气候创新实验室

Impact Hub Shanghai

Climate Tech Study

A Mapping of Assessment Frameworks and Evaluation of Stakeholder Needs

Content

Background

According to a report by International Energy Agency (IEA), most CO_2 emission reductions by 2030 will come from technologies currently available on the market. However, by 2050, nearly half of the required reductions will depend on technologies that are still in the demonstration or prototype stages today. This underscores the urgent need for governments to increase R&D investment, reprioritize innovation strategies, and invest in the demonstration and deployment of clean energy technologies, making these efforts a central part of national energy and climate policies. For China, the timeline to achieve carbon neutrality is short, and the current technological reserves are insufficient. Therefore, it is crucial to accelerate climate technology innovation and advance the research, development, and demonstration of low-carbon, zero-carbon, and negative-carbon technologies to provide robust scientific support for meeting the country's carbon peaking and neutrality goals.

However, the path to commercialization for climate tech startups, particularly those in hardware and deep tech, tends to be more arduous and extended than for startups in other sector. The think tank RMI highlights that climate tech ventures require a higher degree of technological expertise, business acumen, and policy understanding. Established market players demonstrate significant resistance to change, and the capital requirements are significantly higher. Elemental Impact, formerly known as Elemental Excelerator, an impact investment organization that focuses on scaling early-stage climate technologies, also points out that the real challenge for these startups extends beyond technological development; it lies in executing pilot projects, achieving industrial applications, and ultimately scaling up climate solutions.

Recognizing the critical role of innovative climate technologies in achieving climate targets, Impact Hub Shanghai (hereinafter referred to as "Hub Shanghai"), as part of a global network committed to fostering sustainable innovation, established the 1.5DO Climate Innovation Lab in 2022. The Lab focuses on advancing systemic innovation that aligns with climate objectives by enhancing existing processes to better support entrepreneurship and industry collaboration. It continuously identifies, promotes, and implements climate tech startups, facilitating low-carbon transitions and green economic growth across diverse sectors and regions.

Based on our research and work, we find that the challenges faced by climate technology entrepreneurs often ultimately boil down to one key issue: how to demonstrate the potential of their technologies to relevant stakeholders - whether it's their carbon reduction potential or commercial viability. This is crucial in order to attract and secure more funding, talent, and business opportunities based on the results of technology assessments. Our previous work has repeatedly revealed such challenges, as illustrated by the following examples:

Case 1

When Innovative Technology Company A participated in the open innovation program of Fortune 500 Company B, it initially gained recognition from B's domestic innovation center team and was introduced to colleagues responsible for R&D and investment for further technical and economic feasibility assessments. This process extended over several months, during which Company A had to continuously provide various supporting documents. Later, when the domestic innovation center considered recommending Company A to B's overseas headquarters, the headquarters required even more certification documents, including some necessitating paid third-party assessments. While these demands and procedures were legitimate, they posed additional costs and risks for Company A, ultimately causing it to miss the opportunity to collaborate successfully with B's headquarters.

Case 2

Innovative Technology Company C developed a product with potential applications across multiple industries. However, when attempting to engage potential customers, C encountered a significant challenge: the key performance metrics valued by each customer varied greatly, even among those within the same industry. This inconsistency added substantial complexity to C's business development efforts.

Conversely, we have observed partners who, with a clear mandate to support innovative technologies, have assembled robust teams comprising technical scientists, industry experts, and investment specialists. These teams work together to evaluate, cross-verify, and score technologies through a comprehensive framework and scoring system. This approach has enabled them to identify the most promising projects and align these with the right industry needs for pilot collaborations, setting a positive benchmark for the industry.

While scenarios like those in Cases 1 and 2 do not always result in failure, the successful practices highlighted require substantial resources and time, making them difficult to replicate directly across different stakeholders. Given these challenges, case studies and discussions with stakeholders have increasingly emphasized the importance and necessity of developing a widely recognized and applicable assessment system for innovative technologies. Such a system is crucial not only for our work but also for advancing climate technology innovation and supporting the achievement of the 'dual carbon' goals.

To inform our approach, we undertook a detailed analysis of publicly available technology assessment frameworks, both domestic and international, systematically categorizing them by their evaluation objectives and methodologies. Through a statistical breakdown, we examined the dimensions, metrics, and measurement methods these systems employ, identifying notable gaps between existing frameworks and the needs of various stakeholders. To bridge these gaps and provide valuable insights for future framework design, we engaged with stakeholders facing practical challenges in technology assessment. The insights gathered from these conversations aim to serve as a valuable reference for developing more aligned and impactful frameworks. The following sections outline our observations and reflections in detail.

The technology assessment system serves as a crucial bridge for governments, industrial parks, enterprises, and financial institutions to gain a comprehensive understanding of innovative technologies. Its development requires extensive dialogue and collaboration among various stakeholders, which also facilitates the broader application and iterative improvement of the assessment system. With this report, we aim to gradually establish a more open and dynamic communication mechanism for technology assessment within the climate innovation ecosystem. This will enhance the efficiency of 'open innovation' collaboration among enterprises, accelerate the large-scale deployment of climate technology solutions, and ultimately contribute to green economic development and the achievement of carbon peaking and neutrality goals.

Observation on the Current Status of Innovative Technology Assessment Systems

Table 2-1 The list of the 18 technology assessment systems reviewed

Name of Technology Assessment System	Abbreviation	Issuing Entity	Nation	Year of Issue
Directives for Technology Readiness Assessment of Tidal Current Energy Generators	Tidal Current Energy Generators Assessment	State Administration for Market Regulation(SAMR) Standardization Administration of China(SAC)	PRC	2023
Assessment of Emission Reduction Potential and Environmental Impact of Low-Carbon Technologies in the Glass Industry	Technologies Assessment in the Glass Industry	China Building Materials Academy Co., Ltd.	PRC	2023
Assessment Guidelines for Green Technology	/	China Association for Standardization(CAS)	PRC	2022
Guidance for Economic Value Evaluation for Science and Technology Achievements	Economic Valuation Assessment Guidelines	State Administration for Market Regulation(SAMR) Standardization Administration of China(SAC)	PRC	2021
Specifications for Science and Technology Achievements Evaluation	/	China Association of Science and Technology Evaluation and Management of Scientific and Technical Achievement(CASTEM)	PRC	2020
Classification and Definition of the Technology Readiness Levels for New Materials	Technology Readiness Levels for New Materials	State Administration for Market Regulation(SAMR) Standardization Administration of China(SAC)	PRC	2018
Assessment Index System and Method for Energy Saving and Emission Reduction Technologies in Industry	Energy Saving and Emission Reduction Technologies Assessment	Ministry of Industry and Information Technology(MIIT)	PRC	2012
Implementation Details for Post-Assessment of Desulfurization Process Technology for Sintering Exhaust in the Steel Industry	Post-Assessment of Desulfurization Process Technology	Ministry of Industry and Information Technology(MIIT)	PRC	2010
Commercial Adoption Readiness Assessment Tool	CARAT	U.S. Department of Energy	U.S.A.	2023
Extracting CO_2 from the Air: Carbon Capture and Storage	Carbon Capture and Storage Technologies Assessment	Foundation for Technology Assessment (TA-SWISS)	Switzerland	2023
Climate Impact Metrics	/	Net Zero Insights	Portugal	2022
Innovation Impact Assessment	/	Evolved Energy Research(EER) Environmental Defense Fund(EDF)	U.S.A.	2021
Steel Decarbonization Technology Assessment	/	Rocky Mountain Institute (RMI)	U.S.A.	2021
Technology Readiness Level Scale	/	International Energy Agency (IEA)	International	2020
Carbon Reduction Assessment for New Enterprises	CRANE	Prime Coalition Rho Impact	U.S.A.	2020
Technology Readiness Assessment	TRA	U.S. Department of Energy	U.S.A.	2015
Version2 of the Global Greenhouse Gas Abatement Cost Curve	Global GHG Abatement Cost Curve v2.0	McKinsey & Company	U.S.A.	2010
Life Cycle Assessment	LCA[1]	International Organization for Standardization (ISO)	International	2006

1 The LCA primarily references ISO 14040 and ISO 14044, both published in 2006. For dimension and indicator analysis, tools like OpenLCA will be considered as key references.

We focus on assessment systems that are centered on technology as the evaluation object (or whose frameworks can be applied to technology evaluation), have a clearly identifiable indicator structure, and have been publicly released. At the same time, considering practical application needs, we emphasize assessment systems specifically targeting climate technologies. Through an incomplete review of publicly accessible sources such as standards platforms, official websites, and reports, 18 relevant assessment systems were identified globally.

Throughout our research and communication with stakeholders, we found that government agencies, enterprises, universities, and financial institutions often develop their own technology assessment systems tailored to their specific needs (e.g., for technology demonstrations or investment decisions). However, as these indicator structures are not publicly disclosed, they were excluded from our analysis.

In this chapter, we will examine these assessment systems by analyzing their stakeholders, objectives, methods, dimensions, and indicator characteristics. Above is a list of the 18 technology assessment systems reviewed, which will be referenced by their abbreviations throughout the following sections.

2.1 Assessment System Overview

Innovative technology assessment is a multifaceted process that involves evaluating new technologies from various angles, engaging multiple stakeholders across several dimensions. This section distills key insights from the 18 assessment systems examined, highlighting who is involved, the rationale behind assessing these technologies, and the methodologies employed.

2.1.1 Stakeholder Involvement in Assessments

The stakeholders involved in the assessment can be categorized into 2 groups: those responsible for publishing the assessment systems and their target audiences. The former primarily facilitates assessment activities to promote technological advancement and industry development, while the latter includes users who are the intended beneficiaries of these systems.

In the 18 surveyed samples, the issuing entities primarily consist of government agencies, standardization organizations, enterprises, non-profit organizations, research institutions, and think tanks. Meanwhile, the target audiences primarily include researchers from academic institutions, businesses in relevant industries, investors, policymakers, and third-party assessment organizations. Additionally, some assessment systems extend their reach to the general public as their target audience.

Table 2-2 Classification of issuing entities

Region Type	Issuing Entity Type	Number of Assessment Systems
International	Intergovernmental Organization	1
	Standardization Organization	1
China-based	Government	2
	Academic Association	1
	Standardization Organization	2
	Research Institute	1
Foreign/National	Government	1
	Non-Profit Organization/Platform	2
	Think Tank	2
	Consulting Firm	3

International Entities

Intergovernmental Organization

International Energy Agency (IEA)[2], an intergovernmental organization focused on the energy sector, has developed the **Technology Readiness Level Scale**. This assessment system is primarily designed to evaluate the maturity of energy technologies in terms of development and market adoption.

Standardization Organizations

International Organization for Standardization (ISO)[3] published ISO 14040 and ISO 14044 in 2006, establishing crucial guidelines for **Life Cycle Assessment (LCA)**. These standards standardize LCA methodologies, enabling consistent and comparable evaluations of the environmental impacts of products, processes, services, and technologies across their entire life cycle, from resource extraction to disposal and recycling.

China-based Entities

Government

State Administration for Market Regulation[4], in collaboration with Standardization Administration of China, has issued 3 assessment systems: **Tidal Current Energy Generators Assessment**, **Technology Readiness Levels for New Materials**, and **Economic Valuation Assessment Guidelines**. These systems take technological achievements in tidal energy generation systems, new materials, and mature markets, respectively, as their assessment targets. Of these, only the **Economic Valuation Assessment Guidelines** explicitly identifies its target audience, which includes independent research institutes, universities, enterprises, or individuals. While the other two systems do not specify their target audiences, it is plausible that R&D teams, and technology end-users are the primary audiences.

Ministry of Industry and Information Technology[5] has issued 2 assessment systems: **Post-Assessment of Desulfurization Process Technology** and **Energy Saving and Emission Reduction Technologies Assessment**. The former focuses on the assessment of sinter flue gas desulfurization technologies in the steel industry, while the latter evaluates energy-saving and emission reduction technologies across 4 major industrial sectors: production process optimization, resource and energy recovery, pollution control, and product energy efficiency. For the **Post-Assessment of Desulfurization Process Technology**, the primary target audiences includes government agencies, providers of sinter desulfurization process technologies, and enterprises utilizing such technologies in their projects.

2 The International Energy Agency (IEA), established in 1974, serves as a central platform for global energy dialogue. It provides authoritative analysis, data, policy recommendations, and practical solutions to help countries deliver secure and sustainable energy for all.

3 The International Organization for Standardization (ISO), established in 1947, is an independent, non-governmental international body dedicated to developing global industrial and commercial standards. Through its efforts, ISO aims to facilitate international trade, enhance product quality and safety, improve efficiency, and promote technological compatibility across borders.

4 The State Administration for Market Regulation (SAMR) is a ministerial-level agency under the State Council of the People's Republic of China responsible for comprehensive market supervision and management.

5 The Ministry of Industry and Information Technology of the People's Republic of China (MIIT) is a department under the State Council responsible for overseeing the industrial and information sectors. Its main duties include formulating and implementing industry plans, policies, and standards; monitoring daily operations in the industrial sector; promoting the development of major technological equipment and independent innovation; managing the telecommunications industry; guiding information construction efforts; and coordinating national information security.

Academic Association

China Association of Science and Technology Evaluation and Management of Scientific and Technical Achievement[6], an organization at the national level supervised by the Ministry of Science and Technology. The **Specifications for Science and Technology Achievements Evaluation** it issued take scientific and technological achievements, defined as practical outcomes derived from scientific research and technological development, as assessment targets. Meanwhile, the **Specifications for Science and Technology Achievements Evaluation** is primarily intended for the third-party evaluation agencies and the owners of such achievements, who are identified as the key users of it.

Standardization Organization

(Association) **China Association for Standardization**[7] has released **Assessment Guidelines for Green Technology**, which are designed for assessing green technologies that deliver economic, ecological, and social benefits. The system is intended for users on both the demand side of green technology assessments and third-party evaluators—specifically, professional organizations registered with the Green Technology Bank that conduct independent evaluations in line with these standards. Additionally, financial institutions and investment entities are identified as potential users of the assessment outcomes, leveraging the results as references for investment and financing decisions.

(Public Institution) **Standardization Administration of China**[8], in collaboration with the State Administration for Market Regulation, has jointly issued 3 assessment systems, as outlined in the "Government" category above.

Research Institute

China Building Materials Academy Co., Ltd.[9] has published the **Technologies Assessment in the Glass Industry**, which assesses 5 typical low-carbon collaborative governance technologies within the flat glass industry. This assessment system primarily targets glass manufacturing enterprises, offering authoritative guidance to support the comprehensive reduction of greenhouse gas emissions.

6 The China Association of Science and Technology Evaluation and Management of Scientific and Technical Achievement is a national-level social organization dedicated to promoting the transformation of scientific and technological achievements and advancing the construction of an innovative nation.

7 The China Association for Standardization was established in 1978. It is a national legal entity composed of organizations and individuals voluntarily engaged in standardization work. It unites and organizes standardization practitioners across the country, conducts academic exchanges in standardization, develops standards, promotes awareness, provides consulting services, and facilitates international exchanges, with the aim of supporting China's economic and social development.

8 The Standardization Administration of China is a public Institution directly under the State Council, responsible for the management and supervision of national standardization efforts.

9 China Building Materials Academy Co., Ltd. is a prominent national research institution in China specializing in inorganic non-metallic materials. It has secured over 4,000 patents across seven key research domains, including critical materials for integrated circuits, low-carbon building materials, and new energy materials and equipment. This positions it as a significant strategic research institute for industrial advancements in the country.

Foreign Entities

Government

The **U.S. Department of Energy**[10] has developed 2 assessment systems: TRA and CARAT. Initially developed for project funding evaluations, TRA was initially aimed at individual project teams. With global adoption, TRA's user base has expanded to encompass investment institutions, industrial enterprises, innovative technology companies, and government agencies. In contrast, CARAT focuses on evaluating core commercial risks for technologies with market viability, targeting researchers, investors, and project managers engaged in technology risk management and oversight.

Non-Profit Organization/ Platform

The Environmental Defense Fund[11] commissioned Evolved Energy Research to develop an **Innovation Impact Assessment** which evaluates 15 categories of technologies in the energy sector. This assessment primarily targets U.S. policymakers, decision-makers, and other stakeholders.

Prime Coalition[12] has developed **CRANE**, a computational tool tailored to estimate the carbon reduction potential of diverse investment technologies. Designed to serve a broad spectrum of stakeholders — including early-stage investors, incubators, accelerators, government agencies, large corporations, and philanthropists — CRANE currently evaluates 247 technology types across 6 key industries: agriculture, construction, energy, manufacturing, transportation, and carbon removal.

Think Tank

TA-SWISS[13] has published a report titled **Extracting CO_2 from the air: carbon capture and storage**, which assesses five key categories of carbon capture and storage (CCS) technologies. This assessment is primarily directed toward policymakers and the general public.

Rocky Mountain Institute[14] has utilized the **Steel Decarbonization Technology Assessment** in their report titled *Pursuing Zero-Carbon Steel in China*, which assesses technologies aimed at transforming traditional long production processes and developing short production process technologies in the steel industry. The core target audience for this assessment includes relevant government agencies and steel companies.

10 The United States Department of Energy (DOE) is the federal executive agency responsible for formulating energy policies, managing the energy sector, and overseeing the research and development of energy-related technologies, including nuclear power and weapons programs.

11 The Environmental Defense Fund (EDF) is an international non-profit organization dedicated to environmental protection. EDF focuses on various areas, including climate, energy, ecosystems, health, and ocean, committed to providing innovative solutions to reduce climate pollutants.

12 Prime Coalition is a non-profit organization founded in 2014, dedicated to unlocking catalytic capital and transforming the future of climate financing. Each project undertaken by Prime Coalition aims to promote, deepen, or accelerate solutions that can significantly reduce greenhouse gas emissions.

13 TA-SWISS is a foundation entirely funded by public resources. It was established to research the opportunities and risks associated with new technologies, aiming to provide policymakers and the public with practical recommendations that include future action guidelines.

14 Rocky Mountain Institute (RMI) is a think tank founded in 1982. It has established strong collaborations with businesses, policymakers, communities, and NGOs to identify and scale innovative energy solutions.

Consulting Firm

McKinsey & Company[15] has published a report titled **Version 2 of the Global Greenhouse Gas Abatement Cost Curve**, which assesses clean technologies across 10 industries in 21 regions, providing data on various industry technologies for enterprises, scholars, and policymakers.

(Intelligence Platform) **Net Zero Insights**[16] has developed the **Climate Impact Metrics**, targeting policymakers, businesses, and investors. This Metrics focuses on measuring the environmental impact potential of various solar technologies.

Evolved Energy Research[17] has developed the Impact Innovation Assessment, as outlined in the "Non-Profit Organization/ Platform" category above.

15 McKinsey & Company is a management consulting firm known for advising senior executives in both corporations and government.

16 Net Zero Insights, established in 2020, is a prominent market intelligence platform dedicated to climate innovation, serving leading investors, corporations, and research institutions. The company offers critical climate technology data, insights, and research through its climate technology database and market research reports, empowering leaders to drive capital flows toward sustainable initiatives.

17 Evolved Energy Research (EER) is a research and consulting firm focused on questions posed by transformation of the energy economy. Their consulting work and insight, supported by technical analyses of energy systems, are designed to support strategic decision-making for policymakers, stakeholders, utilities, investors, and technology companies.

2.1.2 Assessment Objectives

Various assessment systems demonstrate distinct perspectives and goals in assessing innovative technologies. Chinese assessment system documents tend to adhere to standardized and simple style, primarily focusing on technology screening to advance industry development. In contrast, international and foreign assessment systems often prioritize objectives related to addressing climate change.

Table 2-3 Classification of assessment objectives

Assessment Objectives	Number
Promote technology commercialization	3
Identify opportunities for technology optimization	2
Provide basis for technology investment	3
Provide basis for policy formulation	4
Promote industry development	7
Guide national climate strategy	1

Objective 1: Promote technology commercialization

Comprehensive

The **TRA** is widely recognized for its comprehensive system assessing technology readiness across nine levels. It supports DOE Program Offices in determining which technologies meet commercialization criteria or have commercial potential. **CARAT** underscores the importance for research and development efforts from entities like labs, academia, and companies to align with end-user market needs. As such, it focuses on assessing the commercialization risks of technologies, aiming to enhance the commercial viability of laboratory technologies.

Energy Sector

Given the critical importance of scalability in achieving energy policy objectives, IEA believes that the 9 stages of TRL are insufficient to adequately represent the maturity of energy technologies. To bridge this gap, IEA extended the traditional TRL with 2 additional levels, focusing on commercial viability and competitiveness. This expanded **Technology Readiness Level Scale** offers a more comprehensive assessment of a technology's potential for market scalability within the energy sector.

Objective 2: Identify opportunities for technology optimization

In addition to identifying technologies with commercialization potential, **TRA** also helps uncover associated risks, enabling performance optimization to meet established standards. Similarly, **LCA** identifies opportunities for improvement throughout a technology's life cycle, aiming to enhance its environmental impact performance.

Objective 3: Provide basis for technology investment

CRANE provides data on the climate impact potential of technologies to early-stage investors, incubators, accelerators, government agencies, and large enterprises, supporting stakeholders in making well-informed investment decisions. The **Assessment Guidelines for Green Technology** and the **Specifications for Science and Technology Achievements Evaluation** also highlight that the assessment result can serve as the basis for financial or investment institutions to develop preferential policies or conduct the due diligence process.

Objective 4: Provide basis for policy formulation

Global GHG Abatement Cost Curve v2.0 provides policymakers and researchers with a unified quantitative basis for evaluating the emissions reduction potential of various industrial technologies, supporting informed discussions and policy decisions on reduction actions and targets. **Innovation Impact Assessment** offers a comprehensive reference for government R&D funding strategies in the energy sector. **Assessment Guidelines for Green Technology** align with national industrial and technology policies, aiming to provide comprehensive guidance for the formulation of green technology assessment standards. Additionally, **LCA** not only identifies opportunities for technology optimization, but provides a scientific basis for government and other organizations to shape environmental policies and strategic decisions.

Objective 5: Promote industry development

Chinese assessment systems tend to have policy-oriented objectives, aiming to identify and promote technologies that support industry development. For example, **Energy Saving and Emission Reduction Technologies Assessment** focuses on advancing energy conservation and emissions reduction technologies, encouraging their adoption to drive industrial transformation and upgrading. **Specifications for Science and Technology Achievements Evaluation** primarily serves as a reference for selecting and transacting technologies during the transfer and commercialization of scientific achievements. **Post-Assessment of Desulfurization Process Technology** evaluates desulfurization technologies used in sintering flue gas units that have passed environmental inspections, accelerating the deployment of desulfurization projects in the steel industry. **Technologies Assessment in the Glass Industry** addresses gaps in assessing low-carbon technologies in the glass sector, providing guidance for producers to enhance greenhouse gas control and foster low-carbon development. **Tidal Current Energy Generators Assessment** aims to advance the industrialization of tidal power technologies, emphasizing improvements in reliability and stability.

Foreign assessment systems often embed low-carbon objectives within their frameworks: **Steel Decarbonization Technology Assessment** centers on the future low-carbon transformation and techno-economic development of China's steel industry. **Climate**

Impact Metrics, on the other hand, assesses the environmental potential of climate technology startups, beginning with solar energy ventures, with the goal of advancing net-zero emissions targets.

Objective 6: Guide national climate strategy

Carbon Capture and Storage Technologies Assessment aims to raise public and governmental awareness on negative emissions technologies, fostering dialogue to elevate their role within Switzerland's climate strategy.

2.1.3 Assessment Methods

Assessment methods refer to the specific approaches outlined in the documentation for assessing innovative technologies. The level of detail provided across different assessment system varies significantly. 6 systems offer relatively comprehensive methodologies, presenting a well-structured framework for assessment. 8 systems, however, provide only a general description, defining the use of certain methods without detailed guidance on their application. The remaining 4 systems mention only the assessment dimensions, without specifying the methods employed, and are therefore not elaborated upon in this section.

Comprehensive methodologies offered by six assessment systems

Assessment system 1: Global GHG Abatement Cost Curve v2.0

The **Global GHG Abatement Cost Curve v2.0** aims to establish a unified quantitative basis for assessing technologies across industries. It approaches assessment from a macro-regional perspective, with a minimum focus at the national level. The selection of technologies is based on a boundary standard of €60/tCO_2 from the EU carbon market. In terms of data sources, sector-specific emissions trends are based on industry standards and corporate disclosures—for instance, emissions data for the oil and gas sector are drawn from IEA, the United Nations Framework Convention on Climate Change (UNFCCC), the International Association of Oil & Gas Producers, and the Carbon Disclosure Project. Furthermore, the model incorporates dynamic factors such as opportunity costs and learning costs, which evolve over time, enhancing the scientific robustness of the assessment system.

Assessment system 2: Energy Saving and Emission Reduction Technologies Assessment

The **Energy Saving and Emission Reduction Technologies Assessment** provides a comprehensive methodology for selecting and assessing energy conservation and emission reduction technologies, tailored to the industry's complexity. It includes detailed processes from indicator determination and technology inventory selection to technical surveys and assessments. To meet diverse sub-industry assessment needs, the assessment system offers four distinct methodologies:

- **Multi-criteria comprehensive assessment**, integrating dimensions reflecting energy efficiency and overall environmental impact through mathematical modeling or algorithms.
- **Life Cycle Assessment**, evaluating energy conservation and emission reduction based on seven "Twelfth Five-Year Plan" mandatory indicators generated during product lifecycle processes, using the Energy Conservation and Emission Reduction Assessment Method (ECER)[18]
- **Cost-benefit/effectiveness analysis**, assessing the economic feasibility of solutions by calculating the costs and benefits of clean technologies.
- **Expert-assisted comprehensive assessment**, facilitating rapid parallel comparisons of energy conservation and emission reduction technologies.

Assessment system 3: TRA

The **TRA** is designed to identify technology risks and optimize technologies to achieve the desired maturity. It follows a three-step process model:

- **Identification of Critical Technology Elements (CTE):** This step involves identifying high-risk technologies that are essential for the successful operation of a system or facility.
- **Assessment of Technology Readiness Levels (TRL):** Technologies are assessed using the TRL scale, with assessments conducted in relevant environments. The tested technologies must align with appropriate scale and fidelity requirements to ensure realistic maturity evaluation.
- **Development of a Technology Maturation Plan (TMP):** Conducting further evaluation if CTEs do not meet the expected TRLs at critical decision points.

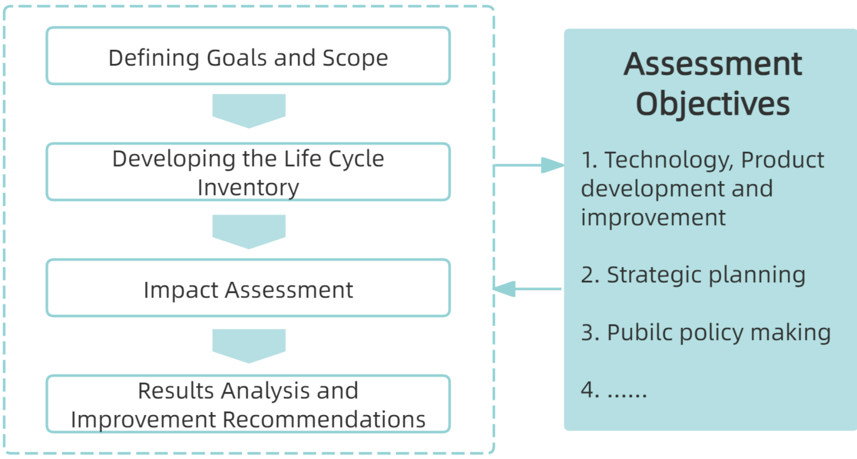
18 The Energy Conservation and Emission Reduction assessment (ECER), is a lifecycle energy-saving and emission reduction evaluation method proposed by institutions such as Sichuan University, Tsinghua University, and Chengdu IKE Co.. This method is based on the LCA framework and focuses solely on analyzing environmental indicators.

Assessment system 4: LCA

LCA serves as a critical framework for evaluating environmental impacts, with a complex and rigorous methodology typically involving the following steps:

- **Defining Goals and Scope:** Establish the purpose and intended use of the assessment, while specifying the system boundaries, functional units, assumptions, and limitations.
- **Developing the Life Cycle Inventory (LCI):** Collect data on all relevant inputs (e.g., raw materials, energy) and outputs (e.g., emissions, waste) within the defined scope. This process results in a comprehensive inventory of data for each stage of the product's life cycle.
- **Impact Assessment:** Assign collected data to various environmental impact categories (such as global warming potential, acidification, toxicity). Using characterization factors, convert the raw inventory data into quantified environmental impact metrics.
- **Results Analysis and Improvement Recommendations:** Analyze the outcomes to identify environmental hotspots and propose actionable recommendations for improvement.

Figure 2-1 The assessment step and application directions of LCA



LCA provides a systematic approach for evaluators to assess environmental impacts. The diagram only illustrates the assessment steps and application directions outlined in ISO 14040 published in 2006.

(Source: ISO)

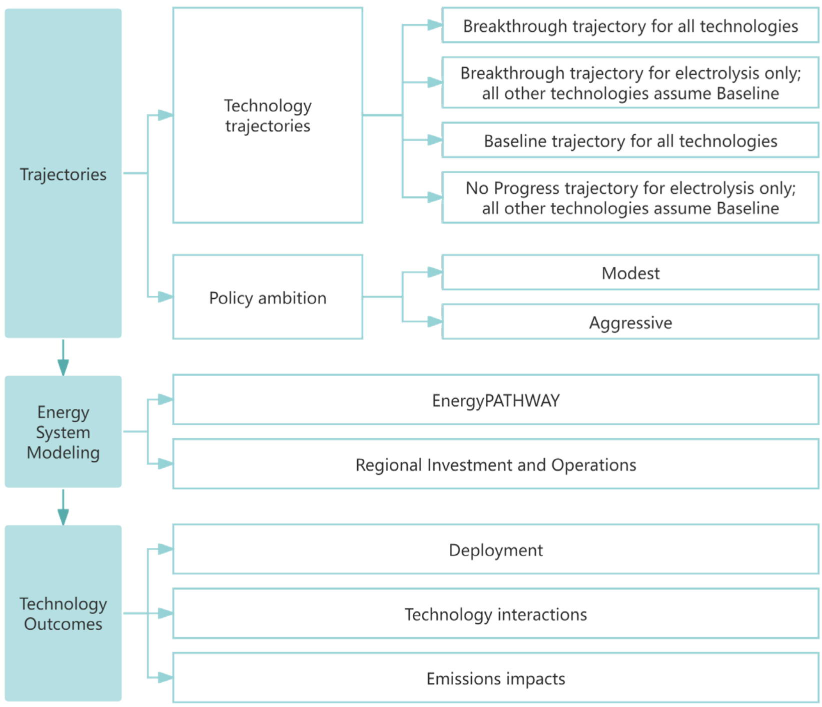
Assessment system 5: CARAT

CARAT emphasizes that effective technology management for achieving commercialization requires addressing not only the technical risks identified by TRA but also risks tied to market adoption. It offers a qualitative, fact-based assessments across 17 risk indicators within 4 key risk domains, focusing on cost variance, application feasibility, and market acceptance. Risk levels are defined using qualitative criteria, and a risk matrix aggregates the number of medium- and high-risk indicators, providing a clear snapshot of the technology's commercial readiness.

Assessment system 6: Innovation Impact Assessment

Innovation Impact Assessment aims to assist governments in prioritizing R&D funding within the energy sector to drive deep economic decarbonization. It selects 15 promising decarbonization technologies and simulates their performance across predefined scenarios. For each technology, it evaluates deployment scale and investment cost trends through 2050 while modeling the interdependencies between technologies at various deployment levels. The assessment results provide policymakers with data-driven insights to formulate optimal R&D funding strategies.

Figure 2-2 The assessment process in the Innovation Impact Assessment



The Innovation Impact Assessment provides evaluation results on the deployment scale, investment cost trends, and interdependencies of various technological pathways within the energy sector. The figure illustrates the assessment's scenario design and the workflow for model application.

(Source: EER & EDF)

Brief descriptions of methods provided by eight assessment systems

In the domestic systems, both the **Tidal Current Energy Generators Assessment** and the **Technology Readiness Levels for New Materials** adopt TRL as their assessment foundation, offering qualitative descriptions for each level's criteria. The **Assessment Guidelines for Green Technology** defines 5 assessment methods, allowing for tailored selection based on specific needs. These include standard comparison, analogical analysis, expert judgment, empirical assessment, and user feedback. The **Economic Valuation Assessment Guidelines** outline 3 economic analysis approaches—yield, market, and cost methods — to assess the economic value of technological achievements, detailing the procedural steps and key factors to consider. The **Technologies Assessment in the Glass Industry** employs hierarchical analysis to score indicators, adjusting their weights through sensitivity analysis based on assessment priorities, ensuring the outcomes align closely with decision-making objectives.

In international systems, **Climate Impact Metrics** assesses the environmental impact potential of solar technologies, using data from approximately 1,000 solar startups. The IEA's **Technology Readiness Level Scale** extends TRL to 11 levels, reflecting the energy sector's focus on deployment scale and offering a finer assessment of technological maturity. **CRANE** modularizes its technology database and incorporates modeling tool to forecast global technological trajectories by adjusting key parameters.

Through an analysis of the 18 assessment systems, focusing on stakeholders, evaluation purposes, and methods, we found that the primary audiences for the assessments include researchers from academic institutions, industry professionals, investors, and policymakers. In terms of assessment entities, Chinese frameworks are mainly developed by government departments, whereas foreign non-governmental organizations are more active in the development of evaluation systems. Regarding evaluation purposes, foreign frameworks often articulate their objectives in relation to climate issues, while Chinese frameworks tend to have a more policy-oriented focus. Concerning assessment methods, only 6 frameworks provide a detailed assessment method structure, while most offer only brief descriptions of their methodologies.

2.2

Analysis of Dimensions and Indicators

Table 2-4 Classification of the 18 assessment systems reviewed

Name of Technology Assessment System	Classification by Level of Comprehensiveness	Is it a Climate Technology Assessment?	"Mitigation" vs. "Adaptation" Focus
Directives for Technology Readiness Assessment of Tidal Current Energy Generators	Focused	○	mitigation
Assessment of Emission Reduction Potential and Environmental Impact of Low-Carbon Technologies in the Glass Industry	Comprehensive	○	mitigation
Assessment Guidelines for Green Technology	Semi-comprehensive	○	dual tendency
Guidance for Economic Value Evaluation for Science and Technology Achievements	Focused	×	/
Specifications for Science and Technology Achievements Evaluation	Comprehensive	×	/
Classification and Definition of the Technology Readiness Levels for New Materials	Focused	×	/
Assessment Index System and Method for Energy Saving and Emission Reduction Technologies in Industry	Semi-comprehensive	×	/
Implementation Details for Post-Assessment of Desulfurization Process Technology for Sintering Exhaust in the Steel Industry	Semi-comprehensive	×	/
Commercial Adoption Readiness Assessment Tool	Focused	×	/
Extracting CO_2 from the Air: Carbon Capture and Storage	Semi-comprehensive	○	mitigation
Climate Impact Metrics	Semi-comprehensive	○	mitigation
Innovation Impact Assessment	Focused	○	mitigation
Steel Decarbonization Technology Assessment	Comprehensive	○	mitigation
Technology Readiness Level Scale	Focused	○	mitigation
Carbon Reduction Assessment for New Enterprises	Focused	○	mitigation
Technology Readiness Assessment	Focused	×	/
Version2 of the Global Greenhouse Gas Abatement Cost Curve	Focused	○	mitigation
Life Cycle Assessment	Focused	○	dual tendency

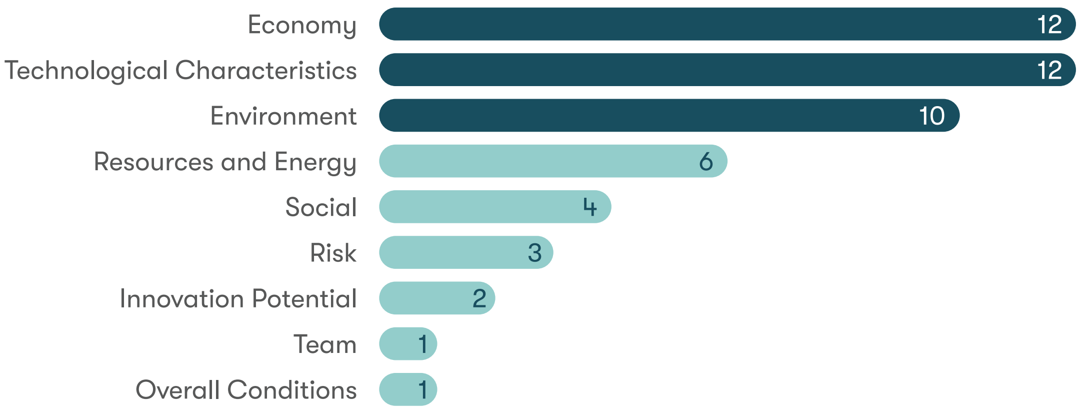
● Comprehensive
● Semi-comprehensive
● Focused

2.2.1 Analysis of Dimensions

Based on the primary indicator classification of the 18 technology assessment systems surveyed, we categorized the assessment dimensions into 9 categories: "Economy," "Technological Characteristics," "Environment," "Resources and Energy," "Social," "Risk," "Innovation Potential," "Team," and "Overall Conditions." We then compiled and summarized the specific sub-indicators under each category. For a detailed breakdown of the types of indicators included in each dimension, refer to section 2.2.2 Overview of Indicators.

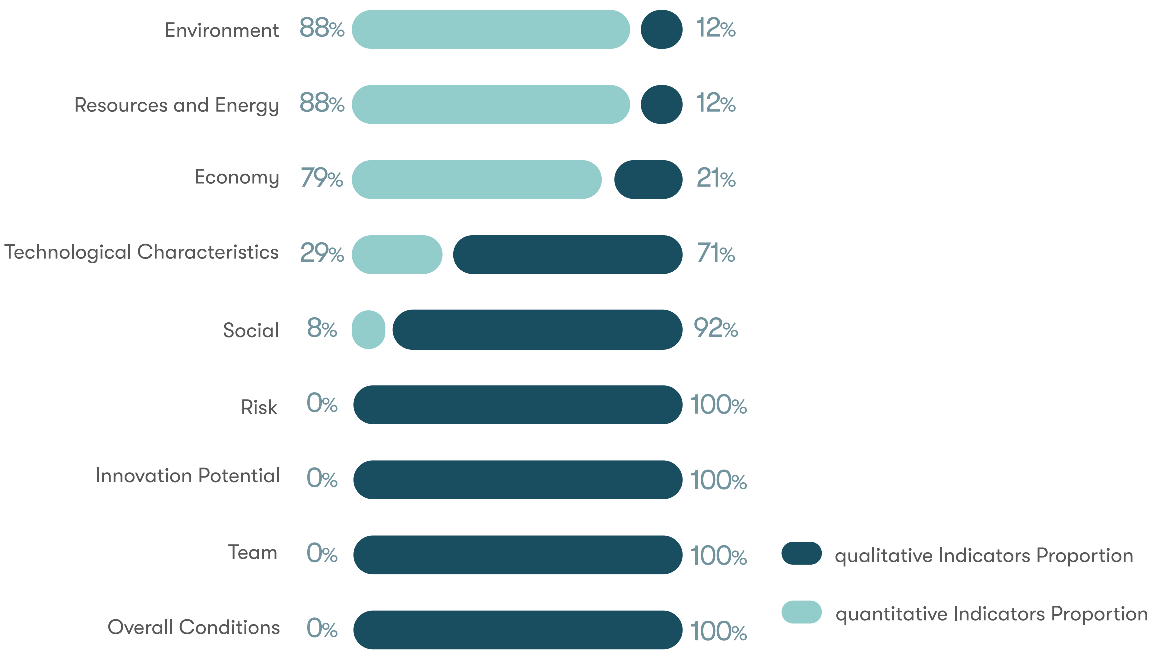
As illustrated in Figure 2-3, the number of assessment systems that include the dimension of "Economy," "Technological Characteristics," and "Environment" is the highest, with more than half of the surveyed systems covering these aspects. In contrast, the number of systems that incorporate the dimensions of "Resources and Energy" and "Social" is relatively smaller.

Figure 2-3 Inclusion of Various Dimensions in 18 Assessment Systems



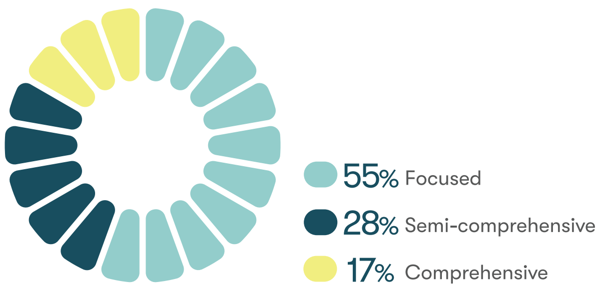
In terms of the proportion of quantitative versus qualitative indicators within each dimension, "Environment," "Resources and Energy," and "Economy" tend to rely more heavily on quantitative indicators. Conversely, In other dimensions, qualitative assessment methods are predominant. We observed that within the "Technological Characteristics" dimension, qualitative indicators are primarily used to assess readiness, advancement and universality. Additionally, approximately 46% (11/24) of the qualitative indicators in this dimension pertain to "Technology Readiness," an indicator widely utilized in both Chinese and international assessment systems.

Figure 2-4 Proportion of Qualitative and Quantitative Indicators in Each Dimension According to 18 Assessment Systems



Further examination of the qualitative and quantitative indicators across each assessment system revealed that only 7 systems primarily use qualitative indicators. In contrast, the remaining 11 systems feature over 60% quantitative indicators, showing an overall trend of being "**quantitative-dominant with qualitative as a supplement**."

Figure 2-5 Classification by Level of Comprehensiveness of 18 Assessment Systems



Based on the 9 aggregated dimensions, we further classified each assessment system into 3 categories: "Comprehensive" (including 5 or more dimensions), "Semi-comprehensive" (including 3 to 4 dimensions), and "Focused" (including 1 to 2 dimensions). The data indicates that comprehensive technology assessment systems are relatively scarce, whereas focused assessment systems are more prevalent. Additionally, **more than half of the 10 focused assessment systems are highly pertinent to climate issues, concentrating on evaluating technologies based on their carbon emission potential and environmental impact. About one-third of these systems emphasize the assessment of "Technological Characteristics" dimensions**.

2.2.2 Analysis of Indicators

Economic Indicators

Cost indicators

Among the 9 assessment systems that include cost-based indicators, there are a total of 16 relevant indicators. Of these, only 1 pertains to the impact analysis of negative emission technologies and is a qualitative indicator describing the cost range of the relevant technology. The remaining 15 indicators are quantitative, with only 3 disclosing their calculation methods: the "Abatement Cost" in Global GHG Abatement Cost Curve v2.0, and the "Investment Cost" and "Operating Cost" in the Energy Saving and Emission Reduction Technologies Assessment.

- Investment Cost

Regarding **"Investment Cost,"** the **Energy Saving and Emission Reduction Technologies Assessment** defines it as the annual investment cost, calculated by discounting the initial investment cost by the interest rate. It specifies that the initial investment cost includes acquisition costs, equipment installation, engineering construction, and other related expenses. Conversely, the **"Investment Cost"** in the **Technologies Assessment in the Glass Industry** refers to a one-time investment in the main equipment and infrastructure necessary for the technology, excluding interest rates in its calculation. The **Assessment Guidelines for Green Technology** in China also includes this indicator but without further interpretation. The **Innovation Impact Assessment** contains a similar indicator, which focuses on trends and shows cost changes from 2020 to 2050, with the data drawn from authoritative literature published by NREL, IRENA, and the IEA.

- Abatement Cost

The **"Abatement Cost"** in **Global GHG Abatement Cost Curve v2.0** represents the cost premium of reducing 1 metric ton of GHGs using low-carbon technologies compared to the Baseline Scenario (Business as Usual, BAU). However, only the basic formula for this indicator is provided, lacking detailed variable calculations. For example, it specifies that the "Full Cost of CO_2e Efficient Alternative" incorporates investment costs, operating costs, and possible cost savings from using the alternative, but excludes transaction costs, taxes, or the consequential economic impacts. Additionally, the indicator is not universally applicable due to variations in cost components such as taxes, subsidies, and interest rates across different countries. In contrast, the **"Unit Cost of Emission Reductions"** in the **Technologies Assessment in the Glass Industry** is not constrained by BAU scenarios. It represents the cost of abating a unit of CO_2 emissions without the need to subtract BAU cost inputs.

- Operating Costs

4 cost indicators are related to "Operating Costs." In the **Energy Saving and Emission Reduction Technologies Assessment**, the main variables for **"Operation Costs"** include annual energy/resource costs and annual raw and auxiliary material costs during technology operation. In the **Technologies Assessment in the Glass Industry**, the relevant indicator **"Operation and Maintenance Cost"** includes the costs of raw materials, water, electricity, and daily maintenance, though it lacks specific formula. Other documents, such as the **Post-Assessment of Desulfurization Process Technology** and the **Assessment Guidelines for Green Technology** also list **"Operation Cost"** as an evaluation indicator but do not provide detailed descriptions.

- Other Cost Indicators

Among other cost indicators, the **"Cost Value"** indicator, though not clearly defined, measures the economic benefits gained from the transformation and application of scientific and technological achievements, representing economic value from a cost perspective. Although the indicator does not specify its calculation method, it outlines steps for assessment, namely: "choosing a specific valuation path," "measuring the replacement or reconstruction cost," "accounting for depreciation of the physical," "functional and economic values and calculating the cost value."

The **"Green Premium"** in **Climate Impact Metrics** refers to the average annual cost difference between coal/gas-fired power and solar power. The calculation method for the **"Engineering and Equipment Cost"** indicator is not publicly available, however, its setting is highly dependent on the application scenario and the technology being assessed, making it relatively more tailored.

Market Indicators

In the category of "Market" indicators, a total of 11 indicators have been set up across 8 assessment systems. 4 indicators are qualitative, describing the market positioning and prospects, while 7 are quantitative, with no specific algorithms disclosed. However, 5 of the 7 quantitative indicators provide clarity regarding their meaning, with 1 outlining assessment methodology steps, 1 offering channels for modifying model data, and 1 introducing the relevant model.

- Market Value

The **"Market Value"** indicator developed by the **Economic Valuation Assessment Guidelines** reflects the economic value of scientific and technological achievements from a market perspective. Though it does not provide a specific calculation method, it offers a detailed description of assessment steps and factors to consider. It specifies that scientific and technological achievements should have a fully developed, active, fair, and transparent trading market, with comparable trading cases available. The main assessment steps include: "collecting trading examples," "selecting comparable examples," "establishing comparison bases," "correcting for trading situations," "adjusting market conditions" and "calculating market value."

- Deployment

The **"Application Potential"** in the **Technologies Assessment in the Glass Industry** measures the market penetration that the technology could achieve by 2030. Similarly, the **"Serviceable Obtainable Market"** metric in **CRANE** estimates the potential future market size that a new technology could capture over a customizable period. The annual projected market size can be adjusted based on the influence of the evaluator's company or the estimated potential impact of the technology. This produces an anticipated market size trend curve from the present to the selected future period. However, this indicator is primarily used to calculate the technology's emission reduction potential.

There are 2 additional indicators related to deployment scale. The **"Installed Capacity"** indicator in the **Climate Impact Metrics** measures the total installed capacity of each solar technology. In contrast, the **"Deployment"** indicator in the **Innovation Impact Assessment** assesses the scale of technology deployment by 2050 under a hypothetical scenario. The former provides static data, whereas the latter presents a dynamic curve illustrating changes over time. The EnergyPATHWAY

(EP) and Regional Investment and Operations (RIO) models identify and optimize boundary conditions, simulating the deployment scale changes of new technologies under 2 policy ambition scenarios and 4 technology development scenarios in energy system, excluding sensitive factors like fossil fuel prices, geological sequestration potential, regional cooperation assumptions, and power-fuel sector coupling.

The **Innovation Impact Assessment** categorizes scenarios into policy ambition scenarios and technology development scenarios. Initially, the system distinguishes the scenarios into modest and aggressive categories based on policy ambition, representing "half of 2020 carbon emissions by 2050" and "net zero emissions by 2050", respectively. Then, the system offers 4 additional scenarios based on technology development:

- All technologies achieve breakthroughs
- All other technologies remain at baseline while only the assessed technology achieves breakthroughs
- All technologies remain at baseline
- All other technologies remain at baseline while only the assessed technology shows no progress.

These scenarios visualize differences by comparing the deployment scale of each technology under various conditions, presenting the technology deployment trajectory from 2020 to 2050.

Environmental Indicators

Greenhouse Gas Emissions

○ Calculation Method

The 7 assessment systems incorporating indicators within the "Greenhouse Gas Emissions" category feature a total of 8 sub-indicators. 7 of these employ quantitative methods, while 1 utilizes a qualitative approach. Despite the prevalence of quantitative analysis, only 2 indicators have their formulas publicly disclosed: "Unit Impact" and "Annual Planned Impact" from CRANE. Additionally, Global GHG Abatement Cost Curve v2.0 describes the calculation method for its "Abatement Potential" indicator in words but does not provide a specific formula.

CRANE primarily assesses the climate impact of a certain technology. It includes a **"Unit Impact"** indicator, representing GHG emission reduction intensity. It subtracts the solution unit emissions of new technologies from the incumbent unit emissions of existing technologies, allowing for the observation of GHG emission reductions per unit of market scale. The **"Annual Planned Impact"** indicator calculates the GHG emissions that can be reduced in a given year by multiplying the "Unit Impact" by the "Serviceable Obtainable Market" that represents the expected market capture size.

The **"Abatement Potential"** indicator in the **Global GHG Abatement Cost Curve v2.0** quantifies the volume difference between the emissions baseline and the emissions after applying various technologies. The emissions baseline is calculated based on factors such as the carbon intensity of specific fossil fuels, the production of basic raw materials, or the fuel consumption per unit of transportation. The quantification of emissions from technology applications typically comes from literature or expert discussion.

○ Scenario Setting

Notably, 5 of the 8 indicators have scenarios (or allow for flexibly scenario settings) to compare the value of technology use under different conditions, or to more scientifically reflect the impact of external environment changes on the abatement potential of certain technologies. Among these, 1 indicator primarily bases its scenario on whether or not to incorporate Carbon Capture and Storage (CCS) technology to predict the potential for abatement, while another applies a full life cycle assessment, allowing for customized scenario calculations according to specific needs.

The remaining 3 indicators involve 2 specific scenarios:

- The **Global GHG Abatement Cost Curve v2.0** published by McKinsey establishes a baseline scenario with key assumptions, including, but not limited to, an annual GDP growth rate of 2.1% in developed countries, 5.5% in developing countries, a global population growth rate of 0.9% (0.2% in developed countries and 1.1% in developing countries), and oil prices at $60 per barrel.

  Additionally, 2 scenarios are set up for the energy sector. One assumes that each low-carbon technology is fully developed to its maximum predicted potential in each geo-market by 2030, based on relative cost competitiveness and each country's need for new generating capacity. The second senario is more conservative, assuming major renewable energy technologies (e.g., wind, solar PV, biomass, etc.) and nuclear energy grow at 50% of the rate in the first scenario, while more fossil-fuel-based generating capacity, some equipped with CCS, will be built.

  This set up allows for a comparison of the abatement potentials of each technology in the energy sector under the two scenarios. Moreover, since the abatement potential and cost of each technology are sensitive to changes in energy prices and interest rates, scenarios can be simulated with varying energy prices and interest rates.

- Both **CRANE** indicators set scenarios for technology application, visualizing differences between scenarios labeled "Higher," "Mid," and "Lower." However, these scenarios lack further clarification of what each represents.

Compared to indicators without scenario settings, those with scenario settings consider a wider range of factors, such as market fluctuations, policy ambition, and the impact of other technologies. However, **it's important to note that since each scenario is built largely on assumptions, the presence or absence of scenario settings cannot serve as a definitive measure of an indicator's professionalism or scientific rigor**.

Technological Characteristics

Technological Advancement

The **Specifications for Science and Technology Achievements Evaluation** issued by CASTEM includes a detailed **"Technological Advancement"** scale. This scale compares the core performance indicators or functional parameters of technological achievements against the data sources like authoritative media reports, third-party tests, standards from national to enterprise, domestic and foreign patents, and publications in core journals. Alternatively, these parameters can be assessed by an expert group. The system then ranks the level of advancement into seven grades, from low to high, to evaluate this indicator.

The rating scale is similar to the TRL, where entry criteria for each grade are predefined and standardized, allowing for a qualitative evaluation based on these criteria to assign a corresponding grade. While the rating scale cannot completely eliminate human bias, its formulation clarifies the scoring standard boundaries, making the evaluation basis more traceable. It also standardizes the concept of "advanced," providing clear meanings of the indicator and its evaluation criteria.

Technology Maturity

In 2020, IEA extended the TRL proposed by DOE from 9 to 11 levels, recognizing that the original TRL was insufficient to meet energy policy goals. The two additional levels are:

- **TRL10:** Technologies are commercial and competitive, but further innovation efforts are needed for integration into energy systems and value chains when deployed at scale.
- **TRL11:** Technology has achieved predictable growth

These new levels refine the assessment of technologies beyond the original commercialization stage, enhancing the "Technology Readiness" indicator's ability to assess the commercialization scale and deployment readiness of technologies.

2.2.3 Climate Technology Assessment Consortium

With the increasing impact of climate change on the environment and economy, global attention and investment in climate technology, particularly mitigation technology, are on the rise. According to the Climate Policy Initiative (CPI), climate mitigation-related financing accounted for 91% of the total global climate financing in 2021/2022. The scientific selection of appropriate climate technologies for making decisions regarding investment, cooperation and other related matters is becoming increasingly important across various sectors. To better understand the characteristics of climate technology-related assessments, we have initiated an observation of assessment systems highly relevant to climate issues.

Of the 18 assessment systems surveyed, 11 are highly relevant to climate issues, assessing climate technologies across various industries. Among these climate-related systems, 3 are from China and are categorized as focused, semi-comprehensive, and comprehensive. The remaining 8 systems are international, consisting of 5 focused, 2 semi-comprehensive, and 1 comprehensive system. **Overall, there is a significant emphasis on focused assessment systems, which prioritize "Environmental Impacts,""Economy," and "Technological Characteristics".**

Given that our work primarily involves mitigation and adaptation technologies within climate tech, we further analyzed the tendencies of the assessment systems towards these categories. Consistent with the global climate finance data, over 80% of the climate-related systems surveyed focus on mitigation technologies. These systems either directly assess the role of technology in mitigation through indicator design or specifically target mitigation technologies. Only 2 assessment systems do not exhibit a clear bias towards mitigation or adaptation. One of these includes adaptation technologies related to environmental governance, ecological protection, disaster prevention and control in its green technology classification table, but without distinguishing between indicators for "mitigation" and "adaptation" technologies. The other system, although capable of assessing the adaptation technologies, favors mitigation due to the difficulty in quantifying adaptation indicators.

How should we evaluate "adaptation" technologies?

In 2001, the UNFCCC formally introduced the concept of Technology Needs Accessment (TNA) at COP 7. Subsequently, needs assessments for "mitigation" and "adaptation" technologies were conducted in developing countries. In 2010, the United Nations Development Program (UNDP) officially launched the *Handbook for Conducting Technology Needs Accessment for Climate Change* (TNA Handbook) to provide guidance on conducting TNAs for climate change. This handbook helps countries make informal decisions about their technology needs and provides a systematic methodology for identifying and prioritizing the technologies necessary for assessing and scaling up prioritized mitigation or adaptation technologies.

After prioritizing the technologies, the TNA Handbook outlines steps to evaluate them, suggesting criteria that need to be fully defined, such as:

- Contribution to national priority development areas (environmental, social, economic priority development areas).
- GHG abatement potential of (mitigation) technologies.
- Potential for (adaptation) technologies to contribute to reducing vulnerability to climate change.
- Life-cycle costs of technology investments (considering upfront investment costs versus operation and maintenance costs).
- Profitability or cost-recovery potential of the technology investment (e.g., internal rate of return and net present value).

The TNA Handbook also suggests additional assessment criteria, such as market potential. Compared to various mitigation technology assessment systems, the main difference in assessing adaptation and mitigation technologies lies in their environmental impact indicators, with adaptation focusing on reducing vulnerability to climate change.

To address disagreements among multiple stakeholders during the assessment process, which can lead to uncertainty in results, the TNA Handbook provides a Multi-criteria Decision Analysis (MCDA) approach. This approach allows stakeholders to reach a consensus through discussion. Additionally, MCDA is combined with sensitivity analysis to test the robustness of the assessment results under internal and external uncertainties, such as scenario changes and weight differences.

To further understand the design characteristics of the indicators, we will explore the "Environmental Impact," "Economy," and "Technological Characteristics," which are of significant concern to climate-related assessment systems.

Environmental Impact Indicators Watch

We have categorized indicators related to environmental impacts (including "resource and energy" indicators) into 2 main categories: **"Positive Environmental Impacts"** and **"Negative Environmental Impacts"**. The former assesses the environmental benefits of a technology, such as "Greenhouse Gas Emission Reduction", "Waste Utilization", "Pollutant Removal Rate", and "Percentage of Clean Energy Use". The latter assesses the extent to which a technology depletes the environment, such as "Greenhouse Gas Emissions", "Ozone Depletion", and "Use of Hazardous Substances". Additionally, there are neutral indicators, such as "Impact on Ecosystems" and "Resource Availability".

Of the 11 climate-related assessment systems studied, 8 include environmental impact indicators. **These systems tend to assess the degree of environmental friendliness of technologies**, considering aspects from the use of raw materials to resource and energy utilization, and pollutant reduction, providing diverse indicators.

Only 2 assessment systems have "Negative Environmental Impact" indicators: the **Assessment Guidelines for Green Technology** from China and the internationally adopted **LCA**. The former also includes positive environmental impact indicators but tends to assess from a negative perspective, focusing on greenhouse gas and other pollutant emissions, resource and energy consumption, and the use of harmful substances. The latter provides a comprehensive evaluation of the overall environmental impact of a technology, considering indicators such as "Greenhouse Gas Emissions", "Ecotoxicity", "Ozone Depletion", and "Particulate Matter".

Economy Indicators Watch

We have categorized economy indicators into **"Cost," "Benefit,"** and **"Market"** indicators, which respectively represent the costs of applying a technology, the potential benefits, and market-related factors.

Among the climate-related assessment system studied, 8 systems involving economic indicators. Of these, 75% (6 out of 8) feature both "Cost" and "Market" indicators. The "Cost" focuses on "Emission Reduction Cost," "Investment Cost," and "Operation Cost," with only 1 system including the "Green Premium" indicator. The "Market" indicators are more diverse, encompassing "Market Size," "Technology Market Penetration," "Market Prospects," and "Market Penetration."

Only 3 assessment systems have set positive economic indicators to assess the "Payback Period," "Economic Feasibility," and "Return on Investment" of the technology. Domestic assessment systems generally cover both "Cost" and "Benefit" indicators, while only 1 foreign assessment system includes a "Benefit" indicator.

Technological Characteristics Indicators Watch

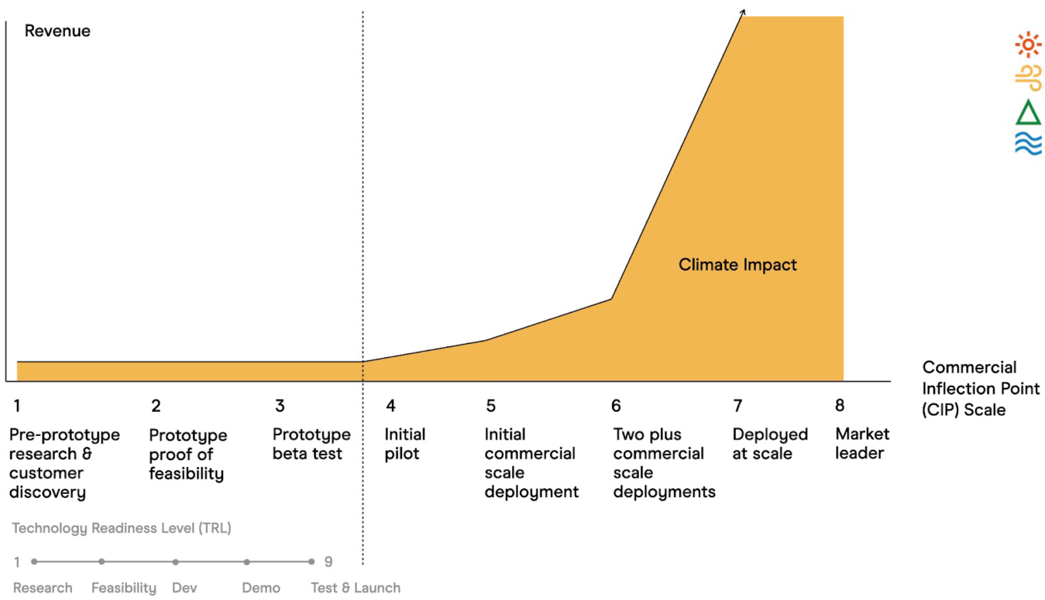
Of the 11 climate-related assessment systems, 7 assess "Technological Characteristics." Each of these systems includes technological soft indicators, which refer to the general traits a technology displays during application. All 7 systems also incorporate the "Technology Readiness" indicator. Other soft indicators, such as "Technological Reliability," "Technological Advancement" and "Achievement of Technological Goals," are primarily featured in 2 Chinese comprehensive and semi-comprehensive assessment systems. Only 2 assessment systems have set technological hard indicators, which pertain to specific performance metrics and functionalities based on experimental or trial data, focusing respectively on "Technical Effective Service Time" and "Product Life".

Through the review and analysis presented in this section, it is evident that the dimensions of "Environmental," "Economy" and "Technological Characteristics" dimensions are the most commonly used. However, the specific indicators used within these frameworks vary widely. Even for similar indicators, definitions and calculation methods differ considerably, and certain indicators may be calculated differently depending on the application context. This variation poses significant challenges to consistency and practical operability in the technology assessment process.

Climate Technology Assessment Needs and Challenges

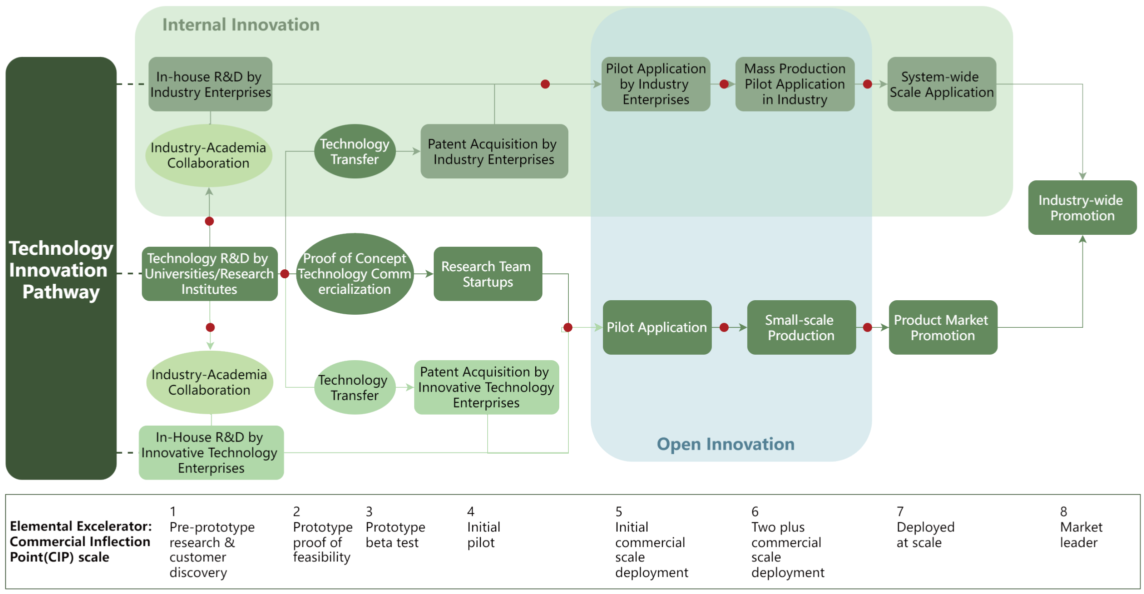
Technology development typiaclly progresses from concept to commercialisation. According to Elemental Impact, a climate technology investment organization that has supported over 130 climate tech companies over the past decade, while product launch marks the culmination of the development cycle, the true inflection point for scaling impact occurs at TRL 9, which they refer to as CIP 4 (Commercial Inflection Point). At this stage, the technology shifts from development to widespread market adoption, highlighting the extended lifecycle of climate technologies beyond the proof-of-concept and R&D phases. This longer lifecycle underscores the importance of deeper stakeholder collaboration and more comprehensive technology assessments, as evidenced by Impact Hub's experience in China.

Figure 3-1 Change in climate impact of technologies at different CIP stages



(source: Elemental Impact)

Figure 3-2 Process from technological innovation to industrial application



Red points represent the segment where technology assessment is needed

(source: Impact Hub Shanghai)

As illustrated in the figure, whether through internal innovation within industrial enterprises or through open innovation, **throughout the various stages of technology research and development, transformation, application, and promotion, technology assessment tools are essential to ensure the scientific selection and evaluation of innovative technologies. These tools enhance the effectiveness of technology application, increase opportunities for securing funding, and reduce the risks associated with industrial technology dissemination. Ultimately, they contribute to the industrialization of innovative technologies and significantly increase their climate impact.**

Building on this understanding, we conducted a series of interviews with think tanks, enterprises, investment institutions, and other relevant stakeholders actively involved in climate technology and technology assessment. The discussions centered around the challenges and needs in developing and applying such systems, providing a multi-perspective view of the technology assessment process.

3.1 Needs Observed

Demander 1: Innovative technology enterprises

Through our discussions with a platform organization specializing in technology incubation, matchmaking, and investment, we learned that **for innovative technology enterprises, the demand for technology assessment should be explored in terms of the value the assessment itself can provide.** This organization typically employs a structured model that includes stages such as "enterprise pitch – expert review – enterprise defense – expert rating." The value of its assessment can be explored from both the assessment process and its results:

- **Assessment Process:** This pertains to the expert resources made available to the enterprise throughout the assessment process, including evaluations and recommendations pertaining to the enterprise's technology, team, business model, and other relevant factors.

- **Assessment Results:** In order to meet the needs of enterprises for commercialization and large-scale application, particular attention is given to the authority and practicality of the assessment results, particularly in terms of their ability to facilitate financing, business partnerships, and other forms of cooperation.

Demander 2: Investment institutions

We found that the interviewed companies (focused on technology incubation, integration, and investment), investment institutions (private equity funds), and think tanks all agree that technology assessment plays a crucial role in the investment decision-making process for investment institutions.

Among these, one think tank's research on investors, including venture capitalists and family offices, revealed that investors' demand for technology assessment is driven by two key factors:

- **Providing Professional Reference Points:** A significant number of investors rely on policy-related keywords to identify potential investment opportunities in new technologies. However, the rapid emergence of innovative technologies across a diverse range of sectors presents a growing challenge for investors in fully understanding the technical landscape of various industries. The increasing demand for expertise and research capabilities, coupled with the pressure to generate returns, highlights the limitations of a policy-driven approach to technology selection. This underscores the need for a systematic technology assessment system to support more informed and well-founded investment decisions.

- **Identifying Key Promising Technologies:** While policy keywords represent certain technology fields with development potential, there are other equally promising areas that may not be recognized by current policies. Without a reliable and systematic technology screening and evaluation framework, investors may remain unaware of these opportunities.

In alignment with the insights presented by this think tank, the interviewed investment institution also acknowledged that in an era of rapid technological advancement, their professional capacity—both within specific technical fields and across interdisciplinary areas such as related industries, finance, marketing, and management—continues to expand. In this context, technology assessment plays an indispensable role in enabling investors to gain a more scientific and comprehensive understanding of the companies in which they invest.

However, these developments also impose higher demands on the developers of technology assessment systems. In addition to clearly defining key reference boundaries, such as technology baselines or industry benchmarks, these systems require deep expertise spanning technology, industry, finance, and market dynamics to deliver more precise and scientifically grounded assessments. Furthermore, developers must integrate knowledge across these domains to create assessment systems that better align with the actual needs of investment organizations.

Demander 3: Parks or local governments

One think tank we interviewed has provided technology demand identification and recommendation services for several governments. Starting from the macro-level industry emissions reduction, they reverse-engineer the emissions reduction needs of specific areas and combine this with local development requirements and feasibility for technology recommendations, or match specific enterprises for implementation. From this think tank's experience, they believe that local governments, based on their economic development and the need for low-carbon industrial transformation, also require support from a technology evaluation framework to a certain extent.

Demander 4: Industry-leading enterprises

As previously stated in Chapter 1, the intricate and protracted evaluation process involving disparate standards poses significant challenges for innovative technology enterprises, while also extending the screening and implementation cycle for leading enterprises in the industry. Furthermore, the absence of rigorous scientific screening standards may result in the selection of innovative technologies with elevated industrialization risks, which could impede the transition to a zero-carbon economy.

Drawing from the team's extensive experience in industrial innovation services, technology assessment plays a crucial role in refining the selection process for innovative technologies. It acts as a "filter" in collaborations between industry-leading enterprises and technology innovators, helping reduce the risks associated with industrialization and application by incorporating well-designed assessment criteria. A transparent assessment system not only enables innovative technology enterprises to provide necessary data more efficiently, but also allows industry-leading enterprises to streamline collaboration, thereby significantly shortening the timeline for selecting and applying new technologies.

3.2 Challenges Observed

In our interactions with various stakeholders and through extensive project work experience, we have identified significant challenges in technology assessment. These challenges primarily stem from stakeholders' limited understanding of the assessment process and the practical difficulties in developing and promoting comprehensive assessment systems. Below are our key observations.

Challenge 1: Lack of awareness among stakeholders

An investor from a private equity fund focused on green technology investments highlighted the issue of stakeholders' insufficient awareness of assessment during the evaluation process:

- **Portfolio Companies:** When investment institutions need to assess portfolio companies, these companies often lack sufficient awareness of the assessment process. They typically haven't established a complete response framework or prepared clear, comprehensive documentation and data for efficient evaluation by the investors.

- **Investors:** When raising funds, LPs (Limited Partners) or investment institutions such as venture capital firms and family offices, often lack awareness of technology assessment. Due to limited knowledge in specific technology fields and the absence of a structured evaluation process, portfolio companies sometimes need to provide knowledge and insights in relevant technical areas to enhance the understanding of LPs or investment institutions about a particular technology field.

Challenges such as poor data collection cooperation and low evaluation efficiency—stemming from the absence of internal processes within portfolio companies—can significantly affect investment progress and decision-making. Additionally, the lack of a comprehensive and systematic technology assessment framework makes it difficult for the technological value of portfolio companies to be fully recognized by investors. These issues suggest that certain stakeholders have yet to fully grasp the critical importance of technology assessment.

Challenge 2: Lack of standardised calculation of assessment indicators

During discussions, both think tanks and private equity investors highlighted two key challenges in assessment: the difficulty of standardizing assessment metrics across industries and the challenge of quantifying environmental benefit indicators. The specific issues are detailed as follows:

- **Difficulty in standardizing the calculation of assessment indicators:** Significant variations between industries result in diverse approaches to assessing innovative technologies, particularly in terms of functional performance, economic benefits, and emission reduction potential. These disparities make it challenging to establish a unified assessment framework for specific evaluation targets, such as technology.

- **Difficulty in quantifying assessment indicators:** The think tank highlighted the challenges in quantifying environmental benefits, particularly with regard to the emission reduction potential indicator. Issues such as double counting of electricity, varying calculation methods across different technologies, and human factors — such as how a technology is applied and its operational efficiency — can all impact the accuracy of emission reduction calculations. These complexities make scientifically determining this indicator one of the key challenges in developing effective technology assessment tools.

The private equity investor also expressed the challenge of developing an assessment system in which environmental benefits are difficult to quantify. In evaluating portfolio companies, this investor prioritizes environmental impacts, such as reductions in carbon emissions and other pollutants driven by innovative technologies or distinctive business models, and a customized assessment approach is designed for each portfolio company. However, quantifying these environmental benefits remains challenging due to several factors:

- **Absence of recognised methods of quantification:** Established methods for calculating environmental benefits, such as carbon footprint assessments, may be insufficient or inconsistent due to variations in industry sectors, technologies, or processes.

- **Absence of assessment reference boundaries:** For some industrial technologies, key reference boundaries — such as assessment baselines or industry benchmarks — can be difficult to determine, which in turn impacts the accuracy of evaluating environmental benefits.

- **Over-complexity of methods to quantify the indicator:** Due to the highly fragmented nature of some companies' supply chains, there are challenges in quantifying their carbon footprint, necessitating complex statistical and calculation processes.

In our project work, we have encountered cases where investment institutions, particularly Corporate Venture Capital (CVC), conduct technology assessments on innovative tech enterprises. Unlike private equity funds, these institutions seek innovation within their own industries, with a strong emphasis on quantifying specific indicators. Their industry-focused approach to technology assessment can, to some extent, alleviate the challenges of indicator quantification. However, while industrial investment can accelerate the R&D and commercialization of innovative technologies, it also tends to confine their development paths within industry boundaries, limiting their full technological potential.

Challenge 3: Barriers to the diffusion of assessment systems

Beyond the challenges of assessment awareness and calculation, a company with an existing technology assessment system highlighted another issue: the difficulty of achieving synergy between the technology side (suppliers, users, or system developers) and the financial side, particularly banks. This reflects a lack of communication and mutual understanding between the two, as well as the absence of effective solutions to foster collaboration. It also underscores the disconnect between the goals of technology assessment — ensuring the long-term viability of innovative tech companies — and the risk-averse nature of traditional banks, which prioritize stability over innovation in lending and credit decisions.

In light of our experience, it seems reasonable to expect that the demand for technology assessment from industry-leading enterprises, investment institutions and other stakeholders will continue to grow alongside the rise of innovative technologies. The numerous challenges previously outlined reflect the fact that an assessment ecosystem in which all stakeholders possess a high level of awareness of technology assessment has yet to be established. At the same time, it is evident that different stakeholders, due to their varying roles, have distinct perspectives on the needs and challenges of the assessment system. Their viewpoints on similar issues may also differ. Insufficient communication can result in one-sided understandings, hindering the ability to develop optimal solutions and potentially limiting opportunities for productive collaboration. This, in turn, may make it challenging to accurately assess the alignment between industrial enterprises and innovative technology enterprises.

It is therefore our belief that, to accurately identify the needs and challenges of technology assessment systems, and to efficiently develop, refine, and promote their application, all stakeholders should fully recognize the importance of these systems and engage in meaningful dialogues. We look forward to not only bringing together diverse perspectives but also actively engaging all parties in co-creation. Our goal is to promote the development of a series of technology assessment systems and enhance their recognition and acceptance across the industry.

4

Recommendations for the Development of Technology Assessment System in China

From our analysis in the previous chapters, we have gained a clearer understanding of the features, application needs, and development challenges of technology assessment systems. There remains considerable room for improvement, and much work lies ahead in expanding their use and adoption. To better connect large enterprises with emerging technologies, foster open innovation ecosystems, and meet the technological demands of climate action, we present four key recommendations for the further development of technology assessment systems.

Recommendation 1: Differentiating technology stages for more targeted assessments

The **TRL** framework divides pre-commercial technologies into nine stages, each with specific benchmarks focused on technical performance. However,technologies that have been commercialized must address the needs of users, including industrial enterprises, innovative tech companies, and investment institutions, facing a broader range of challenges across dimensions such as economy, environmental, and social factors. It is evident that technologies exist at different stages of development, and the focus of development varies at each stage. Our research indicates that while most assessment systems recognize the industry context of a technology, they often overlook its specific stage of development, resulting in a misalignment between the assessment process and the technology's actual maturity. This disconnect can lead to assessments that fail to accurately capture the technology's true potential.

Similarly, based on our extensive experience in facilitating open innovation ecosystems, we have observed that different industries have varying requirements for the stages of innovative technology. A "one-size-fits-all" approach that lacks stage-specific assessment often overlooks promising innovations, leading to missed collaboration opportunities and significantly lowering the success rate of technology matching, which in turn hinders the further development of open innovation ecosystems.

We therefore recommend that stakeholders prioritize stage-specific technology assessments. Developers of assessment systems should not only account for the industry context but also create frameworks that align with the specific developmental stages of technologies. This would allow assessments to more accurately reflect the true capabilities of the technology, enhancing the understanding of potential adopters, reducing collaboration risks, and supporting the growth of open innovation ecosystems.

Recommendation 2: Demand-oriented assessment system design and technology selection

As noted, technology assessments must address the varying needs of users — industrial enterprises, tech innovators, and investors—whose requirements differ based on industry, application scenarios, and strategy. Without a clear understanding of these needs, assessment results hold little value. Our research shows that few assessment systems effectively account for critical factors like industry context and application scenarios. Furthermore, for users, the realization of an innovative outcome often involves multiple technological pathways, each differing in important assessment dimensions such as economy, environmental, and resource factors. Without evaluating these options comprehensively, it's challenging to identify the most suitable solution.

Given these findings, we suggest that developers prioritize user needs when designing assessment dimensions and criteria, tailoring them to different requirements. As discussed in Chapter 2 regarding **Technology Needs Assessment (TNA)** at the national and regional levels, identifying priority sectors and industries first allows for the development of targeted technology lists, frameworks, and standards, ensuring that recommended solutions align with user demands. At the same time, users should adopt a comprehensive approach to evaluating multiple technological pathways, carefully comparing them to select the innovations that best meet their specific needs.

Recommendation 3: Establishing communication mechanisms to foster innovation ecosystem development

Open innovation ecosystems offer significant value and momentum for industrial transformation and the development of innovative technologies. However, as noted in Chapter 1, the lack of effective technology assessment tools and methodologies creates bottlenecks in key processes such as technology matching and joint R&D, hindering both corporate and sector-wide progress towards low-carbon transitions and sustainable development. Our research further reveals that stakeholders in China's technology assessment landscape tend to operate in isolation, with limited communication and collaboration. This disconnect makes it difficult for assessment systems to meet actual needs, and limits the acceptance and credibility of assessment results.

That said, we have also observed encouraging progress, with certain stakeholders already co-developing and sharing assessment frameworks and methodologies, actively advancing industry collaboration and adoption. A notable example comes from the aluminum product carbon footprint calculation sector, where RMI, in partnership with the China Automotive Carbon Digital Technology Center and the China Green-Metal Certification Center, conducted joint research, pilot programs, and extensive discussions. These efforts were aimed at ensuring that the metric design and application are well-aligned with the realities of China's aluminum industry and its supply chain. This collaboration led to the release of a report on the methodology for calculating the carbon footprint of aluminum products in October 2024, sharing their findings with the broader industry.

To drive the continued development of technology assessment systems and establish frameworks that are both scientific and effective, we propose collaborating with stakeholders to create open and inclusive communication channels. This will enhance the efficiency of open innovation and increase the success of collaborative efforts, supporting the transformation of both companies and industries. We also encourage assessment system developers to make their assessment dimensions and indicator frameworks publicly available, fostering greater awareness and engagement from all parties. By promoting broader dialogue, stakeholders will gain a deeper understanding of the challenges surrounding technology assessments, ultimately enabling more informed decision-making and better alignment with assessment needs.

Recommendation 4: Steadily advancing the digitalization and tool-driven development of assessment systems

As artificial intelligence (AI) and big data analytics continue to evolve and mature, we anticipate that technology assessment systems will increasingly move toward digitalization and tool-driven approaches. By allowing users to input or select standards, parameters, databases, and calculation methods, these systems can utilize advanced models to generate more efficient, accurate, and standardized assessment results. However, our research indicates that only 5 of the surveyed assessment systems have developed fully operational tool-based functions, and just 2 of these tools are publicly accessible.

Building on this, we further advocate for the creation of open, transparent professional platforms where stakeholders can share their needs and insights on technology assessments across various scenarios — whether in corporate-initiated open innovation programs, investment decisions by investment institutions focused on innovative technologies, or government efforts to attract investment for green economies. Such platforms would not only promote the broader use of assessment tools and enable valuable feedback for their refinement, but also channel specialized expertise, talent, and resources into the continuous improvement and digital advancement of these systems.

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An Introduction to Organizations

About 1.5DO Climate Innovation Lab

The 1.5DO Climate Innovation Lab, initiated in 2022, provides systemic solutions to address challenges arising from climate change. Through industry research, technological application and implementation, industrial innovation, data platforms and international dissemination, the lab builds a domestic climate innovation ecosystem, enables the development of climate innovation technologies, and promotes the transformation of key emitting industries and regions, ultimately contributing to the achievement of China's dual carbon target and the global 1.5 degree climate vision.

About Makeable

Makeable is an action research platform focused on sustainable innovation developed by Impact Hub Shanghai. It aims to empower the ustainable innovation ecosystem through research, dissemination and industrial capacity-building and to accelerate the realization of the SDGs through innovation.

About Impact Hub Shanghai

Founded in London in 2005, Impact Hub is a global network of impact-driven entrepreneurs, creators, innovators, and intrapreneurs, dedicated to reating a better future for people and the planet. Impact Hub now operates in 100+ cities across 60+ countries. In 2017, Impact Hub Shanghai became the first Impact Hub in Mainland China.

Since then, it has at the forefront of building sustainable innovation ecosystems, offering innovation consulting, entrepreneur support, impact arketing, investment services, and research. It has upported more than 3,000 innovative companies, along with more than 90 industrial enterprises and governmental parks, to lead and build an ecosystem of sustainable development and co-create a better world.

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