Fuel and CO_2 Emissions Savings Calculation Methodology for CHP

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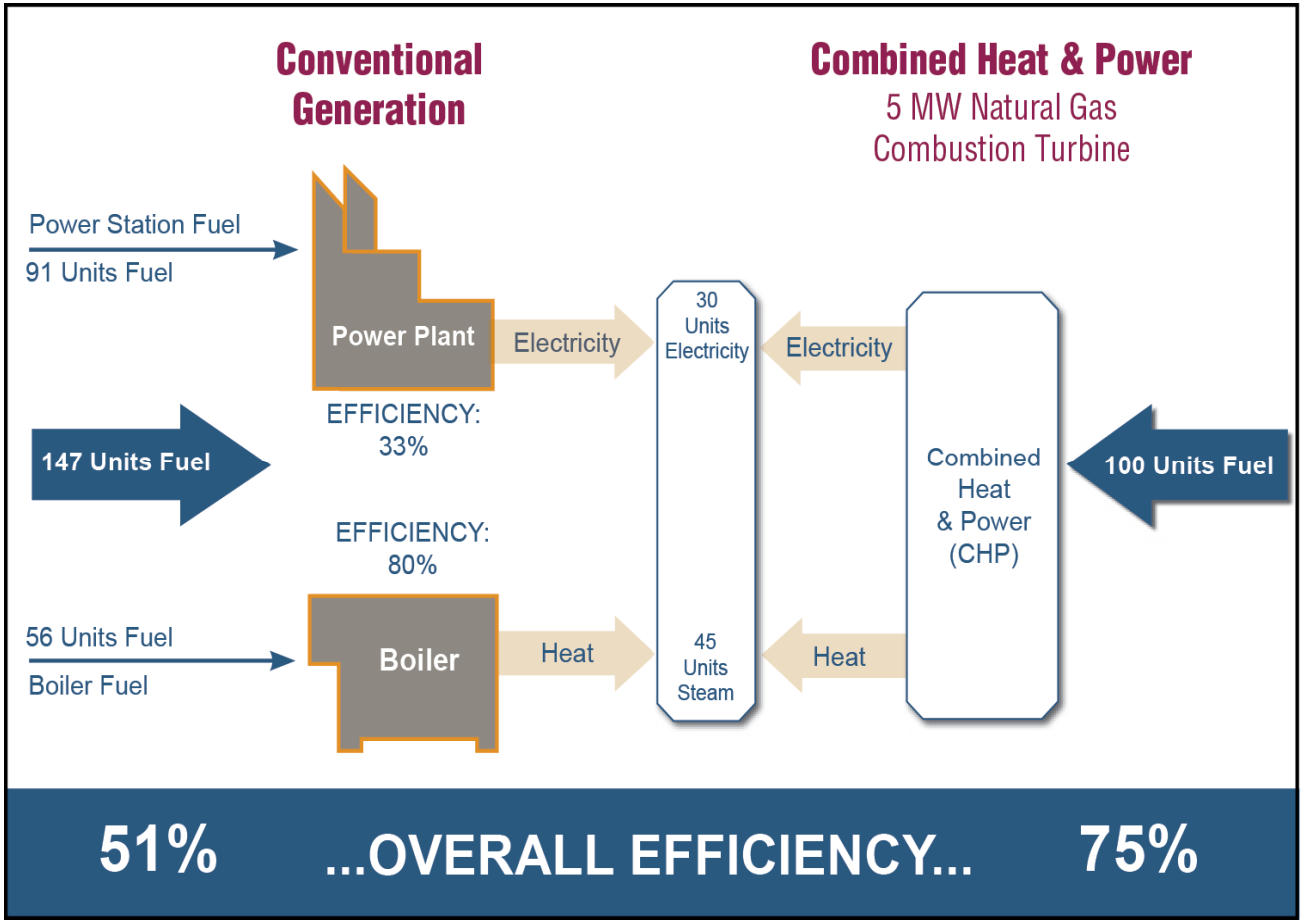
Advantages of CHP

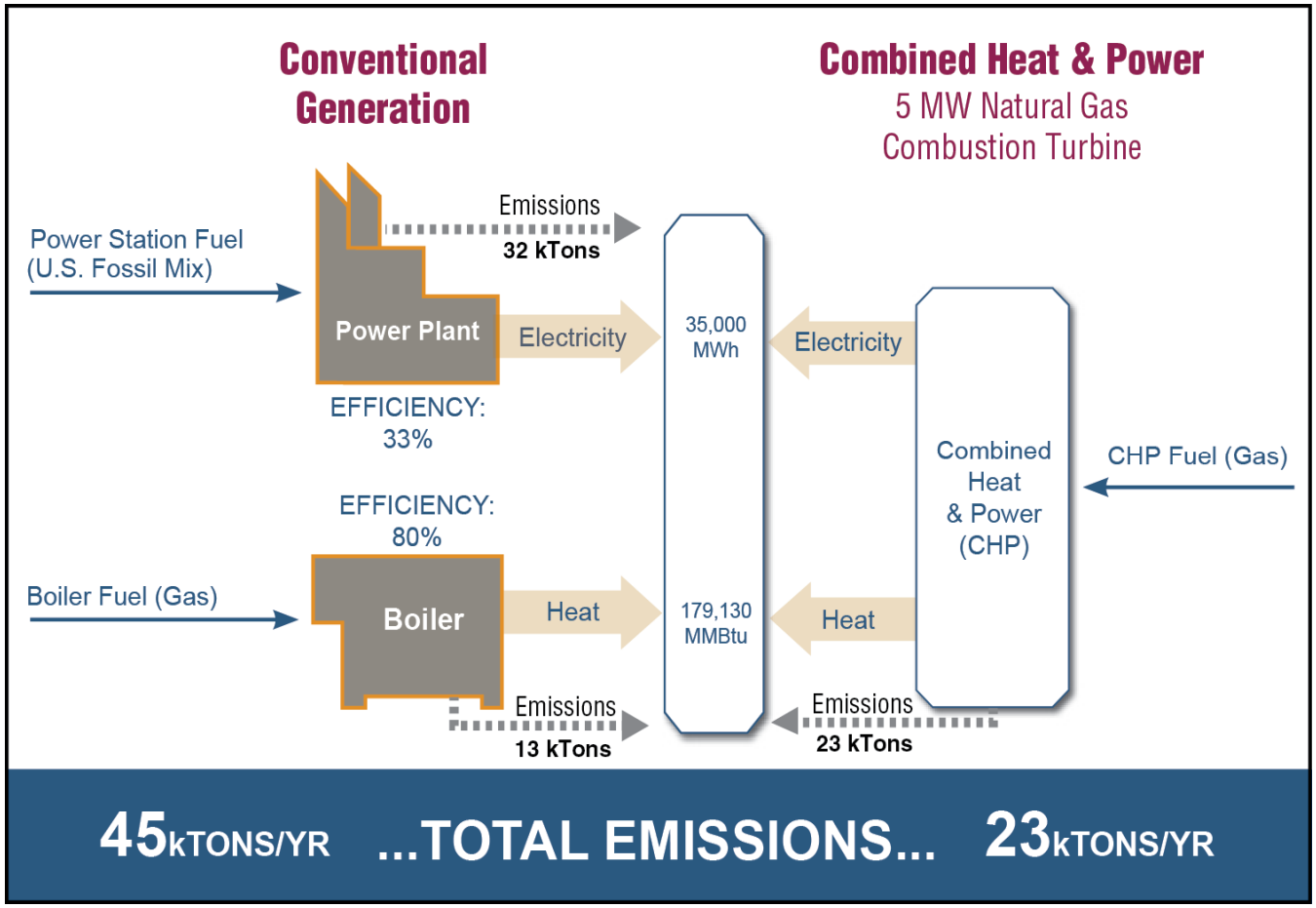
- The simultaneous production of useful thermal and electrical energy in CHP systems leads to increased fuel efficiency.
- CHP units can be strategically located at the point of energy use. Therefore, avoiding the transmission and distribution losses associated with electricity purchased via the grid from central stations.
- The increase in overall fuel use efficiency generally translates to reductions in CO_2 emissions.

CHP is a Clean, Efficient Method of Providing Energy Services



Source: EPA CHP Partnership - 2012

CHP's Increased Efficiency Generally Results in Lower Emissions



Source: EPA CHP Partnership - 2012

How do I Calculate the Energy and CO_2 Savings of my CHP Project?

- CHP energy savings benefits are found in the aggregate reduction of overall fuel consumption – compare the energy use and emissions of the CHP project to the energy use and emissions of supplying those same energy services with separate heat and power.
- Key factors in quantifying CHP savings:
  - What is the energy use and emissions from displaced thermal energy?
  - What is the energy use and emissions from displaced grid electricity?

What is the Recommended CHP Partnership Approach?

- Simple, straightforward approach to estimating the energy and CO_2 emissions benefits of CHP
- Based on readily available information
- Incorporates regional characteristics
- Focused on the savings of a specific project
- Not applicable to calculating carbon footprint or estimating corporate inventories

Calculating Fuel and CO_2 Emissions Savings from CHP

Calculating Fuel Savings

$$F_S = (F_T + F_G) - F_{CHP}$$

Where:

- F_S = total fuel savings
- F_T = avoided fuel use from on-site thermal production
- F_G = avoided fuel use from purchased grid electricity
- F_{CHP} = fuel use by the CHP system.

Calculating CO_2 Savings

$$C_S = (C_T + C_G) - C_{CHP}$$

Where:

- C_S = total CO_2 savings
- C_T = avoided CO_2 emissions from on-site thermal production
- C_G = avoided CO_2 emissions from purchased grid electricity
- C_{CHP} = CO_2 emissions from the CHP system

Fuel and Emissions Avoided at the Site

- Result from displacement of the energy otherwise used to provide heating or cooling services at the site.
- Savings calculated based on useful thermal output of CHP system and efficiency characteristics of avoided thermal equipment

$$F_T = CHP_T / \eta_T$$

Where

F_T = avoided thermal fuel savings, MMBtu

CHP_T = CHP system useful thermal output, MMBtu

η_T = avoided thermal equipment efficiency, %

Fuel Use and Emissions Avoided at the Central Station Power Plant

- Fuel use from avoided central station generation

$$F_G = E_G \times HR_G$$

Where

F_G = fuel use from avoided grid electricity, Btu (kJ)

E_G = total grid generation avoided, kWh

HR_G = central station heat rate, Btu/kWh

- CO_2 emissions from avoided central station generation

$$C_G = E_G \times EF_G$$

Where

C_G = CO_2 emissions from avoided grid electricity, lb (kg)

E_G = total grid generation avoided, MWh

EF_G = central station emission factor, CO_2 lb/MWh

How Much Electricity is Avoided at the Power Plant?

- Some of the electricity that is transmitted over power lines is lost due to resistance, referred to as ***transmission losses***
- Avoiding 1 MWh of purchased electricity onsite means more than 1 MWh of electricity no longer needs to be generated at the central station power plant
- Typically, annual transmission losses are 7% to 10%

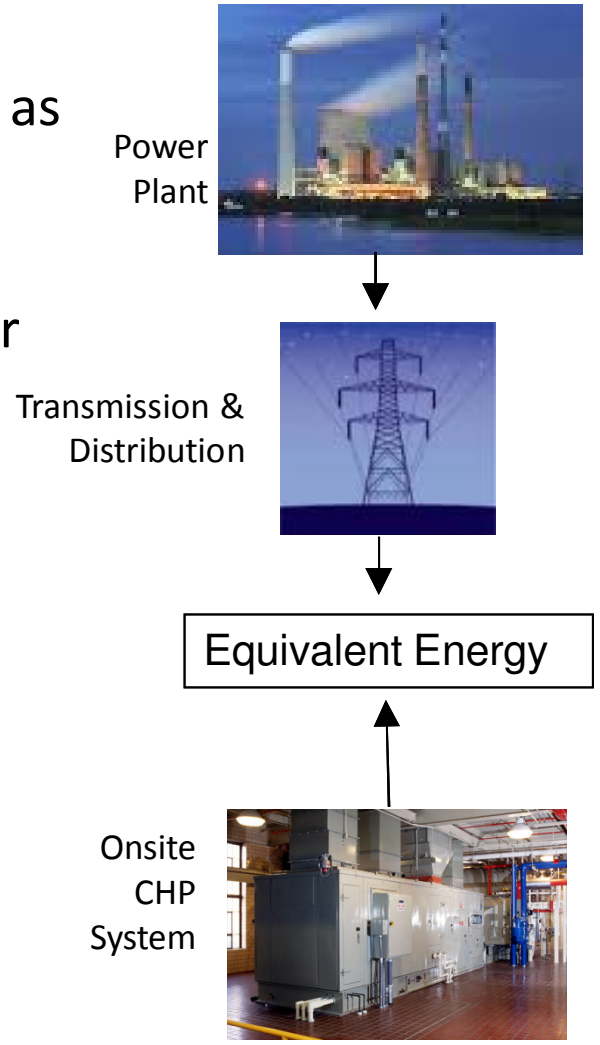
$$E_G = CHP_E / (1 - L_{T\&D})$$

Where

E_G = grid generation avoided, kWh

CHP_E = CHP system electricity output, kWh

$L_{T\&D}$ = transmission and distribution losses, %



What are the Characteristics of Avoided Grid Electricity?

- Geographic factors – what level of regional aggregation most accurately estimates the power supply in my area?
  - Utility company, state, ISO, NERC region
- Heat rate and emissions factors – what are the fuel and emissions factors for electricity avoided at the grid?
- Where do I get the data?

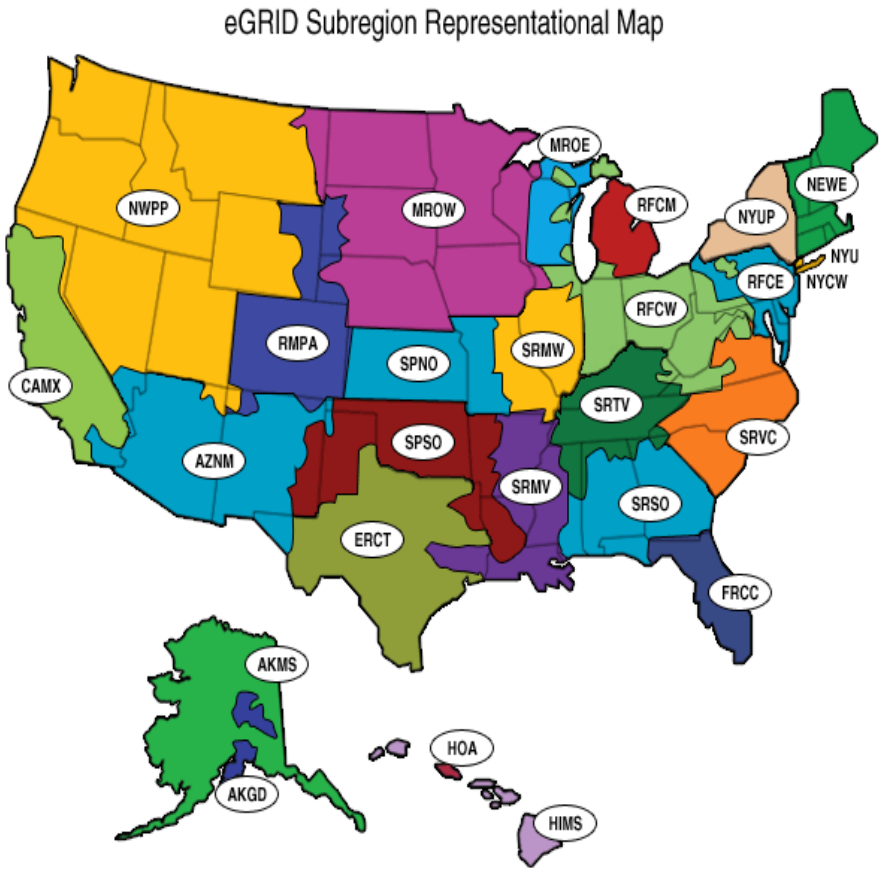
Emissions & Generation Resource Integrated Database (eGRID)

- Globally recognized source of emissions data for electric power generated in the U.S. – current edition is 2005 data
- Based on power plant specific data
  - Plant identification and location
  - Ownership
  - Fuel use and heat rate
  - Emissions (CO_2, CH_4, N_20, NO_x, SO_2, Hg)
- Can be rolled into regional heat rates and emissions factors
  - State, NERC region, eGRID subregions
- www.epa.gov/grid

EPA eGRID Sub-regions

Recommended because:

- Sub-regions generally consist of one or a portion of a power control area, sectioning the grid into areas with similar emissions and resource mix
- Electric generating companies may purchase or export power to/from other generating companies
- State electricity generation may not serve all consumption within the state.
- Sub-regions may be partially isolated by transmission constraints



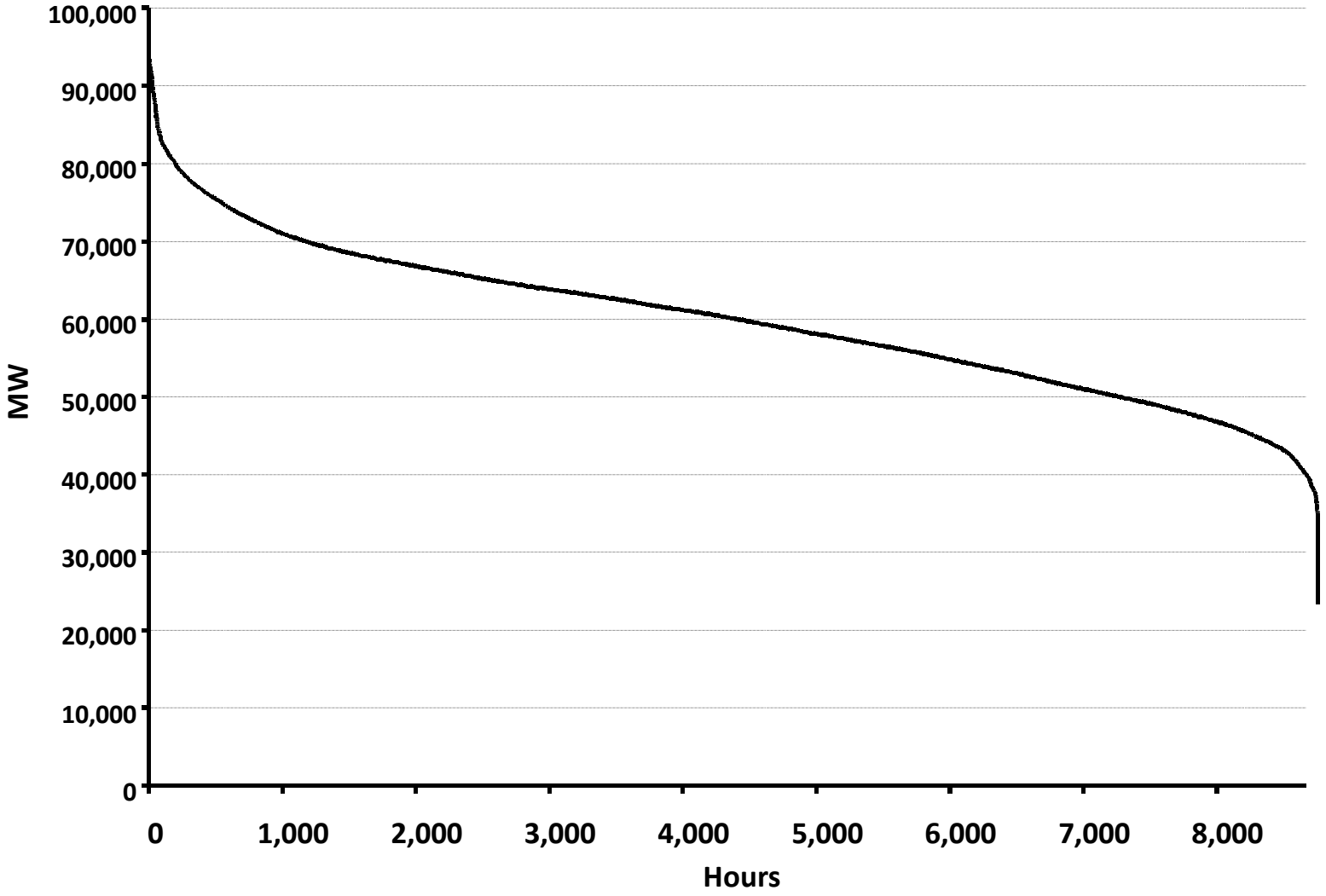
What Grid Power is being Avoided by CHP

- Key factor in estimating the energy and CO_2 emissions savings from CHP
- Ultimate analysis would require time consuming dispatch modeling
- Options for estimating appropriate factors include:
  - All-generation average (including nuclear and renewables)
  - All-fossil average (weighted mix of fossil fuels)
  - Non-baseload average (resource mix coincident with intermediate and peak demand)
  - Average of a specific fuel type
  - Estimate of marginal generation
  - Projection of future installed generation

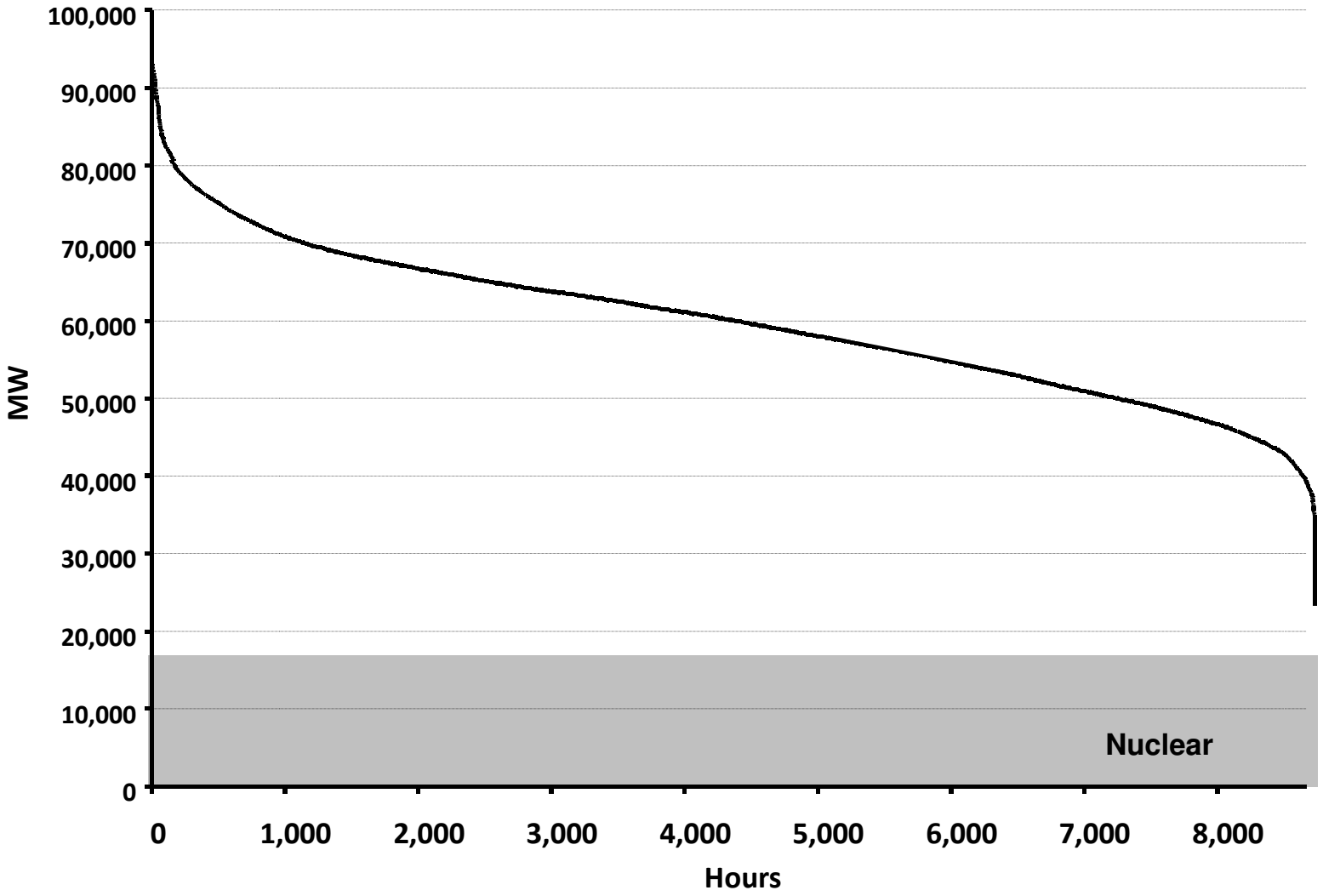
Recommended Factors for Avoided Grid Power

- Nuclear and renewable generation are likely must-run resources, and seasonal/daily variations in power supply and demand are generally met with changes in fossil generation
- CHP typically operates as intermediate (4500 -7000 hours) or base-load (>7000 hours)
- The eGRID all fossil average heat rate and emissions factor are appropriate for baseload CHP
- The eGRID non-baseload average heat rate and emissions factor are appropriate for non baseload CHP

Load Duration Curve – Basic Dispatch Mix



Load Duration Curve



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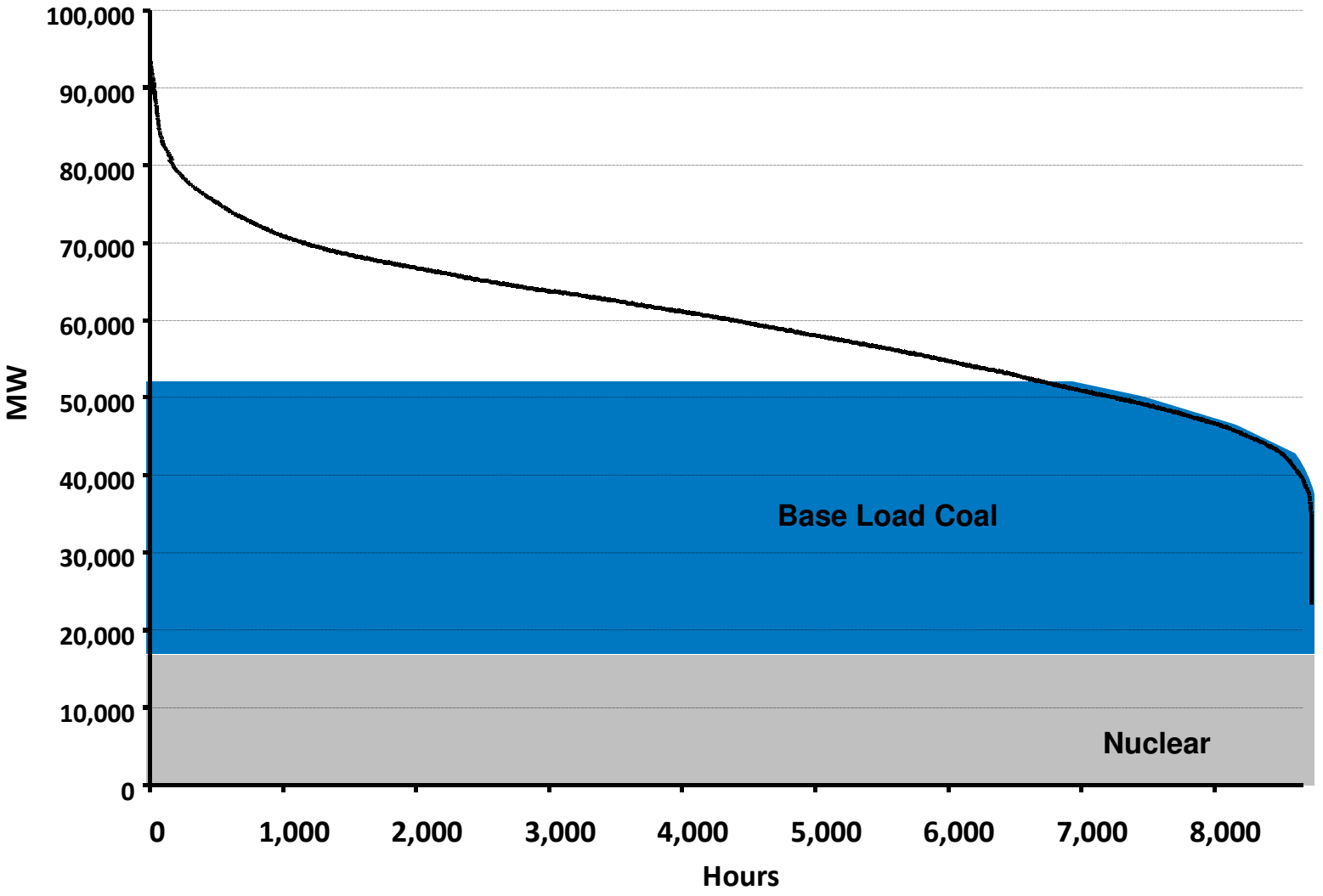

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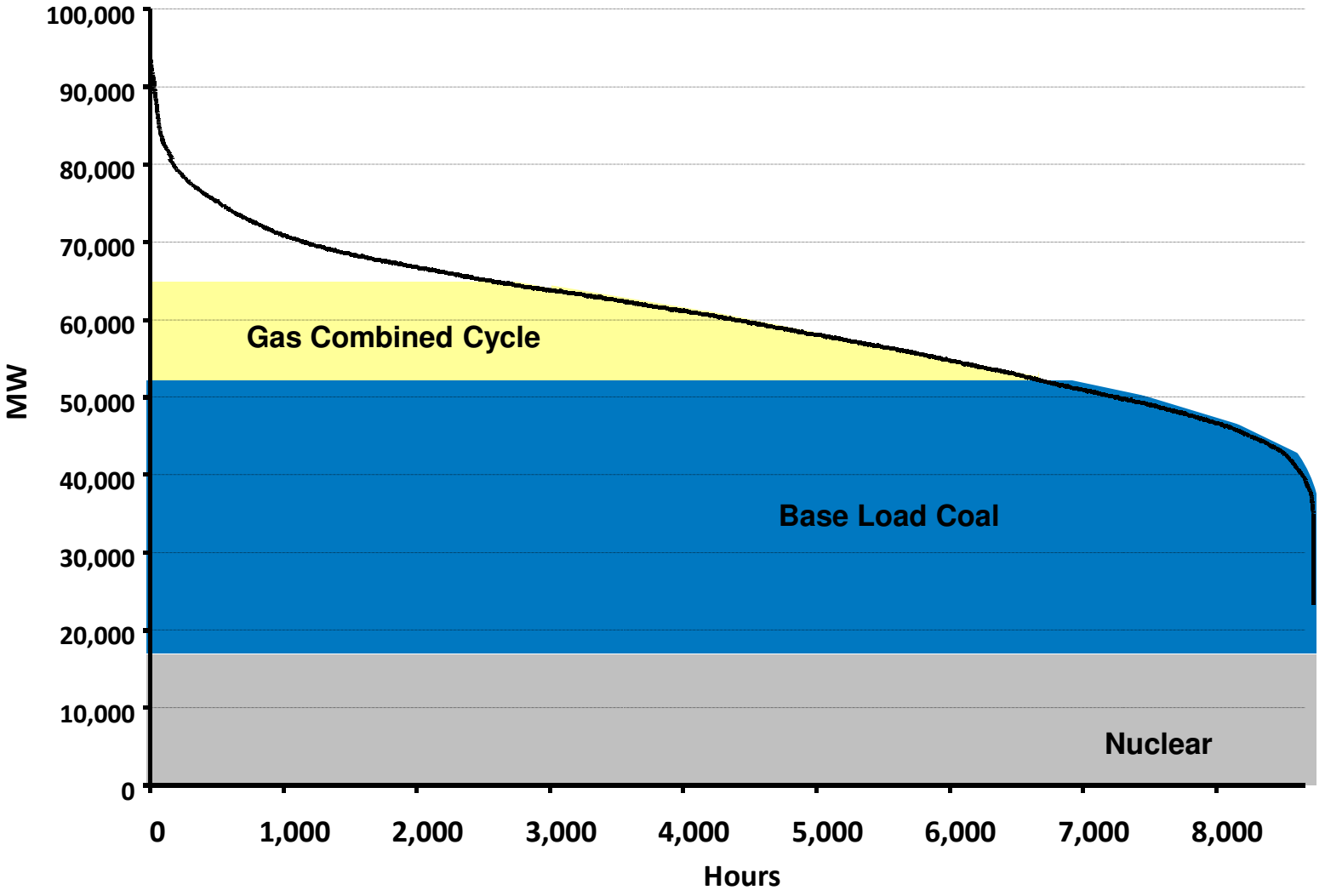

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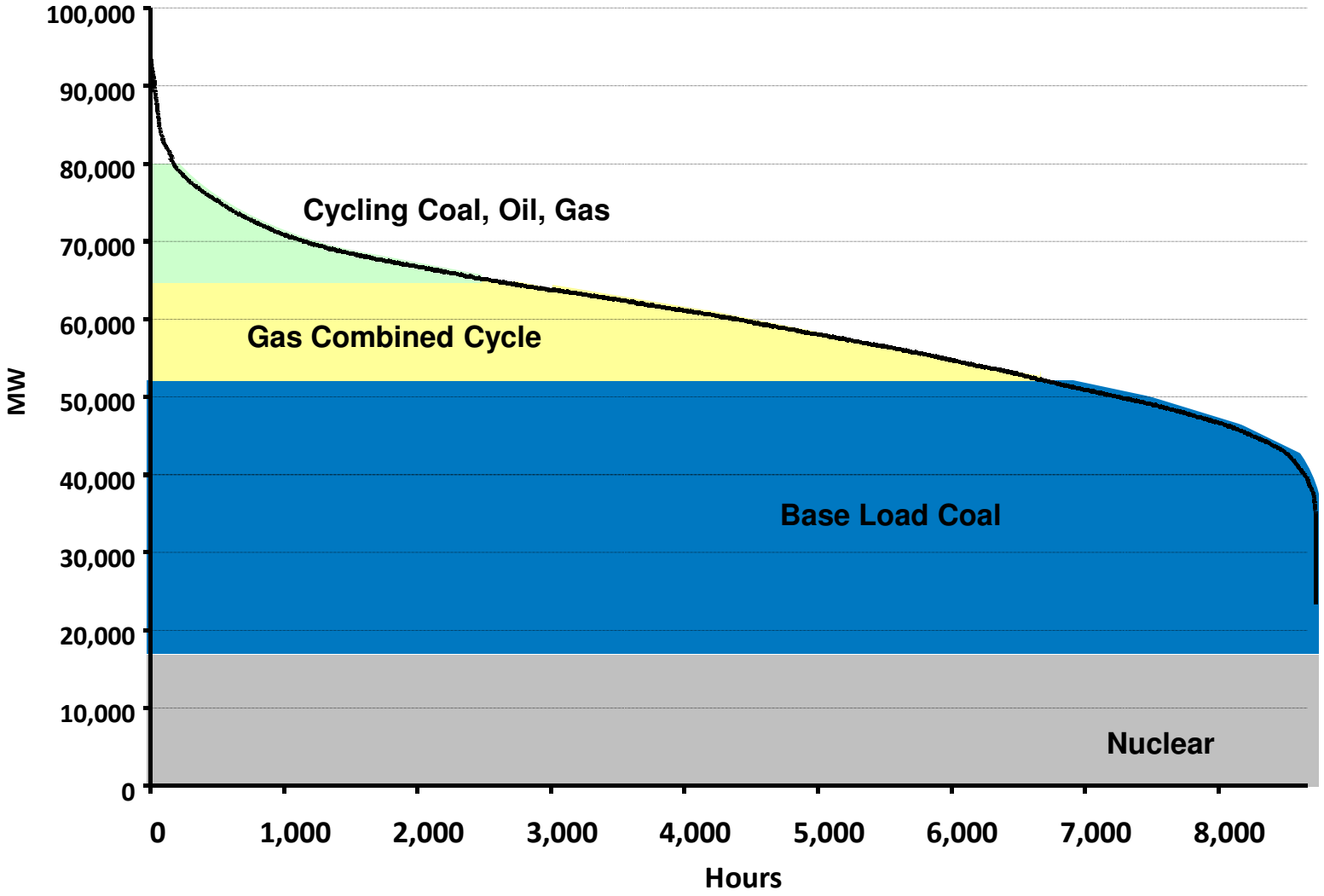

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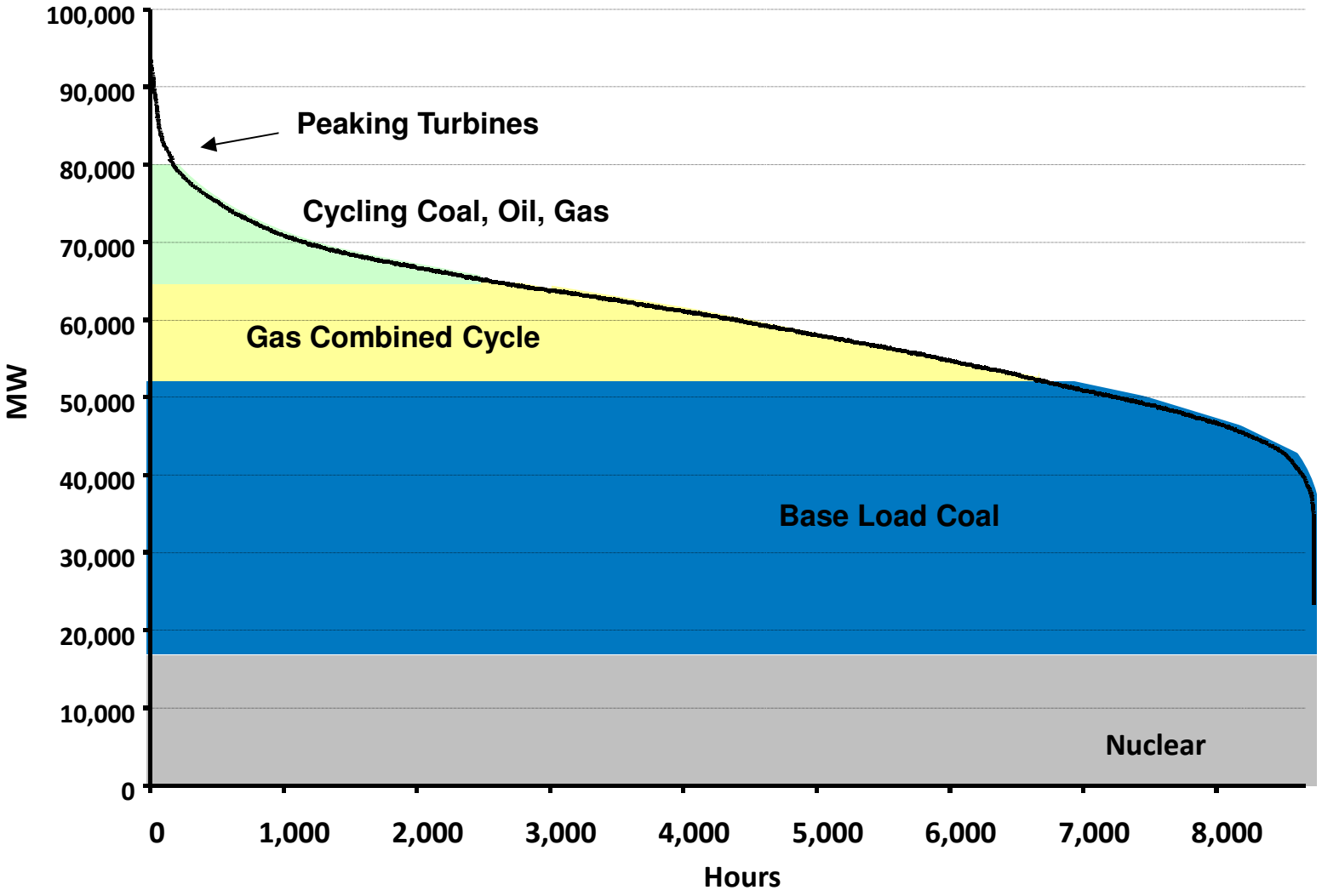

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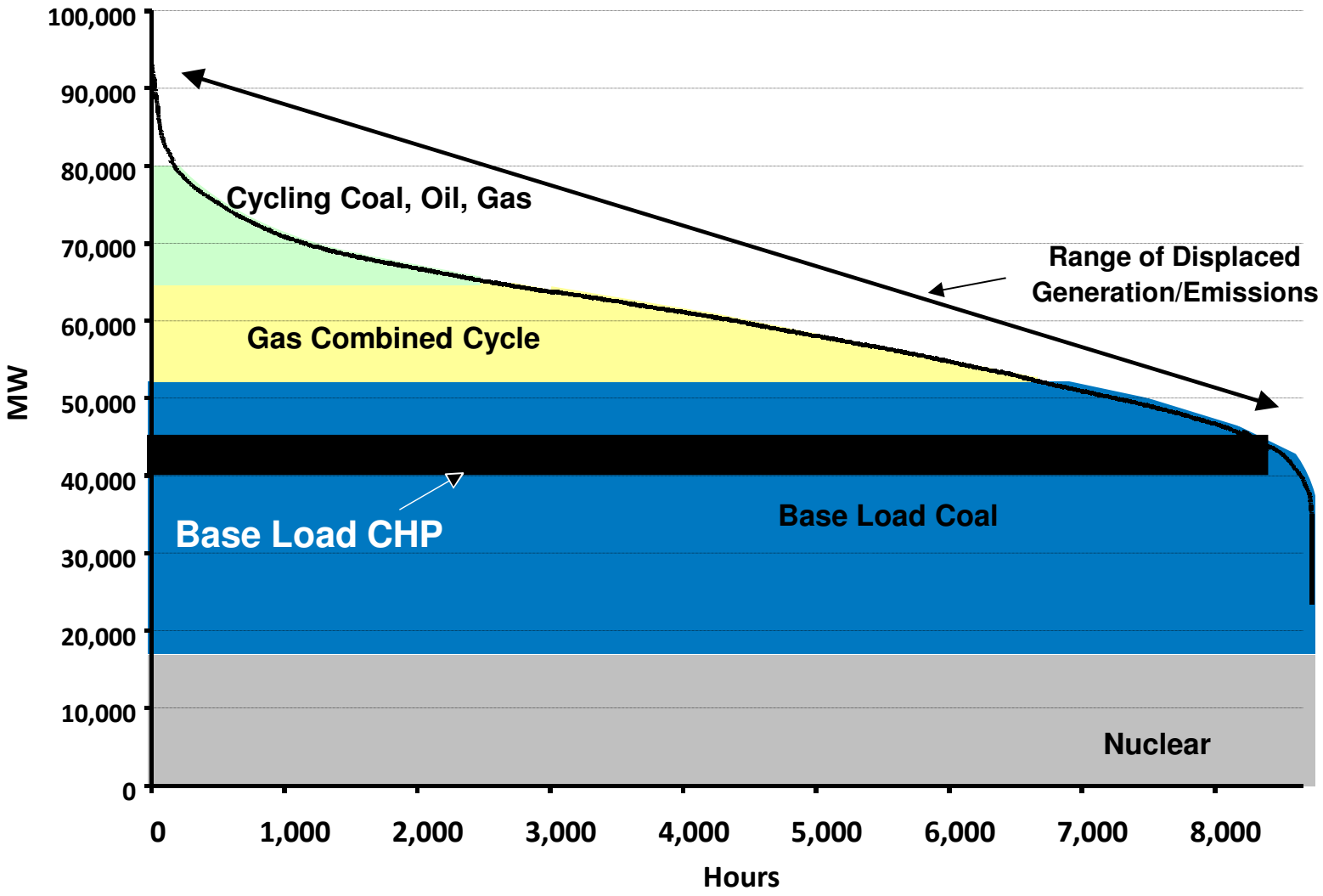

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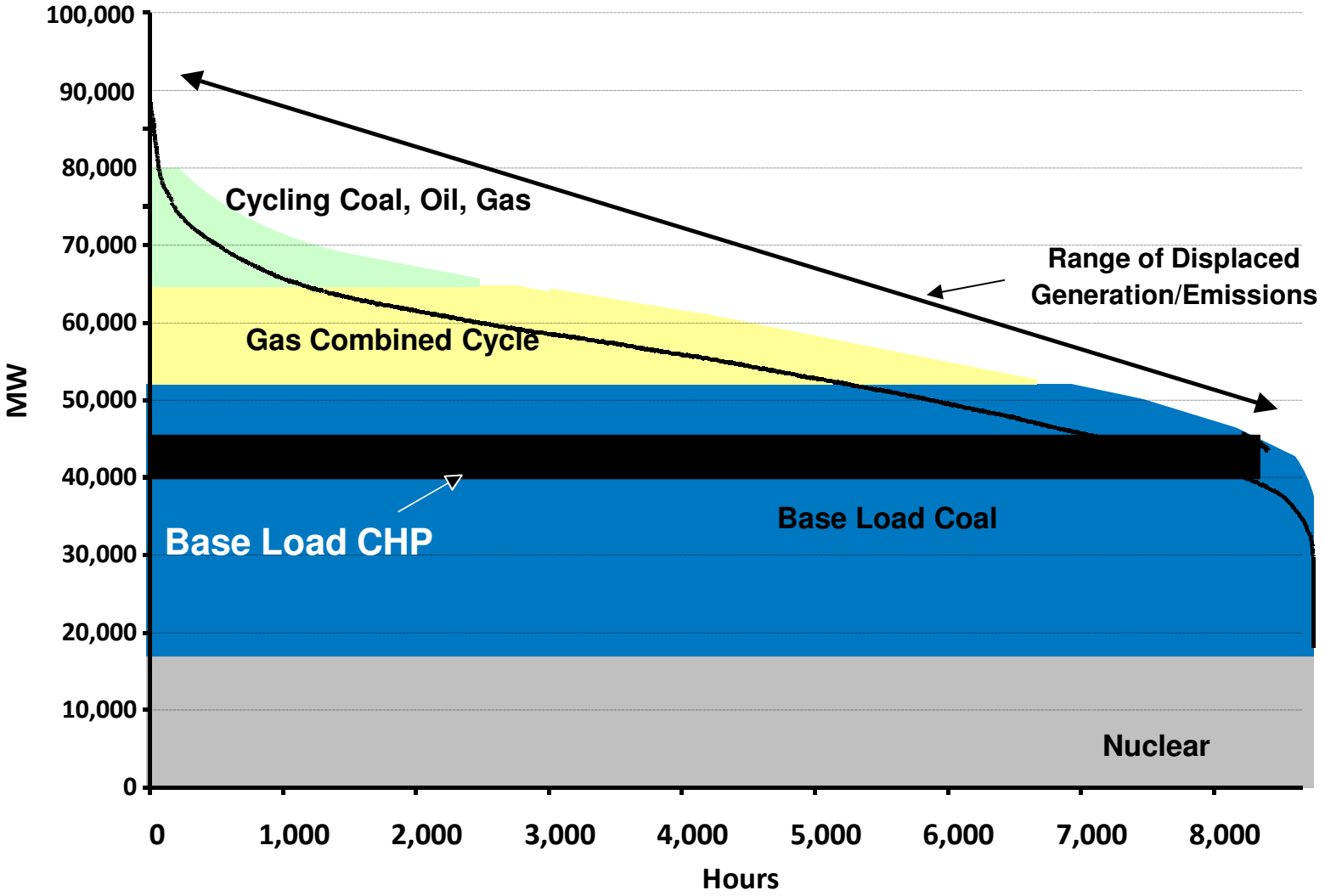

Example Calculation – 5 MW Gas Turbine

- 5 MW natural gas-fired combustion turbine
- 8,497 hours per year (97% availability)
- Heat Rate = 12,590 HHV (27%)
- 42,485 MWh generated on-site
- 45,682 MWh avoided at power plant (7% T&D loss)
- Recoverable thermal energy is 5,000 Btu/kWh
- Displaces a natural gas-fired boiler (80% efficient)
- Located in Chicago (eGRID sub-region is RFC West)

Example Calculation - 5 MW Gas Turbine

RFC West Heat Rate and Emission Factors

Central Station Mix	Heat Rate, Btu/kWh	CO2 Emissions, lbs/MWh
All Generation	7,656	1,538
Non-Baseload	9,879	1,993
All Fossil	9,952	1,978

Example Calculation - 5 MW Gas Turbine

Fuel and Emissions Savings Results

Central Station Mix	Energy Savings, MMBtu/yr	CO2 Savings, MMBtu/yr
All Generation	81,175	19,459
Non-Baseload	182,730	29,852
All Fossil	186,065	29,510

Conclusions

- To quantify the fuel or CO_2 emissions savings of a CHP project, the fuel used and emissions released from the CHP system must be subtracted from the fuel used and emissions that would normally occur without the system (i.e., using conventional separate heat and power).
- To most accurately reflect the generation characteristics of avoided central station generation, the calculations should be based on:
  - The heat rate and emissions factors from the EPA eGRID subregion in which the CHP unit is located
  - The all fossil average heat rate and emissions factor for baseload CHP (annual operating hours > 7000)
  - The non-baseload average heat rate and emissions factor for non baseload CHP (annual operating hours < 7000)