Project: Fermentation CO_2 — From Vented By-Product to On-Site Resource in Winemaking

Candidates	:	TBD
Duration	:	Fall Semester 2026-2027
Report	:	11.12.2026, 11.59pm
Advisor	:	David Singer
Additional Advisors HES	:	Fabian Fischer, Cyril Portmann
Expert / Company	:	
Abbreviation	:	VALCO$_2$
Key Words	:	biogenic CO_2, carbon capture and utilisation, alcoholic fermentation, oenology, circular economy

1. Description

Alcoholic fermentation converts each mole of hexose into two moles of ethanol and two moles of CO_2 — roughly 0.1 t of CO_2 per tonne of wine at 11% vol, released directly to the atmosphere, where it is both a workplace safety hazard and a wasted resource. Swiss production averaged 92 million litres per year over the last decade (75 million litres in the difficult 2024 vintage) [1], placing the national fermentation stream in the order of several thousand tonnes of CO_2 per year — nearly pure, biogenic, and emitted over a few weeks; a comparable territorial assessment in the province of Siena estimated more than 6000 t CO_2 recoverable from local wineries [4]. Because it is biogenic, this CO_2 is not counted in carbon accounting, which removes the regulatory incentive to capture it while leaving open a genuine opportunity for the sector [6]. Meanwhile wineries buy CO_2 and inert gases for tank blanketing, bottling and sparkling wine production, and the European food-grade CO_2 market is largely supplied as a by-product of fossil-based ammonia and hydrogen plants, with recurring supply shortages. Connecting an unused biogenic stream with the sector's own decarbonisation targets [2] and with the broader effort to valorise winemaking by-products [10] is the starting point of this project.

The technical difficulty is not purity but scale, seasonality and dispersion. Recovery technologies developed for high-emission industries transfer poorly to fermentation industries, and the barriers specific to small producers remain little studied [7], while Swiss cellars are numerous and small. The gas leaving a fermenter is also wet and loaded with ethanol and volatile aroma compounds, which can themselves be condensed in successive cooling stages and recovered as a co-product or returned to the fermenting must [11], and any recovery system must not perturb headspace equilibria in a way that jeopardises wine quality [12]. Students will therefore compare several valorisation routes on the same resource [5]: (i) capture, purification and reuse on site (inerting, sparkling wine, dry ice); (ii) mineralisation into a stable, marketable carbonate — the CO_2-AFP strategy converting fermentation CO_2 into sodium carbonate reported a 16.8% reduction of the corporate carbon footprint across scopes 1–3 [3]; (iii) photosynthetic conversion, as demonstrated by a pilot column photobioreactor coupled to a 300 L wine fermentation tank [8] and by raceway and tubular photobioreactors run on brewery fermentation gas [9]; (iv) conversion to chemicals or e-fuels with renewable hydrogen. A critical point to be treated honestly: utilising biogenic CO_2 is not carbon removal unless the carbon is durably stored — the defensible gains are substitution of fossil-sourced CO_2, avoided purchase and transport, and improved supply resilience. The same reasoning applies to purity and drying requirements, which are energy intensive and move the winery away from its core business [6].

Working in interdisciplinary teams, students will produce a complete proposal for a pilot-scale demonstration, not experimental results. It combines a critical state of the art, defined objectives, a process concept with mass and energy balances, an environmental and cost assessment, a resource plan within a ceiling of 250 kCHF, a timeline, and a risk analysis identifying credible causes of failure (overestimated capture efficiency, ethanol and aroma carry-over, oxygen and moisture specifications for food-grade use, energy penalty of compression and liquefaction, three-week operating window against year-round capital, sensory risk to the wine, CO_2 asphyxiation hazards, absence of a local offtaker) with mitigation measures. The three specialisations contribute complementary expertise:

microbial and photosynthetic conversion routes (Applied Biosciences); gas handling, purification, CO_2 quality assurance and purity assessment, reactor concept and scale-up economics (Chemical Development & Production); cellar integration, harvest logistics, gas specifications and sensory impact (Viticulture & Enology). Teams should position their concept within the reality of the Swiss cellar landscape — including shared or mobile capture units — and state under which conditions capturing fermentation CO_2 would not be worth doing.

2. Objectives

State of the art. Origin, quantity and composition of fermentation CO_2; existing capture systems in wineries, breweries and distilleries and their technology readiness; the CCU routes above with reported yields and costs; European and Swiss CO_2 markets, food-grade specifications and the regulatory framework; the accounting status of biogenic carbon and what may legitimately be claimed.

Resource characterisation. Quantify and time-resolve the CO_2 stream for at least two representative Swiss cellar sizes, from sugar-to-alcohol stoichiometry and fermentation kinetics; characterise gas composition (H_2O, ethanol, aroma volatiles, O_2, SO_2) and its evolution during fermentation; establish the cellar's own CO_2 and inert gas demand; identify the mismatch between seasonal supply and year-round demand and the storage or shared-infrastructure options that resolve it.

Process concept. Outline the capture chain (collection manifold and pressure management on the tanks, scrubbing/adsorption, drying, compression, storage or direct conversion); establish mass and energy balances for the retained configurations from sourced literature data; specify output-stream quality against the intended end use; design the experimental programme (capture efficiency, purity, sensory controls on the wine, analytics, replicates, go/no-go criteria) that would validate the concept at pilot scale.

Sustainability, cost and integration. CAPEX and OPEX at equal scale, including the shared-unit scenario; greenhouse gas balance with an explicit distinction between substitution of fossil-sourced CO_2, avoided transport and any durable storage; realistic end-uses and offtakers with their purity, storage and safety constraints; integration into cellar operations during harvest, worker safety, and the credibility of the resulting sustainability claim.

Project planning. Team structure, roles and interfaces across the three specialisations; material, equipment and analytical needs within 250 kCHF; timeline with milestones and go/no-go points; risk analysis (technical, economic, environmental, regulatory, safety) with likelihood, impact and mitigation, and the conditions under which the project should be stopped.

3. Remarks

Templates for the report and additional information will be provided by the advisor.

A draft report must be submitted on 10.11.2026 and will be discussed during an online session on 17.11.2026.

On the due date of the report, the following documents have to be provided by the candidates:

- Report in electronic form (Word and PDF) to the advisor and co-advisors
- The report can be written in English, French or German and should be limited to 20 pages in length (excluding appendices).

4. Evaluation

The final grade of the module will take into account the report (40%), the defense (30%) and an individual interview (30%).

The report will be evaluated according to the following criteria:

	Very good	Good	Slightly insufficient	Significantly insufficient
Context and objctives	Permanent vision of the project context, mastery of all objectives	Sufficient understanding of the context and main objectives of the project, with occasional refocusing required	Insufficient understanding of context and objectives, regular refocusing necessary	Constant reframing of context and objectives or ignoring context and objectives
State of the art	Relevant selection of existing resources, clear summary, clear positioning of the project	Selection of relevant resources, partial summary, positioning of the project presented but not very in-depth	Selection of irrelevant resources, unclear or non-existent project summary and positioning	Selection of irrelevant resources or missing state of the art
Research methodology	Appropriate and well-described research methods. The innovation sought will enable proven advances to be made	The research methods have minor shortcomings which impact the clarity of the research proposal. By large, the innovation actions will allow to fulfill the goals of the project.	The research methods have major shortcomings which significantly impact the clarity of the research proposal. By large, relevant parts of the proposal objectives will not be fulfilled.	Research methods are inappropriate or incomprehensible. The innovation sought will not lead to proven advances
Planification	Tasks and deliverables broken down and planned in a relevant and autonomous manner, realistic planning including resources and costs	Tasks and deliverables cut out and planned in a relevant way after a few modifications	Numerous corrections needed to arrive at a definition of tasks and deliverables and a workable schedule	Unworkable breakdown and planning despite multiple iterations
Clarity and legibility	Clean, concise writing, precise vocabulary, high-quality illustrations described in the text, attractive layout	Acceptable writing (a few spelling mistakes), generally appropriate vocabulary, mostly legible illustrations	Several spelling mistakes per page, often insufficient vocabulary, poor quality or inappropriate illustrations	Spellchecker not used, inappropriate vocabulary, poor quality/inappropriate illustrations, sloppy layout

The defense will be evaluated according to the following criteria:

	Very good	Good	Slightly insufficient	Significantly insufficient
Structured presentation and ability to summarise (15%)	Introduction of context, clear structure, clear, well-argued summary	Adequate structure, some awkward transitions, partial or unargued summary	Unconvincing structure, missing transitions, unconvincing synthesis	Context not introduced, lack of main theme and summary
Presentation materials (15%)	Clean, error-free and legible material, good linkage between presentation and material content	Appropriate support material, usually error-free and legible, used for the presentation	Loaded and illegible media or no control over media content	Overloaded and illegible media and no control over media content
Posture and oral expression (15%)	Open posture, captures the listener's attention, good elocution, appropriate and specific vocabulary	Open posture, lack of dynamism, adequate elocution, mostly appropriate vocabulary	Closed posture, limited contact with the public, limited and/or inappropriate vocabulary, poorly comprehensible oral expression	Closed posture with no contact with the audience, incomprehensible or inaudible speech
Technical depth of the presentation (15%)	Fully convinced of the quality and depth of the work carried out and of its original contribution to TM	Impression that the work carried out has an appropriate technical depth for a TM	The presentation does not allow us to assess the quality and depth of the work carried out	Impression of surface work, no new technical elements linked to TM, the presentation is a smokescreen
Presentation management (15%)	Time limit respected, prepared slides were all dealt with in the same level of detail, self-assessment included in 30 min.	Slight overrun (3 min max) or necessary acceleration during the presentation with a different level of detail for the last slides, self-assessment included in the 33 min.	Overrun of more than 3 minutes or necessary acceleration with more than 3 slides not dealt with or no self-assessment	Overrun of more than 6 minutes or necessary acceleration with more than 6 slides that are not processed or no reaction to the supervisor's warning.
Interacting with listeners and answering questions (25%)	Constructive attitude in discussions, clear answers in line with the questions asked	Constructive attitude in the discussion, imprecise answers in line with the questions	Lack of commitment to the discussion, answers not in phase with the questions	Defensive and/or negative attitude in the exchange, irrelevant responses (avoidance, deflection)

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XX.XX.2026, Sion

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