U.S. EPA's State and Local Energy and Environment Webinar Series

United States Environmental Protection Agency

Emissions Benefits of Energy Efficiency and Renewables

April 18, 2019

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Audio

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  - Tip! Unmute your speakers or headphones
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- Participants are muted

How to Participate

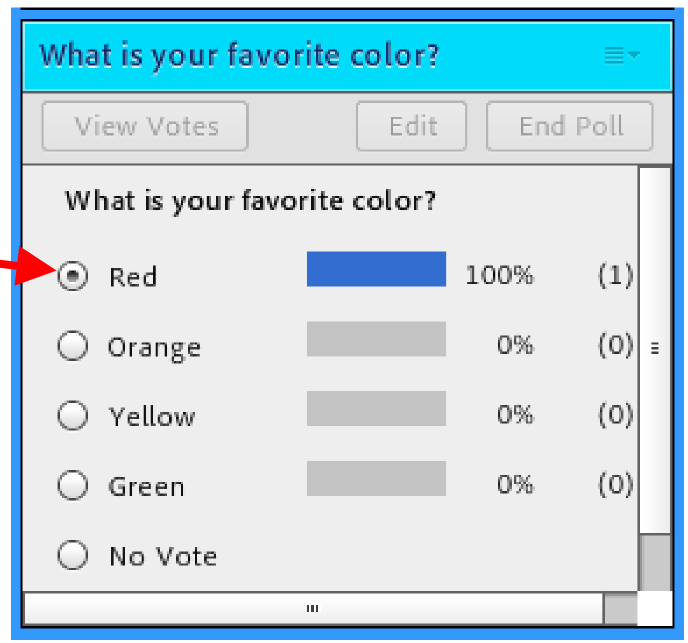
Question and Answer

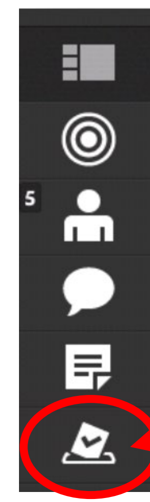
- Enter your question in the Q&A box
- Questions will be moderated at the end
- EPA will post responses to unanswered questions on the State and Local Webinar Series page

How to Participate

Polling

- We'll ask several poll questions during the webinar
- On mobile devices or tablets
  - Exit full screen mode
  - Tap the Poll icon





Today’s Agenda

- **Denise Mulholland,** Senior Program Manager
  U.S. EPA State and Local Energy and Environment Program
- **Jeff Haberl and Juan Carlos Baltazar,** Associate Directors
  Texas A&M Energy Systems Laboratory
- **Eric Shrago, Managing Director – Operations**
  Connecticut Green Bank
- **David Abel, Postdoctoral Researcher**
  University of Wisconsin
- **Question and Answer Session**

Poll 1

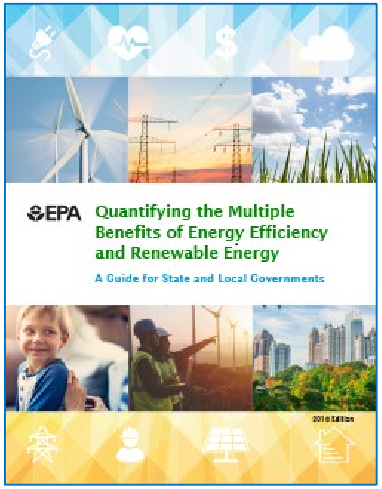
United States Environmental Protection Agency

Methods for Quantifying the Multiple Benefits of Energy Efficiency and Renewable Energy: A Guide for State and Local Governments

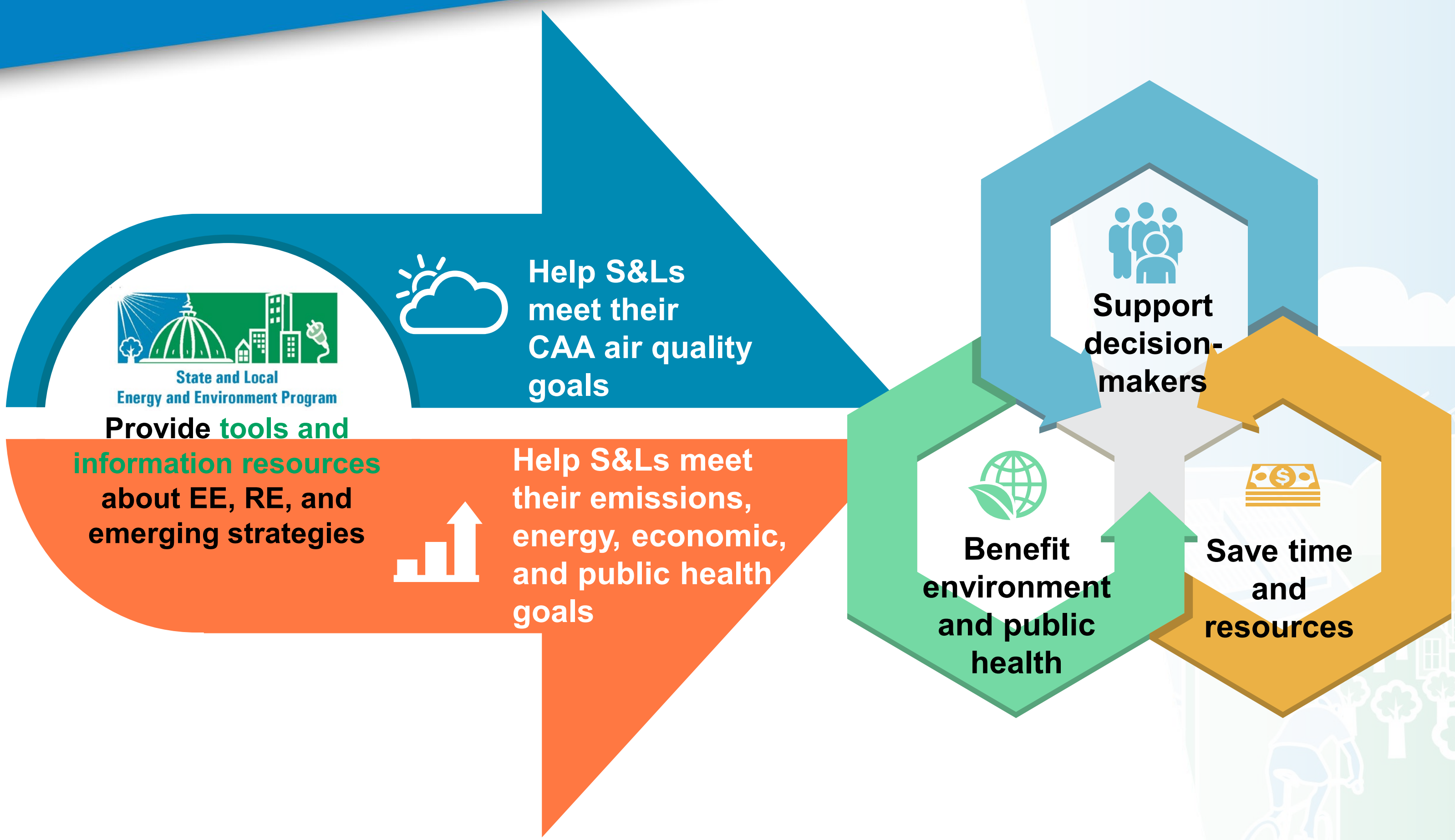
EPA United States Environmental Protection Agency

State and Local Energy and Environment Program

Denise Mulholland
U.S. EPA

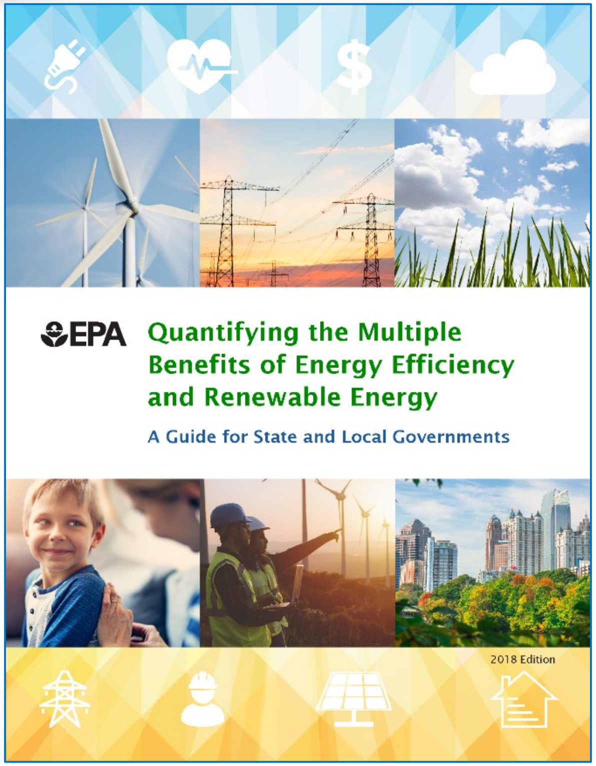


EPA's State and Local Energy and Environment Program



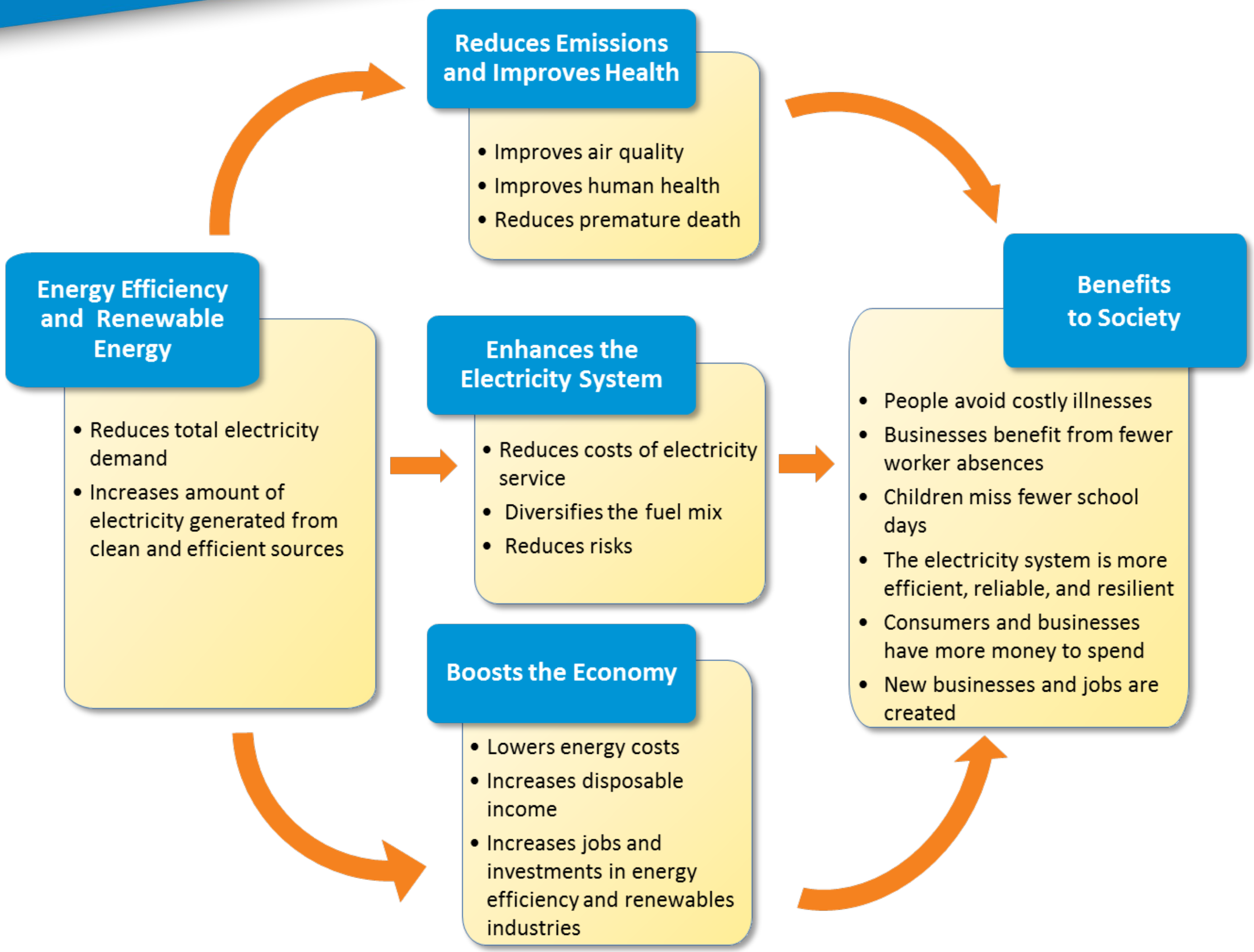
CAA: Clean Air Act
EE: Energy efficiency
RE: Renewable Energy
S&Ls: State and local governments

Quantifying the Multiple Benefits of EE/RE: A Guide for State and Local Governments



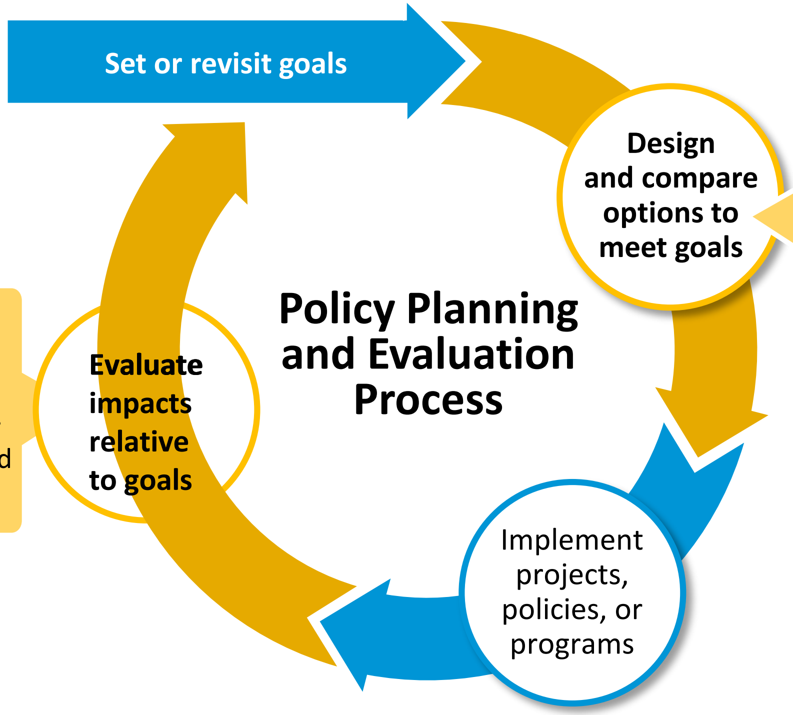
- Part One: What, Why and When to Quantify
- Part Two: How to Quantify
  - Includes many figures and tables that:
    - clearly present methods, tools, and steps to quantify benefits,
    - make it easier to understand the process, and/or
    - help analysts compare across methods and tools.

Part ONE:
What Are the Benefits of EE/RE?



Part ONE:
When to and Why Quantify Multiple Benefits?

- **Quantify multiple benefits** achieved to fully evaluate impacts of projects, policies, or programs implemented
- Promote benefits



- **Quantify multiple benefits** of option(s) under consideration to identify those with greatest potential benefits

Part TWO:
How to Quantify Multiple Benefits?

Step 1

Determine Scope of and Strategy for the Analysis

Key Considerations

- Identifying the purpose, priorities, and constraints
- Understanding the characterization of analytic methods
- Mapping out the strategy for the analysis

Step 2

Determine Direct Electricity Impacts

Step 3

Quantify the Multiple Benefits From Direct Electricity Impacts

Electricity System Benefits

- Primary electricity system benefits
- Secondary electricity system benefits

Emissions and Health Benefits

- Air pollutant, GHG emissions benefits
- Air quality benefits
- Human health benefits

Economic Benefits

- Direct economic benefits
- Indirect economic benefits

Step 4

Use Benefits Information to Support Informed Decision-Making

GHG: Greenhouse Gas

See Part Two, Chapter 1

Choose a Method for Quantifying Impacts: Key Considerations

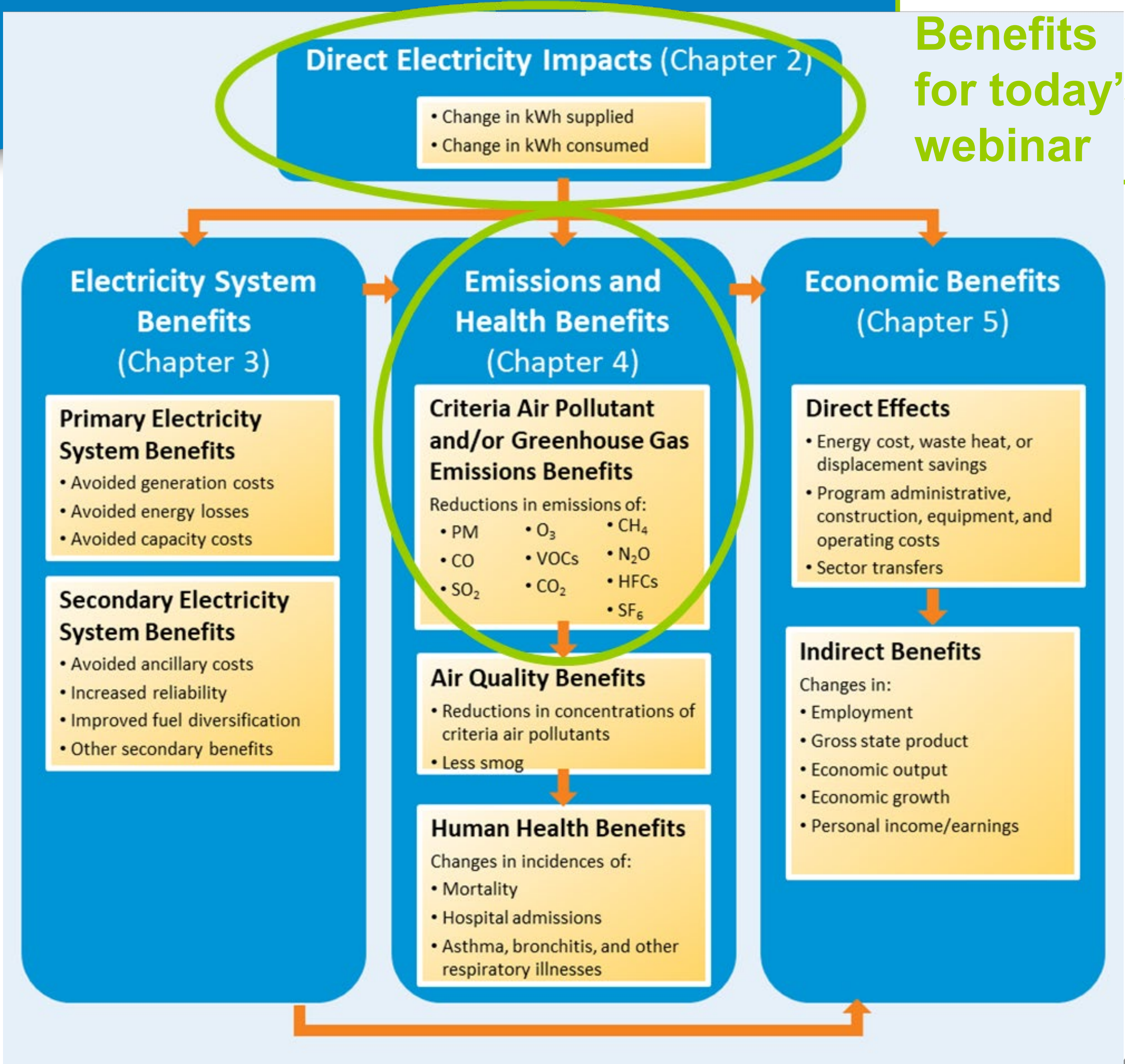
- What benefits emissions do you care about and what methods are available to estimate them?
- What level of rigor is needed?
  - e.g., screening-level vs. regulatory impact analysis
- What is the time period is the analysis (e.g. short term vs long term, prospective vs retrospective)?
- What are the data requirements? What data is available?
- What financial costs or technical expertise are required? What's available?

See Part Two, Chapter 1

Map Out The Benefits to Quantify

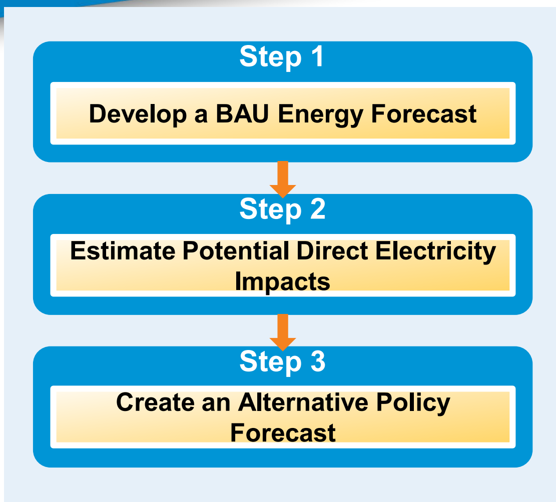
Each Chapter provides:

- Step by step instructions
- Range of basic to sophisticated approaches
- Key considerations
- Case Studies
- List of available tools, data and resources



Benefits for today's webinar

Estimate Direct Electricity Impacts



See Part Two, Chapter 2

- Analysts can adapt existing studies of similar EE or RE programs to their conditions, use data from EE/RE potential studies or conduct new analyses
- Key assumptions to consider (see page 2-23):
  - Program period
  - Program target
  - Anticipated compliance or penetration rate
  - Useful life and persistence of savings
  - Annual degradation factor
  - Transmission and distribution loss
  - Adjustment factor
  - Non-program effects
  - Funding and program administration
  - EE/RE Potential

Compare Quantification Method(s)

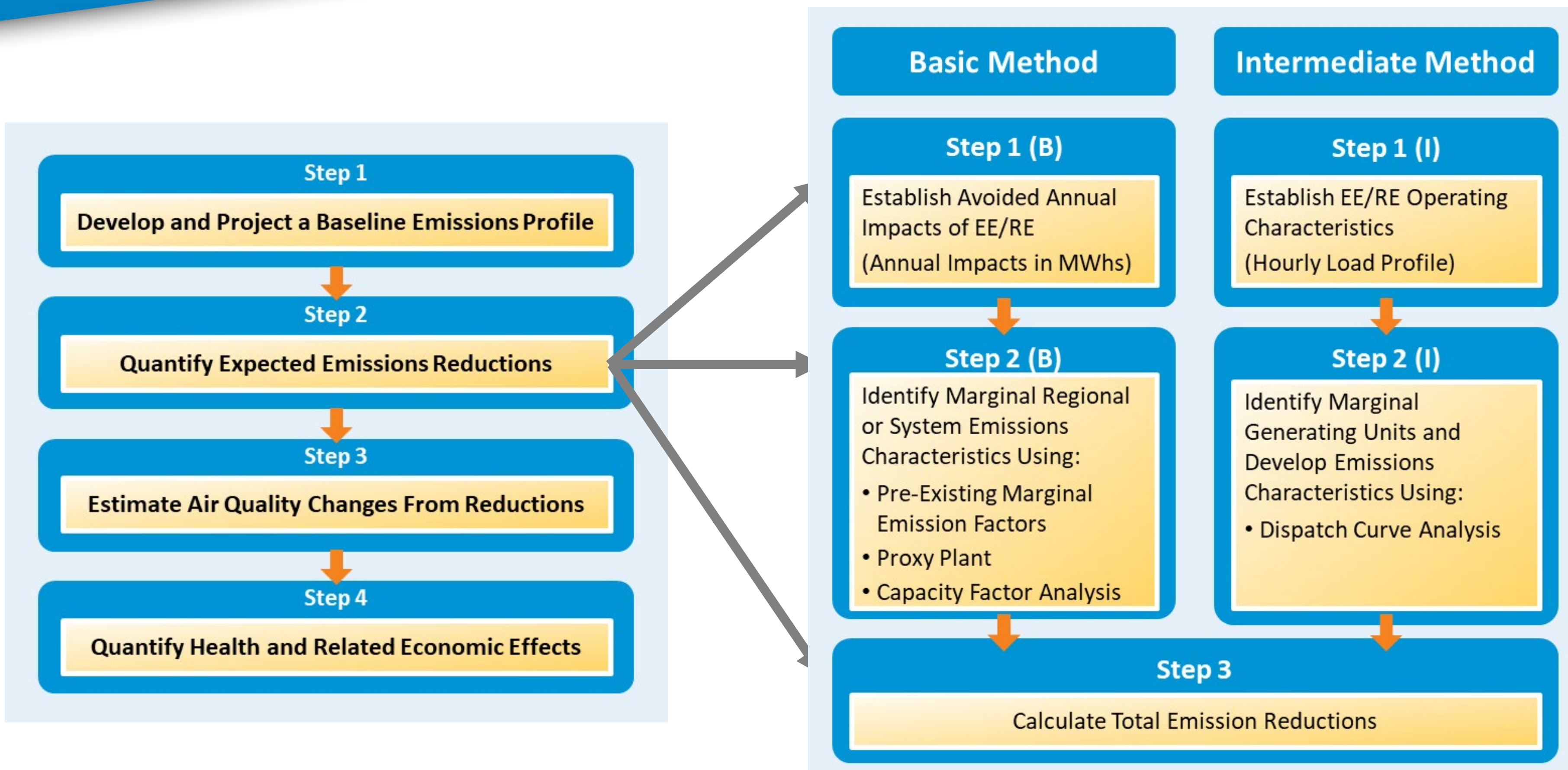
Method	Description	Examples of When to Use	Example Tools
Basic • Adopt pre-existing marginal emission factors • Proxy plant • Capacity factor analysis	Relatively simple static formulations, such as factors	• Short-term analysis; • When time and resources are limited; • Screening	• **eGRID**: Emissions & Generation Resource Integrated Database • **AVERT**: AVoided Emissions and geneRation Tool
Intermediate • Dispatch curve analysis	Require some technical expertise but analysts can make adjustments, reflect different assumptions and savings	• Short-term analysis; • Regulatory compliance (short-term); • Energy planning; • Option comparisons	• **AVERT**
Sophisticated • Economic dispatch • Capacity expansion modeling	Characterized by extensive underlying data and relatively complex formulations	• Short- or long-term analysis; • Regulatory compliance (long-term); • Resource planning; • Multi-sector analysis	• **IPM:** Integrated Planning Model •**JuiceBox**

Table 4-2: Comparison of Basic, Intermediate, and Sophisticated Methods for Quantifying Air Pollutant and GHG Emissions Effects of Energy Efficiency and Renewable Energy Initiatives

Type of Method	Strengths	Limitations	When to Use This Method	Example Tools / Data Sources[a]
Basic				
▪ Methods that often assume consistent energy savings throughout the year and assign marginal emissions rates or specific emissions rates for proxy unit types	▪ Transparent assumptions ▪ Easy-to- understand method ▪ Modest level of time, technical expertise, and labor required ▪ Inexpensive	▪ May be imprecise and less credible than other methods ▪ Limited ability to customize unique load characteristics of different energy efficiency and renewable programs ▪ Not applicable for long-term projections ▪ Do not typically account for imported power ▪ Do not account for myriad of factors influencing dispatch on a local scale, such as transmission constraints or reliability requirements	▪ Screening analysis ▪ Voluntary programs ▪ Evaluating existing programs	▪ AVERT (preexisting marginal emission factors) ▪ ClearPath™ ▪ eCalc ▪ eGRID (preexisting marginal emission factors) ▪ Proxy Plant method ▪ SUPR2
Intermediate				
▪ Methods that can reflect time-of-day impacts throughout the year and use EGUs' dispatch patterns to assess impacts of EE/RE but do not account for detailed assumptions that sophisticated approaches can (e.g., fuel prices, emissions budget trading program effects, dispatch changes)	▪ Transparent assumptions and method ▪ Allow flexibility to adjust EGU fleet and reflect different energy efficiency and renewable energy assumptions and load shapes ▪ May be more credible than basic methods	▪ Require some technical expertise ▪ Do not represent small energy efficiency and renewable energy programs well ▪ Do not typically account for imported power ▪ Do not account for myriad of factors influencing dispatch on a local scale such as transmission constraints or reliability requirements	▪ Regulatory compliance for short-term plans (e.g., NAAQS) ▪ Energy plans ▪ County-level impacts ▪ Analysis of portfolio of energy efficiency and renewable energy programs ▪ Impacts comparison of different energy efficiency and renewable energy programs	▪ AVERT custom analysis ▪ ERTAC EGU forecasting tool ▪ LEAP ▪ Time-Matched Marginal Emissions Model
Sophisticated				
▪ Methods that can provide detailed forecasts of regional supply and demand	▪ More rigorous than other methods ▪ May be perceived as more credible than	▪ May be less transparent than spreadsheet methods ▪ Labor- and time-intensive ▪ Often involve high software licensing	▪ Emissions budget programs ▪ Resource planning ▪ Rate cases	▪ ENERGY 2020 ▪ e7 Capacity Expansion ▪ GE MAPS™

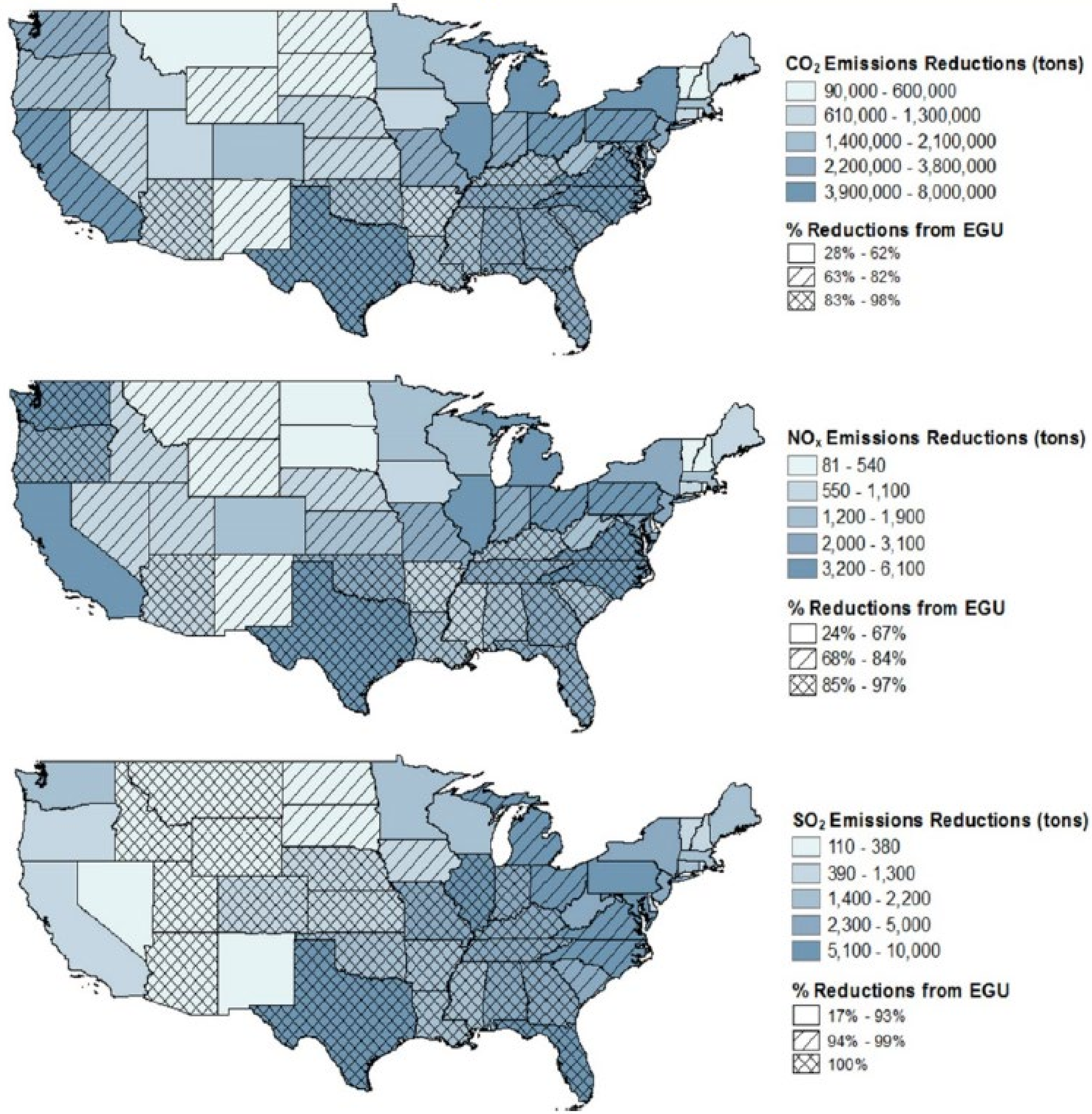
Tables in the Guide help you compare methods in more detail

Use Flowcharts and Figures in the Guide to Navigate the Process



Explore Case Studies

Figure 4-8: Annual Emissions Reductions by State



Source: Levy et al., 2016.
Note: Emissions reductions represent the total reductions from both EGUs and residential combustion sources.

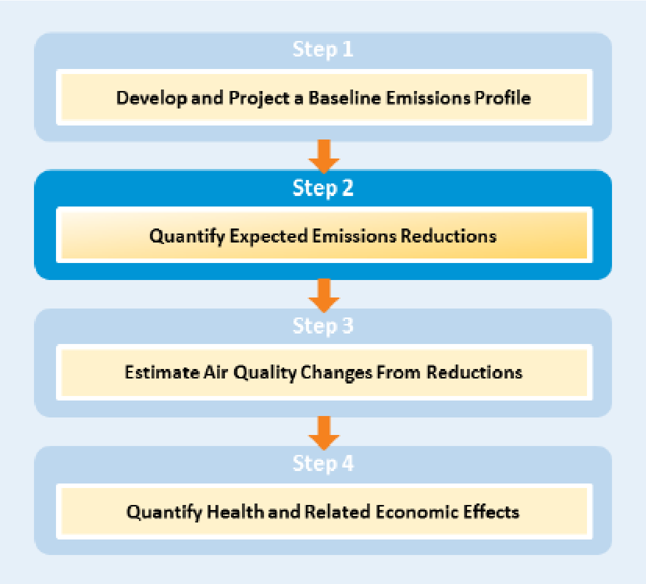
EGU: Electric Generating Units

Learn About Available Tools & Data Resources

United States Environmental Protection Agency

4.4.2. Tools and Resources for Step 2: Quantify Expected Emissions Reductions

Analysts can use a range of available data sources, emission factors, and/or tools to quantify emissions reductions expected from energy efficiency and renewable energy measures.



Establishing Operating Characteristics/Data on Load Profiles

Analysts can use a variety of available data sources to establish the operating characteristics of energy efficiency on an hourly to annual basis, the first step when quantifying criteria air pollutant and/or GHG emissions changes using a basic-to-intermediate method.

- **EPA's Air Markets Program Data (AMPD).** EPA collects data in five-minute intervals from CEMSs at all large power plants in the country. The AMPD is a new system of reporting emissions data, monitoring plans, and certification data, and replaces the Emissions Tracking System that previously served as a repository of SO_2, NO_x, and CO_2 emissions data from the utility industry. http://ampd.epa.gov/ampd/
- **EIA's Electricity Data.** This database contains statistics on electric power plants, capacity, generation, fuel consumption, sales, prices, and customers and can be used to assess generator-specific operating costs, historical utilization, and emissions rates. http://www.eia.gov/electricity/data.cfm
- **New York Independent System Operator (NYISO) Data.** NYISO, a regional grid operator, on hourly regional load data and transfer data between ISOs. http://www.nyiso.com/public/markets_operations/market_data/load_data/index.jsp

For More Information About EPA's Program, Tools, and Resources

United States Environmental Protection Agency

Download the Guide

Denise Mulholland
U.S. Environmental Protection Agency
Mulholland.Denise@epa.gov

State and Local
Energy and Environment Program

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Poll 2

Energy Efficiency and Renewable Energy Impacts on Nitrogen Dioxide Emission Reductions in Texas

Jeff Haberl and Juan Carlos Baltazar

Texas A&M Energy Systems Laboratory

ENERGY SYSTEMS LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

Energy Efficiency and Renewable Energy Impacts on Nitrogen Oxide (NOx) Emission Reductions in Texas

Jeff Haberl, Ph.D.

Bahman Yazdani, P.E.

Juan-Carlos Baltazar, Ph.D., P.E.

ACKNOWLEDGEMENTS

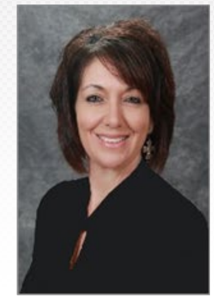
Faculty/Staff: Jeff Haberl, Bahman Yazdani, Juan-Carlos Baltazar, Gali Zilbershtein, Shirley Ellis, Patrick Parker, Angela Rowell

Students: Minjae Shin, Farshad Kheiri, Qinbo Li, Sungkyun Jung, Chul Kim













TCEQ (Texas Commission on Environmental Quality): Vince Meiller, Bob Gifford
Public Utility Commission of Texas (PUCT): Katie Rich, Therese Harris
State Energy Conservation Office (SECO): Dub Taylor, Stephen Ross
Electric Reliability Council of Texas (ERCOT): Paul Wattles, Connor Anderson

Summary

The policy or program analyzed:

- Texas Emissions Reduction Program (TERP)
- Funded by the Texas State Legislature
- Report annually to the TCEQ

The benefits included and why:

- NOx emissions reductions from energy efficiency/renewable energy (EE/RE) Programs in Texas used by TCEQ for weight-of-evidence in the Texas State Implementation Plan (SIP).
- Developed conferences to raise awareness (Clean Air Through Energy Efficiency, Texas Energy Summit)
- Program has also provided on-line tools:
  - International Code Compliance Calculator (IC3)
  - NOx emissions calculator for Texas

Summary

How you quantified the benefits - the models used, data sources, who you collaborated or engaged with.

- Models used include:
  - Change-point Linear models for weather-normalized wind energy savings.
  - Sliding average models for the reliability of wind energy farms.
  - Special-purpose models for comparisons
    - Univ. of Wisconsin solar thermal energy analysis
    - Univ. of Wisconsin Photovoltaic system (PV) analysis
- Data Sources:
  - Collect data annually from four State agencies (SECO, PUC, TCEQ, ERCOT) and four federal agencies [EPA, National Renewable Energy Laboratory, National Oceanic and Atmospheric Administration (NOAA), Energy Information Administration].
- Collaborate:
  - Work closely with TCEQ/EPA for data quality and annual reporting

LEGISLATION

Legislation to Reduce Energy/Emissions 2001 to Present

Senate Bill 5 (77th Legislature, 2001)

Ch. 386. Texas Emissions Reduction Plan

Sec. 386.205. Evaluation Of State Energy Efficiency Programs (with **PUCT**)

Ch. 388. Texas Building Energy Performance Standards

Sec. 388.003. Adoption Of Building Energy Efficiency Performance Standards.

Sec. 388.004. Enforcement Of Energy Standards Outside Of Municipality.

Sec. 388.007. Distribution Of Information And Technical Assistance.

Sec. 388.008. Development Of Home Energy Ratings.

TERP Amended (78th Legislature, 2003)

Ch. 388. Texas Building Energy Performance Standards

[House Bill (HB) 1365] Sec. 388.004. Enforcement Of Energy Standards Outside Of Municipality.

(HB 1365) Sec. 388.009. Energy-Efficient Building Program.

Ch. 388. Texas Building Energy Performance Standards

(HB 3235) Sec. 388.009. Certification of Municipal Inspectors.

TERP Amended (79th Legislature, 2005)

Ch. 382. Health and Safety Code

(HB 2129) Sec. 386.056 Development of Creditable Statewide Emissions from Wind and other Renewables.

(HB 965) Sec. 382.0275 Commission Action Relating to Water Heaters

TERP Amended (80th Legislature, 2007)

Ch. 382. Health and Safety Code

(HB 3693) Sec. 388.003 added subsection (b-1), (b-2), (b-3) that allows SECO to adopt new editions of the International Energy Conservation Code based on written recommendations from the Laboratory.

(HB 3693) Sec. 388.008 Development of Standardized report formats for newly constructed residences.

Ch. 386.252 Health and and Safety Code

(SB 12) Section 388.03 added subsection (b-1), (b-2) allows SECO to adopt new editions of the IECC based on written recommendations from the Laboratory.

TERP Amended (81st Legislature, 2009)

Ch. 382. Health and Safety Code

(HB 1796) Section 23 amends Sec. 386.252 (a) and (b) extends date of TERP to 2019 and requires Commission to contract with Laboratory for creditable EE/RE emissions reductions.

TERP Amended (82nd Legislature, 2011)

Ch. 477.004 Health and Safety Code

(HB 51) Sec. 2, b-2, establishes advisory committee, which including the Laboratory

Sec.3 & 4 amends review of municipal's amendments.

Ch. 388.003e & 388.007c,d Health and Safety Code

(HB 51) Sec. 3 & 4 amends review of municipal's amendments.

Ch. 388.006 Health and Safety Code

(SB 898) Sec. 2, requires the Laboratory to calculate energy savings and emissions reductions for political subdivisions reporting to SECO.

Ch. 39.9051 Utilities Code

(SB 924) Sec. 1g,h and Section 2c,d requires the Laboratory to calculate energy savings and emissions reductions for political subdivisions reporting to SECO.

NO new amendments were passed (83rd Legislature, 2013)

TERP Amended (84th Legislature, 2015)

Section 388.003, Health and Safety Code

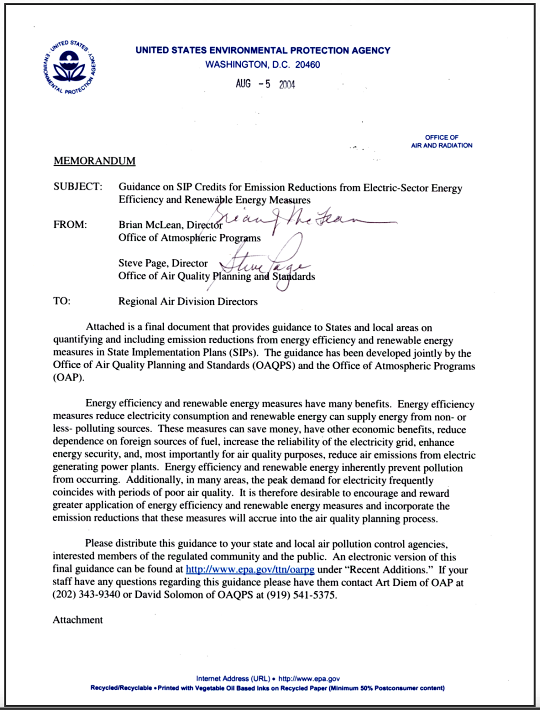
(HB 1736) Sec.1 Establishes the 2015 energy codes as the Texas Building Energy Performance (TBEPS) effective Sept 1, 2016. The state may adopt new codes no sooner than every 6 years. The section also adds Energy Rating Index as a voluntary compliance alternative.

NO new amendments were passed (85th Legislature, 2017)

EPA CRITERIA FOR SIP CREDITS (2004)

Quantifiable: The emission reductions generated by measures to reduce emissions *must be quantifiable* and include procedures to evaluate and verify over time the level of emission reductions actually achieved.

Surplus: Emission reductions *are surplus* as long as they are not otherwise relied on to meet air quality attainment requirements in air quality programs related to your SIP.



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

AUG -5 2004

OFFICE OF
AIR AND RADIATION

MEMORANDUM

SUBJECT: Guidance on SIP Credits for Emission Reductions from Electric-Sector Energy Efficiency and Renewable Energy Measures

FROM: Brian McLean, Director
Office of Atmospheric Programs

Steve Page, Director
Office of Air Quality Planning and Standards

TO: Regional Air Division Directors

Attached is a final document that provides guidance to States and local areas on quantifying and including emission reductions from energy efficiency and renewable energy measures in State Implementation Plans (SIPs). The guidance has been developed jointly by the Office of Air Quality Planning and Standards (OAQPS) and the Office of Atmospheric Programs (OAP).

Energy efficiency and renewable energy measures have many benefits. Energy efficiency measures reduce electricity consumption and renewable energy can supply energy from non- or less- polluting sources. These measures can save money, have other economic benefits, reduce dependence on foreign sources of fuel, increase the reliability of the electricity grid, enhance energy security, and, most importantly for air quality purposes, reduce air emissions from electric generating power plants. Energy efficiency and renewable energy inherently prevent pollution from occurring. Additionally, in many areas, the peak demand for electricity frequently coincides with periods of poor air quality. It is therefore desirable to encourage and reward greater application of energy efficiency and renewable energy measures and incorporate the emission reductions that these measures will accrue into the air quality planning process.

Please distribute this guidance to your state and local air pollution control agencies, interested members of the regulated community and the public. An electronic version of this final guidance can be found at http://www.epa.gov/ttn/oarpg under "Recent Additions." If your staff have any questions regarding this guidance please have them contact Art Diem of OAP at (202) 343-9340 or David Solomon of OAQPS at (919) 541-5375.

Attachment

Internet Address (URL) • http://www.epa.gov
Recycled/Recyclable • Printed with Vegetable Oil Based Inks on Recycled Paper (Minimum 50% Postconsumer content)

Enforceability: Measures that reduce emissions from electricity generation may be: (1) *Enforceable directly* against a source; (2) *Enforceable against another party* responsible for the energy efficiency or renewable energy activity; or (3) Included under our *voluntary measures* policy.

Record Keeping: The *measure should be permanent* throughout the term for which the credit is granted unless it is replaced by another measure or the State demonstrates in a SIP revision that the emission reductions from the measure are no longer needed to meet applicable requirements.

EPA CRITERIA FOR SIP CREDITS (2004)

Quantifiable: The emission reductions generated by measures to reduce emissions *must be quantifiable* and include procedures to evaluate and verify over time the level of emission reductions actually achieved.

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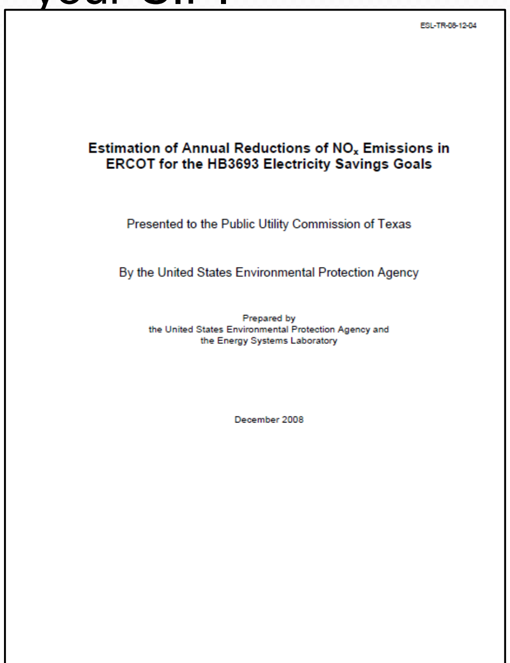


ESL-TR-08-12-04

Estimation of Annual Reductions of NO_x Emissions in ERCOT for the HB3693 Electricity Savings Goals

Presented to the Public Utility Commission of Texas

By the United States Environmental Protection Agency

Prepared by
the United States Environmental Protection Agency and
the Energy Systems Laboratory

December 2008

Enforceability: Measures that reduce emissions from electricity generation may be: (1) *Enforceable directly* against a source; (2) *Enforceable against another party* responsible for the energy efficiency or renewable energy activity; or (3) Included under our *voluntary measures* policy.

Record Keeping: The *measure should be permanent* throughout the term for which the credit is granted unless it is replaced by another measure or the State demonstrates in a SIP revision that the emission reductions from the measure are no longer needed to meet applicable requirements.

ENERGY SAVINGS & NOx EMISSION REDUCTION

International CODE COMPLIANCE CALCULATOR

ESL Calculates & Reports NOx Emissions Reductions for:

1. **Code-Compliant Construction:** Energy savings from new construction
   - ESL Single-family construction
   - ESL Multi-family construction
   - ESL Commercial construction

2. **Green Power Production**: Wind and other renewables

PUBLIC UTILITY COMMISSION OF TEXAS

3. **PUC SB7**: Energy efficiency programs implemented by electric utilities under the Public Utility Regulatory Act §39.905

SECO State Energy Conservation Office

4. **SECO**: Energy-efficiency programs towards school districts, government agencies, city and county governments, private industries and residential energy consumers

5. **A/C Retrofits**: Installation of Seasonal Energy Efficiency Ratio (SEER) 13/14 *replacement* air conditioners in existing residences

SAVINGS FROM RENEWABLES

Blue Wing Solar PV Array ,San Antonio

Solar PV

Sunmaxx Solar Thermal, Fort Hood, TX

Solar Thermal

Dam at Elephant Butte, El Paso, TX

Hydro

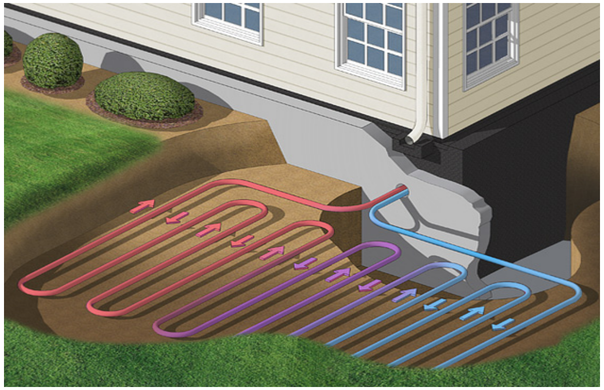
2.5 Miles Southwest of Woodville, TX

Biomass

Aspen Power plant in Lufkin, TX

Landfill Gas

Ground Source Heat Pump



Geothermal

SAVINGS FROM RENEWABLES

Wind

Brazos Wind Ranch, TX.

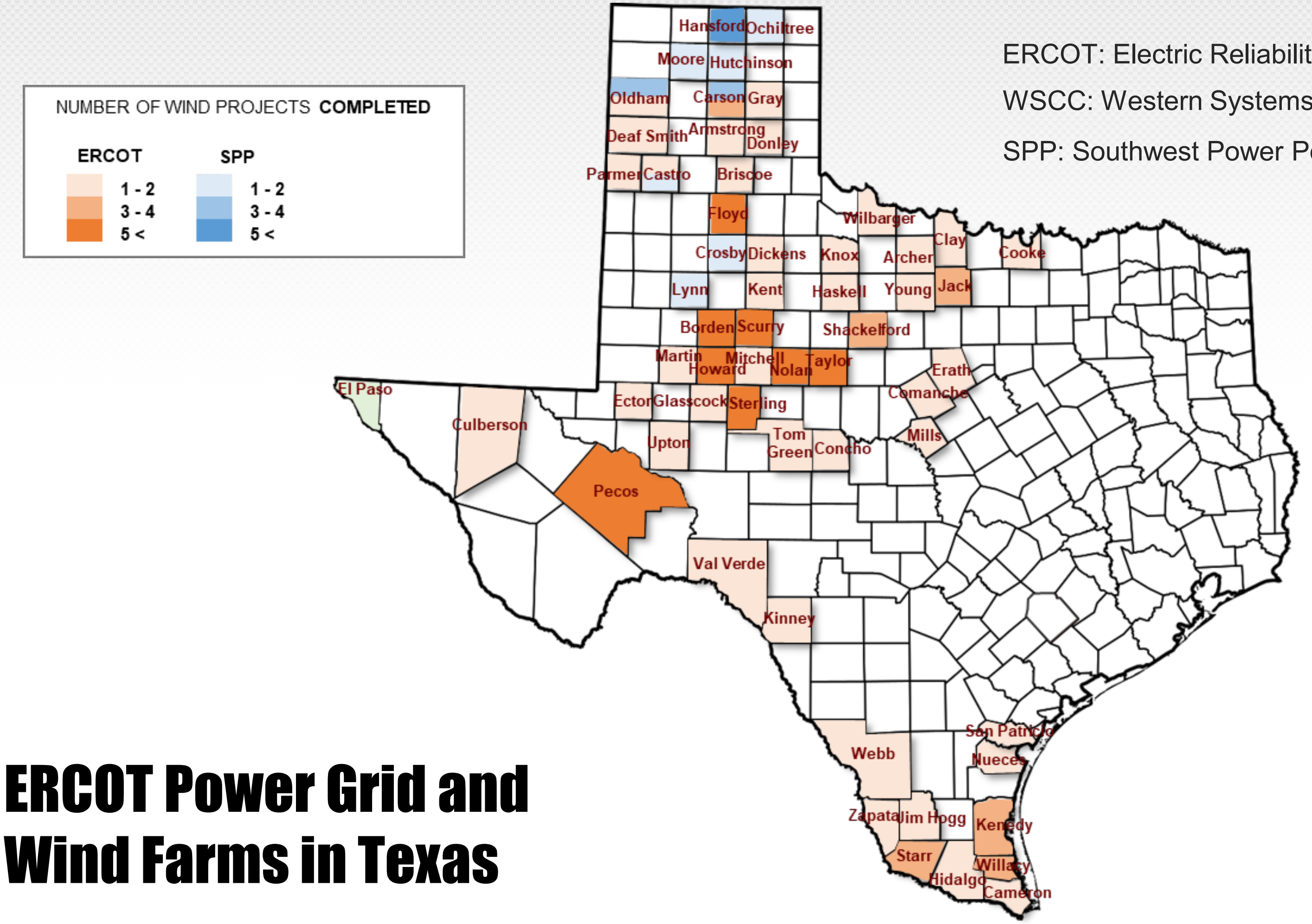
WIND PROJECTS IN TEXAS (2017)

Completed, Announced, and Retired Wind Projects in Texas, as of Dec. 2017

ERCOT: Electric Reliability Council of Texas

WSCC: Western Systems Coordinating Council

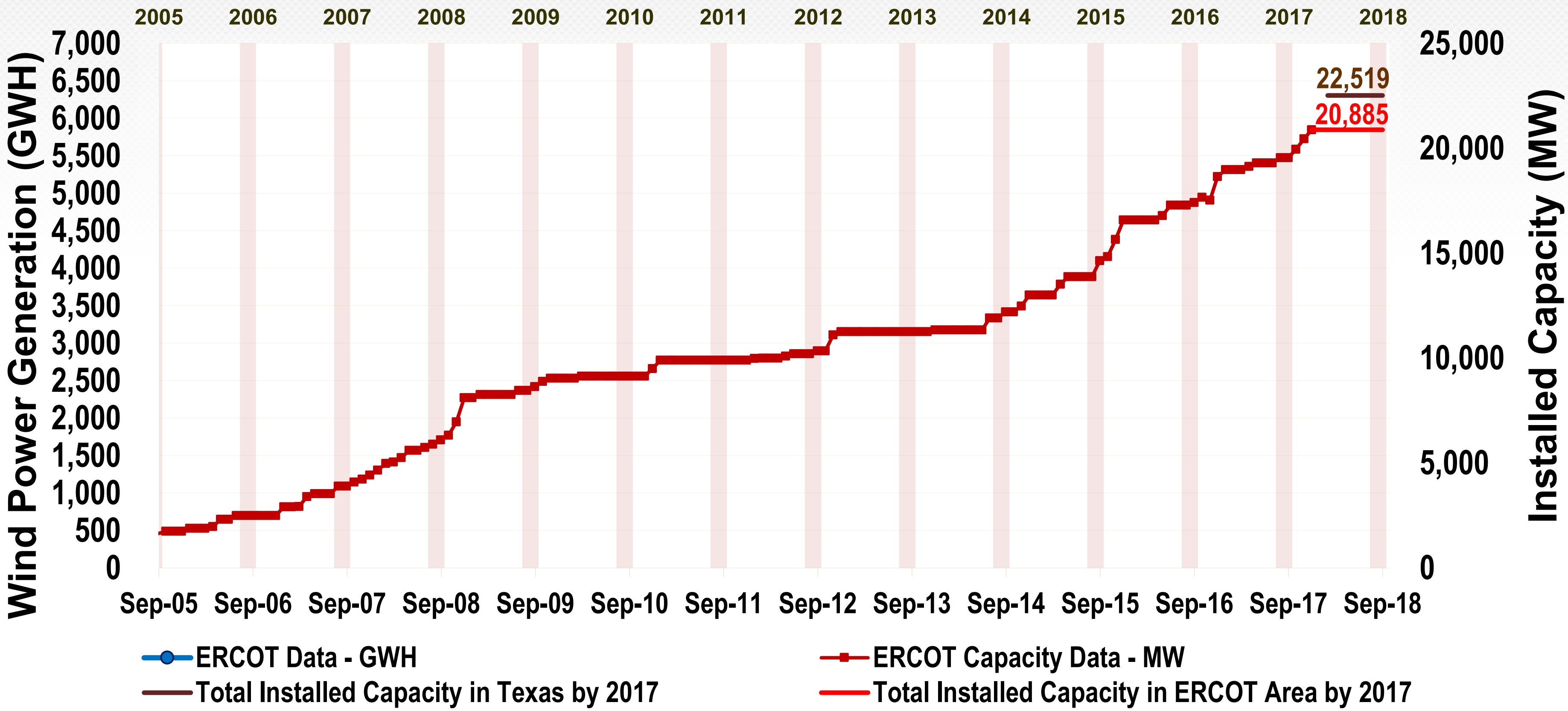
SPP: Southwest Power Pool



ERCOT Power Grid and Wind Farms in Texas

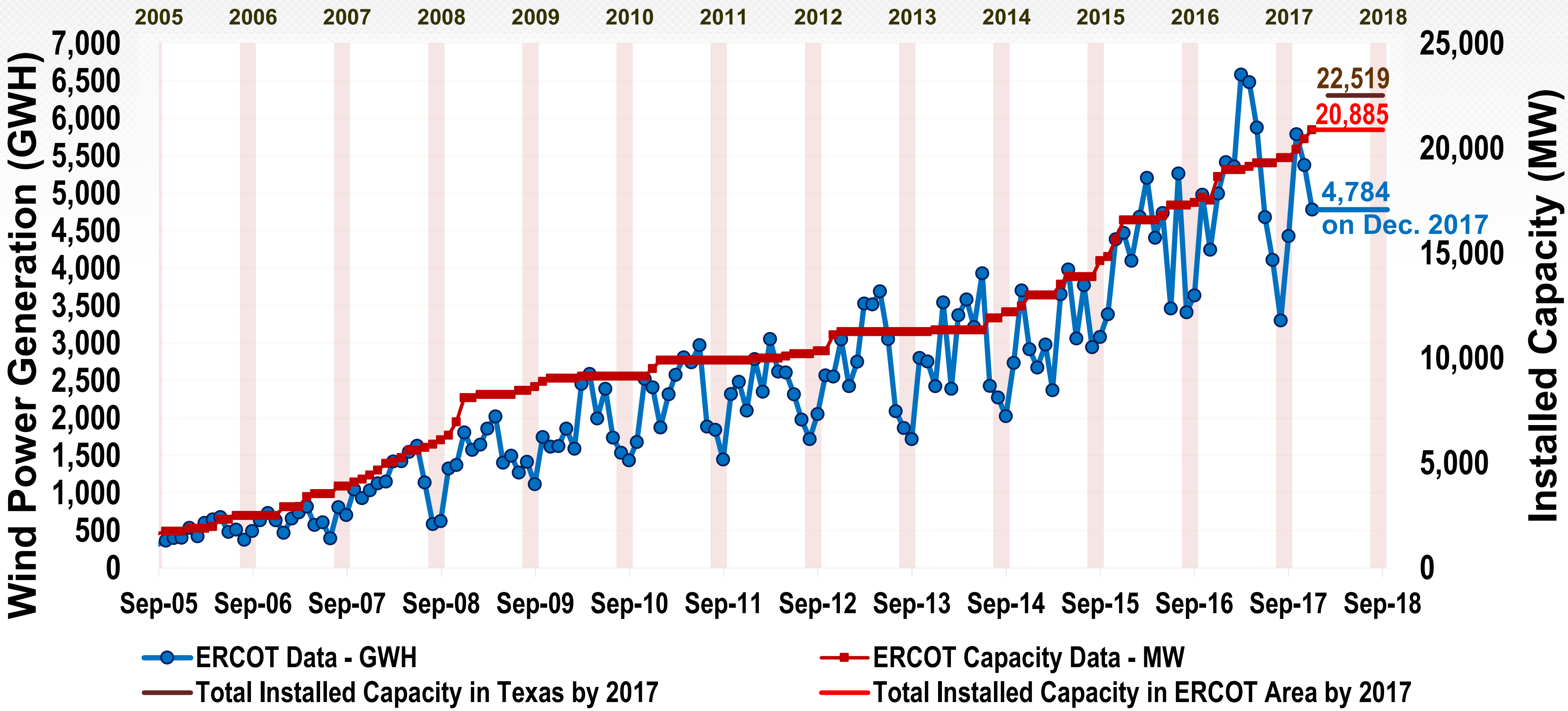
WIND PROJECTS IN TEXAS (2017)

Total Capacity 22,519 MW ERCOT Capacity 20,885 MW



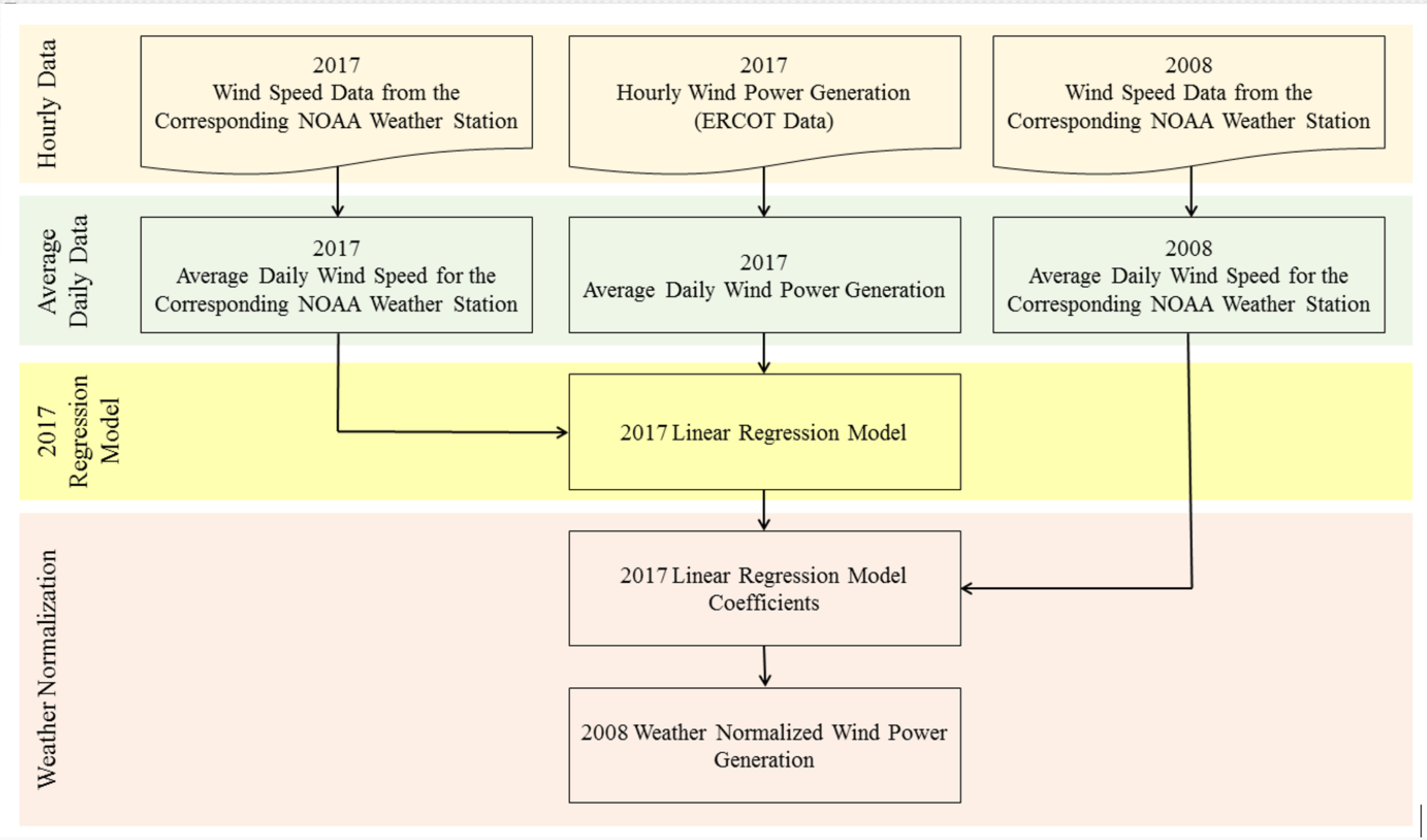
WIND PROJECTS IN TEXAS (2017)

Total Capacity 22,519 MW **ERCOT Capacity 20,885 MW** **Total Wind Power 62,189 GWh**



NOx REDUCTIONS USING EMISSIONS & GENERATION RESOURCE INTEGRATED DATABASE (eGRID)

NOx emissions reductions calculation from Renewable Energy Projects (Wind)



NOx REDUCTIONS USING eGRID

NOx emissions reductions calculation from electricity savings

CONSUMPTION

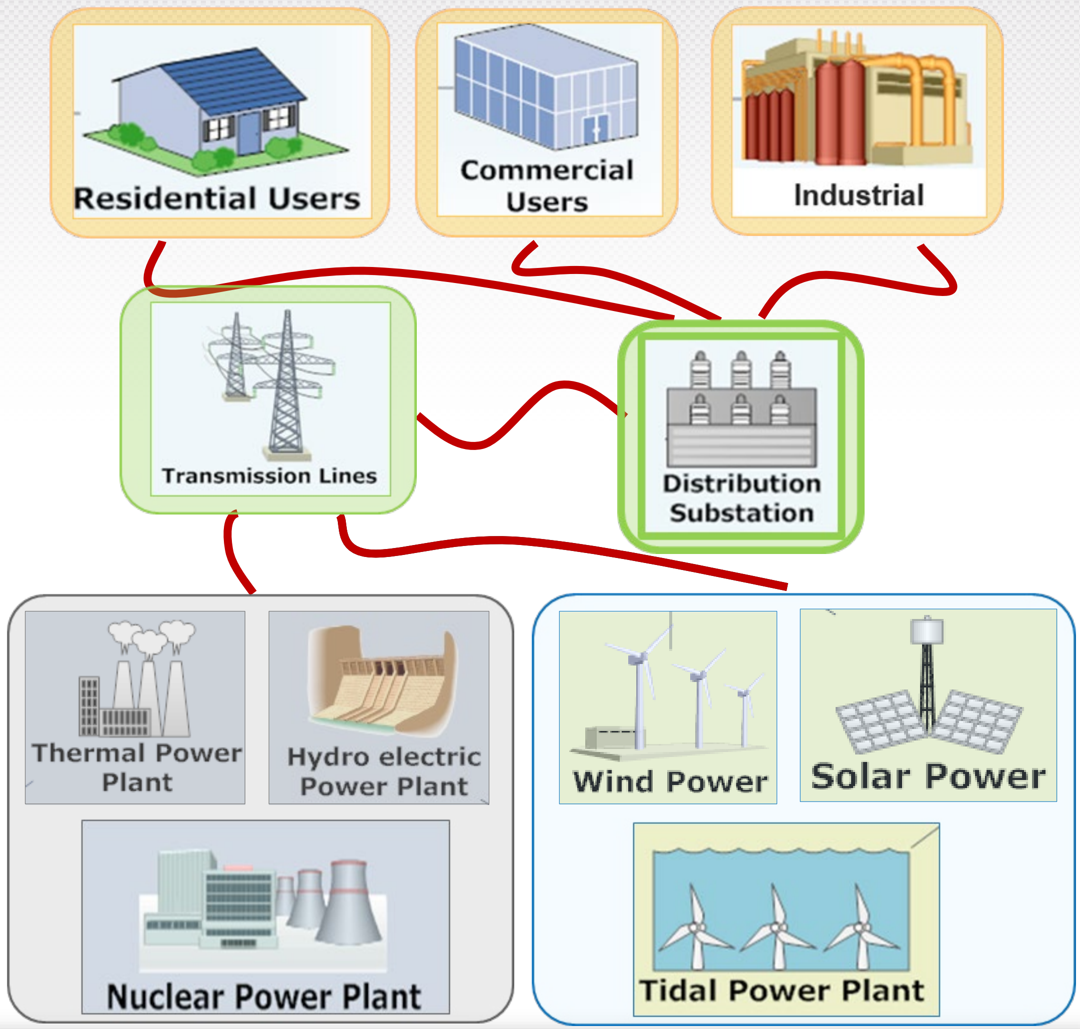
- Residential
- Commercial
- Industrial

TRANSMISSION & DISTRIBUTION

- Transmission Lines
- Sub-Station

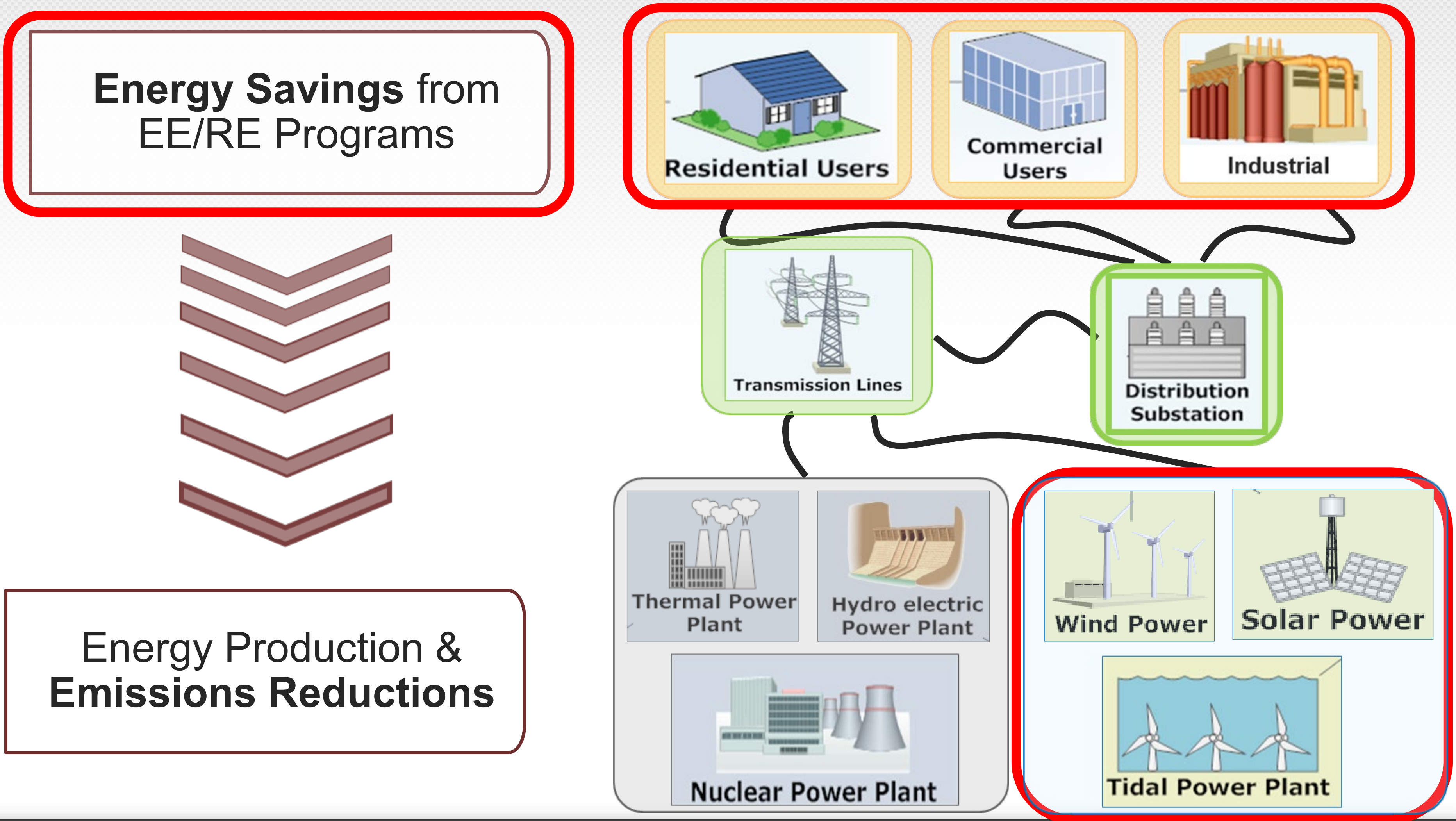
GENERATION

- Conventional
- Renewable



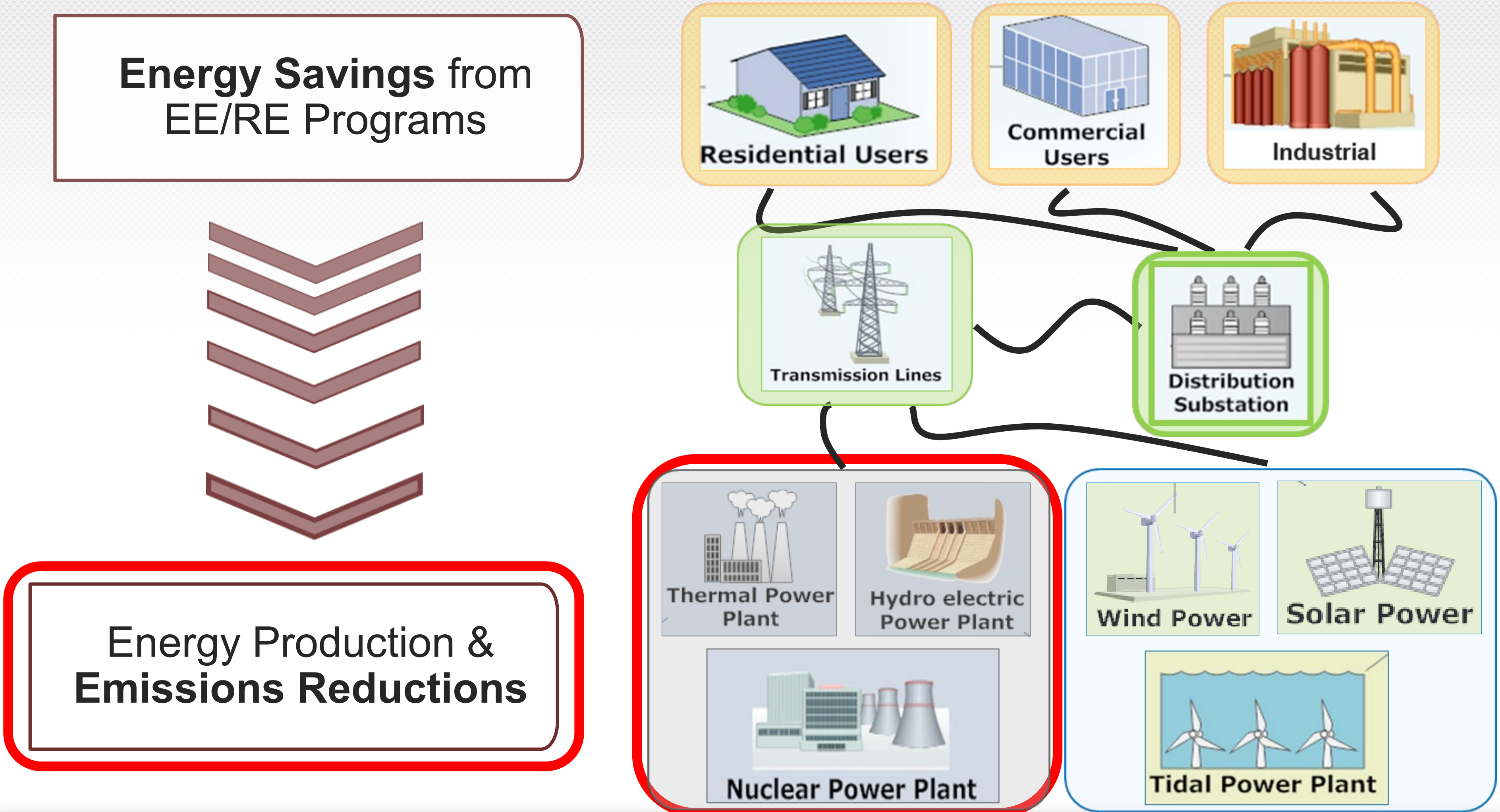
NOx REDUCTIONS USING eGRID

NOx emissions reductions calculation from electricity savings



NOx REDUCTIONS USING eGRID

NOx emissions reductions calculation from electricity savings



NOx REDUCTIONS USING eGRID

NOx emissions reductions calculation from Renewable Energy Projects

- Prototype analysis completed with test site in Randall, Tx.
- Needed to know how to normalize power production to baseyear wind data.

Figure 15: The Enertech Wind Turbine Installed in Randall, Texas

Figure 16: Texas Map Showing Randall (red) and Potter (blue) County

NOx REDUCTIONS USING eGRID

NOx emissions reductions calculation from Renewable Energy Projects

- Analysis showed hourly characteristic wind power profiles using on-site hourly wind speed data.
- However, profiles changed significantly when compared against NOAA hourly wind data (recorded nearby).
- Needed to know how to normalize power production to base-year wind data using NOAA wind data.

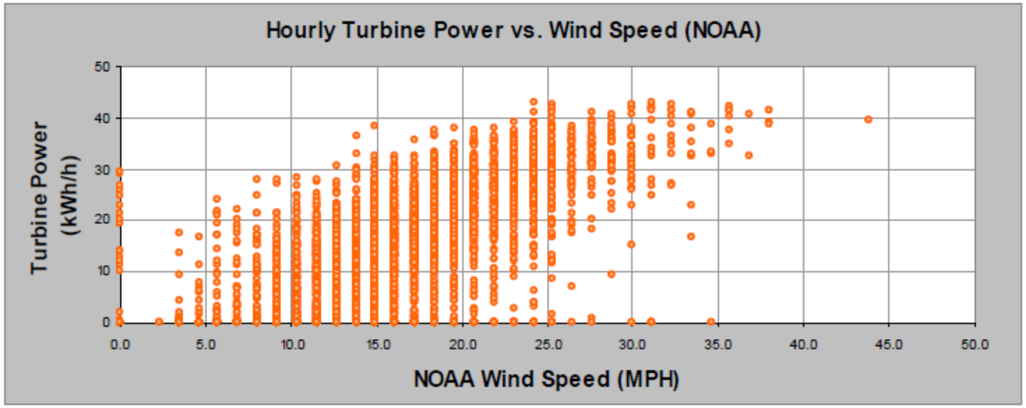
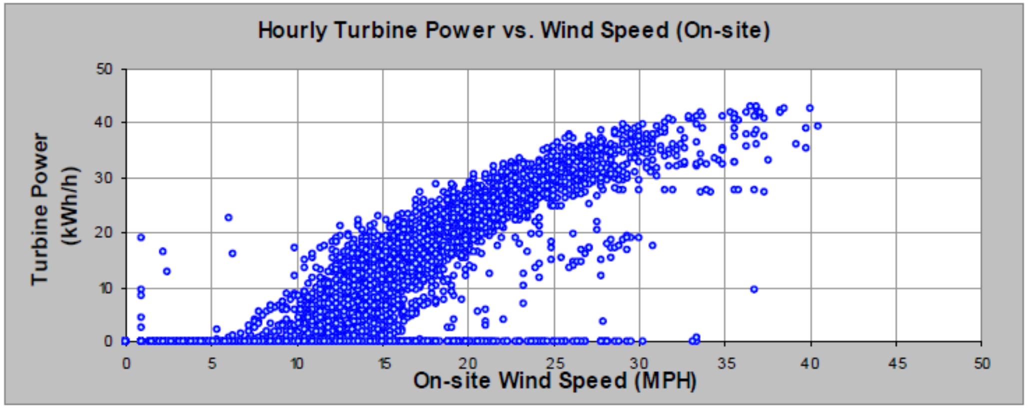


Figure 27: Hourly Turbine Power vs. NOAA-AMA Wind Speed



NOx REDUCTIONS USING eGRID

NOx emissions reductions calculation from Renewable Energy Projects

- Determined that daily analysis performed similarly for on-site AND NOAA wind data.
- Therefore, proposed that daily analysis be used for weather normalizing wind power production.
- Proposed process would use 3P wind power coefficients determined from actual wind power measurements, which could then be transferred to daily base-year conditions (i.e., wind speed) using available NOAA data.
- Process is now used to weather normalize wind power production (all wind farms) for EPA base year.

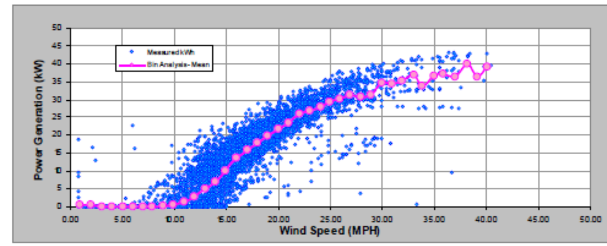


Figure 29: Hourly Turbine Power Bin Analysis

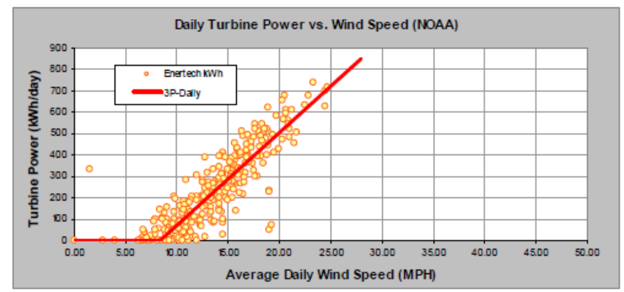


Figure 30: Daily Turbine Power vs. NOAA-AMA Wind Speed

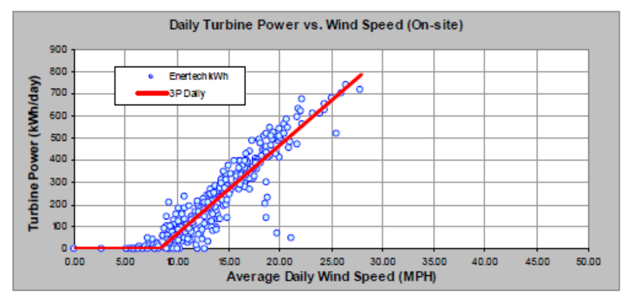
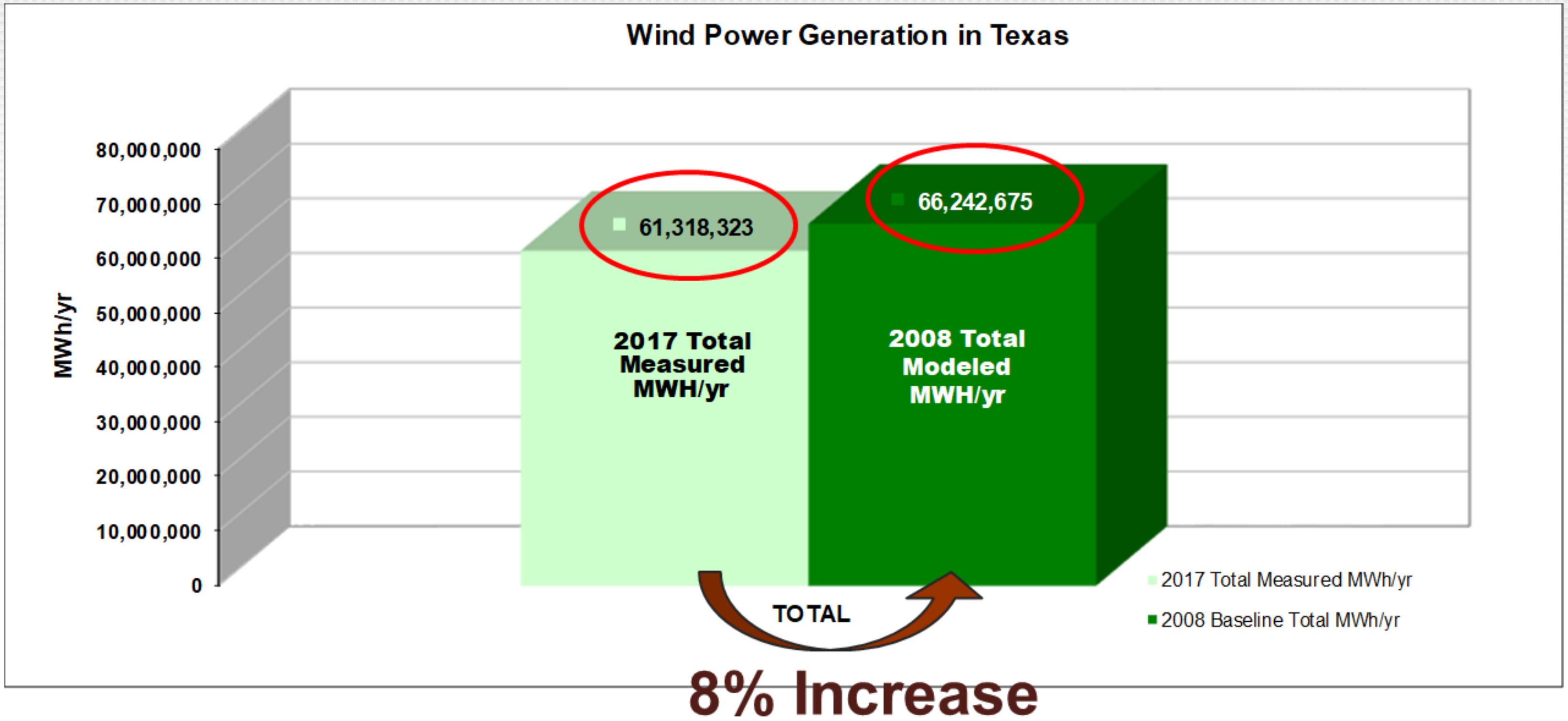


Figure 31: Daily Turbine Power vs. On-site Wind Speed

WIND FARMS CAPACITY/PRODUCTION

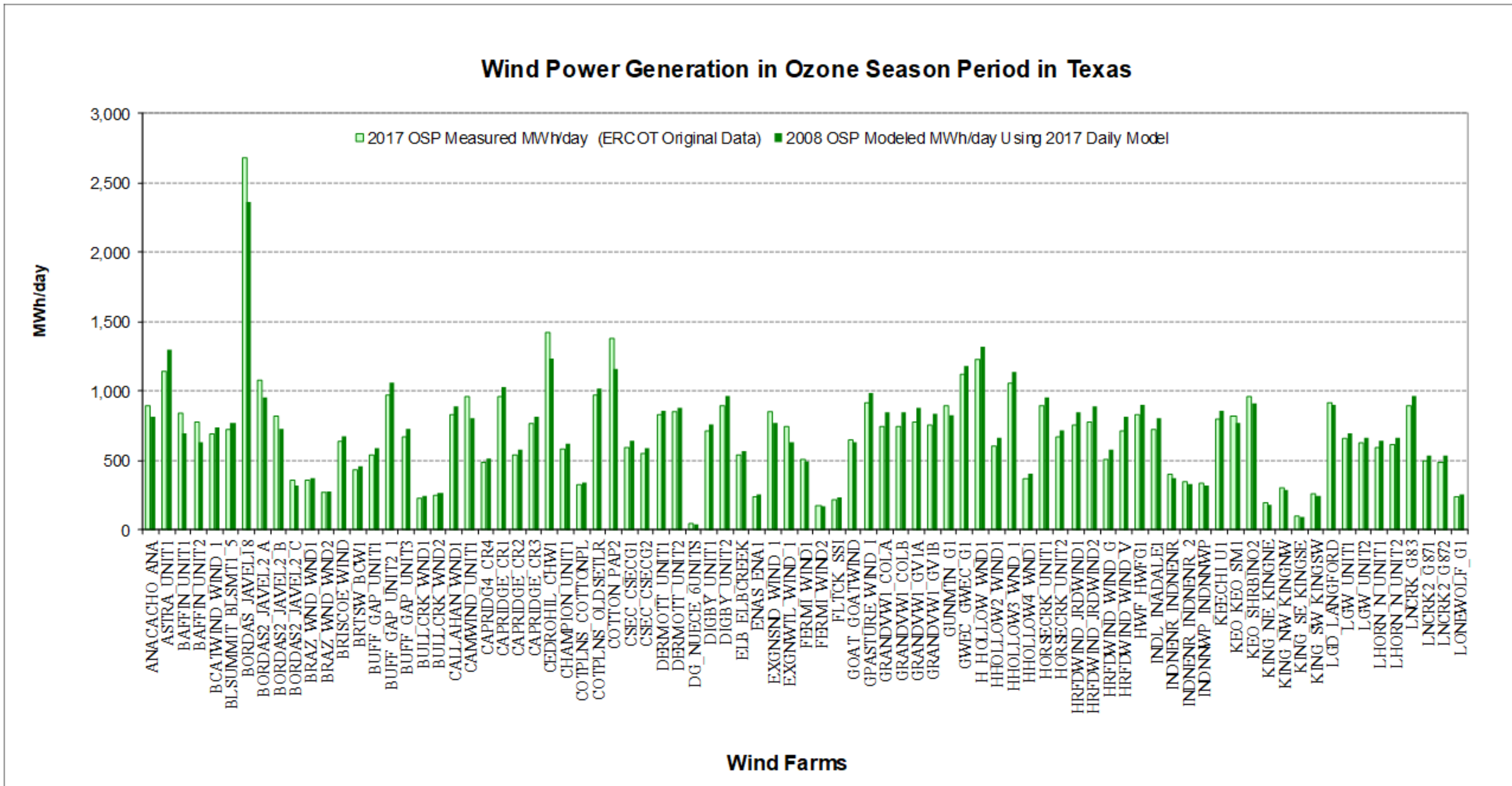
2008 Annual Modeled vs. 2017 Annual Measured



2008 Calculated from 2017 Measured Annual Power Production

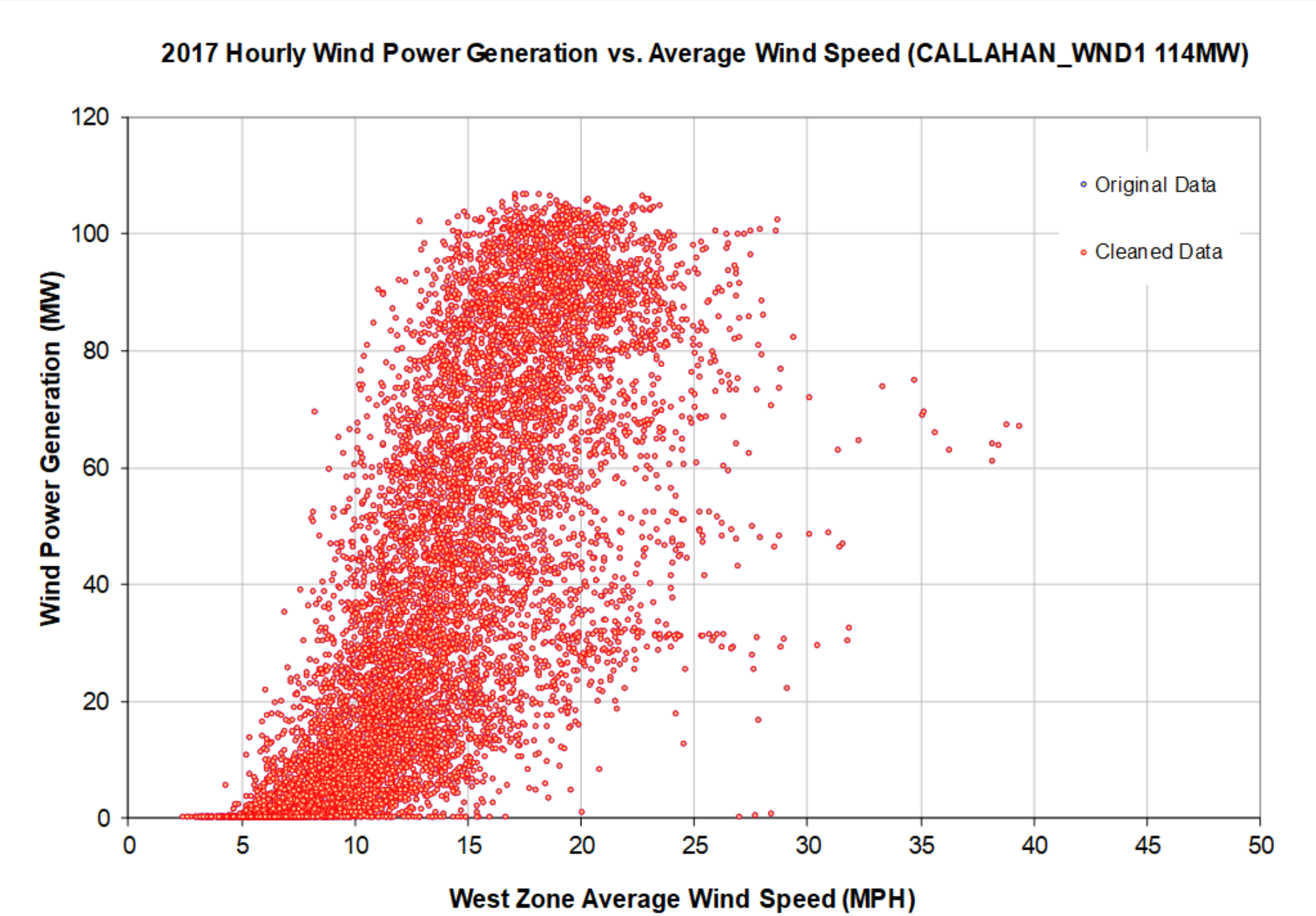
NOx REDUCTIONS USING eGRID

NOx emissions reductions calculation from Wind Energy Projects (2017)



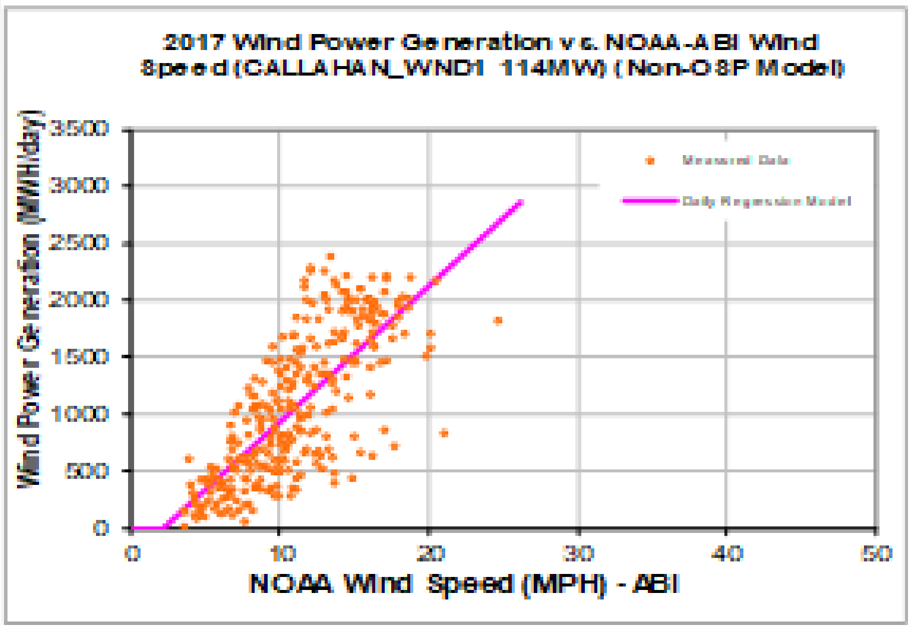
NOx REDUCTIONS USING eGRID

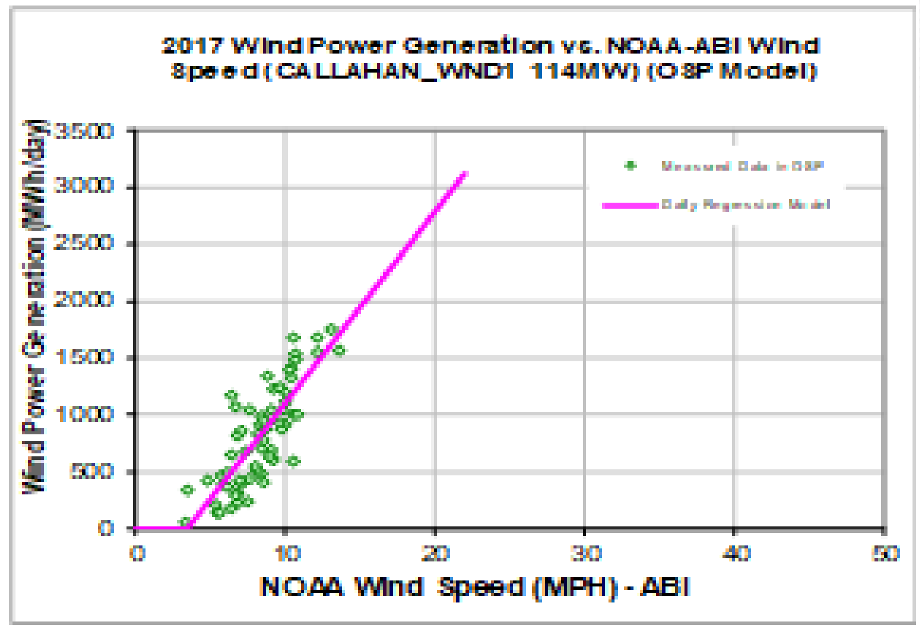
NOx emissions reductions calculation from Renewable Energy Projects (Example: Callahan wind farm)



NOx REDUCTIONS USING eGRID

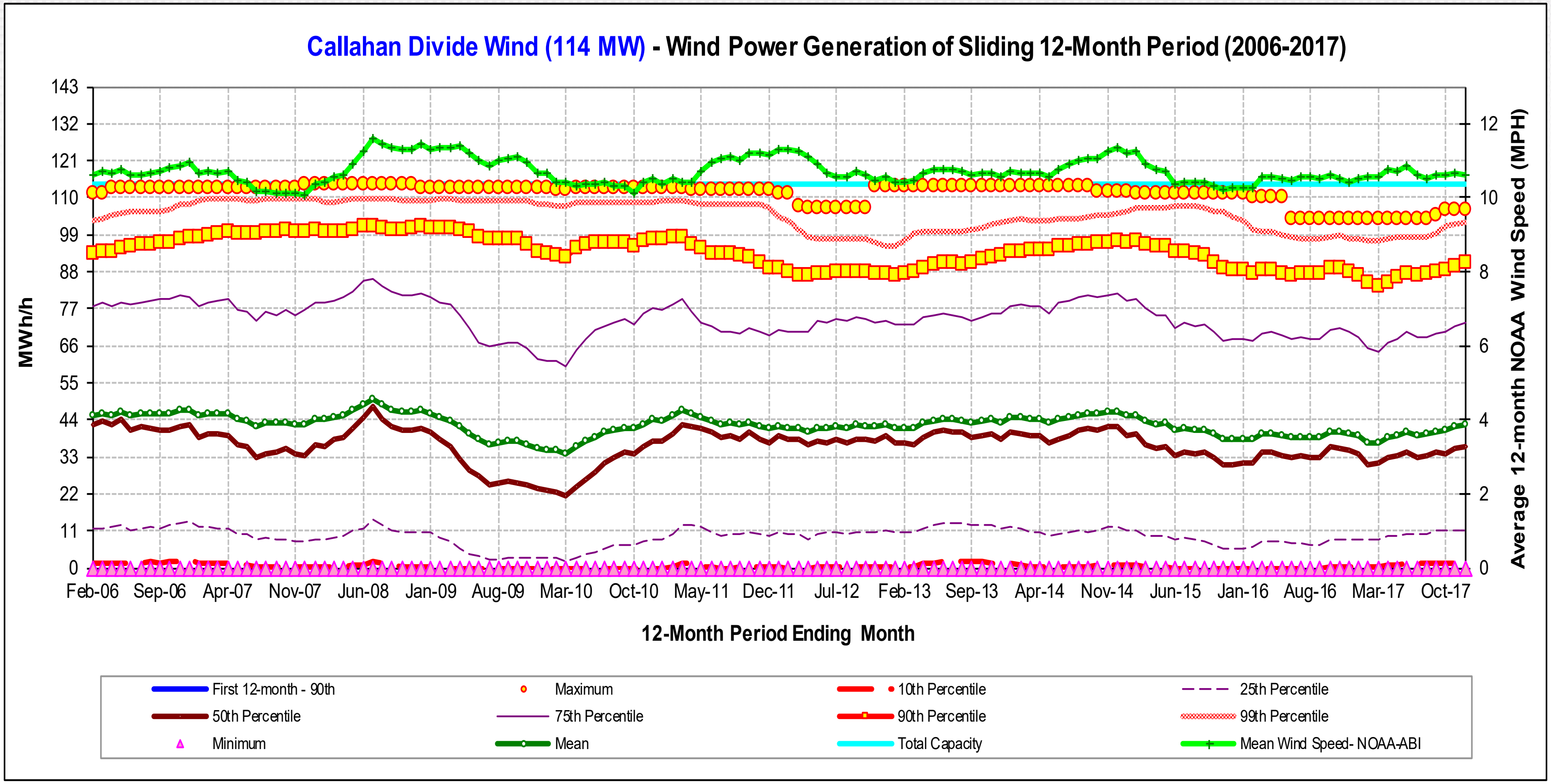
NOx emissions reductions calculation from Renewable Energy Projects (Example: Callahan wind farm)





NOx REDUCTIONS USING eGRID

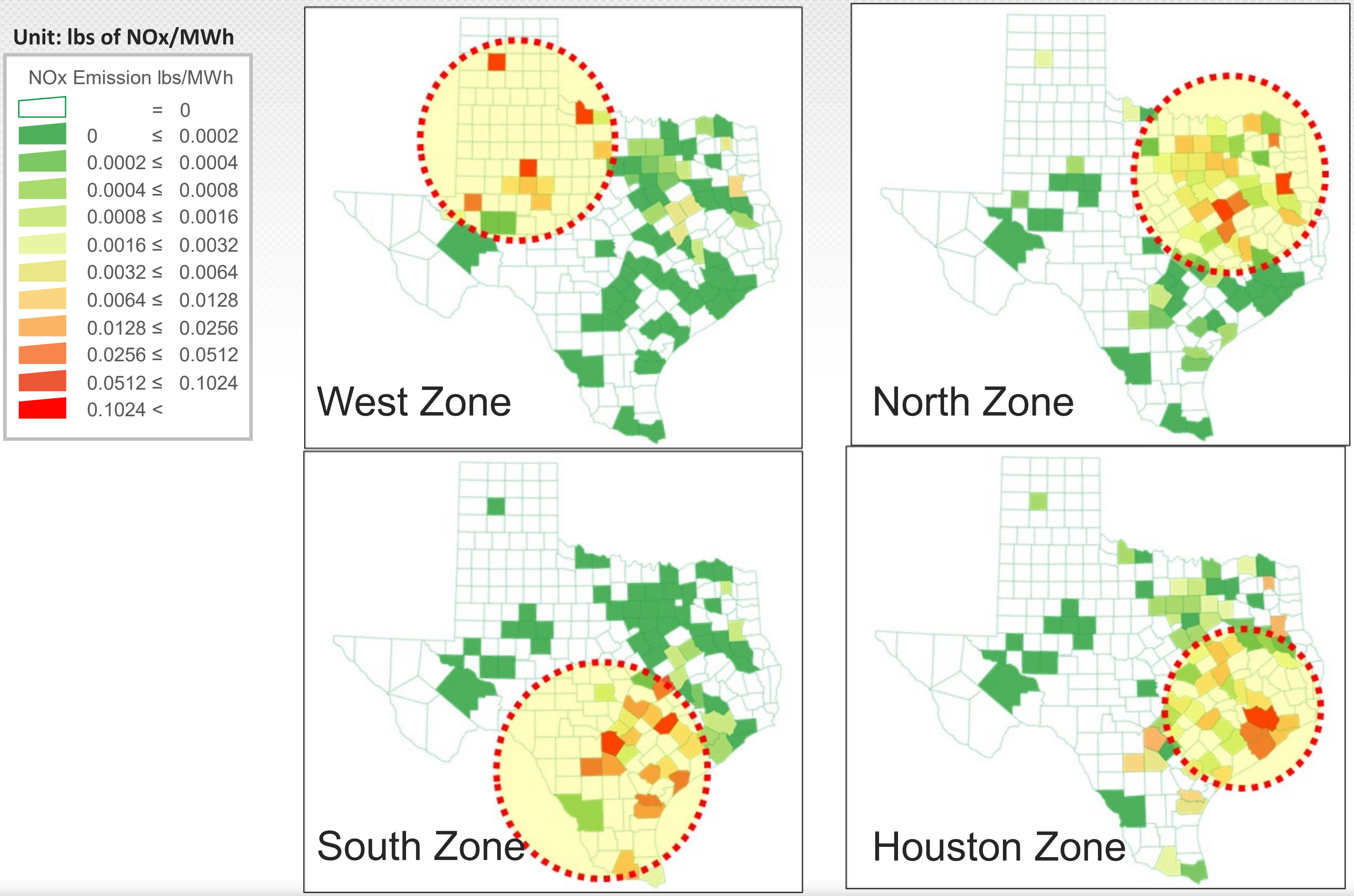
NOx emissions reductions calculation from Renewable Energy Projects (Example: Callahan wind farm)



NOx REDUCTIONS USING eGRID

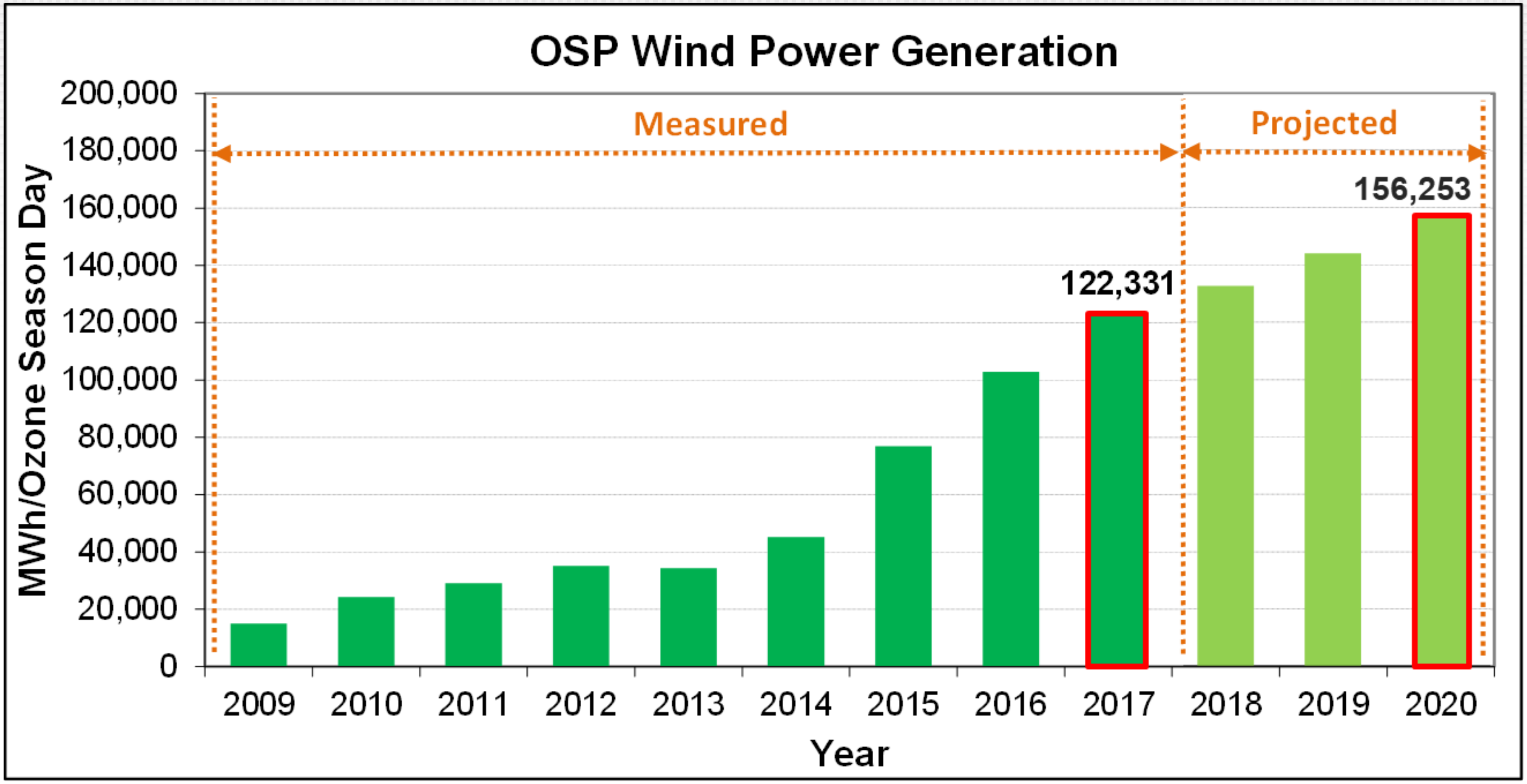
2016 eGRID (**Annual**) for NOx Emissions

Unit: lbs of NOx/MWh



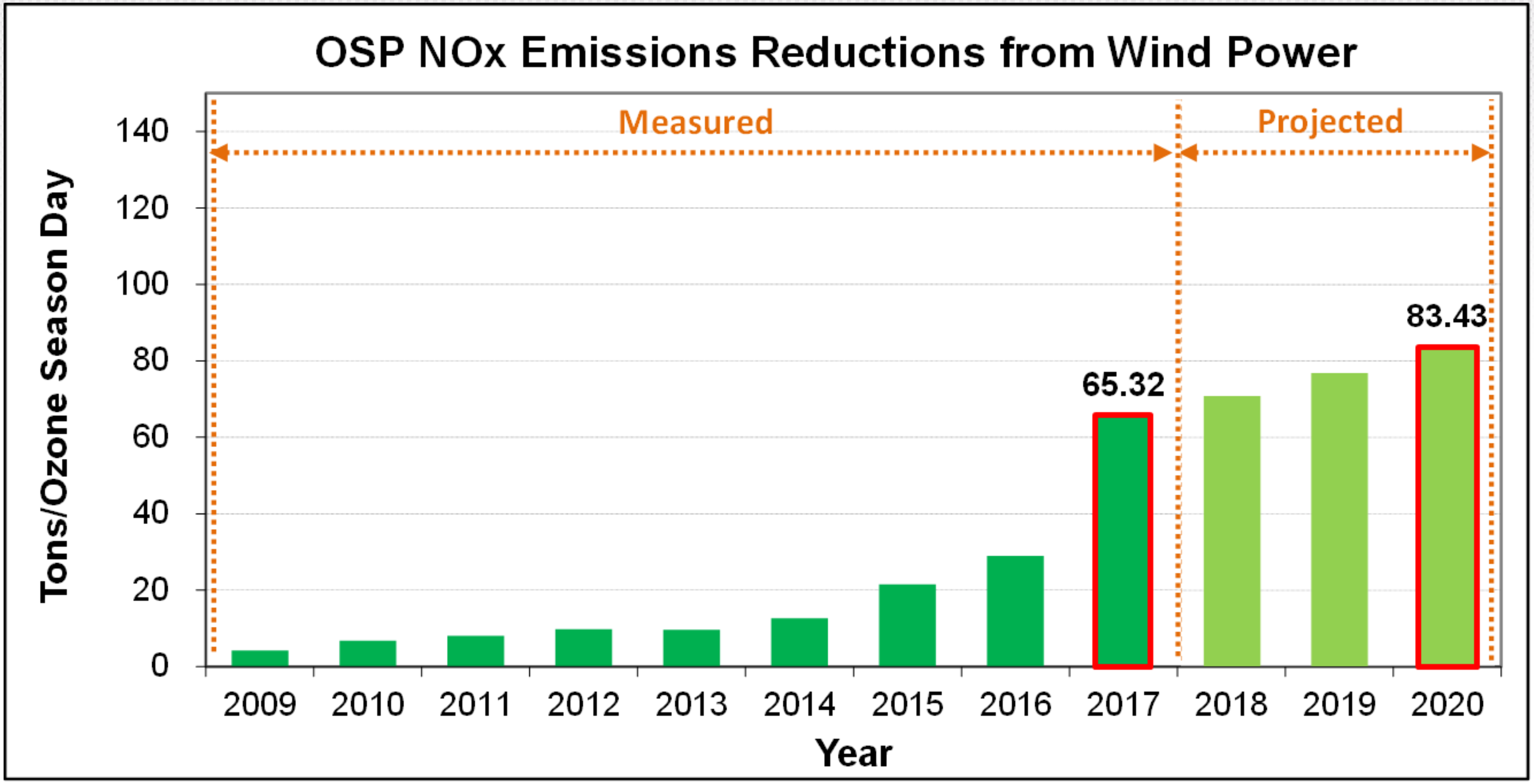
NOx REDUCTIONS FROM WIND POWER

Ozone Season Period (OSP) Power Generation and NOx Emissions Reductions (2008 base year)



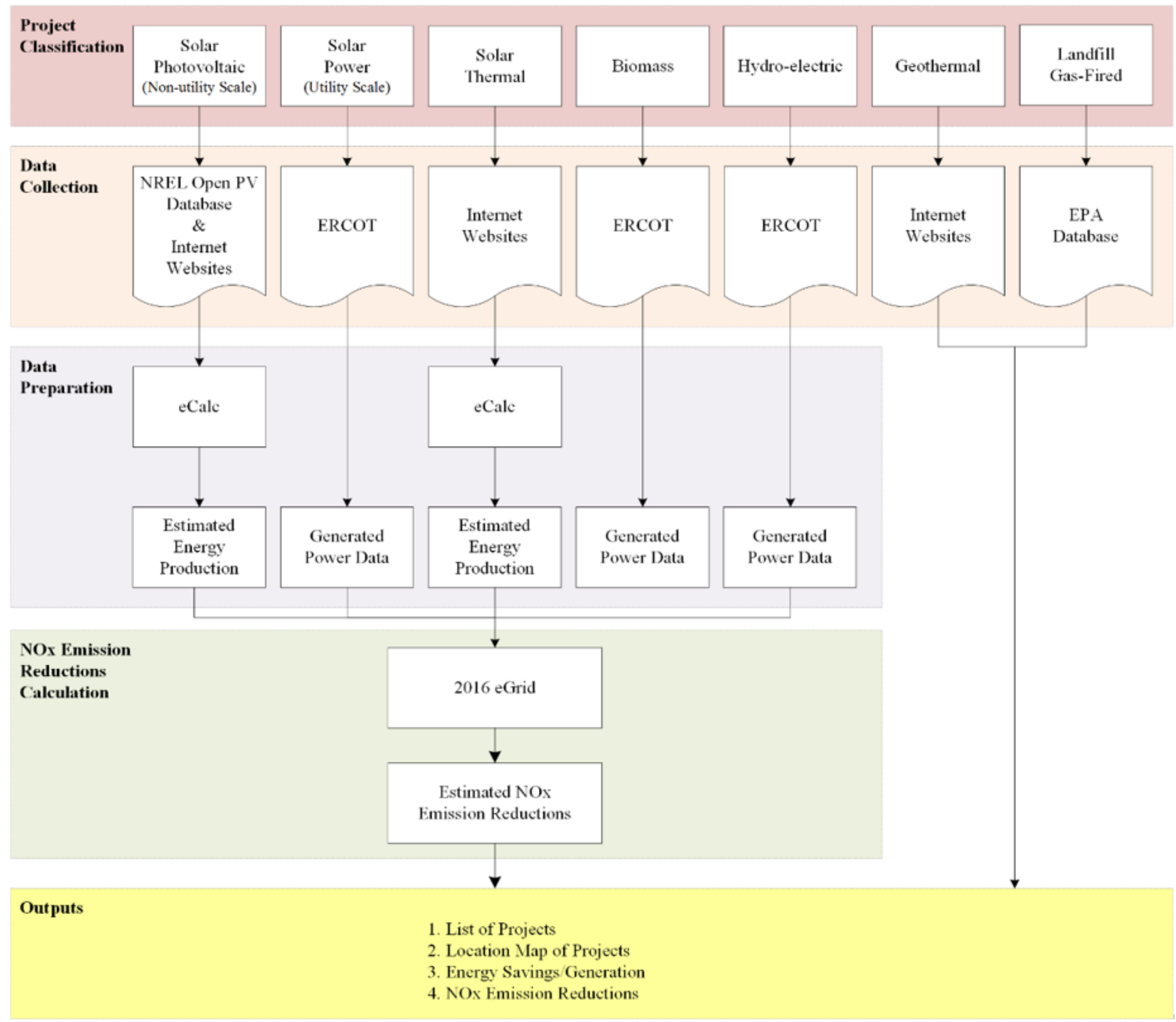
NOx REDUCTIONS FROM WIND POWER

OSP Power Generation and NOx Emissions Reductions (2008 base year)



NOx REDUCTIONS USING eGRID

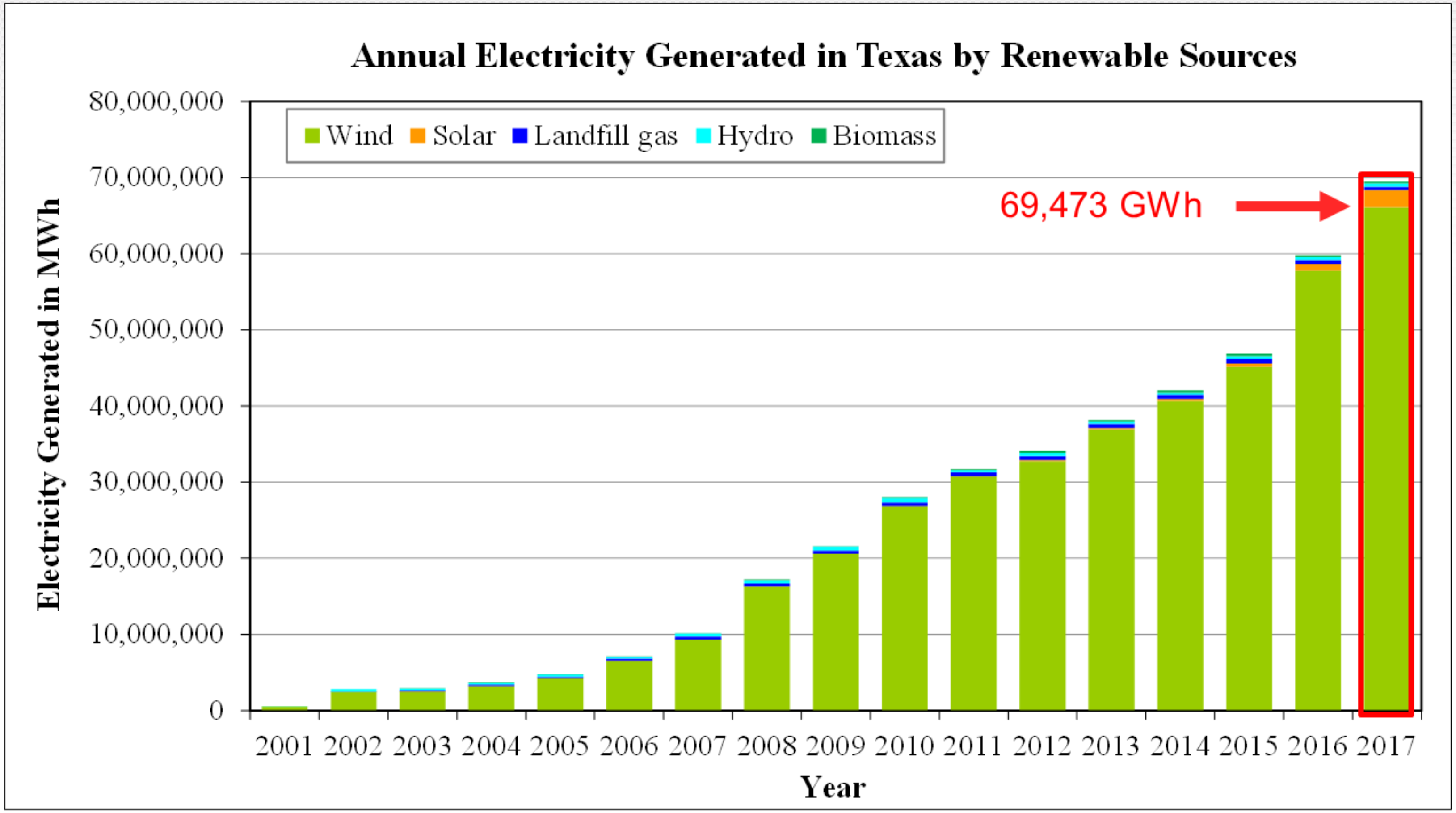
NOx emissions reductions calculation from other renewable energy projects



SAVINGS FROM OTHER RENEWABLES (2001-2017)

Renewables: Biomass, Hydro, Landfill Gas, Solar, Wind

✓ Wind energy is the largest portion



INTEGRATED NOx EMISSIONS REDUCTION

Integrated Emissions Savings Across Agencies To Report Savings To TCEQ and EPA

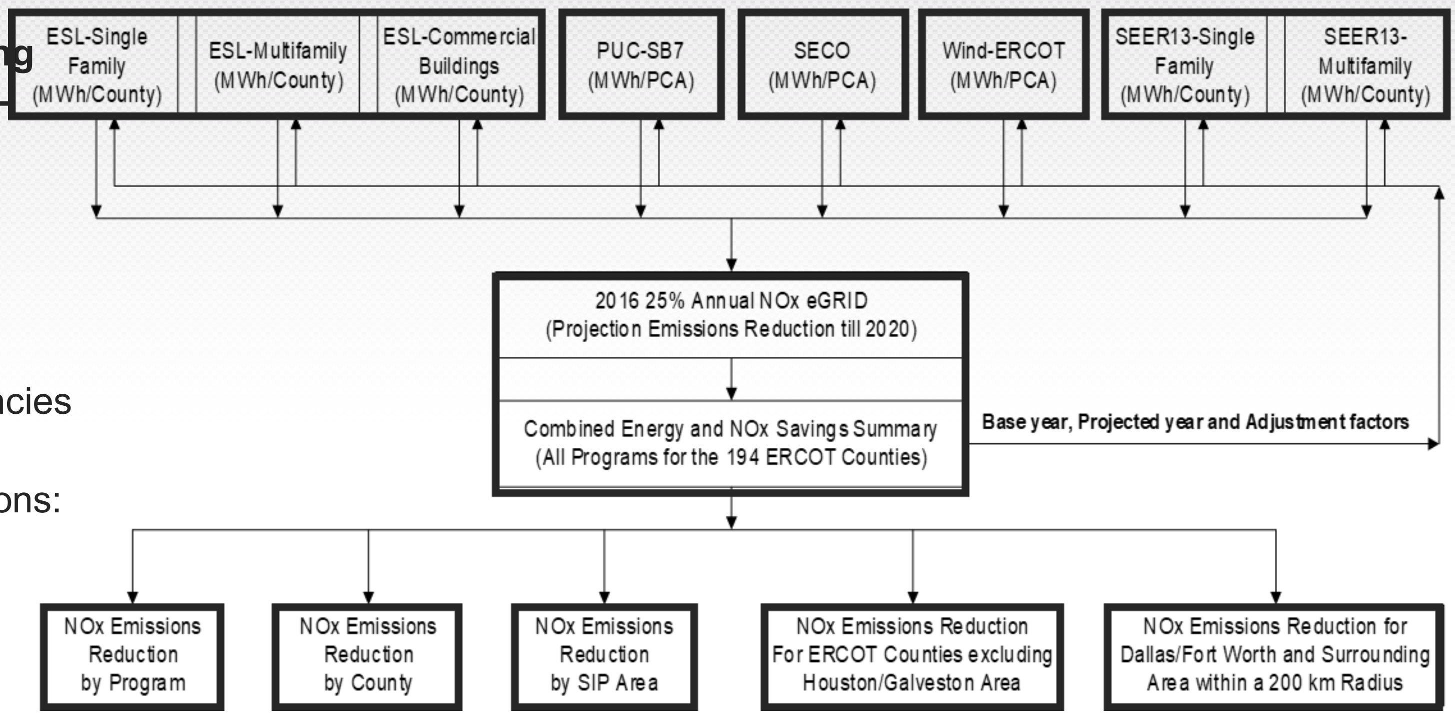
State agencies included:

- **Texas A&M Engineering Experiment Station/ESL**
- **PUC**
- **SECO**
- **ERCOT/Wind**
- **SEER 13/14 Single/Multifamily**

Total savings across agencies

Annual emissions reductions:

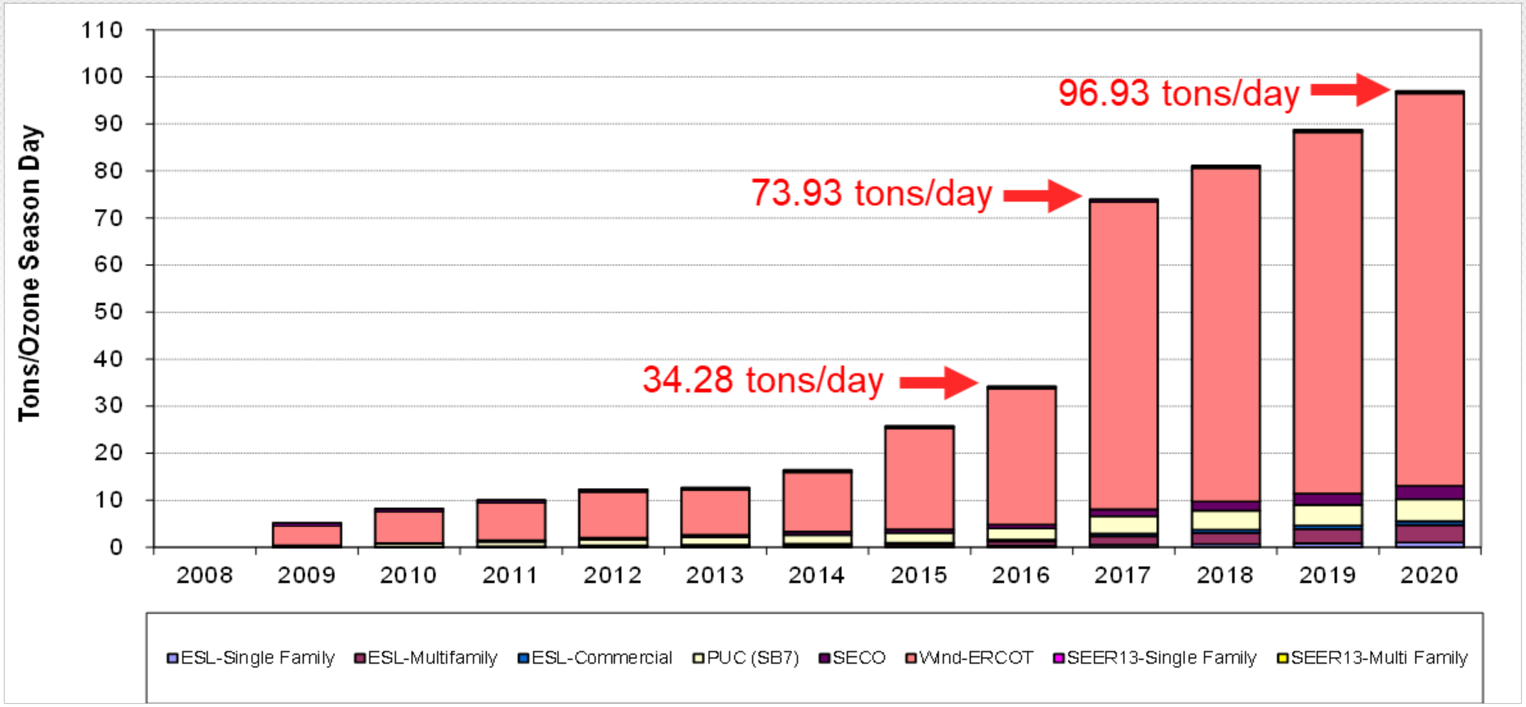
- **By program**
- **By county**
- **By SIP area**
- **By ERCOT counties**
- **By City and Surrounding Area within a 200km Radius**



TCEQ · United States Environmental Protection Agency · Public Utility Commission of Texas · SECO State Energy Conservation Office · ERCOT

INTEGRATED NOx EMISSIONS REDUTION (2008 Baseyear)

2017 Integrated OSP NOx Emissions Reduction Using new 2016 eGrid



2017 integrated OSP NOx Emissions Reduction

- ESL Code Compliance (2.89 tons/day)
- PUC SB7 programs (3.75 tons/day)
- SECO Political Sub.* (1.45 tons/day)
- Green Power (Wind) (65.32 tons/day)
- Residential AC Retrofits (0.52 tons/day)
- ➢ **Total (2017) (73.93 tons/day)**

2020 integrated OSP NOx emissions reduction

- ESL Code Compliance (5.58 tons/day)
- PUC SB7 programs (4.65 tons/day)
- *SECO Political Sub. (2.81 tons/day)
- Green Power (Wind) (83.43 tons/day)
- Residential AC Retrofits (0.45 tons/day)
- ➢ **Total (2020) (96.93 tons/day)**

Summary

The results of the analysis:

- Results reported annually to TCEQ and posted on the ESL's website.
- TCEQ includes results in annual report to the Texas State Legislature.

Outcome/How the multiple benefits/results informed or affected policy

- Funding provides Texas with additional NOx credits for State SIP.

Challenges encountered and how you overcame them; key lessons learned or takeaways:

- Weather normalization important.
- Close coordination between state/federal agencies important.
- Need for careful documentation over 17 year period.

ESL Contact Information

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http://esl.tamu.edu/terp

The Securitization of Solar Home Renewable Energy Credits and Their Emissions Benefits

Eric Shrago

Connecticut Green Bank

Connecticut Green Bank

The Securitization of Solar Home Renewable Energy Credits and Their Emissions Benefits

Connecticut Green Bank
Mission and Goals

Support the strategy to achieve **cheaper**, **cleaner**, and **more reliable** sources of energy while **creating jobs** and supporting **local economic development**

- **Attract** and **deploy private capital investment** to finance the **clean energy policy goals** for Connecticut
- **Leverage limited public funds** to **attract multiples of private capital** investment while **reinvesting public funds over time**
- Develop and implement strategies that **bring down the cost** of clean energy in order to make it more **accessible** and **affordable** to customers
- Support affordable and healthy homes and businesses in distressed communities **reduce energy burden** and **address health & safety**

Connecticut Green Bank
Delivering Results for Connecticut

CONNECTICUT GREEN BANK

- **Investment** – mobilized over $1.3 billion of investment into Connecticut's clean energy economy while raising nearly $50 million in state and local tax revenues
- **Jobs** – created nearly 16,000 total job-years – 6,200 direct and 9,700 indirect and induced
- **Energy Burden** – reducing the energy burden on over 30,000 households and businesses
- **Clean Energy** – deployed more than 285 MW of clean renewable energy helping to reduce over 4.6 million tons of greenhouse gas emissions that cause climate change

Private investment drives economic growth

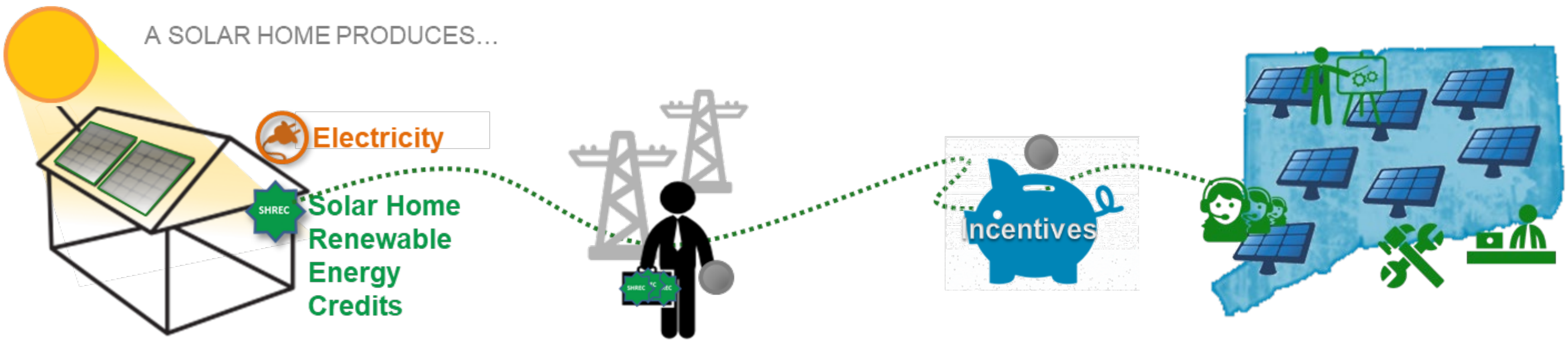
Creates jobs, lowers energy costs, and generates tax revenues

REFERENCES
CT Green Bank data warehouse report from July 1, 2011 through June 30, 2018

The Residential Solar Investment Program (RSIP), Solar Home Renewable Energy Credit (SHREC)-Backed Revenue Bonds

Incentive Business
RSIP and SHREC

CONNECTICUT GREEN BANK



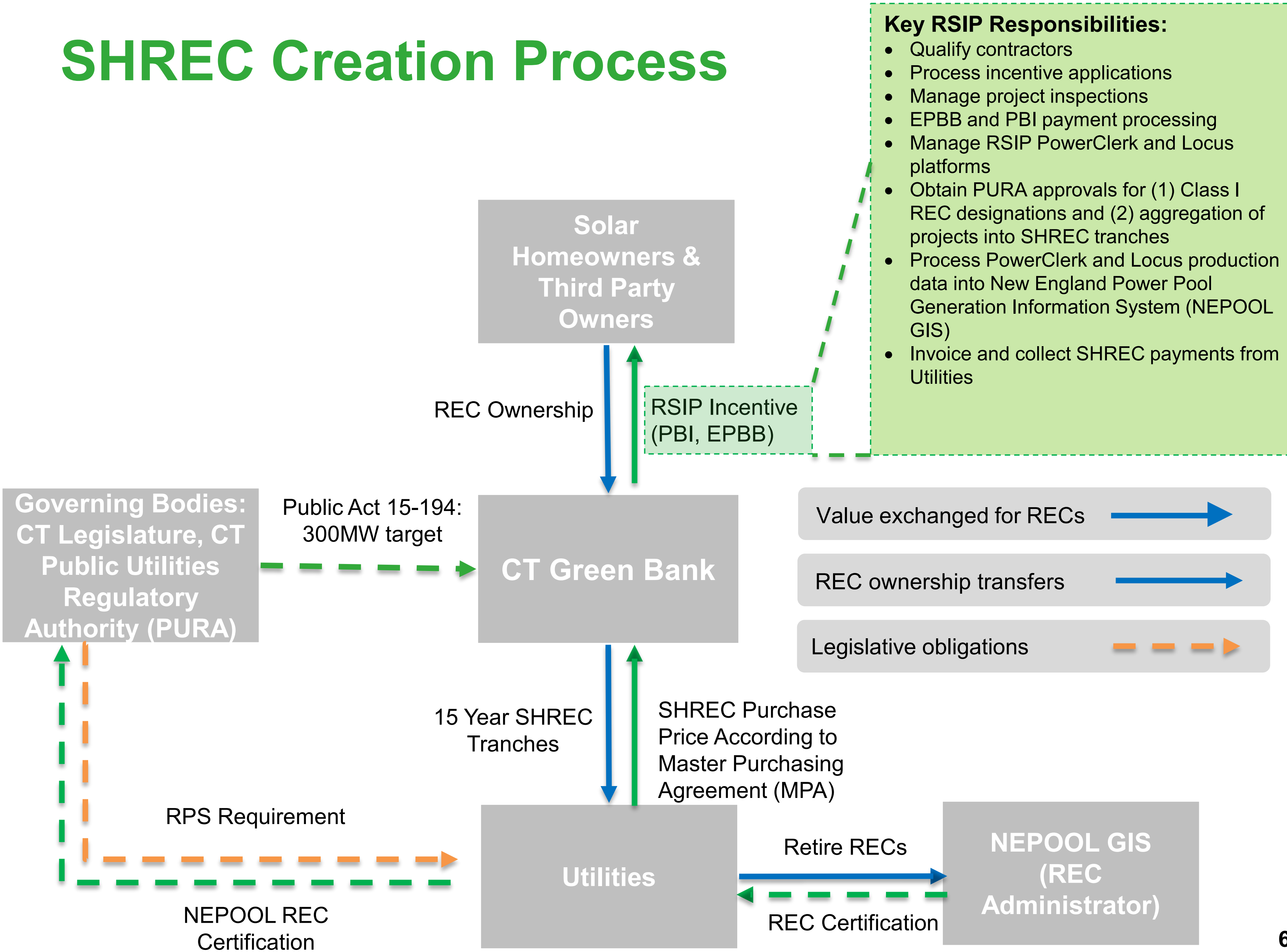
When panels produce electricity for a home, they will also produce Solar Home Renewable Energy Credits (SHRECs). The Green Bank provides upfront incentives through RSIP and collects all the SHRECs produced per statute.

Utilities required to enter into 15-year contracts with the Green Bank to purchase the stream of SHRECs produced. This helps utilities comply with their clean energy goals [i.e., Class I Renewable Portfolio Standard (RPS)].

The Green Bank would then use the revenues from the 15-year fixed price contracts to support the RSIP incentives [i.e., Performance Based Incentives (PBI) and Expected Performance Based By-Down (EPBB) Incentives], cover admin costs, and fund securitization or financing costs.

A public policy with 300 MW target will create more locally-sourced sustainable energy, helping make our power grid more secure and less congested, and also curb pollution.

SHREC Creation Process



SHREC 2019-1
Transaction Overview

CONNECTICUT GREEN BANK

- The Connecticut Green Bank has engaged RBC Capital Markets as sole structuring and placement agent on its inaugural asset-backed security transaction, backed by cash flows received from SHRECs.
- The Green Bank offers incentives to homeowners and third-party owners to install solar photovoltaic (PV) systems.
  - In exchange for its incentives, the Green Bank receives all rights and title to the Class I RECs generated from the systems.
- Under a new MPA between the Green Bank and Connecticut's two Investor-Owned Utilities (Eversource and United Illuminating, collectively the "Utilities"), the Green Bank aggregates SHRECs generated from solar PV systems participating in its RSIP into tranches, and sells those SHREC tranches to the Utilities at a predetermined price over a 15 year tranche lifetime.
  - Eversource is rated A3/A+ (M/S)
  - United Illuminating is rated Baa1/A- (M/S)
- For SHREC 2019-1, the Green Bank will contribute Tranches 1 and 2, which comprise:
  - 14,027 solar PV systems
  - 109 MW
  - 21% homeowner and 79% third-party owner (% of discounted solar asset balance)
  - MPA prices of $50/SHREC for Tranche 1 and $49/SHREC for Tranche 2

What is the impact of the SHREC Bond?
What is the impact investors would have?

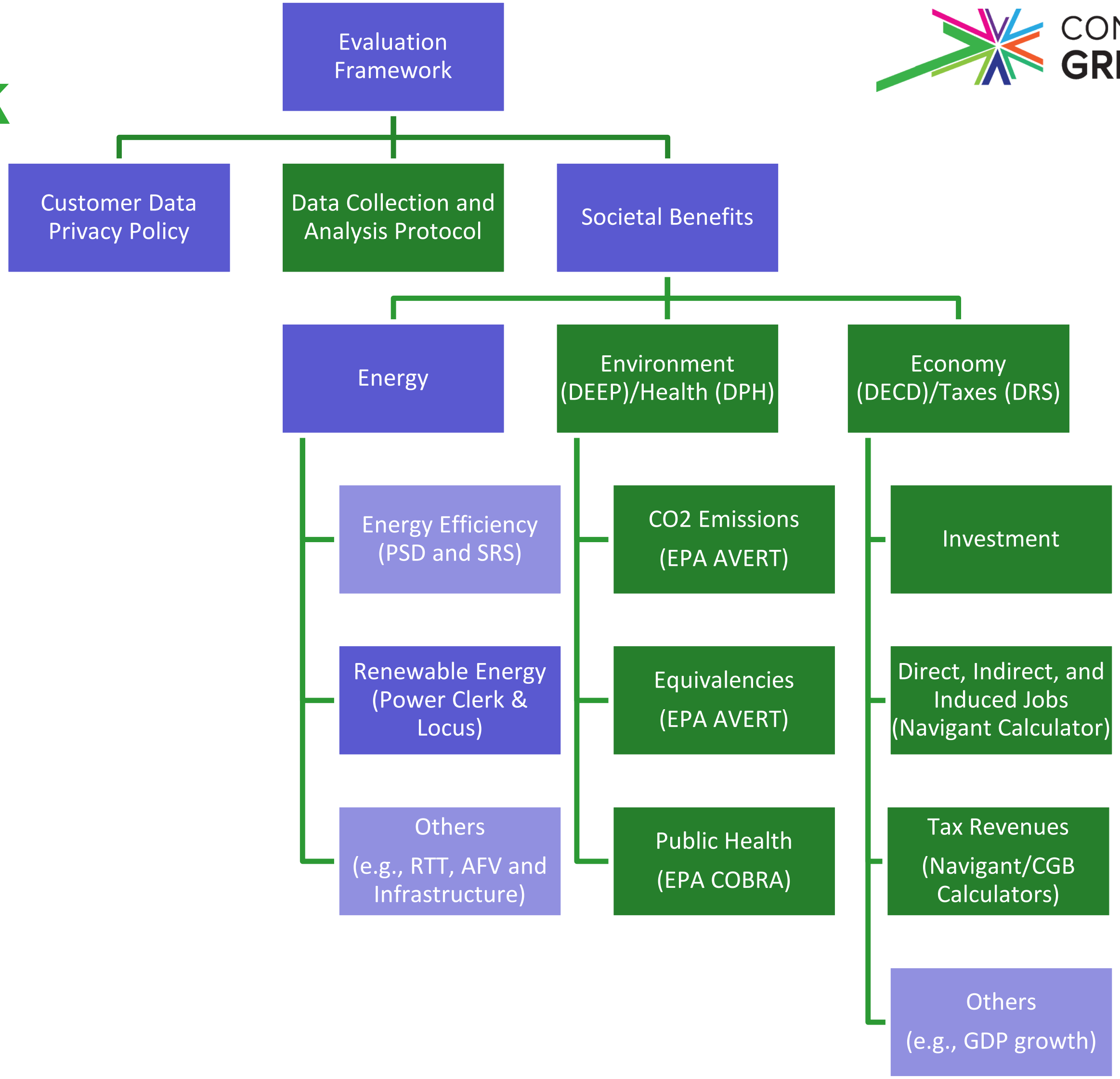
Approach

CONNECTICUT GREEN BANK

- **Bonds assessed and rated per climate bonds initiative standards**
  - The Green Bank engaged Kestrel Verifiers to perform the assessment
  - Certified as a climate bond

- **Getting a label is great but investors want to know, what Impact did they achieve?**
  - What exactly have these bonds achieved?
  - How much greenhouse gas emissions were avoided? How much cleaner is the air because of these investments?
  - What were the public health impacts?
  - What were the economic impacts?

Evaluation Framework



AFV: Alternative fuel vehicle
AVERT: AVoided Emissions and geneRation Tool
COBRA: CO-Benefits Risk Assessment
DEEP: Connecticut Department of Energy and Environmental Protection
DPH: Connecticut State Department of Public Health
DECD: Connecticut State Department of Economic and Community Development
DRS: Connecticut State Department of Revenue Services
GDP: Gross domestic product
PSD: Program Savings Document
RTT: Renewable Thermal Technologies
SRS: Sustainable Real Estate Solutions

Environmental Impact Fact Sheets

EVALUATION FRAMEWORK
SOCIETAL PERFORMANCE

CONNECTICUT GREEN BANK

Environmental Impact Overview

An important measurement of success for the Connecticut Green Bank (Green Bank) and its programs is how our investment activity improves the air quality of the state. This will be measured by the decrease in the amount of nitrogen oxides (NO_x), sulfur dioxide (SO_2) and carbon dioxide (CO_2) and particulate matter emitted by the region's fossil fuel electric generation or transportation due to Green Bank projects.

The Green Bank will use the US Environmental Protection Agency's (EPA) Avoided Emissions and Generation Tool (AVERT) to calculate and report on the environmental benefits of the Green Bank's clean energy investment activity in Connecticut.

Estimated Generation/Savings for 2016 is calculated by using the Avert emissions factors in **Table 1**:

Table 1: AVERT Factors

Technology	CO_2 tons / MWh	NO_x lbs / MWh	SO_2 lbs / MWh
Solar PV	0.5621	0.5754	0.4107
Energy Efficiency	0.5432	0.4803	0.3397
Energy Efficiency/PV	0.5528	0.5285	0.3754
Wind	0.5372	0.4284	0.3333

Using this method, the following is an example of changes to emissions based on 60 MW additions of either clean generation or improved energy efficiency:

Table 2: AVERT Examples

Capacity:	60 MW			
Technology	Annual expected generation change (MWh)	CO_2 savings (tons)	NO_x savings (lbs)	SO_2 savings (lbs)
Solar PV	79,220	44,520	45,580	32,480
Energy Efficiency	63,090	34,260	30,300	21,430
Wind	104,930	56,370	44,920	34,980

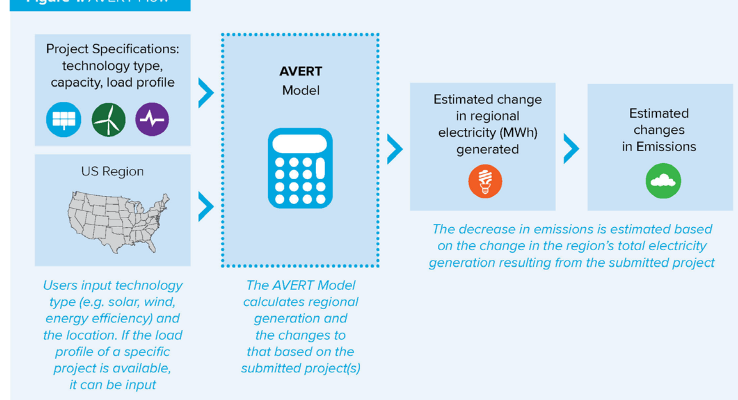
Using the type of calculation outlined above, the Green Bank will include Societal Perspective benefits as well as the environmental impact of its programs in its Comprehensive Annual Financial Report, green bonds issuances, and other communications. Further information about AVERT is available at: https://www.epa.gov/sites/production/files/2015-08/documents/avert_decision_makers_fact_sheet_2-13-14_final_508.pdf

Methodology

Previously, the Green Bank and its predecessor, the Connecticut Clean Energy Fund, estimated these impacts by using the results of the 2007 New England Marginal Emission Rate Analysis to calculate the expected annual and lifetime kWh savings of energy and production of clean energy. After working with the Connecticut Department of Energy and Environmental Protection (DEEP) and the US Environmental Protection Agency, the Green Bank has adopted the EPA's Avoided Emissions and Generation Tool (AVERT) to calculate the air quality benefits associated with Green Bank projects.

AVERT is a complex model that represents the dynamics of electricity dispatch based on the history of actual generation in a selected year for a specified region. For Green Bank purposes, the model generates the expected annual change to regional electricity generation based on a specific clean energy project or projects, then calculates the decline in emissions based on the reduction in resources required. The graphic below is a simplified representation of the model.

Figure 1: AVERT Flow



To maximize the model's accuracy, the Green Bank has derived average project emissions factors by technology (solar, wind, EE) from its completed projects. It then applies these factors to the annual projected generation for individual projects to calculate the estimates of the expected NO_x, SO_2, and CO_2 savings. The Green Bank will update these factors annually based on changes to the regional generation profile and typical project sizes.

Green Bank's Calculations

CONNECTICUT GREEN BANK

- **Energy Impact:**
  - 109 MW Installed Capacity
  - 123,944 MWh annual expected generation
  - 3,098,610 MWh expected lifetime generation

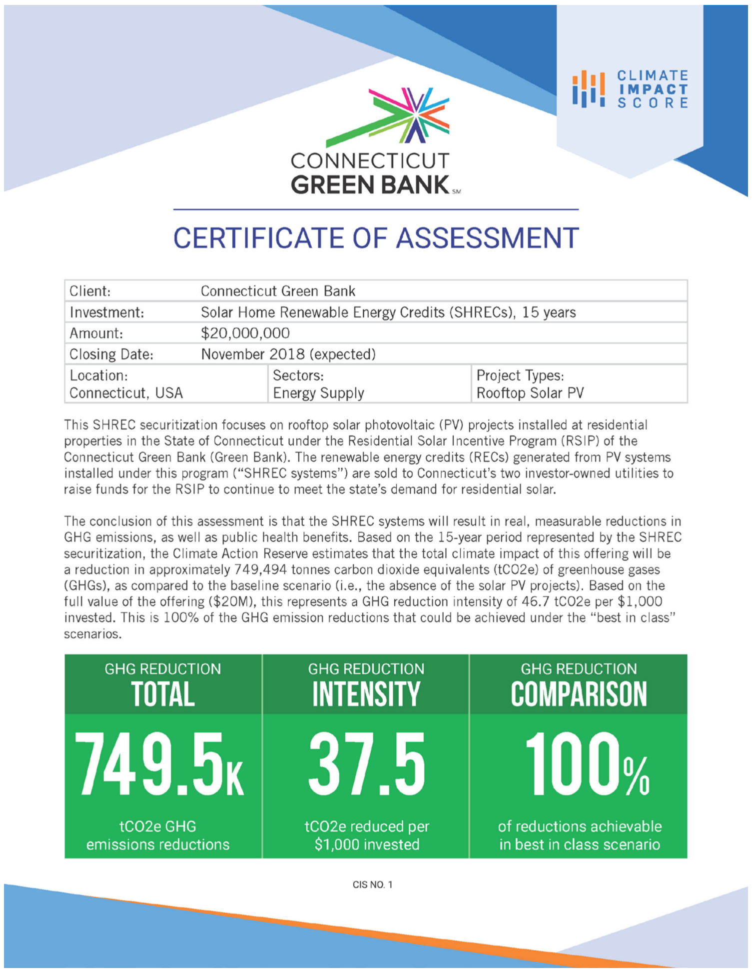
- **Economic Impact:**
  - $39.7 million in Green Bank investment led to 384 million in private investment (10.68 leverage)
  - Created 5,693 Job Years (2,241 direct and 3,452 indirect and induced)

- **Environmental Impact:**
  - Annual Emissions avoidance: 69,322 Tons CO_2, 71,821 lbs NO_x, 57,598 lbs SO_2, 6,038 lbs $PM_{2.5}$
  - Lifetime Emissions avoidance: 1,733,056 Tons CO_2, 1,795,513 lbs NO_x, 1,439,947 lbs SO_2, 150,943 lbs $PM_{2.5}$

But are these independent?

CO_2: Carbon dioxide
NO_x: Nitrogen oxides
SO_2: Sulfur dioxide
$PM_{2.5}$: Particulate matter

Climate Impact Score



CLIMATE IMPACT SCORE

CONNECTICUT GREEN BANK

CERTIFICATE OF ASSESSMENT

Client:	Connecticut Green Bank	
Investment:	Solar Home Renewable Energy Credits (SHRECs), 15 years	
Amount:	$20,000,000	
Closing Date:	November 2018 (expected)	
Location: Connecticut, USA	Sectors: Energy Supply	Project Types: Rooftop Solar PV

This SHREC securitization focuses on rooftop solar photovoltaic (PV) projects installed at residential properties in the State of Connecticut under the Residential Solar Incentive Program (RSIP) of the Connecticut Green Bank (Green Bank). The renewable energy credits (RECs) generated from PV systems installed under this program ("SHREC systems") are sold to Connecticut's two investor-owned utilities to raise funds for the RSIP to continue to meet the state's demand for residential solar.

The conclusion of this assessment is that the SHREC systems will result in real, measurable reductions in GHG emissions, as well as public health benefits. Based on the 15-year period represented by the SHREC securitization, the Climate Action Reserve estimates that the total climate impact of this offering will be a reduction in approximately 749,494 tonnes carbon dioxide equivalents (tCO2e) of greenhouse gases (GHGs), as compared to the baseline scenario (i.e., the absence of the solar PV projects). Based on the full value of the offering ($20M), this represents a GHG reduction intensity of 46.7 tCO2e per $1,000 invested. This is 100% of the GHG emission reductions that could be achieved under the "best in class" scenarios.

GHG REDUCTION TOTAL	GHG REDUCTION INTENSITY	GHG REDUCTION COMPARISON
749.5K	37.5	100%
tCO2e GHG emissions reductions	tCO2e reduced per $1,000 invested	of reductions achievable in best in class scenario

CIS NO. 1

Why the difference with the CGB estimate? Both use AVERT???

- Climate Impact Score uses a more refined estimation of lifetime generation that was slightly different than CGB

- The Climate Impact Score assumes that the grid is cleaning over time and as a whole is getting cleaner so the impact of each system is less in their application of AVERT than in the Green Bank's application

Take-Aways

Green Bank standardizing our forecasts:

- Set guidelines on when we are using P50 and P90 forecasts for different purposes
- Where possible the Green Bank will use actual generation numbers fed to us through Locus and used for filings

Bonds sold April 2 for $38.6 million and the buyers know what their investment achieved

For questions or inquiries please contact:

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Quantifying Air Quality Benefits of Power Sector Transitions using Advanced Interdisciplinary Emissions Modeling

David Abel
University of Wisconsin

Quantifying the Air Quality Benefits of Power Sector Transitions using Advanced Interdisciplinary Emissions Modeling

David Abel, PhD

University of Wisconsin – Madison

Nelson Institute for Environmental Studies

The Holloway Group

Webinar: Electricity Impacts & Emission Benefits of Efficient & Renewable Energy

April 18, 2019

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- Phillip Duran
- Mark Janssen
- Paul Denholm

Energy Analysis and Policy
NELSON INSTITUTE FOR ENVIRONMENTAL STUDIES
WISCONSIN ENERGY INSTITUTE
UNIVERSITY OF WISCONSIN–MADISON

Center for Sustainability and the Global Environment
NELSON INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN–MADISON

WARF
Wisconsin Alumni Research Foundation

HAQAST

NASA

Climate/Weather

Energy Efficiency

Renewable Energy

Health

Buildings

Electricity

Emissions

Air Quality


RESEARCH QUESTIONS & POLICY OBJECTIVES

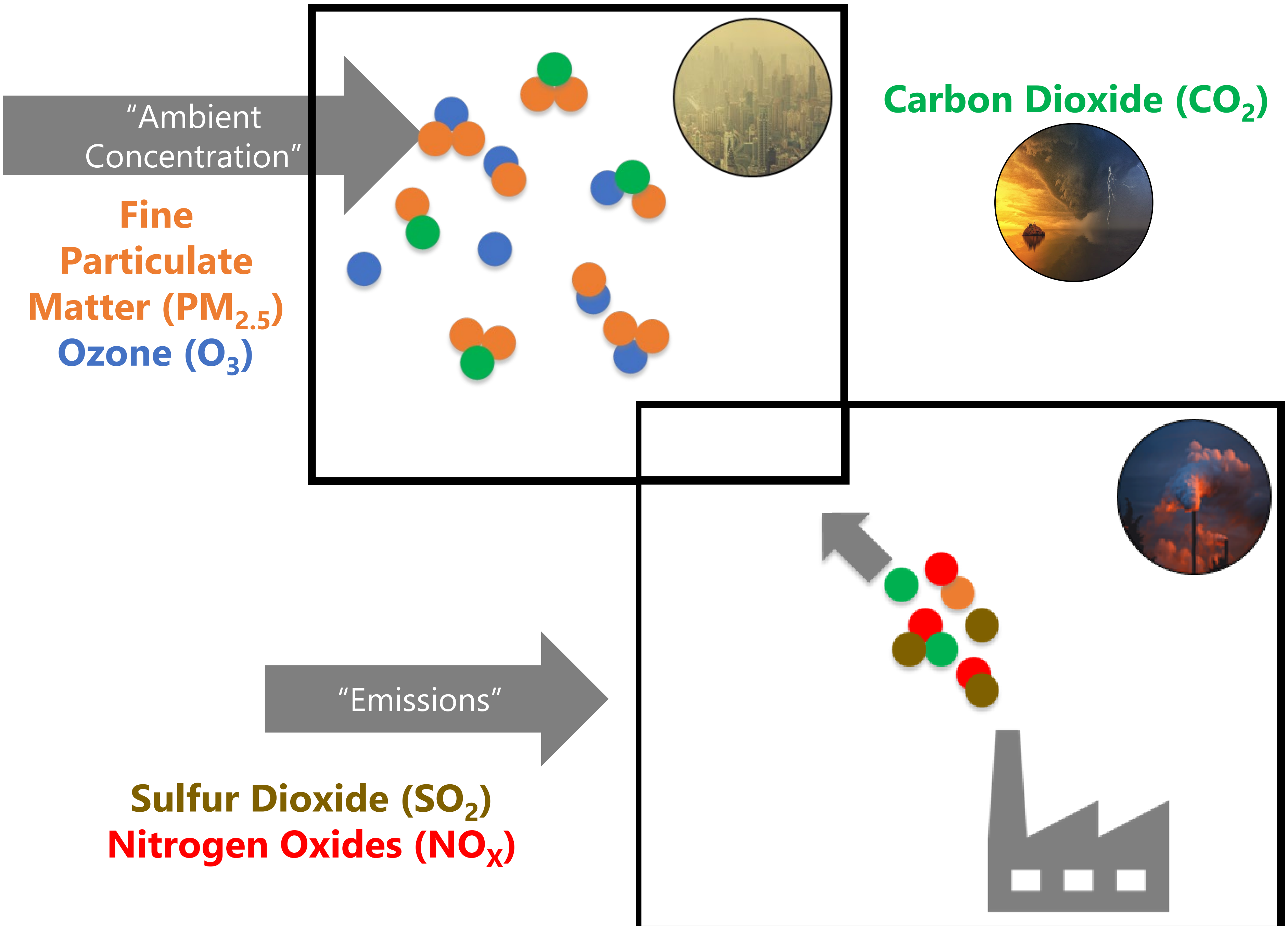
1. Can we improve understanding of the interactions between energy, air, climate, and health?
2. Can we identify and quantify cost-effective win-win solutions?


Buildings

Electricity

Emissions

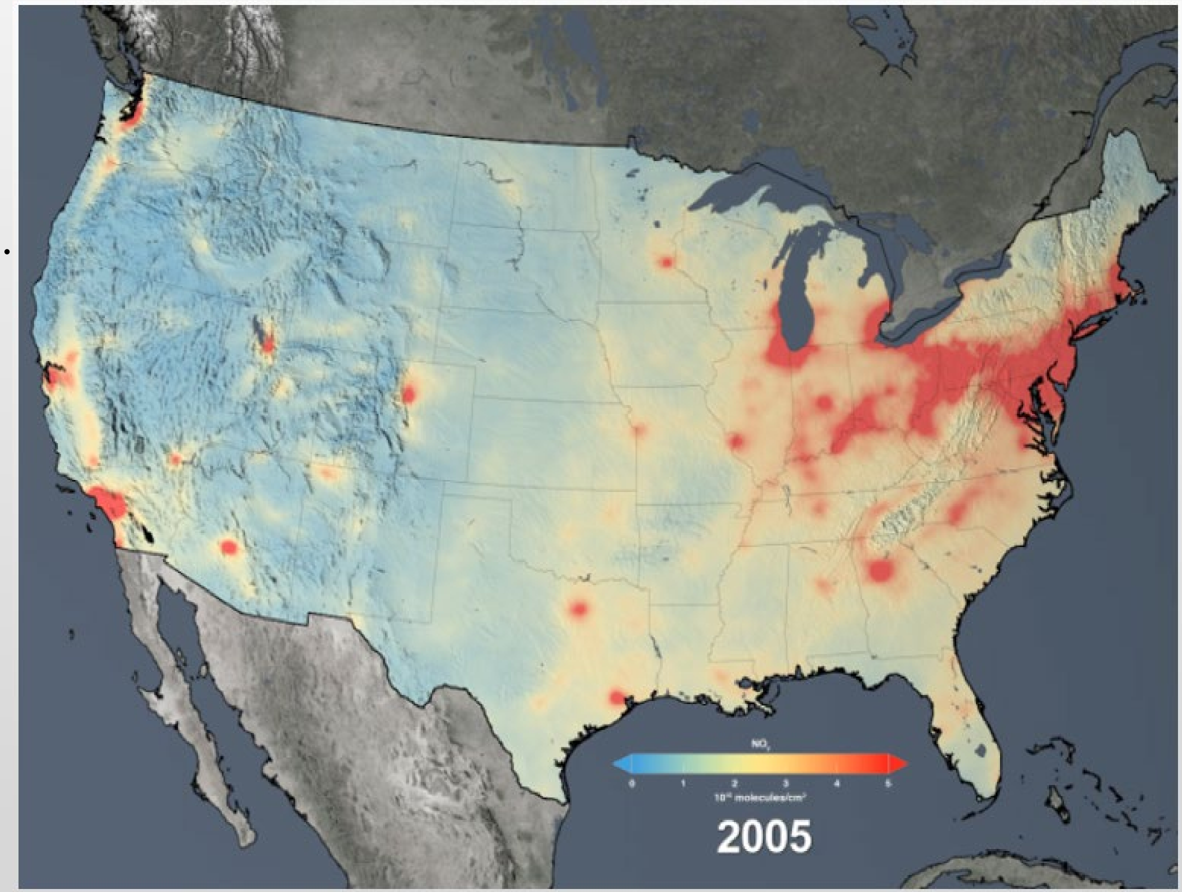
Air Quality



Slide adapted from Tracey Holloway

Why Care?

- **$50 Billion/year** achieving U.S. clean air standards
- ≈**30:1** return in U.S. health benefits
- ≈**100,000 deaths/year** in the U.S.
- **4th highest risk factor** for death globally, ≈7 million deaths/year
- **91% exposed to unhealthy pollution** above World Health Organization air quality guidelines globally.



Lamsal et al., NASA Ozone Monitoring Instrument (OMI), Aura Satellite

World Health Organization | Air Pollution   GBD Compare   EPA | Progress Cleaning the Air and Improving People's Health

Why Care?

- **$50 Billion/year** achieving U.S. clean air standards
- ≈**30:1** return in U.S. health benefits
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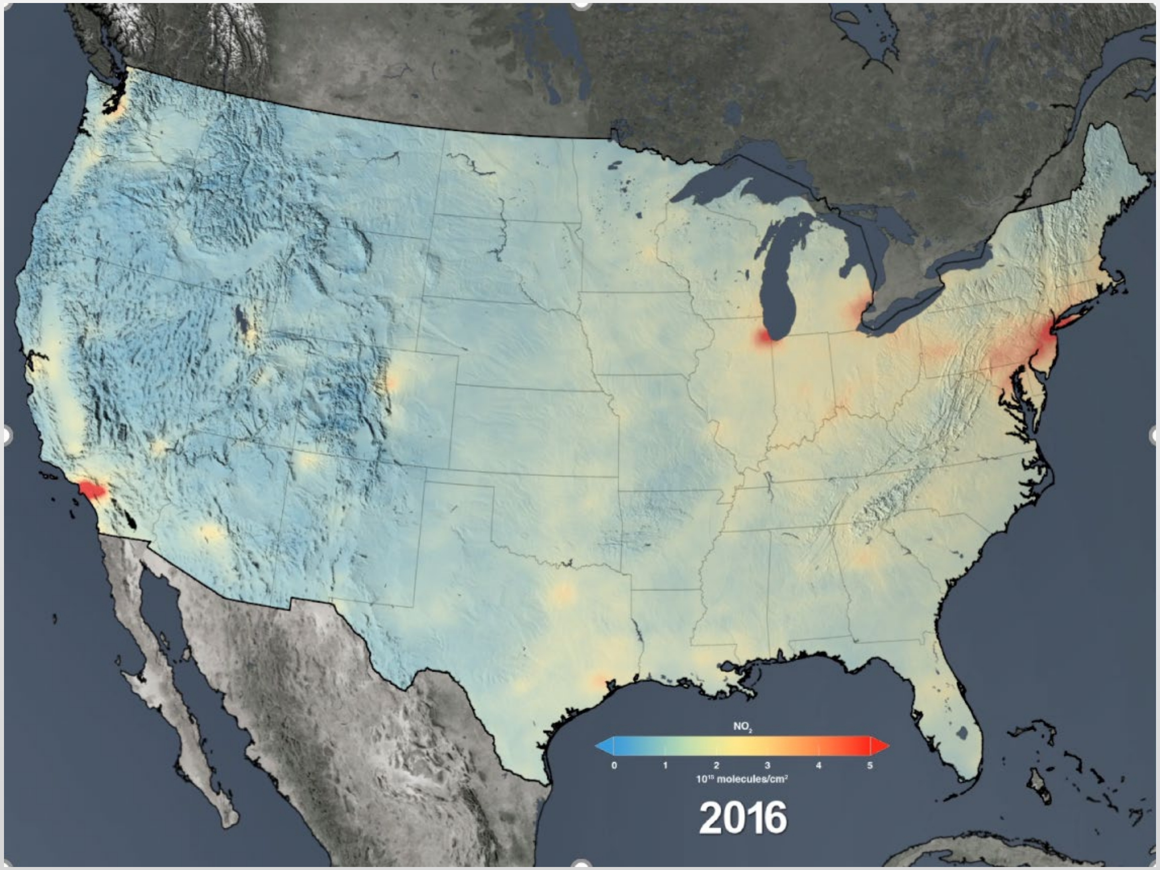


Lamsal et al., NASA Ozone Monitoring Instrument (OMI), Aura Satellite

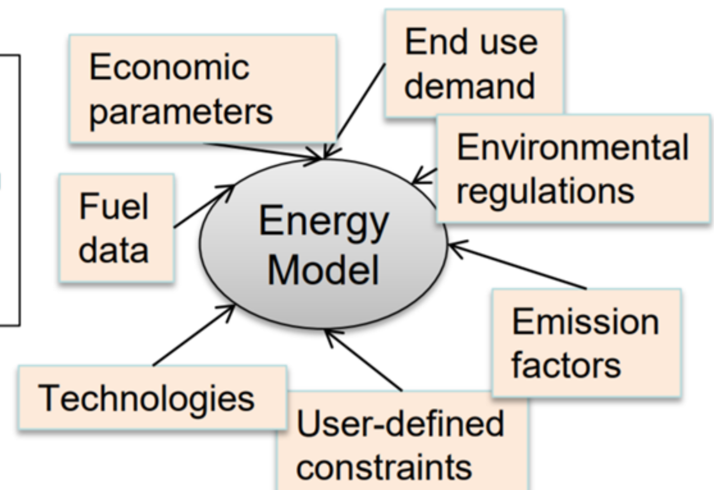
World Health Organization | Air Pollution GBD Compare EPA | Progress Cleaning the Air and Improving People's Health

Energy Modeling & Emissions Quantification (often the most difficult step to integrate into modeling system)

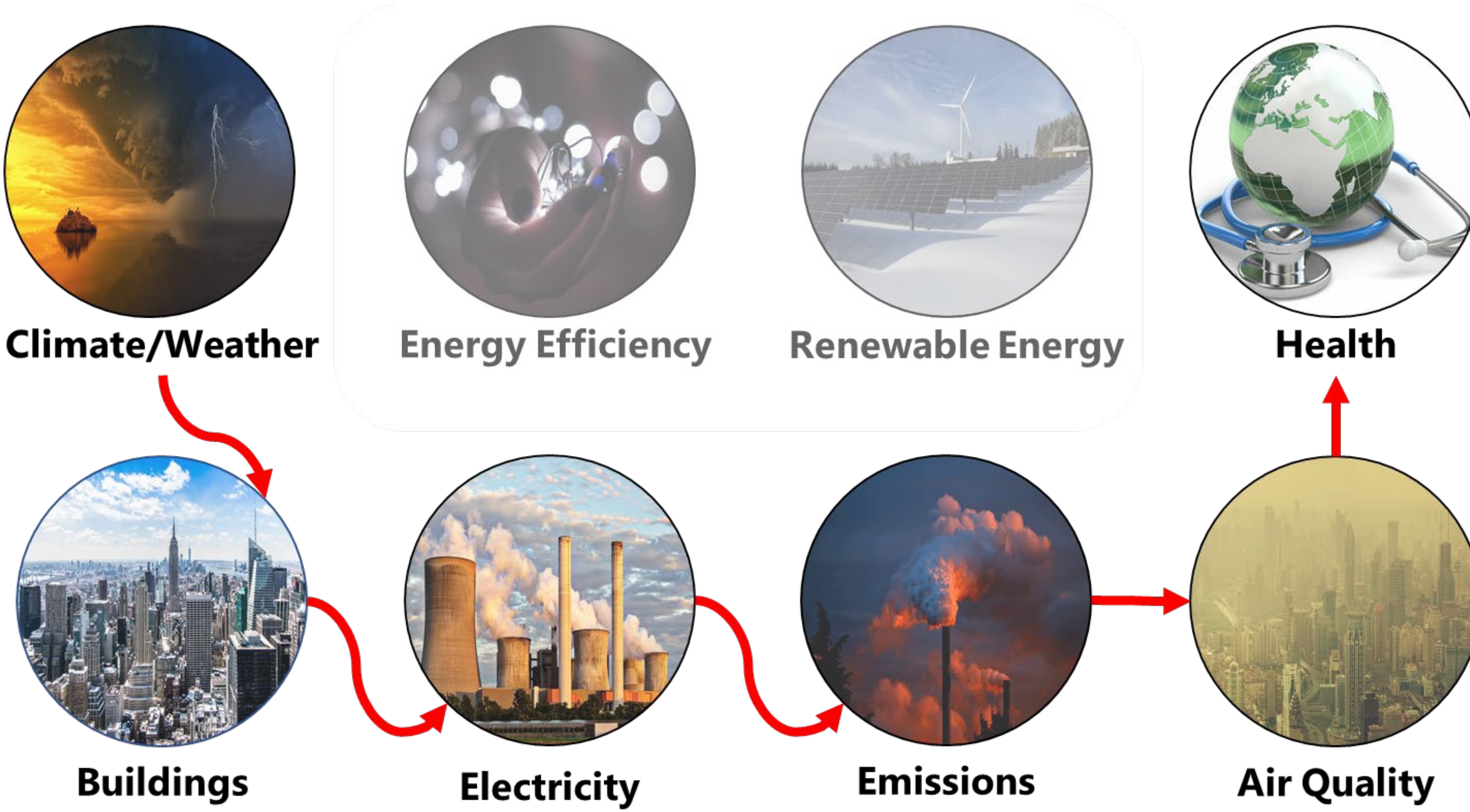
Basic Method	Intermediate Method	Sophisticated Method
eGRID region non-baseload emission rates	Historical hourly emission rates	Energy modeling Dispatch or capacity expansion

Emissions & Generation Resource Integrated Database (eGRID)

AVoided Emissions and geneRation Tool (AVERT)



EPA | AVERT Overview and Step-by-Step Instructions


Climate/Weather
Energy Efficiency
Renewable Energy
Health
Buildings
Electricity
Emissions
Air Quality

PLOS | MEDICINE

RESEARCH ARTICLE

Air-quality-related health impacts from climate change and from adaptation of cooling demand for buildings in the eastern United States: An interdisciplinary modeling study

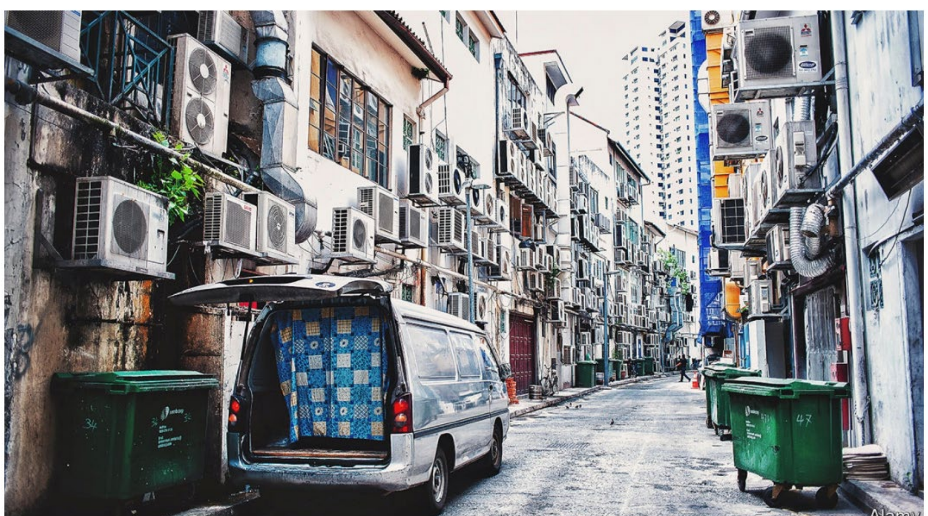
David W. Abel[1]*, Tracey Holloway[1,2], Monica Harkey[1], Paul Meier[3,4,5], Doug Ahl[6], Vijay S. Limaye[1,7], Jonathan A. Patz[1,7]

The Economist

The cost of cool

Air-conditioners do great good, but at a high environmental cost

The rapid growth in their use makes it urgent to limit the damage



nature climate change

research highlights

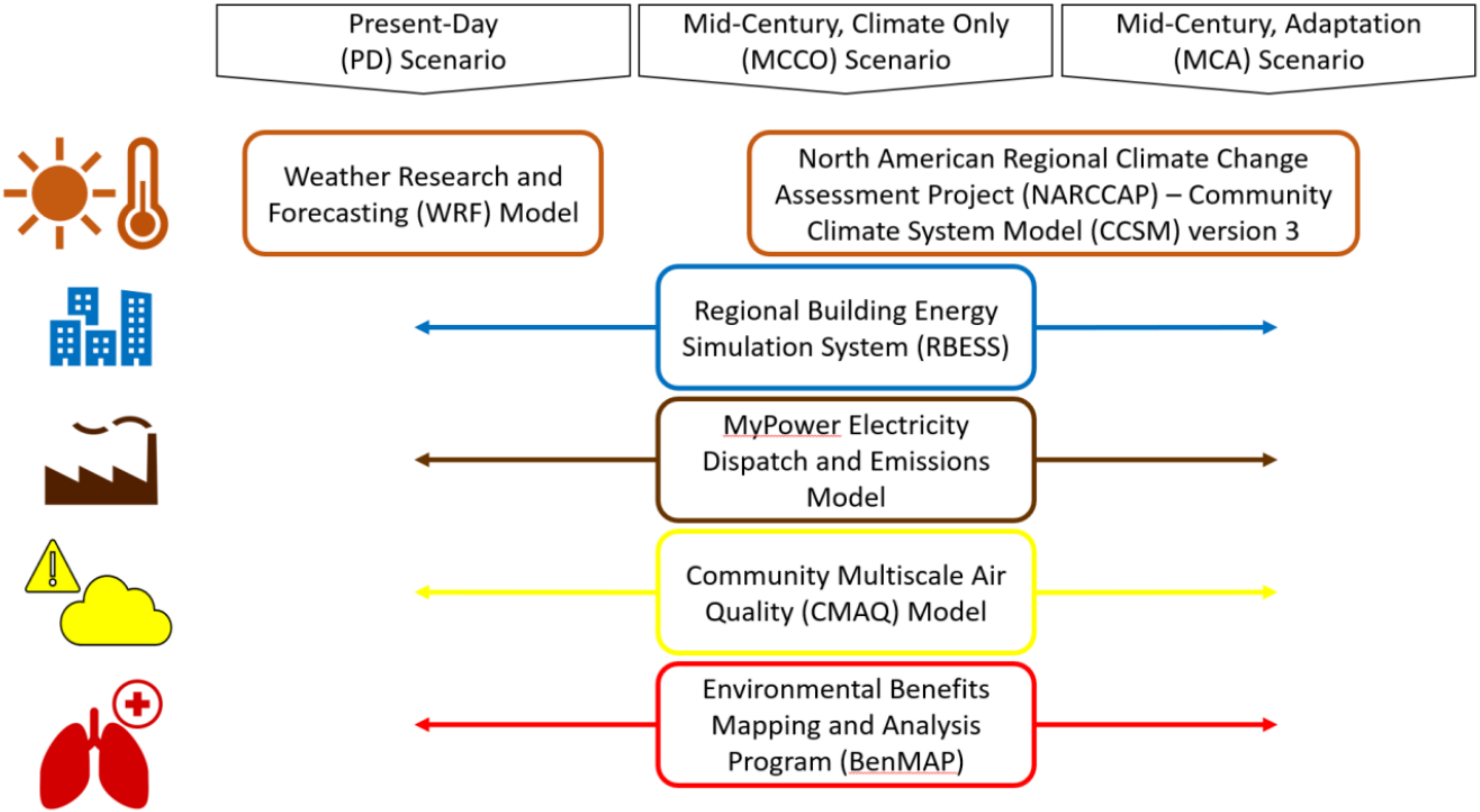
ADAPTATION

Air-conditioned health

PLoS Med. **15**, e1002599 (2018)

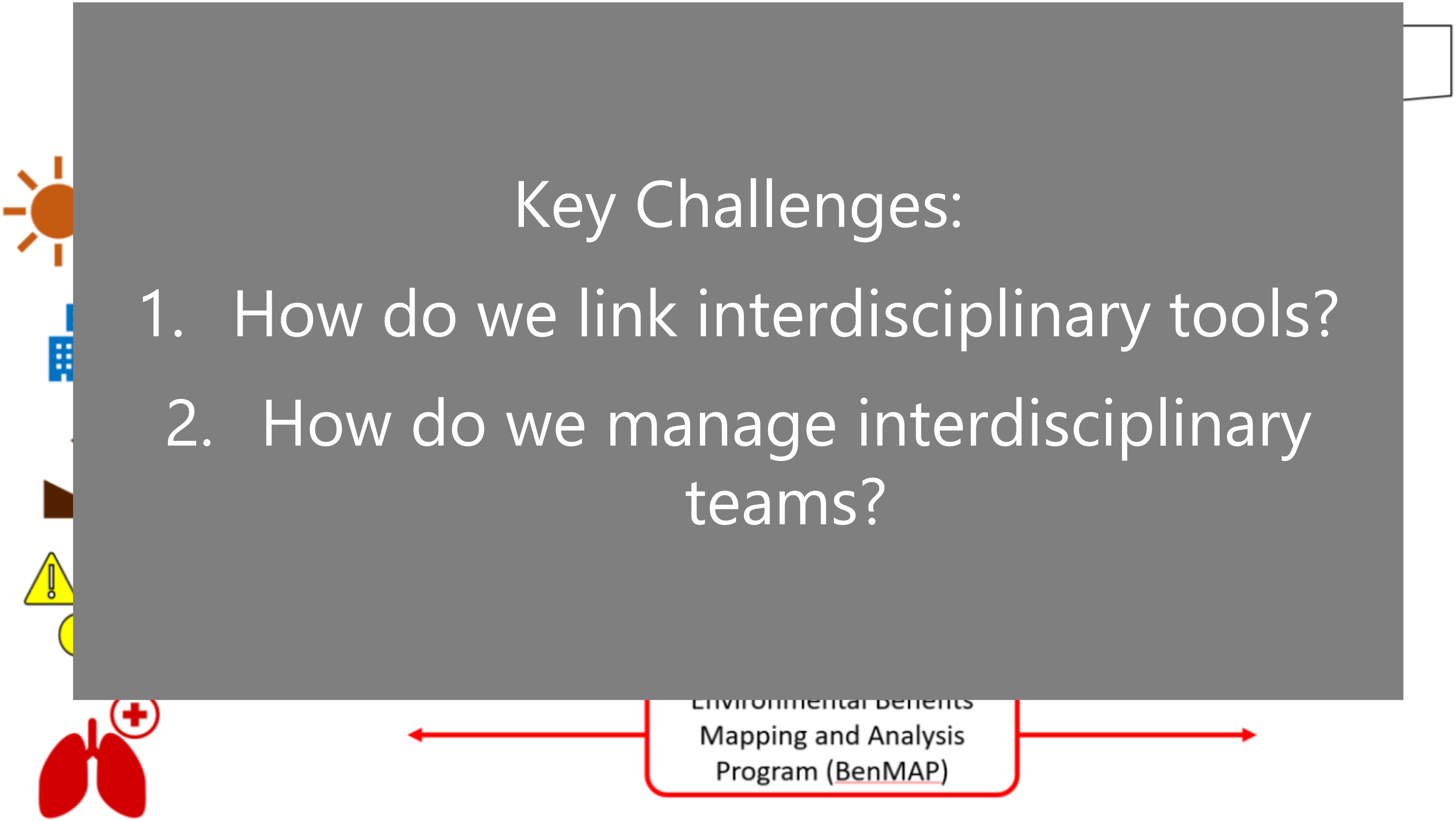
Credit: Kwanchai Lerttanapunyaporn/EyeEm/EyeEm/Getty

Adaptation of Cooling Demand and Air Quality Impacts



Abel et al., *PLOS Medicine* AND Meier et al., 2017, *ERL* AND Schuetter et al., 2014, *ASHRAE*

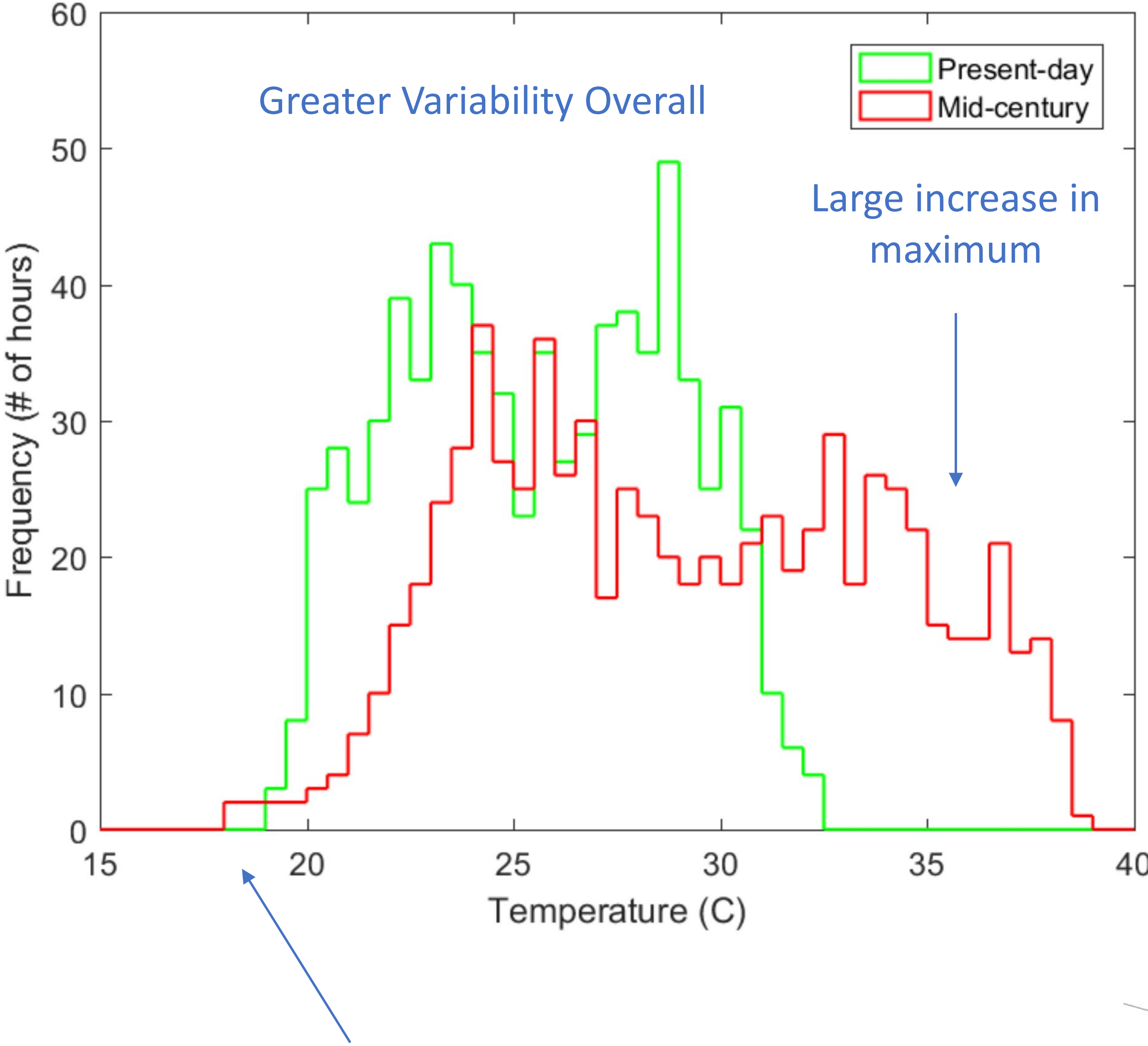
Adaptation of Cooling Demand and Air Quality Impacts



Key Challenges:

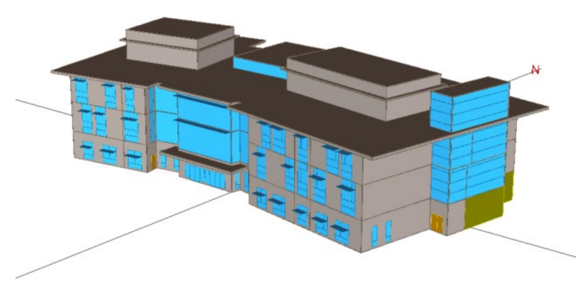
1. How do we link interdisciplinary tools?
2. How do we manage interdisciplinary teams?

Abel et al., *PLOS Medicine* AND Meier et al., 2017, *ERL* AND Schuetter et al., 2014, *ASHRAE*



Small decrease in minimum

39 building prototypes
(85% of energy)

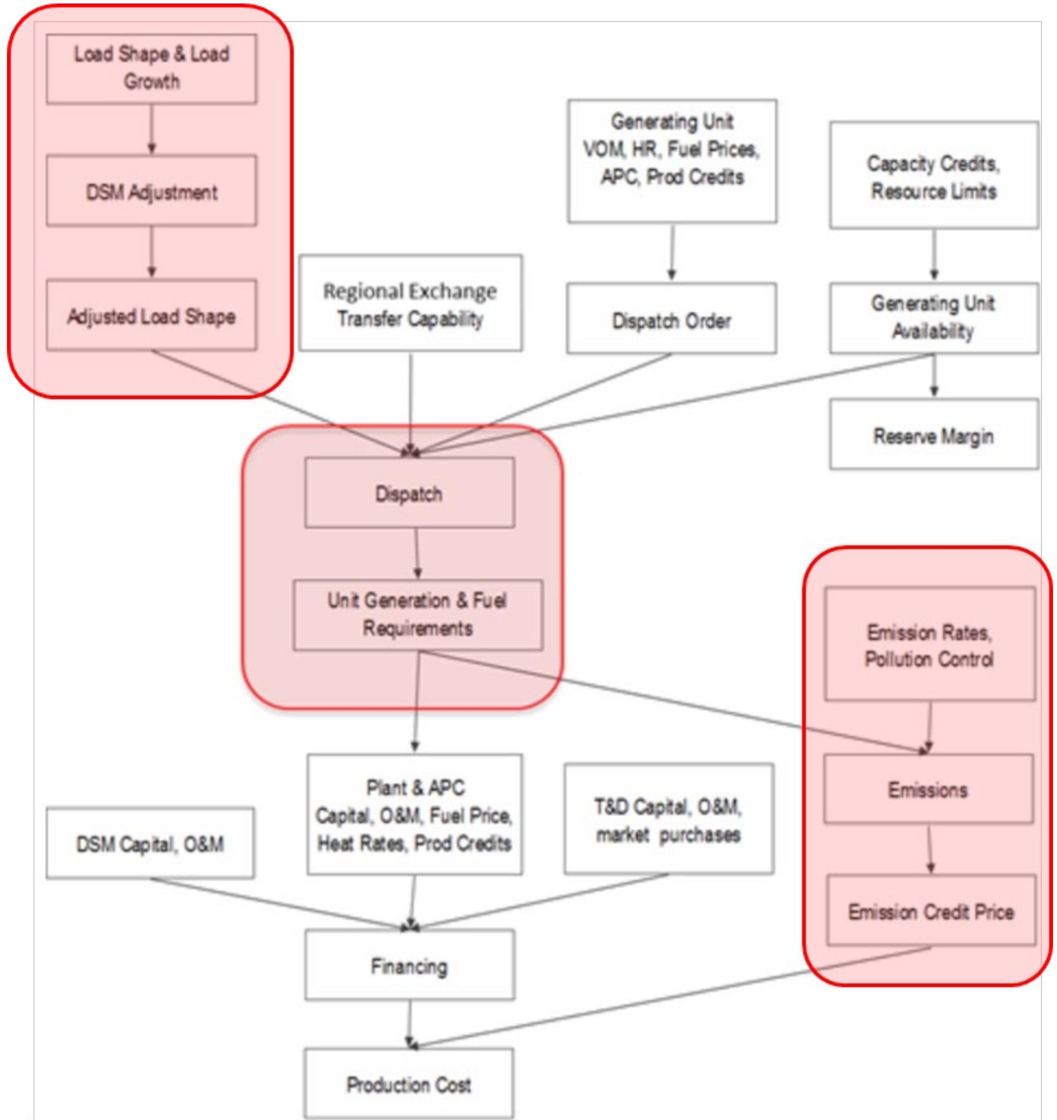


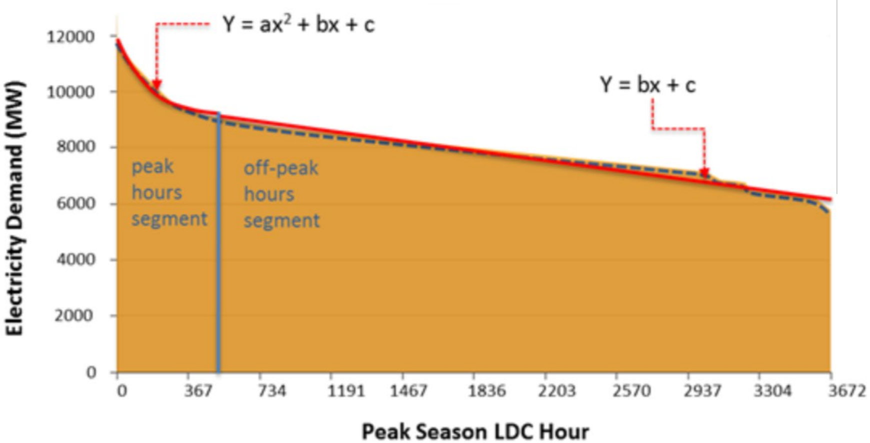
Abel et al., *PLOS Medicine* AND Meier et al., 2017, *ERL* AND Schuetter et al., 2014, *ASHRAE*

Image: https://www.verdicalgroup.com/the-energy-modeling-breakdown/

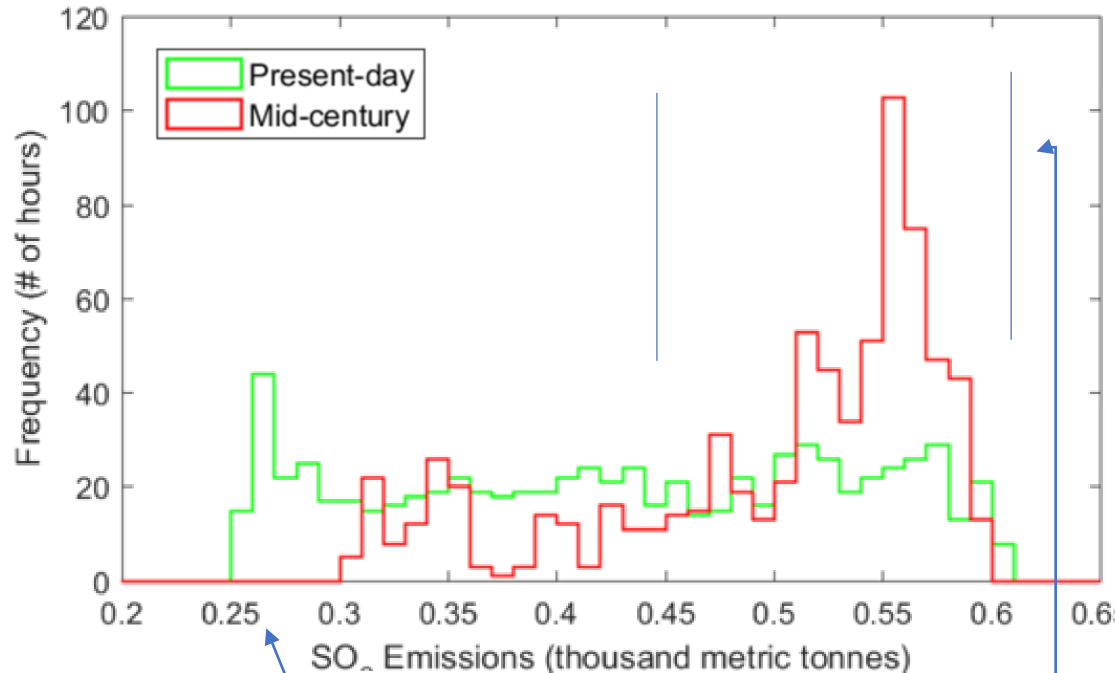
MyPower Model (JuiceBox)

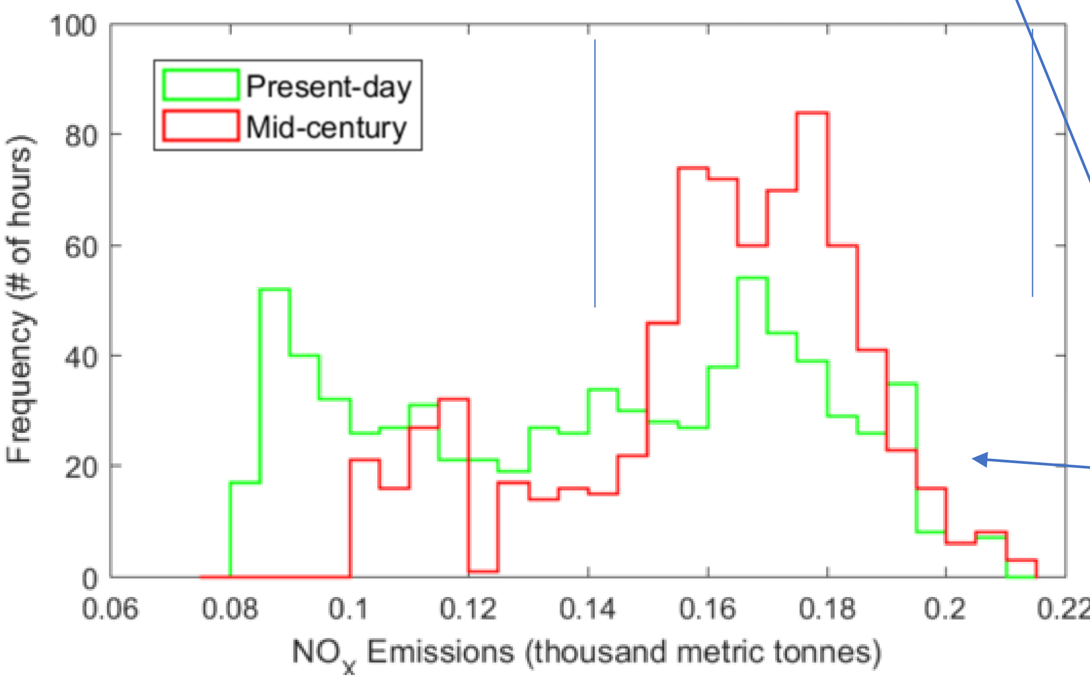
Simultaneous In-Line Calculation of Unit Dispatch and Emissions





New mix of power plants isn't dirtier overall,
but the dirtiest plants run more frequently.

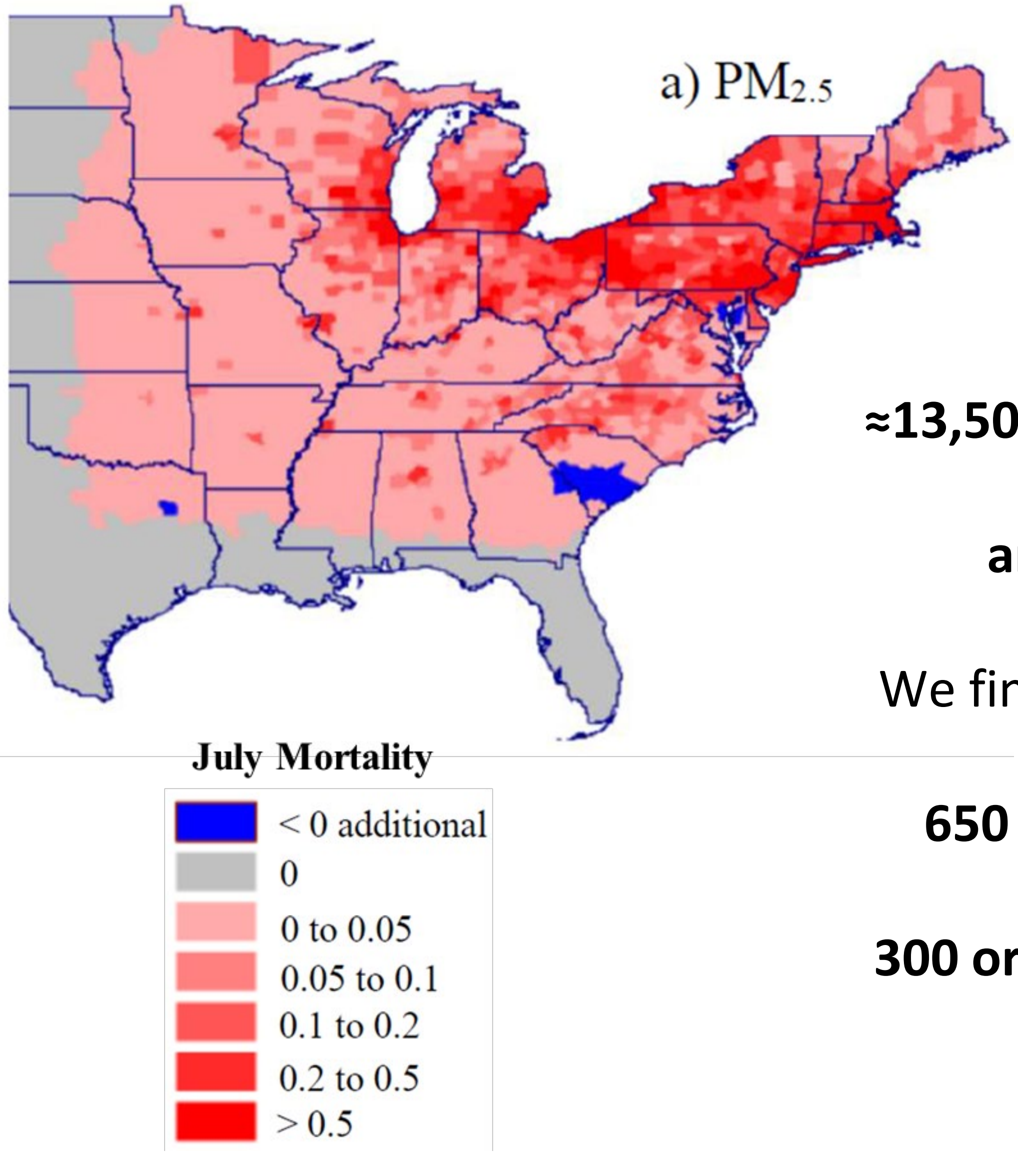




Much greater frequency of hours in upper 50% of range.

Increase in Minimum Emissions
No Change in Maximum Emissions

Abel et al., *PLOS Medicine* AND Meier et al., 2017, *ERL*



Key Findings:

We calculate:

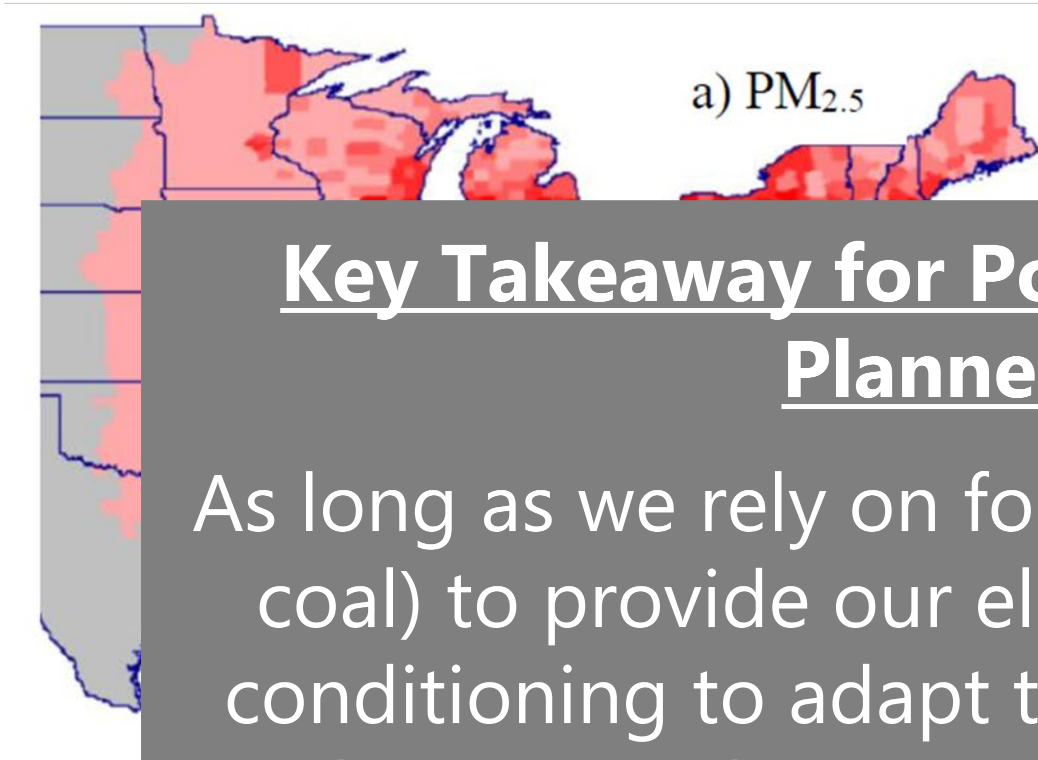
≈13,500 additional deaths annually from $PM_{2.5}$
and ≈3,000 from O_3 exposure.

We find ADAPTATION is responsible for:

650 or 4.8% (≈\$6B) of $PM_{2.5}$-related deaths
300 or 8.0% (≈\$3B) of O_3-related deaths

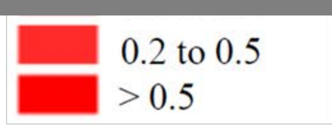
How do we address or manage this?

Abel et al, *PLOS Medicine* AND Meier et al., 2017, *ERL*



<u>Key Takeaway for Policymakers and Planners:</u>

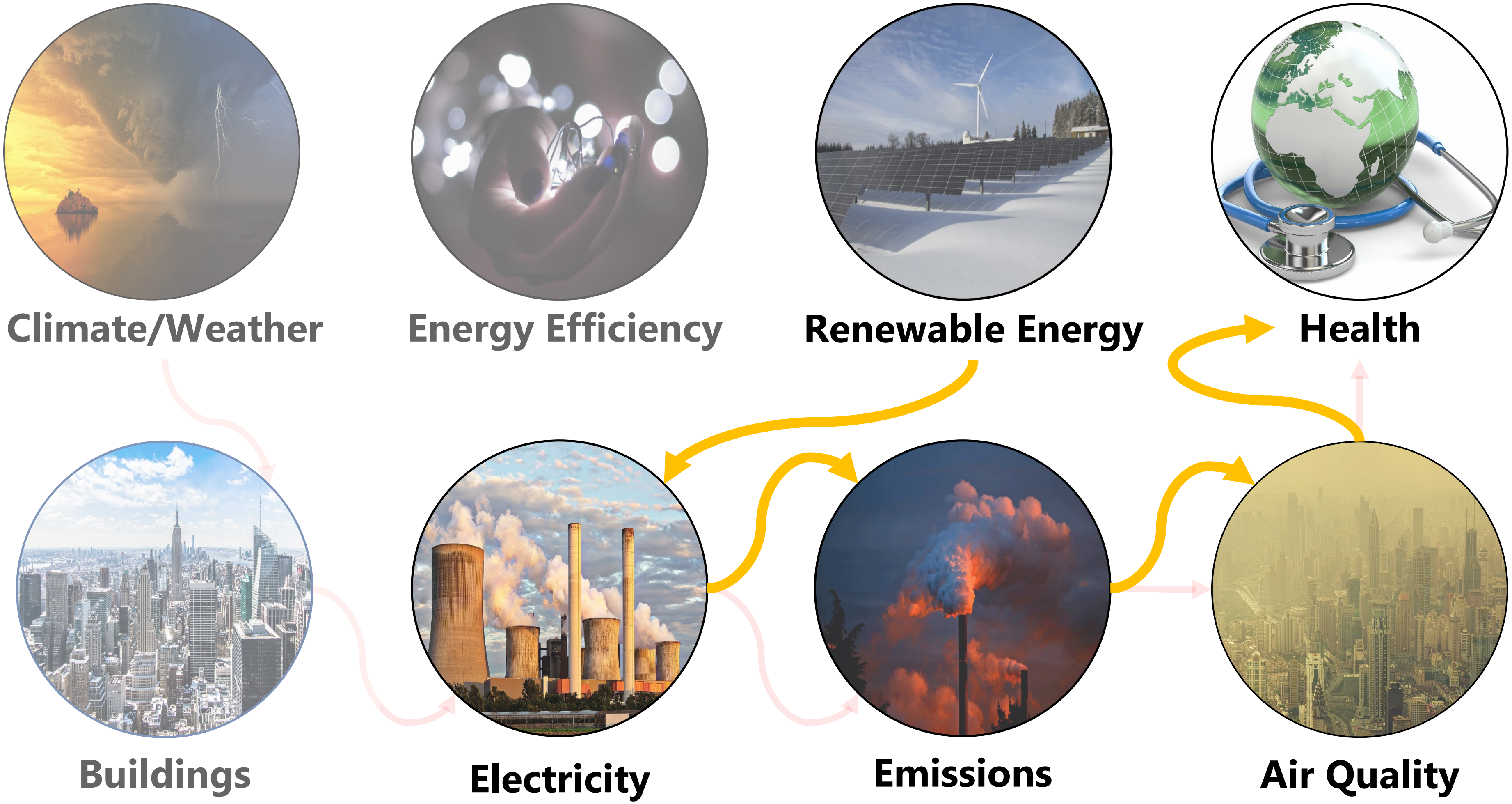
As long as we rely on fossil fuels (especially coal) to provide our electricity, using air conditioning to adapt to warmer climates substitutes adverse air pollution-related outcomes for heat exposure-related outcomes.



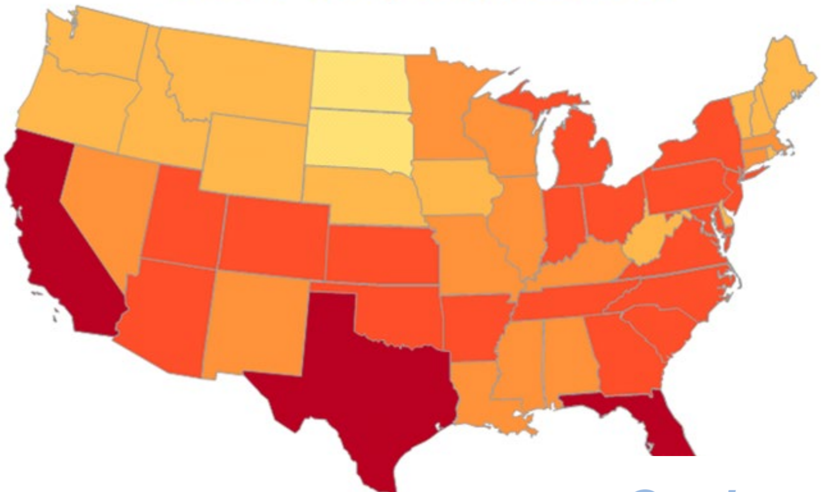
How do we address or manage this?

Abel et al, *PLOS Medicine* AND Meier et al., 2017, *ERL*

Solar Energy for Managing Air Quality



2050 PV Capacity: 632 GW

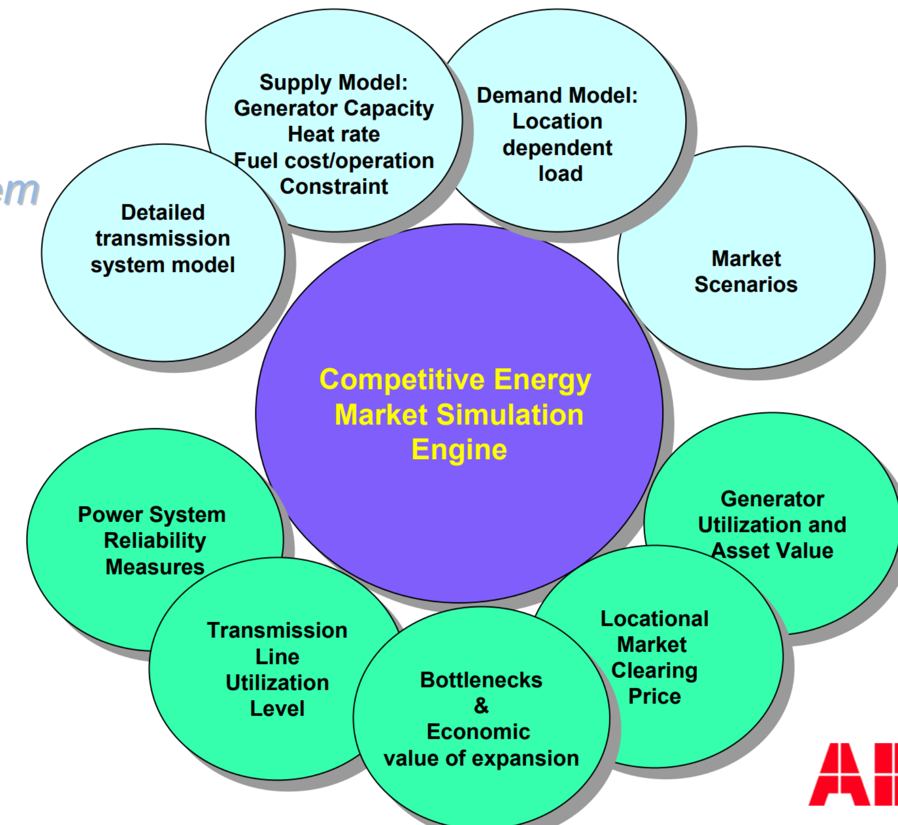


PV Capacity (GW)
< 0.5
0.5 - 1
1 - 5
5 - 10
10 - 30
30 - 50
> 50

The GridView Model

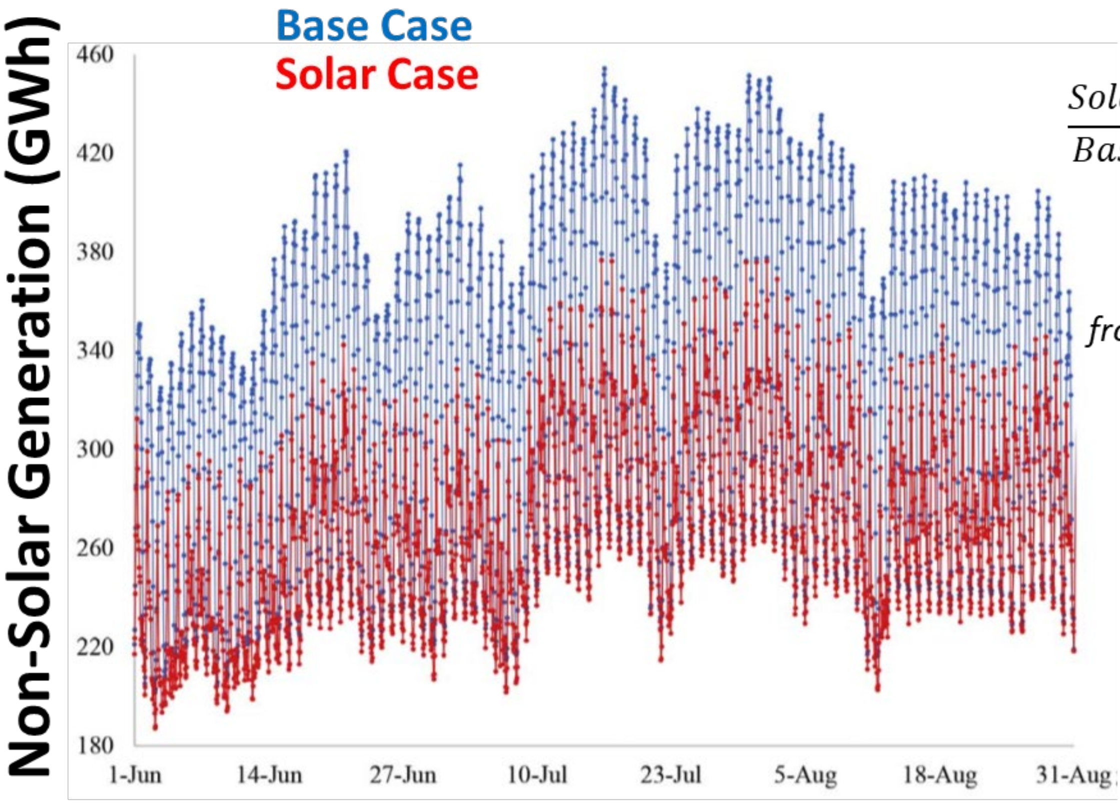
Goal:

Combine Power System Details with Market and Economic Aspects



Abel et al., 2018, *Atmospheric Environment*
PV: Photovoltaic

Solar Case Emissions

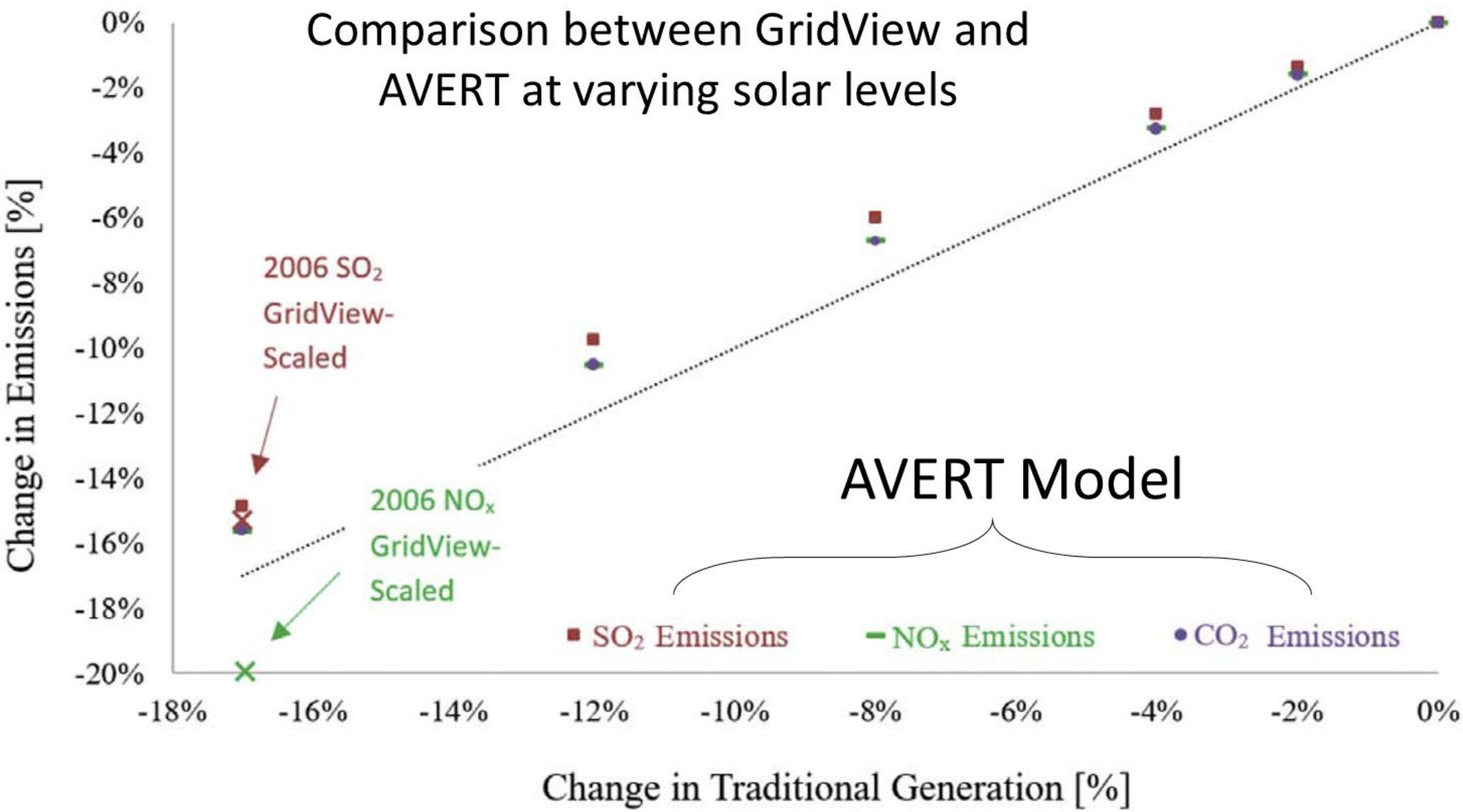


$$\frac{\text{Solar Case Generation}}{\text{Base Case Generation}} \times \text{Base Case Emissions}$$

Base Case Generation: *from GridView*

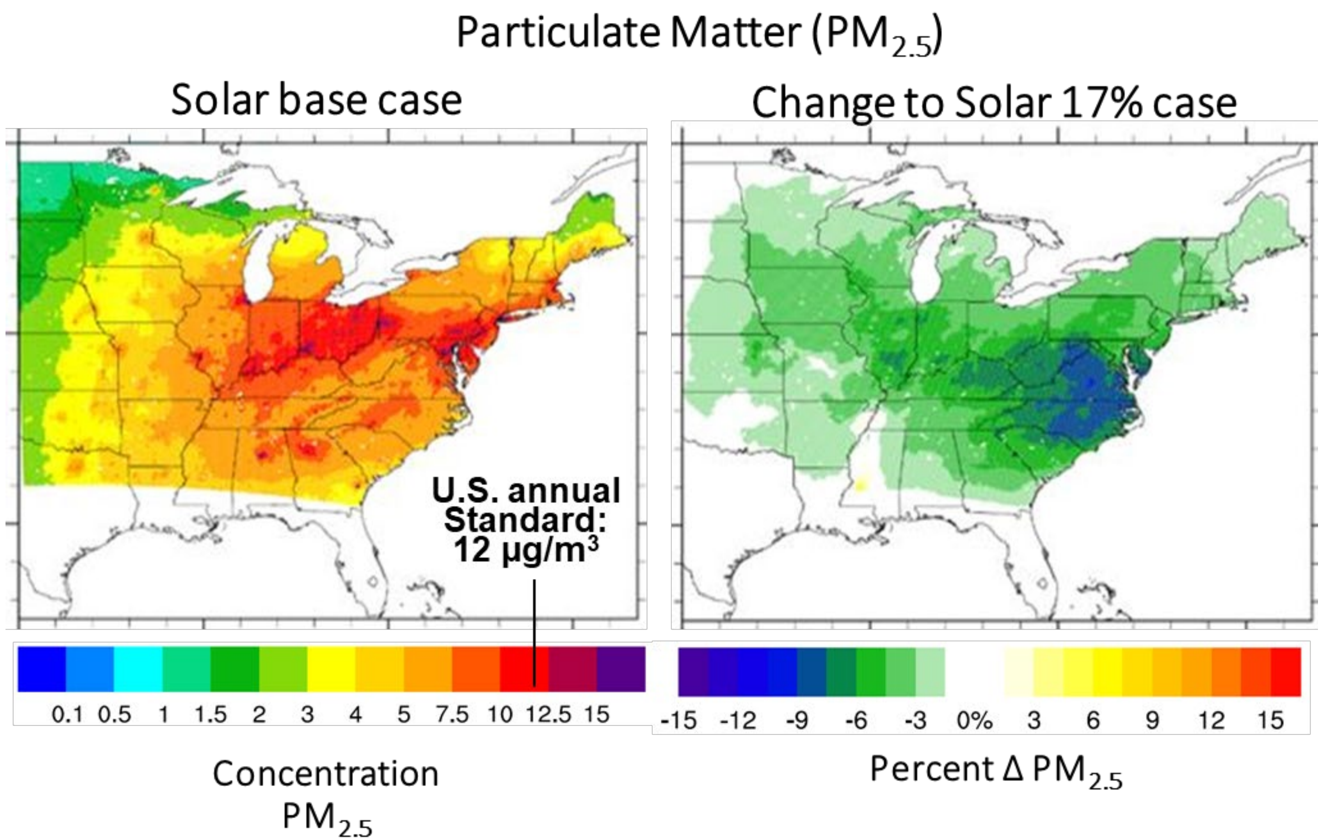
Base Case Emissions: *from EPA's National Emissions Inventory*

	NoPV (tonnes)	PV17 (tonnes)	Difference (tonnes)	Difference (%)
Generation	704 TWh	586 TWh	119 TWh	17%
NO Emissions	250,000	200,000	50,000	20%
NO_2 Emissions	42,000	34,000	8,000	20%
SO_2 Emissions	1,890,000	1,600,000	290,000	15%



Comparison between GridView and AVERT at varying solar levels
0%
-2%
-4%
-6%
-8%
-10%
-12%
-14%
-16%
-18%
-20%
Change in Emissions [%]
2006 SO_2 GridView-Scaled
2006 NO_x GridView-Scaled
AVERT Model
SO_2 Emissions
NO_x Emissions
CO_2 Emissions
-18%
-16%
-14%
-12%
-10%
-8%
-6%
-4%
-2%
0%
Change in Traditional Generation [%]

What are the air and health impacts of expanding solar (17%)?



- **17% solar energy** would reduce $PM_{2.5}$ pollution by **as much as 10% (4.7% average)** over the summer in the Eastern U.S.
- **Health savings of: 1,424 avoided premature deaths ($13.1B)** from $PM_{2.5}$-related causes.

Abel et al., 2018, *Atmospheric Environment*

1. Interdisciplinary computer models of varying complexity are useful for analyzing energy, air, climate, and health.

2. Cost-effective solutions for energy, air, climate, and health management exist

THANK YOU

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Poll 3

United States Environmental Protection Agency

Question and Answer Session

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EPA United States Environmental Protection Agency

Quantifying the Health Benefits of Energy Efficiency and Renewable Energy

May 16, 2019

2 pm Eastern

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