



Shell in Advanced Biofuels

Technology Maturation Process as Applied to IH²® Technology

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Disclaimer

This presentation contains data from Shell's new Sky Scenario. Unlike Shell's previously published Mountains and Oceans exploratory scenarios, the Sky Scenario is targeted through the assumption that society reaches the Paris Agreement's goal of holding global average temperatures to well below 2°C. Unlike Shell's Mountains and Oceans scenarios which unfolded in an open-ended way based upon plausible assumptions and quantifications, the Sky Scenario was specifically designed to reach the Paris Agreement's goal in a technically possible manner. These scenarios are a part of an ongoing process used in Shell for over 40 years to challenge executives' perspectives on the future business environment. They are designed to stretch management to consider even events that may only be remotely possible. Scenarios, therefore, are not intended to be predictions of likely future events or outcomes and investors should not rely on them when making an investment decision with regard to Royal Dutch Shell plc securities.

Additionally, it is important to note that Shell's existing portfolio has been decades in development. While we believe our portfolio is resilient under a wide range of outlooks, including the IEA's 450 scenario (World Energy Outlook 2016), it includes assets across a spectrum of energy intensities including some with above-average intensity. While we seek to enhance our operations' average energy intensity through both the development of new projects and divestments, we have no immediate plans to move to a net-zero emissions portfolio over our investment horizon of 10-20 years. Although, we have no immediate plans to move to a net-zero emissions portfolio, in November of 2017, we announced our ambition to reduce our net carbon footprint in accordance with society's implementation of the Paris Agreement's goal of holding global average temperature to well below 2°C above pre-industrial levels. Accordingly, assuming society aligns itself with the Paris Agreement's goals, we aim to reduce our net carbon footprint, which includes not only our direct and indirect carbon emissions, associated with producing the energy products which we sell, but also our customers' emissions from their use of the energy products that we sell, by 20% in 2035 and by 50% in 2050.

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Discussion topics

- Shell New Energies
- IH²® process technology maturation

New Energies



- **Selective and opportunity driven investment**
- **Capital investment \$1-2 billion per annum average**

New Fuels



- Focus areas:
 - Biofuels
 - Hydrogen
 - Electric mobility
- Work in partnerships and consortia
- Target downstream returns high teens %

Power



- Focus areas:
 - Trading, marketing and customer access
 - Low-carbon generation and storage
- Investment in customer access
- Selective asset ownership
- Target equity returns of 8-12%

New Fuels



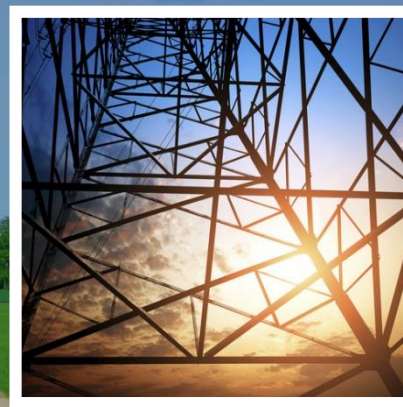
Biofuels

Conventional & advanced biofuels



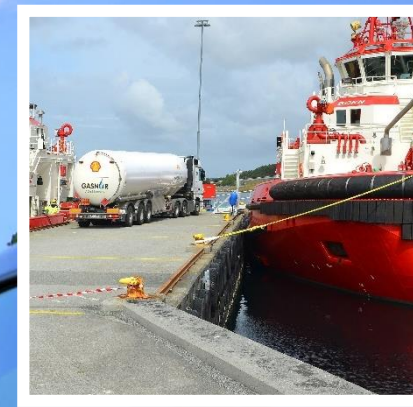
Hydrogen

Active in hydrogen electric



Electric Mobility

Exploring a role in the charging of EVs



Gas for transport

Offering gas to liquids (GTL) and liquefied natural gas (LNG)

Shell and biofuels



Trading & Supply

One of the world's largest blenders and distributors of biofuels



Raízen JV

Production of low-carbon ethanol from Brazilian sugar cane



Advanced Biofuels

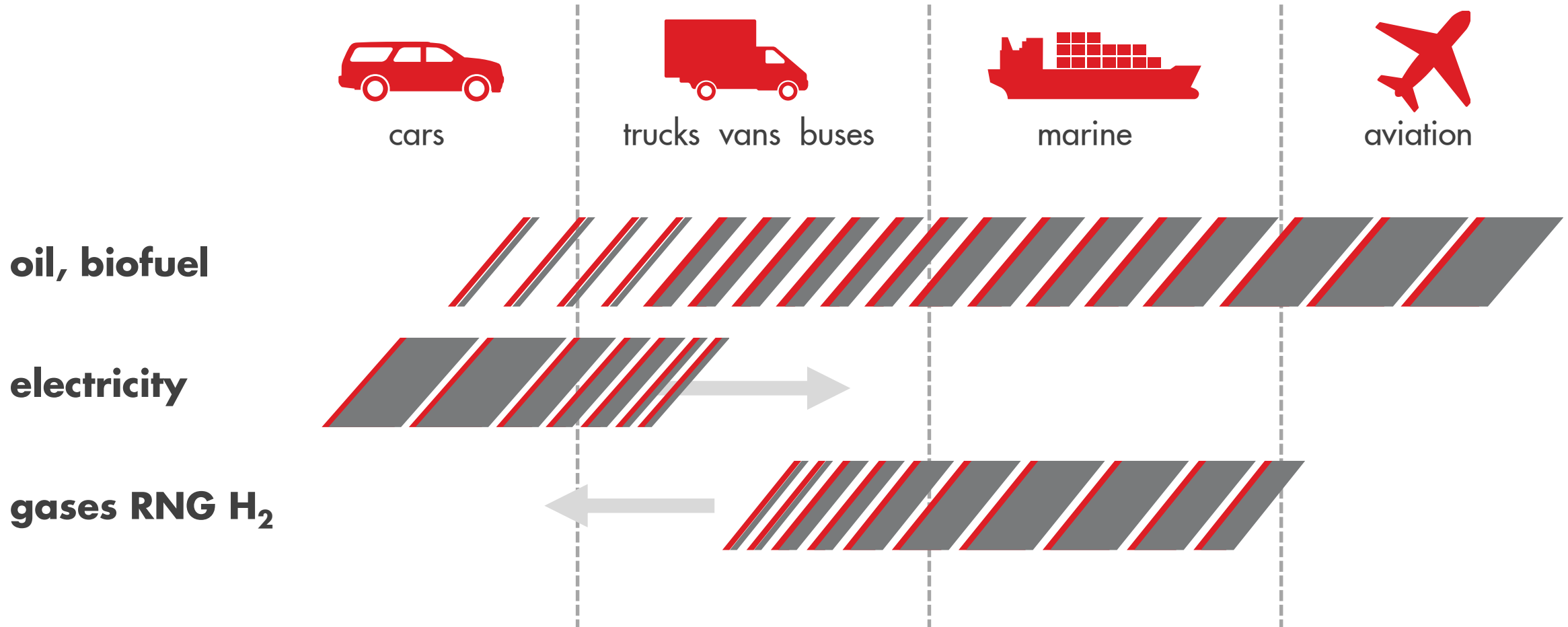
Investing in technologies using alternatives feedstocks such as waste



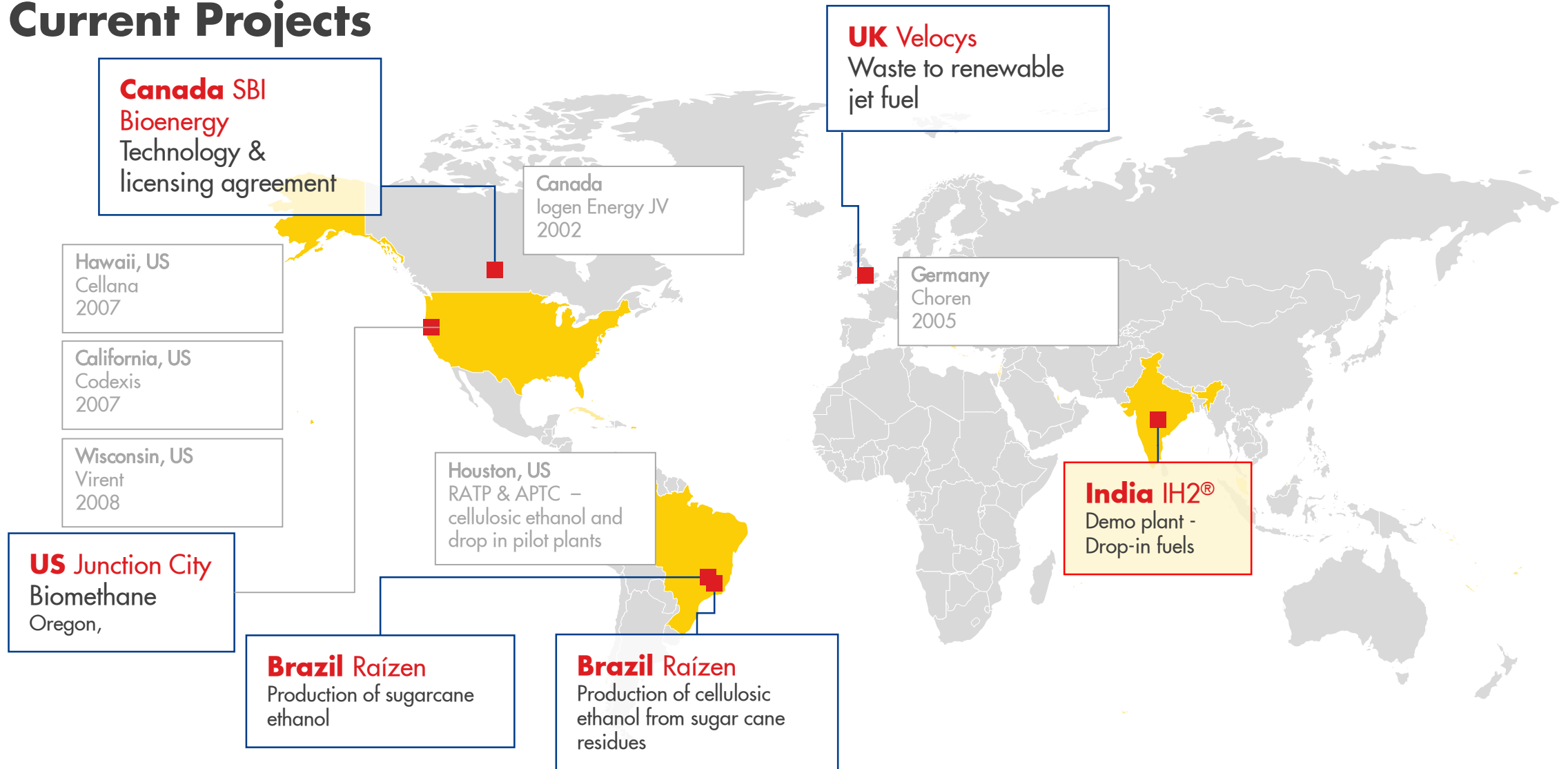
Sustainability

Commitment to the supply and development of sustainable biofuels

Different fuels will have different applications



Current Projects



IH²® Technology

a conversion technology for residual biomass

- Technology invented by US-based Gas Technology Institute (GTI) and further developed in collaboration with CRI Catalyst Company (SC&T) since 2010
- Efficient conversion route for forestry, agricultural and other residues (e.g. sorted MSW) allowing the production of cleaner transportation fuels
- 5 tpd demonstration plant commissioned in October 2017 at Shell's new Technology Centre in Bangalore, India has operated below 5 tpd capacity, modifications nearly complete for restart



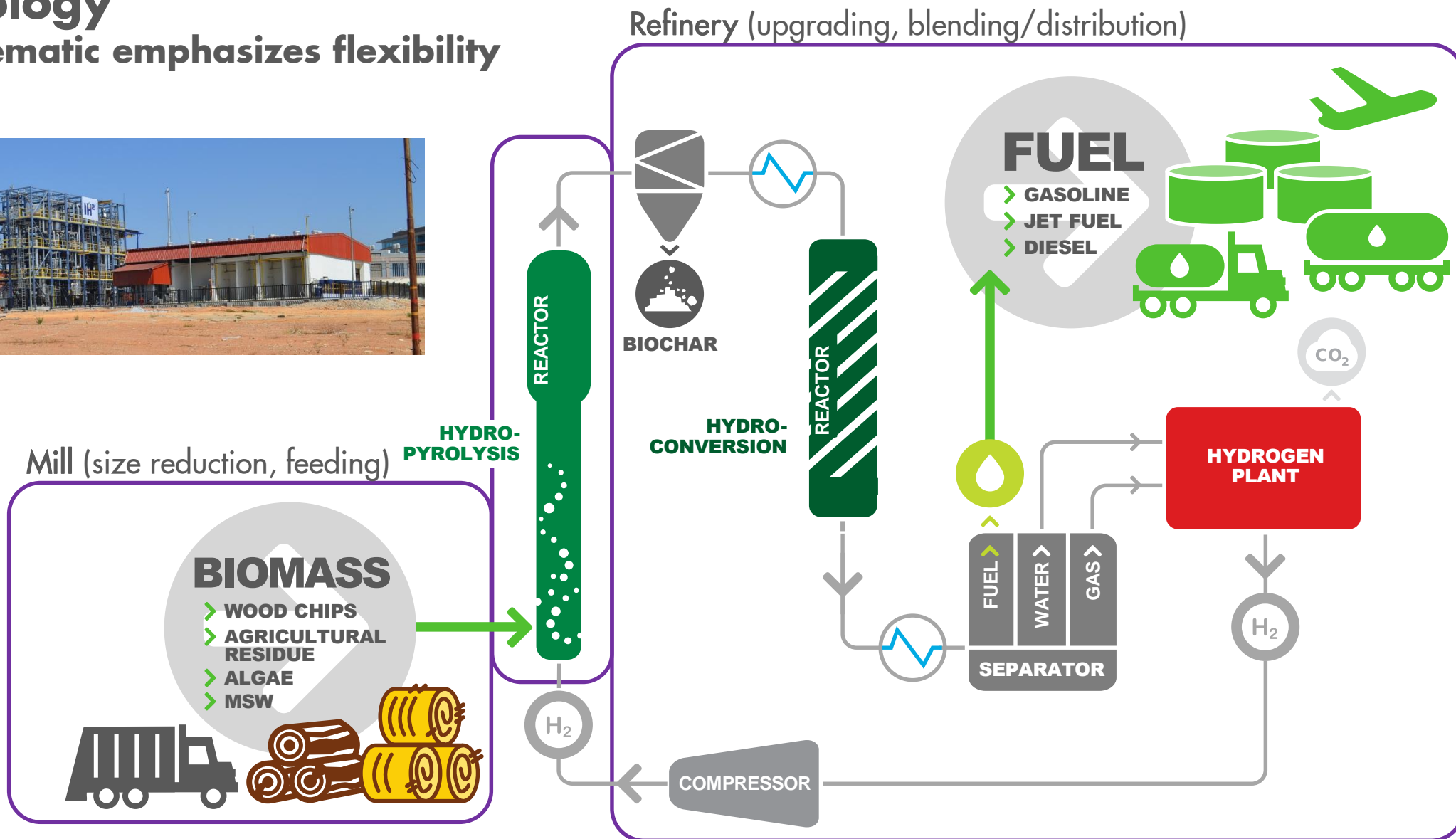
IH²® technology

Simplified schematic emphasizes flexibility



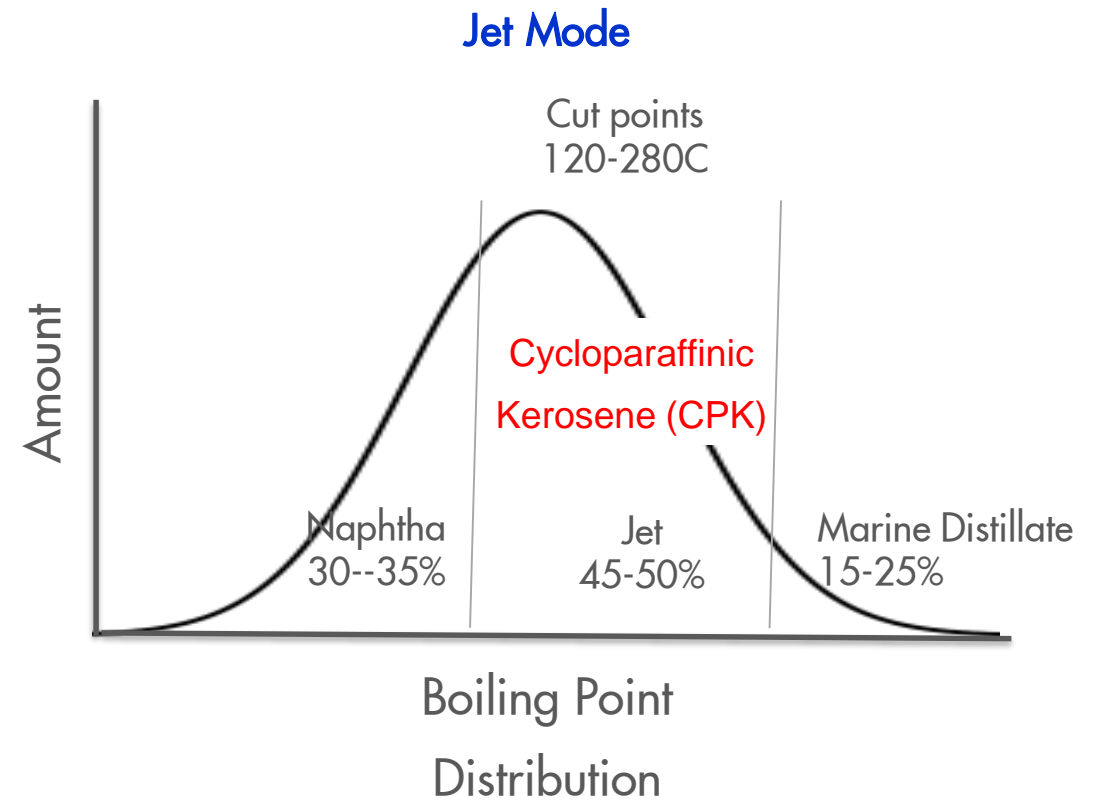
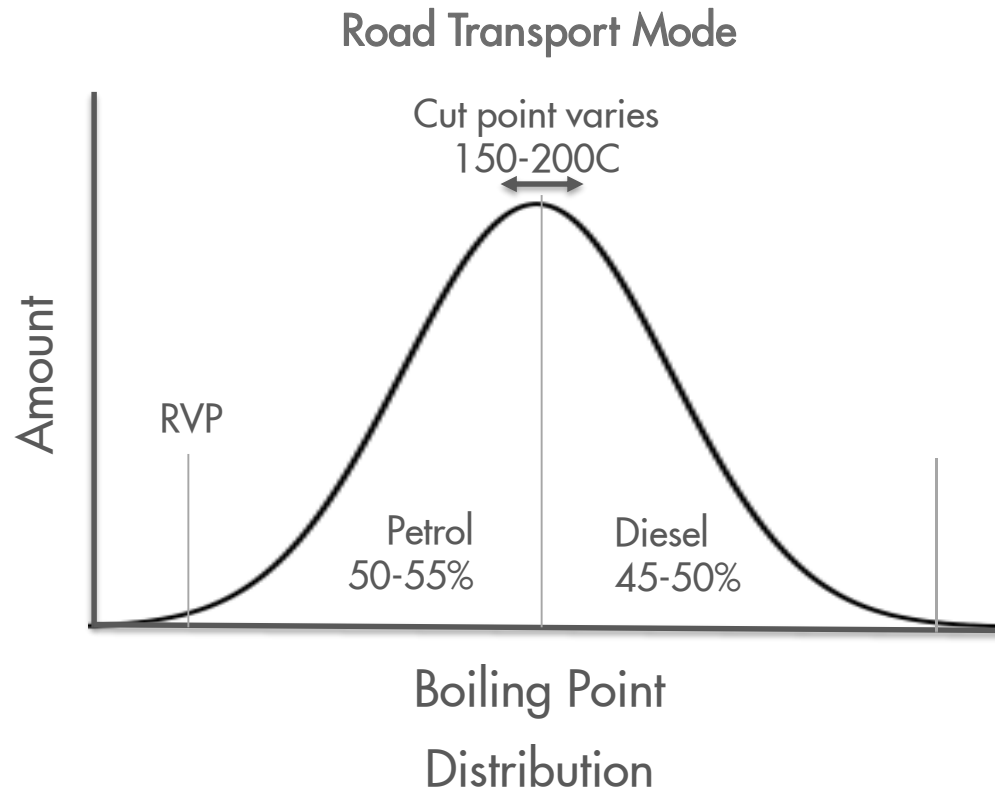
Flexibility

- Feed
- Location
- Integration
- Product



IH²® process - two modes of operation

Road vs Aviation fuel mode



IH²® products: road transport fuels are high quality 'drop in'



GASOLINE / PETROL



Meets ASTM D4814-16d
E10 blend for regular grade



EN 228: Petrol – Jan 2009
E10 blend for regular grade



BS VI compliant (BS IV in place)
E6 blend for regular grade

E10 petrol blends are currently
undergoing qualification processes



DIESEL



Meets ASTM D975-15c



Meets EN 590:2009+A1:2010



BS VI compliant

Diesel is currently undergoing
qualification processes



IH²® products: jet mode fuels are high quality ‘drop in’



Suitable components for
Solvents
Steam cracker feed
Reformer feedstock – bioBTX
Gasoline blending...



Matches the Table 1 Performance
Criteria for:

World-wide Civil Jet Fuel Grade
Jet A/A-1

(e.g. ASTM D1655 & DEF STAN 91-091)

US Military Jet Fuel Grade
JP-8 and F-34

(e.g. MIL-DTL-83133 & DEF STAN 91-87)

Fuel is currently in ASTM
D4054 approval process with
UDRI, NJFC etc having samples



Meets ISO 8217 2017 specs
Very low S content (<5 ppm)
High on DMA/DFA density (fixable)
High on DMB/DFB density (fixable)
Exceeds Residual Fuel Spec

US Navy F-76

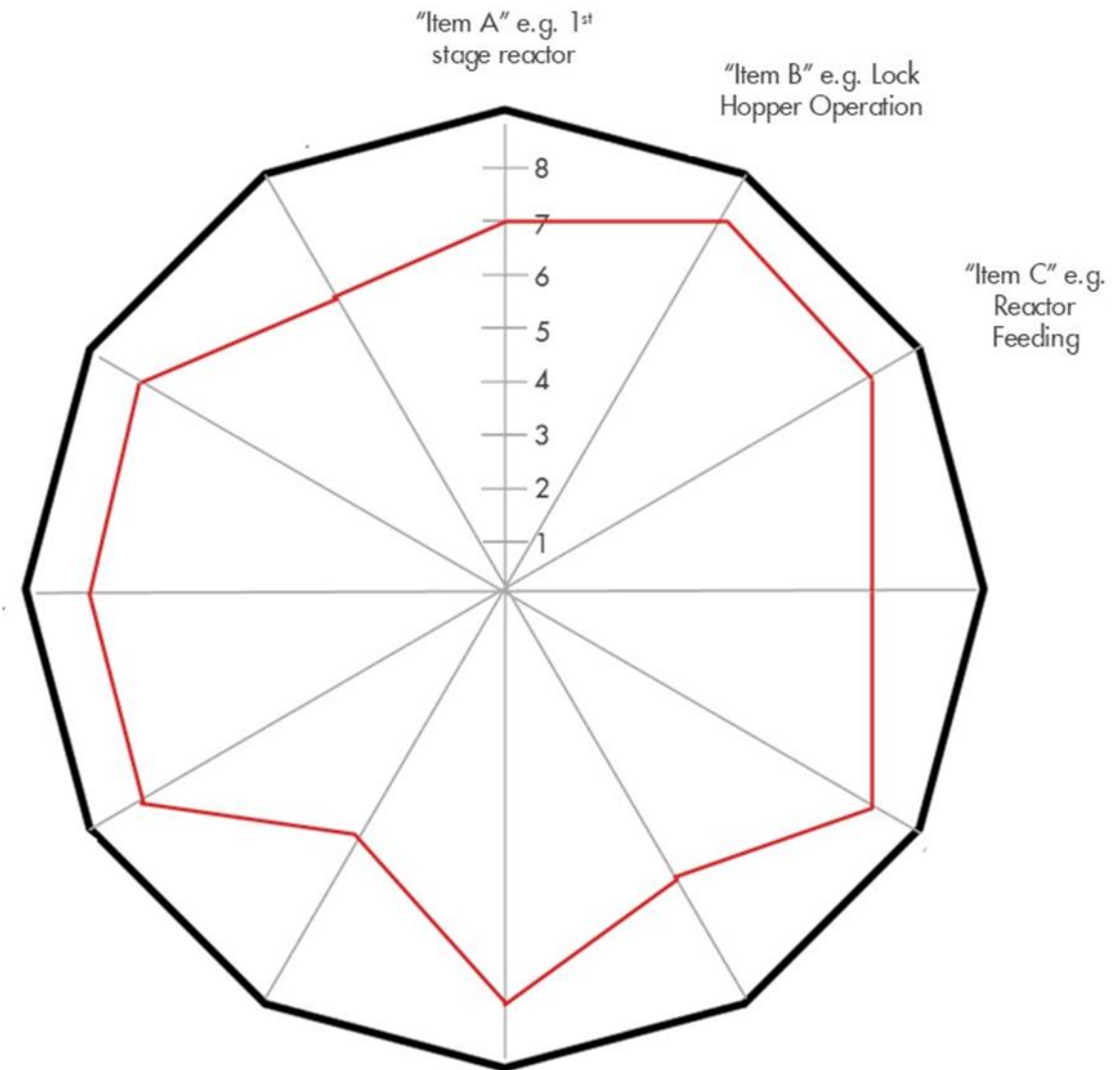
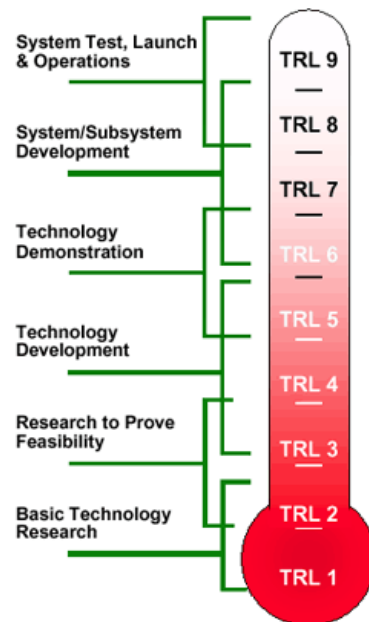
High on density (fixable)
High cetane (value give-away)

Fuels are currently being
evaluated

Technology maturation at demo scale

illustrative 'spider chart' provided for discussion

- Shell uses D gates to describe stage of development and an adapted form of NASA TRL for technology readiness
- IH²® technology, invented by GTI in 2009 is currently in D3 with various subsystems operating in the TRL ranges 5-8
- FEED is at FEL-2 stage/FEL-3 may begin as early as 1/20



Summarizing IH²® technology

IH²® technology...

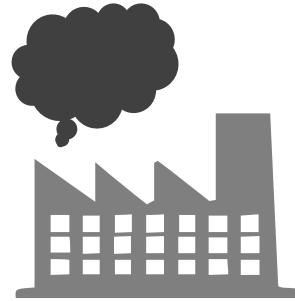
- a location- and feedstock-flexible continuous catalytic thermochemical process under development by Shell using commercial refinery hardware to economically convert forestry, agricultural and sorted municipal wastes into clean-burning 'drop in' renewable hydrocarbon transportation fuels with up to 72% bio-energy recovery and up to 92% GHG reduction.
- invented by Gas Technology Institute in 2009
- developed by SC&T (CRI) with GTI from 2010 onward at Shell's Technology Center in Bangalore, India (STCB)
- flexible with regard to feed and design — stand alone or mill/refinery integrated (build where biomass is)
- designed to meet all fuel specifications of the host country, including ASTM specifications for Jet A/A-1
- economics based upon FEL-2 accuracies are attractive >1000tpd scale. Opex (feed cost) dominates capex in ROI
- at demonstration scale at Shell Tech Center Bangalore

Advanced Biofuels Success Criteria



Right policies and financial support from governments,

- providing stable price signal for investments



Achievement of improved efficiencies by the industry, in both:

- manufacturing technologies
- sustainable feedstocks



Developments in infrastructure:

- vehicle compatibility
- distribution and retail networks

Acknowledgements







Thank You