Application of converting HSD to LNG

Muhammad Husnuari*
Indonesia Asahan Aluminium, Kuala Tanjung, Batu Bara 21657 Sumatera Utara, Indonesia
*Email: husnuari@inalum.id

Abstract. Anode baking furnace uses oil as fuel. The baking process is decisive for the quality and cost of an anode, and the environmental impact. Using natural gas as fuel can reduce the cost production of the anode by $9.45, and reduce emission from combustion in the furnace for CO₂ by 28%, NOₓ by 79%, and SOₓ by more than 95%. Emission reduction correlated to the consumption of NaOH that used for wastewater. NaOH can save by $34,000 per year and make more durability of the equipment. The total profit for this improvement is $1,245,345 per year.

1. Introduction
Anode baking process requires a large amount of fuel oil. Green anodes are transformed to graphitized carbon before being used in electrolysis cells. The transformation process that requires anodes heating up to 1,100 °C [1]. Typically one tonne of baked anodes requires approx. 2.3 Gigajoules energy [2]. The energy is supplied by the combustion of injected fuel in the refractory flue walls. A large amount of fuel oil influences the cost of anode production. While emission of combustion like SOₓ, NOₓ has become a major issue in most industries consuming fossil fuels. Therefore, combustion in anode baking furnace supposed to produce clean emissions and low-cost production [1]. Fuel consumption to produce baked anode in 2015 at PT Inalum can be seen in Table 1.

| Month       | Consumption (Liter) | Energy (MMBtu) | Anode Production (Ton) |
|-------------|---------------------|----------------|------------------------|
| January     | 1,078,946           | 38,734         | 14,376                 |
| February    | 910,197             | 32,676         | 12,707                 |
| March       | 989,270             | 35,515         | 13,587                 |
| April       | 915,136             | 32,853         | 13,296                 |
| May         | 943,813             | 33,883         | 13,376                 |
| June        | 915,164             | 32,854         | 12,839                 |
| July        | 1,050,867           | 37,726         | 14,166                 |
| August      | 1,048,165           | 37,629         | 14,459                 |
| September   | 1,005,089           | 36,083         | 14,044                 |
| October     | 1,012,759           | 36,358         | 14,207                 |
| November    | 922,562             | 33,120         | 13,712                 |
| December    | 977,256             | 35,083         | 13,279                 |
| TOTAL       | 11,769,224          | 422,514        | 164,048                |

A large amount of fuel oil influences anode cost production and affects to the anode sale price. Anode cost production can be seen in Table 2.
## Table 2. Anode cost production using oil.

| Item           | Unit  | Price |
|----------------|-------|-------|
| Coke           | USD/T-BB | 298.78 |
| CTP            | USD/T-BB | 100.87 |
| Butt           | USD/T-BB | 120.13 |
| Oil            | USD/T-BB | 54    |
| Ceramic Ball   | USD/T-BB | 2.1   |
| Caustic Soda   | USD/T-BB | 0.42  |
| Labor          | USD/T-BB | 4.97  |
| **Total Cost** | **USD/T-BB** | **581.27** |

### 2. Strategy overview

The goal of any baking furnace optimization program is to minimize anode cost production. Baking optimization to reduce energy consumption by switching fuel oil into natural gas (Liquefied Natural Gas/LNG) [3]. LNG usage can reduce energy consumption, environmental impact, material uses, maintenance cost. Most of the LNG is produced domestically, it thus helps reduce energy import and save foreign currency. LNG can be applied directly to the anode baking furnace. LNG as fuel has the lowest specific emissions of all types of fossil. The investment cost needed to implement this fuel like modified equipment, build storage tank, vaporizer and piping.

LNG price formulation

\[
\text{LNG Price} = (\text{REP} \times \text{Slope}) + \alpha 
\]

Remark:
1. Slope, determined in accordance following government regulation.
2. REP (Realized Export Price) is price arithmetic from Realized Export Prices per barrels in USD, FOB Indonesia, from all field that classified as Indonesian Crude Oils that have been sold and exported from Indonesia, and published by Indonesia Government and reported by SKK Migas.
3. Alpha (α) is the cost for LNG transportation from source to Arun, filling station, LNG trucking, and regasification.

### 2.1. SWOT analysis

- **Strength (S)**
  - Inalum has experience at operating anode baking furnace.
  - Existing furnace and control temperature are compatible with natural gas.
  - LNG is domestically produced from natural gas.
  - Availability of budget.

- **Weakness (W)**
  - Inalum does not have experience at using LNG.
  - Higher safety standards.
  - Investment for a storage tank, modification of equipment and piping are necessary.
  - Anode baking furnace cannot stop more than 4 hours.
- **Opportunity (O)**
  - Natural gas with low carbon and sulfur content has proven as clean and save fuel as well as economic compared with Diesel oil.
  - Natural gas is plentiful in our country.
  - LNG supplied by pipeline, the port load can be reduced
  - Inalum vision to become aluminum company with environmentally friendly.

- **Threat (T)**
  - LNG prices influenced by the oil prices.
  - Continuity of LNG supplied
  - Awareness of the personnel should be improved.

| Item                      | Unit        | Oil       | LNG       | Remark                 |
|---------------------------|-------------|-----------|-----------|------------------------|
| Caloric value             | MMBtu/Liter | 0.036     | 0.024     |                        |
| Unit Price                | $/MMBtu     | 18        | 15        |                        |
| Energy Price              | $/TBA       | 54.00     | 38.60     |                        |
| Energy Required           | Kg/TBA      | 59.6      | 49        |                        |
| Supply                    | -           | Unstable  | Stable    |                        |
| Environmental             | -           | Bad       | Good      | Low Sulfur             |
| Commodity                 | -           | Import    | Domestic  |                        |
| Infrastructure            | -           | Existing  | Modification |                        |
| Investment                | -           | No        | Yes       |                        |
| Burner                    | -           | Burner oil| Burner gas|                        |
| Maintenance               | -           | Moderate  | Less      | No soot                |
| Chemical Structure        | -           | C₈ to C₂₅ | CH₄ and C₂H₆|                        |
| Operational control       | -           | Controllable | Controllable |                        |
| Flash Point               | °C          | 165       | -167.7    |                        |
| Auto Ignition temp        | °C          | 315.5     | 540       |                        |
| Low Heat Value (LHV)      | MMBtu/Kg    | 0.040     | 0.0468    |                        |
| High Heat Value (HHV)     | MMBtu/Kg    | 0.0439    | 0.0523    |                        |
| Physical State            | -           | Liquid    | Cryogenic Liquid |            |

LNG can be delivered to PT Inalum from the gas station in Belawan with:
1. Tanker ship.
2. Trucking.
3. Pipeline.

Trucking is more possible to do because of economic reasons while waiting for pipeline construction. Using trucking as a delivery unit must be calculated with the required energy in anode baking furnace. Scheduled of trucking used for the arrangement to daily needs. PT Inalum has the experience to arrange it when transferring fuel oil to Baking plant in the past. Daily energy in the Baking plant can be seen in table 4.
**Tabel 4.** The facility required in baking plant.

| Item                        | Unit       | Oil   | LNG   |
|-----------------------------|------------|-------|-------|
| Consumption                 | MMBtu/day  | 1.173 | 1.173 |
| Truck Transport             | MMBtu/Unit | 650   | 400   |
| Truck Required per day      | Unit       | ~ 2   | ~ 3   |
| Day Work                    | Day        | 22    | 22    |
| Truck Required per Month    | Unit       | 60    | 90    |
| Storage tank                | m³         | 200   | 300   |
| Vaporizer                   | Nm³/Hour   | -     | 2000  |
| Piping                      | M          | 400   | 400   |
| Burner ramp                 | Unit       | Burner Oil | Burner gas |

3. **Application and impact analysis**

3.1. **Application**

The monthly average of solar oil consumption is 980,768 liters. It means average energy consumption is 35,210 MMBtu per month. Truck iso tank capacity is 400 MMBtu/truck. Truck LNG has to be transferred to Baking plant every Monday until Friday. The baking plant needs 3 units of trucks each day. Supply chain LNG to anode baking furnace can be seen on the diagram:

![Figure 1. LNG supply chain to baking plant.](image)

3.1.1. **Modification of burner ramp**

Modification of burner ramp needed because existing nozzle, piping, and regulator are specified for fuel oil. Nozzle burner ramp has to be replaced from oil burner to low-pressure burner for natural gas, addition pressure reducing valve and replacement of oil pipe to gas pipe on the burner is also needed.

3.1.2. **Replacement of piping distribution**

Piping distribution from the storage tank into building for fuel oil is different from gas. It needs to be replaced for safety reasons and to avoid leakage.

3.1.3. **Building storage tank and vaporizer**

Storage tank and vaporizer are needed to be built to ensure stability and continuity of operation. Storage tank with capacity 200 m³ and supported by a vaporizer to change from liquid to gas and distribute to furnace as fuel.
3.2. Impact analysis

3.2.1. Cost production
LNG has a cheaper price than fuel oil. Using LNG as fuel can reduce anode production cost. It means anode sales price has more competitive with the other company producing baked anode. Application LNG as new source energy will reduce anode production cost by 15 USD/ton baked anode.

3.2.2. Emission Reduction
Natural gas is the cleanest of the fossil fuels. One of the main drivers for converting oil to gas operation is to reduce emissions, to save on fees and comply with more stringent environmental regulations. The combustion of natural gas releases virtually no sulfur dioxide and ash or particulate matter, and very small amounts of nitrogen oxides. Natural gas emits 28% less carbon dioxide than oil. NOx is reduced by more than 75% and SOx by more than 95% [4].

![FUEL COMPOSITION COMPARISON](image)

*Figure 2. Chemical structure comparison oil and natural gas [5].*

3.2.3. Reduce material consumption
The use of LNG will reduce NOx more than 75% and SOx more than a 95% influence of gas emission and affect the degree of acidity of the water. Water pH closed to neutral so the consumption of NaOH will decrease. With fuel oil, water pH is 3 but with LNG reach 6. Consumption NaOH can be reduced by more than 50 %.

3.2.4. Reduce maintenance cost
The acidity of wastewater influence the durability of equipment, because of acidic water is characteristically corrosive. Water pH using LNG closed to neutral cause corrosivity of equipment will be decreased. It means maintenance cost to repair or to replace equipment such as gas cooler, transfer bend, and brick furnace will decrease too. To obtain good anode quality LNG can be used directly as good as fuel oil so that control of operation parameters such as increased temperature, vacuum pressure, and soaking temperature can be applied with the existing system.

3.2.5. Safety operation
Awareness all personnel should be increased because LNG has different characteristics with LPG. LNG is lighter than air. When leaked, it will dissipate more quickly than LPG, because LPG is heavier than air. Besides it will also pool on the ground. LNG facilities should be designed, constructed, and operated
according to international standards for the prevention and controlling of fire and hazardous explosion, including provisions for safe distances between tanks in the facility and between the facility and adjacent buildings. Implementing safety procedures for loading and unloading LNG to transport systems (e.g. rail and tanker trucks, and vessels), including the use of fail-safe control valves and emergency shutdown and detection equipment [5].

3.2.6. Other issues
Natural gas is plentiful. With the steadily increasing demand for gas, availability and infrastructure are rapidly growing all over the world. Through liquefaction, gas can be transported by ship, truck or pipeline all over the world to meet demand wherever it arises [4].

**Table 5.** Comparison of price, emission, and operational.

| Item        | Unit         | Oil   | LNG   | Different   |
|-------------|--------------|-------|-------|-------------|
| Unit Price  | USD/MMBtu    | 18    | 15    | USD 3 (16%) |
| Energy Cost | USD/MMBtu    | 54.00 | 44.56 | 9.45 (16%)  |
| CO₂         | Kg/MMBtu     | 74.292| 53.001| 28 %        |
| CO          | Kg/MMBtu     | 14.9  | 18.1  | -21 %       |
| NOx         | Kg/MMBtu     | 202.9 | 41.7  | 79 %        |
| SOx         | Kg/MMBtu     | 508.3 | 0.5   | 99.9 %      |
| Particulate | Kg/MMBtu     | 38.1  | 3.2   | 91 %        |
| Maintenance | -            | Moderate | Less          |
| Operational control | - | Controllable | Controllable |
| Commodity   | -            | Import | Domestic  |

4. Cost and benefit analysis
Cost-Benefit analysis for baked anode can be seen in table 6:

Investment = modify of equipment + storage tank + vaporizer
= 124,000 + 600,000 + 400,000
= 1,124,000

Maintenance cost = 5% x investment
= 5% x 1,124,000
= 56,200

Total profit = total merit per year – maintenance cost
= (1,267,545 +34,000) – 56,200
= 1,245,345

Return of Investment (ROI) = total profit : total investment x 100%
= 1,245,345 : 1,124,000 x 100%
= 112.7 %

Pay Back Period (PBP) = total investment : total profit
= 1,040,000 : 738,743
= 0.90 year
### Tabel 6. Cost-benefit analysis using LNG for fuel.

| Item                          | Unit  | Oil   | LNG   | Merit        |
|-------------------------------|-------|-------|-------|--------------|
| Investment:                  |       |       |       |              |
| Modify of Equipment           | USD   | 124,000 |     |              |
| Storage Tank LNG              | USD   | 600,000 |     |              |
| Vaporizer                     | USD   | 400,000 |     |              |
| Maintenance 5 %               | USD/y | 56,200 |       |              |
| Energy Requirement            | MMBtu/y | 422.515 | 422.515 | 1,267,545    |
| Price Value                   | USD   | 18/MMBtu | 15/MMBtu | 1,267,545    |
| Emissions of CO₂              | T/y   | 191   | 136   | Reduce 28%   |
| Emissions of SO₂              | T/y   | 1.306 | 0.001 | Reduce 99%   |
| Emissions of NOₓ              | T/y   | 0.521 | 0.107 | Reduce 79%   |
| NaOH Consumption              | T/y   | 306   | 152   | 34,000       |
| Total Profit                  | USD/y |       | 1,245,345 |              |
| ROI                           | %     |       | 112.7 |              |
| Pay Back Period               | Year  |       | 0.90  |              |

### Tabel 7. Comparison of anode baking cost using oil and LNG.

| Item               | Unit     | Price Used fuel oil | Price Used LNG | Different |
|--------------------|----------|---------------------|----------------|-----------|
| Coke               | USD/T-BB | 298.78              | 298.78         | -         |
| CTP                | USD/T-BB | 100.87              | 100.87         | -         |
| Butt               | USD/T-BB | 120.13              | 120.13         | -         |
| Solar              | USD/T-BB | 54.00               | 44.56          | 9.45      |
| Ceramic Ball       | USD/T-BB | 2.10                | 2.10           |           |
| Caustic Soda       | USD/T-BB | 0.42                | 0.21           | 0.21      |
| Labor              | USD/T-BB | 4.97                | 4.97           |           |
| Total Cost         | USD/T-BB | 581.27              | 572.37         | 9.66      |

A list of anode baking furnace that uses oil and gas as fuel in the world can be seen on the reference from R&D Carbon in Table 8.
Table 8. Anode baking furnace oil and gas based reference around the world.

| Year       | Client                           | Furnace | Fire | Fuel |
|------------|----------------------------------|---------|------|------|
| 1982-1985  | ALUCHEMIE Rotterdam, Holland     | 6       | 12   | Gas  |
| 1989       | COMALCO Beli Bay, S.A Australia  | 1       | 3    | Oil  |
| 1992       | LAURALCO, Canada                 | 2       | 4    | Gas  |
| 1993       | ALUCENTRO, Italy                | 1       | 2    | Gas  |
| 1996       | ALBA, Bahrain                    | 1       | 3    | Gas  |
| 1996       | DUBAL Alumunium, U.A.E          | 1       | 2    | Gas  |
| 1998       | DUBAL Alumunium, U.A.E          | 1       | 2    | Gas  |
| 1999       | ALUSA, South Africa              | 1       | 2    | Gas  |
| 2000       | ALMA (Alcan)                     | 2       | 6    | Gas  |
| 2001       | XIN’AN Carbon Plant, Louyang, China | 1   | 3    | Oil  |
| 2001       | QINGHAI Alumunium Co., Xining, China | 1 | 1    | Gas  |
| 2002       | DUBAL Alumunium, U.A.E          | 1       | 2    | Gas  |
| 2004       | XIN’AN Carbon Plant, Louyang, China  | 1  | 3    | Gas  |
| 2002       | LANZHOU LIANCHENG, China        | 1       | 2    | Gas  |
| 2002       | ALUCHEMIE Rotterdam, Holland     | 1       | 2    | Gas  |
| 2003       | SICHUAN Aostar, Chengdu, China   | 1       | 2    | Gas  |
| 2003       | NANSAN Alumunium, Longkou, China | 1   | 2    | Oil  |
| 2004       | LANZHOU LIANCHENG, China        | 1       | 2    | Gas  |
| 2004       | ALUCHEMIE Rotterdam, Holland     | 1       | 2    | Gas  |
| 2005       | HINDALCO, India                 | 1       | 2    | Oil  |
| 2006/2008  | HORMOZAL, Iran                  | 1       | 2    | Gas  |
| 2009/2010  | EMAL, Abu Dhabi, U.A.E          | 2       | 8    | Gas  |
| 2009/2010  | KAS Alumunium, Kazakhstan       | 1       | 3    | Oil  |
| 2011       | TRIMET, Hamburg                  | 1       | 3    | Gas  |

5. Conclusions

1. Application of LNG as new source energy will reduce the cost of anode production by 9.66 USD/ton baked anode.
2. LNG will reduce SOx by more than 95%, it can save NaOH 50% (34,000 USD/year) and create more durable of equipment life.
3. The application of LNG is necessary for alternative energy and cleaner emission (CO2 emission reduced 54.7 Ton/year).
4. Anode sale has a more competitive price.
5. Total profit at this improvement is USD 1,245,345/year

6. Reference

[1] S. S. Sijabat, Firman Ashad, Ivan Ermisyam, Ade Buandra, Daniel Jimmy P. Hutauruk and Ivan EkoYudho 2019 The Optimization of Soaking Time to Reduce Fuel Consumption While Keeping Good Baked Anode Quality Light Metals 1275-1280.
[2] Mahieu, Pierre, and Patrice Sedmak 2014 Improving fuel gas injection in anode baking furnace Light Metals 1165-1169.
[3] Keller, Felix, Peter O. Sulger, Dr. Markus W. Meier, Dagoberto S. Severo, and Vanderlei
Gusberti 2013 Specific Energy Consumption in Anode Bake Furnaces *Essential Readings in Light Metals* 408-413.

[4] Wartsila Corp 2013 Fuel efficiency in gas conversions More flexibility, less emissions and lower fuel costs.

[5] World Bank 2007 Environmental, Health, and Safety Guidelines for Liquefied Natural Gas (LNG) Facilities.