reFuel.ch project

# The Oman Case

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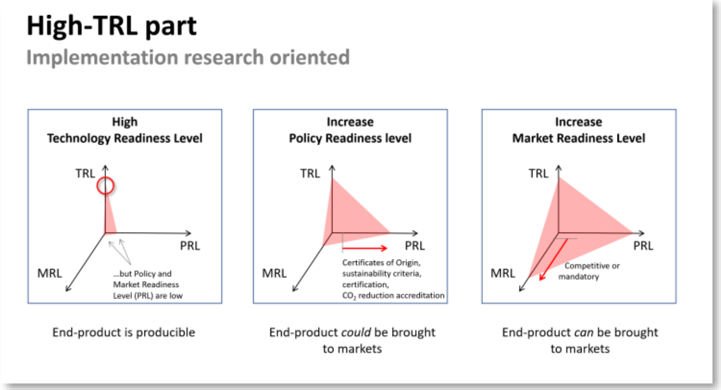
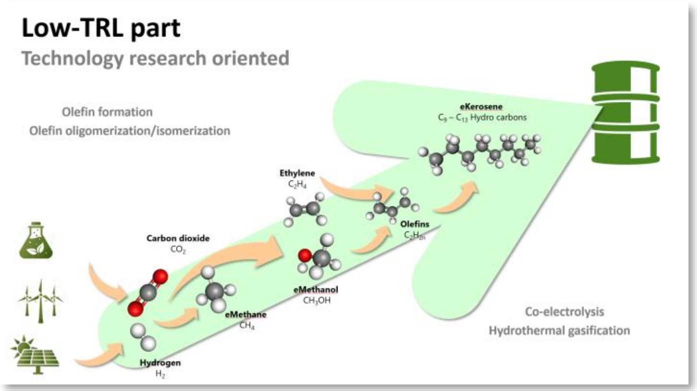
# SWEET project “reFuel.ch“

- **Task:** Development of robust supply paths for sustainable fuels to Switzerland
- **Consortium:** 15 Research groups in 9 Swiss universities and Research institutes + R&D department of one industry company
- **Approach:** Implementation oriented «high-TRL» and technology oriented «low-TRL» task with investigating implementation in a Swiss-Case, a European Case in Span and an Extra-European Case in Oman




Increase of policy and market readiness level




New, more efficient technologies

# Agenda

1. Situation in Switzerland (energy demand)
2. Situation in Oman (energy production potential)
3. Delegated EU directives regarding sustainable fuels
4. Upscaling of an RED-III ready approach

# 1. Situation in Switzerland

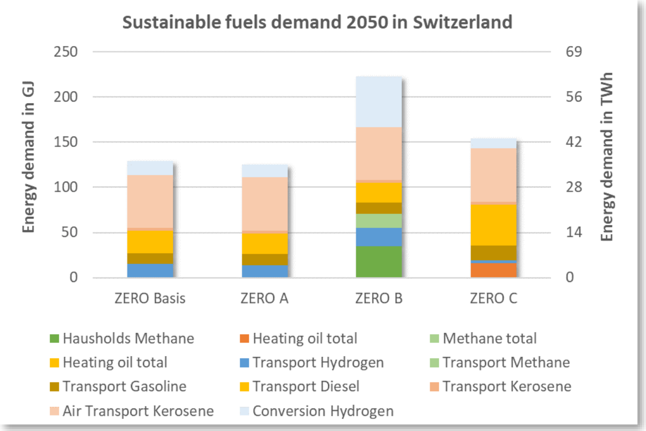
- **Demand of sustainable fuels in 2050 is estimated to be between 110 – 220 GJ or 30 – 60 TWh/a, depending on the different scenarios.**

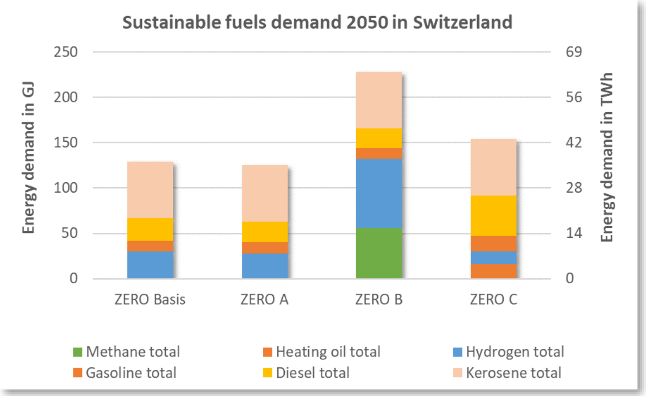
  ZERO Basis: extensive electrification
  ZERO A: more extensive electrification
  ZERO B: use of renewable gases ($PtH_2$/PtG)
  ZERO C: use of renewable liquids (PtL)

  Source: SFOE, Energy perspectives 2050+

- It is expected, that >90% thereof has to be imported.

- One main target of the reFuel.ch project is to develop robust supply pathways for sustainable fuels to Switzerland.



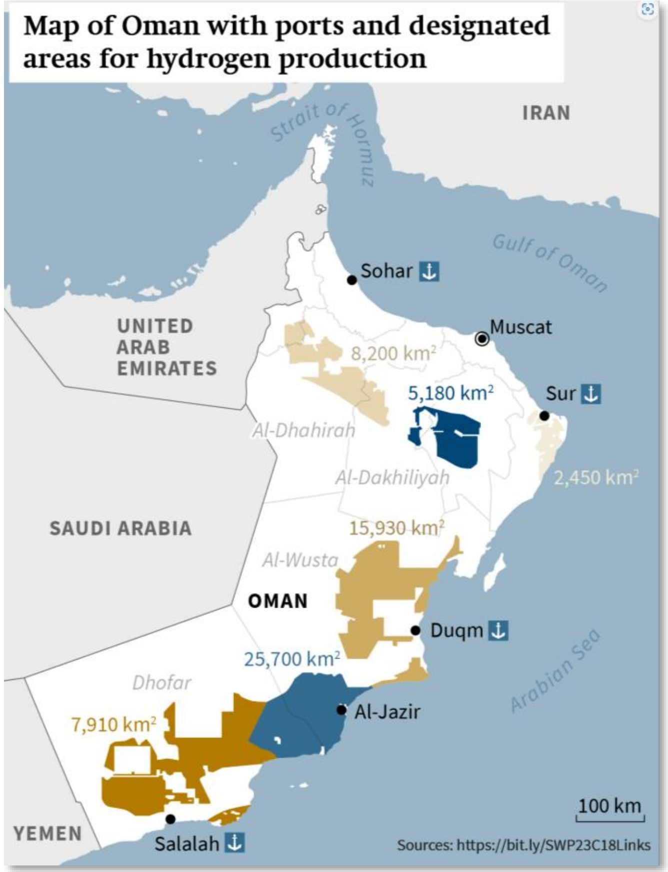



# 2. Situation in Oman

- Oman has designated 50'000 km$^2$ of desert land for $H_2$ and derivates production (rated among the top 10 areas on earth regarding solar radiation and wind).
- Oman aims to produce 1 $Mt_{H2}$/a by 2030, 3.75 $Mt_{H2}$/a by 2040 and up to 8.5 $Mt_{H2}$/a by 2050. The 2040 hydrogen target would represent 80% of Oman's current LNG exports in energy-equivalent terms.
- In deserts one may produce **100 - 120 $GWh_{el}/km^2_{Land}/a$**[1)] by PV. To achieve the 8.5 $Mt_{H2}$/a aim of Oman, a PV equipped land demand of 4'500 - 5'500 km$^2$ would result.

  1) Solar Power Spatial Planning Techniques (irena.org)

- The 50'000 km$^2$ of desert land for $H_2$ production is split in 145 sub-areas, which are made available by tenders. First tenders have already been issued and have been awarded to a consortium of bidders. The first one is the AMNAH consortium led by Mark Geilenkirchen, who joined the reFuel.ch Oman Case Idea Consortium.



# 3. EU directives regarding sustainable fuels

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## Main requirements (according to EU):

- **Additionality of renewable energy**

  The electricity must be generated by new power production systems (max. 3 years old)

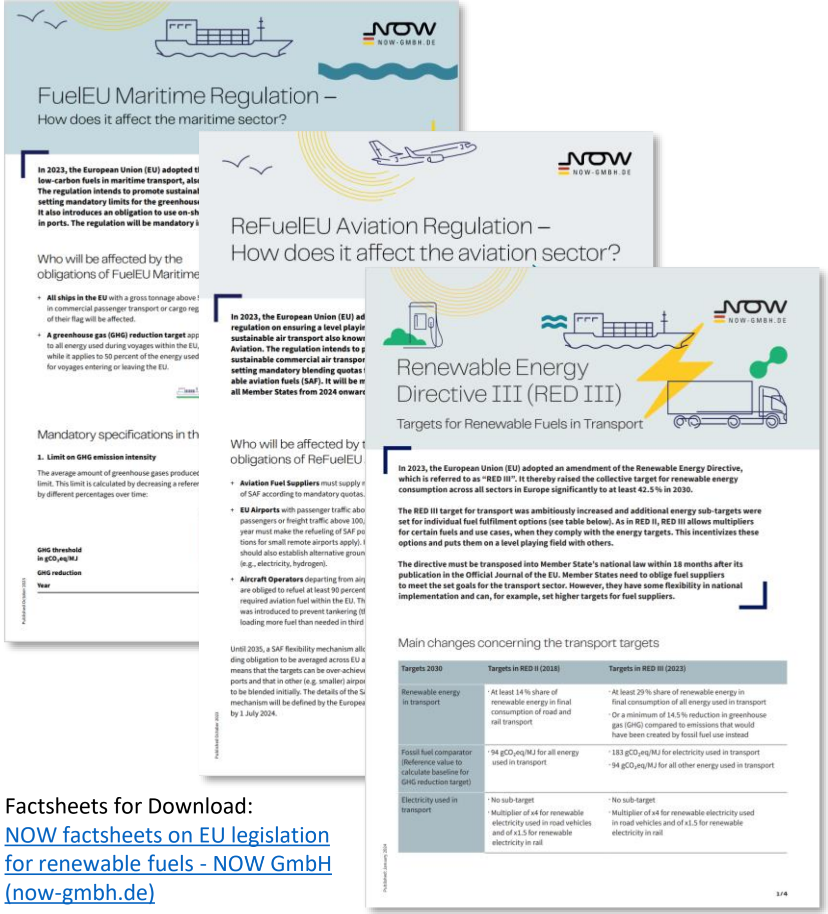
- **Direct coupling with renewable electricity production**

  The PtX plant has to be directly coupled to the renewable electricity power plant or – in case of grid supply – has to follow the electricity production profile.

- **$CO_2$ supply after 2035 by Direct Air Capture**

  Permitted carbon sources for the production of synthetic fuels
  - Direct air capture
  - Biogenic $CO_2$

- **70% of $CO_2$ reduction in whole path**




Factsheets for Download:
[NOW factsheets on EU legislation for renewable fuels - NOW GmbH (now-gmbh.de)]

# 3. EU directives regarding sustainable fuels

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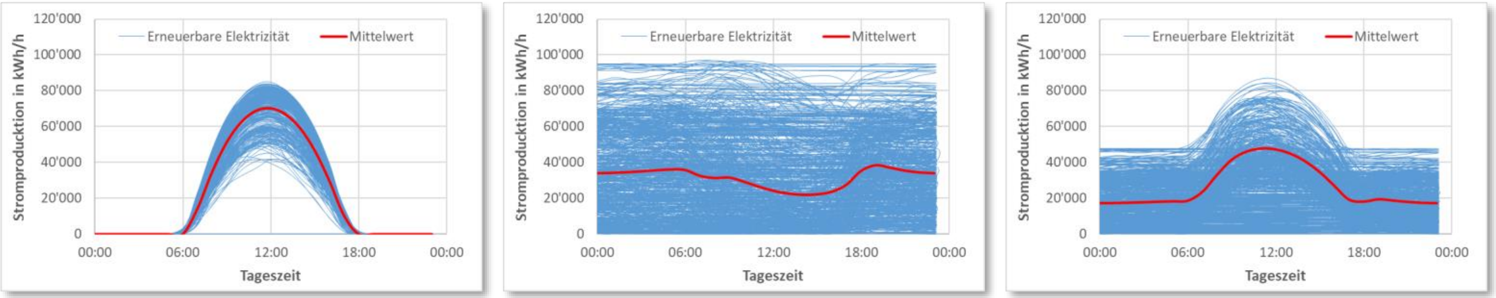
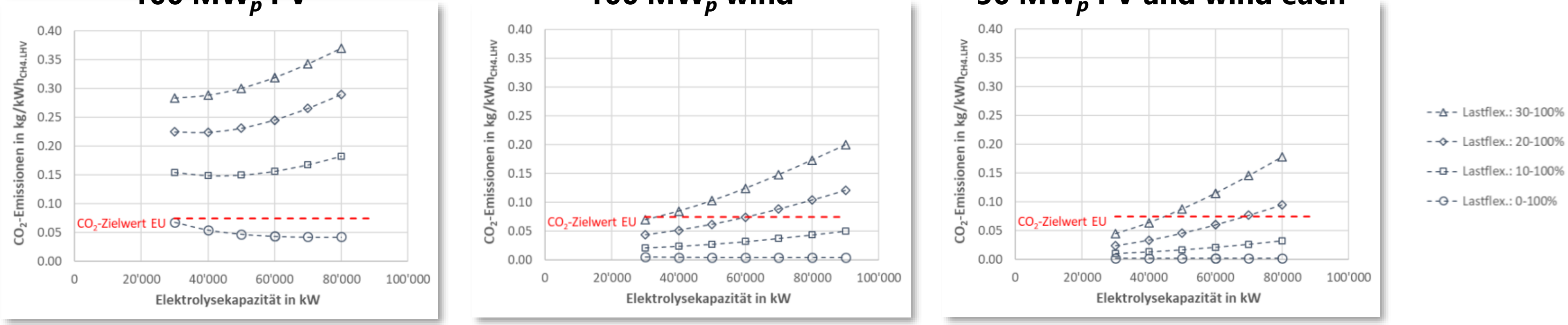
Direct coupling of PtX plant with PV, wind or PV/wind is demanding a high load flexibility of the entire PtX system (PV only: 100 – 0%; Wind only: 100 – 10%; PV/wind combined: 100-20%)




**100 MW$_p$ PV** **100 MW$_p$ wind** **50 MW$_p$ PV and wind each**



# 4. Development/upscaling RED-III ready approach

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Target: supply costs of synth. methane at the boarder below 0.20 EUR/kWh$_{HHV}$ (Swiss biogas as reference) assuming liquefaction, regasification, transport and trade costs at 0.05 - 0.06 EUR/kWh$_{HHV}$.

## Step 1

RED III-ready
Large scale RTTP
plant 2026/27

**Investment (including system integration)**

- 12 MEUR PV
- 25 MEUR Ely
- 6 MEUR Meth
- 50 MEUR DAC[1)]

[1)] 50% of DAC for Step 1 and Step 2 (resulting in 750 EUR/$t_{CO2}$)

= 93 MEUR

43 GWh$_{el}$/a (0.4 km² Land); 6 kt $H_2O$/a; 4 kt$CO_2$/a

**25 MW$_{el.p}$ PtG**

$P_{Ely}$: 13 MW$_{el}$; 1'900 Full-load h/a
Electricity: 20 EUR/MWh; $H_2$: 6.1 EUR/kg

**Production costs and quantity**

- 8.0 MEUR/a CAPEX
- 1.0 MEUR/a OPEX
- 19 GWh/a eMethane
- (0.60 EUR/kWh (incl. CAPEX))
- **0.17 EUR/kWh (w/o CAPEX)**

**Approach:** Hardware sponsored

## Step 2

RED III-ready
“small” large scale
plant 2031/32

**Investment (including system integration)**

- 48 MEUR PV
- 92 MEUR Ely
- 12 MEUR Meth
- 50 MEUR DAC[1)]

[1)] 50% of DAC for Step 1 and Step 2 (resulting in 750 EUR/$t_{CO2}$)

= 202 MEUR

173 GWh$_{el}$/a (1.7 km² Land); 24 kt $H_2O$/a; 15 kt$CO_2$/a

**100 MW$_{el.p}$ PtX**

$P_{Ely}$: 51 MW$_{el}$; 2'000 Full-load h/a
Electricity: 20 EUR/MWh; $H_2$: 4.0 EUR/kg

**Production costs and quantity**

- 14.4 MEUR/a CAPEX
- 3.5 MEUR/a OPEX
- 77 GWh/a eMethane
- **0.23 EUR/kWh (incl. CAPEX)**

**Approach:** Additional costs accepted by market actors

## Step 3

RED III ready
“large” large scale
plant 2036/37

**Investment (including system integration)**

- 740 MEUR PV
- 675 MEUR Ely
- 125 MEUR Meth
- 750 MEUR DAC

resulting in 300 EUR/$t_{CO2}$)

= 2'290 MEUR

3'400 GWh$_{el}$/a (34 km²); 500 kt $H_2O$/a; 300 kt$CO_2$/a

**2 GW$_{el.p}$ PtX**

$P_{Ely}$: 1'100 MW$_{el}$; 2'100 Full-load h/a
Electricity: 13 EUR/MWh; $H_2$: 2.1 EUR/kg

**Production costs and quantity**

- 196 MEUR/a CAPEX
- 44 MEUR/a OPEX
- 1'700 GWh/a eMethane
- **0.14 EUR/kWh (incl. CAPEX)**

**Approach:** Market transformation

# 4. Idea ("RED III ready" demonstrator at Empa)

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**Future Mobility Demonstrator «move»**

battery-electric
hydrogen
synthetic fuels

**PV coupled system**

Flexible thin-film based PV

**Battery buffer storage**

Molten-salt battery storage system

**Onsite hydrogen production**

PEM electrolyser and hydrogen storage system

**Atmospheric $CO_2$ supply (DAC)**

Coupled over waste heat recovery system with electrolyser

**Sorption enhanced methanation**

Load flexible approach (demonstrator under construction)

# Thank you for your attention

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