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Scenario Comparison

Shell Sky and Energy Outlook Scenario D

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Shell Scenarios: Mountains, Oceans and Sky

All three scenarios based on energy system modeling to 2100 (MIT models referenced)

- Persistent / widespread application of CO₂-targeted policy framework, including large scale renewables and CCS

2013 Scenarios (Mountains and Oceans) outline routes leading to net zero emissions around 2100 (short of Paris goal)

- Mountains: more government-led with a top down approach
- Oceans: more bottom-up with a market-driven outcome

2018 Scenario (Sky) holds in the increase in global average temperature to well below 2 deg C

- Outlines "plausible pathway for the future": decarbonizes the global economy, achieves net-zero emissions by 2070
- Achieved via better multi-lateral collaboration to tackle climate and air quality issues
- Fundamental premise is an extension of current efforts is insufficient for the scale of change required
- Necessary transformation requires climate policy action and deployment of disruptive technology at mass scale with strong govt. policy incentivizing innovation and investment

Key Sky assumptions

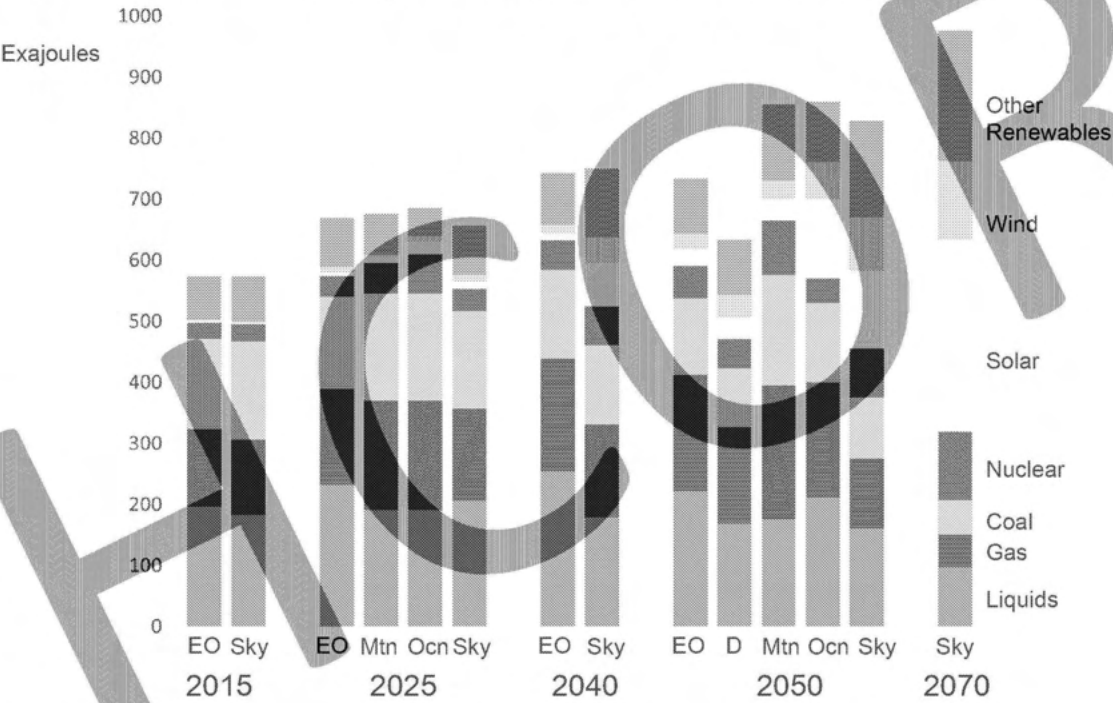
Sky – from now to 2070

1. Consumers preferentially choose low-carbon, high-efficiency options
2. Step-change in efficiency of energy use
3. **Global carbon pricing mechanisms by 2020s; cost of CO₂ embedded in consumer goods and services**
4. **Rate of electrification of final energy triples; global electricity generation is 5x today's level**
5. New energy sources grow up to 50 fold; primary energy from renewables surpasses fossil fuels in 2050s
6. **10,000 large CCS facilities are built, compared to 50 in operation in 2020**
7. Net-zero deforestation; additionally, an area the size of Brazil is reforested

Sample commentary on assumptions:

- Rate of decline in global emissions after 2035 exceeds the rate of growth seen in this century – massive achievement
- Requires complex combination of mutually reinforcing drivers being rapidly accelerated by society, markets and governments
- Concurrent climate policy, disruptive technology at mass scale incentivized by gov't policy for investment and innovation
- First 10 yrs assumes aggressive but plausible capacity-building and ratcheting of policy commitment; after which uncertainties much greater but take full account of characteristics of scale, tech substitution and investment in various sectors of economies required
- Coal: lack of clear development pathway for emerging economics without coal; smelting to make iron required for urbanization and industrialization

Comparison of Primary Energy by Source



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"Other Renewables" includes hydro, geothermal, biomass, and biofuels

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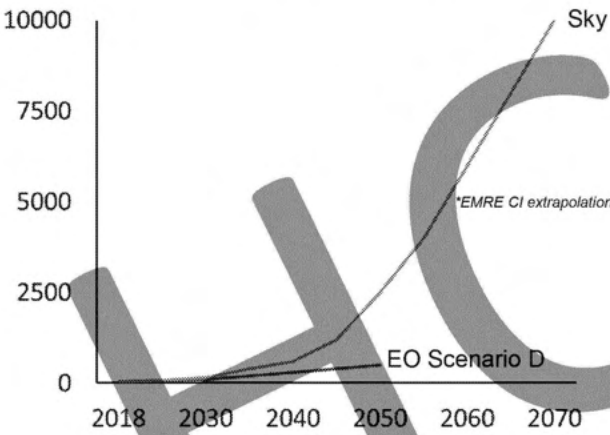
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Scenario D and Sky Comparison

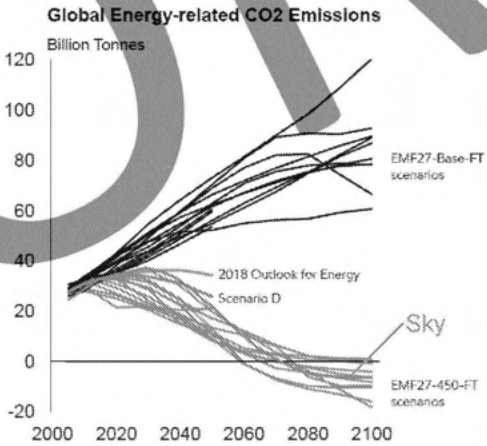
- Similarities:
 - Nations create more stringent policies in the 2025+ timeframe that drive change
 - Major emerging markets (e.g. China) key; requires cost of carbon increase (Sky 2050: \$80-\$175/T, 2070: \$200/T)
 - 2050 estimates of overall oil, gas, coal usage are within 10% (refer to slide 19)
 - Liquid fuels peak in 2020s with large increase in biofuels driven by commercial transportation
- Major differences :
 - Economic impact assumptions (GDP CAGR: Sky +3%, Scenario D -0.3%) and energy demand directional vectors
 - Sky shows increasing energy demand to 2070; EO and Scenario D show declines
 - Sky assumes unspecified tech breakthroughs (e.g. batteries, CCS, H₂) that occur in the 2050– 2070 timeframe
 - Scenario D has ~30% reduction in LDV vehicle miles travelled (VMT) and/or size of car fleet
 - Sky assumes significant re-forestation as means to consume CO₂
- Sky lays out vision for changes needed to attain goals of Paris agreement... and the scale of associated challenges
 - Stresses policy government incentives required
 - Highlights timing for historic evolution of energy systems / business models
 - Constructively acknowledges issues (e.g. lack of low C solutions for certain transport, cement mfg, smelting, some chemical processes, glass mfg, even power.... where some support from conventional needed in 2050)
 - Accepts that technology disruptions will occur in the next 50 years as new value chains created

CCS and CO₂ Emission Breakdown

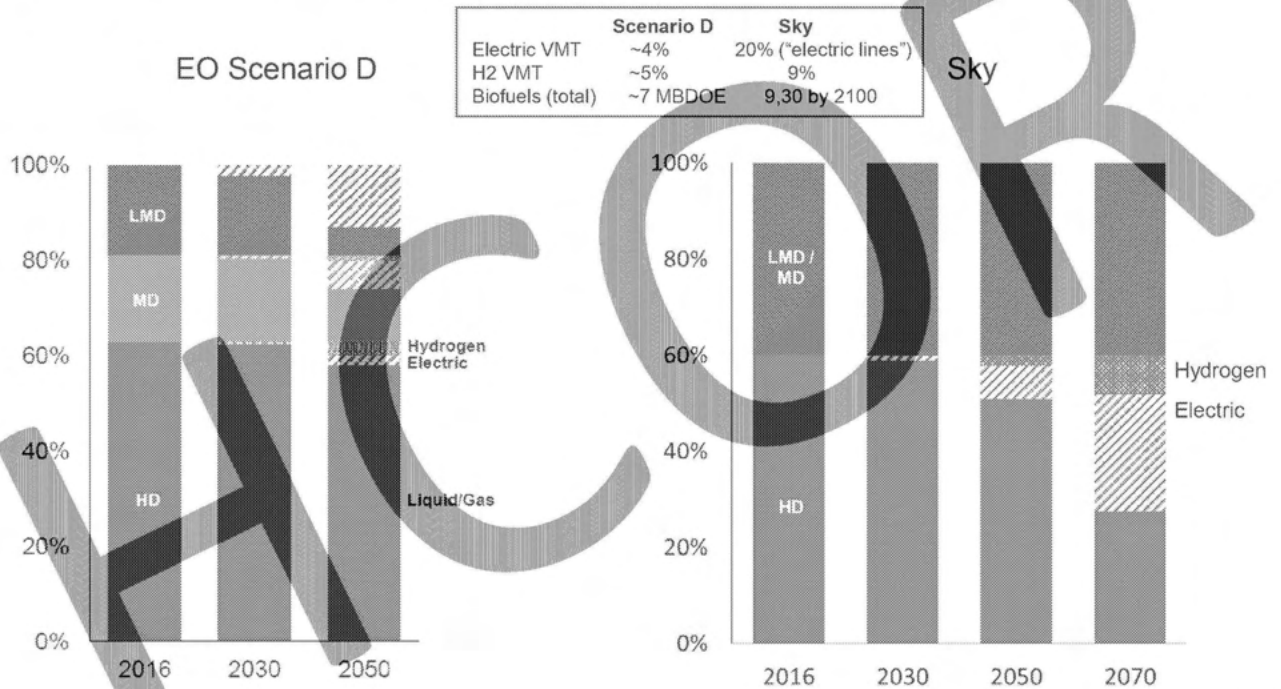
CCS Facilities



CO₂ emissions

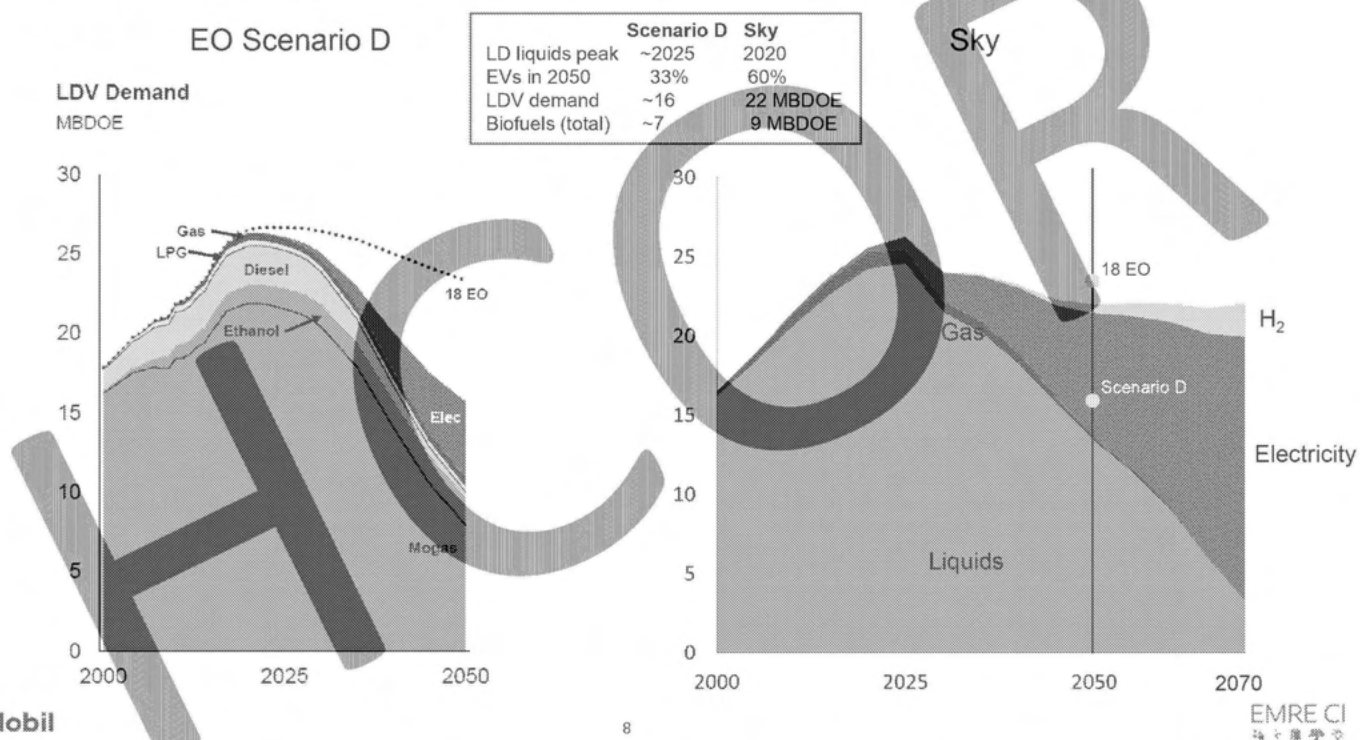


NA Heavy Duty VMT Breakdown



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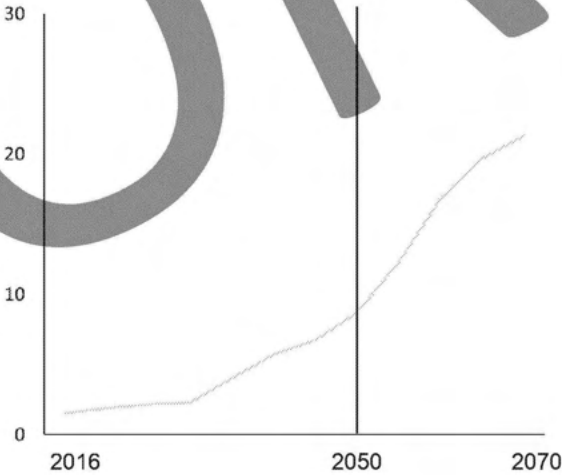
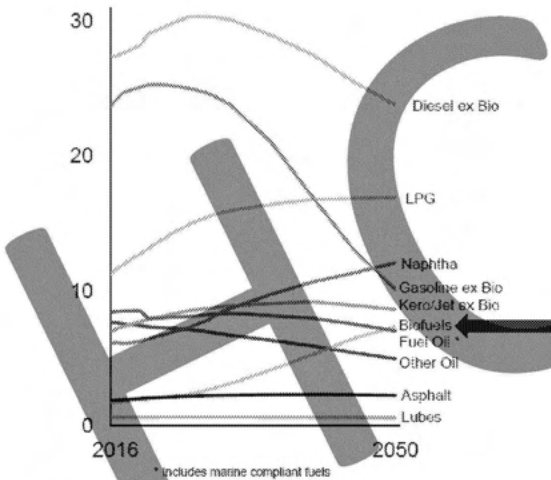
Light Duty Energy Demand Comparison



Biofuels Breakdown

EO Scenario D

Demand By Liquid Fuel
MBDOE



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Additional slides

Key assumptions Scenario D

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- Broad resolve to tighten NDCs leads to more stringent policies 2025+
 - China is a catalyst; leverages business opportunity
 - Economics and energy security still important considerations
 - Societal cost reflected in higher proxy costs, lower GDP growth
- No step change in technology
 - Policy makers favor wind/solar and EV technology
 - Wind/solar penetration 'feasible but costly' w/o grid storage
 - EVs dominate car sales 2040+; make in-roads into trucking
 - CCS and hydrogen are deployed, but global scale is limited
- In 2050 (vs 18 EO):
 - Global GDP -10% (-0.3% CAGR); CO₂ proxy costs doubled
 - Energy-related CO₂ emissions are 25% lower
 - Oil and coal demand are down ~25% and gas ~15%
 - Biofuels are doubled; wind/solar generation + 50%
 - Nuclear and other renewables are largely unchanged

Prediction is very difficult, especially about the future.

-Niels Bohr



1961: "There is practically **no chance** communications space satellites will be used to provide **better** telephone, telegraph, television or radio service inside the United States." — T.A.M. Craven, FCC commissioner

1966: "Remote shopping, while **entirely feasible**, will flop." — Time Magazine

1981: "Cellular phones will **absolutely not** replace local wire systems." — Marty Cooper, inventor

2005: "There's **just not** that many videos I want to watch." — Steve Chen, CTO and co-founder of YouTube

2007: "There's **no chance** that the iPhone is going to get any significant market share." — Steve Ballmer, Microsoft CEO

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