Report on Macroeconomic Impacts of Sectoral Energy Efficiency Initiatives in Bhutan

Department of Renewable Energy

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List of Abbreviations

AAC	Autoclaved Aerated Concrete
CET	Constant Elasticity of Transformation
CGE	Computable General Equilibrium
CPI	Consumer Price Index
EE	Energy Efficiency
FTL	Fluorescent Tubular Lamps
GDP	Gross Domestic Product
IO	Input-Output
LED	Light Emitting Diode
LES	Linear Expenditure System
Nu	Ngultrum
ROW	Rest of the World
SAM	Social Accounting Matrix
TFP	Total Factor Productivity
TOE	Tonnes of Oil Equivalent
USD	United States Dollars

Executive Summary

Under the Energy Plus Programme: Promoting Clean Energy Development in Bhutan -Energy Efficiency (Pack –III), the energy efficient interventions in the Building, Appliances, Transport and Industry sectors have been identified. The potential energy savings and the required investments were estimated sector-wise. Nevertheless, given the quantum of investment required to implement the recommended which is closely around 1.2 Billion USD over next couple of decades, it is envisaged that the whole macroeconomic environment of the country would be affected. In fact, it is important to investigate the pros and cons of such long term and large scale infrastructural investment decisions in the country. Investments considered in the areas like industrial energy efficiency improvement, building energy efficiency, energy efficiency in appliance and efficient transportation system are not only capital intensive but also having cross cutting impacts in the economy as a whole. To better understand the impacts of the interventions in the economy, a general equilibrium approach was introduced using Computable General Equilibrium model to investigate impacts on various essential indicators measuring the long term economic and social implications of various energy efficiency improvement interventions.

A recursive dynamic CGE model was constructed to estimate the macroeconomic impacts of sectoral energy efficiency measures in Bhutan. The sectors include building, electrical appliances, transport and industry. Specifically, the model estimates impact on indicators like Gross Domestic Product (GDP), household income, investment, and trade and government expenditure. In the model the impact on real GDP is estimated, that is, the impact on the quantity produced. GDP is modelled as a function of household expenditure, investment, government spending and net exports. Household income constitutes of the income of all households in the country. In the model households are classified into two types – rural and urban, to capture the difference between the two groups in terms of their income sources, consumption patterns etc.

Five different scenarios related to energy efficiency in these four sectors as well as a scenario with energy efficiency in all the sectors simultaneously were run using the CGE model. The impacts on GDP, household income, aggregate investment and trade and government expenditure were estimated where the key findings are listed below:

- There is positive impact on aggregate GDP but when EE is compared to BAU scenario, there is lower GDP growth (1%) due to high imports. The highest increase in GDP is observed when energy efficiency measures are implemented in the appliances sector.
- There is positive impact on household income when energy efficiency measures are implemented on an aggregate level. It rises from an initial slump of around (~)-1.5% to increase to 1.47% for urban households and slightly more than 1% for rural households. This is due to lower dependence on energy (petroleum products) imports in this scenario.
- The impacts of energy efficiency measures on trade (aggregate exports and imports) are relatively minor. Energy efficiency measures in industries, appliances and buildings sectors leads to lower government expenditure.
- The simultaneous implementation of energy efficiency measures in all the sectors (industries, appliances, buildings and transport) lead to losses in GDP with a simultaneous increase in household income (1.5%). There is a clear trade-off which benefits the equity perspectives. From 2015 to 2025, there is a surge in welfare of about 2% (form -1 to 1). The initial fall is due to very high investments and expenditure on the products. However, the energy savings outweigh the economic losses in the long run.

Households could be adversely affected due to energy efficiency measures in industries, appliances and buildings sectors, while firms may not benefit due to energy efficiency measures in the transport sector. Thus, energy efficiency policies should be supplemented with other policies to reduce the impacts on stakeholders that are adversely affected by such policies. Identification and targeting of stakeholders that are adversely affected by energy efficiency policies are of paramount importance.

1. Computable General Equilibrium Model

Computable General Equilibrium (CGE) models offer a comprehensive design for modelling the general impact of policy changes on the economy. They are specified models of an economy or a region, including all production activities, factors and institutions, including the modelling of all markets and macroeconomic components, such as investment and savings, balance of payments, and government budget. These models incorporate many economic linkages and can be used to explain medium to long-term trends and structural responses to changes in development policy. These models are based on economic theory - market-clearing prices are determined as a result of optimizing decisions by producers and consumers. This tool is usually used for analyse policy reforms that are likely to play a large role in the economy and might have important impacts on other sectors and/or on the flow of foreign exchange or capital. However, CGEs are significantly affected by the assumptions that they are based on which, depending on their definition, can impact on the results. CGEs are data-intensive and are constructed from combined national accounts and survey data that are first compiled into Social Accounting Matrices (SAM).

The Bhutan CGE model incorporates dynamics towards 2030 by solving for a series of static equilibria connected by exogenous evolution of macroeconomic drivers. For each time step macroeconomic drivers like sectoral labour force, sectoral capital stock, sectoral total factor productivity (TFP), and foreign investment were exogenously “shocked” to construct the baseline growth path of the economy.

It might be worth noting that the employed methodology does not use equation of motion of physical capital to update the stock of physical capital. The employed methodology assumes that the evolution of the economy during each time step is represented as the shift of steady-state equilibrium caused by exogenous shocks. This method is consistent with the steady-state equilibrium assumption underpinning static general equilibrium theory. The model is solved using the GAMS software (PATH solver).

This report presents the estimation of the macroeconomic impacts of sectoral energy efficiency policies in Bhutan. The report consists of five major chapters. Chapter 2 describes the Methodology for estimating the macroeconomic impacts used for the analysis. Chapter 3 presents the analytical technique (computable general equilibrium or CGE model), while Chapter 4 discusses the energy efficiency scenarios. In Chapter 5 the macroeconomic impacts are presented, and finally in Chapter 6 the policy implications of energy efficiency measures are discussed.

2. Methodology for Estimating the Macroeconomic Impacts

In this section the construction of a Social Accounting Matrix (SAM) for Bhutan is discussed, which is the key data input for the CGE model. A SAM is a square matrix showing income and expenditure flows in an economy at a point in time. An Input-Output Table for Bhutan, constructed by the Asian Development Bank (ADB) for the year 2007, was the starting point for the construction of the SAM. The Input-Output Table consists of the following production sectors:

- Agriculture
- Forestry and Fishery Products
- Products of Mining and Quarrying
- Basic Metals
- Fabricated Metals
- Machinery
- Equipment and Appliances
- Food, Beverages and Tobacco Products
- Clothing and Wearing Apparel
- Leather and Leather Products
- Products of Wood, Paper and Paper Products
- Other Manufacturing
- Electricity
- Town Gas
- Steam and Hot Water
- Construction Services
- Wholesale and Retail Trade Services
- Transportation, Communication and Supporting and Auxiliary Transport Services
- Financial Intermediation & Insurance
- Auxiliary Services except Compulsory Social Security Services
- Real Estate, Leasing or Rental
- Other Business and Production Services
- Water supply

Apart from the production sectors the other accounts in the Input- Output (IO) Table include taxes/subsidies, value-added (wage and non-wage income), exports/imports, expenditure by households and government, and investment. For each account the row sum equals the column sum, or in other words, income (row sum) equals expenditure (column sum) for each account. The following modifications were done to the IO table for the construction of the SAM:

Sectoral mapping – some sectors of the IO table were aggregated while some other sectors were disaggregated. For example, Food, Beverages and Tobacco Products, Clothing and Wearing Apparel, and Leather and Leather Products, Products of Wood, Paper and Paper Products, and Other Manufacturing sectors of the IO table have been aggregated into a single sector in the SAM called Manufacturing.

Disaggregation of the household account - the household sector in the IO table was disaggregated into urban and rural categories based on data (see Chapters 6 and 8 of Bhutan Living Standards Survey 2012 Report, ADB) about source of income (wage/non-wage) and expenditure patterns of the two household groups. The reason for the disaggregation of the household account in the IO table was to capture the equity (income distribution) aspects of the interventions on the two different household groups. Unless the household account is disaggregated the differences in impacts on the different household groups cannot be captured.

Construction of petroleum products sector - Data on imports (see Statistical Yearbook of Bhutan 2014) and consumption of petroleum products (see Chapter 5 of Bhutan Energy Data Directory, 2005) were used to create the petroleum products sector. Adjustments were done in the 'other manufacturing' sector of the IO table to account for the creation of the petroleum products sector. It is to be noted that Bhutan is completely dependent on the imports of petroleum products to meet the energy demands of the transport sector.

Disaggregation of transport sector by vehicle types – the transport sector in the IO table was disaggregated into four road transport categories (light transport, bikes, heavy transport and public transport). Light transport implies cars and other small four wheelers, bikes are the two wheelers, heavy transport includes trucks, buses, earthmovers, tillers etc. and public transport implies public buses. The row and column vectors for the transport sector in the IO table were disaggregated into four road transport categories each, as mentioned above, using data from the Road Safety and Transport Authority (RSTA) of Bhutan. Data on vehicle ownership by sector/household group, number of vehicles by type, average fuel costs for the different types of vehicles etc. were used to disaggregate the transport sector in the IO table into the four road transport categories. Further, four types of electric transport sectors (electric light transport, electric bikes, electric heavy transport and electric public transport) were constructed corresponding to each of the conventional (fossil fuel based) road transport categories. Data from an earlier project[1] were used to construct the electric transport sectors.

After the above modifications were incorporated into the IO table the IO table was rebalanced using statistical techniques to obtain the SAM (see Figure 1). The final SAM consists of the following accounts. In a SAM each column entry implies expenditure while each row entry implies income for an account. For example, the row entries for the agriculture sector (AGRIC) are 354, 283, 491, 264, 2205, 3521, 3328 and 868. The row entries correspond to income from the sale of agricultural commodities to other sectors of the economy as well as to households, investment and rest of the world (exports). The sum of the row entries is the total income of the agriculture sector. Similarly, the column entries for the agriculture sector are 354, 421, 21, 7, 80, 34, 1, 23, 1, 1, 2, 61, 3562, 6096, 29 and 620. The column entries correspond to expenditure due to the purchase of commodities from other sectors of the economy, due to the payment of wages/profits/taxes, and due to imports from rest of the world. The sum of the column entries is the total expenditure of the agriculture sector. Finally, total income (11314) is equal to total expenditure (11314) of the agriculture sector. The SAM reveals some interesting aspects of the Bhutan economy such as total dependence on imports for meeting demand for petroleum products (valued at 2248million Nu). Significant exports of electricity to the tune of 10470 million Nu and higher income of urban households relative to rural households although the urban population is significantly lower than the rural population. In short the SAM gives us a glimpse of the Bhutan's economy in 2007.

[1] Capacity Building of the National Environment Commission in Climate Change, May 2011

Figure 1: Social Accounting Matrix for Bhutan (2007) (Million Nu)

	AGRIC	MINING	METALS	MANU	PETPROD	ELECTRICITY	CONSRETAIL	LIGHTTRNS	BIKES	HEAVYTRNS	PUBTRNS	ELIGHTTRNS	EBIKES	EHEAVYTRNS	EPUBTRNS	OTHSERV	LAB	CAP	URBANHH	RURALHH	NETCONSTAX	NETPRODTAX	GOVT	SAVINV	ROW	TOT
AGRIC	354			283			491									264			2205	3521				3328	868	11314
MINING			515	1302			1046	53	11	76	11								61	54				-572	950	3507
METALS			330	419			2335	63	12	91	12					24			575	499				828	10299	15486
MANU	421	30	339	2183		35	3729									765			2231	1933				1109	5165	17941
PETPROD	21			39				736	81	1103	98					45			89	37						2248
ELECTRICITY	7	8	750	233		2645	29	13	7	16	6	4	3	5	2	96			276	289				5	10470	14863
CONSRETAIL	80	5	47	229		7	368	39	10	56	9					282			745	781				16129	1182	19968
LIGHTTRNS	34	41	153	202		14	76	79	12	116	13					545			812	478					686	3261
BIKES	1	3	8	108		3	5									151			81	48						408
HEAVYTRNS	23	417	293	601		18	887	155	24	228	26					633								198	1355	4859
PUBTRNS																			296	175						471
ELIGHTTRNS	1	1	1	1		1	1									2			2	2					2	14
EBIKES	1	1	1	1		1	1									1			1	1						11
EHEAVYTRNS	2	2	2	2		2	2									2								2	3	18
EPUBTRNS																			3	3						6
OTHSERV	61	55	139	490		33	754	268	33	400	38					1689			2319	2483			9331	7	681	18783
LAB	3562	204	491	1282		3890	3042	464	53	694	63	5	4	4	2	6769										20531
CAP	6096	420	339	2158		6466	4667	1054	114	1582	138	5	3	9	2	3769										26822
URBANHH																	12891	7968								20859
RURALHH																	7640	9886								17526
NETCONSTAX	29	11	47	134		12	142	22	8	30	7					65			494				113	74	343	1532
NETPRODTAX		291	35	72		7	1515	28	8	39	8					158										2162
GOVT																		4671			1532	2162				8366
SAVINV																		4297	10668	7222			-1079			21107
ROW	620	2018	11997	8201	2248	1729	878	286	35	427	41					3523										32003
TOT	11314	3507	15486	17941	2248	14863	19968	3261	408	4859	471	14	11	18	6	18783	20531	26822	20859	17526	1532	2162	8366	21107	32003	

Source: Asian development Bank

3. Constructing the Computable General Equilibrium (CGE) Model

For the purpose of this study, a recursive dynamic CGE model for Bhutan was developed for assessing the implications of energy efficiency measures in different production sectors. The main source of data for the CGE model is the SAM. The other data used in the analysis pertain to energy savings and investments required for implementing the energy efficiency measures.

The CGE model used in this study is based on Lofgren's model[2]. The model consists of 16 production sectors - Agriculture (AGRIC), Mining (MINING), Metals (METALS), Manufacturing (MANU), Petroleum Products (PETPROD), Electricity (ELECTRICITY), Construction and Retail (CONSRETAIL), Light vehicles (LIGHTTRNS), Two wheelers (BIKES), Heavy vehicles (HEAVYTRNS), Public transport (PUBTRNS), Electric Light vehicles (ELIGHTTRNS), Electric Two wheelers (EBIKES), Electric Heavy vehicles (EHEAVYTRNS), Electric Public transport (EPUBTRNS), Other Services (OTHSERV). There are two factors of production, capital (CAP) and labour (LAB), and two household groups, Urban (URBANHH) and Rural (RURALHH). A general discussion on the features of the CGE model (see Figure 2 for schematic representation) is presented in the following paragraphs.

Key Assumptions for the model:

The following are the key assumptions to establish the general equilibrium of the economy, for the components discussed in the SAM and set to equilibrium to assess the impact of the energy efficiency interventions.

- Producers are assumed to maximize profits and to operate in perfectly competitive markets.
- Households maximize utility subject to income and prices, and the household demand for commodities is modelled through the linear expenditure system (LES). Household income comprises of income derived from labour and capital and transfers from the government and the rest of the world. Households also save part of their income and pay taxes to the government. Savings rate is also fixed.
- Government expenditure is on the consumption of goods and services, transfers to households and subsidies. Government income is from taxes (direct and indirect), and rest of the world. Indirect taxes include production tax, and import and export tariffs. Government savings, which is the difference between government expenditure and income is determined residually.
- Imperfect substitution between domestic goods and foreign goods is allowed for in CGE models. In other words, producers/consumers are free to sell or consume goods from the domestic or foreign market based on relative prices.
- The Armington function is used to capture the substitution possibilities between domestic and imported goods. The import demand function, derived from the Armington function, specifies the value of imports based on the ratio of domestic and import prices.
- The Constant Elasticity of Transformation (CET) function is used to capture substitution possibilities between domestic and foreign sales. The export supply function, derived from the CET function, specifies the value of exports based on the ratio of domestic prices to export prices. The elasticity of substitution determines the relative ease of substitution between domestic and foreign goods in response to changes in relative prices.
- Markets for all goods and services clear through adjustment in prices. The consumer price index (CPI) is chosen as the numeraire and is therefore fixed.

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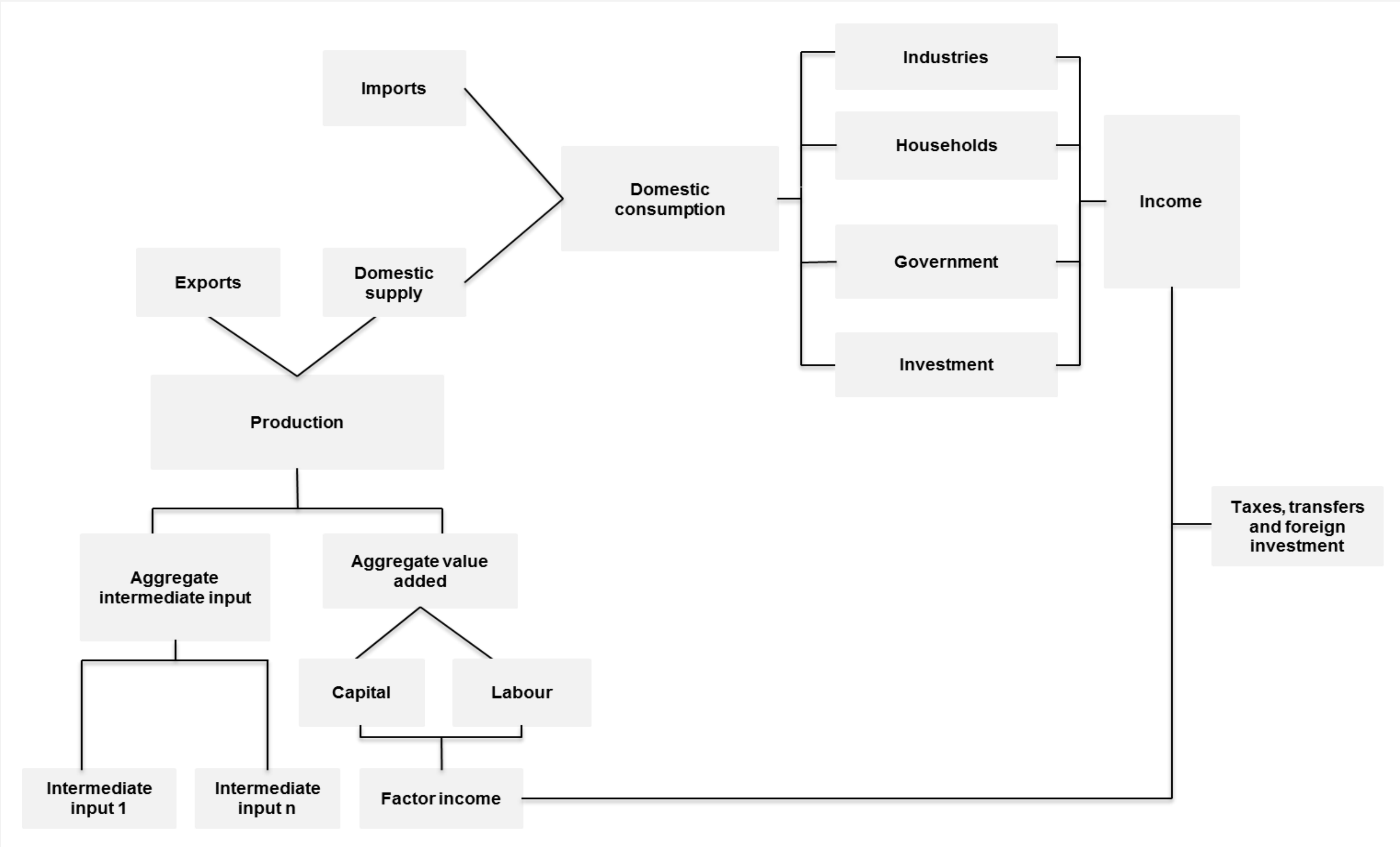
[2] Lofgren et al. 2002

- The model follows a savings-driven closure, that is, aggregate savings is fixed. The saving-investment balance is maintained through adjustment in aggregate investment.
- The model assumes foreign savings to be fixed and the real exchange rate to be flexible. Government consumption and savings is fixed within a period.

The CGE model estimates the macroeconomic impacts of energy efficiency measures in the different sectors. Specifically, the model estimates impact on indicators like Gross Domestic Product (GDP), household income, investment, trade and government expenditure. The indicators and their relation are defined as follows. GDP is the value of all goods and services produced in a country in a year. It is a function of both quantity and price. In the model the impact on real GDP is estimated, that is, the impact on the quantity produced. An increase in real GDP implies that there is increase in the country's output. A decrease in GDP means just the opposite. GDP is a function of household expenditure, investment, government spending and net exports. Household income implies the income of all households in the country. In the model households are classified into two types – rural and urban, to capture the difference between the two groups in terms of their income sources, consumption patterns etc.

A particular policy shock (such as an energy efficiency measure) will have different impacts on the two groups and will thus lead to change in income distribution in the country. Impact on trade is measured through changes in the quantities of aggregate exports and imports. Domestic and international prices as well as the exchange rate determine the quantities of exports and imports in the model. Aggregate investment implies the total investment in the economy, which is determined by domestic and foreign savings. Finally, government expenditure is the value of government expenses on purchases of goods/ services, spending on subsidies etc. The energy efficiency measures are implemented in the CGE model by simultaneously reducing energy consumption of the particular sector and by increasing investment. Data on energy savings and investments, due to the different energy efficiency measures, are used for this purpose.

Figure 2: Schematic Representation of the CGE model



4. Energy Efficiency Scenarios

Five energy efficiency scenarios were modelled with the help of the CGE model. The energy savings and investment requirements are based on certain assumptions. The energy efficiency scenarios are:

Energy Efficiency in industries (Mining, Metals and Manufacturing)

Energy performance of industries can be improved through a systematic effort of focusing on both small-scale, low-cost retrofit measures as well capital intensive large-scale projects at the factory floors.

#	Utility Category	Description
1	Transformer	▶ Effective Loading of Transformer
2	Motor	▶ Downsize and usage of Energy Efficient motors ▶ Enhancement of operating power factor of utilities to improve productivity and reduce Specific Energy Consumption ▶ Provision of permanent star connection for the identified lowly loaded low HP motors
3	Fans	▶ Installation of Variable Frequency Drive ▶ Replacement of bottom cooling fan of centrifugal type with axial type of correct size
4	Pumps	▶ Installation of Variable Frequency Drive
5	Air compressors	▶ Arresting Compressed Air Leakages
6	Illumination	▶ Replacement of existing low-efficiency fixtures (like 40W FTLs) with energy efficient ones

It is estimated that pursuit of EE in the industries sector will entail the following cumulative impact:

- Total energy savings between 2015 and 2030 – 260 thousand TOE
- Total capital expenditure needed to achieve the above savings between 2015 and 2030 – USD 505 million

Energy Efficiency in Transport (Light Vehicles, Two Wheelers, Heavy Vehicles and Public Transport)

Energy performance of the transportation sector can be remarkably improved in Bhutan through systematic adoption of sustainable transportation modalities including electric vehicles, use of public transportation modalities, *etc.* Introduction of electric vehicles (scooters/bikes, cars and buses) and sustainable transport planning in pursuit of EE in the transportation sector is estimated to entail the following cumulative impact:

- Total energy savings between 2015 and 2030 – 145 thousand TOE
- Total capital expenditure needed to achieve the above savings between 2015 and 2030 – USD 147 million

Energy Efficiency in Appliances (Manufacturing)

Energy performance of appliances is expected by replacing existing appliances at their end of life with more energy efficient ones. The energy performance standards set follow the similar benchmarks as set in Thailand and India (the two primary sources of import of appliances in Bhutan) and discourage the buying of non-labelled appliances or such appliances having no clear indication of their energy performance. It is estimated that pursuit of EE in the appliances sector will entail the following cumulative impact:

- Total energy savings between 2015 and 2030 – 346 thousand TOE
- Total capital expenditure needed to achieve the above savings between 2015 and 2030 – USD 432 million

Energy Efficiency in Buildings (Construction and Retail)

Energy performance of buildings can be improved through a systematic effort of focusing on retrofits for existing buildings as well as using energy efficient construction techniques for new buildings.

Intervention	Description
Wall insulation	1 inch rock wool insulation for residential brick houses in cold districts
	1 inch glass wool insulation on walls for institutional and commercial brick buildings in cold districts
Roof insulation	1 inch rock wool insulation on roof for residential houses in winter districts
	1 inch EPS insulation on roof for institutional and commercial buildings in summer districts
Double glazing	6 mm thick Double glazed window with air gap having U Value 3.12
AAC blocks	Use of AAC blocks in NEW residential buildings
	Use of AAC blocks in NEW commercial and institutional buildings
Rat trap wall	Use of rat trap bonding technique in NEW brick residential buildings
	Use of Rat trap wall in NEW brick commercial and institutional buildings
LED lighting	LED lighting in residential houses
	LED lighting in institutional and commercial buildings

Intervention	Description
AC thermostat set point optimization	Using at an optimum thermostat set point (24degreeC) in ACs. For every 1degreeC increase in the thermostat set point, there will be 3% reduction in the compressor power consumption. This measure does not require any investment and the returns are immediate

It is estimated that pursuit of EE in the building sector will entail the following cumulative impact:

- Total energy savings between 2015 and 2030 – 126 thousand TOE
- Total capital expenditure needed to achieve the above savings between 2015 and 2030 – USD 95.3 million

Energy Efficiency in all the above sectors (Mining, Metals, Manufacturing, Light Vehicles, Two Wheelers, Heavy Vehicles, Public Transport, Construction and Retail). It is the sum of the Energy Efficiency interventions in all the sectors. This portrays the overall economy wide impact of the interventions.

4.1 Converting Energy Saving into Economic Value

While using the CGE model framework for assessing the impacts of various energy efficiency measures in the economy, it was important to rightly evaluate the economic value of each unit of saving. Ideally the cost of each unit of utilizable energy should include the extraction, refining, transportation, conversion/processing and distribution costs put together. In a full cost accounting every unit of energy cost should also add up its cost of externalities (environmental, health etc.). Finally, the aggregated cost should be levelized over the life span of the energy generating facility with appropriate discounting and arrive to the net present value of energy cost. In the process of evaluating the impacts of energy efficiency measures, it is assumed that every unit of saved energy is valued in terms of its corresponding capital expenditure required. For example, in building energy consumption, if one unit of energy is saved due to wall insulation intervention, then the cost of that unit of saving is considered as capital cost of getting one unit of rock wool insulation for residential brick houses and one unit of glass wool insulation for institutional and commercial buildings multiplied by the areas covered. However, the estimation of investments required for energy savings achievement do not consider directly the avoided costs of fossil fuels displacement. Overall fuel displacement savings are considered at macroeconomic level. For further detail of the energy to cost estimation used in this study please refer the appendix.

5. Data Input for CGE

The data that were used to run the model were derived from the survey and audit done by EY in the transport, building, appliance and industrial sector. The reports from which the data has been derived are:

- "Bhutan Industry Energy Audit Report" by EY (2015)
- "Bhutan Building Energy Efficiency Study" by EY (2015)
- "Energy Efficiency in Bhutan Electrical Equipment and Appliances Sector" by EY (2015)
- "Energy Efficient Transport in Bhutan: Policies, Strategies and Cost-Benefit Analysis in Transport sector" by EY (2015)

The required parameters as mentioned were derived for each sector in the following manner:

- **Capex**: This is the total expenditure of undertaking all the energy efficiency interventions under a given sector[3]. The cost is incorporate as private investment for each sector.

- **Baseline Energy Consumption:** This is the energy consumption had there been no energy efficiency interventions in any sector.

- **Energy Efficient (EE) Energy Consumption:** This is the energy consumption when all energy efficient interventions are taking place. Energy Savings is the difference between baseline and energy efficient scenario.

- **Monetary value of Savings:** The energy saved is converted to monetary value using the flowing values derived as the price of fuels.

Table 1: Derived Price of Fuels

Price of Fuels		Units
Electricity	2.82	Nu/kWh
Diesel	1.04	million Nu/TJ
Petrol	1.31	million Nu/TJ
Kerosene	0.31	million Nu/TJ
Coal	8.968	million Nu/TJ

(Source: Derived from BPC – Power Data handbook-2013, Data from Statistical Yearbook-2013 and EY survey and audit on all select sectors)

[3] It is important to note that the capital expenditure (Capex) does not run for the entire span of 15 years for any the sectors. The investment done in a particular year will lead to benefits accruing in the future years. To account the maximum possible benefit that can be derived till 2030, the investment to a particular year is set for all the sectors. If investment in the later years had been calculated it would be lead to an erroneous calculation. This is because the benefits would not have been calculated that would still be accruing beyond 2030.

- The **monetary value of one TOE of energy saved** in each sector is different because the composition of fuels is different in the different sectors. Hence, the composite price of one TOE varies across sector.

- The **investment required to save one TOE of energy** in each sector is different because the returns are sector specific.

Table 2: Energy Savings, Consumption and Expenditure Projections - Building Sector

	Capex (million USD)	Savings/ Baseline Consumption %	Energy savings (ES) TOE	Baseline Energy Consumption (EC) TOE	Monetary value of savings (million USD)
2016	38.6	0.1	9,765.7	89,931.9	4.7
2017	44.2	0.1	11,172.0	94,698.3	5.4
2018	50.5	0.1	12,780.8	99,717.4	6.1
2019	57.8	0.1	14,621.2	105,002.4	7.0
2020	66.1	0.2	16,726.7	110,567.5	8.0
2021	75.6	0.2	19,135.3	116,427.6	9.2
2022		0.2	21,890.8	122,598.2	10.5
2023		0.2	25,043.1	129,095.9	12.0
2024		0.2	28,649.3	135,938.0	13.8
2025		0.2	32,774.8	143,142.7	15.8
2026		0.2	37,494.3	150729.3	18.0
2027		0.3	42,893.5	158,718.0	20.6
2028		0.3	49,070.2	167,130.0	23.6
2029		0.3	56,136.3	175,987.9	27.0
2030		0.3	64,219.9	185,315.3	30.9

Table 3: Energy Savings, Consumption and Expenditure Projections – Appliances' Sector

	Capex (million USD)	Savings/ Baseline Consumption %	Energy savings (ES) TOE	Baseline Energy Consumption (EC) TOE	Monetary value of savings (million USD)
2015	45.1	0.2	37,475.2	202,336.9	19.8
2016	47.8	0.2	38,749.3	209,216.4	20.5
2017	48.3	0.2	40,066.8	216,329.7	21.2
2018	51.2	0.2	41,429.1	223,684.9	21.9
2019	52.1	0.2	42,837.7	231,290.2	22.7
2020	54.2	0.2	44,294.1	239,154.1	23.4
2021	56.1	0.2	45,800.1	247,285.3	24.2
2022	58.3	0.2	47,357.3	255,693.0	25.1
2023	60.4	0.2	48,967.5	264,386.6	25.9
2024	62.8	0.2	50,632.4	273,375.7	26.8
2025	65.3	0.2	52,353.9	282,670.5	27.7
2026		0.2	54,133.9	292,281.3	28.6
2027		0.2	55,974.5	302,218.9	29.6
2028		0.2	57,877.6	312,494.3	30.6
2029		0.2	59,845.4	323,119.1	31.7
2030		0.2	37,475.2	202,336.9	19.8

Table 4: Energy Savings, Consumption and Expenditure Projections – Transport Sector

	Capex (million USD)	Baseline Energy Consumption (EC) TOE	Savings/ Baseline Consumption %	Energy savings (ES) TOE	Monetary value of savings (million USD)
2016	0.00	132,373.09	0.00	0.00	0.00

	Capex (million USD)	Baseline Energy Consumption (EC) TOE	Savings/ Baseline Consumption %	Energy savings (ES) TOE	Monetary value of savings (million USD)
2017	0.00	138,329.88	0.00	0.00	0.00
2018	0.00	144,554.72	0.00	0.00	0.00
2019	0.00	151,059.68	0.00	0.00	0.00
2020	20.5	157,857.37	0.00	350.00	0.2
2021	21.9	164,960.95	0.1	10,536.40	7.8
2022	23.5	172,384.19	0.1	11,273.95	8.3
2023	25.1	180,141.48	0.1	12,063.12	8.9
2024	26.9	188,247.85	0.1	12,907.54	9.5
2025	28.8	196,719.00	0.1	13,811.07	10.2
2026		205,571.36	0.1	14,777.85	10.9
2027		214,822.07	0.1	15,812.30	11.7
2028		224,489.06	0.1	16,919.16	12.5
2029		234,591.07	0.1	18,103.50	13.4
2030		245,147.67	0.1	19,370.74	14.3

Table 5: Energy Savings, Consumption and Expenditure Projections –Industry Sector

	Capex (million USD)	Baseline Energy Consumption (EC) TOE	Savings/ Baseline Consumption %	Energy savings (ES) TOE	Monetary value of savings (million USD)
2016	0.00	255,733.2	0.00	0.00	0.00
2017	0.00	262,893.8	0.00	0.00	0.00
2018	22.9	270,254.8	0.03	9,000.0	19.7
2019	31.4	277,821.9	0.04	12,334.0	27.0
2020	34.3	285,600.9	0.05	13,469.0	29.5
2021	37.5	293,597.8	0.05	14,708.1	32.2

	Capex (million USD)	Baseline Energy Consumption (EC) TOE	Savings/ Baseline Consumption %	Energy savings (ES) TOE	Monetary value of savings (million USD)
2022	40.9	301,818.5	0.05	16,061.3	35.2
2023	44.7	310,269.4	0.06	17,538.94	38.4
2024	48.8	318,957.0	0.06	19,152.5	41.9
2025	53.3	327,887.8	0.06	20,914.5	45.8
2026	58.2	337,068.6	0.07	22,838.6	50.0
2027	63.6	346,506.5	0.07	24,939.8	54.6
2028		356,208.7	0.08	27,234.3	59.7
2029		366,182.6	0.08	29,739.8	65.2
2030		376,435.7	0.09	32,475.9	71.2

The table below shows the energy savings and investment requirements for the above scenarios

Table 6: Energy savings and investment requirements for the different sectors (2015-30)

	Industry	Transport	Appliances	Buildings	All sectors
Energy savings (TOE)	260,407	145,926	717,795	442,374	1,566,502
Investment (Million USD)	436	147	557	333	1,473
Investment per unit of energy savings (Million USD per TOE)	0.002	0.001	0.001	0.001	0.005

Source: EY Estimations through modelling exercise

The macro economic impacts of the energy efficiency scenarios are discussed in the next section.

6. Impact Assessment of Policy Interventions

In this section the macroeconomic impacts of energy efficiency measures are discussed. Our discussion is focused on the impacts on GDP, household income (urban and rural), aggregate investment, trade and government expenditure.

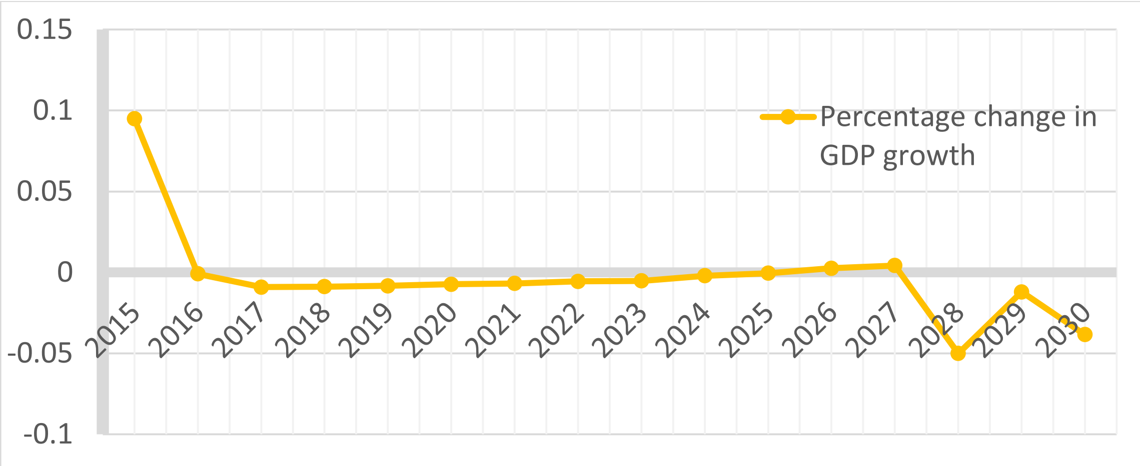
Impact on GDP:

There is a positive impact on GDP but the impact is lower than that in the baseline. There is energy efficiency improvement in industry, appliances and buildings sectors because of higher investment and the negative impact on GDP can be evaluated as a trade-off. There is significant growth in the household income due to energy-cost savings (In terms investigating the impacts of energy efficiency related investment on other important macroeconomic factor like household level income generation, it has been estimated that urban households are having lessor income over the period of time. The main reasons could be reduced disposable income due to increasing cost of energy utilization at household level (procurement of energy efficient appliances at higher prices), reduced employability in the energy service sector due to lack of technical skills operation and maintenance of advance equipment etc. However, over the period of time, the income level is envisaged to go up due to price rationalization of the energy appliances and services in the market followed by the increasing employability in the sector. There is increase in household income even though higher prices of goods and services prevail in the economy in the energy efficient scenario. There is increase in prices of goods and services due to the effects of expensive energy efficiency measures. Increase in prices leads to lower purchasing power of households and therefore there is loss in real income. But the energy savings offsets the loss in purchasing power.

The results further demonstrate that macroeconomic benefits regarding energy efficiency interventions are net positive. Beginning 2016 until 2025 GDP growth rate slightly gets negatively affected compared to the BAU level GDP growth rate. GDP might get affected in the range of 0,01% compared to BAU scenario until 2026. After that GDP growth rate improves compared to BAU but again got affected after 2027. The main reason for such growth decline can be attributed to fresh investment required after ten twelve years of operation of the energy efficiency equipment. Nevertheless, the directions of economic impacts of energy efficiency interventions are positive overall.

In this study we have investigated the impacts of total investments in the economy in terms of deploying various energy efficiency measures and allows the model to endogenously determine the savings required at various agents' level (use of investment driven closure) to meet the investment demand. While using the energy efficiency measures, it is also affecting the macro economy of the country by adjusting the Balance of Payment (BoP) and Current Account deficits. Since Bhutan is fully dependent on fossil fuel import from India therefore, energy efficiency is envisaged to affect the country's GDP in a positive manner.

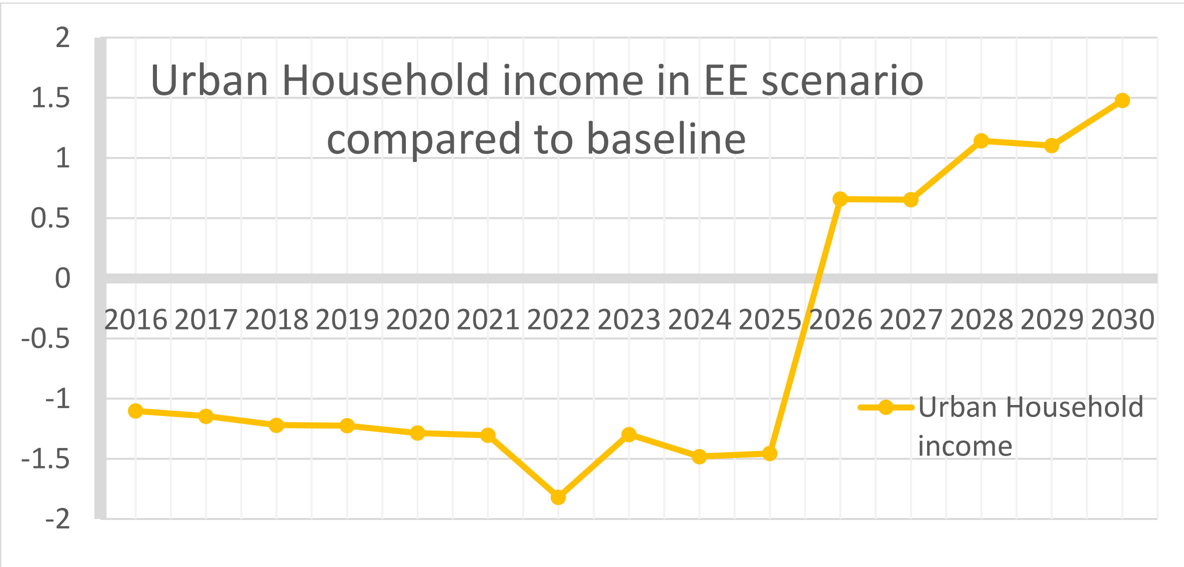
Figure 3: Percentage change in GDP growth in EE Scenario compared to BAU



Source: EY Estimations through modelling exercise

In terms investigating the impacts of energy efficiency related investment on other important macroeconomic factor like household level income generation, it has been estimated that urban households are having lessor income over the period of time. The main reasons could be reduced disposable income due to increasing cost of energy utilization at household level (procurement of energy efficient appliances at higher prices), reduced employability in the energy service sector due to lack of technical skills operation and maintenance of advance equipment etc. However, over the period of time, the income level is envisaged to go up due to price rationalization of the energy appliances and services in the market followed by the increasing employability in the sector.

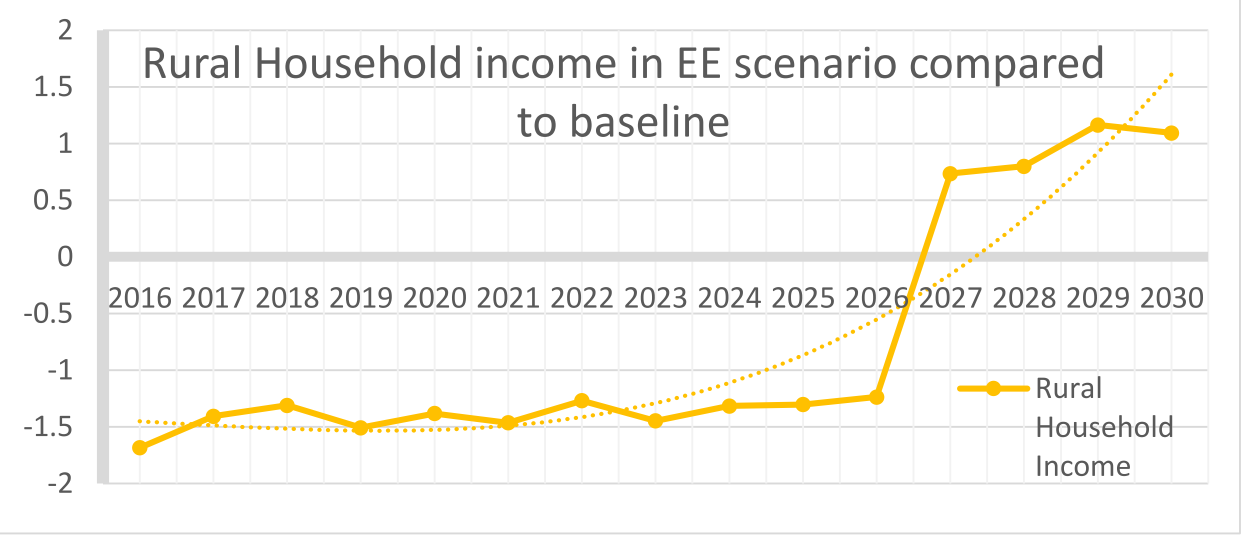
Figure 4: Impact on urban household income



Source: EY Estimations through modelling exercise

Similar to the impacts of energy efficiency related investment on urban household level income generation, it is observed that rural households are having lessor income over the time period. The main reasons would be similar to urban household impacts - reduced disposable income due to procurement of energy efficient appliances at higher prices, reduced employability in the energy service sector due to lack of technical skills operation and maintenance of advance equipment etc. Over the period of time, the income level goes up in rural households, due to price rationalization of the energy appliances and services in the market followed by the increasing employability in the sector.

Figure 5: Impact on rural household income



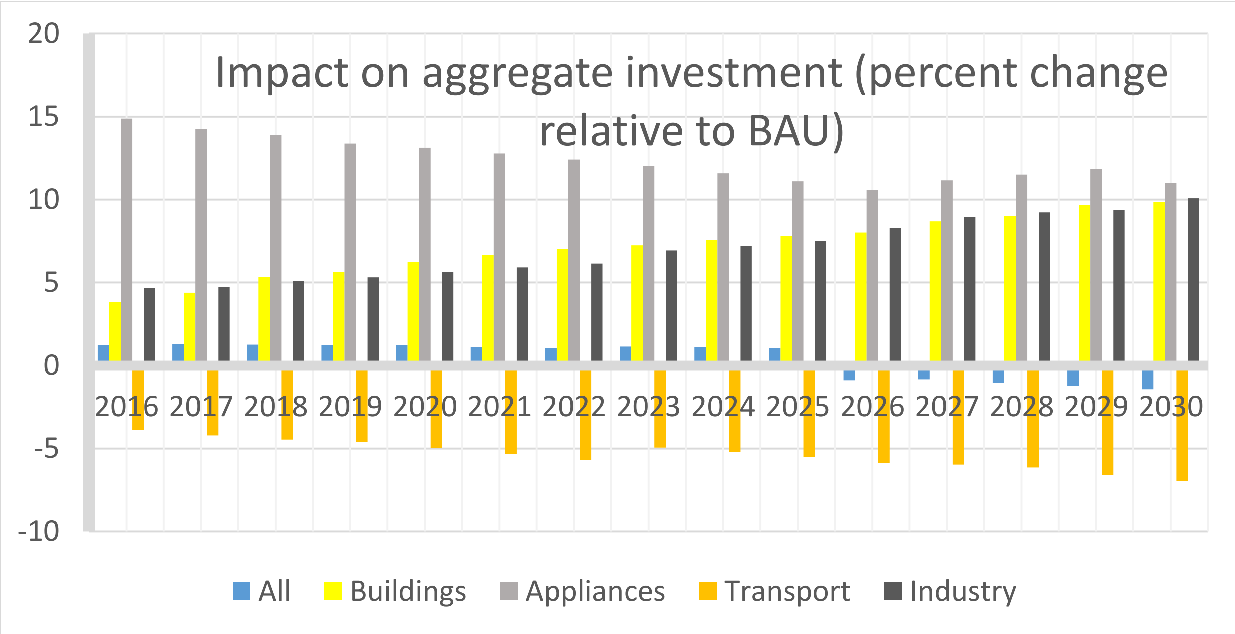
Source: EY Estimations through modelling exercise

Energy savings in the different sectors (other than transport) leads to higher investments (

) in the economy and thus to higher GDP leading to an overall growth over BAU by 5% - 8%. Energy savings in the appliances sector leads to the highest increase in GDP (15% - 10%). Firms utilize the savings in energy expenses to increase their capital expenditure.

The macroeconomic impacts due to energy efficiency in the transport sector are different compared to the impacts observed in case of the other sectors. In case of energy efficiency in the transport sector there is greater loss in GDP due to lower investments in the economy. However, households gain due to relatively lower prices of goods and services. Note that Bhutan imports all of its demand for petroleum products, so energy efficiency in the transport sector leads to lower dependence on imports. This leads to positive terms of trade effects, that is, import prices decline. This in turn results in lower prices in the economy and higher real income of households.

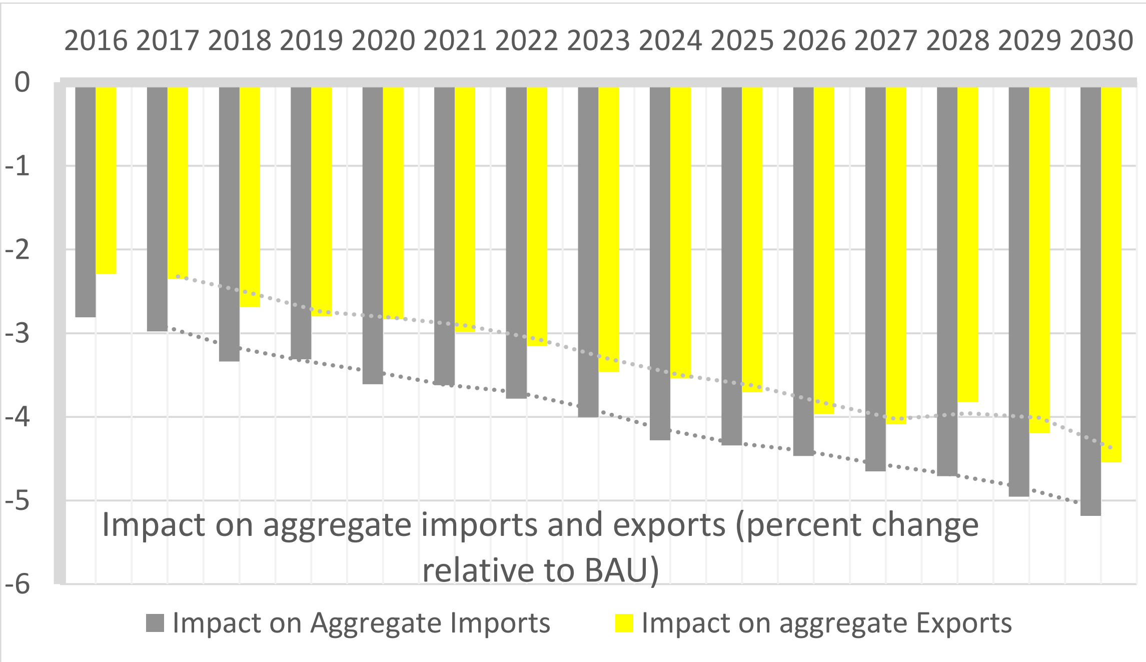
Figure 6: Impact on aggregate investment



Source: EY Estimations through modelling exercise

Effects on trade are minor (around 5% and lower) in the different scenarios.

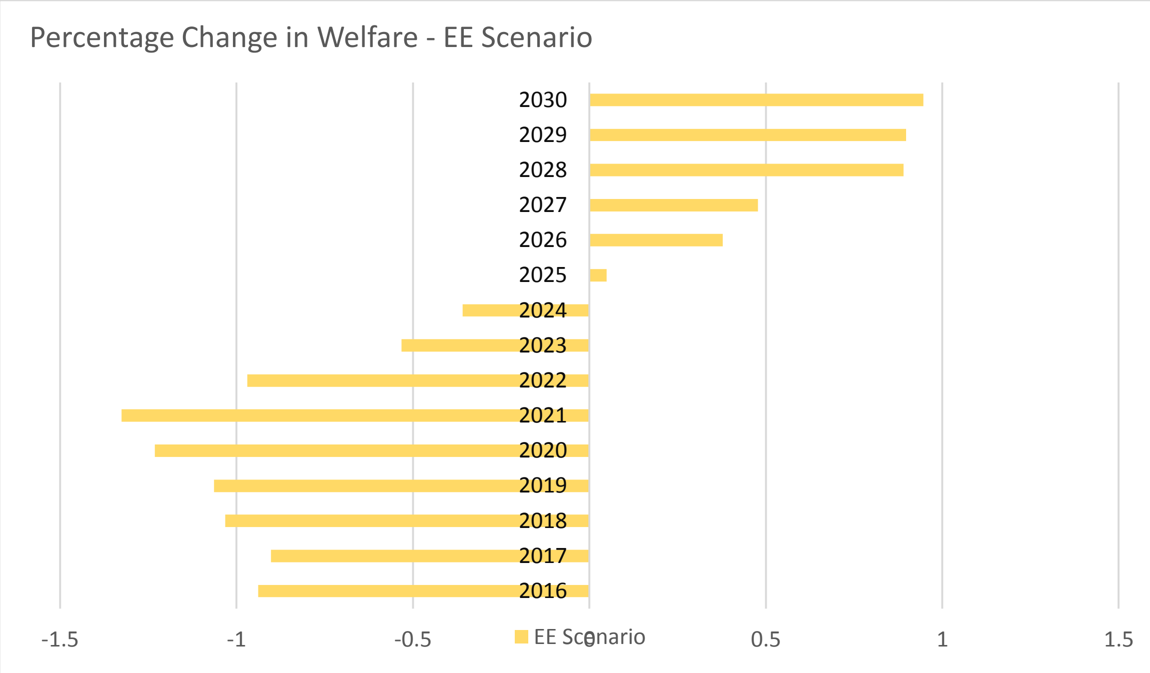
Figure 7: Impact on aggregate imports and exports



Source: EY Estimations through modelling exercise

Thus, the results show that the macroeconomic impacts of energy efficiency measures in different sectors could differ considerably. There is a trade-off between economic efficiency (measured by GDP) and equity (measured by household income). The energy efficiency measures are costly and in the initial stage, it shows negative economic welfare trend (**Error! Reference source not found.**). Therefore, energy efficiency measures in these sectors should be supplemented with other policies (such as employment generation programs) in order to lower the adverse impacts on equity. For example, energy efficiency in the transport sector is beneficial from balance of trade and energy security perspectives. Although there is an initial loss in economic efficiency in the transport sector scenario due to very high upfront cost, energy efficiency in the transport sector could have significant positive impacts on Bhutan and thus should be prioritised.

Figure 8: Impact on Economy Welfare



Source: EY Estimations through modelling exercise

Finally, the results show that on an aggregate level, implementing energy efficiency measures for all the sectors simultaneously could be costly for the economy from both economic efficiency and equity perspectives. There is loss in GDP but household income rises when energy efficiency measures are implemented simultaneously in all the sectors. Consequently, there is a positive impact in the welfare scenario. It is also envisaged that pan country energy efficiency measures also vouch for a robust technical skill development plans for the country which can further buffer the initial economic losses due to income reduction. Nevertheless, energy efficiency measures should be prioritised for Bhutan keeping in view country's inclusive and sustainable developmental objectives.

Summary

The impacts on GDP, household income, aggregate investment, trade and government expenditure estimated can be summarized as follows:

- There is an overall positive impact on national economy due to energy efficiency intervention though slight decline in GDP is observed for certain period of time. The highest increase in GDP is observed when energy efficiency measures are implemented in the appliances sector. Further, energy efficiency measures in these sectors leads to higher investments in the economy.

- There is positive impact on household income when energy efficiency measures are implemented on an aggregate level. It rises from an initial slump of around (~)-1.5% to increase to 1.47% for urban households and slightly more than 1% for rural households. This is due to lower dependence on energy (petroleum products) imports in this scenario.

- The impacts of energy efficiency measures on trade (aggregate exports and imports) are relatively minor.

- Energy efficiency measures in industries, appliances and buildings sectors leads to lower government expenditure.

- The simultaneous implementation of energy efficiency measures in all the sectors (industries, appliances, buildings and transport) lead to losses in GDP with a simultaneous increase in household income (~1.5%). There is a clear trade-off, which benefits the equity perspectives.

- From 2015 to 2025, there is a surge in welfare growth of about 2% (form -1 to 1). The initial fall is due to very high investments and expenditure on the products. However, the energy savings outweigh the economic losses in the long run.

The main policy implication is that energy efficiency measures should be implemented keeping in view the impacts on different stakeholders, and the priorities of the country. Households could be adversely affected due to energy efficiency measures in industries, appliances and buildings sectors, while firms may not benefit due to energy efficiency measures in the transport sector. Thus, energy efficiency policies should be supplemented with other policies (for example employment generation programs or production subsidies) to reduce the impacts on stakeholders that are adversely affected by such policies. Identification and targeting of stakeholders that are adversely affected by energy efficiency policies are of paramount importance.

References

- Lofgren, H., R.L. Harris and S. Robinson (2002) *A Standard Computable General Equilibrium Model in GAMS. Microcomputers in Policy Research 5. International Food Policy Research Institute (IFPRI), Washington DC, USA*
- Asian Development Bank, (2007), *Bhutan Input-Output Tables*, 2007
- Royal Government of Bhutan, (2013), *Economic Development Policy of The Kingdom of Bhutan, 2010, Bhutan*
- Royal Government of Bhutan, (2014), *Statistical Yearbook of Bhutan 2013, Bhutan*
- Royal Government of Bhutan, (2013), *Eleventh Five Year Plan 2013-2018, Bhutan*
- Asian Development Bank, (2012), *Bhutan Living Standards Survey 2012, Bhutan*
- National Statistics Bureau, (2014), *Bhutan Statistical Yearbook, (for 2000-2014), Bhutan*
- Asian Development Bank, May (2011), *Capacity Building of the National Environment Commission in Climate Change*
- Royal Government of Bhutan, (2005), *Bhutan Energy Data Directory (2005), Bhutan*

Reports prepared by EY under this program

- "Bhutan Industry Energy Audit Report" by EY (2015)
- "Bhutan Building Energy Efficiency Study" by EY (2015)
- "Energy Efficiency in Bhutan Electrical Equipment and Appliances Sector" by EY (2015)
- "Energy Efficient Transport in Bhutan: Policies, Strategies and Cost-Benefit Analysis in Transport sector" by EY (2015)
- "Energy Efficiency Awareness Programmes" by EY (2015)
- "Report on Energy Lab Assessment in Bhutan" by EY (2015)
- "Standards and Labelling Manual for Electrical Equipment and Appliances in Bhutan" by EY (2015)
- "Institutional Mapping and Gap Analysis" by EY (2014)

Annex-1

Detail estimation of energy saving investment in energy sector

Buildings sector

Analysis in the buildings sector involved conduction of detailed energy audits to calculate current the total energy loss through components in building envelope using simulation software TRNSYS. This methodology was also used to identify energy efficiency levers in the sector and develop baseline and low carbon scenario (energy loss) for each intervention. The difference of heat loss under each such scenario gives the energy savings potential on application of interventions in kWh per year per square metre of the building envelope. The capital expenditure for implementation of interventions and the potential energy savings is next computed.

Total Capex for 1 year = capex per sqm of envelope (USD) x additional area of application of intervention (sqm)

Total energy savings for 1 year = unit energy savings in kWh per year per sqm of envelope x total area of application of intervention (sqm)

The interventions considered for the buildings sector are presented in the table below.

Table A1: Buildings Sector interventions

Intervention	Description
Wall insulation	1 inch rock wool insulation for residential brick houses in cold districts
	1 inch glass wool insulation on walls for institutional and commercial brick buildings in cold districts
Roof insulation	1 inch rock wool insulation on roof for residential houses in winter districts
	1 inch EPS insulation on roof for institutional and commercial buildings in summer districts
Double glazing	6 mm thick Double glazed window with air gap having U Value 3.12
AAC blocks	Use of AAC blocks in NEW residential buildings
	Use of AAC blocks in NEW commercial and institutional buildings
Rat trap wall	Use of rat trap bonding technique in NEW brick residential buildings
	Use of Rat trap wall in NEW brick commercial and institutional buildings
LED lighting	LED lighting in residential houses
	LED lighting in institutional and commercial buildings
AC thermostat set point optimization	Using at an optimum thermostat set point (24degreeC) in ACs. For every 1degreeC increase in the thermostat set point, there will be 3% reduction in the compressor power consumption. This measure does not require any investment and the returns are immediate

The Exchange rate from Ngultrum to USD has been considered at (1 USD = 67.36 Nu), and inflation rate for cost/ capex at 5%. The other assumptions and calculations may please be referred from Sectoral calculation sheets and Buildings Energy Efficiency Report.

Table A2: Buildings Sector energy savings and investment

	Buildings
Energy savings (TOE)	442,374
Investment (Million USD)	333
Investment per unit of energy savings (Million USD per TOE)	0.001

Industry Sector

The industry sector in Bhutan has been analysed for the following categories of industries:

- Marble
- Ferro alloys and allied sectors
- CementBreweries
- Beverage
- Dolomite
- Limestone

Energy efficiency interventions have been identified and the corresponding energy savings potential for each such intervention is calculated. The interventions applicable across the categories listed above are:

- Replacement of V-Belt with Flat-Belt Drives
- Improvement of power factor in motors through addition of capacitor banks
- Downsize and Usage of Energy Efficient Motors
- Replacement of outdated pumps with right sized energy efficient pumps for blade cooling
- Replacement of 40W FTLs with 36W FTLs
- Installation of servo stabiliser in the lighting distribution board and optimization of operating voltage
- Installation of VFD to the high power cooling water circulation pumps
- Enhancement of operating power factor of utilities
- Downsize and use of auto star-delta-star starters to the identified motors
- Replacement of identified lesser efficient blowers with more energy efficient ones
- Installation of VFD in ID fans
- Replacement of bottom cooling fans of centrifugal type with axial type
- Improvement of insulation in rotary kilns in cement factories outer surface
- Revamping of coal burner systems for efficient combustion of coal inside kilns
- Replacement of lesser efficient fans with high efficiency fans of apt. size
- Replacement of steam heating by electrical heating in bottle warming technique in beverage industry
- Ranking of air compressors based on performance and replacement of inefficient ones with efficient ones
- Improvement of insulation in oil fired boilers
- Arresting steam and compressed air leakages in beverage industry
- Use of electric steam generators in place of oil fired boilers
- Use of furnace oil in place of HSD oil where possible

For each intervention, the energy savings in kWh per kilolitre is obtained from Industries Energy Audit report. The maximum potential energy savings for a particular type of industry in Bhutan (kWh) and investment required to reap such savings on application of an intervention. The other assumptions and calculations may please be referred from Sectoral calculation sheets and Industry sector Energy Efficiency Report.

Table A3: Industry Sector energy savings and investment

	Industry
Energy savings (TOE)	260,407
Investment (Million USD)	436
Investment per unit of energy savings (Million USD per TOE)	0.002

<u>Transport Sector</u>

The analysis for the transport sector is carried out using the following steps:

1 Baseline Emissions due to operation of conventional vehicles = fuel emission factor x fuel consumption

2. Low carbon scenario emissions due to electric bikes = fuel emission factor x reduced fuel consumption

3. Calculation of fuel reduction in kL and fuel weight in kg to estimate energy savings in kilojoules

4. Capex = vehicle cost as investment + recurring cost (Fuel [including Electricity] Cost + maintenance)

The sector specific important assumptions are:

Social Discount Rate	8.5	%
Average run of a 2 wheeler	22	km/day
Kms run by a 2 wheeler in an year in baseline	8,030	Kms
Efficiency of petrol two wheeler	50	Km/L
Petrol consumed by 1 bike in a year	160.6	litres
Range (efficiency) of electric bike	60	Km/charge
No. of charges to run 1 e-bike for required kms.	133.83	Number
Electricity consumed per charge	1.2	Kwh
Electricity to charge1 electric 2 wheeler per year	160.6	Kwh
Cost of 1 electric vehicle -	USD	43,000 Nu
Cost of 1 comparable petrol 2 wheeler -	USD	33,000 Nu
Petrol emission factor	2.27	tCO2/KL
Electricity emission factor from Bhutan	0	tCO2/Kwh
Maintenance cost of e-bike/year	4,000	Nu
Maintenance cost of petrol bike/year	8,000	Nu
Cost of battery every year	10,000	Nu

The other assumptions and calculations may please be referred from Sectoral calculation sheets and Industry sector Energy Efficiency Report. The different EE interventions considered in this sector are introducing EV bus, introducing EV Car, introducing EV bikes, increasing Bus Transit Facility and operating an EE transport system through pedestrianization.

Table A47: Transport Sector energy savings and investment

	Transport
Energy savings (TOE)	145,926
Investment (Million USD)	147
Investment per unit of energy savings (Million USD per TOE)	0.001

Appliances Sector

In this sector, the different appliances and equipment considered and surveyed in Bhutan are:

- Washing machine,
- Refrigerator,
- Lighting bulbs,
- Television,
- Geyser,
- Fan,
- Air conditioner,
- Mixer-Grinder,
- Room heater,
- Microwave oven,
- Combined Heater-cum-Chiller,
- Curry cooker,
- Water boiler, and
- Rice Cooker

For each of these appliances and equipment, the following were estimated:

- Power consumption of washing machine for low income group (kWh)
- Power consumption of washing machine for middle income group (kWh)
- Power consumption of washing machine for high income group (kWh)
- Net Household Power Consumption (kWh)
- Commercial Power Consumption (kWh)
- Institutional Power Consumption (kWh)
- Net Power Consumption from washing machine (kWh)
- Cost of upgradation to energy efficient appliance (million Nu)

The details for assumptions under high EE and low EE scenarios may please be referred from Standards and Labelling (S&L) Report and Sectoral calculation sheets prepared under this project. Hence:

- Capex is the Additional Cost Incurred to Upgrade in Million Nu
- Energy savings is calculated as the energy Savings Potential in GWh from High S&L

Table A5: Appliances Sector energy savings and investment

	Appliances
Energy savings (TOE)	717,795
Investment (Million USD)	557
Investment per unit of energy savings (Million USD per TOE)	0.001