Plenary Session 2:

Asia: Center of Demand and Engine of Accelerated Growth and Innovation

Background Paper
Disclaimer

The observations presented herein are meant as background for the dialogue at the 9th Asian Ministerial Energy Roundtable. They have been prepared in collaboration with Boston Consulting Group and should not be interpreted as the opinion of the International Energy Forum or Boston Consulting Group on any given subject.
Contents

1. Climate change is real
2. Asia has become center of global market growth
3. Asian countries' advancements and challenges in shifting towards innovative low carbon solutions
4. Role of technology in carbon reduction, energy efficiency and transition
5. Role of collaboration in energy transition
6. Key questions and discussion
Contents

1. Climate change is real
2. Asia has become center of global market growth
3. Asian countries' advancements and challenges in shifting towards innovative low carbon solutions
4. Role of technology in carbon reduction, energy efficiency and transition
5. Role of collaboration in energy transition
6. Key questions and discussion
Climate change is posing significant challenges to human civilization

**Impacts in 2100**

**1.5° Paris ambition**

-8 % GDP\(^1\)

- +2 months of droughts\(^2\)
- 41% more burned area in wildfires
- Rising sea levels displace 46 million people; sea level rise of 48cm

**2° Paris goal**

-13 % GDP\(^1\)

- +4 months of droughts\(^2\)
- 62% more burned area in wildfires
- Fewer opportunities for infrastructure adaptation; sea level rise of 56cm

**4+° Current path**

-30 % GDP\(^1\)

- +>10 months of droughts\(^2\)
- 97% more burned area in wildfires
- 470-760 million people at risk; sea level rise of nearly 9 meters

---

1. Per capita, relative to no additional warming 2. Increase in avg. drought duration 3. Severe risk of close-to-annual occurrence

Note: Temperature increase refers to global warming by 2100

Source: UN Intergovernmental Panel on Climate Change (IPCC); Burke et al
Our understanding of climate risks has grown substantially

- **Increasing frequency of extreme weather**: 2x-4x Increase in yearly weather catastrophes since 1980
- **Rising sea levels**: 1-2m Sea level rise over the next decade
- **Risk of displacement**: 2B People could become climate refugees due to rising sea levels by 2100
- **Economic slow-down**: -7.2% Global loss in GDP/Capita by 2100 (relative to no global warming)
- **Growing investor pressure**: $34T AUM by climate sensitive investors
- **Increasing damages**: $222B Average yearly disaster related cost of the last 10 years
- **Cities at risk**: 570 Cities likely to be affected by 0.5m sea level rise by 2050
- **Uncertain projections**: 2X Rate at which sea levels could rise faster than projected

Contents

1. Climate change is real
2. Asia has become center of global market growth
3. Asian countries' advancements and challenges in shifting towards innovative low carbon solutions
4. Role of technology in carbon reduction, energy efficiency and transition
5. Role of collaboration in energy transition
6. Key questions and discussion
Global energy consumption will be driven by growth in Asia

Sources: Natural Earth Country boundaries without large lakes; Natural Earth Country breakaway and disputed areas, BP Energy Outlook, BP Energy Statistics 2022, UN
Asia shows higher growth compared to the rest of the world across drivers

### Population (in Billions)

<table>
<thead>
<tr>
<th>Year</th>
<th>Asia</th>
<th>ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>7.80</td>
<td>5.17</td>
</tr>
<tr>
<td>2021</td>
<td>7.88</td>
<td>5.29</td>
</tr>
<tr>
<td>2030 (P)</td>
<td>8.51</td>
<td>5.17</td>
</tr>
<tr>
<td>2040 (P)</td>
<td>9.16</td>
<td>5.29</td>
</tr>
<tr>
<td>2050 (P)</td>
<td>9.69</td>
<td>5.29</td>
</tr>
</tbody>
</table>

### Energy consumption (in EJ)

<table>
<thead>
<tr>
<th>Year</th>
<th>Asia</th>
<th>ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>257</td>
<td>307</td>
</tr>
<tr>
<td>2021</td>
<td>272</td>
<td>323</td>
</tr>
<tr>
<td>2030 (P)</td>
<td>312</td>
<td>358</td>
</tr>
<tr>
<td>2040 (P)</td>
<td>367</td>
<td>345</td>
</tr>
<tr>
<td>2050 (P)</td>
<td>392</td>
<td>350</td>
</tr>
</tbody>
</table>

### % urban population in the region

<table>
<thead>
<tr>
<th>Year</th>
<th>Asia</th>
<th>ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>50.82</td>
<td>51.45</td>
</tr>
<tr>
<td>2021</td>
<td>51.45</td>
<td>51.45</td>
</tr>
<tr>
<td>2030 (P)</td>
<td>56.67</td>
<td>54.2</td>
</tr>
<tr>
<td>2040 (P)</td>
<td>61.48</td>
<td>53.4</td>
</tr>
<tr>
<td>2050 (P)</td>
<td>65.77</td>
<td>51.0</td>
</tr>
</tbody>
</table>

### Real GDP (in $Trillion)

<table>
<thead>
<tr>
<th>Year</th>
<th>Asia</th>
<th>ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>31.83</td>
<td>35.61</td>
</tr>
<tr>
<td>2021</td>
<td>36.23</td>
<td>40.82</td>
</tr>
<tr>
<td>2030 (P)</td>
<td>41.36</td>
<td>45.4</td>
</tr>
<tr>
<td>2040 (P)</td>
<td>47.16</td>
<td>50.6</td>
</tr>
<tr>
<td>2050 (P)</td>
<td>53.68</td>
<td>53.68</td>
</tr>
</tbody>
</table>

Sources: BP Statistics Review 2022, BP World Outlook 2022, UN Population Division, World Bank, IMF Real GDP Dataset
AP - Asia Pacific region, ROW - Rest of world
Asia will increase its weight on global energy demand, driven by India

Source: BP Statistics Review 2022; BP World Outlook 2022
Contents

1. Climate change is real

2. Asia has become center of global market growth

3. Asian countries' advancements and challenges in shifting towards innovative low carbon solutions

4. Role of technology in carbon reduction, energy efficiency and transition

5. Role of collaboration in energy transition

6. Key questions and discussion
The COVID-19 pandemic slowed global progress in reaching universal access to electricity and clean cooking, reversing years of steady progress. Because the pandemic has slowed the rate of both new grid and off-grid connections, the number of people without access has increased by 2% in 2021.

— IEA

<table>
<thead>
<tr>
<th>Insufficient job creation to mitigate job losses</th>
<th>Low economic diversity beyond fossil fuels</th>
<th>Increased cost of energy risks greater energy poverty</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g., 120k coal mine jobs at risk in South Africa</td>
<td>e.g., Up to 10k people could lose their jobs as lignite coal mines close in Western Macedonia</td>
<td>e.g., Household bill increases in developed and emerging markets</td>
</tr>
</tbody>
</table>

Source: World Bank
### Complex array of issues to consider when embarking on Just Energy Transition journey

<table>
<thead>
<tr>
<th>Workers and employment</th>
<th>Consumer and Community wellbeing</th>
<th>Equitable transition financing</th>
<th>Access to green, affordable energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in job landscape will affect many and require reskilling</td>
<td>Challenging climate conscious divestment, sale or conversion of carbon intensive assets</td>
<td>Lack of access to investment and inadequate flow to the right projects at right time</td>
<td>Inequitable access to energy</td>
</tr>
<tr>
<td>Developing nations need to balance sustainability investments w/socio-economic development</td>
<td>Inequitable Climate change impact as climate hazards continue to unfairly impact vulnerable communities</td>
<td>Developing nations received fraction of financing whilst most exposed to physical impact of climate change</td>
<td>Rising costs driven by investments and shifting supply will affect LMI households, business &amp; trade</td>
</tr>
<tr>
<td>Shift in jobs need to align with inclusion ambitions</td>
<td>Decommissioning and siting decisions may affect vulnerable communities</td>
<td>Fls need to collaborate on terms, drive clarity on funds available, lower financing costs, and consider issuing debt without govt’ guarantees</td>
<td>Slow and complex renewable capacity build-up</td>
</tr>
</tbody>
</table>

Access to green, affordable energy

- Inequitable access to energy
- Rising costs driven by investments and shifting supply will affect LMI households, business & trade
- Slow and complex renewable capacity build-up
Employment | Traditional energy employment roles to bear impact with changing landscape

Energy employment is expected to experience major changes ...

- Change in global clean energy & related industries’ jobs by 2030 (M) under EIA Net-Zero scenario (NZE)

  - Jobs and skillset shift
    - Despite optimistic est. of net 23M jobs created in NZE, skillsets demand will shift towards renewables & clean tech
    - Fossil fuel industries like oil & gas, coal expected to bear most negative impact, potentially with 5M+ lost or shifted
    - Upskilling & monitoring wage decreases will be critical

  - Geographical and temporal impact of transition
    - Workers may not easily find new green jobs available based on geography and timing
    - Communities lacking diversified economies may be severely impacted

  - Diversity and inclusion in labor force
    - Inequality in employment access, gender- and race pay gaps in renewables and clean tech can potentially be exacerbated if not addressed

---

1. Difference in employment by industry in energy supply in the NZE Scenario, Global employment 2019-2030. Innovative technologies include batteries, hydrogen and CCUS

Source: IEA World Energy Outlook People Centered transitions 2021
Community wellbeing | Responsible only for a fraction of emissions, emerging economies disproportionately affected by climate change

Compared to the rest of the world, developing countries have lower carbon emissions...

...but are the most vulnerable to climate change impacts like crop failure and droughts

- Currently, 3B+ people live in areas highly vulnerable to climate impacts; mostly concentrated in Small Island Developing States, South Asia, Central and South America, and much of sub-Saharan Africa

- Inequity, conflict and development challenges heighten sensitivity to hazards; constrain ability to adapt and respond in robust manner

- At-risk communities in developing countries have fewer resources and will be hit the hardest

Bubble dimension represents population size. Population, GDP data and cumulative emissions as of 2020. Vulnerability relates to social, physical, economic and environmental factors, which make people or systems vulnerable to climate change.

Source: World Risk Report, United Nations University Institute for Environment and Human Security (UNU-EHS); World Bank; Our World in Data
Equitable access to financing | Capital gap of $22T between current spending plans and the IEA NZE thru 2030

2021-2030 average annual spend: IEA NZE versus forecast planned & proposed investments

<table>
<thead>
<tr>
<th>Fuels</th>
<th>Electricity</th>
<th>Infrastructure</th>
<th>End-use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
<td>Investment</td>
<td>Investment</td>
<td>Investment</td>
</tr>
<tr>
<td>$B</td>
<td>$B</td>
<td>$B</td>
<td>$B</td>
</tr>
<tr>
<td>570</td>
<td>418</td>
<td>370</td>
<td>120</td>
</tr>
<tr>
<td>500</td>
<td>1,200</td>
<td>700</td>
<td>1,300</td>
</tr>
<tr>
<td>No gap in a Net Zero scenario</td>
<td>$4T gap</td>
<td>$4T gap</td>
<td>$12T gap</td>
</tr>
</tbody>
</table>

PIPE Funds | Top 270 energy companies

Reporting categories aligned with categories included in IEA Net Zero scenarios. Includes largest state-owned national oil companies.
Source: S&P Capital IQ; IEA; Company-stated targets; US government; European Commission; Prequin; BCG CEI Analysis
Access to green, affordable energy | Energy transition in emerging economies being challenged by limitations in energy infrastructure and affordability

Access to electricity is still a large challenge …

Multiple drivers lead to high energy transition costs

- Under the NZE scenario, $36B per annum in investment is needed for universal access by 2030

- APS assumes that 290 million people will remain without electricity access by 2030, requiring $23B in investment each year to meet this target

Increased investments required to finance transition
- New assets infrastructure (e.g., RE, EV)
- Decarbonization of operations & supply chains

Green policies, national & international legislations - e.g., carbon pricing, cross-border carbon taxes

Increased spending on adaptation measures in order to address climate risks

Careful management of trade-offs between access, sustainability & affordability will shape the energy transition

Note: Other investment includes cross sector investments such as DAC, Hydrogen Infrastructure, and CO2 transport and storage Source: S&P Capital IQ; Company-stated targets; IEA World Energy Outlook; BCG CEI Analysis, World Bank; The energy Progress Report 2021
Contents

1. Climate change is real

2. Asia has become center of global market growth

3. Asian countries’ advancements and challenges in shifting towards innovative low carbon solutions

4. Role of technology in carbon reduction, energy efficiency and transition

5. Role of collaboration in energy transition

6. Key questions and discussion
Technology will help drive more than 75% of emissions reductions needed for net zero targets

Emissions reduction required to achieve net zero in 2050

GtCO₂

- Total emission reduction required to 2050: 100%
- Behaviour and avoided demand: 13%
- Energy efficiency: 10%
- Amount from technology: 77%
- Electrification: 22%
- Wind and solar: 21%
- CCUS: 13%
- Hydrogen based: 8%
- Bioenergy: 7%
- Other fuel shifts: 6%

Note: Total emissions reduction required to 2050 includes reduction required from emissions growth between 2020 to 2050 (inc., energy service demand changes from economic and population growth)

Source: IEA “Net Zero by 2050: A Roadmap for the Global Energy Sector” (2021); BCG analysis
Strong drivers push the energy efficiency opportunity globally

Rising energy demand
The global demand for energy is set to increase by 1.4% annually until 2035

Technology push
Materials and system innovation is ahead of the adaption curve, pushing down prices and increasing efficiency for new technologies

Increasing transparency
“Smart” solutions increase the ability to monitor and benchmark energy demand data in real time, increasing the ability to intervene and to measure success

Industry professionalization
Several EE markets (esp. in EU) are starting to mature, increasing available financing and the ability of players to tap existing market potential, while decreasing customer reluctance

Positive economics
Driven by high energy prices, low interest rates and decreasing technology costs, many EE measures are highly NVP-positive today

Political drive
Regulators around the world (but particularly in Europe) are introducing policies to improve EE, investments in public sectors increases
Energy Efficiency | Significant savings are offered by adopting EE methods

Domestic and transport sectors offer greatest potential for energy efficiency savings

Source: BCG Analysis
Electrification | ~77% reduction of CO2 emissions required by 2040 with increasing electricity demand

Electricity demand keeps increasing 2% pa, i.e., 2x faster than global energy demand.

Global electricity generation (in 10^3 TWh)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>10.9</td>
<td>12.2</td>
<td>14.2</td>
<td>16.7</td>
<td>19.8</td>
<td>22.5</td>
<td>26.9</td>
<td>29.7</td>
<td>32.8</td>
<td>36.3</td>
<td>40.1</td>
</tr>
</tbody>
</table>

+2% CAGR

+3.2% CAGR

..yet meeting Paris Agreement requires ~77% emission reduction by 2040

Global power sector CO2 emissions (in Gt CO2)

<table>
<thead>
<tr>
<th>Year</th>
<th>2019</th>
<th>2040 - Stated policies</th>
<th>2040 - Sustainable development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>13.7</td>
<td>12.5</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Warming projected by 2100

<table>
<thead>
<tr>
<th>Intensity (gCO2/kWh)</th>
<th>2019: 463</th>
<th>2040 - Stated policies: 282</th>
<th>2040 - Sustainable development: 67</th>
</tr>
</thead>
</table>

1. Stated policies scenario; Note: IEA’s scenario, stated policies = implement current policies ambition, sustainable development = aligned with Paris Agreement of limiting temperature rise to “well below 2°C”;

Source: IEA World Energy Outlook 2020; IEA Tracking Power 2019; BCG analysis
**Electrification | 5 megatrends driving global development of the power sector to a renewable-driven, digitalized and decentralized system**

1. **Growth and electrification of power demand**
   - Growing energy access in emerging economies, ~60% demand growth expected in Asia and Africa, penetration in rural areas of emerging economies
   - Increase in electric heating and cooling systems, shift from fossil fuel heat systems
   - Increase in consumption and household appliances

2. **Renewables absorbing most of power demand increase**
   - Power demand increases globally from 27 TWh to 39 TWh in 2040
   - In 2040, energy consumption is for 72% absorbed by renewables vs. 19% in 2019, mainly in mature markets
   - Growing electricity demand increases flexibility in supply hours (e.g., EV charging time), allowing renewables to cover a large share of the demand
   - SDS expected share of renewables in 2040: 56% solar PV, 25% wind, 14% other RES, 3% gas, 2% nuclear

3. **Storage (batteries and hydrogen) as key disruptor in electricity systems**
   - Global battery storage installations expected to increase with CAGR of 38% between 2018 and 2030
   - EU H₂ strategy focuses on green H₂ with blue H₂ as a transitory solution
   - Increase in EVs

4. **Digitalization leading to new business models that transform the power industry**
   - Key topic for energy transition with $20bn/y business potential
   - Service becomes focus of the industry, using digital applications

5. **Decentralization and distributed energy resources**
   - Power system shifts from linear transmission to distributed energy solutions with smart meters at its core

---

1. According to IEA Stated Policies Scenario
2. Source: IEA WEO 2020; IEA Digitalization & Energy report; BCG analysis
Wind + Solar | IEA scenarios forecast an annual production increase of 3-5.5x vs recent past

Wind + Solar: Forecasted Average Annual Increase in production 2019-2050 (BToe)

Fast-growing market at 1.3 - 1.7 additional EJ per year (350-450 Twh)

Wind+Solar production:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2019 (EJ)</th>
<th>2050 (EJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEA Stated Policies</td>
<td>4.10</td>
<td>193</td>
</tr>
<tr>
<td>IEA Announced Pledges</td>
<td>5.90</td>
<td>248</td>
</tr>
<tr>
<td>IEA Sustainable development</td>
<td>8.10</td>
<td>316</td>
</tr>
<tr>
<td>IEA Net Zero</td>
<td>9.60</td>
<td>362</td>
</tr>
</tbody>
</table>

Legend:
- Slow Transition
- Dynamic Transition
- Green Ambition Scenarios
- Net Zero Scenarios

1. When unavailable, 2019 data estimated starting from 2018 actuals. Actual data differ across scenarios due to different computation methods used by authors;
2. Minor differences in actual 2019 data between scenarios are driven by different statistics/computation methods across authors.

Source: BP Statistical Review of World Energy; Forecasts from Energy Reports; BCG analysis
Wind | ~$120bn offshore wind capital required annually by 2030, with APAC growing at 24% CAGR to reach second largest offshore wind market

Evolution of offshore wind capex requirements development under IEA’s Sustainable Development Scenario (SDS), USD $B/year

APAC expected to become the second largest offshore wind market by 2030, with different dynamics per region

Offshore Wind Installed Capacity
GW, cumulative

APAC and Emerging Markets

- Strongest energy demand, increasing profit pools as LCOE drops and subsidies remain high
- Market opening, channels and local supply chain still nascent
Solar PV | Installation costs decreased at a 15% CAGR the last decade

Global weighted-average total installed costs for PV (USD/kW)

Average cost of Solar PV installation reduced at a 15% CAGR over the last decade

Average cost of projects commissioned in 2020 was:
- 81% lower than in 2010
- 12% lower than in 2019

Source: IRENA; BCG analysis
Challenges associated with Solar PV

- Bringing down the cost of renewables is critical to the enormous scale-up required
- Complex supply chain associated with solar and wind
- Sufficient and reliable access to critical upstream units: ingot, wafer, mono perc cell, monoperp module
- Increasing scale and diversity in production
- Right infrastructure for deployment
CCUS | To achieve carbon neutrality, there needs to be a significant increase in the deployment of CCS technology

CCUS Total Available Market (TAM), $B

IEA Reference Technology Scenario

Basic scenario

Projected market forecast

Consistent with pledges tracking to 3-degree scenario and BCG current understanding of market forces

IEA 2 Degree Scenario

IEA Beyond 2 Degree Scenario

Global CCUS Market, $B

Some of announced 90 Mtpa projects by 2030 will be cancelled or delayed, but new ~200 Mtpa of projects are “in play”

Note: Carbon prices assumed to be $100/ton
Source: IEA WEO, Energy Technology Perspectives 2017; BCG Analysis
<table>
<thead>
<tr>
<th>Project</th>
<th>Country</th>
<th>Sector</th>
<th>Capture Rate (Mtpa)</th>
<th>Storage or Use</th>
<th>First Operating Yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abu Dhabi CCS</td>
<td>UAE</td>
<td>Iron and Steel Production</td>
<td>0.8</td>
<td>EOR</td>
<td>2016</td>
</tr>
<tr>
<td>Uthmaniya</td>
<td>Saudi Arabia</td>
<td>Natural Gas Processing</td>
<td>0.8</td>
<td>EOR</td>
<td>2015</td>
</tr>
<tr>
<td>Sinopec Qilu</td>
<td>China</td>
<td>Fertilizer Production</td>
<td>0.4</td>
<td>EOR</td>
<td>2019</td>
</tr>
<tr>
<td>Yanchang</td>
<td>China</td>
<td>Chemical Production</td>
<td>0.41</td>
<td>EOR</td>
<td>2020</td>
</tr>
<tr>
<td>CNPC Jilin</td>
<td>China</td>
<td>Natural Gas Processing</td>
<td>0.6</td>
<td>EOR</td>
<td>2018</td>
</tr>
<tr>
<td>Gorgon</td>
<td>Australia</td>
<td>Natural Gas Processing</td>
<td>3.7</td>
<td>Saline Aquifer</td>
<td>2019</td>
</tr>
<tr>
<td>Petrobras Santos</td>
<td>Brazil</td>
<td>Natural Gas Processing</td>
<td>1</td>
<td>EOR</td>
<td>2013</td>
</tr>
<tr>
<td>Alberta Carbon Trunk Line (Agrium)</td>
<td>Canada</td>
<td>Fertilizer Production</td>
<td>0.45</td>
<td>EOR</td>
<td>2019</td>
</tr>
<tr>
<td>Boundary Dam</td>
<td>Canada</td>
<td>Coal Power Generation</td>
<td>1</td>
<td>EOR</td>
<td>2014</td>
</tr>
<tr>
<td>Alberta Carbon Trunk Line (Refinery)</td>
<td>Canada</td>
<td>H2 Production</td>
<td>1.3</td>
<td>EOR</td>
<td>2019</td>
</tr>
<tr>
<td>Great Plains</td>
<td>Canada</td>
<td>Synthetic Natural Gas</td>
<td>3</td>
<td>EOR</td>
<td>2000</td>
</tr>
<tr>
<td>Sleipner</td>
<td>Norway</td>
<td>Natural Gas Processing</td>
<td>1</td>
<td>Saline Aquifer</td>
<td>1996</td>
</tr>
<tr>
<td>Snøhvit</td>
<td>Norway</td>
<td>Natural Gas Processing</td>
<td>0.7</td>
<td>Saline Aquifer</td>
<td>2008</td>
</tr>
<tr>
<td>Illinois Industrial</td>
<td>USA (Illinois)</td>
<td>Chemical Production</td>
<td>1</td>
<td>Saline Aquifer</td>
<td>2017</td>
</tr>
<tr>
<td>Coffeyville</td>
<td>USA (Kansas)</td>
<td>Fertilizer Production</td>
<td>1</td>
<td>EOR</td>
<td>2013</td>
</tr>
<tr>
<td>Petra Nova</td>
<td>USA (Texas)</td>
<td>Coal Power Generation</td>
<td>1.4</td>
<td>EOR</td>
<td>2017</td>
</tr>
<tr>
<td>Air Products SMR</td>
<td>USA (Texas)</td>
<td>H2 Production</td>
<td>1</td>
<td>EOR</td>
<td>2013</td>
</tr>
<tr>
<td>Shute Creek</td>
<td>USA (Wyoming)</td>
<td>Natural Gas Processing</td>
<td>7</td>
<td>EOR</td>
<td>1986</td>
</tr>
</tbody>
</table>

Note: EOR stands for ‘Enhanced Oil Recovery’, a process where CO2 is sold and injected into oil reservoirs to improve flow properties and increase oil production.

Source: Policy Priorities to Incentivise Large Scale Deployment of CCS – The Global CCS Institute, April 2019
Hydrogen | Expected to account for 12-20% of the future energy mix

IEA predicts a substantial increase in green H₂ demand over next 30 years

Mt per year

2020 2030 2040 2050
87 212 391 528

+9% +6% +3%

...deployed across a range of sectors

Power generation  e.g. as balancing fuel, for storage & as ammonia for electricity

Industry  e.g. in chemicals & steel production

Buildings  e.g. in green gas heating systems

Transport  e.g. as fuel for heavy-duty long-haul trucks, as synfuel for aviation & shipping

Source: IEA Roadmap to Net Zero by 2050, IRENA World Energy Transitions Outlook: 1.5C Pathway
Hydrogen | Driving down green H2 cost curve requires reduction in cost of electrolysers and cheaper renewable electricity

Hydrogen production, total cost ($/kg)

Two hurdles to green H2 price competitiveness:
- Price of electrolysers
- Price of renewables
  (competitive at renewables LCOE of ≤€25/MWh)

Incentives for investment in green H2:
- Long-term offtake contracts
- Credit worthy buyers
- Supported by government
- Guarantees

In low-cost gas regions, blue H2 may remain more competitive, assuming no or minimal carbon tax introduced
Large-scale CCUS solutions remain hurdle for blue H2

Note: LCOE - levelized cost of electricity; OSW - offshore wind; model assumptions: cost of green H2 incl. costs of electrolysers, electricity, water; cost of blue H2 incl. CCUS costs and CAPEX, minimal CO2 costs, few CO2 tax assumptions
Source: Interview with IEA experts, BCG case experience, BCG analysis
Hydrogen | Companies have started taking early bets on hydrogen to reduce their grey H2 demand

Hydrogen example: As potential developments proceed, new investors and industrial users lining up to fill capital gap

Announced H2 max capacity plans (mtpa)

Other includes governments, investment firms, and infrastructure players
Source: Global Data; IEA: BCG Center for Energy Impact

NZE scenario projects 5X increase in Hydrogen through 2050

Hydrogen production by fuel (Mt)

Green H2 Focus

Blue H2 Focus
Biofuel | A critical spoke in decarbonization agenda across scenarios

Across scenarios biofuel expected to play a critical role in energy mix

<table>
<thead>
<tr>
<th>Year</th>
<th>Stated policies scenario</th>
<th>Announced pledges scenario</th>
<th>Net zero emissions scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>5.9</td>
<td>2.5</td>
<td>1.3</td>
</tr>
<tr>
<td>2030</td>
<td>9.7</td>
<td>7.1</td>
<td>2.5</td>
</tr>
<tr>
<td>2050</td>
<td>19.9</td>
<td>8.8</td>
<td>4.6</td>
</tr>
<tr>
<td>2020</td>
<td>11.1</td>
<td>4.4</td>
<td>5.0x</td>
</tr>
<tr>
<td>2030</td>
<td>16.0</td>
<td>11.6</td>
<td>3.4x</td>
</tr>
<tr>
<td>2050</td>
<td>19.3</td>
<td>12.2</td>
<td>5.0x</td>
</tr>
<tr>
<td>2030</td>
<td>19.1</td>
<td>12.0</td>
<td>3.4x</td>
</tr>
<tr>
<td>2050</td>
<td>12.0</td>
<td>14.5</td>
<td>7.2</td>
</tr>
</tbody>
</table>

 Liq. biofuels | Biogas

% liquid biofuel in total liquid fuels: 2.28% (Stated policies) → 3.2% (Announced pledges) → 4.9% (Net zero emissions)
% biogas in total gaseous fuels: 0.8% (Stated policies) → 1.6% (Announced pledges) → 5.2% (Net zero emissions)
% biofuels in total liquid+ gas fuels: 1.6% (Stated policies) → 2.5% (Announced pledges) → 5% (Net zero emissions)

1. Sustainable Development Scenario assuming all new policies proposed by governments take place and the world will comply to COP21 and hence rise of temperatures will stay within 1.5°-2°C
Source: IEA World Energy Outlook 2021; BCG Analysis
Biofuel | Unresolved challenges have inhibited further adoption

**Investment**

~$100bn - $270 B

*Investment in biofuels needed until 2030 to meet stated policies scenario target*

- High capex requirement
e.g., 800ktoe biodiesel plant requires $1.3B in capex
  - Advanced biofuels require augmentation of downstream infrastructure e.g., blending terminals, dedicated pipelines
- Low investments
- Uncertainty in profit margins due to variability in feedstock, biofuel and by-product prices

**Technology**

~Zero

*Negligible commercial scale for advanced technologies - 3G, 4G*

- All 1G technologies are well consolidated, but 2G still evolving
- Negligible commercial scale for advanced technologies - 3G, 4G
  - 4G technology still at concept stage
- Various technologies competing for limited funding, feedstock
- High production costs especially for advanced biofuel

**Feedstock**

8% (today) → 45% (NZE)

*Biofuels produced from wastes, residues etc.*

- Fragmented and complex feedstock supply chain
- Competing applications e.g., Forest residue used in paper mfg.
- Poor quality feedstock e.g., Sewage readily available, but low quality leading to high production cost
- Sustainability, land use, and ethical sourcing concerns

---

All the above translates to higher production costs compared to fossil fuels, hence adoption driven through policies and mandates
Biofuel | Several countries have furthered biofuel growth

Leading producer of biofuels worldwide—US biofuel production accounts for nearly 40% of global biofuel production

Second largest biofuel producer with biofuel accounting 15%+ of Brazil’s annual energy consumption. Currently ~49% for bio-ethanol & ~11% biodiesel blend

One of the largest biodiesel producers, Indonesia’s biodiesel blend rate grew from 3% to ~29% over last 7 years

India achieved ethanol blending targets 5 months in advance, thereby advancing E20 target from 2030 to 2025

Source: BP Stats; USDA GAIN Reports; Press Reports; Sweet Fuel-Oxford University Press, 2022
1. Climate change is real
2. Asia has become center of global market growth
3. Asian countries’ advancements and challenges in shifting towards innovative low carbon solutions
4. Role of technology in carbon reduction, energy efficiency and transition
5. Role of collaboration in energy transition
6. Key questions and discussion
Key challenges affect each actor uniquely, but there are levers they can pull to drive a Just Energy Transition

**Key Challenges:**
- De-carbonization costs, complexity & pace
- Socio-economic impact of transition decisions such as plant closure, renewable siting

**Key Levers:**
- Support and invest in your workforce
  - ZE PAK upskill/reskills existing lignite-based generation workforce
- Drive transition to secure sufficient clean energy
  - Tata Power launched grid partnership for low-cost power to 25M people in India

**Key Challenges:**
- Labor shift, workforce impact & ensuring equal access to new labor
- Energy access, security & managing transition pace with geopolitical risks

**Key Levers:**
- Promote equitable workforce transition
  - Malaysia: Green investments in job programs (re-& upskilling)
- Accelerate through investments, policies & incentives
  - India: Climate adaptation fund - $100M+ distributed so far, benefiting ~2M citizens

**Key Challenges:**
- Unproven markets & sub-scale investments lead to perceived risks & unattractive returns
- Challenging holistic view of societal & environmental impact in asset divestment

**Key Levers:**
- Develop & incorporate just transition principles
  - Climate Action 100+
- Scale just energy transition financing globally, and unlock funding for emerging markets
  - Asian Infr. Inv. Bank/Global Energy Alliance for people & planet (mobilizing $1B)

**Key Challenges:**
- Fragmented agendas and different dialogues impact plans across sectors & regions
- Lack of awareness & willingness to consider just dimensions within energy transition

**Key Levers:**
- Drive development of standards
  - World Benchmarking Alliance (WBA), measures JET contributions according to IEA standards
- Advocate for Just Energy Transition
  - The International Trade Union Confederation with CIC, advocated for green new investments for jobs

Select examples – not exhaustive

---

1. Council for Inclusive Capitalism
Contents

1. Climate change is real
2. Asia has become center of global market growth
3. Asian countries' advancements and challenges in shifting towards innovative low carbon solutions
4. Role of technology in carbon reduction, energy efficiency and transition
5. Role of collaboration in energy transition
6. Key questions and discussion
Key Questions

1. How do different energy price trends and governance criteria affect growth and emissions?

2. What role does Asia play in realigning energy value chains and reducing carbon intensity?

3. Which policies and innovative technologies enable Asia to transition through growth and innovation?

4. What could be the way forward to address the issue of technology transfer between developed and developing nations? How have recent geo-political conflicts impacted investment and political will towards clean energy transition?
Thank You!