NAUTILUS INSTITUTE

Republic of Korea LEAP Modeling Effort

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Spent Fuel and Reduction of Radiological Risk after Fukushima and Deep Borehole and Spent Fuel in East Asia WORKING GROUP MEETING

May 28-30, 2013, Beijing, China

OUTLINE OF PRESENTATION

- Introduction: Model Background
- Key Data Sources
- Model Structure
- Key Assumptions Used in Modeling to Date
- Draft Results
- Next Steps in ROK LEAP Modeling Effort

ROK LEAP Model—Background

- **Model development over the period since approximately 2001 by Dr. Kim Hoseok**
  - **Updated to 2010 base year by Dr. Kim**
  - **Dr. Kim sends his greetings to Working Group Colleagues, but could not attend due to his GGGI commitments**
- **Model used by Dr. Kim for a variety of studies in his positions for Korea Environment Institute and for other organizations in Korea**
  - **Published study on use of Landfill Gas is an example**
- **D. von Hippel is running ROK-LEAP for the project with input from Dr. Chung Woo-jin, Dr. Kang Jungmin**

The ROK LEAP Model: Key Data Sources

- Overall: KEEI detailed energy balance tables used as "control total" source for major totals for base year (2010) supply and demand
- Residential—Driven by number of households
  - Energy: 2008 AND 2012 Energy Consumption Survey (MOCIE 2008, 2012), Survey on Electricity Consumption Characteristics of Home Appliances (2006,2012, Electric Power Information System)
  - Heating: # of household by heating type from Statistics Korea
  - Activities: National Demographic Survey (NSO)
- Industrial—Driven by industrial GDP, share of GDP by subsector
  - Energy: 2008,2012 Energy Consumption Survey (MOCIE 2008. 2012), Yearbook of Energy Statistics (MOCIE & KEEI, 2011 and earlier); intensities calculated based on above, below
  - Activities and Fuel Shares: Economic Statistics System, KEEI Energy Statistics Yearbook (2011)

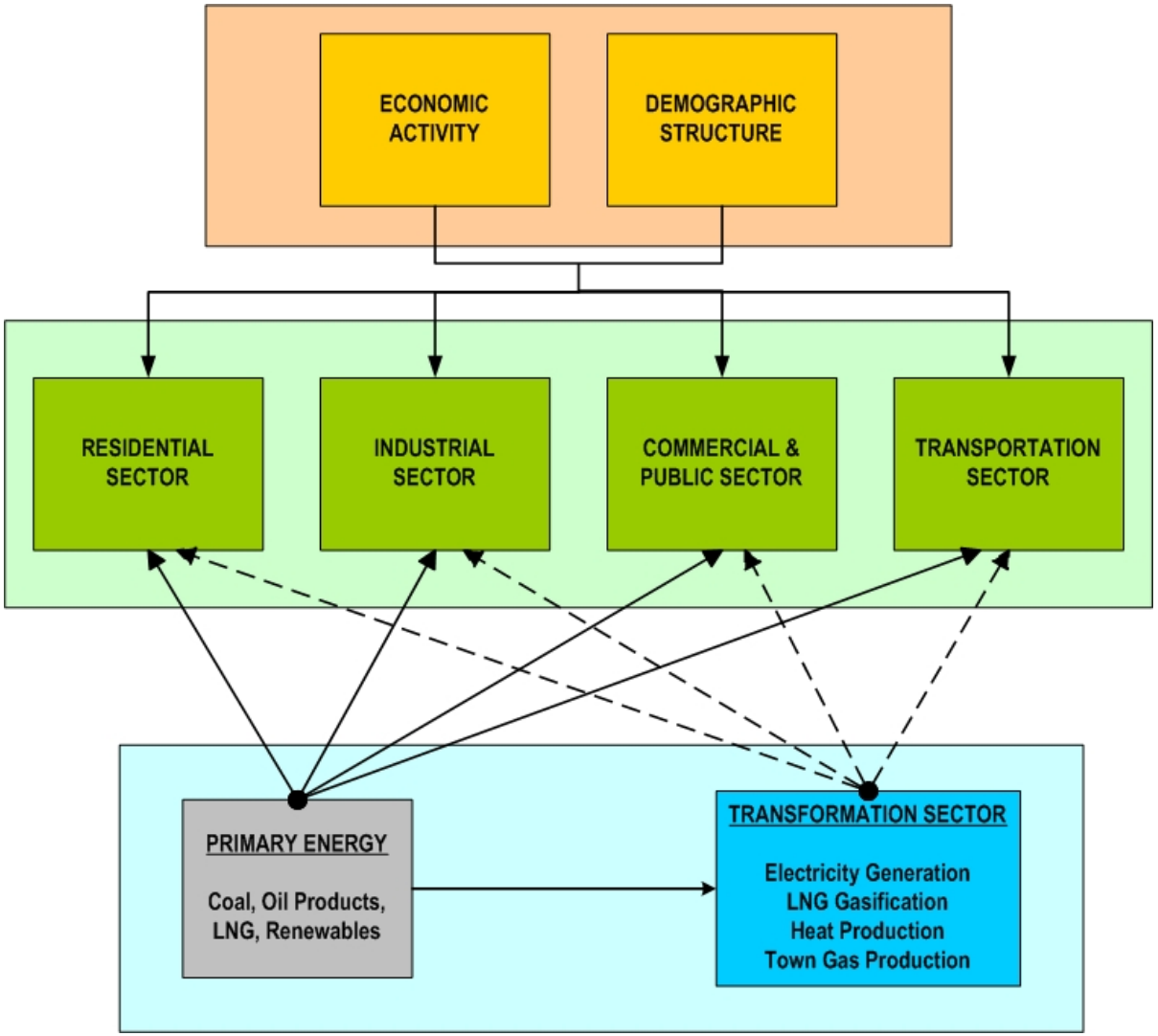
The ROK LEAP Model: Key Data Sources

- Commercial/Public—Driven by building area
  - Energy: 2008, 2012 Energy Consumption Survey (MOCIE 2008, 2012), Yearbook of Energy Statistics (MOCIE & KEEI and earlier)
  - Activities: Sectoral floor space information from 2007 Wholesale & Retail Survey and 2007 Service Industry Survey
  - Recent activity, intensity, and fuel share data from Energy Consumption Survey (KEEI)
  - Some additions to Public energy use based on biomass use as reflected in KEEI 2010 Energy Balance
- Transport—Driven by number of vehicles and travel distance
  - Energy: 2008 and 2012 Energy Consumption Survey (MOCIE 2008, 2012), Yearbooks of Energy Statistics (MOCIE & KEEI)
  - Activities: Fuel Economy & car sales data from KEMCO, Travel distance from Road Safety Corporation , Yearbook of Construction & Transportation Statistics
  - International air travel and water freight transport from KEEI Yearbook

The ROK LEAP Model: Key Data Sources

- Transformation Module Data:
  - Yearbooks of Energy Statistics (MOCIE & KEEI)
  - Korea Electric Power Corporation
  - Korea Gas Corporation
  - Korea Coal Corporation
  - Korea District Heating Corporation
  - Long-term Electricity Sector Plan, Ministry of Knowledge Economy
- Socio-Economic Indicators and Key Assumptions
  - Statistics Korea
  - Bank of Korea
  - - Households
  - Population, Persons per household, and other projections from National Demographic Survey

ROK2013 LEAP Model



The ROK LEAP Model: Demand Structure

DEMAND SECTOR	SUB-SECTORS	ACTIVITY PARAMETERS	FUELS
Residential	**HEAT**: By dwelling type (Traditional, coal, oil, LPG, town gas, central, district, others) **APPLIANCES**: 18 electric appliance types	Households Dwelling types Saturation of end uses (%)	electricity, LPG, heat, coal, kerosene, town gas
Industrial	**Agriculture & Fishery, Mining** **Manufacturing**: divided into 10 business types **Construction**	Industrial sector GDP (Korean Won, or KRW) Shares of each sub-sector (%) Energy intensity (E/KRW) Fuel share (%)	coal, gasoline, kerosene, diesel, fuel oil, LPG, town gas, heat, electricity, **naphtha**

The ROK LEAP Model: Demand Structure

DEMAND SECTOR	SUB-SECTORS	ACTIVITY PARAMETERS	FUELS
Commercial & Public	11 business types: Waste management, wholesale and retail, hotel and restaurant, information & communication, real estate, scientific activities, business support, education, health and social work, art and sports, other services	Floorspace (m^2) Energy intensity ($kcal/m^2$) Fuel share (%)	electricity, LPG, fuel oil, heat, diesel, kerosene, town gas
Transportation	Public, Private, and Business road vehicles, by type, size Mass Transit (road, rail, air) Freight (road, rail, water) International air passenger and water freight	Vehicle population Shares of each vehicle type and size (%) Energy Intensity (E/vehicle) Fuel share	gasoline, diesel, LPG, natural gas, electricity, fuel oil, ethanol, biodiesel

The ROK LEAP Model: Demand Activities Assumptions

Activity/Parameter	2010	2020	2030
Population (million)	48.0	51.4	52.2
GDP Growth Rate (%)	6.30	3.66	2.24
Commercial floor space (million square meters)	412	548	728
Vehicle Population (million vehicles)	17.9	25.5	32.0

THE ROK LEAP MODEL

TRANSFORMATION STRUCTURE

- Electricity T&D
- Electricity Generation — 11 Types of power plants, including Industrial Combined Heat and Power (CHP)
- District Heat production
- Town Gas production
- LNG Gasification
- Oil Refining
- Blast Furnace Gas Production
- Coke Production

D. von Hippel 5/2013

The ROK LEAP Model: Transformation Structure

MODULE	PROCESS TYPES	KEY PARAMETERS	FUELS
Electricity Transmission & Distribution		Losses (%)	
Electricity Generation	Coal steam (bituminous and anthracite) Oil steam, LNG steam Combined cycle (gas) Internal combustion Nuclear (PWR/CANDU) Hydro (PS/non-PS) Renewables	System load factor (%) Process shares (%) Efficiency (%) Base year output Exogenous capacity Merit order (base, intermediate, peak) Fuel share (%)	Coal Fuel oil Natural gas Diesel Nuclear Hydro Renewables
District Heating	Heat only boiler (HOB)	Efficiency (%)	Natural gas, fuel oil, town gas
Town Gas Production		Efficiency (%)	Natural gas, LPG
LNG Gasification		Efficiency (%)	LNG
Oil Refining		Efficiency (%)	Crude oil

THE ROK LEAP MODEL: Assumptions

Key Future Assumptions in Energy Demand

- Residential
  - Driven by number of households, and persons per household declines from ~2.8 in 2010 to 2.4 in 2030
  - Space heating—continued increase in the share of town gas and district heating, and continued slow decline in intensity per housing unit
  - Substantial increase in use of air conditioners, some increases in number of televisions, kimchi refrigerators, vacuum cleaners per household
  - The energy intensity of electric appliance use decreases at a rate sufficient to yield a 25% improvement by 2050 (or 12.5% by 2030)

THE ROK LEAP MODEL: Assumptions

Key Future Assumptions in Energy Demand

- Industrial—Driven by industrial GDP, share
  - Share of value added by Manufacturing falls slowly
  - Within Manufacturing, share of Chemicals decreases markedly over time, (which reduces Naptha use), "Misc Manufacturing" increases to compensate, others remain the same over time
  - All intensities slowly decline over time
- Commercial—Driven by building area, which rises rapidly (by 75% by 2030)
  - Fuel shares and energy intensities remain relatively constant
- Public—Driven by government expenditures, which rise by 75% by 2030
  - Energy intensities, fuel shares don't change

THE ROK LEAP MODEL: Scenarios

Future Energy Paths for the Republic of Korea

- **Business-as-Usual (BAU) path**
  - Assumes generally that existing policies and currently evolving economy/energy sector trends continue
  - Attempts to reach similar fuel use, shares as in recent KEEI and Ministry of Energy projections
  - But as such is a moving target, because plans in ROK are in flux
  - Assumes continued build-out of nuclear reactors to a total of about 43 GW by 2030 (from 19 GW in 2010), but declines slowly after 2050 (not yet considered directly in LEAP)
  - Includes relatively little additional gas-fired capacity, and a slow decline in the use of gas for generation
  - Includes a considerable increase in the use of coal for generation, and of renewable energy use, but for transport (10% by 2030) and for generation (15.5 GW by 2030)

THE ROK LEAP MODEL: Scenarios

KEEI Projections from Late 2012; Units, Tonnes of Oil Equivalent

	2010	2015	2020	2025	2030	2035	AAGR(%) ('10~'35)
Coal	75.9 (28.9)	91.5 (30.8)	104.5 (30.9)	106.6 (29.3)	118.1 (30.4)	123.2 (30.5)	2.0
Oil	104.3 (39.7)	105.5 (35.6)	113.6 (33.6)	115.1 (31.7)	115.9 (29.8)	114.9 (28.5)	0.4
Natural Gas	43.0 (16.4)	45.2 (15.2)	47.5 (14.0)	55.4 (15.3)	54.6 (14.0)	59.3 (14.7)	1.3
Hydro	1.4 (0.5)	1.6 (0.5)	1.6 (0.5)	1.6 (0.5)	1.7 (0.4)	1.8 (0.4)	0.9
Nuclear	31.9 (12.2)	43.9 (14.8)	56.7 (16.8)	66.9 (18.4)	79.5 (20.5)	84.5 (20.9)	4.0
Renewable	6.1 (2.3)	8.9 (3.0)	14.1 (4.2)	17.5 (4.8)	18.9 (4.9)	20.1 (5.0)	4.9
Total	262.6 (100.0)	296.5 (100.0)	337.9 (100.0)	363.1 (100.0)	388.6 (100.0)	403.8 (100.0)	1.7

THE ROK LEAP MODEL: Scenarios

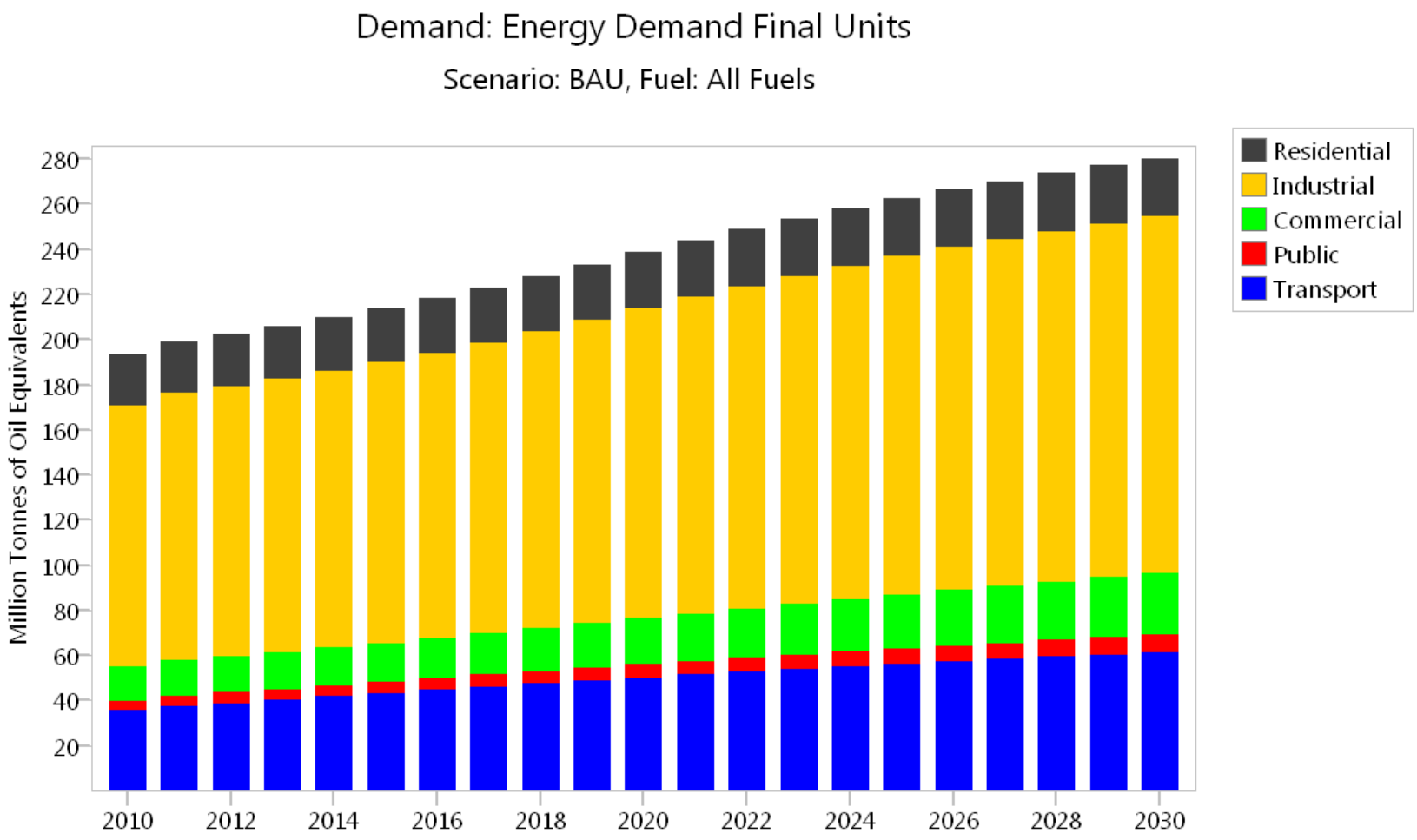
Future Energy Paths for the Republic of Korea

- **Minimum Nuclear (MIN) path**
  - Assumes reactor capacity peaks in 2025 at 35.7 GW, declines to 33 GW by 2030 (and to 25 GW by 2050)
  - To compensate for decreased nuclear capacity, MIN case includes an increase in coal-fired and combined-cycle plants in ratio of 67%/33%
- **Maximum Nuclear (MAX) path**
  - Assumes the same schedule for construction and decommissioning of existing reactors as in the BAU through 2030, but capacity continues to grow slowly through 2050

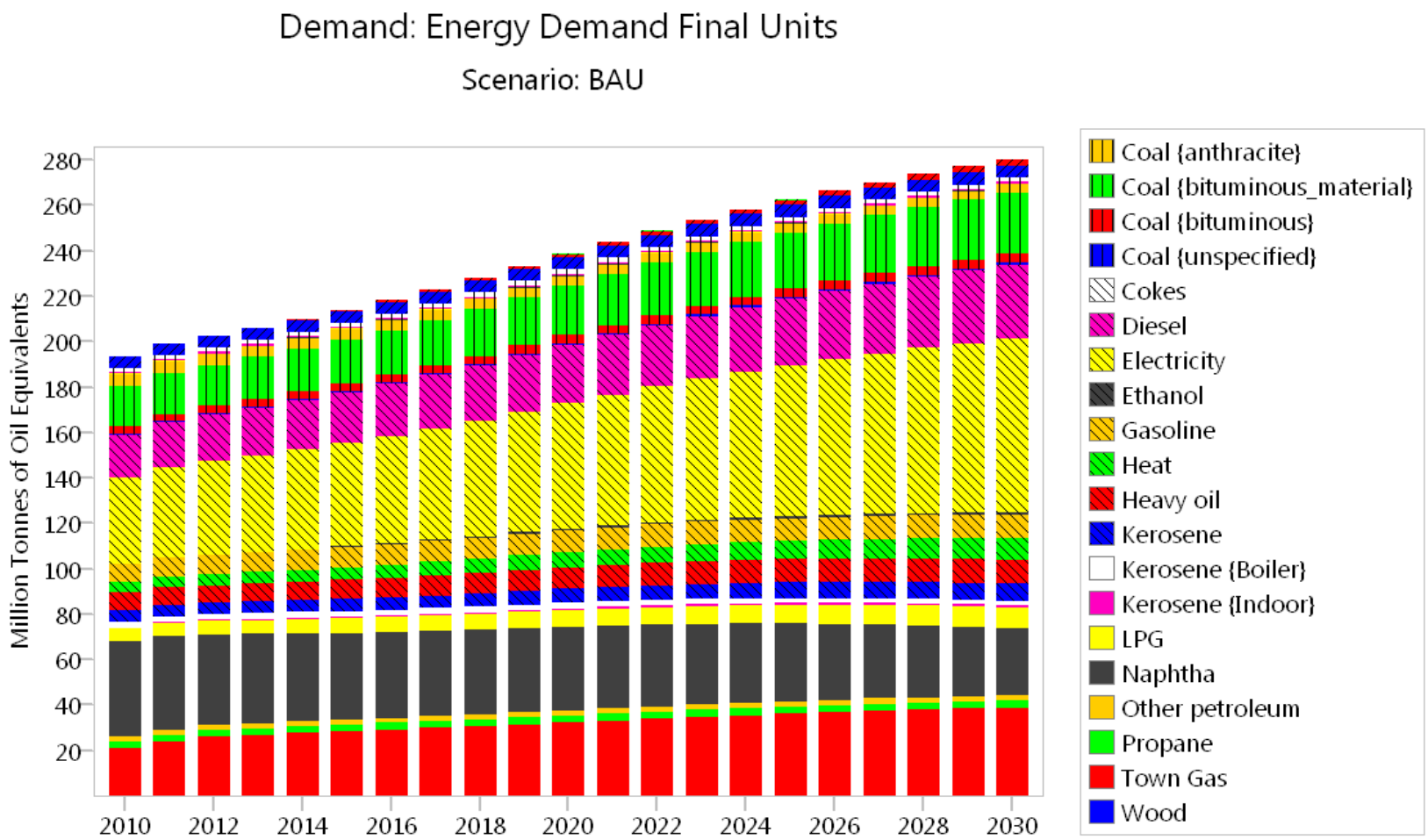
Generation Capacity Projections (GW)

	2007	2010	2015	2020	2025	2030
Antracite Coal	1.1	1.1	0.6	0.6	0.6	0.7
Bituminous Coal	19.3	23.1	28.8	28.8	29.9	31.8
Oil Steam	4.5	4.5	3.5	3.5	2.9	3.1
LNG Steam	1.5	0.9	0	0	0	0
Internal Combustion	0.3	0.3	0.2	0.2	0.2	0.2
Combined Cycle	13.8	15.9	19.3	19.3	20	21.3
	1.8	3.1	3.8	3.8	3.9	4.2
Nuclear	17.7	18.7	25.9	31.5	34.2	36.3
Hydro	5.5	5.5	6.4	6.4	6.6	7
Renewable	1.7	0.7	1.7	2.4	2.5	2.6
Total	67.3	73.9	90.1	96.4	100.9	107.1

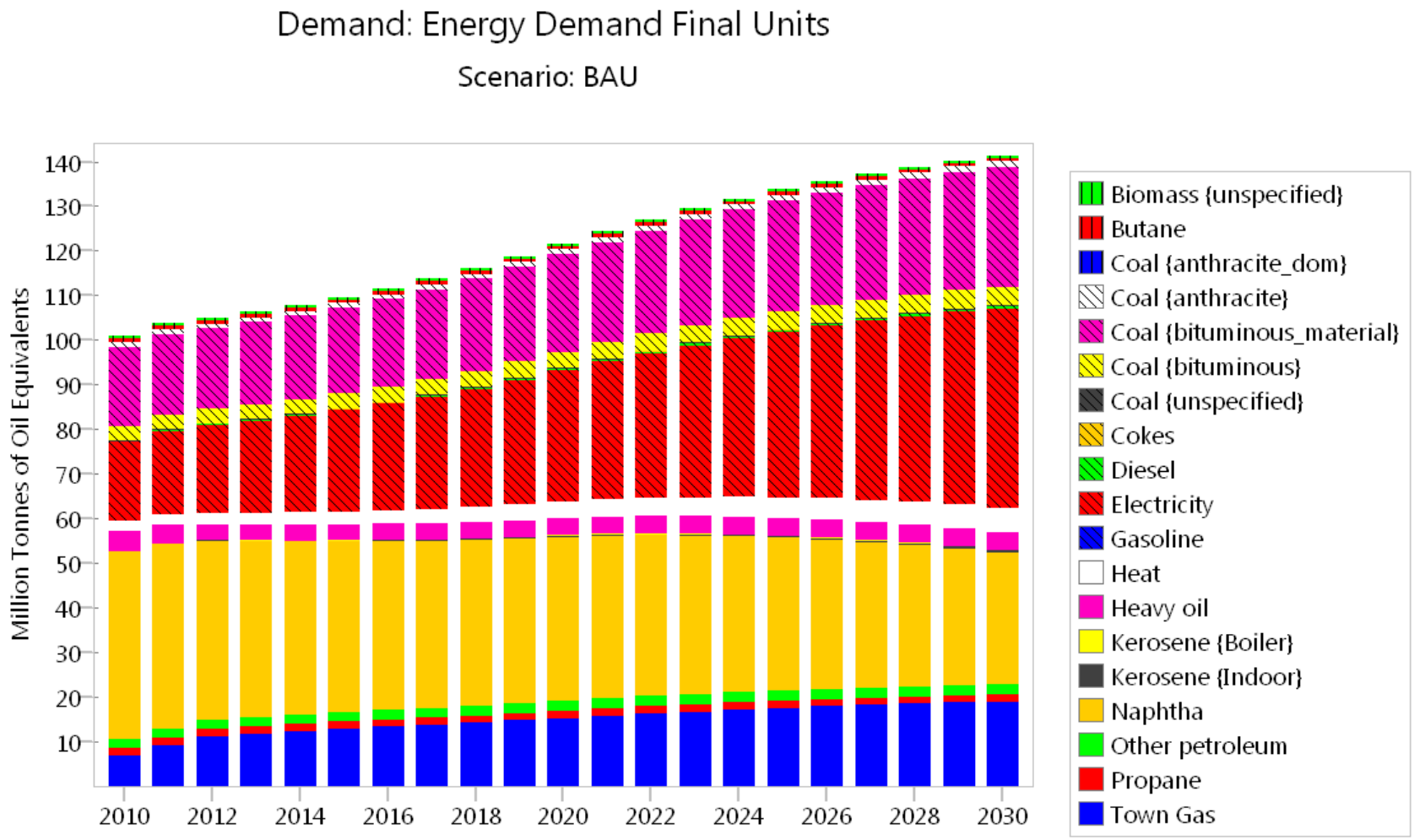
Final Energy Demand by Sector: BAU



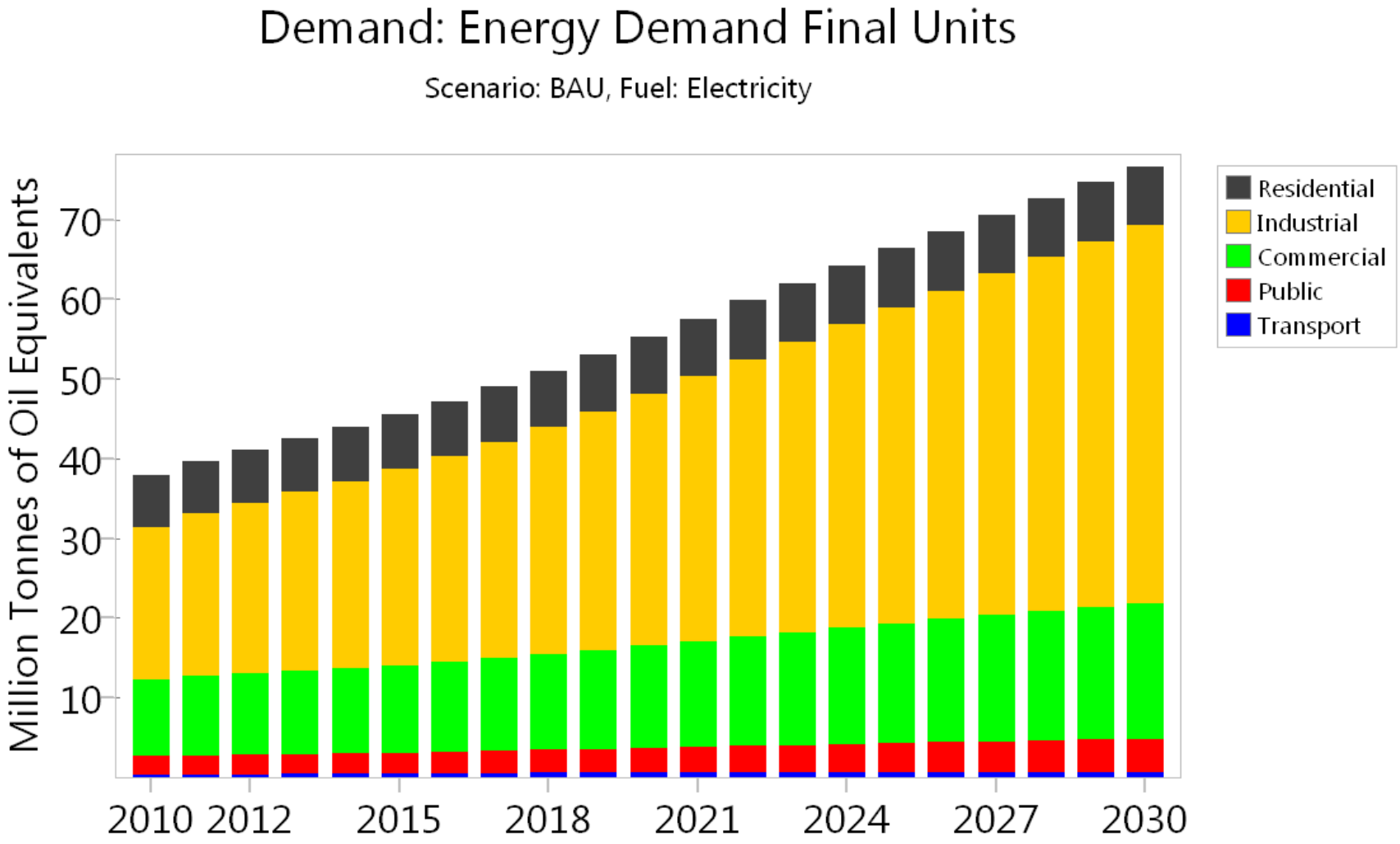
Final Energy Demand by Fuel: BAU



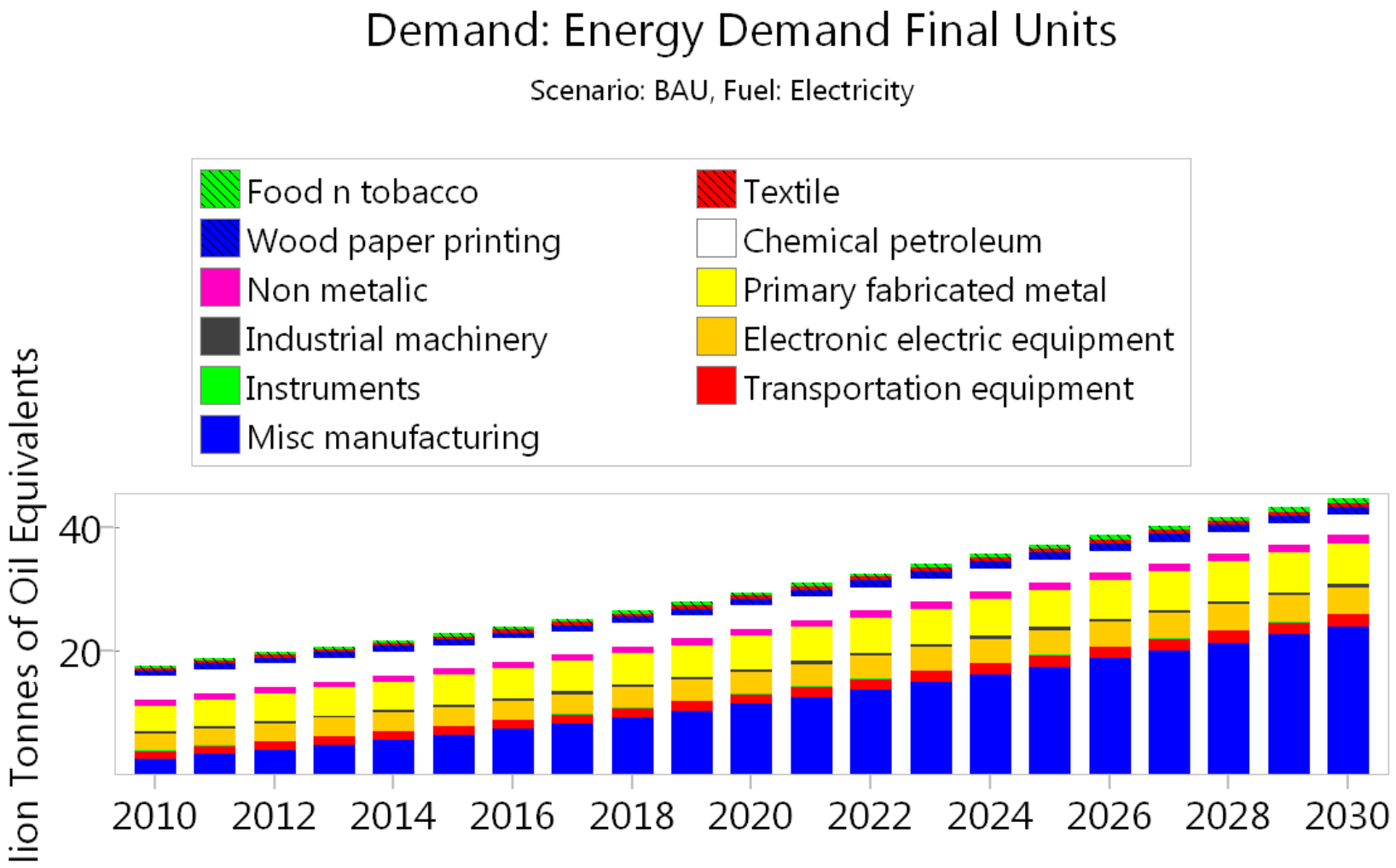
Final Industrial Demand by Fuel: BAU



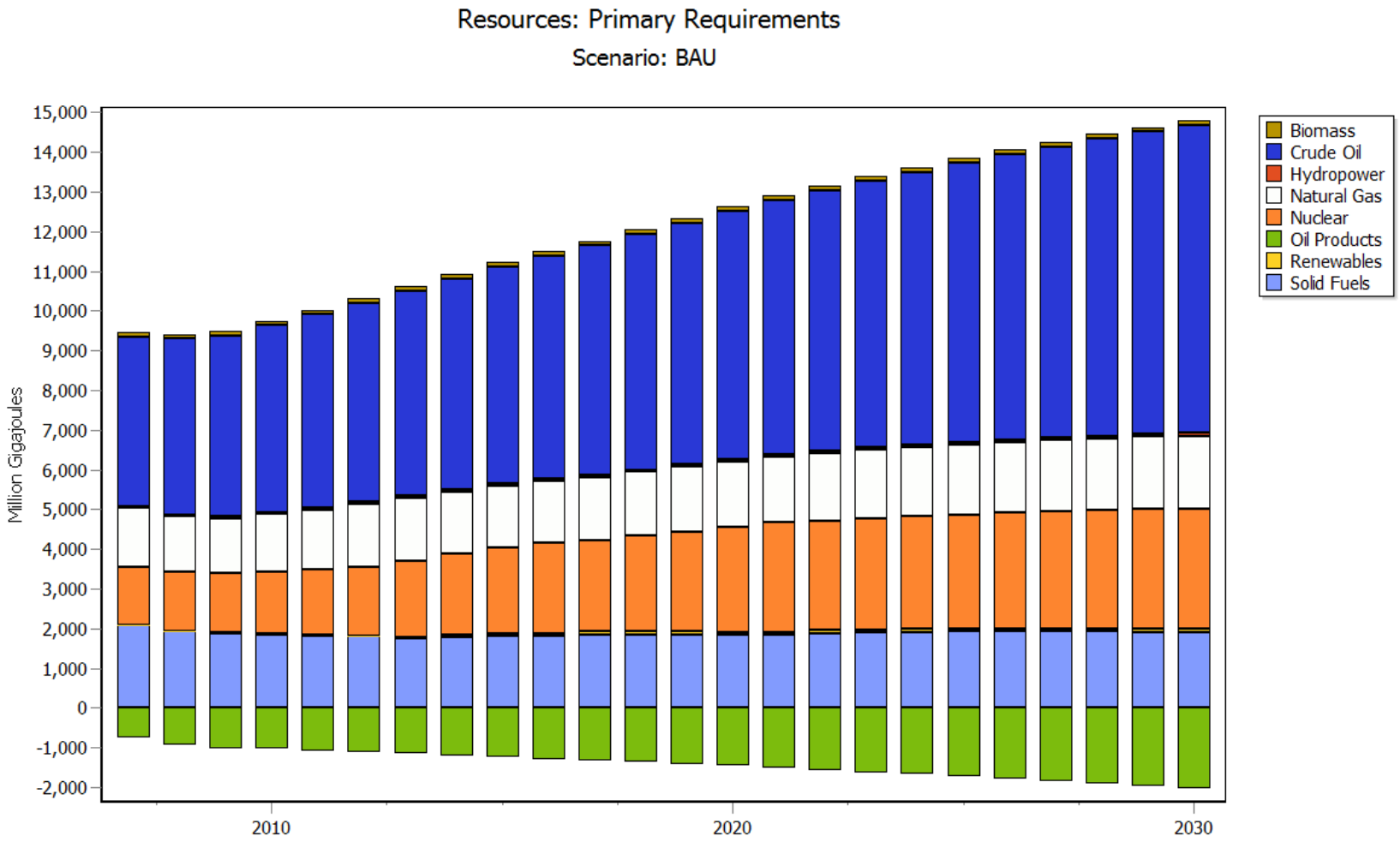
Final Electricity Demand by Sector: BAU



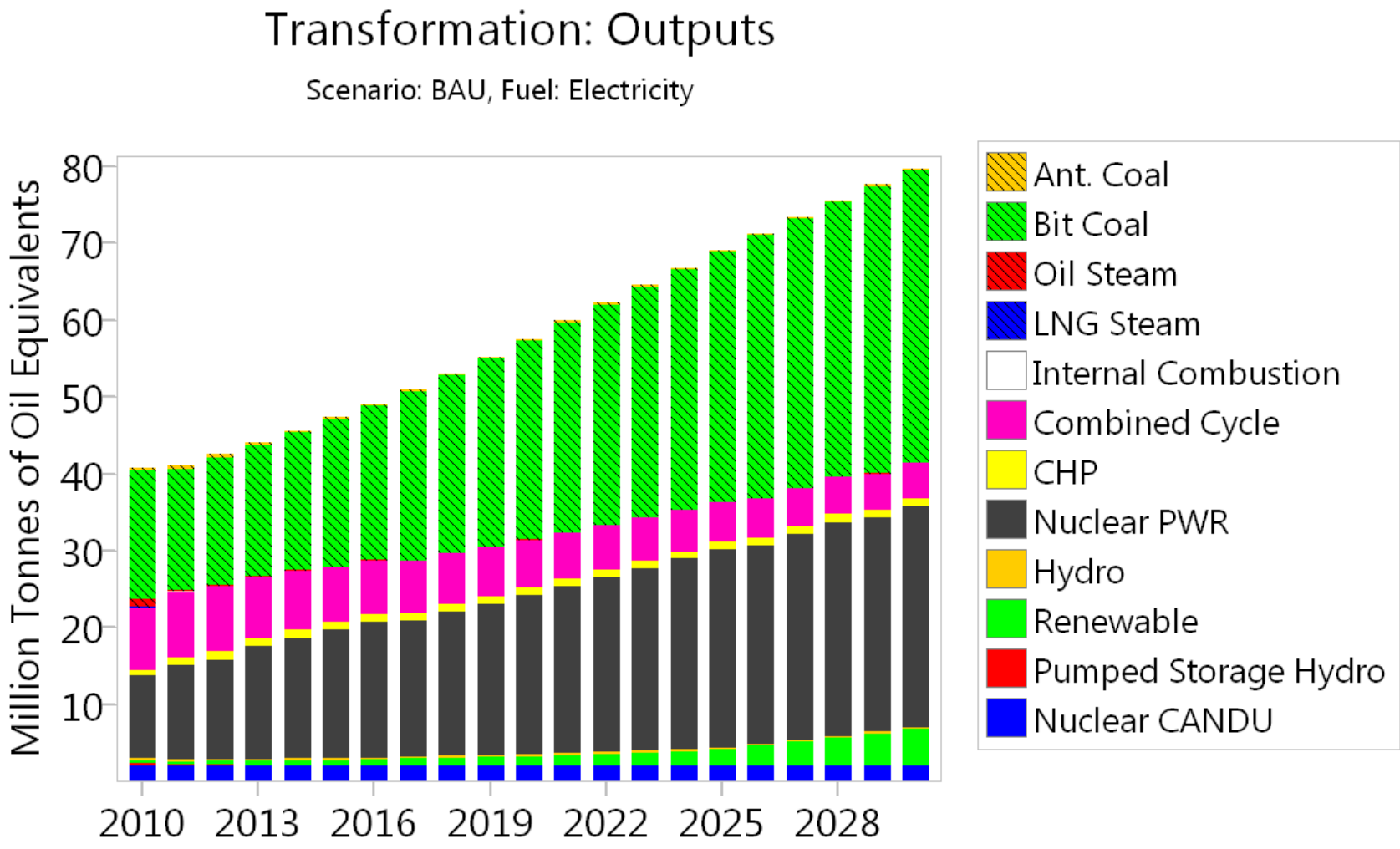
Final Electricity Demand by Sector: BAU



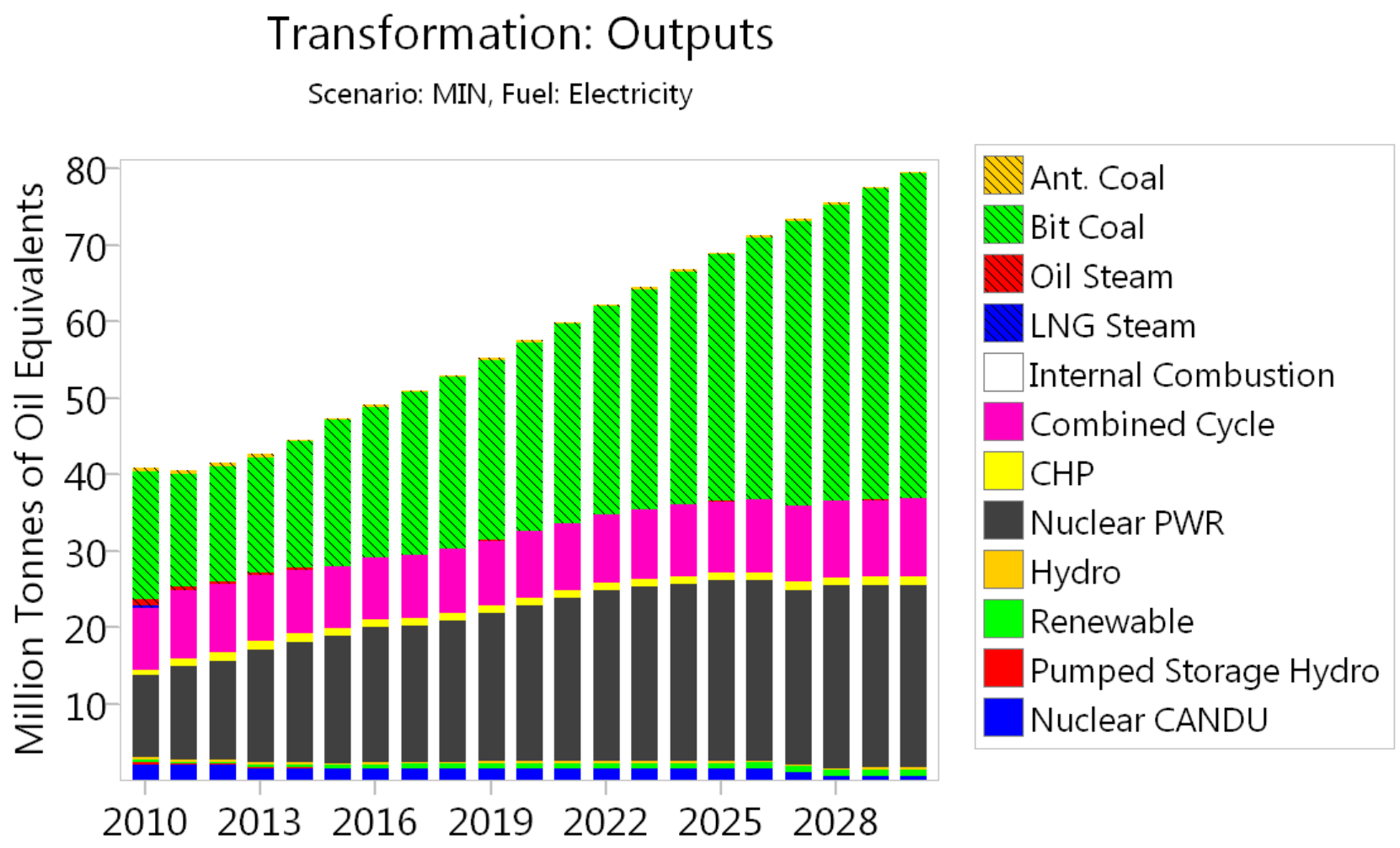
Primary Energy Requirements by Fuel: BAU



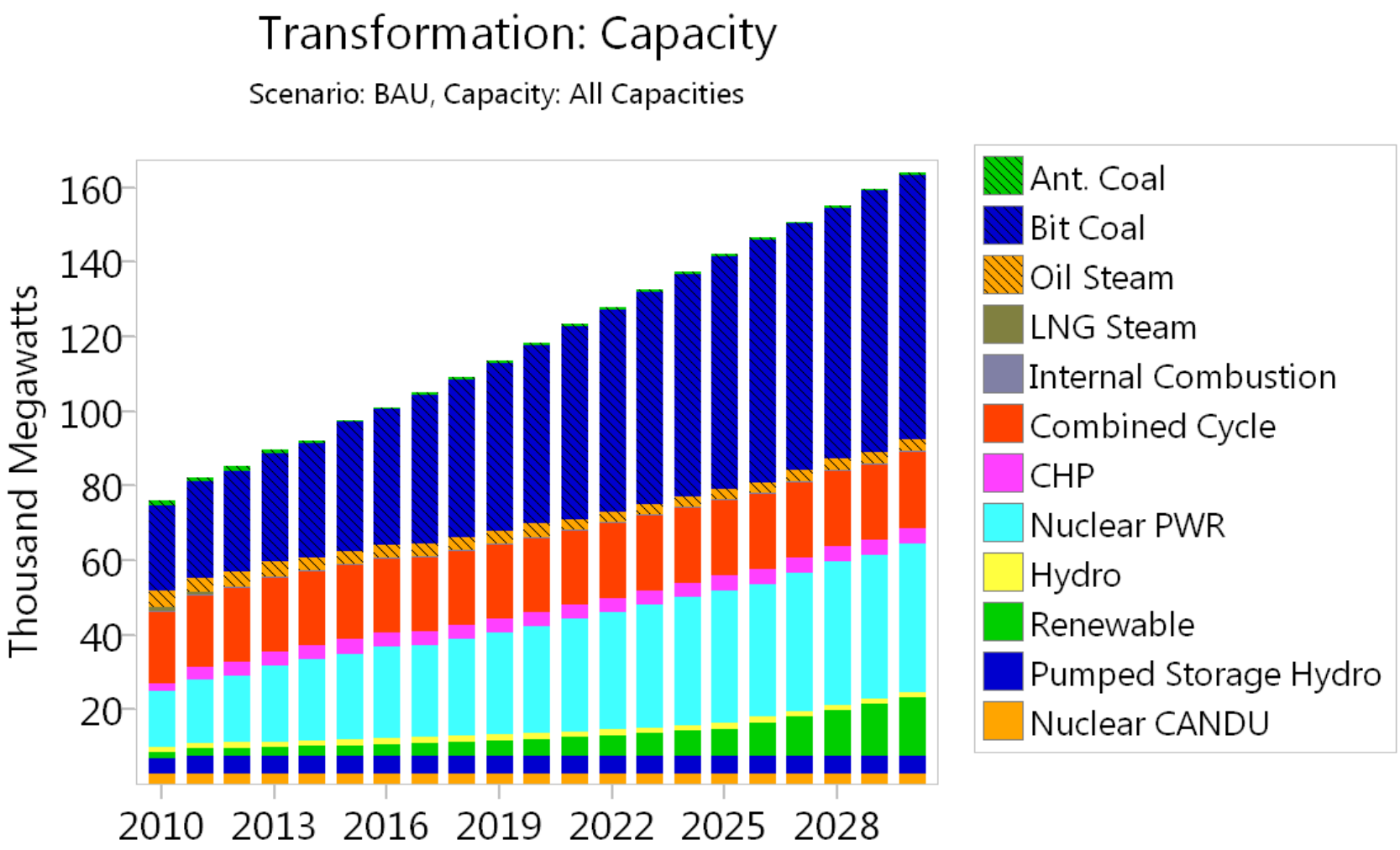
Electricity Output by Type: BAU



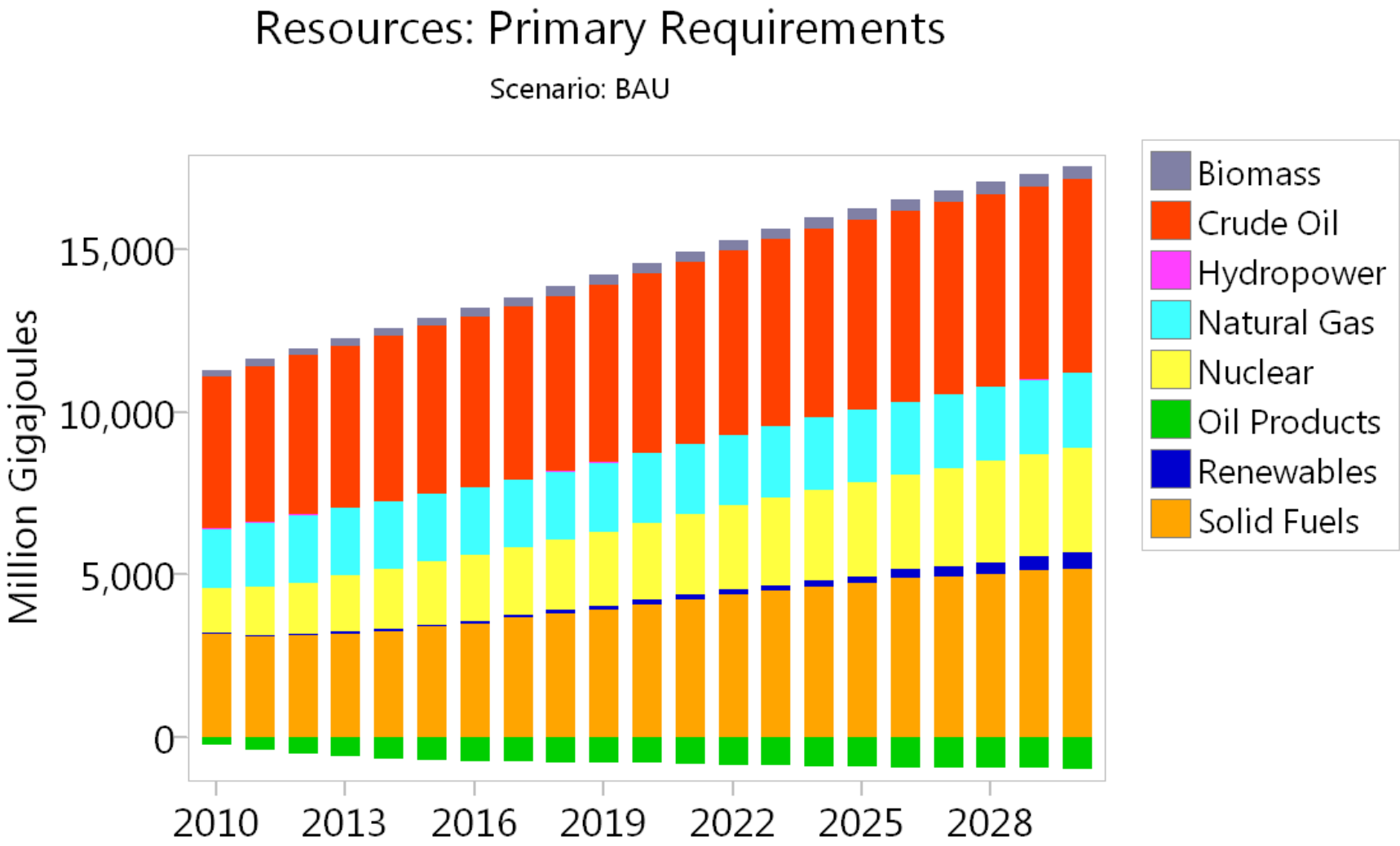
Electricity Output by Type: MIN



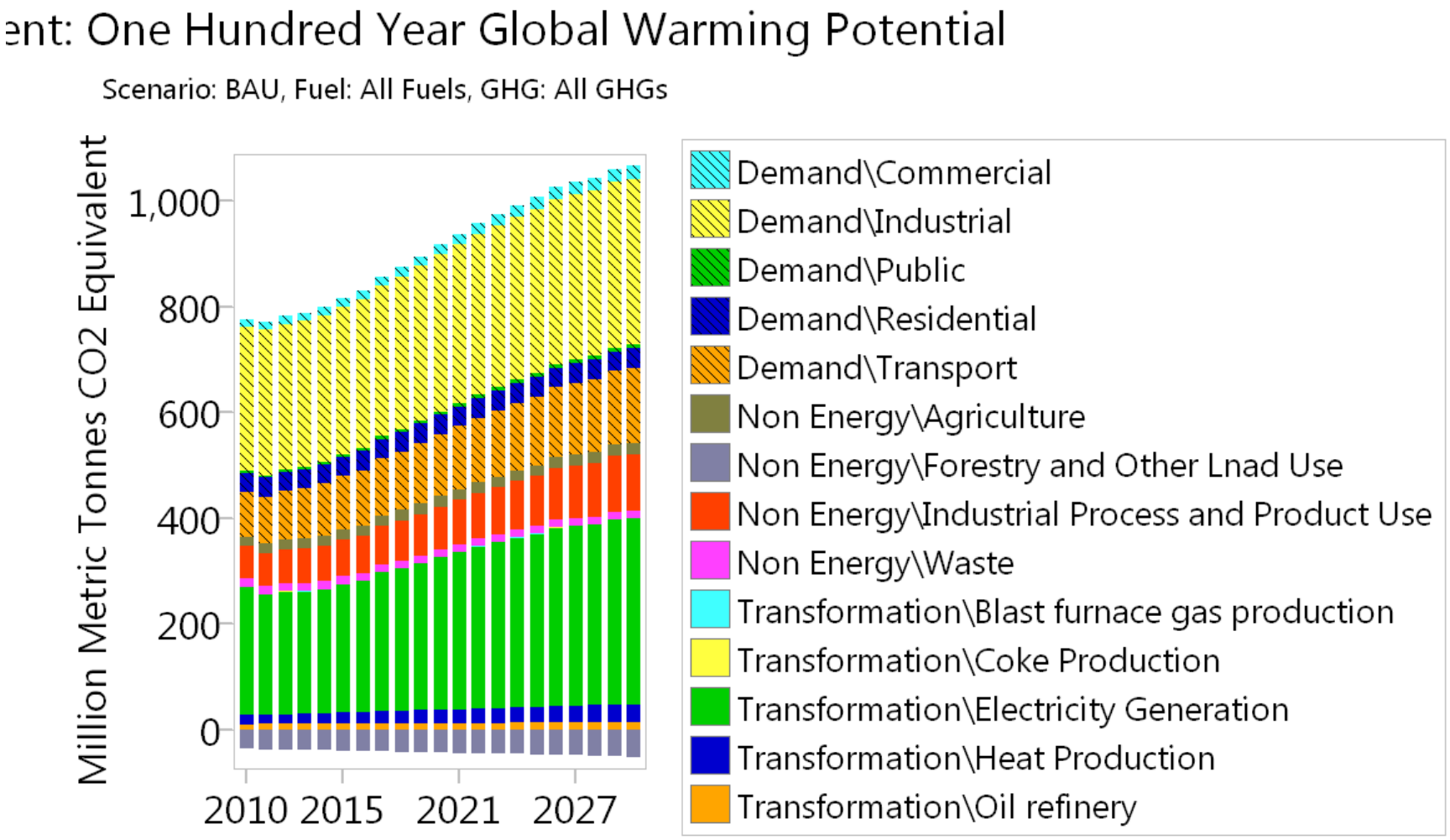
Electric Capacity by Type: BAU



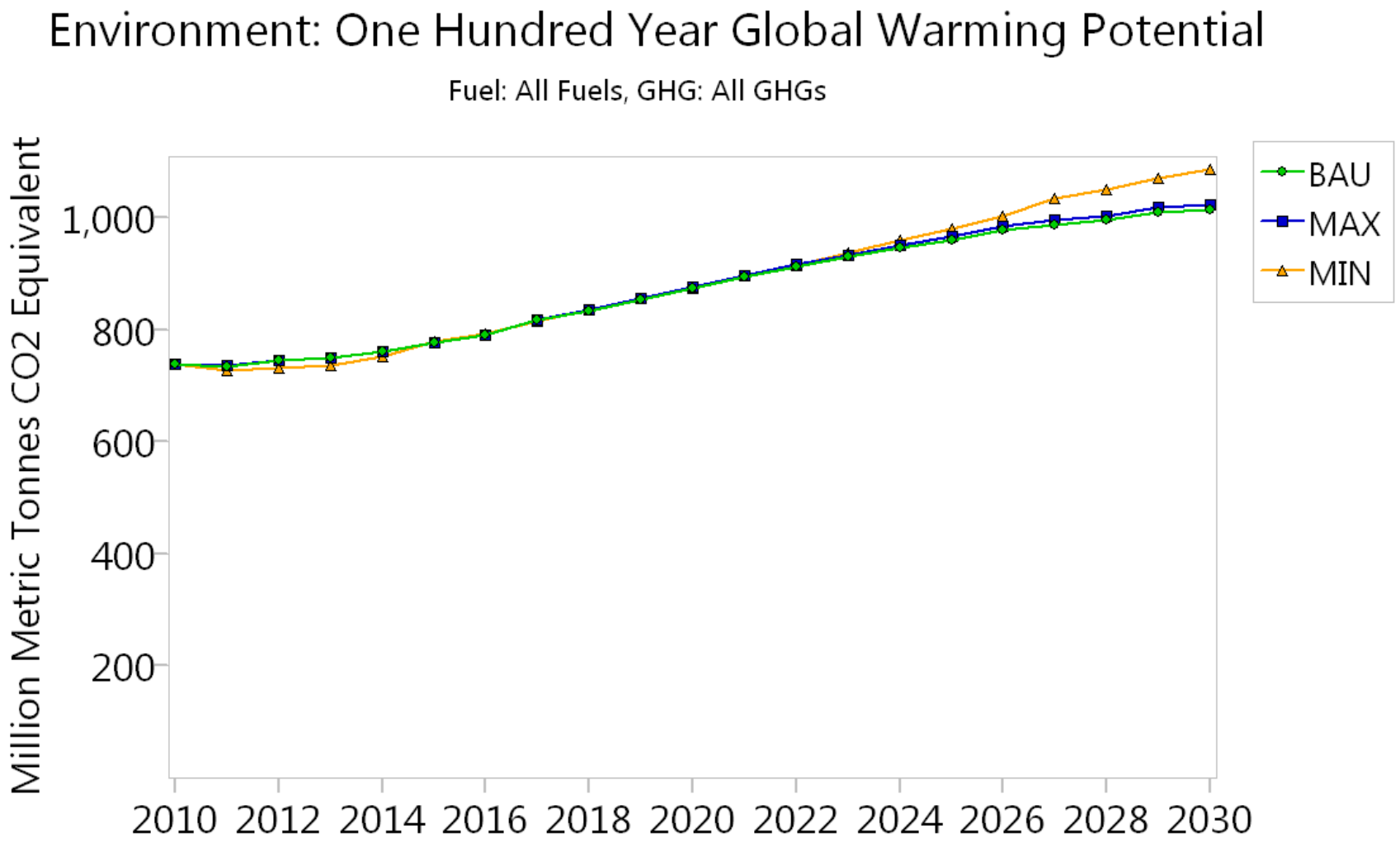
Primary Fuel Use by Type: BAU



GHG Emissions By Sector: BAU Path



GHG Emissions By Scenario



THE ROK LEAP MODEL: Next Steps

- Work with Dr. Chung and Dr. Kang to revise BAU, MIN, MAX Cases for consistency with sources (including any new plans)
- Prepare case approximating newer (2/2013) Ministry of Energy “Target” case
- Review assumptions for all Demand, Transformation branches for reasonableness
- Detail attributes of MIN, MAX, BAU paths as needed for modeling of regional nuclear fuel cycle cooperation

THE ROK LEAP MODEL: Next Steps

- Prepare one or more “National Alternative” cases that focus more on energy efficiency, renewable energy, “green growth”
- Revise older “Regional Alternative” path that includes National Alternative attributes, and also models the inclusion of the ROK in regional energy cooperation initiatives (including with DPRK)

THANK YOU!

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