Finding Pennsylvania's Solar Future

June 14, 2018
Philadelphia

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Vermont Energy Investment Corporation

Overview

- How modeling supports study and stakeholder process
- Review modeling results
- Viability of PA Solar Future across multiple dimensions?
- Implications for next stages of work – key questions

David G. Hill, Ph.D.
Distributed Resources Director
dhill@veic.org

Damon Lane
Lead Analyst
dlane@veic.org

Kate Desrochers
Senior Analyst
kdesrochers@veic.org

“The purpose of models is not to fit the data but to sharpen the questions”

-Samuel Karlin

Finding Pennsylvania's Solar Future

Research objectives

- Convene and engage stakeholders for analytically-based discussions and reporting on Pennsylvania's Solar Future
- Scenarios consider solar in context of total energy economy
- Initial Solar scenario is 10% of in-state sales by 2030
- Transparent accounting – compare energy flows, costs and other impacts between scenarios
- Support workgroups:
  - Regulatory and ratemaking
  - Markets and business models
  - Operations and Interconnection
- Multi-audience reporting and communications

Finding PA Solar Future – Modeling Activities

June 2017 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

September 2017 meeting:

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 – specify additional scenarios

December 2017 meeting:

1. Review the scenarios and combinations
2. Energy results – Economic results – Environmental results
3. Sensitivities to be included in report

March 2018 meeting:

1. Discuss modeling as it supports study and strategies
2. Review sources and assumptions
3. Review results and implications for strategies

June 2018 meeting:

1. Discuss modeling as it supports the study
2. Review results and implications for strategies

Iterative Changes to Modeling:

- Trued up historic solar growth through 2017
- Refined projected solar growth curve – slower at first, faster later
- Revised costs to start with PA-specific data from OpenPV, and transition to national pricing by 2030 as the market grows
- Added effect of PA sales tax and Federal tariff
- Added grid upgrade cost
- Added health impact benefits
- Calculated customer economics, incentive levels, bill impacts
- Increased integration cost to $5/MWh
- Changed presentation of land use impact
- Ensure that no unintended changes after 2030 affect the long term results

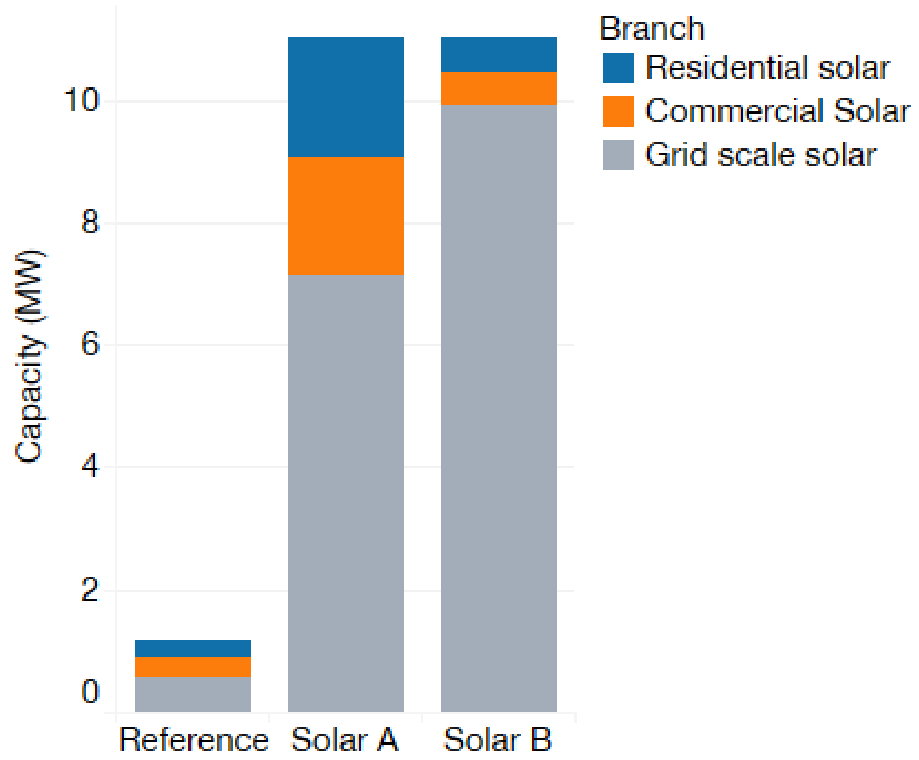
Antioch College

Main Scenario Definitions

	Reference Scenario	Solar A	Solar B
Overall Target	0.5% solar by 2020	10% in-state solar by 2030	10% in-state solar by 2030
Total Solar Capacity in 2030	1.2 GW	11 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)	Assumes AEPS efficiency trends continue support beyond 2020	Assumes AEPS efficiency trends continue support beyond 2020	Assumes AEPS efficiency trends continue support beyond 2020
Federal ITC	Modeled as a reduction in installed costs. Phase out by 2023	Modeled as a reduction in installed costs. Phase out by 2023	Modeled as a reduction in installed costs. Phase out by 2023

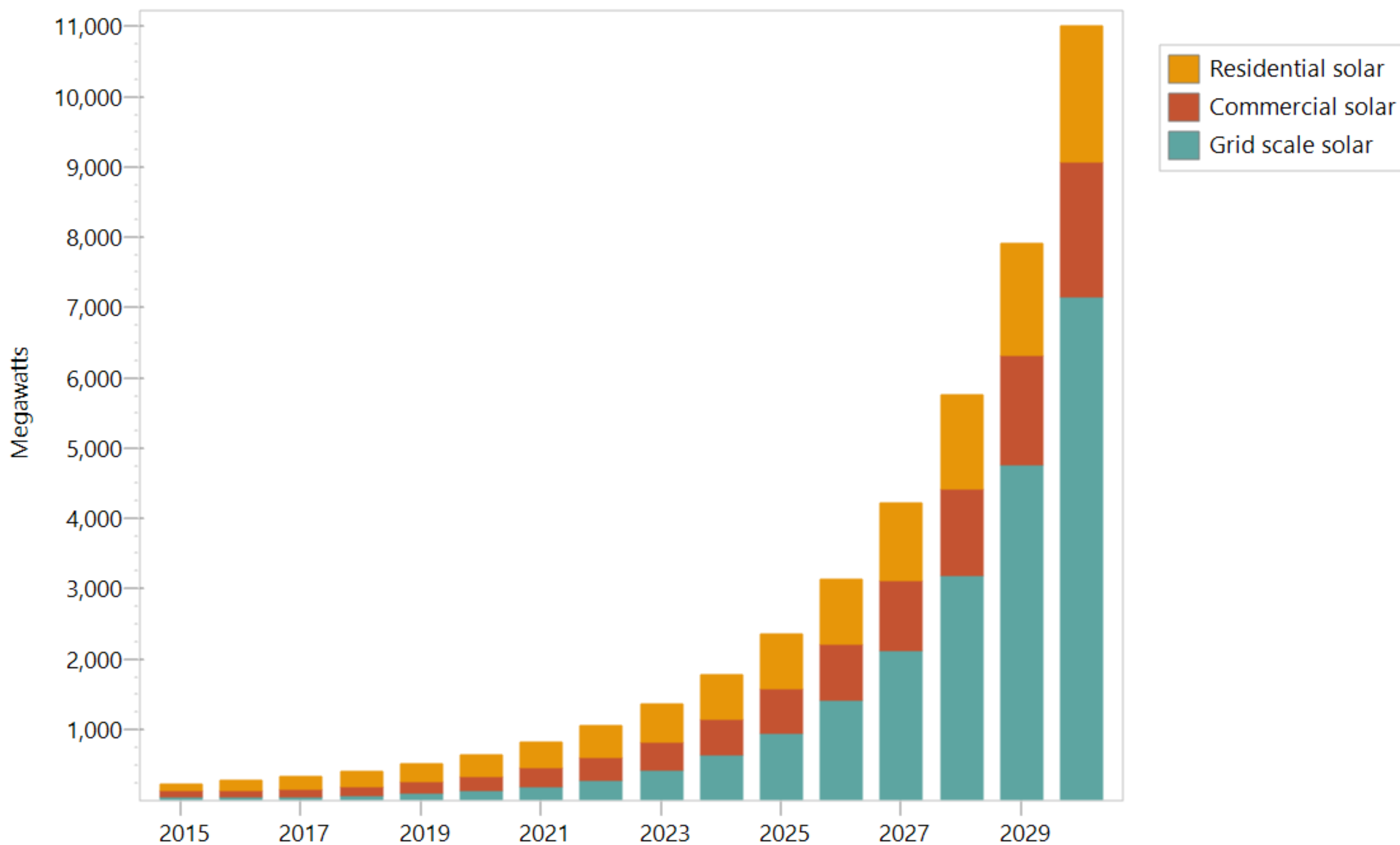
By 2030 PA Solar Future Scenarios have 10x solar capacity than reference

- Both cases rely for majority on grid scale solar
- Solar A also sees significant growth in roof-top/site based markets



Executive Summary Modeling Results

Solar capacity by year and scale in Solar A



Viability?

Economics
Grid Integration
Land Use
Jobs

Economic Benefit Cost Results

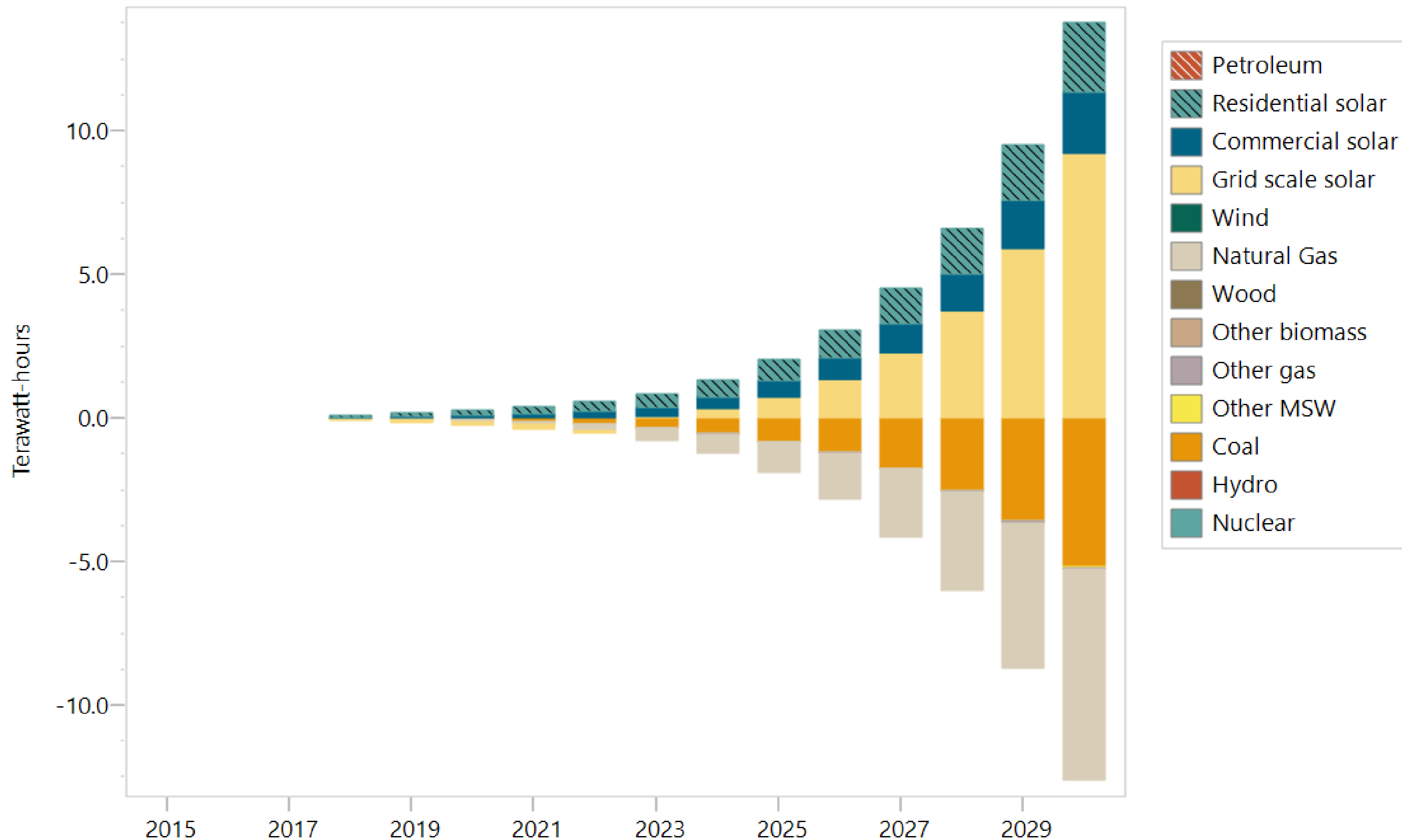
Cumulative cost and benefits 2015-2030 relative to reference scenario

	Solar A	**Solar B**
	Spending or (Savings)	
Grid upgrades	0.1	0.1
Electricity generation	11.6	10.1
Fuel costs	-2.5	-2.5
Externalities	not included	
NPV (economy wide)	**9.2**	**7.7**
Cost of avoided GHG ($/Tonne CO2e)	29	25

Billions of 2017 USD, discounted at 1.75%

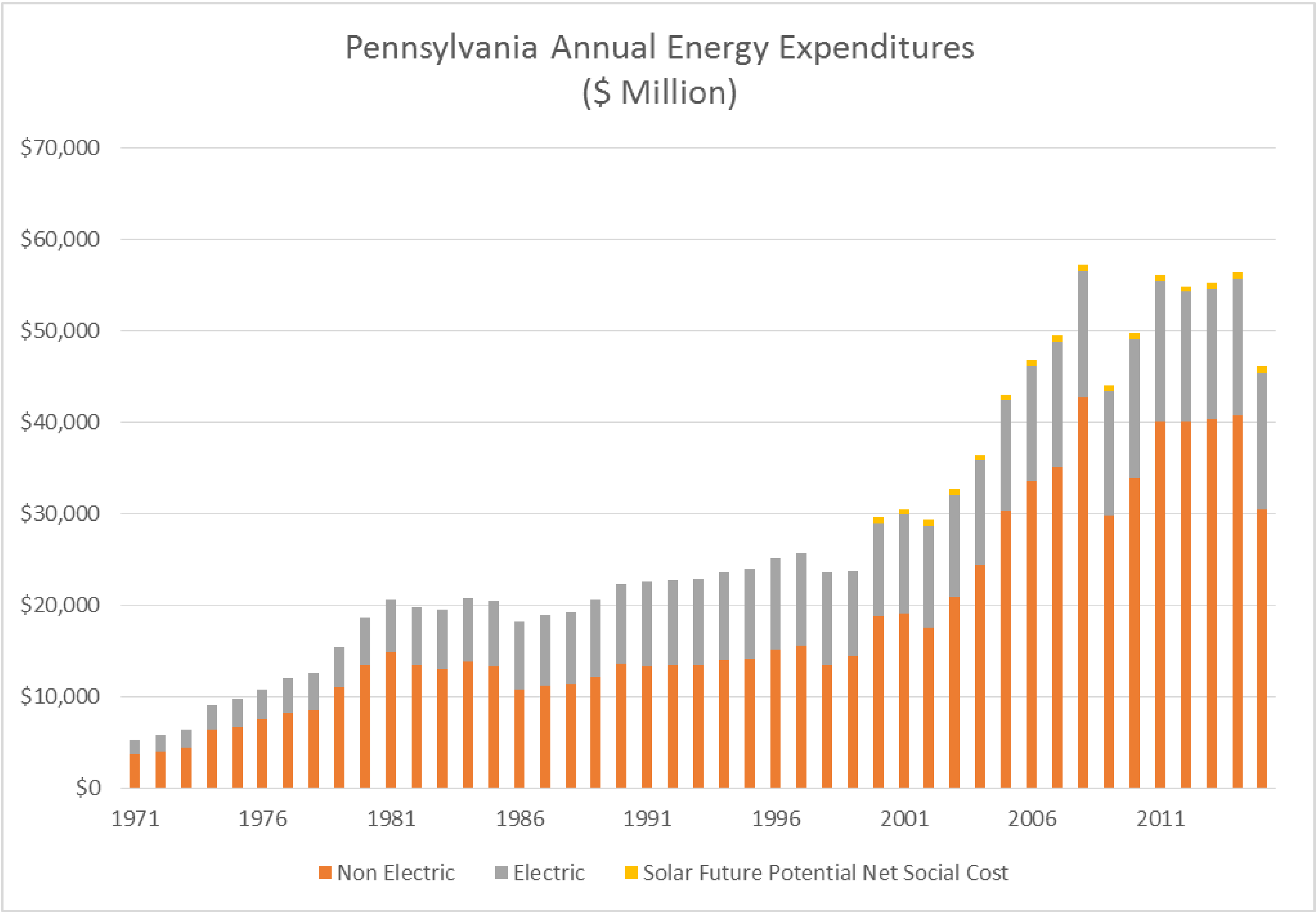
Resource Savings through 2030

Difference in generation between Solar A and reference



Scale of net investment

Scenario investments compared to historic energy expenditures



Modeling findings: Customer's perspective economics

- Residential system in Philadelphia *in 2025*
- Looking for 10 year pay back, as an indicator of wide market acceptance
- What SREC price provides that?

Residential Installation Cost of PA ($/w)	2.5	(Assumed)
PV System Size (kW)	7.5	
Total Installation Cost	*$18,750*	(Assume ITC=0%)
Assumed Solar Generation Factor (kWh/kW/yr)	1.2	
Projected Annual Solar Generation	*9,000*	
Assumed Full Retail Electric Rate ($/kWh)	0.15	
Annual Electric Bill Savings	*$1,350*	
Assumed SREC Life = Target Payback (yrs)	10	
Annual SREC Payment for Payback Target	*$525*	(Backcalculated)
SREC Price to Achieve Target Payback ($/SREC)	***$58***	
Customer's NPV after 20 years	*$7,000*	1.75% real discount rate

Modeling findings: rate impact

Using SREC just determined, find rate impact to average residential bill

2025 PA Electric Sales (Assumed)	150,000,000	MWh
2025 Solar Share Requirement (Assumed)	0.04	(4% in 2025)
2025 SREC Requirement (Calculated)	*6,000,000*	MWh (= SRECs)

Assumed SREC Price in 2025 (Only PA SRECs)	$58	(from previous)
Total Cost to Purchase SRECs in 2025	*$350,000,000*	
Bill line item cost for purchasing 2025 SRECs	*$0.0023333*	$/kWh

Typical PA Residential Customer Usage	10,000	kWh/yr
	833.3	kWh/month

Residential bill increase for 2025 SREC costs	***$1.94***	**per month**
	$23.33	**per year**

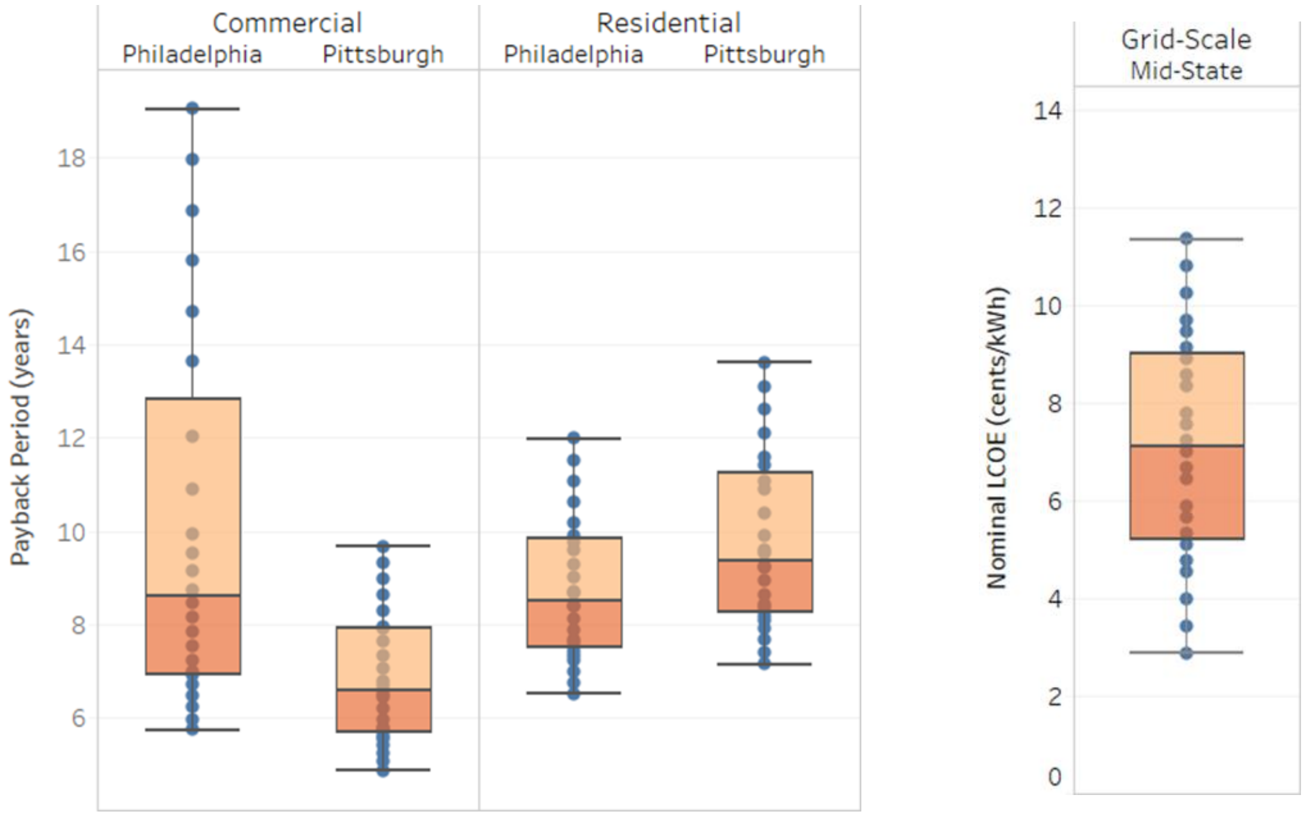
Modeling findings: customer economics

Parameter analysis to consider different inputs

- Increasing precision:
  - Account for panel degradation
  - Account for income tax on SREC income
  - Account for annualized maintenance costs
- Varying the inputs:
  - Today's estimated installed cost, higher and lower
    - ± \$0.50/W in five steps
  - Recent SREC prices and higher
    - \$6/MWh - \$100/MWh in five steps
  - Systems simulated (different costs, generation, electric rates)
    - Residential and Commercial in Pittsburgh and Philadelphia
    - Grid scale outside Philadelphia

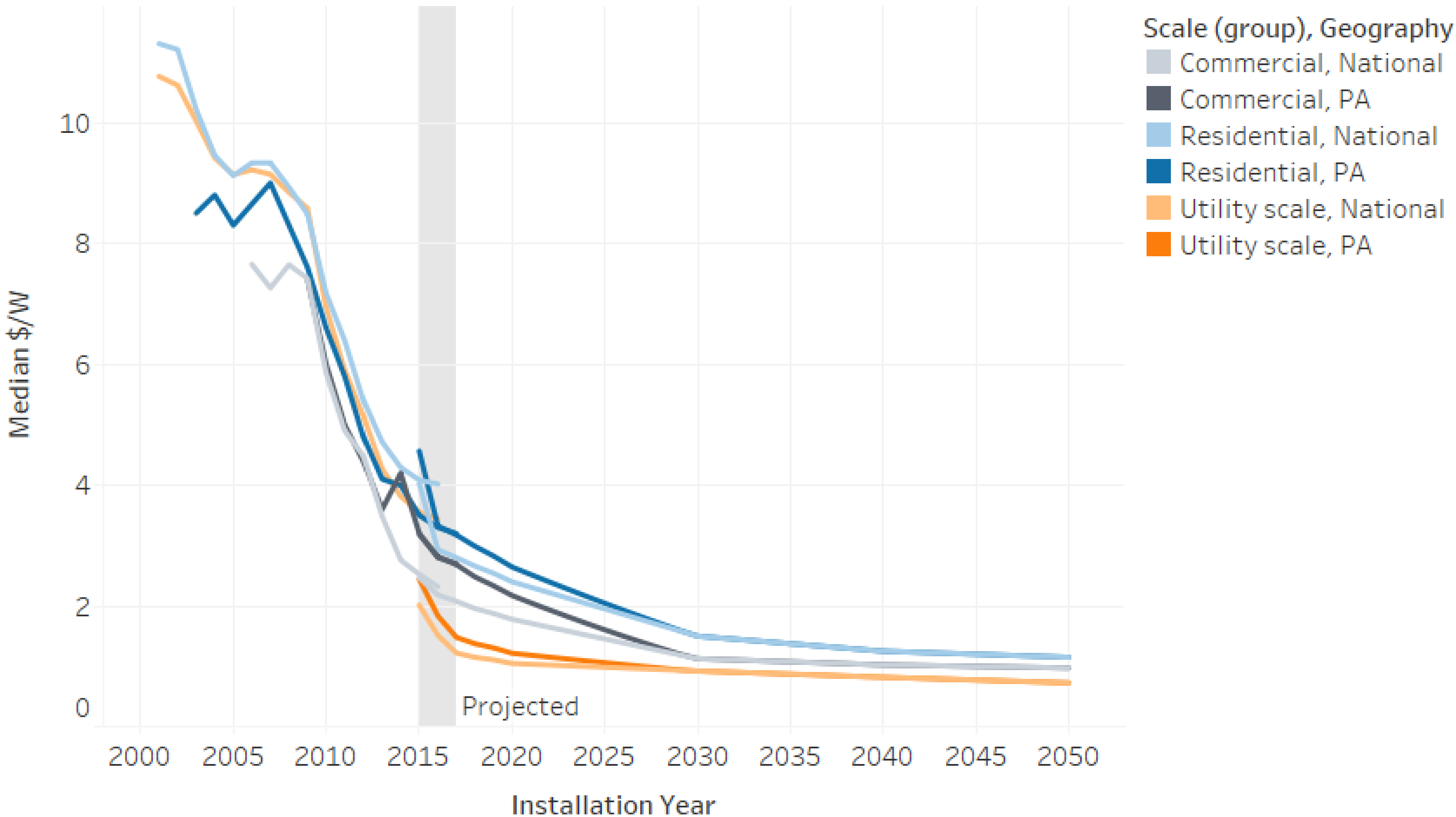
Customer Economics Parametric Analysis

How do changes in module cost and SREC values change customer economics? NREL SAM analysis

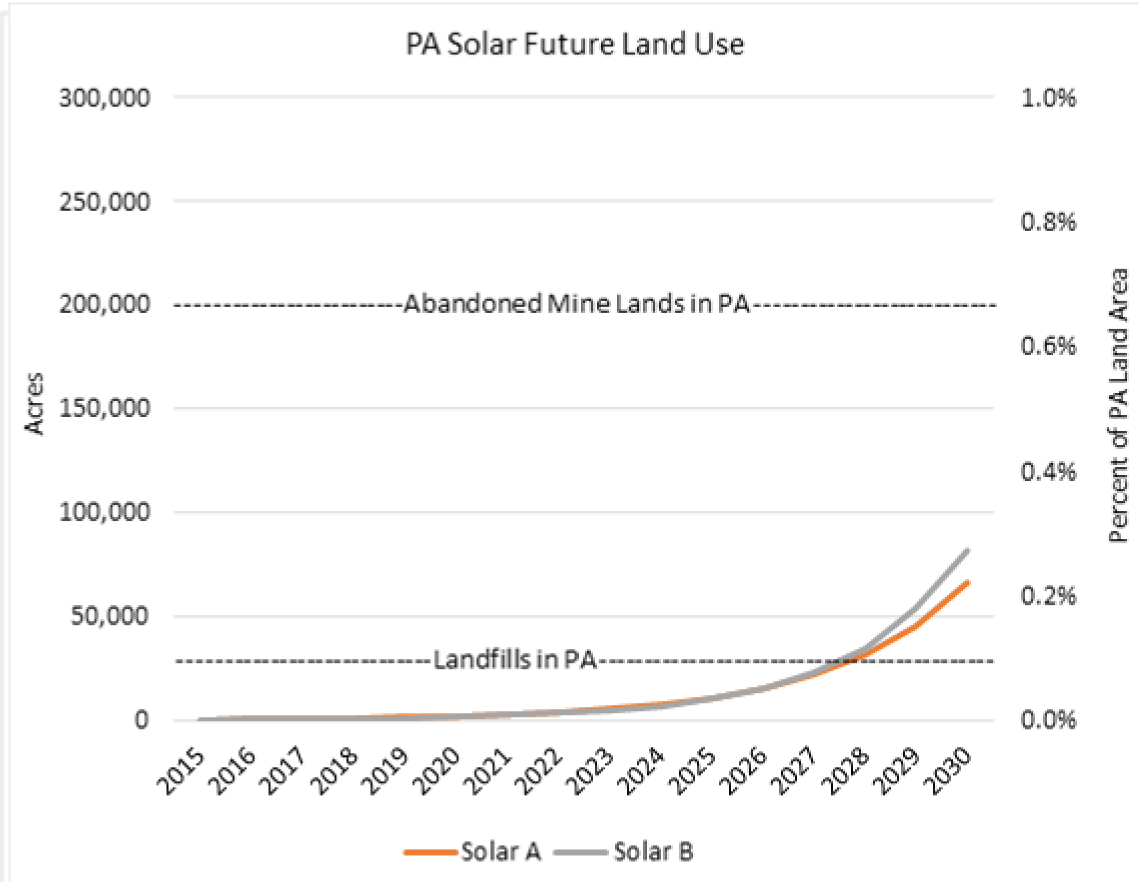


Modeling input: solar prices

Historic PA: OpenPV
National historic and projections: LBL Tracking the Sun 10, NREL 2017 ATB



Viability Land Impact
All scenarios less than 0.3% of land area



- Assumes 100% of grid supply PV is ground mounted, 10% of residential, and 50% of commercial
- Assumes 8 acres per MW
- 10% of electricity from PV requires about 1% of the area used by farms
- Many counties have more land area in farms than the entire state's PV requires

Vermont Energy Investment Corporation

pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION

Viability Land Impact

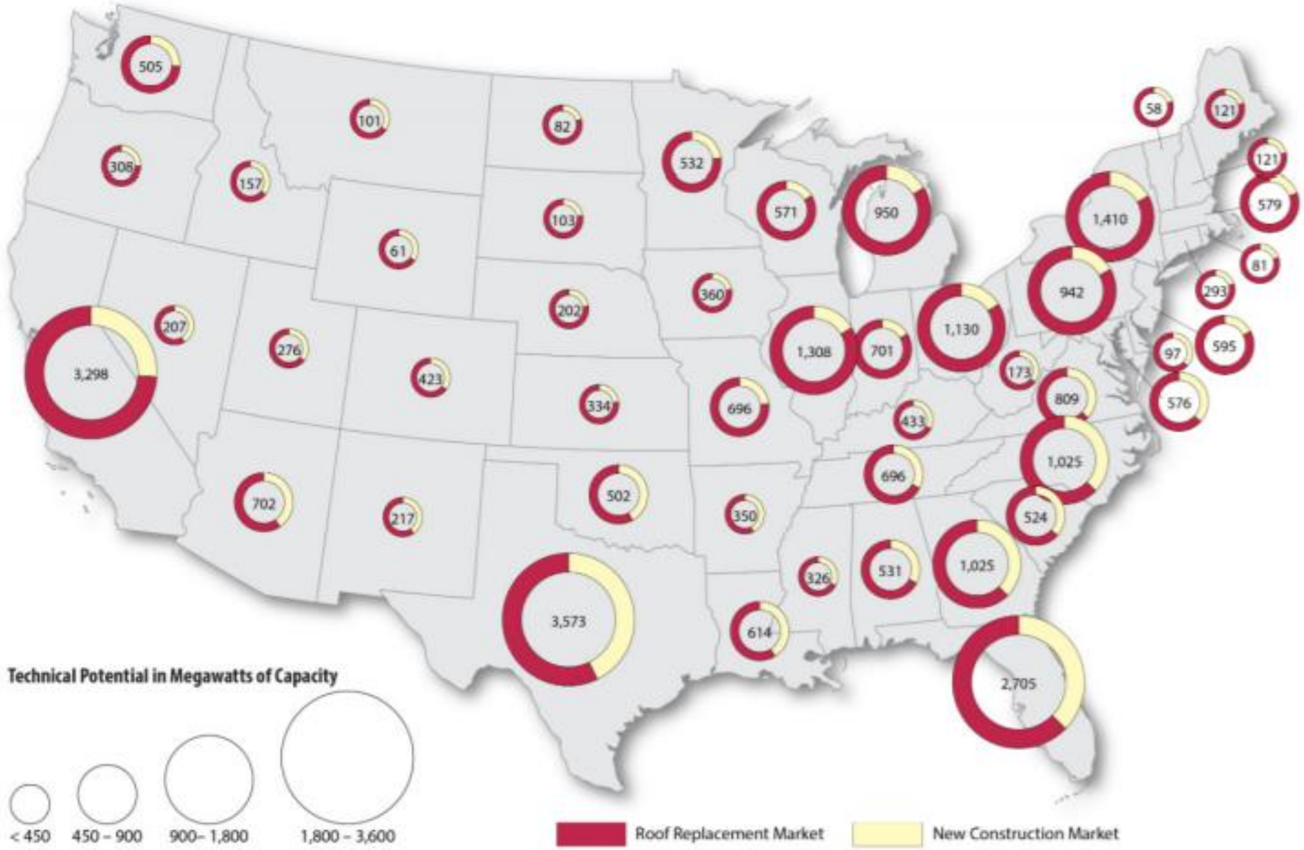


Figure ES-1. Annual average technical potential for residential rooftop PV at time of roof replacement and new construction projected between 2017 and 2030

Kristen Ardani, Jeffrey J. Cook, Ran Fu, and Robert Margolis. 2018. Cost Reduction Roadmap for Residential Solar Photovoltaics (PV), 2017–2030. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20- 70748.

Modeling input: health impacts

Pollutant	Damage Cost	Compliance Cost	Cost Units
Carbon Dioxide	47	4	USD/metric tonne
Nitrogen Oxides	10	0.20	USD/kilogram
Sulfur Dioxides	20	0.035	USD/kilogram

Damage costs for CO2, SO2, and NOx according to
Buonocore et al (Nature 2015, doi:10.1038/nclimate2771)

Compliance costs are based on 2017 auction results from the relevant markets:
- The carbon dioxide price is from the Regional Greenhouse Gas Initiative (RGGI)
- The nitrogen oxides price is a rough estimate based on recent seasonal and annual prices in the monthly spot market
- The sulfur dioxides price is the weighted average of the 2017 spot auction and the advanced auction, for allowances first usable in 2017 and 2024 respectively

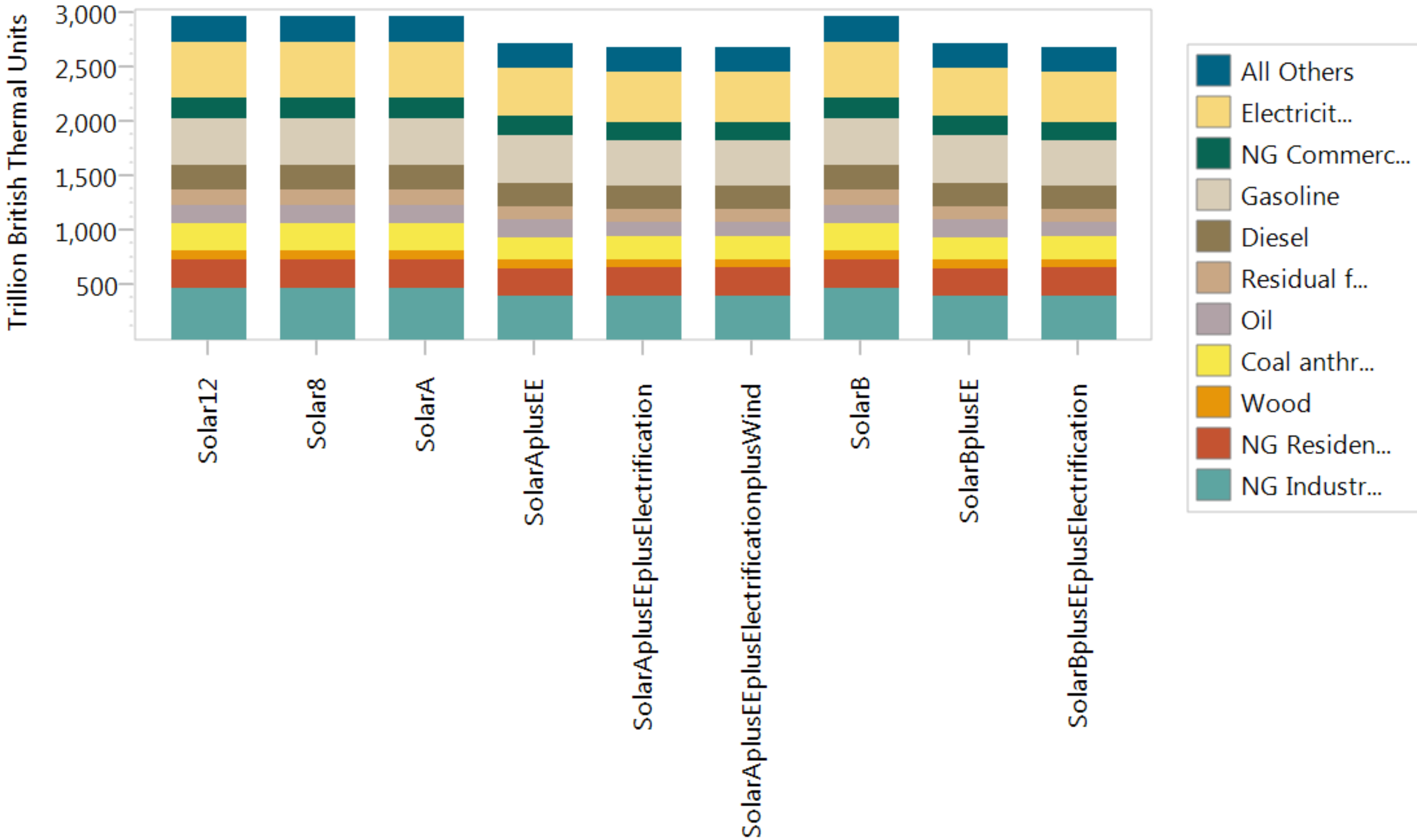
Economic Benefit Cost Results with health and environmental effects

Cumulative cost and benefits relative to reference scenario, 1.75% real discount r

	Solar A	Solar B	Solar A	Solar B
	With damage-based externality costs		With compliance externality costs	
	Spending or (Savings)			
Grid Upgrades	0.1	0.1	0.1	0.1
Electricity Generation	11.6	10.1	11.6	10.1
Fuel Costs	-2.5	-2.5	-2.5	-2.5
Externalities	-34.4	-33.8	-0.9	-0.9
NPV (economy wide)	**-25.2**	**-26.2**	**8.3**	**6.8**

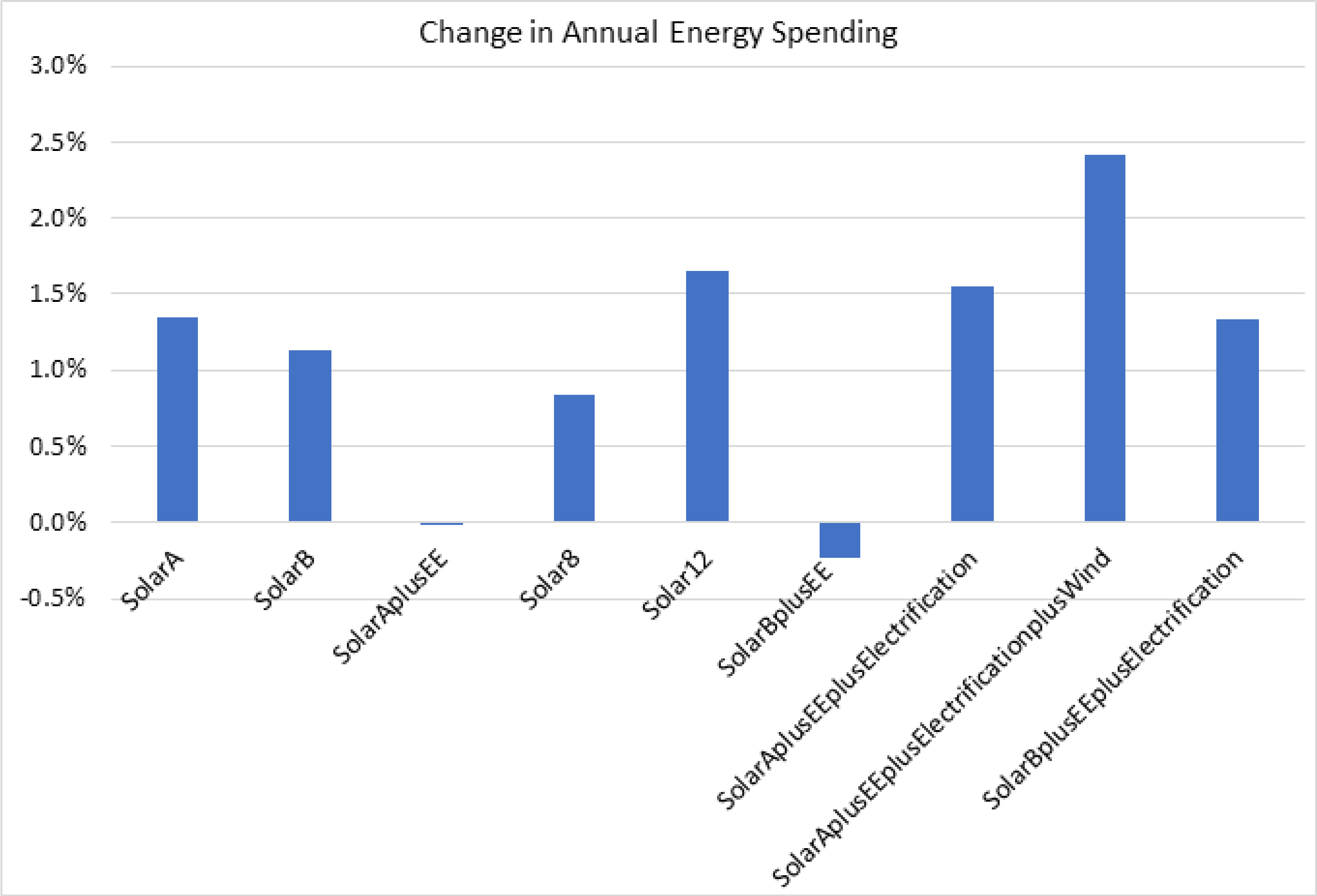
Alternative Scenarios

Total Final Demand in 2030 by Scenario and Fuel (TBtu)



Alternative Scenarios

Difference in total energy spending by scenario



Implementation Phase – Next Steps

- Priority questions or issues where additional modeling can provide value, or catalyze market growth
- Tracking of key metrics
- Analysis of levers to reduce barriers

Thank You!

Discussion & Questions

David Hill
(802) 540-7734
Dhill@veic.org

Damon Lane
(802) 540-7722
Dlane@veic.org

LEAP System

- <u>L</u>ong-range <u>E</u>nergy <u>A</u>lternatives <u>P</u>lanning System
- Transparent accounting framework
- Developed by Stockholm Environment Institute (SEI)
- Decades of use in > 190 countries
- Scenario based: “self-consistent story lines of how an energy system might evolve over time”
- Introductory page on SEI’s website:

  https://energycommunity.org/default.asp?action=introduction

LEAP *Tools for Sustainable Energy Analysis*

Building the Reference 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?

- Energy Data: Energy Information Administration (EIA): State Energy Data System, Residential Energy Consumption Survey (RECS), Annual Energy Outlook (AEO)
- Economic Demographic Data: Census/American Community Survey (ACS), PA Department of Labor and Industry, Center for Rural Pennsylvania

How is the scenario defined, what are the assumptions?

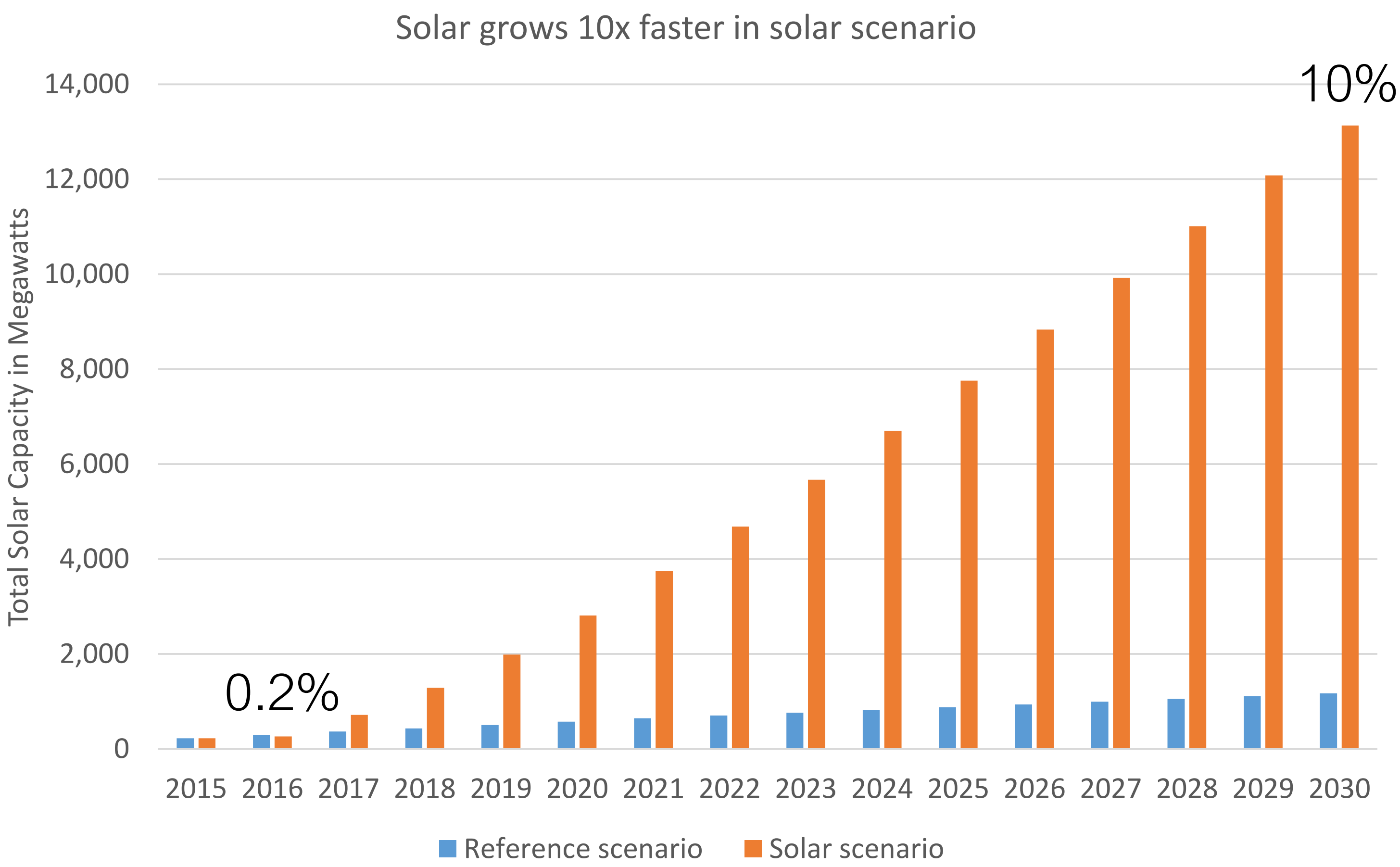
- Meets AEPS in 2021
- Solar and efficiency continue current trends
- CAFE standards met for Light Duty Vehicles
- Federal Tax Credits sunset

Building the initial Solar scenario

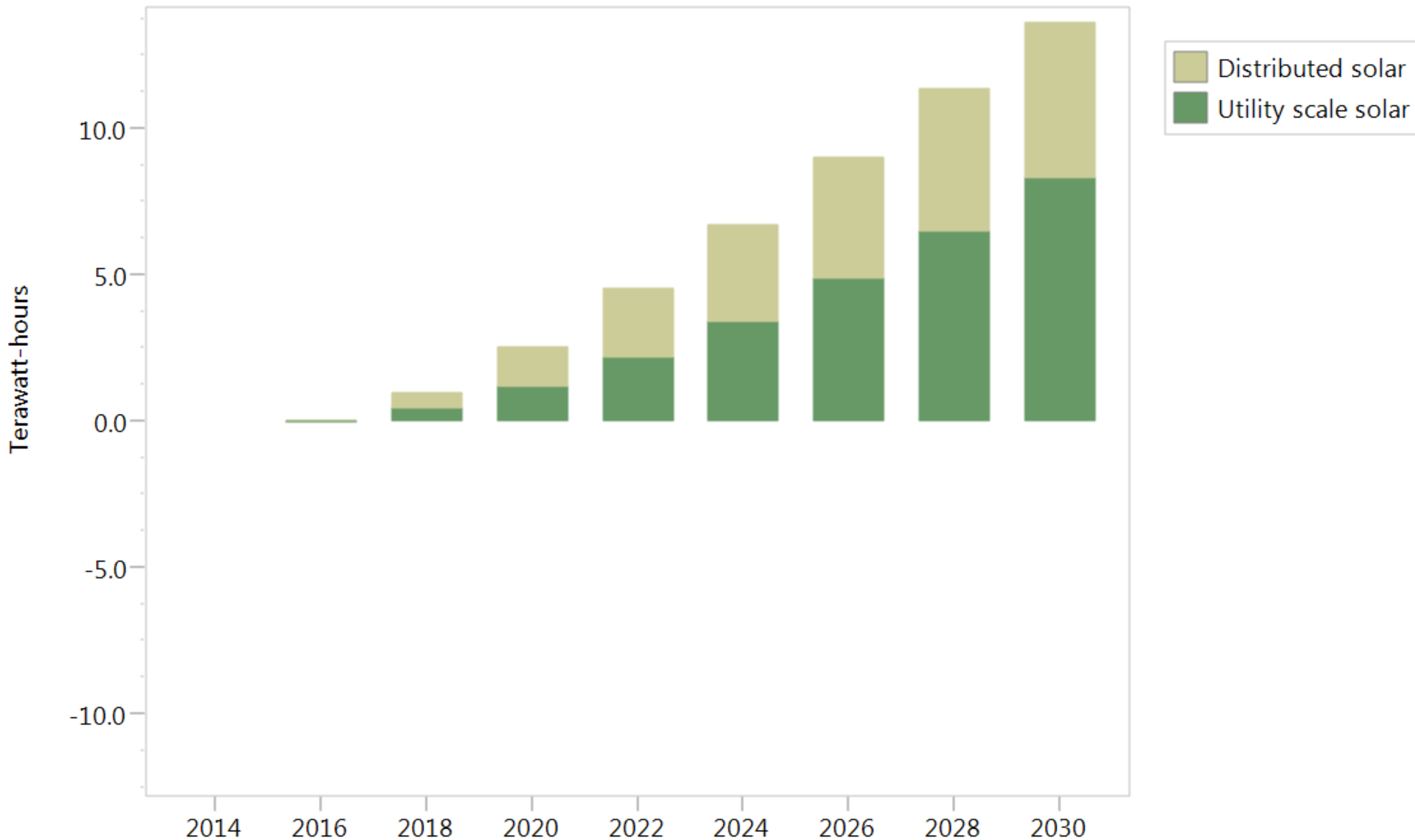
Initial Solar scenario is built upon the Reference scenario

1. Energy, economic and demographic sources and references are the same in both scenarios
2. Energy demand results are therefore the same
3. Increases solar to meet 10% of electric in-state consumption by 2030
4. Half utility-scale and half distributed solar by 2021

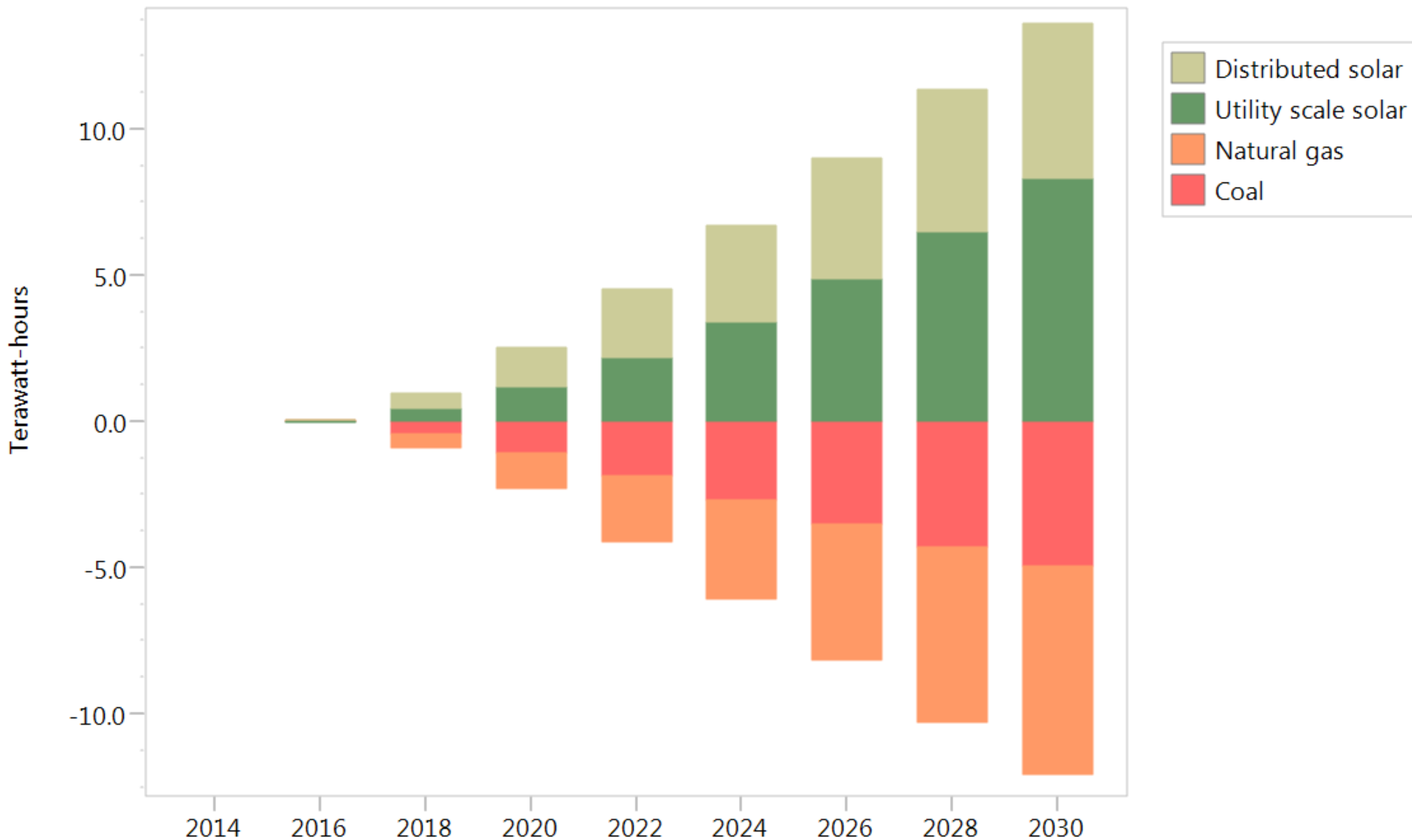
10x more solar capacity by 2030 in Solar scenario compared to Reference



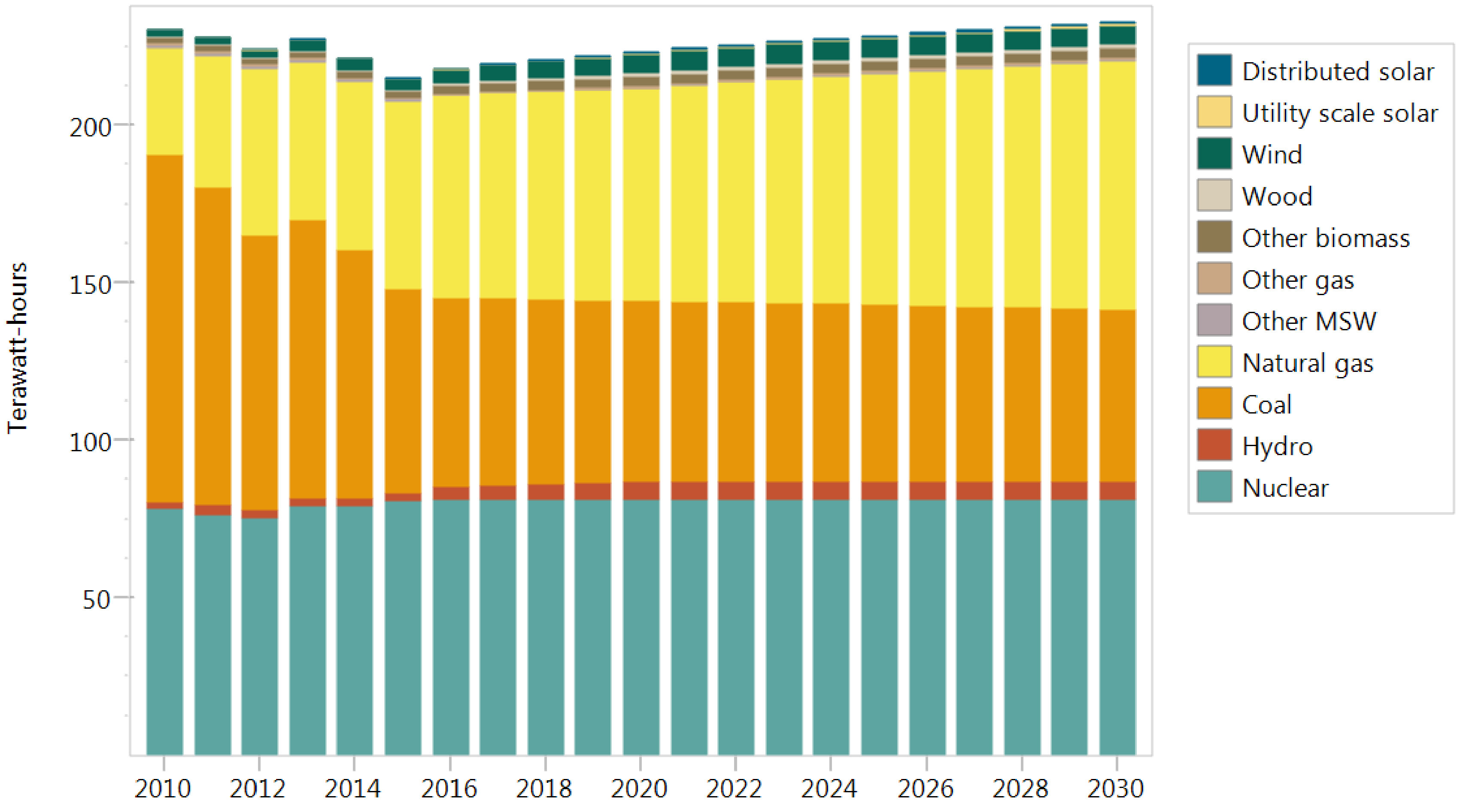
Growing solar production offsets electric generation from coal and natural gas



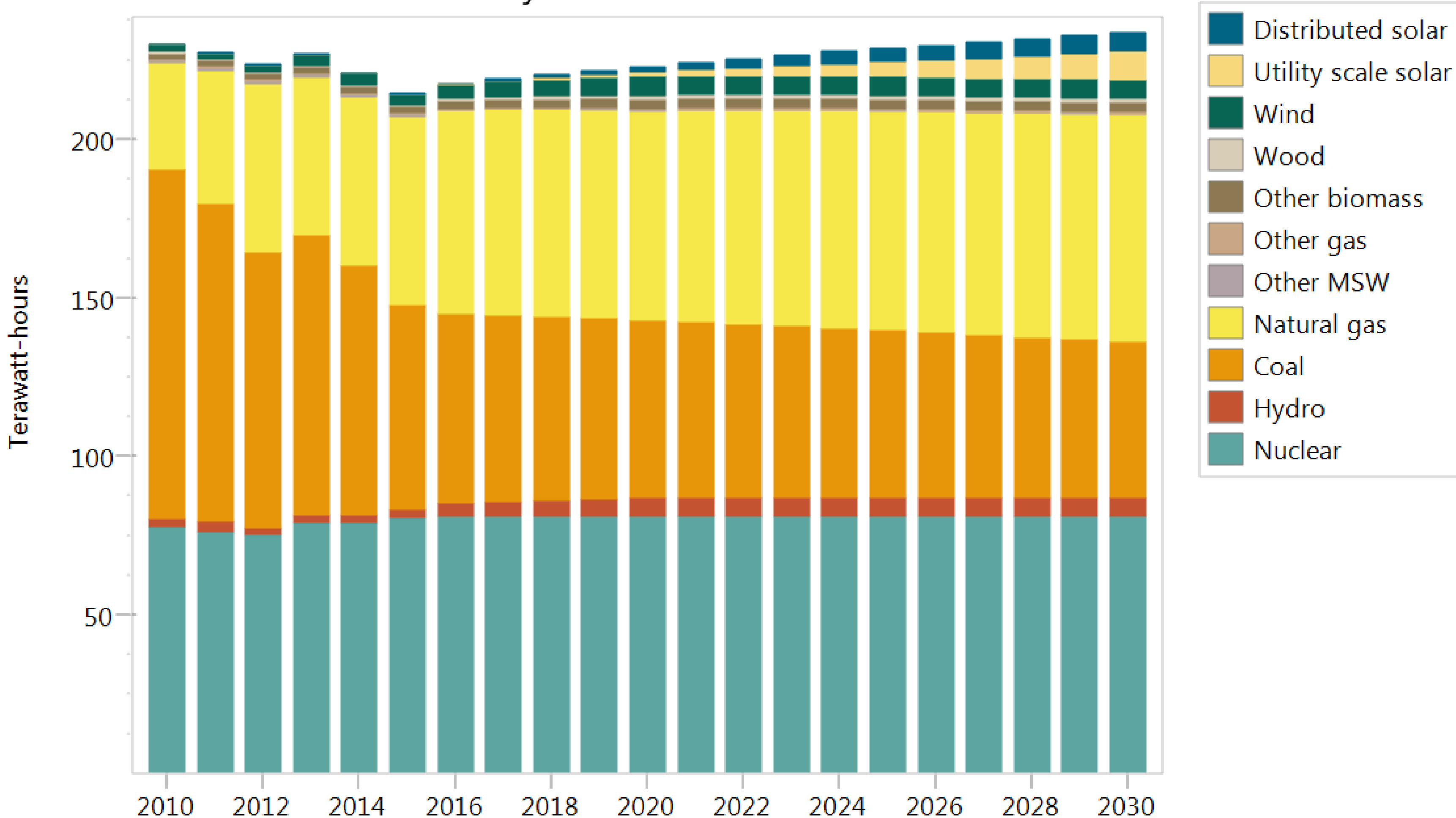
Growing solar production offsets electric generation from coal and natural gas



Generation by fuel in the Reference scenario



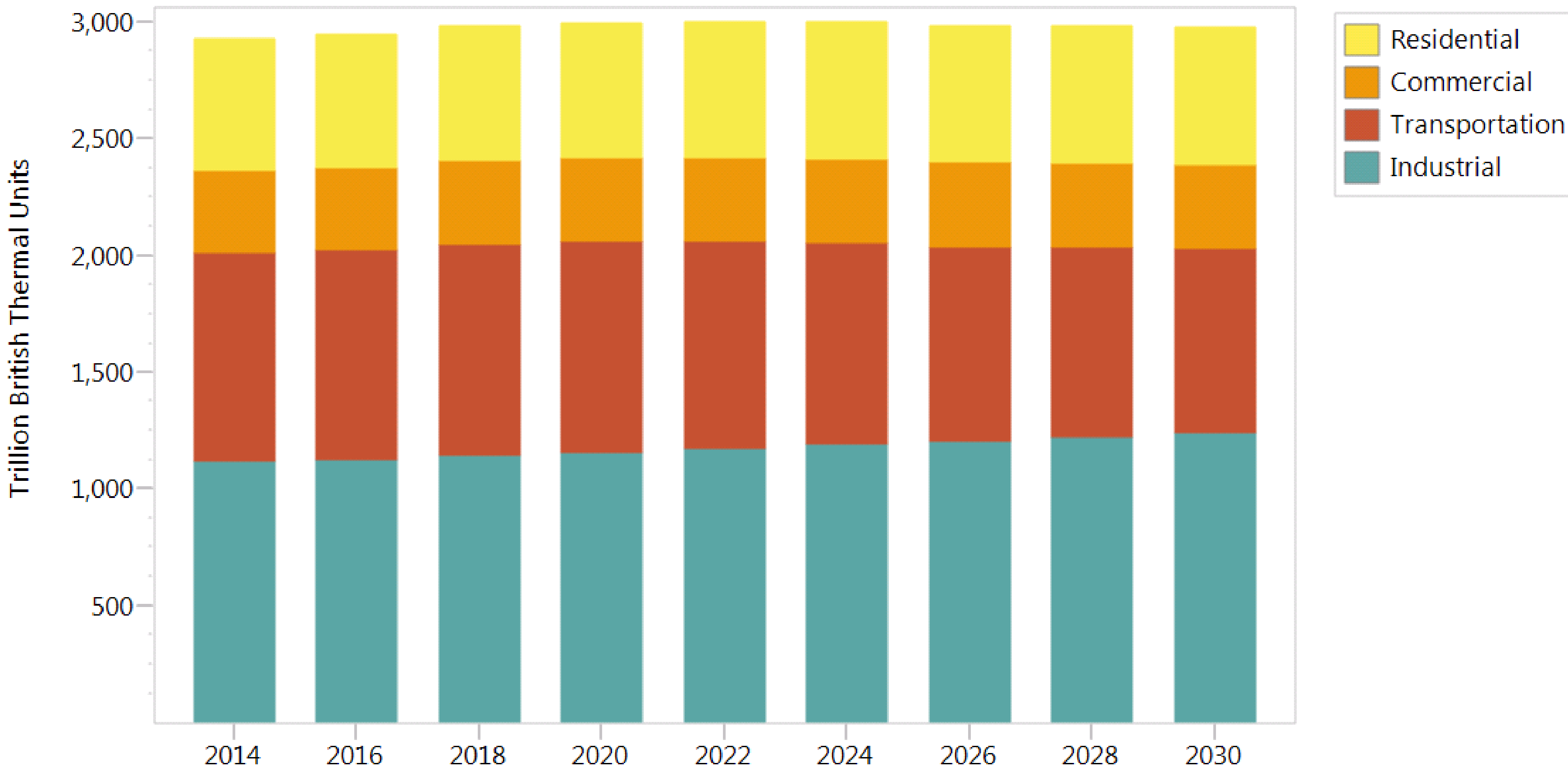
Generation by fuel in the Solar scenario



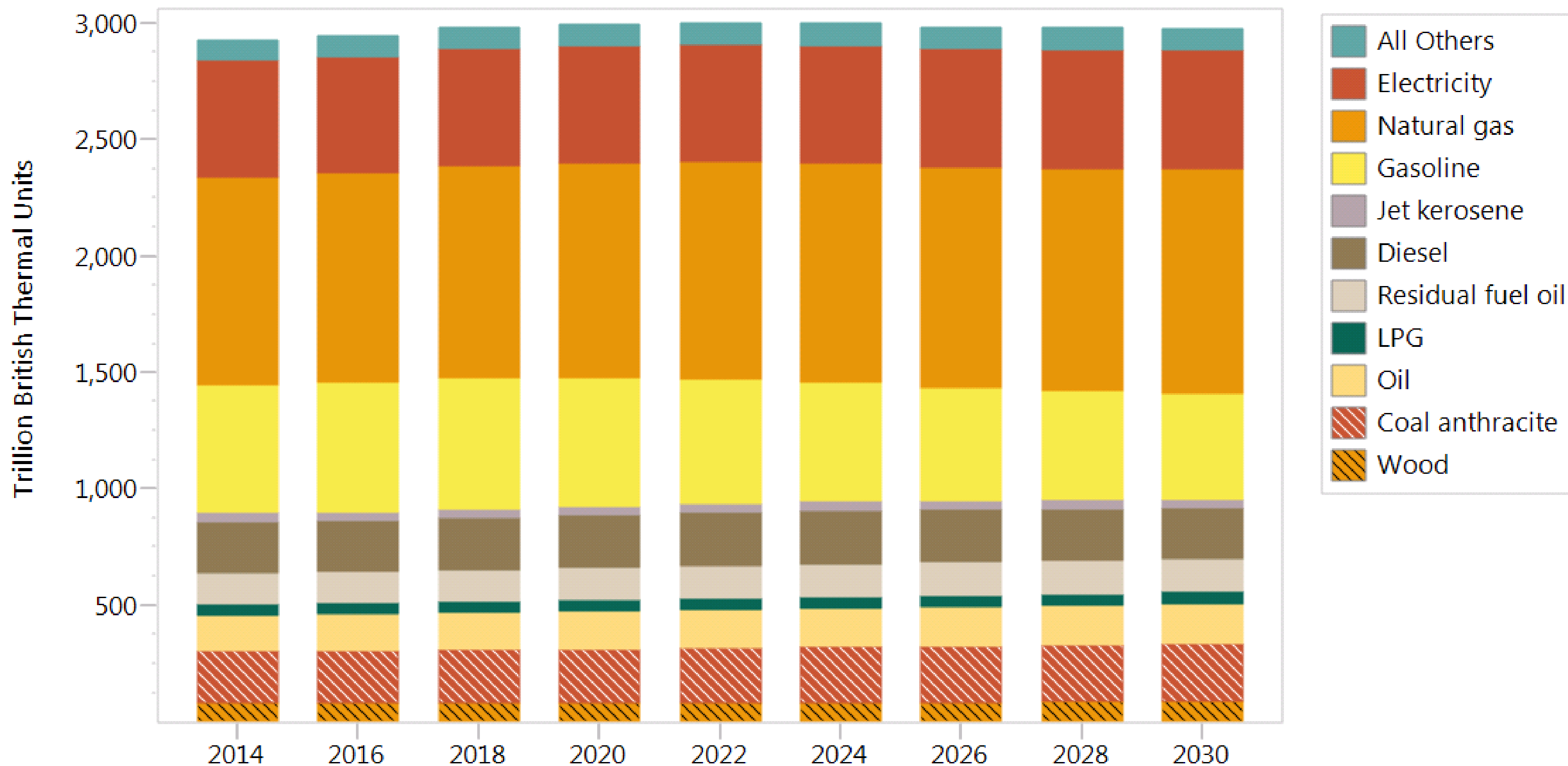
Demand driven

- Demand
  - Residential
    - Single Family
      - Space Conditioning
        - Heating
          - Oil
          - Cord Wood
          - Wood Pellets
          - Natural Gas
          - LPG
          - Electric Resistance
          - Heat Pump
          - Kerosene
          - Biodistillates
        - Cooling
      - Lighting
      - Water Heating
      - Appliances
      - Cooking
      - Plug Loads
    - Multifamily
    - Mobile or Manufactured Homes
    - Seasonal
  - Industrial
  - Commercial
  - Transportation

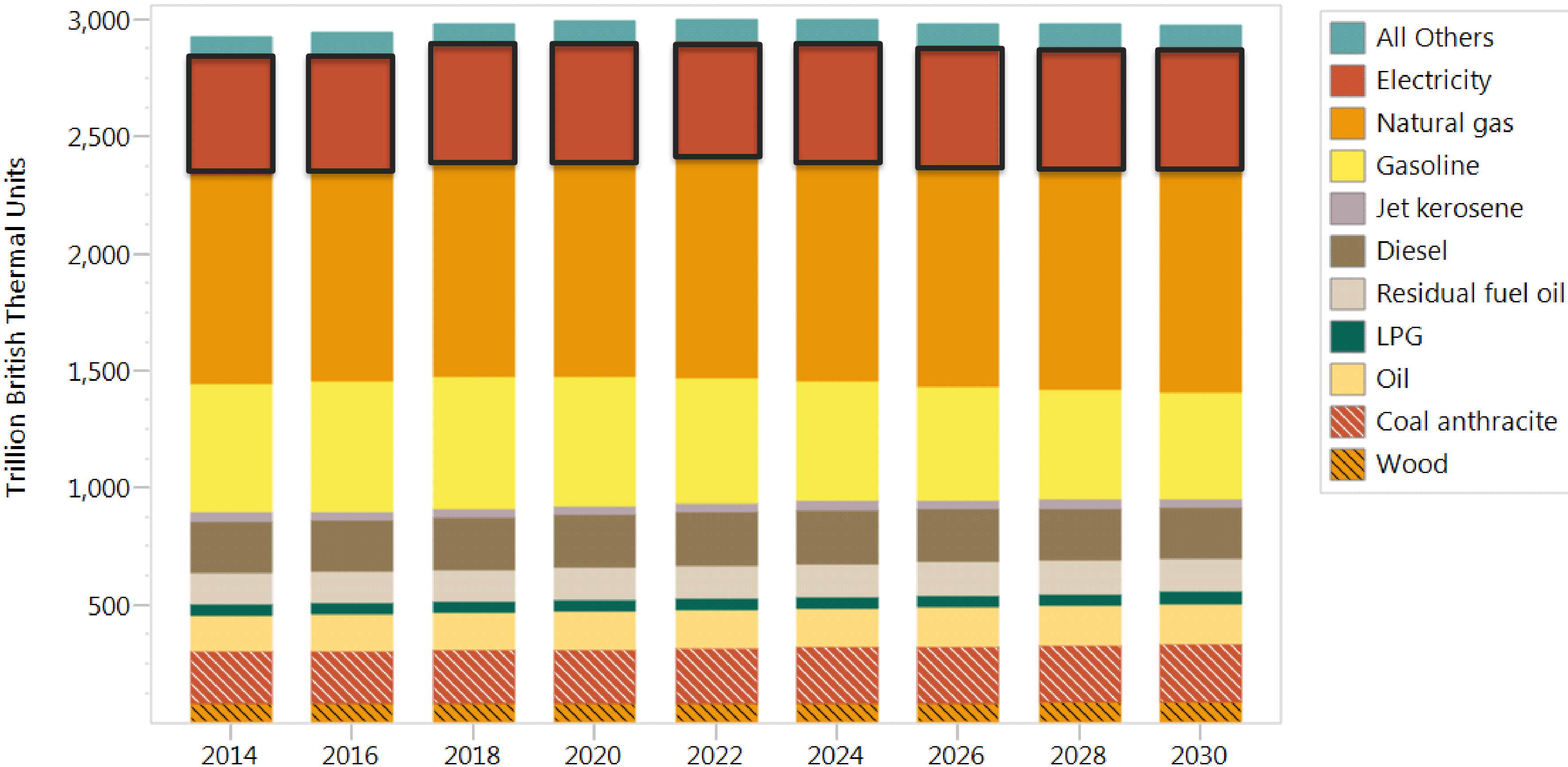
Total energy use relatively level



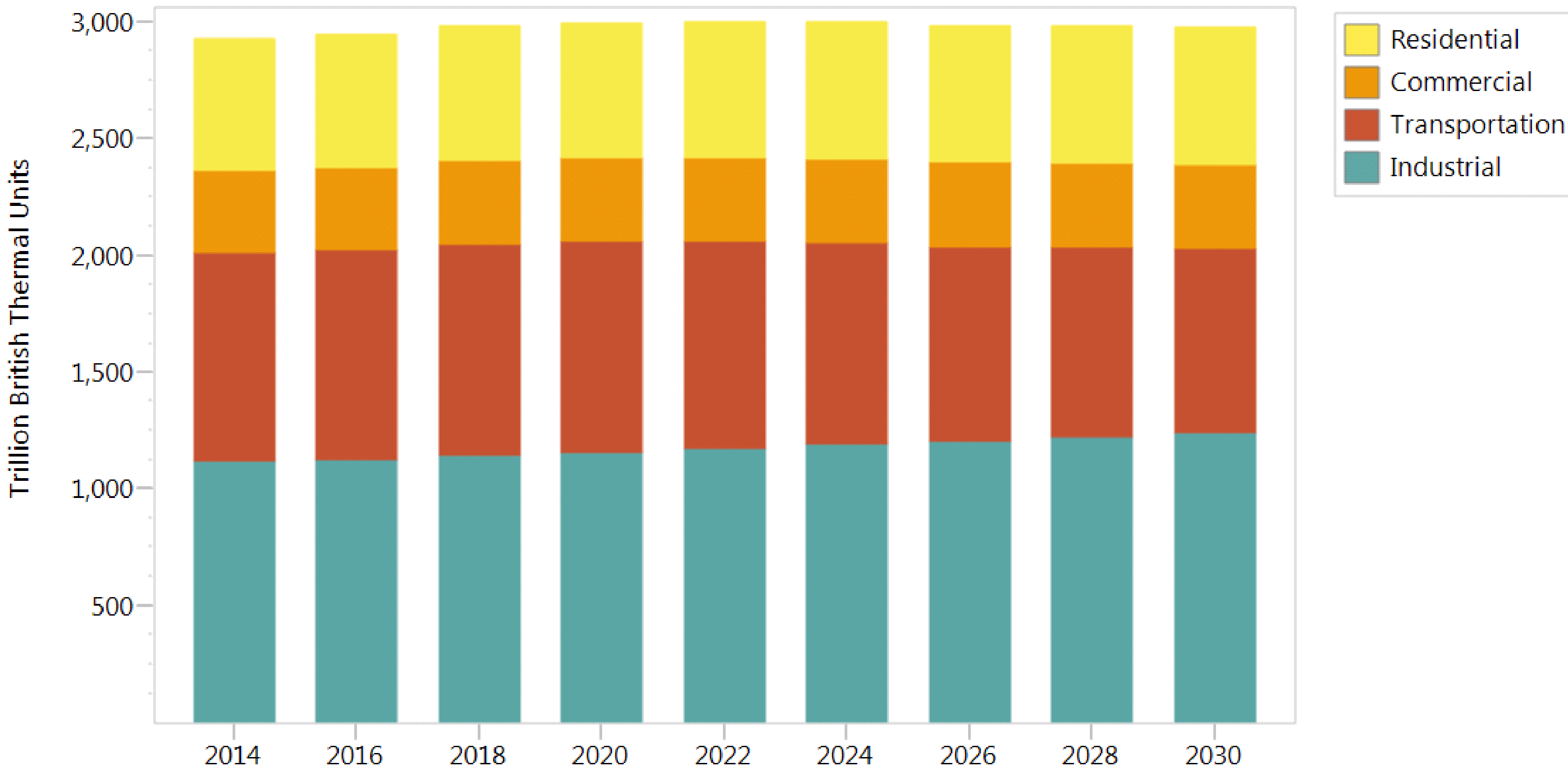
Electricity is 1/5 of total energy consumption



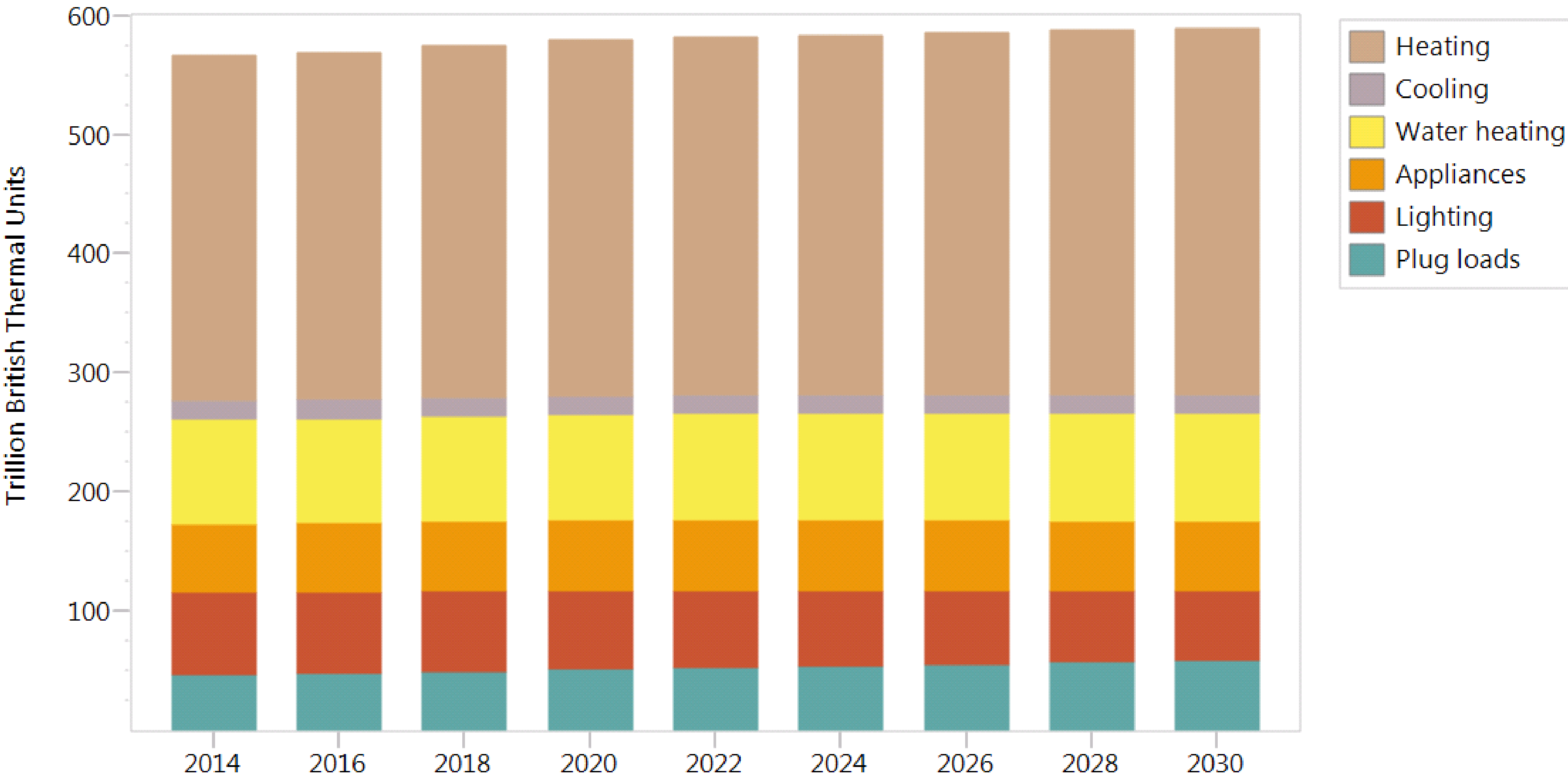
Electricity is 1/5 of total energy consumption



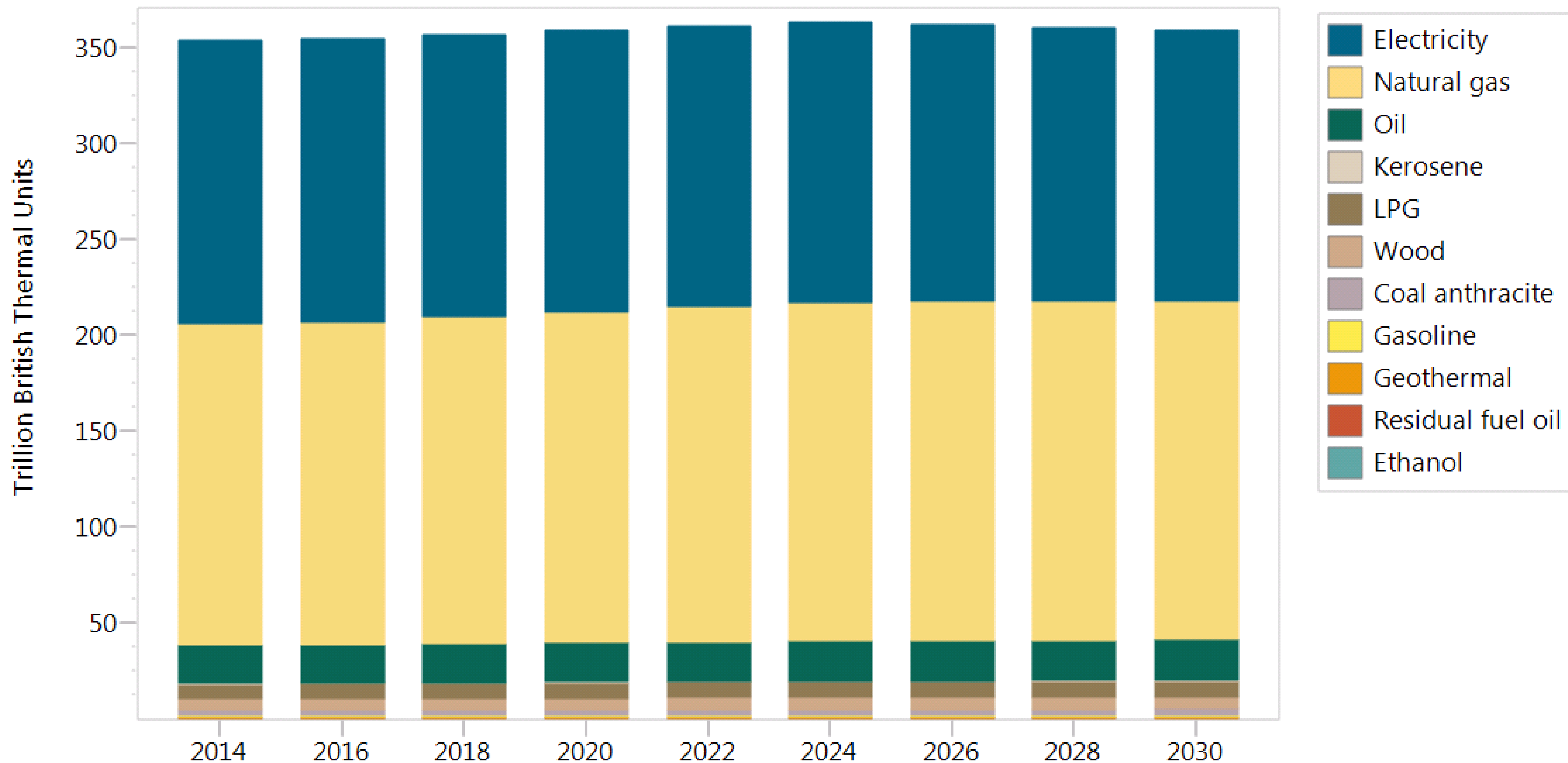
Total energy use relatively level



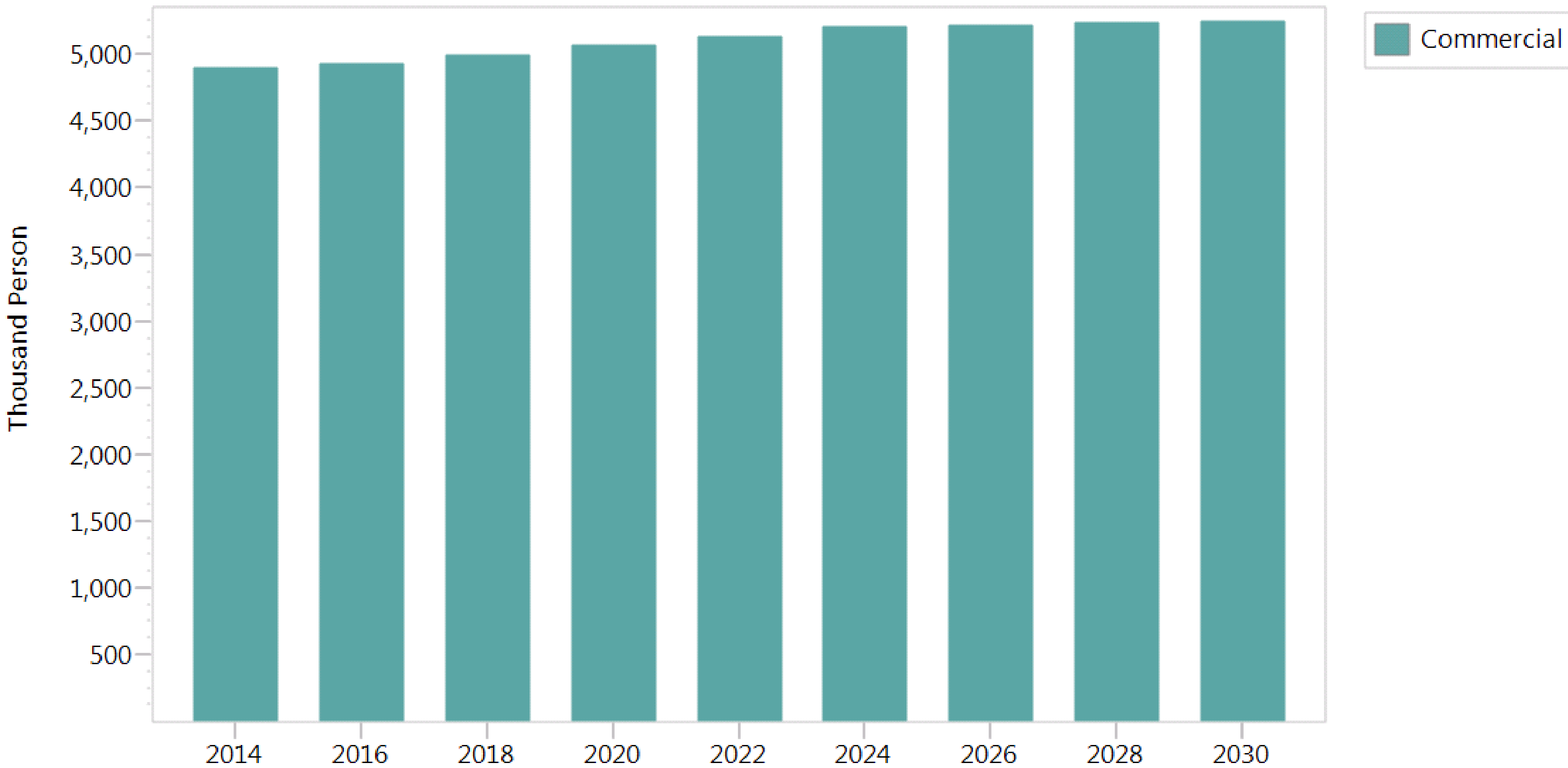
Residential energy dominated by heating



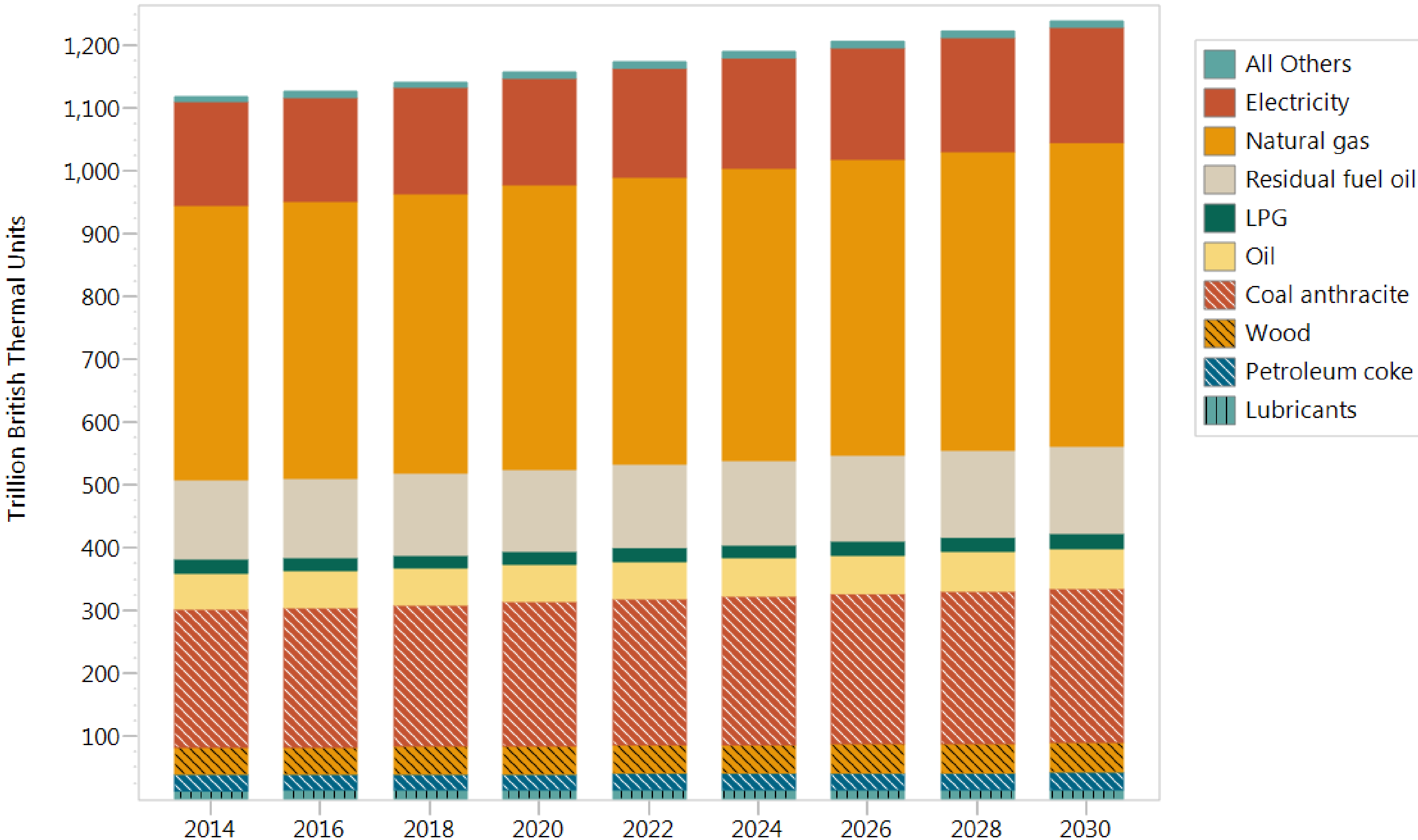
Commercial energy



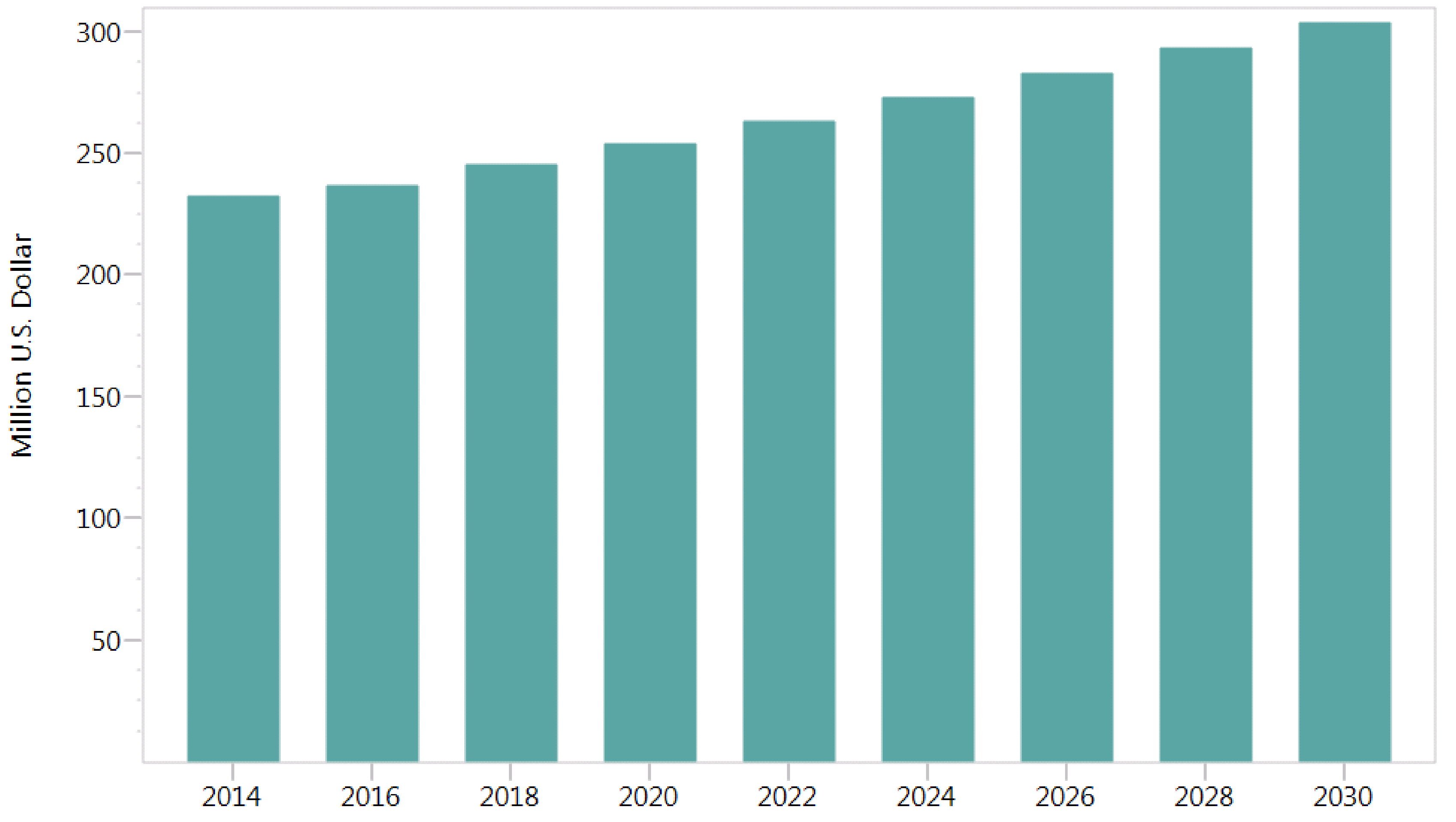
Projected employment drives increase demand



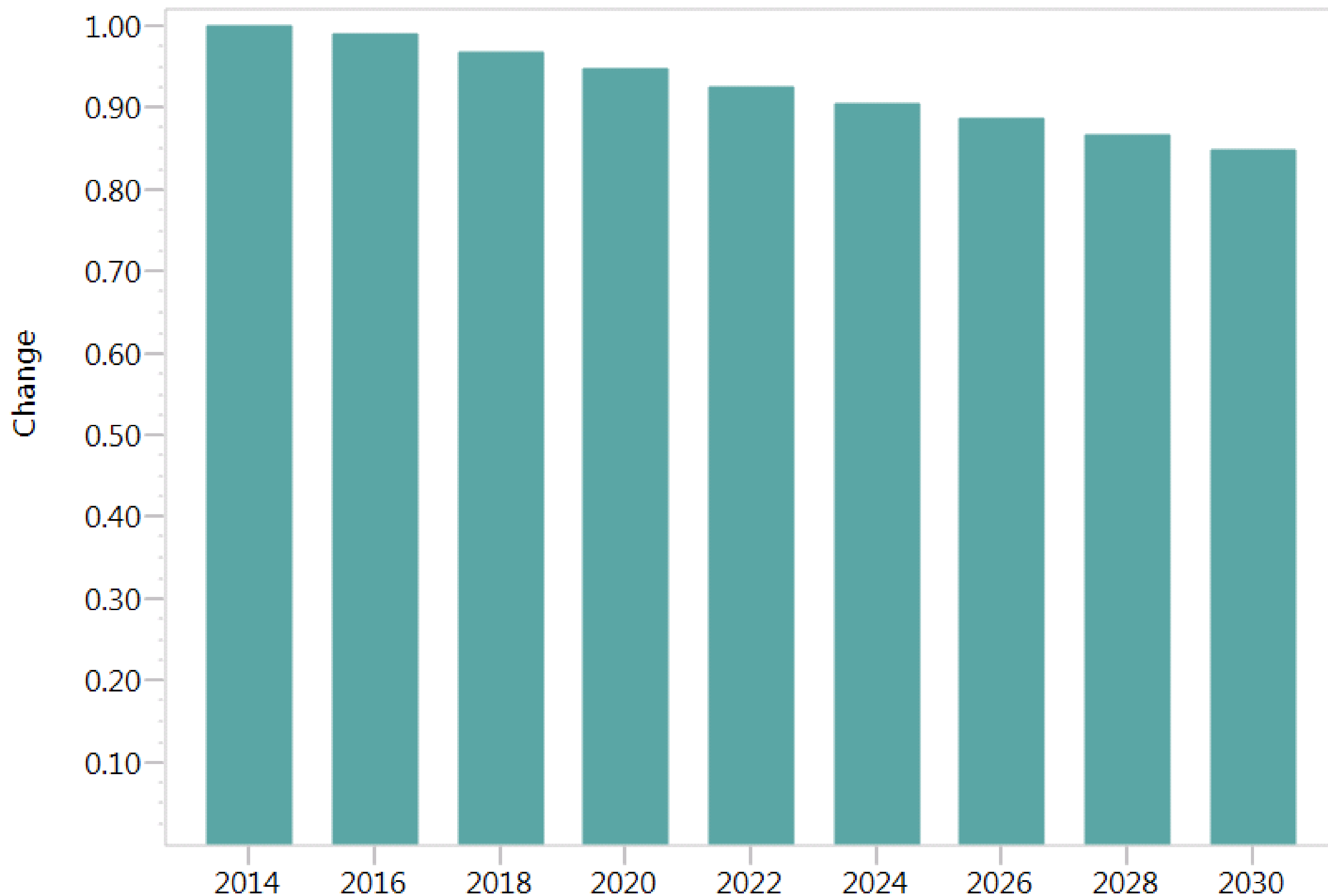
Industrial demand increases by 10%



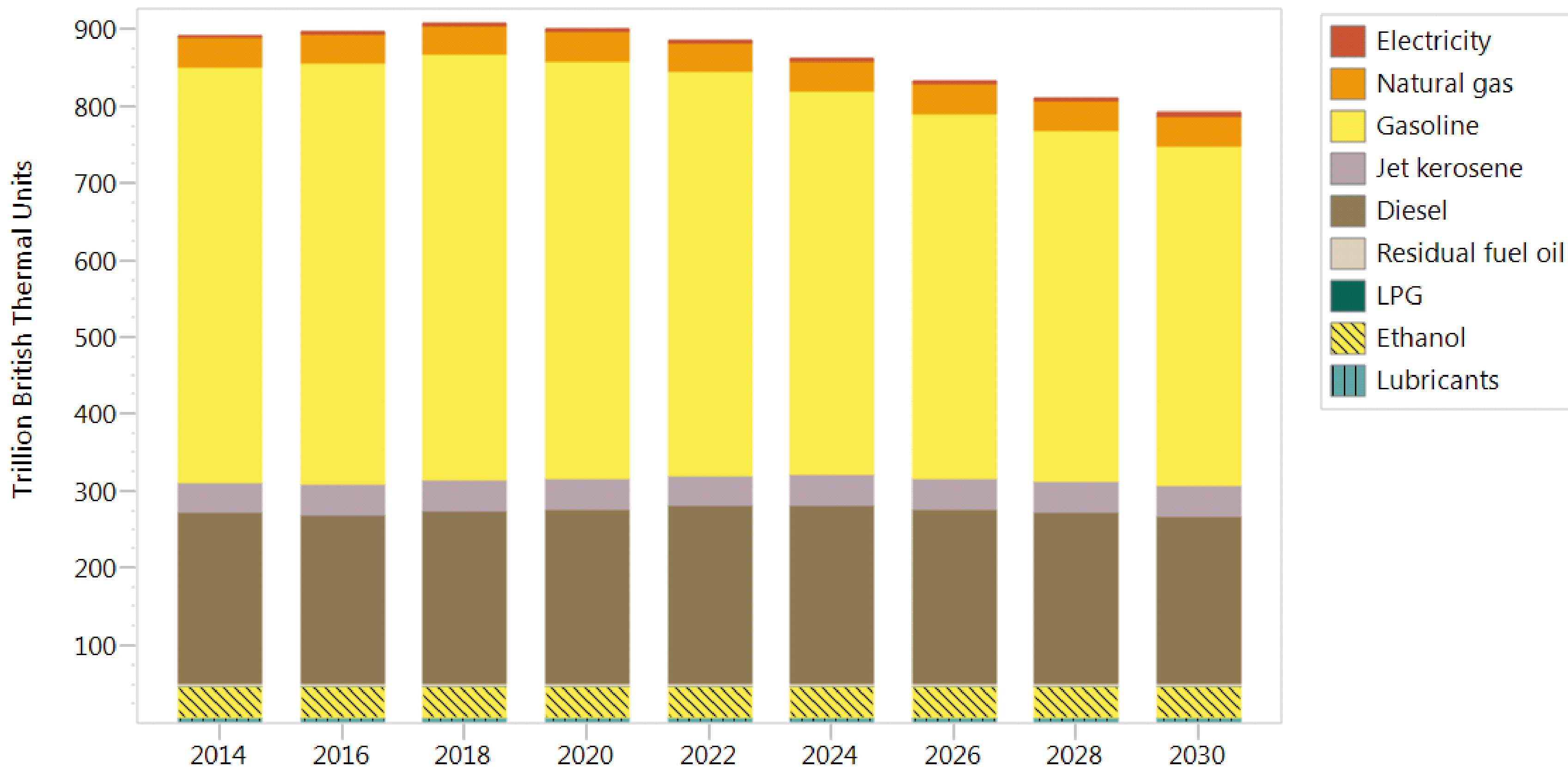
Value of shipments drives increased demand



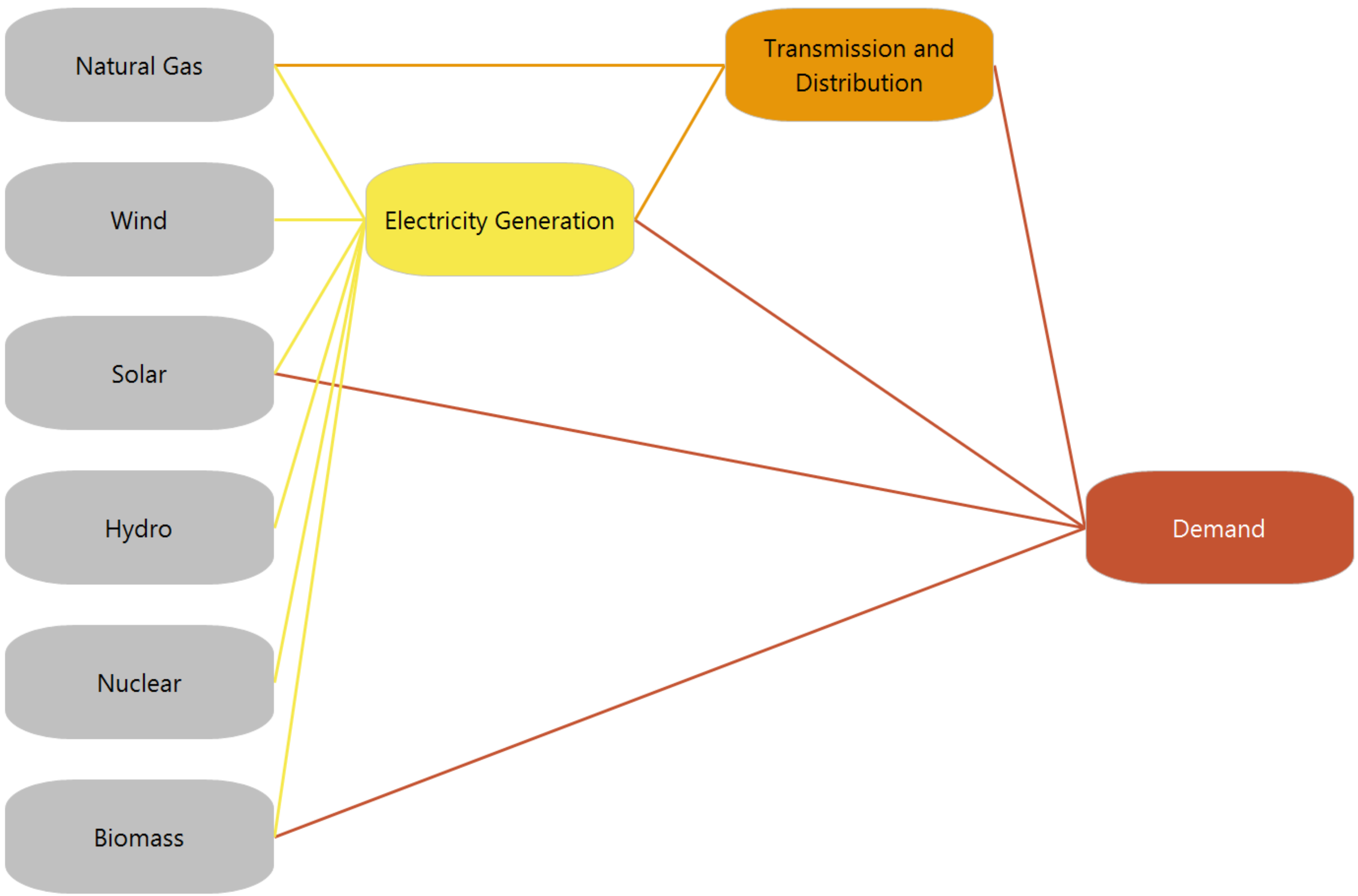
Structural shift in energy required for industry



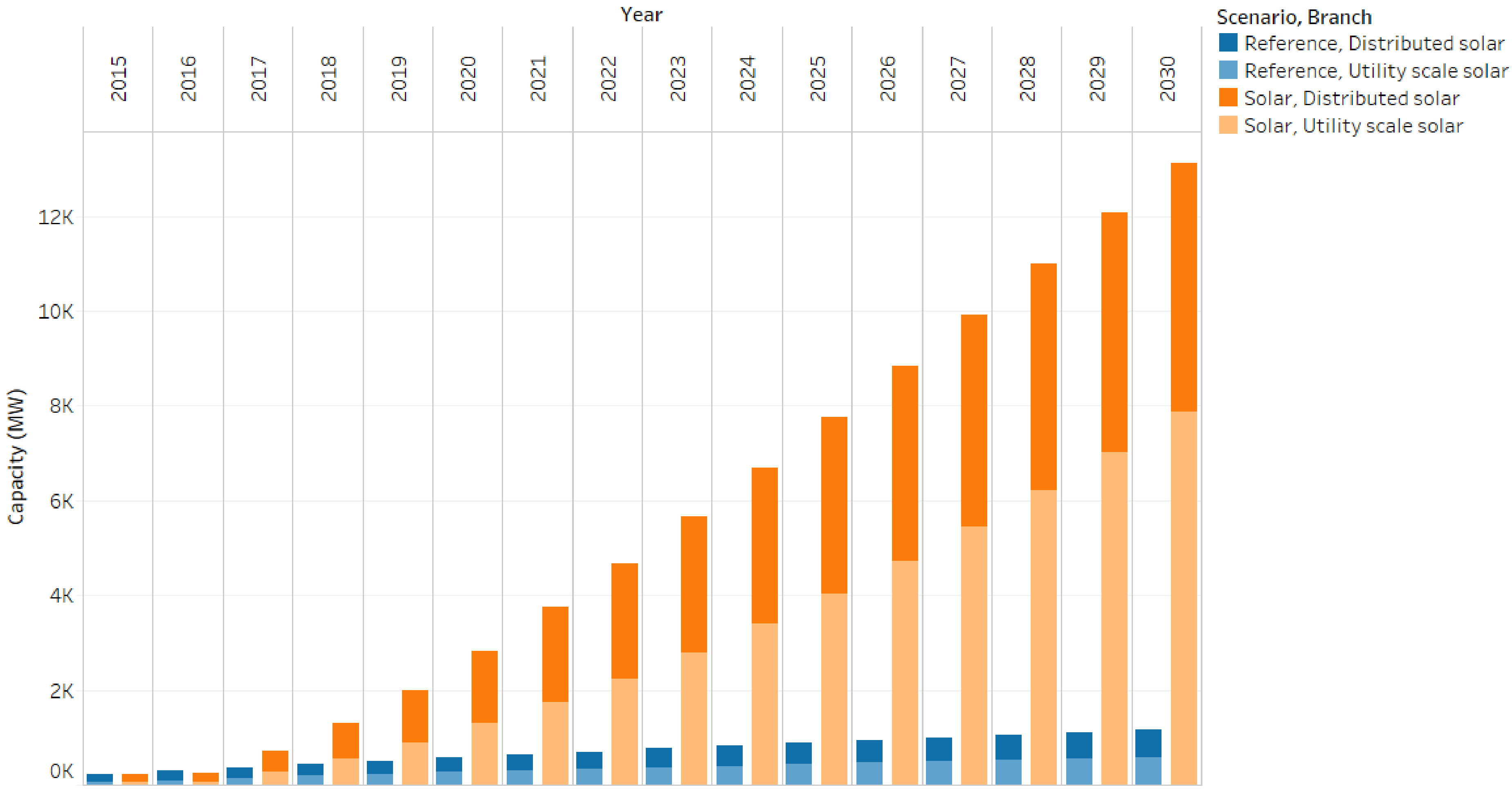
Transportation becomes more efficient and begins to electrify



Resources ← Transformation ← Demand driven



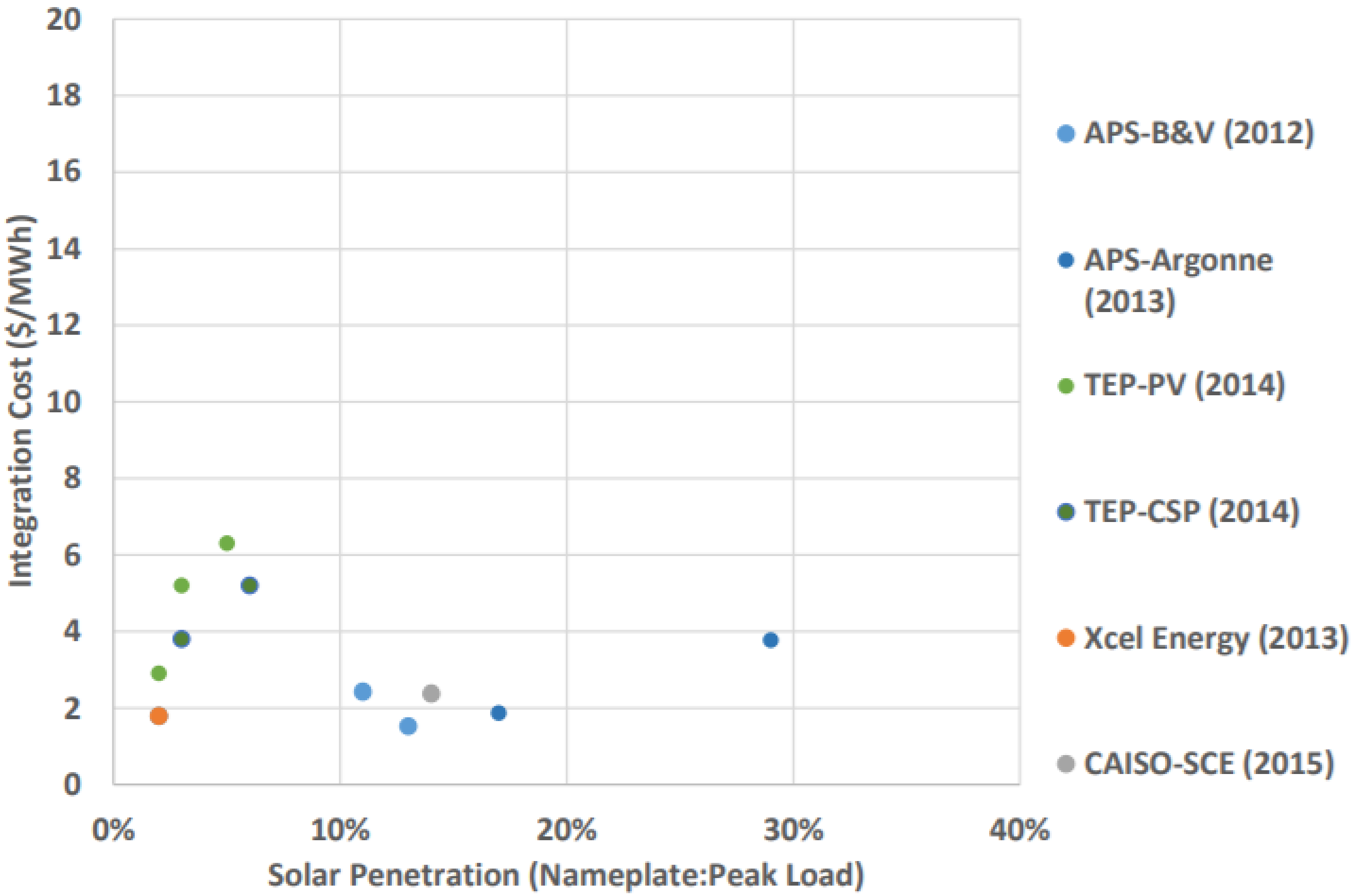
Solar capacity grows in both scenarios, 10x more in the solar scenario



Vermont Energy Investment Corporation

pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION

Viability Grid Integration



Luckow, Patrick, Tommy Vitolo, and Joseph Daniel, 2015. A Solved Problem: Existing measures provide low-cost wind and solar integration. Synapse Energy Economics, Cambridge MA.

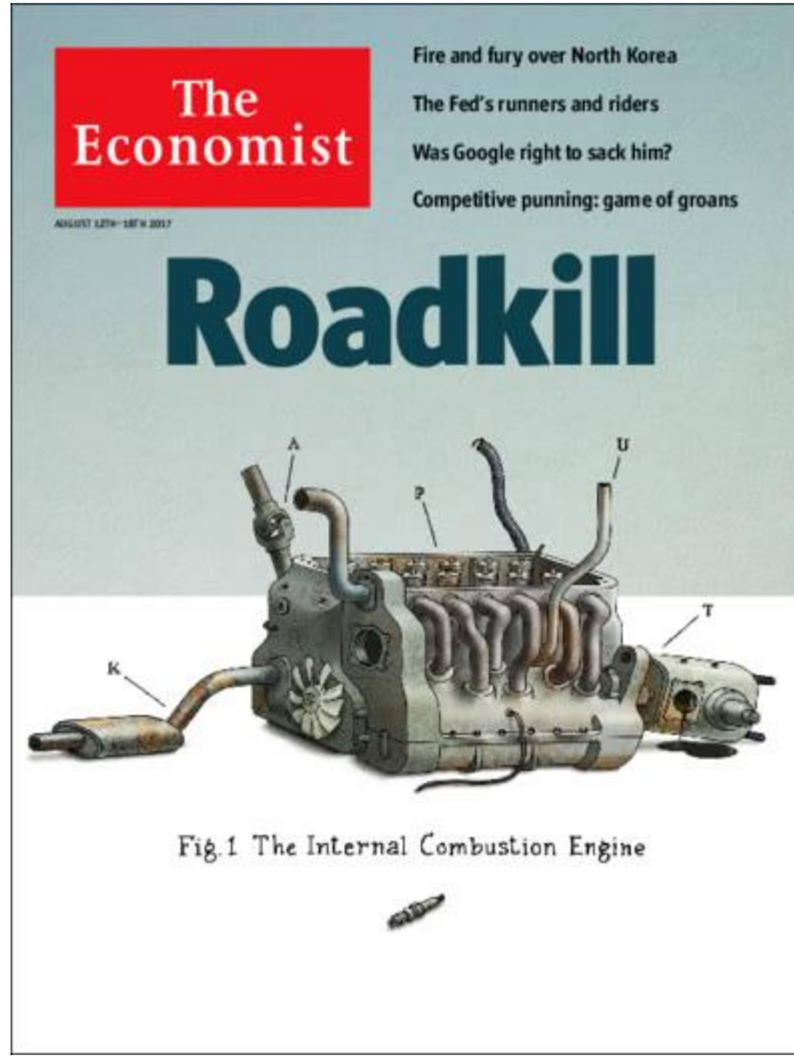
Scenario and modeling questions:

1. Drivers – Higher/lower activity levels?
2. Efficiency – trends of Act 129 continue beyond 2021. Should efficiency increase or slow down?
3. Load growth – vehicle electrification is low. Higher levels? Space conditioning growth or electrification?
4. Exports – electricity exports grow back to 80 TWh per year Alternatives? Should exports grow?
5. What other solar scenarios should we look at?
6. Nuclear market or retirement based reductions in outputs?
7. Other…

Key modeling questions for today’s breakout sessions

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

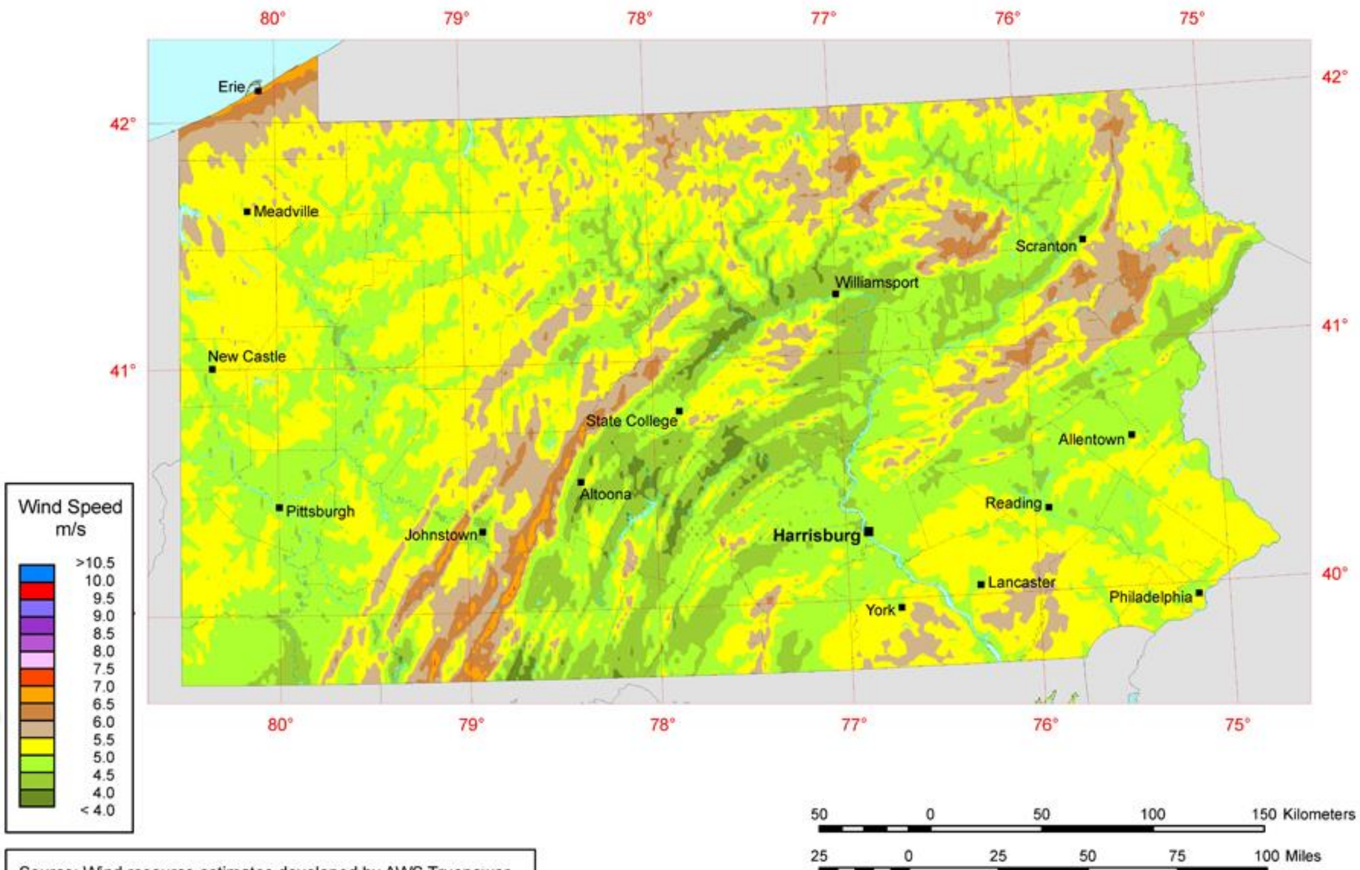
CAPEX: $1,678/kW

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

Pennsylvania - Annual Average Wind Speed at 80 m



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.

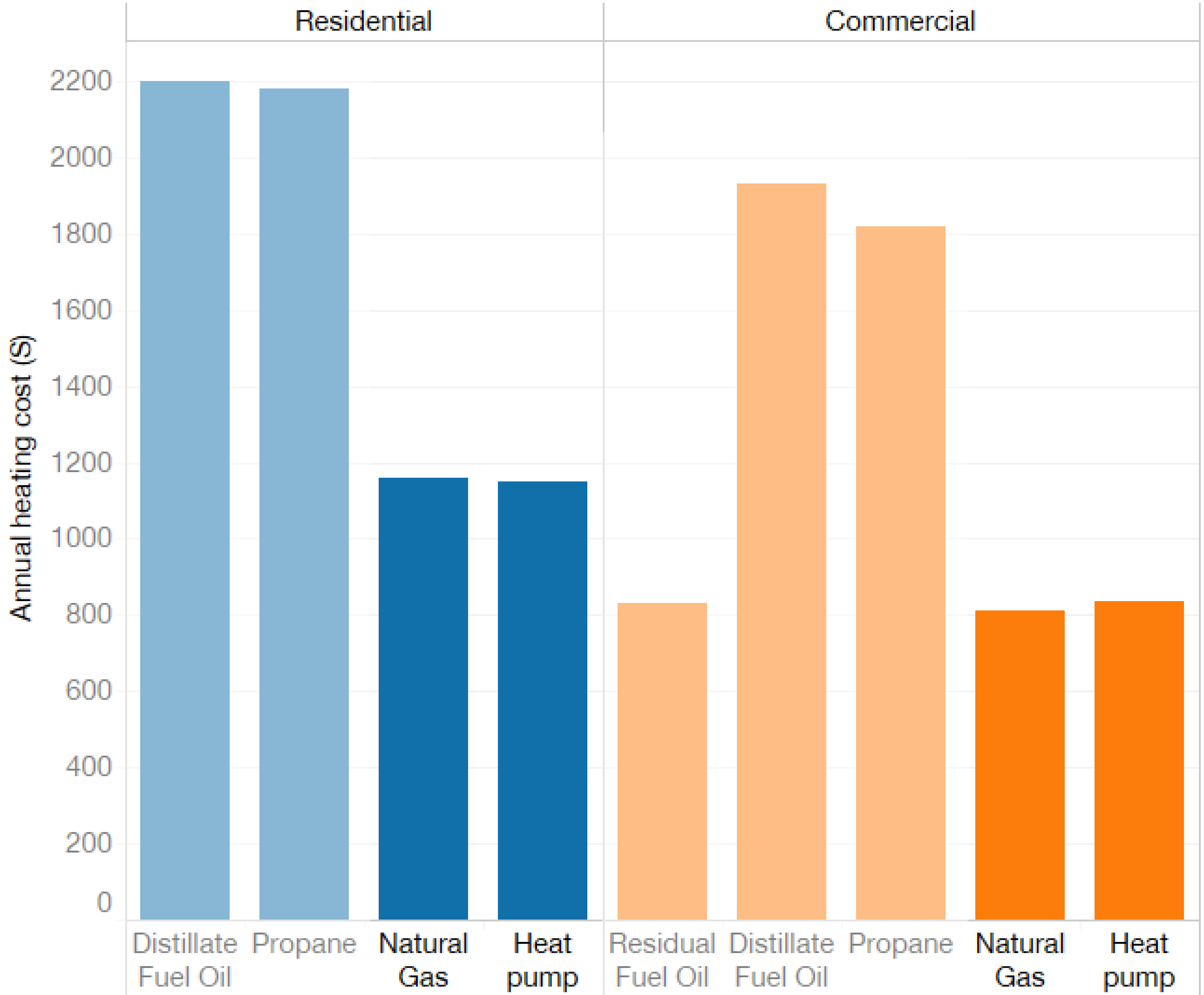
AWS Truepower™ Where science delivers performance.

NREL NATIONAL RENEWABLE ENERGY LABORATORY

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

Heat pumps and gas have comparable operating costs



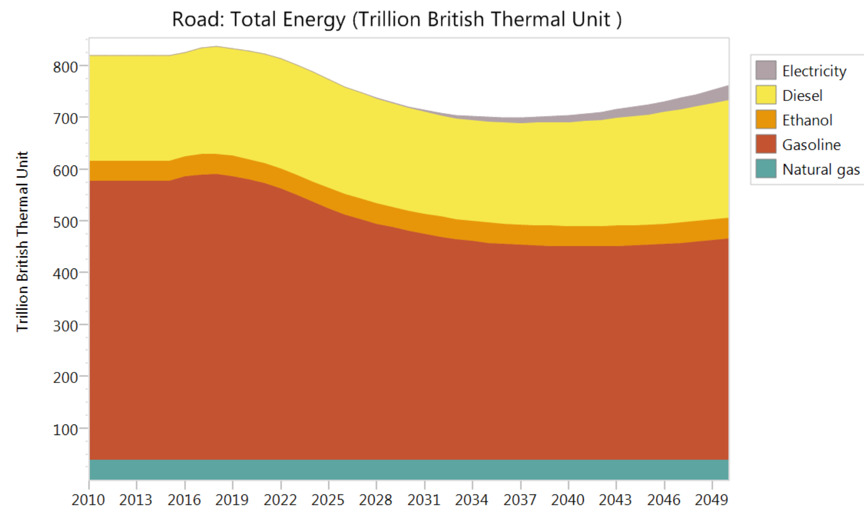
Assumptions:

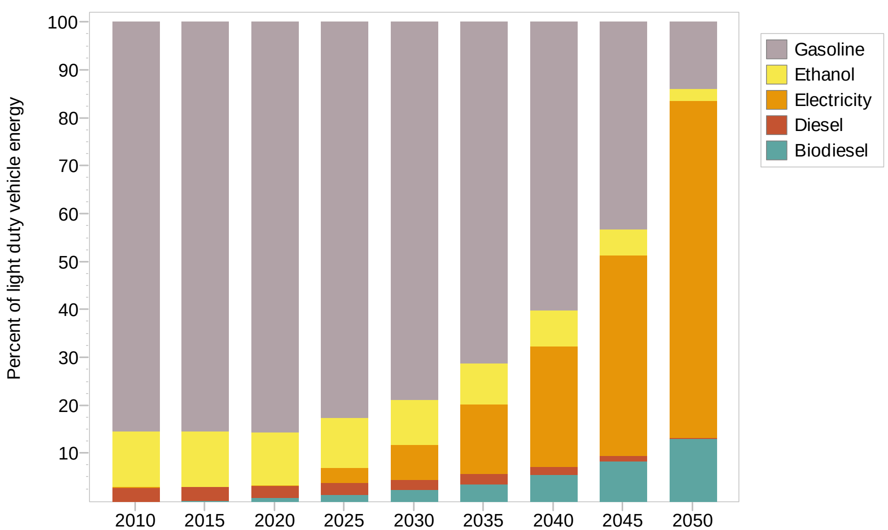
- Existing system efficiencies: oil: 85%, propane: 87%; new systems efficiencies: gas 90%, heat pump 2.8 COP
- Fossil fuel costs from 2017 AEO, volumetric electricity costs in USD/kWh: 0.11 for residential and 0.08 for commercial

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%