Lessons from the Deep Decarbonization Pathways Project

DDPP DEEP DECARBONIZATION PATHWAYS PROJECT

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JGCRI Workshop
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Lessons from the DDPP

- Background
- US Pathways
- DDPP Pathways
- Research Agenda

Background

SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

IDDRI
SciencesPo.

+ Deep Decarbonization Pathways Project

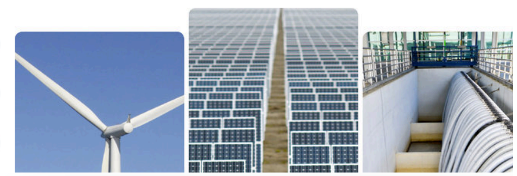
- National blueprints for limiting warming <2°C
- Independent research teams from 16 countries
- ¾ of current CO_2 emissions

+ Goal: change climate policy discussion

- From near-term to long-term
- From incremental to transformational
- From vague commitments to transparent plans

+ Research mirrors new policy architecture

- Reflects national conditions, development goals
- Each team determines own methods
- Bottom-up/hybrid modeling w sectoral detail


SCIENCE

A Path for Climate Change, Beyond Paris

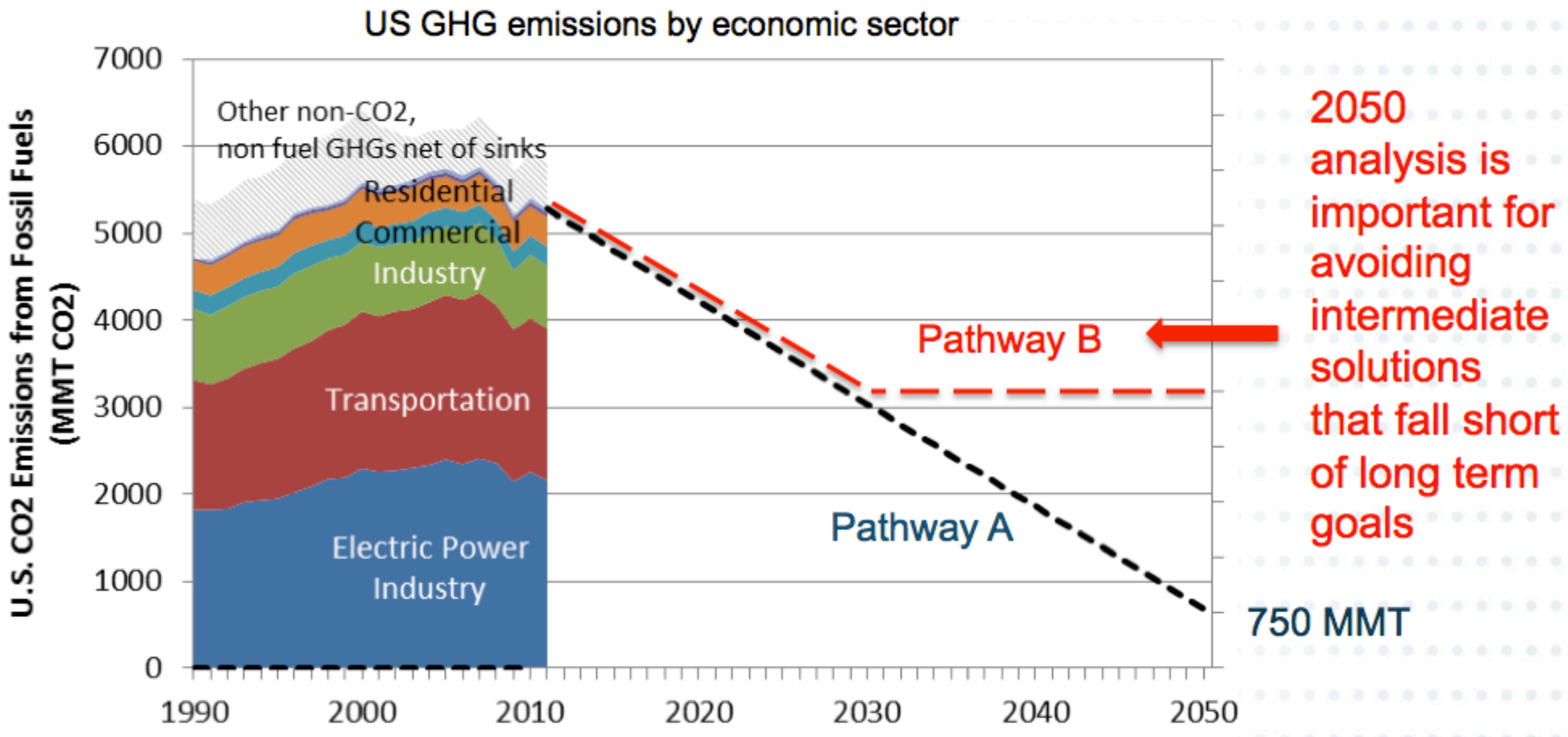
By JUSTIN GILLIS DEC. 1, 2015


UN issued with roadmap on how to avoid climate catastrophe

Report is the first of its kind to prescribe concrete actions that biggest 15 economies must take to keep warming below 2C

Paris Agreement, Article 4, Paragraph 19
"All Parties should strive to formulate and communicate long-term low greenhouse gas emission development strategies…"

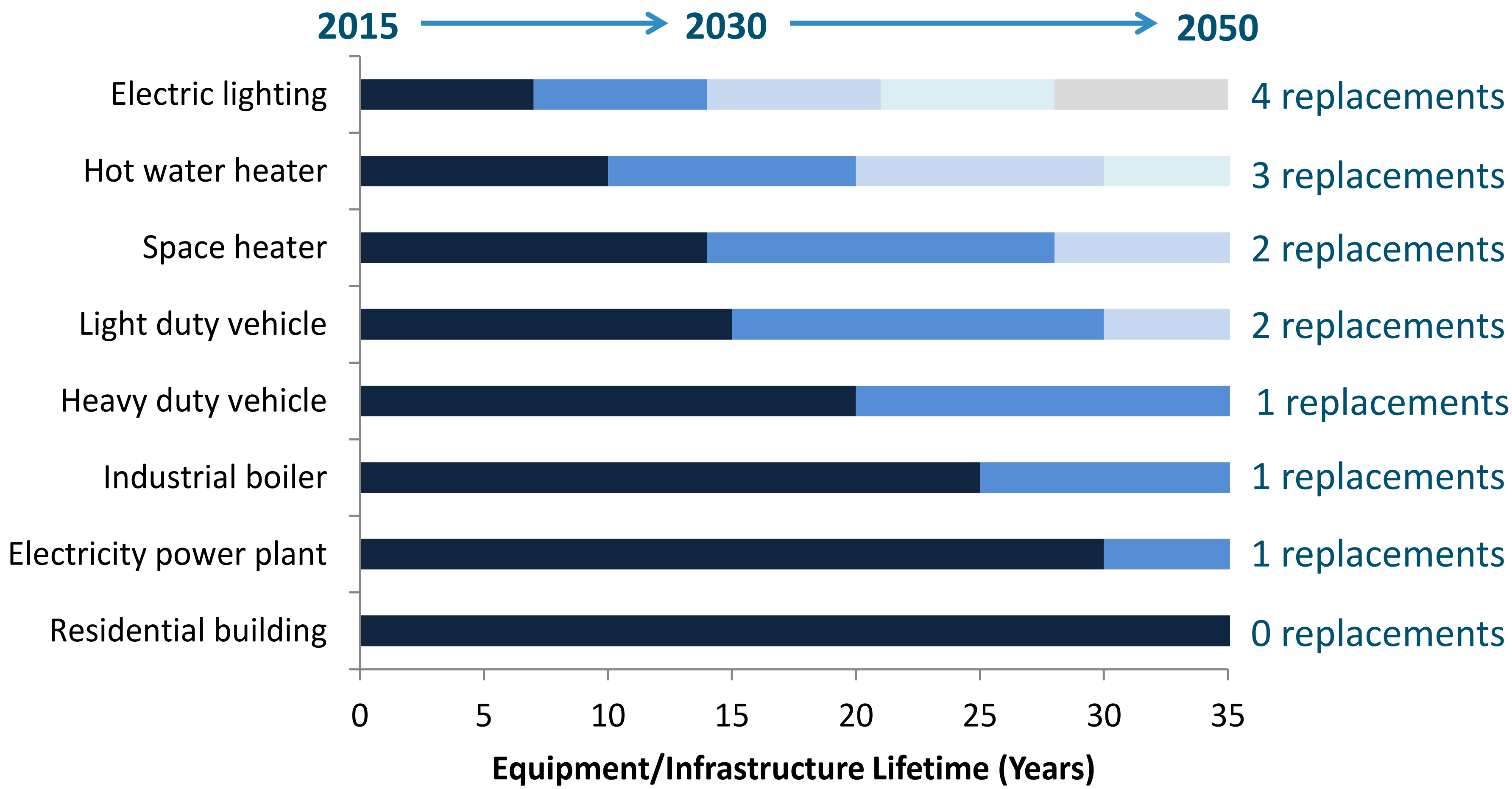
Why Long-Term Strategies? Avoiding Emissions Dead Ends



How to assess NDCs in the absence of a sectorally explicit mid-century strategy?

Long Equipment Lifetimes on Supply and Demand Side of Energy System

- A car purchased today is likely to replaced at most 2 times before 2050.
  A residential building constructed today is likely to still be standing in 2050.



Anticipating forks-in-the-road: Real examples from California

1. Electric vs. Fuel Cell Vehicles

Zero Emissions Vehicles

Electric vehicles

Electric charging infrastructure

Fuel cell vehicles

H2 fuel production: grid electrolysis

2. Electrification vs. Low Carbon Gas in Buildings

Building strategy

Biogas and low-carbon synthetic methane

No building electrification, biogas in pipeline

Electric heat pumps, electrification

Building electrification, no gas pipeline

US Pathways

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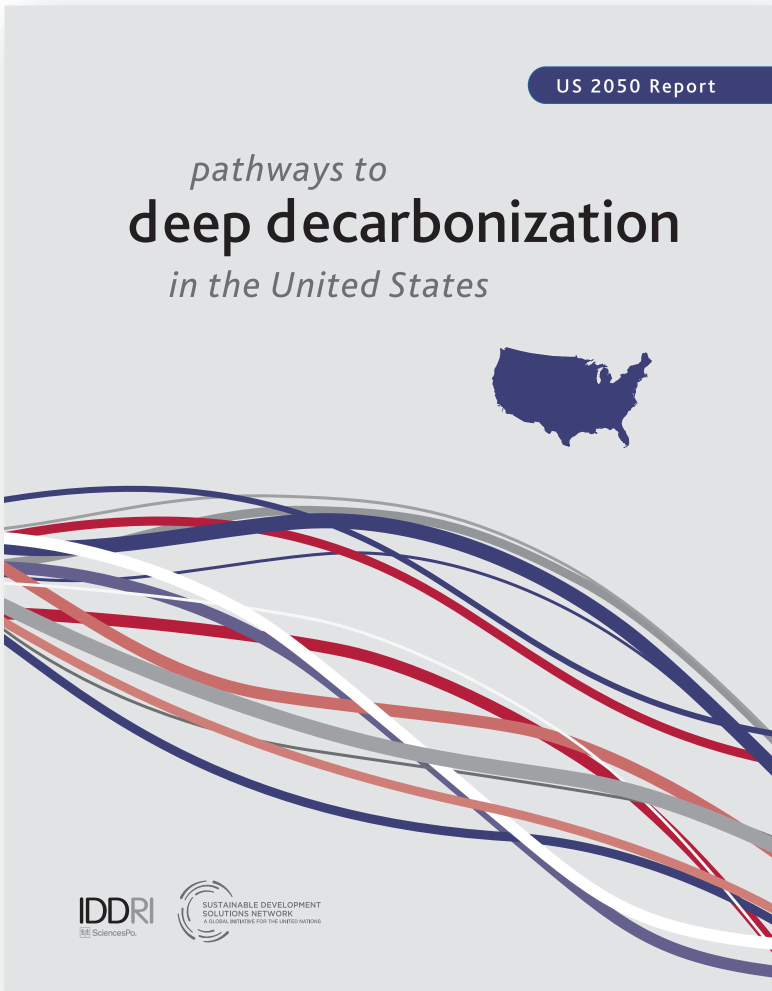
U.S. Pathways Analysis



E3, UC, LBNL, PNNL team

Technical Report, Nov. 2014

What would it take for US to achieve 80% GHG reduction below 1990 level by 2050?

- ***Is it technically feasible?***
- ***What would it cost?***
- ***What physical changes are required?***

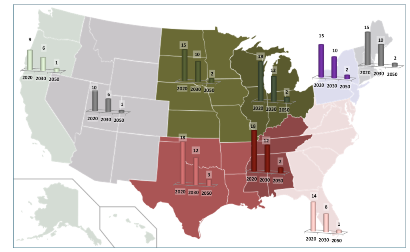
Policy Report, Nov. 2015

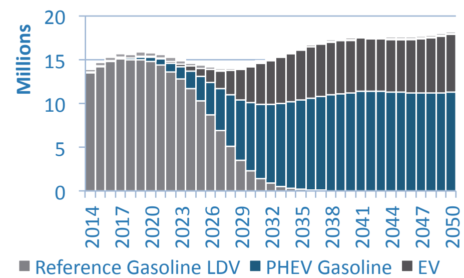
- ***What are the policy implications for the US?***

Reports available at http://usddpp.org

PATHWAYS Used to Model Energy System

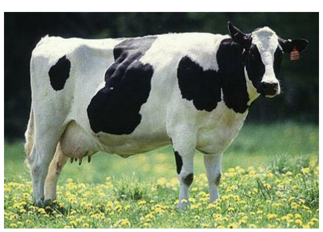
- Energy system model, user-defined scenarios
- 80 demand sectors, 20 supply sectors
- Annual rollover of equipment stock by vintage
- Mimics NEMS architecture
- 9 US census divisions separately modeled
- Hourly electricity dispatch

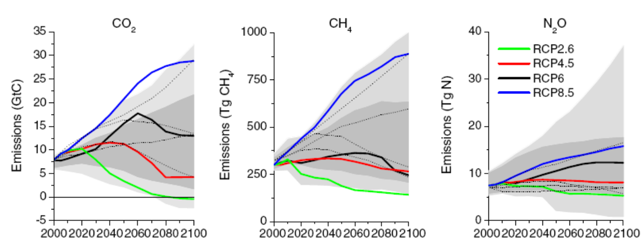


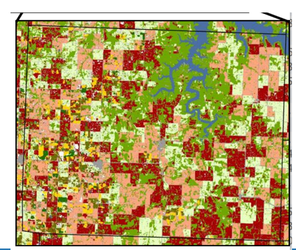


GCAM Used to Model Non-Energy/Non-CO_2 GHGs

- Non-energy and non-CO2 GHG mitigation
- Biomass production and indirect land use change emissions
- Sensitivity to terrestrial carbon sink assumptions







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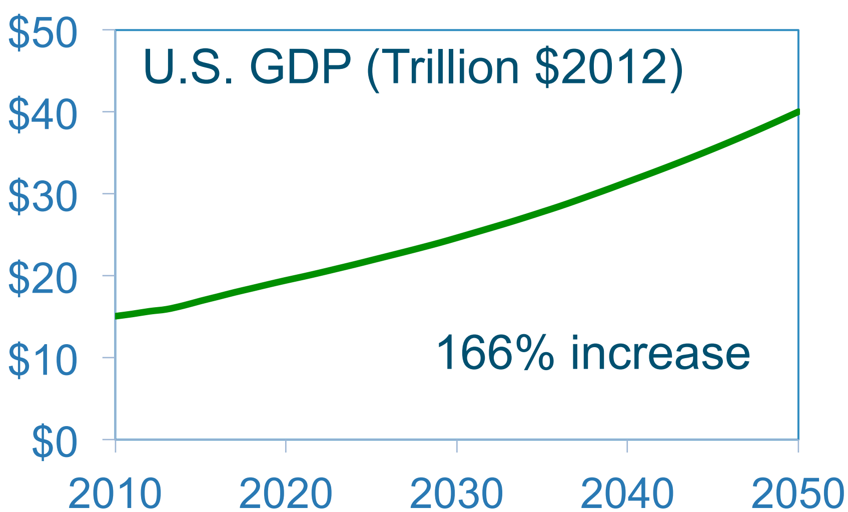
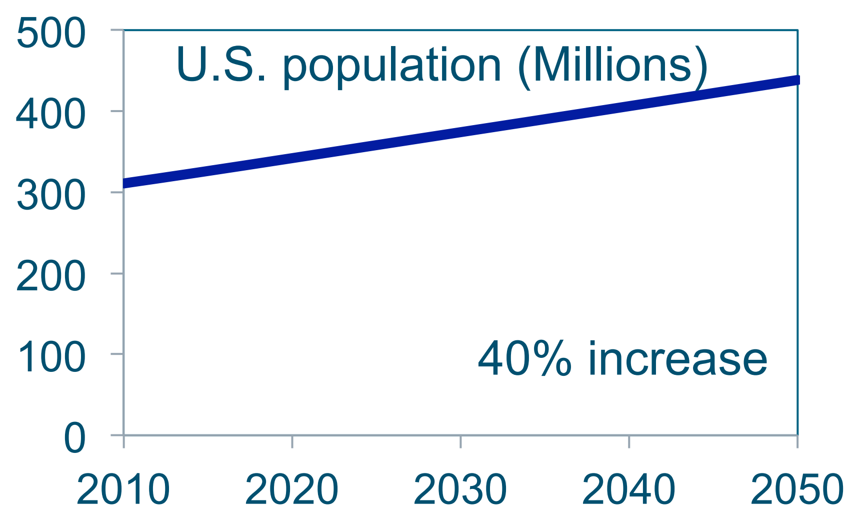
Scenario Design Constraints

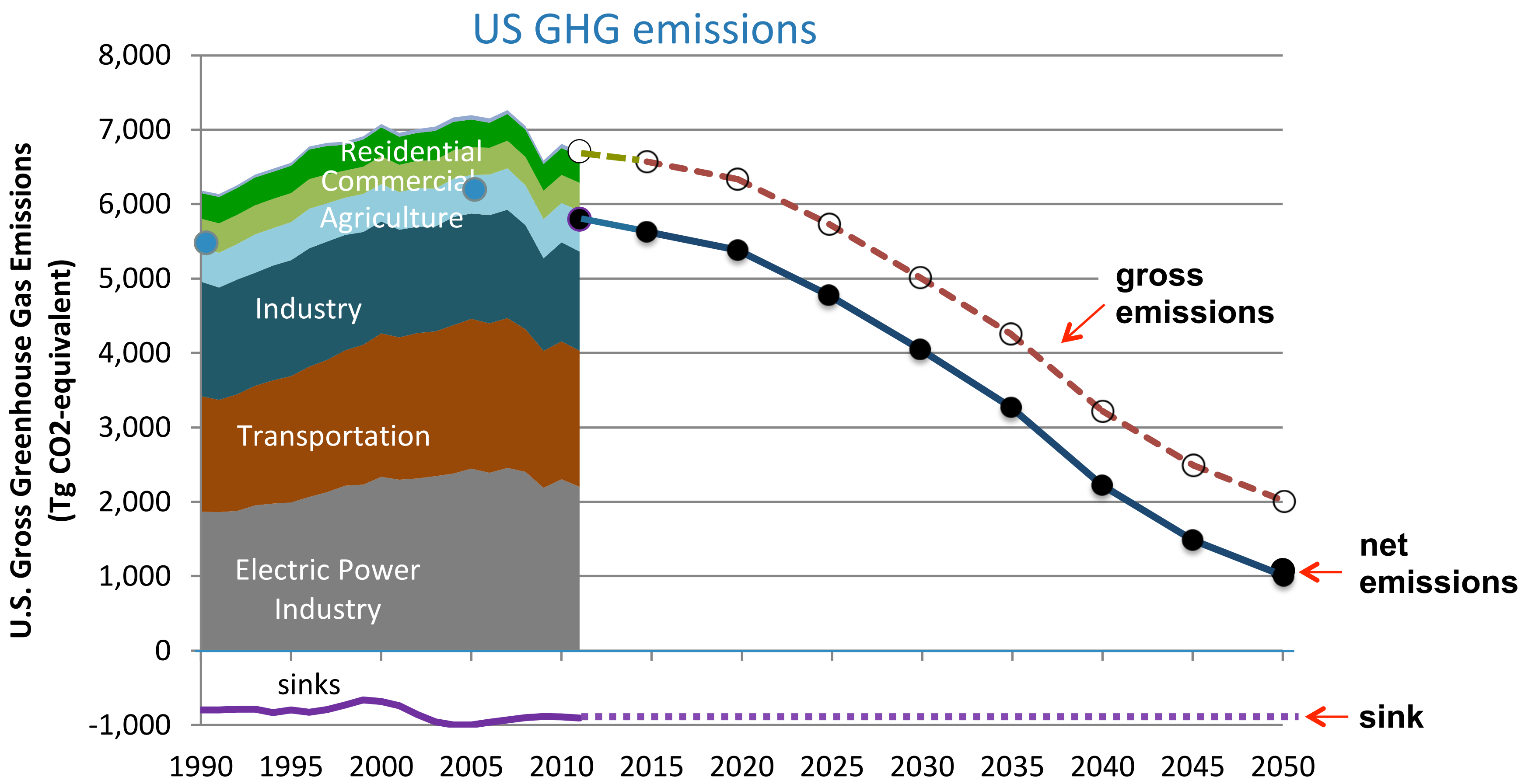
- Infrastructure inertia
- Electric reliability
- Same energy services as EIA forecast
- Technology is commercial or near-commercial
- Environmental limits (biomass, hydro)



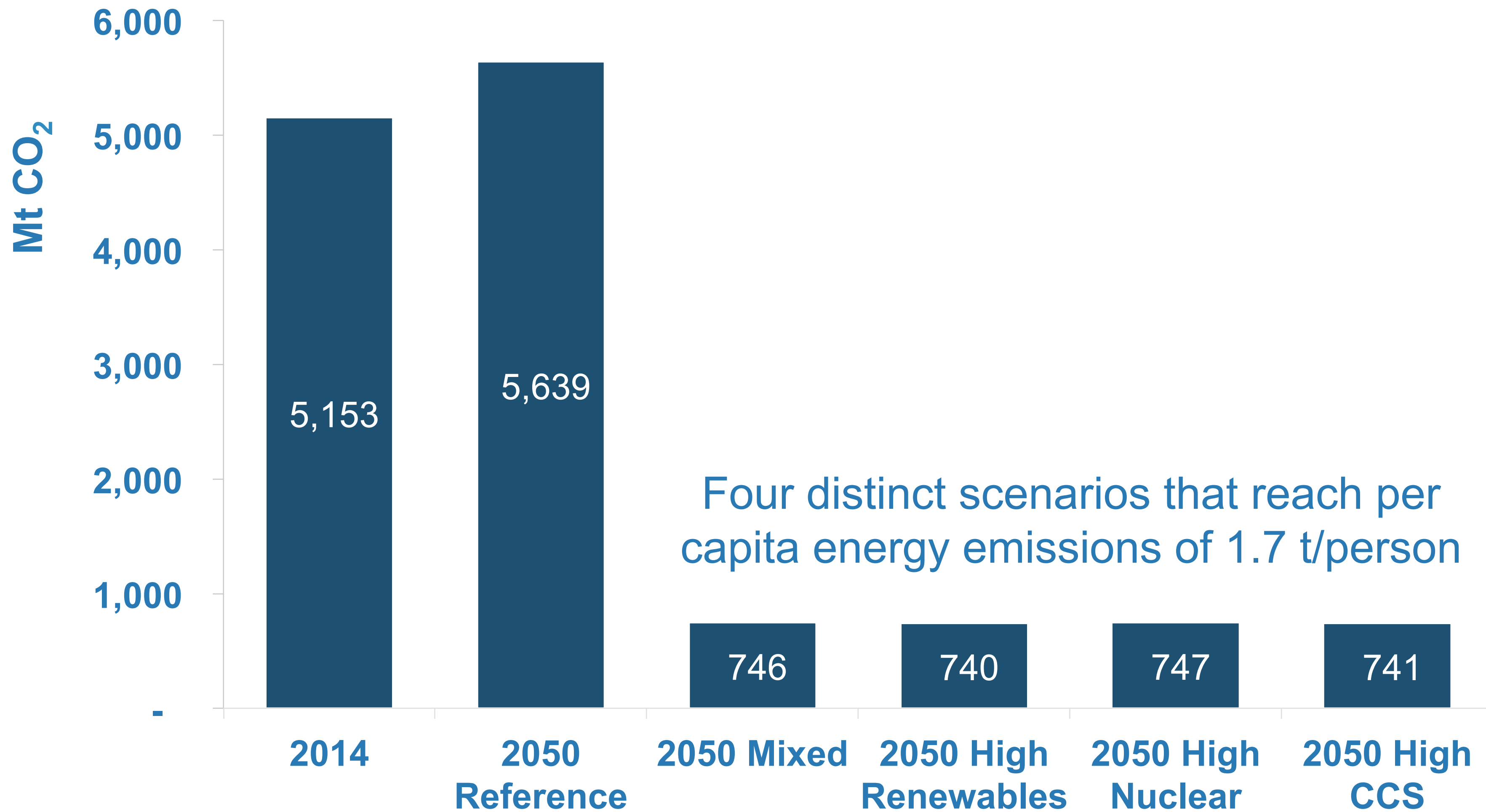


U.S. National Energy Modeling System and 2013 Annual Energy Outlook reference case

80% Reduction in CO_2e by 2050 is Achievable

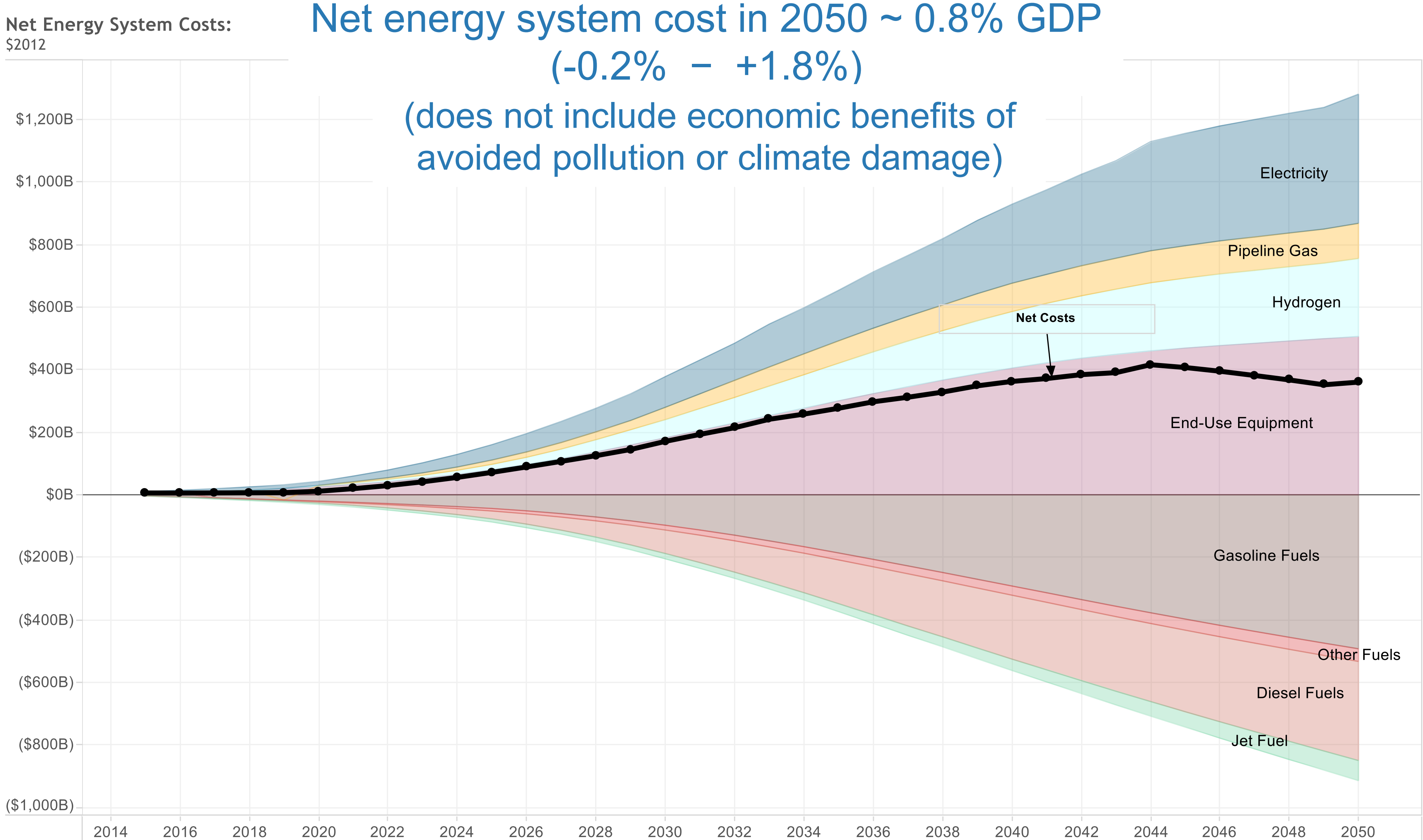


Multiple Feasible Technology Pathways Exist



Deep Decarbonization Cost is Affordable

Net energy system cost in 2050 ~ 0.8% GDP
(-0.2% − +1.8%)
(does not include economic benefits of avoided pollution or climate damage)



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U.S. Results Summarized: Three Seeming Paradoxes

- Deeply decarbonized energy system
  - big change in physical energy system
  - little change in energy services
- Deeply decarbonized energy economy
  - big change in energy economy
  - little change in consumer cost
- Deeply decarbonized macro-economy
  - small net cost relative to GDP
  - significant benefits for macro-economy

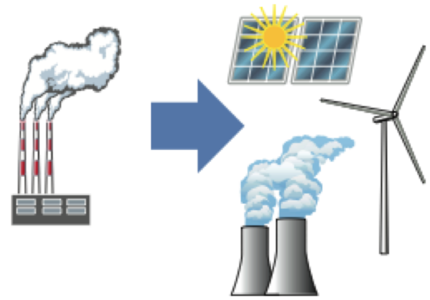
Lessons for Energy System Transition

Three Pillars of Deep Decarbonization Required in All Cases

Strategy

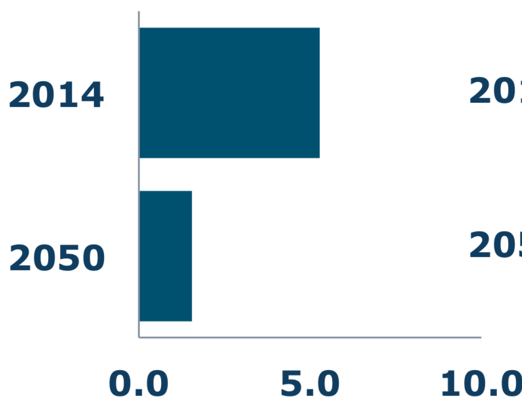
Energy Efficiency

Decarbonization of Electricity

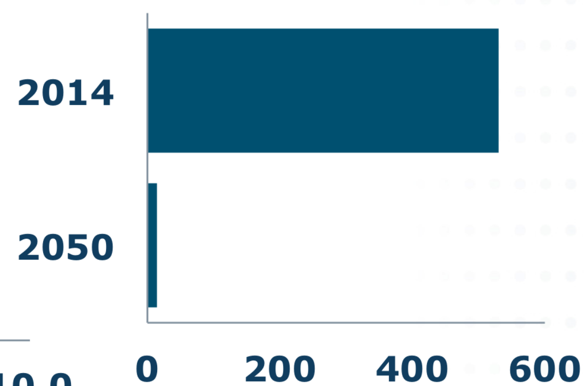


End Use Fuel Switching to Electric Sources

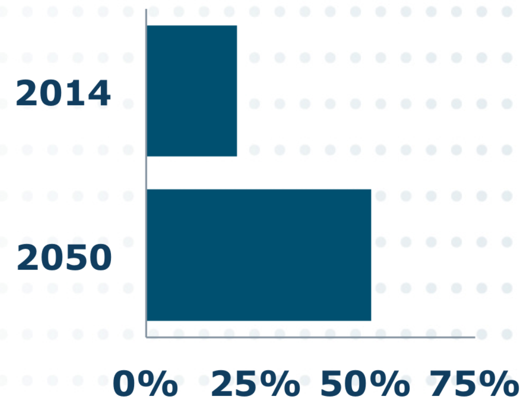
Key Metric of Transformation



Energy Intensity of GDP (MJ/$2005)



Electricity Emissions Intensity (gCO2/kWh)



Share of Electricity and Electric Fuels in Total Final Energy (%)

Pathways to Deep Decarbonization in the United States, Mixed case results

Interactions Among the 3 Pillars: LDV Transition Example

Energy service demand (AEO)

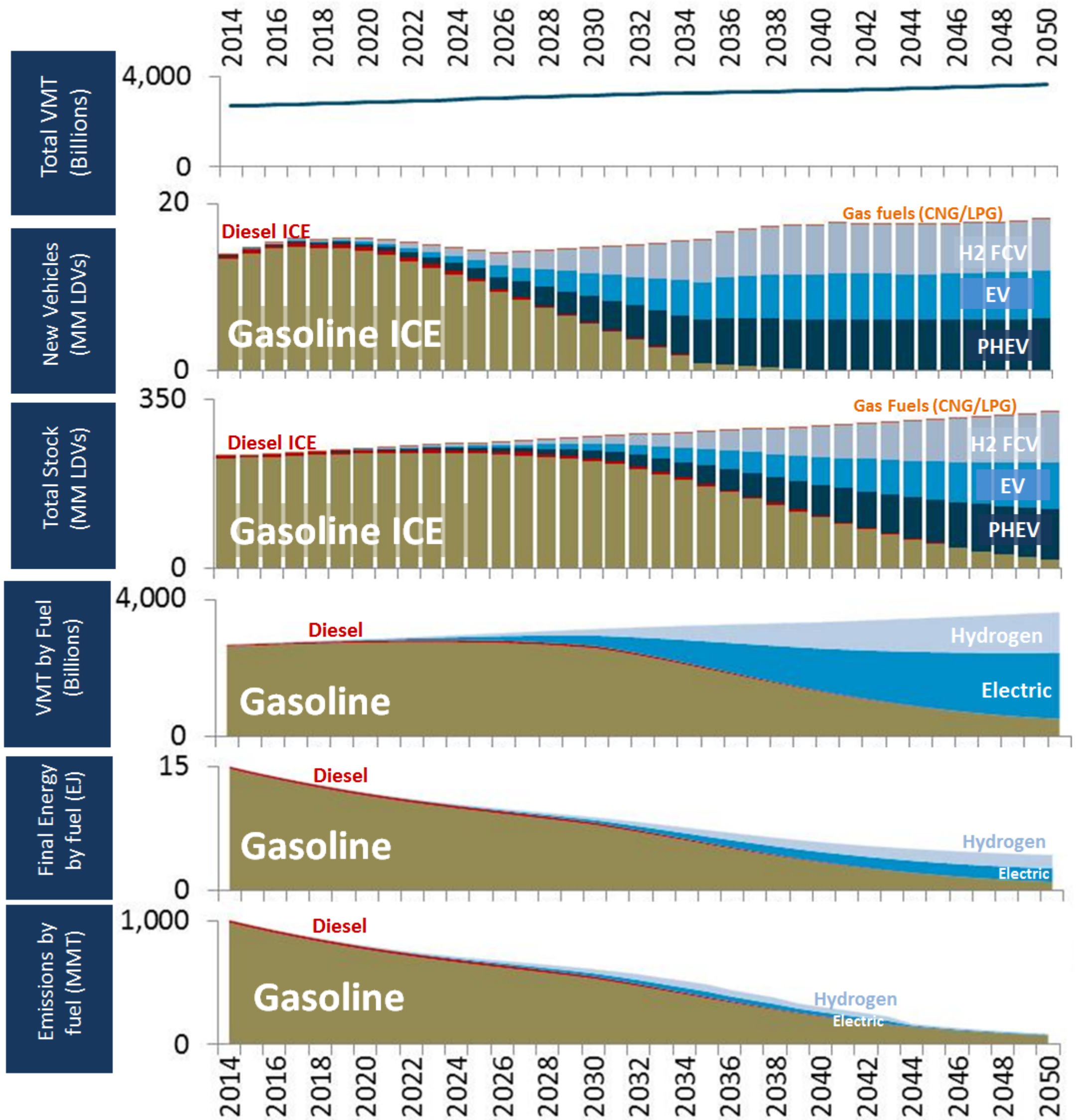
Annual LDV sales

LDV stocks by type

VMT by fuel type

LDV final energy by fuel type

GHG emissions by fuel type



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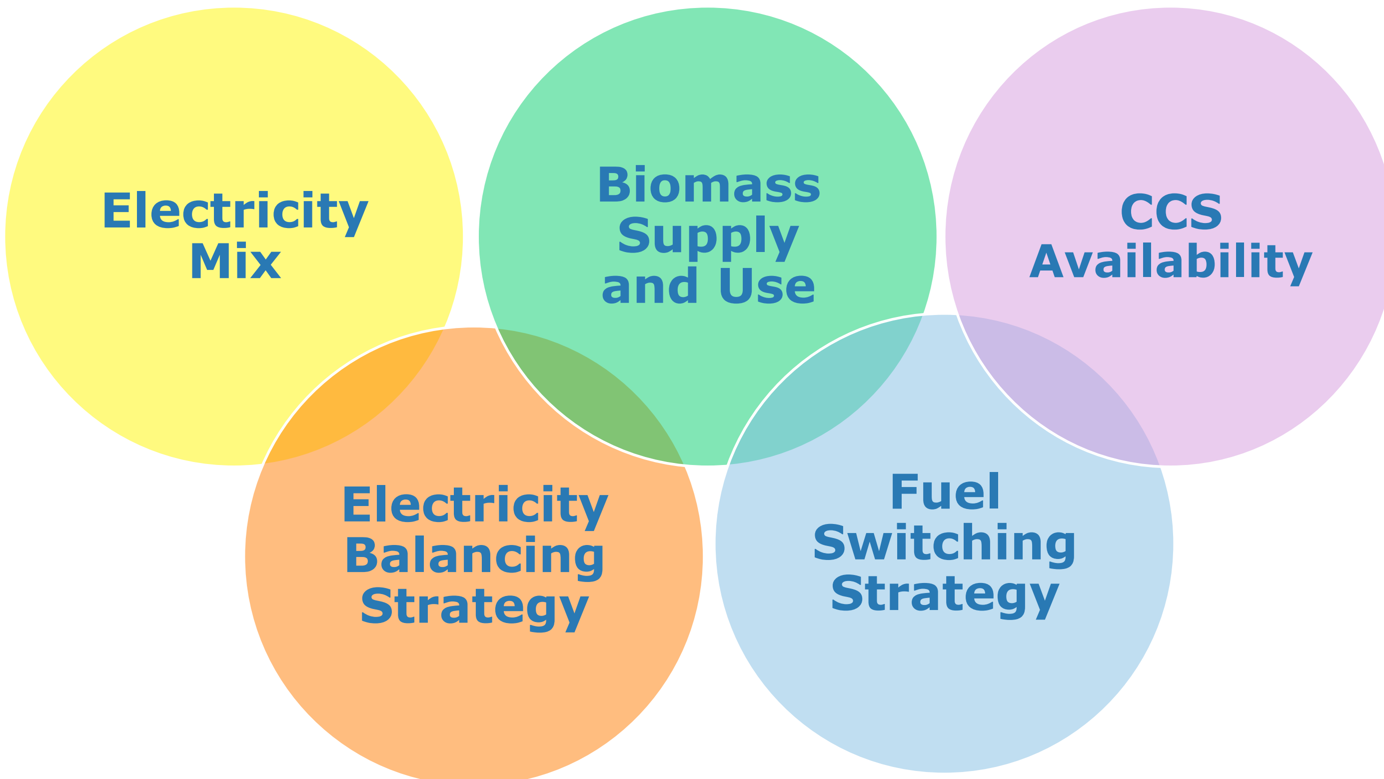
Sectoral Metrics: 2050 Benchmarks for US

Sector	Current Energy System	Deep Decarbonized Energy System	Key Metrics in 2050
Electricity	Coal and natural gas dominated	Renewable, nuclear, or CCS	Double output while reducing CO_2/kWh 30x
Transportation	Oil dominated	Electricity, hydrogen, CNG, LNG, biodiesel	Fuel economy >100 mpg equivalent
Buildings	Natural gas and oil dominate heating	Electrification, end use efficiency	Building energy use >90% electrified
Industry	Fossil fuel dominated	Electrification, CCS, efficiency, low C fuels	Double efficiency, >40% electrification

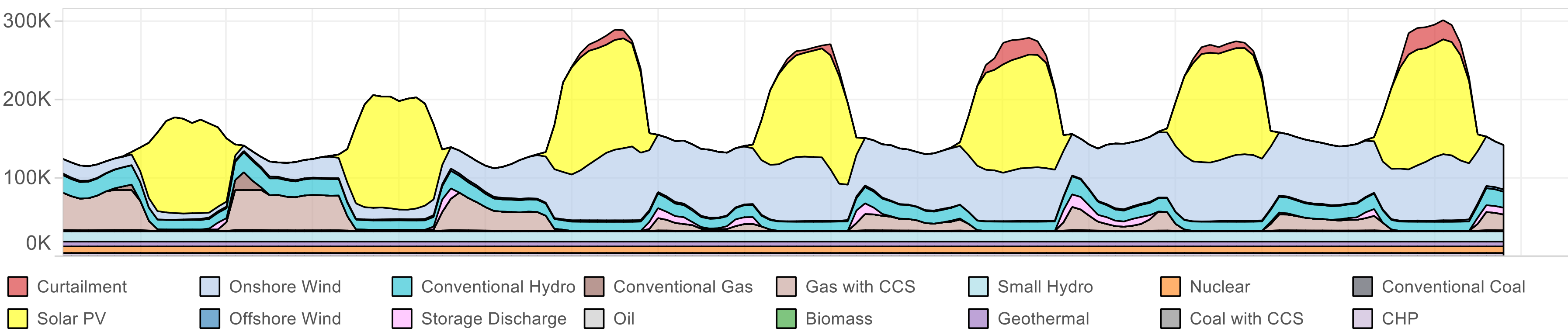
Five Interacting Elements of Deeply Decarbonized Energy Systems



Hourly Electricity Supply & Demand in WECC, High Renewables Case, Week in March 2050

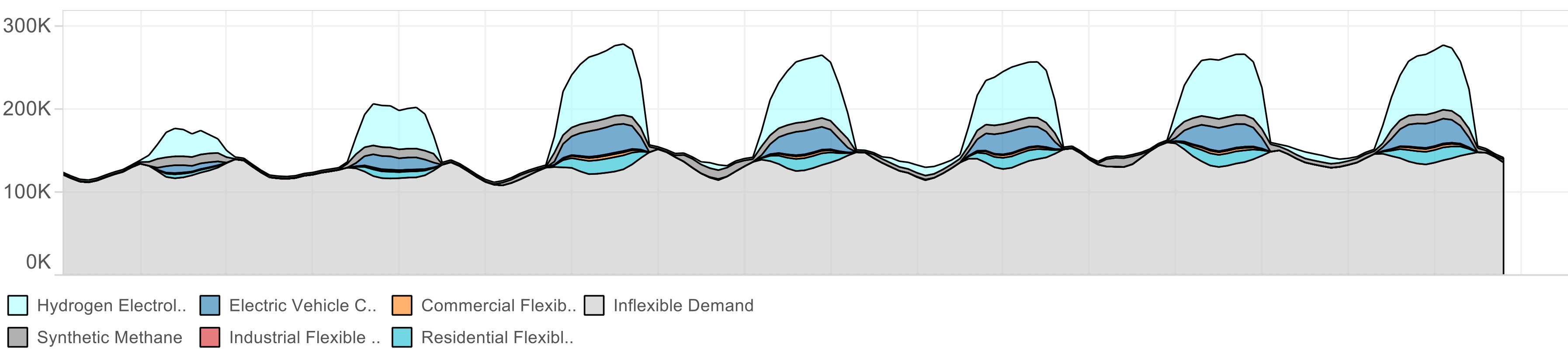
WECC Electricity Generation 3/2/2050 - 3/8/2050:

MWh



WECC Electricity Load 3/2/2050 - 3/8/2050:

MWh



Transformational Perspective Challenges
Some Common Assumptions

Common Assumption	US Pathways Finding
EE is main demand-side strategy	Fuel switching is key demand strategy
Electric gen low growth due to EE	Electric gen ~2x due to electrification
Biomass used for ethanol in LDVs	Biomass used for pipeline gas /HDVs
Hydrogen is costly fuel	Hydrogen is balancing resource + fuel
Storage is key to RE intermittency	Storage has limited role in integration
Coal to NG is key gen transition	NG gen GHGs too high for later years
NG power plants will be stranded	NG plants valuable at low utilization
$/ton is key cost metric	Net system cost is key cost metric

Non-US Pathways

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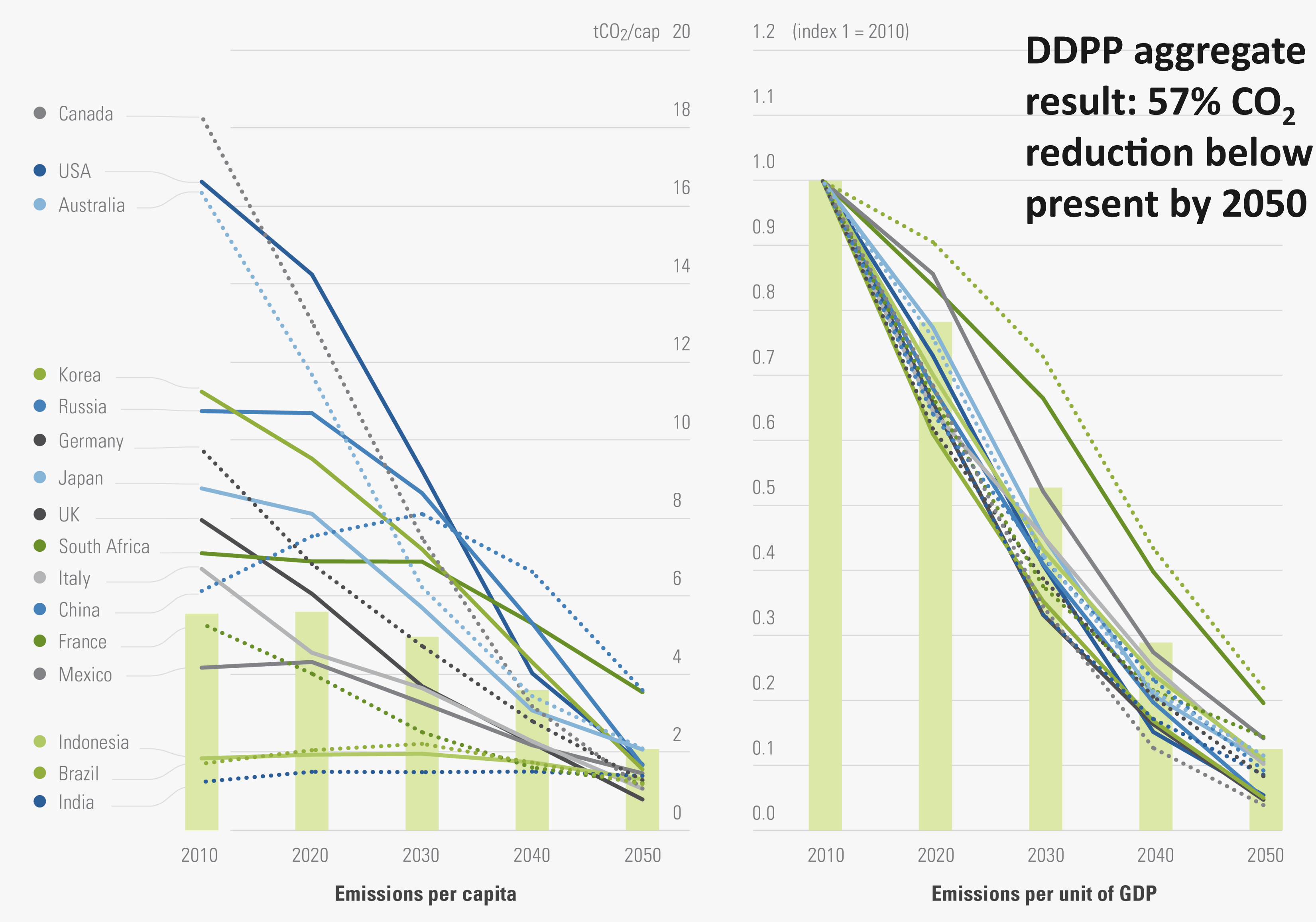
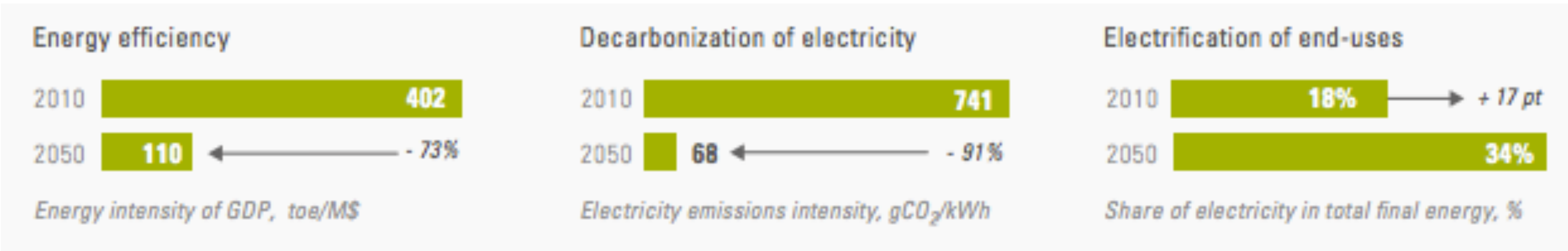
DDPP High Level Results: Aggregate, Per Capita, and Per $GDP CO_2 Emissions



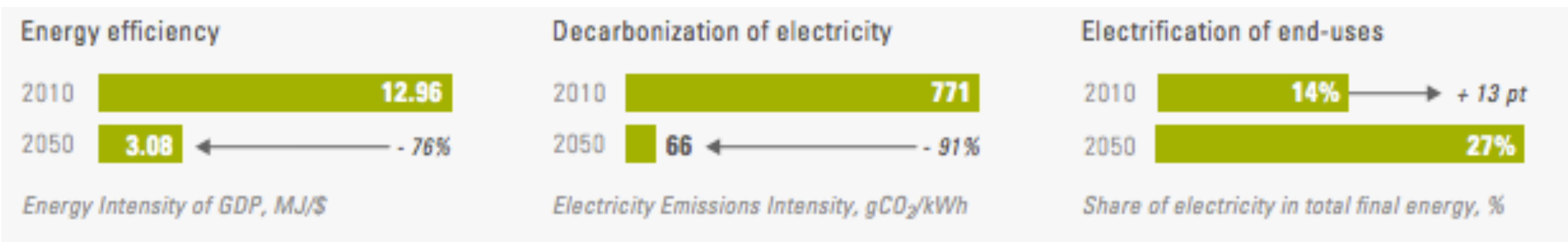
DDPP aggregate result: 57% CO_2 reduction below present by 2050

Three Pillars Results for China, India, UK

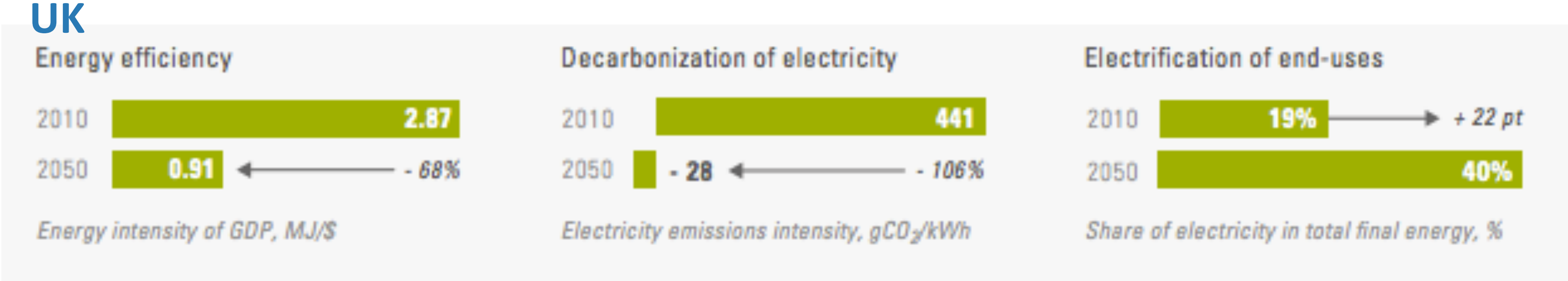
China



India



UK



China Example: Infrastructure Inertia

Figure 10. Variation of CO_2 intensity of electricity over time, by type

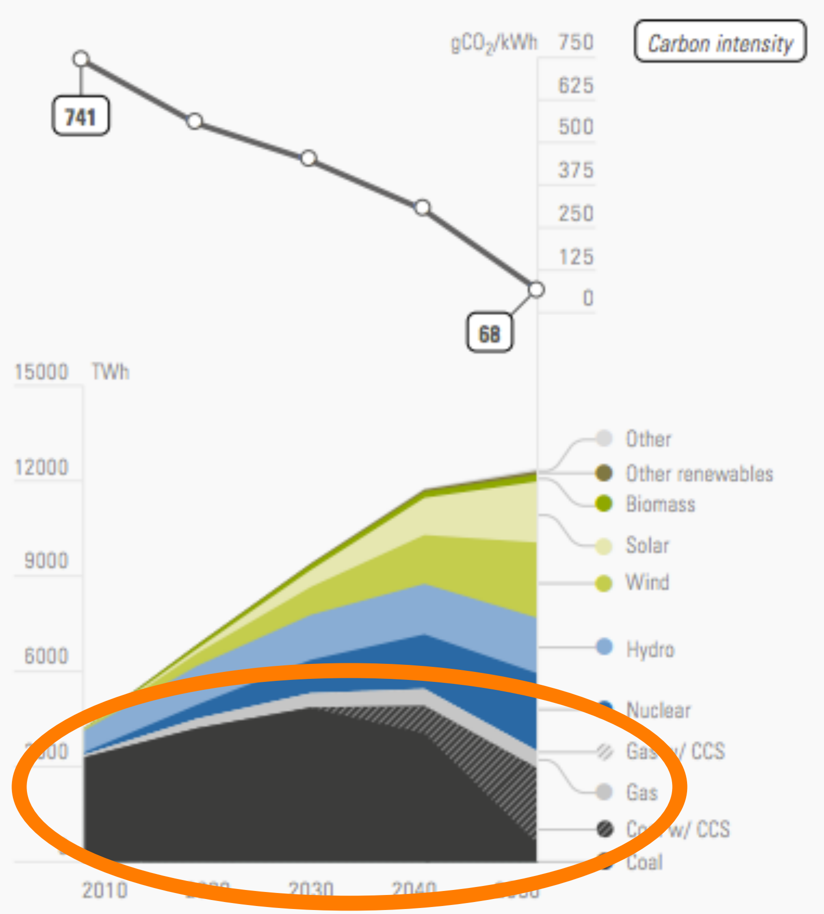
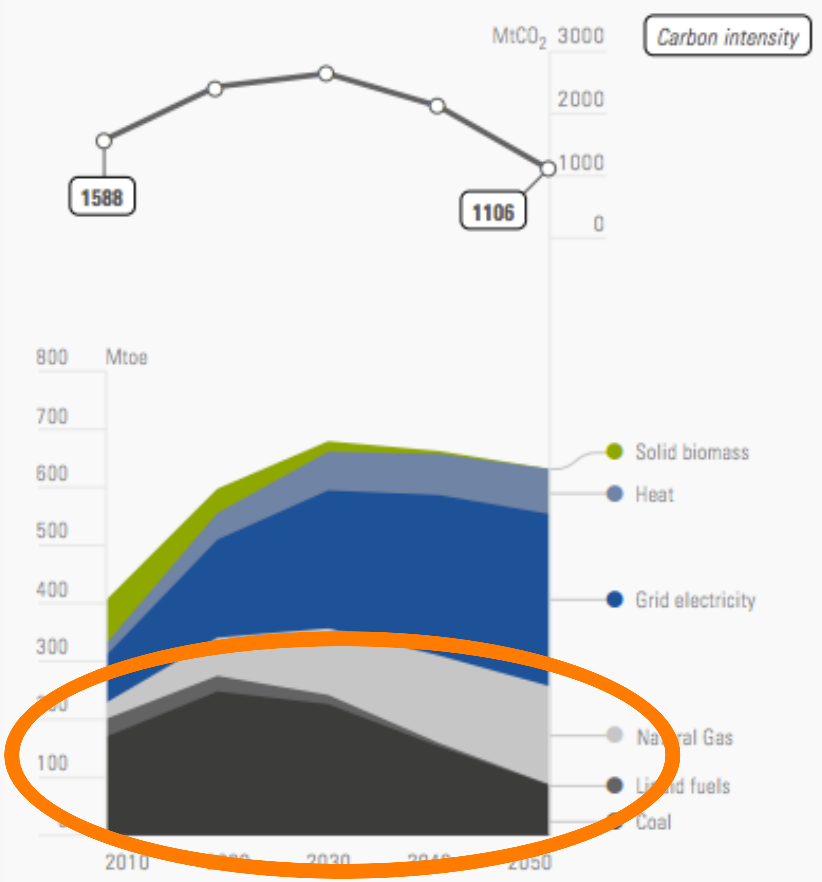
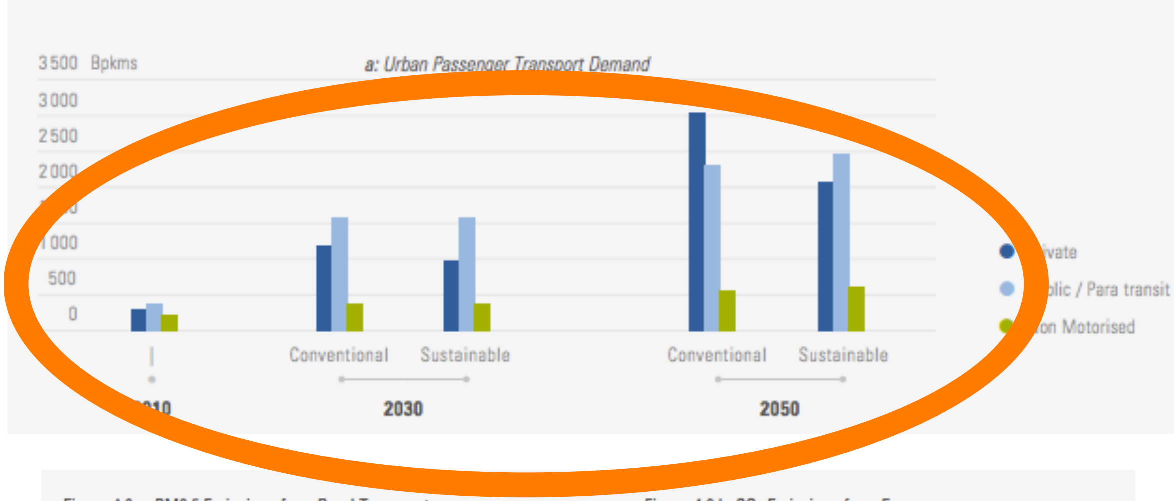


Figure 13. Final energy consumption by fuel for building sector



India Example: Energy Access

Figure 4.2: Passenger Transport Demand



4.5 b: Investments in Electricity Generation

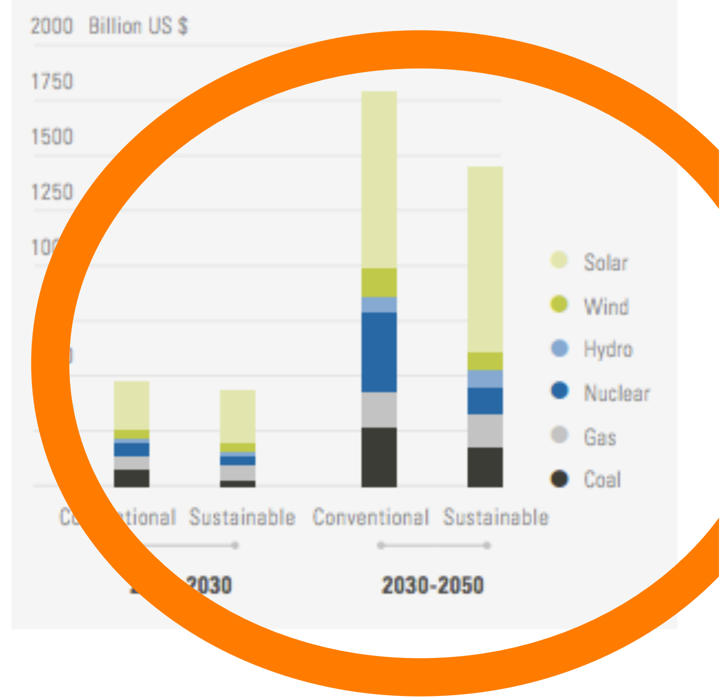
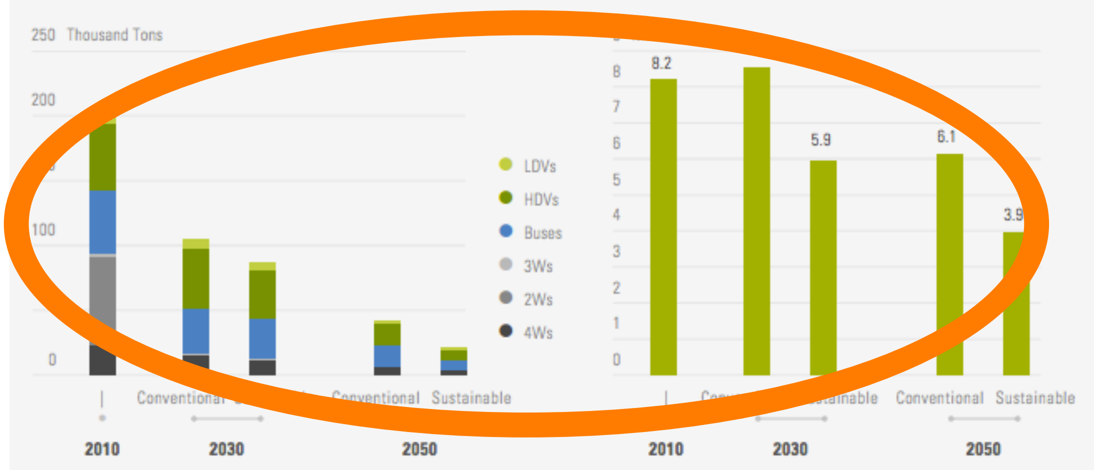


Figure 4.6 a: PM2.5 Emissions from Road Transport

Figure 4.6 b: SO_2 Emissions from Energy



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DDPP Aggregate Clean Technology Market Potential and Its Effect on Costs

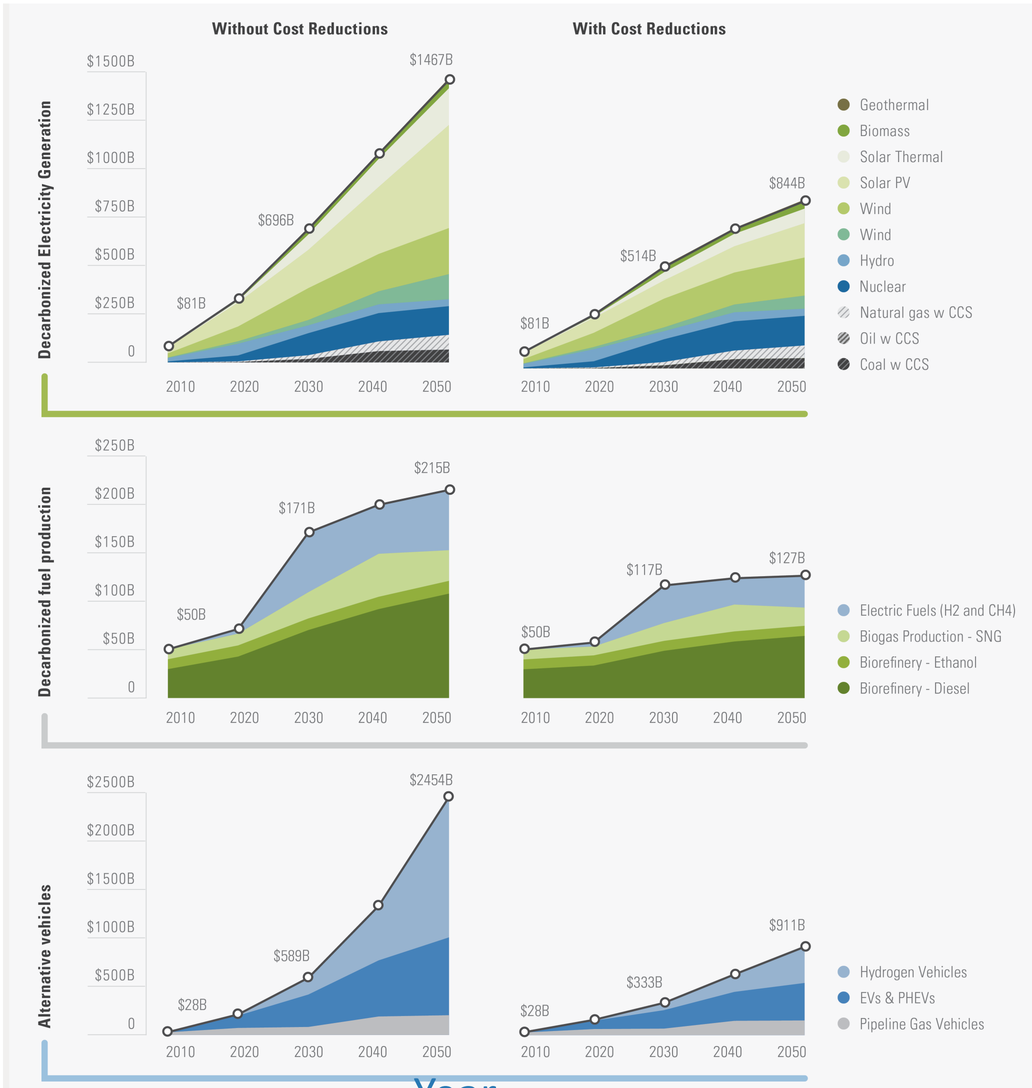
Go-It-Alone

Global Markets

Decarbonized Electricity Generation

Decarbonized Fuel Production

Alternative Vehicles



Vertical axis: cost in $B

Year

Deep decarbonization, global markets, and developing countries

- Low carbon infrastructure build-out is key to the extent and timing of emissions reductions
- Affordability is key to developing country build-out of low carbon infrastructure
- Large global markets to bring down costs is key to affordability
- High-income countries leading on low carbon technology is key to global market development
- Low-income country share in low carbon technology markets is key to sustainable development

Policy Challenges of Deep Decarbonization: A Research Agenda

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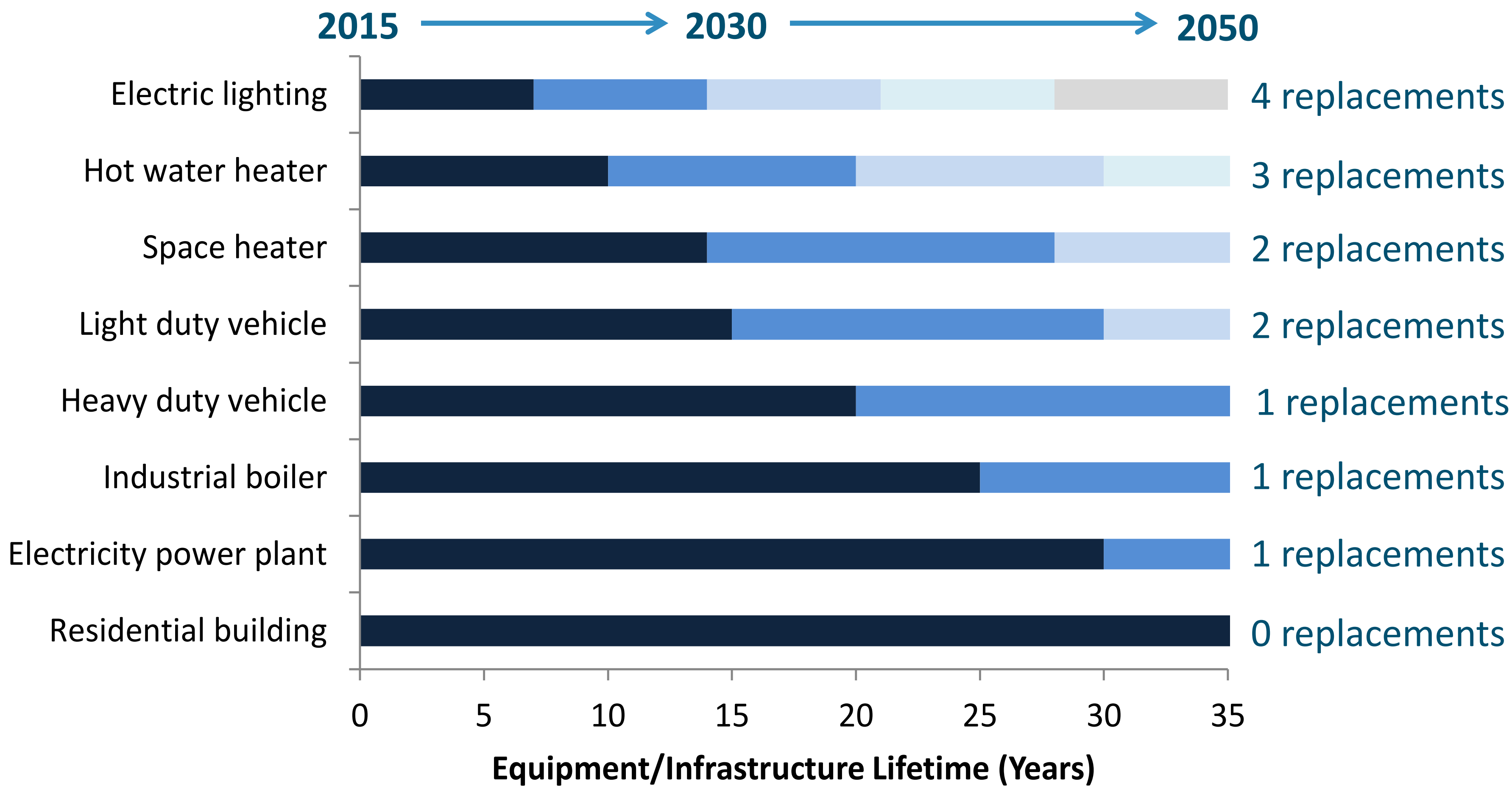
The Policy Landscape

- Energy markets are fragmented and imperfect
- “Energy policy” is divided across national, state, and local jurisdictions
- Energy systems have strong regional identities
- Sector characteristics determine the suitability of policy instruments
- Carbon price alone is not enough, need to think through sector by sector, policy by policy
- Policy research must start with question “what does policy need to accomplish?”

How to incorporate future carbon consequences in current purchasing decisions?

- A car purchased today is likely to replaced at most 2 times before 2050. A residential building constructed today is likely to still be standing in 2050.



How to coordinate across sectors when the institutions don't currently exist?

1. Electric vs. Fuel Cell Vehicles

Zero Emissions Vehicles

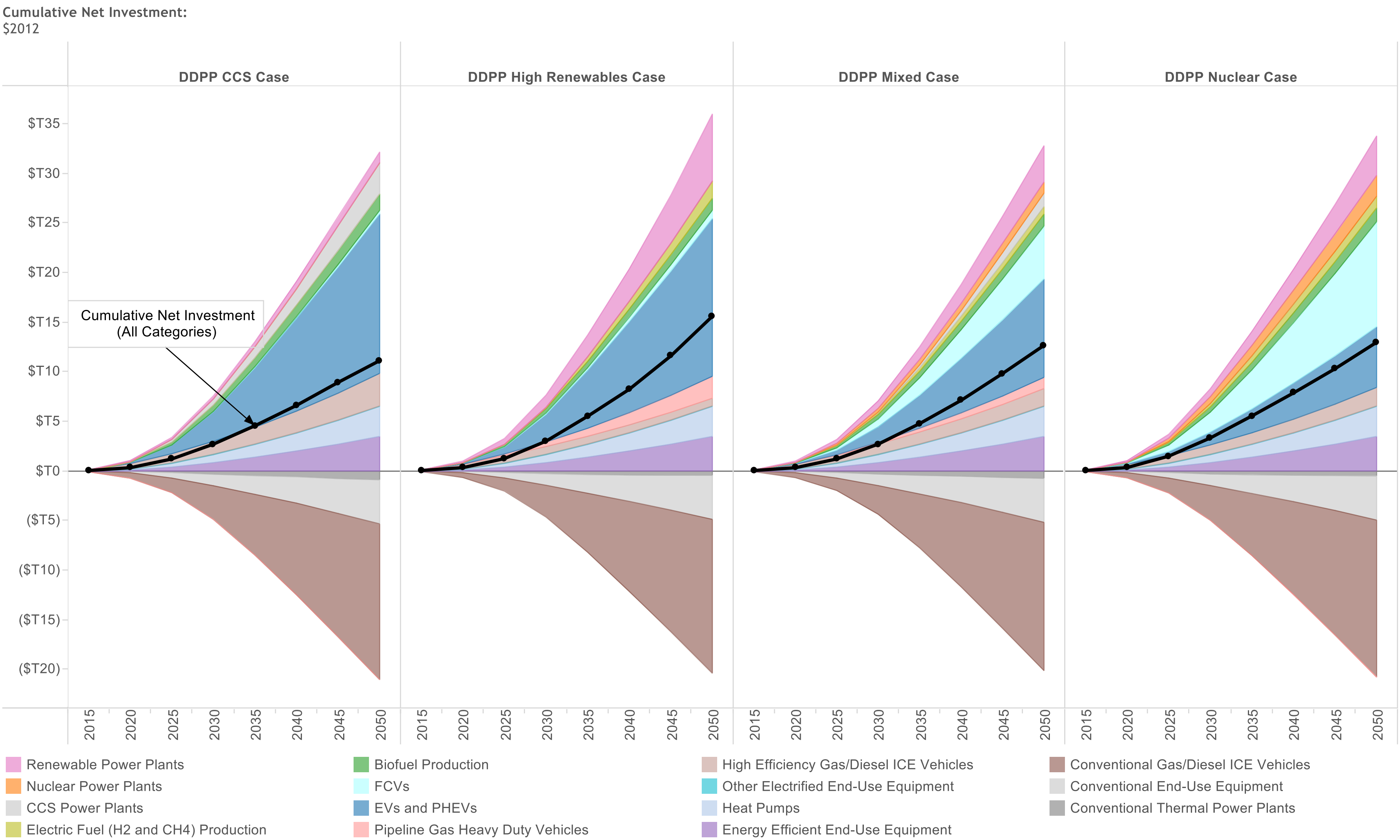
- Electric vehicles — Electric charging infrastructure
- Fuel cell vehicles — H2 fuel production: grid electrolysis

2. Electrification vs. Low Carbon Gas in Buildings

Building strategy

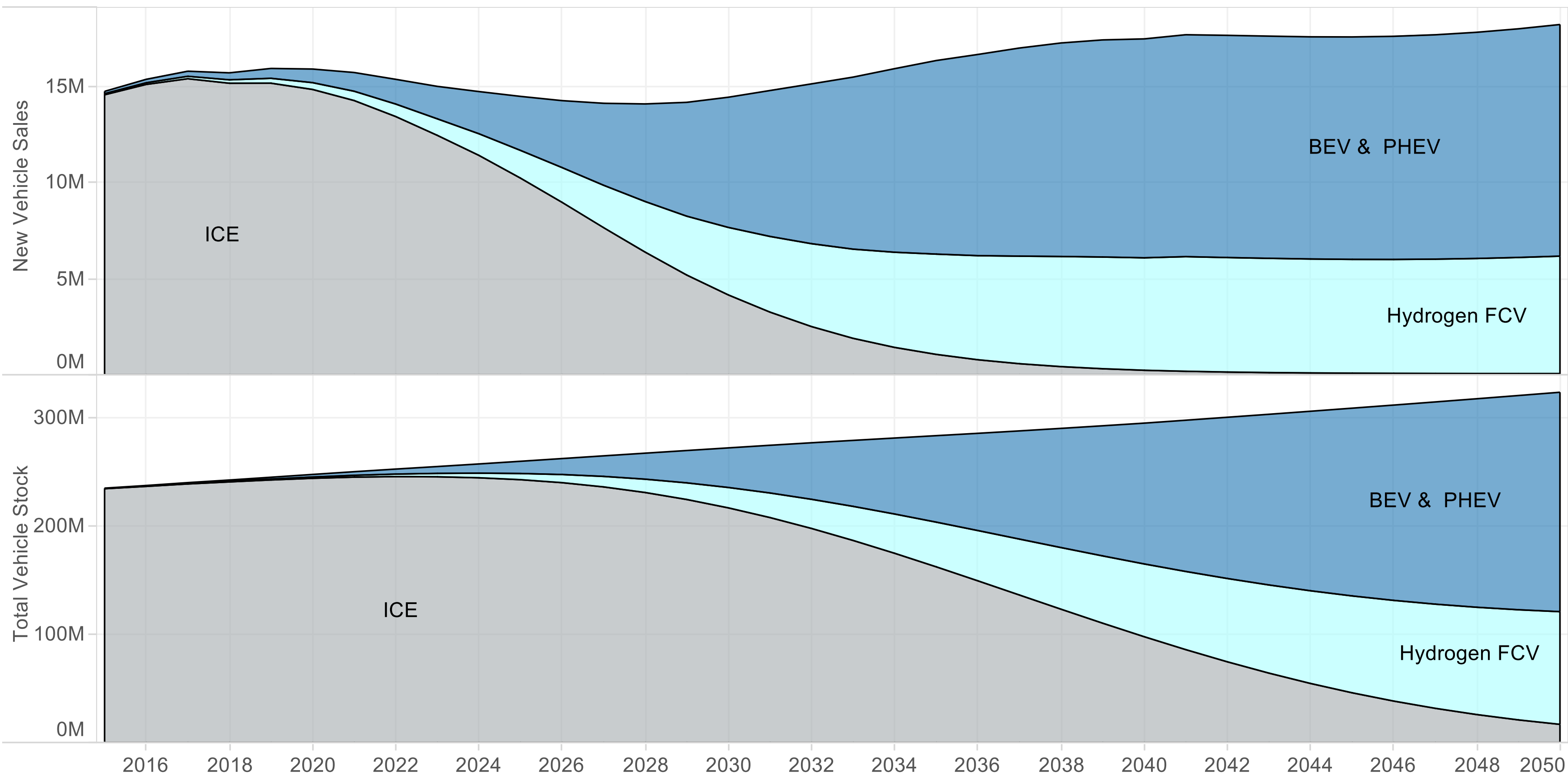
- Biogas and low-carbon synthetic methane — No building electrification, biogas in pipeline
- Electric heat pumps, electrification — Building electrification, no gas pipeline

How to drive investment flows into low carbon equipment and infrastructure?



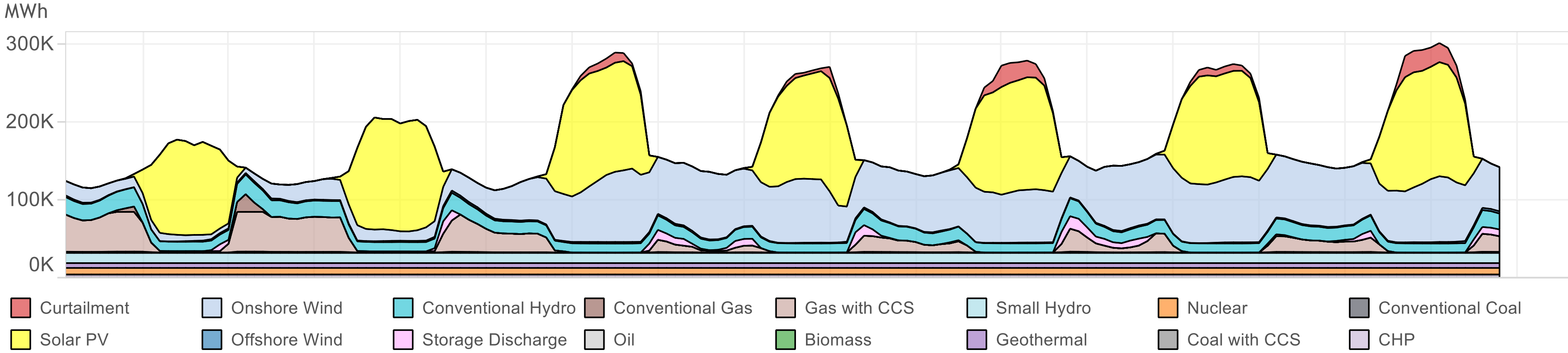
How to drive rapid consumer adoption?

Light-Duty Vehicle Adoption:
vehicles

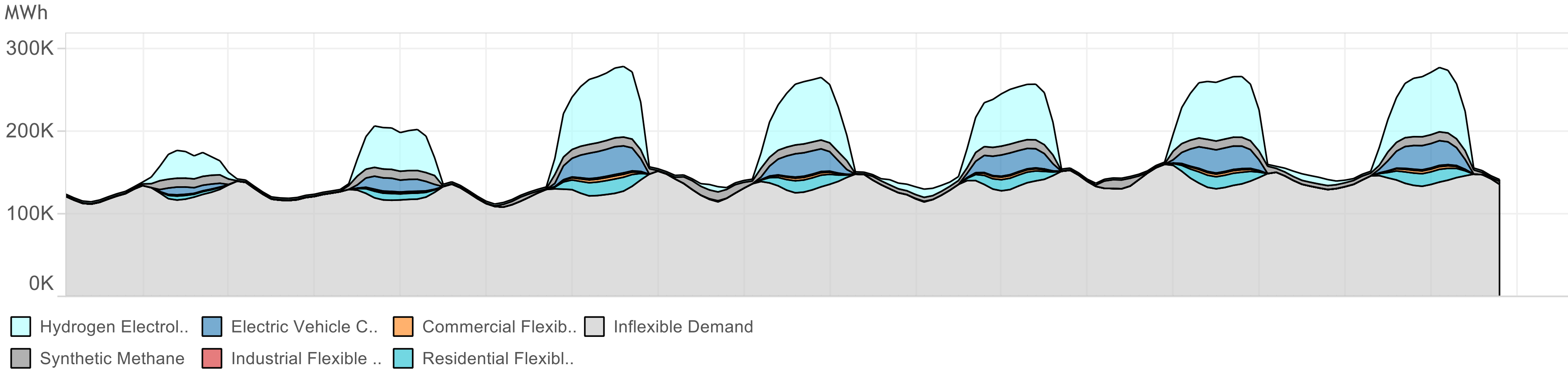


How to reform wholesale electricity markets?

WECC Electricity Generation 3/2/2050 - 3/8/2050:

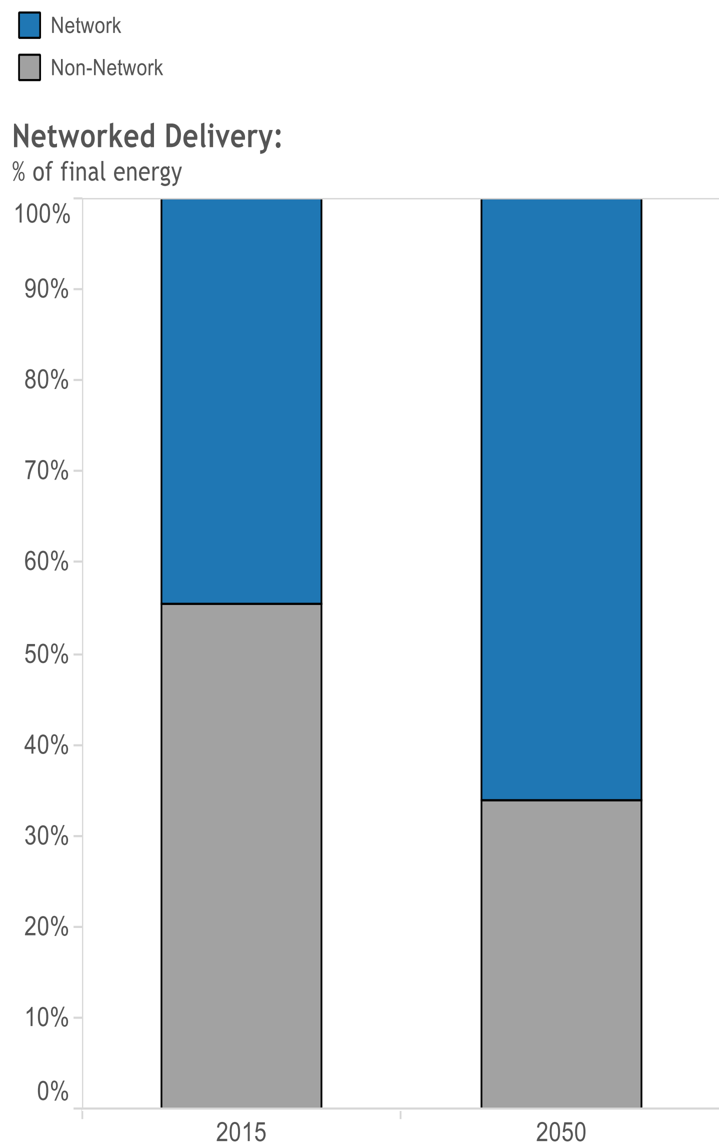


WECC Electricity Load 3/2/2050 - 3/8/2050:

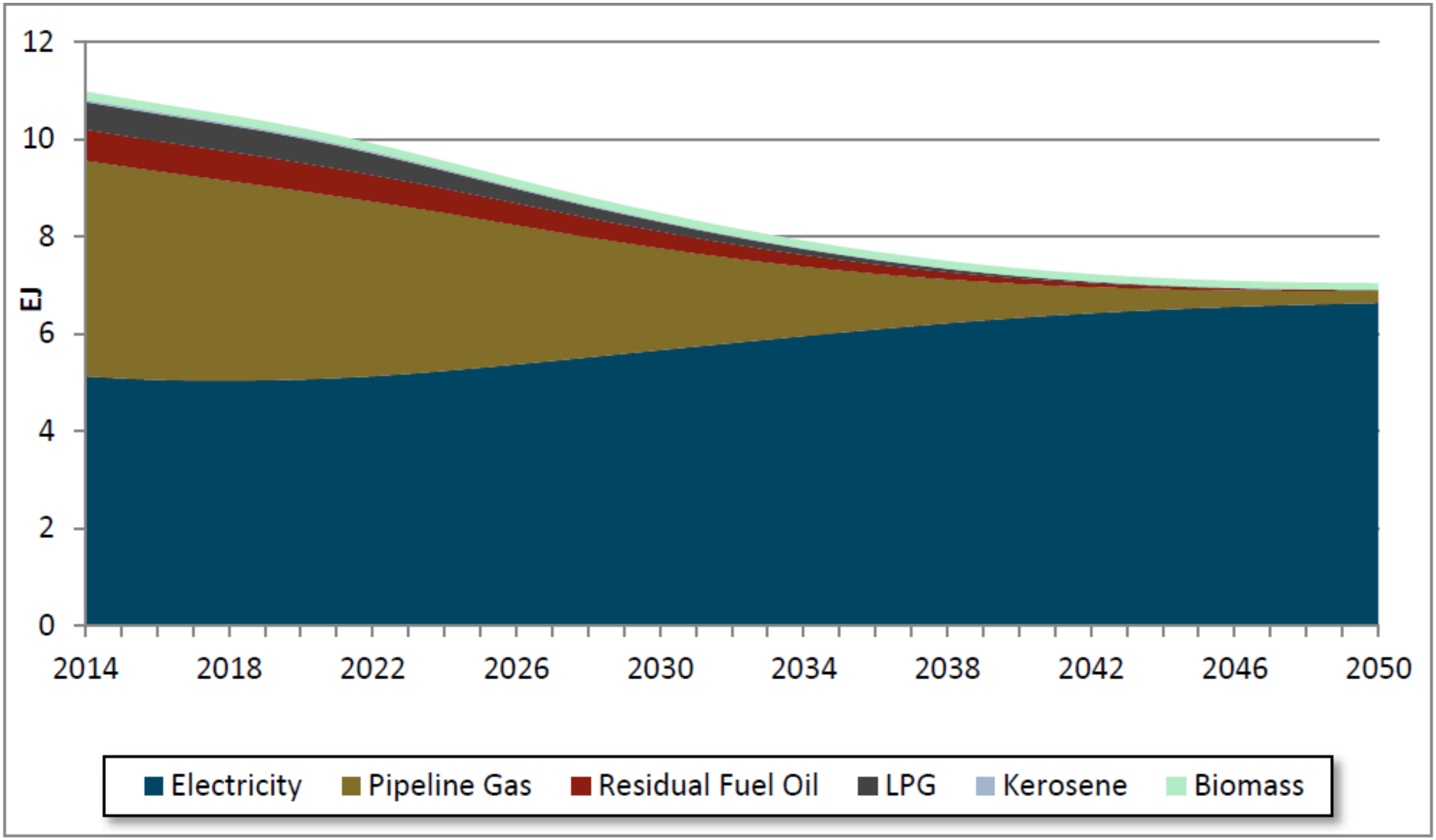


Sustainable business model for network energy suppliers (utilities)?

Are utilities about to be obsolete?



How to drive electrification of buildings?



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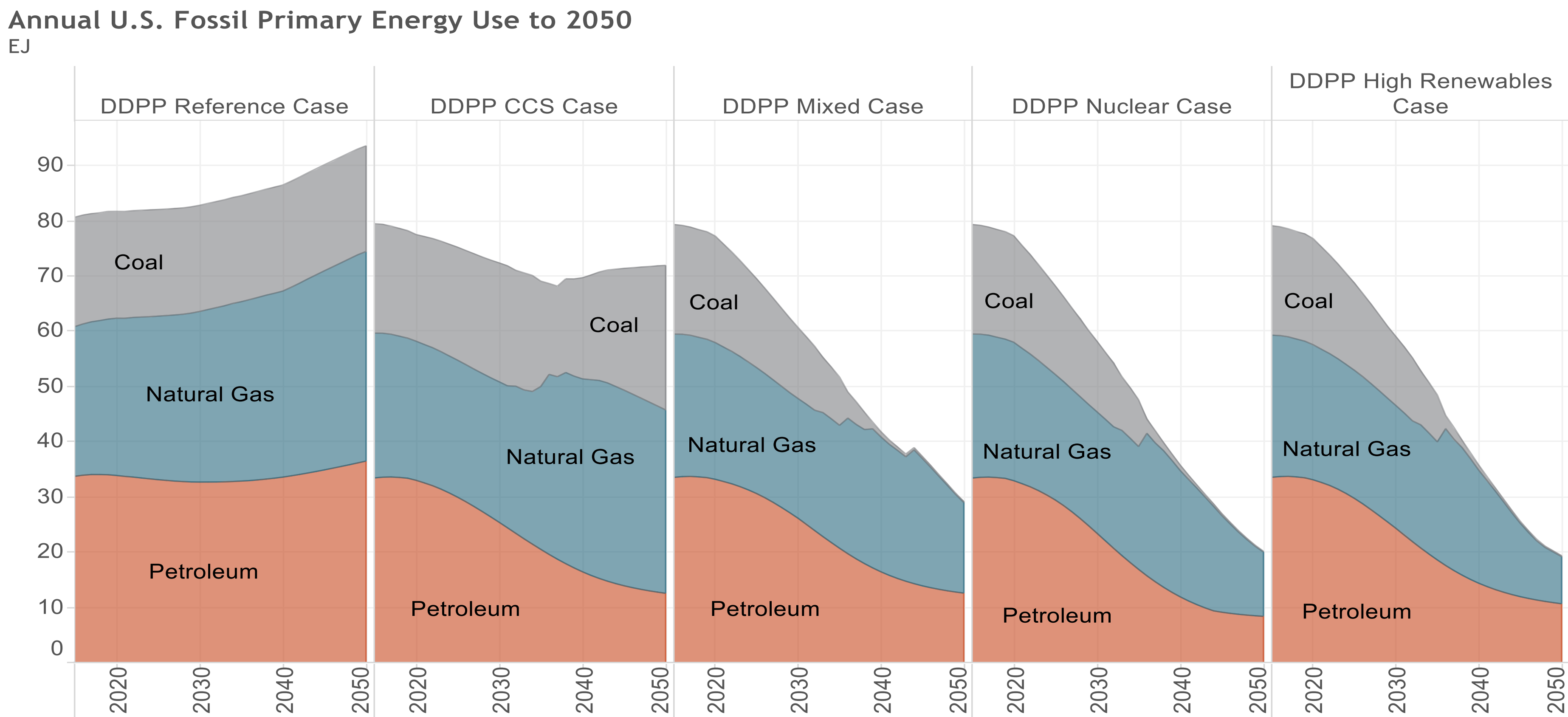
How can governments adjust to declining fossil fuel tax revenues?



How to address distributional effects of low carbon transition?

Average Electric Rate:
2012 cents/kWh

	Distribution	Transmission	Renewables	Variable and Fuel	Conventional Fixed	**Total**
DDPP Reference Case	3.9c	2.0c	2.7c	4.3c	3.9c	16.7c
DDPP Mixed Case	2.8c	2.6c	6.6c	1.8c	5.2c	19.1c
DDPP CCS Case	3.7c	2.0c	3.9c	4.6c	7.6c	21.8c
DDPP High Renewables Case	2.8c	4.5c	10.0c	0.4c	2.0c	19.5c
DDPP Nuclear Case	2.6c	2.6c	6.7c	0.8c	4.7c	17.4c

Ongoing Research

- Pathways analysis at different scales
  - State level: New York & Washington; Under2MOU
  - Regional: Pacific coast partnership
  - Continental: US-Canada-Mexico
- Linking deep decarbonization to co-benefits
  - Air quality: Pathways-INMAP (U.Washington)
  - Land use/siting: Pathways-ORB (U.C. Berkeley)
- Sectoral implementing strategies
  - Carbon sink: DOE C sink (LBNL & Nat. Labs)
  - Regional grid integration: WECC (CAISO)
  - Low carbon gas pilots: SoCal Gas

Ongoing Research

- Improving DDPP-type analyses
  - Open source EnergyPathways model
  - Common template for visualizing pathways
  - Community standards for national modeling
  - Harmonizing boundary conditions for bottom-up
  - Interface with integrated assessment models
- Policy/Research initiatives (DDPP/SDSN/IDDRI)
  - IPCC 1.5 C report
  - Intergovernmental Platform & G20
  - Low Emissions Solutions Conference
  - Sustainable Development Goals
  - Country teams engaged in mid-century strategies

THANK YOU

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www.deepdecarbonization.org

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