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1 Introduction

The public client is the Future – Environment – Society (german: Zukunft – Umwelt - Gesellschaft, ZUG) gGmbH.

ZUG is a wholly federal-owned company. The Federal Ministry for the Environment, Climate Protection, Nature Conservation and Nuclear Safety (BMUKN) represents the Federation alone as shareholder. The company's legal seat is in Bonn, its largest location is in Berlin, and it has an additional location in Cottbus.

Within the scope of its statutory purpose, ZUG assumes non-ministerial tasks for the federal government. ZUG's core business is project management for funding programmes of the federal ministries. ZUG is financed exclusively through contracts.

As a service provider, ZUG also takes on additional assignments for support and consulting, thereby turning a wide range of political focus topics in the area of environmental, nature and climate protection into measures.

Based on the "Coal Region Investment Act (InvKG)" and the "Coal Region Structural Strengthening Act (StStG)", ZUG founded the "PtX Lab Lausitz – Practice Lab for Power and Basic Materials from Green Hydrogen" in March 2021. It is funded by the Federal Ministry for Economic Affairs and Energy (BMWE).

The aim of the PtX Lab Lausitz is to explore the possibilities of environmentally compatible and sustainable production and use of Power-to-X (PtX). Through various formats it promotes interdisciplinary, systemic, sector-specific as well as cross-sectoral discourse on the topic of PtX. The PtX Lab Lausitz simultaneously serves as a knowledge platform, impulse generator and contact point for industry, politics and science. On this basis, key actors in politics, business and society are advised and processes at the national, EU and international level are supported.

The German version of the contract components is the only legally binding version. Any translations serve solely for informational purposes in the tendering process.

Further information can be found at <https://ptxlablausitz.de>

1.1 Background and Problem Statement

The PtX Technology and Market Radar Asia project focuses on gaining insights into the current technology and market developments in the field of PtX technologies in the Asian region. The background is that, in a system of global markets, economies are competing for technology leadership and capacity building (for the manufacture of PtX products). China, as a dominant player, is especially active in driving the market ramp-up of PtX technologies and is therefore part of the analysis.

The results obtained should form the basis for an assessment of the state of the art and the market compared with other world regions and enable the PtX Lab Lausitz to develop policy recommendations primarily for European decision-makers. In addition, the results should give the PtX Lab Lausitz a current overview of PtX-technology manufacturers based in China as well as operators of PtX plants.

China is currently a leader in hydrogen production and has the largest production capacity of green hydrogen, pursuing a long-term intensive capacity expansion of PtX technologies.

Research on the status of technologies along the Technology Readiness Levels (TRL) 4 – 9, their implementation, and market developments of PtX technologies in China is hampered primarily by limited access to foreign-language literature and market-relevant networks. An investigation based solely on English or German literature sources does not provide a sufficiently deep insight into the current market situation. The TRLs are defined as follows:

Table 1: Definitions of Technology Readiness Levels according to EIC Accelerator Funding

	TRL	Description
DEPLOY- MENT	9	System works in operational environment
	8	System was completed and qualified
	7	System prototype was tested in real-life use
DEVELOP- MENT	6	Technology demonstrated in relevant environment
	5	Technology validated in relevant environment
	4	Technology validated in lab

In this context, the objective of the assignment is to carry out the research from a local perspective that reflects the actual situation in China.

1.2 Objective of the Assignment

The project goal is to create a “PtX Technology and Market Radar” for the Asian region, specifically for China.

This performance description outlines the services to be delivered. The assignment encompasses:

- Analysis of the current development status of the selected technologies, including analysis of predefined criteria within a foreign-language literature review in the country's language (TRL 4 – 9, see definition in 1.1),
- Analysis of the implementation status of PtX projects (pilot, demonstration and industrial plants), including analysis of predefined criteria,
- Analysis of the current market situation (exclusively technologies at TRL 9, see definition in 1.1) and emerging market trends.

2 Services to be provided

2.1 Work Package 1: PtX Technology Radar

Work Package 1 comprises a search of all publicly accessible media, including manufacturer websites with product data sheets, scientific publications (peer-reviewed), government publications, market studies, industry-specific databases, and internet articles in the local language concerning the technological status of the listed PtX technologies along TRL 4–9. For each technology, at least five reliable sources must be consulted. The client will possibly provide a literature collection from a previous search.

The definition of the technologies/system boundaries for the analysis has already been carried out and therefore, provisioning them to the contractor is explicitly not part of the contract award. Likewise, the development of policy recommendations is not part of the contract to be awarded. The scope of consideration includes all technologies from resources up to synthesis. Shipping technologies are also included. If some of the listed technologies are found only as integrated sub-processes of a higher-level process chain, they will be considered within the context of that process chain.

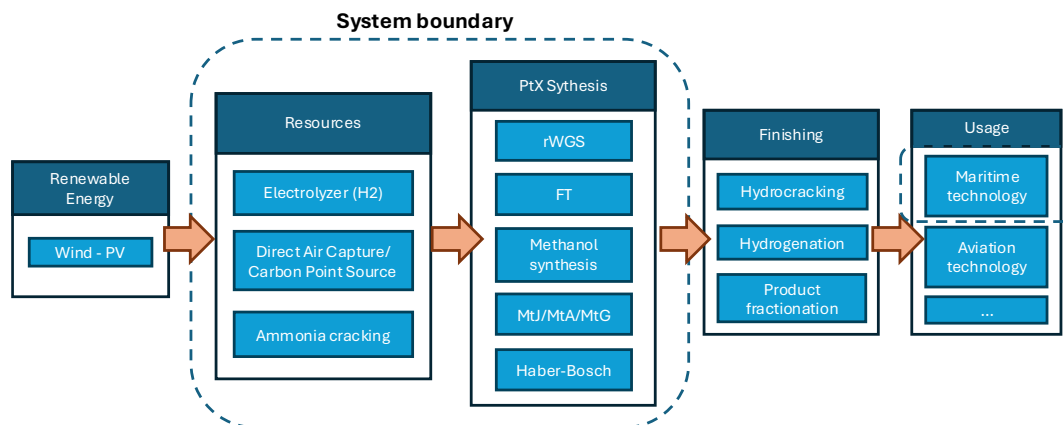


Figure 1: System boundary

In the research, the technologies listed in the following technology catalog (see Table 2) and the Key Enabling Technologies (1 – 4) therein, as well as additional technologies assessed as relevant for PtX production (5), are to be examined based on selected criteria (see Annex, Table 4). The technologies are ordered by priority; the highest priority is given to the Key Enabling Technologies, namely 1 electrolysis technologies, 2 synthesis technologies, 3 green ammonia technologies, and 4 carbon-capture technologies. These are to be prioritized in the research.

Maritime technologies are also part of the research. For each technology from Table 2, at least the following criteria must be presented: a minimum of five manufacturers of the respective technology with offered performance classes, a description of the technology and its special features/advantages compared with the state of the art or competitors, total CAPEX, fixed OPEX (percentage per year of CAPEX), TRL, specific electricity consumption and specific heat consumption (where relevant), as well as the other technology-specific criteria according to Table 4 in the Annex. The criteria for the Key Enabling Technologies are listed in the Annex as items 1 to 10. The criteria for the shipping technologies are items 11 to 13. Changes to the criteria list are only permissible by mutual agreement of both parties.

Table 2: Technology Catalog

Technology Designation	Subcategory
1. Elektrolysis Technologies	1.1. Alkaline Elektrolysis (AEL) 1.2. Polymer Electrolyte Membrane (PEM) Elektrolysis 1.3. Solid Oxide Elektrolysis Cells (SOEC) 1.4. Anion Exchange Membrane (AEM)
2. Synthesis Technologies	2.1. Synthesis-gas production via reverse water-gas shift reaction (rWGS) 2.2. Fischer-Tropsch (FT) synthesis

	2.2.1. High-temperature reactor 2.2.2. Low-temperature reactor 2.3. Methanol synthesis 2.3.1. Carbon-monoxide (CO) methanol synthesis process 2.3.2. Direct carbon-dioxide (CO ₂) methanol synthesis process 2.4. Methanol-to-Jetfuel (MtJ) process (full chain) 2.4.1. Methanol-to-Olefin (MtO) process
3. Ammonia Technologies	3.1. Haber-Bosch process (optimized for variable electricity supply) 3.2. Ammonia cracker
4. Carbon-Capture Technologies	4.1. Direct Air Capture (DAC) Technology 4.2. Carbon capture from point sources
5. Maritime Technologies	5.1. On Board Carbon Capture 5.2. Propulsion systems and on-board energy systems 5.2.1. 2-Stroke internal combustion engine (ICE) 5.2.2. 4-Stroke ICE 5.2.3. Combined Gas and Steam 5.2.4. SOEC 5.2.5. High Temperature-Fuel Cell 5.2.6. PEM-Fuel Cell

If the research identifies no or only few (fewer than three) domestic manufacturers per technology, this will be communicated to the client in a project meeting using reliable sources. After review and approval by the client, the research will be expanded to include international collaborations. The contractor (AN) will continue the research based on the technology catalog and the criteria list in the Annex. If the search for international projects also yields no or only few results, the contractor will inform the client in a project meeting using reliable sources and record this in Interim Report I. If China primarily relies on imports rather than domestic production, this will also be reported to the client in a project meeting and noted in Interim Report I with reference to reliable sources. Imports will then be addressed more comprehensively in the following Work Package 3 (WP 3).

The first interim report must describe all technologies together with the most important manufacturers. In particular, the relevance of each technology in China and its technological maturity must be explained, citing the respective sources. The interim report should also address domestic manufacturing and international collaborations/projects.

For the following partial services, partial acceptances will be agreed. Upon successful acceptance, a milestone payment against the total remuneration, according to the listing, becomes due. The milestone payments are made without legal binding for the final settlement; all objections, rights of reduction, and set offs remain reserved:

- 1) Tabular listing of the findings for all technologies with the respective criteria, in accordance with the definitions in the Annex, including the sources and a bullet point summary of each source in English.
- 2) Interim Report I with a minimum of 10 pages in written form and in English, in which the relevance of all listed PtX technologies as well as their development status, i.e., their TRL, are explained with reference to the sources.

WP 1 Milestones and Outputs

Milestone WP 1, 1.1: The literature in the national language has been reviewed and evaluated regarding the relevant technologies (TRL 4–9) with their criteria as well as the current development status of each technology in China.

Output 1.1.1: Collection of all technologies based on their criteria compiled into an Excel list.

Output 1.1.2: Interim Report I in written form and English, containing a literature overview and evaluation of PtX-relevant technologies for China (in Word, at least 10 pages; tables, figures and bibliography not included).

Output 1.1.3: Presentation of results in the form of a 2-hour internal project workshop I (online).

2.2 Work Package 2: PtX Plant Radar

In this work package, all PtX plants that have already been implemented, are under construction, or are planned (pilot, demonstration, or industrial plants) will be located and recorded in a plant list. All plants operated by domestic and foreign operators must be considered. The client may provide the contractor with a plant list of already identified plants, which the contractor shall supplement with additional entries. The contractor will conduct a search in the local language to identify the plants. All sources must be captured and cited. The following plant types are to be located: e-SAF, e-diesel, e-methanol, e-ammonia and green H₂ plants. Plant-specific attributes must also be captured and documented in the plant list. The following plant attributes are to be collected, with sources for all data indicated:

1. Plant type (e-SAF, e-diesel, e-methanol, e-ammonia, green H₂)
2. Plant operator, indicating domestic or foreign
3. Location
4. Manufacturing process from feedstock to final product (at a level of detail that shows components such as rWGS, FT reactors, compressors, large intermediate storage, relevant material flows)
5. Project status – A) Front-End-Engineering & Design (FEED) / project definition, B) permitting & financing, C) engineering, procurement & construction (EPC phase), D) commissioning & operation)
6. Planned or actual Financial Investment Decision (FID) and production start
7. Type and quantity of main and co-products
8. Electricity demand
9. Type of electricity source (dedicated renewable energy, grid electricity, renewables & grid electricity, nuclear power)
10. Material demands (H₂ demand, CO₂ demand, N₂ demand, water demand)
11. CO₂ source
12. Overall efficiency (energy of end-products and co-products / energy of input products)

13. Carbon efficiency (carbon in end-products and co-products / carbon input)

14. LCOP (price per product output)

The interim report II must document and explain the research results in writing on at least 5 pages. It should specifically address the geographical concentration of the plants as well as their attributes and manufacturers.

The plant list should contain at least 10 entries of PtX plants. If the research yields only few (fewer than three) or no entries, the contractor shall justify this to the client with reliable sources in one of the bi-weekly coordination meetings and record it in written form within Interim Report II.

For the following partial services, partial acceptances will be agreed. Upon successful acceptance, a milestone payment against the total remuneration, as per the listing, becomes due. The milestone payments are made without legal binding for the final settlement; all objections, rights to reduction and set-offs remain reserved:

1. Provision of the fully prepared list of PtX plants localized for China in an Excel spreadsheet and in English.
2. Provision of the complete Interim Report II on the research results of the PtX plants, with at least 5 pages in English, and presentation of the results in an internal project workshop.

WP 2 Milestones and Outputs

Milestone WP 2, 2.1: All relevant data have been collected, cleaned, structured, assigned, and compiled into documents (format appropriate to the content).

Output 2.1.1: Processed plant list with the corresponding plant attributes (Excel plant list).

Output 2.1.2: Interim Report II in the most comprehensive written form possible and in English, identifying and evaluating the PtX plants (Word document, at least 5 pages; tables, figures and bibliography not included).

Output 2.1.3: Presentation of the results and explanation of the data sets in a 2-hour internal project workshop II (online).

2.3 Work Package 3: PtX Market Radar

Based on the results obtained in Work Package 1 (Technology Radar) and Work Package 2 (Plant Radar), a market analysis of PtX technologies for China shall be carried out. Only those technologies defined in Section 2.1 for which market readiness (TRL 9) has been confirmed are to be considered. The reference year is 2025; if data for 2025 are not fully available, the latest available data shall be used. The market analysis shall be performed using recognised macro-economic methods. For all indicators, data sources, calculation methods and assumptions must be presented transparently.

The technologies that have reached TRL 9 shall be analysed with regard to their position in the value-creation chain (raw-material extraction, refining/processing, intermediates/components, final-product manufacturing, distribution, use, recycling/end-of-life). This shall allow conclusions about which value-creation stages are particularly covered by the Chinese PtX

market. For the identified TRL 9 technologies, the market structure (status-quo) along the respective value-creation stages shall be examined. The number and size of companies present in the market must be identified. The market share (in %) that each company holds in the individual technologies, as well as market concentration (Herfindahl-Hirschman Index, HHI), shall be shown and visualised.

Furthermore, domestic demand for the technologies, the level of capacity and overcapacity, the share of the global market, and possible stockpiles shall be recorded.

The degree of competition (identifying possible oligopolies and monopolies) and the ability of companies to influence price formation shall be determined. In this context, the price level (in the local currency and in EUR) and price volatility (reference year and five years prior to the reference year) of the technologies shall be established. Additionally, the price differential between technologies produced in Asia and offered domestically versus those produced in Asia and offered in the EU (nominal, reference year) shall be captured.

A quantitative analysis of export and import data (including major destination and source countries, unit quantities and export volumes in the local currency and in EUR) for the reference year and for five years prior shall also be performed.

The volume of investments (flows and stocks) in the technologies within China, as well as foreign direct investment (from the EU and globally, each in the local currency and in EUR, broken down by technology and by value-creation stage), shall be determined.

For the partial services listed below, partial acceptances will be agreed. Upon successful acceptance, a milestone payment against the total remuneration, according to the schedule, becomes due. The milestone payments are made without legal binding for the final settlement; all objections, rights of reduction and set-offs remain reserved:

1. Provision of the list of market-ready technologies with TRL 9, including their placement in the value-creation chain, and a coordination meeting on the technology selection.
2. Provision of Interim Report III containing the complete market analysis, data interpretation, and presentation of the results in an internal project workshop.

WP 3 Milestones and Outputs

Milestone WP 3, 3.1: The technology selection (TRL 9) and its placement in the value-creation stages has been completed and mirrored with the PtX Lab Lausitz.

Output 3.1.1: List of technologies with TRL 9 and their value-creation stages (format: Excel spreadsheet).

Output 3.1.2: Online discussion on the technology selection.

Milestone WP 3, 3.2: An analysis and interpretation of the data (market analysis) has been carried out and presented to the PtX Lab Lausitz.

Output 3.2.1: Market analysis as an interim report in written form and in English with at least 15 pages (Word file) with text and, if appropriate, figures.

Output 3.2.2: Presentation and explanation of the analysis and interpretation of the results in a 2-hour internal project workshop III (online).

2.4 Work Package 4: Conclusion

After the completion of WP 1-3 (PtX Technology Radar, PtX Plant Radar, PtX Market Radar), all results are available and have been discussed with the client. The contractor hands over the cleaned and consolidated results to the client in the form of a final report and presents them in an internal project workshop.

The final report is the conclusive document for the study. It must be submitted in electronic form and in printable layouts, with all tables and figures clearly and completely labelled in English. Both PDF and Word versions must be made available to the client by the contractor in electronic form. All graphics, diagrams, tables and other non-textual elements of the reports shall be provided as separate files together with the original data and proper labelling, in electronic form, by the contractor to the client.

The English-language final report must be submitted by the contractor at least 2 weeks before the internal final workshop. The final version, approved by the client, must be available in printable layout at least 1 week before the final workshop.

Final Workshop

Once the reports (see above) are available, the contractor will conduct a 4-hour final workshop online via videoconference to present the results. Details will be coordinated with the client. The contractor will coordinate and organise, together with the client, all necessary measures for the final workshop, including agreeing on date, location, participants, agenda and other procedural details. The final workshop will be held in English.

The contractor will prepare a protocol of the workshop and deliver it to the client no later than 2 weeks after the workshop.

For the partial services listed below, partial acceptances will be agreed. Upon successful acceptance, a milestone payment against the total remuneration, according to the schedule, becomes due. The milestone payments are made without legal binding for the final settlement; all objections, rights of reduction and set-offs remain reserved:

1. Finalisation and hand-over of the final reports to the client.
2. Conducting coordination meetings for the closure and the final 4-hour internal project workshop with result presentation by the contractor and delivery of the protocols.

Final payment amounting to 10 % of the contractually agreed total remuneration will be due after full performance and successful final acceptance. This includes the complete and successful acceptance of all partial services, acceptance of the final report, and the successful completion of the final workshop. The final payment will be made on the basis of the concluding review, taking any objections, reductions and set-offs into account.

WP 4 Milestone and Outputs

Meilenstein WP 4, 4.1.1: Project closure with final report.

Output 4.1.1: Final report (written, in English, approximately 30-50 pages).

Output 4.1.2: Closing coordination meeting and final internal project workshop IV with the client and the contractor (hybrid, 4 h).

2.5 Coordination, Workshops, Report

All services must be delivered in English.

For every work package (WP) the contractor shall evaluate all collected data from its own research or from reliable publicly available sources in structured form (Excel/CSV), including source references and methodological information, and provide them to the client (here the PtX Lab Lausitz, part of Zukunft – Umwelt – Gesellschaft gGmbH) in electronic form. In addition, written explanations and, where necessary, supplementary oral explanations shall be made available during the client's scheduled coordination meetings.

The client will designate a main contact person from the PtX Lab Lausitz for the contractor; several staff members will participate in meetings and feedback rounds. The contractor's project manager will be the point of contact for the Lab and will be available for regular exchanges every two weeks during working hours with the Lab's main contact. Project-management responsibility for the client lies with the project manager. At the start, a deputy will also be appointed to act as the contractor's contact in case of illness, vacation or other reasons.

All project meetings will be scheduled in consultation with the client and organised by the contractor. The agenda for each meeting (e.g., regular status meetings, internal project workshops) shall be sent to the client electronically one week in advance. The contractor will chair the meetings and document the outcomes in a protocol, which must be submitted to the client within three working days after the meeting.

A virtual kick-off meeting will take place at the start of the assignment, preferably in the first week after contract award. **All** team members of the contractor, including the project manager, will attend. The organisational framework and further steps of the collaboration shall be defined during this meeting.

The contractor commits to providing a regular update (status meetings) every two weeks. The status meetings shall preferably be oral (videoconference); in justified exceptions it may be via mail. Draft materials must be submitted to the client at least three working days before the status meeting.

After each completed work package (WP 1-3) an internal project workshop (via videoconference) shall be held. Both the client and the contractor's team members shall attend the workshops, as agreed with the client. The contractor is responsible for organising these internal workshops. Each internal workshop at the end of a work package shall be followed by an interim report for that WP, prepared and edited by the contractor. The results of the interim reports and the internal workshops shall be incorporated into an updated version of the interim report. These results will be presented in WP 4 as the final report within a concluding internal project workshop.

Inputs for the internal workshops (documents, figures, etc.) shall be transmitted to the client electronically one week before the scheduled date, just as for client meetings. The contractor shall keep minutes of the internal workshops and deliver them to the client within three working days after the workshop.

The contractor is obliged to prepare reports or results content-wise and make them available to the client. PDF files must be provided in accordance with the German Equal Opportunities Act (BGG) and BITV 2.0. These will be reviewed by the client prior to third-party acceptance. Any necessary improvements shall be made by the contractor (maximum 5 iterations).

Generally, all coordination meetings are held online via videoconference.

Service description

Lot 1 China

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Interviews should primarily be conducted by video conference. If travel becomes unavoidable, travel-related CO₂ emissions must be reduced or avoided in line with this contract. Air travel is only permitted when train travel would exceed 8 hours and has been approved by the client. Train travel shall be given priority. Should unavoidable air travel be required, carbon offsetting must be performed where feasible.

The scope of project coordination is to be included in the work-package budgets.

Costs for Data Sources and Licences:

The contractor shall bear all costs required for performance of the services, in particular those for literature searches, database access and other information sources. This includes access to specialist literature as well as country-specific information sources in China. The contractor shall observe the principles of cost-effectiveness and frugality when selecting data sources.

3 Schedule

The service-delivery period starts with the award of the contract, expected from 1st of June 2026.

The 2-hour kick-off meeting will take place within the first week after award. The project manager and all team members of the contractor and the client will attend the kick-off meeting.

Table 3: planned dates and procedures

Project month 1 (after 4 Weeks)
Topic: PtX Technology Radar (WP1) <ul style="list-style-type: none">- Kick-off meeting- Bi-weekly status meeting- Internal project workshop and results presentation- Technology list in form of an Excelsheet- Interim report(s)
Project month 2 (after 8 Weeks)
Topic: PtX Plant Radar (WP2) <ul style="list-style-type: none">- Bi-weekly status meeting- Internal project workshop and results presentation- Plant list in form of an Excelsheet- Interim report(s)
Project month 3 (after 12 Weeks)
Topic: PtX Market Radar (WP3) <ul style="list-style-type: none">- Bi-weekly status meeting- Internal project workshop and results presentation- Interim report(s)
Project month 4 (after 18 Weeks)

Service description

Lot 1 China

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Topic: Conclusion (WP4)

- Bi-weekly status meeting
- Internal final project workshop and results presentation
- Final report

4 Documents to be submitted with the offer

The evaluation of the offer shall be based on the **Evaluation Matrix** (03_Bewertungsmatrix) document.

To present the cost calculation, the **list of services** document must be completed in full. Any desired comments should be submitted as annexes. Uncertainties in the tender documents and calculation-relevant questions may be raised during the bidders' question period.

Note: file names may not exceed 15 characters.

In order to assess the quality of the offer in addition to price, the following additional explanations and documents must be submitted:

4.1 Content, methodology and organisational implementation

The technical offer shall detail how the professional service delivery and formal quality assurance of the deliverables to be submitted in the event of award will be carried out.

An outline of the understanding of the task with respect to the implementation of the work packages as a whole, as well as an explanation of the planned methodological approach for execution within the work packages, is expected. This should show which personnel are definitively assigned to carry out the contract (the so-called project team) and which role each will assume (project manager / deputy project manager / other team member). It should also explain how the schedule will be maintained in case of staff absence (e.g., due to illness or similar circumstances).

The technical offer shall not exceed **12 pages** (excluding annexes) (average characters per page including spaces: max 2 250). The documents to be submitted shall include:

- a presentation of the understanding of the task,
- a work plan,
- a personnel deployment plan, and
- short profiles.

The work plan, the personnel deployment plan and the short profiles (excerpts from CVs/resumes) are considered annexes and shall not be counted as part of the **12-page** limit.

If the offer is longer, the additional pages will not be taken into account in the evaluation.

A sufficiently detailed work and personnel deployment plan is expected, showing how the complete, on-time processing of the entire scope of work while maintaining consistently high scientific quality will be ensured. The project team must indicate who will take which tasks at what time. The already defined dates must be incorporated and plausible substitution arrangements considered; the scope should not exceed **2 DIN A4** pages.

4.2 Personnel

The experience of the personnel assigned to this contract has a significant impact on the level of contract execution and is therefore evaluated at award level.

Please note the minimum personnel requirements in document Fragebogen zur Eignungsprüfung in der Angebotsphase.

The bidder shall present the required experience of the personnel responsible for executing the contract and demonstrate, in the form of short profiles, that the persons who will provide the services have already delivered comparable services in the past.

Requirements for the short profile as proof of experience:

For each designated technical team member (including the project manager) a short profile in a clear, preferably tabular form shall be submitted, from which it is unmistakably apparent in which of the required topics experience (years of experience) already exists. The scope should not exceed **2 DIN A4** pages per team member.

When evaluating personnel, the following criteria will be taken into account:

4.2.1 Project-management experience in Power-to-X (PtX), e-fuels, hydrogen technologies

Long-term professional experience as well as project-management experience in the area of Power-to-X and/or synthetic fuels and hydrogen technologies will be positively evaluated. Experience will be weighted by the years of the team (all members). Proof shall be provided in the short profile.

4.2.2 Technical experience of a team member in technology assessment based on technical and economic criteria

Long-term professional experience in the assessment of technologies based on technical and economic criteria to support the energy transition, the transformation of fossil raw materials to renewable raw materials and/or the transformation of “hard-to-abate” sectors will be positively evaluated. Proof shall be provided in a reference list.

4.2.3 Technical experience of a team member in market analyses in China

Long-term professional experience in market analysis in China, including data collection and data preparation of market data based on recognised macro-economic methods, will be positively evaluated. Proof shall be provided in a reference list. The number of publications will be taken into account.

4.2.4 Technical experience of a team member in at least three of the relevant PtX technologies

Long-term professional experience in at least three of the key-enabling technologies for PtX—such as electrolyzers, Fischer-Tropsch processes, methanol synthesis, rWGS,

MtJ/MtA/MtG processes, ammonia technologies, or carbon-capture technologies—will be positively evaluated. Experience will be weighted by the years of the team (all members). Proof shall be provided in the short profile.

5 Annex

Table 4: Criteria List of the PtX Technologies

Technology	Criteria
1. Elektrolyzer	<ul style="list-style-type: none"> • Manufacturer • Offered stack power classes (MW) <p>For the highest offered stack power class per manufacturer</p> <ul style="list-style-type: none"> • Description of technology and the specific features/advantages compared to state of the art / competitors • Total CAPEX (€/kW installed capacity, including peripherals such as pipes, pumps, compressors, etc.) • Fixed OPEX (% per year of CAPEX) • TRL • Specific electricity consumption (in kWh_{el}/kg_{H2}) • Only for SOEC: specific heat consumption (in kWh_{th}/kg_{H2}) • Lifetime (in h)
2. Fischer Tropsch Reactor	<ul style="list-style-type: none"> • Manufacturer • Offered plant sizes (capacity in t_{Syn crude}/a) <p>For the highest offered plant size per manufacturer</p> <ul style="list-style-type: none"> • Description of the technology (plant and reactor concept, catalyst, temperature range, pressure range) and the specific features/advantages compared to state of the art /competitors • Total CAPEX (€/t_{Syn crude}/a) • Fixed OPEX (% per year of CAPEX) • TRL • Syngas throughput (e.g. t/d) • Syncrude production rate (e.g. t/d) <ul style="list-style-type: none"> ○ including C1-C4 (gaseous) ○ including C5-C18 (liquid) ○ including C18+ (solid) ○ <i>optional: product distribution</i> • Power consumption (MWh_{el}/t_{Syn crude})

3. Methanolsynthesis (direct synthesis from H₂ and CO₂)	<ul style="list-style-type: none"> • Manufacturer • Offered plant sizes (capacity in t_{Methanol}/a) <p>For the highest offered plant size per manufacturer</p> <ul style="list-style-type: none"> • Description of the technology (plant and reactor concept, catalyst, temperature range, pressure range) and the specific features/advantages compared to state of the art /competitors • Total CAPEX ($\text{€}/t_{\text{Methanol}}/a$) • Fixed OPEX (% per year of CAPEX) • TRL • (Specific) electricity consumption • Carbon efficiency for single pass reactor operation ($C_{\text{Methanol}}/C_{\text{Input}}$) • Hydrogen efficiency for single pass reactor operation ($H_2 \text{ Methanol}/H_2 \text{ Input}$)
4. rWGS	<ul style="list-style-type: none"> • Manufacturer • Offered plant sizes (capacity in t_{Syngas}/a) <p>For the highest offered plant size per manufacturer</p> <ul style="list-style-type: none"> • Description of the technology (plant and reactor concept, catalyst, temperature range, pressure range) and the specific features/advantages compared to state of the art /competitors • Total CAPEX ($\text{€}/t_{\text{Syngas}}/a$) • Fixed OPEX (% per year of CAPEX) • TRL • Carbon efficiency for single pass reactor operation ($CO_{\text{Syngas}}/CO_2 \text{ Input}$) • CO Selectivity (CO purity of syngas in %) • (Specific) energy consumption ($MWh_{\text{el}}/t_{\text{Syngas}}$ and $MWh_{\text{th}}/t_{\text{Syngas}}$)
5. Methanol-to-Olefins reactor	<ul style="list-style-type: none"> • Manufacturer • Offered plant sizes (capacity t_{Olefins}/a) <p>For the highest offered plant size per manufacturer:</p> <ul style="list-style-type: none"> • Description of the technology (plant and reactor concept, catalyst, temperature range, pressure range) and the specific features/advantages compared to state of the art /competitors • Total CAPEX ($\text{€}/t_{\text{Olefins}}/a$) • Fixed OPEX (% per year of CAPEX) • TRL • Olefins production rate (t/time) • Carbon efficiency for single pass reactor operation ($C_{\text{Olefins}}/C_{\text{Methanol}}$) • Hydrogen efficiency for single pass reactor operation ($H_2 \text{ Olefins}/H_2 \text{ Methanol}$)

6. Olefins to Jet-fuel	<ul style="list-style-type: none"> • Manufacturer • Offered plant sizes (capacity $t_{\text{Jetfuel}}/\text{a}$) <p>For the highest offered plant size per manufacturer</p> <ul style="list-style-type: none"> • Description of the technology (plant and reactor concept, catalyst, temperature range, pressure range) and the specific features/advantages compared to state of the art /competitors • Total CAPEX ($\text{€}/t_{\text{Jetfuel}}/\text{a}$) • Fixed OPEX (% per year of CAPEX) • TRL • Carbon efficiency for single pass reactor operation ($C_{\text{Jetfuel}}/C_{\text{Olefins}}$) • Hydrogen efficiency for single pass reactor operation ($H_{2\text{Jetfuel}}/H_{2\text{Olefins}}$) • (Specific) energy consumption ($\text{MWh}_{\text{el}}/t_{\text{Jetfuel}}$)
7. Haber-Bosch reactor	<ul style="list-style-type: none"> • Manufacturer • Offered plant sizes in Ammonia output per year ($t_{\text{Ammonia}}/\text{a}$) <p>For the highest offered plant size per manufacturer:</p> <ul style="list-style-type: none"> • Description of the technology (plant and reactor concept, catalyst, temperature range, pressure range) and the specific features/advantages compared to state of the art /competitors • Total CAPEX without Elektrolysis ($\text{€}/t_{\text{NH}_3}/\text{a}$) • Fixed OPEX without Elektrolysis (% per year of CAPEX) • TRL • Ammonia yield (% for H_2/N_2 recycle ratio) • Ammonia synthesis efficiency (% f for H_2/N_2 recycle ratio) • Heat recovery potential (kWh/t)
8. Ammonia Cracker	<ul style="list-style-type: none"> • Manufacturer • Offered plant sizes in ammonia output per year ($t_{\text{Ammonia}}/\text{a}$) <p>For the highest offered plant size per manufacturer:</p> <ul style="list-style-type: none"> • Description of the technology and its special features/advantages compared to the state of the art / competitors • Total CAPEX ($\text{€}/t_{\text{Ammonia}}/\text{a}$) • Fixed OPEX (% per year of CAPEX) • TRL • (Specific) energy consumption ($\text{J}/\text{t NH}_3$) • Yield ($H_{2\text{Output}}/NH_{3\text{Input}}$) • Partial load capability (% of rated power)

9. Direct Air Capture	<ul style="list-style-type: none"> • Manufacturer • Offered plant sizes in t_{CO_2}/a <p>For the highest offered plant size per manufacturer:</p> <ul style="list-style-type: none"> • Description of the technology and its special features/advantages compared to the state of the art / competitors • Total CAPEX ($€/t_{CO_2}/a$) • Fixed OPEX (% per year of CAPEX) • TRL • CO_2 purity (%) • Arbeitsbeladung ($mmol_{CO_2}/q_{Sorbent}$) • (Specific) energy consumption ($MWh_{el}/t_{CO_2}/a$ and $MWh_{th}/t_{CO_2}/a$)
10. Carbon Capture from point sources	<ul style="list-style-type: none"> • Manufacturer • Offered plant sizes in t_{CO_2}/a <p>For the highest offered plant size per manufacturer :</p> <ul style="list-style-type: none"> • Description of the technology and its special features/advantages compared to the state of the art / competitors • Total CAPEX ($€/t_{CO_2}/a$) • Fixed OPEX (% per year of CAPEX) • TRL • Separation rate (%) • CO_2 purity (%) • (Specific) energy consumption ($MWh_{el}/t_{CO_2}/a$ and $MWh_{th}/t_{CO_2}/a$)
11. Maritime technologies: On Board Carbon Capture	<ul style="list-style-type: none"> • Manufacturer • Offered plant sizes in t_{CO_2}/h <p>For the highest offered plant size per manufacturer:</p> <ul style="list-style-type: none"> • Description of the technology and its special features/advantages compared to the state of the art / competitors • Total CAPEX ($€/t_{CO_2}/a$) • Fixed OPEX (% per year of CAPEX) • TRL • (Specific) energy consumption ($MWh_{el}/t_{CO_2}/a$ and $MWh_{th}/t_{CO_2}/a$) • Separation rate (%) • CO_2 purity (%)
12. Maritime technologies: propulsion systems	<ul style="list-style-type: none"> • Manufacturer • Offered power classes per motor type (MW) • For motors: Subdivision into slow, medium-speed, or fast runners <p>Für die jeweils größte Ausführung eines Motorentyps je Leistungsklasse oder Brennstoffzellensystems / größtes Brennstoffzellen-Einzelmodul:</p>

	<ul style="list-style-type: none"> • Description of the technology and its special features/advantages compared to the state of the art / competitors/ including mono- or dual-fuel capabilities • Total CAPEX (€/MW) • Fixed OPEX (% per year of CAPEX) • TRL • Specific fuel consumption (g/kWh) across all load ranges with defined fuel properties (MJ/kg or kJ/kg). For fuel cell systems, the entire system up to the point of injection into the vehicle electrical system must be considered. For engines, the power output at the engine flange must be taken into account. • For ammonia-powered drive systems: Ammonia or nitrous oxide slip across the load range (min. 25%-100%) in g slip/kg fuel • For fuel cell systems: Degradation rate of the fuel cell stacks per MWh and efficiency loss per degradation rate
13. Maritime technologies: On-board energy systems, energy storage systems, fuel supply systems for ammonia, hydrogen, methanol and LNG	<ul style="list-style-type: none"> • Manufacturer • Total CAPEX (€/MW downstream energy converter) • Fixed OPEX (% per year of CAPEX) • TRL • Description of the technology and its special features/advantages compared to the state of the art / competitors • (Specific) energy consumption ($\text{kWh}_{\text{el}}/\text{kg}_{\text{fuel}}$ and $\text{kWh}_{\text{th}}/\text{kg}_{\text{fuel}}$)