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A LOW-CARBON INDUSTRIAL STRATEGY FOR VIETNAM

CONTENTS

Executive Summary

The world economy is transitioning towards cleaner and less carbon-intensive forms of growth. Demand for low-carbon products is expected to grow at 11% per year, between 2020 and 2050, and could accelerate as the world enters a zero-carbon paradigm. Unprecedented demand for green technology solutions is likely to emerge by the second half of the century as countries face a hard deadline to limit global temperature rise. Regardless of individual country efforts to limit emissions, global demand for green technologies will continue to experience robust growth.

Countries that get a head start in developing low-carbon technologies today will be the major economies of tomorrow. The 'green race' is the idea that economies can strategically position themselves to take advantage of growing low-carbon markets and succeed in capturing global market share. History shows it is prudent to start priming domestic industry early; in 2000, South Korea was in a similar position to Vietnam today and only exported 3% of global low-carbon exports. In 2008 it announced a green growth strategy and in a span of ten years, managed to become one of the global leaders in low-carbon products, exporting nearly 10% of global market share. There is still time for other countries to replicate this experience.

For Vietnam to be competitive in the global low-carbon economy, it requires a robust green industrial strategy to consolidate upon promising opportunities, and this starts with identifying priority sectors. A low-carbon industrial strategy can help pivot Vietnam's economy towards increasingly profitable sectors. Industrial policies can include direct subsidies for innovation and manufacturing, cluster-based policies that reduce costs of key inputs, improved information dissemination through coordinating and planning agencies, and public procurement to catalyse the market for early stage industries.

The right mix of policies will depend on the key market failures which constrain growth today.

Our analysis highlights that energy storage, smart grids, photovoltaics and wind power are key opportunities for Vietnam. Vietnam is well placed to participate in the battery industry supply chain, as a result of its natural endowments of bauxite and titanium. It is endowed with the third largest reserve of bauxite globally. Incentives that create a local electric vehicle market can attract foreign investment and local manufacturing, helping Vietnam gradually diversify away from minerals extraction.

By developing these sectors Vietnam can build domestic industries that position it for growth, through increased productivity, diversified sources of revenue and potentially developing export markets which can form part of an international supply chain.

I**n terms of smart grids, Vietnam's reputation and prowess as an electronics hub has positioned it well in the 'green race'.** Smart grid technology is closely linked to electronics and Vietnam is already competitive in various components that are useful for smart grids. With a long-term perspective and support from new planning agencies, smart grids could be a strength. Crucially, they are required for large scale integration of renewable energy and therefore public procurement processes to improve grid stability could be one route to supporting local industry. Innovation challenge funds and research and development (R&D) collaboration can help to create an enabling environment for private sector activity.

Renewable energy technologies such as wind and solar are promising markets for Vietnam both in terms of manufacturing and local deployment. Photovoltaic cell manufacturing already happens at scale in Vietnam, although a large part of this can be attributed to foreign companies. Ensuring technical transfers benefit domestic players is a priority, coupled with encouraging a domestic market for solar power that prioritises local innovative companies. Public procurement of wind power along Vietnam's long coastline can also help to build a domestic industry. Similar to solar PV, wind manufacturing in Vietnam is dominated by foreign companies.

Policies to encourage technology transfer, such as the creation of knowledge hubs through collaborative R&D funding, can ensure positive long-term impacts from inward foreign direct investment (FDI). The existence of geographical economic clusters highlights the positive impact that an existing supply chain can have in attracting investment and business activity into nearby economies. Vietnam is in close proximity to clean economy leaders such as South Korea and Japan. To increase positive spill overs from these economies, Vietnam can encourage technology transfer through conventional mechanisms, collaborative R&D with foreign organisations, joint ventures and technology licensing; and more unconventional mechanisms such as foreign R&D and company acquisition. Vietnam has an opportunity to accelerate the green industrial transition through neighbours specialised in low-carbon innovation.

Why develop a low-carbon industrial strategy?

THE GLOBAL RACE TO CAPTURE MARKET GROWTH OPPORTUNITIES IN THE LOW-CARBON TRANSITION HAS BEGUN

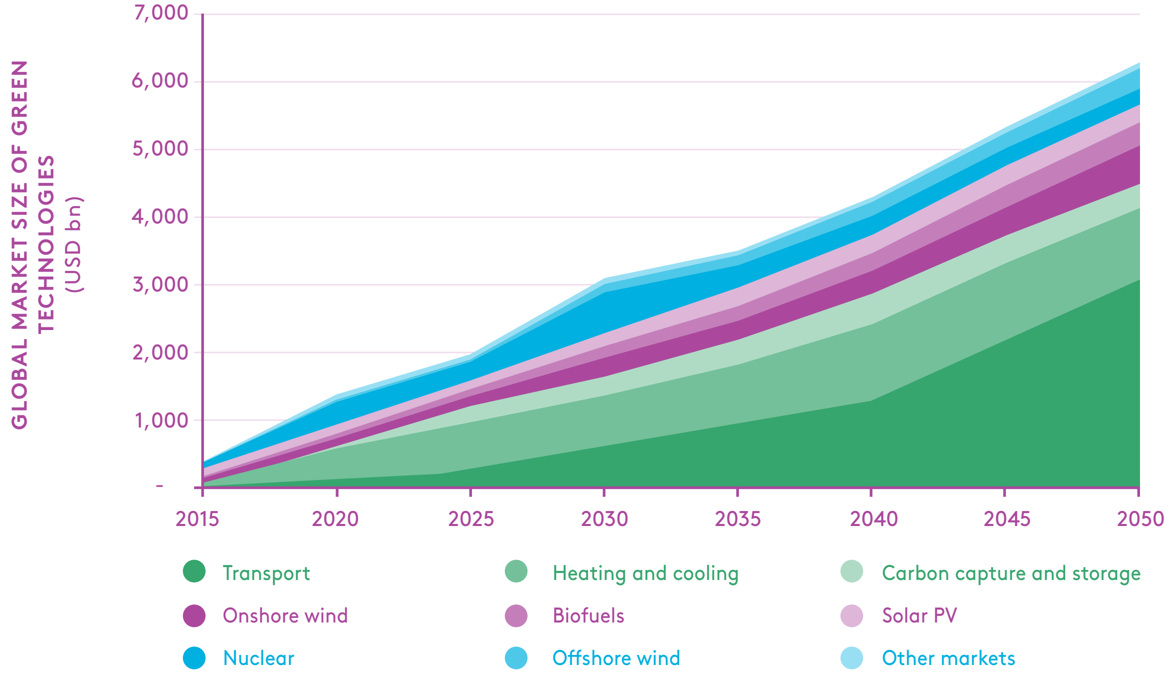
> **We are on the cusp of a new economic era: one where growth is driven by the interaction between rapid technological innovation, sustainable infrastructure investment, and increased resource productivity. This is the only growth story of the 21st century. It will result in efficient, liveable cities; low-carbon, smart and resilient infrastructure; and the restoration of degraded lands while protecting valuable forests. We can have growth that is strong, sustainable, balanced, and inclusive[1].**

The global economy is embracing low-carbon growth. A recent report by the New Climate Economy finds that the next 10-15 years represent a 'use it or lose it' period in economic history, which will see US$90 trillion invested in infrastructure globally by 2030[2]. Ensuring this infrastructure is green is critical to meeting climate and sustainable development goals. But while we're used to thinking that ambitious action towards green growth will come at a cost, the opposite is in fact true. New Climate Economy finds that bold climate action could deliver US$26 trillion in additional value to the global economy by 2030[3]. In other words, green growth is not only important for achieving environmental and social outcomes, it is also the pathway of choice for strong and sustained economic growth.

Developing economies are well placed to take advantage of large anticipated growth in the demand for low-carbon technologies. Meeting the explosion in infrastructure needs will require the production of technologies, products and services. Countries that get a head start in developing low-carbon technologies and manufacturing hubs today will be the major economies of tomorrow. They will help lead the global transition towards clean and sustainable industrial growth. Much like the last wave of globalisation, there will once again be clear first-mover advantage.

The impetus for greener growth is being felt by more and more countries, as environmental degradation, climate change issues and social inequality become increasingly pressing. The carbon-intensive pathway to industrialisation, which has lifted so many countries from developing to developed economies, is no longer seen as the only pathway to achieving development goals. Instead, low-carbon development is increasingly understood to be the best option for maximising economic, environmental and social outcomes. This shift is encouraging and accelerating the global demand for low-carbon technologies. Figure 1 demonstrates how the global demand for low-carbon technologies and services is predicted to grow rapidly over the next 30 years.

FIGURE 1. THE MARKET SIZE FOR LOW-CARBON TECHNOLOGIES WILL CONTINUE TO RAPIDLY EXPAND

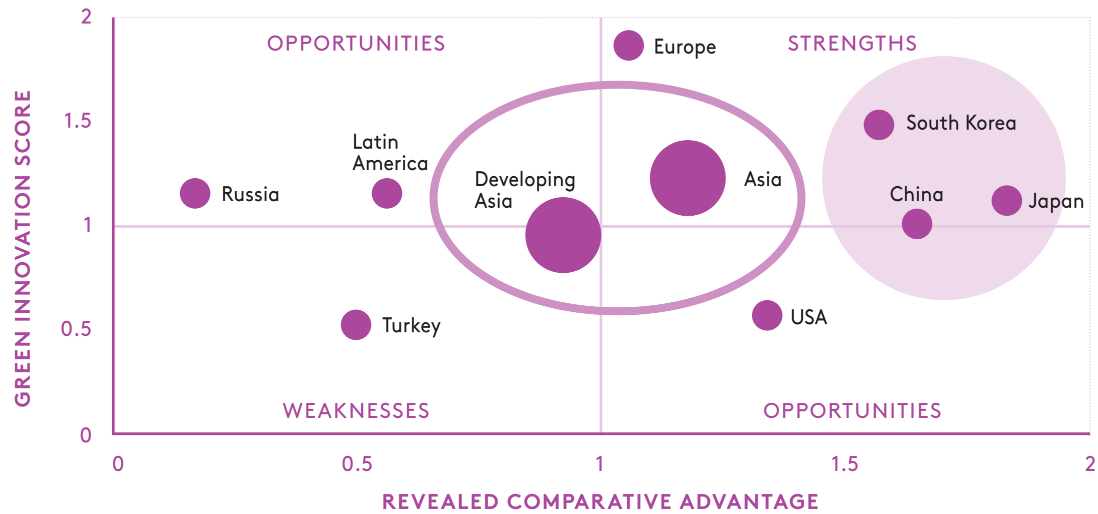


Note: not all low-carbon markets are included, so the estimates for global demand will underestimate expected future market size; Other markets includes buildings, industry, tidal and hydrogen. Source: Vivid Economics, IEA ETP

For countries who position themselves to leverage their latent strengths in green technology innovation or production, this rapid growth in demand for low-carbon technologies signals an economic boom.

The winners will be those countries who position themselves to corner global market share in researching, designing, manufacturing or servicing low-carbon technologies and industries. Figure 2 shows how Asia is clearly ahead of the game globally when it comes to low-carbon goods and services.

FIGURE 2. ASIAN ECONOMIES HAVE A CLEAR STRENGTH IN LOW-CARBON TECHNOLOGIES, WITH DEVELOPING ASIA ON THE CUSP OF COMPETITIVENESS



Note: Developing Asia includes all Asian economies except Japan, South Korea and Taiwan. GIS is calculated using patents filed between 2009 and 2013; RCA is calculated using average RCA between 2008 and 2012. Source: UN COMTRADE 2012; PATSTAT 2013; Srivastav, Fankhauser and Kazaglis (2018).

Developing Asia is on the cusp of being globally competitive in low-carbon sectors. For developing Asia, a combination of natural resources, an increasingly educated workforce, established regional supply chains, and low cost manufacturing capabilities that can be expanded or pivoted towards clean technologies, signals potential to be the engine room of a new green industrial revolution. In this new 'green race'[4], many developing Asian countries already demonstrate clear latent opportunities for clean technologies and industries that can sustain and accelerate their economic growth as the world moves to decarbonise.

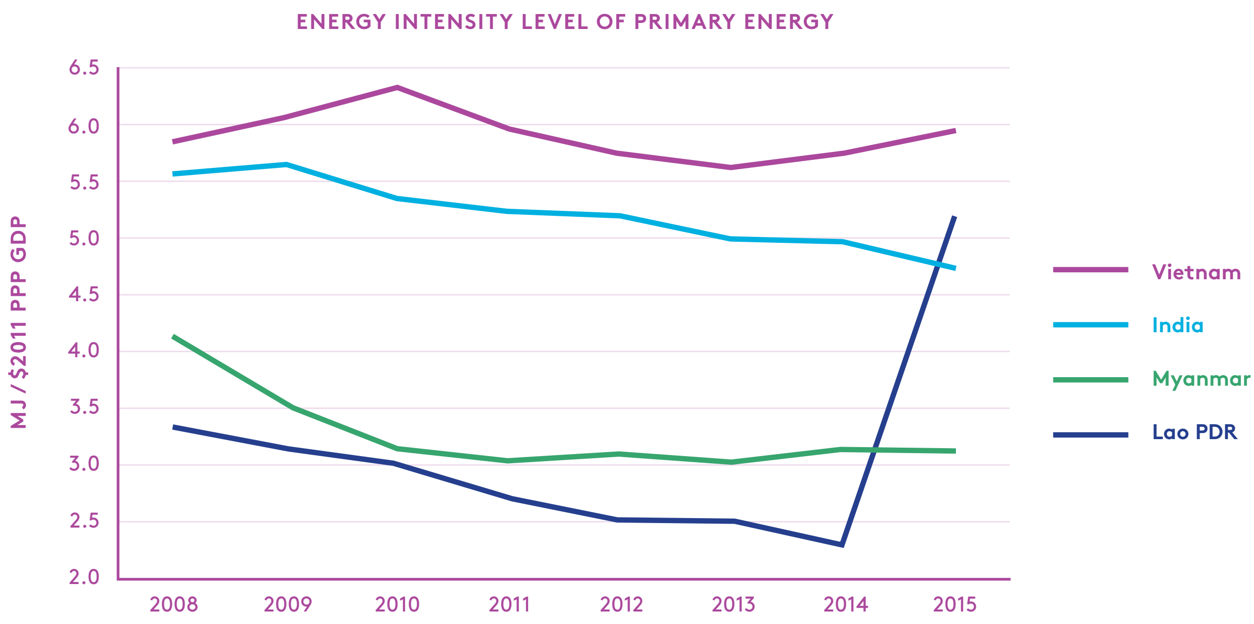
VIETNAM HAS A STRONG ENABLING POLICY ENVIRONMENT FOR GREEN GROWTH, BUT MUCH IS AT RISK IF THESE POLICIES ARE POORLY IMPLEMENTED

Vietnam stands at an inflection point, primed to take advantage of strong policies and human and natural capital to build its competitive advantage in a low-carbon economy.

A low-carbon approach is necessary to maintain the high economic growth Vietnam has experienced in recent years. It is evident that Vietnam's economy is growing fast. Gross Domestic Product (GDP) has increased from US$33.6 billion in 2000 to US$223.8 billion in 2017. However, future growth rates are threatened by surging energy demand, which doubled in the last decade[5] and is forecast to increase by 92% from 2020 to 2035[6].

Figure 3 demonstrates Vietnam's high energy intensity ratio, meaning that more energy is needed to produce one unit of economic output when compared to its neighbouring countries. Vietnam's energy intensity in supply and demand places costs on business (consuming energy) and the government (who must upgrade their energy infrastructure). A low-carbon approach can reduce these costs and help to ensure growth is maintained at current levels.

FIGURE 3. VIETNAM IS CURRENTLY USING MORE ENERGY THAN NEIGHBOURING COUNTRIES TO PRODUCE ONE UNIT OF ECONOMIC OUTPUT



Source: The World Bank, Energy intensity level of primary energy (MJ/$2011 PPP GDP)

Policies seeking sustainable and climate-resilient growth recognise that Vietnam must shape a low-carbon development trajectory. The guiding strategy for Vietnam, the National Socio-Economic Development Strategy (2011-2020)[7], states that development should be sustainable and climate change resilient. It sets three strategic tasks: reducing greenhouse gas emissions intensity of the economy and promoting renewable energy; 'green industrialisation' based on environmentally friendly structures, technologies and equipment; and greening lifestyles and promoting sustainable consumption[8]. Solutions to achieving these include improving the effectiveness and efficiency of energy use, changing the fuel structure in industry and transport (including use of clean energy, development of renewable energy, and building a roadmap to phase out fossil fuel subsidies) and increasing the proportion of new and renewable energy sources in the nation's energy production and consumption[9]. It targets electricity access to most rural households by 2020[10,11] whilst also aiming to achieve medium-to-high income status by 2050[12].

A low-carbon industrial strategy aligns with Vietnam's goals to improve its competitiveness in high value industries. The country has a 2020 goal to increase the value of high tech and green tech products to almost half of GDP[13]. It is estimated that domestic production of renewable energy technologies will be sufficient for both domestic consumption and export by 2050[14].

Vietnam stands to gain substantially if these policies are realised. In particular, higher renewable energy deployment and energy efficiency improvements will help Vietnam reduce the costs of meeting their growing energy demand, while also improving energy security. By some estimates, savings of over US$23 billion to 2030 are predicted from a renewables-led pathway, quadrupling the renewable energy generation capacity in the same period[15]. Vietnam is also well placed to further develop its workforce to one that is more resilient, knowledge-based and higher skilled. This outcome is a core objective of Industry 4.0 and the Socio-economic Development Plan, which has targets to increase the percentage of training in certified courses, decrease the percentage of labour force in Agriculture and increase the percentage in industry and services[16].

However, historical dependency on coal is expected to continue. Under current plans, the country will continue to increase its coal imports to meet rising energy demand, cementing its position as a net importer[17]. It is estimated that by 2025 coal will provide approximately 50% of the installed power capacity[18]. In order to meet this demand coal imports are expected to increase eightfold by 2030, to an estimated 100 million tons from today's 12 million tons[19].

This dependence threatens the multiple government objectives relating to sustainable growth. Reliance on fossil fuel imports is at odds with Vietnam's energy security, economic resilience and green technology development goals. Further, it will put pressure on Vietnam's macroeconomic position, which could lead to a devalued currency, inflation, and pushing its public debt uncomfortably close to its publicly mandated target[20,21]. As one of the world's most vulnerable countries to the impacts of climate change, current activity also poses a material risk to the country's future[22].

Vietnam is a country with much to gain from green growth, but may be at risk if it fails to fully realise the benefits of economic growth, energy security, labour force upskilling and climate resilience that a green industrial strategy can deliver. Now is the right time for Vietnam to fully embrace the many opportunities that low-carbon development can deliver.

VIETNAM CAN GAIN FROM ADOPTING A LOW-CARBON INDUSTRIAL STRATEGY

A low-carbon industrial strategy can help realign Vietnam's economy towards increasingly profitable sectors. Due to global decarbonisation efforts, low-carbon technologies are poised to grow faster than many high carbon alternatives. Across the world, low-carbon hubs are emerging. China is a powerhouse for solar photovoltaic cell manufacture, Japan leads in the production and design of low-carbon vehicles, and South Korea is a specialist in energy storage. The emergence of global and regional supply chains in these products creates a unique opportunity for Vietnam to integrate into new markets. It also creates opportunities to adopt new low-carbon processes that boost industrial productivity. To pivot towards these low-carbon market opportunities, a clear industrial strategy is needed.

A low-carbon industrial strategy encompasses efforts to increase the:

- **Production of low-carbon technologies** i.e. goods and services that measure, prevent, limit, minimise or correct for CO_2 emissions[23]; such as electric vehicles, wind turbines and solar photovoltaic cells.
- **Adoption of low-carbon processes** defined as processes that reduce CO_2 emissions e.g. energy efficiency improvements, materials recycling and new low-carbon methods.

A low-carbon industrial strategy can deliver benefits to government, businesses and the workforce. Similar to other forms of industrial strategy, a low-carbon industrial strategy can restructure the economy towards sectors that are desirable for future development[24]. In Vietnam, desirability of low-carbon industries is due to the benefits they deliver to all members of society, shown in Figure 4. These include benefits for:

- **Government**, which can:
  - Increase energy security by reducing the reliance on imported fossil fuels,
  - Safeguard itself against punitive international action such as domestic standards for imports amongst key trading partners[1].
- **Businesses**, who access new markets and supply chains, and achieve cost savings from energy efficiency improvements.
- **Workforce**, which can acquire new job opportunities from low-carbon industries, which are often more labour intensive than their carbon intensive counterparts. See Figure 5. These industries can also help to develop new, valuable skills through their link to electronics manufacturing.

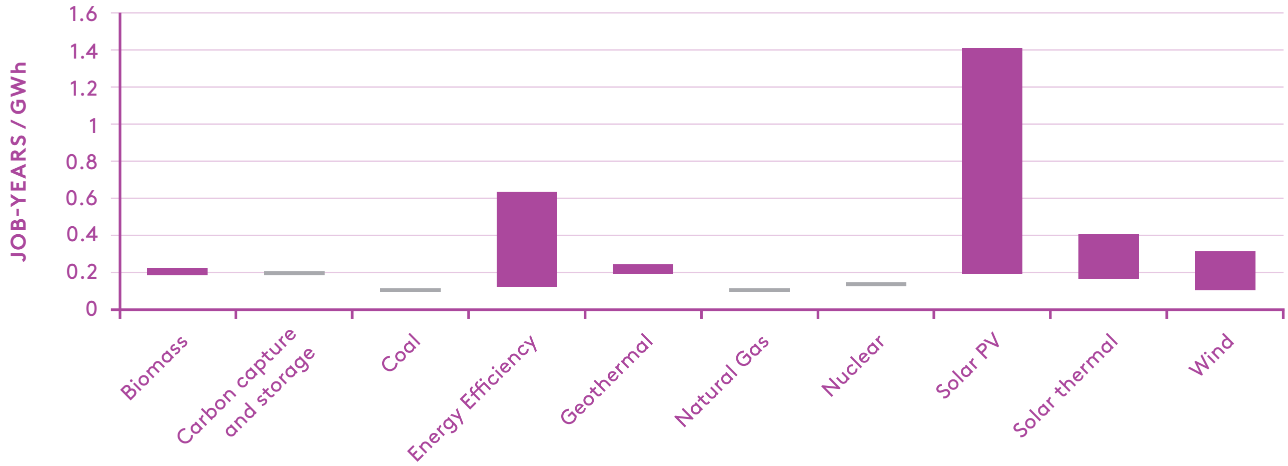
FIGURE 4. A LOW-CARBON INDUSTRIAL STRATEGY ALIGNS WITH KEY PRIORITIES ACROSS VIETNAM'S SOCIETY

GOVERNMENT ACHIEVES MULTIPLE POLICY GOALS	BUSINESSES INCREASE LONG-TERM SUSTAINABILITY	WORKFORCE: IMPROVES LIVING STANDARDS
ENERGY SECURITY	**NEW EXPORT MARKETS**	**JOB OPPORTUNITIES**
RESILIENCE THROUGH DIVERSIFICATION	**STRENGTHENING DOMESTIC INDUSTRY**	**IMPROVED WORK OUTCOMES** DUE TO HIGHER PRODUCTIVITY
ACCESS TO ADDITIONAL FDI	**PRODUCTIVITY BOOST** FROM ENERGY EFFICIENCY MEASURES	**REDUCED CLIMATE RISKS**
LOWER IMPORT BILL		

Source: Vivid Economics

1 This includes border carbon adjustments (BCAs), punitive taxes on imports from countries with less stringent climate policy. French President Macron has proposed imposing BCAs at Europe's external border for countries that fail to enact the Paris Agreement on climate change. This would significantly impact countries relying on demand from the EU export market, including Vietnam.

FIGURE 5. DEPLOYMENT OF RENEWABLE ENERGIES CAN CREATE JOBS

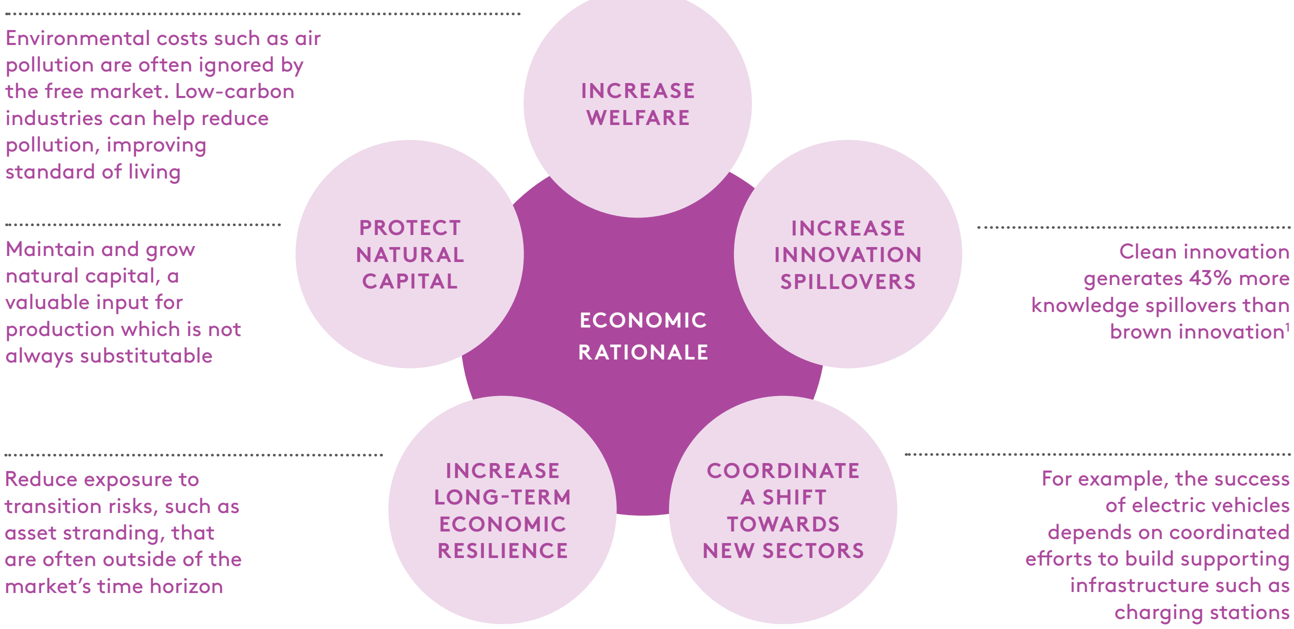


Note: Bars reflect the lower and upper bound of jobs created. Source: Vivid Economics, Wei, Patadia and Kammen (2010).

A low-carbon industrial strategy and climate policy can be self-reinforcing[2]. Low-carbon industries not only help to offset the costs of ambitious climate policy and emissions reduction goals, they also create a political and entrepreneurial will for change[25]. As low-carbon industries expand, they create political coalitions which approve of more ambitious climate policy measures, aligned with international environmental commitments. An affordable low-carbon transition becomes increasingly within reach.

To realise these benefits, government intervention will be necessary. Low-carbon industrial strategies are based on evidence that government intervention can produce positive outcomes, that would not otherwise be achieved by the free market. Why does the market fail? Short time horizons, the lack of market price for valuable goods and services, and inability to coordinate action all affect the functioning of markets in relation to green sectors. Government intervention can target these market failures to 'level the playing field'. Figure 6 highlights the strong economic cases for government intervention.

FIGURE 6. ECONOMIC RATIONALE SUPPORTING GOVERNMENT INTERVENTION IN LOW-CARBON INDUSTRIES

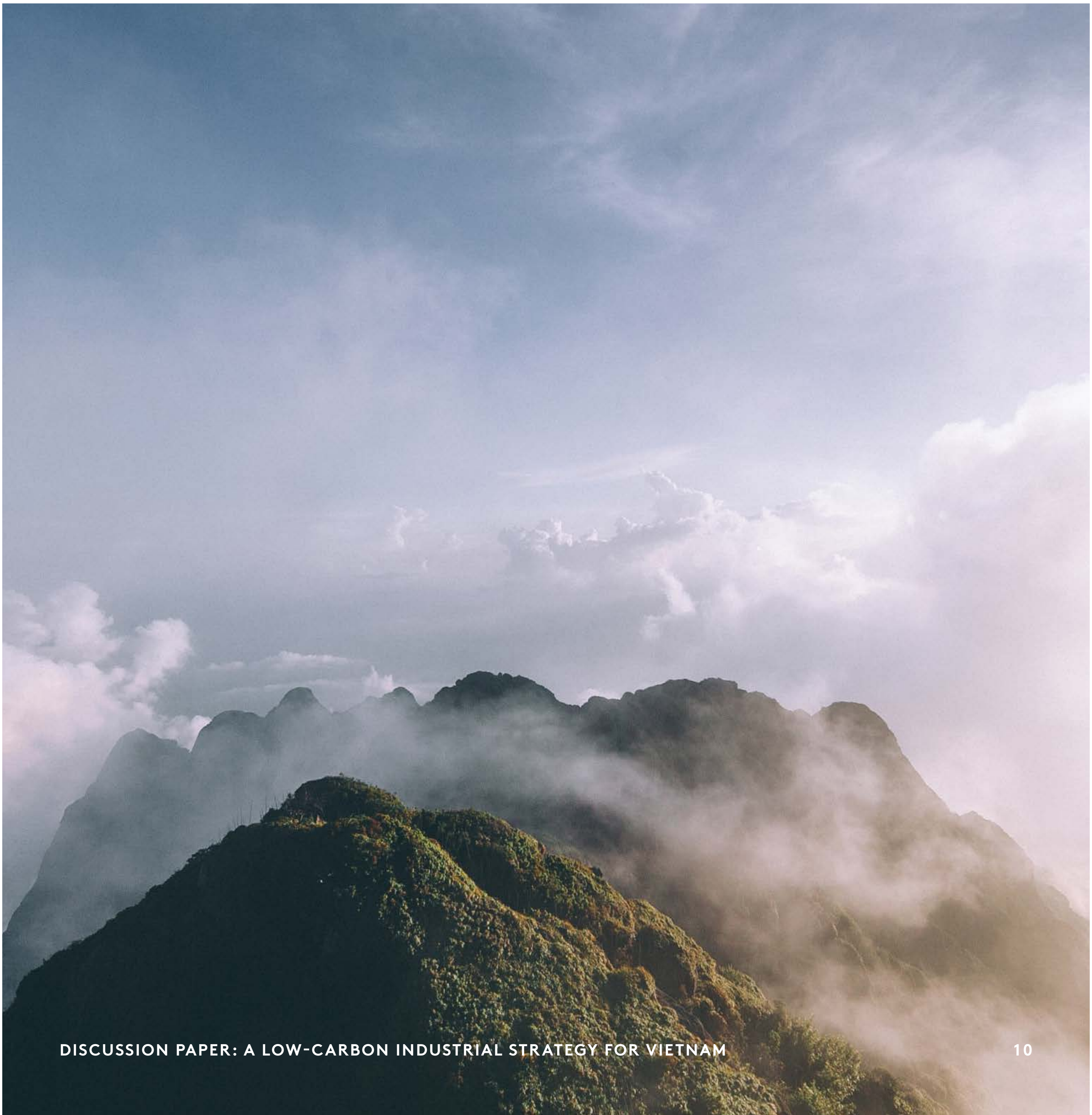


Note: This is proxied by patent data, low-carbon patented inventions receive 43% more citations than carbon intensive inventions. Source: Vivid Economics, Dechezlepretre et al (2017), Fankhauser et al (2017)

2 Climate policy refers to policies which target emissions reductions domestically, via consumption of low-carbon goods. In contrast, a low-carbon industrial strategy targets the production of low-carbon goods.

There are a range of policy and regulatory measures governments can use to drive low-carbon policy. These include:

- **Selective fiscal and financial incentives**, such as direct subsidies to emerging sectors, or tax incentives to attract new businesses.
- **Learning and improving technological capabilities**, such as international research collaboration and labour training subsidies to create the human capital required to absorb foreign innovation and innovate locally.
- **Demand side policies**, such as Feed in Tariffs (FiTs) to drive domestic market growth and attract the development of upstream activity in the low-carbon technology supply chain.
- **Enabling environment and institutions, including planning agencies and coordinating bodies to direct a long-term transition and disseminate information between multiple stakeholders.**
- **Productivity boosting measures, such as subsidising management training** or creating clusters of economic activity which benefit from increased technology transfer and skills spillovers.



What opportunities for low-carbon industrialisation are available to Vietnam?

New market opportunities arising from the low-carbon transition pose a question to governments across the world: how should they prioritise support for low-carbon technologies? Analysis of current export competitiveness and green innovation helps answer this question, and identifies which low-carbon sectors are promising opportunities for strategic support. Our analysis accounts for the benefits to Vietnam from the design, export and production of emerging low-carbon sectors[26].

In which sectors can Vietnam develop a manufacturing and export strength? To help answer this question, our analysis assesses Vietnam's future low-carbon competitiveness across 15 sectors using two indicators:

+ **Export competitiveness** measured by the revealed comparative advantage in a sector. This signals Vietnam's ability to attain and maintain market share in a sector.
+ **Green innovation** measured by green innovation specialisation in a sector. This signals the ability to convert to low-carbon products and processes in a sector.

The higher the score, the better a country performs against each indicator. The rationale behind indicator selection, definitions and analysis are detailed in the Methodology, where we also note the limitations of the framework.

For example, trade data is a robust indicator of relative performance, but it only captures sectors which are exported, and therefore might not capture competitive domestic industries which only serve local consumers.

There are several other factors that might make a sector a high priority for support including:

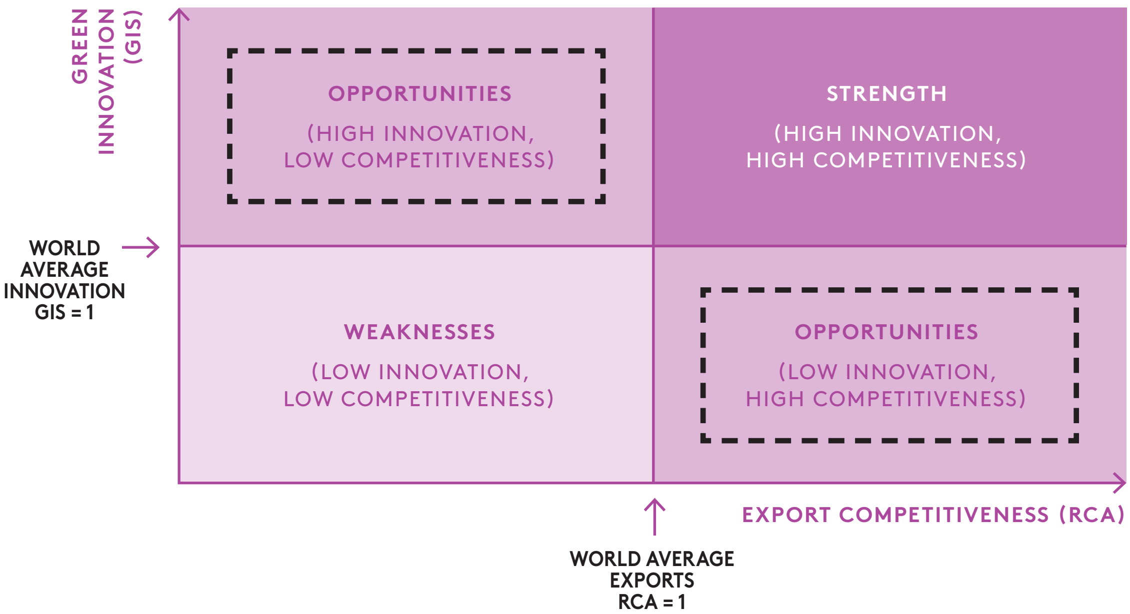
+ Natural resource advantages,
+ Ability to help meet government objectives, and
+ Spillover impacts on other sectors of the economy.

Investment in widely used inputs can for instance boost the productivity of other downstream sectors. South Korea's development of a steel industry, Box 1, is one instance where government support was prioritised due to the positive consequences low cost steel could have on the country's industrialisation trajectory[27]. We analyse each of these factors to help identify the 'low-hanging fruit' that are not observed in our quantitative trade and patent analysis.

Sectors are grouped into strengths, opportunities and weaknesses. To help prioritise policy action, sectors are grouped into three categories, according to their export competitiveness (horizontal, or x-axis) and green innovation (vertical, or y-axis):

+ **Strengths**: sectors where Vietnam has an export specialisation and low-carbon innovation specialisation greater than the world average. Vietnam should seek to maintain its competitiveness and innovative activities in these sectors.
+ **Opportunities ('low-hanging fruit')**: sectors where Vietnam has either an export specialisation or innovation specialisation greater than the world average. Vietnam is well placed to specialise in these sectors but might require strategic support. We consider these opportunities 'low-hanging fruit', as they are typically less costly to develop into a manufacturing strength. These are priority areas for government support.
+ **Weaknesses**: sectors where Vietnam has no export or innovation specialisation (or where trade and patent data does not capture local activity). If Vietnam were to consider developing a specialisation in these sectors, it is likely to require larger policy efforts in the near term.

FIGURE 7. SECTORS ARE GROUPED INTO FOUR QUADRANTS BASED ON EXPORT COMPETITIVENESS AND GREEN INNOVATION SCORES



Note: export competitiveness reflects a sector's revealed comparative advantage (RCA); green innovation reflects a sector's innovation specialisation score (GIS). See Appendix for details on the calculation of these indicators.
Source: Vivid Economics

Our analysis highlights that Vietnam is already a specialist in components required for smart grids and energy storage, with promising opportunities in other technologies such as solar PV and wind power. Figure 8 shows that Vietnam has significant strengths and opportunities in several technologies:

+ Clear strengths in componentry required for smart grids and energy storage, which reflect Vietnam's export and innovation specialisation in electronics manufacturing,
+ A strength in solar photovoltaics manufacturing, which captures manufacturing by foreign and domestic companies located in Vietnam,
+ A particularly high innovation specialisation in biofuels, and,
+ A nascent strength in industrial efficiency and wind power, where it already has a high innovation specialisation.

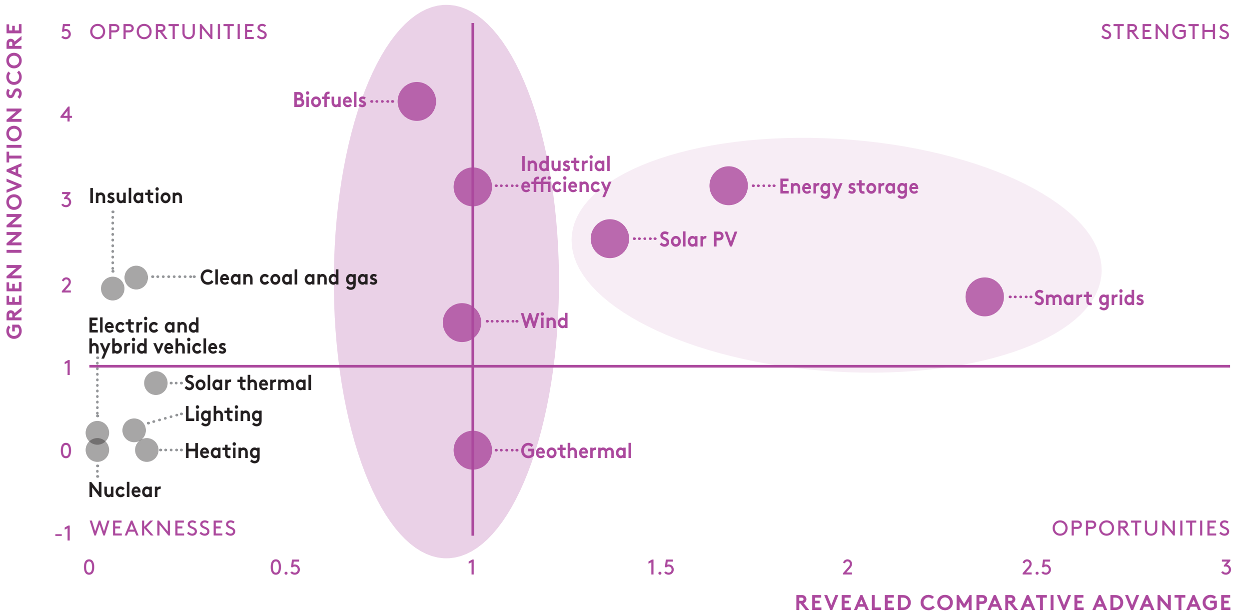
Results often reflect Vietnam's export specialisation in components that are relevant for low-carbon industries. Component specialisation can boost competitiveness in a sector, even if these components are applied elsewhere today.

For instance, semiconductor devices used to manufacture solar photovoltaic cells are closely related to production of other optical devices, TVs and radios[28]. These inputs can be a gateway to higher value-add industry.

Results also do not capture all low-carbon technologies where Vietnam is competitive. Efficient lighting is highlighted as a domestic strength amongst local stakeholders despite poor performance in our indicators. This could be due to a manufacturing process that largely serves domestic demand.

See, Table 1 in Appendix, to understand the products and patents captured within each sector.

FIGURE 8. VIETNAM'S EXPORT POTENTIAL IN LOW-CARBON TECHNOLOGIES



Note: See Appendix for methodology; purple bubbles represent potential priority areas for Vietnam's low-carbon industrial strategy. The light purple oval highlights sectors which are existing strengths; the dark purple oval highlights sectors which are important opportunities. Source: Vivid Economics; PATSTAT 2018b; UNCOMTRADE 2018.

To capture these opportunities, Vietnam must foremost build on its position as a regional leader in low cost manufacturing using 'horizontal' policies that improve cross-sector competitiveness. The World Economic Forum's Global Competitiveness Index 2017-18 found Vietnam ranked 55 out of 137 countries assessed (an improvement on the previous year of 60 out of 138 countries). Likewise, the The Global Innovation Index 2018 report classifies Vietnam as an innovation achiever, sitting high in rankings for both its region and income group for the last 8 years[30].

Vietnam should consider improving its investment climate to attract and retain the talent and investment needed for innovation.

Barriers to business most commonly cited by companies include poor access to finance, inadequately educated workforce, corruption and poor work ethic in the national labour force. To improve competitiveness, Vietnam could improve innovation activity. Vietnam falls behind its neighbours when investing in R&D: in 2013 - the latest available year for data - Vietnam spent 0.4% of its GDP on R&D, compared to Malaysia's 1.3% in 2014 and Singapore's 2% in 2013[31].

Encouraging greater innovation will require increased government spending on R&D and regulatory changes to protect Intellectual Property (IP) systems in Vietnam. Vietnam's innovation would be greatly enhanced by strengthening trust in the government's IP systems.

Of the 524 patents were filed between 1990 and 2019[32], nearly all (98%) of these patents were listed outside of the country[33]. The lack of IP enforcement reduces company and investor confidence in commercialisation of patents within the country[34]. When coupled with business incentives, policy adjustment or direct government investment to increase R&D, Vietnam can create an enhanced national environment for innovation and commercialisation of low-carbon technologies.

Improvements in human capital will also boost Vietnam's competitiveness. While the country performs well in terms of expenditure on education, it has some of the lowest scores globally in tertiary enrolment and knowledge-intensive employment. The country has a relatively low proportion of knowledge-intensive employment that it can draw upon, with managers, professionals and technicians only making up 11% of the workforce (compared to the Philippines at 25.3%)[35]. Further research is needed to understand how Vietnam could build this human capital, encouraging tertiary enrolment and upskilling the workforce to meet industry demands.

By targeting improvements in the business environment towards low-carbon technologies, Vietnam could also unlock large flows of global climate finance. In the last twenty years Vietnam has reformed its investment environment and positioned itself as an attractive destination for foreign investments. The government has focused efforts on industries it deems to be of strategic or social importance, attracting high tech industries by providing a tax holiday for the first four years of profit[36]. Vietnam could focus these tax incentives on low-carbon technologies to capture a share of the global climate finance, currently valued at US$230 billion for private investment[37].

Vietnam has a wide range of incentives designed to encourage renewable energy investment, which includes local content. While the government currently offers incentives such as exemption from import duties if a wind project's materials, components and semi-finished products cannot be manufactured domestically, this analysis indicates that increasing production of wind turbine componentry presents an opportunity for Vietnam. It also has targets to increase the value of domestically manufactured renewable energy components to 30% of the total value of all devices by 2020, and to 60% by 2030[38]. Policies on local content requirements are similar to those introduced by neighbouring countries such as China.

To increase investment, the government should position Vietnam as a manufacturer of components relevant for the low-carbon supply chain. Some experts believe that complete manufacturing will not be feasible in Vietnam due to the small size of the market and low foreign investor appetite[39]. Instead the focus should be on components, in particular parts that require larger investment capital such as gearboxes and generators. US company General Electric is already taking advantage of this opportunity, accounting for 20% of Vietnam's local content manufactured at their Hai Phong plant. This plant employs 500 staff; produces wind turbine generators, electrical control systems and fabrication components, with intentions to increase this as part of their localisation strategy[40].

The incentives for manufacturing can also produce local benefits, with falling price of solar PV offering Vietnam a cheap solution to satisfy increasing energy demand while also growing domestic manufacturing. With an emerging advantage in solar PV exports, Vietnam could seek to further strengthen this sector by incentivising local market deployment. In fact, some foreign companies are already seeking to grow the solar industry in Vietnam. First Solar, one of the United States largest solar manufacturers has recently returned to Vietnam citing the valuable supply chain, a stable political system and the growing needs of the high tech industry as key reasons for this decision[41]. The company hopes to quickly expand production capacity from approximately 2GW in 2017 to 7.6GW by 2020. Other companies are following suit, such as JA Solar, a Chinese solar company, who anticipate some short term hurdles but see that "geographic exposure, prudent cost control, and flexible business model" will bring success in the long term[42].

Vietnam can seize additional benefits from this foreign investment through a range of measures, which may include:

+ **Clustering of industry activity**, for instance through economic zones that provide special incentives for solar PV firms. This clustering can develop a competitive value proposition in Vietnam and enable positive spillovers between local and international firms. Incentives include the provision of hard infrastructure, financial incentives such as low-interest loans, and a 'one-stop-shop' to help businesses acquire licenses and advice on compliance with standards to allow fast clearance of goods.

+ **Training and skills upgrading**, to ensure that human capabilities are able to absorb international know-how. This can be encouraged via grants for vocational skills training or hiring of local labour force and the compulsory secondment of local managers in international firms.

Smart grids can help Vietnam build upon its advanced capability in electronics. Smart grids also offer Vietnam an opportunity to move from components at the lower value end of the supply chain to higher value products with complete manufacturing, providing opportunity for the creation of more skilled jobs. There are already examples of innovation, such as the project between Vietnam's national electricity utility, EVN and Landis+Gyr to deploy smart metering across five of EVN's subsidiaries to quickly process data for billing and outage management[43]. Despite a clear strength in both innovation and production of componentry that can be used for smart grids, these are often not given high consideration in plans for Vietnam's low-carbon transition. For example, upgrades to transmission and distribution infrastructure are typically prioritised in national electricity planning, with smart grids considered to be a 'future' technology.

Yet regional and global demand for smart grid technologies is expected to grow exponentially over the coming decades. By positioning itself to ride this wave of demand, Vietnam could create its niche in the regional renewables supply chain. Complementary policies that support growth in domestic production to capitalise on Vietnam's existing comparative advantage in smart grid componentry, coupled with domestic deployment of smart grid infrastructure, could rapidly grow domestic capability and create a specialisation in smart grid technologies.

Greater investment in smart grids can also help conserve energy, increase reliability and transparency for a 'smarter' energy system. Smart grids are key for enabling increased deployment of renewables, as they are critical for managing intermittency. Without investment in smart grid infrastructure, Vietnam will struggle to meet its renewable energy targets and energy security goals. In 2012 the government outlined a Smart Grid Roadmap as part of the Smart Grid Development Project in Vietnam[44]. Despite being considered a 'future' technology, the project's cost-benefit analysis showed that all identified Smart Grid solutions would have positive net present value. And yet, deployment remains low. Stakeholders familiar with this Roadmap suggest there should be a greater focus on support at the provincial level for implementation, building capacity at the sub-national level and facilitating their access to finance.

Vietnam is uniquely placed to specialise in biofuels, building on existing innovation and natural endowments to become a global leader in sustainable biofuel.

Vietnam is rich in different species of biofuel crops such as jatropha and agricultural residues like rice chaff that could be exploited for biofuel production. Biofuels are a low-carbon technology that can support the transition away from imported fossil fuel dependence. However these benefits and opportunities need to be weighed up against the potential negative social and environmental impacts of unsustainable biofuel production. This is particularly pertinent given the Vietnamese government's orientation to develop and grow biofuel industries to improve energy security by diversifying the country's fuel sources[45]. The Scheme on Development of Biofuels up to 2015 with the Vision to 2025 gives guidance for this orientation, while other regulations seek to give detail[46].

For example, as of 1 January 2018 the government mandated that only five per cent ethanol blends will be made available on the market, with the aim to move to 10% by 2020[47].

The government is seeking to meet this demand by driving innovation, assigning several agencies, universities and industries to research biofuel production in Vietnam and encourage technology transfer. In 2018, the Ministry of Science and Technology along with other local partners invested US$100 million in a carbolosic biomass treatment plant, developed by American scientists, that will produce aviation biofuels and other bioproducts from waste[48].

With specific strategies being developed by the government to use residues of rice, sugarcane, corn etc. some research indicates that there are economically and environmentally beneficial ways of producing sustainable bioenergy production.

As Vietnam seeks to scale up its biofuel production to meet demand and achieve energy security it should do so carefully to minimise negative social and environmental impacts. Policy considerations include; the development of a comprehensive biofuel policy that covers production and investment; a study to estimate the land requirements to meet the projected biofuel demand (to avoid competition with food crops); and further incentivising innovation by upskilling the workforce, investing more in research, encouraging private investment and developing new technologies[49].

BOX 1. CASE STUDY: HOW VIETNAM MOVED UP THE KNOWLEDGE CHAIN AND BUILT A DOMESTIC MANUFACTURING CAPACITY IN TRANSFORMERS

Vietnam's position as one of the few countries that can design and manufacture 500kV transformers demonstrates their ability for technological learning and adaptation. In the early 1990s the government decided to build local manufacturing capacity for these transformers, largely due to their strategic role in the national power system, high demand and expensive import costs.

The Vietnamese Government awarded a local company VND 15 billion (matched by VND 62 billion from the company) to design and manufacture the first 500 kV transformer. The company was also granted access to the national high-voltage laboratory for testing and secured international technical advice. The successful design and manufacture of the first 500 kV transformer raised the confidence of scientists and engineers in Vietnam in the electrical equipment sector.

The technologies and innovations developed for this project are now used to design and manufacture higher-quality 110kV and 220kV transformers, helping Vietnam's manufacturers to maintain their dominance with this range of products in the local market. The clear benefits from this example of government support for R&D, and the knowledge gained, can be used as a case study for growing similar components industries.

Adapted from 'Commitment and Learning in Innovation - The Case of the First 500 kV Transformer Made in Viet Nam' by Hung Vo Nguyen[50].

Finally, Energy Storage will bring stability to the grid, allowing Vietnam to fully realise its renewable energy capacity. Like smart grids, energy storage has the potential to help Vietnam move up the supply chain to provide higher value components or even complete manufacturing of energy storage technologies.

Vietnam is well placed to participate in the battery industry supply chain, endowed with the 3rd largest reserve of bauxite globally along with large reserves of titanium[51]. In doing so they will be able to tap into strong regional demand from automobile and battery manufacturers and a large future global market estimated to be US$45-60 billion for lithium-ion batteries by 2025[52].

These competitive advantages are already being recognised, with growing international interest in Vietnam's storage industry. Positive examples include the joint venture between Vinfast Trading and Production and LG Chem (a South Korean company) to produce lithium-ion batteries for domestic electric scooters and vehicles[53]. General Electric and EVN are undertaking a feasibility study for the deployment of advanced energy storage technologies[54]. These initiatives fit well with Vietnam's Industry 4.0 ambitions, as they will require workforce upskilling (university education) and jobs creation for these sectors, solar PV and smart meters.

Vietnam can capitalise on foreign interest by encouraging collaborative research activities and incentivising a local market for storage. Specific policies might include:

+ Investing in local utility scale storage projects, which can be a cost-effective means to delay investment in upgrading transmission infrastructure, allow for higher penetration of low-cost renewable energy and incentivise the location of storage manufacturers in Vietnam.
+ Fiscal and financial incentives for storage manufacturers, which could include acceleration depreciation on capital, or duty-free import of necessary capital.
+ A policy framework that incentivises joint ventures and collaborative research, for instance by providing joint R&D funding and designating additional incentives for local-international partnerships.

To ensure sustainable growth, this will need to be balanced carefully against social and environmental considerations, not only for extraction but also for end-of-life disposal. Resource extraction is often a key driver of environmental degradation including water contamination, deforestation and acid mine drainage[55]. It can also cause social issues such as inequality, high levels of unemployment and mine-related illnesses[56]. Nonetheless, these minerals will have a crucial role in Vietnam's, and possibly the region's, low-carbon transition. Government regulation and monitoring are critical to ensure these valuable natural endowments can be exploited, without negative social and environmental impacts.

Green growth opportunities focused on scaling up the manufacture of renewable energy components are hampered by domestic market barriers. Addressing barriers to the deployment of renewable energy in Vietnam, coupled with incentives for local content, can rapidly build capability in renewable technologies. Stakeholders cited barriers to renewable energy technologies that include:

+ Power purchase agreements (PPAs) that currently favour fossil fuels, with renewable energy projects considered too risky for most investors. This is in contrast to the trend in other markets where PPAs are designed to realise the benefits of renewables, with these projects seen as less risky than fossil fuel projects.
+ Land access challenges, with project developers purchasing premium sites for renewables generation with little intention of joining the market immediately[57]. When combined with a long approval process, development has been hampered. It is estimated that of the 245 renewable energy projects in Vietnam under consideration in April 2018, 19% have reached the construction phase and only eight per cent have begun operation[58].
+ There is also a perception of geopolitical risk to renewables projects — either due to their proximity to international borders, or technology availability (where country of origin may be seen as a risk factor in terms of quality).

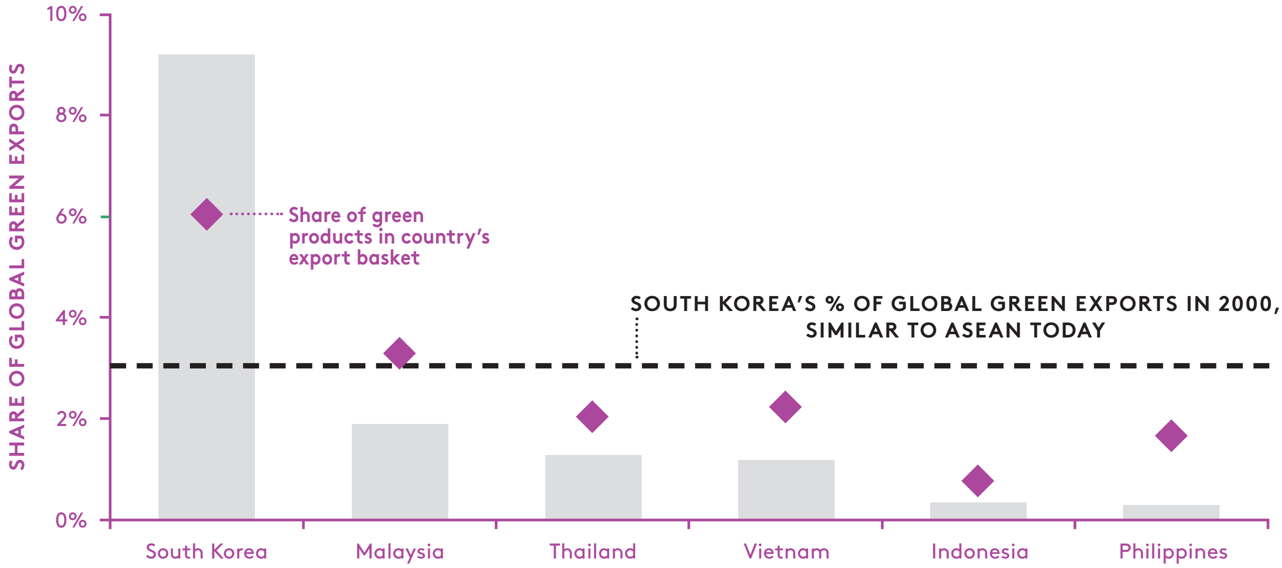
Experts familiar with these barriers argue that a transparent, replicable, and proven project-approval process is needed to bring about meaningful investment in Vietnam's renewable energy industry. Likewise, innovation should be encouraged through pilots, such as floating solar, and developing new energy models that can better integrate distributed energy.

Vietnam can join the regional race

Low-carbon diversification has been achieved by regional players in recent years. Vietnam exported approximately 1% of global low-carbon goods and services in 2017, compared to 9% in South Korea. This picture was different for each country twenty years ago. In 2000, South Korea only exported 3% of global low-carbon exports and was in a similar position as Vietnam today, shown in Figure 9.

In less than two decades, South Korea was able to transform its economy, demonstrating that Vietnam could do the same and providing lessons for how it can achieve this restructuring. Box 2 details these lessons.

FIGURE 9. VIETNAM CAN LEARN FROM SUCCESSFUL REGIONAL COUNTERPARTS, WHO EXPORTED ONLY A SMALL SHARE OF LOW-CARBON EXPORTS TWENTY YEARS AGO

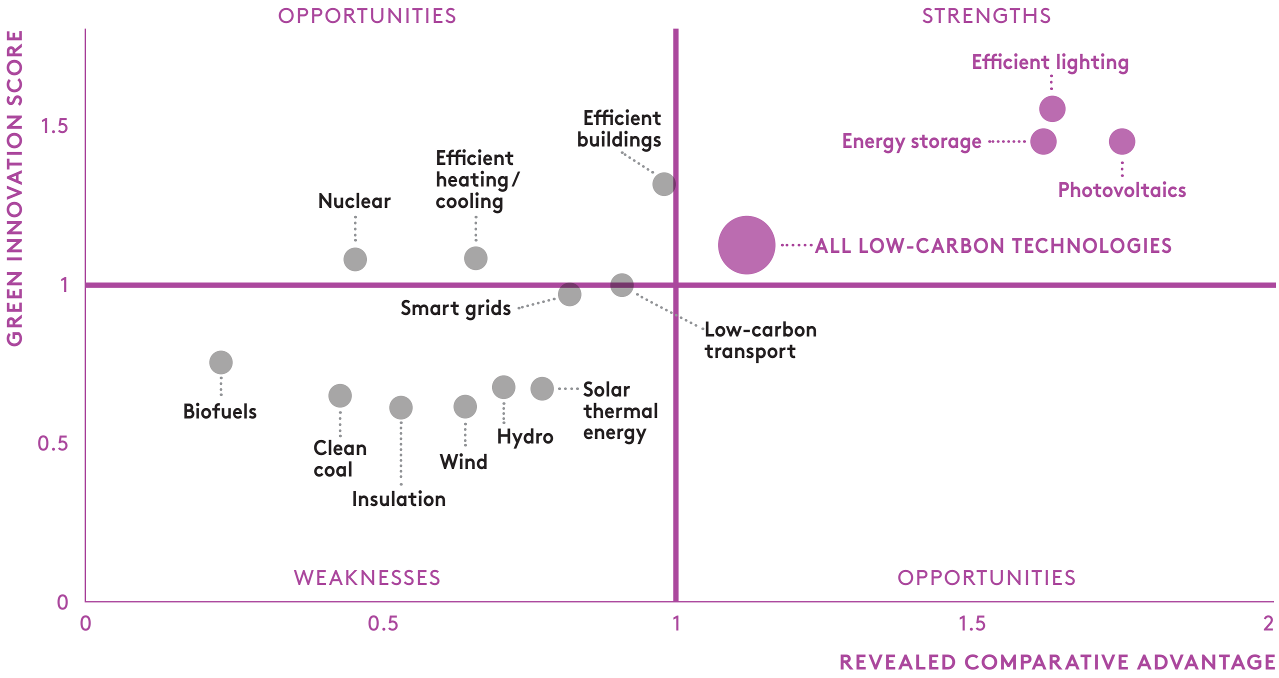


Note: The bars represent the country's share of global green exports, the diamonds represent the proportion of low-carbon exports compared to the country's total exports. GIS is calculated using patents filed between 2009 and 2013; RCA is calculated using average RCA between 2008 and 2012. Source: Vivid Economics

Vietnam can leverage regional strengths in low-carbon technologies to improve its position in the 'green race'. Asia is a leader in low-carbon technologies, due to its large scale of production, exports and patenting of low-carbon goods and services[59]. Figure 10 shows that Asia has an overall strength in low-carbon technologies compared to other regions of the world, with clear comparative advantages in efficient lighting, solar photovoltaics and energy storage.

Asia's comparative advantage reflects the existence of successful low-carbon leaders: Japan, South Korea and China, which together captured nearly 40% of global trade in low-carbon technologies in 2016.

FIGURE 10. ASIAN ECONOMIES HAVE BROAD STRENGTHS ACROSS ALL LOW-CARBON TECHNOLOGIES



GIS is calculated using patents filed between 2009 and 2013; RCA is calculated using average RCA between 2008 and 2012.
Source: UN COMTRADE 2012; PATSTAT 2013; Srivastav, Fankhauser and Kazaglis (2018).

Local supply chains and knowledge hubs could help to attract flows of foreign investment to Vietnam, under a supportive policy environment. The existence of geographical economic clusters highlights the positive spillover impacts that an existing supply chain can have in attracting investment and business activity into nearby economies[60]. Vietnamese businesses can benefit from:

+ **Large regional demand** for components and services used in local low-carbon supply chains,
+ **Opportunities for outsourcing** of labour-intensive manufacturing sectors, as East Asian economies shift towards knowledge intensive products, and
+ **Local know-how and the supply of skilled labour.**

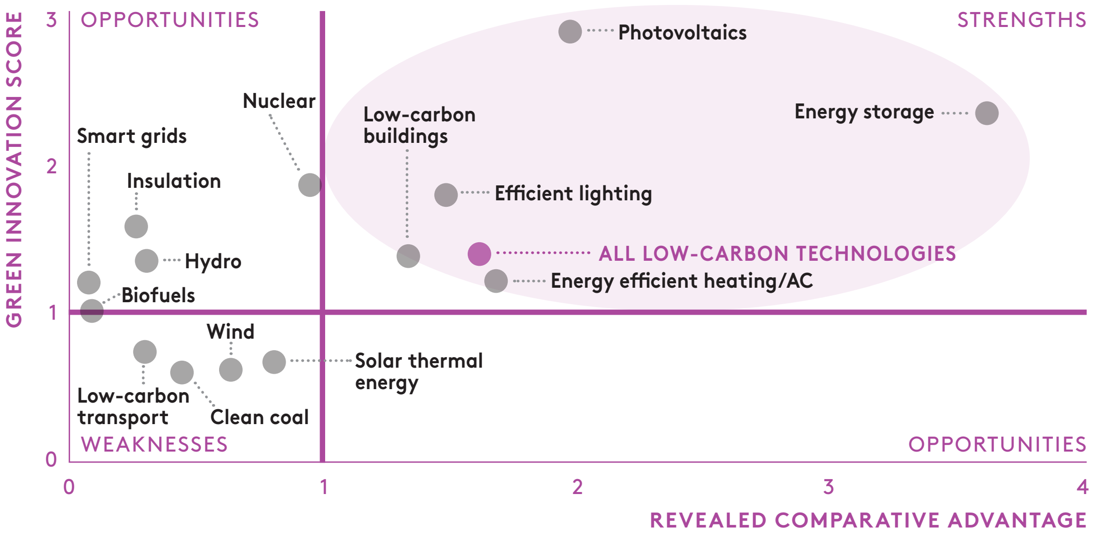
These benefits do not always accrue to the local economy, however. FDI flows have often failed to create long term improvements in the economic growth of a recipient economy, due to minimal local employment generation or skills transfer by foreign companies. Policies to encourage the transfer of goods, capital and skills with regional players are therefore essential to boost Vietnam's global low-carbon competitiveness.

BOX 2: SOUTH KOREA'S RAPID INDUSTRIAL TRANSFORMATION SINCE THE 1970S PROVIDES LESSONS FOR A SUCCESSFUL INDUSTRIAL STRATEGY IN VIETNAM

Despite capturing a large share of global low-carbon trade today, South Korea's success as a low-carbon leader has only been possible through concerted government policy.

In 2016, South Korea captured 9% of global trade in low-carbon technologies, equal to the United States of America. It is highly export competitive in photovoltaics, energy storage, and efficient lighting among other sectors, as shown in the figure below. How did this entrenched specialisation in low-carbon technologies emerge?

FIGURE 11. SOUTH KOREA EXPORTS NEARLY FOUR TIMES MORE THAN THE WORLD AVERAGE IN ENERGY STORAGE, RELATIVE TO TOTAL EXPORTS



GIS is calculated using patents filed between 2009 and 2013; RCA is calculated using average RCA between 2008 and 2012.
Source: UN COMTRADE 2012; PATSTAT 2013.

Two waves of industrialisation and strategic industrial policy were key to the country's current position. During South Korea's first wave of industrialisation, known as the Heavy Chemical Drive (1973-1979), the government aimed to restructure the economy away from its agrarian base. It targeted capital-intensive industries, such as steel and petrochemical processing. Import subsidies for capital inputs and discounted credit for priority sectors helped the country to utilise successful technologies developed elsewhere.

An impressive example of this 'late-follower' strategy is steel, where South Korea utilised technologies developed in Austria and Japan to grow a domestic manufacturing capacity. By 2017, South Korea was the 6th largest producer of steel in the world[61]. The advantage in low-cost steel is also an important driver for South Korea's success in other industries, due to the numerous sectors which require steel as a key input.

The country's export position in automobiles (where it is the 7th largest exporter) signals the positive spillovers that can be achieved through strategic industrial policy[62].

In 2008, the country began to pursue a second wave of low-carbon industrialisation, outlined in its National Strategy of Green Growth 2009-2050 and Green Growth Five Year Plan. Incentives to catalyse the development of low-carbon sectors included:

+ Green credit schemes,
+ Credits for renewable energy producers that installed an energy storage system, and,
+ Eco-industrial parks to reduce industrial emissions, through recycling of waste and shared energy generation.

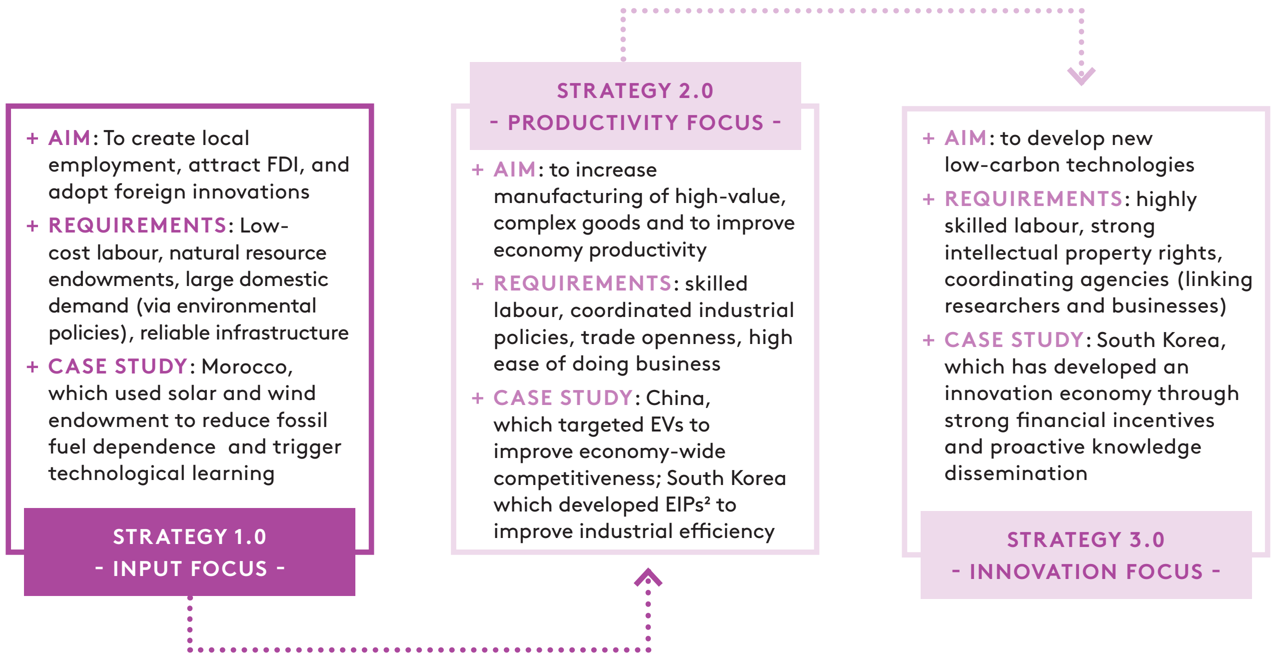
Once again, a coordinated government-led strategy helped to encourage private sector investment.

CONCLUSION

In order to fulfil Industry 4.0, a specialisation in green technologies can enable Vietnam to leverage its innovation and digitalisation to transform the energy and manufacturing sectors. Vietnam stands at an inflection point, primed to take advantage of strong policies and human and natural capital to build its competitive advantage in a low-carbon economy. A low-carbon industrial strategy can help realign Vietnam's economy towards these increasingly profitable sectors and leverage their strengths to improve its position in the 'green race'.

Our analysis highlights that Vietnam is already a specialist in components required for smart grids and energy storage with promising opportunities in other technologies such as solar PV and wind power. Vietnam should consider improving its investment climate to attract and retain the talent and investment needed to build this comparative advantage. Figure 12 suggests how Vietnam could take a staged approach aligned to their development objectives.

FIGURE 12. COUNTRIES CAN CREATE A SUCCESSFUL LOW-CARBON STRATEGY AT EVERY STAGE OF THEIR DEVELOPMENT



Note: GIS is calculated using patents filed between 2009 and 2013; RCA is calculated using average RCA between 2008 and 2012. Source: UN COMTRADE 2012; PATSTAT 2013.

To unlock this green 'industrial revolution' further research is required. To support good policy design, areas of further research could include:

- Research to further understand the current financial value of low-carbon exports, along with the potential value of the expected growth. Given the country's ambitious target for building Vietnam's comparative advantage, with a 2020 goal to increase the value of high tech and green tech products to almost half of GDP it would be worthwhile understanding Vietnam's starting position,
- Key areas for policy enhancement to support achievement of a low-carbon industrial strategy, in particular human capital policies that could drive an increase in university enrolment and knowledge-intensive employment in areas related to priority low-carbon technologies, and
- The mapping of regional supply chains, and the value proposition of neighbouring economies to understand how Vietnam could best exploit its low-carbon technology strengths to create its regional niche.

Appendix

METHODOLOGY

This paper identifies low-carbon industrial opportunities based on a quantitative analysis of low-carbon competitiveness[63]. The paper recognises that the transition to low-carbon growth creates new market opportunities. Countries stand to profit from these new markets, attaining value from the design, export and production of emerging low-carbon sectors[64]. To analyse which sectors a country is well-placed to develop and attain value from, the paper uses an academic framework for assessing low-carbon competitiveness[65]. In line with existing literature, this framework assumes that low-carbon competitiveness is primarily resulting from existing production capabilities and skills[66].

Export competitiveness and innovation specialisation are the indicators used to signal a country's low-carbon competitiveness in a sector. Fankhauser demonstrated that a country's future low-carbon output in a sector is correlated with three factors: the ability to convert to low-carbon products and processes; the ability to capture increased market share in a low-carbon sector; and the current level of green production[67]. Our analysis focuses on two indicators:

+ **Revealed comparative advantage (RCA)**, is used to signal a sector's competitiveness. A country's RCA in a sector is measured as:

$$\frac{\textit{Country } i\textit{'s share of exports in Sector } S}{\textit{Global share of exports in Sector } S}$$

or,

$$RCA_{is} = \frac{e_{is}/\sum_s e_{is}}{\sum_i e_{is}/\sum_s \sum_i e_{is}}$$

where e_{is} is the level of exports from sector ***s*** in country ***i***. The RCA has the following interpretations:

- RCA = 1 implies a country's specialisation in a sector equals the global average specialisation in that sector, it has no advantage or disadvantage over the rest of the world;
- RCA > 1 implies a country specialises in exporting a sector, and is globally competitive;
- RCA < 1 implies a country's share of exports in a sector is below the global average, signalling an export disadvantage.

A high comparative advantage is likely to correspond with a country's ability to attain and maintain market share in a sector in the future, in both its domestic and export market. This assumes that economic specialisation takes time to develop. Intuitively if a country has the skills and technology to produce a good or service for low-cost today, it is likely to be able to produce a similar good or service for a relatively low-cost in the near future.

To calculate RCA, we used UN COMTRADE data (2018) at six-digit level, the highest level of disaggregation:

+ **Green innovation specialisation (GIS)**, is used to signal a sector's potential for low-carbon conversion. A country's GIS in a sector is measured as:

$$\frac{Country's\ green\ patent\ share\ in\ Sector\ A}{Global\ green\ patent\ share\ in\ Sector\ A}$$

or,

$$GII_{is} = \frac{p_{is}^{g} / \sum_s p_{is}}{\sum_i p_{is}^{g} / \sum_{is} p_{is}}$$

where p^{g}_{is} is the number of green patents and p_{is} is the total number of patents in sector ***s*** and country ***i***. The GIS has the following interpretation:

  - GIS = 1 implies a country's low-carbon specialisation in a sector equals the global average in that sector, it has no advantage or disadvantage with respect to innovation;
  - GIS > 1 implies a country specialises in innovating in a sector, and is well-placed to convert to low-carbon segments of that sector;
  - GIS < 1 implies a country is not well-placed to innovate in a sector.

A high GIS corresponds with a country's ability to design and produce low-carbon products and services, and thereby capture new market segments. Low-carbon sectors will often require the rapid development of new technologies and skills. Current manufacturing specialisation in a related technology can therefore be a poor proxy for future low-carbon competitiveness. Intuitively, the resilience of an industry in the near future requires innovating relative to your peers today.

To calculate GIS, the analysis uses EPO's PATSTAT database, a global database covering patent activity across all local country offices. Patents are used as a key metric for innovative activity, and but we recognise that patents do not provide a complete manifestation of a country's innovation potential. Drawbacks include: inability to capture incremental or process oriented innovation; little indication of the value of a technology (high costs of patenting can imply however that a patented technology is perceived as high value); and that patenting in a country does not always correspond with future manufacturing, given other factors that influence firm location.

Based on the RCA and GIS score, sectors are grouped into opportunities, strengths and weaknesses, as shown in Figure 4. The RCA score is calculated as the average RCA in a sector between 2012 and 2016. This is done to prevent anomalous annual data from influencing results. The GIS score is calculated as all patents filed between 1990 and 2019, to reflect the lag time between patent activity and changes in a country's innovation eco-system. Patents filed in Vietnam or filed by an applicant with Vietnamese nationality outside of Vietnam are included under Vietnam's patent activity. We observed high levels of patenting by the latter, who account for 98% of all of Vietnam's low-carbon patent activity.

DEFINITIONS

Trade and patent data in low-carbon sectors

Our analysis looks at 15 low-carbon sectors, and Vietnam's trade and patent activity in each sector. For our analysis of low-carbon competitiveness, detailed in 3.2, a concordance table is created to match low-carbon sectors with associated trade and patent classifications, set out in Table 1. This concordance builds upon and extends existing literature on low-carbon technology trade and patent data[68].

TABLE 1: CONCORDANCE BETWEEN LOW-CARBON SECTORS, AND ASSOCIATED TRADE AND PATENT CLASSIFICATIONS

TECHNOLOGY CLASS	TRADE CLASSIFICATION (HS CODE)	HS CODE DESCRIPTION	PATENT CLASSIFICATION (CPC CODE)	CPC CODE DESCRIPTION
Clean coal and gas	841990	Parts of apparatus for treatment of materials by temperature	Y02C 10/00	CO2 capture or storage (not used, see subgroups)
	841181	Other gas turbines of a power not exceeding 500 kW		
	841199	Parts of other gas turbines	Y02C 20/00	Capture or disposal of GHG other than CO2 (not used, see subgroups)
	841182	Other gas turbines of a power exceeding 5 00 kw		
	841950	Heat exchange units, whether/not electrically heated	Y02E 50/00	Combustion technologies with mitigation potential
	840420	Condensers for steam or other vapour unites		
Biofuels	220720	Ethyl alcohol, other spirits (denatured)	Y02E 50/00	Technologies for the production of fuel of non-fossil origin
	220710	Ethyl alcohol (alcoholic strength 80 degrees of more)		
	382490	Bio-diesel		
Electric and hybrid vehicles	870390	Vehicles principally designed for the transport of persons	Y02T 10/00	Road transport of goods or passengers
			Y02T 90/00	Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigations in the transport sector

Energy storage	850710	Lead-acid electric accumulators (vehicle)	Y02E 60/1	Energy storage
	850720	Lead-acid electric accumulators except for vehicles		
	850730	Nickel-cadmium electric accumulators		
	850740	Nickel-iron electric accumulators		
	850760	Lithium-ion accumulators	Y02E 60/5	Fuel cells
	850780	Electric accumulators		
	850790	Parts of electric accumulators, including separators		
	853224	Fixed electrical capacitors, other than those of 8532.10		
Geothermal	841989	Cooling towers and similar plants for Direct Cooling (without a separating wall) by means of Recirculated Waste	Y02E 10/1	Geothermal
	847960	Evaporative Air Coolers		
	841950	Heat exchange units, whether/not electrically heated		
	841861	Heat pumps other than air-conditioning machines		
	850239	Electric generating sets and rotary converters		

Heating	903210	Thermostats	Y02B 30/00	Energy efficient heating, ventilation or air condition (HVAC)
	841861	Compression-type refrigerating/ freezing equipment whose condensers are heat exchangers or heat pumps other than air conditioning machines		
	841950	Heat exchange units, whether/not electrically heated		
Hydro	841011	hydraulic turbines and water wheels, of a power not >1000kW	Y02E 10/2	Hydro energy
	841012	hydraulic turbines and water wheels, of a power >1000kW but not >10,000kW		
	841013	hydraulic turbines and water wheels, of a power >10,000kW		
	841090	parts (including regulators) of the hydraulic turbines and water wheels of 8410.11-8410.13		
	850164	AC generator (alternator), with an output exceeding 750 kVA		

Industrial efficiency	252390	Hydraulic cements (e.g. slag cement, super sulphate cements). Excluding cement clinkers, Portland cement or aluminate cement.	Y02P 10/00 Y02P 20/00 Y02P 30/00 Y02P 40/00 Y02P 70/00 Y02P 80/00 Y02P 90/00	Technologies related to metal processing Technologies related to chemical industry Technologies related to oil refining and petrochemical industry Technologies related to the processing of minerals Climate change mitigation technologies (CCMTs) in the production process for final industrial or consumer products CCMTs for sector-wide applications Enabling technologies with a potential contribution to GHG emissions mitigation in industry
	840410	Economizers, super-heaters, soot removers, gas recoverees and condensers for steam or other vapour power units		
Insulation	680610	Slag wool, rock wool & similar mineral wools	Y02B 80/00	Architectural or constructional elements improving the thermal performance of buildings
	680690	Mixtures and articles of heat-insulating, sound-insulating or sound-absorbing mineral materials		
	700800	Multiple-walled insulating units of glass		
	701939	Webs, mattresses, boards & similar non-woven products of glass fibres		

Smart grids	902830	Electricity meters	Y02B 70/1	Technologies improving the efficiency by using switched-mode power supplies
			Y02B 70/2	Power factor correction technologies for power supplies
			Y02B 70/3	Systems integrating technologies related to power network operation, communication or information technologies for improving the carbon footprint of the management of the residential or tertiary load
			Y04S 10/00	Systems supporting electrical power generation, transmission or distribution
			Y04S 20/00	Systems supporting the management or operation of end-user stationary applications
			Y04S 30/00	Systems supporting specific end-user applications in the transportation sector
			Y04S 40/00	Smart grids, communication of information technology specific aspects supporting electrical power generation transmission or distribution
			Y04S 50/00	Market activities related to the operation of systems integrating technologies related to power network operation and communication or information technologies

Solar thermal	841919	Instantaneous/ storage water heaters, non electric	Y02E 10/4	Thermal energy
	850300	Parts suitable for use solely or principally with the machines of heading 8501/8502		
	901380	Optical devices, appliances and instruments	Y02E 10/6	Thermal - PV hybrids
	901390	Parts and accessories for optical devices, appliances and instruments		
Solar pv	854140	Photosensitive semiconductor devices, incl. photovoltaic cells whether or not assembled in modules/ made up into panels; light emitting diodes	Y02E 10/5	Solar PV
	850490	Parts for electrical transformers, static converters, and inductors	Y02E 10/6	Thermal- PV hybrids
Wind Wind	850231	Wind-powered electric generating sets	Y02E 10/7	Wind
	730830	Towers and lattice masts, of iron or steel		
	841290	Engine and motor parts		
	850164	AC generator (alternator), with an output exceeding 750 kVA		

Note: HS codes are sometimes included in more than one sector, when comparing the relative trade competitiveness between sectors. This is because the product is relevant to each sector's performance. However, when calculating overall exports in low-carbon technologies, each HS code is only counted once.
Source: Vivid Economics, Dechezlepretre.

LOW-CARBON NATURAL ENDOWMENTS

To analyse a country's low-carbon natural endowments, we look at resources that are commonly used in key low- carbon sectors: solar PV, wind, lighting, batteries and electric vehicles.

Table 2 sets out the natural resource endowments considered in our analysis.

TABLE 2: LOW-CARBON NATURAL ENDOWMENTS

ENDOWMENT TYPE (A-Z)	LOW-CARBON SECTOR
Bauxite	Solar photovoltaics, wind, energy storage, electric vehicles
Aluminium	Solar photovoltaics, wind
Cadmium	Solar photovoltaics
Chromium	Wind
Cobalt	Wind, energy storage, electric vehicles
Copper	Solar photovoltaics, energy storage, electric vehicles
Dysprosium	Wind, energy storage, electric vehicles
Europium	Efficient lighting
Gallium	Solar photovoltaics
Germanium	Solar photovoltaics
Graphite	Energy storage, electric vehicles
Indium	Solar photovoltaics
Iron	Solar photovoltaics, wind, energy storage, electric vehicles
Lead	Solar photovoltaics, wind, energy storage, electric vehicles
Lithium	Energy storage, electric vehicles
Manganese	Wind, energy storage, electric vehicles
Molybdenum	Wind
Neodymium	Wind, energy storage, electric vehicles
Nickel	Solar photovoltaics, energy storage, electric vehicles
Praseodymium	Wind
Selenium	Solar photovoltaics
Silicon/Silica	Solar photovoltaics, energy storage, electric vehicles
Silver	Solar photovoltaics
Tellurium	Solar photovoltaics
Tin	Solar photovoltaics
Titanium	Energy storage, electric vehicles
Vanadium	Energy storage, electric vehicles
Yitrium	Efficient lighting
Zinc	Solar photovoltaics, wind, energy storage, electric vehicles

Source: Vivid Economics, IRENA, 2019; IISD

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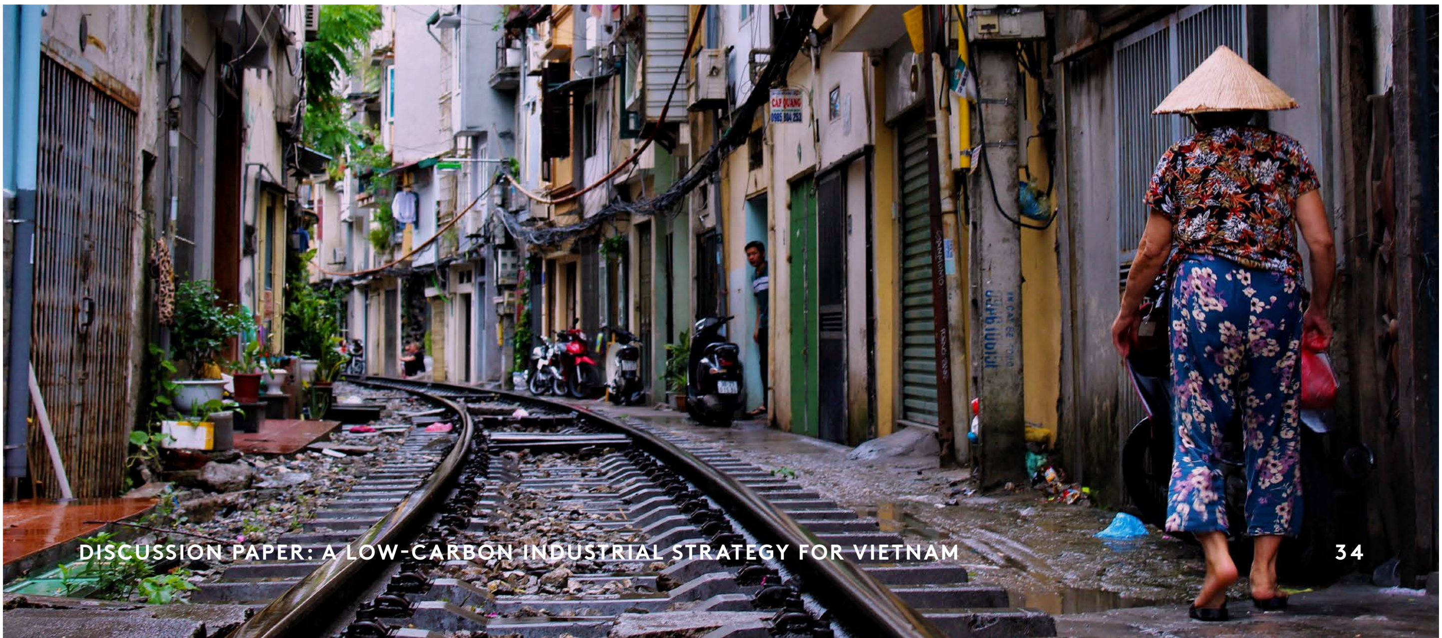

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ClimateWorks Australia develops expert, independent and practical solutions and provides advice to assist the transition to net zero carbon emissions for Australia and Asia Pacific.

A non-profit organisation, ClimateWorks was co-founded in 2009 by The Myer Foundation and Monash University and works within Monash Sustainable Development Institute.

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