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Solutions for Energy Air, Climate & Health

Center Overview

Michelle Bell, Director (Yale)
Roger Peng, acting Co-Director (JHU)
Ben Hobbs, Co-Director on leave (JHU)

Air Climate & Energy (ACE) Center Grant funded by US Environmental Protection Agency Assistance Agreement No. 83587101

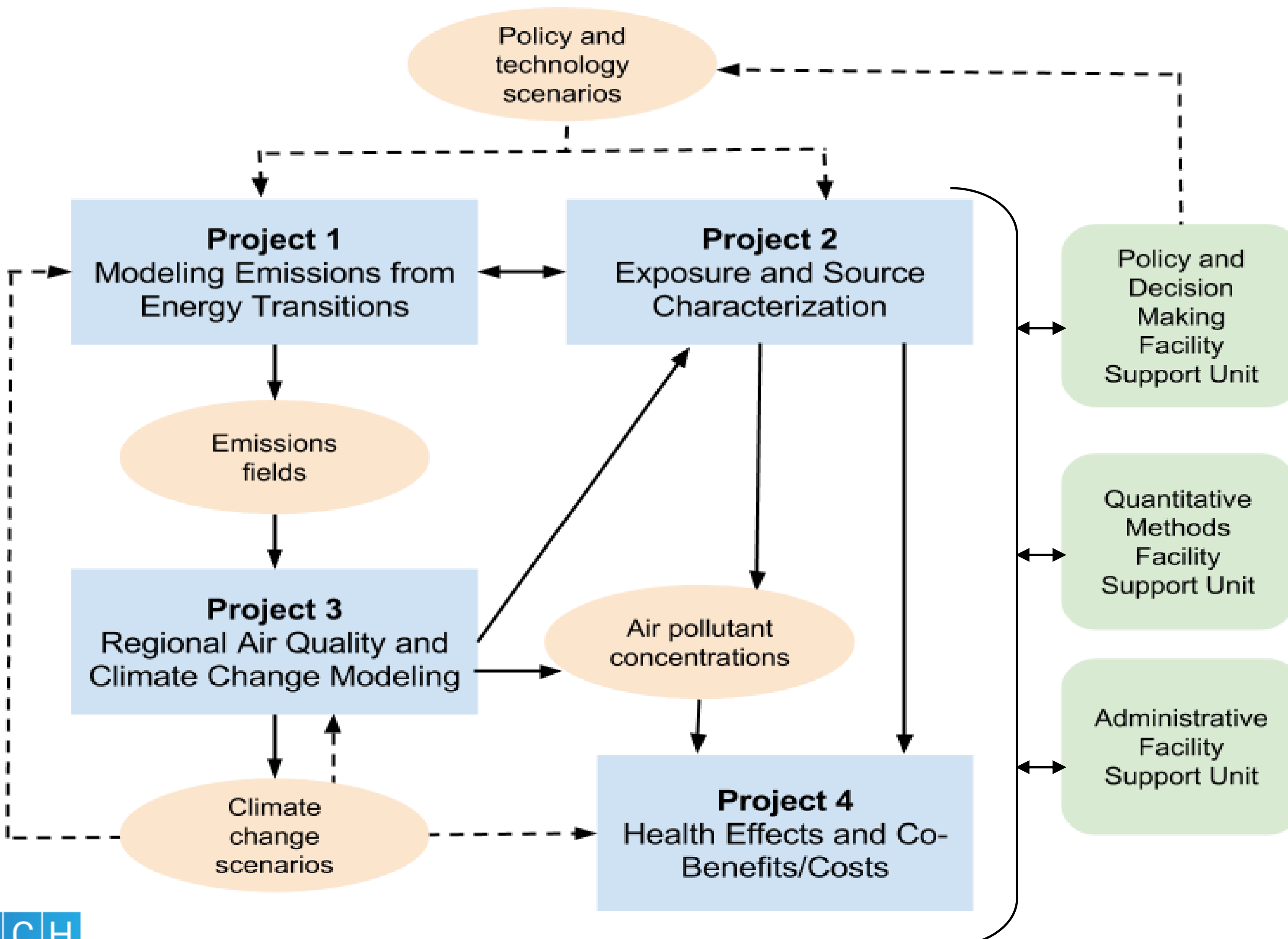
SEARCH Main Objectives

- To investigate energy-related transitions underway across the U.S. by combining state-of-the-science modeling of energy systems, air quality, climate, and health.

- To characterize factors contributing to emissions, air quality and health associated with key energy-related transitions in order to understand how these factors affect regional and local differences in air pollution and public health effects today and under a changing climate.

- To identify key modifiable factors (e.g., transportation, land-use, power generation) and how those factors and their air pollution impacts are likely to change over time.

SEARCH Conceptual Model



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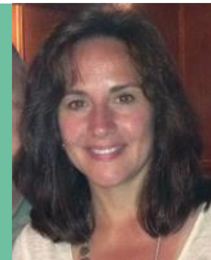

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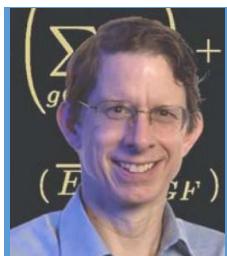


Ben **Ken**

Proj. 1: Energy & Econ modeling


Kirsten **Drew**

Proj. 2: Air pollution measurement & sensors

Yang

Proj. 3: Air & climate modeling

Michelle

Proj. 4: Human health

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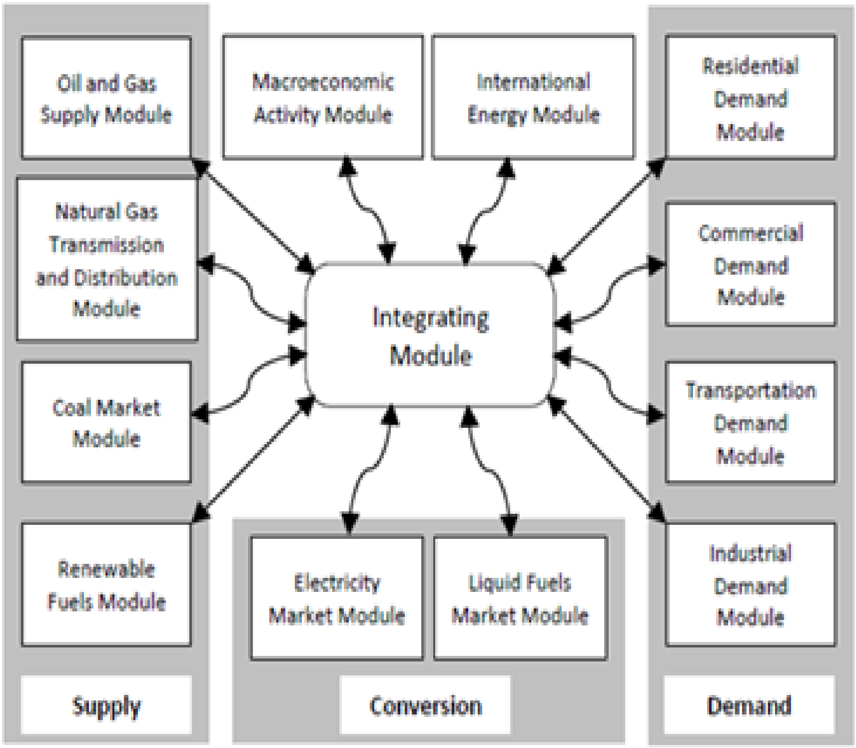
Project 1 – Modeling Emissions from Energy Transmissions

Co-PIs: Ken Gillingham (Yale) and Ben Hobbs (JHU)
With: Julie Zimmerman (Yale), Matt Eckelman (Northeastern),
John Weyant (Stanford), Michael Wara (Stanford), Hugh Ellis (JHU)

Primary Project Objectives:

1. Develop scenarios of major US energy system transitions and their potential interactions with climate change
2. For each scenario, project emissions of a spectrum of pollutants using the National Energy Modeling System (NEMS)
3. Use Life-cycle Assessment (LCA) to incorporate indirect energy use & emissions from the materials processing and manufacturing needed to support new technologies
4. Downscale scenario emissions to temporal & spatial scales needed for air quality simulation
5. Compare downscaled results with results of alternative downscaling approaches for verification

National Energy Modeling System



- Includes 9 Census divisions for most energy sectors
- Emissions for 22 electricity regions
- 12 periods, including 2020, 2030, 2040, and 2050
- Our LCA approach will add resources flows to the model

The level of aggregation necessitates the downscaling to permit air quality simulation

Energy Transition Scenarios

We are modeling several scenarios (with input from the policy & decision-making support team) including combinations of scenarios:

- Baseline – based on AEO 2015
- Shifts in the transportation system to electric vehicles and changes in the amount of driving
- Shift to cleaner marine shipping
- Shift towards greater unconventional oil and natural gas production
- Shift in the electricity grid towards distributed generation and demand response
- Broader shift to a carbon-constrained economy
- Shifts due to climate change

In two workshops, northeast and mid-Atlantic state air regulators provided feedback that helped refine this list

Project 2 - Assessment of Energy-related Sources, Factors, and Transitions using Novel High-resolution Ambient Air Monitoring Networks and Personal Monitors

Co-PIs: Drew Gentner (Yale) & Kirsten Koehler (JHU)
With: Patrick Breysse (CDC), Nicole Deziel (Yale), Howard Katz (JHU), Branko Kerkez (U. Mich.), Jordan Peccia (Yale), Ben Zaitchik (JHU)

Principal Hypothesis: A significant fraction of observed heterogeneity in regional air quality and personal exposure to air pollutants is due to energy-related factors

Key elements:

- Novel portable and stationary multipollutant monitors
- High spatiotemporal monitoring with stationary and personal networks
- Policy-relevant evaluation of how individual and regional energy/sustainability-related choice impact personal exposure and ambient pollution

Project 2 – Objectives:

Objective 1: Develop novel online multipollutant monitors (stationary and portable models) to measure air pollutants and GHGs.

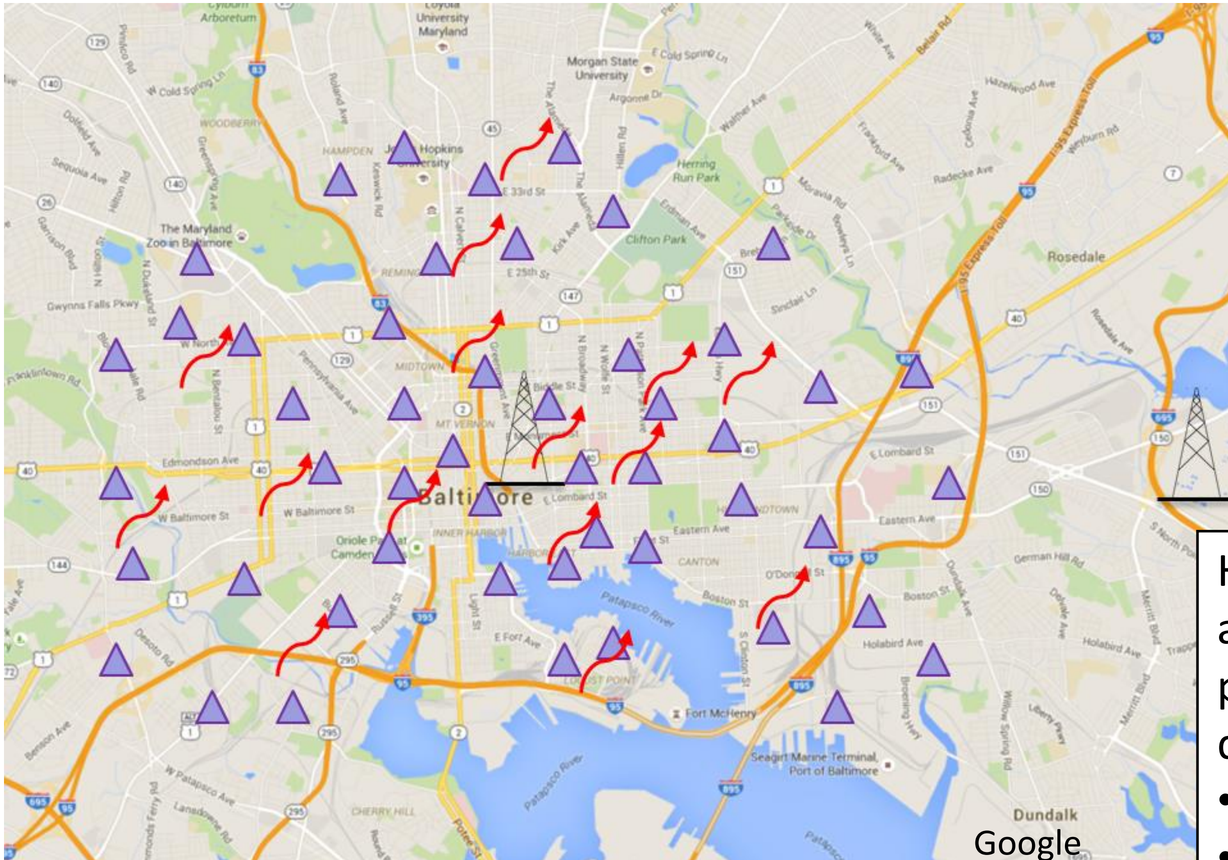
Objective 2: Measure pollutants with high spatiotemporal resolution using a multipollutant stationary monitoring network.

- ~50 monitors at ~100 locations over three years
  - Cover the city of Baltimore
  - Source apportionment for energy-related sources

Objective 3: Measure temporally resolved personal exposures with detailed time-activity information.

- 100 participants (24-hr) with personal multipollutant monitor + GPS
  - 2x by car
  - 2x by bicycle/bus/train

Capturing spatiotemporal heterogeneity



EPA Stations (hourly-weekly data)

Stationary Monitors (time resolution: < hourly)

Portable Monitors (time resolution: < hourly)

High spatial and temporal analyses across multiple platforms are now possible to determine:

- Pollutant dynamics
- Exposure
- Emissions and sources
- Chemistry
- Transport

~50 Stationary monitors with strategic placement across 100 sites in 3 years. Site locations are shown for example only.

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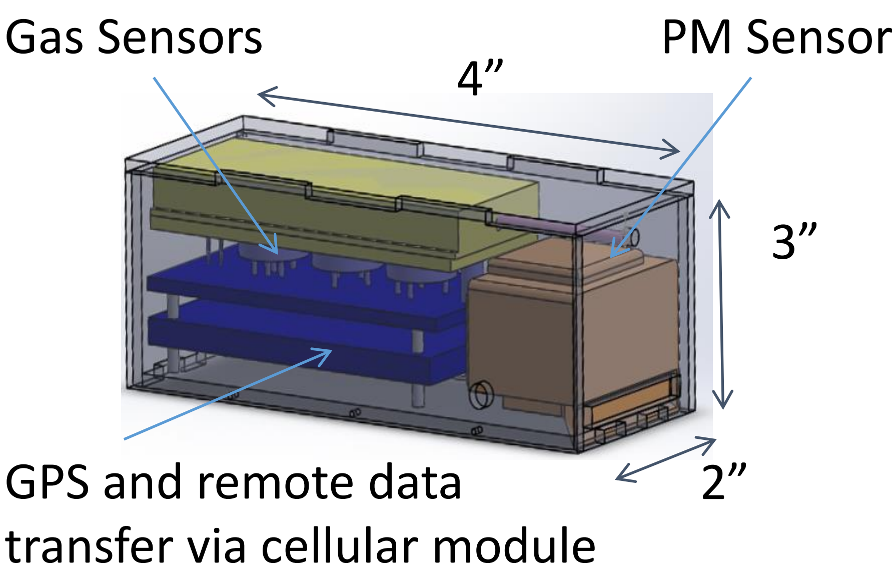
Custom multipollutant monitors for SEARCH

Stationary model: Multipollutant monitor network

Portable model: Wearable multipollutant monitors (no backpack!)



Measured Air Pollutants
Ozone (Tropospheric)
Particulate Matter ($PM_{2.5}$)
Nitrogen Dioxide (NO_2)
Sulfur Dioxide (SO_2) (stationary only)
Carbon Monoxide (CO)
Methane (CH_4)
Carbon Dioxide (CO_2)
Select monitors with sensors for: Size-resolved PM Volatile Organic Compounds Total Oxidative Potential

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What kind of data will we get?

1. **High spatial- and temporal- resolution ambient data**
   - 3 years of hourly or better resolution data at 100 locations
   - Detailed reliability data on low-cost sensor networks
2. **High temporal-resolution data on personal exposures for 100 participants**
   - Personal exposures for multiple pollutants at high temporal resolution paired with GPS for microenvironment analyses
   - Impact of modifiable factors on personal exposures
   - Impact of energy-related sources to personal exposures

There are several cross-project collaborations within our SEARCH Center, and we are interested in connecting our measurements and ambient data analyses with the other centers

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Project 3 - Air Quality and Climate Change Modeling: Improving Projections of the Spatial and Temporal Changes of Multipollutants to Enhance Assessment of Public Health in a Changing World

Key Investigators: Yang Zhang (NC State University), L. Ruby Leung (PNNL), David G. Streets (University of Chicago/ANL), Michelle Bell (Yale University)

Overall Technical Approaches/Innovation:

- Improve/apply a suite of 3-D online coupled climate-air quality models to reliably characterize the temporal/spatial variations of health-related pollutants in North America under a variety of current and future emission/GC scenarios.
- Utilize innovative methods such as chemical data assimilation, inverse modeling, bias correction, and ensemble modeling to effectively minimize model biases and errors in all model application stages including formulations, inputs, and outputs.

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Project 3 - Hypotheses, Scientific Questions & Objectives

- **Hypothesis**
  - The spatiotemporal variations of air pollutants have significant impacts on predicted exposure and human health (HH) effects;
  - Extreme climate change (CC) may have the most significant impacts on air quality (AQ) and HH through compounding effects.
- **Scientific Questions**
  - What are the most plausible energy transitions for max benefits of AQ (and thus HH)?
  - What are the most influential modifiable factors for regional heterogeneity of air pollutants on a variety of temporal and spatial scales in a changing world?
  - What are the compound extreme events leading to extreme AQ episodes with non-linear increase in HH effects and associated uncertainties?
- **Objectives**
  - Improve characterization of the spatiotemporal variations of multipollutants via model improvement, application of bias reduction and uncertainty quantification techniques;
  - Apply the improved models under energy/emission scenarios (Project 1) considering exposure characterization (Project 2) for assessing HH impacts (Project 4);
  - Identify the most important modifiable factors contributing to regional differences in air pollutants (thus HH effects) under current/future emission & global change scenarios.

Project 3 - Expected Results

- A comprehensive suite of 3-D concentration estimates of multipollutants along with climate projections and impacts of compound climate extremes on air quality from a diverse set of scenarios over North America during 2008-2052 encompassing multiple combinations of modifiable factors of future air quality changes consisting of 7+ energy transitions, 2 climate scenarios representing different pathways and carbon policies, 3 global climate models capturing the wide range of large-scale circulation changes, and 3 regional models accounting for air quality/climate feedbacks;
- Results will provide unprecedented information for Project 4 to estimate health effects and for policy makers to develop robust integrated control strategies to effectively improve air quality and human health.

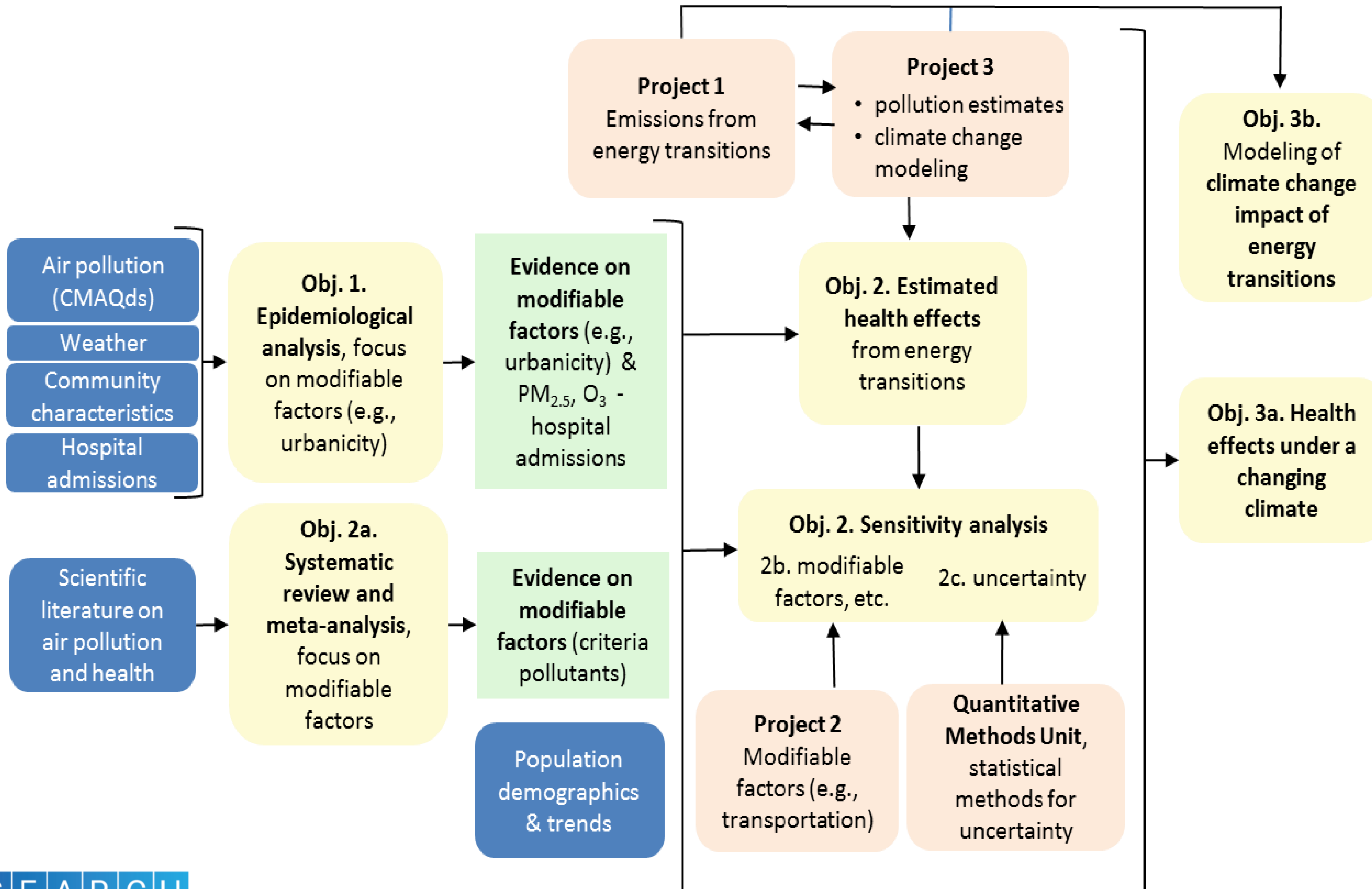
Project 4 – Human Health Impacts of Energy Transitions: Today and Under a Changing World

Michelle Bell (PI)	Yale, Forestry & Environmental Studies
Ji-Young Son	Yale, Forestry & Environmental Studies
Yawei Zhang	Yale, School of Public Medicine
Nicole Deziel	Yale, School of Public Health
Trude Storelvmo	Yale, Dept. of Geology and Geophysics
Roger Peng	Johns Hopkins, Dept. of Biostatistics

Project 4 – Aims (Estimating Health Effects)

1. Bayesian hierarchical modeling of data for the Medicare population for the eastern U.S. (2001-2008) and $PM_{2.5}$ and O_3 estimates from *fused air quality modeling (CMAQ) and air monitoring data;*
2. Linking *concentration changes from energy transitions* for 2010-2050 for the U.S. (Projects 1 and 3) to concentration-response functions from Objective 1 and those identified by *comprehensive systematic reviews and meta-analyses* of key pollutants, with statistical methods to incorporate uncertainty, including information from detailed exposure characterization (from Project 2)
3. Linking *concentration estimates under global change* to health response, and using the multi-model CMIP5 ensemble to estimate the climate change impact of multiple energy transitions

Project 4 – Approach



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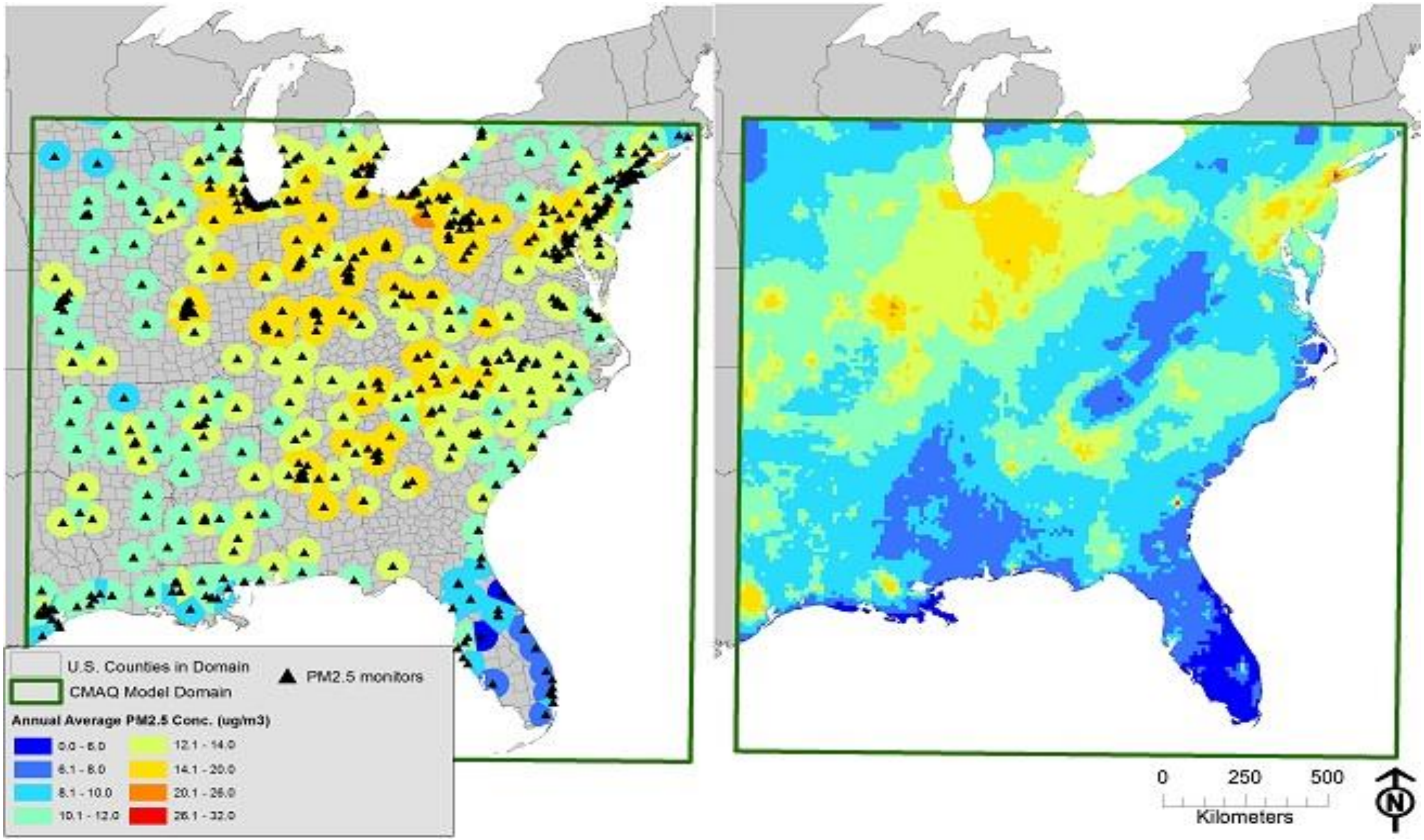
Project 4 – Example (Alternative Exposure Estimates)



Bravo et al. *Environmental Res*earch 2012

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Quantitative Methods Facility Support Unit

- **Roger D. Peng**, *Professor, Department of Biostatistics, Johns Hopkins Bloomberg School of Public Health*
- **Frank Curriero**, *Associate Professor, Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health*

Objectives

- Provide statistical support for all four proposed Center projects, including methods development, design consultation, analytical work, and manuscript preparation
- Conduct statistical methodology research for application in all Center projects when existing approaches are insufficient to address the scientific questions of interest
- Coordinate efforts across projects to ensure that all research findings are reproducible by making computer code and datasets available when possible
- Facilitate integration across different projects

Center Framework

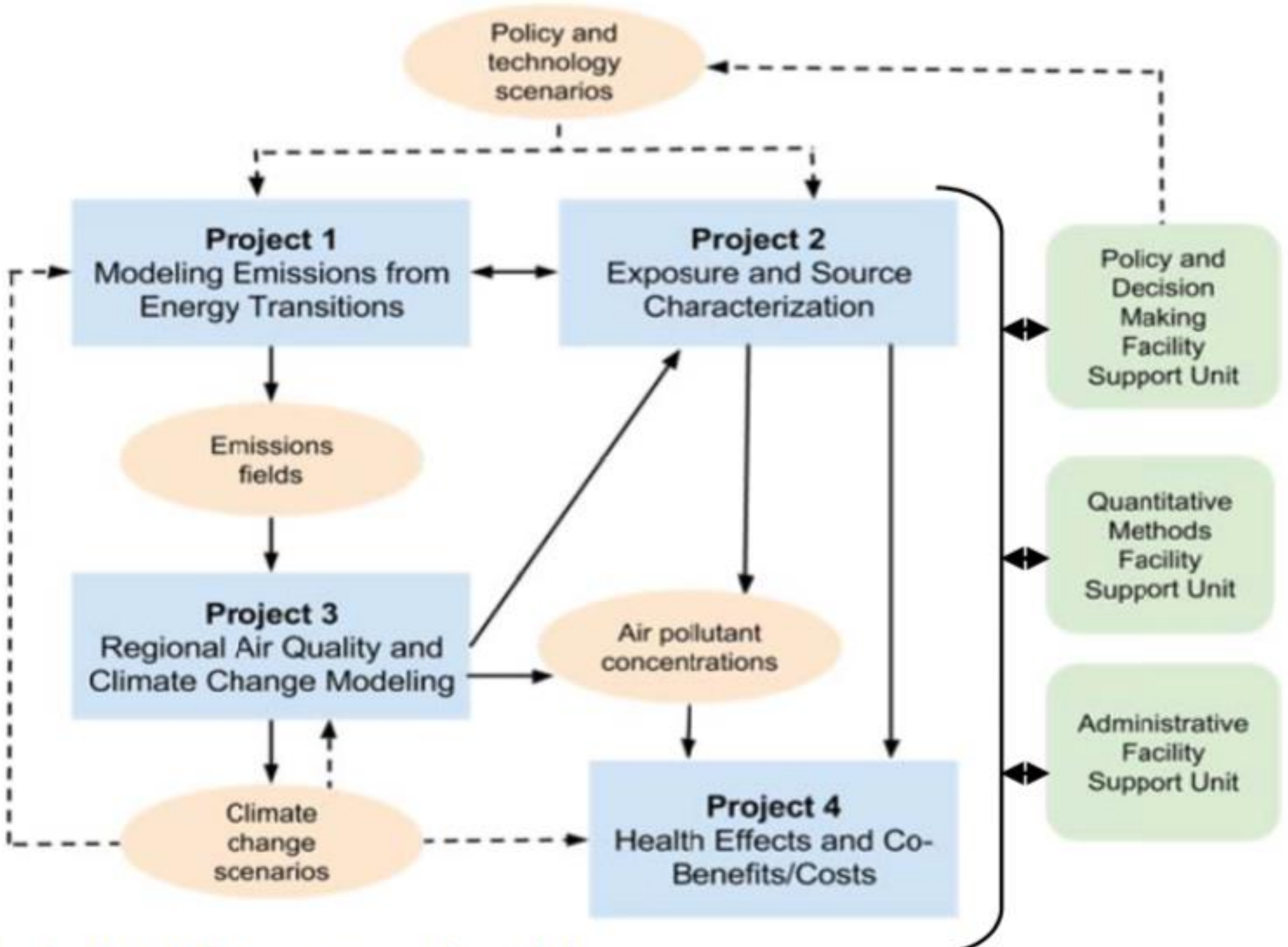

Fig. 3. SEARCH conceptual model

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Cross-cutting Issues

- **Measurement error**: Spatial/Temporal misalignment, downscaling, personal exposure heterogeneity,
- **Propagating uncertainty**: Bayesian methods for integrating uncertainty across exposure/health
- **Spatial design and analysis**: Optimal design for monitor placement, GIS/mapping, exposure prediction
- **Reproducible research + dissemination**: Software, results, data (to the extent allowable)

Policy & Decision Making Support Unit

Dan Esty (PI), *Yale School of Forestry & Environmental Studies, Yale Law School;* Director, *Yale Center for Environmental Law & Policy*

Michael Wara, Associate Professor of Law at *Stanford University;* Faculty Fellow, *Steyer-Taylor Center for Energy Policy and Finance*

Paul Anastas, *Yale School of Forestry & Environmental Studies*, *Department of Chemical Engineering, and Department of Chemistry*; Director, Center for Green Chemistry and Green Engineering

Brad Gentry, *Yale School of Forestry & Environmental Studies;* Director, Program on Private Investment and the Environment; Co-Director, Yale Center for Business and the Environment

Policy & Decision Making Support Unit

- **Purpose:** To bridge the divide which often separates science and policy through an iterative process bringing the science and policy domains together in a regular and robust fashion.

- **Three Objectives**
  1. Foster policy-relevant science
  2. Develop specific energy and environmental policy scenarios for SEARCH research team focus
  3. Facilitate the dissemination of research findings to policymakers and the general public

Outreach to State-Level Air Pollution Policymakers

- Listening session (April 2016) with Northeast States for Coordinated Air Use Management (NESCAUM)
- Webinar (July 2016) with Mid-Atlantic Regional Air Management Association, Inc. (MARAMA)
- Discussion topics:
    - Overview of SEARCH project
    - Time frame for analysis and data availability
    - Coordination with current research
    - Point source pollutants
    - Granularity and political relevance
    - Energy transition scenarios

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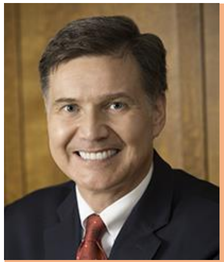

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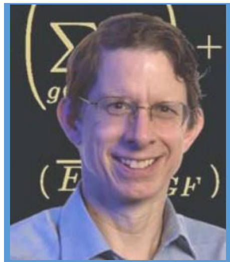


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