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Industrial symbiosis and industrial policy for sustainable development in Uganda

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Abstract

The aim of this article is to analyze how the concept of circular economy and especially the business model of industrial symbiosis can contribute to sustainable development in Uganda. We aim to add to emerging debates around green industrial policies by shedding light on a low-cost solution that can potentially promote a more sustainable industrialization in the Sub-Saharan African context. After sketching the regulatory and policy environment in Uganda, three indicative examples of industrial symbiosis in Uganda are analyzed, based on the result of field research and an online survey. We have found significant mismatch between the supply side of green industrial policies in Uganda (government aims and measures), and the demand side, what local green entrepreneurs would need to improve their competitiveness. Only an incentive and regulatory framework, that takes into account local specificities, builds upon the exploration of existing local good practices and incorporates bottom-up initiatives can successfully promote green development in low-income economies.

Keywords Green industrial policy · Circular economy · Industrial symbiosis · Africa · Uganda

JEL Classification O25 · O38 · O55

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1 Introduction

The recent multiple crises—in the aftermath of the Global Financial Crisis and more recently the energy and food crisis as a consequence of the Russian war in Ukraine—have led to a renaissance of state interventionism in the economy throughout the world (Mazzucato 2021). Consequently, industrial policy is once again back at the agenda of academic and policy debates (Chang and Andreoni 2020), though with a rather extended concept and scope. This re-designed and re-conceptualized new industrial policy aims to "steer a sustainable structural change of our economies and societies towards sustainable human development" (Ferrarinni et al. 2021:1). We aim to contribute to this debate by focusing on green industrial policies, with a special emphasis on the circular economy and industrial symbiosis, to better understand its potential role to promote a more sustainable development in the Sub-Saharan African context.

Given the dynamic population increase and the changing individual consumer behavior, Africa is projected to double its ecological footprint by 2040, and the continent's footprint already exceeds the biocapacity within its borders (AFDB-WWF 2012). External funding is often tied to pursuing greener development pathways. Taking into account Africa's swiftly depleting resources and donor pressure, the new generation of African industrial policies must accomplish their goals of moving up the global value chains and domestic employment creation in a sustainable manner. In this paper, we agree with the argumentation of Rodrik (2014) that goals associated with environmental sustainability require the promotion of green technologies and business models via the tools of industrial policy.

Nevertheless, in poorer countries, and especially in the Sub-Saharan African context, the costly nature of most green solutions in industrialization casts doubt on the viability and feasibility of implementation. Looking at some local practices—based on our field research in May 2021 and June 2022—we are convinced that low-cost, high-impact solutions exist and can contribute to changing the mindset of local policy makers and entrepreneurs and setting industrialization on a sustainable pathway. The study focuses on industrial symbiosis, since it represents a relatively cheap variant compared to other models of circular economy (Bocken et al. 2016) and high-tech green technologies. Industrial symbiosis can be facilitated by good coordination and networking among already existing businesses, and it is not necessarily dependent on huge investments in equipment and technology (like most other green solutions). Consequently, our article aims to formulate green industrial policy recommendations to support initiatives similar to our case study examples, which can, therefore, promote the spread and application of (already existing) good practices, thus contributing to the realization of sustainable, green development in the context of less developed countries.

The article is structured as follows. First, we situate green industrial policy into contemporary context and understanding, then outline its main areas and tools. Second, we present the concept of circular economy and introduce the industrial symbiosis (IS) model while also highlighting potential policy tools to promote it. In the empirical part, first, we sketch the current regulatory environment in

Uganda, and then three indicative examples of industrial symbiosis in Uganda are presented and analyzed. Finally, we conclude and formulate some industrial policy recommendations.

2 Green industrial policy

Before extending on green industrial policy and its policy tools, it might be worth to recall the classic interpretation and rationale of industrial policy (IP), as well as the related debates and critics. In a rather general vein in this paper, we refer to industrial policies as the totality of the government interventions in the economy, which aim to promote the structural transformation of the economy and thereby increase its productivity. The theory and practice of industrial policies go back to centuries. The classic theoretical rationale for state interventions was grouped around the arguments of infant industry, strategic trade and national security, while critics were mostly related to risks of adverse selection and rent-seeking. Notwithstanding, before the global financial crisis of 2007–2009, industrial policy was generally considered an outdated concept among the representatives of mainstream economics.

In terms of practical examples, most often cited cases go back to the East Asian developmental states in the post-war period (Amsden 1989; Johnson 1982; Wade 2014) . Many countries followed suit during the mid and late twentieth century, not only in the Asian region but also in Latin America and Africa. Starting from the 2000s, China's industrial policy aspirations can be highlighted (Barwick et al. 2019; Naughton 2021), while more recently the concept of developmental environmentalism recalls and extends East Asian developmental state traditions to analyze state-led green transition (Mathews et al. 2022). However, in the 5 years following the global financial crisis, more than 84 countries around the world adopted official, formal industrial policy documents (WIR 2018). As a result, the analysis and practice of industrial policy interventions returned to mainstream thinking and, instead of being the common practice of some latecomer peripheral countries, it has now also entered the economic policy toolbox of developed economies.

Accompanying this recent revival of IP practices, numerous scientific works indicate the renaissance of industrial policy in the international academic literature (see among others: Aiginger and Rodrik 2020; Bailey et al. 2015; Bulfone 2022; Chang and Andreoni 2020; Cimoli et al. 2009; Klebaner and Voy-Gillis 2022; Oqubay et al. 2020; Wade 2014). One commonality in this line of research is that new industrial policies are needed to address new, global and intensifying challenges of sustainable development. At the same time, reflecting changes in the structure of the economy and the (global) organization of production, also the scope and delineation of new industrial policies have been altered, and in fact broadened into new territories, new aims and potentially new tools and areas of interventions. To put it short, this re-designed and re-conceptualized new industrial policy aims to "steer a sustainable structural change of our economies and societies towards sustainable human development" (Ferrarinni et al. 2021:1). It is not just that the boundaries of the industrial sector got more blurred (reaching far beyond manufacturing, and inclining into services and even agribusiness), and its geographical relevance goes beyond the

"special cases" of latecomer economies, but also its objectives got much more complex. Beyond the economic aims of structural transformation, upgrading and related objective of increasing productivity, new IP contains among others the aspects of social inclusion and environmentally sustainable development.

In this study, we focus on the latter, namely, green development and the consequent need and potential of green industrial policies. The need to recognize the ecological limits of development and take these into consideration is not new in economic thinking (Meadows et al. 1972). This issue has been revitalized; however, more recently due to newly emerging and intensifying global pressures. It became also evident, that contemporary late developers, such as Sub-Saharan African economies, cannot follow the classic model of industrialization, based on the experiences of industrialized countries, applying the traditional, fossil fuel-intensive and linear model of resource use. A potential answer to all these challenges might be provided by the concept of green growth and development.

Green growth is defined by Rodrik (2014:469) "as a trajectory of economic development that is based on sustainable use of non-renewable resources and that fully internalizes environmental costs, including most critically those related to climate change." Furthermore, he argues that green growth requires green technologies, "production techniques that economize on exhaustible resources and emit fewer greenhouse gasses" (ibid).

Accordingly, the green industrial policy shall focus on the following two dimensions: reducing CO2 emissions and increasing the resource efficiency of the industry. As long as in the context of more developed economies, academic, and political debates are primarily dominated by the former, i.e., concerns about global climate change and CO2 emissions, for latecomers and less developed economies the perspective of green growth focuses much more on the latter issues related to energy and resource security and efficiency (Mathews 2020:269). In other words, in the case of less developed, late-industrializing countries, the driving force in the transition to green growth and development may not be the correction of market failures but the exploitation of new market opportunities.

Consequently, during the process of defining green growth and green industrial policies, one has to take into account both the productivity criterion and the resource efficiency clause since only their joint implementation can reasonably contribute to sustainable development. While the former emphasizes the higher productivity achieved through economic restructuring in order to increase economic growth and improve social well-being, the latter aims to decouple economic development and human well-being from resource depletion and waste production (UNEP 2011). In this vein, in this study, we follow Altenburg and Assmann's definition on green industrial policies as including any government measure aimed to accelerate the structural transformation towards a low-carbon, resource-efficient economy in ways that also enable productivity enhancements in the economy" (Altenburg Assmann 2017:11).

In the case of new technologies, especially green ones, substantial uncertainty and risk is involved in the process of development and commercialization, mainly due to their novelty and the experimental nature of the process. New green technologies are particularly prone to market failures, due to the mispricing of both

inputs, natural resources (such as clean water or air) and outputs, such as waste or environmental pollution (e.g., CO2). This, on the one hand, justifies state intervention and support for green solutions, on the other hand, it also means that green industrial policy must be designed and developed in such a way that it is also suitable for financing a larger number of failures (Rodrik 2014). Nevertheless, this approach is typically relevant and suitable for governments in more developed (or large emerging) economies with strong central state capacities and sufficient autonomy (from interest groups and lobbies) that have significant financial room for maneuver (such as the USA or China), and it is straightforward to see that in the context of less developed, small open economies, "cheaper" solutions may be preferable and more viable.

There are multiple possibilities to adequately reflect environmental aspects in market mechanisms: appropriate pricing of natural resources, internalization of environmental costs, tightening of environmental regulations and better sanctioning of their violation, as well as, for example, terminating state support for fossil fuels, other non-renewable products and phasing out state financing of unsustainable business practices and consumption patterns.

Financial instruments of industrial policy for sustainable development include, among others, research and development subsidies, public procurement, subsidized loans and loan guarantees, as well as direct subsidies and environmental taxes. Non-financial instruments include specific national programs for awareness-raising, dissemination of best practices and capacity-building actions, provision of digital tools or platforms, and support for corporate networking (especially relevant for promoting industrial symbiosis), emissions trading schemes (cap-and-trade systems) and mandatory energy efficiency, or emission standards (Rodrik 2014; World Bank 2021).

Rodrik (2014) also argues that supporting new technologies is more beneficial for the promotion of green transition than limiting market access via customs or special taxation. While the former enables local actors to remain active participants in global supply chains and enter global markets, the latter risks that domestic actors will not have access to new and forward-looking technologies that are of crucial both in terms of international competitiveness and the aspects of sustainable (green) development.

At the same time, the development of the appropriate set of tools, policy mix also depends on the local economic and social structure, as well as the state capacities and autonomy in any given country, since these conditions basically determine the room for maneuver of governments. Consequently, depending on the given local conditions of any country, different green industrial policy toolsets can be effective in promoting the goals of green growth and development.

3 Circular economy and industrial symbiosis

With respect to latecomers and late industrializing developing countries, Mathews (2020) groups green growth and green industry policy around three issues: (1) energy security and transition to renewable energy sources (see Mathews et al.

2022); (2) increasing the efficiency of resource use (i.e., the application of the circular economic model); and (3) innovative financing of green growth, issuing market-based green loans and bonds (see Monasterolo et al. 2022). Below, we focus on the second point, the issue of increasing resource efficiency.

The original concept of the circular economy can be traced back to the Club of Rome's book, The Limits to Growth (Meadows et al. 1972), and the work of Stahel and Reday (1977), while in the last 2 decades, it has received special attention among researchers and political decision-makers to practically become one of the new theoretical frameworks of sustainable development (Geissdoerfer et al. 2017). The circular economy is based on the operating principle of nature, where there is no waste, every output is the input of another process. Thus, the circular approach contrasts with the "take-make-use-dispose" logic of the traditional "linear economy" (Bakker et al. 2014) and argues for the nature-like circulation of material flows within the economy. This means that the value of products, materials, and resources remains in the economy for as long as possible, resulting in minimal waste, and sustainable resource management. According to Bocken et al. (2016) and Bakker et al. (2014), the circular economy can be described as a set of design and business model strategies that are slowing (i.e., reuse), closing (i.e., recycle) and narrowing (i.e., using less materials for production) resource loops. Based on Park et al. (2010) and Stahel (2016), circular economy can be summarized by six fields of actions: take, make/transform, distribute, use, recover, and *industrial symbiosis (IS)*. Compared to the concept of sustainable development, which is difficult to operationalize, the circular economy represents a better alternative with a systemic approach used in the planning, construction and management of production and consumption systems (Salomone et al. 2020) .

Industrial symbiosis is a subfield of industrial ecology, often defined as a collective approach in which the waste or by-product of one company is used by another company as a raw material or important input (Neves et al. 2019). In short, IS focuses on closing pre-consumer (namely industrial) material flows by capturing residues from one entity as raw materials for another (Chertow 2000).

This latter description helps us to better understand the concept from two aspects. First, it highlights the difference between IS and "traditional" waste recycling, which takes place in landfills and waste treatment plants, as IS is about pre-consumer waste or by-products. Therefore, we should not immediately think of the collection and recycling of municipal waste when we talk about industrial symbiosis. Secondly, this definition also emphasizes that industrial symbiosis is a business-to-business (B2B) model.

The spread of the business model of industrial symbiosis, the increasingly intensive academic and political decision-making activity, and the upsurge of research in this direction is due to the fact that the participants recognized and perceived the advantages of this synergistic relationship. More specifically, businesses implementing industrial symbiosis can save costs (e.g., avoiding transport and landfill costs and access to cheaper alternative raw materials) and generate additional income in cases where they can sell their waste (Neves et al. 2019). Resembling to this, Lybaek et al. (2021:1) define IS as "the connection of traditionally separate industries in a collective effort to simultaneously increase competitive advantage and reduce

Table 1 Typology of industrial symbiosis, linked with indicative case studies. Source: own construction, inspired by Neves et al. (2019) and Henriques et al. (2021)

Level	Form of exchange	Actors	Indicative cases
Micro	Internal exchange	One single company	Case 2—Amelia Agro
	External exchange	Two or more companies	Case 1—Hya Bioplastics Case 2—Amelia Agro Case 3—TexFad
Meso	(Eco) Industrial Park	Companies in the industrial park and park management authority	None
	Urban industrial symbiosis	Local community (authority) and companies	None
Macro	Nation-wide industrial symbiosis	Economic sectors	None

environmental impacts by means of by-product exchange and shared infrastructure." This latter interpretation represents a broader approach to IS, as it also includes other aspects of symbiosis, such as the sharing of infrastructure or the joint use of services—especially in the field of waste and water management.

3.1 Typology of industrial symbiosis relationships

One of the most frequently used distinctions between different types of industrial symbiosis concerns the level of implementation, i.e., it refers to the level of partnership formation. The micro level is related to the corporate level; the meso level describes the relationship between companies in geographical proximity, for example, (eco-) industrial parks; while the macro level refers to activities that are carried out at the regional or national level (Neves et al. 2019). In contrast, Henriques et al. (2021) use a different typology, in which they focus more on the "exchange" aspect of industrial symbiosis and distinguish four different levels: internal exchange (circulation and—in-house—utilization of materials within one single company), external exchange (utilization of one company's materials by another company), eco-industrial park, and urban industrial symbiosis. Table 1 summarizes the synthesis of these two typologies, including the three indicative cases, we present in detail later. Accordingly, in this paper, we focus on the micro-level examples (internal and external exchange) of industrial symbiosis.

According to Neves et al.'s (2019) sectoral analysis based on the systematic literature review of 103 articles on the potential of industrial symbiosis, activities related to the manufacturing industry account for 63% of all occurrences, while other sectors such as agriculture, forestry and fishing, electricity and water, and waste management and recycling are other common occurrences. Regarding the types of exchanged waste, organic waste is the absolute leading material (food and food processing waste, biomass, livestock, and fishing waste), followed by rubber, wood, metal, non-metal (e.g., glass, construction and demolition waste, lime-based waste), paper, waste heat and steam, ash, water and wastewater, chemicals, sludge, waste oil, and textile waste.

3.2 Policies promoting industrial symbiosis

Below we focus on the policies that national or local governments can use to promote industrial symbiosis in their countries, regions or municipalities. To overcome IS obstacles, the following strategies are possible tools for (industrial) policies supporting industrial symbiosis:

- In order to facilitate the use of waste, amending the rules and guidelines,
- Providing economic incentives,
- Ensuring dissemination activities,
- Providing training,
- Presentation of supporting entities,
- Use of digital programs and platforms,
- Greater investment in the research and development of technological innovations (Neves et al. 2019:36).

We can also distinguish between top-down and bottom-up, as well as direct and indirect industrial symbiosis policies (Lybaek et al. 2021). Top-down policies are defined as policies formulated by central governments and international or supranational organizations, while bottom-up policies are policies initiated by local stakeholders or provided by local governments, including local incentives, subsidies, and they cover the municipal and regional levels.

Direct policies are defined as policies formulated by a government agency (national, regional, or local government level) that specifically aim to support, promote, or legally enforce industrial symbiosis. The best examples of direct policies are the UK's National Industrial Symbiosis Program, China's policy programs supporting eco-industrial parks (Zhang et al. 2010) or Switch Africa Green Program operated by EU-UNEP (UNEP 2021) sub-programs in the Sub-Saharan African region.

On the other hand, indirect policies are policies that are not specifically designed for industrial symbiosis but influence the development of industrial symbiosis. These cover a very wide range of general framework conditions, such as infrastructure policies, general tax and customs policies (e.g., landfill tax), waste policies and general policies that regulate market conditions for resources, products or services, among others.

We continue by focusing on the regulations and policies promoting the use of waste, as well as economic incentives based on the following arguments. First, intuitively, the participants in the symbiosis must recognize the economic benefits of this activity. That is, the economic component (regulations, policies and incentives) that is essential to encourage companies to establish an industrial symbiosis relationship (Neves et al. 2019). Secondly, we highlight the incentive-based policy support at the local level related to the regulation and planning of land use, which is key to the development of industrial symbiosis (Lybaek et al. 2021), noting that indirect waste management policies are more valuable to industries than direct targeted policies. Furthermore, the view that governments should focus on local incentives instead of top-down regulation is prominent in the literature (see, for example, Kim 2007).

If the economic value of raw materials is very close to that of waste, there is no incentive for companies to use waste in their production processes. In the waste sector, the main purpose of using economic tools is typically to reduce waste generation or to divert waste from landfill to recycling and further utilization (Nahman et al. 2012). In addition, the price companies are willing to pay for waste may not be economically beneficial to the company producing such waste. In this case, companies are also not encouraged to divert waste from landfills and develop a symbiotic relationship.

Industrial symbiosis in Sub-Saharan Africa

Industrial symbiosis is a business model that can potentially contribute to increase productivity by using waste materials that would otherwise not be included in the production input. About 60% of the solid waste generated in Sub-Saharan Africa is organic waste (Kaza et al. 2018), which on this basis represents a huge (mostly untapped) potential.

In contrast to other business or technological models of the green economic transition, industrial symbiosis solutions do not require huge asset investments, since what is primarily required is good coordination between economic actors. Compared to recycling or re-manufacturing, industrial symbiosis focuses more on connecting existing businesses and finding possible synergies with as little additional investment (procurement of machinery and equipment) and other extra infrastructure requirements as possible. Thus, since most African companies do not have the financial resources for huge investments, this circular economy business model may seem like a realistic and feasible solution. Similarly, supporting the spread of industrial symbiosis can be a low-cost intervention for African governments, which are typically short on resources.

In the context of green growth in Africa, other economic tools could be used to promote cost-effectiveness and service efficiency, as well as generate revenue. Nahman et al. (2012) found that moving waste up the hierarchy towards minimization, reuse, and recycling can be achieved primarily through the use of economic tools and incentives, provided they are properly designed and implemented.

In an international comparison, the most limited number of studies, reports, and academic research on the situation of industrial symbiosis is available from the Sub-Saharan African region. This may be due to the actual rarity of cases and relatively low economic activity (number and diversity of companies), lack of general awareness of manufacturing actors, environmental awareness among population and industrial symbiosis practices. However, we are convinced that, in accordance with the above argument, looking at the trends of consumption and waste production in Africa, there are great opportunities in this area, and the spread of the business model of industrial symbiosis can contribute to the continent's green economic growth. Therefore, we briefly summarize recent studies on or related to industrial symbiosis in Africa. Studies on existing models (Agosson et al. 2016—Benin; Rweyendela and Mwegoha 2020—Tanzania) describe the functional characteristics, best practices and benefits but do not detail the influencing role of economic factors and regulation, or their incentives. Mbuligwe and Kaseva (2006) assessed industrial solid waste management and resource utilization practices in Tanzania but did not address how industrial symbiosis and waste utilization could be encouraged through

industrial policy instruments. Others focus on the analysis of possible symbiosis within a company or between different companies and industries, such as Alfaro and Miller (2013) writing about a smallholder economy in Liberia, and Mauthoor (2017) analyzing three industries (slaughterhouses, cooking oil refining, scrap metal recycling) in Mauritius. The latter also briefly argues that subsidies could help these processes but does not go into specific details.

In relation to eco-industrial parks or economic zones and IS programs, the studies basically focus on information dissemination and partner search support activities (Oguntoye et al. 2019—South Africa), focus on feasibility studies and the role of green finance funds (Khisa and Onyuka 2018).—Kenya), to ensure coordination and digital platforms (Brent et al. 2008; Ellen McArthur Foundation 2020—South Africa) and wastewater treatment (Jensen 2020—Ethiopia) as local or national government support activities. Oliyade (2015) identifies sixteen factors for the success of IS and eco-industrial parks in Africa and highlights that "access to finance" is key.

These shortcomings support our basic assumption that the role of industrial policy tools and economic incentives in promoting industrial symbiosis in the Sub-Saharan region is a research field in its infancy. In addition, we try to support the relevance of this research direction with another important finding. Oliyade (2015) argues that smallholder farmers, especially farmers in Africa, think in terms of short-term returns as they have to survive day to day and thus the relatively slow returns generated by industrial symbiosis are not attractive to them. Moreover, he also mentions that a lack of institutional and regulatory support can limit the adoption and implementation of IS practices. Jensen (2020) argues that since the creation of symbiotic relations depends to a large extent on the existence of individual sectors and industries, the relatively low number of companies and the low level of industrial diversity require a rethinking and further research of the possible types of symbiosis.

In summary, compared to other geographical regions, relatively few studies have been conducted in Sub-Saharan Africa on the actual cases of industrial symbiosis, its possible drivers and obstacles. In fact, research results and lessons on the role of economic incentives (specifically landfill taxes and subsidies) in the region do not exist in the field. Therefore, below, we present the partial results of a Ugandan field research, which reveals local examples of industrial symbiosis. First, we briefly justify the choice of country, and then we sketch the Ugandan regulatory and policy environment related to local industrial symbiosis, circular economy, and resource efficiency. Finally, we present three indicative examples: companies, initiatives that implement industrial symbiosis in Uganda, and the analysis of their experiences can be instructive for other countries and actors in the African region.

4 Experiences of a field research in Uganda

Uganda can be considered a white spot in the field of industrial symbiosis research. At the same time, the renaissance of broader industrial policies also reached Uganda, which, like many other sub-Saharan African countries (such as the Republic of

South Africa, Namibia, Zambia, and other East African countries), experimented with an inward-looking industrial policy in the last decade (Behuria 2021), which, typically after the turn of the millennium, replaced an outward-looking industrial policy. While the latter prioritized production for export and integration into global value chains, the new—inward-looking—industrial policy in Uganda (and in other countries of the region, as well) emphasized the needs of domestic companies and serving the domestic market. As a result, the latter type of industrial policy can, in principle, even represent a suitable regulatory and incentive environment for industrial symbiosis.

4.1 Regulatory and policy environment in Uganda

The main framework of Uganda's development policy is the Uganda Vision 2040 (NPA 2007), adopted in 2007, which defines the strategic direction of development in a 30-year perspective. Its main objective is to transform Uganda from a predominantly peasant and low-income country into a competitive, upper-middle-income country. The key projects and policy reforms to be implemented within the framework cover all areas of socio-economic development, including industrialization, human and infrastructural development, urbanization, high technology, and innovation. The "vision" is implemented through six 5-year national development plans within the National Development Planning Framework.

Sustainable and fair development appears among its guiding principles, with particular regard to the preservation of natural resources, such as soil, forests, and wetlands. The state of these resources is endangered by aspects relevant to industrial symbiosis, such as the improper disposal of industrial solid and liquid waste, as well as the merging of electronic waste, radioactive waste, plastics and polyethylene materials, industrial, and medical waste with traditional organic waste (NPA 2007:98). In addition, the goal is to adapt production, consumption and population growth patterns that protect the environment and to promote the development of environmentally friendly technologies and their proper implementation into local use.

In 2017, the Ugandan government adopted the Uganda Green Growth Development Strategy (UGGDS) to operationalize the principles of green growth and accelerate the implementation of the global development goals for the period of 2017–2031 (NPA 2017). UGGDS aims to achieve an inclusive, low-emission economic growth process that emphasizes the effective and efficient use of natural, human, and physical capital while ensuring that natural assets continue to provide for present and future generations. The document defines green growth as "inclusive low emissions economic growth process that emphasizes effective and efficient use of the country's natural, human, and physical capital while ensuring that natural assets continue to provide for present and future generations" (NPA 2017:8). Accordingly, one of the strategy's guiding principles and aims is to increase the efficiency of resource use, which we take as a reference to the utilization of waste materials and industrial symbiosis, among others, in this paper. Furthermore, other similar and relevant arguments appear in the text as to "increase productivity and efficiency, and minimize negligence related to production,

distribution and consumption through better performance of value chains" (NPA 2017:45).

The Third National Development Plan 2020–2025 (NPA 2020) designates sustainable industrialization as the planned path for the country's development, including growth, employment and the creation of sustainable prosperity. There are two specific interventions in the plan that are related to the area of industrial symbiosis. Namely, one is.

> "Applied research and innovation in the field of sustainable consumption and production of the *efficiency of resource use* in order to reduce domestic material consumption per capita" (Chapter 9/goal 1/intervention 5).
> And the second:
> "Modernizing industries to make them sustainable, increasing *resource efficiency and clean and environmentally friendly* wider application of technologies and industrial processes" (Chapter 11/objective 1/intervention 5).

A relatively recent national industrial policy document is in force in Uganda from 2020. Uganda's National Industrial Policy describes its mission as "to accelerate *sustainable industrial transformation* through an increased developmental role of the State, reduced cost of production, and improved quality of manufactured goods" (MTIC 2020:16). In this document, we have identified four interventions that may be related to the topic of our study:

1. Applied research and innovation in the field of *sustainable consumption and production* in order to ensure *resource efficiency* (specific objective 4/intervention 6);
2. Adoption of *resource-efficient* and green technological practices in industries (specific objective 5/intervention 1);
3. Promoting the general validation and adoption of international and national environmental management practices and standards in industries (specific objective 5/intervention 2);
4. Promoting inclusive, climate-resilient and low-emission industrial development through capacity building of industrial actors and issuance of carbon footprint certificates to support the transition of the industrial sector towards carbon neutrality (specific objective 5/intervention 3).

In addition, the industrial policy document refers to the environmental sustainability of industrialization as one of its guiding principles, in the sense that "manufacturing industries will be supported to adopt cleaner and more efficient technologies. Targeted programs includes the promotion of cleaner production practices, recycling of waste, waste disposal management, and resource (energy and water) efficient management programs" (MTIC 2020:19).

Finally, as the last element of the regulatory environment, the Uganda Green Manufacturing Strategy 2021–2025 (MTIC 2021) can be mentioned. It defines green manufacturing as "the application of environmentally and socially sensitive practices to reduce the negative impact of production processes and product

use (PPPU) while striving for economic benefits" (MTIC 2021:5). The strategy describes green manufacturing as involving the design and manufacture of green products or processes that use fewer materials, less energy, substitution of input materials (from toxic to non-toxic materials, and non-renewable materials transition to renewable materials instead). Four of the twelve strategic interventions are directly related to the topic of industrial symbiosis and resource efficiency, and the second strategic intervention is specifically about the enhanced promotion and implementation of resource-efficient and environmental pollution prevention programs.

Overall, we can conclude that the Ugandan regulatory environment has undergone significant transformation over the past 2 decades. While in the 2007 Uganda Vision 2040, environmental aspects are mentioned even tangentially, giving little space and direction to the implementation, the 2017 Green Growth Development Strategy already operationalized the principles of green growth in much more detail. Two specific interventions of the National Development Plan, which is still in force, mention the efficiency of resource use and the use of clean and environmentally friendly technologies. The environmental sustainability of industrialization appears as one of the guiding principles of the 2020 national industrial policy strategy, and a separate strategy for the development of the green manufacturing industry was also adopted in 2021.

4.2 Three indicative examples of industrial symbiosis

Despite the above presented formally supportive-looking and fitting regulatory environment with the strong emphasis on resource efficiency, direct actions to support industrial symbiosis activities are hard to detect on the field. Therefore, below we present three Ugandan examples of the implementation of industrial symbiosis, which were revealed by a field research in Uganda between 1 and 27 May 2021, aiming to explore companies and initiatives applying the concept of circular economy through different business models and technological solutions (see Buda 2022). Cases were selected from Footprint Africa's Circular Economy Case study report (2021) and based on the recommendation of experts at the Uganda Cleaner Production Center and the National Planning Authority. From the seven explored examples, these three cases presented below are highlighted in this paper, as they fit to the definition of industrial symbiosis, which has generally a rare (documented) occurrence in Uganda, as in broader Sub-Saharan Africa.

Following the field research, an online survey was conducted to complement the results. An online questionnaire was sent out to the businesses, with which, among other things, we assessed their needs for the following governmental or non-governmental support: tax reduction for products and services; subsidies for special technical purposes (machines, infrastructure); support in finding potential partners; promotional and marketing support; local or national government orders and purchases; microloans and other subsidized loans; transport support; subsidizing waste delivery; special taxes or regulation for competitors using non-circular models; and support in research and development. From different points of view, each case reveals

interesting experiences and lessons both in terms of the potential of green development and the state intervention intended to promote it. In addition to describing the synergies, we briefly present the economic, environmental, and social benefits these synergies generate. One further commonality in these three cases, besides the implementation of industrial symbiosis practices, is that none of them reported about governmental support or policy implementation which would represent the efforts to increase resource efficiency and cleaner production. Hence, we also discuss what challenges these companies face and what support (industrial policy) solutions would be useful for them.

4.2.1 Case 1—Hya Biopastics

The first case, Hya Bioplastics is a young organization based in Kampala. It started as a pilot project of Makerere University students in 2018. Their goal is to replace plastic by productively utilizing the invasive plant that grows in Lake Victoria, the water hyacinth (Pontederia crassipes), and related research and development. Hya Bioplastics' pilot products are biodegradable "plastic" trays, packaging, coasters, and name tags based on a mixture of dried water hyacinth (a material coming from fishers cleaning up fishing areas), sawdust (from a carpentry) and cassava starch (from cassava farmers). In this sense, this example fits into the external exchange category in the above typology. The customized products are mostly sold to restaurants and bars, and international non-governmental organizations (NGOs). In general, there is a lot of plastic waste in Africa. Since the substitution of plastic in Uganda is still in its initial phase, in the absence of a sufficiently stable demand, Hya Bioplastics has also started producing sawdust-based briquettes, which are sold to poultry farms or households as a substitute for more polluting and less efficient charcoal. The sale of briquettes provides the company with additional income, which allows (by reallocating resources within the company) to finance further research and development related to the production of alternatives to plastic. The sawdust is delivered free of charge by a furniture company, Motiv Creations, whose by-product disposal used to be costly and problematic. Thus, the industrial symbiotic relationship is also realized in this context.

The most important economic benefits generated by Hya Bioplastics are cheaper or even free input prices, additional income for fishermen resulting from easier fish production, improvement of the production efficiency of poultry farmers, more durable and efficient sawdust briquettes, and waste disposal costs saved by the furniture company. Positive environmental effects include reducing or avoiding sawdust deposition, less polluting poultry farming, reducing plastic use, and contributing to the preservation of natural fishing areas and biodiversity. Contribution to the additional incomes of cassava producers and fishermen, and even to the creation or preservation of jobs, can be considered important social benefits.

The young initiative faces many challenges, too. The lack of water resistance of their packaging prototypes requires a significant investment in technological research and development, while cheap imported plastic products represent serious competition. The combined effect of these two factors limits the growth of market share and economical production. Among needs for support, they highlighted tax

Fig. 1 A Hya Bioplastics' biodegradable plate, Source: Hya Bioplastics Facebook page

reductions for products, subsidies for special technical purposes, special taxes and regulations imposed on competitors with non-circular/non-green models, as well as assistance in research and development (Fig. 1).

4.2.2 Case 2—Amelia Agro Africa Ltd.

Our second example is Amelia Agro Africa Ltd., an organic farm in Jinja, Uganda. The farm grows several types of plants and raises animals (chicken, fish, pigs, cows, goats, rabbits), and also sells compost to local farmers. This business is an excellent example of how in-house waste materials can be utilized in circular model and how other companies' waste or by-products can be used as compost, animal feed, or organic pesticides. Thus, this case can be categorized as both internal and external exchange of materials in the above typology. For instance, bagasse (residue from crushing sugarcane) is obtained from sugar companies. Slaughterhouses supply them with blood, guts, and offal, and they also obtain animal skin, fur, and meat scraps from fish processors, and tanneries. The carbon-rich boiler ash from a paper company is a valuable resource for maintaining soil fertility, while brewery by-products, such as spent grain or yeast, are fed to the pigs and used as compost input material. The water hyacinth comes from the sailing club in Jinja and the local hydropower plant operator, and it is used as pig and chicken feed. As a final example, distillery spent wash from spirits manufacturers is also used for composting. The farm's products are sold at the local market and restaurants. Another significant amount of organic waste comes from the peels and food scraps produced in restaurant kitchens. In addition to the supply of incoming organic waste, material circulation and utilization within the

Fig. 2 Boiler ash and other compost elements on the Amelia Agro farm, Source: own photo, 12. 05. 2021

farm is also implemented. Everything is used for feeding or composting, such as animal manure and weeds or other plant residues. One of the competitive advantages of this farm is keeping the nutrient content of the soil at a constantly high level and thus benefiting from increased crop production and animal breeding, besides selling compost. These nutrient-rich raw materials are received for free, the farm's only input-related cost is transportation. In addition, supplier companies can achieve a significant reduction in waste disposal costs.

Avoidance of waste disposal can be highlighted as one of the most important positive environmental effects created by the farm which contributes to the reduction of greenhouse gas emissions resulting from waste decomposition. The improvement of soil quality can also contribute to the increase of carbon sequestration capacity, which can be important in mitigating climate change. The company tries to avoid the use of machines as much as possible, so it employs a relatively high proportion of the human work force and thus creates jobs. Another social aspect is that organic agriculture can contribute to the creation of better nutritional conditions by ensuring higher nutrient and mineral content of food (Fig. 2).

Despite the above advantages, Amelia Agro continues to struggle to achieve profitability, as organic agriculture is very labor-intensive, the results of improving soil nutrient content appear in the longer term, and the local purchasing power for organically grown plants does not allow for significant price differentiation. Moreover, the market presence of imported fertilizer and industrial feed until 2021 represented serious competition for the farm. The latter changed during the 2 years of the research due to the shortage of fertilizers caused by the Russian-Ukrainian war. Since fertilizer has almost disappeared from the local Ugandan and African markets, the competition is now represented by imported and other locally produced composts and organic nutrient mixtures. To offset these challenges, the company's management identified technical support (machinery, infrastructure), connecting with new partners, microcredits and subsidized loans, and research and development assistance as the main support needs from our questionnaire. In addition to this, they mentioned the appearance at individual professional forums (especially international

Fig. 3 Dried banana fiber and banana-textile carpet in the making, Source: own photo, 19.05.2021

development networks and organizations) and the restriction of regulations on waste disposal.

4.2.3 Case 3—TexFad

The third indicative case, TexFad is a non-profit organization active in the handwoven textile sector in the outskirts of Kampala, which fits to the external exchange category in the industrial symbiosis typology. The production of carpets, scarves and other handicraft products is based on two components: clothing materials left as waste or by-products of textile production, while the other one is vegetable fibers extracted from banana stems. The off-cut textile and waste cotton yarn (product from non-functioning production or defective product) is supplied by two cotton businesses: Nytil in Jinja and Fine Spinners in Kampala. The banana tree stems come from local farmers,[1] while the fiber is extracted at TexFad's site and utilized to weave carpets and the remaining parts are used to produce organic fertilizer

[1] For this topic, it is worth knowing a little more about bananas, which are one of the most common crops in Africa. The banana tree bears fruit once. After a banana tree has been harvested, it does not produce any more fruit. The 3–5 m tree remains as waste, with unused potential.

and carbonized briquettes (like in the example of Hya Bioplastics). TexFad is also engaged in further research on the treatment and utilization of banana fiber to replace cotton in the future. Carpets and textiles are usually sold to hotels and apartments, while briquettes and fertilizer are sold to poultry farmers, restaurants, homes, and schools (Fig. 3).

The company takes advantage of lower input costs and contributes to additional income generation for textile producers and banana growers. Households, catering and poultry businesses benefit from more durable and efficient briquettes as a solid energy source. In addition, the supplier companies, especially the two textile factories, can save on waste disposal costs. TexFad also contributes to landfill avoidance, the reduction of greenhouse gas emissions (from outdoor waste decomposition) and air pollution by having its customers use briquettes instead of charcoal for cooking. In addition, the organic fertilizer made from banana residues improves the quality of the soil and its ability to sequestrate carbon. Nevertheless, competition with imported synthetic carpets, fertilizers and charcoal manufacturers remains TexFad's main economic challenge. In relation to policy support, the organization highlighted tax reduction for products and services, subsidies for special technical purposes, promotional and marketing support, microloans and other subsidized loans, subsidizing waste transportation, and special taxes or regulations for competitors using non-circular or non-sustainable models.

5 Discussion

We have analyzed two distinct types (the internal and external exchange) of three existing industrial symbiosis examples in Uganda on the micro-level, as it can be seen in Table 1. Based on the analysis of the case studies presented in the previous section, though each and every company is very different and unique, we can highlight some commonalities in terms of economic, social, and environmental benefits.

The economic advantages relate mainly to cost saving during the production process (such as via cheap or free input, increased productivity in crop production and animal breeding—via maintained nutrient content of the soil, decreased or no costs related to waste disposal). The positive environmental effects can be best captured via improved resource efficiency (including reducing waste production and deposition, reducing plastic use, less polluting activities, more efficient energy sources), reduction of greenhouse gas emissions, as well as improved carbon sequestration capacity, less air pollution, and contributing to the preservation of environment and biodiversity. The social benefits encompass additional incomes for producers, job creation or preservation, as well as better nutritional conditions (via ensuring higher nutrient and mineral content of food).

The case study analysis has, however, also revealed that the examined companies face some common challenges. Technological upgrading requires significant investment in technological research and development—which is very difficult to finance from own resources in the context of sharp price competition (in the light of cheaper import products and limited local purchasing power). The consequential limited potential to increase the market share and improve the profitability of production

Table 2 Support needs of the three presented Ugandan businesses. Source: online questionnaire

Support type	Hiya Bioplastics	Amelia Agro	TexFad
tax reduction for products and services	✔		✔
subsidies for special technical purposes (machines, infrastructure)	✔	✔	✔
support in finding potential partners		✔	
promotional and marketing support			✔
local or national government orders and purchases			
microloans and other subsidized loans		✔	✔
transport support			
subsidizing waste delivery			✔
special taxes or regulation for competitors using non-circular models	✔		✔
support in research and development	✔	✔	
OTHER			
appearance at professional, international development forums		✔	
stricter regulation of waste disposal		✔	

is also challenging, as the activities are often labor-intensive, and some advantages appear in the longer term.

In the table below (Table 2), we summarize the results of the online survey, i.e., the support needs of the businesses searched.

The online survey has revealed only one type of support that was highlighted in all three cases—namely, special technical purpose support. Nevertheless, many additional forms of support have been mentioned that would be required by the analyzed companies. Among the points that received several mentions, we can highlight the tax reduction for products and services of the circular economy, microloans and other subsidized loans, taxation of competitors, and support in R&D. Accordingly, we can conclude, that even if some working examples of industrial symbiosis exist in Uganda, these companies tend to rely on or require government support in order to survive and be able to upscale their operation on a profitable manner. Which points to one of our main findings that besides appropriate regulatory and policy environment, effective and well-tailored, context-specific government measures are needed to improve opportunities of existing companies, and to contribute to upscale the emergence and application of the industrial symbiosis business model. Furthermore, these findings also inform the modification of our consideration about industrial symbiosis being always a low-cost solution for transition to circular economy, mentioned above, mostly only needing good coordination and match-making of waste and by-product generating and using actors. Indeed, the answers from our online survey indicate that financial (fiscal, grant-based, etc.) industrial policy tools and incentives are also necessary

for the facilitation and sustainable operation of business models based on industrial symbiosis.

6 Conclusions

Following the global financial crisis of 2007–2009, the spread of state economic interventions, and thus also the revival of industrial policy became global tendencies. Interventions aimed at promoting green growth and development represent an important new dimension of the new industrial policies. The green industrial policy specifically aims at supplementing the former classic productivity criterion with the resource efficiency clause, since only the joint fulfillment of these can contribute to growth and development taking place in accordance with natural limits. The literature on new industrial policies typically examines the cases of developed countries and formulates relevant and forward-looking insights based on the conditions there (with few exceptions, such as Andreoni et al. 2021; Avenyo and Tregenna 2022; Obeng-Odoom 2022). However, the present study focused on the possibilities of developing countries, specifically Sub-Saharan African countries, in terms of green growth and green industrial policy interventions. The first (and one of the most important conclusions) of the study is that different strategies and different tools and policy mixes can be successful in individual countries due to different circumstances (state structures and capacities, financial room for maneuver).

We analyzed the possibilities of increasing resource efficiency by examining the application possibilities of a model of the circular economy, industrial symbiosis, through three cases in Uganda. The analysis aimed to illustrate how the industrial symbiosis model of the circular economy can contribute to the toolkit of green industrial policy. As the level of waste collection and management in most African countries is concerning (Kaza et al. 2018) and African companies, on the one hand, and African states, on the other hand, are in lack of financial resources for huge investments (Fonta et al. 2018), this business model of circular economy promises solutions for the twofold challenge of economic prosperity in an environmentally sustainable manner.

Both in terms of regulation and practical implementation, the initial building blocks that can represent a good basis for the green transition in Uganda (and Sub-Saharan Africa) exist today, even if for the time being, they represent vague frameworks and sporadic cases. At the same time, we are convinced that in the implementation of existing green visions and plans, it is neither worthwhile nor feasible to follow the practices and guidelines of the developed world, rather the exploration of existing local good practices and the development and implementation of a green industrial policy that fits the conditions can be a more forward-looking strategy. In this, we share Lybaek et al. (2021) and Kim (2007) that when designing the incentive and regulatory frameworks it is important to build upon bottom-up initiatives. However, we take a step further, and argue for a more inclusive approach also in the case of implementing existing green strategies and policies, as government measures should resonate with the needs of business actors. This is exactly what we aimed to illustrate in our analysis (based upon the experiences of the field research, as well as the results of the online survey). Our results show that a gap exists between

high-level strategies and implementation currently in Uganda. More concretely, we have found significant mismatch between the supply side of green industrial policies in Uganda (government aims, regulations and measures), and the demand side, what local green entrepreneurs would need to improve their competitiveness. We have shown on the one hand, that even though the regulatory framework has undergone significant improvements recently and the principles of green growth and development are well operationalized in policy documents, little has been done in terms of implementation and concrete actions. On the other hand, in our case studies and online survey, we have revealed that local green entrepreneurs besides appropriate regulatory and policy environment would need exact and more straightforward government measures to improve the viability and profitability of the industrial symbiosis business model. This means that besides the horizontal-type support of coordination and networking activities, more vertical-type (and sector-specific) financial support and incentives are also necessary to facilitate the operation of this business model. Nevertheless, we are optimistic, as existing, though sporadic cases point to a great potential in terms of green development in low-income context. The added value of the study is the exploration of the Ugandan regulatory environment, as well as—based on the experiences of field research—the search for practical examples that already works today. We believe that summarizing these experiences has helped to better understand the practical application of industrial symbiosis in the context of developing countries and highlighted the main limitations and challenges that these companies face. Among these, we emphasize that profitable operation still encounters difficulties in many cases and is dependent on domestic or international subsidies (or at least international market opportunities and purchasing power), or, in the absence of these, relies on cross-financing from other profitable economic activities within the company.

Regarding the role of the state, one of the main conclusions that can be drawn is that, based on the needs of the three enterprises, financial instruments, subsidies, and interventions related to taxation continue to dominate among the demanded policy tools. It should be highlighted, for example, that all three companies expressed an important need for support regarding the development of technical infrastructure, but tax reduction, microloans, taxation of competitors and research and development contributions would be considered important in two of the three cases. Since the local government is not rich in financial instruments, the international development community must play an important role in this area. In addition to this, of course, non-financial interventions also play an important role in a well-planned coherent industrial policy mix, i.e., "complementary" interventions such as awareness-raising and capacity-building actions, provision of digital tools or platforms, and support for corporate partnering (the latter particularly crucial for industrial symbiosis).

Based upon these insights, we partly modify our above argument that the concept of circular economy in general, and especially the business model of industrial symbiosis, can be considered a possible low-cost solution that can effectively contribute to the economic reduction of environmental burdens (resource consumption and emissions) and thus to the creation of a more sustainable development model in the African context (and probably also beyond, in other low-income economies, though this requires further research). Certainly, industrial symbiosis requires good

coordination and match-making among waste and by-product generators and users, but, in most cases, industrial policy intervention from local and international governmental or non-governmental actors is inevitable to sustainably secure the aimed outcomes of resource efficiency and to reduce the disposal of materials with further economic potentials material on landfilling sites.

Overall, we can conclude that although Uganda and the majority of Sub-Saharan African countries lag behind the more developed countries of the world in terms of economic development and industrialization, this disadvantage can also be an advantage if the goal is sustainable, green economic growth and development. The choice of a cyclical economic model instead of a linear economic development model is easier to implement at a lower level of economic (and social) development due to economic, social and political aspects than later, when the framework of the linear economic model has already been formed, the physical infrastructure has been built and strengthened the power positions of related value chains and interest groups. In other words, we aimed to disprove the previously widespread, conventional view that environmental protection is a luxury of developed countries, and that in developing countries economic growth and poverty reduction should be prioritized first, and then the environmental dimension should or could be considered after reaching a certain level of development to focus. We argued that taking environmental constraints into account can fundamentally change the future development paths of these countries, but for this both the objectives and implementation of top-down development policies (and industrial policies) and local bottom-up initiatives must point in the same direction.

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Declarations

Competing interests The authors declare no competing interests.

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