LEAST-COST ELECTRICITY

BERT DALUSUNG

Director, Preferred Energy Inc.

Member representing RE Developers
National Renewable Energy Board (NREB)

National Energy Policy Review Forum
Climate Change Commission
October 27, 2017

Some facts about our power system

Power System Operation

- Customer demand and system supply must balanced <u>at all times</u>.
- The balancing process is carried out in several time frames.
  - Generating units are typically committed to operation a day ahead to cover the forecasted load profile for that day plus a reserve margin .
  - Scheduling (or economic dispatch) of plant output levels is then carried out on an hourly basis.

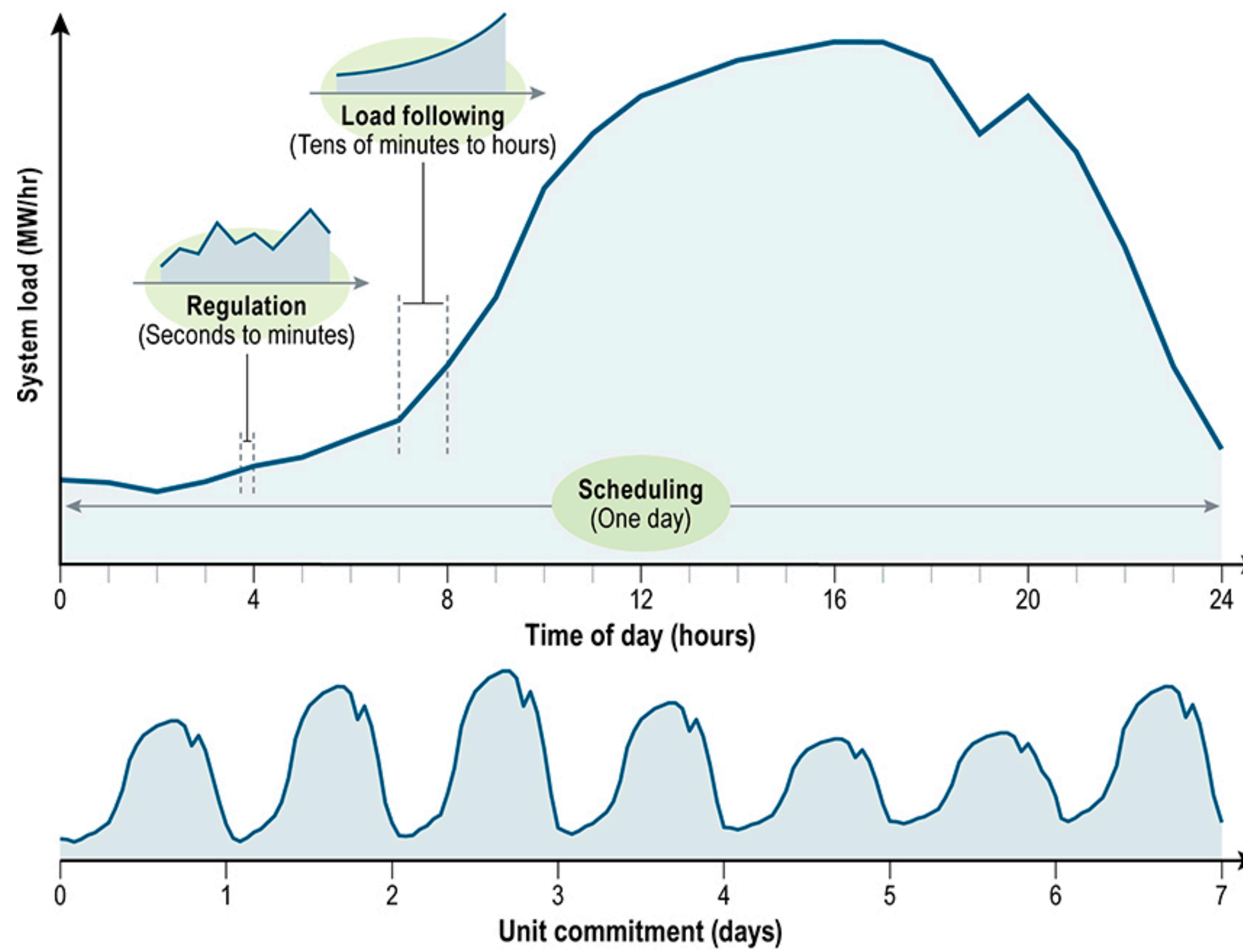

Figure 25-1. Timescales for power system operation

The figure is illustrative and not to scale. The notch at 18–19 hours represents a secondary peak that occurs in some regions in early weekday evenings as commercial load drops off and residential loads ramp up.

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Figure 4. Hourly Demand Profile – Luzon

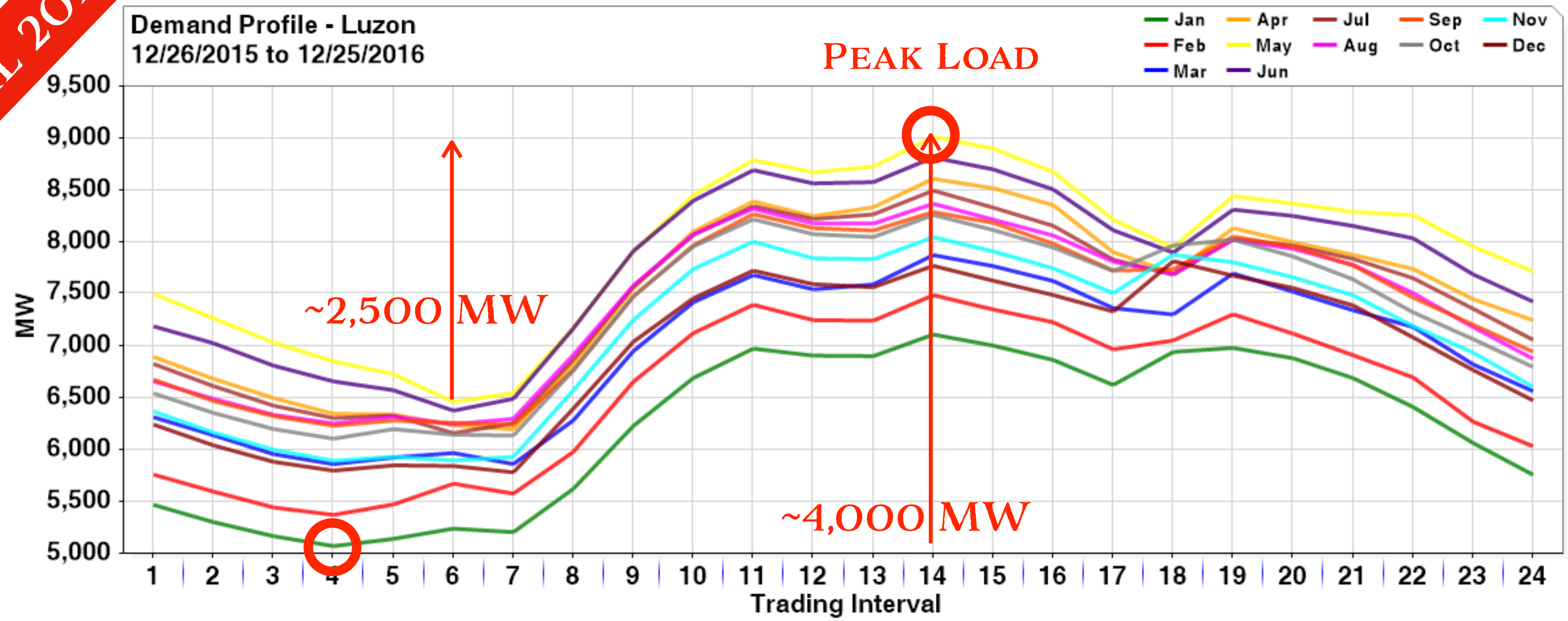
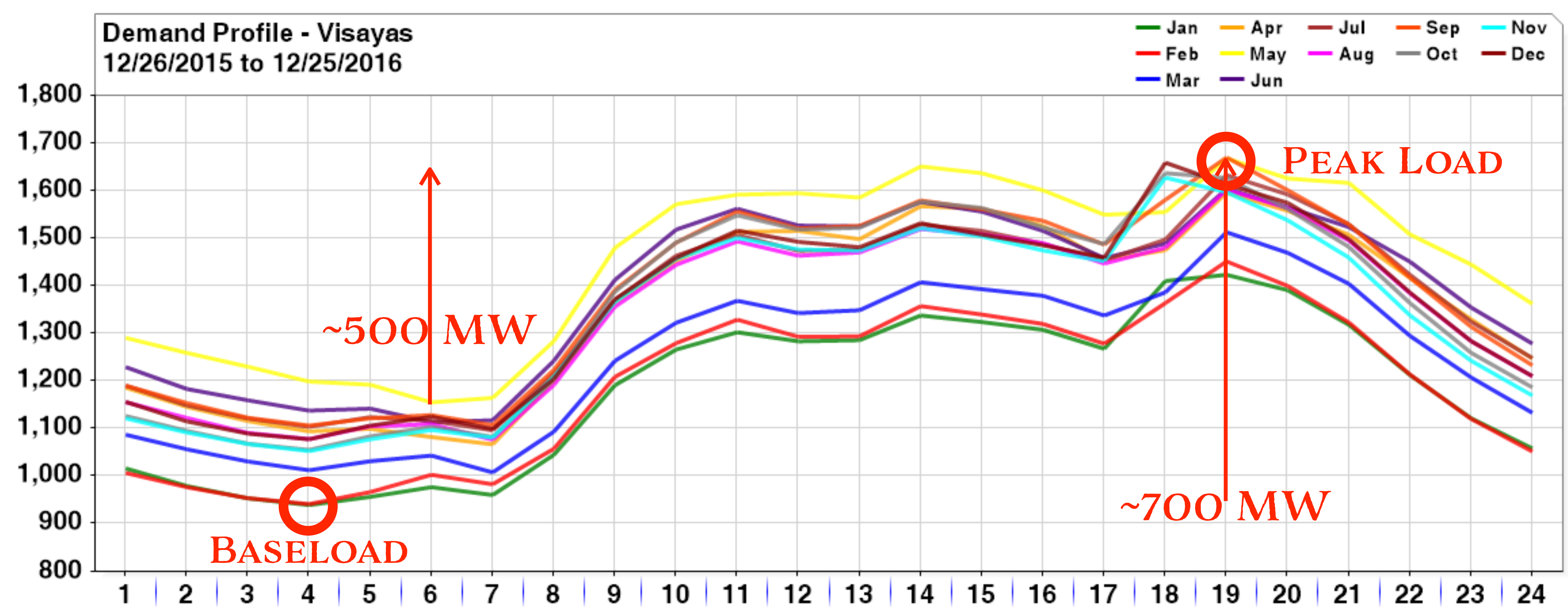
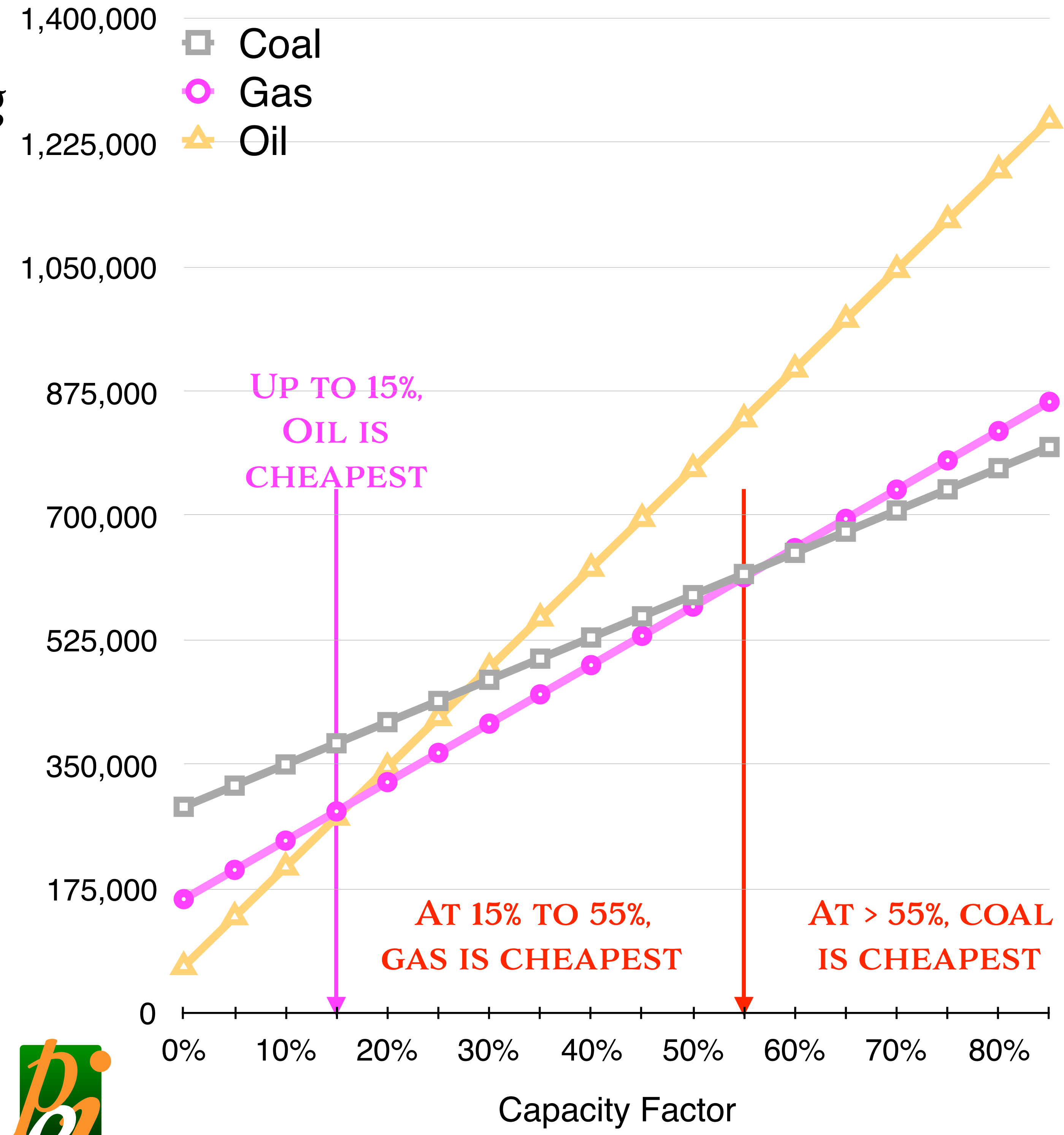


Figure 5. Hourly Demand Profile - Visayas



Key Points

- Different power plants are needed to address the varying loads



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    - In Luzon, the peak occurs during the "solar hours".

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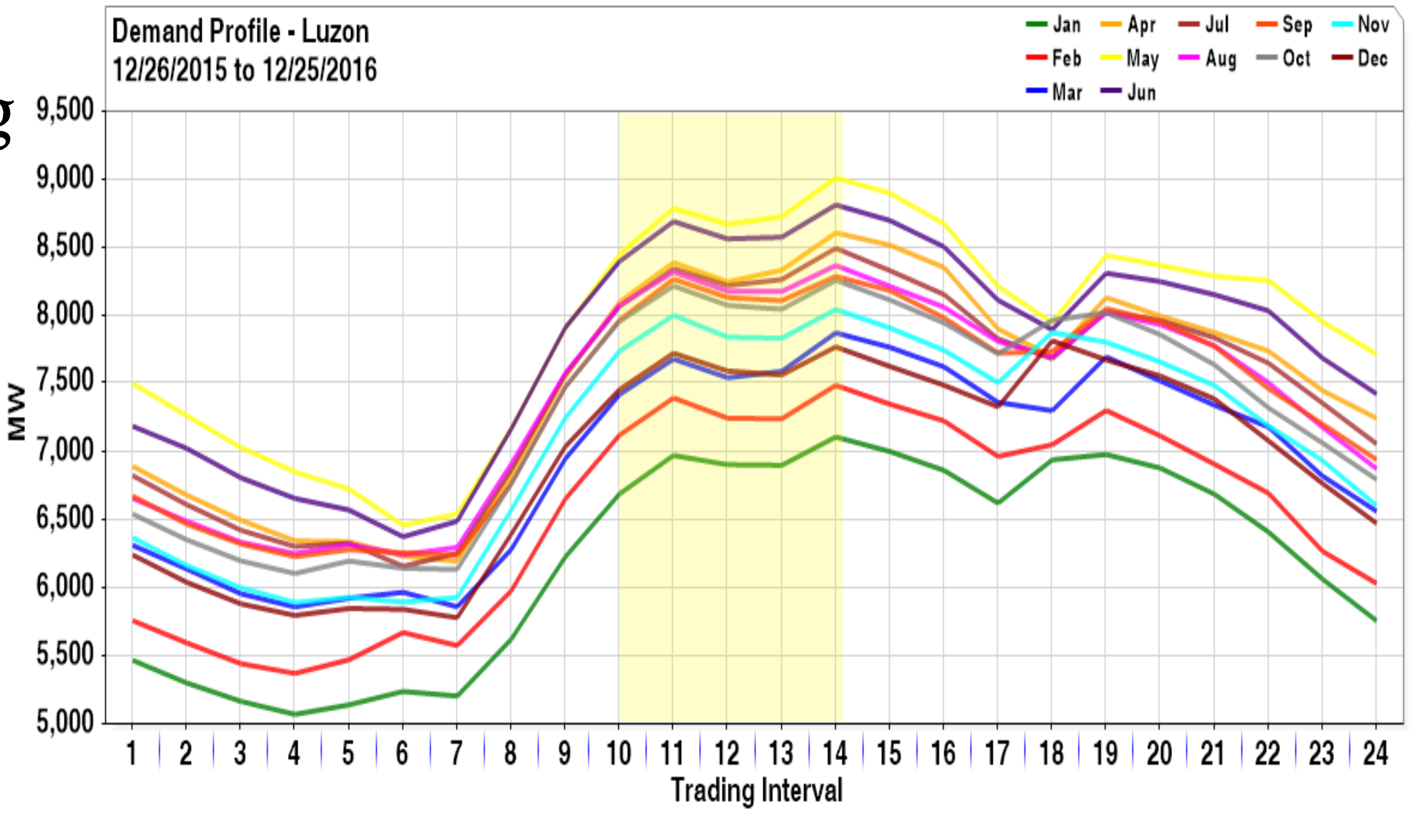

Key Points

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  - In Visayas, the peak occurs at night when wind energy is present. Geothermal is the dominant energy source.

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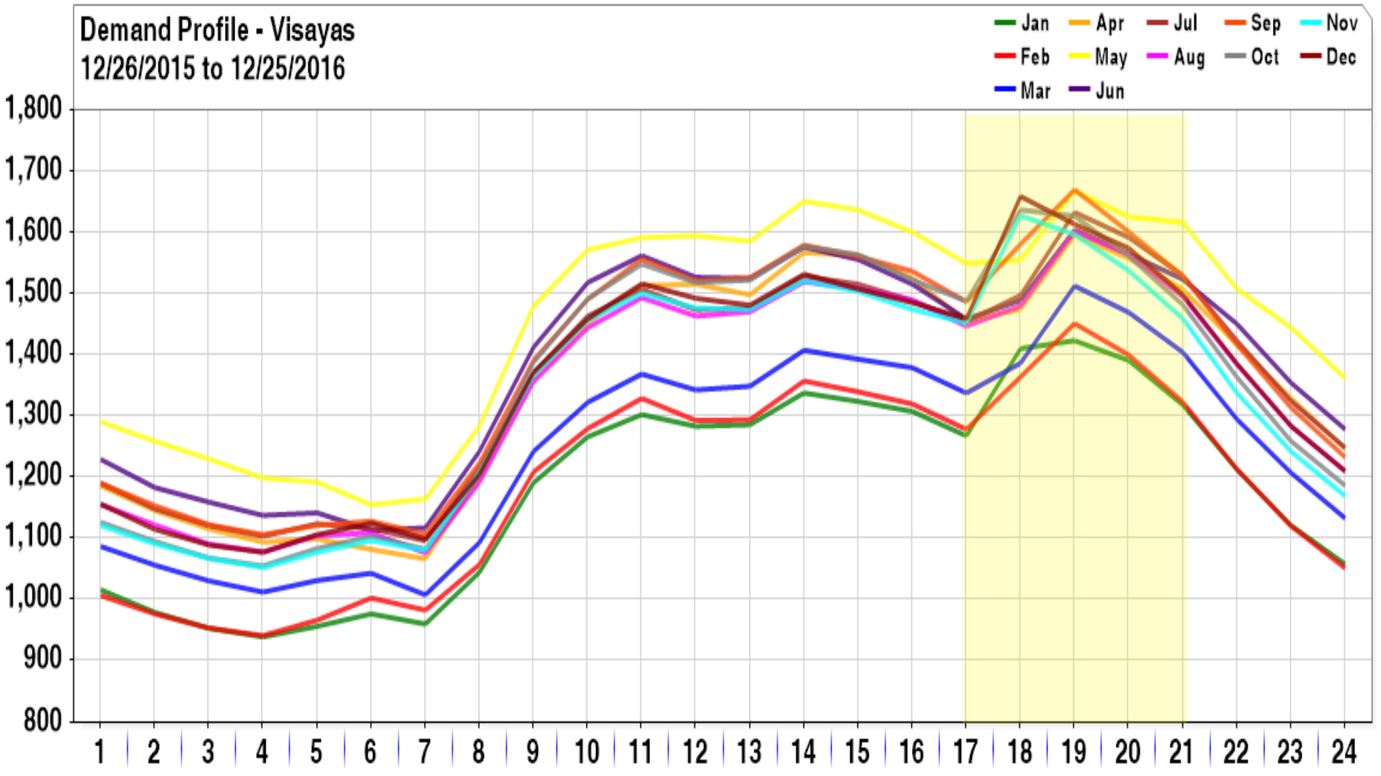

Key Points

- Different power plants are needed to address the varying loads
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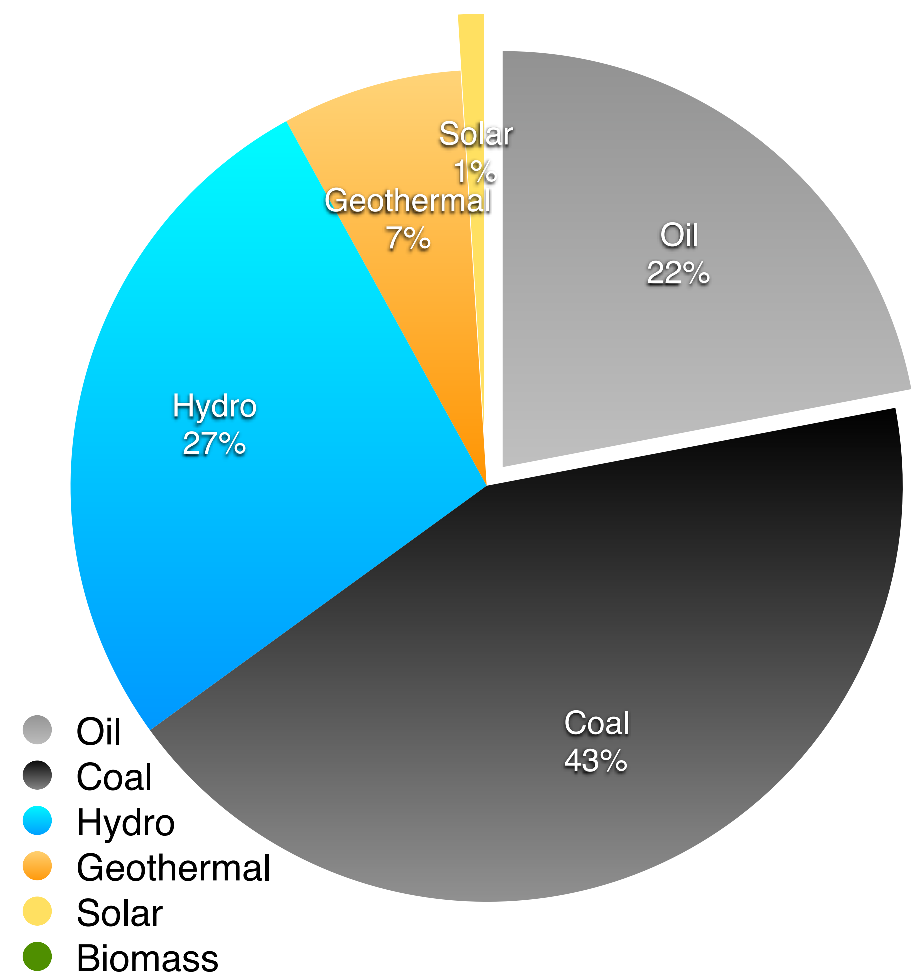
  - In Visayas, the peak occurs at night when wind energy is present. Geothermal is the dominant energy source.
  - In Mindanao, 22% of the power mix is accounted for by oil. Hydro is the traditional energy source.

2016 Mindanao Power Generation Mix



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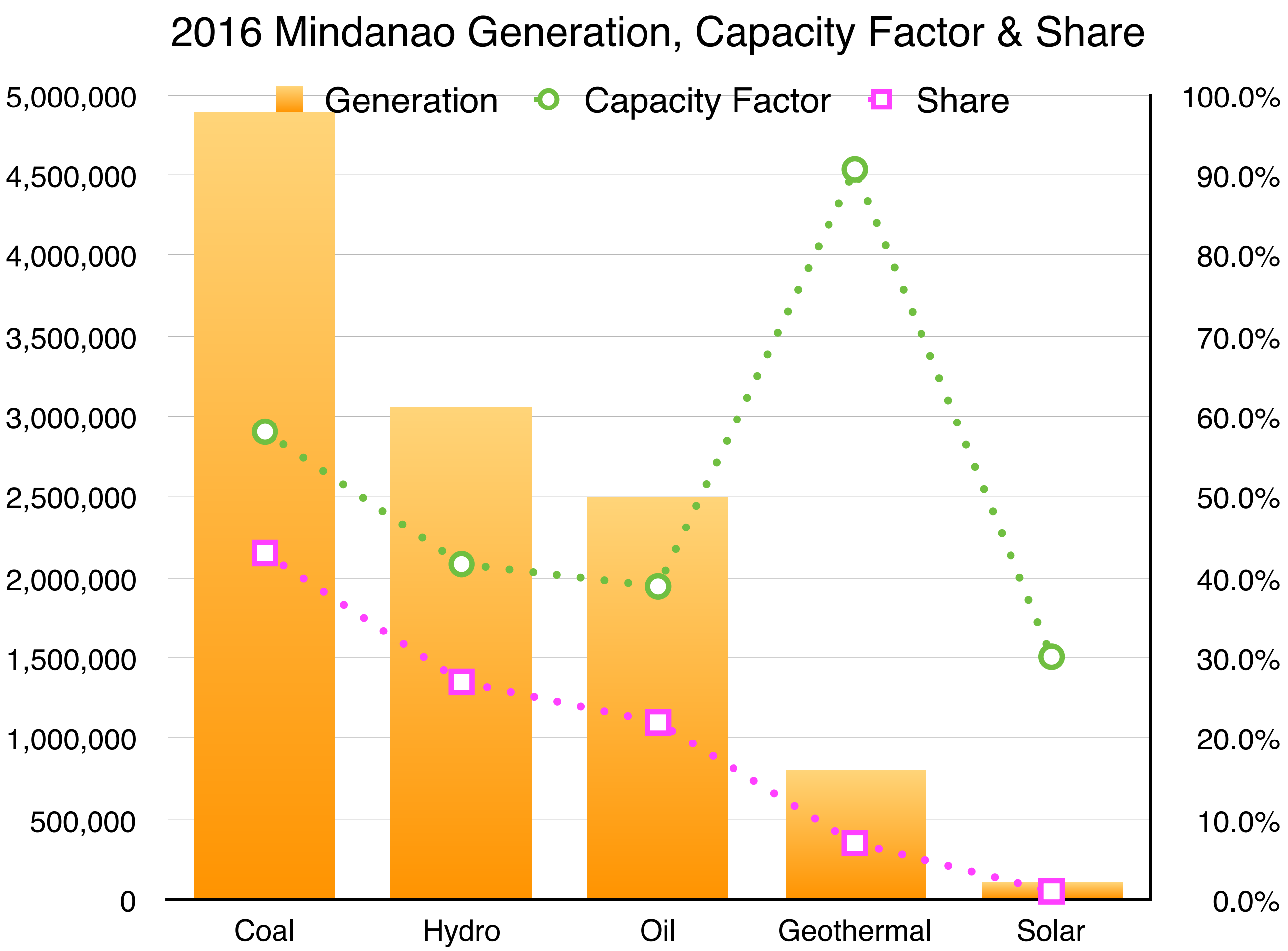

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  - In Visayas, the peak occurs at night when wind energy is present. Geothermal is the dominant energy source.
  - In Mindanao, 22% of the power mix is accounted for by oil. Hydro is the traditional energy source.
- In Luzon and Visayas, the ratio of baseload to peak load is 56% in 2016
  - Thus 44% of the capacity will have to turned on/off or ramped up/down.
  - Hence, the need for flexible generation or power plants that can be operated to follow the load.
- Comparing power plant costs must be done in the context of these power system dynamics

Germany goes for RE with flexible generation

or how Renewables will beat coal & nuclear

Structural change in power generation structures
Historical patterns (average week, stylized)

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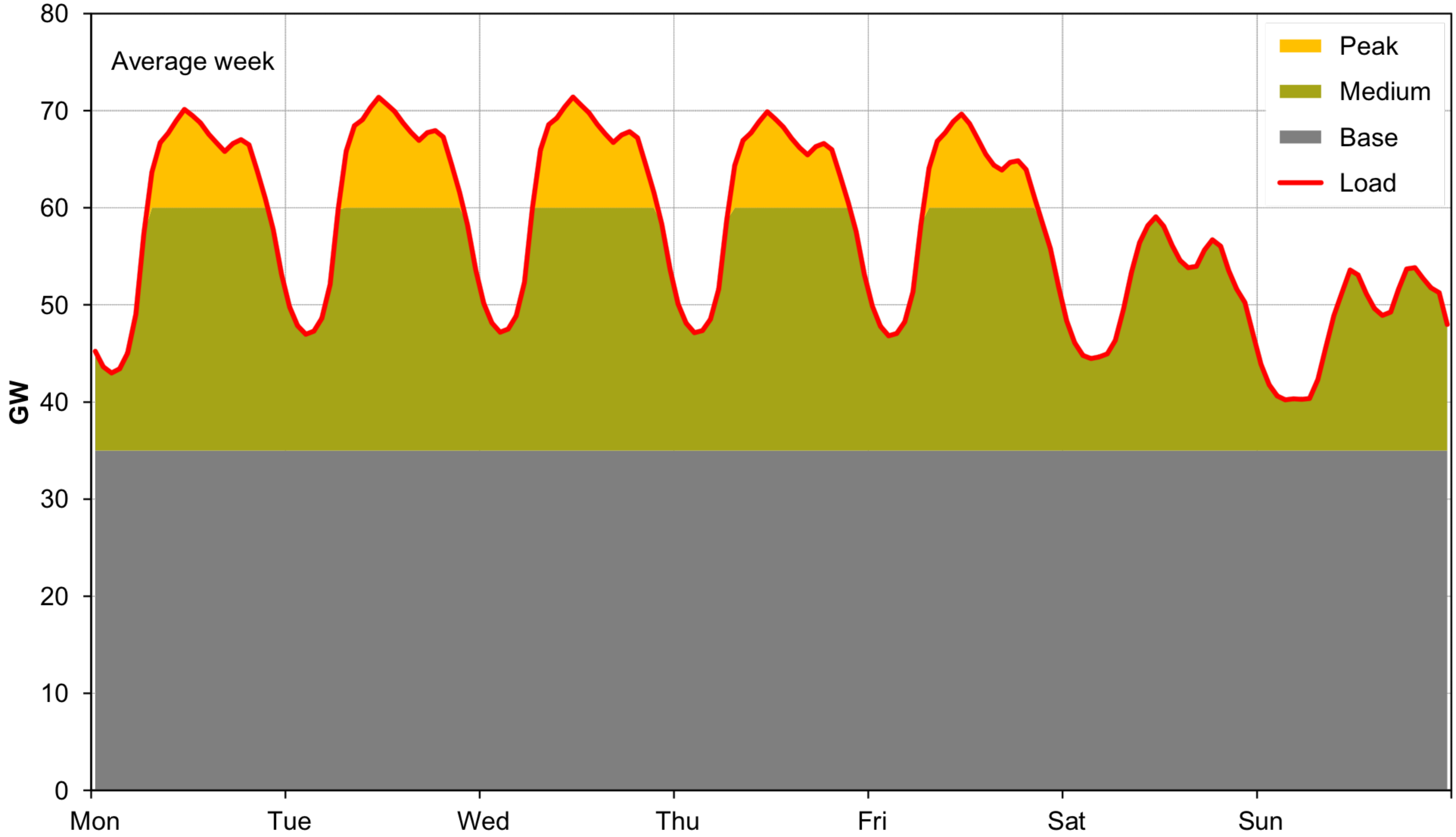
Institut für angewandte Ökologie
Institute for Applied Ecology

This is the usual way of looking at this weekly load curve.



Matthes 2016

Structural change in power generation structures
Historical data 2015 (average week)

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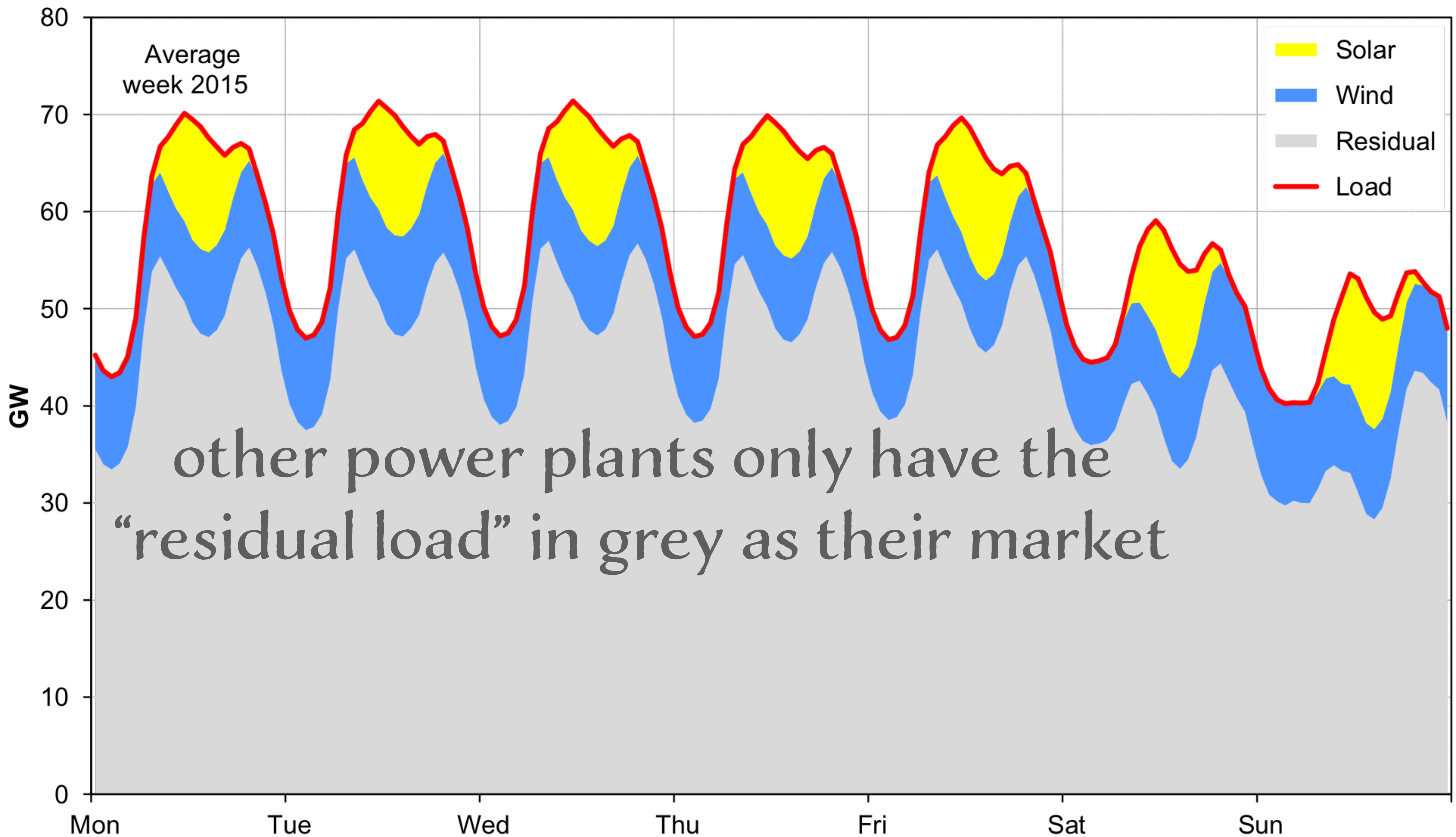
With solar and wind generation at zero marginal cost…



other power plants only have the "residual load" in grey as their market

Matthes 2016

Structural change in power generation structures
Illustrative projection 2025 (average week)

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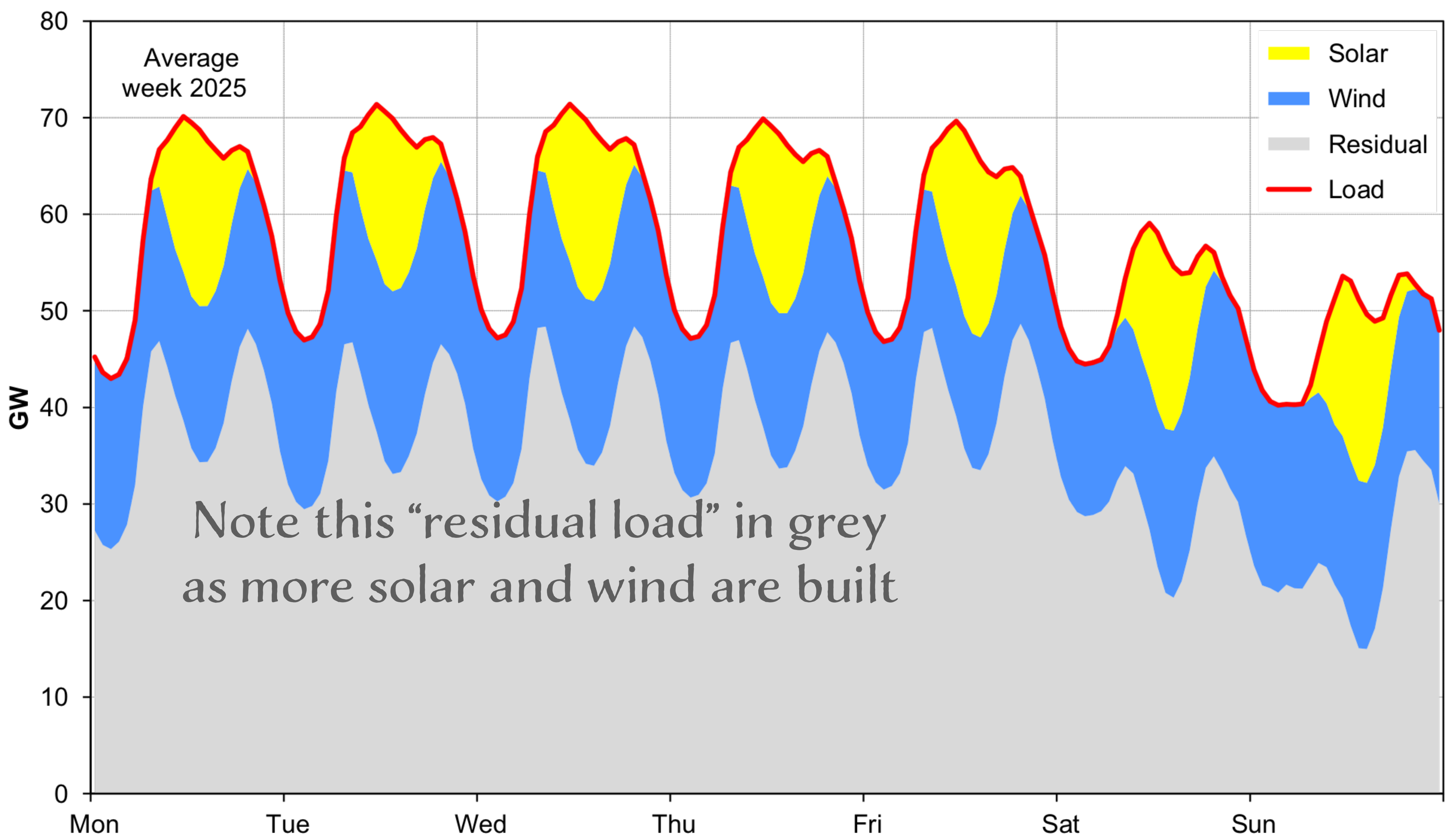
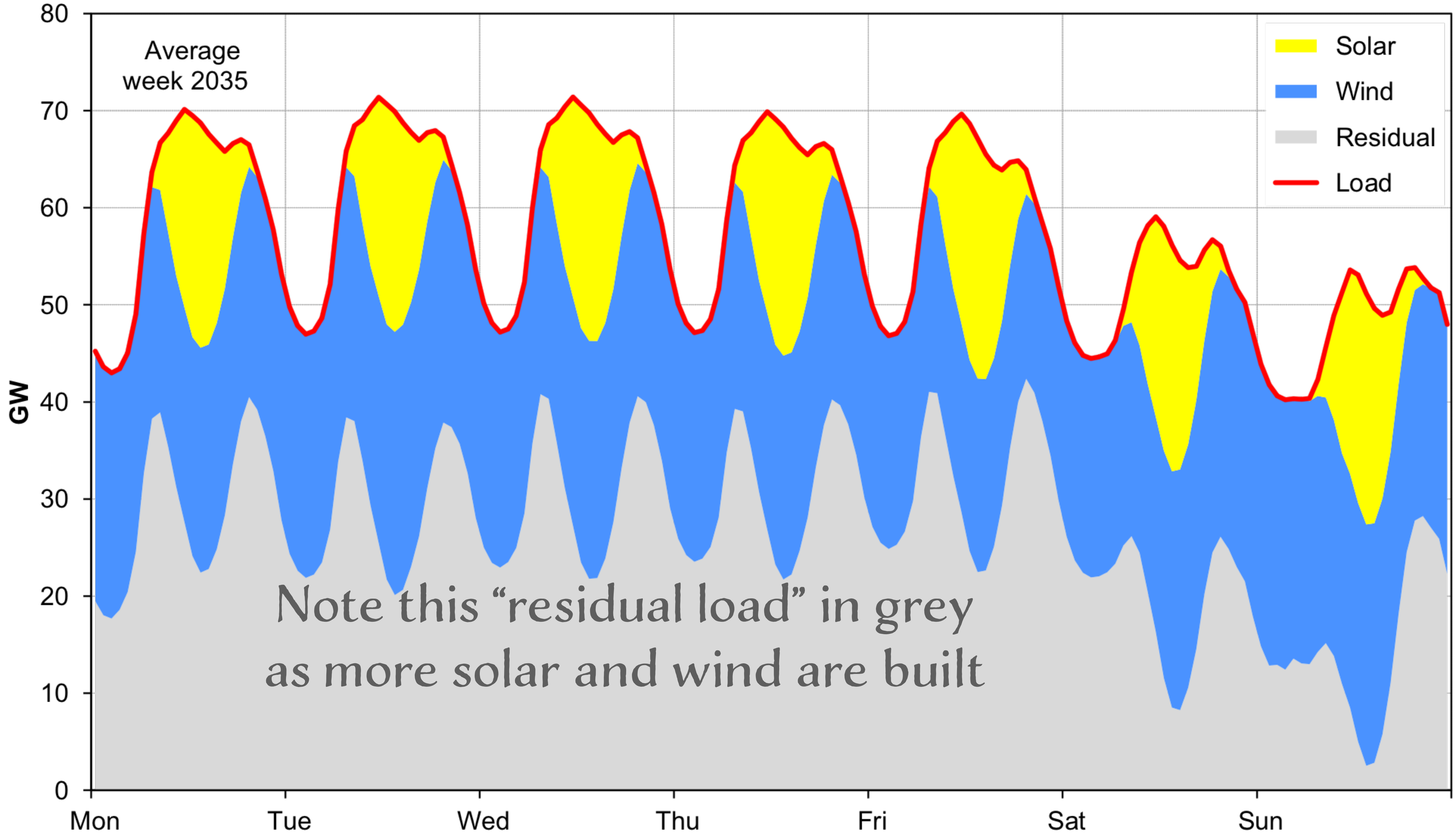


Matthes 2016

Structural change in power generation structures
Illustrative projection 2035 (average week)



Matthes 2016

Structural change in power generation structures
Illustrative projection 2045 (average week)

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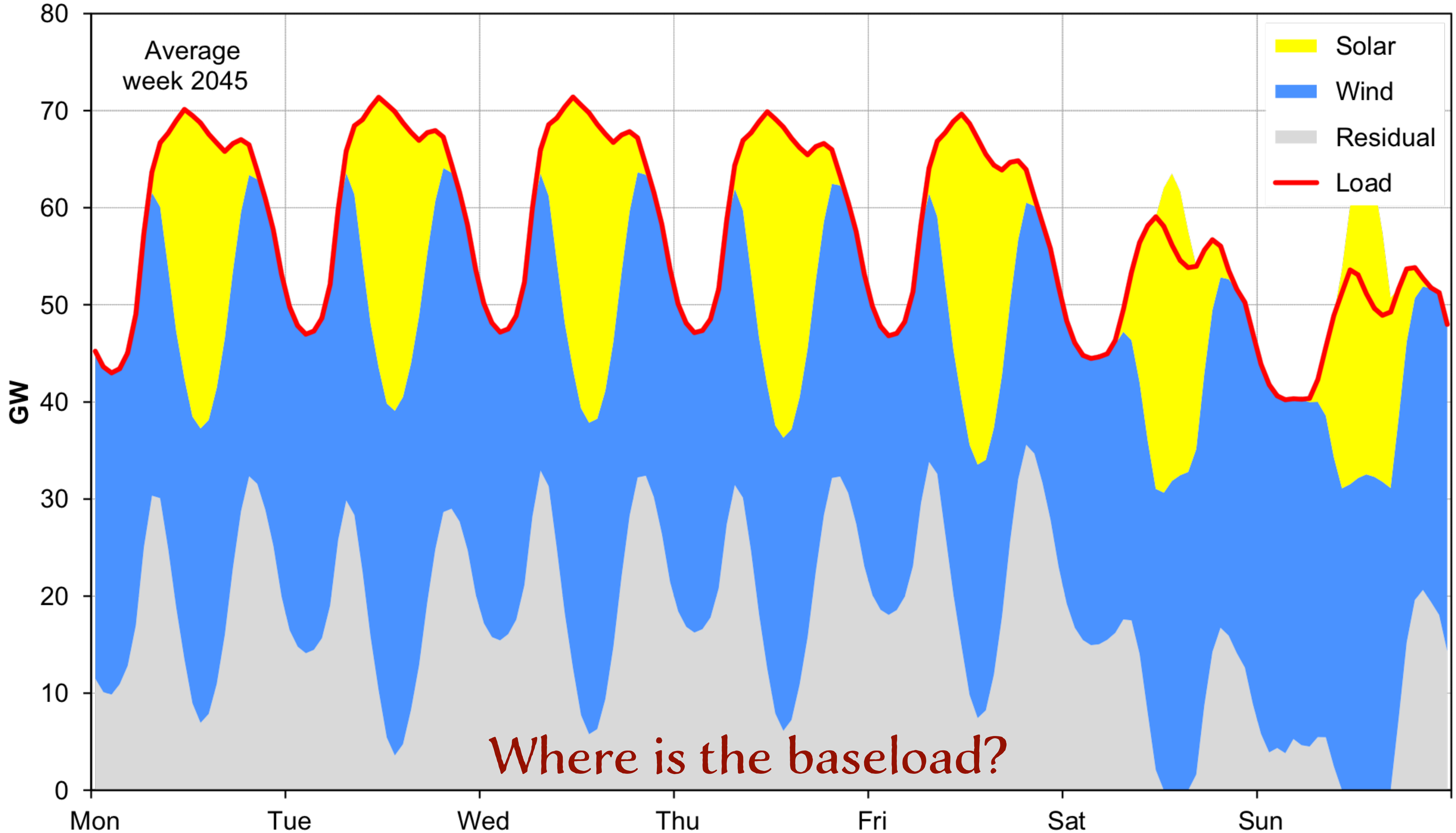
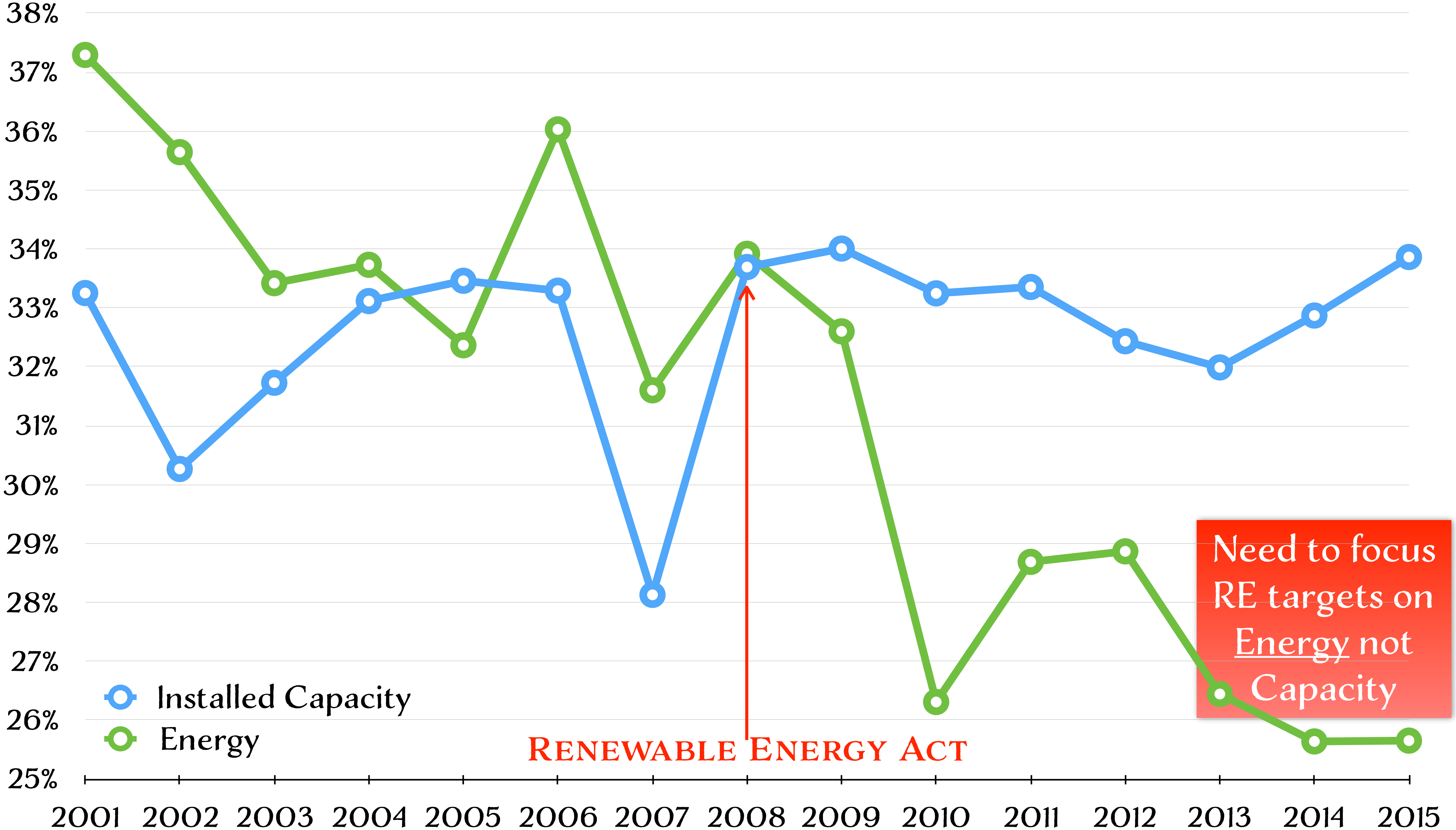


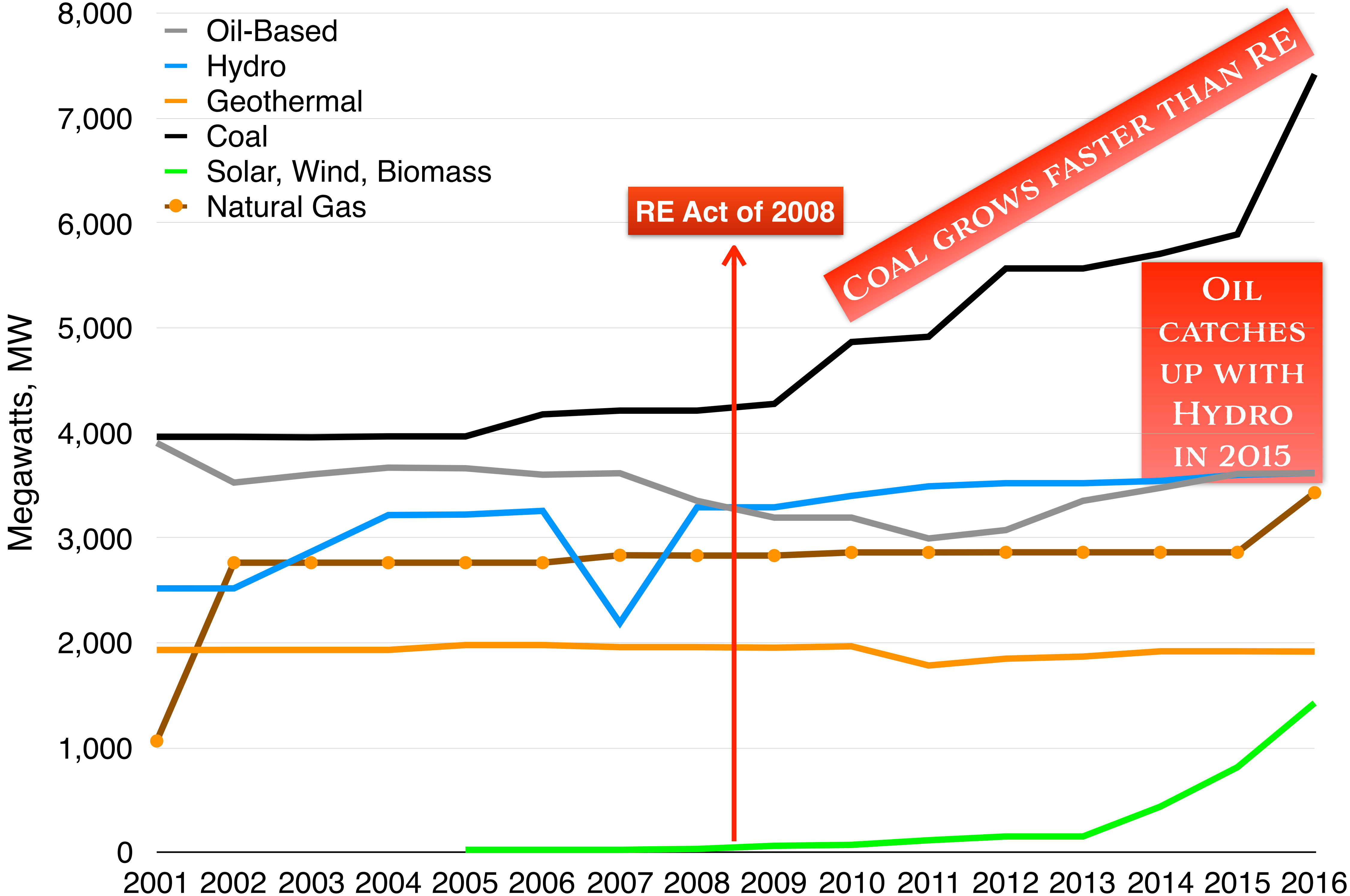
Note this "residual load" in grey
as more solar and wind are built

Matthes 2016

RE Share in energy generation has fallen since 2008

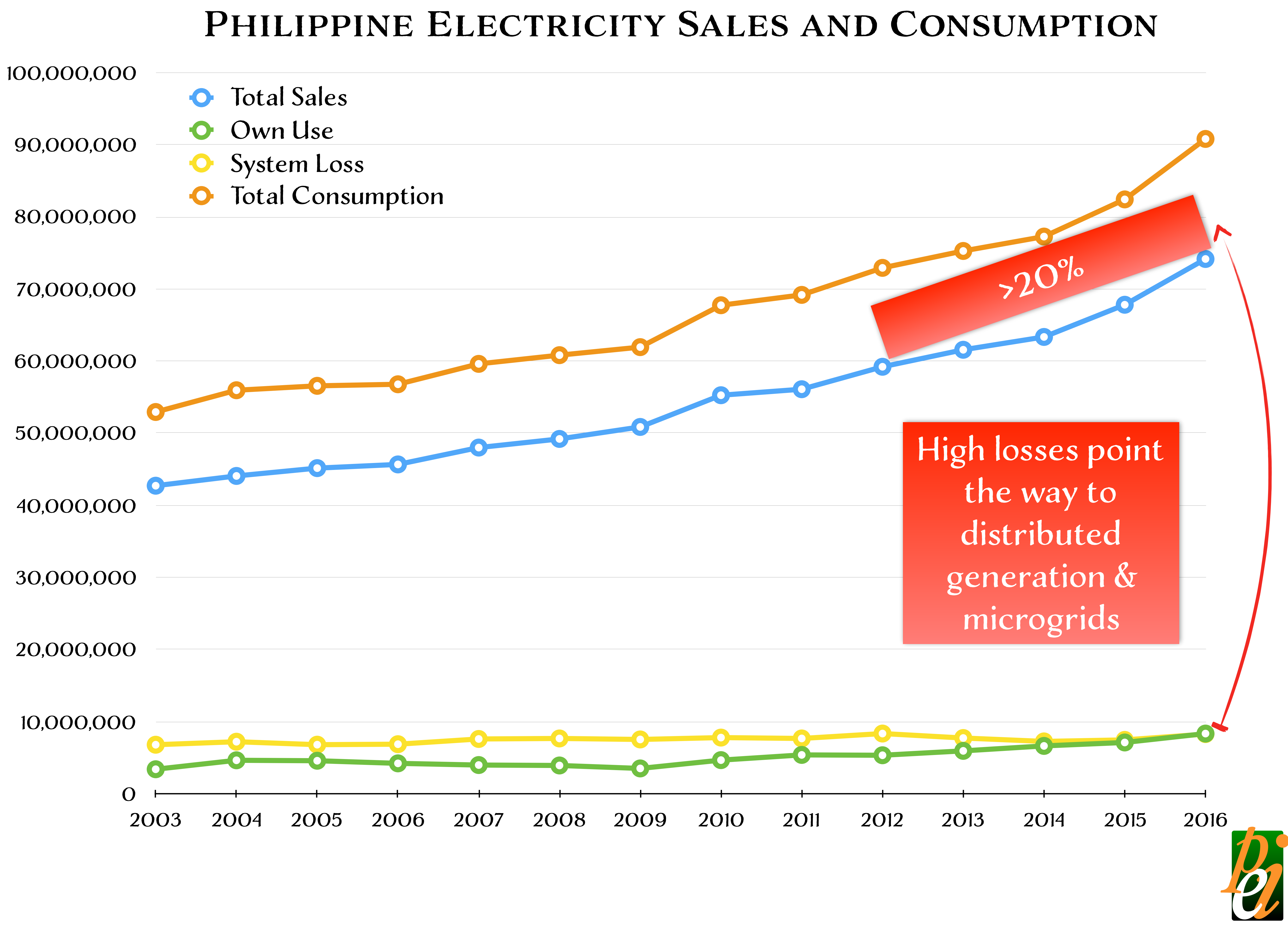


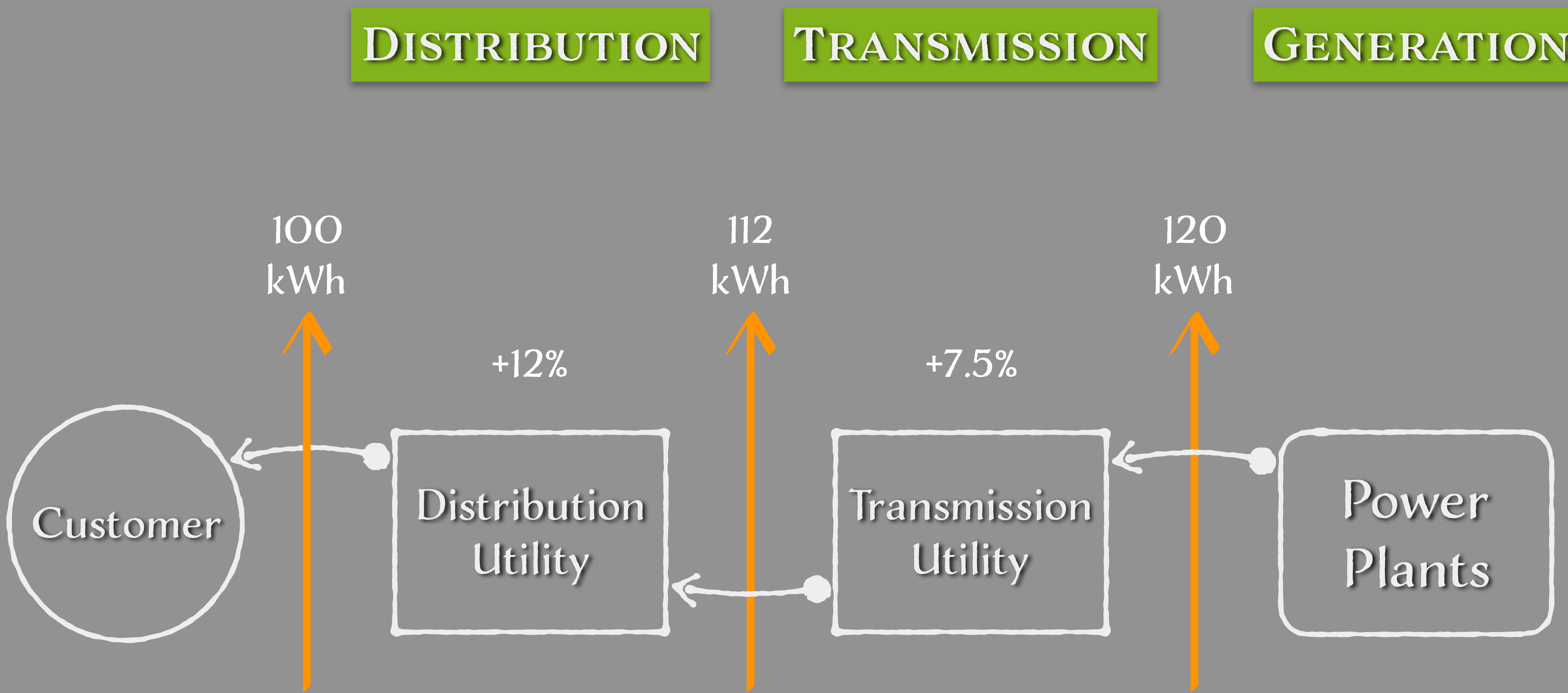
Philippine Power Plant Capacity by Type



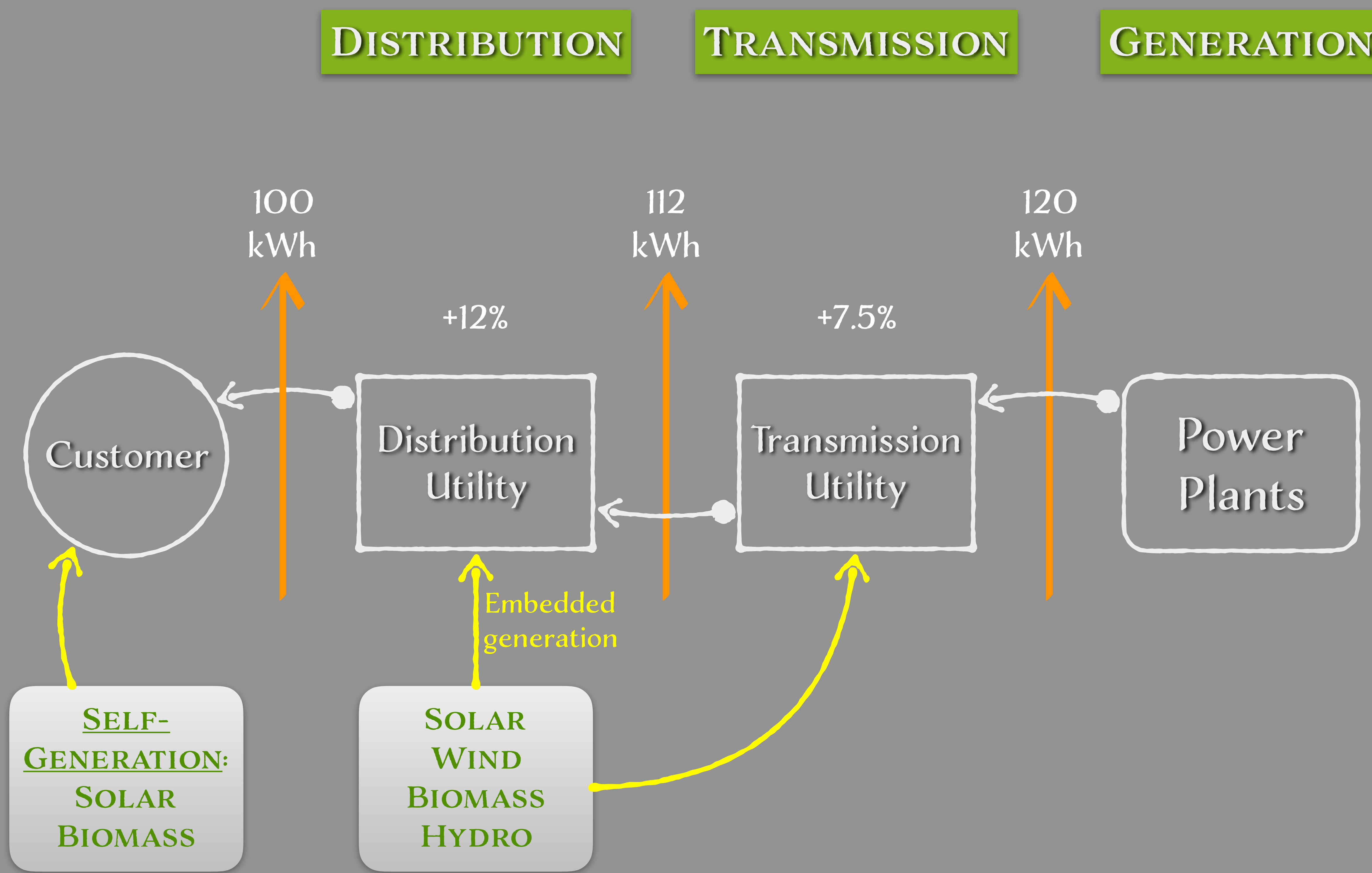
Oil is used to follow the load in the main grid and is the main cause for spot market price spikes.

In the off-grid, Oil performs both base load and load-following duty


Philippine Electricity Sales and Consumption
100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Total Sales
Own Use
System Loss
Total Consumption
>20%
High losses point the way to distributed generation & microgrids
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016



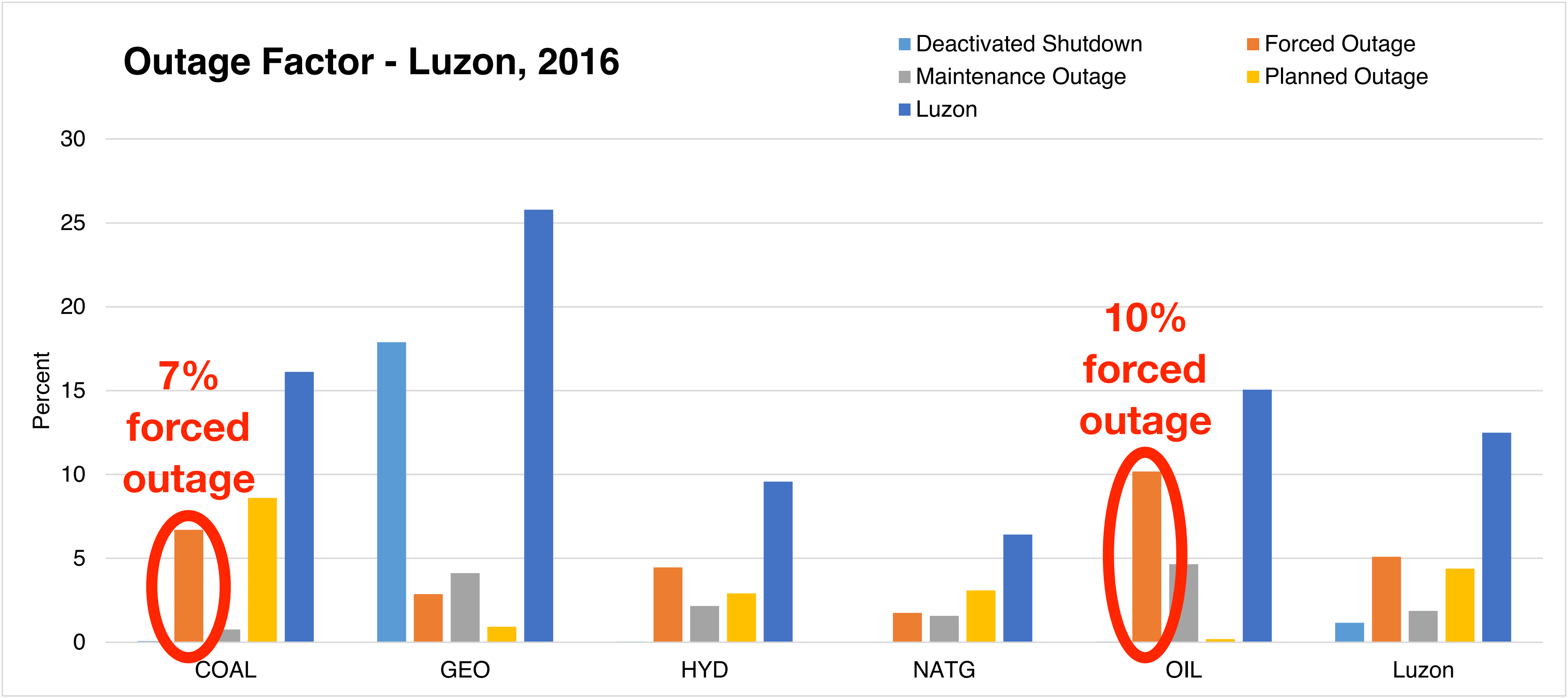
Distribution
Transmission
Generation
100 kWh
112 kWh
120 kWh
+12%
+7.5%
Customer
Distribution Utility
Transmission Utility
Power Plants



Distribution
Transmission
Generation
100 kWh
112 kWh
120 kWh
+12%
+7.5%
Customer
Distribution Utility
Transmission Utility
Power Plants
Embedded generation
Self-Generation:
Solar
Biomass
Solar
Wind
Biomass
Hydro

ACTUAL 2016

Figure 23. Outage Factor – Luzon



- High forced outage rates of coal and oil power plants diminish their claims to reliability
- In Luzon, total outage for coal and oil power plants are at 16% and 15% respectively

Figure 2. Demand and Effective Supply (Ex-ante), May 2017

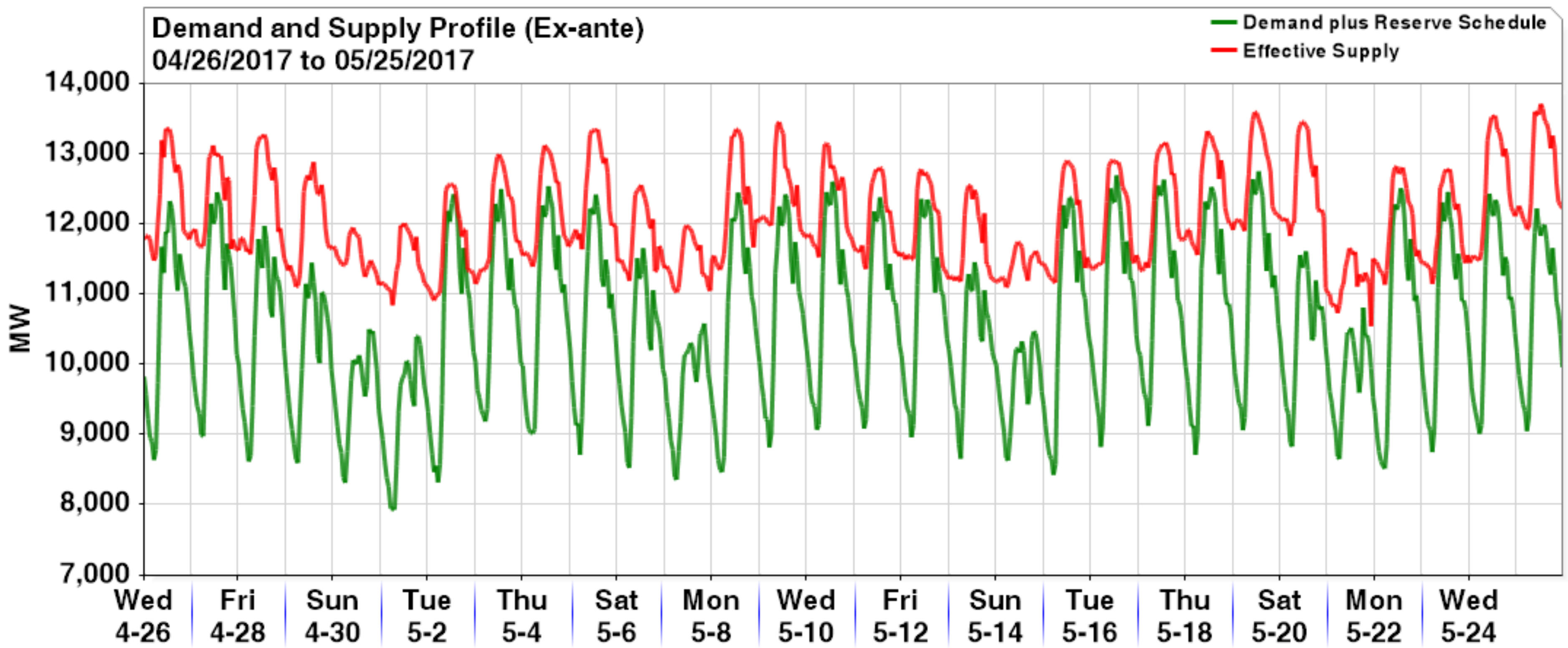
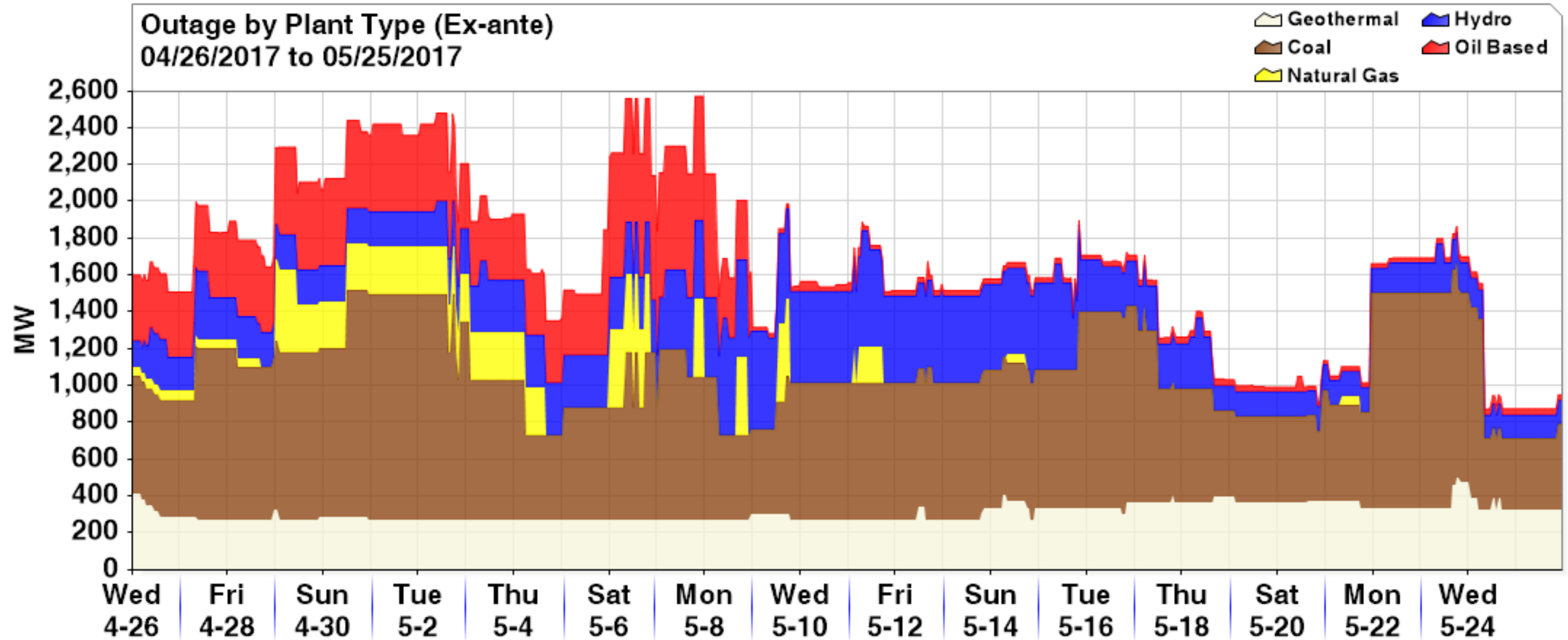
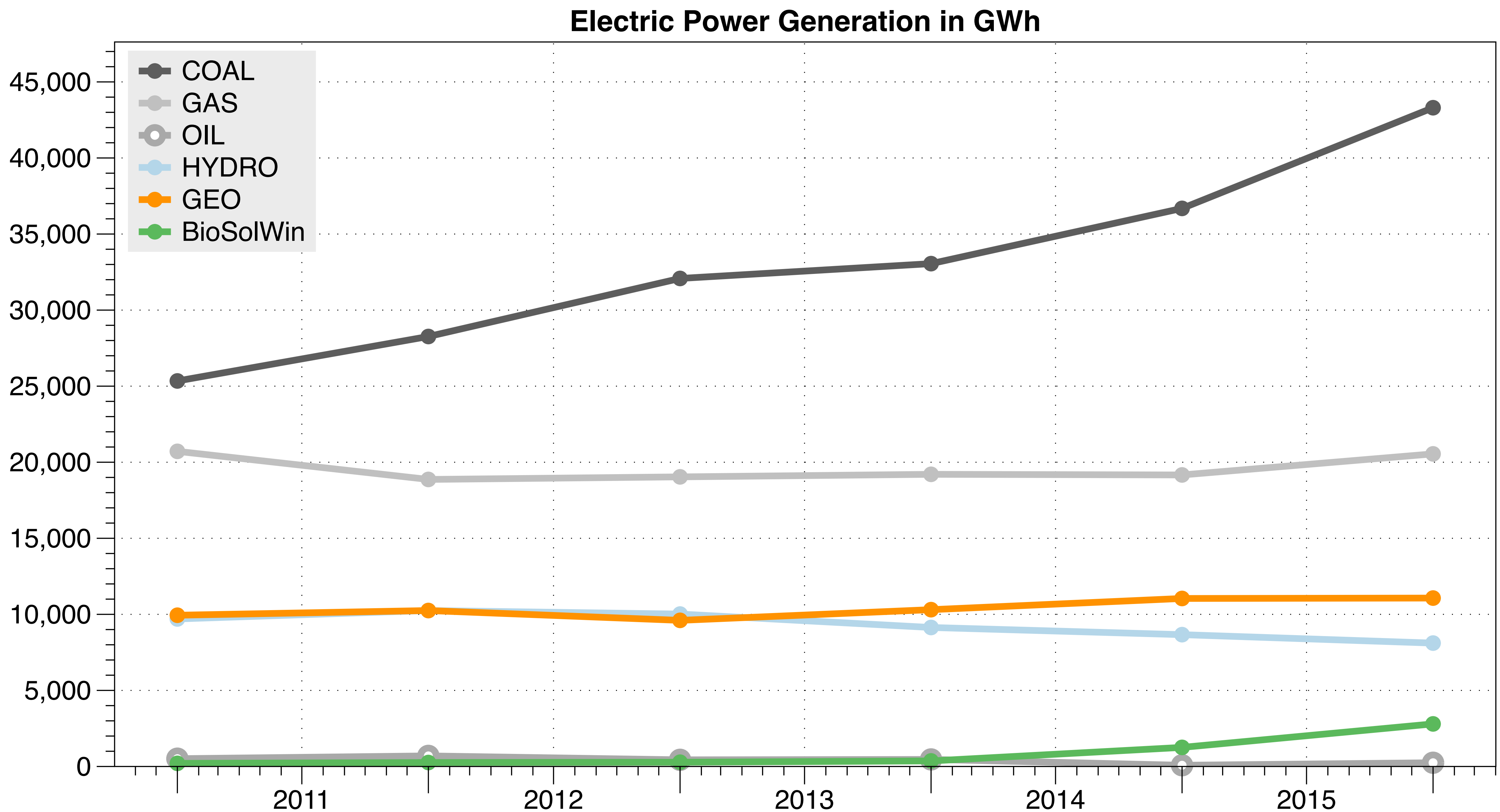


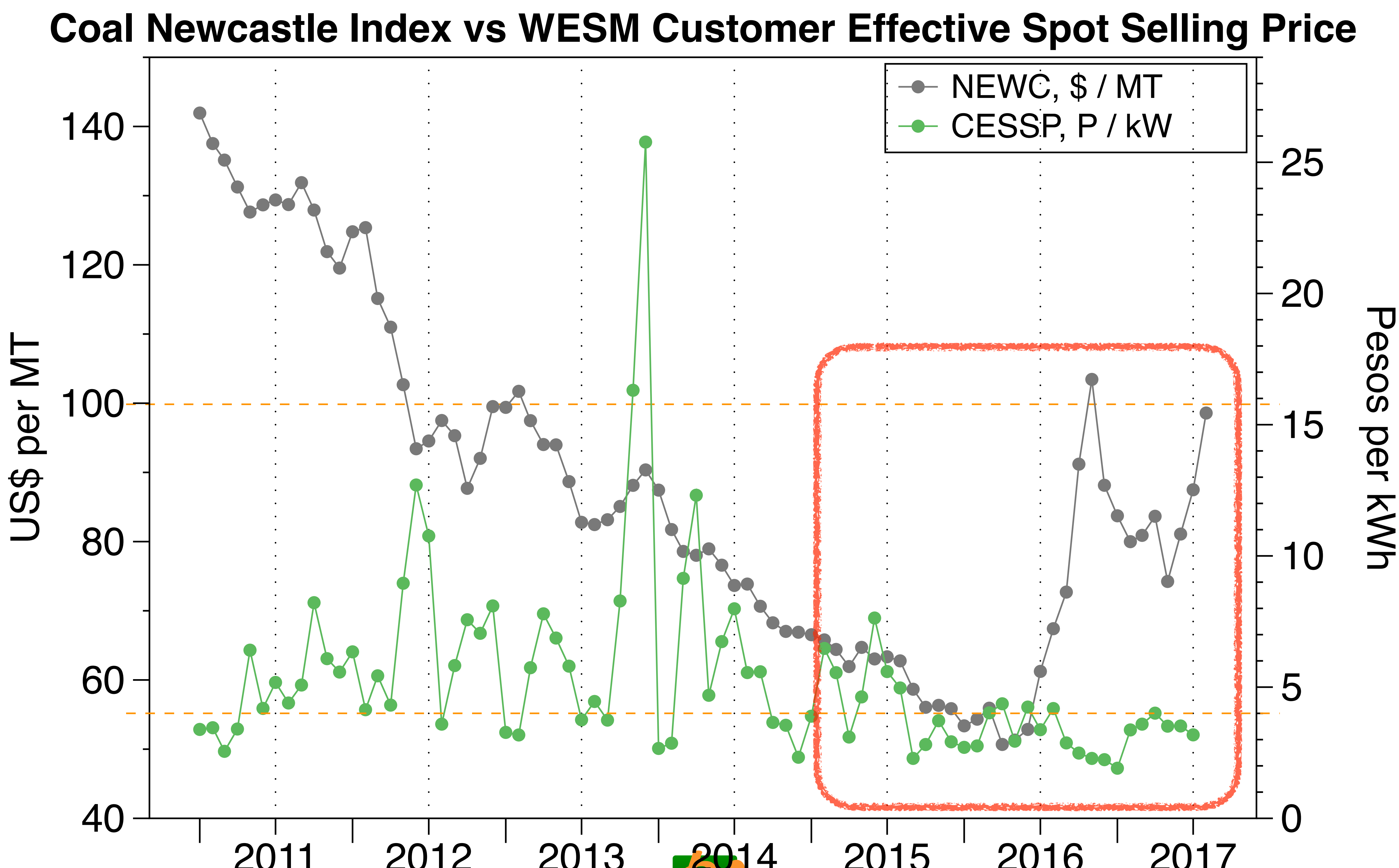
Figure 3. Plant Outage Capacity (by Plant Type), May 2017



Coal power generation dwarfs any other supply

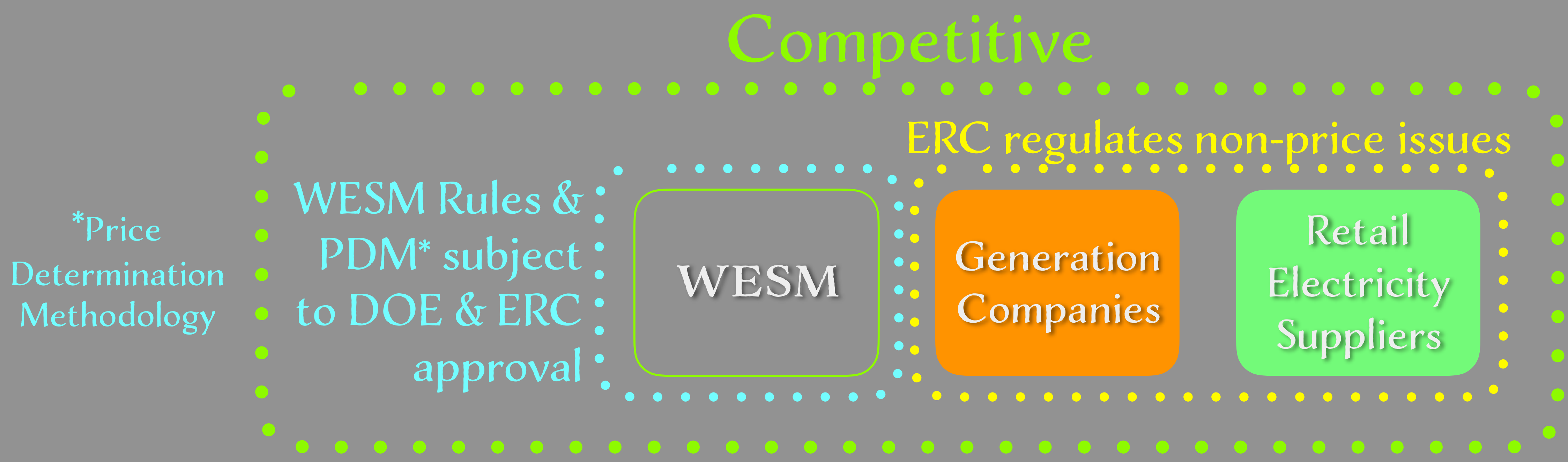


Why are WESM prices low even if coal prices are high?



Least-Cost Planning for Electricity Supply

Adapted from a presentation of ERC Commissioner G. V. C. Yap-Taruc dated 6 December 2016



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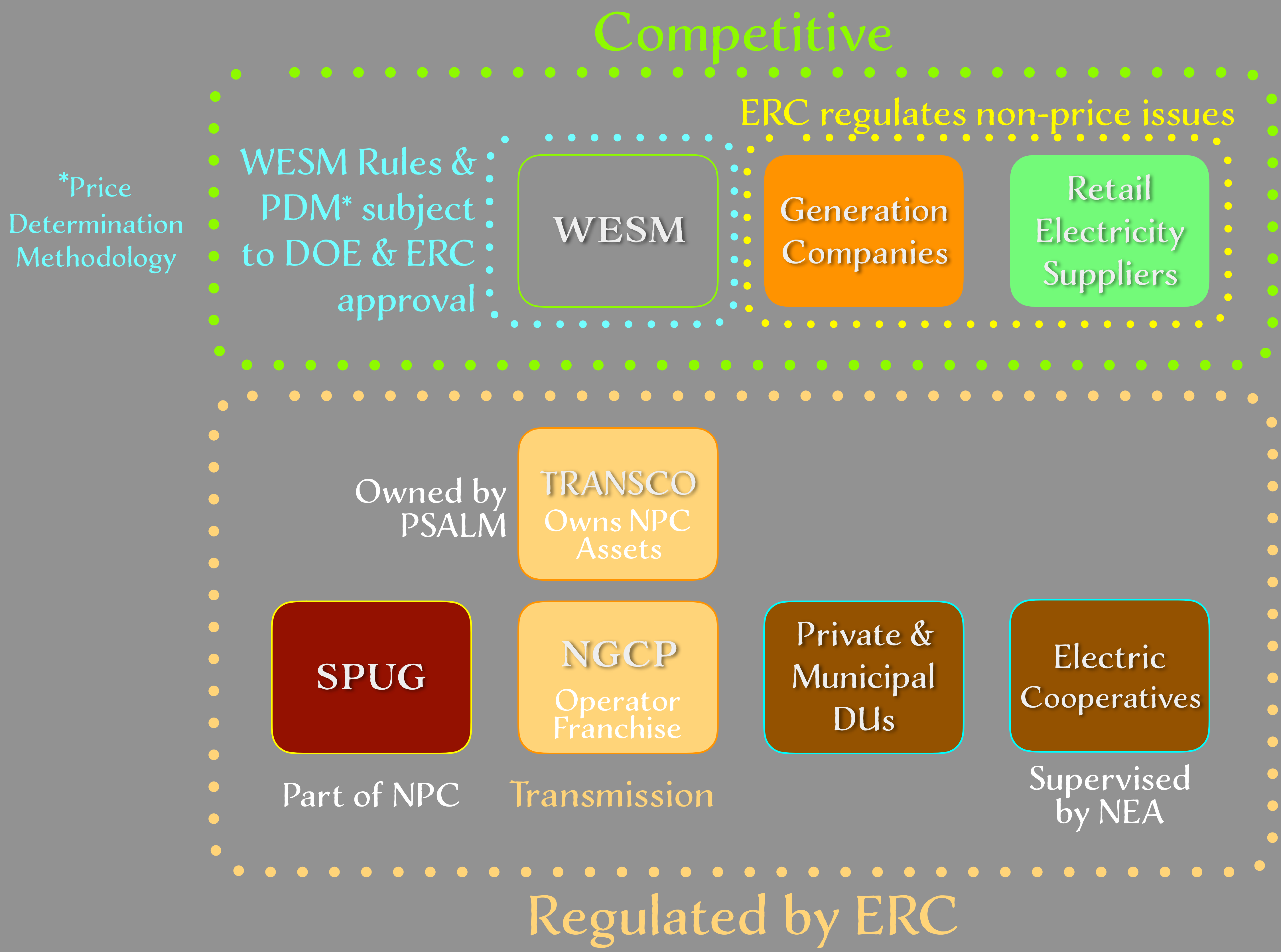

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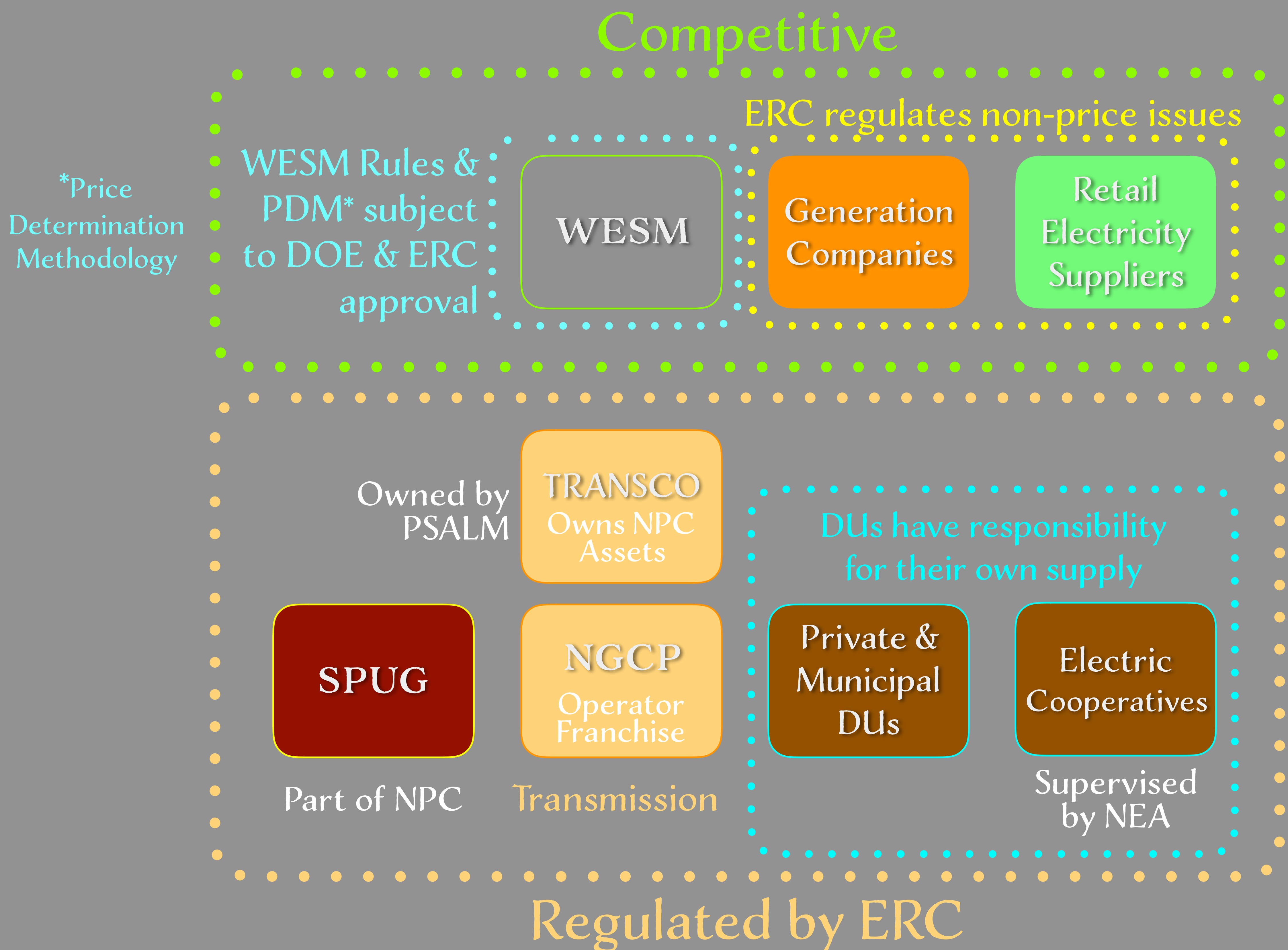

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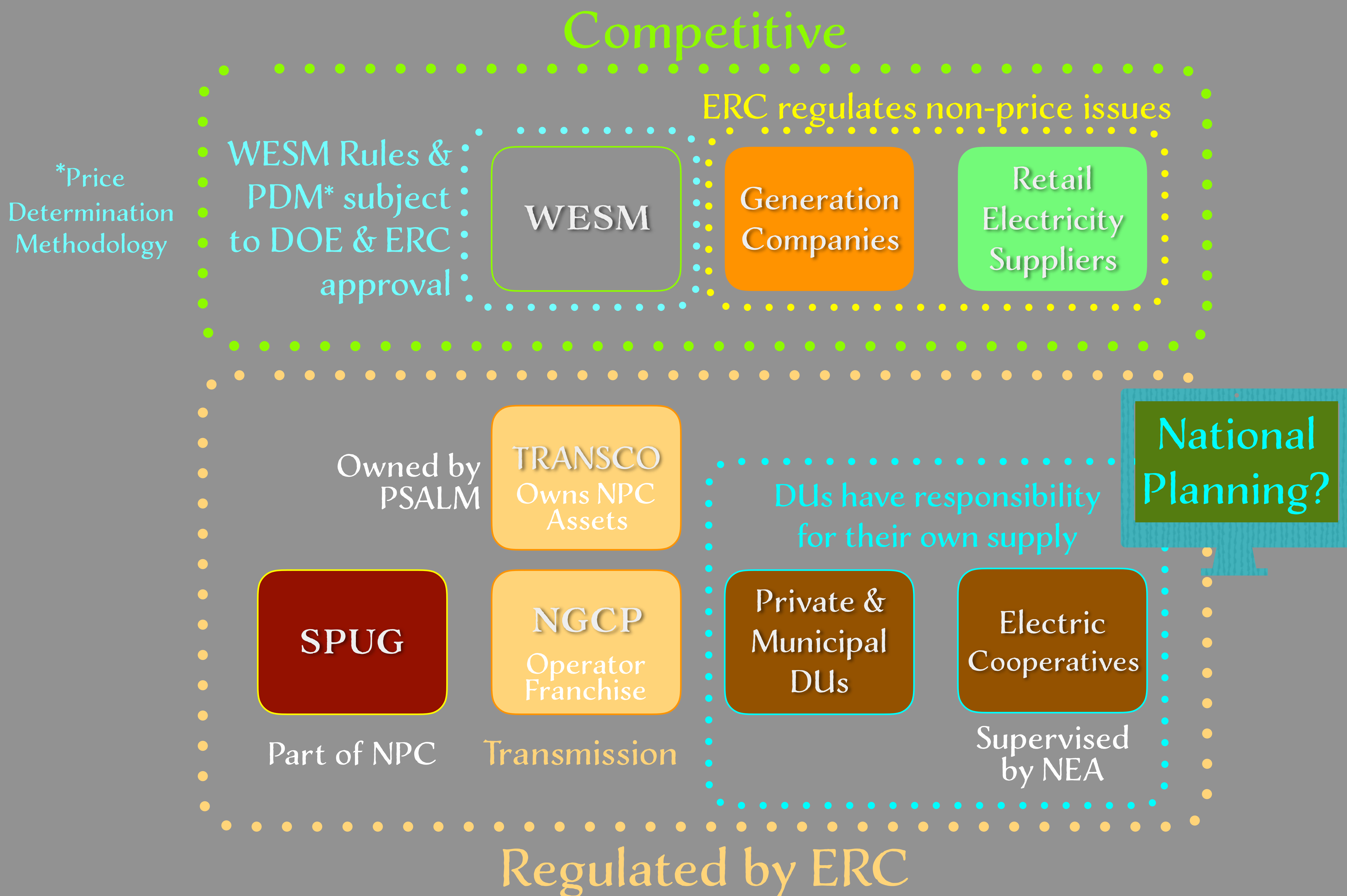
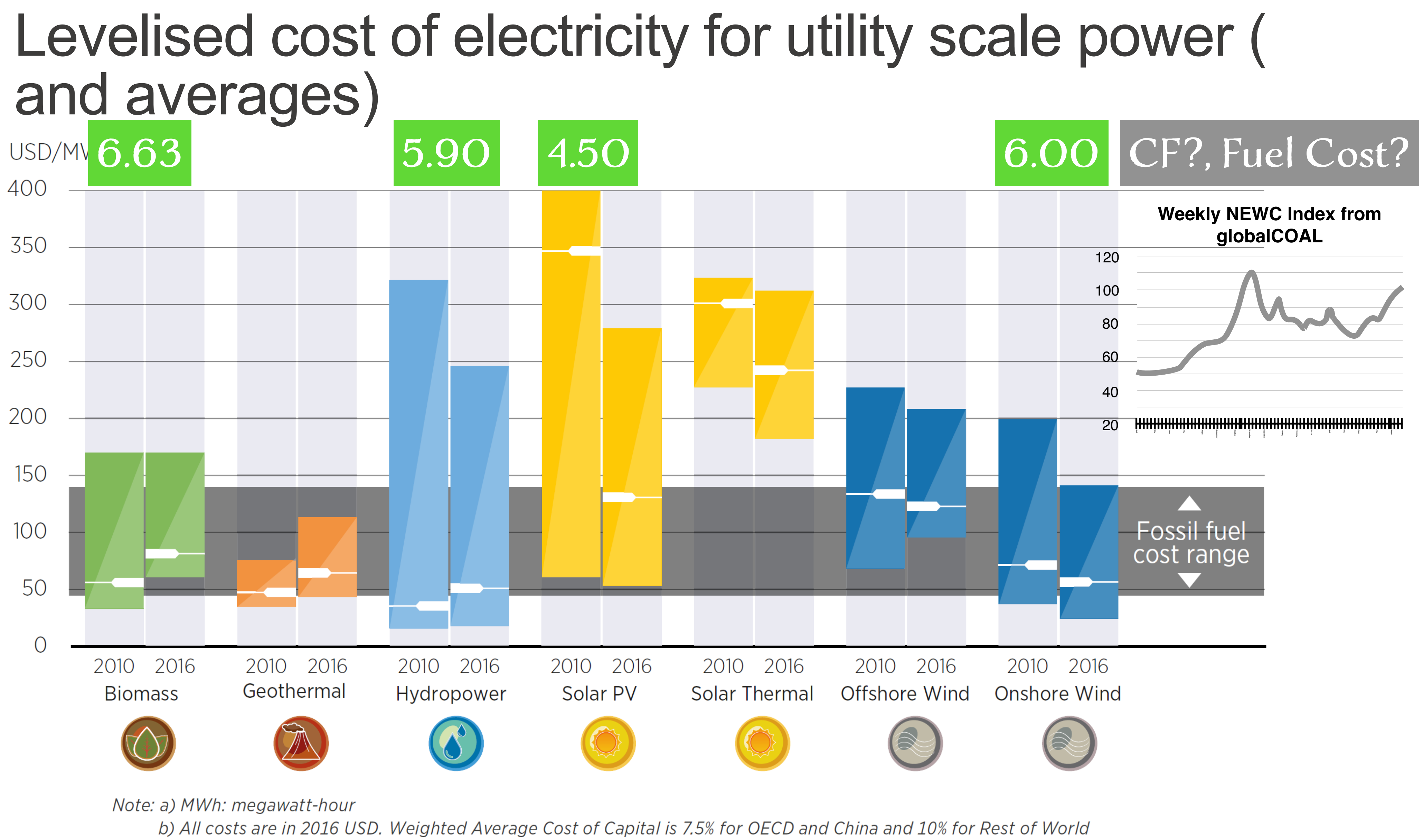


Simplified Optimization Model

Create database of technologies with costs & operating parameters

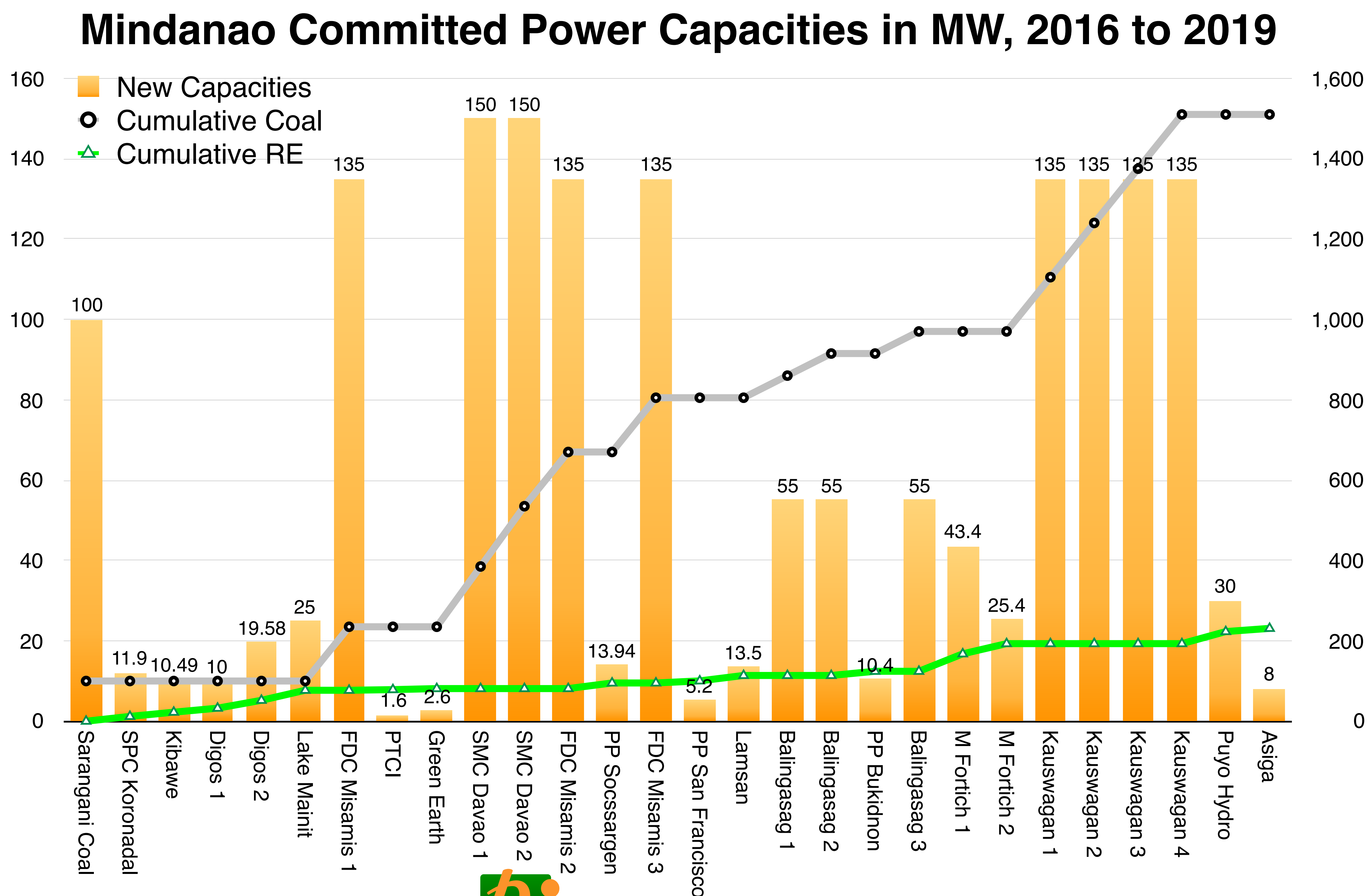


Source: IRENA (2017), REthinking Energy 2017: Accelerating the global energy transformation. International Renewable Energy Agency, Abu Dhabi.

Simplified Optimization Model

Create database of technologies with costs & operating parameters

Existing & committed power plants, their costs and operating parameters



Simplified Optimization Model

Create database of technologies with costs & operating parameters

Existing & committed power plants, their costs and operating parameters

Hourly Load Forecast for next 20 years or more

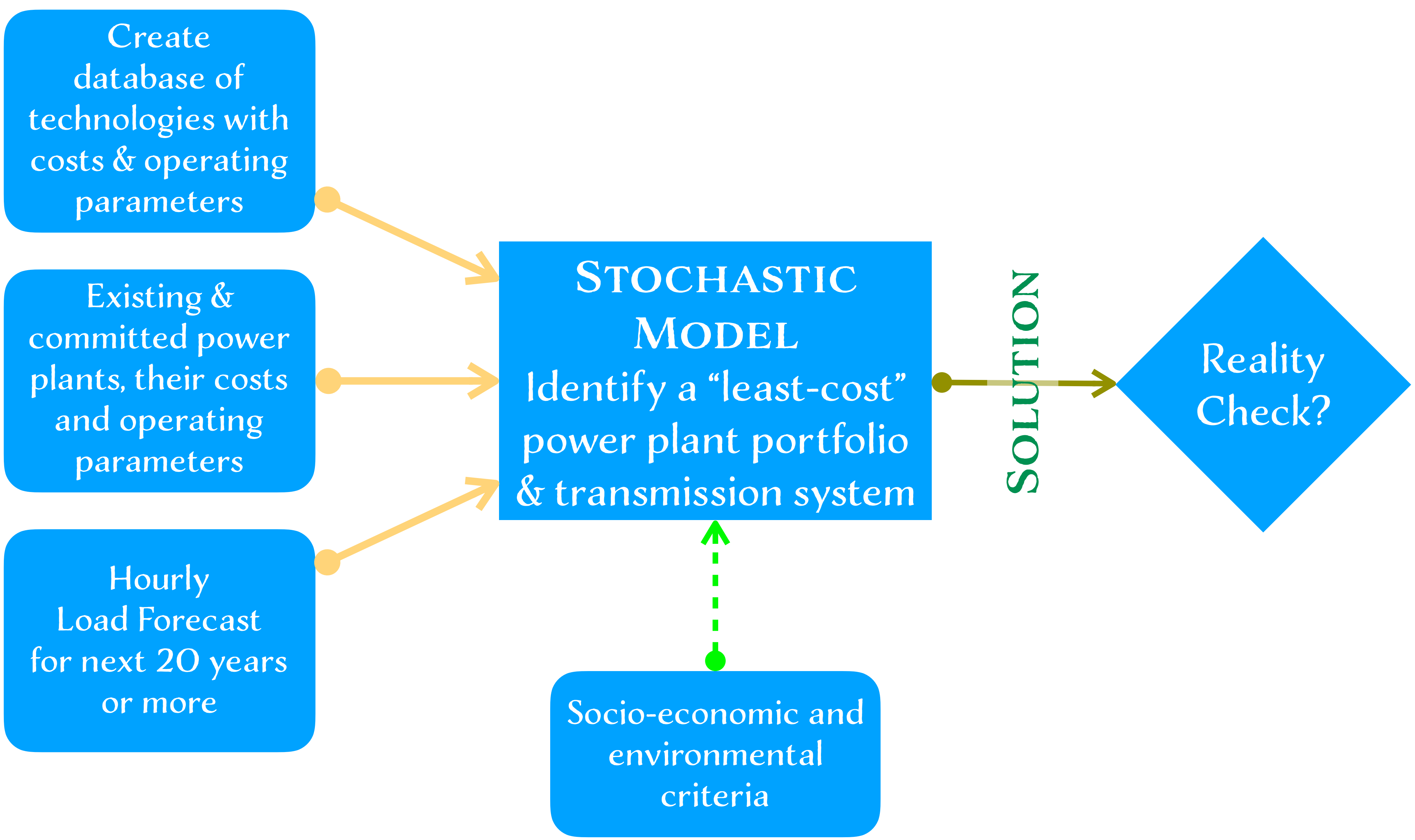
Table 4.2: Summary of Projected Demand per District[3] (MW)

District	Area	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Luzon		**9,127**	**9,474**	**9,934**	**10,368**	**10,821**	**11,249**	**11,694**	**12,164**	**12,657**	**13,161**
MERALCO		**6,764**	**7,047**	**7,294**	**7,561**	**7,822**	**8,107**	**8,404**	**8,716**	**9,029**	**9,356**
1	NCR	4,745	4,943	5,117	5,304	5,486	5,686	5,894	6,114	6,333	6,563
2	North	294	307	317	329	340	352	365	378	392	406
3	South	1,725	1,797	1,860	1,928	1,995	2,068	2,144	2,224	2,304	2,387
North Luzon		**1,824**	**1,876**	**2,063**	**2,204**	**2,361**	**2,474**	**2,588**	**2,710**	**2,850**	**2,987**
1	Ilocos	160	162	173	181	191	199	208	217	228	238
2	Mt. Province	151	155	165	172	183	191	200	209	220	231
3	North Central	197	200	237	249	264	276	290	303	319	334
4	Cagayan Valley	206	214	229	240	255	267	281	295	311	327
5	West Central	322	332	359	381	409	431	455	488	524	560
6	South Central	716	739	821	897	971	1,018	1,056	1,094	1,138	1,181
7	North Tagalog	72	74	79	83	88	93	98	103	110	116
South Luzon		**539**	**552**	**577**	**603**	**638**	**667**	**702**	**737**	**778**	**818**
1	Batangas/Cavite	250	254	264	274	288	298	311	325	340	355
2	Laguna /Quezon	86	88	92	96	102	106	112	118	124	131
3	Bicol	204	210	222	234	249	263	279	295	314	332
Visayas		**1,699**	**1,762**	**1,823**	**1,885**	**1,945**	**2,011**	**2,079**	**2,150**	**2,223**	**2,320**
1	Panay	279	290	300	310	320	330	341	353	365	380
2a	Cebu	879	912	943	975	1,006	1,040	1,075	1,112	1,150	1,200
2b	Bohol	68	71	73	76	78	81	83	86	89	93
3	Leyte-Samar	196	203	211	218	225	232	240	249	257	269
4	Negros	276	287	297	307	316	327	338	350	362	378
Mindanao		**1,669**	**1,803**	**1,927**	**2,044**	**2,141**	**2,229**	**2,320**	**2,415**	**2,512**	**2,658**
1	North Western	211	217	235	255	270	282	295	308	324	343
2	Lanao Area	162	176	192	203	212	223	231	239	249	264
3	North Central	278	364	379	394	407	418	430	441	454	473
4	North Eastern	156	161	183	198	209	224	243	262	274	292
5	South Eastern	591	605	643	682	717	744	771	800	833	886
6	South Western	272	278	296	313	326	338	350	363	378	400
Philippines		**12,494**	**13,038**	**13,684**	**14,296**	**14,906**	**15,487**	**16,092**	**16,727**	**17,392**	**18,138**

[3]Based on the transformer peak demand coincident with the System Peak.
Based on NGCP System Peak Forecast as derived from DOE Forecast Levels, excluding applicable losses

Source: NGCP Transmission Development Plan dated December 2016

Simplified Optimization Model



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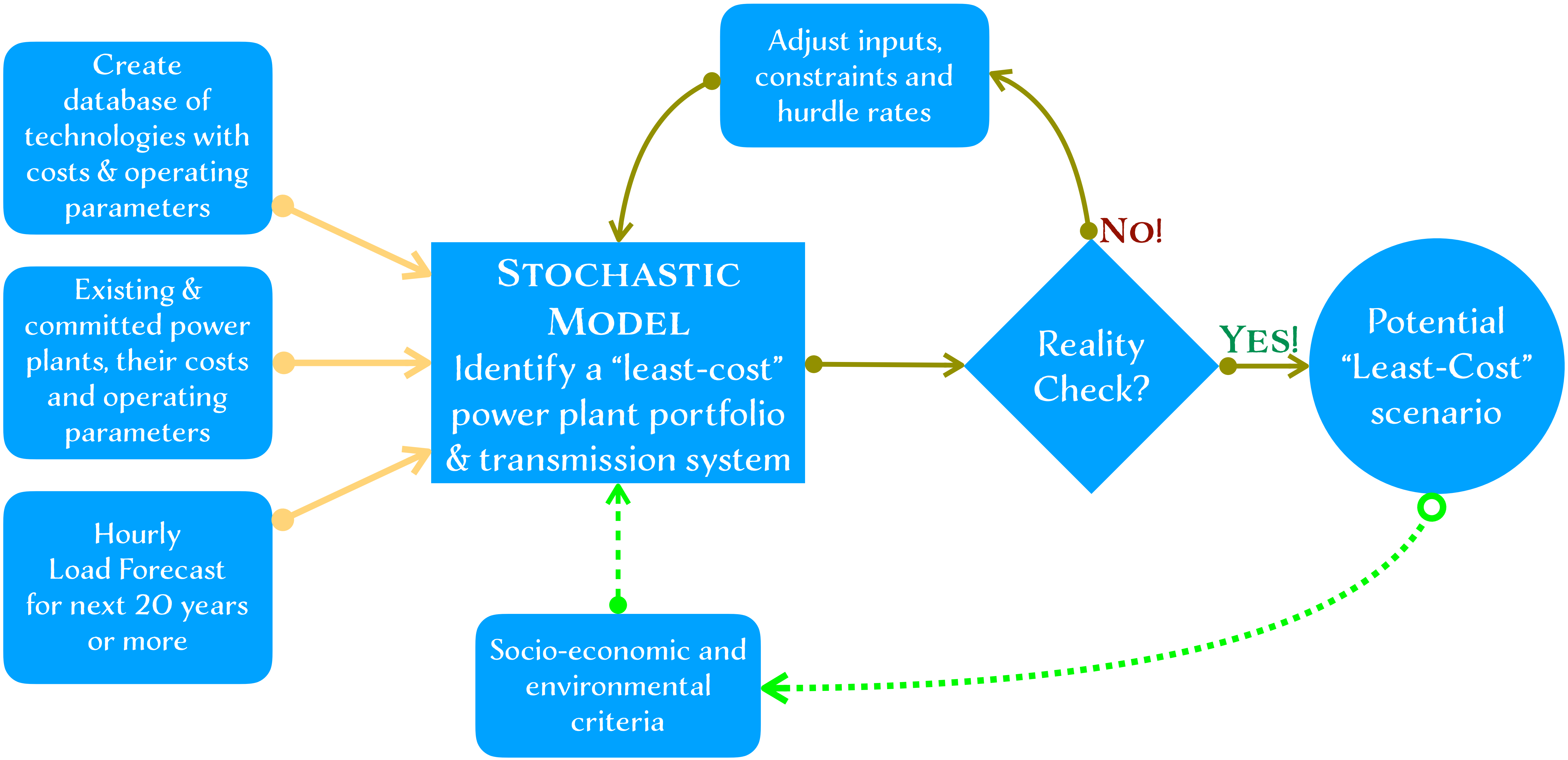

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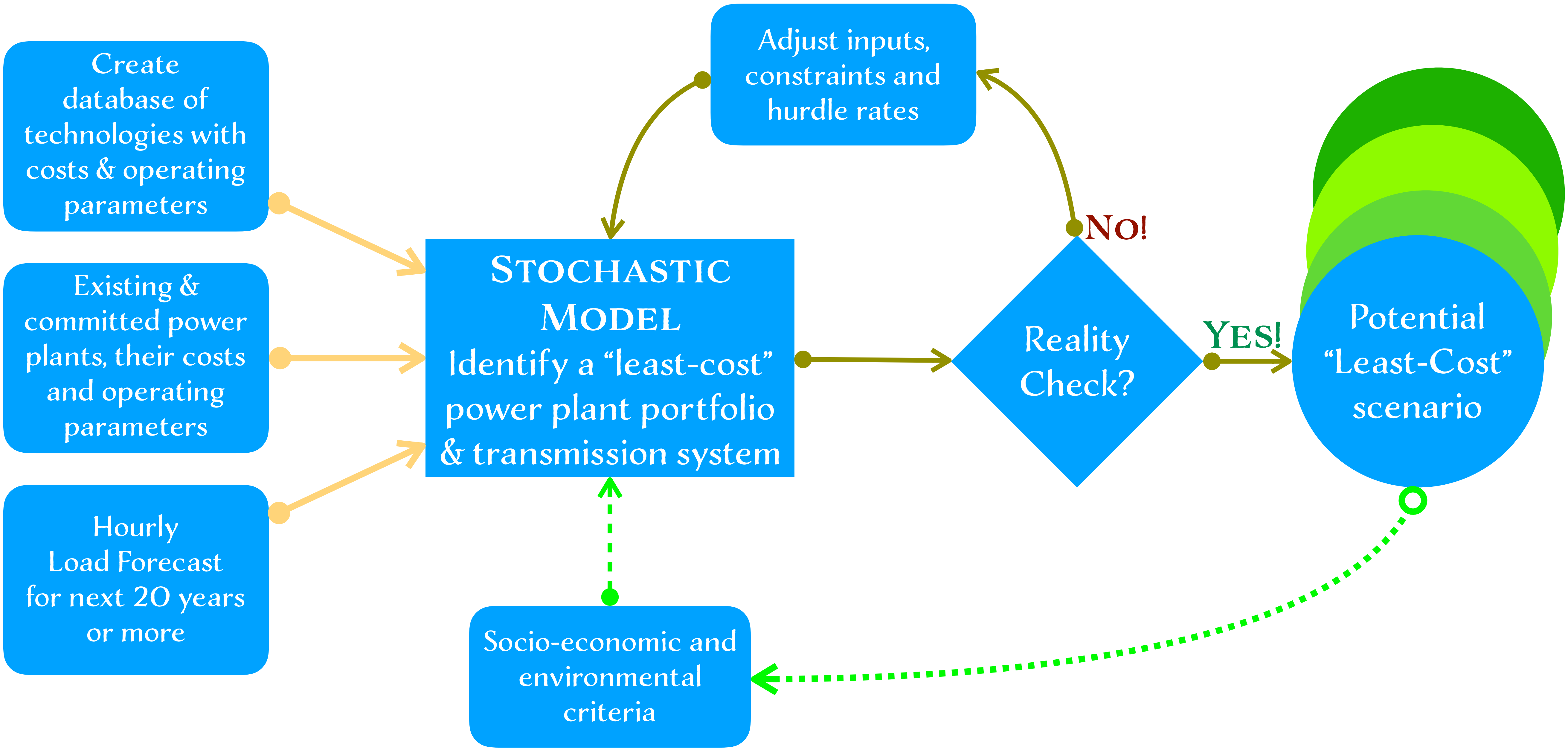
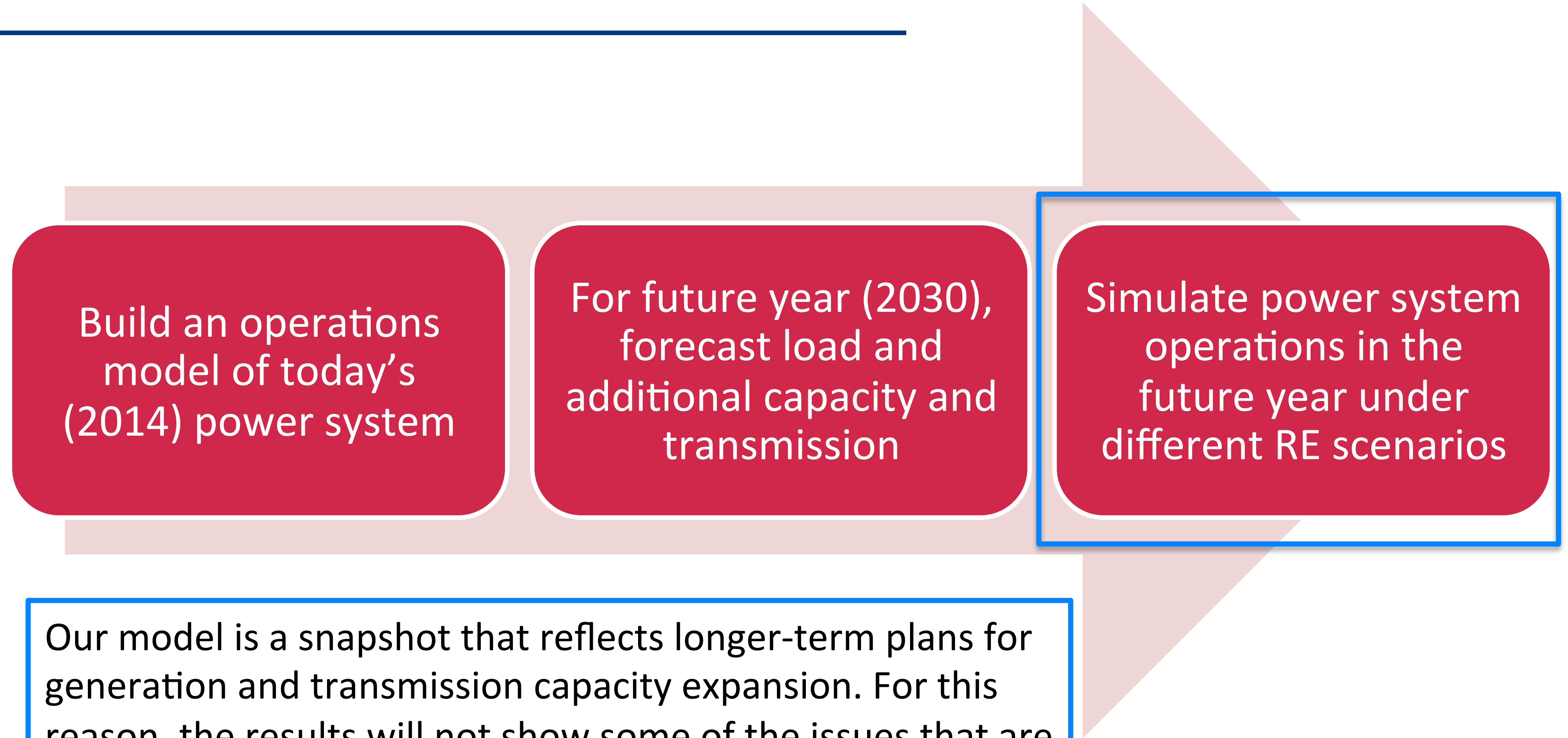


Greening the Grid

Republic of the Philippines
DEPARTMENT OF ENERGY
(Kagawaran ng Enerhiya)

USAID
FROM THE AMERICAN PEOPLE

Methodology and status



Our model is a snapshot that reflects longer-term plans for generation and transmission capacity expansion. For this reason, the results will not show some of the issues that are occurring today (e.g., solar curtailment in Negros).

Greening the Grid uses the PLEXOS production cost model

By 2030, 30% and 50% RE is achievable*

No <u>technical</u> barriers to high RE penetrations; hourly balancing is achievable under the 30% and 50% RE scenarios. The modeled 2030 Luzon-Visayas System includes existing and new power generation facilities.

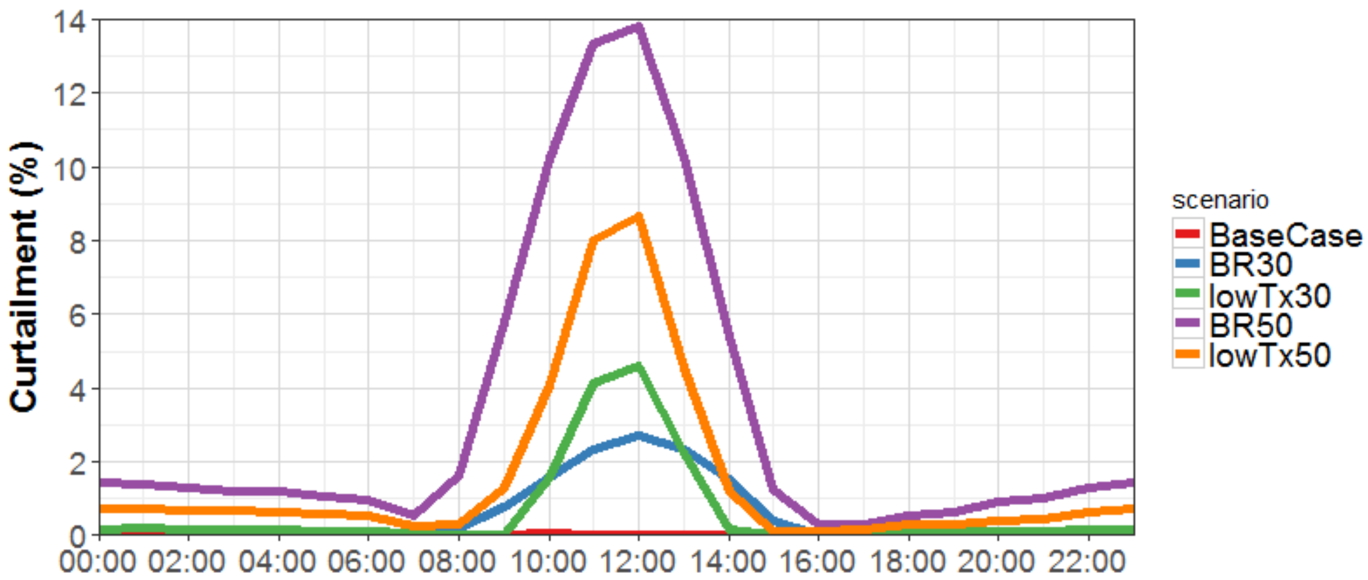
Assuming that the planned evolution of the power system takes place, including additions to both generation and transmission capacity beyond what already exists in 2016.

Solar and wind curtailment is not a major issue in most scenarios

Total annual solar and wind curtailment

Scenario	Curtailment (GWh)	Curtailment %
BaseCase	0.2	<1%
BR30	240	1.1
lowTx30	270	1.3
BR50	2800	6.1
lowTx50	1300	2.9

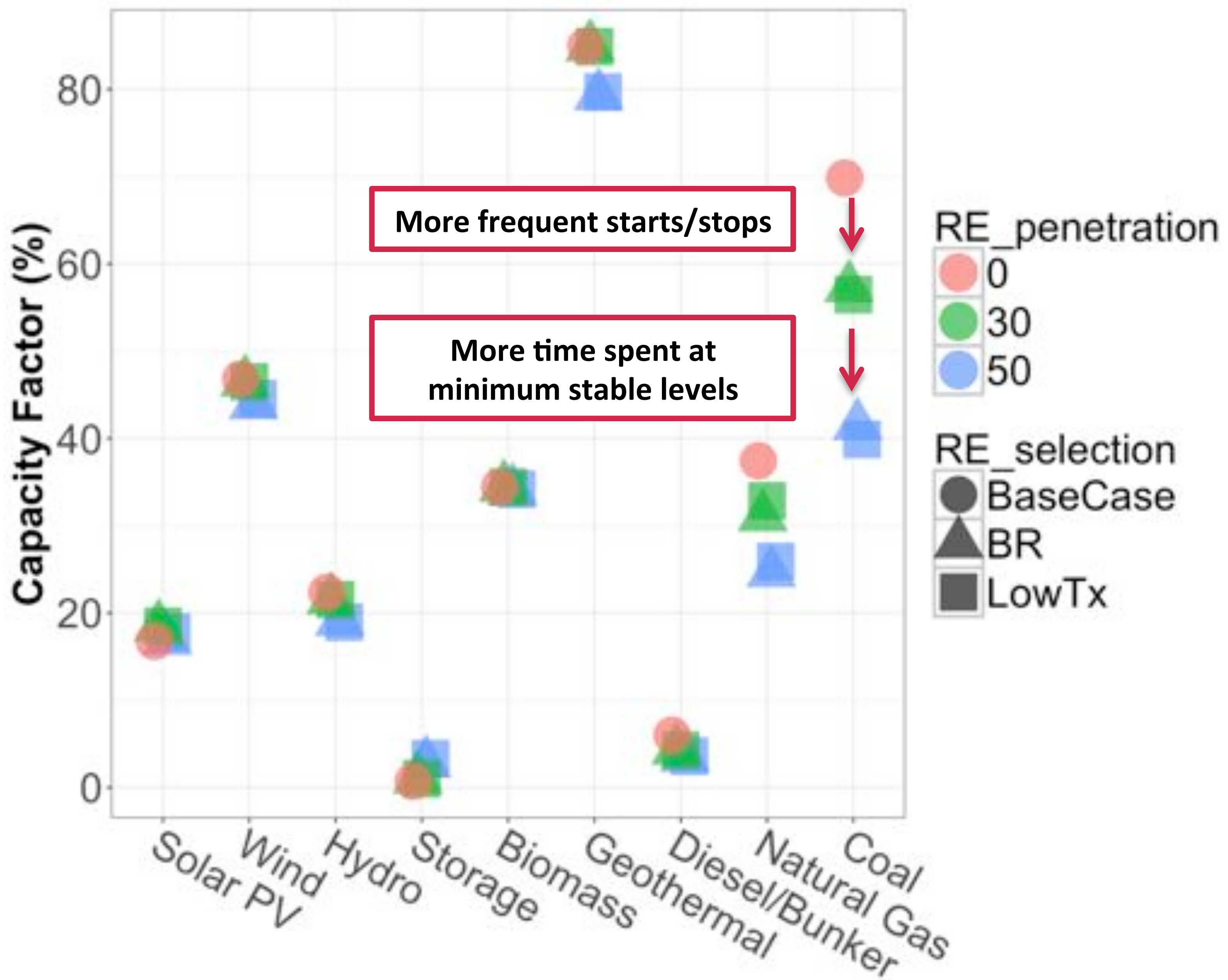
Average hourly solar and wind curtailment



Percent curtailment =
(Total solar and wind curtailment) / (Total available solar and wind energy)

Curtailment becomes most significant in the BR50 scenario. In all scenarios, curtailment is a tool that the operator can use strategically to improve power system flexibility, and hence does not need to be 0 for successful integration.

Higher RE scenarios will change the operation of the conventional fleet



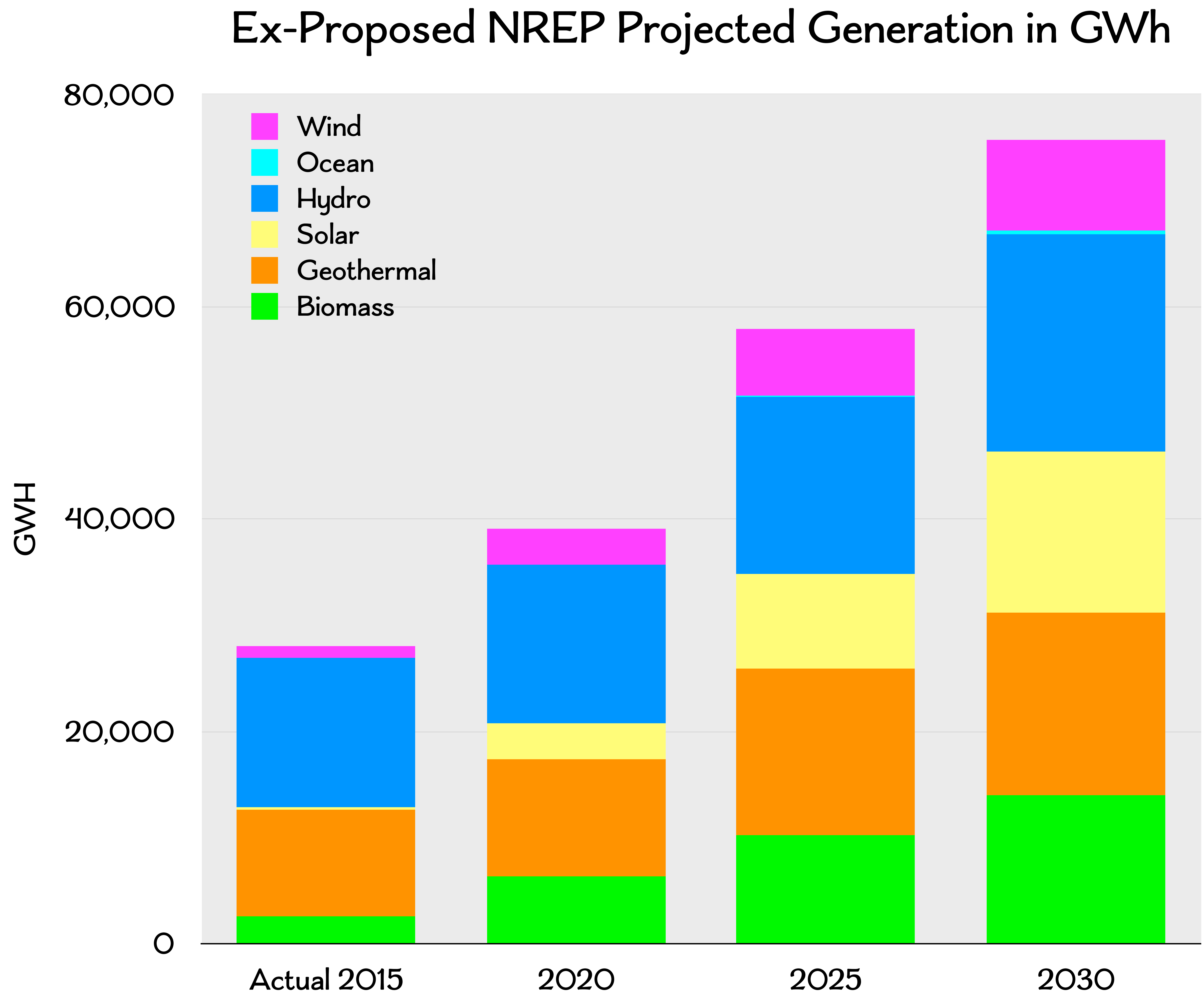
As solar and wind penetration increase, conventional generators (especially coal and natural gas) cycle more frequently and spend more time at their minimum stable levels.

Ex-Proposed NREP: Installation Capacities in MW

Sector	Installed Capacity 2015 (MW)	Target Capacity Additions by 2016 to 2020	2021 to 2025	2026 to 2030	Total Capacity Additions 2016-2030 (MW)	Total Installed Capacity by 2030 (MW)
(1) Biomass						
- Waste to Energy (MSW)	12	50	50	50	150	162
- Biomass	362	500	500	500	1,500	1,862
Total Biomass	374	550	550	550	1,650	2,024
(2) Geothermal						
- Baseload	1,906	183	900	288	1,371	3,277
- Mid-merit		-	-	-	-	-
- Peaking		-	-	-	-	-
Total Geothermal	1,906	183	900	288	1,371	3,277
(3) Solar						
- Utility Scale						
- Ground-mounted	80	1,949	3,250	3,750	8,949	9,028
- Non-Ground mounted	34	51	250	250	551	585
- Net Metering	2	6	8	8	22	24
Total Solar$_{AC}$	116	2,006	3,508	4,008	9,522	9,637
(4) Hydro						
- Large						
- Baseload	3,590	-	217	48	264	3,855
- Peaking		-	333	290	624	624
- Run-of-River	-	192	15	653	860	860
Total Hydro	3,590	192	565	991	1,748	5,339
(5) Ocean	-	-	31	60	91	91
(6) Wind	427	1,000	1,162	1,000	3,162	3,589
TOTAL	6,413	3,931	6,716	6,897	17,544	23,957

Ex-Proposed NREP: RE Based Generation in GWh

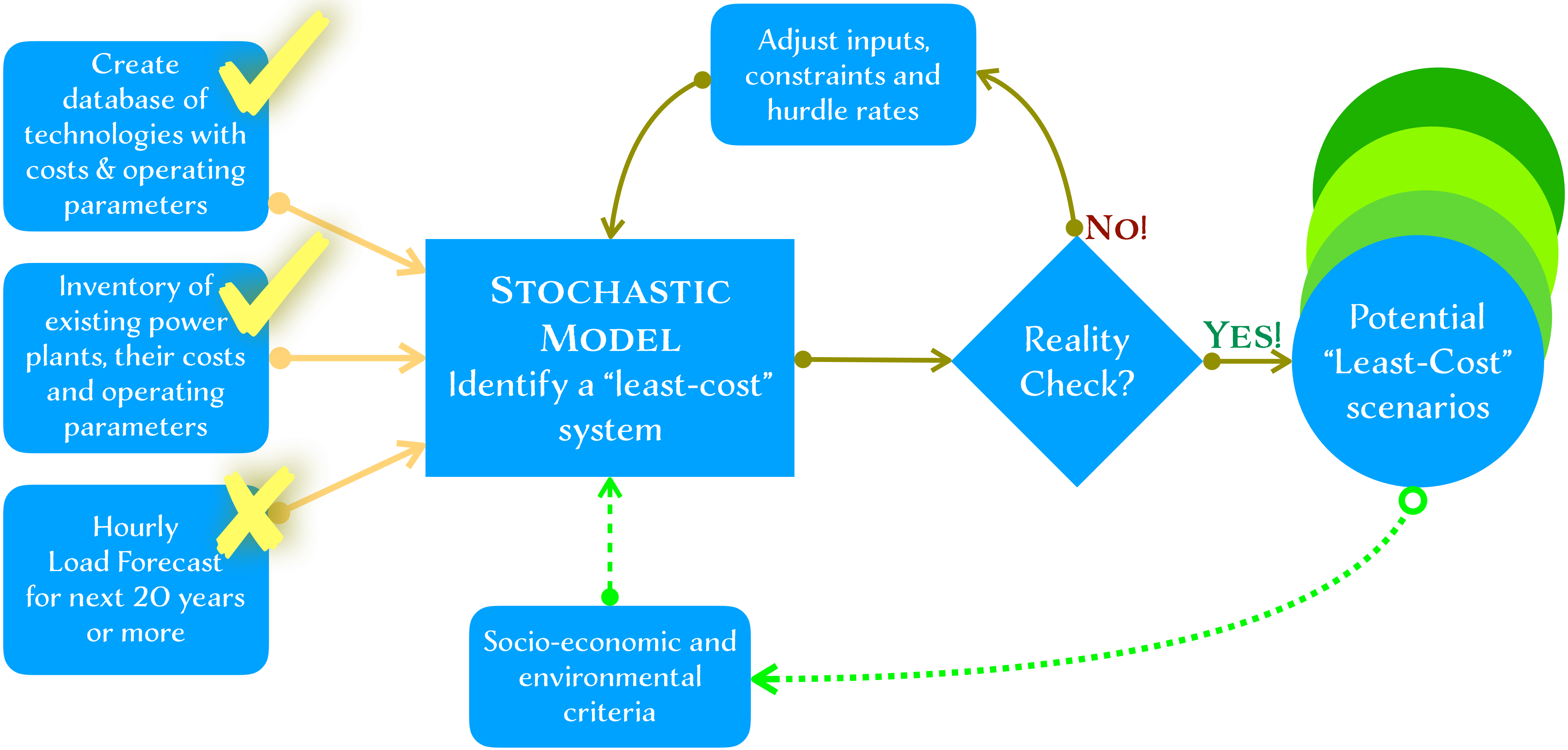
Sector	Total Generation 2015 (GWh)	Target Generation (GWh) by 2020	2025	2030
(1) Biomass				
- Waste to Energy (MSW)	68	353	638	922
- Biomass	2,538	6,042	9,546	13,050
Total Biomass	2,606	6,395	10,184	13,973
(2) Geothermal				
- Baseload	10,019	10,981	15,711	17,225
- Midmerit	-	-	-	-
- Peaking	-	-	-	-
Total Geothermal	10,019	10,981	15,711	17,225
(3) Solar				
- Utility-scale Ground	125	3,198	8,322	14,235
- Building Installed / Non-ground	54	134	529	923
- Net Metering	3	13	25	38
Total Solar	182	3,345	8,877	15,196
(4) Hydro				
- Large				
- Baseload	14,153	14,153	15,008	15,195
- Peaking	-	-	876	1,639
- Run-of-River	-	792	853	3,542
Total Hydro	14,153	14,946	16,737	20,376
(5) Ocean	-	-	121	356
(6) Wind	1,028	3,437	6,237	8,646
TOTAL GWh	27,989	39,104	57,867	75,772
Weighted Average NCF %	50%	43%	39%	36%
Share of Electricity Sales	35%	38%	44%	45%
Electricity Sales in GWh - Gross	81,124	103,537	132,142	168,651
CAGR	5.0%	5.0%	5.0%	5.0%



Ex-Proposed NREP Projected Generation in GWh
80,000
60,000
40,000
20,000
0
GWH
Wind
Ocean
Hydro
Solar
Geothermal
Biomass
Actual 2015
2020
2025
2030

Is the Ex-Proposed NREP least cost?

Is the Ex-Proposed NREP least cost?



Ex-Proposed NREP can be the starting point towards least cost