Energy research to provide solutions for the dual challenge

Adam Usadi
Energy Center Advisor
ExxonMobil

Decarbonisation Technical
Workshop of Energy Innovation

SINGAPORE ENERGY CENTRE

NUS National University of Singapore
NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE
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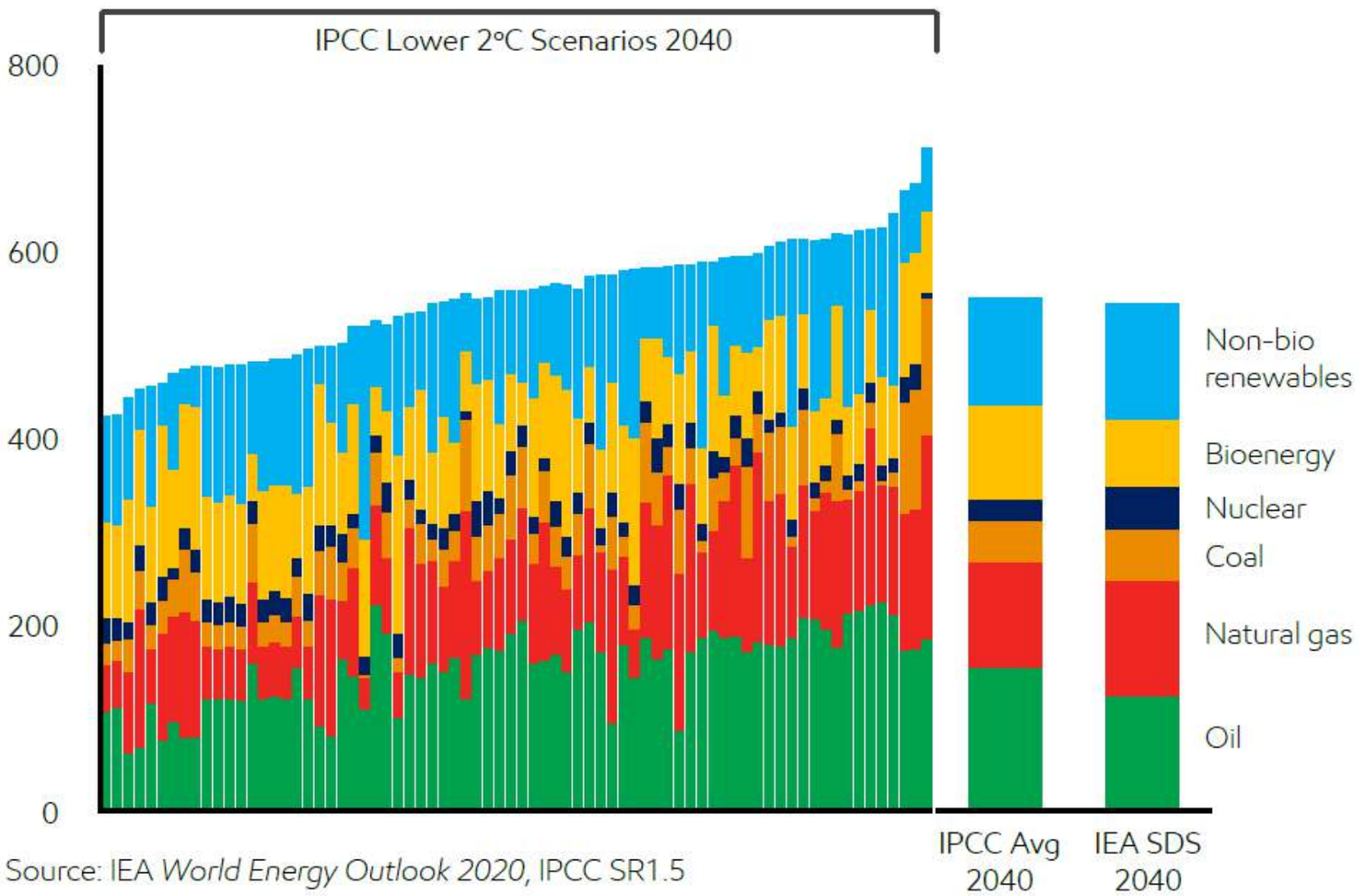
IPCC expects a diverse energy mix in achieving 2°C

2040 global energy demand mix across IPCC Lower 2°C scenarios

(Exajoules)



Source: IEA *World Energy Outlook 2020*, IPCC SR1.5

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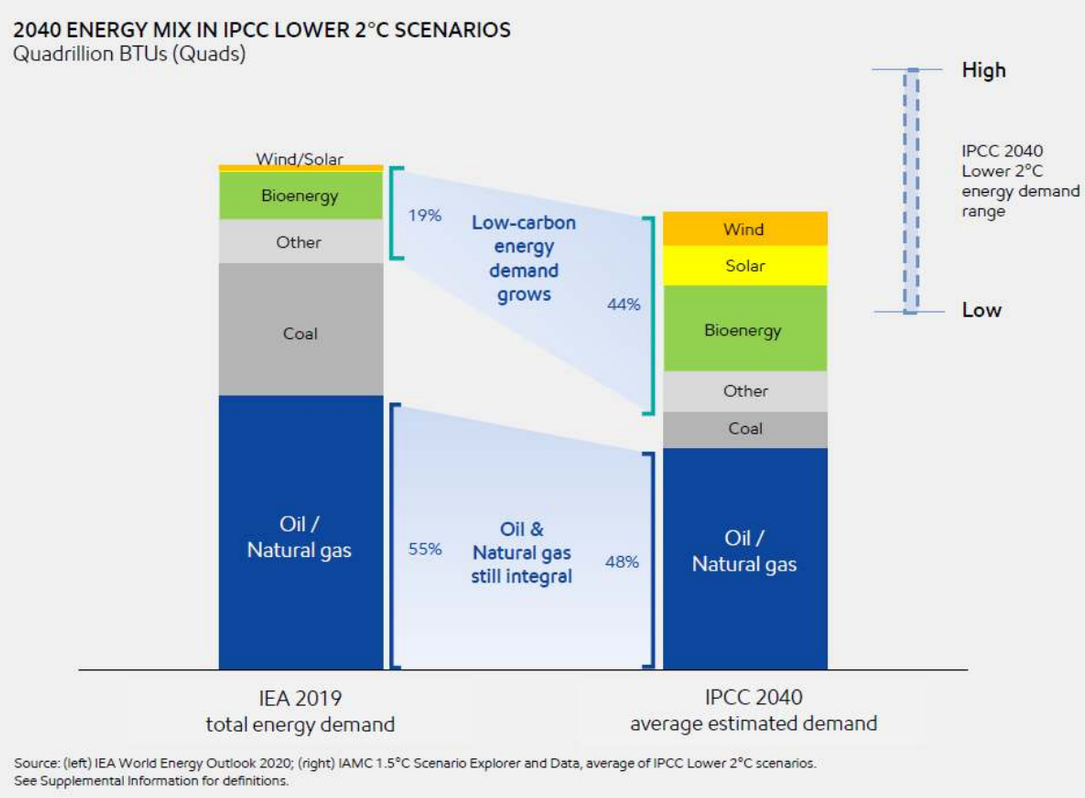
IPCC expects a diverse energy mix in achieving 2°C



- Substantial efficiency gains needed to offset population and economic growth
- Significant growth in low carbon energy
- Oil and natural gas remain essential

Actual signposts suggests 2° C pathway is challenging

Summary of demand growth rates Mean annual demand growth rate 2010-2040		Average of the IPCC Lower 2°C[19]	ExxonMobil 2019 Outlook for Energy	IEA World Energy Outlook 2010-2019
Energy demand	●	▲ 0.3%	▲ 0.9%	▲ 1.3%
Oil	●	▼ (0.5)%	▲ 0.8%	▲ 1.1%
Natural gas	●	▼ (0.1)%	▲ 1.4%	▲ 2.2%
Coal	●	▼ (4.5)%	▼ (0.2)%	▲ 0.4%
Nuclear	●	▲ 2.5%	▲ 1.5%	▲ 0.1%
Bioenergy	●	▲ 2.3%	▲ 0.8%	▲ 1.3%
Non-bio renewables	●	▲ 6.9%	▲ 4.1%	▲ 6.0%

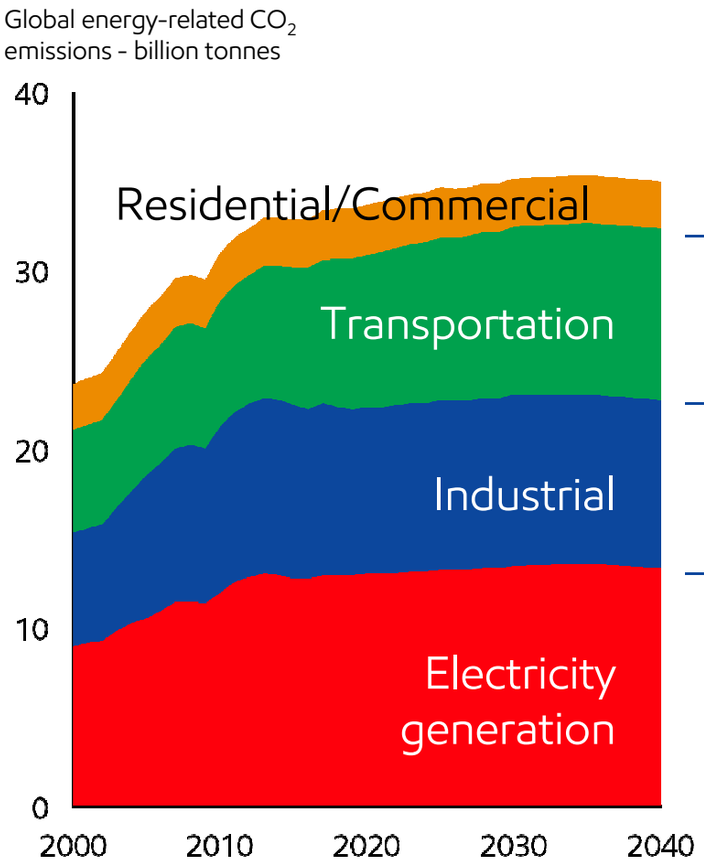
Annual reduction carbon intensity/GDP[28]
(monitoring implementation of Paris Agreement)

7.7%
Needed to stay within 2°C global carbon budget

2.4%
In 2019

Source: 2021 Investor Day content and Updated 2021 Energy & Carbon Summary

CO_2 emissions mitigation requires focus on large scale challenges



R&D focused on enabling and increasing options by reducing costs, physical footprint

Materials (Construction + Operations)

Hydrocarbons+ batteries + H_2 + Biofuels

Catalysts + Processes + CCUS + H_2 (Heating, cooling, pumping)

Natural Gas + CCUS + Renewables + Energy Storage

Source: *2019 Energy Outlook*

Global pandemic and economic downturn may affect details of future projections, but not technical focus of emissions reduction effort

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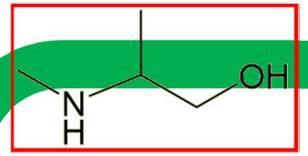
CCS R&D focused on reducing costs, complexity, footprint

Source | Material | Contactor | Process | CO_2 Disposition

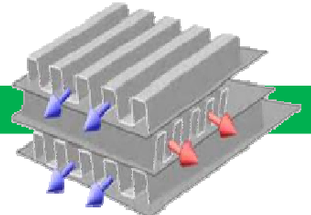
Industrial 8-60 %

Power 4-14 %

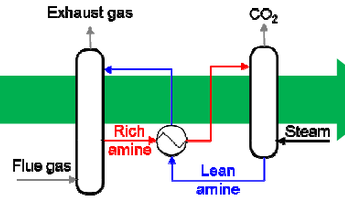
Direct Air 0.04%



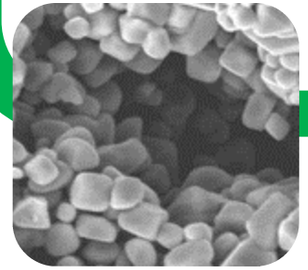
Liquid/Solid



Advanced Contactors



Steam Stripping /Swing Processes

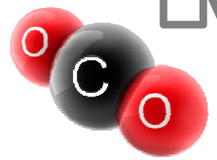


Fuel Cell

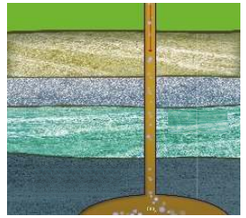
Fuel Cell Stack

Fuel Cell Process

Cleanup, Compress



> 95% CO_2 2200 psig



Sequester underground

Convert into chemicals, fuels…

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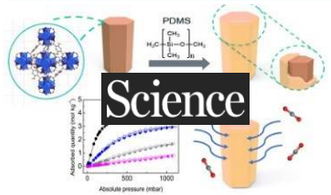
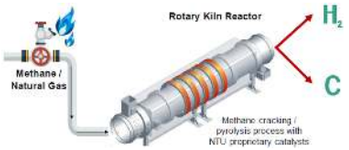
Singapore Energy Center – Example R&D projects/topics

Core Research Projects

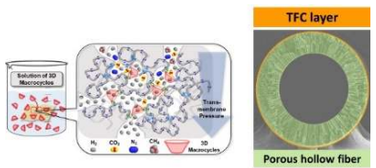


Moisture-Resistant MOFs for CO_2 Capture.

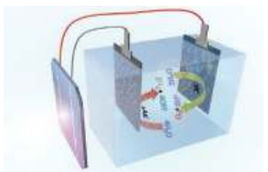


Low-cost robust self-supported catalyst beads for CH_4 cracking

CCU using incineration bottom ash and seawater desalination brine wastes.



Novel membranes for hydrogen separation and CO_2 capture.

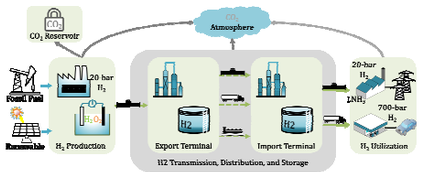


Seawater (photo)-electrolysis for renewable H_2 production

ExxonMobil Collaborative Topics

Develop novel, advanced, stable Materials for CO_2 capture.

Elucidate CO_2 sequestration options for ASEAN



Explore hydrogen development pathways for Singapore / ASEAN

Discover novel biomaterials, and synthesis pathways

SgEC: https://sgec.sg/coreprojects/year-2019/

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Supplemental information

- **Lower 2°C scenarios**. The Intergovernmental Panel on Climate Change (IPCC) published a Special Report on "Global Warming of 1.5°C" and identified 74 scenarios as "Lower 2°C," which are pathways limiting peak warming to below 2°C during the entire 21st century with greater than 66 percent likelihood.
- This presentation includes a number of third party scenarios such as the 74 Lower 2°C scenarios, made available through the IPCC SR 1.5 scenario explorer data, and the IEA's Stated Policies Scenario as well as the IEA's Sustainable Development Scenario. These third party scenarios reflect the modeling assumptions and outputs of their respective authors, not ExxonMobil, and their use and inclusion herein is not an endorsement by ExxonMobil of their likelihood or probability. The analysis done by ExxonMobil on the IPCC Lower 2°C scenarios and the representation thereof aims to reflect the average or trends across a wide range of pathways. Where data was not or insufficiently available, further analysis was done to enable a more granular view on trends within these IPCC Lower 2°C scenarios.

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