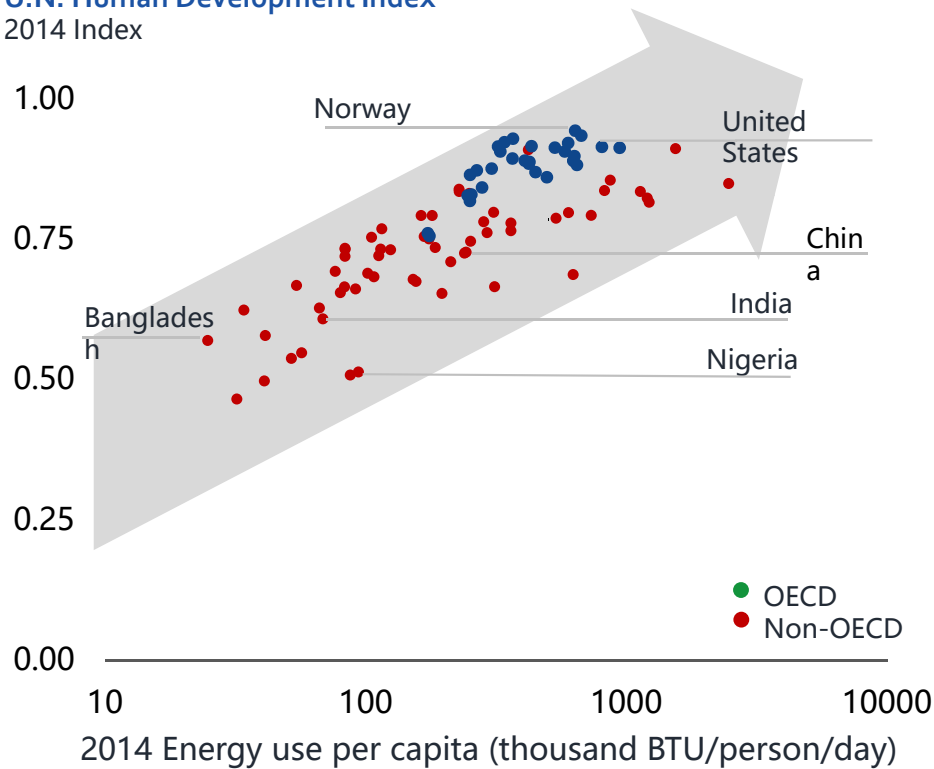
An aerial photograph of a large industrial research and engineering facility, likely an ExxonMobil site. The facility consists of several large, interconnected brick buildings with flat roofs, surrounded by extensive parking lots. The site is situated in a lush, green landscape with rolling hills and a large, blue lake in the background. The sky is clear and bright, suggesting a sunny day.

ExxonMobil Meeting the Dual Energy Challenge

*Ken Del Rossi
Manager, Process Technology Department
ExxonMobil Research and Engineering Company
July 16, 2019*

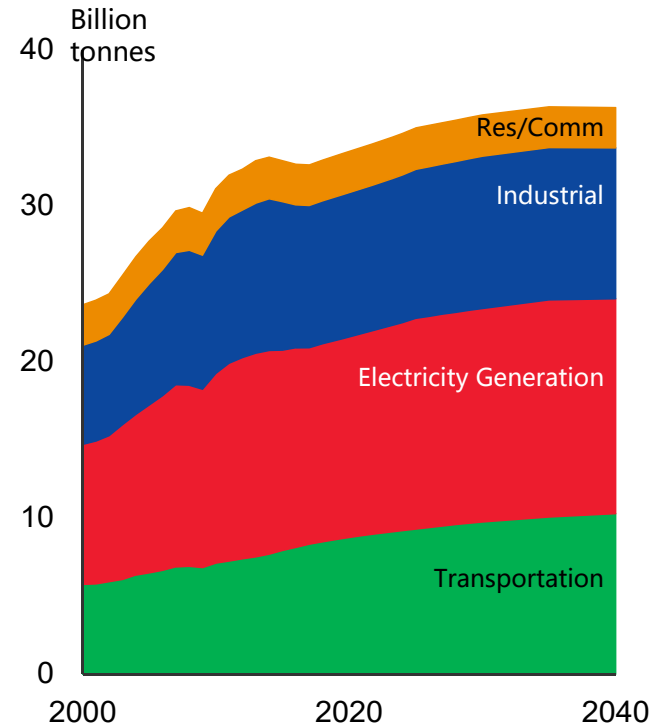
The dual challenge: providing energy while reducing emissions

U.N. Human Development Index
2014 Index



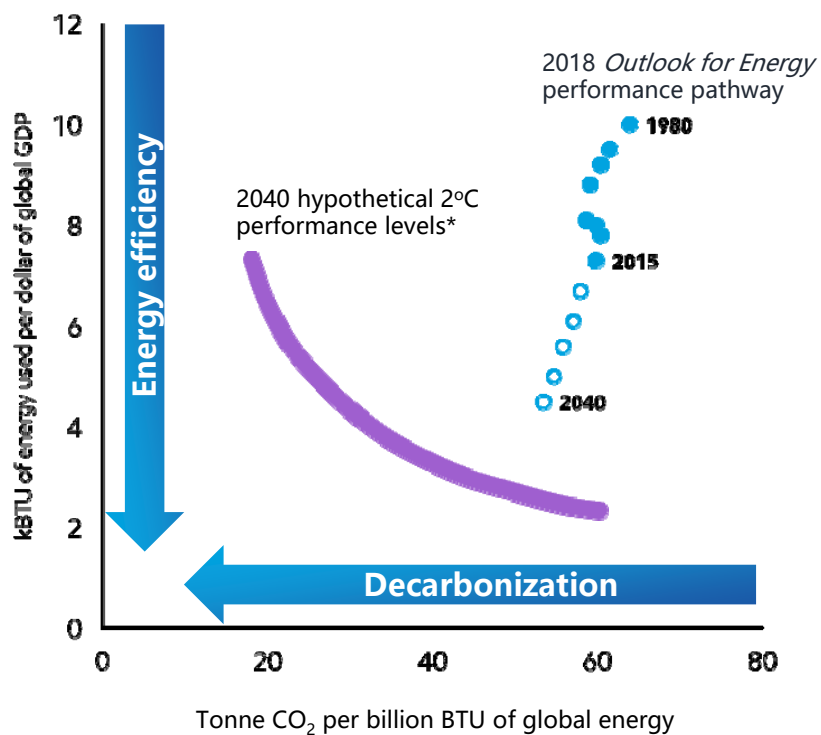
Source: United Nations, ExxonMobil estimates

Sector related CO₂ emissions



Source: EO18

Significant advances required



Indicators of a 2°C pathway

2010 → 2040

Energy use per unit of GDP

Down 50%

Low-GHG electricity

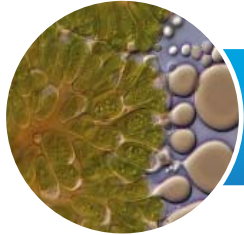
33% →
80%

Biofuels

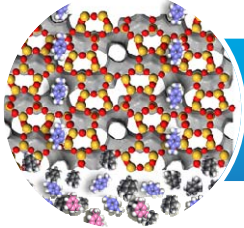
1% →
15%

*Based on average Stanford EMF27 full technology / 450ppm scenarios' CO₂ emissions (~20 billion tonnes including energy and industrial processes), ExxonMobil GDP assumptions consistent with 2018 *Outlook*

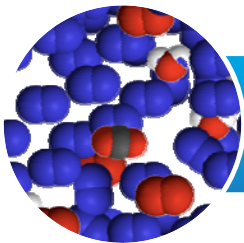
ExxonMobil is working on technology solutions



Biofuels: Affordable and scalable lower-carbon fuels



Process Intensification: Innovative process and/or equipment design with energy-efficient operations

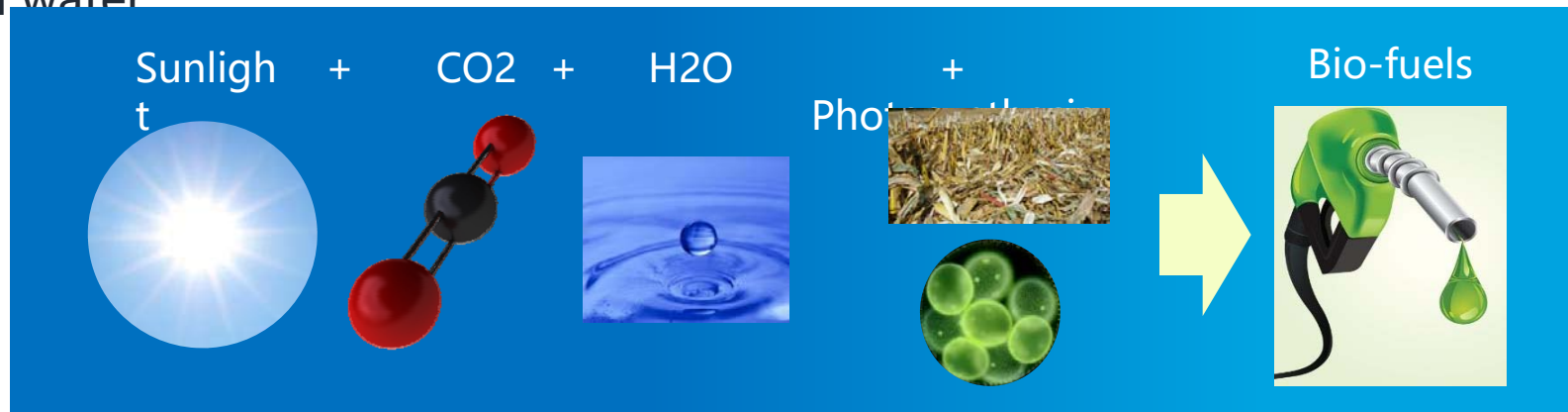


Carbon Capture and Sequestration: Technology options to maximize efficiency and reduce cost

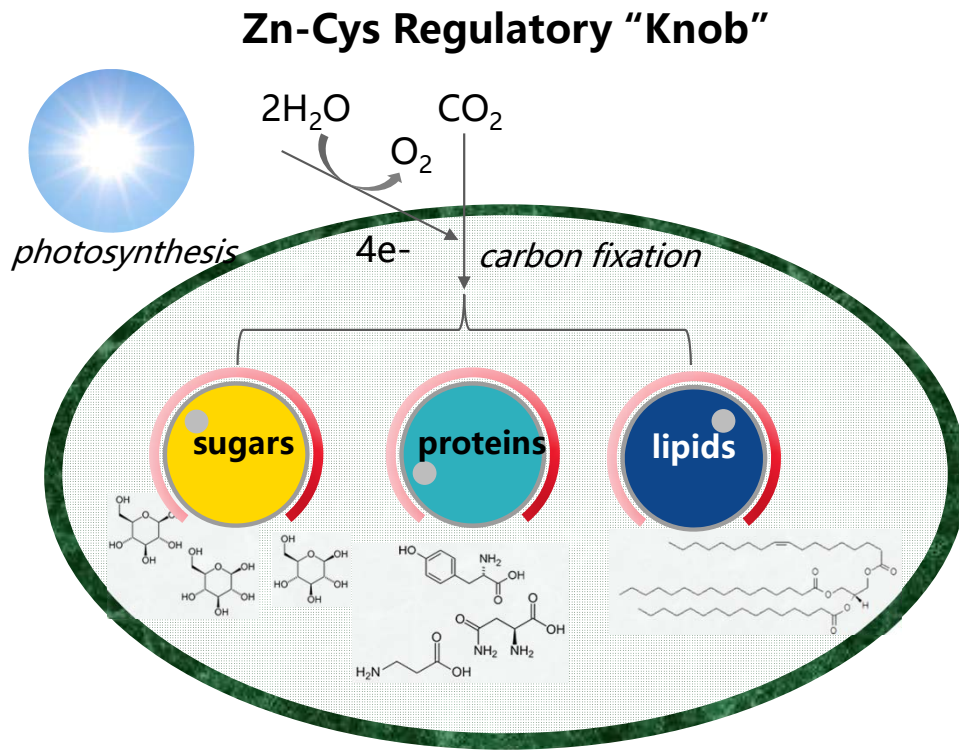
Low emissions transportation with advanced biofuels

Today's approach: Distributed, limited scalability, competes with food and water

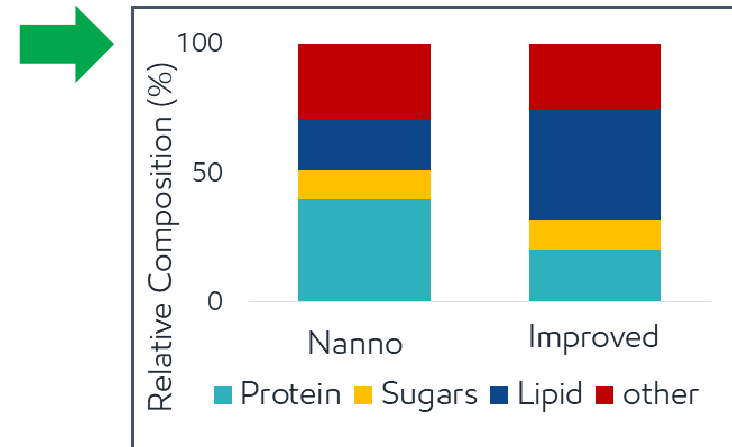
Our research: Global solutions, scalable, non-competitive with food and water



Advances in algae biofuels production



Targeting 10 kbd by 2025



Process Intensification for lower emissions

Today's approach: Energy intensive and complex

Our research: Novel reactor and separations materials, less energy

Near term step: Lab scale fundamentals leading to pilot plant trials



+



+



Fuels
Chemicals

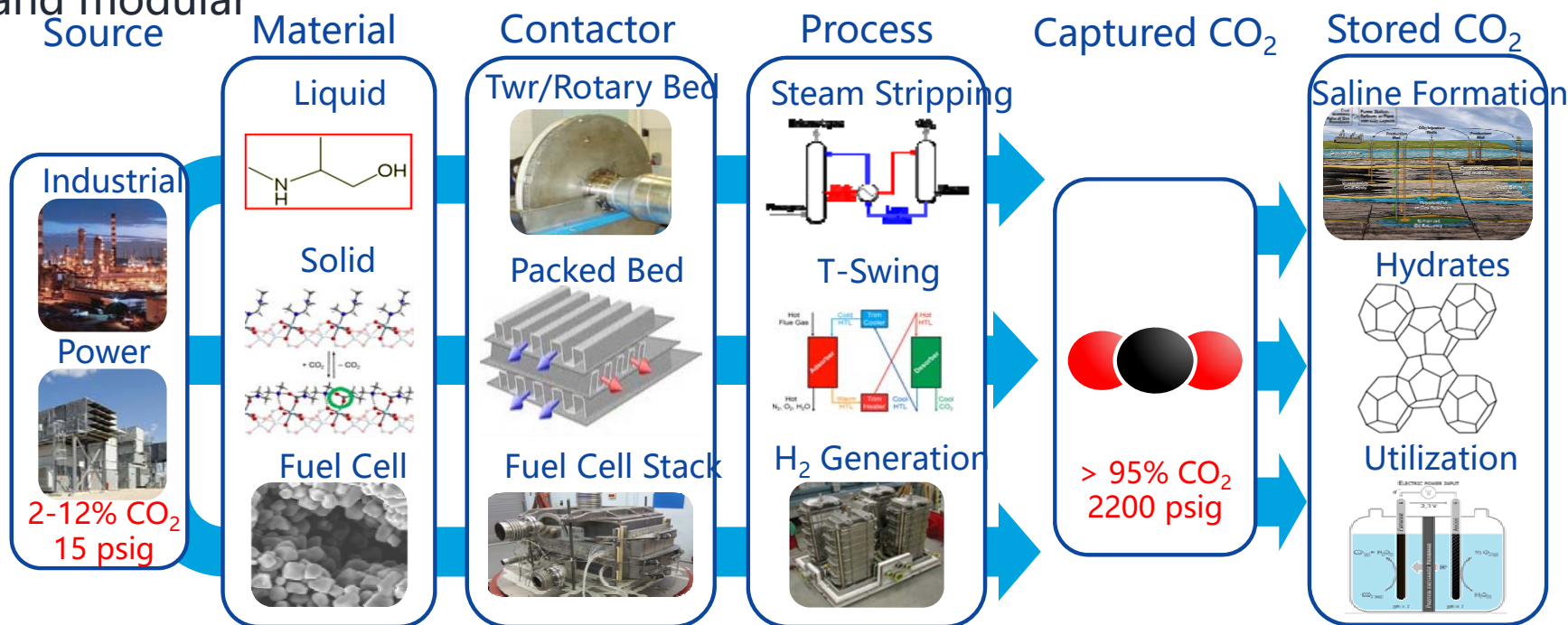
Targeting >25% reduction in CO₂ emissions from processing plants

Carbon Capture, Utilization, and Storage

Today's approach: Power consuming, complex

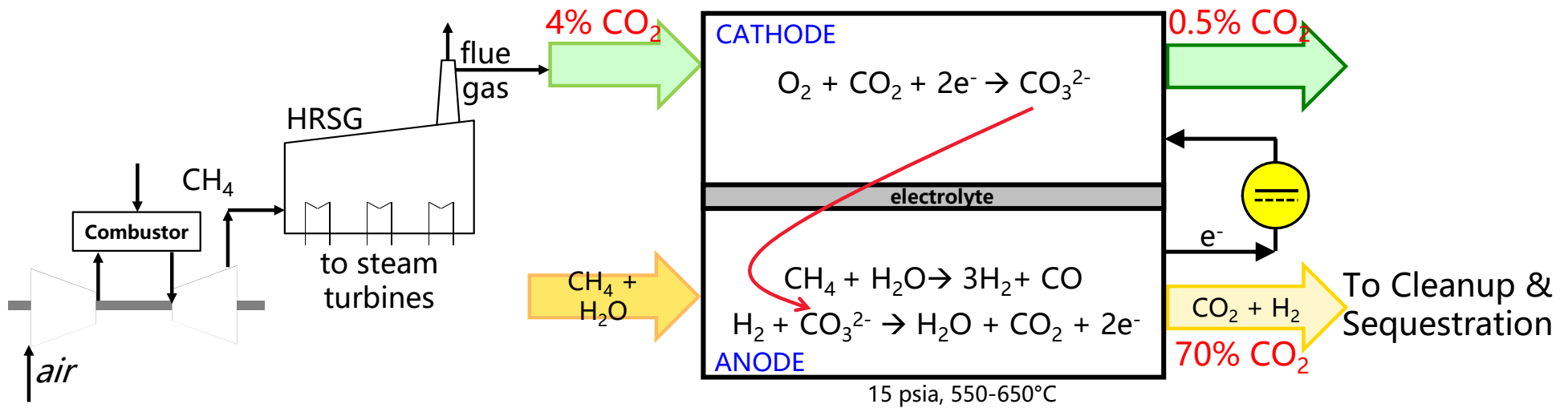
Our research: Capture options seeking power gen or min power loss

and modular



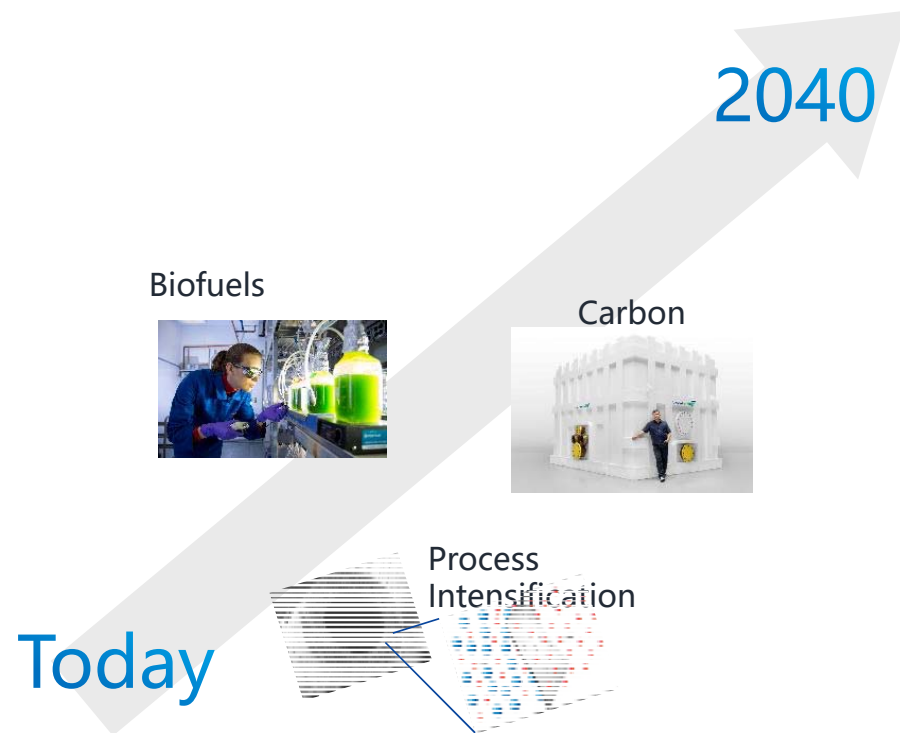
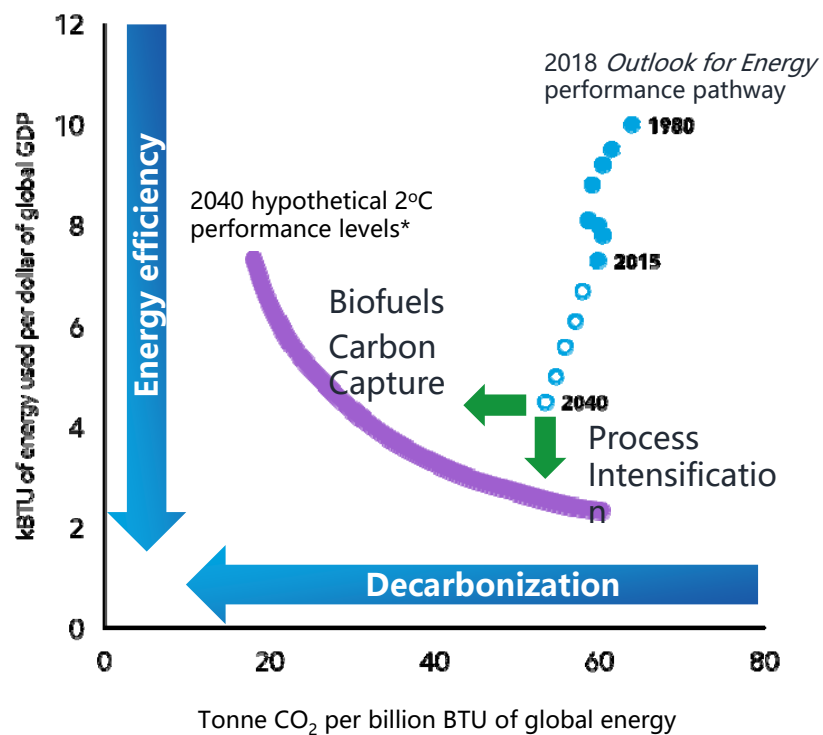
Note: Many other permutations and options exist that are not shown here

Carbonate fuel cells for CO₂ capture



- Cathode reduces O₂ and combines with a CO₂ to form CO₃²⁻
- Anode reforms methane (and larger hydrocarbons) to H₂
- Carbonate ion is transported to the anode through the molten electrolyte
- At the anode, CO₃²⁻ ions oxidize H₂ to H₂O and generate 2 electrons for circuit

ExxonMobil advancing technology solutions



ExxonMobil