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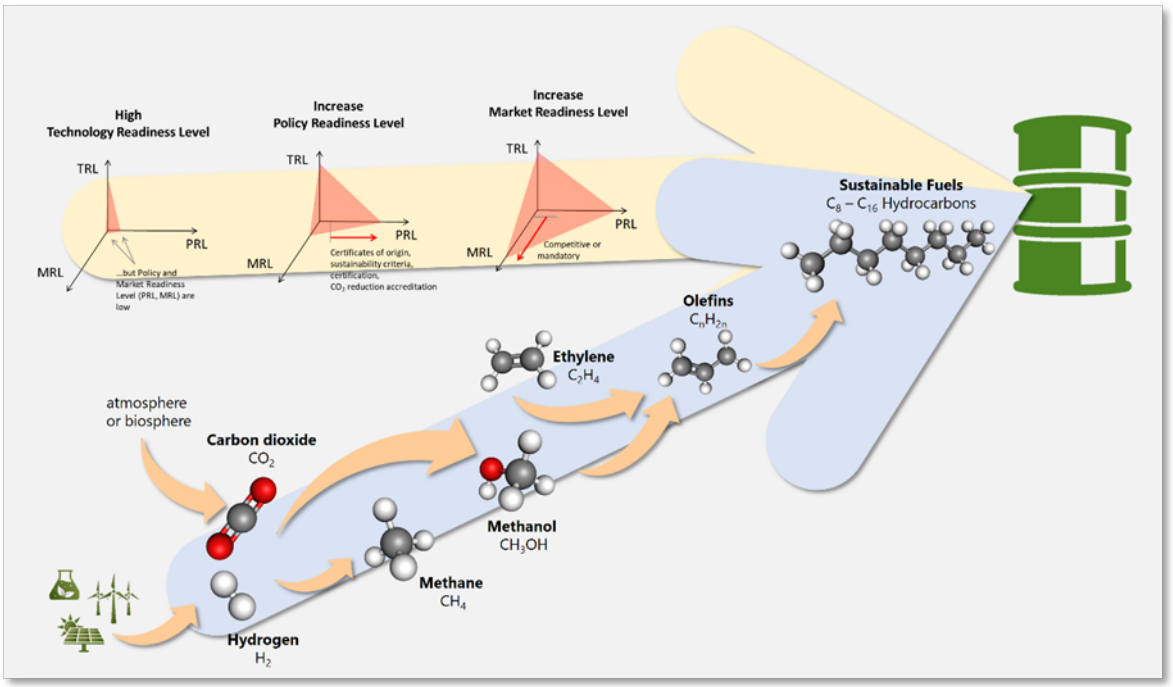
# Annual Report Year 2 – Public Part

# reFuel.ch

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**The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.**

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## Executive Summary

The reFuel.ch consortium has made substantial progress in advancing sustainable fuels and platform chemicals in Switzerland through interdisciplinary collaboration and stakeholder engagement across four strategic objectives.

The consortium enhanced Policy and Market Readiness Levels (PRL and MRL) by expanding its network with 23 new collaboration partners, organizing an annual conference and three Round Table events, and establishing communication channels including www.sweet-refuel.ch, a bi-annual newsletter, and LinkedIn presence. These initiatives facilitated knowledge exchange with stakeholders and strengthened research direction.

Research teams developed the Swiss Energy System Modelling Framework with a comprehensive technology database covering conversion, storage, and transportation technologies for sustainable fuels and platform chemicals. A demand subgroup with Federal Office of Civil Aviation input provided projections for sustainable aviation fuels (SAF) and hydrogen demand. Key publications addressed low-carbon fuels in climate models, direct air capture for aviation, FuelEU Maritime compliance pathways, and optimal production locations for fuels and chemicals from $CO_2$ and low-carbon hydrogen.

The consortium addressed regulatory barriers through presentations on safeguarding EU technological leadership while scaling SAFs. A major achievement was the Oman case study partnership with 28 industrial partners, culminating in an Implementation Programme signed during Oman Sustainability Week. The Swiss Energy Law Association workshop on hydrogen identified key barriers: limited renewable energy supply, regulatory inconsistencies, and the need for regulatory certainty. Analysis revealed that low hydrogen demand until 2035 challenges long-term production projects in Switzerland. Stakeholders emphasized the need for clear targets, economic support mechanisms, and hydrogen clusters.

Significant advances were achieved in selective fuel and chemical production. Researchers optimized lab-scale membrane reactors and investigated sorbents for methanol synthesis. A breakthrough post-synthetic dealumination protocol for OFF zeolites demonstrated that Methanol-to-Jetfuel can surpass Fischer-Tropsch in SAF yields and efficiency. Catalytic Impedance Spectroscopy (CIS) enhanced understanding of methanol-to-olefin mechanisms, while formaldehyde formation modeling provided catalyst optimization insights. Research on integrating Swiss animal manure and bio-waste attracted international interest at major conferences. Successful cold flow model development and microwave sensor testing demonstrated no fundamental obstacles for process scale-up.

## Zusammenfassung

Das reFuel.ch-Konsortium hat durch interdisziplinäre Zusammenarbeit und Einbindung von Stakeholdern wesentliche Fortschritte bei der Entwicklung nachhaltiger Kraftstoffe und Plattformchemikalien in der Schweiz über vier strategische Ziele hinweg erzielt.

Das Konsortium erhöhte die Politik- und Marktbereitschaftsniveaus (PRL und MRL), indem es sein Netzwerk um 23 neue Kooperationspartner erweiterte, eine Jahreskonferenz und drei Round-Table-

Veranstaltungen organisierte und Kommunikationskanäle wie www.sweet-refuel.ch, einen halbjährlichen Newsletter und eine LinkedIn-Präsenz etablierte. Diese Initiativen förderten den Wissensaustausch mit Stakeholdern und stärkten die Forschungsausrichtung.

Die Forschungsteams entwickelten das Swiss Energy System Modelling Framework mit einer umfassenden Technologiedatenbank, die Konversions-, Speicher- und Transporttechnologien für nachhaltige Kraftstoffe und Plattformchemikalien abdeckt. Eine Untergruppe für Nachfrage erstellte mit Input des Bundesamts für Zivilluftfahrt Prognosen für nachhaltige Flugkraftstoffe (SAF) und Wasserstoff. Wichtige Publikationen behandelten $CO_2$-arme Kraftstoffe in Klimamodellen, Direct Air Capture für die Luftfahrt, FuelEU Maritime Compliance-Pfade und optimale Produktionsstandorte für Kraftstoffe und Chemikalien aus $CO_2$ und $CO_2$-armem Wasserstoff.

Das Konsortium befasste sich mit regulatorischen Barrieren durch Präsentationen zur Sicherung der technologischen Führungsrolle der EU bei der Skalierung von SAFs. Eine bedeutende Errungenschaft war die Oman-Fallstudie mit einer Partnerschaft von 28 Industriepartnern, die während der Oman Sustainability Week in einem Umsetzungsprogramm mündete. Der Workshop der Schweizerischen Energierechtlichen Vereinigung (SELA) zu Wasserstoff identifizierte zentrale Barrieren: begrenzte erneuerbare Energieversorgung, regulatorische Inkonsistenzen und die Notwendigkeit von Regulierungssicherheit. Die Analyse ergab, dass die geringe Wasserstoffnachfrage bis 2035 langfristige Produktionsprojekte in der Schweiz erschwert. Stakeholder betonten die Notwendigkeit klarer Ziele, wirtschaftlicher Unterstützungsmechanismen und Wasserstoff-Cluster.

Bedeutende Fortschritte wurden bei der selektiven Kraftstoff- und Chemikalienproduktion erzielt. Forscher optimierten Membranreaktoren im Labormaßstab und untersuchten Sorbentien für die Methanolsynthese. Ein bahnbrechendes post-synthetisches Dealuminierungsprotokoll für OFF-Zeolithe zeigte, dass Methanol-to-Jetfuel Fischer-Tropsch bei SAF-Ausbeuten und Effizienz übertreffen kann. Die katalytische Impedanzspektroskopie (CIS) verbesserte das Verständnis von Methanol-to-Olefin-Mechanismen, während die Modellierung der Formaldehydbildung Einblicke zur Katalysatoroptimierung lieferte. Die Forschung zur Integration von Schweizer Tiermist und Bioabfällen weckte internationales Interesse auf wichtigen Konferenzen. Die erfolgreiche Entwicklung eines Kaltflussmodells und die Erprobung von Mikrowellensensoren zeigten keine grundlegenden Hindernisse für die Prozessskalierung.

## Résumé

Le consortium reFuel.ch a réalisé des progrès substantiels dans le développement de carburants durables et de produits chimiques de plateforme en Suisse grâce à une collaboration interdisciplinaire et à l'engagement des parties prenantes autour de quatre objectifs stratégiques.

Le consortium a amélioré les niveaux de préparation politique et de marché (PRL et MRL) en élargissant son réseau avec 23 nouveaux partenaires de collaboration, en organisant une conférence annuelle et trois événements de table ronde, et en établissant des canaux de communication incluant www.sweet-refuel.ch, une newsletter semestrielle et une présence sur LinkedIn. Ces initiatives ont facilité l'échange de connaissances avec les parties prenantes et renforcé l'orientation de la recherche.

Les équipes de recherche ont développé le Swiss Energy System Modelling Framework avec une base de données technologique complète couvrant les technologies de conversion, de stockage et de transport pour les carburants durables et les produits chimiques de plateforme. Un sous-groupe sur la demande, avec la contribution de l'Office fédéral de l'aviation civile, a fourni des projections pour les carburants d'aviation durables (SAF) et la demande en hydrogène. Les publications clés ont abordé les carburants à faible teneur en carbone dans les modèles climatiques, la capture directe de l'air pour l'aviation, les voies de conformité FuelEU Maritime et les emplacements de production optimaux pour les carburants et produits chimiques à partir de $CO_2$ et d'hydrogène à faible teneur en carbone.

Le consortium a abordé les obstacles réglementaires par des présentations sur la protection du leadership technologique de l'UE lors de la mise à l'échelle des SAF. Une réalisation majeure a été le partenariat de l'étude de cas Oman avec 28 partenaires industriels, aboutissant à un programme de mise en œuvre signé lors de la Semaine de la durabilité d'Oman. L'atelier de l'Association suisse de droit de l'énergie sur l'hydrogène a identifié des obstacles clés : approvisionnement limité en énergie renouvelable, incohérences réglementaires et besoin de certitude réglementaire. L'analyse a révélé que la faible demande en hydrogène jusqu'en 2035 complique les projets de production à long terme en Suisse. Les parties prenantes ont souligné la nécessité d'objectifs clairs, de mécanismes de soutien économique et de pôles hydrogène.

Des progrès significatifs ont été réalisés dans la production sélective de carburants et de produits chimiques. Les chercheurs ont optimisé des réacteurs à membrane à l'échelle du laboratoire et étudié des sorbants pour la synthèse du méthanol. Un protocole révolutionnaire de désalumination post-synthétique pour les zéolithes OFF a démontré que la voie méthanol-carburéacteur peut surpasser Fischer-Tropsch en termes de rendement et d'efficacité SAF. La spectroscopie d'impédance catalytique (CIS) a amélioré la compréhension des mécanismes méthanol-oléfine, tandis que la modélisation de la formation de formaldéhyde a fourni des informations pour l'optimisation des catalyseurs. La recherche sur l'intégration du fumier animal et des biodéchets suisses a suscité un intérêt international lors de grandes conférences. Le développement réussi d'un modèle à flux froid et les tests de capteurs à micro-ondes ont démontré qu'il n'y a pas d'obstacles fondamentaux à la mise à l'échelle du processus.

## Riassunto

Il consorzio reFuel.ch ha compiuto progressi sostanziali nello sviluppo di carburanti sostenibili e prodotti chimici di piattaforma in Svizzera attraverso la collaborazione interdisciplinare e il coinvolgimento delle parti interessate su quattro obiettivi strategici.

Il consorzio ha migliorato i livelli di preparazione politica e di mercato (PRL e MRL) ampliando la sua rete con 23 nuovi partner di collaborazione, organizzando una conferenza annuale e tre eventi di tavola rotonda, e stabilendo canali di comunicazione tra cui www.sweet-refuel.ch, una newsletter semestrale e una presenza su LinkedIn. Queste iniziative hanno facilitato lo scambio di conoscenze con le parti interessate e rafforzato l'orientamento della ricerca.

I team di ricerca hanno sviluppato lo Swiss Energy System Modelling Framework con un database tecnologico completo che copre le tecnologie di conversione, stoccaggio e trasporto per carburanti sostenibili e prodotti chimici di piattaforma. Un sottogruppo sulla domanda, con il contributo dell'Ufficio

federale dell'aviazione civile, ha fornito proiezioni per i carburanti sostenibili per l'aviazione (SAF) e la domanda di idrogeno. Le pubblicazioni chiave hanno affrontato i carburanti a basse emissioni di carbonio nei modelli climatici, la cattura diretta dell'aria per l'aviazione, i percorsi di conformità FuelEU Maritime e le ubicazioni di produzione ottimali per carburanti e prodotti chimici da $CO_2$ e idrogeno a basse emissioni di carbonio.

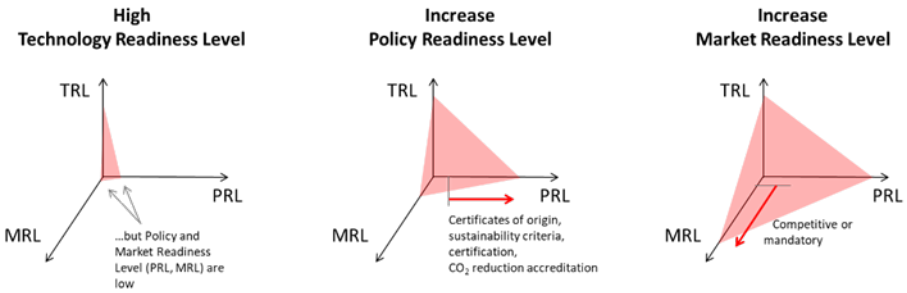
Il consorzio ha affrontato le barriere regolamentari attraverso presentazioni sulla salvaguardia della leadership tecnologica dell'UE nella scalabilità dei SAF. Un risultato importante è stato il partenariato del caso studio Oman con 28 partner industriali, culminato in un Programma di Implementazione firmato durante l'Oman Sustainability Week. Il workshop dell'Associazione svizzera di diritto dell'energia sull'idrogeno ha identificato barriere chiave: fornitura limitata di energia rinnovabile, incoerenze regolamentari e necessità di certezza normativa. L'analisi ha rivelato che la bassa domanda di idrogeno fino al 2035 rappresenta una sfida per i progetti di produzione a lungo termine in Svizzera. Le parti interessate hanno sottolineato la necessità di obiettivi chiari, meccanismi di sostegno economico e cluster dell'idrogeno.

Sono stati raggiunti progressi significativi nella produzione selettiva di carburanti e prodotti chimici. I ricercatori hanno ottimizzato reattori a membrana su scala di laboratorio e studiato sorbenti per la sintesi del metanolo. Un protocollo innovativo di dealuminizzazione post-sintetica per zeoliti OFF ha dimostrato che il percorso Metanolo-Jetfuel può superare Fischer-Tropsch in termini di rese ed efficienza dei SAF. La spettroscopia di impedenza catalitica (CIS) ha migliorato la comprensione dei meccanismi metanolo-olefina, mentre la modellazione della formazione di formaldeide ha fornito indicazioni per l'ottimizzazione dei catalizzatori. La ricerca sull'integrazione del letame animale svizzero e dei rifiuti organici ha suscitato interesse internazionale nelle principali conferenze. Lo sviluppo riuscito di un modello a flusso freddo e i test sui sensori a microonde hanno dimostrato l'assenza di ostacoli fondamentali per l'ingrandimento del processo.

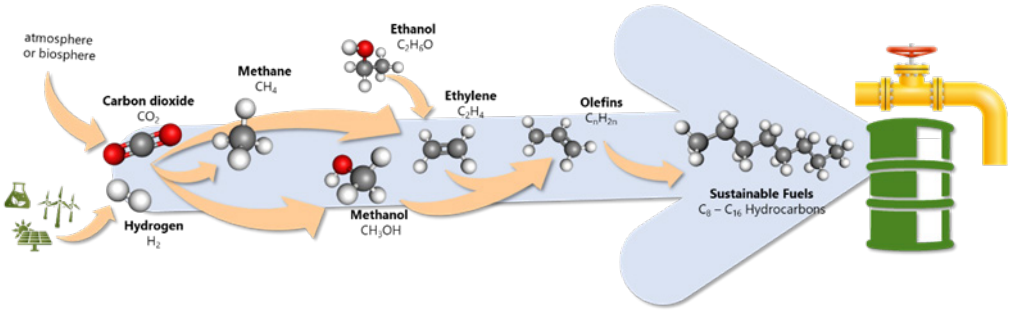
# 1 Work programme overview

The reFuel.ch consortium aims to develop robust supply pathways for annually 30 – 60 TWh of sustainable fuels and platform chemicals by 2050, determined by the Energy Perspectives 2050+ of the Swiss Federals office for Energy (SFOE), whereof the vast majority is expected to be imported. This gives reFuel.ch an international focus, which may be different to other SWEET consortia. The international nature of supply pathways makes it also necessary for Switzerland to take sustainability criteria in the supply chain of those fuels and platform chemicals into account, taking the European regulations, such as FuelEU Maritim, the ReFuelEU Aviation or the Renewable Energy Directive III, into account. The project is divided into an implementation and a technology research-oriented part:

a) Within the implementation-oriented part, including WP1 – 3, research activities towards an increase of policy and market readiness are targeted. This will be achieved by analysis and scenario developments as well as an exchange with industry, market actors and policy makers. Thereby, cooperation partners are invited for exchanges in Round Tables, where information around sustainable fuels and platform chemicals is shared and discussed and a common view on the substitution of fossil resources by sustainable ones will be developed.




b) Within the technology research-oriented part, including WP4 - 7, research on novel technological approaches is done. This includes *i)* advanced processes for methanol synthesis, methanol-to-olefins and olefin-to-fuel conversion, *ii)* direct electrochemical $CO_2$ reduction (co-electrolysis) and *iii)* the manure-to-SAF conversion by hydrothermal liquefaction of biogas.




Besides scientific analysis and technical developments within the work packages, application-oriented research is approached in Case studies. Within a Swiss Case, a European Case (Iberian Peninsula) and an extra-European Case (Oman), the production of sustainable fuels and platform chemicals were initiated. The target of these Cases is to investigate the formation of consortia for the production of sustainable fuels and platform chemicals together with potential project developers, plant suppliers, plant operators and off-takers and to identify hurdles on the way to implementation.

## 2 Progress of activities

### Work packages

Since January 2024, all seven work packages have commenced activities. ReFuel.ch employs over 20 doctoral students and nearly 20 postdoctoral scientists across six years, with all positions now filled despite initial recruitment delays. Several Master and Bachelor Theses on related topics were supervised.

Three work packages focus on sustainability assessment (e.g. life cycle assessment), energy system modelling, and policy research to increase market readiness and investigate various scenarios. Key activities include establishing a screening process for national and international policies to identify regulatory gaps and barriers in sustainable fuel production, scaling, and utilization. Models have been developed to analyse how technology choices affect the broader economy, and a social acceptance

model for eFuels has been created. Stakeholder input from Round Table events led to country risk assessments for importing synthetic fuels.

Four work packages concentrate on improving catalysts, processes, reactors, and systems for enhanced efficiency, selectivity, load-flexibility, and cost reduction. Main technologies include synthetic fuel production from CO2 and water, plus biomass-to-fuel conversions.

Their work included the testing of various gas diffusion electrode materials for CO2 conversion, discovering that in-house materials could be improved with specific coatings like Nafion. They developed new methods for testing bipolar membranes using hydrogen pump configurations and examined electrode structures with high-resolution microscopy to understand layer construction and gas flow efficiency.

Benchmarking systems for enhanced methanol production were established, creating simulation models and defining key performance indicators. They built mathematical models using MATLAB, Python, and OpenFOAM software for reactor design and scaling, while investigating membranes and sorbent materials capable of withstanding conditions up to 50 bar and 250°C. Laboratory equipment was installed for methanol synthesis testing with custom test cells for commercial membranes.

A technical report on manure-to-energy pathways was published. They established proof of principle for converting manure into bio-oil through hydrothermal liquefaction, optimizing critical parameters and preparing metal catalysts. A continuous test rig design was completed for hydrogen-assisted bio-oil production, while a cold-flow model successfully validated sorption-enhanced fluidized bed methanol synthesis concepts.

Towards improving catalysts, researchers investigated offretite zeolite catalysts for methanol-to-olefins conversion, developing a post-synthetic treatment protocol that enhanced selectivity by 12% for certain alkenes and 3% for aromatics while doubling catalyst lifetime. They built small-scale reactor systems for two-step conversion processes and conducted advanced computational studies using molecular dynamics simulations. Process development included cost estimation and environmental assessment using machine learning, with collaboration to compare sustainable aviation fuel production pathways based on ecological and economic criteria.

The consortium focuses on key technologies including CO2 electrolysis, combined water electrolysis and hydrocarbon synthesis, methanol-to-olefins conversion with oligomerization for C8-C16 hydrocarbon formation, and hydrothermal biomass conversion to higher hydrocarbons.

**Internal Exchange platforms**

reFuel.ch uses three interdisciplinary exchange platforms to exploit synergies and foster knowledge exchange within the consortium.

Platform 1 (Design of Scenarios and Transition Pathways) analyses technologies and design transition pathways. Key findings on non-CO2 effects in aviation show that contrails and NOx interactions can be as significant for climate as CO2 emissions. Flight altitude adjustments of ±600m can avoid persistent contrails with 97.5% success rate. Conventional kerosene can be "cleaned" through hydrodesulfurization and hydrodearomatization (HT2 fuel), with cost-benefit analysis showing a net benefit of €10.5 billion. The EU introduced a mandatory Monitoring, Reporting and Verification

framework for non-CO2 effects starting January 2025, marking a paradigm shift from carbon neutrality to climate neutrality.

Expert consultations on demand for sustainable aviation fuels and platform chemicals brought together specialists to address future aviation fuel demand and identify needed platform chemicals in Switzerland. The team gained insights into existing projections for aviation fuel demand and anticipated structural changes in Switzerland's chemical industry. Projections of SAF demand were shared with the Sweet CoSi consortium.

Platform 2 (Technology Innovation Assessment) exploits synergies in catalysis, processes, and analytical technologies. The platform deepened benchmarking discussions on various routes to SAF, noting that while the FT process has been known for a century with limited room for improvement, the more recent Methanol route offers greater efficiency potential.

A comprehensive table of indicators for sustainability assessment was developed and discussed during a Platform 3 meeting in February 2025. The table encompasses three broad categories: environmental, economic, and social indicators. It distinguishes between directly linked and indirectly considered indicators, specifies the regional application level (regional, national, or project-specific), identifies the responsible consortium members for each indicator, and includes preliminary importance ratings. The indicators will be applied to various case studies (e.g., Oman) in 2026 to test their practicability.

**External Exchange (Round Tables)**

The reFuel.ch project connects researchers with industry and government through bi-annual Round Table events that bring together key stakeholders in sustainable aviation fuel development.

In October 2024, an online Round Table on aviation fuels attracted participants from private companies, government offices, associations and academia. The event revealed a critical challenge: companies with resources to invest in sustainable fuel production remain hesitant, while willing investors face difficulties securing funding and purchase agreements. Technology scaling also proved more complex than anticipated. Following these insights, the project team worked with aviation authorities and Canton Zurich to identify three key groups that can drive fuel adoption: regulators, investors, and passengers.

In February 2025, around 100 participants attended an in-person Round Table at Empa in Dübendorf. This event featured direct discussions between researchers and stakeholders on ten key topics, creating opportunities for collaboration and knowledge exchange. The Round Table events consistently receive positive feedback and successfully attract new participants while maintaining existing relationships. Participants particularly value the networking opportunities with other stakeholders and researchers.

The consortium also launched the sweet-reFuel.ch website, published newsletters, and strengthened collaboration with other research consortia through regular meetings and shared planning tools.

**Cases**

It is expected that it will take time for a market to form where sustainable fuels will be bought like fossil fuels are bought today. In order not to be dependent on this eventuality, three cases for the realization of sustainable fuel production plants are included; one in Switzerland, one in Europe (Iberian Peninsula) and one outside Europe (Oman). The goal is to investigate whether consortia can be formed to develop such projects, and what practical barriers exist for their realization.

While the Swiss and the European Case started with the reFuel.ch project beginning of 2024, the Oman Case was started half a year before. This way, the participants were able to join the Green Hydrogen Summit in December 2023 in Muscat/Oman with a Swiss delegation. Roughly 25 persons, entities or associations joined the Oman case. Of these, 14 persons made up the delegation on the Summit in Oman. Since then, the Oman case consortium developed and evaluated a conceptual idea of an approach, which is scalable, compliant with the Renewable Energy Directive III and ready to take off. The work is continued by transforming the idea consortium into a concept consortium to further develop the idea into a project. The next steps are a pre-feasibility study and a full feasibility study.

For the Swiss and the European Case, consortia formation was taking place throughout 2024 and the cases were being developed further. The work programme, as stated in the proposal, allows for the development of case studies, based on pre-feasibility studies out of the WPs, as demonstrated in the Reserve Power Plant case. KTT will actively support such developments including the assessment of alternative funding sources. Yet given the uncertainty around P&D financing future work will aggravate the challenges.

## 3 Highlights of outputs

*Objective: Act as an aggregator for developments and projects between the different stakeholders in the field of sustainable fuels and chemicals.*

The reFuel.ch consortium significantly enhanced Policy and Market Readiness Levels (PRL and MRL) for sustainable fuels and platform chemicals. This was achieved through active engagement with stakeholders via the annual conference and three Round Table events so far. The consortium expanded its network by adding 23 new collaboration partners. Dissemination efforts ranged from the launch of the website **www.sweet-refuel.ch** and the bi-annual newsletter to the creation of a new social media presence on **LinkedIn** to participation at scientific conferences. Research results were shared with stakeholders to gather insights and refine research questions, strengthening the consortium's knowledge base and network.

*Objective: Develop an interdisciplinary understanding of robust and sustainable pathways for fuel and chemicals supply.*

The research teams established interfaces and workflows for the Swiss Energy System Modelling Framework, developing a comprehensive prototype technology database. This database, which includes all conversion, storage, and transportation technologies for sustainable fuels and platform chemicals, harmonizes model runs across different modeling teams and sets a new standard for Swiss energy system modeling, informing policy decisions. A subgroup on demand was formed under Platform 1, with expert inputs from the Federal Office of Civil Aviation, presented projections on demand in Switzerland for sustainable aviation fuels and hydrogen.

Regarding recommendations on strategies to decrease the environmental impact of aviation, the research teams published scientific articles on “The role of low carbon fuels towards net-zero in integrated assessment models and energy system models: A critical review” (Liu et.al. 2025), “The role of direct air capture in achieving climate-neutral aviation” (Brazzola et.al. 2025), and “Prospective Life Cycle Assessment of cost-effective pathways for achieving the FuelEU Maritime Regulation targets” (Ingwersen et.al. 2025). They also identified “Cost-effective locations for producing fuels and chemicals from carbon dioxide and low-carbon hydrogen in the future” (Allgoewer et.al. 2024). These outputs target research, regulatory bodies, and industry partners, contributing to the knowledge needed for energy strategy and climate goals.

*Objective: Provide the scientific basics for a robust strategy to meet the Swiss demand on sustainable fuels and chemicals.*

The consortium addressed regulatory barriers and import strategies, with presentations on “Regulatory Barriers to Scaling SAFs: Safeguarding EU Technological Leadership and Decarbonization Targets in the Context of an Increasingly Interconnected World” at two conferences. At the Round Tables, stakeholder input on additional indicators and utility for different sustainable aviation fuels uptake strategies informed work on risk assessment and modeling assumptions. The Oman case study successfully formed a project development partnership with 28 industrial partners, market actors from Switzerland and Oman, and reFuel.ch research groups, culminating in the signing of an Implementation Programme between Switzerland and Oman during Oman Sustainability Week.

Regarding implementation strategies and policy recommendations, members of the consortium organized the Annual Workshop of the Swiss Energy Law Association (SELA) on “The Hydrogen Revolution: Legal and Regulatory Challenges for Switzerland,” which helped identify key regulatory challenges. For the consortium’s stakeholders, the presentations “Regulatory overview for SAFs: diversity of regulatory approaches” and “Regulatory overview for SAFs: incentives and challenges” highlighted how current regulatory developments address challenges in SAF production (costs, feedstock availability, competition). A critical finding highlighted the role of regulatory certainty in promoting SAF investments and the chicken-and-egg problem between producers and airlines. Stakeholders also were presented findings on Switzerland’s Hydrogen Strategy, country risk assessment, and modeling assumptions. Discussions on the hydrogen strategy highlighted the need for clear national targets, reliable economic support (e.g., insurance agreements, public authority purchase obligations), and the benefits of hydrogen clusters. Barriers identified included limited renewable energy supply for hydrogen production and regulatory inconsistencies between cantonal, Swiss, and European laws. A key conclusion was that low national hydrogen demand up to 2035 would hinder long-term hydrogen production projects in Switzerland.

*Objective: Strengthen the role of Switzerland as technology and knowledge supplier.*

Significant progress was made in developing innovative processes for highly selective production of fuels and chemicals. This included identifying optimal space velocities for lab-scale membrane reactors using novel modeling tools, evaluating and optimizing fabrication methods for membrane supports, and initiating investigations into increasing effective membrane area. Industrially significant sorbents for in-situ water removal in methanol synthesis reactors were investigated, determining sorption isotherms and kinetic parameters under process-relevant conditions. A benchmark was established for concept development and characterizing novel reactors. These achievements, experimentally measured provide valuable insights for future research.

The development of a post-synthetic dealumination protocol for OFF zeolites, leading to a publication, improves overall SAF process efficiency, demonstrating the potential of the Methanol to Jetfuel route to surpass the FT route in SAF yields and energy efficiency. A setup for Catalytic Impedance Spectroscopy (CIS) helps to better understand MtO reaction mechanisms and advance catalyst development. Modeling of formaldehyde formation revealed the sequence of methoxy formation and dimethyl ether as the next likely step, providing useful information for tailoring catalysts and avoiding coke formation.

For pathways to solve the challenging integration of Swiss animal manure and bio-waste into the energy system, a master's thesis laid a solid foundation for further research. The thesis integrated technical, legal, and ecological aspects of manure utilization for biogas production. Findings were presented to stakeholders at the Biomasse Suisse Conference and the EU Biogas Association Conference, sparking international interest due to its novelty and integrated approach. Furthermore, the teams developed and successfully operated a cold flow model and verified and calibrated a microwave-based sensor for mass flow measurement, indicating no fundamental obstacles for process development and proving sufficient for experimental reactor optimization.

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