

Wisconsin National Data Consortium Advisory Board

ARTIMAS & WiNDC: Toward a Canonical Dynamic  
General Equilibrium Framework

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# Overview

- ① Data
- ② Model
- ③ Electricity Disaggregation
- ④ Baselines
- ⑤ Policy

## Current WiNDC-Bluenote data build

- Build for 2014 base year
- Disaggregated 8 electricity generation types for canonical model (50 for full model)
- Aggregated to 9 census regions
- Single household per region (to be disaggregated)
- Aggregated to 12 sectors, 5 energy for canonical model (30 sectors in full model)

# Full ARTIMAS Model

- Perfect foresight model solved in 5-year steps, 2015 – 2060
  - Benchmark: IMPLAN 2013
- Baseline calibration algorithm sets baseline to AEO cases
- 30 sectors mapped to AEO sectors
- Agents: 9 HH by income & 1 gov't
- 9-region model
- Model code will be publicly available

No.	Code	Sector	Output (\$ Bn.)
1.	AGR	Agriculture	492.3
2.	COL	Coal extraction	50.6
3.	MIN	Mining	77.0
4.	BOM	Balance of manufacturing	2,007.8
5.	EGN	Electricity generation	274.8
6.	ETD	Electric trans. & dist	416.5
7.	CNS	Construction	1,250.6
8.	FDP	Food products	878.0
9.	WDP	Wood products	90.9
10.	PPR	Paper products	210.3
11.	OIL	Refined petroleum	501.4
12.	BCH	Bulk chemicals	523.4
13.	BIO	Biofuels manufacturing	125.0
14.	PLS	Plastics	235.0
15.	GLS	Glass	23.8
16.	FMP	Fabricated metal products	372.6
17.	MAC	Machinery	497.8
18.	CPU	Computers	610.2
19.	ELQ	Electrical equipment	158.2
20.	TRQ	Transportation equipment	997.0
21.	COM	Commercial	18,090.5
22.	PUB	Gov't - public goods & enterprises	1,977.3
23.	OGE	Oil & gas extraction	164.5
24.	GAS	Natural gas	177.2
25.	CEM	Cement	7.6
26.	IAS	Iron and steel	143.1
27.	ALU	Aluminum	41.8
28.	TRG	Transportation - ground	456.3
29.	TRA	Transportation - air	174.3
30.	TRW	Transportation - water	60.4

# Canonical Model

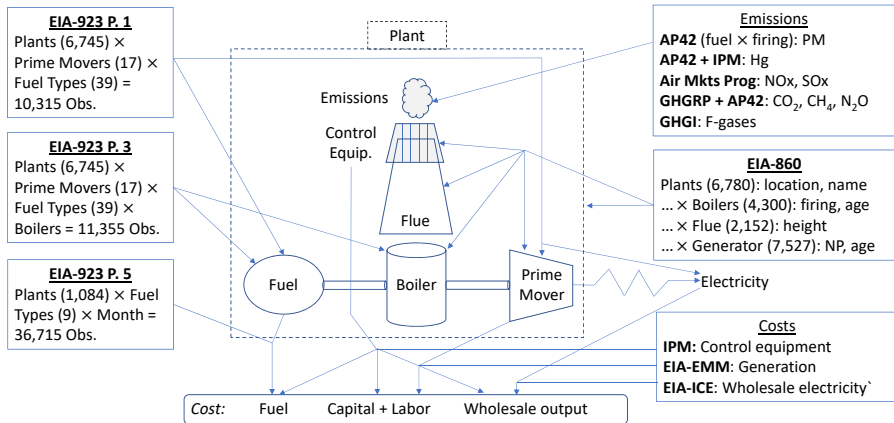
- Intertemporally-optimized model solved in 5-year time steps
- Baseline can be computed (current results) or calibrated to AEO growth & technology assumptions
- Fossil fuel sectors have dedicated resource stocks with calibrated supply elasticities
- Capital adjustment costs imposed
- Trade substitution modeled with Armington aggregation
- All data and programs intended to be publicly available

Micro-level Environmental and Economic Detail of Electricity (MEEDE) dataset is basis for disaggregation

- Built on public sources
- Looking to update, extend historically, & make this publicly available

- EIA
- **Form 923:** generation and fuel consumption data
  - **Form 860:** facility attribute data
  - **Capital costs:** estimates for utility-scale generation
  - **ICE:** InterContinental Exchange wholesale electricity prices
- EPA
- **IPM:** generation & abatement costs, emissions mod. factors
  - **Air Markets Program:** NO<sub>x</sub> & SO<sub>x</sub> emissions
  - **AP42:** PM & Hg emissions factors
  - **GHGRP:** CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub>
  - **GHGI:** F-gas emissions

# Data diagram



# Cost validation

**Table 10. Electric wholesale revenue and cost by region, 2013**

Region	Output		Input (MM 2015\$)				
	Net generation (in thousands of MWh)	Wholesale revenue (MM 2015\$)	Total	Capital	Fixed O&M (labor)	Fuel	Variable O&M (materials)
South Atlantic	760,966	36,060	44,097	20,433	9,761	11,062	2,841
W. South Central	668,391	31,406	28,898	18,056	6,136	2,530	2,177
E. North Central	622,028	30,413	34,592	18,090	9,330	4,817	2,355
Middle Atlantic	426,827	23,672	17,545	9,862	5,629	337	1,718
Mountain	376,409	15,506	17,329	9,257	3,006	3,672	1,394
Pacific (CA, OR, WA)	373,992	15,373	15,959	10,267	3,533	232	1,927
E. South Central	372,759	17,543	16,656	7,015	3,741	4,477	1,423
W. North Central	330,291	15,524	16,453	7,894	3,885	3,794	880
New England	115,365	7,920	7,074	4,177	2,309	83	504
Pacific (AK, HI)	16,764	788	1,064	555	231	189	90
<b>Total USA</b>	<b>4,063,792</b>	<b>194,206</b>	<b>199,669</b>	<b>105,607</b>	<b>47,561</b>	<b>31,193</b>	<b>15,308</b>

Abbreviations: MM = million; MWh = megawatt-hour; O&M = operations and maintenance.

Source: Micro-level Economic and Environmental Detail of Electricity (MEEDE) dataset.



# Disaggregation Process

- 1 Aggregate MEEDE data to a maximal set of technologies
- 2 Generate unit cost vectors on capital, labor, energy (fuel), and materials for each technology
- 3 Generate output share vector for the grid
- 4 Identify linear combination of unit cost vectors with variable materials cost shares that:
  - i. Equals grid unit cost vector from macro data
  - ii. Minimizes distance between MEEDE & solution output share vectors
- 5 Loop over all model periods, disaggregate electric sector in each
- 6 Aggregate disaggregation technologies to smaller set of model technologies weighted by their solution output shares
- 7 Allocate grid inputs from macro data across model technologies based on model technology weights

# Canonical Model: Baselines overview

- Balanced growth (**BG**): all quantities grow at the same rate
- Unbalanced growth (**UBG**): all quantities in a given region grow at the same rate, then compute a nearby equilibrium

<b>Growth %</b>	NEG	MID	ENC	WNC	ESC	SAC	WSC	MTN	PAC
	1.4	1.9	1.3	1.3	2.0	2.0	2.3	2.3	3.2

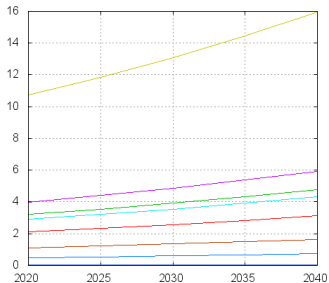
- UBG & energy efficiency improvements, offset by increased value-add:

<b>AEEI %</b>	2025	2030	2035	2040
Stylized	4.9	9.6	14.0	18.2
AEO	0.7	3.7	8.0	12.5

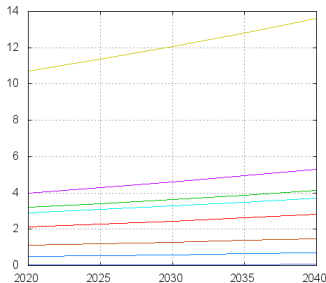
- UBG & Stylized Energy Efficiency (**UBG+EES**) at 1% per annum
- UBG & Fuel-specific Energy Efficiency (**UBG+EEF**), *AEO REF2019*
- UBG & Fuel- and sector-specific Energy Efficiency (**UBG+EEFS**), *AEO REF2019*

# Baselines: Energy Output - Coal

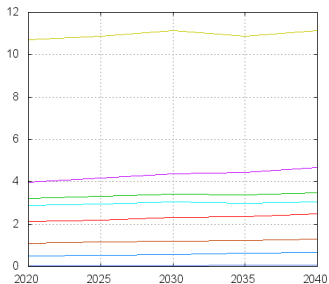
Coal output -- UBG



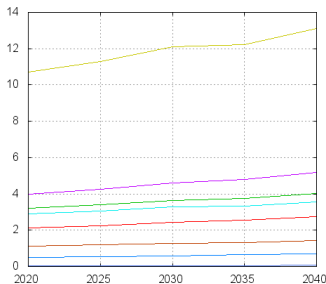
Coal output -- UBG+EES



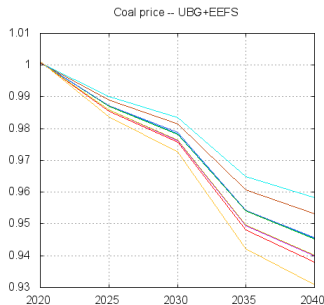
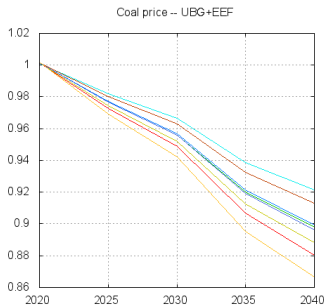
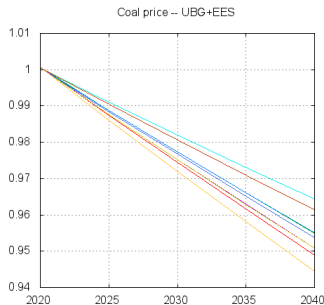
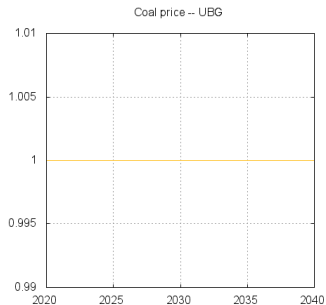
Coal output -- UBG+EEF



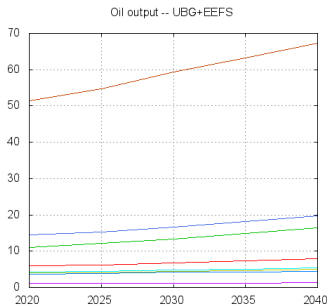
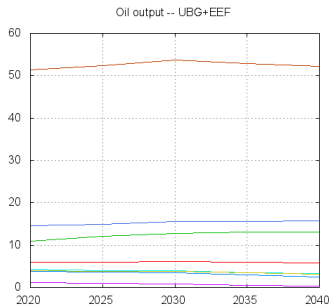
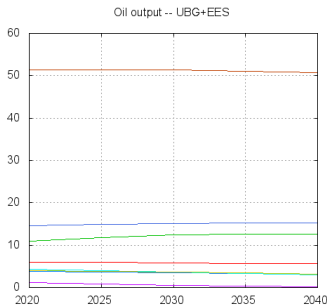
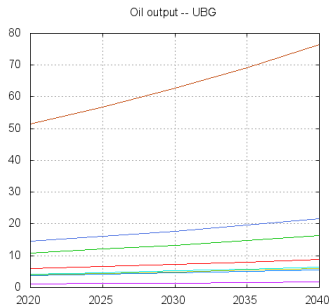
Coal output -- UBG+EEFS



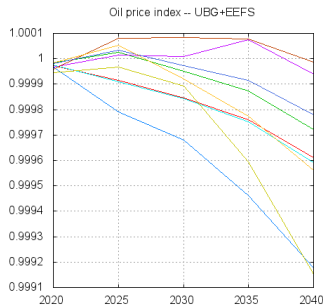
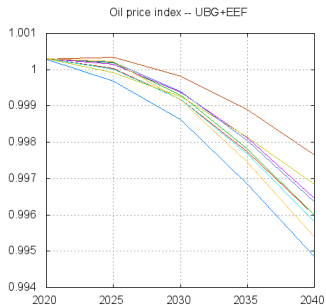
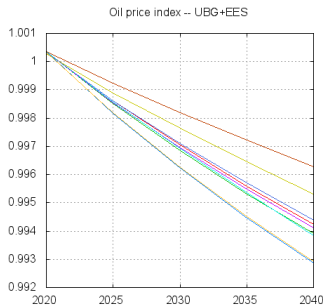
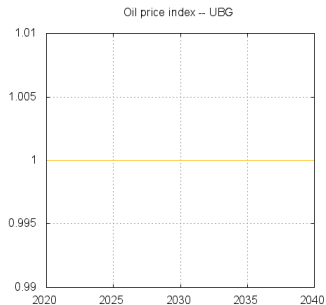
# Baselines: Energy Price - Coal



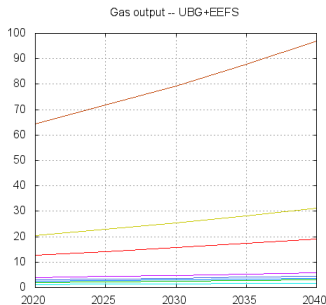
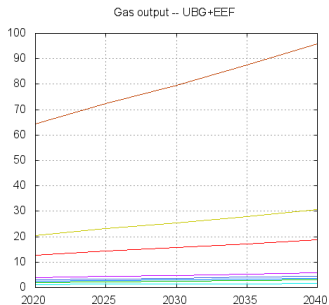
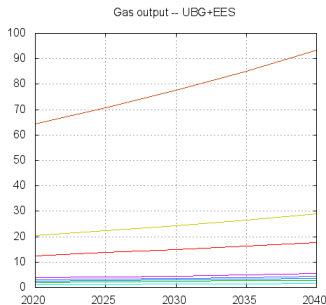
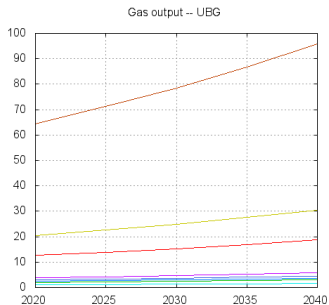
# Baselines: Energy Output - Oil



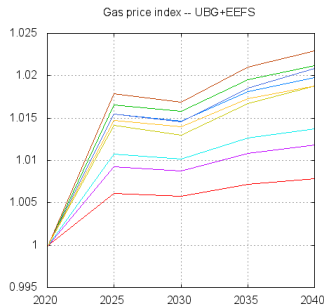
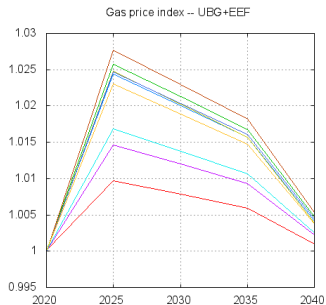
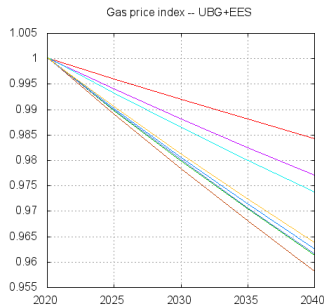
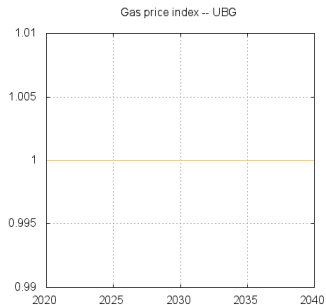
# Baselines: Energy Price - Oil



# Baselines: Energy Output - Gas



# Baselines: Energy Price - Gas





# Takeaways

- Heterogeneity in AEEI can make a significant difference in energy P/Q behavior for a computed baseline
- *Coal*: quantities and prices slightly higher with fuel-sector specific AEEI
- *Oil*: quantities and prices slightly higher with fuel-sector specific AEEI
- *Gas*: prices vary across AEEI implementations but quantities are steady

- Stylized carbon policy: 40% CO<sub>2</sub> abatement relative to baselines