in 170.2 ^{o}C - E06120 CO2 compressor second intercooler: Capacity 3,669 kW, temperature in 220.8 ^{o}C - E06121 CO2 compressor third intercooler: Capacity 2,722 kW, temperature in 177 ^{o}C.
6	Rehabilitation of boiler feedwater preheating system	Increase E04205 feedwater preheater size to recover more heat from pre-reformer furnace exhaust gas (160^{o}C).
7	Rehabilitation of condensers in ammonia chiller system to improve COP	Replacing the water-cooled condenser E04510 with an Evaporative Condenser. The condensing temperature can be reduced from 40.6oC to 33oC (temperature difference of 6.4oC), which can potentially increase the cooling capacity by 6.4%.
8	Optimization of compressed air systems operation	Including 1 or 2 compressors with VSD-drive to avoid frequent in-efficient load/un-load-operations
9	Assessment of potentials for use of biomass, CO2-capture and green hydrogen	There is potential to use biomass for the auxiliary boiler as a replacement for natural gas (NG). However, this option could impact plant operations and require further research. Therefore, it is not a priority at this time.
10	Waste heat recovery from AMO for drying NPK products	Excess heat from AMO section (E04433 Compressed S. Gas Cooler 3: Capacity: 7,719 kW; Operating Temperature: 157.6°C; E04221-E04224 C. Air Cooler: Operating Temperature: 124.8°C) can be transferred via high-pressure hot water to the NPK workshop, where there is a relatively high demand for heat to dry products at approximately 100°C. To implement this, additional heat exchangers and pipelines will be required to transport the waste heat to the consumption site.

11	Waste heat recovery from CO2 compressor intercooler	Utilize wates heat from CO2 compressor intercooler (E06119, E06120, E06121) for the Vacuum Evaporator (E06114) to reduce the low-pressure steam consumption.

4 Selected EE Projects for further supports

This section includes projects that has been chosen to be developed further (Level A)[1].

Table 2 Selected projects (level A mapping)

Optimization of Plate Heat exchangers E21201H-T

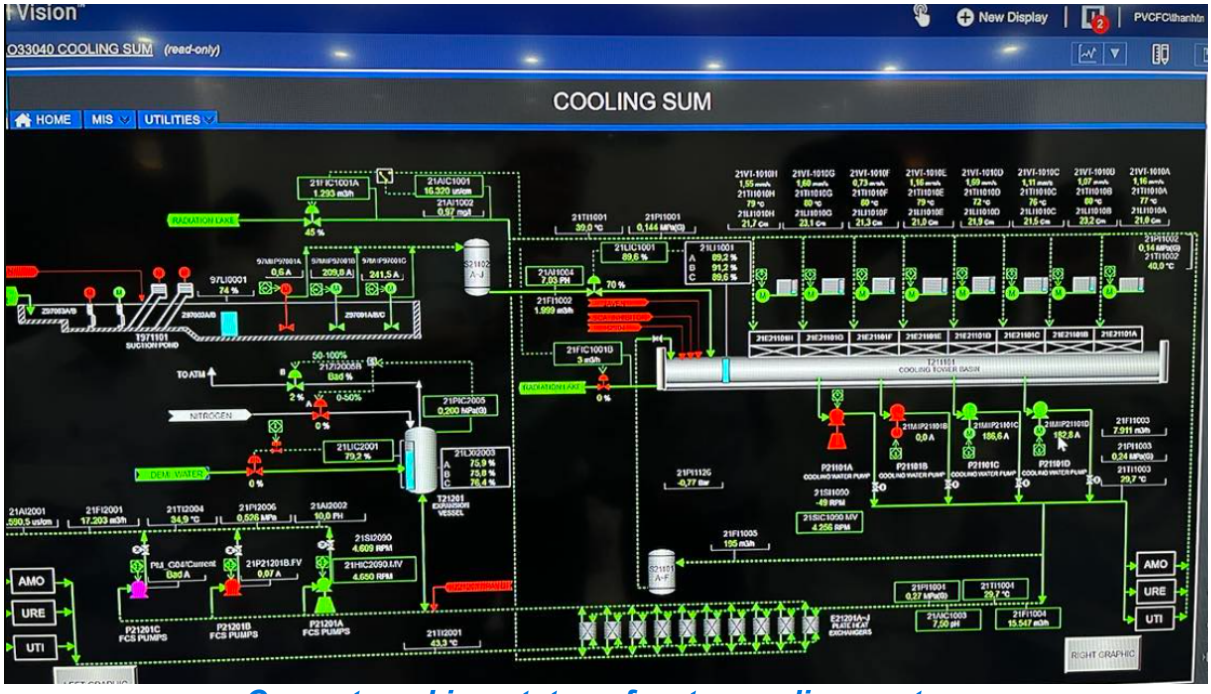
Project information		
Project:	**Project no.**	**Date:**
Enterprise:	**Auditing company:**	**Auditor:**

Project description

Current situation

The fresh cooling water is cooled down by river water through 10 river water-fresh water heat plate exchangers E21201A~J with total duty of 214,225 kW.

Current working status:



Current working status of water cooling system

Current working status of river – fresh water plate heat exchangers

Flow configuration	Counter flow	
Medium	Hot: Water	Cold: Water
Flow (m3/h)	17,203	15,547
T In (oC)	43.3	29.7
T out (oC)	34.9	39

[1] Then project developed at level B is not described in a section for itself because it is included in gross list.

Delta T (K)	8.5	9.3
Heat flow rate Q (kW)	167,064	
Pinch point Delta T-pinch (K)	4.3	
Heat Transfer effective kA (kW/K)	35,360	
Efficiency	0.68	

A delta-T pinch of 4.3 degrees is relatively high compared to other water-to-water plate heat exchangers of similar size, where the best practice design can be as low as 1 degree. However, it is mainly because the current flow both primary and secondary has been reduced by cutting of 01 pumps on each side. The current construction of the heat exchanger system leaves a place for extra plates to minimize delta-T, see photo below.

River – Fresh water plate heat exchangers

Proposed project

Increase size of PHEs by 50%.

Working status of river – fresh water plate heat exchangers after size increases

Flow configuration	Counter flow	
Medium	Hot: Water	Cold: Water
Flow (m3/h)	17,203	15,547
T In (oC)	43.3	29.7
T out (oC)	33.8	40.17
Delta T (K)	9.5	10.47
Heat flow rate Q (kW)	188,023	
Pinch point Delta T-pinch (K)	3.133	
Heat Transfer effective kA (kW/K)	52,332	
Efficiency	0.77	

Fresh cooling water temperature reduces by about 1.1 oC after increasing PHEs size by 50%.

- Reduced ~0.33% energy consumption for compressors (4 stage synth. Gas 16,629 kW, 5 stage air compressors 9,738 kW, and CO2 compressor 11,040 kW) ~ 125 kW
- Reduced ~3% energy consumption for the ammonia chiller 6,176 kW ~ 185 kW

Project illustration (PFD)

Project Budget

Element	Units	Unit costs	Costs
Extra plate for plate heat exchanger	10	14,000	140,000
Installation	10	1,000	10,000
Total	**150,000**		

TIME SCHEDULE

Activity	1	2	3	4	5	6	7	8	9	10	11	12
Pre-feasibility												
Feasibility studies												
Final Investment Decisions					X							

Saving

Energy(annual): 9,811 GJ	**Financial (annual): 98,112 USD**
Co2 (annual): 550 tons	**Simple Payback (years): 1.5**

Risk Analysis

Risk	Likelihood	Impact	Mitigation Measures
Installation delays	Medium	Medium	Develop a detailed timeline and contingency plan. Ensure contractor availability and supply chain readiness.
Cost overrun	Low-Medium	High	Include a buffer in the budget (~10–15%). Use fixed-price contracts with suppliers and contractors.
Underperformance of PHEs	Low	High	Conduct detailed performance modeling and use high-quality materials. Perform rigorous testing post-installation.
Operational disruption	Medium	Medium	Schedule installation during low-demand periods or planned maintenance shutdowns.

Unexpected technical issues	Medium	Medium-High	Perform pre-installation system audits. Include expertise from experienced vendors/engineers.
Inaccurate energy savings estimation	Low	Medium	Use validated models for predictions and monitor performance post-implementation.
Environmental concerns	Low	Low	Ensure compliance with local environmental regulations during installation.
Stakeholder resistance	Low	Medium	Communicate the project's benefits clearly, including cost savings and sustainability impacts.

Non Energy benefits

- Increased production capacity via higher product flows and/or better performance of unit operations
- Support future capacity expansions

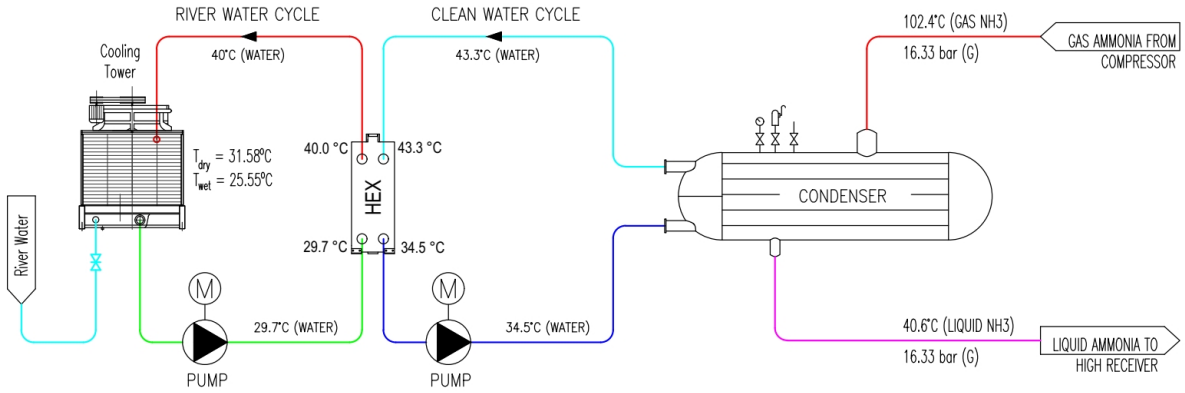
Replacement of Ammonia Refrigeration Condenser by Evaporative Condenser

Project information		
Project:	**Project no.**	**Date:**
Enterprise:	**Auditing company:**	**Auditor:**

Project description

Current situation

The current refrigeration system uses a water-cooled condenser to condense the refrigerant (NH3). The cooling water circulates in a closed water loop (Clean Water) and is cooled by the cooling tower's circulating water (River Water). Due to indirect heat exchange through 2-loops (figure below)., the condensing temperature of the refrigerant is high (~34.5oC), resulting in increased power consumption of the ammonia compressor.

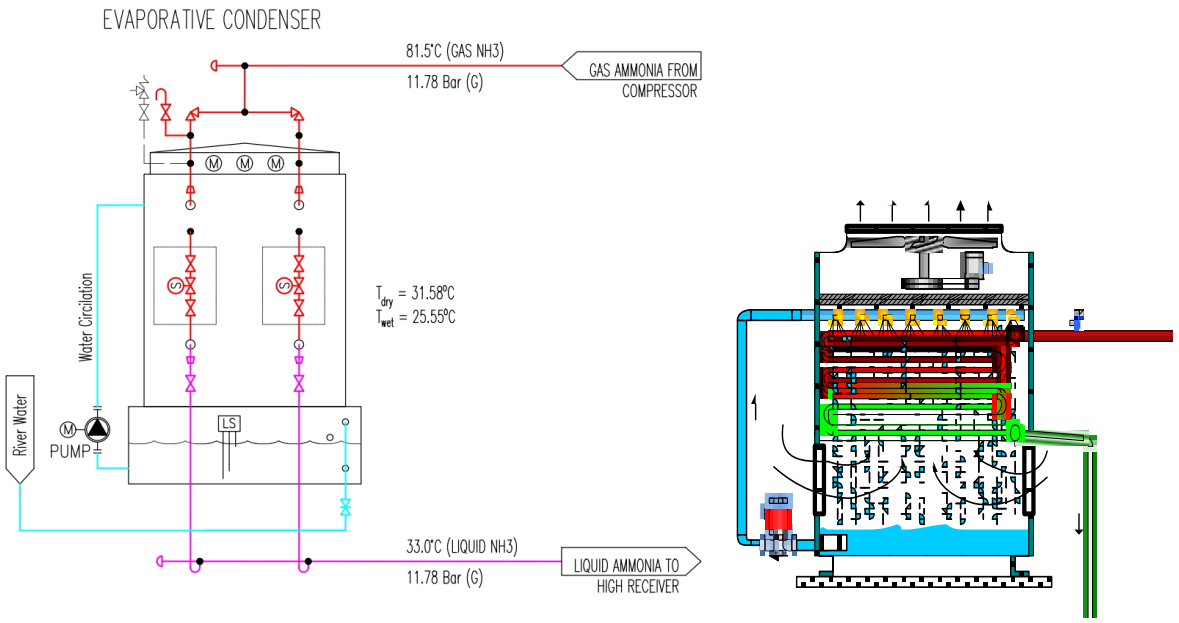


Current situation of the ammonia chiller condenser

Proposed project

In the ammonia refrigeration, if condensing temperature increase 1°C means approx.: 1% lower cooling capacity, 3% lower COP, and 3.1% higher power consumption. Therefore, to improve the energy efficiency of the refrigeration system, the condensing temperature of the refrigerant needs to be reduced. This can be achieved by replacing the water-cooled condenser with an Evaporative Condenser. The condensing temperature can be reduced from 40.6oC to 33oC (temperature difference of 6.4oC), which can potentially increase the cooling capacity by 6.4%, 19.2% higher COP and reduce the 20% power consumption. Reduced ~20% energy consumption for the ammonia chiller 6,176 kW ~ 1,232 kW.

Project illustration (PFD)



Ammonia chiller evaporative condenser

Project Budget

Element	Units	Unit costs	Costs
Evaporative condenser Old condenser removed Installation			
Total	**300,000**		

TIME SCHEDULE

Activity	1	2	3	4	5	6	7	8	9	10	11	12
Pre-feasibility												
Feasibility studies												
Final Investment Decisions					X							

Saving

Energy(annual): 38,806 GJ	**Financial (annual): 388,000 USD/year**
Co2 (annual): 2,134 tons	**Simple Payback (years): 0.77**

Risk Analysis

Risk	Likelihood	Impact	Mitigation Measures
Installation delays	Medium	Medium	Develop a detailed timeline and contingency plan. Coordinate with experienced contractors.
Cost overrun	Low-Medium	High	Include a 10–15% contingency buffer in the budget. Use fixed-price contracts.
Operational disruption	Medium	Medium	Schedule installation during planned shutdown periods.

Underperformance of evaporative condenser	Low	High	Ensure proper design and selection of evaporative condenser. Perform thorough commissioning tests.
Scaling or maintenance issues	Medium	Medium	Establish a regular maintenance plan to manage scaling and fouling risks.
Environmental compliance	Low	Low	Ensure the system adheres to local environmental and safety standards.

Non Energy benefits

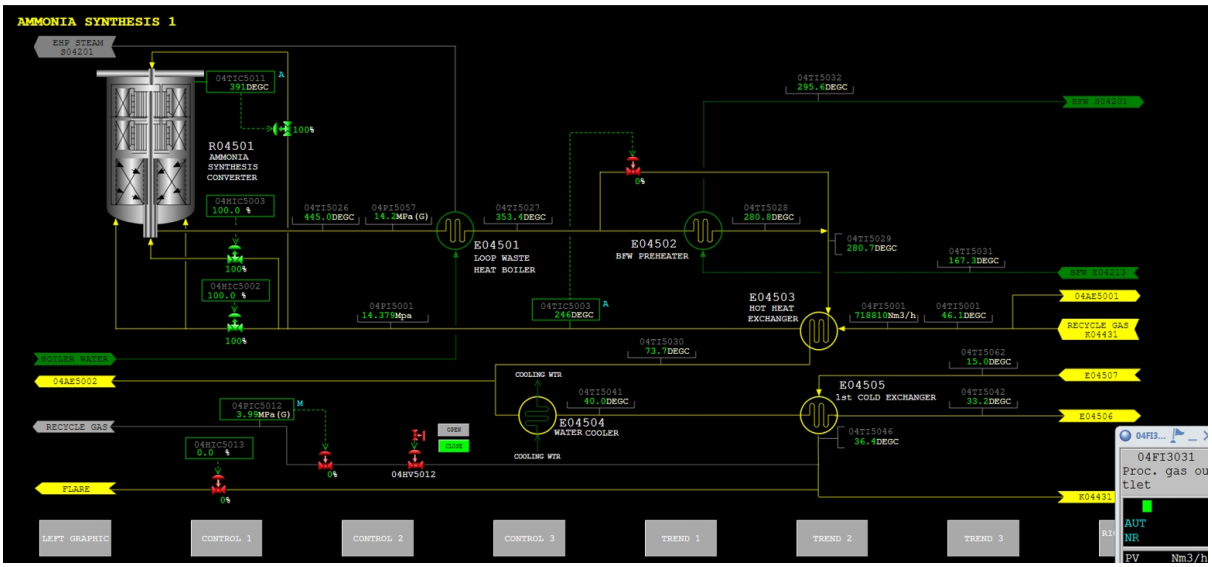
- When the refrigeration system does not use clean water for cooling, the clean water circulation flow can be reduced by approx. 2,750 m3/h (~16% of total fresh cooling water flow). The reduced clean water flow will increase the heat exchange efficiency of the HEX and will reduce the temperature of the clean water, before it is supplied to other processes.
- Support future capacity expansions

Increase E04503 capacity to reduce energy loss at E04504.

Project information		
Project:	**Project no.**	**Date:**
Enterprise:	**Auditing company:**	**Auditor:**

Project description

Current situation



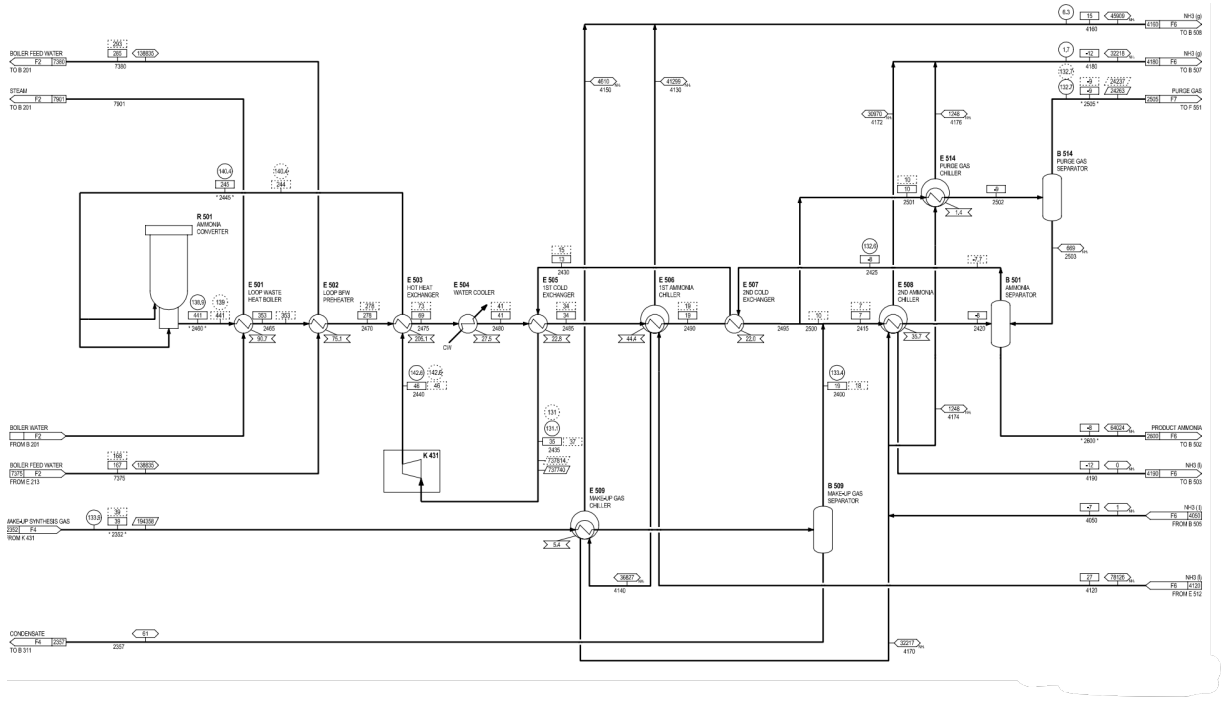
Hot heat exchanger

The gas leaving the synthesis tower R04501 is cooled step by step, before being discharged in the waste heat boiler E04501 from a temperature of about 441oC to 340oC. Next, the gas is cooled to about 280-290oC in the boiler feed water heater E04502 and in the hot heat exchanger E04503, where the synthesis gas is cooled to 65oC by heating the synthesis tower inlet gas. The synthesis gas is then cooled to 41oC in the water chiller E04504 and further down, to 34-35oC in the heat exchanger E04505, which is used to heat the synthesis inlet gas.
E04503 (~195 GJ/h) has high delta-T that can be improved to recover heat and reduce cooling load at E04504.

Proposed project

Increase E04503 capacity by 12% to 234 GJ/h to recover heat and reduce cooling load at E04504. Heat recovery by heating inlet gas from 46.1OC to ~ 270 OC.

Project illustration (PFD)



Hot heat exchanger

Project Budget

Element	Units	Unit costs	Costs
Total	**2,000,000 USD**		

TIME SCHEDULE

Activity	1	2	3	4	5	6	7	8	9	10	11	12
Pre-feasibility												
Feasibility studies												
Final Investment Decisions					X							

Saving

Energy(annual): 131,400 GJ	**Financial (annual): 1,314,000 USD/year**
Co2 (annual): 7,227 tons	**Simple Payback (years): 1.52 years**

Risk Analysis

Risk	Likelihood	Impact	Mitigation Measures
Design or sizing errors in E04503	Low	High	Use advanced modeling and experienced engineering consultants. Perform detailed design reviews.
Cost overrun	Medium	Medium	Include a contingency budget of ~10–15%. Negotiate fixed-price contracts with suppliers.

Installation disruptions	Medium	Medium	Schedule work during planned maintenance shutdowns to avoid unplanned downtime.
Underperformance of E04503	Low	High	Conduct thorough performance testing during commissioning. Choose a proven, high-quality design.
Scaling and fouling issues	Medium	Medium	Regularly monitor and maintain the heat exchanger to prevent performance degradation.

Non Energy benefits

- Reduce cooling load at E04504 by reducing input temperature to ~ 50 OC thus reducing fresh cooling water flow.
- Support future capacity expansions

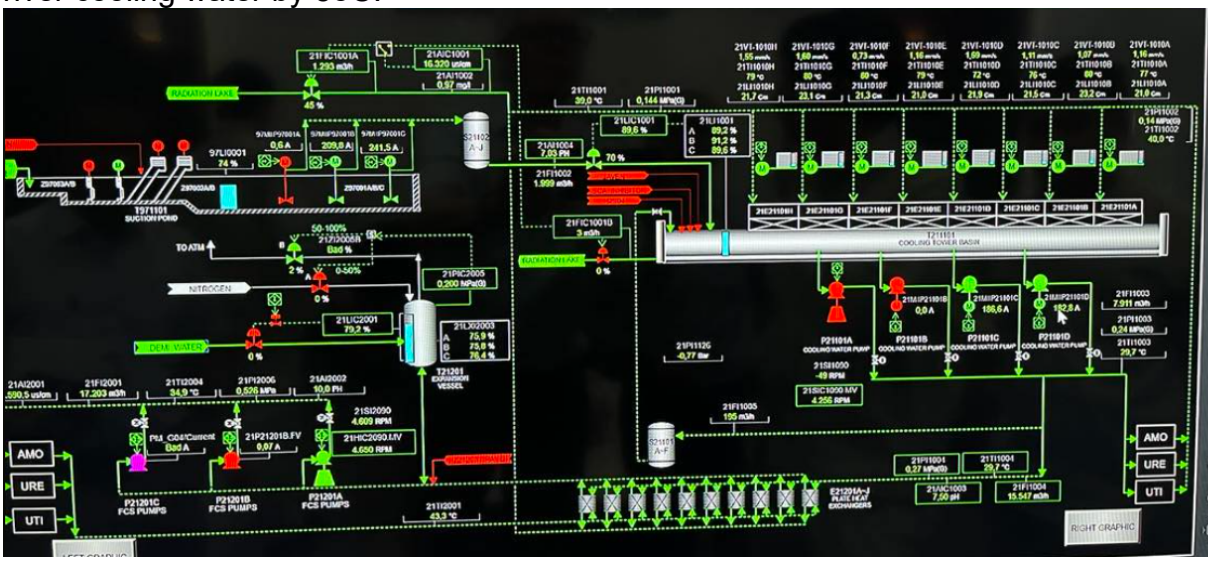
Direct use of cooling tower water for intercooler of compressors

Project information		
Project:	**Project no.**	**Date:**
Enterprise:	**Auditing company:**	**Auditor:**

Project description

Current situation

Freshwater is directly used in condensers and heat exchangers, except for turbine condensers in the plant, to reduce the temperature of process streams. It is then cooled down by Riverwater through Riverwater-freshwater heat exchangers E21201A~J. The temperature of fresh cooling water is higher than the temperature of river cooling water by 5oC.



Water cooling system

Proposed project

There are opportunities to apply cooling tower water directly for process cooling in some areas in stead of using fresh water cooling,

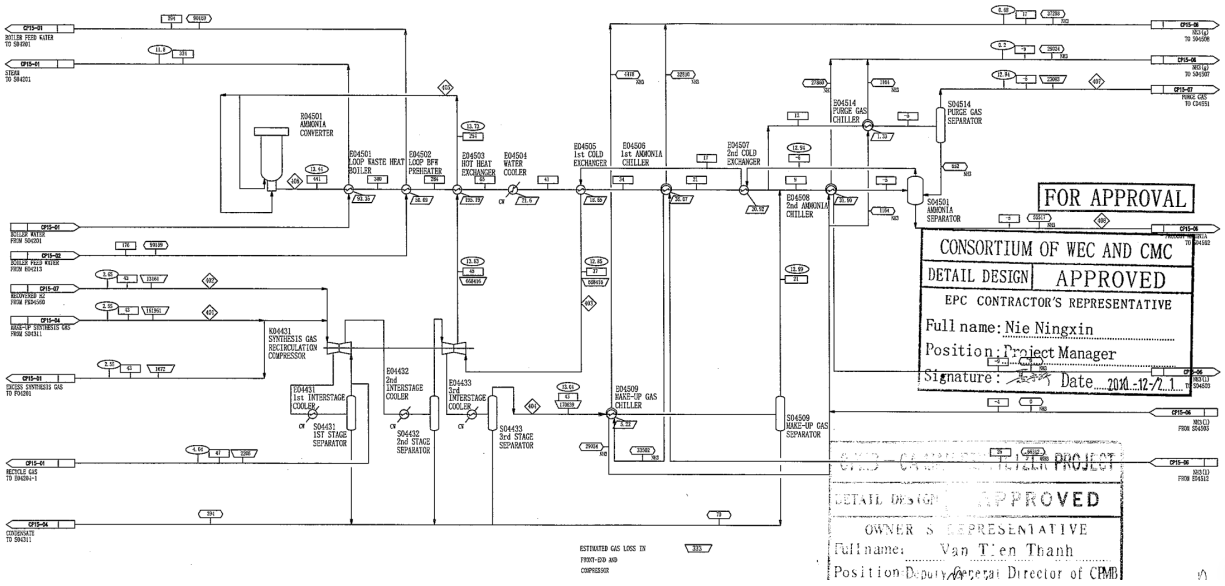
- This will make cooling more efficient due to lower feed temperature of cooling tower water
- This will also increase the capacity on E21201H-T (eventually reducing delta-T)

Promissing locations are:

- Syn Gas compressor intercooler E04431, E04432, E04433 (16,629 kW).
- Air compressor intercooler E04221, E04222, E04223, E04224 (9,738 kW)
- CO2 compressor intercooler E06119, E06120, E06121 (11,040 kW)

By reducing cooling water temperature 5oC, the energy consumption for compressors can reduce ~ 1.65%.

Project illustration (PFD)



Intercooler of synthesis gas compressors

Project Budget

Element	Units	Unit costs	Costs
Piping and Valves	Lot	150,000	150,000
Instrumentation & Control		50,000	50,000
Water Treatment System Upgrade		100,000	100,000
Engineering & Design		50,000	50,000
Installation & Commissioning		100,000	100,000
Contingency		50,000	50,000
Total	**500,000 USD**		

TIME SCHEDULE

Activity	1	2	3	4	5	6	7	8	9	10	11	12
Pre-feasibility												
Feasibility studies												
Final Investment Decisions					X							

Saving

Energy(annual): 49,055 GJ	**Financial (annual): 490,560 USD/year**
Co2 (annual): 2,750 tons	**Simple Payback (years): 1.02 year**

Risk Analysis

Risk Description	Likelihood	Impact	Mitigation Strategy
Inadequate Cooling Tower Water Treatment leading to corrosion/scaling/fouling	2-Medium	3-High	Implement a robust water treatment program with appropriate corrosion inhibitors, biocides, and regular monitoring. Conduct regular inspections of intercoolers.

Incompatibility of materials with cooling tower water	1-Low	3-High	Thorough material compatibility assessment during the design phase. Confirm material specifications with vendors.
Unexpected impact on cooling tower performance	2-Medium	2-Medium	Detailed hydraulic calculations and modeling during the design phase. Monitor cooling tower performance after implementation.
Insufficient cooling capacity from the cooling tower	1-Low	3-High	Verify cooling tower capacity against required cooling load during the design phase.
Increased maintenance requirements for intercoolers	2-Medium	2-Medium	Implement a preventive maintenance program for the intercoolers. Monitor intercooler performance and schedule regular inspections.
Unplanned shutdowns due to cooling system issues	1-Low	3-High	Implement redundancy in the cooling system where feasible. Develop emergency procedures for cooling system failures.

Non Energy benefits

- Reduced Freshwater Consumption. By switching to cooling tower water, the project directly reduces the demand for freshwater resources. This is particularly important in regions with water scarcity or where freshwater treatment is energy-intensive. This aligns with sustainability goals and can improve the plant's environmental footprint.
- Increased Heat Exchanger Capacity/Efficiency. As highlighted in the project description, using colder cooling tower water can increase the capacity and efficiency of existing heat exchangers (E21201H-T).
- Increased Production Capacity/Revenue. If applicable, quantify the potential increase in production output or product quality resulting from improved cooling.