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TIMES
Data Report

Background to Vietnam Energy Outlook Report 2019

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Contents

1 Introduction and background

The TIMES (The Integrated MARKAL-EFOM System) framework is a widely used least-cost optimization methodology employed to inform energy policy and strategic planning. It was developed and is maintained, advanced and promoted by the IEA-ETSAP consortium, the longest running Implementing Agreement of the IEA (International Energy Agency). Currently 19 countries, the EU and two private sector sponsors are participating to ensure the continual advancement of the methodology. TIMES documentation can be found at iea-etsap.org.

TIMES is a multi-sectoral optimization model generator, herein applied to study long-term energy planning for Vietnam. The TIMES-Vietnam model covers all parts of the energy system, from primary energy resources to power plants and other fuel processing plants, ultimately to various demand devices in the demand sectors. An overview of the basic structure of the TIMES-Vietnam model is illustrated in Figure 1-1. Primary energy supplies consist of domestic and imported fossil fuels, and a variety of domestic renewable energy sources. These are characterized by cost-supply curves that define how much is available at a particular price. Power plants and fuel processing plants convert the primary energy sources into final energy carriers, such as electricity and refined petroleum products, which are used in the demand sectors. There are both existing and potential future plants grouped by fuel and type, which are characterized by their existing capacity or investment cost, operating costs, efficiency and other performance parameters.

The model contains five demand sectors: Agriculture, Commercial, Industry, Residential and Transportation. End-use devices specific to each demand sector are characterized by their existing capacity or investment cost, operating costs, efficiency and operating parameters delivering end-use services (such as lighting, cooling, cooking, industrial process heat and motor drive, passenger and freight travel). For most devices there are Existing, Standard, Improved, Better and Advanced options, corresponding to increasing levels of energy efficiency performance. The demands for energy services are determined by projecting the energy demands for the base year (2014), which are derived from the energy balance as part of the calibration process, in accordance with sector-specific drivers, such as GDP growth, GDP per capita growth, industrial production projections, space cooling growth expectations, etc.

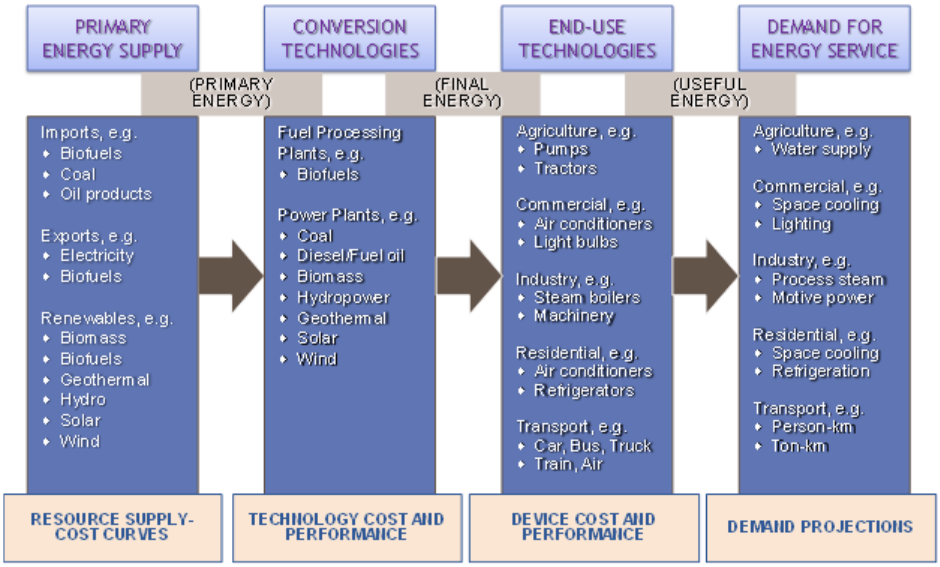

Figure 1-1: TIMES Basic Components

TIMES-Vietnam will determine the least-cost energy system configuration that will meet the annual end-use demands, adhering to in-country limits on resources and any additional policy constraints placed on the model. The total discounted system cost (the TIMES objective function) encompasses all costs arising from the supply (production and import/export) and consumption of energy including fuel expenditures, investments in power plants, infrastructure, purchases of demand devices, and fixed/variable operating and maintenance costs associated with all technologies. In addition, it may include policies such as carbon taxes and other more specific measures.

Figure 1-2 shows how the TIMES-Vietnam model is organized in various sector-based Excel input workbooks containing the model input data. The core templates include the 2014 base year energy balance, the demand projections for each sector, and three files that describe each sector:

- Existing technology database and established base year calibration of each sector (Base Year BY templates);
- New technology options for the refining and power sector as well as for each end-use application, sub-sector, or mode (New Technology NT templates), and
- Constraints on the amount of fuel switching and technology improvement allowed over the planning horizon (User-Constraint UC templates).

The VEDA-FE[1] (Front-End) model management software processes these input templates and allows the running of the Baseline and various policy scenarios. The resulting depiction of the Vietnam energy system is passed to the TIMES model generator (written in GAMS (General Algebraic Modelling System) programming language) and solved employing linear or mixed-integer programming. The TIMES-Vietnam run results are post-processed by VEDA-BE (Back-End), which includes a wide range of customized sets and tables to enable the user to easily examine dynamic pivot tables used for reviewing and analysing model results. Finally, the Base Year Calibration Check workbook helps with ensuring that the 1st year of the model (2014) replicates the initial Energy Balance, and the DWG Results Analysis graphing workbook provides dynamic comparisons of scenarios in graphs and tables ready for use in presentations and reports.

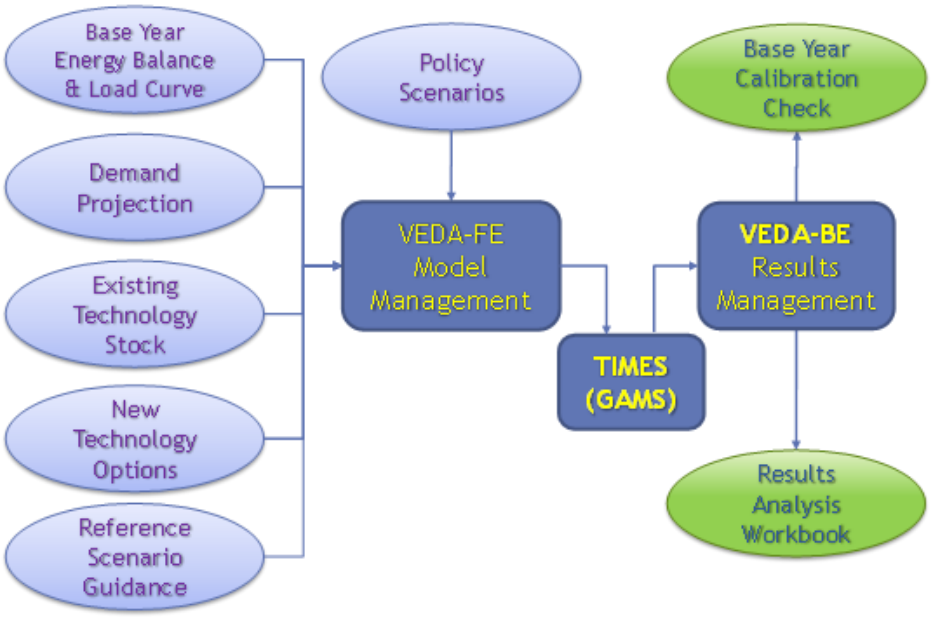

Figure 1-2: TIMES-Vietnam Modelling Platform Overall Structure

[1] VEDA is a powerful, yet user friendly set of tools required by complex mathematical and economic models. Also, it allows smart exploration of the results created by such models and the creation of reports. VEDA is under continuous development, driven by a very strong desire to keep increasing the efficiency and transparency of managing input and output of data-intensive models. The VEDA system is composed of two major subsystems - VEDA Front-End (VEDA_FE) which helps input data and VEDA Back-End VEDA_BE) which helps to analyze the output and gain insights.

2 General assumptions

2.1 Reference energy system

Figure 2-1 shows a simplified Reference Energy System (RES) diagram for supply of primary energy carriers to the power and demand sectors. All the first year values for the supply processes come from the 2014 Energy Balance [1]. As the diagram shows, domestic and imported oil products can supply every demand sector, along with biofuels. Solar energy is available to the Power, Commercial and Residential sectors, while solid biomass is available to the Power, Industry and Residential sectors. Coal is available to the Power and Industry sectors, while hydropower, geothermal, and wind are only available to the Power sector.

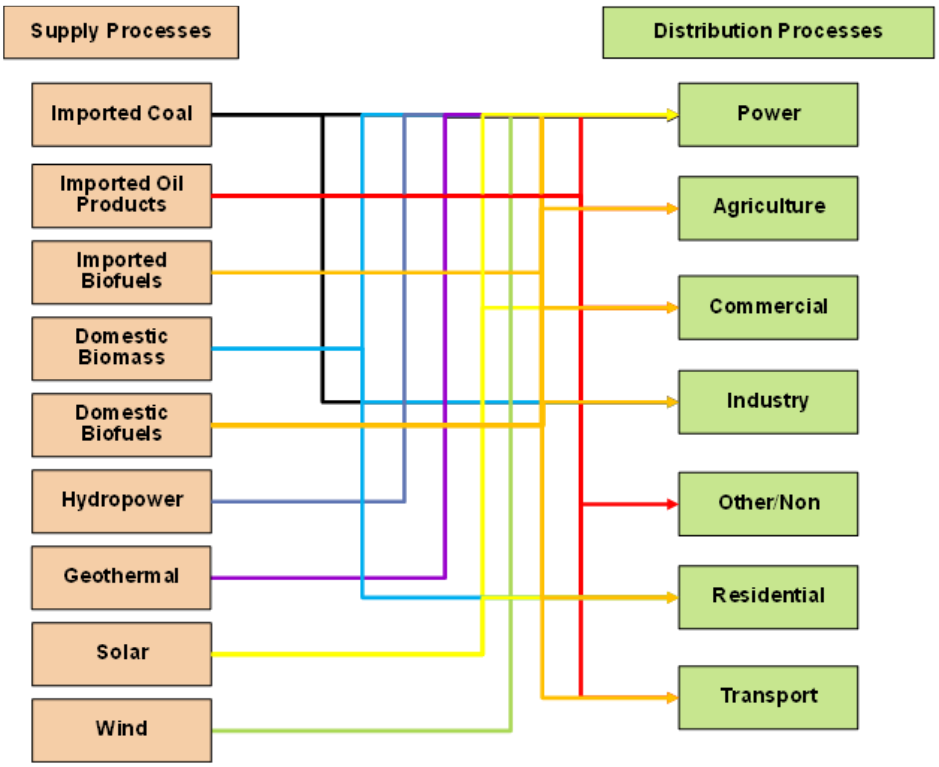

Figure 2-1: RES Diagram for Primary Energy Supply

The minimum data needed for each resource supply is an upper annual (and optionally cumulative) limit and a price for that amount of supply over time, which corresponds to a supply-cost curve. All energy carriers have an upper limit for the base year, which is set according to the Energy Balance as part of the calibration. In addition, future supply limits have been defined for all sources that are limited based on available resource potential studies for domestic supplies and import infrastructure limits, when appropriate. The fu-

ture price for a given amount of supply is based on the latest data for Vietnam as in [2].

2.2 Time resolution

The TIMES-Vietnam model is currently designed with a 2014 base year, and several options to set the model milestone years[2] and periods. One option covers the time horizon until 2050 aggregated in 5-year periods. Another option runs until 2030 in 2-year periods, and a third alternative (shown in Table 2-1) uses a combination of 2- and 3-year periods to hit the key milestone years of 2020, 2025 and 2030. This option provides more detail than the 5-year periods and is being used as the default milestone years for model runs. The model can easily be run for different milestone period intervals if desired.

Energy demands and technologies are generally modelled at annual level, except for electricity, which is modelled at the time-slice level. TIMES-Vietnam is structured with twelve (12) time slices: three seasons (Wet, Intermediate and Dry) and four divisions of the day (day, morning peak, evening peak and night). Table 2-1 shows the overall time slice divisions of the load duration curve into three (3) seasons and four (4) parts of the day.

Table 2-1: TIMES-Vietnam Time Slice Resolution. Milestone years indicated with "Mid".

[2] Milestone years are the years for which results are obtained, i.e. for which plants' investments and operations are optimized within the model.

Season	Time Slice	Code	Fraction of year
Intermediate		I	0.329
	Intermediate Day	ID	0.096
	Intermediate Night	IN	0.123
	Intermediate Morning Peak	IA	0.041
	Intermediate Evening Peak	IE	0.068
Wet		W	0.419
	Wet Day	WD	0.122
	Wet Night	WN	0.157
	Wet Morning Peak	WA	0.052
	Wet Evening Peak	WE	0.087
Dry		D	0.252
	Dry Day	DD	0.074
	Dry Night	DN	0.095
	Dry Morning Peak	DA	0.032
	Dry Evening Peak	DE	0.053
Total		Year	1.000

2.3 Geography resolution

Owing to the nature of the availability of resource supplies and the long-distance transmission lines in Vietnam, three regions are identified in TIMES-Vietnam: North, Central and South for domestic resources (including renewables), refineries, and power plants. The existing capacity of the transmission lines between the regions are reflected in the model, along with the cost for expanding the grid infrastructure in the future. A fourth region (Vietnam) is used to depict the national demand for the five end-use sectors, as regional data on demand is not complete enough to break them out by region. Note also that all imports/exports occur in the overall Vietnam region, except for power trade. Commodities can move between the individual supply regions and overall Vietnam, as needed.

3 Resource potentials and prices

Resource potentials are modelled for each of the three regions with supply capability for every year, implemented as upper bounds in TIMES. Supply potentials are based on several approved sectoral development plans. Supply capabilities are then extrapolated for the future years until 2050.

3.1 Domestic coal, crude oil and natural gas

Domestic coal deposits are in the North. Crude oil fields are mainly located in the South with some fields abroad. Natural gas fields are mainly located in the South with one major future field in the Central region. Fuel prices are taken from [2] and supply potentials from [3] and [4]. Fuel prices and supply potentials for domestic coal, crude oil and natural gas per region are presented in Table 3-1.

Table 3-1: Fuel prices and supply potentials for domestic coal, crude oil and natural gas.

Region	Supply source/ Fuel	Fuel price (USD 2015/GJ)			Supply potential (PJ)		
	Year	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**
North	Coal	3.6	4.1	4.1	975.9	1144.1	1144.1
	Natural Gas	7.5	10.7	10.8	10.9	0.0	0.0
Central	Natural Gas	8.57	9.69	9.77	0.0	241.8	120.9
South	Crude Oil	9.18	10.35	9.36	651.9	177.9	0.0
	Natural Gas	7.53	10.73	10.82	543.7	357.2	89.3

3.2 Import and export

Vietnam is importing coal, oil products and electricity from abroad. In the future, LNG could be imported for power generation and other uses. In addition, Vietnam is exporting coal, crude oil, oil products and electricity to other countries. Import fuel prices are taken from [2]. Electricity import prices and amounts are referred from [5].

Table 3-2: Import and export fuel prices.

Supply source	Fuel	Fuel prices (USD 2015/GJ)		
	Year	**2020**	**2030**	**2050**
Imports	Coal	3.61	3.74	3.90
	Crude Oil	10.20	11.50	10.40
	LPG	33.32	34.32	30.74
	Gasoline	23.27	28.54	39.03
	Jet Fuel	17.71	23.72	33.54
	Kerosene	17.71	23.72	33.54
	Diesel	23.38	29.68	40.07
	Fuel Oil	11.22	17.06	19.91
	Natural Gas	10.48	11.82	11.91
Exports	Coal	3.25	3.63	4.30
	Crude Oil	9.69	10.93	9.88
	Gasoline	22.11	27.11	37.08
	Jet Fuel	16.83	22.53	31.86
	Diesel	22.21	28.20	38.07
	Fuel Oil	10.66	16.21	18.91

Table 3-3: Electricity import prices and bounds.

Region	Fuel price (USD 2015/GJ)			Supply potential (PJ)		
	2020	**2030**	**2050**	**2020**	**2030**	**2050**
China - North	18.6	19.4	21.1	8.8	37.8	37.8
Laos-Central-North	18.7	19.6	21.3	0.0	16.4	16.4
Laos-Central-Central	18.9	19.8	21.5	3.8	27.4	27.4
Laos-Central-Highland	19.1	20.0	21.7	7.0	24.6	24.6

3.3 Hydro power

Hydropower is found in all three regions. Large hydropower (>30MW) almost reaches to the maximum potential by 2020. Hydropower capacity expansion under the PDP7 revised [6] is presented in Table 3-4.

Table 3-4: Hydropower capacity to 2030 (MW).

	2016	2017	2018	2019	2020	2025	2030
North	8879	9362	9546	9732	9861	10651	10911
Central	4736	4772	4924	5144	5504	5564	5564
South	2641	2716	2716	2796	2796	2996	2996

Maximum capacity potentials for small hydropower are 4.088 GW in the North, 2.316 GW in the Centre and 0.35 GW in the South.

3.4 Wind

Land-based wind resource potential estimates have been based on results of the wind resource mapping project supported by the GIZ in collaboration with the Danish Energy Agency, 'Macroeconomic Cost-Benefit Analysis for Renewable Energy Integration' [7]. Based on the modelled wind speed variation profiles for 63 locations in Vietnam [8] and the resource maps in Figure 3-1 [7], a total of 18 areas are modelled by considering 6 regions and 3 wind categories. The three wind categories represent a low, a medium and a high wind speed location.

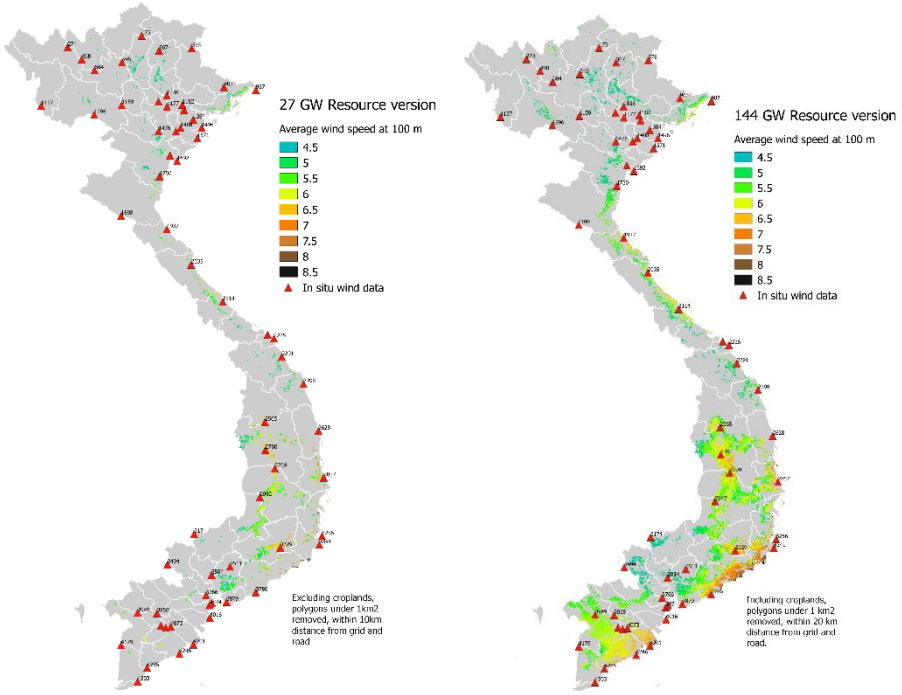

Figure 3-1: Wind resource map and locations of the 63 wind speed locations, left: Before 2030, Right: 2030 and onwards.

Land-based wind resource potential estimates have been based on [10]. The low wind speed class has wind speeds between 4.5-5.5m/s, the Medium between 5.5-6 m/s and High wind speed classes 6 m/s and up at a height of 80m. Wind power potentials and availability factors per region are presented below:

Table 3-5: Wind power potentials in Vietnam (MW).

Region	Total
North	23.28
Central	120.39
South	73.64
Total	217.31

Table 3-6: Wind power availability factors per region and class

Time slice	ID	IN	IA	IE	WD	WN	WA	WE	DD	DN	DA	DE
North												
High	0.30	0.29	0.25	0.31	0.18	0.17	0.18	0.17	0.46	0.39	0.36	0.48
Medium	0.32	0.26	0.38	0.29	0.31	0.21	0.34	0.27	0.43	0.38	0.33	0.43
Low	0.34	0.10	0.33	0.40	0.26	0.13	0.21	0.30	0.15	0.06	0.15	0.11
Central												
High	0.52	0.50	0.51	0.52	0.28	0.24	0.24	0.30	0.60	0.58	0.62	0.60
Medium	0.30	0.32	0.38	0.26	0.33	0.43	0.35	0.26	0.44	0.45	0.48	0.43
Low	0.36	0.28	0.46	0.32	0.14	0.12	0.19	0.12	0.27	0.24	0.41	0.20
South												
High	0.56	0.52	0.58	0.31	0.39	0.33	0.56	0.17	0.46	0.41	0.46	0.48
Medium	0.25	0.22	0.29	0.29	0.31	0.37	0.43	0.27	0.25	0.22	0.26	0.43
Low	0.36	0.10	0.63	0.40	0.19	0.11	0.34	0.30	0.27	0.11	0.40	0.11

3.5 Solar

The solar potentials are based on the draft Vietnam Renewable Energy Development Plan [10]. Solar availability factors per region are derived from [5]. Solar power potentials and availability factors by region are shown in Table 3-7 and Table 3-8.

Table 3-7: Solar power potential (GW).

	Base	High
North	0.1	7.4
Central	70.5	220.8
South	95.7	152.2
Total	166.4	380.5

Table 3-8: Solar power availability factors per region and by time slice.

Time slice	North	Central	South
ID	0.11	0.26	0.26
IN	0.01	0.05	0.04
IA	0.27	0.70	0.71
IE	0.06	0.10	0.10
WD	0.20	0.22	0.20
WN	0.04	0.05	0.05
WA	0.52	0.58	0.59
WE	0.10	0.09	0.08
DD	0.15	0.18	0.21
DN	0.02	0.04	0.04
DA	0.40	0.51	0.61
DE	0.04	0.05	0.06

3.6 Biomass and waste

Biomass types modelled in TIMES-Vietnam include wood, bagasse, rice husk, straw and others. Biomass uses in 2014, which were all domestically produced, are estimated from [11] and reported in Table 3-9.

Table 3-9: Biomass use in the base year 2014 (PJ).

Purpose	Biomass type					Total
	Wood	Bagasse	Rice husk	Straw	Others	
Power						
Cogeneration	6.6	326.9	-	-	-	**333.6**
Heat						
Household cooking	1,118.7	8.5	99.1	91.5	408.2	**1,725.9**
Boiler & kiln	674.0	-	477.5	-	171.8	**1,323.3**
Building material	67.1	-	90.7	-	-	**157.7**
Rice drying	-	-	126.8	-	-	**126.8**
Total	**1,866.5**	**335.4**	**794.1**	**91.5**	**580.1**	**3,667.4**

Biomass potentials by type and per region are taken from draft [11]. Biomass prices are referred from [2]. Biomass supply potentials and prices are presented in Table 3-10.

Table 3-10: Biomass and waste potentials and prices.

Region	Supply source/ Fuel	Fuel price (USD 2015/GJ)			Supply potential (PJ)		
		2020	2030	2050	2020	2030	2050
North	Rice Husk	1.9	2.3	2.3	25.3	25.6	30.7
	Municipal Waste	0.0	0.0	0.0	21.2	16.0	29.7
	Landfill Gas	0.3	0.3	0.3	0.0	0.7	3.9
	Primary Solid Biofuels	1.9	2.4	2.4	118.1	144.1	172.9
	Bagasse	0.2	0.2	0.2	5.6	6.1	9.2
	Biogasoline	24.6	27.4	35.8	4.5	15.5	52.7
	Straw	0.6	0.7	0.7	83.3	84.4	101.3
	Biodiesels	24.7	28.5	36.0	13.7	46.7	157.5
	Biogas	0.6	0.7	0.7	-	4.7	23.4
	Other Biomass	0.4	0.5	0.5	100.6	100.6	120.8
Central	Rice Husk	1.9	2.3	2.3	19.2	19.4	23.3
	Municipal Waste	0.0	0.0	0.0	10.9	8.2	15.3
	Landfill Gas	0.3	0.3	0.3	0.0	0.4	2.0
	Primary Solid Biofuels	1.9	2.4	2.4	164.3	196.2	235.5
	Bagasse	0.2	0.2	0.2	21.7	23.6	28.3
	Biogasoline	31.2	34.8	45.3	4.5	15.5	52.7
	Straw	0.6	0.7	0.7	63.2	64.0	76.8
	Biodiesels	31.3	36.2	45.6	13.7	46.7	157.5
	Biogas	0.6	0.7	0.7	-	4.7	23.4
	Other Biomass	0.4	0.5	0.5	85.2	101.5	121.8
South	Rice Husk	1.7	2.0	2.0	55.0	55.7	66.9
	Municipal Waste	0.0	0.0	0.0	32.2	24.2	45.0
	Landfill Gas	0.3	0.3	0.3	0.0	1.1	5.9

	Primary Solid Biofuels	1.9	2.4	2.4	84.5	98.2	117.8
	Bagasse	0.2	0.2	0.2	24.2	26.4	31.6
	Biogasoline	31.2	34.8	45.3	4.5	15.5	52.7
	Straw	0.6	0.7	0.7	181.3	183.6	220.3
	Biodiesels	31.3	36.2	45.6	13.7	46.7	157.5
	Biogas	0.6	0.7	0.7	-	4.7	23.4
	Other biomass	0.4	0.5	0.5	62.9	73.9	88.6

4 Power sector

4.1 Grid setup and interconnections

Figure 4-1 shows the RES diagram for the Power sector, depicting the primary energy sources consumed by various power generation technology types to produce grid electricity, which primarily goes to the demand sectors. Imports and exports to/from neighbouring countries are also modelled. The power sector is organized into existing power plants, as specified in the Energy Balance and Vietnam Electricity (EVN) data, and new power plant options that are available to meet future needs.

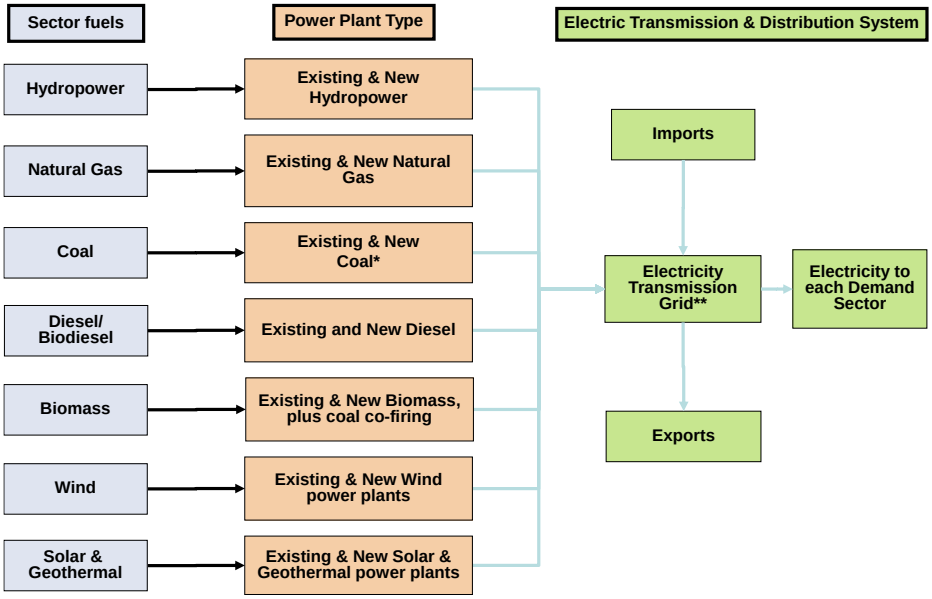

Figure 4-1: Power Sector RES.

Several types of power plant technologies are modelled, including four (4) kinds of hydro plants – extra-large, large, medium and small; several types of coal, natural gas, diesel and biomass-fired power plants, along with central PV and building distributed PV systems for both Residential and Commercial buildings, plus six types of wind power plants based on wind class and distance from transmission grid.

Each region (i.e. North, Central and South) features the grid setup exemplified in Figure 4-1. Regions are interlinked by transmission lines in TIMES-Vietnam. There are two bi-directional links for electricity transmission between regions: (i) North to Central, (ii) Central to North, (iii) Central to South and (iv) South to Central (Table 4-1). Electricity imports/exports are also allowed to each of the three supply regions.

Table 4-1: Capacities and investment costs for regional transmission links.

Connection	Residual capacity 2014 (GW)	Investment cost (USD/kW)	Capacity bounds (GW)
North – Central	2	250	-
Central - South	4	250	-

4.2 Load curve

The load curve for TIMES-Vietnam is built for the base year 2014, with twelve chronological time slices per year. The load duration curve for 2014 is presented in Figure 4-2.

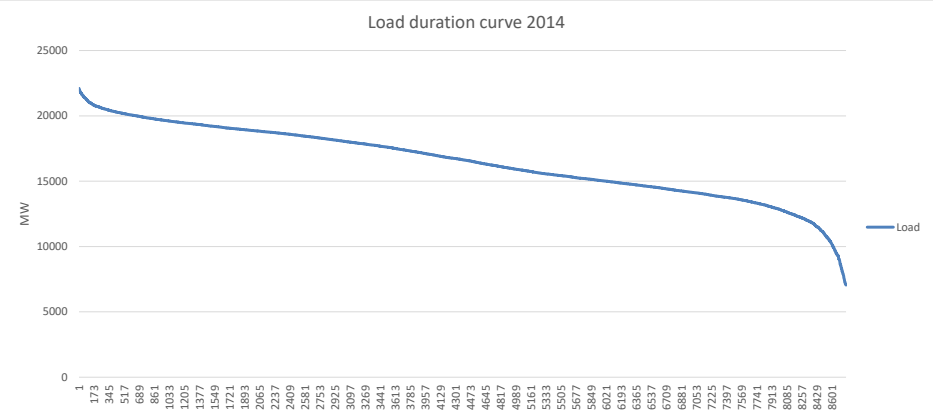

Figure 4-2: Load duration curve 2014.

The TIMES load curve represents an average day considering monthly load curves, as shown in Figure 4-3.

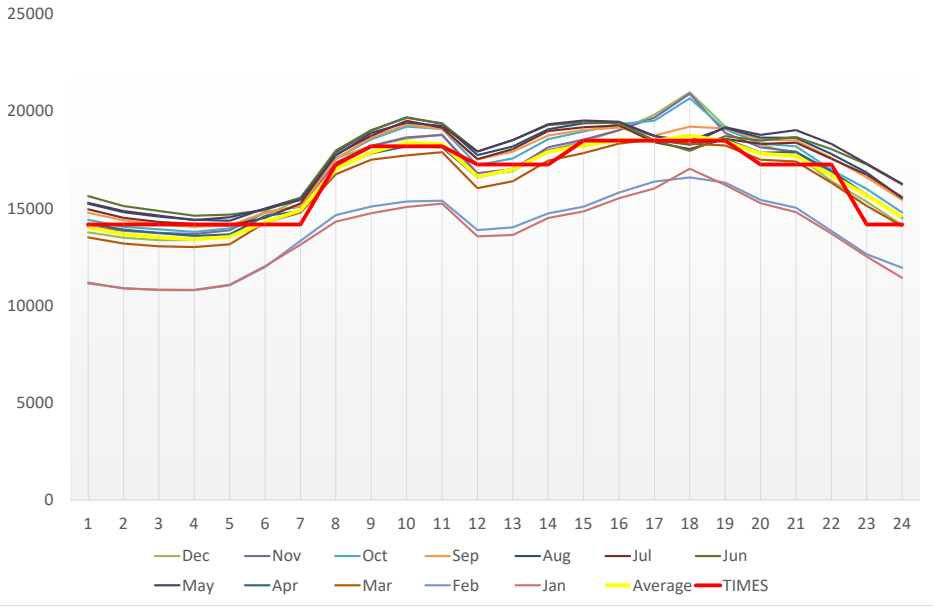

Figure 4-3: Average load curves by month and TIMES load curve for 2014 (GW).

Load curves for sectoral electricity demands are built by authors based on data from a load research by MOIT in 2007. The electricity demand split by sector and time slice is presented in Table 4-2, based on authors' calculations and assumptions.

Table 4-2: Electricity demand split by sector and time slices.

Sector	Demand Split (%)												
	ID	IN	IA	IE	WD	WN	WA	WE	DD	DN	DA	DE	Total
Agriculture	0.095	0.086	0.049	0.069	0.082	0.074	0.043	0.060	0.140	0.127	0.073	0.102	1.000
Industry	0.094	0.091	0.046	0.069	0.081	0.078	0.040	0.059	0.138	0.134	0.068	0.102	1.000
Transport	0.099	0.070	0.055	0.077	0.085	0.060	0.047	0.066	0.146	0.103	0.080	0.113	1.000
Commercial													
Cooling	0.105	0.066	0.060	0.069	0.090	0.057	0.052	0.059	0.154	0.097	0.088	0.101	1.000
Cooking	0.090	0.060	0.045	0.105	0.077	0.052	0.039	0.090	0.132	0.088	0.066	0.154	1.000
Lighting	0.102	0.078	0.030	0.090	0.088	0.067	0.026	0.077	0.150	0.115	0.044	0.132	1.000
Office Equipment	0.090	0.066	0.060	0.084	0.077	0.057	0.052	0.072	0.132	0.097	0.088	0.124	1.000
Building Equipment	0.093	0.105	0.030	0.072	0.080	0.090	0.026	0.062	0.137	0.154	0.044	0.106	1.000
Water Heating	0.105	0.060	0.030	0.105	0.090	0.052	0.026	0.090	0.154	0.088	0.044	0.154	1.000
Residential													
Cooling	0.090	0.105	0.045	0.060	0.077	0.090	0.039	0.052	0.132	0.154	0.066	0.088	1.000
Water Heating	0.075	0.105	0.030	0.090	0.065	0.090	0.026	0.077	0.110	0.154	0.044	0.132	1.000
Refrigeration	0.075	0.105	0.030	0.090	0.065	0.090	0.026	0.077	0.110	0.154	0.044	0.132	1.000
Heating	0.045	0.150	0.030	0.075	0.039	0.129	0.026	0.065	0.066	0.221	0.044	0.110	1.000
Cooking	0.105	0.060	0.030	0.105	0.090	0.052	0.026	0.090	0.154	0.088	0.044	0.154	1.000
ELC Appliances	0.090	0.135	0.030	0.045	0.077	0.116	0.026	0.039	0.132	0.199	0.044	0.066	1.000
Other Applications	0.105	0.090	0.030	0.075	0.090	0.077	0.026	0.065	0.154	0.132	0.044	0.110	1.000

4.3 Existing and committed generation capacity

Individual power plants are grouped in TIMES by type, fuel type, vintage and region. Existing generation capacity by power plant group is presented in Table 4-3, based on EVN and NLDC reports [12].

Table 4-3: Existing power generation capacity by type and region.

Power plant description		Region	Capacity 2014 (MW)	Capacity 2017 (MW)
Domestic Coal- Pulverised coal- North- Old		North	645	540
Domestic Coal- Pulverised coal- North- Recent		North	4230	4230
Domestic Coal- Pulverised coal- North- New		North	0	4050
Domestic Coal- Fluidized bed- North- Recent		North	1565	2765
Domestic Coal- Pulverised coal- Central- Recent		Central	1245	1245
Imported (Steam coal) - Pulverised coal (Captive)		Vietnam	310	465
Domestic Coal- Pulverised coal- South- New		South	0	1244
Imported Coal- Pulverised coal- South- New		South	0	1244
Domestic Coal- Pulverised coal- South- New		South	0	1234
Natural gas (East) - CCGT (Existing)		South	4160	4160
Natural gas (East) - CCGT (Existing BOT)		South	1480	1480
Natural gas (West) - CCGT (Existing)		South	1542	1542
Oil-fired (Existing) (Captive)		North	97	97
Oil-fired (Existing)		South	550	880
Gas turbine (Existing)		South	264	264
Gas steam (Existing)		South	468	468
Hydro - Hydro (Dam) (Existing)	Very large	North	4,360	5,560
	Large	North	1,592	2,372
	Medium	North	777	1,347
	Small	North	1,384	
Hydro - Hydro (Dam) (Existing)	Very large	Central	720	720
	Large	Central	2,841	3,036
	Medium	Central	963	1,013
	Small	Central	547	
Hydro - Hydro (Dam) (Existing)	Very large	South	-	-
	Large	South	2,005	2,155
	Medium	South	269	344
	Small	South	53	

Committed capacities by plant type until 2023 as modelled in TIMES-Vietnam are reported in Table 4-4 and Table 4-5, based on [5].

Table 4-4: RE committed capacities by 2020 (GW).

	North	Central	South	Total
Wind	0.000	0.790	0.430	1.220
Solar	0.100	2.860	1.000	3.960
Small hydro	0.213	0.209	0.000	0.422
Biomass	0.106	0.089	0.069	0.264
MSW	0.070	0.015	0.115	0.200

However for solar PV the development has since then been remarkable due to profitable subsidy schemes. In end of June 2019 the capacity of connected solar PV in Vietnam reached 4460 MW solar PV, respectively, however at this point the EOR19 modelling were already finalised. Comparing with the capacity in the model it shows that in the model year 2020, the model capacity in 2020 is only marginally lower than the realized June 2019 capacity in Vietnam and a correction of this would not in any significant way affect the EOR19 calculation results.

Table 4-5: Committed capacities up to 2030 (GW).

Region	Plant	2018	2019	2020	2021	2022	2023
North	Anthracite (Hard Coal - Domestic) - Steam turbine (PC	0.60	0.00	1.20	0.11	0.11	0.65
	Anthracite (Hard Coal - Import) - Steam turbine (PC	0.00	0.00	1.40	0.00	1.80	3.00
	Natural Gas - Combined cycle	0.00	0.00	0.00	0.00	0.00	0.00
	Hydro - Dam (Medium)	0.18	0.19	0.16	0.25	0.00	0.00
Central	Anthracite (Hard Coal - Domestic) - Steam turbine (PC	0.00	0.00	0.00	0.00	0.00	0.00
	Anthracite (Hard Coal - Import) - Steam turbine (PC	0.00	0.00	0.00	0.00	0.00	0.00
	Natural Gas - Combined cycle	0.00	0.00	0.00	0.00	0.00	1.50
	Hydro - Dam (Medium)	0.00	0.22	0.00	0.00	0.06	0.00
South	Anthracite (Hard Coal - Domestic) - Steam turbine (PC	0.00	0.00	0.00	0.00	0.00	0.00
	Anthracite (Hard Coal - Import) - Steam turbine (PC	0.00	1.20	1.80	1.80	0.00	0.66
	Natural Gas - Combined cycle	0.00	0.00	0.00	0.00	1.80	1.80
	Hydro - Dam (Medium)	0.00	0.00	0.00	0.00	0.00	0.00

4.4 Technology catalogue

Technical and economic data for the power generation technologies that the model may invest in can be viewed in table below. The data is based on [12] as well as some other Vietnamese and international sources. The technology assumptions develop from 2020 to 2050, which means that the costs and efficiencies are assumed to develop depending on the learning curves of the

specific technologies. Details on characteristics for existing and future power planta are reported in Annex 1 and Annex 2.

5 Refinery sector

There are two existing refineries in Vietnam today, with some other candidates for future development. All existing and candidate plants are modelled in TIMES-Vietnam. Production structures of candidate refineries are based on USEPA database[3] for refineries. Table 5-1 identifies each of the refineries existing or under discussion in Vietnam, based on [4] and other media sources.

Table 5-1: Refineries Data Sources.

Refinery	Binh Son Refinery	Nghi Sơn Refinery	Binh Son Refinery Expansion II	Vũng Rô Refinery	Nam Vân Phong Refinery	Long Sơn Refinery
Status	Existing	Existing	Candidate	Candidate	Candidate	Candidate
Region	Central	North	Central	Central	Central	South
Start	2009	2018	2026-2030	2021-2025	2021-2025	2026-2030
Crude Type	Local	Import	Local / Import	Local / Import	Local / Import	Local / Import
Investment (billion USD)		9	10	10	8	10
Capacity (million tons of crude oil)	6.5	10	8.5	10	8	10
Output share (fraction of crude input)	0.960	0.960				
Gasoline	0.388	0.388				
Jet fuel	0.032	0.032				
Diesel oil	0.433	0.433				
Fuel oil	0.018	0.018				
LPG	0.069	0.069				
Non-energy	0.021	0.021				

USEPA data

[3] https://www.epa.gov/air-research/epaus9r-energy-systems-database-use-market-allocation-markal-model

6 Demand sectors

Demand sectors in TIMES-Vietnam include agricultural, industrial, commercial, residential and transport. The industrial sector consists of 12 sub-sectors. Transport sector covers road, rail, waterway and airway transports. Residential sector is broken down into urban and rural. The sectoral shares of final energy consumption in the base year are shown in Figure 6-1.

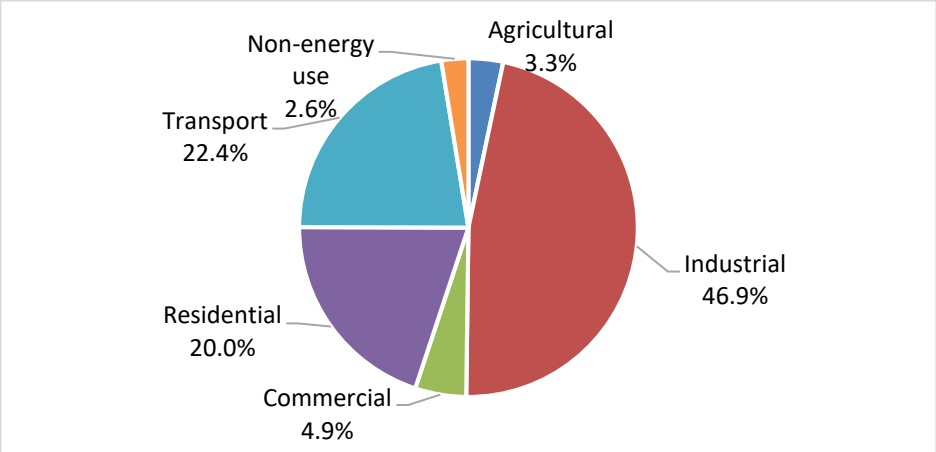

Figure 6-1: Sectoral shares of final energy consumption by 2014.

Data to build and support the calibration of fuel consumption and technology stock by demand end-uses was derived from the various publications identified in Table 6-1.

Table 6-1: Data for building and calibrating the fuel consumption and technology stock by sector

Description	Main data sources
Agriculture • Share of fuel to each demand service, or number of tractors & irrigation pumps by fuel/type	*Calculator 2050 Vietnam*
Commercial • Share of fuel to each demand service, or number of devices by fuel/type	*USAID Vietnam Clean Energy Program–Promoting Energy Efficiency in the Building Sector Project - Building Energy Performance Baselines Study*
Industry • Share of fuel to each demand service, or nature of the process equipment by fuel/type	WB funded studies on benchmarking and audits for various Industry subsectors *National Enterprises Survey program* *Annual Designated Energy Users Reports*
Residential • Share of fuel to each demand service, or number of devices by fuel/type	*Vietnam Household Living Standard Survey* 2014, GSO *Summary of studies on bioenergy power in Vietnam,* GIZ-GDE/MOIT 2014 *Energy Efficiency and Renewable Energy Policy,* Jyukanko Research Institute, Waseda University
Transport • Share of fuel to each transport mode by vehicle fuel/type	*EFFECT MOT results*

The TIMES-Vietnam model solves for the mix of resources and technologies (on both the supply and demand sides) that satisfy the projected demands for useful energy services at the least-cost, considering any additional technical and policy constraints imposed on the model. The projected demands for the five (5) demand sectors (Agriculture, Commercial, Industry, Residential and Transport) represent the economic and demographic development of the country over time. The future demands for energy services are calculated using the base year value, determined by the energy balance decomposition and calibration process, and appropriate drivers of service demand growth.

Agriculture

The Agriculture and Fishing sector accounts for 3.3% of the base year final energy demand and consists of four (4) end-use services as shown in Figure

6-2. Diesel, gasoline and electricity are the key energy carriers supplied to the sector, and both biodiesel and bio gasoline can be made available to the sector as blended fuels with diesel and gasoline for possible use in the future. The other energy carriers are largely used for the Other Services. Data for the determination of the service demand shares and existing technology characteristics was primarily derived from *Calculator 2050 Vietnam*[4].

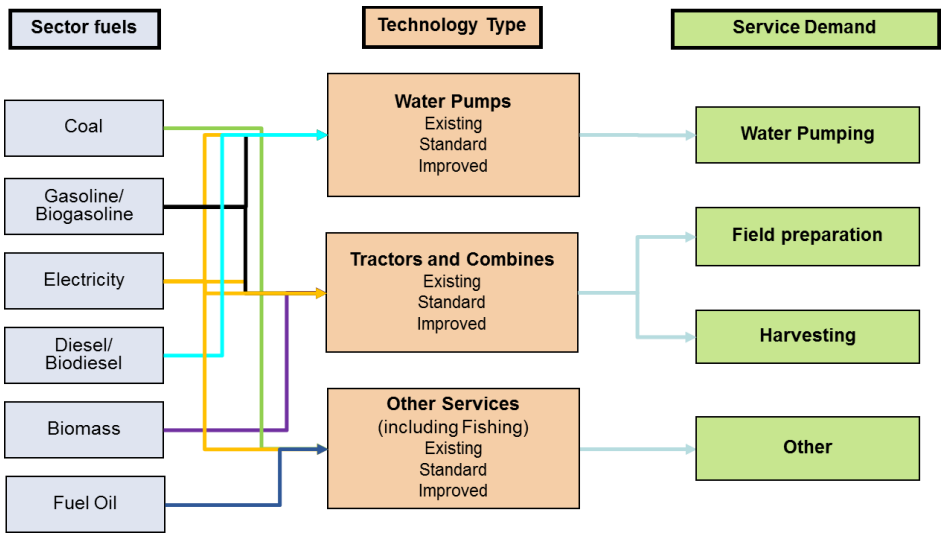

Figure 6-2: Agriculture & Fishing Sector RES.

Agricultural demand devices are classified into existing (Base year), standard and improved types, which are characterized by different costs and efficiencies.

Industrial

The Industry sector accounts for 49% of the base year final energy demand, and is comprised of twelve (12) industrial subsectors as shown in Figure 6-4. The industrial sector cannot be modelled at the process level, due to the wide variations and detail in the industrial process lines and the lack of data resulting from concerns over proprietary information. Instead, each subsector is served by four (4) main energy services: process heat, machine drive, facilities/other, and feedstocks needed to produce the output products. Data for the initial shares for the subsector energy service demands were elaborated

[4] http://vietnamcalculator2050.atmt.gov.vn

from data contained in several recent reports on industrial energy use conducted by the World Bank and MOIT in the form of benchmarking studies and energy audits for various Industry subsectors in [14], [15], [16], [17], [18], [19] and various energy audit reports. The final energy consumption by sub-sector by 2014 is shown in Figure 6-3.

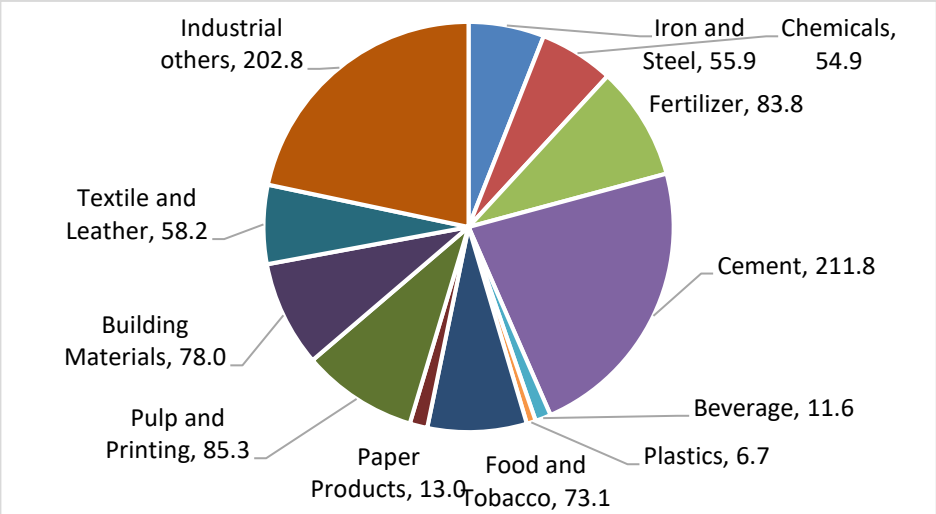

Figure 6-3: Final energy consumption by industrial sub-sector by 2014 (PJ).

The industry sector is characterized by a wide range of fuel and energy types that can provide the four component energy services. Biomass fuels include bagasse, coffee husk, firewood, straw and other organic residues. Biogas is also available from several sources. Auto-generation and co-generation are already occurring in the Pulp and Paper and Food and Tobacco sub-sectors and is a future option in other subsectors. As with the other demand sectors, biodiesel and bio gasoline are available through mixing of these fuels with conventional diesel and gasoline in the future.

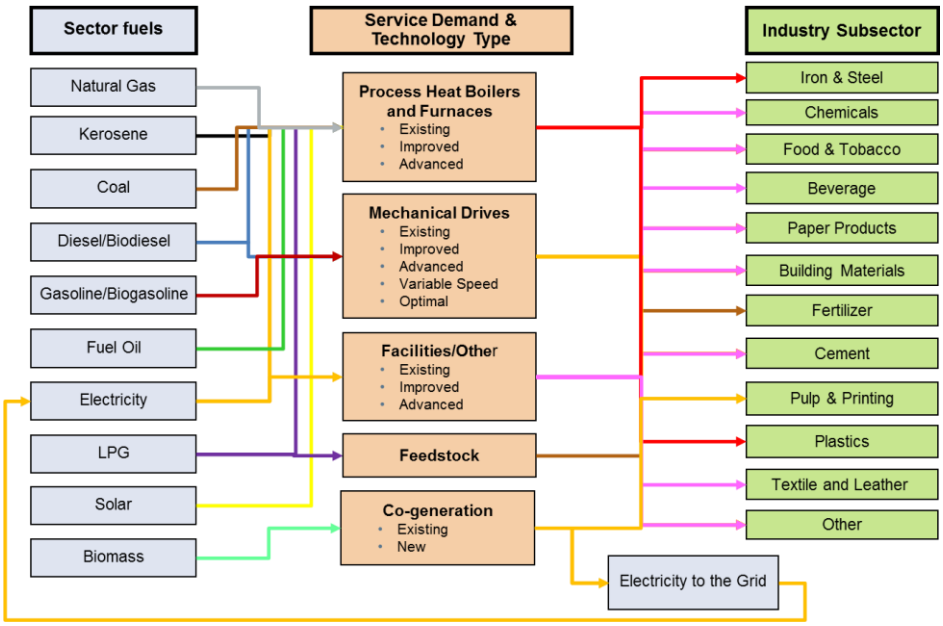

Figure 6-4: Industry Sector RES.

Industrial demand devices are classified into existing (Base year), standard and improved types, which are characterized by different costs and efficiencies. Details on characters of industrial demand devices are presented in **Annex *3***.

Commercial

The Commercial sector accounts for 2.8% of the base year final energy demand, and consist of eight (8) services demand as shown in Figure 6-5. There is a variety of energy carriers used in the sector, but electricity is by far the most dominant one. Data for the determination of the service demand shares and existing technology characteristics were derived from the commercial building survey work in [20].

For the Commercial sector, TIMES-Vietnam contains a large suite of new technology options for each service demand that represent Standard, Improved, Better and Advanced options, based on authors' desktop study of local appliances. Biodiesel and bio gasoline are also available through mixing of these fuels with conventional diesel and gasoline. Distributed PV systems provide electricity directly to the sector (for internal consumption) as well as feeding any excess electricity to the grid. Finally, building efficiency retrofit options are available that reduce building energy demands – primarily for cooling, lighting and water heating. Some of these options may be restricted in the BAU, while they are made available as mitigation measures in the future.

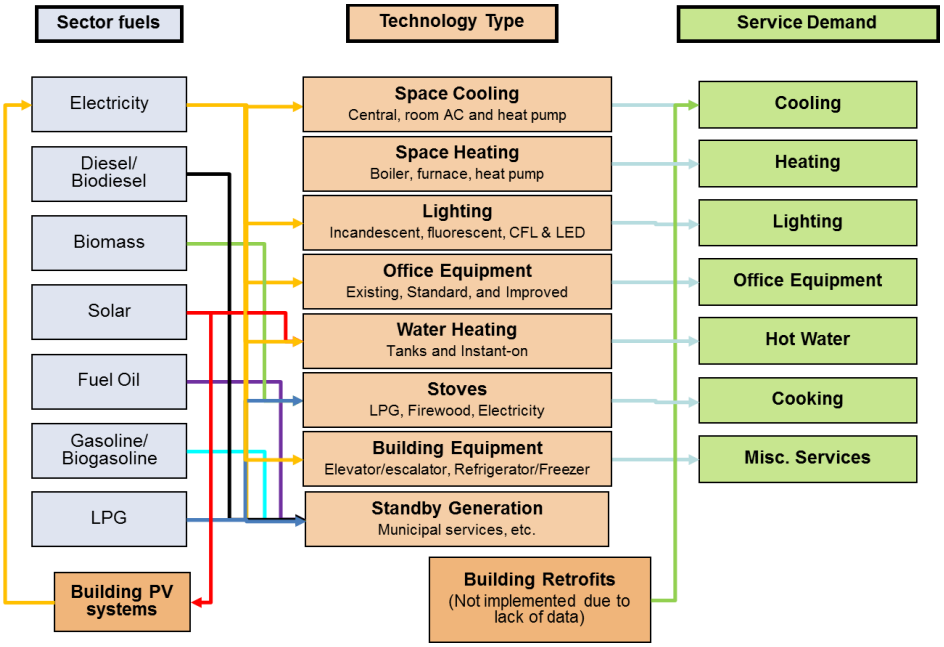

Figure 6-5: Commercial Sector RES.

Commercial demand devices are classified into existing (Base year), standard, improved and advanced types which are characterized with different costs and efficiencies. Details on characters of commercial demand devices are presented in **Annex *4***.

Residential

The Residential sector accounts for 21% of the base year final energy demand, and consist of seven (7) end-use service demands as shown in Figure 6-6. Although there is a variety of energy carriers used in this sector, electricity is by far most dominant, followed by important contributions from firewood and LPG. Data for the energy service demand shares and existing technology characteristics were derived from the *Vietnam Household Living Standard Survey* 2014, GSO and other sources. Owing to the inherent difference between urban and rural energy use patterns, as well as fuel and technology options, the Residential sector is split into Urban and Rural subsectors.

For the Residential sector, TIMES-Vietnam contains a large suite of new technology options for each service demand that represent Standard, Improved, Better and Advanced options, based on USEPA database. Biodiesel and bio gasoline are available through mixing of these fuels with conventional diesel and gasoline. Distributed PV systems provide electricity directly to the sector (for internal consumption) as well as feeding any excess electricity to the grid. Finally, building efficiency retrofit options are available that reduce building

energy demands – primarily for cooling and water heating. Some of these may be restricted in the base scenario, then loosened for other alternative scenarios that incentive them.

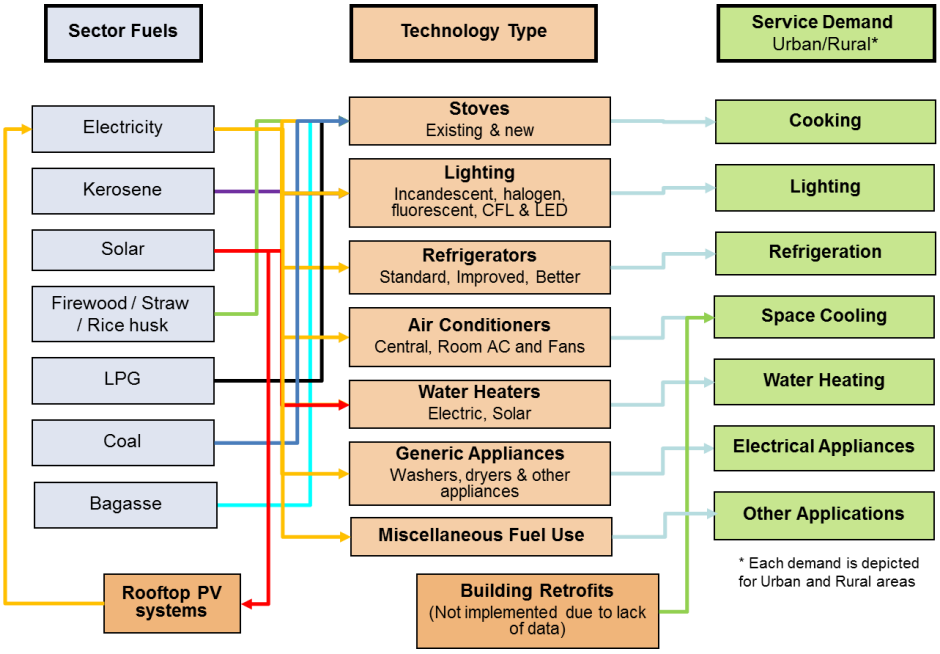

Figure 6-6: Residential Sector RES.

Residential demand devices are classified into existing (Base year), standard, improved and better types which are characterized with different costs and efficiencies. Details on characters of residential demand devices are presented in **Annex *5***.

Transport

The Transport sector accounts for 24% of the base year final energy demand. As the Ministry of Transport (MOT) is already assessing mitigation measures for transport using the EFFECT model in an on-going project [21], mode and fuel shares are tightly controlled in TIMES-Vietnam, based on the scenarios developed through the EFFECT model. Figure 6-7 provides an overview of the sector fuels and final energy demands provided by the model EFFECT.

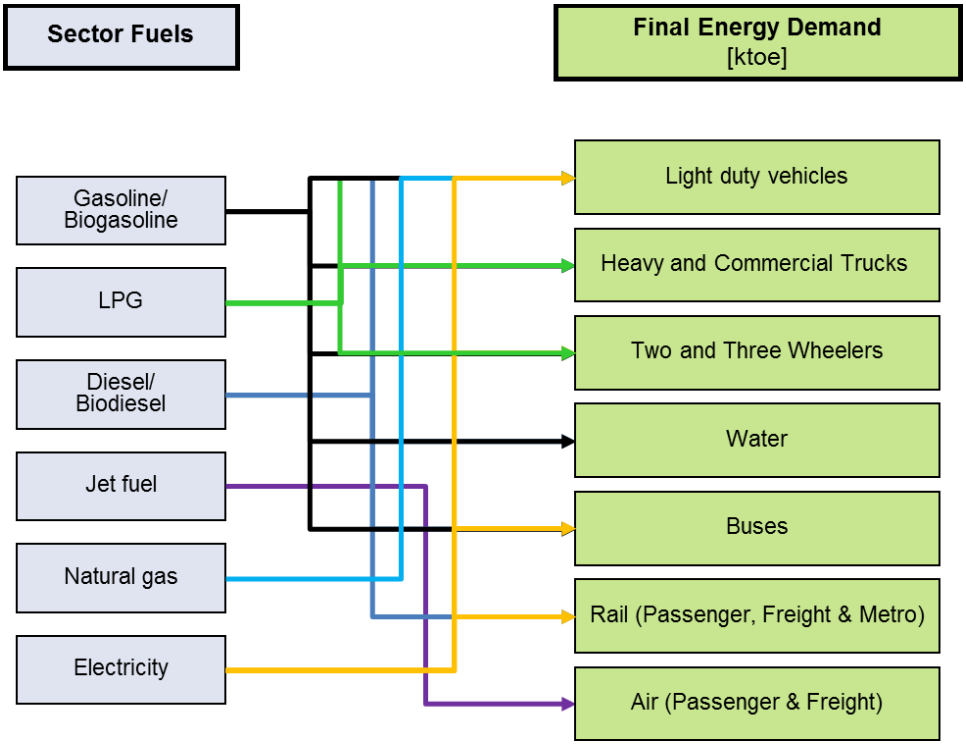

Figure 6-7: Simulation of EFFECT Transport Sector Results.

As a result, the transport sector in the TIMES-Vietnam model replicates the results from the EFFECT model, which includes several mitigation measures. This will enable TIMES-Vietnam to reflect the integrated impacts of the transport sector measures on the other portions of the overall energy system – specifically, their impacts on upstream supply requirements, electricity generation and fuel competition between the various sectors, as a simulation within the overall optimization.

Measures for the transport sector implemented in the EFFECT model include:

- Higher fuel economy standards;
- Modal shift from private to public transport (bus, bus rapid transit, metro);
- Modal shift from road to waterway and railway;
- Gasoline E10 is used in 2025;
- Electric vehicle: electric two-wheeler accounts for 30% of 2W fleet in 2030, electric cars for 33% in 2030, electric bus available from 2025 in Hanoi and Ho Chi Minh City;
- 10% new electric bus sales in period 2020.

Details on characteristics of industrial demand devices are presented in Annex 6.

7 End-use demand projections

General assumptions

The major driver for demands in all sectors is the GDP growth, as assumed in PDP7R. Other important drivers for the different sectors include population, urbanization, sectoral development plans etc. The primary demand drivers include GDP growth, population growth, GDP per capita growth, and the number of persons per household. There are secondary drivers for each demand sector, such as the elasticity of energy use to GDP growth, industrial production projections, and market penetration rates for space cooling, refrigeration and electric appliances. Table 7-1 identifies the main drivers used to project the future demand for energy services that must be met by TIMES-Vietnam in each period.

Table 7-1: Primary Demand Drivers.

Demand Drivers	2014	2016	2020	2025	2030	2035	2040	2045	2050
GDP (US$ billion)	126.6	145.0	190.1	266.6	373.9	524.4	662.9	798.8	917.0
Population (million persons)	90.7	92.8	96.6	100.9	104.4	107.3	109.7	111.5	112.7
Number of persons per household	3.80	3.76	3.69	3.60	3.51	3.42	3.34	3.25	3.17
GDP growth		7.00%	7.00%	7.00%	7.00%	7.00%	4.80%	3.80%	2.80%
Population growth		1.11%	1.03%	0.87%	0.69%	0.55%	0.44%	0.33%	0.22%

Source: GDP in PDP7R [6] and population variables from GSO's population projections [22].

Agriculture

The Agriculture and Fishing sector will account for less than 2% of final energy consumption in 2030. As shown in Figure 7-1, other end-uses, which include Fishing, account for almost 70% of the agriculture energy demand, while water pumping corresponds to almost 20% of the energy consumption in 2030. Diesel fuel accounts for 70% of the energy consumed followed by electricity at

12%.

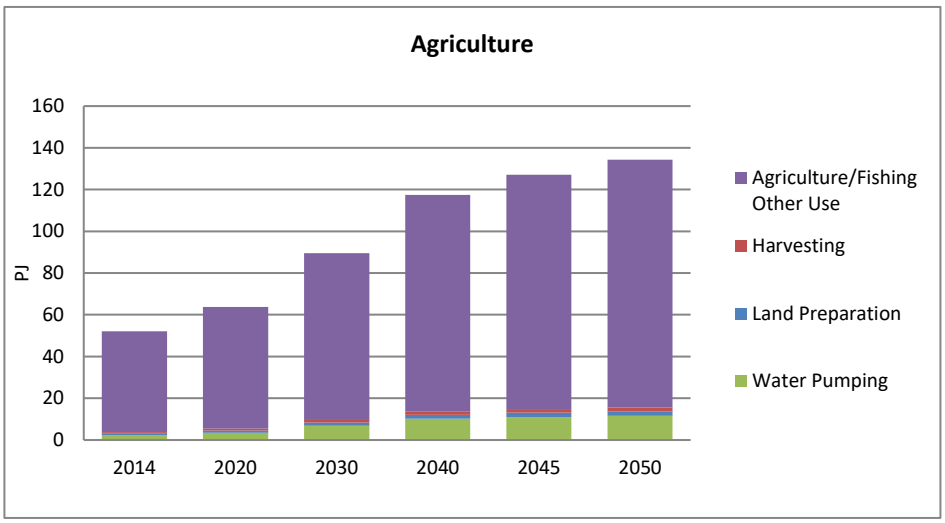

Figure 7-1: Agriculture service demands.

Industrial

The Industry sector will account for more than 55% of final energy consumption in 2030. As shown in Figure 7-2, final energy use grows by 217%, led by Building Materials, Cement, Fertilizer and Other industries. In 2014, final energy use is primarily composed of coal (30%), electricity (33%), biofuels (14%) and natural gas (10%) in 2030.

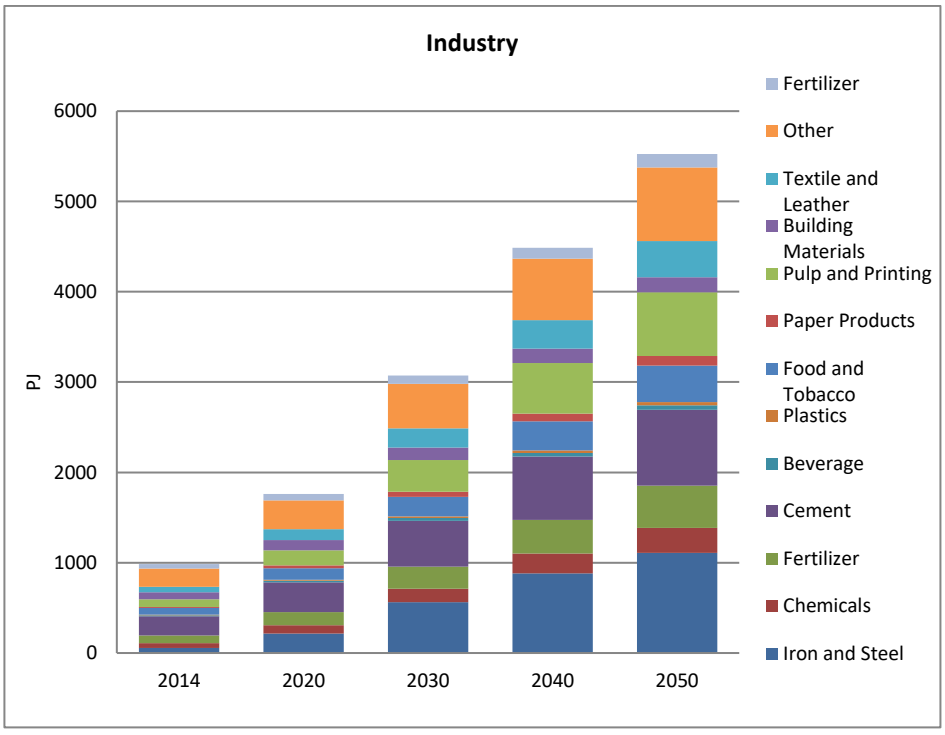

Figure 7-2: Industry sub-sector service demands.

Commercial

The Commercial sector will account for less than 3.5% of final energy consumption in 2030. As shown in Figure 7-3, final energy use grows by 250%, led by space cooling, building equipment, and standby generation. Electricity and diesel fuel grow the fastest and account for more than 80% of the energy consumed, with LPG accounting for the bulk of the rest.

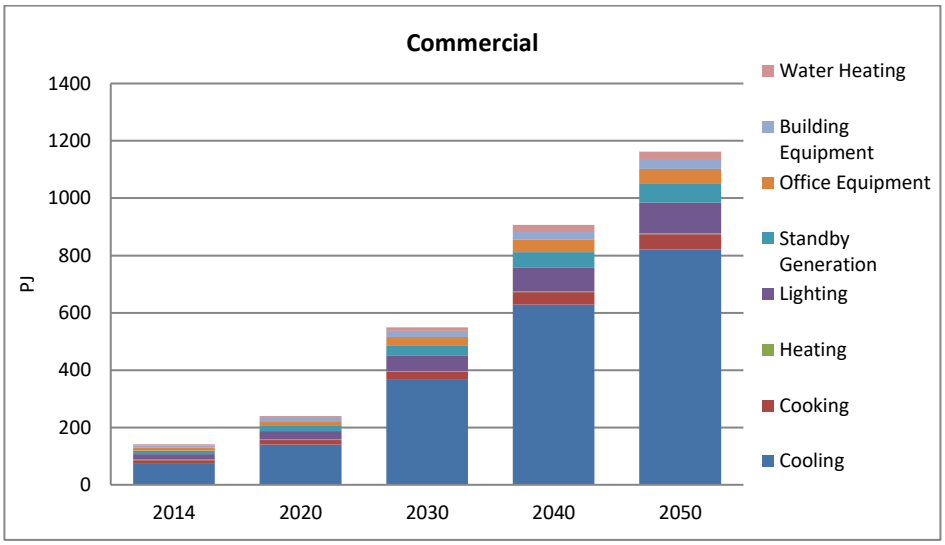

Figure 7-3: Commercial service demands.

Residential

The Residential sector will account for about 16% of final energy consumption in 2030, split into urban and rural subsectors. As shown in Figure 7-4, urban final energy use grows by 180%, led by Cooking, Space Cooling, and Electrical Appliances. Rural final energy use grows by about 80%, dominated by Space Cooling and Appliances, although Cooking still accounts for more than 50% of the energy demand in 2030.

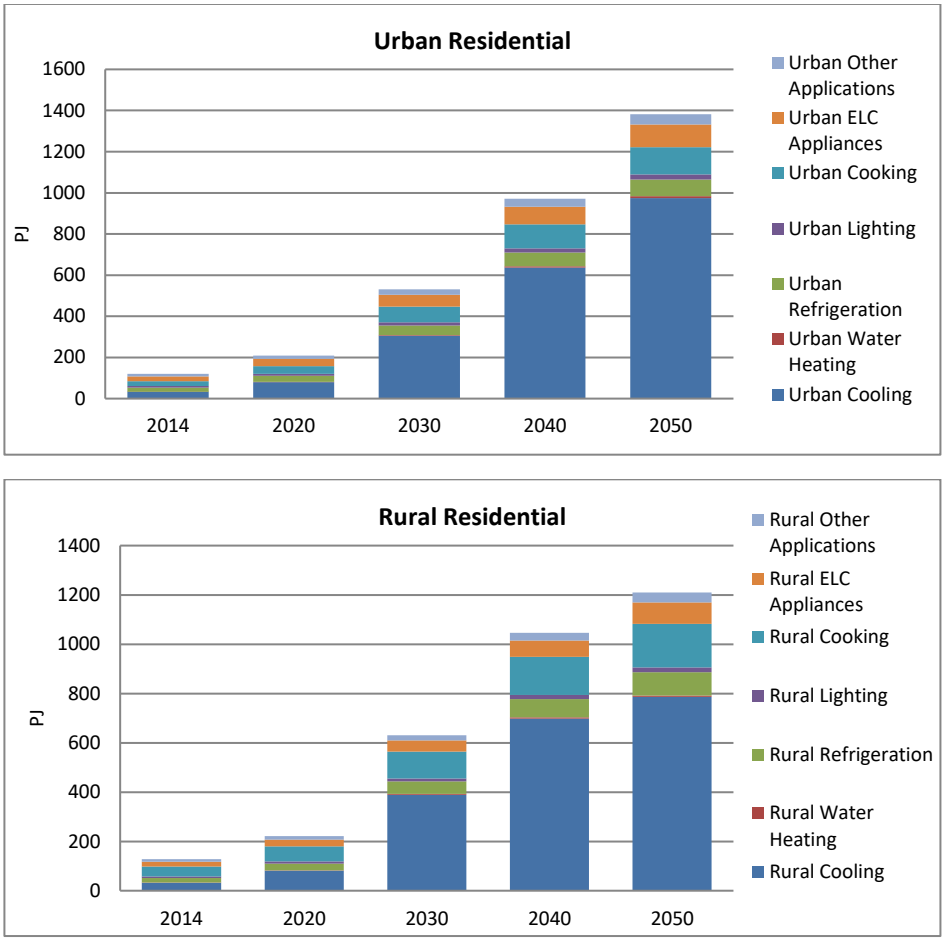

Figure 7-4: Residential sector service demands (urban and rural).

Transport

The Transport sector, as currently modelled in TIMES-Vietnam, accounts for just over 23% of final energy consumption in 2030. As shown in Figure 7-5, final energy use grows by 175%, led by gasoline, diesel and jet fuel.

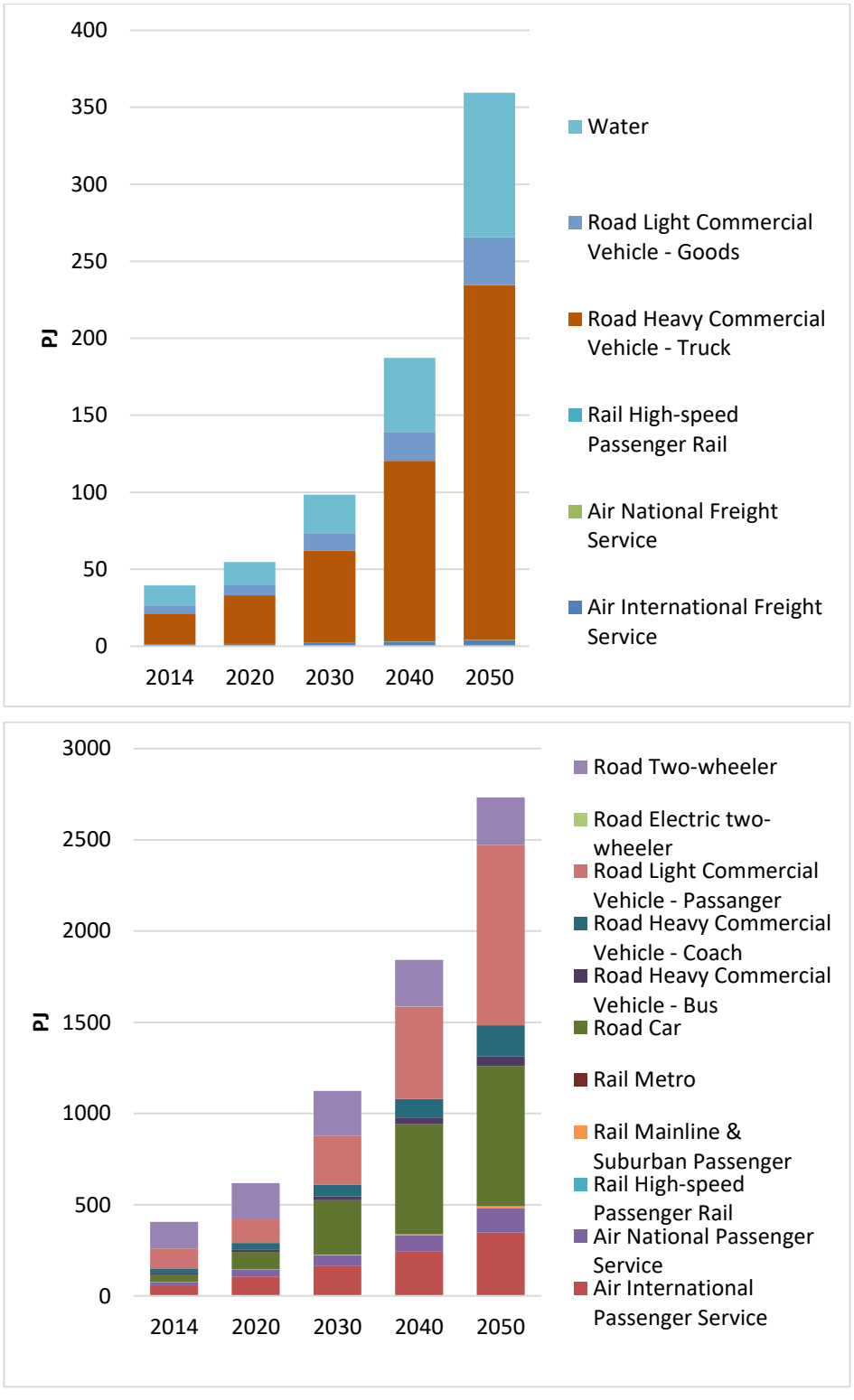

Figure 7-5: Transport sector final energy demands (freight, above and passenger, below).

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Appendix

The appendixes here are reproduced and adapted from [23] to show core data and assumptions for the TIMES-Vietnam model.

Annex 1: Existing power plant characterization

Power Plant Type	Region	Fuel	Installed Capacity [2014]	Remaining Year	Peak Contribution	Efficiency	Fixed O&M (M$/GW)	Variable O&M (M$/PJ)	Availability Factor
Conventional Power Plants									
Anthracite (Hard Coal - Domestic) - Steam turbine (PC - Old)	North	Hard Coal - Domestic	0.65	11	0.95	0.25	25.86	2.53	0.85
Anthracite (Hard Coal - Domestic) - Steam turbine (PC - Recent)	North	Hard Coal - Domestic	4.23	31	0.95	0.35	28.3	2.24	0.85
Anthracite (Hard Coal - Domestic) - Steam turbine (PC - New)	North	Hard Coal - Domestic	0.00	34	0.95	0.37	28.3	2.24	0.85
Anthracite (Hard Coal - Domestic) - Fluidized Bed (Existing)	North	Hard Coal - Domestic	1.57	36	0.95	0.29	28.3	2.24	0.85
Anthracite (Hard Coal - Domestic) - Steam turbine (Recent)	Central	Hard Coal - Domestic	1.25	36	0.95	0.35	25.86	2.53	0.85
Anthracite (Hard Coal - Domestic) - Steam turbine (Captive)	South	Hard Coal - Domestic	0.31	36	0.95	0.35	25.86	2.53	0.85
Anthracite (Hard Coal - Domestic) - Steam turbine (Recent)	South	Hard Coal - Domestic	0.00	34	0.95	0.25	25.86	2.53	0.85
Anthracite (Hard Coal - Import) - Steam turbine (New)	South	Hard Coal - Import	0.00	34	0.95	0.38	25.86	2.53	0.85
Anthracite (Hard Coal - Domestic) - Steam turbine (New)	South	Hard Coal - Domestic	0.00	34	0.95	0.38	25.86	2.53	0.85
Natural Gas - Combined cycle (East)	South	Natural Gas	4.16	36	0.95	0.50	4.45	1.76	0.9
Natural Gas - Combined cycle (BOT)	South	Natural Gas	1.48	36	0.95	0.54	4.45	1.76	0.9
Natural Gas - Combined cycle (West)	South	Natural Gas	1.54	36	0.95	0.49	4.45	1.76	0.9
Natural Gas - Combustion turbine (Existing)	South	Natural Gas	0.26	16	0.95	0.34	3.23	14.34	0.9
Natural Gas - Steam turbine (Existing)	South	Natural Gas	0.47	26	0.95	0.34	27.16	2.07	0.85
Diesel - Combustion turbine (Existing)	South	Diesel	0.55	26	0.95	0.34	3.82	3.4	0.9
Renewable Power Plants									
Primary Solid Biofuels - Steam turbine (PC (Existing))	North	Solid Biofuels	0.02	11	0.9	0.32	13.32	5.95	0.23
Bagasse - Steam turbine (PC (Existing))	North	Bagasse	0.09	11	0.9	0.32	0.12	0.12	0.23
Hydro - Hydro (Dam) (Existing - Very Large)	North	Hydro	4.36	36	0.95	1.00	12.52	4.74	
Hydro - Hydro (Dam) (Existing - Large)	North	Hydro	1.59	36	0.95	1.00	12.52	4.74	
Hydro - Hydro (Dam) (Existing - Medium)	North	Hydro	0.78	36	0.95	1.00	12.52	4.74	
Hydro - Hydro (Dam) (Existing - Small)	North	Hydro	1.40	36	0.9	1.00	14.3	4.77	
Bagasse - Steam turbine (Existing)	Central	Bagasse	0.18	11	0.9	0.32	0.12	0.12	0.23
Hydro - Hydro (Dam) (Existing - Very Large)	Central	Hydro	0.72	36	0.9	1.00	14.3	4.77	

Power Plant Type	Region	Fuel	Installed Capacity [2014]	Remaining Year	Peak Contribution	Efficiency	Fixed O&M (M$/GW)	Variable O&M (M$/PJ)	Availability Factor
Hydro - Hydro (Dam) (Existing - Large)	Central	Hydro	2.84	36	0.9	1.00	14.3	4.77	
Hydro - Hydro (Dam) (Existing - Medium)	Central	Hydro	0.96	36	0.9	1.00	14.3	4.77	
Hydro - Hydro (Dam) (Recent - Small)	Central	Hydro	0.55	37	0.9	1.00	14.3	4.77	
Bagasse - Steam turbine (Existing)	South	Bagasse	0.09	11	0.9	0.32	0.12	0.12	0.23
Hydro - Hydro (Dam) (Existing - Large)	South	Hydro	2.01	36	0.9	1.00	14.3	4.77	
Hydro - Hydro (Dam) (Existing - Medium)	South	Hydro	0.27	36	0.9	1.00	14.3	4.77	
Hydro - Hydro (Dam) (Recent - Small)	South	Hydro	0.05	36	0.9	1.00	14.3	4.77	
Solar - PV Central (Existing)	South	Solar	0.01	36	0.5	1.00	14.3	2.26	
Wind - Onshore (Existing - High)	South	Wind	0.20	21	0.55	1.00	14.3	2.26	

Annex 2: New power plant characterization

Power Plant Type	Fuel	Start Year	Lifetime	Peak Contribution	Construction Leadtime	Efficiency					Investment Cost (M$/GW)					Fixed O&M (M$/GW)	Variable O&M (M$/PJ)	Availability Factor
						2016	2020	2025	2030	2035	2016	2020	2025	2030	2035			
Coal																		
Steam turbine (PC) - Domestic	Hard Coal - Domestic	2016	30	0.9	4	36.0%					1,568			1,694		46.94	0.83	
Steam turbine (PC) – Imported	Hard Coal - Import	2016	30	0.9	4	36.0%					1,568			1,694		46.94	0.83	
Steam turbine (PC) – Domestic biomass co-fire	Hard Coal - Domestic	2020	30	0.9	5	36.0%								1,694		46.94	0.83	
Steam turbine (PC) – Imported Biomass co-fire	Hard Coal - Import	2020	30	0.9	5	36.0%								1,694		46.94	0.83	

Power Plant Type	Fuel	Start Year	Lifetime	Peak Contribu-tion	Construction Leadtime	Efficiency				Investment Cost (M$/GW)					Fixed O&M (M$/GW)	Variable O&M (M$/PJ)	Availability Factor
Super Critical - Domestic	Hard Coal - Domestic	2016	30	0.9	5	39.0%				2,072	2,072		1,904		49.09	0.14	
Super Critical - Import	Hard Coal - Import	2016	30	0.9	5	39.0%				2,072	2,072		1,904		49.09	0.14	
Ultra-Super Critical - Domestic	Hard Coal - Domestic	2016	30	0.9	5	43.0%				2,072		2,072			65.41	0.13	
Ultra-Super Critical - Import	Hard Coal - Import	2020	30	0.9	5	43.0%				2,072		2,072			65.41	0.13	
Integrated Gasif. Combustion Turbine	Hard Coal - Domestic	2020	30	0.95	4		42.3%	45.8%		3,669	3,669	3,595	3,595	3,520	55.66	2.17	0.85
Natural Gas																	
Combined Cycle	Natural Gas	2016	30	0.95	3	51.7%			51.7%	987	987	987	987	987	11.65	1.03	0.9
Advanced Combined Cycle	Natural Gas	2020	30	0.95	3		54.6%	55.0%	55.0%	1,048	1,048	1,030	1,030	1,013	10.59	0.59	0.9
Combustion Turbine	Natural Gas	2016	30	0.95	3	34.3%				1,111	1,111	1,111	1,111	1,111	18.54	1.03	0.9
Advanced Combustion Turbine	Natural Gas	2020	30	0.95	3		37.2%			659	659	646	646	633	7.20	3.15	0.9
Engine	Natural Gas	2016	15	0.95	3	25.0%				1,519					11.91	0.95	
Diesel																	
Combustion Turbine	Diesel	2016	25	0.95		30.0%				1,519					14.30	1.19	
LWR	Nuclear fuel	2016	30	0.95	6	65.2%				5,727	5,441	5,298	5,298	5,155	106.26	0.68	0.9
Renewables																	
Biofuels																	
Steam turbine (PC) - MSW	Municipal Waste	2016	30	0.8		25.0%				2,935					50.20		0.9
Engine - LFG	Landfill Gas	2016	30	0.8		36.0%				1,191					194.46		0.9
Steam Turbine (PC) - Primary Solid Biofuels	Primary Solid Biofuels	2016	30	0.9		31.0%				2,254			2,122				

Power Plant Type	Fuel	Start Year	Lifetime	Peak Contribu-tion	Construction Leadtime	Efficiency				Investment Cost (M$/GW)					Fixed O&M (M$/GW)	Variable O&M (M$/PJ)	Availability Factor
Integrated Gasif. Combined Cycle - Primary Solid Biofuels	Primary Solid Biofuels	2020	30	0.9			38.5%	38.8%	39.4%	40.0%	4,374		4,374	4,374	4,283	56.15	2.46	0.9
Engine - Biogas	Biogas	2016	30	0.8		36.0%					1,191					194.46		0.9
Combined Cycle - Biogas	Biogas	2016	30	0.8		30.0%					995					156.82		0.9
Steam Turbine (PC) - Bagasse	Bagasse	2016	30	0.8		27.1%					1,094					156.82		0.9
Bagasse - Bagasse	Bagasse	2016	30	0.8		45.0%					1,000					179.63		0.9
Geothermal																		
Binary & Flashed Steam	Geothermal	2016	40	0.9	2	35.8%					2,772	2,633	2,564	2,564	2,494	125.77	0.00	0.9
Enhanced System	Geothermal	2025	40	0.9	3						4,810		4,810	4,810	4,680	89.80	1.73	0.9
Hydro																		
Dam (Large)	Hydro	2016	50	0.95	5	100.0%					4,766					11.91	1.19	
Dam (Medium)	Hydro	2016	30	0.9	5	100.0%					3,574					14.30	0.95	
Dam (Small)	Hydro	2016	30	0.8	2	100.0%					2,144					17.87	0.83	
Hydro - Pumped Storage																		
Moc Chau	Electricity	2025	50	0.98	5	77.5%					653		653			11.91	1.19	0.9
Phu Yen East	Electricity	2025	50	0.98	5	77.5%					1,090		1,090			11.91	0.95	0.9
Phu Yen West	Electricity	2025	50	0.98	5	77.5%					890		890			11.91	0.83	0.9
Chau Thon	Electricity	2025	50	0.98	5	77.5%					905		905			11.91	1.19	0.9
Bac Ai	Electricity	2025	50	0.98	5	77.5%					980		980			11.91	0.95	0.9
Don Duong	Electricity	2025	50	0.98	5	77.5%					1,120		1,120			11.91	0.83	0.9
Ninh Son	Electricity	2025	50	0.98	5	77.5%					1,023		1,023			11.91	1.19	0.9
Ham Thuan Bac	Electricity	2025	50	0.98	5	77.5%					1,050		1,050			11.91	0.95	0.9
Solar																		
Thermal Concentrating	Solar	2016	30	0.3	3	100.0%					3,319		4,068	3,973	3,783	74.92		

Power Plant Type	Fuel	Start Year	Lifetime	Peak Contribu-tion	Construction Leadtime	Efficiency	Investment Cost (M$/GW)				Fixed O&M (M$/GW)	Variable O&M (M$/PJ)	Availability Factor
PV Central	Solar	2016	30	0.25		100.0%	1,563	1,362	1,160	1,160	1.19	0.12	
PV Commercial	Solar	2016	30	0.25		100.0%	2,383	1,419	1,256	1,256	1.19	0.12	
PV Residential	Solar	2016	30	0.25		100.0%	2,978	1,476	1,351	1,351	1.19	0.12	
Wind													
Class 3 (low - 10km)	Wind	2016	30	0.25		100.0%	2,561	2,490	2,419	2,419	94.58	0.00	
Class 4 (med - 10km)	Wind	2016	30	0.25		100.0%	2,204	2,105	2,006	2,006	91.58	0.00	
Class 5 (high - 10km)	Wind	2016	30	0.25		100.0%	1,956	1,842	1,726	1,726	88.59	0.00	
Class 3 (low - 20km)	Wind	2016	30	0.25		100.0%	2,946	2,863	2,781	2,781	94.58	0.00	
Class 4 (med - 20km)	Wind	2016	30	0.25		100.0%	2,535	2,421	2,307	2,307	91.58	0.00	
Class 5 (high - 20km)	Wind	2016	30	0.25		100.0%	2,250	2,118	1,985	1,985	88.59	0.00	
Offshore	Wind	2016	30	0.25	3	100.0%	5,544	4,989	4,712	4,435	94.58	0.12	

Annex 3: Industrial demand devices

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availabil-ity/Utilizatio n Factor
				2016	2020	2025	2030	2050			
*** Iron and Steel**											
Sources: Local Energy Centers & ESCOs. 07 Iron and Steel Energy Audits. 2011-2017											
IEVN. Vietnam Low Carbon Options Assessment, Energy sector components – Steel subsector. 2013											
AFD. Establishment of an Energy Savings Scheme in the Steel Sector in Vietnam, Technology Catalogue for Vietnam Iron and Steel Industry. November 2013											
IEVN.FS study of Waste Heat of coke production for power generation in HòaPhát - Dung Quất. 2018											

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/Utilization Factor
Feedstock - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00					19.9	3.2	1
Machine Drive - Electricity - Standard	Electricity	2016	30	1.00					2.2	0.2	1
Facilities/Other - Electricity - Standard	Electricity	2016	30	1.00							1
Process heat - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00					25.7	3.3	1
Process heat - LPG - Standard	LPG	2016	30	1.00					22.0	2.9	1
Process heat - Kerosene - Standard	Kerosene	2016	30	1.00					23.3	3.0	1
Process heat - Diesel - Standard	Diesel	2016	30	1.00					23.3	3.0	1
Process heat - Fuel Oil - Standard	Fuel Oil	2016	30	1.00					24.5	3.2	1
Process heat - Natural Gas - Standard	Natural Gas	2016	30	1.00					22.0	2.9	1
Process heat - Electricity - Standard	Electricity	2016	30	1.00					23.3	3.0	1
Process heat - Cogen Heat - Standard	Cogen Heat	2016	30	1.00					22.0	2.9	1
Feedstock - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.15	1.20	1.22	1.70	23.9	3.8	1
Machine Drive - Electricity - Improved	Electricity	2018	30	1.00	1.15	1.20	1.22	1.70	2.7	0.3	1
Facilities/Other - Electricity - Improved	Electricity	2018	30	1.00	1.15	1.20	1.22	1.70			1
Process heat - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.15	1.20	1.22	1.70	30.8	4.0	1
Process heat - LPG - Improved	LPG	2018	30	1.00	1.15	1.20	1.22	1.70	26.4	3.4	1
Process heat - Kerosene - Improved	Kerosene	2018	30	1.00	1.15	1.20	1.22	1.70	28.0	3.6	1
Process heat - Diesel - Improved	Diesel	2018	30	1.00	1.15	1.20	1.22	1.70	28.0	3.6	1
Process heat - Fuel Oil - Improved	Fuel Oil	2018	30	1.00	1.15	1.20	1.22	1.70	29.4	3.8	1
Process heat - Natural Gas - Improved	Natural Gas	2018	30	1.00	1.15	1.20	1.22	1.70	26.4	3.4	1
Process heat - Electricity - Improved	Electricity	2018	30	1.00	1.15	1.20	1.22	1.70	27.9	3.6	1
Process heat - Cogen Heat - Improved	Cogen Heat	2018	30	1.00	1.02	1.04	1.06	1.11	26.4	3.4	1
CHP - Anthracite	Coal - Domestic	2020	40	0.44					2621.0	73.5	0.6
CHP - Fuel Oil	Fuel Oil	2020	40	0.25					1229.5	42.4	0.6

* Chemicals

Sources: Local Energy Centers & ESCOs. 04 Chemicals Energy Audits. 2011-2017

WB. Benchmark studies and Energy Audits for Chemicals products (Fertilizers-NPK, Paints-solvent, Paints-water)

Machine Drive - Electricity - Standard	Electricity	2016	30	1.00					2.2	0.2	1
Facilities/Other - Electricity - Standard	Electricity	2016	30	1.00							1
Process heat - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00					4.2	0.7	1

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/Utilization Factor
Process heat - LPG - Standard	LPG	2016	30	1.00					4.2	0.7	1
Process heat - Kerosene - Standard	Kerosene	2016	30	1.00					4.2	0.7	1
Process heat - Diesel - Standard	Diesel	2016	30	1.00					4.2	0.7	1
Process heat - Fuel Oil - Standard	Fuel Oil	2016	30	1.00					4.2	0.7	1
Process heat - Natural Gas - Standard	Natural Gas	2016	30	1.00					3.6	0.6	1
Process heat - Cogen Heat - Standard	Cogen Heat	2016	30	1.00					3.6	0.6	1
Machine Drive - Electricity - Improved	Electricity	2018	30	1.00	1.02	1.04	1.06	1.11	2.7	0.3	1
Facilities/Other - Electricity - Improved	Electricity	2018	30	1.00	1.02	1.04	1.06	1.11			1
Process heat - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.02	1.04	1.06	1.11	5.1	0.8	1
Process heat - LPG - Improved	LPG	2018	30	1.00	1.02	1.04	1.06	1.11	5.1	0.8	1
Process heat - Kerosene - Improved	Kerosene	2018	30	1.00	1.02	1.04	1.06	1.11	5.1	0.8	1
Process heat - Diesel - Improved	Diesel	2018	30	1.00	1.02	1.04	1.06	1.11	5.1	0.8	1
Process heat - Fuel Oil - Improved	Fuel Oil	2018	30	1.00	1.02	1.04	1.06	1.11	5.1	0.8	1
Process heat - Natural Gas - Improved	Natural Gas	2018	30	1.00	1.02	1.04	1.06	1.11	4.3	0.7	1
Process heat - Cogen Heat - Improved	Cogen Heat	2018	30	1.00	1.02	1.04	1.06	1.11	4.3	0.7	1
CHP - Anthracite	Coal - Domestic	2020	40	0.44					2621.0	73.5	0.6
CHP - Fuel Oil	Fuel Oil	2020	40	0.25					1229.5	42.4	0.6
CHP - Natural Gas	Natural Gas	2020	30	0.66					576.7	6.4	

* Fertilizer

Sources: Local Energy Centers & ESCOs. 03 Chemicals Energy Audits. 2011-2017

IEVN. Vietnam Low Carbon Options Assessment, Energy sector components – Fertilizer subsector. 2013

Feedstock - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00						0.0	1
Feedstock - Natural Gas - Standard	Natural Gas	2016	30	1.00						0.0	1
Machine Drive - Electricity - Standard	Electricity	2016	30	1.00					2.2	0.2	1
Facilities/Other - Electricity - Standard	Electricity	2016	30	1.00							1
Process heat - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00					4.2	0.7	1
Process heat - LPG - Standard	LPG	2016	30	1.00					3.6	0.6	1
Process heat - Kerosene - Standard	Kerosene	2016	30	1.00					3.6	0.6	1
Process heat - Diesel - Standard	Diesel	2016	30	1.00					3.6	0.6	1
Process heat - Fuel Oil - Standard	Fuel Oil	2016	30	1.00					3.8	0.6	1
Process heat - Natural Gas - Standard	Natural Gas	2016	30	1.00					3.6	0.6	1

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/Utilization Factor
Process heat - Electricity - Standard	Electricity	2016	30	1.00					3.8	0.6	1
Process heat - Cogen Heat - Standard	Cogen Heat	2016	30	1.00					3.6	0.6	1
Feedstock - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.01	1.01	1.02	1.04		0.0	1
Feedstock - Natural Gas - Improved	Natural Gas	2018	30	1.00	1.01	1.01	1.02	1.04		0.0	1
Machine Drive - Electricity - Improved	Electricity	2018	30	1.00	1.02	1.04	1.06	1.11	2.7	0.3	1
Facilities/Other - Electricity - Improved	Electricity	2018	30	1.00	1.02	1.04	1.06	1.11			1
Process heat - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.02	1.04	1.06	1.11	5.1	0.8	1
Process heat - LPG - Improved	LPG	2018	30	1.00	1.02	1.04	1.06	1.11	4.3	0.7	1
Process heat - Kerosene - Improved	Kerosene	2018	30	1.00	1.02	1.04	1.06	1.11	4.3	0.7	1
Process heat - Diesel - Improved	Diesel	2018	30	1.00	1.02	1.04	1.06	1.11	4.3	0.7	1
Process heat - Fuel Oil - Improved	Fuel Oil	2018	30	1.00	1.02	1.04	1.06	1.11	4.6	0.7	1
Process heat - Natural Gas - Improved	Natural Gas	2018	30	1.00	1.02	1.04	1.06	1.11	4.3	0.7	1
Process heat - Electricity - Improved	Electricity	2018	30	1.00	1.02	1.04	1.06	1.11	4.6	0.7	1
Process heat - Cogen Heat - Improved	Cogen Heat	2018	30	1.00	1.02	1.04	1.06	1.11	4.3	0.7	1
CHP - Anthracite	Coal - Domestic	2020	40	0.44					2621.0	73.5	0.6
CHP CCT - Natural Gas	Natural Gas	2020	30	0.66					576.7	6.4	
CHP BST - Natural Gas	Natural Gas	2020	30	0.80					50.2	5.0	

* Cement

Sources: Local Energy Centers & ESCOs. 08 cement Energy Audits. 2011-2017

IEVN. Vietnam Low Carbon Options Assessment, Energy sector components – Cement production. 2013

Machine Drive – Electricity – Standard	Electricity	2016	30	1.00					41.5	3.7	1
Facilities/Other – Electricity – Standard	Electricity	2016	30	1.00							1
Facilities/Other – LPG – Standard	LPG	2016	30	1.00							1
Facilities/Other – Diesel – Standard	Diesel	2016	30	1.00							1
Process heat – Anthracite (Hard Coal – Domestic) – Standard	Coal – Domestic	2016	30	1.00					45.8	4.1	1
Process heat – Anthracite (Hard Coal – Import) – Standard	Coal – Import	2016	30	1.00					45.8	4.1	1
Process heat – Fuel Oil – Standard	Fuel Oil	2016	30	1.00					43.7	3.9	1
Process heat – Rice Husk – Standard	Rice Husk	2016	30	1.00					45.8	4.1	1
Process heat – Primary Solid Biofuels – Standard	Primary Solid Biofu-els	2016	30	1.00					45.8	4.1	1
Process heat – Other Biomass – Standard	Other Biomass	2016	30	1.00					45.8	4.1	1
Process heat – Cogen Heat – Standard	Cogen Heat	2016	30	1.00					39.3	3.5	1

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency				Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/Utilization Factor
Machine Drive – Electricity – Improved	Electricity	2018	30	1.00	1.03		1.11	49.8	4.5	1
Facilities/Other – Electricity – Improved	Electricity	2018	30	1.00	1.03		1.11			1
Facilities/Other – LPG – Improved	LPG	2018	30	1.00	1.03		1.11			1
Facilities/Other – Diesel – Improved	Diesel	2018	30	1.00	1.03		1.11			1
Process heat – Anthracite (Hard Coal – Domestic) – Improved	Coal – Domestic	2018	30	1.00	1.03		1.11	55.0	5.0	1
Process heat – Anthracite (Hard Coal – Import) – Improved	Coal – Import	2018	30	1.00	1.03		1.11	55.0	5.0	1
Process heat – Fuel Oil – Improved	Fuel Oil	2018	30	1.00	1.03		1.11	52.4	4.7	1
Process heat – Rice Husk – Improved	Rice Husk	2018	30	1.00	1.03		1.11	55.0	5.0	1
Process heat – Primary Solid Biofuels – Improved	Primary Solid Biofuels	2018	30	1.00	1.03		1.11	55.0	5.0	1
Process heat – Other Biomass – Improved	Other Biomass	2018	30	1.00	1.03		1.11	55.0	5.0	1
Process heat – Cogen Heat – Improved	Cogen Heat	2018	30	1.00	1.03		1.11	47.2	4.2	1
Process Improvement – Convert to Dry Kiln Process	Conservation	2020	30	1.00				10.0	1.0	1
CHP – Anthracite	Coal – Domestic	2020	40	0.44				2621.0	73.5	0.6
CHP – Fuel Oil	Fuel Oil	2020	40	0.25				1229.5	42.4	0.6
CHP – Rice Husk	Rice Husk	2020	30	0.29				3340.5	37.3	0.6
CHP –Primary Solid Biofuels	Primary Solid Biofuels	2020	30	0.29				3340.5	37.3	0.6
CHP – Other Biomass	Other Biomass	2020	30	0.29				3340.5	37.3	0.6

* Beverage

Sources: Local Energy Centers & ESCOs. 07 Beverage Energy Audits. 2011-2017

WB. Benchmark studies and Energy Audits for Beverage products (Beer production,Non-Alcolhol Carbonnate and Non-carbonnate)

Machine Drive - Electricity - Standard	Electricity	2016	30	1.00				2.2	0.2	1
Facilities/Other - Electricity - Standard	Electricity	2016	30	1.00						1
Process heat - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00				27.1	2.7	1
Process heat - LPG - Standard	LPG	2016	30	1.00				27.1	2.7	1
Process heat - Diesel - Standard	Diesel	2016	30	1.00				24.6	2.5	1
Process heat - Fuel Oil - Standard	Fuel Oil	2016	30	1.00				25.8	2.6	1
Process heat - Natural Gas - Standard	Natural Gas	2016	30	1.00				23.2	2.3	1
Process heat - Electricity - Standard	Electricity	2016	30	1.00				24.5	2.5	1
Process heat - Cogen Heat - Standard	Cogen Heat	2016	30	1.00				23.2	2.3	1
Machine Drive - Electricity - Improved	Electricity	2018	30	1.00	1.03	1.06	1.09 1.20	2.7	0.3	1

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/Utilization Factor
Facilities/Other - Electricity - Improved	Electricity	2018	30	1.00	1.03	1.06	1.09	1.20			1
Process heat - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.03	1.06	1.09	1.20	32.5	3.3	1
Process heat - LPG - Improved	LPG	2018	30	1.00	1.03	1.06	1.09	1.20	32.5	3.3	1
Process heat - Diesel - Improved	Diesel	2018	30	1.00	1.03	1.06	1.09	1.20	29.5	3.0	1
Process heat - Fuel Oil - Improved	Fuel Oil	2018	30	1.00	1.03	1.06	1.09	1.20	31.0	3.1	1
Process heat - Natural Gas - Improved	Natural Gas	2018	30	1.00	1.03	1.06	1.09	1.20	27.9	2.8	1
Process heat - Electricity - Improved	Electricity	2018	30	1.00	1.03	1.06	1.09	1.20	29.4	2.9	1
Process heat - Cogen Heat - Improved	Cogen Heat	2018	30	1.00	1.03	1.06	1.09	1.20	27.9	2.8	1
CHP - Anthracite	Coal - Domestic	2020	40	0.44					2621.0	73.5	0.6
CHP - Fuel Oil	Fuel Oil	2020	40	0.25					1229.5	42.4	0.6

* Plastics

Sources: Local Energy Centers & ESCOs. 13 Plastic Energy Audits. 2011-2017

WB. Benchmark studies and Energy Audits for Plastics products (Bags, Sacks and Tarpaulin, Bottles, Household plastics & Construction plastics)

Machine Drive - Electricity - Standard	Electricity	2016	30	1.00					2.2	0.2	1
Facilities/Other - Electricity - Standard	Electricity	2016	30	1.00							1
Process heat - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00					4.2	0.7	1
Process heat - LPG - Standard	LPG	2016	30	1.00					3.6	0.6	1
Process heat - Kerosene - Standard	Kerosene	2016	30	1.00					3.6	0.6	1
Process heat - Diesel - Standard	Diesel	2016	30	1.00					3.6	0.6	1
Process heat - Fuel Oil - Standard	Fuel Oil	2016	30	1.00					3.6	0.6	1
Process heat - Electricity - Standard	Electricity	2016	30	1.00					3.8	0.6	1
Process heat - Cogen Heat - Standard	Cogen Heat	2016	30	1.00					3.6	0.6	1
Machine Drive - Electricity - Improved	Electricity	2018	30	1.00	1.02	1.04	1.06	1.11	2.7	0.3	1
Facilities/Other - Electricity - Improved	Electricity	2018	30	1.00	1.02	1.04	1.06	1.11			1
Process heat - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.02	1.04	1.06	1.11	5.1	0.8	1
Process heat - LPG - Improved	LPG	2018	30	1.00	1.02	1.04	1.06	1.11	4.3	0.7	1
Process heat - Kerosene - Improved	Kerosene	2018	30	1.00	1.02	1.04	1.06	1.11	4.3	0.7	1
Process heat - Diesel - Improved	Diesel	2018	30	1.00	1.02	1.04	1.06	1.11	4.3	0.7	1
Process heat - Fuel Oil - Improved	Fuel Oil	2018	30	1.00	1.02	1.04	1.06	1.11	4.3	0.7	1
Process heat - Electricity - Improved	Electricity	2018	30	1.00	1.02	1.04	1.06	1.11	4.6	0.7	1
Process heat - Cogen Heat - Improved	Cogen Heat	2018	30	1.00	1.02	1.04	1.06	1.11	4.3	0.7	1

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/Utilization Factor
CHP - Anthracite	Coal - Domestic	2020	40	0.44					2621.0	73.5	0.6
CHP - Fuel Oil	Fuel Oil	2020	40	0.25					1229.5	42.4	0.6
*** Food and Tobacco**											
Sources: Local Energy Centers & ESCOs. 22 Plastic Energy Audits. 2011-2017											
Machine Drive - Electricity - Standard	Electricity	2016	30	1.00					2.2	0.2	1
Facilities/Other - Electricity - Standard	Electricity	2016	30	1.00							1
Process heat - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00					27.1	2.7	1
Process heat - LPG - Standard	LPG	2016	30	1.00					27.1	2.7	1
Process heat - Diesel - Standard	Diesel	2016	30	1.00					27.1	2.7	1
Process heat - Fuel Oil - Standard	Fuel Oil	2016	30	1.00					27.1	2.7	1
Process heat - Natural Gas - Standard	Natural Gas	2016	30	1.00					23.2	2.3	1
Process heat - Rice Husk - Standard	Rice Husk	2016	30	1.00					27.1	2.7	1
Process heat - Primary Solid Biofuels - Standard	Primary Solid Biofuels	2016	30	1.00					27.1	2.7	1
Process heat - Electricity - Standard	Electricity	2016	30	1.00					24.5	2.5	1
Process heat - Cogen Heat - Standard	Cogen Heat	2016	30	1.00					24.5	2.5	1
Machine Drive - Electricity - Improved	Electricity	2018	30	1.00	1.03	1.06	1.09	1.20	2.7	0.3	1
Facilities/Other - Electricity - Improved	Electricity	2018	30	1.00	1.03	1.06	1.09	1.20			1
Process heat - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.03	1.06	1.09	1.20	32.5	3.3	1
Process heat - LPG - Improved	LPG	2018	30	1.00	1.03	1.06	1.09	1.20	32.5	3.3	1
Process heat - Diesel - Improved	Diesel	2018	30	1.00	1.03	1.06	1.09	1.20	32.5	3.3	1
Process heat - Fuel Oil - Improved	Fuel Oil	2018	30	1.00	1.03	1.06	1.09	1.20	32.5	3.3	1
Process heat - Natural Gas - Improved	Natural Gas	2018	30	1.00	1.03	1.06	1.09	1.20	27.9	2.8	1
Process heat - Rice Husk - Improved	Rice Husk	2018	30	1.00	1.03	1.06	1.09	1.20	32.5	3.3	1
Process heat - Primary Solid Biofuels - Improved	Primary Solid Biofuels	2018	30	1.00	1.03	1.06	1.09	1.20	32.5	3.3	1
Process heat - Electricity - Improved	Electricity	2018	30	1.00	1.03	1.06	1.09	1.20	29.4	2.9	1
Process heat - Cogen Heat - Improved	Cogen Heat	2018	30	1.00	1.03	1.06	1.09	1.20	29.4	2.9	1
CHP - Anthracite	Coal - Domestic	2020	40	0.44					2621.0	73.5	0.6
CHP - Fuel Oil	Fuel Oil	2020	40	0.25					1229.5	42.4	0.6
CHP - Rice Husk	Rice Husk	2020	50	0.80					41.5	5.1	
*** Paper Products**											

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/Utilization Factor
Sources: Local Energy Centers & ESCOs. 6 Paper Energy Audits. 2011-2017											
WB. Benchmark studies and Energy Audits for Paper products (Tissues, Printing, Packaging)											
Machine Drive - Electricity - Standard	Electricity	2016	30	1.00					2.2	0.2	1
Facilities/Other - Electricity - Standard	Electricity	2016	30	1.00							1
Process heat - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00					150.9	6.0	1
Process heat - LPG - Standard	LPG	2016	30	1.00					129.4	5.2	1
Process heat - Kerosene - Standard	Kerosene	2016	30	1.00					129.4	5.2	1
Process heat - Diesel - Standard	Diesel	2016	30	1.00					143.7	5.7	1
Process heat - Fuel Oil - Standard	Fuel Oil	2016	30	1.00					143.7	5.7	1
Process heat - Natural Gas - Standard	Natural Gas	2016	30	1.00					129.4	5.2	1
Process heat - Electricity - Standard	Electricity	2016	30	1.00					136.5	5.5	1
Process heat - Cogen Heat - Standard	Cogen Heat	2016	50	1.00					129.4	5.2	1
Machine Drive - Electricity - Improved	Electricity	2018	30	1.00	1.19	1.24	1.28	1.75	2.7	0.3	1
Facilities/Other - Electricity - Improved	Electricity	2018	30	1.00	1.19	1.24	1.28	1.75			1
Process heat - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.19	1.24	1.28	1.75	181.1	7.2	1
Process heat - LPG - Improved	LPG	2018	30	1.00	1.19	1.24	1.28	1.75	155.2	6.2	1
Process heat - Kerosene - Improved	Kerosene	2018	30	1.00	1.19	1.24	1.28	1.75	155.2	6.2	1
Process heat - Diesel - Improved	Diesel	2018	30	1.00	1.19	1.24	1.28	1.75	172.5	6.9	1
Process heat - Fuel Oil - Improved	Fuel Oil	2018	30	1.00	1.19	1.24	1.28	1.75	172.5	6.9	1
Process heat - Natural Gas - Improved	Natural Gas	2018	30	1.00	1.19	1.24	1.28	1.75	155.2	6.2	1
Process heat - Electricity - Improved	Electricity	2018	30	1.00	1.19	1.24	1.28	1.75	163.8	6.6	1
Process heat - Cogen Heat - Improved	Cogen Heat	2018	50	1.00	1.19	1.24	1.28	1.75	155.2	6.2	1
CHP - Anthracite	Coal - Domestic	2020	40	0.44					2621.0	73.5	0.6
CHP - Fuel Oil	Fuel Oil	2020	40	0.25					1229.5	42.4	0.6
*** Pulp and Printing**											
Sources: Local Energy Centers & ESCOs. Energy Audits report of Bai Bang Paper co., . 2011-2017											
Machine Drive - Electricity - Standard	Electricity	2016	30	1.00					2.2	0.2	1
Facilities/Other - Electricity - Standard	Electricity	2016	30	1.00							1
Process heat - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00					143.7	5.7	1
Process heat - LPG - Standard	LPG	2016	30	1.00					129.4	5.2	1
Process heat - Kerosene - Standard	Kerosene	2016	30	1.00					129.4	5.2	1

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/Utilization Factor
Process heat - Diesel - Standard	Diesel	2016	30	1.00					136.9	5.5	1
Process heat - Fuel Oil - Standard	Fuel Oil	2016	30	1.00					143.7	5.7	1
Process heat - Primary Solid Biofuels - Standard	Primary Solid Biofuels	2016	5	1.00					136.9	5.5	1
Process heat - Electricity - Standard	Electricity	2016	30	1.00					136.5	5.5	1
Process heat - Cogen Heat - Standard	Cogen Heat	2016	30	1.00					129.4	5.2	1
Machine Drive - Electricity - Improved	Electricity	2018	30	1.00	1.19	1.24	1.28	1.75	2.7	0.3	1
Facilities/Other - Electricity - Improved	Electricity	2018	30	1.00	1.01	1.01	1.02	1.04			1
Process heat - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.19	1.24	1.28	1.75	172.5	6.9	1
Process heat - LPG - Improved	LPG	2018	30	1.00	1.19	1.24	1.28	1.75	155.2	6.2	1
Process heat - Kerosene - Improved	Kerosene	2018	30	1.00	1.01	1.01	1.02	1.04	155.2	6.2	1
Process heat - Diesel - Improved	Diesel	2018	30	1.00	1.01	1.01	1.02	1.04	164.3	6.6	1
Process heat - Fuel Oil - Improved	Fuel Oil	2018	30	1.00	1.19	1.24	1.28	1.75	172.5	6.9	1
Process heat - Primary Solid Biofuels - Improved	Primary Solid Biofuels	2018	5	1.00	1.19	1.24	1.28	1.75	164.3	6.6	1
Process heat - Electricity - Improved	Electricity	2018	30	1.00	1.19	1.24	1.28	1.75	163.8	6.6	1
Process heat - Cogen Heat - Improved	Cogen Heat	2018	30	1.00	1.19	1.24	1.28	1.75	155.2	6.2	1
CHP - Anthracite	Coal - Domestic	2020	40	0.44					2621.0	73.5	0.6
CHP - Fuel Oil	Fuel Oil	2020	40	0.25					1229.5	42.4	0.6
*** Building Materials**											
Sources: Local Energy Centers & ESCOs. 9 Building Materials Energy Audits. 2011-2017											
Feedstock - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00						0.0	1
Feedstock - Kerosene - Standard	Kerosene	2016	30	1.00						0.0	1
Machine Drive - Electricity - Standard	Electricity	2016	30	1.00					2.2	0.2	1
Facilities/Other - Electricity - Standard	Electricity	2016	30	1.00							1
Facilities/Other - Diesel - Standard	Diesel	2016	30	1.00							1
Process heat - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00					23.2	2.3	1
Process heat - Anthracite (Hard Coal - Import) - Standard	Coal - Import	2016	30	1.00					23.2	2.3	1
Process heat - LPG - Standard	LPG	2016	30	1.00					23.2	2.3	1
Process heat - Fuel Oil - Standard	Fuel Oil	2016	30	1.00					22.1	2.2	1
Process heat - Natural Gas - Standard	Natural Gas	2016	30	1.00					23.2	2.3	1
Process heat - Rice Husk - Standard	Rice Husk	2016	30	1.00					18.6	1.9	1

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/Utilization Factor
Process heat - Primary Solid Biofuels - Standard	Primary Solid Biofuels	2016	30	1.00					18.6	1.9	1
Process heat - Electricity - Standard	Electricity	2016	30	1.00					25.7	2.6	1
Process heat - Cogen Heat - Standard	Cogen Heat	2016	30	1.00					18.6	1.9	1
Feedstock - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.01	1.01	1.02	1.04		0.0	1
Feedstock - Kerosene - Improved	Kerosene	2018	30	1.00	1.01	1.01	1.02	1.04		0.0	1
Machine Drive - Electricity - Improved	Electricity	2018	30	1.00	1.06	1.15	1.24	1.60	2.7	0.3	1
Facilities/Other - Electricity - Improved	Electricity	2018	30	1.00	1.06	1.15	1.24	1.60			1
Facilities/Other - Diesel - Improved	Diesel	2018	30	1.00	1.06	1.15	1.24	1.60			1
Process heat - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.06	1.15	1.24	1.60	27.9	2.8	1
Process heat - Anthracite (Hard Coal - Import) - Improved	Coal - Import	2018	30	1.00	1.06	1.15	1.24	1.60	27.9	2.8	1
Process heat - LPG - Improved	LPG	2018	30	1.00	1.06	1.15	1.24	1.60	27.9	2.8	1
Process heat - Fuel Oil - Improved	Fuel Oil	2018	30	1.00	1.06	1.15	1.24	1.60	26.5	2.6	1
Process heat - Natural Gas - Improved	Natural Gas	2018	30	1.00	1.06	1.15	1.24	1.60	27.9	2.8	1
Process heat - Rice Husk - Improved	Rice Husk	2018	30	1.00	1.06	1.15	1.24	1.60	22.3	2.2	1
Process heat - Primary Solid Biofuels - Improved	Primary Solid Biofuels	2018	30	1.00	1.06	1.15	1.24	1.60	22.3	2.2	1
Process heat - Electricity - Improved	Electricity	2018	30	1.00	1.06	1.15	1.24	1.60	30.8	3.1	1
Process heat - Cogen Heat - Improved	Cogen Heat	2018	30	1.00	1.06	1.15	1.24	1.60	22.3	2.2	1
CHP - Anthracite	Coal - Domestic	2020	40	0.44					2621.0	73.5	0.6
CHP - Fuel Oil	Fuel Oil	2020	40	0.25					1229.5	42.4	0.6

* Textile and Leather

Sources: Local Energy Centers & ESCOs. 9 Textile and Leather Energy Audits. 2011-2017

Machine Drive - Electricity - Standard	Electricity	2016	30	1.00					2.2	0.2	1
Facilities/Other - Electricity - Standard	Electricity	2016	30	1.00							1
Facilities/Other - LPG - Standard	LPG	2016	30	1.00							1
Process heat - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00					23.2	2.3	1
Process heat - LPG - Standard	LPG	2016	30	1.00					23.2	2.3	1
Process heat - Kerosene - Standard	Kerosene	2016	30	1.00					21.1	2.1	1
Process heat - Diesel - Standard	Diesel	2016	30	1.00					21.1	2.1	1
Process heat - Fuel Oil - Standard	Fuel Oil	2016	30	1.00					22.1	2.2	1
Process heat - Natural Gas - Standard	Natural Gas	2016	30	1.00					18.6	1.9	1

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/Utilization Factor
Process heat - Electricity - Standard	Electricity	2016	30	1.00					25.7	2.6	1
Process heat - Cogen Heat - Standard	Cogen Heat	2016	30	1.00					18.6	1.9	1
Machine Drive - Electricity - Improved	Electricity	2018	30	1.00	1.06	1.15	1.24	1.60	2.7	0.3	1
Facilities/Other - Electricity - Improved	Electricity	2018	30	1.00	1.06	1.15	1.24	1.60			1
Facilities/Other - LPG - Improved	LPG	2018	30	1.00	1.06	1.15	1.24	1.60			1
Process heat - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.06	1.15	1.24	1.60	27.9	2.8	1
Process heat - LPG - Improved	LPG	2018	30	1.00	1.06	1.15	1.24	1.60	27.9	2.8	1
Process heat - Kerosene - Improved	Kerosene	2018	30	1.00	1.06	1.15	1.24	1.60	25.4	2.5	1
Process heat - Diesel - Improved	Diesel	2018	30	1.00	1.06	1.15	1.24	1.60	25.4	2.5	1
Process heat - Fuel Oil - Improved	Fuel Oil	2018	30	1.00	1.06	1.15	1.24	1.60	26.5	2.6	1
Process heat - Natural Gas - Improved	Natural Gas	2018	30	1.00	1.06	1.15	1.24	1.60	22.3	2.2	1
Process heat - Electricity - Improved	Electricity	2018	30	1.00	1.06	1.15	1.24	1.60	30.8	3.1	1
Process heat - Cogen Heat - Improved	Cogen Heat	2018	30	1.00	1.06	1.15	1.24	1.60	22.3	2.2	1
CHP - Anthracite	Coal - Domestic	2020	40	0.44					2621.0	73.5	0.6
CHP - Fuel Oil	Fuel Oil	2020	40	0.25					1229.5	42.4	0.6

* Other

Sources: Local Energy Centers & ESCOs. 27 Non- specific subsector Energy Audits. 2011-2017

Feedstock - Kerosene - Standard	Kerosene	2016	30	1.00						0.0	1
Machine Drive - Electricity - Standard	Electricity	2016	30	1.00					2.2	0.2	1
Facilities/Other - Electricity - Standard	Electricity	2016	30	1.00							1
Process heat - Anthracite (Hard Coal - Domestic) - Standard	Coal - Domestic	2016	30	1.00					23.2	2.3	1
Process heat - LPG - Standard	LPG	2016	30	1.00					23.2	2.3	1
Process heat - Diesel - Standard	Diesel	2016	30	1.00					21.1	2.1	1
Process heat - Fuel Oil - Standard	Fuel Oil	2016	30	1.00					22.1	2.2	1
Process heat - Natural Gas - Standard	Natural Gas	2016	30	1.00					18.6	1.9	1
Process heat - Rice Husk - Standard	Rice Husk	2016	30	1.00					22.1	2.2	1
Process heat - Primary Solid Biofuels - Standard	Primary Solid Biofu-els	2016	30	1.00					22.1	2.2	1
Process heat - Electricity - Standard	Electricity	2016	30	1.00					25.7	2.6	1
Process heat - Cogen Heat - Standard	Cogen Heat	2016	30	1.00					18.6	1.9	1
Feedstock - Kerosene - Improved	Kerosene	2018	30	1.00	1.01	1.01	1.02	1.04		0.0	1
Machine Drive - Electricity - Improved	Electricity	2018	30	1.00	1.06	1.15	1.24	1.60	2.7	0.3	1

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/Utilization Factor
Facilities/Other - Electricity - Improved	Electricity	2018	30	1.00	1.06	1.15	1.24	1.60			1
Process heat - Anthracite (Hard Coal - Domestic) - Improved	Coal - Domestic	2018	30	1.00	1.06	1.15	1.24	1.60	27.9	2.8	1
Process heat - LPG - Improved	LPG	2018	30	1.00	1.06	1.15	1.24	1.60	27.9	2.8	1
Process heat - Diesel - Improved	Diesel	2018	30	1.00	1.06	1.15	1.24	1.60	25.4	2.5	1
Process heat - Fuel Oil - Improved	Fuel Oil	2018	30	1.00	1.06	1.15	1.24	1.60	26.5	2.6	1
Process heat - Natural Gas - Improved	Natural Gas	2018	30	1.00	1.06	1.15	1.24	1.60	22.3	2.2	1
Process heat - Rice Husk - Improved	Rice Husk	2018	30	1.00	1.06	1.15	1.24	1.60	26.5	2.6	1
Process heat - Primary Solid Biofuels - Improved	Primary Solid Biofu-els	2018	30	1.00	1.06	1.15	1.24	1.60	26.5	2.6	1
Process heat - Electricity - Improved	Electricity	2018	30	1.00	1.06	1.15	1.24	1.60	30.8	3.1	1
Process heat - Cogen Heat - Improved	Cogen Heat	2018	30	1.00	1.06	1.15	1.24	1.60	22.3	2.2	1
CHP - Anthracite	Coal - Domestic	2020	40	0.44					2621.0	73.5	0.6
CHP - Fuel Oil	Fuel Oil	2020	40	0.25					1229.5	42.4	0.6

Annex 4: Commercial demand devices

Demand Device	Activity / Capacity Units	Fuel	Start Year	Lifetime	Efficiency	Investment (US$2015M)	Fixed O&M (US$2015M)	Availability Factor
*** Space Cooling**								
Central AC-Standard	PJ / PJa	Electricity	2016	15	3.81	40.61	0.85	0.17
Central AC-Improved	PJ / PJa	Electricity	2016	15	5.00	42.75	0.85	0.17
Central AC-Advanced	PJ / PJa	Electricity	2016	15	7.57	67.92	1.36	0.17
VRV/F Central AC-Standard	PJ / PJa	Electricity	2016	15	4.19	44.67	0.22	0.17
VRV/F Central AC-Improved	PJ / PJa	Electricity	2016	15	5.50	47.02	0.22	0.17
VRV/F Central AC-Advanced	PJ / PJa	Electricity	2016	15	8.33	74.71	0.22	0.17
Individual AC-Standard	PJ / PJa	Electricity	2016	10	3.71	44.71	0.89	0.17
Individual AC-Improved	PJ / PJa	Electricity	2016	10	4.00	55.62	1.11	0.17

Individual AC-Advanced	PJ / PJa	Electricity	2016	10	5.65	74.39	1.49	0.17
*** Cooking**								
Range-Standard - Electricity	PJ / PJa	Electricity	2016	5	0.60	15.03	0.40	0.20
Range-Improved - Electricity	PJ / PJa	Electricity	2016	15	0.90	23.25	0.58	0.20
Range-Standard - LPG	PJ / PJa	LPG	2016	8	0.60	12.55	0.99	0.20
Range-Improved - LPG	PJ / PJa	LPG	2016	8	0.62	18.69	1.09	0.20
Stove-Standard - Coal	PJ / PJa	Coal - Domestic	2016	3	0.22	1.81	0.04	0.20
Stove-Improved - Coal	PJ / PJa	Coal - Domestic	2016	3	0.25	2.00	0.04	0.20
*** Lighting**								
Incandescent-Standard	bn-lum-yr / PJa	Electricity	2016	2	0.38	0.21	0.01	0.42
Incandescent-Improved	bn-lum-yr / PJa	Electricity	2016	2	0.45	0.25	0.01	0.42
CFL-Standard	bn-lum-yr / PJa	Electricity	2016	4	1.90	0.96	0.05	0.42
CFL-Improved	bn-lum-yr / PJa	Electricity	2016	4	2.00	1.00	0.05	0.42
Lantern-Standard	bn-lum-yr / PJa	Kerosene	2016	10	0.60	3.57	0.24	0.42
Lantern-Improved	bn-lum-yr / PJa	Kerosene	2016	10	0.65	5.36	0.24	0.42
LED-Standard	bn-lum-yr / PJa	Electricity	2016	15	3.17	2.05	0.10	0.42
LED-Improved	bn-lum-yr / PJa	Electricity	2016	15	3.40	2.25	0.04	0.42
Fluorescent-Standard	bn-lum-yr / PJa	Electricity	2016	9	2.70	0.11	0.01	0.42
Fluorescent-Improved	bn-lum-yr / PJa	Electricity	2016	9	3.01	0.53	0.03	0.42
Fluorescent-Advanced	bn-lum-yr / PJa	Electricity	2016	9	3.30	0.63	0.03	0.42
*** Building Equipment**								
Elevators-Standard	PJ / PJa	Electricity	2016	20	0.95	1956.18	39.12	1.00
Elevators-Advanced	PJ / PJa	Electricity	2016	20	1.00	1999.21	39.98	1.00
Escalators-Standard	PJ / PJa	Electricity	2016	20	0.95	567.91	11.36	1.00
Escalators-Advanced	PJ / PJa	Electricity	2016	20	1.00	610.67	12.21	1.00
*** Water Heating**								
Tank-Standard - Electricity	PJ / PJa	Electricity	2016	15	0.90	32.39	0.65	0.44
Tank-Advanced - Electricity	PJ / PJa	Electricity	2016	15	0.92	35.63	0.71	0.44
Heat Pump-Advanced - Electricity	PJ / PJa	Electricity	2016	12	3.60	194.35	3.89	0.44
Tank-Standard - Coal	PJ / PJa	Coal - Domestic	2016	13	0.60	47.66	0.12	0.44
Tank-Advanced - Coal	PJ / PJa	Coal - Domestic	2016	13	0.75	59.57	0.12	0.44
Tank-Standard - Solar	PJ / PJa	Solar	2016	10	3.60			0.44

Tank-Standard - LPG	PJ / PJa	LPG	2016	10	0.65	20.52	0.41	0.44
Tank-Improved - LPG	PJ / PJa	LPG	2016	10	0.68	22.57	0.45	0.44
Tank-Advanced - LPG	PJ / PJa	LPG	2016	10	0.72	24.82	0.50	0.44
Tank-Standard - Kerosene	PJ / PJa	Kerosene	2016	10	0.65	20.52	0.41	0.44
*** Office Equipment**								
Standard	PJ / PJa	Electricity	2016	10	0.77	187.38	3.75	1.00
Improved	PJ / PJa	Electricity	2016	10	1.00	244.06	4.64	1.00
*** Standby Generator**								
Standard	PJ / PJa	Diesel	2016	10	0.94	617.25	82.30	0.15
Improved	PJ / PJa	Diesel	2016	10	1.00	688.75	91.83	0.15

Annex 5: Residential demand devices

Demand Device	Activity / Capacity Units	Fuel	Start Year	Lifetime	Efficiency	Investment (US$2015M)	Fixed O&M (US$2015M)	Availability Factor
Urban Households								
*** Space Cooling**								
Central-Standard	PJ / PJa	Electricity	2016	15	3.81	40.61	0.85	0.15
Central-Improved	PJ / PJa	Electricity	2016	15	5.00	42.75	0.85	0.15
Central-Better	PJ / PJa	Electricity	2016	15	7.57	103.66	2.07	0.15
Room-Standard	PJ / PJa	Electricity	2016	10	3.21	50.06	0.89	0.15
Room-Improved	PJ / PJa	Electricity	2016	10	4.00	55.62	1.11	0.15
Room-Better	PJ / PJa	Electricity	2016	10	5.65	85.11	1.70	0.15
*** Water Heating**								
Tank-Standard - Electricity	PJ / PJa	Electricity	2016	15	0.90	32.39	0.65	0.10
Tank-Improved - Electricity	PJ / PJa	Electricity	2016	15	0.92	35.63	0.71	0.10
Tank-Better - Electricity	PJ / PJa	Electricity	2016	10	3.60	194.35	3.89	0.10
Tank-Standard - LPG	PJ / PJa	LPG	2016	10	0.65	20.52	0.41	0.10
Tank-Improved- LPG	PJ / PJa	LPG	2016	10	0.68	22.57	0.45	0.10

Tank-Better- LPG	PJ / PJa	LPG	2016	10	0.75	27.08	0.45	0.10
Tank-Standard- Solar	PJ / PJa	Solar	2016	10	1.00	90.70	1.81	0.10
*** Refrigeration**								
Refrigerator-Standard	PJ / PJa	Electricity	2016	15	1.20	239.99	4.80	1.00
Refrigerator-Improved	PJ / PJa	Electricity	2016	15	1.47	266.08	5.32	1.00
Refrigerator-Better	PJ / PJa	Electricity	2016	15	1.83	394.20	7.88	1.00
*** Lighting**								
Incandescent-Standard	PJ / PJa	Electricity	2016	2	0.38	0.50	0.01	1.00
Incandescent-Improved	PJ / PJa	Electricity	2016	2	0.45	0.60	0.01	1.00
CFL-Standard	PJ / PJa	Electricity	2016	4	1.90	2.29	0.05	1.00
CFL-Improved	PJ / PJa	Electricity	2016	4	2.00	2.38	0.05	1.00
LED-Standard	PJ / PJa	Electricity	2016	15	3.17	4.87	0.10	1.00
LED-Improved	PJ / PJa	Electricity	2016	15	3.40	5.36	0.10	1.00
Fluorescent-Standard	PJ / PJa	Electricity	2016	9	2.70	0.27	0.01	1.00
Fluorescent-Improved	PJ / PJa	Electricity	2016	9	3.01	1.25	0.03	1.00
*** Cooking**								
Range-Standard - Coal	PJ / PJa	Coal - Domestic	2016	3	0.22	1.81	0.04	1.00
Range-Improved - Coal	PJ / PJa	Coal - Domestic	2016	5	0.25	2.00	0.04	1.00
Range-Standard - Electricity	PJ / PJa	Electricity	2016	10	0.80	15.03	0.40	1.00
Range-Improved - Electricity	PJ / PJa	Electricity	2016	15	0.90	23.25	0.58	1.00
Range-Standard - LPG	PJ / PJa	LPG	2016	8	0.60	12.55	0.99	1.00
Range-Improved - LPG	PJ / PJa	LPG	2016	8	0.62	18.69	1.09	1.00
Range-Standard - Kerosene	PJ / PJa	Kerosene	2016	5	0.45	4.16	0.08	1.00
Range-Improved - Kerosene	PJ / PJa	Kerosene	2016	5	0.50	4.87	0.08	1.00
Range-Standard - Primary Solid Biofuels	PJ / PJa	Primary Solid Biofuels	2016	3	0.15	0.59	0.01	1.00
Range-Improved - Primary Solid Biofuels	PJ / PJa	Primary Solid Biofuels	2016	3	0.30	2.47	0.05	1.00
*** Electric Appliances**								
Standard	PJ / PJa	Electricity	2016	10	0.77	187.38	3.75	1.00
Improved	PJ / PJa	Electricity	2016	10	0.81	196.75	3.75	1.00
*** Other Appliances**								
Standard	PJ / PJa	Electricity	2016	10	1.05	5.96		1.00
Rural Households								
*** Space Cooling**								

Central-Standard	PJ / PJa	Electricity	2016	15	3.81	40.61	0.85	0.15
Central-Improved	PJ / PJa	Electricity	2016	15	5.00	42.75	0.85	0.15
Central-Better	PJ / PJa	Electricity	2016	15	7.57	103.66	2.07	0.15
Room-Standard	PJ / PJa	Electricity	2016	10	3.21	50.06	0.89	0.15
Room-Improved	PJ / PJa	Electricity	2016	10	4.00	55.62	1.11	0.15
Room-Better	PJ / PJa	Electricity	2016	10	5.65	85.11	1.70	0.15
*** Water Heating**								
Tank-Standard - Electricity	PJ / PJa	Electricity	2016	15	0.90	32.39	0.65	0.10
Tank-Improved - Electricity	PJ / PJa	Electricity	2016	15	0.92	35.63	0.71	0.10
Tank-Better - Electricity	PJ / PJa	Electricity	2016	10	3.60	194.35	3.89	0.10
Tank-Standard - LPG	PJ / PJa	LPG	2016	10	0.65	20.52	0.41	0.10
Tank-Improved - LPG	PJ / PJa	LPG	2016	10	0.68	22.57	0.45	0.10
Tank-Better - LPG	PJ / PJa	LPG	2016	10	0.75	27.08	0.45	0.10
Tank-Standard - Solar	PJ / PJa	Solar	2016	10	1.00	90.70	1.81	0.10
*** Refrigeration**								
Refrigerator-Standard	PJ / PJa	Electricity	2016	15	1.13	239.99	4.80	1.00
Refrigerator-Improved	PJ / PJa	Electricity	2016	15	1.39	266.08	5.32	1.00
Refrigerator-Better	PJ / PJa	Electricity	2016	15	1.74	292.69	7.88	1.00
*** Lighting**								
Incandescent-Standard	PJ / PJa	Electricity	2016	2	0.38	0.50	0.01	1.00
Incandescent-Improved	PJ / PJa	Electricity	2016	2	0.45	0.60	0.01	1.00
CFL-Standard	PJ / PJa	Electricity	2016	4	1.90	2.29	0.05	1.00
CFL-Improved	PJ / PJa	Electricity	2016	4	2.00	2.38	0.05	1.00
LED-Standard	PJ / PJa	Electricity	2016	15	3.17	4.87	0.10	1.00
LED-Improved	PJ / PJa	Electricity	2016	15	3.40	5.36	0.10	1.00
Fluorescent-Standard	PJ / PJa	Electricity	2016	9	2.70	0.27	0.01	1.00
Fluorescent-Improved	PJ / PJa	Electricity	2016	9	3.01	1.25	0.03	1.00
Lantern-Standard - Kerosene	PJ / PJa	Kerosene	2016	10	0.30	1.19	0.01	1.00
Biogas Lantern-Standard	PJ / PJa	Biogas	2016	10	0.30	1.19	0.01	1.00
*** Cooking**								
Range-Standard - Coal	PJ / PJa	Coal - Domestic	2016	3	0.22	1.81	0.04	1.00
Range-Improved - Coal	PJ / PJa	Coal - Domestic	2016	5	0.25	2.00	0.04	1.00
Range-Standard - Electric	PJ / PJa	Electricity	2016	10	0.80	15.03	0.40	1.00

Range-Improved - Electric	PJ / PJa	Electricity	2016	15	0.90	23.25	0.58	1.00
Range-Standard - LPG	PJ / PJa	LPG	2016	8	0.60	12.55	0.99	1.00
Range-Improved - LPG	PJ / PJa	LPG	2016	8	0.62	18.69	1.09	1.00
Range-Standard - Kerosene	PJ / PJa	Kerosene	2016	5	0.45	4.16	0.08	1.00
Range-Improved - Kerosene	PJ / PJa	Kerosene	2016	5	0.50	4.87	0.08	1.00
Range-Standard - Rice Husk	PJ / PJa	Rice husk	2016	3	0.15	0.59	0.01	1.00
Range-Improved - Rice Husk	PJ / PJa	Rice husk	2016	3	0.30	2.47	0.05	1.00
Range-Standard - Primary Solid Biofuels	PJ / PJa	Primary Solid Biofuels	2016	3	0.15	0.59	0.01	1.00
Range-Improved - Primary Solid Biofuels	PJ / PJa	Primary Solid Biofuels	2016	3	0.30	2.47	0.05	1.00
Range-Standard - Bagasse	PJ / PJa	Bagasses	2016	3	0.15	0.59	0.01	1.00
Range-Improved - Bagasse	PJ / PJa	Bagasses	2016	3	0.30	2.47	0.05	1.00
Range-Standard - Straw	PJ / PJa	Straw	2016	3	0.15	0.59	0.01	1.00
Range-Improved - Straw	PJ / PJa	Straw	2016	3	0.30	2.47	0.05	1.00
Range-Standard - Biogas	PJ / PJa	Biogas	2016	3	0.55	7.26	0.15	1.00
Range-Improved - Biogas	PJ / PJa	Biogas	2016	3	0.60	7.98	0.16	1.00
Range-Standard - Other Biomass	PJ / PJa	Other Biomass	2016	3	0.15	0.59	0.01	1.00
Range-Improved - Other Biomass	PJ / PJa	Other Biomass	2016	3	0.30	2.47	0.05	1.00
*** Electric Appliances**								
Standard	PJ / PJa	Electricity	2016	10	0.77	187.38		1.00
Improved	PJ / PJa	Electricity	2016	10	1.00	244.06		1.00
*** Other Appliances**								
Standard	PJ / PJa	Electricity	2016	10	1.05	5.96		1.00

Annex 6: Transport demand devices

Vehicle	Fuel	Capacity (USD/unit)	Fuel share	Activity cost (USD/unit)
Air: International Freight Service				
	JET FUEL	1.175	1.000	0.007
Air: International Passenger Service				
	JET FUEL	58.340	1.000	0.341
Air: National Freight Service				

Vehicle	Fuel	Capacity (USD/unit)	Fuel share	Activity cost (USD/unit)
	JET FUEL	0.011	1.000	0.000
Air: National Passenger Service				
	JET FUEL	15.759	1.000	0.092
Road: Heavy Commercial Vehicle - Bus		9.410		0.119
	ELECTRICITY		0.000	
	COMPRESSED NATURAL GAS		0.000	
	DIESEL		1.000	
	GASOLINE		0.000	
	LPG		0.000	
Road: Heavy Commercial Vehicle - Coach		23.903		0.284
	ELECTRICITY		0.000	
	COMPRESSED NATURAL GAS		0.000	
	DIESEL		1.000	
	GASOLINE		0.000	
	LPG		0.000	
Road: Light Commercial Vehicle - Goods		20.136		0.284
	ELECTRICITY		0.000	
	COMPRESSED NATURAL GAS		0.000	
	DIESEL		0.577	
	GASOLINE		0.423	
	LPG		0.000	
Road: Light Commercial Vehicle - Passenger		5.088		0.071

Vehicle	Fuel	Capacity (USD/unit)	Fuel share	Activity cost (USD/unit)
	ELECTRICITY		0.000	
	COMPRESSED NATURAL GAS		0.000	
	DIESEL		0.615	
	GASOLINE		0.385	
	LPG		0.000	
Road: Heavy Commercial Vehicle - Truck		110.089		0.119
	ELECTRICITY		0.000	
	COMPRESSED NATURAL GAS		0.000	
	DIESEL		1.000	
	GASOLINE		0.000	
	LPG		0.000	
Road: Two-wheeler		145.420		2.334
	ELECTRICITY		0.000	
	COMPRESSED NATURAL GAS		0.000	
	DIESEL		0.000	
	GASOLINE		1.000	
	LPG		0.000	
Road: Three-wheeler		0.070		0.000
	ELECTRICITY		1.000	
	COMPRESSED NATURAL GAS		0.000	
	DIESEL		0.000	

Vehicle	Fuel	Capacity (USD/unit)	Fuel share	Activity cost (USD/unit)
	GASOLINE		0.000	
	LPG		0.000	
Road: Car		41.732		0.659
	ELECTRICITY		0.000	
	COMPRESSED NATURAL GAS		0.000	
	DIESEL		0.077	
	GASOLINE		0.923	
	LPG		0.000	
Rail: Mainline Goods Rail		1.247		0.009
	ELECTRICITY		0.000	
	NAT		0.000	
	DIESEL		1.000	
Rail: High-speed Passenger Rail		0.000		0.000
	ELECTRICITY		0.000	
	NAT		0.000	
	DIESEL		0.000	
Rail: Metro		0.000		0.000
	ELECTRICITY		0.000	
	NAT		0.000	
	DIESEL		0.000	
Rail: Mainline & Suburban Passenger		0.715		0.005
	ELECTRICITY		0.000	
	NAT		0.000	

Vehicle	Fuel	Capacity (USD/unit)	Fuel share	Activity cost (USD/unit)
	DIESEL		1.000	
Water		13.041		0.562
	DIESEL		0.236	
	FUEL OIL		0.000	
	GASOLINE		0.764	