Forward-Looking Source Energy and Emission Factors for the ASHRAE 227P Passive Building Design Standard

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Learning Objectives

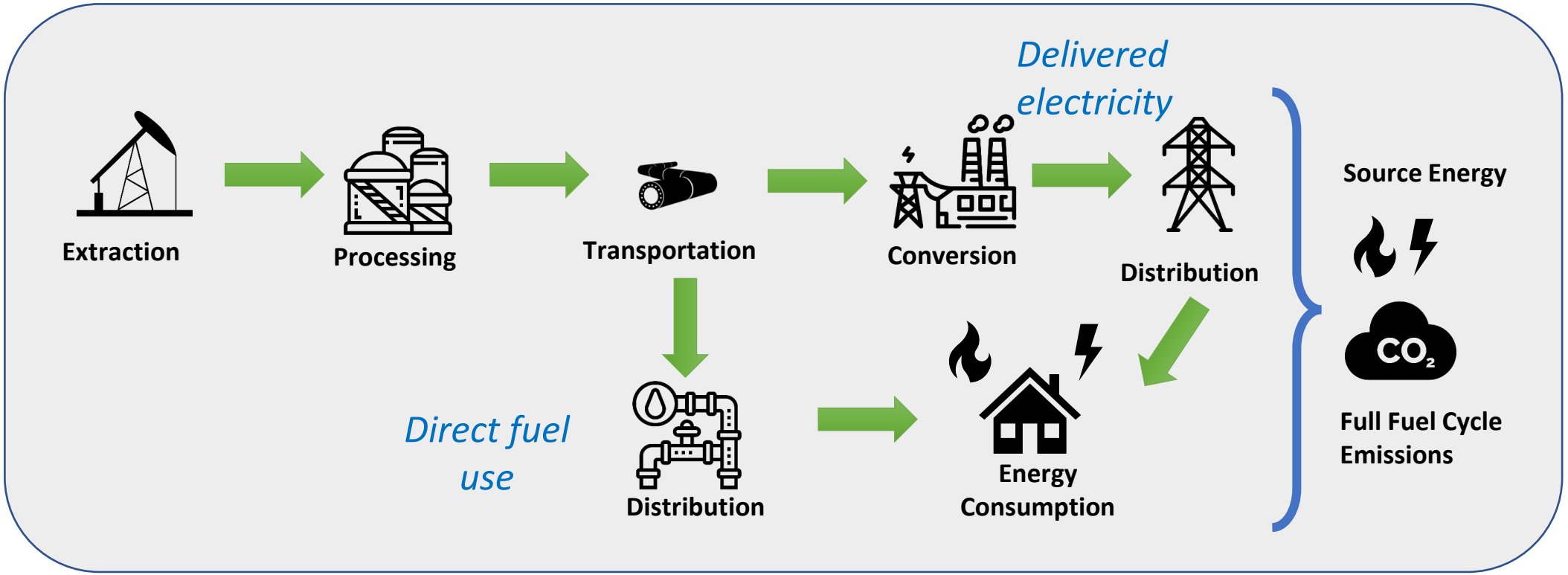
1) Recognize the methodology for creating forward-looking source energy factors
2) Summarize the importance of using forward-looking factors in source energy calculations
3) Understand the difference that both geographic resolution, and time resolution (hourly vs. annual) can make on measuring overall building impact.
4) Understand how future-looking source energy factors influence equipment choices in buildings.

Source Energy Definition

- ANSI/ASHRAE standard 105-2014:
  - Primary or source energy is “site energy plus the estimated energy consumed or lost in the extraction, processing, and transportation of primary energy forms such as coal, oil, natural gas, biomass, and nuclear fuel; energy consumed in conversion to electricity; and energy consumed or lost in transmission and distribution to the building site.”
- Provides the most complete picture of the energy and emissions impacts from building operation

Source Energy

Full-fuel-cycle pathways for determining natural gas primary energy factors for electricity or direct fuel use

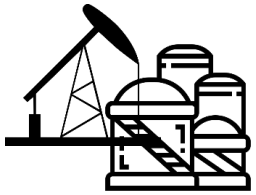


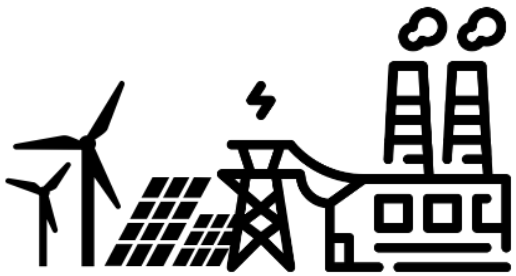
Icons made by Eucalyp, Wanicon, Surang & Freepik from www.flaticon.com

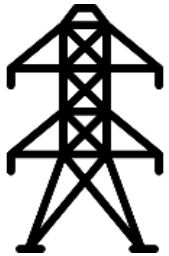
Source Energy Factor Calculation

Per Generation (Fuel) Type

$$\frac{1}{\text{Extraction \& Processing} \times \text{Fuel Conversion Efficiency} \times \text{Distribution \& Transmission Efficiency}} = \text{Source Energy Factor}$$







per generation (fuel) type

Electricity Generation
Source Energy and Emission Factors

Values derived from the eGRID2018 database for each type of power generation, with factors for extraction, processing, transportation, transmission, and distribution energy use applied based on the methodology described in ASHRAE Standard 105-2014R, Second Public Review, Informative Appendix K

Electricity Generation
Source Energy and Emission Factors

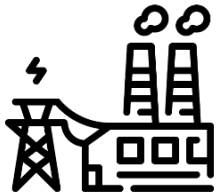
Fuel Type	Extraction	Processing	Transportation	Conversion	Distribution	Cumulative Efficiency	Source Energy Factor	Greenhouse Gas Emission Factor (kg/kWh)
Coal	98	98.6	99	32.2	95.1	29.3	**3.41**	**1.106**
Oil	96.3	93.8	98.8	37.1	95.1	31.5	**3.17**	**0.819**
Natural Gas	96.2	97	99.3	45.3	95.1	39.9	**2.51**	**0.506**
Nuclear	99	96.2	99.9	32.6	95.1	29.5	**3.39**	**0.042**
Hydro	100	100	100	100	95.1	95.1	**1.05**	**0**
Biomass	99.4	95	97.5	100	95.1	87.6	**1.37**	**0.026**
Wind	100	100	100	100	95.1	95.1	**1.05**	**0**
Solar	100	100	100	100	95.1	95.1	**1.05**	**0**
Geothermal	100	100	100	100	95.1	95.1	**1.05**	**0**
Other	100	100	100	20.3	95.1	19.3	**5.18**	**0.953**
Imports, Canada	54.6				94.9	51.8	**1.93**	**0.117**

Upstream Extraction & Processing = GREET Argonne NL | Conversion Efficiencies = eGRID 2018

Source Energy Factor Calculation

for an Electricity Generation Mix

Electricity Generation Mix

 % x **Source Energy Factor** *per generation (fuel) type*

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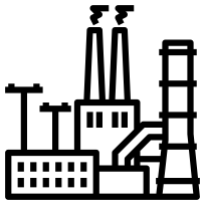
 % x **Source Energy Factor** *per generation (fuel) type*

=

Source Energy Factor

for given electricity generation mix

Phius 2021: Assumed Generation Mix

Based on NREL Standard Scenarios Report → contains 45 potential future grid scenarios.

Uses the '*Mid-Case Scenario*' – reporting on future grid generation & capacity mixes projected out to 2050 **based on policies that were in place as of June 30, 2020**

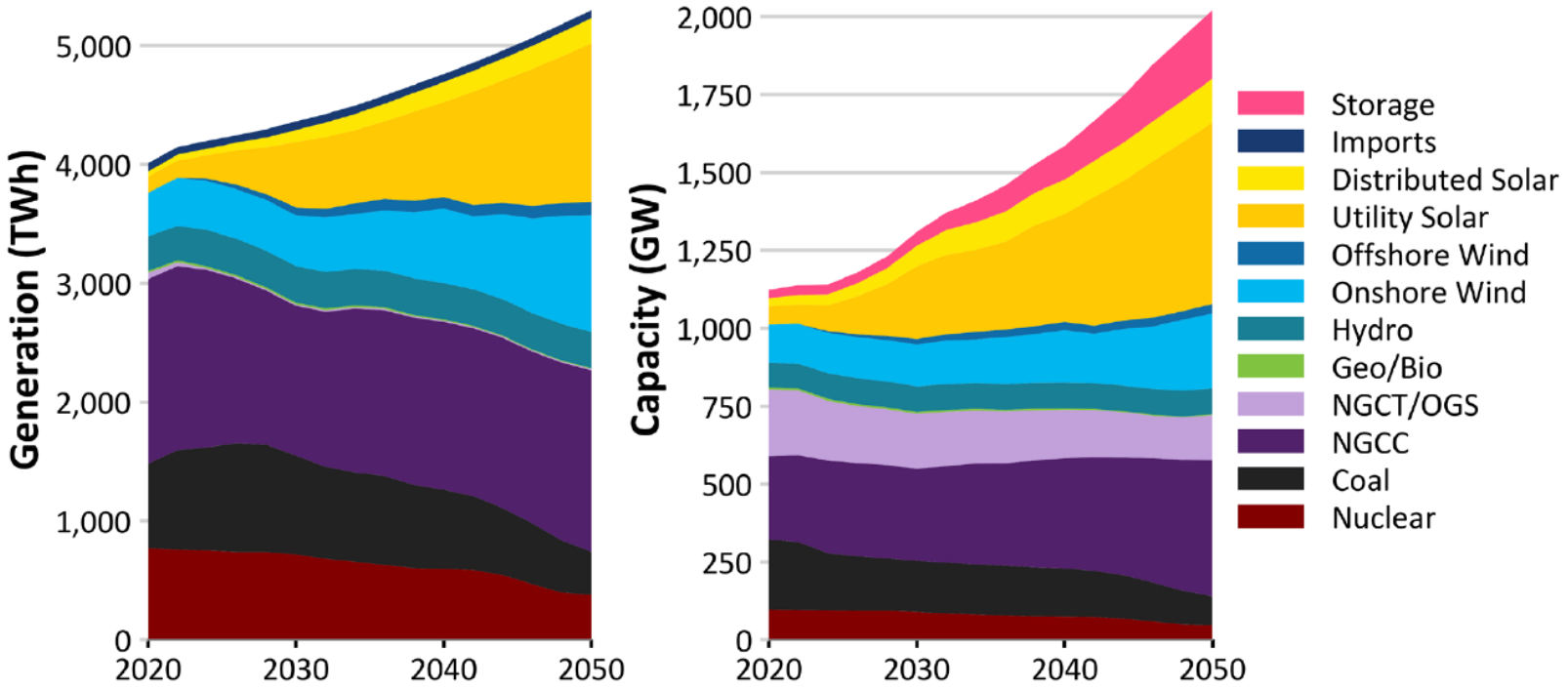


Image Source: NREL Standard Scenarios Report 2020

Program Version	Source to Site Ratio for U.S. Grid Electricity
PHIUS+ 2018	2.8 (past)
Phius 2021	1.8 (future)

ASHRAE 227P Source Energy Factors

Factors considered by the working group:

1. **Time Scale Resolution**
   - Hourly vs. Annual
2. **Electricity Generation Data Mix**
   - Past or future projected
3. **Geographic Resolution**
   - Interconnections (US: 3 + Canada: 1)
   - eGRID Sub-regions (US: 26 + Canada: 13)
   - Balancing Areas (US: 134)

Time Resolution

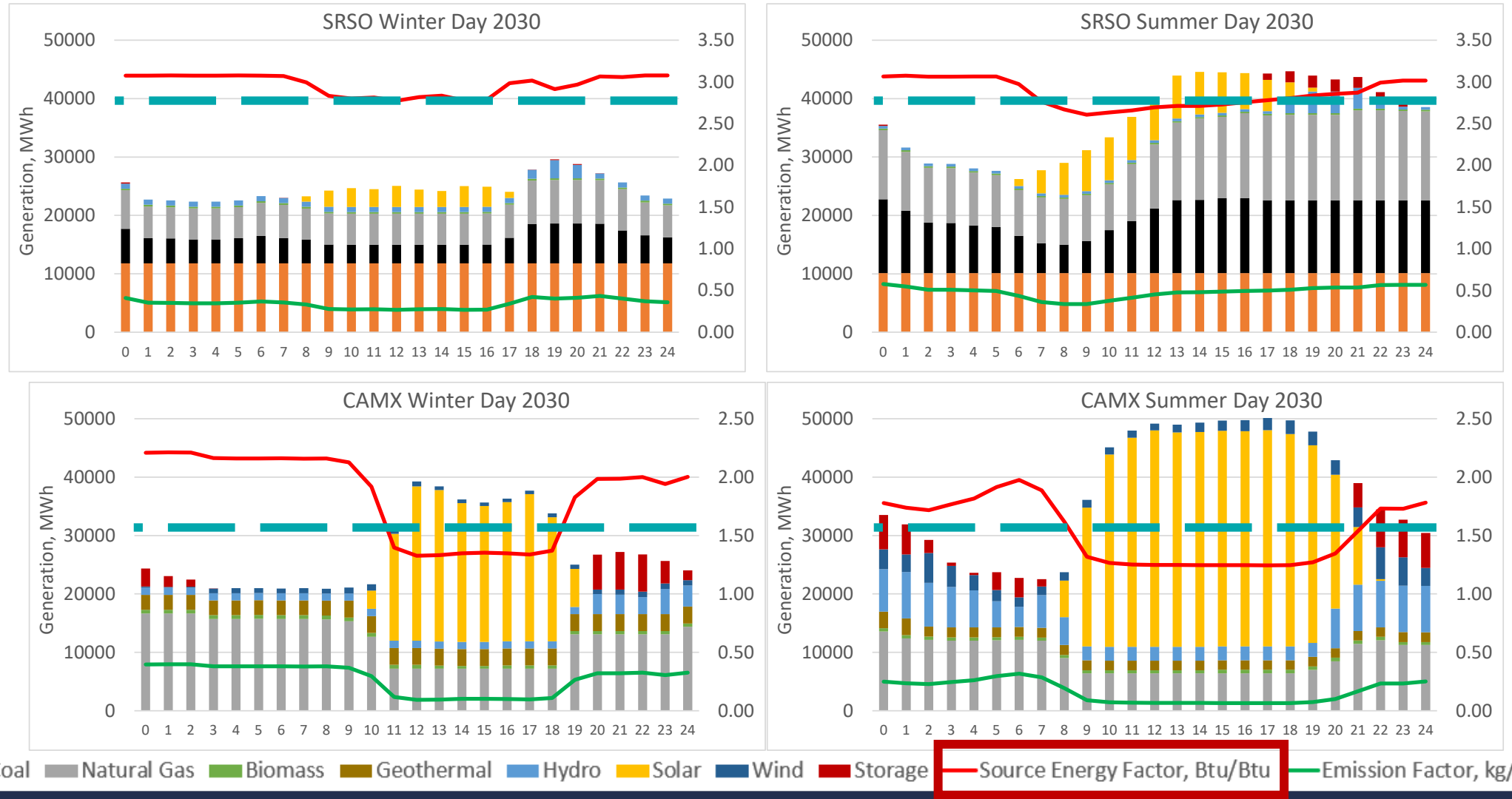
Ultimately both would need to be calculated if both time resolutions were supported for modeling.

	Annual	Hourly
Pros	Simple. Can be used in annual energy models.	Can impact more detailed design decisions. Better accounting of a dynamic factor.
Cons	Less flexibility for tradeoffs.	Many data points, difficult to publish in a standard for multiple scenarios.

Hourly Impacts

SRSO *(Southeast US):* Predominantly nuclear and thermal generation

CAMX *(California):* High solar generation



Electricity Generation Mix Data

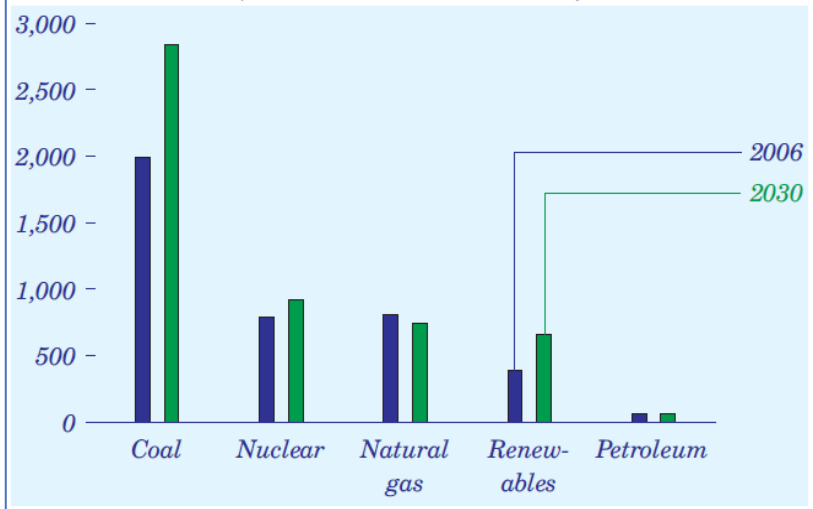
	Past	Future
Pros	Real measured data.	More appropriately reflects the impact of the building's operation over its lifetime.
Cons	Energy generation mix is rapidly changing, values become outdated quickly.	Projections mean making assumptions about the future. How far into the future to go?

Rapid Changes to the Energy Landscape

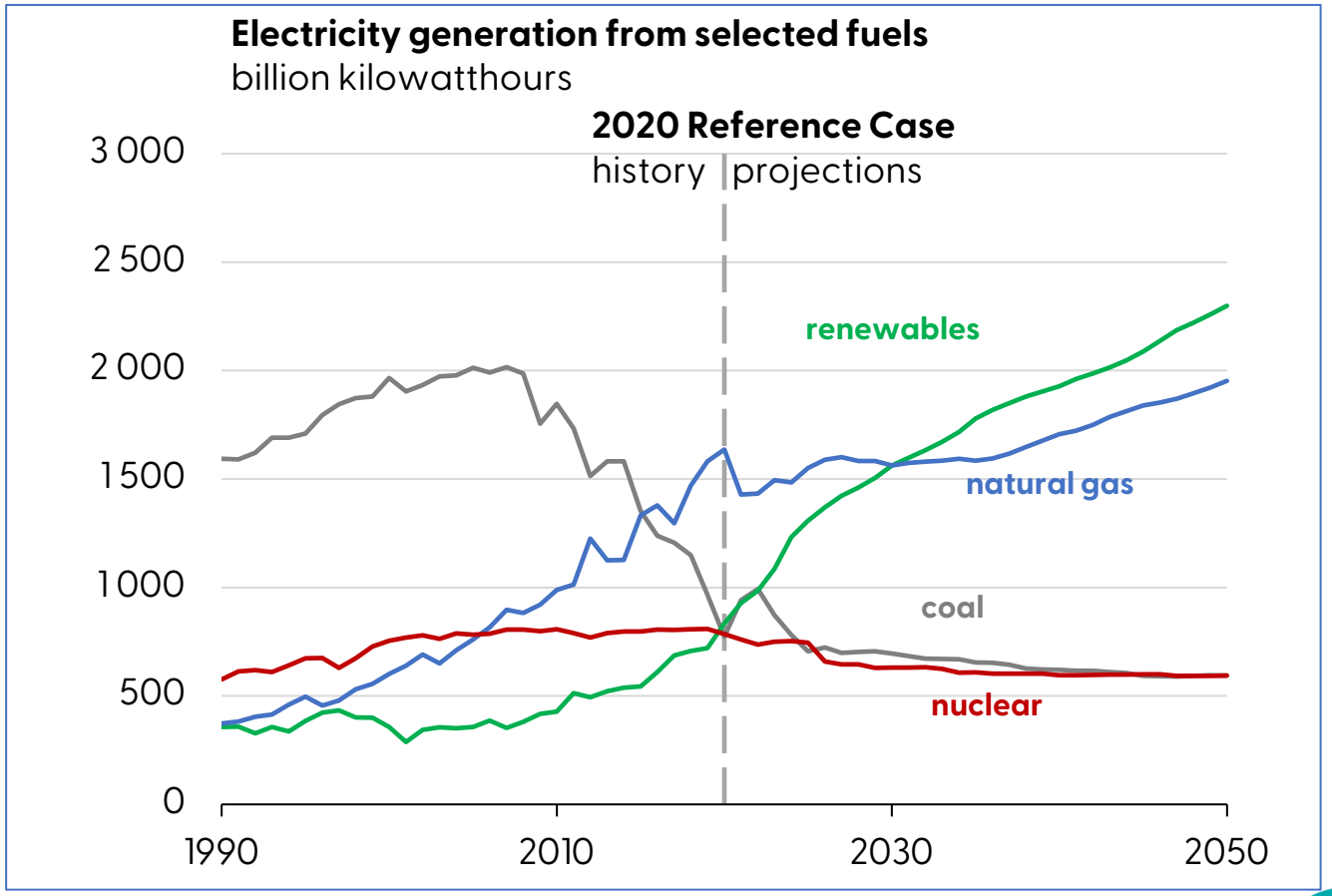
EIA Annual Energy Outlook in 2008 vs. 2021

Coal-Fired Power Plants Provide Largest Share of Electricity Supply

Figure 61. Electricity generation by fuel, 2006 and 2030 (billion kilowatthours)



Coal-fired power plants (including utilities, independent power producers, and end-use CHP) continue to be the dominant source of electricity generation through 2030 (Figure 61). Although natural-gas-fired



Source: EIA Annual Energy Outlook 2008 and 2021

Geographic Resolution

26 eGRID Subregions

- Compromise on size
- Limits imports & exports out of region
- Most accurately reflect generation and emissions from plants in the subregion

- **Overlayed with 134 NREL Cambium Balancing Areas**
  (used for future projections)

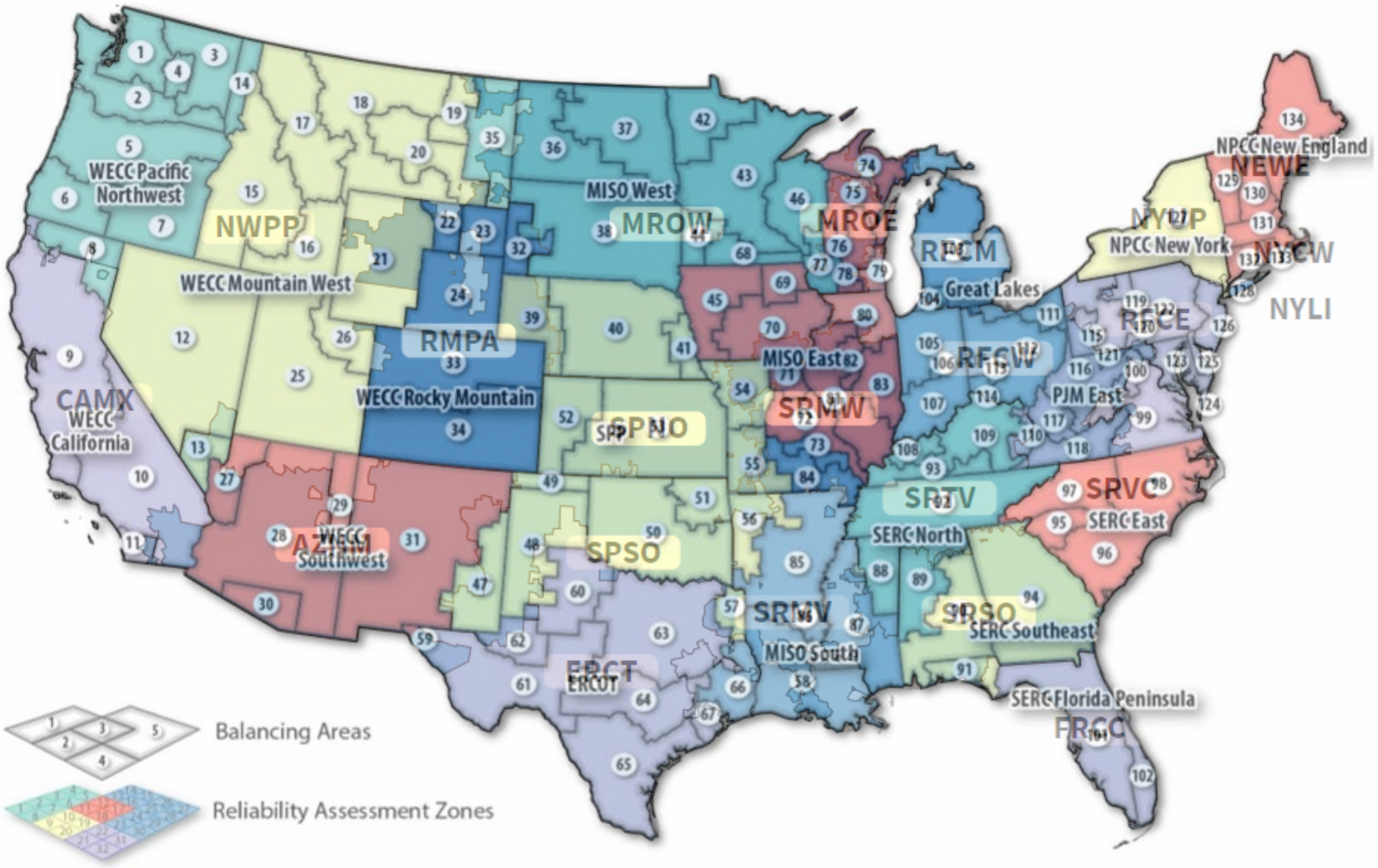
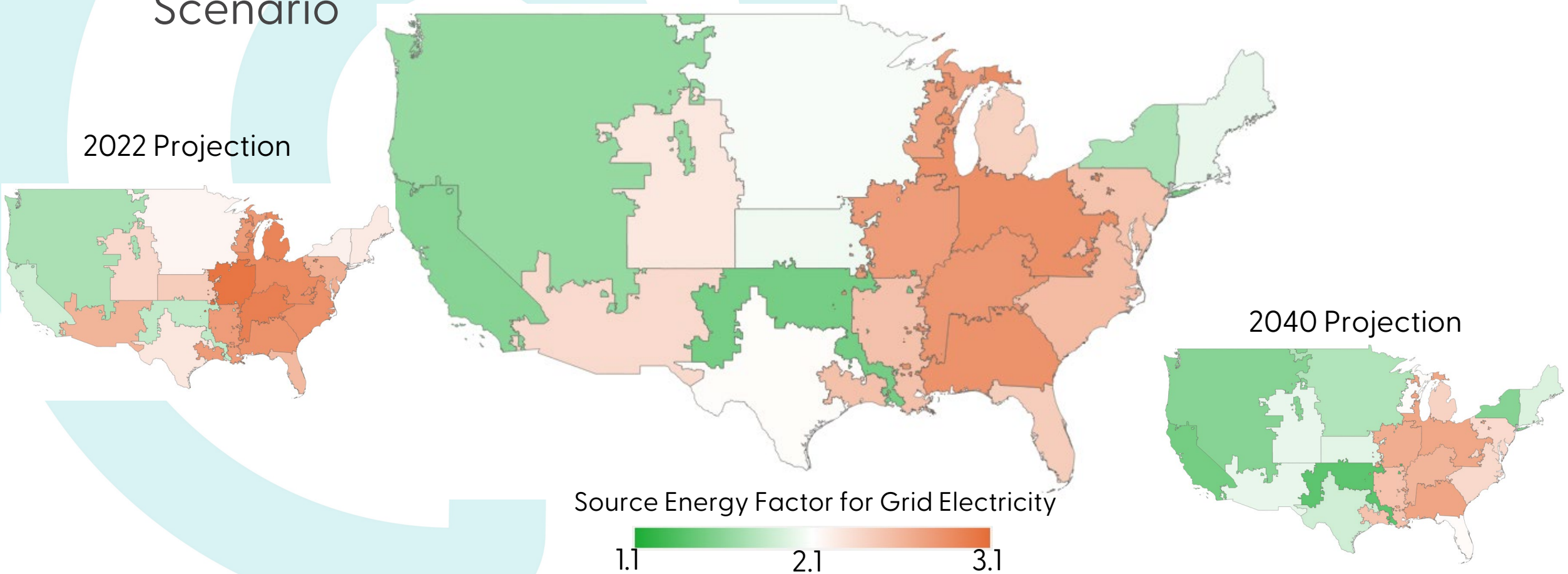


Figure 1. Balancing areas and reliability assessment zones used in Cambium, ReEDS, and PLEXOS

Regional Impacts

- **Example case:** 2030 annual average projected source energy and emissions factors based on NREL Cambium Mid-Case Scenario



ASHRAE 227P (DRAFT) Source Energy Factors

<u>For target setting and calculations</u>:
The same source energy factors and time resolution must be applied to both the baseline and proposed building site energy use.

Time Resolution

Hourly OR Annual

Electricity Generation Mix Data

Past OR Future

Geographic Resolution

eGRID Sub-regions

Transmission and Distribution Losses

National average from eGRID data applied (4.9%)

Considerations for Energy Storage

Long term storage not included in Cambium (future data)
Storage included as whole system loss

Energy Storage

If storage is included in the future grid mix projections:

Treated as overall system loss

$$\text{SEF(incl losses)} = \frac{\text{SEF (no losses)}}{(1 - \text{Storage Loss})}$$

$$\text{Storage Loss} = \frac{(\text{Annual Storage Charging} - \text{Annual Storage Discharging})}{(\text{Total Annual Generation of all Types})}$$

ASHRAE 227P Source Energy Conversion Factors

Generation Mixes

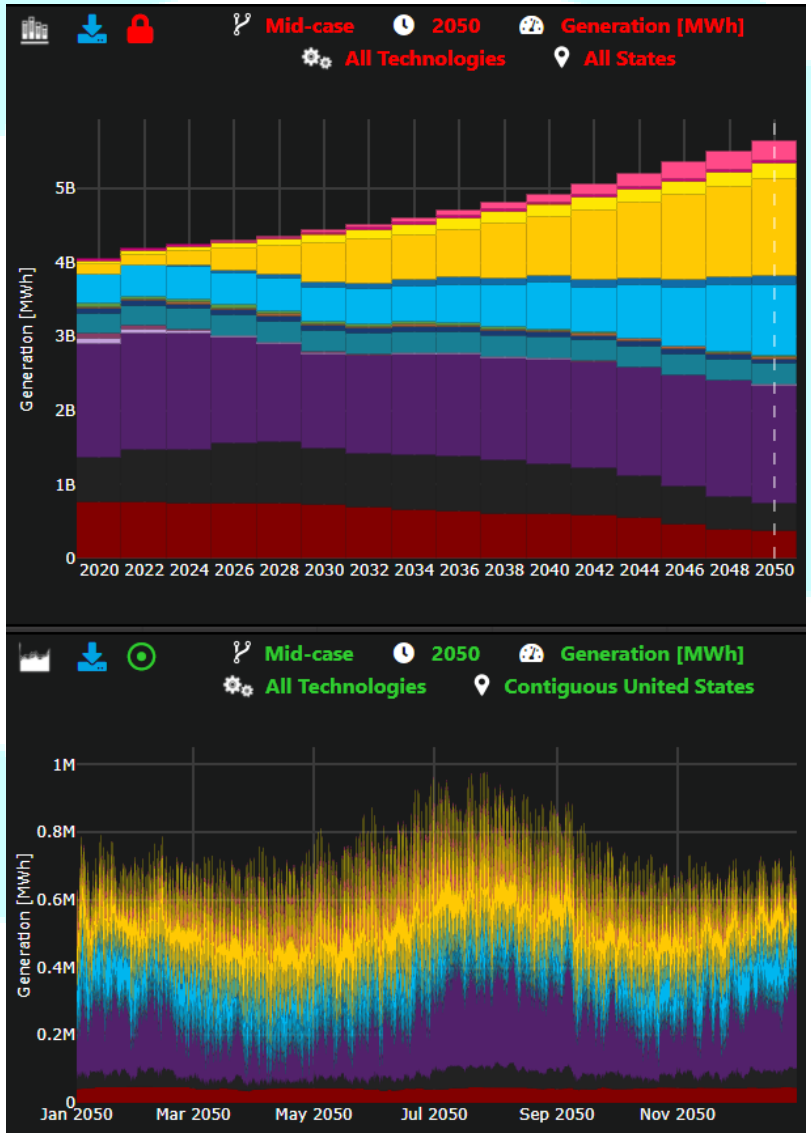
Annual Average: Three options, two published tables.

1. **Historic factors – eGRID2018**
2. **Projected factors* – NREL Cambium model, Mid-Case Scenario**
   - ***Data only available for contiguous US, 2-year projections through 2050**
3. **Calculated – Determined by adopting authority**

Hourly Average: Two options, neither published. Both determined by adopting authority

1. **Calculated Historic factors**
2. **Calculated Projected factors**

Other: Primary Energy Renewable (PER)



Source: NREL Cambium 2020 Data Viewer

eGRID Sub-Region – Future Projections

	2022	2024	2026	2028	2030	2032	2034	2036	2038	2040	2042	2044	2046	2048	2050
ERCT	2.26	2.23	2.21	2.18	2.12	2.05	2.05	1.99	1.95	1.89	1.79	1.8	1.74	1.66	1.61
FRCC	2.57	2.6	2.59	2.57	2.44	2.42	2.4	2.33	2.21	2.13	2.04	2	1.99	1.95	1.98
MROE	2.77	2.78	2.84	2.87	2.72	2.11	2.1	2.12	2.12	2.13	2	1.77	1.78	1.79	1.61
MROW	2.17	2.17	2.17	2.13	2.07	2.03	1.99	1.95	1.81	1.76	1.75	1.62	1.58	1.49	1.44
NYLI	2.23	1.67	1.62	1.56	1.5	1.48	1.44	1.46	1.57	1.55	1.68	1.75	1.75	1.77	1.75
NEWE	2.24	2.18	2.1	2.06	2.01	2	2	1.92	1.93	1.94	1.96	1.89	1.81	1.78	1.74
NYUP	2.2	2.11	1.99	1.93	1.73	1.7	1.68	1.62	1.61	1.57	1.57	1.57	1.55	1.42	1.41
RFCE	2.64	2.6	2.57	2.55	2.51	2.51	2.45	2.44	2.39	2.35	2.31	2.28	2.2	2.15	2.16
RFCM	2.93	2.81	2.81	2.78	2.42	2.41	2.41	2.41	2.39	2.4	2.36	2.38	2.3	2.07	2.06
RFCW	2.89	2.87	2.89	2.89	2.85	2.8	2.78	2.76	2.71	2.69	2.62	2.56	2.46	2.37	2.24
SRMW	3.03	3.05	2.88	2.82	2.77	2.64	2.66	2.65	2.66	2.65	2.66	2.53	2.41	2.22	2
SRMV	2.77	2.7	2.72	2.7	2.52	2.51	2.52	2.51	2.51	2.51	2.51	2.51	2.33	2.33	2.33
SRSO	2.83	2.86	2.91	2.92	2.83	2.82	2.84	2.82	2.75	2.71	2.71	2.69	2.55	2.54	2.51
SRTV	2.96	2.9	2.83	2.84	2.81	2.62	2.63	2.63	2.61	2.6	2.57	2.48	2.37	2.15	2.09
SRVC	2.85	2.83	2.81	2.67	2.56	2.51	2.47	2.43	2.4	2.36	2.24	2.17	2.02	2	1.95
SPNO	2.44	2.21	2.23	2.05	2.03	2.04	2.05	2.06	2.05	1.98	2.03	1.67	1.49	1.52	1.5
SPSO	1.83	1.63	1.57	1.5	1.5	1.49	1.5	1.51	1.44	1.39	1.41	1.34	1.32	1.3	1.27
CAMX	1.88	1.8	1.65	1.59	1.57	1.58	1.55	1.51	1.5	1.49	1.47	1.43	1.41	1.42	1.43
NWPP	1.73	1.69	1.68	1.65	1.64	1.61	1.62	1.62	1.58	1.57	1.57	1.52	1.53	1.53	1.41
RMPA	2.36	2.39	2.37	2.32	2.26	2.2	2.18	2.13	2.09	2	1.92	1.77	1.72	1.63	1.57
AZNM	2.61	2.55	2.55	2.44	2.35	2.3	2.27	2.13	2.05	2	1.99	1.9	1.82	1.79	1.78

ASHRAE 227P (DRAFT) SEF Flexibility

Adopting authorities may always choose to calculate and use their own source energy factors.

This flexibility allows them to develop their own forward-looking factors to align with regional energy and emission-reduction goals

- *If using hourly scenarios, make sure the weather files match the years that the projection is from

Primary Energy Renewable (PER)

Based on a future scenario with a 100% renewable electric grid.

Factors are annual but vary by end-use, which reflects a predicted mix of generation/storage losses, etc. needed to provide that end-use

- Household Electricity
- DHW
- Heating
- Cooling
- Dehumidification

Country	City	Household Electricity	DHW	Heating	Cooling	Dehumidification
US	New York, NY	1.2	1.17	1.52	1.53	1.88

Sample NYC PER Factors. Source Passivhaus Institut (PHI)

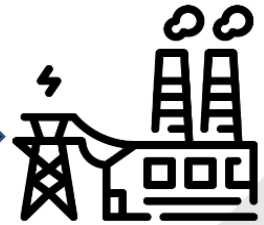
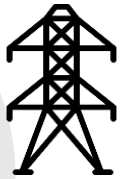
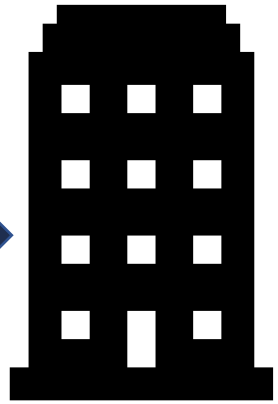
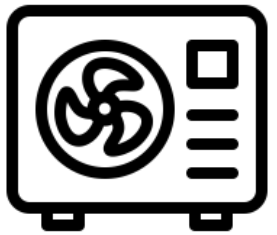
How does this impact design decisions?

General Observations

- Equipment Switching: Future-looking grid mix scenarios have lower grid-electricity source energy factors, making it more competitive to natural gas on a source energy calculation basis.
- Hourly resolution can provide better insight for design decisions like control for on-site energy storage or renewable energy offsets (i.e. what is the source energy factor at the hour that storage is being used on-site or deployed to the grid)

Natural Gas: For Grid Electricity or On-Site?

Grid Electricity

0.83 →  →  → 0.33 →  → 300%  → 1

Fuel Conversion Efficiency & Upstream Losses

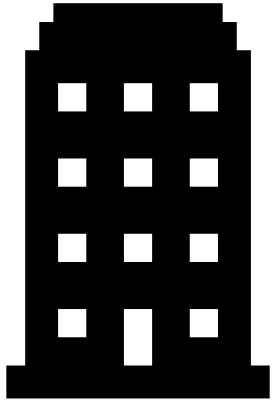
42%

Distribution & Transmission Efficiency

95%

Equipment Efficiency

Direct Use On-Site

1.05 →  → 95%  → 1

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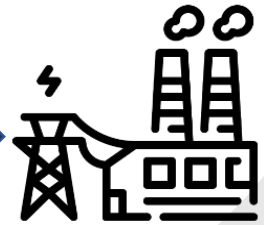
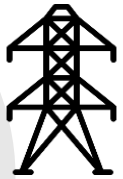
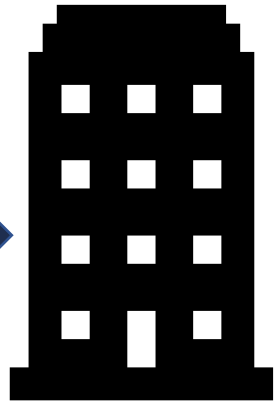
Natural Gas: For Grid Electricity or On-Site?

Grid Electricity

1.05 →  →  → 0.42 →  → 240%  → 1

Fuel Conversion Efficiency & Upstream Losses

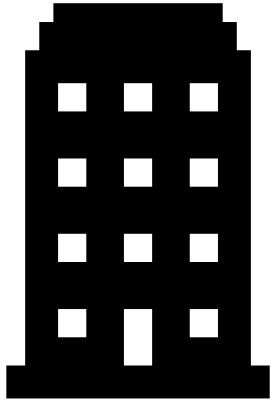
42%

Distribution & Transmission Efficiency

95%

Equipment Efficiency

Direct Use On-Site

1.05 →  → 95%  → 1

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Hourly to Hourly Framework

for calculating Source Energy & Renewable Energy Production Offsets

Hourly Source Energy

Hourly Renewable Energy Offset

Thanks!
Questions?

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