Pakistan Low Carbon Scenario Analysis:

GHG Reference Case Projection - Report

IISD ECN Report with Support of CCRD & PITCO

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ECN
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TABLES AND FIGURES

GLOSSARY / ACRONYMNS

BAU – Business as usual

CH_4 - Methane

CO_2 - Carbon dioxide

CO_2e - Carbon dioxide equivalent

FACC – Framework for Action on Climate Change

GDP - Gross Domestic Product

GHG – Greenhouse Gas

GWh - Giga-watt hours

HFCs - Hydroflurocarbons

HOBC – High Octane Blending Component

HSD – High Speed Diesel

IPCC - Intergovernmental Panel on Climate Change

LDO – Light Diesel Oil

LULUCF - Land Use and Land-Use Change and Forestry

MCF – Methane Correction Factor

Motor Spirits – Equivalent to gasoline

Mt - Megatonnes

MW - Mega-watt

N_2O - Nitrous oxide

NCCP – National Climate Change Plan

PAK-IEM - Pakistan Integrated Energy Model

PJ - Petajoules

PJ- Pentajoule

TJ – Terajoule

TJ - Terajoules

TWh - Tera-watt hours

1. INTRODUCTION

Pakistan is a developing country that is impacted by climate change, while being a small contributor to global GHG emissions. However, national emissions will increase with population, economic, industrial and urban growth. Appropriate low-carbon interventions can help to ensure that Pakistan remains a low emitter as the country develops, without hampering growth. To determine what this future could look like, there is an urgent need to improve the evidence base surrounding GHG emissions and mitigation options in Pakistan. This will be necessary to help plan and implement strategies that respond to priorities identified in its NCCP and Framework for Action on Climate Change (FACC).

The basis for this low-carbon outlook is a good understanding of the current situation in Pakistan and how this could be expected to change under business-as-usual (BAU) growth. This requires an updated reliable GHG emissions inventory – the last complete emissions inventory for Pakistan was completed for the year 1993-94 – as well as reliable projections of emissions for each sector without intervention; a so-called reference case. This reference case is the starting point for the options analysis; assessing different technologies/options and their contribution to both mitigating climate change and Pakistan's broader development priorities.

The following sections provide a sectoral overview of the greenhouse gas emissions reference case that has been developed. This reference case presents historical emissions from 2000 to 2012 and a projection of annual emissions out to 2030, and is the reference case against which the abatement potential of low-carbon development options out to 2030 are expected to be assessed. All major greenhouse gases that are reported under the United Nation Convention on Climate Change (UNFCCC) are included in the reference case. GHG emissions include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and Hydroflurocarbons (HFCs).

The Pakistan Emissions Reference case Projection includes all five IPCC inventory sectors; Energy, Agriculture, Industrial Processes, Land Use and Land-Use Change and Forestry (LULUCF) and Waste Sectors. The Energy sector is sub-divided further into five energy sub-sectors of Residential, Commercial and Agriculture Energy Demand, Industrial Energy Demand, Fossil Fuel Production, Transportation, and Electricity Generation.

2. REFERENCE CASE SCENARIO DEVELOPMENT

The last widely published GHG inventory for Pakistan was completed for the year 1994 (Initial National Communication) and the Second National Communication Inventory for the year 2007 was never fully released. As a result, there was no comprehensive official up to date emissions inventory available for Pakistan, and therefore an independent GHG emissions inventory and projection was developed for this Pakistan Low Carbon Analysis project. Very recently the Global Change Impact Studies Centre (GCISC, 2015) has released a GHG inventory for 2011/12 and overall these results are consistent with the reference case. After a review of the new GCISC inventory, emission factors and parameters related to two emission sources, agricultural soils and solid waste disposal, were revised in order to align the results. As the inventories were developed independently differences should be expected. Although the overall results are nearly identical, there exists important differences in methodologies, activity data and emission factors that should be considered in future inventory work.

The low-carbon analysis contained in this report began with the calculation of historical emissions from 2000 to 2012/13. This preliminary GHG inventory used primarily Tier 1 approaches from IPCC 2006 guidelines and was informed by a comprehensive review of the literature. Tier 2 analysis was strictly limited as these methods require the development of country specific emission factors and the collection of primary data on emission source activities that are currently not available. Data availability varied by sector, with uncertainties in data much higher in the agriculture and forestry and other land use sectors. The collection of country specific emission factors as part of Pakistan's emission inventory process would improve the robustness of GHG estimates. A local validation process was used to help fill data gaps in the inventory by identifying potential sources of information and verifying assumptions.

The reference case presented in this report was developed for a single BAU scenario that aims to represent the most likely future of Pakistan to 2030 in the absence of additional government actions and policies to reduce greenhouse gas emissions. The starting point of the reference case is the development of a historical inventory of GHG emissions between 2000 and 2012/13. Projections to 2030 of emissions are then prepared by making assumptions of how activity related to specific sources of emissions changes over time. The main drivers of emissions are related to economic growth, changes in population, energy supply and prices as well as the adoption of new technologies and the impact of government policies and measures. While multiple reference case scenarios could have been considered in the analysis, a single reference case is selected in order to have a single starting point for the mitigation options analysis. However, there is a high degree of uncertainty related to the drivers of emissions and the final section of the reference case report models and present the impact of different rates of economic growth and assumptions regarding autonomous energy efficiency improvements on emissions.

The intent of the reference case is to capture existing policies and measures that are already in place (e.g., energy efficiency measures, regulations) and to present the most realistic projection of the future given what is known about planned private and public investment. The reference case is developed using a simple accounting type model and does not model individual policies and measures, but rather attempts to extrapolate existing trends and consider changes to energy end-uses, industrial production and activities that result in the generation of greenhouse gas emissions. Mitigation options then can be considered against this reference case to understand how greenhouse gas emissions are expected to be reduced.

The reference case is structured to align with typical GHG Inventory sectors used by the IPCC. GHG emissions are allocated across five sectors for the low-carbon scenario assessment and the energy sector is further sub-divided into the following sub-sectors. The industry sub-sector is broadened to include both energy and industrial process emissions:

- Residential, Commercial and Agriculture Energy Demand (excluding electricity demand);
- Fossil Fuel Production;
- Transportation;
- Electricity generation; and
- Industry

Agriculture, forestry (and other land-use) and waste are the remaining two IPCC-derived low-carbon scenario assessment sectors. Dividing the energy sector into five sub-sectors for the mitigation assessment allows for detailed analysis from demand and supply perspectives. The relationship between the sectors of the low-carbon analysis and the major IPCC sectors in the 2006 and 1996 guidelines is set out in Table 1 below.

TABLE 1: RELATIONSHIP OF EMISSION REFERENCE CASE SECTORS AND SUB-SECTORS TO IPCC GUIDELINE SECTORS

Low-carbon scenario analysis sectors	2006 IPCC guideline sectors	1996 IPCC guideline sectors
Residential and Commercial Energy Demand	Energy	Energy
Fossil Fuel Production		
Electricity Generation		
Transportation		
Industry	Industrial Processes and Product Use	Industrial Processes
		Solvent and other Product Use
Agriculture	Agriculture, Forestry and other Land Use (AFOLU)	Agriculture
Forestry (and other land use)		Land-Use, Land-Use Change and Forestry (LULUCF)
Waste	Waste	Waste

In the following sections the general methodology employed to develop the reference case are reviewed, along with the underlying employed socio-economic trends and projection assumptions.

2.1 Methodology

All GHG emissions are estimated following the principles and guidance of the *2006 IPCC Guidelines* or the *Revised 1996 IPCC Guidelines*. In the simplest form, emissions are estimated by multiplying some type of activity data by an appropriate emission factor. Reference case calculations in this analysis generally follow the Tier 1 approach in the 2006 IPCC Guidelines, but on occasion Tier 2 methods are applied. The Tier 1 method is expressed in Equation 1:

EQUATION 1

$$Emissions_{GHG} = \sum Activity\ Data\ \times Emission\ Factor_{GHG}$$

$Emissions_{GHG}$	= emissions of a given GHG (kg GHG)
Activity Data	= Unit of activity such as TJ of fuel consumption, tonnes of industrial production or waste generation that may be further disaggregated by technology, end-use or fuel type (unit of activity)
$Emission\ Factor_{GHG,}$	= default emission factor of a given GHG that corresponds to the unit of activity (kg GHG gas/unit of activity)

Projections are based on the expected change over time in the activity or in the emission factor. The change in the activity data may be directly related to other socio-economic factors such as changes in population, the economy or technology. A review of socio-economic trends and projection assumptions are provided in the following section.

2.2 Socio-Economic Trends and Projection Assumptions

A number of different factors influence the projection of GHG emissions in Pakistan. **Economic and population growth** as well as the **mix of energy supply resources** are the major drivers of energy and industrial emissions in the projection. Waste emissions are primarily driven by population growth and agricultural emissions are primarily driven by the population of livestock. LULUCF emissions are primarily driven by the factors that impact removal and growth of biomass in forests, that include both economic and population growth. Projections of emissions can vary greatly if these drivers are changed over time, particularly economic growth. Analysis of the implications of the uncertainty surrounding alternative assumptions of economic growth on the modeling results will be included in subsequent drafts.

Technology changes can also substantially impact emission scenarios. No major transitions to low carbon technologies are anticipated in the reference case outside of the electricity sector where a significant supply of new renewable energy from wind and solar are anticipated. Technological innovations in agricultural and livestock processes such as no-till agriculture and livestock feed changes are also not expected to change substantially in the reference case. Otherwise in the model technological changes are driven by expected annual autonomous energy efficiency improvements that are reviewed within each sector and broadly represent the implementation of new technologies (e.g., more energy efficient air conditioning, lighting and vehicles).

Reference case assumptions related to changes in economic growth, population and energy supply resources are discussed below.

2.2.1 Economic Growth

Short-term sectoral growth projections and provisional estimates to 2017-18 from the Eleventh Five Year Plan (Planning Commission, 2012) are summarized in Table 2.

TABLE 2: SECTORAL GROWTH PROJECTIONS 2013 TO 2017

Average Annual GDP Growth Rate	2013-14	2014-15	2015-16	2016-17	2017-18
Overall	4%	4.2%	5.5%	6.5%	7%
Services	4.4%	5%	5.7%	6.8%	7.3%
Agriculture	2.7%	2.9%	3.9%	4%	4%
Industry	4.5%	3.6%	6.4%	8.2%	9%

Pakistan's Vision 2025 targets an average annual growth rate in gross domestic product of 8% between 2015 and 2030. While the Government of Pakistan understandably targets high rates of growth in its development planning, the aggressive targets in Vision 2025 represent the ambition of development objectives rather than historical trends or existing levels of investment. This aggressive target for growth seems as if it will be difficult to achieve given not only the slowing global economy but also the many challenges faced by the economy such as energy supply, low domestic investment, inflation and budget deficits.

A more conservative (but also more likely) average annual overall growth rate in Gross Domestic Product (GDP) of 6% was assumed in the reference case, but low and high growth rates were considered as well in order to consider their impact on emissions. Consideration of the impact of different growth rates on emissions is provided in Section 4. The growth rates selected reflect differentiated growth rates by sector published with the *Pakistan Integrated Energy Model (PAK-IEM)*. Table 3 outlines the assumptions related to economic growth.

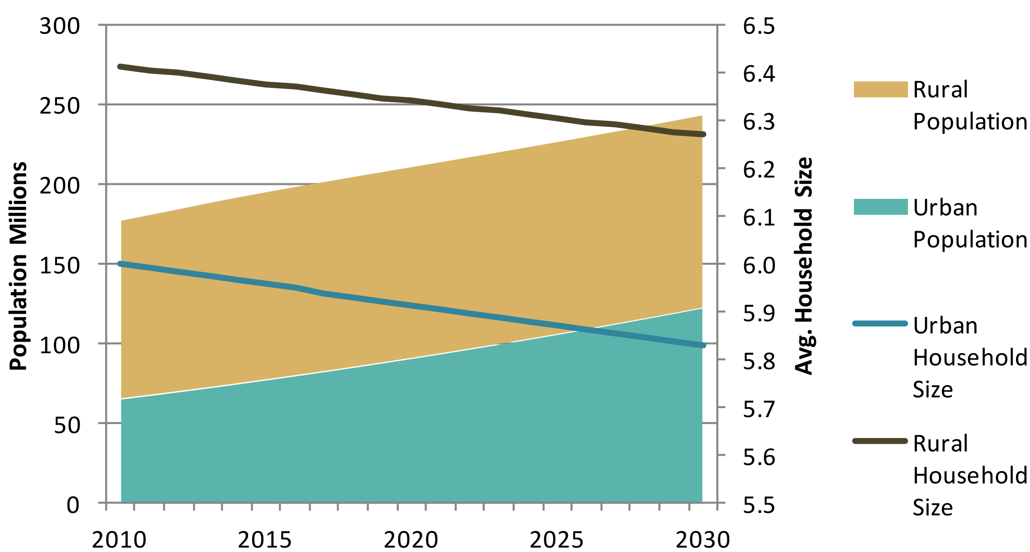
TABLE 3: AVERAGE ECONOMIC GROWTH ASSUMPTIONS FROM 2013 TO 2020

Average Annual GDP Growth Rate	Low	Reference case	High – Vision 2025
Overall	4.0%	6.1%	8.0%
Services	3.5%	5.8%	7.0%
Agriculture	2.4%	3.8%	4.8%
Industry	5.4%	8.4%	10.7%

2.2.2 Population

Reference case projections for population and household size to 2030 are based on data available in the *Pakistan Economic Review 2013-2014* and are shown in Figure 1.

FIGURE 1: POPULATION AND HOUSEHOLD SIZE PROJECTIONS (PERSONS)



2.2.3 Energy Supply

The model of GHG emissions developed does not constrain the supply of energy available or model energy prices such as the price of crude oil and natural gas. The reference case assumes that demand for petroleum fuels can be met by either domestic supply or imports and that their current market share will be fairly constant in the reference case. Major new imports of liquid natural gas (LNG) are modeled to make up for production shortfalls. Significant short-term coal imports or also expected until the development of the Thar coal fields is able to meet demand. Fuel switching for end-use demand is limited outside the transport sector, where existing supply limitations have been inhibiting growth and a decline in overall natural gas consumption of 2% annually is projected based on recent historical trends.

The electricity supply scenario is based on a specific view of what new capacity will be developed and what old capacity will be retired over the reference case time-period (See section 3.5 for a detailed list of capacity additions). The reference case electricity supply is in the reference case is very similar to that expected under Vision 2025 target of 48,000 MW (addition of 25,000 MW). Demand for electricity is expected to continue to outstrip supply in the reference case projection.

2.2.4 Technology Adoption

The reference case model does not track the stock and relative energy efficiency or greenhouse gas intensity and replacement of associated end-uses (e.g., vehicles or appliances). Rather the model tracks on an annual basis the average efficiency value for different end-uses and adjusts this value to represent changes to the overall stock. This annual change in efficiency expressed as a percentage is referred to as the autonomous energy efficiency improvement value. A change of +1% annually indicates an average improvement of the overall stock in efficiency of 1% every year. Adoption of new technologies can then be represented by this value with higher values representing the adoption of low carbon or high efficiency equipment at a higher replacement rate (e.g., replacement of incandescent lighting with LED lighting). Annual autonomous energy efficiency improvements are developed in each of the following five energy sub-sectors and a similar value representing changes to greenhouse gas intensity are employed for other sectors.

3. EMISSION REFERENCE CASE PROJECTION

Sources and sinks from all IPCC sectors have been included in the reference case estimates. This may include some sources that were not included in the inventory prepared by the Pakistan Atomic Energy Commission (PAEC ASAD 2009). This PAEC inventory was not the source of data for this analysis, as primary activity data was collected for all relevant emission sources independently. This activity data is summarized in each of the following sub-sections. Table 3 provides a comparison of the summary results from the PAEC study to the estimates from the reference case for the year 2008.

TABLE 4: COMPARISON OF HISTORICAL EMISSIONS IN 2008 (MT CO_2E)

Sector	Sub-Sector	2008 Emissions - PAEC ASAD, 2009	2008 Emissions - Low Carbon Analysis Reference case)
Energy	Residential, Commercial and Agricultural Energy Demand	78.6	24.8
	Industrial Energy Demand		38.6
	Fossil Fuel Production		10.5
	Electricity Generation	44.4	41.3
	Transportation	31.4	31.8
	Energy Total	**154**	**146**
Agriculture		124	152
LULUCF		8.9	8.9
Industrial Processes		17.5	27.3
Waste		5.5	8.9
TOTAL		**310**	**343**

Figure 2 provides the reference case estimates for year 2012 emissions, and Figure 3 shows the historical reference case and projections of emissions according to reference case estimates. The basis for these figures is elaborated in the sections below. Activity data in the energy sector is expressed in a common unit of Petajoules (PJ) so that the energy content of all fuels can be compared. The sector-specific figures and results are discussed in the sub-sections below.

FIGURE 2: EMISSIONS IN 2012 (MT CO_2E)

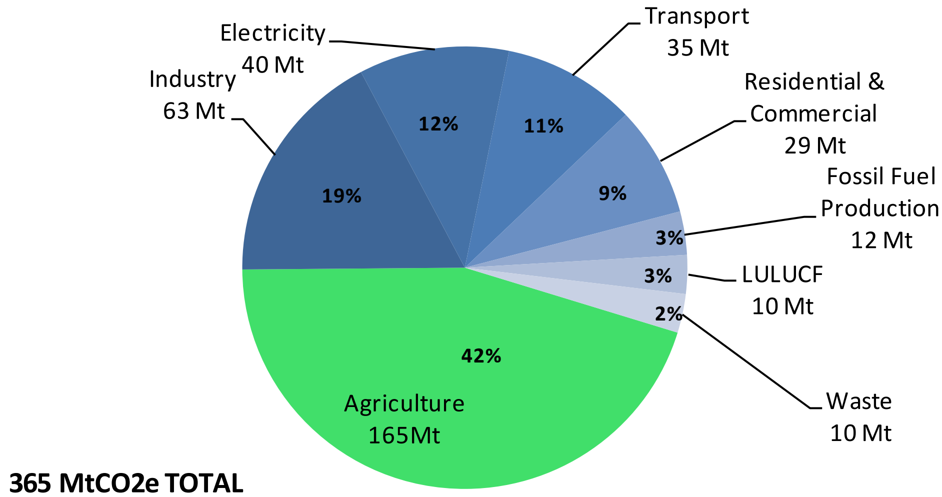
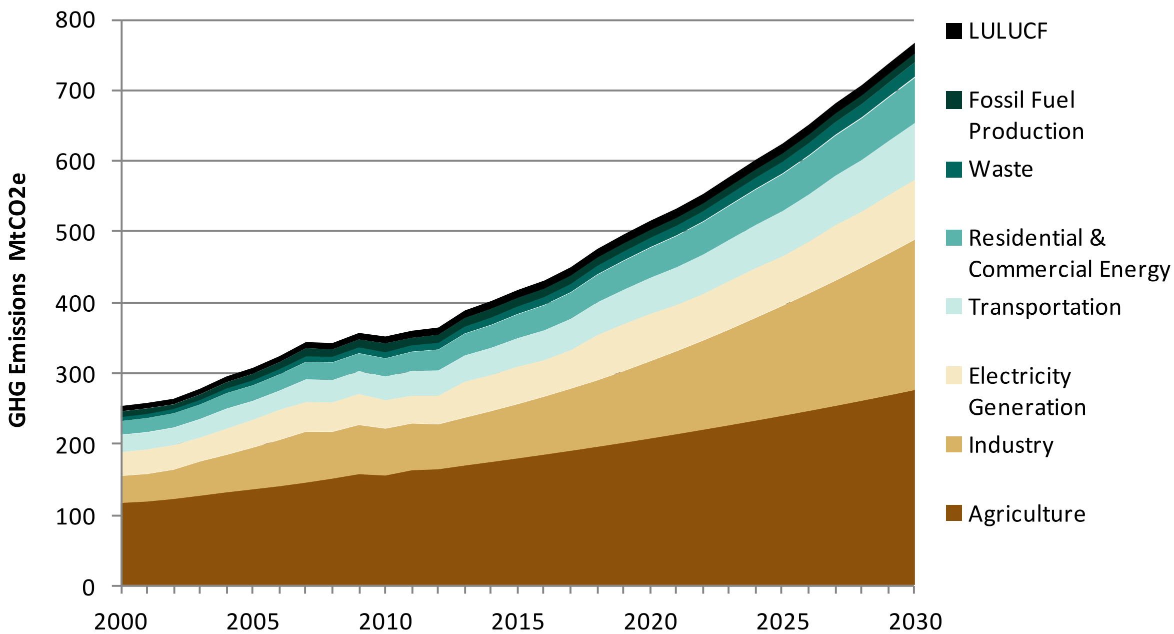


FIGURE 3: EMISSIONS REFERENCE CASE PROJECTIONS (MT CO2E)



3.1 Residential, Commercial and Agriculture Energy Demand Sub-Sector

This sector includes greenhouse gas emissions from the combustion of fossil fuels and biomass consumed in the Residential, Commercial and Agriculture Energy sub-sectors. Note that only the non-CO_2 component of biomass GHG emissions is included as the CO_2 component is included in the LULUCF sector. The sector also does not include indirect emissions from electricity, which are considered in the Electricity Generation Sector. Agriculture emissions included here are only energy related emissions, primarily from water pumping. Agricultural emissions of methane and nitrous oxide from non-combustion related agricultural activities such as enteric fermentation and manure management are covered in the Agriculture Sector. These divisions are made to remain consistent with IPCC Guidelines.

The residential, commercial and agriculture energy sub-sector currently accounts for approximately 10% of overall emissions. An emissions reference case for the sector is developed by estimating the total fossil fuel consumption and then multiplying the total consumption by appropriate emission factors. The data, assumptions and source references used to estimate both historical and projected emissions are outlined in the following section.

3.1.1 Data and assumptions

Total energy use for each major fossil fuel consumed was based on petroleum sales data from 2007 to 2012 provided in the *Pakistan Energy Yearbook 2013* and is summarized in Table 5. The yearbook provides a breakdown of fuel consumption for Residential and Commercial sectors. (Fuels used in Industry Transportation, and for Electricity Generation are addressed in their respective sub-sections below.) Biomass fuel consumption (i.e., wood and agriculture residues) is based on available data from the PAK-IEM model.

TABLE 5: FUEL CONSUMPTION OF RESIDENTIAL AND COMMERCIAL ENERGY SECTOR (PJ)

Sector	Fuel Type	2007	2008	2009	2010	2011	2012
Residential	Kerosene	100	99	87	93	74	101
	LPG	288	265	268	234	224	246
	Natural Gas	4,887	5,127	5,264	5,519	6193	6,831
	Wood	11,226	11,450	11,679	11,913	12,151	12,394
	Agriculture Residues	4,371	4,458	4,547	4,638	4,731	4,826
Commercial	Aviation Fuel	159	158	139	148	118	161
	Motor Spirit	11	11	9	10	8	11
	HOBC	4	4	3	3	3	4
	Kerosene	26	26	23	24	19	26
	HSD	1,223	1,128	1,054	1,013	977	1,010
	LDO	1	1	1	1	1	1
	Furnace Oil	4	4	4	4	3	4
	Lubes&Greases	4	4	3	4	3	4
	LPG	331	305	308	269	257	283
	Natural Gas	681	715	734	769	863	959
Agriculture	LDO	33	32	29	30	24	33

3.1.2 End-use Allocation

While fuel consumption does not need to be allocated to end-uses in order to generate an emissions reference case, it is critical in the analysis of demand side mitigation options that target specific end-uses.

Historical information on the total consumption of different energy consumers (urban households, rural households, commercial and agriculture sub-sectors) is available from the *Pakistan Energy Yearbook 2013*. However, there is little comprehensive information available around the end-uses, where these fuels are ultimately consumed, such as for cooking, lighting and heating water. A number of reports provide details on usage patterns of households and ownership of appliances but this data only indirectly indicates energy consumption. The lack of end-use data is not a challenge that is unique to Pakistan or even to developing countries and requires substantial research and resources to obtain.

End-use allocation is based on estimates from PAK-IEM. Although these estimates are for the year 2007-08, they represent the most comprehensive analysis of end-use consumption available.

Table 5 summarizes the allocation of different fuels to both consumers and specific end-uses.

TABLE 6: ESTIMATE OF END-USE CONSUMPTION BY FUEL AND CONSUMER (%)

Fuel	Consumer	Total Fuel Share by Consumer	Space Heating	Water Heating	Lighting	Cooking	Other	Water Pumping	Tractors
Aviation Fuel	Commercial	100%					100%		
Motor Spirit	Commercial	100%					100%		
HOBC	Commercial	100%					100%		
Kerosene	Urban	6.0%				100%			
	Rural	73.3%			89%	11%			
	Commercial	20.6%			66%	33%			
HSD	Commercial	13.3%					100%		
	Agriculture	86.7%						80%	20%
LDO	Commercial	3.7%					100%		
	Agriculture	96.3%						80%	20%
Furnace Oil	Commercial	100%					100%		
Lubes & Greases	Commercial	100%					100%		
LPG	Urban	20.6%		13%		87%			
	Rural	26.0%				100%			
	Commercial	53.5%	2%	6%		92%			
Natural Gas	Urban	84.0%	8%	23%		69%			
	Rural	3.7%	22%	17%		61%			
	Commercial	12.2%	2%	6%		92%			
Wood	Urban	14.6%	1.3%	13%		80%	4.6%		
	Rural	85.4%	9%	11%		78%	2%		
Agriculture Residues	Urban	11.6%	1.4%	13%		80%	4.6%		
	Rural	88.4%	9%	11%		78%	2%		

3.1.3 Projections

Future growth in end-use consumption was estimated based on expected changes in stock (e.g., the population of end-use appliances), demand and efficiency of relevant end-uses, as summarized in Table 6.

TABLE 7: PROJECTED GROWTH RATES IN RESIDENTIAL, COMMERCIAL AND AGRICULTURAL END-USES (%)

Sector	End-Use	Change in Stock	Change in Demand	Annual Change in Efficiency (Autonomous Energy Efficiency Improvement)
Residential	Space Heating	Based on urban or rural household growth rate projections (3.6% declining to 3.0% for urban households, and 1.3% declining to 0.1% for rural households)	Projections of Service GDP from Pak-IEM Model, adjusted for smaller household size and population growth	-0.5%
	Water heating			-0.5%
	Lighting Fuels			-0.6%
	Cooking			-0.3%
Commercial	Space Heating			-0.5%
	Water heating			-0.5%
	Lighting Fuels			-0.6%
	Cooking			-0.3%
	Other	Overall growth based on Services GDP from PAK-IEM model (5.9% in 2013 declining to 5.4% in 2030)		
Agriculture	Water Pumping	Overall growth based on Agriculture GDP from PAK-IEM model (4.1% in 2013 declining to 3.6% in 2030)		
	Tractors	Overall growth based on Agriculture GDP from PAK-IEM model (4.1% in 2013 declining to 3.6% in 2030)		

Table 8 indicates the total projected future energy consumption of fuels between 2010 and 2030 in five-year increments.

TABLE 8: PROJECTED RESIDENTIAL, COMMERCIAL AND AGRICULTURAL ENERGY FUEL CONSUMPTION (PJ)

Sector	Fuel Type	2012	2015	2020	2025	2030
Residential	Kerosene	4.2	4.6	5.2	5.6	6.2
	LPG	10.3	11.6	14	16.3	19.2
	Natural Gas	286	333	428	535	666
	Wood	519	570	656	729	813
	Agriculture Residues	202	222	253	280	311
Commercial	Aviation Fuel	6.7	8.2	11.1	14.3	18.6
	Motor Spirit	0.5	0.6	0.8	1.0	1.2
	HOBC	0.2	0.2	0.3	0.3	0.4
	Kerosene	1.1	1.3	1.7	2.2	2.8
	HSD	5.6	6.7	9.2	11.9	15.5
	LDO	0.1	0.1	0.1	0.1	0.1
	Furnace Oil	0.2	0.2	0.3	0.4	0.5
	Lubes&Greases	0.2	0.2	0.3	0.4	0.4
	LPG	11.8	14.1	19	24.1	30.8
	Natural Gas	39.9	47.7	63.7	81.3	103.8
Agriculture	LDO	1.4	1.6	1.9	2.3	2.8
	HSD	36.7	41.4	50.6	61.3	73.1

Emission Factors for energy fuel consumption are based on IPCC defaults from the 2006 Guidelines. Emissions are associated with carbon and non-carbon emissions, methane and nitrous oxides. Carbon emissions related to unsustainable harvesting of wood will be included in the Forestry and Land-Use Change Sector. Table 9 summarizes the IPCC default emission factors that are used.

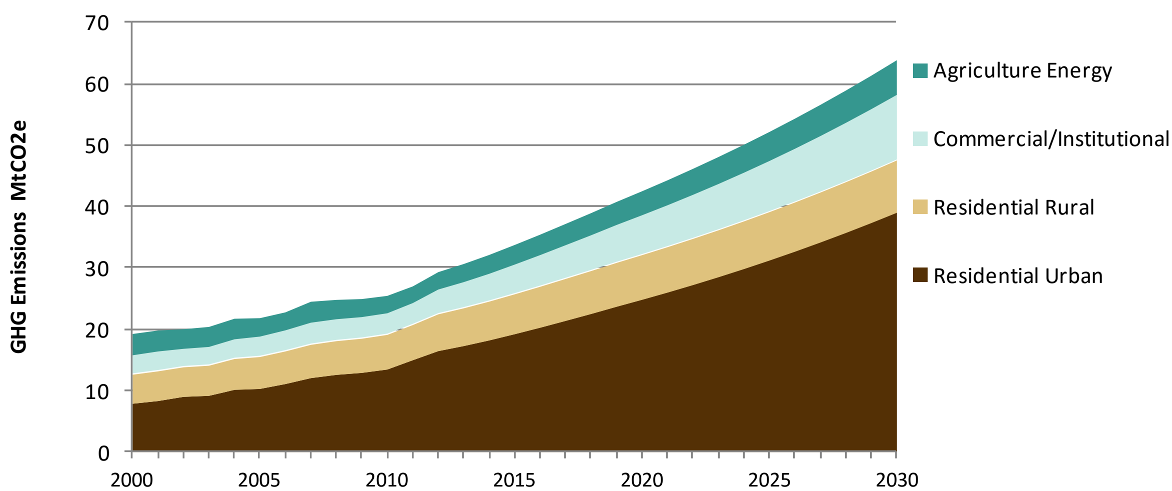
TABLE 9: EMISSION FACTORS BY FUEL (KG CO_2E/TJ)

Fuels	Sector	$kgCO_2e/TJ$
Aviation Fuel	Commercial	72,131
Motor Spirit	Commercial	69,213
HOBC	Commercial	72,305
Kerosene	Commercial, Residential	72,296
HSD	Commercial, Residential	74,496
LDO	Commercial, Agriculture	74,496
Furnace Oil	Commercial	77,796
Lubes & Greases	Commercial	36,796
LPG	Commercial, Residential	62,942
Natural Gas	Commercial, Residential	56,236
Wood	Commercial, Residential	7,540
Agriculture Residues	Commercial, Residential	7,540

3.1.4 Results

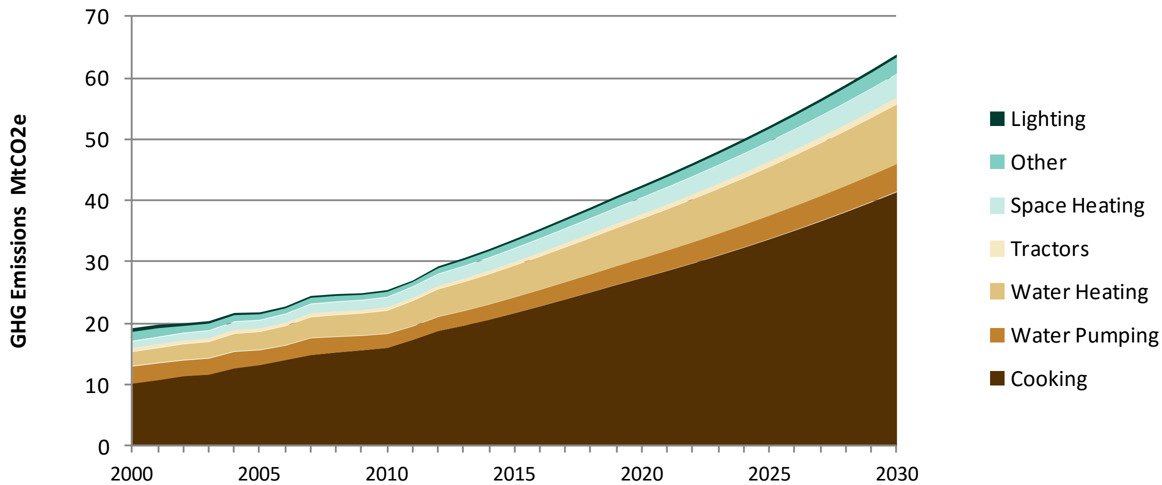
Total GHG emissions for the Residential, Commercial and Agriculture Energy Sub-Sectors are presented in Figure 4.

FIGURE 4: GHG EMISSIONS FROM RESIDENTIAL, COMMERCIAL AND AGRICULTURAL SUB-SECTORS (MT CO_2E)



Total greenhouse gas emissions for the Residential, Commercial and Agriculture Energy sub-sectors are presented in Figure 5, broken down by different end-uses.

FIGURE 5: GHG EMISSIONS FROM RESIDENTIAL AND COMMERCIAL SECTOR END-USES (MT CO2E)



3.1.5 Data gaps and uncertainty

Uncertainty in the emissions reference case is relatively low for the total emissions of fossil fuels as there is a low degree of uncertainty related to the total consumption of these fuels in Pakistan and the associated emissions factors. The uncertainty is higher for biomass fuels as the data on total biomass fuels consumed in Pakistan is based on limited data from the PAK-IEM model.

There is also significant uncertainty in the allocation of emissions to specific end-uses as this data in Pakistan is limited. Future studies that allocate the total consumption of fuels in Pakistan to specific energy end-uses would improve the confidence in the analysis of mitigation options.

Major data gaps to address in the Residential, Commercial and Agriculture Energy sub-sectors include:

1. **Additional, more up-to-date information to derive estimates of end-use consumption by fuel type, besides the PAK-IEM model.** End-use consumption for the residential sector was based on *Household Expenditure Survey 2001* and the *Household Energy Strategy Study* (ESMAP, 1993). End-use consumption for the commercial sector was based on expert judgement and data from the US NEMS model. End-Use consumption for the agriculture sector was based on ADB, 2009. Concerns were highlighted by stakeholders that the allocation of HSD to water pumping may be overstated and that tractor fuel consumption may be a larger proportion of HSD demand given rated capacity and operational characteristics.
2. **Estimates of biomass energy use**. These estimates are currently based on the *Household Energy Strategy Study* (HESS, 1991) and the *Energy Sector Management Assistance Program*

(ESMAP, 2006) and published in the *Pakistan Integrated Energy Model* (PAK-IEM, 2008). The World Bank has funded a Biomass Resource Mapping Study which may provide improved data for estimating biomass energy use. This study was not available for this project.

3. **Implications of black market**. What are the expected consumption and emission effects of "black market" fuels that are not accounted for in the Energy Balance? More work needs to be done to determine the scale of black market activity. However, while the scale is not known precisely it is likely under 5% of total consumption.

3.2 Industry Sub-Sector

This sector includes GHG emissions from the combustion of fossil fuels consumed by industry sub-sectors, as well as emissions that arise from industrial processes (e.g., cement, fertilizer production). It does not include indirect emissions from electricity which are considered in the analysis of the Electricity Generation sub-sector. In addition, combustion emissions associated with crude oil and non-market natural gas are not considered here but rather in the analysis of the Fossil Fuel Production Energy sub-sector.

The industry sub-sector is the second largest category of emissions currently accounting for approximately 18% of total greenhouse gas emissions. An emissions reference case for the Industry Sector's is developed by estimating the total fossil fuel consumption and then multiplying the total consumption by appropriate emission factors. The data, assumptions and source references used to estimate both historical and projection emissions are outlined in the following section.

Industrial process emissions are released from process that chemically or physically transform materials (for example, cement, lime and soda ash are notable examples where there are processes that release a significant amount of CO_2). Different GHGs – including CO_2, CH_4, N_2O, hydrofluorocarbons and perfluorocarbons– can be produced during these processes. Only the major industries with significant emissions from industrial processes that were identified in Pakistan were included. In general, the emissions reference case for the industrial process sector was developed by estimating the total production of an industrial product that in its transformation contributes to GHG emissions, and then multiplying this value by appropriate emission factors.

3.2.1 Data and assumptions

Total energy use for each major fossil fuel consumed was based on petroleum sales data from 2007 to 2012 provided in the *Pakistan Energy Yearbook 2013*. The yearbook provides a breakdown of fuel consumption for industrial sub-sectors.

Table 10 identifies the total consumption of specific fuels for industrial sub-sectors. Total allocation of energy consumption for the Industry Sector is relatively certain as this is based directly on energy balance data from *the Pakistan Energy Yearbook.* As a result we can be confident that overall emissions projected are reasonably accurate for these consumers.

TABLE 10: FUEL CONSUMPTION OF INDUSTRY ENERGY SUB-SECTOR (PJ)

Fuel Type	2007	2008	2009	2010	2011	2012
Motor Spirit	1.7	1.5	1.6	2.1	2.2	2.2
Kerosene	1.4	1.3	1.3	1.8	1.9	1.9
HSD	15.2	13.7	14.0	19.1	20.0	19.5
LDO	0.1	0.1	0.1	0.1	0.1	0.1
Furnace Oil	26.9	24.2	24.8	33.7	35.3	34.3
Lubes & Greases	0.5	0.4	0.4	0.6	0.6	0.6
Natural Gas	361	352	365	329	326	310
Coal	226	163	179	169	170	153

Historical production data was used to estimate emissions from industrial processes. The values of historical production data are provided in Table 11.

TABLE 11: INDUSTRIAL OUTPUT OF PRODUCTS THAT LEAD TO INDUSTRIAL PROCESS EMISSSIONS

Industrial Output	2007	2008	2009	2010	2011	2012
Cement (tonnes)	26,751,000	28,380,000	31,160,000	28,723,000	29,577,000	31,098,000
Soda Ash (tonnes)	365,000	365,300	409,600	378,000	370,700	366,177
Magnesite (tonnes)	1,400	3,500	3,918	8,330	16,826	7,500
Dolomite (tonnes)	260,000	305,000	150,619	306,940	283,768	300,000
Urea Production (tonnes)	4,925,000	4,918,400	5,056,500	4,552,100	4,470,100	4,215,100
Pig Iron (tonnes)	993,400	791,100	483,300	433,100	249,100	201,400
Steel (tonnes)	1,090,000	1,000,000	800,000	800,000	850,000	850,000
HFCs (tonnes)	1,030	1,130	1,229	1,337	1,455	1,583

Source: Cement, Soda Ash and Urea Production (GOP, 2013). Magnesite and Dolomite from (USGS, 2012). Steel from (World Steel Association, 2014). HFCs estimated based on model data (European Commission, 2011). Metallurgical Coke from (Pakistan Bureau of Statistics).

3.2.2 End-use Allocation

Historical information on the total consumption of natural gas for different energy consumers (cement, fertilizer, iron and other industries) is available from the *Pakistan Energy Yearbook.* However, there is little comprehensive information available on the end-use demand where different fuels are ultimately consumed, such as for heat, steam and auto-production of electricity.

End-use allocation is based on estimates from the *Sustainable Energy Efficiency Development Program Report (ADB, 2009)*. Although these estimates are for the year 2007-08, they represent the most comprehensive analysis of end-use consumption available.

Table 12 summarizes the allocation of different fuels to industrial consumers. All emissions are allocated at this time to industrial process emissions and more specific end-uses are not identified.

TABLE 12: ESTIMATE OF FUEL CONSUMPTION BY FUEL AND INDUSTRIAL CONSUMER (%)

<table>
<tr><th>Fuel</th><th>Brick</th><th>Cement</th><th>Fertilizer</th><th>Iron and Steel</th><th>Other Industries</th><th>Sugar</th><th>Textiles</th><th>Pulp and Paper</th></tr>
<tr><td>Motor Spirit</td><td rowspan="6">-</td><td rowspan="6">13.9%</td><td rowspan="6">0%</td><td rowspan="6">3.7%</td><td rowspan="6">66.5%</td><td rowspan="6">6.2%</td><td rowspan="6">5.1%</td><td rowspan="6">4.6%</td></tr>
<tr><td>Kerosene</td></tr>
<tr><td>HSD</td></tr>
<tr><td>LDO</td></tr>
<tr><td>Furnace Oil</td></tr>
<tr><td>Lubes & Greases</td></tr>
<tr><td>Natural Gas</td><td>-</td><td>0.3%</td><td>11.0%</td><td>8.1%</td><td>36.1%</td><td>2.7%</td><td>28.6%</td><td>13.2%</td></tr>
<tr><td>Coal</td><td>32.9%</td><td>67.1%</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

3.2.3 Projections

Future growth in energy end-use consumption was estimated based on expected changes in production and efficiency, as summarized in Table 13.

TABLE 13: PROJECTED ENERGY GROWTH RATES FOR INDUSTRIAL CONSUMERS (%)

Industrial Consumer	Change in Production / Demand	Annual Change in Production Efficiency (Autonomous Energy Efficiency Improvement)
Brick	Projections of Industry GDP from Pak-IEM Model	-1.0% (PAK-IEM)
Cement	Projections of Industry GDP from Pak-IEM Model	1% penalty to 2015, then -1.0% from 2020 to 2030 (PAK-IEM)
Fertilizer	Projections of Agriculture GDP from Pak-IEM Model	-0.5% (PAK-IEM)
Iron and Steel	Projections of Industry GDP from Pak-IEM Model	-0.5% (PAK-IEM)
Other Industries	Projections of Industry GDP from Pak-IEM Model	-0.5% (PAK-IEM)
Sugar	Estimate of 2.5% growth in production (PAK-IEM Model)	-0.5% (PAK-IEM)
Textiles	Estimate of 6.4% growth in production (PAK-IEM Model)	-0.5% (PAK-IEM)

TABLE 14: PROJECTED GROWTH RATES FOR INDUSTRIAL PROCESSES (%)

Industrial Consumer	Change in Production / Demand	Annual Change in Emission Intensity
Cement	Projections of Industry GDP from Pak-IEM Model	-0.5%
Soda Ash		-0.5%
Magnesite		-0.5%
Dolomite		-0.5%
Urea		-0.5%
Metallurgical Coke		-0.5%
Pig Iron		-0.5%
Steel		-0.5%
HFCs		Rising to -3.5% in 2030 due to Alternatives

Table 15 indicates the total future energy consumption of fuels between 2012 and 2030, which was estimated using the expected changes production and efficiency outlined above. Table 15 indicates the projected energy consumption by industrial consumer.

TABLE 15: PROJECTED INDUSTRY ENERGY FUEL CONSUMPTION (PJ)

Fuel Type	2012	2015	2020	2025	2030
Motor Spirit	2.2	2.5	3.5	5.2	7.4
Kerosene	1.9	2.1	3.0	4.4	6.3
HSD	19.5	22.3	31.7	46.4	66.1
LDO	0.1	0.1	0.2	0.3	0.4
Furnace Oil	34.3	39.6	55.9	81.9	116.8
Lubes & Greases	0.6	0.7	1.0	1.4	2.0
Natural Gas	310	317	432	607	842
Coal	153	190	281	412	571

TABLE 16: PROJECTED INDUSTRY ENERGY FUEL CONSUMPTION (PJ)

Industry Type	2012	2015	2020	2025	2030
Brick	50.5	60.6	87	131	191
Cement	112	140	211	306	414
Fertilizer	34.1	37.9	45.1	53.3	62
Iron and Steel	27.3	32.7	47	70.6	103
Other Industries	151	181	260	391	570
Sugar	11.9	12.7	14.0	15.4	16.9
Textiles	91	108	144	192	255

Emission Factors for energy fuel consumption are based on IPCC defaults from the 2006 guidelines. Emissions are associated with carbon and non-carbon emissions, methane and nitrous oxides.

TABLE 17: INDUSTRY ENERGY SUB-SECTOR EMISSION FACTORS BY FUEL (KG CO_2E/TJ)

Fuels	Sector	$kgCO_2e$/TJ
Motor Spirit	All Industry Sub-Sectors	72,305
Kerosene	All Industry Sub-Sectors	72,149
HSD	All Industry Sub-Sectors	74,349
LDO	All Industry Sub-Sectors	74,349
Furnace Oil	All Industry Sub-Sectors	77,649
Lubes & Greases	All Industry Sub-Sectors	36,796
Natural Gas	Cement, Fertilizer, Iron & Steel, Sugar, Textiles, Other Industries	56,152
Coal	Cement, Brick	94,789

TABLE 18: INDUSTRIAL PROCESSES SUB-SECTOR EMISSION FACTORS (KG CO_2E/TONNE)

Industrial Product	$kgCO_2e$/tonne product
Cement	494
Soda Ash	415
Magnesite	522
Dolomite	477
Urea	2.12 (2012)
Metallurgical Coke	108.0
Pig Iron	1,350
Steel	1,294 (2013 88% Basic Oxygen Furnace and 12% Electric Arc Furnace)
HFCs	1,700 (Average)

3.2.4 Results

Total greenhouse gas emissions for the Industrial Energy Sector are presented in Figure 6 and total greenhouse gas emissions for industrial process emissions are presented in Figure 7.

FIGURE 6: GHG EMISSIONS FROM INDUSTRY ENERGY SUB-SECTORS (MT CO_2E)

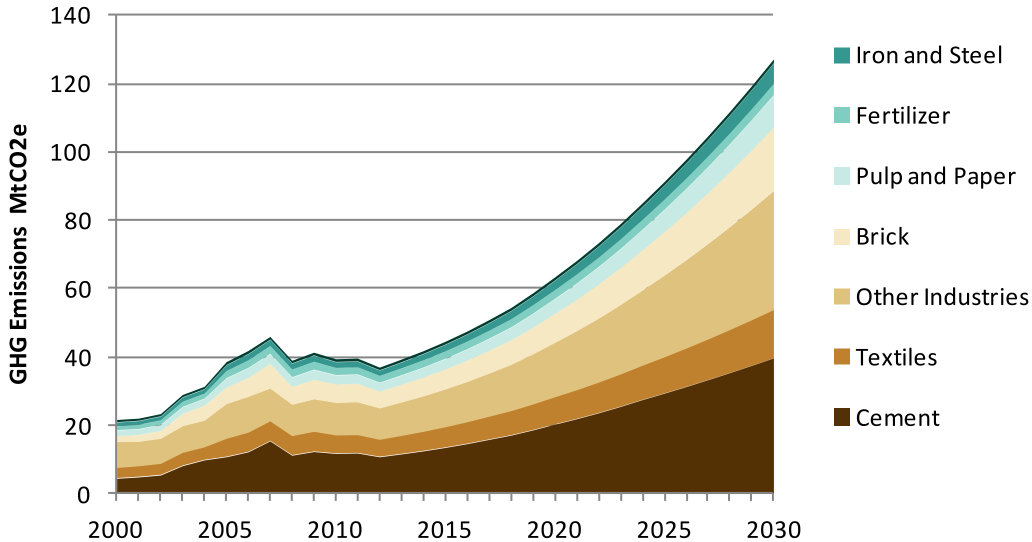
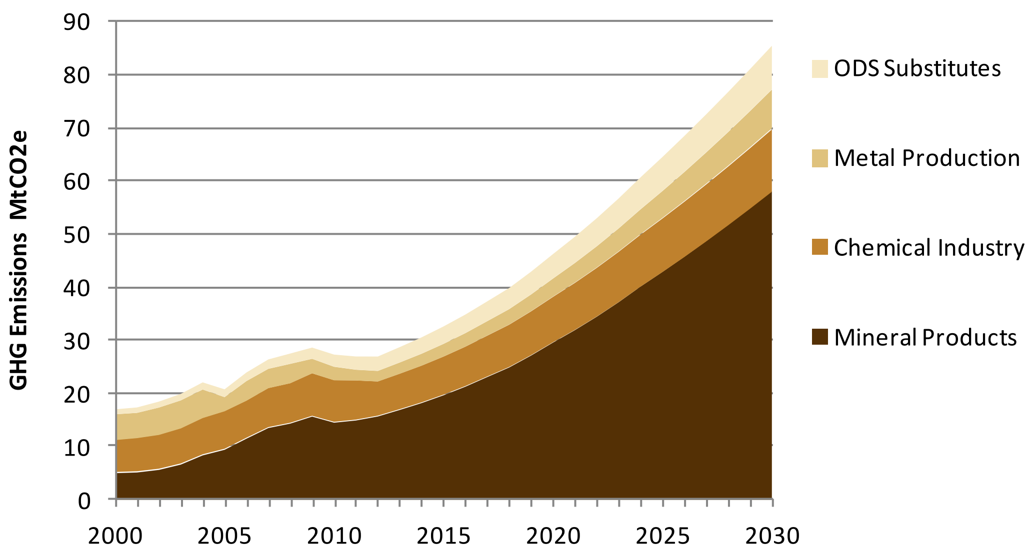


FIGURE 7: GHG EMISSIONS FROM INDUSTRIAL PROCESS SOURCES (MT CO_2E)



The driver in industrial energy emissions is economic growth, and the rate of emission growth in individual industry sub-sectors such as cement, fertilizer and textiles is similar as economic growth rates are not differentiated in the model.

Similarly the driver in industrial process emissions is economic growth and the growth rate in emissions for the mineral products, chemical and metal production is similar. Hydrofluorocarbons or ODS substitutes grow at a slower rate due to the increased availability of low-emission alternatives.

3.2.5 Data availability and uncertainty

Uncertainty in the historical reference case emissions case is relatively low for the total emissions of fossil fuels from Industrial Energy Demand, as there is a low degree of uncertainty related to the total consumption of these fuels in Pakistan and the related emissions factors. The uncertainty is higher for the projections, as the change in production, fuel switching and energy efficiency improvements are difficult to forecast and are based on limited assumptions from the PAK-IEM model.

Major data gaps to address in the Industry sector include:

1. **Additional, more up-to-date information to derive estimates of end-use consumption.** End-use consumption by industry sub-sector and fuel type is estimated based on the results from the *PAK-IEM model*. The end-use consumption was based on a large number of different sources; however, all of these data sources pre-date the year 2009. For natural gas, sub-sector consumption was based on the latest figures in the *Pakistan Energy Yearbook 2012-2013*. Additional and up-to-date information on end-use energy consumption would improve the projection.
2. **Fuel consumption in the oil and gas industry**. Information on this area, including data on refining, is poorly identified in available data, and it is unclear whether self consumption is properly captured (e.g., naptha fuel or refinery gas) in the *Pakistan Energy Yearbook 2012-2013*. In addition there are fugitive methane emissions from the energy sector that are not yet captured in the reference case projections.
3. **Biomass consumption by industry**. If there is significant biomass consumption in some industry sub-sectors it is not captured in the current reference case projection. Note that biomass consumption primarily occurs in cogeneration in the sugar industry which is accounted for in the electricity sector.
4. **Industrial process emissions may be missing**. No data was found on the production of ethylene, styrene, methanol, nitric acid, adipic acid and aluminium. It is likely that most of these products are not produced in Pakistan; however, they should be included if there is domestic production.
5. **Hydroflurocarbon (HFC) emissions**. No data was identified to estimate emissions related to HFCs. Emissions of HFCs can occur during production as well as emissions related to product use. HFC production in Pakistan was not identified but should be included in estimates if production occurs. The majority of emissions are likely to arise as a result of the release of HFCs that are associated with refrigeration and air conditioning products that are imported into the country and HFC bulk imports that are used to recharge this equipment. Average per capita data from India was used to estimate HFC emissions (European Commission, 2011).

3.3 Fossil Fuel Production Sector

This sector includes fugitive, flaring and venting GHG emissions from the fossil fuel production and distribution sector as well as combustion emissions related to un-marketed natural gas and crude oil that is consumed in fossil fuel production. It does not include indirect emissions from electricity which are considered in the analysis of the Electricity Generation sub-sector below. Emissions related to the combustion of refined petroleum fuels are included in analysis of the Industry Energy Demand sub-sector above, even if they are related to fossil fuel production.

The fossil fuel production sector currently accounts for only about 4% of total greenhouse gas emissions. The major GHG emission sources included are identified in the table below.

TABLE 19: FOSSIL FUEL PRODUCTION EMISSION SOURCES

Fossil Fuel	Source of Emissions	Type of Emission
Natural Gas	Processing	Flaring, Fugitive
	Processing Plants	Combustion of un-marketed gas
	Compression Stations	Combustion of un-marketed gas
	Transmission and Distribution	Combustion of un-marketed gas
Crude Oil	Refinery Own Use	Combustion of Crude Oil
	Refinery	Fugitive
Coal	Mining	Fugitive

3.3.1 Data and assumptions

Total energy use for each major fossil fuel consumed was based on production and final sales data between 2007 to 2012 provided in the *Pakistan Energy Yearbook 2013*.

Table 20 identifies the total production of fossil fuels that are produced in Pakistan as well as the marketable gas production and refinery oil production.

TABLE 20: FUEL PRODUCTION AND COMBUSTION (PJ)

Fuel Production	Production or Combustion	2007	2008	2009	2010	2011	2012
Natural Gas	Raw Natural Gas Combusted	165	146	158	184	143	158
	Marketable Natural Gas	665	683	713	703	738	734
Crude Oil	Crude Oil Produced	1,72	1,006	993	1,007	1,029	1,166
	Crude Oil Combusted	4.3	3.7	4.1	4.4	5.6	6.6
Coal	Coal Produced	173	157	146	144	151	133

3.3.2 Projections

Future growth in end-use consumption was estimated based on expected changes in production, as summarized in Table 21. It was assumed that emission factors related to the production of fossil fuels do not change over the reference case.

TABLE 21: PROJECTED GROWTH RATES FOR FOSSIL FUEL PRODUCTION (%)

Fossil Fuel	Change in Production
Natural Gas Production	Declining from 4,100 MMSCF/day in 2015 to 2.6 MMSCF/day by 2024 and then remaining flat until 2030 (Planning Commission, 2016)
Total Natural Gas Supply	Increasing from 4,300 MMSCF/day in 2015 to 6,490 MMSCF/day by 2030 (Planning Commission, 2016)
Coal Production	Increasing from 154 PJ in 2012 to 1,030 PJ in 2030 to match industrial and electricity generation demand.
Crude Oil Production	3,892 Million tons in 2014/15 rising by 3.76% per year to meet demand (OCAC, 2015).
Crude Oil Refined	Increasing at the same rate as crude oil production, requiring a new refinery.

Emission Factors for energy fuel consumption are based on IPCC defaults from the 2006 guidelines. Emissions are associated with carbon and non-carbon emissions, methane and nitrous oxides.

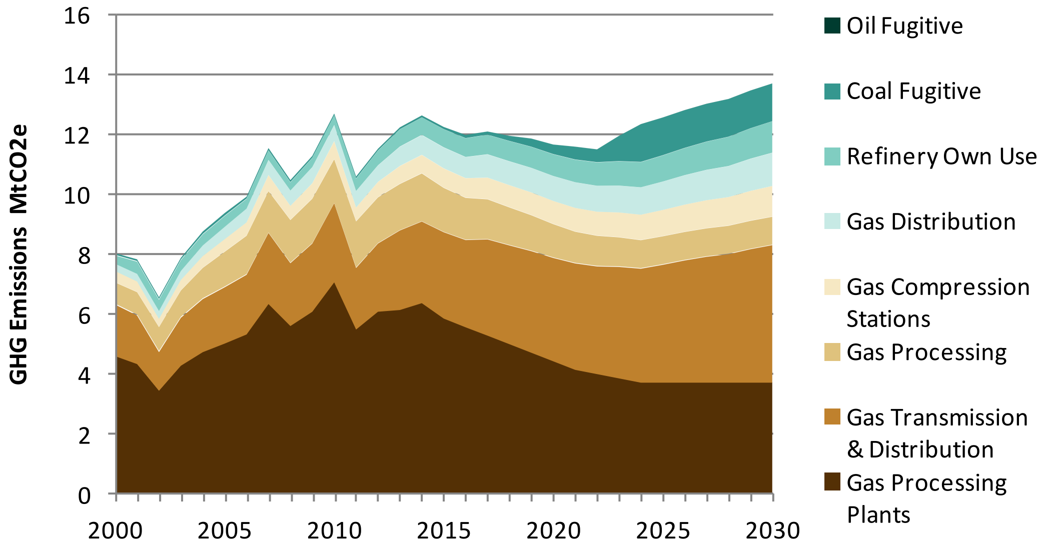
TABLE 22: FOSSIL FUEL PRODUCTION EMISSION FACTORS BY ACTIVITY (KG CO_2E/TJ)

Fossil Fuel	Activity and Source	$kgCO_2e$/TJ
Natural Gas	Fugitive and Flaring (Processing)	2,099
	Combustion (Processing Plants, Compression Stations, Transmission and Distribution)	56,152
Crude Oil	Combustion (Refinery)	73,549
	Fugitive (Refinery)	4
Coal	Fugitive (Mining)	901

3.3.2 Results

Total GHG emissions for the Fossil Fuel Production Sector are presented in Figure 8.

FIGURE 8: GHG EMISSIONS FROM FOSSIL FUEL PRODUCTION (MT CO_2E)



Emissions from fossil fuel production are primarily driven by natural gas production, processing and distribution and as a result of declining production in Pakistan there is an overall decline in emissions even though coal and oil emissions are increasing.

3.3.3 Data availability and uncertainty

Historic production numbers have low uncertainty. Uncertainty in GHG emission estimate is primarily related to the choice of emission factor for historic emissions. Projections of both activity and emission factors into the future have high uncertainty.

Major data gaps to address in the Fossil Fuel Production sub-sector include:

1. **Projections of fossil fuel production**. Current projections are based on limited data available from the Planning Commission and the Oil Companies Advisory Council that provide an indication of projection out to 2020. Projections beyond 2020 should be reviewed.
2. **Tailoring generic emission factors to Pakistan's context**. There is significant uncertainty related to the Tier 1 emission factors used and these could be reviewed to determine if there are better country specific emission factors available or to ensure that they reflect production characteristics in Pakistan.
3. **Greater detail for fugitive emissions**. Several fugitive emission sources related to the distribution of refined petroleum products have been ignored. These are generally small but could be included for completeness.

3.4 Transportation Sub-Sector

This sub-sector of Energy includes carbon dioxide, methane and nitrous oxide greenhouse gas emissions from the combustion of fossil fuels by transport vehicles. Off-road tractor vehicles are handled in analysis of the Residential, Commercial and Agriculture sub-sector above. Consumption of electricity by vehicles has been negligible in the past and is not considered in the reference case.

The transportation sector currently accounts for 11% of total greenhouse gas emissions with more than 90% of these emissions coming from on-road vehicle use.

3.4.1 Methodology

An emissions reference case for the transportation sector is developed for historical emissions by estimating the total fossil fuel consumption and then multiplying the total consumption by appropriate emission factors. Emission projections are developed by projecting the growth in fuel consumption over time accounting for the estimated increased stock of vehicles, increased mileage driven and vehicle fuel efficiency; and then multiplying the total consumption by appropriate emission factors. The data, assumptions and source references used to estimate both historical and projected emissions are outlined in the following section.

3.4.2 Data and assumptions

Total energy use for each major fossil fuel consumed was based on petroleum sales data from 2007 to 2012 provided in the *Pakistan Energy Yearbook 2013*. The yearbook provides a breakdown of fuel consumption for the Transport Sector.

Table 23 identifies the total consumption of various fuels in the transport sector. Total allocation of energy consumption is uncertain as there are reports of black market fuels that are not included in the energy balance data from the *Pakistan Energy Yearbook* 2012-13.

TABLE 23: FUEL CONSUMPTION OF TRANSPORT SECTOR (PJ)

Fuel Type	2007	2008	2009	2010	2011	2012
Aviation Fuel	18.3	19.6	20.7	22.3	20.5	20.1
Motor Spirit	64.1	67.1	85.2	99.5	122	148
HSD	285	260	245	232	229	229
Lubes & Greases	4.5	4.2	4.2	4.3	4.4	4.7
Natural Gas	70.6	86.4	97.0	111	117	98.2

Note: Motor Spirit includes E-10 blended and HOBC fuels

3.4.3 End-use Allocation

Historical information on the total fuel consumption of different vehicle types (aviation, rail, passenger vehicles and freight vehicles) is not readily available. However, there is information available on the total number of road vehicles from the National Transport Research Centre (NTRC, 2012). In addition the PAK-IEM model has information on fuel efficiency and total fuel consumption by vehicle type.

End-use allocation is based on estimates from the *PAK-IEM model*. Although these estimates are for the year 2007-08, they represent the most comprehensive analysis of end-use consumption available.

Table 24 summarizes the allocation of different fuels to vehicle end-uses. This allocation is used for historical years 2000 to 2012.

TABLE 24: ESTIMATE OF FUEL CONSUMPTION BY FUEL AND TRANSPORT END-USE (%)

Fuel	Transport Sub-Sector	Total Fuel Share by Sub-Sector	Aviation	Rail	Passenger Car	Passenger Taxis	Passenger Buses	Passenger Mini-Buses	Passenger Three	Passenger Two	Freight Trucks	Freight Vans
Aviation Fuel	Aviation	100%	100%									
Motor Spirit	Road Passenger	100%			39.2 %	5.5%	31.4 %		5.7%	18.3 %		
Kerosene	Rail	100%		100%								
HSD	Road Passenger	26.4%			26%	1.2%		73%				
	Road Freight	72.4%									87%	13%
	Rail	1.2%		100%								
LDO	Rail	100%		100%								
Furnace Oil	Rail	100%		100%								
Lubes & Greases	Aviation	6.1%	100%									
	Rail	0.6%		100%								
	Road Passenger	60.6%			37%	4.8%	25%	14%	4.5%	15%		
	Road Freight	32.7%										
Natural Gas	Road Passenger	100%			78%	22%						

3.4.4 Projections

Future growth in end-use consumption was estimated based on expected changes in stock (i.e. the number of vehicles), demand (i.e. km driven or freight moved) and efficiency.

TABLE 25: PROJECTED GROWTH RATES IN TRANSPORT END-USES (%)

<table>
<tr><th>End-Use</th><th>Change in Stock of Vehicles</th><th>Change in Demand (e.g., km travelled)</th><th>Annual Change in Efficiency (Autonomous Energy Efficiency Improvement)</th></tr>
<tr><td>Aviation</td><td rowspan="5">Projections of Transport GDP from Pak-IEM Model (+5.5% in 2013 increasing to +5.8% in 2030)</td><td>1% (PAK-IEM)</td><td>-1.0%</td></tr>
<tr><td>Rail</td><td>0% (PAK-IEM)</td><td>0% (PAK-IEM)</td></tr>
<tr><td>Road Passenger Gasoline and Diesel Vehicles (except buses)</td><td>0.5% (PAK-IEM)</td><td>-0.75%</td></tr>
<tr><td>Road Passenger Diesel and Gasoline Buses</td><td>0% (PAK-IEM)</td><td>-0.75%</td></tr>
<tr><td>Freight Diesel and Gasoline Vehicles</td><td>0% (PAK-IEM)</td><td>-1.0%</td></tr>
<tr><td>Natural Gas Vehicles</td><td colspan="3">Overall growth of -2% (Based on historic growth 2007 to 2013)</td></tr>
</table>

Table 26 indicates the total future energy consumption of fuels between 2010 and 2030 in five-year increments, and is based on the expected changes in stock, demand and efficiency seen above.

TABLE 26: PROJECTED TRANSPORT ENERGY FUEL CONSUMPTION (PJ)

Fuel Type	2012	2015	2020	2025	2030
Aviation Fuel	20.1	24.0	32.9	44.2	58.7
Motor Spirit	148	174	234	308	401
HSD	229	267	350	449	570
Lubes & Greases	4.7	5.2	7.3	9.5	12.3
Natural Gas	98.2	92.4	83.5	75.5	68.3

Emission Factors for energy fuel consumption are based on IPCC defaults from the 2006 guidelines. Emissions are associated with carbon and non-carbon emissions, methane and nitrous oxides.

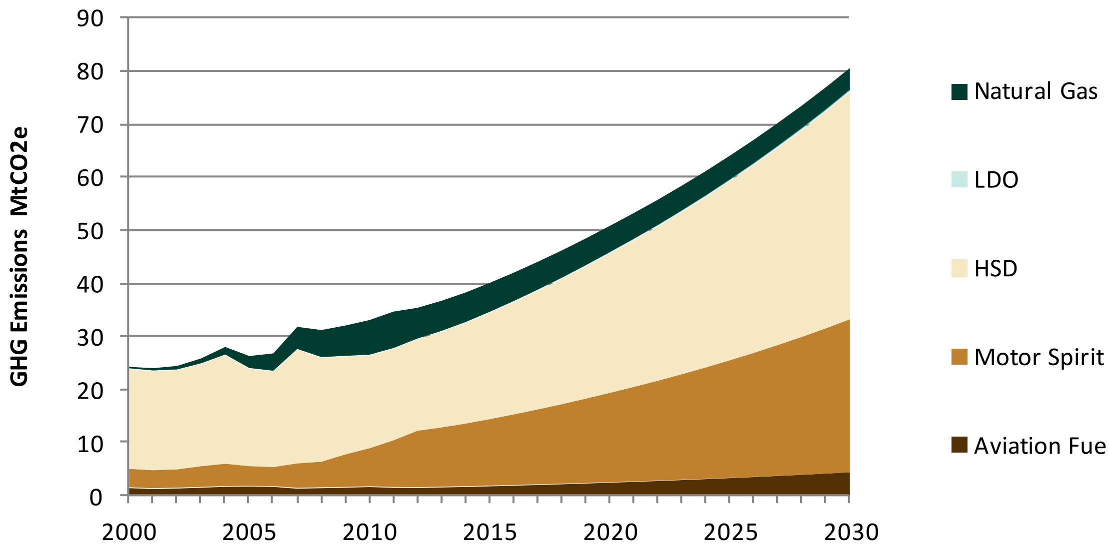
TABLE 27: EMISSION FACTORS BY FUEL (KG CO_2E/TJ)

Fuels	$kgCO_2e$/TJ
Aviation Fuel	72,131
Motor Spirit	72,305
HSD	75,391
Lubes & Greases	36,796
Natural Gas	58,962

3.4.5 Results

Total transport emissions are summarized in Figure 9.

FIGURE 9: TRANSPORT EMISSIONS BY FUEL (MT CO_2E)



Projections of on-road transport vehicles by type are provided in Figure 11 along with the average overall emission intensity of the fleet over time.

FIGURE 10: TRANSPORT EMISSIONS BY TRANSPORT MODE (MT CO_2E)

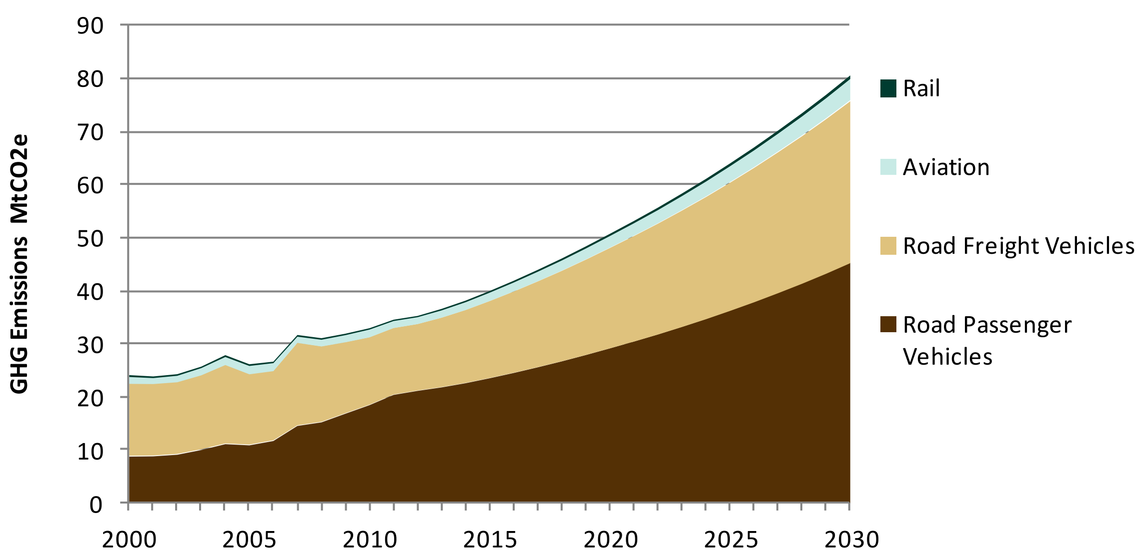


FIGURE 11: ON-ROAD PASSENGER VEHICLE STOCK AND AVERAGE EMISSION INTENSITY (KG CO_2E/KM)

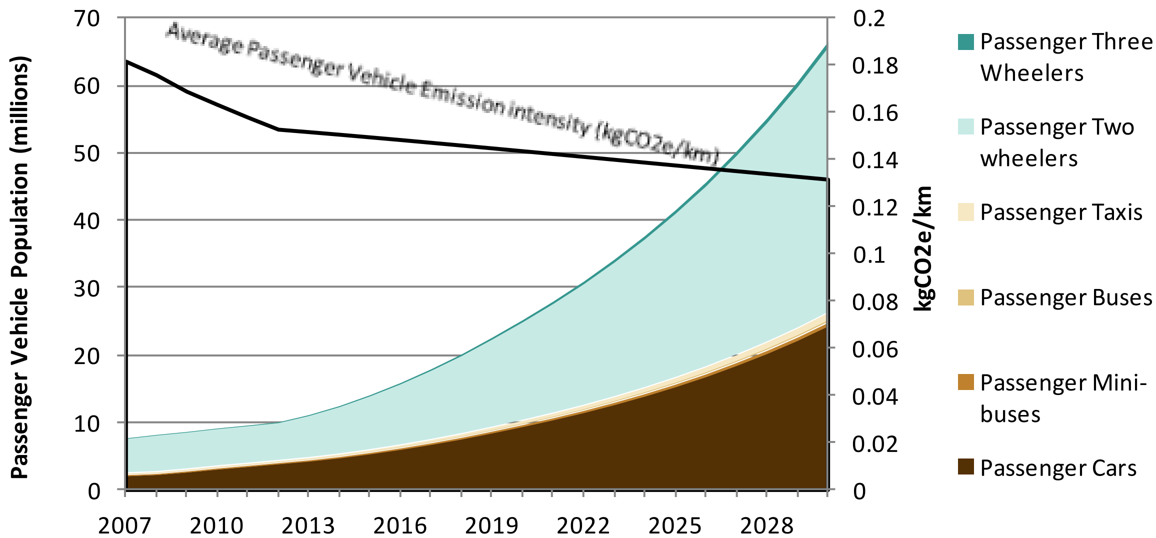
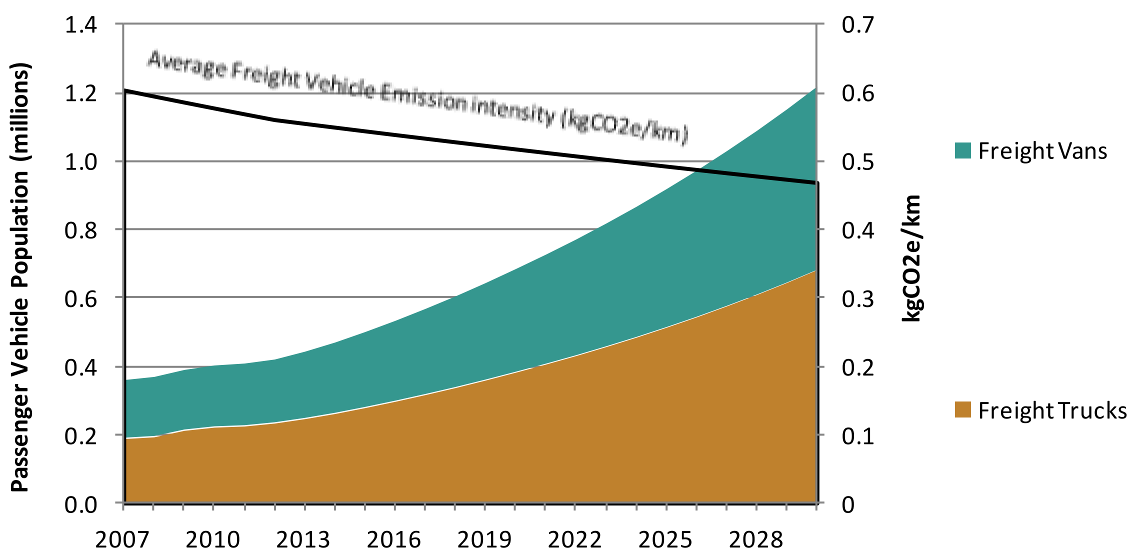
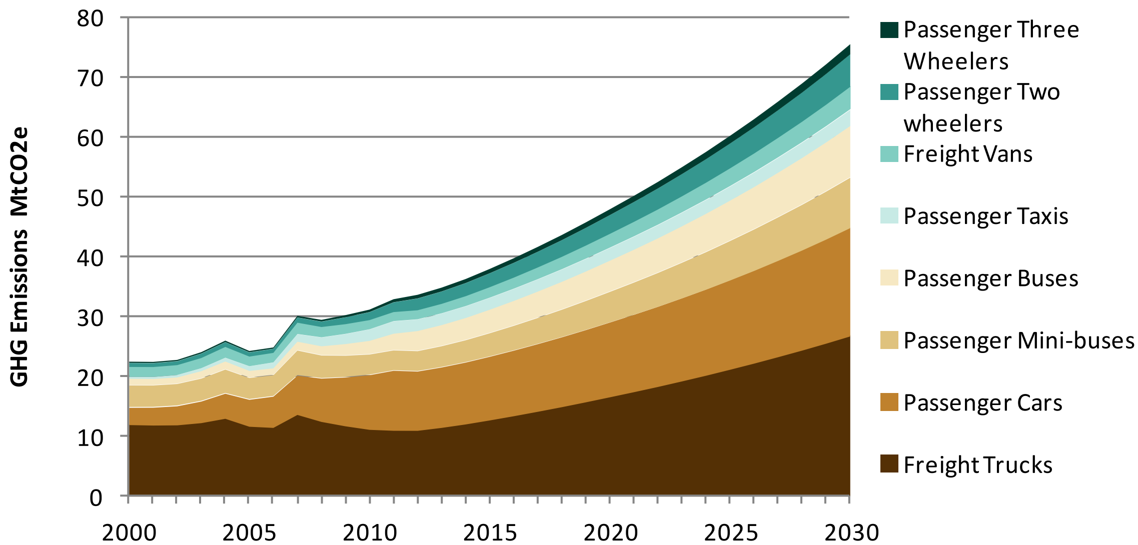


FIGURE 12: ON-ROAD FREIGHT VEHICLE STOCK AND AVERAGE EMISSION INTENSITY (KG CO_2E/KM)



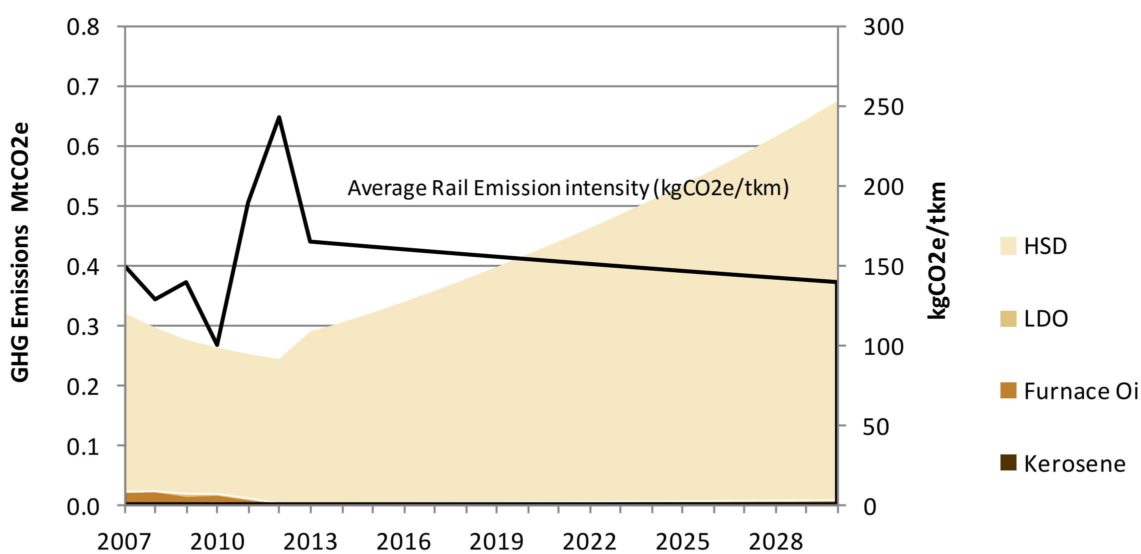
Total GHG emission by on-road vehicle type are provided in Figure 13.

FIGURE 13: ON-ROAD VEHICLE EMISSIONS BY VEHICLE TYPE (MT CO_2E)



Total emissions for rail and average rail emission intensity is indicated in Figure 14.

FIGURE 14: RAIL PASSENGER AND FREIGHT EMISSIONS AND AVERAGE EMISSION INTENSITY (KG MT CO_2E/T KM)



Overall emissions in the transport sector are driven primarily by the increase in population of on-road passenger and freight vehicles. More than 50 million new vehicles are expected to be on the roads by 2030. While rail emissions more than double as well, they remain a very small proportion of overall transport emissions in 2030 (<1%).

3.4.6 Data availability and uncertainty

Uncertainty in the historical reference case emissions case is relatively low for the total emissions of fossil fuels as there is a low degree of uncertainty related to the total consumption of these fuels in Pakistan and the related emissions factors. The uncertainty is higher for projections as the change in production, fuel switching and energy efficiency improvements are difficult to forecast and are based on limited assumptions from the Pakistan IEM Model.

Major data gaps to address in the Transportation sub-sector include:

1. **Impact of black market fuels**. Total on-road fuel consumption may be under-represented due to black market fuels. Estimates of these fuels should be included if available. More work needs to be done to determine the scale of black market activity. However, while the scale is not known precisely it is likely under 5% of total consumption.
2. **Up-to-date vehicle efficiency, stock and use data**. Fuel consumption by vehicle type is based on end-use consumption from the *PAK-IEM Model*. These results are in turn based on a number of different sources; however, all of these sources pre-date 2009. In the reference case projection developed total vehicle population is based on recent results from *National Transport Research Centre* (NTRC, 2012). However, demand (km travelled per vehicle) and fuel efficiency are based on the older data in the *PAK-IEM model*. Any additional and more recent data that could be used to calibrate and improve the model would be helpful. The Pakistan Transport Plan Study (PTPS) 2005-2030 prepared by JICA for example may have better projections of passenger and freight travel demand in terms of passenger-km and ton-km.
3. **More detailed rail data**. Rail data could be divided between freight and passenger with more detailed statistics including passenger train kilometres travelled and freight tonne kilometres. This data and fuel consumption is required for the full period 2000 to 2013.
4. **Marine transport fuel consumption**. Domestic marine transportation GHG emissions (not from bunker fuels) is not estimated in this reference case projection. Total amount of fuel consumption is required to estimate these emissions. This fuel may already be included in another sector of the energy balance (e.g., in other commercial end-use).
5. **Projections for natural gas use in transport**. What are reasonable projections for natural gas consumption in vehicles in Pakistan? Recent historical trend is a decline in natural gas use. If shortages continue, and there is less cost advantage, then it seems reasonable to expect that further declines are likely as people transition to other transport fuels?

6. **Changes in vehicle preferences**. Growth projections in stock and demand should be carefully considered to determine if it is reasonable not to expect a considerable shift in vehicle preference (either fuel choice or passenger vehicle type). Reference case assumes no important shifts. This includes shifts to electric or hybrid electric vehicles that could substantially reduce the emission intensity of transport but it is not deemed likely in the reference case 2015-2030 period.

3.5 Electricity Sub-Sector

This sub-sector includes GHG emissions from the oxidation of carbon contained in fossil fuels during combustion for the production of electricity. Small scale back-up generation and auto-production of electricity is captured in other sectors (e.g., industrial, residential and commercial) and represented by other end-use demand.

Developing a reference case for Pakistan's electricity sector is challenging because there is considerable uncertainty regarding how the sector may grow to meet a large suppressed demand for electricity. Specific plans are in place but assume high growth rates. *Vision 2025* targets 25,000 additional MW by 2025. This corresponds to an average annual growth rate of 6-7% per year, more than double the historical growth between 2000 and 2012. The cost to achieve this growth is staggering (likely greater than $50 billion in capital costs alone and not including considerable additional transmission and distribution costs). This growth is also forecast to occur even though generation technologies that are expected to make up the vast majority of new supply still face considerable barriers to implementation. New announcements that renewables are not expected to make up a large portion of new projects also raises additional challenges for coal and gas supplies.

The methodology for developing the draft reference case was first to take the National Power System Expansion Plan and the electricity forecast from the National Electric Power Regulatory Authority (NEPRA, 2014) to prepare a list of potential projects that may be implemented. PITCO, our project partner in Pakistan then critically reviewed the list to identify projects that were not likely to go forward or that were not included in the list. We then widely consulted with stakeholders to refine the list of projects.

The resulting reference case balances the guidance and projections of individual stakeholders while also considering the substantial barriers to implementation. Barriers include technical, financial, permitting, as well as grid and transmission limitations. The reference case is really a compromise in an effort to identify a single realistic scenario without additional government actions (e.g., policies and regulations) that would encourage low-carbon development. Its purpose is for determining the impact of potential low-carbon mitigation actions. The reference case is also relatively consistent with the ambitious Vision 2025 goal of 25,000 MW of new electricity generation by 2025. In comparison, the reference case has 23,500 MW of new installed generation between today and 2025 and over 29,500 MW by 2030.

An emissions reference case for the electricity sector is developed by estimating the total fossil fuel consumption of different generation technologies and then multiplying the total consumption by appropriate emission factors. Total generation by technology type is estimated by multiplying the installed capacity (megawatt [MW]) of each technology by an average capacity factor (hours per year).

The data, assumptions and source references used to estimate both historical and projected emissions are outlined in the following section. The information for the most part is taken from the *National Power System Expansion Plan 2011-2030*, *World Bank Development Indicators for Pakistan, International Energy Agency Statistics,* and the *2006 IPCC Guidelines* (NEPRA, 2014).

3.5.1 Data and assumptions

Total energy use for each major fossil fuel consumed in the electricity sector was based on data from 2007 to 2012 provided in the *Pakistan Energy Yearbook 2013*.

Table 28 identifies the total consumption of specific fuels for the electricity sector. Total allocation of energy consumption for the electricity sector is relatively certain as this is based directly on energy balance data from the *Pakistan Energy Yearbook 2013.*

TABLE 28: FUEL CONSUMPTION OF ELECTRICITY ENERGY SECTOR (PJ)

Fuel Type	2007	2008	2009	2010	2011	2012
HSD	7.1	7.3	11.0	4.4	8.5	9.2
Furnace Oil	282	302	349	328	302	307
Natural Gas	356	328	298	272	282	297
Coal	3.0	2.1	2.4	1.8	2.0	1.2

Historical capacity factors can be calculated based on the total capacity installed and comparing this to total generation from available activity data in the *Pakistan Energy Yearbook 2013*. Future capacity factors depend on many factors, including peaking demand, resource availability and market pricing conditions. Table 29 identifies the assumed capacity factors from 2013 to 2030 for each of the different electricity generation types and the assumed conversion efficiencies for fossil fuel generation types. These projections are based on a consideration of the historical capacity factors and on typical capacity factors and efficiencies achieved in other jurisdictions. The capacity factors and conversion efficiencies presented are average for all generation plants installed (new and historic) and reflect the impact of new higher efficiency plants coming online.

TABLE 29: AVERAGE CAPACITY FACTORS AND CONVERSION EFFICIENCIES FOR DIFFERENT ELECTRICITY GENERATION TYPES

Generation Type	Capacity Factors	Average Generation Conversion Efficiencies (LHV)
Hydro	50%	-
Nuclear	75%	-
Natural Gas	50%	(new 54%) Average 33% rising to 40.6% in 2030
HSD	60%	33%
Coal	60%	30% rising to 43% in 2030
Wind	25% (rising to 33% by 2030)	-
Furnace Oil	65%	39%
Biomass	30%	32%
Solar	18%	

Transmission and distribution losses are projected to fall from 17.6% in 2012 to 15.6% in 2030 in the reference case. These do not include losses due to theft or unpaid electricity consumption which are accounted for in the reference case. Net imports are projected to increase from 375 GWh in 2012 to 5,000 GWh in 2030 based on the *National Power System Expansion Plan 2011-2030* and the *National Transmission & Despatch Company Power System Statistics* (NTDC, 2014).

Capacities and additions for individual generation plants assumed in the reference case projection are indicated in Table 30 from the year 2000 to the year 2030. Existing plant capacities, plant retirements and planned capacity additions are based on the *National Power System Expansion Plan 2011-2030* as well as the *2013 Energy Yearbook* (NEPRA, 2014). These are the plants that are included in the reference case. In addition 2,400 MW of LNG based power capacity were also added to the reference case as per Phase I of the latest Planning Commission demand and Supply estimates (Planning Commission, 2016).

TABLE 30: CAPACITY AND CAPACITY ADDITIONS FROM 2000 TO 2030 (MW)

Fuel	Plant	(MW	200	200	200	200	200	200	200	200	200	200	201	201	201	201	201	201	201	201	201	201	202	202	202	202	202	202	202	202	202	202	203
Hydro	Allai Khwar	121	0	0	0	0	0	0	0	0	0	0	0	0	0	121	121	121	121	121	121	121	121	121	121	121	121	121	121	121	121	121	121
Hydro	Asrit-Kedam Hyde HPP, IPP	215	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	215	215	215	215	215	215	215	215
Hydro	Azad Pattan HPP, IPP	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	640	640	640	640	640	640	640	640	640
Hydro	Basho	40																											8	16	24	32	40
Hydro	Chakothi-Hattian HPP, IPP	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500	500
Hydro	Chashma Low Head	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184
Hydro	Chichoki Mallian	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Hydro	Chitral	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hydro	Daral	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	37	37	37	37	37	37	37	37	37	37	37	37
Hydro	Dargai	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Hydro	Deg fall Sheikhpura	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	4	4	4	4	4	4	4	4	4	4	4
Hydro	Duber Khwar	130														0	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
Hydro	Dudhnial	792	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	792	792	792	792	792
Hydro	Garam Chashma	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hydro	Ghazi Barotha	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450
Hydro	Golen Gol	106																					21	42	64	85	106	106	106	106	106	106	106
Hydro	Gomal Zam	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Hydro	Gulpur, IPP	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100
Hydro	Harpo	35																				7	14	21	28	35	35	35	35	35	35	35	35
Hydro	Jabban	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
Hydro	Jabori	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Hydro	Jagran (AJ&K)	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Hydro	Jinnah	96	0	0	0	0	0	0	0	0	0	0	0	0	0	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96
Hydro	Kaigah HPP, IPP	548	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	548	548	548	548	548	548
Hydro	Karora	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Hydro	Karot HPP, IPP	720	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	720	720	720	720	720	720	720	720	720	720
Hydro	Keyal Khwar	128																											26	51	77	102	128
Hydro	Khan Khwar	72	0	0	0	0	0	0	0	0	0	0	0	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
Hydro	Khyber Pakhtunkhwa, feasibility study - 3 sites	750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	750	750	750	750	750	750	750	750	750	750	750	750	750	750
Hydro	Koto	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Hydro	Kurram Tangi	83																17	33	50	67	83	83	83	83	83	83	83	83	83	83	83	83
Hydro	Kurrum Garhi	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Hydro	Laraib	84	0	0	0	0	0	0	0	0	0	0	0	0	0	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84
Hydro	Lawi	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69	69	69	69	69	69	69	69	69	69	69	69	69
Hydro	Lower Palas Valley	665	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	665	665	665	665	665	665	665	665
Hydro	Lower Spat Gah	496	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	496	496	496	496	496	496	496	496
Hydro	Machai	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3
Hydro	Madian HPP, IPP	157	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	157	157	157	157	157	157	157	157
Hydro	Mahl	590	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	590	590	590	590	590	590
Hydro	Malakand-III (PEDO)	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81
Hydro	Mangla	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Hydro	Matiltan	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	84	84	84	84	84	84	84	84	84	84	84	84
Hydro	Nandipur	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Hydro	Neelum Jhelum	969																194	388	581	775	969	969	969	969	969	969	969	969	969	969	969	969
Hydro	New Bong Escape	84															84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84
Hydro	Pakpattan Canal	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3
Hydro	Patrind HPP, IPP	147	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	147	147	147	147	147	147	147	147	147	147	147	147	147	147
Hydro	Pehur (PEDO)	18	0	0	0	0	0	0	0	0	0	0	0	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Hydro	Phandar	80																											16	32	48	64	80
Hydro	Punjab	20	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	20	20	20	20	20	20	20	20	20	20	20	20	20
Hydro	Ranolia	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	17	17	17	17	17	17	17	17	17	17	17	17
Hydro	Renala	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hydro	Reshun	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Hydro	Sehra HPP, IPP	130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	130	130	130	130	130	130	130	130	130
Hydro	Shadiwal	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Hydro	Sharmai	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Hydro	Shishi	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Hydro	Shogo-Sin	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	132	132	132	132	132	132	132	132	132	132	132	132
Hydro	Shushai-Zhendoli	144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	144	144	144	144	144	144	144	144	144	144	144	144
Hydro	Suki Kinari HPP, IPP	870	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	870	870	870	870	870	870	870	870	870	870
Hydro	Tarbela	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478	3,478
Hydro	Taunsa	119	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119	119	119	119	119
Hydro	Tungas	198	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	198	198	198	198
Hydro	UCC Main Lower (Chianwali)	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	5	5	5	5	5	5	5	5	5	5	5
Hydro	UCCM Marala	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	8	8	8	8	8	8	8	8	8	8	8
Hydro	Warsak	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
Hydro	Yulbo	238	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	238	238	238	238

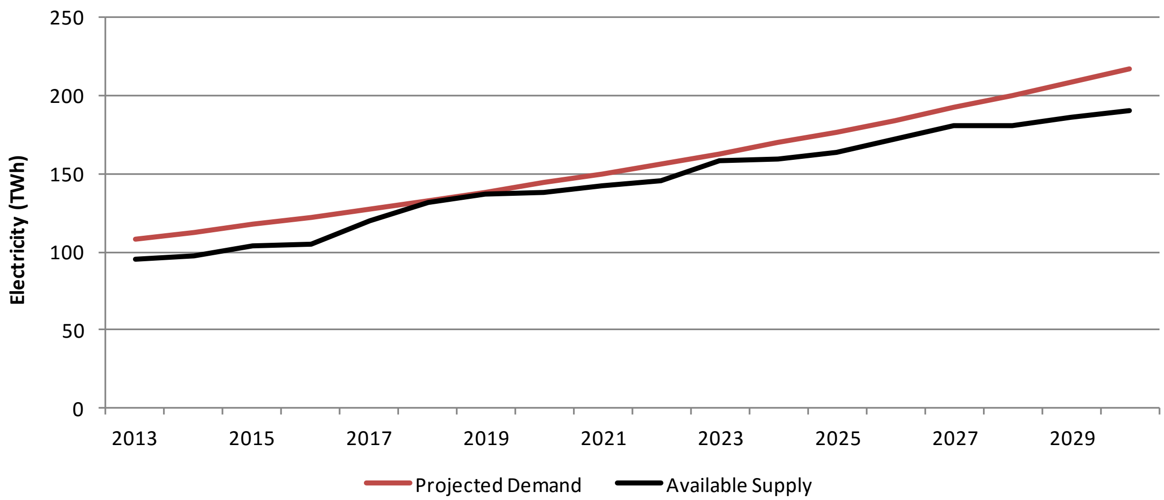
Fuel	Plant	(MW	200	200	200	200	200	200	200	200	200	200	201	201	201	201	201	201	201	201	201	201	202	202	202	202	202	202	202	202	202	202	203
Gas	Altern Energy Ltd.	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Gas	Aggreko (Rental)	0	50	50	50	50	50	50	50	50	50	50	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas	Anoud Power	15	12	12	12	12	12	12	12	12	12	12	12	12	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Gas	Anoud (KESC), # 1, 2, 3																														-12	-12	-12
Gas	Balloki	689	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	689
Gas	Bin-Qasim TPS-I	1,260									1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260	1,260
Gas	Bin-Qasim TPS-II	560	0	0	0	0	0	0	0	0	0	0	0	0	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560
Gas	Bin Qasim #1,2,3,4 (KESC)																														-708	-708	-708
Gas	Chichoki Mallian	525																															
Gas	Davis Energen.	11													0	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Gas	DHA Cogen.	0	94	94	94	94	94	94	94	94	94	94	94	94	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas	Engro Polymer	0	18	18	18	18	18	18	18	18	18	18	18	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas	Engro Power	227											226	226	227	227	227	227	227	227	227	227	227	227	227	227	227	227	227	227	227	227	227
Gas	Faisalabad GTPS	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244
Gas	Faisalabad GTPS, # 5, 6, 7, 8, 9																						-129	-129	-129	-129	-129	-129	-129	-129	-129	-129	-129
Gas	Faisalabad GTPS, # 1, 2, 3, 4																								-72	-72	-72	-72	-72	-72	-72	-72	-72
Gas	Faisalabad SPS	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132
Gas	Faisalabad SPS, # 1, 2																								-92	-92	-92	-92	-92	-92	-92	-92	-92
Gas	Faisalabad	153	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	153	153	153	153	153
Gas	Fauji Kabirwala	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157
Gas	Foundation Power	183	0	0	0	0	0	0	0	0	0	0	0	182	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183
Gas	Guddu	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655	1,655
Gas	Guddu-New	747	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	747	747	747	747	747	747	747	747	747	747	747	747	747	747	747	747
Gas	Guddu, # 1, 2, 3, 4																								-410	-410	-410	-410	-410	-410	-410	-410	-410
Gas	Guddu, # 5, 6, 7, 8, 9, 10																										-429	-429	-429	-429	-429	-429	-429
Gas	Guddu, # 11, 12, 13																						-285	-285	-285	-285	-285	-285	-285	-285	-285	-285	-285
Gas	Habibullah	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140
Gas	Halmore	225	0	0	0	0	0	0	0	0	0	0	0	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225
Gas	ISL	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Gas	ISL	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Gas	Kandra Power Project	120																								120	120	120	120	120	120	120	120
Gas	KAPCO	1,638	1,639	1,639	1,639	1,639	1,639	1,639	1,639	1,639	1,639	1,639	1,639	1,639	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638
Gas	Kot Addu (KAPCO), #2,3,4																																-721
Gas	Kot Addu (KAPCO), #1																												-244	-244	-244	-244
Gas	Karkey (Rental)																	-203	-203	-203	-203	-203	-203	-203	-203	-203	-203	-203	-203	-203	-203	-203	-203
Gas	Korangi TPS	125	0	0	0	0	0	0	0	0	0	0	250	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125
Gas	Korangi GTPS-I	0	0	0	0	0	0	0	0	0	0	0	20	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas	Korangi Town GTPS-II	97	0	0	0	0	0	0	0	0	396	375	88	88	88	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Gas	Korangi CCPP	220	0	0	0	0	0	0	0	0	0	0	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220
Gas	GTPS Kotri	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	36	36	36	36	36	36	36	36	6
Gas	Gulf (Rental)																	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60
Gas	Lahore	153	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	153	153
Gas	Lahore	153	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	153
Gas	TNB Liberty Power	235		235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235
Gas	Nandipur	425	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	425	425	425	425	425	425	425	425	425	425	425	425	425	425	425	425
Gas	Orient Power	225	0	0	0	0	0	0	0	0	0	0	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225
Gas	GTPS Panjgoor	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas	PASMIC	165											110	110	110	165	165	165	165	165	165	165	165	165	165	165	165	165	165	165	165	165	165
Gas	TPS Quetta	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	10	10	10	10	10	10	10	10	10
Gas	Reshma (Rental)																	-177	-177	-177	-177	-177	-177	-177	-177	-177	-177	-177	-177	-177	-177	-177	-177
Gas	Rousch	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
Gas	Saif Power	225	0	0	0	0	0	0	0	0	0	0	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225
Gas	Sapphire	235	0	0	0	0	0	0	0	0	0	0	0	229	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235
Gas	Site GTPS-I	0	20	20	20	20	20	20	20	20	20	20	20	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas	Site GTPS-II	97	88	88	88	88	88	88	88	88	88	88	88	88	88	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Gas	Southern Electric	136	136	136	136	136	136	136	136	136	136	136	136	136	117	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136	136
Gas	Southern Electric, # 1, 2, 3, 4, 5, 6																																-115
Gas	Sumundri (Rental)															-132	-132	-132	-132	-132	-132	-132	-132	-132	-132	-132	-132	-132	-132	-132	-132	-132	-132
Gas	Uch Power	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586	586
Gas	Uch Power-II	404	0	0	0	0	0	0	0	0	0	0	0	0	0	0	381	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404	404
Gas	Walters (Rental)																	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50

Fuel	Plant	(MW	200	200	200	200	200	200	200	200	200	200	201	201	201	201	201	201	201	201	201	201	202	202	202	202	202	202	202	202	202	202	203
Oil	Atlas Power	224										224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224
Oil	Attock Gen Ltd (AGL)	164										165	165	165	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164
Oil	D.I.Khan	689	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	689	689	689	689
Oil	Gul Ahmed, all units (KESC)	128	136	136	136	136	136	136	136	136	136	136	136	128	128	128	128	128	128	128	128	128	0	0	0	0	0	0	0	0	0	0	0
Oil	HUBCO	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292	1,292
Oil	Jamshoro (TPS)	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	188	188	188	188	188	188	188	188	188	188
Oil	Japan Power	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135
Oil	KGTPS #1 to 32 (KESC)																																-87
Oil	Kohinoor Energy	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131	131
Oil	Kohinoor # 1,2,3,4,5,6																														-72	-72	-72
Oil	Lal Pir (AES)	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362
Oil	Liberty Tech.	202	0	0	0	0	0	0	0	0	0	0	0	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202
Oil	NGPS Multan	195									195	195	195	195	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
Oil	Multan #1, 3																								-55	-55	-55	-55	-55	-55	-55	-55	-55
Oil	Muzaffargarh (TPS)	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	514	514	514	274	274	274
Oil	Hubco Narowal	225	0	0	0	0	0	0	0	0	0	0	0	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225
Oil	Nishat Chunian	202	0	0	0	0	0	0	0	0	0	0	0	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202
Oil	Nishat Power	202											202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202
Oil	Pak Gen. (AES)	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365
Oil	Saba Power	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
Oil	SGTPS #1 to 32 (KESC)																																-87
Oil	GTPS Shahdra	44									44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
Oil	Shadara #3,4,5																								-27	-27	-27	-27	-27	-27	-27	-27	-27
Oil	Tapal, all units (KESC)	124	126	126	126	126	126	126	126	126	126	126	126	124	124	124	124	124	124	124	124	124	0	0	0	0	0	0	0	0	0	0	0
Coal	Hub Power Companry (2x660MW imported coal	1,320																			1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320
Coal	Lakhra F.B.C	150	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Coal	Muzaffargarh (Balochistan)	300																															
Coal	Port Qasim (2x660MW imported coal plants)	1,320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320
Coal	Port Qasim - Lucky Electric Power (660MW impo	660																				660	660	660	660	660	660	660	660	660	660	660	660
Coal	Port Qasim - Siddiqsons (350MW imported coal	350																				350	350	350	350	350	350	350	350	350	350	350	350
Coal	Salt Rang Pind Dadan Khan (300MW local coal)	300																															
Coal	Sahiwal (2x660MW imported coal plants)	1,320																			1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320
Coal	Thar Block-I (2x660MW; Shanghai Electric)	1,320																				1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320
Coal	Thar Block-II (2x330MW; Engro Powergen Unite	660	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	660	660	660	660	660	660	660	660	660	660	660	660
Coal	Thar #3	567																					0	0	567	567	567	567	567	567	567	567	567
Coal	Thar # 4 Coal 7	567	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	567	567	567	567	567	567	567	567
Coal	Thar # 5	567	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	567	567	567	567	567	567	567
Coal	Thar # 6	567	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	567	567	567	567	567	567
Coal	Thar # 7	567	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	567	567	567	567	567
Coal	Thar # 8	567	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	567	567	567	567
Coal	Thar # 9	567	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	567	567	567
Coal	Thar # 10	567	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	567	567
Coal	Thar # 11	567	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	567
Diesel	Pasni (TPS)	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nuclear	Chashma-I	325	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	325	325	325	325	325	325	325	325	325	325	325
Nuclear	Chashma-II	325	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	325	325
Nuclear	Chashnup-old (PAEC)	650	325	325	325	325	325	325	325	325	325	325	325	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650
Nuclear	CHASHNUPP-III, Punjab	320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	320	320	320	320	320	320	320	320	320	320	320	320	320	320
Nuclear	CHASHNUPP-IV, Punjab	320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	320	320	320	320	320	320	320	320	320	320	320	320	320
Nuclear	Kanupp-old	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137
Nuclear	Kannup (KESC), #1																							-114	-114	-114	-114	-114	-114	-114	-114	-114	-114
Nuclear	Karachi (Kannup) #2	940	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	940	940	940	940	940	940	940
Nuclear	Karachi (Kannup) #3	940	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	940	940	940	940	940	940
Nuclear	Karachi (Kannup) #?	940	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	940	940	940
Nuclear	Qadirabad	940	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	940	940	940	940	940	940	940	940	940	940

Fuel	Plant	(MW	200	200	200	200	200	200	200	200	200	200	201	201	201	201	201	201	201	201	201	201	202	202	202	202	202	202	202	202	202	202	203
Wind	Burj Wind Energy (Pvt.) Limited	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Wind	China Sunec Energy (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	FFCEL	50	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Foundation Wind Energy-D Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Foundation Wind Energy-] Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Gul Ahmed Energy Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Hartford Alternative Energy (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Hawa Holdings Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Hydrochina Dawood Power (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	JhampirWind Power (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Master Wind Enercw (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Metro Power Company (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Sachal Energy Development (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Sapphire Wind Power Company (Pvt.)Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Tapal Wind Energy (Pvt.) Limited	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Wind	Titan Wind Power (Pvt.) Limited	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Wind	Tenega Generasi Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Three Gorges First Wind Farm Pakistan (Pvt.) Li	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Tricon Boston Consulting Corporation (Pvt.) Lim	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Tricon Boston Consulting Corporation (Pvt.) Lim	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Tricon Boston Consulting Corporation (Pvt.) Lim	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Trident Energy (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	United Energy Pakistan Limited	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100
Wind	United Energy Pakistan Limited	350	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	350	350	350	350	350	350	350	350	350	350	350	350	350	350
Wind	Western Energy (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Wind Eagle Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Wind Eagle Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Yunus Enei'Qv Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Zaver Petroleum Corporation Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Zephyr Power (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Wind	Zorlu and Fauji (Zorlu Enerji Pakistan)	56	0	0	0	0	0	0	0	0	0	0	0	0	1	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56
Biomass	Alliance Sugar Mills Limited	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Biomass	Hamza Sugar Mills Limited	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Biomass	Kamalia Sugar Mills Limited	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Biomass	Layyah Sugar Mills Limited	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
Biomass	Safina Sugar Mills Limited	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Solar	Access Electric (Pvt.) Limited	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Solar	Access Solar (Pvt.) Limited	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Solar	Ayan Energy (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50
Solar	Blue Star Hydel (Pvt.) Limited	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Solar	Bukhsh Energy (Pvt.) Limited	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Solar	DACC Associates	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Solar	Dawood Group Limited	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10
Solar	Fauji Foundation	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Solar	Hanergy Global Solar Asia Pacific Limited - I	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Solar	Hanergy Global Solar Asia Pacific Limited - n	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Solar	Integrated Power Solution (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Solar	Jafri & Associates	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Solar	Janpur Energy Limited	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10
Solar	Janpur Energy Limited	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10
Solar	Nizam Power (Pvt.) Limited	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11	11	11	11	11	11	11	11	11	11	11	11
Solar	Nizam Power (Pvt.) Limited - I	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6	6	6	6	6	6	6	6	6	6	6	6
Solar	Nizam Power (Pvt.) Limited - n	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6	6	6	6	6	6	6	6	6	6	6	6
Solar	Quaid-e-Azam	100																100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Solar	Reliable - ZKB (JV)	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10
Solar	RE Solar I (Pvt.) Limited	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20	20	20	20	20	20	20	20	20	20	20	20
Solar	RE Solar n (Pvt.) Limited	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20	20	20	20	20	20	20	20	20	20	20	20
Solar	Safe Solar (Pvt.) Limited	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Solar	Sanjwal Solar Power (Pvt.) Limited	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Solar	Sino Pak Energy Development Company (Pvt.) L	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10
Solar	Solar Blue (Pvt.) Limited	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Solar	Table Rock Associates	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100
Import	Source unknown	1,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Import	Iran - Pakistan and CASA	1,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
GRAND TOTAL (INCL. IMPORT)			17,802	18,037	18,037	18,037	18,037	18,037	18,037	18,037	19,932	20,300	21,491	23,088	23,455	23,831	24,277	25,932	26,314	30,773	36,042	39,709	39,396	41,178	41,724	44,473	45,572	47,381	49,061	50,559	51,083	52,178	52,596
GRAND TOTAL (NO IMPORT)			17,802	18,037	18,037	18,037	18,037	18,037	18,037	18,037	19,932	20,300	21,491	23,088	23,455	23,831	24,277	25,932	26,314	28,773	34,042	37,709	37,396	39,178	39,724	42,473	43,572	45,381	47,061	48,559	49,083	50,178	50,596

Even with the aggressive deployment of electricity generation in the reference case seen in Table 30 there will remain a gap between available supply and demand. The current supply shortage is estimated to be approximately 13 TWh annually or approximately 5,000 MW of peak generation capacity. Based on the deployment above and demand projections it is expected that the supply shortage will almost be closed by 2018 but then will increase again to 27 TWh in 2030 as shown in Figure 15: comparison of projected Electricity generation demand versus supply (TWh)Figure 15.

FIGURE 15: COMPARISON OF PROJECTED ELECTRICITY GENERATION DEMAND VERSUS SUPPLY (TWH)



3.5.2 End-use Allocation

Historical information on the total electricity consumption by different end-uses in Pakistan (space heating, space cooling, lighting, refrigeration, plugload, industrial processes, water pumping, street lighting) is not readily available. However, information is readily available on the consumption of electricity by different electricity consumers (urban, rural, agriculture, commercial and industrial sub-sectors).

End-use allocation is based on estimates from the *PAK-IEM model*. Although these estimates are for the year 2007-08, they represent the most comprehensive analysis of end-use consumption available and no other domestic sources of data have been identified. The end-use allocation in the Pakistan Integrated Energy Model appears to have been primarily derived from the *Pakistan Household Use of Commercial Energy* (ESMAP, 2006).

Table 31 summarizes the allocation of electricity consumption to different consumers and end-uses.

TABLE 31: ESTIMATE OF ELECTRICITY CONSUMPTION BY CONSUMER AND END-USE (%)

Sector	Total Electricity Share by Sector	Sub-Sector	Total Electricity Share by Sub-Sector	Space heating	Space Cooling	Lighting	Refrigeration	Plug Load	Industrial Processes	Water Pumping	Street Lighting
Residential	47%	Urban	23%		42.9%	25.3%	14.3%	14.0%		3.5%	
		Rural	24%		46.4%	30.2%	6.9%	13.0%		3.5%	
Commercial	8.5%	Commercial	7.9%	1.3%	25.1%	15.1%	7.4%	51.2%			
		Street Lighting	0.6%								100%
Agriculture	10%	Agriculture	10%							100%	
Industry	35%	Brick	3.4%						100%		
		Cement	5.9%						100%		
		Fertilizer	1.9%						100%		
		Iron & Steel	3.1%						100%		
		Other Industries	13.6%						100%		
		Sugar	1.7%						100%		
		Textiles	4.8%						100%		

3.5.3 Projections

Future growth in end-use consumption was estimated based on expected changes in stock (e.g., number of appliances or fixtures), demand and efficiency, and are summarized in Table 32.

TABLE 32: PROJECTED GROWTH IN ELECTRICITY SECTOR END-USES (%)

Sector	End-Use	Change in Stock	Change in Demand	Annual Change in Efficiency (Autonomous Energy Efficiency Improvement)
Urban	Space Cooling	Change in Urban Households (+3.6% in 2013 increasing to +3.0% in 2030)	Change in Services GDP adjusting for household size (+5.9% in 2013 declining to +5.4% in 2030)	-0.5%
	Lighting			-0.6%
	Refrigeration			-0.3%
	Plug-Load			-0.3%
Rural	Space Cooling	Change in Rural Households (+1.2% in 2013 increasing to +0.1% in 2030)	Change in Services GDP adjusting for household size (+5.9% in 2013 declining to +5.4% in 2030)	-0.5%
	Lighting			-0.6%
	Refrigeration			-0.3%
	Plug-Load			-0.3%
Commercial	Space Heating	Projections of Services GDP from Pak-IEM Model (+5.9% in 2013 declining to +5.4% in 2030)		-0.5%
	Space Cooling			-0.5%
	Lighting			-0.6%
	Refrigeration			-0.3%
	Plug-Load			-0.3%
	Street Lighting	Change in Urban Households (+3.6% in 2013 increasing to +3.0% in 2030)		-0.6%
Agriculture	Water Pumping	Based on Forecast of Agriculture GDP (PAK IEM) (+4.1% in 2013 declining to +3.6% in 2030)		
Industrial	Brick	Projections of Industry GDP from Pak-IEM Model (+6.8% in 2013		-0.5%

Sector	End-Use	Change in Stock	Change in Demand	Annual Change in Efficiency (Autonomous Energy Efficiency Improvement)
		increasing to +8.0% in 2030)		
	Cement	Projections of Industry GDP from Pak-IEM Model (+6.8% in 2013 increasing to +8.0% in 2030)		-0.5%
	Fertilizer	Projections of Agriculture GDP from Pak-IEM Model (+4.1% in 2013 declining to +3.6% in 2030)		-0.5%
	Iron & Steel	Projections of Industry GDP from Pak-IEM Model (+6.8% in 2013 increasing to +8.0% in 2030)		-0.5%
	Other Industries	Projections of Industry GDP from Pak-IEM Model (+6.8% in 2013 increasing to +8.0% in 2030)		-0.5%
	Sugar	Estimate of 2.5% growth in stock and demand (PAK-IEM Model)		-0.5%
	Textiles	Estimate of 6.4% growth in stock and demand (PAK-IEM Model)		-0.5%

Table 33 indicates the total future energy consumption of fuels between 2010 and 2030 in five-year increments based on the expected changes in stock, demand and efficiency.

TABLE 33: PROJECTED ELECTRICITY FUEL CONSUMPTION (PJ)

Fuel Type	2012	2015	2020	2025	2030
HSD	9.1	1.0	1.0	1.0	1.0
Furnace Oil	307	326	313	232	243
Natural Gas	297	484	502	460	416
Coal	1.2	14.3	163	283	458

Emission Factors for electricity fuel consumption are based on IPCC defaults from the 2006 guidelines. The coal emission factor is based on lignite coal reflective of the energy density of coal available from the Thar Coal Fields. As some coal with a higher energy density will likely be imported in the period between 2016 and 2020, emissions may be slightly overestimated in this period. Emissions are associated with carbon and non-carbon emissions, methane and nitrous oxides. Table 34 summarizes the IPCC default emission factors that are used.

TABLE 34: EMISSION FACTORS BY FUEL (KG CO_2E/TJ)

Fuels	$kgCO_2e$/TJ
HSD	73,617
Furnace Oil	73,617
Natural Gas	56,069
Coal	94,789

3.5.4 Results

Total generation capacities for different types of generation were based primarily on existing plant capacities, plant retirements, and planned capacity additions by their respective fuel types as seen in the *National Power System Expansion Plan 2011-2030*. Plant-specific information was also cross-referenced at times with the *2013 Energy Yearbook*.

FIGURE 16: ELECTRICITY CAPACITY BY GENERATION TYPE (GW)

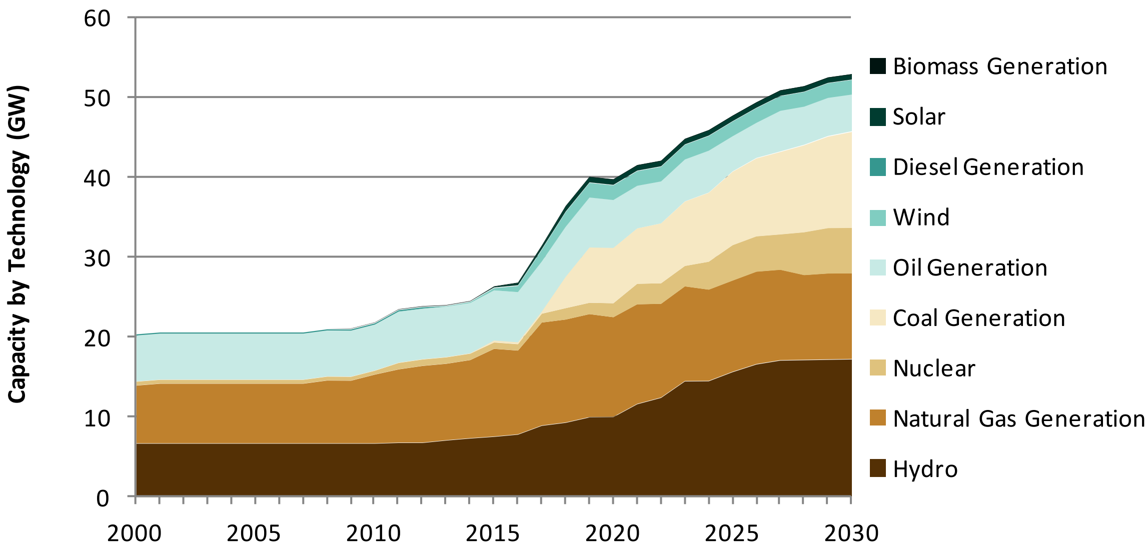
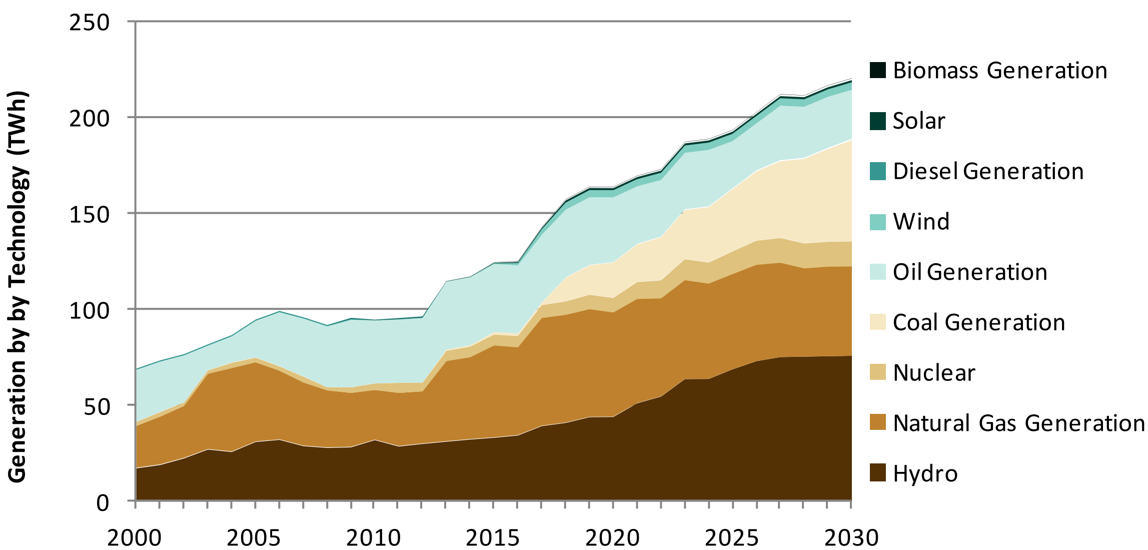


FIGURE 17: ELECTRICITY GENERATION BY GENERATION TYPE (TWH)



Projected electricity consumption is balanced with projected generation and considers net losses from transmission and distribution, self consumption and balance of imports and exports. Total consumption is expected to grow from nearly 100 TWh today to more than 200 TWh in 2030. Figure 18 shows the total electricity consumption by sub-sectors.

FIGURE 18: PROJECTED ELECTRICITY CONSUMPTION BY SUB-SECTOR (TWH)

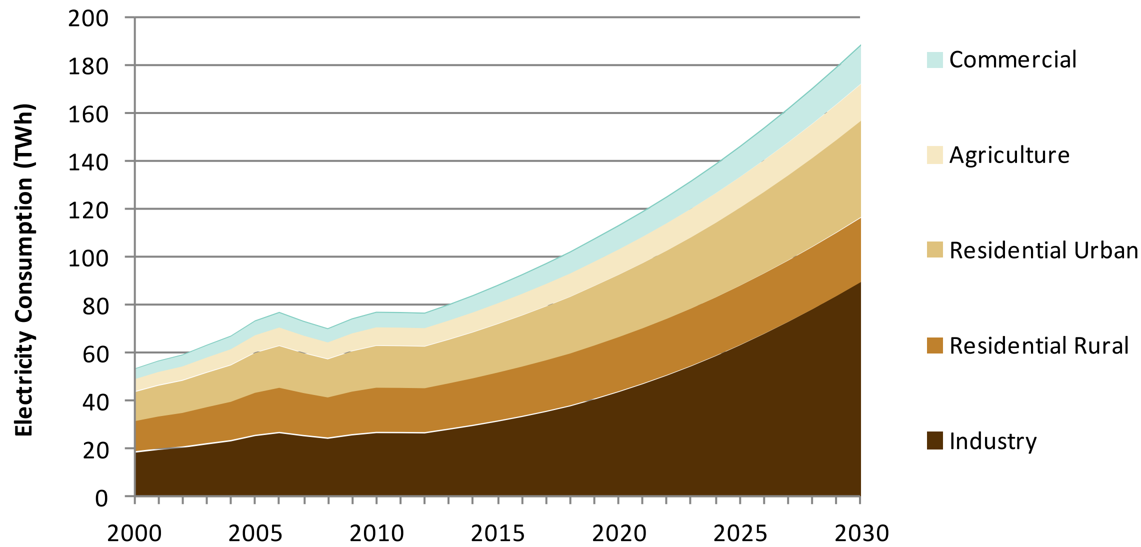


Figure 19 indicates total projected electricity consumption by residential end-uses that are split into rural and urban consumers.

FIGURE 19: PROJECTED RESIDENTIAL ELECTRICITY CONSUMPTION BY END-USE (TWH)

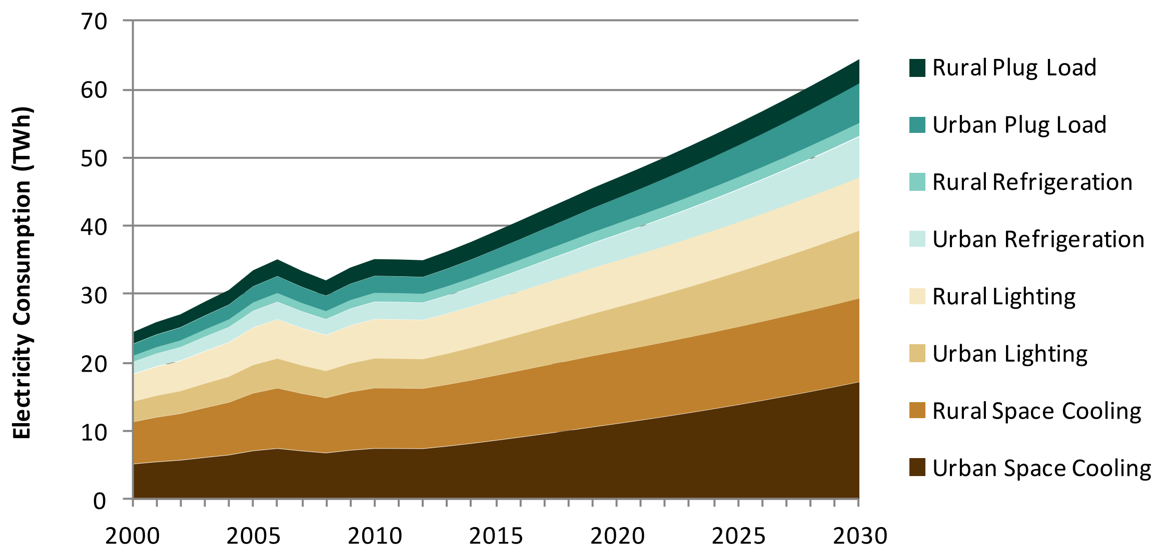


Figure 20 indicates total projected electricity consumption by commercial and agricultural end-uses.

FIGURE 20: PROJECTED COMMERCIAL ELECTRICITY CONSUMPTION BY END-USE INCLUDING AGRICULTURE (TWH)

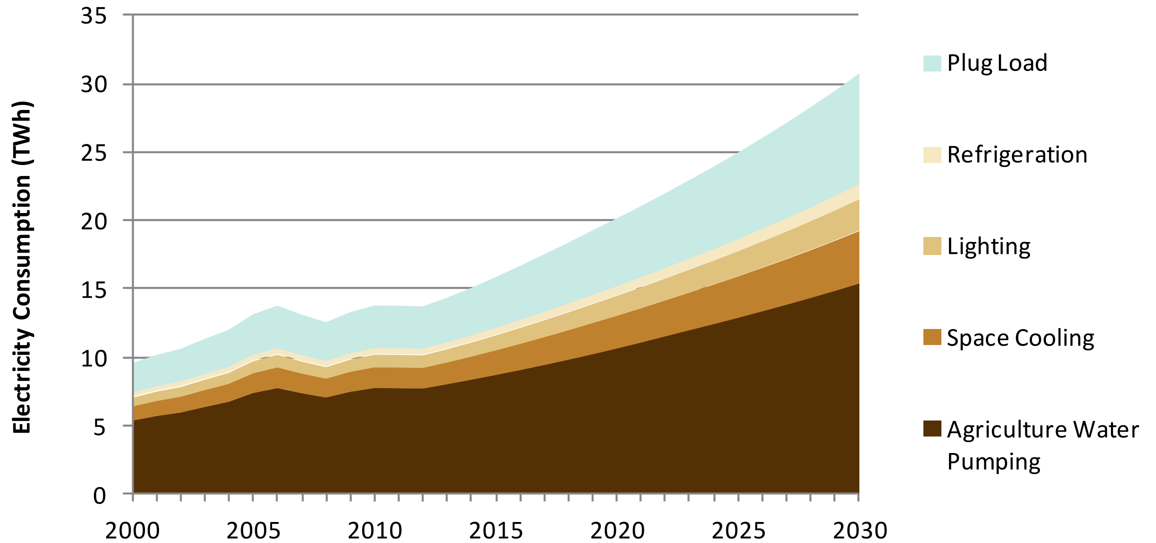
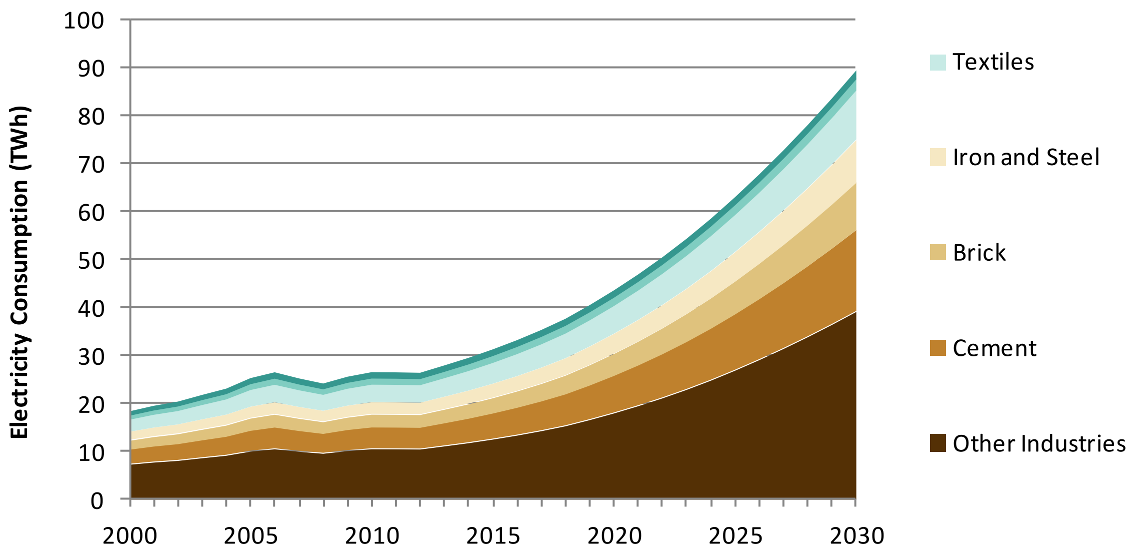


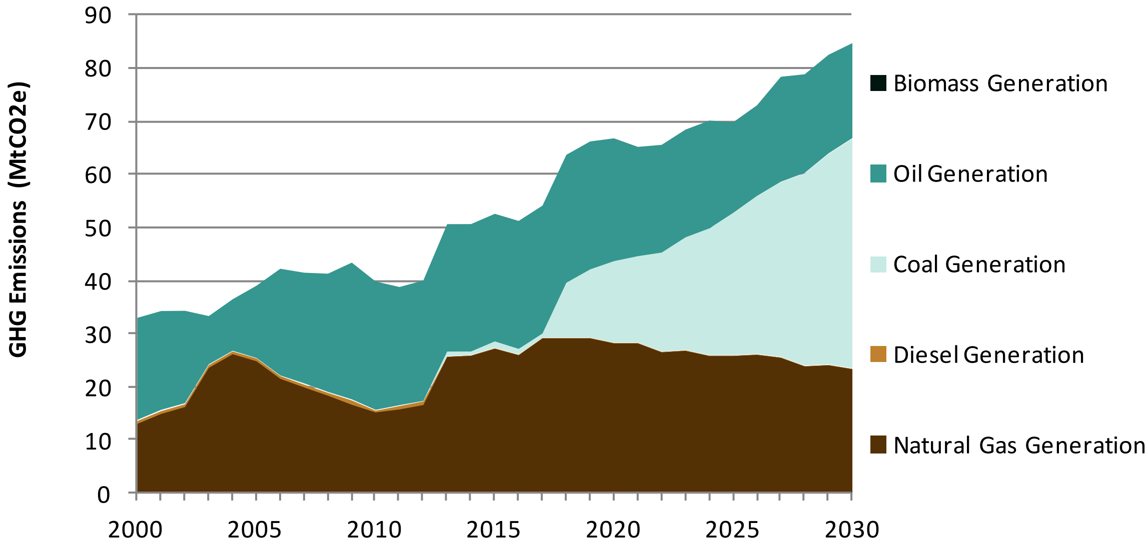
Figure 21 indicates total projected electricity consumption by industrial sub-sectors.

FIGURE 21: PROJECTED INDUSTRIAL ELECTRICITY CONSUMPTION BY SUB-SECTOR (TWH)



Projected reference case greenhouse gas emissions from the electricity sector are illustrated in Figure 22 by generation type.

FIGURE 22: REFERENCE CASE GHG EMISSION PROJECTIONS IN THE ELECTRICITY SECTOR (MT CO_2E)



3.5.5 Data availability and uncertainty

Uncertainty in the historical reference case emissions from electricity is relatively low for the total emissions of fossil fuels as there is a low degree of uncertainty related to the total consumption of these fuels in Pakistan and the related emissions factors. The uncertainty is higher for projections as additions and retirement of different types of generation and average capacity factors and energy conversion efficiencies are difficult to forecast and are based on limited assumptions from the *National Power Systems Expansion Plan 2011-2030, the Energy Yearbook* and the *Pakistan IEM Model* (NEPRA, 2014), which are at time contradictory.

Major data gaps to address in the Electricity Generation sub-sector include:

1. **Divergence from Vision 2025**. The reference case projection of electricity generation, 45,340 MW in 2025 is similar to the Vision 2025 goal (25,000 additional MW by 2025 or ~46,000 MW). Alignment with the Vision 2025 goal was not the goal however, as the true objective is to develop a reference case or business as usual scenario from which it is possible to evaluate potential mitigation options. In this case, it is possible to imagine that a significant amount of low-carbon generation would not happen in the reference case as it requires the support and investment that is related to commitments and actions on climate change. The reference case assumptions should be reviewed carefully with this objective in mind to ensure that it is a reasonable projection of electricity generation in the absence of climate change policies.
2. **Up-to-date information on generation plans, projections, and capacity factors**. Generation plans are in constant flux, so it would be useful for different planning groups to review the reference case generation capacities that are assumed between 2012 and 2030 (Table 30), as well as assumptions regarding average capacity factors and conversion efficiencies (Table 29). Stakeholders have commented that there is an expectation that the average nuclear power capacity factor is likely to increase above 80% and that the solar capacity factor is expected to be closer to 18.5%.
3. **Planned solar capacity**. 681 MW of grid connected utility size solar projects are included in the reference case (by 2018). It is understood that there may be other projects in the pipeline that will be built. More information is required to determine the generating capacity of these projects. Significant distribute solar was not considered in the reference case.
4. **Accurate and up-to-date end-use data**. Electricity end-use demand in residential and commercial sectors are again based on data from the *Pakistan Integrated Energy Model*. More up to date reports and surveys of end-use consumption would be useful in making a more robust analysis.

3.6 Agriculture Sector

Agricultural activities contribute to greenhouse gas emissions through a variety of different processes. CH_4 and N_2O are the only significant greenhouse gases emitted by the Agriculture Sector. CH_4 emissions arise from enteric fermentation and manure management associated with livestock, as well as rice cultivation and prescribed burning of crop residues. N_2O emissions arise primarily from synthetic and natural fertilizers (i.e., manure, crop residues) applied to cultivated soils and are based on IPCC assumptions regarding atmospheric deposition and leaching from soils. Other N_2O emission sources include rice cultivation and prescribed burning of crop residues and are based on land areas or production quantities combined with default IPCC emission factors.

The agriculture sector is examined separately from the Forestry and Other Land-Use Sector. All carbon releases and sinks that are a result of a land conversion from one type to another are included in the forestry sector. The agricultural sector does not include energy emissions from fuel combustion (e.g., water pumping, tractors), which are included in energy sub-sectors above.

The agricultural sector is currently the largest source of GHG emissions of all analyzed sectors. Approximately half of total national emissions are from this sector alone. Despite its prevalence, data required to calculate GHG emissions is lacking and considerable uncertainty remains in the calculation of agricultural emissions compared to energy sectors.

3.6.1 Methodology

An emissions reference case for the agriculture sector was developed by using a number of Tier 1 approaches from the IPCC 2006 Guidelines.[i] Five different types of emission sources are considered in the analysis:

- Enteric fermentation and manure management from livestock;
- Burning of agricultural residues;
- Nitrogen fertilizer use;
- Flooding rice; and
- Agriculture soils

Specific data and assumptions are provided in the following section.

3.6.2 Data and Assumptions

Historic livestock populations are summarized in Table 35.

TABLE 35: HISTORIC LIVESTOCK POPULATION (HEAD OF LIVESTOCK 2000-2013)

	2000	2001	2002	2003	2004	2005	2006
Dairy Cattle	6,815,000	6,945,000	7,080,000	7,217,000	7,359,000	7,504,000	8,720,000
Non-Dairy Cattle	15,189,000	15,479,000	15,778,000	16,086,000	16,398,000	16,714,000	20,838,812
Buffalo	22,669,000	23,335,000	24,030,000	24,800,000	25,500,000	26,300,000	27,334,985
Goats	47,426,000	49,140,000	50,917,000	52,763,000	54,679,000	56,665,000	53,789,000
Sheep	24,084,000	24,236,000	24,398,000	24,566,000	24,744,000	24,923,000	26,488,000
Poultry	292,400,000	330,000,000	346,100,000	352,600,000	372,000,000	433,800,000	477,000,000
Camels	775,000	767,000	758,000	751,000	743,000	736,000	921,000
Asses	3,822,000	3,893,000	3,966,000	4,040,000	4,119,000	4,199,000	4,269,000
Horses	323,000	321,000	318,000	317,000	315,000	313,000	344,000
Mules	175,000	190,000	202,000	218,000	234,000	251,000	156,000
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Dairy Cattle	9,049,000	9,390,000	9,744,000	10,112,000	10493000	10600000	11002168
Non-Dairy Cattle	21,624,000	22,440,000	23,285,000	24,173,000	25,075,000	26,300,000	27297832
Buffalo	28,147,000	29,002,000	29,883,000	29,413,000	31,726,000	32,700,000	33,700,000
Goats	55,245,000	56,742,000	58,279,000	59,858,000	61,480,000	63,100,000	64,900,000
Sheep	26,794,000	27,111,000	27,432,000	27,757,000	28,086,000	28,400,000	28,800,000
Poultry	518,000,000	562,000,000	610,000,000	663,000,000	721,000,000	785,000,000	785,000,000
Camels	933,000	945,000	958,000	970,000	983,000	1,000,000	1,000,000
Asses	4,347,000	4,427,000	4,509,000	4,600,000	4,700,000	4,800,000	4,900,000
Horses	346,000	348,000	350000	352000	354000	400,000	400,000
Mules	159,000	162,000	165,000	167,000	170,000	200,000	200,000

Default emission factors to calculate emissions were taken from the 2006 IPCC guidelines and are based on regional defaults for the Indian Subcontinent and are provided in Table 36 below.

TABLE 36: EMISSION FACTORS FOR DIFFERENT TYPES OF LIVESTOCK

Type of Livestock	Emission Factor Enteric Fermentation $kgCH_4$/head/yr	Emission Factor Manure Management $kgCH_4$/head/yr
Dairy Cattle	46	6
Cattle	25	2
Sheep	5	0.21
Goats	5	0.22
Pigs	1	5
Buffalo	55	5
Horses	18	2.18
Asses / Mules	10	1.19
Camels	46	2.56
Poultry	0	0.023

Source: (GCISC 2015)

Future growth rates of livestock between 2010 and 2030 are likely to be below estimates of the growth in Agricultural GDP. Historic growth rates of livestock between 2000 and 2013 for the main grazing livestock cattle, buffalo, sheep and goats were 4.4%, 3.1%, 1.4% and 2.4% respectively. Growth in poultry was the highest overall of all livestock at 7.9%. Camels, asses, horses and mules were all below a growth rate of 2.0%. There is considerable uncertainty in the livestock census data, but the overall trend is increasing.

Growth in the agriculture sector has been poor in recent years (3.1% in 2011-12 and 3.3% over the last decade). Raising the growth rate of agriculture, which contributes 21.4% to GDP and employs 45% of the labour force is a key driver towards achieving Pakistan *Vision 2025* goals (GoP, 2014). It was assumed that future livestock growth would be below expected agriculture GDP growth as it would be more focused on crops and other agricultural products. All livestock species were projected to grow at an annual rate of 2.0% per year between 2014 and 2030.

3.6.3 Burning of crop residues

The main crops for which crop residues are burned in Pakistan include Maize, Wheat, Sugarcane and Rice. Total crop production is available from the *Pakistan Economic Survey 2012-13* (GoP, 2013). Table 37 identifies the total mass of crops burned.

Table 37: Production of major crops subject to crop residue burning 2007-2012 (t)

Type of Crop or Land	2007	2008	2009	2010	2011	2012
Sugarcane	63,920,000	50,045,000	49,373,000	55,309,000	58,397,000	62,472,000

Wheat	20,959,000	24,033,000	23,311,000	25,214,000	23,473,000	24,231,000
Rice	5,563,000	6,952,000	6,883,000	4,823,000	6,160,000	5,541,000
Maize	3,605,000	3,593,000	3,261,000	3,707,000	4,338,000	4,631,000

The amount of biomass residue burned related to crop production and the emission factors for non-carbon related emissions (CH_4 and N_2O) were was based on 2006 IPCC default values and are provided in Table 38 below.

TABLE 38: QUANTITY OF AGRICULTURAL RESIDUE AND EMISSION FACTORS FOR BURNING OF GRAZING LAND AND CROPLANDS

Type of Crop or Land	Residue to Crop Ratio (t/t)	% of Biomass Burned (%)	Emission Factor (kgCO_2e/ t burned)
Maize	1	5%	33.67
Wheat	1.4	10%	57.88
Sugarcane	0.3	15%	46.08
Rice	1.4	50%	60.4

Future growth in the amount of agricultural residues burned in the reference case is estimated based on agricultural GDP forecast annual growth rates between (4.1% and 3.6%) from the *PAK-IEM Model.*

3.6.4 Nitrogen fertilizer use

The amount of synthetic fertilizer used in Pakistan was estimated from data published in the *Pakistan Economic Survey 2012-2013*. Table 39 provides the historic quantity of synthetic nitrogen fertilizers applied in Pakistan between 2002 and 2009.

TABLE 39: AMOUNT OF DIFFERENT TYPES OF NITROGEN FERTILIZER APPLIED IN PAKISTAN (2007 TO 2012)

	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
Nitrogen Fertilizers expressed in t N	2,925,000	3,034,000	3,476,000	3,134,000	3,207,000	2,886,000

Source: Government of Pakistan (2013). Pakistan Economic Survey 2012-2013. Ministry of Finance and GCISC (2015) for 2012-13.

Default fractions of the total synthetic fertilizer nitrogen emitted to the atmosphere or leached and default emission factors are from the 2006 IPCC Guidelines and summarized in Table 40 below.

TABLE 40: DEFAULT FRACTIONS AND EMISSION FACTORS FOR RELEASES FROM THE APPLICATION OF SYNTHETIC FERTILIZERS

Default Emission Factors and Fractions	Value
$FRAC_{GASF}$	0.1
$FRAC_{LEACH}$	0.3
EF_{GASF}	0.01
EF_{LEACH}	0.0075

3.6.5 *Flooding Rice*

The area of historic rice cultivation was taken from the *Pakistan Economic Survey* (GoP, 2013) and is provided in Table 41 below.

TABLE 41: AREA OF RICE UNDER CULTIVATION BETWEEN 2005 AND 2012 (HECTARES)

Metric	2005	2006	2007	2008	2009	2010	2011	2012
Area (ha)	2,621,000	2,581,000	2,515,000	2,963,000	2,883,000	2,365,000	2,571,000	2,311,000

Al of the area under rice cultivation is irrigated. Default scaling factors for methane emissions, correction factors for organic amendments and seasonally integrated emission factors were drawn from the 2006 IPCC Guidelines and are presented in Table 42.

TABLE 42: RICE WATER MANAGEMENT REGIME EMISSION FACTORS AND COEFFICIENTS

Water Management Regime	Reference case Emission Factor for Intermittently oded fields Kg CH4/ha/day	Scaling Factor for Water Regime during cultivation SFw	Scaling Factor for Water Regime before cultivation SFp	Correction Factors for Organic Amendment
Irrigated – Intermittently Flooded (activity data available for rice ecosystem types, but not for flooding patterns)	1.30	0.78	1.22	1

Source: 2006 IPCC Guidelines, Chapter 5: Cropland. Pages 5.48-5.50.

3.6.6 *Projections*

Agriculture emissions are primarily impacted by the change in the head of livestock, the area of crops under cultivation and the application of synthetic nitrogen fertilizers. The reference case projection assumes the growth rates that are summarized in Table 43.

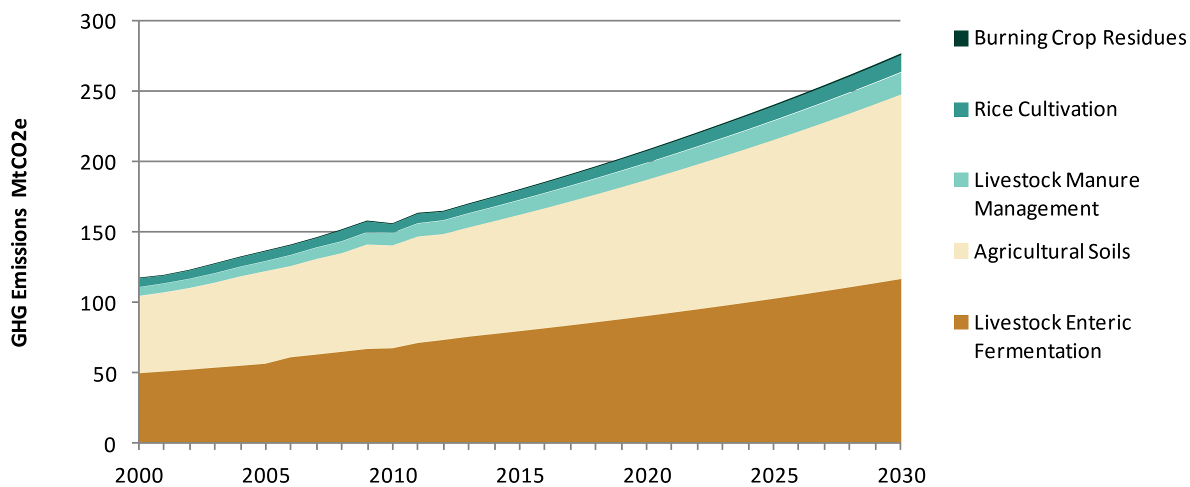
TABLE 43: PROJECTED GROWTH IN AGRICULTURE OUTPUTS (%)

Agriculture Output	Change in Stock	Change in Related Emission Intensity or Efficiency
All Livestock with exception of Buffalo	3% growth annually	No change
Buffalo Livestock	2.1% growth annually (Based on lower historic growth due to the fact that buffalo populations are being impacted by climate change)	No change
Synthetic Fertilizer	Agriculture GDP forecast from PAK-IEM	-0.5% in emission intensity due to improved application and delivery
Crop Production	Agriculture GDP forecast from PAK-IEM	No Change

3.6.7 Results

Total projected greenhouse gas emissions from the agriculture sector by source are indicated in Figure 23.

FIGURE 23: PROJECTED GREENHOUSE GAS EMISSIONS IN AGRICULTURE SECTOR (MT CO_2E)



3.6.8 Data availability and uncertainty

The agricultural sector is the largest source of GHG emissions of the five sectors considered in this low-carbon sectoral study, accounting for over 40% of emissions in 2012. Despite the size and prevalence of the sector, data required to calculate GHG emissions is lacking and considerable uncertainty remains in the calculation of emissions when compared to energy sectors. However, the total historical emissions shown in Figure 23 are within 5% of projections that have been produced by the FAO (FAO, 2014) for Pakistan.

Livestock emissions account for approximately 28 percent of total emissions in Pakistan, yet it is necessary to use default emission factors that are not country specific to estimate these emissions. The uncertainty of these emission factors is expected to be in the range of ± 30 percent to 50 percent. The uncertainty in the projected reference case emissions is even greater as estimates of future populations of livestock also have considerable uncertainty.

Major data gaps in the agriculture sector that need to be addressed:

1. **Use of higher-quality existing emission factors**. In previous inventory work, it is possible that country specific emission factors for Pakistan were derived for *livestock enteric fermentation* emissions and *manure management*. We have aligned emission factors for enteric fermentation, livestock manure management and nitrogen excretion to those that are reported in the 2012 GCISC Inventory report (GCISC, 2015). Estimates could be improved significantly if these could be shared and published with the low carbon analysis team. This also applies to emission factors for calculating direct and indirect nitrous oxide emissions from *agricultural soils*. It was noted by stakeholders that indirect emissions from leaching of N_2O and methane emissions from rice cultivation are likely lower than default values suggest.
2. **Country-specific figures on prevalence of crop burning**. Burning of crop residues emissions relies on estimates of the extent to which these crop residues are burned. We have consulted stakeholders to identify the prevalence of burning and develop values for the analysis, but more detailed study to develop country specific estimates for the practice would improve the estimates.
3. **Country-specific figures on animal waste management systems employed**. The fraction of different livestock that are managed under different animal waste management systems is based on IPCC defaults. Country specific data regarding the fraction of different livestock that are managed under different animal waste management systems would improve the estimates.

3.7 LULUCF Sector

The LULUCF Sector includes estimates of emissions and removals of greenhouse gases associated with increases or decreases of carbon in living biomass as land-use changes occur over time, for example, in the conversion of a forest area to cropland, or when establishing new forest lands through reforestation or afforestation. Current estimates are that the LULUCF sector contributes 3% of total emissions in Pakistan.

The methodology pursued in the 2008 GHG Inventory (PAEC ASAD, 2009) to estimate GHG emissions from the LULUCF sector is that the net carbon change is equal to the total carbon uptake minus the carbon releases. Carbon uptake is estimated for biomass growth that occurs in differentiated forests (conifers, riverian, scrub, plantation and mangroves) as well as for trees on irrigated and non-irrigated farmland (more than 21 million hectares). Carbon releases are estimated from the consumption of forest wood and other biomass for commercial use and traditional fuels (e.g., charcoal, fuel wood). The overall estimated impact was an estimate of net emissions of 8,920 GgCO2e in 2007-08. However, the *2003 Good Practice Guidance for LULUCF* recommends estimating emissions and removals both from land that did not undergo any land-use change, reflecting increase or loss of carbon under the same type of use (e.g. carbon increase in secondary vegetation or even in primary vegetation in managed areas), as well as, conversions of land between the six IPCC land-use categories (Forestland, Cropland, Grasslands, Wetlands, Settlements and Other Lands). The major weakness of the 2008 GHG Inventory method is that it does not appear to accurately account for the high rate of deforestation exhibited in Pakistan over the last several decades. The average deforestation rate between 1990 and 2015 is estimated to be 42,200 ha per year. While the loss of biomass associated with the deforestation of this land is fully considered, it is unlikely that the loss of biomass attributed to harvesting and consumption of forest wood and other biomass for commercial use and traditional fuels is accounted for in other forests.

Another estimate of LULUCF emissions and removals was conducted by the Pakistan Space and Upper Atmosphere Research Commission (Khan et al 2009). The methodology they followed did consider changes in forest and other woody biomass stocks, forest and grassland conversion and abandonment of managed lands. However, of these, only emissions from changes in forest and other woody biomass stocks were estimated (similar to the 2008 inventory), as other emission source categories were judged not to be applicable to Pakistan. Total carbon uptake or increment was estimated at 87,284 Gg, while annual carbon release was estimated at 18,730 Gg. The result is an estimate of a very large sink of 68,676 GgCO2e and a completely different result when compared to the 2008 inventory, which highlights the very high uncertainty of estimating LULUCF removals and sinks.

If we consider the latest FAO Forest Resource Assessment for Pakistan (FAO, 2015) that shows a loss in forest cover of approximately 43,000 ha per year and we estimate the potential loss in biomass associated with the loss in forests and changes in biomass density, it suggests net emissions in the order of 22,000 GgCO2e. While the FAO analysis may not adequately account for the increase in biomass on farmlands this biomass gain is in our view overstated in the 2008 GHG Inventory method. The 2008 GHG Inventory method accounts for an annual net growth rate in biomass of 1 tonne dry-matter biomass per hectare on 19.3 million hectares of farmland. This is very roughly equivalent to a million hectares of new mature forest cover being added every ten years (more than 30% of the existing forest extent).

In the absence of any credible new forest inventory data, we have chosen to adopt the projection forecast for LULUCF from the National Economic & Environmental Development Study for Pakistan (UNFCCC, 2011) that is based on the work completed for the 2008 Emission Inventory (PAEC ASAD, 2009). This Study starts with the estimate of net emissions from the 2008 GHG Inventory for 2008 of 8,920 GgCO2e and reflects reasonable assumptions regarding the continued rate of deforestation and demand for wood biomass for energy and products. Net emissions are forecast to rise from 10,000 GgCO2e in 2011 to 13,000 GgCO2e in 2020 and 15,000 GgCO2e in 2030.

3.7.1 Data and Assumptions

Forest cover in Pakistan (FAO, 2015) is summarized in Table 44.

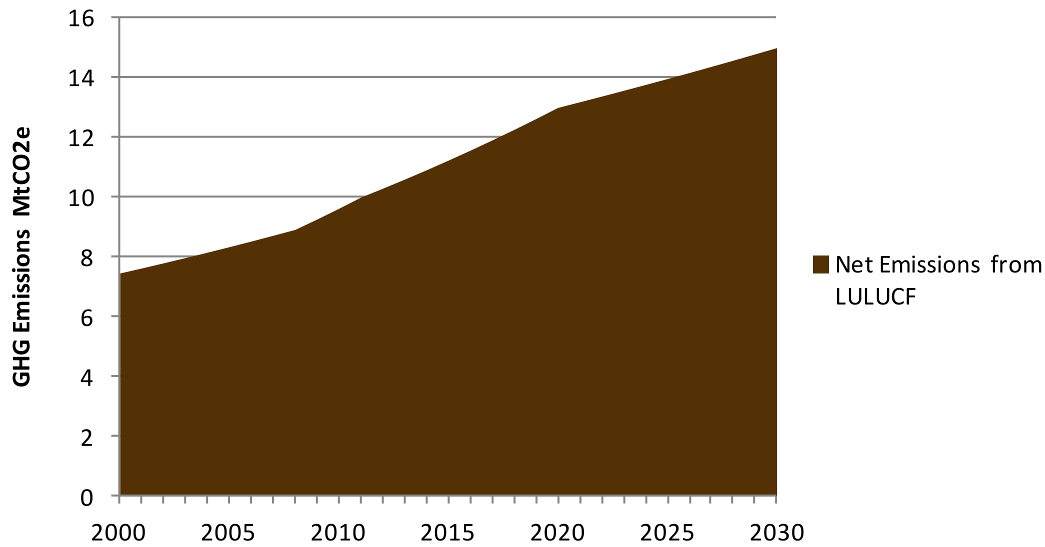
TABLE 44: FOREST COVER IN PAKISTAN (1990-2015)

Classification	1990	2000	2005	2010	2015	Change 1990 to 2015	
						Annual	Total
Forest	2,527,000	2,116,000	1,902,000	1,687,000	1,472,000	-2.14%	-41.7%
Other Wooded Land	1,191,000	1,323,000	1,389,000	1,455,000	1,521,000	0.98%	27.7%
Other Land	73,370,000	73,649,000	73,797,000	73,946,000	74,095,000	0.04%	1.0%
Plantations	234,000	296,000	318,000	340,000	362,000	1.76%	54.7%

3.7.2 Results

Total projected greenhouse gas emissions from the LULUCF sector by source are indicated in Figure 24.

FIGURE 24: PROJECTED NET GREENHOUSE GAS EMISSIONS IN LULUCF SECTOR (MT CO_2E)



3.7.3 Data availability and uncertainty

The LULUCF sector has the highest level of uncertainty of the five sectors considered in this low-carbon sectoral study. Despite the importance of the sector, data required to model and estimate GHG emissions and removals is lacking. Different available estimates vary by several orders of magnitude.

However, to calculate the impact of potential mitigation actions a reference case in LULUCF is not necessarily required if it can be determined that the actions and its emission reduction impacts are incremental.

In order to develop reasonable projections of LULUCF emissions and removals it is important to have a clear understanding of trends that impact biomass growth, accumulation and removals from forest lands as well as croplands. The following information would greatly assist in developing a reference case projection:

1. **Biomass density (tonnes biomass / ha aboveground and belowground) associated with specific forest areas in Pakistan should be collected**. Forest areas should be divided by climatic zones, soil types, level of use or degradation, tree species, average age of forests to identify unique areas with similar biomass density. Consistent representation of these forest lands over time and a national land use classification system that is aligned with IPCC guidance would greatly aid inventory preparation.
2. **Biomass growth data should be collected.** This includes biomass growth or accumulation (tonnes biomass / ha ·yr) associated with different forest areas.

3. **National forest cover assessments should be prepared**. These assessments could be completed using GIS data that captures trends over time.
4. **Trends of forest cover on agricultural lands should be determined.** It is important to understand the change in biomass density on agricultural lands which can be measured by forest cover, as well as determination of the land left fallow to be reclaimed by natural forest, and extent of agroforestry operations.
5. **Detailed surveys of biomass should be conducted**. These surveys should ascertain the amount of biomass (fuelwood, wood for charcoal, commercial harvesting) that is removed from forests and their geographic distribution.

3.8 Waste

Through the processes of disposal, treatment and recycling different types of waste can produce greenhouse gas emissions. The most important gas produced in this source category is methane (CH_4). Two major sources of this type of CH_4 production are solid waste disposal to land and wastewater treatment. In each case, methanogenic bacteria break down organic matter in the waste to produce CH_4. The breakdown of human sewage can also lead to significant amounts of N_2O emissions. The waste sector is the smallest of all the categories of emissions, currently contributing approximately 2% of total greenhouse gas emissions.

3.8.1 Methodology

An emissions reference case for the waste sector was developed by using a number of Tier 1 approaches from the IPCC 2006 Guidelines for methane emissions from domestic and industrial wastewater treatment and N2O emissions from human sewage and CO2, CH4 and N2O emissions from waste incineration. The calculation of methane emissions from Solid Waste Disposal Sites (SWDS) was completed using the Tier 2 First Order Decay Model methodology from the 2006 IPCC Guidelines. The FOD method produces a time-dependent emission profile that better reflects the true pattern of the degradation process over time.

The default IPCC parameters identified in Table 45 were used in the spreadsheet model to estimate the methane generation potential.

TABLE 45: WASTE MODEL IPCC DEFAULT VALUES

Default IPCC parameter	Default values used in model
Methane Correction Factor (MCF)	0.4, Un-managed shallow
	0.8, Un-managed deep
Methane Recovery Factor	0
Fraction of DOC dissimilated	0.5
Methane Generation Rate Constants (yr^{-1}) Default for and Dry Tropical climate zone	0.085, Food Waste, Sewage sludge
	0.065, Garden, Textiles, Disposable nappies
	0.045, Paper
	0.025, Wood and straw
Delay time (months)	6
Fraction of methane (F) in developed gas	0.5

3.8.2 Data and Assumptions

Waste disposal rates are based on estimates prepared by the Pakistan Environmental Protection Agency (Pakistan Environmental Protection Agency, 2005). The percentage of solid waste generated and sent to solid waste disposal sites is assumed to be 60% (Zuberi J. S. and Ali S. F., 2014). Table 46 below summarizes the urban population, waste generation rate and total solid waste produced and sent to landfill for the period between 1970 and 2030.

TABLE 46: URBAN SOLID WASTE GENERATION SUMMARY (1970 TO 2030)

Year	Population	Waste per capita	Total MSW	% to SWDS
	millions	kg/cap/yr	Gg	%
1970	14.7	164.3	2,413	60%
1971	15.3	164.3	2,507	60%
1972	16.6	164.3	2,726	60%
1973	16.6	164.3	2,727	60%
1974	16.6	164.3	2,728	60%
1975	16.6	164.3	2,730	60%
1976	16.6	164.3	2,731	60%
1977	16.6	164.3	2,732	60%
1978	16.6	164.3	2,734	60%
1979	16.7	164.3	2,735	60%
1980	16.7	164.3	2,736	60%
1981	23.8	164.3	3,916	60%
1982	23.9	164.3	3,918	60%
1983	23.9	164.3	3,920	60%
1984	23.9	164.3	3,922	60%
1985	23.9	164.3	3,924	60%
1986	23.9	164.3	3,925	60%
1987	23.9	164.3	3,927	60%
1988	23.9	164.3	3,929	60%
1989	23.9	164.3	3,931	60%
1990	23.9	164.3	3,933	60%
1991	34.7	164.3	5,693	60%
1992	35.8	164.3	5,879	60%
1993	37.1	164.3	6,085	60%
1994	37.1	164.3	6,088	60%
1995	37.1	164.3	6,091	60%
1996	40.8	164.3	6,705	60%
1997	42.1	164.3	6,918	60%
1998	40.0	164.3	6,572	60%
1999	44.8	164.3	7,355	60%
2000	46.1	164.3	7,577	60%
2001	47.5	164.3	7,802	60%
2002	48.3	164.3	7,927	60%
2003	50.0	164.3	8,208	60%
2004	51.3	164.3	8,431	60%
2005	53.9	164.3	8,856	60%
2006	55.8	164.3	9,165	60%
2007	57.7	164.3	9,481	60%
2008	59.7	164.3	9,802	60%
2009	61.9	164.3	10,162	60%
2010	61.9	164.3	10,162	60%
2011	67.6	164.3	11,095	60%
2012	69.9	164.3	11,476	60%
2013	72.3	164.3	11,871	60%
2014	74.7	164.3	12,275	60%
2015	77.3	164.3	12,689	60%
2016	79.8	164.3	13,113	60%
2017	82.5	164.3	13,546	60%
2018	85.2	164.3	13,989	60%
2019	87.9	164.3	14,442	60%
2020	90.7	164.3	14,905	60%
2021	93.6	164.3	15,378	60%
2022	96.6	164.3	15,862	60%
2023	99.6	164.3	16,355	60%
2024	102.6	164.3	16,859	60%
2025	105.8	164.3	17,373	60%
2026	109.0	164.3	17,897	60%
2027	112.2	164.3	18,432	60%
2028	115.5	164.3	18,978	60%
2029	118.9	164.3	19,533	60%
2030	122.4	164.3	20,100	60%

The composition of waste impacts the amount of organic material that is available for anaerobic decay and therefore the projected methane emissions released. The waste composition used in the modelling is presented in Table 47. This waste composition reflects the composition of the waste that is collected and is based on the draft Guidelines for Solid Waste Management (Pakistan Environmental Protection Agency, 2005).

TABLE 47: COMPOSITION OF WASTES IN PAKISTAN

Type	Composition (%)
Plastic and Rubber	5.3%
Metals	0.4%
Paper	2.6%
Cardboard	1.7%
Textiles / Rags	5.5%
Glass	1.4%
Bones	2.3%
Food	17.3%
Animal	3.8%
Green Waste	13.4%
Wood	1.5%
Fines	39.3%
Stones	5.2%
TOTAL	**100%**

Wastewater can be a source of methane if treated or disposed of anaerobically. The emission factors and parameters used to calculate methane emissions from domestic wastewater are presented in Table 48 and Table 49.

TABLE 48: WASTEWATER TREATMENT SYSTEMS AND ASSOCIATED METHANE CORRECTION FACTORS

Treatment System	Urban – Low (80% urban population)	Urban – High (20% urban population)	Rural	MCF
Septic	14%	18%	0%	50%
Latrine	10%	10%	47%	10%
Other	3%	3%	0%	10%
Sewer	53%	53%	10%	13%
None	20%	20%	43%	0%

Source: (IPCC, 2006).

TABLE 49: EMISSION FACTORS AND PARAMETERS TO CALCULATE CH_4 DOMESTIC WASTEWATER EMISSIONS

Parameter	Description	Value	Data Source
BOD	Kg BOD/1000 persons/yr	14,600	(IPCC, 1996 Default parameter)
EF	Kg CH_4 / kg BOD	0.25	(IPCC, 1996 Default parameter)

The activity data, emission factors and parameters used to calculate methane emissions from industrial wastewater are presented in Table 50.

TABLE 50: ACTIVITY DATA, EMISSION FACTORS AND PARAMETERS TO CALCULATE CH_4 INDUSTRIAL WASTEWATER EMISSIONS

Parameter	Description	Value	Data Source
Wastewater Volume	M3/yr (2000 adjusted by industrial GDP growth rate for other years)	344,000,000	(Murtaza, G. And Zia M. H., 2012)
Average COD/m3	Kg COD/m3	4.24	(Murtaza, G. And Zia M. H., 2012) (IPCC, and (IPCC, 2006 default parameters)
EF	Kg CH_4 / kg COD	0.25	(IPCC, 1996 Default parameter)
MCF	(dimensionless)	0.1	(IPCC, 2006 default parameter)

The activity data, emission factors and parameters used to calculate N_2O emissions from industrial wastewater are presented in Table 51.

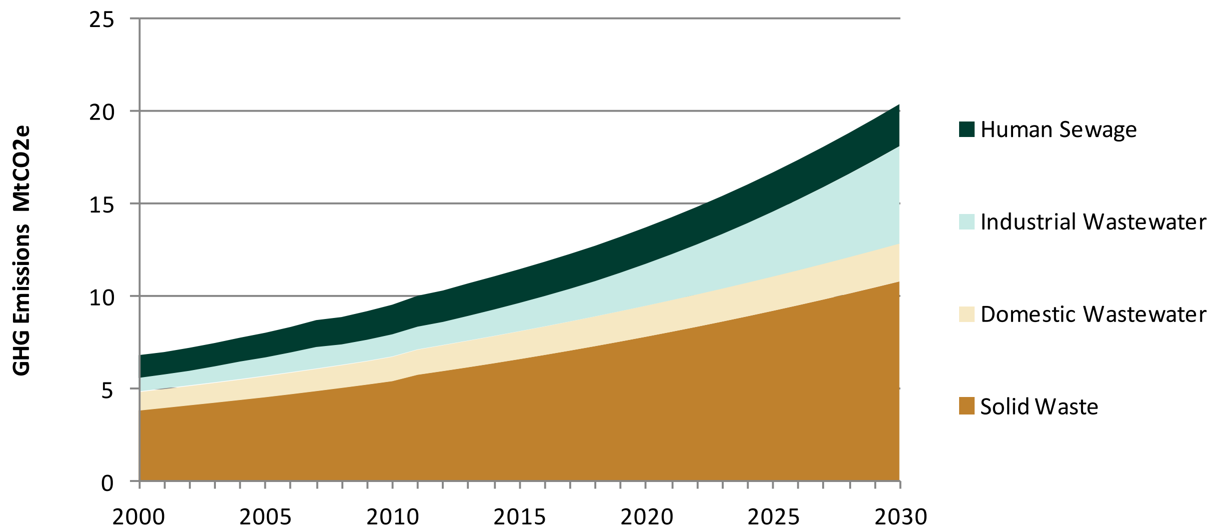
TABLE 51: ACTIVITY DATA, EMISSION FACTORS AND PARAMETERS TO CALCULATE N_2O EMISSIONS FROM HUMAN SEWAGE

Parameter	Description	Value	Data Source
Population	Persons (2010 adjusted for every inventory year)	177.1 million	(GoP, Pakistan Economic Survey)
Per capita Protein consumption	g/person/day (2013)	65.49	(FAOSTAT Database, 2015)
Fraction of nitrogen in protein	kg N/kg protein	0.16	(IPCC, 2006 default parameter)
Emission Factor	kg N2O-N/kg sewage-N produced	0.005	(IPCC, 2006 default parameter)

3.8.3 Results

Total projected greenhouse gas emissions from the waste sector by source are indicated in Figure 25.

FIGURE 25: PROJECTED GREENHOUSE GAS EMISSIONS IN WASTE SECTOR (MT CO_2E)



3.8.4 Data availability and uncertainty

The waste sector contributes to less than 5% of total emissions. Domestic and industrial wastewater is the largest source of overall emissions. With industrial wastewater expected to grow at a substantially higher rate than other waste emission sources.

The uncertainty of these emissions is large. The necessary activity data to describe the volumes of solid waste and wastewater generated are not collected and reported on a regular basis. There is also considerable uncertainty around the proportion of solid waste and wastewater organic matter that is broken down anaerobically to produce CH_4. These methane correction factors (MCF) have uncertainties of more than ±100%.

Major data gaps in the waste sector that need to be addressed:

1. **Use of higher-quality existing methane correction factors (MCF)**. Methane correction factors used for wastewater are primarily estimated to be related to untreated sea, river or lake discharge. These MCF values are estimated to vary in the range between 0 and 0.2 (IPCC, 2006).

2. **Estimates of volumes of Industrial Wastewater Produced**. Estimates were taken from an old source that dates back to the year 2000 (Murtaza, G. And Zia M. H., 2012). This source references the original data source as the Pakistan Water Sector Strategy (PWSS, 2002).
3. **Estimates of volume of Solid Waste sent to Disposal Sites**. Estimates are available from various documents that project that in urban cities between 40% and 50% of waste is collected and put in disposal sites. The fraction of waste sent to landfill of 60% was aligned with the 2012 GCISC Inventory (GCISC, 2015). This figure is highly uncertain and may not account for sites that are too shallow and unmanaged to be considered disposal sites.
4. **Rates of Production of Industrial Wastewater**. The reference case assumes that the generation of industrial wastewater will grow at a similar rate to economic growth in the industrial sector. In reality there may be a shift away from industrial processes that produce significant wastewater as well as improvements in process efficiencies which reduce the amount of industrial wastewater produced. Estimates of these trends in future activities would improve the emission projections of the waste reference case.

4. UNCERTAINTY ANALYSIS

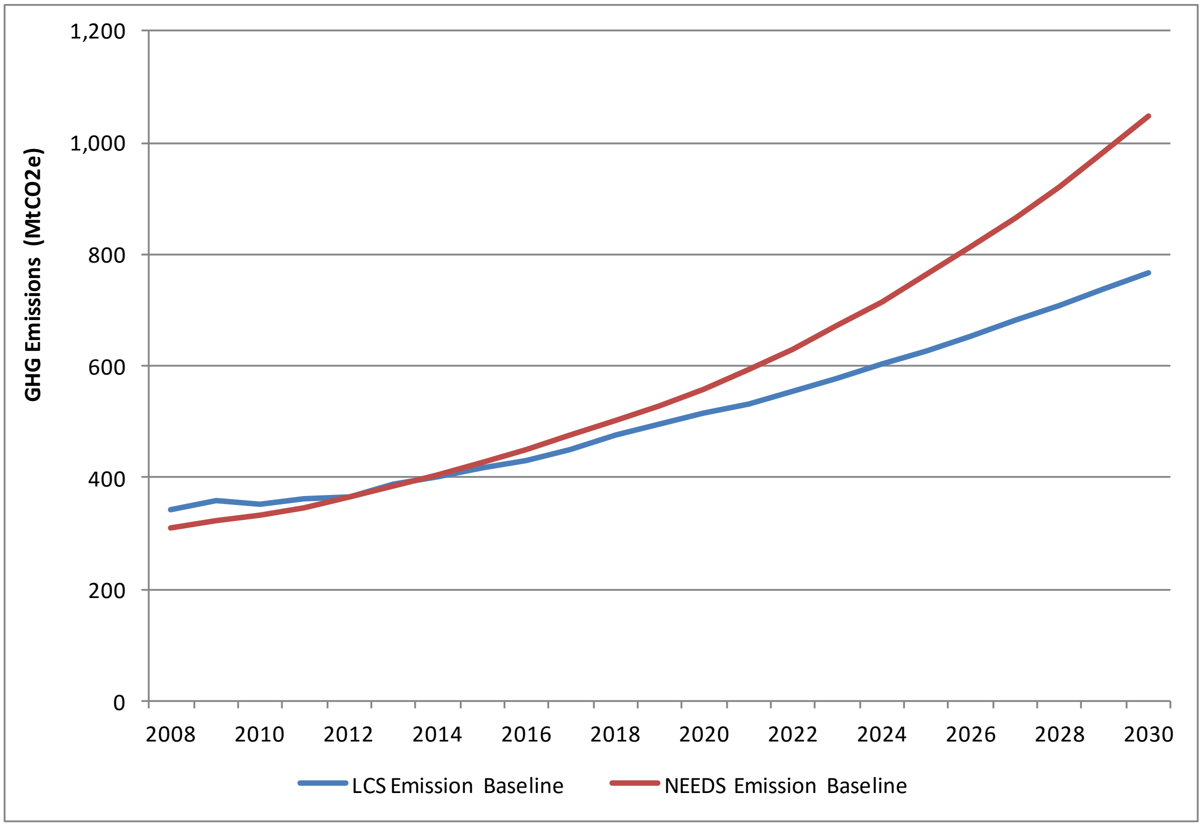
There are significant sources of uncertainty in developing emission projections. There are uncertainties associated with estimating greenhouse gas emissions and there are also uncertainties related to the future drivers of emissions. This analysis considers both of these types of uncertainty to some extent. Reference case and projected greenhouse gas emissions are compared with an independent assessment conducted by the National Economic & Environmental Development Study for Pakistan (UNFCCC, 2011). This assessment is referred to as the NEEDS assessment and a comparison is useful as it allows sector emissions from two independently developed inventories to be compared directly for historic emissions calculated for the year 2008 and a comparison of future projections out to 2030. Section 3.1 below summarizes the comparison.

The main drivers of emissions are related to economic activity and growth, changes in population, energy supply and prices as well as the adoption of new technologies and the impact of government policies and measures. A detailed examination of different drivers cannot be conducted for this emission reference case projection; however, it is possible to consider different rates of economic growth and different assumptions regarding autonomous energy efficiency improvements on emissions to estimate how total emissions might look under different scenarios. Section 3.2 provides an uncertainty sensitivity analysis based on these two parameters.

4.1 Comparison of Reference case with NEEDS Analysis

This section briefly summarizes the differences between the NEEDS assessment and the current LCS project reference case that has been developed for Pakistan. Figure 26 below compares the two projections from 2008 to 2030.

FIGURE 26: COMPARISON OF OVERALL EMISSION PROJECTIONS (MT CO_2E)



The average emission growth rate over the 2008 to 2030 period in the NEEDS baseline is 5.7% versus an average of 3.7% growth rate in LCS Emission Reference case. This can be compared to an historical emissions growth rate between 1994 and 2008 that was estimated in SNC as 3.9% per year.

The LCS reference case has additional years of historical activity data on emission activity when compared to the NEEDS baseline. The NEEDS assessment starts with a baseline historic year of 2008 based on work conducted for the SNC. The LCS reference case incorporates available energy consumption and other emission related activity statistics right up to the year 2012 and 2013.

Table 52 identifies differences in emission for different emission sectors. Following the table reasons for differences are outlined in more detail.

TABLE 52: DIFFERENCE IN EMISSIONS TOTAL AND SECTORS FOR SELECT YEARS

		2008	2012	2015	2020	2025	2030	Average Growth Rate
Total	LCS	343	365	418	516	625	768	3.7%
	NEEDS	309	366	428	557	763	1,046	5.7%
	Diff.	-9.9%	0.1%	2.3%	7.9%	22.0%	36.2%	2.0%
Energy	LCS	146	153	183	235	290	370	4.3%
	NEEDS	157	186	221	295	406	560	6.0%
	Diff.	7.2%	21.9%	21.0%	25.6%	40.3%	51.3%	1.6%
Agri.	LCS	152	165	180	208	240	277	2.8%
	NEEDS	120	141	164	210	293	408	5.7%
	Diff.	-20.9%	-14.6%	-9.3%	0.8%	21.7%	47.3%	2.9%
Industry	LCS	27	27	32	46	64	85	5.3%
	NEEDS	18	21	24	30	39	52	4.9%
	Diff.	-34.2%	-22.0%	-26.2%	-34.9%	-38.6%	-39.0%	-0.4%
LULUCF	LCS	9	10	11	13	14	15	2.4%
	NEEDS	9	10	11	13	14	15	2.4%
	Diff.	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Waste	LCS	9	10	11	14	17	20	3.8%
	NEEDS	6	7	8	9	10	11	3.2%
	Diff.	-38.2%	-30.3%	-31.8%	-34.5%	-40.4%	-46.0%	-0.6%

4.1.1 Energy Sector

There are some differences in total reference case emissions in 2008. It is unclear at this point what the main reasons for these differences are. A detailed review of the SNC emission inventory would be required. It should be noted that energy plus industry emissions are within 1% in 2008 which could indicate that natural gas consumption for fertilizer production is allocated to energy and not industrial processes.

Note that while both projections use an overall GDP forecast growth rate of 6.0%, there is a difference in emission intensity due to the fact that the reference case assumes autonomous energy efficiency improvements as well as a restriction in domestic production of oil and natural gas whereas the NEEDS assessment does not. The LCS assessment production forecast for oil from 2014 is approximately

3.8% growth per year, and the production forecast for natural gas is an average decline in production of 2.7% per year out to 2030.

4.1.2 Agriculture

There are substantial differences in total reference case emissions in 2008. Emissions from agricultural soils is substantially less in the NEEDS Assessment.

Note that while the NEEDS assessment uses a GDP forecast growth rate of 6.0%, the LCS assessment uses a differentiated agricultural GDP growth forecast that is closer to 3.9%. There are also minor annual changes to the emission intensity of fertilizer use over the forecast period (lower emission intensity) that are considered in the LCS assessment.

4.1.3 Industry (Industrial Processes)

There are substantial differences in total reference case emissions in 2008. But note that energy plus industry emissions are within 1% in 2008 which could indicate that natural gas consumption for fertilizer production is allocated to energy and not industrial processes.
The industrial processes sector may also include additional sources of emissions from Hydrofluorocarbons (HFCs) which are Ozone Depleting Substances not included in the Montreal Protocol.

4.1.4 LULUCF

There are no differences in LULUCF reference case emissions for the entire forecast period.

4.1.5 Waste

There are substantial differences in total reference case emissions in 2008. It is unclear at this point what the main reasons for these differences are. A detailed review of the SNC emission inventory would be required.

Note that the LCS assessment uses a very similar overall forecast growth rate in emissions for solid waste and domestic wastewater. The difference is largely due to expected growth in industrial wastewater emissions that are expected to have a much higher growth rate (greater than 8% per year).

4.2 Reference case Projection Sensitivity Analysis

Two different drivers of emissions were varied in the model to determine the impact on future emission projections to 2030. The first driver is the growth rate in the total Gross Domestic Product (GDP). The reference case LCS model uses an average annual overall GDP growth rate of approximately 6.1%, although different sectors such as manufacturing, transport, agriculture and services have differentiated growth rates. The second driver is autonomous energy efficiency improvements (AEEI) that are associated with different end-uses in the model. These assumptions for AEEI improvements are summarized in the individual reference case sectors above (Section 2).

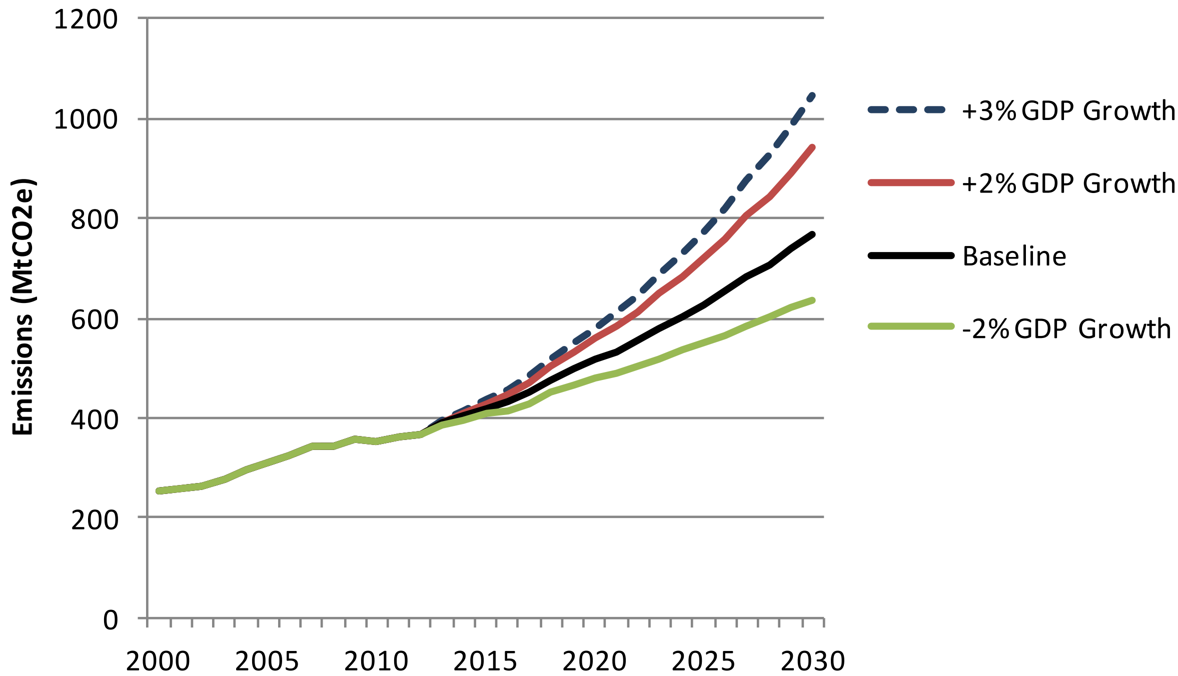
Clearly, energy prices will also have a strong impact on greenhouse gas emissions and all else being equal overall emissions would be expected to increase if energy prices fall, and decrease if energy prices rise in the reference case. Unfortunately, developing elasticities of demand for different fuels and developing energy price scenarios could not be conducted to consider energy prices as a driver of emissions for this project.

4.2.1 GDP Growth

The rate of total growth in Gross Domestic Product (GDP) was varied by considering three alternative GDP growth scenarios compared to the GDP growth in the reference case (6.1% average annual overall GDP growth). A low GDP growth scenario of 2% lower, a high GDP growth scenario of 2% higher that aligns approximately with GDP growth forecasts outlined in Vision 2025 and a third very high growth scenario of 3% higher is also considered that effectively attempts to model a condition where all planned projects are built and growth is substantially spurred by the China-Pakistan Economic Corridor (CPEC).

Figure 27 and Table 53 illustrate the impact of these scenarios relative to the reference case.

FIGURE 27: PROJECTED GREENHOUSE GAS EMISSIONS UNDER FOUR GDP SCENARIOS (MT CO_2E)



1200
1000
800
600
400
200
0
Emissions (MtCO2e)
2000
2005
2010
2015
2020
2025
2030
+3% GDP Growth
+2% GDP Growth
Baseline
-2% GDP Growth

TABLE 53: RELATIVE IMPACT OF GDP GROWTH SCENARIOS TO LCS EMISSION REFERENCE CASE (%)

Scenario	Change in Emissions in 2030	
	(%)	$MtCO_2e$
+3% GDP Growth	36%	+ 278 $MtCO_2e$
+2% GDP Growth	22%	+ 172 $MtCO_2e$
-2% GDP Growth	-17%	-131 $MtCO_2e$

4.2.2 Autonomous Energy Efficiency Improvements

Autonomous energy efficiency improvements built into the reference case LCS model were varied +/- 50% to consider a low improvement in efficiency. For example, freight vehicles are assumed in the model to improve in energy efficiency (i.e., fuel economy) by 1% per year in the reference case model. A high AEEI scenario would consider an improvement in energy efficiency of 1.5% per year and a low AEEI scenario would consider an improvement in energy efficiency of 0.5% per year. The variance of AEEI impacts transportation, industry, residential, commercial and agriculture energy end-uses.

Figure 28 and Table 54 illustrate the impact of these scenarios relative to the reference case.

FIGURE 28: PROJECTED GREENHOUSE GAS EMISSIONS UNDER THREE AEEI SCENARIOS (MT CO_2E)

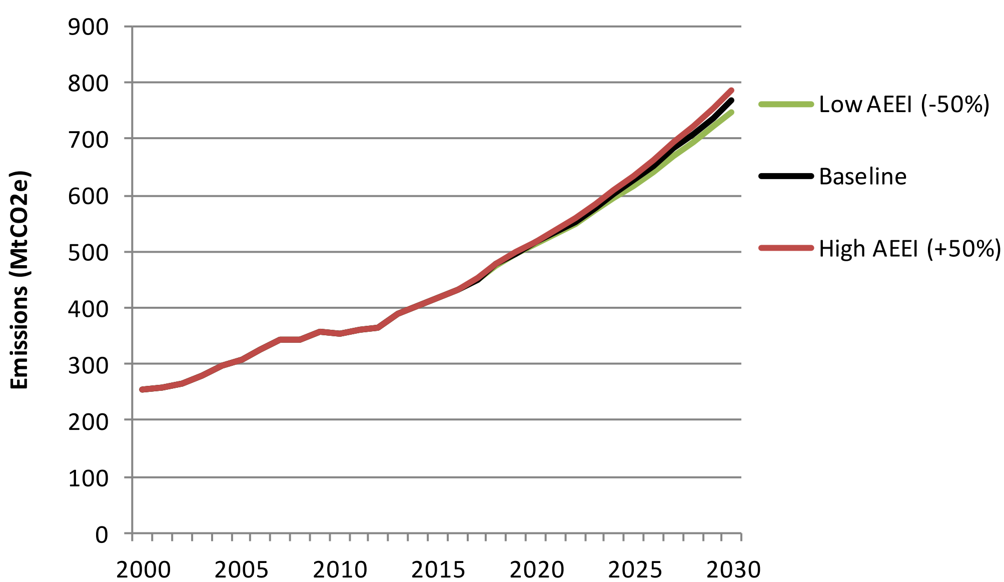


TABLE 54: RELATIVE IMPACT OF AEEI SCENARIOS TO LCS EMISSION REFERENCE CASE (%)

Scenario	Change in Emissions in 2030	
	(%)	$MtCO_2e$
Low AEEI (-50%)	3%	+ 20 $MtCO_2e$
High AEEI (+50%)	-3%	- 19 $MtCO_2e$

4.2.3 Summary of Uncertainty Analysis

The sensitivity analysis indicates that GDP growth is the most important driver of the difference between reference case emission projections to 2030. The NEEDS assessment and the LCS reference case both consider a similar GDP growth rate (approximately 6% per year overall), but the major difference is that the reference case model differentiates GDP growth rates for different sectors and for the energy and industry sectors autonomous energy efficiency improvements are included in the model. The agriculture sector in the LCS reference case model is also decoupled somewhat from GDP growth as some emission sources are linked to lower rates of livestock population growth or other activity data, whereas this is not the case for the Agriculture Sector in the NEEDS assessment. The 6% overall GDP growth rate forecast is also lower than the more aggressive annual average growth rate of 8% of Pakistan's Vision 2025 target.

In comparison to the NEEDS assessment, the LCS reference case is considerably lower by 334 $MtCO_2e$ in 2030. However, if we account for the difference in emissions estimated for 2012 (the red wedge in Figure 27) the difference drops to 241 $MtCO_2e$. In addition, if the impact of the overall high GDP growth rate and low AEEI scenario drivers are both considered, the NEEDS assessment and the LCS reference case are within 10% of total emissions in 2030 (difference of 175 $MtCO_2e$). If no AEEI improvements are considered the NEEDS assessment and the LCS reference case with high GDP growth rate are within 5% (difference of less than 50 $MtCO_2e$).

It is difficult to further identify improvements to the LCS emission reference case that could reduce the uncertainty related to important future emission drivers such as GDP growth, future energy supply and prices as well as the adoption of new technologies and the impact of government policies and measures. A review of these emission drivers, that give weight to both official government forecasts, as well as a realistic projection of the future given what is known about planned private and public investment is required.

REFERENCES

ADB (2009), *Pakistan: Sustainable Energy Efficiency Development Program*. Technical Assistance Consultant's Final Report. Prepared by Hagler Bailly for the Planning Commission.

ADB (2009b), Sustainable Energy Efficiency Development (SEED) – Sector Investment Plan: Approach, Estimates and Schedule, Project Number: ADB TA 7060, May 2009

ESMAP (2006), Pakistan Household Use of Commercial Energy, Energy Sector Management Assistance Programme, Report 320/06, February 2006, IBDR / World Bank, Washington D.C.

European Commission (2011). Joint Research Centre (JRC)/PBL Netherlands Environmental Assessment Agency. Emission Database for Global Atmospheric Research (EDGAR), release version 4.2. http://edgar.jrc.ec.europe.eu, 2011

FAOSTAT Database (2015). Food and Agriculture Organization of the United Nations. Accessed 6-Jan-2015 for 2000 to 2012.

GCISC (2015). *Greenhouse Gas Emission Inventory for the Year 2011-2012*. Global Change Impact Studies Centre. Research Report GCISC-RR-19. November 2015 draft version.

Government of Pakistan (2013). *Pakistan Economic Survey 2012-2013*. Ministry of Finance.

Government of Pakistan (2014). *Pakistan Vision 2025. One Nation – One Vision*. Planning Commission. Ministry of Planning Development and Reform.

ICCT (2015). *Heavy-duty vehicle technology potential around the world*. IEA-PCRA workshop on heavy-duty vehicle fuel efficiency regulations. April 29, 2015. The International Council on Clean Transportation.

ILF (2014). Pakistan Gas Supply-Demand Study. ILF Beratende Ingenieure GmbH. Accessed at: http://www.isgs.pk/growth-in-pakistan-energy-supply-mix-25

IPCC (1996). *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*. Reference Manual. Intergovernmental Panel on Climate Change. Geneva.

IPCC (1996): *Climate Change 1995: The Science of Climate Change.* J.T Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.), Cambridge University Press, Cambridge, UK. Intergovernmental Panel on Climate Change.

IPCC (2000). *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. Intergovernmental Panel on Climate Change. Geneva.

IPCC (2003). *Good Practice Guidance for Land Use, Land-Use Change and Forestry*. Published by the Institute for Global Environmental Strategies. Geneva.

IPCC (2005). *IPCC/TEAP Special Report: Safeguarding the Ozone Layer and the Global Climate System*. Refrigeration Chapter 4. Mobile Air Conditioning Chapter 6 and Residential and Commercial Air Conditioning Chapter 5. Cambridge University Press.

IPCC (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Volume 1 through Volume 8. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

Murtaza, G. and Zia, M. H., (2012). *Wastewater Production Treatment and Use in Pakistan*. Institute of Soil and Enviromnental Sciences, University of Agriculture.

NEPRA (2014). State of Industry Report – 2014. Accessed at: http://www.nepra.org.pk/Publications/State%20of%20Industry%20Reports/State%20of%20Industry%20Report%202014.pdf

NTRC (2008), Motor Vehicles on Road by Region 2006-07, National Transport Research Centre, Islamabad. Also published in Economic Survey of Pakistan 2007-08 by Accountancy (T13.4)

NTRC (2012), Motor Vehicles on Road 2012, National Transport Research Centre, Islamabad. Also published in Economic Survey of Pakistan 2012-13

Oil Companies Advisory Council (2015). Pakistan Oil Report 2014-2015.

PAEC ASAD (2009). Greenhouse Gas Emission Inventory of Pakistan for the year 2007-2008. Pakistan Atomic Energy Commission, Applied Systems Analysis Division. July 31, 2009.

Planning Commission (2016). Demand and Supply Projections from the Planning Commission. Provided in Spreadsheet format on April 14, 2016.

PWSS (2002). *National Water Sector Profile*. Volume 5. October 2002. Pakistan Water Sector Strategy. Ministry of Water and Power, Office of the Chief Engineering Advisor.

World Bank (2014). World Development Indicators. Retrieved from World Bank website: http://data.worldbank.org/country/Pakistan

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