# Finding Pennsylvania's Solar Future

5th Stakeholder Meeting
March 8, 2018
Pittsburgh

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Vermont Energy Investment Corporation

# Overview

- How modeling is used to support the study
- Executive Summary modeling results
- What makes PA Solar Future viable?
- Example of customer economics, implications for incentives

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“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 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 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 meeting:

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

March meeting:

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

# Changes since September meeting:

- 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

Antioch College

# Executive Summary Modeling Results

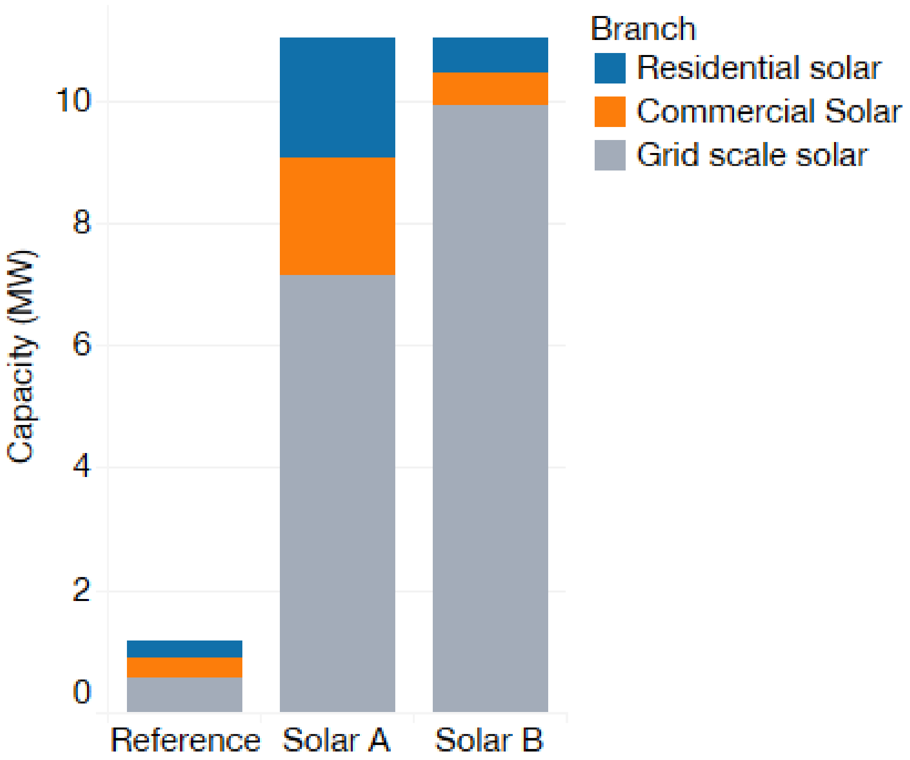
## Main scenario definitions

| | 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 |

# Executive Summary Modeling Results

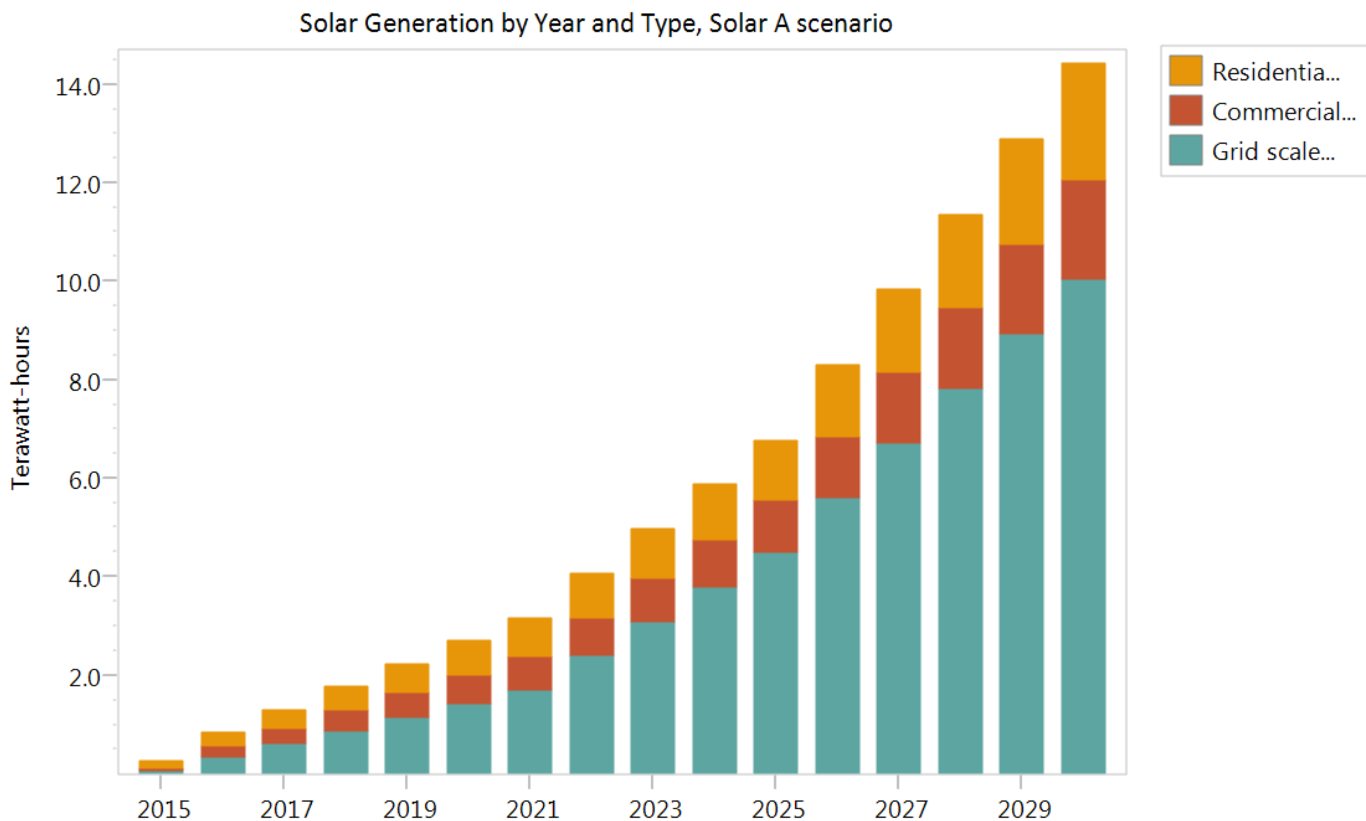
Solar capacity by scenario and scale

- PA Solar Future scenarios have 10x reference
- Both cases rely for majority on grid scale solar



# Executive Summary Modeling Results

Solar capacity by year and scale in Solar A

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# Viability?

Economically
Land Use
Integration
Jobs

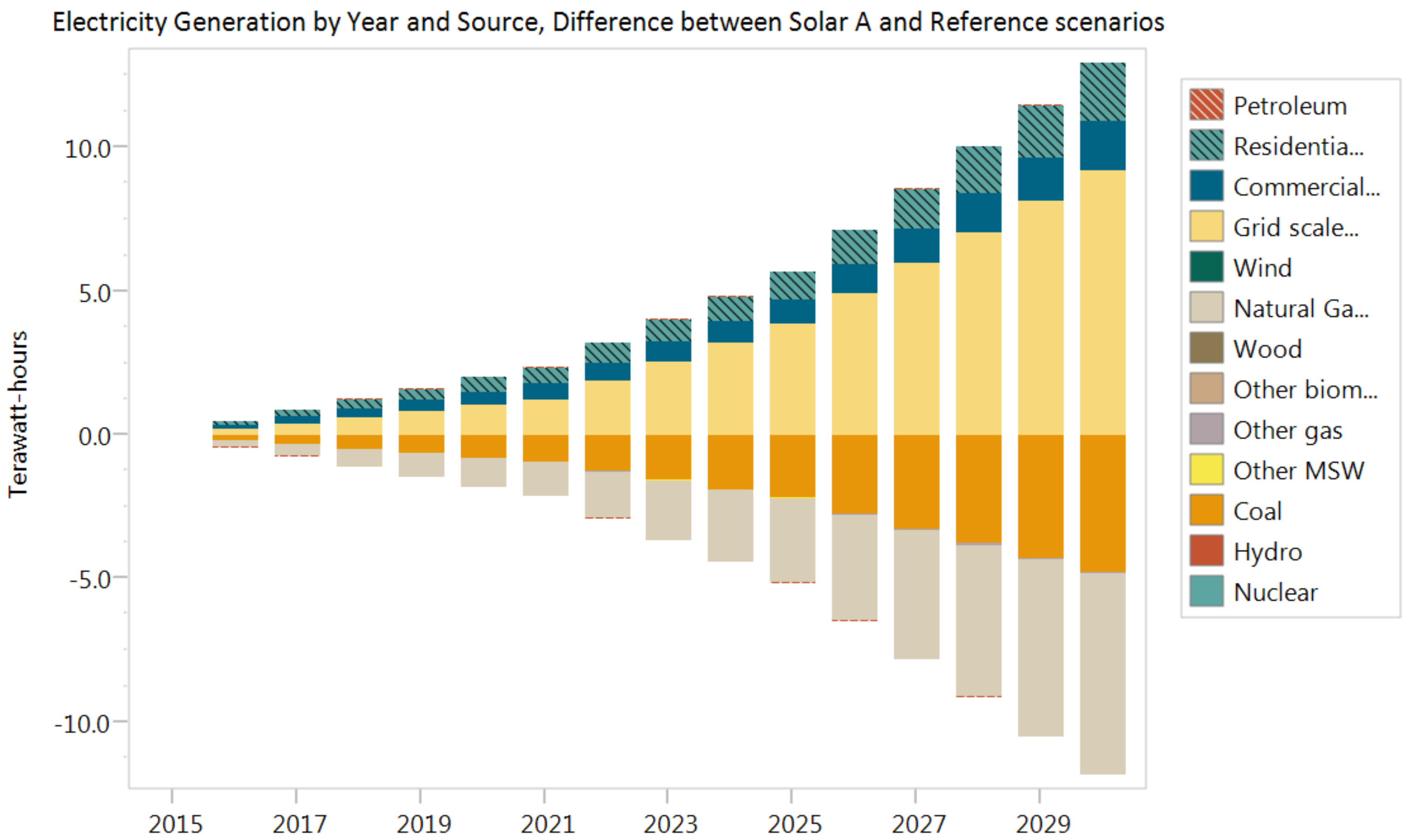
# Economic Benefit Cost Results

## Cumulative cost and benefits relative to reference scenario

| Cumulative Costs and Benefits 2015-2030<br>Relative to Reference scenario | | |
|---|---|---|
| | **Solar A** | **Solar B** |
| Cost or (Savings)<br>Billions of 2017 USD, discounted at 3.75% | | |
| **Transformation** | 10.2 | 8.6 |
| Transmission and Distribution | 0.1 | 0.1 |
| Electricity Generation | 10.0 | 8.5 |
| **Resources** | -0.3 | -0.3 |
| Production | -0.3 | -0.3 |
| **Externalities** | not included | |
| **NPV (society)** | 9.9 | 8.3 |

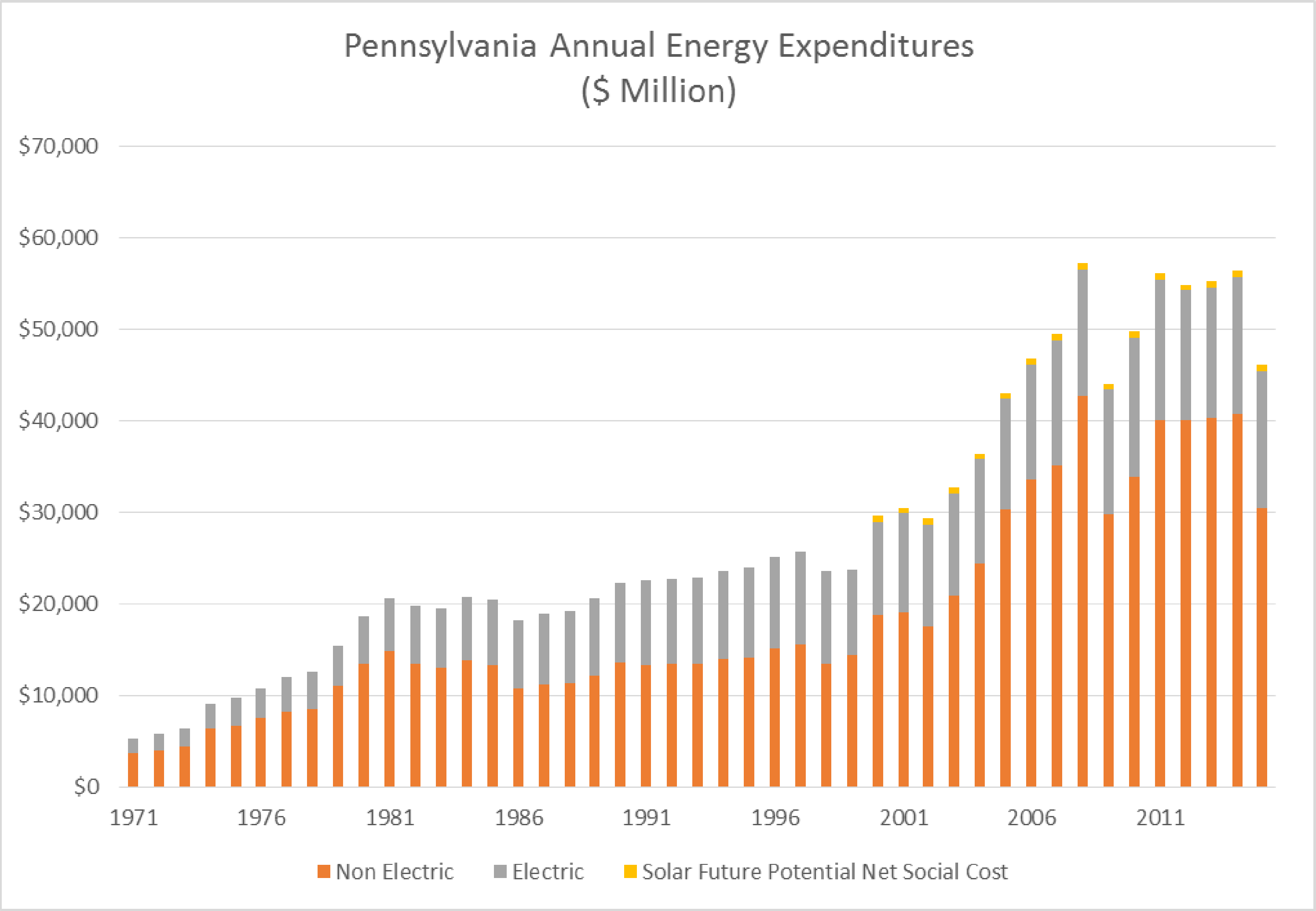
# Economic Benefit Cost Results

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* | 3.75% 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) |

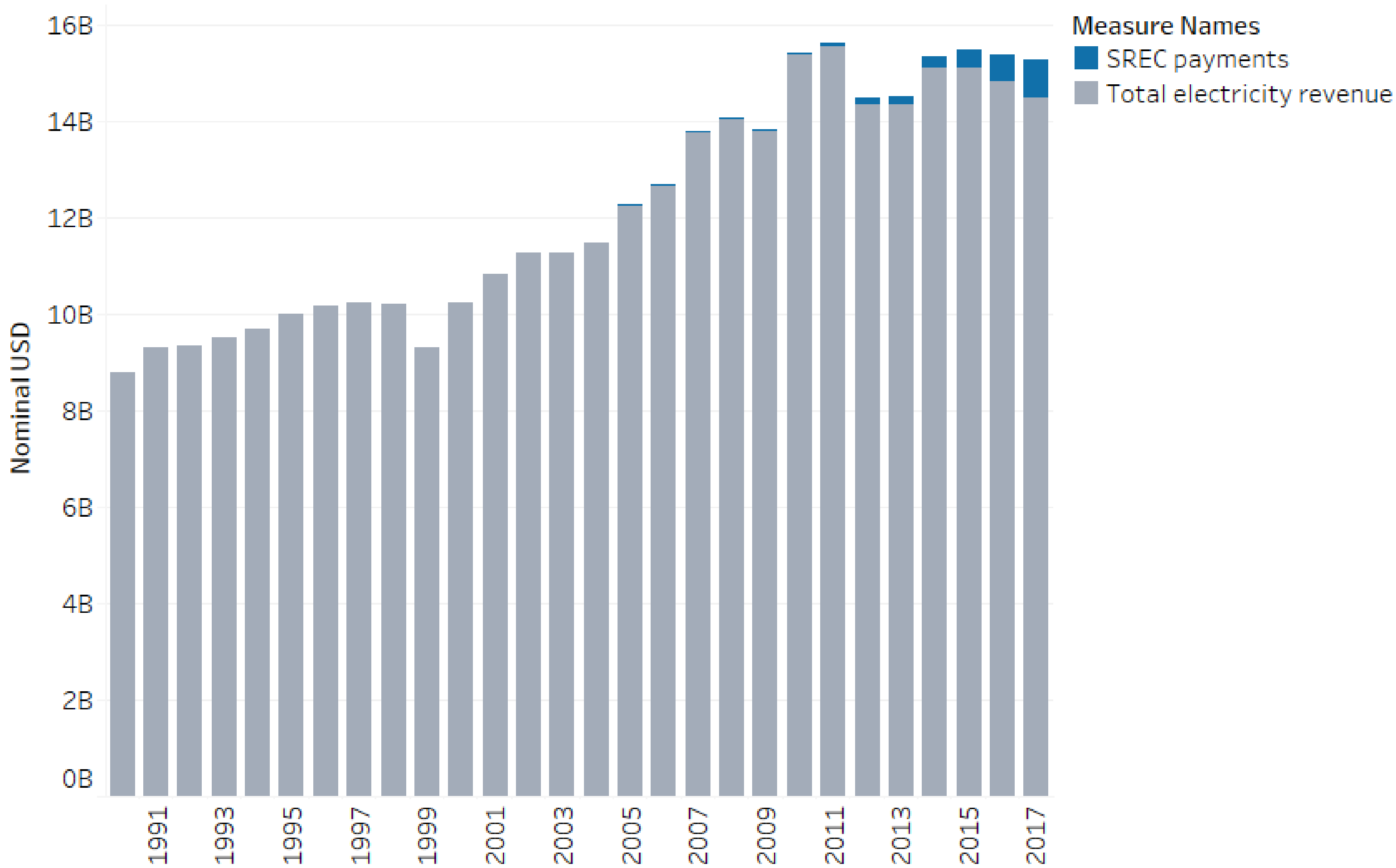
| | | |
|---|---|---|
| Assumed SREC Price in 2025 (Only PA SRECs) | $58 | (from previous) |
| Total Cost to Purchase SRECs in 2025 | *$350,000,000* | |
| Bill line item cost for purchasing 2025 SRECs | *$0.0023333* | $/kWh |

| | | |
|---|---|---|
| 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** |

# Viability of Potential Rate Impact

SREC payments compared to historic electricity spending



# 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, 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, rates)
    - Residential and Commercial in Pittsburgh and Philadelphia
    - Grid scale outside Philadelphia

# Modeling findings: customer economics

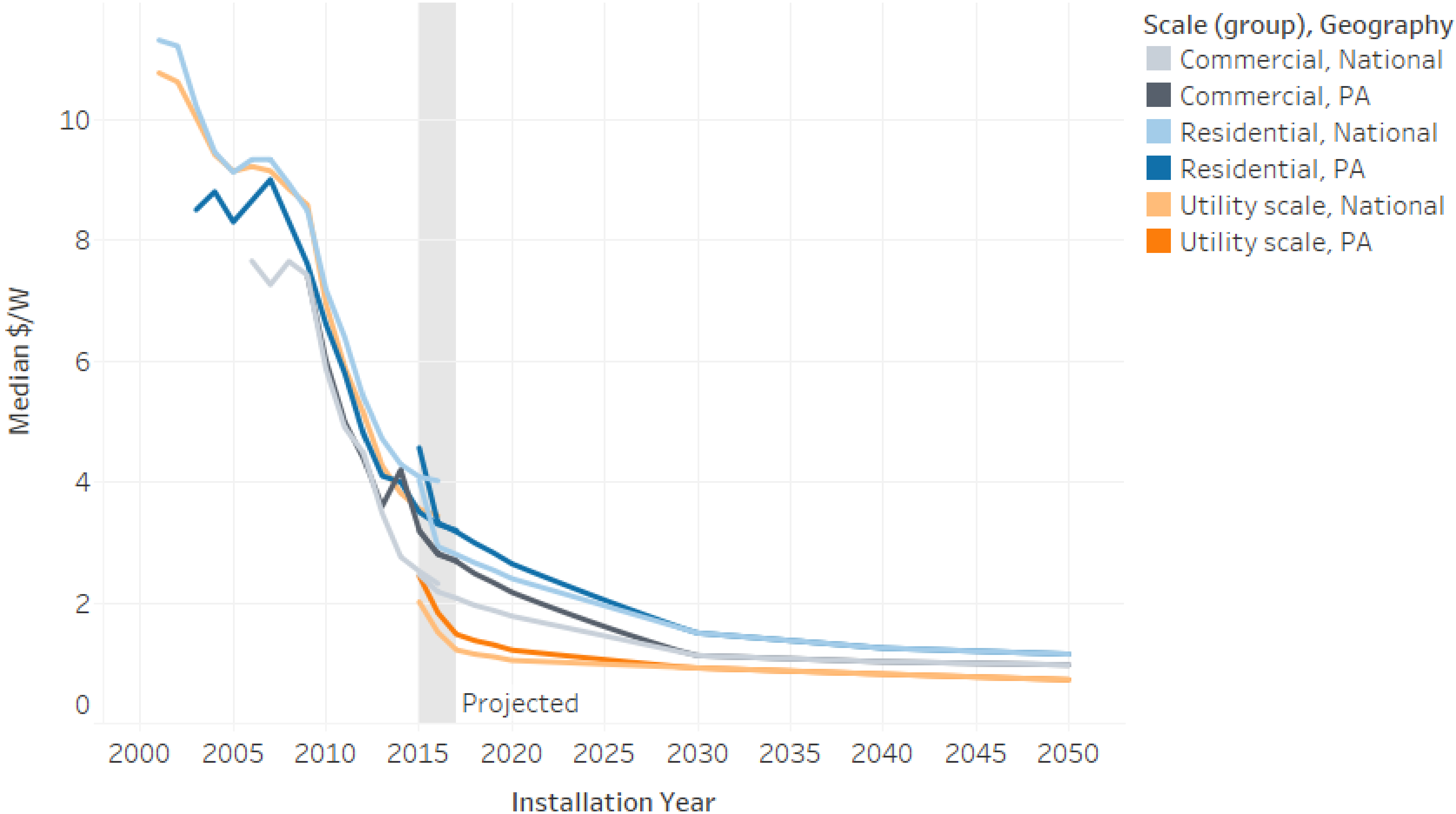
Parameter analysis to consider different inputs

Parameter analysis results: what SREC level is necessary for a 10 year payback, given current today's costs and rates?

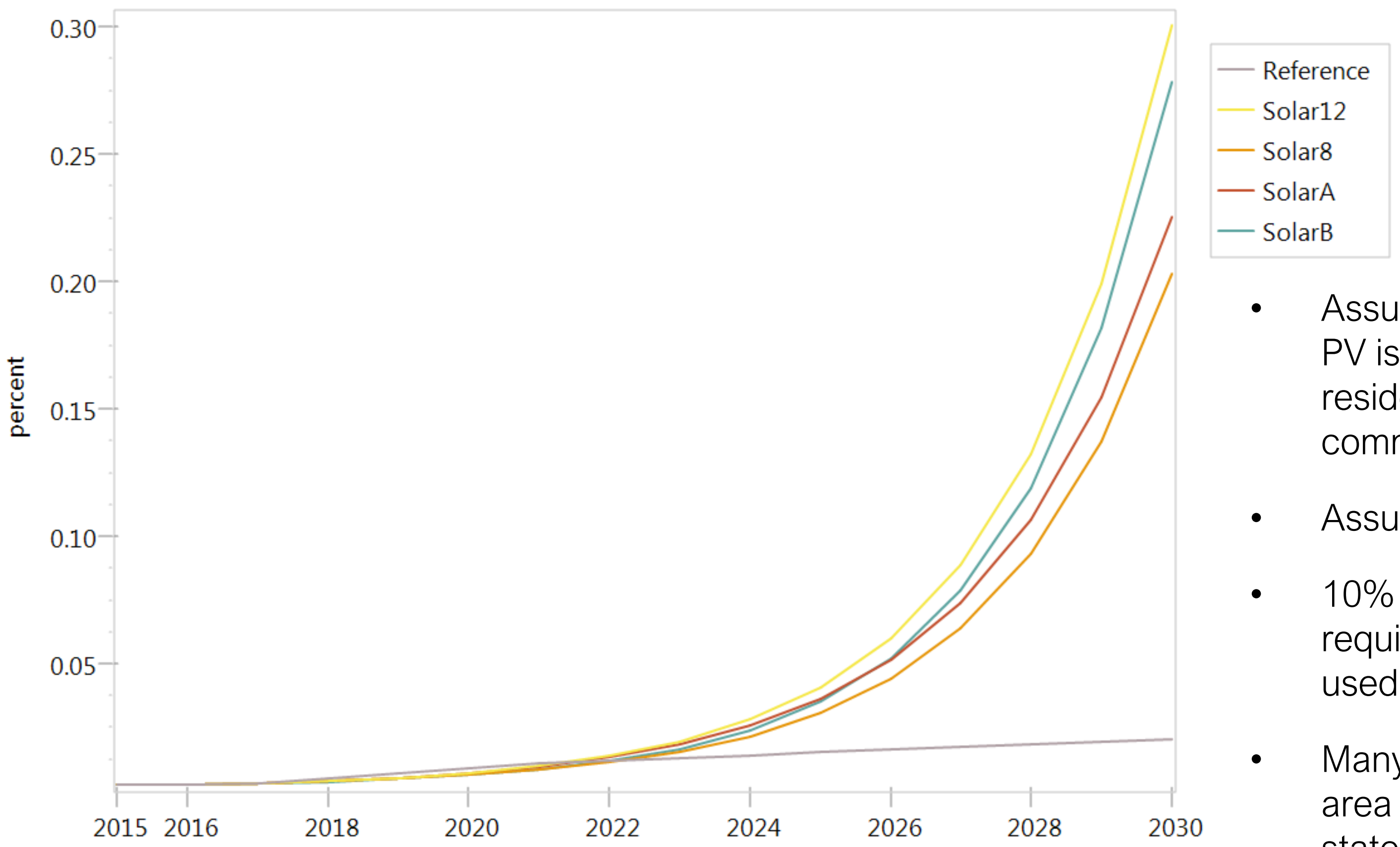
| Location | Scale | Retail Rate ($/kWh) | SREC for 10 year payback |
|---|---|---|---|
| Philadelphia | Residential | 0.138 | $75/MWh |
| Pittsburgh | Residential | 0.141 | $100/MWh |
| Philadelphia | Commercial | 0.123 | $100/MWh |
| Pittsburgh | Commercial | 0.059 | $30/MWh |
| Southeast | Grid scale | 0.072* | $100/MWh |
| * This is a PPA price, not a retail rate | | | |

# Modeling input: solar prices

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



# Viability Land Impact




- 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

# Viability Land Impact

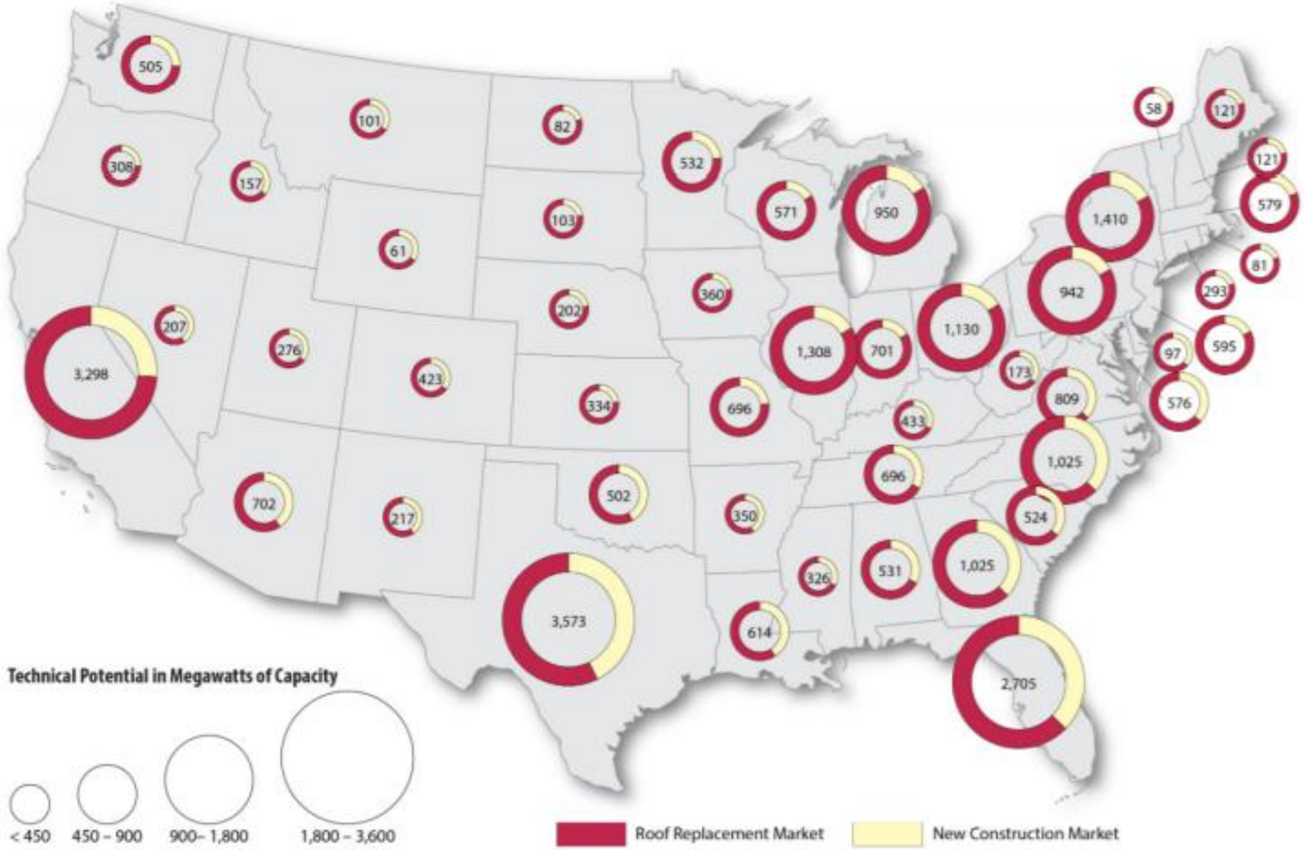
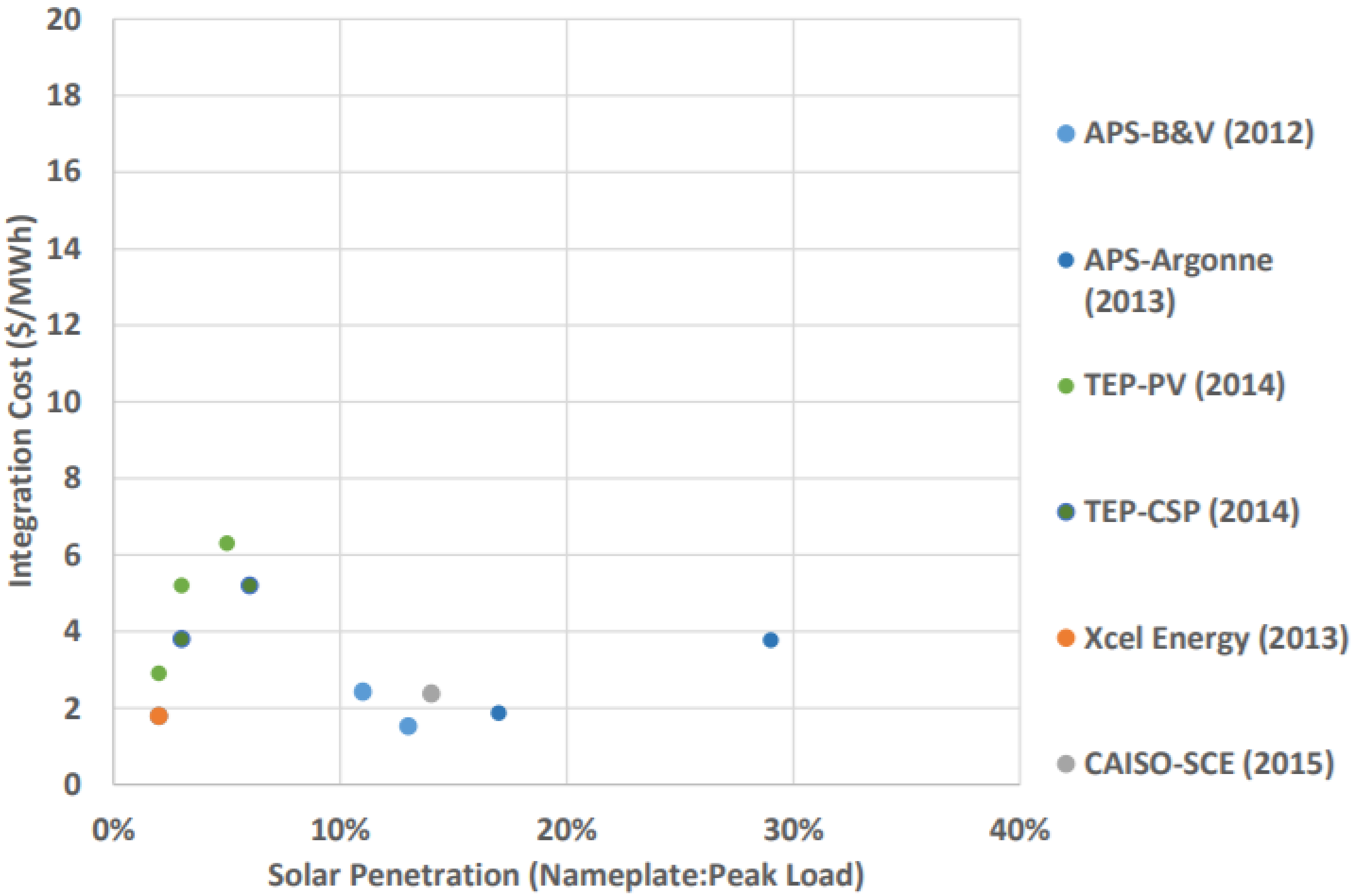



**Figure ES-1. Annual average technical potential for residential rooftop PV at time of roof replacement and new construction projected between 2017 and 2030**

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.

# 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.

# Modeling input: health impacts

Added costs for $CO_2$, $SO_2$, and NOx according to
Fig 4 Buonocore et al (Nature 2015, doi:10.1038/nclimate2771)

| Pollutant | Impact Cost | Cost Units |
|---|---|---|
| Carbon Dioxide | 47 | USD/metric tonne |
| Nitrogen Oxides | 10 | Kilogram |
| Sulfur Dioxides | 20 | Kilogram |

# Economic Benefit Cost Results with health and environmental effects

Cumulative cost and benefits relative to reference scenario

| Cumulative Costs and Benefits 2015-2030<br>Relative to Reference scenario | | |
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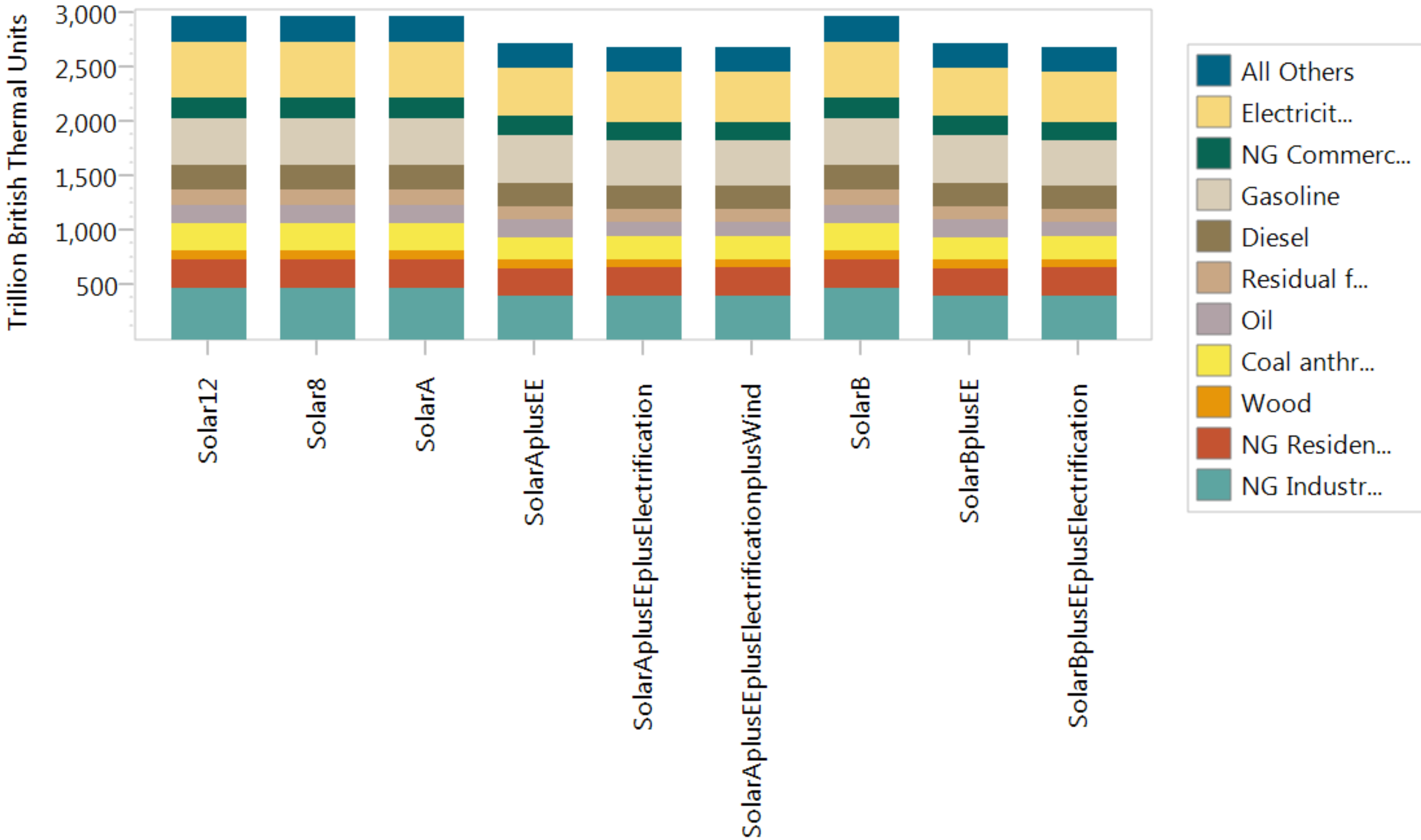
| Electricity Generation | 10.0 | 8.5 |
| **Resources** | -0.3 | -0.3 |
| Production | -0.3 | -0.3 |
| **Externalities** | -4.1 | -3.5 |
| **NPV (society)** | 5.8 | 4.8 |

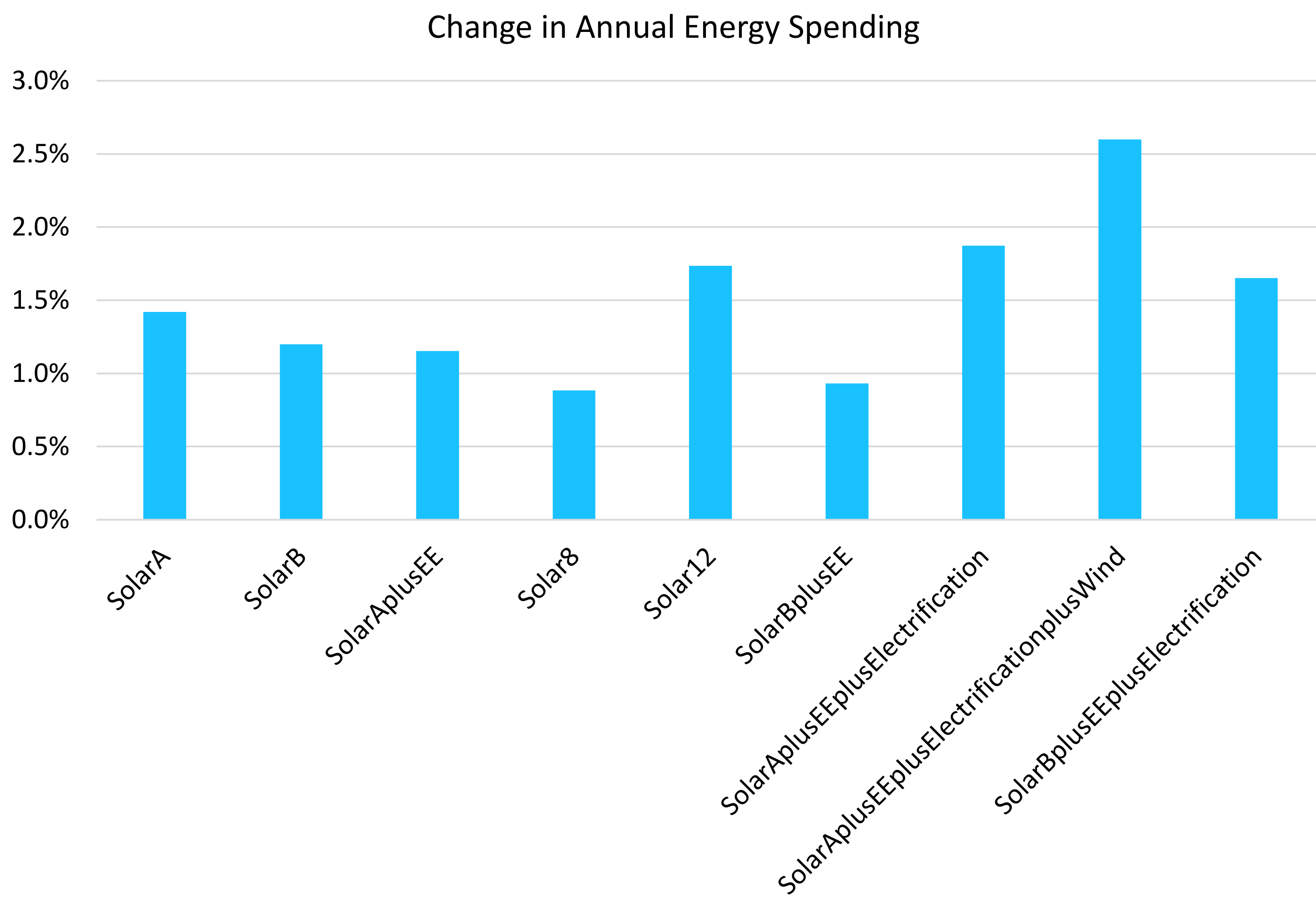
# Alternative Scenarios

## Total Energy Use by Scenario by Fuel (TBtu)



# Alternative Scenarios

Difference in total energy spending by scenario



# Strategies and Modeling

- Viability
- Estimated impacts
- Identification of barriers and or missing data
- Place in common context and framework – a "big picture"
- Sensitivities

# Thank You!

# Discussion & Questions

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# LEAP System

- Long-range Energy Alternatives Planning 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?

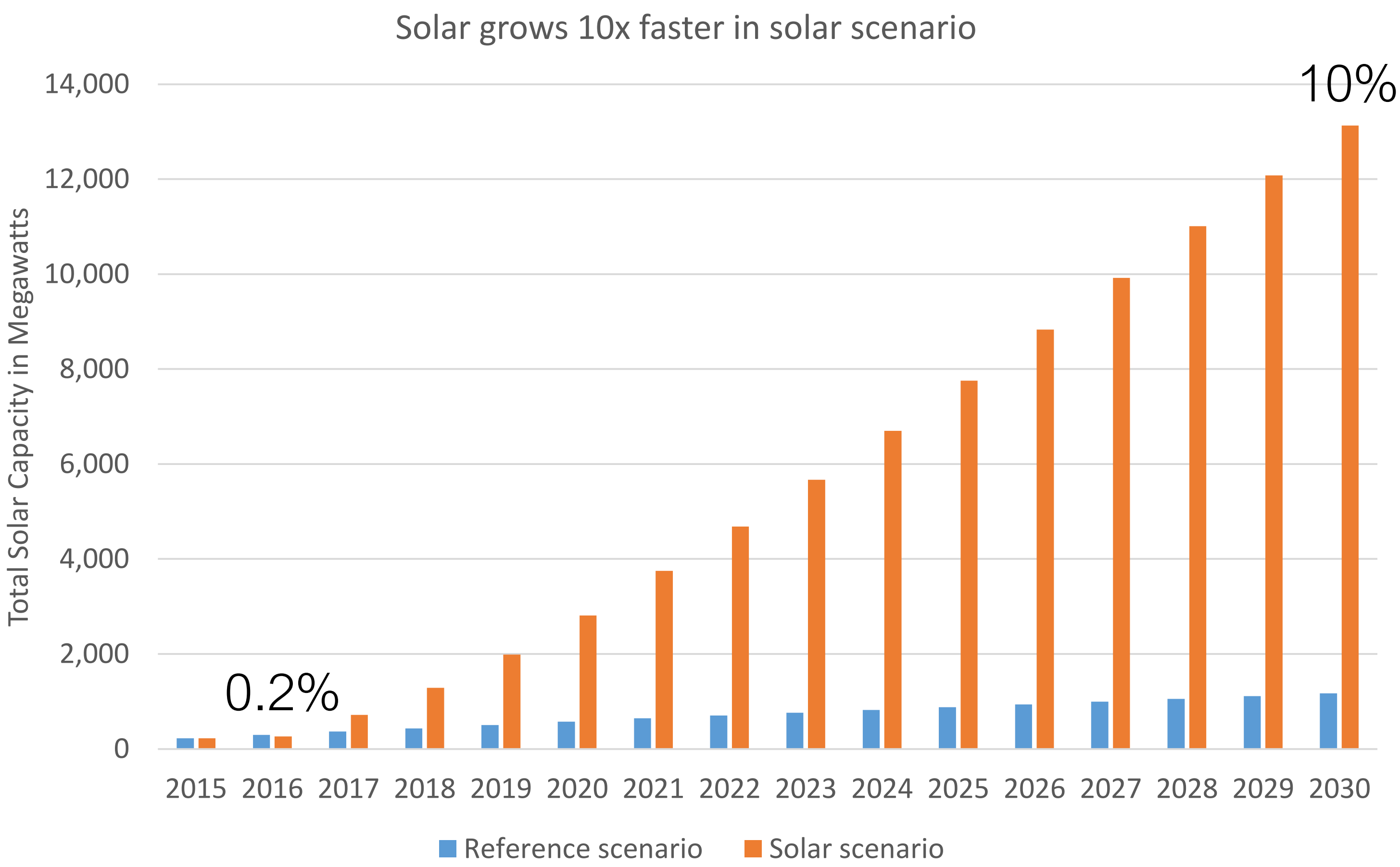
- Meets AEPS in 2021
- Solar and efficiency continue current trends
- CAFE standards met for Light Duty Vehicles
- Federal Tax Credits sunset

# Building the initial Solar scenario

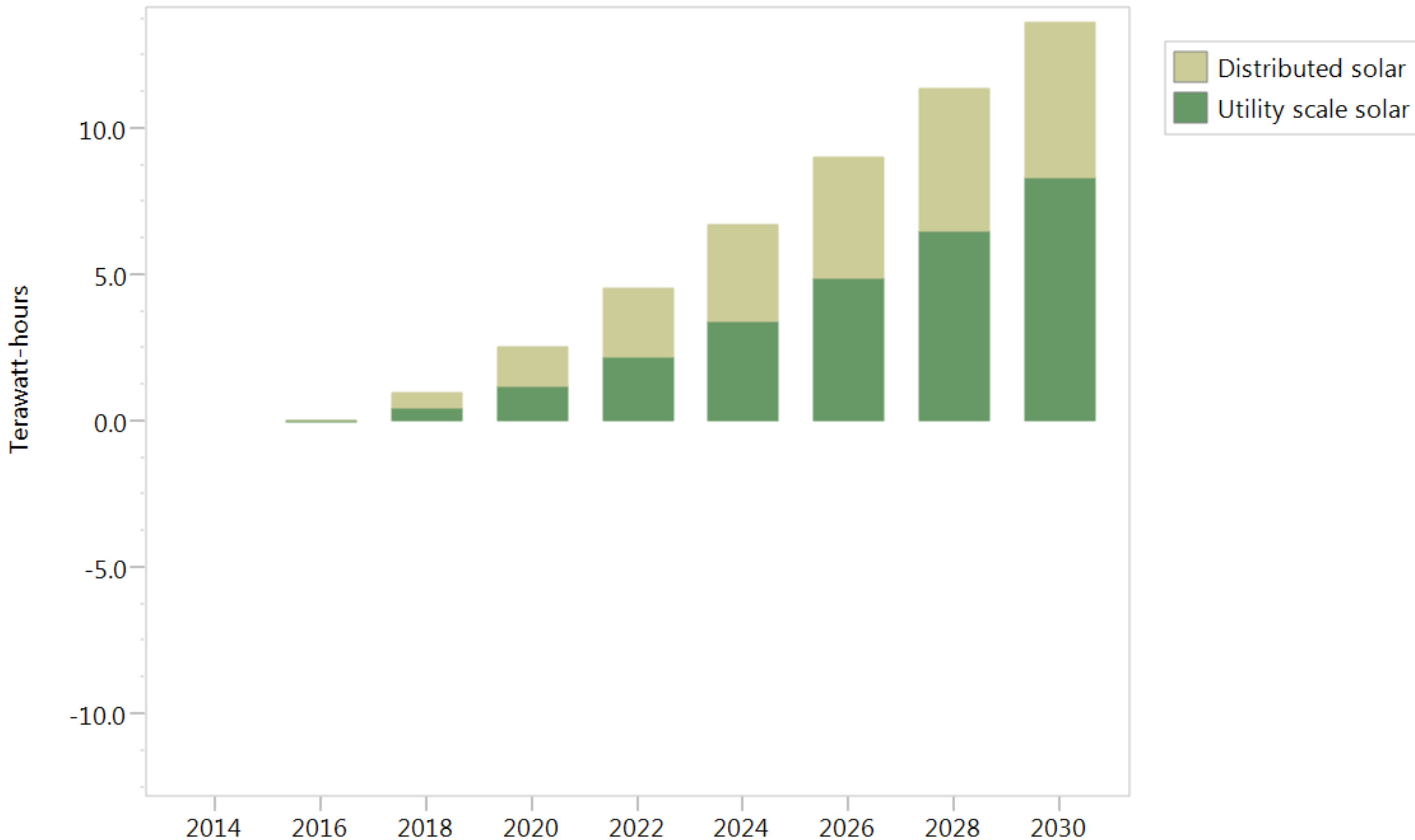
Initial Solar scenario is built upon the Reference scenario

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



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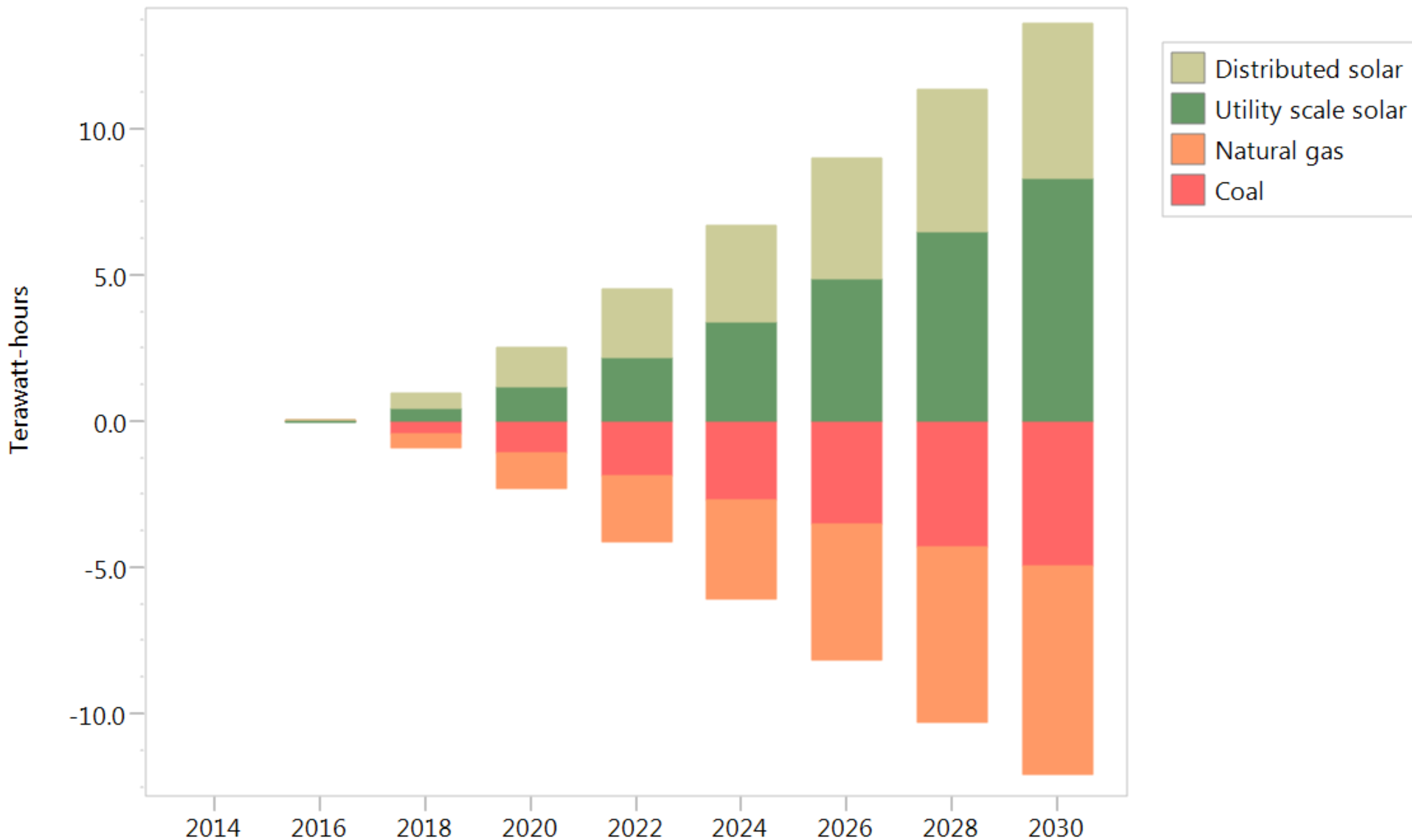
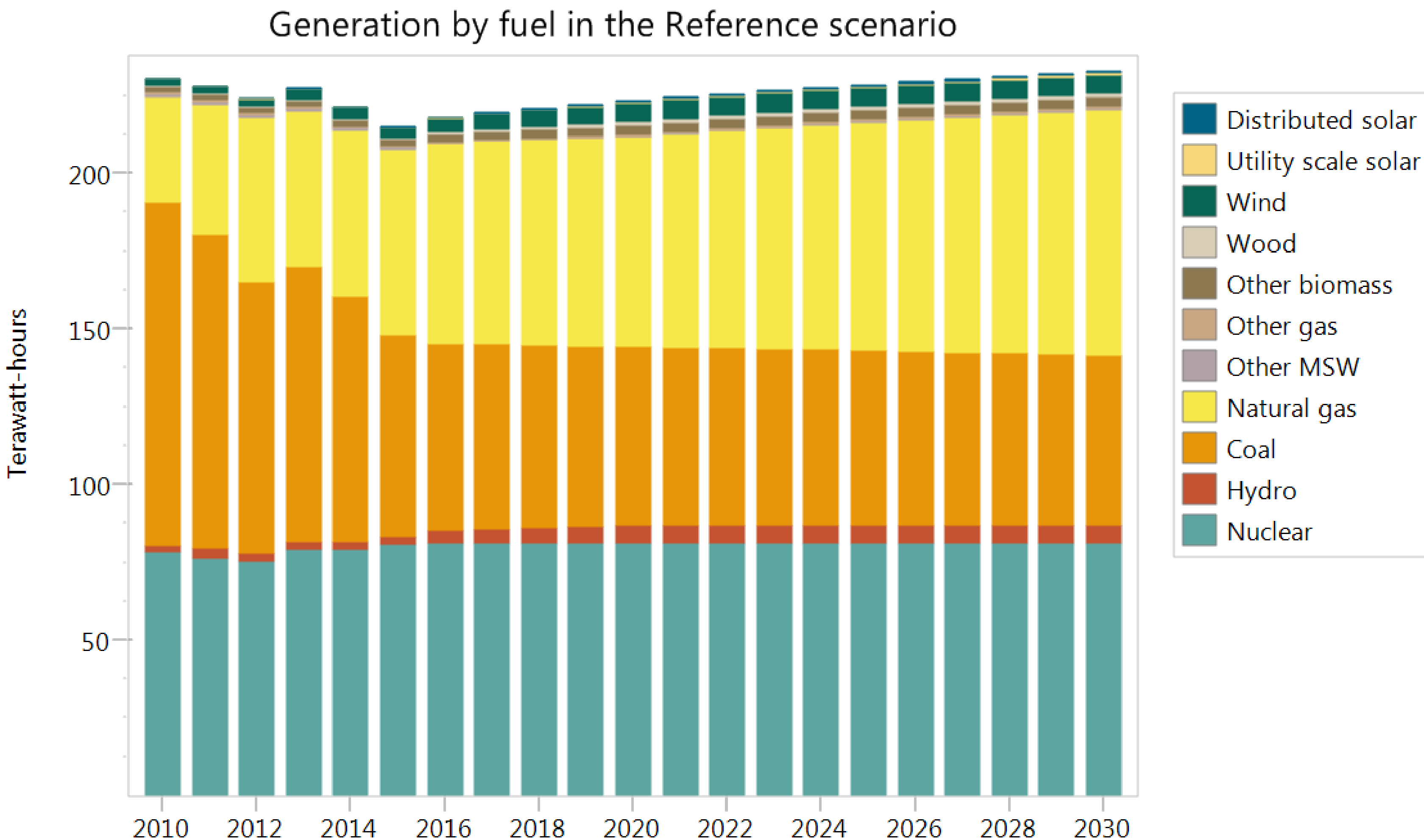
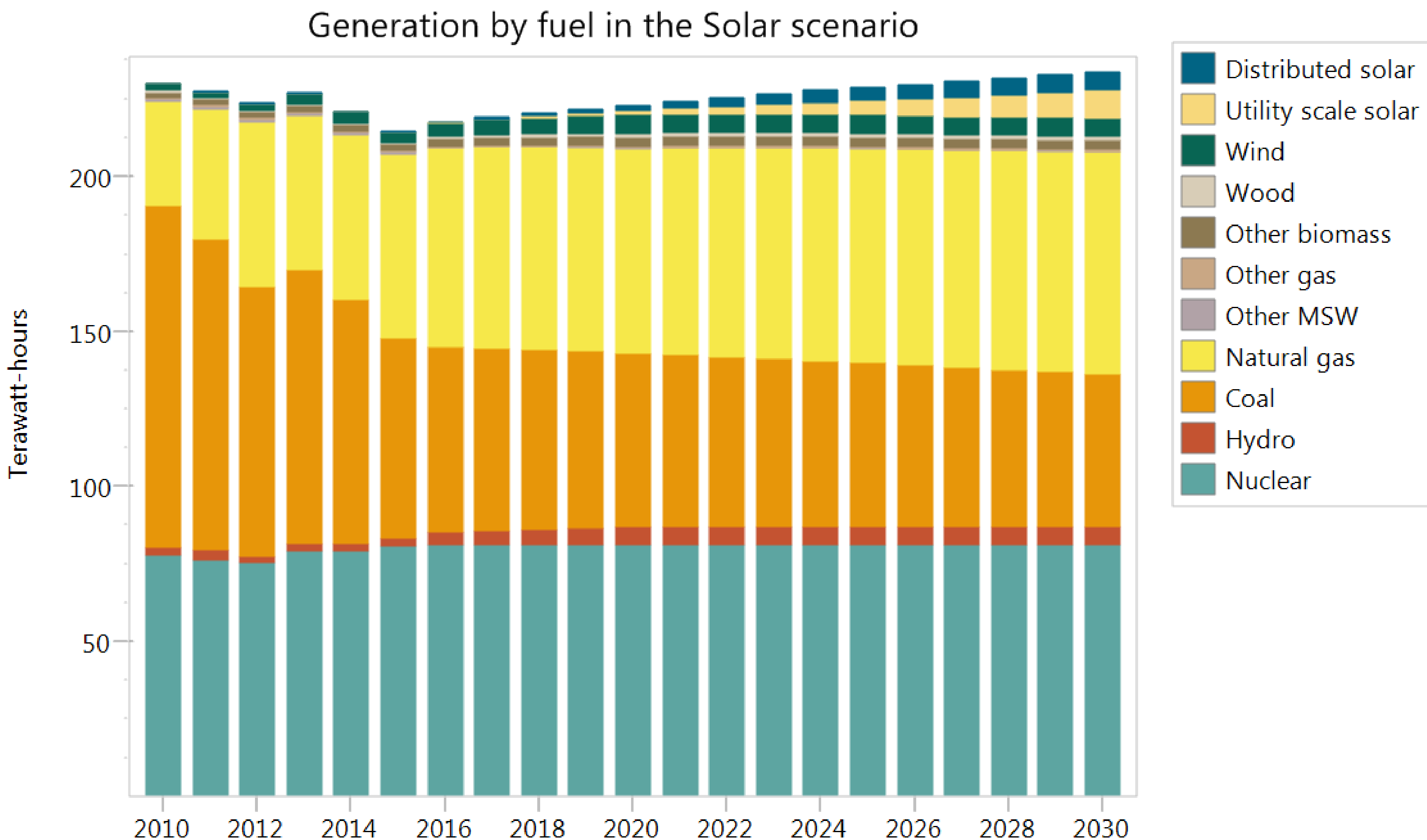




Generation by fuel in the Reference scenario
Terawatt-hours
200
150
100
50
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
Distributed solar
Utility scale solar
Wind
Wood
Other biomass
Other gas
Other MSW
Natural gas
Coal
Hydro
Nuclear



Generation by fuel in the Solar scenario
Terawatt-hours
50
100
150
200
2010
2012
2014
2016
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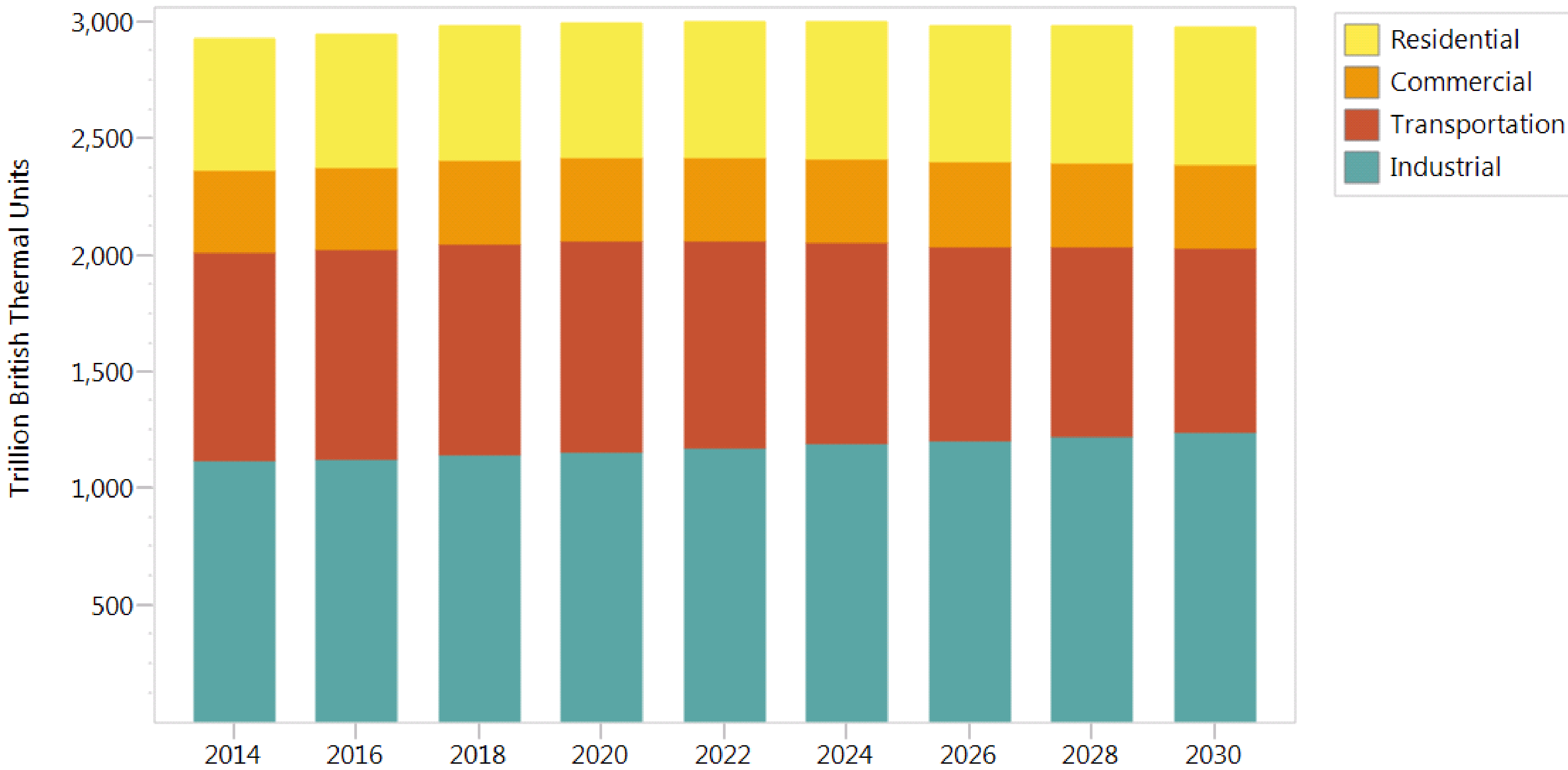
2022
2024
2026
2028
2030
Distributed solar
Utility scale solar
Wind
Wood
Other biomass
Other gas
Other MSW
Natural gas
Coal
Hydro
Nuclear

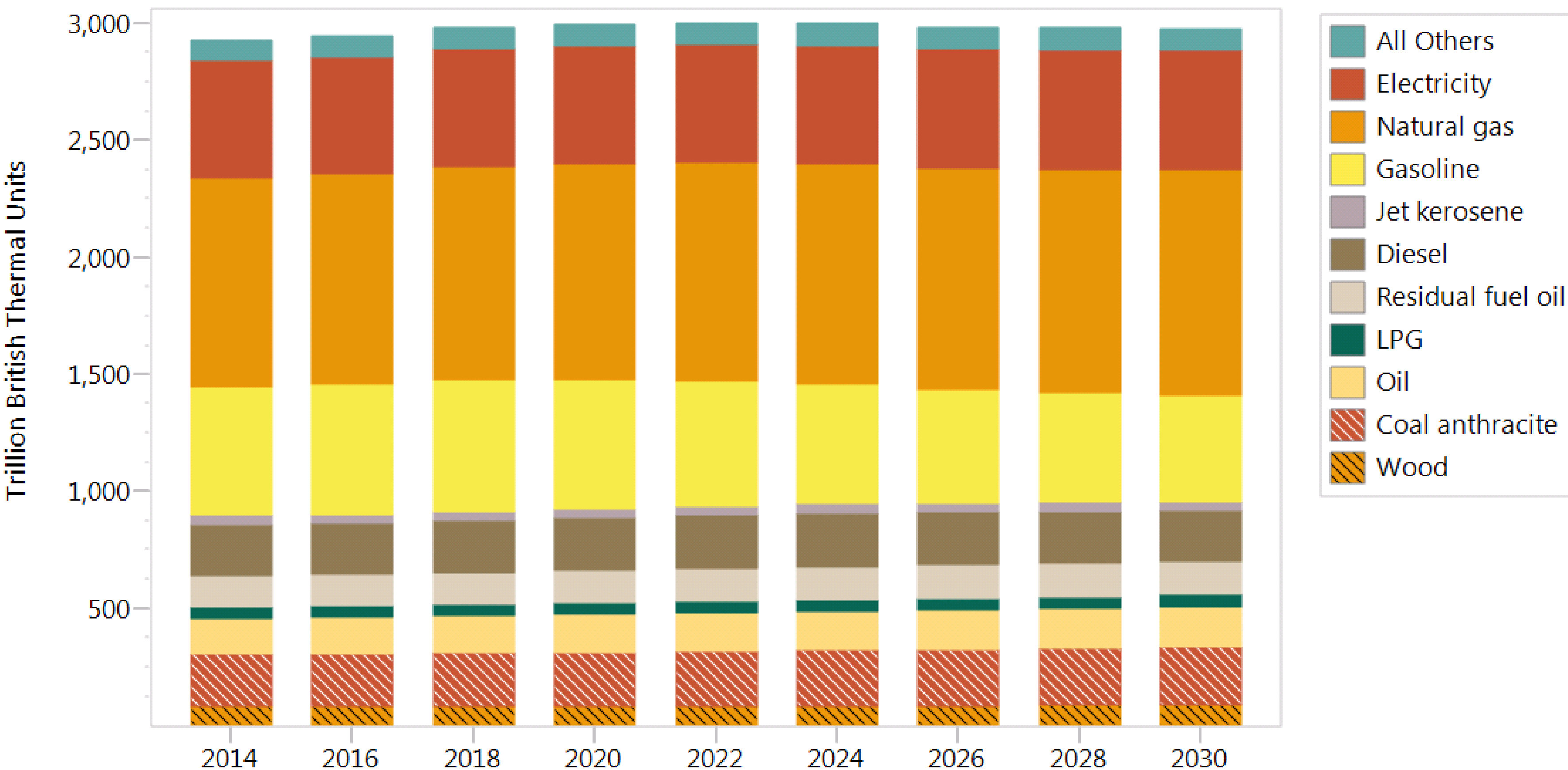
# Demand driven

- 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



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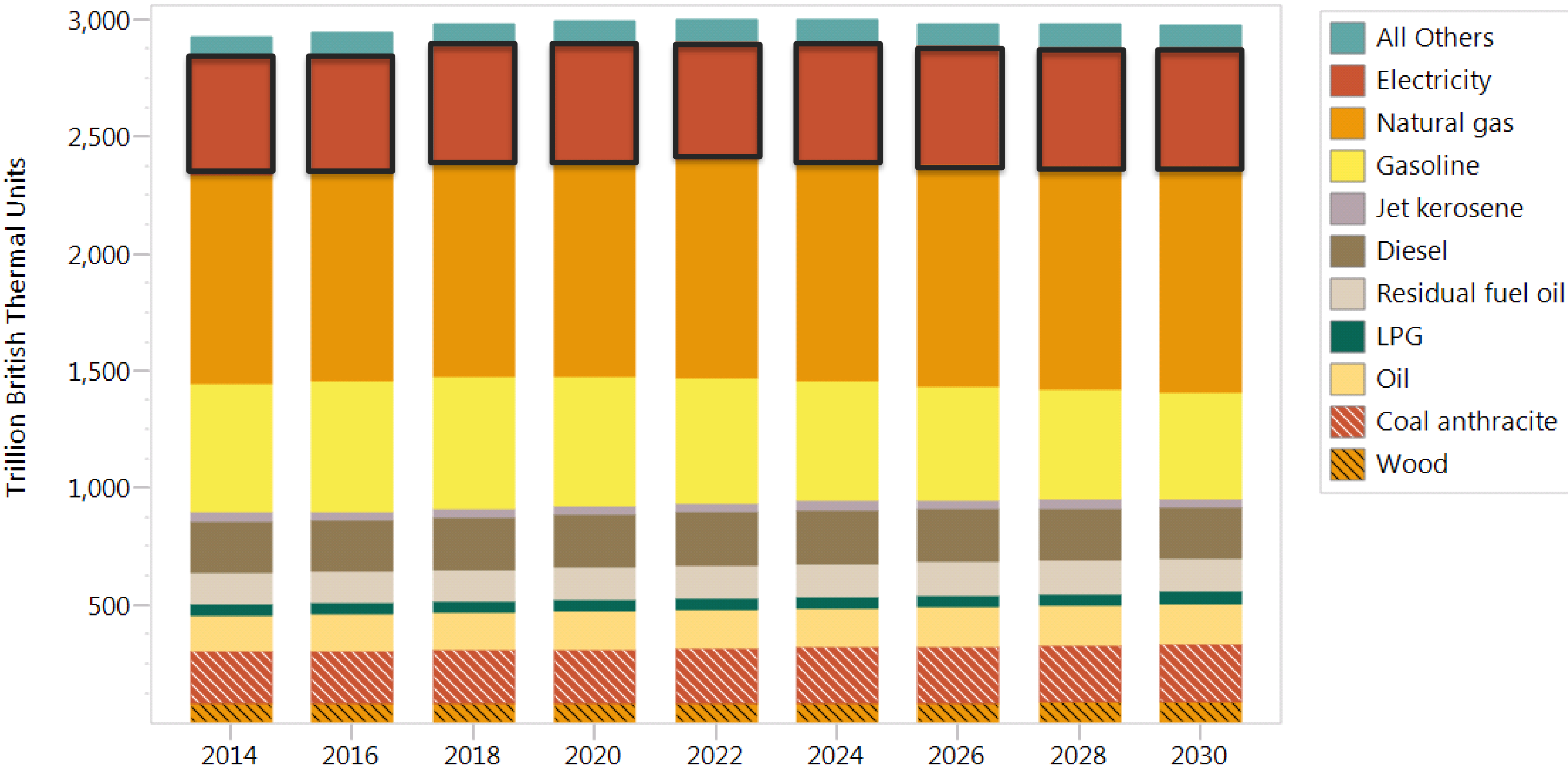
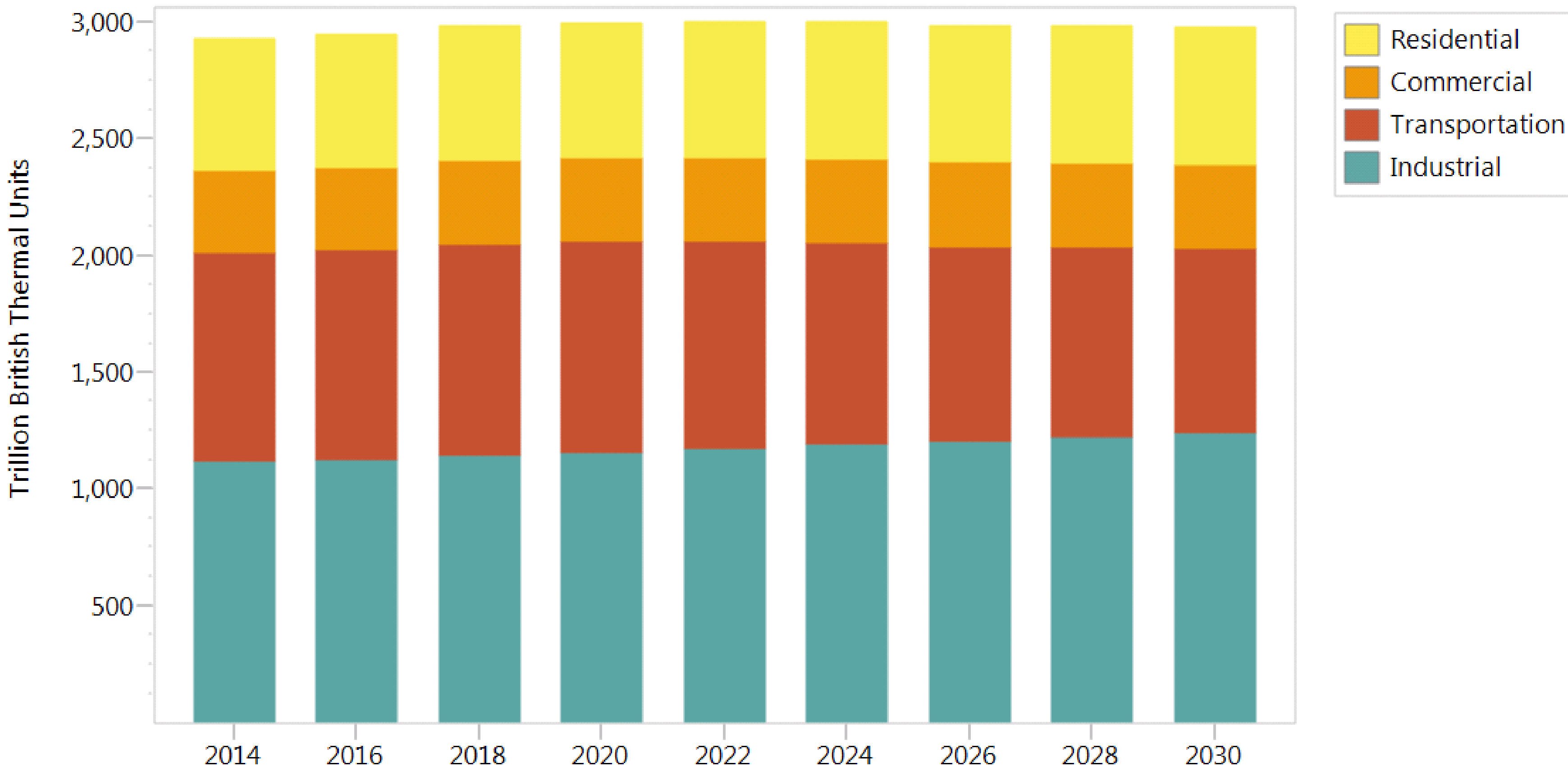
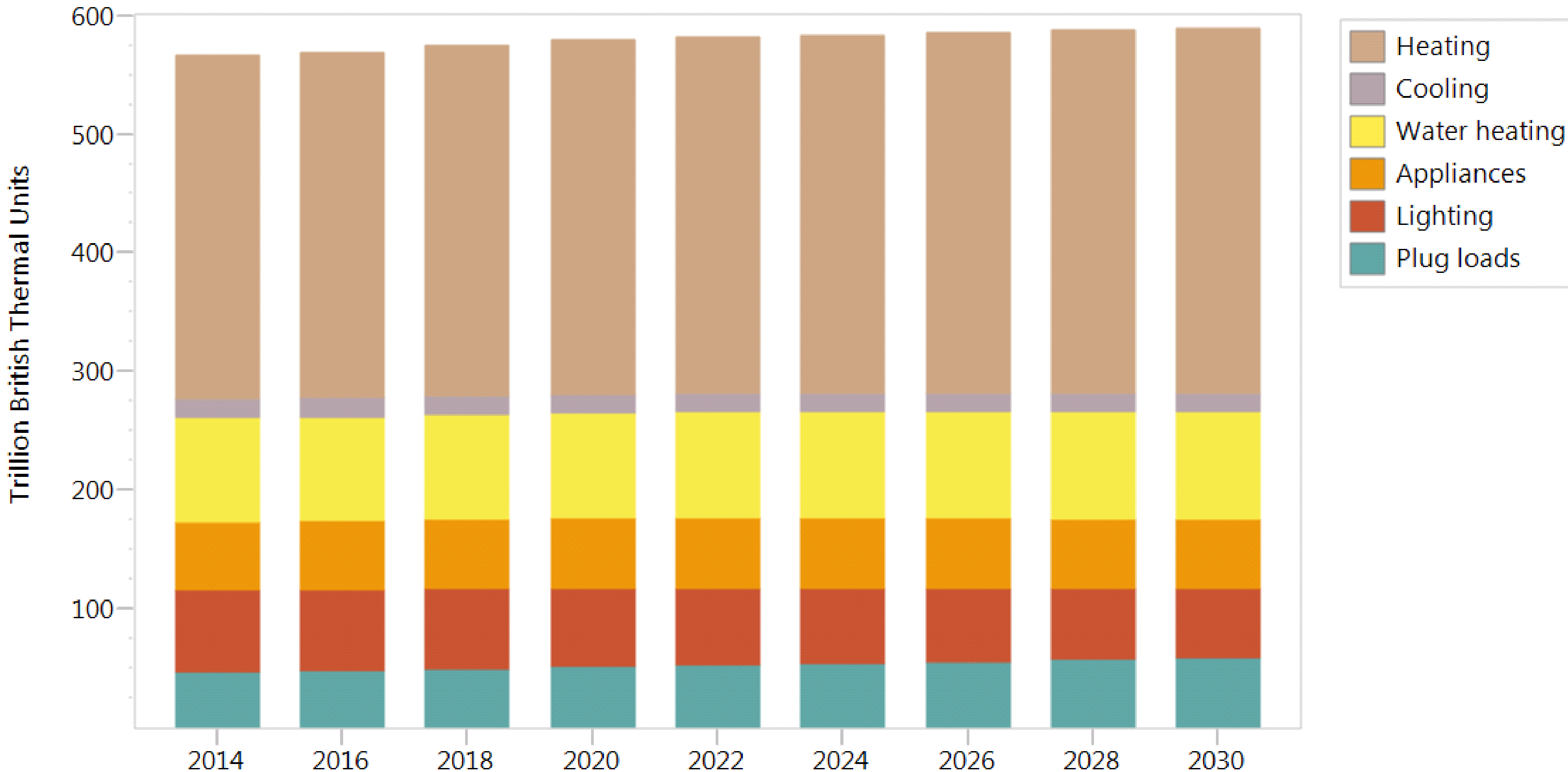


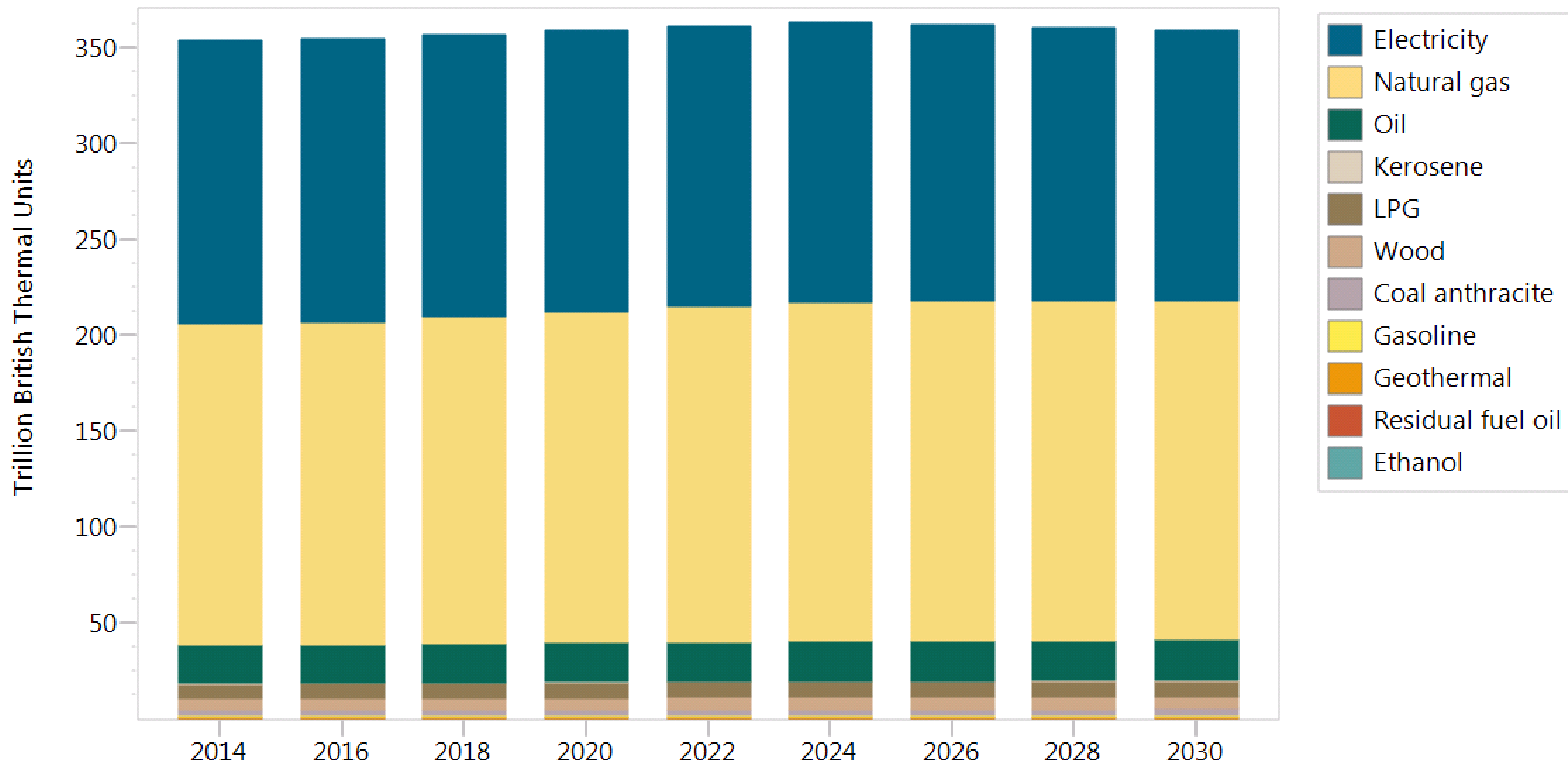
# Total energy use relatively level



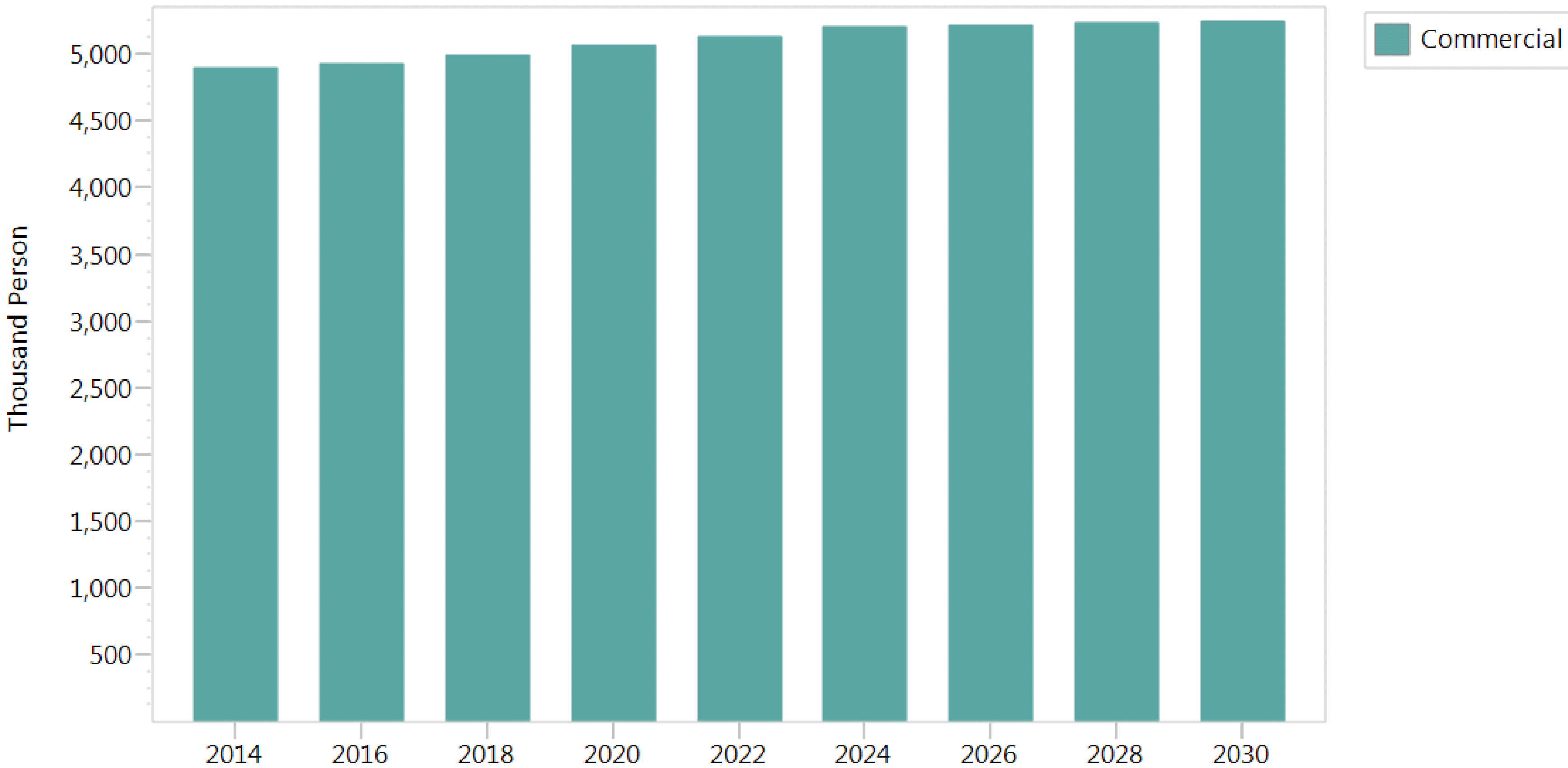
# Residential energy dominated by heating



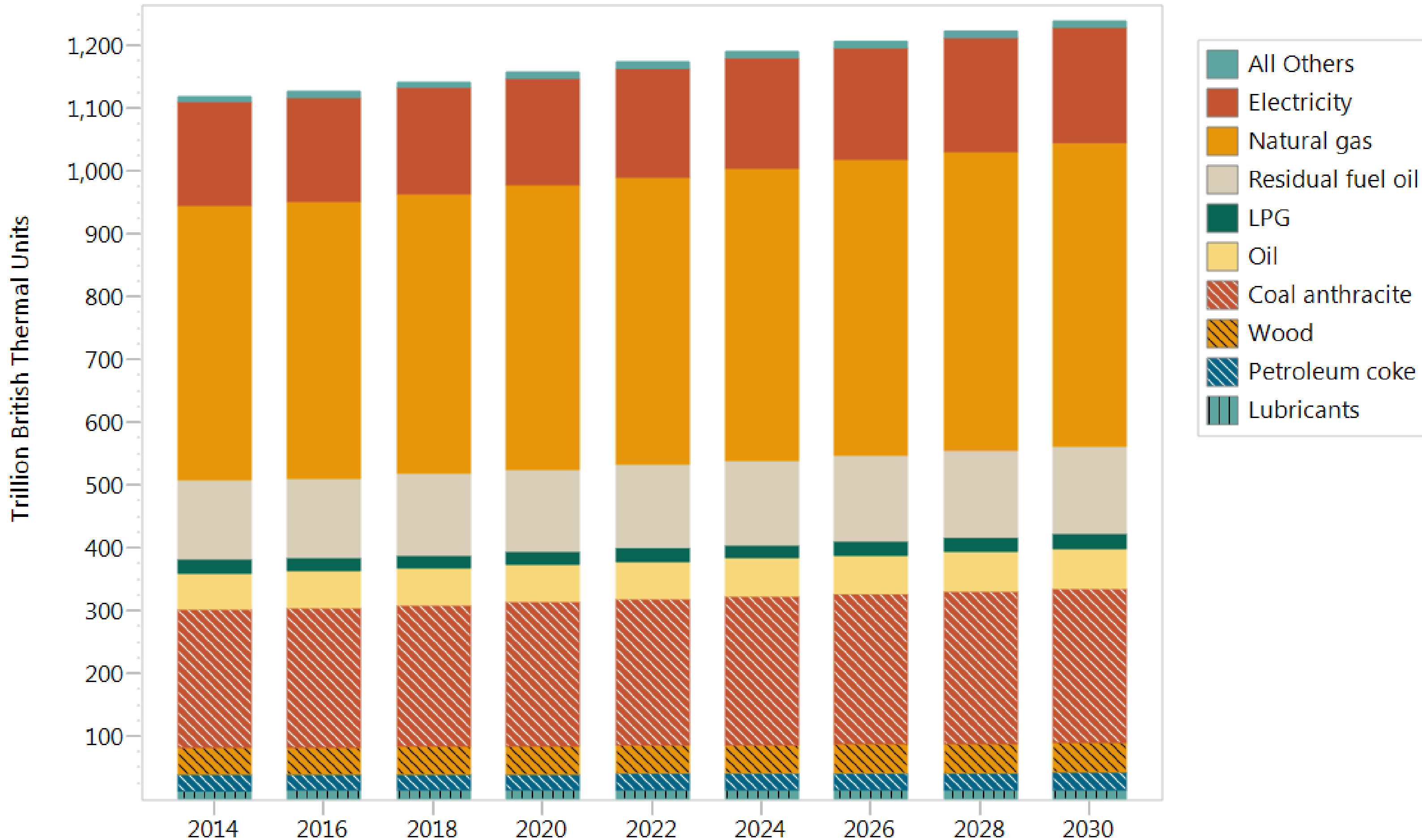
# Commercial energy



# Projected employment drives increase demand



# Industrial demand increases by 10%

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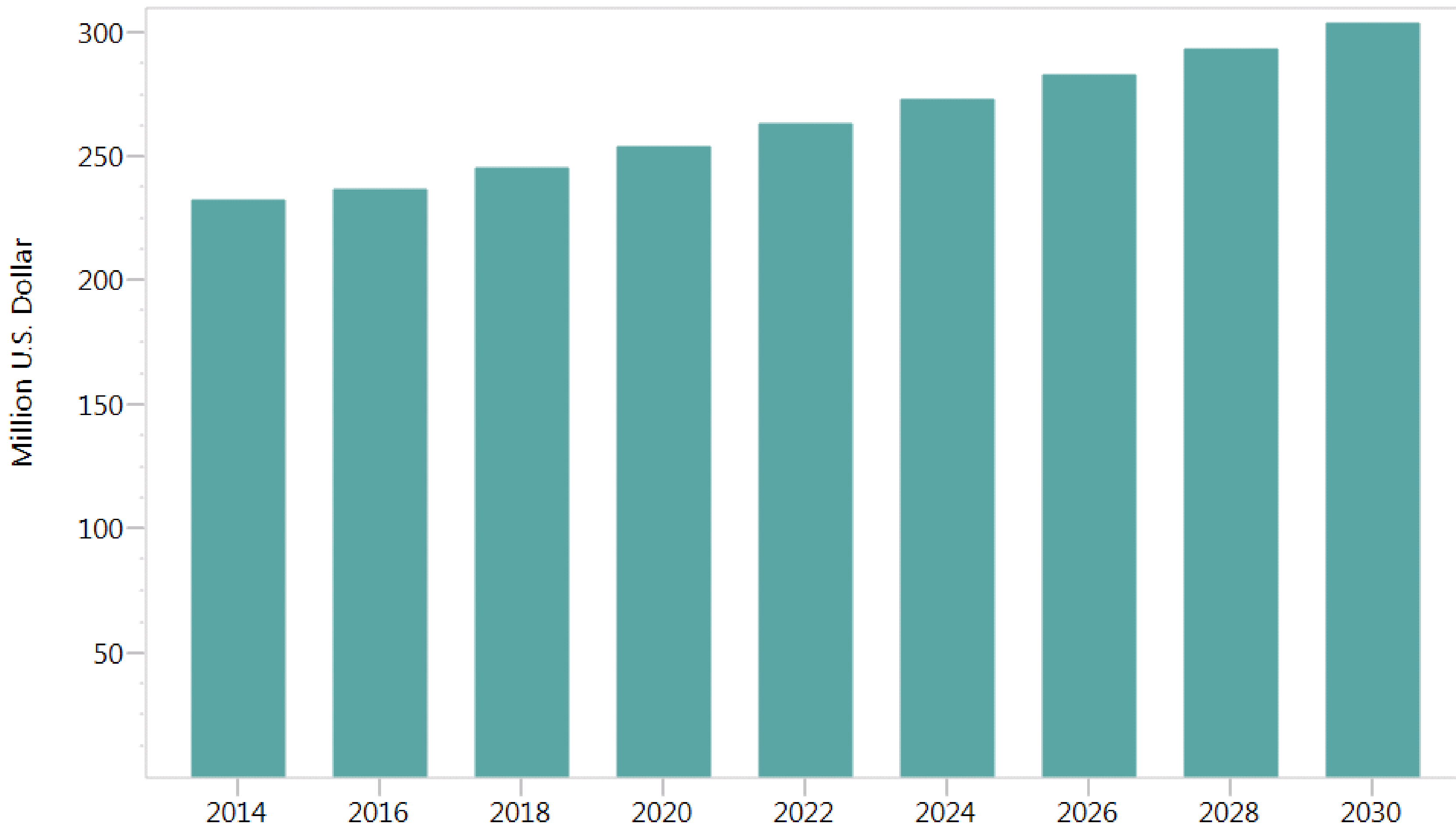
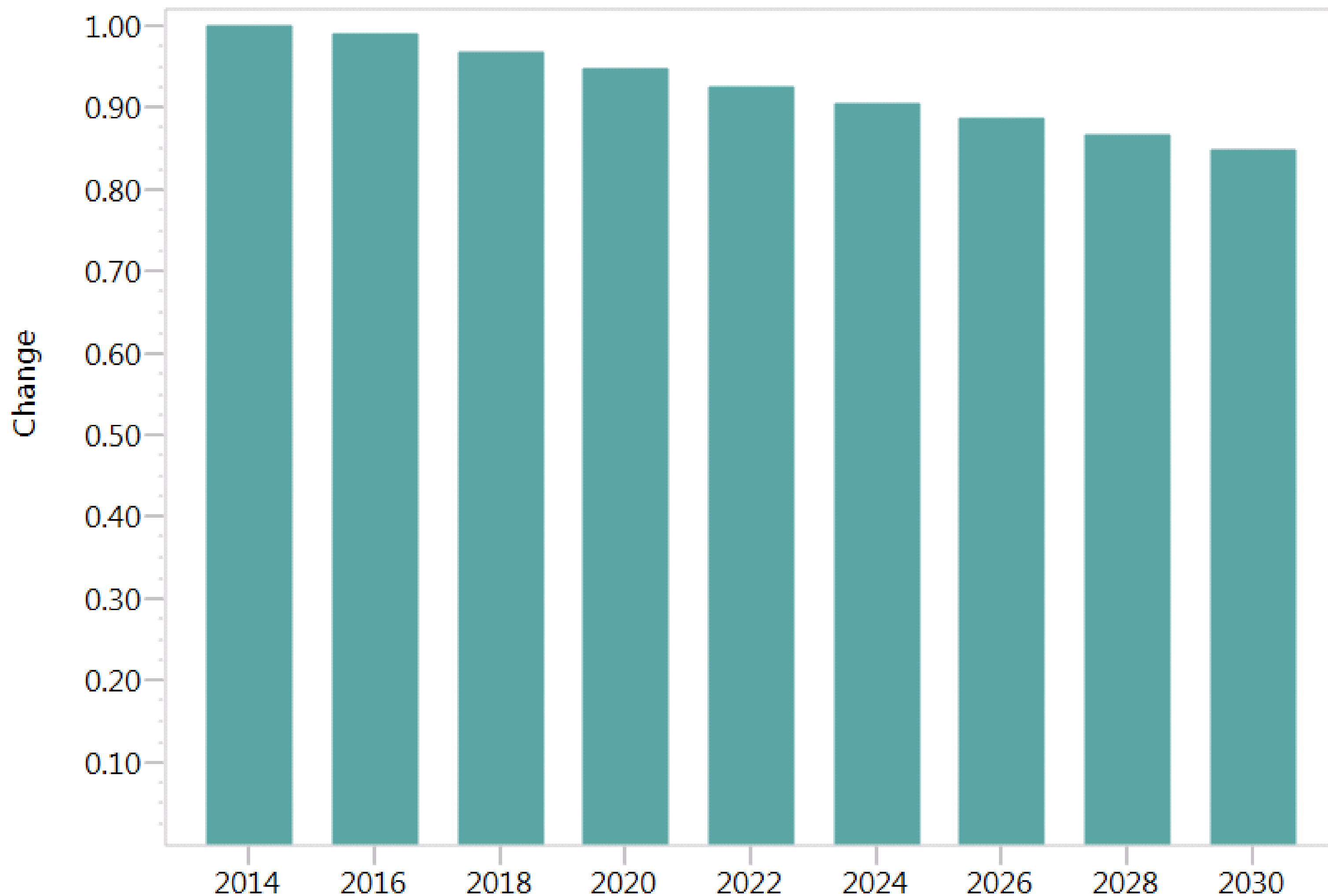
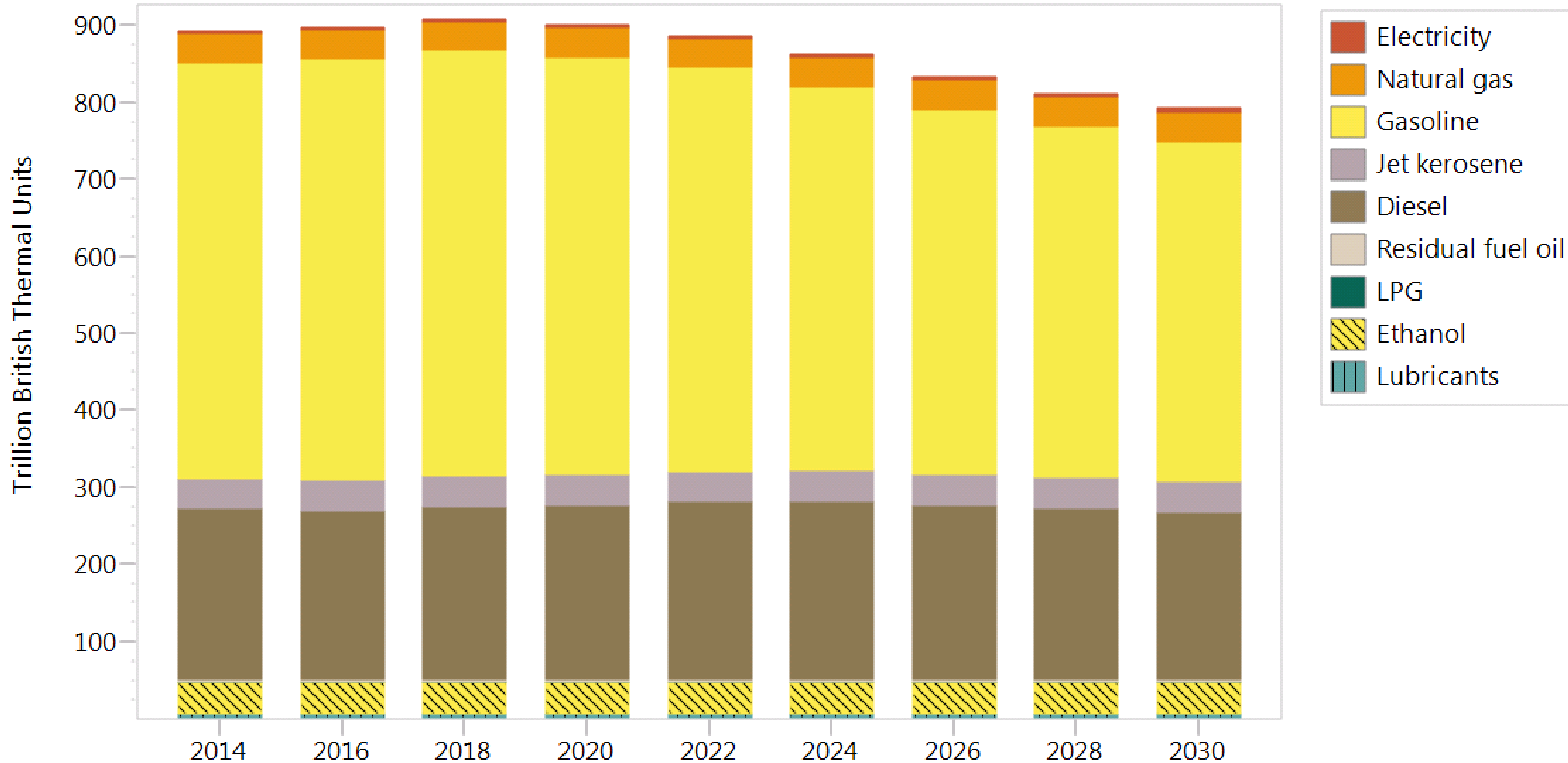
# Value of shipments drives increased demand



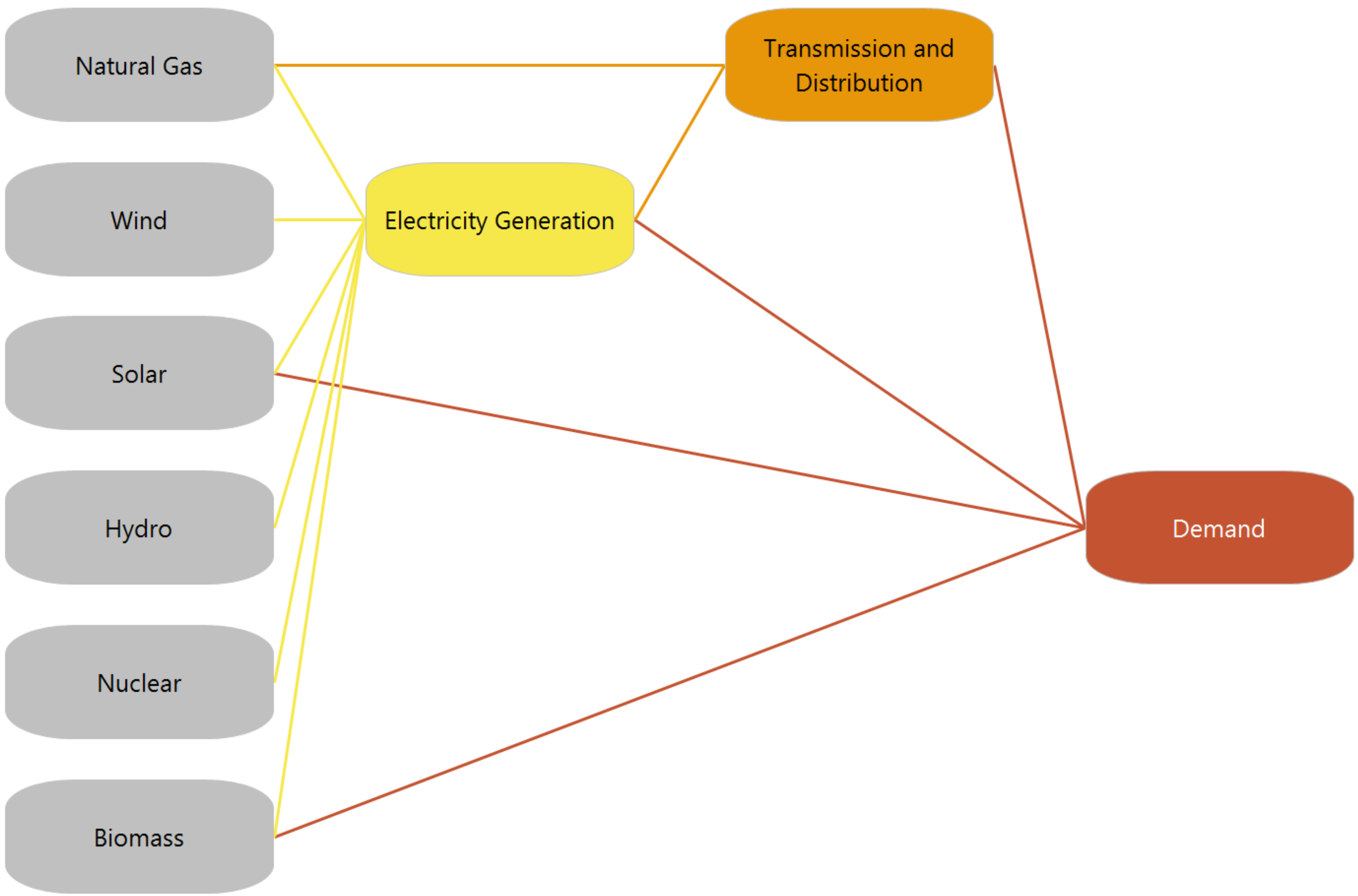
# Structural shift in energy required for industry



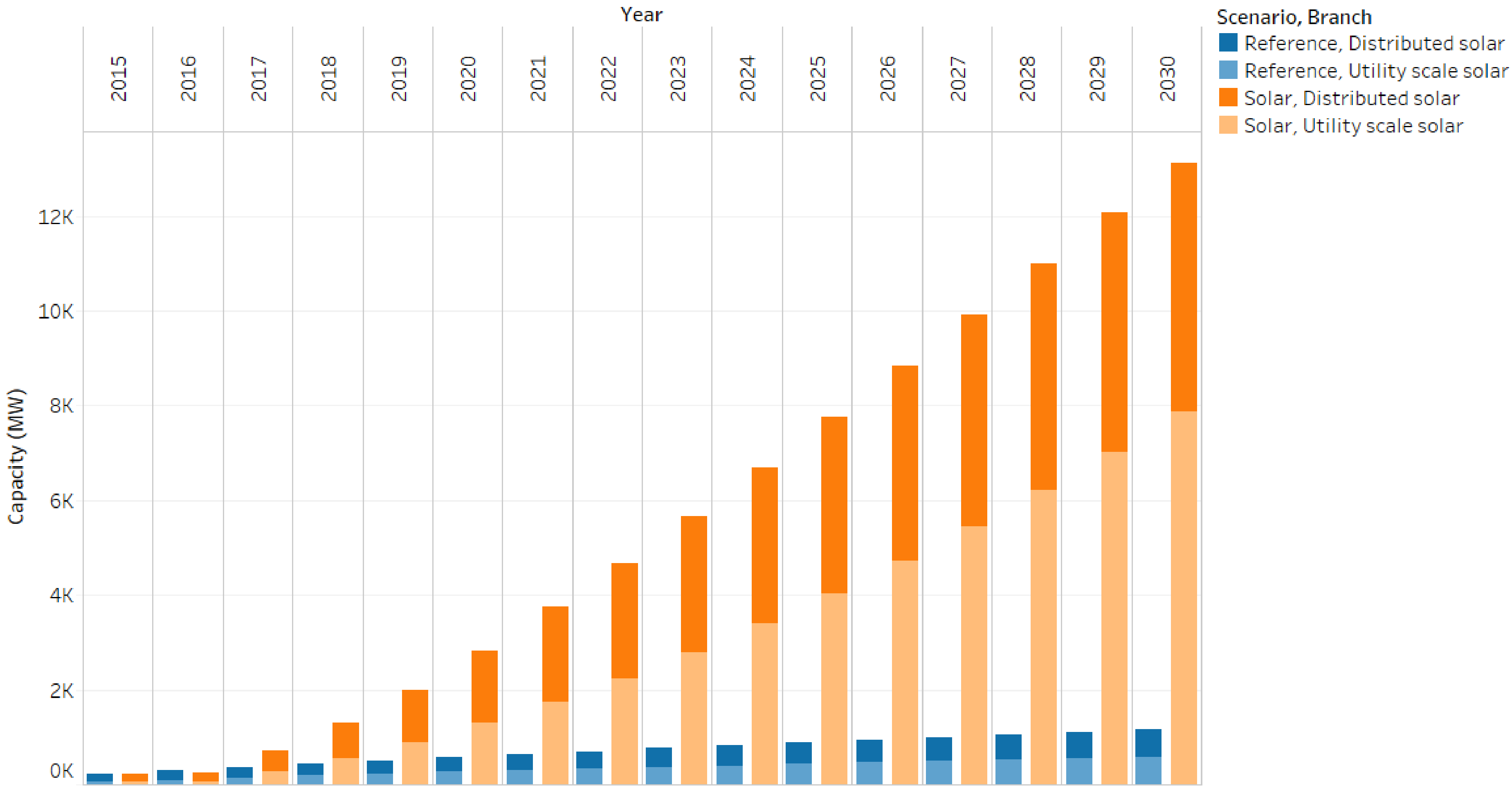
# Transportation becomes more efficient and begins to electrify



# Resources ← Transformation ← Demand driven



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



# 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

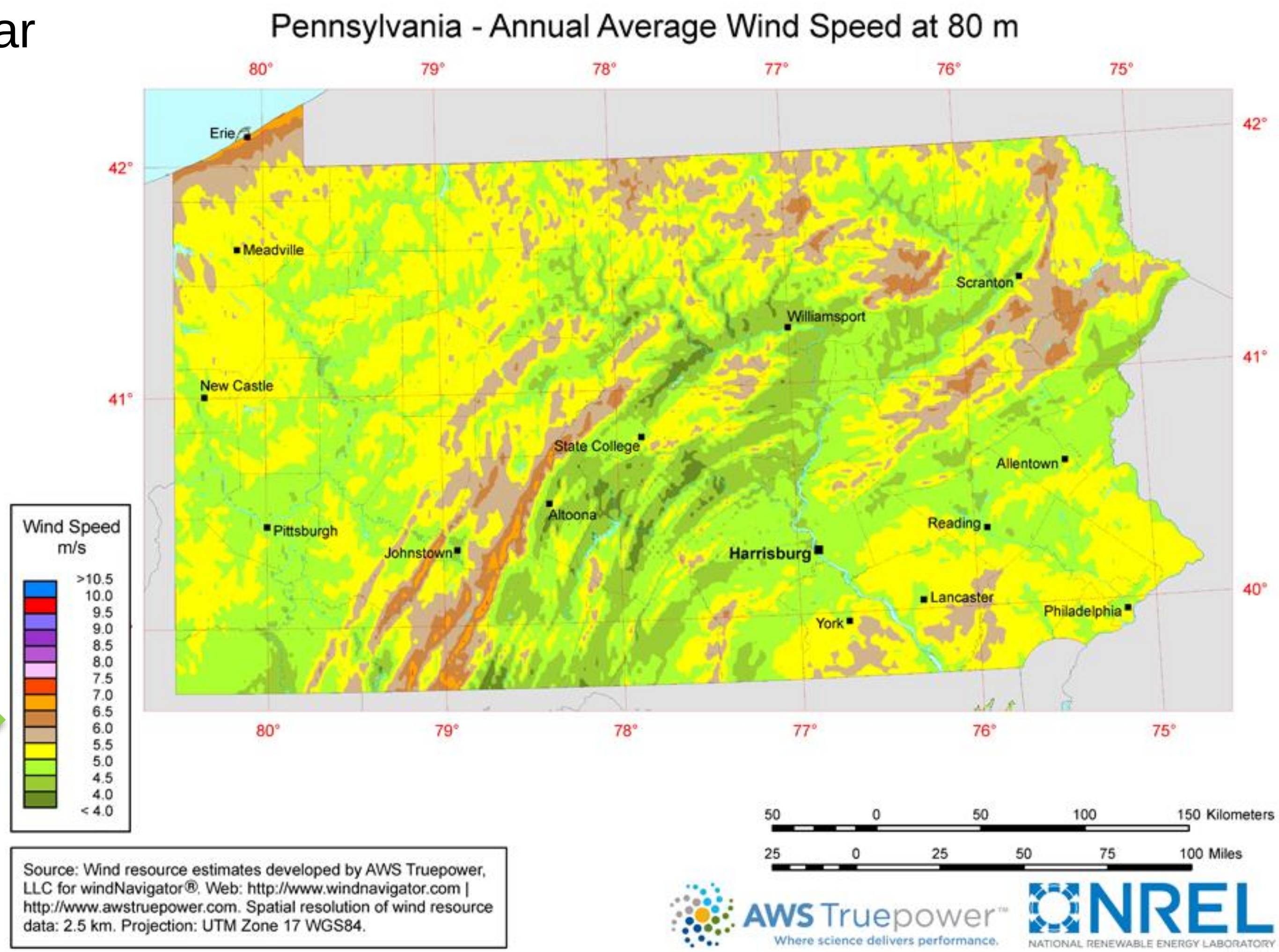
CF: 31%, 2,700 kWh/kW

CAPEX: $1,678/kW

O&M: $51/kW·year

LCOE:$64/MWh

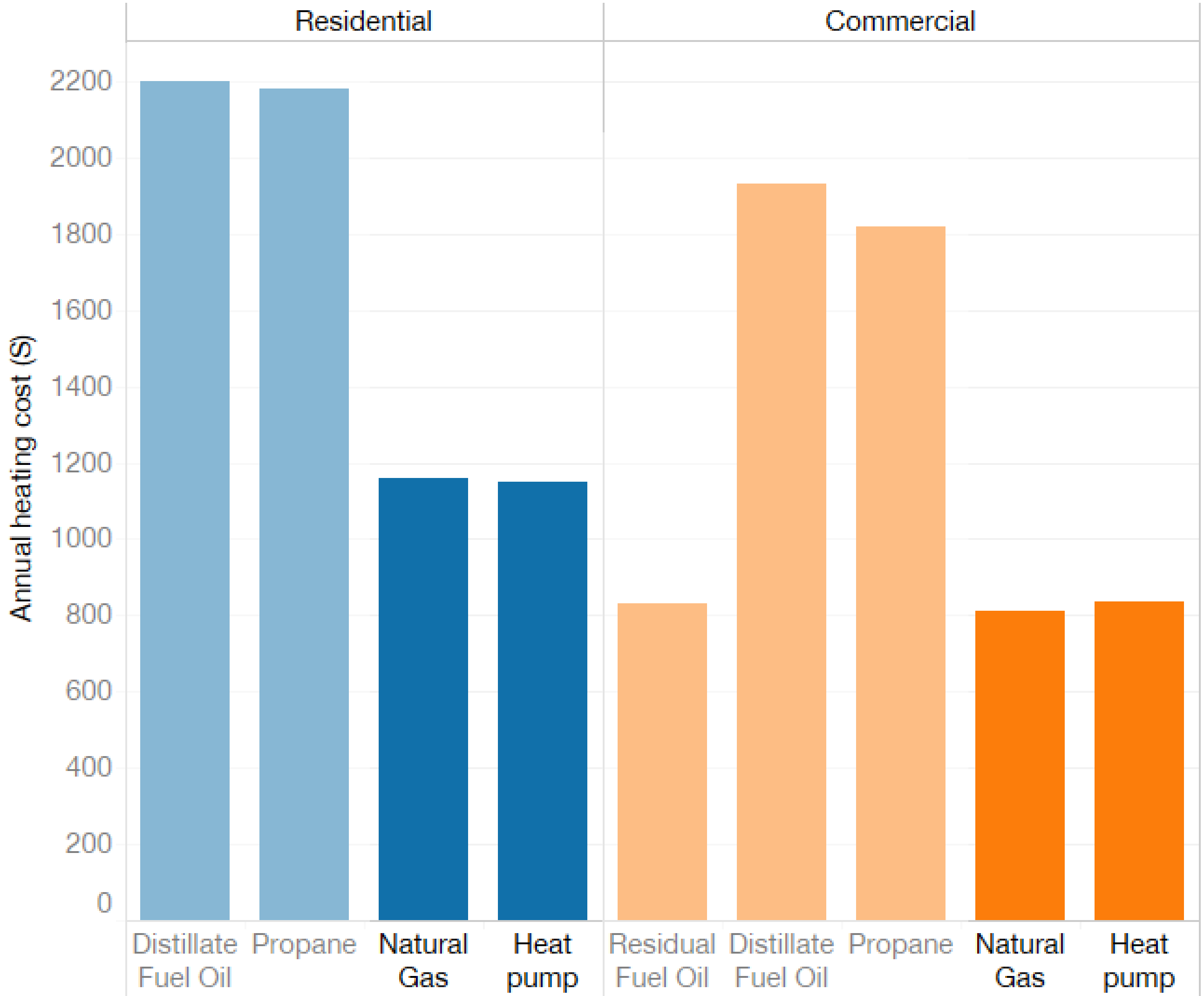
| Techno-Resource Group (TRG) | Wind Speed Range (m/s) | Weighted Average Wind Speed (m/s) |
|---|---|---|
| TRG1 | 7.7 - 13.5 | 8.8 |
| TRG2 | 7.5 - 10.4 | 8.3 |
| TRG3 | 7.3 - 10.5 | 8.1 |
| TRG4 | 7.1 - 10.1 | 7.9 |
| TRG5 | 6.8 - 9.5 | 7.5 |
| TRG6 | 61. - 9.4 | 6.9 |
| TRG7 | 5.3 - 8.3 | 6.2 |
|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



# 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



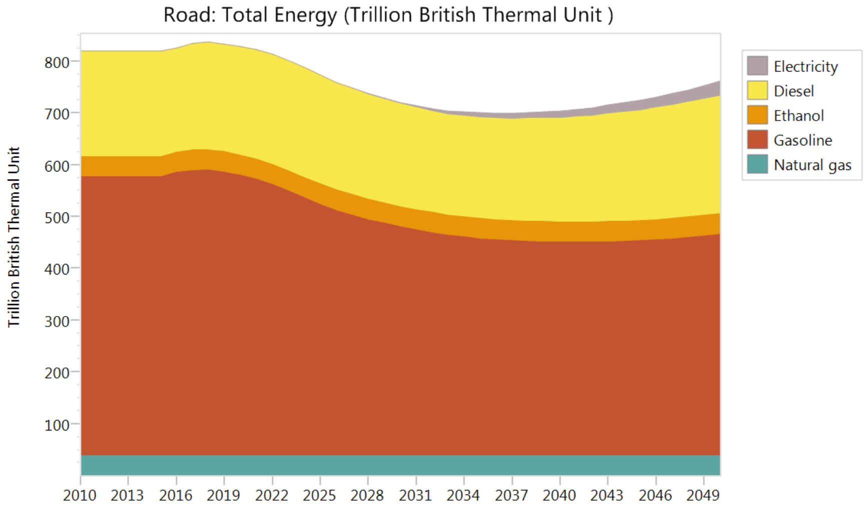

Assumptions:

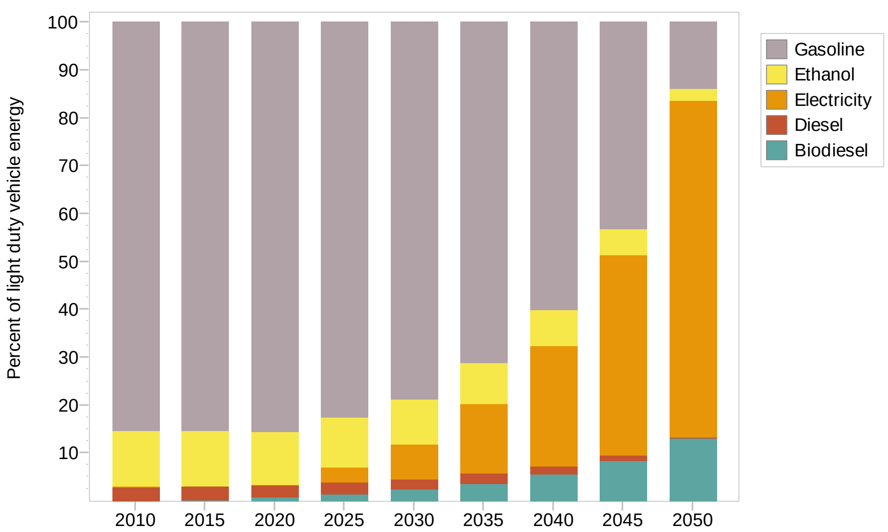
- Existing system efficiencies: oil: 85%, propane: 87%; new systems efficiencies: gas 90%, heat pump 2.8 COP
- Fossil fuel costs from 2017 AEO, volumetric electricity costs in USD/kWh: 0.11 for residential and 0.08 for commercial

# 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%

Vermont Energy Investment Corporation

pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION