Our Mission
• Push the change in technologies and policies needed to get to a zero-emissions, high-energy planet at an affordable cost.

Our Goal
• Achieve zero-emissions energy, waste, agricultural, and forest management systems by 2050.

Our Vision
• Meet the world’s rising energy demand in a way that is financially, socially and environmentally sustainable.
Conventional pollution from coal-fired power (1996-present)
CO2 pollution from electric power sector (2000-present)
Carbon capture utilization & storage (2000-present)
High-emitting diesels (2003-2012)
Short-lived climate forcers (especially BC and CH4) (2000-present)
Negative climate impacts of bioenergy (2006-present)
CH4 emissions from O&G sector (2009-present)
Advanced nuclear technologies (2007-present)
Zero-carbon fuels (2013-present)
WE NEED A BIGGER TOOLBOX

• Safeguarding against the worst impacts of climate change requires a deep (perhaps total) reduction in carbon emissions from the mobility, power, and industrial sectors.
• Traditional advocacy goals—more renewables, more efficiency improvements—are insufficient.
• We need to develop and deploy carbon-free fuels that offer the benefits of oil and coal (flexible, stable, energy-dense, plentiful).
ZERO-CARBON FUELS ARE ESSENTIAL

Table 3.3 | World oil demand by sector in the New Policies Scenario

<table>
<thead>
<tr>
<th>Sector</th>
<th>2000</th>
<th>2015</th>
<th>2040</th>
<th>2015-2040</th>
<th>Ease of substitution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mb/d</td>
<td>%</td>
<td>mb/d</td>
<td>%</td>
<td>Change</td>
</tr>
<tr>
<td>Transport</td>
<td>39.0</td>
<td>51%</td>
<td>51.7</td>
<td>56%</td>
<td>60.5</td>
</tr>
<tr>
<td>Passenger vehicles</td>
<td>18.2</td>
<td>24%</td>
<td>23.9</td>
<td>26%</td>
<td>24.6</td>
</tr>
<tr>
<td>Maritime</td>
<td>3.7</td>
<td>5%</td>
<td>5.0</td>
<td>5%</td>
<td>6.2</td>
</tr>
<tr>
<td>Freight</td>
<td>11.9</td>
<td>16%</td>
<td>16.3</td>
<td>18%</td>
<td>19.7</td>
</tr>
<tr>
<td>Aviation</td>
<td>4.6</td>
<td>6%</td>
<td>5.8</td>
<td>6%</td>
<td>9.3</td>
</tr>
<tr>
<td>Industry</td>
<td>14.4</td>
<td>19%</td>
<td>17.0</td>
<td>18%</td>
<td>22.7</td>
</tr>
<tr>
<td>Steam and</td>
<td>6.1</td>
<td>8%</td>
<td>5.8</td>
<td>6%</td>
<td>6.5</td>
</tr>
<tr>
<td>process heat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petrochemical</td>
<td>8.1</td>
<td>11%</td>
<td>10.7</td>
<td>12%</td>
<td>15.7</td>
</tr>
<tr>
<td>feedstocks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buildings</td>
<td>7.7</td>
<td>10%</td>
<td>7.6</td>
<td>8%</td>
<td>6.0</td>
</tr>
<tr>
<td>Power generation</td>
<td>6.1</td>
<td>8%</td>
<td>5.4</td>
<td>6%</td>
<td>2.9</td>
</tr>
<tr>
<td>Other**</td>
<td>9.4</td>
<td>12%</td>
<td>10.8</td>
<td>12%</td>
<td>11.3</td>
</tr>
<tr>
<td>Total</td>
<td>76.7</td>
<td>100%</td>
<td>92.5</td>
<td>100%</td>
<td>103.5</td>
</tr>
</tbody>
</table>

* Compound average annual growth rate. ** Includes agriculture, transformation, other non-energy use (mainly bitumen and lubricants).

- Electrification is an important tool, but it would solve < half of the global transportation decarb challenge.
- Even if all light-duty passenger vehicles are electrified, there will be significant demand for liquid fuel for other vehicles (35.2 mb/d) in 2040 and beyond.
- Fuel also needed for remote/isolated & backup power gen applications.
Ammonia has to overcome the cost hurdle of being made from natural gas (+CCS) or zero-carbon electricity.

Likely initial demand for low-carbon ammonia-based power?

- Off-grid applications
- Islands and other geographically isolated markets
- Markets that need to balance their supply of variable renewable energy with a flexible, fast ramping source low/zero-carbon power
- Existing fossil power stations, including coal-fired boilers, where it makes economic sense to postpone retirement by fuel-switching to a lower-carbon fuel → ammonia’s ability to facilitate a gradual decrease in the carbon intensity of coal- or natural gas-derived power could be important.
When CATF discusses ammonia’s potential as a power sector fuel, we get three questions:

• FEASIBLE? Does ammonia-based power generation work?
• AFFORDABLE? Can it compete with other power gen options?
• SAFE? Can ammonia be produced, handled, and combusted safely (toxic and conventional pollutants)?

If CATF could design an RD&D agenda to answer those questions ... it would look a lot like IHI’s program.
Can power-to-ammonia-to-power become economically competitive?

Vattenfall/Nuon, *Carbon Neutral Fuels to Enable the Energy Transition* (2017)
• CAA New Source Performance Standards
  • Could ammonia co-firing be used to meet (future) Clean Air Act section 111(d) emission reduction requirements for CO2 at coal boilers?

• 45Q-type policy
  • Would a tax credit for the production of low/zero-carbon ammonia help accelerate commercialization of ammonia-based power gen technologies?

• California Cap-and-Trade
  • CARB has approved six hydrogen-based fuel pathways for compliance with California’s Low Carbon Fuel Standard. Possible precedent for the use of ammonia to comply with CA’s Cap-and-Trade program?