ENERGY STUDIES INSTITUTE

Long Range Energy Analysis of Singapore's Electricity Sector Using the TIMES Modeling Framework

Victor Nian
Research Associate, Energy Studies Institute

Ph.D Candidate in Mechanical Engineering, National University of Singapore

B. ENG (Hons) in Electricity Engineering with Minor in Management of Technology, National University of Singapore

NUS National University of Singapore

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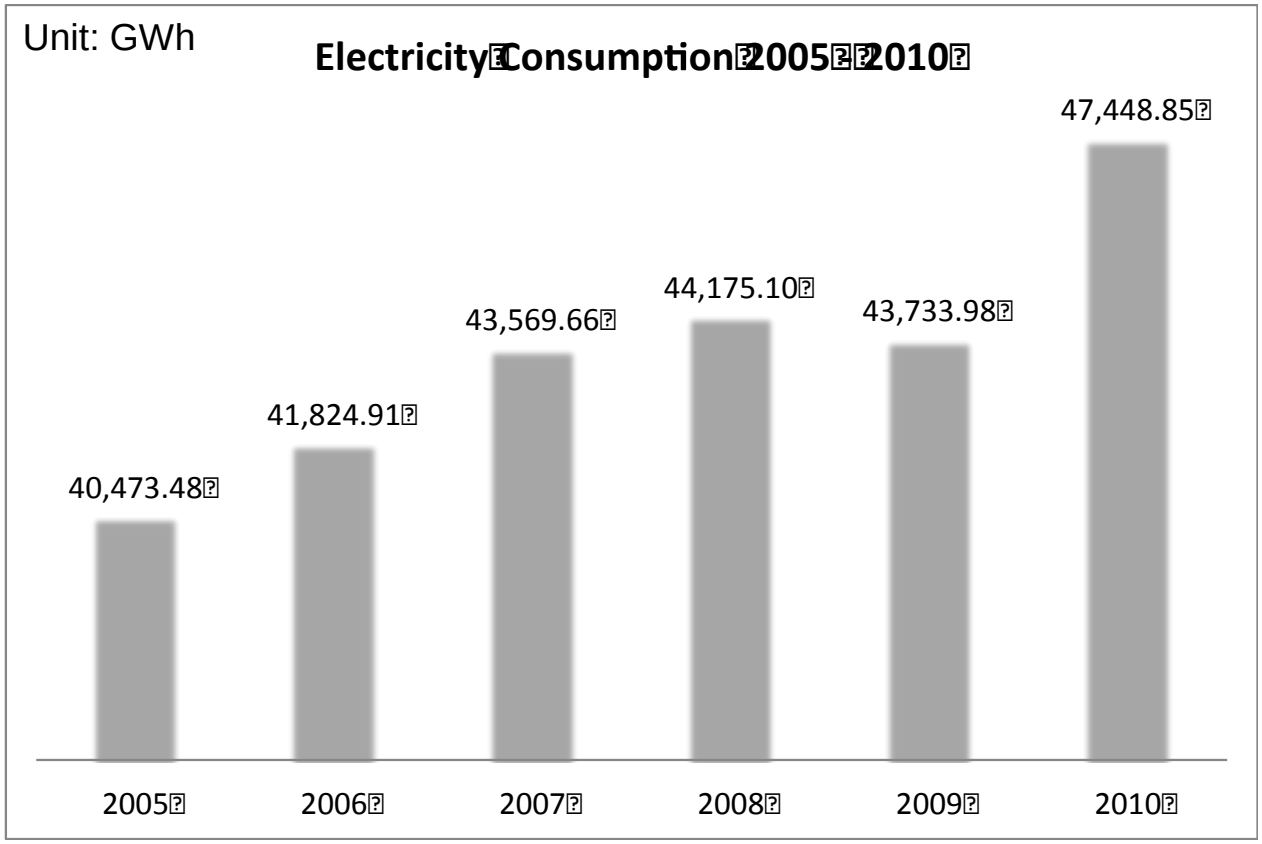
Singapore Electricity Consumptions



Source: EMA 2010

Current Energy Efficiency Improvement Policies in Singapore

	Power Generation	Industry	Buildings	Transport	Households
Promote adoption of energy efficient technology and measures	Clean Development Mechanism				
	$10 Million EASe Scheme Accelerated depreciation allowance Investment allowance				
	Promote cogeneration and trigeneration via industrial land planning and facility siting	Design for Efficiency scheme Grant for Energy Efficient Technologies	Building regulations Government take the lead Energy Smart Mandating Green Mark certified $20 million Green Mark Incentive Scheme Grant to upgrade Building Envelopes Residential building standards	Manage vehicle usage and traffic congestion Improving and promoting the use of public transport Fuel economy labeling Green vehicle rebate Promoting fuel-efficient driving habits	Mandatory labeling Minimum energy performance standards Electricity Vending System Electricity consumption tracking device
Research & Development and Capability-building	Innovation for Environmental Sustainability Fund				
			Green building R&D fund		
	Energy service company accreditation scheme Singapore Certified Energy Manager programme and Training Grant				
Raise awareness	Energy efficiency seminars and workshops Energy efficiency website Public awareness programme				

Objectives for the Modeling Analysis

- Better understand the current situation and the future evolution of Singapore's electricity sector
- Study the options in decarbonizing the electricity sector
- Identify a robust approach to mitigate the dependency on sensitive data
- First "Pour-of-concrete" into technology explicit energy systems modeling

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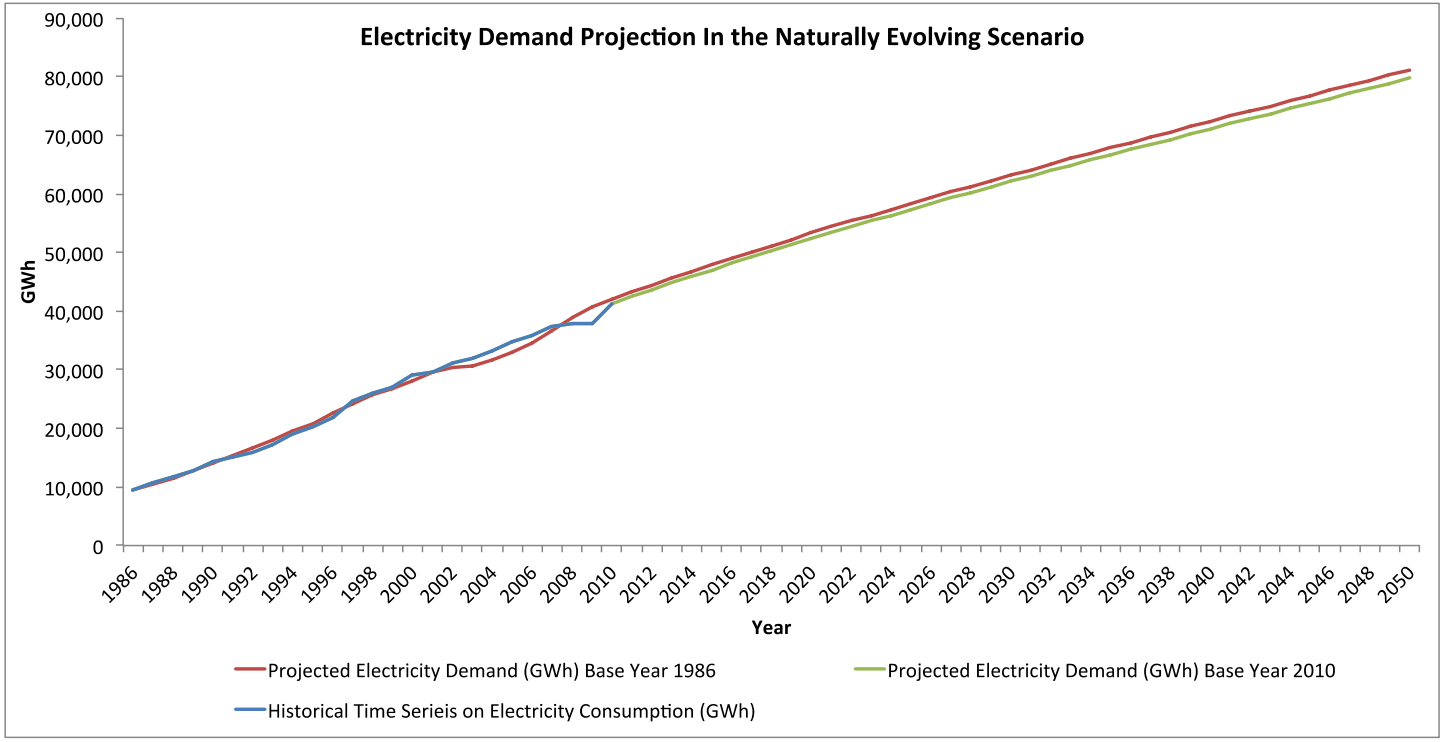
Electricity Demand Projection to 2030 and 2050 in the Naturally Evolving Scenario

- Electricity consumption projection based on the latest official estimation of 6.9 million population by 2030, followed by linear extrapolation to 2050 at about 8.7 million population
- Previous estimation was 5.9 million by 2030, and 6.7 million by 2050



Industry

- Current efficiency improvement policies
  - $10 Million dollars Energy Efficiency Improvement Assistance Scheme (EASe) by NEA and MEWR
- Relevant Industry Sectors and savings potential with the use of Best Available Technologies (BATs)(EJ/Yr, %)
  - Chemicals/Petrochemicals (1.0, 25%)
  - Cement (No data available)
  - Pulp and paper (0.3, 16%)
  - Wafer fab (N.A., 20%)
- Most relevant industrial technology systems and savings potential with the use of BATs (%)
  - Motor systems (20%)

Building

- Current efficiency improvement policies:
  - Green Mark (GM) Scheme
  - Energy Smart Building Labeling Scheme
- Prospect efficiency improvement policies:
  - Efficiency Improvements for Existing Stocks of Buildings
- GM Certification Criteria (% electricity reductions)
  - Platinum (30%)
  - Gold^{PLUS} (25%)
  - Gold (15%)
  - Certified (10%)

Transport

- Current Mode of Transport
  - RTS Network
  - Bus
  - Taxi
  - Private Vehicles
  - Others
- Current transport policies (increase in electricity consumptions)
  - Doubling of RTS network by 2020 Electric Vehicle (EV) test bedding program
  - SMRT-BYD MOU on the distribution of BYD e6 taxi and eBus012 in Singapore
- Prospective transport policies (further increase in electricity consumptions)
  - Trolleybus
  - Tram
  - Bus Rapid Transit (BRT)

Household

- Current efficiency improvement policies
  - Minimum Energy Performance Standard (MEPS) for appliances sold in Singapore
  - Feasibility study on Electricity Vending System (EVS) scheme
  - 10% Energy Challenge to encourage household sector to reduce electricity consumption by 10%

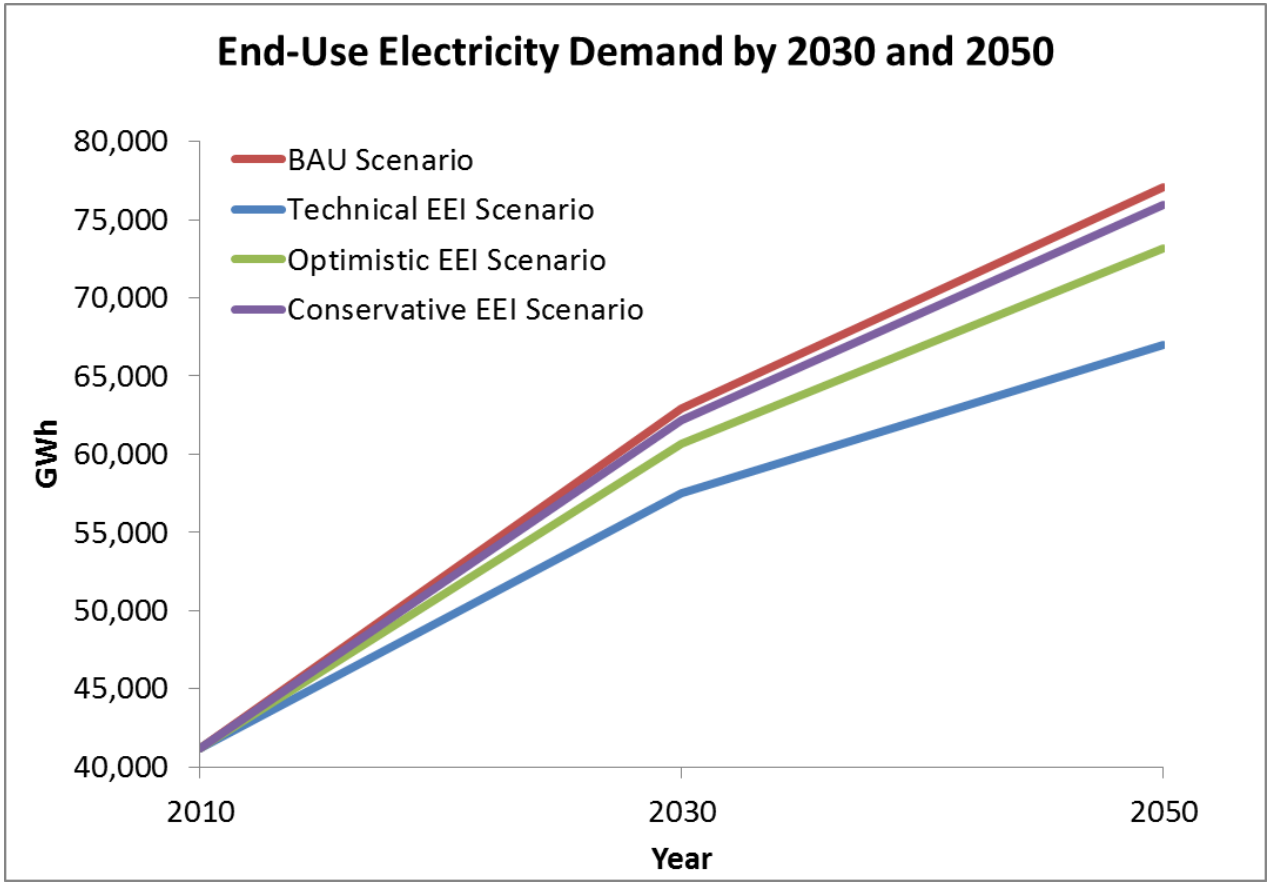
Sectoral Analysis on Energy Efficiency Improvement (EEI) Potentials

Summary of Electricity Demand Reduction Potentials from the Naturally Evolving Scenario

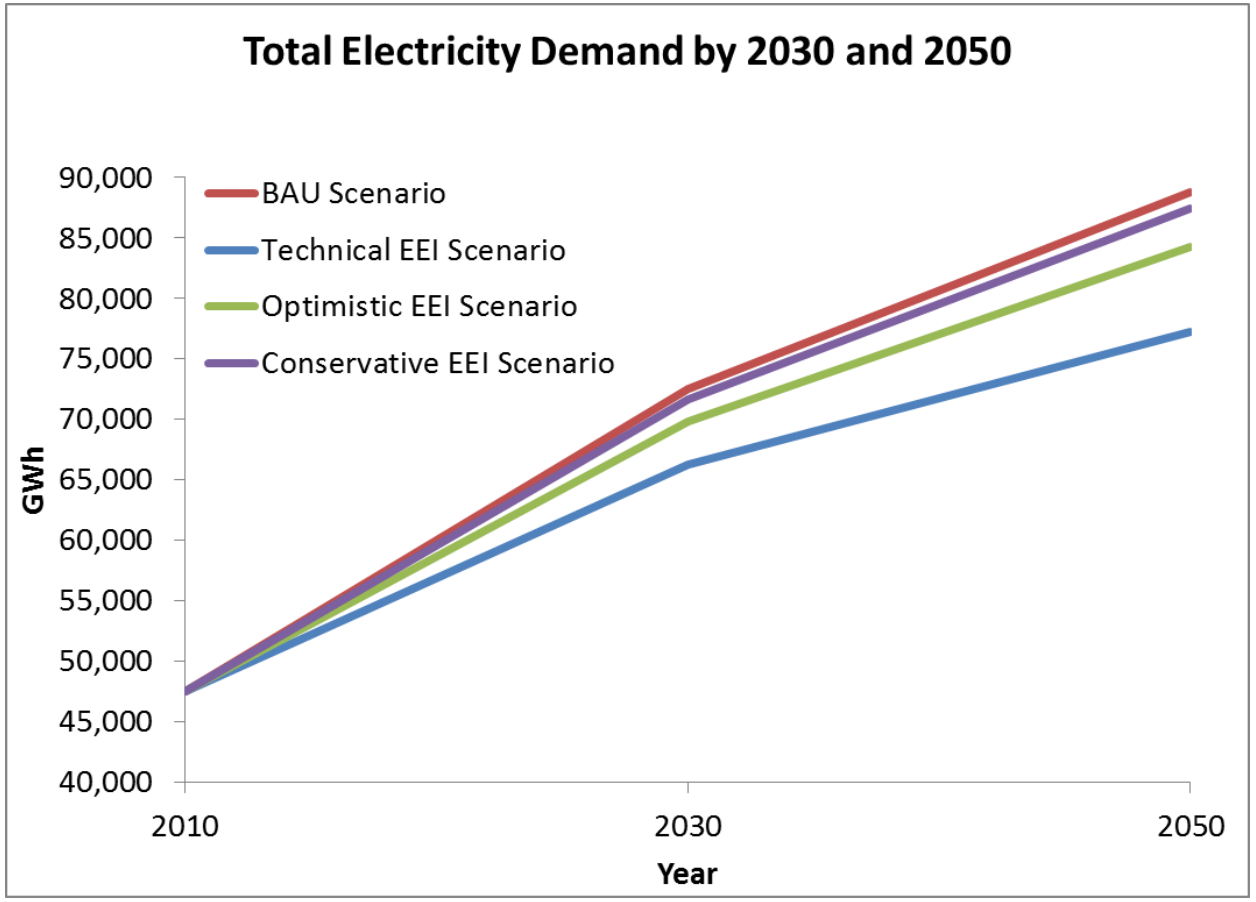
Scenarios	Industry	Building	Transport		Households
BAU	%	%	GWh	%	%
2030	1.0%	3.0%	1738.05	-65.0%*	0.5%
2050	3.0%	6.0%	0.00	0.0%	1.0%
Conservative					
2030	1.5%	6.0%	1739.60	-65.0%	1.0%
2050	5.0%	7.5%	52.00	-1.8%	2.0%
Optimistic					
2030	2.5%	12.0%	1806.93	-67.0%	2.5%
2050	7.0%	15.0%	260.02	-9.1%	5.0%
Technical					
2030	10.0%	20.0%	2502.61	-110.0%	5.0%
2050	20.0%	30.0%	2996.18	-105.0%	10.0%

*Negative sign signifies increase in electricity demand

End-use Electricity Demand Projection to 2050



Total Electricity Demand Projection to 2050



Total Installed Capacity by 2030 and 2050

- at 50% Capacity Factor

Year	Naturally Evolving Scenario	BAU Scenario	Conservative EEI Scenario	Optimistic EEI Scenario	Technical EEI Scenario
2010	10.1	10.1 (**10.2**)	10.1	10.1	10.1
2030	15.3	15.5	15.3	14.9	14.1
2050	19.6	18.9	18.7	18.0	16.5

Singapore Total Installed Capacity at 2010
Published by the Energy Market Authority

Key Learning Points

- A good understanding on the demand side
  - Key electricity consuming technologies and systems in different sectors
  - Breakthroughs and incremental improvements
  - Endogenous and exogenous learning
  - Access to the Best Available Technologies
  - Domestic technology assimilation capacity
- A good understanding on the supply side
  - Current configuration of electricity generators (fuel, installed capacity, vintage, licensing, and company profiles)
  - Electricity generation business in general
  - Regional setting (accessibility of natural resources, “the energy business”)
  - Current policy directions
- A robust methodology to approximate real life operating conditions of the energy system up to at least the base year

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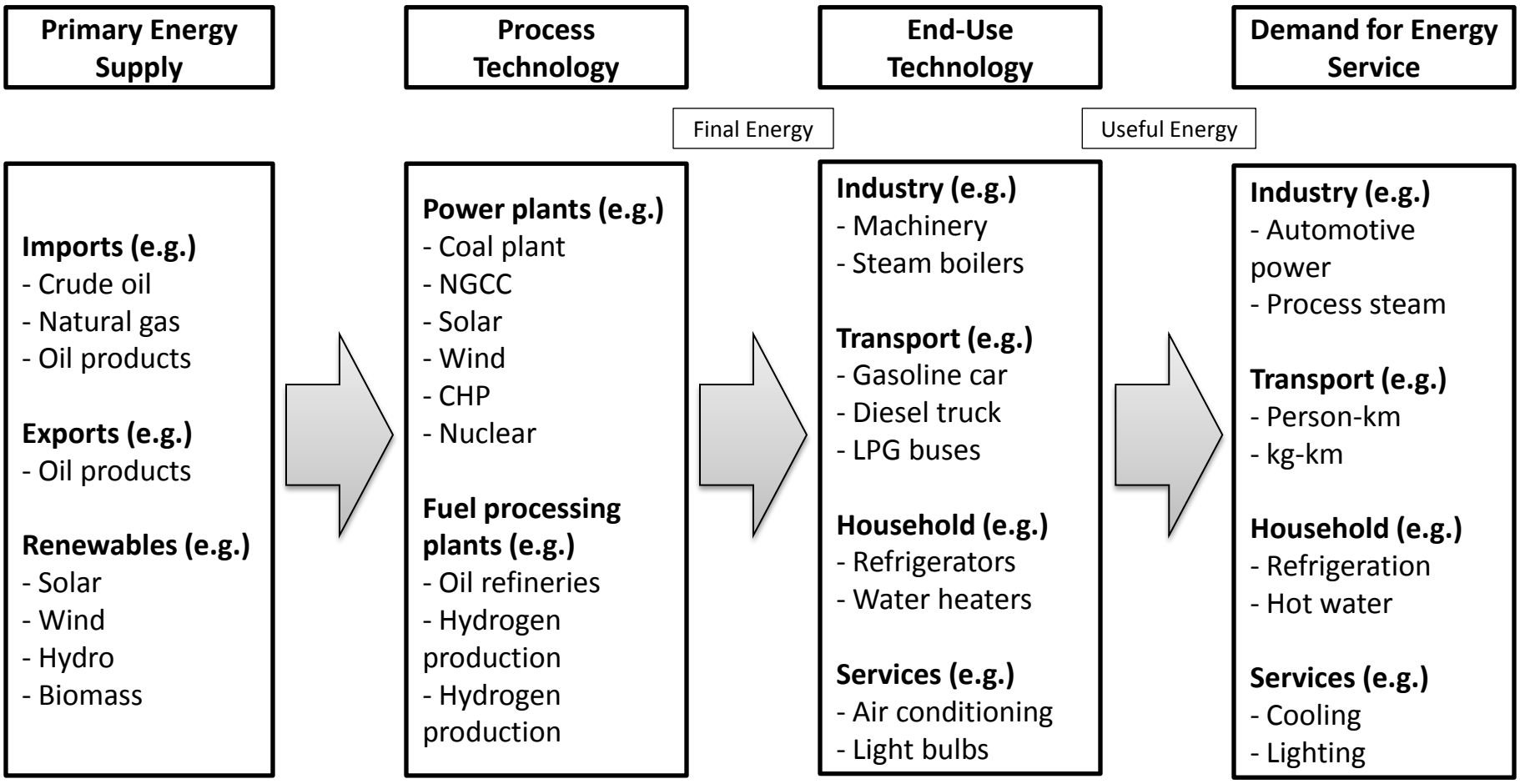
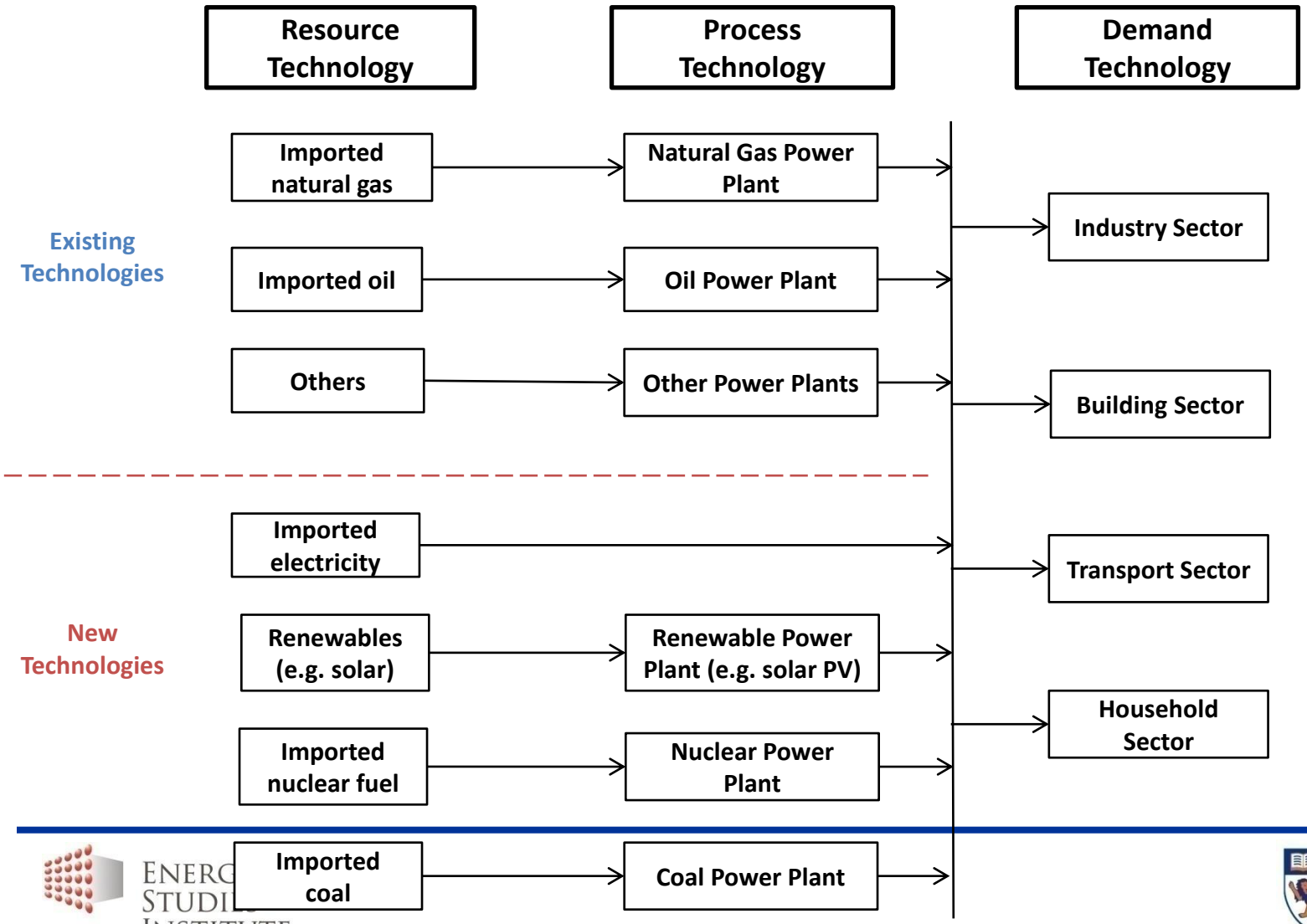
SG-TIMES Reference Energy System



SG-ELC-TIMES Reference Energy System



Some Technical Details on the Model Structure

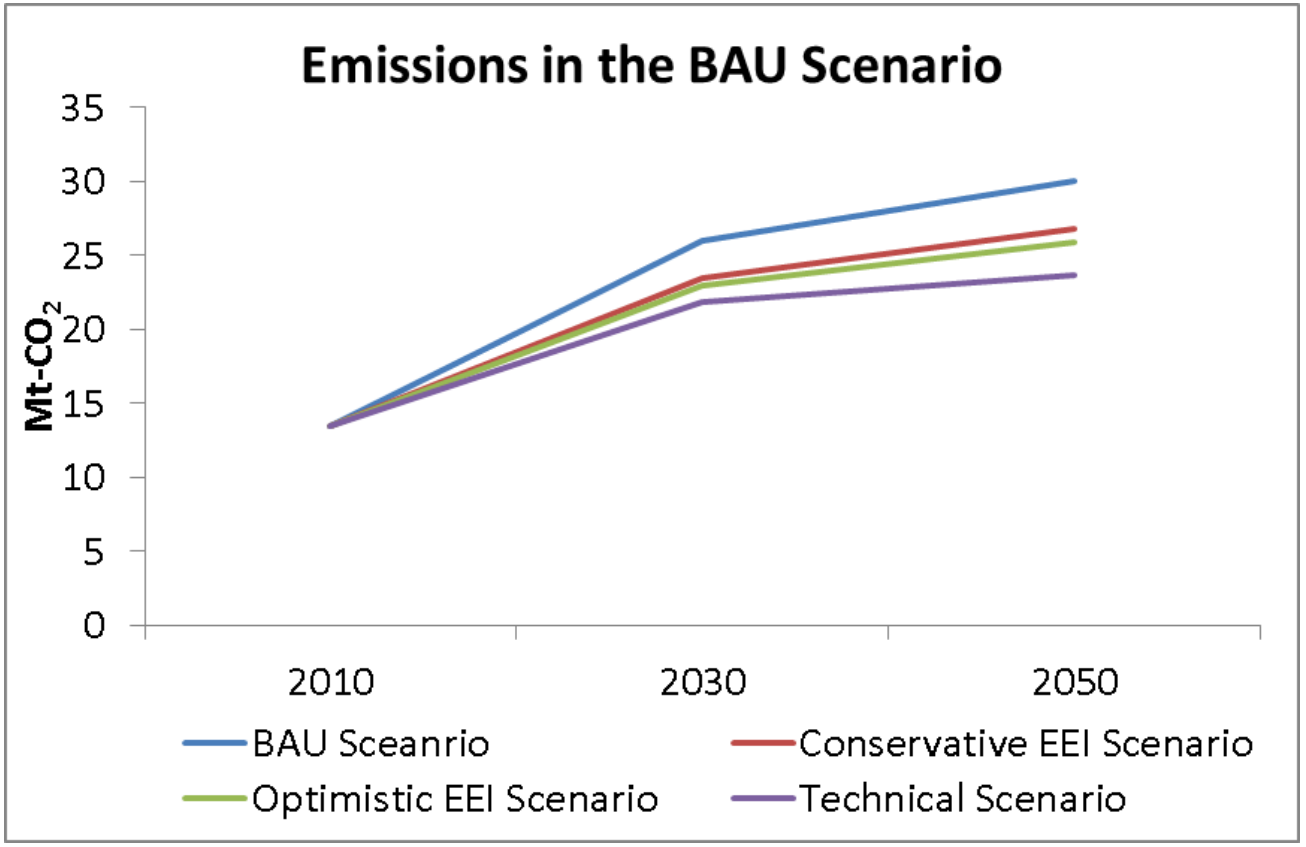
- Time Slices
  - Weekday/Saturday/Sunday -> Day/Night
- Sectoral Electricity Demand
  - Current implementation: aggregated exogenous sectoral electricity demand based on previous analysis
  - *Future implementation: Energy service demand by commodity fraction*
- User constraints derived from policy considerations
  - Emission reduction target
  - Maximum share of coal + HFO power
  - Maximum share/installed capacity of nuclear power
  - Minimum penetration of renewables (solar PV and wind)
- Calibration for the base year

Modelling Scenarios

- Electricity Sector BAU Scenario
  - Emissions by 2030 and 2050
- Emission reduction by 30% by 2030 and 50% by 2050 from the BAU Scenario
  - No constraints on the choice of technologies
  - Fixed range of combined Coal and HFO in the mix
  - Fixed range of combined Coal and HFO, and max Nuclear installed capacity in the mix
- Each model run was based on the four demand scenarios defined earlier
  - For illustration purposes, only the BAU and Technical EEI Scenarios will be presented

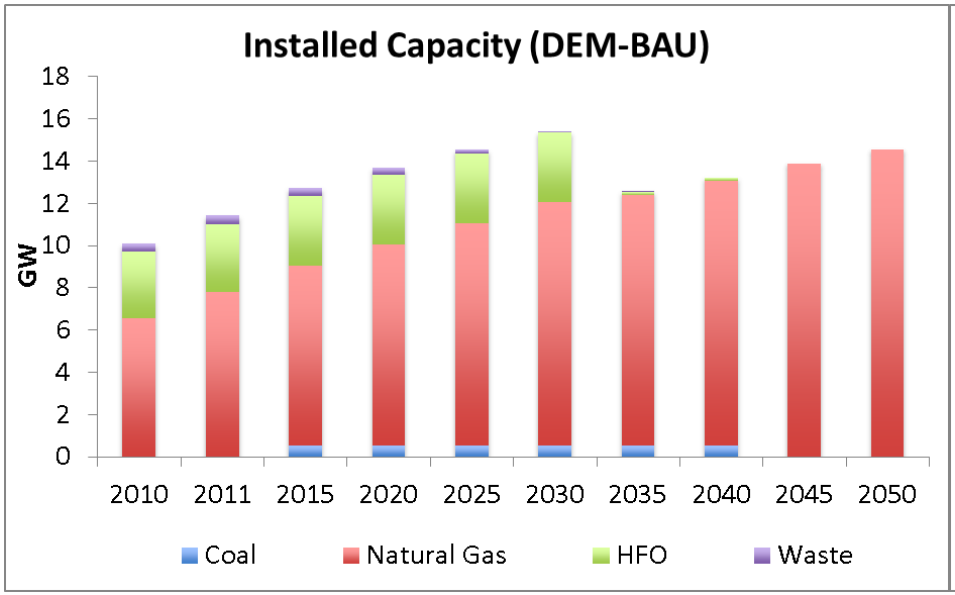
Electricity Sector BAU Scenario 1/3

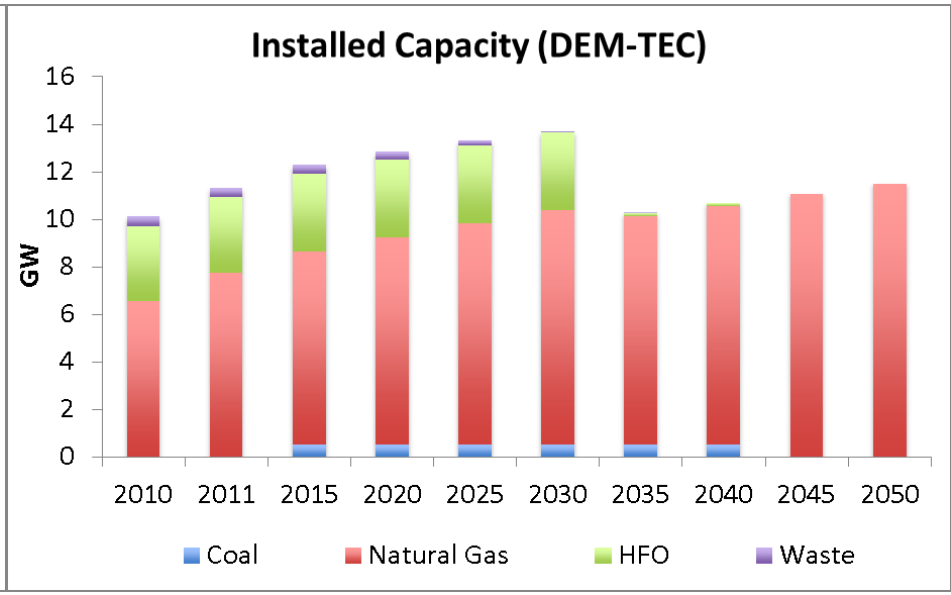
- Emissions



Electricity Sector BAU Scenario 2/3

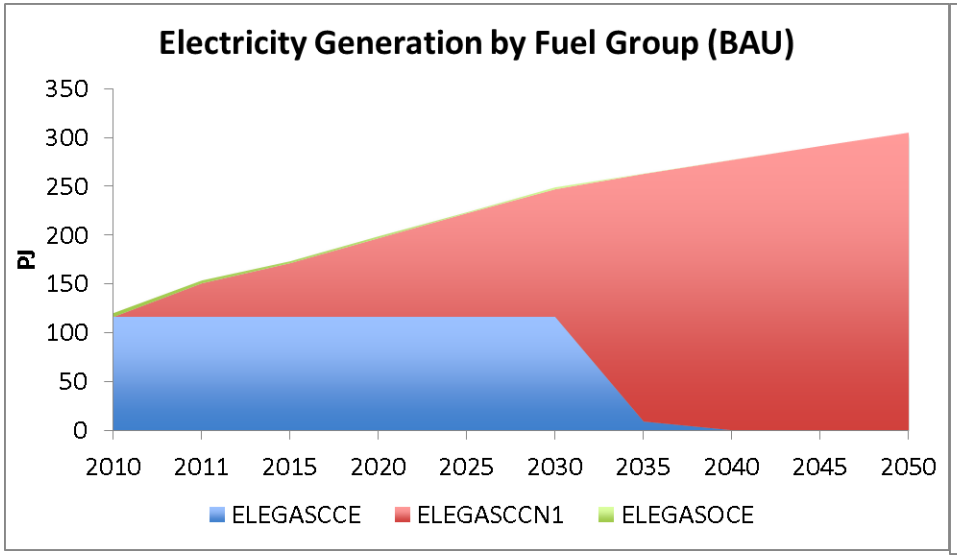
- Installed Capacity

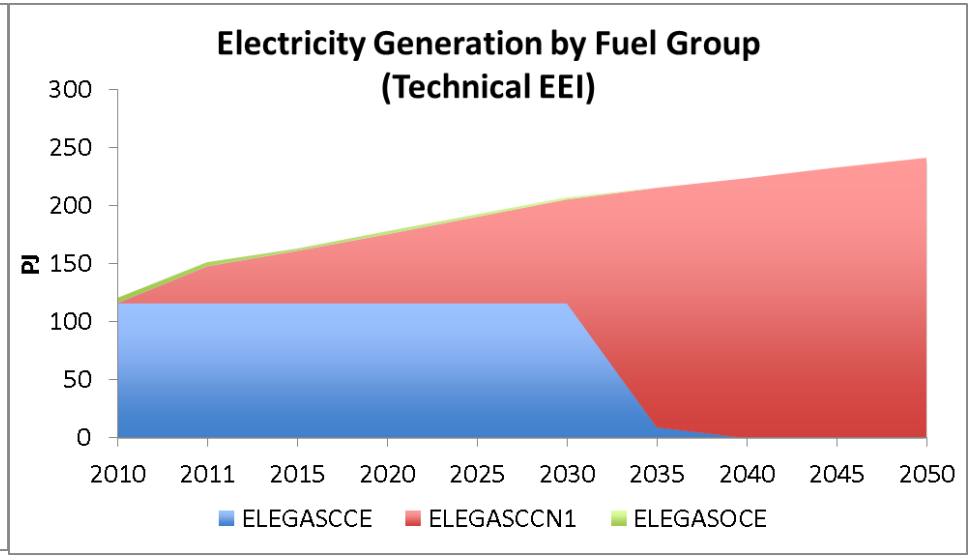




Electricity Sector BAU Scenario 3/4

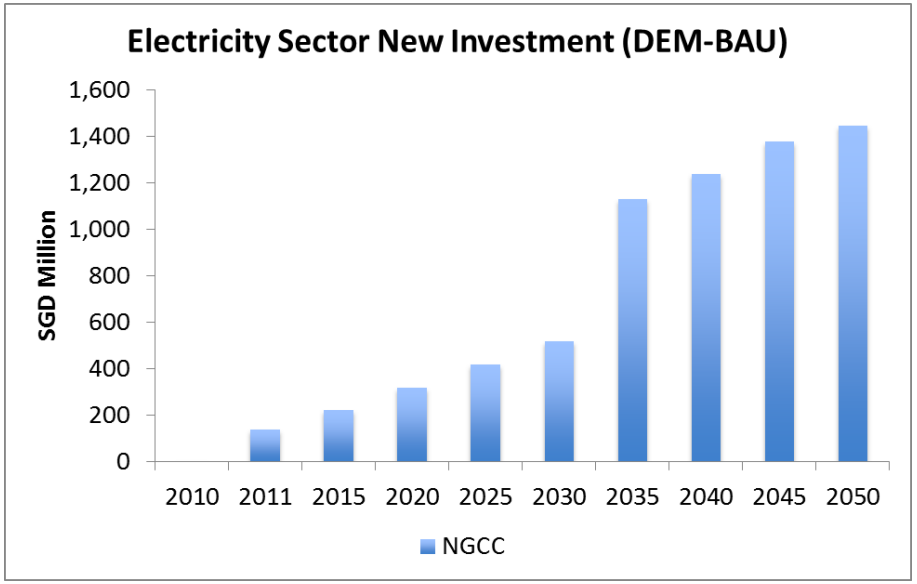
- Fuel mix

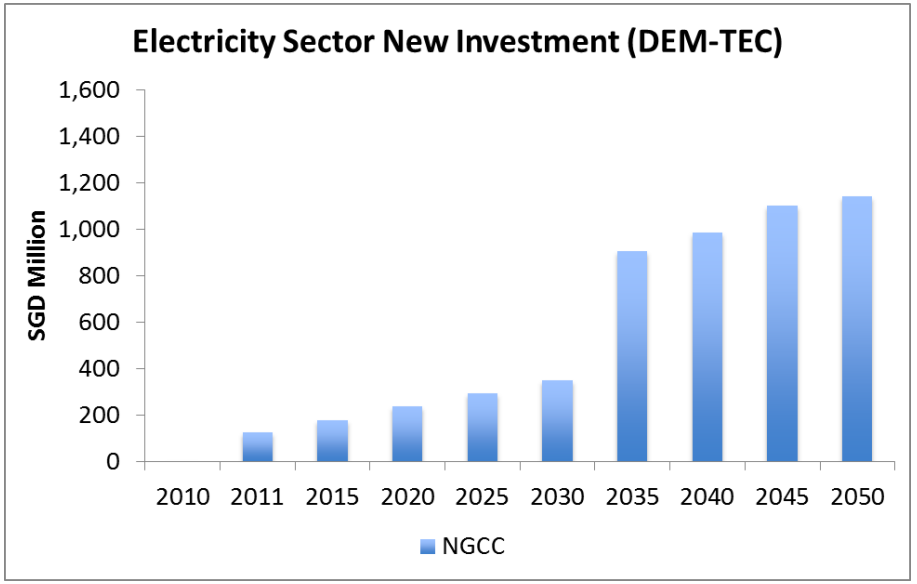




Electricity Sector BAU Scenario 4/4

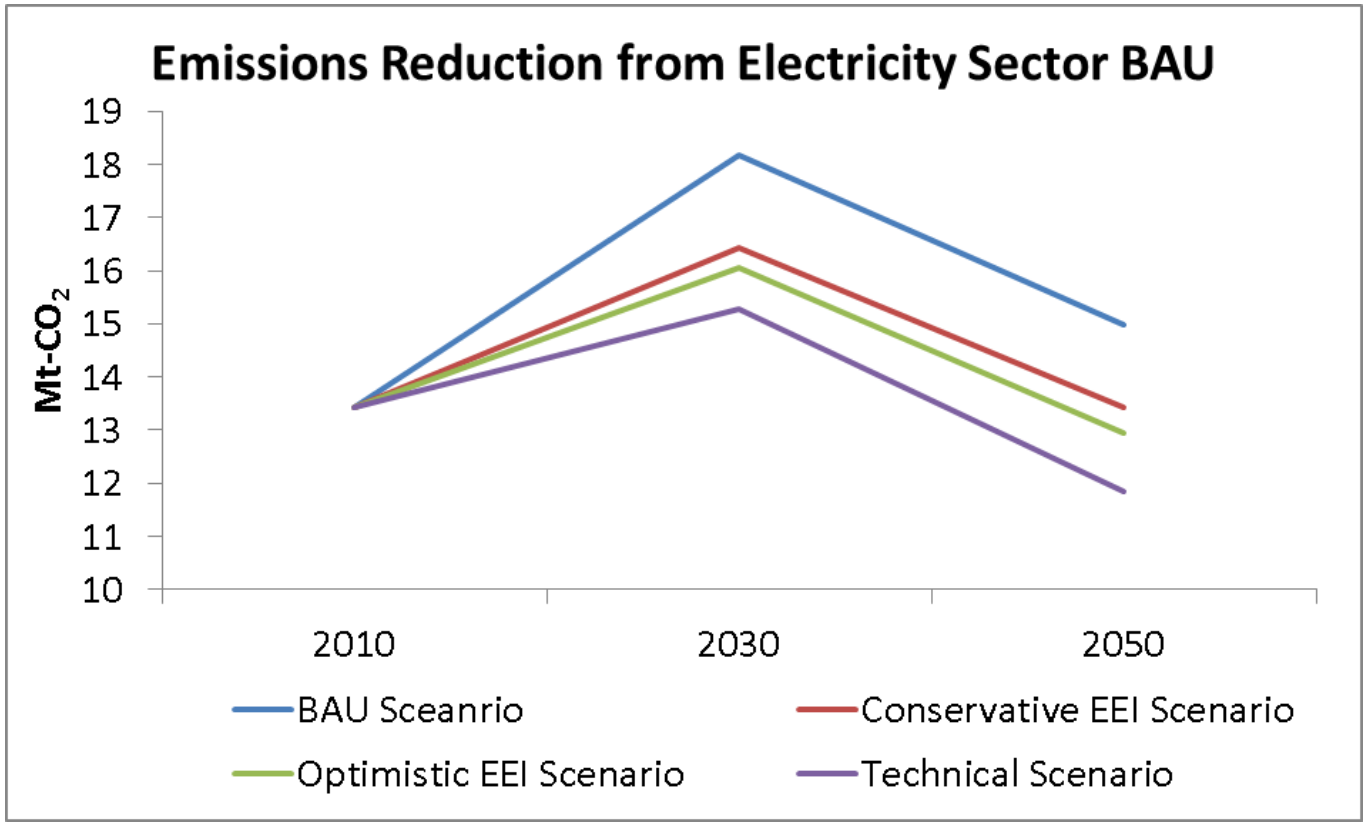
- Investment Schedules





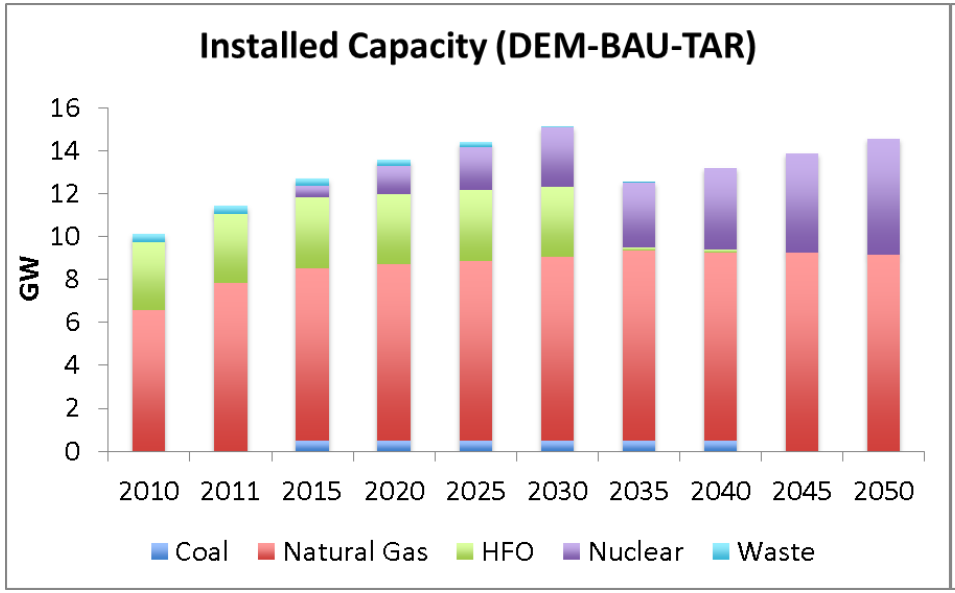
Electricity Sector Emission Reduction Scenario

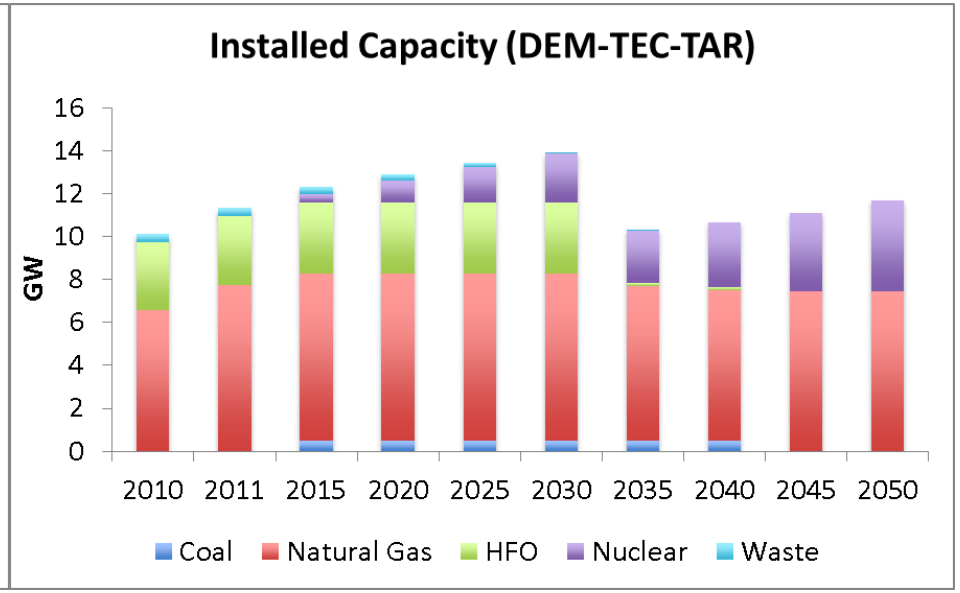
30% Reductions by 2030 and 50% reductions by 2050



Electricity Sector Emission Reduction Scenario 1/3

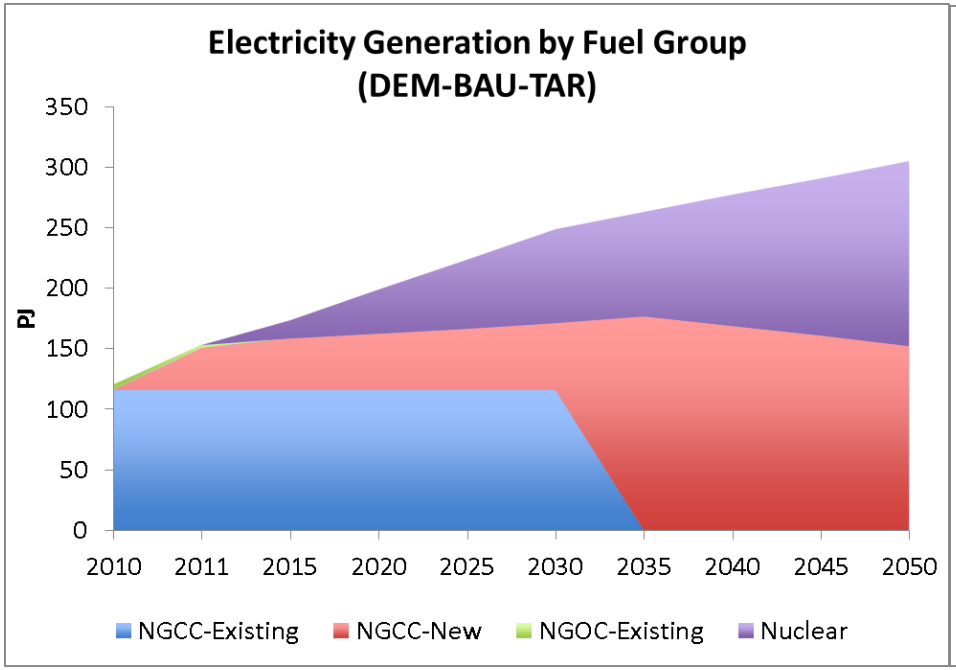
Installed Capacity under No System Constraints

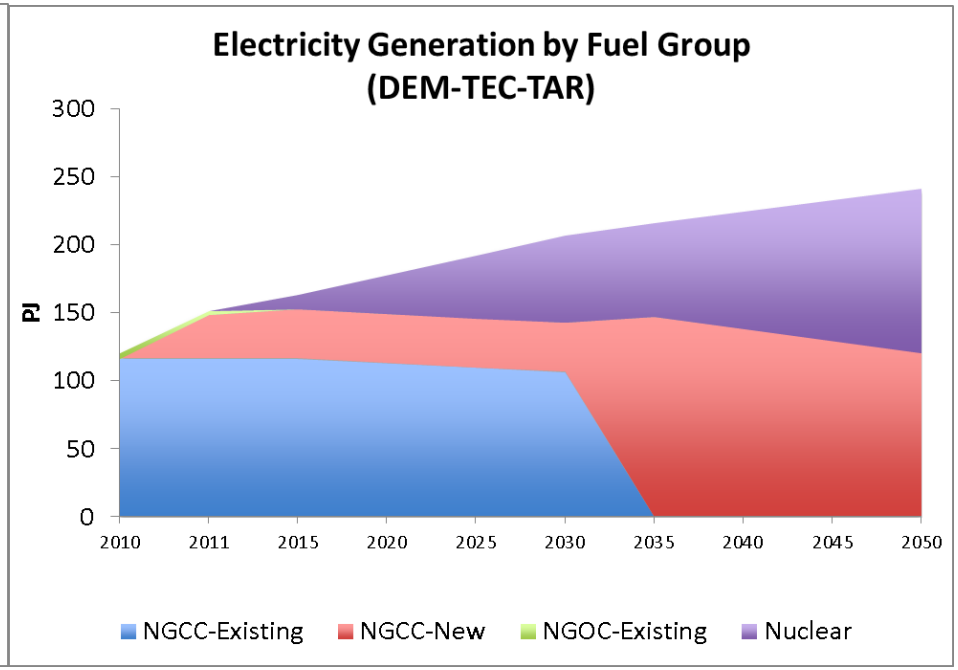




Electricity Sector Emission Reduction Scenario 2/3

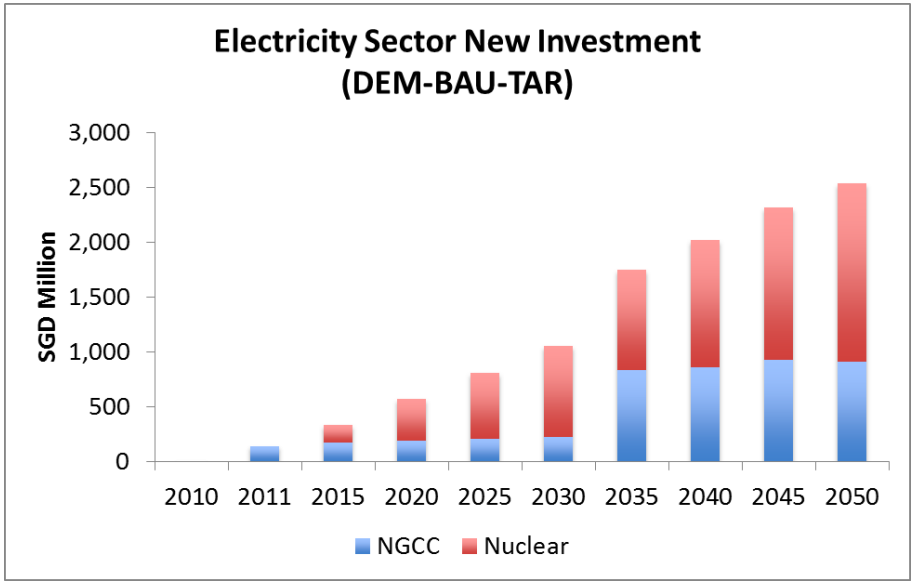
Fuel Mix under No System Constraints

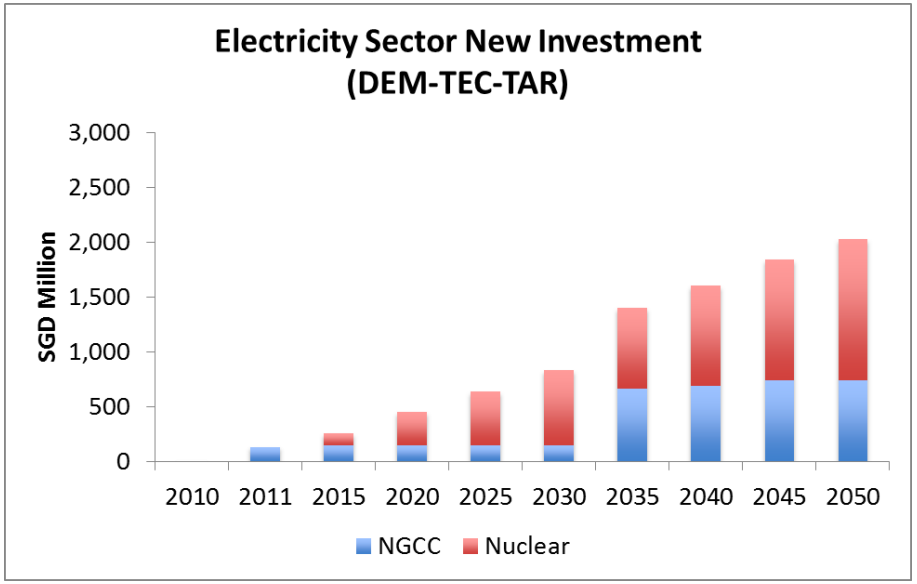




Electricity Sector Emission Reduction Scenario 3/3

- Investment Schedules

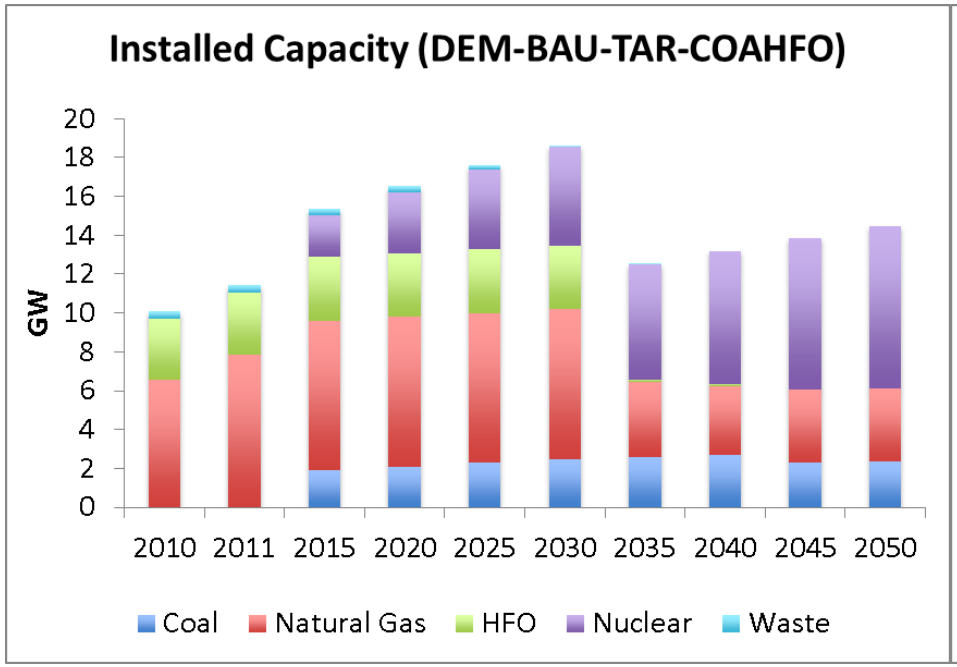


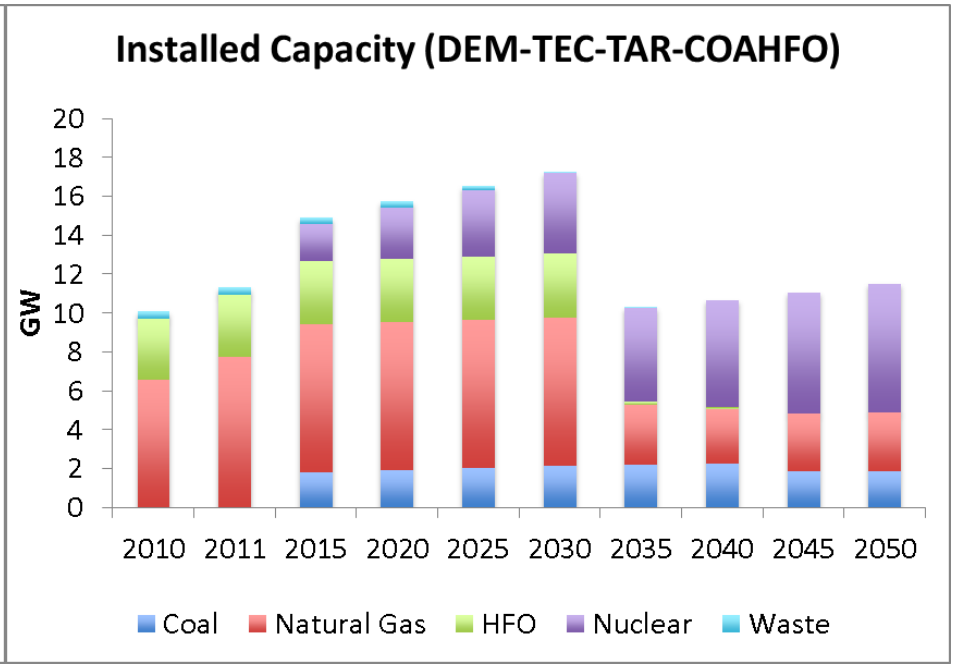


Electricity Sector Emission Reduction Scenario 1/3

- Fixed range of Coal+HFO mix (20% - 30%)

Installed Capacity

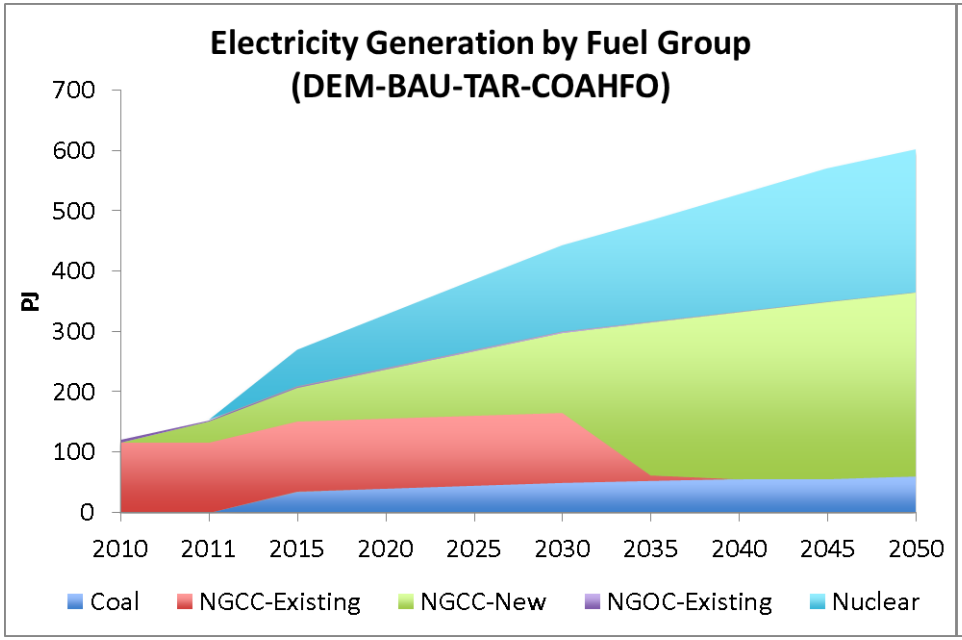


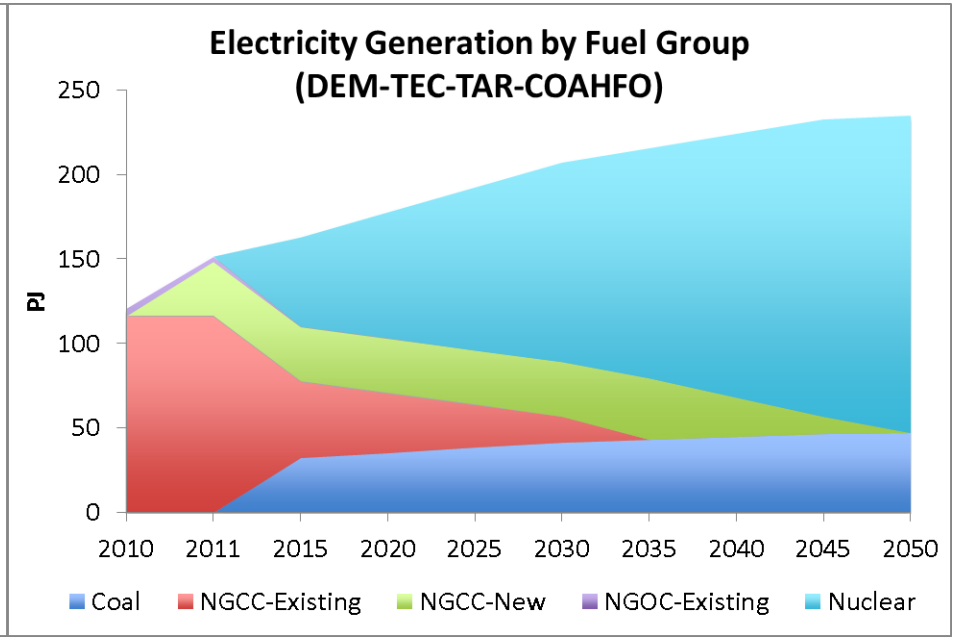


Electricity Sector Emission Reduction Scenario 2/3

- Fixed range of Coal+HFO mix (20% - 30%)

Fuel Mix

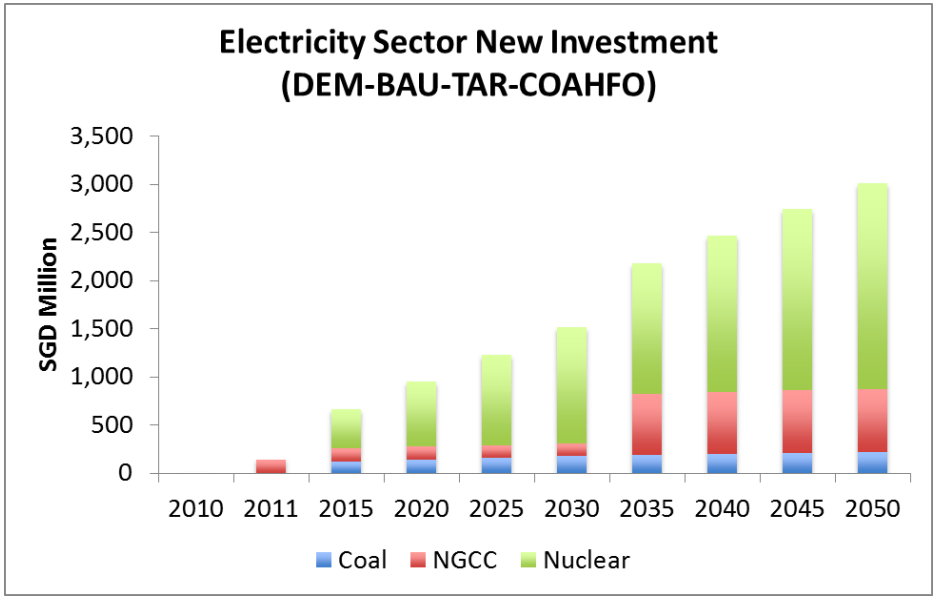


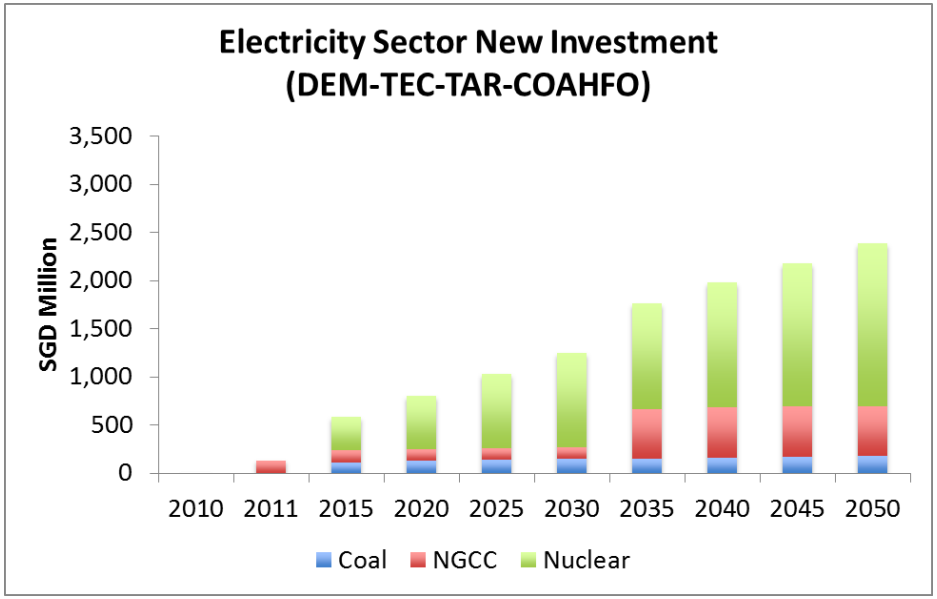


Electricity Sector Emission Reduction Scenario 3/3

- Fixed range of Coal+HFO mix (20% - 30%)

Investment Schedules

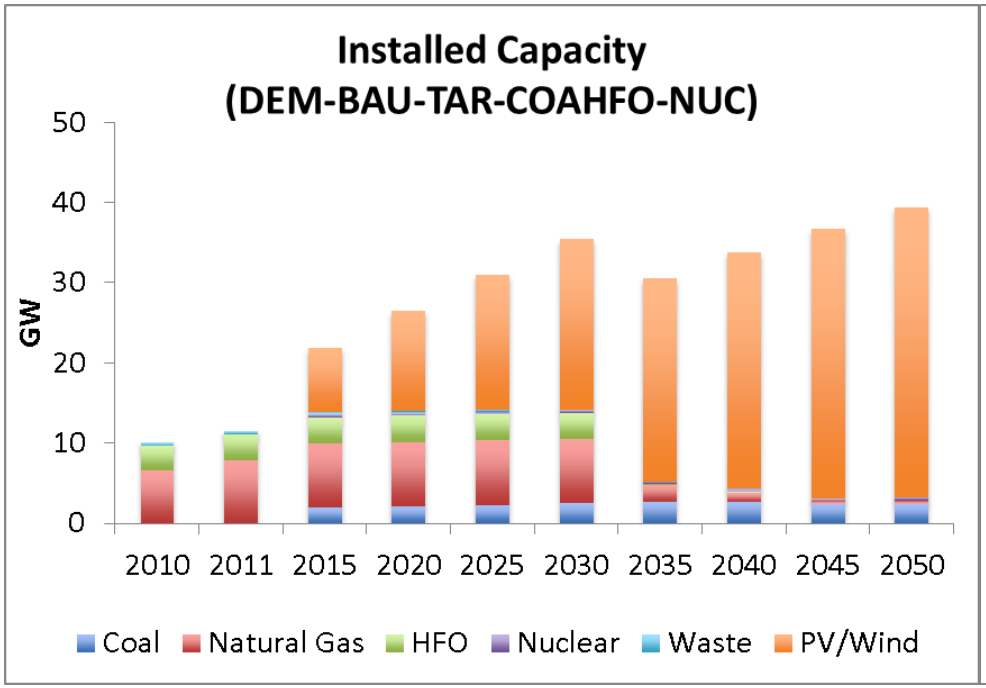


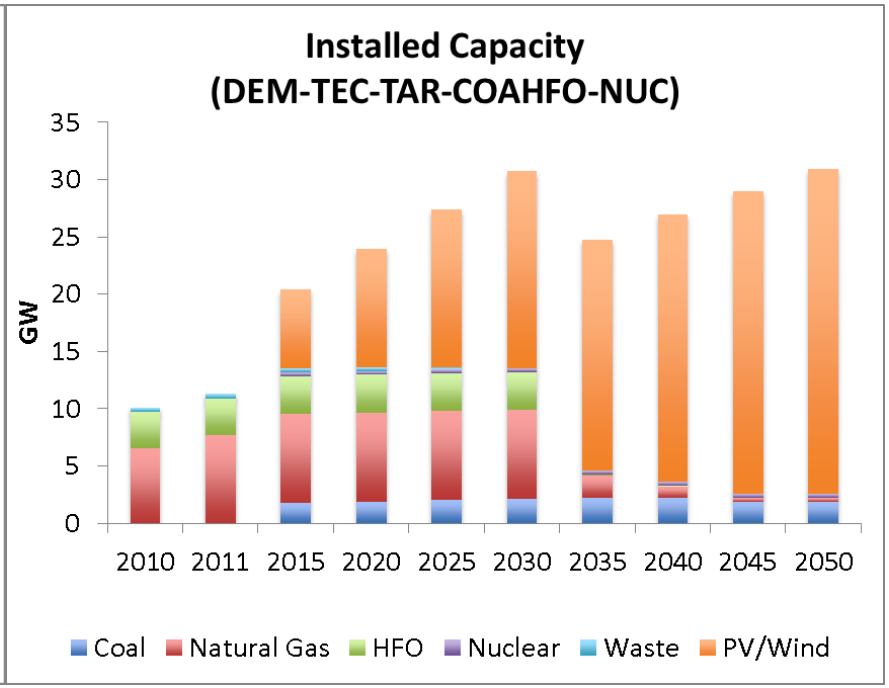


Electricity Sector Emission Reduction Scenario 1/3

- Fixed range of Coal+HFO mix and "Less Nuclear"

Installed capacity under fixed range of Coal+HFO share and max Nuclear capacity (1 GW) in the fuel mix

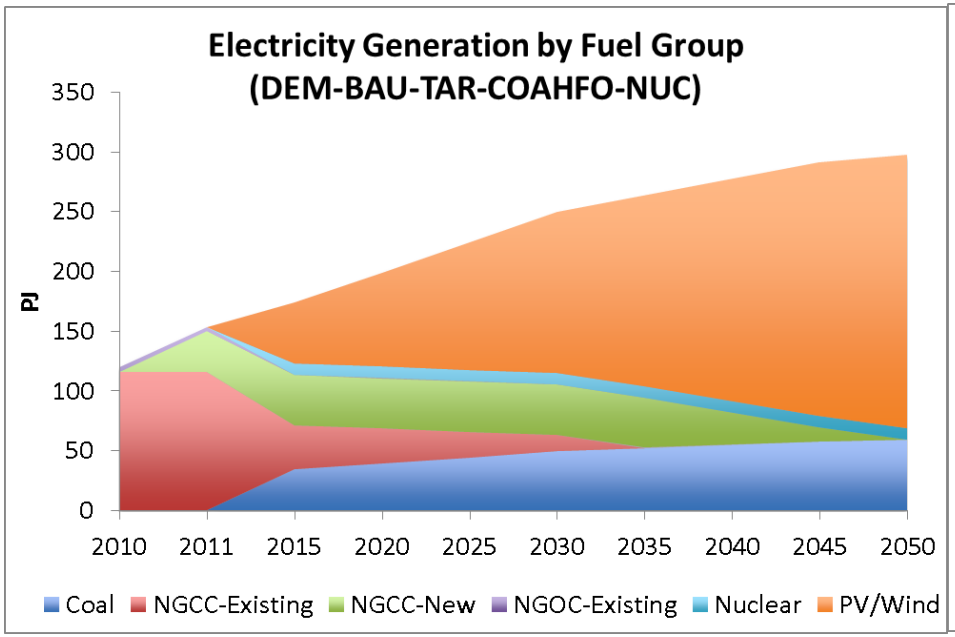


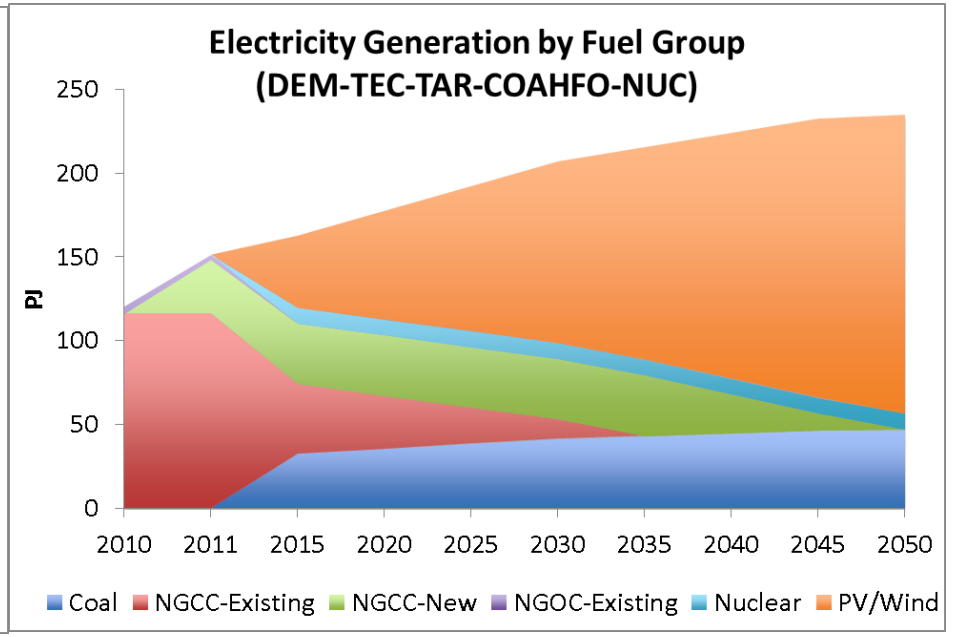


Electricity Sector Emission Reduction Scenario 2/3

- Fixed range of Coal+HFO mix and "Less Nuclear"

Fuel Mix under fixed range of Coal+HFO share, and max Nuclear capacity (1 GW)

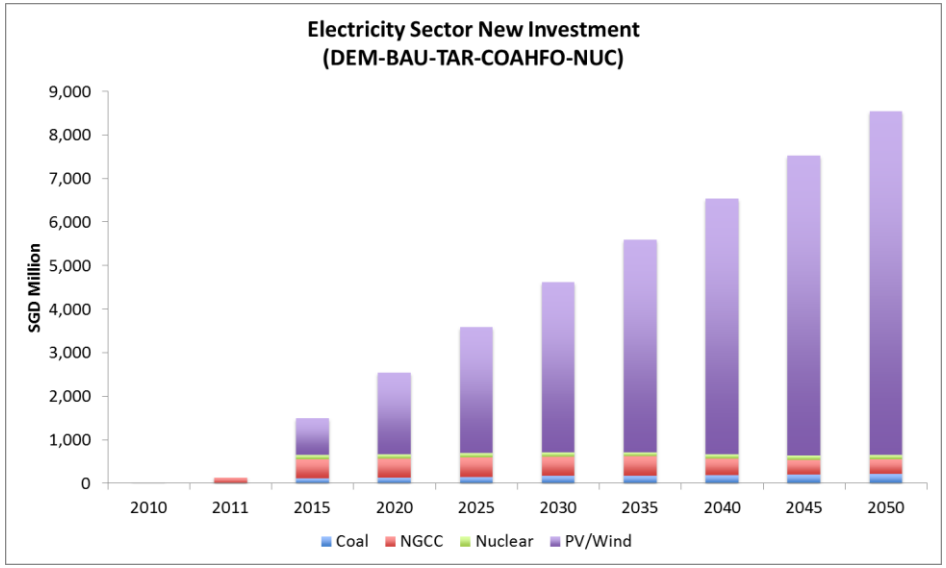


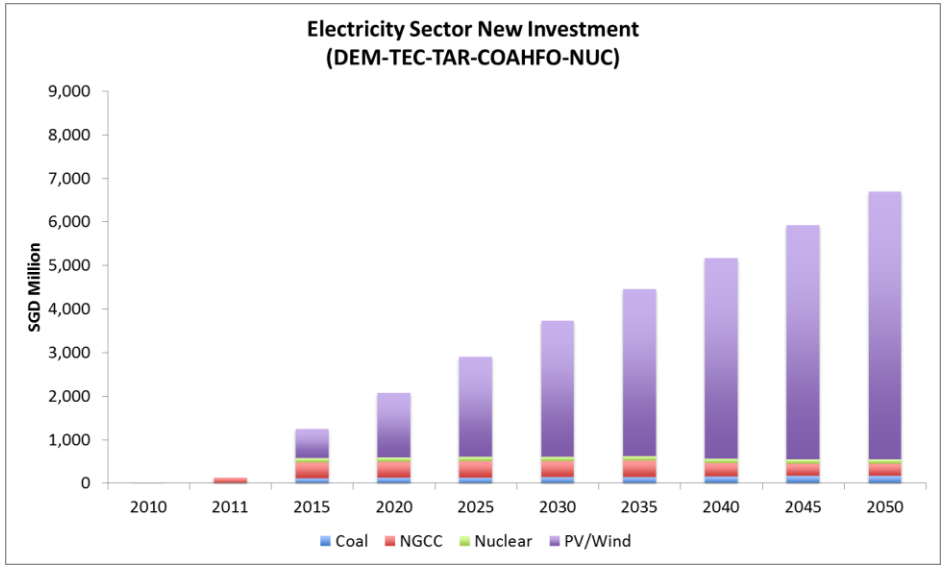


Electricity Sector Emission Reduction Scenario 3/3

- Fixed range of Coal+HFO mix and "Less Nuclear"

Investment Schedules





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Concluding Remarks

- As of now
  - We have developed an electricity sector model using TIMES with accurate calibration for the base year 2010
  - We have identified and tested a methodology to mitigate the dependence on sensitive information
- Next
  - Expanding towards an economy wide TIMES model
  - Expanding towards a multi-regional model for the ASEAN region

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Thank you

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