VIETNAM – GETTING ON A LOW-CARBON ENERGY PATH TO ACHIEVE NDC TARGET

NDC PATHWAYS ANALYSIS
ENERGY SECTOR FINAL REPORT

Prepared for

World Bank and

Ministry of Industry & Trade Vietnam

By

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Policy Analysis for
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List of Acronyms

BAU	Business-as-usual (Baseline)
CCS	Carbon Capture and Storage
CHP	Coupled heat and power
DWG	DecisionWare Group LLC
EE	Energy Efficiency
EFFECT	Energy Forecasting Framework and Emissions Consensus Tool
FEC	Final Energy Consumption
GHG	Greenhouse Gas
GIZ	Gesellschaft fur Internationale Zusammenarbeit (German)
GoV	Government of Vietnam
GW	Gigawatt
IEA-ETSAP	International Energy Agency Energy Technology Systems Analysis Program
MEI	Mitigation Effectiveness Indicator
MOIT	Ministry of Industry and Trade
MONRE	Ministry of Natural Resources and Environment
MOT	Ministry of Transport
NCCC	National Climate Change Committee
NDC	National Determined Contribution
PDPr	Power Development Plan (including r-Revised)
PJ	Petajoule
SEC	Sector Energy Consumption
SP-RCC	Support Program to Respond to Climate Change
RES	Reference Energy System
TIMES	The Integrated TIMES/EFOM System
USEPA	United States Environmental Protection Agency
VEDA	VErsitile Data Analyst (Front-End, FE / Back-End, BE)
WB	World Bank

1 Executive Summary

1.1 Context and Objective

The Government of Vietnam (GoV) submitted its Nationally Determined Contributions (NDC) under the Paris Agreement in 2015, which is committed to reducing greenhouse gas (GHG) emissions by 8 percent compared to the Business-As-Usual Case (BAU) by 2030 with domestic resources and 25 percent with international financial support. Under this context, Ministry of Natural Resources and Environment (MONRE) requested each key line ministry to submit their sectoral targets to achieve the NDC target, and propose new and more ambitious targets for the next round of NDC submission. The energy sector, comprising power generation, Industry, buildings in the Residential and Commercial sectors, and Transport is the single largest source for GHG emissions in Vietnam, accounting for more than 60 percent of GHG emissions now, and more than 85 percent by 2030. The Ministry of Industry and Trade (MOIT) requested World Bank support to assist them in developing its energy sector emission reduction targets and pathways contributing to the national NDC targets.

This World Bank study aims to support the development of the Roadmap for GHG Mitigation in the energy sector up to 2030. More specifically, the primary objectives of this analytical advisory are to support Vietnam in:

(1) developing and reaching consensus on cost-effective low-carbon mitigation options and pathways both on the demand and supply sides to achieve the NDC target;

(2) estimating the total costs and financing needs to achieve the NDC targets, and

(3) evaluating updated NDC targets for the energy sector to determine the least-cost roadmap to achieve the NDC target.

The Vietnam NDC Roadmap arising from this analysis is presented in Section 10 and the effectiveness of the individual mitigation measures examined are discussed in Section 11.

1.2 Methodology and Scenario Definition

The TIMES[1] integrated least-cost energy system optimization platform is employed for this analysis, by tailoring the TIMES-Starter platform to the local conditions to realize the TIMES-Vietnam model. See Appendix A for a full description of the model and Appendix B for the underlying data used. The TIMES-Vietnam model is one of the most widely used least-cost energy sector optimization methodology employed to inform energy policy and strategic planning. It comprehensively examines the entire energy system, capturing generation and peak demand requirements arising from the simultaneous use of electricity across all the demand sectors. TIMES-Vietnam balances the inclusion of cost-effective variable renewable energy (VRE), taking into consideration its seasonal and time-of-day operational characteristics, to determine what role they can play and what is needed in terms of additional baseload and reserve capacity (typically gas and/or storage). It was developed and is maintained, advanced and promoted by the International Energy Agency's Energy Technology Systems Analysis Program

[1] www.iea-etsap.org

(IEA-ETSAP) consortium, the longest running Implementing Agreement of the IEA. However, it is not a substitute for a full power system planning model that considers more system details with respect to dispatch and grid integration. The TIMES model could be updated once the Power Development Plan 8 is in place.

The basic characteristics of the TIMES modelling platform are:

- Encompasses an ***entire energy system*** from resource extraction through to end-use demands ("well-to-wheels") as represented by a Reference Energy System (RES) network;
- Employs least-cost ***optimization;***
- Identifies the most ***cost-effective*** pattern of resource use and technology deployment over time;
- Provides an ***accurate depiction of the power sector*** ensuring that the timing and peaking requirements are met
- Monitors capacity stock turnover and determines ***investment requirements and timing***;
- Provides a framework for the evaluation of mid-to-long-term ***policies and programs*** that can impact the evolution of the energy system;
- Quantifies the ***costs and technology choices*** that result from imposition of the policies and programs, and
- Fosters ***stakeholder buy-in*** and consensus building.

Based on the discussions and agreement with MOIT, this study examined seven scenarios:

- Business-As-Usual (BAU): Represents the baseline scenario in line with MONRE's revised NDC-2 BAU depiction[2] of the power and other energy sector emission profiles, particularly with respect to sectoral emissions, generation mix, and electricity demand. Since MONRE requested different line ministries to develop their NDC targets, it is important to use the same BAU definition by MONRE to ensure consistency;
- 8 percent emission reduction below BAU by 2030 (NDC-8%): Models the original unconditional NDC target submitted under the Paris Agreement. [Later, for discussions at COP25 a 10% target was also examined, and is discussed as part of Section 11.]
- 15 percent emission reduction below BAU by 2030 (NDC-15%): An intermediate emission reduction scenario as requested by MOIT;
- Energy Efficiency (EE) and Renewable Energy (RE) Policy Scenario (EE&RE Policies): This scenario is based on the ambitious RE targets by 2030 (12 GW of solar PV and 6 GW of wind) set in GoV's latest Power Development Plan (PDP-7r) approved in March 2016 after the NDC submission, and the recently approved (in February 2019) Vietnam National Energy Efficiency Program (VNEEP) that set an EE target to reduce final energy consumption 8-10 percent below BAU from 2021 to 2030. MOIT regards this scenario as conditional, as they expect international support to implement the PDP-7r and VNEEP;
- 20 percent emission reduction below BAU by 2030 (NDC-20%): An intermediate emission reduction scenario as requested by MOIT;
- 25 percent emission reduction below BAU by 2030 (NDC-25%): Models the original conditional NDC target submitted under the Paris Agreement, and

[2] Review and Update of Viet Nam's Nationally Determined Contribution for Energy Sector, published by GIZ, 2017.

- 30 percent emission reduction below BAU by 2030 (NDC-30%): This scenario explores a more aggressive scenario than the conditional NDC pledge, as requested by MOIT.

In addition, several sensitivity analyses were performed around key parameters such as natural gas price, alternative power plant technology preferences, and GHG emission fees. Finally, the TIMES-Vietnam model was extended and run to 2050 to explore when Vietnam coal and GHG emissions will peak and what implications there are for the pre-2030 decisions when a longer-term target is imposed that is consistent with the Paris Agreement goal of limiting global temperature increase to 2 degrees C.

The analysis focuses on the parts of the energy sector that are the responsibility of MOIT, whereby the Transport sector (under the jurisdiction of the Ministry of Transport (MOT)) is simulated by imposing the results of the MOT analysis conducted by the World Bank using the EFFECT[3] model. Thus, the Transport sector fuel needs and emissions are factored into the analysis, however the costs and vehicle fleet changes taking place in the sector are not considered in TIMES-Vietnam at this time.

The detailed assumptions of the model are provided in Appendices A and B. It should be noted that the study adopted MOIT's suggested assumptions of a 25 percent reserve capacity margin, power plant investment costs and projected fuel costs, as well as 10 percent discount rate. TIMES is an economic model, but not an econometric one. TIMES-Vietnam discounts all costs to 2015 constant dollars and does not factor in inflation, but does account for real escalation in fuel and technology costs.

1.3 Results of Emission Reduction Scenarios

Vietnam is on the right track to exceed the unconditional NDC target of 8 percent emission reduction below BAU by 2030, and 30 percent emission reduction below BAU by 2030 is readily achievable, if GoV wants to raise the level of ambition in line with the recent IPCC appeal for urgent and extensive efforts to cut climate change risks. The GHG emission trajectory for these scenarios, as shown in Figure 1, demonstrates that the latest EE&RE Policies scenario, based on the VNEEP and PDP-7r, could reduce GHG emissions by 17.8 percent below BAU by 2030, from the entire energy sector, including the power, industrial, residential, commercial, and transport sectors (assuming the medium GHG mitigation scenario for the Transport sector of 15 percent below BAU by 2030). This means that the GoV's proposed sustainable energy policies would lead to emission reduction exceeding the unconditional 8 percent of NDC target. As shown in Figure 2 and Table 1, it is feasible to reach the 30 percent emission reduction target below BAU by 2030, because the NDC-30% scenario would only increase the total investment costs by $975 million per year, accounting for less than 0.3 percent of GDP by 2030, compared to the EE&RE Policies scenario. An important side benefit of such a commitment is a reduction in imports of 19 percent from the BAU for the EE&RE Policies and 29 to 34 percent for NDC-25% and NDC-30% scenarios, producing savings on the order of $8 - $10 billion per year in foreign exchange over the BAU in 2030. The following sections will focus the discussion and

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[3] https://www.climatesmartplanning.org/dataset/energy-forecasting-framework-and-emissions-consensus-effect-tool.html

comparison three of the core emission reduction scenarios: EE&RE Policies, NDC-25% and NDC-30%.

Figure 1: GHG Emission Reduction Trajectory from Each Scenario

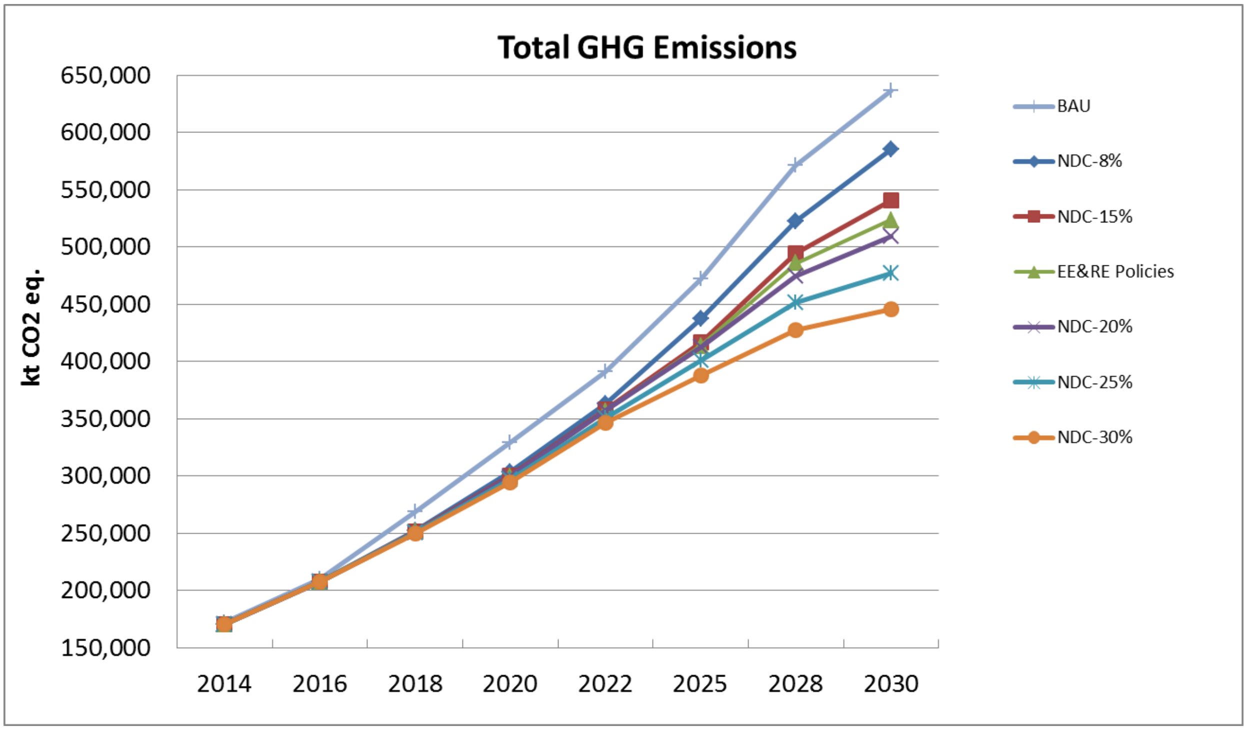
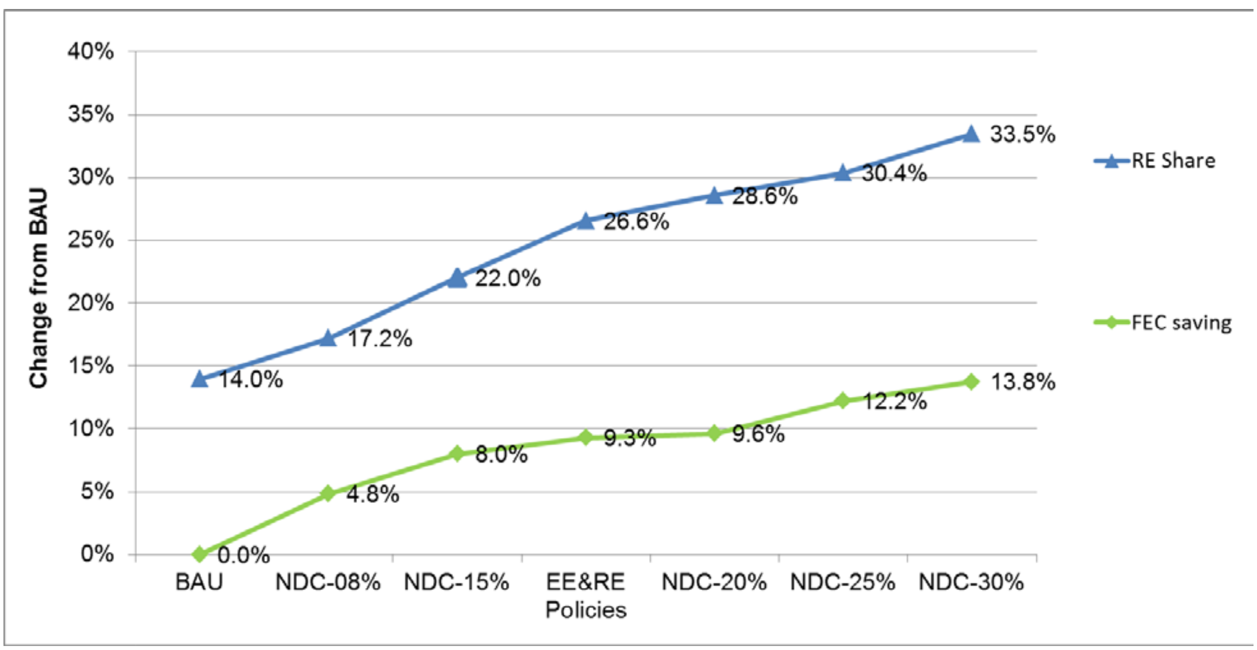


Figure 2: RE Share in the Power Generation Mix and Reduction of Final Energy Consumption below BAU by 2030



The NDC-25% and NDC-30% cases would need to reduce the final energy consumption by 12.2 and 13.8 percent respectively below BAU by 2030, slightly higher than the 8-10 percent target under the VNEEP, and significantly strengthen the RE capacity targets in PDP-7r. The developed countries may provide international financial support to help the GoV to achieve these ambitious emission reduction targets. Since energy efficiency is the lowest cost mitigation option, the team considered more aggressive energy efficiency improvement first, which will significantly lower the energy demand, thereby, avoid building more power plants and reduce the overall investment costs. As shown in Table 1, final energy consumption would be reduced by 9.3 percent below the BAU by 2030 under the EE & RE Policy Scenario, by 12.2 percent under the NDC-25% scenario, and 13.8 percent under the NDC-30% scenario. Energy intensity per unit of GDP would need to reduce 18.8 percent from 2014 to 2030 under the most ambitious NDC-30% scenario, which is feasible to achieve. In addition, the RE share in electricity generation (including large hydropower) would need to increase from 14 percent in the BAU case to 25.9 percent under the EE&RE Policies scenario, 30.4 percent under the NDC-25% scenario, and 33.5 percent under the NDC-30% scenario. For the intermittent RE (solar and wind), the generation shares are 7 percent, 11 percent and 12 percent for the EE&RE Policies, NDC-25%, and NDC-30% by 2030 respectively, which are manageable for grid stability.

Table 1: Summary Results from Each Scenario by 2030

Metric	BAU	NDC-8%	NDC-15%	EE&RE Policies	NDC-20%	NDC-25%	NDC-30%
Energy Sector GHG Reduction (Mt)	-	50.9	95.4	113.3	127.3	159.1	191.0
RE Share in power generation	14.0%	17.2%	22.0%	26.6%	28.6%	30.4%	33.5%
Final energy consumption saving below BAU	-	4.8%	8.0%	9.3%	9.6%	12.2%	13.8%

Cost-effective mitigation opportunities favor ambitious NDC targets. Two metrics of the effectiveness of specific mitigation measures were defined as the Mitigation Effectiveness Indicators, or MEIs: one based in the incremental investment requirement and the other based in the change in system cost. The Investment MEI takes the change in cumulative investment (2018-2030, undiscounted) compared to the Baseline scenario for a specific mitigation measure, and divides that by the cumulative GHG emission reductions for that measure between 2018 and 2030. The Investment MEI provides an overall indication of investment effectiveness, and is appropriate for developing countries where lack of investment funds can be a barrier to meeting NDC goals. The System MEI takes the change in system cost compared to the Baseline scenario for each NDC scenario, and divides that by the cumulative GHG emission reductions for that scenario. The MEI's are similar but not the same as a Marginal Abatement Cost (MAC), because MAC measures are evaluated in isolation and for specific years, while the System MEI covers the entire energy system and the Investment MEI examines specific measures in the context of the entire energy system. This latter point means that the interaction between measures (e.g., electric vehicles affecting power sector choices) is captured by the MEI but not in a typical MAC curve.

Table 2 summarizes the change in total discounted system cost and cumulative (2018-2030) GHG reduction amounts, technology investments needs and fuel savings for each NDC scenario relative to the BAU. The Investment MEI for the entire energy system increases with the NDC level until NDC-25% then decreases for NDC-30%. Investment MEIs for NDC-10% and NDC-15% have relatively low cost and should be pursued by the GoV unconditionally. Interestingly, the NDC-30% scenario has a lower Investment MEI than the NDC-25% scenario, because it has greater implementation of EE and higher utilization of its RE technologies.

All mitigation scenarios have negative System MEIs because the cumulative fuel savings exceeds the higher upfront investment requirements for EE measures as well as building RE power plants rather than fossil-fueled one. For the System MEI, the 15% target with its modest investments in RE and EE has the lowest System MEI, with a savings of $17.1/t. NDC targets of 20% and higher have less cost-effective MEIs, but still produce savings in the range of $12/t to $15/t, and should be supported by the GoV with assistance from the international community.

At the same time, these measures will enhance energy security, reduce balance of payments, and generate local employment benefits for the country. Therefore, the GoV should look to set ambitious targets at the highest end of the range for Unconditional and Conditional commitments.

Table 2: Summary Results – Cumulative Change from BAU for Each Scenario (2018-2030)

Metric / Scenario	**NDC-8%**	**NDC-10%**	**NDC-15%**	**EE&RE Policies**	**NDC-20%**	**NDC-25%**	**NDC-30%**
Investment (M$)	1,124	3,179	5,899	14,994	12,725	1,124	3,179
GHG Reductions (Mt)	738	813	937	1120	1298	738	813
Investment MEI ($/t)	**1.52**	**3.91**	**6.30**	**13.39**	**9.81**	**1.52**	**3.91**
Fuel Savings (M$)	31,265	45,691	46,313	60,457	63,417	31,265	45,691
Change in System Cost (M$)	-9,052	-13,907	-13,822	-15,472	-15,502	-9,052	-13,907
System MEI ($/t)	**-12.26**	**-17.10**	**-14.75**	**-13.82**	**-11.95**	**-12.26**	**-17.10**

1.4 Investment Needs and Net Present Value Costs

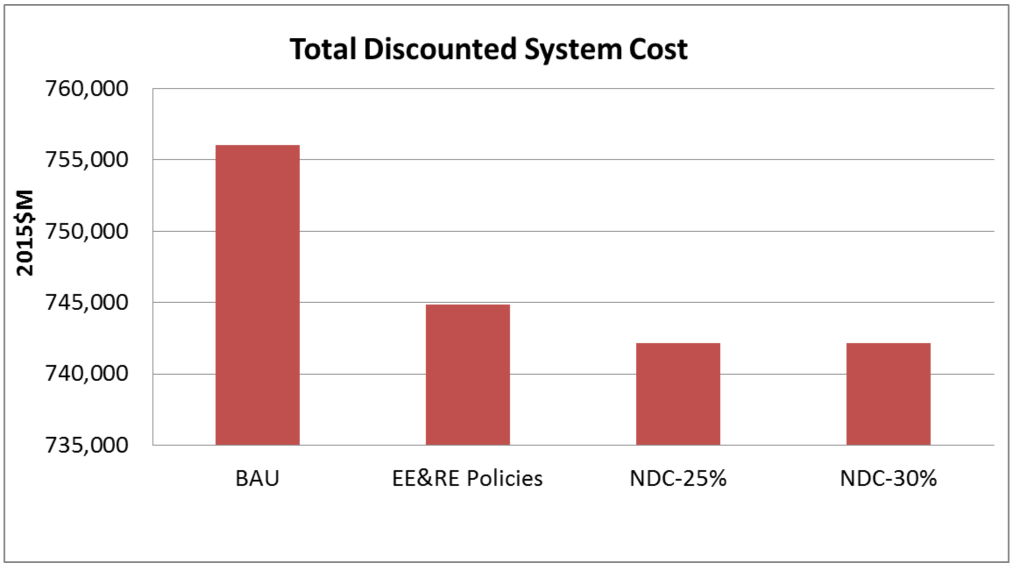
The average annual investment needs from 2018 to 2030 for the entire energy system would need to increase by $1.5 billion for the EE&RE Policies scenario compared to the BAU case, and $625 million and $975 million for the NDC-25% and NDC-30% scenarios compared to the EE & RE scenario. As shown in Table 2, the Power sector investments for newly built capacity have by far the largest share of the investment needs, dominated by the renewable energy investments. For the demand sectors, the annual cumulative investments for the EE&RE Policies, NDC-25% and NDC-30% scenarios are estimated to be $360 million, $870 million, and $1.3 billion respectively, with Industry sector investment growing significantly in the NDC-30% scenario.

Table 3: Cumulative Power Sector Investment (2018-2030)

Power Plant Type	2018-2030 Cumulative Investment (USD Million)			
	BAU	EE&RE Policies	NDC-25%	NDC-30%
Power Sector	**86,937**	**101,178**	**103,125**	**102,880**
Biomass power	0	52	2,079	2,091
Coal conventional	19,555	34,546	19,992	19,893
Coal supercritical	42,300	19,305	22,392	16,296
Gas power	20,985	7,330	7,330	7,330
Large hydropower	4,097	4,098	4,098	4,098
Small hydropower	0	8,060	8,060	11,820
Municipal Solid Waste	0	3,851	3,851	3,851
Solar PV Central	0	10,555	18,104	18,408
Solar PV Distributed	0	2,192	2,268	2,612
Storage	0	2,383	2,404	2,404
Wind	0	8,807	12,548	14,078
Industrial Sector EE	**0**	**2,551**	**4,849**	**7,433**
Residential Sector EE	**0**	**1,246**	**4,496**	**6,354**
Commercial Sector EE	**0**	**562**	**1,138**	**1,768**
Total	**86,937**	**104,975**	**112,470**	**116,667**

While the emission reduction scenarios have higher investment costs compared to the BAU case, the net present value of the total system cost declines due to the fuel expenditure savings. As shown in Figure 3, the net present value of all investments, operation & maintenance (O&M) costs, and fuel costs is reduced by 1.5 percent ($11.2 billion) for the EE&RE Policies scenario, and 1.8 percent ($13.8 billion) for the NDC-25% and 1.9 percent (13.9 billion) for the NDC-30% scenarios compared to the BAU case. This is because the increased investment costs are more than offset by substantial reductions in fuel expenditures (mostly for imported fuels) arising from the increased share of RE generation (backing out fossil fuels) and the reduced consumption of electricity and other fuels owing to more efficient industrial processes, equipment, and appliances. The result is reduced foreign exchange payments for imports and a more competitive overall energy economy. In addition there are many economic development, public health, and social equity opportunities that could arise from such a transition to clean energy, but these were also beyond the scope of this analysis.

Figure 3: Total Discounted System Cost



1.5 Supply-Side Mitigation Options

1.5.1 Energy Supply

Primary energy supply would reduce by 9 percent, 15 percent, and 17 percent for the EE&RE Policies, NDC-25% and NDC-30% scenarios by 2030 compared to BAU. In particular, as shown in Table 4, coal use would decrease by 12 percent, 29 percent, and 37 percent for the EE&RE Policies, NDC-25% and NDC-30% scenarios by 2030 compared to BAU. Crude Oil and Oil products together would also drop by about 10 percent under all the three alternative scenarios compared to BAU by 2030. The reduced coal would mostly be replaced by the growing renewable energy and electricity imports, as well as gas substitution in Industry. The share of renewable energy in primary energy mix would grow 17 percent, 20 percent and 21 percent by 2030 under the EE&RE Policies, NDC-25% and NDC-30% cases. Another key finding of the analysis is that gas has a much higher mitigation value in Industry than in the Power sector, where increasingly competitive RE generation options play a central role to replace coal and gas in the Power sector.

Table 4: Primary Energy Supply (ktoe)

Scenario	2014	BAU	EE&RE Policies		NDC-25%		NDC-30%	
Energy Carrier		2030	2030	Diff BAU 2030	2030	Diff BAU 2030	2030	Diff BAU 2030
Biomass	8,327	17,423	19,136	10%	20,447	17%	21,317	22%
Coal	22,569	105,929	92,719	-12%	75,054	-29%	66,428	-37%
Electricity - Imports	153	590	1,849	213%	2,536	330%	2,536	330%
Gas	10,888	25,292	16,770	-34%	20,746	-18%	21,153	-16%
Hydro	4,975	6,797	7,767	14%	7,767	14%	8,232	21%
Oil Crude	17,739	36,880	33,675	-9%	32,687	-11%	32,591	-12%
Oil Products	13,159	7,945	7,035	-11%	7,130	-10%	7,919	0%
Solar	0	9	1,610	18601%	2,620	30344%	2,680	31036%
Wind	0	0	1,988	-	2,660	-	2,888	-
Total	**77,811**	**200,864**	**182,549**	**-9%**	**171,647**	**-15%**	**165,745**	**-17%**

The EE&RE Policies, NDC-25%, and NDC-30% scenarios would significantly reduce energy imports by 19 percent, 29 percent, and 34 percent respectively, compared to the BAU case by 2030, thereby greatly enhancing energy security. The reduction in energy imports is led by reduced coal imports of 17 percent, 39 percent and 48 percent under the EE & RE Policies, NDC-25%, and NDC-30% scenarios, compared to the BAU case by 2030. Oil imports would drop in the three alternative scenarios by about 10 percent, while natural gas imports decrease relative to the BAU by 2030 because its use in the Power sector is dramatically reduced by more cost-effective RE technologies. However, that decrease is moderated in the NDC-25% and NDC-30% scenarios, where increased gas imports (relative to the EE&RE Policies scenario) are driven primarily by the expanded use of gas in the Industry sector to replace coal. Electricity imports from China and Laos would also more than triple, growing from 6.9 TWh in the BAU to 29.5 TWh in the NDC-25% case by 2030. As noted early this drop in coal, oil, and gas imports can produce annual foreign exchange saving in the range of $8.2 to $10 Billion per year in 2030.

Table 5: Energy Imports (ktoe)

Scenario	2014	BAU	EE&RE Policies		NDC-25%		NDC-30%	
Energy Carrier		2030	2030	Diff BAU 2030	2030	Diff BAU 2030	2030	Diff BAU 2030
Biomass	0	0	0	-	0	-	0	-
Coal	1,428	78,603	65,393	-17%	47,728	-39%	40,834	-48%
Electricity	153	590	1,849	213%	2,536	330%	2,536	330%
Gas	0	10,984	2,462	-78%	6,438	-41%	6,845	-38%
Oil and Products	12,055	40,208	36,438	-9%	35,549	-12%	36,215	-10%
Total	**13,636**	**130,385**	**106,142**	**-19%**	**92,252**	**-29%**	**86,430**	**-34%**

1.5.2 GHG Emission Reductions

As shown in Table 6, the Power and Industry sectors are the main contributors to GHG emission reductions, in terms of both the share of total reductions in any scenario and the growth in GHG reductions as the NDC target is increased.

Table 6: 2030 GHG Emission Reductions relative to BAU (kt)

Sector	NDC-8%	NDC-15%	EE&RE Policies	NDC-20%	NDC-25%	NDC-30%
Agriculture	1,149	590	1,098	1,098	1,012	1,058
Commercial	1,444	740	535	535	1,227	1,343
Industry	24,529	27,342	26,008	27,793	44,168	48,512
Electric Power	15,612	53,866	72,446	82,069	96,160	122,960
Residential	1,206	914	1,501	1,501	2,587	3,075
Supply	1,225	1,498	1,035	1,687	1,355	1,385
Transport	5,730	10,527	10,527	12,621	12,621	12,621
Total	**50,896**	**95,477**	**113,150**	**127,303**	**159,129**	**190,955**

1.5.3 Power Sector

The EE&RE Policies, NDC-25%, and NDC-30% scenarios would significantly boost renewable energy capacity by 2030. As shown in Table 7, coal power capacity would decrease in the three alternative scenarios compared to the BAU case. Some coal power plants, predominantly sub-critical coal power plants are being built, or planned to be built by early 2020s. All future new coal power plants should be super-critical power plants, as this is the most efficient coal power technology at competitive costs, and these coal power plants will lock in a high-carbon future for decades (see Section 9.4.1 on 2050 scenarios for more detailed analysis). The reduced coal power plants would be mostly replaced by the growing renewable generation. The most significant growth in capacity occurs for solar, wind, and small hydropower. The share of RE in total power generation (including large hydropower) would increase from 14 percent in the BAU case to 26.6 percent, 30.4 percent, and 33.5 percent respectively for the EE&RE Policies, NDC-25%, and NDC-30% by 2030 respectively. For the intermittent RE (solar and wind), the generation shares are 7 percent, 11 percent and 12 percent for the EE&RE Policies, NDC-25%, and NDC-30% by 2030 respectively, which are manageable for grid stability. The NDC-25% and NDC-30% scenarios would require a 53 percent and 61 percent increase of the solar PV and wind capacity respectively compared to the EE & RE Policies scenario.

Table 7: New Power Plant Cumulative Capacity - 2018-2030 (GW)

Power Plant Type	Existing Capacity in 2017	Cumulative New Capacity Additions (GW)			
		BAU	EE&RE Policies	NDC-25%	NDC-30%
Biomass power	0.4	0.0	1.3	1.3	1.3
Coal conventional	18.8	14.5	14.3	14.8	14.8
Coal supercritical	0.0	27.7	21.1	14.4	10.5
Gas power	7.9	25.3	8.9	8.9	8.9
Large hydropower	16.1	2.7	2.7	2.7	2.7
Small hydropower	1.3	0.0	4.6	4.6	6.8
Municipal Solid Wastes	0.0	0.0	1.6	1.6	1.6
Solar PV Central	0.0	0.0	10.1	17.6	17.9
Solar PV Distributed	0.0	0.0	1.9	1.9	2.2
Storage	0.0	0.0	2.9	2.4	2.4
Wind	0.0	0.0	6.0	8.0	8.9
Total	**45.1**	**70.3**	**75.5**	**78.2**	**77.9**

The role of natural gas as a mitigation option to replace coal for electricity generation was examined by means of five sensitivity runs, which concluded that gas has a higher mitigation value in the Industry sector to displace coal, as the competitiveness of RE in the power sector reduces both forms of fossil generation. The gas capacity under BAU is unusually high, because the BAU is defined by MONRE for each line Ministry to follow. Thereby, it is a prescribed and official BAU, rather than a least-cost baseline. The new gas power capacity in the alternative scenarios is based on MOIT's suggestions. Lowering the price for gas by 25-33 percent didn't change the fundamentals of the gas/renewables trade-off and priority for increased gas use in Industry. Maintaining electricity generation from gas at the BAU level results in the gas capacity going up slightly, but cuts wind generation in half, solar by one-third, resulting in both solar PV and wind under the government's RE targets.

1.6 Demand-Side Mitigation Options

Final energy consumption would decrease by 9.3 percent, 12.2 percent, and 13.8 percent for the EE&RE Policies, NDC-25%, and NDC-30% scenarios compared to the BAU by 2030. As shown in Table 8, in the EE & RE Policies and NDC-30% scenarios, 45 percent of the final energy consumption (FEC) reductions compared to BAU come from the Industry sector, followed by 28 percent from the Residential sector and 23 percent from the Transport sector. The Agriculture and Commercial sectors combined would contribute only 4 percent of the FEC reduction due to their small share in the FEC.

The EE & RE Policies, NDC-25%, and NDC-30% scenarios would result in a significant transformation of final energy use away from coal and oil products to natural gas, especially in the Industry sector. Of the total FEC reductions by energy type, coal consumption would decrease by 46 percent, 80 percent and 91 percent in the EE&RE Polices, NDC-25% and NDC-30% scenarios respectively, and consumption of oil products would decrease by about 10 percent in all scenarios because of the static nature of the EFFECT Transport sector, which dominate the use of oil products. In the meantime, direct use of natural gas would increase by 36 percent, 88 percent and 93 percent in the EE&RE Polices, NDC-25% and NDC-30% scenarios respectively.

Table 8: Final Energy Consumption by Sector (ktoe)

Scenario	2014	BAU	EE&RE Policies		NDC-25%		NDC-30%	
Sector		2030	2030	Diff BAU 2030	2030	Diff BAU 2030	2030	Diff BAU 2030
Agriculture	1,574	2,611	2,515	-3.7%	2,520	-3.5%	2,494	-4.5%
Commercial	2,369	6,783	6,440	-5.1%	6,281	-7.4%	6,175	-9.0%
Industry	22,336	68,148	63,091	-7.4%	61,840	-9.3%	60,485	-11.2%
Residential	9,507	22,391	19,628	-12.3%	17,968	-19.8%	17,525	-21.7%
Transportation	9,247	25,290	21,898	-13.4%	21,324	-15.7%	21,324	-15.7%
Total	45,032	125,223	113,573	-9.3%	109,932	-12.2%	108,004	-13.8%

Final energy intensity per unit of GDP between 2014 and 2030 would need to decrease by 14.4 percent, 17.3 percent, and 18.8 percent respectively for the EE & RE Policies, NDC-25% and NDC-30% cases. This is feasible to achieve, since Vietnam has the highest energy intensity in Asia. For example, China cut their energy intensity by 19 percent during the 11th Five-Year Plan period from 2005 to 2010, and then again by 18 percent during the 12th Five-Year Plan period from 2011 to 2015. Energy intensity would decrease by 7 percent in the Industry sector and 12 percent in the Residential sector relative to the BAU scenario by 2030 for the EE&RE Policies and decrease by 9 percent in Industry and 20 percent in Residential for the NDC-25% case. The NDC-30% scenario would require the Residential sector energy intensity to decreases by 22 percent and the Industry sector by 11 percent in 2030 relative to the BAU case. Energy intensity for the Commercial and Agriculture sectors would decrease by 9 percent, 11 percent and 13.5 percent relative to the BAU by 2030 for the EE&RE Policies NDC-25% and NDC-30% scenarios.

1.6.1 Industry EE

Six types of emission reduction measures were modelled for the 12 industry subsectors, which comprise the bulk of the industry energy consumption:

- Motor drive efficiency improvements (primarily variable speed drives);
- Process heat efficiency improvements (primarily more efficient boilers and furnaces);
- Facility/Other efficiency improvements (primarily more efficient air conditioning);
- Biomass utilization in boilers & furnaces
- Cogeneration, and
- Industrial process improvements, which reduce the amounts of process heat or motor drive energy needed for a unit of production.

FEC in the industrial sector would reduce 7.4, 9.3 and 11.2 percent under the EE & RE Policies, NDC-25%, and NDC-30% scenarios below BAU by 2030. The Iron & Steel, Cement, Food & Tobacco, and Textiles & Leather sub-sectors provide the largest FEC reductions by 2030. As shown in Table 9, the EE&RE Policies NDC-25% and NDC-30% scenarios would reduce total FEC by about 4.4 Mtoe, 5.8 Mtoe and 7.2 Mtoe below BAU by 2030 respectively. The cement sub-sector would have reductions of about 1.3 Mtoe and the Food & Tobacco sub-sector about 750 ktoe below BAU in all emission reduction scenarios by 2030. However, the reductions in the Iron & Steel sectors below BAU would range from 530 ktoe under the EE & RE Policies scenario to 1300 ktoe under the NDC-30% scenario by 2030. The FEC in the Chemicals subsector would increase a bit because the installed co-generation of power and heat (CHP) provides electricity and process heat to this subsector as well as others.

Table 9: Industry Subsector FEC Reductions in 2030

Industry Subsector	2030 Final Energy Consumption Reduction Compared to BAU (ktoe)		
	EE&RE Policies	NDC-25%	NDC-30%
Beverage	31	41	53
Building materials	118	270	319
Cement	1,162	1,246	1,297
Chemical	192	6	44
Fertilizer	119	221	239
Food & Tobacco	759	684	747
Iron & Steel	532	866	1,307
Other	935	1,289	1,730
Paper Products	64	105	128
Plastics	63	78	82
Pulp & Printing	7	448	513
Textiles & Leather	423	565	753
Total	**4,407**	**5,819**	**7,172**

About 60 percent of Industry sector FEC reduction would come from high efficiency boilers and furnaces, followed by electricity savings due to high efficiency motors and energy savings due to high efficiency lighting, air conditioning, etc. at about 18 percent each. Increased use of biomass (primarily fuelwood, bagasse and rice husk) also makes an important contribution.

Average annual investment needs for industrial EE measures would be about $210 million, $400 million, and $620 million for the EE&RE Policies, NDC-25% scenarios, and NDC-30% scenarios respectively from 2018 to 2030. For a few subsectors the cumulative (2018-2030) investment between the policy and the BAU scenarios is negative because early investments in both CHP and process improvement measures lead to the avoidance of later investments that are savings relative to the BAU.

1.6.2 Residential EE

Final energy consumption in the Residential sector would be reduced by 11.6 percent below the BAU by 2030 for the EE&RE Policies, 19.8 percent for the NDC-25% scenario and 21.7 percent for the NDC-30% scenario. High efficiency air conditioning is the single largest contributor to the reductions in final energy consumption, as shown in Table 10, with high performance refrigerators and appliances accounting for the bulk of the remainder with cleaner cooking fuels and high efficiency lighting at less than 10 percent. In addition, the output of rooftop solar PV systems reaches 1.9 GWh in the EE&RE Policies 2 GWh in the NDC-25% scenario, and 2.2 GWh for the NDC-30% scenario.

Table 10: Residential Sector FEC Reductions by Mitigation Measure

2030 FEC Reduction by Measure (ktoe)	BAU	EE&RE Policies	NDC-25%	NDC-30%
Output of Solar water heaters	3	10	17	17
High performance AC	124	1,351	1,946	2,668
High performance refrigerators	22	326	858	1,324
High performance lighting	7	98	197	328
High efficiency Appliances	24	204	734	1,223
High performance water heater	0	30	30	30
Cleaner cooking fuels	0	211	212	229
Total	**180**	**2,230**	**3,994**	**5,819**

Average annual investment needs for Residential EE measures would be $104 million, $375 million, and $530 million under the EE&RE Policies, NDC-25% cases, and NDC-30% case from 2018 to 2030. Space cooling would account for about 35 percent of the Residential sector EE investments, followed by refrigeration, water heating, electric appliances and cooking.

1.6.3 Commercial EE

Final energy consumption in the Commercial sector would be reduced by 5.1 percent below BAU case by 2030 for the EE&RE Policies, 7.4 percent for the NDC-25% scenarios, and 9 percent for the NDC-30% scenario. High performance air conditioning and lighting end-use applications would provide the majority of the final energy consumption reductions, as shown in Table 11. Solar and high-performance water heaters and high efficiency office equipment comprise the remainder of the Commercial sector mitigation measures.

Table 11: Commercial Sector FEC Reductions by Mitigation Measure

2030 FEC Reduction by Measure (ktoe)	BAU	EE&RE Policies	NDC-25%	NDC-30%
Solar water heaters	5.2	7.8	8.2	21
High performance AC	87	768	1,022	1,150
High performance lighting	18.9	283	567	945
High performance water heater	4.6	64	67	69

2030 FEC Reduction by Measure (ktoe)	BAU	EE&RE Policies	NDC-25%	NDC-30%
High efficiency office equipment	0	10	26	45
Total	**115.7**	**1132.8**	**1,690.2**	**2,230**

Average annual investment needs for Commercial EE measures would be $47 million under the EE&RE Policies, $95 million in the NDC-25% case, and $147 million under the NDC-30% scenario form 2018 to 2030. Space cooling, office equipment, and cooking would account for more than 80 percent of the annual investment needs.

1.7 2050 Scenarios

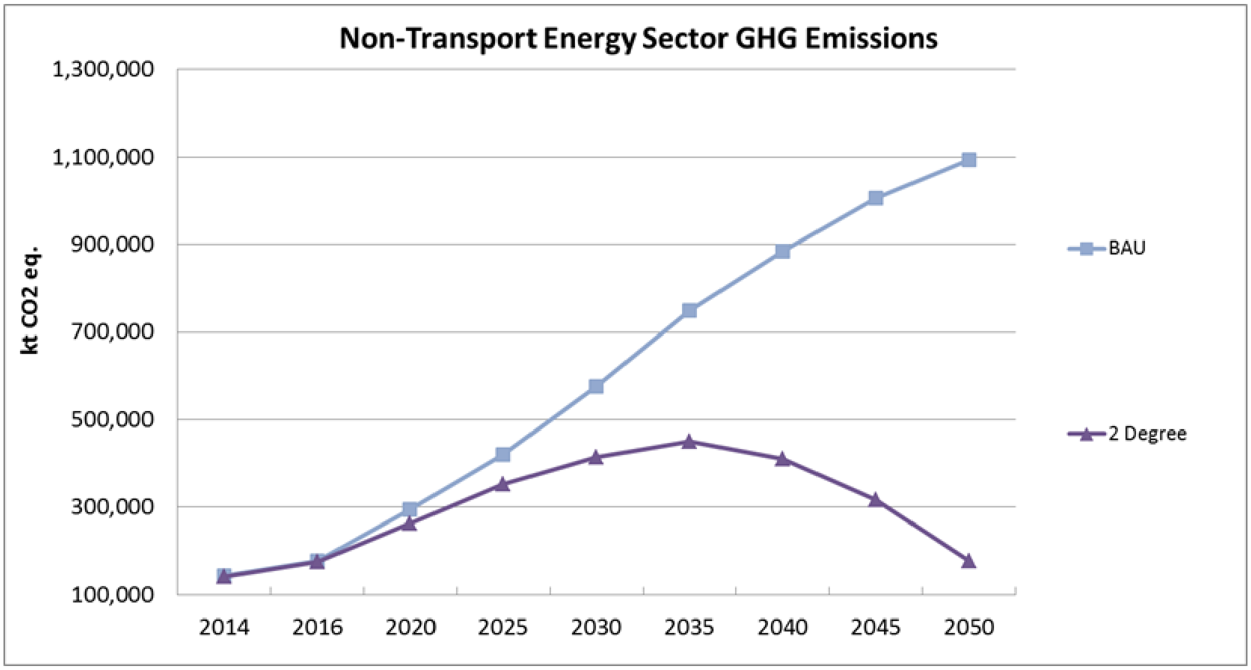
Since the NDC targets are up to 2030, the team examined a series of alternative emission reduction scenarios up to 2030. However, considering that power sector investments typically have lifetimes of 30 years or more, 2030 is a relative short time horizon to consider low-carbon development pathways for Vietnam, particularly given that 14.3 GW of coal power capacity are already being built or planned to be built from now to 2023. Therefore, a more strategic and aggressive scenario up to 2050 was examined to identify the GHG emission and coal consumption peaking timing. Furthermore, to be consistent with the Paris Agreement 2 degree goal, and in response to the IPCC 1.5 AP recommendations for increased ambition, we examined a 2 degree scenario to 2050, by assuming 2 tons CO2 emissions per capita by 2050.

The team also extrapolated the BAU scenario from 2030 to 2050 to see the relative impact of deep emission reductions compared to the BAU by 2050. However, because TIMES-Vietnam does not have detailed data inputs to 2050 for the Transport sector[4], the 2050 2-degree scenario only covers the energy sector without the Transport sector emissions. Based on a population projection of 112.7 million and deducting a share of the emission allowance for Transport, gives a 2050 target of 195.5 Mt.

The analysis of the 2050 2-degree scenario shows that both GHG emissions and coal consumption would need to peak around 2035. The GHG emissions by 2050 would come down to about the 2016 level, and would reduce GHG emissions by 75 percent below the BAU scenario.

[4] Even though TIMES model can incorporate the transport sector calculation, the team only has the outputs of the EFFECT model from the transport sector up to 2030, without any required input data. Thereby it is difficult to include the transport sector for extrapolation to 2050.

Figure 4: GHG emissions peak at 2035 under a 2-degree scenario



The analysis also demonstrated that to achieve the 2-degree target by 2050, 25 GW of coal power capacity would start being phased out in 2035 and be forced to retire early, which demonstrates that the huge build-up of coal power capacity now will have a serious lock-in effect that results in stranded asset of coal power plants after 2030. See Table 12. Given the currently affordable costs of renewable energy, the rising environmental costs, and the difficulty of financing new coal power plants, Vietnam government may consider not building such a large coal power fleet now to avoid the lock-in and stranded assets later on.

Table 12: Some coal power plants would have to retire early to achieve 2-degree goal

Coal Power Plant Capacity and Utilization Factor									
	2014	**2016**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Coal Plant Capacity	8.00	17.02	26.94	26.50	26.50	25.59	22.56	20.56	10.54
Average Utilization	0.52	0.45	0.48	0.65	0.60	0.35	0.22	0.11	0.05

There are many possible emission trajectories from 2030 to the same 2050 end goal, but the slope of the GHG emission curve in 2030 has a lot of impact on the cost of achieving that 2050 goal. This analysis was focused on identifying the least cost pathway for the energy sector.

To achieve the 2-degree goal, RE-based generating capacity would have to increase to 200 GW, 65 percent of electricity generation, and 29 percent of primary energy supply by 2050. Natural gas power plant capacity increases by 42 GW, 18 percent of total capacity. The gas capacity has a utilization factor below 30 percent because its role is primarily balancing variable RE. In addition, 8 GW of electric energy storage are added to help support grid stability. Energy efficiency measures would need to decrease final energy consumption by at least 25 percent below the BAU by 2050, and energy intensity per unit of GDP would need to reduce by 44 percent from 2016 to 2050, with an average of 1.3 percent reduction per year. As shown in Table 13, this scenario would require an average annual investment of $5.5 billion between 2030 and 2050, which represents less than 1 percent of the average GDP for the 2030 to 2050 period.

Table 13: Cumulative Incremental Investment (2030-2050) for 2-Degree Scenario compared to BAU - $ billion

Cumulative Incremental Investment (2020-2050) - $ billion	
Power generation	98
Demand sectors	68
Total	166

1.8 Policy Findings

1.8.1 Supply side mitigation options:

Renewable energy dominates supply-side mitigation measures to replace coal, particularly in the Power sector, and competitive auction scheme is an effective policy to reduce costs for sustainable renewable energy growth. Renewable energy, particularly solar, both central and rooftop systems, and wind in Vietnam are still in their infancy stage. The government's feed-in tariff (FIT) on solar PV and wind has given a boost to renewable energy development in Vietnam. However, given the high feed-in tariff levels, it is not a sustainable policy for a large scale-up of renewable energy, and the GoV's feed-in tariff will expire this year. A recent global trend has seen an increasing number of countries shifted from feed-in tariff to competitive auction schemes, which has led to an immediate price decline of 30-50 percent. In particularly, in such countries as China, India, and South Africa, where coal dominates, solar PV auctions have resulted in solar PV reaching grid parity with coal power plants, eliminating the needs for subsidies. Most of the solar PV auction schemes in developing countries achieved 3-6 US cent/kWh. While each country differs with solar resources, cost of financing, cost of land, and other factors, it is evident that auction scheme through competition can dramatically drive down the costs for solar PV to help countries achieve the ambitious RE targets at an affordable price. In addition, mandatory grid access and transmission infrastructure are also important success factors to scale up RE. Therefore, it is recommended that Vietnam shifts from its FIT approach to competitive auction schemes for utility scale solar PV and wind power plants. Rooftop solar PV can be promoted through net metering rules for electric distribution companies.

Table 14 lists the recommended priority mitigation measures in the Power sector, along with the investment cost, reduction amount and Investment MEI needed to achieve NDC-15 and NDC-30% targets. It is recommended that the GoV consider increasing the level of ambition of the renewable energy target to 18 percent of primary energy mix and 35 percent of power generation by 2030. The level of variable RE encouraged by this analysis is well within reach for Vietnam, where even higher levels are being managed by numerous European countries and is increasingly likely to become the global norm as countries move away from fossil plants. To ensure stability of supply, Vietnam has a large installed base of nature gas fired power plants, which can provide the necessary quick response generation should there be short-term disruption in the variable renewables. Finally, looking beyond 2030 to the longer term implications of the need for the countries of the world to increase their mitigation ambition and commitments, it is strongly recommended that the GoV revisit the status of 14.3 GW of planned additional coal capacity by 2023 so as to avoid the likelihood of stranding conventional coal-fired power plants, where utilization levels would drop below 10%.

Note that the Investment MEIs for RE technologies appear high because they do not include any savings for avoided investments in coal and gas power plants, while the net Investment MEI for the sector, which includes the savings from the avoided coal and gas plants, is significantly lower. The MEI for the Power sector as a whole is quite attractive even at the NDC-30% level.

Table 14: Power Sector Recommendations and NDC-15/30% Scenario Results

RE Technology	Recommended Mitigation Measures	Investment Cost (M$)	Reduction Amount (Mt)	MEI ($/t)
ALL RE	Adopt a competitive auction scheme to replace the Feed in Tariff as a more effective, lower cost policy for promoting renewable energy growth	25,780 / 54,790	644,755 / 906,585	40 / 60
Solar	Promote up to 17.5 GW of solar PV (central and distributed)	6,290 / 21,020	125,150 / 223,100	62 / 83
Wind	Promote up to 8 GW of wind (on-shore and off-shore)	12,010 / 14,080	270,850 / 359,100	44 / 39
Small hydro	Promote up to 5.9 GW of small hydropower	4,960 / 11,820	89,410 / 112,540	55 / 105
Bagasse & Municipal solid waste	Small, but cost-effective. Promote up to 1.5 GW of total capacity	705 / 1,970	54,395 / 111,295	13 / 18
Biomass co-firing with coal	Do not promote. Produced marginal reductions and has a relatively high MEI	3,000 330	39,130 / 3,190	77 / 103
Electric Storage	Promote up to 2.4 GW of Pumped Hydropower and Li-ion battery energy storage for load balancing of VRE (when pushed higher to achieve NDC-30% target	571 / 1,930	NA	NA
Natural Gas	Utilize planned natural gas power plants for backup to Variable RE (VRE) plants	-15,250 / -15,250	619,310 / 644,950	25 / 24
Conventional Coal	Reconsider whether 14.3 GW of planned additional coal capacity by 2023 should be built	No change in investment because plants are forced	-24,826 / 12,780	NA
Supercritical Coal	Promote large-scale RE technologies and EE to displace need for these plants	-476,810 / --874,200	476,810 / 874,200	24 / 26

Net	**Consider increasing the level of ambition of the renewable energy target to 18 percent of primary energy mix and 35 percent of power generation by 2030.**	**2,084 / 16.755**	**412,975 / 1,141,960**	**5 / 15**

1.8.2 Demand side mitigation options

Industry energy efficiency (EE) dominates the demand side mitigation measures to contain demand growth, and the most effective approach to improving industrial EE is to combine mandatory regulations with financial incentives. In the Industry sector, promoting energy efficient industrial process, boilers and motors are the most cost-effective means of reducing industrial emissions. Natural gas and biomass are important mitigation options to replace coal in the Industry sector. Industrial energy efficiency benchmarks are effective tools to improve industrial EE.

Table 15 presents the recommended Industrial sector priority mitigation measures for the sector as a whole and for the key subsectors, along with the investment cost, reduction amount and MEI needed to achieve NDC-15 and NDC-30% targets. Measures that apply to all Industry subsectors include promoting energy efficient industrial process, boilers and motors, which are the most cost-effective means of reducing industrial emissions. In addition to EE measures, switching from coal to natural gas and biomass are important mitigation options in the sector.

At the subsector level, the recommended measures are specific to that subsector, as provided in the table. Note that the Investment MEI for the Industry sector as a whole is on a par with the Power sector as a whole, and that the most attractive subsectors are Cement, Fertilizer, Textiles & Leather and Building materials.

Table 15: Industry Subsector – Recommendations & NDC-15/30% Scenario Results

Subsector	Recommended Mitigation Measures	Investment Cost (M$)	Reduction Amount (Mt)	MEI ($/t)
ALL	Incentives to adopt high efficiency machine drives, boilers and furnaces across all sectors, and specify energy efficiency benchmarks for key Industry subsectors	1,805 / 7,780	190,480 / 334,460	9 / 23
Cement	Combustion cycle optimization, vertical roller mills, dry kilns with multi-stage pre-heaters and pre-calcination, waste heat recovery from co-generation	310 / 2,740	106,935 / 153,690	3 / 18
Iron & Steel	Pulverized coal injection in blast furnaces, steel scrap preheating for electric arc furnaces, waste heat recovery based power generation, other reductions in thermal energy and electrical energy	405 / 900	22,635 / 32,240	18 / 28
Pulp & Printing	Waste paper in the pulping process, high temperature recovery boilers for pulping black liquor combustion, and high efficiency dehydrators for paper-making machines	110 / 950	8,640 / 32,395	13 / 29

Chemicals	Establishing energy management systems, strengthening internal management and maintenance	190 / 360	6,820 / 13,850	28 / 26
Fertilizer	Establishing energy management systems, and strengthening heat recovery systems	60 / 160	12,000 / 26,520	5 / 6
Building materials	Establishing energy management systems, strengthening internal management and maintenance, improving kiln materials, installing absorption chillers to capture waste heat from heat transfer furnaces and drying systems, and investing in new extrusion lines	3 / 560	8,340 / 19,065	0 / 29
Other industries	Establishing energy management systems, strengthening internal management and maintenance, improving kiln torch systems and installing gas vapor recovery equipment	50 / 945	9,655 / 17,765	5 / 53
Textiles & Leather	Establishing energy management systems, and improving processes for fiber production, knitting and dyeing	25 / 235	3,940 / 17,165	7 / 14

In the Residential and Commercial sectors, improving EE for the air conditioning system has by far the biggest EE gains, thereby, tightening energy efficiency standards for air conditioning is a top priority. Given that EE faces many market barriers and failures, international experience, including Vietnamese previous experience, shows that a voluntary approach is not effective, unless it is offered with strong financial incentives. Consumers rarely take EE actions on their own, without mandates or incentives. Therefore, it is recommended that the GoV allocates the VNEEP targets to each province and priority industrial energy-intensive enterprises and hold them accountable to achieve the VNEEP targets.

Table 16 identifies the recommended priority mitigation measures for the Residential and Commercial sectors according to specific demand services in each, along with the investment cost, reduction amount and MEI needed to achieve NDC-15 and NDC-30% targets. Improving EE for the Air Conditioning has by far the biggest energy saving gains; thereby tightening energy efficiency standards for air conditioning is a top priority. Lighting is by far the most attractive set of mitigation measures, while Water Heating has quite a high Investment MEI because of the low emission reductions achieved. Space Cooling measures becomes more cost-effective as the NDC target is increased because of the significantly higher utilization. Important to these sectors is distributed solar generation, where 1.9 GWh to 2.2 GWh of rooftop solar PV systems should be incentivized by 2030.

Table 16: Residential & Commercial Sector – Recommendations & NDC-15/30% Results

Demand Service	Measure	Investment Cost (M$)	Reduction Amount (Mt)	MEI ($/t)
ALL	Allocate the VNEEP targets to each province and hold them accountable to achieve the VNEEP targets	1,310 / 6,015	38,780 / 107,545	40 / 51

Lighting	Incentivize High Efficiency Commercial and Residential Lighting	30 / 65	22,035 / 35,460	1 / 2
Water Heating	Incentivize Solar water heaters and High performance electric water heater	235 / 930	1,235 / 1,880	256 / 690
Space Cooling	Incentivize High performance AC systems for central, window and rooftop systems	690 / 2,125	6,095 / 21,980	250 / 94
Refrigeration	High performance refrigerators	215 / 1,685	2,690 / 18,925	80 / 90
Cooking	Cleaner cooking fuels	155 / 1,270	6,460 / 28,380	-72 / 52

1.8.3 Potential International Assistance

Stronger NDC targets require higher levels of investment in RE power plants of all types. Compared to the BAU, the total RE investment increases from approximately $26 billion in the NDC-10% scenario to $55 billion in the NDC-30% scenario. However, the net power sector investment increases only from about $3 Billion to almost $17 Billion after factoring in the avoided coal and gas power plant investments. This indicates that new international assistance (grants and concessional loans) to the Power sector should increase by about $1 Billion per year, and that loan guarantees be made available for up to $2 Billion per year.

For the Industry sector, the incremental investment needs range from less than $100 Million per year to about $500 Million per year, many of these incremental investments have a 5-year payback or less, and should be mandated by the government in conjunction with specify energy efficiency benchmarks for key Industry subsectors. Measures that have a longer payback could be supported by a low-interest loan fund that is implemented with the support of international donors. Finally, the GoV should consider tax incentives for industry to adopt high efficiency machine drives, boilers and furnaces across all sectors.

For the Residential and Commercial sectors, improving energy efficiency for the Air Conditioning has by far the biggest energy saving gains; therefore, tightening efficiency standards for air conditioning is a top priority that should be supported by international donors, along with technical assistance to research the type of financial incentives that will motivate consumers to take actions on their own.

2 Introduction

The Government of Vietnam (GoV) is promoting a green growth agenda and addressing climate change by enhancing policies and institutions such as the formation of the National Climate Change Committee (NCCC) and the development of Green Growth Strategies and National Climate Change Action Plans. Additionally, Vietnam has ratified its initial commitment to the Paris Agreement, as an 8% reduction in Greenhouse Gas (GHG) emissions by 2030 compared to a baseline or business as usual (BAU) scenario, based on domestic resources only (Unconditional), and a 25% reduction in GHG emissions by 2030 with international support received through bilateral and multilateral cooperation (Conditional), as well as through the implementation of new mechanisms under the Global Climate Agreement.

The GoV has established a cross-ministerial working group to review and update its National Determined Contribution (NDC), to be finalized in 2019. At the same time, the GoV is identifying and developing actions to be implemented through 2020 (pre-NDC implementation) that require strengthening of existing policies and introduction of new policy measures. This is crucial to the achievement of targeted emission trajectories and leveraging international assistance for the conditional mitigation actions. In parallel, the GoV is working on the development of a National Roadmap for GHG Mitigation, a National Monitoring, Reporting and Verification (MRV) system, and a National GHG Inventory system through the Support Program to Respond to Climate Change (SP-RCC).

This project is designed to support the development of the National Roadmap for GHG Mitigation 2021-2030 in the energy sector and to accelerate reforms that can strengthen the country's resilience to climate change and promote a lower-carbon, greener growth, sustainable development pathway. More specifically, the project is to provide guidance to the Ministry of Industry and Trade (MOIT) in determining the mitigation measures and targets needed to substantively contribute to the revised NDC with respect to the reductions that can be achieved from the energy sector (excluding Transport). The TIMES[5] integrated least-cost energy system optimization platform is employed for this analysis. TIMES models have been used for similar energy-sector NDC analysis in Costa Rica, Georgia, and Ukraine, to support least-cost generation planning studies in Armenia and Kuwait, as well as to perform climate policy assessments in the US for various organizations. It was used as the analytic framework for the World Bank Thirsty Energy initiative that examined the water-energy nexus in China and South Africa under climate change uncertainly. Globally, TIMES models are used heavily by many European countries to advise NDC preparation, as well as South Korea, Australia, Japan, Colombia, and elsewhere.

This study has been closely coordinated with the work being done on behalf of Ministry of Natural Resources and the Environment (MONRE) as reflected in *NDC-2 Review and Update of Viet Nam's Nationally Determined Contribution for Energy Sector*, along with the work being carried out on behalf of the Ministry of Transportation (MOT) to design the Transport sector mitigation program, to ensure that input assumptions and where necessary BAU depiction of the evolution of the Vietnam energy sector are consistent across models. As differing methodologies

[5] www.iea-etsap.org

are being used for these three endeavors, the MONRE and MOT results have, in certain cases, been "imposed" on TIMES-Vietnam to harmonize aspects of the models. In particular, for the power sector the generation mix and level of electricity consumption by sector are closely aligned with that of the revised Power Development Plan VII (PDP-7r) used by MONRE. For the Transport sector the MOT BAU and mitigation scenarios results arising from the EFFECT model are imposed on the TIMES-Vietnam Transport sector.

The project Inception Report (June 2018) provided details on the work plan, model platform, model development process, and a brief description of how NDC analysis is undertaken using TIMES. The Baseline Scenario and Mitigation Measures Report (October 2018) focused on the detailed structure the TIMES-Vietnam model, the key data sources used to populate the model inputs, the preliminary primary results of the Baseline (BAU) scenario, including comparisons to the draft NDC-2 report and early results arising from the EFFECT Transport sector model. The report also discussed the candidate mitigation measures for the NDC analysis. The Preliminary Analysis Report (January 2019) included an update on the Baseline scenario and an updated comparison with the NDC-2 results, provided preliminary results for the core NDC scenarios, and revisited the list of potential mitigation measures. The preliminary results examined the investment requirements as a function of the level of Energy Efficient (EE) improvements and Renewable Energy (RE) technology penetration, outside of the Transport sector, in the context of both an 8% Unconditional and a 25% Conditional NDC target. The preliminary analysis provided insights into where in the energy system the most cost-effective mitigation measures arise, and how much new investment is likely to be required to reach each target. This report documents the final NDC pathway analysis, identifies the key mitigation measures by demand sectors and subsectors at the level of specific energy-use services. This final report also provides MOIT with recommendations for its NDC Roadmap and emission reduction commitments.

3 Project Objectives and Work Plan

3.1 Project Overview

The primary objectives of this project are to:

1. Develop and reach consensus on cost-effective low-carbon energy sector (excluding Transport) mitigation options and pathways both on the supply and demand sides to determine the NDC target and pathway;
2. Recommend effective policies to implement the identified cost-effective low-carbon energy mitigation options to achieve the NDC target, and
3. Estimate the total costs and financing needs to achieve the NDC Unconditional and Conditional targets.

The technical approach, which is outlined in Figure 5, is fully in-line with these objectives, and has included:

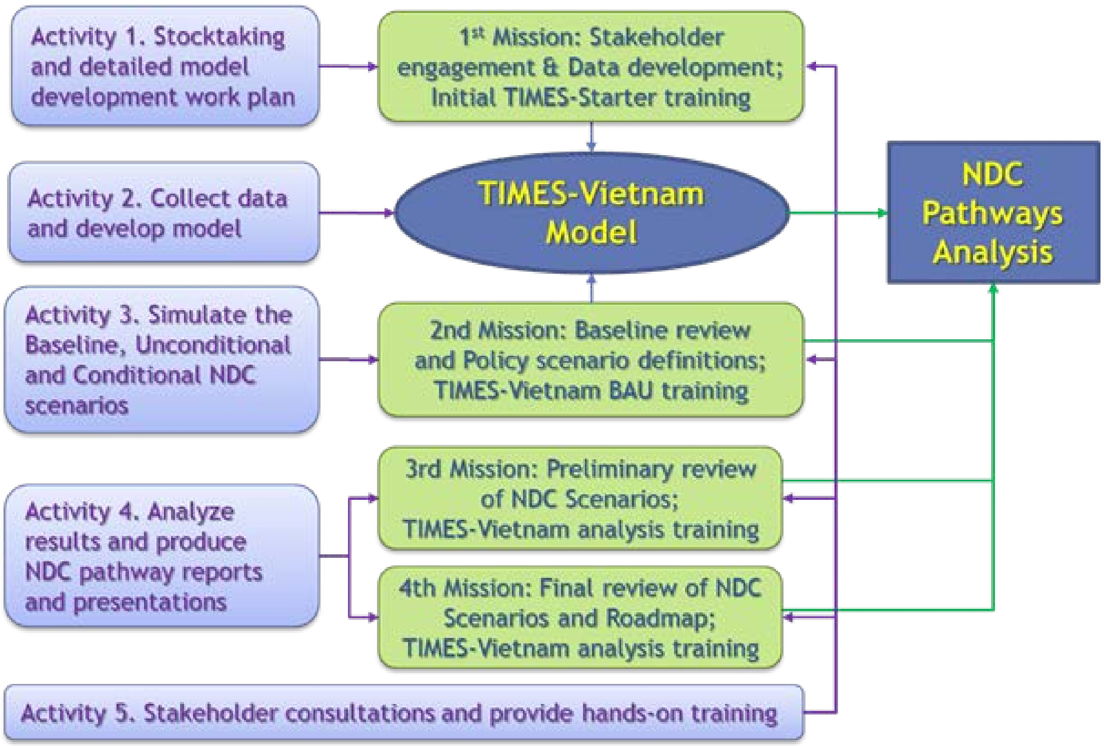
1. Developing a country-specific energy systems model based upon the TIMES-Starter platform with input parameters provided and/or validated by local experts thru Stakeholder engagement, and the formation of a Planning Team to participate in the model development process and takeover ongoing stewardship of the TIMES-Vietnam model;
2. Preparing a ***Business-as-usual (BAU) scenario,*** sometimes referred to as the Baseline (in particular as it relates to the associated emissions projection), based upon current trends and existing policies as of 2014;
3. Imposing on the BAU the ***Proposed*** energy sector mitigation policies and measures being prepared by the local experts and key stakeholders;
4. Developing a ***NDC Unconditional pathway*** to achieve the Unconditional NDC target with domestic resources; and
5. Developing a ***NDC Conditional pathway*** to achieve the Conditional NDC target with international resources and cooperation.

The BAU emission trajectory reflects that of the NDC where actions that took place between 2010 and 2014 with respect to economic growth, deployment of renewable electricity generation and energy efficiency policies in that timeframe are being considered early mitigation actions. In addition to various NDC emission reduction targets, key mitigation policies and measures were based on implementation of the RE targets in the revised Power Development Plan (PDP-7r) and the proposed Vietnam National Energy Efficiency Plan (VNEEP) to reduce final energy consumption 8-10 % below BAU from 2021 to 2030, along with specific mitigation measures in each demand sector.

3.2 Work Plan Overview

The work plan is organized into five (5) main Activities, supported by four (4) in-country missions, as set forth in Figure 5. The Inception Report presented the detailed work plan along with a summary of the issues and concerns discussed during the Inception Mission. The Baseline Review Mission and Report presented the BAU scenario, key data sources, data gaps and possible mitigation scenarios to be examined. The Preliminary Analysis Mission and Report demonstrated the model's technical readiness for the upcoming full NDC analysis, further identifying data issues needing to be resolved. The Final Analysis Review Mission presented the results of the NDC Pathway analysis, as contained herein.

Figure 5: Project Work Plan

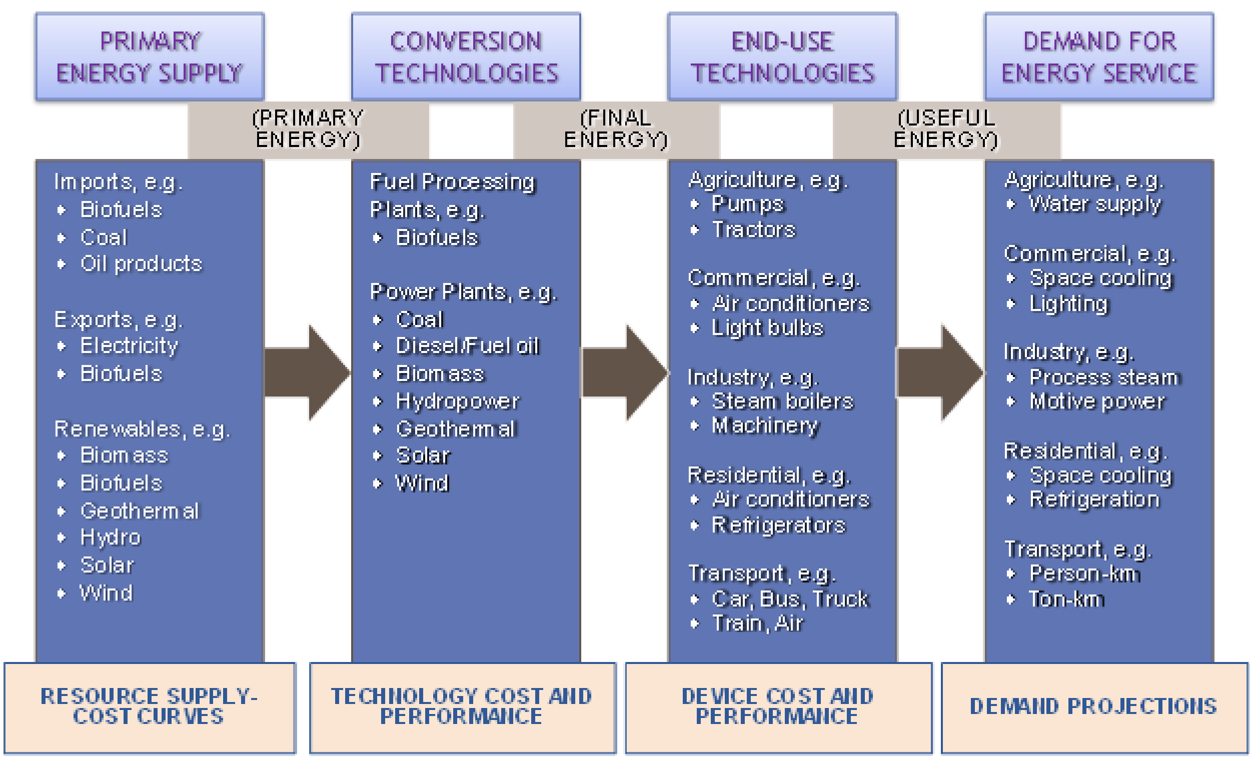


4 TIMES-Vietnam Model

4.1 TIMES-Vietnam Structure

The basic structure of the TIMES-Vietnam model is illustrated in Figure 6. Primary energy supplies in Vietnam consist of both domestic and imported fossil fuels and a variety of domestic renewable energy sources. These are characterized by cost-supply curves that define how much of each resource is available at a particular price. Power plants and fuel processing plants convert the primary energy sources into final energy carriers, such as electricity, refined oil products and pipeline quality natural gas that are used in the demand sectors. These plants are characterized by their investment and operating cost, efficiency other performance parameters, and emission rates. The model contains five main demand sectors: Agriculture, Commercial, Industry, Residential and Transportation. End-use devices specific to each of the demand sector are characterized by investment and operating cost, efficiency and operating parameters delivering end-use services (such as lighting, cooling, cooking, industrial process heat and motor drive, passenger and freight travel), along with the associated emissions. For most devices there are Existing, Standard, Improved, Better and Advanced options. The base year demands for useful energy services are calculated based on the existing device stock and the efficiency of that stock for each end use. Future demands for useful energy services are projected from these base year values in accordance with sector-specific drivers, such as GDP growth, GDP per capita growth, industrial production projections, space cooling growth expectations, etc.

Figure 6: TIMES-Vietnam Model Basic Building Blocks



TIMES-Vietnam solves for the least-cost energy system configuration that will meet the demand projections, 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 production and consumption of energy including fuel expenditures, investments in power plants, infrastructure, purchases of demand devices (other than vehicles, which for this analysis is handled within the context of the EFFECT modeling), and fixed/variable operating and maintenance costs associated with all technologies. In addition it may include policies such as carbon pricing instruments. The discount rate used for all sectors of the model is 10%, and all costs are discounted to 2015.

TIMES is the appropriate modelling framework given that the objective of the study is to develop NDC pathways in the entire energy sector (other than Transport). As a comprehensive full energy sector least-cost optimization model for long-term energy system planning, the power sector analysis in TIMES-Vietnam does not do hourly dispatch as power simulation and planning model would, but its representation of the variability in the power sector is robust enough for the long-term integrated energy planning. TIMES-Vietnam adequately captures the peak demand requirements arising from the simultaneous use of electricity across all the demand sectors for typical days in each season of the year as determined from analysis of a recent hourly load curve for the country. TIMES-Vietnam then balances the inclusion of cost-effective RE, taking into consideration its seasonal and time-of-day operational characteristics, to determine what role they can play and what is needed in terms of additional baseload and reserve capacity (often gas and/or storage). A dispatch model is needed when making individual plant decisions (e.g., location and grid integration), but for the purposes of NDC planning TIMES-Vietnam is an appropriate tool for the task at hand.

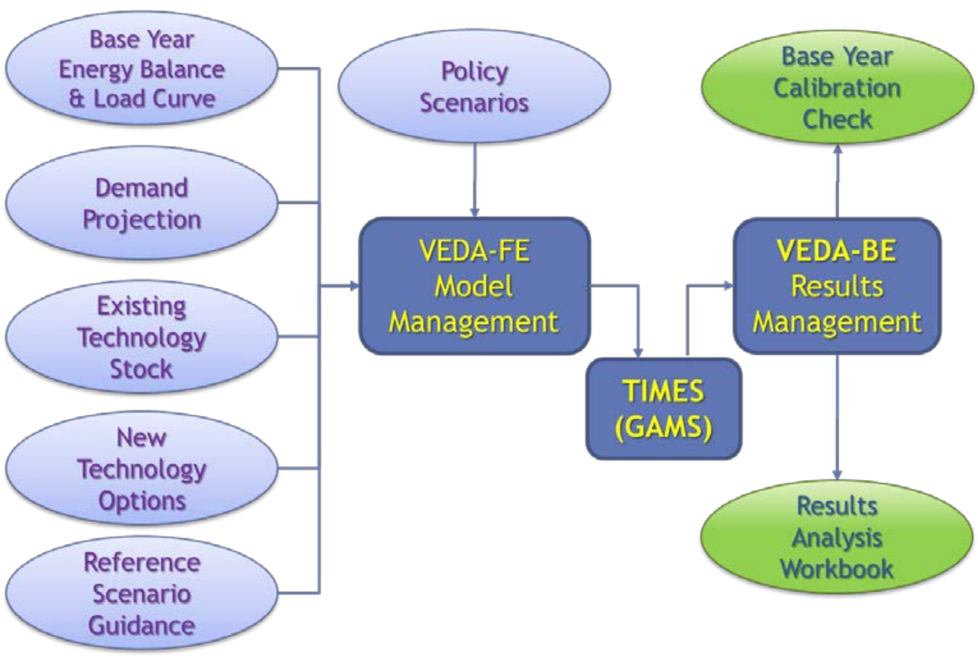
Figure 7 shows how the TIMES-Vietnam modeling platform is organized, consisting of various sector-based “Smart” Excel input workbooks and the model management system VEDA (comprising VEDA-FE (Front-End) and VEDA-BE (Back-End), as described below to oversee handling the model input and outputs respectively). The six categories of input templates are summarized here, and described in more detail in the Appendix A

- Energy Balance is the source of all energy supply and consumption data depicting the actual supply/transformation/consumption pattern (for 4 regions) in the 1st model year (2014);
- Resource supply provides costs and bounds for all domestic and imported resources;
- Base year templates for each sector contain characteristics of all existing power plants, refineries and demand devices, and establish the base year calibration which “seeds” the useful energy demand projection of each sector;
- Demand projections start with the Base Year useful energy demands (arising from the calibration of the 1st year of the model), and use the various demand drivers to calculate useful energy demands in future years;
- New technology templates for each sector contain the characteristics for new power plant and demand device options by end-use application, sub-sector, or mode;
- User constraints for each sector that guide the Baseline and policy scenarios limiting the allowed rates of fuel switching, new technology penetration, and device type shares, and

- Policy scenarios that change some Baseline model inputs and characterize how a policy scenario differs from the Baseline.

These templates are read by the VEDA-FE model management software and prepared as a linear programming problem that is solved for least-cost by GAMS, the modeling language in which TIMES is written. The TIMES-Vietnam optimized results are post-processed by VEDA-BE, which allows the development of customized sets and tables to enable the user to easily create dynamic pivot tables most useful for reviewing and analyzing model results. Finally, the DWG Results Analysis graphing workbook (AXLS) provides dynamic comparison of scenarios in graphs and tables ready for use in presentations and reports (including those appearing in this report).

Figure 7: Overall Structure of the TIMES-Vietnam Modeling Platform



4.2 TIMES-Vietnam Description

This section provides an overview of the TIMES-Vietnam model by examining the configuration of each sectors of the model as depicted in its Reference Energy System (RES) diagram. Each sector RES depicts the fuels and technologies (commodities and processes) that describe the Vietnam energy system in sufficient detail to properly model the intricacies and inter-dependencies that determine the TIMES-Vietnam model design. More details on the model design are included in Appendix A.

4.2.1 Primary Energy Supply

To properly represent the geography of Vietnam with respect to its three separate electricity transmission regions and the regional nature of fossil and renewable energy sources, TIMES-Vietnam was constructed with 3 supply/power regions (North, Central, South) exchanging energy and serving a single demand region (Vietnam). Data limitations necessitate that these 3-

regions serve a single overall Vietnam demand region, which is where all imports and exports also occur.

Figure 8: TIMES-VIETNAM Supply and Power Regions

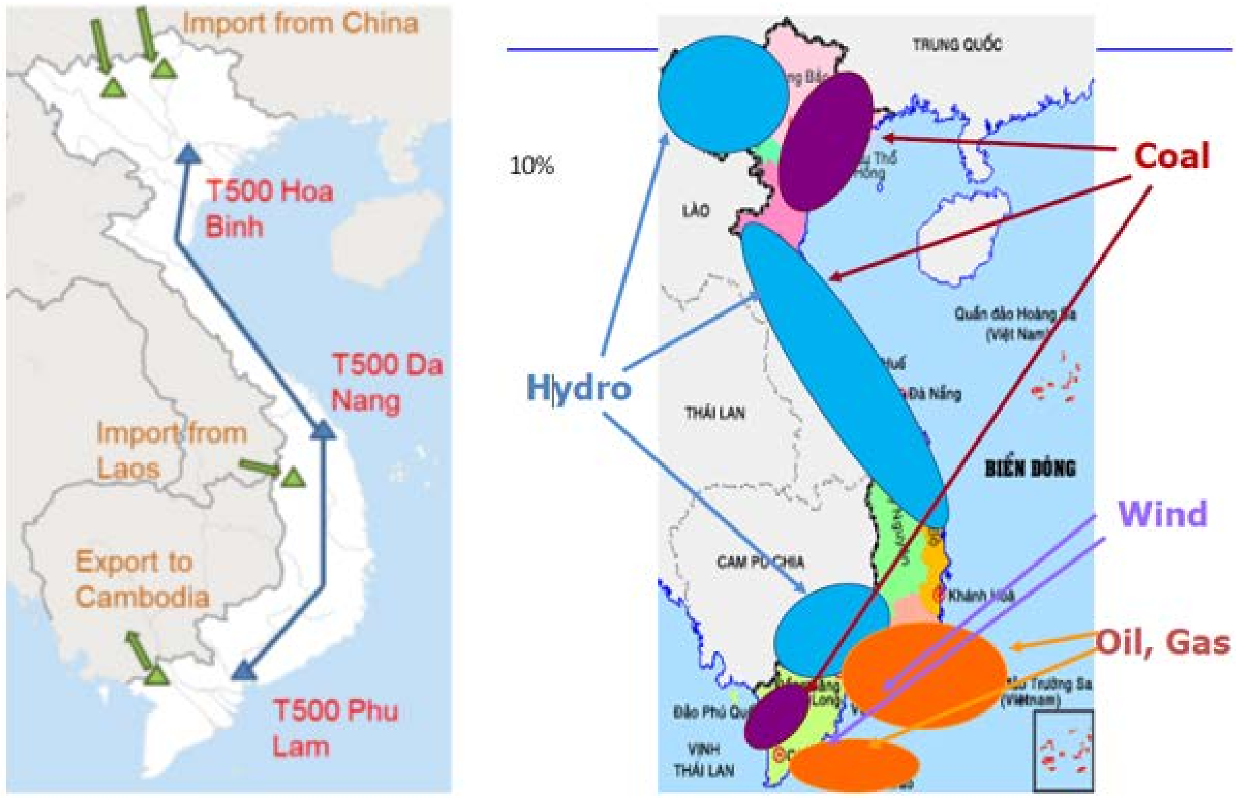


Figure 9 provides an overview of the Supply sector, where supply processes are defined in each of the three supply regions to characterize the current levels and future projected limits of domestic production, with the Vietnam demand region handling imports for coal, crude oil, diesel, gasoline, fuel oil, jet fuel, LPG, kerosene, and bioenergy, and exports of mainly coal and refined petroleum products. The resource limits for renewables (hydropower, solar, wind, and geothermal) are also included in the supply regions. Domestic fuels move from the three supply regions to the overall Vietnam demand region, while import move from the overall Vietnam region to the supply regions as needed. Biodiesel and biogasoline are modelled through blending processes to provide fuels that are compatible with the technology options.

Figure 9: RES Diagram for Primary Energy Supply

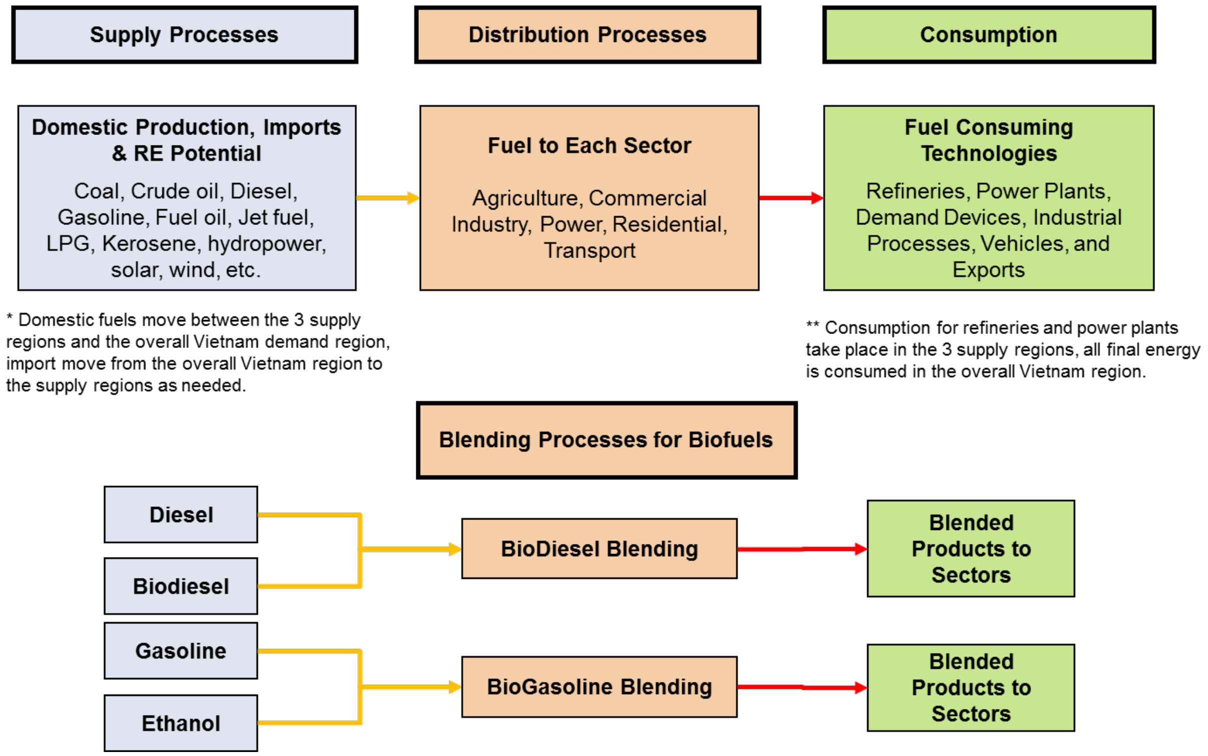


Figure 10 provides an overview of the existing and candidate (new) oil refineries in TIMES-Vietnam. Refineries have both crude oil, natural gas, and a small amount of electricity inputs and produce a similar slate of products. The full set of data characterizing the supply options can be found in Appendix B.4.

4.2.2 Electric Power Sector

Figure 11 provides an overview of the Electric Power sector with existing power plants using coal, natural gas, diesel, biomass, hydropower and wind. New power plant options include these types as well as solar and biofuels. Coal power plant types include conventional, supercritical an ultra-supercritical technology types along with co-firing with biomass. Hydropower plants are classified as very large, large, medium and small. Wind power plants come in six varieties depending on wind resource and distance from the transmission grid, and solar power plants are characterized as central or distributed (no T&D losses) in Commercial and Residential configurations. Transmission grid losses are captured in the electricity grid process, and the distribution system losses, and sector cost differentials, are captured in the distribution process to each sector. The full set of data characterizing both existing and new power plants can be found in Appendix B.5.

Figure 10: Oil Refineries RES

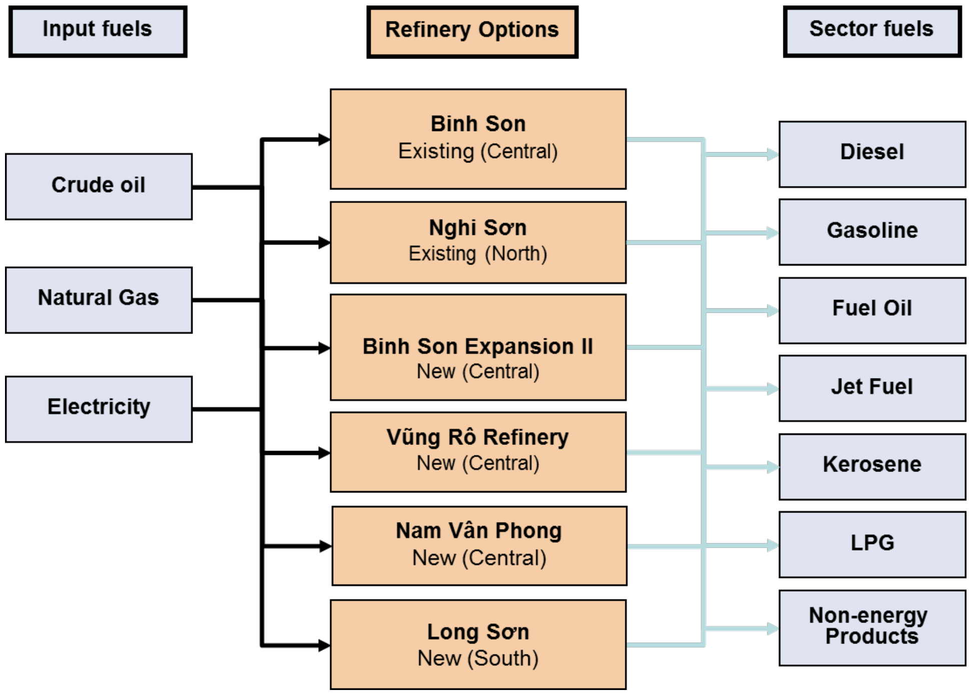
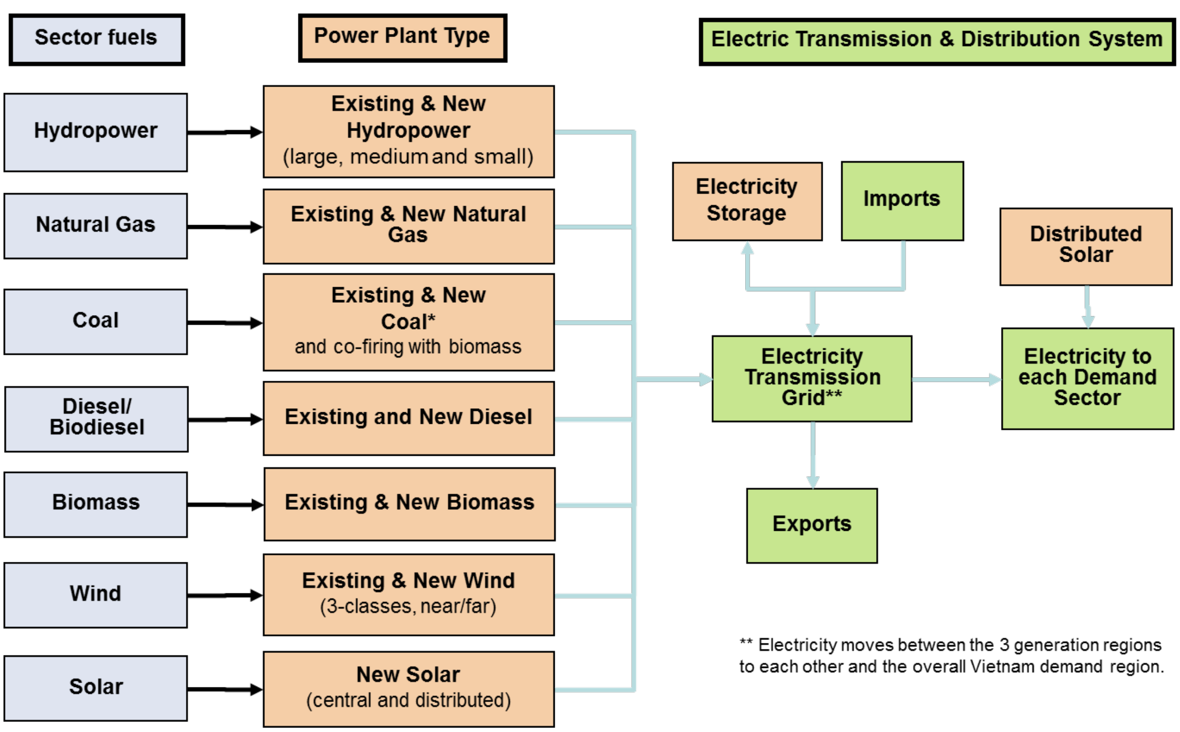


Figure 11: Electric Power Sector RES

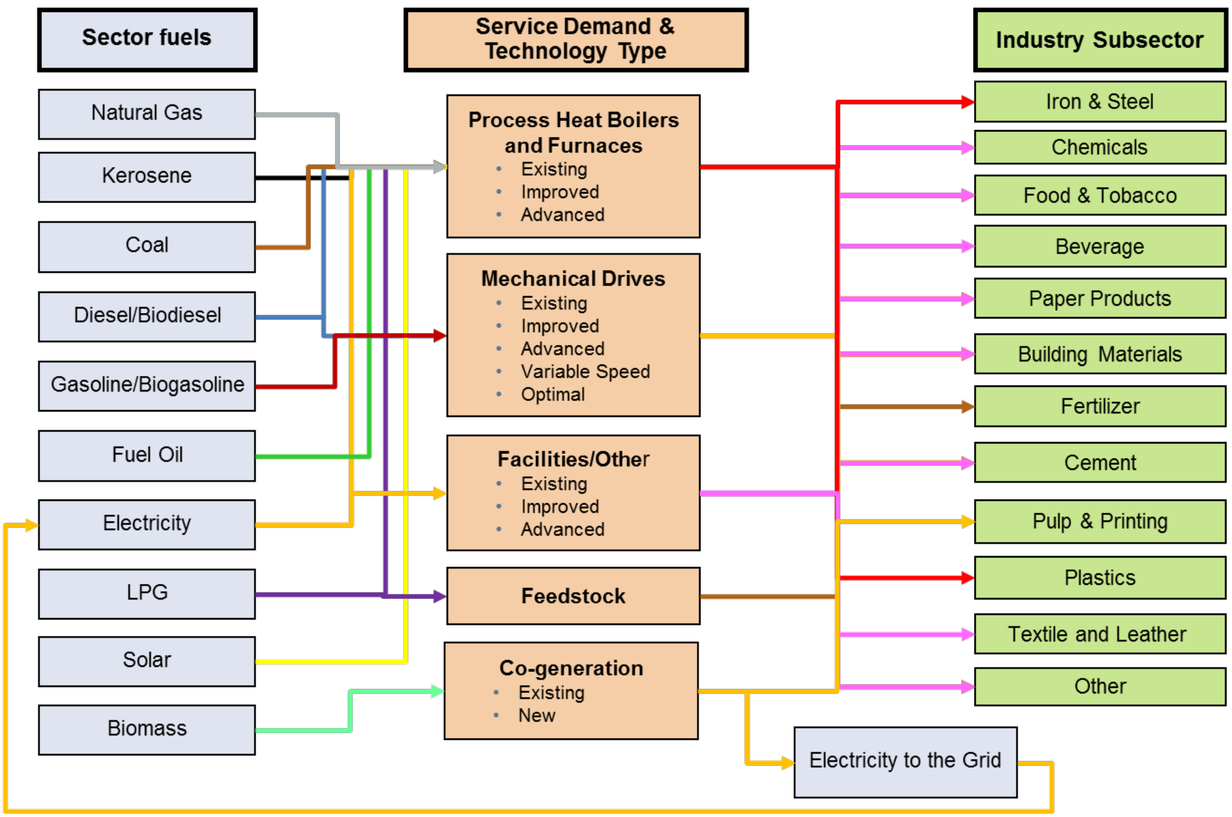


* A small amount of Fuel Oil is used to start the coal plants.

4.2.3 Industry Sector

Figure 12 provides an overview of the Industry sector, which consists of 12 product-based sub-sectors. Each subsector has four basic service demands: process heat, mechanical drive, facilities/other and feedstocks, and each service demand can be supplied by a variety of existing and new technologies. Cogeneration options are also available in all subsectors to reduce final energy use by generating electricity and using waste heat to supply process heat demands. The set of data characterizing the various Industry technologies can be found in Appendix B.6, Table 107, and the drivers for the demand projections in Appendix B.9.

Figure 12: Industry Sector RES



The structure in Figure 12 accounts well for improvements in equipment efficiency, but additional modeling is needed to include possible industrial process improvements, which reduce the levels of process heat and machine drive needed to produce a unit of production, but require investment. Benchmarking studies and audit reports for industry subsectors such as cement, iron and steel, pulp and paper, and other subsectors were analysed according to 15 subsectors to determine the investment costs and the reduction levels of electricity and thermal energy used for process heat, machine drive, and facility/other demand services achieved by each measure. These includes measures such as vertical roller mills or dry kilns with multistage pre-heaters for cement manufacturing, furnace improvements and rolling process improvements for iron and steel manufacturing, and specific measures from almost 150 companies for the other subsectors. The unit investment cost was deterimined for each measure and a weighted cost for each demand service was determined for each subsector by aggregating the individual measures, as shown in Table 17. In addition, the energy savings for each individual measure was also aggregated as a fraction of the total service demad for that subsector, as shown in Table 18. As a result, TIMES-Vietnam can choose to invest in process improvement measures up to the limit imposed by the savings potential. The set of data characterizing the various Industry process improvements can be found in Appendix B.6, Table 107 and Table 108.

Table 17: Industry Process Improvement Investment Costs ($M/PJ)

Subsector	ELC Motor Drive	ELC Facility/Other	ELC Process Heat	Thermal Facility/Other	Thermal Process Heat
Iron and Steel	13.03	18.79	1.11	4.20	2.81
Chemicals	23.77	8.32	2.77	2.48	4.67
Fertilizer	15.99	8.57	-	-	-
Cement	16.31	33.46	46.57	0.06	4.04
Beverage	7.01	42.15	5.55	4.88	10.68
Plastics	34.66	26.67	6.43	1.92	1.53
Food and Tobacco	20.77	26.20	10.73	10.14	11.36
Paper Products	16.49	19.61	-	0.09	2.30
Pulp and Printing	19.49	25.23	7.11	-	17.13
Building Materials	18.12	20.51	-	3.69	1.97
Textile and Leather	20.55	21.58	0.80	0.23	7.48
Other	10.39	14.29	2.87	7.03	20.72

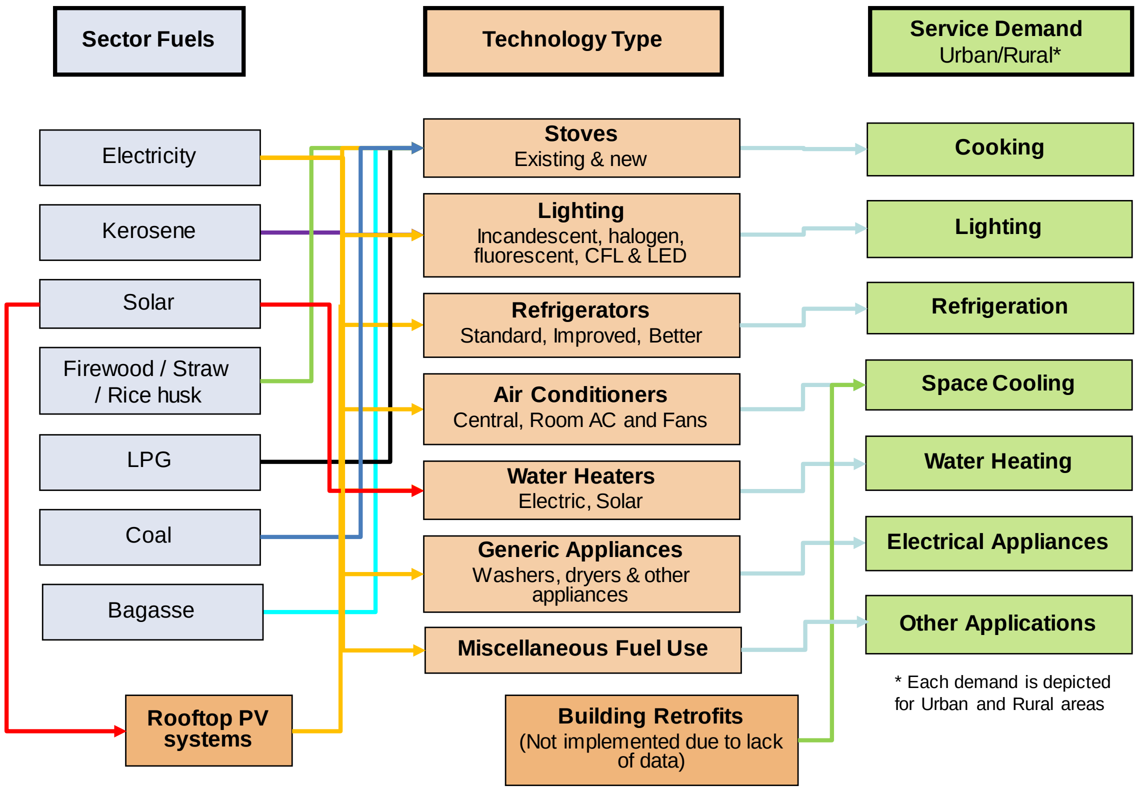
Table 18: Industry Process Improvement Savings Potential (% of total demand)

Subsector	ELC Motor Drive	ELC Facility/Other	ELC Process Heat	Thermal Facility/Other	Thermal Process Heat
Iron and Steel	47.3%	1.9%	11.9%	0.4%	18.8%
Chemicals	9.0%	2.4%	7.1%	1.4%	8.8%
Fertilizer	1.3%	2.6%	0.0%	0.0%	0.0%
Cement	13.6%	3.0%	22.1%	7.7%	4.1%
Beverage	5.1%	11.2%	2.1%	12.7%	14.9%
Plastics	27.7%	20.8%	17.7%	7.4%	8.8%
Food and Tobacco	17.0%	14.2%	4.9%	10.8%	14.4%
Paper Products	18.2%	0.9%	0.0%	5.1%	11.0%
Pulp and Printing	1.3%	14.1%	0.1%	0.0%	5.6%
Building Materials	21.4%	6.2%	0.0%	12.4%	2.4%
Textile and Leather	20.5%	13.0%	23.7%	1.0%	10.8%
Other	19.8%	18.9%	3.2%	12.6%	13.0%

4.2.4 Residential Sector

Figure 13 provides an overview of the Residential sector, which has seven service demands and eight technology types, including roof top PV systems. The full set of data characterizing Residential demand devices can be found in Appendix B.8, and the drivers for the demand projections in Appendix B.9. The model has the capability to include technologies for building efficiency retrofits and green new buildings, but these have not been implemented due to lack of data.

Figure 13: Residential Sector RES



4.2.5 Commercial Sector

Figure 14 provides an overview of the Commercial sector, which has seven service demands and nine technology types, including standby generators and commercial size PV systems. The full set of data characterizing Commercial demand devices can be found in Appendix B.7 and the drivers for the demand projections in Appendix B.9. The model has the capability to include technologies for building efficiency retrofits and green new buildings, but these have not been implemented due to lack of data.

4.2.6 Agriculture/Fishing Sector

Figure 15 provides an overview of the Agriculture/Fishing Sector, which has four service demands supplied by three groups of technology types. The Fishing sector energy demands are included in the Other services.

Figure 14 Commercial Sector RES

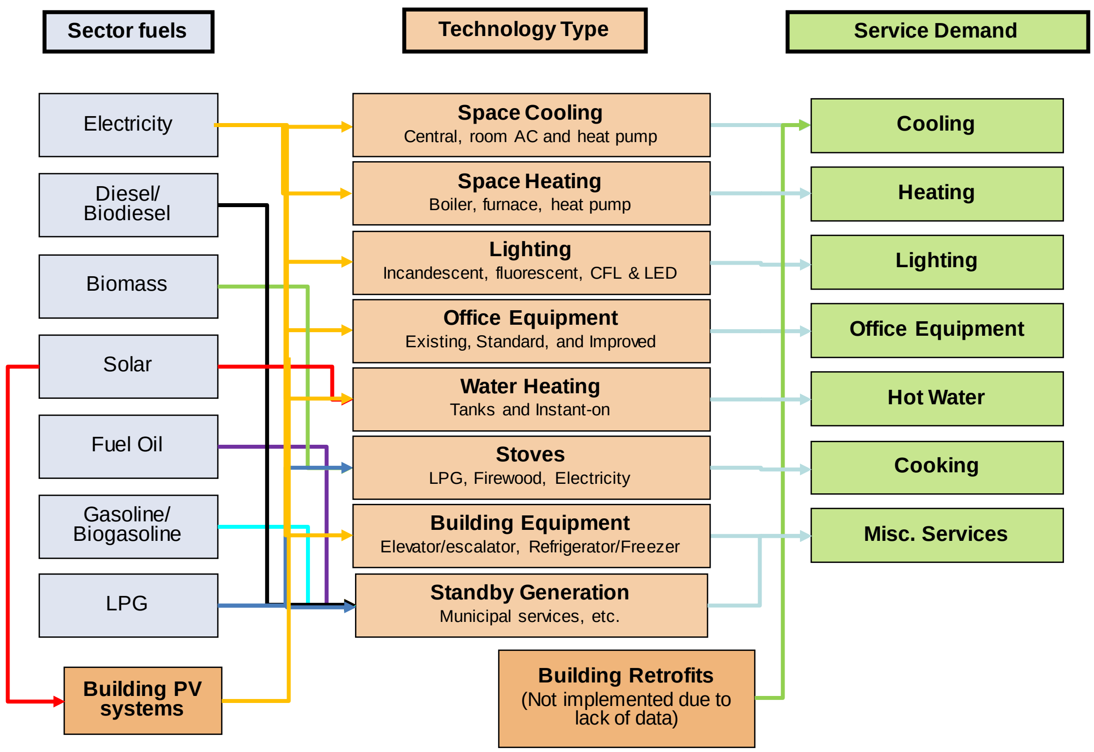
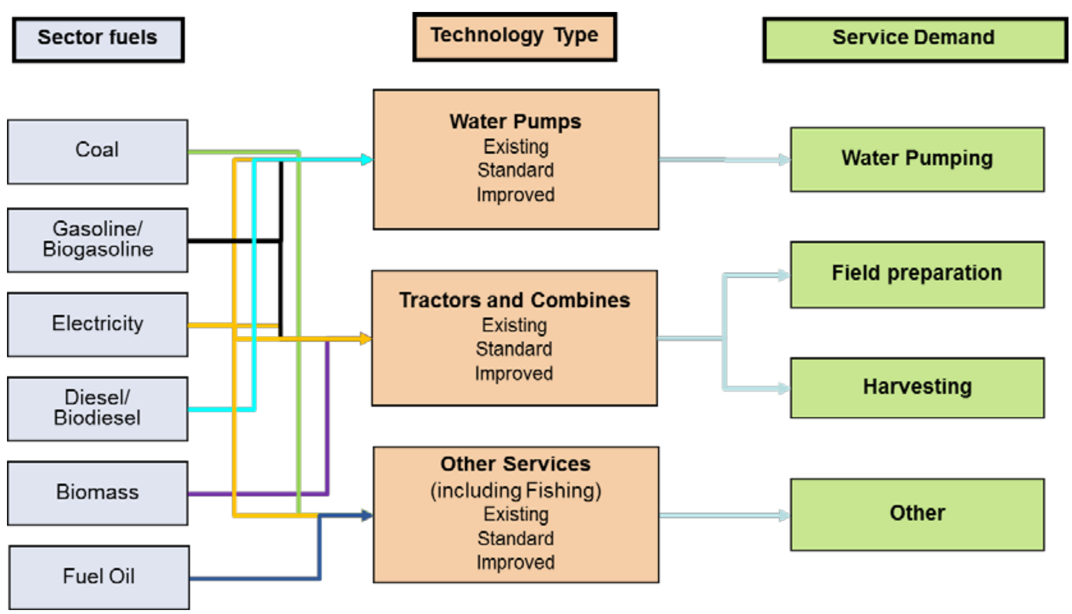


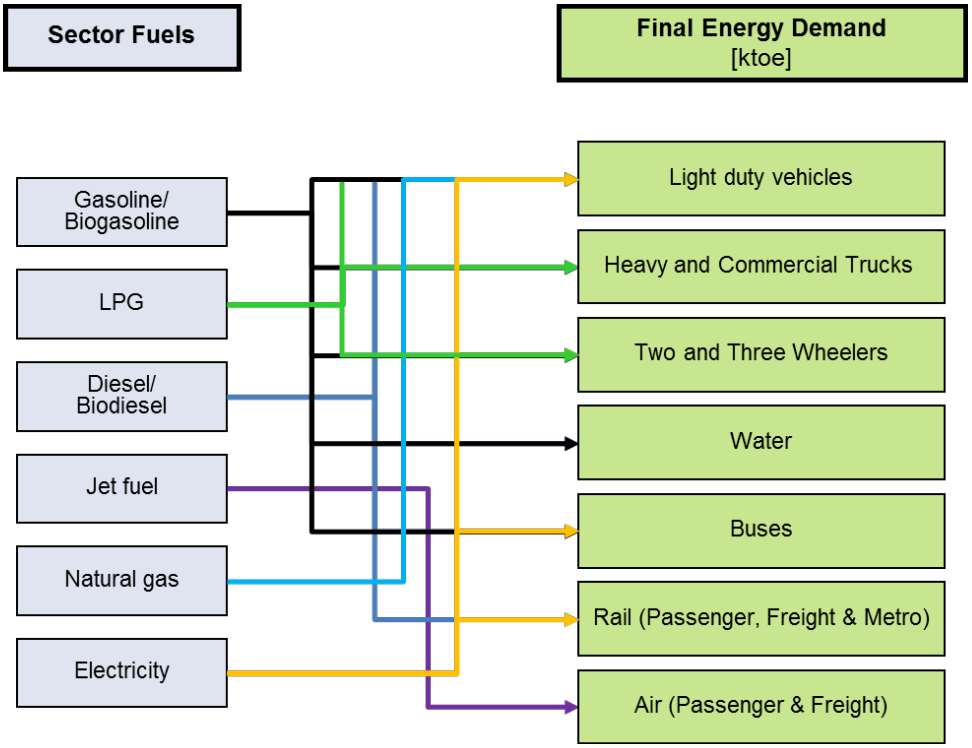
Figure 15: Agriculture/Fishing Sector RES



4.2.7 Transport Sector

The Transport sector is modelled somewhat differently the other demand sectors because of the decision to use results of the study conducted for the Ministry of Transport by the World Bank/GIZ EFFECT team. The results from that study were simulated in TIMES-Vietnam by imposing the transport sector final energy requirements from EFFECT, which ensures that these energy supply requirements are incorporated into the optimization of the remainder of the energy system. Figure 16 provides an overview of the sector fuels and final energy demands provided in the EFFECT results.

Figure 16: Simulation of EFFECT Transport Sector Results



4.2.8 Demand Projections

TIMES-Vietnam 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 Transportation represent the economic and demographic development of the country over time, and drive the model. The future demand for energy services are calculated by extrapolating the base year value from the energy balance according to appropriate drivers of service demand growth for each sector and end-use category out over the planning horizon. The primary demand drivers are provided in Appendix A.6.

4.3 TIMES-Vietnam Database

Details of the TIMES-Vietnam databases are provided in Appendix A, while the data sources used to populate the model input assumptions are described in Appendix B. The data includes:

- Resource supply/import prices and annual limits (if appropriate);
- Refinery costs, efficiency and product output flexibility;
- Power plant costs, efficiency, availability (by time slice for variable RE);
- Demand projections with the underlying drivers, and
- Demand device costs, efficiency and other performance factors.

5 Business-as-Usual Scenario

5.1 Base Year Calibration

Although the base year for the NDC-2 process is 2010, the base year of the TIMES-Vietnam model was selected to be 2014. The rationale for this decision is that the period from 2010-2014 is historical, and thereby is not subject to any decision-making/optimization, and there is a more recent and accurate energy balance along with other data available for 2014. In order to conform to the 2010 base year requirement for full GHG accounting credit, the mitigation actions between 2010 and 2014 are reflected in the Baseline scenario using two mechanisms. The wind, solar and small hydropower additions in this period are excluded from the Baseline (BAU) scenario, and the avoided emissions arising from energy efficiency actions from 2010 to 2014 are added to the TIMES-Vietnam baseline GHG emissions out to 2030. The 2010 to 2014 levels of wind, solar and small hydropower are then included in the NDC mitigation runs and the EE related avoided emissions no longer included. The difference between the BAU (2010) emissions trajectory and the TIMES-Vietnam (2014) Baseline emission trajectory are shown in Table 19.

Table 19: Adjustment to 2014 TIMES-Vietnam Baseline GHG Emissions

Period	BAU (2010)	BAU (2014)	2010-2014 EE Credits
2010	134,848	134,848	0
2014	159,961	161,603	1,642
2020	318,589	322,693	4,104
2025	451,757	458,023	6,266
2030	634,386	644,386	10,000

5.2 BAU Comparison to NDC-2

As shown in Table 20, total electricity generation in TIMES-Vietnam is within 0.1% of the amount in the NDC-2 report, matching the projected gas-fired generation and within 1.2% of the expected coal generation.

Table 20: NDC-2 and TIMES-Vietnam Baseline Electricity Generation Comparison (TWh)

Electric Generation	NDC-2 report		TIMES-Vietnam	
	2020	2030	2020	2030
Large & medium hydropower	66.8	70.9	72.5	75.7
Coal power	144.6	394.8	147.9	389.3
Gas power	44.0	96.1	44.0	96.1
RE (small hydropower)	3.3	3.3	3.3	3.3
Imports	6.4	6.9	6.8	6.9
Total	**265.0**	**572.0**	**274.5**	**571.3**

Table 21 shows that total electricity consumption in 2030 is about 1.8% lower in TIMES-Vietnam compared to the NDC-2 report in 2030, but is slightly higher in 2020 and 2025.

Table 21: NDC-2 and TIMES-Vietnam Baseline Electricity Consumption Comparison (TWh)

Electricity Consumption	NDC-2 Report			TIMES-Vietnam		
	2020	**2025**	**2030**	**2020**	**2025**	**2030**
Agriculture	2.6	3.3	3.9	2.6	3.3	4.0
Commercial + Other	23.12	32.7	53.3	23.2	33.7	49.1
Industry	132.8	218.0	327.1	153.6	229.3	318.7
Residential	82.0	111.6	146.7	71.0	104.6	150.8
Total	**240.5**	**365.7**	**531.1**	**250.6**	**371.1**	**522.9**

Table 22 compares the TIMES-Vietnam Baseline GHG emissions to the NDC-2 emissions, which overall are less than 1% lower. Important sectoral differences are explained, such as the TIMES-Vietnam Agriculture sector includes Fishing energy use and its Commercial includes Other from NDC-2 report. The largest differences in the comparison are for Crude Oil exploitation, where the TIMES-Vietnam emissions follow the domestic production limits developed by VIE which decline starting in 2025, while the NDC-2 data has these emissions growing through 2030 owing to increased levels of domestic production.

Table 22: NDC-2 and TIMES-Vietnam Baseline GHG Emissions Comparison (kt CO2 eq)

GHG Emissions	NDC-2			TIMES-Vietnam		
	2020	**2025**	**2030**	**2020**	**2025**	**2030**
Agriculture	1,642	1,673	1,667	5,368	6,213	7,338
Commercial	5,493	7,280	9,831	4,941	6,452	7,901
Industry	66,916	79,047	92,044	72,110	90,032	111,429
Power Sector	154,129	254,154	398,581	169,680	274,853	396,964
Residential	10,561	10,027	9,447	9,149	10,457	10,850
Supply	34,510	39,129	42,915	26,489	27,652	24,710
Transport	47,283	64,777	88,745	41,313	56,535	77,349
Total	**320,534**	**456,086**	**643,230**	**329,051**	**472,194**	**636,542**

5.3 Primary Energy Supply

5.3.1 Domestic & Imported Resources

As shown in Figure 17, the total primary energy grows by 161% lead by coal, electricity and oil products. However, domestic supplies increase to about 70,000 ktoe in 2022 thru 2025 and then decline to have an overall 4% increase by 2030. Figure 18 shows that domestic production of coal and biofuels grow, but natural gas production only grows until 2025 and then declines, and crude oil production peaks in 2022 and then declines. Figure 19 shows that imports increased by over 900%, led by the steady and significant growth in imported coal, crude oil, and refined oil products. Natural gas imports are minimal in the BAU.

Figure 17: Baseline – Total Primary Energy Supply

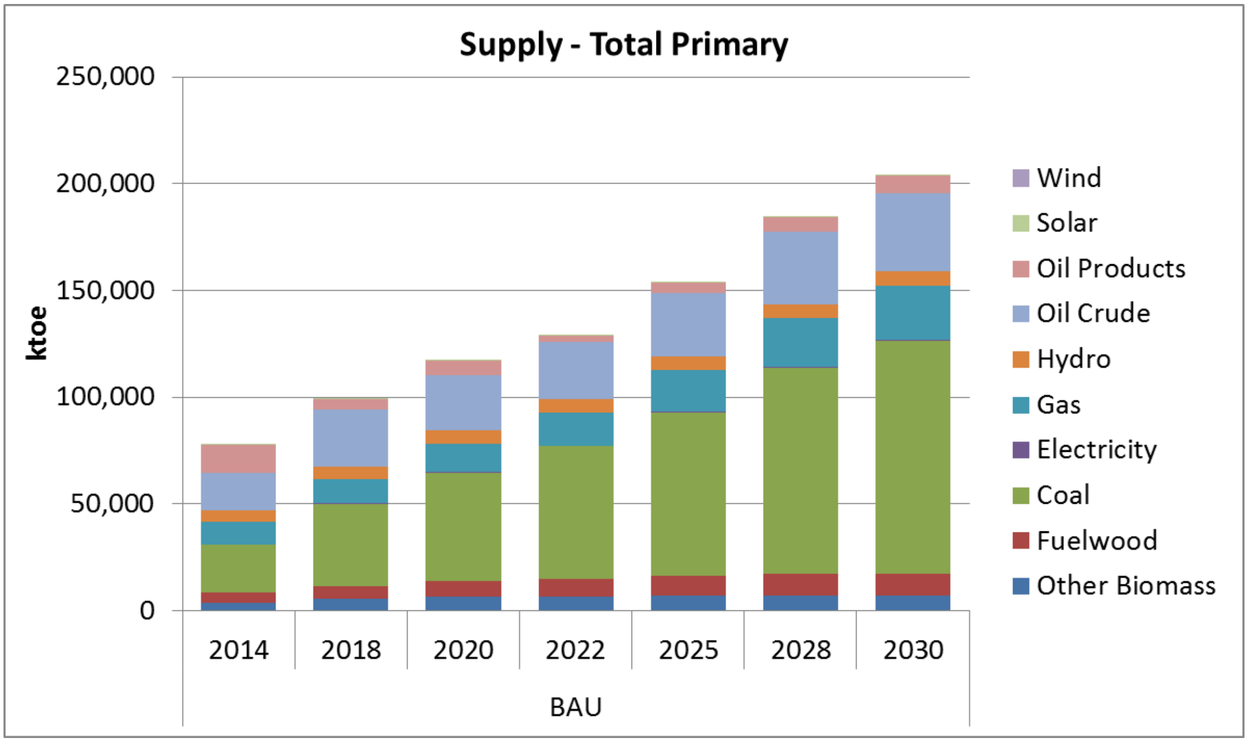


Figure 18: Baseline - Domestic Primary Energy

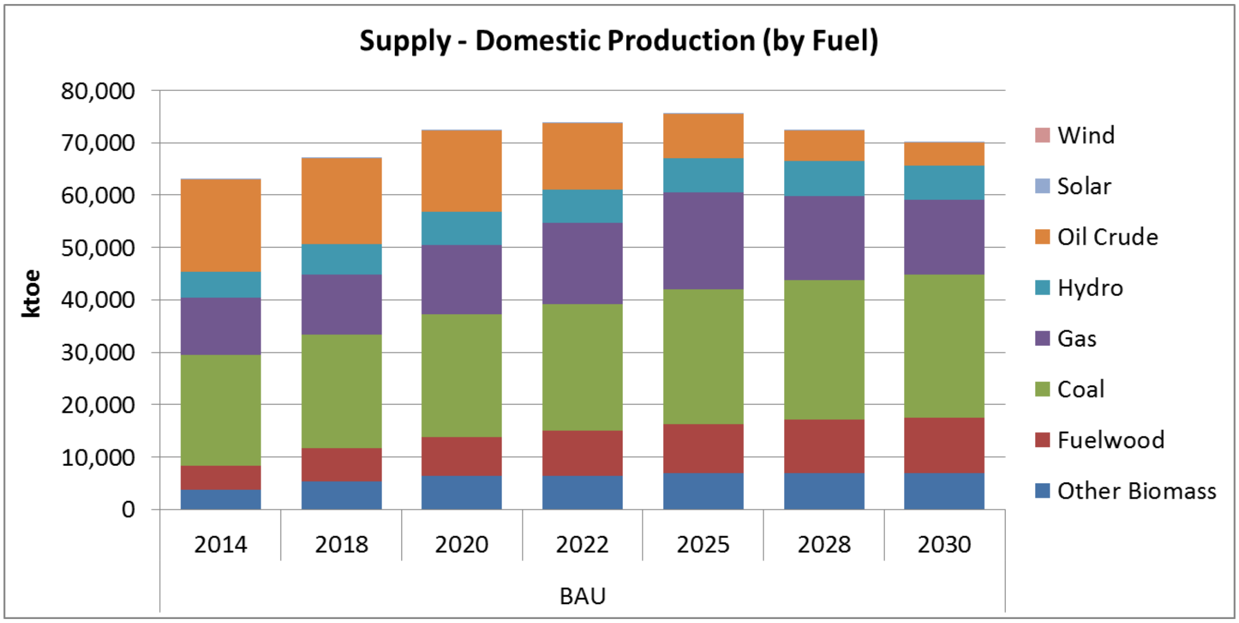
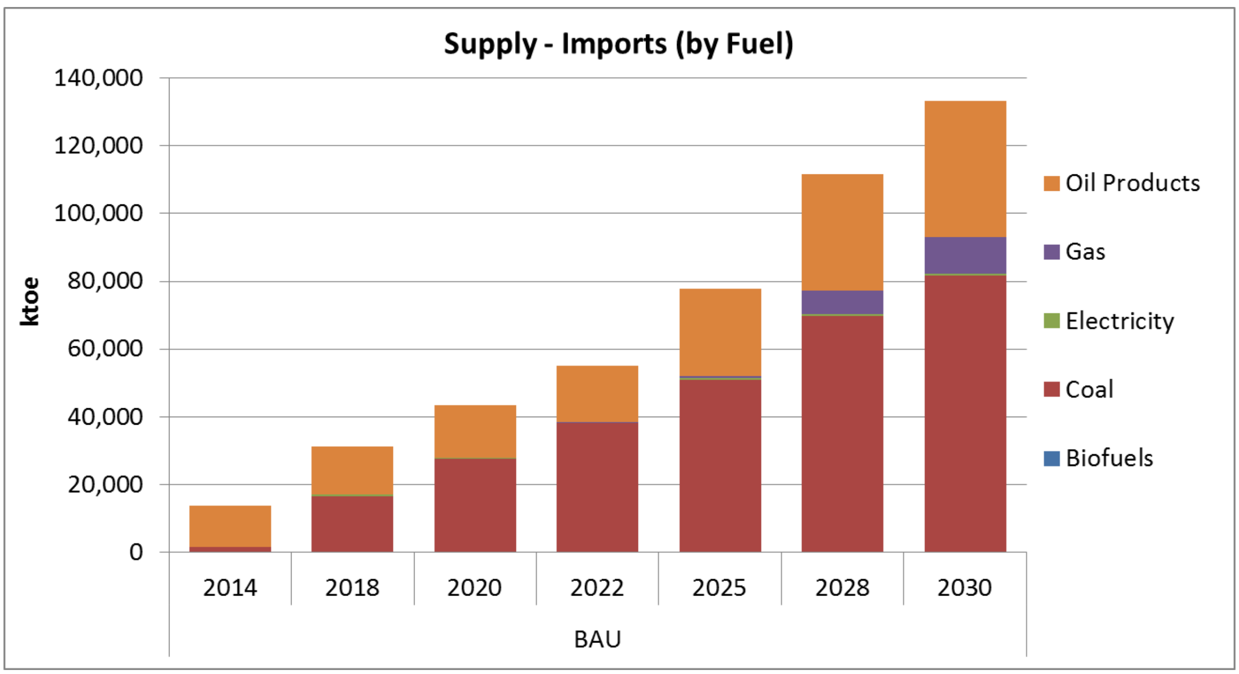


Figure 19: Baseline – Imported Primary Energy



5.3.2 Oil Refineries

Figure 20 shows that the existing refinery continues to use domestic crude, while crude oil imports start in 2018 with the initial operation of the Nghi Son refinery. As Figure 21 shows, the model prefers building new refineries compared to importing refined oil products, as all the known refinery options are implemented before 2030. This choice is based on the life-cycle economics between the two options, and does not account for global competitive pressures that might make financing new refineries difficult. However, the demand for refined oil products, and the resulting impact on GHG emissions will be minimally affected by this choice, so this has been kept in the Baseline. Figure 22 shows the product slate from the refineries, which is dominated by diesel and gasoline.

Figure 20: Refinery Inputs

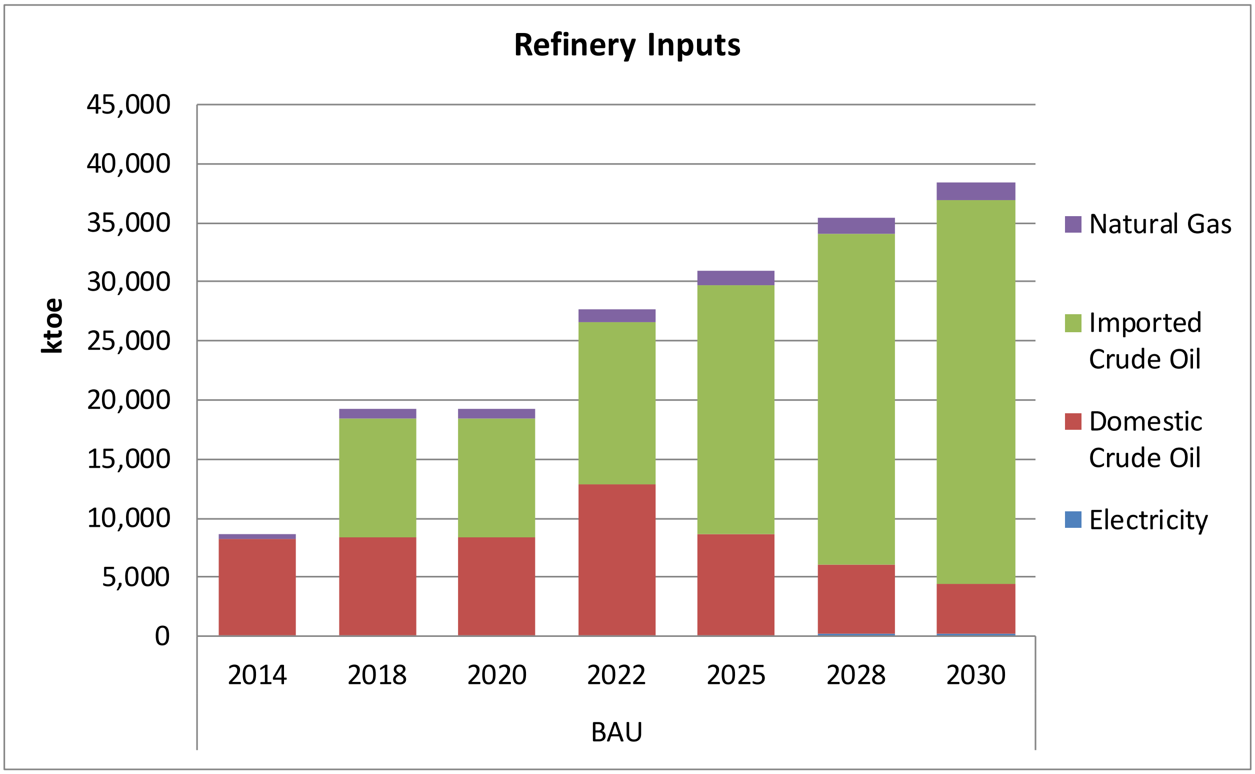


Figure 21: Refinery Operation

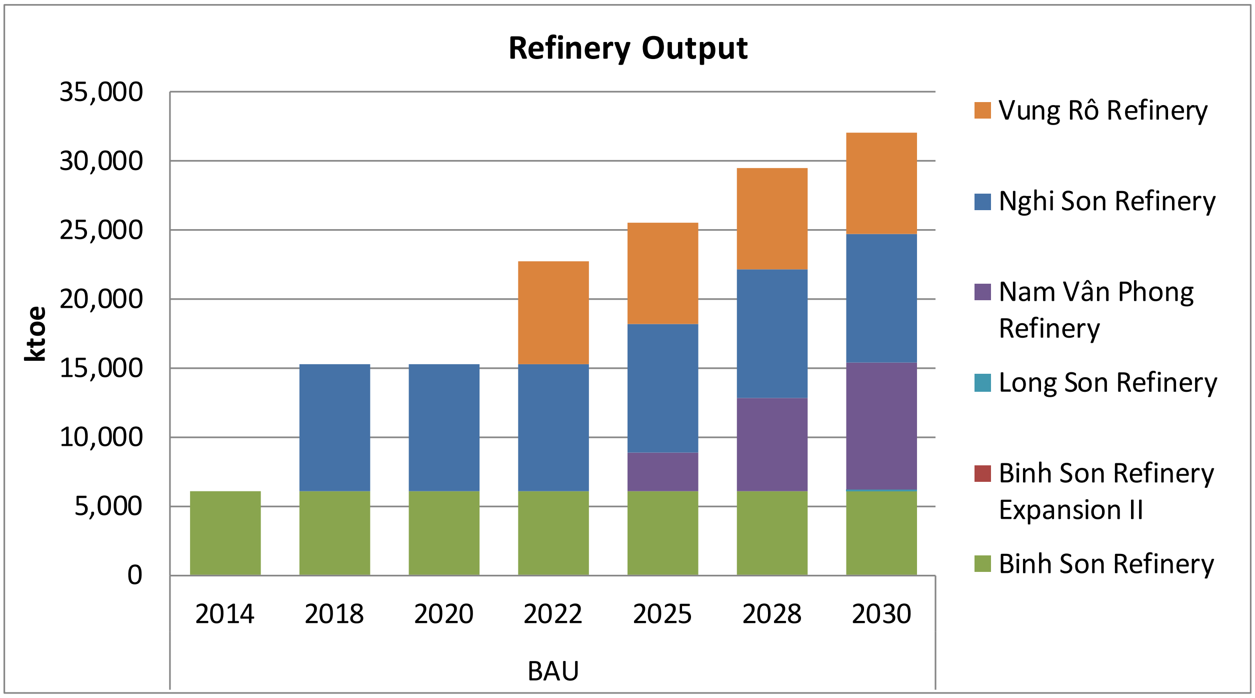
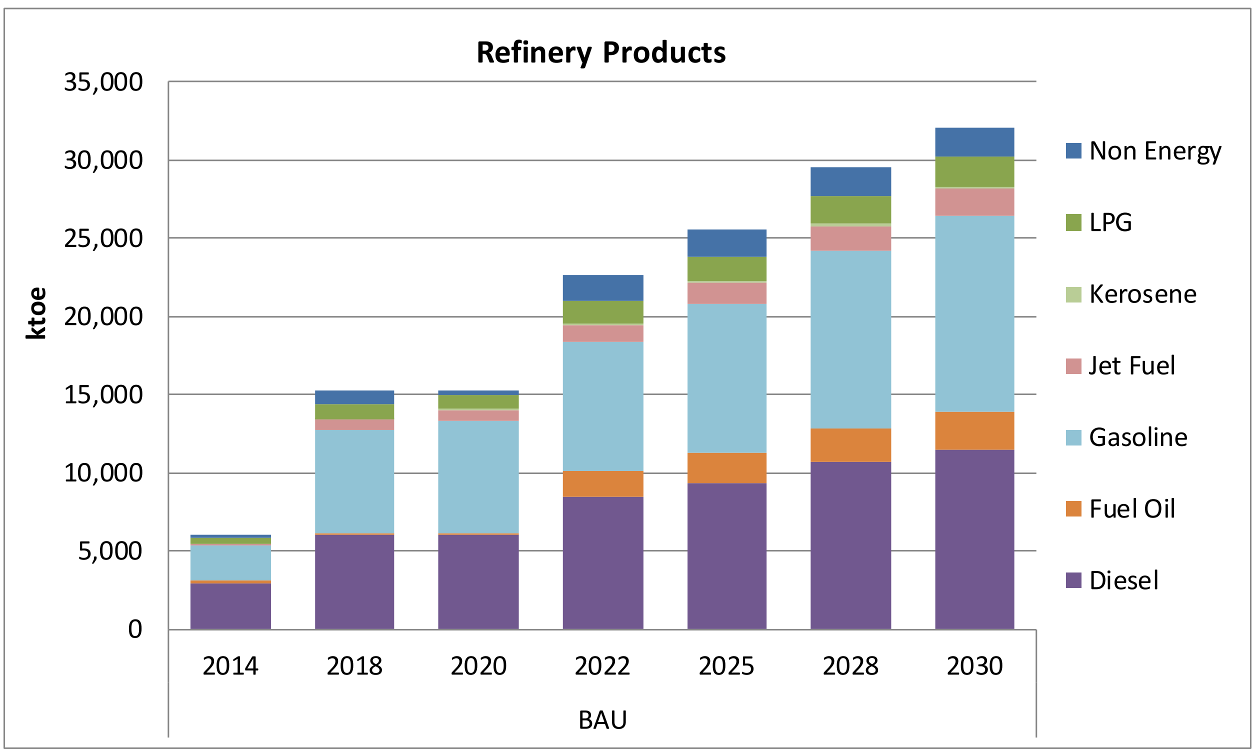


Figure 22: Refinery Product Slate



5.4 Power Sector

As shown in Figure 23, electricity generation in the Baseline scenario increases by 304% between 2014 and 2030, and the 2030 generation mix is dominated by coal-fired power plants (68.3%), with significant contributions from natural gas (16.8%) and hydropower (13.6%). Figure 24 shows that total power plant capacity also grows significantly, with 2030 plant configuration of coal (49.8%) and natural gas (31.2%) plants growing faster than hydropower (18%), which has limited additional potential in the country. Figure 25 shows the timing of new power plant builds under the Baseline scenario. New builds start in 2018 and consist of 39 GW of coal and 44 GW of gas-fired generation by 2030. Note that under the BAU assumptions renewables are kept at the limited level in the MONRE NDC-2 report, and 14.3 GW of new coal power plants are planned for implementation by 2023. By 2030 total installed capacity reach 103.2GW, with a 25% peak reserve margin imposed.

Figure 23: Baseline Electricity Generation

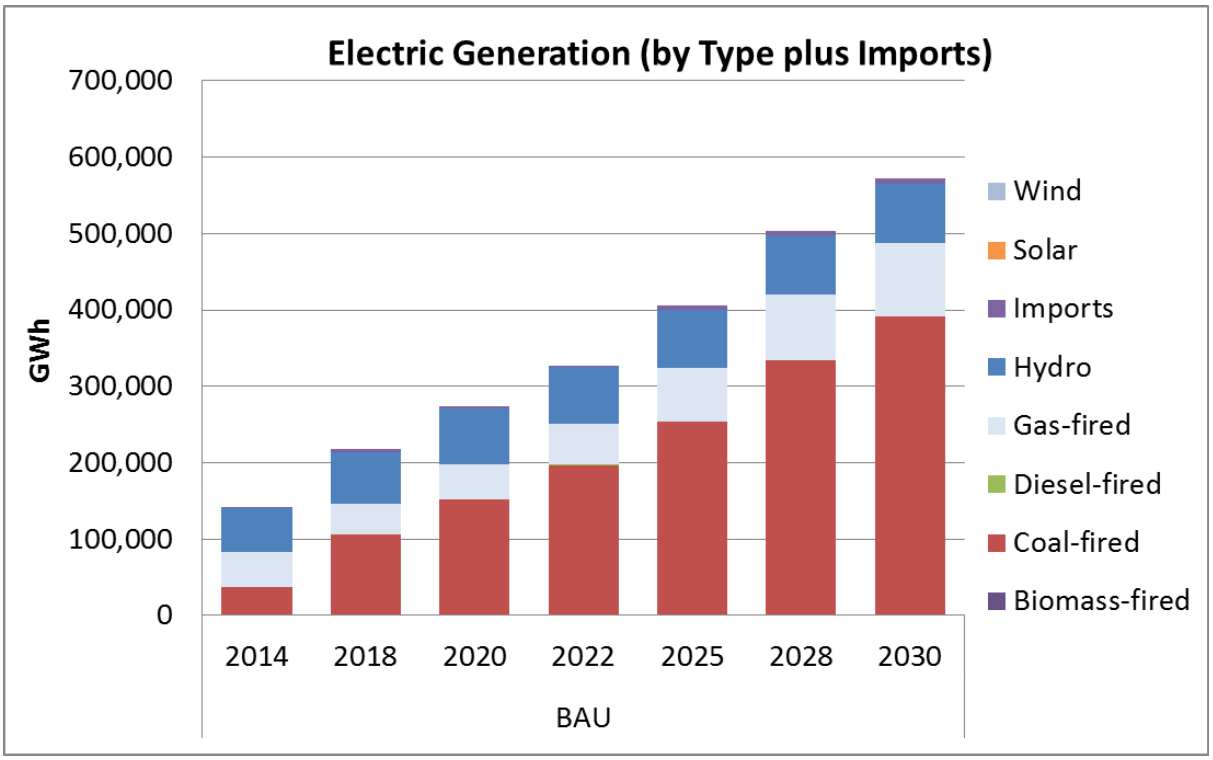


Figure 24: Baseline Electric Power Plant Capacity

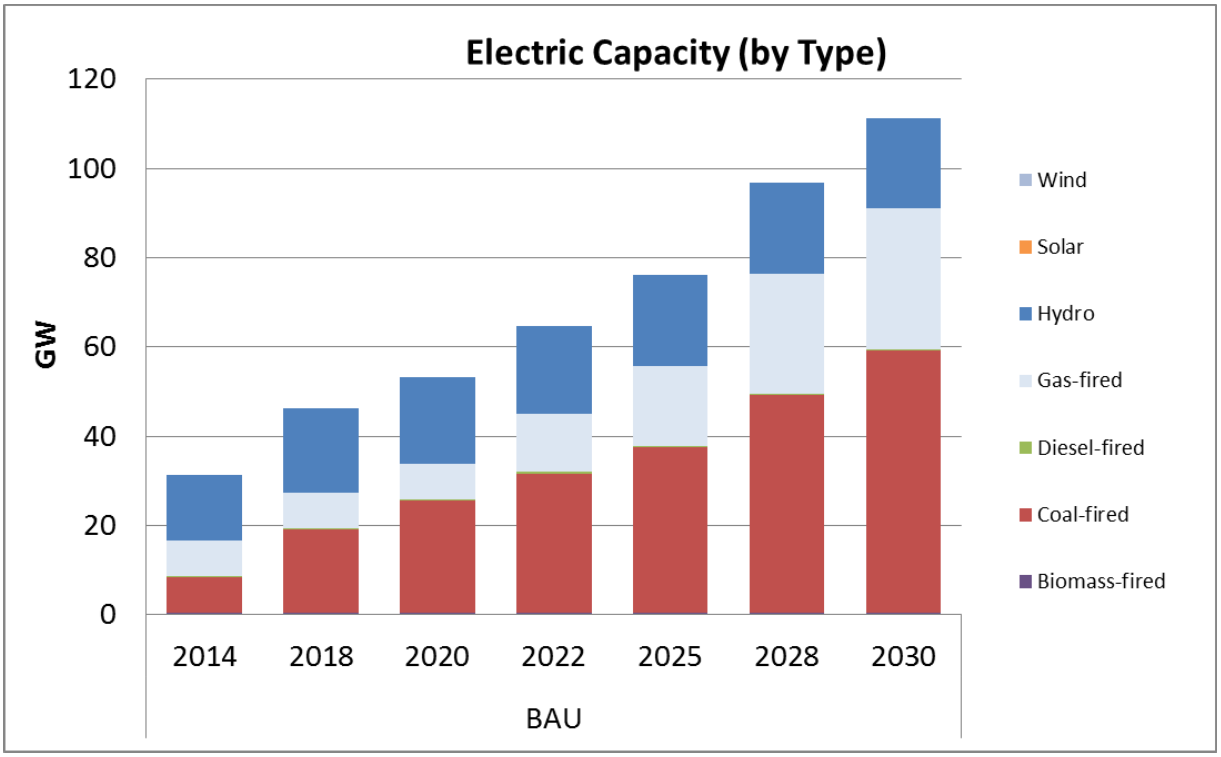
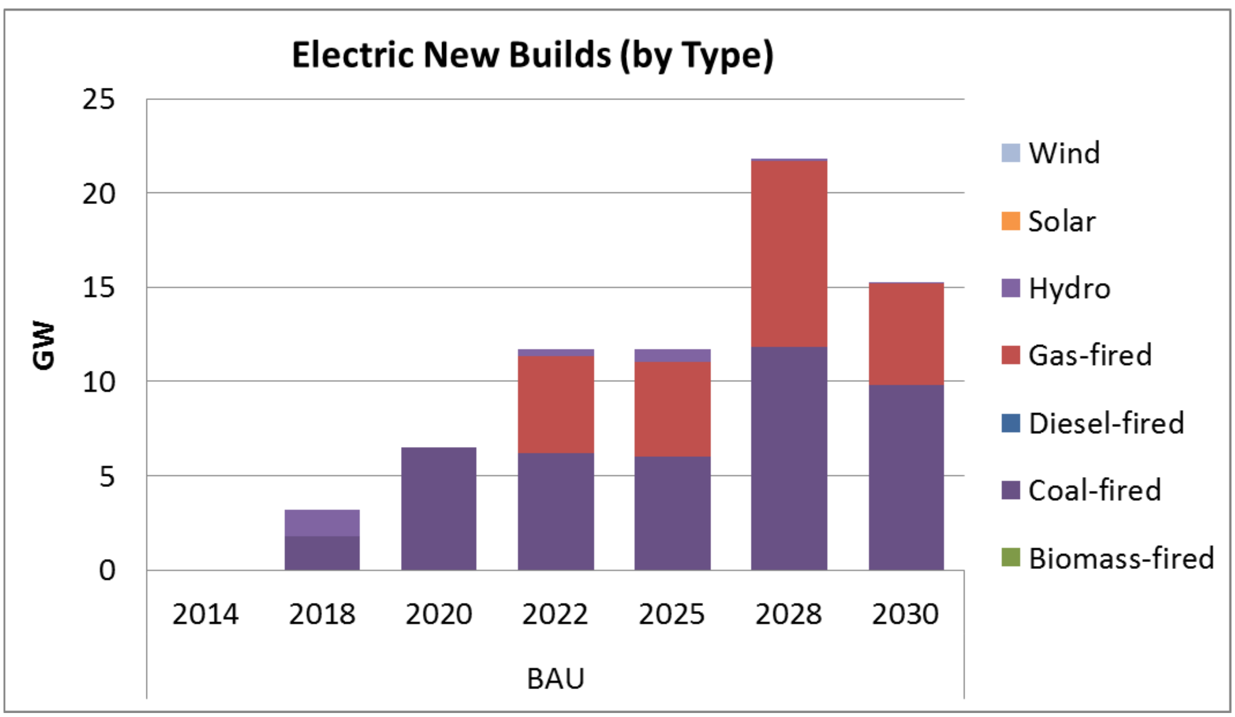
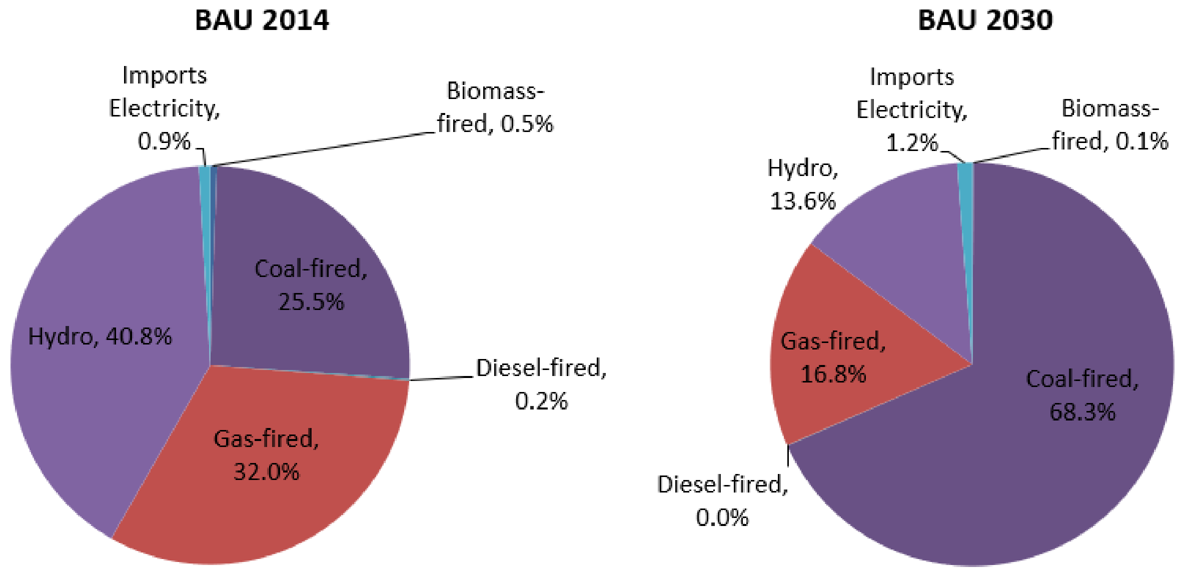


Figure 25: Baseline New Power Plant Additions



The change in the BAU electricity generation mix from 2014 to 2030 is readily seen in Figure 26.

Figure 26: Baseline Generation Mix 2014 vs 2030



5.5 Final Energy to the Demand Sectors

Figure 27 shows that the Final Energy Consumption (FEC) by sector for the Baseline scenario grows by 178%, led by the Industry, followed by Transport and Residential sectors, with the growth in Industry more than half of the total growth in FEC. As shown in Figure 28 electricity use grows the most (302%), followed by natural gas (176%), refined oil products (172%) and coal (119%), while bioenergy grows by 89%, and there is very little contribution from other renewables.

Figure 27: Final Energy Demand by Sector

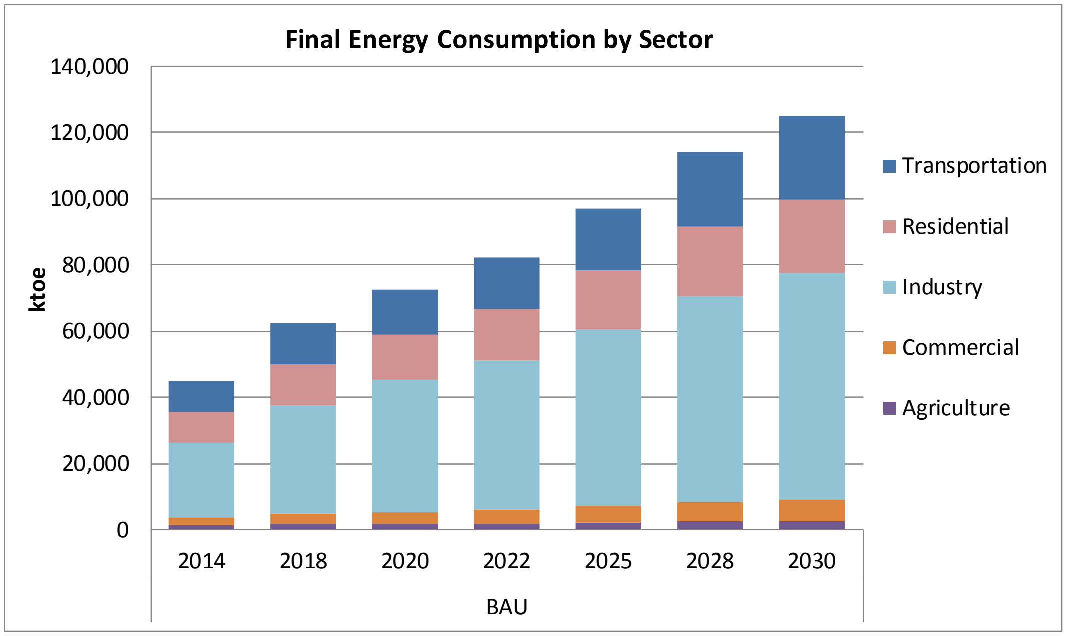
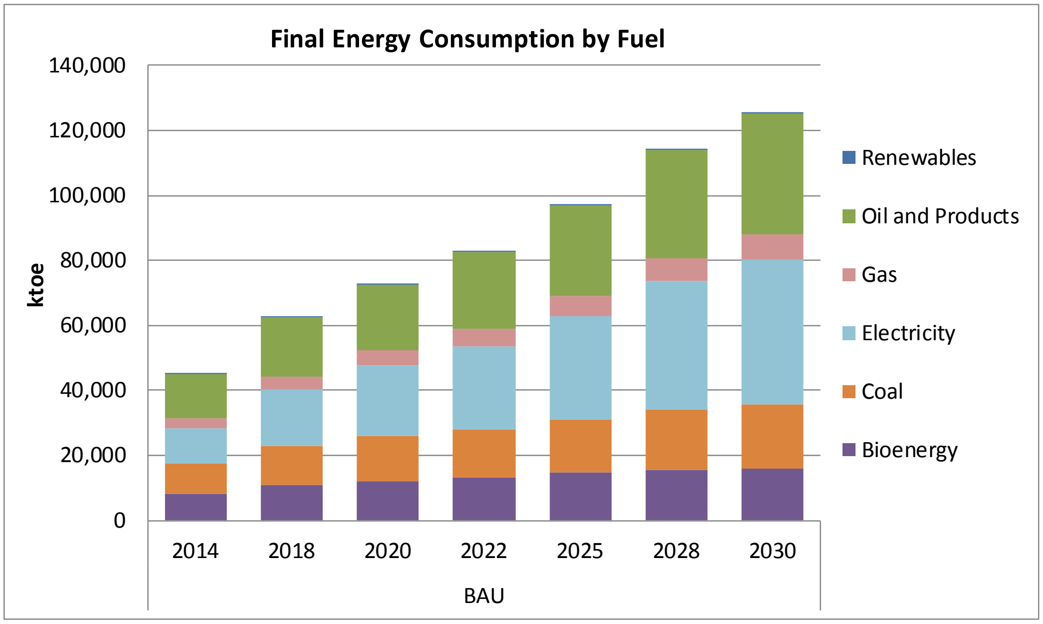
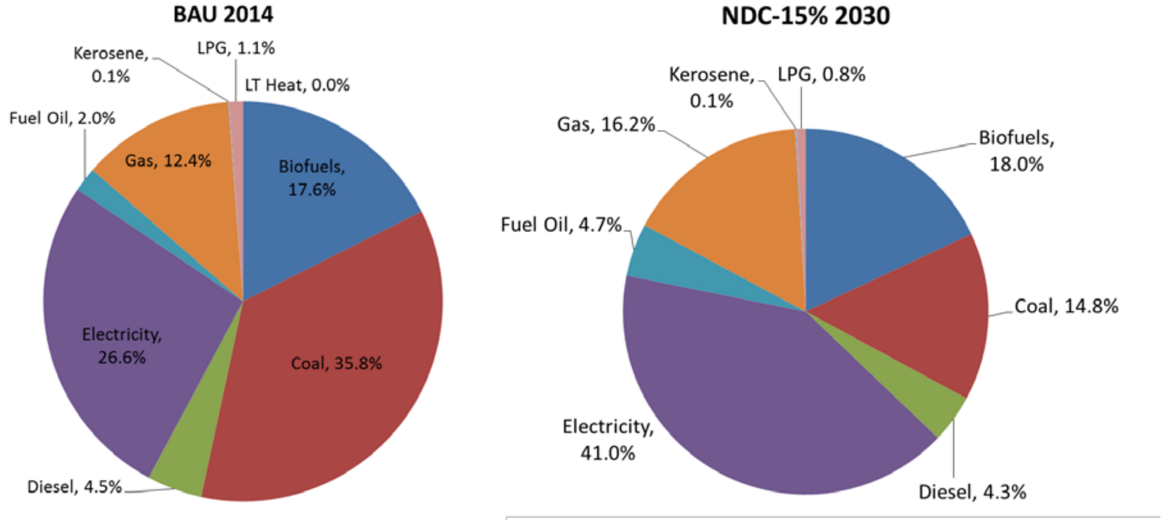


Figure 28: Final Energy Demand by Fuel



As can be seen in Figure 29 there are important structural changes that need to take place in the industrial sector with electricity stepping in to displace coal use. This is particularly critical in the Iron & Steel subsector for process heat, but also for coupled heat and power (CHP) and process heat in Chemicals, and process heat in Paper Products and Textiles subsectors.

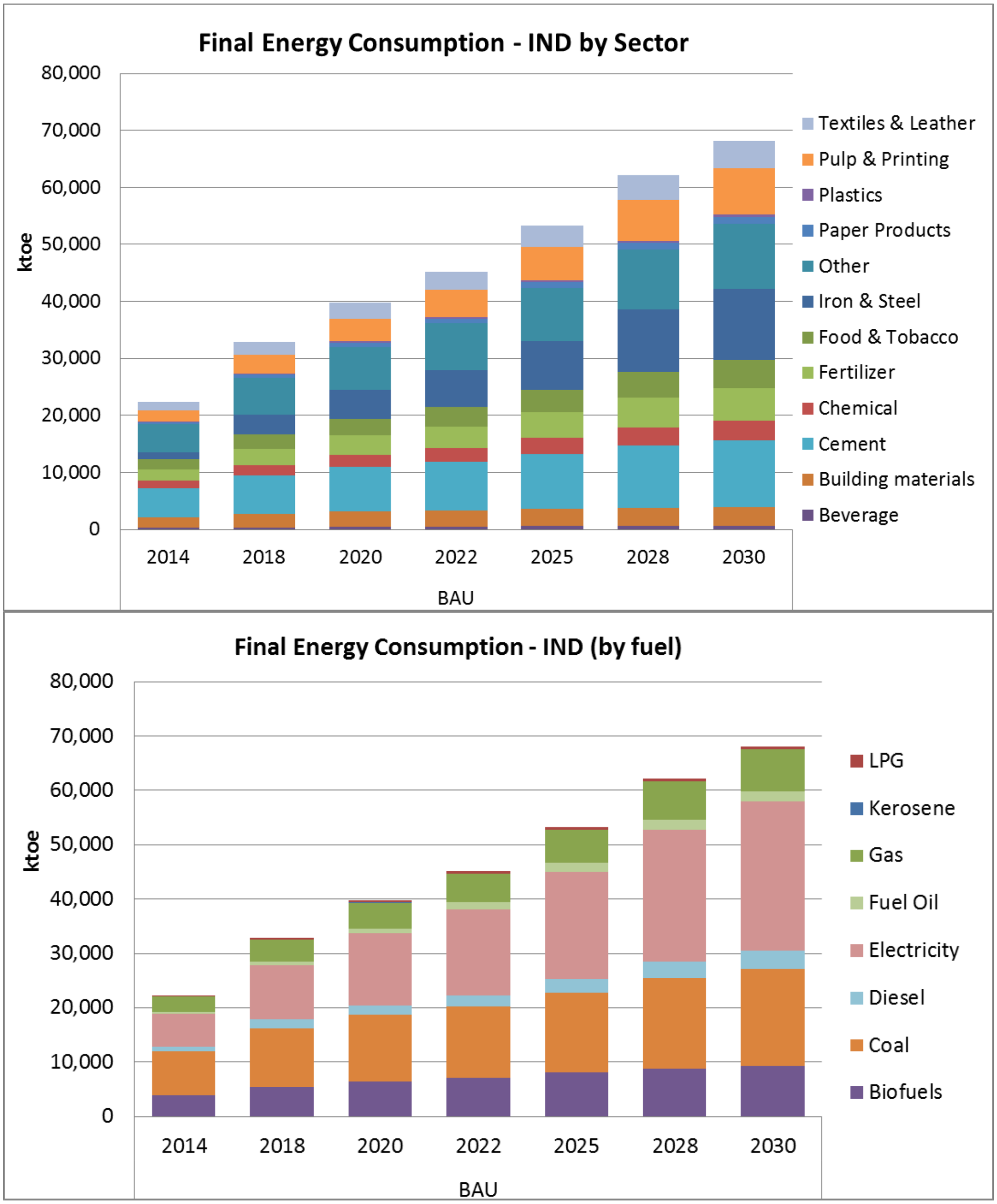
Figure 29: Industrial Sector Fuel Mix in 2030 – BAU vs NDC-15%



5.5.1.1 Industry sector

The Industry sector accounts for about 54% of final energy consumption in 2030. As shown in Figure 30, FEC grows by 205%, led by the Iron & Steel (829%), Cement (132%), Pulp & Printing (293%), Textiles and Leather (249%) and Other (135%) subsectors. Fuels used are primarily electricity (39.9%), coal (27.3%), biofuels (12.3%) and natural gas (11.2%).

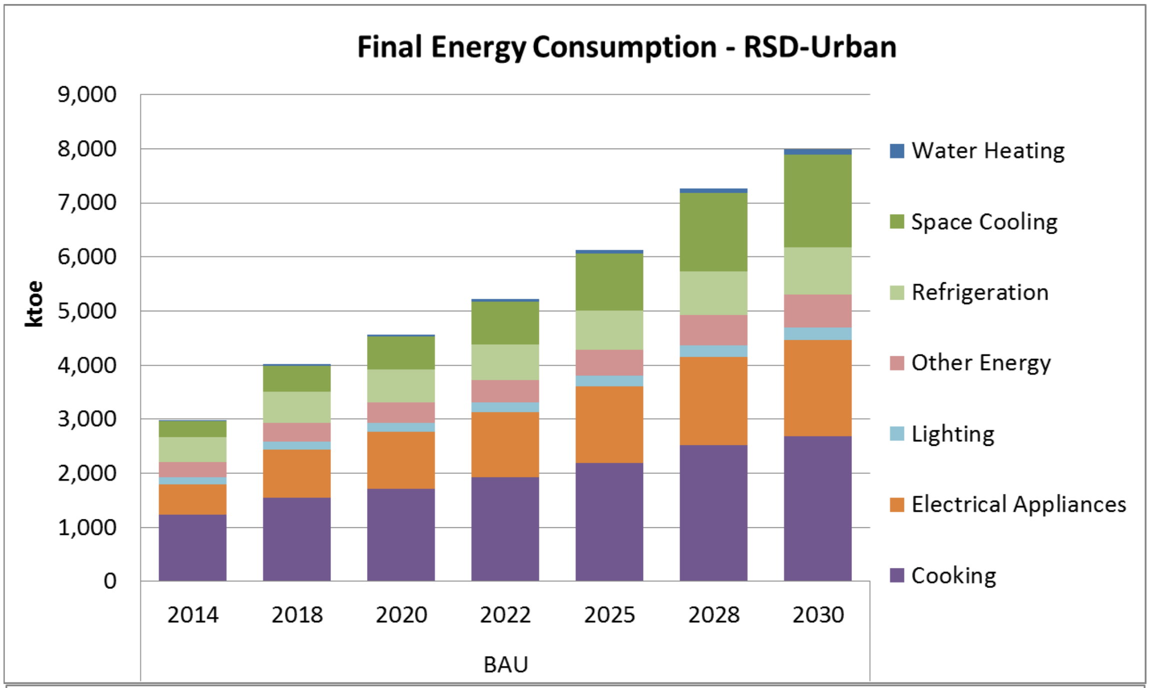
Figure 30: Industry FEC by Subsector and Fuel Use



5.5.1.2 Residential sector

The Residential sector accounts about 18% of FEC in 2030, and is split into Urban and Rural subsectors. As shown in Figure 31, Urban FEC grows by 168%, led by Cooking (120%), Space Cooling (501%), and Electrical Appliances (216%). Rural FEC grows by about 124%, dominated by Space Cooling (636%) and Appliances (192%), although Cooking still accounts for more than 60% of the Rural energy demand in 2030.

Figure 31: Residential Sector FEC by Demand



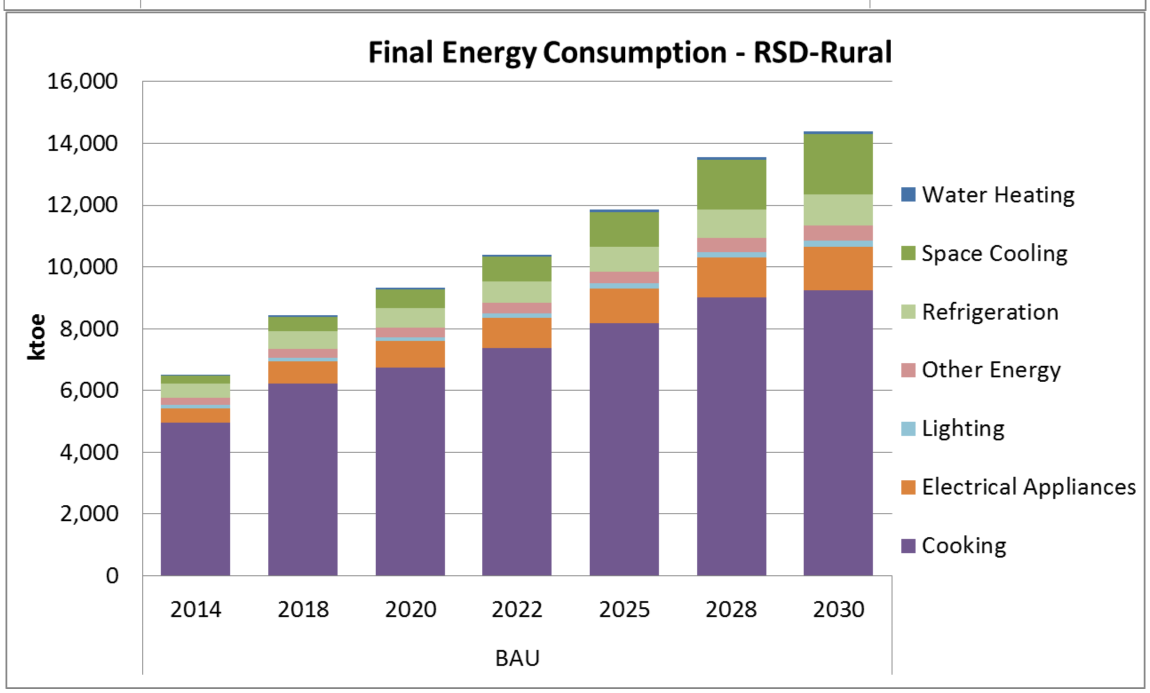
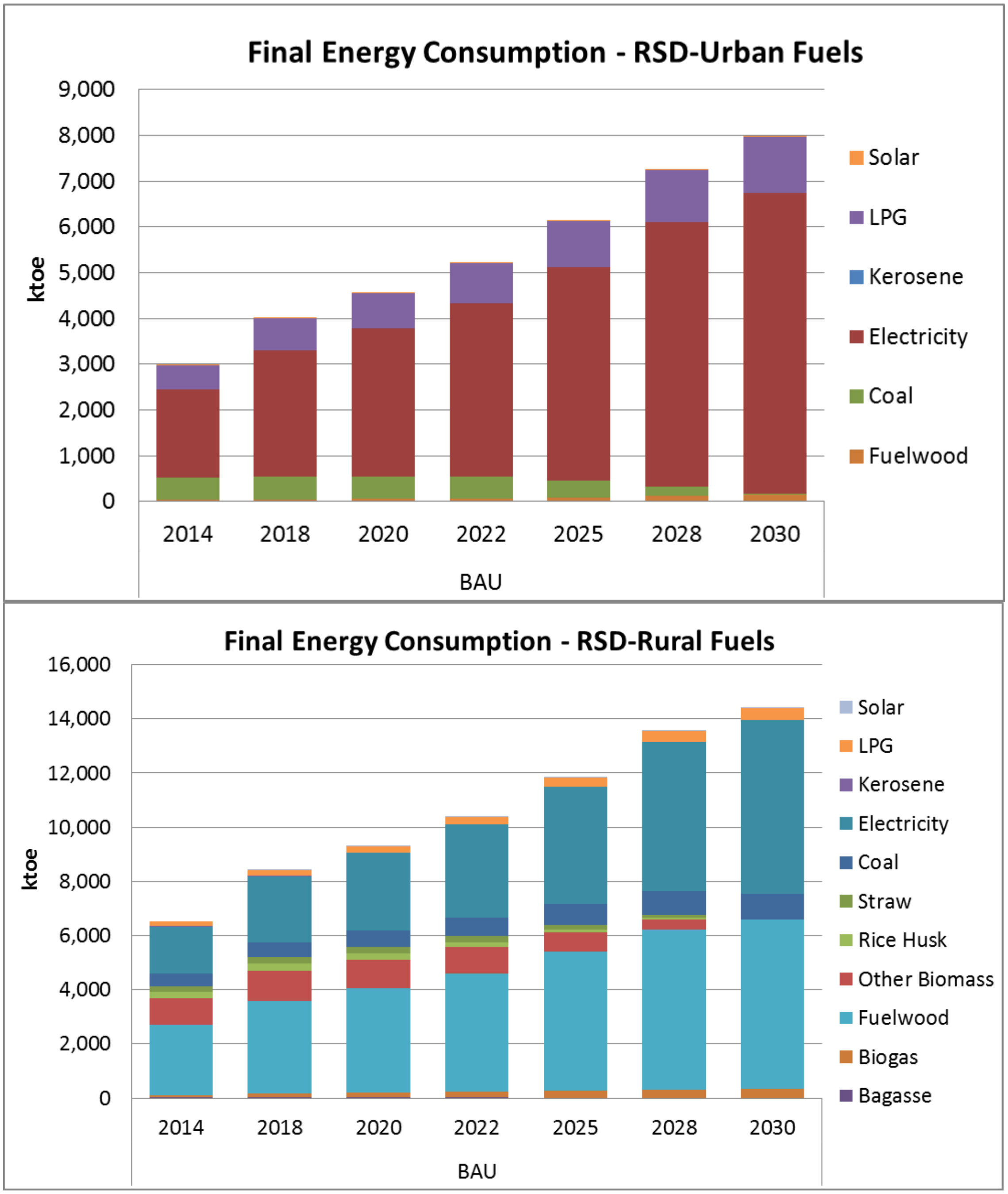


Figure 32 shows that Urban FEC consists primarily of electricity (81.7%) and LPG (16%), while Rural FEC is primarily electricity (44.5%), a couple of biomass (50%), and coal (6.5%) along with some LPG. Incentives for more modern technology is likely necessary reduce Rural biomass use, though that is not seen in the current BAU as such policies are not in place at this time.

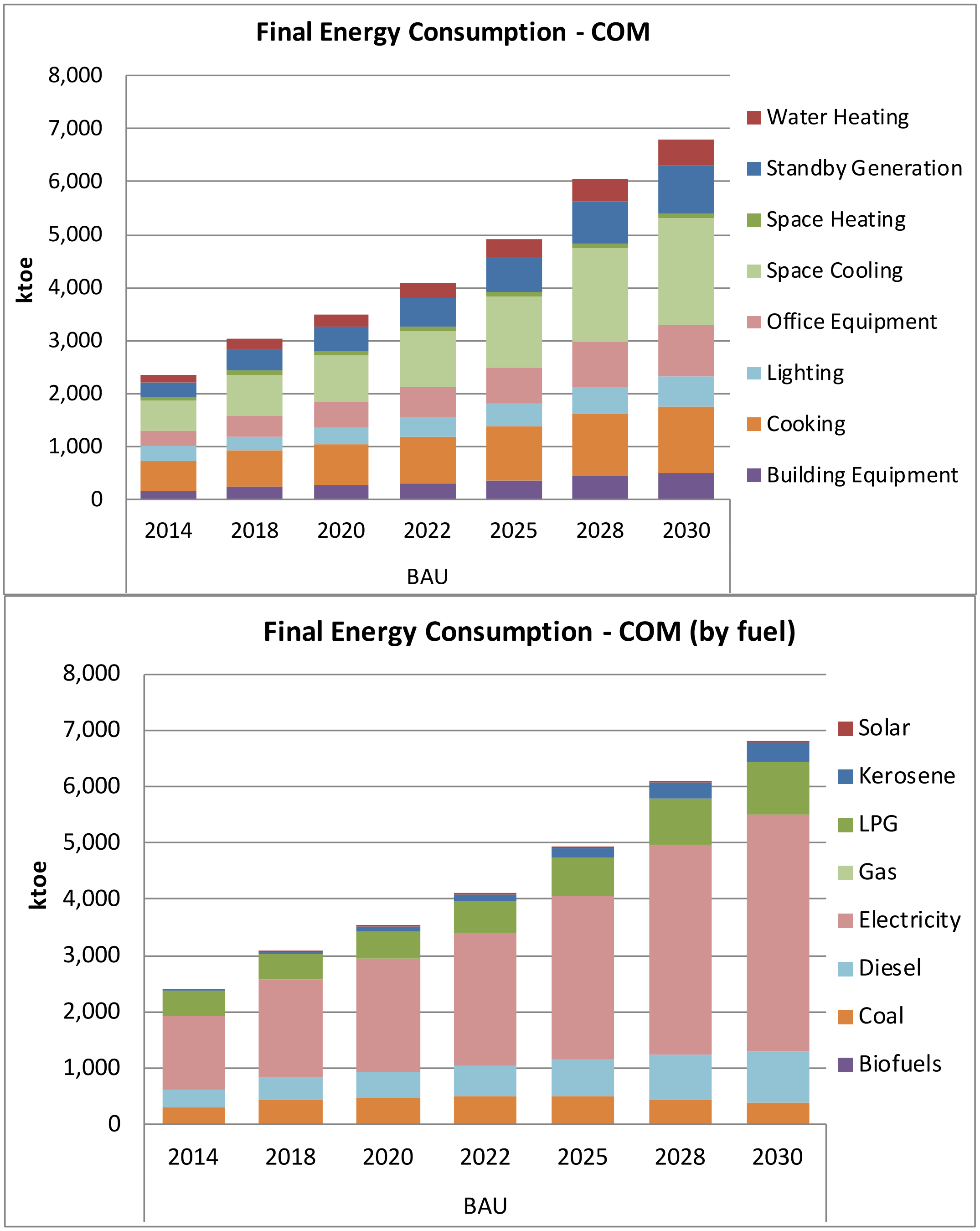
Figure 32: Residential Urban and Rural Sub-sectors Fuel Use



5.5.1.3 Commercial sector

The Commercial sector accounts for just over 5.4% of final energy consumption in 2030. As shown in Figure 33, FEC grows by 186%, led by space cooling (258%), building and office equipment (190/260%), along with cooking (118%). Electricity (220%) and diesel fuel (204%) grow the fastest and together with LPG account for about 89% of the energy consumed in the sector, with kerosene, coal and some solar accounting for the rest.

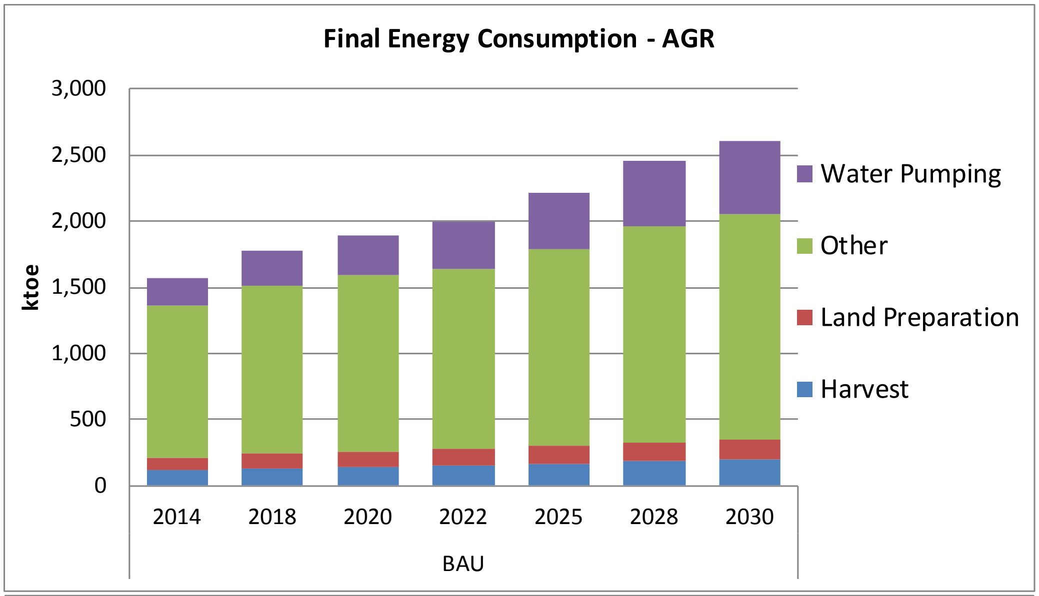
Figure 33: Commercial Sector FEC by Demand and Fuel Use

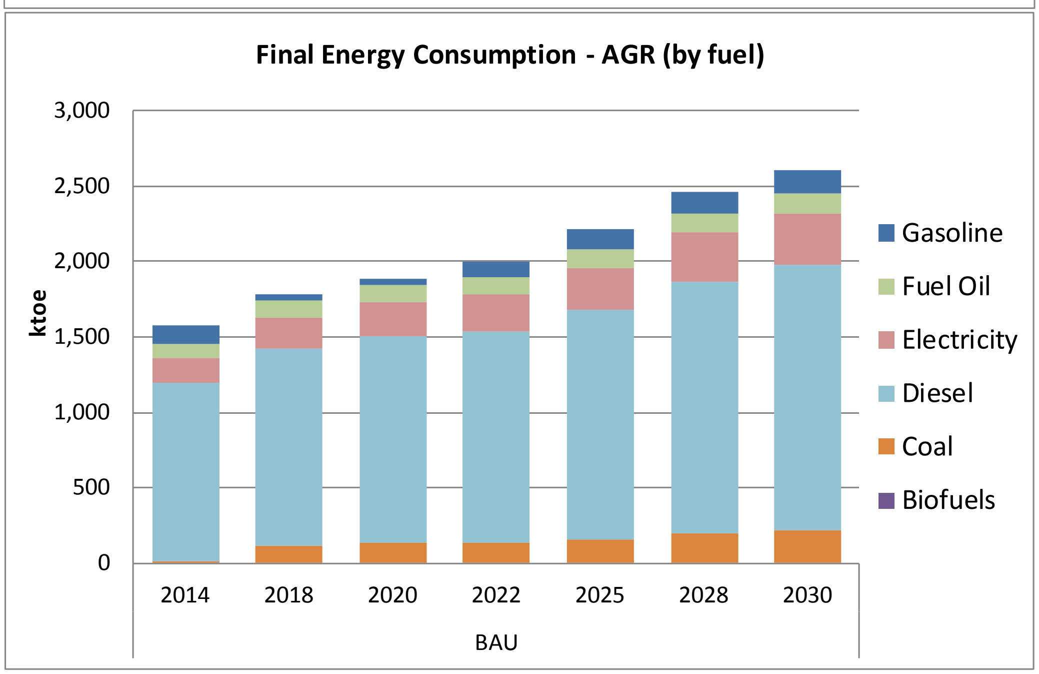


5.5.1.4 Agriculture & Fishing sector

The Agriculture and Fishing sector accounts for less than 2.1% of FEC in 2030. As shown in Figure 34, Other end-uses, which includes Fishing, accounts for 65.4% of the energy demand, while water pumping consumes almost 21.2% and grows the most (165%). Diesel fuel (mainly for tractors) account for 67.1% of the energy consumed followed by electricity at 13.2%.

Figure 34: Agriculture Sector FEC by Demand and Fuel Use

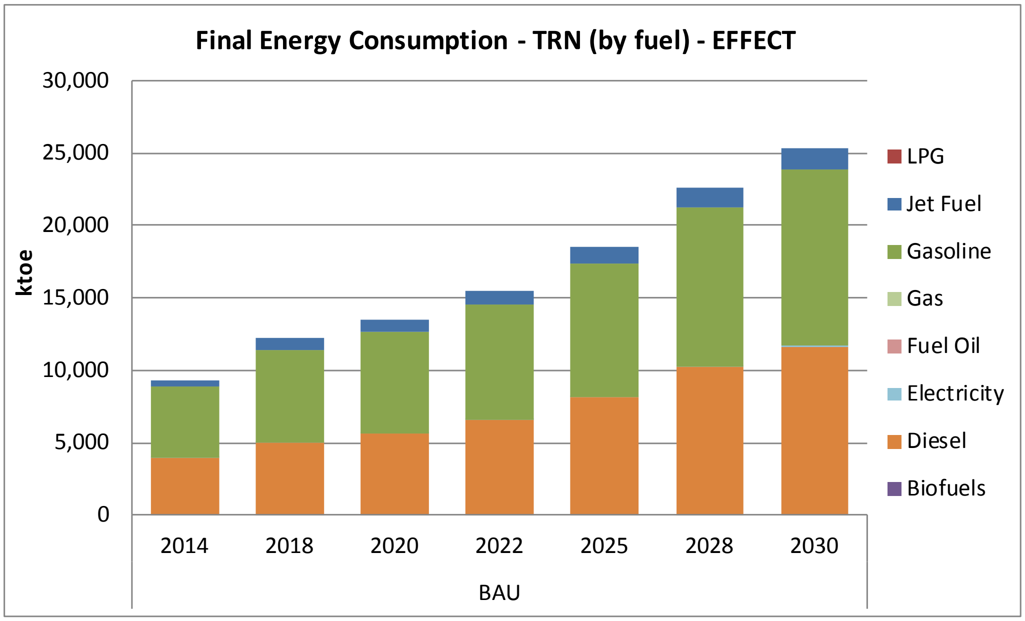




5.5.1.5 Transport sector

The Transport sector simulation of the EFFECT model BAU scenario results are shown in Figure 34, The sector accounts for 20.2% of FEC in 2030, with FEC growing by 178%, led by diesel, gasoline, and jet fuel.

Figure 35: Transport Sector Fuel Use



5.5.2 GHG Emissions

Figure 36 shows the energy system GHG emissions from the Baseline scenario by sector and gas. GHG emissions grow by 272%, led by the Power (560%), Industry (148%) and Transport (174%) sectors, where these sectors comprise 63.3%, 17.6% and 11.7% of total energy sector emissions in 2030. Upstream methane emissions from coal mining and oil & gas production account for 3.6% of 2030 emissions.

Figure 36: Baseline GHG Emissions (kt CO2 eq.)

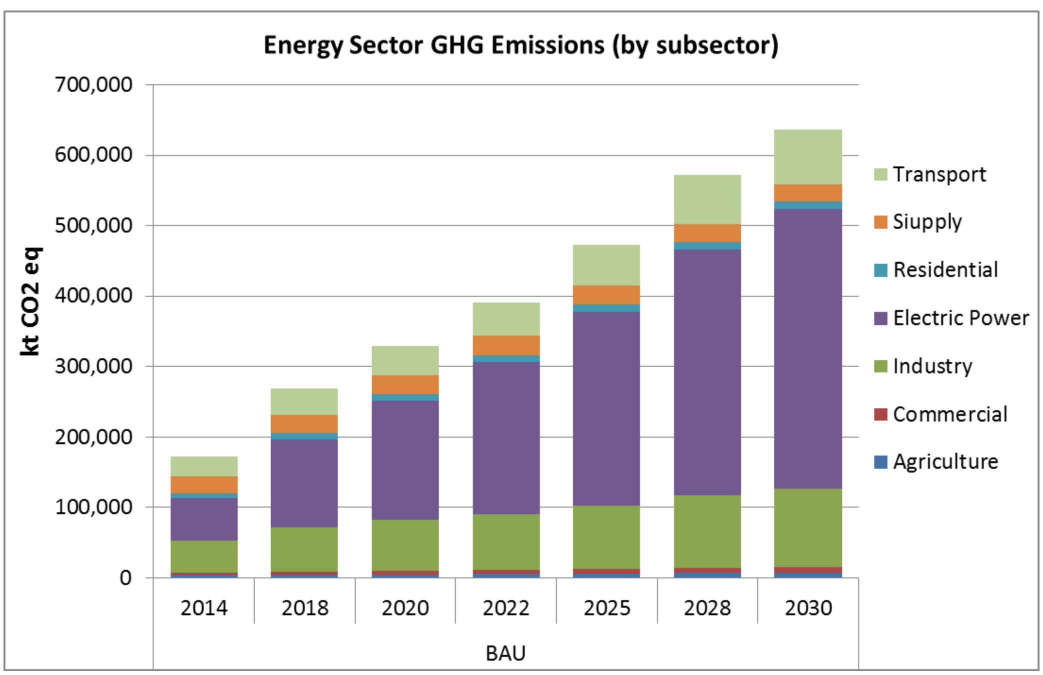


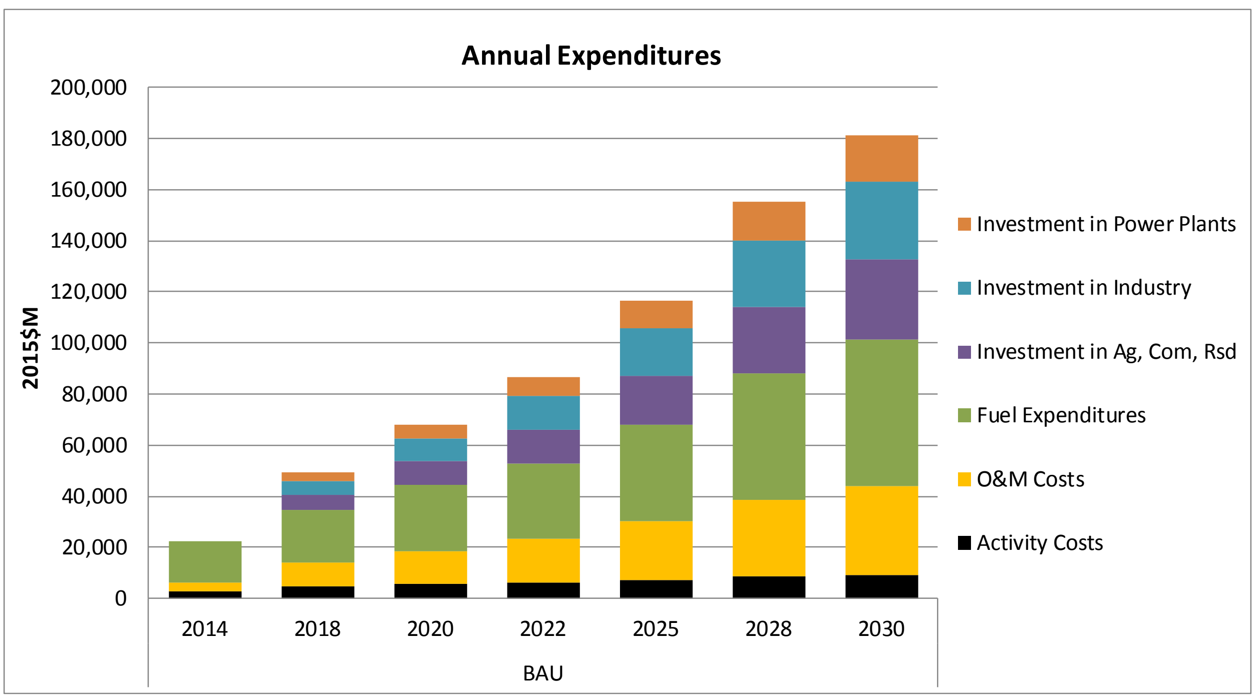
Table 23: Bzseline Industry Sector Emission Breakdown (kt CO2 eq.)

Industry Subsector	2014	2016	2018	2020	2022	2025	2028	2030
Beverage	258	292	339	380	413	453	491	512
Building materials	4,491	4,348	4,652	4,881	4,782	4,625	4,405	4,257
Cement	15,243	16,671	18,943	20,955	21,922	23,072	24,080	24,570
Chemical	3,375	3,798	4,619	5,429	5,981	6,874	7,813	8,429
Fertilizer	5,623	6,453	8,035	9,616	10,818	12,622	14,667	16,030
Food & Tobacco	742	831	941	1,016	1,047	1,301	2,363	3,019
Iron & Steel	1,674	2,406	4,341	6,294	7,988	10,865	13,863	15,891
Other	2,693	2,954	3,192	3,340	3,382	3,419	4,536	4,843
Paper Products	891	1,083	1,466	1,868	2,076	2,352	2,655	2,837
Plastics	268	177	212	245	264	298	330	350
Pulp & Printing	7,341	8,783	11,206	13,507	15,534	18,469	21,941	24,085
Textiles & Leather	2,416	2,915	3,768	4,565	5,041	5,685	6,267	6,609
Total	45,015	50,710	61,715	72,095	79,247	90,036	103,410	111,433

5.5.3 Annualized Expenditures

Figure 37 shows the annual energy system payments for investments (supply and demand) fuels, operation and maintenance activities. Energy system annual expenditures grow by 430%, led by Fuel expenditures (32%) and Annualized Investment in Power Plants (10%), Industry efficiency (17%) and efficiency investments in the Agriculture, Commercial and Residential sectors.

Figure 37: Annual Expenditures (USD Millions)



6 GHG Mitigation Measures and Scenarios

To examine options and determine the least-cost Unconditional and Conditional NDC Pathways a host of scenarios were examined that limit the total GHG emissions from the energy sector (excluding Transport, which is handled via the simulation of the EFFECT results) while employing a number of possible mitigation measures to achieve the targeted reduction levels. This section first describes how EE and RE options are handled in TIMES-Vietnam, next identifies the mitigation measures available for each sector, and then provides an indication of the scenarios examined.

6.1 Handling of EE&RE in the Various Scenarios

Though TIMES is a least-cost optimization model, it does so within limits imposed to reflect local circumstances and policies. To the end, the following control was imposed on the model for the various scenarios including those introduced to guide the amount of fuel switching permitted, change in technology types (e.g., central vs. room a/c), and uptake of energy efficient demand devices (percent of new device purchases that are improved/better/advanced by 2030), along with RE maximum annual build rates and total potential.. The RE controls are the same for all scenarios, outside of the BAU, taken from the IES RE Integration study, with maximum potentials proved by VIE. The data characterizing the various demand devices can be found in Appendices B.6 thru B.8 for each demand sector and in Appendix B.5 for the RE and other power sector technologies.

The basic constraints for each of the main scenarios examined are summarized here.

(1) The BAU scenario was designed to align with the power generation, electricity consumption and GHG emissions, as defined in the MONRE NDC-2 report, as requested by MOIT. The constraints and the alignment of the TIMES-Vietnam and MONRE BAUs is described in detail in Section 5.1 and 5.2, where no RE and little EE improvement is permitted (1% of new device purchases can be high efficiency).

(2) For all the 8%, 15%, 20%, 25%, and 30% scenarios, the GHG emissions are constraints, and the energy mix is the least-cost optimized results. EE devices are permitted to reach 5%, 15%, 20%, 30% and 50% respectively.

(3) For the EE&RE policy scenario, the PDP-7r RE capacity targets and VNEEP EE reduction targets are the constraints, along with 15% of EE devices permitted, and the GHG emission reduction is the result.

6.2 Measures and Metrics

The TIMES-Vietnam model includes a large number of GHG mitigation options in each sector of the energy system, starting with cleaner resources and renewable energy supplies that can be accessed, cleaner power plants and renewable energy technologies, energy efficient end-use devices and energy conservation technologies and processes. This section presents the key measures and the model metrics that will be used to determine the impact of specific policy scenarios.

6.2.1 Supply

Natural gas use, biofuels production and electricity imports are the key supply sector metrics used in this analysis, as shown in Table 24 along with their 2030 BAU value. Natural gas use reduces GHG emissions when used to replace coal use. Expansion of biofuels, of all types, reduces GHG emissions when fossil fuels are displaced. Electricity imports (occurring from Laos and China) can reduce in-country emissions, but not necessarily global emissions, and can heighten energy security concerns.

Table 24: Supply Sector Measures and BAU Level in 2030

Measure	Description	BAU in 2030
Natural gas use	Natural gas production & imports (ktoe) Share of total primary energy	22,292 12.9%
Biofuel production	Biofuel production (ktoe) Share of total primary energy	17,423 8.6%
Electricity imports	Electricity imports (GWh) and Share of total supply	6,860 1.2%

6.2.2 Power Sector

The specific metrics used in the power sector include the overall supply of electricity from renewables (RE) sources, along with the specific contributions from a number of RE technologies, as well as higher efficiency coal power plants, as shown in Table 25. Note that many of these options do not appear in the BAU scenario, while others have significant shares in 2030. For the 2050 sensitivity analysis, power plant options for nuclear and coal with carbon capture and sequestration (CCS) were added.

Table 25: Power Sector Measures and BAU Level in 2030

Measure	Description	BAU in 2030
Promote RE-based electricity	Total RE electricity (GWh) and Share of total supply	4,106 0.7%
Promote wind	Wind generation (GWh) Share of total supply	0 0.0%
Promote central solar	Central solar generation (GWh) Share of total supply	0 0.0%
Biomass power plants [including bagasse]	Wood and bagasse generation (GWh) Share of total supply	806 0.1%
Landfill gas power plants	Landfill gas generation (GWh) Share of total supply	0 0.00%
MSW power plants	MSW generation (GWh) Share of total supply	0 0.0%

Measure	Description	BAU in 2030
Biogas power plants	Biogas generation (GWh)	0
	Share of total supply	0.0%
Small hydro power plants	SHP generation (GWh)	3,300
	Share of total supply	0.6%
Coal-Biomass co-firing plants	Coal and biomass generation (GWh)	1,739
	Share of total supply	0.3%
Super-critical coal power plants	Supercritical coal generation (GWh)	181,304
	Share of total supply	31.7%

Note that the high penetration of super-critical coal in the BAU scenario is due to the requirement to align power sector emissions with the NDC-2 report projection.

6.2.3 Industry Subsectors

For the Industry sector there are five general measures, including motor drive and process heat boiler and furnace efficiency, as well as biofuels utilization in boilers and furnaces and cogeneration using fossil and RE resources. These are followed by subsector specific process improvement measures that reduce the demand for motor drive, process heat or facility/other energy. These measures, shown in Table 26, act in addition to some efficiency improvement technology options contained in each industry subsector. However, for the Baseline none of the measures are permitted as well as limited efficiency improvements.

Table 26: Industry Subsector Process Improvement Measures

Subsector	Measure	Description
General	Motor Drive Efficiency improvements	Electricity savings due to high efficiency motors (GWh)
	Process Heat Efficiency improvements	Energy savings due to high efficiency boilers and furnaces (ktoe)
	Facility/Other Efficiency improvements	Energy savings due to high efficiency lighting, AC, etc. (ktoe)
	Biofuels utilization in boilers & furnaces	Increase in biofuels utilization (ktoe)
	Cogeneration	Increase in cogeneration capacity (GW)

Iron & Steel	EE measures such as pulverized coal injection in blast furnaces, preheat steel scrap for electric arc furnaces, waste heat recovery based power generation, and other reductions in thermal energy and electrical energy.	Electricity savings due to high efficiency motors (GWh)
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)
		Energy savings for high efficient facilities (ktoe)
Chemicals	EE measures to optimize air compressed & steam systems, add variable speed drives and efficient lighting, etc.	Electricity savings due to high efficiency motors (GWh)
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)
		Energy savings for high efficient facilities (ktoe)
Fertilizer	EE measures for variable speed drives, optimization of air compressed & steam systems, and using CHP system and heat recovery process improvements.	Electricity savings due to high efficiency motors (GWh)
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)
		Energy savings for high efficient facilities (ktoe)
Cement	EE measures to optimize combustion cycle, apply waste heat recovery for clinker furnace, reduce crushing energy with vertical mills, and other savings.	Electricity savings due to high efficiency motors (GWh)
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)
		Energy savings for high efficient facilities

		(ktoe)
Beverages	EE measures for beer production, carbonate beverage production, and non-carbonate beverage production thru optimize air compressed & steam systems, variable speed drives, and heat pumps.	Electricity savings due to high efficiency motors (GWh)
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)
		Energy savings for high efficient facilities (ktoe)
Plastics	EE measures for variable speed drives and efficient lamps, etc.	Electricity savings due to high efficiency motors (GWh)
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)
		Energy savings for high efficient facilities (ktoe)
Food & Tabaco	EE measures to install variable speed drives, efficient air compressor, efficient chillers, and efficient lighting.	Electricity savings due to high efficiency motors (GWh)
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)
		Energy savings for high efficient facilities (ktoe)
Paper Products	EE measures for waste heat recovery from paper drying to reduce heating requirements, and Variable speed drives, optimization of air compressed & steam systems, using CHP system	Electricity savings due to high efficiency motors (GWh)
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)
		Energy savings for high efficient facilities

		(ktoe)
Pulp & Printing	EE measures to Thermo-mechanical pulping, increased use of recycled pulp, and Black liquor gasification plants to cogenerate steam, and Variable speed drives, optimization of air compressed & steam systems	Electricity savings due to high efficiency motors (GWh)
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)
		Energy savings for high efficient facilities (ktoe)
Bricks	Modernize brick production by applying efficiency measures and Increasing production unburnt bricks	Electricity savings due to high efficiency motors (GWh)
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)
		Energy savings for high efficient facilities (ktoe)
Textiles	EE measures for boiler improvements, variable speed drives and efficient lamps in fiber production, knitting and dyeing	Electricity savings due to high efficiency motors (GWh)
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)
		Energy savings for high efficient facilities (ktoe)
Other	EE measures for boiler improvements, variable speed drives and efficient lamps in fiber production, knitting and dyeing	Electricity savings due to high efficiency motors (GWh)
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)
		Energy savings for high efficient facilities

		(ktoe)

6.2.4 Buildings Sectors

6.2.4.1 Residential

The Residential sector includes these five key measures and also includes high performance refrigerators, general appliance efficiency, solar PV and hot water, and cleaner cooking fuels, including biogas, as shown in Table 27.

Table 27: Residential Sector Measures and BAU Level in 2030

Measure	Description	BAU in 2030
Solar PV	Rooftop solar generation (GWh) Share of total electricity	0 0.0%
Solar water heaters	Solar hot water heater use (ktoe) Share of total demand	3 1.7%
High performance AC	Use of high efficiency AC (ktoe) Share of total demand	124 1.0%
High performance refrigerators	Use of high-efficiency refrigerators (ktoe) Share of total demand	30 1.4%
High performance lighting	Use of energy-saving lighting or LEDs (ktoe) Share of total demand	7 1.0%
Appliance efficiency	Use of high efficiency appliances (ktoe) Share of total demand	24 1.0%
High performance water heater	Use of efficient water heaters (ktoe) Share of total demand	0 0.0%
Biogas for cooking	Use of biogas for cooking (ktoe) Share of total demand	330 2.8%
Cleaner cooking fuels	Use of electric and LPG stoves (ktoe) Share of total demand	982 8.2%

6.2.4.2 Commercial

There are five key measures examined in the Commercial sector, as shown in Table 28 along with their BAU level in 2030, consisting of solar PV and water heating systems, high performance air conditioners, high performance lighting, and more efficient water heaters.

Table 28: Commercial Sector Measures and BAU Level in 2030

Measure	Description	BAU in 2030
Solar PV	Use of rooftop solar (GWh)	0.0
	Share of total supply	0.0%
Solar water heaters	Use of solar hot water heaters (ktoe)	5.2
	Share of total supply	1.1%
High performance AC	Use of high efficiency AC [ktoe]	87.4
	Share of total supply	1.0%
High performance lighting	Use of energy-saving lighting (ktoe)	18.9
	Share of total supply	1.5%
More efficient water heaters	Use of efficient water heaters (ktoe)	4.6
	Share of total supply	1.5%

6.2.5 Transport Sector

The EFFECT Transport team provided four sets of model results corresponding to their BAU scenario and three mitigation scenarios. These are labelled:

- EFFECT-BAU: Baseline;
- EFFECT-M1-09: Modest mitigation;
- EFFECT-M2-15: Mid-level mitigation, and
- EFFECT-M3-19: High mitigation.

The various EFFECT scenarios were incorporated into the TIMES-Vietnam Unconditional and Conditional NDC pathway targets so as to best reflect a comprehensive GHG mitigation strategy for the country. The EFFECT-BAU scenario is used to simulate the Transport sector for the BAU runs. The EFFECT-M1-09 scenario achieves a 9% GHG emission reduction in the Transport sector and is used with the 8% and 10% Unconditional NDC target scenarios. The EFFECT-M2-15 scenario achieves a 15% GHG emission reduction in the Transport sector and is used with the 12% and 15% NDC target scenarios as well as the EE&RE Policies scenario. The EFFECT-M3-19 scenario achieves a 19% GHG emission reduction in the Transport sector and is used with the 20%, 25% and 30% Conditional NDC target scenarios, and the 2050 sensitivity runs.

6.3 EE&RE Polices and NDC Target Scenarios

This Vietnam energy sector NDC analysis examines scenarios for various GHG reduction levels from the Business-as-Usual (BAU) projection with the goal of determining an appropriate cost-effective target for the country. Scenarios of 8%, 10%, 12% and 15% reductions from BAU by 2030 were examined in the context of an Unconditional NDC target and the 8%, 15% cases are discussed in Section 7 along the EE&RE Policies scenario. Scenarios of 20%, 25% and 30% reductions from BAU by 2030 were examined in the context of a Conditional NDC target and are discussed in Section 8. The EE&RE Policies scenario is based on implementation of the RE targets in the PDP-7r and the proposed VNEEP EE target to reduce final energy consumption 8-10 % below BAU from 2021 to 2030, which is defined as:

- PDP-7r RE targets for 2030, including
    - 12 GW of installed solar power (central and distributed);
    - 6 GW of installed wind power;
    - 3.28 GW of biomass-fired power;
    - 30 GW from large and small hydro, and
- 8-10% reduction in Final Energy Consumption (FEC).

For each GHG reduction scenario, various combinations of energy efficiency (EE) and renewable energy (RE) were examined to determine the optimum configuration of EE and RE for each of these scenarios, looking for a balanced policy approach to achieving each NDC target, and taking into consideration that there is just over a decade till 2030. Although aggressive EE policies tend to result in lower overall system cost, for the reasons noted below, a slightly more costly but more balanced approach is recommended and has been adopted for this analysis.

The rationale for a balanced policy approach stems from the fact that EE and RE measures come with increased upfront investment requirements, which are counter-balanced by significantly reduced expenditures for fuels. Also, there is a clear tradeoff between EE and RE, in that when EE penetration levels are higher, RE share levels are lower (since less electricity overall is needed). In addition, while RE costs are coming down, so is the price of coal and gas based upon the latest IEA projections. This keeps these fossil fuels in the mix when combined with EE, which reduces the uptake of RE from a strictly least-cost perspective. In addition, there is a big difference between the ability of the government to get millions of people to spend limited capital on EE as opposed to encouraging investment in RE power plants. In the case of EE the government can mandate appliance and building shell standards, but then may need to provide price support to enable those less affluent to participate.

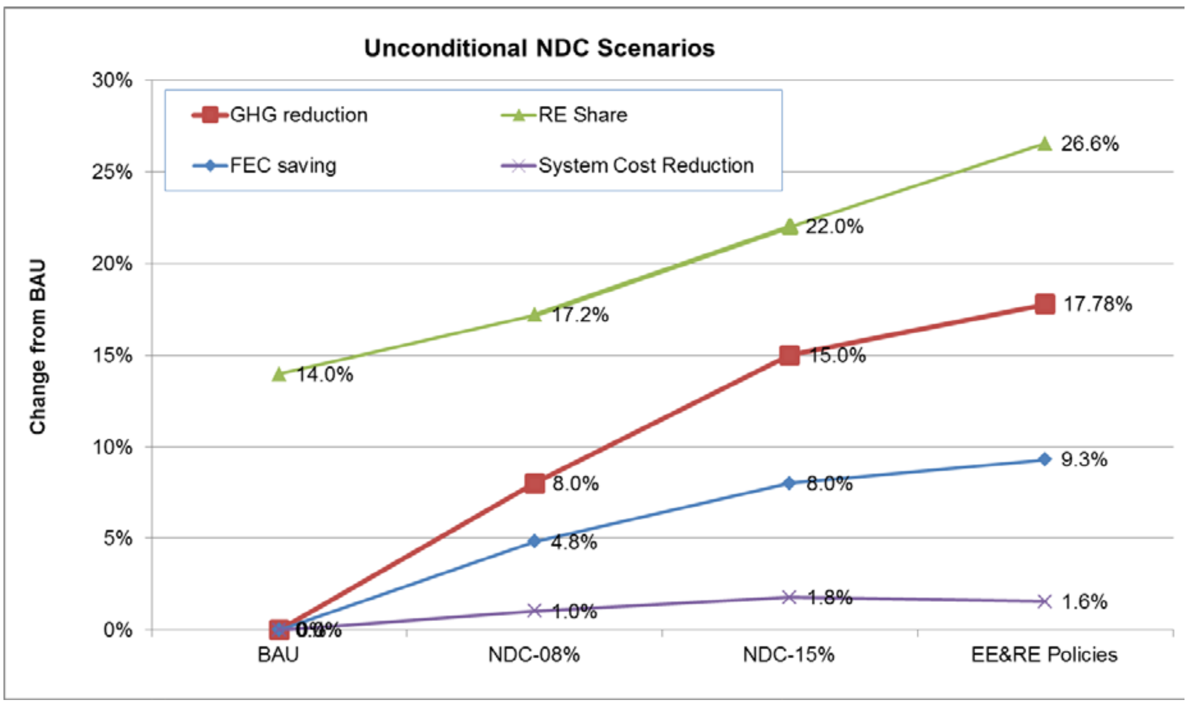
In addition to the suite of NDC target runs reported on in Sections 7 and 8, sensitivity runs were done looking at possible GHG emission prices in 2030, as well as gas price assumptions and looking out to 2050. These are briefly reported on in Section 9. Then, based upon the analysis undertaking the NDC Roadmap is outlined in Section 10, and the effectiveness of the individual mitigation measures are discussed in Section 11.

7 Assessment of Unconditional NDC Scenarios

7.1 Overview

This section presents options for the energy sector to achieve Vietnam's Unconditional NDC target by examining the following four scenarios: BAU, NDC-8%, NDC-15% and EE&RE Policies, as shown Figure 38. The figure plots the percent reductions in GHG emissions, FEC (owing to the uptake of EE), and total discounted costs of the energy system (which is the net present value of all investments, operating, fuel and other costs associated with the energy system), along with the share of RE in total electricity supply. These percentages are calculated against the BAU for all energy sectors. The Transport sector energy use and emissions are included in the overall TIMES-Vietnam results, but the fuel costs and vehicle purchase/operating costs are not as the EFFECT results were imposed and thereby not subject to the overall optimization of the energy system. This results in a comprehensive picture of the energy system, but provides a focused optimization on the portions of the energy system covered by MOIT.

Figure 38: Unconditional GHG Reduction Scenario Results



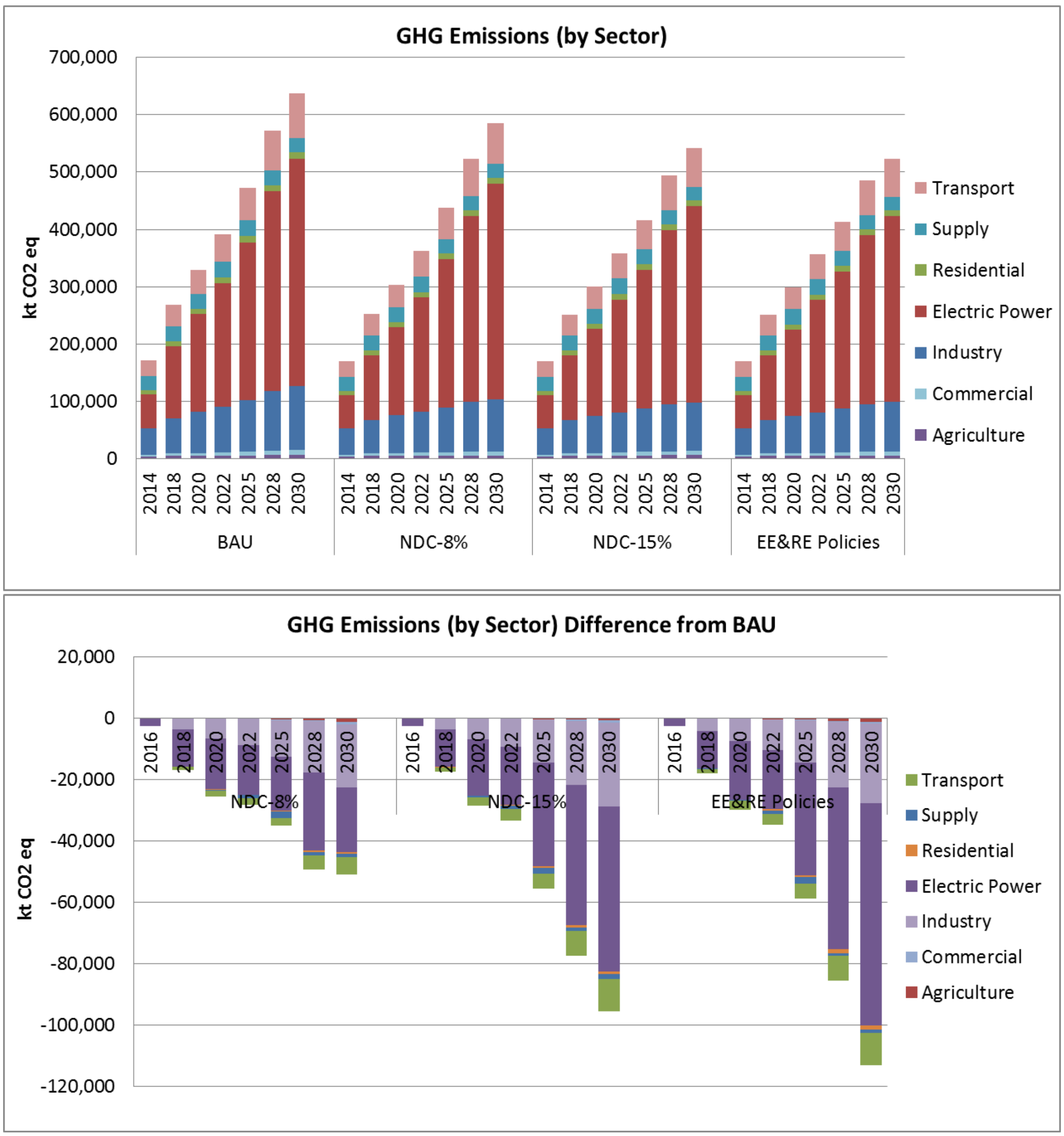
The NDC-8% scenario achieves an 8% reduction in energy sector GHG emissions due to the cost-effective shares of RE electricity (17.2%) and EE (4.8%) that are implemented. The scenario produces a 1.0% reduction in total system cost. The NDC-15% scenario raises the RE electricity share to 22%, while increasing the FEC reduction to 8%. The reduction in energy system cost reaches 1.8%, as the additional investment in EE devices is offset over time by reductions in expenditures on fuel. The EE&RE Policies scenario achieves a 17.8% reduction in energy sector GHG emissions by raising the RE share to 26.6% and increasing the FEC reduction to 9.3%. The result indicates that the EE&RE Policies scenario can more than meet the previously established Unconditional NDC target, but at a higher overall system cost (about

$2 billion) compared to the NDC-15% case. More details are provided on the modeling results in Appendix C.

7.2 GHG Emissions

Figure 39 shows the GHG emissions (on the top) and the change in emissions from the BAU scenario (on the bottom) for the three Unconditional scenarios. The figure shows that almost all emission reductions come from the Power and Industry sectors, followed by Transport. Total emissions reductions in 2030 grow from 51 million metric tons per year (Mt/yr) in the NDC-8% scenario to 95 Mt/yr in NDC-15% and 113 Mt/yr in the EE&RE Policies scenarios.

Figure 39: Unconditional GHG Reduction Scenarios – GHG Emissions



7.3 Supply and Power Sectors

7.3.1 Energy Supply

In the Unconditional and EE&RE Policies scenarios the Supply sector impacts are relatively modest. The utilization of natural gas decreases by 34% compared to the BAU as renewables largely replace gas and not coal – especially given the large forced builds of coal plants in 2022 and 2023. The utilization of various biofuels increases modestly between the BAU and the Unconditional scenarios, moving from 8.6% of primary supply to between 10% and 11% in all three scenarios, as shown in Table 29. The increased use of bioenergy consists primarily of fuelwood, bagasse and rice husk, but there is important utilization of MSW and Landfill gas in the Power sector and biogas utilization in the Rural residential sector.

In the BAU scenario, only electricity imports from China occur, but in the NDC and EE&RE Policies scenarios, the imports from China increase by 50% and imports from Laos grow to account for two-thirds of all electricity imports by 2030.

Table 29: Unconditional GHG Reduction Scenarios – Supply & Power Sector Measure Results

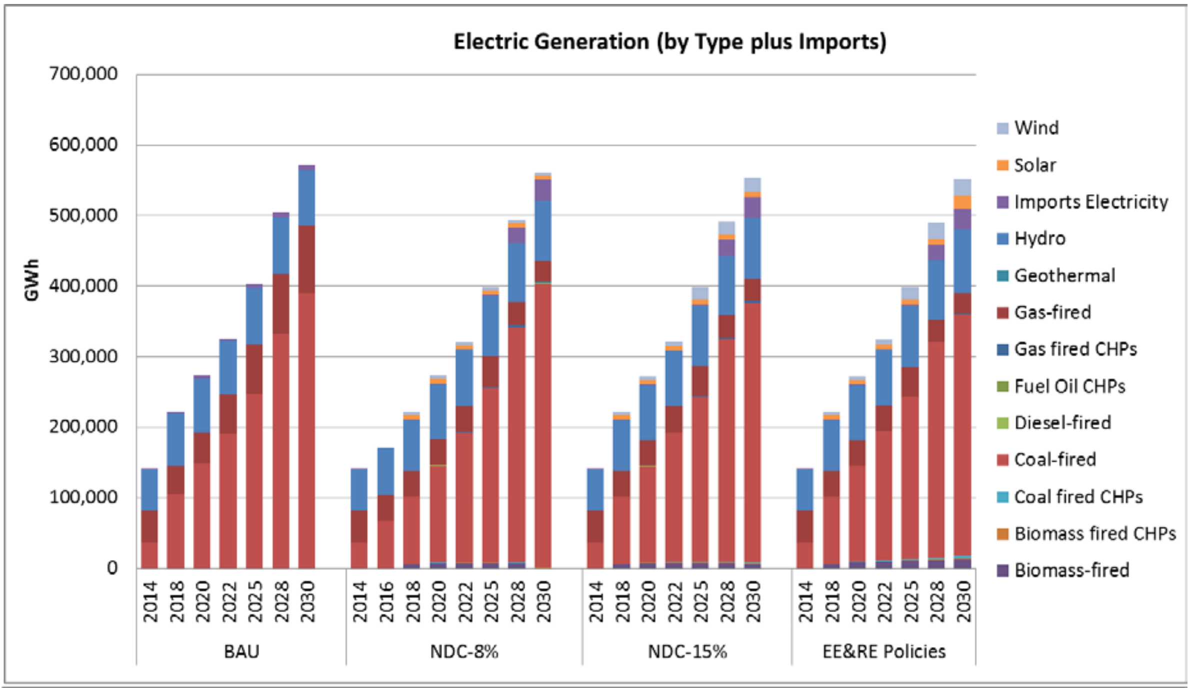
Measure	Description	BAU	NDC-8%	NDC-15%	EE&RE Policies
Natural gas consumption	Natural gas consumption (ktoe)	25,292	15,352	17,049	16,771
	Share of total primary energy	12.6%	8.0%	9.3%	9.4%
Biofuel production	Biofuel production (ktoe)	17,423	20,020	20,060	19,138
	Share of total primary energy	8.7%	10.4%	11.0%	10.7%
Electricity imports	Electricity imports (GWh)	6,860	29,500	29,500	29,500
	Share of total supply	1.2%	4.6%	5.4%	5.4%

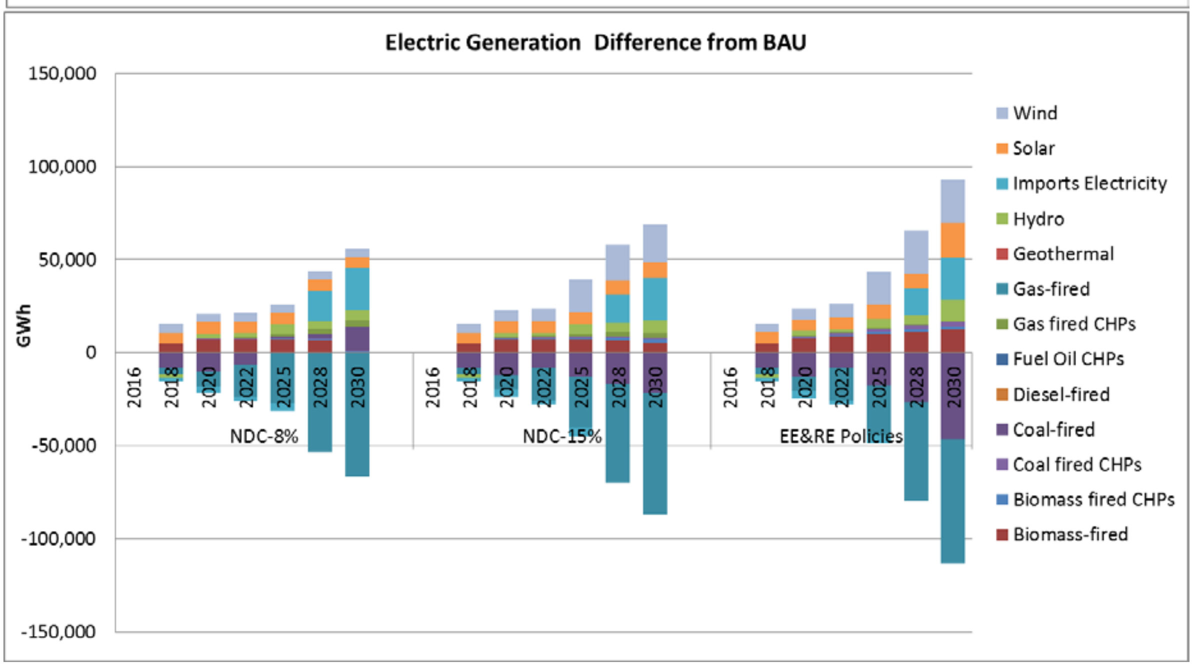
7.3.2 Electricity Generation

Figure 40 shows the electricity generation (on the top) and the change in generation from the BAU scenario (on the bottom) for the Unconditional and EE&RE Policies scenarios. Total electricity generation decreases by only 2% to 3.6% percent, but in all scenarios, some coal and gas-fired generation is replaced by solar, hydropower, biomass and wind power plants. The NDC-8% scenario favors imports from China and Laos of wind over solar, but the cost of these imports if quite difficult to predict. The NDC-15% and EE&RE Policies scenarios grow both solar and wind generation, with the NDC-15% scenario adding more wind power, while the EE&RE policies scenario has more balanced generation from each.

As shown in Table 30, the Power sector shows important growth in RE-based electricity, with the contributions from central RE power plants providing most of the additional RE-based electricity, with small hydropower, distributed solar and biomass CHP plants providing the remainder. Small hydropower grows to almost 2% of total supply in all the Unconditional scenarios, followed by bagasse cogeneration plants that grow in capacity as the GHG cap is strengthened. MSW and Landfill gas power plants are built and operated in the NDC-15% and EE&RE Policies scenarios, but make relatively small contributions. It should also be noted that natural gas does not play a major mitigation role in the Vietnam power sector, with its share of generation dropping from 17% in the BAU to 5.5% in the three reduction scenarios, because the gas is more valued in Industry to replace coal and increasingly serves to balance RE as needed.

Figure 40: Unconditional GHG Reduction Scenarios – Electricity Generation





Super-critical coal power plants, which comprise 36% of 2030 electricity supply in the BAU, drops to 27% and 25% in NDC-15% and EE&RE Policies scenarios, respectively. Coal-biomass co-firing plants increase to 3.6% in the NDC-15% scenario, but in the EE&RE Policies scenario they are displaced by RE technologies.

Table 30: Unconditional GHG Reduction Scenarios – Power Sector Measure Results

Measure	Description	BAU	NDC-8%	NDC-15%	EE&RE Policies
Promote RE-based electricity	Central RE electricity (GWh) Share of central supply	79,855 14.0%	91,278 14.3%	98,132 18.0%	118,992 21.9%
Promote wind	Wind generation (GWh) Share of total supply	0 0.0%	4,653 0.7%	20,091 3.7%	23,180 4.3%
Promote central solar	Central solar generation (GWh) Share of total supply	0 0.0%	6,058 0.9%	6,058 1.1%	15,577 2.9%
Biomass power plants [including bagasse]	Wood and bagasse generation (GWh) Share of total supply	806 0.1%	701 0.1%	2,637 0.5%	9,506 1.7%
Landfill gas power plants	Landfill gas generation (GWh) Share of total supply	0 0.00%	0 0.00%	218 0.61%	218 0.62%
MSW power plants	MSW generation (GWh) Share of total supply	0 0.0%	0 0.0%	3,361 0.6%	3,361 0.6%
Biogas power plants	Biogas generation (GWh) Share of total supply	0 0.0%	0 0.0%	0 0.0%	0 0.0%
Small hydro power plants	SHP generation (GWh) Share of total supply	3,300 0.6%	10,441 1.6%	10,441 1.9%	14,912 2.7%
Coal-biomass co-firing plants	Coal and biomass generation (GWh) Share of total supply	1,385 0.2%	10,447 1.6%	17,541 3.2%	0 0.0%
Super-critical coal power plants	Supercritical coal generation (GWh) Share of total supply	206,098 36.0%	184,358 28.8%	149,885 27.4%	135,121 24.8%

7.3.3 Power Plant Capacity Additions and Investment Requirements

The timing of new power plant additions is shown in Figure 41 for the 2020, 2025 and 2030 periods, and Table 31 provides the cumulative capacity additions by power plant type. In all scenarios gas-fired capacity decreases, but upcoming firm coal-fired plant builds result in an ongoing presence for coal over the planning horizon, though under the NDC-15% and even more so with EE&RE Policies less coal is added in the later years. These scenarios all replace coal and gas power plants with solar, small hydro and wind capacity. Cumulative power plant capacity and investment are about the same in the BAU, NDC-8% and NDC-15% scenarios, though they do increase by 2.4% in the EE&RE Policy scenario. Table 32 gives the corresponding cumulative investment requirements.

Figure 41: Unconditional Scenarios – Power Plant Capacity Additions (2020-2030)

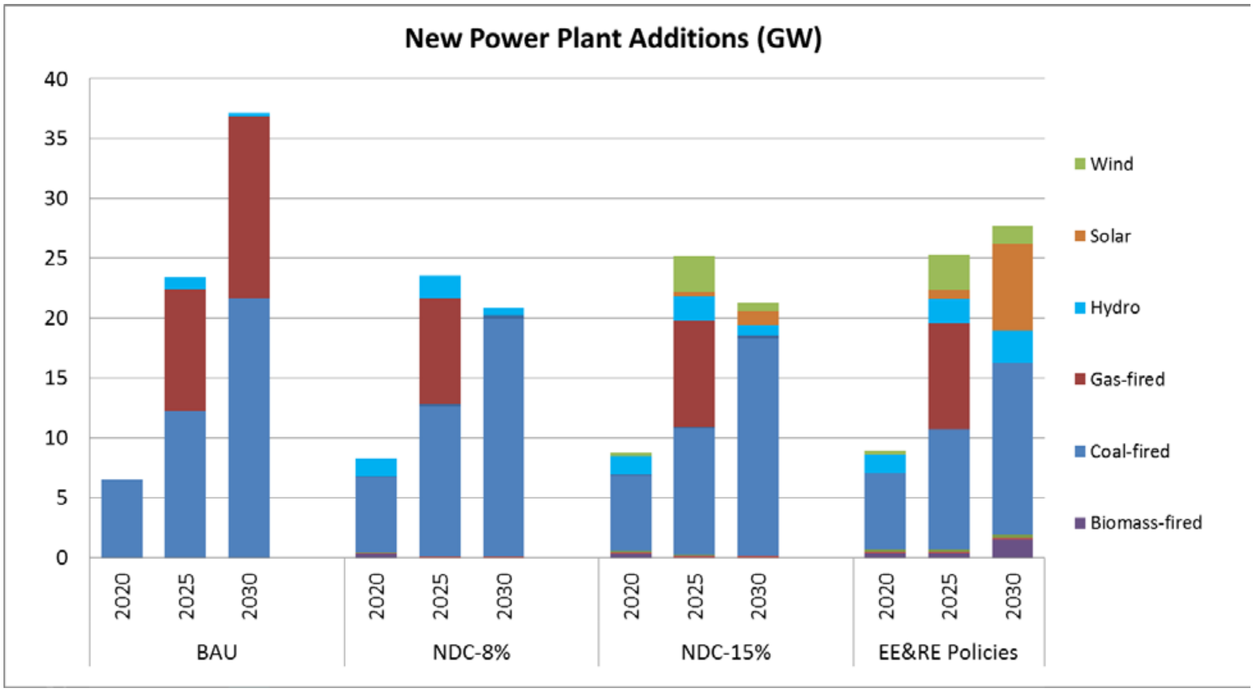


Table 31: Unconditional Scenarios – Power Plant Capacity Additions (2020-2030)

Plant Type	Cumulative Capacity Additions (GW)			
	BAU	NDC-8%	NDC-15%	EE&RE Policies
Biomass-fired	0.0	0.0	0.0	0.1
Coal-fired - Conventional	14.5	15.2	16.7	14.3
Coal-fired Super Critical	27.7	27.8	20.1	18.1
Coal-fired with Biomass	0.0	0.4	0.4	1.2
Gas-fired	25.3	8.9	8.9	8.9
Hydro – Large & Medium	2.7	1.1	2.7	2.7
Hydro - Small	0.0	2.8	2.8	4.6
Municipal Solid Waste	0.0	0.5	0.5	1.6
Solar Central	0.0	4.0	4.0	10.1
Solar Distributed	0.0	0.0	1.6	1.9
Storage	0.0	0.0	0.0	2.4
Wind	0.0	1.2	5.2	6.0
Total	**70.3**	**61.8**	**62.9**	**72.0**

Table 32: Unconditional Scenarios – Power Plant Investment (2020-2030)

Plant Type	Cumulative Investment (USD Million)			
	BAU	NDC-8%	NDC-15%	EE&RE

				Policies
Biomass-fired	0	618	618	2,163
Coal-fired - Conventional	19,305	19,305	19,305	19,305
Coal-fired Super Critical	42,300	43,205	31,154	28,376
Coal-fired with Biomass	250	1,156	3,243	0
Gas-fired	20,985	7,330	7,330	7,330
Hydro – Large & Medium	4,097	1,583	4,098	4,098
Hydro - Small	0	4,957	4,957	8,060
Municipal Solid Waste	0	1,245	1,250	3,851
Solar Central	0	4,486	4,486	10,502
Solar Distributed	0	0	1,807	2,263
Storage	0	0	0	2,404
Wind	0	1,788	7,400	8,987
Total	**86,937**	**85,672**	**85,647**	**97,338**

7.4 Final Energy Use

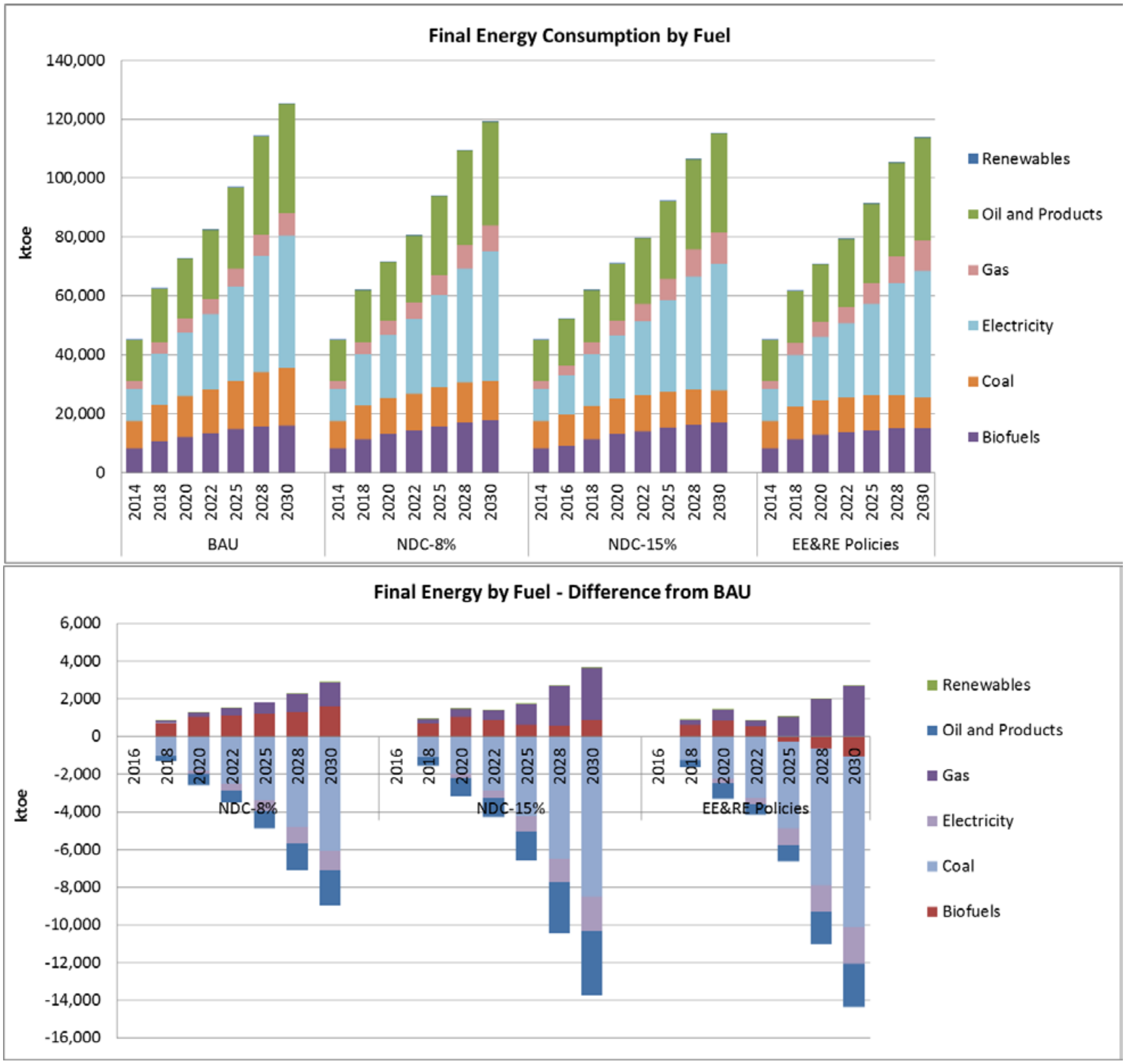
Figure 42 shows the total FEC by sector and the change in consumption from the BAU scenario. The figure shows modest reductions in overall energy use, with reductions in coal, oil products and electricity somewhat offset by increases in biofuels and natural gas use. Overall FEC is reduced by 4.8%, 8%, and 9.3% in 2030 for the NDC-8%, NDC-15% and EE&RE Policies scenarios respectively. Note that the reduction in oil products consumption is due to the EFFECT scenario selected, where the NDC-8% scenario uses EFFECT-M1-09 and the NDC-15% and EE&RE scenarios use EFFECT-M2-15.

Table 33 shows the final energy intensity per unit of GDP in 2030 by sector for each scenario is in line with the reduction in consumption. The Industry sector is responsible for about half of the improvements, followed by Transportation and Residential.

Table 33: Final Energy Intensity (FEC/GDP) in 2030 (kgoe/$1000)

Sector	BAU	NDC-8%	NDC-15%	EE&RE Policies
Agriculture	7.0	6.7	6.8	6.7
Commercial	18.1	17.6	17.3	17.2
Industry	182.3	174.5	169.7	168.7
Residential	59.9	56.9	55.7	52.5
Transportation	67.6	62.5	58.6	58.6
Total	334.9	318.2	308.1	303.8
Change relative to BAU	**NA**	**-5.0%**	**-8.0%**	**-9.3%**

Figure 42: Unconditional GHG Reduction Scenarios – Final Energy Use

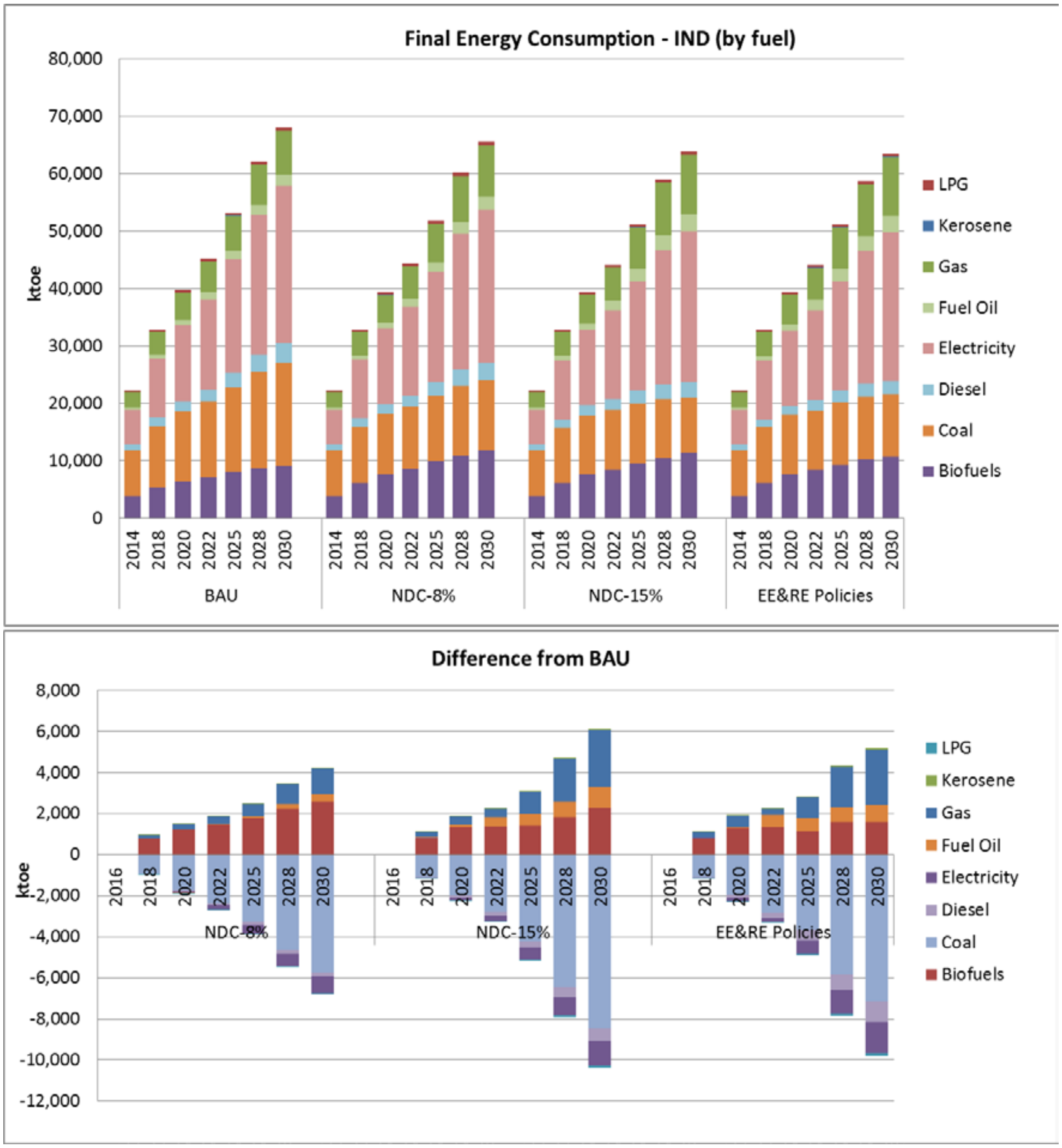


7.5 Industry Sector Energy Use

7.5.1 Overview

Figure 43 shows the Industry sector FEC (on the top) and the change in energy use from the BAU scenario (on the bottom). The figure shows that relative to the BAU, major reductions in coal, along with some electricity and diesel that are offset by increases in biofuels, fuel oil and natural gas. The sector undergoes a significant reduction in coal use (35% to 53%), while gas consumption in 2030 grows from 11% of Industry FEC in the BAU to 14% for the NDC-8% scenario and 16% for the NDC-15% and EE&RE Policies scenarios.

Figure 43: Unconditional GHG Reduction Scenarios – Industry Energy Use



7.5.2 Industry Subsectors

Figure 44 shows the final energy use and changes from BAU by subsector. For these scenarios, the Cement, Other, Iron & Steel, and Textiles & Leather subsector generate the largest reductions in FEC. Overall FEC reductions are 3.7%, 6.2% and 6.8%, respectively. The planning horizon of 2030 does not permit time for greater changes, and some data limitations, such as the rate of industrial CHP adoption could be changed if there was a specific policy.

Figure 44: Unconditional GHG Reduction Scenarios – Industry Subsector Energy Use

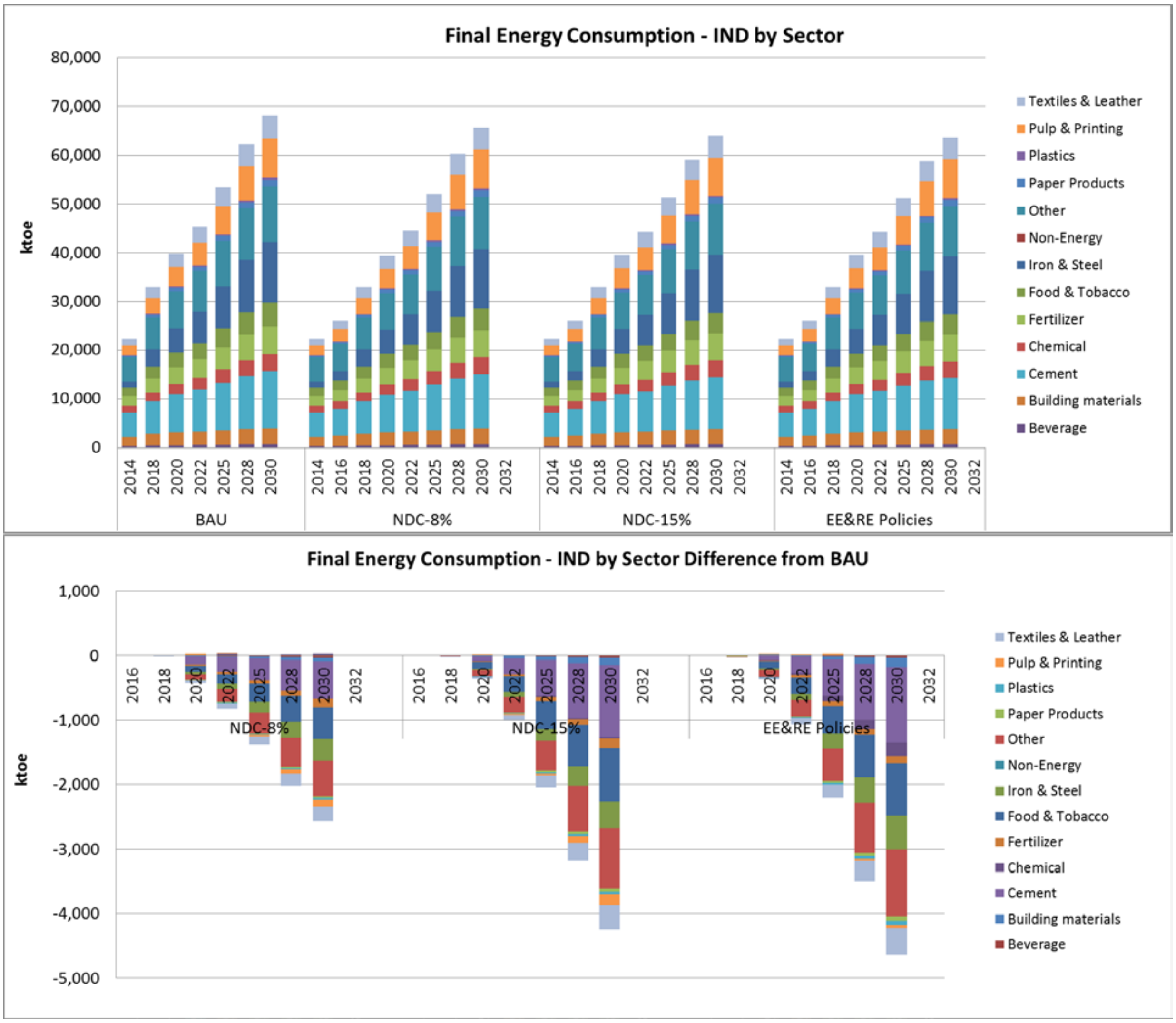


Table 34 shows the final energy intensity per unit of GDP in 2030 by Industry subsector for each scenario, with intensity reductions a bit above consumption savings as industry gets more efficient overall. The largest improvements occur for the Cement, Other and Food & Tobacco subsectors.

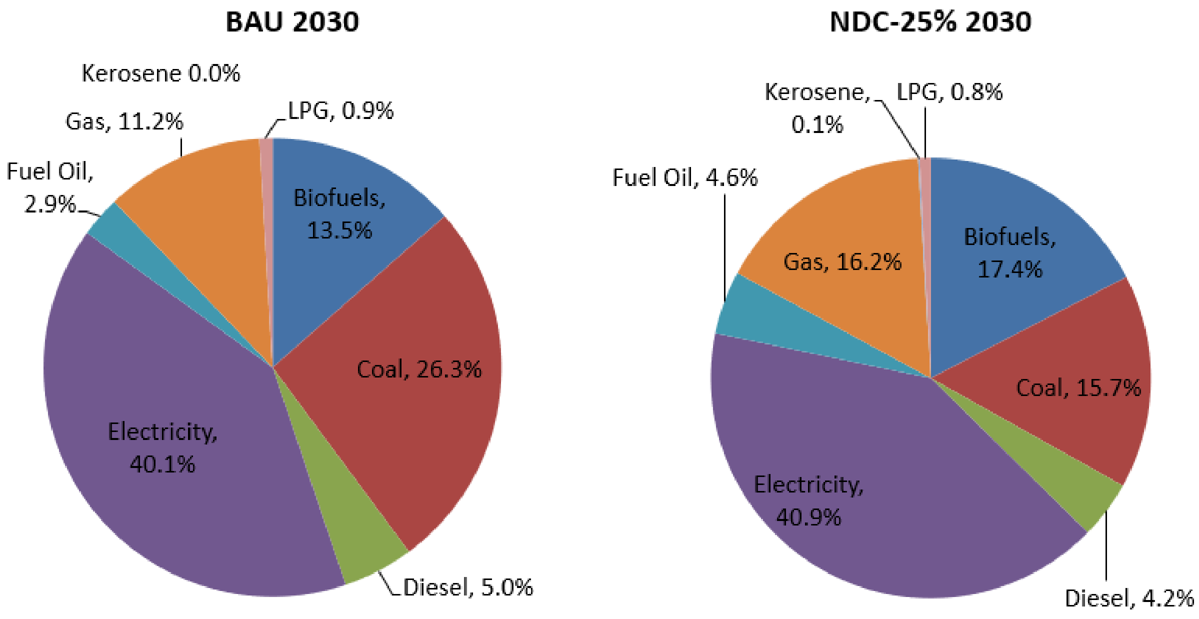
Table 34: Energy Intensity by Industry Subsector (kgoe/$1000)

Subsector	BAU	NDC-8%	NDC-15%	EE&RE Policies
Beverage	1.8	1.7	1.8	1.8
Building materials	8.7	8.6	8.4	8.4
Cement	31.4	29.9	28.4	28.3
Chemical	9.2	8.8	9.2	8.7
Fertilizer	15.2	14.8	14.8	14.9
Food & Tobacco	13.3	12.0	11.1	11.1

Iron & Steel	33.2	32.3	32.1	31.7
Other	30.4	29.0	28.0	27.7
Paper Products	3.4	3.3	3.3	3.3
Plastics	1.1	1.1	1.0	1.0
Pulp & Printing	21.4	21.0	20.9	21.3
Textiles & Leather	13.0	12.4	12.0	11.8
Total sector	182.3	174.5	169.7	168.7
Change from BAU		**-4.3%**	**-6.9%**	**-7.4%**

A key finding of the analysis is that gas has a much higher mitigation value in Industry than in the Power sector, where increasingly competitive RE generation options play a central role. As can be seen in Figure 45 there are important structural changes that need to take place in the Industrial sector with gas and biomass stepping in to displace coal use. This is particularly critical in the Iron & Steel subsector for process heat, but also for CHP and process heat in Chemicals, and process heat in Paper Products and Textiles subsectors. The biomass shift is important in the Building Materials, Cement, and Other subsectors for process heat.

Figure 45: Industrial Sector Fuel Mix in 2030 – BAU vs EE&RE Policies



General Industry sector improvements include motor drive efficiency improvements (4.9% to 6.3%), process heat efficiency improvements (3.8% to 6.8%) and facility efficiency improvements (2.6% to 11.2%). Biofuels utilization in boilers & furnaces increases from 12% in the BAU (8,403 ktoe) to over 17% in the reduction scenarios, and cogeneration capacity increases to 0.7% to 1.0% of total generating capacity. The final energy savings across all subsectors ranges from 4.1% to 7.7% compared with the BAU in 2030, with the addition of 1.1 GW to 1.3 GW of industrial CHP capacity. Table 35 provides full details by energy service demand.

Table 35: Unconditional GHG Reduction Scenarios – Industry Sector Measure Results

Sub-sector	Measure	Description	NDC-8%	NDC-15%	EE&RE Policies
General	Motor Drive Efficiency improvements	Electricity savings due to high efficiency motors (GWh)	632	750	818
		Reduction of electricity to Machine Drive	4.9%	5.8%	6.3%
	Process heat Efficiency improvements	Energy savings due to high efficiency boilers and furnaces (ktoe)	1,552	2,693	2,842
		Reduction of FEC to Process Heat	3.7%	6.4%	6.7%
	Facility/Other Efficiency improvements	Energy savings due to high efficiency lighting, AC, etc. (ktoe)	240	542	870
		Reduction of FEC to Facilities/Other	3.3%	7.4%	11.8%
	Biofuels utilization in boilers & furnaces	Biofuels utilization (ktoe)	11,826	11,527	10,832
		Share of final energy to Industry	18.0%	18.0%	17.1%
	Cogeneration	Cogeneration capacity (GW)	0.6	0.7	0.7
		Share of total electric capacity	0.7%	0.9%	1.0%
Iron & Steel	EE measures such as pulverized coal injection in blast furnaces, preheat steel scrap for electric arc furnaces, waste heat recovery based power generation, and other reductions in thermal energy and electrical energy.	Electricity savings due to high efficiency motors (GWh)	109	109	142
		Reduction of electricity to Machine Drive	0.9%	0.9%	1.1%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	245	218	213
		Reduction of FEC to Process Heat	2.0%	1.8%	1.7%
		Energy savings for high efficient facilities (ktoe)	-26	117	203
		Reduction of FEC to Facilities/Other	-0.2%	0.9%	1.6%
Chemicals	EE measures to optimize air compressed & steam systems, add variable speed drives and efficient lighting, etc.	Electricity savings due to high efficiency motors (GWh)	15	15	19
		Reduction of electricity to Machine Drive	0.4%	0.4%	0.6%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	168	174	175
		Reduction of FEC to Process Heat	4.9%	5.1%	5.1%

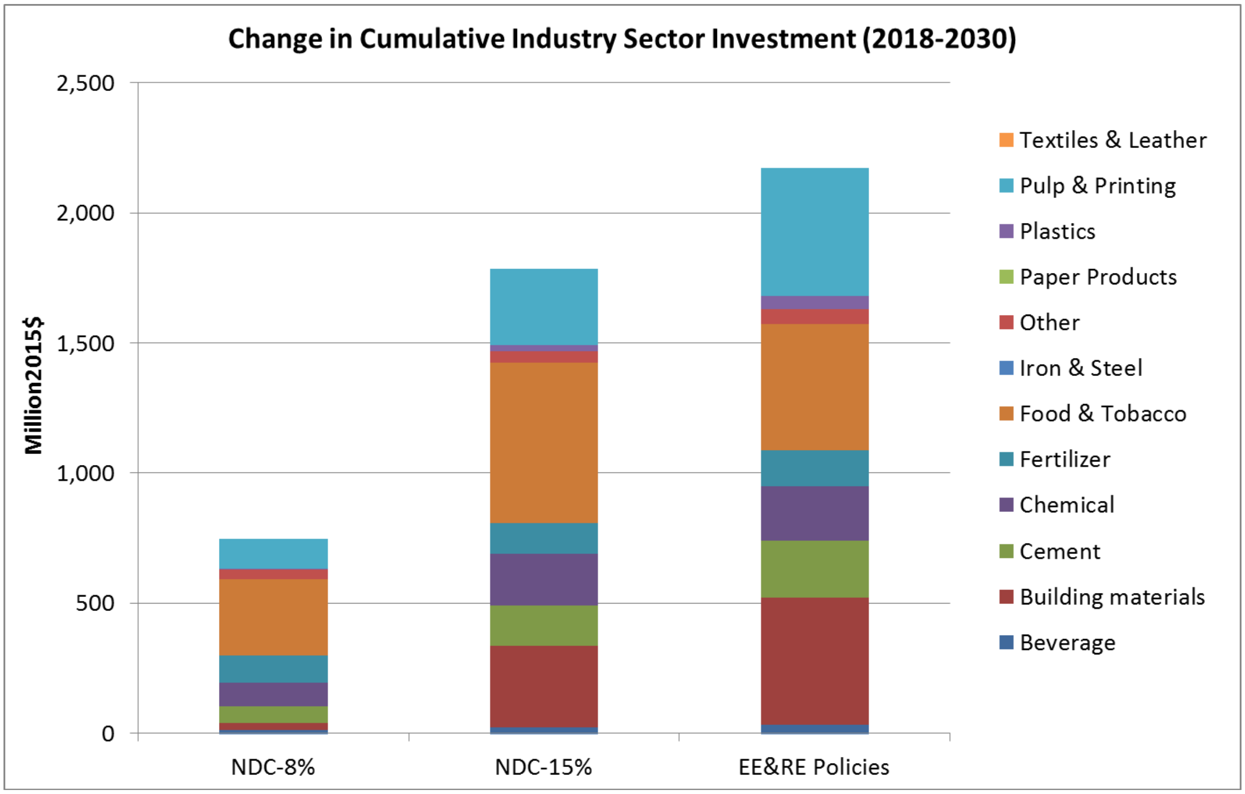
Sub-sector	Measure	Description	NDC-8%	NDC-15%	EE&RE Policies
		Energy savings for high efficient facilities (ktoe)	2	11	14
		Reduction of FEC to Facilities/Other	0.0%	0.3%	0.4%
Fertilizer	EE measures for variable speed drives, optimization of air compressed & steam systems, and using CHP system and heat recovery process improvements.	Electricity savings due to high efficiency motors (GWh)	6	6	6
		Reduction of electricity to Machine Drive	0.1%	0.1%	0.1%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	2	3	2
		Reduction of FEC to Process Heat	0.0%	0.1%	0.0%
		Energy savings for high efficient facilities (ktoe)	4	4	4
		Reduction of FEC to Facilities/Other	0.1%	0.1%	0.1%
Cement	EE measures to optimize combustion cycle, apply waste heat recovery for clinker furnace, reduce crushing energy with vertical mills, and other savings.	Electricity savings due to high efficiency motors (GWh)	43	43	43
		Reduction of electricity to Machine Drive	0.4%	0.4%	0.4%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	496	1,083	1,123
		Reduction of FEC to Process Heat	4.2%	9.2%	9.6%
		Energy savings for high efficient facilities (ktoe)	43	43	73
		Reduction of FEC to Facilities/Other	0.4%	0.4%	0.6%
Beverages	EE measures for beer production, carbonate beverage production, and non-carbonate beverage production thru optimize air compressed & steam systems, variable speed drives, and heat pumps.	Electricity savings due to high efficiency motors (GWh)	6	6	6
		Reduction of electricity to Machine Drive	0.9%	0.9%	0.9%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	24	24	24
		Reduction of FEC to Process Heat	3.6%	3.6%	3.6%
		Energy savings for high efficient facilities (ktoe)	2	2	3
		Reduction of FEC to Facilities/Other	0.3%	0.3%	0.5%
Plastics	EE measures for variable speed drives and efficient lamps, etc.	Electricity savings due to high efficiency motors (GWh)	2	14	34
		Reduction of electricity to Machine Drive	0.4%	3.3%	8.0%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	19	25	27
		Reduction of FEC to Process Heat	4.6%	6.0%	6.3%

Sub-sector	Measure	Description	NDC-8%	NDC-15%	EE&RE Policies
		Energy savings for high efficient facilities (ktoe)	0	3	3
		Reduction of FEC to Facilities/Other	0.0%	0.7%	0.7%
Food & Tobacco	EE measures to install variable speed drives, efficient air compressor, efficient chillers, and efficient lighting.	Electricity savings due to high efficiency motors (GWh)	35	35	35
		Reduction of electricity to Machine Drive	0.7%	0.7%	0.7%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	176	264	264
		Reduction of FEC to Process Heat	3.5%	5.3%	5.3%
		Energy savings for high efficient facilities (ktoe)	38	53	75
		Reduction of FEC to Facilities/Other	0.8%	1.1%	1.5%
Paper Products	EE measures for waste heat recovery from paper drying to reduce heating requirements, and Variable speed drives, optimization of air compressed & steam systems, using CHP system	Electricity savings due to high efficiency motors (GWh)	12	12	23
		Reduction of electricity to Machine Drive	0.9%	0.9%	1.8%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	26	26	26
		Reduction of FEC to Process Heat	0.3%	1.4%	1.6%
		Energy savings for high efficient facilities (ktoe)	4	18	20
		Reduction of FEC to Facilities/Other	0.3%	1.4%	1.6%
Pulp & Printing	EE measures to Thermo-mechanical pulping, increased use of recycled pulp, and Black liquor gasification plants to cogenerate steam, and Variable speed drives, optimization of air compressed & steam systems	Electricity savings due to high efficiency motors (GWh)	44	85	85
		Reduction of electricity to Machine Drive	0.5%	1.1%	1.1%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	111	155	240
		Reduction of FEC to Process Heat	1.4%	1.9%	3.0%
		Energy savings for high efficient facilities (ktoe)	2	2	2
		Reduction of FEC to Facilities/Other	0.0%	0.0%	0.0%
Bricks	Modernize brick production by applying efficiency measures and Increasing production unburnt bricks	Electricity savings due to high efficiency motors (GWh)	9	36	36
		Reduction of electricity to Machine Drive	0.3%	1.1%	1.1%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	0	-2	31
		Reduction of FEC to Process Heat	0.0%	-0.1%	0.9%

Sub-sector	Measure	Description	NDC-8%	NDC-15%	EE&RE Policies
		Energy savings for high efficient facilities (ktoe)	46	84	111
		Reduction of FEC to Facilities/Other	1.4%	2.6%	3.4%
Textiles	EE measures for boiler improvements, variable speed drives and efficient lamps in fiber production, knitting and dyeing	Electricity savings due to high efficiency motors (GWh)	60	97	97
		Reduction of electricity to Machine Drive	1.2%	2.0%	2.0%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	169	249	250
		Reduction of FEC to Process Heat	3.5%	5.1%	5.2%
		Energy savings for high efficient facilities (ktoe)	6	44	90
		Reduction of FEC to Facilities/Other	0.1%	0.9%	1.8%
Other	EE measures for boiler improvements, variable speed drives and efficient lamps in fiber production, knitting and dyeing	Electricity savings due to high efficiency motors (GWh)	292	292	292
		Reduction of electricity to Machine Drive	2.6%	2.6%	2.6%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	138	376	471
		Reduction of FEC to Process Heat	1.2%	3.3%	4.1%
		Energy savings for high efficient facilities (ktoe)	119	180	273
		Reduction of FEC to Facilities/Other	1.0%	1.6%	2.4%

Figure 46 plots the cumulative investment requirements for specific industry subsectors. Some subsectors show cumulative savings in certain time periods as early investment in more efficient devices and processes lowers future investment costs compared to the BAU. Also, early CHP investments reduce later investment costs relative to the BAU because of the avoided purchases of new process heat boilers. Overall the incremental investment needs for the NDC-8% are $750 million, with $1.78 billion needed for the NDC-15% scenario, and $2.18 billion for the EE&RE Policies scenarios, reflecting the stronger energy efficiency targets in the latter. The higher level of investment in the Pulp & Printing and Food and Tobacco sub-sectors is due to the move to biomass CHP with their higher investment costs in the later periods.

Figure 46: Unconditional Scenarios – Industry Sector Investment (2018-2030)



7.6 Building Sector Energy Use

7.6.1 Residential

Overall FEC in the Residential sector is reduced 4.2%, 7.1% and 12.3% for the NDC-8%, NDC-15% and EE&RE Policies scenarios respectively. Figure 47 shows the Urban Residential FEC (on the top) and the change in energy use from the BAU scenario (on the bottom). The figure shows reductions come mostly from fuelwood early and electricity along with LPG as the mitigation level rises in later years.

Figure 47: Unconditional GHG Reduction Scenarios – Urban Residential Energy Use

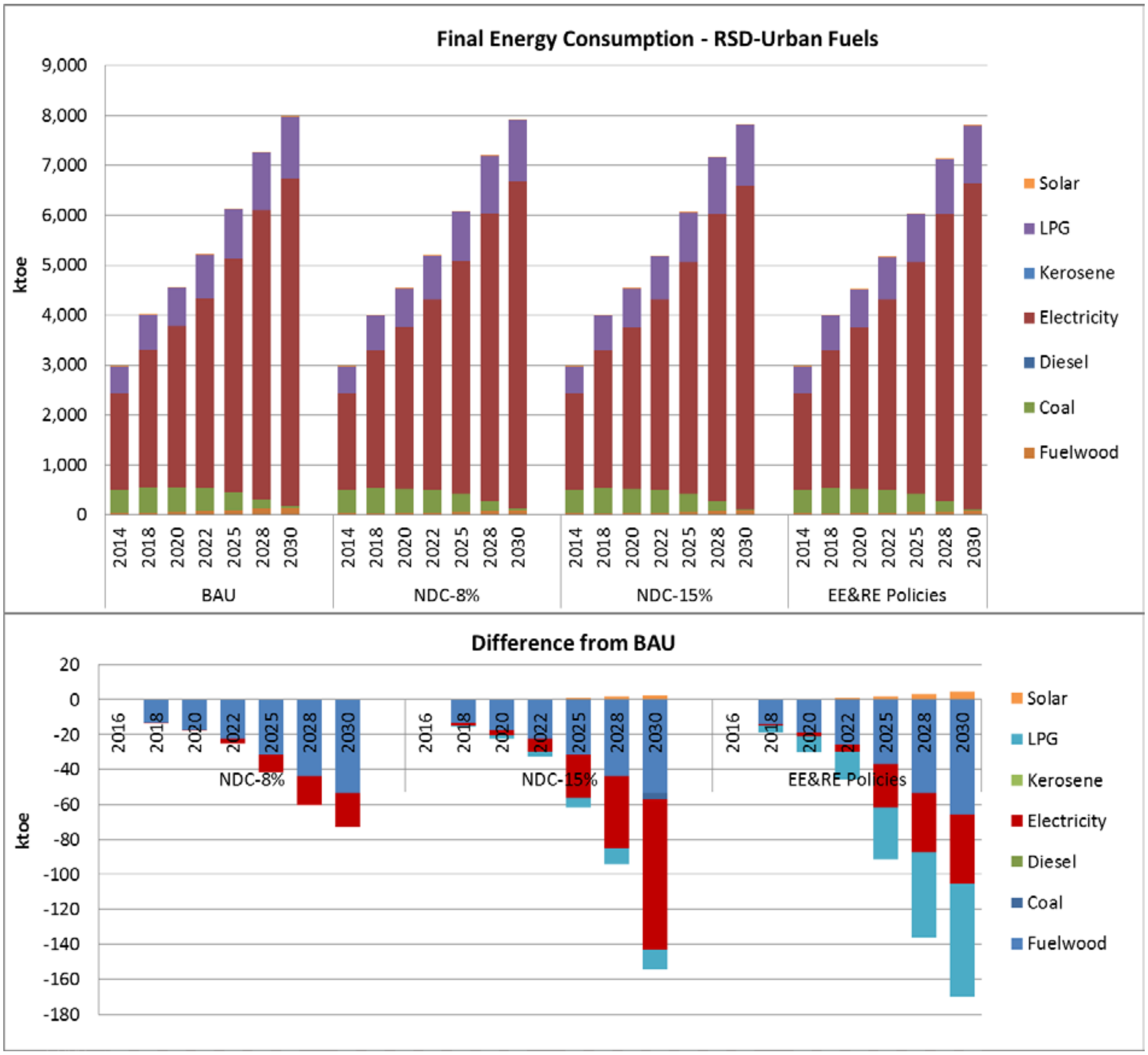


Figure 48 shows the Rural Residential FEC (on the top) and the change in energy use from the BAU scenario (on the bottom). The figure shows reductions come primarily from fuelwood use offset by slight increases in electricity growth. Note also that use of straw, rice husk and other biomass decline to zero by 2030 as households move to more modern fuels.

Figure 48: Unconditional GHG Reduction Scenarios – Rural Residential Energy Use

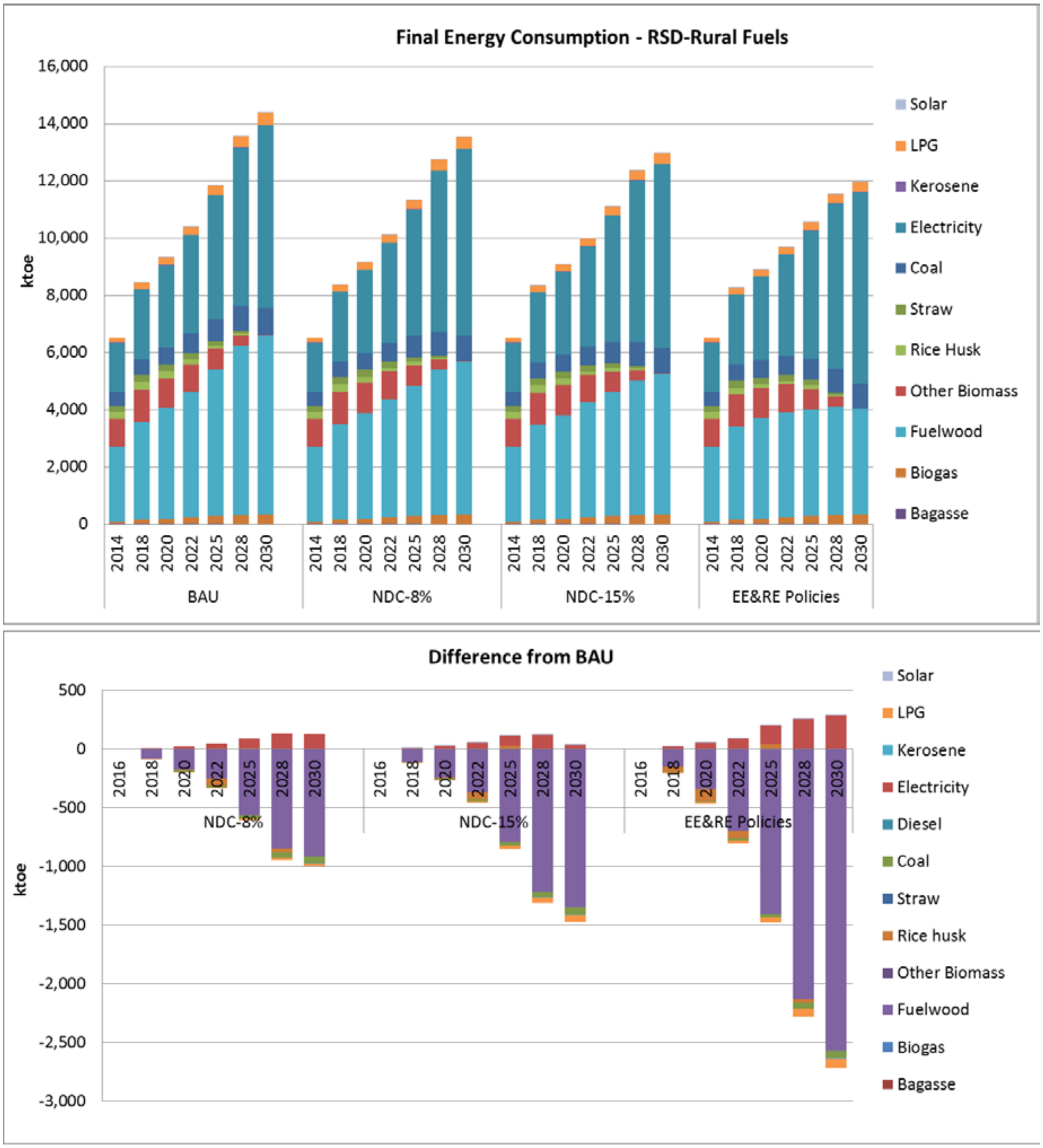


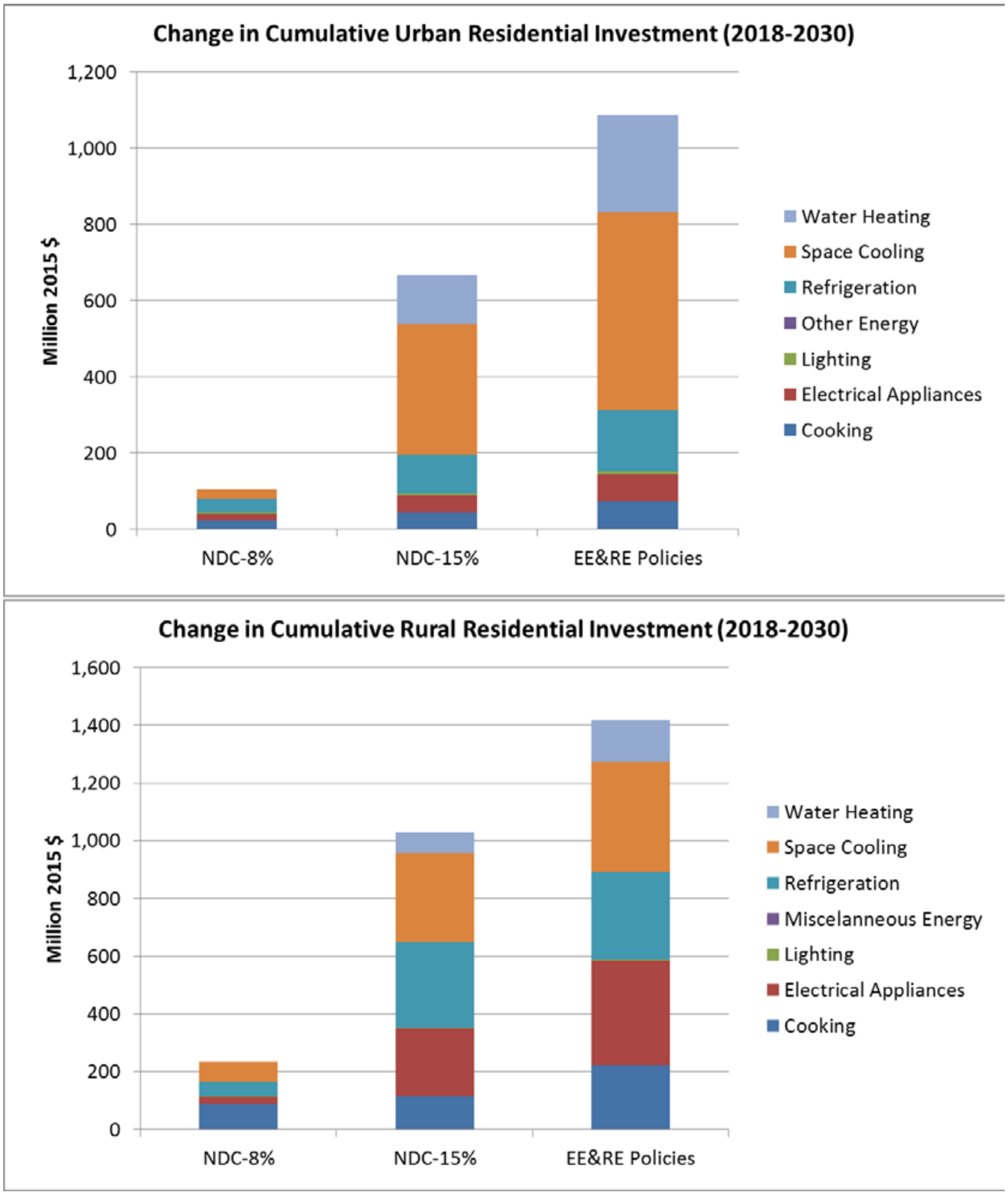
Table 36 shows the mitigation contributions. The combined Urban and Rural Residential sector measures include around 2 GWh of electricity from rooftop PV systems while solar water heating increases from 3 ktoe in the BAU to 10 ktoe in the EE&RE Policies scenario. The greatest improvements come from high performance AC systems, high performance (LED) lighting, and more efficient electric appliances. These cover between 13% and 18% of total demand for each end-use application.

Table 36: Unconditional GHG Reduction Scenarios – Residential Sector Measure Results

Measure	Description	BAU	NDC-8%	NDC-15%	EE&RE Policies
Solar PV	Rooftop solar generation (GWh)	0	0.0	1.5	2.0
	Share of total supply	0.0000%	0.0000%	0.0001%	0.0002%
Solar water heaters	Solar hot water heater use (ktoe)	3	3	7	10
	Share of total demand	1.7%	1.7%	3.4%	5.1%
High performance AC	Use of high efficiency AC (ktoe)	124	0	1,244	1,659
	Share of total demand	1.0%	0.0%	10.0%	13.3%
High performance refrigerators	Use of high-efficiency refrigerators (ktoe)	22	99	302	385
	Share of total demand	1.0%	4.6%	13.9%	17.7%
High performance lighting	Use of energy-saving lighting/LEDs (ktoe)	7	33	66	98
	Share of total demand	1.0%	5.0%	10.0%	15.0%
Appliance efficiency	Use of high efficiency appliances (ktoe)	24	68	245	367
	Share of total demand	1.0%	2.8%	10.0%	15.0%
Biogas for cooking	Use of biogas for cooking (ktoe)	330	331	330	331
	Share of total demand	2.8%	3.0%	3.1%	3.5%
Cleaner cooking fuels	Use of electric and LPG stoves (ktoe)	0	116	93	261
	Share of total demand	0.0%	1.1%	0.9%	2.8%

Figure 49 plots the cumulative incremental investment requirements for the Urban and Rural portions of the Residential sector. The investments are grouped according to specific end-use services. Overall investment needs range from about $340 million for the sector in NDC-8% to about $1.7 billion in NDC-15%, and $2.5 billion in the EE&RE Policies scenario. Space cooling, water heating and refrigeration investments account for more than half of the requirement, followed by electrical appliances and cooking.

Figure 49: Unconditional Scenarios – Residential Sector Investment (2018-2030)



7.6.2 Commercial

Figure 50 shows the Commercial sector FEC (on the top) and the change in energy use from the BAU scenario (on the bottom). Overall FEC in the Commercial sector is reduced 2.4%, 4.4% and 5.1% for the NDC-8%, NDC-15% and EE&RE Policies scenarios respectively. The figure shows that almost all FEC reductions come from electricity use, except for the substitution of coal and kerosene for cooking with electricity. Note that solar for hot water appears in the NDC-8% and NDC-15% scenarios, but not in the EE&RE scenario, where RE is focused on the Power sector.

Figure 50: Unconditional GHG Reduction Scenarios – Commercial Sector Energy use

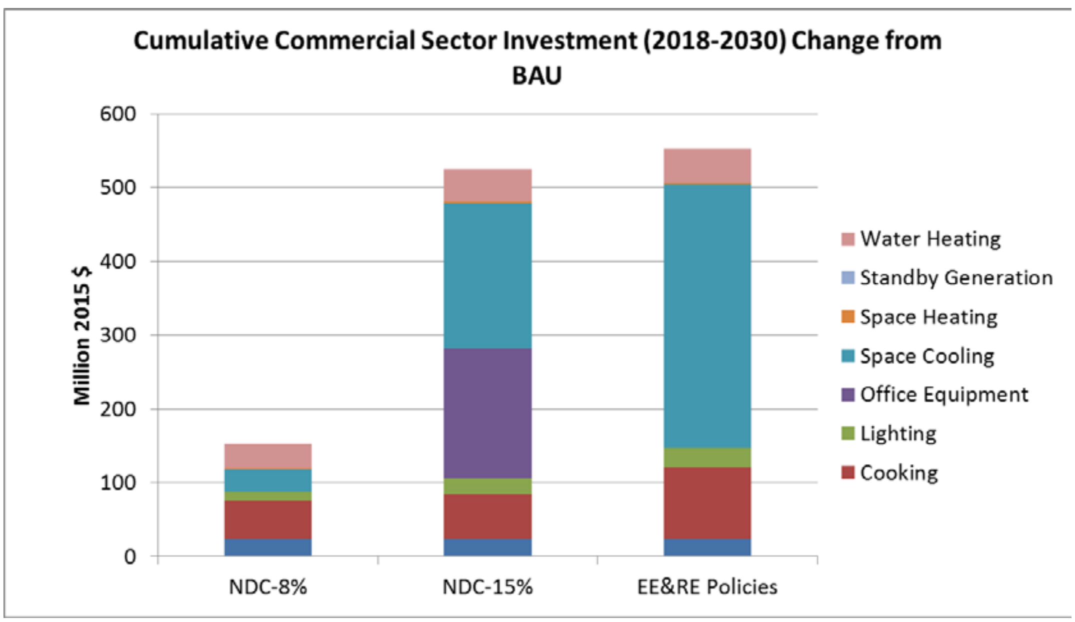
As shown in Table 37, the greatest improvements come from high performance AC systems, high performance (LED) lighting, and more efficient water heaters. High performance AC systems cover 8% to 10% of total cooling demand, while high performance (LED) lighting and more efficient water heaters increase from 1.5% of the demand in the BAU to 7.5%, 15%, and 22.5% in the mitigation scenarios. Commercial sector PV systems grow to 0.9 GWh in the NDC-15% and EE&RE Policies cases.

Table 37: Unconditional GHG Reduction Scenarios – Commercial Sector Measure Results

Measure	Description	BAU	NDC - 8%	NDC- 15%	EE&RE Policies
Solar PV	Use of rooftop solar (GWh)	0.0	0.0	0.9	0.9
	Share of total supply	0.0%	0.0000%	0.0003%	0.0003%
Solar water heaters	Use of solar hot water heaters (ktoe)	5.2	40.8	58.2	8.2
	Share of total supply	1.1%	8.6%	12.3%	1.7%
High performance AC	Use of high efficiency AC [ktoe]	87	0	770	879
	Share of total supply	1.0%	0.0%	8.8%	10.1%
High performance lighting	Use of energy-saving lighting (ktoe)	18.9	94	189	283
	Share of total supply	1.5%	7.5%	15.0%	22.5%
More efficient water heaters	Use of efficient water heaters (ktoe)	4.6	23	46	64
	Share of total supply	1.5%	8.1%	17.6%	26.8%

Figure 51 plots the cumulative investment requirements for the Commercial sector. The investments are grouped according to specific end-use services. Overall additional investments over the BAU are $150 million for NDC-8%, $525 million for NDC-15%, and rise to $550 million in the EE&RE Policies scenario. Space cooling investments account for more than half the reductions, followed by office equipment and water heating.

Figure 51: Unconditional Scenarios – Commercial Sector Investment (2018-2030)



7.7 Agriculture

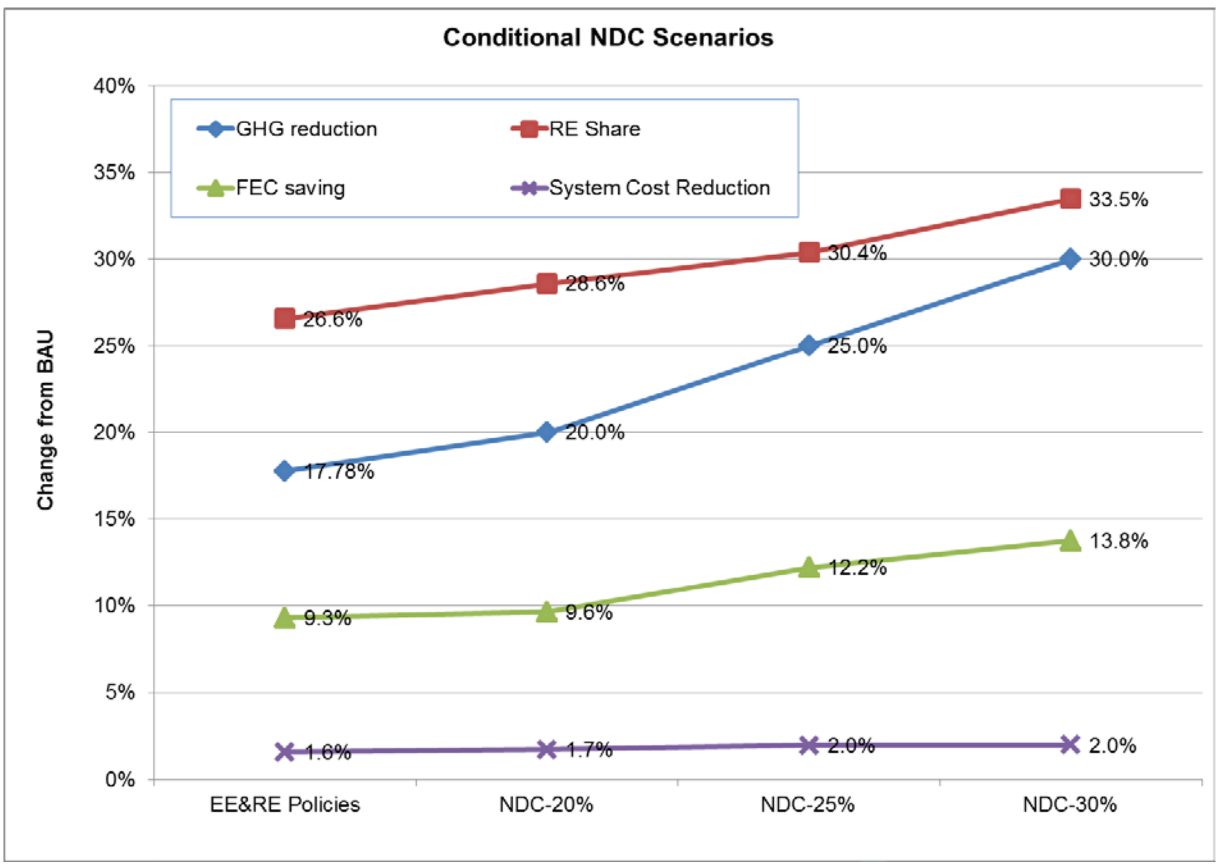
The only substantive area for improvement in the Agriculture sector is associated with electricity use for water pumping, along with some displacement of coal for other uses by fuel oil. But as the sector FEC is only around 2% of the total its contribution is minor.

8 Assessment of Conditional NDC Assessment

8.1 Overview

Figure 52 shows the Conditional NDC targets of 20%, 25% and 30%, along with the EE&RE Policies scenario for comparison. Note that all these scenarios show lower energy system cost (larger cost reduction) compared to the BAU owing to substantive fuel savings arising from EE promotion and RE development. The NDC-20% scenario has a larger RE share and more FEC reduction than the EE&RE Policies case, adding 17.7 GW of central and distributed solar and 8 GW of wind. The NDC-25% and NDC-30% scenarios increase the share of solar capacity to 19.5 and 20.1 GW while maintaining wind capacity at just over 8 GW. The share of RE generation increases from 26.6% in the EE&RE scenario to 28.6%, 30.4% and 33.5%, respectively, and the FEC reduction moves from 9.3% to 9.6% to 12.2% and 13.8%. The costs of these reduction levels are all about 2% lower than the BAU scenario, which is a net present value of approximately $14 billion over the planning horizon, mainly due to the lower life-cycle cost and reduced expenditure on fuel arising from the introduction of more EE & RE. More details are provided on the modeling results in Appendix C.

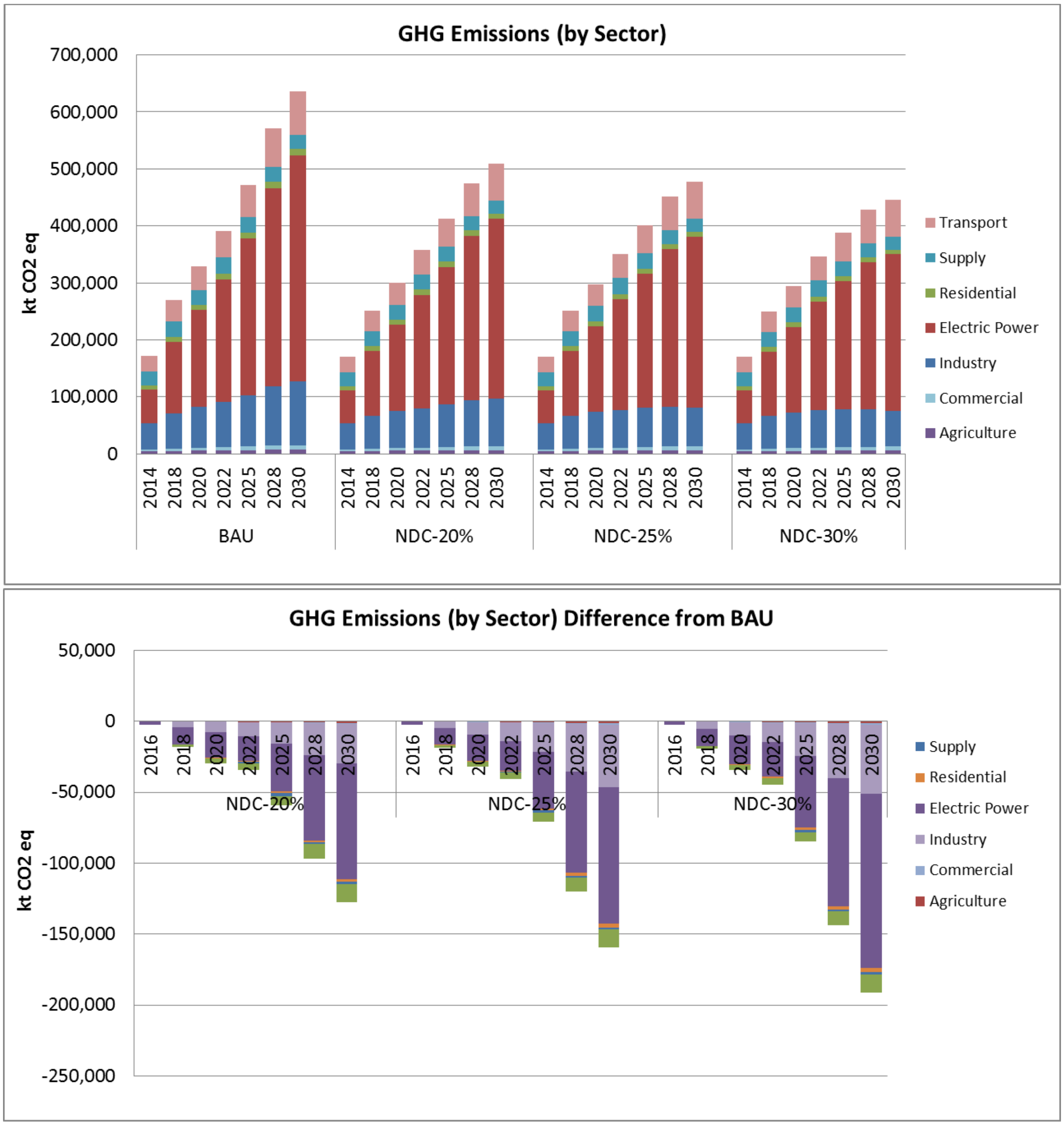
Figure 52: Conditional GHG Reduction Scenario Results



8.2 GHG Emissions

Figure 53 shows the GHG emissions (on the top) and the change in emissions from the BAU scenario (on the bottom) for these three Conditional scenarios. The figure shows that, as with the Unconditional scenarios, almost all emission reductions come from the Power and Industry sectors, with Power dropping 21%, 24%, and 31% in 2030 compared with the BAU, with Industry seeing 25%, 40% and 44% reductions in the respective NDC scenarios.

Figure 53: Conditional GHG Reduction Scenarios – GHG Emissions



8.3 Supply and Power Sectors

8.3.1 Energy Supply

Supply sector impacts for the Conditional scenarios are also relatively modest. The utilization of natural gas decreases by only 16% compared to the BAU as more variable renewables require more gas use for backup and the higher reduction levels require more gas to replace coal in the Industry sector. The utilization of various biofuels increases to almost 13% of primary supply, compared to 11% in the Unconditional scenarios. Fuelwood, Bagasse and Other biomass account for most for the increase, but there is important utilization of MSW and Landfill gas.

Imports from China and Laos do not change compared to the Unconditional scenarios, because they reach their full potential in all scenarios. However, the imports share of total electricity increases slightly as it is turned to as it is seen as carbon free source of electricity, where by 2028 imports from both China and Laos reach their transmission capacity limits.

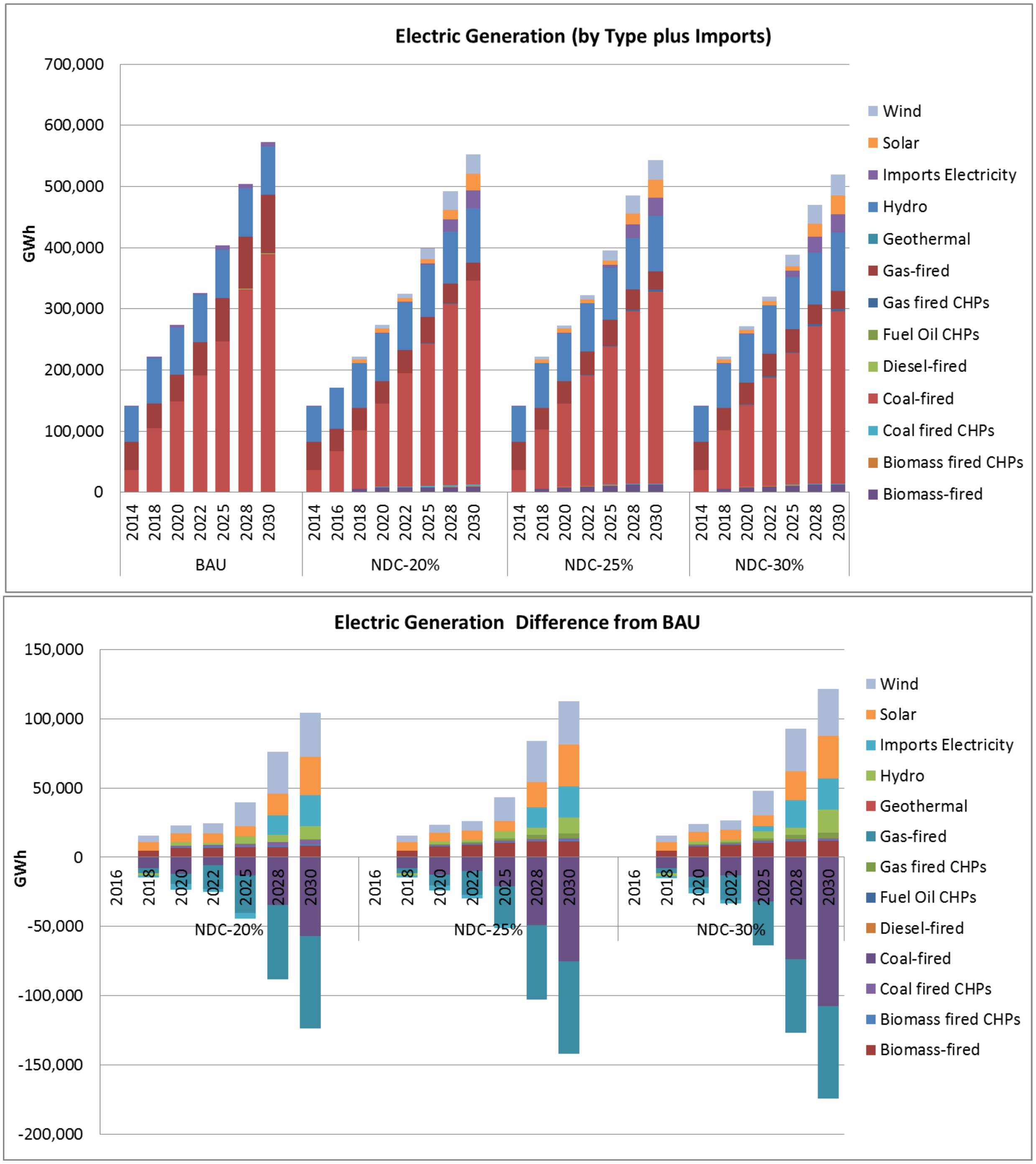
Table 38: Conditional GHG Reduction Scenarios – Supply & Power Sector Measure Results

Sector	Measure	Description	BAU	NDC-20%	NDC-25%	NDC-30%
Supply	Natural gas consumption	Natural gas supply (ktoe)	25,292	16,924	20,746	21,153
		Share of total primary energy	12.6%	9.6%	12.1%	12.8%
	Biofuel production	Biofuel production (ktoe)	17,423	19,137	20,447	21,317
		Share of total primary energy	8.7%	10.8%	11.9%	12.9%
	Electricity imports	Electricity imports (GWh)	6,860	29,500	29,500	29,500
		Share of total supply	1.2%	5.4%	5.5%	5.8%

8.3.2 Electricity Generation

Figure 54 shows the electricity generation (on the top) and the change in generation from the BAU scenario (on the bottom). The figure shows that the total electricity generation decreases 3.4% to 9.3%, but that in all scenarios, coal and gas-fired generation are replaced by solar, hydropower, biomass and wind power plants. These scenarios see most of the growth in RE generation from solar, hydropower and wind, with solar growing by 48% for the NDC-20% scenario compared to the EE&RE Policies scenario, 63% in the NDC-25% case and by 67% for the NDC-30% cases, while wind grows by 38% to 45% over the EE&RE Policies case.

Figure 54: Conditional GHG Reduction Scenarios – Electricity Generation



Power sector changes are more significant than for the earlier mitigation scenarios. There is important growth in RE-based electricity, with the contributions from central RE power plants providing most of the total contribution to RE-base electricity, with distributed solar and biomass CHP plants providing the remainder. The contributions from small hydro, MSW and Landfill gas power plants are the same as in the earlier mitigation scenarios, while the contribution from bagasse cogeneration plants remains the same as in the EE&RE Policies scenario.

Table 39: Conditional GHG Reduction Scenarios – Power Sector Measure Results

Sector	Measure	Description	BAU	NDC-20%	NDC-25%	NDC-30%
Power	Promote RE-based electricity	Central RE electricity (GWh)	79,855	122,149	130,016	135,792
		Share of central electricity supply	14.0%	22.4%	24.4%	26.6%
	Promote wind	Wind generation (GWh)	0	31,905	30,939	33,594
		Share of total supply	0.0%	5.8%	5.8%	6.6%
	Promote central solar	Central solar generation (GWh)	0	24,449	27,241	27,510
		Share of total supply	0.0%	4.5%	5.1%	5.4%
	Biomass power plants [including bagasse]	Wood and bagasse generation (GWh)	806	5,572	8,866	8,958
		Share of total supply	0.1%	1.0%	1.7%	1.8%
	Landfill gas power plants	Landfill gas generation (GWh)	0	218	218	218
		Share of total supply	0.00%	0.62%	0.63%	0.66%
	MSW power plants	MSW generation (GWh)	0	3,361	3,361	3,361
		Share of total supply	0.0%	0.6%	0.6%	0.7%
	Biogas power plants	Biogas generation (GWh)	0.00	0.00	0.00	0.00
		Share of total supply	0.0%	0.0%	0.0%	0.0%
	Small hydro power plants	SHP generation (GWh)	3,300	13,132	14,912	20,328
		Share of total supply	0.6%	2.4%	2.8%	4.0%
	Coal-Biomass co-firing plants	Coal and biomass generation (GWh)	1,385	10,453	3,715	3,182
		Share of total supply	0.2%	1.9%	0.7%	0.6%
	Super-critical coal power plants	Supercritical coal generation (GWh)	206,098	121,811	106,914	78,196
		Share of total supply	36.0%	22.3%	20.0%	15.3%

Super-critical coal power plants make a smaller contribution to total electricity supply in the Conditional scenarios, and their share decreases as the mitigation target level increases, having only 15.3% share in the NDC-30% scenario. Coal-Biomass co-firing plants also have a smaller share, as the RE technologies are more cost-effective.

8.3.3 New Power Plant Capacity and Investment

The timing of new power plant additions is shown in Figure 55 for the 2020, 2025 and 2030 periods, and Table 40 provides the 2018-2030 cumulative capacity additions by power plant type. In all scenarios, coal and gas-fired capacity is replaced by solar, wind and small hydro. For the NDC-20% scenario, small hydro, solar, and wind capacity grow by 3.9 GW, 15.8 GW and 8.2 GW respectively, the NDC-25% scenario increases them by 4.6 GW, 17.6 GW and 8.2 GW respectively, and the NDC-30% scenario increases small hydro to 6,8 GW and grows solar to 17.9 GW and wind to 8.9 GW. Overall capacity needs increase for all three mitigation scenarios as more RE plants with relatively low capacity factors are added.

Figure 55: Conditional Scenarios – Power Plant Capacity Additions (2018-2030)

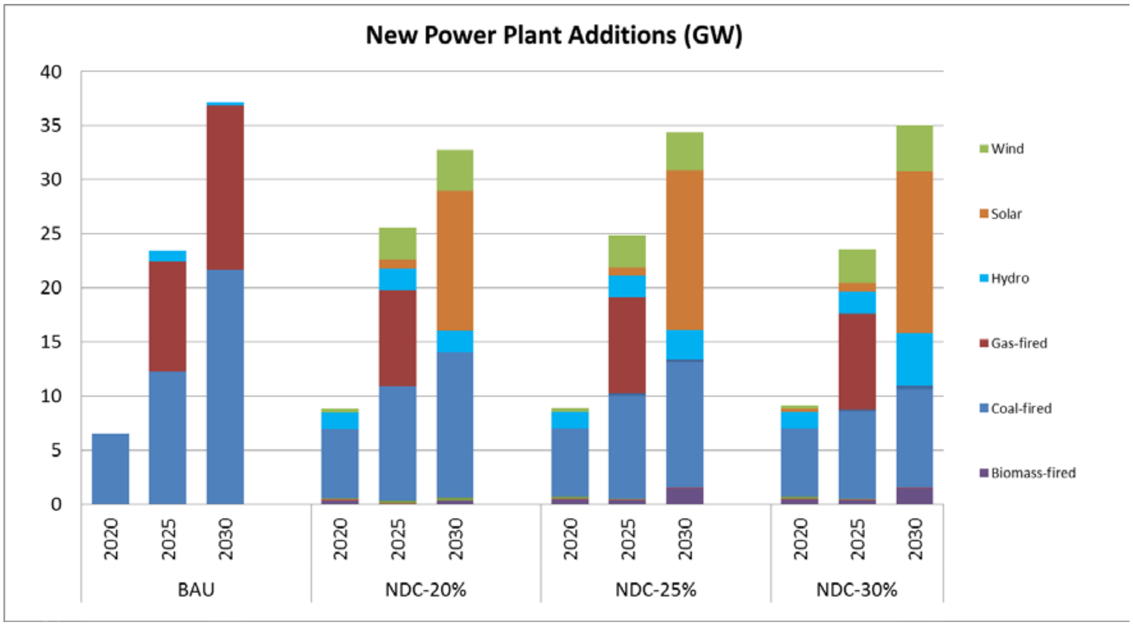


Table 40: Conditional Scenarios – Power Plant Capacity Additions (2020-2030)

Plant Type	Cumulative Capacity Additions (GW)			
	BAU	NDC-20%	NDC-25%	NDC-30%
Biomass-fired	0.0	0.7	1.3	1.3
Coal-fired - Conventional	14.3	14.3	14.3	14.3
Coal-fired Super Critical	27.7	16.4	14.4	10.5
Coal-fired with Biomass	0.2	1.4	0.5	0.4
Gas-fired	25.3	8.9	8.9	8.9
Hydro – Large & Medium	2.7	2.7	2.7	2.7
Hydro - Small	0.0	3.9	4.6	6.8
Municipal Solid Waste	0.0	0.5	1.6	1.6
Solar Central	0.0	15.8	17.6	17.9
Solar Distributed	0.0	1.9	1.9	2.2
Storage	0.0	0.0	2.4	2.4
Wind	0.0	8.2	8.0	8.9
Total	**70.3**	**74.7**	**78.2**	**77.9**

Cumulative power plant investment follows the same pattern as the capacity needs, and Table 41 gives the cumulative investment details. Even with continued improvements in the competitiveness of solar and wind technology, the NDC-20% case requires $11.9 billion more than the BAU scenario, the NDC-25% case requires $16.1 billion more than the BAU scenario, while the NDC-30% scenario requires only $15.9 billion more than the BAU. However, the associated fuel saving and reduced total electricity demand of 3% to 9% for these Conditional scenarios both contribute to an overall savings for the entire energy system of $11.5 billion, $13.8 billion and $13.9 billion, respectively.

Table 41: Conditional Scenarios – Power Plant Investment (2020-2030)

Plant Type	Cumulative Investment (USD Million)			
	BAU	NDC-20%	NDC-25%	NDC-30%
Biomass-fired	0	1,071	2,079	2,091
Coal-fired - Conventional	19,305	19,305	19,305	19,305
Coal-fired Super Critical	42,300	25,472	22,392	16,296
Coal-fired with Biomass	250	1,933	687	588
Gas-fired	20,985	7,330	7,330	7,330
Hydro – Large & Medium	4,097	4,098	4,098	4,098
Hydro - Small	0	6,825	8,060	11,820
Municipal Solid Waste	0	1,250	3,851	3,851
Solar Central	0	16,279	18,104	18,408
Solar Distributed	0	2,268	2,268	2,612
Storage	0	0	2,404	2,404
Wind	0	13,001	12,548	14,078
Total	**86,937**	**98,831**	**103,125**	**102,880**

8.4 Final Energy Use

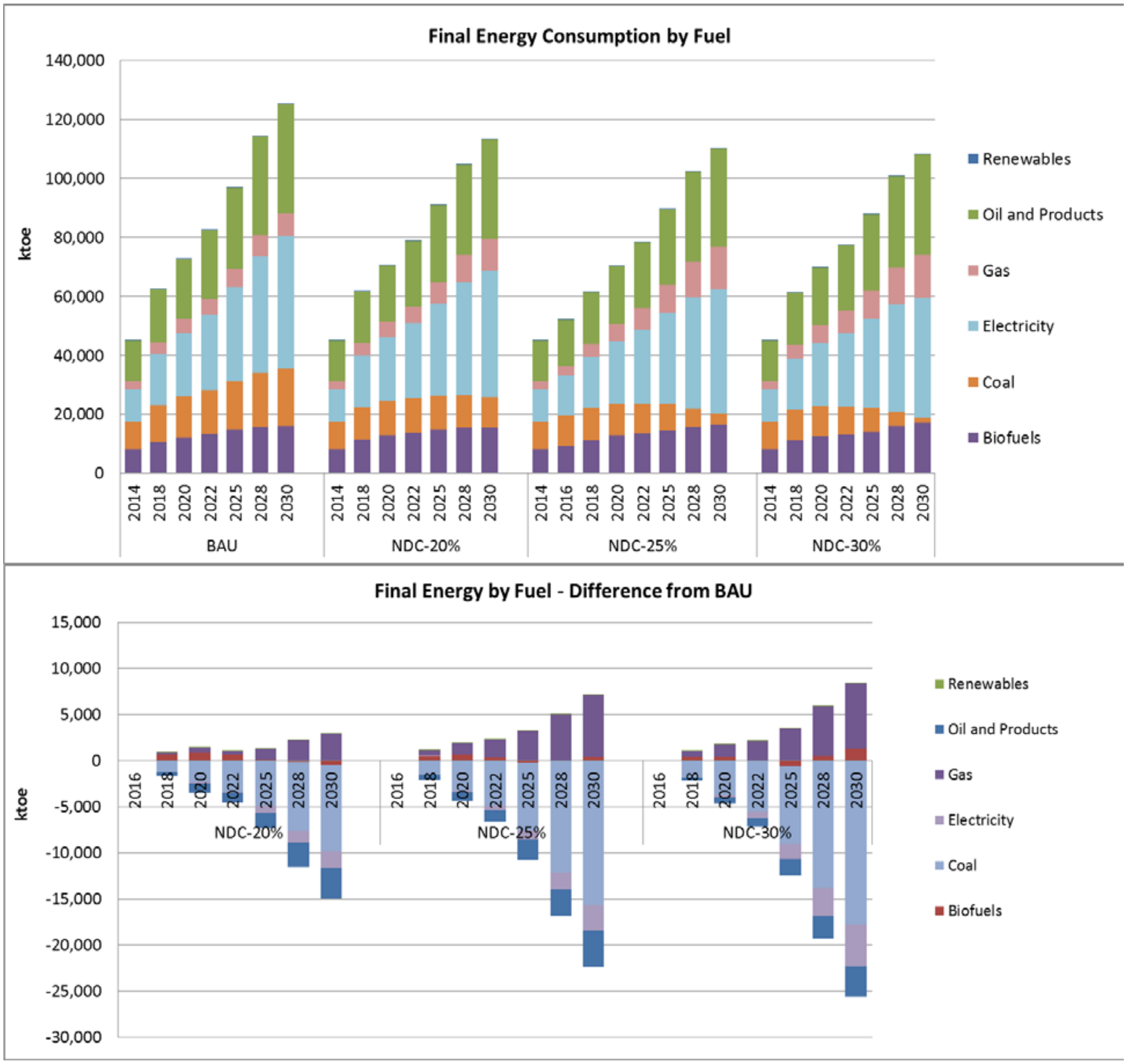
Figure 56 shows the total FEC (on the top) and the change in consumption from the BAU scenario (on the bottom). The figure shows the reductions in overall energy use, with reductions in coal, oil products and electricity being slightly offset by increases in biofuels and natural gas use. Overall FEC is reduced by 9.6%, 12.2%, and 13.8% in 2030 for the NDC-20%, NDC-25% and NDC-30% scenarios respectively. Note that the reduction in oil products consumption is constant due to the use of the EFFECT-M3-19 scenario results for the Conditional targets.

Table 42 shows the final energy intensity per unit of GDP in 2030 by sector for each scenario is in line with the reduction in consumption. The Industry sector is responsible for about half of the improvements, followed by Transportation and Residential.

Table 42: Final Energy Intensity (FEC/GDP) in 2030 (kgoe/$1000)

Sector	BAU	NDC-20%	NDC-25%	NDC-30%
Agriculture	7.0	6.7	6.7	6.7
Commercial	18.1	17.1	16.8	16.5
Industry	182.3	169.2	165.4	161.8
Residential	59.9	52.5	48.1	46.9
Transportation	67.6	57.0	57.0	57.0
Total	**334.9**	**302.6**	**294.0**	**288.9**
Change relative to BAU		-9.7%	-12.2%	-13.7%

Figure 56: Conditional GHG Reduction Scenarios – Final Energy Use

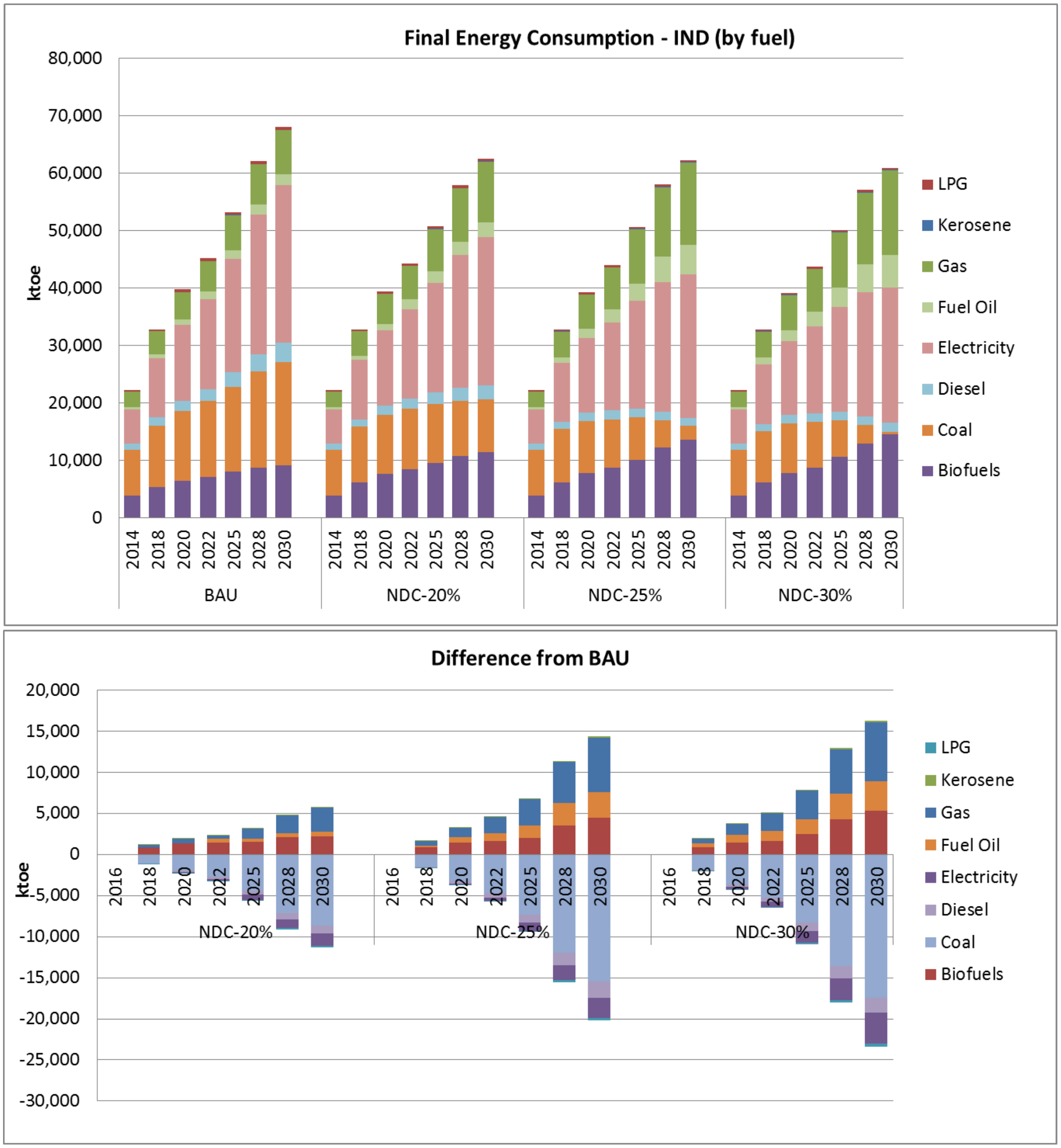


8.5 Industry Sector Energy Use

8.5.1 Overview

Figure 57 shows the Industry sector FEC (on the top) and the change in energy use from the BAU scenario (on the bottom). The figure shows reductions, compared to the BAU, in coal, diesel, LPG and electricity use offset by increases in biofuels, fuel oil and natural gas. The NDC-20% scenario has about the FEC reduction as the EE&RE Policies scenario (7%), while the NDC-25% and 30% cases increase the Industry sector fuel savings to 9% and 11%. Gas consumption in 2030 grows from 11% of Industry FEC in the BAU to 17% for the NDC-20% scenario, 23% for the NDC-25% scenarios and 24% for the NDC-30% scenario.

Figure 57: Conditional GHG Reduction Scenarios – Industry Subsector Energy Use



8.5.2 Industry Subsectors

General Industry sector improvements include motor drive efficiency improvements (6.3% to 18.4%), process heat efficiency improvements (6.7% to 8.4%) and facility efficiency improvements (11.8% to 16%). Biofuels utilization in boilers and furnaces increases from

13.6% in the BAU to 17.9% to 23.8% in these scenarios and cogeneration capacity remains the same as in the Unconditional scenarios at about 1.0% of total generating capacity (0.7 GW).

Overall Industry sector energy savings appear small, but these are in line with the overall energy system FEC reduction. Also, as Figure 57 shows, the sector undergoes a significant reduction in coal use (48% to 91%), while the use of natural gas, biofuels and fuel oil increases to offset the coal savings. The planning horizon of 2030 does not permit a time for greater changes, and some data limitations, such as the rate of industrial CHP adoption could be increased if there was a specific policy. Figure 58 shows the contributions by each subsector to final energy use and changes from BAU.

Figure 58: Conditional GHG Reduction Scenarios – Industry Subsector Energy Use

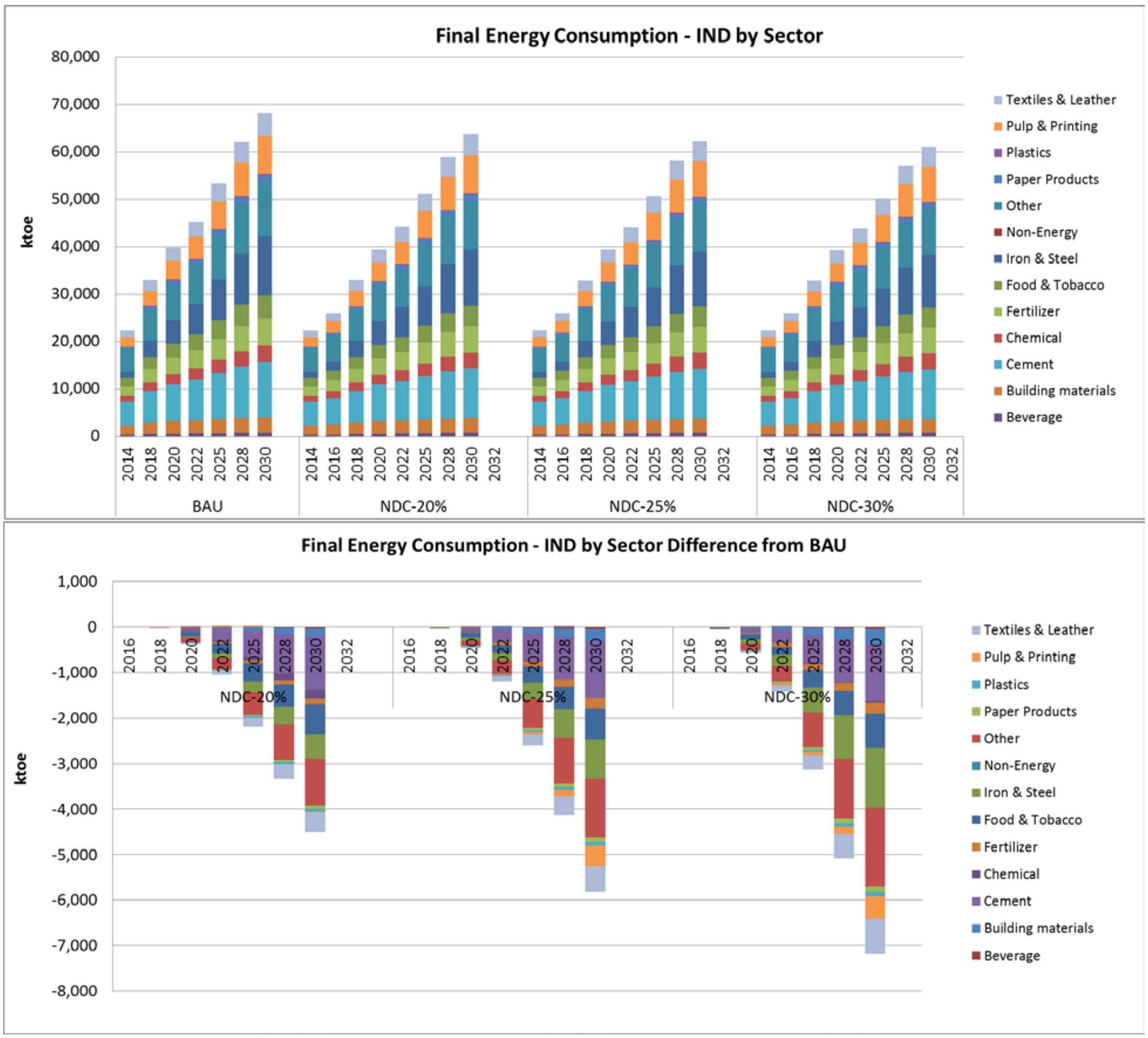


Table 43 shows the final energy intensity per unit of GDP in 2030 by Industry subsector for each scenario, with intensity reductions a bit above consumption savings as industry gets more efficient overall. The Largest improvements occur for the Other, Iron & Steel and Cement followed by Textiles & Leather and Food & Tobacco subsectors.

Table 43: Energy Intensity by Industry Subsector (kgoe/$1000)

Subsector	BAU	NDC-20%	NDC-25%	NDC-30%
Beverage	1.8	1.8	1.7	1.7
Building materials	8.7	8.3	8.0	7.9
Cement	31.4	28.3	28.1	28.1
Chemical	9.2	8.7	9.2	9.1
Fertilizer	15.2	14.9	14.6	14.6
Food & Tobacco	13.3	11.5	11.5	11.3
Iron & Steel	33.2	31.7	30.9	29.7
Other	30.4	27.7	27.0	25.8
Paper Products	3.4	3.3	3.2	3.1
Plastics	1.1	1.0	0.9	0.9
Pulp & Printing	21.4	21.3	20.2	20.0
Textiles & Leather	13.0	11.8	11.5	11.0
Total sector	182.3	169.2	165.4	161.8
Change from BAU		**-7.2%**	**-9.2%**	**-11.2%**

A key finding of the analysis is that gas has a much higher mitigation value in industry than in the power sector where increasingly competitive RE generation options play a central role. As can be seen in Figure 59 there are important structural changes that need to take place in the industrial sector with natural gas and biomass stepping in to reduce coal use by 86% in the NDC-25% scenario. This is particularly critical in the Iron & Steel subsector for process heat, but also for CHP and process heat in Chemicals, and process heat in Paper Products and Textiles subsectors. The biomass shift is important in the Building Materials, Cement, and Other subsectors for process heat.

Figure 59: Industrial Sector Fuel Mix in 2030 – BAU vs NDC-25% Policies

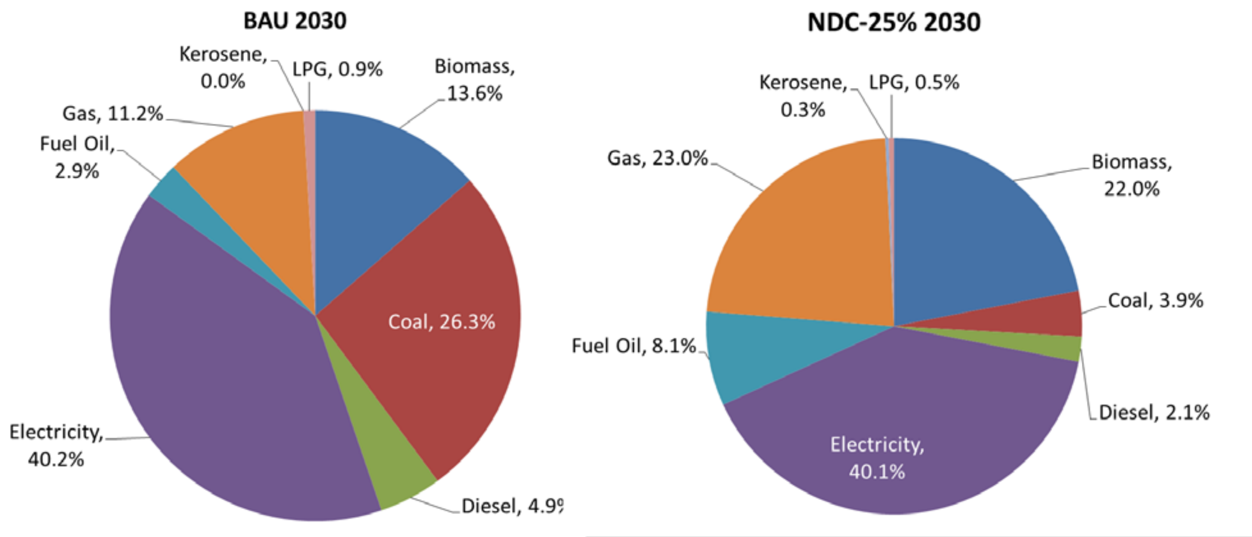


Table 44 provides full details of mitigation measure results by energy service demand.

Table 44: Conditional GHG Reduction Scenarios – Industry Sector Measure Results

Industry	Measure	Description	NDC-20%	NDC-25%	NDC-30%
General	Motor Drive Efficiency improvements	Electricity savings due to high efficiency motors (GWh)	815	1,644	2,378
		Reduction of electricity to Machine Drive	6.3%	12.7%	18.4%
	Process heat Efficiency improvements	Energy savings due to high efficiency boilers and furnaces (ktoe)	2,848	2,945	3,533
		Reduction of FEC to Process Heat	6.7%	7.0%	8.4%
	Facility/Other Efficiency improvements	Energy savings due to high efficiency lighting, AC, etc. (ktoe)	870	1,179	1,179
		Reduction of FEC to Facilities/Other	11.8%	16.0%	16.0%
	Biofuels utilization in boilers & furnaces	Biofuels utilization (ktoe)	11,415	13,684	14,535
		Share of final energy to Industry	17.9%	22.0%	23.8%
	Cogeneration	Cogeneration capacity (GW)	0.7	0.7	0.7
		Share of total electric capacity	0.9%	0.8%	0.8%
Iron & Steel	EE measures such as pulverized coal injection in blast furnaces, preheat steel scrap for electric arc furnaces, waste heat recovery based power generation, and other reductions in thermal energy and electrical	Electricity savings due to high efficiency motors (GWh)	139	483	531
		Reduction of electricity to Machine Drive	1.1%	3.9%	4.3%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	216	207	598
			1.7%	1.7%	4.8%
		Energy savings for high efficient facilities (ktoe)	203	203	203
		Reduction of FEC to Facilities/Other	1.6%	1.6%	1.6%

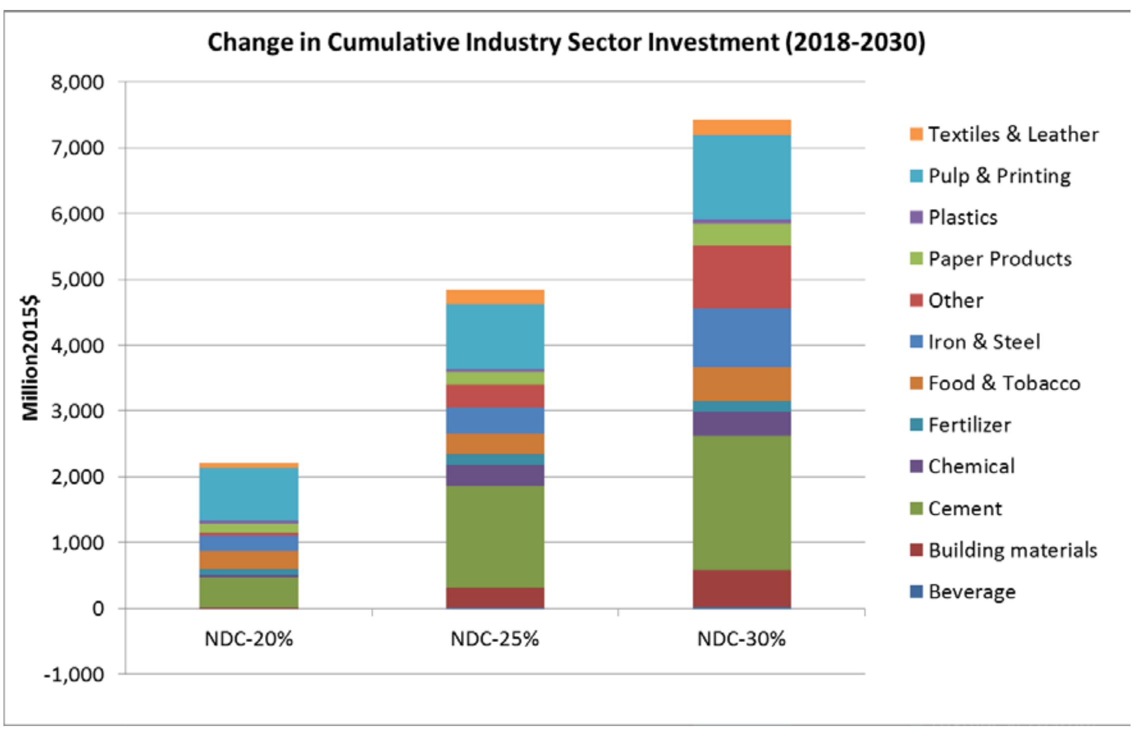
Industry	Measure	Description	NDC-20%	NDC-25%	NDC-30%
	energy.				
Chemicals	EE measures to optimize air compressed & steam systems, add variable speed drives and efficient lighting, etc.	Electricity savings due to high efficiency motors (GWh)	19	44	43
		Reduction of electricity to Machine Drive	0.6%	1.3%	1.3%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	175	182	220
		Reduction of FEC to Process Heat	5.1%	5.3%	6.4%
		Energy savings for high efficient facilities (ktoe)	14	14	14
		Reduction of FEC to Facilities/Other	0.4%	0.4%	0.4%
Fertilizer	EE measures for variable speed drives, optimization of air compressed & steam systems, and using CHP system and heat recovery process improvements.	Electricity savings due to high efficiency motors (GWh)	6	6	6
		Reduction of electricity to Machine Drive	0.1%	0.1%	0.1%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	3	2	3
		Reduction of FEC to Process Heat	0.1%	0.0%	0.0%
		Energy savings for high efficient facilities (ktoe)	4	4	4
		Reduction of FEC to Facilities/Other	0.1%	0.1%	0.1%
Cement	EE measures to optimize combustion cycle, apply waste heat recovery for clinker furnace, reduce crushing energy with vertical mills, and other savings.	Electricity savings due to high efficiency motors (GWh)	43	43	53
		Reduction of electricity to Machine Drive	0.4%	0.4%	0.5%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	1,123	1,123	1,123
		Reduction of FEC to Process Heat	9.6%	9.6%	9.6%
		Energy savings for high efficient facilities (ktoe)	73	138	138
		Reduction of FEC to Facilities/Other	0.6%	1.2%	1.2%
Beverages	EE measures for beer production, carbonate beverage production, and non-carbonate beverage production thru optimize air compressed & steam systems, variable speed drives, and heat pumps.	Electricity savings due to high efficiency motors (GWh)	6	13	25
		Reduction of electricity to Machine Drive	0.9%	1.8%	3.6%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	24	24	24
		Reduction of FEC to Process Heat	3.6%	3.6%	3.6%
		Energy savings for high efficient facilities (ktoe)	3	6	6
		Reduction of FEC to Facilities/Other	0.4%	0.9%	0.9%
Plastics	EE measures for variable speed drives and efficient lamps, etc.	Electricity savings due to high efficiency motors (GWh)	34	35	38
		Reduction of electricity to Machine Drive	8.0%	8.2%	9.0%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	27	38	39
		Reduction of FEC to Process Heat	6.3%	9.0%	9.3%
		Energy savings for high efficient facilities	3	5	5

Industry	Measure	Description	NDC-20%	NDC-25%	NDC-30%
		(ktoe)			
		Reduction of FEC to Facilities/Other	0.7%	1.1%	1.1%
Food & Tobacco	EE measures to install variable speed drives, efficient air compressor, efficient chillers, and efficient lighting.	Electricity savings due to high efficiency motors (GWh)	35	73	91
		Reduction of electricity to Machine Drive	0.7%	1.5%	1.8%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	264	264	306
		Reduction of FEC to Process Heat	5.3%	5.3%	6.2%
		Energy savings for high efficient facilities (ktoe)	74	97	97
		Reduction of FEC to Facilities/Other	1.5%	2.0%	2.0%
Paper Products	EE measures for waste heat recovery from paper drying to reduce heating requirements, and Variable speed drives, optimization of air compressed & steam systems, using CHP system	Electricity savings due to high efficiency motors (GWh)	23	64	77
		Reduction of electricity to Machine Drive	1.8%	5.0%	6.0%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	26	26	35
		Reduction of FEC to Process Heat	1.6%	1.6%	1.6%
		Energy savings for high efficient facilities (ktoe)	20	20	20
		Reduction of FEC to Facilities/Other	1.6%	1.6%	1.6%
Pulp & Printing	EE measures to Thermo-mechanical pulping, increased use of recycled pulp, and Black liquor gasification plants to cogenerate steam, and Variable speed drives, optimization of air compressed & steam systems	Electricity savings due to high efficiency motors (GWh)	85	85	85
		Reduction of electricity to Machine Drive	1.1%	1.1%	1.1%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	244	431	500
		Reduction of FEC to Process Heat	3.1%	5.4%	6.2%
		Energy savings for high efficient facilities (ktoe)	2	7	7
		Reduction of FEC to Facilities/Other	0.0%	0.1%	0.1%
Bricks	Modernize brick production by applying efficiency measures and Increasing production unburnt bricks	Electricity savings due to high efficiency motors (GWh)	36	118	118
		Reduction of electricity to Machine Drive	1.1%	3.6%	3.6%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	31	28	75
		Reduction of FEC to Process Heat	0.9%	0.9%	2.3%
		Energy savings for high efficient facilities (ktoe)	110	124	124
		Reduction of FEC to Facilities/Other	3.4%	3.8%	3.8%
Textiles	EE measures for boiler improvements, variable speed drives and efficient lamps in fiber production, knitting and	Electricity savings due to high efficiency motors (GWh)	97	168	357
		Reduction of electricity to Machine Drive	2.0%	3.5%	7.4%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	249	250	250

Industry	Measure	Description	NDC-20%	NDC-25%	NDC-30%
	dyeing	Reduction of FEC to Process Heat	5.1%	5.2%	5.1%
		Energy savings for high efficient facilities (ktoe)	91	159	159
		Reduction of FEC to Facilities/Other	1.9%	3.3%	3.3%
Other	EE measures for boiler improvements, variable speed drives and efficient lamps in fiber production, knitting and dyeing	Electricity savings due to high efficiency motors (GWh)	292	513	954
		Reduction of electricity to Machine Drive	2.6%	4.5%	8.4%
		Energy savings due to high efficiency boilers, furnaces and processes (ktoe)	471	374	374
		Reduction of FEC to Process Heat	4.1%	3.3%	3.3%
		Energy savings for high efficient facilities (ktoe)	273	402	402
		Reduction of FEC to Facilities/Other	2.4%	3.5%	3.5%

Figure 60 plots the cumulative incremental investment requirements for specific Industry subsectors for the three Conditional scenarios. Average annual investment needs range from about $183 million in NDC-20% to about $404 million in NDC-25%, and $620 million in the NDC-30% case. This significant incremental investment increase for the NDC-30% case is not surprising given the 2030 planning horizon for the analysis. A more radical transformation of the sector will take more time, and future analyses should look out to 2050. This result also shows that the NDC-25% case needs about $240 million in additional annual investment compared to the EE&RE Policies case.

Figure 60: Conditional Scenarios – Industry Sector Investment (2018-2030)



8.6 Building Sector Energy Use

8.6.1 Residential

Final energy reduction for the Residential sector increases to 12.4%, 19.8% to 21.7% for the NDC-20%, NDC-25% and NDC-30% scenarios respectively. Figure 61 shows the Urban Residential FEC (on the top) and the change in energy use from the BAU scenario (on the bottom). The figure shows reductions come mostly from fuelwood early, with strong electricity and LPG reductions occurring in the later years as more efficient demand devices are employed.

Figure 61: Conditional GHG Reduction Scenarios – Urban Residential Energy Use

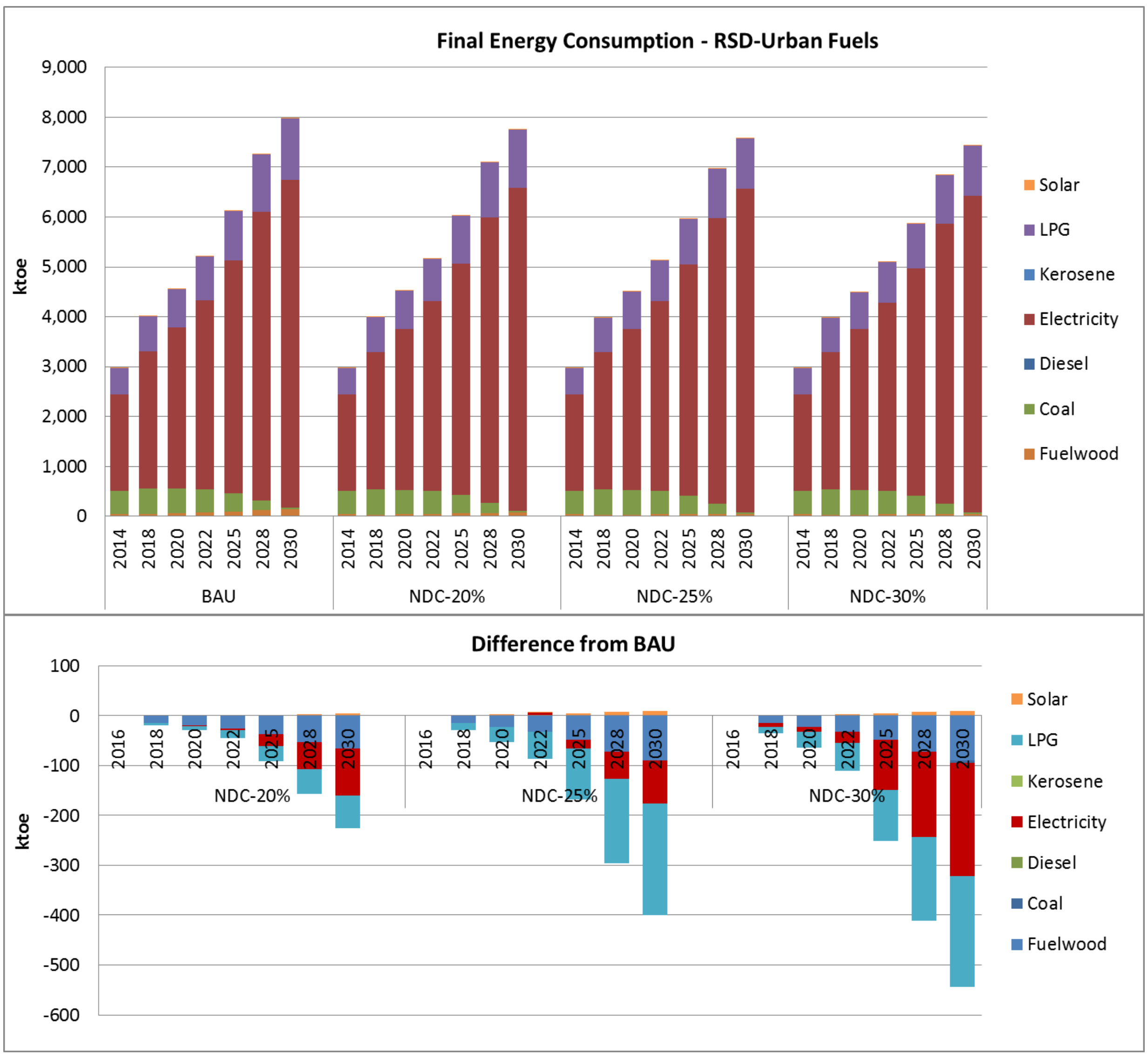
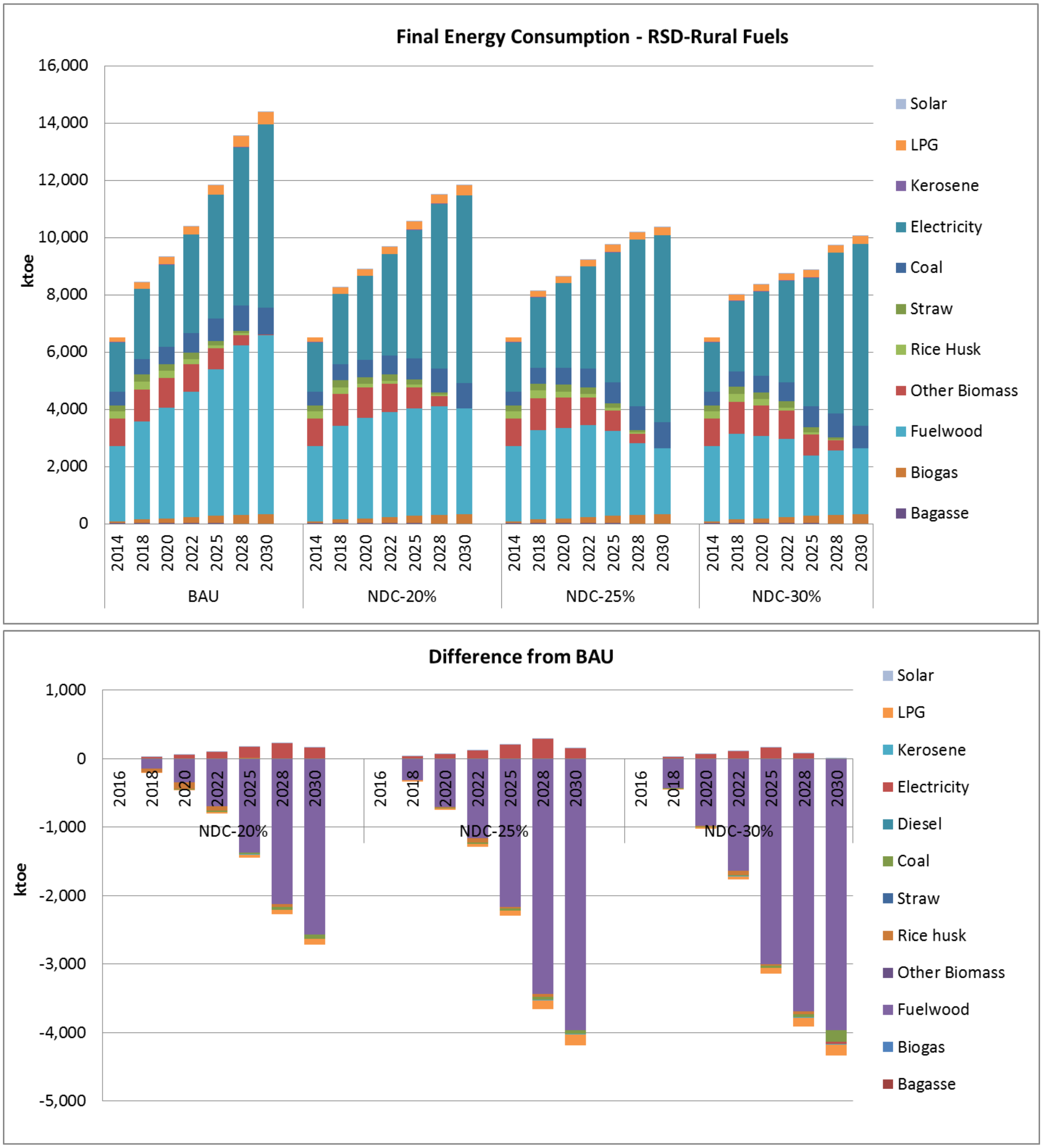


Figure 62 shows the Rural Residential final energy use (on the top) and the change in energy use from the BAU scenario (on the bottom). The figure shows reductions come primarily from fuelwood and LPG use offset by slight increases in electricity use. Note also that use of straw, rice husk and other biomass decline to zero by 2030.

Figure 62: Conditional GHG Reduction Scenarios – Rural Residential Energy Use



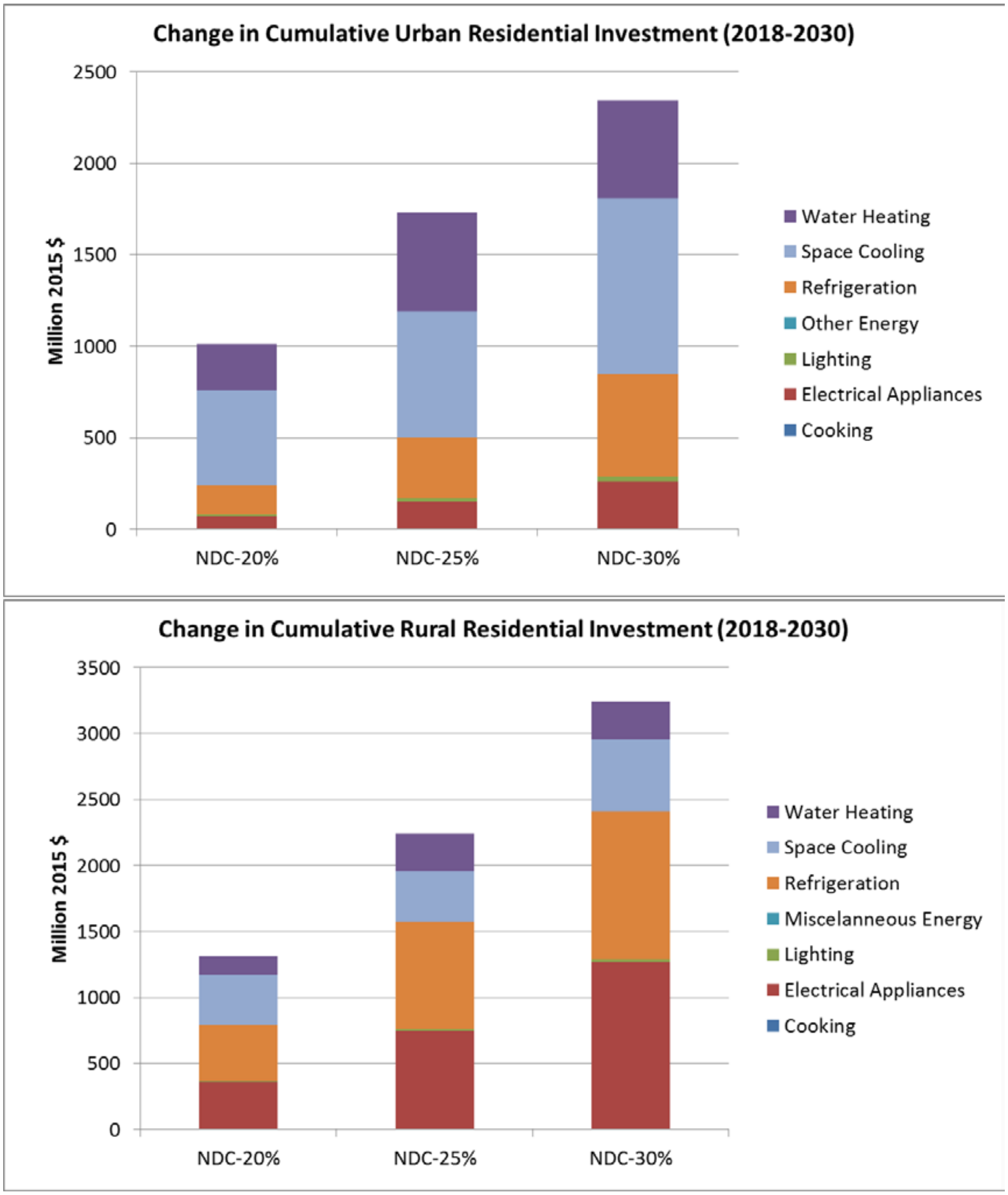
The Residential sector measures include about 2 GWh of electricity from rooftop PV systems, while solar water heating increase from the BAU share of 1.7% to 8.7% in the NDC-25% and NDC-30% scenarios. The greatest improvements come from high performance AC systems, refrigerators and electrical appliances, along with LED lighting, which meet up to 21%, 60%, 50% and 50% of their respective service demand, respectively.

Table 45: Conditional GHG Reduction Scenarios – Residential Sector Measure Results

Measure	Description	BAU	NDC-20%	NDC-25%	NDC-30%
Solar PV	Rooftop solar generation (GWh)	0	2.0	2.0	2.2
	Share of total supply	0.0000%	0.0002%	0.0002%	0.0002%
Solar water heaters	Solar hot water heater use (ktoe)	3	10	17	17
	Share of total demand	1.7%	5.1%	8.7%	8.7%
High performance AC	Use of high efficiency AC (ktoe)	124	1,659	1,946	2,668
	Share of total demand	1.0%	13.3%	15.6%	21.4%
High performance refrigerators	Use of high-efficiency refrigerators (ktoe)	22	439	858	1,324
	Share of total demand	1.0%	20.2%	39.4%	60.8%
High performance lighting	Use of energy-saving lighting or LEDs (ktoe)	7	98	197	328
	Share of total demand	1.0%	15.0%	30.0%	50.0%
Appliance efficiency	Use of high efficiency appliances (ktoe)	24	367	734	1,223
	Share of total demand	1.0%	15.0%	30.0%	50.0%
Biogas for cooking	Use of biogas for cooking (ktoe)	330	331	331	332
	Share of total demand	2.8%	3.5%	4.1%	4.3%
Cleaner cooking fuels	Use of electric and LPG stoves (ktoe Share of total demand)	0	211	182	137
		0.0%	2.2%	2.3%	1.8%

Figure 63 plots the cumulative investment requirements for the Urban and Rural portions of the Residential sector. The investments are grouped according to specific end-use services. Overall annual incremental investment needs range from about $220 million for combined Urban and Rural in NDC-20% case, $375 million in the NDC-25% case, and $530 million in the NDC-30% case.

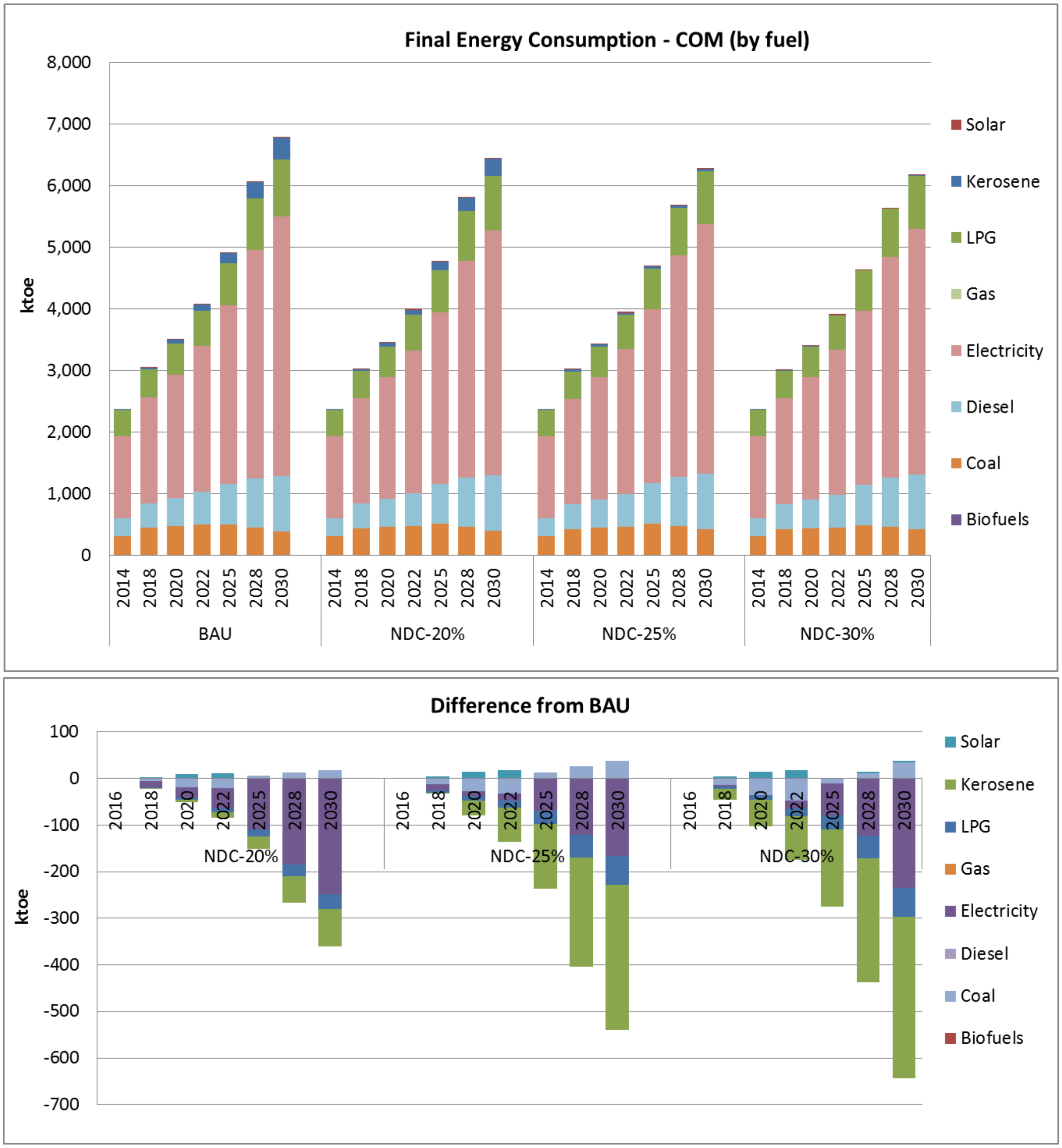
Figure 63: Conditional Scenarios – Residential Sector Investment (2018-2030)



8.6.2 Commercial

Figure 64 shows the Commercial sector FEC (on the top) and the change in energy use from the BAU scenario (on the bottom). The FEC reductions are 5%, 7% and 9%, respectively compared to the BAU, and the figure shows that almost all emission reductions come from electricity and kerosene use, with some coal dumped early in the more stringent mitigation scenarios.

Figure 64: Conditional GHG Reduction Scenarios – Commercial Sector Energy Use



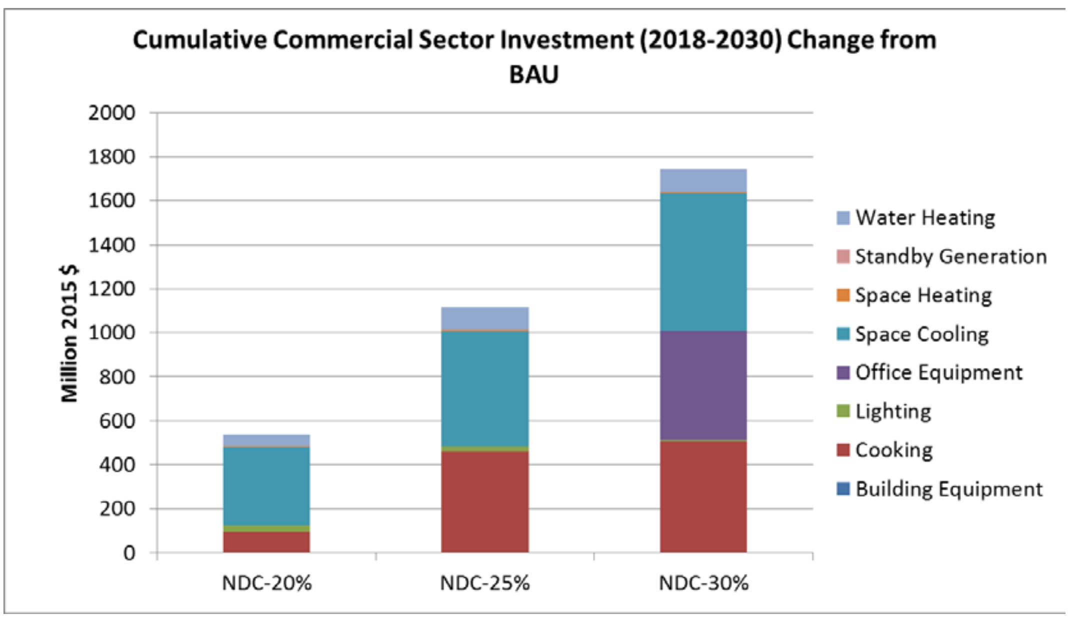
The Commercial sector measures include up to 1.2 GWh of building-integrated PV systems and 5.2 ktoe to 8.2 ktoe of solar water heating. The improvements from high performance AC systems are about the same as in the EE&RE Policies scenario, while the use of high performance lighting increases to 45% and 75% in the NDC-25% and NDC-30% scenarios.

Table 46: Conditional GHG Reduction Scenarios – Commercial Sector Measure Results

Measure	Description	BAU	NDC Cond -20%	NDC Cond -25%	NDC Cond -30%
Solar PV	Use of rooftop solar (GWh)	0.0	0.9	0.9	1.2
	Share of total supply	0.0%	0.0003%	0.0003%	0.0003%
Solar water heaters	Use of solar hot water heaters (ktoe)	5.2	5.2	5.2	8.2
	Share of total supply	1.1%	1.1%	1.1%	1.7%
High performance AC	Use of high efficiency AC [ktoe]	87	729	564	715
	Share of total supply	1.0%	8.3%	6.5%	8.2%
High performance lighting	Use of energy-saving lighting (ktoe)	18.9	283	567	945
	Share of total supply	1.5%	22.5%	45.0%	75.0%
More efficient water heaters	Use of efficient water heaters (ktoe)	4.6	64	58	58
	Share of total supply	1.5%	26.8%	23.5%	23.5%

Figure 65 plots the cumulative incremental investment requirements for the Commercial sector. The investments are grouped according to specific end-use services. Average annual incremental investment needs range from about $50 million in NDC-20% case, about $95 million in the NDC-25% cases, and about $150 million in the NDC-30% case. For this sector, there is a 55% increase in investment for the NDC-30% case compared to the NDC-25% case. Space cooling and office equipment investments account for more than half the requirement, followed by cooking and water heating.

Figure 65: Conditional Scenarios – Commercial Sector Investment (2018-2030)



9 Sensitivity Analyses

9.1 Setting a GHG Emission Price

An alternate approach to the Conditional NDC target for Vietnam, calling for international cooperation, could be determined by setting a price on GHG emissions going forward. The NDC target runs discussed in Sections 7 and Section 8 set a limit on GHG emissions for the energy sector resulting in transformation of the energy sector to achieve the specific reduction level. A GHG emission price is a way to evaluate what level of emission reductions could be achieved in Vietnam by setting a price (tax) on GHG emissions. With this in mind, TIMES-Vietnam was run looking at future emission prices starting at US$10/ton today and going to $10/20/30/40/50/100 per ton in 2030, employing the EFFECT-M1 for the $10 run, EFFECT-M2 for the $20/30 runs and EFFECT-M3 for the higher carbon price runs respectively. The GHG reduction levels achieved for each of the emission prices are shown in Figure 66, and Table 47 shows the level of emission reductions in 2030, the percent reduction from BAU, and the level of revenue generated by 2030.

Figure 66: GHG Emissions under Emission Price Scenarios

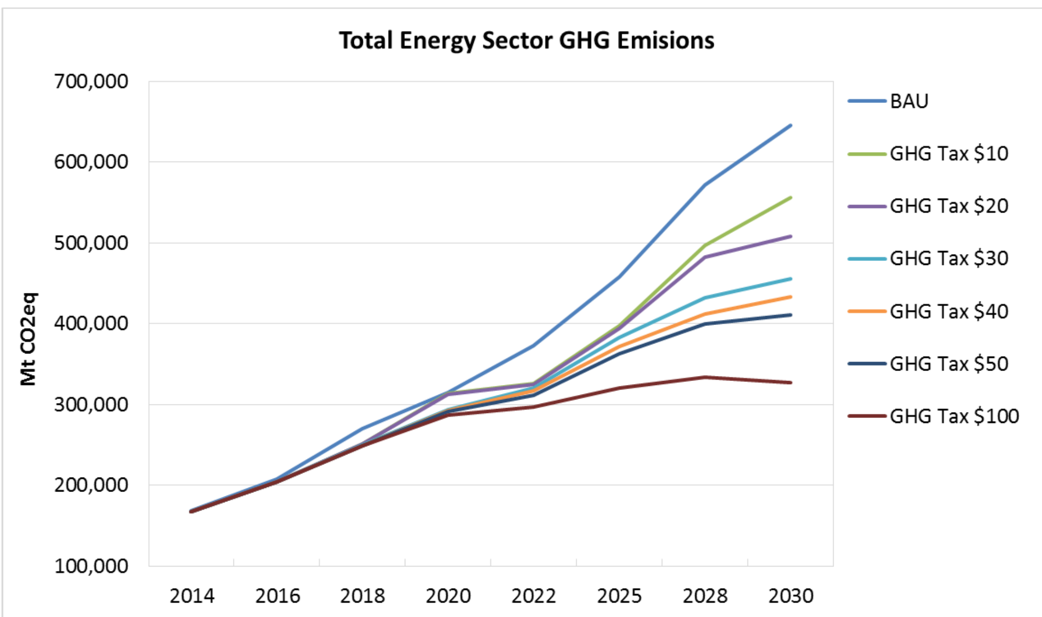


Table 47: GHG Emission Price Runs Summary Results

Emission Price (2015M$/t CO_2eq)	2030 Emission Reduction (Mt CO_2eq)	2030 Percent Reduction	Revenue Generated (2015 billion $)
$10	83	13%	$ 15.86
$20	137	21%	$ 22.62
$30	177	28%	$ 27.93
$40	200	31%	$ 33.75
$50	218	34%	$ 38.23
$100	293	46%	$ 59.05

Note that the $40/t and higher GHG emission prices achieve significantly more reductions by 2030 than the scenarios examined in Sections 7 and 8. Not surprisingly the most attractive mitigation measures for each sector are for the most part the same ones identified in each corresponding NDC scenario.

9.2 Gas Sensitivity Runs

The role of gas as a mitigation option to replace coal for electricity generation was examined by means of five sensitivity cases run off the NDC-25% core reduction scenario. The runs reinforce the fact that gas has a higher mitigation value in the Industry sector to displace coal, as the competitiveness of RE in the power sector reduces both forms of fossil generation.

- Lowering the price for gas by 15% slightly increases gas generation, but does not add capacity, as the gas is largely used for load balancing, and the added gas generation reduces coal and wind generation about equally. A 2nd gas sensitivity run holds LNG prices flat from 2020 (M$8.00/PJ), a 25-33% reduction in price over the planning horizon. Looking at the NDC-25% mitigation scenario, the lower gas price had a bigger impact, but still didn't change the fundamentals of the gas/renewables trade-off and priority for increased gas use in Industry. Although no additional gas capacity was added, gas-fired generation returns close to levels seen in the BAU scenario, while coal drops 28% from the BAU (with earlier gas prices coal generation dropped 23%), but solar drops 30% and wind 23% from the NDC-25% with higher gas prices. Industry gas consumption in 2030 is 52% above the BAU for the 2nd gas price case as compared to 41% above with the slightly lower gas price run.
- Maintaining gas generation at the BAU level results in the gas capacity going up ever so slightly, pointing out that planned gas plant builds in 2022 may end up operating with very low utilization factor. However, the forced gas-fired generation does cut wind generation in half, solar by one-third, and coal by more than10%. This reinforces the finding that the RE techs are displacing the gas generation because they are more cost-effective, but that gas remains competitive as noted below.
- Requiring that gas capacity is the same at that of the BAU results in little change in the generation mix, however requiring 100% back-up capacity equal to that of the variable RE (solar and wind) does result in 40% more gas-fired generation at the cost of $3 Billion more over the planning horizon
- Limiting coal capacity to the 2025 BAU level (about 32 GW), does not increase gas capacity, but increases gas generation to about two-thirds of the BAU level, and increases RE generation and capacity to the levels found in the core policy scenario.

Interestingly, the change in total discounted system cost is only about $1.5 billion higher for the forced gas generation sensitivity and about $2 billion for the sensitivity limiting coal plant capacity, which are not that much relatively speaking, and thereby can be considered as a near-optimal result. These findings highlight the key Power sector tradeoffs between coal, gas and RE techs and the critical importance of promoting gas substitution in Industry.

The shift from coal and gas use in the BAU to RE for electricity generation is seen across all the policy scenarios, where gas-fired generation only approaches the level of the BAU when explicitly forced to do so or if prices are lowered at least 33% from IEA forecast levels.

In terms of Final Energy Consumption (FEC), when gas generation rises there is a corresponding drop of about 10% in gas to Industry, turning to oil products instead. But as noted there is still substantial fuel switching to gas occurring in the sector.

9.3 Enhanced Energy Efficiency Runs

In the core model runs, conservative estimates were made in terms of how much EE improvement could be achieved over the next decade, where it was assumed that at most 20% of new demand device purchased would be those with improved energy efficiency. Here we examine enhanced efficiency runs of up to 30% new high efficiency devices for the NDC-25% and NDC-30% scenarios (designated as +EE). The NDC-30%+EE scenario does not increase the reduction in final energy consumption compared with the NDC-25%+EE run, because less costly reductions appear to be available in the power sector. Therefore, a NDC-30% scenario which allows up to 50% adoption of high efficiency demand devices by 2030 designated as ++EE) was done to provide more context.

Table 48: Final Energy Consumption Reduction in 2030 compared to BAU

Sector	NDC-25%+EE	NDC-30%+EE	NDC-30%++EE
Agriculture	-3.5%	-4.1%	-4.5%
Commercial	-7.4%	-8.6%	-9.0%
Industry	-9.3%	-9.2%	-11.2%
Residential	-19.8%	-20.3%	-21.7%
Transportation	-15.7%	-15.7%	-15.7%
Total	**-12.2%**	**-12.4%**	**-13.8%**

Conventional coal does not change as these are all existing or committed new builds that are completed by 2023. Going from NDC-25%+EE to NDC-30%+EE increases the new capacity additions by 2.8 GW by replacing 5.3 GW of coal with 5 GW of solar power and 0.9 GW of wind. Gas capacity remains unchanged across the mitigation scenarios. However, for the NDC-30%++EE case, total new builds are reduced by 3.1 GW of solar capacity as more EE decreases the total electricity demand.

Table 49: Cumulative New Power Plant Additions: 2018-2030 (GW)

Fuel	BAU	NDC-25%+EE	NDC-30%+EE	NDC-30%++EE
Biomass & Bagasse	0.0	1.3	1.4	1.3
Coal-fired - Conventional	14.5	14.8	14.3	14.8
Coal-fired Super Critical	27.7	14.4	9.6	10.5
Gas-fired	25.3	8.9	8.9	8.9
Hydro – Large & Medium	2.7	2.7	2.7	2.7
Hydro - Small	0.0	4.6	6.8	6.8
MSW & LFG	0.0	1.6	1.5	1.6

Fuel	BAU	NDC-25%+EE	NDC-30%+EE	NDC-30%++EE
Solar Central	0.0	17.6	22.1	17.9
Solar Distributed	0.0	1.9	2.4	2.2
Storage	0.0	2.4	2.4	2.4
Wind	0.0	8.0	8.9	8.9
Total	**70.3**	**78.2**	**81.0**	**77.9**

The investment needs in the power sector move from a $16.2 billion increase above BAU for NDC-25%+EE to $29 billion for NDC-30%+EE, for a net increase of over $12 billion. The NDC-30%++EE scenario shows an increase from the BAU of $15.9 billion, or $0.3 billion below the NDC-25%+EE scenario.

Table 50: Power Sector Cumulative Investment (2018-2030)

Plant Type	BAU	NDC-25%+EE	NDC-30%+EE	NDC-30%++EE
Biomass & Bagasse	0	2,079	2,243	2,091
Coal-fired - Conventional	19,555	19,992	19,305	19,893
Coal-fired Super Critical	42,300	22,392	14,956	16,296
Gas-fired	20,985	7,330	7,330	7,330
Hydro – Large & Medium	4,097	4,098	4,098	4,098
Hydro - Small	0	8,060	11,820	11,820
MSW & LFG	0	3,851	3,639	3,851
Solar Central	0	18,104	33,030	18,408
Solar Distributed	0	2,268	2,867	2,612
Storage	0	2,404	2,404	2,404
Wind	0	12,548	14,134	14,078
Total	**86,937**	103,125	115,823	102,880

The demand sector investments do not change much between the +EE runs, as expected because the change in final energy consumption is also limited. Both the NDC-25%+EE and the NDC-30%+EE scenarios increase the demand sector investment needs by about $9.5 billion, while the NDC-30%++EE scenario increases the demand sector investment needs by about $13.8 billion, about a $4 billion increase over the NDC-30%+EE scenario.

Table 51: Demand Sector Cumulative Investment (2018-2030)

Sector	NDC-25% UC30	NDC30% UC30	NDC30% UC50
Commercial	1,138	1,375	1,768
Industry	4,849	5,009	7,433
Residential	4,496	4,831	6,354
Total	9,345	9,840	13,787

Compared to the NDC-25%+EE scenario, the NDC-30%+EE scenario requires a net increase of $13 billion, mostly in the Power sector, and the NDC-30%++EE scenario requires a net increase of $4.1 billion – mostly in EE measures.

GDP in 2030 is projected at $374 billion, and the annual investment cost of all three scenarios relative to the BAU is at most 1.1% of GDP in 2030, though if striving to reach 30% reduction in emissions the ++EE scenario with its RE vs EE trade-off provides a more cost-effective way of reaching this more ambitious target.

Table 52: Annual Investment ($ billion) Relative to BAU (2018-2030)

Sector	NDC-25%+EE	NDC30%+EE	NDC30%++EE
Power Sector	1.19	2.17	2.48
Demand sectors	0.87	0.94	1.30
Total	2.06	3.11	3.78
Share of 2030 GDP	0.6%	1.0%	1.1%

9.4 Looking to the Long-term: 2050 Scenarios

A key lesson learned from this analysis is that 2050 goals must be considered when developing 2030 targets. Given that power sector investments typically have lifetimes of 30 years or more, 2030 is a relative short time horizon to consider a low-carbon development pathway for Vietnam, particularly given that 14.3 GW of coal power capacity are already being built or planned to be built from now to 2023. Therefore, a more strategic and aggressive scenario out to 2050 was examined to identify the GHG emission and coal consumption peaking timing.

9.4.1 2050 Scenarios

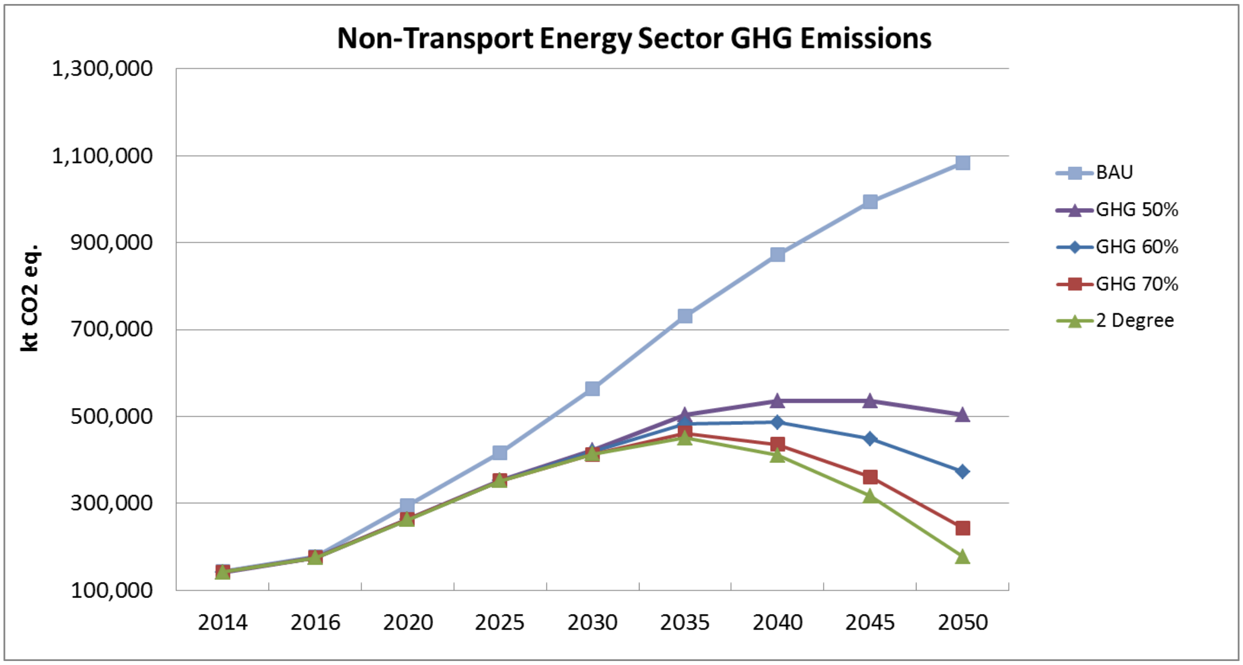
The TIMES-Vietnam model was extended to 2050 and additional runs were made building on the core NDC-25% scenario to examine the “tipping” point for the use of coal and the peak timing for GHG emission, as well as the implication for power sector investments made when only looking out to 2030. These sensitivity runs help establish the validity of the 2030 model results and to examine what appears possible by 2050.

In addition to extrapolating the BAU scenario, the most important changes to the model in order to run out to 2050 was the raising of the RE built rates post 2030 to allow higher growth levels than specified in the IES RE Integration report, and allowing higher levels of EE device purchases in 2030 - reaching an upper limit of 90% by 2050. However, the maximum potential of the RE options was not adjusted. Also, new power plant options for nuclear and coal with carbon capture and sequestration (CCS) were added.

For the 2050 runs, in addition to assessing GHG reductions of 50%, 60% and 70% below the projected BAU scenario, an absolute target of 2 tons per capita by 2050 was examined, corresponding to the Paris Accord 2^{o}C goal (2-Degree). Given the projected 2050 population of 112.7 million, the 2050 target becomes 225.5 Mt in 2050. Because mitigation actions after 2030 were restricted in the EFFECT Transport sector, the Transport emissions were removed from the cap and the target for the non-transport energy sectors was limited to 86.7% of the total allowance, which becomes a 2050 target of 195.5 Mt.

Figure 67 shows the GHG emission profiles for these sensitivity runs, and shows that GHG emissions would need to peak around 2035 for all scenarios except the NDC-50% case, which peaks in 2040. Coal use peaks in 2035 for all scenarios. For the 2-Degree scenario, GHG emissions by 2050 would come down to about the 2016 level, and would reduce GHG emissions by 74 percent below the BAU scenario.

Figure 67: GHG Emissions Looking Out to 2050



As shown in Table 53, the 2050 sensitivity analysis also demonstrated that to achieve the 2-degree target by 2050, 25 GW of coal power capacity would start being phased out in 2035 and be forced to retire early, which demonstrates that the huge build-up of coal power capacity now will have a serious lock-in effect that results in stranded asset of coal power plants after 2030. Given the currently affordable costs of renewable energy, the rising environmental costs, and the difficulty of financing new coal power plants, Vietnam government may consider not building such a large coal power fleet now to avoid the lock-in and stranded assets later on.

Table 53: Coal Power Plant Capacity and Utilization under the 2-Degree goal

Coal Power Plant Capacity and Utilization Factor									
	2014	2016	2020	2025	2030	2035	2040	2045	2050
Coal Plant Capacity	8.00	17.02	26.94	26.50	26.50	25.59	22.56	20.56	10.54
Average Utilization	0.52	0.45	0.48	0.65	0.60	0.35	0.22	0.11	0.05

The BAU has 14.3 GW of planned coal capacity coming on-line between 2018 and 2023. A sensitivity run was made which does not force the 4.3 GW of planned capacity in 2023. In this run, the discounted energy system cost decreases by over $500 million for the 2-Degree case. New power plant capacity additions increase from 224 GW in the 2050 BAU by 84.5 GW in the 2-Degree scenario. Most of the new capacity is in the form of solar, wind and nuclear.

To achieve the 2-degree goal, RE-based generating capacity would have to increase to 200 GW, 65 percent of electricity generation, and 29 percent of primary energy supply by 2050, which is in line with expectations for much of Europe as well as China[6]. Natural gas power plant capacity increases by 42 GW, 18 percent of total capacity. The gas capacity has a utilization factor below 30% because its role is primarily balancing variable RE. In addition, 2.4 GW of electric energy storage are added to help support grid stability. Energy efficiency measures would need to decrease final energy consumption by at least 25 percent below the BAU, and energy intensity per unit of GDP would need to reduce by 44 percent from 2016 to 2050. This scenario would require an average annual investment of $5.5 billion between 2030 and 2050, which represents an annual amount less that 1 percent of the average GDP for the 2030 to 2050 period.

Table 54: Cumulative Power Plant Additions (2020-2050)

Cumulative New Power Plant Additions: 2020-2050 (GW)		
Power Plant Type	**BAU-50**	**2-Degree**
Biomass & Bagasse	0.1	2.3
Coal-fired - Conventional	14.3	14.3
Coal-fired Super Critical	122.7	19.4
Gas-fired	81.1	56.1
Hydro – Large & Medium	5.6	5.1
Hydro - Small	0.0	8.3
MSW & LFG	0.0	2.2
Nuclear	0.0	10.9
Solar Central	0.0	144.6
Solar Distributed	0.0	8.5
Storage	0.0	2.4
Wind	0.0	34.2
Total	**223.9**	**308.4**

Cumulative power plant investment 2020-2050 for the 2-Degree scenario increases by $105 billion, and the demand sector cumulative investment is $94 billion, so that the total cumulative investments is $194 billion. The average annual investment over the 30 years from 2020 to 2050 is 1.0% and 1.3%, respectively.

[6] http://europa.eu/rapid/press-release_MEMO-16-3987_en.htm

Table 55: Power Sector Cumulative Investment (2020-2050)

Power Sector Cumulative Investment: 2020-2050 ($Million)		
Power Plant Type	**BAU-50**	**2-Degree**
Biomass & Bagasse	94	3,108
Coal-fired - Conventional	19,075	19,238
Coal-fired Super Critical	183,858	29,344
Gas-fired	67,957	47,561
Hydro – Large & Medium	14,077	11,094
Hydro - Small	0	12,452
MSW & LFG	0	4,912
Nuclear	0	48,822
Solar Central	0	208,143
Solar Distributed	0	9,029
Storage	0	2,404
Wind	0	93,720
Total	**285,061**	**489,828**

Table 56: Cumulative Demand Sector Investment (2020-2050) for 2-Degree Scenario - $ billion

Demand Sector Cumulative Investment (2020-2050)	
Sector	**2-Degree Scenario**
Commercial	19,364
Industry	40,960
Residential	33,689
Total	**94,013**

9.4.2 Coal with CCS Technology

Two interesting findings were observed while doing the 2050 sensitivity runs. First, the model did not choose power plants using coal with CCS technology for Vietnam, and the a run was made where 1 GW of coal with CCS to be built in 2030 and forced to operate at 80% capacity factor. The result was a $1.25 Billion increase in the discounted system cost with the CCS technology forcing out nuclear and central solar.

10 NDC Roadmap

This section provides a Roadmap for implementation targets and monitoring measures in the energy sector to contribute to achieving the GoV's desired NDC targets. It is based primarily on the 2030 analysis, though noting some important considerations arising from the 2050 look to the future. The Roadmap highlights the level and timing of investment required, and prioritizes the key policies and measures necessary over the next decade to make that happen. It lays out the critical role to be played by EE and RE, but also highlights the need to carefully manage domestic gas resources and more expensive imports, as an important consideration for the GoV as it updates its NDC target and plans to implement the necessary roadmap to achieve it.

10.1 NDC Targets

The Executive Summary provides a concise discussion of the analysis undertaken, with Figure 1 and Figure 2 providing an overview of the various emission reduction scenarios, which examined what Vietnam can accomplish by 2030. The analyses in Section 7 shows that the 8% reduction target is easily achievable, partly due to early actions taken by Vietnam in the 2010-2014 timeframe, along with many cost-effective measures that are currently available and can be cost-effectively implemented. The analysis also shows that the NDC-15% target is less ambitious than the EE&RE Policies scenario, which includes more RE capacity and stronger promotion of EE. The analyses in Section 8 shows that compared to the BAU, the NDC-30% target requires an annual increase in EE investments of $1.29 billion for the Industry, Residential and Commercial sectors, and an annual average increased investment for the Power sector of $1.33 billion, which pushes the share of RE electricity slightly above 33%. Given the relatively modest incremental cost the NDC-30% scenario is used to underpin the Roadmap that lays out what it will take for the GoV to achieve a higher level of ambition as being called for by the UNFCCC. Energy Supply

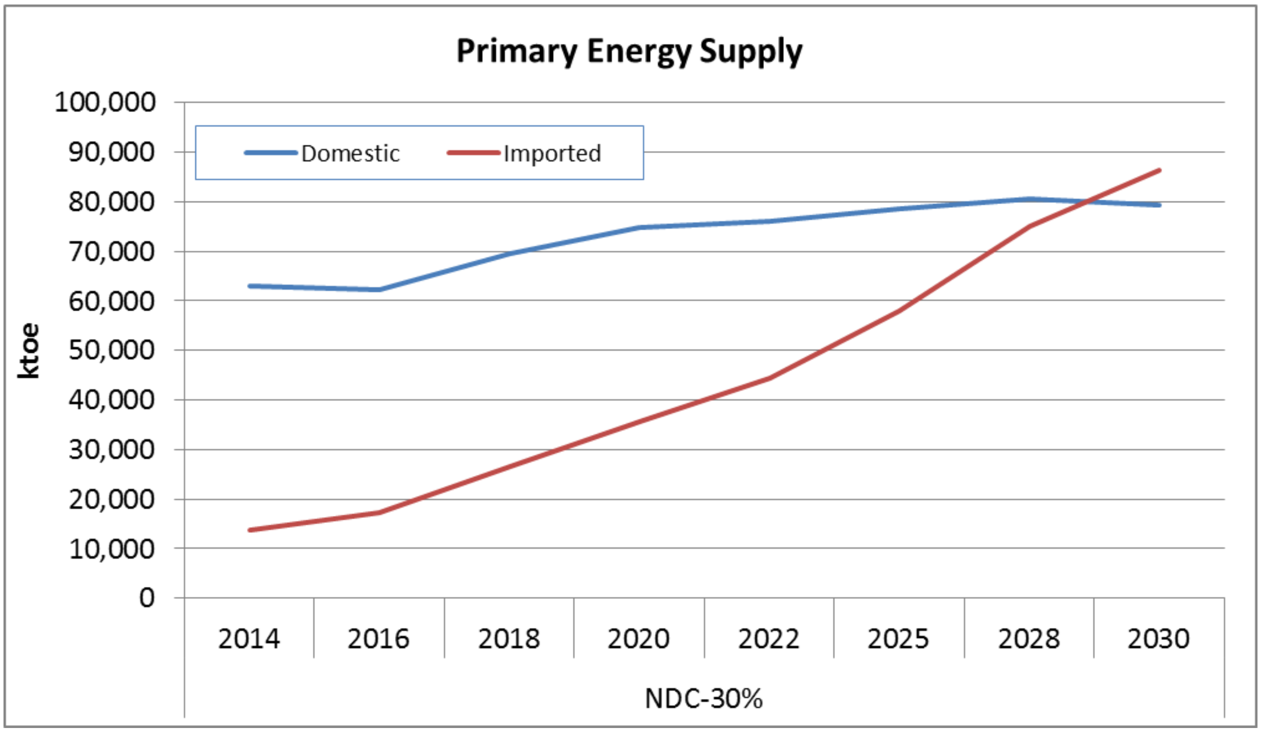
Reducing coal consumption and growing RE energy use are major components of the NDC roadmap. As shown in Table 57, primary energy supply increases by 113% between 2014 and 2030 lead by coal (43.9 Mtoe), crude oil (14.9 Mtoe) and natural gas (10.2 Mtoe). Biomass utilization grows by 13 Mtoe followed by hydropower (3.3 Mtoe), solar (2.7 Mtoe) and wind (2.9 Mtoe). The share of fossil primary energy is 78% in 2030 (compared to 88% in the BAU), with coal use decreasing from 53% to 40% against the BAU, and natural gas use remaining about the same at 13% of primary supply.

As shown in Figure 68, domestic production grows by only 26% as the supply of both crude oil and gas diminishes. Table 58 shows the breakdown on domestic energy supplies, and highlights the limited production of coal, and dwindling production of crude oil starting in 2020 and natural gas starting in 2025 as reserves are depleted. Biomass account for most for the domestic production increase, and consists of fuelwood, bagasse and other solid biomass, but with important utilization of biogas and landfill gas.

Table 57: NDC-30% Case – Primary Energy Requirements (ktoe)

Energy Carrier	2014	2020	2025	2030
Biomass	8,327	15,138	17,603	21,317
Coal	22,569	43,031	59,286	66,428
Electricity - Imports	153	299	903	2,536
Gas	10,888	13,045	17,238	21,153
Hydro	4,975	6,736	7,319	8,232
Oil Crude	17,739	25,673	27,702	32,591
Oil Products	13,159	6,359	4,372	7,919
Solar	0	574	673	2,680
Wind	0	504	1,547	2,888
Total	**77,811**	**111,359**	**136,643**	**165,745**

Figure 68: NDC-30% Case – Domestic and Imported Primary Energy Supply (ktoe)



Coal imports grow dramatically, even under this relatively ambitious scenario, and this should be cause for concern. Energy imports grow by some 534%, led by dramatic growth in coal imports (39.4 Mtoe) as well as crude oil and refined oil products (24.1 Mtoe). By 2030 energy imports exceed domestic production by 7.2 Mtoe. Table 59 shows a breakdown of energy imports by type. Gas imports are 38% lower than in the BAU levels. The growth in coal imports comes primarily from "lock-in" decisions being made by the planned installation of new coal-fired capacity by 2023, as discussed in the next section.

Table 58: NDC-30% Case – Domestic Primary Energy Production (ktoe)

Energy Carrier	2014	2020	2025	2030
Biomass	8,327	15,138	17,603	21,317
Coal	21,142	23,307	25,720	25,595
Gas	10,888	13,045	17,238	14,307
Hydro	4,975	6,736	7,319	8,232
Oil Crude	17,739	15,570	8,460	4,250
Solar	0	574	673	2,680
Wind	0	504	1,547	2,888
Total	**63,071**	**74,874**	**78,559**	**79,270**

Given the current transmission capacity, electricity imports from China and Laos are fully utilized in the mitigation scenarios (as GHG "free"), meeting 1.5% of total primary supply.

Table 59: NDC-30% Case – Primary Energy Imports (ktoe)

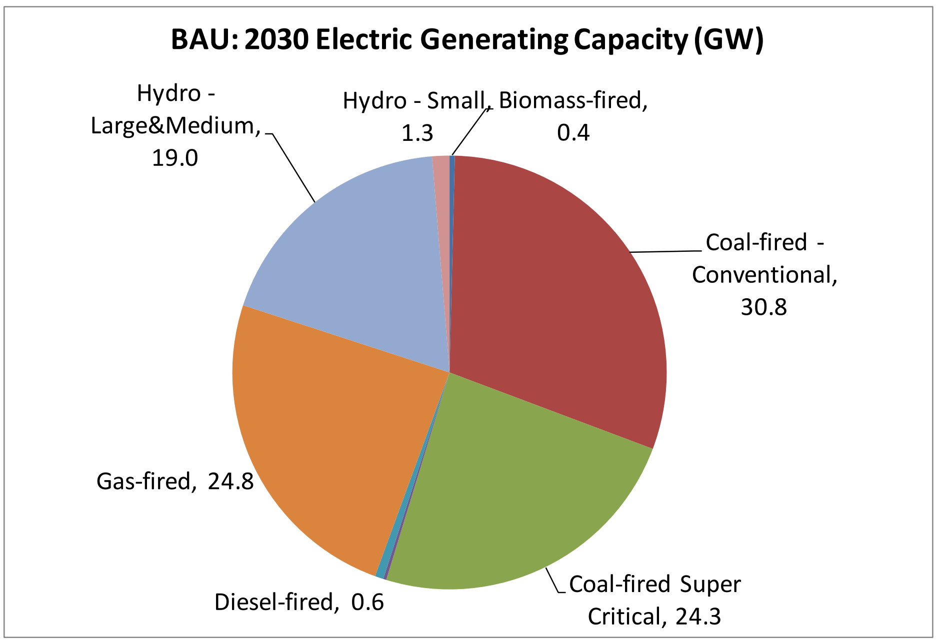
Energy Carrier	2014	2020	2025	2030
Biomass	0	0	0	0
Coal	1,428	19,724	33,566	40,834
Electricity	153	99	903	2,536
Gas	0	0	0	6,845
Nuclear	0	0	0	0
Oil and Products	12,055	15,839	23,428	36,215
Total	**13,636**	**35,663**	**57,896**	**86,430**

10.2 Power Sector

Building new RE power plants is the priority undertaking for the power sector component of the NDC pathway. Figure 69 shows the dramatic transformation of the total installed capacity from the BAU to the NDC-30% case. Compared to the BAU scenario, which has 55.1 GW of coal capacity, 20.3 GW of hydro and 24.8 GW of gas, the proposed NDC-30% power plant mix consists of 41.7 GW of coal, 27.1 GW of hydro, and 15.6 GW of gas, with 32.5 GW of solar, wind and biomass. The share of fossil plants in the capacity mix is deceptive when considering likely post-2030 increased ambition and the potential for stranded coal assets after 2030, as their utilization factor in the 2050 2-Degree scenario drop to 8% for conventional coal and 25% for gas, as discussed in Section 1.7 and Section 9.4. This result raises a serious concern that the planned 14.3 GW of conventional coal being added to the generation mix by 2023 will become stranded assets after 2030 – a decision that will only add to the ultimate cost as the GoV looks to achieve increasingly ambitious NDC goals. The RE growth highlights the need for significant progress to be made in the next decade to promote the RE industry and establish market mechanisms to facilitate even more rapid adoption in the decades that follow. The timing for the new capacity additions to come online can be seen in Table 60. Gas-fired capacity decreases relative to the BAU due to the fact that gas has a higher value for mitigation actions in the Industry sector, where there are few renewable alternatives (other than biomass for process heat and CHP).

To achieve this transformation the Roadmap calls for total RE capacity additions to increase from 2.5 GW in 2020 to 11.5 GW in 2025 and 20.4 GW in 2030. Distributed solar and wind capacity increase substantial later in the decade, with almost 14 GW of central solar added in 2028 and 2030 (with electricity storage built in 2030 as the share of RE in the generation mix grows). A large amount of supercritical coal is built in the latter half of the decade, again with the warning that when looking out towards to 2050 and more stringent emission reduction levels even these more advanced plants see their utilization plummet under the 2050 2-Degree scenario.

Figure 69: Power Plant Installed Capacity in 2030



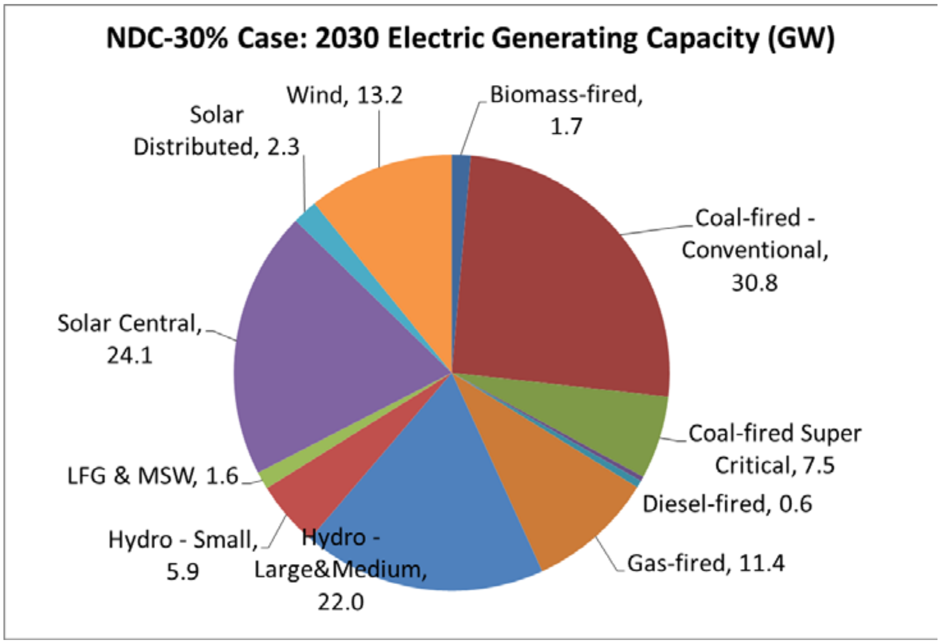


Table 60: NDC-30% Case – Power Plant Capacity Additions per period[7]

Plant Type	Capacity Additions per Period (GW)						
	2016	2018	2020	2022	2025	2028	2030
Biomass-fired	0.0	0.4	0.1	0.1	0.2	0.2	0.2
Coal-fired - Conventional	0.0	1.8	6.3	6.2	0.0	0.0	0.0
Coal-fired Super Critical	0.0	0.0	0.0	0.0	1.4	5.3	3.8
Coal-fired with Biomass	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Gas-fired	0.0	0.0	0.0	5.1	3.8	0.0	0.0
Hydro – Large & Medium	0.2	0.7	0.4	0.1	1.2	0.2	0.1
Hydro - Small	0.0	0.4	1.1	0.0	0.6	0.0	4.6
Municipal Solid Waste & LFG	0.0	0.2	0.3	0.0	0.0	0.0	1.1
Solar Central	0.0	4.0	0.0	0.0	0.0	8.0	5.9
Solar Distributed	0.0	0.0	0.3	0.4	0.4	0.5	0.6
Storage	0.0	0.0	0.0	0.0	0.0	0.0	2.4
Wind	0.0	1.2	0.3	0.3	2.8	3.3	1.0
Total	**0.2**	**8.7**	**8.8**	**12.3**	**10.9**	**17.5**	**19.6**

Table 61 shows that financing the power plant expansion for the Roadmap will require on the order of $6.2 billion per annum in the 2020 period growing to $13.5 billion per year in the 2030 period. Overall, coal and gas plants require 39% and 7% of the new financing respectively, with RE needing 49% (including MSW and storage).

[7] There are no new additions to diesel or fuel oil fired power plants.

Table 61: NDC-30% Case – Power Plant Investment per Period

Plant Type	Power Plant Investment ($ Billion)						
	2016	2018	2020	2022	2025	2028	2030
Biomass-fired	0.00	0.62	0.19	0.27	0.36	0.42	0.22
Coal-fired - Conventional	0.00	2.39	8.47	8.44	0.00	0.00	0.00
Coal-fired Super Critical	0.00	0.00	0.00	0.00	2.37	8.23	5.69
Coal-fired with Biomass	0.00	0.00	0.00	0.00	0.59	0.00	0.00
Gas-fired	0.00	0.00	0.00	4.22	3.11	0.00	0.00
Hydro – Large & Medium	0.29	1.04	0.61	0.21	1.85	0.23	0.16
Hydro - Small	0.00	0.74	1.97	0.00	1.12	0.00	7.99
Municipal Solid Waste & LFG	0.00	0.54	0.68	0.01	0.01	0.01	2.61
Solar Central	0.00	4.49	0.00	0.00	0.00	8.16	5.76
Solar Distributed	0.00	0.00	0.34	0.46	0.55	0.62	0.65
Storage	0.00	0.00	0.00	0.00	0.00	0.00	2.40
Wind	0.00	1.79	0.47	0.46	4.02	5.86	1.49
Total	**0.29**	**11.61**	**12.72**	**14.07**	**13.97**	**23.53**	**26.97**

10.3 Demand Sectors

10.3.1 Final Energy Use

The industry sector account for more than 50% of final energy use in 2030, and natural gas use grows significantly in the demand sectors to displace direct use of coal – especially in Industry. Although the 2030 final energy consumption in the NDC-30% case is 10.5% lower than the BAU, the overall final energy use grows by 140% led by growth in Industry (38.2 Mtoe), Transport (12.1 Mtoe), and Residential (8.0 Mtoe), with Commercial growing 3.8 Mtoe and Agriculture growing 0.9 Mtoe, as shown in Table 62.

Table 62: NDC-30% Case – Final Energy Use by Sector (ktoe)

Sector	2014	2020	2025	2030
Agriculture	1,574	1,849	2,137	2,494
Commercial	2,369	3,412	4,637	6,175
Industry	22,336	39,102	49,899	60,485
Residential	9,507	12,864	14,753	17,525
Transportation	9,247	12,452	16,441	21,324
Total	**45,032**	**69,679**	**87,868**	**108,004**

Table 63 shows that natural gas use in the demand sectors grows by 430% (12.0 Mtoe), followed by electricity at 264% (29.3 Mtoe), oil products at 145% (20.1 Mtoe) and biomass at 112% (9.1 Mtoe).

Table 63: NDC-30% Case – Final Energy Use by Fuel (ktoe)

Energy Carrier	2014	2020	2025	2030
Biomass	8,117	12,449	14,081	17,226
Coal	9,247	10,285	7,960	1,742
Electricity	11,087	21,257	30,251	40,370
Gas	2,770	6,060	9,600	14,751
Oil and Products	13,811	19,611	25,965	33,891
Renewables	0	17	10	23
Total	**45,032**	**69,679**	**87,868**	**108,004**

10.3.2 Industry Sector

As shown in Table 64, the Industry subsectors with the highest energy use are Iron & Steel, Cement and Other, followed by Pulp & Printing, Fertilizer and Food & Tobacco, where growth from current levels reach 765% for Iron & Steel, over 250% for Paper Products and Pulp & Printing, and almost double for Textiles & Leather, Fertilizer and Chemicals, and that despite the cost-effective EE measures implemented.

Table 64: NDC-30% Case – Final Energy Use by Industry Subsector (ktoe)

Sub-Sector	2014	2020	2025	2030
Beverage	277	439	537	633
Building materials	1,863	2,649	2,883	2,946
Cement	5,059	7,698	9,094	10,490
Chemical	1,312	2,143	2,725	3,397
Fertilizer	2,001	3,391	4,362	5,455
Food & Tobacco	1,747	2,868	3,528	4,222
Iron & Steel	1,334	4,938	7,979	11,096
Other	4,844	7,404	8,628	9,653
Paper Products	311	690	933	1,156
Plastics	161	256	299	341
Pulp & Printing	2,037	3,965	5,687	7,486
Textiles & Leather	1,390	2,783	3,519	4,100
Total	**22,336**	**39,225**	**50,174**	**60,976**

Table 65 shows the 2030 final energy reductions by Industry subsector and their percent reduction compared to the BAU scenario. The Cement, Other, Food & Tobacco and Iron & Steel subsectors account for over 65% of all Industry sector final energy use reductions. As noted earlier, a key finding of the analysis is that gas has a much higher mitigation value in Industry than in the Power sector where increasingly competitive RE generation options play a central role. As can be seen in Figure 59 (Section 8.5.2), there are important structural changes that need to take place in the Industrial sector with gas and biomass stepping in to displace coal use. This is particularly critical in the Iron & Steel subsector for process heat, but also for CHP and process heat in Chemicals, and process heat in Paper Products and Textiles subsectors. The biomass shift is important in the Building Materials, Cement, and Other subsectors for process heat.

Table 65: NDC-30% Case – 2030 Final Energy Reductions by Industry Subsector

Subsector	2030 Reduction in Final Energy Use Compared to BAU	
	ktoe	% Reduction
Beverage	53	7.8%
Building materials	319	9.8%
Cement	1257	10.7%
Chemical	44	1.3%
Fertilizer	239	4.2%
Food & Tobacco	747	15.0%
Iron & Steel	1307	10.5%
Other	1730	15.2%
Paper Products	128	10.0%
Plastics	82	19.4%
Pulp & Printing	513	6.4%
Textiles & Leather	753	15.5%
Total	**7172**	**10.5%**

About 60 percent of Industry sector mitigation measures are due to high efficiency boilers and furnaces, followed by electricity savings due to high efficiency motors and energy savings due to high efficiency lighting, air conditioning, etc. at about 18 percent each. The roadmap for the Industry sector has five general components that apply to all subsectors to varying degrees. These are listed in Table 66 along with the level of savings generated in the NDC-30% scenario compared to the BAU.

Table 67 provides a breakdown of cumulative Industry sector incremental investment needs by subsector. Overall, cost-effective investments in subsector process improvements and CHP result in cumulative savings as BAU investments in less efficient process heat boilers and furnaces are avoided for the Cement, iron & Steel, Paper Products and Textiles & Leather subsectors. Annual incremental investment for the full sector is in the range of $600 Million.

Table 66: NDC-30% Case – Industrial Sector Mitigation Measure Contributions in 2030

Mitigation Measure	Reduction	Percent
Electricity savings due to high efficiency motors (GWh)	2,378	18.4%
Energy savings due to high efficiency boilers and furnaces (ktoe)	3,533	8.4%
Energy savings due to high efficiency lighting, air conditioning, etc. (ktoe)	1,179	16.0%
Biomass utilization (ktoe)	14,535	23.8%
Cogeneration capacity (GW)	0.7	0.8%

Table 67: NDC-30% Case: Incremental Industrial Sector Investment (2018-2030)

Industry Subsector	Cumulative Incremental Investment: 2018-2030 (USD million)
Beverage	27
Building materials	560
Cement	2,040
Chemical	361
Fertilizer	163
Food & Tobacco	511
Iron & Steel	900
Other	944
Paper Products	349
Plastics	55
Pulp & Printing	1,285
Textiles & Leather	237
Total	**7,433**

10.4 Residential Sector

Final energy consumption in the Residential sector is reduced by 13.2 percent below the BAU. High efficiency air conditioning, cleaner cooking fuels and high performance refrigeration provide the majority of the reductions in final energy consumption, as shown in Table 68. Rooftop PV systems, high efficiency lighting and appliances, and solar water heaters provide the remainder of the Residential sector mitigation measures.

Table 68: NDC-30% Case – Residential Sector Mitigation Measures

Measure	Contribution	Percent of Energy Service Met
Output of Rooftop Solar PV (GWh)	2.2	0.2%
Output of Solar water heaters (ktoe)	17	8.7%
High performance AC (ktoe)	2,668	21.4%
High performance refrigerators (ktoe)	1,324	61%
High performance lighting (ktoe)	328	50%
High efficiency Appliances (ktoe)	1,223	50%
Cleaner cooking fuels (ktoe)	513	6.4%

Note that unlike the Power and Industry sector, where early action is highly encouraged – actually essential to achieve the more ambitious mitigation targets - there is a little more time (as the current device stock expires) to encourage the kinds of structural changes needed in the buildings sector, allowing time to put in place the kinds of rules and regulations (e.g., appliance standards) that will be necessary to implement this transformation.

Space cooling and Refrigeration account for 51% of the annual investment needs, followed by Electrical appliances (24%), Water heating (13%) and Cooking (12%). A breakdown of cumulative incremental investment needs by end-use is shown in Table 69 split for the Urban and Rural subsectors. The timing of Residential sector annual investment needs range from about $200 million in 2022 to about $900 million in 2030.

Table 69: NDC-30% Case –Residential Subsector Cumulative Investments (2018-2030)

Residential End Use Service	Cumulative Investment: 2018-2030 (USD million)		
	Urban	Rural	Total
Cooking	524	490	767
Electrical Appliances	900	900	1,523
Lighting	35	35	54
Refrigeration	1,143	1,250	1,684
Space Cooling	1,071	1,333	1,501
Water Heating	824	824	824
Total	**4,496**	**4,831**	**6,354**

10.5 Commercial Sector

Final energy consumption in the Commercial sector is reduced by 6 percent below the BAU by 2030. High performance air conditioning and lighting end-use applications would provide the majority of the final energy consumption reductions, as shown in Table 70. Solar and high performance water heaters comprise the remainder of the Commercial sector mitigation measures.

Table 70: Commercial Sector Mitigation Measures (2018-2030)

Measure	NDC-30%
Solar water heaters (ktoe)	8.2
High performance AC (ktoe)	715
High performance lighting (ktoe)	945
High efficiency office equipment (ktoe)	45
High performance water heater (ktoe)	58

A breakdown of cumulative incremental investment needs by end-use is shown in Table 71. Sector investment needs total $1.77 billion, and the annual investment needs range from about $25 million to about $150 million. Space Cooling, Cooking and Office Equipment account for about 80% of the annual investment needs.

Table 71: Roadmap Scenarios – Commercial Sector Cumulative Investments (2018-2030)

Commercial End Use Service	Cumulative Investment: 2018-2030 (USD million)
Building Equipment	23
Cooking	503
Lighting	9
Office Equipment	496
Space Cooling	623
Space Heating	8
Water Heating	106
Total	**1,768**

11 Mitigation Effectiveness

11.1 Introduction

This Section provides a deeper dive into the sectoral and end-use details underlying the mitigation results for the NDC-25% reduction mitigation scenario. The goal of this deeper dive is to more specifically identify which mitigation measures, by sectors and end-use service, should be prioritized if the emission reduction level associated with a NDC-25% target by 2030 is to be achieved.

The two critical metrics of effectiveness for mitigation measures are the incremental investment requirement and the emission reduction achieved. Looking cumulatively over the planning horizon, a Mitigation Effectiveness Indicator (MEI) is defined which corresponds to the cumulative undiscounted additional investment over the Baseline scenario for a mitigation measure, divided by the cumulative GHG reduction for that measure between 2018 and 2030. Therefore, the MEI provides an overall indication of investment effectiveness, and is similar but not the same as a Marginal Abatement Cost (MAC), which subtracts the saved fuel costs, and where MAC measures are evaluated in isolation and for specific years, while the MEI examines measures in the context of the entire energy system. This latter point means that the interaction between measures (e.g., electric vehicles affecting power sector choices) is captured by the MEI but not in a typical MAC curve. The MEI focuses on allocation of investment needs, which is most critical for developing countries looking to increase their NDC ambition.

The MEIs presented in this section were constructed by constraining overall GHG emissions, not defining specific policies, so the least-cost choice of measures varies between each scenario, for example, as will be discussed in more detail later:

- Commercial sector emission reductions initially come mostly from Lighting demands, but as the target level is raised, more reductions come from first Space Cooling and then Cooking and Water Heating. As a result, the Lighting MEIs are low and basically flat across all target levels, while the Space Cooling MEI starts high under modest targets (because of limited use only late in the planning horizon) but drop dramatic when called upon more heavily under higher mitigation levels, and
- Cost effective investments in CHP for a few industrial sectors provide process heat and on-site electricity that reduce investment needs for conventional process heat boilers and yields negative MEIs for modest targets. These turn positive under stronger reduction targets, as the CHP potential is reached.

Besides not reflecting the fuel saving, the Power sector MEIs are based on their investment expenditures and the avoided investment in coal and natural gas plants is not explicitly taken into consideration.

11.2 Supply and Power Sectors

Under the NDC-25% case, the share of RE in the primary energy mix grows to 19%, while coal use decreases by 29%, and natural gas use increases 14%, due to increased consumption by Industry. Coal imports decrease 39% due to less coal-fired generation, while natural gas imports drop only 2% compared to the BAU, as less gas-fired generation is offset by expanded use of gas in Industry to replace coal.

Table 72 shows the existing power plant capacity in the Base year and the total power plant capacity in 2030 for the various NDC targets. In the NDC-10% case, conventional coal existing stock and planned new coal power plant builds lock in a high-carbon future, although 5.1GW less Super Critical plants are built. The share of RE in total power generation (including large hydropower) increases to 29.4% (163 TWh), and the share for variable RE in total generation grows to 7% (39.6 TWh). Combined solar PV and wind capacity reach 13.6 GW in 2030.

In the NDC-25% case, conventional coal existing stock and planned (firm) new builds continue to lock in a high-carbon future. The capacity of Super Critical plants is reduced by 11.8 GW, although 10.4 GW are still built by 2030. By 2030 total coal generation drops 22% (83 TWh). The share of RE in total power generation (including large hydropower) increases to 36.1% (194 TWh), while the share of variable RE in total generation grows to 11% (61 TWh), which is manageable for grid stability. Combined solar PV and wind capacity reach 27.4 GW.

Table 72: Power Plant Capacity Additions (GW)

Power Plant Type	Existing Capacity	Total Capacity in 2030 (GW)				
		BAU	NDC-10%	NDC-15%	NDC-25%	NDC-30%
Biogas-fired	0.0	0.0	0.0	0.0	0.2	0.1
Biomass & Bagasse	0.4	0.4	0.8	0.9	1.5	1.6
Coal-fired – Conventional	18.8	30.8	30.8	30.8	30.8	30.8
Coal-fired Super Critical	0.0	25.6	20.5	18.1	13.9	10.4
Coal-fired with Biomass	0.0	0.2	0.6	2.4	0.5	0.4
Diesel-fired	0.3	0.3	0.3	0.3	0.3	0.3
Gas-fired	7.9	33.6	15.2	15.2	15.2	15.2
Hydro – Large & Medium	17.7	19.1	19.1	19.1	19.1	19.1
Hydro – Small	1.3	1.3	4.1	4.1	5.9	8.1
Landfill gas	0.0	0.0	0.0	0.0	0.0	0.0
Municipal Solid Waste	0.0	0.0	0.5	0.5	1.6	1.6
Solar Central	0.0	0.0	4.0	4.0	17.5	17.9
Solar Distributed	0.0	0.0	1.6	1.6	1.9	2.2
Storage	0.0	0.0	0.0	0.0	0.0	0.0
Wind	0.0	0.0	8.0	7.7	8.0	8.9
Total	**46.3**	**111.3**	**105.4**	**104.5**	**116.3**	**116.4**

Figure 70 shows the cumulative incremental investment in the Power Sector for the range of NDC targets. In all cases, the RE plants require higher investment, but much of that cost is offset by the avoided investment in new coal and gas plants, although about US$18 Billion additional investment is needed over the planning horizon to achieve the NDC-25% reduction target.

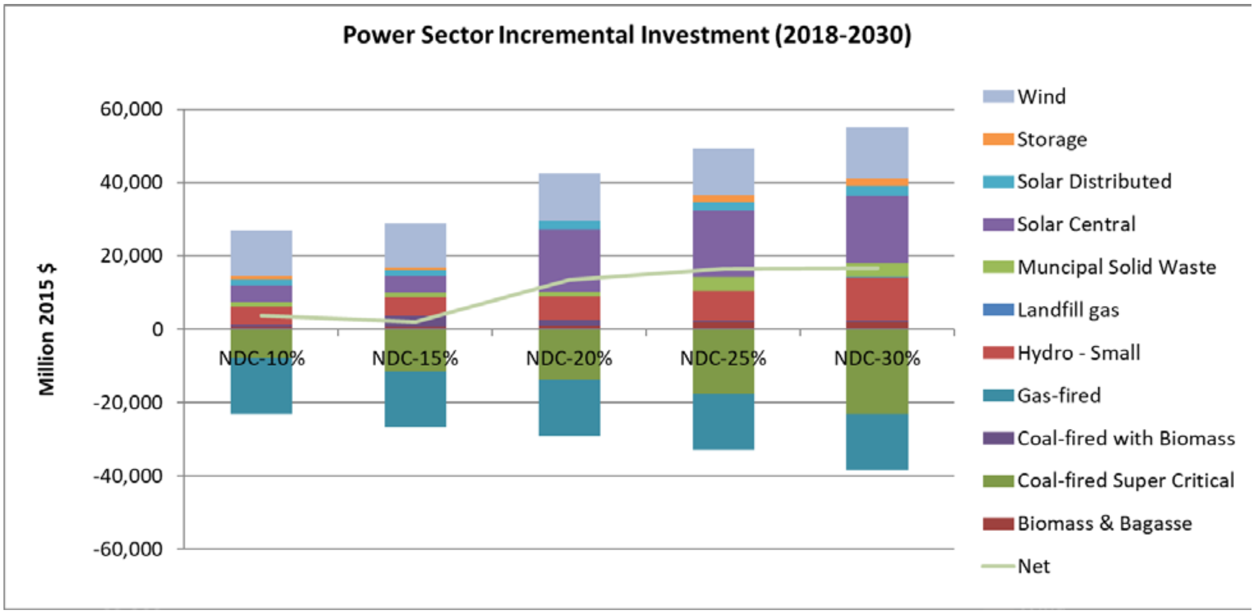


Figure 70: Power Sector Investment Requirements and Reductions (2018-2030)

Table 73 shows the change in cumulative lump sum investment from the Baseline scenario by power plant type for each NDC scenario. The NDC 10% scenario requires RE investment of $12.5 Billion, but given the avoided coal and gas power plant investments, the overall net additional funds needed amounts to less than $3.8 Billion, which is $240 million per year. The NDC-25% and NDC-30% scenarios require net additional funds of about US$16.5 Billion or a little more than US$1.2 Billion per year. The NDC-30% scenario pays for the additional RE capacity (wind & small hydropower) with less supercritical coal capacity.

Electricity generation drops by 8% to 14% as the NDC reduction target increases from the NDC-10% to the NDC-30% scenario, due to energy efficiency measures. The share of electricity generated from coal-fired plants drops from 68.6% in the BAU to 58% for NDC-30%, while the total RE generation moves from 14% in the BAU to 35% in NDC-30%, with Variable RE running a very manageable 7% to just over 12% of total generation.

Table 73: Cumulative Power Sector Investment (2018-2030) – Change from BAU (M$)

Technology	NDC-10%	NDC-15%	NDC-20%	NDC-25%	NDC-30%
Biogas-fired	0	0	0	135	124
Biomass & Bagasse	618	703	911	1,943	1,967
Coal-fired Super Critical	-7,831	-11,449	-13,775	-17,684	-23,115
Coal-fired with Biomass	545	3,000	1,674	427	328
Gas-fired	-15,251	-15,251	-15,251	-15,251	-15,251
Hydro – Large & Medium	0	0	0	0	0
Hydro - Small	4,957	4,957	6,359	8,060	11,820
Landfill gas	28	28	28	28	28
Municipal Solid Waste	1,223	1,223	1,223	3,823	3,823
Solar Central	4,486	4,486	16,985	18,104	18,409
Solar Distributed	1,807	1,807	2,268	2,263	2,612
Storage	680	571	0	1,930	1,930
Wind	12,534	12,009	13,001	12,676	14,080
Net	**3,796**	**2,084**	**13,424**	**16,455**	**16,755**
Total RE	**26,332**	**25,784**	**40,774**	**48,963**	**54,793**

Table 74 shows the change in cumulative GHG emissions from the Baseline scenario by power plant type for each NDC scenario. The contributions for each RE technology were calculated based on their annual electricity generation and the average grid emission factor. The overall grid emission factor was used rather than the emission factors of coal, natural gas, or oil-fired power plants because the model does not identify what fraction of the electricity replaced by each RE technology is generated by coal, gas or oil-fired plants. Note that the Total Power sector emission reductions are calculated in the model and are not based on this assumption. Wind, central solar, small hydropower, MSW and biomass plants are the largest contributors at NDC-10%. As the NDC level is increased, wind, solar and biomass grow the most, followed by small hydropower, while the contribution from MSW remains constant. Total Power Sector emission reductions are much lower than the RE contribution for NDC-10% because of the growth in coal-fired generation, but it exceeds the RE contribution at NDC-30% because of the higher proportion of both RE and EE reductions. Large & medium hydro technology shows a negative change in emissions from the BAU scenario, because in the NDC scenarios the installation of new Large & Medium hydro capacity is delayed because the availability of small hydro and other renewable technologies, and this delay in capacity additions reduces the total generation over the period by large & medium hydro so the change in emission reductions is negative.

Table 74: RE Plant GHG Emission Reductions (2018-2030) – Cumulative Change from BAU (kt)

Technology	NDC-10%	NDC-15%	NDC-20%	NDC-25%	NDC-30%
Biomass & Bagasse	53,600	54,395	62,022	110,760	111,294
Hydro – Large & Medium	-16,056	-16,056	-16,056	-16,056	-16,056
Hydro - Small	89,408	89,408	94,134	99,868	112,537
Landfill gas	2,097	2,097	2,097	2,097	2,097
Municipal Solid Waste	63,721	63,721	63,721	63,721	63,721
Solar Central	108,512	108,512	197,008	209,823	223,099
Solar Distributed	16,639	16,639	24,662	24,650	31,609
Storage					
Wind	280,053	270,852	351,535	349,368	359,039
Total RE	**620,134**	**644,754**	**816,477**	**864,800**	**906,585**
Total Power Sector	**281,960**	**412,975**	**619,897**	**815,488**	**1,141,960**

Table 75 shows the Investment MEIs for the individual RE technologies. Note that the Investment MEI calculation for individual RE technologies does not include any savings (investment or fuel costs) from avoided coal or gas plants, because the model controls these variables independently, and does not attribute savings to particular technologies. Thus, these RE Investment MEIs are best evaluated in the context of other RE technologies. Biomass, landfill gas and MSW have low Investment MEIs, while wind, solar and small hydropower have moderate Investment MEIs. Also, the Investment MEIs for many technologies increase with the NDC level as more capacity is added late and so has limited utilization before 2030.

In addition, the Investment MEI is presented for all RE technologies as a set, along with the Investment MEI for the total Power Sector. The total RE Investment MEI increases as the NDC target is increased, but the total Power Sector Investment MEI peaks at NDC-20% and decreases for NDC-25% and NDC-30%, which indicates the benefits of a rapid deployment of higher levels of central solar and wind plants, as well as small hydro and municipal solid waste.

Table 75: Investment Mitigation Effectiveness Indicator – MEI ($/t)

Technology	NDC-10%	NDC-15%	NDC-20%	NDC-25%	NDC-30%
Biogas-fired					
Biomass & Bagasse	12	13	15	18	18
Hydro – Large & Medium	0	0	0	0	0
Hydro - Small	55	55	68	81	105
Landfill gas	13	13	13	13	13
Municipal Solid Waste	19	19	19	60	60
Solar Central	41	41	86	86	83
Solar Distributed	109	109	92	92	83
Storage					

Wind	45	44	37	36	39
Total RE	**42**	**40**	**50**	**57**	**60**
Total Power Sector	**13**	**5**	**22**	**20**	**15**

Figure 71 and Figure 72 illustrate the mitigation effectiveness of various Power sector mitigation measures. For each figure, the left side shows the share of emission reductions for the top measures in the Power sector, and the right side shows the emission reduction amounts as blue bars, and the MEI as red dots. The emission reductions from each RE technology were based upon the RE generation level and the BAU grid emission factor.

The biggest impact on the Power sector of moving from NDC-10% to NDC-25% is the curtailment of 18.4 GW of gas-fried and 5.2 GW of super-critical coal plants. As reduction amounts increase from 10% to 25% wind, central solar, small hydro and distributed solar need to play a more substantial role, adding 8 GW, 4 GW, 2.8 GW and 1.6 GW, respectively.

For the NDC-10% case, wind and solar shows a similar MEI, however, for the NDC-25% case, the MEI for both solar technologies increases as more capacity is added late in the modeling period to meet the higher target.

The NDC-25% case requires higher levels of RE across the board (as well as EE), and the overall RE MEI increases by 43% (from $42/t to $57/t), which highlights the critical role of International assistance.

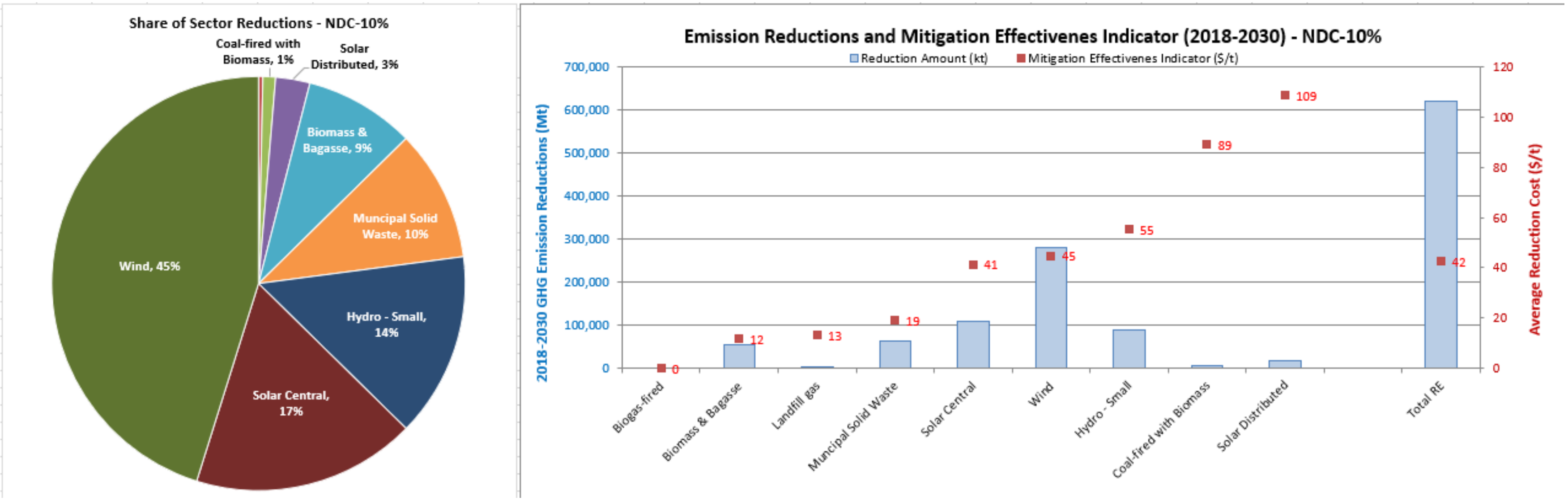


Figure 71: Power Sector Emission Reductions and Investment MEI (2018-2030) for NDC-10% Scenario

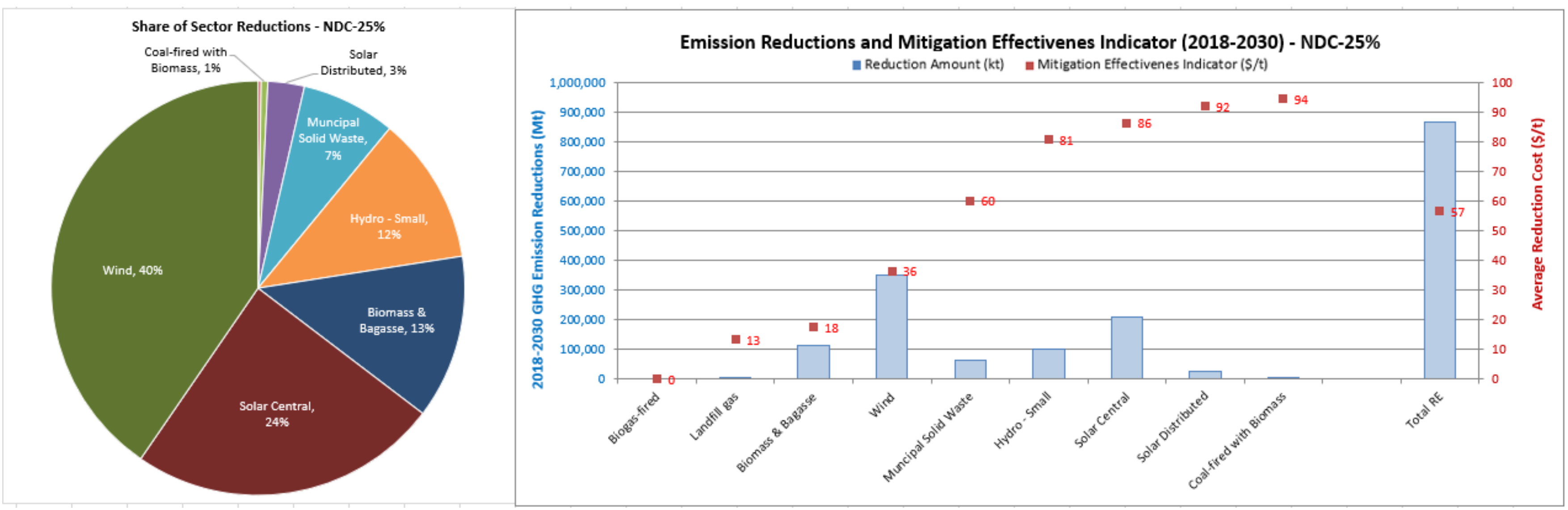


Figure 72: Power Sector Emission Reductions and Investment MEI (2018-2030) for NDC-25% Scenario

11.3 Industry Sector

First, overall results for the Industry sector, showing contributions from each of the 12 Industry subsectors are presented. Next, the breakdown of each subsector by demand service (process, heat, machine drive, facilities, and feedstocks) is provided in the subsection that follows.

11.3.1 Key Industry Subsectors

Figure 73 shows the cumulative incremental investment for each Industry subsector. As the NDC target level increases, the investment needs for Cement, Pulp & Printing, Iron & Steel and Other industries grow the most. To achieve more than a 20% GHG reduction, a major restructuring of the Cement industry is required.

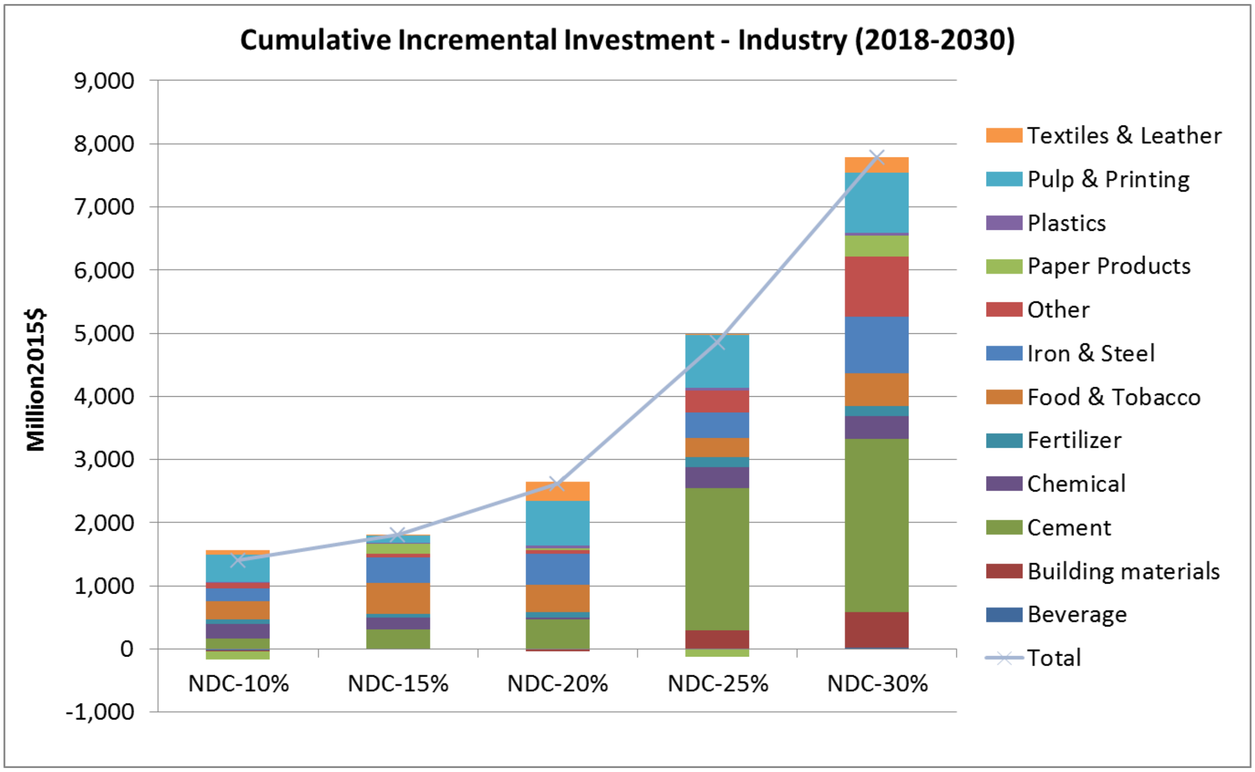


Figure 73: Industry Sector - Cumulatiive Incremental Investment (2018-2030)

Table 76 the change in cumulative lump sum investment from the Baseline scenario for each Industrial subsector, which underpins the determination of their Investment MEI. For the NDC-25% scenario some US$2.2 Billion and US$828 Million additional needs to be put into the Cement and Pulp & Printing sub-sectors respectively. Several subsectors show negative changes in investment costs compared to the BAU, which are the result of fuel switching to more efficient boilers and furnaces. In particular, the Beverages and Paper Products subsectors replace diesel, fuel oil and coal boilers and furnaces with natural gas, while the Building Materials subsector replaces fuel oil, coal and natural gas boilers and furnaces with biomass, and the Paper Products subsectors replaces fuel oil and coal boilers and furnaces with natural gas and CHP. In some subsectors, such as Building materials, the values seem to jump because the model makes capacity addition decisions in increments, and both the timing and the size of those incremental additions do not necessarily change in a continuous fashion as the NDC target level is increased.

Table 76: Cumulative Industrial Sector Investment – Change from BAU (M$)

Subsector	NDC-10%	NDC-15%	NDC-20%	NDC-25%	NDC-30%
Beverage	-21	-13	-14	2	27
Building materials	-17	3	-27	297	560
Cement	168	308	465	2,246	2,740
Chemical	232	191	27	327	361
Fertilizer	71	58	86	164	163
Food & Tobacco	292	491	437	311	511
Iron & Steel	202	406	490	398	900
Other	88	48	55	346	944
Paper Products	-127	155	33	-121	331
Plastics	4	23	50	51	55
Pulp & Printing	438	109	703	828	950
Textiles & Leather	73	26	308	2	237
Net	**1,403**	**1,804**	**2,613**	**4,849**	**7,780**

Table 77 shows the change in cumulative GHG emission reductions from the BAU scenario for each Industrial sector, Note that for the total Industry sector, the NDC-25% scenario requires 1.9 times the reductions as the NDC=10% scenario, and the NDC-30% scenario needs 2.1 times, while the NDC20% scenario requires only 1.3 time the reductions as NDC-10%.

The Cement subsector consistently makes the greatest contributions, ranging from 64% to 46% of the total. Other subsectors with important contributions are Iron & Steel, Pulp & Printing and Fertilizer, and subsectors with significant growth are Building materials, Textiles & Leather, and Chemicals.

Table 77: Cumulative GHG Emission Reductions (2018-2030) – Change from BAU (kt)

Subsector	NDC-10%	NDC-15%	NDC-20%	NDC-25%	NDC-30%
Beverage	187	232	388	883	970
Building materials	7,188	8,339	9,213	17,979	19,064
Cement	103,813	106,933	110,983	137,255	153,688
Chemical	4,630	6,822	8,878	12,279	13,854
Fertilizer	8,588	12,000	15,206	24,000	26,518
Food & Tobacco	9,356	9,915	10,191	11,550	12,099
Iron & Steel	20,619	22,635	23,456	31,669	32,237
Other	5,024	9,655	10,351	16,196	17,764
Paper Products	194	1,643	2,149	7,502	8,087
Plastics	124	-277	-313	585	616
Pulp & Printing	2,170	8,638	17,889	27,646	32,396

Textiles & Leather	80	3,942	5,549	14,706	17,165
Total	**161,973**	**190,479**	**213,940**	**302,249**	**334,459**

Table 78 shows the Investment MEI for the Industry sector as a whole and by subsector. As a whole, the Industry sector has relatively low Investment MEIs, which are comparable to those for the total Power sector. However, significant differences occur between the subsectors. At the higher NDC targets, Cement, Fertilizer and Textiles & Leather have low MEIs, while Plastics and Other have high Investment MEIs. Negative Investment MEIs result from investment savings due to fuel switching to natural gas biomass and CHP and represent low hanging fruit.

Table 78: Investment Mitigation Effectiveness Indicator – MEI ($/t)

Subsector	NDC-10%	NDC-15%	NDC-20%	NDC-25%	NDC-30%
Beverage	-112	-58	-36	2	28
Building materials	-2	0	-3	17	29
Cement	2	3	4	16	18
Chemical	50	28	3	27	26
Fertilizer	8	5	6	7	6
Food & Tobacco	31	49	43	27	42
Iron & Steel	10	18	21	13	28
Other	17	5	5	21	53
Paper Products	-654	94	15	-16	41
Plastics	32	60	84	88	90
Pulp & Printing	202	13	39	30	29
Textiles & Leather	917	7	55	0	14
Total	**9**	**9**	**12**	**16**	**23**

Figure 74 plots the reduction level achieved by each subsector as the blue bars and the MEI for that subsector as the red dots. The subsectors are arranged by ascending order of MEI, and the figure shows the relative significance of the Cement subsector, which accounts for 46% of Industry emission reductions, and with a fairly attractive MEI of $16/t. Also clearly illustrated are the low reduction potentials from the Beverages and Plastics subsectors and the very high MEI for the Plastics subsector.

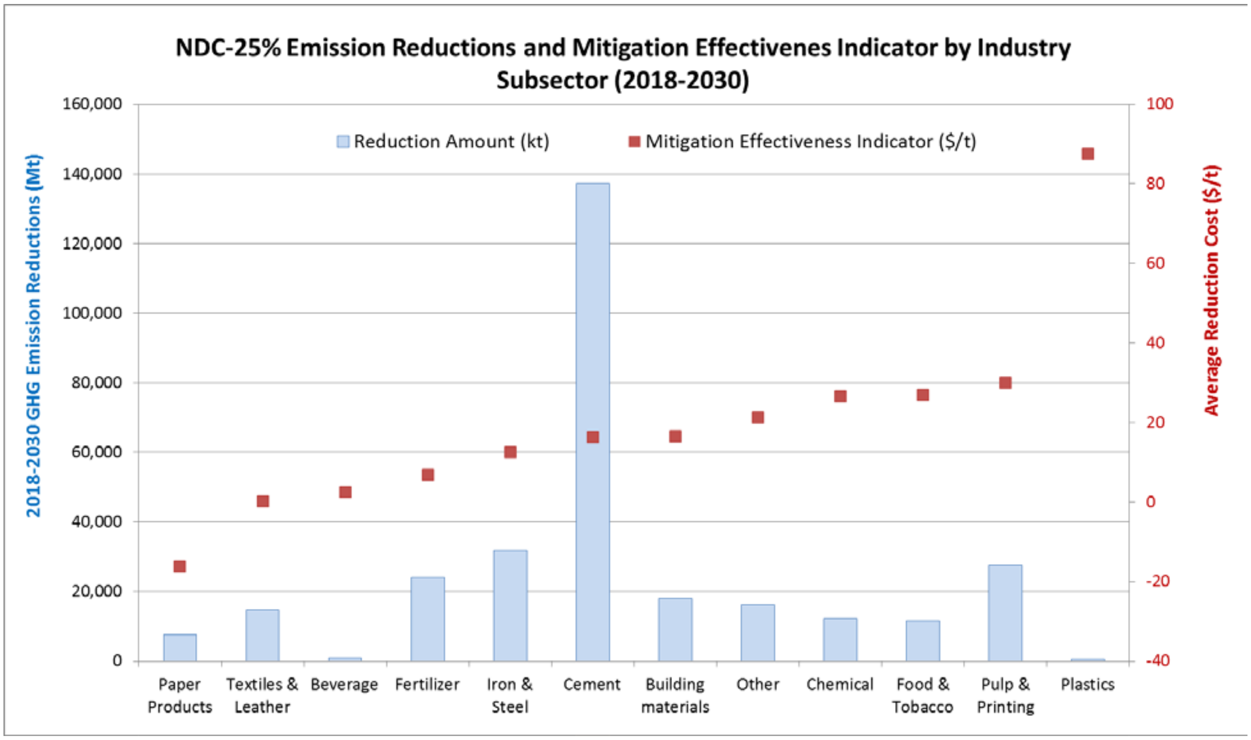


Figure 74: Emission Reductions and Investment MEI (2018-2030) for NDC-25% Scenario

11.3.2 Key Subsector Mitigation Measures

Within each subsector, the emission reductions were further divided according to the basic demands services, such as Machine Drive, Process Heat, Feedstock and Facilities. The emission reduction and MEI for the largest 16 emission reduction measures in the Industry sector are identified in Figure 75 and Figure 76 for the NDC-10% and NDC-25% cases, respectively. Each measure accounts for at least 5 Mt of CO2 eq. reductions, and the set of measures spans eight subsectors: Cement, Iron & Steel, Pulp & Printing, Chemicals, Fertilizers, Building materials, Textiles & Leather, and Other. Ten of the measures are Process Heat related, while four are Machine Drive measures with one each for Facilities and Feedstocks. The MEI ranges from zero to less than $25/t. Feedstock reductions show zero because they require no capital investment – only feedstock switching.

With NDC-10%, cost-effective CHP produces negative MEIs for Process Heat in several subsectors, and other MEIs are less than $10/t, indicating that modest emission reductions in Industry are extremely cost-effective. Cement Process Heat improvements are key, consistently producing the most significant emission reductions. With the NDC-25% case, the MEIs increase, but remain below $25/t.

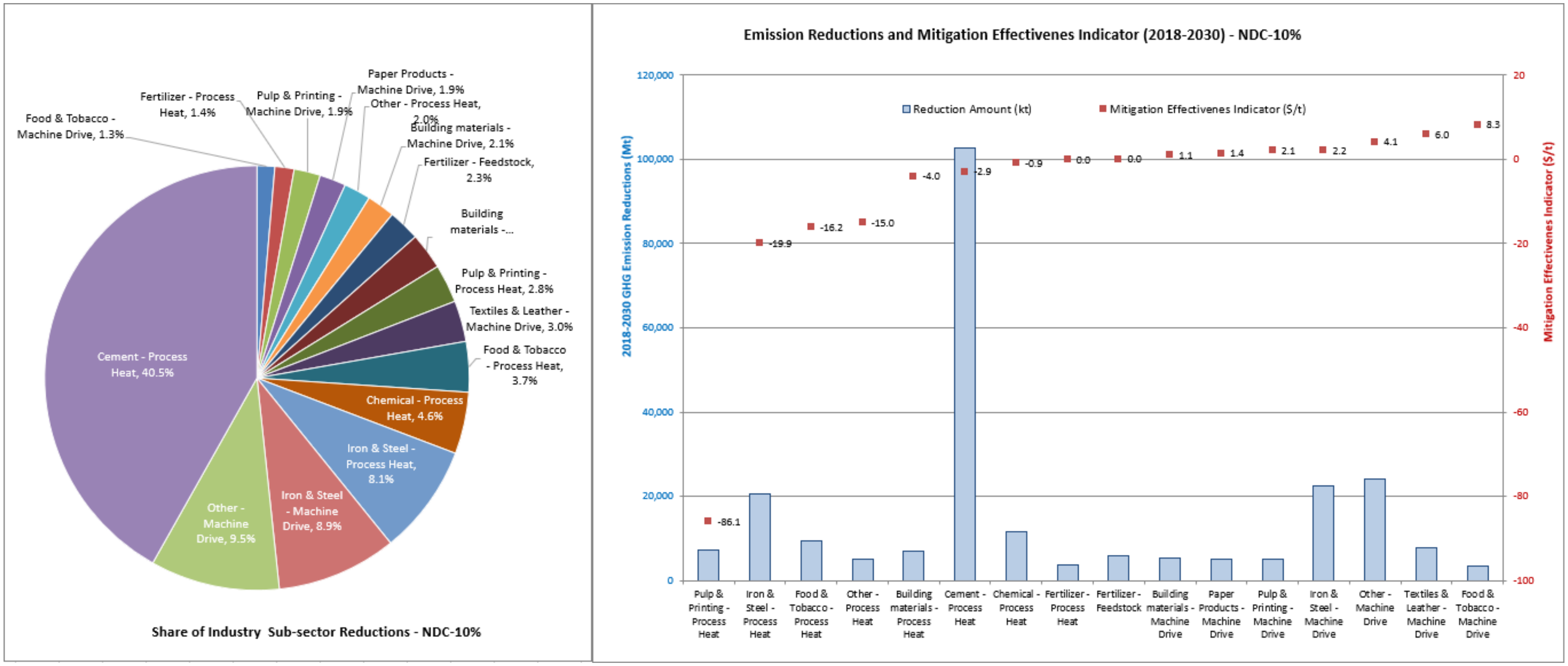


Figure 75: Industry Subsector Mitigation Measure Emission Reductions and Investment MEI (2018-2030) for NDC-10% Scenario

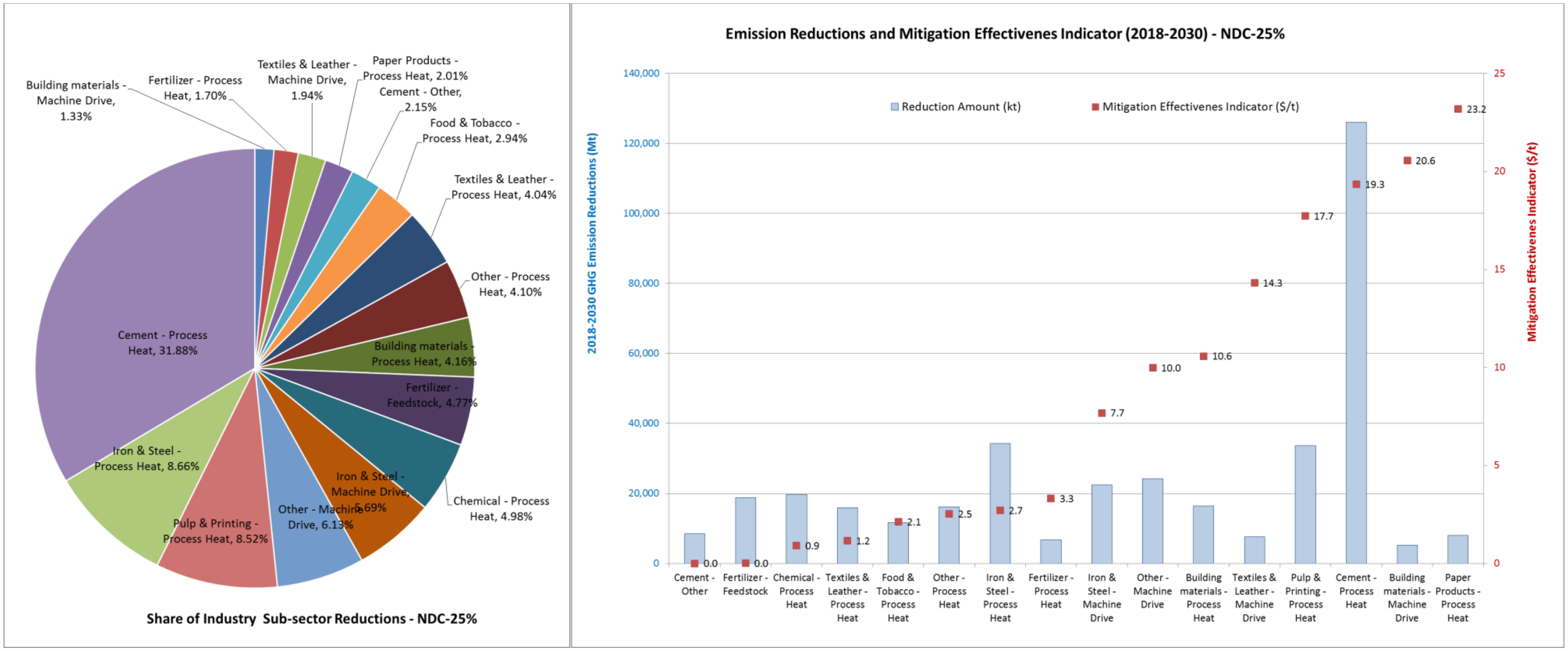


Figure 76: Industry Subsector Mitigation Measure Emission Reductions and Investment MEI (2018-2030) for NDC-25% Case

As shown in Table 44, the sector-wide contributions from Machine Drive and Process Heat, as well as Facility lighting and air conditioning, over all the Industry subsectors are core to achieving the necessary reductions in the sector to reach the NDC-25% target.

Table 79: Overall Industry Sector Mitigation Measure Results – NDC-25% Case

Mitigation Measure	Reduction	Percent
Electricity savings due to high efficiency motors (GWh)	1,644	12.7%
Energy savings due to high efficiency boilers and furnaces (ktoe)	2,945	7.0%
Energy savings due to high efficiency lighting, air conditioning, etc. (ktoe)	1,179	16.0%
Biomass utilization (ktoe)	13,684	22.0%
Cogeneration capacity (GW)	0.7	0.8%

Table 79 provides overall Industry sector metrics that MOIT can use to track progress towards meeting the emission reduction goals for the NDC-25% scenario. Specifically, by 2030 the emission reduction measures should reduce electricity consumption for Machine Drive and Facility use by at least 12%, while energy use for Process Heat should drop by 7%, and about 13.6 Mtoe of biofuels should be utilized along with 700 MW of industrial CHP installations.

Measures to reduce Machine Drive emissions are all efficiency-based equipment and process improvements. However, Process Heat emission reduction measures include not only efficiency improvements for boilers and furnaces, and cogeneration, but also fuel switching from coal to natural gas and biofuels. By 2030 under the NDC-25% scenario, about 15.5 Mtoe of coal use by Industry is replaced by 6.7 Mtoe of natural gas, 4.5 Mtoe of biofuels, and 3.1 Mtoe of fuel oil.

11.4 Industry Subsector Details

Priority measures for the eight highest impact subsectors are summarized below.

11.4.1 Equipment Efficiency Measures

Machine drives, boilers and furnaces are common industrial equipment that have a variety of existing and future technology options for replacing old equipment and meeting demand growth. Data on these technology options in terms of investment level, operating cost, efficiency, and lifetime is largely sourced from the US Environmental Protection Agency and the Danish Energy Agency databases for variable speed drives, condensing and other more efficient boiler and furnace designs, and combined heat and power options.

11.4.2 Cement Subsector Process Improvement Measures

Process improvements in the Cement subsector include measures to optimize the combustion cycle, reduce clinker furnace heat loss, and reduce crushing energy. Specific measures include: vertical roller mill, dry kilns with multi-stage pre-heaters and pre-calcination, waste heat recovery from co-generation, the introduction of a pre-grinder, reducing kiln shell heat losses, and other combustion system improvements. More specific information on these measures can be found in "Conduct Rapid Specific Energy Consumption Analysis in Cement Sector," Vietnam Energy Efficiency Carbon Crediting Program, November 2017.

11.4.3 Iron & Steel Subsector Process Improvement Measures

Process improvements in the Iron & Steel subsector include measures such as pulverized coal injection in blast furnaces, steel scrap preheating for electric arc furnaces, waste heat recovery based power generation, other reductions in thermal energy and electrical energy related to blast furnaces, electric arc furnaces, hot rolling presses, cold rolling presses, steel pipe production, long coated sheets processes, and coking plant. More specific information on these measures can be found in "Establishment of an Energy Savings Scheme in the Steel Sector in Vietnam," Technology Catalogue for Vietnam Iron and Steel Industry, November 2013 and "Establishment of an Energy Savings Scheme in the Steel Sector in Vietnam," Final Report, December 2014.

11.4.4 Pulp & Printing Subsector Process Improvement Measures

Process improvements in the Pulp & Printing subsector include measures such as waste paper in the pulping process, high temperature recovery boilers for pulping black liquor combustion, and high efficiency dehydrators for paper-making machines. More specific information on these measures can be found in Source: Vietnam Low Carbon Options Assessment, (Energy sector components), IEVN 2013, and "Assessment of Energy Saving Potential in the Pulp and Paper Industry," Clean Production and Energy Efficiency In Vietnam, Deliverable 7 Final Report, November 2016.

11.4.5 Chemical - Process Heat

Process improvements in the Chemicals subsector include measures establishing energy management systems, strengthening internal management and maintenance, supplying hot air to high temperature burners, replacing resistance heaters for plastic molding machines, and increasing insulation for injection molding machines, stone powder heat baths, stone mixing tanks acid cooking pots, and oil tanks for acid coating machines.

11.4.6 Fertilizer Subsector Process Improvement Measures

Process improvements in the Fertilizer subsector include measures establishing energy management systems, and strengthening heat recovery systems.

11.4.7 Building materials

Process improvements in the Building materials subsector include measures establishing energy management systems, strengthening internal management and maintenance, improving kiln materials, installing absorption chillers to capture waste heat from heat transfer furnaces and drying systems, and investing in new extrusion lines.

11.4.8 Other Subsector Process Improvement Measures

Process improvements in the Other industries subsector include measures establishing energy management systems, strengthening internal management and maintenance, improving kiln torch systems, installing gas vapor recovery equipment for dispensing stations, implementing recovery systems at CNG loading stations, insulating the heating barrel of plastic injection machines and installing heat recover systems for heat treatment furnaces.

11.4.9 Textiles & Leather Subsector Process Improvement Measures

Process improvements in the Textiles & Leather subsector include measures establishing energy management systems, and improving processes for fiber production, knitting and dyeing, such as using iinsulated plastic extruder heads, heat recovery from waste water discharge, and reducing other heat losses.

11.5 Residential and Commercial Sectors

Figure 77 and Table 80 show the cumulative incremental investment (above the BAU) for Residential sector energy efficiency investments, which increases proportionally for all end-use services as the GHG reduction target increases, but are less than 20% of the net power sector investment. Space Cooling and Refrigeration account for more than half the investment needs.

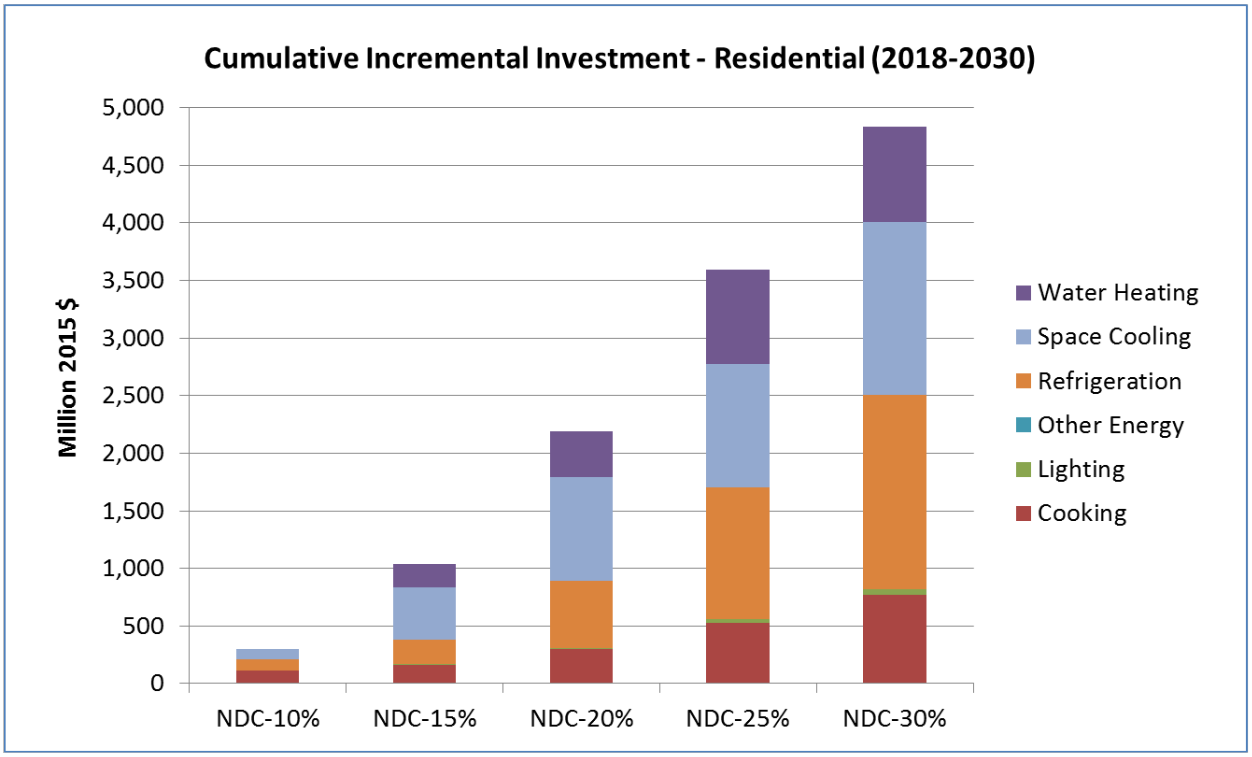


Figure 77: Residential Sector – Cumulative Incremental Investment

Table 80: Residential Sector Investments (2018-2030) – Change from BAU (M$)

Service Demand	NDC-10%	NDC-15%	NDC-20%	NDC-25%	NDC-30%
Cooking	112	163	297	524	767
Lighting	5	7	13	35	54
Other Energy	0	0	0	0	0
Refrigeration	95	214	582	1,143	1,684
Space Cooling	89	452	899	1,071	1,501
Water Heating	0	200	399	824	824

Total	**121**	**1,035**	**2,190**	**3,596**	**4,831**

Table 81 shows the change in cumulative GHG emission reductions from the Baseline scenario for each Residential sector service demand. Note that for the total Residential sector, the NDC-25% scenario requires 5.5 times the reductions as the NDC-10% scenario, and the NDC-30% scenario needs 7.7 times, while the NDC-20% scenario requires 3.2 time the reductions as NDC-10%.

Cooking demands consistently make the largest single emission reduction contribution, while Lighting, Refrigeration and Space Cooling demands increase the most when moving from the NDC-10% scenario to the higher NDC scenarios.

Table 81: Residential Sector GHG Emission Reductions (2018-2030) – Change from BAU (kt)

Service Demand	NDC-10%	NDC-15%	NDC-20%	NDC-25%	NDC-30%
Cooking	4,635	6,427	10,480	18,202	20,769
Lighting	2,322	4,409	6,460	11,529	14,799
Space Cooling	750	1,000	4,648	6,043	11,724
Refrigeration	1,083	2,689	5,383	11,094	18,926
Water Heating	0	427	854	1,761	1,761
Total	**8,790**	**14,951**	**27,825**	**48,629**	**67,979**

Table 82 shows the MEI for each Residential sector service demand and the sector as a whole. As a whole, the Residential sector has relatively high MEIs, especially for Water Heating. However, Lighting and Cooking have very low MEIs. The MEIs for Space Cooling decline as the NDC target is increased because of their greater utilization.

Table 82: Residential Sector Mitigation Effectiveness Indicator – MEI ($/t)

Service Demand	NDC-10%	NDC-15%	NDC-20%	NDC-25%	NDC-30%
Cooking	24	25	28	29	37
Lighting	2	2	2	3	4
Space Cooling	118	452	194	177	128
Refrigeration	88	80	108	103	89
Water Heating	0	468	468	468	468
Total	**14**	**69**	**79**	**74**	**71**

Figure 78 and Table 83 shows the cumulative incremental investment (above the BAU) for Commercial sector energy efficiency investments, which consist primarily of Space Cooling measures at low GHG target levels, but include Cooking and Office Equipment investments for the 20% to 30% targets.

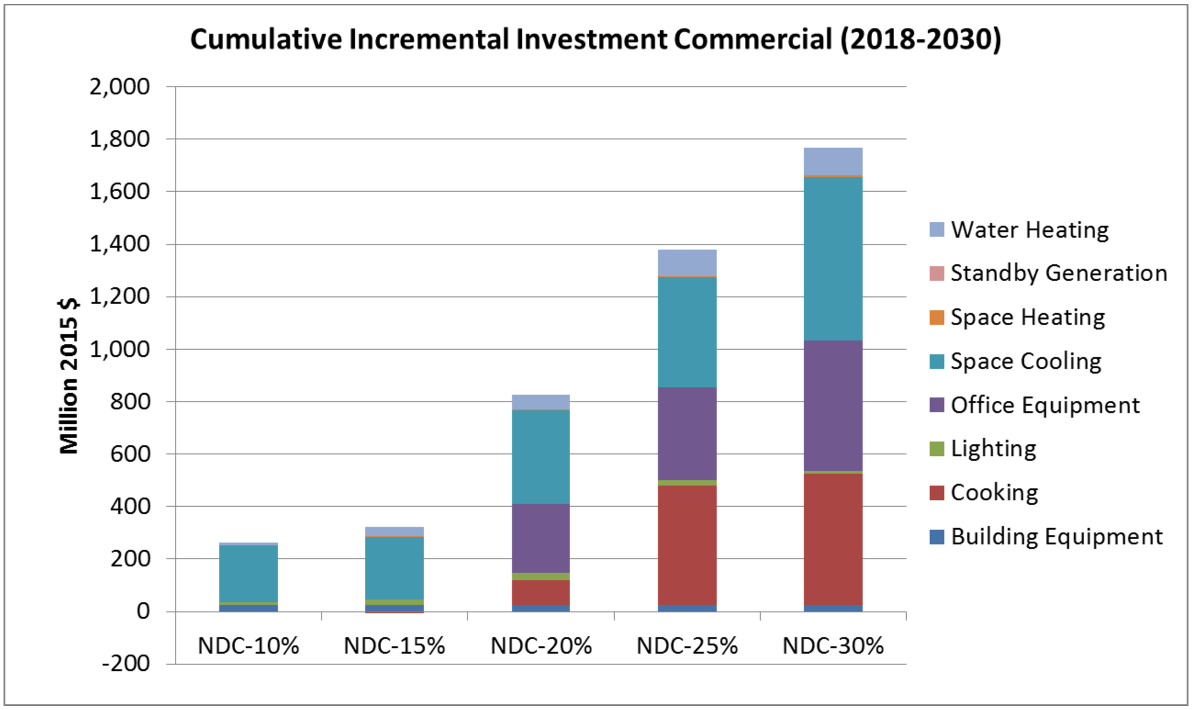


Figure 78: Commercial Sector – Cumulative Incremental Investment

Table 83: Commercial Sector Investments (2018-2030) – Change from BAU (M$)

Service Demand	NDC-10%	NDC-15%	NDC-20%	NDC-25%	NDC-30%
Building Equipment	23	23	23	23	23
Cooking	-2	-5	96	456	503
Lighting	12	22	27	20	9
Office Equipment	0	0	263	354	496
Space Cooling	215	238	357	419	623
Space Heating	1	2	3	6	8
Standby Generation	0	0	0	0	0
Water Heating	12	37	56	102	106
Total	**262**	**276**	**476**	**516**	**1,185**

Table 84 shows the change in cumulative GHG emission Reductions from the Baseline scenario for each Commercial sector service demand. Note that for the total Commercial sector, the NDC-15% and higher scenarios require between 2 and 3 times the reductions of the NDC-10% scenario. Lighting measures provides the most reductions, especially for the NDC-10% case, but Space Cooling and Cooking measures provide significant reductions as the NDC target increases.

Table 84: Commercial Sector GHG Emission Reductions (2018-2030) – Change from BAU (M$)

Service Demand	NDC-10%	NDC-15%	NDC-20%	NDC-25%	NDC-30%
Building Equipment	0	0	0	0	0
Cooking	20	31	1,312	5,979	7,610
Lighting	11,420	17,625	18,137	19,476	20,658
Office Equipment	0	0	0	0	0
Space Cooling	1,262	5,097	6,667	8,767	10,254
Space Heating	130	268	427	814	928
Standby Generation	0	0	0	0	0
Water Heating	594	810	2,134	2,819	117
Total	**13,428**	**23,831**	**28,677**	**37,855**	**39,566**

Table 85 shows the MEI for each Commercial sector service demand and the sector as a whole. Note that the negative values for Cooking result because at the lower NDC target levels the longer lifetime of the more efficient stoves results is some minor investment savings relative to the BAU scenario. This is not seen in the higher NDC scenarios as the investment needs for more efficient stoves exceed this savings. As a whole, the Commercial sector has relatively low MEIs, which are comparable to those for the total Power sector. However, significant differences occur between the subsectors.

Table 85: Commercial Sector Investment Mitigation Effectiveness Indicator – MEI ($/t)

Service Demand	NDC-10%	NDC-15%	NDC-20%	NDC-25%	NDC-30%
Building Equipment	0	0	0	0	0
Cooking	-87	-170	73	76	66
Lighting	1	1	1	1	0
Office Equipment	0	0	0	0	0
Space Cooling	171	47	54	48	61
Space Heating	6	6	6	7	8
Standby Generation	0	0	0	0	0
Water Heating	21	45	26	36	910
Total	**20**	**12**	**17**	**14**	**30**

Figure 79 on the left shows the share of emission reductions for the top measures in the Commercial and Residential sectors for the NDC-10% case. On the right, the figure shows the emission reduction amounts as blue bars, and the Investment MEI as red dots. The top eight measures in the Commercial and Residential sectors are arranged in order of increasing Investment MEI. For the NDC-10% case, Lighting measures from both sectors account for 62% of all reductions followed by Cooking. These measures have the lowest Investment MEI and are selected first, while the Investment MEIs for Space Cooling are high, because investments are large and come later, which reduces their impact by 2030. Investment MEIs for the Residential and Commercial sector as a whole are $13.7/t and $19.5/t because of the predominance of low-cost Lighting and Cooking measures.

Figure 80 shows the same Commercial and Residential sector information for the NDC-25% case. Lighting and Cooking continue to make strong contributions, but they reach their limits, and Space Cooling and Refrigeration grow to almost 32% of needed reductions. Investment MEIs for the Residential and Commercial sector as a whole grow to $74/t and $13.6/t because of the relatively high Investment MEIs for refrigeration and space cooling measures.

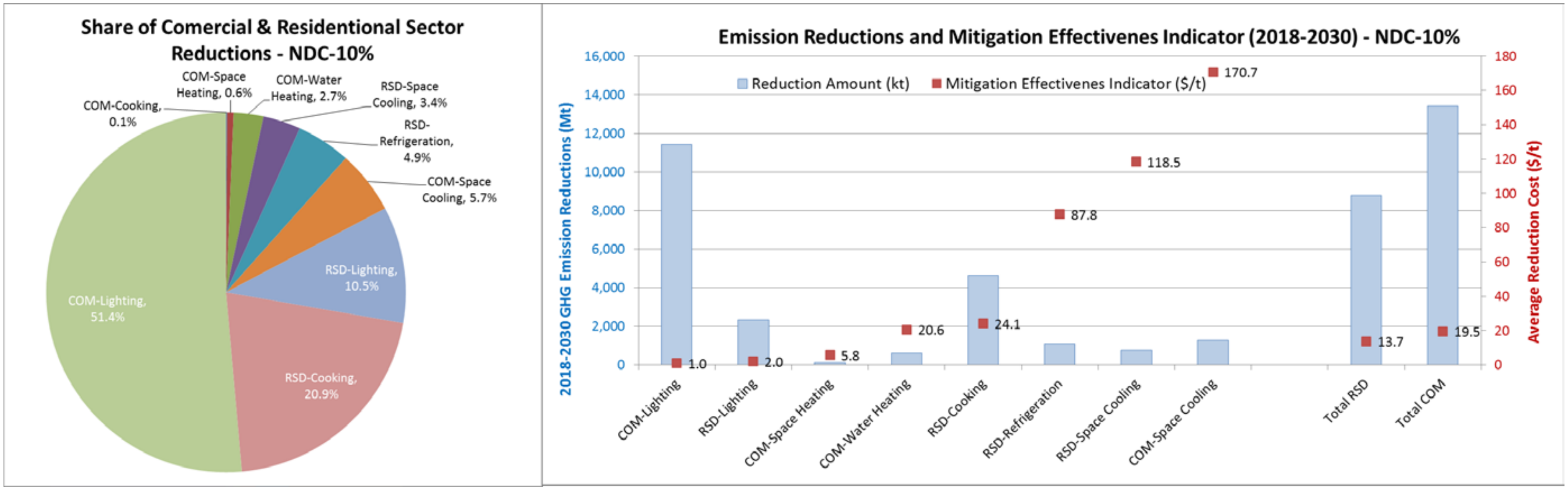


Figure 79: Residential and Commercial Sectors -Investment Mitigation Effectiveness – NDC-10%

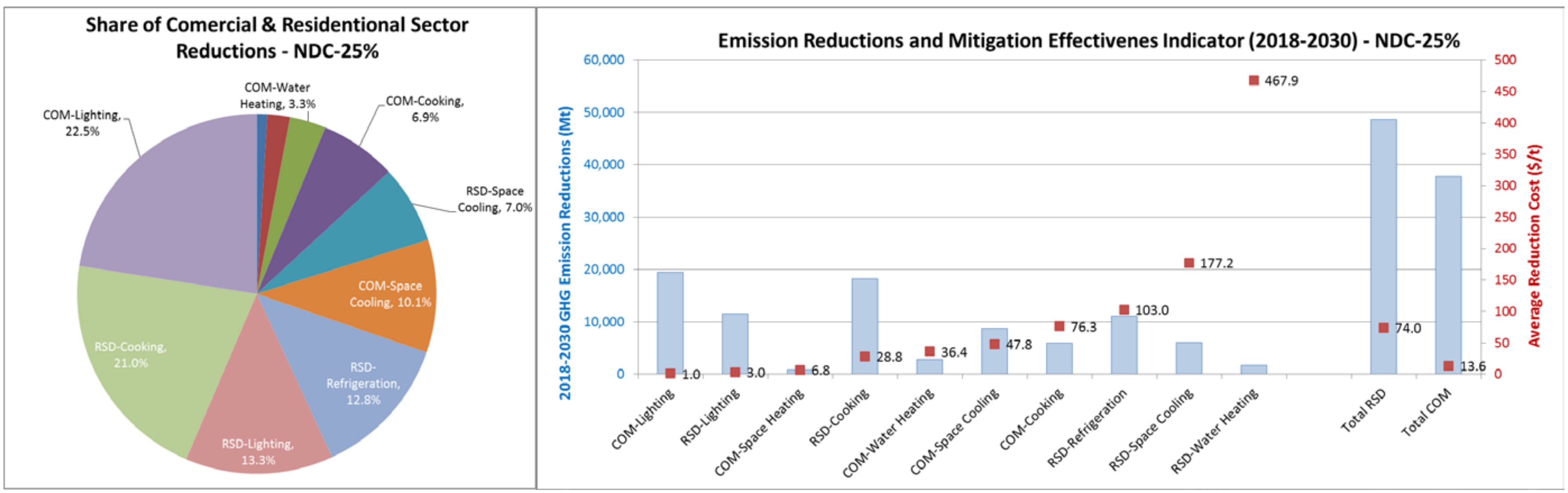


Figure 80: Residential and Commercial Sectors – Investment Mitigation Effectiveness – NDC-25

12 Conclusions and Follow-on Suggestions

12.1 Priority Mitigation Measures

This report highlights the key policies and measures that will need to be adopted by Vietnam to achieve noticeable reduction of the country's GHG emissions in line with that required by the Paris Accord. The analysis employed an advanced multi-region TIMES-Vietnam model to examine two primary NDC Pathways to assess possible Unconditional and Conditional NDC commitments. The bottom-line is that by promoting modest increases in EE and RE within the energy sector, the Unconditional target (ranging from 8% to 15% reduction) can be achieved without major disruption to the energy sector. For more ambitious Conditional targets (ranging from 20% to 30% reduction) much more substantial investment in EE and RE will be required. Most importantly, in spite of the higher upfront costs for such improved devices and RE power plants, their lifecycle costs are extremely attractive, resulting in enhanced energy security (owing to reduced imports) and a more competitive energy-economy for the country going forward. In addition to the critical roles to be played by EE and RE, how to manage dwindling gas supplies is highlighted as an important consideration for the GoV as it sets NDC targets and puts in place the policies necessary to implement the Roadmap.

Renewable energy dominates supply-side mitigation measures to replace coal, particularly in the power sector, and Table 86 lists the recommended priority mitigation measures in the sector needed to achieve NDC-25% target, with the exception of storage, which as noted pertains only to the NDC-30% case.

Variable renewable energy (VRE) in Vietnam, particularly solar and wind, is still in infancy stage. The government's feed-in tariff (FIT) on solar PV and wind has given a boost to renewable energy development in Vietnam. However, the GoV's FIT will expire this year, and given the high FIT levels it is not sustainable when significantly scaling up renewable energy. A recent global trend has seen an increasing number of countries shifting from FITs to competitive auction schemes, which has led to an immediate price decline of 30-50 percent. In particularly, in countries such as China, India, and South Africa, where coal dominates, solar PV auctions have resulted in solar PV reaching grid parity with coal power plants, eliminating the needs for subsidies. Most of the solar PV auction schemes in developing countries achieved 3-6 US cent/kWh. While each country differs with solar resources, cost of financing, cost of land, and other factors, it is evident that auction scheme through competition can dramatically drive down the costs for solar PV to help countries achieve the ambitious RE targets necessary at an affordable price. In addition, mandatory grid access and transmission infrastructure are also important success factors to scale up RE. Therefore, it is recommended that Vietnam shifts from FITs to competitive auction schemes for solar PV and wind, and GoV may also consider increasing the level of ambition of the renewable energy target to 18 percent of primary energy mix and 35 percent of power generation by 2030.

The level of renewables encouraged by this analysis is well within reach for Vietnam, where even higher levels are being managed by numerous European countries and is increasingly likely to become the global norm as countries move away from fossil plants. A further consideration with respect to the variable nature of solar and wind is ensuring stability of supply. Owing to the large installed base of nature gas fired power plants, which can provide the necessary quick response generation should there be short-term disruption in the variable renewables, the Vietnam electric sector will be able to accommodate the level of VRE recommended.

Finally, when looking beyond 2030 to the longer term implications of the need for the countries of the world to increase their mitigation ambition and commitments, it is (strongly) recommended that the GoV revisit the status of 14.3 GW of planned additional coal capacity by 2023 so as to avoid the likelihood of stranding conventional coal-fired power plants, where utilization levels would drop below 10%.

Table 86: Power Sector – Recommended Priority Mitigation Measures

RE Technology	Recommended Mitigation Measures
ALL RE	Adopt a competitive auction scheme to replace the Feed in Tariff as a more effective, lower cost policy for promoting renewable energy growth
Solar	Promote up to 17.5 GW of solar PV (central and distributed)
Wind	Promote up to 8 GW of wind (on-shore and off-shore)
Small hydro	Promote up to 5.9 GW of small hydropower
Bagasse & Municipal solid waste	Small, but cost-effective. Promote up to 1.5 GW of total capacity
Biomass co-firing with coal	Do not promote. Produced marginal reductions and has a relatively high MEI
Natural Gas	Utilize planned natural gas power plants for backup to Variable RE (VRE) plants
Electric Storage	Promote up to 2.4 GW of Pumped Hydropower and Li-ion battery energy storage for load balancing of VRE (when pushed higher to achieve NDC-30% target

Industry energy efficiency (EE) dominates the demand side mitigation measures to curtain consumption, and the most effective approach to improve industrial EE is to combine mandatory regulations with financial incentives. Industrial energy efficiency benchmarks are effective tools to improve industrial EE. As shown in Table 87, the recommended Industrial sector priority mitigation measures include promoting energy efficient industrial process, boilers and motors, which are the most cost-effective means of reducing industrial emissions. The table provides the recommended measures at the subsector level. In addition to EE measures, switching from coal to natural gas and biomass are important mitigation options in the sector.

Table 87: Industry Subsectors – Recommended Priority Mitigation Measures

Subsector	Recommended Mitigation Measures
ALL	Incentives to adopt high efficiency machine drives, boilers and furnaces across all sectors, and specify energy efficiency benchmarks for key Industry subsectors
Cement	Combustion cycle optimization, vertical roller mills, dry kilns with multi-stage pre-heaters and pre-calcination, waste heat recovery from co-generation
Iron & Steel	Pulverized coal injection in blast furnaces, steel scrap preheating for electric arc furnaces, waste heat recovery based power generation, other reductions in thermal energy and electrical energy
Pulp & Printing	Waste paper in the pulping process, high temperature recovery boilers for pulping black liquor combustion, and high efficiency dehydrators for paper-making machines
Chemicals	Establishing energy management systems, strengthening internal management and maintenance
Fertilizer	Establishing energy management systems, and strengthening heat recovery systems.
Building materials	Establishing energy management systems, strengthening internal management and maintenance, improving kiln materials, installing absorption chillers to capture waste heat from heat transfer furnaces and drying systems, and investing in new extrusion lines.
Other industries	Establishing energy management systems, strengthening internal management and maintenance, improving kiln torch systems and installing gas vapor recovery equipment
Textiles & Leather	Establishing energy management systems, and improving processes for fiber production, knitting and dyeing

Table 88 identifies the recommended priority mitigation measures for the Residential and Commercial sectors according to specific demand services in each. Improving EE for the Air Conditioning has by far the biggest energy saving gains; thereby tightening energy efficiency standards for air conditioning is a top priority. Given that EE faces many market barriers and failures, international experience, including Vietnamese previous experience, showed that voluntary approach is not effective, unless it is offered with strong financial incentives. Consumers rarely take EE actions on their own, without mandates or incentives. Therefore, it is recommended that the GoV allocates the VNEEP targets to each province and priority industrial energy-intensive enterprises and hold them accountable to achieve the VNEEP targets.

Table 88: Residential & Commercial Sector – Recommended Priority Mitigation Measures

Demand Service	Measure
ALL	Allocate the VNEEP targets to each province and hold them accountable to achieve the VNEEP targets
Lighting	Incentivize High Efficiency Commercial and Residential Lighting
Water Heating	Incentivize Solar water heaters and High performance electric water heater
Space Cooling	Incentivize High performance AC systems for central, window and rooftop systems
Refrigeration	High performance refrigerators
Cooking	Cleaner cooking fuels
Distributed generation	Incentivize 1.9 GWh to 2.2 GWh of rooftop solar PV systems by 2030
Space Heating	Commercial space heating is too small to warrant promotion

12.2 Capacity Building

This undertaking has seen the successful development of an initial sophisticated TIMES-Vietnam model and its application to examine and identify least-cost energy system development pathways for Vietnam, as part of advising MOIT's of the energy sector contribution to the nation's NDC aspirations and targets.

While a critical first step for advising the national NDC deliberations, NDCs are required to be ongoing and more ambitious over time, thus it is essential that TIMES-Vietnam be a "living" model stewarded by local experts able to maintain, update, advance and apply the modeling to the critical questions arising over the coming decades as Vietnam joins other leading countries to effectively address climate change. With this in mind as series of workshops, webinars and exercises have been conducted with the aim of leading to the eventual stewardship and ongoing use of the planning platform by country experts. In order for these efforts to seed success in this regard, it is essential that there is:

- Strong commitment by the appropriate Ministries and other government agencies responsible for the actually implementation of the policy recommendations arising from the undertaking;
- Engagement of the key stakeholders in the energy sector to foster buy-in of the approach and the results;
- Access to the best available data to underpin the analytical framework;

- Employment of best TIMES practices, tools and techniques, and
- An appropriately skilled group of technically astute energy sector experts trained in the principles, operation and application of the TIMES-Vietnam model constituting a Planning Team.

For the most part these critical areas have been addressed during the project, though stakeholder engagement was primarily limited to the Workshops, and the Planning Team capacity building has as of yet not risen to where the local skills are strong enough to assure quality stewardship of TIMES-Vietnam on an ongoing basis.

A Planning Team of energy sector experts was organized to oversee and eventually take ownership and responsibility for the ongoing stewardship of the TIMES-Vietnam model. Training for the Planning Team was conducted during four project review missions, and a series of remote learning webinars, aimed at providing the Planning Team with a basic understanding of the concepts and nature of the TIMES-Vietnam model, and familiarized them with what is involved to successfully work with the TIMES-Vietnam model.

A critical step in the training process was seen as an extensive set of exercises prepared to reinforce how to work with the tools and advance the understanding of TIMES-Vietnam. In addition, WebEx sessions were arranged to go over the exercises and allow the Planning Team members to ask questions and receive clarification on the training material, model support tools (VEDA and the Analytics results handling workbook) and TIMES-Vietnam model itself. However, it appears that the underlying issue with respect to the Planning Team gaining the confidence necessary to take on full responsibility for the ongoing stewardship of TIMES-Vietnam is a lack of time devoted to working with it outside of the workshops and webinars. A modeling platform such as TIMES requires devotion and dedication, in particular during the learning phase, to gain a proper in-depth understand of the model basics, nature of the data, and model management tools designed to facilitate working with TIMES-Vietnam. Repeated attempts to encourage the Planning Team to complete exercises and take on tasks independently have not born fruit.

So as this phase of the project winds down there is still the need for advance the skills of the Planning Team. The recommended way for this to be done going forward is discussed in the next section, where the key is a stronger mandate from MOIT, and perhaps other Ministries and institutions, to invest the time and energy necessary to master TIMES-Vietnam. The best way to do this would be very specific requests from MOIT/Ministries to advance and apply the model.

12.3 Advancement of TIMES-Vietnam

Although a comprehensive multi-region TIMES-Vietnam model was assembled, refined and applied for this analysis of Vietnam's least-cost NDC Pathway for the core energy sector (excluding Transport), some areas for improvement remain. The short list of potential improvements includes:

- Additional analysis using the 2050 model to examine the costs and benefits of planned near-term coal and gas-fired power plants.
- Full regionalization of the model by disaggregating the demand sectors by supply regions;

- Development of better information for the Commercial and Residential by means of surveys;
- Characterization of building retrofit / green buildings options;
- Introduction of own-price elasticities for key demand sectors to move towards a part-equilibrium version of TIMES-Vietnam with endogenous elastic energy service demands;
- Harmonization and integration with Balmorel to examine the robustness of the proposed future power sector expansion plan, and
- Incorporation of a fully detailed representation of the Transportation sector.
- Additional tailoring of the Starter-based industry subsector design to Vietnam-specific data by identifying the major processes currently used in each subsectors and the specific process improvements that may be implemented in the future.
- Migration to NewVEDA, and updating of the GAMS/VEDA maintenance.

Regarding the last point, the current analysis was limited by the EFFECT “simulation” of the Transport sector, which constrains the ability of MOIT to properly plan for the possible transformation of the sector with respect to increase use of electric and perhaps CNG vehicles. These issues could have substantive impacts on both the power and refinery sectors. Expanding the TIMES-Vietnam coverage to include the Transportation sector, while retaining the ability to impose the EFFECT/MOT perspective on the model, will enable MOIT to more robustly explore the low-carbon development pathway.

At the same time there are GHG mitigation opportunities from non-energy GHG sources (e.g., agriculture, forestry, industrial processes) that can also be including in TIMES-Vietnam to provide comprehensive coverage to all GHG sources and sinks. Together the resulting platform would be in a position to serve as an integrating framework for the GoV contributing to the preparation of future NDC baselines and mitigation ambitions.

These and other advancements to TIMES-Vietnam should be considered for potential follow-on activities, where the emphasis would be put on the Planning Team carrying out the design, implementation and assessment of each, and other improvements yet to be identified, mentored by DWG. Included in any such follow-on endeavor should be adequate time for additional capacity building, including more remote learning sessions as described in the previous section and to monitor progress at regular frequent intervals.

Appendix A: TIMES-Vietnam Model Description

A.1. Customizing the TIMES-Starter for Vietnam

The TIMES framework is the most 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. Currently 19 countries, the EU and two private sector sponsors are participating to ensure the continual advancement of the methodology. DWG on behalf of ETSAP has recently advanced the process of assembling new TIMES models via the TIMES-Starter platform.

A.2 TIMES-Starter

The TIMES-Starter platform is comprised of an integrated full-sector energy system model that employs best practices and is built upon a peer-reviewed database. The model is assembled in a set of interactive Excel templates readily customized to a base-year energy balance, resource supply and power plant characteristics. It has a comprehensive model management platform that overseas all aspects of working with TIMES including integration of the Excel workbooks, model structure diagramming, various technology views, job submission, along with dynamic pivot tables and an interactive multi-case graphical comparison and metrics workbook to facilitate interpreting model results and their communication to decision-makers.

The components of the Starter platform are shown in Figure 81, and examples of the configuration of the TIMES-Starter model for Vietnam are provided in the next section. The steps involved in transforming the Starter model to TIMES-Vietnam are listed in Table 89, and details regarding the activities associated with each step are described in more detail in the TIMES-Starter Guidelines (see to gain access to the ETSAP TIMES-Starter platform).

To date DWG has successful employed the TIMES-Starter for Turkey (where the PMR there is now supporting additional advance training by DWG for various Ministries), China (where the IEA employed the TIMES-Starter to build a part of the China region of Energy Technology Perspectus model), for the Partnership for Market Reform (PMR) in Costa Rica --- which has major synergies for the design of NDC pathways as sought by Vietnam, and and most recently in Armenia. At the same time, since posting the TIMES-Starter platform on the ETSAP website in December 2018, as of the beginning of April 2019 more than 50 interested energy system modellers have downloaded framework.

Figure 81: TIMES-Starter Platform

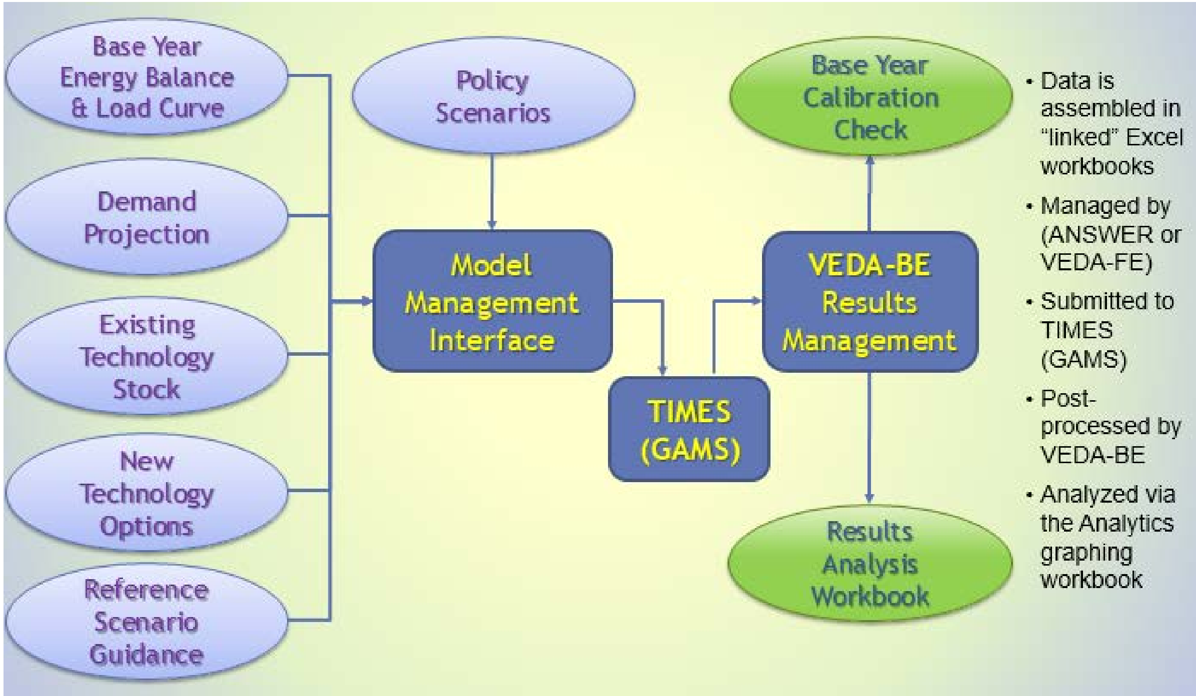


Table 89: Transforming TIMES-Starter for Vietnam

1. Enter the base year energy balance and sector decomposition of fuel usage
2. Reference Energy System (RES) tailored by eliminating commodities not relevant (or add missing ones)
3. Describe power sector configuration and 1st year operation
4. Adjust the timeslices (setup with 4-seasons, 3 time-of-days) and shape the load curve
5. Run and refine the base year calibration
6. Provide prices for primary energy resources not found in the US9r database
7. Pick the future technologies to be allowed, and adjust cost, efficiency and availability where necessary
8. Adjust the demand drivers
9. Introduce all physical limits on resources
10. Introduce all known planned new power plant and infrastructure builds
11. Introduce all current policies
12. Adjust the Reference guidance mechanisms (rates of fuel switching, new technology penetration, and device shares)
13. Run and refine the baseline and planned policy scenarios
14. Do any necessary adjustments to the VEDA-BE Sets & Tables and Analytics workbook for handling results
15. Tailor the standard policy scenarios provided and run

16. Refine model behavior
17. Identify NDC Measures and Policies
18. Conduct NDC analysis
19. Prepare recommendations on the Policies and Measures to shape the NDC Roadmap

A.3 TIMES-Vietnam Model Overview

The basic structure of the TIMES-Vietnam model is illustrated in Figure 82. Primary energy, in the form of domestic and imported fossil fuels, and a variety of domestic renewable energy sources are available to meet the energy demands of the country. These energy resources 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, oil products and natural gas, which are used for electricity generation and 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 final energy carriers are consumed in end-use devices, specific to each demand sector, that are used to satisfy the demands for energy services in that sector. The model contains five demand sectors: Agriculture, Commercial, Industry, Residential and Transportation. Each demand sector is characterized by a specific set of end-use devices that deliver end-use services (such as lighting, cooling, cooking, industrial process heat, motor drive, passenger and freight travel). These existing and potential new end-use devices are characterized by their existing capacity or investment cost, operating costs, efficiency and other performance parameters. For most new devices there are Standard, Improved and Advanced options. The demands for energy services are determined by projecting the base year energy demands, 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.

TIMES-Vietnam solves for the least-cost energy system configuration that will meet the demand projections, adhering to in-country limits on resources and any additional policy or technical constraints imposed on the model. The total discounted system cost (the TIMES objective function) encompasses all costs arising from the production and consumption of energy including fuel expenditures, investments in power plants, infrastructure, purchases of demand devices, fixed/variable operating and maintenance costs associated with all technologies, and sector delivery charges. In addition, it may include policies such, as GHG targets and taxes, and other more specific measures.

Figure 82: TIMES Basic Components

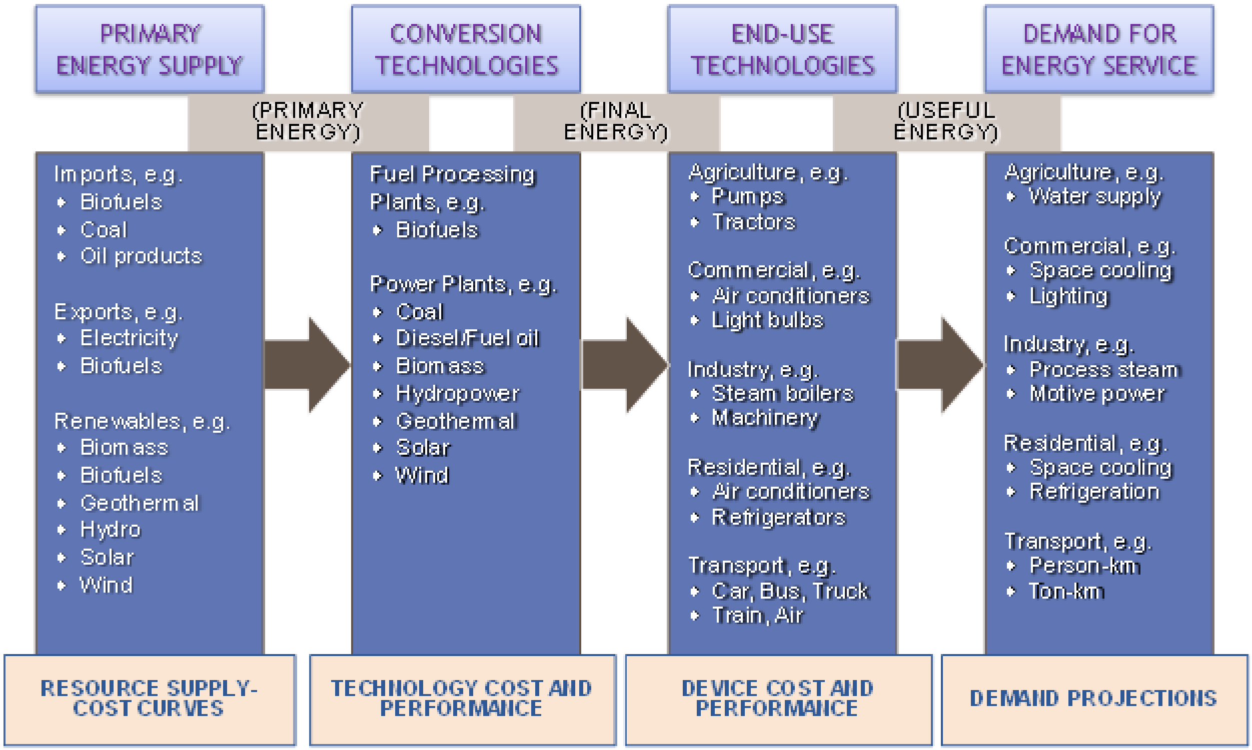
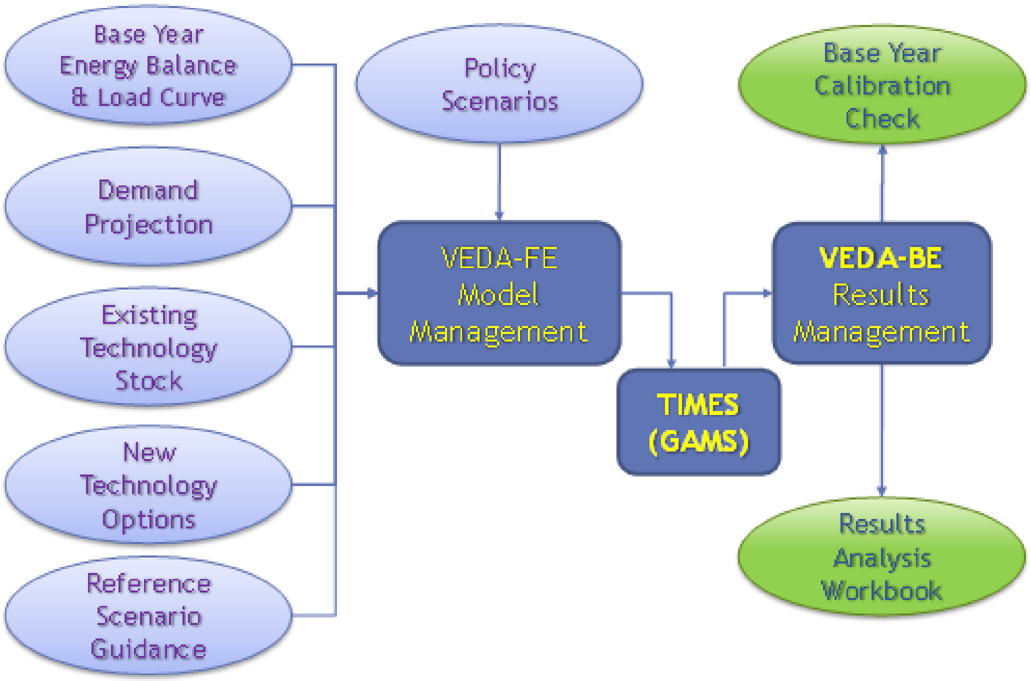


Figure 83 shows how the TIMES-Vietnam model is organized in various sector-based Excel workbooks containing the model input data. The core templates include the 2014 base year energy balance, the demand projections for each sector, and three files that describe each sector:

- Existing technologies and establishment of the base year calibration of each sector (BY templates);
- New technology options for the refining and power sector as well as for each end-use application, sub-sector, or mode (NT templates), and
- Constraints on the amount of fuel switching, device type change, and technology improvement allowed over the planning horizon (UC templates).

The VEDA-FE (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 programming language) and solved employing linear or mixed-integer programming. The TIMES-Vietnam model 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 and analyze model results by means of dynamic pivot tables. Finally, the Base Year Calibration Check workbook helps with ensuring that the 1st year of the model replicates the initial Energy Balance, and the DWG Results Analysis graphing workbook (AXLS) provides dynamic comparisons of scenarios in graphs and tables ready for use in presentations and reports.

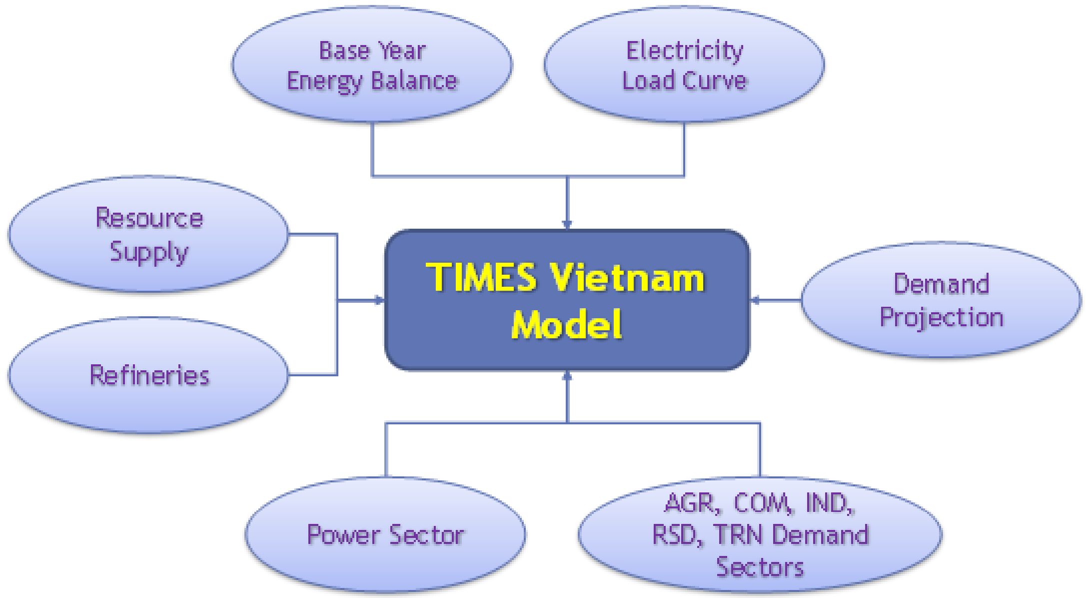
Figure 83: TIMES-Vietnam Modeling Platform Overall Structure



A.4 TIMES-Vietnam Description

This section provides an overview of the underlying structure of the TIMES-Vietnam model, including its Reference Energy System (RES), which is the graphic depiction of all the inter-dependent commodities and processes in the Vietnam energy system. The summaries that follow are designed to show how each sector of the model is structured and provide context for the discussion of the Baseline scenario and the design of the mitigation measures in the next chapters. The core data components of the TIMES-Vietnam model are depicted in Figure 84.

Figure 84: TIMES-Vietnam Core Components



A.5.1 Resolution in Time

The TIMES-Vietnam model is currently designed with a 2014 base year, and a several optional sets of model milestone periods. The core set used for the NDC Pathway analysis goes to 2030 in a combination of 2 and 3 year periods to hit the key milestone years of 2020, 2025 and 2030. Alternate milestone horizons proceed from 2014 in 2-year periods while yet another runs out to 2050, though neither is not being employed for the current analysis. The model can easily be run for different milestone period intervals if desired.

TIMES-Vietnam tracks most energy carriers annually, except for electricity, which is modeled 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 90 shows the milestone periods used the NDC Pathway analysis along with the overall time slice divisions of the load duration curve. In addition to shaping the supply-side load duration curve from the annual load curve, a reserve margin is applied that raises the required level of installed capacity by 25% above the peak demand determined from the annual time-slice with highest demand.

Table 90: TIMES-Vietnam Default Milestone Years and Time Slice Resolution

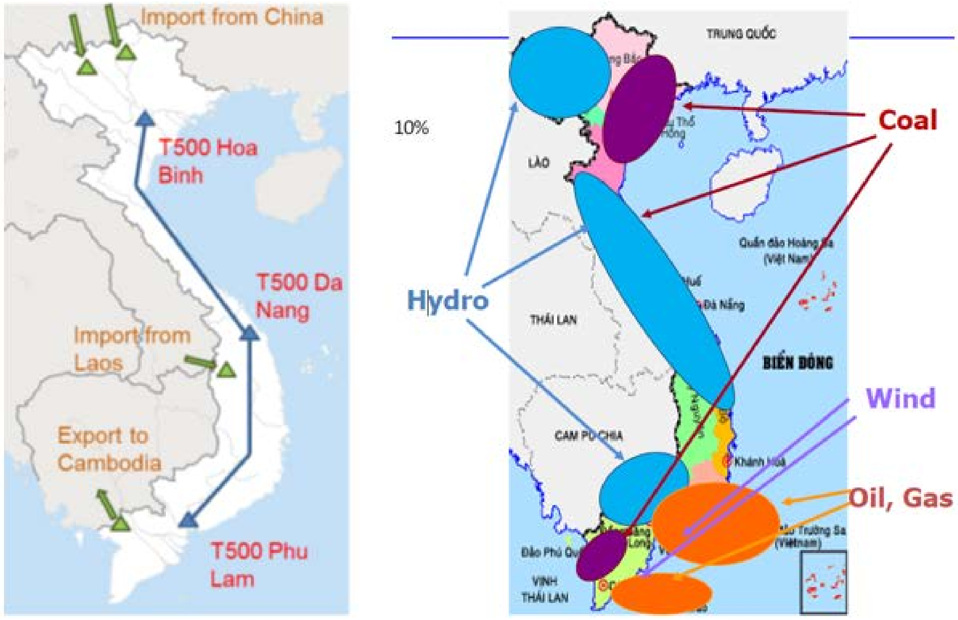
BaseYear											
2014			1	2	3	4	5	6	7	8	9
PeriodLength	Start		2014	2015	2018	2020	2022	2024	2027	2030	2032
1	Mid		2014	2016	2018	2020	2022	2025	2028	2030	2034
3	End		2014	2017	2019	2021	2023	2026	2029	2031	2036
2	Lnth		1	3	2	2	2	3	3	2	5

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			1.000

A.5.2 Regionalization

Owing to the dispersed 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, see Figure 85. The existing capacity of the transmission lines between the regions are reflected in the model, along with the cost for expanding the infrastructure in the future. A fourth region (Vietnam) is used to depict the national demand for the five (5) end-use sectors, as regional data on demand is not complete enough to break them out by region. Note also that all imports/exports other than electricity occur in the overall Vietnam region. Commodities move between the individual supply regions and overall Vietnam as needed.

Figure 85: Regionalization of TIMES-Vietnam



A.5.3 Naming Conventions

The TIMES-Vietnam model relies on the strict use of naming conventions for all commodities and processes that serve to both organize the information, thereby making it easy to recognize each component, as well as facilitate the assembly of the VEDA-BE (and AXLS) reporting tables. Table 91 shows the naming convention for energy commodities. A similar approach is used for emissions and all processes. These naming conventions allow the use of consistent rules for creating customized sets of commodities or processes that do not need to be updated when new processes or commodities are added to the model, as long as they adhere to the Root and Sector components naming principles. Table 91 also shows an example of how the supply of renewable hydropower for electricity would start as SUPRNWHYD and be transformed into PWRRNWHYD for use at the power plant. A similar approach is used for all sectors.

Table 91: TIMES-Vietnam Commodity Naming Conventions

Energy Carrier Root	Description	Energy Carrier Qualifier	Description
BIO	Biomass	ANT	Anthracite
COA	Coal	PSF	Biomass (primary solid fuel)
GAS	Natural Gas	BIT	Bituminous
NUC	Nuclear	BRI	Briquettes
OIL	Oil and Oil Products	CCO	Coke
RNW	Renewables	COI	Crude
Other	Can be added as needed	DSL	Diesel
		FOI	Fuel Oil
Energy Sector	**Description**	GEO	Geothermal
AGR	Agriculture sector	GSL	Gasoline
COM	Commercial sector	HYD	Hydro
IND	Industrial sector	JET	Jet Fuel

<table>
<tr><td>PWR</td><td>Electric Generation</td><td>KER</td><td>Kerosene</td></tr>
<tr><td>RSD</td><td>Residential sector</td><td>LFG</td><td>Landfill Gas</td></tr>
<tr><td>SUP</td><td>Supply & Imports/Exports</td><td>LIG</td><td>Lignite</td></tr>
<tr><td>TRN</td><td>Transportation sector</td><td>LNG</td><td>Liquefied Natural Gas</td></tr>
<tr><td colspan="2" rowspan="10">Supply of renewable hydropower would start as SUPRNWHYD and would be transformed to PWRRNWHYD for consumption at the power plant.</td><td>LPG</td><td>Liquefied Petroleum Gas</td></tr>
<tr><td>MSW</td><td>Municipal Solid Waste</td></tr>
<tr><td>NAT</td><td>Natural Gas</td></tr>
<tr><td>RBG</td><td>Bagasse</td></tr>
<tr><td>RCC</td><td>Coffee husk</td></tr>
<tr><td>SOL</td><td>Solar</td></tr>
<tr><td>WAS</td><td>Waste</td></tr>
<tr><td>WIN</td><td>Wind</td></tr>
<tr><td>URN</td><td>Uranium</td></tr>
<tr><td>Others</td><td>Can be added as needed</td></tr>
</table>

Power plants names clearly identify the nature (electric only or coupled heat & power), fuel consumed, equipment type, and plant type (e.g., combined cycle, large/medium/small hydro, central/distributed PV).

Similarly, naming conventions for demand devices look to identify aspects of the sector, demand service (e.g., heating, cooling, lighting, etc.), nature of the technology or device type (furnace, air conditioner, light bulb, etc.), the fuel consumed, and quality of the device). For example, residential cooling devices would have their names built using the conventions below, resulting in RCBELCRST for a standard room air conditioner. The specific naming conventions for each sector are defined on the Setup tab for each sector base year template.

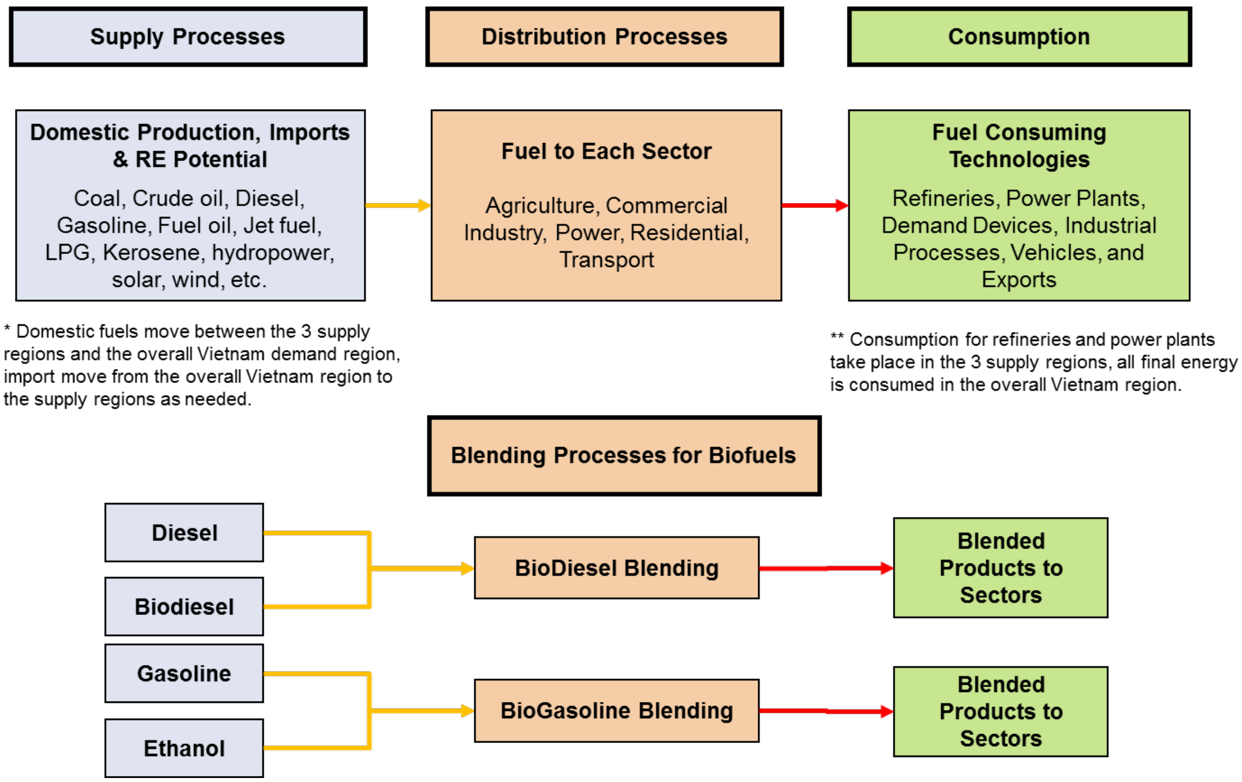
- Sector: R - Residential
- Service: C - Cooling
- Building Type: B - Households
- Fuel: ELC - Electricity
- Device Type C/R/H - Central/Room air conditioner/Heat pump
- Device Quality ST/IM/BE/AD- Standard/Improved/Better/Advanced

A.5.4 Primary Energy Supply

Figure 86 shows a simplified RES diagram for supply of primary energy to the power and demand sectors. All the first year values for the supply processes come from the 2014 Energy Balance. The energy carriers are transferred to each sector through distribution processes that rename the energy carrier for each consuming sector (e.g., SUPOILFOI is change to PWROILFOI for use by the power sector). These processes are also used to track emissions (by fuel type), losses (transmission and distribution) and apply sector fuel price adjustments (e.g., delivery costs, cross-subsidies).

As the diagram shows, domestic and imported oil products go to 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, and hydropower, geothermal, and wind are only available to the Power sector.

Figure 86: RES Diagram for Primary Energy Supply

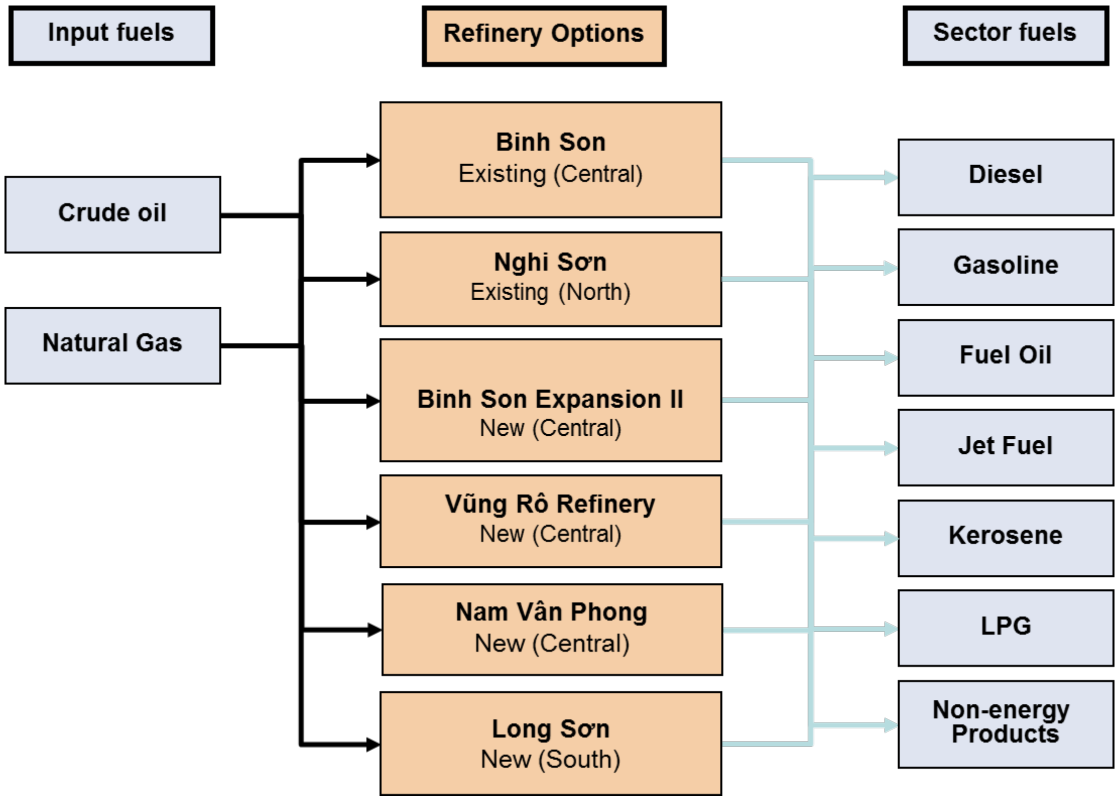


The minimum data needed for each resource supply is an upper annual limit (and optional cumulative) and a price for that amount of supply over time. All energy carriers have a 1st year upper limit, which is set according to the Energy Balance as part of the calibration. In addition, future supply limits have been defined for all sources that are limited based on available resource potential studies for domestic supplies, and importation infrastructure limits when appropriate. The future price for a given amount of supply is based on the latest data for Vietnam, along with IEA projections for world crude oil prices.

A.5.5 Refineries

The existing refineries and a number of planned future refineries being considered are depicted in each of the supply regions. The refineries produce a wide slate of petroleum products that find their way to the Power and demand sectors as appropriate. The basic depiction of refineries in TIMES-Vietnam is shown in Figure 87, indicating that the refineries can use either domestic or imported crude, along with requiring auxiliary natural gas and electricity, to produce seven different products.

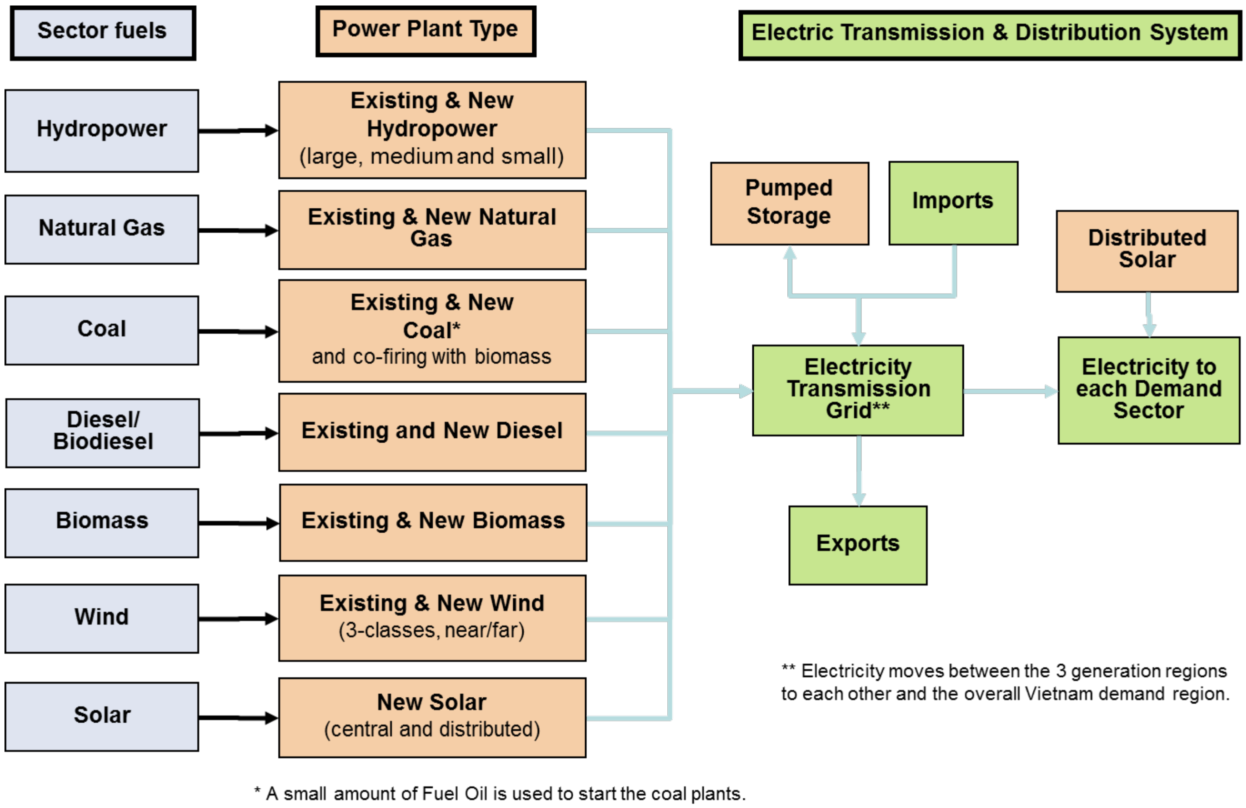
Figure 87: RES Diagram for Existing and Candidate Refineries



A.5.6 Power Sector

Figure 88 shows the RES diagram for the Power sector, depicting the primary energy sources that are consumed by various power plant technology types to produce grid electricity that primarily goes to the demand sectors. Imports and exports to/from neighboring 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 88: 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.

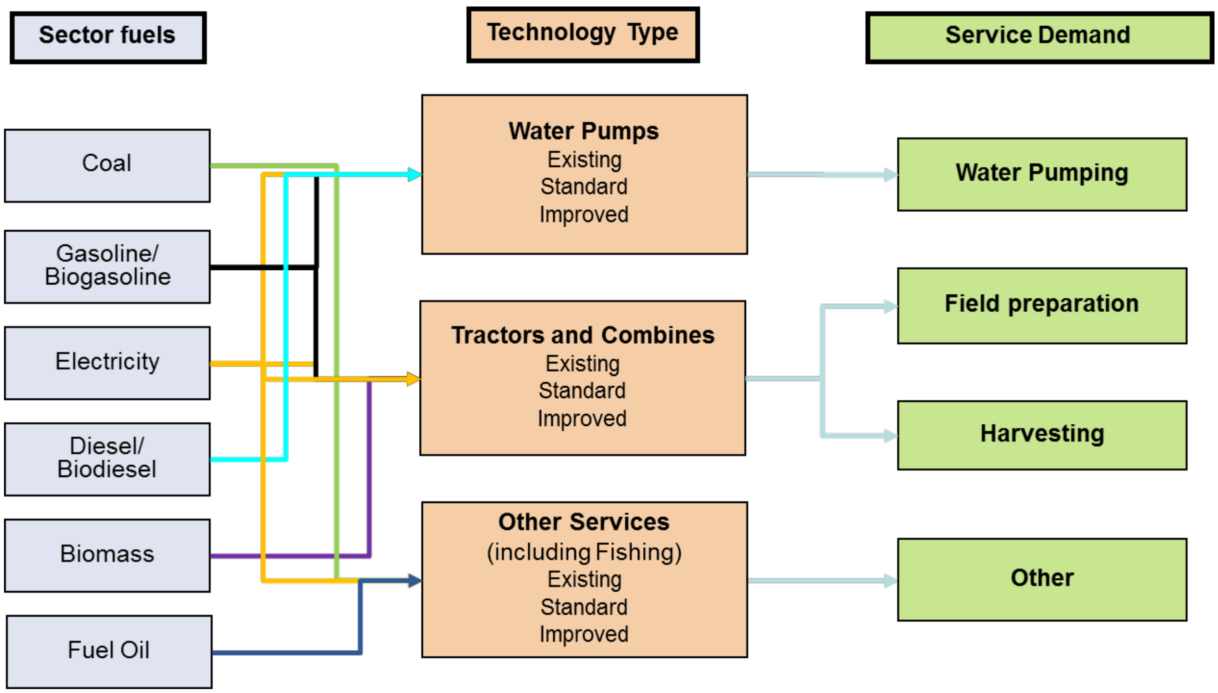
A.5.7 Demand Sectors Summaries

There are five (5) demand sectors depicted in TIMES-Vietnam: Agriculture, Commercial, Industry, Residential and Transportation. Each sector (except for Transport, which is tied to the EFFECT modeling results) is further divided into the main end-use services essential to meet these demands (such as lighting, cooling, cooking, industrial process heat and motor drive). The following sections describe the basic RES structure of each sector, including the fuels, technologies and end-use services depicted in the model.

A.5.7.1 *Agriculture and Fishing*

The Agriculture and Fishing sector accounts for 3.2% of the base year final energy demand, and consists of four (4) end-use services as shown in Figure 89. Diesel, gasoline and electricity are the key energy carriers supplied to the sector, and both biodiesel and biogasoline 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*.

Figure 89: Agriculture & Fishing Sector RES

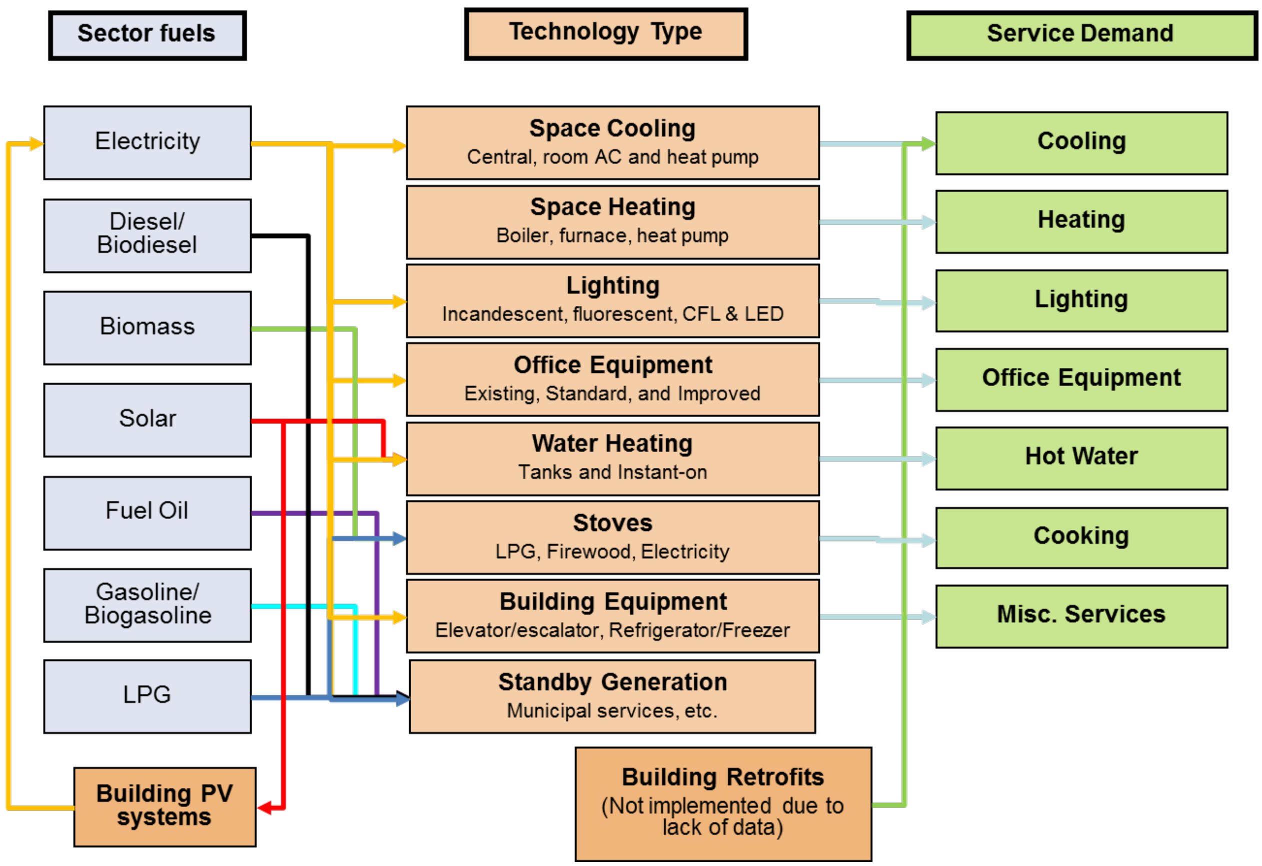


A.5.7.2 *Commercial*

The Commercial sector accounts for 2.8% of the base year final energy demand, and consists of eight (8) services demand as shown in Figure 90. There are 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 done on behalf of USAID *Vietnam Clean Energy Program–Promoting Energy Efficiency in the Building Sector Project - Building Energy Performance Baselines Study*.

For the Commercial sector TIMES-Vietnam contains a large suite of new technology options for each service demand that represent potential options for Standard, Improved, Better and Advanced devices based on USDOE and IEA data. Biodiesel and biogasoline 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). Finally, building efficiency retrofit options can be added that could reduce building energy demands – primarily for cooling, lighting and water heating. However, due to the lack of data these have not been incorporated into the model at this time. In general, the more advanced devices are restricted in the BAU, then loosened for mitigation measures that incentive them.

Figure 90: Commercial Sector RES

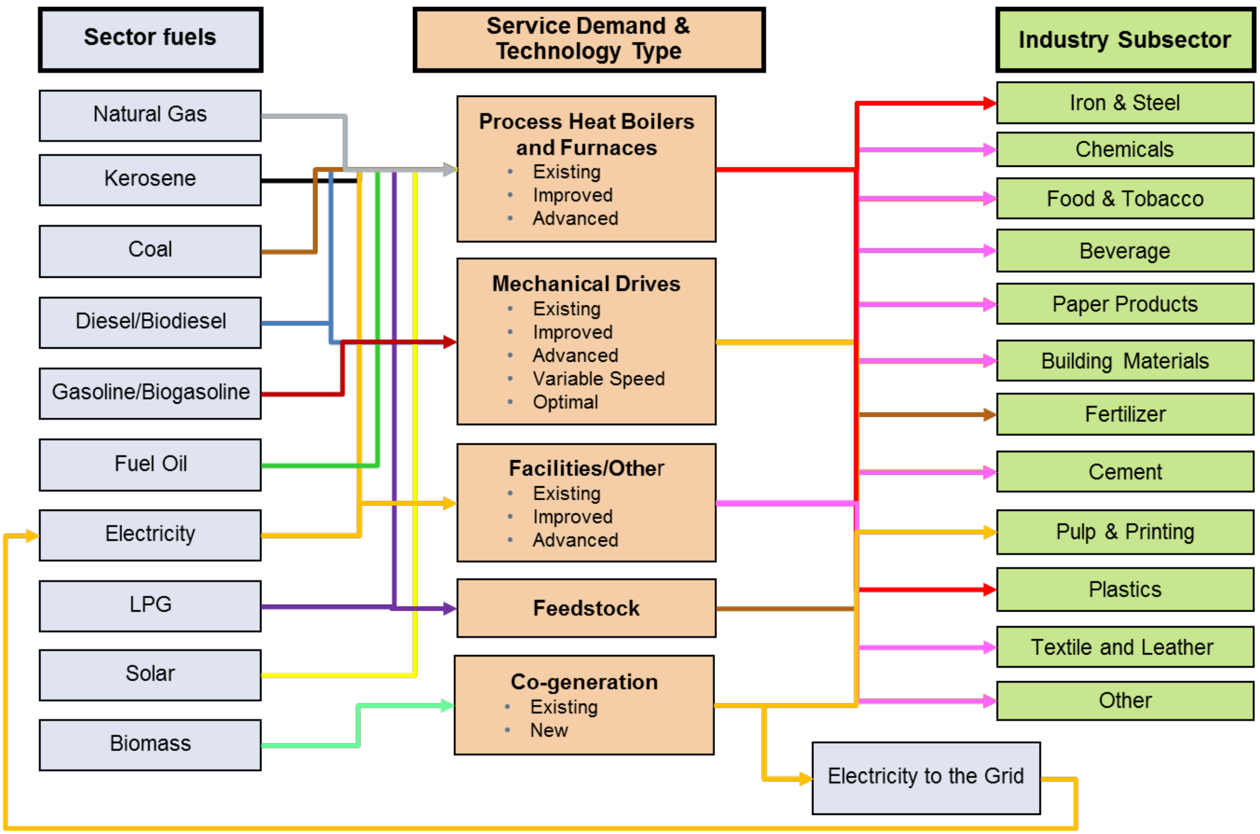


A.5.7.3 *Industry*

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 91. The Industry sector is not able to be modelled at the process level due to the wide variations in many industrial process line details 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 their output products. Data for the initial shares for these subsector energy service demands were developed from several recent reports on industrial energy use conducted by the World Bank in the form of benchmarking studies and energy audits for various Industry subsectors.

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 subsectors, and is a future option in other subsectors. As with the other demand sectors, biodiesel and biogasoline are available through mixing of these fuels with conventional diesel and gasoline in the future. Some of these options may be restricted in the BAU, then loosened for mitigation measures that incentive them.

Figure 91: Industry Sector RES

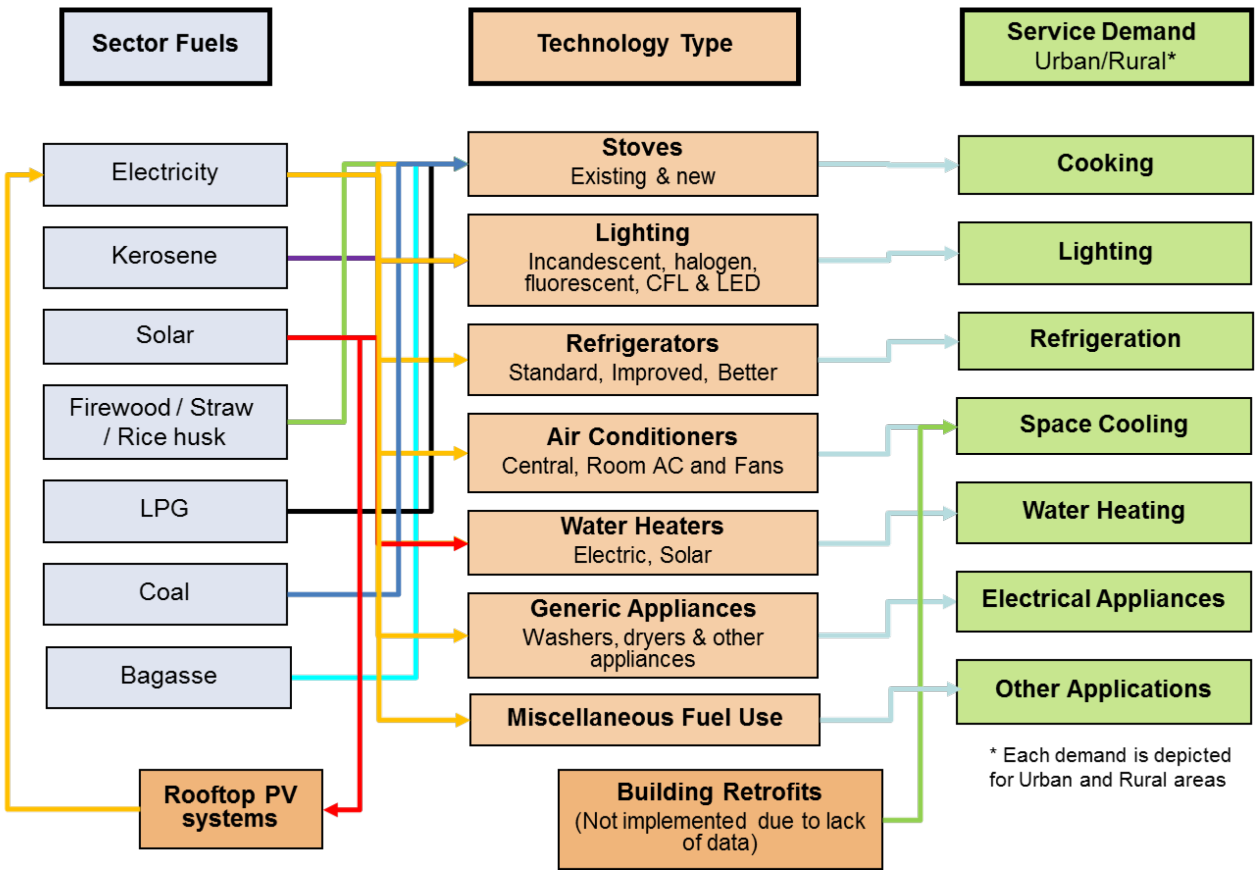


A.5.7.4 *Residential*

The Residential sector accounts for 21% of the base year final energy demand, and consists of seven (7) end-use service demands as shown in Figure 92. Although there are 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 inherit 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 potential options for Standard, Improved, Better and Advanced devices based on USDOE and IEA data. Biodiesel and biogasoline are available through mixing of these fuels with conventional diesel and gasoline. Distributed PV systems provide electricity directly to the sector (for internal consumption) Finally, building efficiency retrofit options can be added that could reduce building energy demands – primarily for cooling, lighting and water heating. However, due to the lack of data, these have not been incorporated into the model at this time. In general the more advance devices are restricted in the BAU, then loosened for mitigation measures that incentive them.

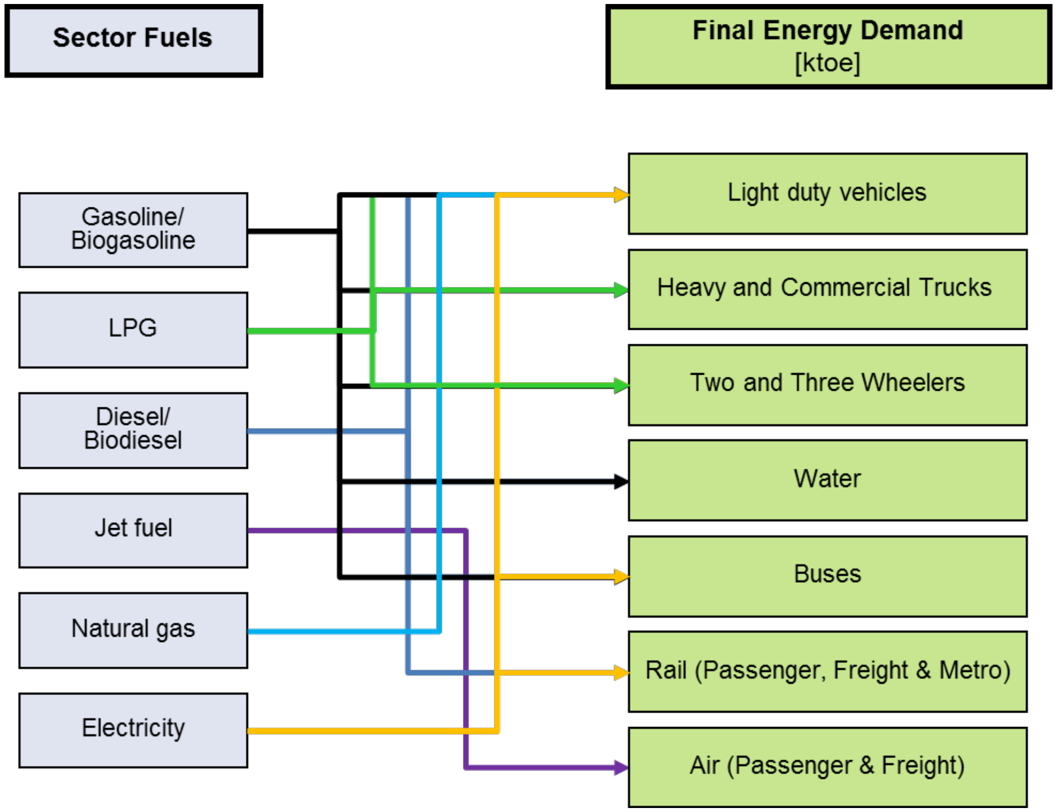
Figure 92: Residential Sector RES



A.5.7.5 *Transport*

The Transport sector accounts for 24% of the base year final energy demand. Although the TIMES-Starter model contains a detailed characterization of the Transport sector for the various transport modes, including road, rail, ship and airplane, as well as covering both passenger and freight transport demands, it was setup to simulate the sector according to the results arising from the EFFECT modeling work undertaken on behalf of MOT, because it is responsible for Transport sector mitigation measures in the NDC-2 process. As agreed at the BAU Review Workshop, the transport sector BAU and mitigation measure results arising from the EFFECT model have been imposed on TIMES-Vietnam by fixing the FEC to the sector over the entire planning horizon. This enables 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.

Figure 93: TIMES-Starter Passenger Transportation Structure



A.6 End-use Service Demand Projections

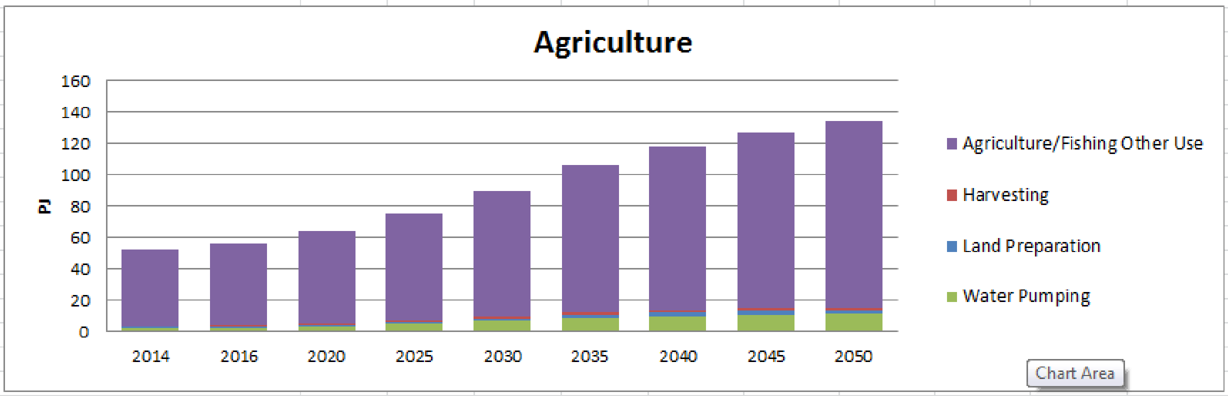
As noted at the beginning of this chapter, the TIMES-Vietnam model solves for the mix of resources and technologies (on both the supply and demand sides) that satisfy the projected demands for useful energy services at the least-cost considering any additional technical and policy constraints imposed on the model. The projected demands for the five (5) demand sectors: Agriculture, Commercial, Industry, Residential and Transportation represent the economic and demographic development of the country over time, and drive the model. The future demand 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 out over the planning horizon. The primary demand drivers, which are shown in Table 92, 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, market penetration rates for space cooling, refrigeration and electric appliances.

Table 92: 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%
GDP/pop growth		5.82%	5.91%	6.08%	6.26%	6.41%	4.34%	3.46%	2.57%
Persons per household growth		-0.50%	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%

The resulting useful energy demands are shown by sector in Figure 94 through Figure 99.

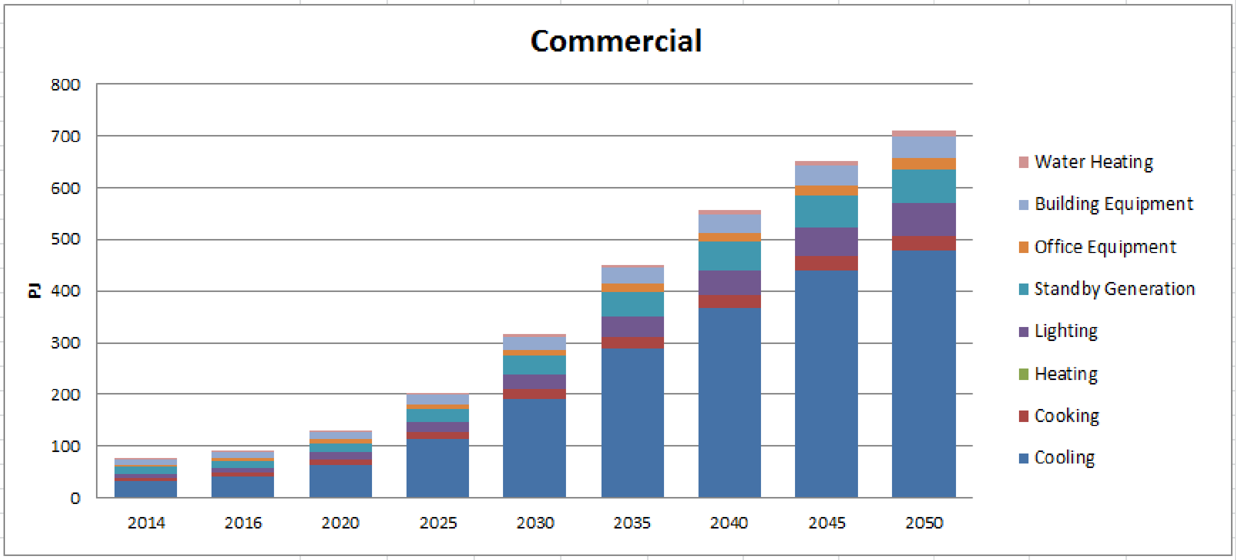
Figure 94: Agricultural Sector Useful Energy Demand



Agriculture Useful Energy Demand

	2014	2016	2020	2025	2030	2035	2040	2045	2050	Growth
Water Pumping	2.19	2.56	3.50	5.00	6.92	8.96	10.18	11.02	11.64	430%
Land Preparation	0.89	0.95	1.08	1.26	1.48	1.73	1.92	2.07	2.19	146%
Harvesting	0.74	0.79	0.90	1.05	1.23	1.44	1.60	1.73	1.83	146%
Agriculture/Fishing Other Use	48.26	51.40	58.30	68.24	79.88	93.51	103.74	112.31	118.63	146%
Total	**52.09**	**55.70**	**63.77**	**75.56**	**89.51**	**105.63**	**117.43**	**127.13**	**134.28**	158%

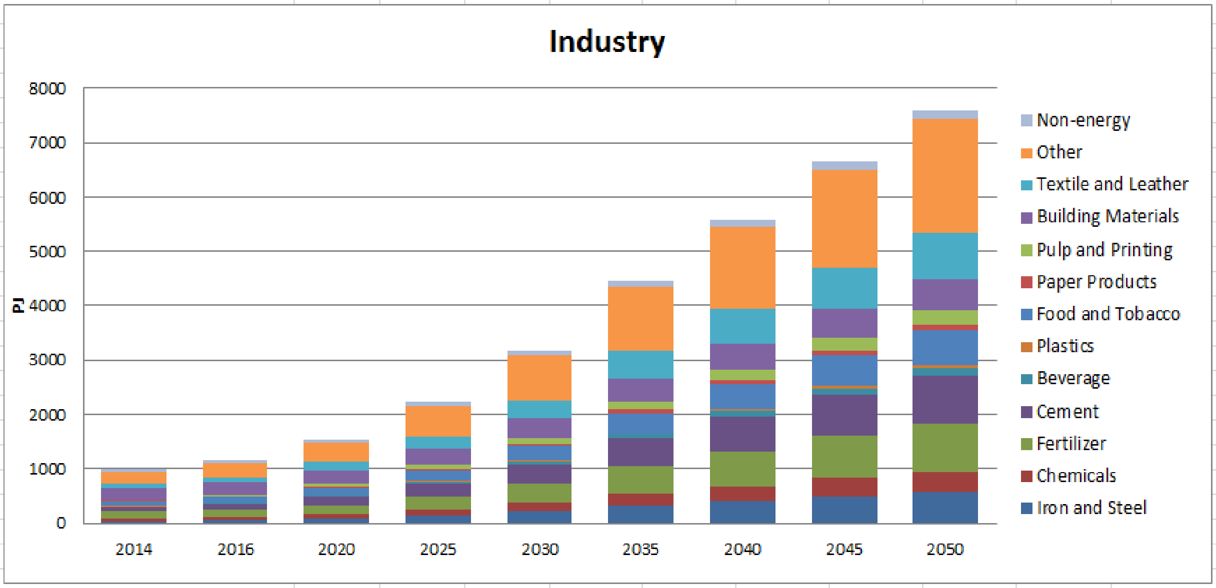
Figure 95: Commercial Sector Useful Energy Demand



Commercial Useful Energy Demand

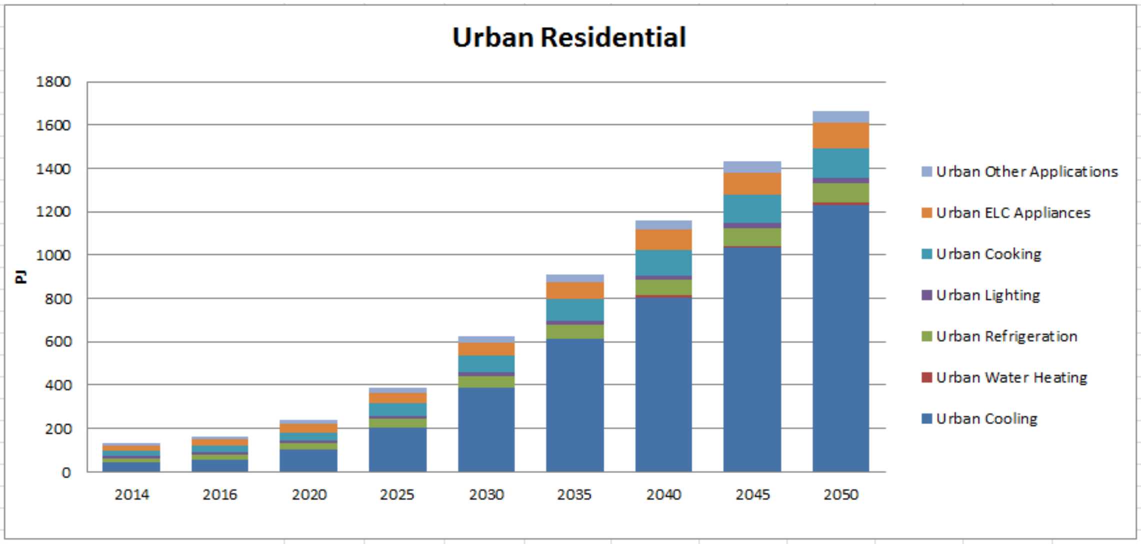
	2014	2016	2020	2025	2030	2035	2040	2045	2050	Growth
Cooling	31.27	39.74	62.96	111.93	192.63	288.66	366.28	438.95	478.27	1430%
Cooking	7.61	8.71	11.12	14.61	18.55	22.79	25.66	27.67	28.85	279%
Heating	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	70%
Lighting	7.92	9.31	12.85	19.23	27.87	39.09	48.30	56.10	62.67	691%
Standby Generation	12.33	14.11	18.50	25.95	35.22	46.25	54.56	61.07	65.46	431%
Office Equipment	4.63	5.30	6.94	9.43	12.79	16.25	18.30	20.10	21.55	366%
Building Equipment	9.11	10.43	13.67	18.56	25.19	32.00	36.02	39.58	42.43	366%
Water Heating	1.66	1.90	2.49	3.50	4.91	6.66	8.04	9.17	9.97	500%
Total	**74.55**	**89.53**	**128.57**	**203.23**	**317.19**	**451.73**	**557.19**	**652.67**	**709.23**	**851%**

Figure 96: Industry Sector Useful Energy Demand



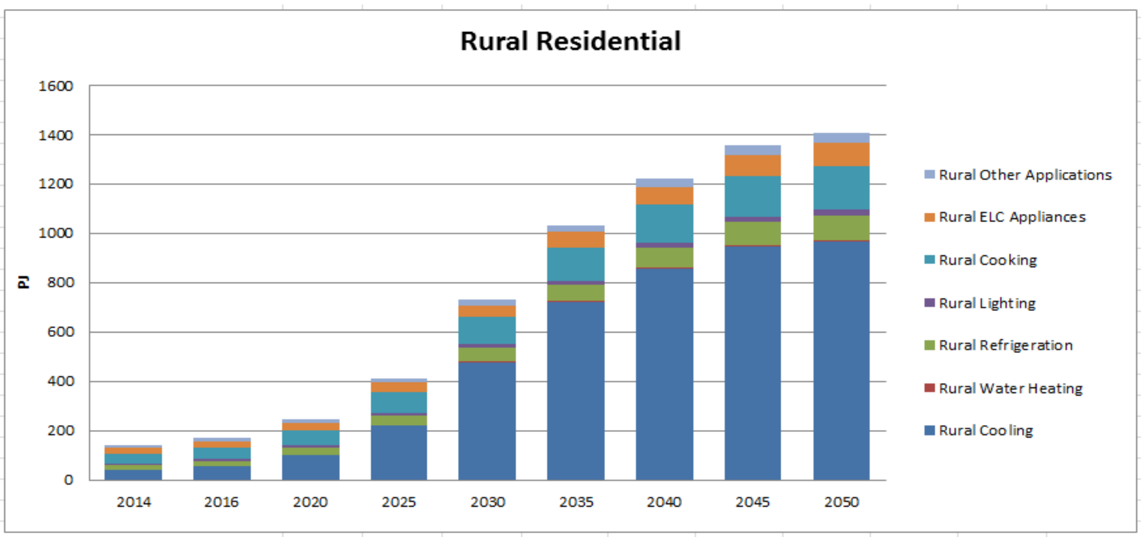
Industry Useful Energy Demand	2014	2016	2020	2025	2030	2035	2040	2045	2050	Growth
Iron and Steel	35.59	45.13	72.54	127.27	216.40	323.89	409.45	493.38	566.41	1491%
Chemicals	52.54	60.15	78.85	110.59	155.11	217.54	275.01	331.38	380.43	624%
Fertilizer	123.00	140.82	184.59	258.89	363.11	509.28	643.81	775.77	890.62	624%
Cement	84.90	103.67	150.68	232.90	348.60	505.13	638.56	769.45	883.36	940%
Beverage	11.82	14.43	20.97	32.41	48.52	70.30	88.87	107.09	122.94	940%
Plastics	6.25	7.16	9.38	13.15	18.45	25.88	32.71	39.42	45.25	624%
Food and Tobacco	88.91	101.79	133.42	187.14	262.47	368.12	465.36	560.75	643.77	624%
Paper Products	15.33	17.55	23.00	32.26	45.25	63.46	80.22	96.67	110.98	624%
Pulp and Printing	25.52	31.16	45.29	70.01	104.78	151.84	191.94	231.29	265.53	940%
Building Materials	208.25	223.08	255.99	304.04	361.10	428.88	482.87	530.51	568.70	173%
Textile and Leather	83.26	101.67	147.77	228.41	341.87	495.38	626.23	754.60	866.31	940%
Other	199.81	243.97	354.61	548.12	820.39	1188.78	1502.79	1810.83	2078.91	940%
Non-energy	51.24	54.57	63.84	77.67	94.50	112.23	132.33	154.91	179.58	250%
Total	**986.41**	**1145.14**	**1540.94**	**2222.87**	**3180.54**	**4460.71**	**5570.16**	**6656.03**	**7602.79**	671%

Figure 97: Urban Residential Useful Energy Demand



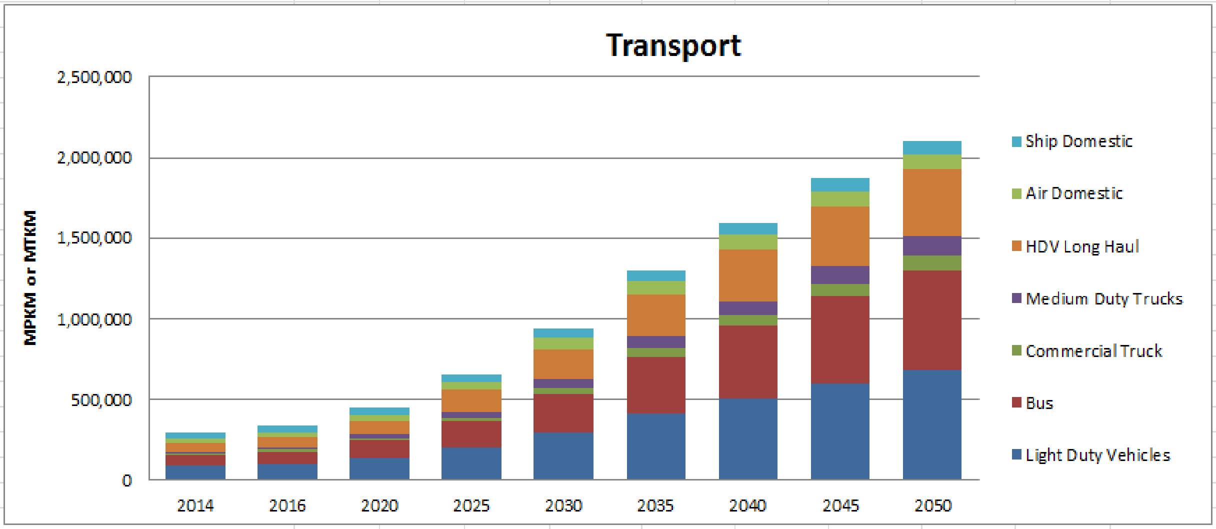
Residential Useful Energy Demand	2014	2016	2020	2025	2030	2035	2040	2045	2050	Growth
Urban Cooling	41.52	56.44	101.69	203.84	385.78	610.87	806.01	1035.08	1233.87	2872%
Urban Water Heating	1.01	1.20	1.71	2.60	3.92	5.49	6.72	8.00	9.28	823%
Urban Refrigeration	20.92	24.01	30.52	39.50	50.88	62.53	71.88	80.43	87.12	316%
Urban Lighting	8.39	9.29	11.13	13.49	16.30	19.61	22.32	24.72	26.64	218%
Urban Cooking	23.69	27.72	37.98	54.82	76.88	101.49	117.96	128.44	134.95	470%
Urban ELC Appliances	25.19	29.29	37.60	49.09	61.86	77.56	91.79	105.57	118.00	368%
Urban Other Applications	12.79	14.54	17.83	22.60	28.48	35.71	42.26	48.60	54.33	325%
Total	**133.50**	**162.49**	**238.45**	**385.94**	**624.10**	**913.25**	**1158.93**	**1430.84**	**1664.19**	1147%

Figure 98: Rural Residential Useful Energy Demand



Residential Useful Energy Demand	2014	2016	2020	2025	2030	2035	2040	2045	2050	Growth
Rural Cooling	38.44	52.90	99.26	218.82	477.94	718.58	857.41	947.41	965.80	2412%
Rural Water Heating	1.71	1.92	2.40	3.19	4.24	5.17	5.48	5.58	5.45	218%
Rural Refrigeration	19.64	22.51	29.28	39.95	53.60	67.10	79.29	91.07	101.66	418%
Rural Lighting	6.78	7.51	8.99	10.90	13.17	15.85	18.03	19.97	21.53	218%
Rural Cooking	40.82	46.74	61.27	83.49	110.36	137.00	155.90	169.75	178.36	337%
Rural ELC Appliances	21.79	24.77	30.38	38.51	48.53	60.85	72.01	82.82	92.57	325%
Rural Other Applications	10.18	11.57	14.19	17.99	22.67	28.42	33.64	38.69	43.24	325%
Total	**139.36**	**167.92**	**245.76**	**412.86**	**730.51**	**1032.97**	**1221.75**	**1355.29**	**1408.60**	911%

Figure 99: Transport Sector Useful Energy Demand



Transport Useful Energy Demand	2014	2016	2020	2025	2030	2035	2040	2045	2050	Growth
Light Duty Vehicles	89,070	103,067	138,585	202,728	291,280	409,603	506,660	600,592	681,967	666%
Bus	62,891	74,858	106,057	163,931	245,362	355,538	449,453	541,581	621,757	889%
Commercial Truck	9,051	10,773	15,263	23,593	35,312	51,168	64,684	77,943	89,482	889%
Medium Duty Trucks	14,931	17,528	24,158	36,075	52,152	72,975	88,998	103,421	114,463	667%
HDV Long Haul	54,252	63,690	87,778	131,078	189,496	265,158	323,376	375,785	415,907	667%
Air Domestic	22,493	25,753	33,757	47,345	66,404	78,868	86,735	93,529	98,885	340%
Ship Domestic	39,331	41,524	46,284	53,007	60,708	69,527	75,455	79,894	82,524	110%
Total	**543,252**	**610,212**	**776,302**	**1,065,274**	**1,454,231**	**1,949,365**	**2,341,847**	**2,705,184**	**2,999,767**	**452%**

A.7 TIMES-Vietnam Database

A.7.1 Overview of Model Structure

The TIMES-Vietnam model database consists of a set of Excel workbooks that comprise the input files that are read into the VEDA-FE model management software. The components of the database are organized into the following categories of Excel workbooks:

- EB – Energy Balance for the 1st year of the model and current load curve;
- SUP – Resource supply, refineries and imports;
- BY – Base year existing technologies and calibration procedure;
- NT – New technology options;
- DEM – Demand drivers and projections;
- UC – Fuel switching and technology improvement user controls, and
- Trade – Trade between the regions.

There are BY, NT and UC workbooks for each sector as defined below:

- Electric generation technologies [PWR];
- Agriculture demand devices [AGR];
- Commercial demand devices and conservation measures [COM];
- Industrial subsector service demands and demand devices, [IND];

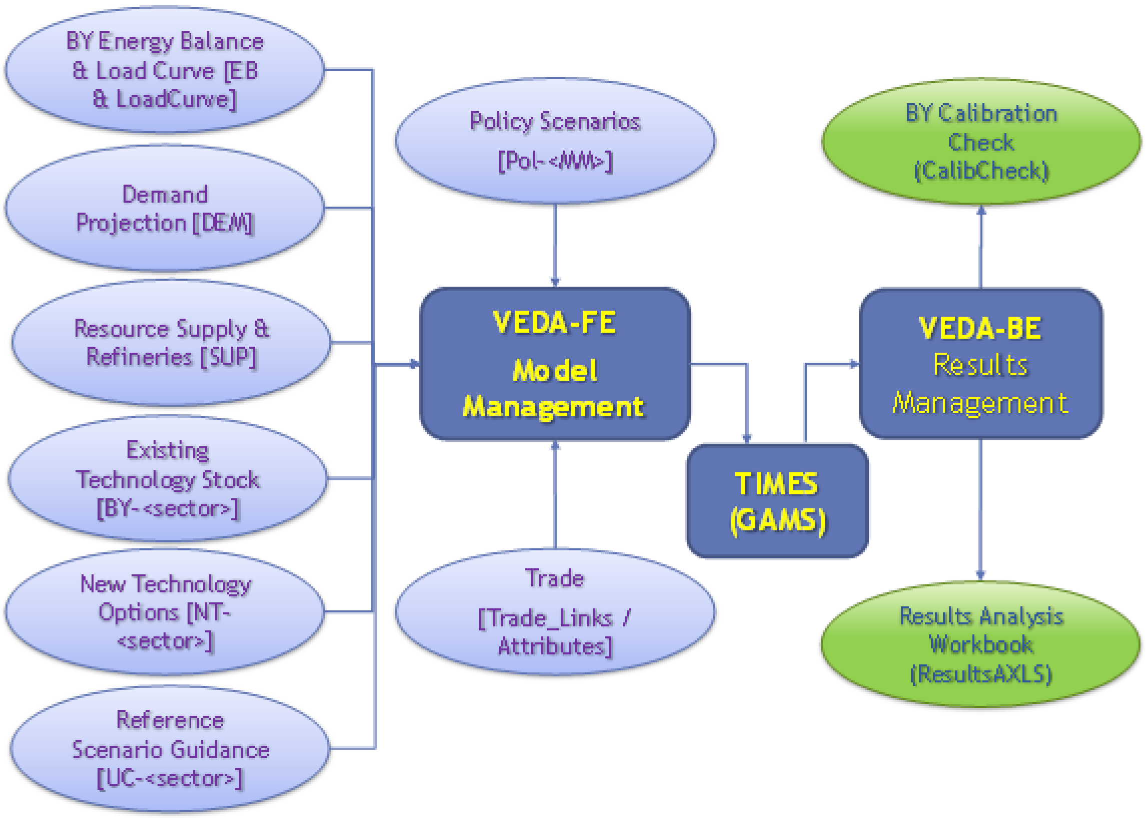
- Residential demand devices and conservation measures [RSD], and
- Transportation vehicles by mode [TRN].

Figure 100 is an elaboration of Figure 7, in that it includes the key naming elements of templates represented by each of the model data categories. In addition, there are four (4) supporting workbooks to assist with:

- Ensuring that all the inter-dependencies between the linked workbooks are properly established (DependencyCheck);
- Analysis of the electricity load duration curve (LoadCalibration_Vietnam) to determine the model time slices and service demand load fractions;
- Checking how the base year model results compare to the original energy balance (CalibCheck), and
- Analyzing and comparing run results using the Results Analytics graph comparison workbook (ResultsAXLS).

The figures depicting model results throughout this report come directly from the ResultsAXLS, which enables up to four (4) alternate scenarios to be examined side-by-side. In addition it provides scenario difference graphs, produces period cumulative summaries and comparison information, and calculates metrics summarizing key model results over the planning horizon (e.g., total cost, new power plant builds, energy production/consumption, and emissions). Additional sheets have been prepared which provide the information for the various mitigation measure tables populating Sections 7, 8 and 11, as well as the NDC Pathway summary tables appearing in Appendix E.

Figure 100: TIMES-CR Model Structure Overview



A.7.2 TIMES-Vietnam Template Summaries

Table 93 lists the core model templates encompassing the TIMES-Vietnam Baseline scenario. The model BY templates reside in the VEDA_Model\TIMES-Vietnam(v#.#) folder. The NT templates reside in the SubRES sub-folder under it, and the UC and policy scenario templates reside in the SuppXLS subfolder. The Trade Links and Trade Attributes templates reside in the Trades subfolder under SuppXLS, and the ResultsXLS subfolder contains the CalibCheck and ResultsAXLS files.

Table 93: TIMES-Vietnam Core Model Input Templates

Input Template / Folder	Description
TIMES-Vietnam(v#.#)	**Base Year (BY)**
EB_Vietnam(2014reg)	Energy balance data file that is a common repository for each of the sector base year templates
LoadCalibration-Vietnam	Workbook that facilitates the calculation of time slices for the year (seasonal and time of day) based on the base year load curve and the derivation of an appropriate load duration curve for the model
VT_Vietnam_AGR	Base year existing technologies and calibration procedure for Agriculture sector end use services

Input Template / Folder	Description
VT_Vietnam_COM	Base year existing technologies and calibration procedure for Commercial sector end use services
VT_Vietnam_DEM	Overall demand drivers and sector-specific drivers for development of the future useful energy demand projections
VT_Vietnam_IND	Base year existing technologies and calibration procedure for each Industrial sub-sector and its end use services
VT_Vietnam_PWR	Base year existing power plants and calibration procedure for Power plant availability factors [with EB/SETUP/Calibration sheets for each supply region]
VT_Vietnam_RSD	Base year existing technologies and calibration procedure for Residential sector end use services [with Urban/Rural breakout]
VT_Vietnam_SUP	Cost and available supply of all domestic and imported energy sources along with refineries [with EB/SETUP/Calibration sheets for each supply region]
VT_Vietnam_TRN_EFF	Base year existing technologies and calibration procedure for each Transportation mode and for passenger and freight end use demands
\SubRES_TMPL	**New Technology Options**
SubRES_NT-AGR	Cost, efficiency, start date and operating characteristics for new technology options for Agriculture sector end use services
SubRES _NT-COM	Cost, efficiency, start date and operating characteristics for new technology options for Commercial sector end use services
SubRES _NT-IND	Cost, efficiency, start date and operating characteristics for new technology options for Industry sub-sector end use services
SubRES _NT-PWR / Trans	Cost, efficiency, start date, availability and bounds for new power plant options [Note that only PWR requires ad active SubRES_NT-PWR_Trans template assigns the future power plants to appropriate regions and sets limits when appropriate.]
SubRES _NT-RSD	Cost, efficiency, start date and operating characteristics for new technology options for Residential sector end use services
SubRES _NT-TRN	Cost, efficiency, start date and operating characteristics for new technology options for Passenger and Freight Transport modes
SuppXLS	**Scenarios and User Constraints (UCs)**
Scen_UC-AGR/xx	User constraints to limit the allowable rate of fuel switching and technology improvement in the Agriculture sector to 5 to 30% by 2030
Scen _UC-COM/xx	User constraints to limit the allowable rate of fuel switching

Input Template / Folder	Description
	and technology improvement in the Commercial sector to 5 to 30% by 2030
Scen _UC-IND/xx	User constraints to limit the allowable rate of fuel switching and technology improvement in the Industry sector to 5 to 30% by 2030
Scen _UC-RSD/xx	User constraints to limit the allowable rate of fuel switching and technology improvement in the Residential sector to 5 to 30% by 2030
Scen_EFFECT-BAU / M1/M2/M3	The EFFECT model results provide for the BAU and 3 mitigation scenarios
Scen _ForceOpLo	Ensures minimum operation of existing power plants
\SuppXLS\Trades	**Inter-regional Trade**
ScenTrade_Trade_Links	Establishes the inter-region trade matrix for each commodity
ScenTrade_Trade_Attributes	Applies data to appropriate trade links, such as current capacity limit, expansion and/or O&M costs
ResultsXLS	**Results Processing**
Vietnam_CalibCheck	Compares the model Base year results to the Energy balance as a check of calibration details.
Vietnam_ResultsAXLS	Compares up to 4 scenarios graphically with trend, difference, horizon summary and metrics tables and graphs
Pol-Check_AXLS	Present a cross-check that MPMs that imposed limits on the energy sector (e.g., GHG cap) indicating where the constraint was met or not

A.7.3 Template Structure

The structure of the core TIMES-Vietnam BY and NT workbooks are summarized in Table 94 and Table 95, which identify the worksheets that are found in each sector-based workbook. The worksheets in italics are the ones loaded into the VEDA-FE and thereby establishing the TIMES-Vietnam model.

Table 94: Structure of BY Model Input Workbooks

Worksheet	Description
EB	Sector based Energy Balance information from the Energy Balance workbook. [BYs only]
SETUP	Selection of the commodities and processes available in the TIMES-Vietnam. Also includes periods and USD price conversion factors through a link to the Energy Balance workbook. The Setup sheet links to the EB tab to identify the commodities used in the sector.
<Source Data>	Copies of any source data used for depicting existing power plants, end-use shares, technology limits, etc.

Worksheet	Description
Calibration	The calculation sheet where the energy balance is apportioned by end-use service and the initial year technology stock established for each sector. [BYs only]
Commodities	Defines all energy carriers, demand services, emissions and materials by their name, description, units and set memberships. These entries are controlled by the SETUP sheet, in most cases. [BYs only. Note: commodities needed for future processes must be specified in the BY]
CommData	Specifies base year demand levels, time-slice demand fractions for end-use services supplied by electricity, and data for mapping sector emissions to overall GHG emissions. [BYs only]
Processes	Defines all process technologies by their name, description, units and set memberships. These entries are controlled by the SETUP sheet
ProcData_<sect>	One or more sheets with the data for the existing technologies in the sector.
ProcData_XPRCs	Data for the sector-based fuel distribution processes.
EPA-Tech Data_<qual>	Declaration and data sheets from the EPA-US9r providing the source values for the technology options.
Other Tech data	Declaration and data sheets from the Pak-IEM, Energy Community-EE databases, etc., providing source values for technology options not in the EPA database.

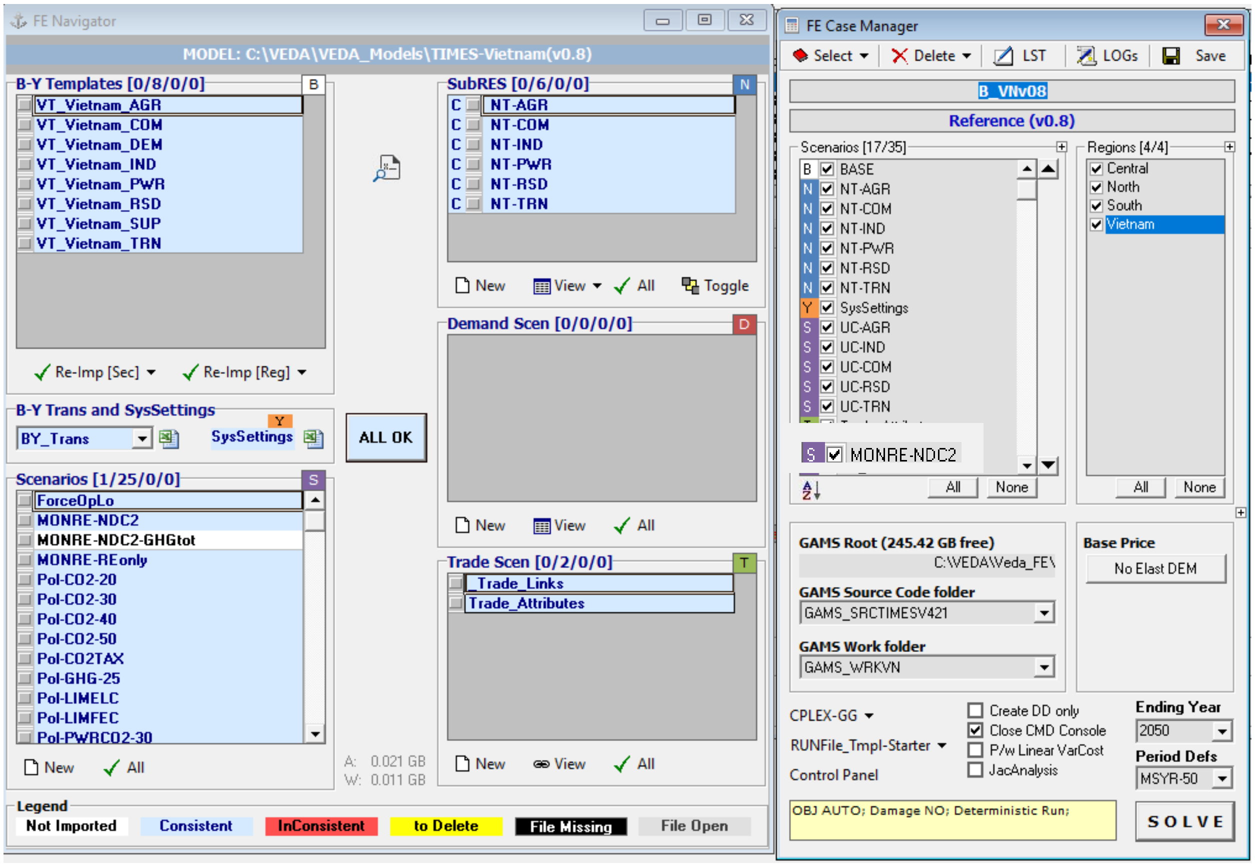
Table 95: Structure of NT Model Input Workbooks

SETUP	All commodities and technology type names and descriptions are linked to the SETUP sheet in the sector BY template, long with milestone periods and USD price conversion factors.
<Sector>	Contains both process declarations and data for the suite of new technologies available to the sector.
EPA-Tech Data_<qual>	Declaration and data sheets from the EPA-US9r providing the source values for the technology options.
Other Tech data	Declaration and data sheets from the Pak-IEM, Energy Community-EE databases, etc., providing source values for technology options not in the EPA database.

A.7.4 Handling Templates in VEDA-FE

Each of the model input templates identified in the previous section are loaded into corresponding scenarios in VEDA-FE. All the templates in the BY quadrant are loaded into the BASE scenario, while all those in the subfolders are loaded into scenarios based upon their file name. VEDA-FE remembers which template is loaded into each scenario and the last time it was loaded, and in response to refreshing the Navigator form (via [F5]) provides an indication of whether or not a template has been changed since last loaded, in which case the VEDA database needs to be SYNChed for all identified scenarios. The scenarios are then combined to conduct model runs. Figure 101 shows the Navigator and Case Manager setup for the BAU run. Because TIMES will process the model inputs according to the order of the scenarios in the run list, it is important to ensure they are ordered to properly represent the run design.

Figure 101: VEDA-FE Navigator Template Organization and Baseline Scenario Specification



Appendix B: Primary Data Sources and Model Input Datasheets

Note that all values in the tables that follow are interpolated between periods and extrapolated out to the last model year.

The data collection process entails four (4) steps:

1. Identification of existing data sources, focusing initially on the data used for the Power Development Plan #7 Revised (PDP-7r), supplemented by other stakeholder contributions and sources;
2. Gap analysis to determine what's missing or can be improved and propose viable representative assumptions (which often entails expert judgment), and
3. Assessment and preparation of the data for the model, and
4. Entry into the model input data templates.

The sections that follow touch on each of these activities.

B.1 Data Needs

Based upon the need for a complete set of current energy sector data, aspects of the changes embodied already in Vietnam between 2010 – 2014, and the modeling being done for MONRE using EFFECT/LEAP, it is recommended that 2014 be the base year (BY), that is 1st 1-year period of the model.

The following is a summary of the basic data needed to the TIMES-Vietnam model:

- Energy balance for latest year available compatible with the IEA format, ideally broken down to sub-sector/end-use consumption levels, this will become the calibrated base year for the model;
- Energy sector demand drivers, such as GDP and population projections, commercial building expansion rates, industrial sub-sector activity projections, and elasticity data connecting GDP or GDP per capita indicators to likely energy demand;
- Data on all existing and near-term planned new power plants, including fuel type, efficiency, operating costs, availability factor, and local investment cost for new plants;
- Hourly load curve for the base year (that will be turned into a load duration curve), and information on the seasonal and daily factors impacting the electricity load shape (including the timing of electricity use by the different demand services in each sector (e.g., commercial lighting mainly during the day while residential primarily at night);
- Survey data on energy use for all demand sectors indicating which fuels are used for each energy service (e.g., percent of total electricity consumed in the residential sector for lighting, a/c, cooking, water heating, refrigeration, etc), or the current device stock;
- Determination of what level of process detail exists for the key industry sectors [WB reports to be reviewed];
- Desired details for the transport sector: vehicle stocks by type and class, e.g. compact, full and sport utility vehicle (SUV) cars, light and heavy trucks, buses and mini-buses. [EFFECT data, other MOT sources];
- Current production rates and production limits on all domestic resources, and accessible reserves out to 2050;
- Current capacities for imported and exported energy carriers;

- Information (product slate and costs) for any refineries operating or planned in the country, and
- Summary of current policies.

The TIMES-Starter will provide default characterization (based upon the US Department of Energy (DOE) technology characterization data as embodied in the US Environmental Protection Agency (EPA) US9rT model) for all technologies, most notable investment and operating costs along with performance information (availability and efficiency), which will need to be reviewed by local counterparts and adjusted to reflect conditions in Vietnam.

B.2 Key Data Sources

Given their knowledge of the Vietnam energy sector, their extensive modeling expertise, their connections with key stakeholder and players in the energy sector VIE is an ideal partner for the assembling, readying and initial application of TIMES-Vietnam. As such they are familiar and have in-hand many of the key data sources that will populate the TIMES-Vietnam model, as reflect in Table 96.

Table 96: Key Resource Documents Reviewed to Date

Resource	Source, Date
Vietnam's INDC	GoV, 2015
Technical Report on Vietnam's INDC	MONRE, 2015
Vietnam Energy Sector Assessment, Strategy and Road Map	ADB, December 2015
Vietnam Renewable Energy Development Project to 2030 with Outlook to 2050	MOIT, Dept. of Renewable Energy (presentation)
Viet Nam's Power Development Plan	MOIT Presentation, April 2017
Vietnam Energy Outlook Report	Danish Energy Agency, 2017
Vietnam Power Generation Guide	Export,gov, 2018
Energy Balance of Viet Nam by 2020	MOIT, 2009
Vietnam Energy Statistics 2015	Institute of Energy, 2017
GHG Emissions, Scenarios, and Mitigation Potentials in the Energy and Transport Sectors of Viet Nam	ADB, 2013
Background Analysis of Marginal Abatement Costs for the Green Growth Strategy	UNDP-MI, 2012
Charting a Low Carbon Development Path for Vietnam. World Bank	WB, 2014
US9rT Model documentation – for the default characterization of all technologies not directly sourced from Vietnam	US Environmental Protection Agency (pending, Fall 2019, contact Carol Lenox for US9rT database)

Note that all values in the tables that follow are interpolated between periods and extrapolated out to the last model year.

B.3. Energy Balance

Regional energy balances are developed based on MOIT's Vietnam Energy Statistics 2015.

Table 97: Regional Energy Balance Base Year 2014 – North (KTOE)

	Coal - Domestic	Coal - Import	Crude oil - Domestic	Crude oil - Import	LPG	Gasoline	Jet fuel	Kerosene	Diesel	Fuel Oil	Other petroleum products	Natural gas	Biomass	Hydro	Solar heat	Wind power	Electricity	Total
Domestic Production	21,142											186	5,391	2,653	0.034	0.0		**29,372**
Import	1,428				794	2,557	1,246	30	5,061	765	1,104						200	**13,184**
Export	-3,351		-9,492		0	-189	-440	0.0	-395	-121	-21.7						-76	**-14,086**
Stock changes	-581																	**-581**
TPES	**18,638**		**-9,492**		**794**	**2,368**	**806**	**30**	**4,666**	**644**	**1,083**	**186**	**5,391**	**2,653**	**0.034**	**0**	**124**	**27,889**
Oil refineries																		**0**
Gas processing (transfer)																		**0**
Main activity electricity plants	-8,362								-0.840					-2,653		0.0	4,807	**-6,209**
Loss & Own use																	-546	**-546**
Net Electricity Production																	5,353	

Table 98: Regional Energy Balance Base Year 2014 – South (KTOE)

	Coal - Domestic	Coal - Import	Crude oil - Domestic	Crude oil - Import	LPG	Gasoline	Jet fuel	Kerosene	Diesel	Fuel Oil	Other petroleum products	Natural gas	Biomass	Hydro	Solar heat	Wind power	Electricity	Total
Domestic Production			17,740									10,504	4,171	874	0.026	7.0		**33,296**

	Coal - Domestic	Coal - Import	Crude oil - Domestic	Crude oil - Import	LPG	Gasoline	Jet fuel	Kerosene	Diesel	Fuel Oil	Other petroleum products	Natural gas	Biomass	Hydro	Solar heat	Wind power	Electricity	Total
Import																		
Export																		
Stock changes																		
TPES			**17,740**									**10,504**	**4,171**	**874**	**0.026**	**7**		**33,296**
Oil refineries																		
Gas processing (transfer)																		
Main activity electricity plants	-841								-55.66	-118		-7,726	-49	-874		-7.0	5,708	**-3,963**
Loss & Own use																	-648	**-648**
Net Electricity Production																	**5,060**	

Table 99: Regional Energy Balance Base Year 2014 – Central (KTOE)

	Coal - Domestic	Coal - Import	Crude oil - Domestic	Crude oil - Import	LPG	Gasoline	Jet fuel	Kerosene	Diesel	Fuel Oil	Other petroleum products	Natural gas	Biomass	Hydro	Solar heat	Wind power	Electricity	Total
Domestic Production													3,182	1,539	0.020			**4,721**
Import																		
Export																		
Stock changes					-2	21	-1.4	-3	10	2.4								**26**
TPES					**-2**	**21**	**-1**	**-3**	**10**	**2**			**3,182**	**1,539**	**0.020**			**4,747**
Oil refineries			-8,248		389	2,318	100		2,950	137	141							**-2,211**
Gas processing (transfer)					184							-194						**-10**
Main activity electricity plants														-1,539			1,772	**233**
Loss & Own use																	-201	**-201**
Net Electricity Production																	**1,570**	

Table 100: Regional Energy Balance Base Year 2014 – National Demand (KTOE)

	Coal - Domestic	Coal - Import	Crude oil - Domestic	Crude oil - Import	LPG	Gasoline	Jet fuel	Kerosene	Diesel	Fuel Oil	Other petroleum products	Natural gas	Biomass	Hydro	Solar heat	Wind power	Electricity	Total
TFEC	**9,435**		**0**	**0**	**4,707**	**904**	**27**	**6,702**	**569**	**1,365**	**1,224**	**2,770**	**12,696**	**0**	**0.08**	**0**	**11,045**	**51,445**
Industry	8,180				0		7.3	1,027	337	224		2,770	3,662				5,950	**22,158**
Iron & Steel	356						0.0	51	12	4.6							427	**850**
Fertilizer	618						0.1	7	2	1.8		2,226					83	**2,938**
Chemical	351						0.5	53	11	1.4		544					294	**1,255**
Cement	934						0.0	0	2	0.0							235	**1,171**
Building Material	3,527						0.5	0	19	24.3			1,026				1,026	**5,624**
Beverage	31						0.0	79	60	3.0			0				110	**282**
Food & Tobacco	576						0.6	200	104	8.9			2,636				528	**4,054**
Textile & Leather	1,349						0.3	72	0	16.6							550	**1,989**
Paper products	222						0.0	23	15	3.1							103	**366**
Pulp & Printing	91						0.4	9	38	2.9							469	**610**
Plastic	0						0.1	2	0	1.1							145	**149**
Non-specific sub-sectors	125						4.8	532	75	156.0							1,978	**2,871**
Agriculture	17				116			316	0.0								163	**611**
Transport	0				4,592	904		5,049	232								476	**11,252**
Commercial	314						3	294	0.0	440							527	**1,578**

	Coal - Domestic	Coal - Import	Crude oil - Domestic	Crude oil - Import	LPG	Gasoline	Jet fuel	Kerosene	Diesel	Fuel Oil	Other petroleum products	Natural gas	Biomass	Hydro	Solar heat	Wind power	Electricity	Total
Household	925						17	15	0.0	702			9,034		0.080		3,930	14,622
Non-energy use							0	0			1,224							1,224

B.4. Resource Energy Supply and Prices

Table 101: Resource Supply - North

Supply Source	Fuel	Cost (USD2015M/PJ)						Supply capability (PJ)				
		2014	2016	2020	2025	2030	2035	2016	2020	2025	2030	2035
Imports												
Electricity - China	Electricity	18.06	18.23	18.57	18.99	19.42	19.85	5.37	8.82	37.80	37.80	37.80
Domestic Supply												
Extraction - Hard Coal	Hard Coal - Domestic	3.47	3.47	3.56	3.71	4.09	3.48	838.25	975.85	1076.87	1144.12	
Extraction Natural Gas	Natural Gas	4.92	4.92	7.53	9.45	10.73	11.01	5.46	10.92	10.92	0	
Rice Husk	Rice Husk	1.72	1.72	1.86	2.37	2.27	2.27		25.30		25.62	
Municipal Waste	Municipal Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.22		15.97	
Landfill Gas	Landfill Gas	0.28	0.28	0.28	0.28	0.28	0.28	0.00	0.02		0.72	
Primary Solid Biofuels	Primary Solid Biofuels	1.79	1.79	1.94	1.61	2.36	2.36		118.08		144.07	
Bagasse	Bagasse	0.14	0.14	0.15	0.14	0.19	0.19		5.64		6.15	
Biogasoline	Biogasoline	29.28	25.41	24.61	26.33	27.45	29.25	0.84	4.52	8.03	15.51	
Straw	Straw	0.51	0.51	0.61	0.55	0.74	0.74		83.33		84.38	
Biodiesels	Biodiesels	27.28	23.88	24.72	26.92	28.54	30.38	1.89	13.75	24.19	46.72	
Biogas	Biogas	0.51	0.51	0.61	0.55	0.74	0.74				4.68	
Other Biomass	Other Biomass	0.36	0.36	0.39	0.32	0.47	0.47		100.64		100.64	

Table 102: Resource Supply - Central

Supply Source	Fuel	Cost (USD2015M/PJ)						Supply capability (PJ)				
		2014	2016	2020	2025	2030	2035	2016	2020	2025	2030	2035
Imports												
Electricity – Laos Central-North	Electricity	18.24	18.41	18.75	19.18	19.61	20.04	0.0	0.0	0.0	16.4	16.4
Electricity – Laos Central-Central	Electricity	18.42	18.59	18.94	19.37	19.81	20.24	1.8	3.8	27.4	27.4	27.4
Electricity – Laos Central-Highland	Electricity	18.60	18.77	19.12	19.56	20.00	20.44	2.7	7.0	13.7	24.6	24.6
Domestic Supply												
Extraction - Natural Gas	Natural Gas			8.57	8.57	9.69	9.73	0.0	0.0	241.8	241.8	241.8
Rice Husk	Rice Husk	1.72	1.72	1.86	2.37	2.27	2.27		19.2		19.4	
Municipal Waste	Municipal Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.0	10.9		8.2	
Landfill Gas	Landfill Gas	0.28	0.28	0.28	0.28	0.28	0.28	0.0	0.0		0.4	
Primary Solid Biofuels	Primary Solid Biofuels	1.79	1.79	1.94	1.61	2.36	2.36		164.3		196.2	
Bagasse	Bagasse	0.14	0.14	0.15	0.14	0.19	0.19		21.7		23.6	
Biogasoline	Biogasoline	37.09	32.18	31.17	33.35	34.77	37.04	0.8	4.5	8.0	15.5	
Straw	Straw	0.51	0.51	0.61	0.55	0.74	0.74		63.2		64.0	
Biodiesels	Biodiesels	34.56	30.25	31.32	34.10	36.16	38.48	1.9	13.7	24.2	46.7	
Biogas	Biogas	0.51	0.51	0.61	0.55	0.74	0.74				4.7	
Other Biomass	Other Biomass	0.36	0.36	0.39	0.32	0.47	0.47		85.2		101.5	

Table 103: Resource Supplies - South

Supply Source	Fuel	Cost (USD2015M/PJ)						Supply capability (PJ)				
		2014	2016	2020	2025	2030	2035	2016	2020	2025	2030	2035
Extraction - Crude Oil	Crude Oil (Domestic)	6.43	6.43	9.18	9.00	10.35	9.81	721.39	651.88	354.20	177.94	83.32
Extraction - Natural Gas	Natural Gas	4.92	4.92	7.53	9.45	10.73	11.01	408.33	543.66	526.11	357.24	201.63
Rice Husk	Rice Husk	1.55	1.55	1.68	2.13	2.04	2.04		55.04		55.74	
Municipal Waste	Municipal Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.15		24.20	
Landfill Gas	Landfill Gas	0.28	0.28	0.28	0.28	0.28	0.28	0.00	0.04		1.09	
Primary Solid Biofuels	Primary Solid Biofuels	1.79	1.79	1.94	1.61	2.36	2.36		84.50		98.15	
Bagasse	Bagasse	0.14	0.14	0.15	0.14	0.19	0.19		24.19		26.36	
Biogasoline	Biogasoline	37.09	32.18	31.17	33.35	34.77	37.04	0.84	4.52	8.03	15.51	
Straw	Straw	0.51	0.51	0.61	0.55	0.74	0.74		181.31		183.60	
Biodiesels	Biodiesels	34.56	30.25	31.32	34.10	36.16	38.48	1.89	13.75	24.19	46.72	
Biogas	Biogas	0.51	0.51	0.61	0.55	0.74	0.74				4.68	
Other Biomass	Other Biomass	0.36	0.36	0.39	0.32	0.47	0.47		62.86		73.87	

Table 104: Other Resource Imports/Exports

Supply Source	Fuel	Cost (USD2015M/PJ)					
		2014	2016	2020	2025	2030	2035
Imports							
Hard Coal	Hard Coal - Import	4.18	4.18	3.61	3.50	3.74	3.78
Crude Oil	Crude Oil (Import)	7.15	7.15	10.20	10.00	11.50	10.90
LPG	LPG	31.81	31.81	33.32	33.91	34.32	32.79
Gasoline	Gasoline	17.61	17.61	23.27	26.48	28.54	30.91
Jet Fuel	Jet Fuel	12.71	12.71	17.71	21.25	23.72	26.26
Kerosene	Kerosene	12.71	12.71	17.71	21.25	23.72	26.26
Diesel	Diesel	16.55	16.55	23.38	27.07	29.68	32.11
Fuel Oil	Fuel Oil	8.71	8.71	11.22	12.20	17.06	18.66
Non-Energy Oil Products	Non-Energy Oil Products	11.91					
Natural Gas	Natural Gas	9.75	9.75	10.48	11.06	11.82	11.82
Exports							
Hard Coal (Domestic)	Hard Coal - Domestic	2.97	3.00	3.25	3.45	3.63	3.79
Crude Oil (Domestic)	Crude Oil (Domestic)	6.79	6.79	9.69	9.50	10.93	10.36
Gasoline	Gasoline	16.73	16.73	22.11	25.16	27.11	29.36
Jet Fuel	Jet Fuel	12.08	12.08	16.83	20.19	22.53	24.95
Diesel	Diesel	15.73	15.73	22.21	25.72	28.20	30.50
Fuel Oil	Fuel Oil	8.27	8.27	10.66	11.59	16.21	17.73
Non-Energy Oil Products	Non-Energy Oil Products	11.32	0.00	0.00	0.00	0.00	0.00
Electricity	Electricity	35.41	35.81	36.22	36.16	37.24	38.37

Sources:

IE, "Revised Power Development Plan in 2011 - 2020 with outlook to 2030," Institute of Energy, Hà Nội, 2015.
Ea Energy Analyses, Institute of Energy, "Long term fuel price projections for Vietnam," Hanoi, 2019.
VIMCC, "Coal Development Plan Revised to 2020, with Outlook to 2030," 2016.
VPI, "Oil and Gas Development Plan up to 2025, with outlook to 2035," VPI, Hà Nội, 2016.
IE, "Revised Power Development Plan in 2011 - 2020 with outlook to 2030," Institute of Energy, Hà Nội, 2015.
Ea Energy Analyses and DHI GRAS, "Macroeconomic Cost-Benefit Analysis for Renewable Energy Integration" 2017.

B.5. Power Sector

Table 105: Existing Plant Characterization

Power Plant Type	Region	Fuel	Installed Capacity [2014]	Remaining Years	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	
Hydro - Hydro (Dam) (Existing - Large)	Central	Hydro	2.84	36	0.9	1.00	14.3	4.77	

Power Plant Type	Region	Fuel	Installed Capacity [2014]	Remaining Years	Peak Contribution	Efficiency	Fixed O&M (M$/GW)	Variable O&M (M$/PJ)	Availability Factor
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	

Table 106: 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	
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	

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**			
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	
Nuclear *[not currently used]*																		
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				
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

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			
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		
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																		

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			
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	

Sources:

IE, "Revised Power Development Plan in 2011 - 2020 with outlook to 2030," Institute of Energy, Hà Nội, 2015.

Ea Energy Analyses, Institute of Energy, "Vietnamese technology catalogue," Hanoi, 2019

B.6. Industry Subsectors

Table 107: Characterization of Industrial sector

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency 2016	Efficiency 2020	Efficiency 2025	Efficiency 2030	Efficiency 2050	Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/ Utilization Factor
*** 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											
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 / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/ Utilization Factor
				2016	2020	2025	2030	2050			
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 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											

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/ Utilization Factor
				2016	2020	2025	2030	2050			
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 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

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/ Utilization Factor
				2016	2020	2025	2030	2050			
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 Biofuels	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
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)

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/ Utilization Factor
				2016	2020	2025	2030	2050			
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
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

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/ Utilization Factor
				2016	2020	2025	2030	2050			
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
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 / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/ Utilization Factor
				2016	2020	2025	2030	2050			
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** 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

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/ Utilization Factor
				2016	2020	2025	2030	2050			
*** 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 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

Process / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/ Utilization Factor
				2016	2020	2025	2030	2050			
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 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 / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/ Utilization Factor
				2016	2020	2025	2030	2050			
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 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 / Technology	Input Fuel	Start Year	Lifetime	Efficiency					Investment (US$2015M)	Fixed O&M (US$2015M)	Availability/ Utilization Factor
				2016	2020	2025	2030	2050			
Process heat - Primary Solid Biofuels - Standard	Primary Solid Biofuels	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
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 Biofuels	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

Table 108: Industry Mitigation Measures by Sub-sector

#	Name company	Subsector	Total energy use (TOE)	Electricity - Cost/saving (M VND/TOE)	Electricity - Saving/Consumption (%)	Thermal - Cost/total saving (M VND/TOE)	Thermal - Saving/Consumption (%)
1	Vietnam Beer Factory Company Limited	Beer	10,512	35.14	6.3%	0.00	0.0%
2	Saigon Beer Factory	Beer	1,905	35.93	11.2%	46.61	11.4%
3	Sai Gon Binh Tay Beer Joint Stock Company	Beer	5,550	13.65	3.4%	23.38	17.3%
4	Coca-cola Beverages Viet nam Co., Ltd	Beverage	1,611	16.00	10.8%	18.87	4.6%

#	Name company	Subsector	Total energy use (TOE)	Electricity - Cost/saving (M VND/TOE)	Electricity - Saving/Consumption (%)	Thermal - Cost/total saving (M VND/TOE)	Thermal - Saving/Consumption (%)
5	Hanoi Crown Limited Company	Beverage	2,215	7.47	3.4%	0.00	0.0%
6	PepsiCo Vietnam Foods Company - Hoc Mon Factory	Beverage	5,506	104.78	1.2%	0.00	0.0%
7	PEPSICO Corporation - Hoc Mon Factory	Beverage	4,837	27.60	12.6%	0.00	0.0%
8	Vietnam COCA COLA Company Limited	Beverage	3,803	19.55	7.0%	16.38	7.6%
9	Tan Hiep Phat Trading Service Company Limited	Beverage	3,030	13.11	10.9%	14.51	14.9%
10	Vietnam Milk Joint Stock Company - Thong Nhat Milk Factory	Beverage	3,205	14.12	1.6%	40.76	9.0%
11	Cau Sen ., JSC	Building material	1,357	10.17	8.0%	0.00	0.0%
12	Tahaka Tuynel Brick Factory	Building material	1,201	15.07	15.2%	0.92	2.4%
13	Thach ban Joint Stock Cooperation	Building material	5,049	17.56	8.9%	10.33	0.3%
14	Mikado Hung Yen ., JSC	Building material	10,235	28.99	1.3%	0.00	0.0%
15	Dong Trieu Viglacera ., JSC	Building material	846	14.25	15.4%	43.57	7.3%
16	TOTO Vietnam Co ,Ltd	Building material	3,500	9.38	0.7%	17.86	2.1%
17	Thien Loc Nguyen Company Limited	Building material	3,141	29.19	11.2%	0.00	0.0%
18	Bao Chau Long An Company Limited	Building material	2,526	24.28	23.0%	5.89	12.4%
19	Vietnam Saint Gobain Company Limited	Building material	1,502	0.00	5.6%	0.00	0.0%
20	Hoàng Long Cement JSC	Cement	6,778	11.19	1.2%	0.00	0.0%
21	Thang Long Cement Joint Stock Company	Cement	5,740	17.74	14.8%	0.00	0.0%
22	Vietnam Holcim Cement Company Limited - Cat Lai Factory	Cement	4,001	40.83	0.3%	2.35	7.7%
23	Ha Long Cement Company Limited	Cement	2,789	13.47	5.5%	0.00	0.0%
24	Vietnam Holcim Cement Company Limited - Hiep Phuoc	Cement	1,464	79.71	0.7%	0.00	0.0%
25	Ha Tien 1 Cement Joint Stock Company - Kien Luong Factory	Cement	140,257	42.70	30.4%	4.34	1.2%
26	Trạm Nghiền Thủ Đức	Cement	8,218	87.52	1.3%	0.00	0.0%
27	Ha Tien Kien Giang Cement Joint Stock Company	Cement	3,538	36.84	10.4%	12.52	4.1%
28	Ha Tien 1 Cement Joint Stock Company - Long An Factory	Cement	2,994	9.74	0.6%	0.00	0.0%
29	Cosani Joint Stock Company	Chemical	1,094	14.58	11.5%	11.25	1.0%
30	TENMA (HCM) Vietnam Co.,ltd	Chemical	1,838	22.27	11.0%	7.94	8.8%
31	Petrovietnam Petrochemical and Textile Fiber Joint Stock Company	Chemical	16,219	8.17	0.4%	3.08	1.4%
32	Công ty Phân bón Việt Nhật- Nhà máy phân bón NPK	Chemical	2,138	12.55	1.8%	27.96	6.9%
33	Ho Chi Minh City Chemical JSC	Chemical	578	15.54	7.4%	12.71	4.9%
34	Lamthao Fertilizers and Chemicals ., JSC	Fertilizer	6,507	6.38	3.9%	0.00	0.0%
35	VanDien Fused Magnesium Phosphate Fertilizer Joint Stock	Fertilizer	34,322	10.73	2.4%	0.00	0.0%

#	Name company	Subsector	Total energy use (TOE)	Electricity - Cost/saving (M VND/TOE)	Electricity - Saving/Consumption (%)	Thermal - Cost/total saving (M VND/TOE)	Thermal - Saving/Consumption (%)
36	Vietnam Fertilizers Joint Stock Company	Fertilizer	15,626	12.89	0.1%	0.00	0.0%
37	Hanoi Liwayway food industry Co., Ltd	Food	957	10.10	3.5%	69.35	14.4%
38	C.P. Việt Nam Livestock Co.,Ltd	Food	3,691	12.85	8.6%	26.97	4.8%
39	Mangyang - Gia Lai flour processing plant; Quang Ngai Agricultural products and foodstuff ., JSC	Food	708	8.44	13.0%	8.44	10.0%
40	Saigon Tobacco Company Limited	Food	5,977	31.89	8.6%	2.08	9.9%
41	Hung Vuong Food Processing Export Company	Food	413	26.54	9.9%	0.00	0.0%
42	Cautre Export Goods Processing Joint Stock Company	Food	1,644	75.30	15.1%	10.01	7.0%
43	Saigon Viet Long Joint Stock Company	Food	308	32.81	17.4%	0.00	0.0%
44	Saigon Seafood Joint Stock Company	Food	1,339	48.34	10.3%	3.83	4.3%
45	Vissan Production Animal Industry Company Limited	Food	1,507	26.13	4.5%	11.13	7.8%
46	C.P. Vietnam Livestock Corporation	Food	6,959	6.50	1.3%	3.86	12.4%
47	Hai Thanh Food Import Export Company Limited	Food	890	17.25	4.7%	42.27	9.1%
48	A Chau Nutrition Company Limited	Food	993	9.81	1.0%	4.55	11.6%
49	Bien Hoa- Tri An Sugar Factory	Food	1,675	24.90	6.2%	36.22	11.0%
50	Vietnam Japan Food processing enterprises Joint Stock Company	Food	338	162.89	3.2%	0.00	0.0%
51	Bien Hoa- Ninh Hoa Company Limited	Food	2,300	11.86	15.0%	130.65	12.5%
52	Ut Xi Seafood Processing Joint Stock Company	Food	2,737	15.52	2.1%	20.22	4.1%
53	CADOVIMEX II Seafood Processing and Import Export JS	Food	2,192	14.18	6.9%	0.00	0.0%
54	Hoa Hung Company Limited	Food	868	138.92	2.6%	5.20	5.0%
55	Binh An Seafood Joint Stock Company	Food	1,529	4.35	6.5%	0.00	0.0%
56	Ca Mau Fisheries Service and Processing Joint Stock Company	Food	873	97.00	0.2%	0.00	0.0%
57	Cantho Import-Export Seafood Joint Stock Company (Caseamex)	Food	2,755	14.72	14.0%	0.00	0.0%
58	Lien Hiep Production and Trade Company Limited	Food	640	15.77	14.2%	0.00	0.0%
59	Minhthanh Export Garments Limited Company	Garment	222	111.79	24.1%	0.00	0.0%
60	Coats Phong Phu Company Limited	Garment	4,200	19.49	5.3%	11.09	0.9%
61	Vinh Tien Textile Joint Stock Company	Garment	161	19.24	13.0%	0.00	0.0%
62	Vietnam DINSEN Company Limited - DIN LING Factory	Garment	237	9.77	27.9%	14.49	10.8%
63	Viet Thanh Textile Company Limited	Garment	229	13.40	4.1%	0.00	0.0%
64	ALLIANCE ONE Company Limited	Garment	5,825	23.65	2.0%	3.33	5.3%
65	Viet Nam Samho Company Limited	Leather	5,325	14.34	11.1%	18.22	3.3%
66	Freetrend Industrial Company Limited	Leather	8,305	12.40	6.0%	3.91	8.8%

#	Name company	Subsector	Total energy use (TOE)	Electricity - Cost/saving (M VND/TOE)	Electricity - Saving/Consumption (%)	Thermal - Cost/total saving (M VND/TOE)	Thermal - Saving/Consumption (%)
67	Freetrend Industrial A Company Limited	Leather	5,827	0.00	0.0%	29.21	3.6%
68	JIA HSIN Company Limited	Leather	889	4.02	2.5%	10.33	3.7%
69	CT TNHH T	Leather	1,952	55.05	9.6%	0.00	0.0%
70	Viet Nam POU HUNG Company Limited	Leather	954	71.47	19.2%	0.00	0.0%
71	Lac Ty Company Limited	Leather	486	54.65	12.6%	0.00	0.0%
72	Dong Phuong Vung Tau Company Limited	Leather	304	20.60	6.4%	0.00	0.0%
73	Hai My Company Limited	Leather	355	10.67	1.6%	5.38	6.2%
74	Geruco-Quang Tri Wood ., JSC	Other	6,892	7.94	14.3%	7.94	1.5%
75	Pisico Hue Export Product Processing ., JSC	Other	113	18.15	23.2%	0.00	0.0%
76	Lixil Inax Vietnam Corporation	Other	4,638	8.61	4.1%	232.56	0.4%
77	Chu Dau Ceramic ., JSC	Other	1,401	27.41	11.5%	15.75	16.8%
78	Takahata Precision Vietnam Co., Ltd	Other	1,276	13.15	3.4%	46.15	0.0%
79	Vietnam Brother Industry Limited Company	Other	2,233	20.21	9.9%	30.00	11.1%
80	Vietnam UMC Electric Limited Company	Other	2,399	14.74	1.8%	0.00	0.0%
81	Spindex Industries (Hanoi) Co.,Ltd	Other	660	5.92	0.6%	0.00	0.0%
82	Chain & Free - Wheel Dong Anh.., LTD	Other	16,490	13.23	9.0%	0.00	0.0%
83	Yamaha Motor Parts Manufacturing Vietnam	Other	4,737	6.55	6.2%	38.12	1.7%
84	Showa Auto - Parts Vietnam	Other	7,527	10.73	6.4%	12.97	0.6%
85	Goshi- Thang Long Auto Parts	Other	2,222	36.67	3.2%	0.00	0.0%
86	Musashi Auto Parts Vietnam	Other	1,286	17.51	0.4%	0.00	0.0%
87	Furukawa Automotive Parts Vietnam Company Limited	Other	4,200	27.72	6.8%	15.44	6.3%
88	Nidec Vietnam Corporation	Other	2,469	5.73	6.7%	0.00	0.0%
89	Vietnam Juki Company Limited	Other	2,859	8.36	3.1%	12.52	13.0%
90	Mtex Company Limited	Other	2,046	19.31	1.8%	15.61	0.0%
91	Nissei Electric Company Limited 1	Other	3,847	0.62	0.4%	1.68	1.4%
92	Nissey Electric Company Limited 2	Other	1,430	20.47	8.4%	0.00	0.0%
93	Sai Gon Petro Corporation	Other	1,680	12.97	13.0%	45.37	13.0%
94	Petrovietnam Southern Gas Joint Stock Company	Other	5,594	29.64	1.3%	52.24	0.9%
95	Nguyen Hoang Company Limited	Other	80	12.64	10.9%	0.00	0.0%
96	Vietnam Poh Huat Joint Stock Company	Other	1,753	8.27	16.6%	0.00	0.0%
97	RK RESOURCES Company Limited	Other	2,422	19.31	5.7%	0.00	0.0%

#	Name company	Subsector	Total energy use (TOE)	Electricity - Cost/saving (M VND/TOE)	Electricity - Saving/Consumption (%)	Thermal - Cost/total saving (M VND/TOE)	Thermal - Saving/Consumption (%)
98	Satimex Joint Stock Company	Other	768	8.62	21.5%	0.00	0.0%
99	Saigon Development Joint Stock Company	Other	192	8.69	18.9%	0.00	0.0%
100	Minh Quan Paper factory	Paper	838	11.35	18.2%	31.45	6.4%
101	AFC Paper Company Limited	Paper	4,512	3.20	12.7%	0.38	0.1%
102	Kraft VINA Paper Company Limited	Paper	72,479	19.06	1.8%	0.00	1.7%
103	Vinh Hue Paper Joint Stock Company	Paper	11,181	20.73	0.9%	5.46	11.0%
104	Hung Thinh Paper Joint Stock Company	Paper	1,196	5.99	0.3%	23.82	6.8%
105	Minh Long 1 Company Limited	Paper	8,468	11.48	1.0%	2.08	1.3%
106	Plastic Young Pioneers., JSC	Plastic	4,287	18.62	2.6%	0.00	0.0%
107	Hiep Thanh Plastic Trading-Manufacturing JSC	Plastic	2,580	16.45	8.8%	0.00	0.0%
108	Saigon Plastic Joint Stock Company	Plastic	339	6.81	33.6%	0.00	0.0%
109	TNHH SX TM DV Thịnh Khang	Plastic	2,945	19.38	1.2%	12.25	16.1%
110	RKW Lotus Company Limited	Plastic	301	3.67	16.6%	0.00	0.0%
111	Dai Dong Tien JSC- 2015	Plastic	2,771	7.40	9.2%	0.00	0.0%
112	Rang Dong Plastic JSc	Plastic	1,062	321.53	14.7%	0.00	0.0%
113	Maitai Company Limited	Plastic	1,634	23.62	24.3%	0.00	0.0%
114	PET Plastic JSC	Plastic	1,570	34.97	6.2%	0.00	0.0%
115	Ngoc Nghia Industry - Service - Trading JSC - Cu Chi Factory	Plastic	2,203	14.71	4.9%	0.00	0.0%
116	Tan Tien Plastic packaging Joint-stock Company.	Plastic	3,695	8.87	20.2%	0.00	0.0%
117	Do Thanh Plastic Factory	Plastic	425	15.78	0.1%	0.00	0.0%
118	LIVING & LIFE Company Limited	Plastic	291	16.74	29.6%	12.13	0.0%
119	Bai Bang Paper Mill	Pulp	96,803	22.70	15.5%	15.78	5.6%
120	Luu Xa Steel factory -TISCO STEEL	Steel	1,459	14.70	4.8%	0.00	0.0%
121	Vietnam steel pipe Co., Ltd	Steel	641	9.46	1.0%	21.10	1.9%
122	SSE Steel Co., Ltd	Steel	12,234	9.00	0.1%	9.00	0.4%
123	Nha Be Steel Joint Stock Company	Steel	5,218	90.49	12.1%	16.41	26.1%
124	A Chau Steel Joint Stock Company	Steel	2,104	24.00	0.1%	0.38	18.8%
125	Thiên Thai Company	Steel	4,527	6.15	14.2%	8.97	12.9%
126	Tây Đô Steel Joint Stock Company	Steel	2,266	8.64	1.7%	5.46	1.2%
127	CT TNHH X	Textile	21,697	16.05	4.8%	2.00	6.4%
128	28 Corporation One Member Limited Liability Company	Textile	8,242	30.81	1.7%	8.00	0.2%

#	Name company	Subsector	Total energy use (TOE)	Electricity - Cost/saving (M VND/TOE)	Electricity - Saving/Consumption (%)	Thermal - Cost/total saving (M VND/TOE)	Thermal - Saving/Consumption (%)
129	Vietnam PAIHO Company Limited	Textile	3,209	21.24	9.7%	0.00	0.0%
130	Thanh Cong Textile Garment Investment Trading Joint Stock Company	Textile	8,526	27.62	9.2%	0.00	0.0%
131	CHIN HSIN Company Limited	Textile	2,755	6.75	6.3%	1.77	6.4%
132	Dong Quang Knitting Company Limited	Textile	4,033	17.40	22.6%	0.00	0.0%
133	Vietnam Kim May Organ Company Limited	Textile	3,974	20.23	11.9%	27.47	0.3%
134	Hanoi Textile Joint Stock Cooperation - Bacninh Fiber Factory	Textile & Garment	2,220	20.97	2.8%	0.00	0.0%
135	Hanoi Textile Joint Stock Cooperation - Dong Van Fiber Factory	Textile & Garment	2,704	12.87	2.6%	0.00	0.0%

B.7. Commercial Sector

Table 109: Commercial Sector Device Characterization

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

Demand Device	Activity / Capacity Units	Fuel	Start Year	Lifetime	Efficiency	Investment (US$2015M)	Fixed O&M (US$2015M)	Availability Factor
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

Sources:

MOIT. Vietnam Calculator 2050, Technical consultation for Vietnam Calculator 2050 – Household and Industry sections. 2012

USAID. Vietnam Clean Energy Program–Promoting Energy Efficiency in the Building Sector Project. 2017

MOST. Vietnam National Standards for Home appliances (TCVN). 2013-2017

Website of popular Home appliance Retailers and manufacturers (price data)

Website of Labeling program (nhannangluong.com)

B.8. Residential Sector

Table 110: Residential Sector Device Characterization

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

Demand Device	Activity / Capacity Units	Fuel	Start Year	Lifetime	Efficiency	Investment (US$2015M)	Fixed O&M (US$2015M)	Availability Factor
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

Demand Device	Activity / Capacity Units	Fuel	Start Year	Lifetime	Efficiency	Investment (US$2015M)	Fixed O&M (US$2015M)	Availability Factor
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

Demand Device	Activity / Capacity Units	Fuel	Start Year	Lifetime	Efficiency	Investment (US$2015M)	Fixed O&M (US$2015M)	Availability Factor
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

Sources:

GSO. The household living standard Survey Program 2014

MOIT. Vietnam Calculator 2050, Technical consultation for Vietnam Calculator 2050 – Household and Industry sections. 2015

GIZ-GDE/MOIT 2014. Summary of studies on supporting mechanism for development of grid-connected bioenergy power in Vietnam

MOST. Vietnam National Standards for Home appliances (TCVN).2013-2017

Website of popular Home appliance Retailers and manufacturers (price data)

Website of Labeling program (nhannangluong.com)

B.9. Demand Drivers

Table 111: Major Socio-Economic Demand Drivers

Driver	Unit	2014	2016	2020	2025	2030	2035
GDP	Billion 2015 USD	126.6	145.0	190.1	266.6	373.9	524.4
Population	Million persons	90.7	92.8	96.6	100.9	104.4	107.3
Number of Persons per Household		3.80	3.76	3.69	3.60	3.51	3.42
GDP growth	%/year		7.0%	7.0%	7.0%	7.0%	7.0%
Population growth	%/year		1.1%	1.0%	0.9%	0.7%	0.6%
GDP/Population growth	%/year		5.8%	5.9%	6.1%	6.3%	6.4%
% Change of Persons per Household	%/year		-0.5%	-0.5%	-0.5%	-0.5%	-0.5%
% Change of Non-energy Consumption	%/year		3.2%	4.0%	4.0%	4.0%	3.5%

Sources:

IE (2015). Revised Power Development Plan in 2011 - 2020 with outlook to 2030.

GSO (2016). Population forecast 2014-2049

Appendix C: Model Results Summary

This Appendix presents a host of detailed results arising from the model runs examining the Unconditional and Conditional NDC Pathways. Each is presented for the indicative years of 2014, 2020, 2025 and 2030, along with the difference (absolute and percent) from the BAU scenarios, both in table form and for the former graphs as well. These help to provide the analytic rigor behind the discussion in Section 10 outlining the recommended NDC Pathways. Table 112 provides a short description of each of the Summary and Supporting Tables.

Table 112: Description of Model Summary Tables

Table	Description
Summary	Main results including Total System Cost, Primary Energy, Imports, Power Plant Capacity/Generation/New Builds/Investment, FEC, Fuel Expenditure, Device Purchases, GHG Emissions
Primary Energy Supply	Energy supply by fuel type
Imports	Imports by fuel type
Power Plant Picture (4)	Power Plant Capacity/Generation/New Builds/Investment by type
FEC (3)	FEC by fuel and sector, and by Industry sub-sector
GHG Emission	GHG Emission by sector
Expenditures	Expenditure by category investment (for power plants and devices) & operating costs (fixed and variable), fuel expenditures, taxes
Energy Intensity (2)	FEC/GDP by sector and Industry sub-sector
Emission Intensity	GHG/GDP by sector

The specific mitigation measures underpinning these summary results were first introduced in Section 6, and their results are discussed and presented in Sections 7, 8 and 11 for the Unconditional and Conditional analysis and their effectiveness, resulting in the storylines describing the least-cost NDC Pathways.

C.1 Summary Table

NDC Pathways Analysis: Summary Table

Scenario		BAU					NDC-8%				
Metrics	Year	2014	2020	2025	2030	CUM	2014	2020	2025	2030	CUM
Total System Cost	2015$M					$ 768,443					$ 760,522
	% diff										-1.03%
Primary Energy	ktoe	77,811	116,655	153,245	200,864	2,415,086	77,811	113,262	148,033	191,789	2,338,340
	% diff							-2.91%	-3.40%	-4.52%	-3.18%
Imports	ktoe	13,636	42,992	77,146	130,385	1,141,177	13,636	38,267	71,232	117,232	1,038,180
	% diff							-10.99%	-7.67%	-10.09%	-9.03%
Power Plant Installed Capacity	GW	31.41	53.26	76.14	111.35		31.41	60.55	83.52	102.47	2030
	% diff							13.67%	9.69%	-7.98%	-7.98%
Electrity Generation	GWh	142,052	274,016	403,817	572,207	6,166,950	142,052	273,161	398,556	561,539	6,089,693
	% diff							-0.31%	-1.30%	-1.86%	-1.25%
Power Plant Builds	GW		6.50	23.43	37.12	70.46		8.27	23.52	20.86	61.58
	% diff							27.38%	0.42%	-43.81%	-12.60%
Power Plant Investment	2015$M		$ 8,721	$ 27,454	$ 46,240	$ 82,415		$ -	$ -	$ -	$ 83,374
	% diff							-100.00%	-100.00%	-100.00%	-4.42%
Final Energy Consumption	ktoe	45,032	72,609	96,908	125,223	1,519,810	45,032	71,308	93,832	119,187	1,476,578
	% diff							-1.79%	-3.17%	-4.82%	-2.84%
Fuel Expenditures	2015$M	$ 16,514	$ 26,519	$ 37,988	$ 58,087	$ 601,623	$ 16,514	$ 24,867	$ 35,877	$ 54,721	$ 571,362
	% diff							-6.23%	-5.56%	-5.80%	-5.03%
Demand Device Purchases	2015$M		$ 125	$ 243	$ 329	$ 3,218		$ 124	$ 245	$ 330	$ 3,245
	% diff							-0.46%	0.99%	0.31%	0.85%
GHG Emissions (CO2eq)	kt	172,104	329,051	472,194	636,542	7,187,079	172,104	303,451	437,219	585,619	6,682,082
	% diff							-8%	-7%	-8.0%	-7.03%
Energy Sector GHG Emissions (CO2eq)	kt	143,863	287,738	415,658	559,193		143,863	264,040	383,212	514,000	
	% diff									-8.1%	

NDC Pathways Analysis: Summary Table

Scenario		NDC-15%					EE&RE Policies				
Metrics	Units / Year	2014	2020	2025	2030	CUM	2014	2020	2025	2030	CUM
Total System Cost	2015$M					$ 754,689					$ 756,497
	% diff					-1.79%					-1.55%
Primary Energy	ktoe	77,811	112,607	143,670	182,483	2,283,411	77,811	112,380	142,343	179,098	2,265,529
	% diff		-3.47%	-6.25%	-9.15%	-5.45%		-3.67%	-7.11%	-10.84%	-6.19%
Imports	ktoe	13,636	37,493	65,469	107,336	971,121	13,636	37,056	65,079	102,684	955,150
	% diff		-12.79%	-15.14%	-17.68%	-14.90%		-13.81%	-15.64%	-21.25%	-16.30%
Power Plant Installed Capacity	GW	31.41	61.02	85.64	104.99	2030	31.41	61.20	85.97	111.75	2030
	% diff		14.56%	12.48%	-5.71%	-5.71%		14.89%	12.91%	0.36%	0.36%
Electrity Generation	GWh	142,052	272,803	398,377	554,199	6,068,789	142,052	272,848	398,099	551,569	6,061,759
	% diff		-0.44%	-1.35%	-3.15%	-1.59%		-0.43%	-1.42%	-3.61%	-1.71%
Power Plant Builds	GW		8.75	25.17	21.26	64.10		8.90	25.32	27.69	70.86
	% diff		34.68%	7.44%	-42.73%	-9.03%		37.08%	8.10%	-25.42%	0.56%
Power Plant Investment	2015$M		$ 466	$ 4,183	$ 964	$ 85,939		$ 466	$ 4,183	$ 2,550	$ 95,226
	% diff		-94.66%	-84.76%	-97.92%	-1.48%		-94.66%	-84.76%	-94.48%	9.17%
Final Energy Consumption	ktoe	45,032	70,935	92,060	115,184	1,451,543	45,032	70,718	91,310	113,573	1,440,766
	% diff		-2.31%	-5.00%	-8.02%	-4.49%		-2.60%	-5.78%	-9.30%	-5.20%
Fuel Expenditures	2015$M	$ 16,514	$ 24,453	$ 34,307	$ 52,073	$ 552,283	$ 34,429	$ 24,546	$ 34,429	$ 51,614	$ 551,986
	% diff		-7.79%	-9.69%	-10.35%	-8.20%		-7.44%	-9.37%	-11.14%	-8.25%
Demand Device Purchases	2015$M		$ 129	$ 255	$ 345	$ 3,366		$ 127	$ 253	$ 335	$ 3,327
	% diff		3.55%	4.91%	5.00%	4.62%		1.69%	4.08%	1.91%	3.40%
GHG Emissions (CO2eq)	kt	172,104	300,616	416,672	541,061	6,429,394	172,104	299,270	413,502	523,365	6,353,641
	% diff		-9%	-12%	-15.0%	-10.54%		-9%	-12%	-17.8%	-11.60%
Energy Sector GHG Emissions (CO2eq)	kt	143,863	262,094	365,050	474,239		143,863	260,748	361,880	456,543	
	% diff				-15.2%					-18.4%	

NDC Pathways Analysis: Summary Table

Scenario		BAU					NDC-20%				
Metrics	**Year**	**2014**	**2020**	**2025**	**2030**	**CUM**	**2014**	**2020**	**2025**	**2030**	**CUM**
Total System Cost	2015$M					$ 768,443					$ 755,341
	% diff										-1.70%
Primary Energy	ktoe	77,811	116,655	153,245	200,864	2,415,086	77,811	112,246	141,949	176,542	2,252,373
	% diff							-3.78%	-7.37%	-12.11%	-6.74%
Imports	ktoe	13,636	42,992	77,146	130,385	1,141,177	13,636	37,284	64,579	98,714	935,718
	% diff							-13.28%	-16.29%	-24.29%	-18.00%
Power Plant Installed Capacity	GW	31.41	53.26	76.14	111.35		31.41	61.04	86.04	116.83	2030
	% diff							14.60%	13.00%	4.93%	4.93%
Electrity Generation	GWh	142,052	274,016	403,817	572,207	6,166,950	142,052	273,256	399,079	552,974	6,076,689
	% diff							-0.28%	-1.17%	-3.36%	-1.46%
Power Plant Builds	GW		6.50	23.43	37.12	70.46		8.76	25.55	32.71	75.94
	% diff							34.93%	9.06%	-11.89%	7.78%
Power Plant Investment	2015$M		$ 8,721	$ 27,454	$ 46,240	$ 82,415		$ 466	$ 4,183	$ 6,564	$ 99,122
	% diff							-94.66%	-84.76%	-85.80%	13.64%
Final Energy Consumption	ktoe	45,032	72,609	96,908	125,223	1,519,810	45,032	70,532	90,877	113,158	1,436,587
	% diff							-2.86%	-6.22%	-9.64%	-5.48%
Fuel Expenditures	2015$M	$ 16,514	$ 26,519	$ 37,988	$ 58,087	$ 601,623	$ 16,514	$ 24,494	$ 34,643	$ 51,151	$ 551,035
	% diff							-7.64%	-8.81%	-11.94%	-8.41%
Demand Device Purchases	2015$M		$ 125	$ 243	$ 329	$ 3,218		$ 127	$ 253	$ 335	$ 3,327
	% diff							1.69%	4.08%	1.91%	3.40%
GHG Emissions (CO2eq)	kt	172,104	329,051	472,194	636,542	7,187,079	172,104	299,457	412,998	509,234	6,291,932
	% diff							-9%	-13%	-20.0%	-12.45%
Energy Sector GHG Emissions (CO2eq)	kt	143,863	287,738	415,658	559,193		143,863	261,553	363,012	444,505	
	% diff									-20.5%	

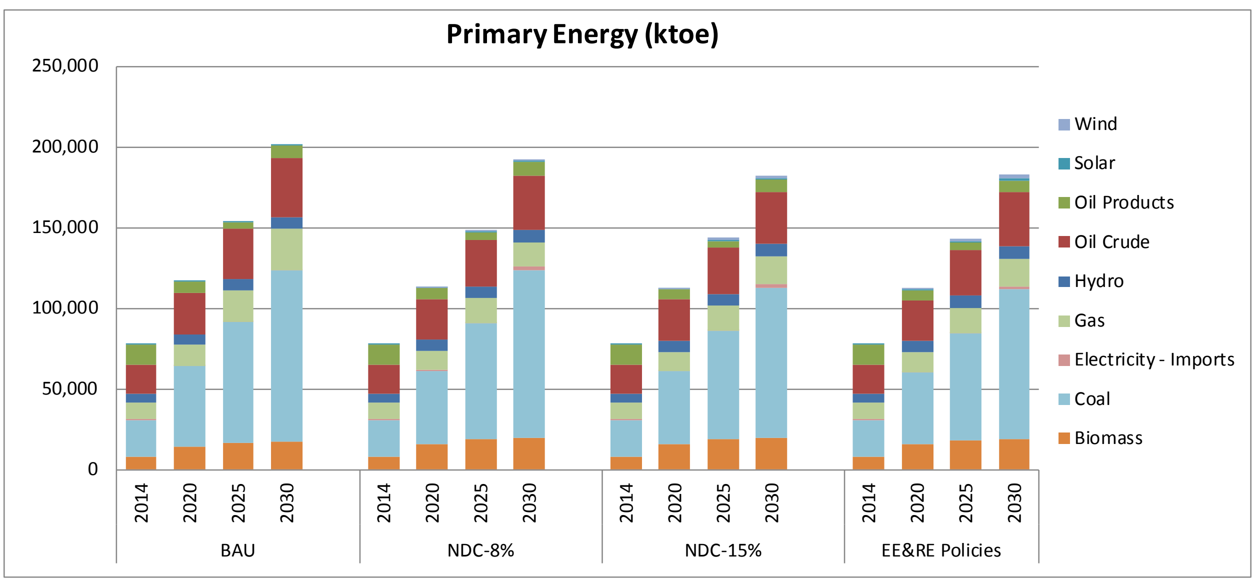
NDC Pathways Analysis: Summary Table

Scenario		NDC-25%					NDC-30%				
Metrics	**Year**	**2014**	**2020**	**2025**	**2030**	**CUM**	**2014**	**2020**	**2025**	**2030**	**CUM**
Total System Cost	2015$M					$ 753,376					$ 753,335
	% diff					-1.96%					-1.97%
Primary Energy	ktoe	77,811	111,860	139,829	171,647	2,223,264	77,811	111,159	136,643	165,745	2,183,848
	% diff		-4.11%	-8.75%	-14.55%	-7.94%		-4.71%	-10.83%	-17.48%	-9.57%
Imports	ktoe	13,636	36,255	60,276	92,252	888,960	13,636	35,663	57,896	86,430	850,449
	% diff		-15.67%	-21.87%	-29.25%	-22.10%		-17.05%	-24.95%	-33.71%	-25.48%
Power Plant Installed Capacity	GW	31.41	61.13	85.42	117.85	2030	31.41	61.41	84.39	117.55	2030
	% diff		14.77%	12.20%	5.84%	5.84%		15.29%	10.84%	5.57%	5.57%
Electrity Generation	GWh	142,052	273,212	395,981	542,603	6,020,943	142,052	271,761	388,060	519,089	5,893,453
	% diff		-0.29%	-1.94%	-5.17%	-2.37%		-0.82%	-3.90%	-9.28%	-4.43%
Power Plant Builds	GW		8.85	24.85	34.34	76.96		9.13	23.54	35.07	76.66
	% diff		36.28%	6.06%	-7.50%	9.23%		40.54%	0.48%	-5.54%	8.80%
Power Plant Investment	2015$M		$ 466	$ 4,183	$ 6,111	$ 101,013		$ 466	$ 4,477	$ 7,347	$ 100,768
	% diff		-94.66%	-84.76%	-86.78%	15.80%		-94.66%	-83.69%	-84.11%	15.52%
Final Energy Consumption	ktoe	45,032	70,112	89,427	109,932	1,415,804	45,032	69,679	87,868	108,004	1,399,681
	% diff		-3.44%	-7.72%	-12.21%	-6.84%		-4.04%	-9.33%	-13.75%	-7.90%
Fuel Expenditures	2015$M	$ 16,514	$ 24,265	$ 33,609	$ 49,129	$ 537,273	$ 33,365	$ 24,246	$ 33,365	$ 48,602	$ 534,563
	% diff		-8.50%	-11.53%	-15.42%	-10.70%		-8.57%	-12.17%	-16.33%	-11.15%
Demand Device Purchases	2015$M		$ 133	$ 257	$ 344	$ 3,428		$ 135	$ 268	$ 353	$ 3,518
	% diff		6.92%	5.67%	4.60%	6.55%		8.24%	10.23%	7.37%	9.33%
GHG Emissions (CO2eq)	kt	172,104	297,074	401,365	477,407	6,105,235	172,104	294,820	387,592	445,580	5,914,225
	% diff		-10%	-15%	-25.0%	-15.05%		-10%	-18%	-30.0%	-17.71%
Energy Sector GHG Emissions (CO2eq)	kt	143,863	259,169	351,379	412,678		143,863	256,915	337,607	380,851	
	% diff				-26.2%					-31.9%	

C.2 Primary Energy & Imports

NDC Pathways Analysis: Primary Energy (ktoe)									
Scenario	BAU				NDC-8%				
Energy Carrier	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Biomass	8,327	13,869	16,282	17,423	8,327	15,565	18,900	20,020	15%
Coal	22,569	50,065	75,033	105,929	22,569	45,831	71,615	103,232	-3%
Electricity - Imports	153	469	568	590	153	148	189	2,536	330%
Gas	10,888	13,016	19,274	25,292	10,888	11,974	15,333	15,352	-39%
Hydro	4,975	6,521	6,873	6,797	4,975	6,736	7,287	7,267	7%
Oil Crude	17,739	25,673	30,993	36,880	17,739	25,673	28,889	33,760	-8%
Oil Products	13,159	7,042	4,217	7,945	13,159	6,407	4,895	8,656	9%
Solar	0	1	4	9	0	528	525	565	6465%
Wind	0	0	0	0	0	400	400	400	-
Total	77,811	116,655	153,245	200,864	77,811	113,262	148,033	191,789	-5%

NDC Pathways Analysis: Primary Energy (ktoe)										
Scenario	NDC-15%					EE&RE Policies				
Energy Carrier	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Biomass	8,327	15,585	18,641	20,060	15%	8,327	15,556	17,767	19,138	10%
Coal	22,569	45,253	67,123	92,750	-12%	22,569	44,788	66,028	87,641	-17%
Electricity - Imports	153	113	171	2,536	330%	153	104	208	2,536	330%
Gas	10,888	12,143	15,799	17,049	-33%	10,888	12,295	15,689	16,771	-34%
Hydro	4,975	6,736	7,319	7,382	9%	4,975	6,736	7,319	7,767	14%
Oil Crude	17,739	25,673	28,324	32,591	-12%	17,739	25,673	28,617	33,675	-9%
Oil Products	13,159	6,068	4,212	7,594	-4%	13,159	6,191	4,586	7,967	0%
Solar	0	531	585	793	9119%	0	533	634	1,610	18603%
Wind	0	504	1,496	1,727	-	0	504	1,496	1,993	-
Total	77,811	112,607	143,670	182,483	-9%	77,811	112,380	142,343	179,098	-11%

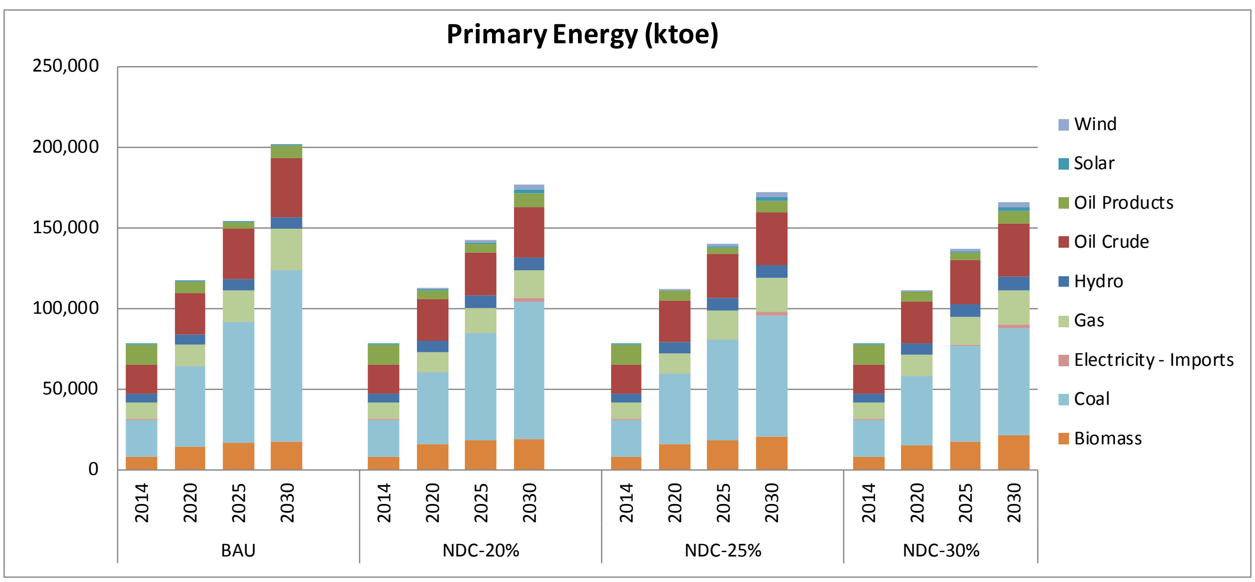


NDC Pathways Analysis: Primary Energy (ktoe)

Scenario	BAU				NDC-20%				
Energy Carrier	**2014**	**2020**	**2025**	**2030**	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**
Biomass	8,327	13,869	16,282	17,423	8,327	15,405	17,767	19,137	10%
Coal	22,569	50,065	75,033	105,929	22,569	44,996	66,489	84,963	-20%
Electricity - Imports	153	469	568	590	153	122	209	2,536	330%
Gas	10,888	13,016	19,274	25,292	10,888	12,284	15,783	16,924	-33%
Hydro	4,975	6,521	6,873	6,797	4,975	6,736	7,319	7,614	12%
Oil Crude	17,739	25,673	30,993	36,880	17,739	25,673	27,084	31,657	-14%
Oil Products	13,159	7,042	4,217	7,945	13,159	5,993	5,167	8,596	8%
Solar	0	1	4	9	0	533	634	2,373	27471%
Wind	0	0	0	0	0	504	1,496	2,743	-
Total	**77,811**	**116,655**	**153,245**	**200,864**	**77,811**	**112,246**	**141,949**	**176,542**	**-12%**

NDC Pathways Analysis: Primary Energy (ktoe)

Scenario	NDC-25%					NDC-30%				
Energy Carrier	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**
Biomass	8,327	15,413	17,979	20,447	17%	8,327	15,138	17,603	21,317	22%
Coal	22,569	43,858	62,588	75,054	-29%	22,569	43,031	59,286	66,428	-37%
Electricity - Imports	153	120	360	2,536	330%	153	99	903	2,536	330%
Gas	10,888	12,914	17,753	20,746	-18%	10,888	13,045	17,238	21,153	-16%
Hydro	4,975	6,736	7,319	7,767	14%	4,975	6,736	7,319	8,232	21%
Oil Crude	17,739	25,673	27,456	32,687	-11%	17,739	25,673	27,702	32,591	-12%
Oil Products	13,159	6,104	4,241	7,130	-10%	13,159	6,359	4,372	7,919	0%
Solar	0	538	637	2,620	30344%	0	574	673	2,680	31036%
Wind	0	504	1,496	2,660	-	0	504	1,547	2,888	-
Total	**77,811**	**111,860**	**139,829**	**171,647**	**-15%**	**77,811**	**111,159**	**136,643**	**165,745**	**-17%**

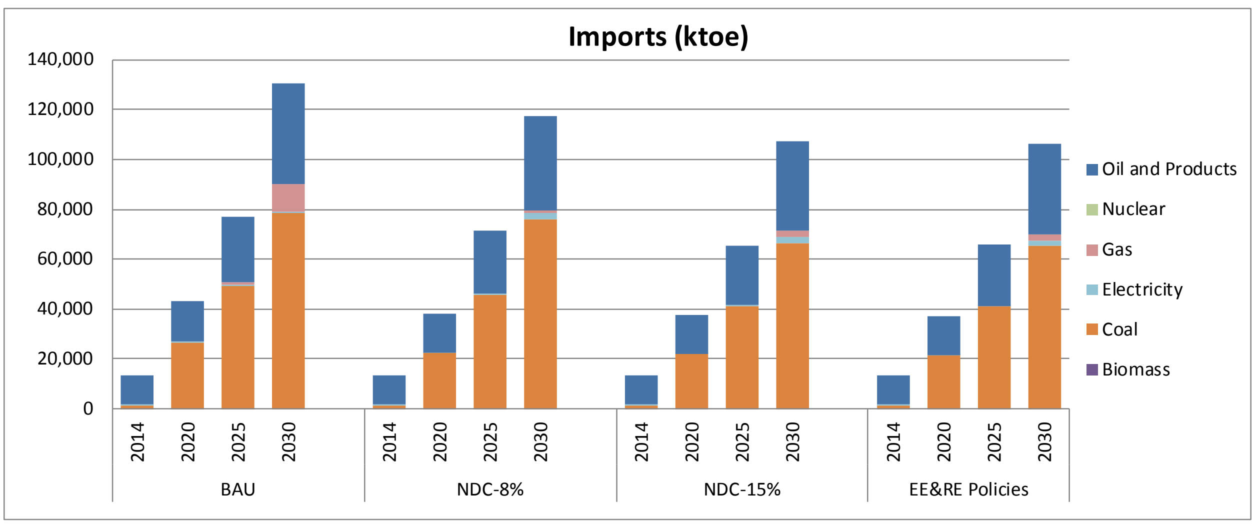


NDC Pathways Analysis: Imports (ktoe)

Scenario	BAU				NDC-8%				
Energy Carrier	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Biomass	0	0	0	0	0	0	0	0	-
Coal	1,428	26,757	49,314	78,603	1,428	22,523	45,895	75,905	-3%
Electricity	153	469	568	590	153	148	189	2,536	330%
Gas	0	0	673	10,984	0	0	0	1,045	-90%
Nuclear	0	0	0	0	0	0	0	0	-
Oil and Products	12,055	15,766	26,592	40,208	12,055	15,595	25,147	37,745	-6%
Total	13,636	42,992	77,146	130,385	13,636	38,267	71,232	117,232	-10%

NDC Pathways Analysis: Imports (ktoe)

Scenario	NDC-15%					EE&RE Policies				
Energy Carrier	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Biomass	0	0	0	0	-	0	0	0	0	-
Coal	1,428	21,946	41,403	66,218	-16%	1,428	21,481	40,308	60,314	-23%
Electricity	153	113	171	2,536	330%	153	104	208	2,536	330%
Gas	0	0	0	2,741	-75%	0	0	0	2,464	-78%
Nuclear	0	0	0	0	-	0	0	0	0	-
Oil and Products	12,055	15,434	23,895	35,841	-11%	12,055	15,471	24,563	37,370	-7%
Total	13,636	37,493	65,469	107,336	-18%	13,636	37,056	65,079	102,684	-21%

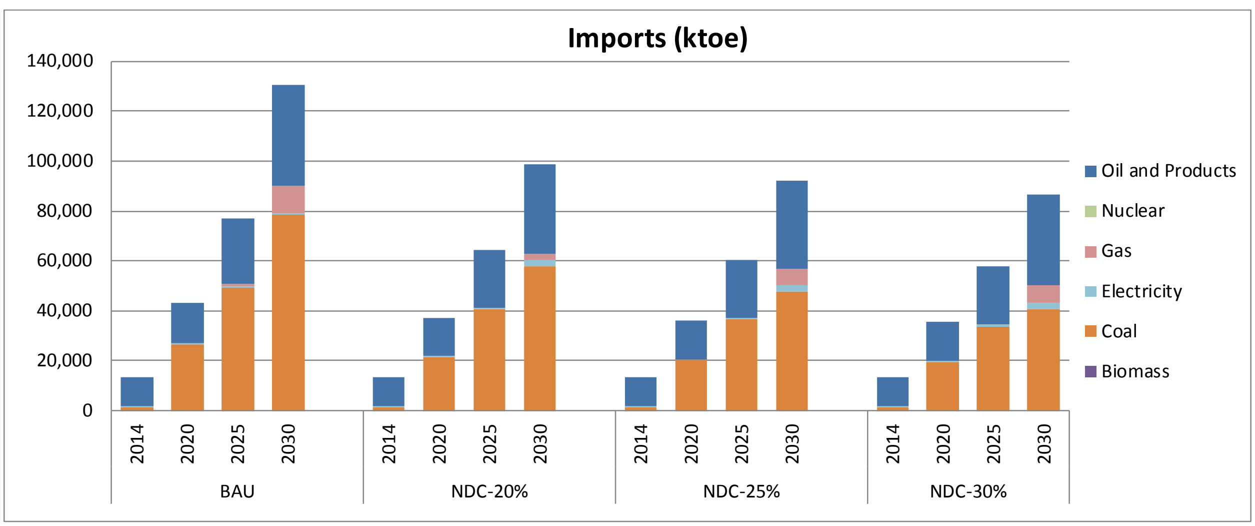


NDC Pathways Analysis: Imports (ktoe)

Scenario	BAU				NDC-20%				
Energy Carrier	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Biomass	0	0	0	0	0	0	0	0	-
Coal	1,428	26,757	49,314	78,603	1,428	21,689	40,769	57,637	-27%
Electricity	153	469	568	590	153	122	209	2,536	330%
Gas	0	0	673	10,984	0	0	0	2,616	-76%
Nuclear	0	0	0	0	0	0	0	0	-
Oil and Products	12,055	15,766	26,592	40,208	12,055	15,474	23,600	35,924	-11%
Total	**13,636**	**42,992**	**77,146**	**130,385**	**13,636**	**37,284**	**64,579**	**98,714**	**-24%**

NDC Pathways Analysis: Imports (ktoe)

Scenario	NDC-25%					NDC-30%				
Energy Carrier	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Biomass	0	0	0	0	-	0	0	0	0	-
Coal	1,428	20,551	36,868	47,728	-39%	1,428	19,724	33,566	40,834	-48%
Electricity	153	120	360	2,536	330%	153	99	903	2,536	330%
Gas	0	0	0	6,438	-41%	0	0	0	6,845	-38%
Nuclear	0	0	0	0	-	0	0	0	0	-
Oil and Products	12,055	15,584	23,048	35,549	-12%	12,055	15,839	23,428	36,215	-10%
Total	**13,636**	**36,255**	**60,276**	**92,252**	**-29%**	**13,636**	**35,663**	**57,896**	**86,430**	**-34%**



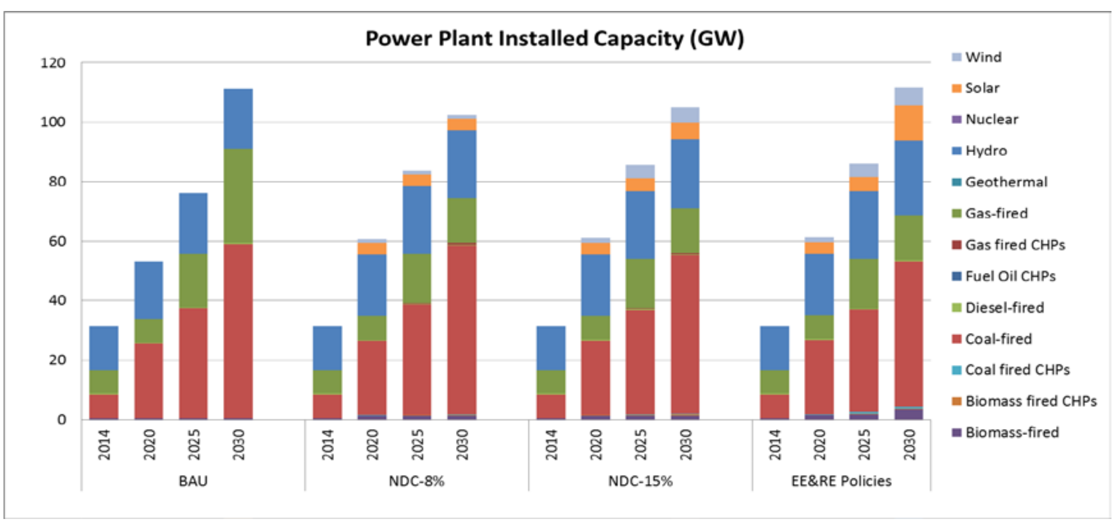
C.3 Power Sector

NDC Pathways Analysis: Power Plant Installed Capacity (GW)

Scenario	BAU				NDC-8%				
Plant Type	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Biomass-fired	0.39	0.39	0.39	0.39	0.39	1.30	1.31	1.32	235.0%
Biomass fired CHPs	0.00	0.00	0.00	0.00	0.00	0.04	0.09	0.15	-
Coal fired CHPs	0.00	0.00	0.00	0.00	0.00	0.08	0.12	0.12	-
Coal-fired	8.00	25.21	37.02	58.67	8.00	25.03	37.08	56.97	-2.9%
Diesel-fired	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.0%
Fuel Oil CHPs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Gas fired CHPs	0.00	0.00	0.00	0.00	0.00	0.04	0.21	0.47	-
Gas-fired	7.91	7.91	17.93	31.65	7.91	7.91	16.65	15.16	-52.1%
Geothermal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Hydro	14.84	19.47	20.52	20.36	14.84	20.69	22.60	22.83	12.1%
Nuclear	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Solar	0.00	0.00	0.00	0.00	0.00	3.96	3.96	3.96	-
Wind	0.00	0.00	0.00	0.00	0.00	1.22	1.22	1.22	-
Total	31.41	53.26	76.14	111.35	31.41	60.55	83.52	102.47	-8.0%

NDC Pathways Analysis: Power Plant Installed Capacity (GW)

Scenario	NDC-15%					EE&RE Policies				
Plant Type	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Biomass-fired	0.39	1.30	1.31	1.33	236.39%	0.39	1.41	1.77	3.28	731.6%
Biomass fired CHPs	0.00	0.11	0.21	0.35	-	0.00	0.11	0.21	0.32	-
Coal fired CHPs	0.00	0.16	0.23	0.23	-	0.00	0.23	0.42	0.69	-
Coal-fired	8.00	25.03	35.16	53.29	-9.17%	8.00	25.03	34.60	48.95	-16.6%
Diesel-fired	0.27	0.27	0.27	0.27	0.00%	0.27	0.27	0.27	0.27	0.0%
Fuel Oil CHPs	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	-
Gas fired CHPs	0.00	0.04	0.17	0.41	-	0.00	0.04	0.06	0.09	-
Gas-fired	7.91	7.91	16.65	15.16	-52.09%	7.91	7.91	16.65	15.16	-52.1%
Geothermal	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	-
Hydro	14.84	20.69	22.71	23.19	13.91%	14.84	20.69	22.71	24.97	22.6%
Nuclear	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	-
Solar	0.00	3.96	4.40	5.52	-	0.00	3.96	4.75	12.00	-
Wind	0.00	1.54	4.52	5.23	-	0.00	1.54	4.52	6.01	-
Total	31.41	61.02	85.64	104.99	-5.71%	31.41	61.20	85.97	111.75	0.4%

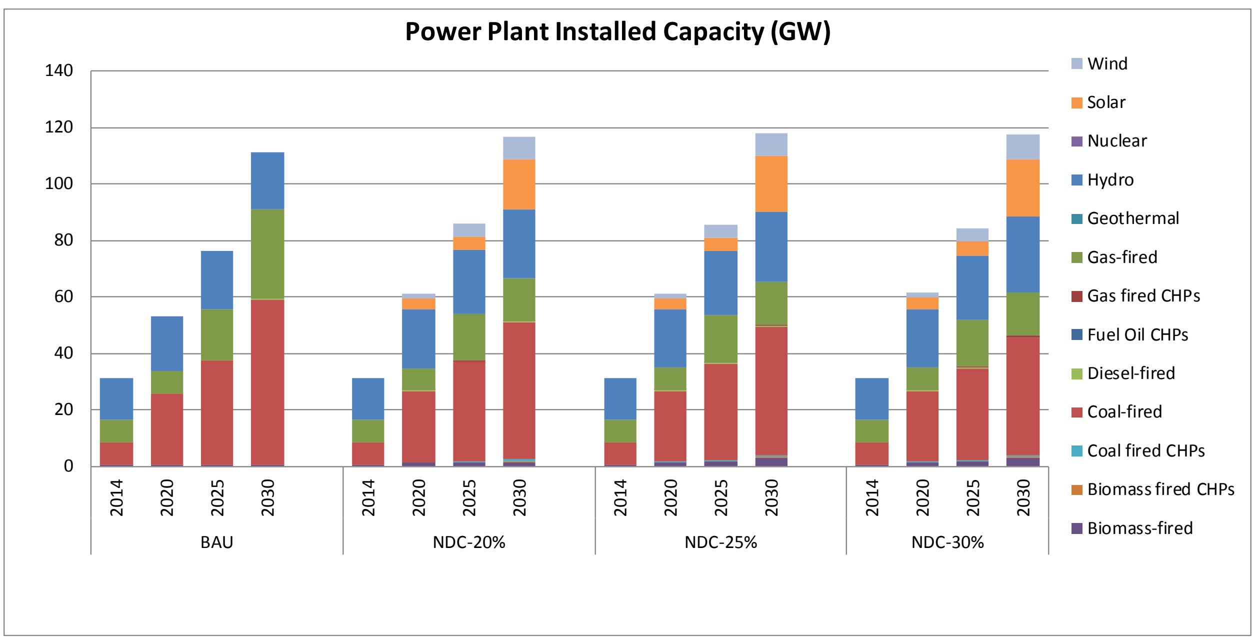


NDC Pathways Analysis: Power Plant Installed Capacity (GW)

Scenario	BAU				NDC-20%				
Plant Type	**2014**	**2020**	**2025**	**2030**	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**
Biomass-fired	0.39	0.39	0.39	0.39	0.39	1.51	1.68	1.70	330.0%
Biomass fired CHPs	0.00	0.00	0.00	0.00	0.00	0.11	0.16	0.22	-
Coal fired CHPs	0.00	0.00	0.00	0.00	0.00	0.23	0.33	0.39	-
Coal-fired	8.00	20.17	32.47	55.99	8.00	20.37	30.02	42.52	-24.1%
Diesel-fired	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.0%
Fuel Oil CHPs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Gas fired CHPs	0.00	0.00	0.00	0.00	0.00	0.15	0.35	0.68	-
Gas-fired	7.91	10.92	21.85	35.13	7.91	7.91	11.14	18.59	-47.1%
Hydro	14.84	19.46	20.71	20.29	14.84	20.70	21.87	25.57	26.0%
Solar	0.00	0.00	0.00	0.00	0.00	4.43	5.22	11.54	-
Wind	0.00	0.00	0.00	0.00	0.00	1.54	3.25	8.59	-
Total	**31.78**	**51.58**	**76.07**	**112.46**	**31.78**	**57.60**	**74.68**	**110.44**	**-1.8%**

NDC Pathways Analysis: Power Plant Installed Capacity (GW)

Scenario	NDC-25%					NDC-30%				
Plant Type	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**
Biomass-fired	0.39	1.55	1.83	3.28	731.59%	0.39	1.60	1.83	3.28	731.6%
Biomass fired CHPs	0.00	0.08	0.18	0.22	-	0.00	0.12	0.26	0.30	-
Coal fired CHPs	0.00	0.23	0.37	0.45	-	0.00	0.23	0.33	0.41	-
Coal-fired	8.00	20.37	28.83	38.55	-31.16%	8.00	20.37	26.63	36.22	-35.3%
Diesel-fired	0.65	0.65	0.65	0.65	0.00%	0.65	0.65	0.65	0.65	0.0%
Fuel Oil CHPs	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	-
Gas fired CHPs	0.00	0.19	0.34	0.68	-	0.00	0.15	0.26	0.59	-
Gas-fired	7.91	7.91	11.65	13.77	-60.82%	7.91	7.91	11.78	11.63	-66.9%
Hydro	14.84	20.70	21.87	29.12	43.50%	14.84	20.70	23.39	30.62	50.9%
Solar	0.00	4.43	5.22	14.38	-	0.00	4.43	5.22	20.04	-
Wind	0.00	1.54	4.52	10.44	-	0.00	1.54	4.52	13.50	-
Total	**31.78**	**57.65**	**75.46**	**111.54**	**-0.82%**	**31.78**	**57.69**	**74.87**	**117.23**	**4.2%**

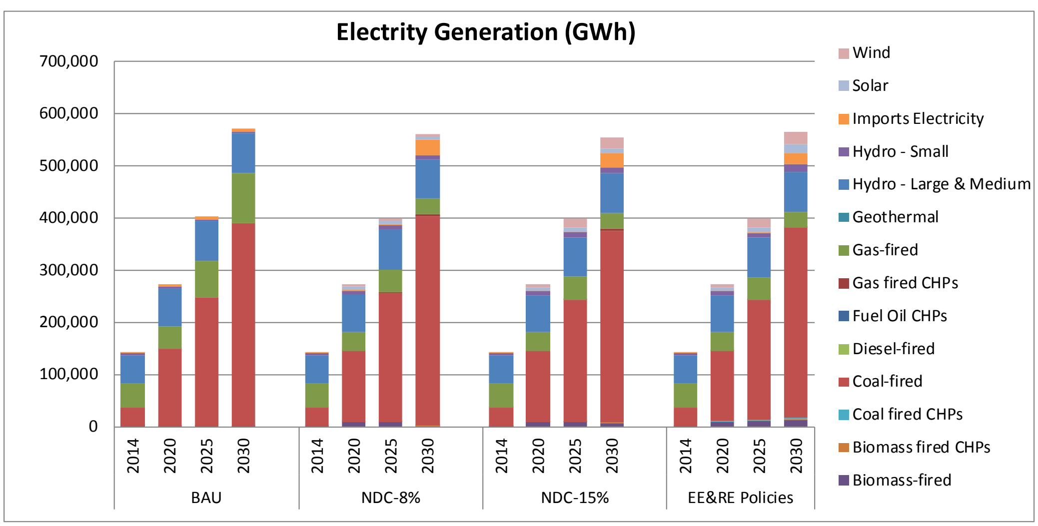


NDC Pathways Analysis: Electrity Generation (GWh)

Scenario	BAU				NDC-8%				
Plant Type	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Biomass-fired	779	806	806	806	779	7,720	7,826	701	-13.0%
Biomass fired CHPs	0	0	0	0	0	159	368	599	-
Coal fired CHPs	0	0	0	0	0	351	511	511	-
Coal-fired	36,175	147,869	246,368	389,334	36,175	137,521	247,358	402,039	3.3%
Diesel-fired	73	59	59	59	73	59	59	59	0.0%
Fuel Oil CHPs	0	0	0	0	0	0	0	0	-
Gas fired CHPs	0	0	0	0	0	265	1,518	3,378	-
Gas-fired	45,387	43,990	70,045	96,100	45,387	36,310	43,259	29,523	-69.3%
Geothermal	0	0	0	0	0	0	0	0	-
Hydro - Large & Medium	54,559	72,543	76,630	75,749	54,559	71,144	75,927	74,078	-2.2%
Hydro - Small	3,300	3,300	3,300	3,300	3,300	7,200	8,821	10,441	216.4%
Imports Electricity	1,778	5,450	6,610	6,860	1,778	1,722	2,198	29,500	330.0%
Solar	0	0	0	0	0	6,058	6,058	6,058	-
Wind	0	0	0	0	0	4,653	4,653	4,653	-
Total	142,052	274,016	403,817	572,207	142,052	273,161	398,556	561,539	-1.9%

NDC Pathways Analysis: Electrity Generation (GWh)

Scenario	NDC-15%					EE&RE Policies				
Plant Type	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Biomass-fired	779	7,720	7,826	6,216	671.7%	779	8,403	10,935	13,085	1524.3%
Biomass fired CHPs	0	436	869	1,423	-	0	436	872	1,315	-
Coal fired CHPs	0	712	989	993	-	0	999	1,833	3,014	-
Coal-fired	36,175	135,726	233,093	367,568	-5.6%	36,175	134,908	228,891	342,560	-12.0%
Diesel-fired	73	59	59	59	0.0%	73	59	59	59	0.0%
Fuel Oil CHPs	0	0	0	0	-	0	0	0	0	-
Gas fired CHPs	0	265	1,193	2,926	-	0	265	360	461	-
Gas-fired	45,387	36,310	43,109	31,092	-67.6%	45,387	36,310	42,924	29,523	-69.3%
Geothermal	0	0	0	0	-	0	0	0	0	-
Hydro - Large & Medium	54,559	71,144	76,298	75,417	-0.4%	54,559	71,144	76,298	75,417	-0.4%
Hydro - Small	3,300	7,200	8,821	10,441	216.4%	3,300	7,200	8,821	14,912	351.9%
Imports Electricity	1,778	1,311	1,983	29,500	330.0%	1,778	1,204	2,418	29,500	330.0%
Solar	0	6,058	6,736	8,472	-	0	6,058	7,287	18,543	-
Wind	0	5,862	17,401	20,091	-	0	5,862	17,401	23,180	-
Total	142,052	272,803	398,377	554,199	-3.1%	142,052	272,848	398,099	551,569	-3.6%

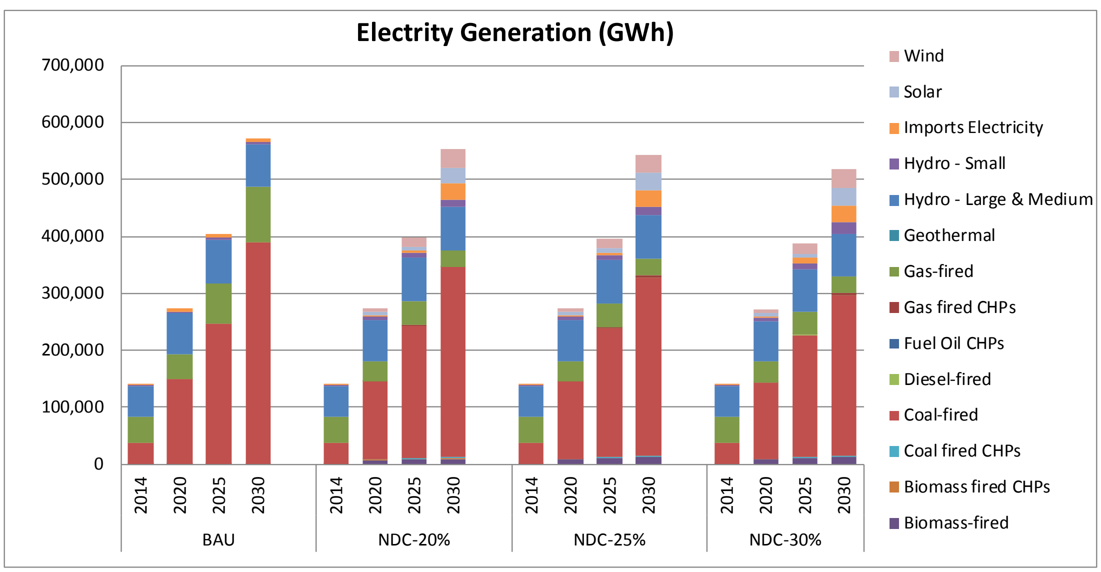


NDC Pathways Analysis: Electrity Generation (GWh)

Scenario	BAU				NDC-20%				
Plant Type	**2014**	**2020**	**2025**	**2030**	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**
Biomass-fired	779	806	806	806	779	7,735	7,841	9,151	1035.9%
Biomass fired CHPs	0	0	0	0	0	436	786	962	-
Coal fired CHPs	0	0	0	0	0	782	1,648	3,037	-
Coal-fired	36,175	147,869	246,368	389,334	36,175	135,991	233,243	332,406	-14.6%
Diesel-fired	73	59	59	59	73	59	59	59	0.0%
Fuel Oil CHPs	0	0	0	0	0	0	0	0	-
Gas fired CHPs	0	0	0	0	0	265	360	461	-
Gas-fired	45,387	43,990	70,045	96,100	45,387	36,310	42,902	29,523	-69.3%
Geothermal	0	0	0	0	0	0	0	0	-
Hydro - Large & Medium	54,559	72,543	76,630	75,749	54,559	71,144	76,298	75,417	-0.4%
Hydro - Small	3,300	3,300	3,300	3,300	3,300	7,200	8,821	13,132	297.9%
Imports Electricity	1,778	5,450	6,610	6,860	1,778	1,415	2,434	29,500	330.0%
Solar	0	0	0	0	0	6,058	7,287	27,421	-
Wind	0	0	0	0	0	5,862	17,401	31,905	-
Total	**142,052**	**274,016**	**403,817**	**572,207**	**142,052**	**273,256**	**399,079**	**552,974**	**-3.4%**

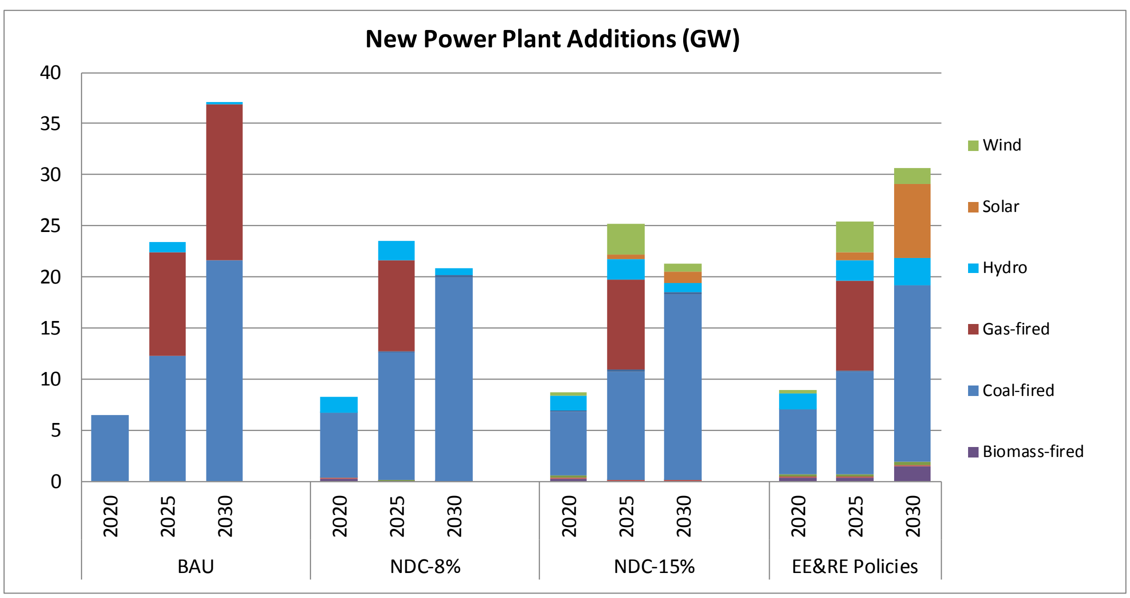
NDC Pathways Analysis: Electrity Generation (GWh)

Scenario	NDC-25%					NDC-30%				
Plant Type	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**
Biomass-fired	779	8,465	11,003	12,445	1444.9%	779	8,465	11,003	12,537	1456.3%
Biomass fired CHPs	0	436	645	869	-	0	436	645	877	-
Coal fired CHPs	0	712	989	1,010	-	0	712	992	1,040	-
Coal-fired	36,175	135,308	225,469	313,905	-19.4%	36,175	133,656	214,593	281,520	-27.7%
Diesel-fired	73	59	59	59	0.0%	73	59	59	59	0.0%
Fuel Oil CHPs	0	0	0	0	-	0	0	0	0	-
Gas fired CHPs	0	265	1,543	3,810	-	0	280	1,556	3,788	-
Gas-fired	45,387	36,310	42,280	29,523	-69.3%	45,387	36,310	37,884	29,523	-69.3%
Geothermal	0	0	0	0	-	0	0	0	0	-
Hydro - Large & Medium	54,559	71,144	76,298	75,417	-0.4%	54,559	71,144	76,298	75,417	-0.4%
Hydro - Small	3,300	7,200	8,821	14,912	351.9%	3,300	7,200	8,821	20,328	516.0%
Imports Electricity	1,778	1,393	4,185	29,500	330.0%	1,778	1,155	10,500	29,500	330.0%
Solar	0	6,058	7,287	30,213	-	0	6,482	7,712	30,906	-
Wind	0	5,862	17,401	30,939	-	0	5,862	17,998	33,594	-
Total	**142,052**	**273,212**	**395,981**	**542,603**	**-5.2%**	**142,052**	**271,761**	**388,060**	**519,089**	**-9.3%**



NDC Pathways Analysis: Power Plant Builds (GW)									
Scenario	BAU				NDC-8%				
Plant Type	2020	2025	2030	Cum	2020	2025	2030	Cum	Cum Diff BAU
Biomass-fired	0.00	0.00	0.00	0.00	0.28	0.01	0.01	0.30	-
Biomass fired CHPs	0.00	0.00	0.00	0.00	0.04	0.05	0.06	0.15	-
Coal fired CHPs	0.00	0.00	0.00	0.00	0.08	0.04	0.00	0.12	-
Coal-fired	6.50	12.24	21.66	40.39	6.31	12.49	19.89	38.69	-4%
Diesel-fired	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Fuel Oil CHPs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Gas fired CHPs	0.00	0.00	0.00	0.00	0.04	0.17	0.26	0.47	-
Gas-fired	0.00	10.13	15.20	25.34	0.00	8.85	0.00	8.85	-65%
Hydro	0.00	1.05	0.26	1.31	1.53	1.91	0.64	4.08	212%
Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Wind	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Total	6.50	23.43	37.12	67.04	8.27	23.52	20.86	52.66	-21%

NDC Pathways Analysis: Power Plant Builds (GW)										
Scenario	NDC-15%					EE&RE Policies				
Plant Type	2020	2025	2030	Cum	Cum Diff BAU	2020	2025	2030	Cum	Cum Diff BAU
Biomass-fired	0.28	0.01	0.01	0.30	-	0.37	0.36	1.51	2.24	-
Biomass fired CHPs	0.11	0.11	0.14	0.35	-	0.11	0.11	0.11	0.32	-
Coal fired CHPs	0.16	0.06	0.00	0.23	-	0.23	0.19	0.27	0.69	-
Coal-fired	6.31	10.58	18.13	35.02	-13.3%	6.31	10.01	14.35	30.68	-24.1%
Diesel-fired	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	-
Fuel Oil CHPs	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	-
Gas fired CHPs	0.04	0.13	0.24	0.41	-	0.04	0.02	0.02	0.09	-
Gas-fired	0.00	8.85	0.00	8.85	-65.1%	0.00	8.85	0.00	8.85	-65.1%
Hydro	1.53	2.01	0.90	4.45	239.5%	1.53	2.01	2.68	6.22	374.9%
Solar	0.00	0.44	1.12	1.56	-	0.00	0.79	7.25	8.04	-
Wind	0.32	2.98	0.72	4.01	-	0.32	2.98	1.49	4.79	-
Total	8.75	25.17	21.26	55.18	-17.7%	8.90	25.32	27.69	61.92	-7.6%

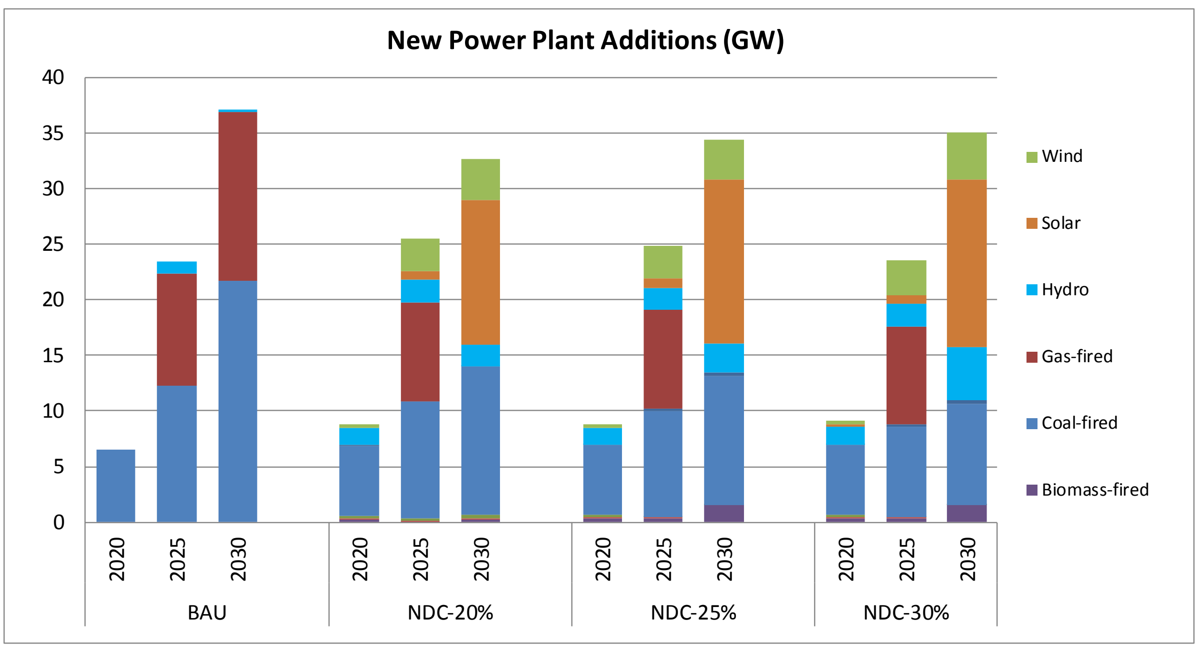


NDC Pathways Analysis: Power Plant Builds (GW)

Scenario	BAU				NDC-20%				
Plant Type	2020	2025	2030	Cum	2020	2025	2030	Cum	Cum Diff BAU
Biomass-fired	0.00	0.00	0.00	0.00	0.28	0.01	0.27	0.56	-
Biomass fired CHPs	0.00	0.00	0.00	0.00	0.11	0.09	0.04	0.24	-
Coal fired CHPs	0.00	0.00	0.00	0.00	0.18	0.20	0.32	0.69	-
Coal-fired	6.50	12.24	21.66	40.39	6.31	10.60	13.39	30.29	-25%
Diesel-fired	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Fuel Oil CHPs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Gas fired CHPs	0.00	0.00	0.00	0.00	0.04	0.02	0.02	0.09	-
Gas-fired	0.00	10.13	15.20	25.34	0.00	8.85	0.00	8.85	-65%
Hydro	0.00	1.05	0.26	1.31	1.53	2.01	1.97	5.52	321%
Solar	0.00	0.00	0.00	0.00	0.00	0.79	12.97	13.76	-
Wind	0.00	0.00	0.00	0.00	0.32	2.98	3.73	7.03	-
Total	6.50	23.43	37.12	67.04	8.76	25.55	32.71	67.02	0%

NDC Pathways Analysis: Power Plant Builds (GW)

Scenario	NDC-25%					NDC-30%				
Plant Type	2020	2025	2030	Cum	Cum Diff BAU	2020	2025	2030	Cum	Cum Diff BAU
Biomass-fired	0.38	0.36	1.51	2.25	-	0.38	0.36	1.51	2.25	-
Biomass fired CHPs	0.11	0.05	0.05	0.21	-	0.11	0.05	0.06	0.22	-
Coal fired CHPs	0.16	0.06	0.00	0.23	-	0.16	0.06	0.01	0.24	-
Coal-fired	6.31	9.55	11.52	27.39	-32.2%	6.31	8.09	9.06	23.46	-41.9%
Diesel-fired	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	-
Fuel Oil CHPs	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	-
Gas fired CHPs	0.04	0.19	0.32	0.55	-	0.04	0.19	0.31	0.54	-
Gas-fired	0.00	8.85	0.00	8.85	-65.1%	0.00	8.85	0.00	8.85	-65.1%
Hydro	1.53	2.01	2.68	6.22	374.9%	1.53	2.01	4.82	8.37	538.9%
Solar	0.00	0.79	14.76	15.56	-	0.27	0.79	15.02	16.08	-
Wind	0.32	2.98	3.48	6.78	-	0.32	3.13	4.28	7.73	-
Total	8.85	24.85	34.34	68.04	1.5%	9.13	23.54	35.07	67.73	1.0%

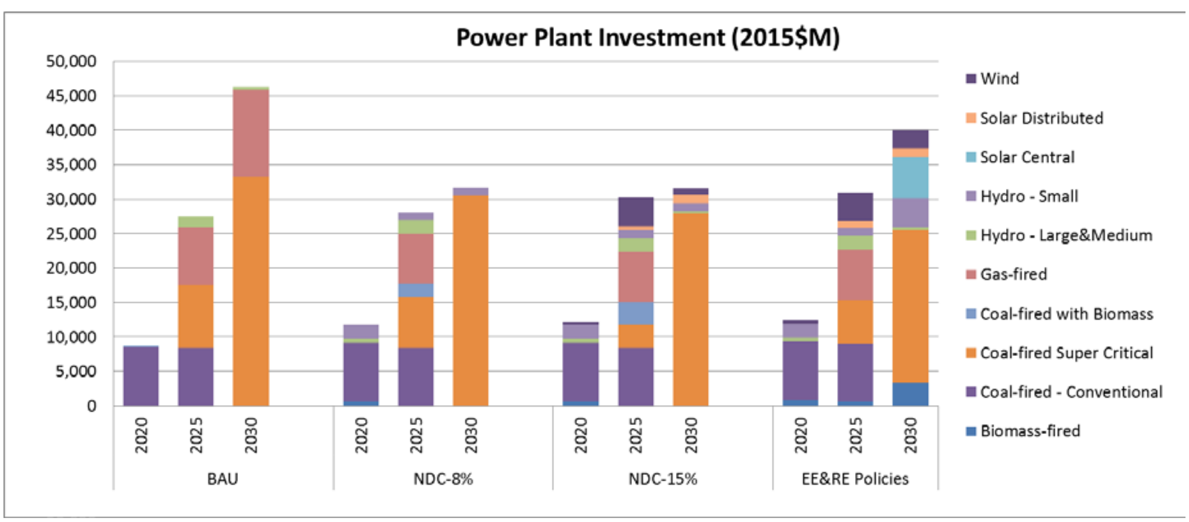


NDC Pathways Analysis: Power Plant Investment (2015$M)

Scenario	BAU				NDC-8%				
Plant Type	2020	2025	2030	Cum	2020	2025	2030	Cum	Cum Diff BAU
Biomass-fired	$ -	$ -	$ -	$ -	$ 681	$ 13	$ 8	$ 703	-
Coal-fired - Conventional	$ 8,471	$ 8,445	$ -	$ 16,916	$ 8,471	$ 8,445	$ -	$ 16,916	0%
Coal-fired Super Critical	$ -	$ 9,042	$ 33,258	$ 42,300	$ -	$ 7,311	$ 30,562	$ 37,873	-10%
Coal-fired with Biomass	$ 250	$ -	$ -	$ 250	$ -	$ 1,931	$ -	$ 1,931	673%
Gas-fired	$ -	$ 8,393	$ 12,592	$ 20,985	$ -	$ 7,330	$ -	$ 7,330	-65%
Hydro - Large&Medium	$ -	$ 1,575	$ 390	$ 1,965	$ 608	$ 1,900	$ -	$ 2,508	28%
Hydro - Small	$ -	$ -	$ -	$ -	$ 1,969	$ 1,125	$ 1,125	$ 4,219	-
Solar Central	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-
Solar Distributed	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-
Wind	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-
Total	**$ 8,721**	**$ 27,454**	**$ 46,240**	**$ 82,415**	**$ 11,729**	**$ 28,055**	**$ 31,695**	**$ 71,479**	**-13%**

NDC Pathways Analysis: Power Plant Investment (2015$M)

Scenario	NDC-15%					EE&RE Policies				
Plant Type	2020	2025	2030	Cum	Cum Diff BAU	2020	2025	2030	Cum	Cum Diff BAU
Biomass-fired	$ 681	$ 13	$ 13	$ 708	-	$ 850	$ 651	$ 3,338	$ 4,838	-
Coal-fired - Conventional	$ 8,471	$ 8,445	$ -	$ 16,916	0.0%	$ 8,471	$ 8,445	$ -	$ 16,916	0.0%
Coal-fired Super Critical	$ -	$ 3,280	$ 27,874	$ 31,154	-26.4%	$ -	$ 6,216	$ 22,160	$ 28,376	-32.9%
Coal-fired with Biomass	$ -	$ 3,243	$ -	$ 3,243	1198.7%	$ -	$ -	$ -	$ -	-100.0%
Gas-fired	$ -	$ 7,330	$ -	$ 7,330	-65.1%	$ -	$ 7,330	$ -	$ 7,330	-65.1%
Hydro - Large&Medium	$ 608	$ 2,058	$ 390	$ 3,056	55.5%	$ 608	$ 2,058	$ 390	$ 3,056	55.5%
Hydro - Small	$ 1,969	$ 1,125	$ 1,125	$ 4,219	-	$ 1,969	$ 1,125	$ 4,228	$ 7,322	-
Solar Central	$ -	$ -	$ -	$ -	-	$ -	$ -	$ 6,016	$ 6,016	-
Solar Distributed	$ -	$ 546	$ 1,261	$ 1,807	-	$ -	$ 1,002	$ 1,261	$ 2,263	-
Wind	$ 466	$ 4,183	$ 964	$ 5,612	-	$ 466	$ 4,183	$ 2,550	$ 7,199	-
Total	**$ 12,195**	**$ 30,222**	**$ 31,627**	**$ 74,044**	**-10.2%**	**$ 12,363**	**$ 31,008**	**$ 39,944**	**$ 83,315**	**1.1%**

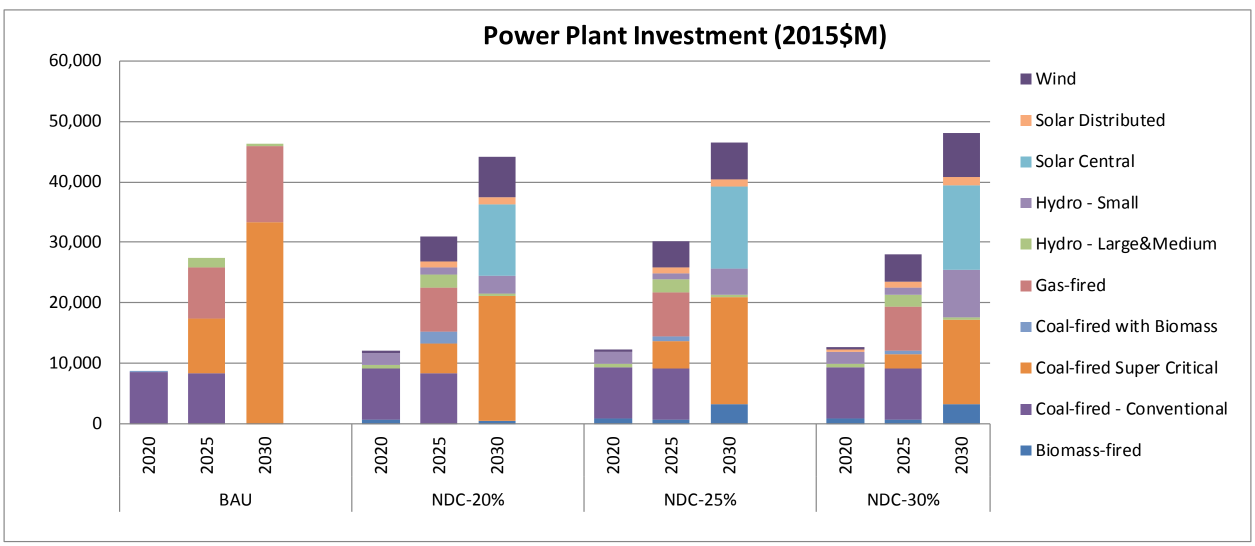


NDC Pathways Analysis: Power Plant Investment (2015$M)

Scenario	BAU				NDC-20%				
Plant Type	2020	2025	2030	Cum	2020	2025	2030	Cum	Cum Diff BAU
Biomass-fired	$ -	$ -	$ -	$ -	$ 681	$ 13	$ 463	$ 1,158	-
Coal-fired - Conventional	$ 8,471	$ 8,445	$ -	$ 16,916	$ 8,471	$ 8,445	$ -	$ 16,916	0%
Coal-fired Super Critical	$ -	$ 9,042	$ 33,258	$ 42,300	$ -	$ 4,873	$ 20,600	$ 25,472	-40%
Coal-fired with Biomass	$ 250	$ -	$ -	$ 250	$ -	$ 1,933	$ -	$ 1,933	674%
Gas-fired	$ -	$ 8,393	$ 12,592	$ 20,985	$ -	$ 7,330	$ -	$ 7,330	-65%
Hydro - Large&Medium	$ -	$ 1,575	$ 390	$ 1,965	$ 608	$ 2,058	$ 390	$ 3,056	56%
Hydro - Small	$ -	$ -	$ -	$ -	$ 1,969	$ 1,125	$ 2,992	$ 6,086	-
Solar Central	$ -	$ -	$ -	$ -	$ -	$ -	$ 11,793	$ 11,793	-
Solar Distributed	$ -	$ -	$ -	$ -	$ -	$ 1,002	$ 1,266	$ 2,268	-
Wind	$ -	$ -	$ -	$ -	$ 466	$ 4,183	$ 6,564	$ 11,213	-
Total	**$ 8,721**	**$ 27,454**	**$ 46,240**	**$ 82,415**	**$ 12,195**	**$ 30,960**	**$ 44,069**	**$ 87,224**	**6%**

NDC Pathways Analysis: Power Plant Investment (2015$M)

Scenario	NDC-25%					NDC-30%				
Plant Type	2020	2025	2030	Cum	Cum Diff BAU	2020	2025	2030	Cum	Cum Diff BAU
Biomass-fired	$ 874	$ 651	$ 3,239	$ 4,764	-	$ 874	$ 651	$ 3,252	$ 4,777	-
Coal-fired - Conventional	$ 8,471	$ 8,445	$ -	$ 16,916	0.0%	$ 8,471	$ 8,445	$ -	$ 16,916	0.0%
Coal-fired Super Critical	$ -	$ 4,645	$ 17,747	$ 22,392	-47.1%	$ -	$ 2,368	$ 13,928	$ 16,296	-61.5%
Coal-fired with Biomass	$ -	$ 687	$ -	$ 687	175.0%	$ -	$ 588	$ -	$ 588	135.6%
Gas-fired	$ -	$ 7,330	$ -	$ 7,330	-65.1%	$ -	$ 7,330	$ -	$ 7,330	-65.1%
Hydro - Large&Medium	$ 608	$ 2,058	$ 390	$ 3,056	55.5%	$ 608	$ 2,058	$ 390	$ 3,056	55.5%
Hydro - Small	$ 1,969	$ 1,125	$ 4,228	$ 7,322	-	$ 1,969	$ 1,125	$ 7,987	$ 11,081	-
Solar Central	$ -	$ -	$ 13,618	$ 13,618	-	$ -	$ -	$ 13,922	$ 13,922	-
Solar Distributed	$ -	$ 1,002	$ 1,266	$ 2,268	-	$ 335	$ 1,002	$ 1,275	$ 2,612	-
Wind	$ 466	$ 4,183	$ 6,111	$ 10,760	-	$ 466	$ 4,477	$ 7,347	$ 12,290	-
Total	**$ 12,388**	**$ 30,124**	**$ 46,601**	**$ 89,113**	**8.1%**	**$ 12,723**	**$ 28,043**	**$ 48,102**	**$ 88,868**	**7.8%**



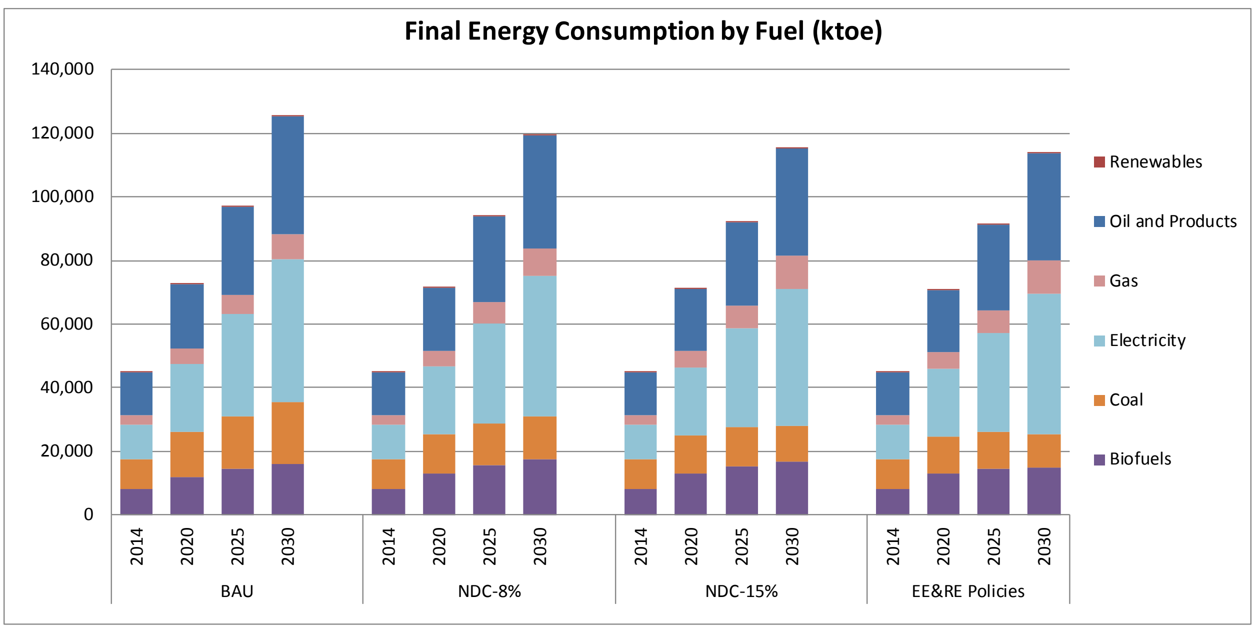
C.4 Final Energy Consumption

NDC Pathways Analysis: Final Energy Consumption by Fuel (ktoe)

Scenario	BAU				NDC-8%				
Energy Carrier	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Biofuels	8,117	12,049	14,652	15,983	8,117	13,078	15,850	17,606	10.2%
Coal	9,247	13,994	16,441	19,508	9,247	12,161	13,058	13,454	-31.0%
Electricity	11,087	21,545	31,907	44,963	11,087	21,416	31,313	43,930	-2.3%
Gas	2,770	4,736	6,151	7,638	2,770	4,989	6,752	8,902	16.5%
Oil and Products	13,811	20,285	27,754	37,123	13,811	19,656	26,854	35,250	-5.0%
Renewables	0	1	4	9	0	7	4	44	413.4%
Total	45,032	72,609	96,908	125,223	45,032	71,308	93,832	119,187	-4.8%

NDC Pathways Analysis: Final Energy Consumption by Fuel (ktoe)

Scenario	NDC-15%					EE&RE Policies				
Energy Carrier	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Biofuels	8,117	13,097	15,266	16,871	5.6%	8,117	12,892	14,393	14,942	-6.5%
Coal	9,247	12,013	12,225	10,986	-43.7%	9,247	11,743	11,814	10,448	-46.4%
Electricity	11,087	21,338	31,080	43,159	-4.0%	11,087	21,319	31,046	42,994	-4.4%
Gas	2,770	5,158	7,267	10,386	36.0%	2,770	5,309	7,176	10,325	35.2%
Oil and Products	13,811	19,319	26,215	33,717	-9.2%	13,811	19,443	26,874	34,848	-6.1%
Renewables	0	10	5	65	654.8%	0	12	7	15	78.3%
Total	45,032	70,935	92,060	115,184	-8.0%	45,032	70,718	91,310	113,573	-9.3%

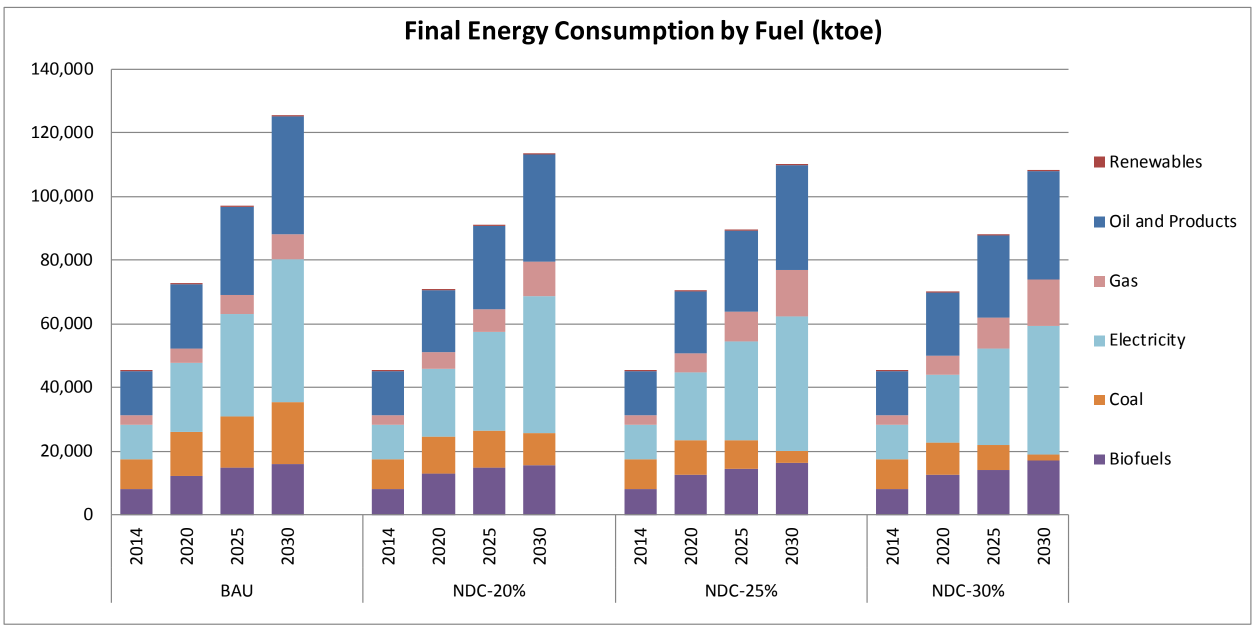


NDC Pathways Analysis: Final Energy Consumption by Fuel (ktoe)

Scenario	BAU				NDC-20%				
Energy Carrier	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Biofuels	8,117	12,049	14,652	15,983	8,117	12,917	14,742	15,525	-2.9%
Coal	9,247	13,994	16,441	19,508	9,247	11,692	11,498	10,166	-47.9%
Electricity	11,087	21,545	31,907	44,963	11,087	21,368	31,151	43,139	-4.1%
Gas	2,770	4,736	6,151	7,638	2,770	5,298	7,337	10,561	38.3%
Oil and Products	13,811	20,285	27,754	37,123	13,811	19,244	26,141	33,751	-9.1%
Renewables	0	1	4	9	0	12	7	15	78.3%
Total	45,032	72,609	96,908	125,223	45,032	70,532	90,877	113,158	-9.6%

NDC Pathways Analysis: Final Energy Consumption by Fuel (ktoe)

Scenario	NDC-25%					NDC-30%				
Energy Carrier	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Biofuels	8,117	12,725	14,432	16,380	2.5%	8,117	12,449	14,081	17,226	7.8%
Coal	9,247	10,718	9,092	3,811	-80.5%	9,247	10,285	7,960	1,742	-91.1%
Electricity	11,087	21,370	30,875	42,221	-6.1%	11,087	21,257	30,251	40,370	-10.2%
Gas	2,770	5,928	9,394	14,341	87.7%	2,770	6,060	9,600	14,751	93.1%
Oil and Products	13,811	19,355	25,624	33,158	-10.7%	13,811	19,611	25,965	33,891	-8.7%
Renewables	0	17	10	23	161.6%	0	17	10	23	161.6%
Total	45,032	70,112	89,427	109,932	-12.2%	45,032	69,679	87,868	108,004	-13.8%

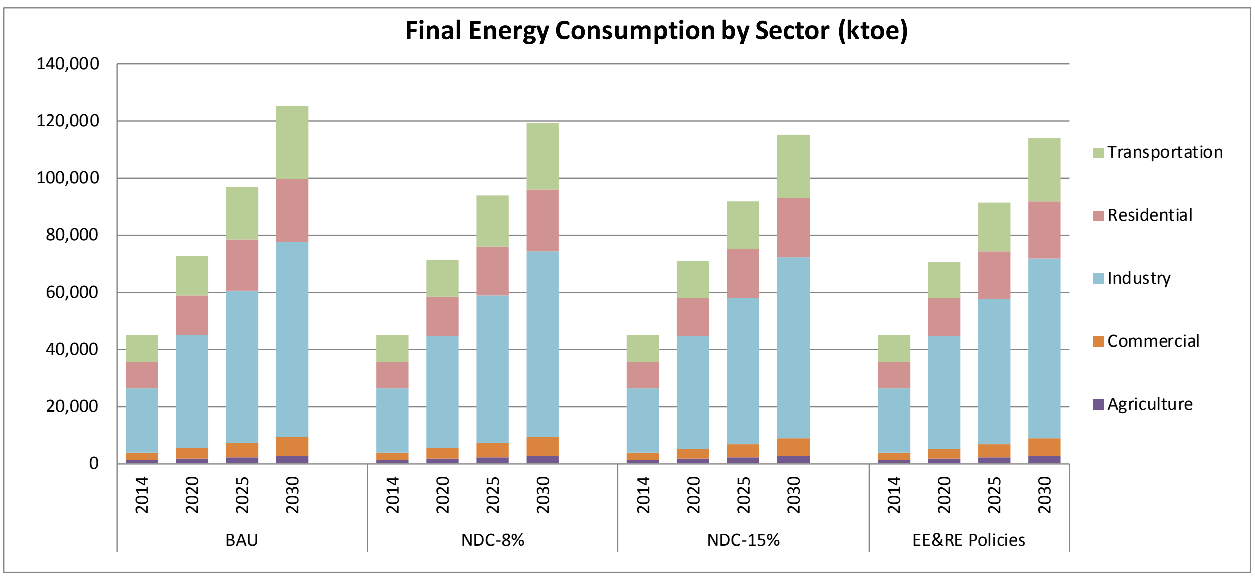


NDC Pathways Analysis: Final Energy Consumption by Sector (ktoe)

Scenario	BAU				NDC-8%				
Sector	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Agriculture	1,574	1,891	2,212	2,611	1,574	1,889	2,191	2,547	-2.5%
Commercial	2,369	3,500	4,912	6,783	2,369	3,482	4,852	6,617	-2.4%
Industry	22,336	39,796	53,299	68,148	22,336	39,327	51,707	65,220	-4.3%
Residential	9,507	13,886	17,980	22,391	9,507	13,701	17,430	21,452	-4.2%
Transportation	9,247	13,537	18,505	25,290	9,247	12,909	17,651	23,351	-7.7%
Total	**45,032**	**72,609**	**96,908**	**125,223**	**45,032**	**71,308**	**93,832**	**119,187**	**-4.8%**

NDC Pathways Analysis: Final Energy Consumption by Sector (ktoe)

Scenario	NDC-15%					EE&RE Policies				
Sector	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Agriculture	1,574	1,878	2,173	2,550	-2.3%	1,574	1,873	2,155	2,515	-3.7%
Commercial	2,369	3,467	4,794	6,483	-4.4%	2,369	3,460	4,766	6,440	-5.1%
Industry	22,336	39,332	50,995	63,442	-6.9%	22,336	39,309	50,856	63,091	-7.4%
Residential	9,507	13,626	17,185	20,810	-7.1%	9,507	13,445	16,620	19,628	-12.3%
Transportation	9,247	12,631	16,913	21,898	-13.4%	9,247	12,631	16,913	21,898	-13.4%
Total	**45,032**	**70,935**	**92,060**	**115,184**	**-8.0%**	**45,032**	**70,718**	**91,310**	**113,573**	**-9.3%**

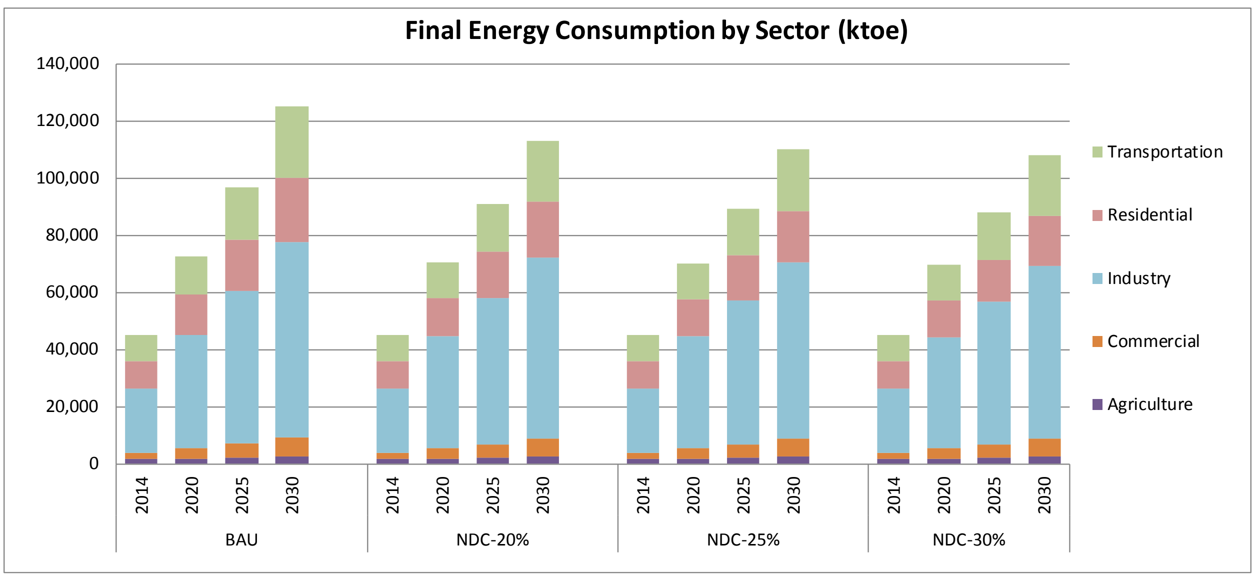


NDC Pathways Analysis: Final Energy Consumption by Sector (ktoe)

Scenario	BAU				NDC-20%				
Sector	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Agriculture	1,574	1,891	2,212	2,611	1,574	1,873	2,155	2,515	-3.7%
Commercial	2,369	3,500	4,912	6,783	2,369	3,460	4,766	6,440	-5.1%
Industry	22,336	39,796	53,299	68,148	22,336	39,302	50,895	63,268	-7.2%
Residential	9,507	13,886	17,980	22,391	9,507	13,445	16,620	19,611	-12.4%
Transportation	9,247	13,537	18,505	25,290	9,247	12,452	16,441	21,324	-15.7%
Total	**45,032**	**72,609**	**96,908**	**125,223**	**45,032**	**70,532**	**90,877**	**113,158**	**-9.6%**

NDC Pathways Analysis: Final Energy Consumption by Sector (ktoe)

Scenario	NDC-25%					NDC-30%				
Sector	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Agriculture	1,574	1,854	2,152	2,520	-3.5%	1,574	1,849	2,137	2,494	-4.5%
Commercial	2,369	3,435	4,689	6,281	-7.4%	2,369	3,412	4,637	6,175	-9.0%
Industry	22,336	39,215	50,424	61,840	-9.3%	22,336	39,102	49,899	60,485	-11.2%
Residential	9,507	13,155	15,720	17,968	-19.8%	9,507	12,864	14,753	17,525	-21.7%
Transportation	9,247	12,452	16,441	21,324	-15.7%	9,247	12,452	16,441	21,324	-15.7%
Total	**45,032**	**70,112**	**89,427**	**109,932**	**-12.2%**	**45,032**	**69,679**	**87,868**	**108,004**	**-13.8%**

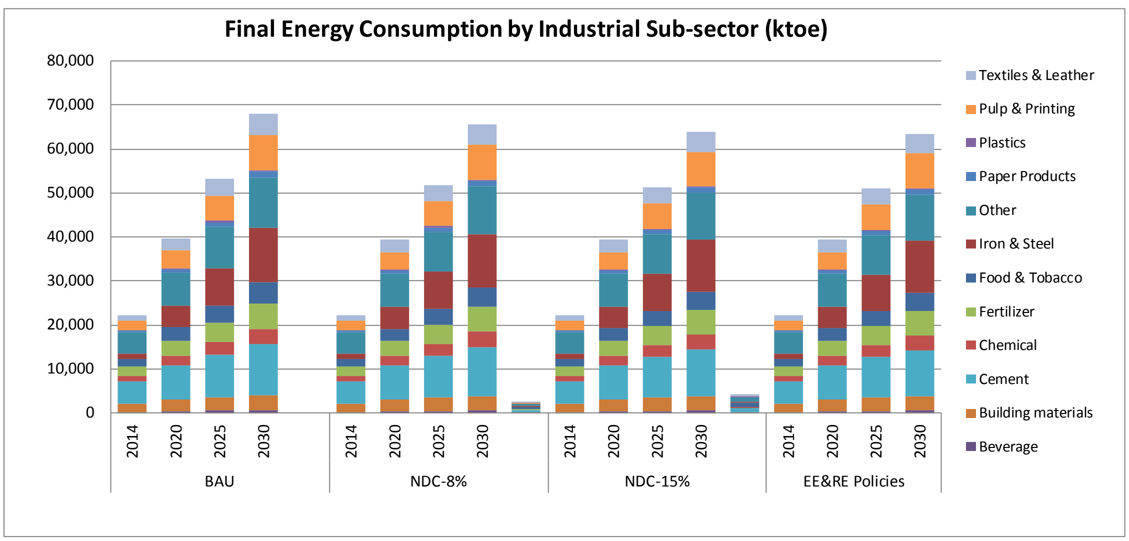


NDC Pathways Analysis: Final Energy Consumption by Industrial Sub-sector (ktoe)

Scenario	BAU				NDC-8%				
Sub-Sector	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Beverage	277	442	559	686	277	438	542	654	-4.7%
Building materials	1,863	2,683	3,044	3,265	1,863	2,672	3,016	3,211	-1.7%
Cement	5,059	7,787	9,693	11,747	5,059	7,666	9,351	11,166	-4.9%
Chemical	1,312	2,148	2,761	3,442	1,312	2,145	2,760	3,468	0.8%
Fertilizer	2,001	3,415	4,483	5,694	2,001	3,399	4,434	5,565	-2.3%
Food & Tobacco	1,747	2,981	3,913	4,969	1,747	2,879	3,631	4,467	-10.1%
Iron & Steel	1,334	5,032	8,530	12,403	1,334	4,997	8,363	12,075	-2.6%
Other	4,844	7,553	9,397	11,383	4,844	7,463	9,073	10,833	-4.8%
Paper Products	311	705	1,002	1,284	311	703	990	1,252	-2.5%
Plastics	161	264	339	423	161	258	327	402	-5.0%
Pulp & Printing	2,037	3,957	5,755	7,998	2,037	3,979	5,734	7,894	-1.3%
Textiles & Leather	1,390	2,829	3,822	4,853	1,390	2,792	3,691	4,619	-4.8%
Total	22,336	39,796	53,299	68,148	22,336	39,394	51,914	65,606	-3.7%

NDC Pathways Analysis: Final Energy Consumption by Industrial Sub-sector (ktoe)

Scenario	NDC-15%					EE&RE Policies				
Sub-Sector	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Beverage	277	440	544	656	-4.5%	277	440	544	655	-4.6%
Building materials	1,863	2,668	2,985	3,147	-3.6%	1,863	2,700	2,995	3,122	-4.4%
Cement	5,059	7,720	9,145	10,632	-9.5%	5,059	7,717	9,132	10,565	-10.1%
Chemical	1,312	2,145	2,735	3,424	-0.5%	1,312	2,144	2,675	3,250	-5.6%
Fertilizer	2,001	3,399	4,416	5,546	-2.6%	2,001	3,399	4,420	5,574	-2.1%
Food & Tobacco	1,747	2,878	3,490	4,134	-16.8%	1,747	2,877	3,481	4,158	-16.3%
Iron & Steel	1,334	5,014	8,343	11,986	-3.4%	1,334	5,005	8,296	11,871	-4.3%
Other	4,844	7,457	8,934	10,457	-8.1%	4,844	7,450	8,894	10,347	-9.1%
Paper Products	311	703	979	1,233	-3.9%	311	702	973	1,220	-5.0%
Plastics	161	257	316	381	-10.0%	161	256	306	360	-15.0%
Pulp & Printing	2,037	3,970	5,727	7,829	-2.1%	2,037	3,965	5,779	7,953	-0.6%
Textiles & Leather	1,390	2,803	3,643	4,477	-7.8%	1,390	2,800	3,626	4,429	-8.7%
Total	22,336	39,454	51,258	63,902	-6.2%	22,336	39,455	51,120	63,503	-6.8%

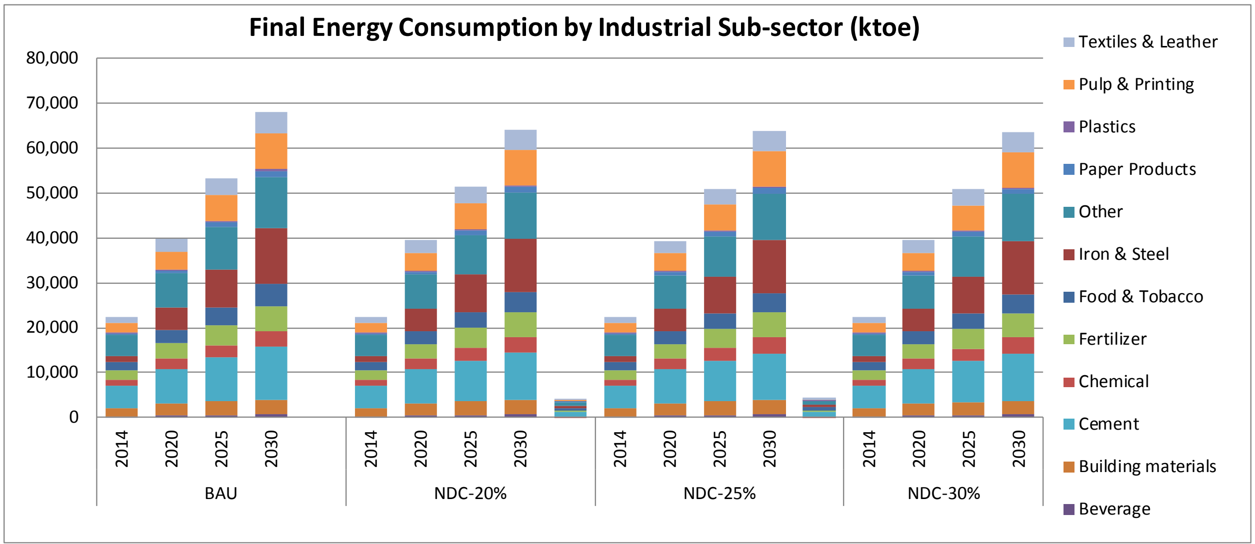


NDC Pathways Analysis: Final Energy Consumption by Industrial Sub-sector (ktoe)

Scenario	BAU				NDC-20%				
Sub-Sector	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Beverage	277	442	559	686	277	440	544	653	-4.9%
Building materials	1,863	2,683	3,044	3,265	1,863	2,700	2,995	3,149	-3.6%
Cement	5,059	7,787	9,693	11,747	5,059	7,717	9,132	10,565	-10.1%
Chemical	1,312	2,148	2,761	3,442	1,312	2,202	2,829	3,561	3.5%
Fertilizer	2,001	3,415	4,483	5,694	2,001	3,395	4,421	5,574	-2.1%
Food & Tobacco	1,747	2,981	3,913	4,969	1,747	2,877	3,576	4,341	-12.6%
Iron & Steel	1,334	5,032	8,528	12,399	1,334	5,005	8,295	11,869	-4.3%
Other	4,844	7,553	9,397	11,382	4,844	7,450	8,894	10,501	-7.7%
Paper Products	311	705	1,002	1,284	311	702	973	1,220	-5.0%
Plastics	161	264	339	423	161	256	306	360	-14.9%
Pulp & Printing	2,037	3,957	5,755	7,998	2,037	3,965	5,705	7,799	-2.5%
Textiles & Leather	1,390	2,829	3,822	4,852	1,390	2,800	3,626	4,429	-8.7%
Total	22,336	39,796	53,297	68,141	22,336	39,509	51,296	64,022	-6.0%

NDC Pathways Analysis: Final Energy Consumption by Industrial Sub-sector (ktoe)

Scenario	NDC-25%					NDC-30%				
Sub-Sector	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Beverage	277	440	544	653	-4.9%	277	440	543	650	-5.4%
Building materials	1,863	2,719	2,995	3,149	-3.6%	1,863	2,698	2,982	3,118	-4.5%
Cement	5,059	7,660	9,075	10,508	-10.5%	5,059	7,714	9,118	10,532	-10.3%
Chemical	1,312	2,221	2,795	3,547	3.1%	1,312	2,200	2,751	3,493	1.5%
Fertilizer	2,001	3,384	4,332	5,529	-2.9%	2,001	3,381	4,327	5,522	-3.0%
Food & Tobacco	1,747	2,803	3,418	4,208	-15.3%	1,747	2,858	3,402	4,177	-15.9%
Iron & Steel	1,334	5,005	8,295	11,869	-4.3%	1,334	4,995	8,248	11,759	-5.2%
Other	4,844	7,450	8,894	10,501	-7.7%	4,844	7,443	8,937	10,469	-8.0%
Paper Products	311	702	973	1,220	-5.0%	311	700	967	1,207	-6.0%
Plastics	161	256	306	360	-14.9%	161	256	302	348	-17.8%
Pulp & Printing	2,037	3,967	5,727	7,831	-2.1%	2,037	3,957	5,697	7,792	-2.6%
Textiles & Leather	1,390	2,800	3,626	4,429	-8.7%	1,390	2,798	3,610	4,382	-9.7%
Total	22,336	39,407	50,980	63,803	-6.4%	22,336	39,439	50,885	63,447	-6.9%



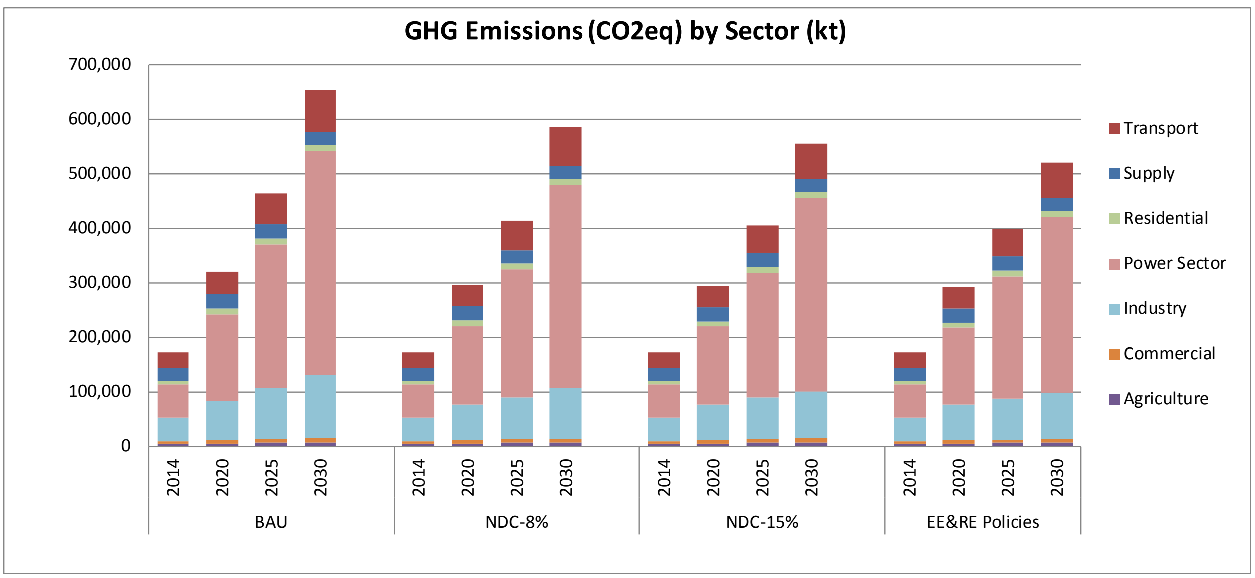
C.5 Emissions

NDC Pathways Analysis: GHG Emissions (CO2eq) by Sector (kt)

Scenario	BAU				NDC-8%				
Sector	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Agriculture	4,413	5,368	6,213	7,338	4,413	5,247	5,821	6,291	-14.3%
Commercial	3,391	4,941	6,452	7,901	3,391	4,886	6,341	6,860	-13.2%
Industry	45,015	72,110	90,032	111,429	45,015	65,703	77,889	91,048	-18.3%
Power Sector	60,077	169,680	274,853	396,964	60,077	153,091	257,366	375,879	-5.3%
Residential	7,131	9,149	10,457	10,850	7,131	9,035	10,114	10,220	-5.8%
Supply	23,835	26,489	27,652	24,710	23,835	26,078	25,681	23,702	-4.1%
Transport	28,241	41,313	56,535	77,349	28,241	39,411	54,007	71,619	-7.4%
Total	172,104	329,051	472,194	636,542	172,104	303,451	437,219	585,619	-8.0%

NDC Pathways Analysis: GHG Emissions (CO2eq) by Sector (kt)

Scenario	NDC-15%					EE&RE Policies				
Sector	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Agriculture	4,413	5,377	5,889	6,748	-8.0%	4,413	5,266	5,723	6,240	-15.0%
Commercial	3,391	4,864	6,339	7,162	-9.4%	3,391	4,835	6,253	7,366	-6.8%
Industry	45,015	65,337	76,152	84,086	-24.5%	45,015	64,928	76,414	85,421	-23.3%
Power Sector	60,077	151,379	241,002	343,085	-13.6%	60,077	150,614	238,059	324,491	-18.3%
Residential	7,131	8,993	9,985	9,936	-8.4%	7,131	8,900	9,696	9,350	-13.8%
Supply	23,835	26,145	25,683	23,221	-6.0%	23,835	26,204	25,734	23,674	-4.2%
Transport	28,241	38,522	51,623	66,822	-13.6%	28,241	38,522	51,623	66,822	-13.6%
Total	172,104	300,616	416,672	541,061	-15.0%	172,104	299,270	413,502	523,365	-17.8%

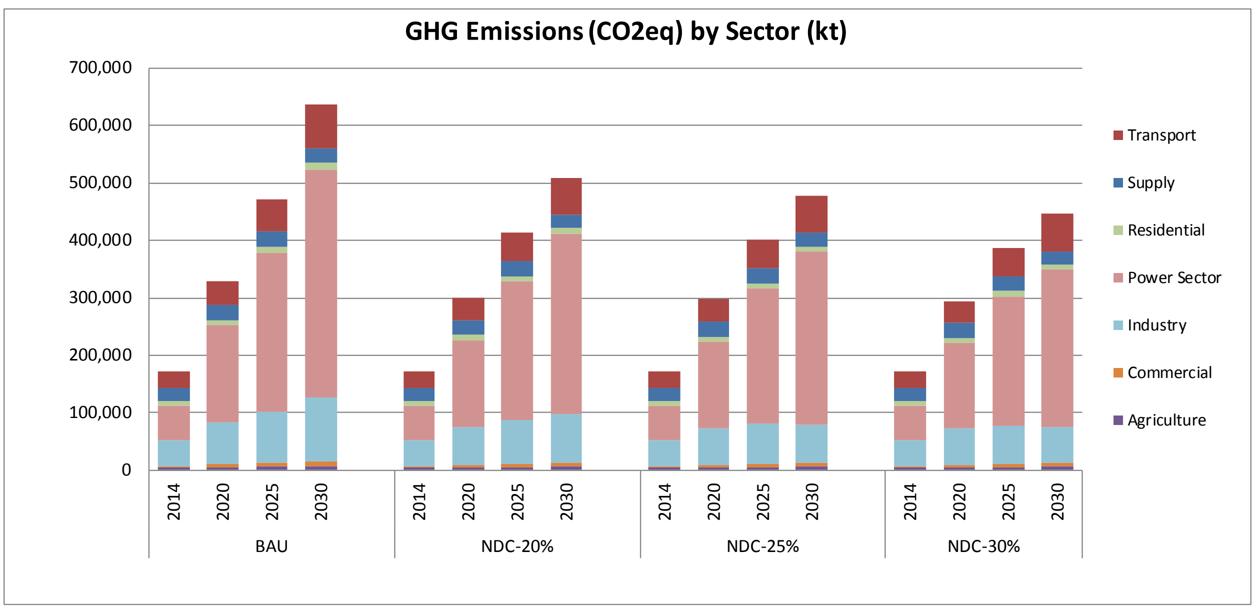


NDC Pathways Analysis: GHG Emissions (CO2eq) by Sector (kt)

Scenario	BAU				NDC-20%				
Sector	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Agriculture	4,413	5,368	6,213	7,338	4,413	5,266	5,723	6,240	-15.0%
Commercial	3,391	4,941	6,452	7,901	3,391	4,835	6,253	7,366	-6.8%
Industry	45,015	72,110	90,032	111,429	45,015	64,719	74,946	83,636	-24.9%
Power Sector	60,077	169,680	274,853	396,964	60,077	151,632	241,118	314,891	-20.7%
Residential	7,131	9,149	10,457	10,850	7,131	8,900	9,696	9,350	-13.8%
Supply	23,835	26,489	27,652	24,710	23,835	26,200	25,276	23,022	-6.8%
Transport	28,241	41,313	56,535	77,349	28,241	37,905	49,986	64,729	-16.3%
Total	**172,104**	**329,051**	**472,194**	**636,542**	**172,104**	**299,457**	**412,998**	**509,234**	**-20.0%**

NDC Pathways Analysis: GHG Emissions (CO2eq) by Sector (kt)

Scenario	NDC-25%					NDC-30%				
Sector	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Agriculture	4,413	5,253	5,785	6,327	-13.8%	4,413	5,236	5,613	6,281	-14.4%
Commercial	3,391	4,702	5,911	6,674	-15.5%	3,391	4,598	5,727	6,558	-17.0%
Industry	45,015	63,050	69,410	67,259	-39.6%	45,015	62,526	66,744	62,720	-43.7%
Power Sector	60,077	150,997	234,968	300,800	-24.2%	60,077	149,422	224,608	274,416	-30.9%
Residential	7,131	8,720	9,132	8,263	-23.8%	7,131	8,632	8,865	7,775	-28.3%
Supply	23,835	26,449	26,174	23,355	-5.5%	23,835	26,501	26,050	23,100	-6.5%
Transport	28,241	37,905	49,986	64,729	-16.3%	28,241	37,905	49,986	64,729	-16.3%
Total	**172,104**	**297,074**	**401,365**	**477,407**	**-25.0%**	**172,104**	**294,820**	**387,592**	**445,580**	-30.0%



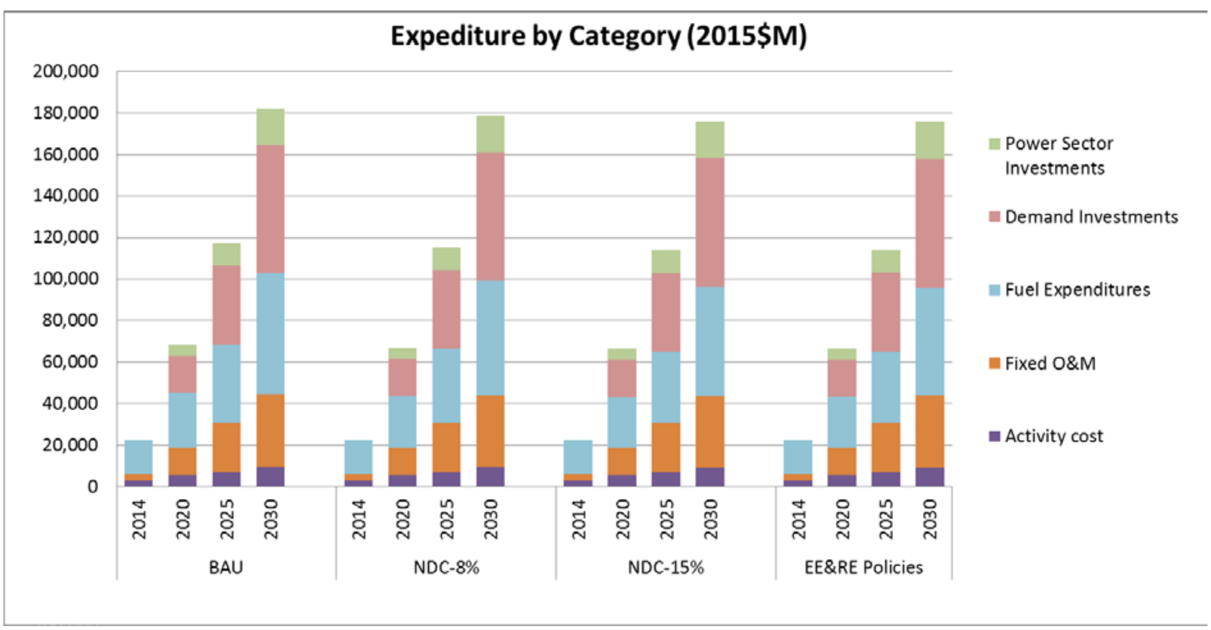
C.6 Expenditures

NDC Pathways Analysis: Expediture by Category (2015$M)

Scenario	BAU				NDC-8%				
Sector	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Activity cost	3,094	5,638	7,428	9,415	3,094	5,578	7,318	9,552	1.5%
Fixed O&M	2,998	13,025	23,128	35,043	2,998	13,192	23,229	34,811	-0.7%
Fuel Expenditures	16,514	26,519	37,988	58,087	16,514	24,867	35,877	54,721	-5.8%
Demand Investments	0	17,931	37,912	61,565	0	17,933	37,927	61,589	0.0%
Power Sector Investments	0	5,293	10,844	17,942	0	5,287	10,841	17,949	0.0%
Taxes	0	0	0	0	0	0	0	0	-
Total	**22,606**	**68,406**	**117,300**	**182,052**	**22,606**	**66,857**	**115,192**	**178,621**	**-1.9%**

NDC Pathways Analysis: Expediture by Category (2015$M)

Scenario	NDC-15%					EE&RE Policies				
Sector	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Activity cost	3,094	5,568	7,251	9,115	-3.2%	3,094	5,573	7,245	9,182	-2.5%
Fixed O&M	2,998	13,206	23,307	34,797	-0.7%	2,998	13,203	23,316	34,861	-0.5%
Fuel Expenditures	16,514	24,453	34,307	52,073	-10.4%	16,514	24,546	34,429	51,614	-11.1%
Demand Investments	0	17,945	37,987	62,028	0.8%	0	17,957	38,047	62,236	1.1%
Power Sector Investments	0	5,278	10,831	17,918	-0.1%	0	5,272	10,814	17,890	-0.3%
Taxes	0	0	0	0	-	0	0	0	0	-
Total	**22,606**	**66,451**	**113,683**	**175,930**	**-3.4%**	**22,606**	**66,551**	**113,851**	**175,783**	**-3.4%**

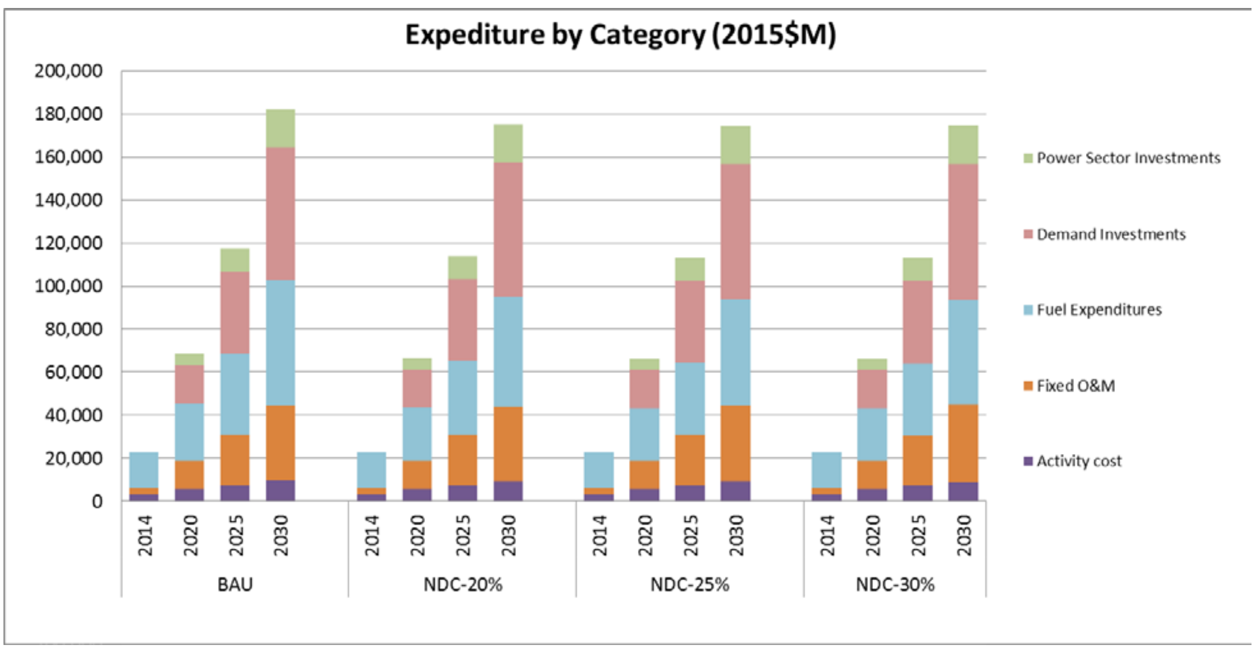


NDC Pathways Analysis: Expediture by Category (2015$M)

Scenario	BAU				NDC-20%				
Sector	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Activity cost	3,094	5,638	7,428	9,415	3,094	5,574	7,245	9,106	-3.3%
Fixed O&M	2,998	13,025	23,128	35,043	2,998	13,196	23,291	34,792	-0.7%
Fuel Expenditures	16,514	26,519	37,988	58,087	16,514	24,494	34,643	51,151	-11.9%
Demand Investments	0	9,028	19,077	30,947	0	9,042	19,150	31,300	1.1%
Power Sector Investments	0	5,293	10,844	17,942	0	5,272	10,814	17,890	-0.3%
Taxes	0	0	0	0	0	0	0	0	-
Total	22,606	68,406	117,300	182,052	22,606	66,493	114,040	175,204	-3.8%

NDC Pathways Analysis: Expediture by Category (2015$M)

Scenario	NDC-25%					NDC-30%				
Sector	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Activity cost	3,094	5,581	7,238	9,069	-3.7%	3,094	5,560	7,135	8,794	-6.6%
Fixed O&M	2,998	13,192	23,308	35,594	1.6%	2,998	13,193	23,367	35,980	2.7%
Fuel Expenditures	16,514	24,265	33,609	49,129	-15.4%	16,514	24,246	33,365	48,602	-16.3%
Demand Investments	0	9,060	19,223	31,561	2.0%	0	9,066	19,341	31,806	2.8%
Power Sector Investments	0	5,272	10,821	17,892	-0.3%	0	5,279	10,838	17,990	0.3%
Taxes	0	0	0	0	-	0	0	0	0	-
Total	22,606	66,298	113,166	174,460	-4.2%	22,606	66,276	113,118	174,625	-4.1%



C.7 Energy and Emission Intensity

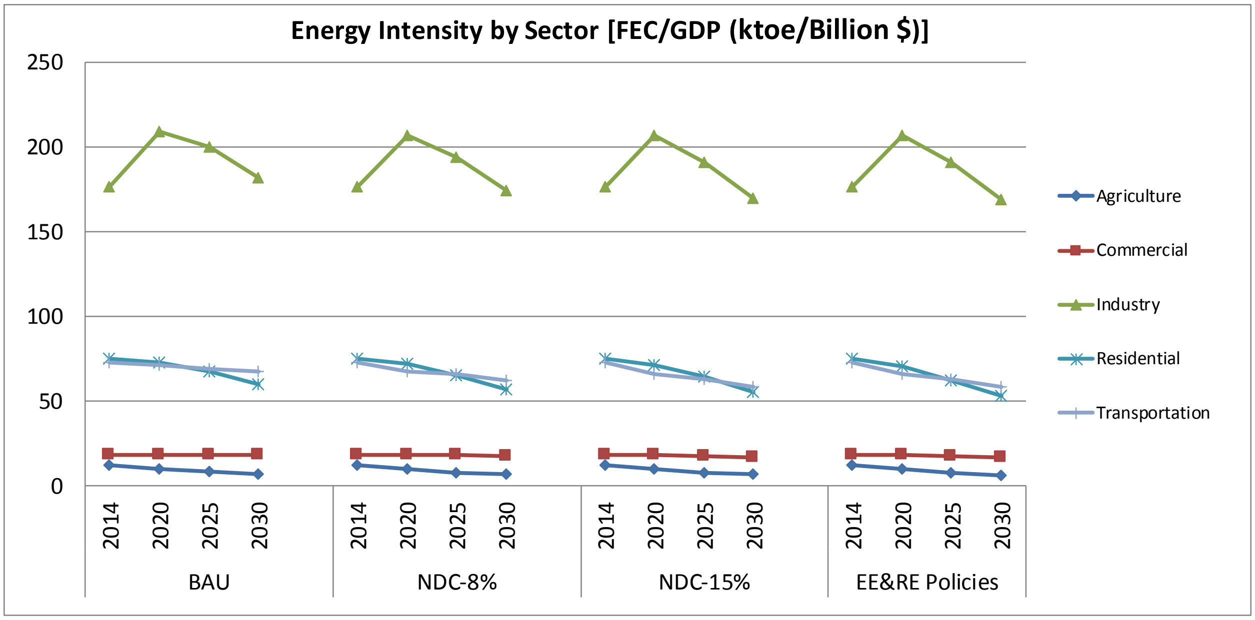
Energy intensity for the Industry sector increases from 2014, the base year, to 2020 before declining. The model assumes aggressive growth in Industry sector energy demand by 2020, but the model only starts applying EE measures in 2018, and there is little time for these measures to have an impact on the energy intensity. After 2020, we see most of the influence of EE measures to reduce energy intensity. This result is an artifact of a prescribed BAU scenario which maintains the status quo from 2010, and does not reflect the implementation on MEPS in the 2010-2016 time frame in order to still claim credit for those reductions.

NDC Pathways Analysis: Energy Intensity by Sector = FEC / GDP

Scenario	BAU				NDC-8%				
Sector	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Agriculture	12.4	9.9	8.3	7.0	12.4	9.9	8.2	6.8	-2.5%
Commercial	18.7	18.4	18.4	18.1	18.7	18.3	18.2	17.7	-2.4%
Industry	176.4	209.4	199.9	182.3	176.4	206.9	194.0	174.4	-4.3%
Residential	75.1	73.1	67.4	59.9	75.1	72.1	65.4	57.4	-4.2%
Transportation	73.0	71.2	69.4	67.6	73.0	67.9	66.2	62.5	-7.7%
Total	**355.6**	**382.0**	**363.5**	**334.9**	**355.6**	**375.2**	**352.0**	**318.8**	**-4.8%**

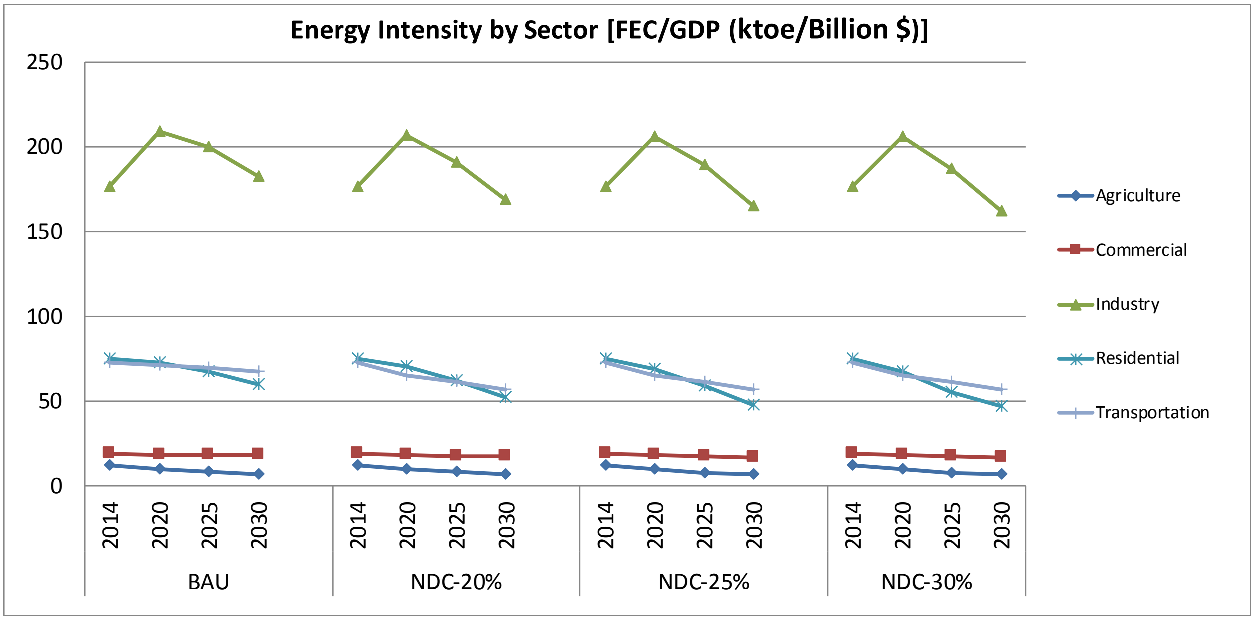
NDC Pathways Analysis: Energy Intensity by Sector = FEC / GDP

Scenario	NDC-15%					EE&RE Policies				
Sector	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Agriculture	12.4	9.9	8.2	6.8	-2.3%	12.4	9.9	8.1	6.7	-3.7%
Commercial	18.7	18.2	18.0	17.3	-4.4%	18.7	18.2	17.9	17.2	-5.1%
Industry	176.4	206.9	191.3	169.7	-6.9%	176.4	206.8	190.8	168.7	-7.4%
Residential	75.1	71.7	64.5	55.7	-7.1%	75.1	70.7	62.3	52.5	-12.3%
Transportation	73.0	66.5	63.4	58.6	-13.4%	73.0	66.5	63.4	58.6	-13.4%
Total	**355.6**	**373.2**	**345.3**	**308.1**	**-8.0%**	**355.6**	**372.1**	**342.5**	**303.8**	**-9.3%**



NDC Pathways Analysis: Energy Intensity by Sector = FEC / GDP									
Scenario	**BAU**				**NDC-20%**				
Sector	**2014**	**2020**	**2025**	**2030**	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**
Agriculture	12.4	9.9	8.3	7.0	12.4	9.9	8.1	6.7	-3.7%
Commercial	18.7	18.4	18.4	18.1	18.7	18.2	17.9	17.2	-5.1%
Industry	176.4	209.4	199.9	182.3	176.4	206.8	190.9	169.2	-7.2%
Residential	75.1	73.1	67.4	59.9	75.1	70.7	62.3	52.5	-12.4%
Transportation	73.0	71.2	69.4	67.6	73.0	65.5	61.7	57.0	-15.7%
Total	**355.6**	**382.0**	**363.5**	**334.9**	**355.6**	**371.1**	**340.9**	**302.7**	**-9.6%**

NDC Pathways Analysis: Energy Intensity by Sector = FEC / GDP										
Scenario	**NDC-25%**					**NDC-30%**				
Sector	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**
Agriculture	12.4	9.8	8.1	6.7	-3.5%	12.4	9.7	8.0	6.7	-4.5%
Commercial	18.7	18.1	17.6	16.8	-7.4%	18.7	18.0	17.4	16.5	-9.0%
Industry	176.4	206.3	189.2	165.4	-9.3%	176.4	205.7	187.2	161.8	-11.2%
Residential	75.1	69.2	59.0	48.1	-19.8%	75.1	67.7	55.3	46.9	-21.7%
Transportation	73.0	65.5	61.7	57.0	-15.7%	73.0	65.5	61.7	57.0	-15.7%
Total	**355.6**	**368.9**	**335.5**	**294.0**	**-12.2%**	**355.6**	**366.6**	**329.6**	**288.9**	**-13.8%**

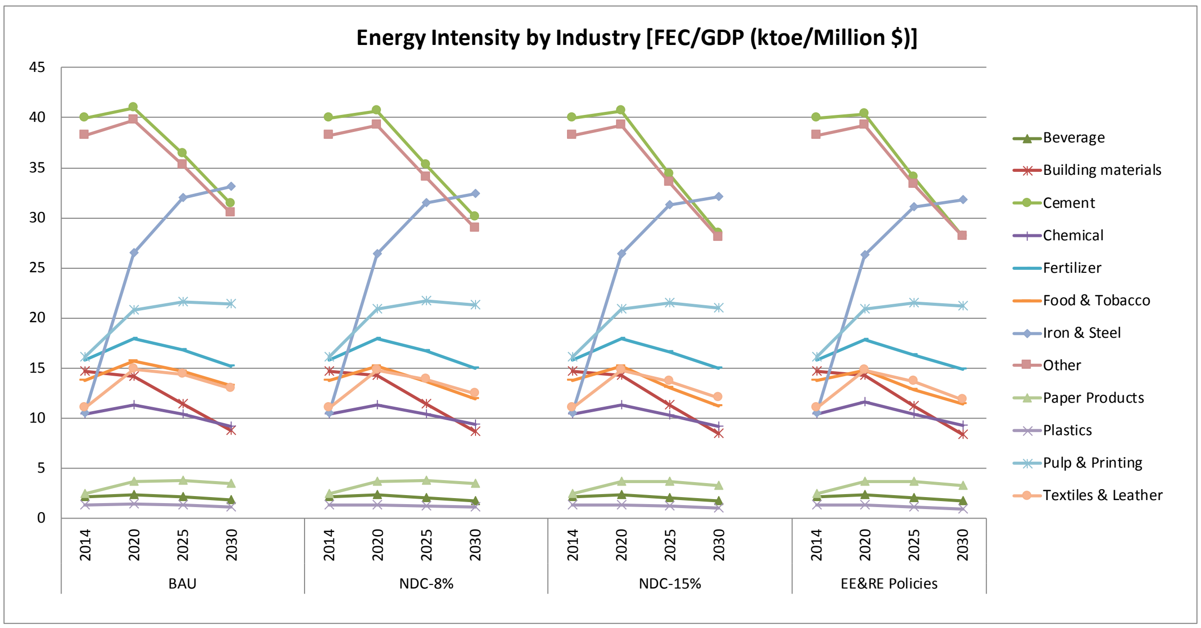


The Iron & Steel subsector and to a lesser degree the Pulp & Printing subsector have increasing energy intensity over time. This is because each has an extremely high demand growth, Iron & Steel increasing a factor of 10 between 2014 and 2030. There is significant EE implementation in each subsector by 2030, but it is not able to fully offset the increased energy demand.

NDC Pathways Analysis: Energy Intensity by Industry = FEC / GDP

Scenario	BAU				NDC-8%				
Sub-Sector	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Beverage	2.2	2.3	2.1	1.8	2.2	2.3	2.0	1.8	-4.4%
Building materials	14.7	14.1	11.4	8.7	14.7	14.2	11.4	8.7	-0.6%
Cement	39.9	41.0	36.4	31.4	39.9	40.6	35.3	30.0	-4.5%
Chemical	10.4	11.3	10.4	9.2	10.4	11.3	10.3	9.3	1.3%
Fertilizer	15.8	18.0	16.8	15.2	15.8	17.9	16.8	15.0	-1.4%
Food & Tobacco	13.8	15.7	14.7	13.3	13.8	15.2	13.6	11.9	-10.1%
Iron & Steel	10.5	26.5	32.0	33.2	10.5	26.4	31.5	32.4	-2.4%
Other	38.2	39.7	35.2	30.4	38.2	39.3	34.0	29.0	-4.8%
Paper Products	2.5	3.7	3.8	3.4	2.5	3.7	3.7	3.4	-0.6%
Plastics	1.3	1.4	1.3	1.1	1.3	1.4	1.2	1.1	-4.9%
Pulp & Printing	16.1	20.8	21.6	21.4	16.1	20.9	21.7	21.3	-0.6%
Textiles & Leather	11.0	14.9	14.3	13.0	11.0	14.8	13.9	12.4	-4.6%
Total	**176.4**	**209.4**	**199.9**	**182.3**	**176.4**	**208.0**	**195.6**	**176.2**	**-3.3%**

NDC Pathways Analysis: Energy Intensity by Industry = FEC / GDP										
Scenario	NDC-15%					EE&RE Policies				
Sub-Sector	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Beverage	2.2	2.3	2.0	1.8	-4.5%	2.2	2.3	2.0	1.8	-4.6%
Building materials	14.7	14.0	11.2	8.4	-3.6%	14.7	14.2	11.2	8.4	-4.4%
Cement	39.9	40.6	34.3	28.4	-9.5%	39.9	40.6	34.3	28.3	-10.1%
Chemical	10.4	11.3	10.3	9.2	-0.5%	10.4	11.3	10.0	8.7	-5.6%
Fertilizer	15.8	17.9	16.6	14.8	-2.6%	15.8	17.9	16.6	14.9	-2.1%
Food & Tobacco	13.8	15.1	13.1	11.1	-16.8%	13.8	15.1	13.1	11.1	-16.3%
Iron & Steel	10.5	26.4	31.3	32.1	-3.4%	10.5	26.3	31.1	31.7	-4.3%
Other	38.2	39.2	33.5	28.0	-8.1%	38.2	39.2	33.4	27.7	-9.1%
Paper Products	2.5	3.7	3.7	3.3	-3.9%	2.5	3.7	3.7	3.3	-5.0%
Plastics	1.3	1.3	1.2	1.0	-10.0%	1.3	1.3	1.1	1.0	-15.0%
Pulp & Printing	16.1	20.9	21.5	20.9	-2.1%	16.1	20.9	21.7	21.3	-0.6%
Textiles & Leather	11.0	14.7	13.7	12.0	-7.8%	11.0	14.7	13.6	11.8	-8.7%
Total	**176.4**	**207.6**	**192.3**	**170.9**	**-6.2%**	**176.4**	**207.6**	**191.8**	**169.8**	-6.8%

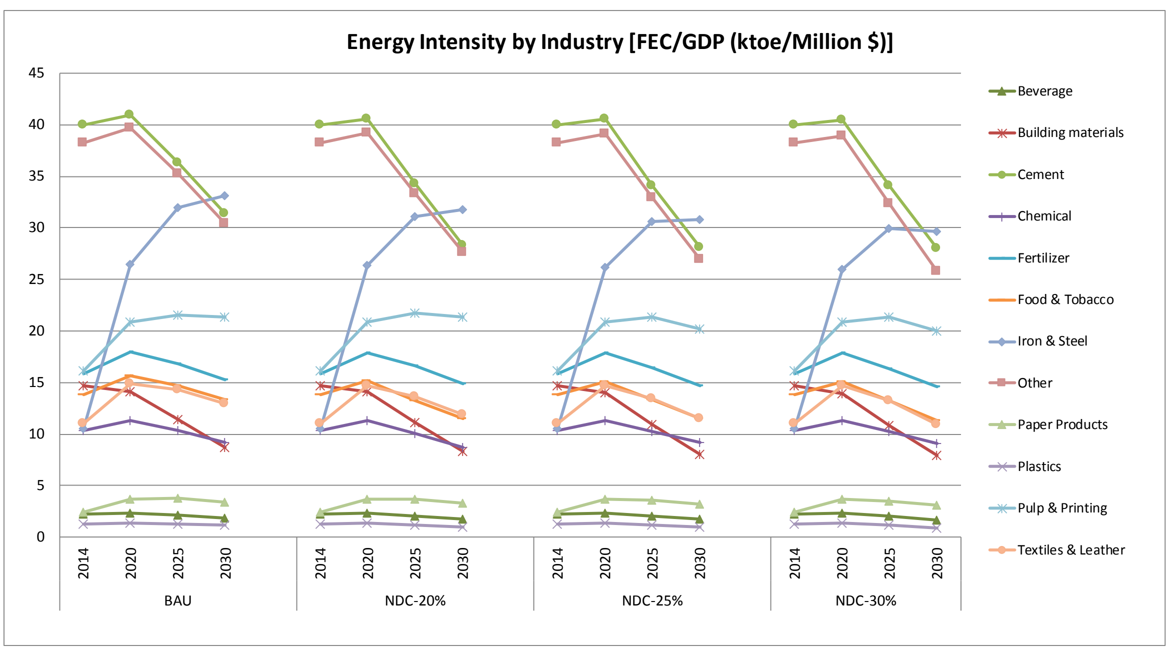


NDC Pathways Analysis: Energy Intensity by Industry = FEC / GDP

Scenario	BAU				NDC-20%				
Sub-Sector	2014	2020	2025	2030	2014	2020	2025	2030	Diff BAU 2030
Beverage	2.2	2.3	2.1	1.8	2.2	2.3	2.0	1.8	-4.6%
Building materials	14.7	14.1	11.4	8.7	14.7	14.1	11.1	8.3	-5.2%
Cement	39.9	41.0	36.4	31.4	39.9	40.6	34.3	28.3	-10.1%
Chemical	10.4	11.3	10.4	9.2	10.4	11.3	10.0	8.7	-5.6%
Fertilizer	15.8	18.0	16.8	15.2	15.8	17.9	16.6	14.9	-2.1%
Food & Tobacco	13.8	15.7	14.7	13.3	13.8	15.1	13.2	11.5	-13.3%
Iron & Steel	10.5	26.5	32.0	33.2	10.5	26.3	31.1	31.7	-4.3%
Other	38.2	39.7	35.2	30.4	38.2	39.2	33.4	27.7	-9.1%
Paper Products	2.5	3.7	3.8	3.4	2.5	3.7	3.7	3.3	-5.0%
Plastics	1.3	1.4	1.3	1.1	1.3	1.3	1.1	1.0	-15.0%
Pulp & Printing	16.1	20.8	21.6	21.4	16.1	20.9	21.7	21.3	-0.3%
Textiles & Leather	11.0	14.9	14.3	13.0	11.0	14.7	13.6	11.8	-8.7%
Total	176.4	209.4	199.9	182.3	176.4	207.5	191.8	170.2	-6.6%

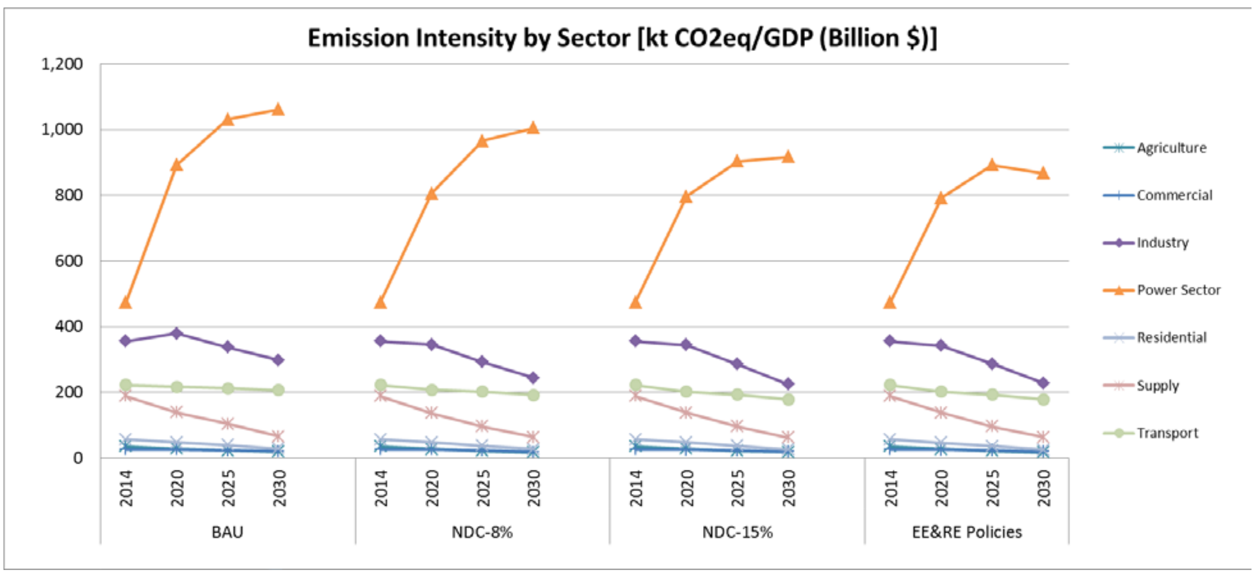
NDC Pathways Analysis: Energy Intensity by Industry = FEC / GDP

Scenario	NDC-25%					NDC-30%				
Sub-Sector	2014	2020	2025	2030	Diff BAU 2030	2014	2020	2025	2030	Diff BAU 2030
Beverage	2.2	2.3	2.0	1.7	-6.0%	2.2	2.3	2.0	1.7	-7.8%
Building materials	14.7	14.0	11.0	8.0	-8.3%	14.7	13.9	10.8	7.9	-9.8%
Cement	39.9	40.5	34.1	28.1	-10.6%	39.9	40.5	34.1	28.1	-10.7%
Chemical	10.4	11.3	10.3	9.2	-0.2%	10.4	11.3	10.2	9.1	-1.3%
Fertilizer	15.8	17.9	16.4	14.6	-3.9%	15.8	17.8	16.4	14.6	-4.2%
Food & Tobacco	13.8	15.1	13.3	11.5	-13.8%	13.8	15.1	13.2	11.3	-15.0%
Iron & Steel	10.5	26.2	30.6	30.9	-7.0%	10.5	26.0	29.9	29.7	-10.5%
Other	38.2	39.1	32.9	27.0	-11.3%	38.2	39.0	32.4	25.8	-15.2%
Paper Products	2.5	3.7	3.6	3.2	-8.2%	2.5	3.6	3.5	3.1	-10.0%
Plastics	1.3	1.3	1.1	0.9	-18.4%	1.3	1.3	1.1	0.9	-19.4%
Pulp & Printing	16.1	20.9	21.4	20.2	-5.6%	16.1	20.9	21.3	20.0	-6.4%
Textiles & Leather	11.0	14.7	13.4	11.5	-11.6%	11.0	14.6	13.2	11.0	-15.5%
Total	176.4	207.0	190.2	166.7	-8.5%	176.4	206.4	188.2	163.1	-10.5%



DC Pathways Analysis: Emission Intensity by Sector = kt CO2eq / GD									
Scenario	**BAU**				**NDC-8%**				
Sector	**2014**	**2020**	**2025**	**2030**	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**
Agriculture	34.8	28.2	23.3	19.6	34.8	27.6	21.8	16.8	-14.3%
Commercial	26.8	26.0	24.2	21.1	26.8	25.7	23.8	18.3	-13.2%
Industry	355.4	379.4	337.7	298.0	355.4	345.7	292.2	243.5	-18.3%
Power Sector	474.4	892.7	1,031.1	1,061.7	474.4	805.5	965.5	1,005.3	
Residential	56.3	48.1	39.2	29.0	56.3	47.5	37.9	27.3	
Supply	188.2	139.4	103.7	66.1	188.2	137.2	96.3	63.4	-4.1%
Transport	223.0	217.4	212.1	206.9	223.0	207.4	202.6	191.6	-7.4%
Total	1,358.9	1,731.3	1,771.3	1,702.5	**1,358.9**	**1,596.6**	**1,640.1**	**1,566.3**	**-8.0%**

NDC Pathways Analysis: Emission Intensity by Sector = kt CO2eq / GDP										
Scenario	**NDC-15%**					**EE&RE Policies**				
Sector	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**
Agriculture	34.8	28.3	22.1	18.0	-8.0%	34.8	27.7	21.5	16.7	-15.0%
Commercial	26.8	25.6	23.8	19.2	-9.4%	26.8	25.4	23.5	19.7	-6.8%
Industry	355.4	343.8	285.7	224.9	-24.5%	355.4	341.6	286.7	228.5	-23.3%
Power Sector	474.4	796.5	904.1	917.6		474.4	792.4	893.0	867.9	
Residential	56.3	47.3	37.5	26.6		56.3	46.8	36.4	25.0	
Supply	188.2	137.6	96.3	62.1	-6.0%	188.2	137.9	96.5	63.3	-4.2%
Transport	223.0	202.7	193.7	178.7	-13.6%	223.0	202.7	193.7	178.7	-13.6%
Total	**1,358.9**	**1,581.7**	**1,563.1**	**1,447.1**	**-15.0%**	**1,358.9**	**1,574.6**	**1,551.2**	**1,399.8**	-17.8%



NDC Pathways Analysis: Emission Intensity by Sector = kt CO2eq / GDP									
Scenario	**BAU**				**NDC-20%**				
Sector	**2014**	**2020**	**2025**	**2030**	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**
Agriculture	34.8	28.2	23.3	19.6	34.8	27.7	21.5	16.7	-15.0%
Commercial	26.8	26.0	24.2	21.1	26.8	25.4	23.5	19.7	-6.8%
Industry	355.4	379.4	337.7	298.0	355.4	340.5	281.1	223.7	-24.9%
Power Sector	474.4	892.7	1,031.1	1,061.7	474.4	797.8	904.5	842.2	
Residential	56.3	48.1	39.2	29.0	56.3	46.8	36.4	25.0	
Supply	188.2	139.4	103.7	66.1	188.2	137.8	94.8	61.6	-6.8%
Transport	223.0	217.4	212.1	206.9	223.0	199.4	187.5	173.1	-16.3%
Total	1,358.9	1,731.3	1,771.3	1,702.5	**1,358.9**	**1,575.6**	**1,549.3**	**1,362.0**	**-20.0%**

NDC Pathways Analysis: Emission Intensity by Sector = kt CO2eq / GDP										
Scenario	**NDC-25%**					**NDC-30%**				
Sector	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**	**2014**	**2020**	**2025**	**2030**	**Diff BAU 2030**
Agriculture	34.8	27.6	21.7	16.9	-13.8%	34.8	27.6	21.1	16.8	-14.4%
Commercial	26.8	24.7	22.2	17.9	-15.5%	26.8	24.2	21.5	17.5	-17.0%
Industry	355.4	331.7	260.4	179.9	-39.6%	355.4	329.0	250.4	167.8	-43.7%
Power Sector	474.4	794.4	881.4	804.5		474.4	786.2	842.6	734.0	
Residential	56.3	45.9	34.3	22.1		56.3	45.4	33.3	20.8	
Supply	188.2	139.2	98.2	62.5	-5.5%	188.2	139.4	97.7	61.8	-6.5%
Transport	223.0	199.4	187.5	173.1	-16.3%	223.0	199.4	187.5	173.1	-16.3%
Total	**1,358.9**	**1,563.0**	**1,505.6**	**1,276.9**	-25.0%	**1,358.9**	**1,551.2**	**1,454.0**	**1,191.8**	-30.0%