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Joint STEM lab facility

Research and Innovation for Industrial Growth

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Executive Summary

This feasibility study of a **Joint STEM Industrial Product Development Facility in Rwanda** was carried out by Technopolis Group for NIRDA and its partner Enabel to help determine the relevance, need, and expected socioeconomic benefits of investing into this project.

The vision

The Government of Rwanda Vision 2020 sets out ambitions to drive economic transformation from a subsistence agriculture economy to a knowledge-based society. Specially, in its new 7-Year Government Programme (2017-2024), the Government sets new industrial policy objectives by increasing domestic production for local consumption and improving export competitiveness of the country. Industrialisation and enhancing innovation capacities of the private sector are central to attaining a structural shift in the export base to high-value goods and services. Rwandan is positioning itself as a proof of concept hub.

The proposed Joint STEM Industrial Product Development Facility (hereafter the STEM lab facility) is a key contribution, promoted by NIRDA, to improve the competitiveness of existing industries in order to increase their export potential and/or their potential to undertake import substitution, and to enable a new generation of industrial entrepreneurs to innovate and to integrate international value chains by technology acquisition and transfer and through applied research and development (R&D).

The STEM Lab facility will act as an **industrial technology incubation hub** for industrial innovators (ie existing industries and industrial entrepreneurs) drawing on STEM to **develop prototype products and components ready for industrialisation**.

This industrial product development facility will **bring together private innovators, experienced industrial mentors, academia, and other key stakeholders**. The innovators will have access to advanced technologies and will be given the tools and coaching necessary to acquire and upgrade their technical industrial skills and business capabilities. This will in turn enable them to recruit more young Rwandans into higher value jobs created by their own company development.

Under this overarching goal, the core functions of the STEM lab facility are to:

- Identify (homegrown) solutions for local need - This will be supporting the development of specific ultra-modern technologies as part of the “Made in Rwanda” brand
- Incubate young Rwandan innovators with a keen interest in STEM-related industrial product development - The facility will be supporting innovators to create new start-up companies and increase the competitiveness of existing companies
- Enable industry to outsource R&D to a lab with the right equipment, standards, service provided - The industry will be encouraged to commission applied research and development projects at commercial prices
- Inspire the wider community through the investment in emerging technology - It is important the facility attracts the future STEM professionals but also that it encourages the industry to invest in R&D and manufacture modern hardware products at industrial scale

A Theory of Change and logic model is proposed which underlines how the activities will result in a series of outputs including the development of ideas, upskilling of workforce and a steady pipeline of clients. Those outputs are leading to increased collaboration, prototypes ready for market which themselves will help reach the impact.

Why a joint STEM industrial research and development facility in Rwanda?

The rationale for a Joint STEM Industrial Product Development Facility in Rwanda is shared by the main research, innovation and industrial stakeholders: there is a need for a comprehensive service offer where Rwandan-based industries can access prototype testing facilities and link with research organisations. The STEM lab facility addresses a gap in service provision. A comprehensive service provision will help unlock business opportunities, allowing the country to position on three industrial value chains where disruptive technologies present big opportunities (mechatronics, energetics, and industrial software) to develop locally based products or exportable products; there is an urgent need to offer more job opportunities for STEM graduates in the country, and avoiding brain-drain.

Removing barriers to industrial scale-up

The path towards industrialisation in Rwanda faces a number of issues. First, **Rwandan based industries tend not to have R&D departments.** There is no industrial scale machinery and equipment for prototype testing available to the industry. In the absence of prototype testing in Rwanda, the industry is forced to externalise testing to other countries (eg Volkswagen conduct prototyping in South Africa). The industry is interested in having access to (other) lab equipment for advanced prototype testing. Local industry is interested in commissioning prototype testing to the STEM lab facility and is interested in working together with STEM graduates to develop and test prototypes.

The **collaboration between industry and universities** is weak due to the fragmentation in the Science Technology and Innovation (ST&I) system. There are yet few examples of collaborations such the Integrated Polytechnic Regional College (IPRC) (eg through training, student internship, professional internships).

There is a need for **providing young graduates and technicians training** on, for example, electronic design (eg PCB, Embedded programming, PCB fabrication), machining techniques (eg sheet metal, CNC, welding, painting technologies and techniques, magnetics design and fabrication, automation, hydraulics and pneumatics design, programming and fabrication) and business planning (eg investment mobilization, marketing, sales, operations).

Filling a market gap in the Rwanda innovation ecosystem

The idea of the STEM facility is welcomes by industry players. There are **no industrial scale machinery and equipment for prototype testing available to the industry**. Technology companies are looking for the opportunities for prototype testing. The testing is welcomed both as part of a commissioned research contract and as a working partnership with STEM graduates/academics. There are low regulatory barriers in Rwanda making the country a good testbed for prototype development.

As for the second group of users: graduates, start-ups and entrepreneurs, the spaces currently on offer leave room for a new facility. The STEM lab facility will fill in a gap in the offer by **providing a space where entrepreneurs can develop innovative hardware based products and components**.

A significant issue is the lack of technological transfer from researchers to businesses. The facility is an opportunity to create **a space where knowledge transfer can occur**. Students are interested in the opportunities that may results from strengthening the relationship between the industry and academia. Students from technical or engineering background in STEM are looking for new job or internship opportunities. Because academic institutions do not have the possibility to have state-of-the-art labs, the STEM lab facility is an opportunity for students to be trained through such partnerships. With a facility run by the industry and for the industry rather than by academics, it will easily answer the industry's needs and constitute a push factor for demand.

Focusing on emerging technologies that serve best the mix of import substitution and export strategy

The market environment of Rwanda is evolving quickly. The country's rapid growth is coupled with increasing exports[1] and different possibilities regarding international markets and trade balance.

On the one hand, there are strong arguments for supporting more integration and more trade. The World Bank[2] and the International Growth Center[3] are major supporters of this trend and support the notion that, with only 12 million inhabitants, the domestic market of Rwanda is insufficient to allow Rwandan firms to benefit from scale economies. In this perspective, Rwanda has to take part in global trade and position itself in international value chains. More specifically, Rwanda should produce and export high-value processed products and import low-value raw materials as inputs. On the other hand, the Rwandan industry is looking to reduce its dependence on imports. To build components, Rwandan firms currently imports raw materials from India and China, but they would like to produce these inputs domestically instead. Therefore, in the view of the stakeholders from Rwanda's industry, developing technologies that allow import substitution would be beneficial to help built national capacity.

It is key to be strategic about which products can be produced in Rwanda considering economics and practicality. For example, consulted experts expressed that PCB and SMB manufacturing would not be desirable in Rwanda after the prototyping stage. It is also cheaper to buy a sensor on the international market rather than manufacture it in Rwanda. This is partially due to the lowering cost of sensors in the past decade[4]. Moreover, sensors specificities depend on the industry in which they are used, it is more important the engineer knows what type of sensor is needed for a product than actually manufacturing a specific type of sensor[5].

In this regard, there are several sectors related to STEM that have potential to grow in Rwanda. Three specific technological domains are highlighted whose development will support economic growth. They are likely to generate innovation, business opportunities and exports for Rwanda. The three market are also rapidly growing and driven by strong consumer demand:

- **Energetics** - electrical energy supply (EES)
- **Mechatronics** - mineral processing, agro-processing, construction
- **Industrial software systems** - focus on data analytics and embedded systems

The STEM facilities in Kigali will benefit to these sectors because their development requires investment in Research Development and Innovation (RD&I) infrastructure, and also because they will profit from collaborations across the RD&I value chains. These nascent markets present huge opportunities, both as sectors for entrepreneurs and innovators, but also for the industry in general to increase value proposition. Energetics, mechatronics and industrial software systems also provide possibilities on the international markets, as drivers of export growth and as substitutes to foreign imports.

Offering job opportunities for STEM graduates

Tertiary education is a key determinant for Rwanda to achieve and sustain high growth rates. In this perspective, the Government of Rwanda has been investing substantially in education. 11% of total government expenditures is currently dedicated to education, among which 20% go to tertiary education[6]. Fields of study related to STEM are particularly important for Rwanda's growth, as they are

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[1] Data World Bank, available on https://data.worldbank.org/indicator/NE.EXP.GNFS.ZS?locations=RW&view=chart

[2] World Bank. 2019. "Future Drivers of Growth in Rwanda: Innovation, Integration, Agglomeration, and Competition." Conference Edition. World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO

[3] Sheperd & Twum, Review of industrial policy in Rwanda - Data review, comparative assessment, and discussion points, November 2018, F-38426-RWA-1, International Growth Centre.

[4] Honrubia, M, *Industrial IoT is booming thanks to a drop in Sensor Prices,* 17 august 2017, URL: https://www.ennomotive.com/industrial-iot-sensor-prices/

[5] Kerns J, *Practical tips for specifying sensors*, 4 April 2015, URL: https://www.machinedesign.com/sensors/practical-tips-specifying-sensors

[6] World Bank data, retrieved from https://data.worldbank.org/indicator

essential to develop the manufacturing and the technology sectors. In 2016-2017, 9,238 students were enrolled in tertiary education in STEM (including ICT) in different institutions[7].

The relative share of graduates specialising in key sectors related to STEM is however relatively low. Only 6% are enrolled in engineering, manufacturing and construction and 9% in sciences, against almost the half in social sciences, business and law[8]. For Rwanda to grow a knowledge-based economy and a strong industry, the number of students in science and engineering needs to increase[9], and the STEM curricula needs to be more attractive, and more connected with the industry's demand. While the STEM graduates struggle to find relevant employment, the business sector reports an inadequately educated workforce which is not ready for the transition to the labour market and even rates it as the second constraint to do business in Rwanda[10]. It raises key challenges related to the employability of STEM graduates, and disconnection between the business needs and the curricula.

The services

NIRDA has scoped out a space for innovators to work. The design is **a 3-floor building on the campus of the University of Rwanda**.

The services provided by the facility and its staff will be the following: incubation services, mentoring services, a state-of-the-art STEM lab, R&D and testing services for the industry and finally capacity building and outreach. It is foreseen that the combination of these services will reinforce the local innovation ecosystem and improve the quality of industrial products and components, ultimately making the industry and SMEs more competitive and impactful. The investment required in the facility need to cover the **integration of (smart) hardware and software for the production of industry standard products and components ready to go to market**.

The operationalisation

The recommended **legal structure** for the "STEM lab facility" is that of a private company owned by Government of Rwanda with formal delegated powers to NIRDA. Government shall own 100% of the shares but progressively, shareholding shall be opened up for other stakeholders to own shares. This legal structure is considered a preferred option mainly because the initiative as foreseen would require a flexible structure that can bring in additional expertise (mentors and researchers) without incurring a delay. It would also be important to avoid any procurement challenges to enable the facility to adjust to the needs of industry. To ensure a high-quality implementation and financial sustainability of the facility, the governance and management model have to be built on partnerships, good selection and recruitment practices and a mentorship model. The preferred legal structure will allow the STEM lab facility to independently determine fees for selected services offered to industry, university and other stakeholders it would also allow the facility to interact and co-invest with other (private) companies.

Regarding the **allocation of lab time**, SMEs and industry applicants can put in a request for lab time any time. Because the industry is the primary payer of the facility, they will have a preferential access to the labs. SMEs will also enjoy reserved time slots.

For start-ups, time requests will be project specific. The graduates, researchers and entrepreneurs will have access to the facility and labs when there is no reserved access. Time requests should be put in for specific machinery, in collaboration with the lab manager. There should be no cap on time requests. The lab managers may not grant the time request, especially if there is no/low capacity. For each client group,

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7 University of Rwanda, Carnegie Mellon University, African leadership University, African Institute for Mathematical Sciences, Rwanda's Polytechnical College, NSIR, 2017

8 NSIR, 2017

9 RDB, Rwanda ranked 29th globally in 2019 World Bank Doing Business Report, URL: https://rdb.rw/rwanda-ranked-29th-globally-in-2019-world-bank-doing-business-report/

10 2019 World Bank Doing Business Report, URL: https://rdb.rw/rwanda-ranked-29th-globally-in-2019-world-bank-doing-business-report/

target allocation and upper limits are made around foreseen allocation of lab time (eg target lab time allocated to industry led project is 35% and the upper limit is 50%).

In order to maximise the capacity of the lab equipment, we suggest running three shifts, as is done at Africa Improved Food illustrating that local industry operates 24/7.

The **management** roles of the facility consist of a mix of skillset that combines a team of “business” oriented people having deep experience in supporting graduates and entrepreneurs to set-up and scaling-up start-ups (incubation & mentoring activities of the facility), and a team of “engineers” running and maintaining the machinery of the STEM lab with a good knowledge of the industries’ needs. This group of people attached to the STEM lab does not only run the operation of the equipment but also needs to have experience to add value to the operations.

We strongly recommend hiring an experienced lab manager. This person will be in charge of effectively running the labs, overseeing their use, managing the staff and ensuring the relevant staff is present to oversee prototyping and testing activities. Ideally, the lab manager will have (extensive) expertise in the three areas of work of the facility. It is important that the candidate has international experience, knows of similar or complementary facility in and outside Rwanda. He/she will be assisted in daily activities and running operations by engineers and technicians in energetics, mechatronics and industrial software systems. The team of engineers and lab technicians should be expanding with the activities and success of the STEM lab. We suggest the team build from a total of seven FTE staff (a lab manager, support staff and technicians).

A **cost and benefit analysis** of the Joint STEM lab facility has been conducted comparing the cost of investment with the expected benefit.

The set-up cost are estimated at $19m (building and equipment), the annual running costs (staff of the facility, external mentors, overheads) are estimated at $0,63m per year for a team of 13 full time employees (FTE) which corresponds to the preferred scenario aligned with the scope of services as described in **Error! Reference source not found.**, plus an additional $4m to maintain a state of the art equipment within the facility over a period of 25 years.

The wide economic and social benefits accrued 25 after the launch of the facility are estimated at $107m, which includes wage premium for people benefiting from training programmes, estimated value of the supported start-ups, estimated value of wages for additional jobs created, estimated income earned by STEM lab facility for commissioned research, and commercial rate charged to large companies for using the lab equipment.

Considering only the revenue to the facility, ie the income from renting out workspace to incubatees/start-ups; the royalties on patents and trademarks in relation to successful incubatees; the charging industry for their use of the STEM lab facilities, and the income earned from commissioned research (totalling $49,1m over 25 years), the break-even point of the facility will be reached in year 7 of operations, and 10 years of operations when only 75% of the targeted revenue is secured. This calculation excludes the initial capital investment of $19m and the wider benefits to stakeholders.

This cost-benefit analysis assumes that the facility will be a highly prestigious one with no debilitating challenges in attracting interested parties to the facility. It is also assumed that the facility itself, including the staff in charge can add value to industry and incubatees. As a result of this assumption the assumed benefits / revenues are high.

The critical success factors

There is a business case for a Joint STEM Industrial Product Development Facility in Rwanda, and expected benefits exceed the cost of investing in it. However, considering the relative novelty of such an initiative in a nascent national innovation ecosystem, the project bears some risks, and from the study team perspective, success will depend on a few key elements that NIRDA has to keep in mind when implementing the initiative:

- **Sourcing and recruitment of customers** – one of the key risks for any facility is building a sustainable pipeline of customers. The result of not building this pipeline in a timely manner will imply that it will take longer to breakeven and this will put a strain on resources. For the incubation facility, sourcing and deal flow is of particular importance, and for that purpose to build close ties with the universities and research organisations (ie generating a flow of researcher projects).
- **Collaboration** for generating a deal flow of customers and providing high added value services. The preferred option assumed that industry is interested in collaborating with academia. To date, there has been little collaboration of this kind in Rwanda and the culture of collaboration is nascent. This means that the facility will have to push hard at stimulating collaboration and building a culture of collaboration to generate a deal flow of users of the STEM lab facility.

  Collaboration also means pushing forward cooperation between the founders and start-ups incubated in the facility. The design of the incubation facility space has to facilitate interactions across the different founders and start-ups that will be supported by the team to generate cross-fertilisation and innovations.

  The facility will have to network with other business and innovation support organisations in the country and external experts and mentors (nationally and internationally) in order to propose the best value for money for its customers. Indeed, deploying a comprehensive service offer does not mean the STEM lab facility will offer the service by its own, but must be in position to propose to its customers the relevant experts and expert organisations to support them (subsidiarity principle).
- **Uniqueness and professional standards -** Incubation offer is not unique in Rwanda– there is a growing landscape of industry support services and many support young entrepreneurs. Yet a main revenue stream is expected to come from royalties from IP protected by successful incubatees. As a result, it signals the incubation offer of the facility must provide strong added value and professional standards (vis à vis the existing incubation offer) to incubatees to keep attracting projects and individuals and make them successful to generate royalties. One of the key elements is therefore the content and quality of incubation/acceleration program that the incubation facility will offer to its tenants. This program should at least include coaching services to founders and entrepreneurs on business model, HR and governance management of the company, access to finance, innovation marketing.
- **People, people and people** – the ability of the STEM lab facility to attract (and retain) talented staff and to combine the relevant set of skills (finance, business, engineer background with soft skills such as coaching, network building, and communication) will put the facility to the test. The facility will have to recruit a top manager for both the lab facility and the incubation facility with people capable to coach founders and entrepreneurs, to challenge their ideas, their business models, their management structure and their innovativeness. At this moment in time there is little expertise to lead this type of facility in the country. Recruiting the right staff will enable the facility to offer customers added value. The building and equipment on their own cannot deliver this (long-term) added value. The STEM lab facility will have to recruit both nationally and internationally and will have to pay attention to run dedicated training programmes for staff.
- **Detailed specifications of the equipment and machinery** in each of the three market areas (energetics, mechatronics, and industrial software) will need to be checked in detail by sectoral experts, with respect to SMEs and industrial needs, with technical specificities and with respect to the induced costs. The main targeted customers of STEM lab equipment and machinery will be existing SMEs and industries, as it is hard to anticipate the new of incubated start-ups, the very nature of the necessary equipment varies considerably from one startup to another.
- **Embedding STEM lab machinery in education programmes at the Universities** – it is recommended to make sure that the STEM lab equipment are used by education programmes at the universities, not only to guarantee the use of the machinery, but also to train academic staff and students to state-of-the-art equipment, then increasing their employability on the labour market. In this regard, the detailed specifications of the equipment and machinery should be made in close connection with (local) university departments to make sure they are relevant to the curricula, and to get their commitment (MoU signed with relevant university departments) to include the STEM lab equipment as part of their education programmes.

1 Introduction

1.1 This report

This feasibility study was carried out by Technopolis Group for NIRDA and its partner Enabel to help determine the relevance, need, and expected socioeconomic benefits of investing in a joint STEM industrial research and development facility in Rwanda.

This report presents the findings of the data gathering activities (ie desk and literature review, stakeholder interviews, first site visit and cost-benefit analysis).

The present assignment is aimed at providing an objective, evidence-based and holistic assessment of the feasibility of a STEM industrial research and development facility in Rwanda. It will also explore options for implementation of the facility. More specifically, the objectives of the study are to:

- Provide evidence about the needs for a STEM facility in Rwanda
- Define the tasks and services of the STEM facility
- Define the governance structure and operation of the STEM facility
- Estimate the costs and benefits of the STEM facility
- Present a tentative roadmap for the STEM facility

1.2 Methodological approach

- **Desk research and document review:** The research team has carried out a review of all documentation received from NIRDA. The literature review included documentation about NIRDA, the STI ecosystem in Rwanda and the region, examples of facilities and previous assessments of the policies of Rwanda as well as PowerPoint presentations and summaries by NIRDA.
- **Site visits and stakeholders' interviews**: The study team interviewed a diverse group of stakeholders (21 interviews) in June-July 2019. We have engaged with a high variety of stakeholders directly involved in the design or implementation of STEM policies or projects. Interviewees ranged from the industry to government officials, academics and international development agencies. In total we interviewed representatives from HEIs (3), a donor (1), start-ups (4), national government (1), industry (7) managers of innovation spaces (4), and a manager of training space (1). Eighteen interviews took place face-to-face and three were phone interviews. These interviewees allowed us to collect information on the STEM ecosystem in Rwanda, identify needs and gaps in the current ecosystem, gather information on existing innovation spaces/ incubators.
- **Workshop with the steering board:** A meeting took place on the 28th of June with representatives of NIRDA, the University of Rwanda and Technopolis. The team presented the results of the first site visit and worked with members of the steering board to agree on the future facility's scope, objectives and beneficiaries.
- **Stakeholder workshop**: A brainstorming and validation workshop was held 23 September, 2019 in Kigali. Around 30 participants were present from a variety of organisations including HEIs, incubators, start-ups, and donors.

1.3 NIRDA and its purpose

The National Industrial Research and Development Agency (NIRDA), established by the law n'51/2013 of 28/03/2013 replaces the Institute of Scientific and Technological Research.

NIRDA has been mandated with a mission to enable a (next) generation of industrial innovators to become competitive through technology monitoring, acquisition, development and transfer and applied research, contributing to Rwanda's vision for 2050. Vision 2050 focuses on five priorities, which underpin the design, policies and actions of National Strategy for Transformation (NST-1).

The Government of Rwanda set itself specific targets in Vision 2020 aimed at driving Rwanda's journey to economic transformation from a subsistence agriculture economy to a knowledge-based society. The new NIRDA strategy accentuates a vital and practical approach to supporting Rwandan industries through technology acquisition and applied research and development. This renewed emphasis reflects the vision of the Government of Rwanda, as defined in the new 7-Year Government Programme (2017-2024), Priority Area 4, which underscores the central role of industrialisation to attain a structural shift in the export base to high-value goods and services, with the aim of growing exports by 17 per cent annually.

NIRDA supports the community of innovators by:

1. Identifying new sub-sectors or value chains where investment by the private sector would likely lead to export growth or import substitution
2. Improving the competitiveness of existing industries in order to increase their export potential or their potential to undertake import substitution

These objectives are fully in line with government's industrial policy objectives of increased domestic production for local consumption and improved export competitiveness. They are also fully in line with **government's trade policy objectives**[11] of:

- Increased productivity, competitiveness and diversified sustainable productive capacities for trading nationally, sub-regionally, regionally and internationally
- Increasing investment, including foreign direct investment, into production of competitive goods and services for the export market
- Strengthened science, technology and innovation policies, strategies and institutions including intellectual property laws, in support of industrial development and creative knowledge-based industries

NIRDA's mission echoes the ninth Sustainable Development Goal (SDG-9), and aligns with many other SDGs, including those related to poverty eradication, creating full and productive employment, protecting the environment, achieving gender equality and the empowerment of women and girls, etc.

1.4 NIRDA and its approach

The NIRDA Strategic Plan (2018-2022) is being implemented through a range of programmes, services and projects delivered primarily in partnership with the private sector. NIRDA is also contributing to other public and private initiatives to strengthen the competitiveness of Rwanda industry, as outlined in Vision 2020. It sits at the performance level, pushing for scientific research, technological development and productive innovation.

There are five pillars establishing the framework for the NIRDA strategy[12]:

- Key Pillar 1: Institutional capacity development: This ensures NIRDA has the institutional capability and capacity to implement the Strategic Plan 2018-2022
- Key Pillar 2: Technology and operational monitoring: NIRDA will establish a sound knowledge base of technology developments within the region and globally to allow the selection of priority value chains for technological upgrading. Knowledge will underpin decision making at all levels of the institution. NIRDA will clearly identify when and how NIRDA's interventions have led to increases in the productivity and competitiveness of supported enterprises
- Key Pillar 3: Technology acquisition, commercialisation and transfer: NIRDA will support partner enterprises in selected value chains to help them improve their competitiveness through the

[11] Government of Rwanda, 7-year Government Programme: National Strategy for Transformation (NST1), 2017 - 2024

[12] NIRDA strategic Plan 2018-2022

acquisition and commercialisation of appropriate technologies. NIRDA will support the replication of successful pilot projects by a large number of private enterprises

- Key Pillar 4: Applied research and technology foresight: NIRDA will undertake pre-commercial exploratory applied research and development leads to the development of an area of capability or a technology platform that is likely to lead to increased competitiveness or the opening of a new market opportunity. NIRDA will identify emerging technologies likely to yield the greatest economic and social benefits to Rwanda in the future and will **provide innovation laboratories for testing and prototyping new technology for future industries**. We will undertake collaborative projects with frontier industry technology providers and build networks to promote innovations for future industries
- Key Pillar 5: Business and technical development and advisory services to support industries: NIRDA will support and develop market systems designed to improve the access Rwandan enterprises have to business and financial services, so that they are more able to compete in national, regional and global markets and better equipped to develop, acquire or transfer the technology they require

1.5 Objectives of the Joint STEM Industrial Product Development Facility

1.5.1 Introduction to the Joint STEM Industrial Product Development Facility

The proposed Joint STEM Industrial Product Development Facility will be a part of the activities supporting NIRDA's objectives that have the objective to:

1. Improve the competitiveness of existing industries in order to increase their export potential or their potential to undertake import substitution
2. Identify new sub-sectors or value chains where investment by the private sector would likely lead to export growth or import substitution

The facility is also intended as a major investment that will allow contributing to:

1. Promote industrialisation and industry's contribution to GDP
2. Support the creation of jobs relevant to STEM graduates
3. Help establish Rwanda as a globally competitive knowledge-based economy

NIRDA plays a key role enabling a generation of industrial innovators to become competitive through technology monitoring, acquisition, transfer and applied research and development.

The facility will be focused on the development of prototype products and components ready for industrialisation (industry standard products). It is key the products developed at the facility are of high-quality. On the other hand, the innovators will have access to advanced technologies, will be given the tools and coaching necessary to acquire and upgrade their technical industrial skills and improve their business capabilities. This will in turn enable them to recruit more young Rwandans into higher value jobs created by their own company development.

The facility will be expected to support the creation and development of "job/business creators" and it is expected that this community will have a positive multiplier effect on the economy. This is in line with the objective of NIRDA to promote industrialisation and the industry's contribution to GDP. In this light, the Economic Transformation Pillar of the National Strategy for Transformation (NST1) presents a strategy to accelerate private-sector-led economic growth and increased productivity[13]. One of the identified priority areas to which the facility will contribute is job creation (over 214,000 jobs to be created annually), establishing Rwanda as a globally competitive knowledge-based economy by

[13] The economic transformation will "accelerate inclusive economic growth and development founded on the private sector knowledge and Rwanda's natural resources". Source: National Strategy for Transformation 2017-2024, 7 years Government Program

promoting innovations and improving skills. The future facility will also support the priority area to promote industrialization and exports of high-value goods and services, growing exports by 17% annually.

1.5.2 Purpose of the STEM lab facility

NIRDA supports the development of specific ultra-modern technologies as part of the "Made in Rwanda" brand which will form a strong export base and position Rwanda as a globally competitive producer and developer of smart products/devices.

According to NIRDA's plan, the Joint STEM Industrial Product Development Facility (also called STEM lab facility in the report) will act as an industrial technology incubation hub for industrial innovators drawing on STEM to **develop prototype products and components ready for industrialisation**. The industrial product development facility will bring together private innovators, experienced industrial mentors, academia, and other key stakeholders.

Under this overarching goal, the core functions of the STEM lab facility are to:

1. Identify (homegrown) solutions for local need - This will be supporting the development of specific ultra-modern technologies as part of the "Made in Rwanda" brand
2. Incubate young Rwandan innovators with a keen interest in STEM-related industrial product development - The facility will be supporting innovators to create new start-up companies and increase the competitiveness of existing companies
3. Enable industry to outsource R&D to a lab with the right equipment, standards, service provided - The industry will be encouraged to commission applied research and development projects at commercial prices
4. Inspire the wider community through the investment in emerging technology - It is important the facility attracts the future STEM professionals but also that it encourages the industry to invest in R&D and manufacture modern hardware products at industrial scale

The facility will focus on three industrial areas that were identified by NIRDA. These are areas where disruptive technologies present big opportunities for Rwanda:

- Mechatronics
- Energetics
- Industrial software development

1.5.3 Theory of change/logic model of the STEM lab facility

To achieve its main mission, NIRDA has to collaborate with public institutions, private sectors or entrepreneurs who wish to invest in new or improved industrial research products, in the framework of producing high-quality value-added products for both local and international markets.

In instances where support for RD&I development is needed to make investment in the value chain attractive to the private sector or where appropriate technology cannot be acquired (or where such technology needs significant adaptation to make it viable in a Rwandan environment), then the STEM lab facility can support.

Indeed, pre-commercial exploratory applied research and development leads to the development of an area of capability or a technology platform that is likely to lead to increased competitiveness or the opening of a new market opportunity.

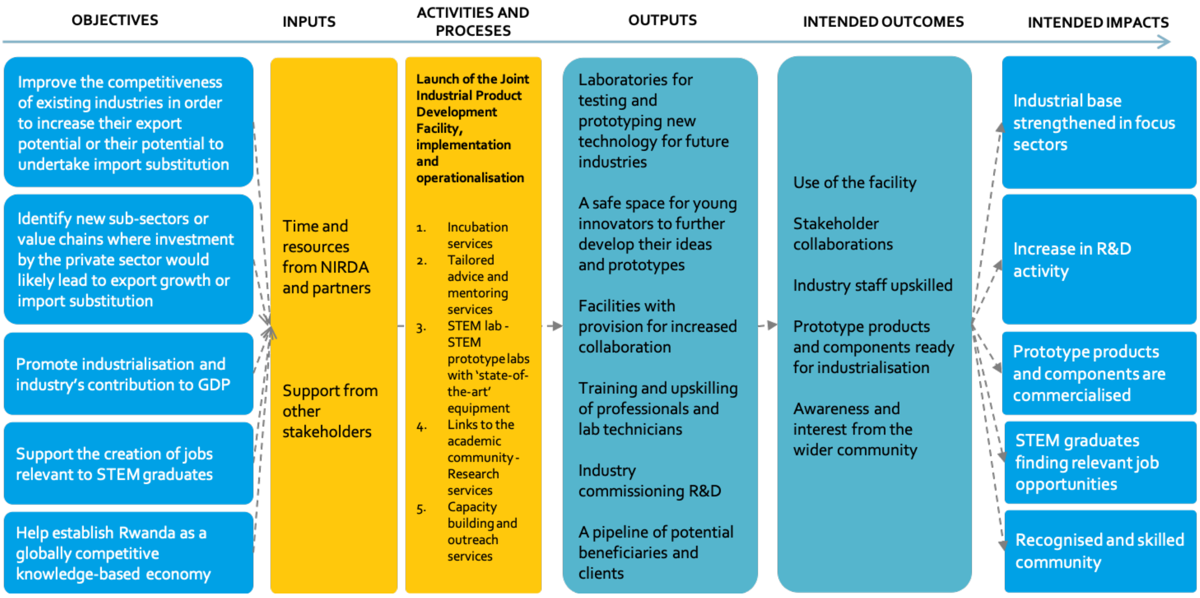
These impacts of the facility will be reached through the following intervention as outlined by means of Figure 1. An important aspect of the facility will be to link the industry and HEIs, fostering exchanges between the two communities and support future partnerships.

On basis of the objectives stated for the facility, five main activities will be implemented:

1. **Incubation services**, supporting entrepreneurs and start-ups in their development.
2. **Tailored advice and mentoring services**, targeting entrepreneurs and graduates to acquire the necessary skills they need to run a successful company and/or excel at research and development.
3. **STEM lab - STEM prototype labs with 'state-of-the-art' equipment**, offering the opportunity to lab users to develop new industrial products.
4. **Links to the academic community - Research services**, which will materialise in commissioned research from the industry when it does not have the capacity to pursue research on improving its products, expand its usage or develop an entirely new product.
5. **Capacity building and outreach services,** in order to ensure interest from potential users.

The logic model underlines how the activities will result in a series of outputs including the development of ideas, upskilling of workforce and a steady pipeline of clients. Those outputs are leading to increased collaboration, prototypes ready for market which themselves will help reach the impacts.

Figure 1 Joint Industrial Product Development Facility logic model and theory of change



Source: Technopolis Group, 2019

Prior to the establishment of the foreseen facility, a modern 'state of the art' physical space for Rwandan innovators is planned to be **launched in 2019. The STEM lab facility will be built on the soon to be established STEM 4 INDUSTRY Hub, a smaller initiative focussing on supporting entrepreneurs develop ideas into first-stage prototypes.** The STEM 4 INDUSTRY Hub will focus on the development of homegrown, problem-based, data-driven, innovative smart solutions. It will provide technical and business services for successful incubation of industrial product development.

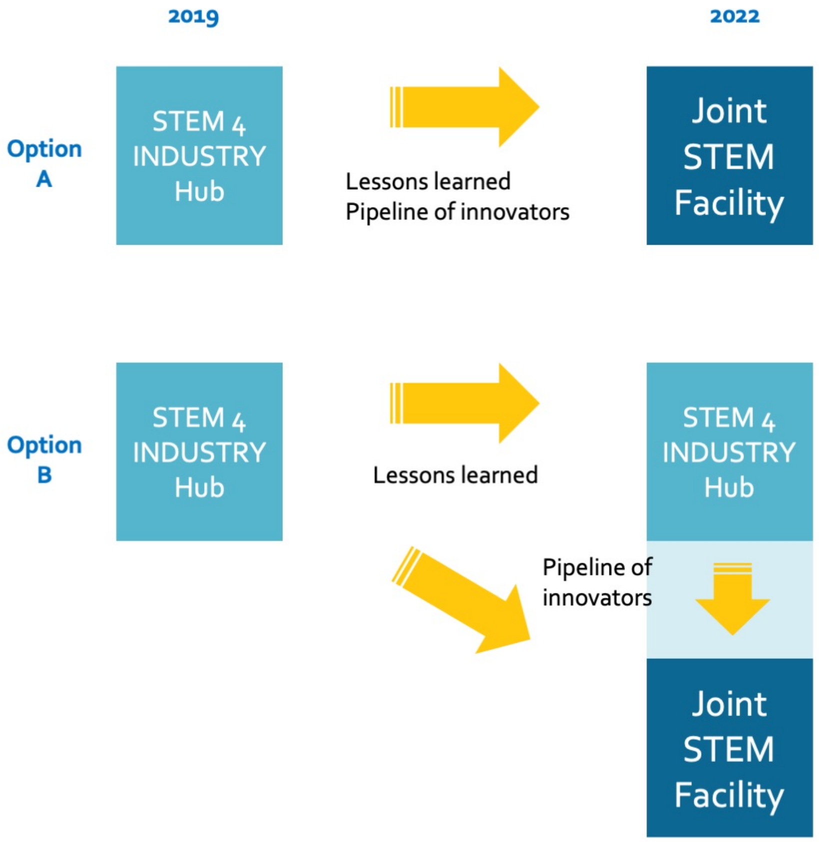
The STEM 4 INDUSTRY Hub will offer a first opportunity for NIRDA to **cement relationships with the University of Rwanda**, testing the working agreements and pipelines. The STEM 4 INDUSTRY Hub will target STEM graduates, therefore having a narrower scope than the STEM facility.

The STEM 4 INDUSTRY Hub will be an incubator/accelerator space for prototyping with light machinery and will also help develop entrepreneurs' soft skills. The STEM 4 INDUSTRY Hub will work on sectors that are relevant for NIRDA and the Ministry of ICT.

It is possible the two STEM initiatives (the STEM 4 INDUSTRY Hub that is currently being launched and the Joint STEM lab facility which is the focus of this document) overlap once the STEM lab facility is running. A decision will be made on whether the STEM 4 INDUSTRY Hub should be dissolved or whether it should be integrated as part of the STEM lab facility, once this is launched. These two options are presented in the figure below. The decision will depend on the maturity of the wider ecosystem and the quality of support provided to start-ups at the time of the launch of the STEM lab facility. Stakeholders (eg FabLab, Klab, 250Startups) have already invested in supporting start-ups and there are plans for other initiatives to be launched in this space.

- Option A: If the ecosystem has sufficiently matured by the time the Joint STEM facility is opened to the public the STEM 4 INDUSTRY Hub will be dissolved and integrated in the STEM facility. In this case, the equipment located in the STEM 4 INDUSTRY Hub is moved to the facility or collaborating institutions.
- Option B: If the ecosystem has not matured sufficiently and more support is needed to build a pipeline of innovators the STEM 4 INDUSTRY Hub is merged into the STEM facility and incubation activities (supporting entrepreneurs in their first stages of prototype development) will continue by the STEM lab. Any equipment associated with the STEM 4 INDUSTRY Hub will then be moved to the facility.

Figure 2 Integration of the STEM 4 INDUSTRY Hub with the STEM lab facility



Source: Technopolis Group, 2019

2 Needs assessment

The local ecosystem in Rwanda is a mix of universities, technical colleges and facilities that are often supported by a public body. The local ecosystem in STEM is actively progressing despite barriers such as limits in IT infrastructures and difficulties in accessing investments. However, there is a disconnect between the industry and the current offer from universities, especially regarding industrial hardware development. The upcoming STEM lab facility is meant to address some of the key shortcomings.

2.1 Skills and capacity

Rwanda has created some of the most favourable background conditions on the continent to help it grow its research and innovation system.

A series of interlinked policies under the umbrella of Vision 2050 covering education, healthcare, internet access and improved conditions for doing business have transformed the environment for research and innovation in the country. This is backed up by the World Economic Forum global competitiveness report's judgment that Rwanda has the strongest institutions in the region. The Africa Innovation Policy Manifesto was signed in Kigali and includes signatories from three Rwandan based innovation hubs.

Rwanda's competitive advantages include[14]:

- Cheap labour compared to other countries in the region
- Young and dynamic workforce (98% of the population is under 50 years and 43% is under 16 years)
- Most favourable business environment in the Region (29th place to do business in the world[15] 2019 and 2nd in Africa)
- Low levels of corruption - zero tolerance (2nd for Government transparency in Africa[16])
- World class ICT infrastructure (1st in the world for network readiness 2nd in the world of ICT promotion[17])
- Strong and visionary leadership
- Bi-lingual business environment (French and English)

Tertiary education is a key determinant for Rwanda to achieve and sustain high growth rates. The Government of Rwanda has been investing substantially in education. 11% of total government expenditures is currently dedicated to education, among which 20% go to tertiary education[18]. As a result, tertiary education is expanding quickly, and Rwanda is experienced low but rapidly rising tertiary enrolments. More specifically, enrolments in tertiary education have more than doubled in the last 10 years, going from 3,5% in 2006 to 8% in 2016[19]. Moreover, the public university system was rationalised in 2013 to create the University of Rwanda, a research and teaching focused university, from a number of previous smaller public universities. This research focused university is complemented by a growing

[14] USAID, *Kigali Innovation City*, UNCTAD World Investment Forum 2016, Project Profile, URL: https://d3n8a8pro7vhmx.cloudfront.net/eatradehub/pages/2478/attachments/original/1470045106/Kigali_Innovation.pdf?1470045106

[15] RDB, Rwanda ranked 29th globally in 2019 World Bank Doing Business Report, URL: https://rdb.rw/rwanda-ranked-29th-globally-in-2019-world-bank-doing-business-report/

[16] Transparency international, *Index 2018*, URL: https://www.transparency.org/cpi2018

[17] Ministry of ICT and Innovation, *Rwanda's Degital Transformation*, 5th eGovernance Conference, May 2019, Tallinn, https://2019.egovconference.ee/wp-content/uploads/sites/2/2019/02/Paula-Ingabire-Rwandas-Digital-Transformation.pdf

[18] World Bank data, retrieved from https://data.worldbank.org/indicator

[19] World Bank data, retrieved from https://data.worldbank.org/indicator

number of private universities focused more on teaching. The GoR has also planned and invested in Technical and Vocational Education and Training (TVET).

However, this upward trend in education has been slowing down in the last years. The share of government expenditures for education have shrunken from 17% in 2011 to 11%, and the proportion of Rwandans enrolling in tertiary education has been steady since 2013[20].

Fields of study related to STEM are particularly important for Rwanda's growth, as they are essential to develop the manufacturing and the technology sectors. Therefore, the Government of Rwanda has been investing considerably in Life Science & STEM sectors, both regarding infrastructure and human capacity development. In 2016-2017, 9,238 students were enrolled in tertiary education in STEM (including ICT) in different institutions[21]: University of Rwanda, Carnegie Mellon University, African leadership University, African Institute for Mathematical Sciences, Rwanda's Polytechnical College.

Table 1 Students enrolled in tertiary education 2016-2017, Rwanda

Field of Education	*Enrolment*
Natural Sciences, Mathematics and Statistics	3,977
Information and Communication Technologies	3,325
Engineering, Manufacturing and construction	1,936
Business, Administration and Law	

The relative share of graduates specializing in key sectors related to STEM is rather low. Among the students enrolled in tertiary education, only 6% are enrolled in engineering, manufacturing and construction and 9% in sciences, against almost the half in social sciences, business and law[22]. For Rwanda to grow a knowledge-based economy and a strong industry, the number of students in science and engineering needs to increase[23].

A key issue noted by local stakeholders is the struggle faced by STEM graduates to find relevant employment. A first possible explanation is the relatively high youth unemployment rate in Rwanda, even for graduates of higher education. The share of youth without employment was 22,6% in 2017, and the rate was only slightly inferior for graduates from higher education (19,6%)[24]. Also, the general skills mismatch between graduates and the industry's demand affects the hiring. Business people report an inadequately educated workforce which is not ready for the transition to the labour market and even rate it as the second constraint to do business in Rwanda[25].

Different initiatives are contributing to overcome the obstacles to youth unemployment. For instance, the Rwandan Development Board (RDB) has set out (in 2019) a roadmap for the launch of an **Innovation Proof of Concept Hub**, with the intention to position Rwanda as a 'Living lab' for Africa, to attract innovators from abroad, to provide them support to test their ideas in Rwanda, and to help them expand their innovation into other African markets.

[20] World Bank data, retrieved from https://data.worldbank.org/indicator

[21] NSIR, 2017

[22] NSIR, 2017

[23] RDB, Rwanda ranked 29th globally in 2019 World Bank Doing Business Report, URL: https://rdb.rw/rwanda-ranked-29th-globally-in-2019-world-bank-doing-business-report/

[24] International Labour Organisation data, retrieved from https://ilostat.ilo.org/data/country-profiles/

25 2019 World Bank Doing Business Report, URL: https://rdb.rw/rwanda-ranked-29th-globally-in-2019-world-bank-doing-business-report/

Other initiatives include the **African Design group**, funded by MASS design group in 2016 and provides fellowships to design graduates to achieve impact in their chosen fields and the **Rwanda Coding Academy**. It is a 2019 initiative funded by the Government of Rwanda in partnership with the Swedish International Development Cooperation Agency (SIDA). The Academy provides high level software engineering courses. It is based at Nyabihu TVET School and has an initial intake of 60 students. It plans to roll out to five provinces of Rwanda and graduate 300 students per year.

Rwanda has attracted funding for multiple Centres of Excellence. In 2016, the University of Rwanda was able to secure four of the 24 **centres of excellence** being established under the ACE 2 World Bank initiative:

- African Centre of Excellence in Energy for Sustainable Development (ACEESD) and
- African Centre of Excellence in Internet of Things (ACEIoT) both hosted at the College of Science & Technology
- African Center of Excellence for Teaching and Learning Mathematics and Science (ACEITLMS), College of Education
- African Centre of Excellence for Data Sciences (ACE-DS), College of Business & Economics

Moreover, in 2017 the African Leadership University's (ALU) opened its **Business School** in Kigali. ALU offers undergraduate courses with an innovative loan financing model and aims to train three million ethical and entrepreneurial leaders for Africa using a project-based approach to education.

Box 1 Youth employment initiatives

Harambee is a youth employment accelerator that creates bridge between graduates and employers. They understand the specific needs of companies in terms of skills and attitude and match it with youth. When there is a gap between the demand of the industry and the skills of the youth, Harambee takes care of closing this gap by providing trainings to the graduates. They mostly work on English proficiency and on soft skills that are not learned at schools/universities such as speaking abilities and professionalism. Regarding STEM sectors, they also develop the graduates' problem-solving abilities and digital literacy. Hence, Harambee's work fully depends on the needs of the industry and is demand-driven.

Originally from South Africa, the concept of Harambee was implemented in Rwanda in 2018. Since then, Harambee has placed 300 graduates in jobs and traineeships and has 2,800 applicants. They work with graduates from 18 to 35 years old with any type of education, from primary to master's degree. The employment opportunities are various as Harambee works with big companies that are ready to hire 10 to 20 graduates, but also smaller companies that are looking for 1 or 2 people or for the public services. For STEM, Harambee already worked with the LEAPR lab, coaching graduates to take part in the fellowship on flying robots, telecom and remote sensing and other activities of the lab.

When starting with Harambee, the graduates take part in a one-day employability workshop, and then enter the database which allows them to receive potential job opportunities and related specific trainings. In order to work only with the most motivated graduates, Harambee uses tools to track some aspects of their behaviour, notably attendance and activity. In Rwanda, the program Harambee is funded by private and public sources and collaborates with the Ministry of Education.

The **Next Einstein Forum** (NEF) is an initiative, founded by AIMS, that aims at making Africa a global hub for science, technology and excellence. Main activity is the organisation of the NEF Global Gathering, a large scientific conference taking place every two years that positions science at the centre of global development efforts and includes political and industry leaders. They also established the NEF platform that creates public engagement on the importance of technology and the NEF community of scientists composed of young experienced researchers in STEM. NEF is policy-focused and its activities connect science, society and policy with the goal to leverage science for human development globally, while raising awareness on African research.

NEF shows interest to engage with NIRDA regarding the STEM facilities lab by providing expertise and mentoring to entrepreneurs. NEF has the necessary knowledge as the NEF Community works on technologies and is aware of new trends in the STEM fields while having strong links with the industry and insights on the development of industrial R&D.

2.2 Barriers to industrial scale up

Rwanda faces a number of issues in view of scaling up industry. On basis of the document review, interviews and workshops the research team has held, the following difficulties are identified:

1. Rwandan based industries tend not to have R&D departments

There is no industrial scale machinery and equipment for prototype testing available to the industry. In the absence of prototype testing in Rwanda, the industry is forced to externalise testing to other countries (eg Volkswagen conduct prototyping in South Africa). Moreover, the industry has no or limited labs to develop prototypes.

It should be noted that private sectors' R&D expenditures data collection has gaps. The only sector with recent data on R&D expenditures is agriculture research, thanks to surveys made by Agricultural Science and Technology Indicators (ASTI)[26].

2. Low level of collaboration between industry and universities

The collaboration is weak due to the fragmentation in the ST&I system. However, some industry players are now collaborating with universities such as the Integrated Polytechnic Regional College (IPRC) (eg through training, student internship, professional internships). Some stakeholder suggest that recently there has been an increased interest towards the commissioning of research and prototype development.

3. Lack of specialist training and soft skills

There is need for providing young graduates and technicians training on , for example, electronic design (eg PCB, Embedded programming, PCB fabrication), machining techniques (eg sheet metal, CNC, welding, painting technologies and techniques, magnetics design and fabrication, automation, hydraulics and pneumatics design, programming and fabrication) and business planning (eg investment mobilization, marketing, sales, operations).

4. Sourcing investment and finance

While investments are difficult to acquire, some investments have already been made in providing entry-level prototyping (eg KLab and Westervelle Makerspace). Moreover, the industry is interested in having access to (other) lab equipment for **advanced prototype testing.** Local industry is interested in commissioning prototype testing to the STEM lab facility and is interested in working together with STEM graduates to develop and test prototypes.

The next barrier is related to the context of Rwanda rather than the extent of the business policies in place.

5. Transport / import of raw materials

Because Rwanda is a landlocked country and has road transport is sometimes compromised, access to raw materials may be a serious challenge to shift to a higher industrialisation base. This also has some impact on prototype development. Raw materials are costly. This is due to the high VAT on equipment (40%-50% tax). because of the limited specialist training provided, some stakeholders suggest that there is a lack of understanding about the option of raw material available to product designers/developers. This lack of awareness has potential to limit opportunities to implement policies or programmes to decrease the costs. It also links to the ambition of the upcoming facility to mass produce or not the prototypes that will be developed inside its walls.

For the manufacturing industry in general it is very hard to compete with China, particularly in a landlocked country with few natural resources. For example, making li-ion batteries, PCB and SMB

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[26] UNESCO Global Observatory of Science, Technology and Innovation Policy Instruments (GO-SPIN), Mapping research and innovation in the Republic of Rwanda - Country profile, 2015, URL: https://en.unesco.org/go-spin/country-profiles

manufacturing is hardly practical or economical. Prototyping can be done in Rwanda but production tends to be outsourced to China.

2.3 Complementing the wider research and business ecosystem

2.3.1 Facilities available in Rwanda

If/when invested in, the STEM lab facility has to complement the existing research and business support offer in Rwanda. It is best practice the facility builds on and adds value to the existing business support offer, ensuring long-term success. The Figure 3 illustrates how the new facility could position itself.

Members from industry welcome the idea of the STEM facility for several reasons:

- There are no industrial scale machinery and equipment for prototype testing available to the industry
- Technology companies are looking for the opportunities for prototype testing, based on the survey conducted by the study team. The testing would be welcomed both as part of a commissioned research contract and as a working partnership with STEM graduates/academics[27].
- There are low regulatory barriers in Rwanda making the country a good testbed
- Moreover, some industrial players have invested in equipment (eg CNC milling, lathe machine, 3D printers, test bench for calibration testing)

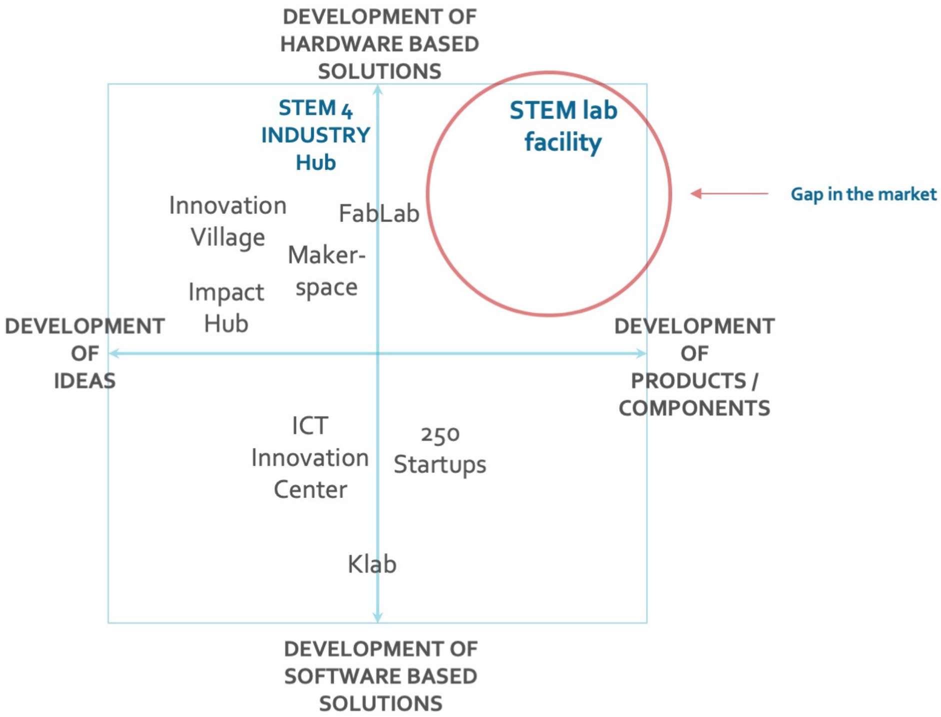
As for the second group of users: graduates, start-ups and entrepreneurs, the currently available spaces leave room for a new facility. The STEM lab facility would fill in a gap in the offer by providing a space where entrepreneurs can develop hardware based concrete products.

A significant issue raised was the lack of technological transfer from researchers to businesses. The facility would be an opportunity to create a space where transfer could occur. Building up the relationship between the industry and academia would also be welcomed for students. Students from technical or engineering background in STEM are looking for new job or internship opportunities. Because academic institutions do not have the possibility to have state of the art labs, the STEM lab facility would be an opportunity for students to be trained through partnerships. With a facility run by the industry and for the industry rather than by academics, it would easily answer the industry's needs and constitute a push factor for demand.

Moreover, several interviewees were adamant there is a lack of products development at the moment, with a focus in many spaces on software. This is due to software development being cheaper, requiring less equipment and little consumables. Moreover, scaling a software solution is practically free compared to scaling up the production of hardware. Nonetheless, hardware production is believed to have a potential stronger spill over effect on employment. Rwanda also faces many challenges where hardware solutions are needed such as agriculture irrigation or energy production and storage.

[27] Companies/stakeholders interested in both were REMCO, Positivo Electronics, Vision technologies, Mvend, MTN

Figure 3 Space available for graduates, start-ups and entrepreneurs



Source: Technopolis Group, 2019

2.3.2 Description of the existing ecosystem in Rwanda

As shown in the previous figure, most Rwandan spaces focus on the development of ideas. There is a certain preference for spaces that develop either software-based solutions or a mix of hardware, but none focus solely on hardware. This is where the STEM 4 INDUSTRY Hub and the facility can add clear value for entrepreneurs, and the industry. The existing spaces are summarised below:

- **FabLab Rwanda**, established in 2016, is a small space for selected entrepreneurs to develop their first stage hardware products or prototypes (eg furniture, carved signs) and gain experience in using technology. The facility operates in a similar way to a Makerspace: entrepreneurs have access to relevant equipment such as 3D printers and wood cutting machines. The facility does not promote the development of high-tech products, rather the facility is helping make existing sectors more productive by introducing entrepreneurs to advanced technology. FabLab has a customer base that is commissioning the production of (a smaller number of) hardware solutions. There are a dozen FabLab entrepreneurs. A share of their revenue obtained through commissioned work goes to FabLab. FabLab is a semi-public structure, which is part of a global network of FabLabs, which run a great international programme called Fabacdamy. FabLab managers expressed interest to collaborate with the STEM facility. Fablab is partnering with 250 startups/JICA in opening five other fablabs around the country. Equipment for the first has already been bought.
- **KLab Rwanda**, in existence since 2012, is a space for technology where students, fresh graduates, entrepreneurs and innovators come to work on their ideas/projects to turn them into viable business models. It is a space where entrepreneurs work, meet and develop software. KLab offers mentoring and host events, workshops, bootcamp, hackathons and networking sessions to promote collaboration/partnerships, investment and financing. KLab is a semi-public structure. The KLab also hosts the programme 250startups. KLab managers expressed interest to collaborate with the STEM facility.
- **Impact Hub Kigali**, in existence since 2012, is a co-working community and event space. In that sense it does not give access to equipment, nor does it focus on a specific type of innovation. The

team also offers consulting services in design thinking, supporting the implementation of innovation projects. Impact Hub is a private, membership-based structure.

These three structures are signatories of the Africa Innovation Policy Manifesto which gathers 90 innovation hubs across 32 countries. The manifesto was adopted in Kigali in 2018 and aims to "accelerate digital transformation and contribute to more equitable, inclusive and sustainable development of our economies and societies".

- **Innovation Village,** launched in 2015**,** is a partnership between Village Group and the Government of Rwanda to promote literacy and culture and inspire innovation. The space is located on the rooftop of the Kigali Public Library is 855 square meters, it is made up of 3 main sections. One for event, one for kids and a media space with access to audio and video equipment as well as computers and tablets. There is also a workshop and co-working space.
- **Leapr labs** run a large variety of workshops and training in the STEM area, with a strong focus on telecommunication and infrastructure (eg satellites and drone technologies). They work in partnership with Rwandan defence forces and Rwandan telecommunication. Leapr labs also works with a dozen start-ups, mostly digital ones.
- **Makerspace Kigali,** launched in 2019**,** is part of Westerwelle Start up Haus (a co-working place). It focuses on supporting innovators, taking ideas from prototype to the field, while running training and workshops across the subject of design, digital fabrication, crafts, agri-tech, textiles and mechatronics.
- **Digital Transformation Centre,** launched in 2019, is a tech hub with 24/7 access to high-speed internet to innovators and providing an ecosystem of mentors and well-stocked hardware equipment. It is financed by the Government of Rwanda and the German Development Agency. The centre is to be home to Digital Solutions for Sustainable Development (DSSD) project which is very important to many partners implementing digital solutions. It is going to become a physical space for digitalization efforts.
- **Kigali Innovation City (KIC),** launched in 2018, an Information and Communications Technology (ICT) park, is a Government of Rwanda flagship project designed to accelerate development of Rwanda's ICT sector and transform Rwanda into a knowledge-based economy. KIC was to house various facilities including a research & development (R&D) facility, ICT training centres, software build and test labs, specialized institutions of higher learning and a business incubation centre[28]. It currently features an innovation and knowledge hub consisting of world-class learning institutions and tech companies with room for additional firms. New investment was announced by the Government of Rwanda in August 2019, to develop, finance, construct and operate commercial components of the Kigali Innovation City. The investment should have several impacts such as fostering private investment (eg to accelerate the delivery of infrastructure), attract innovation-driven enterprises and stimulate strategic partnerships. Going forward, KIC should enable investors to develop technologies, prove new concepts and scale in Rwanda[29].
- **ICT Innovation centre,** launched in 2019, is focusing on audio-visual technology. It operates two different programmes; incubation for start-ups and training of students. It aims at developing the ICT eco-system of Rwanda and is aligned with Rwanda's digital transformation plan. The centre has five training rooms, three conference halls, three multimedia rooms and two testing rooms. In June 2019 accommodates 12 start-ups and has already enrolled 28 students. The facility cost $5.6 million to set up, co-financed by the Korea International Co-operation Agency (KOICA)[30].

In addition, projects support the ecosystem:

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[28] Rwanda Gateway, Kigali Innovation City, 4 July 2018, URL: https://rwandagateway.com/o/kigali-innovation-city

[29] The New Times, *Government, Africa50 to establish firm to develop Kigali Innovation City project*, 27 August 2019, URL: https://www.newtimes.co.rw/business/government-africa50-establish-firm-develop-kigali-innovation-city-project

[30] The New Times, *Rwanda unveils ICT innovation centre for audio-visual technology*, 21 June 2019, URL: https://www.newtimes.co.rw/news/rwanda-audio-visual-technology

- **ICT Innovation Ecosystem Strengthening Project,** launched in 2017, is a project led by the Government of Rwanda with JICA (Japan International Cooperation Agency). The project aims to create a conducive and innovation emerging ecosystem in Rwanda by October 2020. To attain its objective, it has identified four targets:
    1. Innovative ICT enabled activities in ICT and other different sectors are promoted especially through private sector initiative.
    2. Policy framework to support ICT entrepreneurs and innovation promotion activities is formulated.
    3. Business relation between Rwandan and Japanese companies related to ICT is strengthened.
    4. Innovative ICT use development practices borne by the Project are recognized and effectively utilized by multiple stakeholders within and beyond Rwanda.

    Under its first target, the project supports the FabLab, KLab and 250startups initiatives.

- **250Startups** is a project financed by JICA supporting the private sector. It provides 6-month support to a batch of 10 entrepreneurs who are selected after a selection process. All graduates can apply however a prototype has to be presented. While the project does not specifically focus on an area, all but one of the supported businesses work on software. Hosted by KLab, 250Startups provides mentorship, legal and financial advice.

Academia is also part of the ecosystem by training students, arranging traineeships with the industry and doing research.

- **INES-Ruhengeri** is a specialized Institution in Applied Fundamental and Social Sciences. As an applied sciences institution it has 16 different laboratories (eg computer, food processing, microbiology, chemistry) which help in teaching/learning, research and community service activities. It also leads 15 research projects, including entrepreneurship, land governance or education. Through partnerships the university started a Business Incubation Centre, which helps students to shape business ideas into bankable or project ideas that can be sponsored. This centre was supported by AGEA (Africa Germany Entrepreneurship Academy) in collaboration with Leipzig University in Germany, Kwame Nkrumah University of Science and Technology (KNUST) in Ghana and INES-Ruhengeri.
- **AIMS**, the African Institute for Mathematical Sciences, is a Pan-African network of centers of excellence for post-graduate training, research and public engagement in mathematical sciences. It is soon domiciled in Kigali Innovation City and aims at graduating a critical mass of Africa's best mathematicians. It recently launched a Machine Intelligence master's degree.

    AIMS recently created the Quantum Leap Africa (QLA), a facility that houses 20 researchers, 60 graduate students and 5 research support staff. QLA has two objectives, one is to "catalyse top quality high impact research in data science, smart systems engineering and drive the future IT revolution through quantum information"[31]. The second is to train the next generation of innovators in information science and technology. As such QLA, conducts theoretical and practical research, organizes workshops and fellowships in quantum science. The centre specializes in smart systems and design, data science and big data analytics and quantum information.
- The **International Centre for Theoretical Physics,** located in the University of Rwanda, can supply top scientists. It hosts colloquia and train at postgraduate level about condensed matter physics, physics of the solid-earth and high energy, cosmology and astroparticle physics. The institution also leads research in these areas.
- **Carnegie Mellon University** is an important actor of the Rwandan ICT sector. CMU's school of engineering offered its first degree in Africa, a Master of Science in information technology, in 2012. The university added a Master of Science in electrical and computer engineering program in 2014.

[31] Quantum Leap Africa, URL: https://quantumleapafrica.org/

The university also has strong links with the industry, arranging internships and collaborative research. It relocated its site to a permanent space in Kigali Innovation City in summer 2019.

Some of these spaces have or have access to physical labs. For example, until recently, Carnegie Mellon University was located in the same building as FabLab, ensuring a closeness between students, researchers and the lab ecosystem. AIMS hosts a quantum. Lab and INES-Ruhengi has many labs which are primarily accessible to their students. However, INES-Ruhengi is undertaking the task of bridging and narrowing the gap between academia and the industry. The university has already recruited a person in charge of bridging the divide[32]. On this basis, one can expect the labs of the institute to be open to the industry.

On top of the current ecosystem, the launch new spaces was recently announced:

- **Norrsken Foundation** (Sweden) has just announced they are opening a new co-working space/ hub innovation space. Details are unknown.
- **UN-HABITAT** is planning to open an office in Rwanda. The project focus is online for overall Rwanda projects known to date. Details on the offer of the facility/office are unknown.
- **GIZ** launched in May 2019 the project "Digital Solutions for Sustainable Development" (DSSD) which advises Rwandan institutions on the implementation of the Smart Rwanda Master Plan (2016-2020) and its priority projects. It is to collaborate with the international private sector, research institutions and civil society. It also includes a small electronics lab. The physical space of the DSSD is where the STEM 4 INDUSTRY Hub is currently incubated and where meetings of the community about AI, blockchain, AR, VR and IoT technologies are co-organised by NIRDA and its partners.

The Table 2 presents in more details the main services in Rwanda as well as the type of services they offer. Overall, the spaces and projects currently in place are recent with most emerging in the late 2010s. This might explain why none of the services currently offer research services, incubation services and mentoring services. However, it is also possible it is due to resources (HR or financial) constraints.

Overall, the academic actors do not offer incubation services, while naturally the more operational-oriented actors and spaces do not use resources on fundamental research. Generally, the mentoring services offer is large in Rwanda with several actors supporting entrepreneurs. However, we would note that the scale of the mentoring differs. While under the 250startups project entrepreneurs receive weekly mentoring with financial and legal help, the support provided at other spaces is not as comprehensive. As a general good practice to foster the offers of the upcoming facility in mentoring, the research team recommends making use of the expertise of the local actors who mentor entrepreneurs.

Table 2 Innovation spaces in Rwanda

	Fields/area	Type of innovation	Incubation services	Research services	Mentoring services	Hardware or software lab	Year founded	Public or private structure
KLAB	ICT: Education, Financial Services, FinTech, Information Technology	Incremental	Yes	No	Yes	IT entrepreneurs' space Software	2012	Semi-Public
FABLAB	Hardware, electronics	Incremental	No	No	No	Hardware	2016	Semi-Public
Impacthub	Design Thinking	Incremental	Yes	No	Yes	None	2012	Private

[32] Beacon of hope Rwanda, INES-Ruhengeri promoting Applied Sciences, 25 April 2019, URL: http://www.beaconofhoperwanda.com/ines-ruhengeri-promoting-applied-sciences/

250Startup	ICT	Incremental	Yes	No	Yes	Software	2017	Semi-Public
Makerspace	Design, digital fabrication, crafts, agri-tech, textiles and mechatronics.	Incremental	Yes	No	Yes	Primarily hardware	2019	Semi-Public
Leapr Lab	Telecommunication, Robotics	Incremental	No	No	Yes	Primarily software	2017	Private
Carnegie Mellon University	Robotics, educations, and Technology	Incremental	No	Yes	Yes	Both	2011	PPP
Innovation Village	Multimedia and tech firm designing community centred platform	Incremental	No	No	No	None	2015	PPP

Source: Technopolis Group, 2019

2.3.3 Description of the existing ecosystem outside Rwanda

There are many spaces for innovation across the world. At least a handful could be of interest to NIRDA. We have selected spaces mostly from Europe and Africa. In Africa, there are not many examples of structures specialised in hardware product development because they are high risks and high costs investments and therefore investors have generally focused on software. One of the objectives of the mapping was to understand how services proposed elsewhere are implemented and to take away specific learnings that are relevant to the case of Rwanda. The objective is not to replicate one specific model of implementation for this is unlikely to work in the context of Rwanda.

The oldest – and biggest - institutions TNO, Fraunhofer and Kirdi offer all types of services in a variety of fields. In the short term, it is not possible for the STEM lab facility to match their success in incubation and research. Nonetheless, we recommend drawing lessons from the experience in running a multi-objective structure. TNO and Fraunhofer have sub-structures dedicated to business incubation, allowing them to be flexible and connected to the needs and opportunities of entrepreneurs and innovators. The separate structures are linked with one another and both are headquartered/ located in Berlin. TNO ensures its relationship with the industry through established Joint Innovation Centres, working closely with the business sector in conducting various types of research.

Sensor City based in the UK also take on the three roles which illustrates that in principle it is possible for a facility to offer a wider scope of services. It is specialised in sensor technology, which is one of the focus areas of the STEM lab facility. Sensor City is a collaboration between the University of Liverpool and Liverpool John Moores University, in a context where the transfer of knowledge and impact is high on the University agenda. This is unlike the context in Rwanda where Universities have less track of collaborating across sector.

Again, mentoring services are ubiquitous hinting they are a common task on which the future facility could gather much support, best practices etc.

An interesting case is mHUB based in Chicago which has software and hardware lab with a preponderance of hardware. It has labs in metal, textile, water and else and extensive incubation and mentoring services. mHUB was founded by the local industry after an extensive review of barriers to growth and which solutions were needed. In a fashion that fits the objective of the STEM facility, mHUB links local manufacturers, university researchers and entrepreneurs to push for physical product innovation. The team is rather large with 21 persons working for the structure which hosts 10 labs in about 6,000 square meters.

We detail two examples of innovation spaces in African countries, one private and one public:

CcHUB (Co-Creation Hub) is a private initiative supporting innovations by being both an incubator and accelerator space for Nigerian start-ups. Mentoring is a primary support of the structure. CcHUB partners with private companies to apply technology to social issues. CcHUB also offers a small physical space with a library and a makerspace for entrepreneurs to develop their ideas. Next to these activities, the structure supports organisations by proposing consulting services in various forms (eg workshops, trainings). This structure therefore has a rather large portfolio of activities, while essentially focusing on its core: incubation.

In early 2019, CcHUB launched a design lab in Kigali[33] to tackle the common challenge business face to be sustainably growing: design and innovation. This new space will focus on the same areas as CcHUB in its home country, proposing a space where product designers and engineers will collaborate with scientists and stakeholders to apply emerging technologies to systemic problems.

Kirdi is the public industrial research and development institute of Kenya. A large structure, it is a horizontal actor which leads industrial research in the country. Industrial research at Kirdi covers research, technology and innovation which takes the form of multidisciplinary research to develop technology, products and process but also formulate policies.

On top of its research agenda, Kirdi provides three types of MSME support. It incubates startups, offers common manufacturing facilities and assists MSMES in industrial product development.

- At Kirdi, the incubation lasts for a maximum of 6 months. Interestingly, the incubation is also offered in virtual form
- Kirdi makes common manufacturing facilities available to MSMEs in six areas including food technology, engineering development, textile technology and ceramics and building materials
- The public structure strives to help MSMEs design and manufacture products that "reach a competitive quality range"[34] in order for Kenya enterprises to sell locally, regionally and internationally

The structure generates income through its technology transfer and extension services. These are: common manufacturing and commercial production, incubation services, management of pilot processing plants, testing services, sale of intellectual property-based products and services, consultancy and training services.

Table 3 Innovation spaces outside Rwanda

Organisation name – sector/ domain	Type of innovation	Incubation services	Research services	Mentoring services	Hardware or software lab	Year founded	Public or private structure
TNO (NL) Research and technology - Focus on transitions or changes in five social themes: industry, healthy living, defense & safety, environment and energy.	Disruptive	Yes, Delft	Yes	Knowledge transfer to SMEs	Both	1932	Semi-Public
Fraunhofer (DE) Research and technology	Disruptive	Yes, Fraunhofer Venture	Yes	Training	Both	1949	Semi-Public

[33] Techpoint Africa, CcHub launches Africa's first design hub in Rwanda, 14 February 2019, URL: https://techpoint.africa/2019/02/14/cchub-launches-design-hub-in-rwanda/

[34] Kirdi website, Product Development, URL: https://www.kirdi.go.ke/index.php/msms-support/product-development

Ultrahack (FI) Consists of one main event, with several other long-term objectives: Coding; Innovation platform; Hackathon; Accelerator; Long-term development runway for projects	Incremental / disruptive	Accelerator	No	Yes, some	Software	2015	Private
mHUB Chicago (USA) Metal, plastics, electronics, textile, water, wood, laser cutting	Disruptive	Yes	No	Yes	Primarily Hardware	2016	Private
Waitro Research & technology - Research areas: Energy, Waste management & environment, agriculture, food & nutrition, water, sanitation, life science & biotech, health & medicine, mobility & transport,	Incremental	No	No	No	None		Public
Sensor City (UK) Sensors	Incremental	Yes	Yes	Yes	Both	2014	Public
CcHUB (NGR) Smart infrastructure, fintech, education, digital security, governance, health and well-being	Incremental	Yes	No	Yes	Software	2010	Private
Kirdi (KE) Mechanical engineering; - Energy and power resources; leather technologies; textile technology; industrial chemistry environment; chemical engineering; electrical engineering; ICT; Mining	Disruptive	Yes	Yes	Yes	Hardware	1979	Public
Kemri (KE) Clinical research; Population health; Health systems; Vaccines, etc.	Incremental	No	Yes	Yes		1979	Public

Source: Technopolis Group, 2019

2.4 Market trends

The market environment of Rwanda is evolving quickly. The country's rapid growth is coupled with increasing exports[35] and different possibilities regarding international markets and trade balance.

On the one hand, there are strong arguments supporting more integration and more trade. The World Bank[36] and the International Growth Center[37] are major supporters of this trend as they argue that with only 12 million inhabitants, the domestic market of Rwanda is insufficient to allow Rwandan firms to benefit from scale economies. In this perspective, Rwanda has to take part in global trade and to position itself in international value chains. More specifically, Rwanda should produce and export high-value processed products and import low-value raw materials as inputs. On the other hand, the Rwandan industry is looking to reduce its dependence on imports. To build components, Rwandan firms currently imports raw materials from India and China, but they would like to produce these inputs domestically

35 Data World Bank, available on https://data.worldbank.org/indicator/NE.EXP.GNFS.ZS?locations=RW&view=chart

36 World Bank. 2019. "Future Drivers of Growth in Rwanda: Innovation, Integration, Agglomeration, and Competition." Conference Edition. World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO

37 Sheperd & Twum, Review of industrial policy in Rwanda - Data review, comparative assessment, and discussion points, November 2018, F-38426-RWA-1, International Growth Centre.

instead. Therefore, in the view of the stakeholders from Rwanda's industry, developing technologies that allow import substitution would be beneficial.

It is key to be strategic about which products can be produced in Rwanda considering economics and practicality. For example, consulted experts expressed that PCB and SMB manufacturing would not be desirable in Rwanda after the prototyping stage. It is also cheaper to buy a sensor on the international market rather than manufacture it in Rwanda. This is partially due to the lowering cost of sensors in the past decade[38]. Moreover, sensors specificities depend on the industry in which they are used, it is more important the engineer knows what type of sensor is needed for a product than actually manufacturing a specific type of sensor[39]. In Kenya, a recent project to measure the capital air quality used sensors that were locally assembled[40], a good example of valorisation of the technology.

The rapid development of Rwanda creates a context that is ripe for innovation and the launch of new projects. Different stakeholders are currently taking advantage of the effervescence in Kigali to test ideas and catch opportunities in different businesses. Kigali's Special Economic Zone is a good illustration of the ebullition of ideas and opportunities in Rwanda. This burgeoning environment catches the attention of foreign investors as well, notably Motorola who will establish a service centre, a training centre a SCADA (Supervisory Control and Data Acquisition) centre and an IoT (Internet of Things) centre in Rwanda under a public-private partnership signed with the Rwanda Development Board. The company will be using Rwanda as its main base from where it will coordinate most of its activities and services that span across neighbouring countries. The deal was signed[41] in May 2019 and activities are expected to develop to local ICT capacity and support Rwanda as an ICT hub of East Africa[42].

In this regard, there are several sectors related to STEM that have potential to grow in Rwanda. NIRDA has highlighted three specific technological domains whose development will support growth. They are likely to generate innovation, business opportunities and exports for Rwanda. The three market are also rapidly growing and driven by strong consumer demand.

- Energetics - electrical energy supply (EES)
- Mechatronics - mineral processing, agro-processing, construction
- Industrial software systems - focus on data analytics and embedded systems

The STEM facilities in Kigali will benefit to these sectors because their development requires investment in R&DI infrastructure, and also because they will profit from collaborations across the R&DI value chains. These nascent markets present huge opportunities, both as sectors for entrepreneurs and innovators, but also for the industry in general to increase value proposition. Energetics, mechatronics and industrial software systems also provide possibilities on the international markets, as drivers of export growth and as substitute to foreign imports.

2.4.1 Market demand for Energetics - electrical energy storage (EES)

In the global market, energy consumption growth is related to economic growth which is fastest in Asia and Africa: between 3% and 4% per year on average. Moreover, the expected trend for consumption is a 110% increase for the continent by 2050. Energy-intensive manufacturing (basic chemicals, food, iron and steel, non-ferrous metals, non-metallic minerals, paper, and refining) is expected to shift toward

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[38] Honrubia, M, *Industrial IoT is booming thanks to a drop in Sensor Prices,* 17 august 2017, URL: https://www.ennomotive.com/industrial-iot-sensor-prices/

[39] Kerns J, *Practical tips for specifying sensors*, 4 April 2015, URL: https://www.machinedesign.com/sensors/practical-tips-specifying-sensors

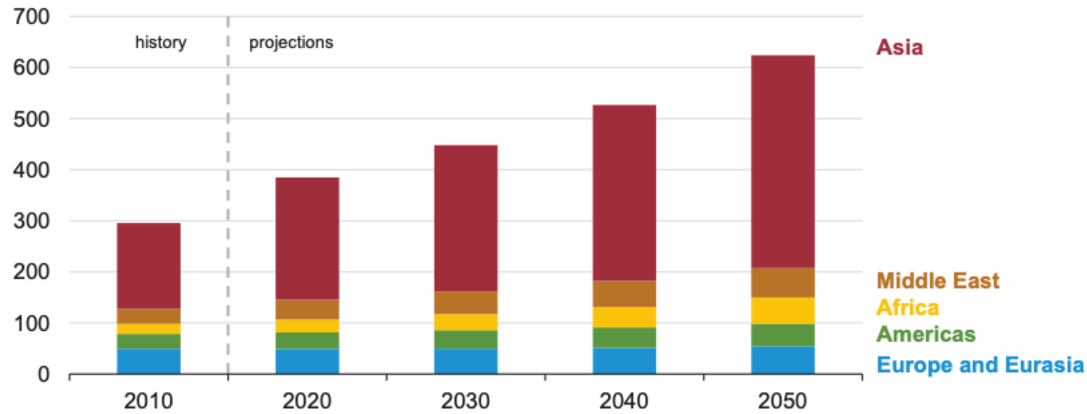
[40] Mugendi E, *Measuring Nairobi's air quality using locally assembled low-cost sensors,* 9 May 2018, URL: https://medium.com/code-for-africa/measuring-nairobis-air-quality-using-locally-assembled-low-cost-sensors-94a356885120

[41] *Motorola Solutions General Manager, Yuval Hanan signed the agreement.*

[42] The New Times, *Rwanda, Motorola sign agreement to develop tech capacity,* 11 May 2019, URL: https://www.newtimes.co.rw/business/rwanda-motorola-sign-agreement-develop-tech-capacity

India, China but also Africa by 2050[43]. Besides, residential and commercial consumption in Africa is expected to grow by respectively an average of 2.5% and 2.4% a year from 2018 to 2050[44]. Vehicle travel is expected to increase significantly in Africa as well, while the Central and West Africa oil production is expected to plummet by 2050 for being less cost competitive[45]. This constitutes an opportunity for electricity-based solutions especially with the cost of battery storage declining fast[46].

Figure 4 Projection of energy consumption by region in quadrillion British thermal units



Source: US Energy Information Administration, 2019

NIRDA has identified electrical energy storage (EES) as a sector capable of generating growth in Rwanda. EES has a wide application in small electronic devices and telecommunication devices. Rechargeable batteries also play an important role in powering electric vehicles and in the development of hybrid and electric cars. In addition, electrical energy storage allows the deployment of renewables on a larger scale by improving their reliability and solving the issue of intermittent supply associated with renewables. Lithium ion (Li-ion) batteries are one of the key electric energy storage techniques.

EES and rechargeable batteries are becoming increasingly widespread and the sector is on the rise with important growth perspectives. Globally, the market for electrical energy storage generates revenues of $90 billion, and this figure is expected to reach $635 billion in 2025. More specifically, the Li-ion batteries market was worth $12 billion in 2018 and is expected to double in the next 4 years. The rise of the sector is also occurring in the region of Rwanda: renewables in East Africa will total 11,185 GWh in 2020 among which EES technologies are expected to tap at least 50% of the market.

Regarding Rwanda alone[47], the country consumed 1,330 GWh of energy in 2018, with a share of 72% of renewables. The renewables represent a market of $202 million per year that is expected to grow to $576 million per year in 2035. Also, the development of EES and renewables in Rwanda might have the capacity to solve one of the main obstacles for Rwandan businesses which is the price and access to electricity. Electrical energy storage allows to serve better electricity consumers without increasing energy production, and to improve the reliability of renewables which is likely to help firms access electricity.

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[43] US Energy Information Administration, *International Energy Outlook 2019,* 24 September 2019, URL: https://www.eia.gov/outlooks/ieo/pdf/ieo2019.pdf

[44] US Energy Information Administration, *International Energy Outlook 2019,* 24 September 2019, URL: https://www.eia.gov/outlooks/ieo/pdf/ieo2019.pdf

[45] US Energy Information Administration, *International Energy Outlook 2019,* 24 September 2019, URL: https://www.eia.gov/outlooks/ieo/pdf/ieo2019.pdf

[46] International Energy Agency, World Energy Outlook 2018

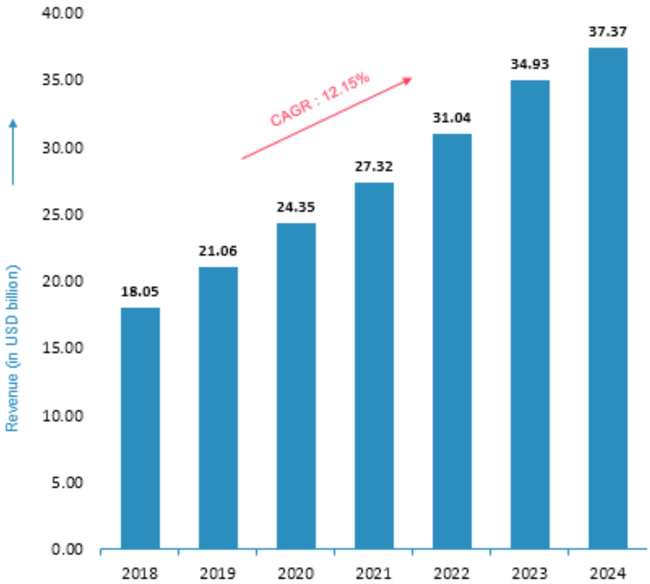
[47] Joint STEM Product Development Facility Terms of Reference on Focus Areas June 2018

2.4.2 Market demand for mechatronics applications

Mechatronics combines mechanics, electronics and computer sciences, and are commonly used in a wide range of industries.

Industrial robotics was valued at $18 billion in 2018 and is expected to reach a value of $37.4 billion by 2024. By end-user industry, automotive holds the highest market share (about 33%), followed by electrical and electronics with 30.4%. The food and beverage market is expected to witness the highest compound annual growth rate of 14.5% during the forecast period[48].

Figure 5 Global Industrial Robots Market: Revenue in USD billion, 2018-2024



Source: Mordor Intelligence, 2018

It is a fast-growing research and development area, for example in the agricultural sector. Agricultural drones represent a market of $1.8 billion in 2018, globally with a compound annual growth rate of 21%. These make 53% of the agricultural robots and mechatronics market, the rest is shared between robotic milking (28%), autonomous tractors (15%) and various other technologies such as mining robots (4%). The global area of agricultural robots and mechatronics is expected to grow by 25% by 2024[49].

Rwanda's economy will benefit from the development of mechatronics in several sectors: [50]

Agriculture - Developing mechatronics in the field of agriculture has the potential to boost significantly the sector, by addressing the issues of low agricultural productivity and by developing export products. Agriculture in Rwanda needs to be modernized in terms of mechanization, both regarding production and post-harvest activities. Increasing automation in agricultural processes and widening the use of machines in agriculture will boost productivity and foster Rwanda's competitiveness on international agricultural markets. Additionally, the post-harvest losses due to poor storage conditions create sunk costs that could be reduced by developing high-tech storage facilities with mechatronics.

Mechatronics is necessary to develop further the agro-processing industry. The sector is experiencing a dynamic growth in Rwanda and the country has the potential to become a leader in exports of processed

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[48] Mordor Intelligence, Global industrial Robotics Market – Growth, Trends, and Forecast (2019-2024), 2019, URL: https://research.mordorintelligence.com/reports/industrial-robotics-market

[49] Mordor Intelligence, Global Agricultural Robots and Mechatronics Market – Growth, Trends, and Forecast (2019-2024), 2019, URL: https://research.mordorintelligence.com/reports/agricultural-robots-and-mechatronics-market

[50] Joint STEM Product Development Facility Terms of Reference on Focus Areas June 2018

food. Developing technologies related to mechatronics in the field of agro-processing will make the sector more efficient, more innovative and more competitive.

Mechatronics can support the introduction of modern agricultural practices such as precision farming and "smart farming". These techniques enable the delivery of the exact nutriments necessary to the cultures by combining use of sensors, mechanisation and data analysis. This type of farming allows to increase yields and lower costs which fosters competitiveness, and to develop farming models that are in line with the environment and more resilient against climate change. Some initiatives related to the use of mechatronics in precision farming have taken place in Rwanda. However, the country has been lagging behind its neighbours (Kenya, Uganda, Tanzania) where drones are widely used for agriculture[51].

Garment manufacturing - The garment manufacturing sector is nascent in Rwanda and has the potential to become a driver of growth for the country, and to stimulate the development of the domestic industry. Mechatronics will serve to develop machines and increase automation. In 2019, NIRDA launched an open call inviting the textile and garment industry to demonstrate the needs and potential of this value chain.

Mining - Rwanda has a comparative advantage in mining activities and has the potential to increase its exports. Increasing automation in the sector, more specifically through Optical Sorting systems, will boost the sector and generate productivity gains. Currently 80% of the mining activity is artisanal and mechanization could generate 30% additional value.

Construction - As a quickly growing country, Rwanda has a booming construction sector. Mechatronics has applications in this field in regard to security: encouraging safety at construction sites through the improvement of existing methods and introducing onsite security systems.

Smart City and Sensor Technology - Kigali is facing an increasingly important traffic congestion, which has negative impacts on the economy as a whole[52]. To address the issue, mechatronics will be effective to manage the city traffic problems using Smart City Wireless Sensor Network (WSN).

2.4.3 Market demand for industrial software systems

An embedded system is an electronic system in which the hardware circuitry includes software programming to provide effective solutions. Embedded systems are generally applied in the following industries: automotive, telecommunication, healthcare, industrial, consumer electronics and military and aerospace. The current market is led by North America and more recently Asia. Globally, with a compound annual growth rate of 5.4%, the market is expected to amount to $261.8 billion in 2025[53]. The high growth can be explained by increasing trends of IoT coupled with advanced automation technologies and a rising demand for wireless communications, consumer electronics etc. The expected number of IOT devices is expected to grow to 22 billion by 2025[54]. IoT platforms for manufacturing[55] are also expected to boom in the coming years, reaching over $12 billion in 2024.

51 Technopolis Group, Study on unlocking the potential for the 4th industrial revolution in Africa, African Development Bank, July 2019, Draft final report.

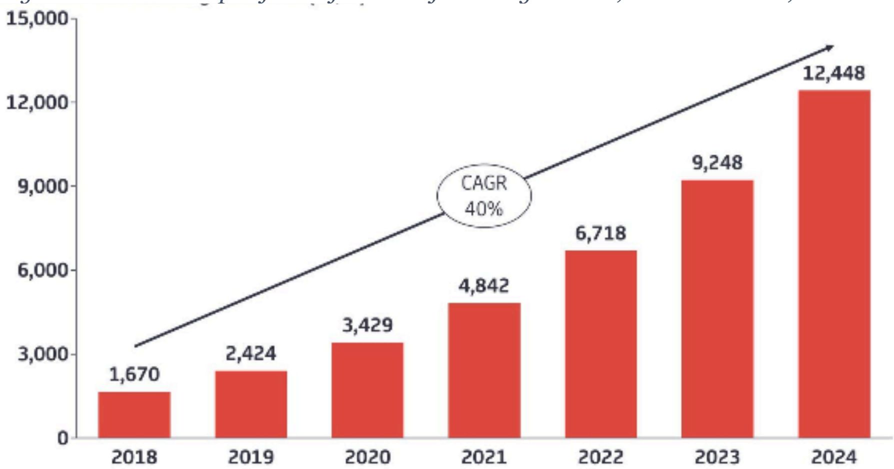
52 The New Times, The nuisance of Kigali traffic jam, 2 September 2016, URL: https://www.newtimes.co.rw/section/read/203170

53 Marketwatch, Press Release, 17 August 2019, URL: https://www.marketwatch.com/press-release/at-536-cagr-embedded-system-market-size-raising-to-usd-26184-billion-by-2025-2019-08-17

54 Marketwatch, Press Release, 17 August 2019, URL: https://www.marketwatch.com/press-release/at-536-cagr-embedded-system-market-size-raising-to-usd-26184-billion-by-2025-2019-08-17

55 The IOT for manufacturing platforms account for both factory and non-factory settings therefore standardised (eg facturies, plants) and custom products environments (offshore oil sites and mines)

Figure 6 Global IOT platforms for manufacturing market, in USD million, 2018-2024



Source: IOT Analytics, 2019

The sector of industrial software has been identified as a potential driver of business opportunities for Rwanda. Indeed, industrial software systems have a lot of applications related to the development of consumer electronics. For example, there are potential applications in emission control in electric and hybrid vehicles.

There are interesting opportunities is the video games sector, and more particularly in the development of virtual reality (VR), augmented reality (AR), mixed reality (MR). The gaming industry embraces the technology and is closely related to its development. *A number of games are shaped for prepared indoor environments; others allow players to experience digital game play in a real-world environment*. The development of technical knowledge has enabled AR/VR/MR to become more advanced while increasingly affordable. Moreover, the technology behind AR/VR/MR is rising beyond the video games industry and is being adopted in more traditional industries, such as tourism, hospitality and some services. It provides ways to improve and diversify the supply of services, possibly with opportunities to develop concepts of visiting Rwanda in augmented, virtual or mixed reality. Further democratisation of AR/VR/MR technologies will benefit additional industries such as transports, navigation, attractions, language live translation, etc.

The Korea International Co-operation Agency (KOICA), in collaboration with Rwanda Development Board (RDB), recently opened an ICT Innovation centre at the Integrated Polytechnic Regional Centre (IPRC-Kigali). One of the focus areas of that centre is to develop video games. It is useful for the upcoming STEM lab facility to be informed of the specific research done through this initiative and work to complement it rather than overlap.

Industrial software systems support the development of Artificial Intelligence, Machine Learning, Deep Learning and other predictive analytics. These technologies are expanding quickly globally and will become increasingly vital in the future. Opportunities are accessible to Rwanda. Sub-Saharan population rapid growth combined with improved power supply, high-speed internet, more early-stage investment funding, and increase in smartphone use have created a fertile environment for Africa's emerging AI industry – in particular in education, finance, and health. Moreover, the big data technologies are an essential component for the development of "Smart Farming", alongside with mechatronics.

The analysis of the virtual reality market is encouraging and indicates that from a $5,409 billion market size in 2017, it is likely to reach $60,901 billion by the end of 2023. Sensors are expected to emerge as one of the largest components by the end of 2022 with a market surpassing $2,2 billion of revenues. Regarding the IoT market, Rwanda is experiencing an exponential growth of mobile phone subscriptions with the share of connected Rwandans shifting from 3.25% in 2006 to 70.48% in 2015. The wide use of phones opens new opportunities in the field of telecommunications, including the emerging IoT sensors and data collection, e-commerce, USSD applications, Tap and Go technology, etc.

3 Services to be offered

The STEM lab facility will need to provide the conditions for Rwanda to **leapfrog into the Fourth Industrial Revolution**. To do so, it will offer a range of services in its dedicated building.

The services provided by the facility and its staff will be the following: incubation services, mentoring services, a state-of-the-art STEM lab, R&D and testing services for the industry and finally capacity building and outreach. The combination of these services can adequately reinforce the local innovation ecosystem and improve the quality of industrial products, ultimately making the industry and SMEs more competitive and successful.

3.1 A unique facility

Rwanda is fully aware of the need for digital transformation. Rwanda's Vision 2050 and the 7 Year Government Programme (2017-2024) aim to establish Rwanda as a globally competitive knowledge-based economy. NIRDA's current strategy but also the country's 20-year ICT policy and strategy, and the establishment in 2019 of a digital transformation cluster showcase that policymakers are planning to harness the opportunities of the Fourth Industrial Revolution.

Smart technology adoption is at an early stage in Africa, opportunities are yet to be explored by manufacturers. This is where the facility should add value to relevant sectors in Rwanda and the region. While awareness of the technologies (sensors, big data, robotics, 3D printing) is high among stakeholders that were interviewed, there is no widespread adoption of these technologies yet. Because Rwanda is not 'weighted down' by the need to adapt past infrastructures, the potential to develop new models and be among early adopters in Africa is high. With new trends of crowdsourcing and open innovation, many innovations are shared and fast track the development of embedded system and smart technologies.

There are a number of obstacles to industrialisation, including a gaps in the provision of an efficient electricity infrastructure and internet network, lack of IP protection, and lack of (soft/technical) skills in the workforce. Improving infrastructure will enable the development of technologies and products that can support the success of (new) companies.

Smart technologies can be the key to Rwanda's industrial future. Examples already exist such as a solutions that enable people to consult doctors remotely by mobile phone and solutions that make use of blockchain technology to allow smartphone users to transact and pay for goods and services. However, the country is looking to leapfrog into this 'revolution' to develop new products, services and processes but also make Rwandan companies competitive on the local and global market through the development of unique solutions.

Besides supporting the competitiveness of the current industry sectors, it is key for NIRDA to support new investment possibilities in sectors where the potential for growth is high. This involves investing in **disruptive technologies and transformative change** rather than investing (only in) incremental innovation.

The success of the upcoming STEM facility will be built on its comprehensive service offer. Based on an analysis of the ecosystem in Rwanda, there is a gap to be filled in STEM industrial hardware production. The investment required in the facility needs to cover the **integration of (smart) hardware and software for the production of industry standard products and components ready to go to market**.

3.2 Service offer

NIRDA has scoped out a space for innovators to work. The design is a 3-floor building on the campus of the University of Rwanda. The STEM lab facility thereby provides an opportunity to invest in a built project that is located close to academia[56]. This decision is made in line with the best practice of:

- Investing in a quality building and grow-on space that allows foster a sense of community and a vibrant ecosystem.
- Identifying a convenient and central location that generates sufficient footfall and interaction between academics and the local business community

The services to be offered by the STEM facility are the means to reach its objectives. The figure below is an illustration of what will be offered once the facility is established. By providing a comprehensive service offer to a wide variety of users, all members/users will thrive by being part of a dynamic and innovative community.

Figure 7 Services offered by the STEM facility

		DELIVERY PARTNERS
Incubation services	•Work space - open space and shared offices •Meeting space •Marketing, operationalisation, commercialisation, and knowledge transfer services •Support with Intellectual Property protection	Marketing, operationalisation, commercialisation, knowledge transfer services, and IP services, to be provided in partnership with universities and other stakeholders
Tailored advice and mentoring services	•Design labs for hardware and software •Space for reviewing the prototype architecture, ie the product function and system •Space for reviewing the manufacturing design, ie the scaled-up version of the prototype	Mentoring services to be provided in partnership with a network of experts
STEM lab	•STEM prototype labs with 'state-of-the-art' equipment •Space to develop commercially viable prototypes	Possibility for (global) industry to support
Links to the academic community	•R&DI and testing services for industry	Research services, product development and innovation and testing services to be provided by universities
Capacity building and outreach services	•Partnerships •Training to industry •Promotion of the facility to the wider community	Possibility for training to industry to be provided in partnership with international partners

Source: Technopolis Group, 2019

3.2.1 Incubation services

A six month incubation programme is proposed for start-ups.

Representatives from 250 startups suggested that soft skills are lacking among entrepreneurs. There is a need to support start-ups to carry-out their market research, develop a sound business plan, train them to pitch to investors. Incubation services are paramount and will help start-ups to develop a product that has the potential to add value. A point of importance for entrepreneurs is legal guidance,

[56] Market research shows that there are no clear alternative options for the built project: Space in the industrial zone (free zone) is expensive; Kigali has unused (office) space but this is not fit for purpose: lacks foundational structure and noise-proofing

particularly when looking at intellectual property protection. Current research is looking at how to improve intellectual property agreements/regulations in Rwanda. This work is led by WIPO in collaboration with the Ministry of ICT. NIRDA is an active contributor to this capacity-building effort and is looking to build on the recommendations that will come out of this initiative to help determine the IP agreements in relation to the incubation programme. Entrepreneurs need guidance on identifying and filing for the right intellectual protection of their innovation. For example, a survey conducted last year with members of KLab revealed that 70% had not done market research before prototyping[57].

The facility will support start-ups in their journey to raise investment.

Representatives from Carnegie Mellon University (CMU) and University of Rwanda (UR) suggested that the incubation services would be welcomed by graduates from these universities as well as by graduates from IPRC, give they all are interested in accessing incubation space and the current offer provides limited access. The graduates from CMU are likely to be interested in a cybersecurity lab/incubator with tools where they could develop businesses. UR already has a business incubator, however it welcomes the idea of an incubator focused on industrial product development. The UR Business Incubation programme faces several challenges such as limited access to highly qualified trainers, hub managers or specialized staff. Under the incubation services, the facility will offer space for increased collaboration (eg co-working space).

Offering daily structure to start-ups through the incubation programme is important in order for the programme to be effective. As start-ups acquire additional skills and start to ‘think as a business’, mentoring can be lighter and/or more personalised. The STEM facility can then provide more advicne on how to scale-up and how to ‘arrange manufacturing’.

3.2.2 Tailored advice and mentoring services

Beyond the initial incubation stages, start-ups will need further guidance and advice as they progress and develop their prototypes/components. SMEs and larger industry will benefit from similar support.

The STEM lab facility will invite researchers, graduates, start-ups, SMEs, and industry to develop their first-stage prototype ideas into second-stage prototypes and components, through a process of testing and calibration. The prototypes and components developed and tested at the facility will be developed ready for commercialisation, in Rwanda or abroad.

We have identified a need for advice and mentoring services both for professionals and young entrepreneurs/graduate students. The mentoring will involve domain experts asking technical questions and providing advice (eg on how to calibrate the prototype, how to use resources efficiently, how to improve product functionality, what materials are best suited, etc. The in-house experts will challenge assumptions and rationales behind the solutions. They will review technical data and information backing the project in order to establish if there is a favourable ground to develop the product. It is key the new facility offers a strong value-addition to both start-ups by providing them with a high-quality support. This will improve their survival rate.

There is already an offer helping entrepreneurs with their start-ups. In the industry, there is a strong need for capacity building, as industry specialists know what innovation is needed however they lack the resources and sometimes expertise to develop their products accordingly. On basis of this state of play, the new facility will aim to fill in the capacity gap that currently exists. In line with best practice, this part of the service offer will be offer in collaboration with partners. These partners will be academic institutions but also organisations that have a good understanding of the needs of the industry.

3.2.3 STEM lab

The STEM lab and the equipment made available is a major selling point of the proposed facility. There is a strong will from stakeholders, both industry and academic to gain access to such facility. The

[57] Interview with JICA, 28 June 2019

objective is to create state of the art prototypes that can be commercialized. The STEM lab will be a space to develop those products, however mass production will remain externalised in order to maintain the costs down.

In supporting start-ups, SMEs and industry, NIRDA strives to deliver them a quality label in user-centred approach[58] which will facilitate the process for start-ups and SMEs applying for public procurement. NIRDA could testify of a **lab-tested solution**, in line with international standards (a "seal of approval"), making the prototypes developed at the facility eligible for public procurement. It should be noted that Rwanda has the ambition that government entities procure 10% of their budget to help start-ups and SMEs develop solutions.

The STEM facility will cover three areas, calling for somewhat different equipment in order to prototype. For example, energetics need battery components while they have the need for an electronic lab as well as the mechatronics. Developing industrial software systems for example call for electronics as well but also a software lab. The equipment needs but also their size directly stems from:

- The choice of (sub-)areas of focus - The areas of focus have been defined to be energetics, mechatronics and software embedded systems
- The position in the value-chain - The foreseen facility focuses on manufacturing, specifically design and (sub)assembly (eg integrated systems for batteries). Experts underlined the importance of clearly setting for each area whether the ambition of the facility would be to produce ready-to-market prototypes and externalise mass production or if mass production would rather be done in Rwanda.
- The desired outcomes in terms of product development and commissioned R&D - These relate to the desired deliverables and long-term targets of the facility.
- Technical training to use the equipment – Lab users need to receive training on the equipment. This technical expertise will also have to be mastered by the lab manager and trainers. On basis of what are the priorities in terms of training, it is possible a specific model or size of machine would be preferred. A few reasons would be ease of handling, environment, health and safety[59], cost of repairs and consumables.
- The target users (entrepreneurs vs. industry) - Representatives from industry suggest that they would be interested in having access to (other) lab equipment for advanced prototype testing. Academics underlined the importance for students and graduates to have access to ubiquitous equipment. This way, they can develop versatile skills. Stakeholders from the ecosystem mentioned the importance for the facility to acquire equipment that can ensure the growth of the start-ups for up to 2 years. Therefore, there are two targets to the facility, and two equipment needs that may align but also differ.
- The choice of equipment - The equipment needs to be appropriate for protype development, but also allow the team to explore opportunities in the frame of the commissioned R&D activities. On the other hand, too complex or large machinery would hinder capacity as it would require extensive training, much more consumables and drive costs up (energy consumption, consumables, taxes etc.). Acquiring more uncommon or specialised equipment also means the costs of set-up, maintenance and repairs and replacement tend to be higher.

The STEM lab will be open to the industry, entrepreneurs and to researchers and graduate students. The first will use it to develop products, improve existing products and research new applications while students will use it to gain dexterity and expertise using the equipment. In the short term there will be development of products and in the middle term development of expertise among young graduates.

[58] NIRDA has gained expertise in user-centred approach through support by Fraunhofer in 2019.

[59] The Environmental, Health and Safety General Guidelines are drawn by the World Bank for good industry practice. See: https://www.ifc.org/wps/wcm/connect/29f5137d-6e17-4660-b1f9-02bf561935e5/Final%2B-%2BGeneral%2BEHS%2BGuidelines.pdf?MOD=AJPERES&CVID=jOWim3p

It is recommended that **the STEM labs primarily respond to the needs of the industry and driving innovation led by the public sector** however, it is key to make sure the facility also stays relevant for graduates, by offering them a space where they can develop their skills, conduct research but also receive training and mentoring. The space for the industry and the space for the graduates and entrepreneurs typically are separate but in the same building. The graduates should and will have access to the STEM labs however it is possible these do not fit exactly their specific needs. If this raises an issue, we recommend the STEM lab staff arranges access to other labs of the existing ecosystem, on an ad-hoc basis. Considering the investment made into the Kigali Innovation City and its visibility among both the industry, the international community and the general public, it would be beneficial for the STEM facility to envisage collaboration. This could be done at different levels for example arranging (ad-hoc or permanent) access to specific machinery for members of both spaces or co-organising events.

We foresee the graduates from partner universities will be able to make use of the technical labs through their education programs. This guarantees not only that the facility equipment will be used, but also that academic staff and students are properly trained to use them, helping close the gap between industry needs in terms of skills from graduates and the training received at the moment.

The STEM lab will also be open to the members of NIRDA staff whose duties and responsibilities are to develop products and technologies, specifically in the areas of STEM.

The lab will be located close to the UR, which has a department of creative design, offering courses on, for example, interaction design. It is useful to identify and ensure links between the facility and the department that may gain by training students on machines in the labs.

This type of services should be driven by NIRDA but in partnership with other stakeholders (eg IPRC, College of Polytechnic). Once the private sector is able to take on these services there is no longer a case for NIRDA to drive the facility (ie no market failure).

> The MHub in Chicago (USA) is an interesting case of a facility offering a various range of engineering labs on top of a coworking space, incubation and mentoring services. As a privately funded initiative, MHub clearly targets private actors, thus it does not offer research services. In this structure, the labs are also core to the activities and business model. The labs cover both software and hardware production and innovation. They are solely dedicated to entrepreneurs and companies. This means that the offer of the STEM lab will have to consider the needs of students and graduates in terms of schedule, ease of use etc.

3.2.4 Links to the academic community

The links between the facility and the academics will be assured in part through the physical space where the facility will be established: on the campus of the University of Rwanda. The link with the department of architecture will be ensured by developing workshops/programmes for students in supporting with prototyping.

The links will also exist with the department of design, which is not located in Kigali but in the southern province of Rwanda. There is an absence of available facilities for the course, especially in product design but also communications design. However, the design courses have a great potential value for graduate students aiming to become entrepreneurs and innovators. Therefore, the collaboration between the STEM lab facility and the course managers should aim to produce highly skilled graduates and projects with great outcomes. These should bring added value to the industrialisation of Rwanda through their innovations.

A key element of the STEM lab facility is its role in helping companies develop and adapt technological solutions, on the one hand reducing the costs for the firms by commissioning R&D and on the other hand, ensuring research is pursued in areas where opportunities for increased competitiveness exist. As mentioned, testing services go together with research. There is a growing share of revenues to be expected from the research activities.

Looking at the examples provided previously, most initiatives do not provide incubation services, tailored advice and mentoring services, access to a STEM lab and links to the academic community. One exception that does provide all four components is Sensor City, a collaboration between the University of Liverpool and Liverpool John Moore's University. However, Sensor City is an initiative solely focused on sensor technology. Based on a closer review of some of these initiatives, as well as the shortcomings faced by SensorCity, it is evident that a comprehensive service offer targeted to multiple types of stakeholders is very challenging to deliver. The review of comparable infrastructures illustrates the need for working with delivery partners in order to deliver the best service possible.

3.2.5 Capacity building and outreach services

Capacity building was deemed important by all interviewed stakeholders.

Examples from other structures showcase the importance of a strong supporting network both in and outside of Rwanda. For example, Fablab has partners in France (undergraduate students visit the facility each year) and also has industry partners in the US and Japan that provided initial backing and equipment / software. The Government of Rwanda also provided some financial support to the facility however this support is running out as the initiative matures. Fablab is not looking for additional donors at the moment of reporting (Summer 2019).

The facility should build on existing expertise and the local ecosystem. Interviewed stakeholders see a strong benefit in working with the NIRDA STEM lab facility. However, there needs to be a clear understanding of the STEM lab facilities' goals among stakeholders. NIRDA will **build capacity** to operate state-of the-art facilities through:

- Creating partnerships with international universities, eg providing opportunities for Rwandan researchers and technicians to learn via participation in exchange programmes. These partnerships will cover training, matchmaking with industry and academia. A recommendation is to ensure the presence of lecturers in the facility for training and exchanging with the industry on basis of a consultancy contract. They would be assisted by students. The partnerships with academia would also ensure lectures are given from professors on site at the University of Rwanda, through the same consultancy service, as well as masterclasses. It should be noted that thanks to its specific expertise, NIRDA would support curricula development. Highly recognised institutes such as Fraunhofer and TNO would also be proposed to partner and run similar courses as what was done in user-centred approach in 2019 by Fraunhofer.
- Providing young researchers with the opportunity for on-the job learning as research/lab assistants
- Internal training programmes, eg, following a small-scale-version of a train-the-trainer approach

NIRDA will also invest in promoting the facility in locally and in the region (to industry). It will promote via the organisation of:

- Open days & pro-active promotion of the facility to the wider community
  - Organize with partners competitions for young innovators - to tackle critical challenges, transform ideas into products and beyond, attract talents and build stronger businesses
  - Running competitions for 100 best ideas at schools and undergraduate programmes, to be rewarded with a private tour of the facilities
  - Roadshows across the country / region – targeting industry

In terms of **outreach** to the general public, many scientific institutions across European countries open their doors to the wider public one a year, inviting the wider community to learn about science and the contribution it makes and encouraging younger generations to become future scientists. Emerging countries (including China and India) are investing in international collaboration with leading universities, offering, amongst others, post-doc opportunities to learn to work with state-of –the-art equipment, enabling training a new generation of scientists.

It is key the STEM lab facility ensures a set of activities towards the industry, showcasing the added value of the facility for the industry. This could be done through demonstrating research and product development results but also inviting the industry to visit the labs and see the equipment as well as meeting the engineers and technicians.

It is important the STEM lab facility capitalises on the already existing efforts by partnering with relevant stakeholders. Like the STEM lab facility activities, the objective is to hand over the lead for these activities to partners.

To reach out to the new generation of innovators, the Creativity Lab organises a Kids Innovation Program teaching robotics, engineering and programming to children. This program is designed to involve, engage & provide kids with the opportunity to become Tech-Innovators, critical thinkers, and creative problem-solvers.

Fablab- Rwanda also opens its doors once per year to schools, - teaching schools how to use the machinery.

3.2.6 Summary of value addition by type of commercial facility member

Table 4 provides an overview of the service offer to start-ups and SMEs and larger companies. The services offer to SMS and larger companies is alike.

It should be noted that incubation programme is a six-month intensive training. On top of this six month training, incubate/start-ups will still have access to the facility for one year. This includes access to tailored advice and mentoring services, the STEM lab (in agreement with the STEM lab manager), and links to the academic community.

SMEs and industry access the STEM lab facility on a (rolling) membership basis.

Table 4 Overview of service offer by beneficiary type

	Type of added-value from activities	**Start-ups**	**SMEs**	**Industry**
Incubation services	Support in business development, marketing, HR, operationalisation	X		
	Review of product design	X		
	Advice on Intellectual Property	X		
	Office space / grow-on space	X	X*	X*
Tailored advice and mentoring services	Support with reviewing the product architecture and manufacturing design	X	X	X
	Identification of new/emerging technologies / materials etc	X	X	X
STEM lab	Access to state-of-the-art equipment	X	X	X
	Prototype (component) development / testing and calibration services		*X*	X
	User-centred approach label / certificate	X	X	X
Links to the academic community	Partnership opportunities with academics /experts	X	X	X
	RD&I testing and research services		X	X
Capacity building and outreach	Training / professional development		X	X

*The STEM lab can negotiate the provision of office space to SMEs and industry

4 Governance and operations

4.1 Legal structure

The preferred legal structure for the "STEM lab facility" is that of a private company owned by Government of Rwanda with formal delegated powers to NIRDA. Government shall own 100% of the shares but progressively, shareholding shall be opened up for other stakeholders to own shares.

This legal structure is considered a preferred option mainly because the initiative as foreseen would require a flexible structure that can bring in additional expertise (mentors and researchers) without incurring a delay. It would also be important to avoid any procurement challenges to enable the facility to adjust to the needs of industry. The preferred legal structure avoids substantial procurement challenges and recruitment challenges.

To ensure a high-quality implementation and financial sustainability of the facility, the governance and management model have to be built on partnerships, good selection and recruitment practices and a mentorship model. The preferred legal structure will allow the STEM lab facility to independently determine fees for selected services offered to industry, university and other stakeholders it would also allow the facility to interact and co-invest with other (private) companies.

It is recommended that NIRDA assumes overall responsibility for the running of the facility. Assuming ownership is important to ensure that this is concentrated effort, and that the services to be delivered at streamlines, and not dispersed in what still is an emerging eco-system. Moreover, public sector support will be required to ensure the (short-term) sustainability of the initiative.

As provided for in the Company Law, the STEM lab facility will be best positioned as a social enterprise that provided a public good and it should request the Registrar general for a waiver to add the abbreviation "Ltd" to its name. Tax deductions on training, and research and development (R&D) expenditure (eg equipment and raw materials) may be applicable. STEM lab facility dividend policy will be strictly 100% retained earnings. Any cash surplus/ "profit" generated will be fully reinvested.

Table 5 Legal options considered

	Advantages	Disadvantages
Option 1: Department within NIRDA	No administrative delay to launch the initiative	Substantial procurement challenges and recruitment challenges Challenge raising funding (ie the initiative is not immediately attractive to private investors and donors may have restrictions on funding public organisations)
Option 2: Not-for-Profit autonomous centre under NIRDA (preferred option)	No substantial procurement challenges and recruitment challenges	The administrative process to launch the initiative takes about one year Need to ensure finances for the first (seven-ten) years are assured
Option 3: Company for profit	No procurement challenges and recruitment challenges	Challenge raising private funding (ie the initiative is not immediately attractive to private investors) Possible challenge in re-investing profit in future proofing and/or scaling-up

In addition to the options presented in the table above, it has also been considered to embed the facility at one of the local universities. This option was ruled out as universities are hesitant to take on such initiative at this point in time and because the regulatory framework for universities poses substantial challenges on recruitment and procurement.

4.2 Building partnerships

Building partnerships has positive long-term impacts on the sustainability of the facility and its activities. For this reason, NIRDA will/should embrace additional relevant partnerships with local stakeholders of different sectors and international partnerships that can help push the initiative to the frontier and/or can help build relevant bridges. Partnership agreements will be formalised by means of a memorandum of understanding (MoU). It is recommended that NIRDA ensures the STEM lab facility builds a pipeline of (local) innovators through:

- Building partnerships with local universities, developing career opportunities for graduates through training. NIRDA is setting MoUs with HEIs in Rwanda and abroad to build a pipeline of researchers and graduates that want to develop a prototype/component for industrial application. The STEM lab facility is a joint proposal between NIRDA and the University of Rwanda (UR) and NIRDA and UR have already signed a MoU
- Actively promoting the facility to industry ('business outreach programme') and explaining the value of the lab equipment for industry (eg opportunity to increase performance, sales volume by improving products/components)
  - Providing prestigious training opportunities (for lab management, for lab technicians) offered by international experts
- Building a network of angel investors and venture capital firms that visit and/or are associated with (eg through MoUs) the STEM lab facility
- Developing joint research programmes with industry (to explore avenues to improve products/components, eg by using local materials)

Identified (additional) partners of value for the STEM facility include (amongst other) :

- IPRC Tumba is interested in developing a Memorandum of Understanding (MoU) with NIRDA.
- Harambee, Inkomo, AIMS and Bag Innovation for capacity building activities.

NIRDA will oversee the STEM lab facility for as long as the initiative is expected to yield social and economic benefits, that outweigh the cost of investment and as long as there is a need for public sector support in, amongst other, building cross-industry partnerships

4.3 Complement to the ST&I value chain

Access to the incubation, mentoring services and labs will be a differentiating marker for the STEM facility. For example, at 250 startups, because the beneficiaries do not have the means to pay for access to the services, the programme covers their travel expenses and offer its services for free to incubated entrepreneurs. FabLab chose a different option by building a pipeline of clients, mostly public bodies and the industry, that are commissioning the development of products and deducts a share of the revenues for the functioning of the lab.

The team proposes the following offer on costs for its different services (Table 6). Besides costs incurred by type of user, access to licences and software should always be included in the membership as well as access to meeting rooms and participation to events organised by the facility. The internet, front desk, printers, parking and miscellaneous services of the facility will be accessed for free. However, a small charge may incur for specific demands.

The recent graduates, start-ups and researchers will have a full access to the incubation and mentoring services and labs for free. The incubates will sign an intellectual property agreement with the facility, ensuring a share of their net revenues will go to the facility, in case they are successful with their product.

The financial model of the facility depends on the charges to the SMEs and the industry for the access to the labs. Entrepreneurs will be assisted in launching a successful product or service.

The SMEs will enjoy reduced rates to access the lab, considering they do not have the financial power of industry members. By joining the facility SMEs not only get access to the labs but also get connections to the mentors, industry partners, and potential investment opportunities. The objective for the SMEs is to ensure growth.

The industry will have access to state-of-the-art machinery, researchers dedicated to improving their products and a network of potential partners. The industry pays the commercial rate for the access to the lab which includes storage, front desk services, mailing, loading dock etc.

Table 6 Lab services and cost by type of user

	Incubation services	**Mentoring services**	**Access to hardware / software lab**
Recent graduates, start-ups and researchers	Free of charge	Free of charge, prerequisite	Free of charge
SMEs	n/a	n/a	Reduced rates
Industry	n/a	n/a	Commercial rates

4.4 Management – key roles

The management roles of the facility consist of ensuring the success of the activities. Mentors and experts will provide support to graduates and entrepreneurs for their incubation and mentoring activities. The STEM lab also needs a manager and a team to run and maintain machinery. Similarly, capacity building and outreach and communication services will be handled by professionals.

There is a specific need regarding the employees of the STEM lab. They do not only run the operation of the equipment but also need to have experience to add value to the operations.

4.4.1 Recruitment needs

The research team recommends the activities of the STEM facility will be supervised by the Director of the Laboratory Unit of NIRDA, acting as managing director. He will be closely cooperating with an experienced **lab manager**. This person will be in charge of effectively running the labs, overseeing their use, managing the staff and ensuring the relevant staff is present to oversee prototyping and testing activities.

Ideally, the lab manager will have (extensive) expertise in the three areas of work of the facility. Because the lab manager has to think strategically, it is important is has international experience, knows of similar or complementary facility in and outside Rwanda.

While the lab manager will be in charge of steering the strategy for the STEM lab, he/she will be assisted in daily activities and running operations by engineers and technicians.

It is key the **head engineer** is experienced. He/she will be responsible for running the equipment, installing software, maintain and update equipment and consumables. The lead engineer needs to be sufficiently experienced with the equipment and in the areas of STEM to understand where and how to add value to a prototype or research. This person will also have a key role as a technical mentor, to technicians but also graduates and entrepreneurs.

The team of **engineers and lab technicians** will assist the head engineer through their knowledge and technical abilities in energetics, mechatronics and industrial software systems. We foresee a team with junior and more experienced profiles, all having experience in product design and/or industrial machinery. The team of engineers (managing a specific lab) and lab technicians should be expanding with the activities and success of the STEM lab. We suggest the team build from a total of seven FTE staff (a lab manager, support staff and technicians).

These can be products of IPRCs (Integrated Polytechnic Regional College) in country and will be responsible for implementing and maintaining the technology in the country.

The design activities that are foreseen in the hardware and software labs call for a **design and marketing specialist**.

Mentors will have experience running incubation activities with a thorough knowledge of national and international funding.

Identifying experienced staff with the right expertise and with the ability to provide day-today support is absolutely crucial to the success of the STEM lab facility.

- NRDA will recruit nationally/internationally
- NRDA will run internal training programmes for staff - this could follow a small-scale-version of a train-the-trainer approach

The STEM lab facility can build on ongoing activities. Fraunhofer, the German research institute driving applied research, is especially active as a service provider for capacity and skills development. The Fraunhofer Center for Responsible Research and Innovation (CeRRI) conducts a training, organised by GIZ and in collaboration with NIRDA, on human centred design. Two of NIRDA staff are part of the trainees as well as other actors from the national innovation ecosystem. The IZM[60] is also planning on training technical participants in IoT prototyping for electronic components manufacturing.

4.4.2 Skillset

The specific skills expected from employees of the STEM lab include a thorough knowledge of li-ion batteries and DMFC (direct-methanol fuel cell) but also deep training in developing and applications in mechatronics. For the type of foreseen innovation and product development, the team has identified a set of transversal skills and expertise:

- Electrochemistry: materials level
- Pumped Hydroelectric Storage (PHS)
- Engineering designer and controller
- Electrical engineer
- Civil Engineer
- Materials scientist

Recruited individuals are requested to hold a Master degree (for engineers), Bachelor or a diploma from IPRCs and the University of Rwanda (for lab technicians). For example, the IPRC Tumba offers a course on design and the Polytechnical College of the University of Rwanda focusses on applied STEM which is highly relevant for the facility. Preferred majors are:

- Electrical and Electronics Engineering

[60] The Fraunhofer Institute for Reliability and Microintegration IZM helps companies assemble robust and reliable electronic systems

- Electronics and Telecommunication
- Electronics and Instrumentation
- Computer Engineering, Computer Science, Software Engineering
- Information System
- Any other engineering related field is acceptable, as long as the individual can justify a passion for embedded system innovations.

4.5 Entry criteria and process

4.5.1 For recent graduates, start-ups and researchers

The entry criteria for recent graduates, start-ups and researchers will be to submit a proposal for prototype development. They will be selected to join the facility through a two-stage process[61]:

- **Stage 1**: Applicants must submit a written proposal describing their concept / idea, the product architecture, the equipment needed to develop the product/components, their understanding the market
- **Stage 2**: Interview round, applicants must demonstrate a first stage prototype

The jury will evaluate proposals on the following criteria:

- Innovativeness of the concept
- Quality of the prototype
- Business opportunities in Rwanda (eg import substitution) and abroad (export) and ability to scale-up
- Capacity to address local socio-economic and environmental challenges

The jury will also put emphasis on respecting the parity and diversity of cohort members.

The team foresees the following process for organising lab time across cohorts. In the first stage of operation, the selection of users and time allocation to use the equipment will be made on a rolling basis – applicants can put in a request at any time.

Once a pipeline of requests for lab time / equipment is built-up, the selection of users and time allocation to use the equipment is determined on a quarterly basis, after the selection and lab time allocation for the (three month) cohort of STEM graduates and young innovators is made.

4.5.2 For SMEs and industry

While STEM facility members (ie recent graduates, start-ups and researchers) will benefit from incubation and mentoring services and will be encouraged to use the lab for free, the members from the industry will be given preferential lab access at **commercial rates**. The rates will be determined by top management and time allocation will be agreed with the lab manager. It shall be noted that industry led proposals involving student internships and professional internships will be encouraged.

The example of DESY (Deutsches Elektronen-Synchrotron, the German research centre in particles) justifies providing preferential access to industry. DESY reaches out towards industry and encourages contacts and co-operations with companies, in order to make available the generated knowledge and to promote its application to industrial questions.

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[61] The project 250startups functions with a similar staged selection process that takes place twice a year. After a written proposal, applicants are interviewed and invited to a 3-day bootcamp during which applicants test their first prototype with potential users. This is followed by the final selection of a cohort of 10.

Early stage start-up and innovators (non-members) and SMEs will be given preferential lab access at **reduced commercial rates**. The rates will be determined by top management based on set criteria and time allocation will be agreed with the lab manager.

Taking the example of the MHub in Chicago, rates reach 200$ a month for unlimited access to (the ten) labs. For the members/companies looking to develop occasional products and commission research, the rate is 450$ per month. On this basis, the team suggests the SMEs pay about half price compared to the commercial rates.

MHub in Chicago[62] charges rates for companies 'just getting stated', which reach $200 a month for unlimited access to ten prototyping and production labs. For more established companies looking for occasional access to the facilities, the Mhub rate is $450 per month. The $200 rate is proposed as a target for SMEs looking to use the STEM lab and the $450 is proposed as a target for industry (local, regional, international). In contrast to the example of MHub, the commercial fees are applicable to established companies: SMEs (defined eg as organisations with less than 250 employees) and larger companies (those with 250 or more employees).

4.5.3 Allocation of lab time

Regarding the **allocation of lab time**, SMEs and industry applicants can put in a request for lab time any time. It shall be underlined that the overbooking factor (demand vs availability) is usually 3/2 - 6/1. Based on standard practices, Because the industry is the primary payer of the facility, they will have a preferential access to the labs. SMEs will also enjoy reserved time slots.

For start-ups, time requests will be project specific. The graduates, researchers and entrepreneurs will have access to the facility and labs when there is no reserved access. Time requests should be put in for specific machinery, in collaboration with the lab manager. There should be no cap on time requests. The lab managers may not grant the time request, especially if there is no/low capacity.

The allocation of hardware / software lab time will be determined by the lab manager, in consideration of the proposal and based on his/her expertise:

- In allocating time, the lab manager considers the type of request and the applicant profile
- The lab manager monitors use of specific equipment and other resources made available, in line with agreement made
- Time is allocated for service and maintenance before and after the use of equipment
- Affiliated researchers can use any un-booked time. This includes overnight time. Although this may be a 'new' way of working to some stakeholders it is considered best practice to make full use of state-of-the-art (eg this is common practice at DESY). Moreover, some tests/prototype developments take longer than office hours.

The table below illustrates the foreseen allocation of time.

Table 7 Allocation of lab time, target and limitations by user

	Recent graduates, start-ups and researchers	**Research / research services commissioned**	**Industry commissioned projects**	**Industry led projects**	**Other (outreach and training)**
Target	25%	5%	35%	35%	1%
Upper limit	Up to 50%	Up to 10%	Up to 50%	Up to 50%	Up to 5%

[62] See: https://mhubchicago.com; https://mhubchicago.com/page/plans-pricing

In order to maximise the capacity of the lab equipment, the team suggests running three shifts, as is done at Africa Improved Food since local industry operates 24/7.

According to a local facility manager, obtaining a pipeline of clients and a pipeline of 'innovators' was not a challenge and the equipment can be used at 100% capacity. It should be noted that, whilst this of course is desirable, many new facilities do struggle to operate at 80%-100% (or even 50%) capacity in their first years of operation. Key challenges are delivering committed services in time (eg a suggestion is overbooking given the limited equipment). Another challenge is delivering quality to clients.

5 Costs and benefits

5.1 Introduction

This cost and benefits analysis is conducted in consideration of the scope of the initiative as set out in the previous chapter. It outlines the financial needs for the construction, operation and future proofing of the STEM lab facility.

The costs and access to the labs is a paramount aspect of the facility. Primary access to the industry enables the facility to invest its resources on its activities in promoting RD&I and industrialisation. Free access for graduates and start-ups ensures the facilities supports these target groups to innovate and develop prototypes. This chapter outlines the expected benefits from investment in the facility, for both industry members and future incubatees.

A Cost-Benefit Analysis (CBA) is conducted comparing the costs of investment with the expected benefits. The CBA considers a set of 'preferred outcomes' and also presents alternative options for implementation. The options are compared against the baseline estimate of not investing.

The study also considers the financial sustainability of investing in the STEM lab facility. This analysis considered the cost of operation and the revenue accrued over time. The calculations consider a 25-year period. The analysis shows that the STEM lab facility could become financially sustainable by year eight. Thereby the analysis shows that there will be scope for future revenue streams to be reinvested into upgrading the facilities and other maintenance costs.

The costs and benefits analysis does not consider inflation rates (eg real estate price inflation). This means that rates charged in 2022 are assumed to stay constant. Similarly, a wage premium is calculated, and the calculations assume that wages do not increase overtime. The is of course a major simplification. Other assumptions made and an overview of the calculations is presented in Appendix B.

5.2 Estimated costs of the STEM lab facility

5.2.1 Capital investment

In order to set-up a STEM lab facility a considerable amount of upfront investment is needed. NIRDA has received quotes on the initial costing. There are no costs associated with the use of the land (this is made freely available by the University of Rwanda).

- Built project – total costs are estimated at $11m
- State-of-the-art equipment, including training and ICT-support for use of the equipment, 45% taxes and shipping - these costs are estimated at $8m

The estimate for state-of-the-art equipment assumes a single source procurement based on a preliminary list of equipment. Once the final list of equipment is outlined it may be possible to bundle the equipment into packages and receive more competitive bids from the market. Also, under the preferred legal option (ie the establishment of a not-for-profit autonomous centre under NIRDA) single source procurement should not be a required route. This could help push cost down. It may also be possible to benefit from tax deductions on training, and research and development (R&D) expenditure. Capital investment may not be tax deductible.

There may however be a need to procure equipment that was not initially anticipated and this will increase costs. The cost of raw materials has also not been costed separately and this may also create some financial pressure in the short run.

Considering a more long-run perspective, in order to maintain a state-of-the art facility there will be a need to upgrade the facility's equipment. A 'soft' upgrade is assumed every ten years at a cost of $2m. This results in $4m in replacement costs over a period of 25 years.

5.2.2 Operating costs

Operating costs are estimated looking at prospective personnel costs and overhead. The STEM lab facility will be run by staff with a range of expertise. This will involve recruiting a mix of local, regional and international staff. It will also involve recruiting staff with varying degrees of seniority, managerial staff that will manage a particular division, including the technical lab, versus other senior positions involved in providing the facility's support services. The table below presents wage estimations. The salaries presented for locally hired employees are based on available information on public wages in Rwanda retrieved from the WageIndicator Foundation[63]. The salaries used for internationally recruited positions were obtained by assuming a significant mark-up from local salaries. The reason for this is the need to offer a competitive salary package in order to attract suitable candidates from abroad.

Given the salary of lab managers in (for instance) the US and UK are roughly double the estimates for international managerial staff, a $40k salary package may not be enough to recruit the expertise from the countries that have advanced technical expertise in running these types of facilities. It is therefore assumed that recruitment will first target lab managers from the region (or from other emerging economies such as Turkey, China) and if no suitable candidates are identified to broaden recruitment to other countries. The employment package could be adjusted for each recruitment attempt. In order to facilitate this, we include an additional $50,000 per year in order to support the recruitment of international/regional staff. This discretionally fund can also be used to offer training to regional/local staff and to encourage international networking (eg one-month placement at a facility such as M-lab).

For every position in the STEM facility 100% of salary are assumed to cover overhead costs. The cost of recruiting support staff, eg HR, admin, etc are not included in the cost estimated for these are assumed by the other departments at NIRDA.

A comprehensive service offer could be provided with a team of 13 Full Time Equivalent (FTE) staff.

It is assumed that additional expertise will have to be recruited from elsewhere on a part-time basis (universities / international networks etc). A budget envelope of $80,000 per year is set aside for recruiting experts and mentors that will advise the start-ups beyond the initial incubation phase. In addition, a budget envelope of $40,000 per year is set aside for recruiting researchers that will work on commercial projects, thereby helping foster links between academia and industry

Table 8 Annual salaries

	International / regional	Local
Senior / managerial level	$40,000	$20,000
Support staff (personnel with a STEM degree and other relevant expertise)	$20,000	$10,000

Table 9 Annual personnel costs for preferred option

Services	International	Local	Costs
Incubation		1 senior 2 support staff	$80,000
Tailored advice and mentoring		0.5 senior	$20,000
STEM lab	1 senior 2 support staff	2 senior 2 support staff	$280,000
Research		0.5 senior	$20,000
Capacity building and outreach		1 senior 1 support staff	$60,000
Personnel costs (internal)	3 FTE	10 FTE	$460,000

[63] https://mywage.org/rwanda

Additional costs - recruitment/benefit package	$50,000
Additional costs - advice & mentoring	$80,000
Additional costs - research (academic link)	$40,000
Total	**$630,000**

5.3 Estimated economic impact / benefit

Investment in the STEM lab facility is estimated to create substantial wider economic and social benefits for Rwanda. The return on investment will accrue in the long term. Therefore, a 25-year timeframe is considered for estimating the economic benefits.

In order to have a view of the different types of specific benefits that the STEM lab facility can be expected to create we consider the facility's intended impacts (see chapter 1).

Several of the intended benefits can be monetised and benefits can be calculated against a 25-year timeframe (starting from the launch of the facility). A summary of these monetised benefits is reported in Table 10. The steps taken in order to obtain these estimates are discussed in the under the next subheadings for each individual benefit.

Table 10 Estimated benefits accrued 25 after the launch of the STEM lab facility (US million dollar)

STEM lab facility service offer	Benefits	Note	Value
Incubation services & Tailored advice and mentoring services / STEM lab	Wage premium	Estimated value of the wage premium earned on top of base salary	$4.1m
	Start-ups	Estimated value of start-ups	$99.0m
	Additional jobs created	Estimated value of wages for additional jobs created	$0.9m
STEM lab	Product innovation - commercial fees	Commercial rates charged for using the facilities	$0.2m
Links to the academic community research services	R&D spent on labour	R&D spent on labour for developing new prototypes	$0.7m
	Commissioned projects	Estimated income earned by STEM lab facility for commissioned research	$2.2m
Total			**$107.2m**

5.3.1 Wage premium

One of the estimated economic benefits resulting from the incubation services provided through the facility is the additional income for trained individuals. The incubation services of the facility provide individuals with six months' worth of intensive training. On top of this six month training, incubatees will still have access to the facility for one year.

To estimate the value of the resulting wage we assume a 6% premium. This is based on prior research on the benefit of human capital formation at CERN (a prestigious research institute) conducted by Florio et al (2015) who estimated that a 12% wage premium could be attributed to each researcher over a career spanning 40 years. These researchers spent at least a year in training. It is assumed that those benefitting from the incubation programme will be supported for a six-month period. We therefore assume the wage premium in this case to be half the effect found by Florio et al.

We apply this premium to an indicative salary an individual taking training at the STEM facility can be expected to earn. Specifically, we assume a salary of 566,221 RWF (approx. $622) per month which corresponds to the wages for positions such as research assistant fellow and lab technician at NIRDA[64].

Assuming training is provided to cohorts of 15 incubatees for a period of six months this means that 30 individuals will complete training on a yearly basis. In principles, these individuals will be able to enjoy their wage premium from the moment they complete the training.

On this basis, we estimate the value of the wage premium enjoyed by trained individuals within the first 25 years of operation of the STEM lab facility to be around $4.1m. This is a conservative estimate as it assumes there are no further salary increases during this timeframe.

Beyond the 25-year period, we estimate the 'full effect' of training provided within the first 25 years of the facilities' lifetime to be worth $8.4m, assuming every trained individual enjoys their wage premium for a period of 25 years.

5.3.2 Start-ups

One of the objectives of the STEM lab facility is to support the creation of start-up businesses.

250Startups is a programme that was launched in 2018 with the ambition of promoting the ICT sector in Rwanda with a focus on young entrepreneurs. One of the objectives of 250Startups is to have 100 start-ups by 2025 with a total net worth of $50m (ie on average $500,000 in profit-earning years). We 'benchmark' the target of 250Startups against the projected success for the STEM lab facility. If the STEM lab facility incubation programme supports 30 incubatees per year and the start-ups graduating from this programme have a 30% change of survival[65], the STEM lab facility would be able to generate around nine successful start-ups per year. This survival rates is comparable with previously calculated rates for Rwandan incubators. This rate is typically associated with 'pre-incubation'. If the facility is able to attract incubatees that have successfully graduated from pre-incubation initiatives, the survival rates could increase towards 70%. The calculations assume survival rates remain 30% over the next 25+ years, which may be conservative. The survival rates is dependent on the ability of the STEM lab to attract start-ups with good ideas, amongst other. The survival rate will also dependent on the quality of the service to be offered, where high-quality support is associated with high survival rates and higher returns on revenue.

Assuming the created start-ups do not start generating revenues in their first three years of operation, we estimate a total cumulative value of generated start-ups over 25 years of $99.0m (9*$500,000 [yr4] + (9 +9)*$500,000 [yr5] etc). The average revenue per start-up is $440,000 and if using this figure the total estimated benefit would have been the same (ie $440,00*25*9 = $99.0m). Start-ups may of course earn some revenue in the first three years; this would be a sign of success.

5.3.3 Additional jobs created

In addition to the value associated with the creation of new start-ups, benefits will also accumulate in terms of the jobs created by said start-ups, as a results of the provision of tailored advice and mentoring services and access to the lab facilities which will essentially enable start-ups to scale-up and go to market.

To express the value of this benefit in monetary terms we make the following assumptions. Firstly, we benchmark against previous estimates of a start-ups' survival rate, which is approximately 30% after the first year[66]. Prior experiences with business incubation in Rwanda indicate that the average size of start-

64 Retrieved from: https://mywage.org/rwanda/salary/public-wages/irst-nirda

65 Brink, A., Cant, M., & Ligthelm, A. (2003). Problems experienced by small businesses in South Africa. Paper for the Small Enterprise Association of Australia and New Zealand 16th Annual Conference, Ballarat, 28 Sept-1 Oct, 2003.

66 Brink, A., Cant, M., & Ligthelm, A. (2003). Problems experienced by small businesses in South Africa. Paper for the Small Enterprise Association of Australia and New Zealand 16th Annual Conference, Ballarat, 28 Sept-1 Oct, 2003.

ups after one year in terms of employees is 2.8[67]. This is a conservative estimate considering the nature of the manufacturing industry. Based on the creation of nine start-ups per year (only some start-ups are estimated to be successful) and a base salary of $7,474 for created positions we obtain the monetary value of additional employment. To estimate the additionality of these benefits we take into account an unemployment rate of 20% for graduates one year after their graduation.[68] Based on these parameters, we estimate a value of $0.9m for a total estimated 611 new jobs created.

In the calculation it is assumed that 20% of the STEM graduates remain unemployed only for one year. If we were to assume that this group remains unemployed for two years, the estimated value of jobs created doubles ($1.8m). Also, if unemployment of STEM graduates were to drop to 10% (ie a higher demand for STEM graduates) then the estimated value of jobs created halves ($0.5m). This means that the estimates of additionality offered are sensitive to changes in the demand for labour (amongst other).

Table 11 Estimated benefits of job creation (US dollar)

Parameters	**Value**
Number of incubatees per year	30
Survival rate after 1 year	30%
Average start up size after 1 years	2.8
Annual wage	$7,474
Unemployment one year after graduating	20%
The number of jobs created per year	25
Total jobs after 25 years (value)	611
Total jobs (value)	190,203
Total jobs after 25 years (value)	$4,564,882
Additionality per year	$38,041
Additionality after 25 years	**$912,976**

5.3.4 *Product innovation (R&D spent)*

The STEM lab facility aims to support industry to become more competitive (including on the international market) through product innovation. A close measure of the future contribution of the STEM lab facility to product innovation would comprise of additional profits derived from having produced new products by means of prototype development at the STEM lab facility. This value is difficult to capture. Estimates are provided for R&D spent by industry at the facility.

5.3.4.1 Commercial fees

A conservative proxy for product innovation is the total sum of commercial rates charged for using the facilities plus labour costs, for this represents an investment by industry in R&D.

Taking the example of the MHub in Chicago[69], rates for companies 'just getting stated' reach $200 a month for unlimited access to ten prototyping and production labs. For more established companies looking for occasional access to the facilities, the rate is $450 per month.

[67] Aggarwal, R., Siddiqaliali, B., & Kumar, P. (2012). Technology and business incubation a proven model to promote technology innovation and entrepreneurship in Rwanda. International Journal of Business and Public Management, Vol. 2(2): 47-50

[68] International Labour Organisation data, retrieved from https://ilostat.ilo.org/data/country-profiles/

[69] See: https://mhubchicago.com; https://mhubchicago.com/page/plans-pricing

The $200 rate is used as a target for SMEs looking to use the STEM lab and the $450 is used as a target for industry (local, regional, international). In contrast to the example of MHub, the commercial fees are applicable to established companies: SMEs (defined eg as organisations with less than 250 employees) and larger companies (those with 250 or more employees). These are reduced rates.

The facility will look to engage with industry through different means. It is assumed that the facility will be able to attract paying customers. It will be nevertheless challenging to attract industry with an interest in developing prototypes at the facility and it is key for this service to be promoted in the region, so that the STEM lab facility can have a wider reach/customer base. For the first three years it is assumed that five SMEs will use the facility per year (for one month - $200 per month) and that five larger firms will use the facility (for one month - $450 per month). After the first three years it is assumed that 15 SMEs will use the facility per year (for one month - $200 per month) and that ten larger firms will use the facility (for one month - $450 per month).

The number of members is assumed low because the industry sector in Rwanda is still emerging and RD&I investment in low. A growth after the first three years is assumed because the facility will be better placed to attract industry from the region once it has grown its brand. In this regard, the first industry members could be positioned as champions. If the STEM lab facility can successfully position itself, it may be that industry will choose to be a member for a longer period of time, during which it may not (continuously) use the STEM lab but can benefit from the connection to academic and start-up community. Of course, this is a best-case scenario.

After 25 years of operating the total revenue to the facility would amount to $175k.

5.3.4.2 R&D spent on labour

The time spent by each organisation on prototype development at the facility is also estimated. It is assumed that two staff will oversee the prototype testing. Their salary costs ($623 per month – see section on jobs created) is accumulated across 25 years of operation and the sum of this amounts to $722k.

5.3.5 Value of commissioned projects

As part of its service offering, the STEM lab facility will provide research services in the form of commissioned projects. The model is somewhat alike to the offering of Fablab (ie industry commissions a service to STEM lab facility members/affiliated researchers) and the service to be delivered is the development of an advanced prototype.

We assume that the STEM lab facility will be able to generate an average revenue worth of $0.1m from commissioned research projects. This estimate is benchmarked against the performance target of FabLab which currently is about $0.1m.

We assume that it will take about seven years to reach this revenue level since it will take a certain amount of time for the STEM lab facility to attract clients, gain practical experience, and build a track record in running commissioned projects. Specifically, we estimate annual revenues to start at $30k and gradually increase by approximately $10k per year until reaching $0.1m by year seven.

The resulting value of revenues from commissioned projects over the course of 25 years adds up to $2.2m.

5.4 Cost-benefit analysis

5.4.1 Options and associated costs

Overall, we consider 5 different options for the STEM facility. The first of these is a baseline option in which no facility is set-up, no investments are made, and no benefits are accrued.

The second option is the preferred option and represents a comprehensive service offer. This means that the STEM lab and tailored advice and mentoring services form the facility's core service offer while incubation, links to the academic community, and capacity building and outreach are offered as complementary services.

Table 12 Preferred option – Comprehensive service offer

	Core service offer	Complementary service offer
Incubation services		✓
Tailored advice and mentoring services	✓	
STEM lab	✓	
Links to the academic community		✓
Capacity building and outreach		✓

The first alternative to the preferred option, option 3, will be primarily focused on industry as a customer. This means that the same portfolio of services is offered as in option 2 with the exception of incubation services, which are not provided by the STEM lab facility at all.

Table 13 Option 3 – Industry as a core customer

	Core service offer	Complementary service offer
Incubation services	✗	✗
Tailored advice and mentoring services	✓	
STEM lab	✓	
Links to the academic community		✓
Capacity building and outreach		✓

Option 4, on the other hand, will be predominantly research oriented. The key difference with option 2 is that the links to the academic community are now offered as a core service rather than a complementary service.

Table 14 Option 4 – Research oriented facility with industry-academia links

	Core service offer	Complementary service offer
Incubation services		✓
Tailored advice and mentoring services	✓	
STEM lab	✓	
Links to the academic community	✓	
Capacity building and outreach		✓

In contrast, the 5th and final option will not offer any services providing links to the academic community.

Table 15 Option 5 – No focus on industry-academia partnerships

	Core service offer	Complementary service offer
Incubation services		✓
Tailored advice and mentoring services	✓	

STEM lab	✓	
Links to the academic community	✗	✗
Capacity building and outreach		✓

The differences between these options are also be reflected in the amount of time and resources allocated to each of the facility's services (see Table 16) and the amount of personnel required (see Table 17).

Table 16 Target resource allocations, rough estimations of targets

	Option 1 (baseline)	Option 2 (preferred option)	Option 3 (Industry as a core customer)	Option 4 (Research oriented facility with industry-academia links)	Option 5 (No focus on industry-academia partnerships)
Recent graduates, start-ups and researchers	0%	25%	0%	17%	35%
Research / research services commissioned	0%	5%	13%	20%	14%
Industry commissioned projects	0%	35%	43%	45%	0%
Industry led projects	0%	34%	43%	17%	50%
Other (outreach and training)	0%	1%	1%	1%	1%

The personnel requirements associated with each option also account for the differences in total cost. There are three key differences that are worth noting. Firstly, option 3 of the STEM lab facility provides no incubation services as part of its offering. This means no personnel is required in this department, but it also implies no royalties are earned on resulting start-ups. Secondly, option 4 has a stronger focus on the provision of research services meaning investment in this component is doubled. Lastly, option 5 does not focus on academic research meaning no investment is required in this area.

Table 17 Personnel needs per option (FTE) (excluding outsourced)

	Option 1 (baseline)	Option 2 (preferred option)	Option 3 (Industry as a core customer)	Option 4 (Research oriented facility with industry-academia links)	Option 5 (No focus on industry-academia partnerships)
Incubation	0	3	0	3	3
Advice & mentoring	0	0.5	0	0.5	0.5
STEM lab	0	7	7	7	7
Research (academic link)	0	0.5	0.5	2	0
Capacity building & outreach	0	2	2	2	2
Total	**0**	**13**	**9.5**	**14.5**	**12.5**

5.4.2 Revenue to the facility

Revenue to the facility includes:

- Income from renting out workspace to incubatees/start-ups
- Income from royalties on patents and trademarks in relation to successful incubatees
- Income from charging industry for their use of the STEM lab facilities
- Income earned from commissioned research

The revenue from commercial fees charged to industry and the estimated income earned from commissioned research have been specified earlier in this chapter. However, the other revenue streams require some further elaboration.

5.4.2.1 Rentable workspace

The initial investment in the built project includes an investment in the creation of business space for incubatees/start-ups. It is typical for incubators to offer a mix of hot-desking space and dedicated office space. The incubation programme will run for six months and for the first three months, the STEM lab facility will offer the incubatees hotdesking space free of charge. For the remainder of the incubation programme the incubatees can opt to rent space at the STEM lab facility. The facility will offer 'grow-on-space' for one additional year after the completion of the incubator programme. Mentoring/ advice services and lab access will also be provided for one additional year after the completion of the incubation programme and the start-ups will still have access to the STEM lab equipment (based on agreements made) and for this reason is expected that renting space at the facility (at the right price) can bring substantial added value to the start-ups. Of course some start-ups will choose to work from alternative locations.

The following assumptions are made:

- Half of the startups taking part in the incubation programme will pay for three months of hotdesking space
- 25% of the startups taking part in the incubation programme will pay for an additional 12 months of dedicated desk space
- 20% of the startups taking part in the incubation programme will pay for an additional 12 months of private office space. It is assumed that the average occupancy is three people

The total estimated income per year from renting out space is around $433,746 and after 25 years this amounts to $10.7m in revenue (see Appendix A for a breakdown).

5.4.2.2 Value of royalties

The facility will support the incubatees to develop and test their prototype and will help them protect their Intellectual Property (IP) in return for an agreed royalty. It is assumed that half of the incubatees that are expected to be successful (on average 4.5 per year) will protect their IP using a patent and a similar proportion will register a trademark. In practice some may not register a patent or a trademark and some may register both. The model assumes that there will be a royalty agreement (patent, trademark or other) with each incubate/start-up. IP agreements are negotiated. It is assumed that on average a patent royalty is agreed at 25% on gross profit for 20 years after generating revenue and a trademark royalty is agreed at 10% on gross profit for 10 years after generating revenue.

We assume a conservative margin of gross revenue of 20% which is consistent with gross profit margins in the electrical equipment industries in emerging markets[70]. Note that the revenue from royalties of a 20% margin and a 25% patent royalty is equivalent to a 5% royalty agreement on profit.

[70] Based on Damodaran, A. (2018). Operating and Net Margins by Industry. Retrieved from: http://people.stern.nyu.edu/adamodar/New_Home_Page/dataarchived.html#returns

Based on these parameters and the total value of successful start-ups (as reported in the section outlining the estimated value from start-ups) we estimate royalties to amount to approximately $36m after 25 years. In the first three years (following 'graduation'), the revenue of start-ups is assumed zero, and hence it is assumed that the STEM lab facility will not earn any revenue from royalties, which would have an impact on the financial sustainability of the STEM lab facility in the short-run. More typically, growth rates tend to grow exponentially and revenue may have a bell-curve shape. The calculations assume zero growth rate from year four onwards which is a simplification.

5.4.3 Cost-benefit analysis - results

Based on the features of each of the options described above, a comparison can be made of the total revenue and costs. The initial capital investment and the wider economic benefits are not considered in this equation.

The results across each for the options is presented in Table 18. In sum, for three options the benefits are expected to outweigh the costs. The net benefit of option 3 expected to be negative. The reason for this is the absence of incubation services and therefore no revenues are earned from renting out incubation space and no revenue in the form of royalties from successful start-ups that are created. It must be noted however, that the estimated benefits from 'product innovation', as proxied by R&D spent, is a crude measure that does not take into account the full economic benefits of supporting local industry's competitiveness and these wider economic benefits associated.

The revenue after subtracting costs for option 2 (the preferred option) is $29.4m. The initial capital investment of $19m ($11m for the built project and $8m for equipment) can also be subtracted from this figure, which would imply that total revenue after total costs are estimated at $19.4m.

Based on the calculations, option 2 (the preferred option) yields a slightly higher net benefit than option 4 and 5. Because the results are based on gross assumptions these estimations are sensitive to change and fluctuations.

Table 18 Total costs and total benefits after 25 years (in million US dollar), excluding initial capital investment

	Option 1 (baseline)	*Option 2 (preferred option)*	*Option 3 (Industry as a core customer)*	*Option 4 (Research oriented facility with industry-academia links)*	*Option 5 (No focus on industry-academia partnerships)*
Revenue - Rent from workspace	$0	$10.7	$0	$10.7	$10.7
Revenue - Royalties	$0	$36.0	$0	$36.0	$36.0
Revenue - Commercial fees	$0	$0.2	$0.2	$0.2	$0.2
Revenue - Commissioned projects	$0	$2.2	$2.2	$04.4m	$0
A. Total Benefits	$0	$49.1m	$2.4m	$51.3m	$46.9m
B. Total Costs	$0	$19.8m	$15.3	$22.3m	$18.3m
Benefits after subtracting costs (A – B)	**$0**	**$29.4m**	**-12.9$**	**$29.1m**	**$28.7m**

A comparison between option 3, 4 and 5, conveys that industry-academia partnerships can be hugely beneficial to all stakeholder groups but there are risks (and costs) associated from investing in the creation of these partnerships. Option 2 presents a conservative investment in the creation of such partnerships. If this investment does prove to be successful, there is opportunity to scale-up activities in this domain.

5.5 Financial sustainability

To assess the financial sustainability of the preferred option we consider the behaviour of cost and benefits associated with the facility over time. In order to provide a more accurate representation over the value of net benefits accrued over the 25-year timeframe, the net present value (NPV) of said benefits must be calculated.

The reason this is necessary is because the future value of a given amount of money is less than the value of the same amount in the present. This is due to the effect of inflation as well as the earnings that could have been realised through alternative investments.

To obtain the NPV associated with the preferred option of the STEM facility we follow the formula below

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t}$$

Where R_t is the net benefit per year, i is the discount rate or the rate of return that could have been earned on alternative investments, and t is number of years.

In our estimation we use a discount rate of 5% which is equal to the most recent interest rate as set by the National Bank of Rwanda in August 2019[71]. This results in an NPV of $12.9m over a 25-year period in direct benefits to the STEM lab facility.

Projecting the NPV of net benefits on an annual basis allows us to identify the point at which a break-even point is reached. Specifically, we consider the cumulative NPV of net benefits which are negative up to year 7. Therefore, we estimate that a break-even point will be reached in year 7 of operations (see Table 19).

Table 19 Break-even point of preferred option

	Total Cost	Total Benefit	Net Benefit	NPV	NPV (cumulative)
Year 1	$630,000	$358,560	-$271,441	-$271,441	-$271,441
Year 2	$630,000	$476,996	-$153,004	-$145,718	-$417,159
Year 3	$630,000	$486,996	-$143,004	-$129,709	-$546,867
Year 4	$630,000	$658,746	$28,746	$24,832	-$522,036
Year 5	$630,000	$826,246	$196,246	$161,452	-$360,583
Year 6	$630,000	$993,746	$363,746	$285,005	-$75,579
Year 7	$630,000	$1,161,246	$531,246	$396,424	$320,845
Year 8	$630,000	$1,328,746	$698,746	$496,586	$817,431
Year 9	$630,000	$1,486,246	$856,246	$579,541	$1,396,972
Year 10	$630,000	$1,643,746	$1,013,746	$653,470	$2,050,441
Year 11*	*$2,630,000*	$1,801,246	-$828,754	-$508,783	$1,541,658
Year 12	$630,000	$1,958,746	$1,328,746	$776,890	$2,318,549
Year 13	$630,000	$2,116,246	$1,486,246	$827,597	$3,146,146
Year 14	$630,000	$2,228,746	$1,598,746	$847,849	$3,993,995

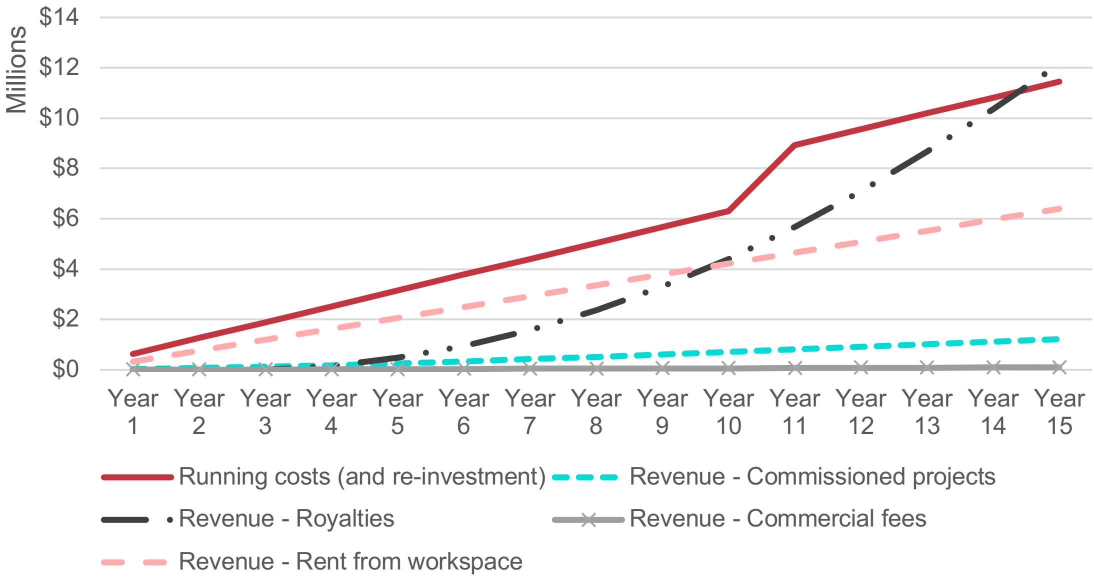
[71] Retrieved from https://tradingeconomics.com/rwanda/interest-rate

Year 15	$630,000	$2,341,246	$1,711,246	$864,296	$4,858,291
Year 16	$630,000	$2,453,746	$1,823,746	$877,253	$5,735,544
Year 17	$630,000	$2,566,246	$1,936,246	$887,017	$6,622,560
Year 18	$630,000	$2,678,746	$2,048,746	$893,861	$7,516,421
Year 19	$630,000	$2,791,246	$2,161,246	$898,042	$8,414,464
Year 20	$630,000	$2,903,746	$2,273,746	$899,799	$9,314,262
Year 21	$2,630,000	$3,016,246	$386,246	$145,572	$9,459,834
Year 22	$630,000	$3,128,746	$2,498,746	$896,906	$10,356,740
Year 23	$630,000	$3,241,246	$2,611,246	$892,654	$11,249,394
Year 24	$630,000	$3,241,246	$2,611,246	$850,147	$12,099,541
Year 25	$630,000	$3,241,246	$2,611,246	$809,664	**$12,909,205**

Note * replacement of equipment: $2m

This is due to the gradual increase in revenues earned on commissioned research projects as well as the ROI earned from start-ups that start generating revenue at this point in time (see Figure 8).

Figure 8 Cumulative costs and revenues



5.5.1 *Limitations and risks*

This cost-benefit analysis assumes that the facility will be a highly prestigious one with no debilitating challenges in attracting interested parties to the facility. It is also assumed that the facility itself, including the staff in charge can add value to industry and incubatees. As a result of this assumption the assumed benefits / revenues are high. There are also several cost factors that have not been explicitly accounted for. This includes costs for raw materials, administrative staff, and other discretionary costs for the organisation of events, lunches etc. The risks associated with the investment options are summarised below.

- Recruitment of key staff – the ability of the STEM lab facility to attract (and retain) talented staff will out the facility to the test. At this moment in time there is little expertise to lead this type of facility in the country. Recruiting the right staff will enable the facility to offer customers value added. The building and equipment on their own cannot deliver this (long-term) value added. In the short term, it may mean that the facility does not have the capacity to recruit

- Recruitment of customers – one of the key risks for any facility is building a sustainable pipeline of customers. The result of not building this pipeline in a timely manner will imply that it will take longer to breakeven and this will put a strain on resources
- Collaboration – the preferred option assumed that industry is interested in collaborating with academia. To date, there has been little collaboration of this kind in Rwanda and the culture of collaboration is nascent. This means that the facility will have to push hard at stimulating collaboration and building a culture of collaboration. To some extent the success of the facility is also dependent on changes in attitudes in the wider RD&I landscape.
- Incubation offer is not unique – there is a growing landscape of industry support services and many support young entrepreneurs. As a result, it may be that the incubation offer of the facility is simply not competitive. This will mean that the facility may forgo a future revenue stream (royalties) from successful incubatees.

Table 20 presents the NPV per year of operating when only 75% of the targeted revenue is secured. If revenue streams do not build up successfully it will take an additional three years to breakeven (by year 10 only). This may make it difficult for the facility to reinvest in equipment and maintenance.

Table 20 Break-even point of preferred option accounting for risk, revenue is 75% of target

	Total Cost	Total Benefit	Net Benefit	NPV	NPV (cumulative)
Year 1	$630,000	$268,920	-$361,080	-$361,080	-$361,080
Year 2	$630,000	$357,747	-$272,253	-$259,289	-$620,369
Year 3	$630,000	$365,247	-$264,753	-$240,139	-$860,508
Year 4	$630,000	$494,060	-$135,941	-$117,431	-$977,938
Year 5	$630,000	$619,685	-$10,316	-$8,487	-$986,425
Year 6	$630,000	$745,310	$115,310	$90,348	-$896,077
Year 7	$630,000	$870,935	$240,935	$179,789	-$716,288
Year 8	$630,000	$996,560	$366,560	$260,507	-$455,781
Year 9	$630,000	$1,114,685	$484,685	$328,054	-$127,727
Year 10	$630,000	$1,232,810	$602,810	$388,576	$260,849
Year 11	$2,630,000	$1,350,935	-$1,279,066	-$785,235	-$524,386
Year 12	$630,000	$1,469,060	$839,060	$490,581	-$33,805
Year 13	$630,000	$1,587,185	$957,185	$532,996	$499,191
Year 14	$630,000	$1,671,560	$1,041,560	$552,361	$1,051,552
Year 15	$630,000	$1,755,935	$1,125,935	$568,673	$1,620,225
Year 16	$630,000	$1,840,310	$1,210,310	$582,180	$2,202,405
Year 17	$630,000	$1,924,685	$1,294,685	$593,110	$2,795,515
Year 18	$630,000	$2,009,060	$1,379,060	$601,679	$3,397,194
Year 19	$630,000	$2,093,435	$1,463,435	$608,087	$4,005,281
Year 20	$630,000	$2,177,810	$1,547,810	$612,521	$4,617,802
Year 21	$2,630,000	$2,262,185	-$367,816	-$138,626	$4,479,176
Year 22	$630,000	$2,346,560	$1,716,560	$616,146	$5,095,322
Year 23	$630,000	$2,430,935	$1,800,935	$615,649	$5,710,971
Year 24	$630,000	$2,430,935	$1,800,935	$586,333	$6,297,304
Year 25	$630,000	$2,430,935	$1,800,935	$558,412	$6,855,716

Note * replacement of equipment: $2m

6 Roadmap

The figure below presents a tentative roadmap. The timeline for the evaluation of outcomes/impact of the facility is set against the roadmap of NST 1 (2024). It is envisaged that the facility will be operationalized in 2022, possibly with a subset of activities being launched as early as 2021.

The roadmap allows for a process evaluation before the facility is operationalised and for an evaluation after it is operationalised.

As part of NIRDA's mandate (Key Pillar 4), NIRDA will identify emerging technologies likely to yield the greatest economic and social benefits to Rwanda in the future. Any insights generated from this 'horizon scanning' will be useful to finetune the service & business model of the STEM lab facility. The sustainability of the STEM ab facility should be continually monitored.

Details on monitoring and evaluation are set out in Appendix C.

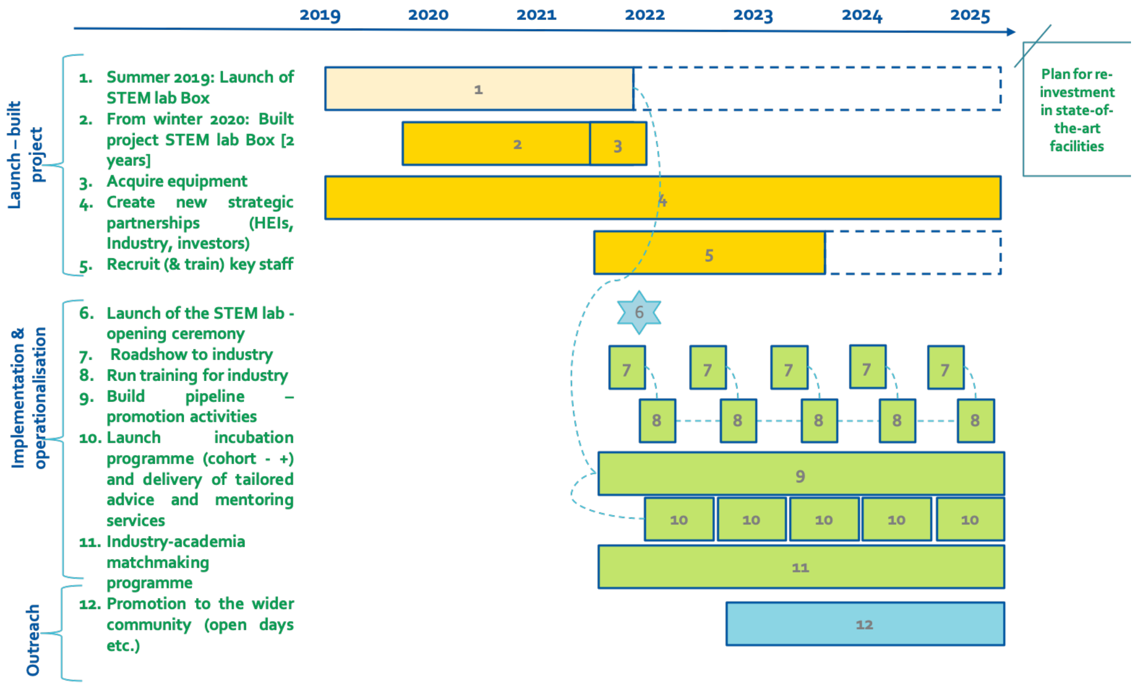
Activities to account for before operationalisation are:

- The completion of the built project, in line with the specifications
- The acquisition of equipment, in line with the specifications
- The creation of new partnerships, formalised by means of MoUs
- The recruitment of key staff (to be contracted by the date of the launch) that will oversee the facility
- The training of other staff, including in the use of equipment

Activities to account for after operationalisation are:

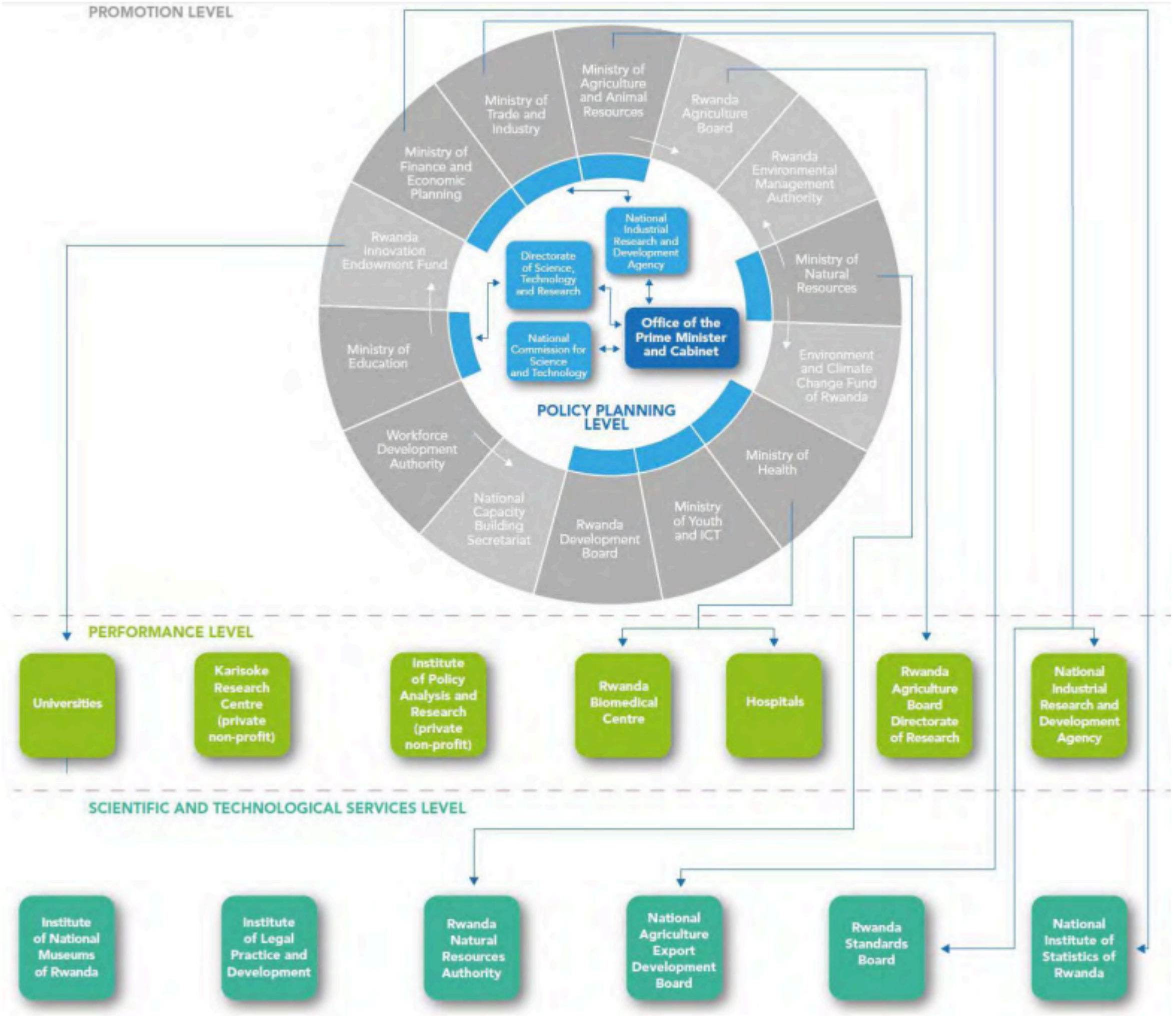
- Investment in the promotion of the facility (eg nr of roadshows and nr of participants)
- Number of training provided to industry, encouraging industry invest in R&D
- The launch of the incubation programme, the number of incubatees and their progress overtime (deployment of prototype, scale-up, survival rate, number of employees, revenue, net revenue etc.)
- The number of commissioned projects, industry-academic joint projects, etc
- The promotion of the initiative to the wider community, eg number of open days and nr of visitors

Figure 9 STEM lab facility roadmap to 2025



Appendix A Rwanda's public sector and innovation system

Figure 10 Organizational chart showing Rwanda's public sector research and innovation system



Source: UNESCO, 2015

Appendix B Costs and benefits analysis

B.1 Economic benefits

Table 21 Overview of estimated economic benefits

STEM lab facility service offer	Assumed benefit	Note	Report section	Value in million USD
Incubation services & Tailored advice and mentoring services	Wage premium	Estimated value of the wage premium earned on top of base salary	B.1.1	USD 4.1
	Start-ups	Estimated value of start-ups	B.1.2	USD 99.0
	Additional jobs created	Estimated value of wages for additional jobs created	B.1.3	USD 0.9
STEM lab	Product innovation - commercial fees	Commercial rates charged for using the facilities	B.1.4	USD 0.2
Links to the academic community research services	R&D spent on labour	R&D spent on labour for developing new prototypes	B.1.5	USD 0.7
	Commissioned projects	Estimated income earned by STEM lab for commissioned research	B.1.6	USD 2.2
TOTAL				USD 107.2

B.1.1. Wage premium

Table 22 Assumptions – Wage premium

The incubation programme is a prestigious programme that offers entrepreneurs a unique opportunity

Individuals that follow the incubation programme will acquire additional expertise and/or will benefit from opportunities

As a result of partaking in the incubation programme individuals will benefit from a wage premium later in life

Incubatees follow a half year incubation programme. The facility will take two cohorts per year. Each cohort will take on 15 incubatees

The wage premium is assumed to be 6%. The 6% wage premium is half of the 12% wage premium which researchers are estimated to earn in relation to having undertaken a 1+ year training at CERN, see: http://cds.cern.ch/record/2635864/files/CERN-ACC-2018-0025.pdf?version=

Annual wages of a (former) incubatee are assumed $7,474 (ie RWF 566,221 https://mywage.org/rwanda/salary/public-wages/irst-nirda).

Incubates will benefit from wage premium of $448 which is earned on top of the base salary (ie $7,474).

Over a period of 25 years, the first cohort will benefit from a wage premium for 24.5 years, the second cohort will benefit from a wage premium for 24 years, the third cohort will benefit from a wage premium for 23.5 years etc.

Incubatees will not benefit from additional wage increases

Table 23 Wage premium per incubatee

	Value of premium – full year's wage	Value of premium – half year's wage
Value per incubate	USD 448	USD 224
Value for 15 incubatees	USD 6,727	USD 3,363
Value for 30 incubatees	USD 13,453	*[Not applicable to calculations]*

Table 24 Value of the wage premium

Year	Premium earned	Additional half years' premium earned	Annual value of premium	Cumulative value
Year 1	USD 0	USD 3,363	USD 3,363	USD 3,363
Year 2	USD 13,453	USD 3,363	USD 16,817	USD 20,180
Year 3	USD 26,907	USD 3,363	USD 30,270	USD 50,450
Year 4	USD 40,360	USD 3,363	USD 43,724	USD 94,174
Year 5	USD 53,814	USD 3,363	USD 57,177	USD 151,351
Year 6	USD 67,267	USD 3,363	USD 70,630	USD 221,981
Year 7	USD 80,720	USD 3,363	USD 84,084	USD 306,065
Year 8	USD 94,174	USD 3,363	USD 97,537	USD 403,602
Year 9	USD 107,627	USD 3,363	USD 110,991	USD 514,593
Year 10	USD 121,081	USD 3,363	USD 124,444	USD 639,037
Year 11	USD 134,534	USD 3,363	USD 137,897	USD 776,934
Year 12	USD 147,988	USD 3,363	USD 151,351	USD 928,285
Year 13	USD 161,441	USD 3,363	USD 164,804	USD 1,093,090
Year 14	USD 174,894	USD 3,363	USD 178,258	USD 1,271,347
Year 15	USD 188,348	USD 3,363	USD 191,711	USD 1,463,058
Year 16	USD 201,801	USD 3,363	USD 205,165	USD 1,668,223
Year 17	USD 215,255	USD 3,363	USD 218,618	USD 1,886,841
Year 18	USD 228,708	USD 3,363	USD 232,071	USD 2,118,912
Year 19	USD 242,161	USD 3,363	USD 245,525	USD 2,364,437
Year 20	USD 255,615	USD 3,363	USD 258,978	USD 2,623,415
Year 21	USD 269,068	USD 3,363	USD 272,432	USD 2,895,847
Year 22	USD 282,522	USD 3,363	USD 285,885	USD 3,181,732
Year 23	USD 295,975	USD 3,363	USD 299,338	USD 3,481,070
Year 24	USD 309,428	USD 3,363	USD 312,792	USD 3,793,862
Year 25	USD 322,882	USD 3,363	USD 326,245	USD 4,120,107

B.1.2. Start-ups

Table 25 Assumptions – Start-ups

Incubatees follow a half year incubation programme. The facility will take two cohorts per year. Each cohort will take on 15 incubatees; ie 30 per year The survival rate is 30%; 9 [additional] start-ups survive per year, see also http://www.mku.ac.ke/research/images/journals/vol%202/Technology%20and%20business%20incubation%20a%20proven%20model%20to%20promote%20technology%20innovation%20and%20entrepreneurship%20in%20Rwanda%5B1%5D.pdf Start-ups do not have sales in their first 3 years and from year 4 onwards their revenue is USD 500,000. This revenue is considered a conservative estimate for the manufacturing industry

Table 26 Value of start-ups

Year	Incubatees per year	Start-ups that survive	Value of start-ups	Cumulative value of start-ups

Year 1	30	9.0	USD 0	USD 0
Year 2	30	9.0	USD 0	USD 0
Year 3	30	9.0	USD 0	USD 0
Year 4	30	9.0	USD 4,500,000	USD 4,500,000
Year 5	30	9.0	USD 4,500,000	USD 9,000,000
Year 6	30	9.0	USD 4,500,000	USD 13,500,000
Year 7	30	9.0	USD 4,500,000	USD 18,000,000
Year 8	30	9.0	USD 4,500,000	USD 22,500,000
Year 9	30	9.0	USD 4,500,000	USD 27,000,000
Year 10	30	9.0	USD 4,500,000	USD 31,500,000
Year 11	30	9.0	USD 4,500,000	USD 36,000,000
Year 12	30	9.0	USD 4,500,000	USD 40,500,000
Year 13	30	9.0	USD 4,500,000	USD 45,000,000
Year 14	30	9.0	USD 4,500,000	USD 49,500,000
Year 15	30	9.0	USD 4,500,000	USD 54,000,000
Year 16	30	9.0	USD 4,500,000	USD 58,500,000
Year 17	30	9.0	USD 4,500,000	USD 63,000,000
Year 18	30	9.0	USD 4,500,000	USD 67,500,000
Year 19	30	9.0	USD 4,500,000	USD 72,000,000
Year 20	30	9.0	USD 4,500,000	USD 76,500,000
Year 21	30	9.0	USD 4,500,000	USD 81,000,000
Year 22	30	9.0	USD 4,500,000	USD 85,500,000
Year 23	30	9.0	USD 4,500,000	USD 90,000,000
Year 24	30	9.0	USD 4,500,000	USD 94,500,000
Year 25	30	9.0	USD 4,500,000	USD 99,000,000

B.1.3. Additional jobs created

Table 27 Assumptions – Jobs created

Incubatees follow a half year incubation programme. The facility will take two cohorts per year. Each cohort will take on 15 incubatees; ie 30 per year The survival rate is 30%; 9 [additional] start-ups survive per year The average size of a start-up after one year is 2.8 (see http://www.mku.ac.ke/research/images/journals/vol%202/Technology%20and%20business%20incubation%20a%20proven%20model%20to%20promote%20technology%20innovation%20and%20entrepreneurship%20in%20Rwanda%5B1%5D.pdf) Annual wages of staff at the start-up are $7,474 (ie RWF 566,221 https://mywage.org/rwanda/salary/public-wages/irst-nirda) Unemployment one year after graduating is assumed 20%

The number of jobs created per year though the incubation programme is estimated as follows: cohort size (30) X survival rate (30%) X average start-up size (2.8) = 25 The associated value of this job creation is 25 X $7,474 = $190,203, and after 25 years this is $190,203 x 24 = $4,564,882 The additionality of the incubation programme per year is $190,203 x 20% (unemployment rate) and after 25 years it is $4,564,882 X 20% = $912,976 Wage increases are not accounted for

B.1.4. Commercial fees

Table 28 Assumptions – Commercial fees

Industry pays a monthly fee for using the facility The average duration of using the STEM lab facility is 1 month (1 month fee) The monthly fee of unlimited access to lab equipment is $200 for SMEs and £450 for larger companies In the first 3 years 5 SMEs and 5 larger companies pay a 1 month membership fee From year 4 onwards 15 SMEs and 10 larger companies pay a 1 month membership fee

Table 29 Value of commercial fees

	SMEs - members	Industry - members	SMEs - fees	Industry - fees	Combined fees	Cumulative fees
Year 1	5	5	USD 1,000	USD 2,250	USD 3,250	USD 3,250
Year 2	5	5	USD 1,000	USD 2,250	USD 3,250	USD 6,500
Year 3	5	5	USD 1,000	USD 2,250	USD 3,250	USD 9,750
Year 4	15	10	USD 3,000	USD 4,500	USD 7,500	USD 17,250
Year 5	15	10	USD 3,000	USD 4,500	USD 7,500	USD 24,750
Year 6	15	10	USD 3,000	USD 4,500	USD 7,500	USD 32,250
Year 7	15	10	USD 3,000	USD 4,500	USD 7,500	USD 39,750
Year 8	15	10	USD 3,000	USD 4,500	USD 7,500	USD 47,250
Year 9	15	10	USD 3,000	USD 4,500	USD 7,500	USD 54,750
Year 10	15	10	USD 3,000	USD 4,500	USD 7,500	USD 62,250
Year 11	15	10	USD 3,000	USD 4,500	USD 7,500	USD 69,750
Year 12	15	10	USD 3,000	USD 4,500	USD 7,500	USD 77,250
Year 13	15	10	USD 3,000	USD 4,500	USD 7,500	USD 84,750
Year 14	15	10	USD 3,000	USD 4,500	USD 7,500	USD 92,250
Year 15	15	10	USD 3,000	USD 4,500	USD 7,500	USD 99,750
Year 16	15	10	USD 3,000	USD 4,500	USD 7,500	USD 107,250
Year 17	15	10	USD 3,000	USD 4,500	USD 7,500	USD 114,750
Year 18	15	10	USD 3,000	USD 4,500	USD 7,500	USD 122,250
Year 19	15	10	USD 3,000	USD 4,500	USD 7,500	USD 129,750
Year 20	15	10	USD 3,000	USD 4,500	USD 7,500	USD 137,250
Year 21	15	10	USD 3,000	USD 4,500	USD 7,500	USD 144,750
Year 22	15	10	USD 3,000	USD 4,500	USD 7,500	USD 152,250
Year 23	15	10	USD 3,000	USD 4,500	USD 7,500	USD 159,750

Year 24	15	10	USD 3,000	USD 4,500	USD 7,500	USD 167,250
Year 25	15	10	USD 3,000	USD 4,500	USD 7,500	USD 174,750

B.1.5. R&D spent on labour

Table 30 Assumptions – Labour

The average duration of industry using the STEM lab facility is 1 month and during this month two employees work full time on the industry R&D project In the first three years 10 SMEs/larger companies work on an R&D project at the facility From year 4 onwards 25 SMEs/larger companies work on an R&D project at the facility Annual wages of industry staff are $7,474 and the monthly wage is $623 Wage increases are not accounted for

Table 31 Value of R&D investment on labour

	Companies	Wage paid per company	R&D investment in labour	Cumulative R&D investment in labour
Year 1	10	USD 1,246	USD 12,457	USD 12,457
Year 2	10	USD 1,246	USD 12,457	USD 24,914
Year 3	10	USD 1,246	USD 12,457	USD 37,371
Year 4	25	USD 1,246	USD 31,142	USD 68,513
Year 5	25	USD 1,246	USD 31,142	USD 99,655
Year 6	25	USD 1,246	USD 31,142	USD 130,797
Year 7	25	USD 1,246	USD 31,142	USD 161,939
Year 8	25	USD 1,246	USD 31,142	USD 193,081
Year 9	25	USD 1,246	USD 31,142	USD 224,224
Year 10	25	USD 1,246	USD 31,142	USD 255,366
Year 11	25	USD 1,246	USD 31,142	USD 286,508
Year 12	25	USD 1,246	USD 31,142	USD 317,650
Year 13	25	USD 1,246	USD 31,142	USD 348,792
Year 14	25	USD 1,246	USD 31,142	USD 379,934
Year 15	25	USD 1,246	USD 31,142	USD 411,076
Year 16	25	USD 1,246	USD 31,142	USD 442,219
Year 17	25	USD 1,246	USD 31,142	USD 473,361
Year 18	25	USD 1,246	USD 31,142	USD 504,503
Year 19	25	USD 1,246	USD 31,142	USD 535,645
Year 20	25	USD 1,246	USD 31,142	USD 566,787
Year 21	25	USD 1,246	USD 31,142	USD 597,929
Year 22	25	USD 1,246	USD 31,142	USD 629,072
Year 23	25	USD 1,246	USD 31,142	USD 660,214
Year 24	25	USD 1,246	USD 31,142	USD 691,356
Year 25	25	USD 1,246	USD 31,142	USD 722,498

B.1.6. Commissioned projects

Table 32 Assumptions – Commissioned projects

The value of commissioned project will increase gradually over the first years
In the first year the facility will be able to attract USD 30,000 in commissioned projects
By year 8 the facility will be able to attract USD 100,000 in commissioned projects

Table 33 Value of commissioned projects

	Value of project commissioned	Cumulative value
Year 1	USD 30,000	USD 30,000
Year 2	USD 40,000	USD 70,000
Year 3	USD 50,000	USD 120,000
Year 4	USD 60,000	USD 180,000
Year 5	USD 70,000	USD 250,000
Year 6	USD 80,000	USD 330,000
Year 7	USD 90,000	USD 420,000
Year 8	USD 100,000	USD 520,000
Year 9	USD 100,000	USD 620,000
Year 10	USD 100,000	USD 720,000
Year 11	USD 100,000	USD 820,000
Year 12	USD 100,000	USD 920,000
Year 13	USD 100,000	USD 1,020,000
Year 14	USD 100,000	USD 1,120,000
Year 15	USD 100,000	USD 1,220,000
Year 16	USD 100,000	USD 1,320,000
Year 17	USD 100,000	USD 1,420,000
Year 18	USD 100,000	USD 1,520,000
Year 19	USD 100,000	USD 1,620,000
Year 20	USD 100,000	USD 1,720,000
Year 21	USD 100,000	USD 1,820,000
Year 22	USD 100,000	USD 1,920,000
Year 23	USD 100,000	USD 2,020,000
Year 24	USD 100,000	USD 2,120,000
Year 25	USD 100,000	USD 2,220,000

B.2 Costs

Table 34 Operational costs for each option

	FTE staff	Total annual running costs	Total running costs (25 years)	Total running costs (25 years) in million USD
Option 1 – Do nothing	0	USD 0	USD 0	USD 0

Option 2 – Comprehensive service offer	13	USD 630,000	USD 19,750,000	USD 19.8
Option 3 – Industry as core customer offer	9.5	USD 450,000	USD 15,250,000	USD 15.3
Option 4 – Research oriented facility for industry-academia	14.5	USD 730,000	USD 22,250,000	USD 22.3
Option 5 – No focus on industry-academia partnerships	12.5	USD 570,000	USD 18,250,000	USD 18.3

Table 35 Budget for equipment replacement

	Total
Equipment replacement (every 10yrs)	USD 4,000,000

Table 36 FTE internal staff (excluding outsourced)

	Option 2 – Comprehensive service offer	Option 3 – Industry as core customer offer	Option 4 – Research oriented facility for industry-academia	Option 5 – No focus on industry-academia partnerships
Incubation	3	0	3	3
Advice & mentoring	0.5	0	0.5	0.5
STEM lab	7	7	7	7
Research (academic link)	0.5	0.5	2	0
Capacity building & outreach	2	2	2	2
TOTAL	13	9.5	14.5	12.5

Table 37 Operational costs (annual) – Option 2 – Comprehensive service offer & preferred option

Services	Estimated running costs (FTE/year)	Overhead	Senior / international	Support staff / international	Senior / local	Support staff / local	Totals
			USD 40,000	*USD 20,000*	*USD 20,000*	*USD 10,000*	
Incubation	3	100%			1	2	USD 80,000
Advice & mentoring	0.5	100%			0.5		USD 20,000
STEM lab	7	100%	1	2	2	2	USD 280,000
Research (academic link)	0.5	100%			0.5		USD 20,000
Capacity building & outreach	2	100%			1	1	USD 60,000
Personnel costs (internal)	13		1	2	5	5	USD 460,000
Additional costs - recruitment/benefit package							USD 50,000

Additional costs - advice & mentoring	USD 80,000
Additional costs - research (academic link)	USD 40,000
Total	**USD 630,000**

Table 38 Operational costs (annual) – Option 3 – Industry as core customer

Services	Estimated running costs (FTE/year)	Overhead	Senior / international	Support staff / international	Senior / local	Support staff / local	Totals
			USD 40,000	*USD 20,000*	*USD 20,000*	*USD 10,000*	
Incubation	0	100%			0	0	USD 0.00
Advice & mentoring	0	100%			0		USD 0.00
STEM lab	7	100%	1	2	2	2	USD 280,000
Research (academic link)	0.5	100%			0.5		USD 20,000
Capacity building & outreach	2	100%			1	1	USD 60,000
Personnel costs (internal)	9.5		1	2	3.5	3	USD 360,000
Additional costs - recruitment/benefit package							USD 50,000
Additional costs - advice & mentoring							USD 0
Additional costs - research (academic link)							USD 40,000
Total							**USD 450,000**

Table 39 Operational costs (annual) – Option 4 – Research oriented facility for industry-academia

Services	Estimated running costs (FTE/year)	Overhead	Senior / international	Support staff / international	Senior / local	Support staff / local	Totals
			USD 40,000	*USD 20,000*	*USD 20,000*	*USD 10,000*	
Incubation	3	100%			1	2	USD 80,000
Advice & mentoring	0.5	100%			0.5		USD 20,000
STEM lab	7	100%	1	2	2	2	USD 280,000
Research (academic link)	2	100%			1	1	USD 60,000
Capacity building & outreach	2	100%			1	1	USD 60,000
Personnel costs (internal)	14.5		1	2	5.5	6	USD 500,000
Additional costs - recruitment/benefit package							USD 50,000

Additional costs - advice & mentoring	USD 80,000
Additional costs - research (academic link)	USD 100,000
Total	**USD 730,000**

Table 40 Operational costs (annual) – Option 5 – No focus on industry-academia partnerships

Services	Estimated running costs (FTE/year)	Overhead	Senior / international	Support staff / international	Senior / local	Support staff / local	Totals
			USD 40,000	*USD 20,000*	*USD 20,000*	*USD 10,000*	
Incubation	3	100%			1	2	USD 80,000
Advice & mentoring	0.5	100%			0.5		USD 20,000
STEM lab	7	100%	1	2	2	2	USD 280,000
Research (academic link)	0	100%			0	0	USD 0
Capacity building & outreach	2	100%			1	1	USD 60,000
Personnel costs (internal)	12.5		1	2	4.5	5	USD 440,000
Additional costs - recruitment/benefit package							USD 50,000
Additional costs - advice & mentoring							USD 80,000
Additional costs - research (academic link)							USD 0
Total							**USD 570,000**

B.3 Revenue to the facility

Table 41 Overview of estimated revenue to the facility, in million USD

STEM lab facility service offer	Assumed revenue	Note	Report section	Option 2 – Comprehensive service offer (preferred option)	Option 3 – Industry as core customer offer	Option 4 – Research oriented facility for industry-academia	Option 5 – No focus on industry-academia partnerships
Incubation services & Tailored advice and mentoring services	Rentable workspace	Revenue from renting out workspace to incubatees/start-ups	A.3.1	USD 10.7	USD 0	USD 10.7	USD 10.7
	Royalties	Revenue from royalties on patents and trademarks in relation to successful incubatees	A.3.2	USD 36.0	USD 0	USD 36.0	USD 36.0

STEM lab	Product innovation - commercial fees	Commercial rates charged for using the facilities	A.2.4	USD 0.2	USD 0.2	USD 0.2	USD 0.2
Links to the academic community research services	Commissioned projects	Estimated income earned by STEM lab for commissioned research	A.2.6	USD 2.2	USD 2.2	USD 4.4 (2.2X2)	USD 0
TOTAL				USD 49.1	USD 2.4	USD 51.3	USD 46.9

B.3.1. *Rentable workspace*

Table 42 Assumptions – Rentable workspace

Industry does not rent workspace

The incubation programme has a duration of 6 months

The facility will offer 'grow-on-space' for one additional year after the completion of the incubator programme. Mentoring / advice services and lab access will also be provided for one additional year (12 months) after the completion of the incubation programme

As part of the incubation programme the start-ups can have 3 months of free workspace

Half of the startups taking part in the incubation programme will pay for an additional three months of hotdesking space (eg for the remainder of the incubation programme)

25% of the startups taking part in the incubation programme will pay for an additional 12 months of dedicated desk space (eg the six months following the completion of the incubation programme)

20% of the startups taking part in the incubation programme will pay for an additional 12 months of private office space. It is assumed that the average occupancy is three people.

The facility will be able to charge rates that is an average of commercial rates and subsidised rates

In the first year the facility will only generate income in month 4-12

Table 43 Income from rentable space

Type of space	Number of users	Rental income (average)	Duration in months	Income (per year)
Hotdesk	40	USD 189	3	USD 22,650
Dedicated desk	20	USD 247	12	USD 59,160
Private office (pp)	48	USD 611	12	USD 351,936
TOTAL				**USD 433,746**

Table 44 Rental costs at comparable office space in Kigali

Venue	Type of space	Dollar per month	Reference
Impact hub	Hotdesk	USD 264	http://kigali.impacthub.net/membership/
Westerwelle	Hotdesk	USD 110	https://www.coworker.com/rwanda/kigali/westerwelle-start-up-haus-kigali
Westerwelle	Dedicated desk	USD 220	https://www.coworker.com/rwanda/kigali/westerwelle-start-up-haus-kigali
Collaborate Coworking	Hotdesk	USD 150	https://www.coworker.com/rwanda/kigali/collaborate-coworking

Collaborate Coworking	Private office	USD 500	https://www.coworker.com/rwanda/kigali/collaborate-coworking
Regus Kigali City Tower	Hotdesk	USD 231	https://www.coworker.com/rwanda/kigali/regus-kigali-city-tower
Regus Kigali City Tower	Dedicated desk	USD 273	https://www.coworker.com/rwanda/kigali/regus-kigali-city-tower
Regus Kigali City Tower	Private office	USD 722	https://www.coworker.com/rwanda/kigali/regus-kigali-city-tower

Table 45 Revenue from rentable workspace

	Rentable workspace	Cumulative rent
Year 1	USD 325,310	USD 325,310
Year 2	USD 433,746	USD 759,056
Year 3	USD 433,746	USD 1,192,802
Year 4	USD 433,746	USD 1,626,548
Year 5	USD 433,746	USD 2,060,294
Year 6	USD 433,746	USD 2,494,040
Year 7	USD 433,746	USD 2,927,786
Year 8	USD 433,746	USD 3,361,532
Year 9	USD 433,746	USD 3,795,278
Year 10	USD 433,746	USD 4,229,024
Year 11	USD 433,746	USD 4,662,770
Year 12	USD 433,746	USD 5,096,516
Year 13	USD 433,746	USD 5,530,262
Year 14	USD 433,746	USD 5,964,008
Year 15	USD 433,746	USD 6,397,754
Year 16	USD 433,746	USD 6,831,500
Year 17	USD 433,746	USD 7,265,246
Year 18	USD 433,746	USD 7,698,992
Year 19	USD 433,746	USD 8,132,738
Year 20	USD 433,746	USD 8,566,484
Year 21	USD 433,746	USD 9,000,230
Year 22	USD 433,746	USD 9,433,976
Year 23	USD 433,746	USD 9,867,722
Year 24	USD 433,746	USD 10,301,468
Year 25	USD 433,746	USD 10,735,214

B.3.2. Royalties

Table 46 Assumptions – Royalties

Incubatees follow a half year incubation programme. The facility will take two cohorts per year. Each cohort will take on 15 incubatees; ie 30 per year

The survival rate is 30%; 9 [additional] start-ups survive per year Start-ups do not have sales in their first 3 years and from year 4 onwards their revenue is USD 500,000. This revenue is considered a conservative estimate for the manufacturing industry Half of the start-ups/companies successfully protect their IP using a patent Half of the start-ups/companies register a trademark Patent royalty is agreed at 25% on gross profit for 20 years after generating revenue. Trademark royalty is agreed at 10% on gross profit for 10 years after generating revenue • https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/321618/iprpricebooklet.pdf • https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/321618/iprpricebooklet.pdf • https://www.gov.uk/guidance/university-and-business-collaboration-agreements-lambert-toolkit Assumption margin of gross revenue is 20% The revenue from royalties of a 20% margin and a 25% patent royalty is equivalent to a 5% royalty agreement on profit

Table 47 Value of royalties

	Start-ups with patent	Start-ups with trademark	Royalties - patents	Royalties - trademarks	Royalties - total IP	Cumulative
Year 1	0	0	USD 0	USD 0	USD 0	USD 0
Year 2	0	0	USD 0	USD 0	USD 0	USD 0
Year 3	0	0	USD 0	USD 0	USD 0	USD 0
Year 4	4.5	4.5	USD 112,500	USD 45,000	USD 157,500	USD 157,500
Year 5	4.5	4.5	USD 225,000	USD 90,000	USD 315,000	USD 472,500
Year 6	4.5	4.5	USD 337,500	USD 135,000	USD 472,500	USD 945,000
Year 7	4.5	4.5	USD 450,000	USD 180,000	USD 630,000	USD 1,575,000
Year 8	4.5	4.5	USD 562,500	USD 225,000	USD 787,500	USD 2,362,500
Year 9	4.5	4.5	USD 675,000	USD 270,000	USD 945,000	USD 3,307,500
Year 10	4.5	4.5	USD 787,500	USD 315,000	USD 1,102,500	USD 4,410,000
Year 11	4.5	4.5	USD 900,000	USD 360,000	USD 1,260,000	USD 5,670,000
Year 12	4.5	4.5	USD 1,012,500	USD 405,000	USD 1,417,500	USD 7,087,500
Year 13	4.5	4.5	USD 1,125,000	USD 450,000	USD 1,575,000	USD 8,662,500
Year 14	4.5	4.5	USD 1,237,500	USD 450,000	USD 1,687,500	USD 10,350,000
Year 15	4.5	4.5	USD 1,350,000	USD 450,000	USD 1,800,000	USD 12,150,000
Year 16	4.5	4.5	USD 1,462,500	USD 450,000	USD 1,912,500	USD 14,062,500
Year 17	4.5	4.5	USD 1,575,000	USD 450,000	USD 2,025,000	USD 16,087,500
Year 18	4.5	4.5	USD 1,687,500	USD 450,000	USD 2,137,500	USD 18,225,000
Year 19	4.5	4.5	USD 1,800,000	USD 450,000	USD 2,250,000	USD 20,475,000
Year 20	4.5	4.5	USD 1,912,500	USD 450,000	USD 2,362,500	USD 22,837,500
Year 21	4.5	4.5	USD 2,025,000	USD 450,000	USD 2,475,000	USD 25,312,500
Year 22	4.5	4.5	USD 2,137,500	USD 450,000	USD 2,587,500	USD 27,900,000
Year 23	4.5	4.5	USD 2,250,000	USD 450,000	USD 2,700,000	USD 30,600,000
Year 24	4.5	4.5	USD 2,250,000	USD 450,000	USD 2,700,000	USD 33,300,000
Year 25	4.5	4.5	USD 2,250,000	USD 450,000	USD 2,700,000	USD 36,000,000

Appendix C Monitoring and Evaluation

This appendix provides a succinct guide for monitoring progress and evaluating the outcomes and impact of investment in the STEM lab facility.

Monitoring involves systematically collecting data on the activities undertaken at the facility on a year by year (or quarterly) basis. Monitoring can be used to assess whether activities are 'on track'. Data collected prior to the launch of the facility should feed into a process evaluation which will help inform progress made and will identify obstacles (if any), and these findings feed into the renewal and improvement of the facilities' offer.

Regular monitoring and outcome evaluation / reporting should take place once the facility is up and running and should reflect on the intended and unintended outcomes and impact of the facility on the beneficiaries and on the wider community. The outcomes and impact of the facility will be evaluated against the objectives of the facility, which are too:

1. Improve the competitiveness of existing industries in order to increase their export potential or their potential to undertake import substitution
2. Identify new sub-sectors or value chains where investment by the private sector would likely lead to export growth or import substitution
3. Promote industrialisation and industry's contribution to GDP
4. Support the creation of jobs relevant to STEM graduates
5. Help establish Rwanda as a globally competitive knowledge-based economy

Monitoring and Evaluation (M&E) will also consider the Theory of Change of the facility, which has been outlined in Chapter 1 (section 1.4.3).

An overview of tentative evaluation questions/ indicators is provided in the table below.

Table 48 Tentative indicators for M&E

	Process evaluation questions / indicators	**Outcome evaluation questions/ indicators**
Laboratories for testing and prototyping & Incubation space	• Is the built project on track? • Is the facility built in line with the specification and (safety) requirements • Has the (Stage 1) equipment been purchased/acquired in line with specifications and is it fully operational?	• % capacity used – rental space, by type and quarter • Revenue from rental space, by type and by quarter • Revenue from rental space as a proportion of the operational (staff) costs of the incubator • % capacity used – equipment (by user type and over time) • What additional equipment has been purchased?
Collaboration between NIRDA and partners	• Number and type of partnerships between the facility and other stakeholders formalised by an MoU or other written or contractual agreement	• Number and type of partnerships between the facility and other stakeholders formalised by an MoU and a statement describing outcomes from collaborating
Recruitment	• Number of prospective key staff identified, by seniority • Number of prospective mentors identified • Number of prospective affiliated researchers identified	• Number of key staff recruited, by seniority / year • Staff turnover (internal), by year • Number of mentors that contributed, by year • Number of prospective affiliated researchers that contributed
Training and upskilling of professionals and lab technicians	• Number of staff trained to use equipment acquired, by type of equipment • Number of staff with expertise to adjust calibrations, make basic repairs and maintenance, by type of equipment • Number of prospective staff and/or potential users trained to use	• Number of staff trained to use equipment acquired, by type of equipment / year • Number of staff with expertise to adjust calibrations, make basic repairs and maintenance, by type of equipment / year • Number of training programmes provided to industry members, by year

	equipment acquired, by type of equipment • Safety training/other relevant certificates earned	• Number of industry members that received training, by year
Incubation	• Number of incubatees enrolled, by cohort and thematic focus • Number of start-ups that benefitted from the STEM lab facility and are bringing a prototype/component to market, by cohort and thematic focus • Pipeline of prospective incubatees	• Number of incubatees enrolled, by cohort and thematic focus • Number of start-ups that benefitted from the STEM lab facility and are bringing a prototype/component to market, by cohort and thematic focus • Start-up survival rate, by cohort and thematic focus (year 1, year 2, year 3 etc) • Number of (additional) jobs created, by cohort • Sales of former incubatees, by cohort • Export sales of former incubatees, by cohort • Profit of former incubatees, by cohort • Number of Patents registered, by cohort • Number of Trademarks registered, by cohort • Number of other IP agreements registered, by cohort • Revenue earned from royalties, by year • Pipeline of prospective incubatees, by year
Industry	• Number of prospective industry (champions) identified, by tech domain • Number of prospective industry (champions) hosted/served, by tech domain	• Number industry that have used the STEM lab / number of months used / by year • Number of commissioned research projects • Eg value of commissioned research, by year • Value of membership fees earned from industry using the STEM lab facility • Number of prototypes/components developed by industry in the STEM lab • Involvement of STEM graduates by industry in prototype development
Outreach	• n/a	• Number of research outreach events and number of attendants, by year • Number of demo-days organised and number of attendants, by year • Number of roadshows for industry organised / attendance, by year and region • Number of open days/ attendance, by year
Financial / sustainability	• Are costs in line with initial estimates? • Is perspective revenue in line with initial estimates?	• Cost, by service and year – Eg value/cost of mentorship, by year – Eg cost of affiliated researchers, by year • Revenue, by service and year • Cost as a percentage of revenue, by service and year/quarter • Statement on financial sustainability, including reflections on need for re-investment

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