Project 2X to 2050

Accelerating the Clean Energy Transition Reliably and Affordably

Neva Espinoza
Director Research & Development

TMCES Workshop
February 13, 2020

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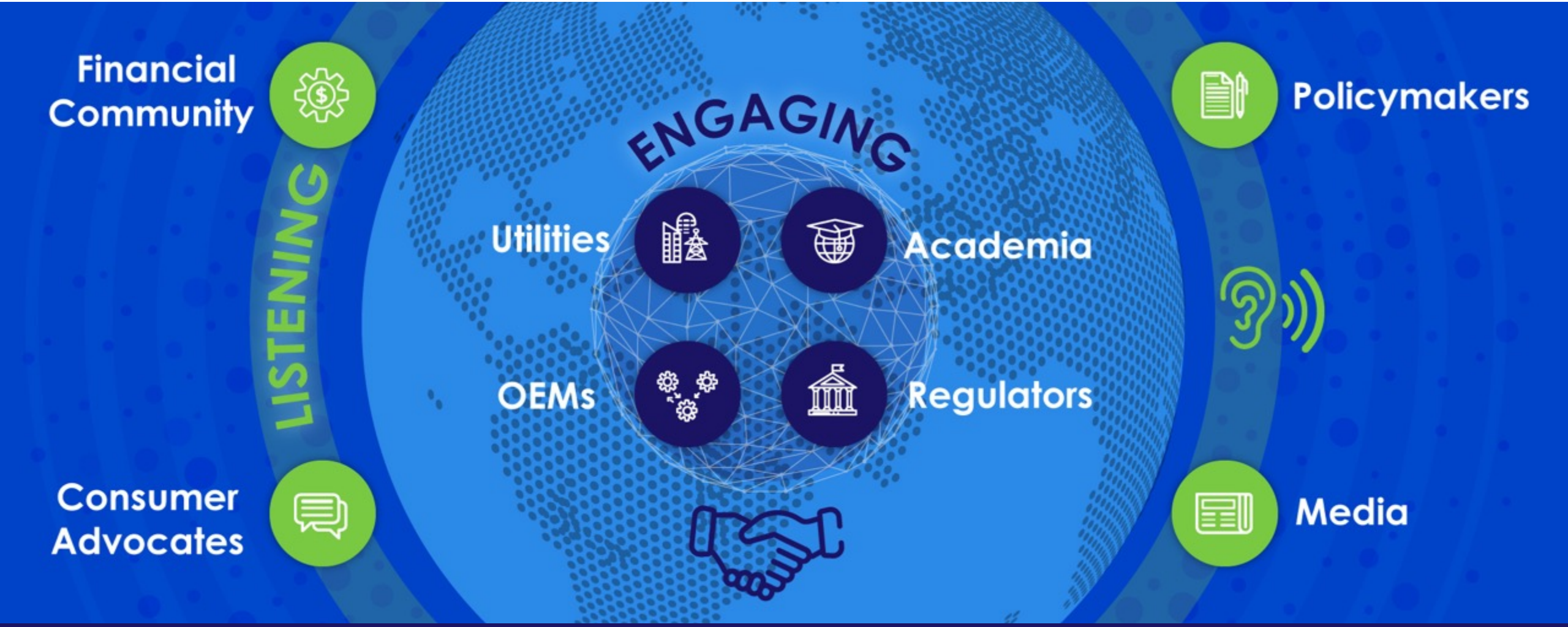
EPRI: Leading Collaborative Energy R&D Around the World



EPRI advances energy technologies and informs decision-making through ~$420M in collaborative annual research involving nearly 400 entities in ~40 countries - spanning the generation, delivery, and use of electricity.

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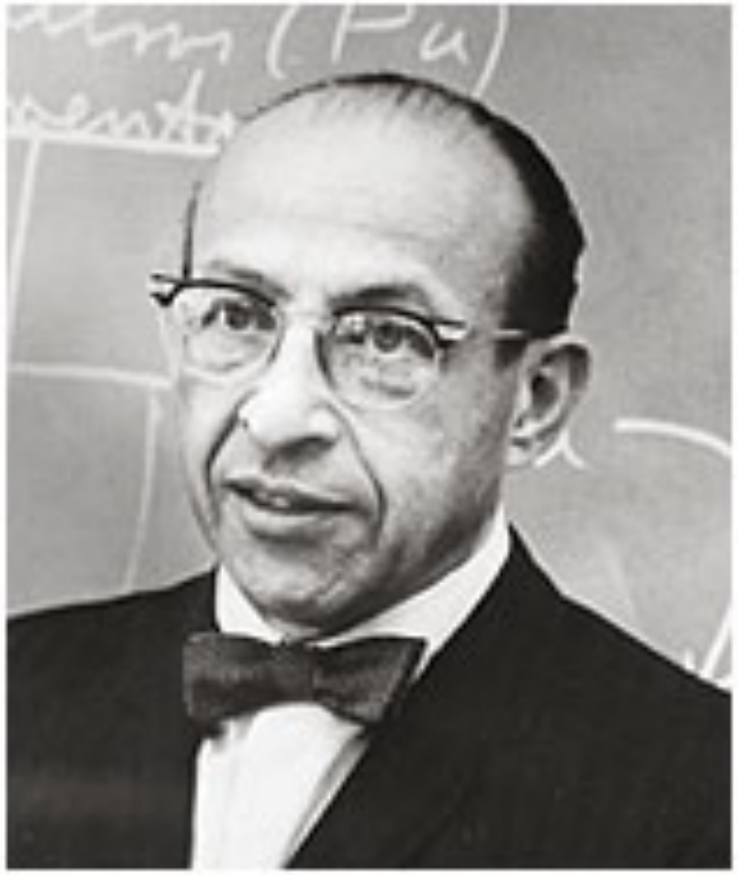
Our Role



Chauncey Starr
EPRI Founder

"You can't wipe out society and make a whole new society. You have to deal with the society that exists. But you have to figure out how you're going to change it to something that's better."

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Our Global Challenge

- **Affordable**
- **Reliable**
- **Safe, and**
- **Clean Energy**

While Also Improving the Quality of Life for Everyone

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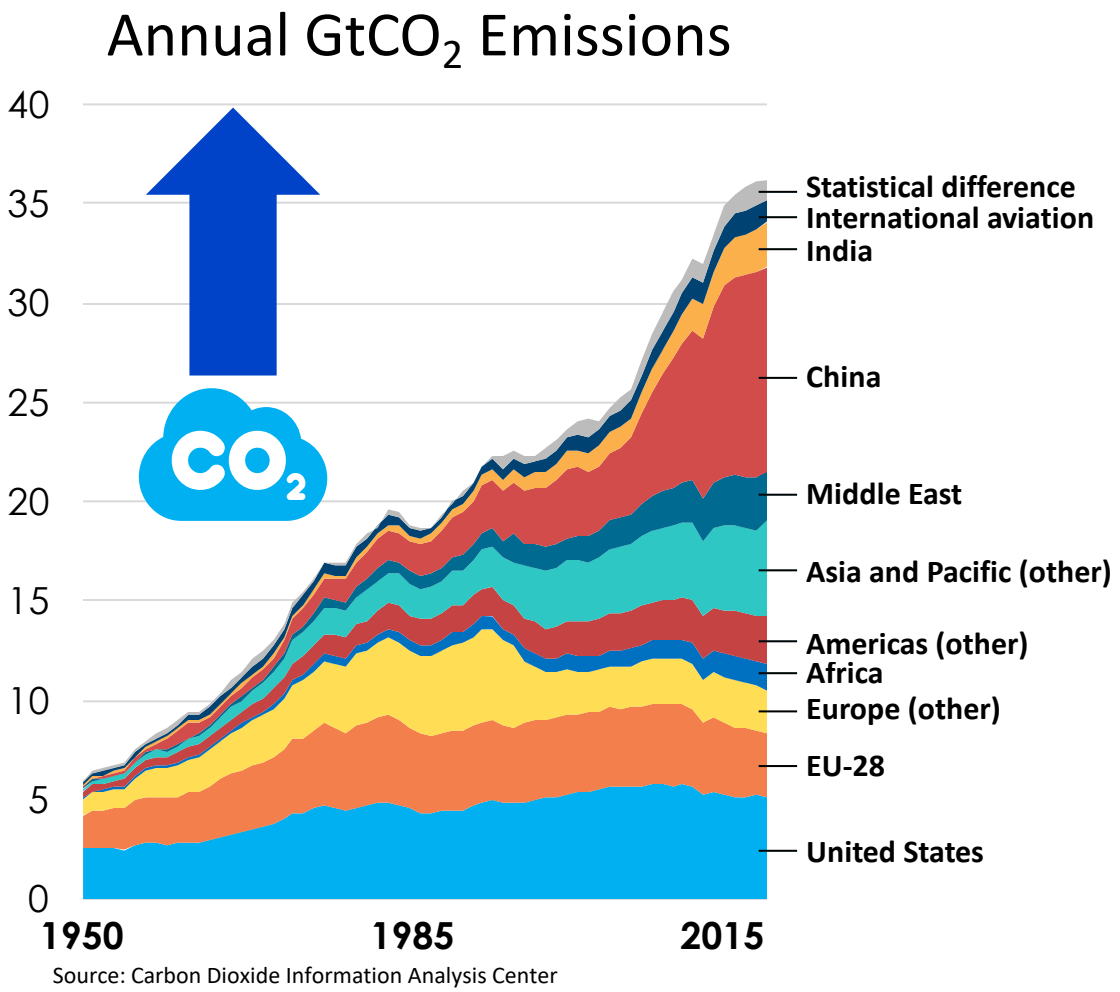
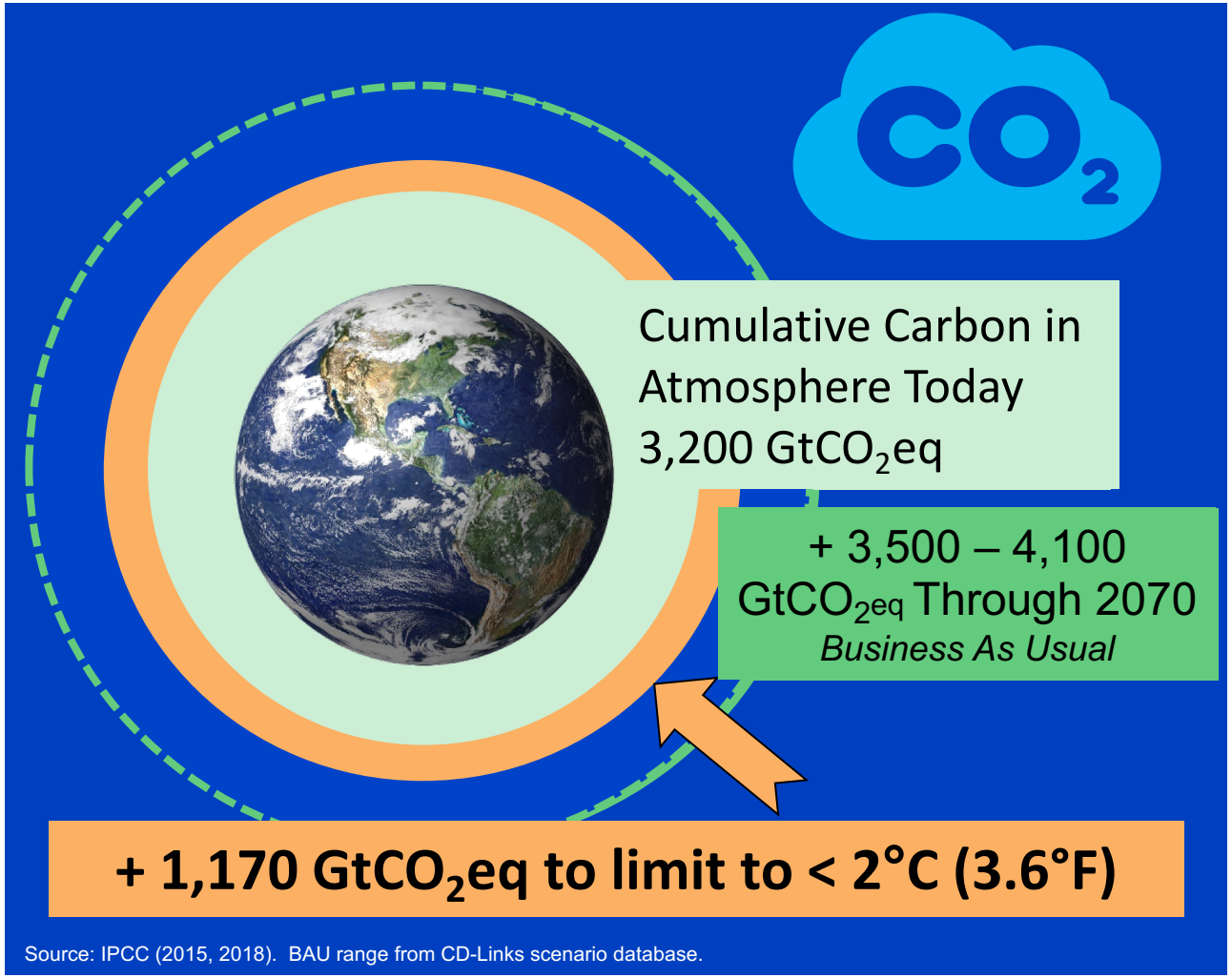
Less Carbon



Source: Carbon Dioxide Information Analysis Center



Source: IPCC (2015, 2018). BAU range from CD-Links scenario database.

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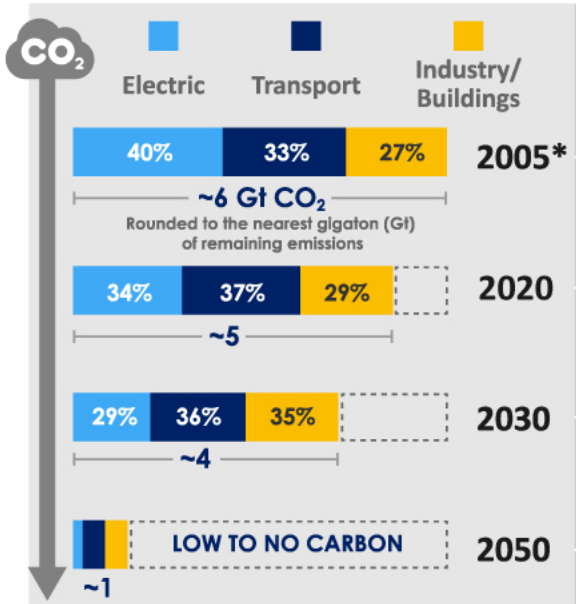
EPRI ELECTRIC POWER RESEARCH INSTITUTE

PROJECT 2X TO 2050

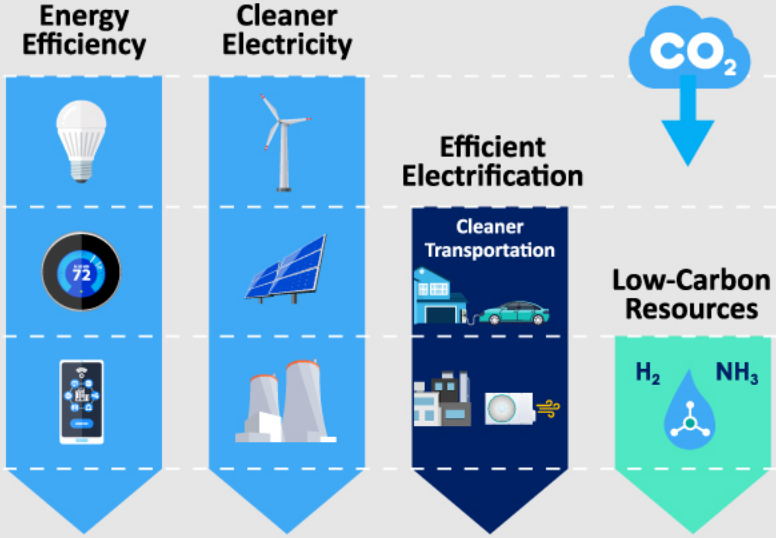
Accelerating Carbon Reduction Across the Economy

U.S. Energy-Related CO_2 Emissions

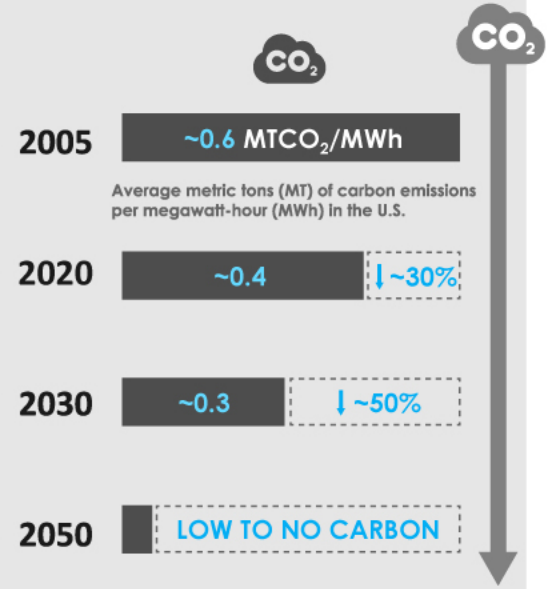


*The U.S. reference year for the Paris Climate Agreement

The Carbon Reduction Technology Timeline



Cleaner Electricity Generation



Historical data from EIA *Monthly Energy Review*, February 2019. 2030 projections from *US-REGEN 2X reference case.*

Next Steps: Expanding Low-Carbon R&D

The Path to 2030: Accelerating Demonstration and Deployment

20% of vehicle miles traveled are EVs

30 GW of flexible resources (2-4 hours)

Accelerating Electric Vehicle (EV) Adoption and Grid Modernization

- Renewable/EV-Ready Integrated Grid
- EV Charging Infrastructure and Customer Behavior
- 30 GW of Grid Flexibility, Including Energy Storage
- Fleet Electrification

The Path to 2050: Creating Affordable, Low-Carbon Options

Hydrogen, biofuels, and related, low-carbon resources

Advancing Low-Carbon Resources

- Advanced Renewables and Nuclear Generation
- Hydrogen Gas Turbines and Thermal Power Plants
- Hydrogen Blending in Pipeline Infrastructure
- Carbon Capture, Utilization, and Storage

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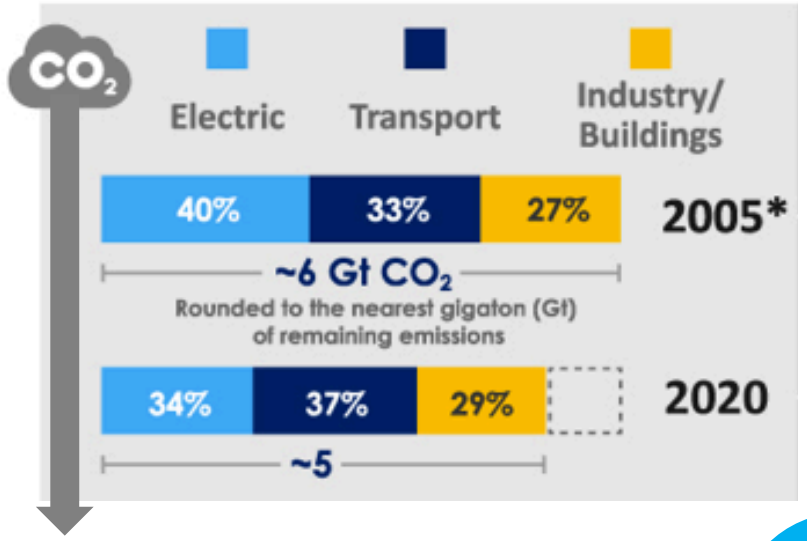
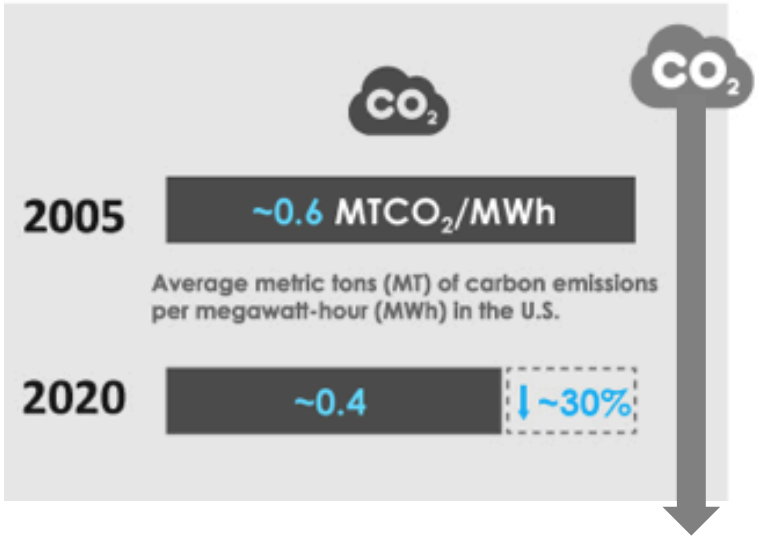
U.S. Energy-Related CO_2 Emissions

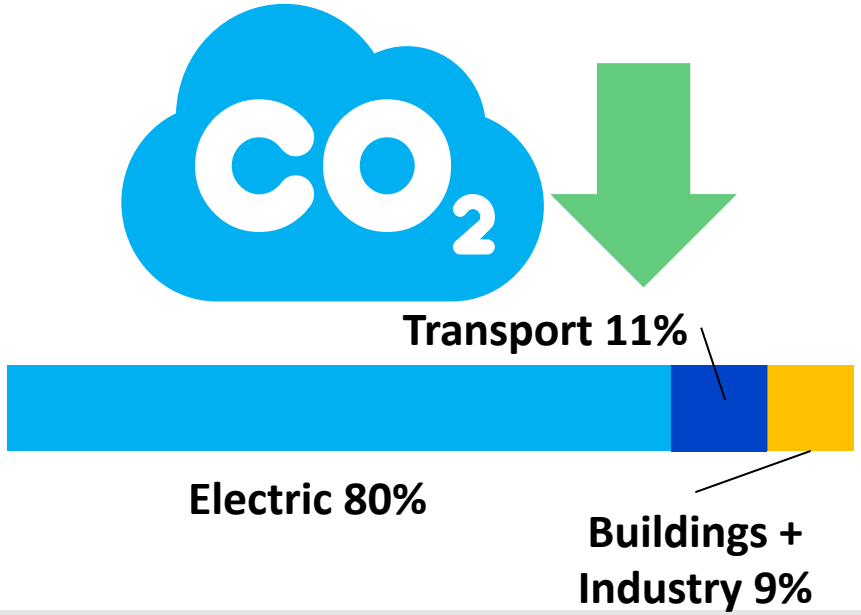


Cleaner Electricity Generation



While Global CO_2 Emissions Rose Since 2005,

36 Nations Have Reduced Emissions



The US accounted for 44% of Global CO_2 Reductions.

The Electric Sector accounted for 80% of US CO_2 Reductions

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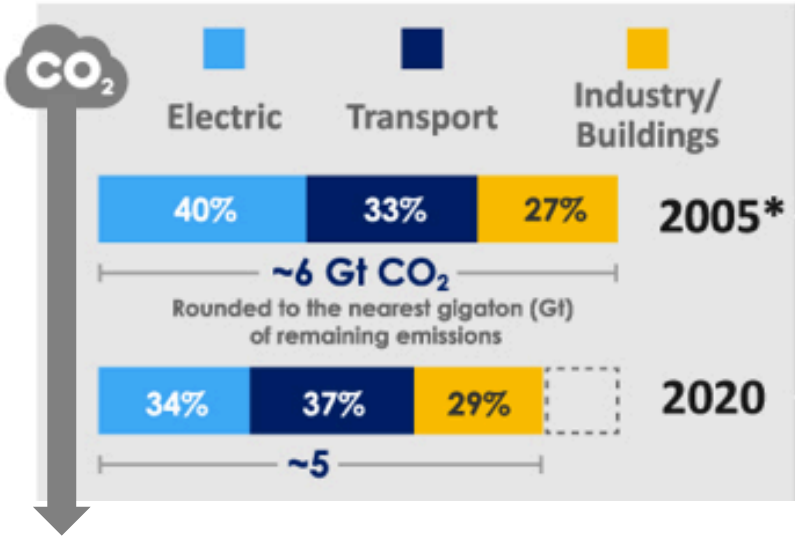
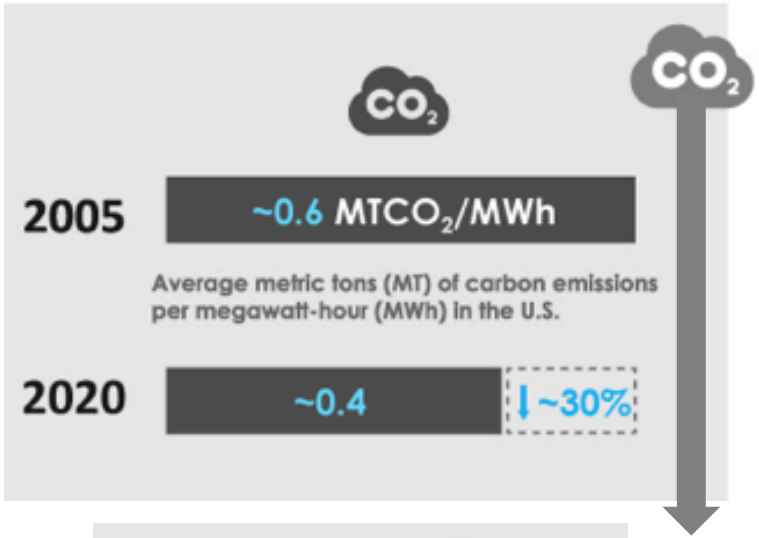
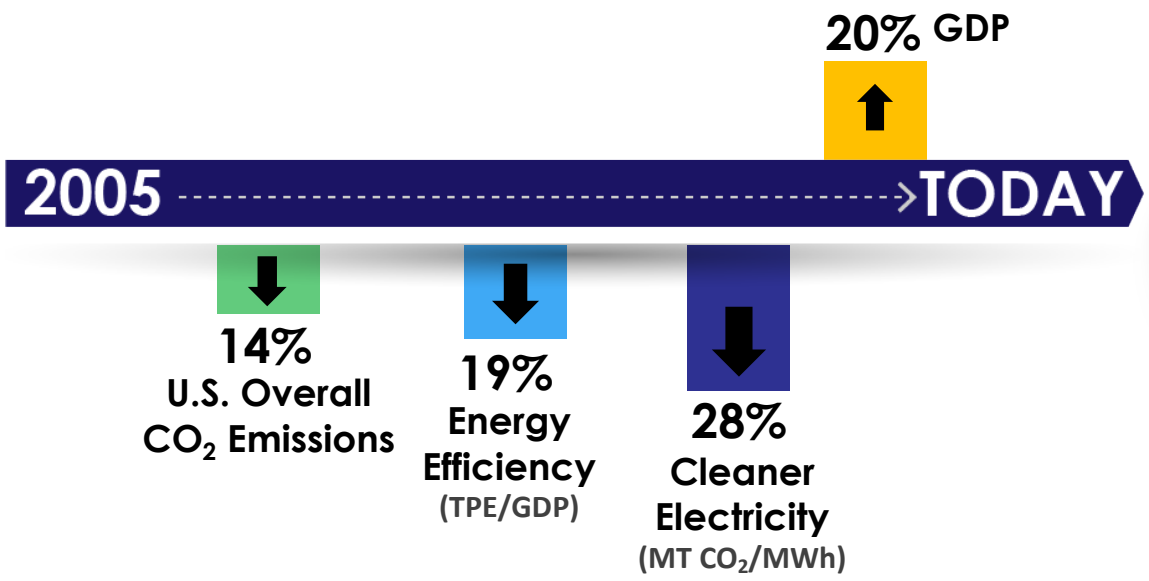
U.S. Energy-Related CO_2 Emissions

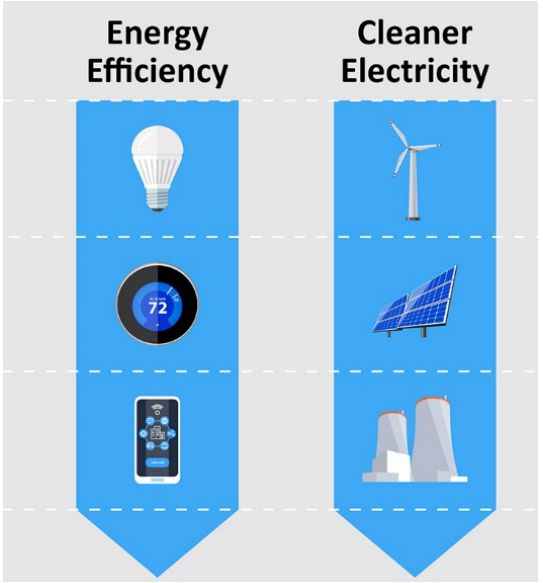


Cleaner Electricity Generation





Essentially no increase in real electric price



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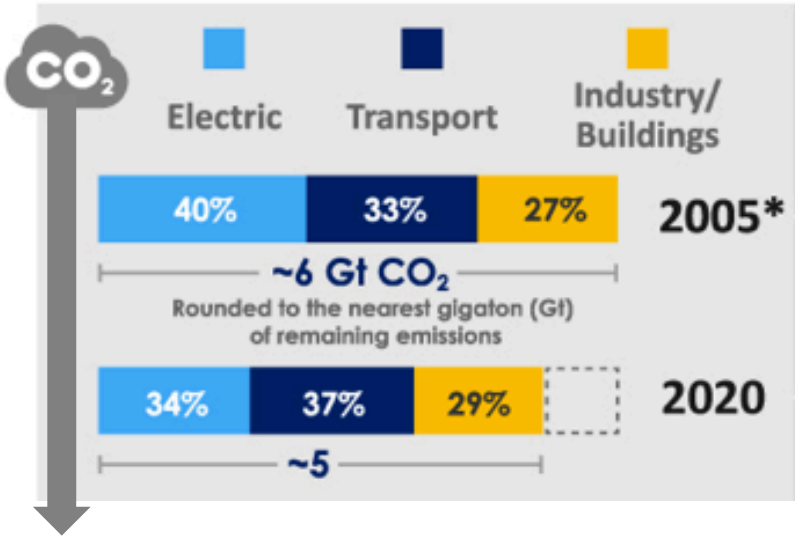
U.S. Energy-Related CO_2 Emissions



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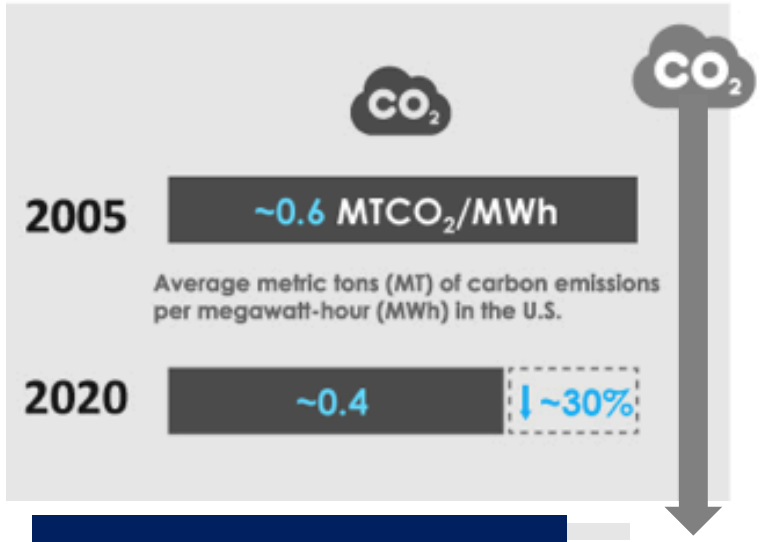

2005 ----------> TODAY

How will we achieve 2X in 2030?

2005 ----------> 2030 20

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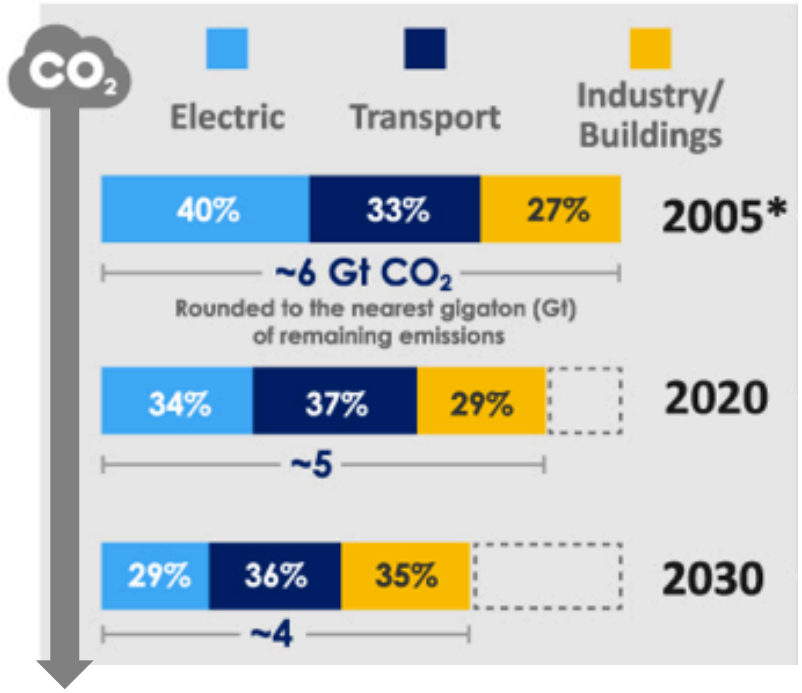
U.S. Energy-Related CO_2 Emissions



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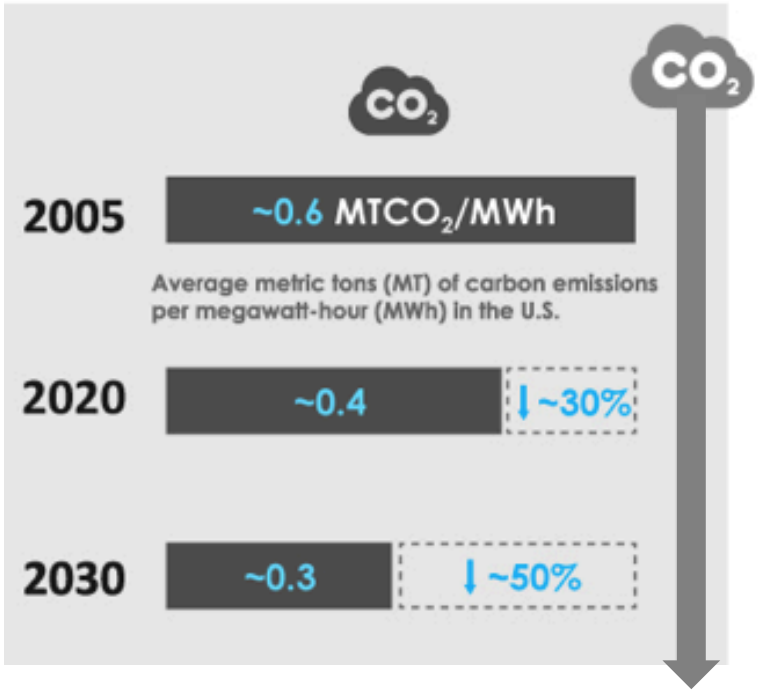

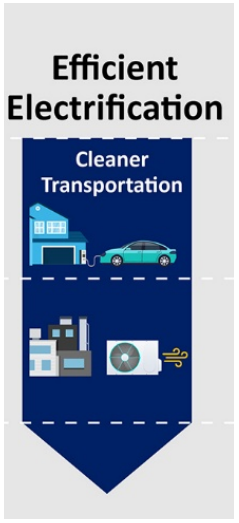

2005 ----------> 2030 20

U.S. Overall CO_2 Emissions 29%

Energy Efficiency (TPE/GDP) 43%

51% Cleaner Electricity (MT CO_2/MWh)

23% Cleaner Transport (MT CO_2)

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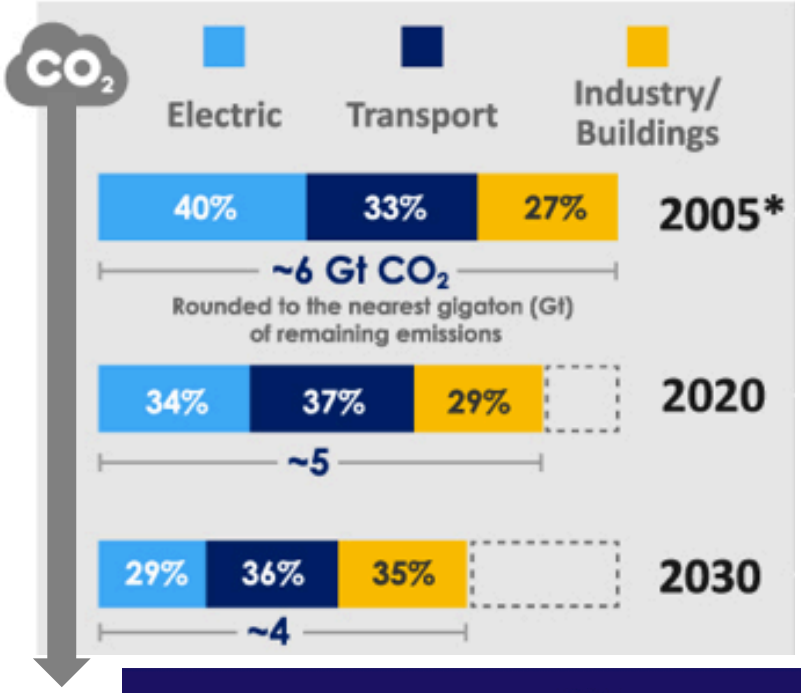
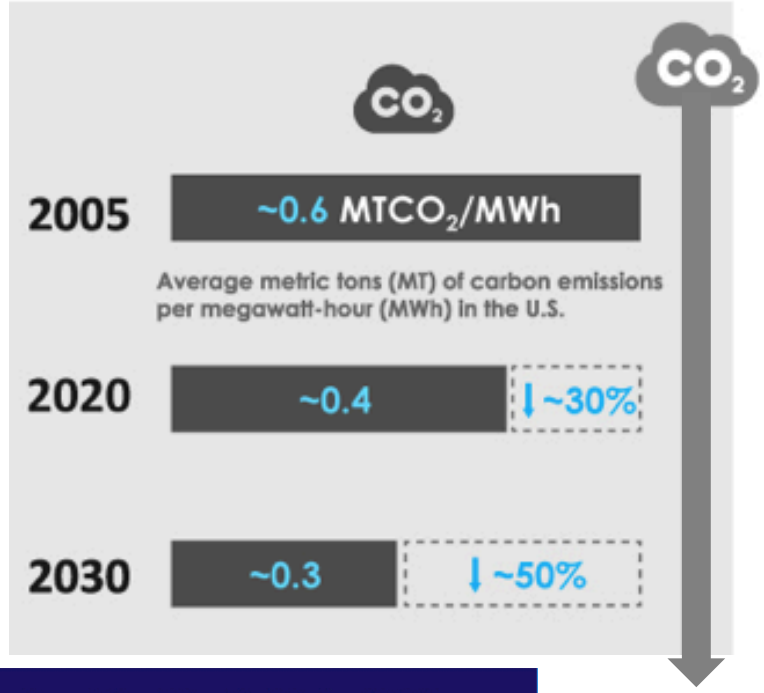
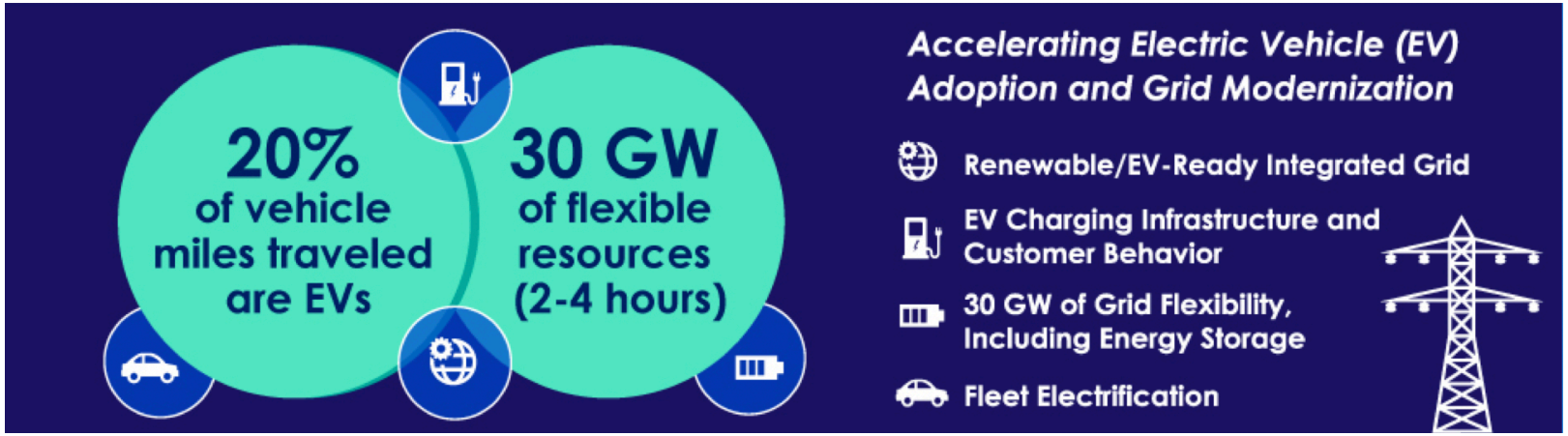
U.S. Energy-Related CO_2 Emissions



Cleaner Electricity Generation





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Carbon Free Generation

BIO

WITH CO_2 CAPTURE

ELECTRIFICATION

20% of vehicle miles traveled are EVs

Gasoline | Electricity | Natural Gas | Other

Household with 1 Gasoline Vehicle and 1 Electric Vehicle

Average Energy Bill: $4,050/year 11%↓

Average CO_2 Emissions: 15 tCO_2/year 17%↓

Household with 2 Gasoline Vehicles

Average Energy Bill: $4,528/year

Average CO_2 Emissions: 18 tCO_2/year

Household with 2 Electric Vehicles

Average Energy Bill: $3,571/year 21%↓

Average CO_2 Emissions: 12 tCO_2/year 34%↓

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Carbon Free Generation

BIO

WITH CO_2 CAPTURE

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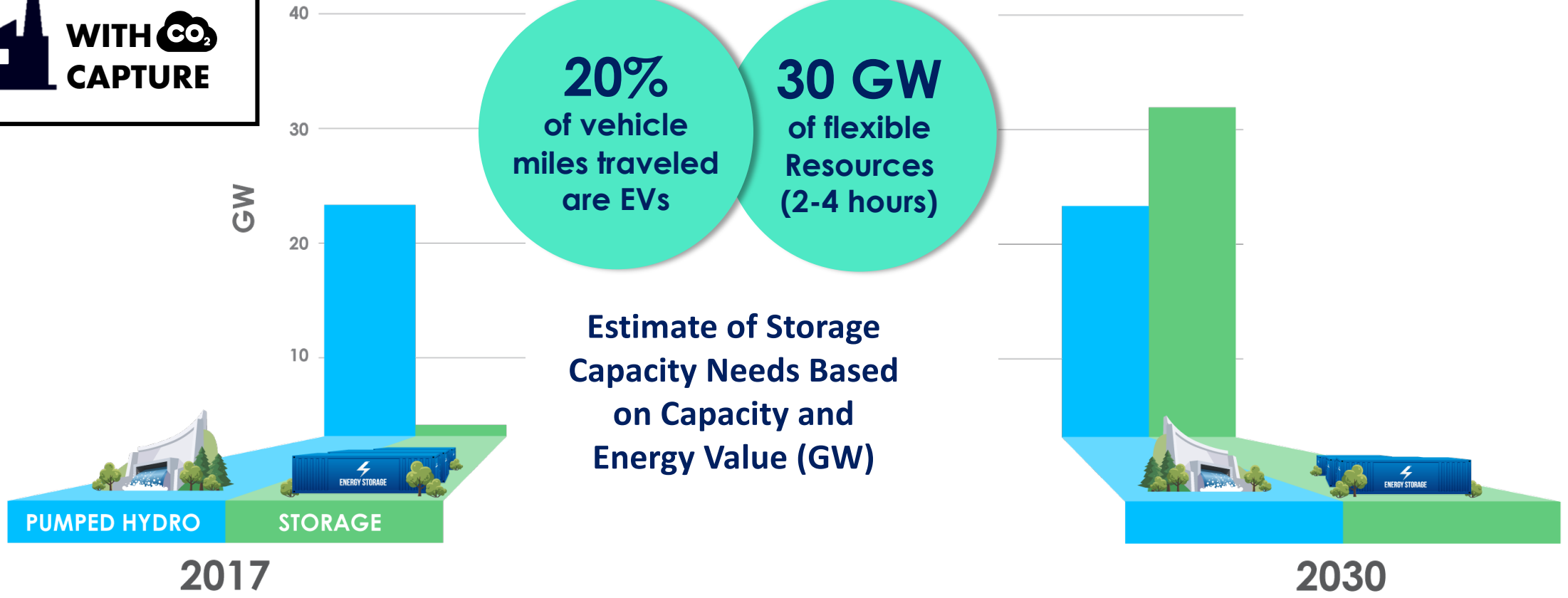
ELECTRIFICATION

20% of vehicle miles traveled are EVs

30 GW of flexible Resources (2-4 hours)



Estimate of Storage Capacity Needs Based on Capacity and Energy Value (GW)

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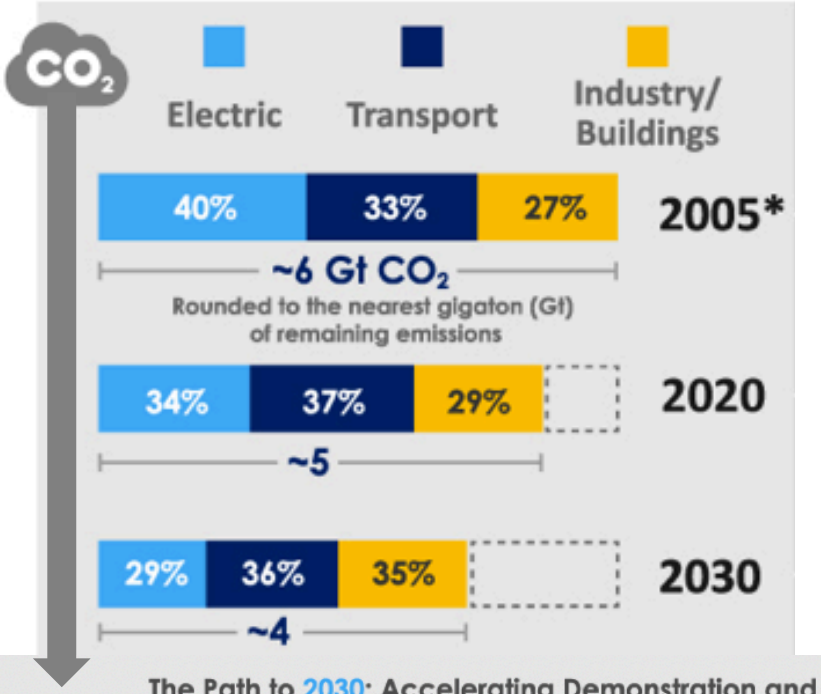
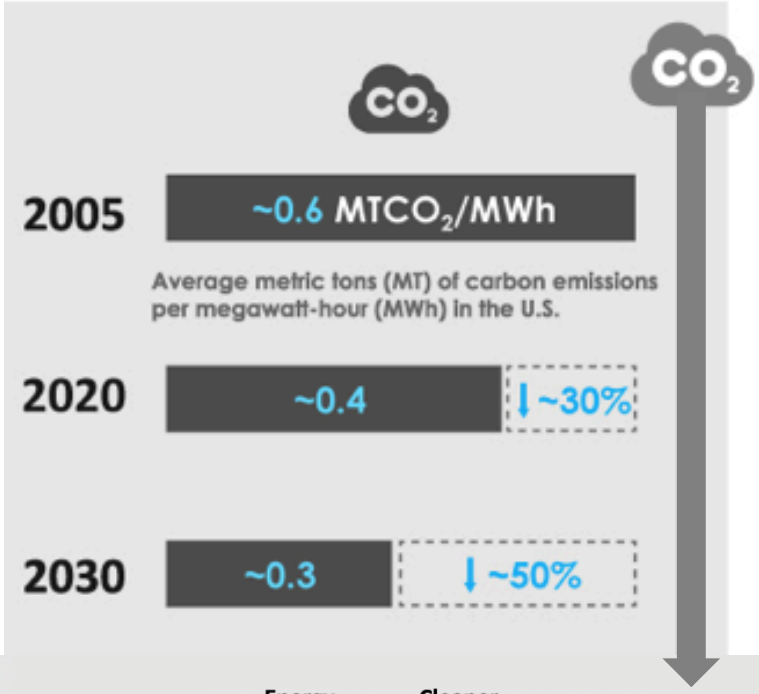
Project 2X

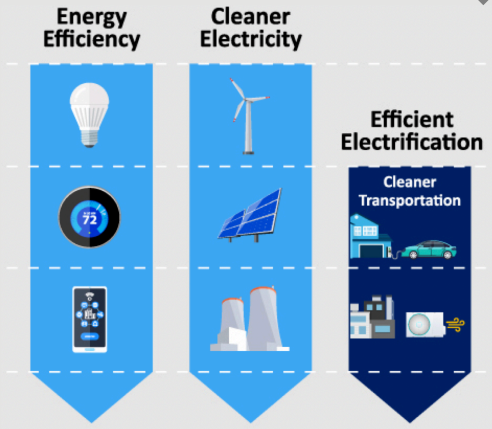
U.S. Energy-Related CO_2 Emissions



Cleaner Electricity Generation



The Path to 2030: Accelerating Demonstration and Deployment



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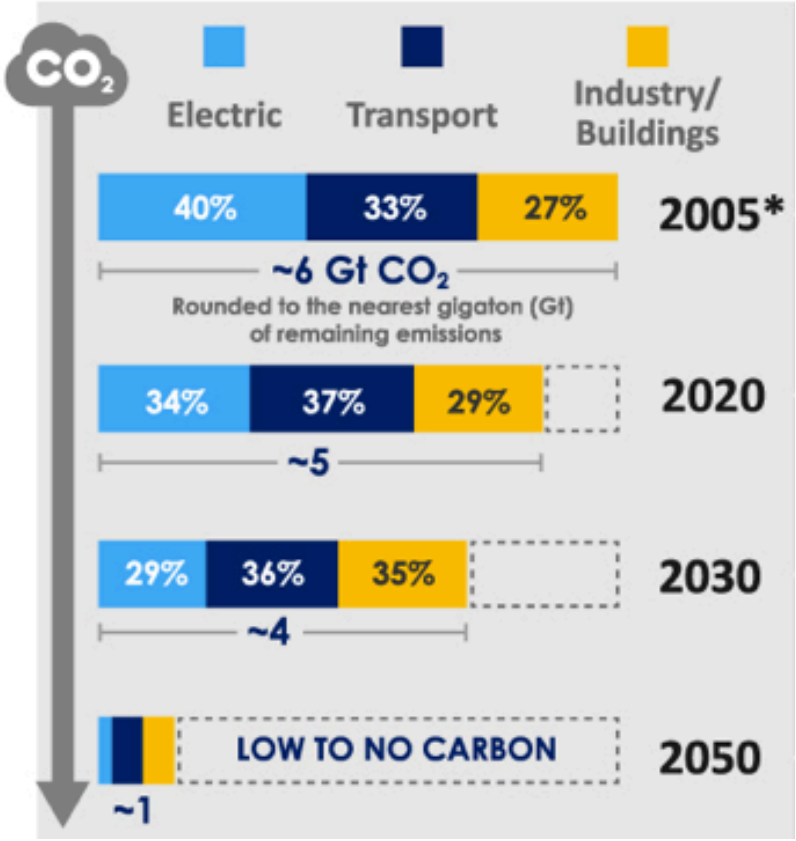
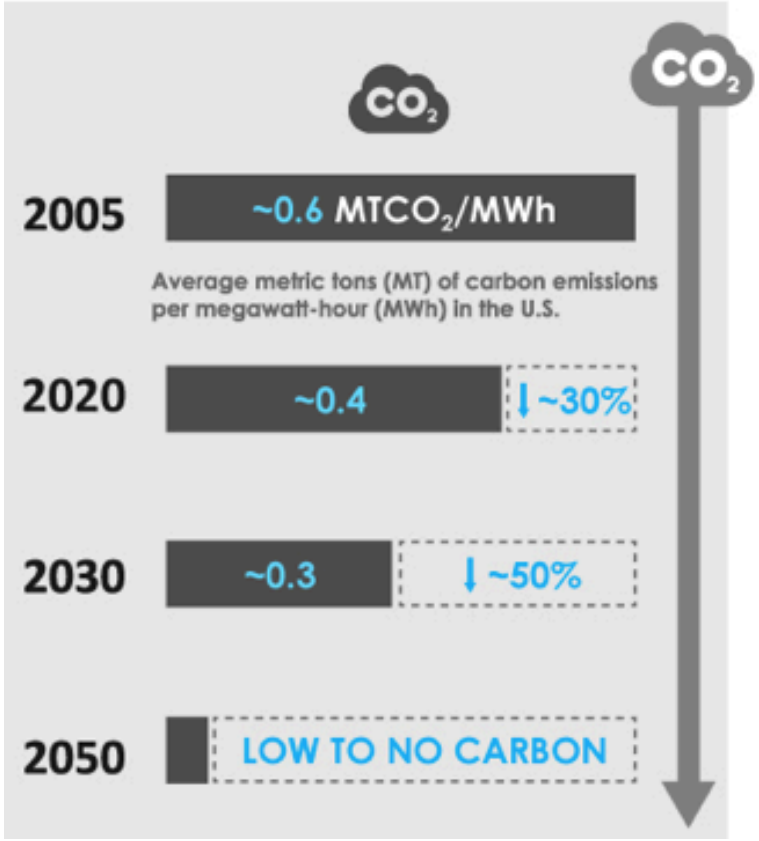


Cleaner Electricity Generation



The tools that have enabled reductions through 2030 will not be enough to achieve deep decarbonization by 2050.

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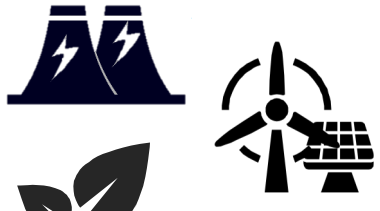
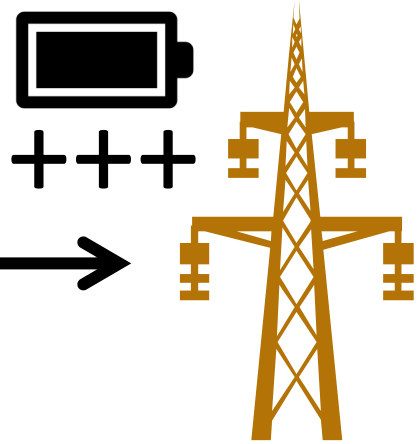
Carbon Free Generation

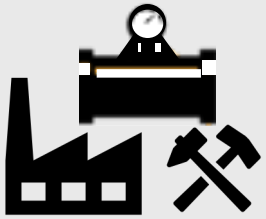




ELECTRIFICATION

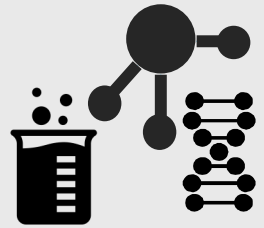
What does the next phase of decarbonization look like?
How will we electrify 'hard to electrify' places?

Shipping & Heavy-Duty Transportation

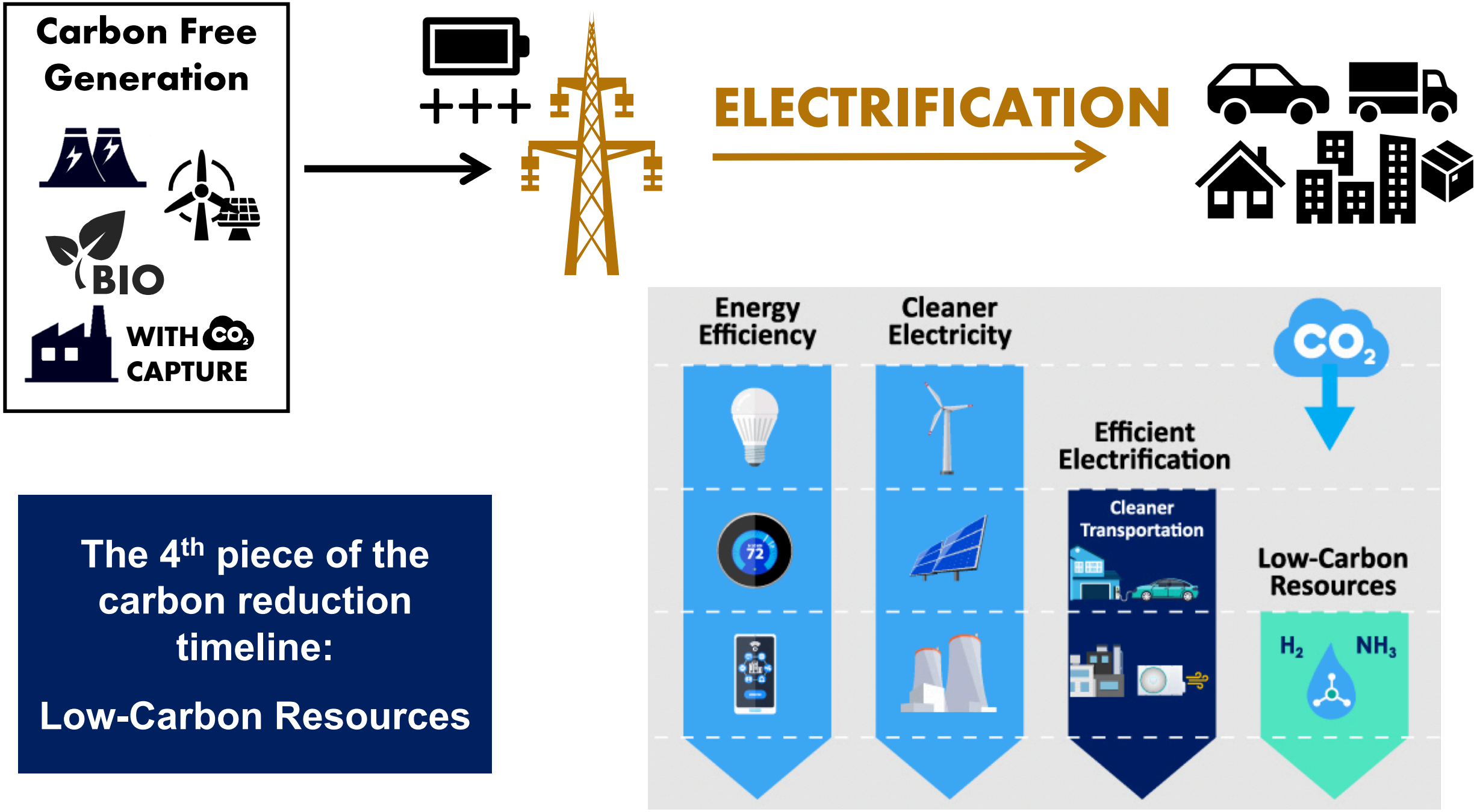


Oil & Gas Steel

High Grade Heat



Chemical Production



The 4th piece of the carbon reduction timeline:

Low-Carbon Resources

Carbon Free Generation

BIO

WITH CO_2 CAPTURE

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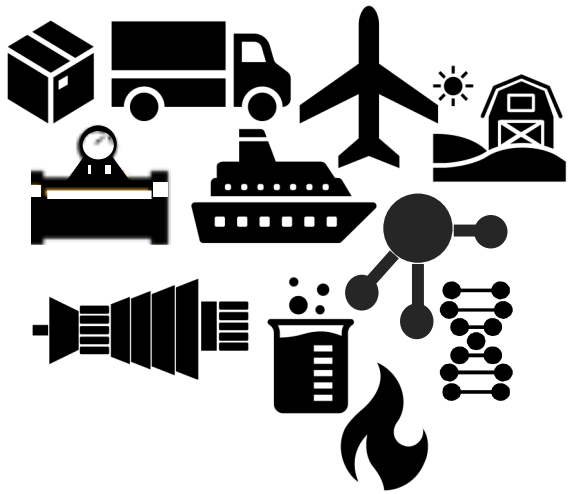
ELECTRIFICATION

INDIRECT ELECTRIFICATION

Alternate Energy Carriers

LOW CARBON FUELS



Carbon Free Generation

BIO

WITH CO_2 CAPTURE

Carrier Production Technologies

BIO

Reformation or Gasification w/ CO_2 Capture

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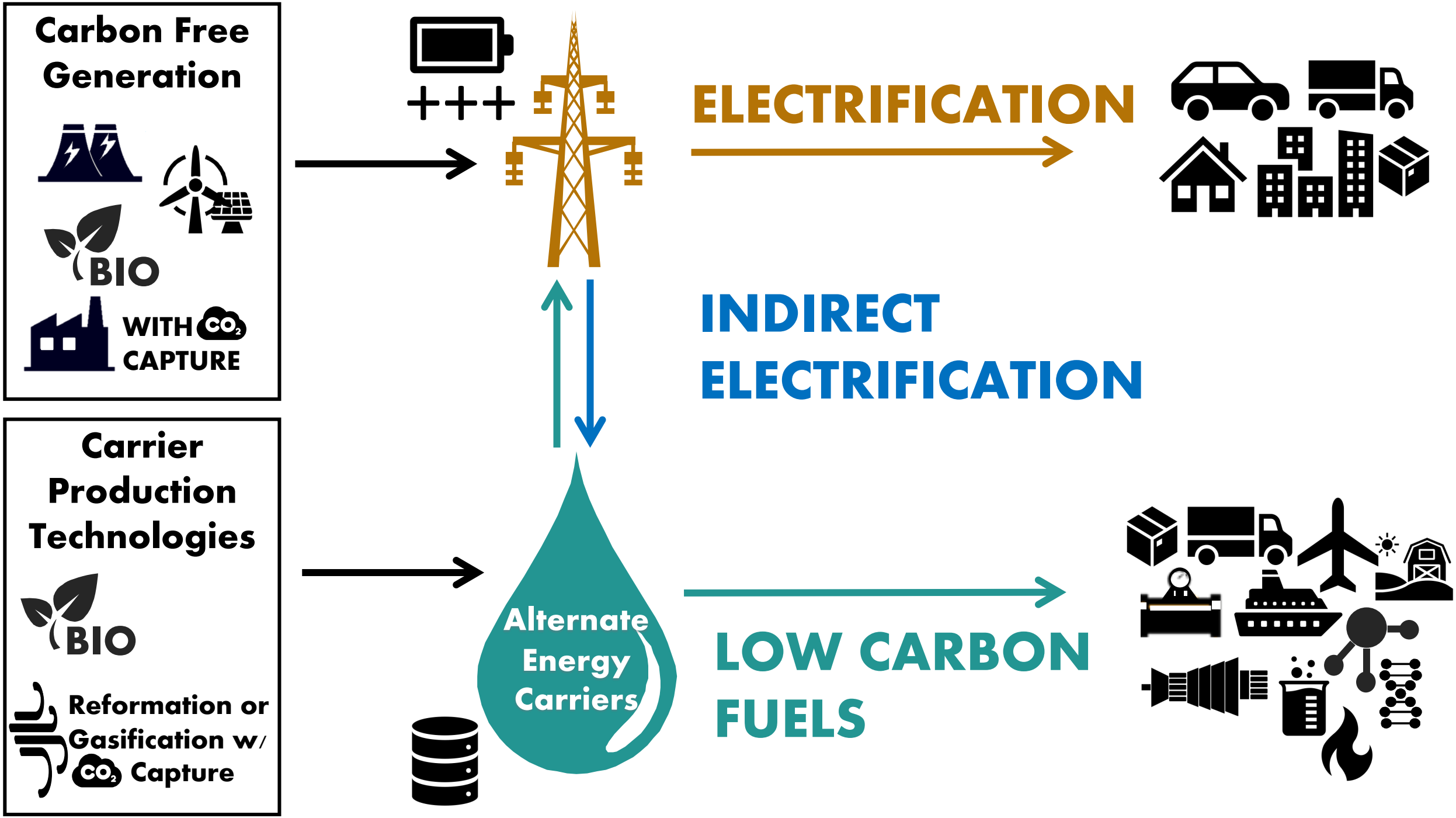
ELECTRIFICATION

INDIRECT ELECTRIFICATION

Alternate Energy Carriers

LOW CARBON FUELS


Carbon Free Generation
BIO
WITH CO2 CAPTURE
ELECTRIFICATION
INDIRECT ELECTRIFICATION
Carrier Production Technologies
BIO
Reformation or Gasification w/ CO2 Capture
Alternate Energy Carriers
LOW CARBON FUELS

Need Focused R&D Pathway

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DECARBONIZING THE POWER SUPPLY

Carbon Free Generation

BIO

WITH CO_2 CAPTURE

ELECTRIFICATION

INDIRECT ELECTRIFICATION

Carrier Production Technologies

BIO

Reformation or Gasification w/ CO_2 Capture

Alternate Energy Carriers

LOW CARBON FUELS

Carbon Free Generation

BIO

WITH CO_2 CAPTURE

ELECTRIFICATION

H_2O

INDIRECT ELECTRIFICATION

ENERGY CARRIER PRODUCTION

Carrier Production Technologies

BIO

Reformation or Gasification w/ CO_2 Capture

Alternate Energy Carriers

LOW CARBON FUELS

Carbon Free Generation

BIO

WITH CO_2 CAPTURE

Carrier Production Technologies

BIO

Reformation or Gasification w/ CO_2 Capture

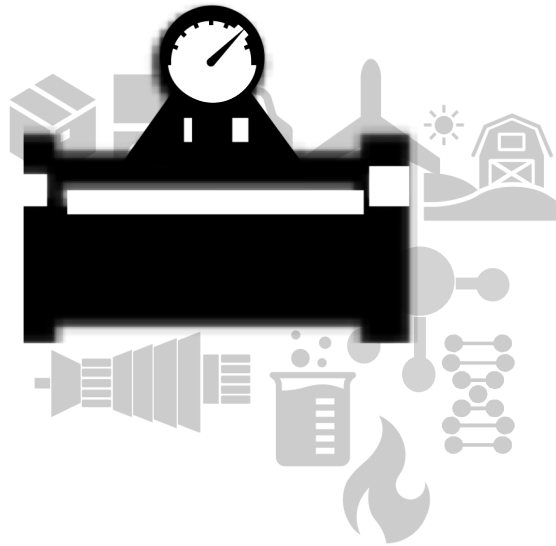
ELECTRIFICATION

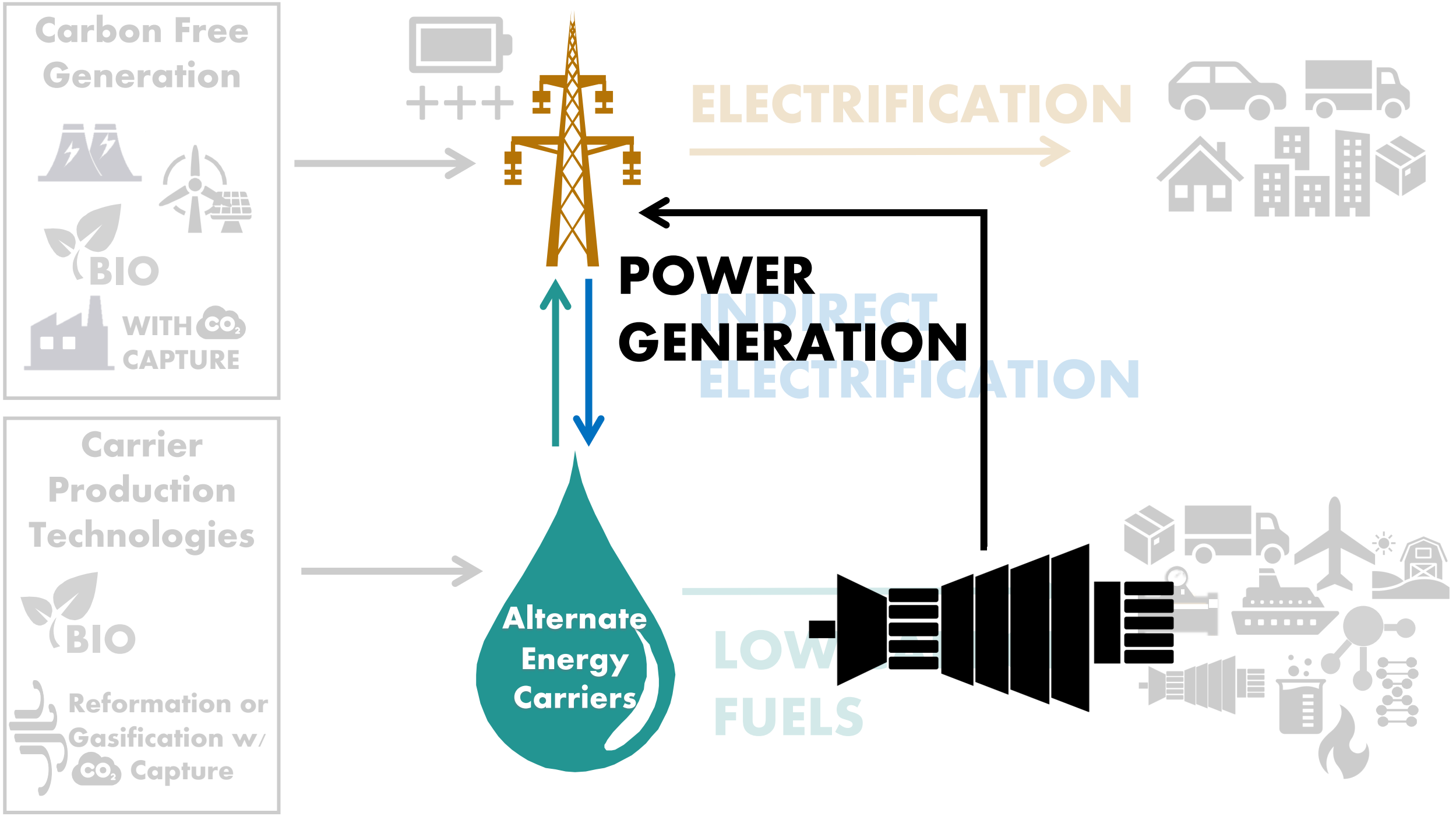
INDIRECT ELECTRIFICATION

Alternate Energy Carriers

LOW CARBON FUELS

NATURAL GAS PIPELINE




Carbon Free Generation
BIO
WITH CO2 CAPTURE
Carrier Production Technologies
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ELECTRIFICATION
POWER GENERATION
INDIRECT ELECTRIFICATION
Alternate Energy Carriers
LOW
FUELS

Carbon Free Generation

BIO

WITH CO_2 CAPTURE

Carrier Production Technologies

BIO

Reformation or Gasification w/ CO_2 Capture

ELECTRIFICATION

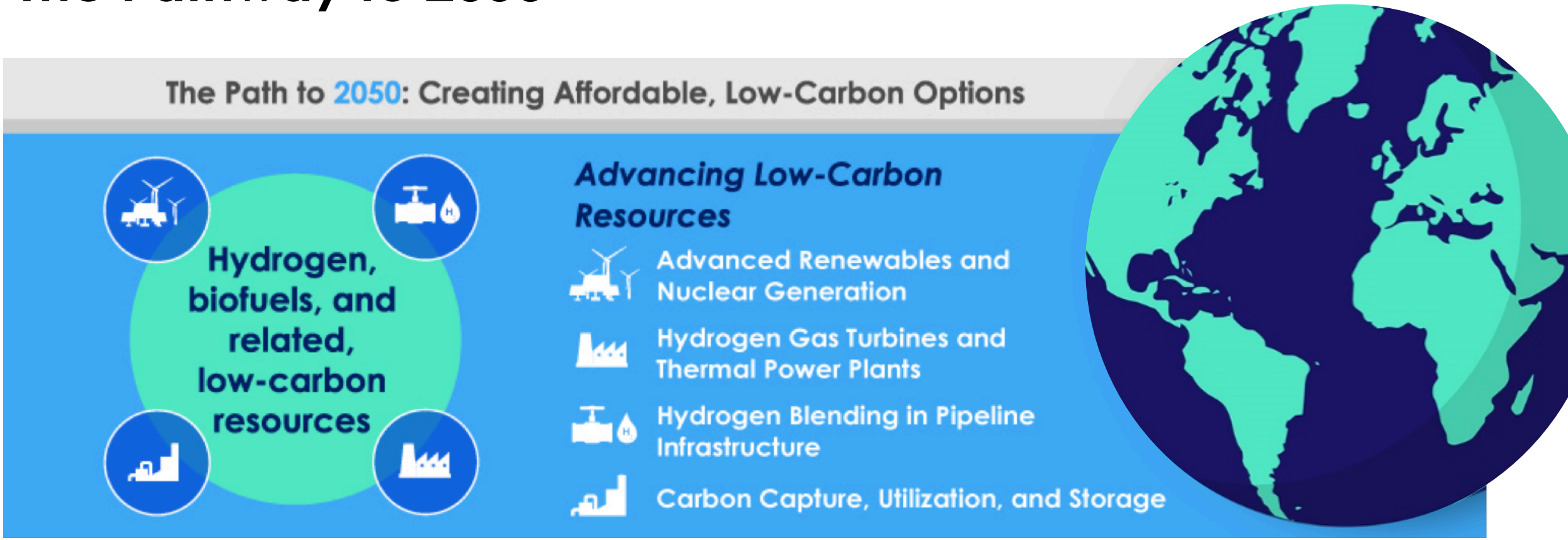
INDIRECT ELECTRIFICATION

END USE APPLICATIONS

Alternate Energy Carriers

LOW CARBON FUELS

The Pathway to 2050



Technical and Implementation Challenges to Overcome

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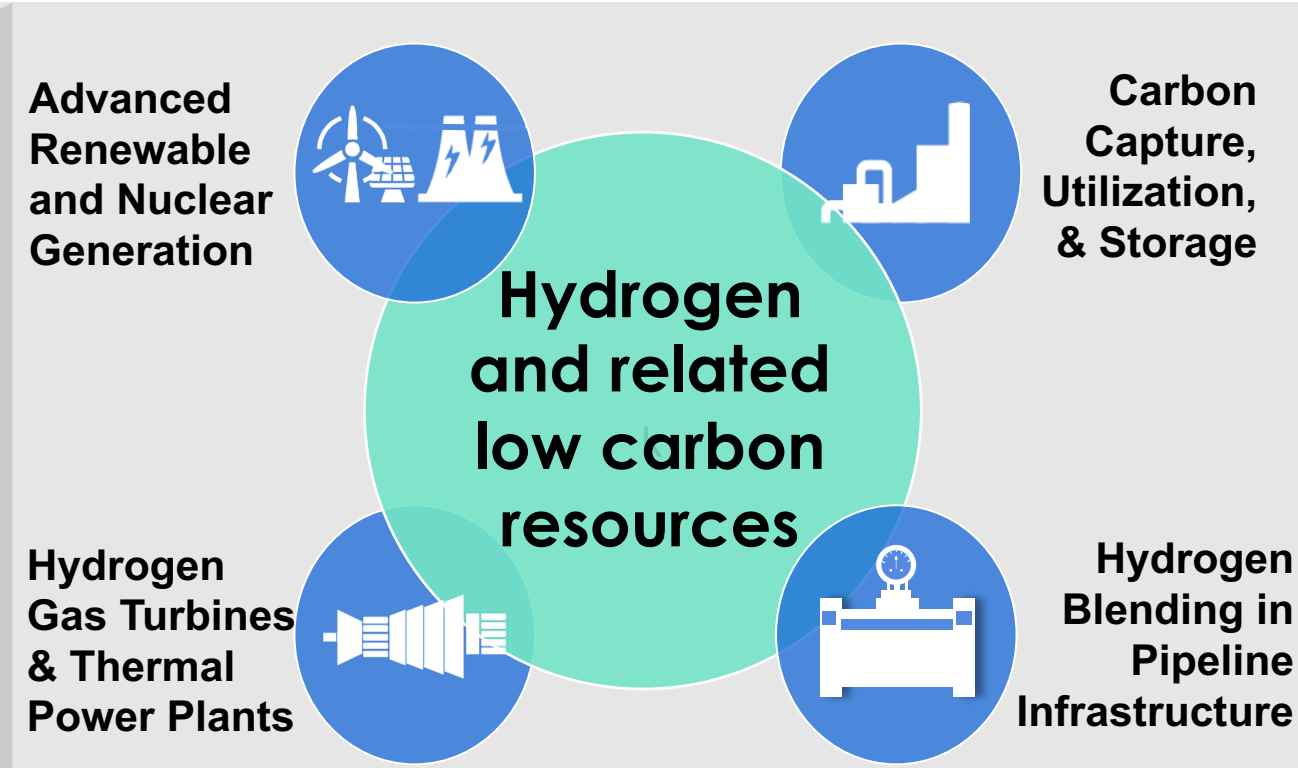
Low-Carbon Resources Initiative

... to 2050

The **Low-Carbon Resources Initiative** (LCRI) is a five-year, focused R&D commitment to develop the pathways to advance low-carbon technologies for large-scale deployment. This initiative is jointly led by **EPRI and GTI**. The goal of the initiative is to enable a risk-informed understanding of options and technologies enabling significant economy-wide decarbonization through global partnerships and demonstrations, applied engineering developments, and technology acceleration of the most promising options.

WHY H_2 and related, low-carbon resources

- **Enable infrastructure** for future low-carbon fuel options
- **Electrify sectors** such as bulk transportation, large industries, and heating networks in cold climates
- **Create** clean power utilizing combustion turbines
- **Provide** cleaner, safer environment for society



VALUE CO_2

- **Individual commitment** to environmental, social, and governance (ESG) efforts
- **Increase optionality** of low-carbon solutions
- **Leverage investments** across relevant sectors
- **Identify approaches** to mitigate stranded assets

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Closing thoughts

- **Path to 2030 is clear – must continue to make great progress on cleaner generation and smarter grid with more emphasis on**
  - Electrification of transportation sector
  - Energy storage as a grid asset for enhancing flexibility
  - Transmission build out to access and deliver clean electricity

- **Path 2030 to 2050 – very important, but less clear and will require low carbon technologies to advance for large scale deployment**
  - ***Technology R&D is vital for affordability and reliability and optionality***
  - Not 100% renewables – must have other viable technologies too
  - Gas, Hydrogen, Carbon Capture & Storage & Nuclear will all play roles
  - ***The time to act is now to get ready for beyond 2030 Deeper Decarbonization***

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Together...Shaping the Future of Electricity

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Neva Espinoza
nespinoza@epri.com
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