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Bioenergy Retrofits for Europe's Industry

The Alcohol-To-Jet process: A Retrofit for 1G ethanol plants

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Andrew Hull, Swedish Biofuels

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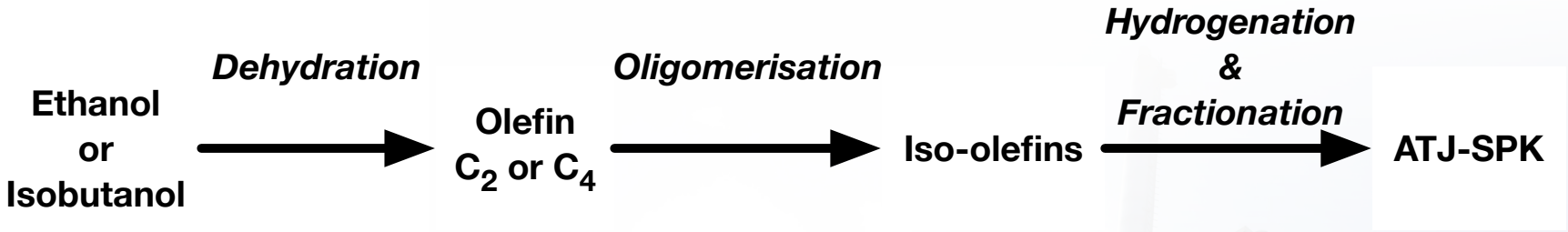
Swedish BioFuels™

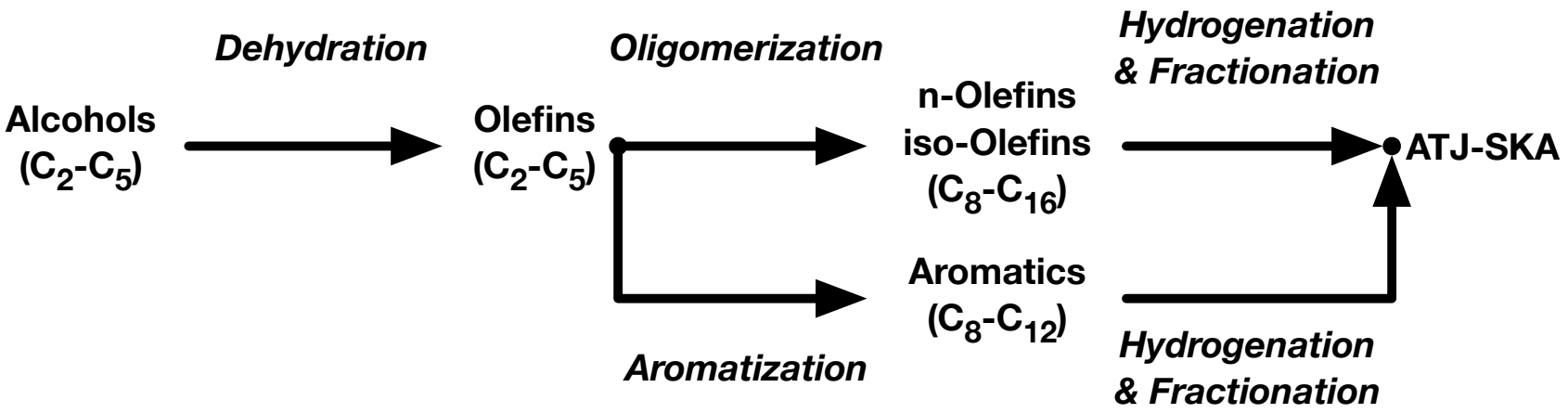
ATJ Process

- Alcohol To Jet (ATJ) process was developed by Swedish Biofuels (SB), patent of 2004
- First demonstrated for DARPA[1] in 2009 by SB in Stockholm, Sweden
- ATJ-SPK certified at ASTM during 2016 to 2018 at 50:50 blend with fossil jet fuel – no aromatics
- SB leading new ASTM certification for 100 % replacement of fossil jet fuel as ATJ-SKA [†] – includes aromatics

Overall ATJ-SPK process



Overall ATJ-SKA process



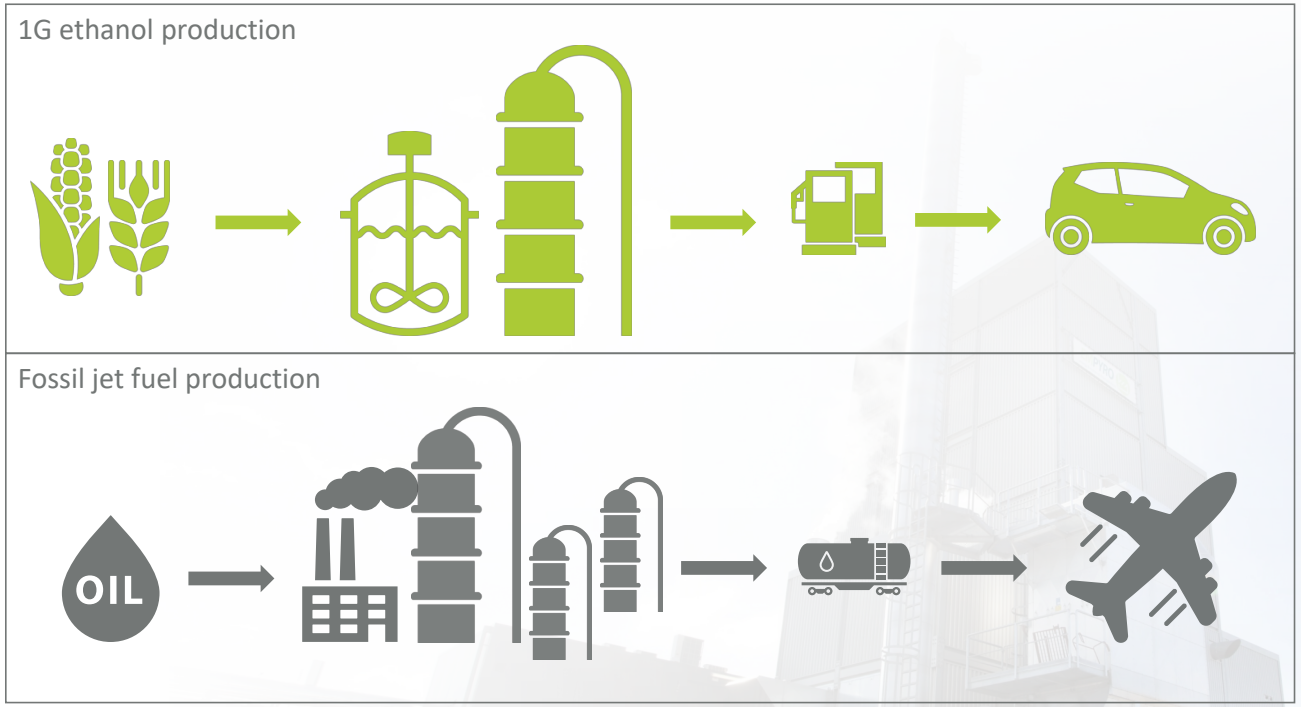
[†] Alcohol to jet – synthetic kerosene with aromatics

[1] Defense Advance Research Projects Agency

Current scenario

1G ethanol from grain

Kerosene from crude oil



Retrofit scenario

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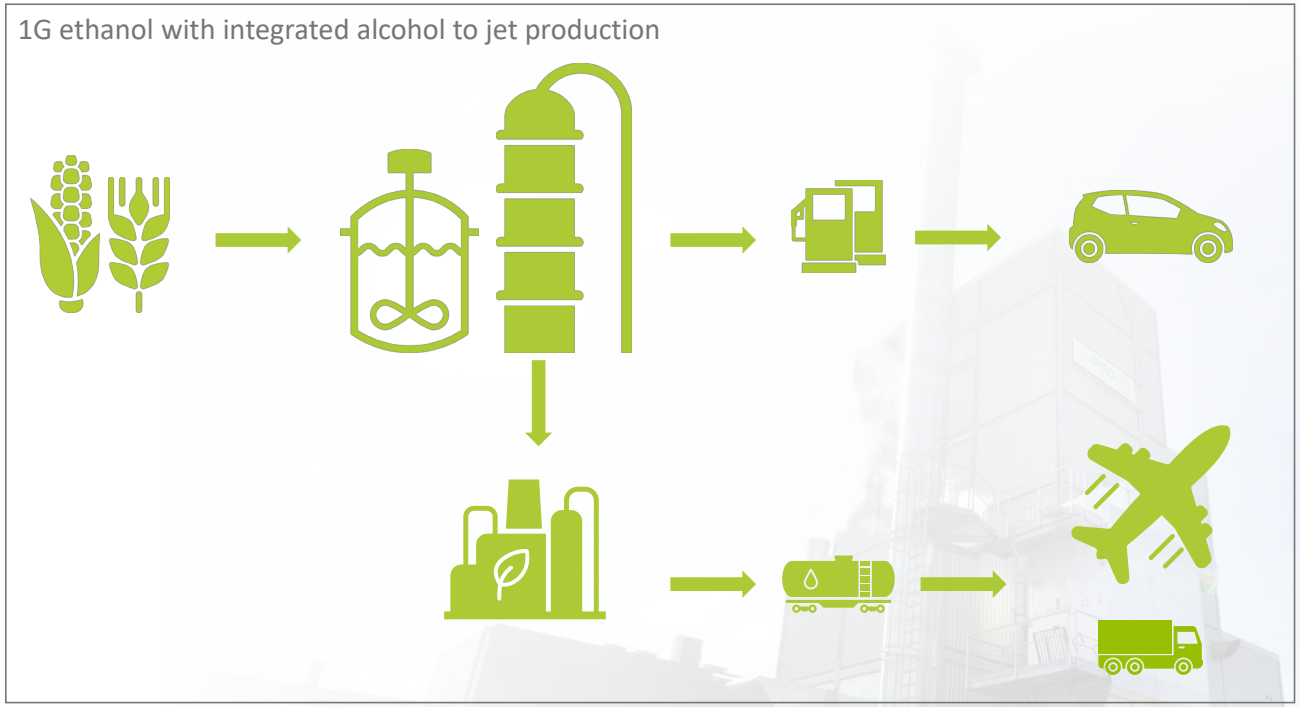
- 1G ethanol from grain (VERTEX)
- Sustainable aviation fuel using alcohol to jet ATJ) technology from Swedish Biofuels
- Products

  SAF (ATJ-SKA) 100 % replacement for fossil jet fuel

  Diesel – used locally or sold on market

  Gasoline – used locally or sold on market



Alternative scenario

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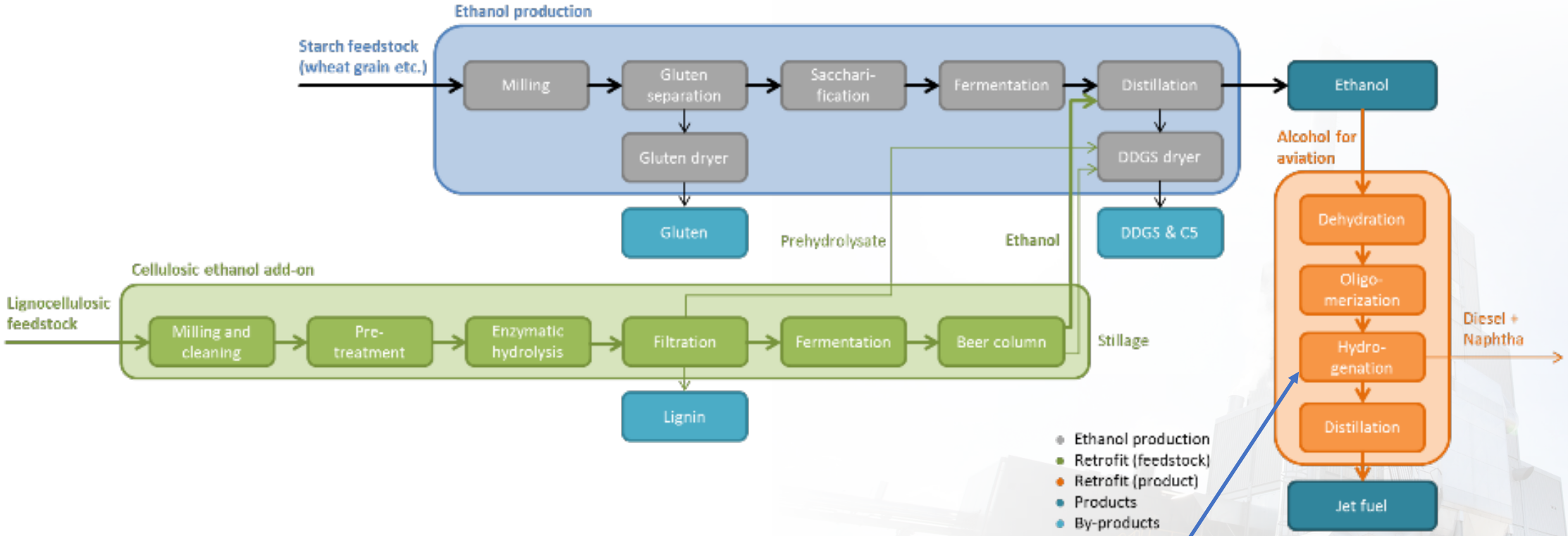
- 1G ethanol from grain
- Transport
- Sustainable aviation fuel using alcohol to jet (ATJ) technology from Swedish Biofuels
- Products

  SAF (ATJ-SKA) 100 % replacement for fossil jet fuel

  Diesel – used locally or sold on market

  Gasoline – used locally or sold on market

Supply chain



NB. No additional hydrogen needed in SB ATJ process

Market assessment

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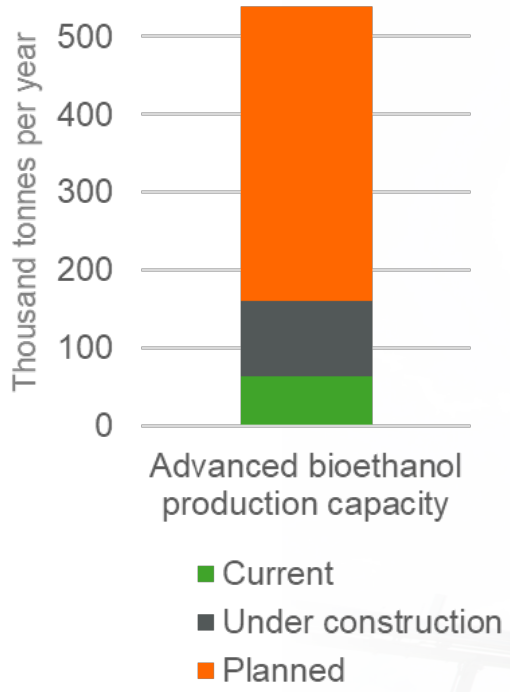
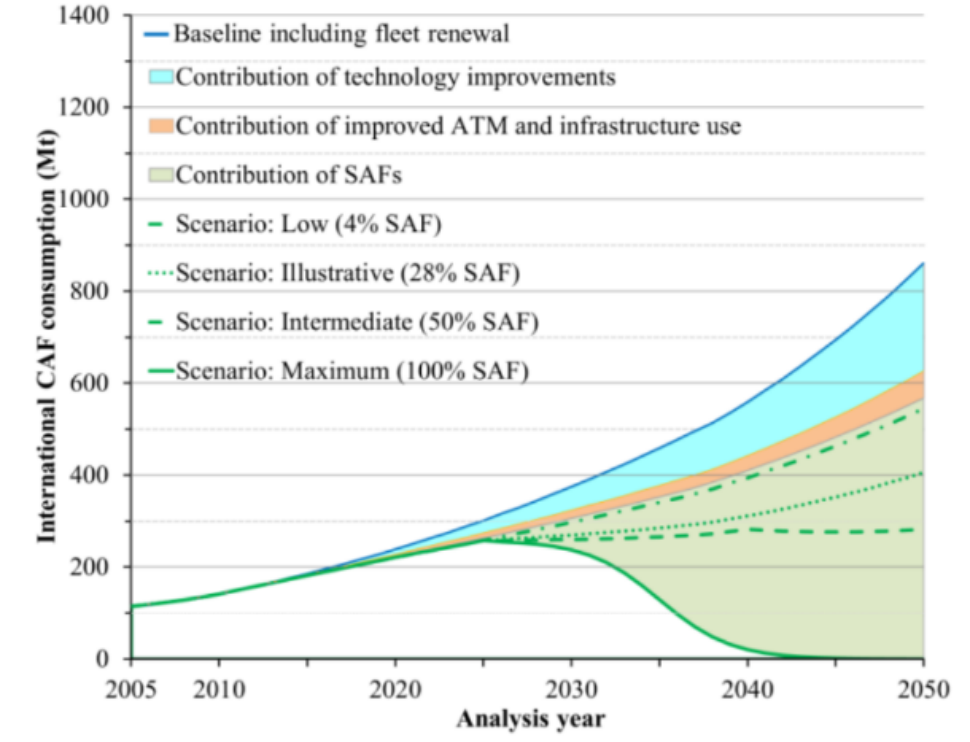
- Feedstock available
  - Substantial 1G ethanol production worldwide
  - Large planned increases in advanced bioethanol production capacity in Europe
- Large demand for SAF
  - 100 % replacement of fossil jet fuel needed – also reduces costs

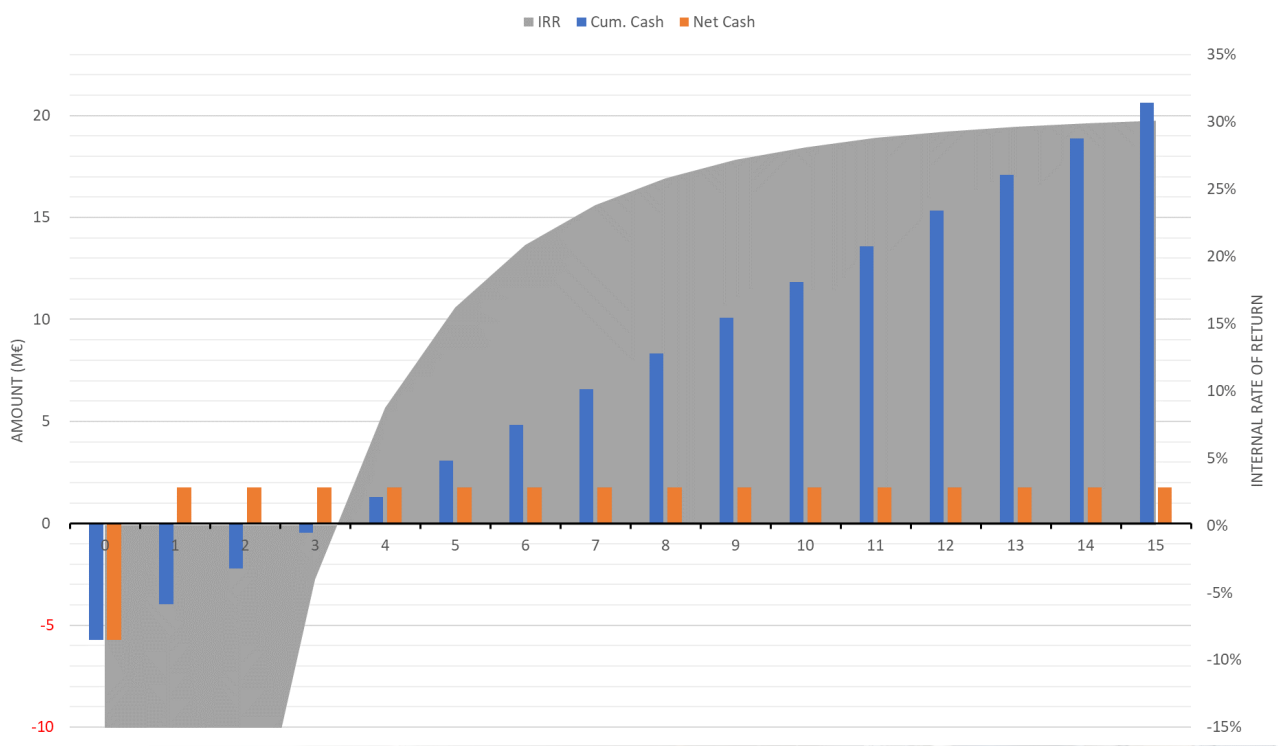




Data: ICAO

Techno economic assessment

- Main economic result
  - IRR† 30 %
- Other considerations
  - Volatility of oil market
  - Recent increases in SAF price
  - Changes in feedstock costs
  - Stability of policy framework



† internal rate of return

Environmental assessment

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Scenario	Emissions per MJ of fuel (gCO_{2eq}/MJ)	Saving compared to REDII (%)
Baseline Scenario	53.26	43.34
Current retrofit scenario based on existing 1G bioethanol plant	52.23	44.00
Sustainable retrofit scenario	**4.93**	**95.00**
Current alternative scenario based on existing 1G bioethanol plant	53.67	40.33
Sustainable alternative scenario	**5.13**	**94.50**

Risks

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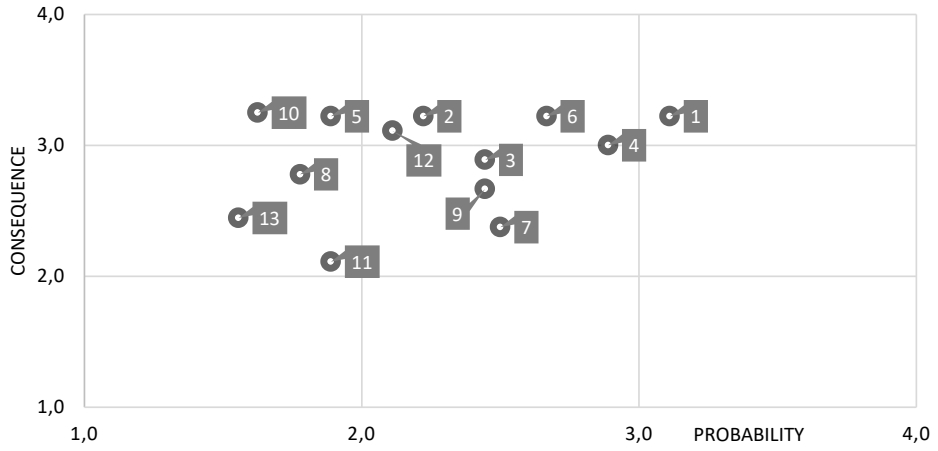
No.	Risk	Probability (1 = low, 4 = high)	Consequence (1 = little, 4 = severe)	Total risk (1-16)
1	ATJ kerosene is not considered advanced biofuel when utilizing maize-based ethanol, EtOH plant has to undergo 2 retrofits, (i) from 1G to advanced fuels, (ii) to ATJ adaption	3,1	3,2	10,0
4	Increasing prices for sustainable feedstock for ethanol production	2,9	3,0	8,7
6	Unsupportive or only short-term policies frameworks lead to changes in the market (e.g. green premiums)	2,7	3,2	8,6

– mainly 1,4,6; out of 13 considered



KPIs

- Swedish Biofuels ATJ technology is GHG emissions neutral
- Potential to achieve negative carbon emissions by integrating side streams
- Swedish Biofuels ATJ-SKA technology gives a complete, 100 %, replacement for fossil jet fuel

KPI	Value Current energy supply	Value Sustainable energy supply
Carbon dioxide Equivalent Emission Reduction of supply chain and operation	44%	**95%**
Increased efficiency of resources consumption	Not estimated	Not estimated

Main learning

- Technical economic assessment – Revenue much higher than investment
- Market assessment – Large demand for SAF and significant increase in advanced bioethanol production, so feedstock availability not a burden
- Sustainability assessment – ATJ plant is CO_2 neutral. Renewable energy supplies are important for all stages of production

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Thank you!

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Q: Integrate or Segregate

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- Main considerations relate to
  - Green energy mix
  - Transport distance
- Integrate
  - Utility of side streams – e.g. biogenic carbon dioxide capture and use in ATJ-SKA plant can lead to **negative carbon emissions**
- Standalone
  - Flexibility
- Both work; circumstances dictate