ELECTRIFICATION OF COOKING & HEATING DEMAND OF DOMESTIC GAS CONSUMERS: FINANCIAL AND ENVIRONMENTAL IMPACTS

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CERTIFICATE

This is to certify that this thesis entitled: **"Electrification of Cooking & Heating Demand of Domestic Gas Consumers: Financial and Environmental Impacts"** submitted by **Mr. Talha Khalid** is accepted in its present form by the School of Economics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree in Master of Philosophy in Economics.

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Author's Declaration

I, **TALHA KHALID,** hereby state that my MPhil thesis titled **"Electrification of Cooking & Heating Demand Of Domestic Gas consumers: Financial And Environmental Impacts"** is my own work and has not been submitted previously by me for taking any degree from Pakistan Institute of Development Economics or anywhere else in the country/world. At any time if my statement is found to be incorrect even after my Graduation the university has the right to withdraw my MPhil degree.

Date: 06-09-2024

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ABSTRACT

Energy Consumption in a given economy is directly correlated with the economic activity of the country. Pakistan's final energy consumption has witnessed 87.5% growth from FY-05 to FY-21. The progressive increased final energy consumption has transpired into greater reliance on imported energy fuels, which has increased from 30% in the total energy of FY-05 to 51% in the total energy supplies of FY-21. Resultantly, the enhanced reliance has posed detrimental impacts on the current account and fiscal balance of the country.

The local gas reserves of Pakistan are depleting at the rapid pace. The production of local gas has witnessed a decrease of -0.80% (CAGR) during the period of FY 2011-2021. At the same time, the demand has witnessed an increase of 2.40 % (CAGR) over the same period. This has resulted in the progressively higher share of RLNG in the gas mix, resulting in greater exposure to current account imbalance and rising circular debt on account of diversion of expensive RLNG to the domestic consumers at subsidized rates. At the same time, the electricity demand in winter falls by 60% of the respective peak demand in summer. This provides an intrinsic opportunity for the electrification of the existing and future's domestic cooking and heating demand for electricity-based appliances.

The study assesses the prospective of the electrification of cooking, space heating and water heating demand for different consumer categories of gas sector. The study has formulated four scenarios based on different gas slab of domestic consumers and assesses the net impact on the consumer's affordability, current accounts, fiscal subsidies and carbon emissions. The results indicate the positive externality of the proposed transition by means of reduction of the net emissions as well as reduced burden on the current and fiscal accounts. At the same time, the findings also demonstrate that the existing applicable tariffs of electricity and gas sector for domestic consumers are not feasible to give effect to the cost-neutral transitions for different slabs, however, the same may be effectuated by the series of interventions in both the gas and electricity sectors which have been mentioned in the respective sections.

Key Words: Grid parity, Generation Expansion, Current Account, Fiscal subsidies, Emissions

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LIST OF ABBREVIATIONS

BAU	Business-As-Usual
CAGR	Compound Annual Growth Rate
CPI	Consumer Price Index
DSM	Demand Side Management
EJ	Exajoules
ESMAP	Energy Sector Management Assistance Program
GHG	Greenhouse gas
GWP	Global Warming Potential
HIES	Household Integrated Economic Survey
IEA	International Energy Agency
IEP	Integrated Energy Plan
IGCEP	Indicative Generation Capacity Expansion Plan
IPCC	Inter Governmental Panel on Climate Change
LES	Local Energy System
MMSCF	Million Standard Cubic Feet
MTOE	Million Tonnes of Oil Equivalent
MW	Megawatt
NEP-21	National Electricity Policy 2021
NE Plan	National Electricity Plan 2023
NAP	National Adaption Plan
NEPRA	National Electric Power Regulatory Authority
OGRA	Oil and Gas Regulatory Authority
SNGPL	Sui Northern Gas Pipelines Limited
SSGCL	Sui Southern Gas Company Limited
WACOG	Weighted Average Cost of Gas
WEF	World Economic Forum
WPI	Wholesale Price Index

CHAPTER 1

INTRODUCTION

1.1 Background

Energy consumption is a significant driver that simulates economic activity in a country (Waleed et al., 2018). While energy consumption per unit of GDP varies across the economies, there is a significant increase in the global final energy consumption. Per International Energy Agency (IEA), the world's total final energy consumption has increased from 194 EJ in 1973 to 418 EJ in 2019, which is an increase of approximately 115% over the last 46 years.

In the last two and half years, the energy commodity prices have witnessed enhanced volatility which has impacted the fiscal and current accounts balance of the energy importing countries. The global geo-political shocks as well as post Covid-19 recovery remained the primary drivers for such volatility (Khalid, 2022). Per the estimates of the world bank, the 10% increase in the global oil prices increase the Consumer Price index (CPI) by 0.2-0.6% and Wholesale Price index (WPI) by 0.8% (World Bank 2022).

The excessive dependency on the fossil fuels coupled with the negative externality due to release of carbon emissions in the atmosphere has accelerated the natural process of global warming. The Paris Agreement, which was adopted by 196 parties at the United National Climate Change Conference (COP 21) in Paris, France on 12th December,2015, has the overall goal of holding the increase in global temperature to well below 2 degree Celsius above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5 degree Celsius above pre-industrial levels. This entails that the greenhouse gas emissions must peak before 2025 and should decline by approximately 43% by the year 2030. Subsequently, the CoP 28 which was held in UAE from November 30th to December 13th 2023, it was stressed that on all the governments to speed up the transition away from fossil fuels to renewables in the next round of climate commitments.

At present, the global economies are devising the energy transition pathways to achieve a secure, affordable and sustainable energy supplies which are aligned with the overall goals of the Paris Agreement. The energy transition pathway entails increasing share of renewables in the generation mix, promoting energy efficiency and conservation, electrification of final energy use sectors (electric vehicles, heat pumps, cooking etc.), promoting clean hydrogen & its derivatives and integration of bioenergy coupled with the carbon capture and storage (IRENA, 2022).The final energy consumption of Pakistan has also increased rapidly over the last few decades. Per the statistics from the Hydrocarbon Development institute (*Pakistan Energy Yearbook 2005 & 2021*), the final energy consumption of Pakistan has increased from 32.1 Million Tonnes of Oil Equivalent (MToE) in FY-05 to 60.2 MtoE in FY-21, an increase of 87.5 % over the period of 16 years only. At the same time, the increasing demand for the energy to fuel economic growth and growing population's energy needs has progressively enhanced Pakistan's reliance on imported energy sources. Pakistan derives energy primarily from oil, gas, coal, hydro, nuclear and renewables. A snapshot of the relevant share of the primary energy sources for FY-05 and FY-21 is provided below in Figure 1.1, which shows that the share of imported energy supplies has increased from 30 % to 51 % over the same period

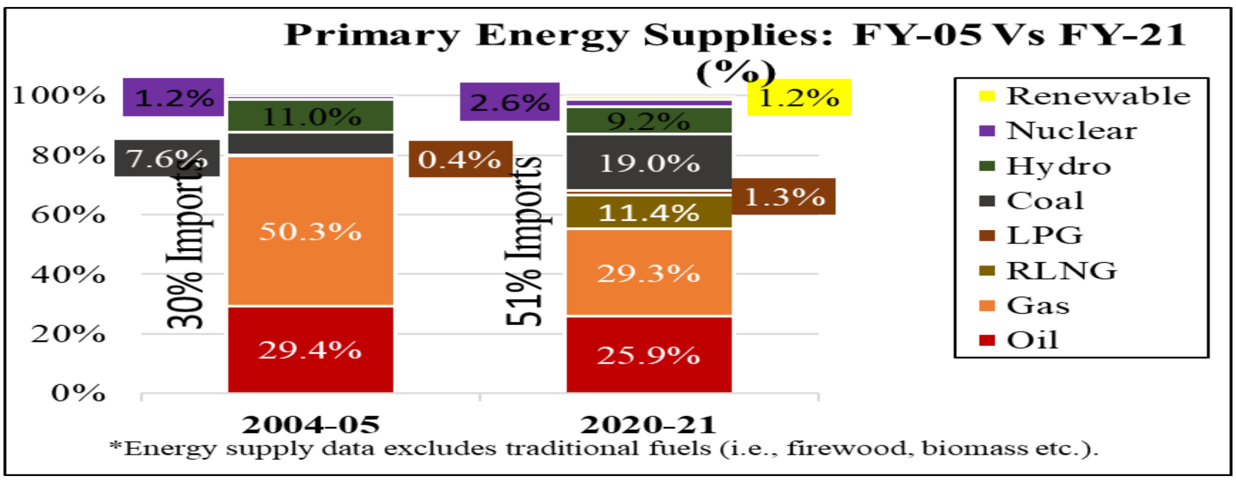


Figure 1.1: Primary Energy Supplies of Pakistan
Source: Pakistan Energy Yearbook (2005&2021)

The progressively increased reliance on imported fuels has negatively impacted the energy security of the country. At the same time, the higher share of imported fuels in the total energy mix has placed significant exposure of the end consumer's affordability, current account, and the fiscal space of the government on the movement of the global energy commodities and geo-political landscape. The figure below shows the trend of the crude oil movement and the share of the petroleum products in the total imports of the country (Khalid, 2022).

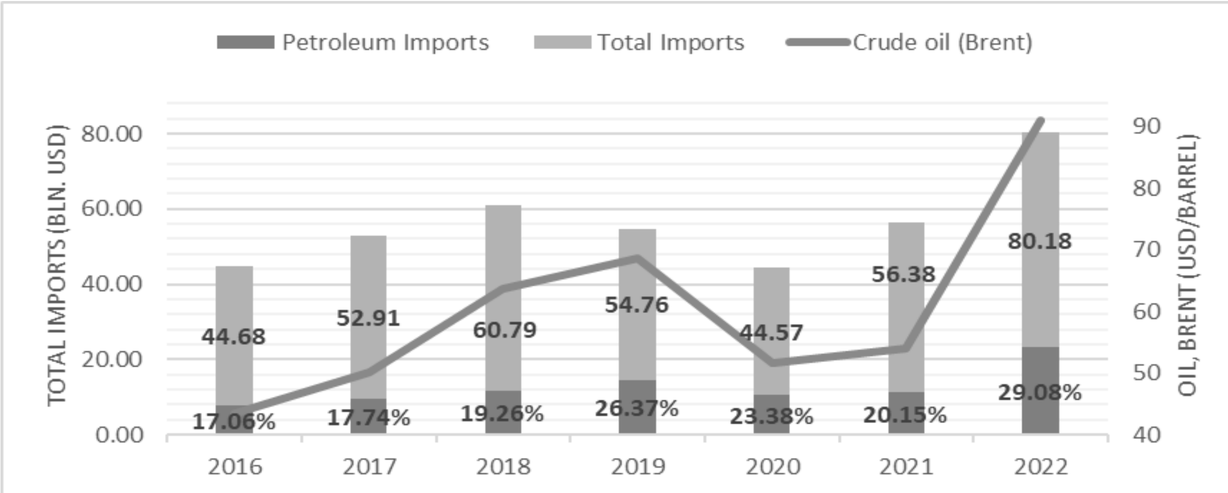


Figure 1.2: Share of petroleum imports in total imports of Pakistan
Source: Pakistan Bureau of Statistics

The trend indicates that movements of the brent crude oil price impacts the percentage share of petroleum imports in the total imports of the country. As evident, the total share of petroleum product was 17.06 % in FY-16 and the corresponding annual average price of the brent crude was 43.44 $/barrel. The same share was 29.08 % in FY-22 when the corresponding brent crude oil price was approximately 91.07 $/barrel.

On the fiscal side, the share of energy subsidy in the total budget has increased from 3.82% in FY-16 to 15.87% in FY-22. This is primarily attributed to the increase in the cost of supply of energy commodities for the end consumers, increase in energy demand and the efforts of the government to cater for the affordability concerns of the consumers. It is pertinent to mention here that the average 10% increase in the global oil price results in approximately 3% increase in the Consumer Price Index (CPI) and approximately 8% increase in the Wholesale Price Index (WPI) in Pakistan (World Bank, 2022)

The local reserves of gas in Pakistan is depleting at the rapid pace and the corresponding gas demand for the gas is increasing, thereby resulting in the increase of imports and the load management to match the supply and demand. The following table shows the trend of the local gas production (in billion cubic meters) and the corresponding consumption in the gas sector of Pakistan (Bp, n.d.)

Table 1.1: Natural Gas production and consumption in Pakistan

Year	**2011**	**2013**	**2015**	**2017**	**2019**	**2021**	**2011-23**
Production (bcm)	35.3	35.6	35	34.7	32.7	32.7	-0.80%
Consumption (bcm)	35.3	35.6	36.5	40.7	44.5	44.8	2.40%

Source: B.P, Statistical review of World Energy 2022

The trend clearly demonstrates the overall declining trend of local gas production and corresponding increasing trend in the gas consumption. The sharp dip in the year 2020 is primarily on account of the disruption caused by CoVID-19. The Compound Annual Growth Rate (CAGR) for the period of 2011-21 translates to 2.4% and -0.8% for consumption and production respectively. Without any sustainable intervention, the widening deficit shall require addition of new gas sources through local discoveries, G2G agreements and incremental RLNG procurements.

On the electricity side, the projected 10-year expansion plans will yield almost 88 % of indigenous mix and 70 % of clean energy generation for Pakistan (NEPRA, 2023). The following figure shows the snapshot of the generation mix for FY-22 and FY-31 respectively.

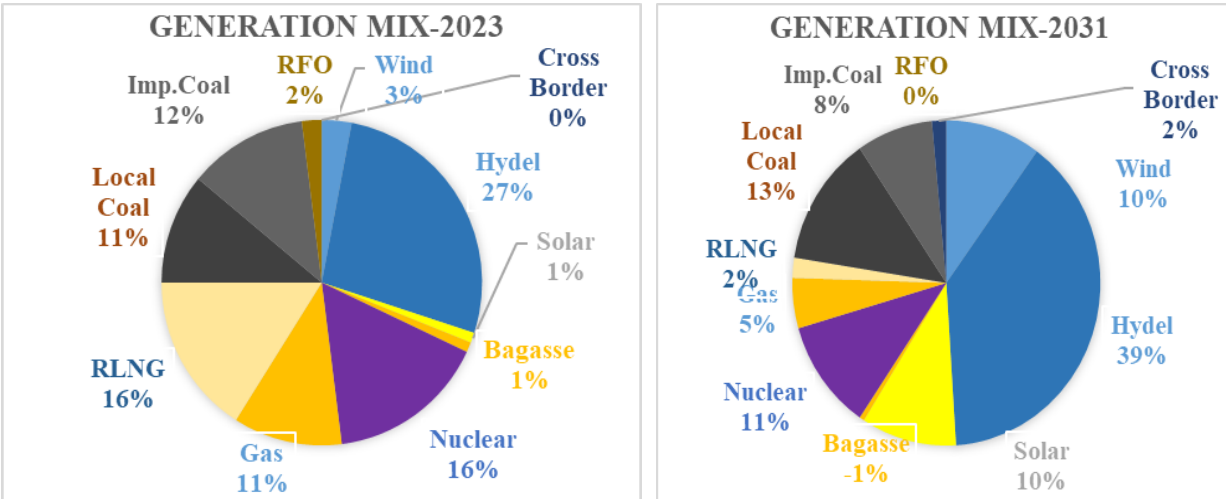


Figure 1.3: Snapshot of Pakistan's generation Mix: FY 23 Vs. FY 31
Source: Indicative Generation Capacity Expansion Plan 2022-31

As evident from the figure, the local & imported coal, RLNG, Gas and RFO constitute 52% of the total generation mix whereas for the year FY-31, the same share will decrease to 28% of the generation mix. This is primarily on account of the addition of the cheap hydel, wind, solar and nuclear energy in the system. Depletion of local gas reserves leading to greater exposure to imported fuels coupled with the progressive indigenization and decarbonization of electricity generation mix provides an opportunity for gradual electrification of space heating, cooking, and water heating demand of the domestic gas consumers.

The global efforts to limit the temperature rise to 1.5 degree Celsius have resulted in the development of energy transition scenarios and associated roadmap across different economies to enable progressive decarbonization of the energy sector (De La Peña et al., 2022) (Gatto, 2022). World Economic Forum (WEF) terms energy transition as the progressive shift towards inclusive, sustainable, affordable and secure energy system (*WEF Fostering Effective Energy Transition, 2019*). This will eventually result in the growing share of electricity to meet the final energy demands on energy consumers across the globe. It is estimated that around 50% of the global energy mix will be shifted towards electricity and hydrogen (McKinsey, 2022).

1.2 Research Problem

Depletion of local gas reserves of Pakistan coupled with growing gas demand at a rapid pace has led to progressive greater reliance on imported RLNG as well as sub-optimal allocation of local gas to the various segments of the economy. For FY-21, RLNG constituted 33% of all the gas supplied through the pipeline system (OGRA, 2021). The progressive increasing reliance on imported RLNG has negatively impacted the energy security of the country and poses detrimental impacts on the current and fiscal accounts of the Government. This can be elaborated from the fact that the total import bill for RLNG increased from 0.35 billion dollars in 2003 to 3.95 billion dollars 2021. At the same time, the stock of the circular debt of the gas sector, on account of the diversion of expensive RLNG to the domestic sector at below the cost of service/gas price differential, has accumulated to almost 623 billion rupees from FY-18 to January 2024.

At present, around 22% of the households have access to pipeline gas in Pakistan. The domestic consumers of the gas sector constitute almost 98.8 % of all the consumers and consume 20% of the pipeline gas on an annual basis (OGRA, 2021). It is pertinent to mention here that the total consumption of the domestic category in the total sales reaches as high as 50% in the peak winter months in Sui Northern Gas Pipelines Limited (SNGPL) system. This is the primary reason of diverting the expensive RLNG to the domestic sector at below the cost of service in the peak winter months. On the contrary, for the electricity sector, the peak demand reduces in winter by almost 60% of the respective peak summer demand (NEPRA State of Industry Report 2022), resulting in the curtailment of the cheap and indigenous power plants to balance overall demand & supply position. This not only results in the non-utilization of the spare generation capacity available in winter seasons but also results in increasing the overall cost of supply to the electricity consumers.

This first comprehensive study evaluates the potential of electrification of the cooking, space heating and water heating applications of gas consumers and provides impacts on the energy burden of household, fiscal and current accounts of Government and carbon emissions of existing and future gas consumers. The results will enable devising a consolidated policy and regulatory framework to inform long term energy transitions. At the same time, the results of the study shall also provide the anchoring parity to ascertain the tariffs of different gas and electricity slabs of domestic consumers in the process of annual rebasing of end consumer tariffs.

1.3 Objectives of the study

The primary objective is to quantify the potential volume of gas that can be saved through progressive electrification of cooking and heating demand for the existing and prospective new domestic consumers in the gas sector. Likewise, the electricity required for transition in the domestic sector. Secondly, the research shall also capture the quantitative estimates of the proposed transition on consumer affordability, fiscal space, current account and carbon emissions.

1.4 Research Questions

The research study aims to provide answers and quantitative estimates of the following research questions:

i) What is the potential saving of gas volume (MMSCF) for the progressive transition of domestic consumers' gas-based cooking and heating demand to electricity, under multiple scenarios?

ii) What are the incremental impacts of the Progressive Electrification (PE) scenarios against the Business-As-Usual (BAU) scenario on the following indicators:
   a) Domestic consumer affordability;
   b) Government fiscal space ;
   c) Current account;
   d) Carbon emissions.

iii) What additional generation resources are required in the electricity sector for each scenario?

iv) What is the optimal gas tariff for different slabs of domestic gas consumers to enable cost-effective transition of heating and cooking to electricity?

1.5 Significance of Research

The combined set of quantitative estimates shall guide the Ministry of Energy, OGRA, and NEPRA in carrying out subsequent tariff rebasing and designing incentive packages/ policy instruments. This will enable progressive transition of the heating demand to electricity on a sustainable basis. It is worth pointing out that the said transition is also aligned with the long-term energy transition roadmap by the International Renewable Energy Agency (IRENA), which envisages a target of a 20% reduction of emissions through electrification of transport and heating applications (IRENA,2022).

1.6 Organization of Study

This research study has been organized into six (6) chapters. The first chapter deals with the introduction and significance of research. The second chapter deals with the literature review. The data and associated methodology have been discussed in Chapter 3 whereas the results and associated discussions have been covered in Chapter four (4). The second last chapter of this study deals with the detailed analysis of the quantitative results. Finally, chapter six (6) of this study draws the conclusion and provides for the detailed policy recommendations to give effect to sustainable energy transition.

CHAPTER 2

LITERATURE REVIEW

2.1 Preamble

The literature review has been provided with the focus on efforts being carried out to assess the potential of electrification of cooking and heating applications in different parts of the world and the quantification of effects of such proposed transition. Besides, such literature review also provides the methodology adopted for ascertaining the impact of electrification of proposed applications.

2.2. Global literature on electrification of heating and cooking applications:

The global efforts of navigating the energy transition to attain net-zero targets have placed greater emphasis on increasing the share of electricity (as a primary source of energy carrier) as well as enhancing its percentage share in the end-use sectors. IRENA, in its annual report of World Energy Transition Outlook 2021 (IRENA, 2022), has projected an increase in the share of electricity (as the primary source of energy carrier) from 21% in 2018 to 50% in 2050. At the same time, electrification in end-use transport and heating sectors shall constitute 20% of the total emission reduction target of 36.9 GtCo2/year in 2050. Resultantly, a significant portion of contemporary research on the energy transition agenda is focused on the assessment/evaluation of electrification of heating demand on the socio-economic indicators and associated roadmap to facilitate the said transition.

Hammerle & Burke (2022) evaluated the impact on energy consumption and greenhouse emissions from replacing heaters and hot water systems with the more-efficient electric appliances in Australian homes. The results demonstrate a large reduction in natural gas consumption and a smaller increase in the electricity demand from the national grid. The study further concludes that the net impact on carbon emissions is dependent on the emission factor of the National Grid.

Decarbonization of the residential water heating system in Californian households have been studied in detail by Raghavan (2017) by means of development and evaluation of multiple long term scenarios. The authors utilized mix of water heating technologies in the development of the long-term stock turn-over model. The results demonstrate the potential reduction of annual greenhouse gas emissions by 80% from 1990 levels, resulting in the annual savings of over 10 Million Metric Tons by 2050. The study also highlights that the overall cost of transition is dependent upon the future cost reduction of heat pumps and solar thermal water heating equipment, the energy cost and consumption of the hot water in the households.

Jing et al. (2022) have investigated the role the local energy system (LES) can play in attaining long-term energy decarbonization targets. The representative case of Wales was evaluated, and it was concluded that decarbonizing the local heating sector is vital for attaining energy emission targets and requires at least 46% installation of heat pumps in the residential sector by 2035. The study further provides evidence of a greater than 300% increase in electricity demand without the incorporation of any flexibility on the electricity infrastructure. However, the electricity peak demand would increase by less than 200% with the addition of flexibility in the grid infrastructure.

The economic valuation of the conversion of LPG stove to induction-based stove for effectuating clean energy transition has been carried out recently in Indonesia. The problem statement of the study (Hakam et al., 2022) focuses on the excess energy subsidy by the Government of Indonesia on LPG cylinders and the availability of excessive supply of electricity. The results validate the economic viability of induction-based electric stove compared to their LPG-based counterparts with savings of $0.64/month/household with a 300 Watts solution and savings of $1.42/month/household for a 500 Watts induction solution. While the proposed transition enables effective utilization of the surplus electricity capacity, it also serves as an essential instrument for navigating the clean energy transition.

The social side of the clean energy transition has been evaluated by Karpinska & Śmiech (2021) in Poland. The primary aim of the study is to examine the impact of changing energy sources on the extent and depth of energy poverty in Poland. While evaluating the impact of energy burden on different quantiles of households, the study points to the negative impact of transition on the vulnerable households and therefore proposes necessary policy shields to protect the most vulnerable households of the given economy.

The impacts on carbon emissions, on account of deployment of the heat pumps for space heating in residential homes in six different regions across the USA, have been evaluated by (Pistochini et al., 2022) over the horizon of 15 years (2022-2036). The results conclude that the residential pumps installation, in place of natural gas furnaces, will reduce the overall greenhouse emissions under the different geographic and climatic settings. More specifically, the analysis shows emission reductions for electric heat pumps over furnaces to be 38-53% for carbon dioxide, 53-67% for 20-year global warming potential (GWP) and approximately 44-60% for the horizon of 100-year GWP.

Anna M.Brockway et al.(2018) evaluated the impact of conversion of water and space heating from natural gas to electricity on the annual emissions of the California's households. The study matched the temporal load profiles of space and water heating with the corresponding grid-level emissions. The results demonstrate reduction of annual carbon emissions by 50-70 % and 46-54 % for water and space heating respectively, attesting a feasible policy intervention to meet deep decarbonization targets.

The Energy Sector Management Assistance Program (ESMAP) carried out a detailed study of primary household energy sources for cooking and heating in 52 developing economies. The study (ESMAP, 2020) illustrates the actual real-world contexts whereby the levelized cost of deployment of cooking solutions is lower than the current applicable expenses on biomass. The study further concludes that the projected cost of 2025 makes the cooking-based energy transition more valuable. Lastly, and most importantly, the ESMAP study points out the institutional and commercial challenges that need to be overcome to ensure a rapid and sustainable e-cooking based transition.

Keith Dennis (2015) has evaluated the electrification as end-use option for meeting the climate goals. The study highlights the immediate reduction of the carbon dioxide emissions with adoption of the beneficial electrification technologies available in field. While the existing environmental targets cannot be met without targeting the reduction in carbons signatures of the households, the study stresses the need of alignment of policy incentives with the long-term climate targets of the economy.The benefits of cooking on the induction stove compared to the LPG and electric resistance-based heaters have been evaluated under a multi-dimensional matrix by the Martinex-Gomerz et.al (2015). The matrix evaluated the temperature, time to cook, electric grid parameters, concentration of CO and CO_2 and the microbiological & physiochemical changes as a results of cooking on the aforementioned three technologies. The results highlight higher concentration of CO and CO2 (even with exhaust hood cooking) in case of LPG stoves. Furthermore, cooking on induction stove has shown better response during the heating process and energy efficiency which in-turn shows favorable incremental impact on the cooking time, energy consumption, cost to the end user, taste and vitamin preservation.

Although significant efforts have been made in the recent past to evaluate the impacts of electrification of heating and cooking demand on the individual variables, namely, consumer's affordability and emissions, none of the studies have so far evaluated the integrated impact of electrification on the economic, environmental and financial variables. At the same time, the contemporary studies/publications (on evaluating the impact on affordability and emissions) are not primarily informed through the detailed long-term generation expansion framework. For most of the cases, the simple cost-benefit analysis and the grid emission factors have been utilized, which bear significant geographical and temporal variations. This study shall utilize the ten-year long-term generation expansion framework to evaluate the integrated impacts and suggest policy measures to effectuate rapid transition. Lastly, this study shall serve as a roadmap for Pakistan and other developing economies to guide their respective energy transition plans under an all-inclusive framework.

2.3. Framework of clean energy transition in Pakistan

The clean energy transition and utilization of clean energy for heating and cooking applications has been the consistent theme to effectuate the net-zero transition of the country. Accordingly, the same has been provided across the legal and regulatory framework of different sectors of the economy.

The Pakistan National Adaption Plan (NAP) 2023 (NAP,2023) by the Ministry of Climate Change provides an all-inclusive framework for implementing adaptation, promoting inclusivity and facilitation collaboration among different stakeholders and also serves an effective tool to foster climate finance mobilization. The NAP also provides the holistic overview of the climate risk being faced by the country, provides comprehensive strategy for adaption and chalks out adaption strategy and priorities in key seven areas, namely, agriculture-water nexus, natural capital, urban resilience, human capital, disaster risk management, and gender, youth, and social inclusion. The objective 2 ("*Empower Vulnerable Groups through Fostering Climate-Resilient Livelihoods"*) of the key area ("*Gender, Youth, and Social Inclusion*") requires introduction of the energy-efficient and low-cost cooking technologies for promoting sustainable cooking practices. The exact stipulation is placed below:

No.	Objective & Initiative	Key Responsible Entity
2.1	Introduce energy-efficient, low-cost cooking technologies tailored to women's needs to promote sustainable cooking practices	Provincial, ICT, GB and AJK Energy Departments; Tech Incubators; Research Institutions

The National Energy Efficiency & Conservation Policy 2023 (NEEC-2023) identifies the mechanism to facilitate institutionalization, operationalization and implementation of energy efficiency and conservation in the country. The NEEC-2023 provides key policy interventions for the sectors of: Industry, Building, Transport, Energy (Power and Petroleum), and Agriculture Sectors. The NEEC-2023 sets the targets of saving 1.05 MTOE of energy resulting in emission reduction of 6.1MTCO2 by 2030. The measures include, inter-alia, the following:

- Jointly establish Energy Efficiency & Conservation cells at all the Distribution Companies (DISCOs) for the capacity development of power sector entities to implement the EE&C measures for system improvement.
- Implementation of Demand Side Management (DSM) programs in collaboration with MIRAD (Market Implementation & Regulatory Affairs Department).
- Establish evaluation mechanism of energy efficient appliances during basic load profiling for new electricity and gas connection across commercial, household, industrial, agriculture sectors by 2024.

The policy envisages the formulation of institutional mechanism for implementation of EE&C measures and development of evaluation criteria of energy appliances during the process of load profiling for new electricity and gas connections. This shall also require resetting the pricing, taxation and tariff adjustments to effectuate clean energy transition.

The National Electricity Policy 2021 (NEP-21), as approved by the Council of Common Interests (CCI) on 21st June 2021, chalks out the integrated policy framework that provides key policy intervention on the nine (9) distinct areas of the power sector for secure, sustainable and affordable supply of electricity. The policy stipulation 5.6.7 of the NEP-21 states that:

"Further, the Government may announce, from time to time, various concessional packages to incentivize additional consumption to minimize such costs."

Similarly, the section 5.8 ("*Integrated Planning*") envisages development of the integrated energy plan which will enable attainment of the policy goals, namely, *Access to Affordable Energy, Energy Security, and Sustainability*. The clean energy transition of cooking and heating application shall serve as the key area for optimization under the Integrated Energy Plan (IEP).

The National Electricity Plan (NE-Plan) 2023 (NE-Plan,2023) serves as the implementation framework to enable effective implementation of the National Electricity Policy 2021. The NE-Plan 2023 provides the twenty (20) priority areas, strategic directives underneath each priority area and responsibilities of each entity for its implementation. The priority area 12 (Incentive Schemes) acknowledges provision of necessary incentives and mechanism to serve as a tool for accelerating clean energy transition. The strategic directive-69 stipulates that:

"69. *Incentive mechanisms / schemes shall be utilized as a tool to facilitate accelerated energy transition and economic growth. Such mechanisms shall account for:*

a) *predictability through consistency of policy directives.*

b) *cross sectoral integration and optimization.*

c) *efficient utilization of resources*

d) regional competitive tariffs for productive consumer."

The plan envisages the application of incentive schemes and concessional packages through a predictable policy framework that enables cross-sectoral integration and optimization while ensuring most optimal use of resources. This provides a compelling need to evaluate, plan and implement the transition of cooking and heating based domestic gas applications to electricity, thereby providing enabling a sustainable transition which is aligned with the overall policy and strategic landscape of the energy sector.

The updated Nationally Determined Contributions 2021 (NDC 2021),as submitted by the Pakistan in October 2021, provides the future commitments (voluntary and conditional) of carbon emission reductions by 2031. Pursuant to the NDC 2021, the total emissions in 2016 stood at the level of 405.1 MTCO2 eq which was increased to 489.87 MTCO2 eq in 2018. For the year 2030, the business-as-usual emissions are projected to be 1603 MTCO2 eq which will be reduced to 801.8 MTCO2 eq through voluntary and conditional interventions. The high priority interventions include 60% of electricity generation through renewables in 2030 and ban on incremental capacity expansion through coal based power plants.

At present, the integrated assessment of the transition of domestic gas demand (for cooking and heating to electricity) has not been carried in the research work. The first step in devising the roadmap for the transition, as stipulated in the relevant legal, policy and regulatory framework, implies quantification of the available potential and evaluation of the impact of transition under each scenario on the technical, financial , and environmental variables of interest. This research will not only quantify the said impacts but will also determine the tariff parities in the gas sector required for effectuating the proposed transition.

CHAPTER 3

DATA AND METHODOLOGY

3.1 Introduction:

This chapter presents the data employed and the methodology adopted to assess the potential for electrification of cooking and heating applications for the gas consumers of SNGPL and SSGCL. This chapter also provides for the scenarios defined under this study (based on the consumption slabs of domestic gas consumers) to effectuate the gas-to-electricity transition.

3.2 Methodology:

The process of evaluating the impact of transition of gas-based cooking, space heating and water heating demand to electricity and its consequent impacts on the consumer's affordability, fiscal and current account and environmental emissions has been segregated into multiple steps. For the purpose of bringing clarity, the process of has been divided into distinct components, namely, gas sector, emissions, electricity sector and the cost benefit analysis.

3.3 Gas Sector

3.3.1 Slab wise gas consumption:

The basic process commenced with the evaluation of consumption patterns of different households of gas over the period of twelve (12) months. This enabled capturing the monthly variations on account of utilization of gas for different domestic applications. For this purpose, the microdata of the domestic gas consumers of SNGPL and SSGCL for the year FY-22 was employed. The microdata of both the gas distribution companies was consolidated for a system level analysis. Subsequently, the total gas consumption data for 10.67 million gas consumers was divided into different slabs to capture the share of total consumption in each slab as well as movement across the slabs during the summer and winter months. This provides an accurate analysis of gas consumption in different applications. The total number of consumers in each slab and their corresponding percentages is provided in the tables below:

Table 3.1: Total gas consumers in each slab (Mln. No.)

Slabs hm3	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22
<=0.5	6.47	6.44	6.46	5.83	4.78	3.48	3.17	4.02	5.41	6.51	6.89	6.82
0.5-1	3.25	3.30	3.30	3.48	3.76	3.52	3.22	3.67	3.67	3.17	2.89	2.99
1.01-1.5	0.63	0.64	0.63	0.84	1.27	1.82	1.94	1.62	1.05	0.68	0.60	0.56
1.51-2	0.16	0.16	0.16	0.29	0.56	0.95	1.10	0.71	0.32	0.17	0.16	0.14
2.01-2.5	0.05	.05	0.05	0.09	0.15	0.42	0.56	0.30	0.10	0.05	0.05	0.04
2.51-3	0.02	0.02	0.02	0.04	0.06	0.21	0.29	0.14	0.04	0.02	0.02	0.02
3.01-4	0.01	0.01	0.01	0.03	0.04	0.16	0.24	0.09	0.02	0.01	0.01	0.01
>4	0.04	0.02	0.01	0.03	0.03	0.08	0.11	0.05	0.02	0.01	0.01	0.06

Source: Microdata of Domestic gas consumers

The corresponding percentage of each consumer in the given slab for each month is provided. below:

Table 3.2: Total gas consumers in each slab (%)

Slabs hm3	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22
<=0.5	60.6	60.3	60.6	54.6	44.7	32.6	29.7	37.9	50.7	61.0	64.6	63.9
0.5-1	*30.5*	*30.9*	*30.9*	*32.6*	*35.2*	*33.0*	*30.2*	34.4	34.4	29.7	27.1	28.0
1.01-1.5	5.95	6.05	5.94	7.91	11.9	17.0	18.2	15.2	9.9	6.4	5.6	5.2
1.51-2	1.57	1.57	1.52	2.73	5.27	8.96	10.3	6.72	3.03	1.68	1.55	1.37
2.01-2.5	0.50	0.50	0.48	0.93	1.47	3.98	5.26	2.90	1.00	0.54	0.51	0.45
2.51-3	0.21	0.20	0.19	0.43	0.59	1.98	2.80	1.34	0.39	0.22	0.21	0.20
3.01-4	0.17	0.15	0.14	0.37	0.38	1.50	2.26	0.90	0.26	0.16	0.16	0.17
>4	0.40	0.19	0.17	0.35	0.30	0.76	1.10	0.50	0.26	0.18	0.17	0.62

Source:Microdata of Domestic gas consumers

The gas consumption in each slab, as obtained from the microdata for the year FY-22, is provided below:

Table 3.3: Gas consumption in each slab (%)

Slabs hm3	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22
<=0.5	28.3	29.0	29.5	23.7	16.6	8.47	6.40	11.4	21.4	30.4	32.1	29.2
0.5-1	*41.0*	*42.4*	*42.8*	*39.2*	*36.3*	*26.2*	*21.9*	31.0	39.6	40.2	39.0	39.1
1.01-1.5	13.2	13.7	13.6	15.8	20.3	22.1	21.4	22.4	18.9	14.7	13.9	12.2
1.51-2	4.99	5.09	4.95	7.82	13.1	16.5	17.2	14.0	8.21	5.48	5.40	4.54
2.01-2.5	2.07	2.08	2.02	3.43	4.59	9.39	11.2	7.81	3.53	2.30	2.30	1.93
2.51-3	1.07	1.01	0.99	1.95	2.24	5.71	7.31	4.43	1.70	1.15	1.18	1.05
3.01-4	1.07	0.95	0.93	2.12	1.82	5.41	7.36	3.69	1.40	1.06	1.10	1.16
>4	8.12	5.69	5.16	5.90	4.87	5.96	7.02	5.06	5.12	4.65	4.87	10.7

Source:Microdata of Domestic gas consumers

Looking carefully at the trend in the tables above, it clearly depicts the shifting of gas consumers from the lower slab to the higher slabs during peak winter months. For example, almost 61% of total gas consumers fall in slab less than 0.5 hm3 during the month of July. However, the share decreases to 30% in the peak winter month of January. Similarly, the gas total gas consumption in slab less than 0.5m3 is 28% during the month of July. However, the total consumption share in the same slab (less than 0.5 hm3) reduces to 6% in the month of January, demonstrating the shifting of gas consumption in the higher slabs during the winter month.

3.3.2 Consumption profile for heating applications:

The Household Integrated Economic Survey 2018-19 (HIES 2018-19) microdata was employed to evaluate the share of the cooking, space and water heating in the total annual gas consumption of each household. The total gas consumption for different quantiles was estimated based on the response to the survey question of the expenditures incurred for different heating applications. Resultantly, the total share of the cooking, space heating and water heating applications comes out as under:

Table 3.4: Share of heating applications in total gas consumption of households (%)

Cooking	Space Heating	Water Heating
67%	21%	12%

Source: HIES (2018-19)

It is pertinent to mention here that the %age share of heating application is the average share of different quantiles. The households of highest quantiles who receive uninterrupted gas supply during the winter month utilize the gas for all the sub-applications (i.e., cooking and heating) without compromising the specific use. On the contrary, the households who face load shedding during the winter months have to compromise the cooking applications as well as space & water heating applications.

The similar analysis of the domestic gas consumption has recently been carried out by Ministry of Planning, Development & Special Initiatives. Based on the results of the report, which are premised on the outcomes of Pakistan's Integrated Energy Model-2010, the cooking applications consumes 76% (on average) of the total gas consumption of domestic consumers. Similarly, the water heating and space heating share in the total domestic consumption has been estimated to the tune of around 11.4 % and 12.3 % respectively.

3.3.3 Appliance wise gas consumption in different quantile:

The number of gas appliances in each quantile and the corresponding consumption of appliances has been computed using the HIES 2018-19 microdata. The total number of appliances in each quantile is provided in the table below:

Table 3.5: Total number of appliances in each household quantile

Appliances	Consumption/hour (m3)	No. of Appliances (Thousands) Q1	Q2	Q3	Q4	Q5	Total
single burner stove	0.3	711	1319				**2030**
double burner stove	0.556			2040	3416	5912	**11368**
heater single plate	0.276	66	189				**255**
heater double plate	0.504			256	629	2262	**3147**
Gas oven single burner	0.402	4	7	18	30		**59**
Gas oven, double burner	0.744					538	**538**
Gas geyser, without baffle	0.624	2	30	66	297	1762	**2157**

Source: HIES (2018-19)

3.3.4 Domestic system gas demand projections:

The annual system demand projections for the SNGPL and SSGCL has been computed using the demand growth pattern for the last 10 years for the domestic sector. Resultantly, the CAGR of SNGPL and SSGCL comes out to be 5% and 3% respectively. The total system wise demand from the year 2024 to 2033 is provided as under:

Table 3.6: Annual domestic gas demand projections (FY 24-33)

Year	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
Domestic Demand (MMCFD)	*655*	*688*	*723*	*759*	*797*	*837*	*878*	*922*	*968*	1017
Domestic Demand (BSCF)	239.2	251.1	263.7	276.9	2907	305.3	320.6	336.6	353.4	371.1

The demand projection assessment shall assist in the evaluation of the impact of the existing as well as future gas demand for heating and cooking applications.

3.4: Carbon emissions from gas-based applications:

For the purpose of the calculating the gas emissions as a result of burning of methane, the greenhouse gas emission factors, as published in the Pakistan's Second National Communication on Climate Change, has been utilized. The Greenhouse gas (GHG) emissions of different applications are placed as under:

Table 3.7: GHG emission factors for different applications

Category	Fuel	CO2 (t/ TJ)	CH4 (kg/ TJ)	N2O (kg/ TJ)
Energy Industries	Diesel oil	73.2	3	0.6
	Furnace oil	76.5	3	0.6
	Coal local	94	1	1.4
	Natural gas	55.7	1	0.1
Manufacturing Industries	Gasoline	68.5	-	-
	Kerosene	71	-	-
	Diesel oil	73.2	2	0.6
	Furnace oil	76.5	2	0.6
	Coal imported	92.5	10	1.4
	Coal local	94	10	1.4
	Natural gas	55.7	5	0.1
Transport	Jet Kerosene	70.7	0.5	2
	Natural gas	55.7	50	0.1
	LPG	62.3	-	-
	Gasoline	68.5	20	0.6
	Diesel oil	73.2	5	0.6
	Furnace oil	76.5	5	0.6
Other sectors	Kerosene	71	10	0.6
	Diesel oil	73.2	10	0.6
	LPG	62.3	-	-
	Natural gas	55.7	5	0.1

Source: Pakistan's Second National Communication on Climate Change

For the purpose of calculations, the GHG emission factors of natural gas in the energy industries have been used. The corresponding CO2 equivalency, as by in Inter Governmental Panel on Climate Change (IPCC), is provided below:

Table 3.8: CO2 Equivalency factor for 100 years GWP

Category	Fuel	CO2 (t/ TJ)	CH4 (kg/ TJ)	N2O (kg/ TJ)
Energy Industries	Diesel oil	73.2	90	159
	Furnace oil	76.5	90	159
	Coal local	94	30	371
	Natural gas	55.7	25	29.8
Manufacturing Industries	Gasoline	68.5	0	0
	Kerosene	71	0	0
	Diesel oil	73.2	60	159
	Furnace oil	76.5	60	159
	Coal imported	92.5	300	371
	Coal local	94	300	371
	Natural gas	55.7	150	26.5
Transport	Jet Kerosene	70.7	15	530
	Natural gas	55.7	1500	26.5
	LPG	62.3	0	0
	Gasoline	68.5	600	159
	Diesel oil	73.2	150	159
	Furnace oil	76.5	150	159
Other sectors	Kerosene	71	300	159
	Diesel oil	73.2	300	159
	LPG	62.3	0	0
	Natural gas	55.7	150	26.5

Source: IPCC

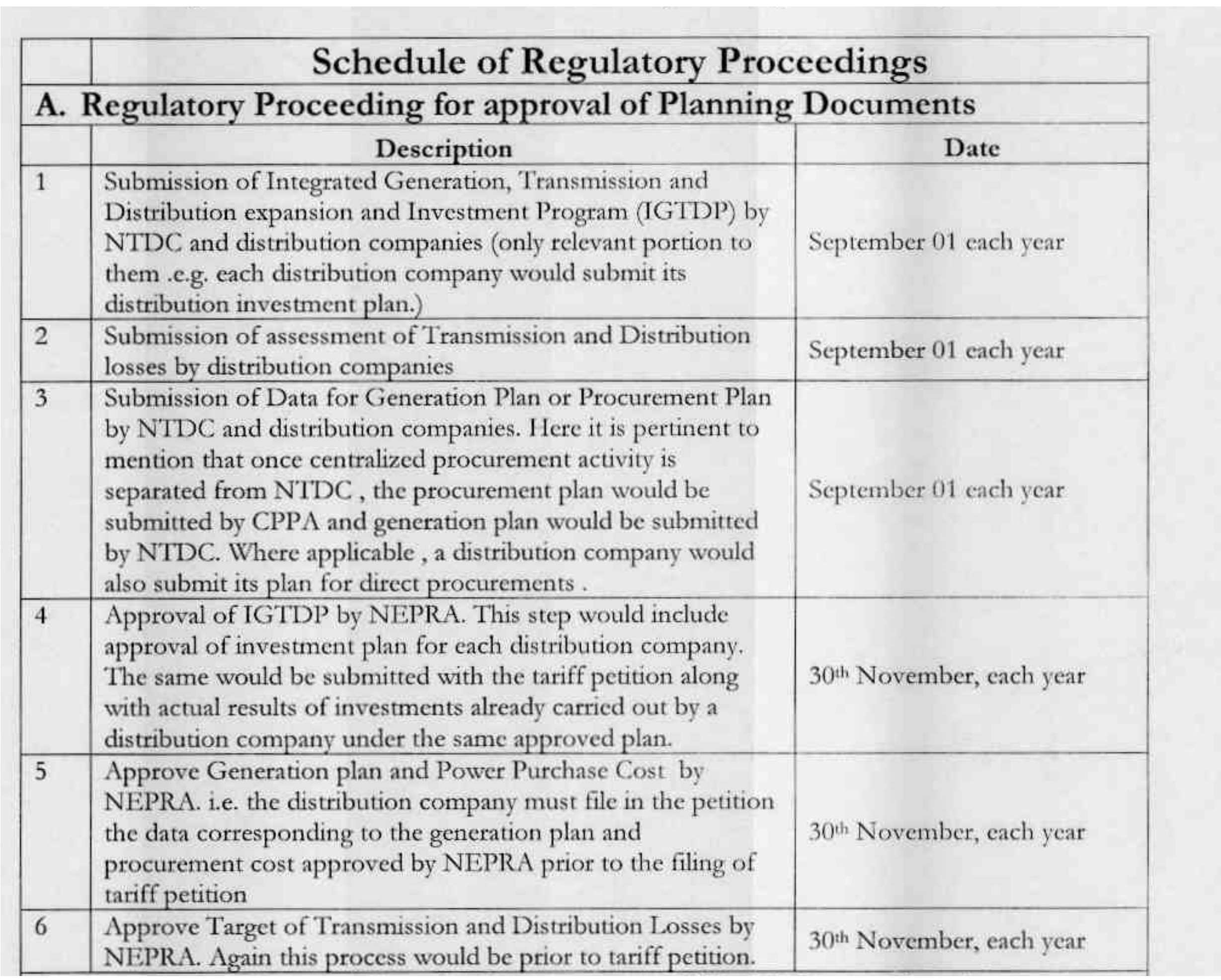
The reference provided by the IPCC shall serve the purpose of computing the release of CO2 equivalent in the atmosphere by burning MMSCF of natural gas in the domestic applications of heating and cooking applications in Pakistan.

3.5 Electricity Sector:

For the purpose of evaluating the impact of gas-based applications transition to the electricity, it is necessary to assess the base framework that is currently in field for the purpose of generation expansion. The logical steps to evaluate the base assessments are provided in the subsequent sub-sections.

3.5.1 Generation expansion framework:

The power sector of Pakistan carries our long-term generation expansion on the basis of least-cost principle while taking into account all the applicable technical, commercial and legal constraints. Each year, NTDCL collects the data from the relevant stakeholders and uses the standard generation expansion model (with multiple scenarios) to evaluate the most optimum generation mix that meets the future demand of electricity at the least cost while taking into account the constraints of the system. The relevant schedule of regulatory proceedings for the approval of planning document (NEPRA End Tariff Methodology and Process), as provided in NEPRA's Consumer Service Manual, is reproduced below:



	Schedule of Regulatory Proceedings	
A. Regulatory Proceeding for approval of Planning Documents		
	Description	**Date**
1	Submission of Integrated Generation, Transmission and Distribution expansion and Investment Program (IGTDP) by NTDC and distribution companies (only relevant portion to them .e.g. each distribution company would submit its distribution investment plan.)	September 01 each year
2	Submission of assessment of Transmission and Distribution losses by distribution companies	September 01 each year
3	Submission of Data for Generation Plan or Procurement Plan by NTDC and distribution companies. Here it is pertinent to mention that once centralized procurement activity is separated from NTDC , the procurement plan would be submitted by CPPA and generation plan would be submitted by NTDC. Where applicable , a distribution company would also submit its plan for direct procurements .	September 01 each year
4	Approval of IGTDP by NEPRA. This step would include approval of investment plan for each distribution company. The same would be submitted with the tariff petition along with actual results of investments already carried out by a distribution company under the same approved plan.	30th November, each year
5	Approve Generation plan and Power Purchase Cost by NEPRA. i.e. the distribution company must file in the petition the data corresponding to the generation plan and procurement cost approved by NEPRA prior to the filing of tariff petition	30th November, each year
6	Approve Target of Transmission and Distribution Losses by NEPRA. Again this process would be prior to tariff petition.	30th November, each year

Figure 3.1: NEPRA's Schedule of Regulator Proceedings
Source: NEPRA's Consumer Service Manual

The aforementioned figure shows that the NTDCL, which is primarily responsible for preparation of Indicative Generation Capacity Expansion Plan, is bounded by the regulations to submit the generation expansion and transmission expansion plan by 1st September each year. For the purpose of this analysis, the latest IGCEP 2022-31 as approved by the NEPRA dated 1st February 2023 has been assumed for evaluation of the impact of electrification of heating and cooking demand.

In the NEPRA's approved IGCEP 2022-31, the NTDCL has prepared the base case (recommended case) as well as five additional scenarios. For the purpose of this study, the base case results have been assumed. Pursuant to the approved IGCEP 2022-31, the annual demand for capacity and energy for the electricity sector has been estimated as under:

Table 3.9: Projected demand growth for power generation

Year	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31
Peak Demand (MW)	28,436	29,054	30,583	32,105	33,688	35,430	37,191	39,086	41,338
Energy (TWh)	156.4	164.4	172.0	180.4	188.6	197.6	206.7	216.4	228.5

Source: IGCEP 22-31

The cumulative CAGR for the peak demand and energy over the period of FY 23-31 turns out to be 4.87% and 4.49% respectively. Pursuant to the projected demand, the optimized least cost-based generation expansion portfolio under the base case has been selected. The results are populated below for reference:

Table 3.10: Candidate project additions in IGCEP 22-31 under normal scenario

Fiscal Year	Coal Fired Steam Local Coal	Coal Fired Steam Local Coal KE	HPP	HPP KE	Solar Utility MW_p	Solar Feeder/DG MW_p	Solar KE MW_p	Wind NTDC	Wind KE	Bagasse	Per Year Capacity Addition	Cumulative Capacity Addition
2024	-	-	-	-	-	500	-	-	-	-	500	500
2025	-	-	10	-	3,120	750	150	500	50	-	4,580	5,080
2026	-	-	13	-	1,300	750	150	500	50	-	2,763	7,842
2027	-	990	-	-	1,094	-	150	-	50	-	2,284	10,126
2028	-	-	-	-	-	-	150	2,894	50	-	3,094	13,220
2029	-	-	360	-	-	-	150	583	50	-	1,143	14,364
2030	-	-	993	82	-	-	150	-	50	-	1,275	15,639
2031	-	-	2,130	-	-	-	150	-	50	-	2,330	17,969
Total	**-**	**990**	**3,506**	**82**	**5,514**	**2,000**	**1,050**	**4,477**	**350**	**-**	**17,969**	

Source: IGCEP 2022-31

The results show that approx. 17,969 MW is added in the system over the horizon of FY 24-31. Note that these additions are over and above the future committed generation in the system that is expected to materialize in future years.

The cumulative addition of candidate and committed generation over the same horizon is depicted below for reference:

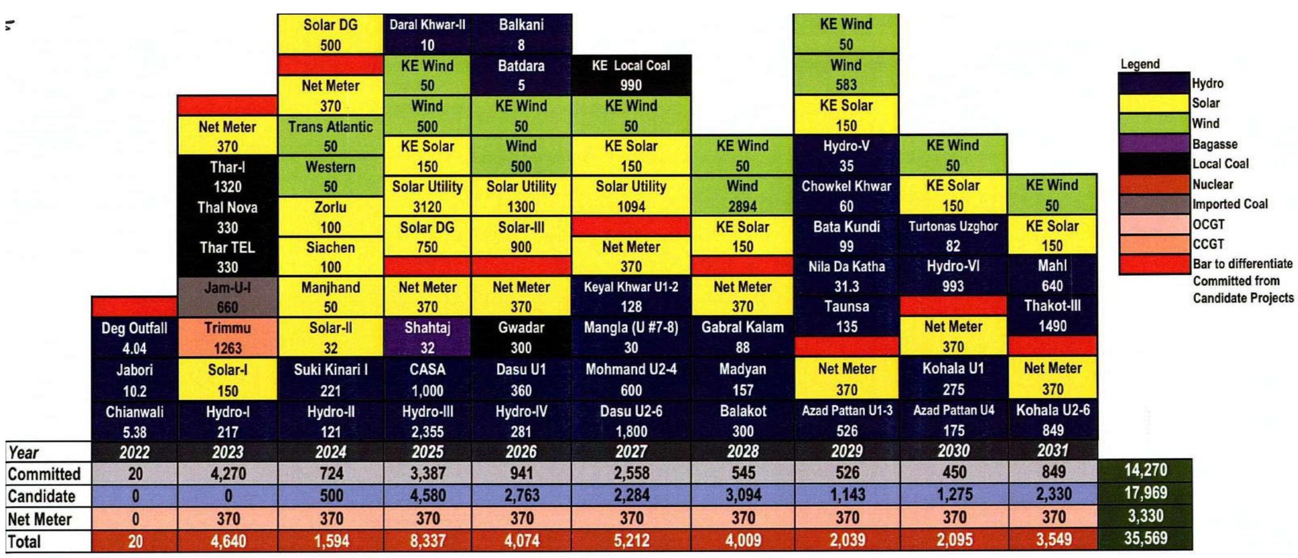


Figure 3.2:Annual Generation Induction under IGCEP 22-31
Source: IGCEP 2022-31

The figure above demonstrates that the cumulative of 35,569 MW of total capacity is added in the system by the year FY-31 wherein 17,969 MW is the candidate addition (based on least cost), 14,270 MW is the committed capacity, and the remaining 3,330 MW is inducted under the phenomenon of net-metering.

The addition of capacity in the system has resulted in the progressively increasing share of the fixed capacity charges and reduction of the variable charges in the total cost of supplying electricity to the consumers. This is evident from the fact that the capacity payments constituted around 21.8% of the total wholesale cost (the energy payments shared was around 78.2%) in the year FY-13 which has increased to around 67.6% in year FY 2024 (as determined in the tariff rebasing of NEPRA for FY-24). The progressive electrification of the gas demand shall enable leveraging the fixed cost of the surplus capacity, resulting in the reduction of tariffs for all the consumers of electricity. It is pertinent to mention here that the loadshedding in the system, despite having generation excess capacity, is primarily carried out to cover the commercial losses that incur due to the high theft and low recovery issues in the specific areas. Per the applicable policy in field, all the feeders are categorized on the basis of the Aggregate Technical & Commercial (AT&C) losses. Resultantly, the loadshedding hours on each feeder is determined by the percentage of AT&C losses. Further, the seasonal and occasional loadshedding is carried out on account of the transmission /grid and fuel constraints in the system.

The base scenario of IGCEP, as approved the NEPRA, has been taken as the reference case for evaluation of incremental impacts on electricity sector by triggering the progressive electrification of heating and cooking demand of gas sector. The process of development of model in PLEXOS and evaluation of the incremental impact is provided in detail in the following section.

3.5.2 Model development for generation expansion:

The incremental generation in the system shall impact the process and results of the generation expansion in the system. It is quite likely that the transition of heating and cooking demand from the gas sector shall trigger requirement of incremental generation fleet in the power system to cater for the said demand. The response to this query is the area of the long-term generation optimization scenario that is solved using the available mathematical solvers in the market.

For the purpose of this study, the tool namely PLEXOS has been utilized to evaluate the future generation expansion with incorporation of transition scenario of heating and cooking in the electricity system. Plexos has been the renowned energy market simulation engine that is deployed across the electric, water, and gas sector for evaluating the cost-effective solutions to the expansion and operational decision. This tool has been globally utilized widely in the public utilities, private business under both the regulated and open-market settings. At the same time, the NTDCL has utilized Plexos for the development of the generation expansion plan (IGCEP 2022-31) of Pakistan, which makes it ideal for utilization of Plexos to evaluate the impact of said transition.

The Plexos allows to model the power system under different sections. The main electric system allows for modelling the generation system, fuel and fuel contracts, emission and reserves for the system. The transmission section allows for modelling the system demand in zones and nodes and define transmission infrastructure to connect demand with supply. Lastly, the tool allows for defining the financial parameters, general constraints and add multiple data profiles to represent scenarios. The general GUI of the Plexos tools is provided below:

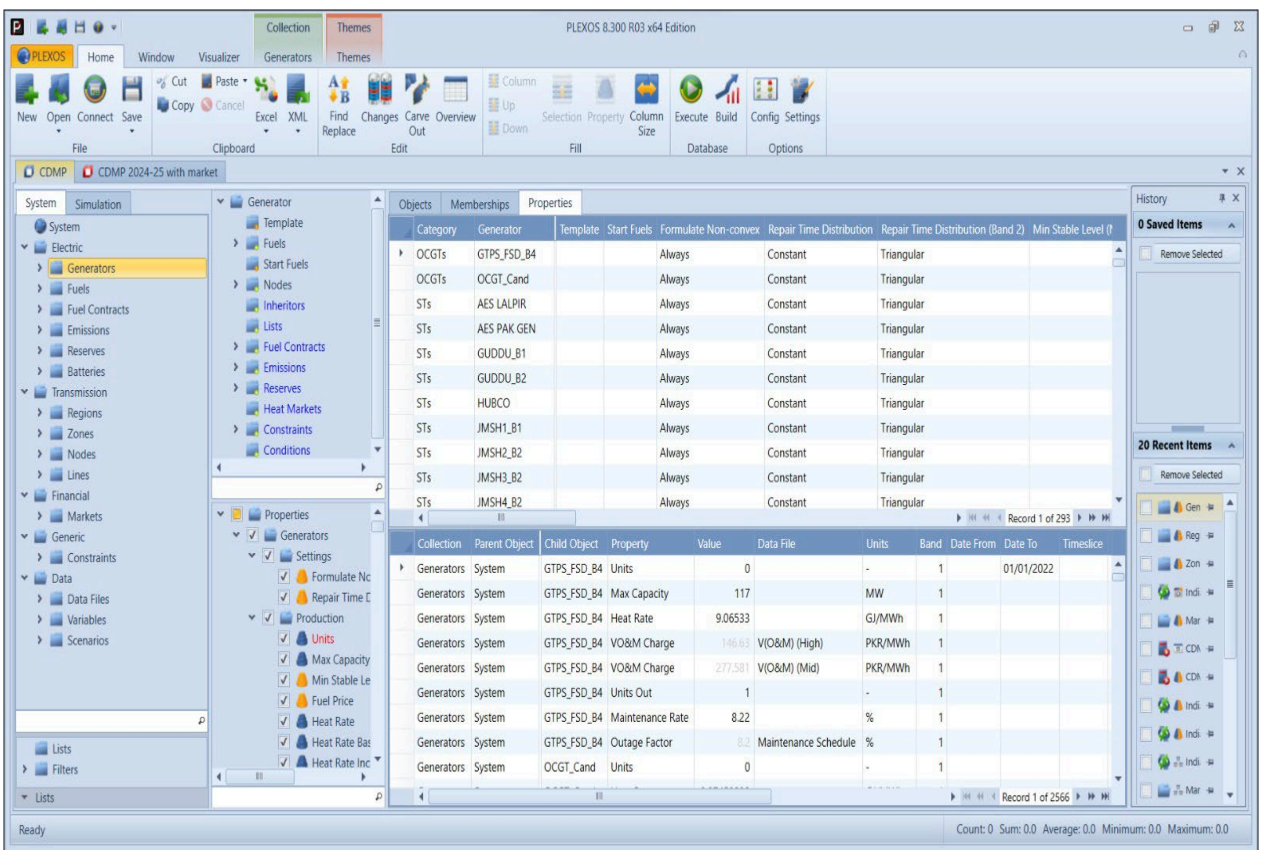


Figure 3.3: Plexos GUI for modelling generation expansion

3.6 Scenarios development:

For the purpose of meaningful and practical analysis, the multiple scenarios were formulated and the impact of each scenario on the pre-determined variables were measured. The applicable slabs of the domestic gas consumers were utilized as reference to formulate the scenarios of transition to electricity. This eventually led to the development of the following scenarios for evaluation:

Table 3.11: Scenarios for gas to electricity transition

Scenarios	Consumption Slab
S1	Consumption (C1) >4hm3
S2	3hm3< Consumption (C2) <4hm3
S3	2hm3< Consumption (C3) <3hm3
S4	1hm3< Consumption (C4) <2hm3

i. For the first scenario (S1), the highest domestic consumption category was considered for evaluation of impact on account of heating and cooking demand conversion to electricity. This is comparatively most feasible scenario as the existing rates as well as financial well-being of the consumers can facilitate rapid transition, provided the cost-benefit analysis make a feasible solution under this scenario.

ii. The second scenario (S2) was primarily built around the consumers whose monthly consumption remain greater than 3 hm3 and less than 4 hm3 for a given month. The consumers under this and above category tend to exhibit greatest shift in their consumption pattern between the summer and winter months, thereby implying greater utilization of gas for space and water heating applications.

iii. The scenario S3 accounts for all the consumers whose given monthly consumption remain higher than 3 hm3 and less than 2 hm3.

iv. Scenario S4 caters for the consumer whose monthly consumption remains between the band of 1hm3 and 2 hm3.

Under each scenario, the gas monthly base demand was evaluated for each heating application (cooking, space heating and water heating) over the period of FY 24-31. For the same scenario, the volume of gas released as a result of transition of heating applications to electricity as estimated. The corresponding electricity generation required to meet the incremental heating and cooking demand was also quantified for each scenario.

The incremental electricity generation was evaluated which was superimposed on the base demand of the IGCEP 2024-31 model and the generation capacity expansion plan was simulated to capture the resultant impacts of this transition on the electricity sector in terms of the additional generation capacity and energy required to meet the said demand. More specifically, this enabled capturing the following incremental results:

i. Generation (MW) additions in the National grid system
ii. Generation cost
iii. Emissions
iv. Consumer burden

3.7 Cost benefit analysis:

The process of evaluation of impact of transition on the consumer was commenced through the assessment of the existing tariffs of gas and electricity for domestic households. Per the applicable regulatory process in vogue, the respective regulator sets the tariff for each category of consumer based on the projected sales and the cost of such sales (including regulated losses and previous year adjustments). The proposed rate of the regulator is referred to the Ministry of Energy which further adjusts the cross-subsidies, incorporates the tariff differential subsidies, surcharges and duties, leading to the final notification of the tariff by the Government.

The existing applicable tariff of electricity and gas sector for the domestic consumers are provided in the tables below:

Table 3.12: Applicable tariffs for domestic gas consumers (notified on Nov 1st, 2023)

Slabs	Rate (Rs. /MMBTU)
upto 0.25 hm3	300
upto 0.6 hm3	600
upto 1 hm3	1000
upto 1.5 hm3	1200
upto 2 hm3	1600
upto 3 hm3	3000
upto 4 hm3	3500
Above 4 hm3	4000

Table 3.13: Applicable tariffs for domestic electricity consumers (notified on 25th July 2023 with addition of projected fuel price and capacity adjustments)

Slabs	Rate (Rs. /kWh)
0-100	18.34
101-200	24.81
201-300	29.00
301-400	36.69
401-500	39.90
501-600	41.32
601-700	42.46
Above 700	47.38
Three (3)-Phase	41.28

Subsequently, the typical monthly consumption pattern of each scenario was evaluated which was further segregated into different applications of heating and cooking. For each scenario, the amount of gas released, and the resultant gas bill was evaluated due to the shifting of consumption on electricity. Similarly, the total electricity bill was evaluated after catering for the said transition. The total difference in the utility bills for gas and electricity enable computation of net energy burden on the consumer. It is pertinent to mention here that the capital cost to procure the devices was also included to estimate more robust cost benefit analysis for each scenario.

3.8 Data Sources

The microdata of the domestic consumers of the SNGPL and SSGCL has been utilized for evaluating the consumption-wise and consumer-wise statistics in the gas sector. For evaluating the share of the cooking, space, and water heating in the total annual gas consumption of each household, the Household Integrated Economic Survey 2018-19 (HIES 2018-19) microdata was employed . Similarly, the number of gas appliances for each quantile was estimated using the HIES 2018-19 microdata.

For the electricity sector, the IGCEP's approved base case formed basis for evaluating the incremental impacts of the proposed transition on the generation expansion and dispatch. On the commercial side, the applicable tariffs of the domestic gas and electricity consumers have been evaluated using the annual tariff determinations of the OGRA and NEPRA respectively. Lastly, for evaluating the impacts of the environmental emissions, the GHG emission factors of the IPCC have been utilized.

CHAPTER 4

RESULTS AND DISCUSSION

This section provides the quantitative estimates of the impacts on the pre-defined variables for each scenario as a result of effectuating the gas-to-electricity transition for space heating, water heating and cooking applications. For clarity and logical flow, the results have been segregated into four distinct scenarios. For each scenario, the consumption statistics (based on microdata analysis) were evaluated on monthly basis. Subsequently, the implications of natural gas savings for the said scenario and incremental generation expansion (based on the least cost expansion) have been evaluated. In the last part, the total impacts of transition have been consolidated in each scenario and the net impact on the consumer's affordability, fiscal and current account impacts and the environmental emissions have been calculated to determine the feasibility of transition under existing arrangements as well as steps required to effectuate the transition.

4.1 Scenario definition:

The consumption slabs of domestic gas consumers have been taken as reference for the purpose of scenario definition and assessment of impacts underneath each scenario. The resultant scenarios have been shown in table 3.11 and has been reproduced again for reference:

Table 4.1: Scenarios definition

Scenarios	Consumption Slab
S1	Consumption (C1) >4hm3
S2	3hm3< Consumption (C2) <4hm3
S3	2hm3< Consumption (C3) <3hm3
S4	1hm3< Consumption (C4) <2hm3

As the demand of the gas for the domestic consumers is projected to increase significantly (in case no significant intervention is carried out) in the subsequent years, the same impact has been incorporated in the analysis to carry out the comprehensive assessment of the proposed transition. Based on the demand growth of domestic consumers in the previous years as well as inputs from the SNGPL and SSGCL, the following annual demand projections have been assumed:

Table 4.2: Annual demand projections for domestic gas consumption

Category	2024	2025	2026	2027	2028	2029	2030	2031
SNGPL (Domestic)	5%	5%	5%	5%	5%	5%	5%	5%
SSGCL (Domestic)	3%	3%	3%	3%	3%	3%	3%	3%
Total (Domestic)	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%

Source: Author's estimation

In the following sub-sections, the detailed analysis and corresponding results against each scenario have been provided:

The consumption of gas by the different gas equipment, as a result of operation for one hour, is provided in the table below. The same reference consumption of equipment will be utilized for analysis in the subsequent sections:

Table 4.3: Estimated Per hour gas consumption of gas appliances

Appliances	Gas Consumption/hour (m3)	Electricity Consumption/hour (kWh)
Single burner stove	0.3	2.4
Double burner stove	0.556	4.3
Heater single plate	0.276	0.9
Heater double plate	0.504	1.2
Oven single burner	0.402	1.8
Oven double burner	0.744	5.3
Geyser without baffle	0.624	2.0

Source: World Bank

4.2 Scenario S1: Consumption greater than 4hm3 (C1>4hm3):

4.2.1 Consumption Profiles:

The monthly consumption profile for the year FY 21-22 for the consumption slab of greater than 4 hm3 has been provided in the table below:

Table 4.4: Monthly profile of consumers with consumption greater than 4hm3

Months	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	June-22
No. Of Consumers (thousands)	42.6	20.6	18.6	37.0	32.5	80.9	11.7	52.9	27.4	19.6	18.3	65.6
Consumptions (1000 hm3)	46.4	31.9	28.7	37.5	36.9	59.9	78.1	44.4	34.3	25.8	25.3	59.0

Source: Ministry of Energy (Petroleum Division)

It is pertinent to mention here that most of the consumption under this slab is shared by multiple households under a single meter. The device consumption under the quantile Q-5 for different devices, as computed under HIES 2018-19, is as under:

Table 4.5: Daily gas consumption of devices under the slab of greater than 4m3

Category of Consumption	Stoves	Heaters	Gas Oven	Water Heating
Greater than 4hm3	0.01112	0.06047	0.01488	0.04367

Source: Ministry of Energy (Petroleum Division)

Based upon the total consumption in the given slab and the number of households that is fed by a single meter, the total consumption by different applications under the slab of greater than 4 hm3 is as under:

Table 4.6: Monthly consumption of gas by different devices under the monthly slab of greater than 4hm3 (1000 hm3)

Device	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	June-22
Stove	431.3	296.9	267.1	157.2	38.6	54.6	71.2	45.8	75.6	116.2	235.8	549.3
Oven	32.4	22.3	20.1	11.8	2.9	4.1	5.3	3.4	5.6	8.7	17.7	41.3
Geysers				208.4	106.4	226.5	295.6	163.2	204.9	133.4		
Heater					221.1	313.7	409.4	232.4	56.7			

Source: Author's estimation

With the transition of gas consumption to electricity, there would be the requirement of the incremental power generation at the wholesale level. The incremental electricity generation requirement to meet the said demand has been evaluated as under:

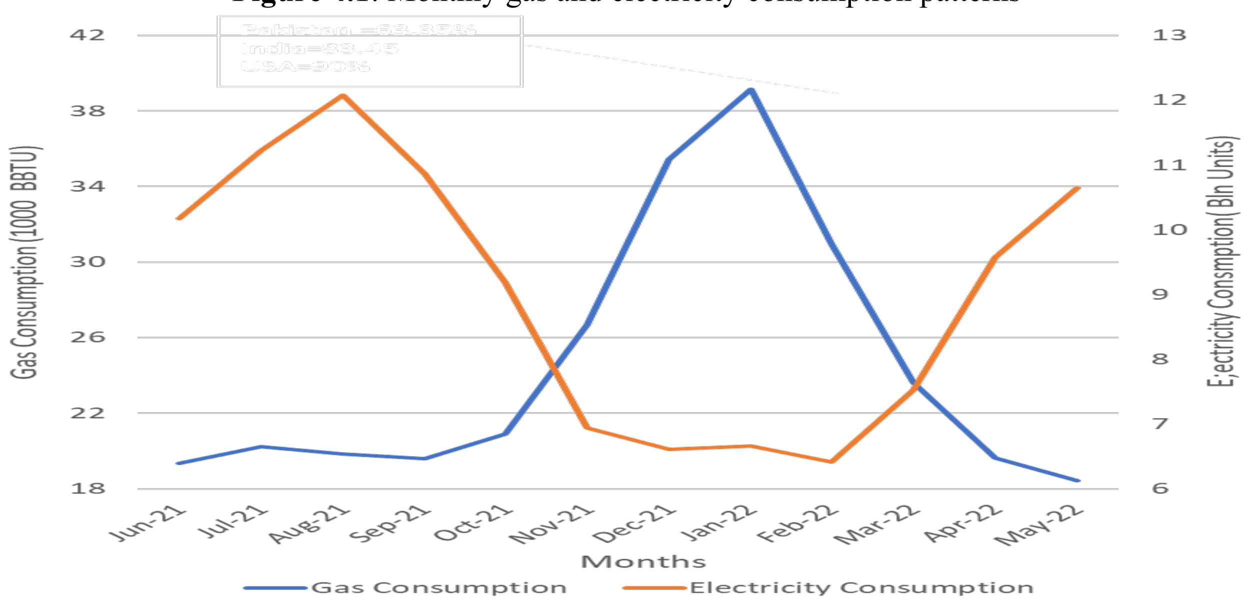
Table 4.7: Expected monthly consumption of electricity (Million Units) by different devices under the slab of greater than 4hm3

Devices	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	June-22
Stoves	332	228.6	205.6	121.0	29.7	42.0	54.8	35.2	58.2	89.4	181.2	422.8
Ovens	23.1	15.9	14.3	8.4	2.0	2.9	3.8	2.4	4.0	6.2	12.6	29.4
Geysers				66.8	34.1	72.6	94.7	52.3	65.6	42.7		
Heaters					52.6	74.7	97.4	55.3	13.5			

Source: Author's estimation

The low demand in the electricity sector during the winter months provides an ideal opportunity to utilize existing generation capacity in the system to meet this incremental demand. The months electricity consumption pattern for one complete year is provided in the figure below:

Figure 4.1: Monthly gas and electricity consumption patterns



4.2.2 Annual gas and electricity projections:

Based upon the annual demand growth, as provided in table 4.2, and the monthly consumption profiles of gas consumption, the annual projected gas demand and equivalent electricity requirement to effectuate transition in the slab of greater than 4hm3 is provide in the following table:

Table 4.8: Projected annual domestic gas demand and equivalent electricity consumption for slab greater than 4hm3

Year	2024	2025	2026	2027	2028	2029	2030	2031
Projected Gas Demand (Mln. Hm3)	5.54	5.78	6.041	6.30	6.58	6.87	7.18	7.50
Equivalent Electricity Demand (Bln. Units)	3.52	3.67	3.84	4.01	4.18	4.37	4.56	4.76
Gas Volume Released after transition (Mln.Hm3)	0.11	0.24	0.46	0.97	1.70	2.33	3.02	3.76

Source: Author's estimation

4.2.3 Generation additions & dispatch analysis:

Based on the incremental projected demand, the net generation additions in the system and the generation mix for each year has been computed using long term generation expansion model. The results of the simulation with annual incremental capacity expansion in the system is provided below:

Table 4.9: Net capacity additions in the grid for S1 scenario

Year	2024	2025	2026	2027	2028	2029	2030	2031
Capacity Addition (MW)	-	-	-	-	41	-	-	-

It is pertinent to highlight here that the mere 41 MW incremental capacity addition is required to meet the demand of the transmission under this slab of gas consumers. This is primarily on account of the fact that the existing and planning generation capacity in the grid system is significantly over and above the prevailing demand in the system (specifically for the winter months). . With the proposed transition of heating demand to electricity in the winter season, the incremental demand can be easily managed by the available transmission infrastructure in the system. As major of the demand increased is expected to be in the centre region, the proposed transition will enable greater stability of the grid and efficient utilization of the cheap resources in the south region primarily on account of the enhanced transfer capability of South-Centre transmission corridor .

Similarly, the annual dispatch factor of generation capacity based on multiple fuels is provided in the dispatch analysis below:

Table 4.10: Annual dispatch analysis for S1 scenario

Fuel	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
Bagasse	0.8%	0.7%	0.7%	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%
Coal	15.7%	14.5%	13.9%	13.8%	12.5%	12.0%	10.9%	11.3%	10.1%
Gas	9.3%	8.5%	8.0%	6.9%	6.2%	5.8%	4.9%	3.9%	1.6%
HSD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydel	26.5%	26.8%	27.1%	28.6%	32.6%	32.7%	32.9%	36.9%	44.9%
Imp Coal	13.9%	13.1%	15.8%	14.4%	11.6%	10.8%	10.7%	12.2%	9.4%
Import	0.3%	1.2%	2.3%	2.0%	1.9%	1.8%	1.7%	1.7%	1.5%
Mix (Captive)	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Nuclear	16.0%	16.0%	14.8%	13.2%	12.6%	12.9%	12.0%	10.9%	11.7%
RFO	2.3%	1.1%	0.6%	0.2%	0.2%	0.2%	0.3%	0.0%	0.0%
RLNG	10.5%	9.8%	5.0%	4.1%	2.5%	2.7%	5.2%	2.7%	1.1%
Solar	1.3%	4.2%	7.4%	8.7%	8.6%	8.6%	8.7%	8.4%	8.3%
Wind	3.5%	3.9%	4.3%	7.2%	10.6%	11.7%	12.0%	11.3%	10.8%
Grand Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100%**

Source: Author's estimation

4.2.4 Cost benefit analysis:

With the applicable tariff of gas and electricity, the net impact of the proposed transition on the consumer for different applications is computed as under:

Table 4.11: Cost Benefit analysis (annual PKR) for S1 scenario

Application	Annual Electricity Bill	Annual Gas Bill	Appliance Cost	Annual Profit (+)/Loss(-)	Pay Back
Water Heating	99,302	59,314	26,600	- 39,988	-
Space Heating	85,350	82,558	192,000	- 2,792	-
Cooking oven	145,302	20,186	25,470	- 125,116	

Table 4.12: Cost Benefit analysis during winter months (Nov-Feb) for S1 scenario (PKR)

Application	Winter Electricity Bill	Winter Gas Bill	Appliance Cost	Profit (+)/Loss(-)	Pay Back
Water Heating	72,871	53,286	26,600	- 19,585	-
Space Heating	82,488	81,497	192,000	- 991	-
Cooking (Stove)	47,771	14,485	25,470	- 33,286	-

The cost benefit analysis has been carried out for the entire year as well as for the winter months only (November-February). As evident from the tables above, none of the heating applications through electricity is viable for the either case at the existing prices of electricity and gas. It is pertinent to mention here that the applicable gas tariff for different domestic consumers provides for the last slab benefit, however, the same benefit is not available for the electricity sector. This difference of the incentive mechanism makes the transitioning of gas consumers to electricity even more infeasible. In the next chapter, the grid parity to attain this transition for different slabs has been calculated which will form basis for the policy interventions.

4.2.5 Impact on fiscal space and current account:

With the transition of the consumption of gas slab greater than 4hm3, the annual impact on the fiscal and current accounts have been calculated. For the purpose of computation of current account, it is envisaged that the incremental consumption avoided in the gas sector is available on the RLNG rates. The projected annual average RLNG rates, based on the long-term future projections of Spot market, are as under:

Table 4.13: Projected annual average RLNG rates ($/MMTBU)

Years	2024	2025	2026	2027	2028	2029	2030	2031
RLNG Rates	12.35	11.57	12.47	10.68	10.66	10.60	10.52	10.70

Source: Author's estimation

The resultant impact on current account in the following table.

Table 4.14: Annual impact on current account for S1 scenario

Years	2024	2025	2026	2027	2028	2029	2030	2031
Impact on current account (Mln. $)	1.13	(1.87)	(9.50)	(47.38)	(51.12)	(76.82)	(85.41)	(103.44)

The analysis demonstrates that excluding the year of 2024 that witness an unfavorable impact on the current account, there is a progressive reduction of exposure on the current account with the proposed transition under the given scenario.

With the proposed transition, there is a tendency of reduction in prices of electricity due to capacity leverage. At the same time, this will result in reduction of inbuilt subsidy, as paid through tariff differential subsidy, by the finance division.

The projected net annual impact on the fiscal space is provided as under:

Years	2024	2025	2026	2027	2028	2029	2030	2031
Incremental Subsidy (+) / Surplus (-)	(334)	(3,686)	(6,721)	(13,725)	(23,418)	(23,837)	(25,419)	(27,863)

Tax Collection	191	267	358	545	569	(1,106)	(2,942)	(5,363)
Net Saving	525	3,953	7,079	14,269	23,987	22,731	22,477	22,500

Table 4.15: Annual impact on fiscal subsidy (Mln Rs.) for S1 scenario

From the table, it is evident that the proposed transition is beneficial for the overall fiscal space of the federal government. The net savings to the fiscal space is Rs. 525 million for FY-24 which increases to almost Rs. 22.5 billion annually in the year of FY-31.The major reason of the small fiscal savings in FY-24 25 is primarily due to the fact that net tariff increases in the electricity sector due to the transition is not very significant, thereby resulting in comparatively reduced fiscal saving. Furthermore, the major increase in fiscal saving from FY 25 to FY-28 is due to the fact that the transition of gas consumers to electricity is higher in percentage terms for the same period with comparatively higher saturation in the later years .

It is pertinent to mention here that the consumers under the slab for monthly consumption of greater than 4hm3 cross-subsidize the remaining the gas consumers of the lower slab. This transition of consumers to electricity will result in greater requirement of subsidy in the gas sector. On the contrary, inclusion of such consumers' consumption in the electricity sector will increase the electricity consumption slab, resulting in reduction of tariff-differential/cross subsidy being disbursed to the lower slabs of electricity consumers. It is worth mentioning here that the commercial losses (on account to electricity theft) is not much relevant in such analysis as the existing consumers already utilizing electricity without paying the bills have no incentive to utilize gas (and pay its bills) for space heating and cooking (provided they have the associated gas connection).

4.2.6 Impact on environmental emissions:

The transition of consumption to electricity shall have two impacts on the carbon emission. The emission of gas sector shall reduce based on reduced appliances used for the cooking, space and water heating. At the same time, the total emissions of electricity sector may increase based on the annual dispatch and power plants involved to meet the incremental demand. The total impact on the emissions on annual basis has been provided in the table which include both the impact of gas and electricity sector as well as overall net impact on the emissions over the study horizon.

Table 4.16: Impact on annual emissions for S1 scenario

Years	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
Gas Emission (Mln.MTon)	(0.035)	(0.080)	(0.128)	(0.192)	(0.350)	(0.279)	(0.290)	(0.468)
Electricity Emissions (Mln.MTon)	0.045	0.101	0.196	0.201	0.380	0.178	0.206	0.289
Net Emissions (Mln.MTon)	0.010	0.020	0.068	0.008	0.030	(0.100)	(0.084)	(0.178)

The results indicate that the despite of having increased emissions for the first few years, there are subsequent negative emissions in the later years (primarily because of greater penetration of renewables in grid system resulting into lower carbon signatures of the national grid). On the cumulative basis, the net emission reduction over the study horizon is to the tune of -0.226 Million MTons.

4.3. Scenario S2: Consumption greater than 3hm3 and less than 4 hm3(4hm3>C2>3hm3):

4.3.1 Consumption Profiles:

The monthly consumption profile for the year FY 21-22 for the consumption slab of greater than 3 hm3 has been provided in the table below:

Table 4.17: Monthly profile of consumers with consumption greater than 3hm3 and less than 4hm3

Months	**Jul-21**	**Aug-21**	**Sep-21**	**Oct-21**	**Nov-21**	**Dec-21**	**Jan-22**	**Feb-22**	**Mar-22**	**Apr-22**	**May-22**	**June-22**
No. Of Consumers	17.9	15.6	15.1	39.8	40.7	16.0	24.1	95.7	27.6	17.3	16.8	18.5

(thousands)												
Consumptions (1000 hm3)	612.1	532.0	516.6	135.8	138.2	543.9	819.2	324.12	938.8	590.2	573.3	638.5

Source: Ministry of Energy (Petroleum Division)

The device consumption under the quantile Q-4 for different devices, as computed under HIES 2018-19, is as under:

Table 4.18: Daily gas consumption of devices under the slab of consumption greater than 3hm3 and less than 4hm3

Category of Consumption	Stoves	Heaters	Gas Oven	Water Heating
hm3	0.01112	0.04031	0.00804	0.03743

With the total consumption, as provided in the given slab, the total consumption by different applications under the given slab is as follows:

Table 4.19: Monthly consumption of gas by different devices under the slab of consumption greater than 3hm3 and less than 4hm3 (1000 hm3*)*

Devices	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	June-22
Stoves	58.8	51.1	49.6	62.4	19.1	64.5	97.2	43.3	24.3	29.1	55.0	61.3
Ovens	2.3	2.0	2.0	2.5	0.8	2.6	3.9	1.7	.9	1.2	2.2	2.4
Geysers				70.9	45.2	229.5	345.7	132.3	56.4	28.6		
Heaters					73.0	247.1	372.2	146.6	12.1			

Source: Ministry of Energy (Petroleum Division)

The corresponding incremental electricity generation requirement to meet the said demand, had the said transition already taken place, is provided below:

Table 4.20: Expected monthly consumption of electricity (Million Units) by different devices under the slab of consumption greater than 3hm3 and less than 4hm3.

Devices	**Jul-21**	**Aug-21**	**Sep-21**	**Oct-21**	**Nov-21**	**Dec-21**	**Jan-22**	**Feb-22**	**Mar-22**	**Apr-22**	**May-22**	**June-22**
Stoves	45.2	39.3	38.2	48.0	14.7	49.3	74.8	33.3	18.7	22.4	42.4	47.2
Ovens	2.2	1.9	1.9	2.4	0.7	2.4	3.7	1.5	0.9	1.1	2.1	2.3
Geysers				22.7	14.4	73.5	110.8	42.4	18.0	9.1		
Heaters					17.3	58.8	88.6	34.9	2.8			

Source: Author's estimation

4.3.2 Annual gas and electricity projections:

Based upon the annual demand growth of gas consumption, the annual projected gas demand and equivalent electricity requirement to effectuate transition in the slab of consumption greater than 3hm3 and less than 4hm3 is provide in the following table:

Table 4.21: Projected annual domestic gas demand and equivalent electricity consumption under the slab of consumption greater than 3hm3 and less than 4hm3

Year	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
Projected Gas Demand (Mln. hm3)	2.61	2.73	2.85	2.97	3.1	3.2	3.4	3.5
Equivalent Electricity Demand (Bln. Units)	1.30	1.37	1.43	1.48	1.55	1.62	1.69	1.76

Gas Volume Released after transition (Mln.Hm3)	0.05	0.12	0.25	0.52	0.93	1.33	1.76	2.24

Source: Author's estimation

4.3.3 Generation additions & dispatch analysis:

Based on the incremental projected demand, the net generation additions in the system and the generation mix for each year is provided in the table below:

Table 4.22: Net capacity additions in the grid for S2 scenario

Year	2024	2025	2026	2027	2028	2029	2030	2031
Capacity Addition (MW)	-	-	-	50	-	58	-	-

Table 4.23: Annual dispatch analysis for S2 scenario

Fuel	2024	2025	2026	2027	2028	2029	2030	2031
Bagasse	0.7%	0.7%	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%
Coal	14.5%	13.9%	13.8%	12.6%	12.0%	10.9%	11.2%	10.2%
Gas	8.5%	8.0%	6.9%	6.3%	5.8%	4.9%	3.9%	1.7%
HSD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydel	26.8%	27.1%	28.6%	32.6%	32.6%	32.7%	36.9%	44.6%
Imp Coal	13.1%	15.8%	14.4%	11.6%	11.0%	10.9%	12.2%	9.4%
Import	1.2%	2.3%	2.0%	1.9%	1.8%	1.7%	1.7%	1.5%
Mix (Captive)	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%

Nuclear	16.0%	14.8%	13.2%	12.6%	12.8%	12.0%	10.9%	11.7%
RFO	1.1%	0.6%	0.2%	0.2%	0.2%	0.3%	0.0%	0.0%
RLNG	9.8%	5.1%	4.1%	2.4%	2.8%	5.2%	2.9%	1.2%
Solar	4.2%	7.4%	8.6%	8.6%	8.6%	8.8%	8.5%	8.3%
Wind	3.9%	4.3%	7.3%	10.6%	11.7%	12.0%	11.3%	10.8%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: Author's estimation

The aforementioned demonstrates the progressive higher share of renewables in the energy mix in the future years, thereby resulting in more clean and indigenous energy mix of the national grid. This will not only result in reducing the annual incremental carbon emissions from the grid but also contribute towards improving the overall energy security.

4.3.4 Cost benefit analysis:

At the applicable tariff of gas and electricity, the net impact of the proposed transition on the consumer for different applications is as under:

Table 4.24: Cost benefit analysis (annual PKR) for S2 scenario

Application	Annual Electricity Bill	Annual Gas Bill	Appliance Cost	Annual Profit (+)/Loss (-)	Pay Back
Water Heating	102,069	35,470	26,600	- 66,599	-
Space Heating	69,088	36,597	192,000	- 32,490	-
Cooking (Stove)	174,070	15,165	25,470	- 158,905	-

Table 4.25: Cost benefit analysis during winter months (Nov-Feb) for S2 scenario (PKR)

Application	**Winter Electricity Bill**	**Winter Gas Bill**	**Appliance Cost**	**Annual Profit (+)/Loss (-)**	**Pay Back**
Water Heating	76,039	30,466	26,600	- 45,573	-
Space Heating	66,967	35,905	192,000	- 31,062	-
Cooking (Stove)	58,185	9,627	25,470	- 48,558	-

As evident, the cost benefit analysis does not show feasible transaction for the consumers under this slab at the existing applicable tariffs. This requires intervention from the government to make it commercial feasible solution for the consumers. One such proposal has been discussed in chapter 5 and the revised cost benefit analysis has been carried out. Similarly, chapter 6 provides the policy recommendation to facilitate procurement of the electric appliances by the prospective consumers undergoing gas-to-electricity transition.

4.3.5 Impact on fiscal space and current account:

With the transition of the consumption of consumers under the given scenario, the annual impact on the fiscal and current accounts have been calculated. It is pertinent to mention here that the impact includes the offsetting impact of on account to transition to the electricity sector.

Table 4.26: Annual impact on current account for S2 scenario

	2024	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
Impact on current account (Mln $)	(0.26)	(2.19)	(6.82)	(23.47)	(29.89)	(45.37)	(54.10)	(67.44)

With the proposed transition, there is a tendency of reduction in prices of electricity due to capacity leverage. This will result in reduction of inbuilt subsidy, as paid through tariff differential subsidy, on the accounts of the finance division.

The projected annual subsidy impact is provided as under:

Table 4.27: Annual impact on fiscal subsidy (Mln Rs.) for S2 scenario

Years	2024	2025	2026	2027	2028	2029	2030	2031
Incremental Subsidy (+) / Surplus (-)	(383)	(5,294)	(8,961)	(9,206)	(20,943)	(21,603)	(26,565)	(34,091)
Tax Collection	186	214	190	(1,310)	(1,614)	(4,000)	(6,169)	(9,002)
Net Saving	569	5,508	9,151	7,895	19,330	17,603	20,396	25,088

4.3.6 Impact on environmental emissions:

The transition of consumption to electricity shall have two impacts on the carbon emission. The emission of gas sector shall reduce based on reduced appliances used for the cooking, space and water heating. At the same time, the total emissions of electricity sector may increase based on the annual dispatch and power plants involved to meet the incremental demand. The total impact on the emissions on annual basis has been provided in the table which include both the impact of gas and electricity sector as well as total net impact on the economy as a whole.

Table 4.28.: Impact on annual emissions for S2 scenario

Years	2024	2025	2026	2027	2028	2029	2030	2031
Gas Emissions (Million MTon)	(0.028)	(0.041)	(0.404)	(0.085)	(0.010)	(0.075)	(0.073)	(0.144)
Electricity Emissions (Million	0.031	0.048	0.429	0.088	0.021	0.034	0.038	0.065

MTon)								
Net Emissions (Million MTon)	0.003	0.007	0.025	0.003	0.011	(0.041)	(0.036)	(0.078)

The results demonstrate progressive reduction of net emissions in the future years with the transition of consumers under this scenario. The cumulative reduction of emissions over the study horizon is estimated to the tune of 0.106 million tons.

4.4. Scenario S3: Consumption greater than 2hm3 and less than 3 hm3 (3hm3>C3>2hm3):

4.4.1 Consumption profiles

The monthly consumption profile for the year FY 21-22 for the consumption slab of greater 2hm3 and less than/equal to 3 hm3 has been provided in the table below:

Table 4.29: Monthly profile of consumers with consumption greater than 2hm3 and less than 3hm3

Months	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	June-22
No. Of Consumers (thousands	762.0	738.2	710.3	144.7	219.5	635.9	860.6	452.5	149.1	813.2	768.7	691.9
Consumptions (1000 hm3)	179.9	173.7	167.2	343.8	517.2	151.9	206.4	107.5	350.6	191.6	181.4	163.8

Source: Ministry of Energy (Petroleum Division)

The device consumption under the quantile Q-3 for different devices, as computed under HIES 2018-19, is as under:

Table 4.30: Daily gas consumption of devices under the slab of consumption greater than 2hm3 and less than 3hm3

Category of Consumption	**Stoves**	**Heaters**	**Gas Oven**	**Water Heating**

hm3	0.01112	0.02520	0.00804	0.03119

Source: Ministry of Energy (Petroleum Division)

With the total consumption, as provided in the given slab, the total consumption by different applications under the given slab is as follows:

Table 4.31: : Monthly consumption of gas by different devices under the slab of consumption greater than 2hm3 and less than 3hm3 (1000 hm3*)*

Device	**Jul-21**	**Aug-21**	**Sep-21**	**Oct-21**	**Nov-21**	**Dec-21**	**Jan-22**	**Feb-22**	**Mar-22**	**Apr-22**	**May-22**	**June-22**
Stoves	172.8	166.9	160.7	173.0	95.8	237.4	322.6	188.8	106.6	102.9	174.3	157.4
Ovens	7.02	6.78	6.5	7.0	3.8	9.6	13.1	7.6	4.3	4.1	7.0	6.3
Geyers				163.7	188.7	703.6	956.2	480.1	206.3	84.4		
Heater					228.6	568.3	772.3	398.9	33.2			

Source: Author's estimation

The corresponding incremental electricity generation requirement to meet the said demand, had the said transition already taken place, is estimated as under:

Table 4.32: Expected monthly consumption of electricity (Million Units) by different devices under the slab of consumption greater than 2hm3 and less than 3hm3

Devices	**Jul-21**	**Aug-21**	**Sep-21**	**Oct-21**	**Nov-21**	**Dec-21**	**Jan-22**	**Feb-22**	**Mar-22**	**Apr-22**	**May-22**	**June-22**
Stoves	133.0	128.4	123.7	133.1	73.7	182.7	248.3	145.3	82.1	79.2	134.1	121.1
Ovens	6.6	6.4	6.1	6.6	3.6	9.1	12.4	7.2	4.0	3.9	6.6	6.0
Geyers				52.4	60.4	225.5	306.5	153.9	66.1	27.0		
Heaters					54.4	135.3	183.9	94.9	7.9			

Source: Author's estimation

4.4.2 Annual gas and electricity projections:

Based upon the annual demand growth, the annual projected gas demand and equivalent electricity requirement to effectuate transition in the slab of greater than 2hm3 and less than 3hm3 is provided in the following table:

Table 4.33: Projected annual domestic gas demand and equivalent electricity consumption under the slab of consumption greater than 2hm3 and less than 3hm3

Year	2024	2025	2026	2027	2028	2029	2030	2031
Projected Gas Demand (Mln. Hm3)	7.54	7.88	8.22	8.58	8.96	9.36	9.77	10.21
Equivalent Electricity Demand (Bln. Units)	3.98	4.15	4.34	4.53	4.73	4.94	5.16	5.38
Gas Volume Released after transition (Mln.Hm3)	0.15	0.34	0.70	1.46	2.60	3.71	4.90	6.20

Source: Author's estimation

4.4.3 Generation additions & dispatch analysis:

Based on the incremental projected demand, the net capacity additions in the system and the generation mix for each year is provided in the table below:

Table 4.34: Net capacity additions in the grid for S3 scenario

Year	2024	2025	2026	2027	2028	2029	2030	2031
Capacity Addition (MW)	-	-	-	-	-	460	35	176

Table 4.35: Annual dispatch analysis for S3 scenario

Fuel	2024	2025	2026	2027	2028	2029	2030	2031
Bagasse	0.7%	0.7%	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%
Coal	14.5%	13.9%	13.8%	12.5%	11.9%	10.8%	11.1%	9.9%
Gas	8.5%	8.0%	6.8%	6.1%	5.8%	4.8%	3.8%	2.1%
HSD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydel	26.7%	27.1%	28.5%	32.4%	32.4%	32.6%	36.6%	44.2%
Imp Coal	13.2%	15.8%	14.2%	11.5%	10.9%	11.0%	11.9%	9.3%
Import	1.2%	2.3%	2.0%	1.8%	1.8%	1.7%	1.7%	1.5%
Mix (Captive)	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Nuclear	15.9%	14.7%	13.2%	12.6%	12.6%	11.8%	10.8%	11.6%
RFO	1.1%	0.7%	0.2%	0.2%	0.2%	0.3%	0.0%	0.0%
RLNG	9.8%	4.9%	4.1%	2.5%	2.9%	4.9%	3.0%	1.2%
Solar	4.2%	7.5%	8.9%	8.9%	9.0%	9.2%	8.9%	8.7%
Wind	3.9%	4.3%	7.4%	10.8%	11.8%	12.2%	11.5%	10.9%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: Author's estimation

As evident from the table above, the increasing share of renewables (including hydel generation) in the total mix will result in reduction of total annual emissions from the national grid as well as more energy secure system.

4.4.4 Cost benefit analysis:

At the applicable tariff of gas and electricity, the net impact of the proposed transition on the consumer for different applications is as under:

Table 4.36: Cost benefit analysis (annual PKR) for S3 scenario

Application	Annual Electricity Bill	Annual Gas Bill	Appliance Cost	Annual Profit (+)/Loss (-)	Pay Back
Water Heating	82,976	23,928	26,600	- 59,048	-
Space Heating	42,420	17,964	192,000	- 24,456	-
Cooking (Stove)	171,910	12,772	25,470	- 159,138	-

Table 4.37: Cost benefit analysis during winter months (Nov-Feb) for S3 scenario (PKR)

Application	Winter Electricity Bill	Winter Gas Bill	Appliance Cost	Annual Profit (+)/Loss (-)	Pay Back
Water Heating	62,056	20,031	26,600	- 42,025	-
Space Heating	41,108	17,543	192,000	- 23,565	-
Cooking (Stove)	57,006	7,510	25,470	- 49,496	-

4.4.5 Impact on fiscal space and current account:

With the transition of the consumption of consumers under the given scenario, the annual impact on the fiscal and current accounts have been calculated. It is pertinent to mention here that the impact includes the offsetting impact of on account to transition to the electricity sector.

Table 4.38: Annual impact on current account for S3 scenario

	2024	2025	2026	2027	2028	2029	2030	2031
Impact on current account (Mln $)	(0.11)	(5.19)	(17.74)	(67.69)	(82.19)	(124.96)	(146.05)	(180.54)

The projected annual subsidy impact is provided as under:

Table 4.39: Annual impact on fiscal subsidy (Mln Rs.) for S3 scenario

Years	2024	2025	2026	2027	2028	2029	2030	2031
Incremental Subsidy (+) / Surplus (-)	(823)	(6,265)	(10,577)	(5,921)	(24,538)	(29,226)	(46,296)	(65,867)
Tax Collection	174	173	(7)	(3,056)	(2,857)	(5,017)	(6,079)	(8,764)
Net Saving	996	6,438	10,570	2,865	21,681	24,209	40,216	57,103

4.4.6 Impact on environmental emissions:

The transition of consumption to electricity shall have two impacts on the carbon emission. The emission of gas sector shall reduce based on reduced appliances used for the cooking, space and water heating. At the same time, the total emissions of electricity sector may increase based on the annual dispatch and power plants involved to meet the incremental demand. The total impact on the emissions on annual basis has been provided in the table which include both the impact of gas and electricity sector as well as total net impact on the economy as a whole.

Table 4.40.: Impact on Annual Emissions for S3 scenario

Years	2024	2025	2026	2027	2028	2029	2030	2031
Gas Emissions (Million MTon)	(0.851)	(1.183)	(0.396)	(0.256)	(0.064)	(0.267)	(0.269)	(0.507)
Electricity Emissions (Million MTon)	0.861	1.206	0.477	0.265	0.100	0.138	0.157	0.261
Net Emissions (Million MTon)	0.011	0.023	0.081	0.010	0.036	(0.129)	(0.112)	(0.245)

As expected, the results demonstrates that the net emission reduce to the tune of 0.325 Million Tonnes of CO_2 over the study horizon under the scenario S3.

4.5. Scenario S4: Consumption greater than 1hm3 and less than 2 hm3(2hm3>C4>1hm3):

4.5.1 Consumption profiles

The monthly consumption profile for the year FY 21-22 for the consumption slab of greater than 1 hm3 and less than 2hm3 has been provided in the table below:

Table 4.41: Monthly profile of consumers with consumption greater than 1hm3 and less than 2hm3

Months	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	June-22
No. Of Consumers (thousands)	803.1	813.7	796.0	113.6	184.1	278.0	305.4	234.1	138.0	864.0	771.6	707.7
Consumptions (1000 hm3)	104.4	105.6	103.2	151.1	254.2	389.7	431.4	321.2	182.0	112.3	100.6	919.6

Source: Ministry of Energy (Petroleum Division)

The device consumption under the quantile Q-1 for different devices, as computed under HIES 2018-19, is as under:

Table 4.42: Daily gas consumption of devices under the slab of consumption greater than 1hm3 and less than 2hm3

Category of Consumption	**Stoves**	**Heaters**	**Gas Oven**	**Water Heating**
hm3	0.01500	0.01656	0.02010	0.02496

Source: Ministry of Energy (Petroleum Division)

With the total consumption, as provided in the given slab, the total consumption by different applications under the given slab is as follows:

Table 4.43: Monthly consumption of gas by different devices under the slab of consumption greater than 1hm3 and less than 2hm3 (1000 hm3)

Devices	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	June-22
Stoves	970.4	981.9	959.9	923.5	746.4	974.5	1078.7	889.1	766.5	718.8	935.4	855.1
Ovens	73.1	73.9	72.3	69.5	56.2	73.4	81.2	66.96	57.7	54.1	70.4	64.4
Geyers				518.4	871.5	1712.8	1895.9	1341.1	879.2	349.5		
Heaters					867.4	1,136.4	1,257.9	915.2	116.7			

Source: Author's estimation

The corresponding incremental electricity generation requirement to meet the said demand, had the said transition already taken place, is provided below:

Table 4.44: Expected monthly consumption of electricity (Million Units) by different devices under the slab of consumption greater than 1hm3 and less than 2hm3

Devices	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	June-22
Stoves	791.1	800.5	782.4	752.8	608.4	794.4	879.3	724.8	624.8	586.0	762.5	697.1
Ovens	32.7	33.1	32.4	31.2	25.2	32.9	36.4	30.0	25.9	24.3	31.6	28.9
Geyers				166.1	279.3	548.9	607.6	429.8	281.7	112.0		
Heaters					282.8	370.5	410.1	298.4	38.0			

Source: Author's estimation

4.5.2 Annual gas and electricity projections:

Based upon the annual demand growth, as provided in table 4.2, and the monthly consumption profiles of gas consumption, the annual projected gas demand and equivalent electricity requirement to effectuate transition in the slab of greater than 1hm3 and less than 2 hm3 is provided in the following table:

Table 4.45: Projected annual domestic gas demand and equivalent electricity consumption under the slab of consumption greater than 1hm3 and less than 2hm3

Year	2024	2025	2026	2027	2028	2029	2030	2031
Projected Gas Demand (Mln. Hm3)	25.57	26.7	27.8	29.1	30.4	31.7	33.1	34.6
Equivalent Electricity Demand (Bln. Units)	17.3	18.0	18.8	19.7	20.5	21.4	22.4	23.4
Gas Volume Released after transition (Mln.Hm3)	0.51	1.08	2.14	4.48	7.84	10.76	13.92	17.33

Source: Author's estimation

4.5.3 Generation additions & dispatch analysis:

Based on the incremental projected demand, the net generation additions in the system and the generation mix for each year is provided in the table below:

Table 4.46: Net capacity additions in the grid for S4 scenario

Year	2024	2025	2026	2027	2028	2029	2030	2031
Capacity Addition (MW)	-	-	66	-	-	-	-	-

Table 4.47: Annual dispatch analysis for S4 scenario

Fuel	2024	2025	2026	2027	2028	2029	2030	2031
Bagasse	0.7%	0.7%	0.7%	0.7%	0.6%	0.6%	0.6%	0.5%
Coal	14.4%	13.8%	13.7%	12.9%	11.8%	10.8%	10.6%	9.9%
Gas	8.5%	7.9%	7.0%	6.1%	5.8%	4.9%	3.8%	2.7%
HSD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydel	26.7%	26.9%	28.3%	31.8%	31.7%	31.7%	35.1%	42.1%
Imp Coal	13.1%	16.1%	14.6%	11.4%	11.5%	11.3%	12.7%	9.8%

Import	1.2%	2.3%	2.0%	1.8%	1.7%	1.7%	1.6%	1.4%
Mix (Captive)	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Nuclear	15.8%	14.7%	13.1%	12.3%	12.4%	11.7%	10.6%	11.1%
RFO	1.1%	0.6%	0.2%	0.2%	0.2%	0.2%	0.0%	0.0%
RLNG	10.1%	5.3%	4.1%	2.8%	2.8%	4.9%	3.8%	2.3%
Solar	4.2%	6.8%	7.5%	7.9%	8.4%	8.3%	8.0%	7.8%
Wind	3.9%	4.8%	8.7%	11.9%	13.1%	13.9%	13.0%	12.3%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: Author's estimation

4.5.4 Cost benefit analysis:

At the applicable tariff of gas and electricity, the net impact of the proposed transition on the consumer for different applications is as under:

Table 4.48: Cost benefit analysis (annual PKR) for S4 scenario

Application	Annual Electricity Bill	Annual Gas Bill	Appliance Cost	Annual Profit (+)/Loss (-)	Pay Back
Water Heating	66,842	15,969	26,600	- 50,873	-
Space Heating	38,493	9,453	138,000	- 29,040	-
Cooking (Stove)	239,819	16,084	15,570	- 223,734	-

Table 4.49: Cost benefit analysis during winter months (Nov-Feb) for S4 scenario (PKR)

Application	Winter Electricity Bill	Winter Gas Bill	Appliance Cost	Annual Profit (+)/Loss (-)	Pay Back
Water Heating	50,172	12,683	26,600	- 37,489	-
Space Heating	37,310	9,178	138,000	- 28,132	-
Cooking (Stove)	82,318	8,079	15,570	- 74,239	-

As evident from the tables above, the proposed transition under this scenario is not viable at the applicable gas and electricity tariffs.

4.5.5 Impact on fiscal space and current account:

With the transition of the consumption of consumers under the given scenario, the annual impact on the fiscal and current accounts have been calculated. It is pertinent to mention here that the impact includes the offsetting impact of on account to transition to the electricity sector,.

Table 4.50: Annual impact on current account for S4 scenario

	2024	2025	2026	2027	2028	2029	2030	2031
Impact on current account (Bln $)	6.93	(6.15)	(40.31)	(222.27)	(231.86)	(351.16)	(385.05)	(463.85)

The projected annual subsidy impact is provided as under:

Table 4.51: Annual impact on fiscal subsidy (Bln Rs.) for S4 scenario

Years	2024	2025	2026	2027	2028	2029	2030	2031
Incremental Subsidy (+) / Surplus (-)	(4,228)	(13,973)	(27,049)	(42,691)	(77,704)	(112,320)	(169,517)	(233,742)
Tax Collection	951	1,506	3,057	3,137	7,035	9,459	15,308	16,531
Net Saving	5,179	15,479	30,106	45,828	84,739	121,779	184,826	250,273

4.5.6 Impact on environmental emissions:

The transition of consumption to electricity for this consumption slab is provided in the table below:

Table 4.52: Impact on Annual Emissions for S4 scenario

Years	2024	2025	2026	2027	2028	2029	2030	2031
Gas Emissions (Million MTon)	(0.132)	(0.294)	(0.526)	(0.918)	(0.924)	(1.598)	(1.777)	(2.671)
Electricity Emissions (Million MTon)	0.182	0.395	0.862	0.958	1.072	1.099	1.360	1.783
Net Emissions (Million MTon)	0.050	0.101	0.336	0.041	0.148	(0.498)	(0.417)	(0.888)

The net emission witnesses increase trend in the initial years, however, the progressive reduction in the net emission in the later years exceed the initial increase. The net reduction in emissions over the study horizon is to the tune of -1.127 Million MTon.

CHAPTER 5

ANALYSIS OF QUANTITATIVE RESULTS

5.1 Introduction

This section provides the detailed analysis of the quantitative results obtained for different slabs and the evaluation of different modalities necessary to effectuate transition for different consumer slabs. In the previous chapter, the impact of transition on the highest and lowest slabs have been evaluated on the consumer costs, emission, subsidies and foreign exchange. Each parameter (under consideration) shall be comparatively evaluated for all the scenarios in the individual sections of this chapter to provide consolidated and comprehensive analysis for informed decision making.

5.2 Cost benefit analysis:

At the existing applicable tariff, the proposed transition of gas to electricity for heating and cooking application is not viable (in terms of their financial viability) for all the consumers. The slabs wise gain\loss is provided below for all the evaluated slabs.

Table 5.1: Cost-benefit analysis of transition on different slabs with applicable gas and electricity tariff (PKR)

Slab	Space Heating (Gain/Loss)	Water Heating (Gain/Loss)	Cooking (Gain/Loss)
Greater than 4 hm3	- 991	- 19,585	- 33,286
Between 3 and 4 hm3	- 31,062	- 45,573	- 48,558
Between 2 and 3 hm3	- 23,565	- 42,025	- 49,496
Between 1 and 2 hm3	- 28,132	- 37,489	- 74,239

It is evident from the table 5.1 that the proposed transition in not viable for all the slabs at the present rates for all the applications. Furthermore, the cost of transition witnesses the increasing trend as we move towards the lower slabs of gas consumption. In the following sub-sections, the cost-benefit analysis has been evaluated under multiple scenarios through extension of incremental incentive package for winter months as well as required gas tariffs to effectuate the transition.

5.2.1 Extension of winter incremental package:

As already discussed in chapter 1, there is a significant spare capacity available in the system for utilization during winter month. Extending the package to all the gas consumers for shifting to electricity by charging the marginal rates for the incremental consumption for the electricity consumers. It is pertinent to mention here that the winter packages had been implemented (on marginal cost basis) in the previous years to provide affordable supply to domestic and industrial consumers. However, for the year FY 24, the package was evaluated but not extended due to the technical constraints in the system. With the prospective mitigation of transmission constraints expected at the end of December 2025, it provides an opportunity to re-evaluate and extend the same in the next winter season.

For the winter months, the marginal units that supply electricity are the RLNG units in the center. At the spot RLNG rate of 11 $/MMBTU, the per unit wholesale rates, grossed up by the relevant technical losses, translates to the tune of Rs. 23.46/kwh. At the proposed marginal cost, to be charged on the incremental consumption (against the reference consumption of the same month of the previous year), the revised cost benefit analysis for different slabs is as under:

Table 5.2: Cost-benefit analysis of transition with incremental package for electricity in winter months (PKR)

Slab	Space Heating (Gain/Loss)	Water Heating (Gain/Loss)	Cooking-Winter (Gain/Loss)	Cooking-Annual (Gain/Loss)
Greater than 4 hm3	34,617	11,873	- 12,664	- 104,494
Between 3 and 4 hm3	4,653	- 5,031	- 17,522	- 127,869
Between 2 and 3 hm3	- 1,990	- 9,550	- 19,639	- 129,281
Between 1 and 2 hm3	- 8,402	- 10,982	- 30,705	- 180,200

From the table, it is evident that extending the winter incentive packages for the electricity sector results in the favorable transition for the first two slabs for space heating and only for first slab for the application of water heating. This also concludes that mere incentivizing the electricity consumption through the seasonal packages without amending the tariff rates for the gas sector shall not enable sustainable and cost-neutral transition. In the following section, the gas parities have been evaluated for different applications for effectuating gas-to-electricity transition.

5.2.2 Tariff increase for gas slabs :

The alternate mechanism to achieve the transition parity is to increase the gas rates of the different slabs to effectuate said transition. The required increase of gas tariffs shall not be same for the different slabs. In the table below, the comprehensive analysis has been presented that reflects the require tariff increase for different slabs to achieve the transition parity in different applications.

Table 5.3: Tariff revision required for viable gas-to-electricity transition: space heating (with inclusion of winter package)

Consumption Slab	Sales Price (Rs. /MMBTU) - Variable Charges	Applicable Tariff	Difference	% Change Required in tariff
upto 1 Hm3	2350	1000	1350	135%
upto 2 Hm3	2850	1600	1250	78%
upto 3 Hm3	3000	3000	0	0%
upto 4 Hm3	3200	3500	-300	-
Above 4 Hm3	3500	4000	-500	-

Table 5.4: Tariff revision required for viable gas-to-electricity transition: space & water heating (with inclusion of winter package)

Consumption Slab	Sales Price (Rs. /MMBTU) - Variable Charges	Applicable Tariff	Difference	% Change Required in tariff
upto 1 Hm3	2800	1000	1800	180%
upto 2 Hm3	3100	1600	1500	94%
upto 3 Hm3	3250	3000	250	8%
upto 4 Hm3	3500	3500	0	-
Above 4 Hm3	4000	4000	0	-

Table 5.5: Tariff revision required for viable gas-to-electricity transition: cooking, space & water heating (with inclusion of winter package)

Consumption Slab	Sales Price (Rs. /MMBTU) - Variable Charges	Applicable Tariff	Difference	% Change
upto 1 Hm3	3150	1000	2150	215%

upto 2 Hm3	3800	1600	2200	138%
upto 3 Hm3	5000	3000	2000	67%
upto 4 Hm3	6500	3500	3000	86%
Above 4 Hm3	7000	4000	3000	75%

Based on the aforementioned parities, the highest tariffs increase is required for the conversion of all the three applications to the electricity counterpart, whereas the least increase is required for the conversion of the space heating applications. The parities provided above serve as a reference for the Ministry of Energy and the Oil & Gas Regulatory Authority (OGRA) to gradually increase the gas tariffs for effectuating the progressive transition of different gas-based applications to electricity.

5.3 Impact on current account:

All the scenarios of gas transition exhibit a positive impact on the current account balance of the country. The scenario wise impact of the proposed transition is consolidated in the table below. It is pertinent to mention here that the current amount computation takes into consideration the incremental foreign investment required to meet the incremental electricity supply for the transitioned consumers.

Table 5.6: Impact of gas-to-electricity transition on current account

Slab	Forex Saving (Mln $)	Forex Required (Mln $)	Net Saving (+)/Deficit(-) (Mln $)
Greater than 4 hm3	659	145	514
Between 3 and 4 hm3	381	61	320
Between 2 and 3 hm3	1,060	192	868
Between 1 and 2 hm3	3,042	723	2,319

5.4 Impact on fiscal space:

The impact of proposed transition on the fiscal space is consolidated and provided in the table below for each scenario.

Table 5.7: Impact of gas-to-electricity transition on fiscal space (Mln. Rs)

Years	2024	2025	2026	2027	2028	2029	2030	2031
Greater than 4 hm3	525	3,953	7,079	14,269	23,987	22,731	22,477	22,500
Between 3 and 4 hm3	569	5,508	9,151	7,895	19,330	17,603	20,396	25,088
Between 2 and 3 hm3	996	6,438	10,570	2,865	21,681	24,209	40,216	57,103
Between 1 and 2 hm3	5,179	15,479	30,106	45,828	84,739	121,779	184,826	250,273

The results show the favorable impact of the proposed scenario for all the cases. This provides inherit opportunity to incentive the said transition by expending the fiscal savings to subsidize electricity consumption by the consumers of electricity.

5.5 Impact on environmental emissions:

Environmental impacts are favorable for all the proposed transition scenarios. This is primarily on account of the larger reduction in the emissions due to avoidance of gas burning against the small increase for the incremental electricity generation. The grid emission factor is progressively reducing due to addition of clean and green energy mix. This enables in attainment of overall net negative emissions because of the proposed transition. The consolidated reduction in emissions is provided below:

Table 5.8: Net impact of gas-to-electricity transition on net carbon emissions

Slabs	Net Emission Reduction (Million (2024-31)
Greater than 4 hm3	-0.226
Between 3 and 4 hm3	-0.104
Between 2 and 3 hm3	-0.325
Between 1 and 2 hm3	-1.128

The reduction of the carbon emissions on such a massive scale provides an ideal opportunity to finance such project from the Green Climate Fund (GCF). Besides, the emission reduction can be traded in the international exchanges which provides the mechanism to leverage the cost incurred by the consumers of gas sector for the transitioning their gas-based application. With the existing rate of 1.5 $/M, the net revenue that can be earned over the study horizon is estimated in the table below:

Table 5.9: Net revenue against selling of emission credits in the international market

Slabs	Revenue Earned (Million Dollars) (2024-31)
Greater than 4 hm3	0.34
Between 3 and 4 hm3	0.16
Between 2 and 3 hm3	0.49
Between 1 and 2 hm3	1.69

CHAPTER 6

CONCLUSION AND POLICY RECOMMENDATIONS

6.1 Conclusion

The decrease in the indigenous gas reserves of Pakistan, coupled with the growing population and associated energy demand, has negatively impacted the over-all socio-economic and environmental indices of the country. The growing dependence on the imported gas , for the cooking and heating applications by the domestic consumers, as well has severely compromised the energy security of the company. Resultantly, the change in the global energy commodity prices directly impacts the overall current account of the country as well as affordability of the end consumers. This also result in placing pressure on the available fiscal space of the government, so to avoid relaying the full-scale transmission effects on the consumers. Lastly, the net environmental emission, as result of meeting ever increasing cooking and heating demand through the gas, witness a growing trend.

The generation expansion portfolio of power sector in Pakistan will result in the attainment of around 88% of the indigenous mix and 70% of green mix by 2030. At the same time, there is a significant dip in the demand of the electricity during the winter months, leaving a substantial amount of generation capacity standard that can be utilized for the incremental consumption during the peak winter months. With the capacity cost of the existing generation portfolio as a as sunk cost, the marginal cost of incremental generation is the pure fuel cost (and the variable operation and maintenance cost), which is substantially lower than the applicable tariff for the end consumers.

The constraints of the gas sector and the opportunity available in the power sector provides the feasible option for progressive transition of water heating, space heating and cooking demand of the gas to the electricity sector. The results demonstrate that the proposed transition shall have a positive impact on the government fiscal space, current account and the environmental emissions. The cost benefit analysis for the consumer undergoing transition is only favorable for the slabs of greater than 4 hm3. In order to make a favorable value proposition for the lower slabs, the fundamental tariff restructuring of both the electricity and gas sector is required in the phase-wise approach. Provided further, the cost-benefit analysis has been carried out for one year based on the cost of investment and expected cash flow earned as a result of transition. Based on the projected multi-year tariffs for gas and electricity, the net present value can be evaluated for the multi-year horizon.

6.2 Policy recommendations:

The progressive transition of gas consumer base to electricity for the applications of space heating, water heating and cooking shall require technical, commercial, and administrative interventions by the Government. With the existing processes and the underlying regulatory framework, there is no special incentive for the consumer to the effectuate said transition. The following key policy recommendations are placed to effectuate sustainable transition of heating and cooking applications of domestic consumers to electricity:

- The tariff structure of the gas sector for the domestic consumers should be progressively revised with the following considerations:
  - The highest slabs of domestic gas consumers should be charged tariff which is reflective of the prices of LPG in the commercial market;
  - The tariffs of lower slabs should be progressively increased in the successive four iterations to match the grid parity, as mentioned in table 5.5;
  - The electricity tariff should incentivize the transition of domestic gas consumers. For this purpose, the Cabinet should announce incremental consumption package for the winter months of November to February of each fiscal year. The reference consumption of domestic consumers in the previous years of the same months should be utilized as a reference to evaluate the incremental units consumption. Further, such package should be available for consecutive three (3) years to ensure certainty of cashflows for the consumers who need to carry out initial capital investments for the procurement of equipment.
- The concessional on-bill financing scheme needs to be rolled out by the State Bank, in collaboration with Ministry of Energy and Distribution companies, to enable getting the cheap finance for the procurement of heating and cooking equipment. The on-bill financing has been effectively utilized in the global space for effectuating the energy efficiency and emission reduction initiatives. The distribution companies shall develop and

maintain the credit worthiness of its consumers. The commercial banks, under the regulatory oversight of the state bank, shall approve the list of the eligible vendors for equipment. The credit rating coupled with the vendor list can support in approval of individual case for the disbursement of concessional loans to the consumers.

- The Weighted Average Cost of Gas (WACOG) should be implemented in the gas sector and the allocation of gas should be assigned at first in the priority list to the most productive consumer category.
- The National Energy Efficiency and Conversation Authority (NEECA) may be mandated to steer the development of framework for evaluation, quantification and trading of the emission targets in the International Market. Besides, the revenue earned from the said selling may be directed to subsidize the procurement and use of electrical equipment for the heating and cooking applications.

REFERENCES

Bp. *Statistical Review of World Energy 2022*.

Cooking with Electricity | A Cost Perspective | *ESMAP*. (n.d.). https://www.esmap.org/cooking_with_electricity_a_cost_perspective

De La Peña, L., Guo, R., Cao, X., Ni, X., & Zhang, W. (2022). Accelerating the energy transition to achieve carbon neutrality. *Resources, Conservation and Recycling*, *177*, 105957. https://doi.org/https://doi.org/10.1016/j.resconrec.2021.105957

Gatto, A. (2022). The energy futures we want: A research and policy agenda for energy transitions. *Energy Research & Social Science*, *89*, 102639. https://doi.org/https://doi.org/10.1016/j.erss.2022.102639

Hakam, D. F., Nugraha, H., Wicaksono, A., Rahadi, R. A., & Kanugrahan, S. P. (2022). Mega conversion from LPG to induction stove to achieve Indonesia's clean energy transition. *Energy Strategy Reviews*, *41*, 100856. https://doi.org/https://doi.org/10.1016/j.esr.2022.100856

Hammerle, M., & Burke, P. (2022). From natural gas to electric appliances: Energy use and emissions implications in Australian homes. *Energy Economics, 110*(C). DOI: 10.1016/j.eneco.2022.106050

IRENA. (2022). *World Energy Transition Outlook*.

Jing, R., Hua, W., Lin, J., Lin, J., Zhao, Y., Zhou, Y., & Wu, J. (2022, November 1). Cost-efficient decarbonization of local energy systems by whole-system based design optimization. *Applied Energy*. https://doi.org/10.1016/j.apenergy.2022.119921

Karpinska, L., & Śmiech, S. (2021, December 1). Will energy transition in Poland increase the extent and depth of energy poverty*? Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2021.129480

Dennis, K. (2015). Environmentally Beneficial Electrification: Electricity as the End-Use Option. *The Electricity Journal, 28*(9), 100-112. https://doi.org/10.1016/j.tej.2015.10.001

Khalid, T. (2022). Fuel subsidies to curb cost-push inflation: a case study of Pakistan to assess the impact of untargeted subsidies on fiscal space and current accounts. *Polityka Energetyczna – Energy Policy Journal*, *25*(4), 5–26. https://doi.org/10.33223/epj/156594

Martínez-Gómez, J., Ibarra, D., Villacis, S., Cuji, P., & Cruz, P. R. (2016). Analysis of LPG, electric and induction cookers during cooking typical Ecuadorian dishes into the national efficient cooking program. Food Policy, 59, 88-102. https://doi.org/10.1016/j.foodpol.2015.12.010

McKinsey. (2022). *Global Energy Perspective 2022 Executive Summary*.

National Adaption Plan of Pakistan. (2023).

National Electricity Plan 2023. (2023).

NEPRA. (2023). *Indicative Generation Capacity Expansion Plan:2022-31*.

NEPRA Industry Report 2022. (n.d.). *NEPRA state of Industry Report 2021-22*.

OGRA. (2021). *Petroleum Industry Report 2020-21*.

Pakistan Energy Yearbook 2005..

Pakistan Energy Yearbook 2021.

Pistochini, T., Dichter, M., Chakraborty, S., Dichter, N., & Aboud, A. (2022). Greenhouse gas emission forecasts for electrification of space heating in residential homes in the US. *Energy Policy*, *163*, 112813. https://doi.org/https://doi.org/10.1016/j.enpol.2022.112813

Raghavan, S. V., Wei, M., & Kammen, D. M. (2017). Scenarios to decarbonize residential water heating in California. *Energy Policy*, 109, 441-451. https://doi.org/10.1016/j.enpol.2017.07.002

Waleed, A., Akhtar, A., & Pasha, A. T. (2018). Oil consumption and economic growth: Evidence from Pakistan. *Energy Sources, Part B: Economics, Planning, and Policy*, *13*(2), 103–108. https://doi.org/10.1080/15567249.2017.1354100

WEF Fostering Effective Energy Transition 2019.

World Bank. (2022). *Reshaping Norms: A New Way Forward*. https://doi.org/10.1596/978-1-4648-1857-8