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INNOVATION IN GLOBAL INDUSTRIAL DOWNSTREAMING: AN OVERVIEW LITERATURE ABOUT OPPORTUNITIES, CHALLENGES AND POLICY DIRECTIONS

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Abstract

Downstream industry has become an important strategy in transforming the global economy, especially in developing countries rich in natural resources Power nature. This article serves as a review of the literature comprehensive to innovation in the downstream global industry with a highlight of forms of innovation, strategic opportunities, challenges, implementation, and policy implications. Through approach analysis thematic against 25 journals relevant of 100 journals indexed by Scopus (2003–2023), this research identify role crucial of innovation technology and digitalization — such as bioprocess, real-time information receiving (RTIR), as well as adoption of Industry 4.0— in increase efficiency and value add in sector downstream. This study also highlights the opportunity integration of bioeconomics and economic circular, and challenges like limitations on infrastructure, cost height, and obstacles to regulation. Implications policy shows the importance of synergy between the regulation industry, the environment, and innovation, as well as the need for support towards MSMEs, R&D, and infrastructure downstream. Study results: This gives a runway conceptual and practical for formulation of downstream strategy based on adaptive innovation to global and local dynamics.

Keywords : ***downstreaming industry, innovation, digitalization, economy circular, policy industry***

INTRODUCTION

In the landscape, the global economy continues to grow, developing downstream industry has become a crucial strategy for many countries to increase mark plus product, creating field work, and strengthening their resilient economy. The concept of " downstream " refers to a series of activities processing raw materials into goods, half So or goods who has a mark plus more tall in the chain, a mark industry, up to distributed and marketed to consumers (Gimenes et al., 2021; Yetkin Özbük & Coşkun, 2020).

Various sources of literature highlight the importance of operation downstream in various sectors, as well as discussions about investment in the sector downstream, like oil and gas (Appiah, Possumah, Ahmat, et al., 2021). In the Indonesian context, downstreaming is done to utilise the potential source Power abundant natural resources, which have been This more Lots exported in the form of raw materials, making Indonesia vulnerable to fluctuating global prices (Rifin et al., 2020). The aim is to transform the structural economy from one based on exploitation of natural resources becomes an economy based on innovation and technology. As a pillar in transformation, this downstream aiming reduces export raw (eg, coconut palm oil into olein), creating field Work new fields, strengthening the local economy, and reducing dependence on imports (PAGE, 2023).

To speed up and improve the effectiveness of downstream processes, innovation plays a central role. Innovation can come true through adopting new technology, developing efficient business models, and integrating more systems good the chain (Mujahid Ghouri et al., 2021). Literature shows diverse forms of relevant innovation with downstream processes in various sectors. For example, in bioproduction, innovative biological and engineering downstream techniques continue to be developed (Gimenes et al., 2021; Tabatabaei et al., 2020; Mancini et al., 2020). Beyond the core production process, digitalization and Industry 4.0 technologies also bring significant innovation to the downstream, especially in the chain supply (supply chain. Adoption technology like real-time information

receiving (RTIR) using Industry 4.0 technology in operation downstream can give an important outlook for the company and create a mark for the customer (Mujahid Ghouri et al., 2021). Draft strategic alignment that utilizes capability technology information is also relevant for successful competitive (Mujahid Ghouri et al., 2021). Business model development innovation is also important for SMEs in implementing Industry 4.026. Even in the context environment, evaluation and optimization performance environment in processing downstream, such as for polyhydroxyalkanoate (PHA), involves an approach based on cycle life in need innovation in evaluation (Saavedra del Oso et al., 2021).

Remember the importance of downstream as an industrialization strategy and the crucial role of innovation in it, as well as the diversity of contexts and challenges that arise in various industries and countries. This article aims to critically examine the trend of innovation in downstream global industry-based collection literature provided. Overview This will focused on identification various form innovation (technology, digitalization /Industry 4.0, integration systems, business models), the opportunities it creates (e.g. utilization of domestic market, advantages competitive), challenges in its implementation (for example obstacle regulations and policies, limitations source power, competition industry), as well as the implications to formulation policies (eg. support policy For adjustment industry, regulation environment, policy investment) with referring to the evidence from various sectors covered in sources literature. Based on background behind said, the question proposed research is as following: What are the form innovation main applied in the downstream process industry globally, Opportunities strategic what results from implementation innovation in downstream various sector industry, What are the challenges main issues faced in implementation innovation downstreaming in various countries and sectors, How direction policies that can support innovation in downstream industry in a way sustainable.

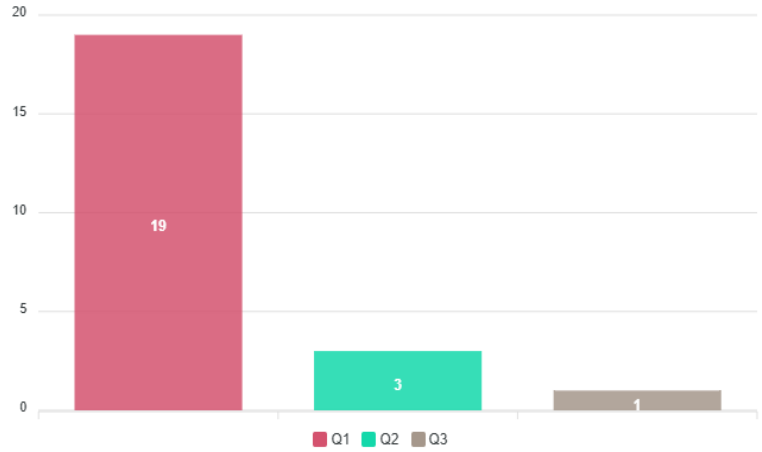
Research gap in this study is Most of it study previously about downstream industry highlight dynamics innovation in context sector or a specific area , such as industry oil and gas in Ghana, protease production in Brazil, or bioprocesses in Europe . Studies This has give contribution important in understand forms innovation specific , such as adoption Industry 4.0 technology or development of bio-based products. However, the approach tend separate and not integrated in a way multi-sector and also multi-country. In addition , many study that only identify challenge or opportunity in a way general, without to describe concrete and applicable policies. Issues strategic like integration upstream-downstream, evaluation quantitative to impact digitalization, as well as relatedness between downstream with the agenda of bioeconomy and economy circular also not yet Lots discussed in a way explicit, especially in context of development strategy national in developing countries.

The research gap in this study is that Most of it studies previously conducted about the downstream industry highlight dynamic innovation in context sectors or specific areas, such as industry oil and gas industry in Ghana, protease production in Brazil, or bioprocesses in Europe. Studies. This has contributed to understanding forms of innovation specific to, such as the adoption of Industry 4.0 technology or the development of bio-based products. However, the approach tends to be separate and not integrated in a multi-sector and multi-country way. In addition, many studies that only identify a challenge or opportunity in a general way, without describing concrete and applicable policies. Issues strategic like integration upstream-downstream, evaluation quantitative to impact digitalization, as well as relatedness between downstream with the agenda of bioeconomy and economy circular, also not yet discussed explicitly, especially in the context of development strategy national in developing countries.

LITERATURE REVIEW

This section reviews literature relevant to be base theoretical and empirical for understanding innovation in the downstream global industry. Overview This shared becomes three-part main: approach relevant theoretical, various forms identified innovations in the downstream process, and summary studies of empirical cross-sector and enriching areas understanding about practice downstreaming. From 100 journals Scopus collected , then 25 journals were selected, which were considered the most relevant, with classification like the following:

Graph 2.1 Classification Selected Scopus Journals



Source : journal data about downstream industry processed in the application Watase Uake research

Chapter Sections: This also reviews several approaches that consist of:

a) Approach Theoretical

Several theoretical frameworks give a lens for analyzing role innovation in the downstream industry:

Resource Based View (RBV)

This theory emphasizes that superiority competitive a company originates from source internal power that it has. In the context of downstreaming, RBV is relevant because this strategy often needs source Power specific, rare, difficult to imitate, valuable, cannot replace, and cannot be easily transferred (inimitable, valuable, non-substitutable, immobile) (Appiah, Possumah, & Sanusi, 2021). Source Power This can be nature, tangible (eg, asset, physical, technology, resources Power financial), or intangible (eg, skills, knowledge, capabilities, reputation). According to RBV, successful companies in downstreaming, especially in competitive sectors like downstream oil and gas in Ghana, require source power and core competencies to outdo competitors. Capabilities technology information, for example, is highlighted as its relevance for success competitiveness (Mujahid Ghouri et al., 2021).

Industrial Ecology

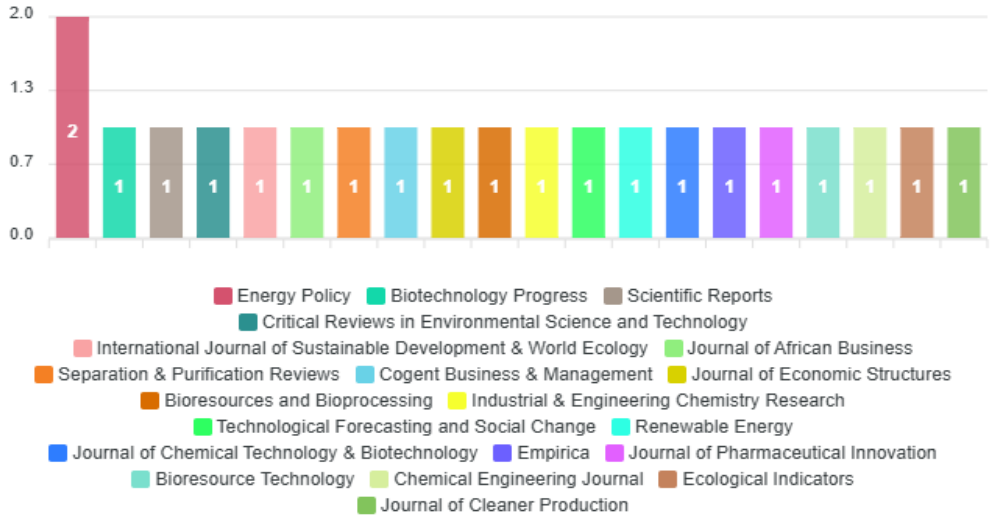
Approach This sees the system industry in an analogous ecosystem nature, emphasizing interconnection and material cycles for reaching sustainability (Yuan et al., 2022). In context downstream, Industrial Ecology is relevant for understanding how the industrial process can be integrated in a way ecological to reduce the impact environment and optimize the use of source power. A study of coordination economy-industrial-ecological in the Yangtze River Economic Belt, China, for example, analyzes the connection between the economy and the ecological industry. Ecology industry as a subsystem covers pressure ecological, consumption source power, management ecological, and technological green. Development economy and ecological industry aims to integrate superior ecological development, encouraging the economy and ecology industry, as well as grow the green industry. This gives a base theoretical framework for downstreaming that not only increases the market economy but also contributes to a sustainable environment.

Techno-economic Analysis (TEA)

TEA is a tool used to evaluate eligibility, technical, and economic from a process or innovation (Ramdin et al., 2021). In downstreaming, TEA is very important for evaluating whether a route processing material, raw or semi-finished, becomes a product worth more tall worthy in a commercial one. Literature show Use of TEA in evaluate processes such as electroreduction of CO2 to C27 products, production of astaxanthin and protein based plants, as well as evaluation of bioproduction and processing processes downstream for product like sour citric (Mores et al., 2021) and acid succinate (Mancini et al., 2020) TEA helps identify cost, potential income, and

challenges technical from innovation downstreaming, providing base based on proof For taking decision investment and policy. Here is Graph 2.1 Classification Journal seen from the Study Area managed with Watase Uake in a way independent of the writer.

Graph 2.2 Classification Journal Based on Study Area



Source : journal data about downstream industry processed in the application Watase Uake research

b) Form Innovation in Downstream

Innovation in downstream to materialize in various form, often involving progress technology, digitalization, and operational model development:

Technology Bioprocess

The bio sector shows Lots of innovation in processing downstream processes and downstream techniques. This includes improving biogas production through downstream strategies. Innovation is also significant in the production and processing of enzymes, such as proteases, including techniques for purification and application industry. Production biochemistry important like sour citric and acid succinate also continues innovate in the fermentation process and techniques processing downstream (Mores et al., 2021; Mancini et al., 2020) In industry biopharmaceuticals, development antibody monoclonal (mAbs) involve processing downstream, with innovation going to manufacturing sustainable biomanufacturing and exploration technique bioseparation alternative like two phase system water (aqueous two-phase systems).

Digitalization of the Chain Supply and Adoption of Industry 4.0

Technology and the concept of Industry 4.0 play an important role in optimizing operation downstream, especially in chain supply (Mujahid Ghouri et al., 2021). Implementation technology reception information time real-time information receiving (RTIR) using Industry 4.0 technology in operation downstream can give an important outlook for the company and create a mark for the Customer. Capabilities, technology information, and digitalization support chain supply. The literature also highlights the importance of adopting system information systems (IS) for businesses to survive and improve performance in a competitive environment. Topics like the digital supply chain, IoT, blockchain, and analytics business are a growing area of research relevant to downstreaming.

Development of Bio-based Production

Sources indicate innovation in producing material chemicals and other products from non-fossil fuels. These include bioproduction of sour citric and acid succinate, which can originate from biomass. Transformation of CO2 and glycerol (which can originate from biomass like coconut palm oil) becomes material chemistry like ethylene and acid glycolic through electroreduction is also an innovation (Ramdin et al., 2021). The biopharmaceutical industry that produces mAbs from microorganisms or cell culture is also part of the production bio- bio-based. In addition, the analysis of techno-economics is also applied to production products

such as astaxanthin and protein-based plants, showing interest in utilizing source Power vegetables for product worth plus.

The following is Table 2.1 Innovation in downstream processes, which is general Can seen to be more comprehensive in reading the innovation process downstreaming:

No.	Author	Innovation in downstream processes
1	Gyamfi et al. (2023)	This Research Focuses On The Relationship Between the Economy and the Environment
2	Diem et al. (2022)	A New Methodology For Measuring Systemic Economics
3	Yuan et al. (2022)	The Study Uses Comprehensive Evaluation, Lotka-Vol
4	Appiah et al. (2021)	Identifying Factors Influencing Investment Intention
5	Bauer and Minceva (2021)	The Study Uses Comprehensive Evaluation, Lotka-Vol
6	Mores et al. (2021)	Innovation Of Environmentally Friendly Methods for Industry
7	Mujahid et al. (2021)	Downstream Innovation: SaaS For Real-time Customers
8	Ramdin et al. (2021)	Design of Post-Reduction Complex C2+ Product Separation
9	Saavedra et al. (2021)	Alternative Downstream PHA Recovery Optimization.
10	Zhang et al. (2021)	Wastewater Treatment Technology And Efficiency
11	Appiah et al. (2020)	Sources Do Not Discuss
12	Rifin et al. (2020)	Sources Do Not Discuss
13	Tabatabaei et al. (2020)	Biological Techniques For Purification And Improvement
14	Yetkin and Co?kun (2020)	Sources Do Not Discuss
15	Yuan et al. (2020)	Sources Do Not Discuss
16	Gimenes et al. (2019)	Aquatic Two-phase System (ATPS) Is Called A New Method
17	Mancini et al. (2019)	Sources Do Not Discuss
18	McNulty et al. (2019)	Plant-based Production Platform
19	Yang et al. (2019)	Innovations Include Chromatography, Filtration
20	Fu et al. (2018)	downstream company equity investment in upstream increases efficiency
21	Wang et al. (2016)	Downstream Feed-In Tariff policy: PV power plant subsidies drive the market.
22	Mazzanti et al. (2014)	Downstream emission intensity triggers upstream sectors to adopt eco-innovation to reduce their carbon footprint
23	Tran et al. (2013)	Adoption of alternative bioseparation techniques (MC, Pptn) improves bioproduct purification, complements chromatography
24	FAULÍ-OLLER et al. (2011)	Downstream mergers drive upstream R&D innovation, cost reduction
25	Buehler and Schmutzler (2008)	Downstream company investment reduces product transformation costs, improves process efficiency

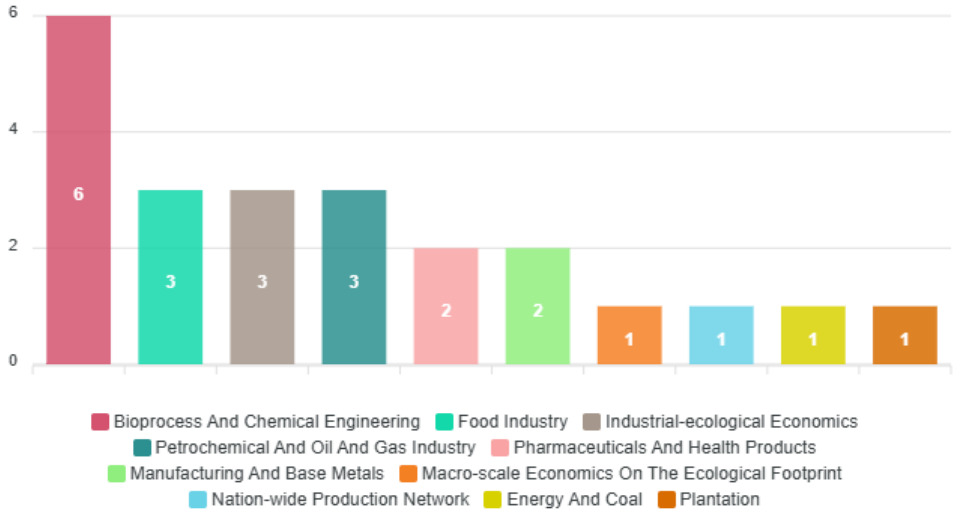
c) Cross-Sector and Regional Studies

Various studies in literature show practice and challenges downstream in various sectors and contexts, geographical:

Energy, Food, Oil and Gas, and Chemical Sector

Downstreaming is very relevant in the sector **energy** (biogas production (Tabatabaei et al., 2020), biofuel from coconut palm oil (Rifin et al., 2020), technology CO2 reduction (Ramdin et al., 2021; Mazzanti et al., 2015), **food** (processing coconut palm oil become product food like cooking oil, mitigation waste food in the chain supply downstream (Yetkin Özbük & Coşkun, 2020), bioproduction material addition food like sour citric (Mores et al., 2021), **oil and gas** (investment and strategy in the sector) downstream oil and gas, for example in Ghana (Appiah, Possumah, & Sanusi, 2021;(Appiah, Possumah, Ahmat, et al., 2021) and the adoption of technology in China, as well as **chemical** and **bio- based** (production biochemistry such as proteases (Gimenes et al., 2021), acids citric acid succinate, as well as conversion of CO2 to material chemistry. The biopharmaceutical sector (production of mAbs) is also an important industry sector with a focus on downstream. Next is Graph 2.2 Classification Journal Based on Downstream Sector. Can see below:

Graph 2.2 Classification Journal Based on Downstream Sector

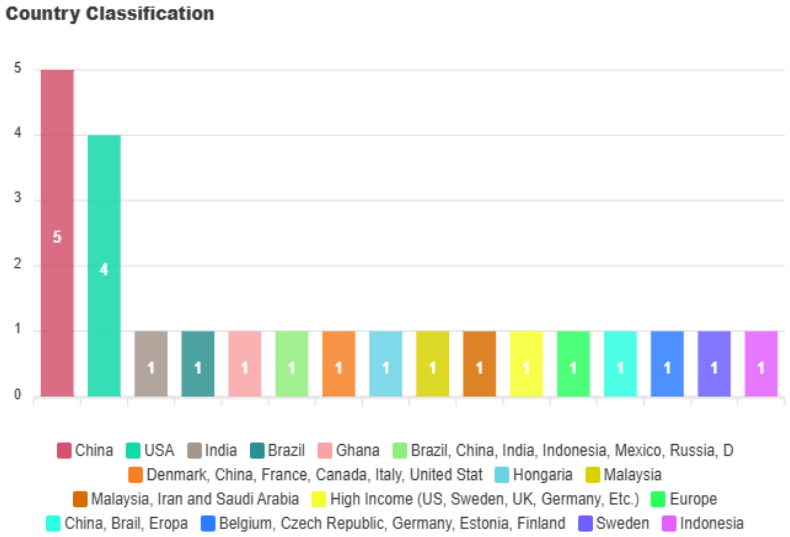


Source : journal data about downstream industry processed in the application Watase Uake research

Country and Regional Context

The study includes various countries and regions. In **China**, the focus is on coordinating the economy ecological industry in the Yangtze River Economic Belt shows effort sustainable downstreaming (Yuan et al., 2022; Zhang et al., 2021), as well as studies about IT capabilities in chain supply (Mujahid Ghouri et al., 2021) and adoption of RTIR in the sector oil and gas (Mujahid Ghouri et al., 2021). **Ghana** gives perspective from developing countries, analyzing factors that influence SME investment in the sector oil and gas downstream from the corner view strength industry, macro-environment, and RBV (Appiah, Possumah, & Sanusi, 2021). **Brazil** appears in context studies of bioproduction protease and as part of ecological analysis in E736 countries. **Indonesia** is a case in point, with attention big on the downstreaming sector of coconut palm oil. To increase market add, subtract, export raw materials, and take advantage of domestic markets, including efforts going to economic circular and green. **Developed** countries like **the US** and **Europe** are a source of innovative environment and bioprocess (Mazzanti et al., 2015), though policies sometimes cause challenges for export from developing countries (eg, palm oil from Indonesia). The **E7** group of countries (including Brazil, China, India, Indonesia, Mexico, Russia, Turkey) became object studies related connection globalization economy, consumption energy, and impact environment, which is relevant with context downstreaming in developing countries Other studies also cover countries and regions such as Ghana, Uganda, BRICS, and European countries. Other related innovation (Mazzanti et al., 2015; Tabatabaei et al., 2020). The following are journals that have been classified in country of place research by researchers in the form Chart 2.3 Classification of Countries of Place Study:

Chart 2.3 Classification of Countries of Place Study



Source : journal data about downstream industry processed in the application Watase Uake research

Review literature. This underlying runway theoretical For understand downstream innovation, identify various forms of innovation that occur, and present empirical evidence from diverse sectors and regions, to determine the basis for further analysis more carry on about opportunities, challenges, and implications of policy.

RESEARCH METHOD

This section explains the methodology used for conducting a comprehensive review literature about innovation in the downstream global industry, based on scientific articles that have been reviewed.

a) Method

Study: This adopted approach studies literature review (literature review. This method was chosen to synthesize and integrate findings from various studies to provide a comprehensive understanding about landscape innovation in downstream global industry, as well as identify opportunities, challenges, and directions for relevant policies based on existing empirical and theoretical.

Review done on articles indexed in the Scopus database, 3 in the range of time, year 2003 to 2023. Election period. This aims to catch the latest in literature about innovation and the downstream industry, especially with the emergence technology new technologies and changes in global policy. It needs to be noted that specific details about keyword search, query strategy, and selection process are the right start for producing gathering sources used in the review. This is not explained in a way explicit in the resources provided.

b) Criteria Inclusion

Articles scientific included in the review. This was chosen based on criteria inclusion as follows:
Studies that are explicit to study innovation in the context downstream industry (downstream processes/operations). Context downstream This covers transformation material raw or semi-finished products, becoming products worth plus high, and optimization operations and supply chains at the end stage.

Relevant studies with sectors of industry that become the focus of review, including, however, not limited to, energy, food, oil and gas, and chemicals.

The study includes analysis at the level company, industry, or macro (regional/country), relevant to global and cross-regional contexts.

Journals Scopus collected in accordance with the theme with downstream industry, as many as 100 journals, when deepened, executed criteria inclusion, 25 relevant journals remaining with downstream industry.

c) Analysis Thematic

Articles that met the criteria for inclusion were then analyzed using thematic analysis. The analysis process involves identification, coding, and categorization of patterns or themes the key that appear in literature. The main thing that becomes the focus of analysis is based on the framework conceptual research and includes::

Approach theory used to explain or analyze innovation in downstreaming, such as Resource-Based View (RBV), Industrial Ecology, and Techno-economic Analysis (TEA).

Identification forms emerging innovations in process and operation downstreaming, including innovation technology, processes, and digitalization, such as technology real-time information receiving - RTIR and the Industry 4.0 concept.

Review studies across sectors and regions, noting the sector industry studied, location, geographical studies (countries or regions such as China, Ghana, Brazil, Indonesia, as well as developed countries in the US and Europe and the context-specific study..

Identification challenges and opportunities associated with innovation downstreaming, which may appear from internal factors, micro-environment (industry), or macro-environment (economic, political, social, technological, environmental, legal). Available sources touch on challenges specific to the management of waste food, issues of sustainability in the industry, coconut palm oil, or technical issues in bioprocessing.

Collection recommendation is a policy in the literature. For pushing or supporting innovation in the downstream industry, including the policy, policy-related environment, and economy.

Through thematic analysis, research aims to give a structured description of existing knowledge, identify research gaps, and provide a strong foundation for discussion about policy implications. Specific process coding and development theme from gathering articles used for review. This is not explained in a way that Details are provided in the sources provided.

RESULT AND DISCUSSION

This section serves findings mainly from the review literature about innovation in downstream global industry, followed by with discussion deep about opportunities, challenges, and implications, policy based on synthesized evidence from articles scientifically reviewed.

a) Main Findings

Review literature to identify several themes mainly related to innovation in the context downstream industry:

Innovation Technology in Bioprocess and Related Sectors

Literature shows that innovative technology, including innovative biological and process, is very prominent in the downstream process, especially in the bioprocess sector (Tabatabaei et al., 2020). The study highlights innovation biological For increase biogas production and quality, describing two phase system aquatic (ATPS) as method new in downstream process For protease enzymes (Gimenes et al., 2021), and discuss paradigm changing manufacturing as well as role technology bioseparation alternative in processing downstream biopharmaceuticals (Tran et al., 2014). Although available resources No in a way specific compare domination innovation technology cross all type innovation (organization, marketing, etc.) or all relevant sectors (such as oil and gas in a way public outside context specific), findings from sector bioprocess in a way strong support presence significant innovation technology / biological in downstreaming. In the sector related to energy and chemistry, there is are focus on process innovation such as electroreduction of CO2 to produce C2 products, including downstream process modeling and separation. Process innovation is also seen in the industry of coconut palm oil, such as development factory without steam (steamless) and conversion of used cooking oil into biodiesel.

Digitalization for Efficiency and Real-time Decision Making

Digitalization, in particular the implementation of Industry 4.0 technology, has discovered support efficiency in operational and enabling taking decisions based on real-time information in the supply chain downstream. Studies empirical in a way explicit researching real-time information (RTIR) using Industry 4.0 technology in operation downstream in the sector retail, food & beverage (F&B), and accommodation. This study shows how RTIR is operated downstream to help the company not only in planning, but also in creating a mark for customers. Implementation technology such as SaaS (Software as a Service) from Industry 4.0

perspectives for RTIR are explored, linking them with the involvement customer (CE) (Mujahid Ghouri et al., 2021). This confirms the role of digitalization in optimizing processes and interactions at the downstream chain mark.

b) Opportunities Innovation

Review literature to identify several opportunities key for innovation in the push downstream industry:

Diversification Product Based on Biomass

There is an opportunity significant diversification product through the utilization of biomass and waste becomes a product worth plus high price. Examples identified in literature covering production sour succinate (SA) from material standard bio-based (Mancini et al., 2020) conversion oil used cooking oil into biodiesel, utilization product side agro-industry. For biogas production (Tabatabaei et al., 2020), as well as potential waste, congested coconut, and valuable palm oil, tall.

Integration of Bioeconomy and Circular Economy

Downstream innovation the more closely related close with the principle of bioeconomics and the economic circular. Literature, in a way, explicitly discusses Circular Economy in the Food and Beverage Industry, including the management of waste and recycling plastic (Mancini et al., 2020). The concept of biorefinery for production material chemistry, bio-bio-bio-bio-bio-bio-based, and utilization of waste in system digestion, anaerobic for biogas, is a manifestation of integration. The study also touched on the network symbiosis industry as part of the economic cycle.

Adaptation Technology Low Carbon and Renewable Energy

Adoption and development of technology that reduces carbon and utilizes renewable energy is an important opportunity. Biogas and biomethane production from biomass and biodiesel production from oil used cooking oil. Is this example real? In addition, research about the electroreduction of CO2 for producing material chemistry value shows a direction of innovation in utilizing carbon. Literature is too general in discussing eco-innovation, which aims to reduce CO2 emissions (Mazzanti et al., 2015).

c) Challenges: Implementation Innovation

Implementation innovation in the downstream industry faces various challenges:

Costs, Obstacles, Regulations, and Limitations

Challenge-related investment technology covers higher expectations , analysis, valuation, traditional, weak procurement, non-compliance technology, and affects negatively on existing product /service, and management share information (Mujahid Ghouri et al., 2021). In the sector of recycling, repeated plastic, limitations on downstream technology become obstacles, together with a supply material standard that is not quality from upstream, resulting in a lack of segregation of waste. Collection of oil used for cooking oil for biodiesel also faces challenges like non-existent regulation and competition from the private sector. Regulatory environment in export markets (such as the Resolution Parliament Europe related to CPO import) can become an obstacle to significant regulation (Rifin et al., 2020).

The Gap or Imbalance between Upstream and Downstream Innovation

Literature implies that coordination between stages upstream and downstream is very important, and imbalance can become a challenge. In the industry, recycling repeat plastic, limitations on the side downstream (technology) and upstream (supply) quality, in a way, simultaneously hinder the industry. Another review discusses the integration sector upstream/ downstream sectors in the context innovation environment. Study of integration vertical also shows how the decision investment downstream can be influenced by the structure upstream. This highlights the need for an integrated approach to push innovation throughout the chain.

d) Discussion Implications Policy

Findings from the review literature. This own implication is important for the formulation of supportive policies for innovation in the downstream industry:

Importance of Synergy Between Industrial Policy, Environment, and Innovation

Various sources emphasize the crucial role of policy in pushing innovation and downstreaming sustainability (Mazzanti et al., 2015). Policy government (such as the National Economic Recovery program and the Job Creation Law in Indonesia) can become a response to the challenge. Support policy required for

accompanying promotion technology, such as repair management, collection of waste on the side introduction technology, and recycling. Policies on oil and gas have a significant influence to intention investment intentions. A policy that effective environment, such as implementing a cost-effective environment and controlling the source of Power strategically, is considered important for a sustainable environment in the context of a globalized economy. This shows that effective policy must be naturally synergistic, integrating objective industry, environment, and innovation.

The need for Support Specific
Research and Development (R&D) Incentives

Collaboration between industry and center research /university is very important for innovation, technically possible , not owned by the company internally (PAGE, 2023). Intensity R&D expenditure was also found to influence coordination industrial-ecology (Yuan et al., 2022), showing that policy needs push R&D investment.

Support towards Micro , Small and Medium Enterprises (MSMEs)

There is a need for support for MSMEs to improve their contribution to the digital economy and reduce the gap in technology in the implementation of Industry 4.0. Policies need to facilitate MSME access to technology downstream and real-time information.

Investment Infrastructure Downstream Technology

Along with promoting innovative technology, policy must consider support for repair infrastructure downstream. Examples in industry recycle repeated plastic show that limitations of technology downstream are an obstacle (PAGE, 2023). In addition, the policy needs to support the adjustment industry in exploiting the domestic market and strengthening the downstream sector, which may need investment infrastructure.

In general, overall, results review shows that innovation in downstream global industry is driven by progress technology and digitalization, offering opportunities in utilization of biomass and economic model integration, but faced with challenges, costs, regulations, and complexity in interconnection upstream-downstream. Answer challenges and take advantage of opportunities. This needs a framework, coordinated policies, and targeted support, especially for R&D, SMEs, and infrastructure downstream.

CONCLUSION

Review literature. This analyzes role innovation in downstream global industry, identifying opportunities, challenges, and implications of policy. Based on the synthesis of literature findings, some main conclusions can be drawn:

a) **Innovation is a booster of the main effectiveness downstream in sectors global industry.**
Various studies show innovative technology (such as bioprocesses and industrial processes) and digital (such as RTIR in Industry 4.0) enhance efficiency, creating mark add, and diversifying product downstream. Innovation is a catalyst for movement and improvement value at the downstream stage.

b) **Supporting policies and ecosystems for integrated innovation is crucial for facing structural and technological challenges.**

Downstream, based on innovation, faces challenge high cost and limited human resources. Policy government, including support for R&D incentives, MSME assistance in adopting technology, and investment infrastructure, as well as synergy policy, industry, environment, and innovation, are very much needed. Innovation downstream develops optimally in an integrated ecosystem with supportive policies.

c) **Further study is required for exploring downstream strategies based on adaptive innovation in the context of local and global dynamics.**

Remember diversity sectoral and geographical literature and the influence of global dynamics, research is deeply required. Future study areas can cover mechanism adaptation innovation in various contexts, bridging the upstream-downstream gap, handling challenge costs /HR, and roles innovation in resilience and the economy circular chain supply downstream.

As a cover, innovation transforms downstream global industry, the effectiveness of which depends on the policy strategy and ecosystem integration. Future studies are crucial for guiding innovation strategy adaptive downstreaming.

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NO	AUTHOR	CONTEXT AREA OF STUDY	COUNTRY	THEORETICAL FOUNDATION	Industrial Sector	Innovation in downstream processes	Industrial Sector	Opportunities and Challenges	Key For Increasing Power competitive industry
1	Gyamfi et al. (2023)	E7 Economy	Brazil, China, India, Indonesia, Mexico, Russia, D	Economic Growth and Environmental Degradation	Macro-scale Economics On The Ecological Footprint	This Research Focuses On The Relationship Between Economy and Environment	refers to economic relations between E7 countries	E7 countries face environmental challenges, but have opportunities in renewable energy and sustainable agriculture.	E7 countries need to implement strict regulations, green taxes and alternative energy investments for economic sustainability.
2	Diem et al. (2022)	Supply Chain Management	Hungary	Network Science	Nationwide Production Network	A New Methodology For Measuring Systemic Economics	reduce systemic risk and increase economic resilience	Challenge Supply chain vulnerabilities are difficult to assess; Opportunity Quantify a company's systemic risk with granular data.	Critical enterprise monitoring, risk mitigation through redundancy, and network transparency are necessary for
3	Yuan et al. (2022)	Yangtze River Economic Belt (YREB)	China	Industrial-ecological Economy	Industrial-ecological Economics	The Study Uses Comprehensive Evaluation, Lotka-Vol	balanced development between economy and ecology	Opportunities are YREB's green growth and development	focus on coordination, green transformation, and R&D

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NO	AUTHOR	CONTEXT AREA OF STUDY	COUNTRY	THEORETICAL FOUNDATION	Industrial Sector	Innovation in downstream processes	Industrial Sector	Opportunities and Challenges	Key For Increasing Power competitive industry
								poles; challenges are pollution and regional imbalances.	
4	Appiah et al. (2021)	Conducted In The Downstream Oil And Gas Industry In Ghana	India	Integrates Resource-Based View (RBV) Theory, Theory Of Constraints, And Theory Of Strategic Positioning	Petrochemical And Oil And Gas Industry	Identifying Factors Influencing Investment Intention	The journal found that resource-based strategies a	Identifying enablers offers innovation opportunities for competitiveness, addressing the challenges of resource constraints and stringent policies.	implies better government support policies
5	Bauer and Minceva (2021)	Techno-economic analysis of plant platforms for antimicrobial protein production with a focus on improving food safety.	USA	Techno-economic Analysis - TEA	Industrial-ecological Economics	The Study Uses Comprehensive Evaluation, Lotka-Vol	Competitive Production Cost	Plant-based platforms have the potential to produce cheap AMP, but the challenges are upstream-downstream costs and	Policy implications support the development of new production platforms to improve food security and reduce the

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NO	AUTHOR	CONTEXT AREA OF STUDY	COUNTRY	THEORETICAL FOUNDATION	Industrial Sector	Innovation in downstream processes	Industrial Sector	Opportunities and Challenges	Key For Increasing Power competitive industry
								market acceptance.	economic burden of disease.
6	Mores et al. (2021)	Industrial Biotechnology, Bioprocess, Separation and Purification (Downstream Processing), Fermentation.	China, Brazil, Europe	Microbial Fermentation And Downstream Processing Separation Techniques	Pharmaceuticals And Health Products	Innovation Of Environmentally Friendly Method For Industry	efficiency of sustainable bioproduction of citric	Opportunities include alternative raw materials and new technologies, but challenges include high costs and complexity of downstream processes.	Policies are needed to support sustainable downstream research, precipitation waste management, and renewable raw materials.
7	Mujahid et al. (2021)	Empirical study reception Industry 4.0 real-time information on operations downstream retail , F&B, and accommodation .	Malaysia	Theory of Information Sharing (ToIS)	Food Industry	Downstream Innovation: SaaS For Real-time Customers	Industry 4.0 SaaS adoption for RTIR customers	Opportunities for adoption of Industry 4.0 technologies (SaaS, RTIR) increase SMEs' CE, but implementation challenges are	Encourage technology investment to enhance the competitiveness of digital SMEs.

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NO	AUTHOR	CONTEXT AREA OF STUDY	COUNTRY	THEORETICAL FOUNDATION	Industrial Sector	Innovation in downstream processes	Industrial Sector	Opportunities and Challenges	Key For Increasing Power competitive industry
								not yet established.	
8	Ramdin et al. (2021)	Electroreduction of CO2/CO to C2 product , modeling , separation downstream , integration systems , and analysis economy .	USA	Separation And Purification Of CO2/CO Electroreduction Products	Bioprocess And Chemical Engineering	Design Of Post-reduction Complex C2+ Product Separation	reduction of electrolyzer , electricity and system	Opportunities lie in industry integration, challenges include high costs and scale-up	requires incentives and regulations
9	Saavedra et al. (2021)	This research focuses on the downstream processing of PHA as a bio-based material to replace conventional oil-based plastics.	Europe	Life Cycle Assessment (LCA) And Life Cycle Costing (LCC)	Bioprocess And Chemical Engineering	Alternative Downstream PHA Recovery Optimization.	Process optimization and biorefinery integration	Integration of PHA processing in biorefinery with green solvents faces challenges of high energy, cost, and lack of data.	Integration of LCA into design supports a sustainable bioeconomy, informs bioplastic value chain policies, and encourages

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NO	AUTHOR	CONTEXT AREA OF STUDY	COUNTRY	THEORETICAL FOUNDATION	Industrial Sector	Innovation in downstream processes	Industrial Sector	Opportunities and Challenges	Key For Increasing Power competitive industry
									industrial symbiosis.
10	Zhang et al. (2021)	Yangtze River Economic Belt (YREB)	China	Sustainable Development	Industrial-ecological Economics	Wastewater Treatment Technology And Efficiency	sustainable decoupling of economic growth	YREB has the potential to improve water efficiency for sustainable development, but faces challenges of water scarcity and pollution.	Policy implications include provincial targets, water-saving technologies, industrial adjustment, urbanization, and virtual water trading for SD.
11	Appiah et al. (2020)	Downstream oil and gas sector in Ghana	Ghana	Porter's Five Forces Model	Petrochemical And Oil And Gas Industry	Sources Do Not Discuss	facilitating SME participation in the downstream s	The opportunities include revenue and services, while the challenges come from competition	Policies must consider local industry and regulations to encourage SME participation in oil and gas

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NO	AUTHOR	CONTEXT AREA OF STUDY	COUNTRY	THEORETICAL FOUNDATION	Industrial Sector	Innovation in downstream processes	Industrial Sector	Opportunities and Challenges	Key For Increasing Power competitive industry
								and downstream oil and gas market forces.	downstreaming .
12	Rifin et al. (2020)	Evaluation of the impact of restrictions on Indonesian palm oil exports to the European Union, especially the Netherlands as the main and connecting market.	Indonesia	General Equilibrium Model	Plantation	Sources Do Not Discuss	Downstream investment and product diversificatio n	Opportunity exist in the domestic market and sector downstream , the challenge decline demand and price term short	Policy must support adjustment industry to exploit the domestic market and strengthen sector downstream .
13	Tabatabae i et al. (2020)	Biological innovation improves biogas production and quality from biomass and waste through anaerobic digestion.	Malaysia, Iran and Saudi Arabia	Anaerobic Digestion (AD) And Microbial Biotechnology	Bioprocess And Chemical Engineering	Biological Techniques For Purification And Improvement	Reducing costs and increasing efficiency downst	Opportunities include increasing value and sustainability, while the main challenges are upscaling, high costs, and lack of data.	Policy implications include R&D support, economic incentives, and strict regulations for the adoption of biogas

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NO	AUTHOR	CONTEXT AREA OF STUDY	COUNTRY	THEORETICAL FOUNDATION	Industrial Sector	Innovation in downstream processes	Industrial Sector	Opportunities and Challenges	Key For Increasing Power competitive industry
									biological innovations.
14	Yetkin and Co?kun (2020)	Factors Causing Food Waste In Downstream Entities Of The Food Supply Chain	High Income (US, Sweden, UK, Germany, Etc.)	Organizational Theory	Food Industry	Sources Do Not Discuss	Sources not discussed	Reducing downstream food waste is a huge sustainability opportunity, but is constrained by complexity between entities.	Downstream policies should target downstream entity-specific waste factors, such as donation regulations, standards, and public awareness.
15	Yuan et al. (2020)	China's Downstream Oil Supply Chain Security Disrupted As Crude Imports Hit Snags	China	Quantitative Assessment And System Simulation Applied To Supply Chain Analysis	Petrochemical And Oil And Gas Industry	Sources Do Not Discuss	Sources did not discuss the key to increasing industry	The challenge of downstreaming is that supply is vulnerable to imports, the opportunity is to strengthen it through	Downstream impact on increasing reserves , infrastructure , industrial reform , and diversification energy for

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NO	AUTHOR	CONTEXT AREA OF STUDY	COUNTRY	THEORETICAL FOUNDATION	Industrial Sector	Innovation in downstream processes	Industrial Sector	Opportunities and Challenges	Key For Increasing Power competitive industry
								quantitative identification of weak points.	resilience supply
16	Gimenes et al. (2019)	General description of characteristics, production, downstream processes, and industrial applications of protease enzymes	Brazil	Principles Of Enzymology, Microbiology (related To Fermentation For Production), And Biochemical/Separation Engineering (related To Downstream Processes)	Bioprocess And Chemical Engineering	Aquatic Two-phase System (ATPS) Is Called A New Method	The sources did not discuss the key to the industry	The global protease market opportunity is large, but the main challenges for downstreaming are high costs (70-90% of total costs) and efficiency.	Required policies that encourage research and investment in downstream strategies economical cost For sustainability industry .
17	Mancini et al. (2019)	Production of succinic acid (SA) as an important biological building block from renewable biomass via biorefinery, focusing on	Denmark, China, France, Canada, Italy, United Stat	Biorefinery Processes	Bioprocess And Chemical Engineering	Sources Do Not Discuss	Integrated biorefinery key to competitive succinic	The SA biomass market is growing rapidly, but challenges include high downstream costs and a lack of large-scale	Source support research and development For production chemistry sustainable bio- based even though No discuss

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NO	AUTHOR	CONTEXT AREA OF STUDY	COUNTRY	THEORETICAL FOUNDATION	Industrial Sector	Innovation in downstream processes	Industrial Sector	Opportunities and Challenges	Key For Increasing Power competitive industry
		downstream techniques						standardized technology.	implications policy .
18	McNulty et al. (2019)	Techno-economic analysis of plant platforms for antimicrobial protein production to improve food safety.	USA	Techno-economic Analysis - TEA	Food Industry	Plant-based Production Platform	reduce production costs	Opportunities: AMP production costs are competitive; Challenges: high initial costs and strict regulations for new products.	Policies that make it easier agreement regulation support downstream novel based product plant like AMP
19	Yang et al. (2019)	Economic analysis of antibody biopharmaceutical production	USA	Economic Analysis	Bioprocess And Chemical Engineering	Innovations Include Chromatography, Filtration, An	Reduce costs, increase productivity and flexibility	Downstreaming has the potential to reduce costs and increase efficiency, but the challenge is that upstream and downstream	Downstream have a chance forward , but implications policy specific regarding the FDA's operational mode yet discussed .

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NO	AUTHOR	CONTEXT AREA OF STUDY	COUNTRY	THEORETICAL FOUNDATION	Industrial Sector	Innovation in downstream processes	Industrial Sector	Opportunities and Challenges	Key For Increasing Power competitive industry
								costs are still high.	
20	Fu et al. (2018)	supply chain management	China	Economic Analysis	Manufacturing And Base Metals	downstream company equity investment in upstream, increase efficiency	power dynamics in supply chains	Downstream investments increase productivity, but challenges arise from market structure and cost efficiency.	The source did not discuss specific policy implications for downstreaming.
21	Wang et al. (2016)	Energy Economics and Policy	China	Economic Analysis	Energy And Coal	Downstream Feed-In Tariff policy: PV power plant subsidies drive the market.	renewable energy, especially solar PV	The huge opportunities of clean energy and FIT face challenges of cost, financing, capacity and technology.	Downstream policies boost domestic demand and manufacturing performance, essential for downstreaming of the PV industry.

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NO	AUTHOR	CONTEXT AREA OF STUDY	COUNTRY	THEORETICAL FOUNDATION	Industrial Sector	Innovation in downstream processes	Industrial Sector	Opportunities and Challenges	Key For Increasing Power competitive industry
22	Mazzanti et al. (2014)	environment and sustainability	Belgium, Czech Republic, Germany, Estonia, Finland	Porter Hypothesis (PH)	Manufacturing And Base Metals	Downstream emission intensity triggers upstream sectors to adopt eco-innovation to reduce carbon footprint	technological and organizational innovation	Downstreaming opportunities are driven by policy and market expectations; the main challenge is policy integration across sectors	Downstreaming policies must be sector/region specific and integrate value chains coherently.
23	Tran et al. (2013)	adoption and evaluation technique bioseparation alternative For processing downstream scale big in biomanufacturing	Sweden	Technology Adoption	Pharmaceuticals And Health Products	Adoption of alternative bioseparation techniques (MC, Pptn) improves bioproduct purification, complements chromatography	reduce drug costs and increase productivity	The opportunities are reducing costs and increasing productivity, the challenges are technical, economic, logistical, regulatory barriers.	Support the gradual adoption of alternative techniques and technological improvements to increase effectiveness and efficiency.

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NO	AUTHOR	CONTEXT AREA OF STUDY	COUNTRY	THEORETICAL FOUNDATION	Industrial Sector	Innovation in downstream processes	Industrial Sector	Opportunities and Challenges	Key For Increasing Power competitive industry
24	FAULÍ-OLLER et al. (2011)	industrial economics or applied microeconomics	Spain	Industrial Organization Theory	General Industrial Economic Sector	Downstream mergers drive upstream R&D innovation, cost reduction	Downstream mergers drive upstream R&D, thereby low	Downstream mergers drive upstream R&D, thereby lowering production costs and increasing competitiveness.	Antitrust authorities should consider the positive impacts of downstream mergers on upstream R&D for optimal policy.
25	Buehler and Schmutzler (2008)	industrial economy		Industrial Organization Theory	General Industrial Economic Sector	Downstream company investment reduces product transformation costs, improves process efficiency	increased efficiency through investment	The research opportunity is to understand the motives for vertical integration, the challenge is to model complex endogenous decision interactions.	Downstream and antitrust policies must take into account vertical integration to increase investment and pressure competitors.