HEAT EXCHANGER WORLD CONFERENCE & EXPO AMERICAS

2022

Industrial Revolution 2.0
Renewable Energy - ESG

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Tricord Consulting

(Phillips 66, Retired-Aug 2022)

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Is it? - ESG, Sustainability or GHG ?

2022

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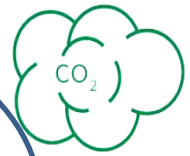
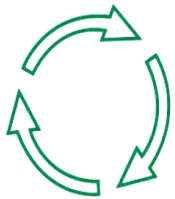
Air Water Waste



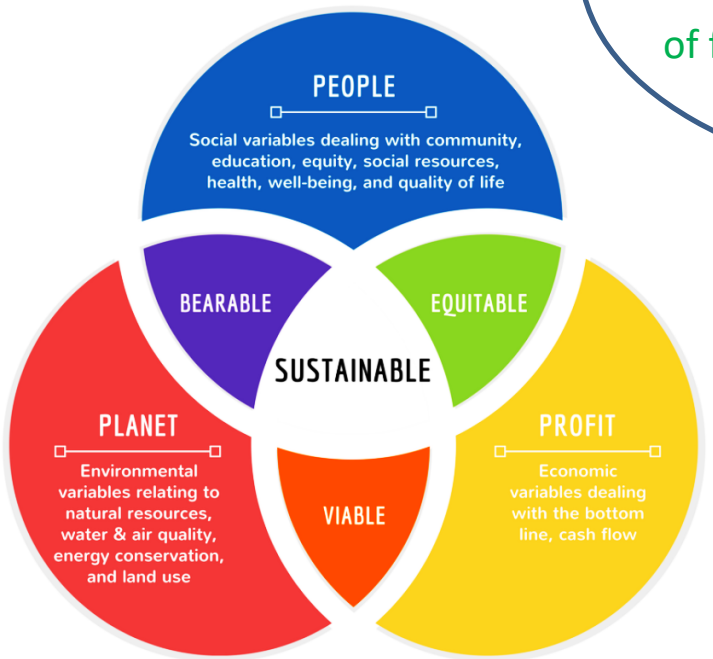


E S G

- Environmental,
- Social Responsibility,
- Governance

Sustainability

"meeting the needs of the present without compromising the ability of future generations to meet their own needs."



***GHGs - Anthropogenic* (man made)**

Mitigation

Adaptation

Greenhouse Gases (GHG)

CO2: ~80% of GHGs

CO2e = CO2 "equivalents"

CH4: **25x** = CO2e - ~10% of GHGs

N2O: **298x** = CO2e - ~7% of GHGs

Triple Bottom Line

- People
- Planet
- Profit

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Sources of Anthropogenic (man made) GHGs

2022

(Sankey chart)

~49 B Metric Tons (MT)

~73% - Energy Use (~36 B MT)

Transport (~8 B MT)

Elect / Heat (~15 B MT)

Buildings (~3 B MT)

Other combustion (~1 B MT)

Manufact / Construct (~6 B MT)

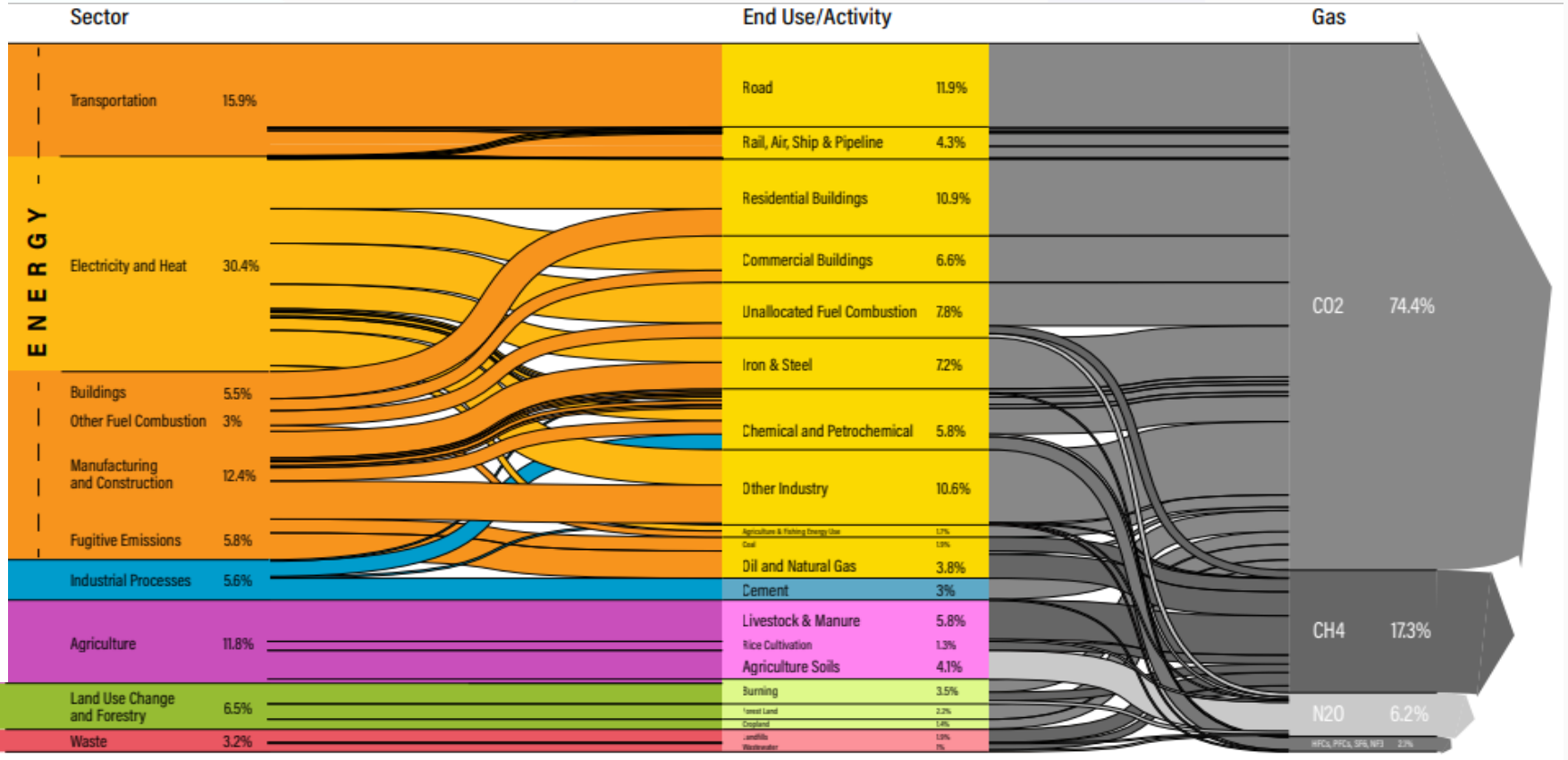
Fugitives (~3 B MT)

Industry (~3 B MT)

Agriculture (~6 B MT)

Land Use (~3 B MT)

Waste (~1 B MT)



1 Billion Metric Tons = 1 Giga tonne

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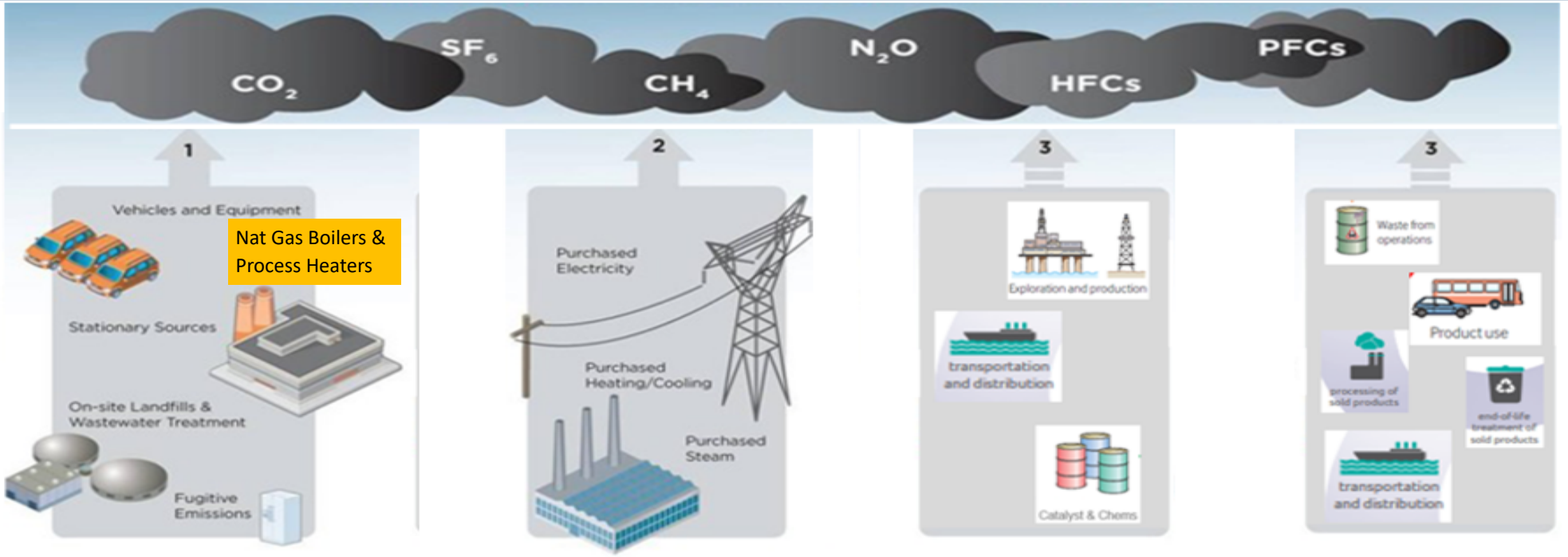
"Scopes" of GHGs



SCOPE 1:
Greenhouse gas emissions from sources owned or operated by company

SCOPE 2:
Greenhouse gas emissions from the generation of energy (elect, heat/steam, cooling) purchased by the company

SCOPE 3:
Greenhouse gas emissions from sources not owned or operated by company *but used in company activities*

SCOPE 3:
Greenhouse gas emissions from sources not owned or operated by company *but related to company activities*

Manufacturing – ~15% of World GHGs

2022

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Mitigate Manufacturing GHG emissions

Industrial-process innovation
Electrification of heat sources, green steelmaking, green cement making

Circular economy
Battery recycling, chemical cellulosic recycling, heat recovery, plastics recycling

Reduce carbon energy combustion

- Improve energy efficiency
  - Minimize process heat give-away
  - Electric replace steam driven pumps/comps

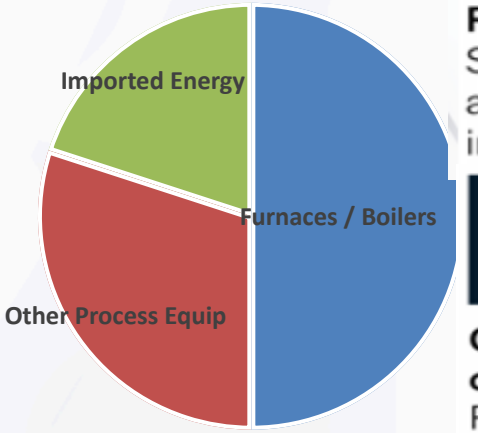
Fuel switch

- Import and/or generate "renewable" energy
- Renewable Nat Gas replace Nat Gas
- Green hydrogen co-mingle with or replace Nat Gas
- Others?

Capture emitted GHGs from carbon combustion

- For re-use (non-emitting)
- For sequestration

Mfg Example Source of GHGs



Renewables
Solar, wind (onshore and offshore), grid innovation

Carbon removal, capture, and storage
Point-source carbon capture, direct air capture

Hydrogen
Electrolyzers, fuel cells, methane pyrolysis

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Fugitives - ~5% of World GHGs

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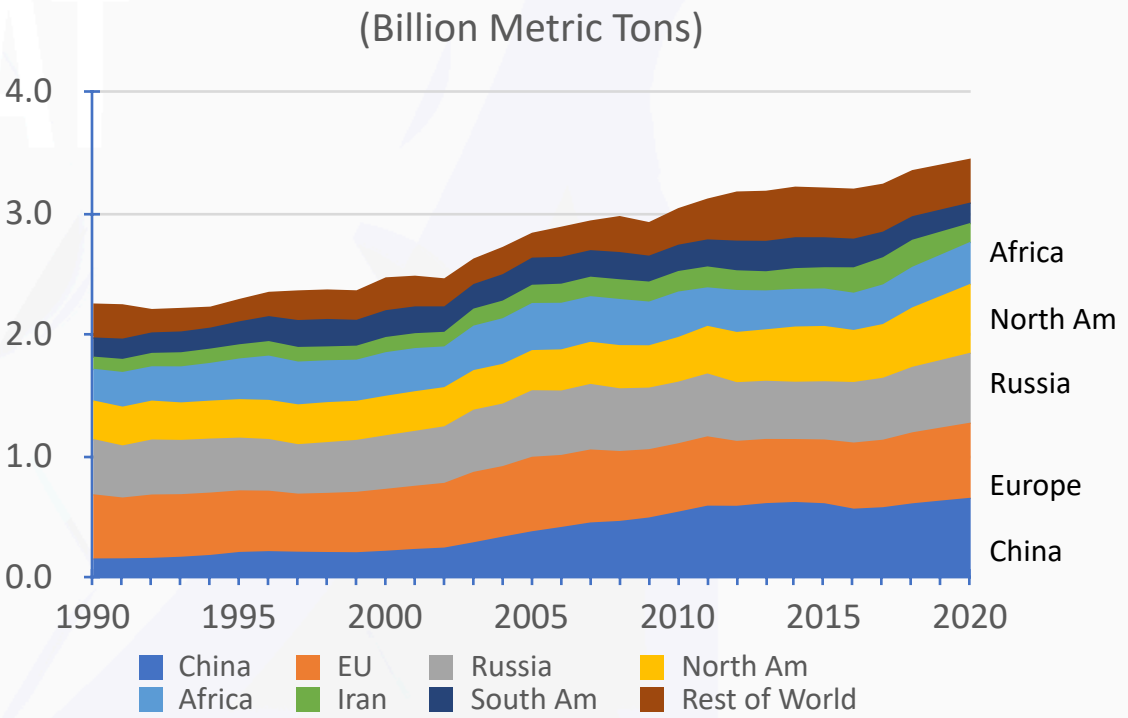
Sources – VOCs, Methane

- Valves & Components
- Tanks
- Landfills

Ways to mitigate

- Improve GHG data quality
  - real time vs estimates
- Improve fugitives monitoring
  - near real time vs periodic manual (M21)
    - cameras, sensors, etc.
- Low leak valves & components
- Dome tanks, capture and recycle vapors
- Capture landfill “renewable nat gas (RNG)”



Greatest opportunity for fugitives reductions:

China Europe Russia North America Africa

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Energy Consumed – ~30% of World GHGs

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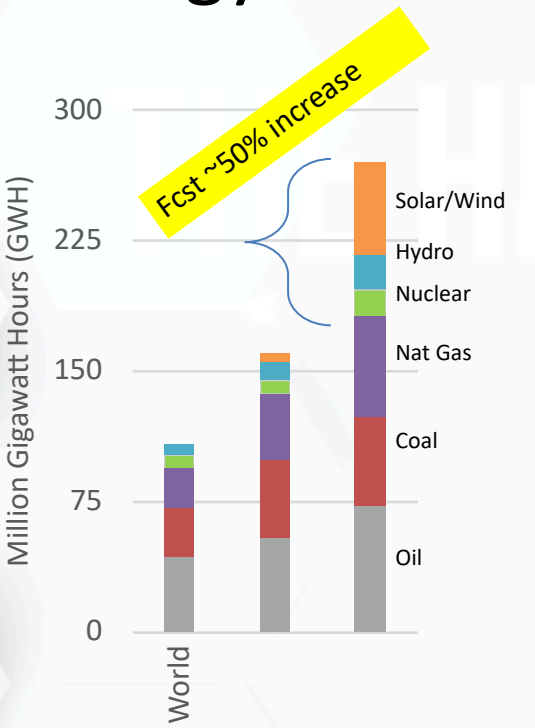

~10X increase in wind/solar
(*non-continuous, intermittent supply*)
Back-up supply needed:

- **Battery**
- ***"Dispatchable"* sources (ie. Nat Gas)**
- **"Stored" surplus renewables**

Renewables
Solar, wind (onshore and offshore), grid innovation

Hydrogen
Electrolyzers, fuel cells, methane pyrolysis

Batteries and energy storage
Electric-vehicle batteries, long-duration energy storage, pumped hydro

Carbon removal, capture, and storage
Point-source carbon capture, direct air capture

Solar: 5,000-10,000 acres per GW
Wind: 50,000-80,000 acres per GW

1 GW = 1 million kilowatts = Power for ~750,000 homes

Example - 50 Million GWh of solar
~250 million acres of solar farms

- Texas is ~170 million acres

Transportation – ~15% of World GHGs

2022

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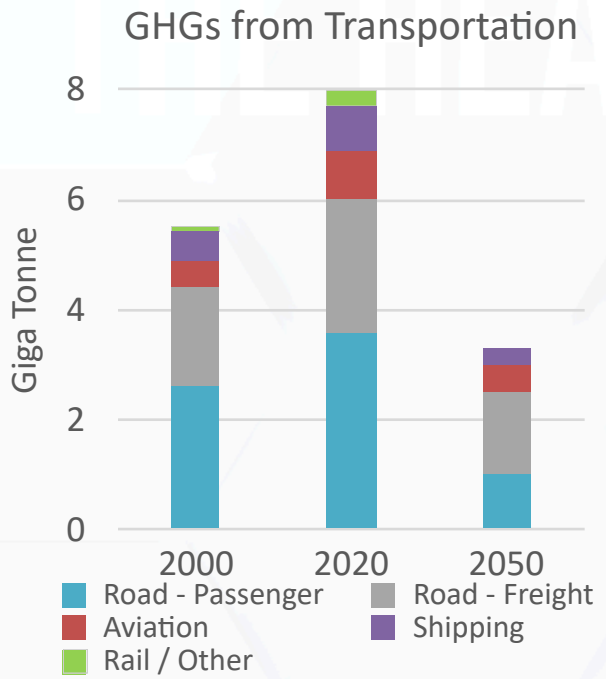
Sustainable fuels
Advanced biofuels, e-fuels

Batteries and energy storage
Electric-vehicle batteries, long-duration energy storage



GHG emission mitigations
Fuel carbon intensity (CI)
Battery, Plug-in hybrid EVs
Alternate Fuels – Biofuels, CNG, LNG, H2, fuel cells
Fuel energy intensity
Improved Internal Combustion Engine technology
Transport system infrastructure efficiency
Public transport, cycling, walking
Urban planning – reduce distance traveled
Modal shift – High speed rail

- Fcst - 75% reduction in passenger transport GHGs
- Significant transition in passenger transport “mix” and “mode”

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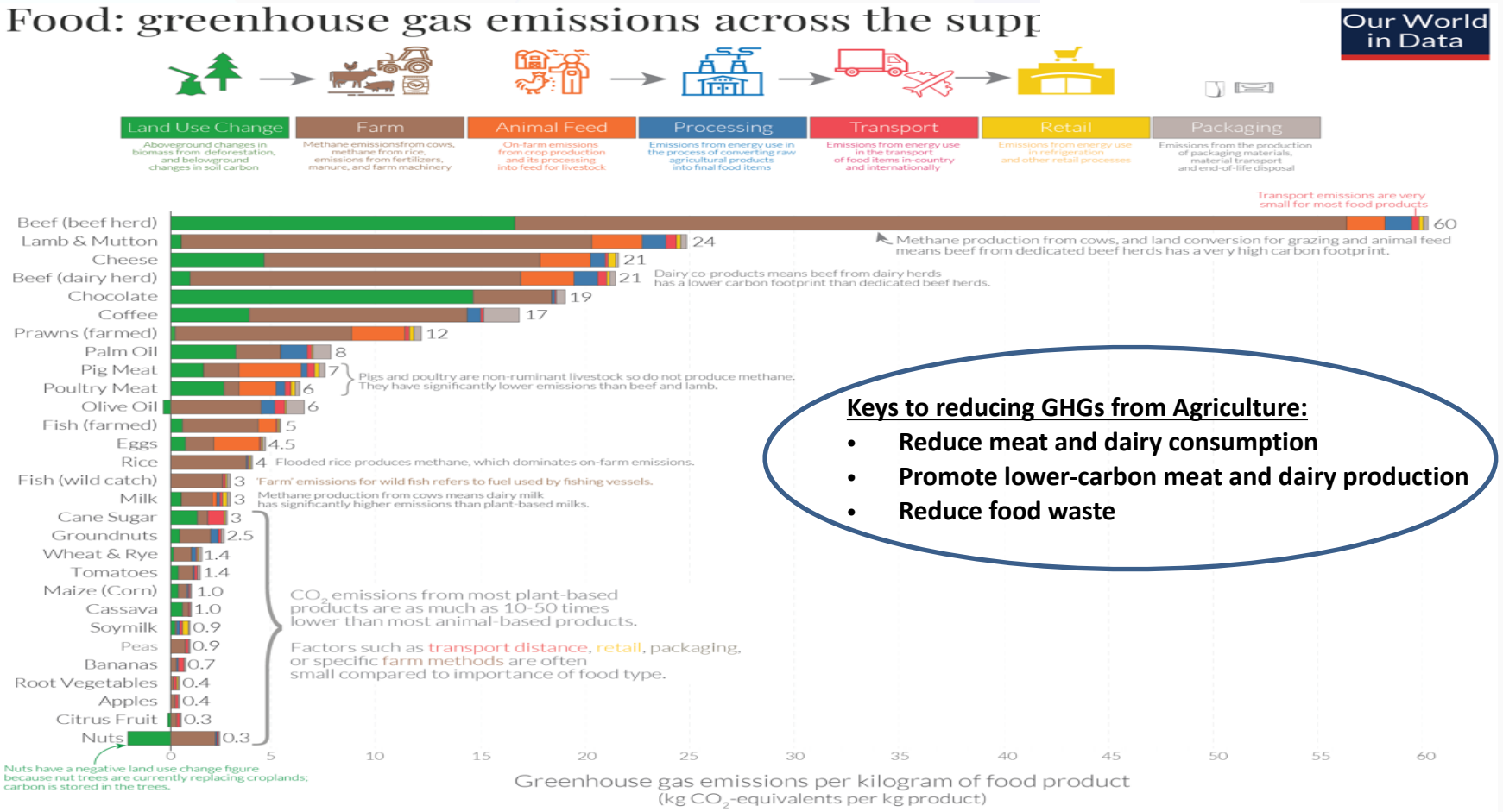
Agriculture & Land Use – ~20% of World GHGs

Agriculture and food
Precision agriculture, crop preservation, regenerative tech, alternative proteins

Nature-based solutions
Monitoring and verification for forests, peatlands, mangroves



Keys to reducing GHGs from Agriculture:

- **Reduce meat and dairy consumption**
- **Promote lower-carbon meat and dairy production**
- **Reduce food waste**

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Technologies to Watch

2022

Technologies to watch

Electrification

- Electric-vehicle batteries
- Battery-control software
- Efficient building systems
- Industrial electrification

Agriculture

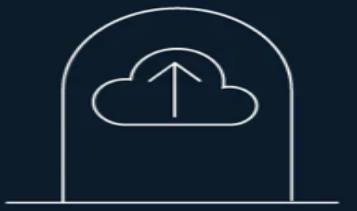
- Zero-emissions farm equipment
- Meat alternatives
- Methane inhibitors
- Anaerobic manure processing
- Bioengineering

Power grid

- Long-duration storage
- Advanced controls
- Software and communications
- Vehicle-to-grid integration
- Building-to-grid integration
- Next-generation nuclear
- High-efficiency materials

Hydrogen

- Low-cost production
- Road-transport fuel
- Ammonia production
- Steel production
- Aviation fuel



Carbon capture

- Pre- and postcombustion capture technologies
- Direct air capture
- Bioenergy with carbon capture and storage
- Biochar
- CO_2-enriched concrete

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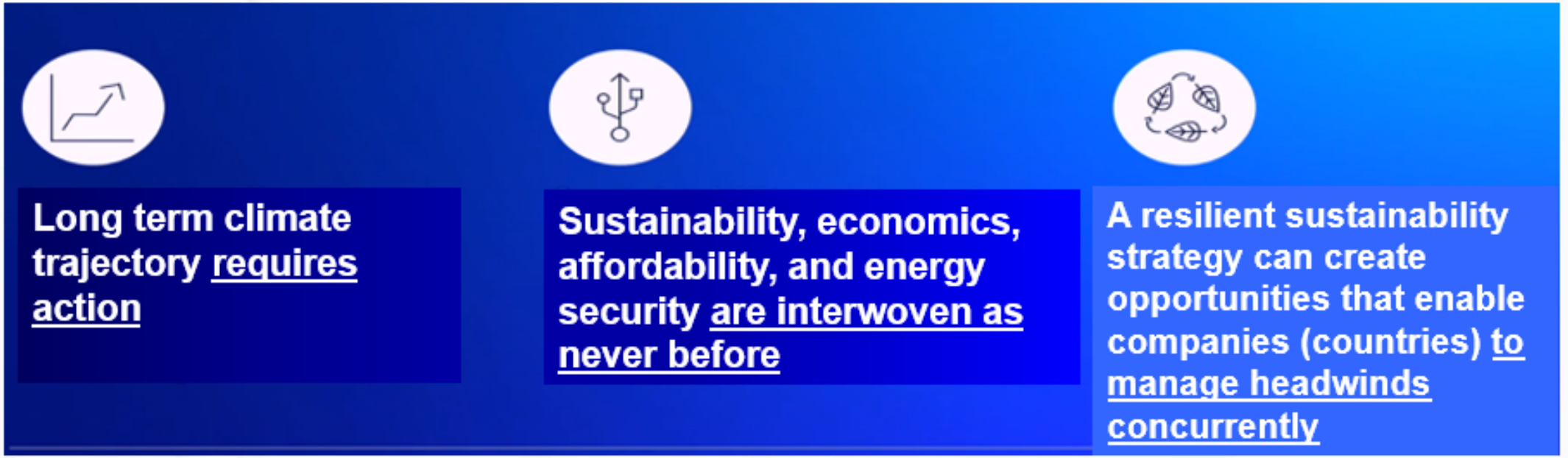
Mitigation and Adaptation

Companies benefit – adjust to the present while focusing on the future



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Thank You

And

Enjoy The Conference

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