Times (and the Grid) are A-Changin’

Publicly Available, Forward-Looking Electricity Databases for GHG and LCA Projections

ACLCA Webinar (May 11, 2022)

Joshua Kneifel (NIST)
Pieter Gagnon (NREL)
Matt Jaimeson (NETL)
Disclaimer:

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
Electricity and Climate Change

Electricity is important
• Direct and indirect input
• 25% of U.S. GHG emissions

Electric Grid
• Has changed since 2010
  • Lowered emissions
• Will continue to change
  • ↓ Coal & Nuclear
  • ↑ Nat Gas & Renewables
Regional Differences

Current grid fuel mixes are non-uniform
- Fuel Type
  - Coal: 0% to 31%
  - Renewables: 2% to 41%
  - Nuclear: 0% to 31%
- Emissions rates vary

Future changes in fuel mixes will be non-uniform
- Federal/state/local policy
- Local resources & economics
- Grid imports/exports
## Operational Electricity Data & Uses

### Electricity Datasets
- US LCI
- Ecoinvent
- GABI
- ANL’s GREET
- NREL’s Cambium
- Federal LCA Commons Electricity Baseline

### Modeling & Decision Support Tools
- LCA Modeling
- Whole Building LCA (WBLCA)
- GHG Reporting
- Future GHG Estimates

### Variations in Datasets
- Vintage & Source of Emissions & Technology Mix
- Regionalization
- Methodology and Boundary Conditions
- Emissions Rates Metrics

### Common Underlying Datasets
(e.g., eGRID)

### Multiple types of analysis & purposes

### Need more transparency, consistency, & guidance
### Variations across Datasets

<table>
<thead>
<tr>
<th>Vintage and Source</th>
<th>Regionalization</th>
<th>Methodology and Boundary Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions Data</td>
<td>National</td>
<td>Emissions Estimates</td>
</tr>
<tr>
<td>• Year</td>
<td>NERC Region/Sub-region</td>
<td>Reported v Projected</td>
</tr>
<tr>
<td>• Per unit of energy</td>
<td>Balancing Authorities (BAs)</td>
<td>Scope/Boundary</td>
</tr>
<tr>
<td>Technology Mix Data</td>
<td>Generation &amp; Emissions Assessments (GEAs)</td>
<td>Supply chain</td>
</tr>
<tr>
<td>• Year</td>
<td>States</td>
<td>Generation v Consumption</td>
</tr>
<tr>
<td>• By location</td>
<td></td>
<td>Impact method</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• AR4 v AR5 v AR5 w/feedback</td>
</tr>
</tbody>
</table>

- **Emissions rates vary by base year of data**
- **Emissions rates vary by aggregation level**
- **Emissions rates vary by methodology**
## Emissions Rate Metrics

<table>
<thead>
<tr>
<th>Attributional</th>
<th>Consequential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Describes the state of the grid and allocates emissions to end-uses</td>
<td>Estimates the impact of a change in electricity consumption</td>
</tr>
<tr>
<td>(All Datasets)</td>
<td>(Ecoinvent and Cambium)</td>
</tr>
<tr>
<td>Emissions Inventory or Footprint</td>
<td>Marginal emission rates</td>
</tr>
<tr>
<td>Average Emissions Rate</td>
<td>Different future scenarios</td>
</tr>
<tr>
<td>Generation vs Consumption based emissions rates</td>
<td>Different time scales</td>
</tr>
</tbody>
</table>

When to use one or a combination of these emissions rates?
Agenda

Introduce Two Datasets
- Federal LCA Commons / NETL
- Electricity LCI Baseline and Extension
- EIA projections
- NREL
  - Cambium Electricity CO2e Index
  - NREL Scenario Projections

Need for Consistency and Guidance
- Data Comparisons
- Factors causing Differences

Path Forward
- Emission Rates Metrics
- Data Source
- Future Scenarios
- Regionalization
Electricity Baseline

Matt Jaimeson (NETL)
Model Framework Summary

Goals
• High quality data for technology evaluation
• Assessment of regional impacts/benefits
• Consistent national baseline

Objectives
• Complete inventory for U.S. power consumption in 2016
• Open-source data
• Transparent modeling approach
• Coordination with EPA and DOE

>7,000 Generation Facilities
68 BalancingAuthorities
10 FERC Market Regions
Project Workflow

Steps to development of LCI data for U.S. consumption mixes

Facility-Level Generation for Reporting Year by Gen Type
Coal, Gas, Oil, Nuclear, Hydro, Wind, Solar PV, Solar Thermal, Geothermal, Biomass
EIA 923/860

Map Reported Inventory to Facility
EPA AMPD, NEI, TRI, RCRA, DMR

Collect Fuel Use/Sourcing Data by Facility
EIA923/860

Supply Chain Inventory
NETL

Water Use
EIA/NETL

Facility Const. Inventory
NETL/EPA

Aggregation of Life Cycle Inventory into Generation Mixes Based on Region Detail
EIA 923/860

Trading Model to Develop Consumption Mixes
EIA 930

Mfg., Const., Operation Inventory
NETL/NREL/EPA

Canadian Imports
CA NEB

- Fossil (Coal, Gas, Oil)
- Non-Fossil (Nuclear, Hydro, Wind, Solar, Geo)
Project Workflow
Steps to development of LCI data for U.S. consumption mixes

Facility-Level Generation for Reporting Year by Gen Type
Coal, Gas, Oil, Nuclear, Hydro, Wind, Solar PV, Solar Thermal, Geothermal, Biomass
EIA 923/860

Map Reported Inventory to Facility
EPA AMPD, NEI, TRI, RCRA, DMR

Collect Fuel Use/Sourcing Data by Facility
EIA923/860

Supply Chain Inventory
NETL

Water Use
EIA/NETL

Facility Const. Inventory
NETL/EPA

Aggregation of Life Cycle Inventory into Generation Mixes Based on Region Detail
EIA 923/860

Mfg., Const., Operation Inventory
NETL/NREL/EPA

Trading Model to Develop Consumption Mixes
EIA 930

Canadian Imports
CA NEB

Fossil (Coal, Gas, Oil)
Non-Fossil (Nuclear, Hydro, Wind, Solar, Geo)
Example Consumption Mix Development

Develop generation data for all reporting facilities in the U.S.

Facility-Level Generation for Reporting Year by Gen Type

Generation Data

• Use EIA 860/923 data to determine facility-level generation in model year
• Map facilities to Balancing Authorities and FERC Market Regions
• >7,000 Facilities representing greater than 95% of 2016 generation
Example Consumption Mix Development
Develop generation data for all reporting facilities in the U.S. – Southwest FERC Region

Facility-Level Generation for Reporting Year by Gen Type

<table>
<thead>
<tr>
<th>Fuel Category</th>
<th>Percent of Generation</th>
<th>Facility Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOMASS</td>
<td>0%</td>
<td>5</td>
</tr>
<tr>
<td>COAL</td>
<td>34%</td>
<td>6</td>
</tr>
<tr>
<td>GAS</td>
<td>26%</td>
<td>43</td>
</tr>
<tr>
<td>GEOTHERMAL</td>
<td>0%</td>
<td>1</td>
</tr>
<tr>
<td>HYDRO</td>
<td>10%</td>
<td>22</td>
</tr>
<tr>
<td>MIXED</td>
<td>2%</td>
<td>6</td>
</tr>
<tr>
<td>NUCLEAR</td>
<td>24%</td>
<td>1</td>
</tr>
<tr>
<td>OIL</td>
<td>0%</td>
<td>1</td>
</tr>
<tr>
<td>SOLAR</td>
<td>3%</td>
<td>93</td>
</tr>
<tr>
<td>SOLAR THERMAL</td>
<td>0%</td>
<td>1</td>
</tr>
<tr>
<td>WIND</td>
<td>1%</td>
<td>9</td>
</tr>
</tbody>
</table>

Generation Data

- Use EIA 860/923 data to determine facility-level generation in model year
- Map facilities to Balancing Authorities and FERC Market Regions
- Southwest Region:
  - 188 Facilities
  - 642 Tracked emissions
  - 3.5% of 2016 Generation
Project Workflow

Steps to development of LCI data for U.S. consumption mixes

- **Facility-Level Generation for Reporting Year by Gen Type**
  - Coal, Gas, Oil, Nuclear, Hydro, Wind, Solar PV, Solar Thermal, Geothermal, Biomass
  - *EIA 923/860*

- **Map Reported Inventory to Facility**
  - EPA AMPD, NEI, TRI, RCRA, DMR

- **Collect Fuel Use/Sourcing Data by Facility**
  - *EIA923/860*

- **Supply Chain Inventory**
  - NETL

- **Water Use**
  - EIA/NETL

- **Facility Const. Inventory**
  - NETL/EPA

- **Aggregation of Life Cycle Inventory into Generation Mixes Based on Region Detail**
  - *EIA 923/860*

- **Trading Model to Develop Consumption Mixes**
  - *EIA 930*

- **Canadian Imports**
  - CA NEB

**Legend:**
- **Fossil (Coal, Gas, Oil)**
- **Non-Fossil (Nuclear, Hydro, Wind, Solar, Geo)**
Example Consumption Mix Development
Combine reported inventory for generating facilities – Southwest FERC Region

Map Reported Inventory to Facility

Facility Inventory Data
- EPA Air Markets Program Data (AMPD) used for CO$_2$, SO$_2$, NO$_X$
- Connected with EPA Standardized Emission and Waste Inventories (StEWI) Python interface for NEI, TRI, and RCRA
Project Workflow
Steps to development of LCI data for U.S. consumption mixes

Facility-Level Generation for Reporting Year by Gen Type
Coal, Gas, Oil, Nuclear, Hydro, Wind, Solar PV, Solar Thermal, Geothermal, Biomass
EIA 923/860

Map Reported Inventory to Facility
EPA AMPD, NEI, TRI, RCRA, DMR

Collect Fuel Use/Sourcing Data by Facility
EIA923/860

Supply Chain Inventory
NETL

Water Use
EIA/NETL

Facility Const. Inventory
NETL/EPA

Aggregation of Life Cycle Inventory into Generation Mixes Based on Region Detail
EIA 923/860

Trading Model to Develop Consumption Mixes
EIA 930

Mfg., Const., Operation Inventory
NETL/NREL/EPA

Canadian Imports
CA NEB

U.S. DEPARTMENT OF ENERGY

17
Example Consumption Mix Development

Connect power plant to fuel supply chain information

Collect Fuel Use/Sourcing Data by Facility

Fuel Use/Sourcing

- EIA 923 operating data includes fuel receipts and sources
- Use NETL fossil fuels supply chain models for coal, natural gas, and petroleum

2016 Coal Consumption by Source Mine

<table>
<thead>
<tr>
<th>State</th>
<th>Mine ID</th>
<th>Mine Name</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>WY</td>
<td>4800977</td>
<td>BLACK THUNDER</td>
<td>7.60E+05</td>
</tr>
<tr>
<td>WY</td>
<td>4801353</td>
<td>NORTH ANTELOPE ROCHELLE MINE</td>
<td>1.81E+06</td>
</tr>
<tr>
<td>NM</td>
<td>2902257</td>
<td>EL SEGUNDO</td>
<td>2.85E+05</td>
</tr>
<tr>
<td>WY</td>
<td>4801337</td>
<td>ANTELOPE COAL MINE</td>
<td>1.04E+06</td>
</tr>
</tbody>
</table>
Project Workflow
Steps to development of LCI data for U.S. consumption mixes

- Facility-Level Generation for Reporting Year by Gen Type
  - Coal, Gas, Oil, Nuclear, Hydro, Wind, Solar PV, Solar Thermal, Geothermal, Biomass
  - EIA 923/860

- Map Reported Inventory to Facility
  - EPA AMPD, NEI, TRI, RCRA, DMR

- Collect Fuel Use/Sourcing Data by Facility
  - EIA923/860

- Supply Chain Inventory
  - NETL

- Water Use
  - EIA/NETL

- Facility Const. Inventory
  - NETL/EPA

- Aggregation of Life Cycle Inventory into Generation Mixes Based on Region Detail
  - EIA 923/860

- Mfg., Const., Operation Inventory
  - NETL/NREL/EPA

- Trading Model to Develop Consumption Mixes
  - EIA 930

- Aggregation of Life Cycle Inventory into Generation Mixes Based on Region Detail
  - EIA 930

- Canadian Imports
  - CA NEB

- Fossil (Coal, Gas, Oil)

- Non-Fossil (Nuclear, Hydro, Wind, Solar, Geo)
Example Consumption Mix Development
Modeling the coal supply chain emissions

Supply Chain Inventory

NETL Coal Mining and Delivery Baseline Model
- Regionalized emissions inventory reflective of U.S. coal mining operations in 2016
- >80 inventory items tracked
- Data sources include EIA, EPA (GHGRP, TRI, NEI), MSHA, USGS

Coal Basin
- Central Appalachia
- Central Interior
- Gulf Lignite
- Illinois Basin
- Lignite
- Northern Appalachia
- Powder River Basin
- Rocky Mountain
- Southern Appalachia
- West/Northwest

Extraction Type
- Underground
- Surface

Coal Type
- Bituminous
- Subbituminous
- Lignite

Transportation Mode
- Conveyor Belt
- Ocean Freighter
- River Barge
- Train
- Truck
Project Workflow

Steps to development of LCI data for U.S. consumption mixes

Facility-Level Generation for Reporting Year by Gen Type
Coal, Gas, Oil, Nuclear, Hydro, Wind, Solar PV, Solar Thermal, Geothermal, Biomass
EIA 923/860

Map Reported Inventory to Facility
EPA AMPD, NEI, TRI, RCRA, DMR

Collect Fuel Use/Sourcing Data by Facility
EIA923/860

Supply Chain Inventory
NETL

Water Use
EIA/NETL

Facility Const. Inventory
NETL/EPA

Aggregation of Life Cycle Inventory into Generation Mixes Based on Region Detail
EIA 923/860

Trading Model to Develop Consumption Mixes
EIA 930

Canadian Imports
CA NEB

Mfg., Const., Operation Inventory
NETL/NREL/EPA

Fossil (Coal, Gas, Oil)
Non-Fossil (Nuclear, Hydro, Wind, Solar, Geo)
Example Consumption Mix Development

Develop generation data for all reporting facilities in the U.S.

<table>
<thead>
<tr>
<th>Fuel Category</th>
<th>Percent of Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOMASS</td>
<td>0%</td>
</tr>
<tr>
<td>COAL</td>
<td>34%</td>
</tr>
<tr>
<td>GAS</td>
<td>26%</td>
</tr>
<tr>
<td>GEOTHERMAL</td>
<td>0%</td>
</tr>
<tr>
<td>HYDRO</td>
<td>10%</td>
</tr>
<tr>
<td>MIXED</td>
<td>2%</td>
</tr>
<tr>
<td>NUCLEAR</td>
<td>24%</td>
</tr>
<tr>
<td>OIL</td>
<td>0%</td>
</tr>
<tr>
<td>SOLAR</td>
<td>3%</td>
</tr>
<tr>
<td>SOLAR THERMAL</td>
<td>0%</td>
</tr>
<tr>
<td>WIND</td>
<td>1%</td>
</tr>
</tbody>
</table>

Aggregation of Life Cycle Inventory into Generation Mixes Based on Region Detail

- Use EIA 860/923 data to determine facility-level generation in model year
- Map facilities to Balancing Authorities and FERC Market Regions
Project Workflow

Steps to development of LCI data for U.S. consumption mixes

Facility-Level Generation for Reporting Year by Gen Type
- Coal, Gas, Oil, Nuclear, Hydro, Wind, Solar PV, Solar Thermal, Geothermal, Biomass
  - EIA 923/860

Map Reported Inventory to Facility
- EPA AMPD, NEI, TRI, RCRA, DMR

Collect Fuel Use/Sourcing Data by Facility
- EIA923/860

Supply Chain Inventory
- NETL

Water Use
- EIA/NETL

Facility Const. Inventory
- NETL/EPA

Aggregation of Life Cycle Inventory into Generation Mixes Based on Region Detail
- EIA 923/860

Trading Model to Develop Consumption Mixes
- EIA 930

Canadian Imports
- CA NEB

Legend:
- Gray: Fossil (Coal, Gas, Oil)
- Blue: Non-Fossil (Nuclear, Hydro, Wind, Solar, Geo)
Example Consumption Mix Development

Incorporating trading algorithm to account for direct and indirect transactions

Trading Model to Develop Consumption Mixes

Modeling of Electricity Transactions

- Input-output approach developed by Qu et al.
- Transfer is enabled through infinite electricity supply chains
- Virtual flows of emissions should follow the pattern of intergrid electricity transfers

Definitions:

- $p_x = \text{Production in Grid } x$
- $c_x = \text{Consumption in Grid } x$
- $T_{yx} = \text{Transfer of electricity from Grid } y \text{ to Grid } x$


Trading Model Output

Percentage of Consumption Mix

Generating FERC Region: CAISO, Canada, ERCOT, ISO-NE, MISO, NYISO, Northwest, PJM, SPP, Southeast, Southwest

Consuming FERC Region: CAISO, ERCOT, ISO-NE, MISO, NYISO, Northwest, PJM, SPP, Southeast, Southwest
Generation vs Consumption Comparison

FERC Regions - Global Warming Potential, 2016 data year

Global Warming Potential (IPCC AR5, 100-yr) kg CO₂e/MWWh delivered

- CAISO: Generation 424, Consumption 439
- ERCOT: Generation 663, Consumption 663
- ISO-NE: Generation 447, Consumption 400
- MISO: Generation 788, Consumption 766
- Northwest: Generation 472, Consumption 440
- NYISO: Generation 357, Consumption 323
- PJM: Generation 580, Consumption 578
- Southeast: Generation 572, Consumption 583
- Southwest: Generation 593, Consumption 604
- SPP: Generation 697, Consumption 703
Forthcoming EIA-based Projections

- AEO projections from Reference and Low Renewable Cost Cases at Electricity Market Module (EMM) Regions
- Align (EMM) regions with balancing authority areas
- Apply new generation mixes (percent generation) based on projections
- Use existing consumption mix
Interacting with the resulting datasets

Multiple platforms for different prospective user bases

LCA Practitioners
- ✔ JSON-LD and ILCD exports
- ✔ Choose selected region and export full product system to openLCA for connection with rest of system

Energy and Env Analysts
- ✔ Create customized technology mix and inventory
- ✔ Explore inventory and TRACI impacts for selected region
- ✔ Add advanced technologies

Researchers & Developers
- ✔ Complete transparency into inventory dev
- ✔ Flexibility to adjust model parameters
- ✔ Integration into other frameworks

lcacommons.gov/lca-collaboration
netl.doe.gov/LCA
github.com/USEPA/ElectricityLCI
Cambium

Pieter Gagnon (NREL)
What is NREL’s Cambium Database?

Public database of GHG emissions, costs, and operational metrics for the U.S. electric sector through 2050

Three “business-as-usual” style projections

Two national decarbonization projections

ReEDS
Projects the evolution of the electric grid through 2050

PLEXOS
Simulates the hourly operation of future grids

Cambium
Calculates new metrics; builds the database

Cambium database
Hourly through 2050
Operational metrics
Cost metrics
Emission metrics

Three “business-as-usual” style projections:

1. Three “business-as-usual” style projections
2. Two national decarbonization projections

Cambium calculations and builds the database from 2020 to 2050.

ReEDS projects the evolution of the electric grid through 2050.

PLEXOS simulates the hourly operation of future grids.

Cambium database:
- Hourly through 2050
- Operational metrics
- Cost metrics
- Emission metrics

Three “business-as-usual” style projections:
- Three projections are shown, each representing different scenarios.

Two national decarbonization projections:
- Two national decarbonization projections are illustrated, showcasing the reduction in generation through 2050.

Graphs and charts show the evolution of generation (in TWh) from 2020 to 2050, with different lines representing various types of energy generation sources.
Geographic Resolution

**Model Resolution**
134 “balancing areas”
356 resource regions

**Data Resolution**
134 “balancing areas”
20 GEA regions
States
National

Cambium Generation and Emission Assessment Regions
2021 Version
What Emissions are in Cambium?

Three Greenhouse Gases
  Carbon Dioxide
  Methane
  Nitrous Oxide

Two Stages
  Direct Combustion
  Precombustion (fuel extraction, processing, transportation)
4 Types of Emission Metrics

**Average Emission Rates – Generation**  Attributional
Average emission rate of all generation in a given region

**Average Emission Rates - Consumption**  Attributional
Average emission rate of all generation consumed by a given region

**Short-run marginal emission rate**  Consequential
Emission rate of the next unit of electricity considering the grid’s structure as fixed

**Long-run marginal emission rate**  Consequential
Emission rate of the next unit of electricity considering how load could influence the grid’s structure
4 Types of Emission Metrics

Average Emission Rates – Generation
Average emission rate of all generation in a given region

Average Emission Rates - Consumption
Average emission rate of all generation consumed by a given region

Short-run marginal emission rate
Emission rate of the next unit of electricity considering the grid’s structure as fixed

Long-run marginal emission rate
Emission rate of the next unit of electricity considering how load could influence the grid’s structure
How do we calculate long-run marginal emission rates?

Example long-run marginal emission rate
(There are important diurnal trends, although using annual values is fine as well!)
Data Access

www.nrel.gov/analysis/cambium.html

Scenario Viewer and Data

Marginal Emission Rate Workbooks

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the Strategic Analysis Office within the Office of Energy Efficiency and Renewable Energy in the U.S. Department of Energy. The views expressed in the deck do not necessarily represent the views of the DOE or the U.S. Government.
Current CO$_2$e Dataset Variability

Joshua Kneifel (NIST)
## Transparency, Consistency, and Guidance

<table>
<thead>
<tr>
<th>1</th>
<th><strong>Federal Government</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electrification of Buildings</td>
</tr>
<tr>
<td></td>
<td>Green Electricity</td>
</tr>
<tr>
<td></td>
<td>Report GHG emissions/savings</td>
</tr>
<tr>
<td></td>
<td>Include GHG emissions/SCC in decisions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2</th>
<th><strong>State / Local Governments</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Buy Clean / Green</td>
</tr>
<tr>
<td></td>
<td>Adopting green standards / codes</td>
</tr>
<tr>
<td></td>
<td>Focus on CO₂e</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3</th>
<th><strong>Standard/Code/Certification</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green Material and Resources</td>
</tr>
<tr>
<td></td>
<td>Whole Building LCA (WBLCA)</td>
</tr>
<tr>
<td></td>
<td>CO₂e Index for Operational Energy (ASHRAE 189.1; RESNET)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4</th>
<th><strong>Private Sector and NGOs</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Public Trust in LCA Results</td>
</tr>
<tr>
<td></td>
<td>Acceptance &amp; Protection on Environmental Claims (e.g., EPDs, CO₂e reporting)</td>
</tr>
</tbody>
</table>
Annual Average CO₂e Emissions Rates

Emissions Data Year ranges from 2014 to 2020 and Technology Mix Year ranges from 2014 to 2022 (projected) across datasets.

Generation vs Consumption Mix varies across datasets.

Impact method (AR4, AR5, AR5 w/ feedback) & boundary conditions (process flows included) vary.

Calculations use total output & emissions except Cambium (input-based & modeling deployment).
Future Scenarios

- **Cambium**
  - Bi-annual projections
  - Mid-Case

- **GREET**
  - 5-yr step function
  - EIA Ref. (AEO2020)

- **NETL (forthcoming)**
  - Annual projections
  - EIA Ref. (AEO2022)
  - EIA Low-Ren. Cost
Emissions Rate Metrics

- National kg CO$_2$e /MWh
  - Average (Avg)
  - Short-Run Marginal (SRM)
  - Long-run Marginal (LRM)
- Absolute and relative values vary by location
  - EX) FL vs CA vs KY
Aggregation Regions

- eGRID Subregions
- Cambium GEAs
- Electricity Baseline BAs

NOTE: GREET (State) and IE4B (6 “Regions”)
Guidance is needed

Which emissions rate(s)?

Which current or future grid scenario(s)?

What level of aggregation?

What methodology and boundary conditions?

What dataset(s)?
### Path Forward

<table>
<thead>
<tr>
<th>Annual Data Updates</th>
<th>Expansions Under Consideration</th>
<th>Roundtables on Guidance and Standardization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambium</td>
<td>Electricity Baseline</td>
<td>Roundtable(s)</td>
</tr>
<tr>
<td>NREL Scenarios</td>
<td>Add Cambium Projections</td>
<td>Emission Rates Guidance</td>
</tr>
<tr>
<td>More Detailed</td>
<td>Electricity CO₂e Study</td>
<td>Consider other areas</td>
</tr>
<tr>
<td>Public Dataset</td>
<td>Compare</td>
<td>• Regions</td>
</tr>
<tr>
<td>Electricity Baseline</td>
<td>Areas to improve/standardize</td>
<td>• Future scenarios</td>
</tr>
<tr>
<td>EIA Projections</td>
<td></td>
<td>• Impact methods</td>
</tr>
<tr>
<td>Expansion of datasets available</td>
<td>Determine needed improvements</td>
<td>• Time-scale</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Uncertainty</td>
</tr>
</tbody>
</table>

Guidance Documents

- Cambium
- NREL Scenarios
- More Detailed Public Dataset
- Electricity Baseline
- EIA Projections

- Electricity Baseline
  - Add Cambium Projections
  - Electricity CO₂e Study
    - Compare
    - Areas to improve/standardize

- Roundtable(s)
  - Emission Rates Guidance
  - Consider other areas
  - Regions
  - Future scenarios
  - Impact methods
  - Time-scale
  - Uncertainty
References:

EIA, Annual Energy Outlook 2022, https://www.eia.gov/outlooks/aeo/

EPA, Emissions & Generation Resource Integrated Database (eGRID), https://www.epa.gov/egrid

NREL, Cambium, https://www.nrel.gov/analysis/cambium.html

ANL, GREET, https://greet.es.anl.gov


Thank You!

Questions or Comments?

Joshua Kneifel (NIST)
joshua.kneifel@nist.gov

Pieter Gagnon (NREL)
pieter.gagnon@nrel.gov

Matt Jaimeson (NETL)
matthew.jamieson@netl.doe.gov