Financing of PtX Projects in Non-OECD Countries

Submitted to:

H2Global-Stiftung

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This Report summarizes the findings of different Work Packages elaborated by Frankfurt School of Finance & Management, jointly with Perspectives and Planet Power Finance during the last quarter of 2022, as part of the assignment commissioned by H2Global Stiftung (Foundation). The purpose of the H2Global Stiftung is to promote the protection of the environment and the climate as well as the promotion of science and research. The purposes will be achieved by measures that serve to promote the production and use of Green Hydrogen and other climate-neutral energy carriers (climate-neutral or defossilised energy carriers) at national and international level. In this context, H2Global Stiftung is also in charge of implementing the H2Global instrument to promote PtX technology and market ramp-up through an auction scheme for green hydrogen imports.

Interviews were held with investors, financial institutions, and other relevant stakeholders. All opinions expressed in this document are those of the authors.

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Abbreviations

AEM	Anion Exchange Membrane
CAPEX	Capital Expenditure
COD	Commercial Operation Date
CRI	Carbon Recycling International
CSP	Concentrated Solar Power
DFIs	Development Finance Institutions
ECA	Export Credit Agencies
EPC	Engineering, Procurement, and Construction
EU	European Union
EURIBOR	Euro Interbank Offered Rate
FA	Formic Acid
FID	Final Investment Decision
HTF	Heat Transfer Fluid
IEA	International Energy Agency
ISPT	Institute for Sustainable Process Technology
JV	Joint Venture
LCOE	Levelized Cost of Electricity/Energy
LIBOR	London Interbank Offered Rate
LOHC	Liquid Organic Hydrogen Carriers
MU	Monetary Unit
MENA	Middle East and North Africa
NPV	Net Present Value
O&M	Operations & Maintenance
OECD	Organization for Economic Cooperation and Development
OPEX	Operational Expenses
PEM	Proton Exchange Membrane
PPAs	Power Purchase Agreements
PTC	Parabolic Trough Collector
PtX	Power-to-X
PV	Photovoltaics
R&D	Research & Development
RE	Renewable Energies
ROI	Return on Investment
SDG	Sustainable Development Goal
SOE	Solid Oxide Electrolysis
SOEs	State-Owned Enterprises
STC	Standard Test Conditions
TA	Technical Assistance
ToR	Terms of Reference
WP	Work Package

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Selected defined terms

PtX	Power-to-X covers processes for converting electricity (power) to an energy carrier ("X"), which can be in gaseous form (e.g., hydrogen and methane) or liquid synthetic fuels (e.g., methanol, ammonia, synthetic diesel, and kerosene). Also referred to as Powerfuels, electrofuels, e-fuels, Power-to-Gas for gaseous fuels, Power-to-Liquids for liquid fuels.
PtX projects	Includes the range of activities from generation to transportation: i). power generation using renewable energies, ii) electrolysis of water, iii) processing of hydrogen into downstream products, vi) transport of the final product to the customer.

1 Executive Summary

H2Global aims to accelerate the global market ramp-up of green hydrogen and its derivatives in several countries such as Brazil, Namibia, South Africa, among others. To this end, H2Global Stiftung has identified the **need for a deeper understanding of the financing gaps that PtX projects face in different markets**. The Present Report includes a summary of the research in this regard conducted by Frankfurt School of Finance & Management with its project partners, Planet Power Finance and Perspectives.

On the basis of practical experiences shared by PtX project stakeholders (developers, financial institutions, among others), a number of take-aways can be derived regarding **challenges and success factors of Power-to-X (PtX) financing in non-OECD countries**.

i. **The PtX market in non-OECD countries is in a nascent stage.** More than 680 clean hydrogen projects, with a rated capacity of at least 1MW and a total investment volume of over US$ 240bn until 2030, have been announced recently, but only projects worth US$ 22bn have reached financial investment decision (FID) or are under construction or operational (McKinsey, 2002). By far the biggest share of those projects is located in OECD-countries. **The number of projects in non-OECD countries with a rated electrolyzer capacity over 10MW and FID reached is very limited.** According to the latest IEA hydrogen project database, there are only 18, and out of these, only 6 are located outside of China. (IEA, 2022).

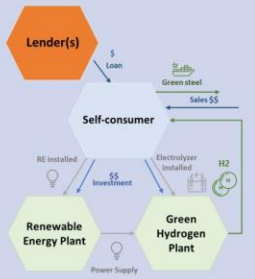
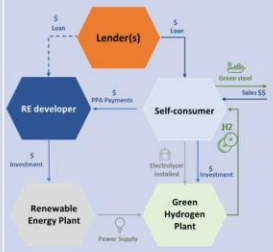
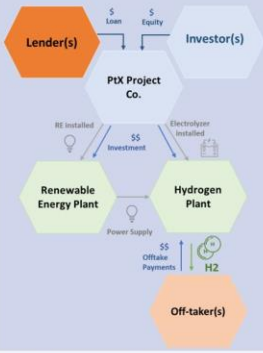
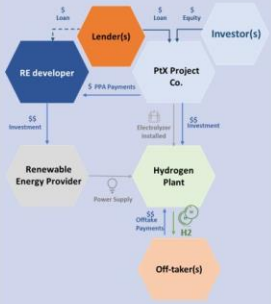
ii. **In this line, the experience and activities of the interviewees is limited as of now**. Even though Development Finance Institutions (DFIs) and banks recognize the fast pace at which PtX projects are being announced and thus see this sector as a future core sector for their financing activities, **none of the interviewed financiers has invested substantial amounts yet**. Many of them have been approached by governments or project developers and have various PtX-projects in their pipeline (mostly for pre-feasibility studies) but very few have already gotten involved in financing those, mostly through grants. Most of the interviewed DFIs have launched dedicated PtX-working groups, which shows the perceived importance and lack of understanding of this emerging working field.

iii. **However, to ramp up PtX investments, it is necessary that financial institutions are willing and able to finance the projects in such leverage levels and for relatively long tenors** as required for the project to be financially feasible. This is because, given that PtX projects are highly capital intensive, there are very few investors with sufficient funds to finance the project entirely with equity.

iv. **Due to the novelty of the PtX industry, it becomes indispensable that project risks are fully or partially mitigated, which depends on the specific business model**, as different factors can fundamentally alter cash inflows. In this sense, we distinguish two main models: “Captive Model”, PtX produced in large scale on site for self-consumption (i.e., to serve as feedstock to petroleum refining, ammonia, and methanol production, among others), and “Merchant Model”, PtX produced in large scale for sale (i.e., shipped and sold as gas or liquid).

v. **In addition, given the segmented value chain of PtX projects (RE, electrolyzer, storage/processing, shipping, use), investments can be bundled (under one Engineering, Procurement, and Construction -EPC- contract) or can be separated into several projects** (with different borrowers and financing mechanisms). It is essential that investors have access to the financing suiting their specific needs.

Figure 1: Business Models of PtX Production

Business Model	1. Captive Model		2. Merchant Model	
	1.1. Bundled	1.2. Unbundled	2.1. Bundled	2.2 Unbundled
RE Plant Owner	Self-consumer	RE Developer	PtX Developer	RE Developer
H2 Plant Owner		Self-consumer		PtX Developer
H2 Consumer			Off-taker*	Off-taker*
Schematic of business model				
Overview	Green H2 consumer invests in both RE and H2 plants	Green H2 consumer invest only in H2 plant but signs a PPA	PtX developer invests in both RE and H2 plants	PtX project is split in 2 SPVs: H2 plant and RE plant
Finance Scheme	Corporate debt, equity and/or grants (Total CAPEX)	Corporate debt, equity and/or grants (only green H2 CAPEX)	1.1 + Project finance**	1.2 + Project finance**
Example	E.g., a Steel maker invests in a PtX plant for self consumption (to produce green steel).	E.g., a Steel maker invests in a H2 plant for self consumption (to produce green steel) powered via a solar PPA.	E.g., a PtX developer exports gaseous H2 from North of Africa to Europe via gas pipelines	E.g., H2 plant powered via PPA with a RE provider. The Green H2 will be sold to an offtaker.

Notes: * Off-takers can be domestic or foreign (export) customers
** Project finance availability is highly dependent on cash flow predictability, hard currency and off-taker's creditworthiness, among others

(Frankfurt School-UNEP Centre Analysis, 2022)

vi. **The main perceived barriers by investors and financiers revolve around the nascent stage of the green PtX market**. On the demand side, uncertainties around prices, regulations and standards seem to limit the appetite of buyers to commit with long term offtake agreements. On the supply side, we note an apparent squeeze on the key equipment suppliers who are unable to commit with firm delivery deadlines and to provide technical guarantees, and a latent risk of technological advances that could make current technology not competitive. Another very important risk factor is the transportation and logistics of the green PtX products, which several investors might be reluctant to absorb. Those are basic points that must be solved before a PtX project is able to be financed under a non-recourse project finance scheme.

vii. **Which financing instruments are required and available, and at which conditions is very project specific. Also, strong governmental support is a key success factor, and availability of instruments to de-risk investments – such as first-loss guarantees from DFIs.** Such instruments could give more confidence to commercial debt providers on the repayment capacity of the projects. Another example are concessional loans and grants; such instruments can enable investors (equity providers) to attain the minimum required return sufficiently high to make the project attractive to them. For first mover projects (with relatively high-risk perception and high CAPEX), such instruments are needed. In a second stage, with a track record of PtX projects, the participation of additional financiers will be enhanced as project bankability will improve.

viii. **The first projects may not be fully non-recourse and may require guarantees from sponsors capable of bearing risks on the supply and demand side**. It is probable that first movers are companies that

develop green PtX to decarbonize its operations (e.g., ammonia manufactures, fertilizer plants, steel mills, etc.).

ix. **The minimum return required by capital providers to invest in a PtX project is directly dependent on the risks perceived by investors and financiers in these locations (the higher the risk, the higher the required return[1]). F**or OECD countries the real required return on equity tends to be single digit, whereas in non-OECD countries, equity providers apply a "risk premium", which results in double digit required return in many cases. For investors to be willing to invest in a PtX project, the expected return of the project should be above the hurdle rate. For this to become a reality, several actions could enhance PtX competitiveness.

   a. **PtX production would need to be remunerated at a price high enough such that investments are attractive for capital providers**. In this sense, the H2Global instrument can definitely be a game changer by helping to set the standards of future PtX fuel auctions.

   b. **On the cost of capital side,** actions to reduce risk perception are essential (capacity needs assessments, including recommendations and upcoming capacity building to enhance local national capacities to better serve investments embedded into the national contexts, insurance instruments, aligning expectations, Technical Assistance activities, supporting financing institutions, etc.)

   c. **In addition, project developers and financiers would greatly benefit from a "global PtX-finance knowledge hub" that supports with know-how and information[2] on financing options for a PtX-project regardless its location**. If such information is centrally collected and made available to PtX project developers and financiers, industry ramp-up would be expedited and transaction costs would be reduced. It is worth mentioning the progress in this sense achieved through the Working Group 4 "Investment Funds and Financing Approaches" from the H2Global Foundation.

[1] And the higher the floor price needed to make the project financially attractive.

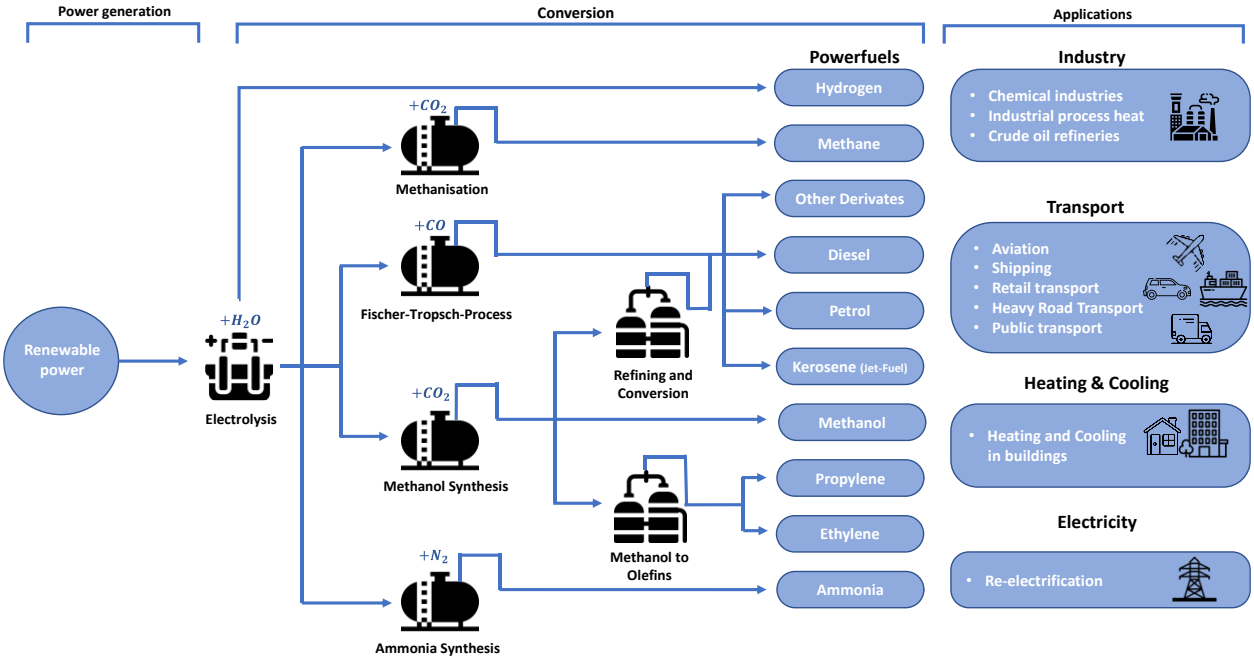
[2] Important information includes overview of governmental and regional PtX support (host country/region of project), overview of DFIs active in the region, and their PtX-specific offerings, overview of commercial banks with interest/experience in PtX, and their PtX-specific offerings, overview of private PtX-funds offering PtX-financing, overview of public and private support schemes for green PtX, such as the US hydrogen tax credit, the H2Global instrument, etc., overview of carbon pricing instruments, such as Art. 6 of the Paris Agreements, voluntary carbon markets, emissions trading schemes etc., from which the PtX project could benefit, overview of green PtX prices in different markets and harmonization of their certification criteria.

2 Introduction

With the global energy transition moving into a new phase, all sectors of the economy need to go through drastic changes to reach net zero. Given that some sectors can only achieve net zero GHG emissions through non-fossil gaseous and liquid energy carriers such as PtX products (i.e., green H_2 and downstream products), PtX projects are gaining momentum.

The H2Global Stiftung aims to promote environmental and climate protection, in particular through measures designed to promote the production and use of Green Hydrogen and other climate-neutral energy carriers on a national and international level. Such other energy carriers include hydrogen-based synthetic energy carriers (PtX products, also referred to as Powerfuels), as illustrated below:

Figure 2: Power-to-X products



(German Energy Agency, 2022)

To reach the global target of climate neutrality, it is essential to support the defossilization of non-OECD countries. For that purpose, H2Global Stiftung aims to accelerate the global market ramp-up of green hydrogen and its derivatives in countries with high exporting potential such as Brazil, Namibia, South Africa, among others. To this end, H2Global Stiftung has identified the need for a deeper understanding of the financing gaps that PtX projects face in different markets.

With this objective, H2Global Stiftung has commissioned Frankfurt School of Finance, jointly with its project partners, Planet Power Finance and Perspectives, to conduct research to identify and investigate gaps for the financing of PtX projects in non-OECD countries.

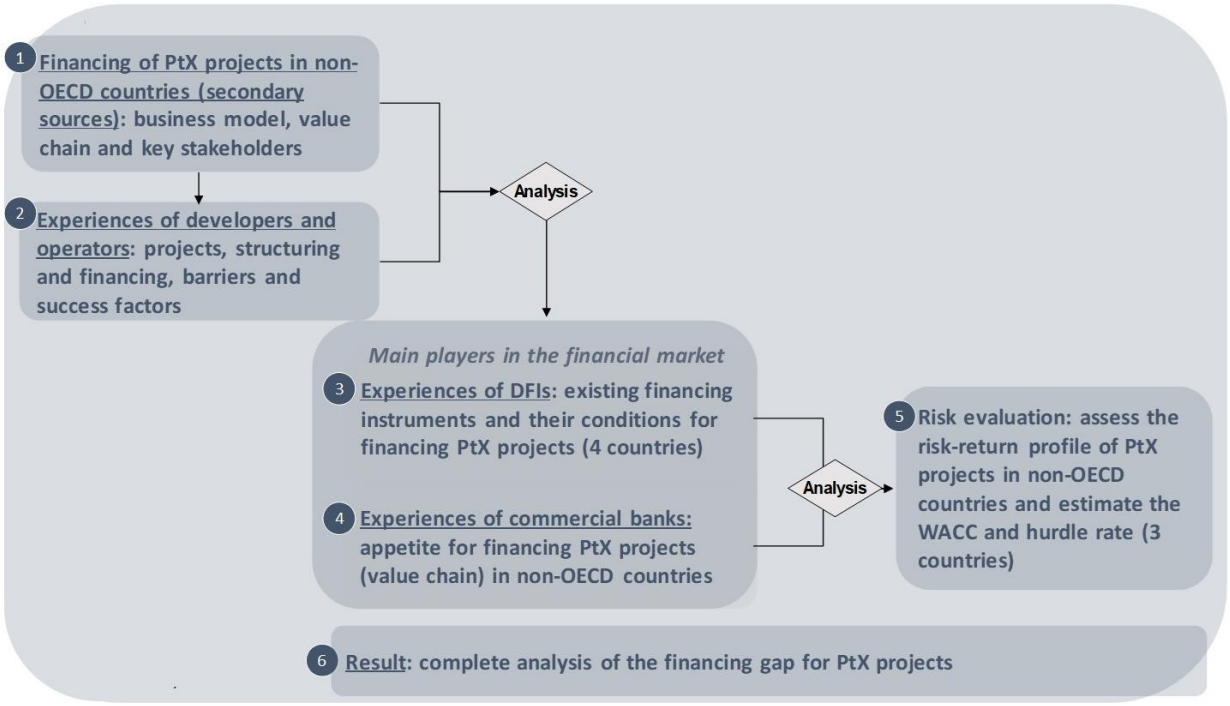
The Present Report includes a summary of the main take-aways regarding the financing landscape and bankability of PtX projects in non-OECD countries.

2.1 Methodology

We have analysed secondary sources (please refer to References) and conducted research by using the keywords "financing, green hydrogen, barriers" in combination with the following country names Brazil, India, Morocco, Namibia, South Africa, and China, among others, in the Google Scholar search engine. The search was complemented by Frankfurt School's literature databases, where the university has subscriptions to many academic literature portals. In addition, we have conducted interviews to investors, developers, financial institutions, and infrastructure funds active in non-OECD countries.

The methodology followed is illustrated in the Figure below:

Figure 3: Project Methodology



(Frankfurt School-UNEP Centre, based on H2Global Terms of Reference, 2022)

2.2 Structure of this Report

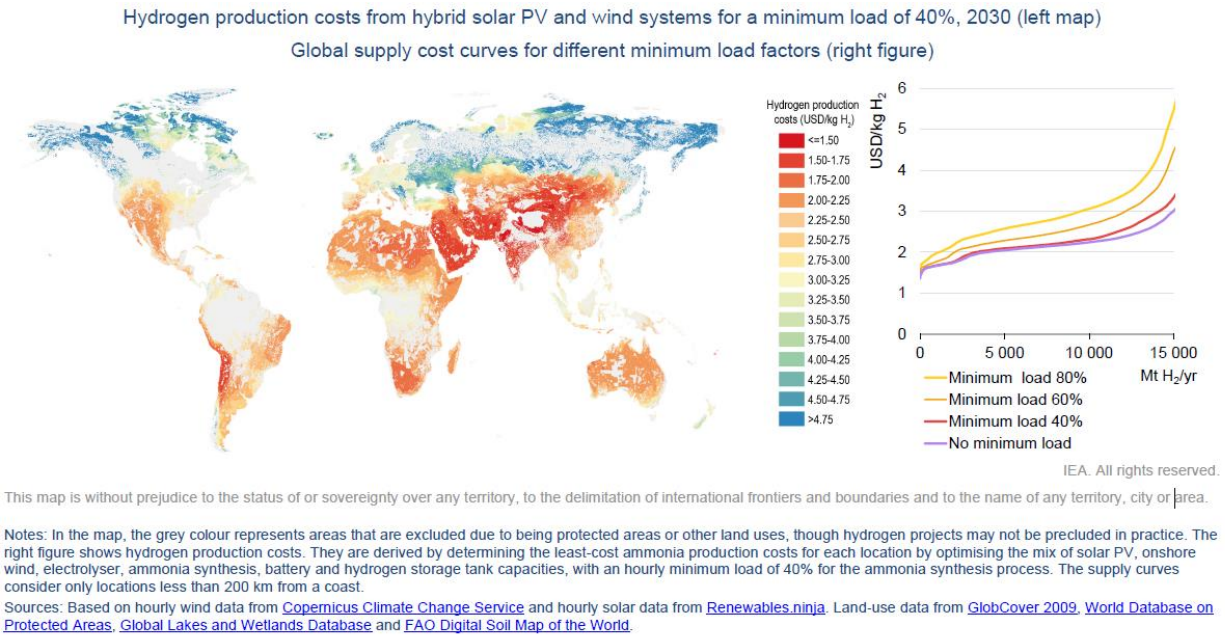
This Report presents the main findings of the conducted research and, after the previous Executive Summary and the current Introduction, includes the following structure:

- **Chapter 3** explores the scene for PtX production in non-OECD countries. It presents a long list of target countries to consider.
- **Chapter 4** assesses the investment needs for PtX projects.
- **Chapter 5** examines the financing structures and business models for PtX projects.
- **Chapter 6** summarizes main barriers, perceived risks and success factors gathered through interviews with developers, DFI, commercial banks and financial investors.
- **Chapter 7** summarizes the findings regarding the cost of capital.
- **Chapter 8** concludes with the main take aways from the research.

3 Non-OECD countries where green hydrogen can be produced efficiently

We have assessed potential target countries where green hydrogen can be produced efficiently. IEA identified promising areas for PtX production that include non-OECD countries located worldwide (IEA, 2019). The following figure shows estimated hydrogen costs from hybrid solar PV and onshore wind systems in the long term.

Figure 4: Green hydrogen costs in the long term



(IEA, 2022)

Moreover, if we consider the estimated future hydrogen exports by country, the following non-OECD countries stand out: Argentina, Brazil, Angola, Morocco, Namibia, South Africa, Egypt, Mauritania, Oman, Saudi Arabia, UAE, India, Kazakhstan, and Viet Nam (IEA, 2022).

To further identify “best-suited” PtX producers, we have considered the country-specific context in terms of the most relevant criteria to identify attractive markets for low-cost green hydrogen production. These criteria (PtX drivers) are listed below:

Table 1: Drivers of PtX production (selection criteria)

Nr.	Criteria
1	Geographical location, energy trade connections (pipelines, ships, tanker shipping, etc.)
2	Renewable energy costs (chiefly utility scale solar and wind), track record
3	Potential local demand (e.g., developed fertilizer industry, mining and steel production)
4	Progress in terms of regulation roadmap, and pipeline (at least in development phase)
5	Investor appetite: regulatory certainty, cash flow predictability and political stability
6	Technological know-how, presence of competent local companies

In addition, we identified PtX projects in non-OECD countries, to assess the maturity in these markets. The following ranking of attractive PtX countries was elaborated based on a combination of the previous mentioned elements and the consultant team knowledge.

Table 2: List of selected PtX countries

Rank	Region	Country	Comments
1	MENA	Morocco	Closest distance to EU among non-OECD countries, with track record on solar and wind and stable government.
2	MENA	Egypt	Close to EU, existence of local gas export industry and government committed to green hydrogen economy.
3	LAC	Brazil	Large internal demand, competitive RE resources, world's 4th largest destination for foreign direct investment.
4	APAC	India	Abundant resources, low country risk, potential infrastructure and very large internal demand. World's 8th destination for foreign direct investment.
5	MENA	Saudi Arabia	Ministry of Energy announced the goal of becoming the world's largest hydrogen producer.
6	SSA	Namibia	Incipient industry and low local demand but with abundant RE resources and stable political environment.
7	SSA	South Africa	Track record in RE and presence of local demand.
8	LAC	Paraguay	100% RE electricity matrix with low cost, close to Brazil and Argentina, with availability of river navigation.

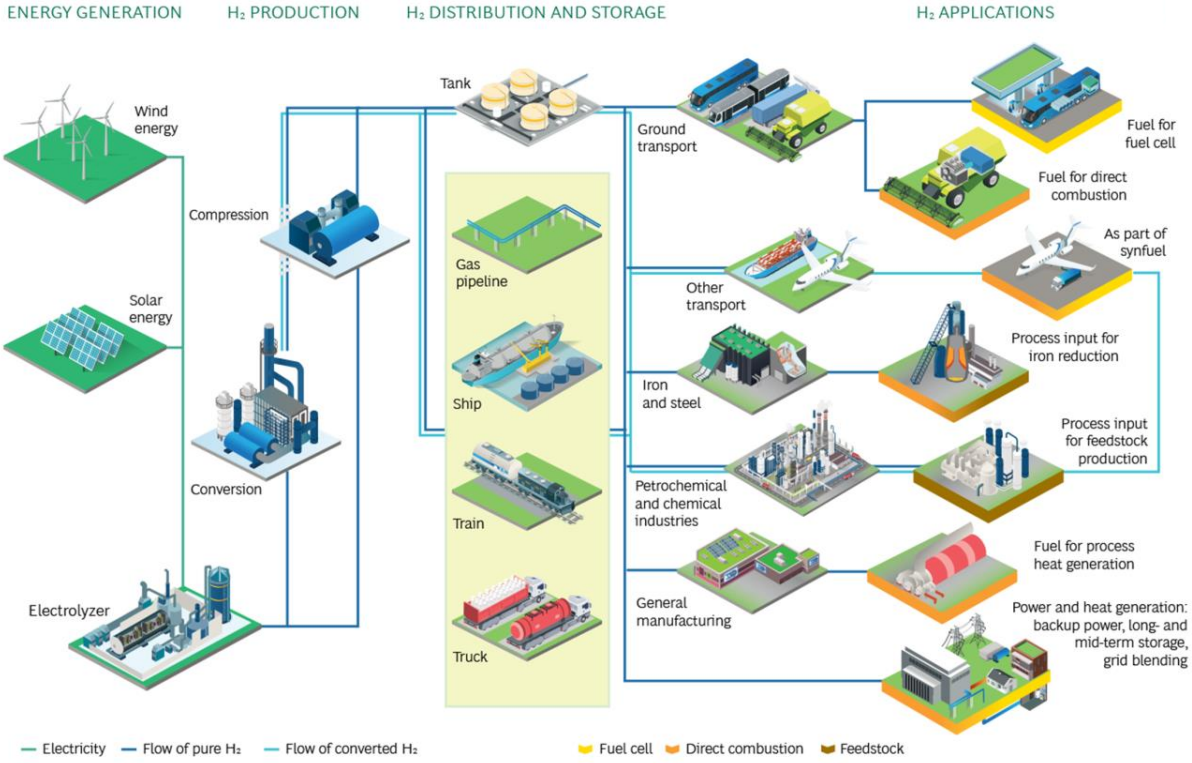
4 Capital Investment Needs

PtX projects encompass the entire production chain: from power generation using renewable energies (RE), electrolysis of water, further processing of hydrogen into downstream products, and transport of the final product to the customer (project ToR). In sum, PtX projects can be divided into the following primary segments:

1. RE generation
2. Green hydrogen production, conversion, including compression and storage
3. Transportation, including vessels and pipeline (when needed)

The value chain is illustrated in the figure below:

Figure 5: PtX project value chain



(BCG, 2021)

As such, to evaluate the investment needs of PtX projects, the variables that are essential to analyse, include the following:

1. CAPEX of renewable power generation capacity (wind, solar PV, geothermal, biomass, hydropower, etc., as applicable)
2. CAPEX of electrolyzer and all associated equipment needed as applicable[3] (conversion, compressor, and storage)
3. CAPEX of transport infrastructure, if needed (export of the PtX products)

[3] All equipment needed to produce, convert, compress, store hydrogen should be accounted for, as applicable.

As PtX projects are initially very capital intensive, it is required that the business case and profitability analysis start with an estimation of "sources" (debt and equity) and "uses" of funds (initial investment effort, i.e., CAPEX). The initial investment effort, as is the case of large scale RE projects, is covered to a substantial extent by debt providers. Equation 1 below shows this identity:

Equation 1: Investment and Financing Needs

$$Sources\ of\ funds = Uses\ of\ funds$$

$$Debt + Equity\ = CAPEX_i + CAPEX_{ii} + CAPEX_{iii}$$

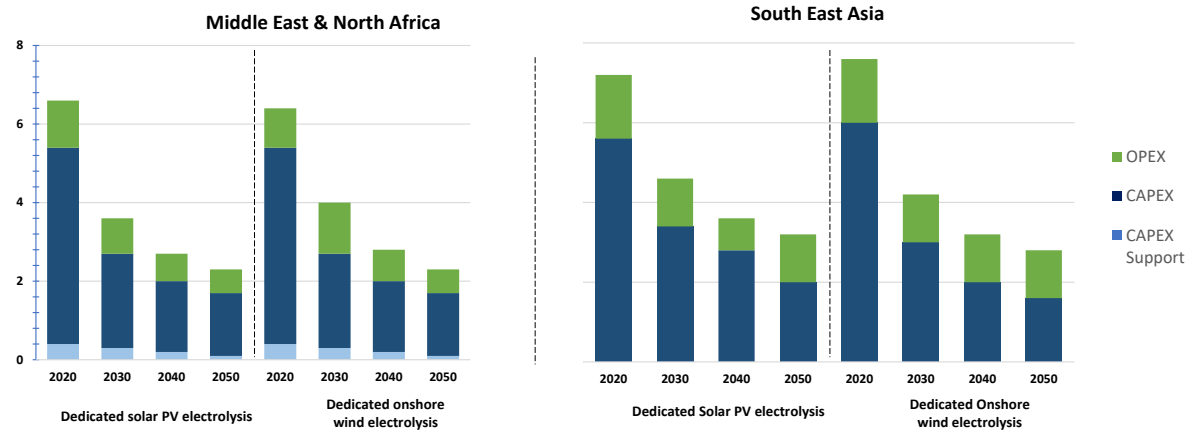
Table 3: Sources and Uses Nomenclature

Nomenclature	Unit	Meaning
Debt + Equity	Monetary Unit (MU)	Sources of funds to cover capital needs (i.e., equity plus financing required); the business model (expected cash flows, risks associated to these), partly determines the financing structure and conditions.
$CAPEX_i$	MU	Capital expenditure of renewable power generation capacity (PV, wind, etc.).
$CAPEX_{ii}$	MU	Capital expenditure of electrolyzer, conversion, compressor and storage.
$CAPEX_{iii}$	MU	Capital expenditure of transport infrastructure, if needed (export of the PtX products)

From the research of advanced projects in non-OECD countries, we see CAPEX ranges from US$ 120 m towards US$ 9.5 bn for commercial projects. It becomes clear that PtX projects are highly capital-intensive investments, requiring a large initial outlay for the construction of the assets and procuring of equipment (CAPEX). Once the asset has been built, OPEX is relatively low.

The following Figure shows green H_2 levelized cost (USD/kg H_2) segmented by CAPEX and OPEX, for MENA and Southeast Asia (SEA):

Figure 6: H2 costs in different regions, segmented by CAPEX and OPEX



(DNV, 2022)

The Figure above illustrates the high weight of CAPEX over total green H_2 costs, the expected future reduction in CAPEX, and the differences in costs between regions. The cost differences are due to several reasons; assumptions to the cost calculations include:

- Ratio of power output to electrolyzer capacity is assumed 0.7 for solar, 1.0 for onshore wind.
- Annual operating hours for solar (2020-2050): 1800-2600 in MENA; 1700-1900 in SEA.

- Annual operating hours for onshore wind (2020-2050): 3400-4150 in MENA; 2550-3750 in SEA.
- Lifetime for hydrogen production capacity 25 years.
- Lifetime for solar PV: 30 years.
- Lifetime for onshore wind: 30-35 years[4].
- Electrolyzer stack lifetime: 72000 hours in 2020, 80500 hours in 2050.
- CAPEX for electrolysis including stack: 880 USD/kW in 2020.
- CAPEX for solar PV (in USD/kW) in 2020; 823 in MENA, 760 in SEA.
- CAPEX for onshore wind (in USD/kW) in 2020: 1380 in MENA, 1220 in SEA.
- Additional engineering & procurement cost is assumed as 35% for all technologies.
- Learning rate for electrolyzers: 15% in 2020 reducing to 12% in 2050, for solar panels: 26% in 2020 reducing to 16% in 2050; for wind turbines: 16%.
- Discount rate:13% (2020), 10% (2030), 8% (2050) in MENA and SEA. High discount rates in 2020 reflect the risk premium of hydrogen production.
- Annual H2 production OPEX: 3% for electrolyzers. Short term H_2 storage and transport cost: 0.4-0.3 USD/kgH2 for solar electrolysis, 0.5-0.4 USD/kgH2 for onshore wind electrolysis.

In sum, PtX projects are highly capital-intensive investments that include several assets (RE, electrolyzer, etc.); as such, securing financing is indispensable to enhance investments. In the following Section we dive deep into financing of PtX projects.

[4] This assumption is considered optimistic.

5 Financing of PtX projects in non-OECD countries

As PtX projects are very capital intensive, in the absence of financing appetite, PtX projects will simply not ramp up, as there are very few investors with sufficient funds to finance the project entirely with equity. For equity providers to invest, the leverage must be relatively high. For example, considering only large-scale RE, leverage between 60% and 80% of total CAPEX is usual. In other words, the debt provider typically contributes between two and three times the amount contributed through equity.

Hence, for investments in PtX to ramp up, it is necessary that financial institutions are willing and able to finance the projects in such leverage levels and for relatively long tenors as required for the project to be financially feasible.

PtX projects are long term investments. Once the project reaches Commercial Operation Date (COD), the profitability calculations assume a long-term period (at least 20-25 years for PtX projects). In this sense, any change on the conditions that determine revenues[5] (e.g., regulatory framework, default of off-taker), has a significant economic impact on the return on investment (ROI). Ultimately, revenue risk can push the developer to a situation of default due to the impossibility of servicing the debt.

Therefore, investors care about their return, but in combination with the risks assumed. It therefore seems clear that the main concerns of investors depend on the business model, as several factors can fundamentally alter cash inflows. In this sense, we distinguish two main models:

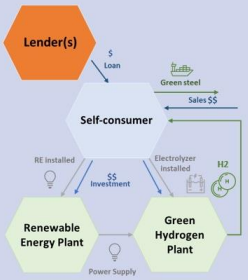
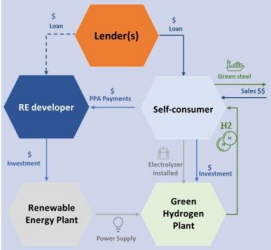
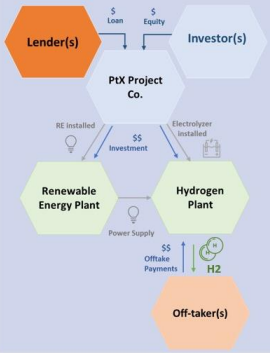
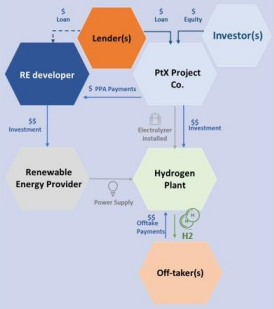
- "Captive Model": PtX produced in large scale on site for self-consumption (i.e., to serve as feedstock to petroleum refining, ammonia, and methanol production, among others).
- "Merchant Model": PtX produced in large scale for sale (i.e., shipped and sold as gas or liquid).

In addition, given the segmented value chain of PtX projects (RE, electrolyzer, conversion, storage/processing, shipping, use), investments can be bundled (under one Engineering, Procurement, and Construction -EPC- contract) or can be separated into several projects (with different borrowers and financing mechanisms). It is essential that investors have access to the financing suiting their specific needs.

Considering the above, the Figure below segments the business models in four main alternatives:

[5] When the return on investment depends on a third party, a government, or a private offtaker, what causes the most uncertainty for investors is the potential risk that cash inflows are lower than expected.

Figure 7: Business Models of PtX production

Business Model	1. Captive Model		2. Merchant Model	
	1.1. Bundled	1.2. Unbundled	2.1. Bundled	2.2 Unbundled
RE Plant Owner	Self-consumer	RE Developer	PtX Developer	RE Developer
H2 Plant Owner		Self-consumer		PtX Developer
H2 Consumer			Off-taker*	Off-taker*
Schematic of business model				
Overview	Green H2 consumer invests in both RE and H2 plants	Green H2 consumer invest only in H2 plant but signs a PPA	PtX developer invests in both RE and H2 plants	PtX project is split in 2 SPVs: H2 plant and RE plant
Finance Scheme	Corporate debt, equity and/or grants (Total CAPEX)	Corporate debt, equity and/or grants (only green H2 CAPEX)	1.1 + Project finance**	1.2 + Project finance**
Example	E.g., a Steel maker invests in a PtX plant for self consumption (to produce green steel).	E.g., a Steel maker invests in a H2 plant for self consumption (to produce green steel) powered via a solar PPA.	E.g., a PtX developer exports gaseous H2 from North of Africa to Europe via gas pipelines	E.g., H2 plant powered via PPA with a RE provider. The Green H2 will be sold to an offtaker.

Notes: * Off-takers can be domestic or foreign (export) customers
** Project finance availability is highly dependent on cash flow predictability, hard currency and off-taker's creditworthiness, among others

(Frankfurt School-UNEP Centre Analysis)

Textbox 1: Mechanisms to enhance bankability of PtX projects

To ensure project bankability, stable and predictable cash flows backed by offtake agreement(s) with (a) creditworthy party(ies) are essential. One of the main challenges therefore lies in determining a stable and predictable pricing mechanism in the medium and long term.

The most important thing to bear in mind is that any type of measure that involves "short-term" guarantees or immediate assurances is totally unsuccessful in attracting investment in this field, precisely because, in order to make them profitable, it is necessary to reduce the greater risk associated with the cost of capital (considering a 20–25-year investment lifetime).

Worldwide, there is no single methodology but rather there are different formulations associated with each market, each financial system and each regulatory environment (e.g., the former pricing and incentive systems for RE have varied including Feed in Tariffs, Feed in Premiums, tax credits, Renewable Portfolio Standard, etc.). For example, the recent Inflation Reduction Act (IRA) in the US introduces a tax credit of up to $3 per kilogram clean hydrogen production. Thus, the regulatory context is also a driver of profitability; for example, the following options have a direct impact on project attractiveness:

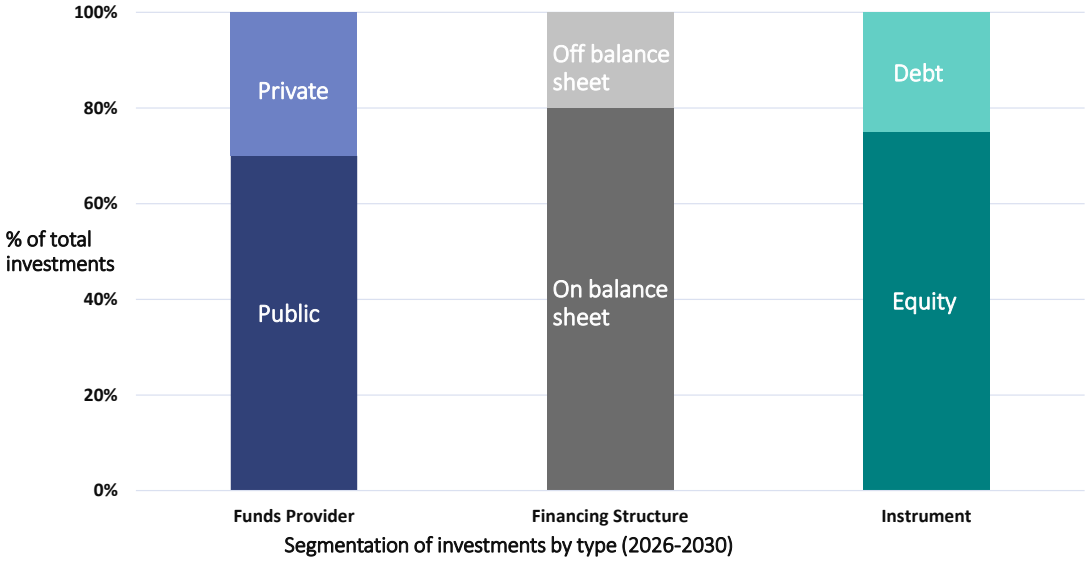
1. Ability to sell excess RE to the grid
2. Ability to sign Power Purchase Agreements (PPAs) with third parties (in hard currency)
3. "Wheeling[6]" of renewable electricity from optimal wind and PV sites

For new capital-intensive projects such as PtX, project finance will play an important role, provided that there is certainty regarding business models and cash flows. In the shorter term, on-balance sheet financing with equity from large players combined with public funds will be the norm. Indeed, ramping up PtX projects will require an initial reliance on public funding and financial incentives, such as tax breaks or revenue guarantees (IEA, 2022). Finance from development finance institutions, including concessional funds and guarantees, play an important role in supporting first-of-a-kind projects in developing countries (Kane & Gil, 2022). As commercialization models become clearer, export credit agencies and larger institutional investors may emerge as sources of finance for projects of larger sizes, underpinned by project finance structures and long-term offtake agreements (IEA, 2022).

[6] Wheeling refers to the supply of RE from a generator to an offtaker located in another area.

The availability and characteristics of the financing are very much project and country specific. However, some general conclusions can be drawn. IEA analysis shows that in the short term the type of financing structure will tend to be on-balance sheet, with important participation of state-owned enterprises (SOEs) and public finance institutions and funds, with a higher contribution of equity/grants than debt. For sake of clarity, on-balance sheet items are defined as assets or liabilities that are recorded on a company's balance sheet and, thus, can affect the financial overview of the business and its covenants, while off-balance sheet items, however, are not considered assets or liabilities as they are owned or claimed by an external source, and do not affect the financial position of the business.

Figure 8: Segmentation of financing of green hydrogen investments



(IEA, 2022)

Textbox 2: Project status and segmentation – Example Brazil

As per the research of existing projects, one can note the extreme differences in capacities of the proposed projects: pilot (<10MW), small/medium (10-100MW) and large (>100MW).

For the first, we expect funding to be raised by innovation grants and internal R&D budgets, which are supported by government regulations, e.g., Brazil's FINEP innovation grant (FINEP, s.d.) or ANEEL R&D Law (Canal Energia, 2022).

For the second ones, we expect the project will be focused on one (or few) captive customers, located close to the PtX project, financed on-balance sheet or, depending on the guarantee schemes, on a project finance structure. The Brazilian Development Bank has launched in June 2022 a special credit program for green hydrogen projects, covering up to 80% of the CAPEX, i.e., max BRL 300 million or approximately US$ 57 million (BNDES, 2022).

For the third group, we have seen those being announced by foreign companies, focused on green hydrogen and PtX exports. However, given the sheer amount of CAPEX and installed capacity, we see the need for a more structured approach, dividing the projects into scopes and eventually obtaining different financing packages for each scope. As indicated previously, projects of larger sizes are underpinned by project finance structures and long-term offtake agreements.

It is essential that investors have access to the financing suiting their specific needs. The financing terms to undertake the construction of the PtX project vary greatly from project to project (and country to country), but there are usually some common denominators:

- Interest rate: spread plus the variable reference interest rate (either EURIBOR[7] or LIBOR[8]), sufficiently low to make the investment profitable for equity providers (positive NPV[9]).
- Tenor: sufficiently long to reflect the lifetime of PtX projects and enabling repayments.
- Leverage: Indebtedness high enough to cover CAPEX needs, e.g., around 70% of the total funding requirements.
- Guarantees: project finance requires that during the construction period there is recourse to the shareholder. Technology guarantees needed (as PtX projects are relatively new, financial institutions are conservative).

The financing structure will depend on the nature of the specific project, as each project has unique risks, considering:

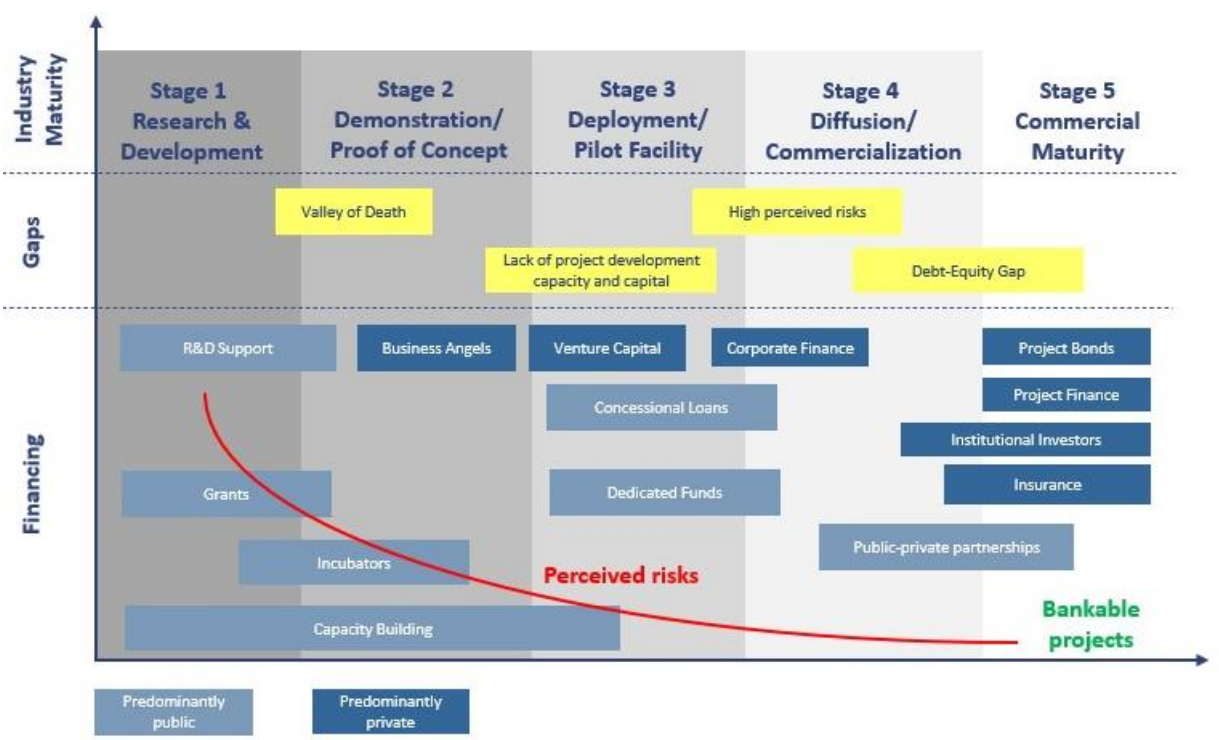
- Business model (captive/merchant) and use case (as a replacement for natural gas in power generation, as energy storage, as heat supply for industries, for the transport sector, etc.).
- Participation of the various parts of the value chain (production, transport and storage, and end use).

In addition, the financial alternatives differ depending on the project stage. During early development, projects carry a significant risk that is reduced only once all permits have been secured and the legal, operational and financial viability has been demonstrated. Although the investment requirements are modest in the initial stages, third-party financing is usually not available. This leaves the financial burden to project developers, who are often poorly capitalized and unable to fully develop projects on their own. However, after the development phase, risks are significantly lower (bankability is enhanced) and more financial alternatives are available.

The figure below includes an indicative mapping of different financing instruments that could be used for funding projects in different industry maturities, from R&D stage to commercial maturity. It is important to highlight that below figure is not intended to be an exhaustive account of the possible financing instruments but only indicate the different possibilities depending on the perceived risk.

[7] Euro Interbank Offered Rate - the basic rate of interest used in lending between banks on the European Union interbank market and also used as a reference for setting the interest rate on other loans.
[8] London Interbank Offered Rate - the basic rate of interest used in lending between banks on the London interbank market and also used as a reference for setting the interest rate on other loans.
[9] Net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. It is used to evaluate if a project is accretive or not to the business.

Figure 9: Mapping of Financing Instruments



(Frankfurt School-UNEP Centre)

Depending on several factors, e.g., country, technology, end-use, and so on, we may assume a different maturity to the PtX industry. Given the criteria of relevant projects set by H2Global (over 10MW electrolysis capacity and FID reached), one can affirm such projects would happen from Stage 3 onwards. In the following paragraphs we describe the most feasible financing alternatives for such PtX projects.

5.1 Corporate Finance

It refers to the request for debt with the financial statements of the company as collateral. Then the company is liable for its repayment based on the value that the lenders grant to the company, so that the total equity is compromised. For this reason, we refer to “on balance sheet financing” or "full recourse", since it is the entire company that ends up being liable in the event of a possible default on the debt. The borrower should be willing and able to use corporate financing, as follows:

- Ability: only companies with very solid financial statements and a large size would have access to the debt that a PtX project usually needs.
- Willingness: as the debt required is high and it would affect the indebtedness of the company (and the risks), many companies are not willing to opt for this option.

For many PtX project developers, access to corporate debt is not an alternative. Only large companies with strong revenues in hard currency, such as oil, mining or steel companies would be able to obtain a USD/EUR denominated corporate loan. Another possibility would be a large utility company with a regulated monopoly with power to transfer cost to end users.

5.2 Project Finance

Financing against the project means that the financial institution lends cash against the guarantee of the project cash flow generation in the future. For this reason, we refer to “off balance sheet financing” or "no/limited recourse", as repayment is based on the cash flows generated by the PtX project, without additional guarantees from the developer, even in the worst predictable cases, technically or economically, that could occur in the project. Project finance will be needed to ramp projects of large size, as it allows for long-term financing (typically up to 20 years) and high levels of leverage (in many cases up to 80% of the total investment required). However, it is also a complex, expensive and time-consuming financing alternative.

5.3 Public-Private Partnerships

A partnership can be formed in different set-ups among public and private entities. One common set-up is the Joint Venture (JV) which is generally characterized by shared ownership, shared returns and risks, and shared governance. JVs are an increasingly popular form of business partnership on renewable energy projects and play a key role in the energy transition process. Recently, the green hydrogen landscape has seen major joint ventures, both in developed and developing economies. For example, in India, the government-owned Indian Oil Corp (IOC.NS), the country's top refiner, the private businesses Larsen & Toubro (LART.NS) and ReNew Power will form a joint venture to develop the green hydrogen sector. The three companies have signed a binding term sheet to jointly develop green hydrogen projects (Verma, 2022).

5.4 Investment Funds specialized in green hydrogen

Such vehicles invest in PtX projects and companies, mainly in the form of equity. IEA highlights six such funds, traded publicly and launched since the start of 2021 (IEA, 2022). They are already worth over USD 0.9 billion, including the HydrogenOne Capital Fund, which is backed by Ineos and has invested in Doosan Fuel Cell and unlisted companies Sunfire and NanoSUN. A larger fund, the Clean Hydrogen Infrastructure Fund, which is not publicly traded, closed its first round of fundraising at USD 1.1 billion in January 2022 and has since raised a further USD 0.4 billion, including from the Japan Bank for International Cooperation, France’s public reinsurer (CCR), and anchor investors Air Liquide, TotalEnergies and VINCI. It has so far invested around USD 0.2 billion in start-ups such as Hy2gen and two hydrogen projects.

5.5 Project Bonds

At times when project finance is not easy to obtain in the banking market due to its illiquidity, the alternative of project bonds has arisen. This type of financing requires stable and proven cash flows and no construction risk, admits higher amounts of debt and allows the realization of the value of the project. A credit rating of AAA is required. For example, Plug Power Inc., a US hydrogen fuel cell provider, launched a convertible green bond offering to fund its hydrogen strategy in the US in May 2020, highlighting a potential addressable hydrogen economy market valued at US$ 2.5 trillion (roughly € 2.31 trillion) in their bond launch presentation (Baker, 2021). In March 2021, Northern Gas Networks also tapped into the green bond market to fund their hydrogen transition, launching a £ 1 million (roughly € 1.12 million), 1.6%, 10-year green-transition bond alongside Abundance, a UK crowdfunding platform. In France, Air Liquide raised € 500 million with a significantly oversubscribed 0.461%, 10-year Green Euro Medium Term Note.

5.6 Concessional Financing

Concessional finance is finance below market rate that is offered by DFIs, often in collaboration with multilateral funds and/or governments, to developing countries to accelerate development objectives. The term concessional finance does not mean a specific or single type of financial instrument but covers a range of below market rate products used to accelerate climate or development objectives. Examples are loans, grants, equity investments, and first loss guarantees.

6 Experiences of PtX Projects in non-OECD countries

The present study gathered practical experiences of PtX project developers about challenges and success factors of PtX financing in selected non-OECD countries. Also, existing financing instruments offered by development finance institutions for PtX projects in those countries were identified and analyzed. Finally, the requirements of commercial banks for the financing of PtX projects have been surveyed.

6.1 Pipeline of projects in non-OECD countries

More than 680 clean hydrogen projects (with a rated capacity of at least 1MW and a total investment volume of over US$ 240bn until 2030) have been announced recently, but only projects worth US$ 22bn have reached financial investment decision (FID) or are under construction or operational. By far the biggest share of those projects is located in OECD-countries (McKinsey, 2002).

The eligibility criteria for this analysis – a rated electrolyzer capacity of at least 10MW, location in non-OECD countries, FID reached - are met by only 18 projects globally according to the latest IEA hydrogen project database (IEA, 2022). Out of these 18 projects, only 6 are located outside of China. This means that the **number of projects qualified for the analysis in this report is extremely limited.**

Interviews have been conducted in Brazil, India, Morocco, Paraguay, Saudi Arabia and Uruguay for at least one hour, with a view to provide sufficient time for discussing the questions while not overstraining interviewees time. All interview partners were informed of the purpose of the study and that their company names will be kept anonymous, if desired.

One common observation is that interview partners were very open to discuss generic financing questions and were able to disclose information on the overall project structures (e.g., installed capacity, electricity sources, planned utilization of PtX) and project/financing partners. Not all of them, however, were able to disclose detailed financial information such as IRR, cost of debt etc. More details can be found in the following sections.

6.2 PtX project developers' point of view

The interviews show the diversity and variety of challenges PtX project developers face. To find the commonalities and differences, a semi-quantitative analysis of responses was conducted by categorizing and counting the key challenges and success factors named by the interviewees. It needs to be considered, however, that the limited number of interviews does not allow for statistically significant evaluations.

6.2.1 Perceived risks and barriers

The key challenges named by interviewees are related to:

1. Project feasibility relies on a combination of many variables, such as infrastructure availability, competitive electricity price / power-purchase agreement (PPA) / RE-energy potential, water availability, existing technical know-how of service providers
2. Availability of required equipment and guarantees on its performance
3. Geopolitical situation impacting cost- and price structures,
4. Lack of reliable off-takers being willing to pay a premium for 'green' products, and
5. Regulatory uncertainties in the EU as a key export market and harmonized global standards regarding carbon intensity of low-carbon hydrogen (uncertainty regarding eligibility of a product to meet RED-requirements or be considered as a 'green' fuel)

The first aspect is likely the most relevant one, because a robust investment analysis is the foundation for finding financial structures and partners to get engaged.

6.2.2 Success factors

Consequently, the key success factors for PtX projects are:

1. Finding a good project design in a favorable environment (infrastructure, electricity price / power-purchase agreement (PPA) / RE-energy potential, water availability, technical know-how of service providers), allowing project developers to derive a bankable business model.
2. An attractive investment case (IRR; NPV) is pre-condition for mobilization of required finance,
3. Likewise, solid PPAs and off-take-agreements are key for successful projects;
4. De-risking of technology risks in the PtX-context, e.g., by guarantees from technology providers, insurances or export-credit-agencies;
5. Availability of PtX-relevant infrastructure as required in the project context, e.g., pipelines, PtX-terminals.

6.3 Development Finance Institutions

Suitable financial instruments to support PtX projects include a wide range of mechanisms: on the one hand, governmental funding instruments, and on the other hand, mechanisms offered by financial institutions:

1. Governmental instruments such as subsidies, tax incentives (e.g., US Inflation Reduction Act), and contracts for differences or auction mechanisms (e.g., H2Global), among others
2. Financial products such as (partial) grants, fund structures, first-loss guarantees, revolving concessional loans, risk mitigation instruments, project finance, insurances, among others.

The focus of this report the latter in which the **role** DFIs play, supporting private sector development in emerging and developing countries, is **highly important** as can be seen from many years of financing renewable energy projects. Mostly publicly owned, DFIs offer different instruments that help **de-risking projects to make them bankable** or provide financing instruments **helping project to reach Final Investment Decision (FID).**

To complement the status-quo inventory of suitable funding instruments for PtX-projects, seven DFIs were approached for structured interviews. The questions addressed the following key aspects of PtX financing at DFIs:

- Existing financing instruments for financing PtX projects (or parts of it), cost of debt
- Scope and eligibility criteria
- Experience of those instruments with PtX so far (if any)
- Any planned new instruments at DFIs
- General experience regarding PtX projects

Common observation are that DFIs:

- Seem to be highly interested in helping to fund green PtX projects, not only investing in the production of PtX products, but also financing the complete PtX supply chain.
- So far have very limited practical experience with specific PtX-funding (due to the early market stage and limited number of funding requests), as a matter of fact, none of the DFIs interviewed, has invested substantial amounts yet.

- While most DFIs intend to apply the same funding instruments to PtX projects as they apply to renewable energy and other infrastructure projects, few of them intend to create specific funding instruments with subsidized rates (knowing the difficulty to ramp-up the PtX market).
- DFIs typically combine different funding instruments and financing sources to a single project; in particular if larger funding volumes are required.
- All of them have been approached by governments or project developers and have various PtX projects in their pipeline (mostly for pre-feasibility studies) but only three DFIs have already gotten involved in financing those, mostly through grants.
- Most of the interviewed DFIs have launched dedicated PtX-working groups, which shows the perceived importance and lack of understanding of this emerging working field. Only two of the DFIs have jointly channeled grants to a pilot project in South Africa.
- Also, many of them have not yet decided if they will support exclusively green PtX projects or if they would also explore other low-carbon PtX opportunities.

6.3.1 Perceived risks and barriers

The main barrier for the interviewed DFIs in order to get involved in large-scale investments in green PtX projects is the very limited number of actual projects in non-OECD countries. All of the interviewees perceive the **incipient governmental support in non-OECD countries** as one of the main barriers for a substantial ramp-up of green PtX technologies. Five of them see the **high costs of the current technologies and especially the substantial CAPEX** as one of the main hurdles to achieve cost parity with fossil fuel-based hydrogen derivates. Therefore, all DFIs see signed long-term offtake agreements (in the best case with floor prices) as one of the main criteria in order to access their financing instruments since they are not willing to take market risks. This shines light on one of the biggest issues regarding a global ramp-up of those technologies since **DFIs are not willing to invest in projects without offtake agreements** and most off takers are not willing to sign long-term contracts without the respective project having reached financial investment decision ("chicken and egg situation").

Another important point mentioned by four of the interviewees is the **missing regulations and globally accepted standards regarding import criteria and fixed definitions of low-carbon hydrogen** in target markets like the EU. Without those regulations and standards in place most project developers are reluctant to channel big investments in PtX-projects. Two interviewees mentioned the **missing local competences to deal with new technologies, and limited availability of large-scale project finance in non-OECD** as additional hurdles. Also, the risk-aversity and the missing "venture-capital" spirit in regions like the EU are hampering a substantial scale up. Interestingly, the **lack of demand for green PtX products** was only mentioned by one interviewee as a main hurdle.

An additional issue that has to be addressed during the implementation of PtX-projects in non-OECD countries is – according to some interviewee – the **risk of exploitation of those countries**. If PtX projects are implemented with imported technologies by foreign investors with the objective to export the PtX products to developed countries, there is the risk that it results in little domestic benefits. Some interviewees explicitly mentioned the **relevance of SDG criteria**, meaning that projects with local benefits – such as job creation, local technical development, local emission reductions etc. – may get a higher ranking (but details are yet unclear).

6.3.2 Success factors

For a successful ramp up of PtX investments, the risks and barriers identified (and summarized above) need to be addressed. All DFIs offer very similar financing mechanisms including concessional/non-concessional loans and guarantees. Two of the DFIs also offer equity investments. The usual investment volume ranges from approximately US$ 20-150 million with one DFI doing financing of up to US$ 1.5 billion. Loan durations normally range from 10 to 20 years. The major success factor for securing financing by DFIs is, first of all, **a bankable business plan with long-term offtake agreement/s in place**. Ecological and social criteria have to be considered and must be met, documented, and monitored. In addition, the project alignment with the Paris Agreement and its **contribution to the SDGs** is increasingly a pre-requisite for DFI financing. **Strong governmental support and solid public institutions** further enhance potential funding applications.

6.4 Commercial Banks and Financial Investors

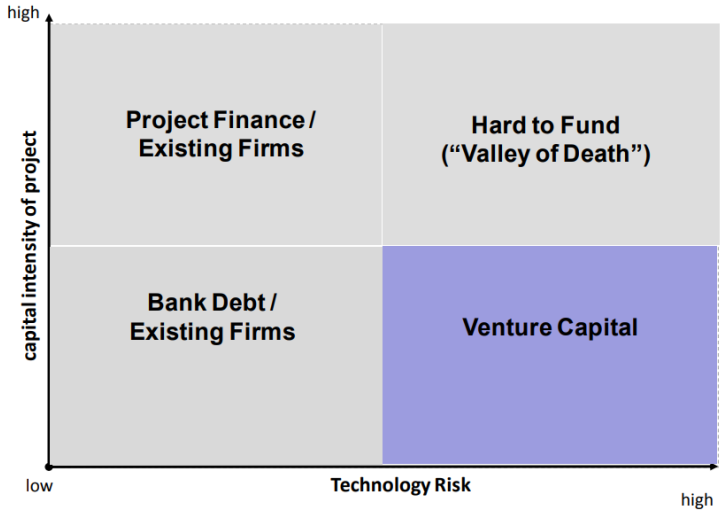
The most common way for commercial banks to get engaged in financing of large-scale projects is through classical project financing or through corporate financing, or a combination of both:

- **Project financing** by commercial banks typically means that that the bank lends cash (debt) to the project developer with the view that debt can be repaid over time by the project's cash flow generation in the future. Hence, only the **project itself is used as a guarantee**.
- In **corporate financing**, the borrowing company as a whole takes liability for debt repayment. In this case, the financial situation of the borrower will be assessed by the bank ("**on balance sheet financing**"). That means that for small companies, it is more challenging to get large-scale loans required to finance large infrastructure project such as renewable energy- or PtX-projects.

In both cases, commercial banks aim to mitigate default risks. Key project related risks are:

- Technology risks – i.e., new technologies are considered higher (default) risk;
- Market risks – in particular in new markets, such as PtX, where supply and demand patterns and, hence, prices and volumes are not yet established;
- Country specific risks – includes risk of asset expropriation by government of the country the project is located, political interference, and legal uncertainty, etc.; and
- Geopolitical risks – e.g., global commitment for ambitious climate targets and willingness to accelerate transformation of energy systems.

Figure 10: Access to different financing types of projects, depending on risks and capital intensity



(Ghosh & Nanda, 2010)

Both renewable energy projects and PtX projects are capital intensive. For renewable energy projects, the technology risk was perceived high in the early 2000s (with resulting financing challenges and high-risk premiums), but today is considered low to medium for most RE technologies. In line with this, more private sector financing options became accessible over time and financing conditions for large-scale RE projects have improved dramatically since then. OECD estimates that the share of project finance in new RE-investment increased from 16% in 2004 to 52% in 2015 (OECD, 2016).

In contrast to this, PtX projects rank much lower on the technology readiness scale and yet need to prove their large-scale applicability and reliability. Hence, **risk mitigation measures by public institutions and/or DFIs will be important to de-risk and facilitate commercial banks offering feasible debt conditions to PtX project developers.** During the project, 2 commercial banks and 2 investment funds that already are, or are planning to become active in the field of PtX financing, have been interviewed to understand better perceived barriers and success factors. The questions addressed the following key aspects of PtX financing from their perspective:

- Existing financing instruments for financing PtX projects, cost of debt
- Scope and eligibility criteria
- Experience with PtX financing, perceived risks and barriers
- Success factors

It is important to highlight that none of the interviewed commercial banks and institutions have yet executed a deal with a PtX project in non-OECD countries. The commercial banks have plenty of experience with RE-finance (both OECD and non-OECD), but **none of them has closed a deal funding large-scale electrolyzers or other PtX infrastructure.** As the PtX market in non-OECD countries is in an early stage, opportunities for and practical experience with PtX-project financing for commercial banks still have to evolve.

6.4.1 Perceived risks and barriers

The risks and barriers perceived by commercial financial institutions match well with those perceived by DFIs: **market uncertainties** (cost of production; price and demand volume risks) and **technology uncertainties**. Note that for the latter, concerns seem to focus on **electrolyzer performance and reliability**, not (yet) so much about downstream infrastructure. Hence, it needs to be emphasised that commercial banks take risks related to technology and market situation very serious. This will likely change and expand to a more holistic risk-evaluation once the first real projects apply for funding.

Another key risk addressed by commercial banks is the **immaturity of PtX markets**, i.e., the fact that hydrogen and other PtX products are not yet standardised commodities of trade. This means that each investment is subject to higher off-take and market risks.

6.4.2 Success factors

For enhancing the ability of commercial banks to contribute to the financing of PtX-projects, the following aspects are key:

1. Willingness of one or several parties to take volume and price risks.
2. Mitigation of technology risks by investors and/or technology providers.

Mitigation of volume and price risks

Volume and price risks can be reduced by different market players, each with specific instruments.

Interviewees most frequently called for governmental support, but often without specifying exact means. Classical instruments for governments would be guarantees (first-loss insurance) and/or grants, but also market security instruments mitigating price and volume risks (e.g., by favourable offtake-agreements or mandates for green hydrogen and derivates), but also clear political visions (national hydrogen strategies) and support schemes specifically for PtX investments.

Some interviewees pinpointed to specific instruments, such as the US Inflation Reduction Act, support from export credit agencies (ECA), and price instruments as the one of H2Global.

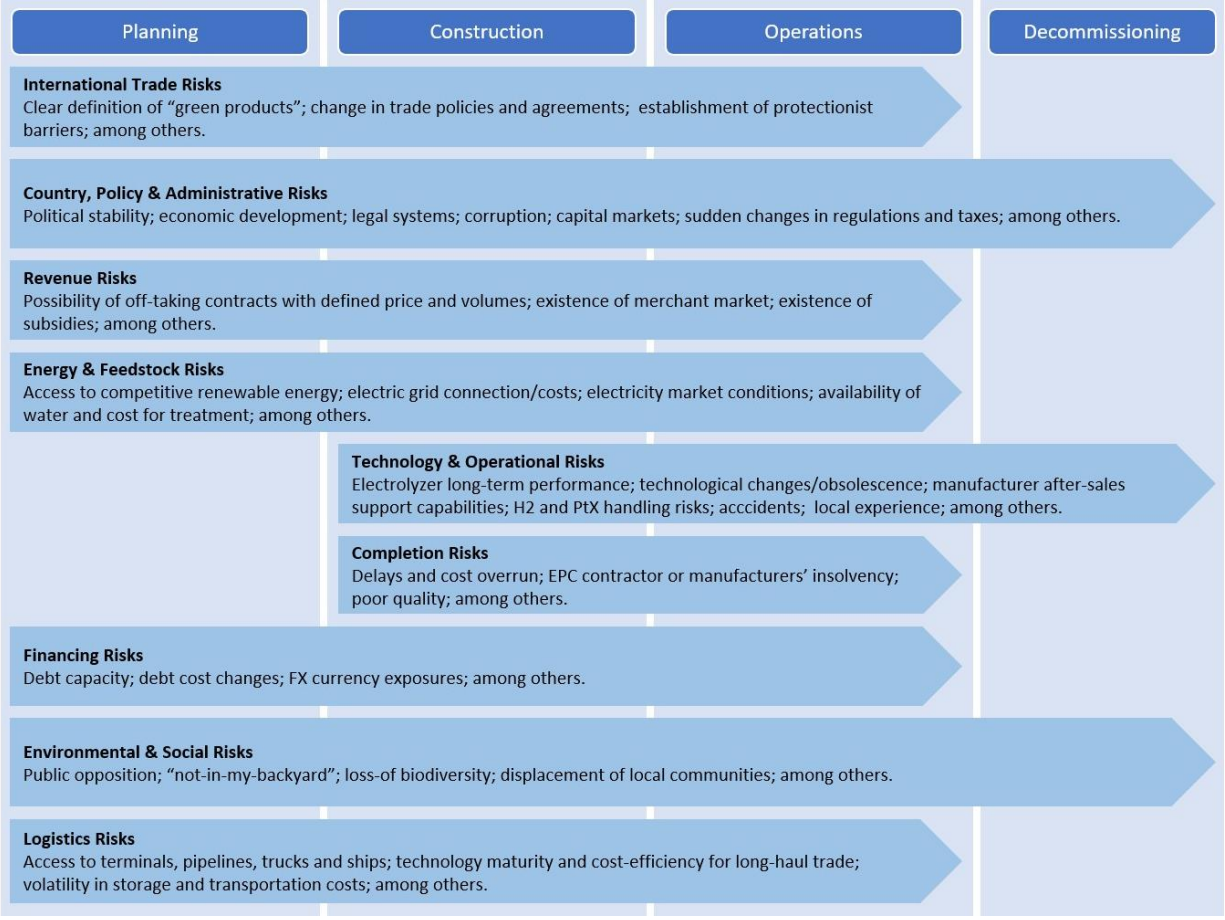
Mitigation of technology risks

A mitigation of technology risks could be partially achieved by guarantees of technology providers; however, they seem not able to provide sufficient comfort to financiers yet. Technology risks can be reduced by different market players, dedicated insurances, governmental securities, and potentially export credit agencies, but those mechanisms seem to be not yet available in the market.

6.5 Assessment of the Main Perceived Risks

Based on the interviews and secondary data regarding risk management, the present study brings a simplified diagram of the main perceived risks and their presence during the life cycle of a PtX project defined in four phases: planning phase (covering the first technical and formal preparation of the project development), the construction phase (covering the construction of the PtX plant), the operations phase (covering operation and maintenance, and depending on the support scheme selling of the PtX product), and finally the decommissioning phase (when the plant should be dismantled and equipment sold/scrapped). For a more comprehensive description on the risks, please see the Annex 1 - "Main Risk Categories".

Figure 11: Main risks for PtX project by project phase (non-exhaustive)



(Frankfurt School-UNEP Centre analysis)

The risks manifest in different ways depending on the specific countries' dynamics; however, one can cluster those risks in three main groups and gather common findings for those countries:

Table 4: Clustering of risk categories and findings from interviews (non-exhaustive)

Group	Risk Categories	Findings from interviews
Institutional Framework	1. Local, Policy & Administrative 2. International Trade	Most respondents highlighted the lack of a global PtX market backed by clear and stable international standards. They also added the need for speeding up local government support to ramp-up projects.
Technical Feasibility	3. Technology & Operational 4. Completion 5. Logistics	The electrolysis supply chain seems to be underdeveloped and not able to deliver all guarantees required by investors and financiers to mitigate technical risks.
Economic-Financial Feasibility	6. Energy & Feedstock 7. Revenue 8. Financing 9. Environment & Social	Competitive RE resources can be found in the selected countries with few differences on the electric sector regulation that may add more risks to projects; however there seems to be a common difficulty among the projects to obtaining these 3 key milestones: PPA, offtake agreement and long-term financing.

(Frankfurt School-UNEP Centre analysis)

Due to the novelty of the PtX industry, it becomes indispensable that these risks are fully or partially mitigated, which depends on the specific business model.

On the one hand, **captive models** are the ones in which the green hydrogen producer and the consumer are from the same economic group. In such a case, we assume the investor would have to rely on corporate debt or grants because the green hydrogen plant economics would be dependent on the financial performance of the final product sales (e.g., steel, fertilizers, etc.) and captive projects tend to be of smaller size (than merchant ones). For those projects, investors should do a make-or-buy consideration if it would be cheaper or less-risky to purchase green hydrogen from third parties as well as to evaluate how feasible is the adoption of green feedstocks in the market it operates.

Merchant models, on the other hand, are the ones in which the green hydrogen producer and the consumer are from different economic groups. In such a case, if the project cash flows are backed by long-term agreements with creditworthy counterparties, and financiers are confident that the project can meet its financial obligations, it is possible that the developer could have a project finance structure in place. For those projects, an analysis on marginal cost of production, compared to other alternatives in the market is necessary to ensure that the plant will be economically feasible through its useful life, even after the offtake agreements expire.

In terms of battery limits of a project, we call **bundled projects** those projects in which other infrastructures, e.g., RE solar plant, transmission line, pipeline, terminals, etc. are also part of the total CAPEX of the project. This type of bundling provides more control to the project developer and operator; however, it significantly increases the CAPEX to be financed by DFIs and banks. If a project is "bundled", this could be a sign that the location of the PtX project is underdeveloped and lacks competitive complementary infrastructure. Conversely, an **unbundled project** is the one that the total CAPEX refers exclusively to the green hydrogen plant, what would theoretically allow more leverage in case the project is well structured. On the other hand, financiers would be keener to analyze the RE PPA agreement and

other logistics service agreements as the plant would be more dependent on third parties. Such a risk can be mitigated if the project is in a country with a competitive and stable energy price and a free market.

Regardless of the case above, the risk analysis must be able to demonstrate to financial institutions that there will be a high probability of debt repayment even in the worst-case scenario.

The risks that are not assumed by the shareholders, or covered by the insurance companies, must be contractually distributed between the shareholders and the contractors. In a renewable energy project, risk-sharing contracts are usually standardized, so that negotiations typically revolve around the details of the risks.

Textbox 3: Necessary conditions and risk perception

It is necessary to distinguish between necessary conditions for PtX investments to happen and risk factors. The former are conditions that need to be fulfilled for investors to consider investing, and the latter are questions that determine their risk perception of the project (and hence their return requirements).

The necessary conditions can be posed as binary (yes/no) questions, including:

- Is there an offtake agreement secured?
- Is the renewable energy secured, e.g., with a signed PPA?

The answers to the above questions are decisive for the bankability of the project and there is no subjectivity involved.

However, risk perception does vary amongst investors, as it depends on their own perspective on project risks, which are sometimes based on subjective questions. Considering that a project is defined as risky if there is a high probability that cash flows are lower than expected, some relevant questions that determine how risky a project is, include the following ones:

- Political risks (very relevant for those investments in less geopolitically stable geographical areas such as some non-OECD countries): what is the probability of default produced by specific government actions?
- Revenue: is the offtake contract long term? Is the offtaker creditworthy? Are there any other revenue alternatives in case the offtaker defaults?
- Energy & Feedstock: to what extent are the renewable energy and water secured throughout the lifetime of the project? If there is a PPA, what is the quality?
- Technology & Operational: is there a performance guarantee? Is the O&M contractor trustworthy?
- Completion: is the EPC contractor trustworthy?

Each investor can answer the above questions differently, as these are not based solely on facts (e.g., years in business) but also on opinions (e.g., the commitment of project partners). In sum, investor expectations are not homogeneous and therefore, the required returns vary between investors.

7 Cost of Capital

In terms of the minimum return (hurdle rate) required by capital providers for a generic PtX project, we estimated the reasonable range for three countries (Brazil, India, and Morocco), as rates cannot be directly observed. The minimum return required by investors for investing in a PtX plant in the specific locations analyzed is directly **dependent on the risks perceived by investors and financiers in these locations**.

Our results show that for the reference PtX project in the three countries analyzed, as expected, WACC in 2022 varied between countries (and between different locations in a given country), **between 4% and 10% (in USD and real terms)**.

For investors to be willing to invest in a PtX project, the expected return of the project should be **above the hurdle rate**. For this to become a reality, several actions could enhance PtX competitiveness.

In terms of revenues, PtX production would need to be remunerated at a price high enough such that investments are attractive for capital providers. Considering the current financing landscape (the WACC indicated above, determined by the cost of debt and required return to equity, and debt/equity ratio), the price needed to remunerate the green hydrogen is currently not provided by the market. In other words, in many cases **green hydrogen investments are not cost-competitive in the absence of incentives**.

Conversely, given the current green hydrogen prices, on the cost of capital side, there is a gap between the current financing conditions and risk-return required, and the needed (lower) cost of debt and required returns on equity to enable PtX ramp up. In this sense, **actions to reduce risk perception are essential** (capacity needs assessments, including recommendations and upcoming capacity building to enhance local national capacities to better serve investments embedded into the national contexts, insurance instruments, aligning expectations, TA activities, supporting financing institutions, etc.).

8 Conclusions

Through the present study, the following conclusions can be derived:

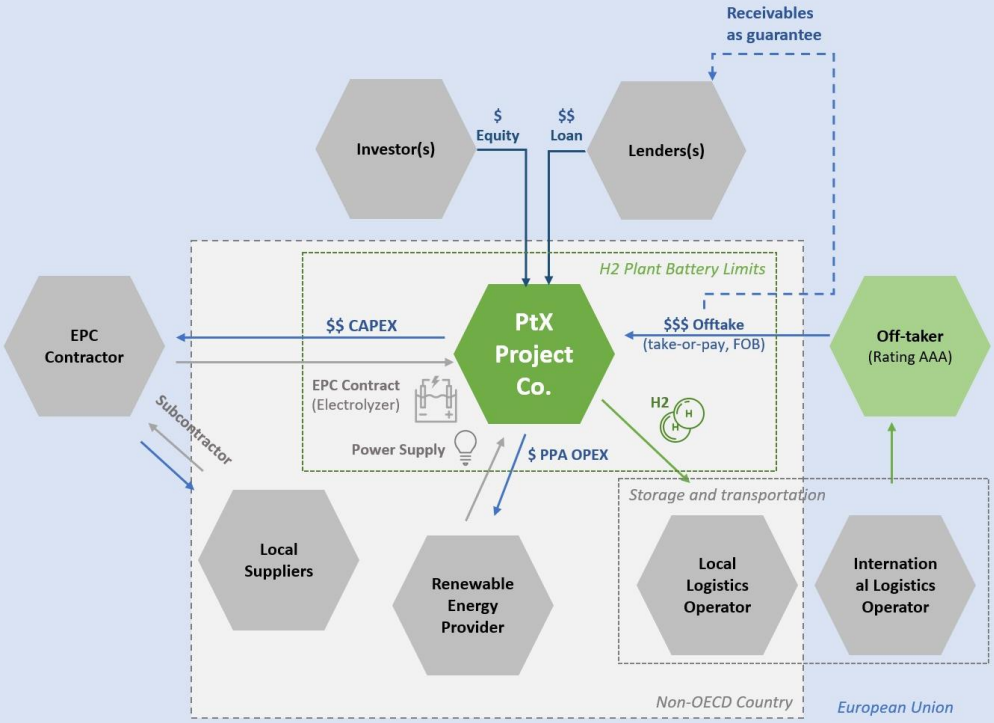
- **The main perceived barriers by the investors and financiers revolve around the nascent stage of the green PtX market**. On the demand side, uncertainties around prices, regulations and standards seem to limit the appetite of buyers to commit with long term offtake agreements. On the supply side, we note an apparent squeeze on the key equipment suppliers who are unable to commit with firm delivery deadlines and to provide technical guarantees, and a latent risk of technological advances that could make current technology not competitive. Another very important risk factor is the transportation and logistics of the green PtX products, which several investors might be reluctant to absorb. Those are basic points that must be solved before a PtX project is able to be financed under a non-recourse project finance scheme.
- **Indeed, in today's market uncertainties, the key success factor for any PtX-project is to find a project design in a favorable environment (considering location, technology, electricity prices, infrastructure availability, product – e.g., H_2, ammonia – and secured offtake agreements) that results in a viable business model**. A viable business model is a necessary condition for mobilizing third-party financing.
- **Which financing instruments are required and available, and at which conditions is very project specific. Also, strong governmental support is a key success factor, and availability of instruments to de-risk investments – such as first-loss guarantees from DFIs.** Such instruments would give more confidence to commercial debt providers on the repayment capacity of the projects. Another example are concessional loans and grants; such instruments can enable investors (equity providers) to attain the minimum required return to make the project attractive to them. For first mover projects (with relatively high risk perception and high CAPEX), such instruments are needed. In a second stage, with a track record of PtX projects, the participation of additional financiers will be enhanced as project bankability improves.
- **In this sense, all interviewed DFIs are open to – and highly interested – to get engaged in PtX-financing.** They will likely apply the same financial instruments and similar criteria/conditions as in the case of 'pure' renewable energy project finance. As of today, they have gained extensive experience with RE finance and appropriate risk mitigation measures and instrument blending. They will probably apply a higher risk ranking to PtX projects due to limited market experience and prevailing market and political uncertainties, but relevant structures and processes exist, which is a key difference to RE finance 20 years ago.
- **However, commercial banks so far had less exposure to PtX-project financing requests; even if these financiers are also interested to get into PtX financing, none of them has financed a PtX project so far.** Commercial banks naturally look at PtX financing from a commercial point of view and appear more risk averse than DFIs and project developers. One can expect this to be reflected in their terms and conditions for PtX-finance.
- **There are two key types of PtX project developers: large corporates and classical project developers**. Large corporates (e.g., governmentally owned) in some cases have solid governmental backing and can finance the projects 'on balance sheet', whereas classical (smaller) project developers very often lack sufficient own funds to fully finance the projects and, therefore, access to suitable financing instruments and governmental support is more critical.

- **The first projects may not be fully non-recourse and may require guarantees from sponsors capable of bearing risks on the supply and demand side**. It is probable that first movers are companies which develop green PtX to decarbonize its operations (e.g., ammonia manufactures, fertilizer plants, steel mills, etc.). In terms of funding options, concessional loans, grants, and corporate debt are the most usual, although these options may not be the most adequate for larger size projects.
- **For larger size export-oriented projects, we see many announcements, but none has achieved FID because the pre-conditions to achieve bankability are very hard to attain under the current landscape.** If those pre-conditions are achieved and the project is de-risked enough to be funded through non-recourse project finance, our understanding is that cost of capital itself should not be much different from other large infrastructure projects. On the equity side, we even believe that several players may be willing to accept lower returns on investment to be the first movers in the green PtX market.
- **Return requirements are not observable and are investor and project specific (the higher the risk, the higher the required return), so we have asked investors about their risk perception and required returns.** Results show that for OECD countries the real required return on equity tends to be single digit, whereas in non-OECD countries, equity providers apply a "risk premium" which results in double digit required return in many cases. For investors to be willing to invest in a PtX project, the expected return of the project should be above the hurdle rate. For this to become a reality, several actions could enhance PtX competitiveness.
- **Lack of reliable long-term off-takers being willing to pay a premium for 'green' products (optimally with a floor price), and the fact that hydrogen and other PtX are not yet standardized commodities of trade are the main barriers hindering PtX ramp-up.** PtX production would need to be remunerated at a price high enough such that investments are attractive for capital providers. There is still a gap between the price needed to remunerate the green hydrogen that is not currently provided by the market. In this sense, instruments such as H2Global can have a catalytic effect on the market.
- **In addition, actions to reduce risk perception are essential to lower the cost of capital** (capacity needs assessments, including recommendations and upcoming capacity building to enhance local national capacities to better serve investments embedded into the national contexts, insurance instruments, aligning expectations, TA activities, supporting financing institutions, etc.)
- **Project developers and financiers would greatly benefit from a 'global PtX-finance knowledge hub' that supports with know-how and information on financing options for a PtX-project regardless its location**. If all such information is centrally collected and made available to PtX project developers and financiers, industry ramp-up can be expedited and transaction costs can be reduced significantly. Such „knowledge hub" can include relevant information such as:
  - Overview of governmental and regional PtX support (host country/region of project)
  - Overview of DFIs active in the region, and their PtX-specific offerings
  - Overview of commercial banks with interest/experience in PtX, and their PtX-specific offerings
  - Overview of private PtX-funds offering PtX-financing
  - Overview of public and private support schemes for green PtX, such as the US hydrogen tax credit, the H2Global instrument, etc.

Textbox 4: Bankability issues of PtX projects

To detail some of the take-aways, we have defined a PtX reference project, as follows: an industrial investor, local or international, plans to develop **PtX Project Co.** a project company that will procure renewable energy from a local provider (e.g., trader, utility, etc.) and will produce green hydrogen exclusively to export. To build the electrolysis plant, PtX Project Co. plans to hire a consortium formed by a European electrolysis specialist and a local civil engineering company. The investors plan to use a combination of equity and debt to finance the project and seek a non-recourse (or limited resource) long term finance. This merchant PtX project focused on exports is illustrated below:

Figure 12: PtX Reference Project (Merchant Unbundled)



(Frankfurt School-UNEP Centre analysis)

Considering the above case, there are key bankability issues to consider, which are listed below.

Table 5: PtX Project Co. Bankability Sheet Exercise (non-exhaustive)

Main Cash Flow Elements	Project Features to be Designed	Bankability Issues
Revenues (USD/EUR)	▪ [xx years] take-or-pay offtake agreement; ▪ a [xx credit rating] buyer; ▪ [fixed/floating price]; ▪ and [price adjustment mechanism]; ▪ [fixed or flexible] volumes; ▪ [xx%] of plant capacity committed; ▪ [cost, insurance, freight] or [free on board].	▪ Key to have certainty about price and volumes. ▪ Logistic is a key risk and it is likely to be outsourced to a specialized company. ▪ Logistics risk should be contractually addressed in a way that ultimately it is allocated to the party with more capacity to handle it. ▪ Tenders, such as the H2Global recently announced could help a lot answering some of those questions.
CAPEX (USD/EUR)	▪ Electrolysis technology; ▪ Supplier's track record; ▪ Onsite construction; ▪ Contract model.	▪ Most of the unknown risks come from electrolyzer providers. ▪ EPC lump sum certain date contracts, as well as technical insurances, could help reduce interface risks.
OPEX (Local Currency)	▪ [xx years] RE Power Purchase agreement; ▪ [xx%] of CAPEX on plant operations & maintenance.	▪ OPEX currency mismatch with other cash flows could be addressed contractually. ▪ Availability of local technical staff and capable suppliers is key for operational success.
Debt (USD/EUR/Local Currency)	▪ [xx years] long term [non-/limited] recourse finance; ▪ [xx %] of CAPEX; ▪ [xx %] interest rate; ▪ Covenants and guarantees.	▪ Project analysis to ensure its cash flows able to repay debt. ▪ DFIs may provide competitive concessional loan but process could be cumbersome, while commercial banks may require credit enhancement from DFIs. ▪ Typical guarantees would be offtake receivables, performance, while covenants are debt service coverage ratio, among others.
Equity (USD/EUR/Local Currency)	▪ [xx%] return on equity; ▪ [xx years] payback; ▪ [xx] maximum exposure.	▪ Investors may require higher returns and/or shorter payback period than renewable energy projects. ▪ To reduce exposure size, project might modular, so investment ramp-up progresses in line with commercial development.

(Frankfurt School-UNEP Centre analysis)

Annex: Main Risk Categories

Risk	Description
International Trade Risks Trade barriers, political uncertainties, and regulatory risks	This specific risk refers to the possibility of countries having conflicting policies for green hydrogen which could, for example, hamper projects' competitiveness in the exporting to a specific country (e.g., definition of green PtX, additionality, trade conflicts, etc.). Since there the global framework for green hydrogen is still under development, changes on the criteria and incentives may impact projects' economics.
Local Policy & Administrative Risks Country risk, political, regulatory, administrative and tax risks	Country risk means the possibility of a government entity to fail honoring its obligations or the possibility of such a government suffer political instabilities. Regulatory and administrative risks refer to the possibility of a sudden change in regulations negatively impacting project's feasibility and the possibility of difficulties or impossibilities of obtain the necessary documents and licenses (e.g., environment license, right-of-way, etc.). Last one is the risk of the government change tax levels after project started operations reducing the project's free cash flow.
Revenue Risks Price, volume, market, and offtake credit risks	Due to the inexistence of a global merchant market for PtX products, developers and financiers require long term "take or pay" contracts with creditworthy off-takers or other forms of assuring project's revenues, such as tax incentives, FiT or CfD schemes. These are paramount for the bankability of project finance and its absence imposes great risk to the project in the current stage of the market.
Energy & Feedstock Risks Renewable energy competitiveness, grid and water access risks	Over 50% of the green hydrogen production cost comes from renewable energy, thus, under the project finance structure, it is vital to ensure that energy supply and its price is stable and foreseeable. This can be assured via long-term PPAs, a solid regulatory framework and the availability of a cost competitive grid network. Alternatively, project developers may include the construction and operation of a renewable energy plant dedicated to the PtX project what increases project CAPEX and complexity but can reduce uncertainties about energy supply.
Technology & Operational Risks Technology and operational risks	Although electrolysis is a well-known technology, there is limited track record of its large-scale deployment and of its long-term performance. Also, there are new technologies being developed what could reduce the green hydrogen production costs but not yet field proven. These create some uncertainties on the project's long term operational assumptions, thus, leading financiers to be more conservative offering shorter tenors and asking more contingencies.
Completion Risks Delivery, construction, interface, and operational risks	Delays in the construction process and cost overruns are common impacts but weak construction services can also have impact on the long-term plant performance. These risks are usually mitigated by good project management practices and contractual arrangements between project and contractors. The electrolyzer industry needs massive investments to meet expected demand but faces balance sheet limitations and competitive risks. Miscalculations could lead to financial and operational issues impacting their ability to deliver equipment on time on budget and to provide long term maintenance services to the project. Interface risk is when a project includes several "smaller" projects (RE generation, electrolyzer, storage and transport). There is a risk of schedule/specifications mismatch which can impact total project's cash flow.
Financing Risks Bankability, inflation, currency, multi-project, insurance risks	Financing risk is the risk of increasing financing costs, in particular debt financing costs. These can be caused by a loan that doesn't cover the full lifetime of the project, or interest rates that are not fixed, etc. In some extreme cases, when project cannot find refinance opportunities, it can face insolvency risk.

Risk	Description
	Another important point is the currency risk which occurs when currencies of income streams and refinancing streams do not match. This is specifically severe for countries with volatile currencies. Like the interface risk, multi-project risk refers to the fact that each of these "smaller" projects can have different finance structures and, for some reason, the performance of one part of project could impact the whole. Due to novelty of the large scale electrolyzer plant, insurers may charge expensive fees for the first movers.
Environment & Social Risks Environment impacts, social acceptance, etc.	In medium to large scale projects, negative effects on the environment and the society/communities can occur. Environmental risk can include the loss of biodiversity and or the destruction of natural eco-systems. An example for a social risk is necessary resettlements of households which can have serious negative effects if not implemented properly. The Equator Principles provide a good guidance how to analyze environmental and social risk.
Logistics Risk Storage and transportation risks	Terminals, pipelines, and ships are all high CAPEX investments and, sometimes those are not owned by the project. There is a risk that the cost to storage and transport PtX products from producer to consumer increases and negatively impacts the project's financials. The project can partially mitigate such risks by owning it directly or by signing long-term commitments with infrastructure owners (e.g., leasing, charter, or tolling fees). There is also the technology risk as there are still under development the technologies to handle large-scale H2 and several are still not economically feasible.

(Frankfurt School-UNEP Centre analysis)

References

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