The Flemish industry carbon circular and low in CO_2 by 2050 through the development of marketable innovative technologies in Flanders by 2040

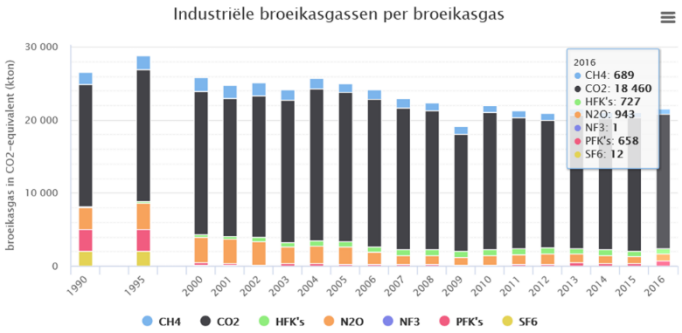
Flanders Industry Innovation MOONSHOT

1. Introduction and Context

On December 12th 2015, 195 countries, including Belgium, committed themselves in Paris to fight global warming by signing the Climate Agreement. The 195 countries recognized climate change as an urgent and possibly irreversible threat to humanity and the planet. Therefore, the greatest possible cooperation between all countries is required. The global objective is to limit the average global temperature increase 'clearly' below 2 degrees Celsius by 2100, compared to the pre-industrial period. Additional efforts will be made to limit the temperature increase even further to 1.5 degrees. Hence, Flanders aims to reduce its own greenhouse gas emissions by 35% by 2030 (compared to 2005). The Flemish government supports the European long-term objective of reducing greenhouse gas emissions by 80% to 95% by 2050 (compared to 1990). Flanders (like the rest of Europe) will have to break with the past and achieve a radical transformation to a climate-friendly and sustainable society.

The transition to a climate-friendly economy and society, in which virtually no greenhouse gasses are emitted, will be a great challenge for Flanders due to its high population density, its high export, its relatively large energy consumption, and the lack of space for the installation of alternative systems. Additionally, the Flemish industry is energy-intensive and highly dependent on fossil-based raw materials. In 2016, the total greenhouse gas emission in Flanders resulted in 77.7 million ton of CO_2 equivalent (Mt CO_2 eq), of which 36% originated from industrial sectors (27.9 Mt CO_2 eq). The energy-intensive industries in Flanders, which are covered by the EU emissions trading system (EU ETS), represented 80% (22.4 of the 27.9 Mt CO_2 eq) of these industrial greenhouse gas emissions in the same year. On a sector level, the refining, chemical and iron & steel sectors in Flanders together represented nearly 90% of these Flemish industrial ETS emissions. Approximately 86% of the industrial greenhouse gas emissions in 2016 originated from carbon dioxide or CO_2. Therefore, CO_2 is acknowledged as the most significant industrial greenhouse gas in Flanders.

In 2016 is 85,9% van de uitstoot van industriële broeikasgassen afkomstig van koolstofdioxide of CO_2.



Bron: MIRA op basis van EIL (VMM)

In 2016 the total Flemish energy consumption was 1232 Peta Joule (PJ). The energy consumption by the industry (both for raw materials and energetic use) was equivalent to 673 PJ or 55% of the total Flemish energy consumption. The non-energetic use (the use of fuels as feedstock) by industry concerned 279 PJ or 22.6% of Flanders' total energy consumption in 2016. The most important fuel sources (both non-energetic and energetic use) for industry were naphtha (165 PJ), natural gas (133 PJ), electricity (94 PJ), other fuels (76 PJ) and coal / coke (84 PJ).

From these figures, it is clear that reducing the energy consumption and CO_2 emissions by energy-intensive industries in Flanders, as a contribution to the European climate objectives, will be a major challenge. The only road to success is a radical transformation to smart use of carbon in industry and society. Drastically reducing the use of carbon is virtually impossible, given the indispensable nature of the element carbon in the most essential consumer and energy products, produced and used by our industry and society. Therefore, our industry and society will have to deal with carbon (and its use) in a smarter way in order to accomplish a **'carbon-smart[1]'** economy. This can be achieved by considerably increasing the added value per ton of carbon (for example by circularity of carbon, generating added value with the same carbon atom several times), by reducing the net loss of carbon to the atmosphere (as CO_2) to virtually zero (e.g. by more efficient production processes and by using captured CO_2 as a building block for chemicals and products), and by extending the lifetime of carbon in products by a considerable factor (e.g. double or quadruple).

[1] In this document preference is given to the term 'carbon-smart' instead of 'low-carbon'. After all, the 'decarbonization' of the energy-intensive industry (including chemistry and refining) is intrinsically impossible, since a large part of this industry is based on the element 'carbon'. Inevitably, carbon-containing raw materials are needed to produce a range of products for almost all downstream sectors. Bio-based plastics, for example, like fossil-based plastics, are built to a very large extent from the carbon atom. CO_2 emissions (and their reduction) are the primary objective and not carbon as such. The use of the terms 'carbon-smart' and 'low in CO_2' is therefore more relevant than the use of the term 'low-carbon '.

2. 'Flanders Industry Innovation MOONSHOT' as innovation spearhead in Flemish climate policy

2.1 Need for a 'MOONSHOT' for the Flemish industry

The aforementioned context of the challenge for Flanders shows that an intelligent approach is required to successfully initiate a transition to a carbon-smart economy and society. The historical incremental evolutions, such as implemented in emissions and energy consumption will not be sufficient to achieve a complete transition to a carbon-smart industry. There is a need for a major (worldwide) industrial transition in the coming decades. An important precondition is that the intended change should not affect the competitiveness of the Flemish energy-intensive industry, as this would lead to a geographical shift in production capacity to other regions of the world, which will aggravate the problem rather than solve it.

There is a need for an ambitious, thorough and widely supported effort to realize a fundamental solution to this unprecedented social climate and energy challenge. It is clear that – because of their substantial impact – the refining, chemical and iron & steel sectors (together with the research community and the government) will play an important role in achieving this. New technologies, products, raw materials and production processes will be needed.

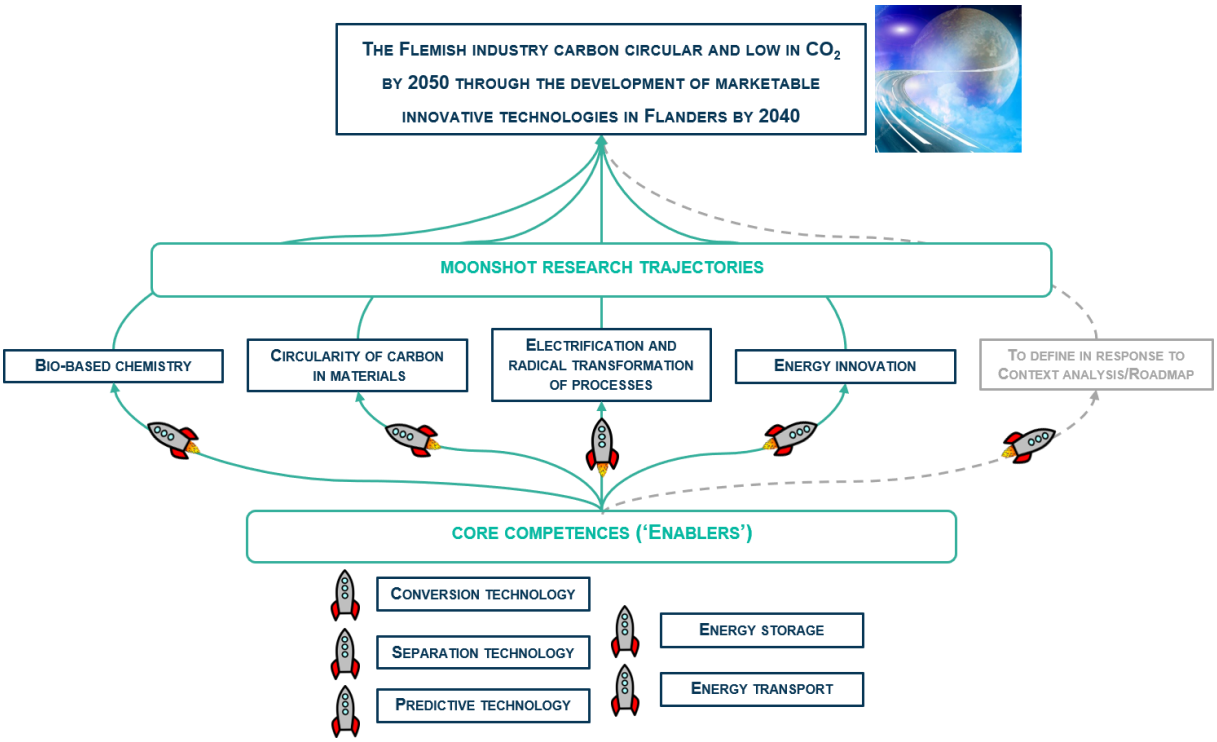
The recent cluster policy of Philippe Muyters, Flemish Minister of Work, Economy, Innovation and Sport, has led to the establishment of a number of innovative corporate networks and spearhead clusters that focus on the development of innovative breakthrough technologies, services and processes through cross-sectoral cooperation, linked to socially important themes with an economic added value for Flemish companies, including the chemical and energetic transition. This is why the (spearhead) clusters were challenged by Min. Muyters to implement the intended effort through a MOONSHOT, for which the budget of 2019 provided €20 million of recurring innovation funds for the next 20 years. Given the crucial role that chemicals and plastics play in both CO_2 emissions and in avoiding them, by providing breakthrough solutions that other sectors count on to make their products more sustainable, CATALISTI was asked to take the lead and to develop the strategic innovation and research agenda for the Flemish MOONSHOT (in synergy with the other spearhead clusters). To ensure a quick start of the MOONSHOT-process, the next steps to be taken were identified. All this must ensure that technological breakthroughs will be realized by 2040, which after implementation (taking into account investment cycles of ± 10 years) will contribute to achieving the Flemish climate objectives by 2050, while maintaining economic added value. In order to continuously adjust and follow up this strategic but important choice for Flanders – in collaboration with the Flemish industry –, a dedicated governance and consultation structure was developed for this MOONSHOT.

2.2 Main focus points of the MOONSHOT

The Flemish industry carbon-smart and low in CO_2 by 2040 translates into the ambition to transition to a carbon-smart energy-intensive industry in 2050 that contributes to a climate-friendly society. Innovative research within this initiative will ensure that a contribution is made to the development of breakthrough technologies in Flanders by 2040 to implement new and better processes, with which new and unique, carbon-smart products can be produced. Both aspects (processes and products) can make a significant contribution to reducing CO_2 emissions in Flanders in the future.

The MOONSHOT consists of four essential and closely connected research trajectories: 1) bio-based chemistry that leads to unique added-value products, 2) circularity of carbon in materials, 3) electrification and radical transformation of processes, and 4) energy innovation. These four MOONSHOT research trajectories are supported by and can build on five core competencies ('enablers') for which top expertise is present in Flanders, being 1) conversion technology, 2) separation technology, 3) predictive technology, 4) energy storage and 5) energy transport.

Additional factors and new opportunities for research and innovation that will be mapped out by a 'Context analysis/Roadmap' (explained in section 2.4) and that cannot be placed under the first four research trajectories may possibly be further elaborated and investigated in a fifth research topic.



Research trajectory 'Bio-based chemistry'

The first MOONSHOT research trajectory (MOT 1) will provide access to unique and added-value bio-based raw materials, materials and products via biomass. There is an urgent need to offer more sustainable alternatives to the current traditional molecules and materials based on fossil raw materials, in case the current materials will ultimately get burned and cause additional CO_2 emissions. Renewable raw materials, combined with more energy-efficient processes, will reduce the CO_2 footprint in Flanders. Both biomass waste streams and sustainable primary biomass streams will be converted into renewable basic building blocks in bio-refineries. Inventive new separation processes will make the difference by reducing energy requirements and production costs. The intrinsic functionalities and properties that are present in these natural products are retained and will lead to new, sustainable, safe and improved products that in turn make climate-friendly applications possible.

The following objectives will be pursued:

1. Develop at least 2 new bio-based chemical products up to TRL 6 in Flanders by 2025, followed by at least 2 new products to TRL 6 every 5 years. The new products have at least equivalent functionality/value and/or new functionality with a potential higher added value compared to similar products based on fossil raw materials.
2. The products and processes will be more sustainable (carbon footprint, environmental impact) than their fossil-based counterparts.

Within the following preconditions:

3. The products are based on stable, competitively priced supply chains/raw materials from the circular use of biomass and rational use of crops.
4. The end products must be able to play an important role in (future) Flemish industrial value chains and have considerable market potential on global scale.

Research trajectory 'Circularity of carbon in materials'

The second MOONSHOT research trajectory (MOT2) aims at the development of a circular production and use chain of carbon and carbon-containing materials. The main objective of this research trajectory is to keep carbon in materials in circulation for as long as possible (throughout the value chain). The initial focus here is on plastics, which are omnipresent in our daily lives and which offer a wide range of properties and possibilities. For example, lightweight and innovative plastic materials in means of transport help to save energy, and packaging materials (usually made up of several layers of plastic) ensure that food can be stored in a reliable way, consequently reducing food waste. At the end of the life cycle of plastics, however, there are still major challenges, such as increasing the recycling percentage of plastics, which means that the added value per ton of carbon (as input) can be increased considerably. Extensive research into the mechanical and chemical recycling of complex plastics, which contain several types of material, will ensure that, at the end of their cycle of use, products can be transformed into building blocks for new products. Attention is paid to the development of innovative materials and their use in specific designs to improve the recyclability of products. Even with the above concepts, a (small) fraction of virgin raw materials will be needed to compensate for imperfections in recycling and reuse. Non-fossil raw materials can be used as necessary supplement, such as bio-based monomers (link with MOT1) and monomers made from the direct reuse of captured CO_2 (so-called 'Carbon Capture and Utilization (CCU)') (link with MOT3). Overall, the impact of these scenarios on sustainability will have to be studied and monitored thoroughly in order to create a true circular plastics economy.

The following objectives will be pursued:

1. Develop technology to be able to recycle 70% of post-consumer volume (contaminated) polyolefins (TRL 6) by 2030 (by combining mechanical and chemical recycling, but with the main contribution expected from new technology for chemical recycling). With the ambition to be able to transform 75% of all polyolefin-type plastics at the end of their cycle of use into building blocks for new products, by 2040.
2. Develop technology to be able to recycle 60% of post-consumer volume of heteropolymers (TRL 6) by 2030 (by combining mechanical and chemical recycling, but with the main contribution expected from new technology for chemical recycling). With the ambition to

be able to transform 80% of all heteropolymer-type plastics (polyamides, polyurethanes, PET) at the end of their cycle of use into building blocks for new products, by 2040.

3. By 2030, 2 chemical platforms for more easily recyclable plastics ('chemical design for recyclability') will be developed up to TRL 6. These platforms are focused on high-quality plastics for technical applications (heteropolymers).

Within the following preconditions:

4. By 2040, the technology must enable to obtain 75% of all plastics that are put into circulation in Flanders via (mechanical & chemical) recycling (or biomass or CCU).
5. Resulting in a drastic reduction in CO_2 emissions (e.g. through the combustion of end-of-life plastics) in the order of 1 million ton of CO_2/year.

Research trajectory 'Electrification and radical process transformation'

In the third part of the MOONSHOT (MOT3), attention is directly focused on CO_2 emissions. The net emission of CO_2 must be avoided by radical transformation of current processes, in order to achieve a carbon-smart industry. A switch to electrified industrial processes (e.g. cracking installations) and the application of innovative and low-energy separation processes and mild biotechnological conversions (see MOT1) is part of the solution. There is also a need for innovation in the conversion of electricity to heat, which is much more efficient than the current traditional conversion via resistance. These large efficiency gains are needed to close the price gap between natural gas and electricity as fuel. Extensive research is also needed into capturing carbon that is emitted as CO_2. For example, the industry can be fed with smart carbon (see MOT2) or the captured CO_2 can be stored (temporarily) (so-called 'Carbon Capture and Storage (CCS)'). However, there is a high cost barrier associated with capture of CO_2. Therefore, the challenge here is to capture CO_2 efficiently with new technologies and in an integrated way, to subsequently convert it into usable raw materials (such as monomers for plastics, cf. MOT2) or to store them. Carbon-free hydrogen is essential for these conversions and at the same time offers opportunities for sustainable production of ammonia (from nitrogen gas and carbon-free hydrogen); the current production process of ammonia (from nitrogen gas, water vapor and carbon monoxide) is characterized by significant CO_2 emissions. Hydrogen and ammonia can also act as an energy carrier in the transport and storage of energy (link with MOT4, energy innovation).

The following objectives will be pursued:

1. 60% reduction in 'CO_2 emission/ton produced' by the (petro)chemical industry (main contribution to be expected from electrification of steam cracking and ammonia production, replacement of distillation by membrane processes, substitution of the traditional chemical processes by biotechnology), for which at least 1 technology will be developed to TRL 6 by 2035.
2. Economically profitable CO_2 capture & purification, both capture from point sources (originating from chemistry, steel and energy production) and Direct Air Capture. At least 1 technology will be developed up to TRL 6 by 2025.
3. Economically profitable conversions of captured CO_2 as a raw material for the Flemish industry. The most important contribution can be expected from the conversion of CO_2 to CO, MeOH and DME; and the subsequent conversion of C1 feedstock into added-value products. At least 1 technology will be developed up to TRL 6 by 2025.

4. Cost-efficient (< €2.000/ton) hydrogen production (either remote or in-situ), characterized by low CO_2 emissions. At least 1 technology is to reach TRL 6 by 2025.

Within the following precondition:

5. CO_2 capture and purification is economically viable for capture at point sources at €20-30/ton and for Direct Air Capture at €50-100/ton.

Research trajectory 'Energy innovation'

Many of the technologies in the aforementioned MOONSHOT research trajectories, however, depend on the availability of cheap carbon-free electricity, heat and hydrogen[2] for commercial success. However, the need for sustainable energy generation also poses a number of challenges for the energy system: increasing electrification, and the switch to carbon-free energy require additional investments. Moreover, technologies based on sun and wind have an intermittent character: energy production is becoming less predictable. Breakthroughs in the field of carbon-free energy production and the development of flexible innovative applications and storage, together with local energy (grid) optimization between industrial processes and energy deployment, with the focus on the costs and benefits of new value chains, sustainability, infrastructural needs and new opportunities for cross-border industrial areas are therefore also necessary within the set moonshot ambition, and will be studied within the fourth MOONSHOT research trajectory (MOT4).
A substantive MOT proposal is developed by the relevant spearhead clusters (CATALISTI, Flux50) and, going forward, they will operationally monitor and direct MOT4. The quantitative aspect of the objectives that will be pursued, require final approval by the MOT core team (by end of August 2019).

The overall ambition, by 2040, is to develop technologies that enable to offer 80% of the total energy demand of the Flemish industry-intensive industry (chemical, petrochemical and steel sectors) as CO_2 neutral/sustainable energy[3] in an economic cost-effective way, which corresponds to a CO_2 emission reduction in the order of 10 million ton CO_2/year, with disruptive contributions in the following areas:

1. By 2030, develop at least 3 innovative technologies to TRL 6 to provide CO_2 neutral/sustainable energy[3] to meet the increasing energy demand (estimated at 70 TWh) of the industry, followed by at least 2 innovative technology every 5 years (TRL 6).
2. Develop at least 2 innovative technology to TRL 6 for transport and storage of energy[3] by 2030, with at least 1 innovative technology to TRL 6 every 5 years thereafter.
3. By 2030, the development of a novel generation of flexibility algorithms, 3 innovative processes "designed for flexibility" and a portfolio of cross-sectoral models that ensure that +20% of the industrial energy[3] demand is provided by flexibility.

Within the following precondition:

4. CO_2 neutral/sustainable energy generation is economically viable when the price is comparable to energy prices form internationally competitive regions for the chemical industry.

[2] Carbon-free hydrogen is produced in a fundamentally different way: by separating water with sustainably generated electricity into oxygen and hydrogen (via electrolysis).

[3] Electricity, heat and other energy vectors

MOONSHOT core teams

In order to ensure high-quality content of the MOONSHOT research trajectories, a core team is nominated for each respective MOT that will take responsibility for the scientific implementation of the research trajectory. These core team members from Flemish knowledge institutes distinguish themselves on the basis of a number of criteria:

- Relevant top expertise with regards to the topic
- (Inter)national recognition
- Complementarity of the expertise between the core members
- Institutional balances and size of the parent institute
- Expertise regarding the MOONSHOT enablers

Within each core team, a **spokesperson** has been designated who acts as a point of contact. The core team is completed by the addition of a CATALISTI-MOONSHOT project manager. The operating principle of the MOT, as basis for project generation, is explained in more detail below (section 3 and Addendum).

Core team MOT 'Bio-based chemistry'

- **Bert Sels** (KU Leuven; expert heterogeneous catalysis, biomass conversion)
- Karolien Vanbroekhoven (VITO; expert separation, TEA)
- Wim Soetaert (UGent/BBEUPP; expert biocatalysis, fermentation)
- Bert Maes (UAntwerpen; expert homogeneous catalysis, biomass conversion)
- Isabelle Monnaie (CATALISTI)

Core team MOT 'Circularity of carbon in materials'

- **Filip Du Prez** (UGent; expert polymer chemistry & 'design for recycling')
- Isabel De Schrijver (Centexbel; expert plastics)
- Louis Pitet (UHasselt; expert bio-based polymers)
- Dirk De Vos (KU Leuven; expert chemical recycling)
- Wannes Libbrecht (CATALISTI)

Core team MOT 'Electrification and radical process transformation'

- **Kevin Van Geem** (UGent; expert chemical processing & process intensification)
- Bert Bouwman (VITO; expert conversion technologies & techno economics)
- Joeri Denayer (VUB; expert separation processes)
- Luc Van Ginneken (CATALISTI)

Core team MOT 'Energy innovation'

- **Johan Martens** (KU Leuven; expert solar fuels)
- **Lieve Helsen** (KU Leuven; expert thermal networks)
- Michel De Paepe (UGent; expert heat and combustion dynamics)
- Jan Vaes (VITO; expert P-2-X)
- Jeroen van Walsem (CATALISTI)

2.3 Innovation and cross-sectoral cooperation as a key to success

The MOONSHOT aims to develop and realize new and unique technology by 2040 that will make the intended transition to a carbon-smart economy by 2050 possible (in accordance with the European Climate Targets). This ambitious effort offers opportunities for and requires thorough research and technological innovations in the energy-intensive sectors (with a focus on the refining, chemical and iron & steel sectors) in the defined MOONSHOT research trajectories. A mix of different technologies will have to be applied within and between these industrial sectors. There is therefore a clear need for 'mission-oriented' R&D&I to bring all of these breakthrough technologies and energy innovations from the laboratory to the market (in particular by supporting pilot and demonstration projects). In addition to the development of breakthrough technologies, the creation of value chains and business cases by and for companies is an indispensable aspect of the MOONSHOT. In this context, sufficiently mature research and valorization projects will be passed on to the regular operation of the most relevant spearhead cluster. Consequently, there is once again room within the MOONSHOT budget to tackle fundamental issues. This transfer is primarily the responsibility of the Operational team (see section 3. *Governance model*) in close collaboration with the respective spearhead cluster(s).

The aim will be to create maximum leverage on the Flemish means for innovation, aided by European means, which will become available in the coming years to make carbon-smart solutions economically viable and to arrive at new solutions that are not yet matured, or even unknown by the current market. After all, climate is central to Horizon Europe, the European Commission's proposal for the new EU research and innovation program. The European Commission proposes to invest 35% of the budget of nearly €100 billion in research linked to climate objectives. The approach of supporting projects and innovations must provide the possibility to financially support risky, disruptive innovation. The EU is in the process of introducing such new instruments. One of these instruments is the "European Innovation Council (EIC)", which will focus on the radically new, pioneering products, services and processes. In addition, the Innovation Fund under the EU Emissions Trading System (EU ETS) will support demonstration of breakthrough technologies on a commercial scale. All this offers opportunities for a solid package of research, innovation and implementation activities for the coming ten years. In the context of the intended MOONSHOT ambition, Flanders must make maximum use of these European resources in order to achieve its own climate and energy objectives.

Flanders has the ambition to play a pioneering role in the field of research and innovation. We possess a high level of education and a great deal of technological expertise within universities, knowledge institutes and companies, both multinationals and SMEs. The Flanders industry innovation MOONSHOT will give companies and knowledge institutes the opportunity to develop and market their pioneering innovations more quickly and more focused. The business community, the research world and the government can reinforce each other, and are allies in tackling the climate challenge.

The MOONSHOT innovation program and the intended transition to a carbon-smart economy are therefore an important opportunity for Flanders to position itself as a top region for research and innovation in the energy-intensive sectors of society. In addition, it also provides a framework for

further internationalization, as the breakthrough technologies and energy innovations developed in Flanders can also be valorized in other regions to address important energy and climate issues.

In addition to extensive innovation, cross-sectoral cooperation and synergy are indispensable for achieving a carbon-smart industry, where new value chains and new business models can be set up. Cross-sectoral cooperation is situated mainly on two main levels, i.e. 1) energy efficiency and the use of sustainable energy, and 2) material efficiency and the use of sustainable raw materials. Much can be achieved by optimizing the use of raw materials and material flows in industrial core areas through cooperation between companies. The (petro)chemical sector and the steel sector play an important role in connecting sectors and the transition to a more circular economy:

- ✓ These sectors are highly energy-intensive and therefore the largest consumers of energy;
- ✓ These sectors are also the most important emitters of CO_2;
- ✓ They have a central role and position, since their large range of products is used in almost all downstream sectors (e.g. for the production of lightweight materials, for the production of installations, insulation materials for homes and transport, production of transport fuels, etc.);
- ✓ The focal point of these sectors is usually clustered in ports, which over time have developed an extremely efficient infrastructure for transporting raw materials, energy and (intermediate) products.

From these sectors, synergies with the more downstream sectors (including textiles, paper, food, logistics, non-metallic minerals, etc.) can be exploited and provide positive spillovers (also for smaller, local companies). As leverage in this regard, results and opportunities obtained by the MOONSHOT initiative can be further elaborated as intercluster projects in the transition priorities 'Circular economy', 'Industry 4.0' and 'Energy'.

Within this MOONSHOT ambition, space will be provided for both the conversion of existing industry and the construction of new industry, with the aim of Flemish prosperity based on a carbon-smart and circular production.

2.4 Context analysis/Roadmap

In support of the MOONSHOT (and the research trajectories with their defined solution approaches), insights obtained from a yet-to-be-conducted 'Context analysis/Roadmap' will be used as further input. This analysis, in the form of a report prepared by an external consultant, will be based on input from companies and economic actors in Flanders and on existing (scientific) information. This Context analysis/Roadmap will identify factors that are initially difficult to influence, but that must be taken into account. Examples of this are technological developments, political developments, the knowledge base at knowledge institutes and companies, the economic business climate, legislation and regulations, and infrastructural developments.

From this Context analysis/Roadmap, more clarity must be obtained about desired knowledge focus and acceleration, barriers and necessary legislative/economic preconditions with regard to industrial implementation, infrastructural needs, necessary policy measures, facilitating levers, etc. In order to create a framework as favorable as possible to realize the innovation program with all stakeholders involved and in a timely manner.

3. Governance model of the MOONSHOT

As described above, this MOONSHOT aspires to develop breakthrough technologies that, on the one hand, have a direct impact on the sectors with the highest CO_2 emissions and thus on the fulfillment of the European objective and, on the other hand, on emissions occurring more downstream in the chain (e.g. in production and processing of plastics) and therefore also on the fulfillment of the Flemish objective. Intrinsically, the development of technology will also contribute to the storage and transport of sustainable energy.

Mission-oriented technological research (and its further development) will have to be clearly identified and evaluated in order to be adjusted – if necessary – in a timely manner. In addition to the responsible governance, this also requires an independent operational organization. Since the MOONSHOT aims for a 'lean and mean' innovation landscape and its focus is mainly in the area of two spearhead clusters (in particular CATALISTI and Flux50), it is decided not to set up a new structure. Given the fact that the center of gravity of these developments relates to (petro)chemical processes and products, the governance and the operational team are hosted by CATALISTI as a guest structure.

The governance of the MOONSHOT initiative is hereby embedded in the legal CATALISTI structure. An independent Governance Board or Steering Committee – consisting of CEOs and executives from the (petro)chemical sector, the steel industry and the energy sector, supplemented with the necessary broad-economic knowledge – will monitor the strategy and vision of the MOONSHOT and will approve final project proposals for submission to the VLAIO decision-making body (Hermes Beslissingscomité, HBC).

The procedure for identifying projects and initiatives within the MOONSHOT is the one that is successfully used today within the regular operation of the CATALISTI spearhead cluster, and whereby the Board of Directors, which mainly consists of company representatives, co-directs the innovation and bears operational responsibility. For energy topics, the Board of Directors of the relevant cluster (Flux50 or other in the future) will take this responsibility.

The scientific validation of the proposed initiatives within the moonshot will be done by an independent Scientific Advisory Board (WAR), which will be composed according a specific procedure – that guarantees objectivity, competence and continuity.

Finally, a 'Stakeholder Consultation Group' will be installed to guarantee broad social support.
The table below provides a schematic overview of the different tasks and responsibilities.

		GOVERNANCE						HBC
		Consultant (Context analysis/ Roadmap)	Operational team Catalisti	Scientific Advisory Board	Stakeholder Consultation Group	Governance Board	Responsible cluster	HBC
0.	Start up year 1: base document preliminary study	Validation	Content	Advice		Validation		
1.	Split main challenge into subchallenges	Input	Proposal based on Context analysis/Roadmap	Advice	Advice	Validation		
2.	Identification research programs and projects	Input	Proposal	Advice	Advice	Validation		
3.	Roadmap setup and timing for research programs and projects	Input	Proposal	Advice	Advice	Validation		Validation
4.	Identification responsible cluster to manage research programs and projects		Proposal			Validation	BoD agreement, no agreement or adjustment required	
5.	Brokerage of projects		Preparation transfer @Responsible cluster				Each cluster for its projects	
6.	Safeguard consistency of programs/projects and timing of roadmap		X					
7.	Project validation prior to submission to VLAIO			Advice (step 2)		X (step 3)	X (step 1)	
8.	Legal rubber stamp with regard to liability		X				BoD Catalisti	
9.	Project approval of project and allocation of funding							X
10.	Final approval to initiate project					X		
11.	Follow up progress individual project		X				X	
10.	Roadmap progress		Follow up, adjust, report		Notification	Notification		Notification
11.	Roadmap modification / discontinuation research track / addition new research track		Proposal	Advice	Advice	Decision		Notification
12.	Transfer valorisation project to regular cluster operation		Proposal			Notification	BoD agreement, no agreement or adjustment required	Notification
13.	Follow up global roadmap incl. transferred projects		X			Notification		Notification

Within the MOONSHOT initiative, an operational budget is allocated to the host organization CATALISTI to guarantee follow-up, evaluation, benchmarking and communication.
In first instance, the cluster set of project instruments and the accepted procedures with regard to agreements between applicants and HBC, will be used within the MOONSHOT.

In consultation with VLAIO and the Cabinet Innovation, is has been decided to start immediately with 'acceleration projects', which allow the build-up of critical mass around strategic research topics within the identified MOONSHOT research trajectories (MOTs). Short-term, sharply defined cluster SBOs ("sprint" cSBOs) will be submitted. If permitted within the available instruments, a limited budget will also be used to accelerate research opportunities that have already proven their feasibility at low TRL. Within the moonshot, these initiatives are referred to as "Later Stage Innovation Projects". CATALISTI is in charge of directing this, as mandated by Min. Muyters on March 23rd 2019.

In addition to the MOONSHOT initiative, short-term research initiatives are actively pursued across the spearhead clusters (SPCs), with the aim of maximally financing these from the widely available budget for intercluster projects.

The practical modalities of the mandate are being further elaborated and agreed upon. One of the elements is the installation of a governance structure that respects and monitors the objectives of the MOONSHOT and that guarantees optimal cooperation with other actors within the Flemish innovation landscape and the Flemish industry.
The knowledge institutes must commit to follow up and coordinate all involvements in the different clusters, relevant to the MOONSHOT research trajectories, consistent and transparent with regard to the Context analysis/Roadmap.

The management of the MOONSHOT initiative takes place on several levels:

Operational management

Based on the general objectives, the high level ambitions and – at a later stage – the input from the Context analysis/Roadmap, concrete, supportable project proposals are identified and brokered by the operational team, in collaboration with the knowledge partners and other relevant stakeholders. Active prospecting of potential project ideas and active involvement of relevant actors and their competencies takes place in collaboration between the operational team and the MOONSHOT core teams. The Addendum at the end of this document provides more information in this regard. The selection procedure used here is based on the one that has been successfully implemented in recent years by the spearhead clusters. Open innovation is central here, aimed at close cooperation between the knowledge partners and a business drive that is based on the commitment of the companies. The procedure guarantees objectivity and openness to all stakeholders. This 'tollgate' procedure is shown schematically below, respectively for cSBO and 'Later Stage Innovation' projects.

Both the purpose of the detailed projects and initiatives and the way in which this goal is achieved, are presented to those responsible for innovation at the companies with sufficient scientific and technical knowledge relevant to the research topic. For chemical and chemistry-related topics, this is the CATALISTI Board of Directors. The Governance Board appeals to a Scientific Advisory Board, which is supported ad hoc by external experts (in case of cSBO projects, and when necessary), in order to formulate a clear advice on the project proposals and initiatives to be supported.
Subsequent to the scientific advice to and the approval by the Governance Board, the project/initiative assessment is converted into a formal advice by VLAIO and the operational team, according to the current SPC procedure. This advice is approved by the CATALISTI Board of Directors, as legal responsible/representative, prior to forwarding to the HBC (in case of cSBO) for a formal decision. When required, the MOONSHOT Governance Board determines the priority of the projects approved by HBC.

MOONSHOT Governance Board (MGB)

The MGB is assigned

- To monitor and support coordination, in first instance, with the Cabinet Innovation and Economy, but also to guarantee the relationship with other relevant cabinets and administrations;
- To evaluate and stimulate MOONSHOT initiatives within the set objective;
- To evaluate the government's compliance with the engagement and to consult with the government in the event of identified or necessary deviations;
- To safeguard the pursuit of fundamental breakthroughs in basic research, the accelerated upscaling of promising technologies and the transfer to economic actors, via the regular (spearhead cluster) channels to achieve implementation in industry in the short term;
- To evaluate the applicability in other sectors and to stimulate and initiate consultation with those sectors;
- To follow up the regulatory framework and to discuss it with the government if necessary.

Identical to its role in regular support for companies and knowledge institutes, the Hermes Decision Committee finally grants support to the proposed initiatives within the MOONSHOT.

The MGB meets at least twice a year and is prepared by the MOONSHOT operational team, and moderated by the CATALISTI Managing Director who will act as secretary.

The MOONSHOT Governance Board consists of a group of experienced business managers with a clear vision on the industry branches involved (initially the chemical, petrochemical, steel and energy producing industry), on the impact of climate objectives and on cross-sectoral importance for the Flemish economy.
Representatives of the industrial sectors:

- Chemical: Peter Roose, Eastman
- Petrochemical: Jacques Beuckelaers, Total; Jan Michielsens, Exxon Mobil
- Steel: Manfred Van Vlierberghe, Arcelor Mittal
- Energy: Jan Mertens, Engie

Presidents of the Spearhead clusters:

- CATALISTI: Wouter De Geest
- Flux50: Jan Jaeken
- De Blauwe Cluster: Geert Noels
- SIM: Karin Vercauteren
- Flanders Food: Jan Vander Stichele
- VIL: Danny Van Himste

Government:

- observer of the Flemish Agency for Innovation and Entrepreneurship (VLAIO): Mark Andries or Annie Renders
- observer of the Department of Economy, Science and Innovation (EWI): Johan Hanssens

Secretary and organization: CATALISTI Managing Director, Jan Van Havenbergh (observer)
Representatives of the federations are invited ad hoc.

The composition of the Government Board will be adjusted if necessary after completion of the Context analysis/Roadmap study.
The Governance Board ensures that valorizable concepts are absorbed in the regular spearhead activities and entrusts the operational team with the task of making this transfer possible.
The Governance Board has an obligation to provide information to the spearhead clusters and to the Hermes Decision Committee. This communication is the operational responsibility of the managing director of CATALISTI, both via the formal SPC consultation meetings and via informal contacts.

Scientific Advisory Board (WAR)
Based on the preparatory work of the operational team, and in line with the results of the Context analysis/Roadmap study, projects and initiatives will be set up together with the Flemish knowledge partners and the MOT operational structure. In order to be able to assess both scientific and economic relevance, quality and uniqueness (via a proven procedure within the SPCs), the Governance Board is advised by a Scientific Advisory Board, consisting of a number of permanent

renowned experts, ad hoc and if necessary, in line with the VLAIO evaluation procedure, supported with subject-specific experts.

- It is decided to involve 7 scientific experts, 3 of which with a business background, in the MOONSHOT. Knowledge of the relevant sectors and CO_2 issues are a requirement here.
- The WAR is assisted by ad hoc experts with specific scientific knowledge in the relevant research area of the project proposals.
- Starting September 15th 2019 the Scientific Advisory Board has following members:
    - Industrial experts: Rudolf Koopmans, Tony Van Osselaer and Erik Van Praet
    - Flemish academic experts: Guy Marin and Ronnie Belmans
    - International academic experts: Hans Kuipers (TU Eindhoven) and Katrien Bernaerts (U Maastricht)

Evaluation procedure WAR (cSBO)

The evaluation of the project proposals is the responsibility of the WAR and takes place in two phases, as schematically indicated below.

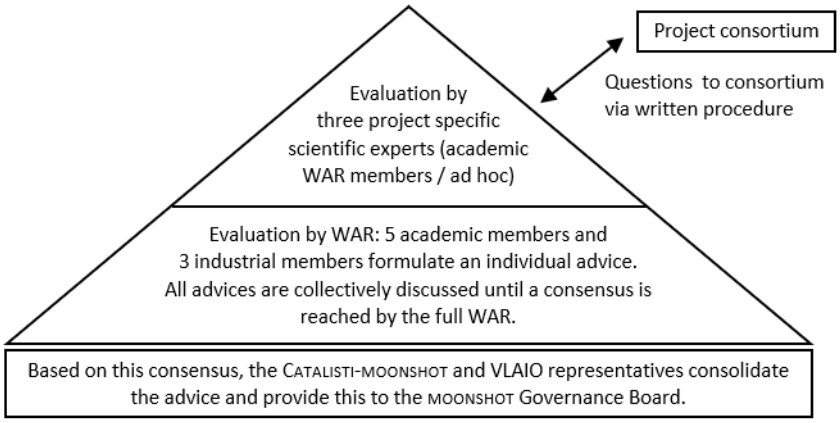
In the first instance, the full project proposal will be evaluated by three academic experts, appointed for their subject-related expertise, and in line with the VLAIO evaluation procedure (composition of the expert panel in consultation with VLAIO and the SPC team), each of which formulates an evaluation taking into account the MOONSHOT cSBO-specific evaluation criteria. These three project-specific scientific experts can 1) be selected from the academic members of the WAR or 2) be added to the expert committee ad hoc if there are insufficient WAR members with project-related professional knowledge. The selected experts in no way have a compromising interference with either the submitting research groups/researchers or the research topic.

In this first phase of the evaluation procedure, the 3 experts are asked, on the basis of an evaluation matrix, to evaluate the submitted project proposal with specific focus on two parts of the project application, namely the scientific project description and the intended valorization. Any questions that the individual experts wish to submit to the consortium are submitted and answered via a written procedure.

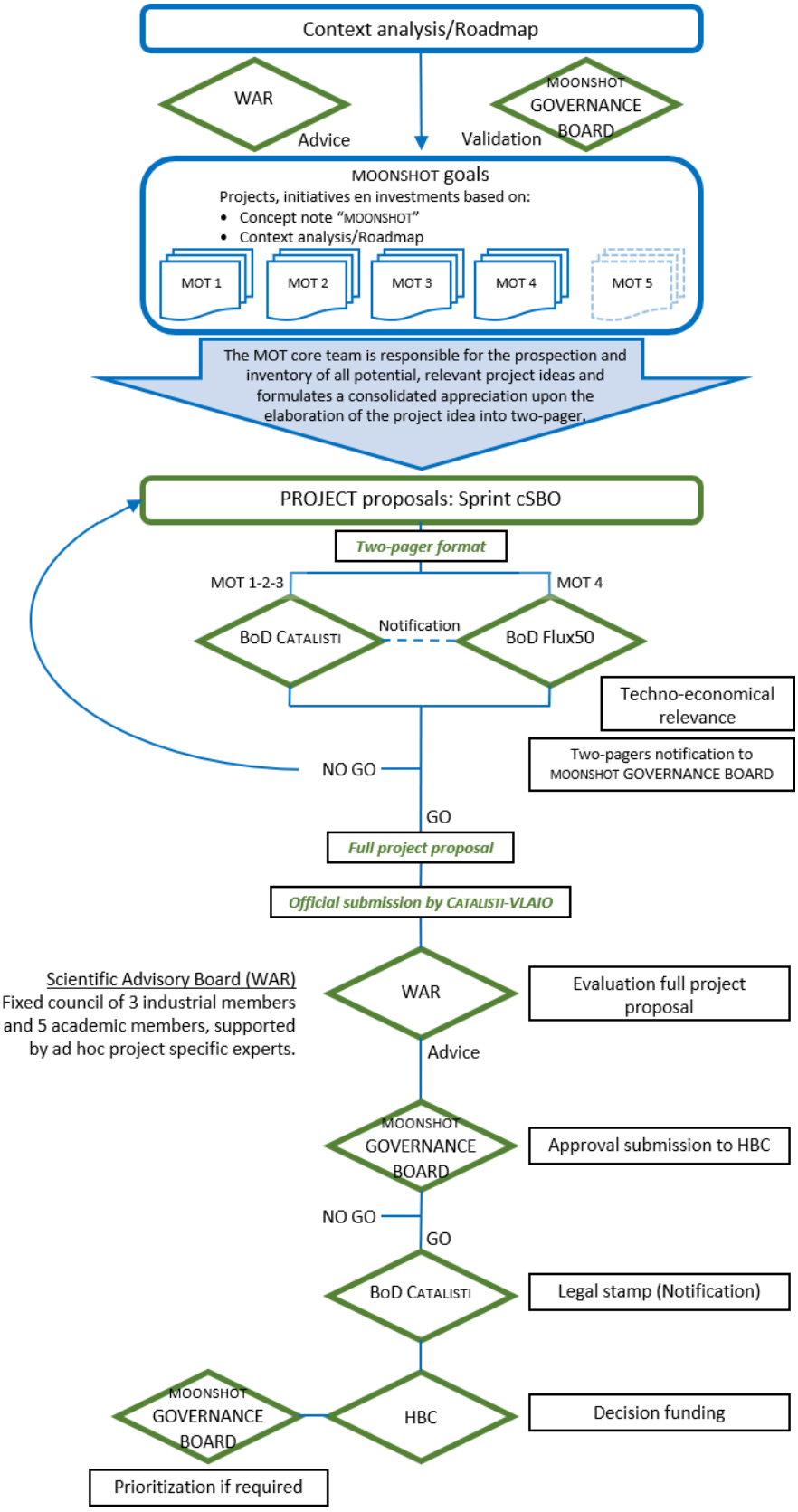
Subsequently, the full project proposal, together with the three evaluation reports, is provided to all (8) members of the WAR. The WAR assesses the project proposal with attention for all criteria, and each member of the WAR formulates an individual advice. They can rely on the evaluation of the scientific experts with regard to the scientific and valorization aspect of the application, and furthermore specifically assess the fit of the project proposal with the high-level MOONSHOT objectives and contribution to the MOONSHOT roadmap.

To conclude the evaluation procedure, all evaluations are collectively discussed within the WAR, in the presence of the CATALISTI-MOONSHOT project managers and a representative of VLAIO. As a result of this discussion, a consolidated advice is formulated by the CATALISTI-MOONSHOT and VLAIO representatives, in agreement with the WAR, which must allow the MOONSHOT Governance Board to finance the right projects in an objective manner.

The assessment criteria on which the experts base their evaluation are described in the manual drawn up for a cSBO project application in the context of the MOONSHOT initiative.


Project consortium
Questions to consortium via written procedure
Evaluation by three project specific scientific experts (academic WAR members / ad hoc)
Evaluation by WAR: 5 academic members and 3 industrial members formulate an individual advice. All advices are collectively discussed until a consensus is reached by the full WAR.
Based on this consensus, the CATALISTI-MOONSHOT and VLAIO representatives consolidate the advice and provide this to the MOONSHOT Governance Board.

Schematic representation of the 'tollgate' procedure (cSBO):

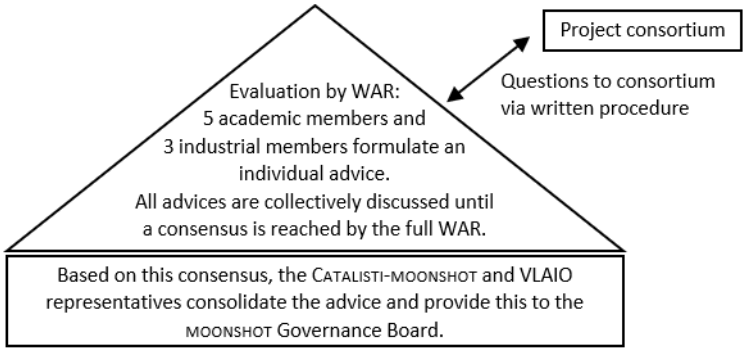


Evaluation procedure WAR ('Later Stage Innovation' Projects)

The evaluation of the 'Later Stage Innovation' Project proposals is the responsibility of the WAR and procedure is schematically shown in the figure below.

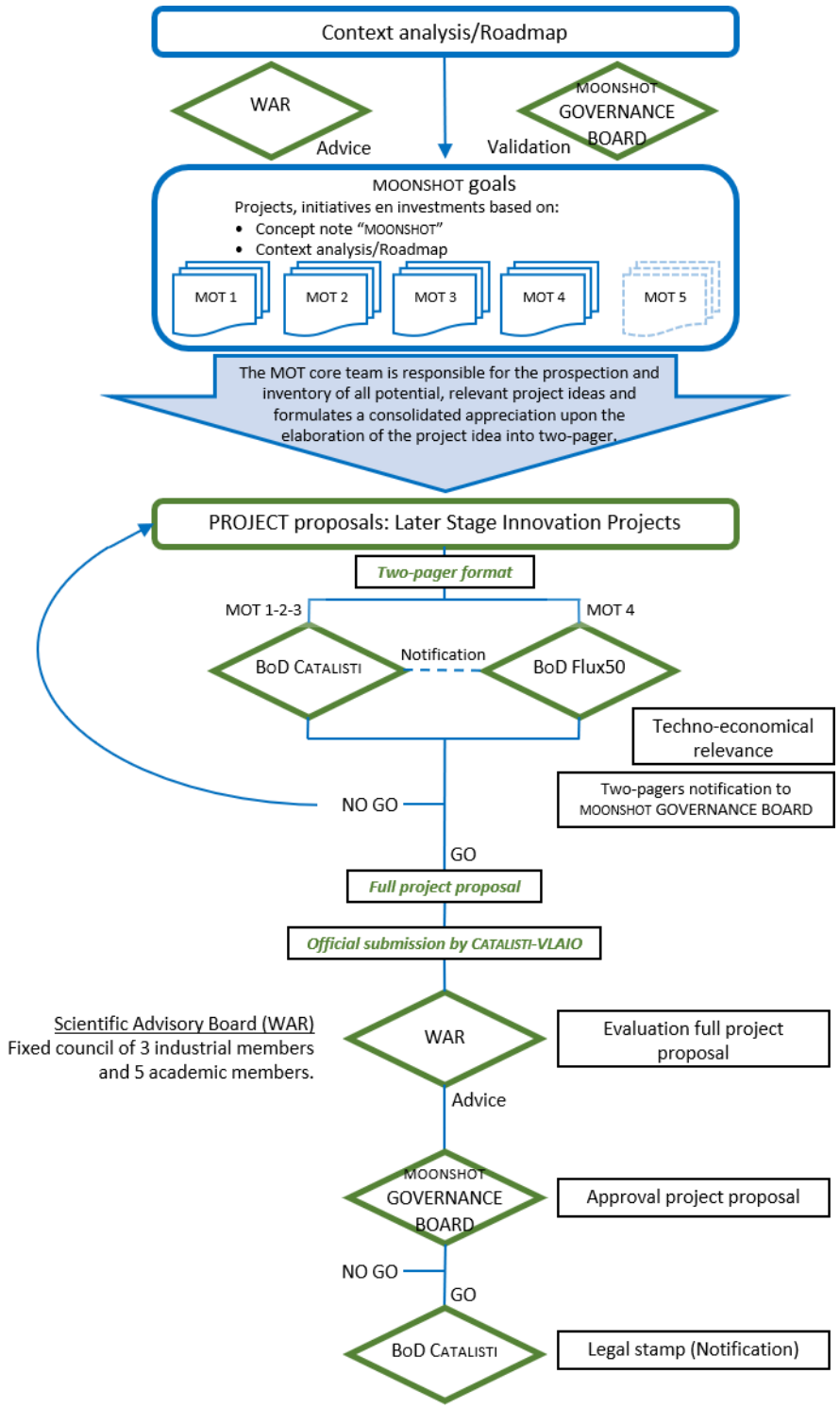
The full project proposal is provided to all 8 members of the WAR. The WAR assesses the project proposal with attention for all specific criteria, and each member of the WAR formulates an individual advice and appreciation on the basis of an evaluation matrix. The assessment criteria on which the WAR members base their evaluation are described in the manual drawn up for a 'Later Stage Innovation' Project application. Any questions that the individual WAR members wish to submit to the consortium are submitted and answered via a written procedure.

Subsequently, all evaluations are collectively discussed within the WAR, in the presence of the CATALISTI-MOONSHOT project managers and a representative of VLAIO. As a result of this discussion, a consolidated advice is formulated by the CATALISTI-MOONSHOT and VLAIO representatives, in agreement with the WAR, which must allow the MOONSHOT Governance Board to finance the right projects in an objective manner.



The Tollgate procedure for 'Later Stage Innovation' Projects is schematically represented below.

Schematic representation of the 'tollgate' procedure ('Later Stage Innovation' Projects):

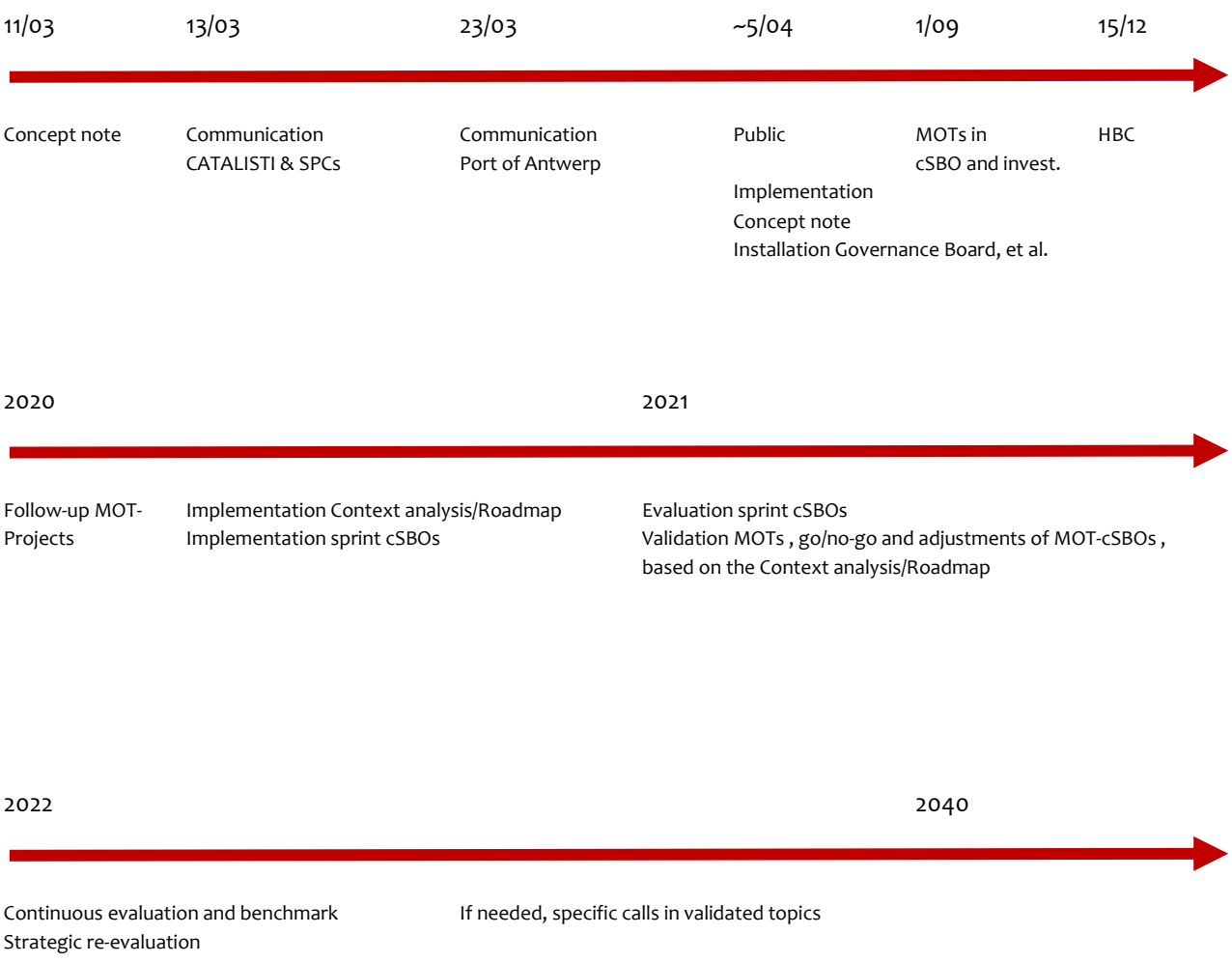


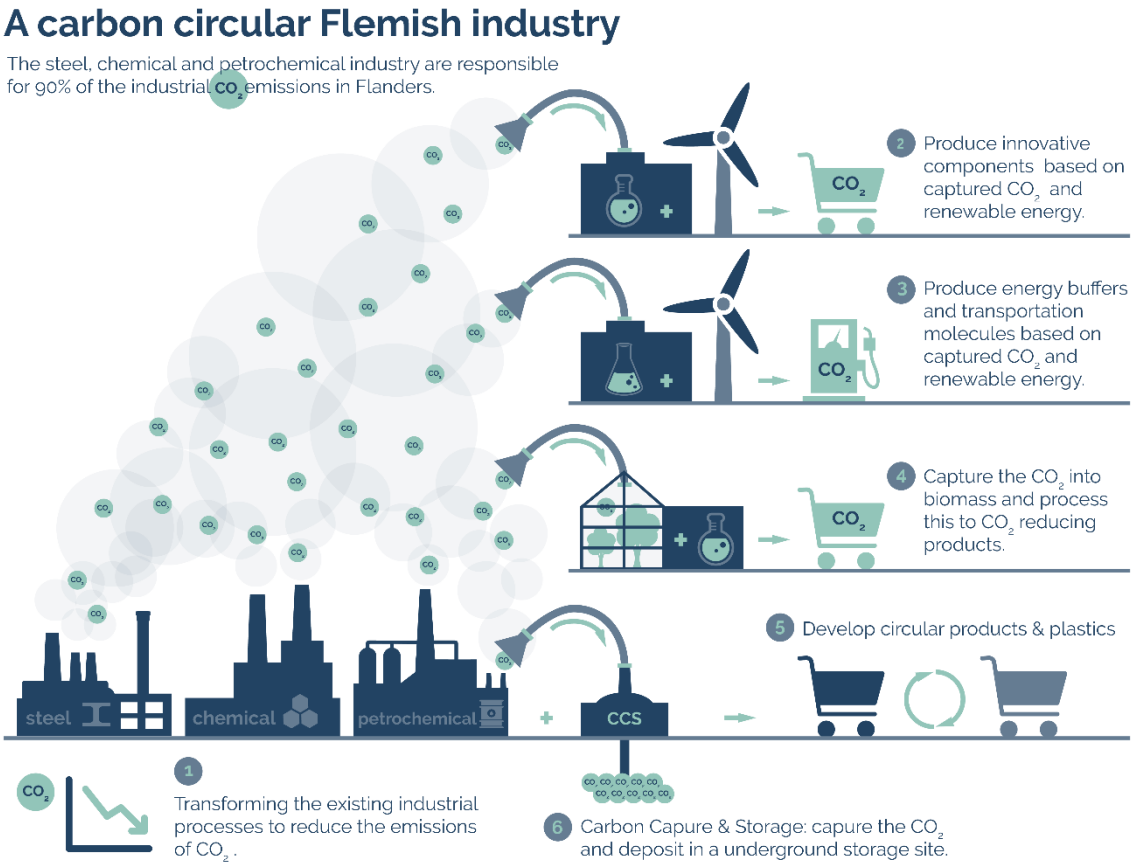
Stakeholder Consultation Group

The MOONSHOT initiative aims to make a significant contribution to the technologies that focus on climate objectives. In view of the broad social importance, it is therefore advisable to set up a consultative body that on the one hand provides an information platform for the activities and ambitions of the MOONSHOT for the Flemish industry and, on the other hand, aims to achieve this

through constructive dialogue ensuring broad support for the current MOONSHOT trajectories. Possible members of this Stakeholder Consultation Group may include: BBL, VOKA, VARIO, VLIR, industry federations (such as Agoria, essenscia, Fevia), SOCs, Cabinets (Innovation, Energy, Environment), dept. EWI and VLAIO. This Stakeholder Consultation Group meets once a year.

Indicative time schedule, to be refined in view of the Context analysis/Roadmap




A carbon circular Flemish industry
The steel, chemical and petrochemical industry are responsible for 90% of the industrial CO_2 emissions in Flanders.
2 Produce innovative components based on captured CO_2 and renewable energy.
3 Produce energy buffers and transportation molecules based on captured CO_2 and renewable energy.
4 Capture the CO_2 into biomass and process this to CO_2 reducing products.
5 Develop circular products & plastics
steel
chemical
petrochemical
CCS
1 Transforming the existing industrial processes to reduce the emissions of CO_2 .
6 Carbon Capure & Storage: capure the CO_2 and deposit in a underground storage site.

Addendum: identification and exploration of supportable projects and initiatives - procedure

The MOONSHOT initiative is originally a bottom-up initiative, driven on the one hand by the social need for a climate-friendly solution for the CO_2 emission problem and, on the other hand, driven by corporate ambition to provide these solutions.
When identifying the appropriate/correct initiatives and projects, it is important to use these ambitions and the stakeholders involved as a guide. Hence, the traditional mechanism of "open call" project acquisition is less appropriate. Within this MOONSHOT initiative, a "guided" project brokerage procedure is therefore chosen. More specifically, this means that the process of project identification of the spearhead clusters as used within the regular CATALISTI operation will be modified.
From strategic analysis with the companies, "enablers" were identified: conversion technology, separation technology, predictive technologies and energy storage and transport. KPIs and objectives are defined as concrete as possible for each MOONSHOT research trajectory. The combination of the intended enablers with the MOTs results in a very specific research field in which projects fit that contribute to achieving the CO_2 objectives.
From this point of view, it has been decided to set up a core team of Flemish knowledge experts per MOT. The main purpose of this MOT structure is to frame the projects and initiatives relevant to the respective MOT within the MOT objectives (KPIs and activities), to discuss internally and to ensure that, in the first instance, a 4-liner and, at a later stage, a two-pager is generated that is sufficiently supported by the knowledge partners and that has been assessed by the company experts via the CATALISTI-MOONSHOT representative.
Given the scientific and substantive link of the MOTs with both the knowledge partners and the (later) adopting companies, which by definition are linked to a specific spearhead cluster, MOT 1-3 are connected with CATALISTI and MOT4 with Flux50, naturally with the necessary interaction, and if required with other SPCs.

Creating projects/initiatives

MOT core team

The MOT core team consists of 3-4 knowledge experts from Flemish knowledge centers with generally recognized and proven expertise and competence in the respective MOONSHOT research trajectory, and are widely acknowledged by their fellow researchers in this field. Supported by a CATALISTI-MOONSHOT project manager, external communication regarding activities, proposals and results is prepared by the core team. They are also the engines of the MOT pool, where they discuss the proposed project ideas and the link with the basis of the MOT and its KPIs and objectives. The MOT spokesperson communicates with regards to the vision, results and views of the respective MOT to external parties and stakeholders or to the governance. Together with the CATALISTI-MOONSHOT project manager, the spokesperson also provides guidance in the activities and deliverables of this MOT.

MOT pool

This "collection" of Flemish knowledge experts in the field of the respective MOT, is expected to have a good overview of all relevant competencies related to this MOT. Under the direction of the CATALISTI-MOONSHOT representative, this MOT pool is the basis for new projects and initiatives that

will lead to a proposal under the MOONSHOT initiative. This MOT pool must therefore be connected with all relevant competencies and expertise present in Flanders, and if necessary outside Flanders.

Project development

Starting from the objectives of the respective MOT KPIs, ideas are inspected within the MOT pool. Competencies, pathways, valorization opportunities and contribution to the MOT/CO_2 KPIs are discussed on the basis of the introduced ideas. This results in a consortium of at least 2 knowledge institutes and at least 3 research groups, that makes a 4-liner, and in the subsequent phase, a two-pager.

The MOT core team does not have decisive influence, but can be supportive and guiding in the elaboration of the two-pagers and, in consensus, can provide accompanying advice.

END OF THE NOTE