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Economic and Environmental Feasibility of Coal to Liquids and Coal to Gas from Thar Coal in Pakistan

[Document subtitle]

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Introduction

Exploratory initiatives for the liquefaction and gasification of coal have been taken up by numerous countries in a bid to achieve energy security. Pakistan is one of the latest countries to jump on the bandwagon of coal to liquid/ gas conversion processes as the country's prime minister signaled towards this move in his address to the world during the United Nation's climate ambition summit last year[1].

The move isn't surprising, since the technology has been known to the world since World War II[2], Pakistan has an abundance of coal reserves and an equally humongous oil import bill, a huge portion of which is dedicated towards the power sector and transportation sector that it would like to get rid of. Yet the cost implications and the environmental burden of producing energy this way seems to be lost on the decision-making bodies in the country. This research aims to shed light on the economic implications of such a move on the prices of fertilizer, transportation fuel and electricity in Pakistan along with the scale of environmental pollution that would certainly come along with such a move.

Global situation for CTL/ CTG plants

For a long time, South Africa was the only country to operate an oil from coal plant in the world. South African coal, oil and gas corporation SASOL, set up this plant (SASOL-I) in Sasolburg in 1955 with a capacity of turning 4.5 million metric tons of coal into 160 million gallons of gasoline plus various co-products annually. Building on the success of SASOL I, SASOL II and III were eventually established at Secunda to achieve a combined output of 150,000 barrels per day. The move was made to reduce South Africa's reliance on imported oil amidst an atmosphere of rising crude oil prices. Sasol's coal to oil conversion proved to be a big deal in reducing the country's dependence on foreign fuels as by 1988, SASOL was already supplying around 30% of South Africa's oil demand[3]. By 2004 SASOL had entered the fuel retail market of South Africa as well[4].

Following South Africa's story of success many countries including the United States and Indonesia have ventured into producing liquid fuel from coal but seldom were able to achieve commercial success. One of the reasons for this could be the fact that SASOL's success has always been propped by massive subsidies which other countries have been unable to match[5]. China remains the single exception to this case and to date remains the only country actively investing in this domain. China's first commercial Coal to Liquids (CTL) plant was initiated by the Shenhua Group Corporation in Inner Mongolia in 2003. The plant has been operational since 2009 with a capacity of producing 22,000bbl per day of liquid fuel and an upfront cost amounting to $3.2 bn[6]. By 2014, China was reported to have at least seven Coal to Liquids power plants, seven synthetic natural gas power plants and three coal to gasoline/hydrogen power plants in operation or planning. In addition various other power plants were being used for coal's conversion to other chemicals such as Ammonia, methane, urea, acetic acid, methanol and butanol[7]. Although President Xi recently suggested that China's coal consumption would peak by 2025 at the Biden Earth

Summit[8], the country's significant history of coal liquefaction and gasification still has a long way to go. In 2014 the country's National Energy Administration laid out plans to produce 50 billion cubic meters of synthetic natural gas from coal by 2020, accounting for almost 10% of China's domestic gas demand[9]. In 2016 this goal was revised to 1.64 Bcf/d of coal-to-gas production capacity by 2020. However, the pace of synthetic natural gas (SNG) production couldn't keep up with these plans and SNG only accounted for 2% of China's natural gas production in 2018[10]. This was mostly owing to stricter environmental regulations and the subsequent increase in the cost of developing coal to gas facilities. At present there are 4 major operational SNG power plants in China, while five more have been planned under the country's 13th five year plan[11].

Pakistan's plans for CTL/CTG processes

Pakistan first began exploring the idea of utilizing Thar coal for conversion to gas with Dr. Samar Mubarik Mand's underground coal gasification (UCG) project in Thar Coal Block V. The Government of Sindh allotted Thar Coal block V to the project in 2009, but despite years of research and an injection of Rs. 4.9 billion, the project could not deliver on the thousands of megawatt of cheap electricity through UCG it had initially promised. [12][13] A forensic probe was officially launched into the project in 2018, to assess why the project had failed on both technical and financial grounds[14].

Pakistan's mantra for indigenization of energy resources has now shifted and a new idea in the form of coal gasification and liquefaction (Surface) has emerged since then. Ever since open-pit mining activities have commercially commenced in the Thar region and the mined coal is being fed into power plants situated within Thar Coal blocks for power generation, the government has been exploring ideas of converting Thar coal to gas and diesel as an alternate fuel source to imported fuels which have been burdening the country's economy[15]. The government has already reached out to China Ghazuba and China Coal in this regard, while four leading fertilizer and power generation companies; HUBCO, Engro, Fauji Fertilizer and Fatima Group have been assigned with the task to initiate a (Surface) coal liquefaction and gasification project for the production of petroleum products in Pakistan[16]. Previously three of these companies Engro Fertilizer, Fauji Fertilizer and Fatima Fertilizer had been instructed by the government to carry out a feasibility study for the production of fertilizer using synthetic natural gas produced from Thar coal as a fuel and feedstock[15]. It thus seems that Pakistan wants to explore the option of Coal to Liquid and Coal to Gas technology mainly for fertilizer production. Oracle Power PLC intends to install a "Coal Gasification (Urea/Fertilizer) and Coal-to-Liquids" plant in Thar Coal Block-VI[17]. The company boasts of its partner China National Coal Development Corporation ('CNCDC') being an expert in the 'clean coal' arena and recently submitted a policy proposal to the Ministry of Energy, Petroleum division for coal to gas and coal to liquid development in Pakistan. The policy proposal outlines a draft commercial framework through which coal to gas/ coal to liquid development in Thar Coal Block VI could be fast tracked[18]. Based on the proposal, the petroleum division has worked out a policy draft for converting Thar coal into liquids and gas, with very attractive incentives including tax breaks and a simplified licensing process[19].

In addition to fertilizer production, there could also be a possibility of power generation from gas and diesel produced from CTG/CTL facilities as alluded to by the PM's recent announcement at the Climate Ambition Summit.

"As far as our indigenous coal goes, we have decided to produce energy either by coal to liquid or coal to gas so that we do not have to burn coal to produce energy".

Premier Imran Khan at the Climate Ambition Summit, December 2020

Economic Feasibility of Coal to Liquids (CTL) and Coal to Gas (CTG) facilities in Pakistan

High Cost of Production

As indicated above, Pakistan's plan for Coal to Liquid/ Gas could have economic implications for three main sectors in the country; 1) Fertilizer sector 2) Transportation Sector and 3) Power Sector, as their dependence on imported fuels such as diesel and liquified natural gas is the greatest. A review of recent literature available on the system and performance costs of CTL liquids puts the cost of producing a barrel of liquid fuel from coal liquefaction between $70-100[20][21][22]. Factors affecting this range are capital cost of the CTL facilities themselves, O&M costs and the cost of coal. The capital cost of facility is the largest expense, followed by operation and maintenance costs and the cost of coal. Coal costs can contribute to as much as 10-20% of the total cost of production depending upon the type and quality of coal, usually the higher the coal's quality, the higher will be the production costs[23].

Depending upon the size of the facility, capital costs for CTL/CTG facilities can also vary:

Table 1 Estimated costs of CTL industries in the US in 2010. The costs for emission reduction or government funding or grants are not included in these estimates. Source[23]

	One 20 000 b/d plant	One 80 000 b/d plant	One Mb/d Industry
Capital investment	$1.5-$4 billions	$6-$24 billions	$60-$160 billions

For Coal to Gas facilities, analysis of Chinese facilities producing synthetic natural gas (SNG) in three major regions of China i.e. Xinjiang, Inner Mongolia and Liaoning reveals an average cost of production for SNG to be 2.2 CNY/Nm^3 or a break even oil equivalent price of $62/bbl [24].

It is worth noticing here that setting up a CTL/CTG plant would require an investment of billions of dollars at least. The Shenhua Coal to Liquids facility in Inner Mongolia with a production capacity of 4 million tonnes of oil products annually was set up in 2003 at a cost of $3.2 billion[6]. The Kemper County Clean Coal plant took $7.5 billion to complete, was $4 billion over budget, and wasn't even successful in converting coal to synthetic natural gas that would then be used to produce electricity, as purported by the initial plans for the power plant[25]. Not much has changed in terms of technology to indicate that the cost of setting up these plants would go down in Pakistan. As with the case of coal development through the China Pakistan Economic Corridor, Pakistan is seeking Chinese support to mobilize the massive amount of funds required for coal to liquids/gas development. Chinese debt does not come cheaply and requires high rates of return to make the investment attractive to Chinese developers, so the costs of setting up CTL/CTG plants through Chinese finance would be higher that what is observed in the rest of the world. These inflated costs would in turn affect the cost of production of fuel and ultimately be passed down to consumers in the form of higher commodity prices.

Impact on fertilizer prices in Pakistan

According to a news source around 85% or more of the cost of production for fertilizer is owing to the cost of natural gas which is used a feedstock for the production process[26]. Fertilizer plants in Pakistan receive gas at varying prices, some receive extremely low-priced gas from Mari Gas, some receive locally produced gas from Sui Northern Gas Pipeline Limited (SNGPL) while others receive imported liquified Natural Gas (LNG), the price of which varies according to prevailing LNG prices in international markets[26]. Most of the supply to these fertilizer power plants is highly subsidized with rates falling even lower than $1 per mmbtu. Under the fertilizer policy 2001, two of the biggest fertilizer plants in the country; Fatima fertilizer and Engro fertilizer have been receiving feed gas at a discounted tariff of $0.70 per mmbtu since 2001[27]. Another major player in the Industry Fauji fertilizer bin Qasim (FFBQ) had its gas tariff extended for another five years at Rs302 per mmbtu (million British thermal unit) for feedstock and Rs1,023 per mmbtu for power generation, steam and housing colonies, which translates to around USD 1.97 per mmbtu and USD 6.67 per mmbtu respectively[28]. In comparison, the average cost of production for Chinese coal to SNG plants calculated as 2.2 CNY/Nm^3 equates to USD 9.2 per mmbtu, and this is when the price of coal in China has been ranging from USD 21 to USD 27 per ton[24]. The cost of Thar coal being mined in Thar coal block II is costing the Engro Power Generation Thar Ltd. USD 69.7 per ton[1]. This means that the cost of producing SNG from Thar Coal could very likely be much higher than USD 9.2 per mmbtu, exceeding the cost of even imported LNG which usually ranges between USD 9-10/ mmbtu[29].

Impact on transportation fuel prices in Pakistan

As of June 2019, Pakistan's recoverable oil reserves stood only at 568 million barrels. Due to such limited availability, Pakistan has to import most of its oil in order to meet its oil demand[30]. A development plan prepared for the Oil and Gas Industry prepared by the Ministry of energy in 2020 reports that local oil accounts for only 16% of the oil consumption in Pakistan and the rest has to be imported. The same holds true of petroleum products as well and the local refinery sector

[1] Figures taken from fuel adjustment tariffs for Engro Power Generation Thar Ltd. for March, 2021 (https://nepra.org.pk/tariff/Tariff/IPPs/003%20Coal/Engro%20Powergen%20Thar/2021/TRF-301%20EPTPL%20FPA%20Feb%202021%2010-03-2021%2013764-68.pdf)

caters to only 50% of the local petroleum products demand. Pakistan's total import volume for oil reached 17.97 Million Metric Tonnes (MMT) in 2019, including 9.2 MMT of imported crude oil and 8.76 MMT as refined oil products. Imported refined oil products mainly comprise of automobile gasoline, high speed diesel and high sulfur fuel oil, which is what the government aims to replace with liquid fuel produced from CTL technology.[31]

Table 2 Cost of Imported Petroleum $/ barrel (bbl)- June 2018-2019 Products in Pakistan (Source: Pakistan Energy Yearbook)[31]

Products	Import	2014	2015	2016	2017	2018
100/LL	Quantity/t	130,000	47,000	110,271	119,278	236,538
	Value/MM$	131	044	053	058	147
	Price $/b	135.25	125.19	64.05	65.05	83.65
HOBC	Quantity/t				135,794	86,441
	Value/MM$				0.78	0.60
	Price $/b				76.87	92.94
HSD	Quantity/t	2,568,000	3,277,000	3,064,764	3,796,040	3,845,272
	Value/MM$	2343	2107	1128	1749	2127
	Price $/b	122.40	86.26	49.39	61.82	74.24
HSFO	Quantity/t	6,529,000	6,701,000	5,219,995	5,869,157	3,791,786
	Value/MM$	4135	3060	1145	1731	1401
	Price $/b	84.96	61.26	29.43	39.56	49.61
LSFO	Quantity/t			903,147	663,889	455,588
	Value/MM$			235	29	183
	Price $/b			34.84	46.32	53.93
Motor Spirit	Quantity/t	2,296,000	3,322,000	4,251,563	4,561,112	4,928,112
	Value/MM$	2292	2202	2098	2339	366
	Price $/b	133.92	88.93	66.20	68.80	83.52
Total	Quantity/t	**11,523,000**	**13,347,000**	**13,549,740**	**15,145,270**	**13,343,737**
	Value/MM$	**8901**	**7413**	**4659**	**6184**	**6985**
	Price $/b	**103.63**	**74.51**	**46.13**	**54.78**	**70.26**

Note: 100/LL : Aviation Fuel, HOBC: High-Octane Blending Component, HSD: High Speed Diesel, HSFO: High Sulphur Furnace Oil, LSFO: Low Sulphur Furnace Oil, Motor Spirit: Petrol (Gasoline)

As indicated by the table above, the cost of importing HOBC in 2018 was $92.94 per barrel, High Speed Diesel was $74.24/bbl and motor spirit or gasoline was $83.52/bbl. Cost of production of CTL products has been estimated around $70-100/bbl from our literature review. This provides an average production cost of $85/bbl. The costs of importing HSD and gasoline are lower than $85/bbl, while that of HOBC is higher, meaning that CTL could potentially be cost-competitive with transportation fuels, however it would all depend on the cost of coal and achieving economies of scale for such operations. The average cost of production from CTL($85/bbl) has been calculated when the cost of coal ranged from USD50-60 per ton[21]. In Pakistan the cost of Thar coal is nearing almost $70/ton, this could potentially lead to a higher cost of production in Pakistan, rendering these fuels uneconomic for the transportation sector too.

Having enough coal to liquid conversion capacity would certainly be a factor as well. Pakistan may only be able to replace a very small amount of transportation fuels from the CTL options being explored at the moment. SASOL with its years of operations and multiple coal liquefaction facilities with a capacity of around 160,000 barrels per day, is only able to meet 30% of the country's fuel demands, not to mention the fact that SASOL's synfuel operations are propped up by massive subsidies from the government[2], resulting in higher fuel prices for consumers[32].

Impact on electricity prices in Pakistan

Thermal based power generation in Pakistan relies mainly on three types of fuel, Residual Fuel Oil (RFO), Natural Gas/ RLNG or High Speed Diesel (HSD). SASOL has proven that both Residual Fuel Oil and Diesel can be produced from CTL operations[33]. Synthetic Natural Gas can also be used to produce electricity, however life-cycle emissions for these options could be significantly higher than just producing electricity from coal (to be addressed later). This section looks at the economic impact of electricity production from synfuels in Pakistan.

For RFO and HSD, a sensitivity analyses was carried out for fuel costs (Rs./ KWh) that would result from a high, low and average cost of production from CTL operations. Current fuel costs for power plants operating on HSD in Pakistan amount to Rs. 20/KWh [3]on average, while for RFO they average around Rs. 12/ KWh.

To calculate the impact of producing fuel from CTL operations, a high, average and low cost of production scenario was examined using $70-100 per barrel as our range for the production costs. The results obtained have been listed down in Table 3(For calculations see Appendix-A.) Producing RFO through CTL processes and using it for power generation could translate to fuel costs between 17.9-25.5 PKR/KWh, while for High Speed Diesel this figure could be anywhere between 15.8-22.5 PKR/KWh.

[2] IISD experts estimate that coal-based fuels produced by Sasol's Secunda Plant received in excess of ZAR 8 billion in total government support during 2019. (Source: https://www.iisd.org/articles/south-africans-are-paying-pollution-pump)

[3] Average calculated from fuel costs obtained through NEPRA Fuel Adjustment Tariffs for Engro energy Pvt. Ltd. Halmore Power and Orient Power. More details provided in Appendix-A

Table 3 Fuel Costs that could result from CTL operations for RFO and HSD in Rs./KWh based on production estimates from Chinese CTL power plants

	High	**Average**	**Low**
Cost of Fuel production from CTL (USD/barrel)	100	85	70
	Fuel costs/KWH (PKR/KWH)		
RFO	25.5	21.7	17.9
HSD	22.5	19.2	15.8

For natural gas, cost of production of synthetic natural gas was assumed to be 2.2 CNY/NM[24] (based on estimates calculated for 3 Chinese SNG power plants), which equates to a fuel cost of Rs. 10.4/ KWH (See Appendix-A for more details on the methodology). In comparison average fuel costs for power plants operating on imported re-liquified Natural Gas, which coal to gas power plants ideally seek to replace exist at Rs. 8.3/KWh on average[4].Meanwhile renewable energy such as solar and wind is becoming increasingly competitive in Pakistani markets, with the National Electric Power Regulatory Authority(NEPRA) having recently awarded tariffs as low as 3.2 cents per KWh for wind and solar power projects in the country[34].

The calculated fuel costs were then used to estimate the effect this would have on electricity tariffs in Pakistan encapsulated by Fig 1 to Fig 3 (For methodology see appendix-A).

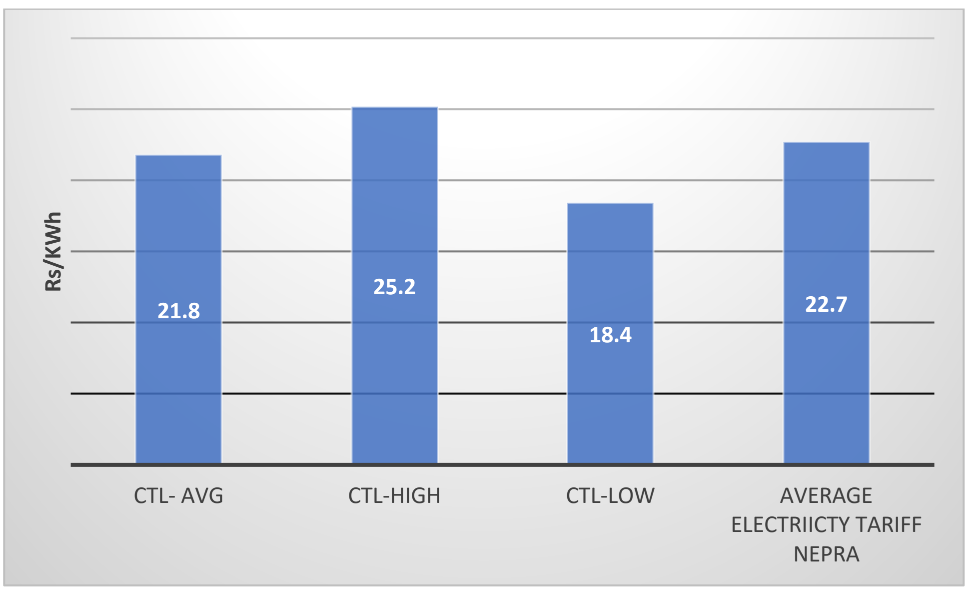

Figure 1:Effect on average electricity tariffs for diesel based generation, due to fuel produced from Coal to Liquid operations

[4] Average calculated from fuel costs obtained through NEPRA Fuel Adjustment Tariffs for Engro energy Pvt. Ltd. Halmore Power and Orient Power. More details provided in Appendix-A

The figure above demonstrates that tariffs for electricity generation on diesel produced from CTL operations could go as high as Rs. 25.2/ KWH, however if production costs from CTL can be brought down to $70/ barrel, electricity produced this way could actually be competitive with electricity produced from diesel imports in Pakistan. But, this is all contingent upon prevailing coal prices in the country.

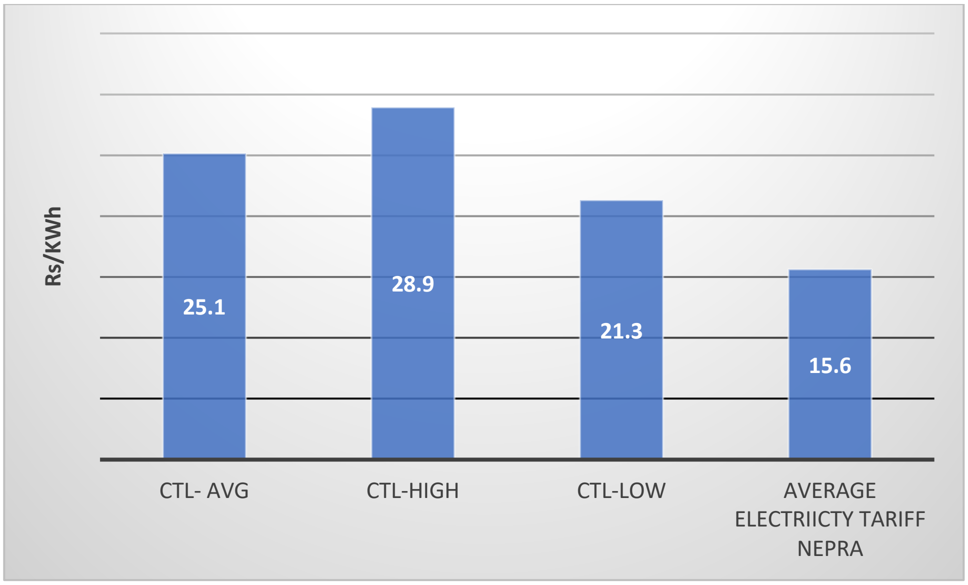

Figure 2 Effect on average electricity tariffs for generation from fuel oil produced via CTL

Average electricity tariffs for RFO based power generation exist at around Rs. 15/KWh on average. If residual fuel produced from CTL operations is used for power generation, this could lead to much higher tariffs falling within the range of Rs. 21- Rs. 29/KWh.

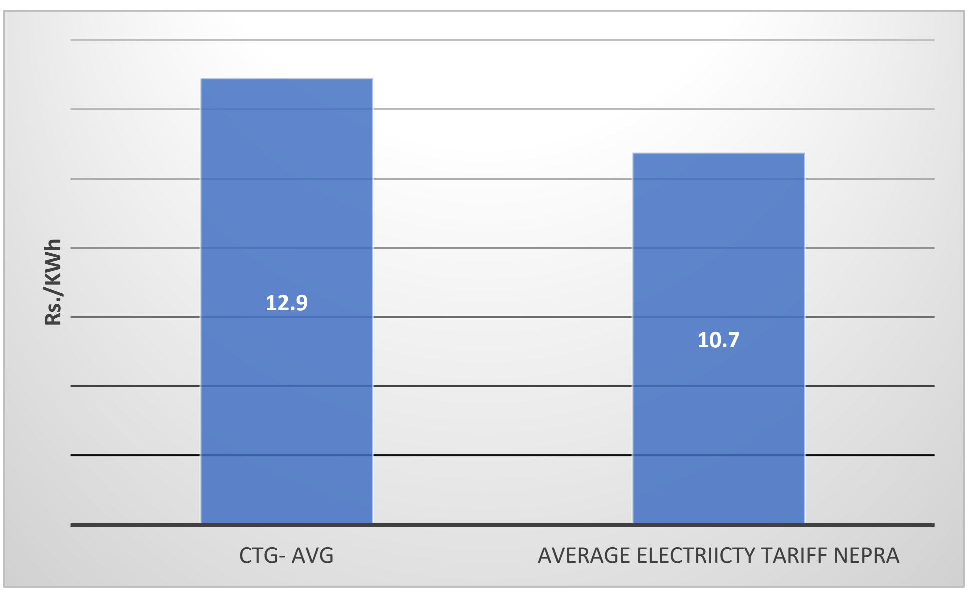

Figure 3 Effect on electricity tariffs for synthetic natural gas based generation produced from Coal to Gas operations

Producing electricity from synthetic natural gas could raise the average electricity tariff in the country by almost Rs. 2.20 as demonstrated by Figure 3 above. This is however, when the cost of production of SNG has been assumed at 2.2. CNY/Nm^3, which is only possible where coal costs in China range between USD 21 to USD 27 per ton. The effect on electricity tariffs will be much higher if the current cost of Thar coal, which nears USD 70/ ton is used in the production process.

Life Cycle Environmental Impacts from CTL/CTG

In addition to the economic costs associated with a move towards Coal gasification and liquefaction, the environmental costs of such a move could be an eye-opener for decision makers too. Research indicates that for every ton of liquid fuel (a combination of gasoline and diesel) produced from coal liquefaction, about 5 tons of coal will be consumed[22]. Thus, any large-scale development of coal to liquid fuels will lead to an increase in mining activities in the country, creating hazardous chemical waste and ground water contamination. Coal liquefaction also consumes 3 times more water than a conventional oil refinery, while producing 13 times as much wastewater[22]. The same holds true of CO2 emissions which can be twice as high when using coal derived fuel in comparison to conventional gasoline for transportation. This is due to the fact that, when coal to liquid fuel is used for transportation or electricity generation, two streams of pollution are generated, one for the coal to liquid conversion process and the other as exhaust fumes from the burning of fuel in power plants or vehicles.

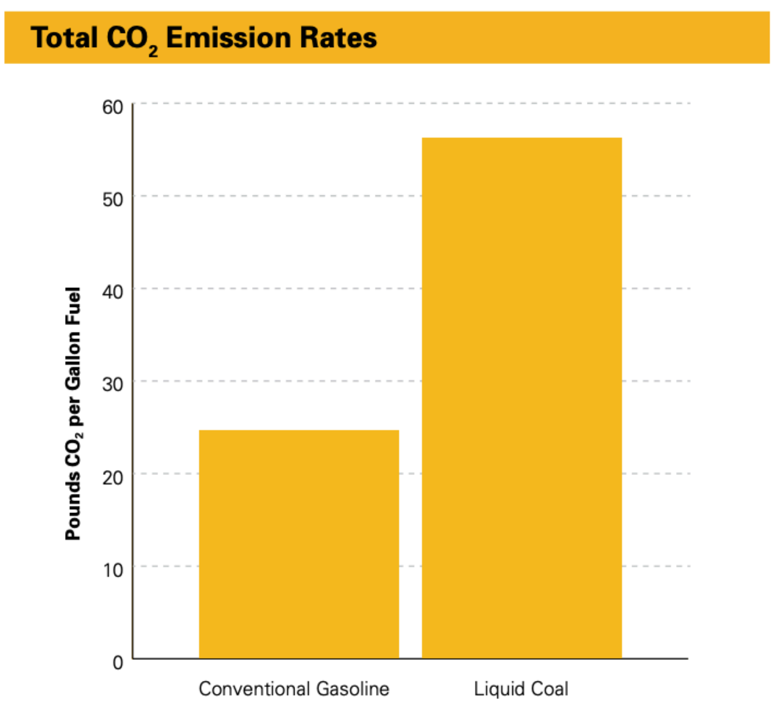

Figure 4 Comparison of life cycle emissions from CTL fuels vs conventional gasoline. Source: NRDC [35]

Synthetic natural gas is no different than CTL when it comes to the production process itself or electricity generation from SNG. SNG has a significantly higher carbon and environmental footprint than conventional natural gas. Life cycle GHG emissions for SNG are almost seven times higher, while electricity generation from SNG could lead to life-cycle GHG emissions which are 36-82% higher than pulverized coal fired power[36]. This is due to the fact that amount of electricity required for the conversion of coal to gas is remarkable. Vast quantities of electricity are consumed by the Air separation Unit which supplies oxygen during the coal conversion process.

Conclusion

The verdict is quite clear, switching to coal to liquids/ coal to gas options for fertilizer production, transportation fuels or electricity generation can not only be economically prohibitive, but also come with great environmental costs. The high amount of water consumption is particularly troubling. Thar where most of Pakistan's indigenous coal is located is a water scarce region already. Diverting water flows towards CTL/CTG power plants may not only endanger the availability of water for residents of the area, but may also result in diverting of agricultural water flows downstream of the region. Pakistan's need to diversify its energy mix and reduce reliance on imported fuels is understood, but unless the cost of locally producing coal from the Thar region becomes significantly lower, a move towards CTL/CTG could have serious economic implications for the country's economy and the regular consumer, as these costs will ultimately be passed on to them. In a world, where countries are increasingly aiming for carbon neutrality, Pakistan's dependence and lock in of coal-based energy production, will not only reverse the progress the nation has made in terms of environmental commitments, but also increase the country's GHG emissions significantly. So much so, that it may lose its status as a low-emitter in the global scheme of carbon emissions.

Appendix- A

Methodology for determining effect of CTL/CTG fuels on electricity tariffs in Pakistan

1. Fuel costs for CTG/CTL options in Rs./KWh were calculated by dividing average calorific values obtained for RFO and HSD in Pakistan by average heat rates for HSD/RFO power plants in Pakistan. This gave us the fuel consumption per KWh for these power plants in kg/ KWH, which was converted to barrels/KWH. This was then multiplied by the cost of production obtained from our literature review i.e. USD 70-100/barrel to arrive at the cost of fuel per unit of electricity in USD/KWh (later converted to PKR/KWh- Exchange rate :1 USD- 158.49 PKR)
2. For Synthetic Natural Gas, the value of 2.2 CNY/Nm^3 was converted to PKR/ Cft. Cost per BTU of energy from natural gas was calculated by multiplying by average calorific value of natural gas found in Pakistan (value taken from Pakistan Energy Yearbook- 2019), assuming that syngas produced from CTG would be of the same quality. The resulting value in PKR/ BTU was then multiplied by the average heat rate of natural gas power plants operating in Pakistan to arrive at a final fuel cost in PKR/ KWH.
3. To determine impacts on tariffs, these fuel charges were substituted into the NEPRA determined formula for tariff calculation. NEPRA approved tariffs contain a capacity charge, a variable O&M charge and a fuel charge. The table below calculates average values for different tariff components for NEPRA determined tariffs.

HSD					
Name of plant	Variable O&M	Capacity charge	Total tariff without fuel costs (Jan-March 21)	Current Fuel Costs (Jan-21)	Total Tariff
Engro Energy PVT. Ltd	0.5376	1.2935	1.8311	20.39	22.22
Halmore Power Gen	0.8796	3.205	4.0846	19.6	23.68
Orient Power	0.5845	1.5039	2.0884	20.192	22.28
Avg. NEPRA Tariff			2.67	20.06	22.73

Gas					
Name of plant	Variable O&M	Capacity charge	Total tariff without fuel costs	Current Fuel Costs	Total Tariff
Halmore Power Gen	0.6094	3.1667	3.7761	9.4229	13.20
Engro Energy Pvt. Ltd	0.5268	1.2673	1.7941	7.124	8.92
Orient Power	0.3565	1.4716	1.8281	8.2927	10.12

Avg. NEPRA Tariff			2.47	8.28	10.75

RFO					
Name of plant	Variable O&M	Capacity charge	Total tariff without fuel costs	Current Fuel Costs (Jan-21)	Total Tariff
Nishat Chunian	1.4482	1.3236	2.7718	11.9674	14.7392
Atlas Power	1.4482	1.4568	2.905	12.3983	15.3033
Narowal	1.3117	3.3468	4.6585	12.2017	16.8602
Avg. NEPRA Tariff			3.45	12.19	15.63

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