Finding Pennsylvania's Solar Future

3rd Stakeholder Meeting

September 14, 2017

Philadelphia, PA

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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U.S. Department of Energy

Vermont Energy Investment Corporation

Overview

- Review model approach
- Preliminary results
- Costs
- Sources/documentation

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Modeling workflow

June meeting:

1. Reference and initial Solar scenarios
2. Familiarize workgroups with model, results, output capabilities, and stakeholders' ability to provide input and feedback
3. Detailed module review - identify questions, recommendations for additional data or analysis

Today:

1. Results for Reference and initial solar scenarios
2. Cost/Benefit initial results, import/export balance, power dispatch, land use
3. Key questions for future modeling

Winter meeting:

1. Revisions to scenarios based on feedback
2. What can we model to help the discussion?
3. Regional analyses? (e.g., by metro area or utility territory)

Changes to the model since June meeting:

- Split “Distributed Solar” into residential and commercial to reflect their different costs and performance (tilt angles)

- Two solar scenarios:
  - 65% grid-scale, 17.5% residential, 17.5% commercial
  - 90% grid-scale, 5% residential, 5% commercial

- Revised coal, natural gas, and oil to reflect amounts crossing into/out of PA
  - Previously had correct consumption, but was not reflecting which were indigenous and which were imported or exported

- Added costs for fuels, solar projects, and O&M for all electricity generators

Solar scenarios

Solar scenarios are built on the Reference scenario

- Energy, economic and demographic sources and references are the same in both scenarios
- Energy demand results are therefore the same
- Increases solar to meet 10% of electric in-state consumption by 2030
- Two versions vary by distributed vs grid-scale solar

	Reference Scenario	SolarA	SolarB
Overall Target	0.5% solar by 2020	10% in-state solar by 2030	
Total Solar Capacity in 2030	1.2 GW	11 GW	
Distributed Capacity in 2030	0.6 GW	3.9 GW (35% of total) ½ residential and ½ commercial	1.1 GW (10% of total) ½ residential and ½ commercial
Grid Scale Capacity (>3MW) in 2030	0.6 GW	7.1 GW (65% of total)	9.9 GW (90% of total)
Alternative Energy Portfolio Standard (AEPS)	No additional requirements after 2020	Assumes similar support beyond 2020	
Federal ITC	Modeled as a reduction in installed costs. Phase out by 2023		

The Reference/business-as-usual scenario

Why create this scenario?

- Model reflects historical data and projects business-as-usual
  - Used as a baseline to compare scenario results

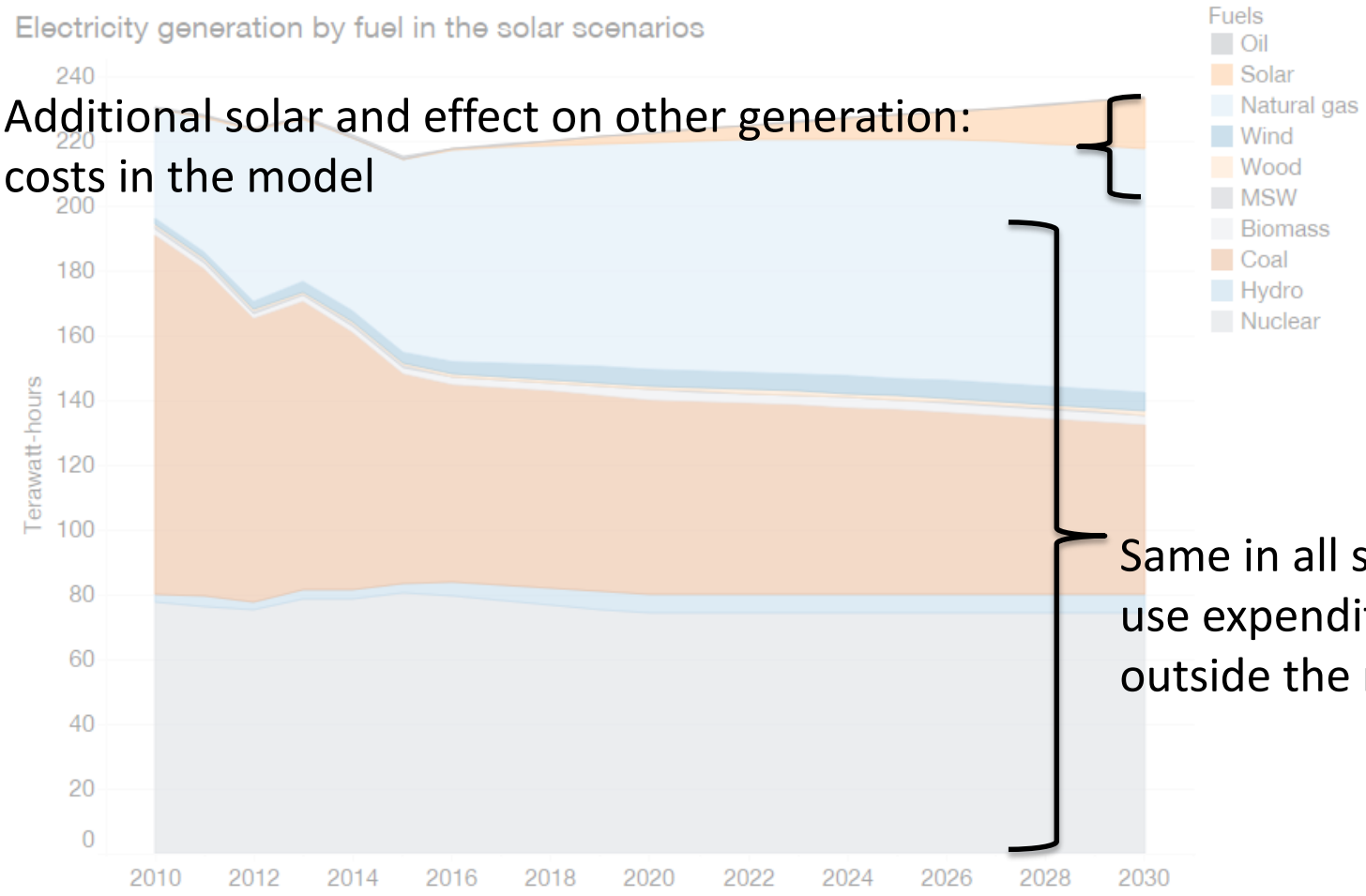
What are the sources?

- Economic & Demographic Data: Census/American Community Survey (ACS), PA Department of Labor and Industry, Center for Rural Pennsylvania
- Energy Data: Energy Information Administration (EIA): State Energy Data System, Residential Energy Consumption Survey (RECS), Annual Energy Outlook (AEO)
- Electric Generation capacity factor and costs: National Renewable Energy Laboratory (NREL) 2016 Annual Technology Baseline

How is the scenario defined, what are the assumptions?

- Meets AEPS in 2021
- Solar and efficiency continue current trends
- CAFE standards met for Light Duty Vehicles
- Federal Tax Credits sunset: residential ends in 2021, and commercial in 2023

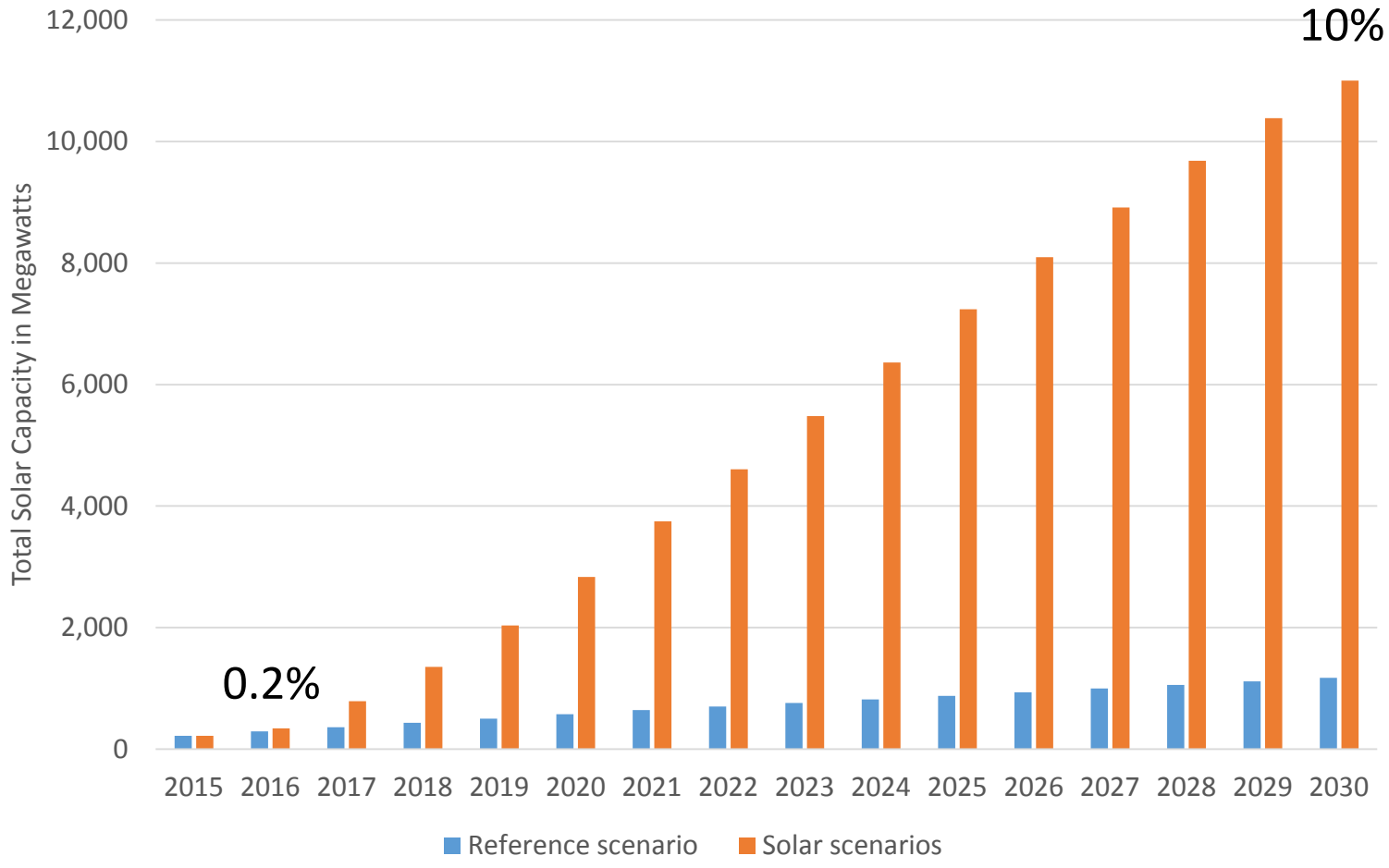
Modeling difference between scenarios



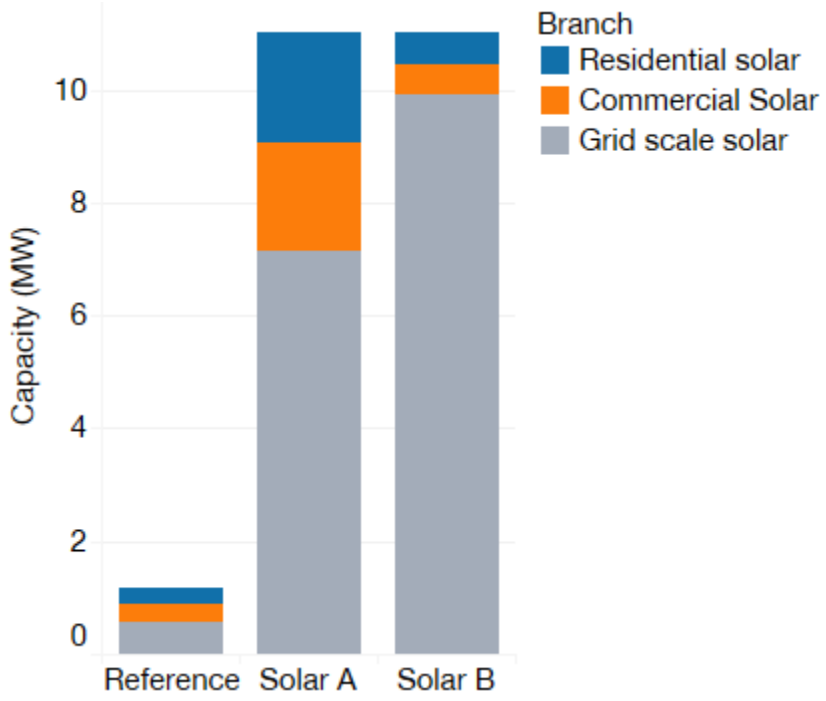
Additional solar and effect on other generation: costs in the model

Same in all scenarios: use expenditure sources outside the model

10x more solar capacity by 2030 in Solar scenarios compared to Reference



2030 solar capacity by scenario



Preliminary economic results

- Investing in solar, saving on other electric generating fuels at existing plants
- Currently, does not off set new capital investments for other types of generation
- Does not assume major change in export of electricity and other fuels

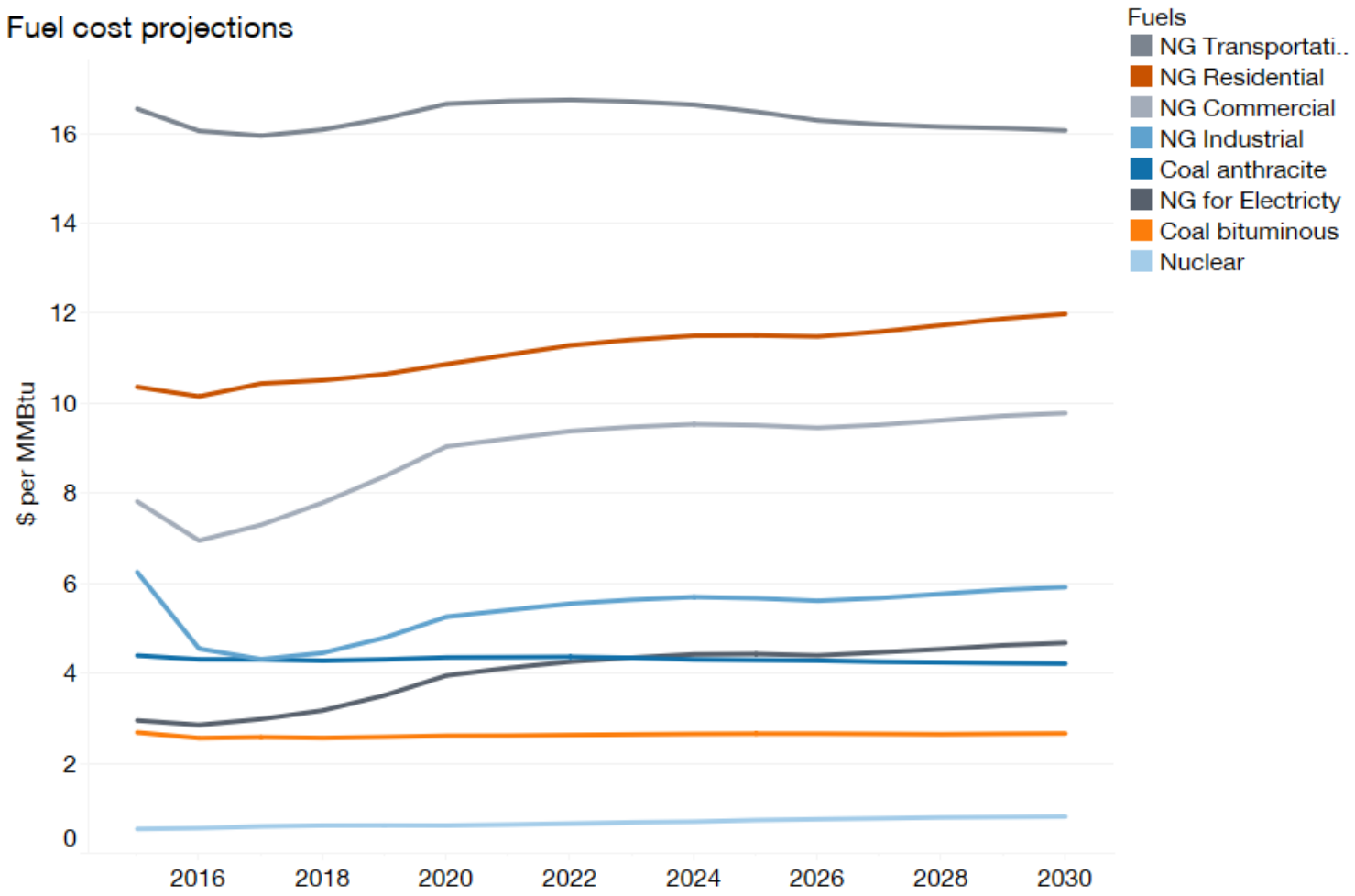
Prelim. economic results

- Net positive benefits $30-$50 million by 2030
  - Cumulative spending of nearly $500 million on solar
  - Over $500 cumulative savings from reductions of coal and gas generation
  - Net investments of less than 0.01% of annual expenditures
- Context: annual energy expenditures in PA: $45 billion

Cumulative costs and benefits of Solar scenarios relative to the Reference scenario, 2015-2030, discounted at 1.75% to 2017

	SolarA $ million (2017)	SolarB $ million (2017)
Demand	-	-
Residential	-	-
Commercial	-	-
Industrial	-	-
Transportation	-	-
Transformation	480	484
Transmission and distribution	-	-
Electricity generation	480	484
Gas production	-	-
Oil refining	-	-
Resources	-508	-536
Production	-508	--536
Imports		
Exports		
Unmet requirements	-	-
Environmental externalities	-	-
Non-energy sector costs	-	-
Net present value	-28	-52
GHG savings (million tonnes CO2e)	-	-
Cost of avoiding GHGs (U.S. dollar / tonne CO2e)	-	-

Source for fuel costs



EIA's Annual Energy Outlook (AEO) 2017, Reference scenario, Mid-Atlantic region

Cost assumptions

Discount rate[1]

- 1.75%
  - We are considering large scale changes and potential public policy, not an investment for a utility or other organization
  - Therefore utility WACC e.g. may not be the most appropriate estimate of the discount rate
  - We are considering a societal investment for societal benefits, similar to the Societal Cost Test (SCT), which uses a low discount rate reflecting higher valuing of future savings.
  - The SCT does not have a specific source for a rate, but it is lower than that for the similar Total Resource Cost (TRC) Test, which can use the 10-year Treasury bill rate, which has averaged near 2.25% for the past five years

Inflation rate

- 2.0%
  - Target rate for the Federal Reserve. PA's Independent Fiscal Office assumes this rate is achieved in their Economic and Budget Outlook

1. Regulatory Assistance Project & Synapse, *Energy Efficiency Cost-Effectiveness Screening*, http://www.synapse-energy.com/sites/default/files/SynapseReport.2012-11.RAP_.EE-Cost-Effectiveness-Screening.12-014.pdf

Source for costs – efficiency

- Scenario modeling focuses on the difference between scenarios: business-as-usual, and some scenario(s) of interest
- All scenarios in this model so far have identical demand
- Therefore, the costs in the demand module are the same (e.g. no investment in efficiency beyond the reference is included)
- If we propose a scenario with higher efficiency (e.g. to lower the in-state electricity consumption and reduce the amount of solar necessary to reach 10%), or more demand response and flexible load to accommodate more renewables, we will add the incremental costs to the model

Source for costs – electricity generation

- Initial cost analysis leans heavily on NREL's annual cost and performance data.[1]
  - Provides capital cost, O&M cost, capacity factor for all generation
  - We are using the "Mid case" of three cases
  - Open to rigorous local data
    - E.g. 2015 Gable report on solar costs, but when we applied year-to-year declines to update this data, the costs came in below national averages, making us skeptical, or requiring the PA specific year-to-year changes
    - Gable and LBNL Tracking the Sun data both show PA to be near the national average in solar pricing, so we are using national data directly; one source for current and projected prices

1. NREL (National Renewable Energy Laboratory). 2017. *2017 Annual Technology Baseline*. Golden, CO: National Renewable Energy Laboratory. http://atb.nrel.gov/.

Electricity generation characterization - solar

	Residential	Commercial	Grid-scale
Capacity Factor (DC/AC, %)	14%	12%	16%
(kWh/kW)	1,205	1,091	1,433
Capital Cost ($/kW)			
2017 w/o incentive	2,800	2,078	1,219
2017 w/ ITC	1,960	1,454	854
2030 (ITC gone)	1,500	1,126	921
O&M 2017 ($/kW·year)	21	16	12

NREL (National Renewable Energy Laboratory). 2017. *2017 Annual Technology Baseline*. Golden, CO: National Renewable Energy Laboratory. http://atb.nrel.gov/.

Key modeling questions for today's breakout sessions

- Should there be more efficiency?
- What if wind grew to 10% of in-state sales too?
- Natural gas is growing as a heating fuel. Will geothermal or new cold climate heat pumps complement or compete with gas?
- Are electric vehicles about to take off? What if they grow faster than we project?

Should there be more efficiency?

- Ramp up from 0.8% per year to 2%?
- In some or all of the scenarios?

What if wind grew to 10% of in-state sales too?

- Wind currently grows 7.8% per year until 2021 to meet AEPS, then stops
  - from 1.3 GW (2.5% of sales) in 2015 to 1.85 GW (3.5%) in 2021
- Grow wind to meet 10% of in-state electricity in 2030?
  - That would require about 5.2 GW of capacity
  - 10% year-over-year growth would get there
  - There are 7 GW of viable sites in the NREL Eastern Wind Dataset

Electricity generation characterization – wind

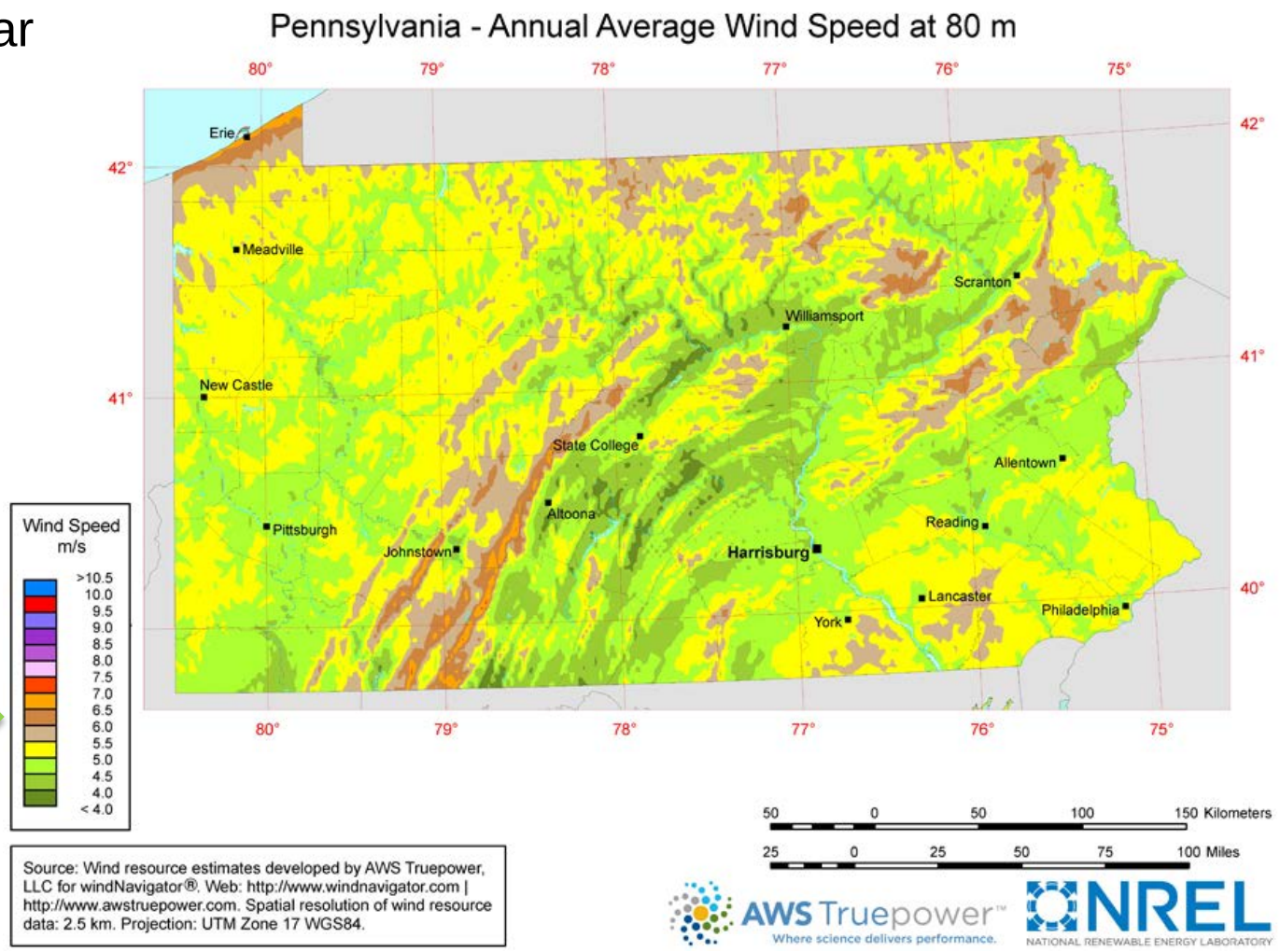
CF: 31%, 2,700 kWh/kW

CAPEX: $1,678/kW

O&M: $51/kW·year

LCOE:$64/MWh

Techno-Resource Group (TRG)	Wind Speed Range (m/s)	Weighted Average Wind Speed (m/s)
TRG1	7.7 - 13.5	8.8
TRG2	7.5 - 10.4	8.3
TRG3	7.3 - 10.5	8.1
TRG4	7.1 - 10.1	7.9
TRG5	6.8 - 9.5	7.5
TRG6	61. - 9.4	6.9
TRG7	5.3 - 8.3	6.2
TRG8	4.7 - 6.6	5.5
TRG9	4.1 - 5.7	4.8
TRG10	1.6 - 5.1	4.0

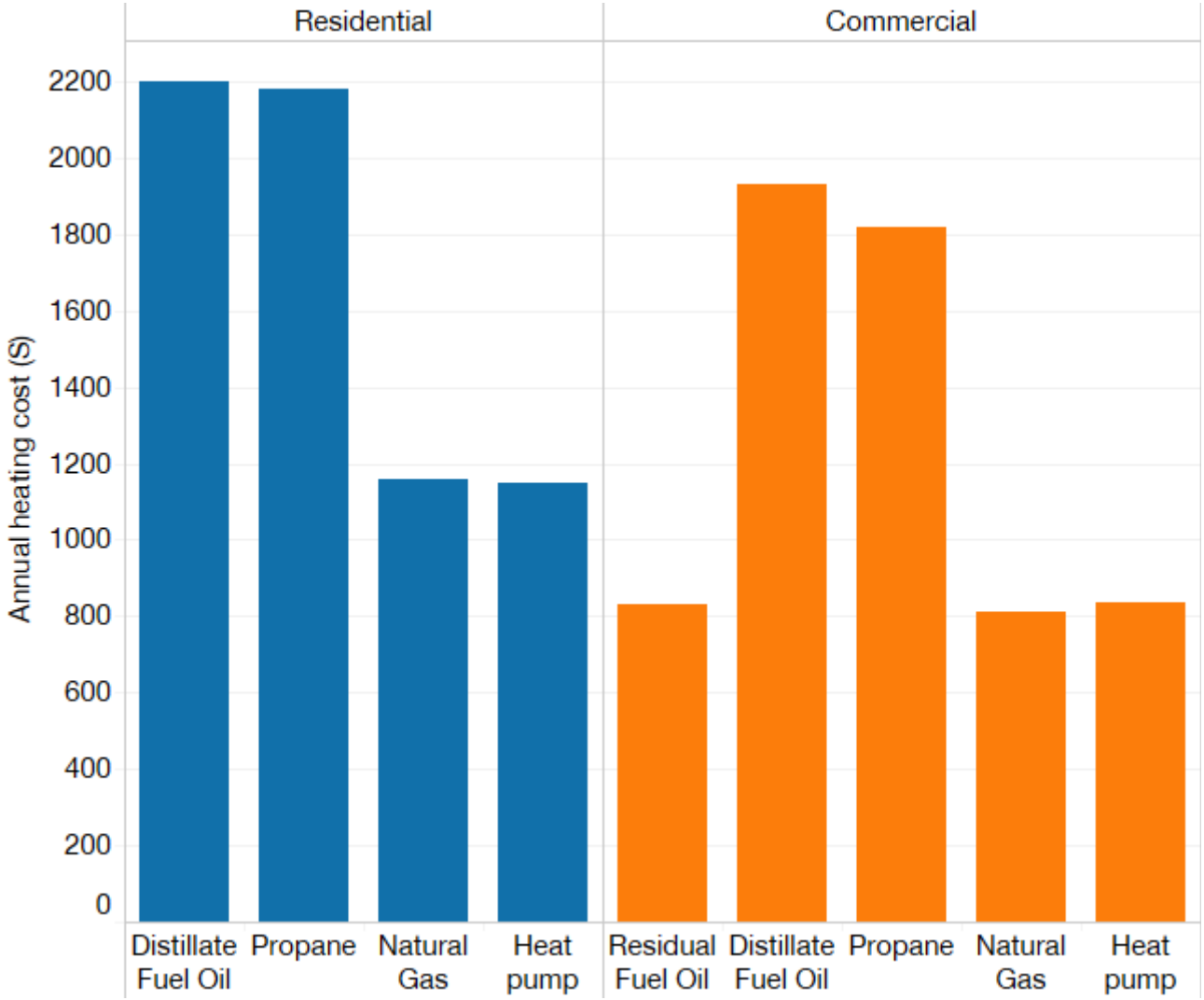


Source: Wind resource estimates developed by AWS Truepower, LLC for windNavigator®. Web: http://www.windnavigator.com | http://www.awstruepower.com. Spatial resolution of wind resource data: 2.5 km. Projection: UTM Zone 17 WGS84.

Will cold climate/geothermal heat pumps have an impact?

- PA home heating is 51% natural gas, 22% electricity, 18% oil, 4% propane, 5% other
- The trend is for gas to expand and replace the others
- But,
  - Gas lines do not and will not reach everyone
  - Electricity already reaches practically everyone
  - New cold climate heat pumps work down to -20°F
    - They are selling quickly in Maine and Vermont and some are installed as the sole source of heat, though many homes retain their old system for backup.
  - Geothermal heat pumps have been shown to be cost effective in PA, especially in new construction and commercial installations

Will heat pumps have an impact?



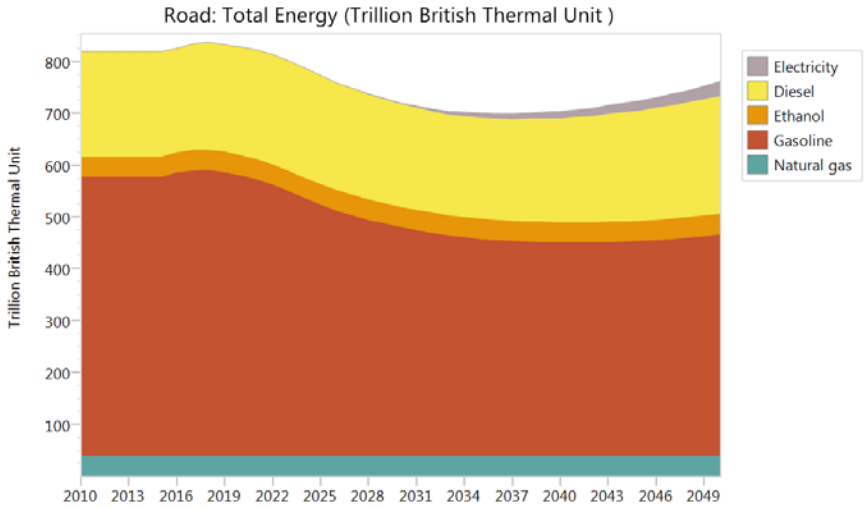
Assumptions:

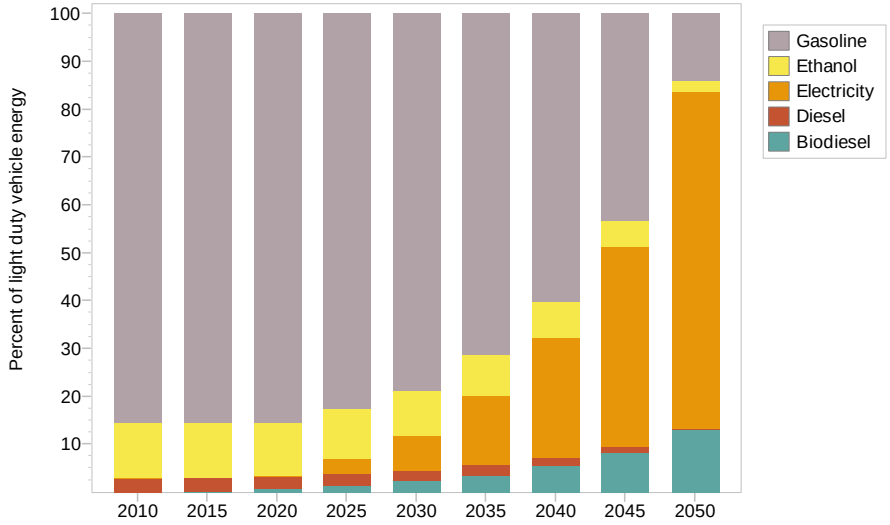
- Existing system efficiencies: oil: 85%, propane: 87%; new systems efficiencies: gas 90%, heat pump 2.8 COP
- Fossil fuel costs from 2017 AEO, volumetric electricity costs in USD/kWh: 0.11 for residential and 0.08 for commercial

Are electric vehicles about to take off? What if they grow faster than we project?

In the graph at right, EVs grow according to these annual rates:

- 2015-2025: 30% per year
- 2025-2035: 50% per year
- 2035-2050: 8% per year





Grow faster at first to account for near zero initial market share? Grow to replace most gasoline by 2050?

- 2015-2025:100%
- 2025-2035: 20%
- 2035-2050: 10%

Documentation

- We will continue to summarize sources in presentations and reports
- Model itself is available upon request
- Data and source for every input is documented in a spreadsheet (sample below) that is available upon request and will be an appendix in the report

Area:	PASF 2017.6.1	Ver:	2										
Branch Path	Variable	Scenario	Regio	Scale	Units		Expression	Level 1	Level 2	Level 3	Level 4...		
Key\Commercial employees	Activity Level	Current Account	Statewide		employees		4892410	Key Assumptio	Commercial employees			PA Dept of Labor and Industry Employment long t	
Key\Commercial employees	Activity Level	Reference	Statewide		employees		InterpFSY(2024,5203870, 2050, 5400000	Key Assumptio	Commercial employees			PA Dept of Labor and Industry Employment long t	
Key\Commercial employees	Activity Level	Solar	Statewide		employees		InterpFSY(2024,5203870, 2050, 5400000	Key Assumptio	Commercial employees			PA Dept of Labor and Industry Employment long t	
Key\Industrial employees NU	Activity Level	Current Account	Statewide		employees		898740	Key Assumptio	Industrial employees NU			PA Dept of Labor and Industry Employment long t	
Key\Industrial employees NU	Activity Level	Reference	Statewide		employees		InterpFSY(2024,925910)	Key Assumptio	Industrial employees NU			PA Dept of Labor and Industry Employment long t	
Key\Industrial employees NU	Activity Level	Solar	Statewide		employees		InterpFSY(2024,925910)	Key Assumptio	Industrial employees NU			PA Dept of Labor and Industry Employment long t	
Key\Light duty VMT NU	Activity Level	Current Account	Statewide		miles		(1-28%)*276562502*365	Key Assumptio	Light duty VMT NU			Pennsylvania Highway Statistics 2015 Highway Da	
Key\Light duty VMT NU	Activity Level	Reference	Statewide		miles		(1-28%)*276562502*365	Key Assumptio	Light duty VMT NU			Pennsylvania Highway Statistics 2015 Highway Da	
Key\Light duty VMT NU	Activity Level	Solar	Statewide		miles		(1-28%)*276562502*365	Key Assumptio	Light duty VMT NU			Pennsylvania Highway Statistics 2015 Highway Da	
Key\Heavy duty VMT NU	Activity Level	Current Account	Statewide		miles		(28%)*276562502*365	Key Assumptio	Heavy duty VMT NU			Pennsylvania Highway Statistics 2015 Highway Da	
Key\Heavy duty VMT NU	Activity Level	Reference	Statewide		miles		(28%)*276562502*365	Key Assumptio	Heavy duty VMT NU			Pennsylvania Highway Statistics 2015 Highway Da	
Key\Heavy duty VMT NU	Activity Level	Solar	Statewide		miles		(28%)*276562502*365	Key Assumptio	Heavy duty VMT NU			Pennsylvania Highway Statistics 2015 Highway Da	
Key\Industrial Shipped $K	Activity Level	Current Account	Statewid	Thousan	Dollars		232238725	Key Assumptio	Industrial Shipped $K			Total value of shipments and re https://factfinde	
Key\Industrial Shipped $K	Activity Level	Reference	Statewid	Thousan	Dollars		Growth(1.8%)	Key Assumptio	Industrial Shipped $K			Projected to grow at national rate from AEO	
Key\Industrial Shipped $K	Activity Level	Solar	Statewid	Thousan	Dollars		Growth(1.8%)	Key Assumptio	Industrial Shipped $K			Projected to grow at national rate from AEO	
Key\Residential\People per household	Activity Level	Current Account	Statewide		People		2.29205	Key Assumptio	Residential	People per household		Census Population / ACS Housing Data	
Key\Residential\People per household	Activity Level	Reference	Statewide		People		2.29205	Key Assumptio	Residential	People per household		Census Population / ACS Housing Data	
Key\Residential\People per household	Activity Level	Solar	Statewide		People		2.29205	Key Assumptio	Residential	People per household		Census Population / ACS Housing Data	
Key\Residential\Population	Activity Level	Current Account	Statewide		People		12802503	Key Assumptio	Residential	Population		US Census number	
Key\Residential\Population	Activity Level	Reference	Statewide		People		InterpFSY(2020, 13230170, 2030, 13759	Key Assumptio	Residential	Population		The Center for Rural Pennsylvania, "Pennsylvan	
Key\Residential\Population	Activity Level	Solar	Statewide		People		InterpFSY(2020, 13230170, 2030, 13759	Key Assumptio	Residential	Population		The Center for Rural Pennsylvania, "Pennsylvan	
Key\Residential\Occupied Housing Units	Activity Level	Current Account	Statewide		Households		4958859	Key Assumptio	Residential	Occupied Housing Units		Census DP04 Housing table for Pennsylvania, 201	
Key\Residential\Occupied Housing Units	Activity Level	Reference	Statewide		Households		4958859	Key Assumptio	Residential	Occupied Housing Units		Census DP04 Housing table for Pennsylvania, 201	
Key\Residential\Occupied Housing Units	Activity Level	Solar	Statewide		Households		4958859	Key Assumptio	Residential	Occupied Housing Units		Census DP04 Housing table for Pennsylvania, 201	
Key\Residential\Unoccupied Housing Uni	Activity Level	Current Account	Statewide		Households		626752	Key Assumptio	Residential	Unoccupied Housing Units		Census DP04 Housing table for Pennsylvania, 201	
Key\Residential\Unoccupied Housing Uni	Activity Level	Reference	Statewide		Households		626752	Key Assumptio	Residential	Unoccupied Housing Units		Census DP04 Housing table for Pennsylvania, 201	
Key\Residential\Unoccupied Housing Uni	Activity Level	Solar	Statewide		Households		626752	Key Assumptio	Residential	Unoccupied Housing Units		Census DP04 Housing table for Pennsylvania, 201	
Key\Residential\All Households	Activity Level	Current Account	Statewide		Households		Occupied Housing Units[Households	Key Assumptio	Residential	All Households		Calculated in the model	
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Key\Residential\All Households	Activity Level	Solar	Statewide		Households		Population[People] / People per hou	Key Assumptio	Residential	All Households		Calculated in the model	
Key\Residential\Lighting and Plug Loads\	Activity Level	Current Account	Statewide		MMBTU		23.3	Key Assumptio	Residential	Lighting and Plu	SF Light and Plu	EIA RECS Data, Table CE4.7, Household	O:\Consul
Key\Residential\Lighting and Plug Loads\	Activity Level	Reference	Statewide		MMBTU		23.3	Key Assumptio	Residential	Lighting and Plu	SF Light and Plu	EIA RECS Data, Table CE4.7, Household	O:\Consul
Key\Residential\Lighting and Plug Loads\	Activity Level	Solar	Statewide		MMBTU		23.3	Key Assumptio	Residential	Lighting and Plu	SF Light and Plu	EIA RECS Data, Table CE4.7, Household	O:\Consul
Key\Residential\Lighting and Plug Loads\	Activity Level	Current Account	Statewide		MMBTU		9.3	Key Assumptio	Residential	Lighting and Plu	MF Light and Pl	EIA RECS Data, Table CE4.7, Household	O:\Consul

Thank You!

Discussion & Questions

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