Can fleet electrification benefit air quality and human health?

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Introduction

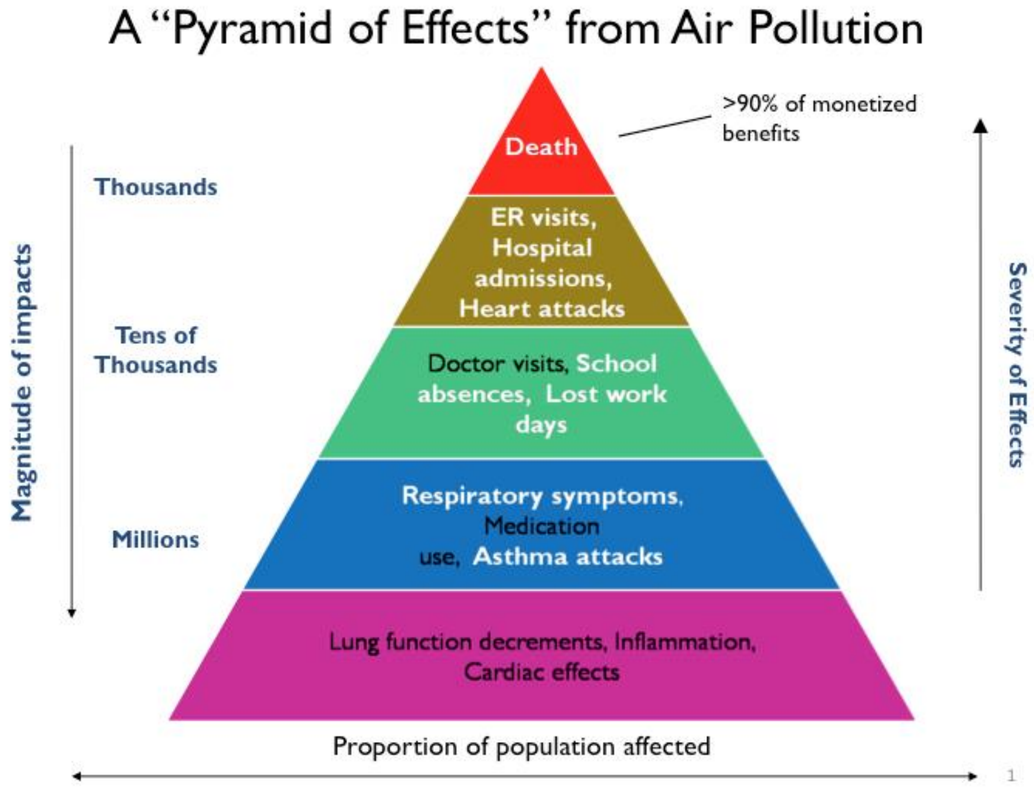
- Transport, in its own right, is an important sector of the economy

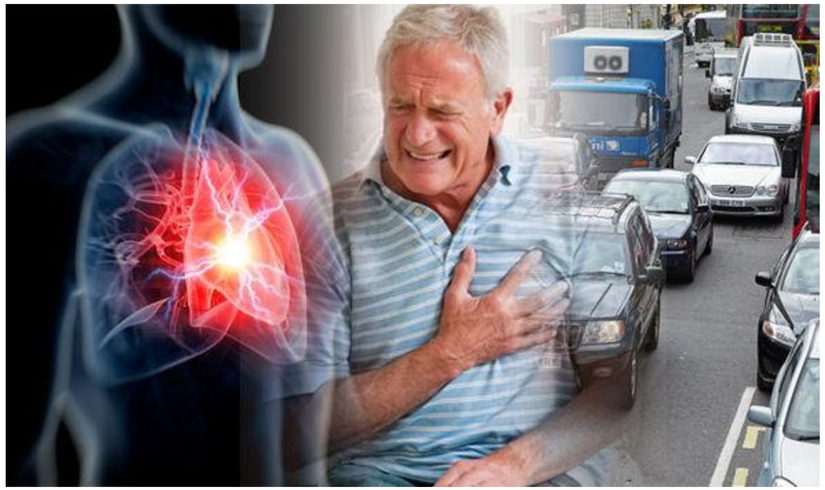
  - It provided the foundation for the notable increases in economic development and worldwide income over the past half century

  - The transportation sector drives economic development and enhances the quality of life for humans

- Unfortunately, transportation is also a significant source of Green House Gases (**GHG**) and air pollution
- Transport accounts for about 64% of global fossil fuel consumption, 27% of all energy use, and 23% of energy-related CO_2 (as a GHG) emissions (*The World Bank, 2021*)
- GHG cause climate change by trapping heat

- According to the Third and Fourth National Climate Assessment Reports, some of the long-term effects of global climate change in the United States are as follows:
  - Temperatures will continue to rise
  - Frost-free seasons will lengthen
  - Changes in precipitation patterns
  - More droughts and heat waves
  - Hurricanes will become stronger and more intense
  - Sea level will rise 1-8 feet by 2100
  - Arctic likely to become ice-free





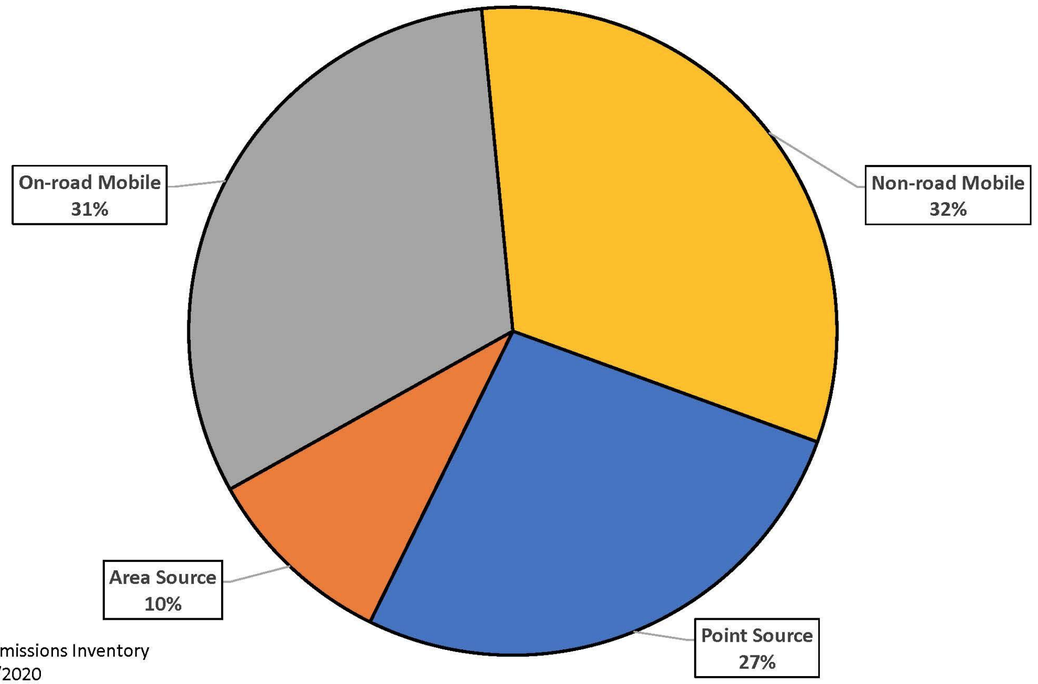
- **In addition**, emissions from transportation contribute to the formation of surface ozone and $PM_{2.5}$, causing poor air quality and, consequently, a threat for human health

- Both ozone and $PM_{2.5}$ are known to be harmful to human health, causing premature deaths and both severe and minor morbidities (e.g., hospital admissions and asthma exacerbations)

- Each year, almost 185,000 deaths can be directly attributed to pollution from vehicles (*The World Bank, 2021*)

- Cities will be home to some 6.7 billion residents by 2050, equivalent to 2/3 of the projected global population
- The number of light duty vehicles on the road will double to reach 2 billion by 2050 (*The World Bank, 2021*)
- The population of the Houston Area is expected to grow by 50% by 2040 with respect to 2013
- Potentially leading to a significant increase in passenger travels and freight activity

2017 Houston-Galveston-Brazoria Area NO_x Emissions



Counties:
Brazoria
Chambers
Fort Bend
Galveston
Harris
Liberty
Montgomery
Waller

Source: TCEQ Emissions Inventory
Updated: 10/1/2020

- On-road vehicle traffic, which includes trucks and passenger vehicles, is predicted to increase 30%-80% by 2040 in Houston area (*Texas Transportation Institute*)
- With an increase in both population and on-road vehicles, transportation-related emissions would likewise increase
- Mobile sources in Houston-Galveston-Brazoria area contributed to 63% of NOx emissions (important precursor of surface ozone) in 2017 (*TCEQ, 2019*)

- What can be done to ward off environmental disaster due to the on-road emissions?
- The answer is simple: **Electric Vehicles**!
- EV advantages:
  - No tailpipe NOx emissions
  - No tailpipe GHG
  - Reducing respiratory disease
  - Higher lifetime
  - Lower maintenance fees

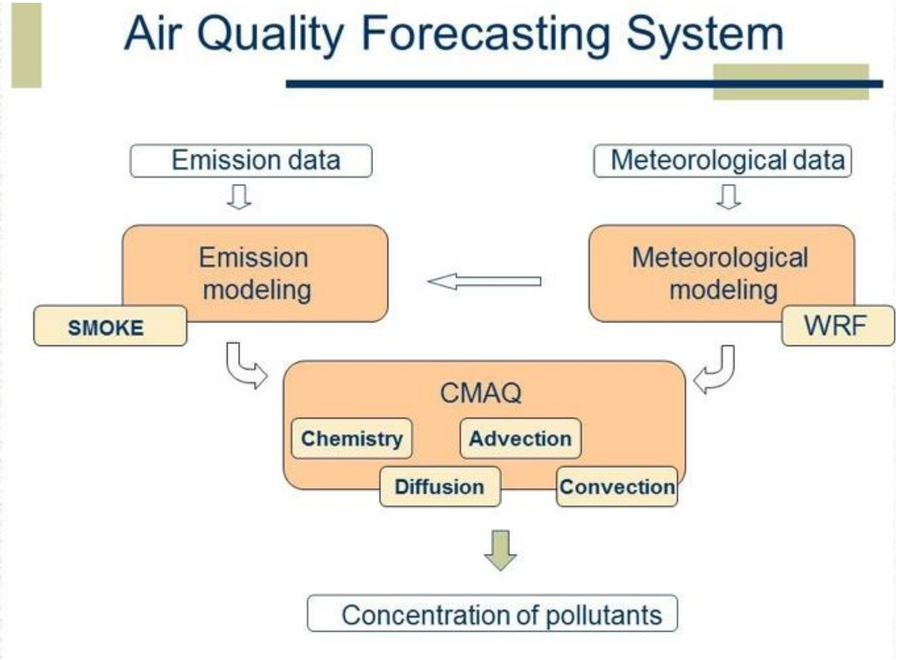
Our previous studies

- We set up WRF-SMOKE-CMAQ air quality modeling platform in our clustered system that gives us the ability to investigate a wide range of atmospheric related topics

- **WRF** (Weather Research and Forecasting Model) simulates meteorological variables

- **SMOKE** is used to prepare emissions input data for Air Quality Models (AQM)

- **CMAQ** is an AQM that is developed and maintained by scientists in USEPA



We developed future projections (to 2040) for on-road mobile emissions and evaluated several scenarios with varying levels of emission control, fleet electrification and turnover

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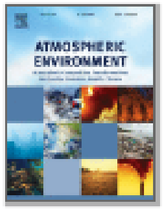
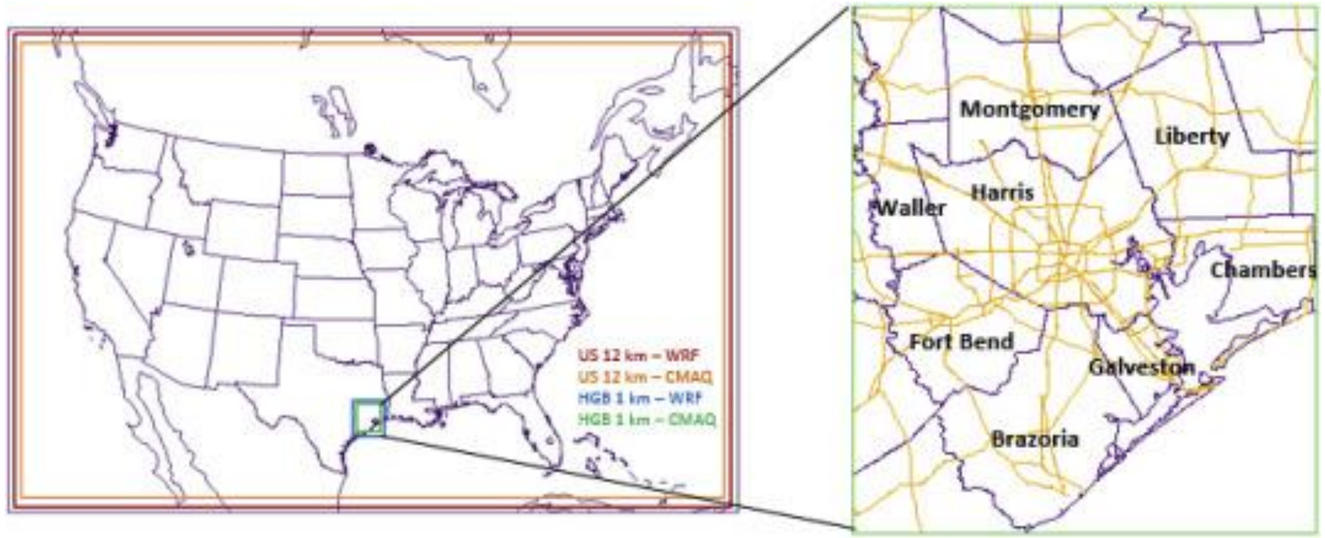
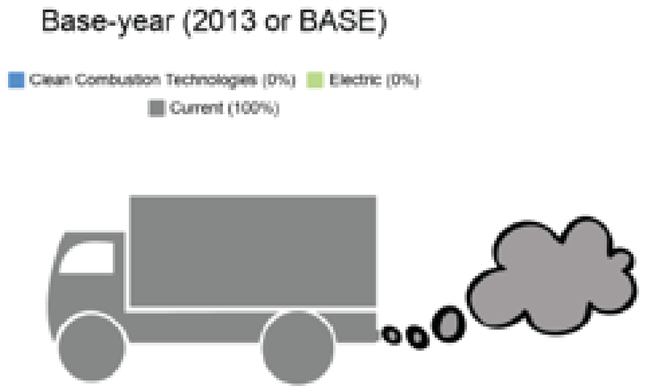


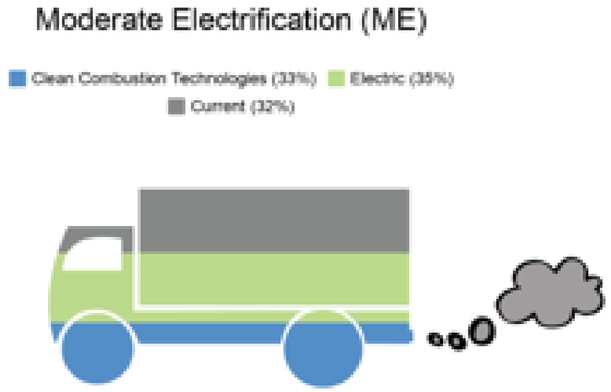
Potential impacts of electric vehicles on air quality and health endpoints in the Greater Houston Area in 2040

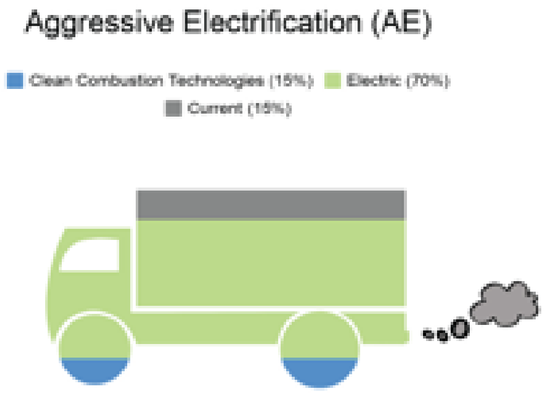
Shuai Pan [a, e], Anirban Roy [a], Yunsoo Choi [a], Ebrahim Eslami [a], Stephanie Thomas [b], Xiangyu Jiang [c], H. Oliver Gao [d, e]

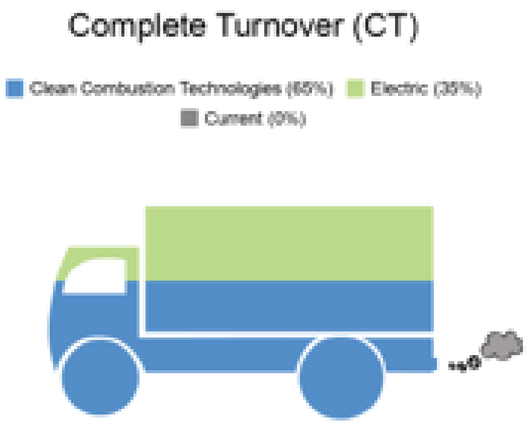
- Set up **Fine Resolution** (1km×1km) Modeling System over HGB area
  - A unique technique to investigate the atmospheric constituents behavior in a fine resolution
  - It takes efforts, time, and resources







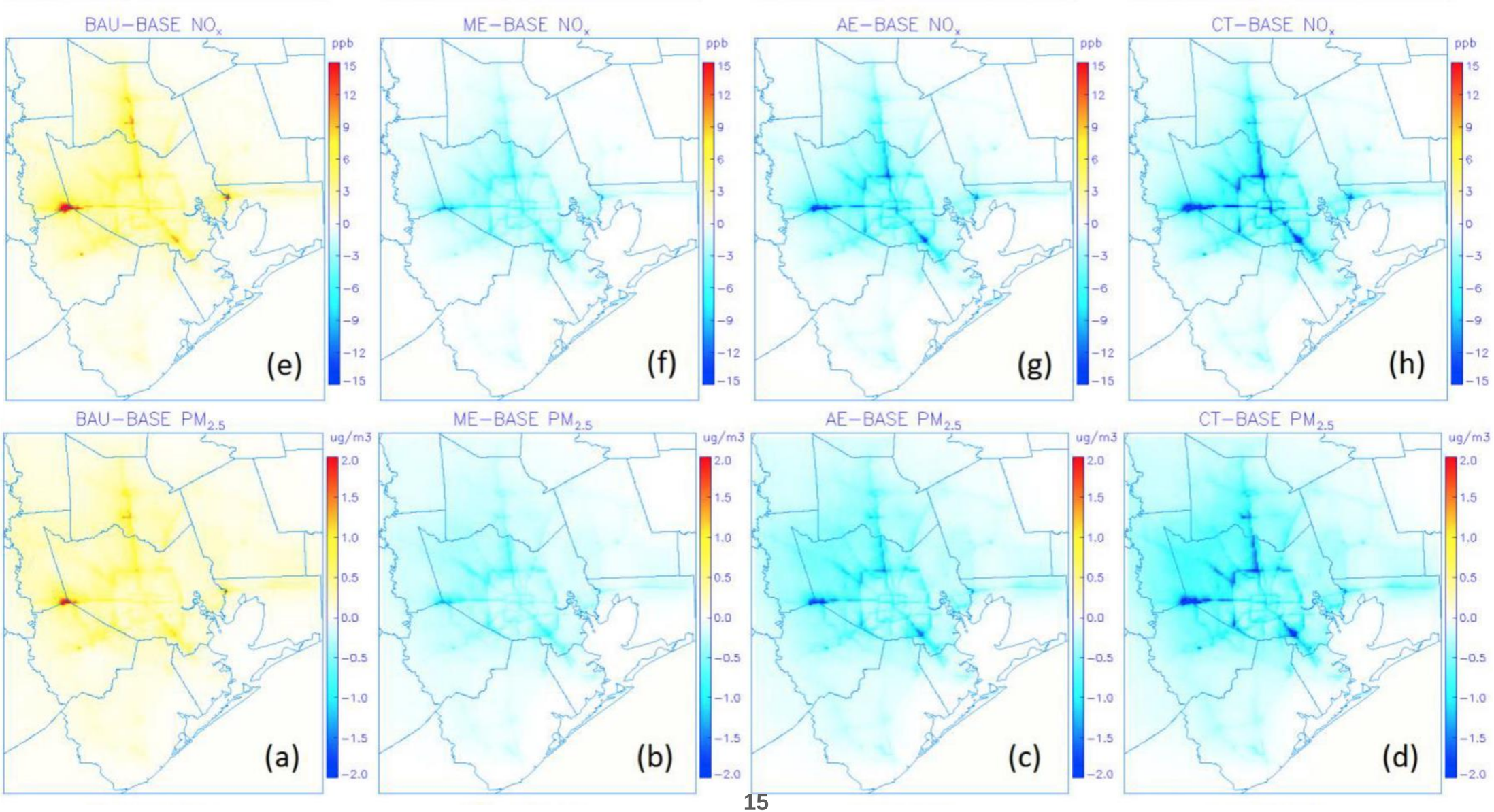


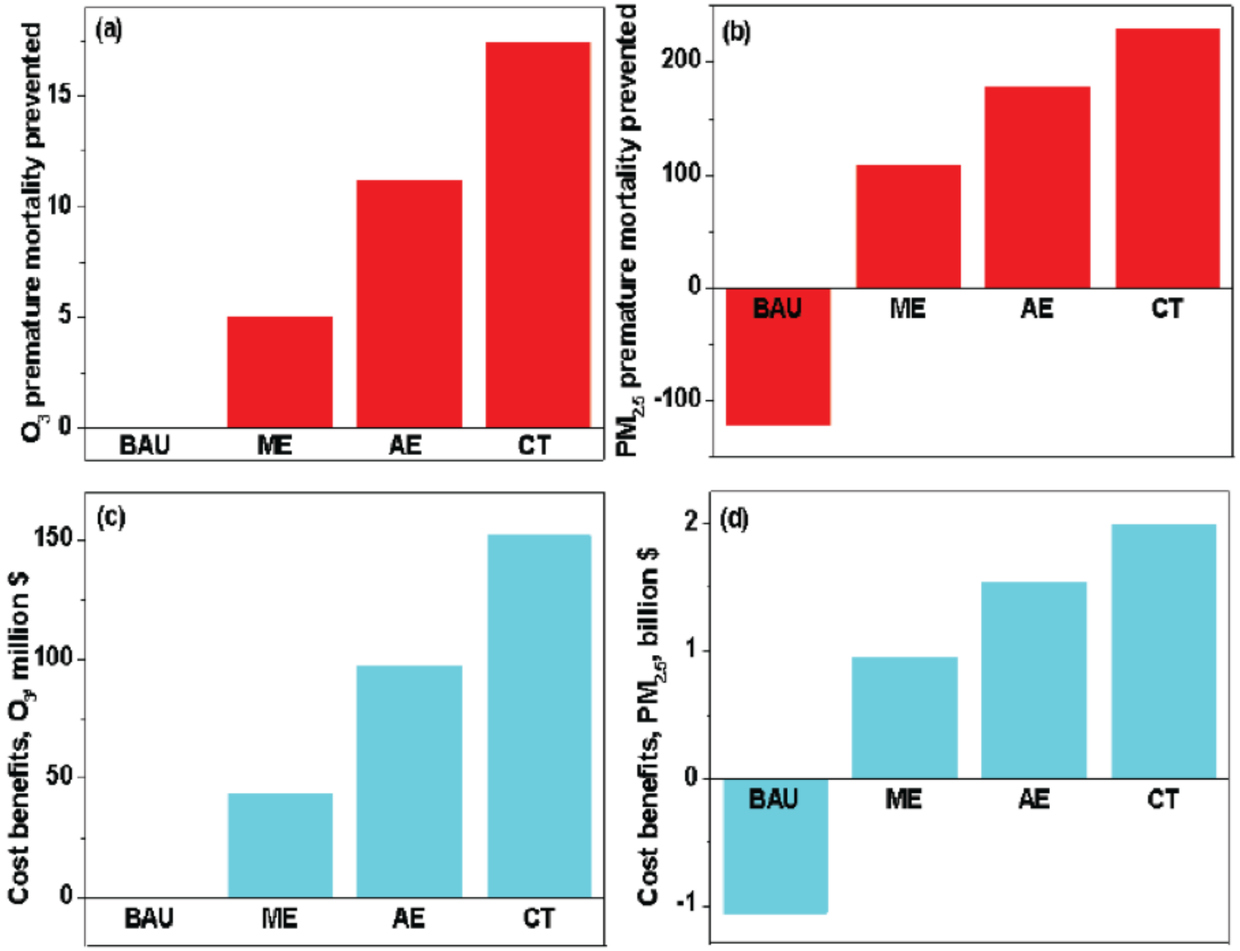


- We defined four different plausible scenarios to investigate the impacts of fleet electrification on the air quality and human health in HGB area

Simulation Scenario	Percentage Fleet Turnover		
	New	Electric	Current
Base year (BASE)	0	0	100
Business As Usual (BAU)	0	0	100
Moderate Electrification (ME)	33	35	32
Aggressive Electrification (AE)	15	70	15
Complete Turnover (CT)	65	35	0

Both NOx (an important precursor of ozone) and $PM_{2.5}$ would decrease in ME, AE, and CT scenarios and increase in BAU scenario





- We used BenMap model to estimate the health benefits from improvements in air quality due to the fleet electrification
- BenMap is created by USEPA
- Results from the complete turnover scenario suggest a ~95% reduction in both NOx and $PM_{2.5}$ leading to substantial health and cost benefits from ozone and $PM_{2.5}$ exposure

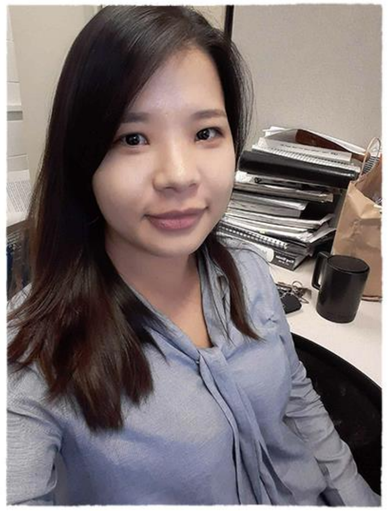
Table 5. Estimates of prevented O_3-induced morbidities and benefits in the future year scenarios.

Scenarios	Asthma exacerbation, one or more symptoms	Benefits [Million Dollars, in 2015 currency year]
Business As Usual	-1,213	-0.076
Moderate Electrification	7,534	0.475
Aggressive Electrification	16,119	1.016
Complete Turnover	24,652	1.554
	Emergency room visits, Asthma	
Business As Usual	-0.96	-0.001
Moderate Electrification	20	0.010
Aggressive Electrification	43	0.023
Complete Turnover	67	0.036
	School loss days	
Business As Usual	-833	-0.088
Moderate Electrification	5,518	0.585
Aggressive Electrification	11,844	1.255
Complete Turnover	18,153	1.924
	Hospital admission, All respiratory	
Business As Usual	-0.05	-0.002
Moderate Electrification	4	0.133
Aggressive Electrification	8	0.294
Complete Turnover	13	0.459

Notation: Positive values indicate the number of prevented morbidities and benefits achieved, while the negative values indicate an increase in the number of morbidities and economic losses.

On-going/near future works

Numerical Modeling members



Jia Jung

Bavand Sadeghi

Arman Pouyaei

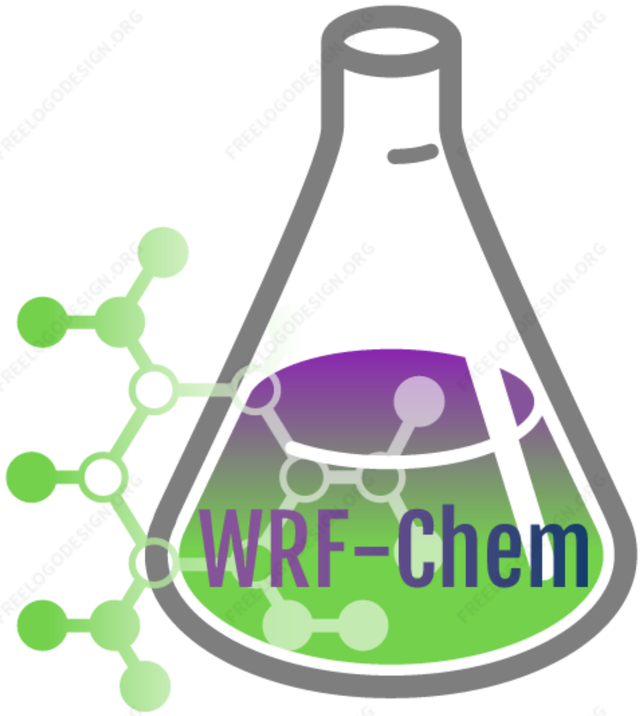
Ali Mousavinezhad

Hadi Zanganeh Kia

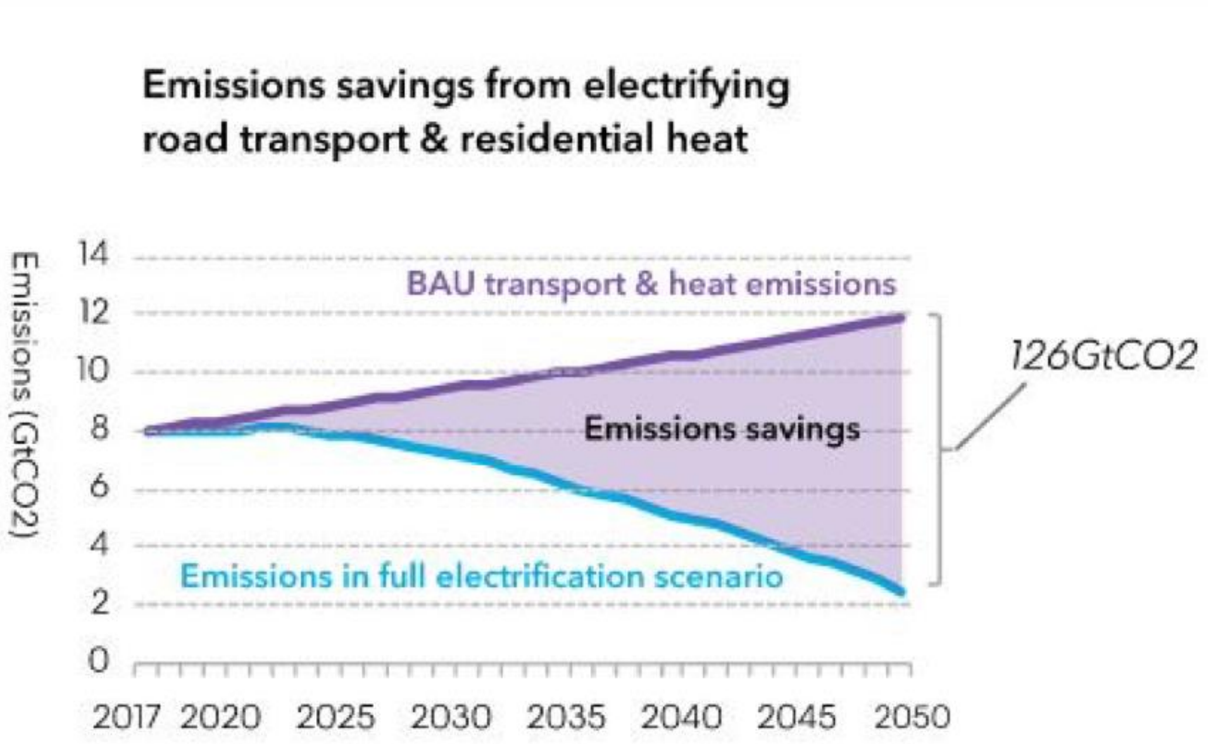
Delaney Nelson

Semko Momeni

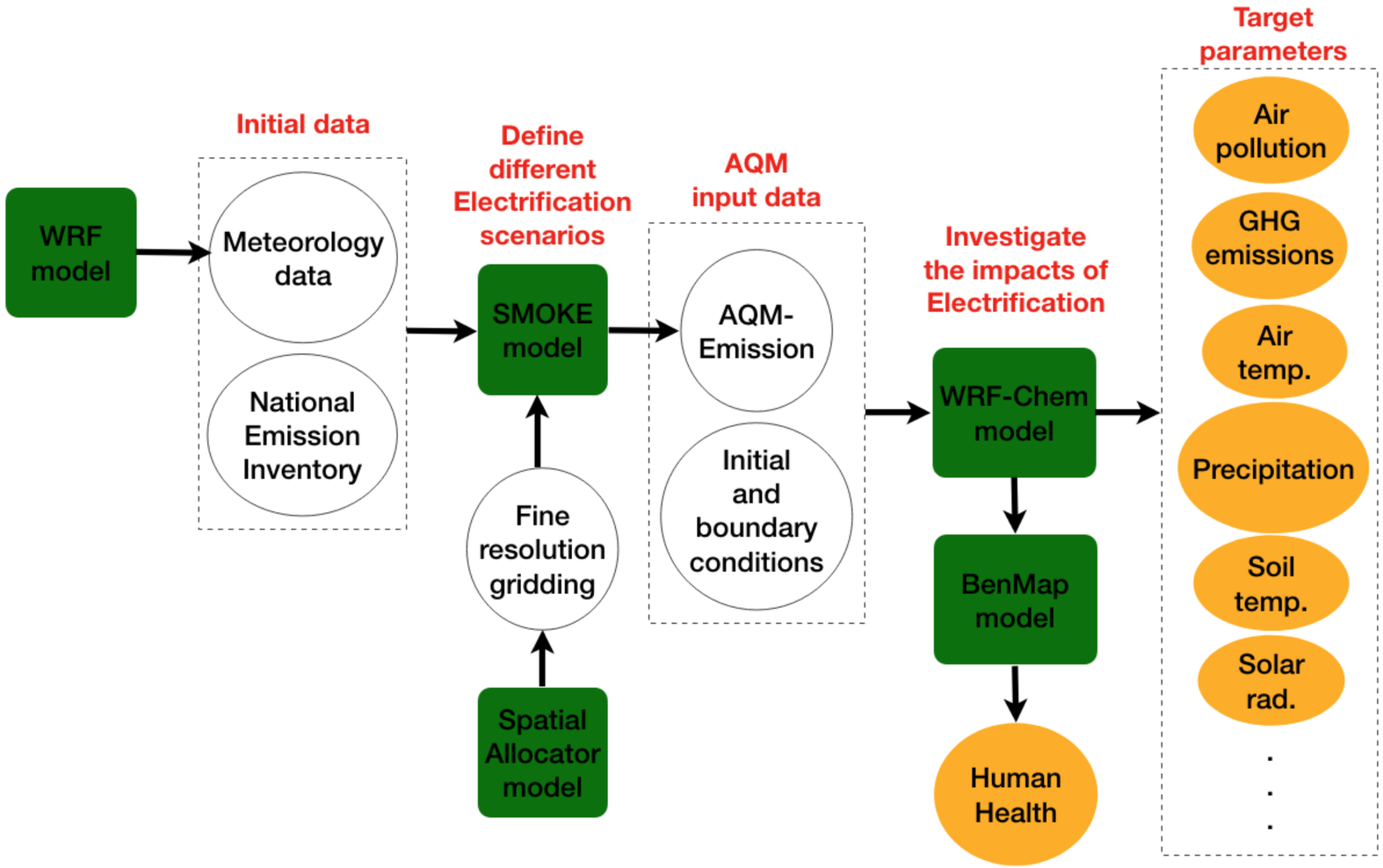
Jincheol Park



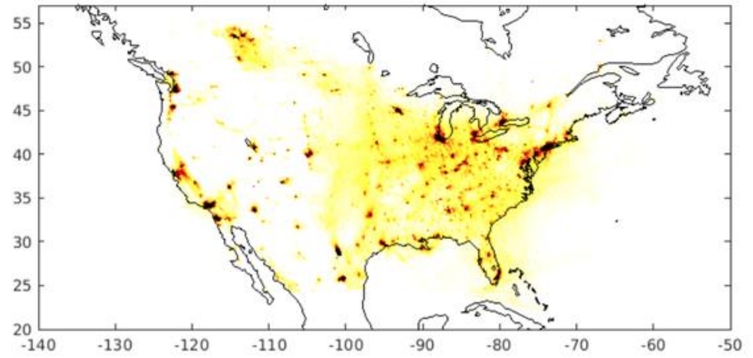
- In addition to WRF-SMOKE-CMAQ platform, recently we have set up WRF-Chem model on our clustered system
- WRF-Chem is the Weather Research and Forecasting (WRF) model coupled with Chemistry
- WRF-Chem was developed and maintained by NOAA/ESRL and DOE/PNNL
- Currently we are setting up the WRF-Chem fine resolution modeling system



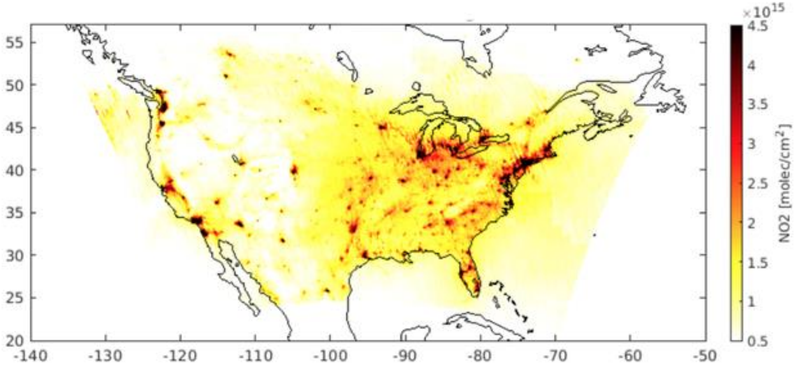
- Emissions in full electrification scenario (on-road sources and residential heat) would decrease CO_2 emission by 126Gt by 2050 (*New Energy Outlook 2019*)
- In addition to GHGs, aerosols (including $PM_{2.5}$) also have impacts on the radiation budget.
- WRF-Chem has online coupled chemistry and meteorology, useful for examining two-way interactions between chemistry, aerosols, meteorology, and radiation
- WRF-Chem model gives us the ability to investigate both air pollution issues and regional impact of climate change/weather of GHG/air pollutants.



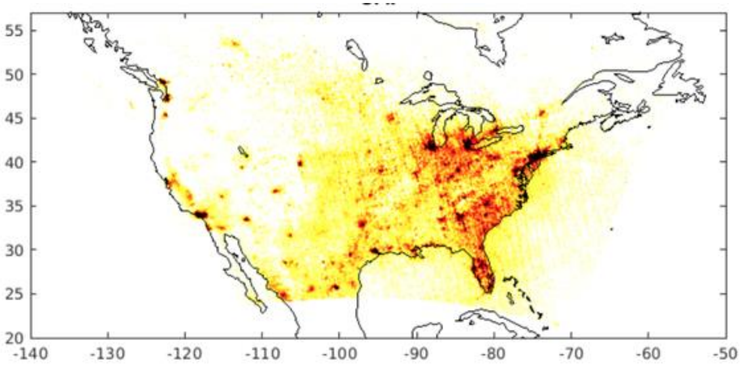
CMAQ NO_2



WRF-Chem NO_2



Remote sensing OMI NO_2



AI Modeling members

Dr. Ryan Yeo

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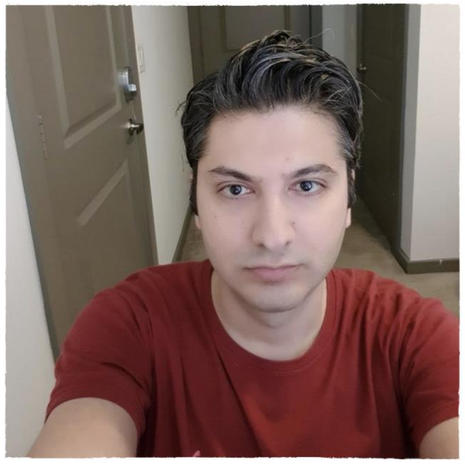

Masoud Ghahremanloo

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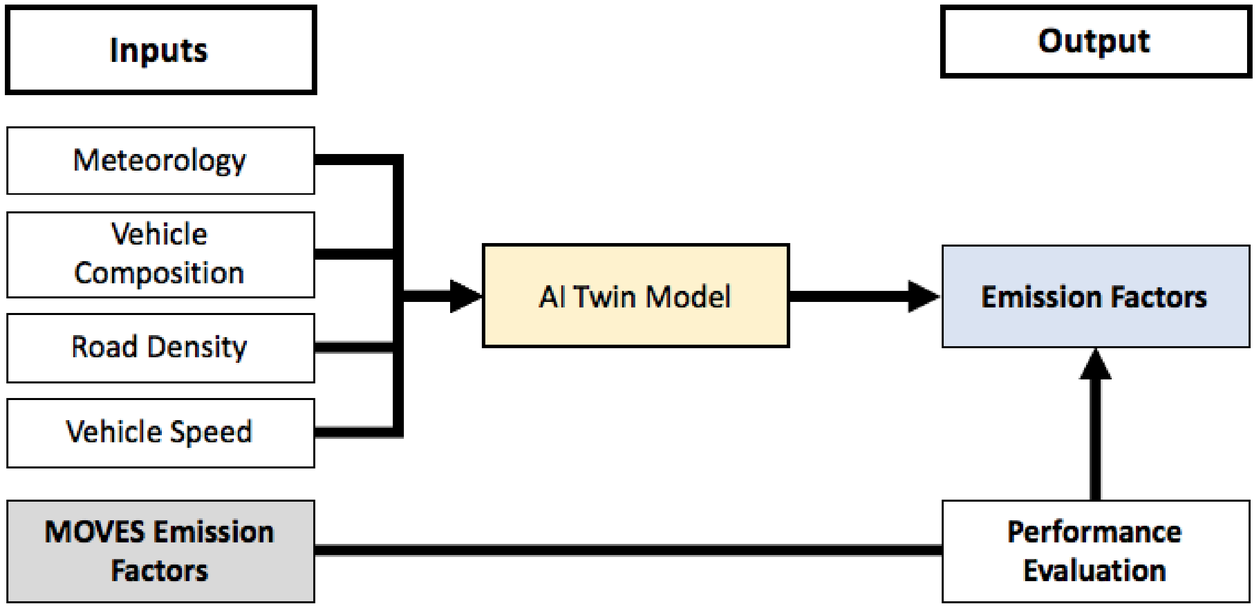
Deveshwar Singh



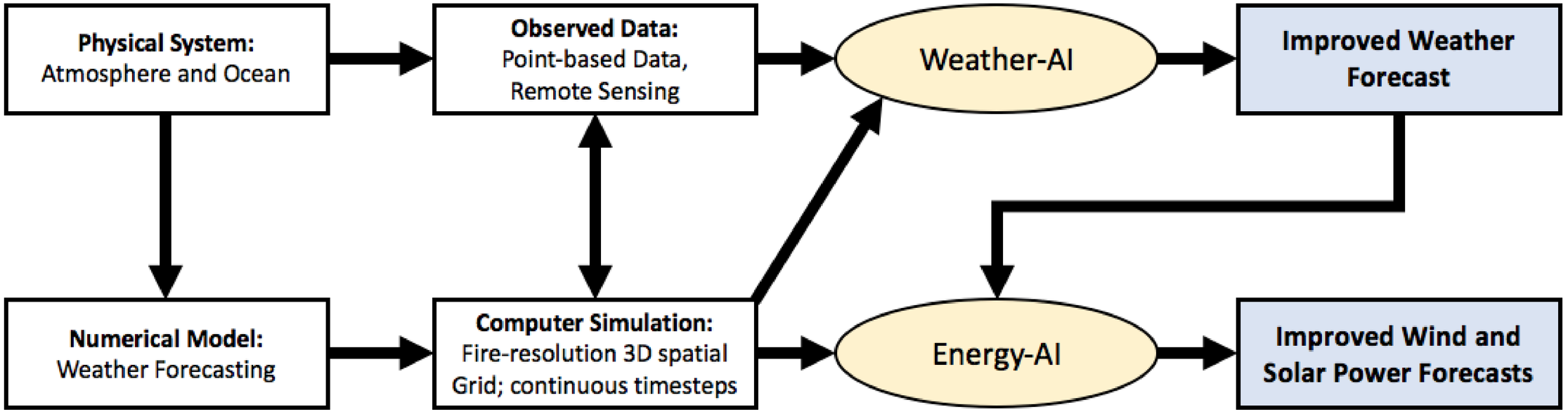
- In our AI modeling group, we are developing some ideas related to electrification:

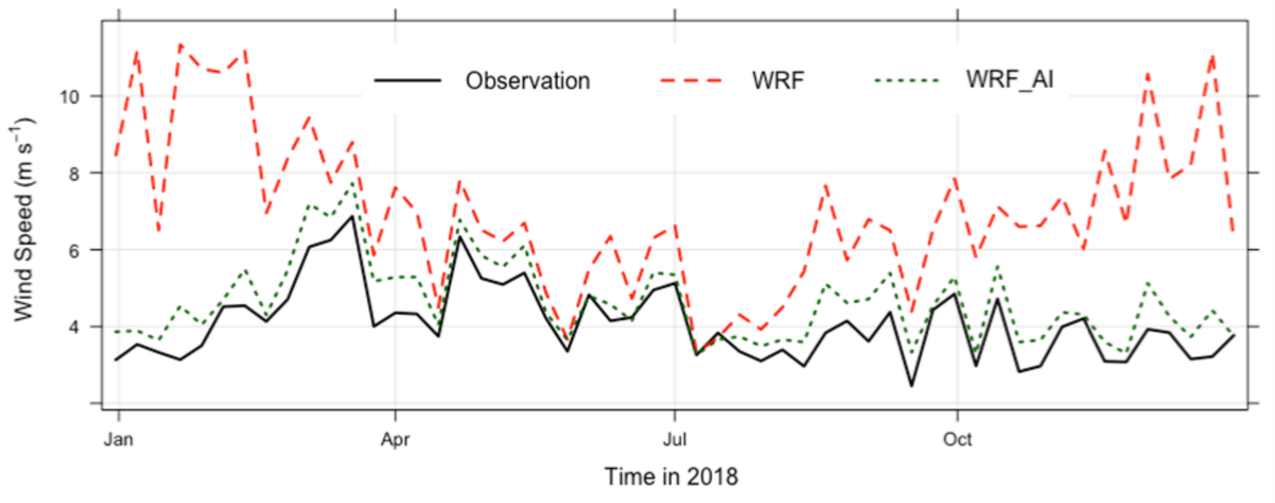
1. Create a Digital-Twin of the MOVES model

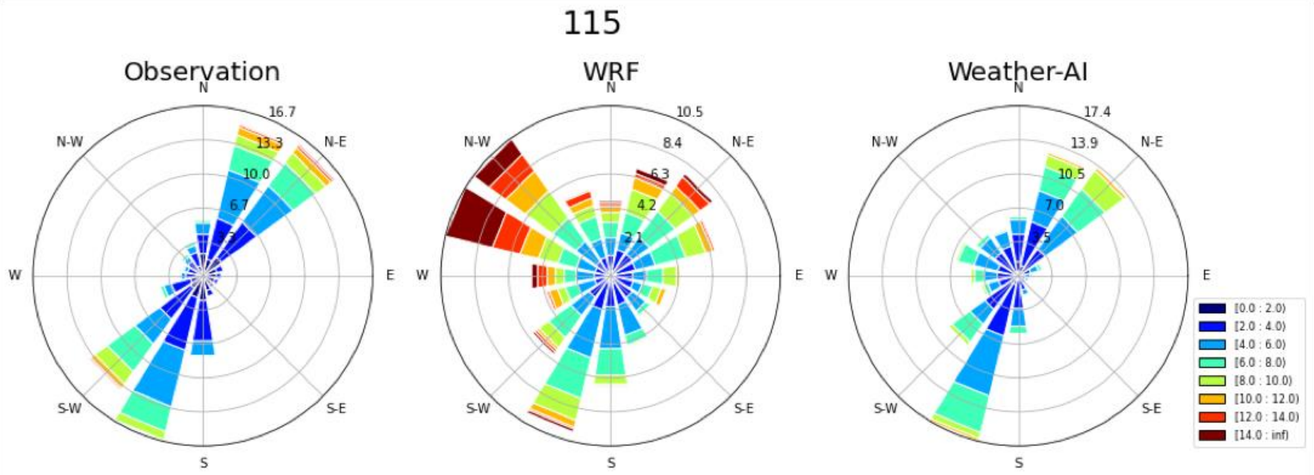
   MOVES is a emission modeling system that estimates emissions for mobile sources, but running is timely expensive.

   - The Digital-Twin allows us to create near real-time estimates of emission factors.
   - We can dynamically create various scenarios on EV adoption impact on emissions at various temporal and spatial resolutions.

2. Utilize Deep Learning to improve weather forecasts up to 24 hours ahead in time
    - Accurately forecasting wind- speed and direction is still difficult for weather models
3. Leverage Deep Learning forecast power output based on improved weather forecasts

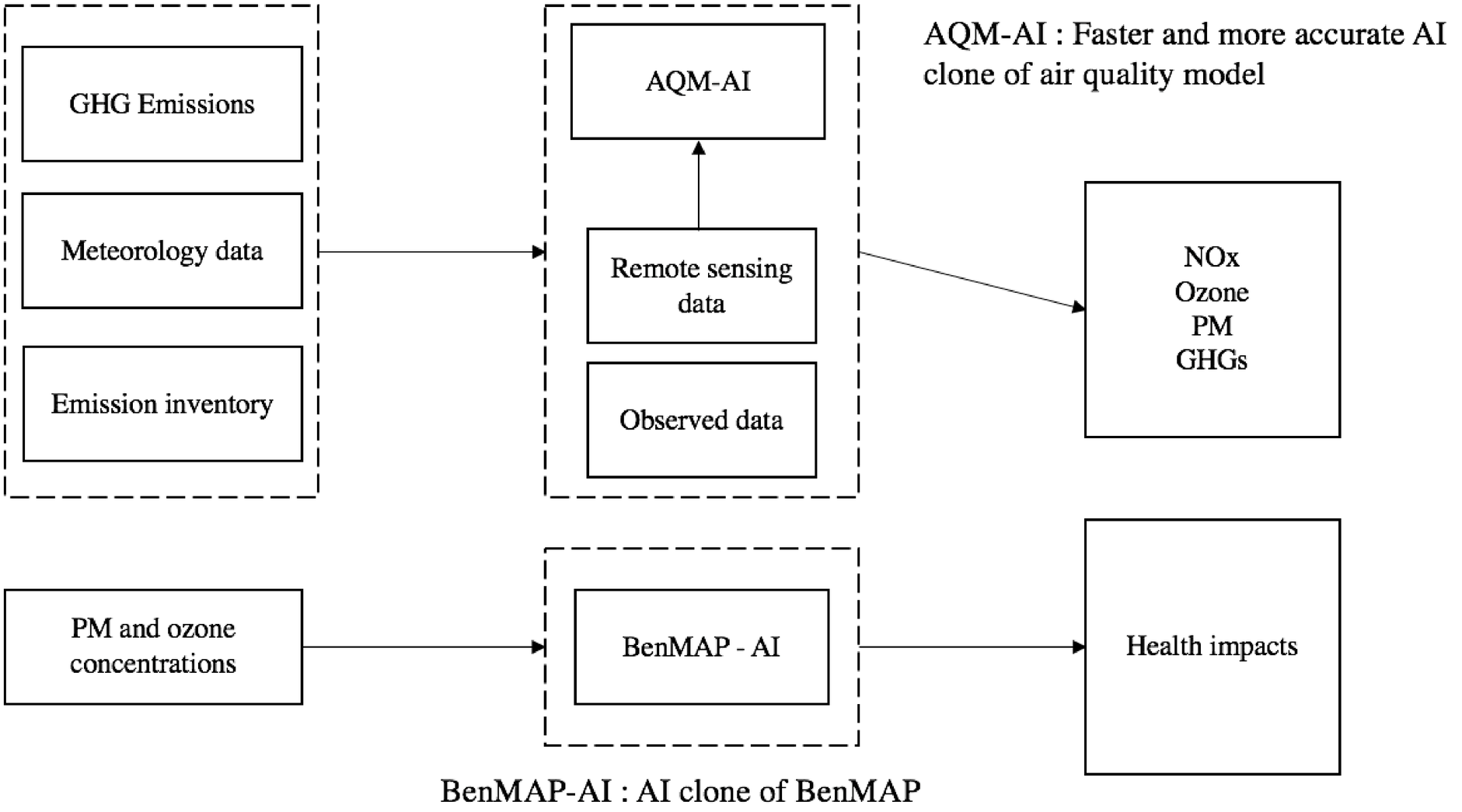






- Our current system can optimize WRF forecasts in near real-time with significant improvements.
- We achieved an average increase of 27% in forecasting accuracy for surface wind.
- We plan to extend the forecasting period to 3-7 days ahead.

Combination of Numerical Modeling and AI technology


GHG Emissions
Meteorology data
Emission inventory
AQM-AI
Remote sensing data
Observed data
AQM-AI : Faster and more accurate AI clone of air quality model
NOx
Ozone
PM
GHGs
PM and ozone concentrations
BenMAP - AI
Health impacts
BenMAP-AI : AI clone of BenMAP

"Prices are down, range is up and home charging stations make it easier to plug in"

By John R. Quain, AARP, December 2, 2020

We are open to collaboration