EU–CHINA
BRIDGE

Building Roadmaps to Industrial
Decarbonisation and Green Economy
through EU-China Cooperation

D3.1 – Two EU-China technology inventories on promising low-emission technology options for EIIs: Summary and Documentation

WP3 – Technology demonstration, upscaling and roadmaps

https://www.eu-china-bridge.eu

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EC Summary Requirements

1. Changes with respect to the Description of the Action (DoA)

No changes with respect to the work described in the DoA.

2. Dissemination and uptake

The inventories are publicly available.

3. Short summary of results (<250 words)

The key results of Deliverable 3.1 are two technology inventories for promising low-emission technologies in the steel and petrochemical industries as part of the EU-China BRIDGE project. These inventories are intended to support the transition to climate-neutral industries in Europe and China. They contain detailed descriptive and quantitative data on selected breakthrough technologies, including TRL and development status. The technologies were selected based on criteria such as net-zero compatibility and high CO_2 reduction potential. The inventories will be made publicly available as Excel files on Zenodo and are used internally for technology roadmaps and techno-economic modelling. The technology data is also converted to an interactive interface on the I2AMParis platform.

4. Evidence of accomplishment

This report as well as the associated inventory excel files.

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Preface

EU-CHINA BRIDGE will support the transition to a climate-neutral and resilient society in both Europe and China by jointly advancing knowledge on technology innovations and roadmaps for decarbonising energy intensive industries, co-creating innovative modelling by combining cutting-edge bottom-up and integrated assessment modelling to quantify net-zero sustainable pathways, and developing the most updated and comprehensive emissions data. It will intensively engage relevant stakeholders from both regions, enhancing dialogues, and fostering mutual learning among policymakers, industries, and experts. It will deliver two open-source EU-China joint technology inventories of promising net-zero emission technology options for the iron & steel and chemical industries, two co-implemented demonstrations of promising technologies in China, and co-created scale-up paths and roadmaps of the selected industrial technologies in both regions. It will also develop the most up-to-date, high-resolution, multi-sectoral, national and regional GHG and short-lived climate pollutant emission inventories as well as dynamic monitoring of key emission sources at high spatiotemporal granularity. A state-of-the-art modelling framework will be developed, exploiting and advancing cutting-edge and established modelling tools for EU and China, using the latest emissions data, representing technology and policy options, enabling assessment of socioeconomic impacts, covering multiple economic sectors and regions, and offering high spatial and technology detail. The enhanced models will be used to co-produce net-zero pathways for the EU and China, explicitly assessing co-benefits and trade-offs of climate policies with other societal goals while exploring cooperation policies and governance to drive the global transformation and assessing the distributional and global-level implications of the two regions' decarbonisation. The pathways will be documented in new workspaces in the I²AM PARIS platform.

WI – Wuppertal Institut fuer Klima, Umwelt, Energie gGmbH	DE
E3M – E3-Modelling AE	GR
IIASA – Internationales Institut fuer angewandte Systemanalyse	AT
UoB – The University of Birmingham	UK
ICCS – Institute of Communication and Computer Systems	GR
HOL – HOLISTIC IKE	GR
ITE – University of Kassel	DE
THU-SA – Tsinghua University	CN
THU-CE – Department of Chemical Engineering, Tsinghua University	CN
THU-DESS – Department of Earth System Science, Tsinghua University	CN
RUC – Renmin University of China	CN
SDU – Shandong University	CN
CHINACOAL – China National Coal Group Corporation	CN
BITARIM – Advanced Research Institute of Multidisciplinary Sciences, BIT	CN
FULONG – Inner Mongolia Fulong Heating Engineering Technology Co., LTD	CN
BIT-ME – School of Mechanical Engineering, Beijing Institute of Technology	CN

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1 Introduction

As part of the EU–China BRIDGE project, technology inventories have been developed to compile a set of near-zero greenhouse gas (GHG) emission technologies for steelmaking and petrochemical production. These industries are of central importance in the project, as they are energy-intensive with high GHG emissions and therefore play a key role in achieving climate neutrality in Europe and China. In addition, these sectors are important economic drivers whose transformation requires innovative technologies and effective industrial policies, which emphasises the project's focus on the joint development of knowledge bases, technologies and roadmaps in these areas.

The inventories provide detailed descriptive information on selected breakthrough technologies, including a technology overview, Technology Readiness Level (TRL), and current development status in both the EU and China. They also include quantitative technical data such as material and fuel inputs and outputs for each process, associated atmospheric CO_2 emissions or uptake, energy balances, and key economic parameters.

The joint creation of these technology inventories is intended to facilitate knowledge exchange between experts in the EU and China and to strengthen mutual understanding of the technological options and their potential to contribute to climate-neutral industrial transformation in both regions.

The inventories are made available as Deliverable 3.1 in the form of excel files. They will both be published and used internally to support the development of technology roadmaps for the European steel and chemical industries. The following supplementary report explains the procedure for preparing the inventories and provides additional information for a better understanding of the files provided.

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2 Methodology

2.1 Selection of technologies

A set of global breakthrough near-zero emission technologies was identified based on defined criteria, which are summarized below for both industries.

Chemical technology requirements (except reference technology):

- Compatibility with a net-zero chemical industry (i.e., efficiency improvements to conventional technologies not included, technologies that still have residual fossil emissions not included).
- Focus on the petrochemical value chain, relevant for polymer production (HVC production: ethylene, propylene, benzene, toluene, xylenes, butadiene). (i.e., not ammonia or other parts of the chemical sector, no specialty chemicals or other small-volume chemicals)
- Technologies more commonly mentioned in discussion, at relatively higher TRL. (No TRL limit was set, and since options are far more developed for olefins compared to aromatics, a lower development stage is accepted for aromatics production.)
- Large potential with regards to feedstock substitution (e.g. sugar routes not considered).

Steel technology requirements (except reference technology):

- Potential to significantly reduce CO_2 emissions compared to the conventional BF-BOF route in order to be compatible with a net-zero future and to roughly comply with future green steel standards. Technologies expected to be based mainly on unabated fossil fuel use not included.
- Additional consideration of technologies with slightly lower reduction potential - in case they play an important role in current decarbonisation strategies.
- Relatively high TRL indicating short- to medium term availability of the technology. Technologies in the phase of basic scientific research not considered.
- Current discussion and active development: The technology should not be at a standstill, but should be a topic in professional circles, be actively developed or implemented in practice. Public information regarding the technology should be available.

In addition, the suitability of these technologies for application in the EU and China was analysed. For the China-specific analysis, national policy documents, industry reports, and peer-reviewed journal articles were also taken into account.

In addition to the common set of breakthrough technologies, additional options tailored to national contexts were identified. For example, given that approximately 90% of steel production in China currently relies on the blast furnace–basic oxygen furnace (BF-BOF) route, the injection of hydrogen into blast furnaces has been identified as a potential emission reduction technology for steelmaking in China. However, coal (or other fossil based injection) can only be replaced by hydrogen in the blast furnace to a limited extent. The process can therefore contribute to a certain reduction in GHG emissions from the blast furnace route in the short term, but it does not fulfil the above-mentioned criterion of a very far-reaching reduction. It was therefore not considered in the technology selection for the creation of inventories.

The identified technologies were also presented at the EU-China stakeholder co-creation workshop held in China in October 2024 and subsequently validated during the stakeholder co-creation workshop in the EU in March 2025. The purpose of this approach was to provide an opportunity for feedback on the original technology selection and to monitor emerging discussions about other technologies that might need to be

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included in the analysis.

2.2 Structure of the Excel files provided

All inventories are structured as follows: For a defined route, all individual technology steps of this route are described in separate sheets. This makes it possible, for example, to describe the energy and material balance of individual process steps as well as process-specific challenges in detail and per related product of this technology. (For example, for a DRI plant, specific data are given per tonne of DRI and for EAF per tonne of crude steel - while process flow data for a Methanol synthesis are given per tonne methanol.) The technology sheets are in turn summarised in an additional sheet for the entire route. As an example, the H_2-DRI-EAF route for steel production consists of the technology sheets for the DRI shaft furnace and the EAF and an additional route sheet that summarises the data of the individual technologies for the entire route from the raw material input to the final product under consideration and additionally specifies, for example, challenges that arise for the implementation of the route as a whole.
Product-related cost data (ranges of estimated cost per t of product in 2030 and 2050) have only been calculated for entire process routes, not for individual technologies contained within these routes.

The inventories cover the following items and parameters:

- Both technology & route sheets:
  - Basic description and process flowchart
  - Critical scaling potentials and challenges
  - Material and fuel inputs and outputs
  - Atmospheric CO_2 emissions or uptake
  - Energetic inputs and outputs (Electricity & heat)
- Technology sheets only:
  - TRL and expected readiness year
  - Existing pilots and projects
  - Economic parameters (Depreciation period, Capex/Opex)
- Route sheets only:
  - Technologies included
  - Required conditions for implementation
  - Advantages compared to other routes
  - Cost range per t of product 2030 / 2050
  - CO_2 mitigation cost range compared to conventional reference route
  - CO_2 mitigation potential

In addition, exogenous price assumptions for relevant products such as coking coal, hydrogen, electricity and biomass were defined for both sectors, taking into account price ranges for the years 2030 and 2050.

2.3 Technologies identified for the inventories

For **steelmaking**, inventories have been created for the following routes and technologies for crude steel (cs), not including steel finishing:

- Conventional Blast Furnace-Basic Oxygen Furnace (BF-BOF, reference route)
- Conventional Blast Furnace-Basic Oxygen Furnace (BF-BOF) Retrofit with Carbon Capture and Storage (CCS) – BF-BOF_CCS
- Direct reduced iron (DRI) using hydrogen (H_2-DRI) or natural gas (NG-DRI)

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- 1) Steelmaking by DRI melting in a downstream electric arc furnace – DRI-EAF
- 2) Further reduction and combined smelting of DRI in an electric smelting furnace (ESF) and subsequent steelmaking in BOF – DRI-ESF-BOF
- NG-DRI-EAF combined with CCS

- Direct electrification of steelmaking through iron electrolysis processes:
  - Low temperature electrowinning (alkaline iron electrolysis) – AEL-EAF
  - High temperature molten oxide electrolysis – MOE
- Secondary steel production in the EAF – scrap-EAF

For high value **chemicals**, inventories have been created for the following routes and technologies:

- Technologies:
  - 1. Steam cracking - conventional naphtha
  - 2. Pyrolysis of plastic waste
  - 3. Steam cracking - pyrolysis oil
  - 4. Direct Air Capture (DAC)
  - 5. Fischer-Tropsch products from concentrated CO_2
  - 6. Steam cracking - FT-naphtha
  - 7. Gasification of plastic waste - fluidized bed
  - 8. Biomass gasification - fluidized bed
  - 9. Biomass gasification - bioliq concept
  - 10. Methanol synthesis from syngas
  - 11. Methanol production from concentrated CO_2
  - 12. Methanol-to-Olefins (MTO)
  - 13. Methanol-to-Aromatics (MTA)
  - 14. Carbon Capture and Storage (CCS)
- Routes:
  - Conventional steam cracking of fossil naphtha (reference route)
    - Consists of technologies: 1
  - Steam cracking of waste-based pyrolysis oil
    - Consists of technologies: 2, 3
  - Steam cracking of CO_2-based FT-naphtha
    - Consists of technologies: 4, 5, 6
  - Olefin production from waste-based methanol
    - Consists of technologies: 7, 10, 12
  - Olefin production from biomass-based methanol
    - Consists of technologies: 8, 10, 12
    - Fluidized bed gasification (technology 8) is assumed in the route calculations due to lower estimated costs, but entrained flow gasification on pre-processed biomass (such as in technology 9) is a potential alternative
  - Olefin production from CO_2-based methanol
    - Consists of technologies: 4, 11, 12
  - Aromatics production from waste-based methanol
    - Consists of technologies: 7, 10, 13
  - Aromatics production from biomass-based methanol
    - Consists of technologies: 8, 10, 13

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    - Fluidized bed gasification (technology 8) is assumed in the route calculations due to lower estimated costs, but entrained flow gasification on pre-processed biomass (such as in technology 9) is a potential alternative
- Aromatics production from CO_2-based methanol
    - Consists of technologies: 4, 11, 13
- Additionally, CCS technology (number 14) is an optional addition to all routes, including the reference route.

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3 Outlook

3.1 Anticipated inventory updates

The data has been compiled to the best of our knowledge (as of April 2025).
However, it is possible that findings from the further course of the project may result in a need for updates. This is particularly true for the definition of exogenous price assumptions, which are not only used for the evaluation of technologies (completed for the current deliverable), but also for the creation of roadmaps, which takes place later in the project and has not yet been started as of April 2025.

Price assumptions for energy and material depend heavily on the sources used, the respective world region, the target year and the underlying framework data on economic development. To provide meaningful route inventories and especially complete production costs for the routes analysed, we defined preliminary price data. These reflect prices in target years 2030 and 2050.

Therefore, as work on parts of the project relating to the inventories will continue until 2026, we are reserving the option of making adjustments to the inventories as the project progresses. Apart from price assumptions, this also applies to process data that might become publicly available as technology development and research advances.

3.2 Planned public presentation of results

Following the submission of the deliverable and in cooperation with the project partner HOLISTIC, the inventories will be made publicly available in May 2025 in different ways:

- The inventories (Excel files) will be centrally hosted on **Zenodo**. Here, the datasets are given a DOI that remains unchanged even in case of updates at a later stage of the project. The hosted files will be available here: https://zenodo.org/communities/eu-china-bridge/
- Via the Zenodo DOI, the inventories will be linked on the **EU-China BRIDGE website**.
- The technology data from the inventories will be uploaded to an interactive interface on the platform **I2AMParis**. This open-source platform facilitates sharing documentation as well as in- and outputs of different modelling tools related to the exploration of decarbonisation pathways. In this way, we enable easier access to our results and enhance transparency and collaboration within the climate and energy modeling community. The interactive interface on I2AMParis will allow users to select, filter and compare the technologies analysed in a user-friendly way. Furthermore, in parallel to the project website, the original inventories (Excel files) will also be linked here via the Zenodo DOI mentioned above.
  All inventory data on I2AMParis will be accessible via the following link: https://iamparis.eu/datastories/tech_inventories

3.3 Further use of inventories within BRIDGE

Within the BRIDGE project, quantitative data acquired or updated for the inventories will foremost be used for the techno-economic modelling in WP3.5 and 3.6. The inventories will further form the basis for discussion aimed at better integration of EII breakthrough technologies in Integrated Assessment Models (WP 5 and 6).

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