Distribution of Sustainable Aviation Fuel to Enhance Climate Benefits

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Feasible Sustainable Aviation Fuel Deployment Strategies in Europe to Increase its Overall Climate Benefits

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Elisabeth Woeldgen

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Motivation

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- The EU and the UK are both introducing a **SAF mandate** to develop the production and usage of SAF.

Table 1: ReFuel EU and UK SAF mandates

	2025	2030	2035	2040	2045	2050
ReFuel EU mandate	2%	6%	20%	32%	38%	70%
UK SAF mandate		10%				

- The focus of these mandates is the reduction in **CO_2 emissions**.
- Following a transition period of 10 years giving flexibility to fuel suppliers to choose where to deliver SAF, it will have to be **uniformly distributed** across airports (with exceptions).
- The uniform distribution might lead to non-CO_2 benefits for SAF usage to not be fully realised.

Change in EF_{total} with the use of SAF

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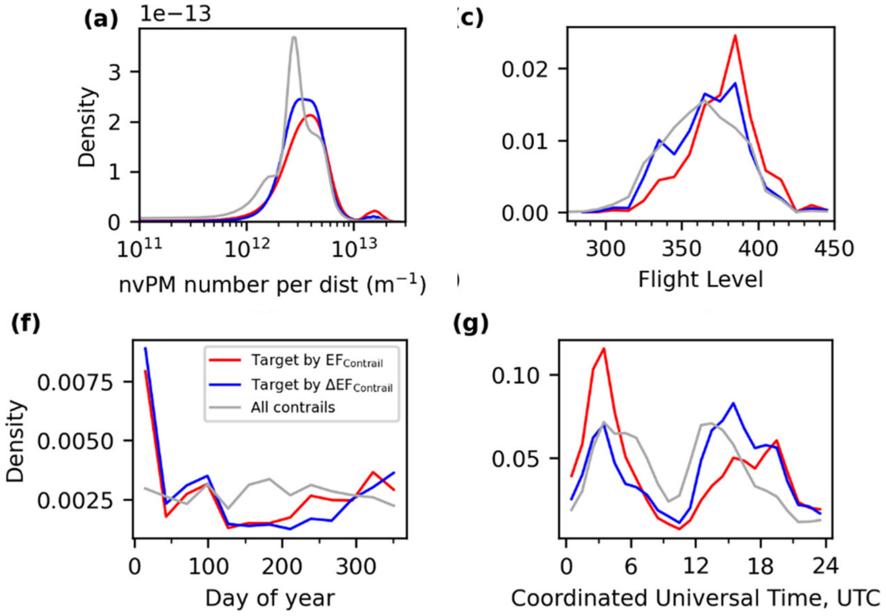
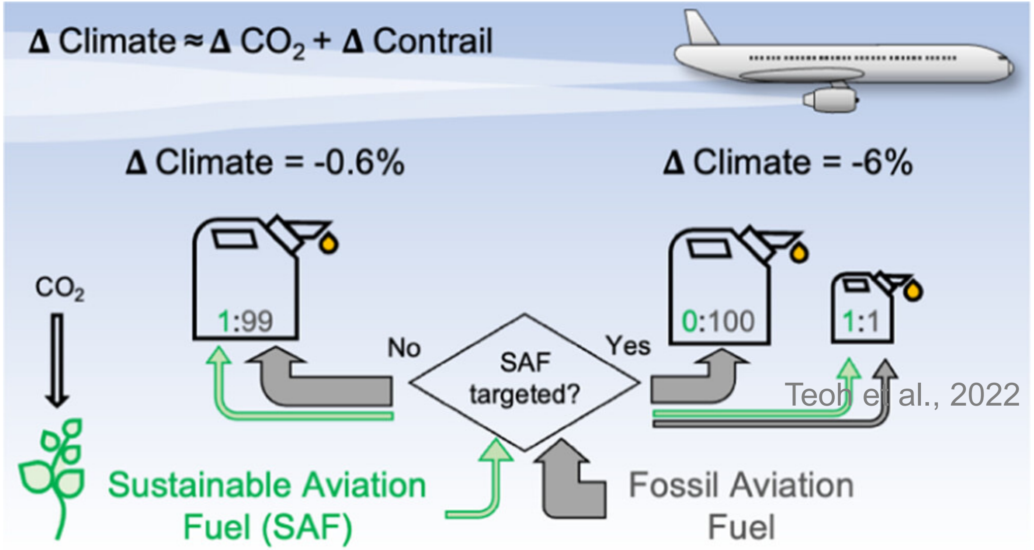
Teoh et al. studied the theoretical best case climate benefit of allocating SAF on specific flights.



Probability density function of the nvPM emissions, flight level, day of the year and time of the day for all contrail-forming flights (grey lines), as well as the subset of flights that are targeted with SAF at a 50% blending ratio by descending order of their $EF_{contrail}$ (red lines) or $\Delta EF_{contrail}$ (blue lines).



Reductions in EF_{total} from the SAF allocation by $\Delta EF_{contrail}$ with a **50%** $\boldsymbol{p_{blend}}$ (−6.5 to −6.2%) is approximately **9 to 15 times larger** than the baseline scenario with uniform distribution (−0.8 to −0.4%)*.

→ Are there any <u>FEASIBLE</u> SAF deployment supply chains that have an additional non-CO_2 benefit?

* Depending on the assumed reduction in CO2 life cycle emissions from SAF.

1

Objectives

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What are **feasible** SAF **distribution strategies** to enhance climate benefits of ReFuelEU and UK SAF mandates?

What are feasible distribution scenarios?

What are the associated **climate benefits**?

What are the additional **supply chain** costs?

Which of the distribution scenarios has the best cost benefit **ratio**?

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Traditional SAF Supply Chain

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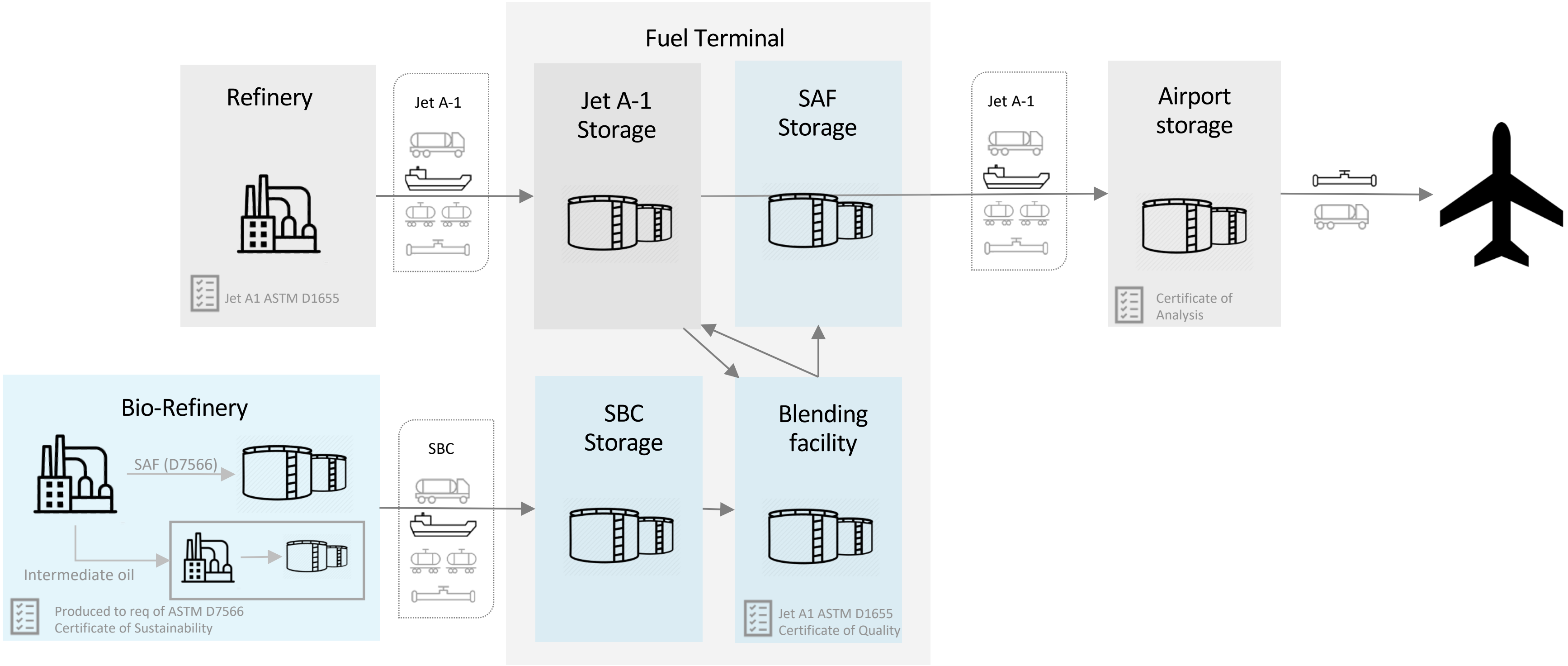

Deployment Strategies – Baseline

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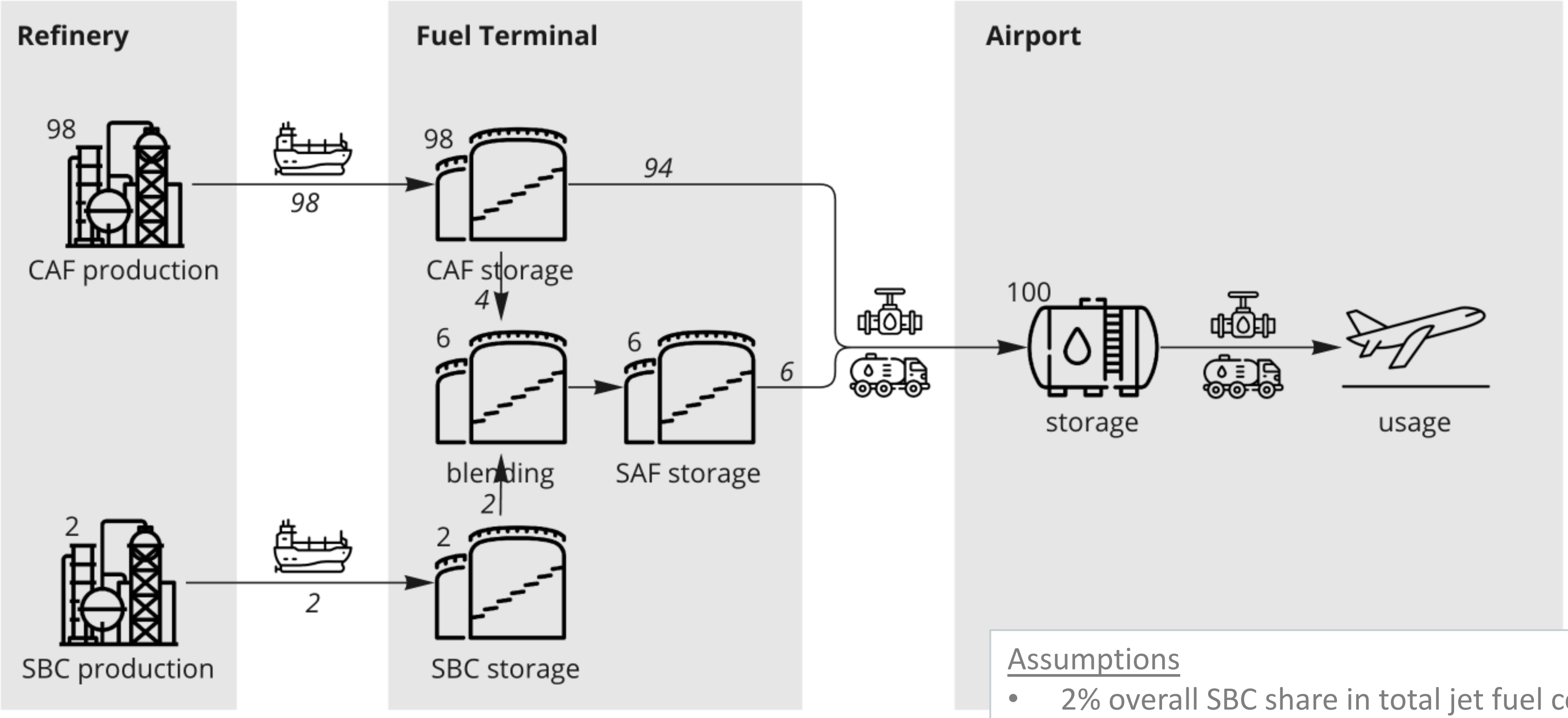
Baseline



Assumptions

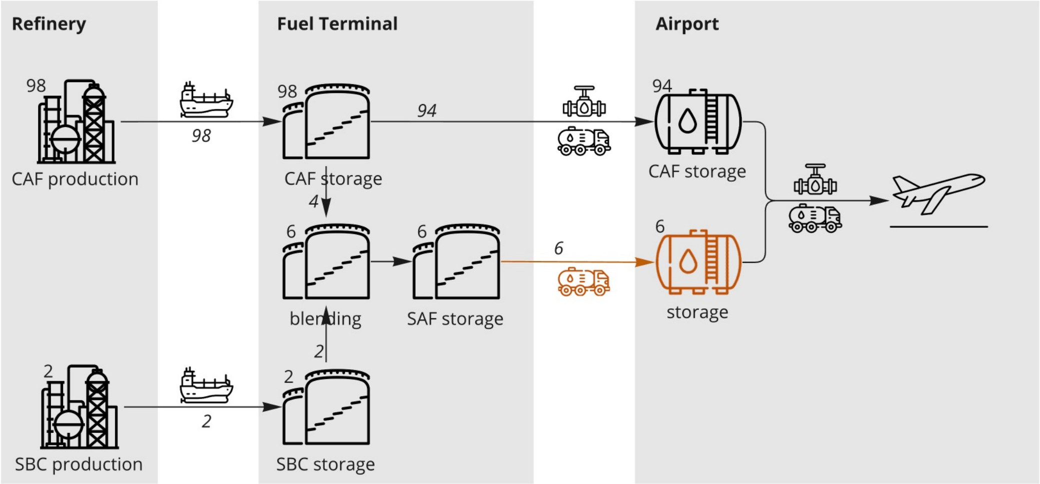
- 2% overall SBC share in total jet fuel consumption.
- SBC volumes are blended with a 1/3 SBC – 2/3 CAF ratio.
- Year-long operations for SBC production and blending.

3 Deployment Strategies

<u>Assumptions</u> – Diurnal

- A fixed mass of SAF supply is supplied to airports every day by road tanker.
- SAF is stored in separate (additional) tanks at the airport.
- SAF is transferred to A/C the same way as with conventional aviation fuel (CAF).
- Targeted distribution: all flights departing from 16:00 local time will be provided with SAF at a **10% blend ratio** until the supply runs out (total SBC volumes amount to 2% of total jet fuel supply).

Diurnal Supply SAF to A/C between 1600 – 0300 UTC.

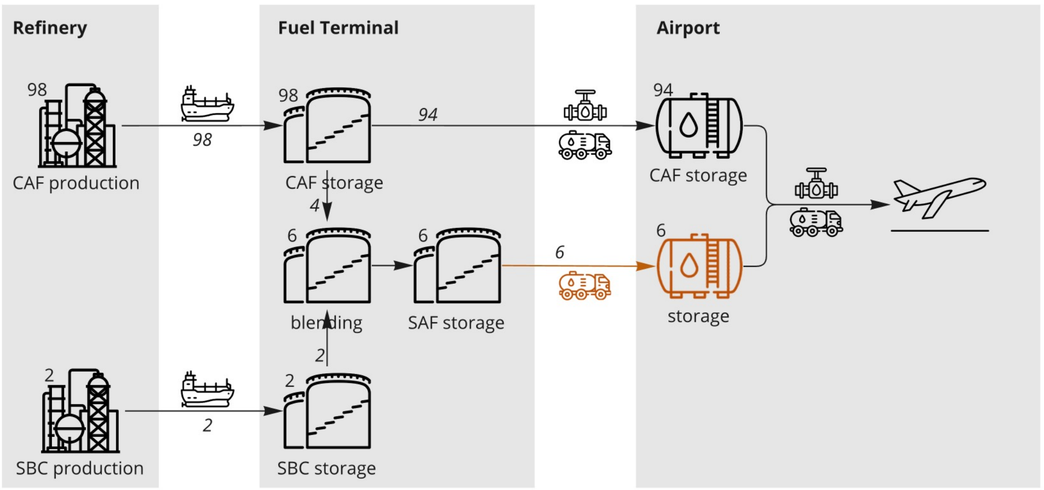


3 Deployment Strategies

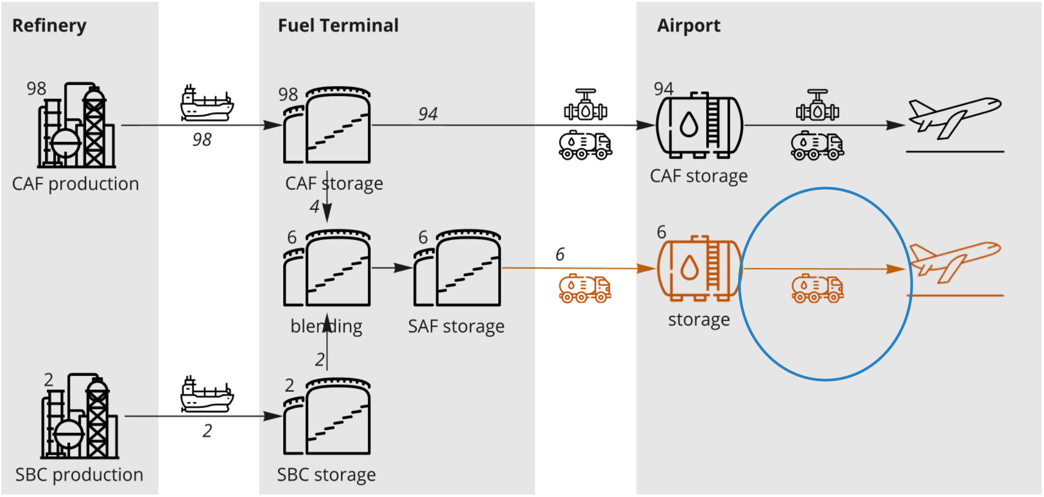
Assumptions – Diurnal and flight characteristics

- A fixed mass of SAF supply is supplied to airports every day by road tanker.
- SAF is stored in separate (additional) tanks at the airport.
- SAF is transferred to specific A/C only by refueler tank (no hydrant system).
- Targeted distribution: all flights departing from 16:00 local time will be provided with SAF at a **10% blend ratio** until the supply runs out (total SBC volumes amount to 2% of total jet fuel supply) .

Diurnal Supply SAF to A/C between 1600 – 0300 UTC.



Diurnal and flight characteristics Supply SAF to A/C between 1600 – 0300 UTC and on A/C - engine combination with highest warming contrail formation.



3 Deployment Strategies

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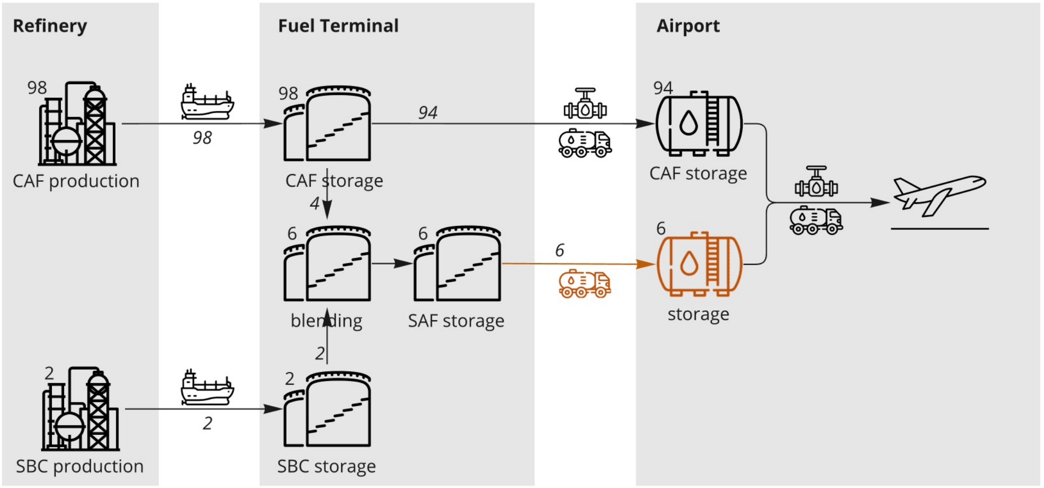
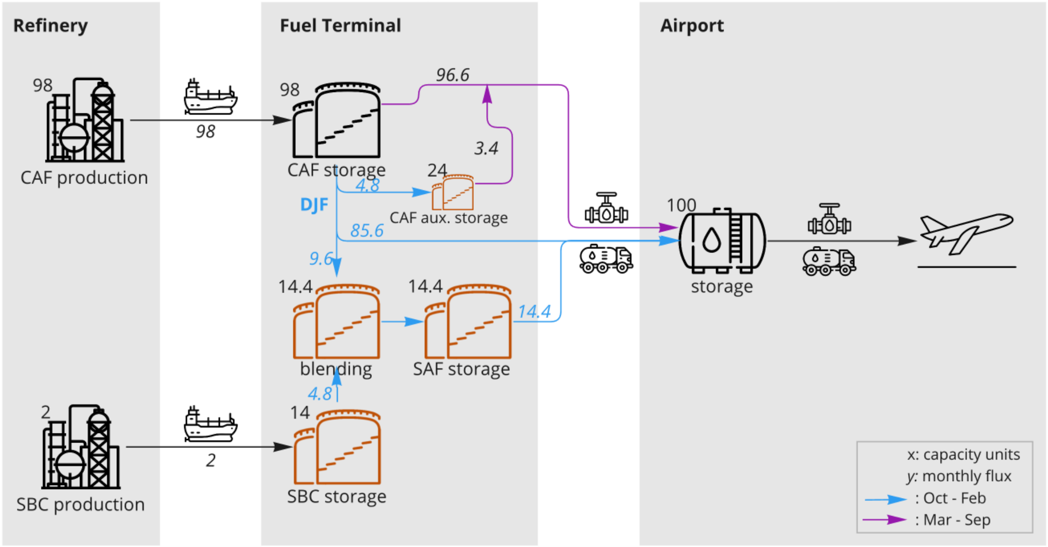
Assumptions – Seasonal
- SAF is only used from October to February.
- SBC is produced all year-long and stored at a fuel terminal.
- When SAF is used, more CAF is stored at the terminal.
- SAF is transported to airports, stored at airports and refueled on A/C the same way as CAF.
- Uniform distribution during the autumn and winter months, where the mean SAF blend ratio is 7.3% (total SBC volumes amount to 2% of total jet fuel supply).
- Current scenario assumes distribution to top 20 airports only.

Diurnal Supply SAF to A/C between 1600 – 0300 UTC.



Seasonal Supply SAF to airports from October to February.



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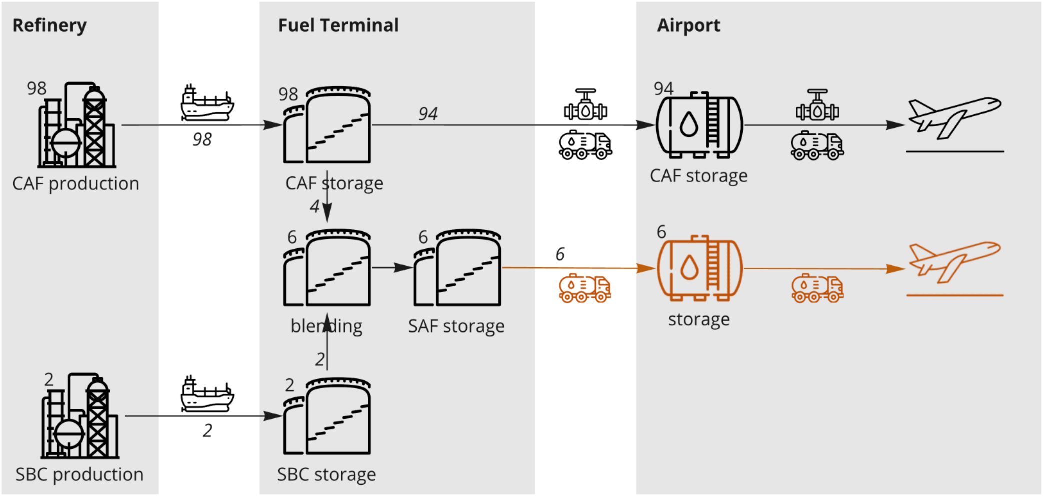

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Which of the distribution scenarios has the best cost benefit **ratio**?

4 Overview Contrail Model

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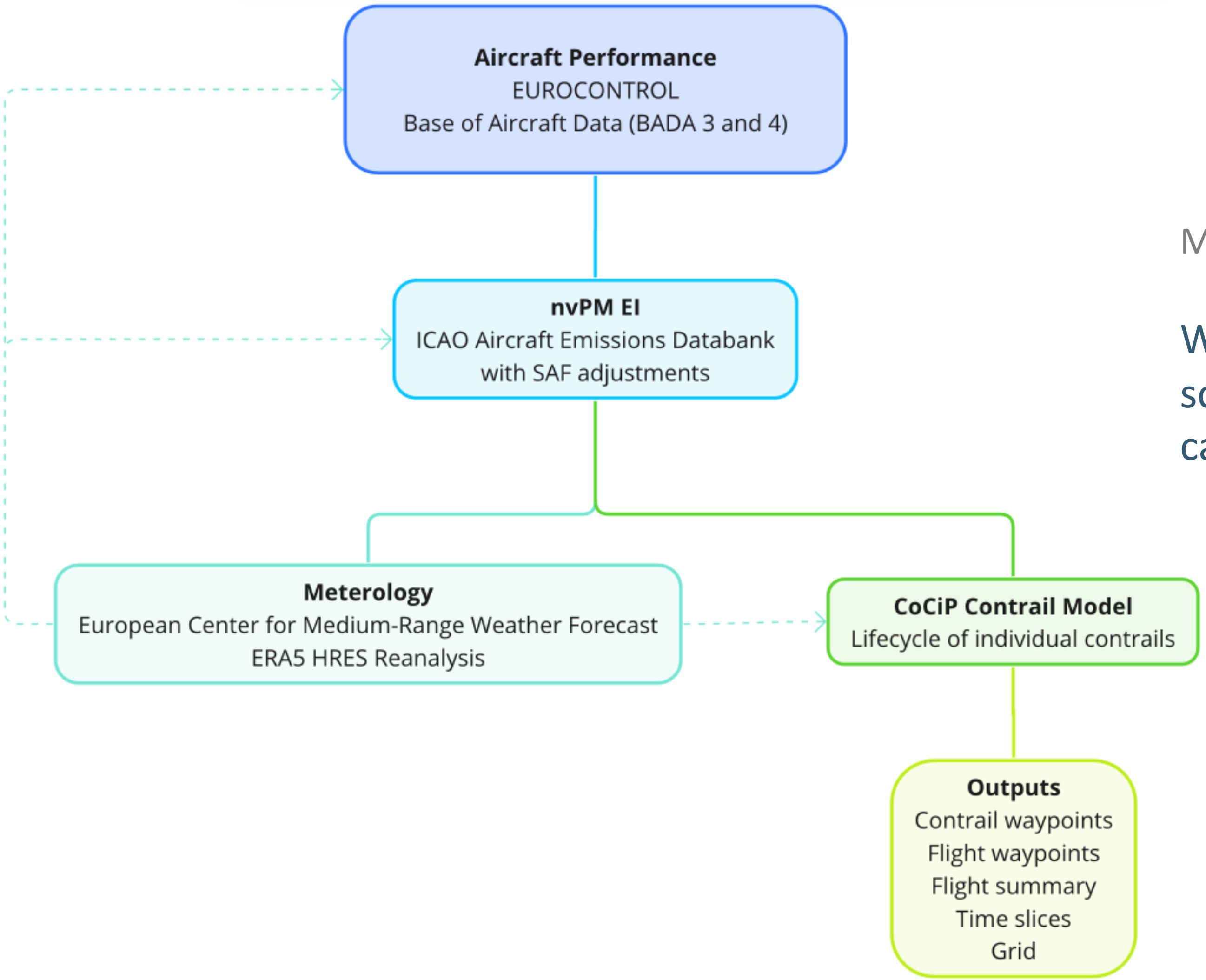

More details in Teoh et al., 2022.

We run the model for our SAF distribution scenarios (including the baseline) to calculate the $EF_{contrail}$ change.

4 Preliminary $EF_{contrail}$ results

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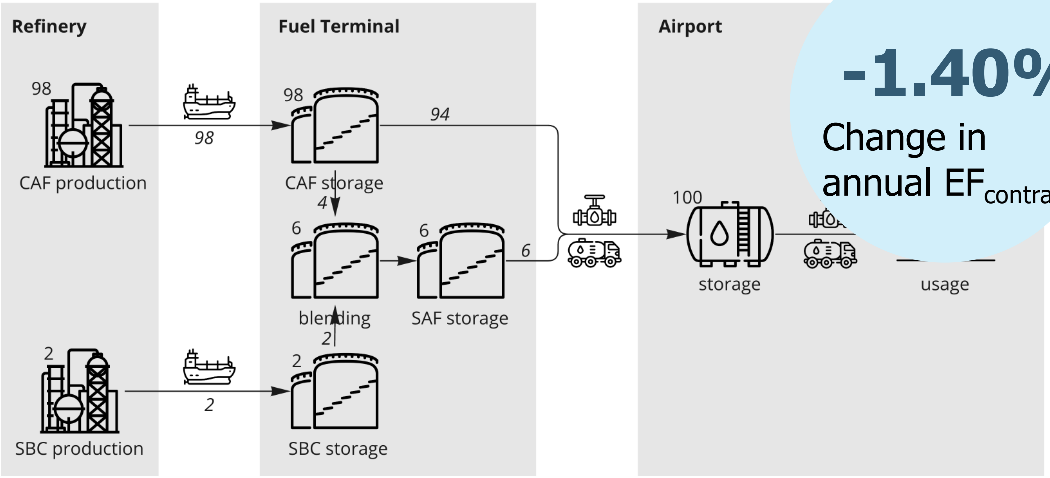
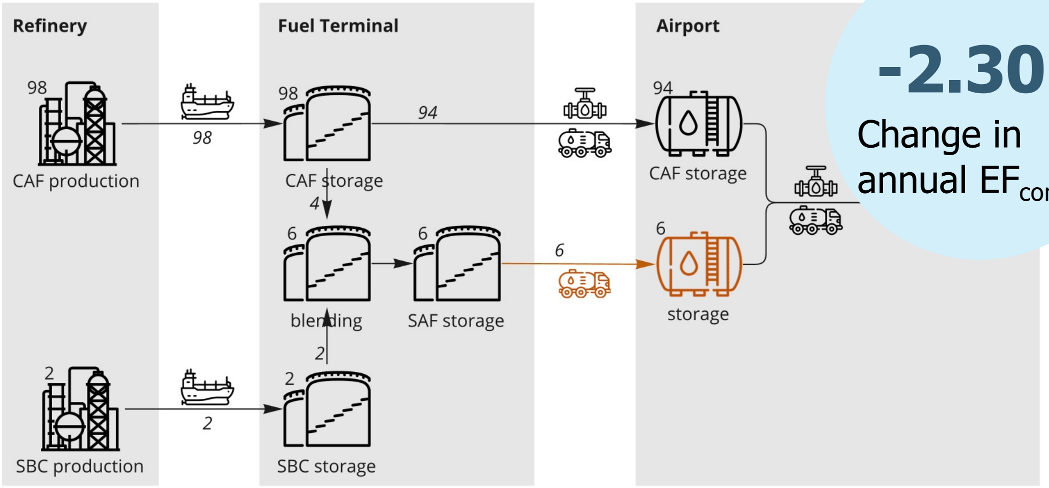
Baseline



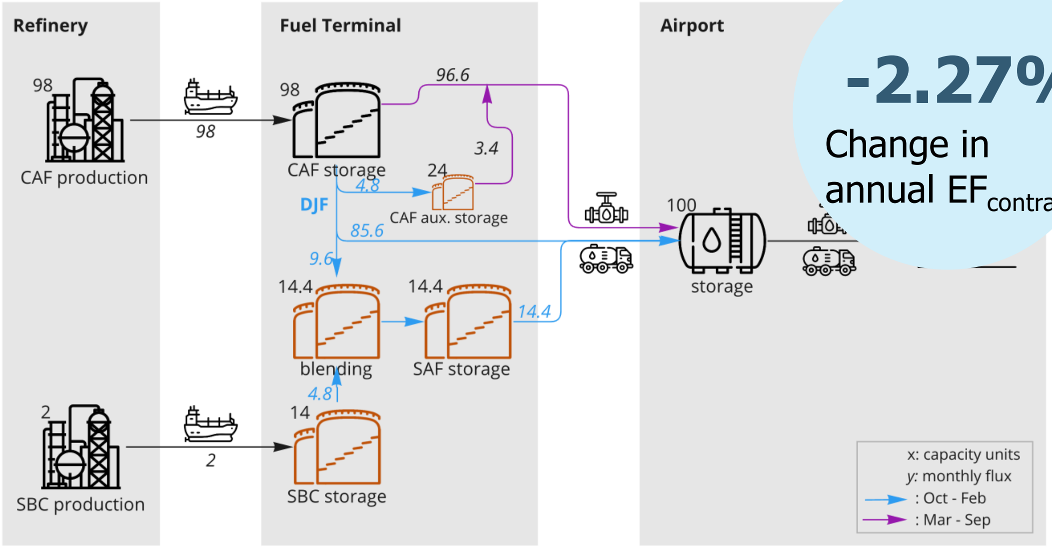
-1.40%
Change in annual $EF_{contrail}$

Diurnal Supply SAF to A/C between 1600 – 0300 UTC.



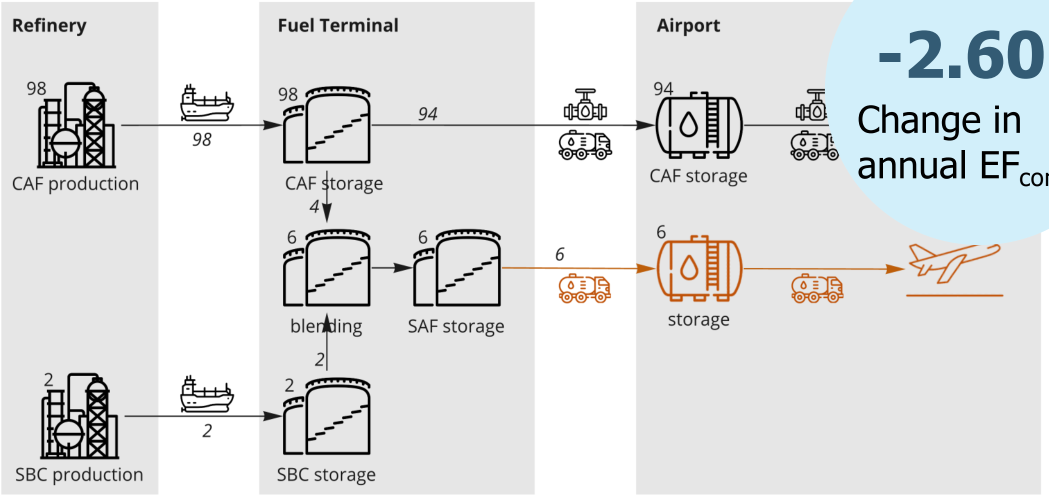
-2.30%
Change in annual $EF_{contrail}$

Seasonal Supply SAF to airports from October to February.



-2.27%
Change in annual $EF_{contrail}$

Diurnal and flight characteristics Supply SAF to A/C between 1600 – 0300 UTC and on A/C - engine combination with highest warming con



-2.60%
Change in annual $EF_{contrail}$

4 Preliminary $EF_{contrail}$ results

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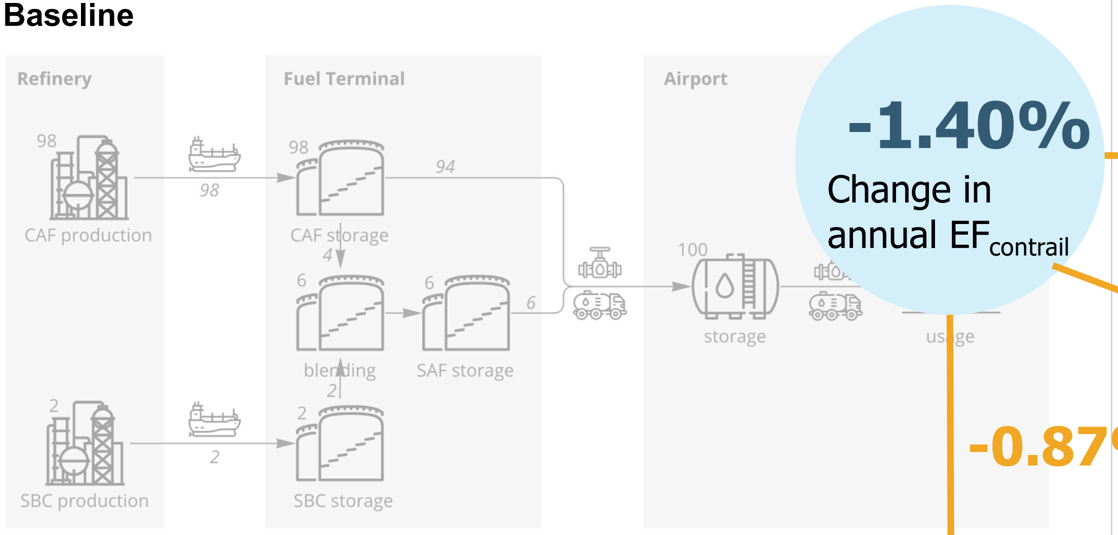
Baseline



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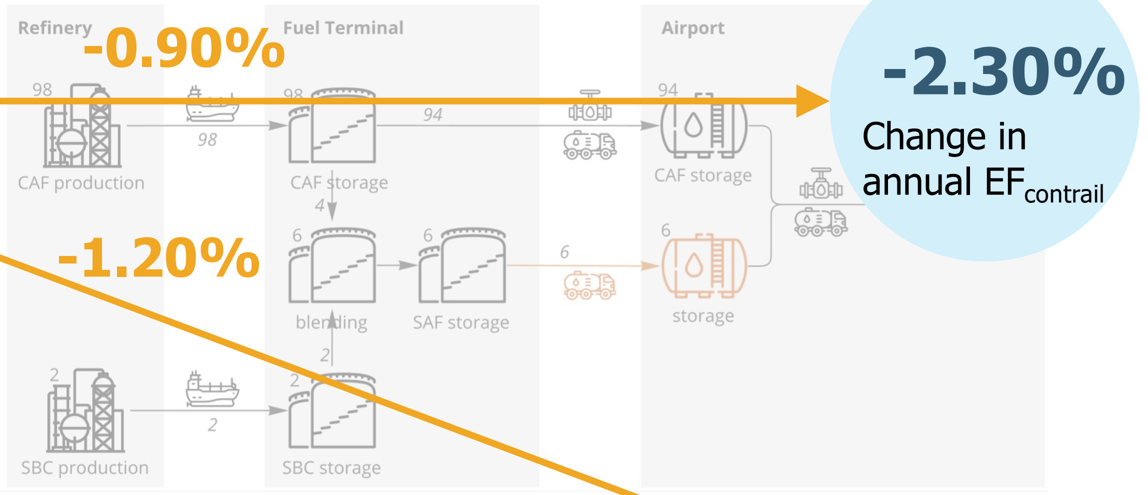
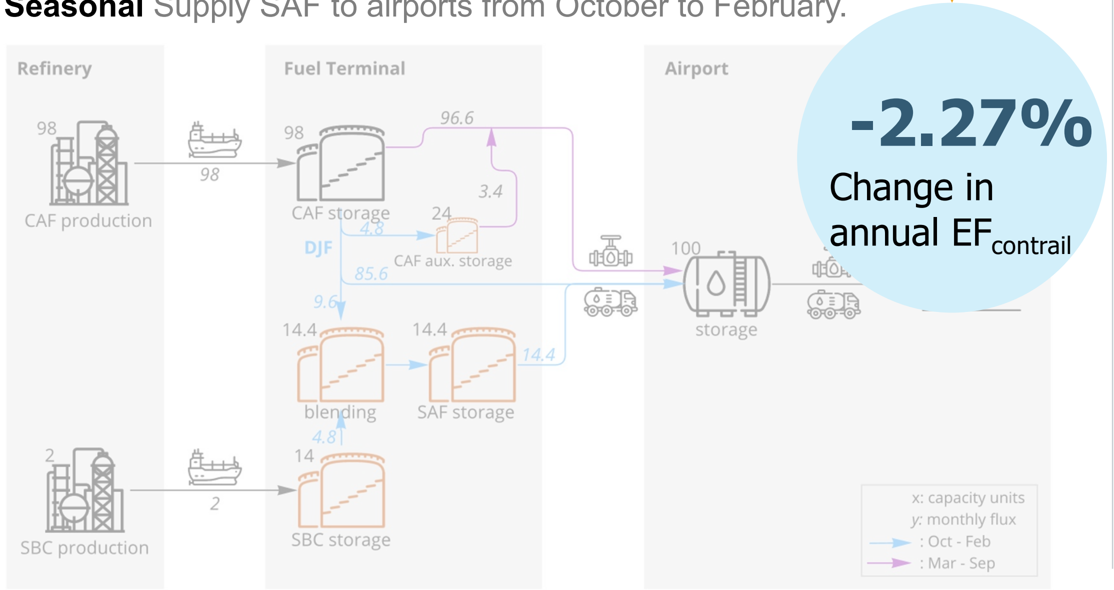


Seasonal Supply SAF to airports from October to February.



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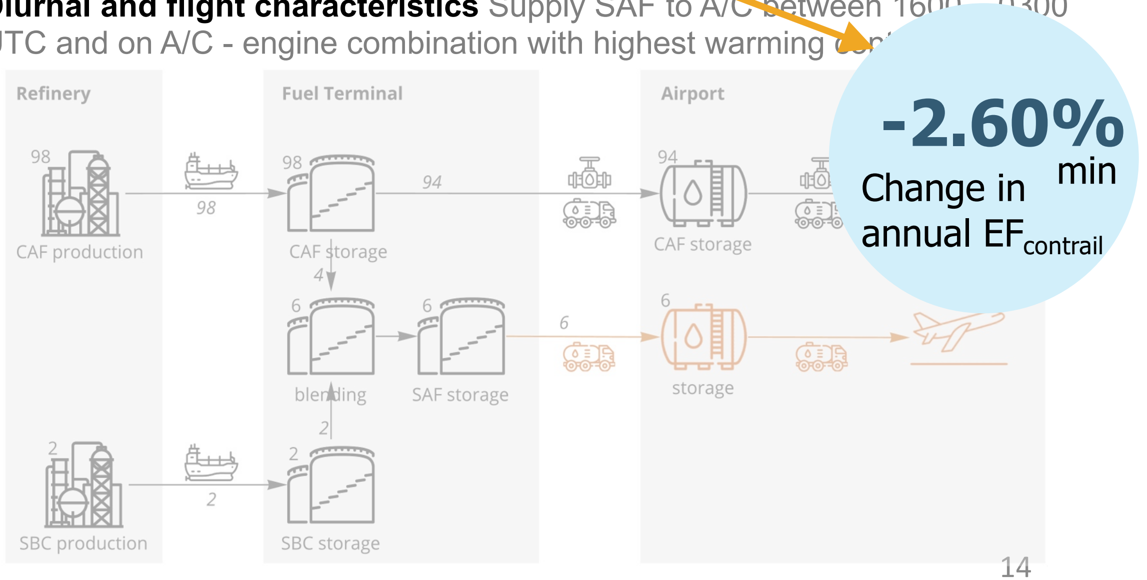

$EF_{contrail}$ Valuation

Valuation of $EF_{contrail}$ in monetary terms:

$$CO_2EF[J] \approx AGWP_{CO_2,TH} \times m_{CO_2} \times S_{earth}$$

(Teoh et al., 2022)

EF calculated for every scenario

$$S_{earth} = 5.101 * 10^{14}\ m^2$$

$$AGWP_{CO_2,20} = 7.947 * 10^{-7}\ sWm^{-2}kg^{-1}$$
$$AGWP_{CO_2,100} = 2.917 * 10^{-6}\ sWm^{-2}kg^{-1}$$

$$\text{Monetary estimate of } EF_{contrail} = m_{CO_2} \times \text{Damage cost}$$

$100\ EUR/t_{CO_2}$
EU ETS projected for 2026-2030 for the EU

4 $EF_{contrail}$ Valuation

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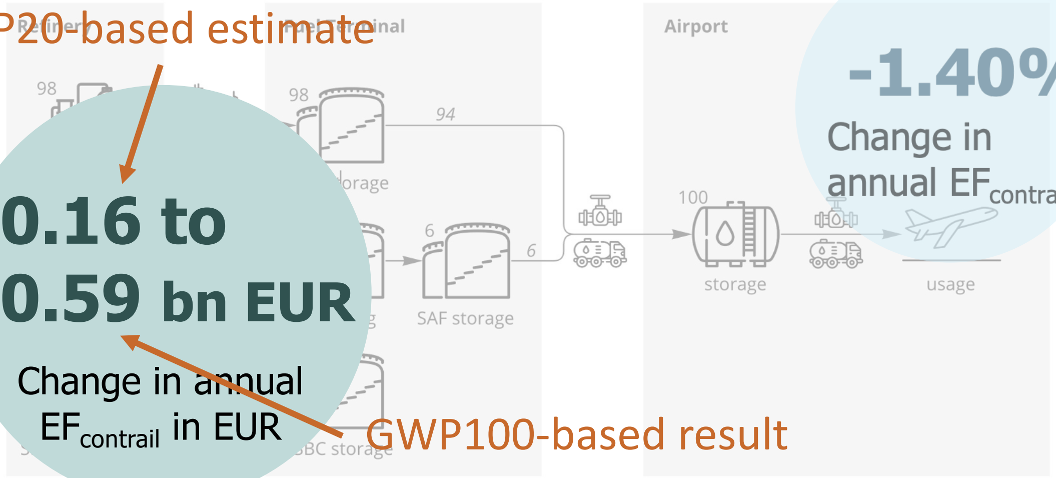
Baseline



GWP20-based estimate

-0.16 to
-0.59 bn EUR

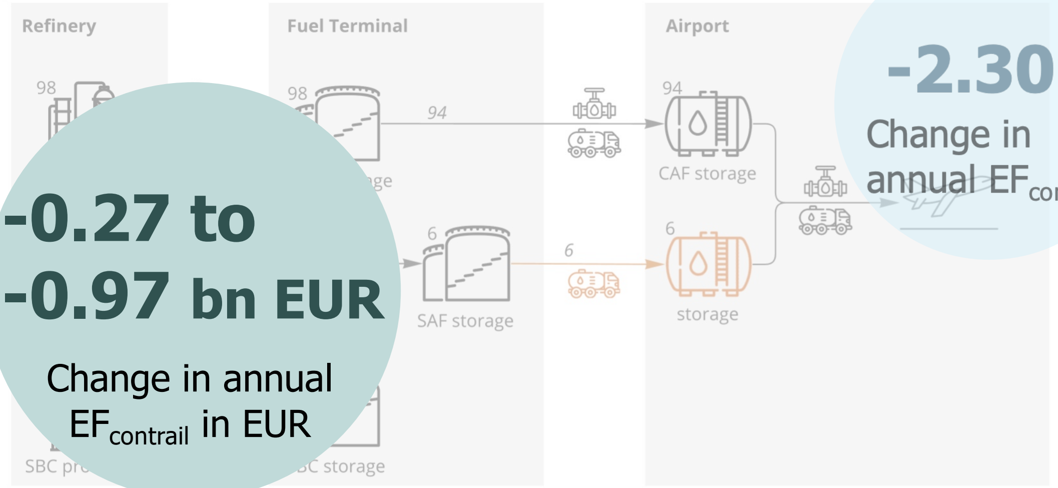
Change in annual $EF_{contrail}$ in EUR

GWP100-based result

-1.40%

Change in annual $EF_{contrail}$

Diurnal Supply SAF to A/C between 1600 – 0300 UTC.



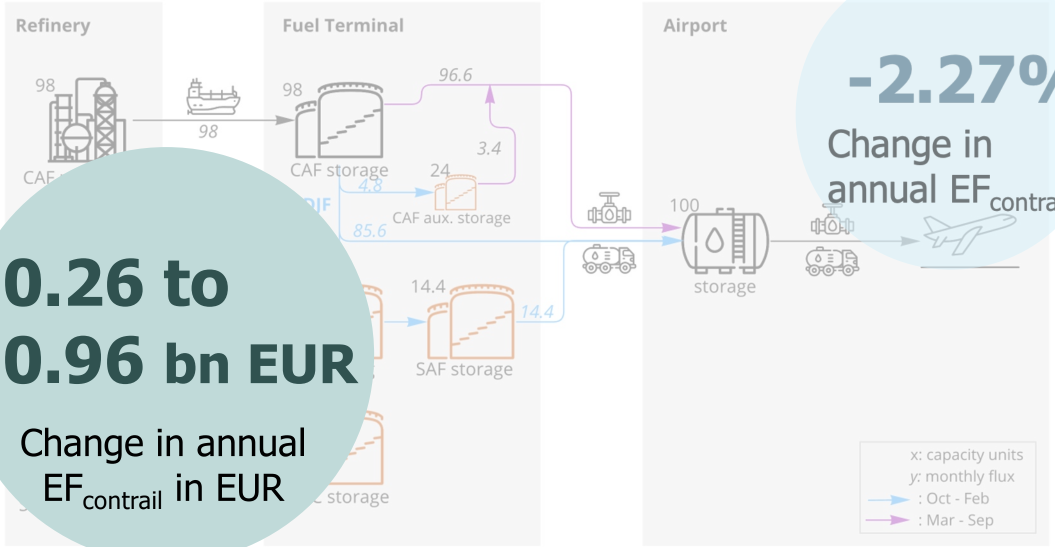
-0.27 to
-0.97 bn EUR

Change in annual $EF_{contrail}$ in EUR

-2.30%

Change in annual $EF_{contrail}$

Seasonal Supply SAF to airports from October to February.



-0.26 to
-0.96 bn EUR

Change in annual $EF_{contrail}$ in EUR

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Change in annual $EF_{contrail}$

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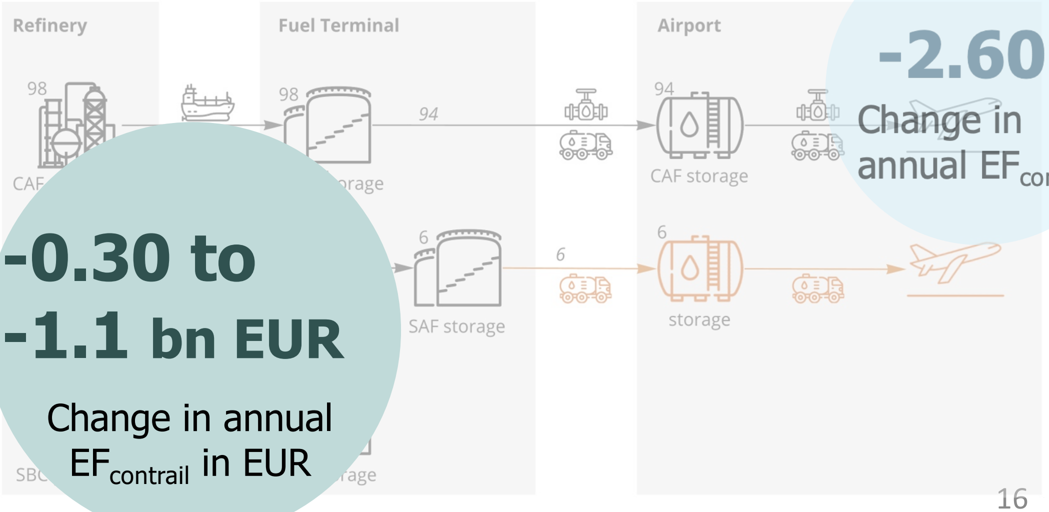


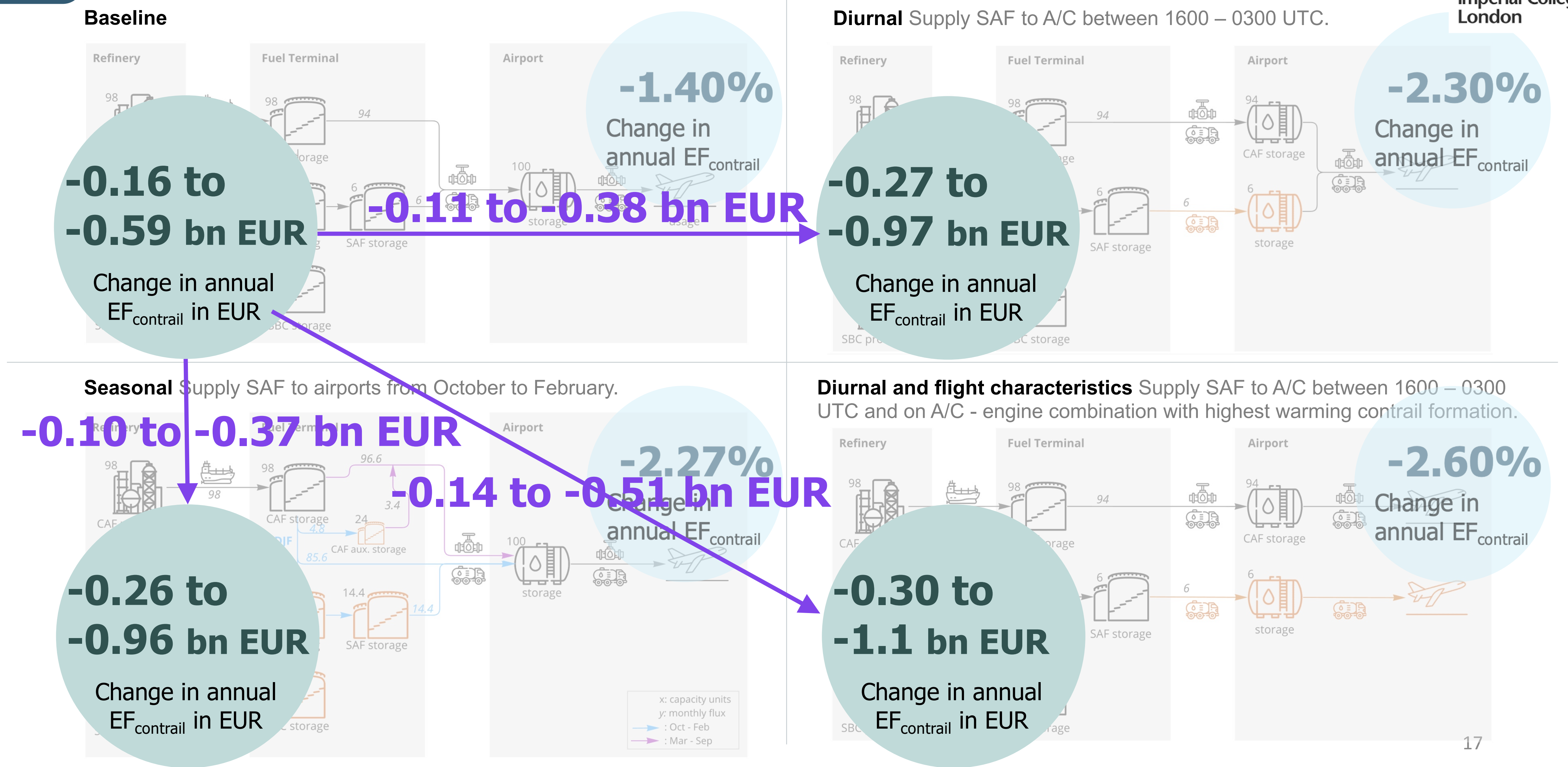
-0.30 to
-1.1 bn EUR

Change in annual $EF_{contrail}$ in EUR

-2.60%

Change in annual $EF_{contrail}$

4 $EF_{contrail}$ Valuation



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4 Overview Cost Model

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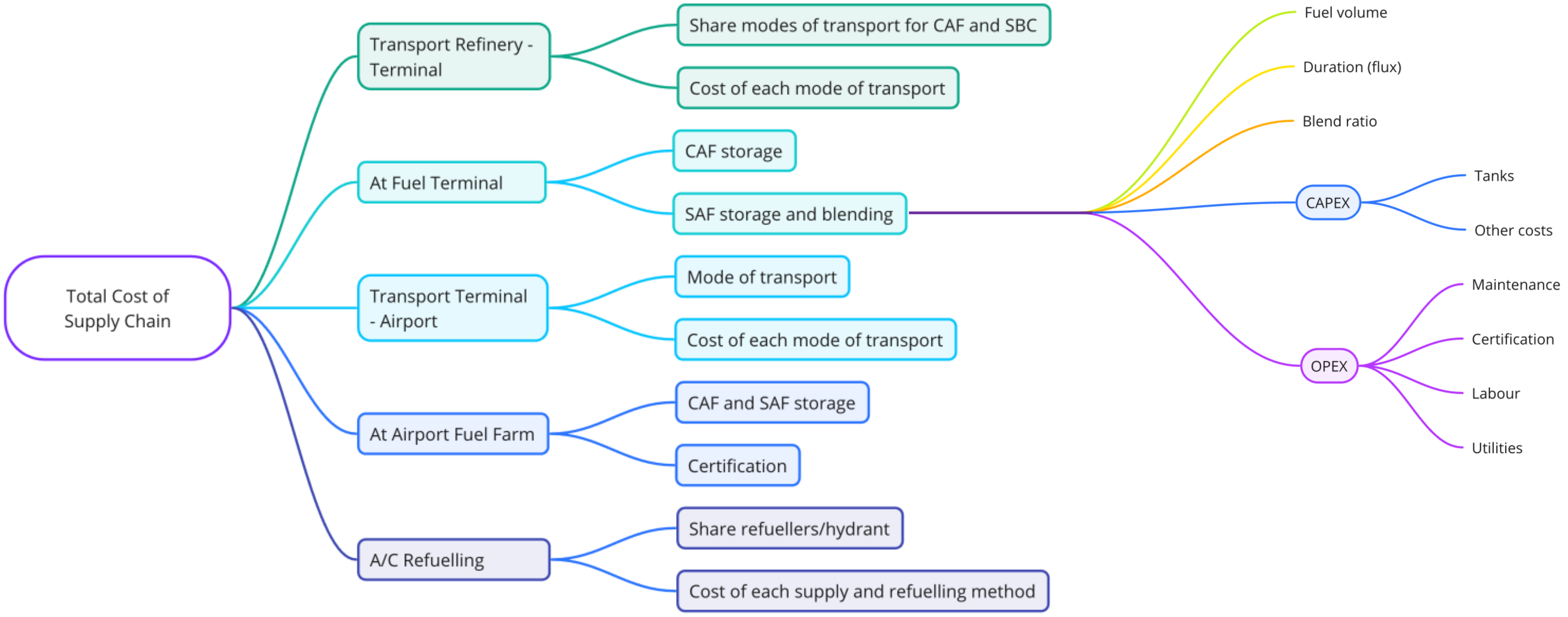

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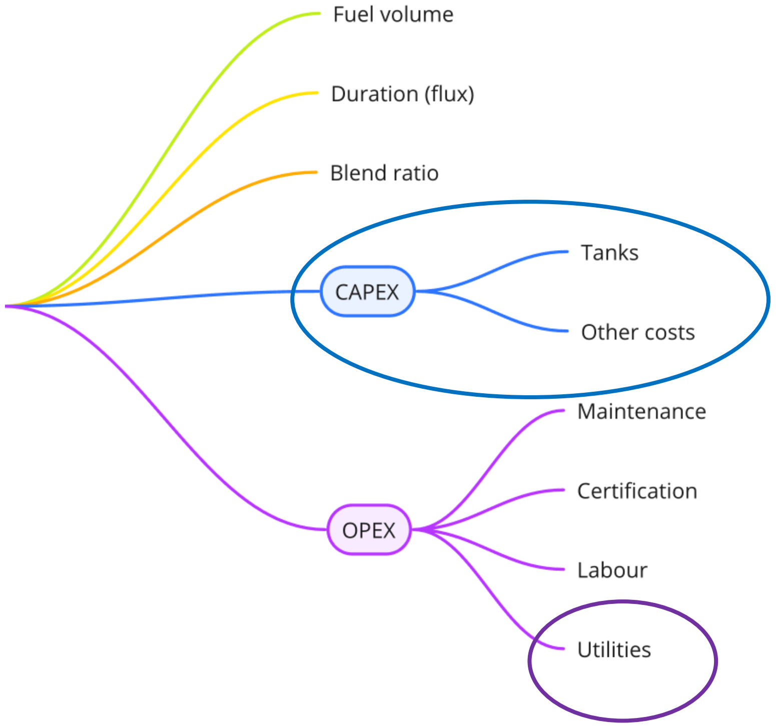

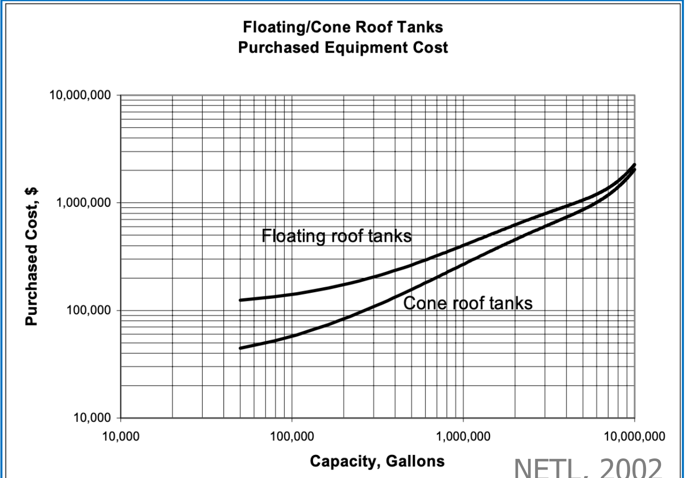

NETL, 2002

51 4000 m³ storage tanks	Value
Volume [m³]	4000
Cost [EUR]	681.335
Nb tanks	51
Cost of tanks [EUR]	34.748.095
Infrastructure cost [EUR]	173.740.476
Total cost [EUR]	217.175.595
Yearly CAPEX incl depreciation period [EUR]	8.687.024

$$Powerconsumption\,[kWh] = Time\,(un)loading \times \frac{Flow\ rate \times Height \times Density\ \times Gravity}{pump\ efficiency}$$

$$Utilities\ cost[EUR] = (Pump\ power\ consumption + Background\ cons) \times Energy\ price$$

51 4000 m³ storage tanks	Value
Flow rate [m³/hr]	1000
Density [kg/m³]	757
Pump efficiency [%]	85
Height [m]	10,84
Time (un)loading [hr]	13,035
Energy price [EUR/kWh]	0.21

51 4000 m³ storage tanks	Value
Background consumption [kW]	1
Pump power consumption [kWh]	26.30
Energy price [EUR/kWh]	0.21
Utilities cost [EUR]	342,890

4 Supply Chain Costs – Preliminary

Distribution scenario	Supply Chain Costs – base case (change relative to baseline scenario) [bn EUR]	Supply Chain Costs – worst case [bn EUR]
Baseline	4.390	4.607 (+0.22)
Diurnal	4.562 (+0.17)	4.821 (+0.26)
Diurnal + FC	4.564 (+0.17)	4.824 (+0.26)
Seasonal	4.502 (+0.11)	4.778 (+0.28)

4 Costs comparison – Preliminary

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Distribution scenario	**Supply Chain Costs – base case** (change relative to baseline scenario) [bn EUR]	**Supply Chain Costs – worst case** [bn EUR]	**Monetised $EF_{contrail}$** Benefit with the use of SAF **20 years TH** [bn EUR]	**Monetised $EF_{contrail}$** Benefit with the use of SAF **100 years TH** [bn EUR]
Baseline	4.390	4.607 (+0.22)	0.56 – 1.06 (Δ = 0.50)	0.16 – 0.29 (Δ = 0.13)
Diurnal	4.562 (+0.17)	4.821 (+0.26)	0.97 – 1.89 (Δ = 0.92)	0.27 – 0.51 (Δ = 0.24)
Diurnal + FC	4.564 (+0.17)	4.824 (+0.26)	1.10 – 1.94 (Δ = 0.84)	0.30 – 0.53 (Δ = 0.23)
Seasonal	4.502 (+0.11)	4.778 (+0.28)	0.96 – 1.70 (Δ = 0.74)	0.26 – 0.46 (Δ = 0.20)

- The range in the last two columns comes from different characteristics in the distribution scenarios.
- **The preliminary results seem to indicate that the net benefit highly depends on the value chosen for the GWP, 20 or 100 years time horizon, more than the supply chain input values.**

4 Summary and next steps

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- We developed a set of SAF deployment scenarios for the EU and the UK that can be employed in practice to enhance the climate benefit of SAF usage.
- We used a contrail model to estimate EF changes from these deployment scenarios compared to a uniform SAF distribution and valued these changes in monetary terms.
- We built a SAF cost model along the supply chain and used it to estimate the additional costs of these deployment scenarios compared to a uniform SAF distribution to airports.
- Preliminary results seem to indicate that the question of whether these alternative distribution scenarios are net beneficial might depend on the metric chosen to express $EF_{contrail}$ in CO_2 equivalent units.
- Validation of the cost model with additional industry actors will allow us to further sharpen the pencil on the supply chain cost side.

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Thank you very much!

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