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Abstract

Airports do not play a direct role in the physical supply chain of SAF, but the use of SAF can have a large contribution to reducing an airport's scope 3 greenhouse gas emissions.

To determine the suitability of co-locating an eSAF facility on an airport, a framework for assessing a site for an eSAF facility is developed. This framework serves to contribute to the overall aim of the TULIPS of accelerating emission reduction and efficient resource use at airports. This framework can be used to assess all eSAF facility sites and is used in this report to determine the suitability of airports as an eSAF facility site.

The suitability of an airport as a site is dependent on the current airport location and characteristics and its surrounding industries. None of these factors can be changed easily, making airports a more restrictive location for an eSAF facility compared to other industrial site locations. Furthermore, operating an onsite eSAF facility would impact airport operations, increasing the complexity of operating an eSAF facility on airport grounds.

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VI. LIST OF ACRONYMS

Acronym	Meaning
ASTM	ASTM International, formerly known as American Society for Testing and Materials
ATEX	Atmosphere Explosible and abbreviated name of European Directive 2014/34/EC
CAPEX	Capital Expenditure
DAC	Direct Air Capture
EI	Energy Institute
eSAF	SAF produced from hydrogen and CO ₂
JIG	Joint Inspection Group
PtL	Power-to-Liquids
RE	Renewable Energy
RED-II	EU Renewable Energy Directive II
SAF	Sustainable Aviation Fuel
TULIPS	Demonstrating lower polluting solutions for sustainable airports across Europe



1 Executive Summary

Airports have a unique position of being at the intersection of airlines, fuel suppliers, fuel operators, governments and communities. They are exceptionally well-placed to support the scale-up of SAF. Currently, airports do not have a direct role in the physical supply chain of SAF. In this report, a framework for assessing a site for an eSAF facility is created to aid the project development of eSAF facilities. The site selection is an important part of the project as a site can have a large impact on risks, timelines and investment and operational costs. Secondly, this framework is used to evaluate the suitability of an airport as a site for an eSAF facility. This report serves to contribute to the overall aim of the TULIPS of accelerating emission reduction and efficient resource use at airports.

The framework includes general site assessment factors that are fundamental to the success of the development and operation of an eSAF facility. These factors, for example, impact the construction process, operational requirements, profitability, and scope for future expansion. The factors presented are based on SkyNRG's experience in previous eSAF facility projects. Setting up an eSAF facility on airport grounds requires the airport to meet basic process and legal requirements. In addition to these requirements, secondary requirements are important to improve site favourability.

Evaluating airports as a site for an eSAF facility, it was found that the main process limiting factors are area availability and supply of renewable electricity and biogenic CO₂ to the facility. The main legal limit factors are the zoning plan of airports and the social acceptability of the facility. Additionally having synergies with other nearby facilities and having access to existing infrastructure is an important secondary requirement that would make an eSAF facility on airport grounds more feasible. The majority of these factors can be difficult to manage as they are external risks, limiting the suitability of airports as sites. Furthermore, operating an onsite eSAF facility would impact airport operation and require changes to the existing jet fuel infrastructure on airport grounds. These factors increase the complexity of operating the facility and increase the eSAF production costs.



2 Introduction

2.1 Report as part of TULIPS

This report on a site assessment framework for an eSAF facility is part of the TULIPS project, which is a Horizon 2020 project funded by the EU. The goal of TULIPS is to accelerate the implementation of innovative and sustainable technologies towards lower emissions at airports. Topics covered include a) improved multi-modal shift for passengers and freight, reduce traffic congestion and offer seamless green travel options, b) improved airside infrastructure for future electric/hybrid aircraft infrastructure, c) smart energy solutions to manage airport operations, d) integrating hydrogen fuel cell technology into current ground support equipment, e) enabling large scale supply of SAF fuel along with the preparation of an EU clearing house, f) circular economy, and g) UFP mitigation.

More specifically, this report constitutes deliverable 5.2, part of TULIPS work package 5 which focuses on scaling up the SAF market. This deliverable details a methodology to assess the suitability of a site for an eSAF facility and describes the parameters that need to be considered. Additionally, the suitability of an airport as a site for an eSAF facility is detailed.

2.2 Report set-up

Sustainable Aviation Fuel (SAF) is seen as an important solution to decarbonize the aviation sector in the short and medium term, as it can be used in the current fuel systems and is, to a limited extent, commercially available. SAF is made from various sustainable feedstocks which are divided into 2 categories: SAF derived from biogenic feedstocks and eSAF. For eSAF production, renewable electricity is used to produce green hydrogen which is combined with CO₂ as feedstock for the production of fuels.

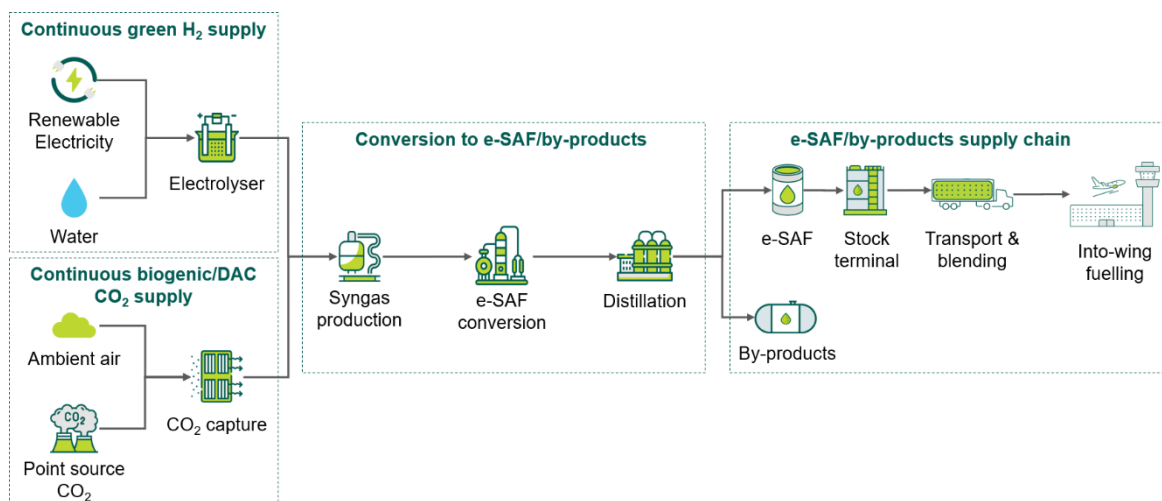


Figure 1 Main building blocks of an eSAF supply chain.



This document serves as a framework to assess the suitability of a site for an eSAF facility. The site selection is an important part of the project as a site can have a large impact on risks, timelines and investment and operational costs. A project developer can use the methodology described in this document to assess one or more sites and understand their suitability. In the next section, the parameters that need to be taken into account are described, including the desired characteristic per parameter. In the sections thereafter, the document focuses on on-airport eSAF production by listing the parameters that are key when looking into an airport site and by going into the effect of such a facility on airport operations. Finally, the conclusion summarizes the main findings.



3 General Site Assessment Factors

The location of an eSAF facility can have a large impact on the development of the facility. For example, it can impact the construction process, operation requirements, profitability, and the scope for future expansion. The factors used to evaluate a site are therefore important for the success of the project. These factors presented in this section are based on SkyNRG's experience in previous eSAF facility projects.

In this section, the general factors for an eSAF facility site assessment are discussed, and subdivided per topic. Multiple factors must be considered to bring the most advantages to the project, including site specifications and costs, raw material supply and product transportation, available utilities and existing infrastructure, and environmental regulations, shown in Figure 2. The key site assessment factors when evaluating airports as an eSAF facility are discussed in Section 4.

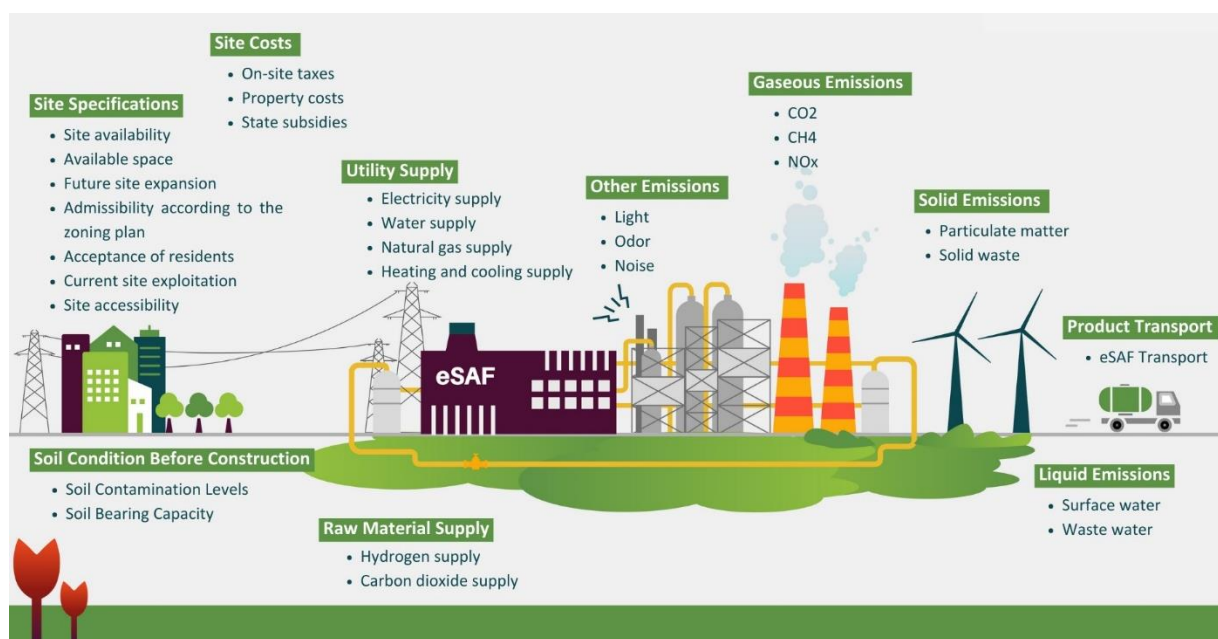


Figure 2 Summary of all site assessment factors for an eSAF facility.

3.1 Site Specifications and Costs

To ensure that the site location can be bought and the plant can be constructed and operated, site specifications and costs must be considered. The site selected must be available for purchase, is affordable, can accommodate area requirements, is accessible, and can obtain permits for construction. Table 1 provides the summary of all the site specifications and cost assessment factors that are desired for an eSAF facility.



Table 1 Site specifications and site costs assessment factors and desired characteristics

	Factors	Desired Characteristics
Site Specifications	Site availability	The site should be available for purchase or lease.
	Available space	The site has sufficient area for minimum plant requirements.
	Future site expansion	The site has sufficient area for future expansion of the facility.
	Admissibility according to the zoning plan	No changes in the zoning plan are required.
	Acceptance of Residents	The installation is aligned with the regional vision and accepted by the local residents.
	Current site exploitation	The preference for a green or brown field plant is dependent on available facilities and plant requirements.
	Site accessibility	The site is accessible by at least one type of transportation mode; road, marine, or rail.
Site Costs	On-site Taxes	Affordable on-site taxes.
	Property costs	Affordable property costs.
	State subsidies	State subsidies are available for the site.

Site Availability

A site's availability for purchase or leasing determines whether the site can be bought or used. The site must be available for the implementation of construction plans. This requires the (current) owner of the site to be willing to sell or lease. Some site owners (e.g. ports) will have their assessment methodology to determine whether a new activity is suitable for the envisioned plot. Additionally, the land should be free from any hindrance such as environmental contamination or legal disputes. These issues can take a long time to resolve.

Available space

The required area for a plant is given by its minimum layout requirements. This includes areas for the plant production facilities, offices, parking spaces, and other required facilities. In an eSAF facility, hydrogen production on-site will increase the minimum area required for the electrolyzers and hydrogen storage. The available space must also fulfil the ATEX zone requirements. These are minimum safety requirements for workplaces and equipment used in zones with explosion or combustion risks. Depending on the zone rating, safety distance, specific equipment, and protective systems are required. There must be sufficient area to accommodate these requirements. Without sufficient area, the plant cannot be constructed.

Future site expansion

If a plant expansion is likely, the site area will require a larger area than the minimum layout area. Having an available area for expansion is not a requirement for facility construction and operation, but it is a desired characteristic, especially, when an expansion in production volume is expected.



Admissibility according to the zoning plan

A zoning plan includes detailed rules on how a certain plot of land or area can be used. Industrial installations can only be constructed and operated in an industrial zoning plan. If the site is not situated in an industrial zoning plan, the zoning plan must be changed. The changing of zoning change can be time-consuming and adds risks as there is no guarantee of receiving a permit for construction and operation.

One of the factors that the zoning plan determines is the maximum building and non-building height. Industrial installations often have high-rising structures such as flares that are needed to ensure operational safety. If a permit cannot be obtained for the minimum non-building installation height, the plant is not permitted to be constructed.

Acceptance of Local Stakeholders

There is a large risk that the permitting process is challenged when the industrial installation is not accepted by the local residents or does not align with the regional vision/plan. The storage and transportation of hydrogen at a large scale is relatively new. There may be safety concerns from local residents and local authorities, such as municipalities and local environmental protection offices, which may impact the process of receiving a permit. Full consideration must be given to the safe location of the plant that will not impose additional risk to nearby populations.

Current Site Exploitation

Using currently exploited sites can reduce start-up costs and time. In an exploited site, all the required permits and legal proceedings have been completed. This reduces the amount of time and effort to obtain all legal documentation. The main disadvantage of exploited sites is the lack of flexibility, which is limited by the existing facilities, or the costs of demolishing (part of) the existing equipment. Greenfield facilities offer higher design flexibility to meet the project needs and during operation, newer facilities, require lower maintenance costs, however, all facilities must be constructed.

Site Accessibility

The site is required to be accessible for bringing process equipment to the site and for the process feed and products to be transported from and to the site. Ideally, accessibility should not necessitate the construction of new transportation infrastructure.

Site Costs

The costs associated with the site do not prohibit the operation or construction of the installation, but they can have an impact on the selection process. Some of the costs that should be taken into consideration include on-site taxes (i.e. environmental taxes), property costs (i.e. property rental costs), and state subsidies on the site.



3.2 Raw Material Supply and Product Transport

For a reliable production of eSAF, a constant supply of feedstock is needed. The feedstock must be available at a suitable price and volume. The plant is best located near the source of the major raw material source and primary product market to minimize the costs of transporting the feedstock and the product. Synergies to nearby facilities or access to existing infrastructure such as transportation infrastructure or storage facilities can also play a role in reducing investments and costs for raw material supply and product transport. Table 2 summarizes key desired characteristics concerning raw material supply and product transportation.

Table 2 Raw material supply and product transport site assessment factors and desired characteristics

	Factors	Desired Characteristics
Raw Material	Hydrogen Supply	Access to cheap and reliable base load hydrogen and existing infrastructure for transport and storage.
	Carbon Dioxide Supply	Access to biogenic CO ₂ sources and existing infrastructure for transport and storage.
Product	eSAF Transport	The location is near a primary market and blending site with access to existing infrastructure for transport.

Hydrogen Supply

Hydrogen is the key feedstock to the process in terms of impact on the economic performance of the plant. It is important for the site to have access to a cheap and reliable source of hydrogen. Hydrogen can be produced on-site or offsite and transported to the facility. If hydrogen is produced on-site, renewable electricity should be available at a low cost. Renewable electricity can be accessed through a grid connection or a direct connection with a renewable electricity producer. When there is a direct connection with a renewable energy producer, there is often an intermittent production of renewable energy. If there is intermittent availability of renewable electricity, electrolysers will need to be oversized and buffering or storage facilities for hydrogen are needed. This impacts the CAPEX and area requirements for the facility.

When hydrogen is produced off-site, it must be transported to the site. Transporting large volumes of hydrogen through an existing infrastructure, such as hydrogen pipelines or repurposed natural gas pipelines, can significantly lower the cost of delivery. At smaller volumes, cryogenic liquid tanker ships or trucks can also be used, but to access it water or road access is needed¹. See also chapter 3 in the Feasibility report of NLR (TULIPS Deliverable 2.1) in which the increasing amounts of renewable electricity and green Hydrogen-transport are described.

¹ R. Ortiz Cebolla, F. Dolci and E. Weidner Ronnefeld, "Science for Policy Briefs: Assessment of Hydrogen Delivery Options," Publications Office of the European Union, Brussels, 2022.



Carbon Dioxide Supply

Carbon dioxide is another key feedstock for eSAFs. CO₂ can be transported on-site from a point source. This requires the site to be near a biogenic CO₂ point source that can be captured and transported. The most cost-effective delivery is through a CO₂ pipeline. Existing pipeline infrastructure can substantially reduce the delivery costs. Other modes of transportation, such as rail or road transport, can be considered, but these options are constrained by the volumes that can be transported. Alternatively, when using direct air capture (DAC) to capture the carbon dioxide, the captured CO₂ must be compressed and stored to ensure a constant supply of the feedstock.

eSAF Transport

The site location should be easily accessible to a blending location and primary market to minimize transportation costs. This is especially true for products that are produced in bulk quantities such as transportation fuels. The blending of SAF requires mixing equipment and infrastructure for the transport and storage of neat SAF and certified jet fuel. Blending can occur in refineries or ad hoc blending facilities on an existing tank terminal. Often, blending occurs in refineries due to their accessibility to existing jet fuel infrastructure.

The price of eSAF is expected to have a premium compared to conventional fuels, the distance to the blending site and the primary market will therefore have a lower impact on the overall sales price. Nevertheless, it is preferable for the site to have access to major forms of transportation such as road, rail, waterway, or seaport. The product can also be inserted into an existing pipeline network if available.

3.3 Availability of Utilities

Chemical processes invariably require utilities. Utilities can be produced on-site or accessed through existing infrastructures or synergies with other nearby facilities. Access to utilities through an existing infrastructure and synergies can reduce the required CAPEX and plant complexity significantly. Table 3 provides a summary of the primary utilities and site selection needs.

Table 3 Primary utility site assessment factors and desired characteristics

Factors	Desired Characteristics
Electricity	An electricity grid connection is available on-site at the required voltage level and the required grid capacity is available.
Water utilities	Water utilities are available nearby or synergies with nearby facilities exist. No additional water utility equipment is required onsite.
Natural gas	Competitively priced natural gas with access to existing infrastructure is available.
Heating and cooling utilities	Available heat and cooling utilities are available nearby or synergies with nearby facilities exist. No production of these utilities is required onsite.



Electricity

The site should have access to a sufficient amount of renewable electricity at a suitable price. Large quantities of electricity will be used for the process and green hydrogen production, if produced on-site. The site must have a direct connection to a RE production site or be connected to the grid. If connected to the grid, it is important to determine whether the additional electricity demands can be handled by the grid.

The type of grid connection will be impacted by the size of the facility. In the Netherlands, when the electricity demand is below 100MW, the local low- or medium-voltage grid can be connected. If a higher amount of electricity is needed, the national high-voltage grid must be connected. Other factors such as local grid emissions can also play a role during site selection, but the primary concern for eSAF facilities is obtaining a sufficient amount of electricity.

Water utilities

Water utilities include cooling water, process water, and wastewater treatment. The site should be located near a source of water of suitable quality and should have access to a wastewater treatment system. Cool water and process water can be drawn from local sources and upgraded on-site, if needed, or purchased from a local supplier. When purchased, the site will require access to the water grid connection. The plant will also need access to a wastewater treatment system. Without access, the plant will need to perform wastewater treatment on-site. Without the existing infrastructures, the site would need to construct these utilities to meet the facility's needs, increasing CAPEX and site complexity.

Natural gas

A competitively priced fuel must be available on-site for steam and power generation. Natural gas must be transported to the production site. The easiest mode of transport of natural gas is through a natural gas grid connection. Alternatively, other modes of transport may be used if the natural gas grid infrastructure is not available for access. Depending on the setup, an eSAF facility could also function without natural gas input.

Heating and cooling utilities

Different levels of steam and cooling water must be available at the site. These utilities can be purchased or produced on-site. Access to existing heating and cooling utilities through utility providers or synergies with nearby industrial facilities helps reduce the CAPEX and complexity of the facility.

3.4 Emissions

Industrial installations must obtain an emission permit, granted by local authorities in accordance with corresponding EU Emission Directives. The emission limits granted in the permits are dependent on the equipment types, zoning area, neighbouring activities, and the location of the



site. Emission limits may be more stringent in areas closer to nature reserves and residential areas, for example. These permits cover emissions to the air, water, land, generation of waste, noise, and light shown in Table 4.

Table 4 Site emissions as site assessment factors and the site's desired characteristics

	Factors	Desired Characteristics
Gaseous Emissions	CO ₂	The plant's CO ₂ emissions are below the site-specific limits.
	CH ₄	The plant's CH ₄ emissions are below the site-specific limits.
	NO _x	The plant's NO _x emissions are below the site-specific limits.
Liquid Emissions	Surface water	The plant's surface water values are below the site-specific limits
	Wastewater	The plant's wastewater values are below the site-specific limits
Solid Emissions	Particulate matter	Plant's particulate matter emissions are below the site-specific limits
	Solid waste	Solid waste can be disposed of on-site.
Other Emissions	Light	The plant's light emissions are below the site-specific limits.
	Odor	The plant's odour emissions are below the site-specific limits.
	Noise	The plant's noise emissions are below the site-specific limits.

Gaseous emissions

Key gaseous emissions are CO₂, CH₄, and NO_x. Site-specific emission limits will determine whether changes in the installation are required to reduce the emissions to under the limit. NO_x emission limits can be particularly stringent in areas near nature reserves due to regulations on NO_x deposition in nature. If limits cannot be met, protection measures must be implemented to avoid NO_x deposition.

Liquid Emissions

Liquid wastes can be disposed of in surface waters. The emission limits of the surface water determine the level of wastewater treatment required. The ecological status of the surface water can also impact the programmes of measures required for emergency responses and measures to protect and restore the bodies of water.

Alternatively, liquid waste can be collected, sent to a wastewater treatment centre, and discharged. Waste water produced must meet the emission limits determined by the wastewater treatment system. If the wastewater exceeds these limits, wastewater pre-treatment must be done on-site.

Solid Emissions

Solid emissions can be in the form of particulate matter or solid waste from the production process. If a plant's particulate matter emissions do not meet the emission limits, changes to the installations



are required. Solid waste produced can either be disposed of at the site or transported from the site to a chemical disposal location. The ability of the plant to dispose of solid waste on-site can reduce transportation or solid waste treatment costs.

Other Emissions

Other emissions that occur are noise, light, and odour emissions. All these emissions must be kept under site-specific limits. If the emission limits cannot be met, protection measures must be implemented to reduce the emissions to below the site limits.

3.5 Soil Conditions

The soil conditions can have a large impact on site selection. The soil conditions determine the investment needs to remediate or prepare the site for construction. The key soil condition factors that should be taken into account are shown in Table 5. It is preferable for a site to have available information on the soil conditions. This information is available when the site has been exploited.

Table 5 Soil condition site assessment factors and desired characteristics

Factors	Desired Characteristics
Soil Contamination	No soil contaminations above limit values on site and soil remediation is not needed.
Soil Bearing Capacity	Soil-bearing capacity is sufficient for the equipment and industrial site.

Soil Contamination

Soil contamination has a large impact on the soil structure and its hydrogeology. These parameters impact the required planned soil protection measures and facilities. The level of soil contamination may require soil remediation before construction. This can add additional costs and time.

Soil Bearing Capacity

The soil-bearing capacity is the capacity of the soil to support the loads that are applied to the ground above. It is dependent on soil type, density, and other characteristics. These factors impact the structures in plants such as heavy uniform loads, individual loads, and dynamic loads. If the load capacity is not sufficient, additional soil preparation and the construction of a foundation will be needed to upgrade the soil to reach a sufficient level adding additional costs.



4 Key Site Assessment Factors for eSAF Facilities on Airports

In the previous section, general site assessment factors were discussed. The factors can be divided into essential and secondary requirements. For a site to be selected, it must fulfil all the basic processes and legal requirements. These are the minimum requirements that the site must achieve for plant construction and operation to be possible. On the other hand, the secondary requirements do not need to be met, but it increases the attractiveness of the site. In this section, the key basic process, legal requirements, and secondary requirements when selecting a site for an eSAF facility are discussed. These requirements are summarized in Figure 3.

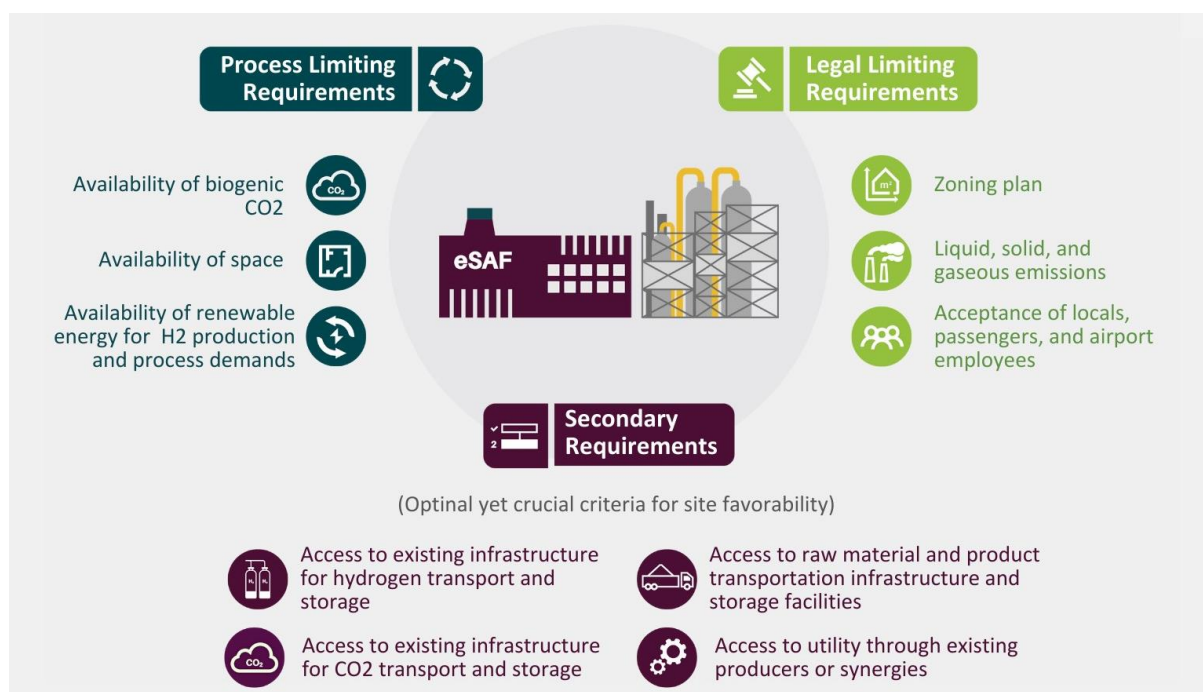


Figure 3 The key factors when evaluating an airport as a site for an eSAF facility can be divided into process limiting requirements, legal limiting requirements, and secondary requirements.

These requirements will be extended to determine key constraints of eSAF facilities on airports. It is important to note that, the requirements discussed are not exhaustive and the aim of this section is to capture the key requirements that are seen as a challenge to meet.

Legal Limiting Requirements

A facility may meet all the basic process requirements, but without legal permission, it cannot be constructed and operated. The site zone plan is one of the factors that have a large impact on site selection. It is preferable for the site to be in the correct zoning plan since obtaining or changing the zoning plan can be time-consuming and costly and it is not guaranteed to be granted. The type of zoning plan also determines regulations enforced on the facility. Key regulations relevant to



eSAF facilities are non-building height and allowable emissions. Often, when the site is near residential areas or nature reserves, these regulations become more stringent.

Airports are often outside industrial areas and can be in residential areas. This will likely add challenges to achieving all legal requirements. First, a request for a zoning plan change is most likely needed. This increases the external risks of the site. Secondly, the facility must meet the regulations required for the zone plan. Emission restriction can be more stringent than industrial sites and the maximum allowable non-building height may prevent the construction of high-rising structures, such as flares. These factors are therefore key legal assessment factors when evaluating airports as an eSAF facility site. In addition to quantitative legal requirements, when the site is situated near a residential area, the perception of the eSAF facilities and large-scale hydrogen production, storage, and transportation by locals can become a large risk to receiving legal permission for construction and operation.

Process Limiting Requirements

For an eSAF facility to be economically viable, the minimum production volume should be 100kta. Many smaller airports, such as the Rotterdam The Hague Airport, consume less fuel than this minimum production volume. This limits these eSAF facilities to larger airport hubs with larger fuel consumption. To sustain the minimum production volume, the site must have sufficient area and material and energy inputs

Airports have limited available space which can impact the feasibility of constructing an eSAF facility. Often when an area is available, the space is meant for airport operational purposes or green zones. In green zones, the area is subjected to non-industrial plants with strict regulations concerning limits on access and height of facilities. If an area is available for an eSAF facility to be constructed, the required safety distances around the facility will have an impact on the future use of the surrounding area, impacting the feasibility of an on-site eSAF facility.

In addition to the area, the facility requires a sufficient supply of process inputs. In eSAF facilities, the key inputs are renewable electricity and biogenic CO₂. Renewable electricity can be obtained through direct connection with the grid or a renewable electricity producer. When there is a direct connection with a renewable energy producer, the site needs to be located near a renewable energy producer. For a site to connect with a grid, the grid must be sufficiently decarbonized and be able to support high electricity demands from the facility. Grid congestion, for example, is a major concern when electricity is drawn from the grid to an eSAF facility. An electrical grid with these desired characteristics is not common, resulting in access to renewable electricity is a key process constraint during site selection for both sites on and off-airports.

When sufficient renewable energy cannot be accessed for green hydrogen production, green hydrogen can be produced offsite and transported instead. Consequently, the process limiting factors of having access to sufficient renewable electricity changes to sourcing, transportation, and storage of hydrogen at a large scale. Having access to biogenic CO₂ is another process limiting



factor. The site needs to be located near another facility that produces biogenic CO₂. Airports are often located outside industrial areas and away from point sources of biogenic CO₂. Alternatively, CO₂ can be directly captured from the air. In this case, CO₂ supply is no longer a limiting aspect as it can be produced on-site.

Other secondary requirements

With sufficient available area, material, and energy input for the facility, the facility must have access to these streams. Having access to synergies and existing infrastructure is a key secondary requirement. These factors allow for the transportation and offsite production and storage of energy and material inputs and output to and from the facility without major investments. This is especially important when there is a limited available area for the facility and limited skilled personnel. For example, hydrogen can be stored offsite if there is a nearby storage facility. This reduces the CAPEX, area requirements for the storage and personnel with speciality knowledge on the storage and transportation of hydrogen. Having access to existing infrastructure and synergies can be a challenge for areas outside industrial areas, such as airports.



5 Impact on Airport Operations

Operating an on-airport eSAF facility will have an impact on the operations of the hosting airport. Changes in the current airport jet fuel infrastructure will be required along with the construction of i.a. infrastructure for the plant’s inputs. In addition, safety will have to be demonstrated.

5.1 Onsite SAF Blending and Transportation

Neat SAF is not considered a drop-in fuel and cannot be used directly. It must be blended with a fossil jet and demonstrate compliance with the governing standard of ASTM D7566 for aviation turbine fuel containing synthesized hydrocarbons. Once the fuel is considered to meet ASTM D7566 specifications, it will be considered and handled as an ASTM D1655 certified conventional jet fuel. This allows blended SAF to enter conventional jet fuel handling, storage, and distribution in compliance with JIG and EI standards for supply chain practices and control. See Figure 4 for the illustration of the main steps and standards of compliance to SAF to enter airport grounds.

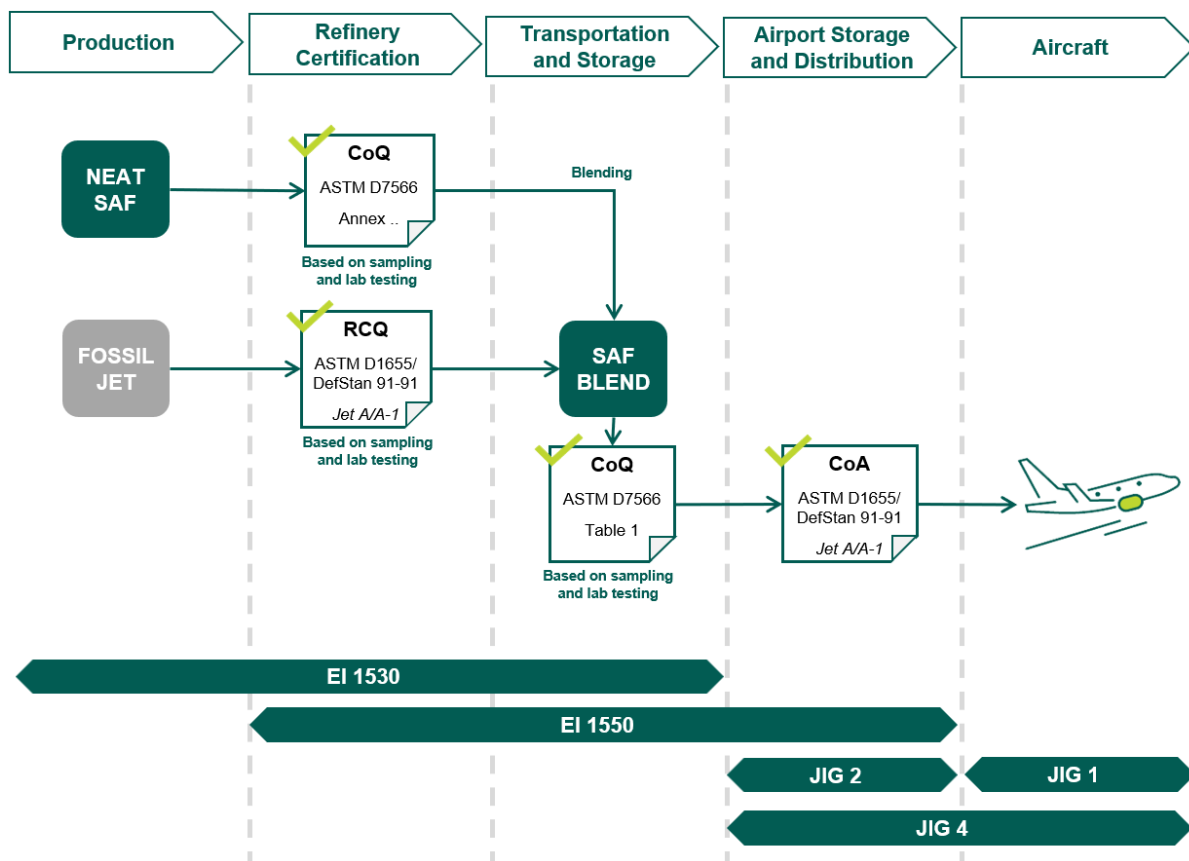


Figure 4 The main steps and standards of compliance in the conventional SAF supply chain. CoQ = Certificate of Quality, CoA = Certificate of Analysis. These certificates are required to demonstrate compliance with the standards and enable the fuel to become certified.

When SAF is produced on airport grounds, the fuel will already be on airport grounds before blending and certification, violating the current standard jet fuel supply chain practices. Although SAF blending on airport grounds has not been done at a commercial scale, it has been done on a



few rare occasions. On these occasions, enormous amounts of effort are required to gain special operating permissions including setting up special safety measures, and operating procedures, and gaining unanimous agreement from all stakeholders involved. This results in an increase in difficulty in fuel delivery and costs to the SAF. Attempts to set up on-site blending facilities have been criticized and discouraged due to the complexity and challenges that arise from on-site blending.

The challenges in on-site blending include segregating the conventional jet fuel from neat SAF and meeting the blended SAF specifications. Setting up an onsite blending facility requires a guarantee that neat SAF is completely segregated from the conventional jet fuel system. This may require the construction of a new airport jet fuel storage and distribution infrastructure.

During the blending of neat SAF, special attention must be paid to the composition and characteristics of neat SAF and fossil jet fuel. Aromatics in ASTM D7566, for example, is required to be present at a minimum of 8%vol. Neat SAFs often lack aromatics, requiring the sourcing of fossil jets with a higher percentage of aromatics to ensure that this aromatic requirement can be met. This increases the complexity of sourcing and transportation of fossil jets within the airport distribution system.

In addition to these challenges, the airport size and its existing jet fuel infrastructure will also have an impact on the handling of the SAF on-site. For smaller airports, the volumes of the SAF produced can be much larger than what its jet fuel distribution system can handle. If the jet fuel distribution and storage system and type are not adequate, infrastructural changes are required. For example, smaller airports that use transportation of jet fuel with trucks may be required to add jet fuel pipelines to accommodate the new jet fuel volumes on airport grounds.

5.2 Raw Material Transportation and Infrastructure

Operating a minimum eSAF facility with a production capacity of 100kta will require the transportation of hydrogen and carbon dioxide amounts in the same order of magnitude as the production capacity. At these amounts, truck and train deliveries are logistically impossible, requiring hundreds of daily deliveries. The most feasible mode of transportation would be through a pipeline. Consequently, a hydrogen and carbon dioxide pipeline infrastructure must be put in place and a connection between these pipelines and the source of raw material must be established. In the Netherlands, for example, a hydrogen pipeline system is currently under construction in which a connection point would need to be established to the airport and the eSAF facility.

5.3 Other impacts

The impact on an on-site eSAF facility extends beyond infrastructure and logistical changes. Airport staff members and associated supply chain partners must be trained and build up the knowledge to be able to monitor installations for the production, transportation, and storage systems of eSAF



and all the raw materials required for the facility. Furthermore, airports must guarantee safety regulations and gain the public trust by operating an onsite eSAF facility. Implementing a hydrogen infrastructure, for example, has faced scepticism towards its safety. Airports must be able to demonstrate and gain public trust that hydrogen can be safely transported and consumed on airport grounds. This is particularly important for airports located in densely populated areas which are more vulnerable to public opinion.



6 Conclusion

This framework provides a set of factors to help with the initial assessment of site suitability for an eSAF facility. The output of the report can support all future innovation projects related to an eSAF facility site selection by increasing the efficiency of the selection process. This framework has demonstrated that an eSAF facility site is required to fulfil basic processes and legal requirements for construction and operation to be possible. Nevertheless, fulfilling all the basic requirements does not necessarily mean that a site will be selected. There are secondary requirements that determine the favourability of each site.

When airports are assessed as potential locations of an eSAF facility, the main process limiting factors are area availability for facility construction and expansion and the supply of renewable electricity and biogenic CO₂ to the facility. The main legal limiting factors for airports are the zoning plan of airports and the social acceptability of the facility. These factors can have a large impact on the selection process since they are external risks that can be difficult to manage. In addition to these factors, having synergies with other nearby facilities and having access to existing infrastructure is an important secondary requirement that would make an eSAF facility more feasible.

These limitations show that the suitability of an airport is dependent on the current airport site and characteristics and its surrounding industries. None of these factors can be changed easily, making airports a more restrictive location for an eSAF facility compared to other site locations for industrial facilities. Additionally, the impact on airport operation and changes are expected to operate an on-site eSAF facility. Airports will need to build knowledge train staff and adapt the current airport infrastructure to be able to accommodate an onsite SAF facility. Overall, these factors increase the complexity of operating the facility on-site and increase the costs of the SAF being produced.