Study of HK & SG Start-Up Ecosystems

for Transforming Telecom Business and Decarbonization

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Executive Summary

Over recent years, the telecommunication industry worldwide has not only become a key incubator for new areas of application but also actively embracing innovative technologies, applications, and strategies, including but not limited to 5G and IoT. Nevertheless, the industry as a whole has barely benefitted from the fallout compared to major Over-the-Top players. How can traditional telecommunication companies partner wisely with other sectors, particularly tech startups, to better address looming challenges in the ICT industry, spur innovation, and achieve better environmental sustainability?

The paper presents a systematic examination of the current development of the telecommunication industry and tech-based startups as well as the synergistic relationship between the two, with a focus on Hong Kong and Singapore – the major hubs for financial and innovation in Asia. Part 1 briefly outlines the pain points of the telecom industry and the startup ecosystems in Hong Kong and Singapore. Using social network analysis (Neo4J) to delve into telecom-related startups, Part 2 investigates several prospective fields of innovation that are pertinent to the industry, explores technological sectors of potential, and examines differences in modes of collaboration. Part 3 includes data and visualization to compare the revenue performance of OTT internet giants and leading telecom operators. The paper provides insights on how to reshape the collaborative relationship between telcos and startups to ensure a greater extent of monetization within the telecommunication industry. The concept of "Spiral Synergy" and rationales for decoupling it between the telecom operators and startups are discussed. Part 4 examines how Hong Kong and Singapore have established thriving ecosystems to nurture and support startup businesses focused on low carbon and renewable energy economy, and explores start-ups contribute technological efforts in improving the decarbonization of the ICT industry. Based on the examination, the paper delivers strategic suggestions on how telecommunication companies should work with startups to result in a more innovative, competitive, and greener industry.

1 Introduction

1.1 Pain points of the telecom industry

Emerging technologies and the ever-changing social economics are shifting the landscape of the worldwide telecommunication industry. Due to the COVID-19 pandemic, an increasing number of people become confined to their homes and dependent on wireless and broadband service on a global scale, resulting in a significant surge in data traffic in city centers, urban regions, and suburban areas. To fulfill the ongoing demand for faster data connection and higher bandwidth, the industry has made greater efforts in deepening its network capacity with increasing fiber and wireless deployments[1]. Along with the new trends come a fresh set of challenges, putting the traditional telecom companies into a disadvantageous position in the competition with major digital service providers. Telco businesses should identify and deal with pain points faced by the industry in order to build and maintain a competitive edge.

The greatest pain point of the telecom industry can be shown in the words of Francesco Venturini, a Senior Managing Director at Accenture: "With the 4G rollout, telecoms were the engine that powered a new economy. But it was other players that actually monetised that transformation"[2]. 4G communications were first launched in 2009 and have since powered and revolutionized the world to the digital economy. The infrastructure has become a key platform that accelerated growth in the technology sector and incubated whole new areas of application, including but not limited to Cloud, IoT, Robotic, Automation, AR/VR, SaaS/PaaS, AI/ML, E-commerce, Blockchain, NFTs, and Metaverse. The aforementioned list includes all technologies that harnessed the increased data connectivity provided by telecommunications infrastructure and blossomed since the introduction of 4G. Despite being the stepping stone for growth, telecommunications companies have barely benefitted from the fallout. With the advent of 5G infrastructure on the horizon, the telecom industry should take the advantage of new and upcoming technologies, monetizing its network assets to avoid the failings of the 4G launch.

The second pain point that the telecom industry should overcome is the high customer churn rate – one of the biggest threats to revenue loss. The average monthly churn rate of major wireless companies varies from 1.9% to 2.1%, while the average annual churn rate ranges from 10% to 67%. According to the Industry retention surveys, customers are generally satisfied with the price, product, and technical performance; poor customer support and communication have been the main reason for customers to terminate any subscription[3]. A report from Ericsson reveals that customers must invest great time and effort in their interactions with telecom service providers regardless of the goal of the contact – customers require 2.2 tries and 4.1 days on average to finish an inquiry. The satisfaction level is greatly impacted as a result of the tedious procedure. If it takes more than one day to complete a task, the percentage of satisfied customers drops by approximately 30%, and if it takes three to four days, it drops by 50%. Moreover, major over-the-top (OTT) businesses such as Amazon, Netflix, Tencent, and Google have set high consumer expectations in terms of receiving personalized service without losing a "sense of being in control and making well-informed decisions"[4]. Quickly capturing and responding to user needs in a rapidly changing market has become the key to driving customer loyalty and preventing retention.

This brings us to the next challenge – the lack of effective digitalization strategies. The economic opportunities of the telecommunication industry have declined in the past few years as consumers value the online experiences offered by digital giants over those provided by telcos. McKinsey & Company's article on telecom's critical reinvention has suggested three disruptions faced by the industry that fuels the decline in the economy: (1) "customer-back disruption": digital-native and tech-centric leaders are leveraging technology to enhance the digitalized experience, raising consumers' expectations about what the telecom industry should deliver; (2) "business-model disruption": AI, big data, the Internet of Things (IoT) along with other technologies have shifted the traditional ways of business operations; (3) "new-entrant disruption": non-traditional service providers such as software as a service (SaaS), over-the-top (OTT), and software-defined wide area networking (SD-WAN) have created viable alternatives to traditional companies, leading to a more competitive environment[5]. Not all operators react and adapt to the disruptions quickly, and many are insensitive to the vast volumes of data and workflow processes. Yet, the success of telcos depends on their expansion in analytic capacity, the all-around transformation from network architecture to operation mode, the construction of integrated agile systems, and digital transformation.

1.2 Start-up ecosystems in Hong Kong and Singapore

Despite the persistent economic recessions brought on by the worldwide pandemic, governments and companies in the Asia-Pacific region are stepping up their attempts to create startup ecosystems of creativity, resilience, and capacity for change. Among all, the ecosystems of Hong Kong and Singapore have grown significantly in vibrancy. Supportive government regulations, accommodating venture capital, well-transformed digital infrastructure, expansive talent pool, as well as incubators and accelerators, jointly make the vital ingredient for success.

The total number of start-ups in Hong Kong was 12% up from the number in 2020 and hit an all-time high of 3,755, according to the Invest Hong Kong 2021 Startup Survey. The trend toward digitalization grows with the expanding number of startups, fuelling exciting advancements in E-commerce, Information Technology, digital entertainment, and other digitally centralized sectors[6]. Digital transformations have also been applied in non-traditional tech sectors. In 2019, Hong Kong Monetary Authority (HKMA) licensed eight virtual banks that provide financial services fully online taking the advantage of developing technologies. While each virtual bank represents a possibility of 9.5 billion HKD ($1.2 billion) in average yearly income, it is anticipated that Hong Kong's virtual banking sector would generate $9.7 billion in annual income by 2025 and serve 24.9% of the city's present population[7]. Additionally, HKMA unveiled the "Fintech 2025" strategy last year in an effort to encourage Hong Kong's financial industry to enhance data infrastructure and fully integrate technologies like artificial intelligence, blockchain, and cloud computing[8].

Singapore's startup ecosystem has grown by leaps and bounds over the past decades. Now ranked No.1 in the APAC in StartupBlink's Startup Ecosystem Index 2022, the nurturing ecosystem was not developed until the 1990s: there were 741 and 168 Singaporean startups

registered on AngelList and Techlist.asia respectively in January 2015, and the number reaches over 4,000 according to the Singapore Department of Statistics, with an estimated collective contribution of $89 billion. One of the vital factors that contribute to the fast-growing startup scene is the well-built infrastructure and connectivity of the city: Singapore is ranked top in Asia for "digital infrastructure, 4G network coverage, investment in information and communication technology (ICT), and ICT laws" by the Asian Digital Performance Index of the Economist Intelligence Unit (EIU)[9].

Startup founders in both HK and SG are also actively involved in turning the environmental crisis into opportunities for making a difference by developing green financing solutions. More entrepreneurs are aware of the trend of Environment, Social, and Corporate Governance (ESG) and the net-zero objectives implemented. Compared to the statistics in 2018, there has been a lauded increase of 141.86% in Hong Kong startups in the verticals of sustainable or green technology. Green techs in Singapore are also vibrant with support from venture capital funds, mentorship from research institutes, and government allocation of capital. According to Honson To, chairman of KPMG Asia Pacific, Asia will play a pivotal role in pursuing a more sustainable future, and emerging startups are instrumental in advancing the technologies to "reduce carbon emissions and promote more responsible stewardship of the environment".

2 Startup Ecosystem overview

2.1 Startup Ecosystem in Singapore and Hong Kong

As financial and innovation hubs of Asia, Hong Kong and Singapore both host vibrant startup communities totalling over 7,000 startups.

	Hong Kong[10]	Singapore[11]
Startups	3,755	4,008
Co-work spaces, incubators, accelerators	124	227
Investors	n/a	631

For this in-depth research, we analyzed over 6,000 startups within these two ecosystems, in which more than 2,000 startups can be associated with "top 10 telecom tech trends & innovations"[12]

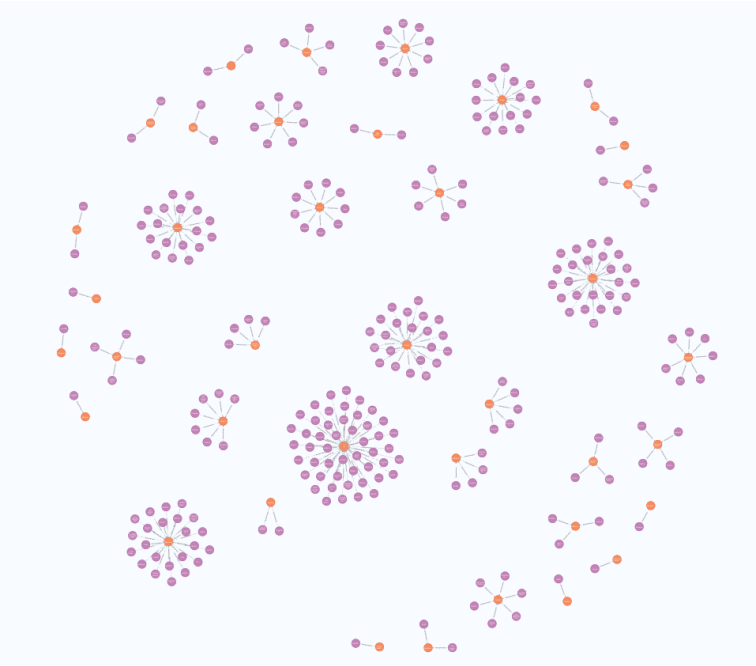

Figure 1 Overview of the map (not all the nodes are displayed)

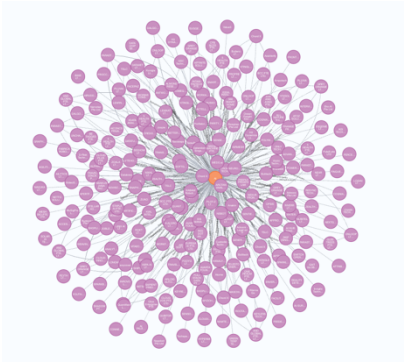

Figure 2 Map of AI industry

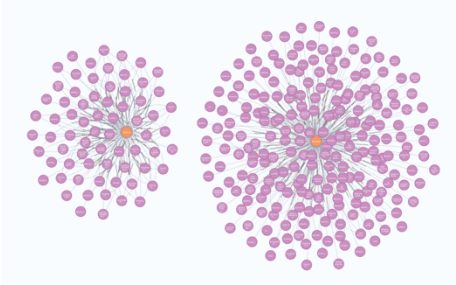

Figure 3 Map of Gaming and Education

2.2 Micro-ecosystem of Telecom related startups

Internet of Things

IoT devices are perhaps one of the most well-known technologies which leverage increased bandwidth and connectivity. With applications in smart homes, building management, smart city and more, IoT gives impressionable experiences to users changing living standards on a daily basis. Ampotech[13] from Singapore have developed IoT devices for energy monitoring. Their proprietary smart power meter device logs usage power usage and anomalies, sending data to their cloud platform. The data can be applied to residential, commercial, and industrial applications via integrations with enterprise IoT data platforms or cloud-based building management. Headquartered in HKSTP, Bluetech IoT[14] focuses on the hygiene and sanitation applications of IoT. Including the wireless real-time monitoring of toilet availability, queue time, odour level, and remaining soap or toilet paper amount. These IoT sensors work in tandem with Smart signages and vacancy-indicating lamps for customer transparency and property management to optimize sanitation practices.

Connectivity Technologies

Connectivity has played the role of enabler of emerging technologies. Connectivity technologies, both wired and wireless, bridge upstream telecommunications bandwidth to downstream end users. The proliferation of IoT devices brings novel problems requiring novel solutions. Waveboost[15] from Singapore tackles issues with powering IoT devices with an integrated radio frequency wireless power and connectivity solution. Trinity photonics[16]

constructed the WiFi6 over optical network for HKSTP and 70+ schools providing zero dead zone connectivity as a core component of smart city infrastructure.

5G

5G technology not only raises the ceiling for connection speeds, but also revolutionizes connection latency, a key roadblock for multi-device interactions. Reduced latency with 5G networks will make the technology the backbone for end-user telecommunication applications. Software-only sim cards from SIMO[17], a Singaporean startup, provides users with mobile internet access across 135 countries with cloud-based 5G multi-carrier network of 200+ providers. With a portfolio of 5G hardware, Casa technologies[18] from HKSTP can optimize architecture for Cloud, Edge and on-premise solutions to meet the individual demands of residential, business and industrial users.

Artificial Intelligence and Machine Learning

Connectivity and data are synergistic with new sensors and devices such as IoT devices providing increasing data points. AI and ML solutions extract meaningful information from ever-inflating data sources. The healthcare sector is a hotbed for AI and Machine learning applications with permutative complexity, human and financial costs driving demand for optimization with computation. Peach Intelliheath[19] from Singapore tackles the macro issues applying AI with predictive patient diagnostics and outcome in both in-patient and residential scenarios. Bloom standard[20] from HKSTP focuses on ultrasound imaging for children. Their proprietary device leverages AI-driven onboard image interpretation, providing improved availability of critical medical device.

High-resolution content

High-resolution content such as VR/AR, media, entertainment and gaming have increased user penetration which mirrors smartphone adoption rates and bandwidth accessibility. The growth in these high-quality, large file size content compel high-speed transmission but also low latency personal connectivity. High quality video streaming solutions, such as Atlastream[21] from Singapore leverages low latency improvements from 5G technologies.
AIPhotonics[22] from HKSTP, delivers high realism VR with 3D photography and LiDAR scanning.

Cyber security

Increased digitization is coupled with further risks to cyber-attacks. The race between security and exploitation permutates every iteration of telecommunications technology. Scrutiny for every asset and connection is furthered with IoT device implementation. Cyber security startups safeguard future security weak points in different applications. Block Armor[23] from Singapore applies blockchain technologies to IoT devices. ADVstar laboratory[24] from HKSTP provide threat monitoring, intelligence and analysis services.

Cloud Computing

Cloud computing has integrated on-demand computing power, business applications and data infrastructure onto a single platform. Cloud integration has provided the stage for end-user product delivery. This business model has become the norm for the technology with Semut technologies[25] from Singapore providing end-users with business services such as ERP and Edtech solutions together with integrated development tools such as MySQL, Database and search algorithms. Disaster recovery and data analysis services provided by startups like cloud ocean software technology[26] from HKSTP extends storage and processing power offerings of simple cloud and data services.

Communication Models

With the influx of personal devices, platforms and interacting users comes an upsurge of network communications. Communication channels such as machine-to-machine (M2M), vehicle-to-everything (V2X), device-to-device (D2D), human-to-machine may differ with changing hardware and software but all require protocol and regulation with communication models. WiFi 6 and other new standards for communications channels are the basis for new products both for consumers and businesses. Energy management platform from Resync technologies[27] operate on the cloud and exemplifies application of communication channels from IoT devices to end-users via D2D, M2M and human-machine communication layers. Esix Limited[28] from HK is an alternate example with innovations in bi-directional communication protocols for device remote control.

Software Defined Networks

Software-defined networking technology is one important breakout for enhancing the dynamic network management and network utilization efficiency. Hong Kong Startup, GL technologies[29], specialises in creating compact size travel routers and gateways that are highly efficient at running VPN or SD-WAN, which makes them a powerful security option for remote workforce using the enterprise network or network communications between multiple offices or stores.

Edge Computing

As opposed to centralized cloud solutions, Edge computing delivers computation and storage to the end-user. Implementation of edge computing technology synergizes with 5G to improve end-user experience for high data and connectivity requirement applications. Singapore startup, Nife[30], provides enterprises with scalability solutions for software, application and web deployment with proximate computation and data storage with edge computation infrastructure. The technology can also be part of a larger solution by vertically integrating, hardware, software, UI development and data analytics such as that implemented by Compathnion Technology in HK[31]

2.3 Characteristics of Startups

Analysis of these 10 technology trends illustrates the inter-woven nature of technology development. Whilst each technical area is differentiated with individual specializations and niches, their inter-dependencies allow the ecosystem to thrive as a whole.

Problems tackled by startups in the above analysis are diverse, requiring specific solutions integrating several disciplines. Startups, formed by small teams of domain specialists, tackle specific user problems with bespoke solutions. These user-centric solutions have high operational visibility and generate high-quality user engagement. The roles of startups are also well differentiated. The review of startups above already includes SaaS, Platforms, integrators, infrastructure, service providers, hardware and software development. Startups have fewer constraints in exploring business strategies to fit market needs. The 10 technologies reviewed are intrinsically connected to the Telecommunications industry and serve as easy-to-approach targets for collaboration to achieve organic technological development in the telecommunications sector. The startups of these technologies also represent pathways to engage a broader user base beyond basic telecommunications services. The Biomedical, Energy, Facility Management, Entertainment and Education industries are all industries that, in a non-exclusive manner, have value chains indirectly connected to the telecommunications industry through the startups sampled in the 10 technology sectors reviewed

3 Accelerate transformation of telecom industry via startups

In the previous section, we studied over 7,000 startups in Hong Kong and Singapore and summarize the characteristics of the startups. In the following section, we will start with the telecom's pain points in the 4G era in the past decade. By digging into the fundamental differences between telecom operators and Internet tech companies, we will propose an innovation path for the telecom industry by initiating a new ecosystem with the startups.

3.1 A historical recap of 4G rollout

Before elaborating on the ecosystem initiated by the telecom operators and start-ups, some basic facts of the 4G era will be reviewed first. About a decade ago, mobile carriers poured billions of dollars into high-speed 4G networks only to see technology giants such as Apple Inc., and Google/Alphabet walk away with most of the profits (Zhao, S. 2021)[32]. 4G communications were first launched in 2009 and have since powered and revolutionized the world to the digital economy. The infrastructure has become a key platform that accelerated growth in the technology sector and incubated whole new areas of application, such as smartphones, mobile social media, video-driven platforms, etc. With the 4G rollout, telecoms built the infrastructure that powered the digital economy, but it was the OTT players and mobile phone manufacturers that monetized it.

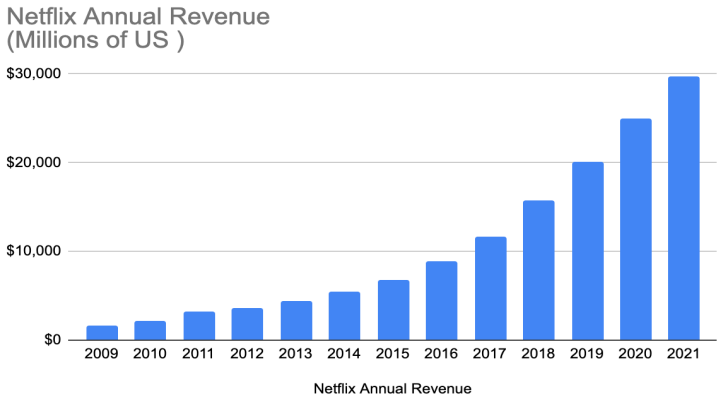

Figure 1 Netflix (2009-2021)[33]

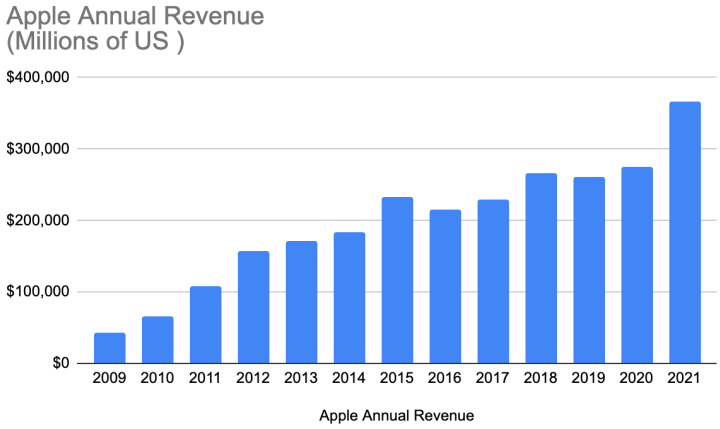

Figure 2 Apple Inc.(2009-2021)[34]

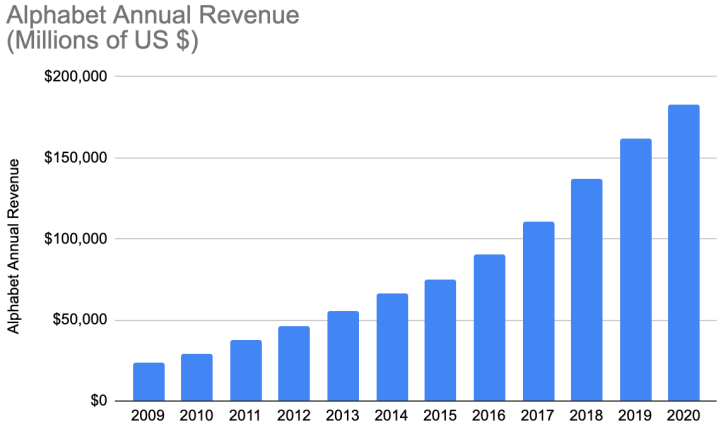

Figure 3 Alphabet/Google (2009-2020)[35]

The CAGR (Compound Annual Growth Rate) of Netflix, Apple, and Alphabet /Google are 26.74%, 20.45%, and 20.93% from 2008 to 2021, respectively. The revenue during the period has increased more than 10 times.

On the other hand, if we compare the CAGR with that of the top Five telecom operators from 2008 to 2021. The CAGR of AT&T, Verizon, Deutsche Telekom, Nippon Telegraph And Telephone ("NTT"), and China Mobile is 2.43%, 2.46%, 4.46%, 1.47%, and 5.71%, respectively. Only China Mobile has barely doubled its revenue, from 411,810 Million RMB in 2008 to 848,258 Million RMB in 2021[36373839]. The other largest telecom operators grew less than 50% in the past 13 years.

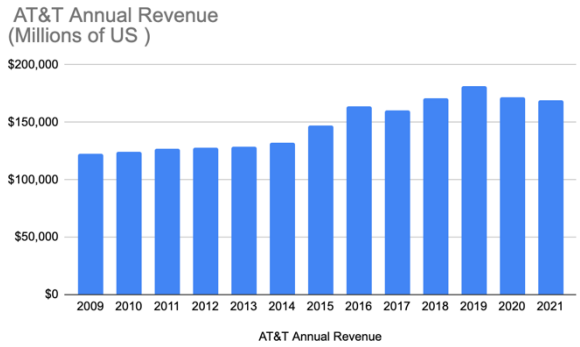

Figure 4 AT&T (2009-2021)

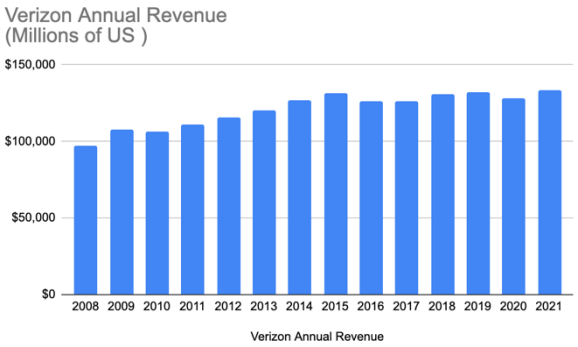

Figure 5 Verizon (2009-2021)

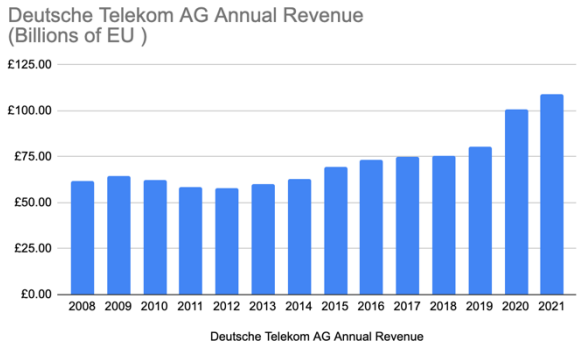

Figure 6 Deutsche Telekom (2009-2021)

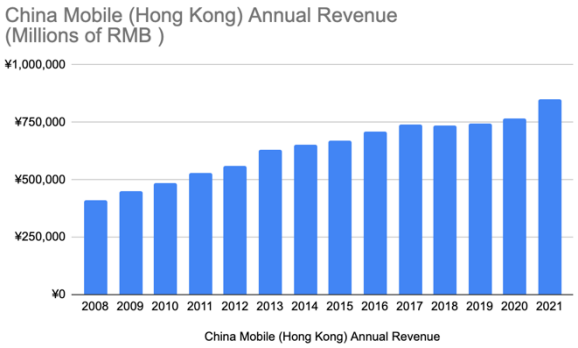

Figure 7 China Mobile (2009-2021)

Not only have the OTT Internet giants gained huge success and business achievement during the 4G era, but also unicorns. According to CB Insights[40], almost 1,200 unicorns have been founded in the past ten years and their valuation in total is 3,853 billion USD, which is 1.7 times the total market cap of the largest telecom operators in the world[41].

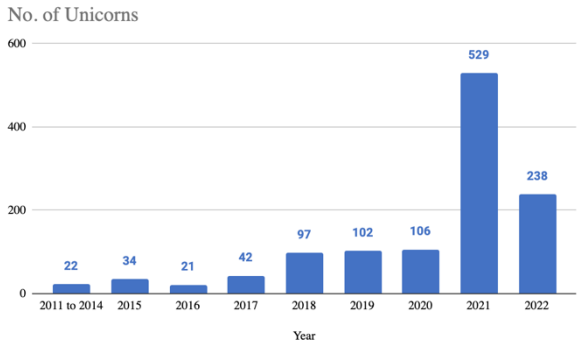

Figure 8 Number of Unicorns (2011 - 2022)

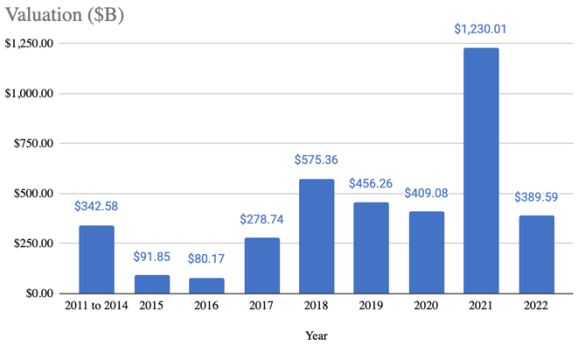

Figure 9 Valuation of Unicorns (2011-2022)

As mentioned earlier in the previous session, the start-ups are, rather than contributing the revenue or increasing the market cap of the telecom operators, accelerating the telecom operators' innovation and fully utilizing the telecom infrastructure. Numbers, especially in quantitative comparison, are simple, if not brutal, in honesty. The introduction of 4G, which took massive investment from the Telecom industry, not only sparked growth in competing technology companies but even damaged the financial outlook of the industry, diverting critical investments to other fertile competitors.

The outlook of start-ups comes in stark contrast to the telecommunications industry. As analysed in the previous section, Telecom operators can maintain organic technological development with innovations and vertical integrations with startups that are intimately connected with the industry. Startups tackling specialist problems easily go beyond the traditional market reach of telecom operations to discover blue ocean markets of other industries. This collaboration is where we believe startups can provide telecom operators with the greatest opportunities.

3.2 A new initiative of telecom industry

To understand our initiative of "telco less, telco-plus more", let's start with two stories. The first story is DBS's banking transformation in "Live More, Bank Less". DBS, as one of the leading banks in Asia, seeks a better way to run its banking service. Essentially, DBS realized that people don't need banking from banks for banking itself; Instead, people need banking to live well. Therefore, DBS decided to change its slogan to " Live More, Bank Less" because it believed that the best bank should not aim to provide the best banking services but provide the best lifestyle experience to its customers via banking. The second story is about Alibaba. Alibaba neither owns nor operates any manufacturies. However, it provides more products than the largest manufacturer in the world, Alibaba sells products from millions of factories by owning none. In our research, we have found that the biggest barrier to telecoms innovation and transformation is not the level of the advance of technologies but simply its mindset or business model. To overcome such a barrier, we will initiate a new way of innovation by creating synergy between telecom operators and startups.

Before introducing our research outcome, we will introduce a Chinese idiom from the Art of War "If you know the enemy and know yourself, you need not fear the result of a hundred battles". From the history of the development of the telecom industry, stability and persistence are the basic protocol of all telecom services. Therefore, telecom operators, for a long time, always seek long-lasting solutions, partnerships, and business models for their tremendously heavy CAPEX infrastructures. Telecom operators seldom realize the protocol of "long-lasting" practice is a burden in innovation because the words stability, persistence, and long-lasting are so correct, and there is no way to be wrong. Unfortunately, our research shows that working well with startups, especially the greatest ones, telecom operators must give up the insistence on "long-lasting" but adapt to the uncertainty of "temporary". It may be difficult for you to understand what has just been mentioned, and the upcoming explanation will help you go through it.

If the concept of "long-lasting" and "temporary" bothers you, here is a story about "temporary". In the early days, for instance, Google/Alphabet was the customer that all the telecom operators would strive their best to strike a deal with. No one would deny that Google was a golden customer, as the cash cow of the telecom operators in their BCG matrix. One day, Google decided to open its internal IT infrastructure as Google Cloud Platform ("GCP") services to the public. On the same day, the so-called golden customer of all the telecom operators switched to the killer competitor for all telecom operators. Ali-cloud, AWS, and Azure went through a similar process to Google's. However, the story has not ended yet. Ten years ago, business customers left telecom operators and embraced cloud operators because of the low cost of the cloud. Nowadays, business customers offload their cloud services from cloud operators to data center collocation in telecom operators for the same reason, cost. But nowadays, the shift is not because of the low cost of telecom operators but rather the high cost of cloud services, as shown in the below table.

Table 1 Business Customer IT Infrastructure Cost

	10 years ago	Present
Telecom operators	High cost	Low cost
Cloud operators	Low cost	High cost

The operators mentioned in the table only consist of business customers, or large corporations, more precisely. If small and medium business customers ("SMEs") or public and individual users ("users") are considered, the full picture will be revealed.

Table 2 Inclusion of SME and Individual Users

	Telecom operators		**Cloud operators**	
	10 years ago	Present	10 years ago	Present
	Cost Consideration			

Large corporations	High cost (Leaving)	Low cost (Re-loading)	Low cost (Joining)	High cost (Off-loading)
	Inclusion of the "un-IT"			
SME	NONE	Medium	Small	Large
Users	NONE	NONE	NONE	Large

In the above table, the most important contribution of cloud operators is the inclusion of SMEs and individual users in using telecom IT infrastructures. Going through the process above, cloud operators have their roles played in telecom operators as golden customers, killer competitors, and partners of Co-opetition. In short, without understanding such dynamic roles playing of the startups, telecom operators can't create a spiral synergy with startups.

3.3 The Innovation Model of Spiral Synergy

Decades ago, the telecom operators might not have had a chance to know about the development pattern of the cloud startups at that time or so-called cloud operators today. To create synergy with startups, telecom operators need to understand the lifecycles of the startups. As shown in the below diagram, the startups will go through 5 phases, Minimum Viable Product (MVP), Product (Market Fit), Channel (Product Fit), and Maturity[42]. In the earlier case about cloud operators, they are in the post-maturity phase, and the post-maturity phase is not included in our discussion here. When startups have entered the post-maturity phase, the synergy between telecom operators and startups is more on the business operation or commercial negotiation rather than the co-innovation process, called "Spiral Synergy".

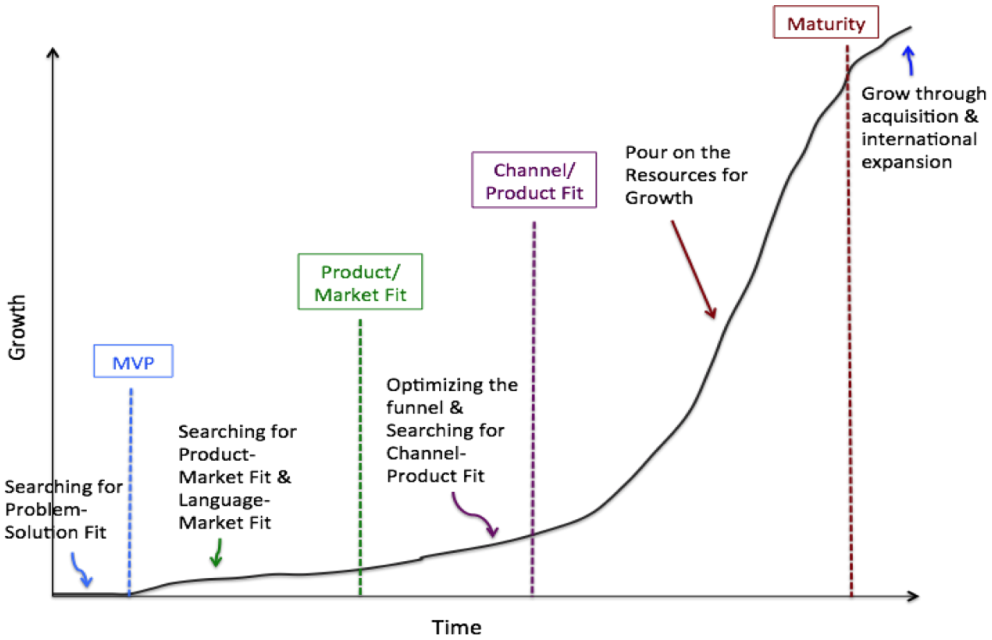

Figure 10 The 5 Phases of The Startup Growth Lifecycle[43]

Each startup will have its phase of growth lifecycle. Before working or partnering with startups, telecom operators need to identify not only the startup's growth lifecycle phase but also its position in the BCG Matrix of telecom operators. The relationship or partnership between telecom operators and startups keeps changing when the startup grows in different phases. Before integrating the BCG Matrix[44] of Telecom Operators and the Growth Lifecycle of Startups, let's look at the product lifecycle diagram.

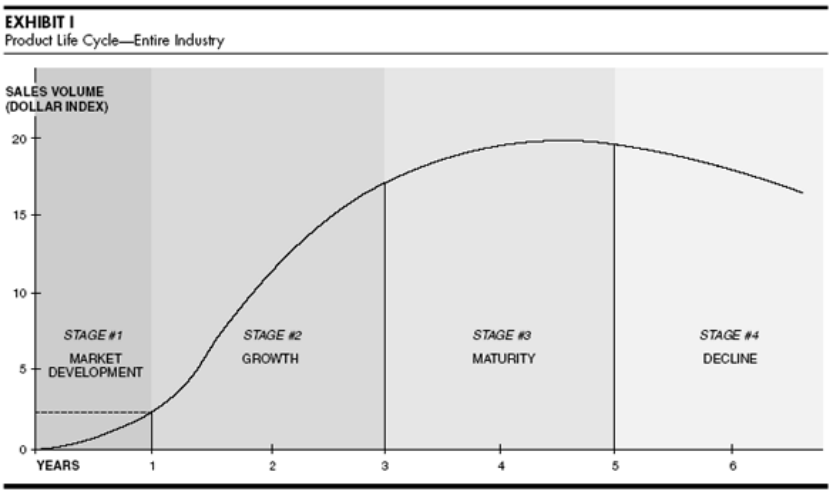

Figure 11 Product Life Cycle -Entire Industry[45]

The Telecom industry, with heavy CAPEX investments in infrastructure and ultra-long project implementation periods, is not as agile as startups when implementing product development and innovation. Together with the product life cycle, BCG Matrix is a popular model for defining the status of multiple products in the telecom operators' portfolios.

Figure 12 BCG Matrix[46]

The innovation pattern inside the telecom operators is similar to the mapping below:

Table 3 PLC and BCG Matrix mapping

Product Life Cycle	BCG Matrix position
Stage 1: Development	Question mark
Stage 2: Growth	Star
Stage 3: Maturity	Cash cow
Stage 4: Decline	Pet

In the model of Spiral Synergy, the Startups Growth Lifecycle can integrate and/or replace the telecom operators' product lifecycle, by which the telecom operators can always maintain the product portfolios in Question mark and Star of the BCG Matrix. As shown in the below diagrams, the telecom operators can leverage the startups to either accelerate the product development lifecycle from stage 1 and stage 2 to stage 3 or launch the startups' products and solutions under their own business or services.

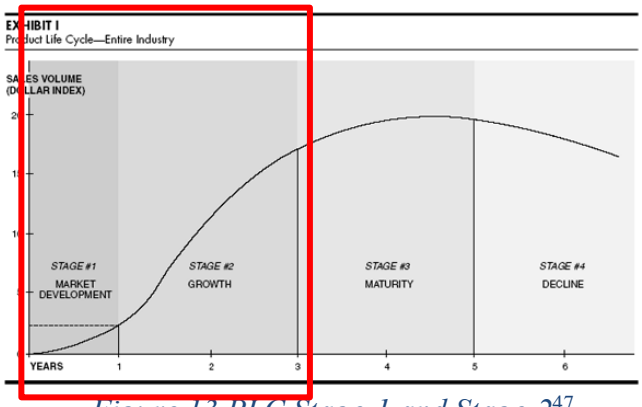

Figure 13 PLC Stage-1 and Stage-2[47]

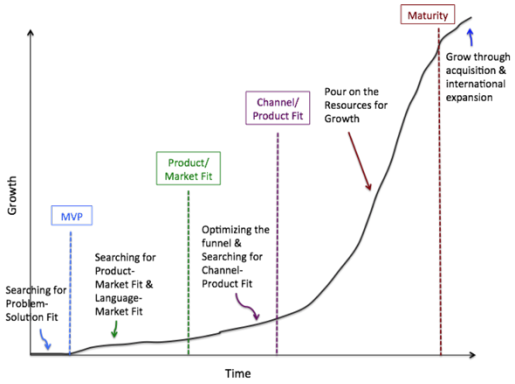

Figure 14 Startups Growth Lifecycle[48]

For instance, if a telecom operator launches 5G infrastructure, the number of 5G users is in organic growth due to there being no "killer applications". With the startups' solutions and applications in AR/VR or metaverse, the consumers will adapt to 5G much faster, by which the 5G product of telecom operator will be accelerated the PLC's growth stage. At the same time, with the well-established 5G infrastructure, the startups' products and applications can be more easily accessed by end users and accelerate Startups Growth Lifecycle, as shown in the below diagram.

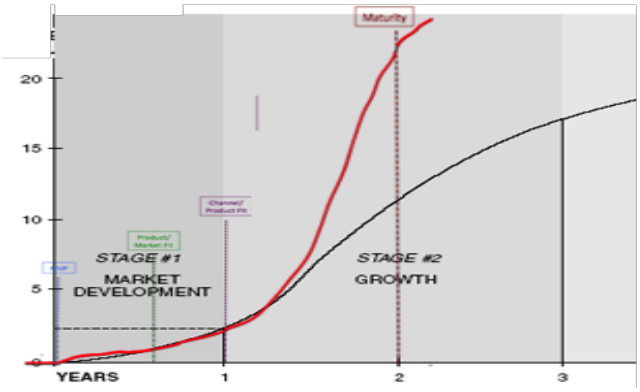

Figure 15 Integration of Telecom Opertors' PLC and Startups Growth Lifecycle

3.4 The crucial component of the Spiral Synergy Model

Before moving to the most important part of the Spiral Synergy Model, let's have a quick recap of the previous discussion. Inspired by the idea of "Live More, Bank Less", we have the "telco less, telco-plus more". With the story of cloud operator and telecom operator, we mentioned the telecom operators' preference for "long-lasting" and the partnerships of "temporality". It should be also be kept in mind that cloud operators have an inherently different approach to business, switching between that competition and cooperation when engaging with telecom operators. Lastly, we mentioned the telecom operators' product lifecycle and Startups' Growth Lifecycle, and their integration can accelerate both parties' development. Keeping the relationship dynamics between startups and telecommunications operators in mind, there is one last piece to the puzzle, which is to **Decouple the Spiral Synergy**. Successful startups must grow fast and outspeed the telecom operators in their post-maturity stage. In other words, what if the startup could not outspeed the telecom operators in their post-maturity stage, they might not be qualified as partners in the model of Spiral Synergy from the telecom operator's perspective. Therefore, telecom operators, to a certain extent, need to put the interests of the startups over their own. By doing this, the telecom operators can expand their roles and business territory outside the telecom sectors and gain economic benefits from the startups.

4 ESG and Decarbonisation of the telecom industry

In this section, we will summarise the developments of ESG and Green Finance in Hong Kong and Singapore. We will compare Hong Kong and Singapore's ESG regulations and Green Finance initiatives and discuss areas for future development. This section will also discuss the status of decarbonisation in the global telecommunications industry and the role of startups in assisting the industry's efforts to decarbonise.

4.1 HK and SG's ESG and Green Finance Development

In recent years, ESG investing has seen a significant rise in popularity. Businesses and governments have grown increasingly aware of the environmental and societal aspects of conducting business. With Hong Kong and Singapore being two of the most prominent financial centres of Asia, the two respective governments have sought to meet the demands of investors and the market. Both have taken their own approaches to facilitate and regulate the development of ESG practices and green financial infrastructure. In 2019, The Stock Exchange of Hong Kong Limited ("HKEX") issued amendments to the "Environmental, Social and Governance Reporting Guide"[49]. The changes placed a heavier focus was placed on effective governance and oversight of ESG matters. The requirements apply to all SFC-registered funds rather than solely ESG-focused funds. As a result, the regulations will assist in meeting local and international investor demands for access to climate-based risk information. Singapore on the other hand has focused on

ESG-focused funds. On 28 July 2022, the Monetary Authority of Singapore (MAS) released a circular regarding new disclosure and reporting guidelines[50] for ESG Funds. Once the guidelines enter force on 1 January 2023, ESG funds must ensure their publicly listed names are not misleading and also place increased focus on their ESG developments, efforts and goals in their annual reports. Singapore's regulation alongside meeting ESG-focused investment demands will increase fund transparency and mitigate Greenwashing in Singaporean ESG markets.

Singapore also has greater experience in the implementation of FinTech in developing its ESG investment infrastructure. The MAS in partnership with a Fintech company, Hashstacs Pte Ltd, has launched a new ESG Registry, ESGpedia[51]. The platform describes itself as aiming to "enhance the mobilisation of ESG capital". The registry connects financial institutions, regulators and investors with certified ESG and sustainability data of Singapore-registered companies across various sectors. Under Project Greenprint, the MAS has also partnered with other FinTech companies to develop other ESG platforms including the Greenprint Marketplace, which will connect green fintech and technology providers to investors, financial institutions and corporates; the Greenprint Common ESG Disclosure Platform, where companies can upload corporate-level sustainability data, which will be mapped against various standards and frameworks. With consent, the portal can also facilitate the transfer of data to authorised stakeholders for analysis; and the Greenprint Data Orchestrator, which collects sustainability data from multiple data sources - including the ESG Disclosure Portal, major ESG data providers, utility providers, and relevant sectoral platforms. The data orchestrator provides consent-based access to these sources to better support investment and financial decisions. The Greenprint platforms are set for launch between late 2022 to 2023. Both Hong Kong and Singapore's progress in the regulation of ESG and development of Green finance is still very much in their infancy. It can be seen from the regulations and initiatives seen thus far that Hong Kong and Singapore have taken different approaches. Whilst Hong Kong focuses more on the mitigation of climate risk and increased transparency from companies, Singaporean initiatives focus more on the consideration of environmental opportunities, such as the development of partnerships between companies.

Hong Kong and Singapore are both poised to play a major role in their respective areas, Hong Kong has opportunities in its connections to the Greater Bay Area connecting the Chinese and International ESG markets. In August 2021 a memorandum[52] of understanding between the HKEX and the Guangzhou Futures Exchange was signed, laying the groundwork for strategic cooperation in promoting sustainability and facilitating the development of the Guangdong-Hong Kong-Macao Greater Bay Area. There is room for further integration of the local market and its international connections with the Mainland market. Singapore, on the other hand, has opportunities as the financial centre of Southeast Asia and as a member state of ASEAN, as such, it will continue to play an integral role in coordinating and facilitating Green finance between Southeast Asian and international markets.

4.2 Decarbonization in the Telecommunications industry

Addressing climate change and decarbonizing our economy has become the challenge of our generation. The Paris Agreement[53] has brought together 196 parties around a global framework to ratchet down greenhouse gas (GHG) emissions with each involved country putting forward increasingly advanced climate goals on a five-year cycle. The legally binding agreement aims to keep the global temperature rise at 1.5 degrees Celsius in a streamlined reporting process with strong transparency. This requires transformative efforts across different sectors. According to the 2021 PBL report[54], the annual global greenhouse gas emissions in 2020 are estimated to be around 49.8 gigatonnes of carbon dioxide equivalent (GtCO2 eq). To determine how we may abate GHG emissions effectively and how technology can involve in delivering a greener industry, we must know where the emissions originate from. Looking at the sectoral breakdown of the global GHG emissions gathered by Climate Watch[55], the emissions come from almost every major societal function. 76% of the global emissions came from energy-related activities, with the majority coming from the production and combustion of fossil fuels. Following the energy sector, 12% of emissions came from Agriculture, 6.1% from industrial processes, and 3.3% each from Waste and Land-Use Change and Forestry.

The ICT industry has rapidly expanded in recent years with unprecedented structural changes to the global economy. It stands as the cornerstone for the increasingly digital economy driven by non-physical outputs and diffuses to a less-technologically centred sector, playing essential roles in all facets of social and economic life. While the ICT industry and ICT-enabled sectors have made critical contributions to employment and economic growth, it contributes to the growing carbon footprint from all its life cycle stage. Currently makes up for 2.1% to 3.9% of total GHG emissions incurring the supply chain truncation into account, ICT's contribution to global emissions is expected to grow with its expansion. Some studies prior to 2015 predicted that the carbon footprint of ICT would rise over time, with a 40% increase between 2002 and 2012. Since the industry began from zero in the middle of the twentieth century, ICT emissions have increased steadily along with our overall global carbon footprint, but the rate of increase is estimated to be twice as fast[56]. Three categories are often used to categorize greenhouse gas emissions: direct emissions from a business, such as those from fuel combustion and corporate cars, are under Scope 1; Scope 2 emissions are indirect emissions that result from using purchased electricity or other types of energy; other indirect GHG emissions fall under scope 3, such as those produced by a company's value chain or by consumers using its manufactured goods. Based on the report of 19 telecom companies to CDP, Scope 3 - mostly from capital goods, consumer products, and services - accounts for nearly half of the overall emissions of the industry. Scope 1 and 2 jointly contribute to one-third of the total emissions, and the main source is the purchase or production of energy for networks and IT, followed by some amount of fossil fuels required to run offices, fleets of vehicles, and different staff activities[57].

The ICT industry must significantly reduce its ecological footprint within the sector and enable carbon savings in other industries to achieve climate targets. Overall, the ICT industry is a major adopter of renewable energy sources (RES), and it paves the way for a global energy

transition. Efficiency improvements and the use of RES in data centres and networks enable telcos to handle more data while generating the same level of emissions. A report by Ericsson [lviii] suggests that the carbon emissions of ICT can be cut by up to 80% if all electricity consumption can be fulfilled with renewable energy (ca. 0.1 kgCO2e/kWh). Under the RE100 framework[58], twenty-one top ICT companies have collaboratively committed to 100% renewable electricity. Additionally, 29 operator groups representing 30% of global mobile connections are committed to the new Science-Based Target (SBT)[59] to develop a sector-specific decarbonization pathway. For each ICT sub-sector, the SBT establishes a pathway for reducing emissions over the next ten years (2020–2030). For instance, mobile network carriers must cut emissions by at least 45% over the decade. The growth of renewable energy worldwide can be accelerated by known financial instruments. As more corporate consumers want to advance clean energy objectives and help reduce emissions, green tariff schemes that allow corporations to buy renewable energy projects and related Renewable Energy Certificates (RECs) are growing in the US and Europe. Moreover, telecom operators and energy providers can work together to assist in a long-term transition to energy from renewable sources by using power purchase agreements (PPAs) to obtain renewable energy. Some telecom providers have also issued green bonds to fund transformation initiatives in line with environmental goals. With the help of green bonds, telecom companies may diversify their funding sources, particularly by turning to ESG-conscious investors.

Another potential for the ICT industry is to reduce carbon emissions across multiple sectors by making current infrastructures smarter and energy efficient. According to the SMARTer 2030 report[60], ICTs can cut worldwide GHG emissions by 9.1 GtCO2e by 2020 and 12.08 GtCO2e in 2030 from all sectors, which is five times greater than the estimated GHG emissions within the industry. This will reduce global GHG emissions by 20% and keep the emissions at 2015 levels, separating economic expansion from the increase in emissions. ICTs have become an important part of other technologies because they offer the computing capacity and intelligence required to function better. The SMARTer 2030 report estimates that ICT will enable eight economic sectors, including energy, food, health, learning, buildings, mobility & logistics, work & business, and manufacturing, to jointly generate $11 trillion in sustainable benefits per year by 2030. Take the mobile telecommunication subsector as an example, the application of the internet of things (IoT) and the behavioral changes in personal smartphone usage facilitate the other industries' decarbonization efforts: for instance, the use of mobile technology for real-time processing and simulation of data allows better inventory management, and it reduces the overall level of area needed and energy spent on storage; smart grids that heavily rely on mobile technology help monitor power demand and transmission in the energy industry in an effective way; smartphone usage reduces travel for commuting and leisure[61].

There are emerging innovations that help with the decarbonization progress of ICT: (1) big data, data science, and AI; and (2) the IoT. The combination of the two collectively support system and process optimization for energy efficiency in everyday internet-connected objects, bringing new, disruptive business models, and encouraging the cross-sectoral implementation of smart energy management strategies. One example is that of ZTE's PowerPilot platform[62] which has

utilised machine-learning and data analysis AI technologies at 5G base stations, which ensures network energy conservation while maintaining reliable network performance for users. It automatically acquires network data from the radio access network (RAN) domain and conducts collaborative analyses of cross-domain data, assisting in the identification of energy-saving scenarios and forecasting of network traffic trends, generating energy conservation strategies based on the analyses. The PowerPilot platform as of February 2022, has been implemented at 30 networks over 800,000 sites. ZTE reports the implementation of the PowerPilot AI platform has led to a 20% increase in smartphone battery life and a 20-25% decrease in power consumption by 5G base stations, alongside an annual reduction of 2 million kg of CO2 emissions for every 1000 5G base stations. Innovations in the ICT infrastructure will also support the increasing growth patterns seen globally in internet traffic. From 2015-2021, there was a 260% increase in data centre workloads, a 440% increase in internet traffic and a 60% increase in internet users worldwide[63]. Forecasts expect growth to steadily continue with mobile data traffic set to quadruple by 2027, With 5G's share of mobile data traffic projected to reach 60%. The switch from 4G to 5G cellular networks will allow faster, data-intensive network transfers for IoT devices, which will result in more data being distributed and analyzed. The implementation of 5G also brings significant improvements in energy consumption per traffic unit. Whilst studies show that 5G networks require 1.4∼2 times the number of base stations than 4G networks and thus energy consumption 2∼3 times higher[64] (due to the decreased coverage area by 5G base stations), a 2020 study by Nokia and Telefónica found that 5G networks are more energy efficient, up to 90% more; per traffic unit than legacy 4G networks[65]. These aforementioned centric innovations have the potential to propel future reductions in GHG emissions, offsetting carbon footprints generated along the way. However, it is to be noted that there is a lack of publicly available whole network-level assessments on the emissions and energy consumption of 5G[66].

Overall, the ICT industry could become a vital sector for the transition to a net zero world. It has given us a route of acceleration in every aspect of our society and turned UN Sustainable Development Goals (SDGs) from possibilities into actions. It should be noted that there are obstacles to the rollout of the previously mentioned new technologies, one such being the underappreciation of the telecommunications industry by investors. In an August 2022 Goldman Sachs report on "Telecoms: The Fibre & 5G Decarbonization debate"[67], investment data from over 4500 ESG funds was compared with the ESG funds' investments in various sub-sectors being weighed against the sub-sectors' respective weights in the MSCI All Country World Index. The report found telecommunications to be underappreciated by ESG fund holdings, with diversified and wireless telecommunications being 15% and 24% underweight, respectively. However, the report notes that communications infrastructure is gaining recognition from investors, being 51% overweight in ESG fund holdings. To advance the further development and rollout of telecommunications technologies, businesses and investors must recognise the growing importance of the telecommunications industry in reducing our global carbon footprint and emissions. Where possible financial institutions and governments should step in to facilitate the integration of energy-efficient telecommunications into financial, economic and societal systems.

4.3 The role of start-ups in improving Decarbonization of the telecoms industry

Technology is essential for attaining carbon neutrality, in which innovation and start-ups have a unique role to play. A few prominent game-changing industry leaders cannot resolve the climate change concerns alone. Global startups and technology developers need to establish proactive gestures to jointly contribute to the cause.

An example of a tech startup that strives to accelerate decarbonization efforts is Ampd Energy[68], an incubatee of the Hong Kong Science and Technology Park Corporation (HKSTP) that introduced cutting-edge energy storage technology: Ampd offers a trustworthy and ecologically sustainable alternative to polluting diesel generators. While a typical diesel generator at a construction site emits roughly 100 tonnes of carbon dioxide annually, which is comparable to the greenhouse gas emissions from about 22 constantly driven gasoline-powered automobiles, Ampd claims that their products generate up to 85% less carbon dioxide than conventional diesel generators and have no exhaust pollutants, such as nitrogen oxides and sulfur dioxide during the same time period[69]. The flagship product named the "Enertainer", branded as the "next-generation energy storage system", is a 7.3-tonne, 2.6-meter-tall box packed with 30,000 lithium-ion battery cells. It will provide a clean and secure alternative to enable Indonesia and nations alike with shoddy energy networks to maintain the functionality of residential, commercial, and industrial applications during power outages[70]. Arbabzadeh et. al.'s research paper titled "the role of energy storage in deep decarbonization of electricity production"[71] demonstrates the value of Ampd's battery energy storage system: taking California as an example, Arbabzadeh et. al. find that adding 60 GW of renewable energy without energy storage leads to a 72% CO2 reduction (compared to the scenario with no green energy), with around one-third of the renewable energy being reduced. However, with only 9% renewable curtailment, energy storage technologies may provide 90% CO2 reductions from the same renewable penetrations. Furthermore, Enertainers offer data analysis opportunities in addition to environmental advantages, which is "conducive to raising project efficiency as well as the digitalization of construction", as commented by Ampd's deputy chairman. The units also offer enhanced safety and less noise since electric power is quieter than diesel engines and doesn't require hazardous fuels.

Green Koncepts[72] is a Singaporean technology-based startup enterprise that utilizes IoT solutions and cloud-based systems to harness real-time energy consumption for real estate companies, intending to improve sustainability and operational efficiency. Its award-winning cloud energy management application Energetix integrated sensors, meters, controllers, building management systems, and other IoT devices to enhance energy efficiency for cities, structures, data centers, businesses, and residences. It gives KPIs like energy usage intensity, efficiency, consumption trends, and more, enabling the construction teams to track building energy efficiency without number crunching or expensive data integration. As per the company's claims, its smart building management may assist businesses in up to 30% operational cost reduction. A client that has benefitted from the improved efficiency is DBS Newton Green, the first net-zero bank building

in Singapore. With the integration of Green Koncepts' technology, the 30-year-old, four-story office building has been refurbished and has decreased its energy use by 70%[73].

A successful example of a start-up reducing telecommunications industry emissions is that of the partnership between O2 Telefónica and the "The Climate Choice" startup[74]. O2, the Telefónica branch responsible for operations in the United Kingdom, has set the goal of carbon neutrality by 2025, and an emission-free supply chain by 2040. The Climate Choice Platform will assist O2 Telefónica 's efforts to decarbonise its supply chain (Scope 3 emissions), it aims to do so by collecting climate-focused data from around 1,000 suppliers. The Climate Choice then makes use of software to analyse the received data, providing O2 Telefónica with a basis for a Scope 3 Decarbonization strategy. The Climate Choice has also offered O2 Telefónica's top 40 suppliers to carry out a "software-driven climate rating" to uncover potential strategies for further decarbonisation. Lara Obst, The Climate Choice's Co-Founder and Managing Director, stated that "The success of the corporate climate transformation stands and falls with the Decarbonization of the supply chain. Up to 90% of a company's emissions occur in Scope 3." The Climate Choice has demonstrated the potential of software startups in assisting industry reduction of Scope 3 emissions. Through their facilitation of data transfer and data analysis, climate transparency is further increased, assisting companies and their suppliers in achieving climate goals.

With this new direction of reaching beyond net zero, a global-wise initiative to innovate will be essential to addressing the climate crisis. The StartUs Insights concludes innovative trends in the telecom sectors including 5G, advancements in connectivity, 5G & Network Infrastructure, Cloud Computing, and other areas which will revolutionize the industry. Collaborating with startups and adopting prospective technology will gain the telecom industry a competitive advantage in efficiency, both operationally and sustainably.

5 Conclusion

In the course of this paper, we have explored the startup ecosystems and their relationship with the telecommunications industry. The growing startup communities in Hong Kong and Singapore have over 7,000 startups with many success stories. Micro -ecosystems of more than 2,000 startups directly leverage technologies that are directly connected to the Telecommunications value chain. Startups exhibit strengths in specialized problem solving and user-centric solutions providing high quality customer engagement. Startups in this ecosystem are easy to approach targets for collaboration to achieve organic technological development of the telecommunications sector. Startups examined in the examples can serve as pathways to engage a broader user base to other industries, beyond traditional telecom markets. In our analysis of pain points within the Telecom industry, risk aversion and the pursuit for long-lasting solutions, partnerships and business models comes in stark contrast to the temporary nature of innovative startups. To amalgamate the strengths of Startups into Telecom industry practices will require adoption of a new mindset and collaboration model. Successful adoption and incorporation of startups into a synergistic ecosystem can accelerate and grow Telecom industries, sparking business transformation. The telecom industry can aspire to Alibaba as a model of such business

transformation, and sell products from millions of factories by owning none. ESG is one of the hottest topics in the startup ecosystem and could be a target industry for startup engagement for the Telecom industry. The governments in both Hong Kong and Singapore have started ESG and green finance initiatives. Telecom companies can leverage the supportive regulatory infrastructure. The telecom industry and startup ecosystem can work together in accomplishing decarbonization for the future.

With diligent self reflection, we recognize the inadequacy of quantitative support for the qualitative observations and analysis conducted in this paper. It is in our best wishes that the industry can produce success cases to substantiate the forward looking concepts that were put forth. In reviewing the relationship of the telecom industry and startups, we proposed an innovation model for spiral synergy as a pathway for collaboration. With a synergistic ecosystem to drive transformation, the telecom industry can achieve stronger value by being **Telco Less, Telco+ more**".

6 Future Steps

The research paper serves as the first step and foundation of our future endeavors. Through the documented data and the mapping analysis between the startup ecosystem and telcos, our team will identify avenues of innovation for the telecom industry by probing into startups' life cycles and ultimately restructure the value chain of the telecom industry. We would look at the CII (Corporate Innovation Index) as an example and develop guidelines for implementing new practices in telecommunication organizations. The CII is a set of multi-dimensional assessment matrices developed by the Asia-Pacific Institute of Business (APIB), the Chinese University of Hong Kong, to measure and enhance innovation capability among Hong Kong's corporates and SMEs. The index has been compiled based on the IPO model, integrating three major factors including resource (input), enabler (process), and value (output). 12 factors in total measure the maturity of innovation capability across these three dimensions: resource includes company culture, market environment, organization resources; enabler comprises leadership, digital transformation, collaboration, talents management, customer co-creation, and commercialization; and output covers business performance, intellectual outcome, and business model enhancement. Though our research began with a close look at startups in Hong Kong and Singapore, we will expand our scope to other regions within the Asia Pacific to gain a more comprehensive understanding of best practices for innovation and transformation in the telecom sector[75].

Our next step is to roll out a pilot project to experiment with the framework developed through the paper as well as initiate the cooperation model and operation flow between the startups and telcos. We have got contacted a network of potential industrial representatives who have shown interest in partnering and could potentially benefit from the project.

The final step is to optimize the solution by creating a rigorous model of innovation after testing and fine-tuning it on our existing customer base for validation and eventual commercialization. We will incorporate machine learning tools to dynamically identify trends and provide intelligent recommendations based on real-time analytics and eventually scale it to support

additional markets and customers in the future. By doing so, we will be able to automate processes and reduce operational costs while creating value for end customers.

To sum up, the aim of our thesis project is to innovate and implement a new framework that can be customized and applied across the telecommunications landscape to spark organizational transformation in the digital age.

7 Reference

[1] *Deloitte United States*. (2022). 2022 telecom industry outlook. Retrieved September 13, 2022, from https://www2.deloitte.com/us/en/pages/technology-media-and-telecommunications/articles/telecommunications-industry-outlook.html.

[2] Person. (2021, July 7). *Fighting for the ROI on 5G*. Mobile Magazine. Retrieved October 9, 2022, from https://mobile-magazine.com/mobile-operators/fighting-roi-5g

[3] Hughes, A. (n.d.). *Churn reduction in the telecom industry*. DB Marketing, Database Marketing Institute, Retrieved September 13, 2022, from http://www.dbmarketing.com/telecom/churnreduction.html.

[4] *Ericsson.* (n.d.). The zero-touch customer experience. https://www.ericsson.com/en/reports-and-papers/consumerlab/reports/the-zero-touch-customer-experience

[5] Gaibi, Z., Jones, G., Pont, P., & Vaidya, M. (2021, May 13). *A blueprint for telecom's critical reinvention*. McKinsey & Company. Retrieved Sep 16, 2022, from https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/a-blueprint-for-telecoms-critical-reinvention

[6] *Investhk releases annual survey results in 2021 and announces StartmeupHK Festival will return in May 2022*. InvestHK. (2021, November 1). Retrieved September 13, 2022, from https://www.investhk.gov.hk/en/news/investhk-releases-annual-survey-results-2021-and-announces-startmeuphk-festival-will-return-may-2022.html

[7] AI, Measureable. (2022, June 29). *Who Is Leading the Virtual Bank Race in Hong Kong?* Derived From Data News. Retrieved September 14, 2022, from https://dfdnews.com/2022/07/29/who-is-leading-the-virtual-bank-race-in-hong-kong/.

[8] Hong Kong Monetary Authority. (2021, June 7). *The HKMA unveils "Fintech 2025" strategy*. Hong Kong Monetary Authority. Retrieved September 16, 2022, from https://www.hkma.gov.hk/eng/news-and-media/press-releases/2021/06/20210608-4/

[9] Pangarkar, N., & Vandenberg, P. (2022, September 7). *Singapore's ecosystem for Technology Startups and lessons for its neighbors*. Asian Development Bank. Retrieved September 13, 2022, from https://www.adb.org/publications/singapore-ecosystem-technology-startups

[10] StartmeupHK, J. C. H. of. (2021, October 21). *Hong Kong's Startup Ecosystem*. StartmeupHK. Retrieved October 18, 2022, from https://www.startmeup.hk/about-us/hong-kongs-startup-ecosystem/

[11] *Startup SG - the Singapore Startup Ecosystem*. Startup SG - The Singapore Startup Ecosystem. (n.d.). Retrieved October 18, 2022, from https://www.startupsg.gov.sg/

[12] *Top 10 telecom industry trends & innovations*. StartUs Insights. (2022, September 7). Retrieved October 15, 2022, from https://www.startus-insights.com/innovators-guide/top-10-telecom-industry-trends-innovations-in-2021/

[13] Environmental Protection Agency. (n.d.). *Historical GHG Emissions*. EPA. Retrieved October 13, 2022, from https://www.epa.gov/climate-indicators/climate-change-indicators-global-greenhouse-gas-emissions

[14] *Smart washroom*. Blutech Hygiene and Smart Washroom Solution. (2022, July 18). Retrieved October 13, 2022, from http://blutech.io/

[15] WaveBoost. (n.d.). Retrieved October 13, 2022, from https://www.waveboost.net/

[16] Trinity Photonics. (n.d.). Retrieved October 13, 2022, from https://www.tphoton.com/

[17] Simo. (n.d.). Retrieved October 13, 2022, from https://www.simo.co/

[18] Casa Systems. (n.d.). Retrieved October 13, from 2022 http://www.casa-systems.com/

[19] Peach intellihealth. (n.d.). Retrieved October 13, 2022, from http://peachih.com/

[20] Bloom Standard. (n.d.). Retrieved October 13, 2022, from https://www.bloomstandard.com/

[21] Atlastream. (n.d.). Retrieved October 13, 2022, from https://atlastream.net/

[22] AIPhotonics. HKSTP. (n.d.). Retrieved October 14, 2022, from https://www.hkstp.org/our-community/innovator-directory/company-details?company=aiphotonics-limited

[23] Block Armour. (n.d.). Retrieved October 13, 2022, from https://www.blockarmour.com/

[24] ADVstar. (n.d.). Retrieved October 13, 2022, from https://advstar.org/

[25] Semut technologies. (n.d.). Retrieved October 13, 2022, from https://semut.io/

[26] Cloud Ocean Software Technology. (n.d.). Retrieved October 13, 2022, from http://www.cloudoceantech.com/

[27] Resync Technologies. (n.d.). Retrieved October 13, 2022, from https://www.resynctech.com/

[28] Esix Limited. (n.d.). Retrieved October 13, 2022, from https://esix.co/en/

[29] *Site-to-site network (SD-WAN)*. Site-to-Site Network - GL.iNet. (2019, June 24). Retrieved October 18, 2022, from https://www.gl-inet.com/solutions/site-to-site/
[30] Nife. (n.d.). Retrieved October 13, 2022, from https://nife.io/
[31] Compathnion Technology. (n.d.). Retrieved October 13, 2022, from https://www.compathnion.com/
[32] Zhao, S. (2021, August 10). Telcos seek killer app to recoup billions spent on 5G. Bloomberg.com. Retrieved October 17, 2022, from https://www.bloomberg.com/news/articles/2021-08-10/telcos-seek-killer-app-to-recoup-billions-spent-on-5g-networks
[33] *Netflix revenue 2010-2022: NFLX*. Macrotrends. (n.d.). Retrieved October 18, 2022, from https://www.macrotrends.net/stocks/charts/NFLX/netflix/revenue
[34] *Apple Revenue 2010-2022: AAPL*. Macrotrends. (n.d.). Retrieved October 18, 2022, from https://www.macrotrends.net/stocks/charts/AAPL/apple/revenue
[35] *Alphabet revenue 2010-2022: Goog*. Macrotrends. (n.d.). Retrieved October 18, 2022, from https://www.macrotrends.net/stocks/charts/GOOG/alphabet/revenue
[36] *Telecom revenues*. Macrotrends. (n.d.). Retrieved October 18, 2022, from https://www.macrotrends.net/
[37] *China Mobile Annual Report*. China Mobile Limited - Investor Relations > Financial Reports. (n.d.). Retrieved October 18, 2022, from https://www.chinamobileltd.com/en/ir/reports.php
[38] *NTT Annual report*. NTT. (n.d.). Retrieved October 18, 2022, from https://group.ntt/en/ir/library/annual/
[39] AG, D. T. (2022, September 26). *Deutsche Telekom Financial results*. Deutsche Telekom. Retrieved October 18, 2022, from https://www.telekom.com/en/investor-relations/publications/financial-results
[40] *The complete list of Unicorn Companies*. The Complete List Of Unicorn Companies. (n.d.). Retrieved October 17, 2022, from https://www.cbinsights.com/research-unicorn-companies
[41] The Largest telecommunication companies by market cap is 2,217 billion USD. *Largest telecommunication companies by market cap*. CompaniesMarketCap.com - companies ranked by market capitalization. (n.d.). Retrieved October 17, 2022, from https://companiesmarketcap.com/telecommunication/largest-telecommunication-companies-by-market-cap/
[42] Bass, L. (2016, May 31). *5 phases of the startup lifecycle: Morgan Brown on what it takes to grow a startup*. Medium. Retrieved October 17, 2022, from https://medium.com/tradecraft-traction/5-phases-of-the-startup-lifecycle-morgan-brown-on-what-it-takes-to-grow-a-startup-50b4350f9d96
[43] Bass, L. (2016, May 31). *5 phases of the startup lifecycle: Morgan Brown on what it takes to grow a startup*. Medium. Retrieved October 17, 2022, from https://medium.com/tradecraft-traction/5-phases-of-the-startup-lifecycle-morgan-brown-on-what-it-takes-to-grow-a-startup-50b4350f9d96
[44] *What is the growth share matrix?* BCG Global. (n.d.). Retrieved October 17, 2022, from https://www.bcg.com/about/overview/our-history/growth-share-matrix
[45] Levitt, T. (1965). *Exploit the product life cycle* (Vol. 43). Graduate School of Business Administration, Harvard University.
[46] *What is the growth share matrix?* BCG Global. (n.d.). Retrieved October 17, 2022, from https://www.bcg.com/about/overview/our-history/growth-share-matrix
[47] Levitt, T. (1965). *Exploit the product life cycle* (Vol. 43). Graduate School of Business Administration, Harvard University.
[48] Bass, L. (2016, May 31). *5 phases of the startup lifecycle: Morgan Brown on what it takes to grow a startup*. Medium. Retrieved October 17, 2022, from https://medium.com/tradecraft-traction/5-phases-of-the-startup-lifecycle-morgan-brown-on-what-it-takes-to-grow-a-startup-50b4350f9d96
[49] Hong Kong Exchanges and Clearing Limited. (n.d.). *Appendix 27 environmental, Social and Governance Reporting Guide: Rulebook.* Appendix 27 Environmental, Social and Governance Reporting Guide | Rulebook. Retrieved October 10, 2022, from https://en-rules.hkex.com.hk/rulebook/environmental-social-and-governance-reporting-guide-0
[50] Government of Singapore. (2022, July 28). *CFC 02/2022 disclosure and reporting guidelines for retail ESG funds.* Monetary Authority of Singapore. Retrieved October 13, 2022, from https://www.mas.gov.sg/-/media/MAS/Regulations-and-Financial-Stability/Regulations-Guidance-and-Licensing/Securities-Futures-and-Fund-Management/Regulations-Guidance-and-Licensing/Circulars/CFC-02-2022-Disclosure-and-Reporting-Guidelines-for-Retail-ESG-Funds.pdf
[51] Government of Singapore. (2022, July 27). *Green FinTech.* Monetary Authority of Singapore. Retrieved October 13, 2022, from https://www.mas.gov.sg/development/fintech/Green-FinTech

[52] Hong Kong Exchanges and Clearing Limited. (2021, August 27). *HKEX signs Mou with Guangzhou Futures Exchange.* HKEX Group. Retrieved October 13, 2022, from https://www.hkex.com.hk/News/News-Release/2021/210827news?sc_lang=en#:~:text=Hong%20Kong%20Exchanges%20and%20Clearing,Kong%2DMacao%20Greater%20Bay%20Area.

[53] *The Paris Agreement*. Unfccc.int. (n.d.). Retrieved October 5, 2022, from https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

[54] Olivier, Jos G.J. (2022, August). Trends in Global CO2 and Total Greenhouse Gas Emissions 2021 Summary Report. PBL Netherlands Environmental Assessment Agency. Retrieved October 15, 2022, from https://www.pbl.nl/sites/default/files/downloads/pbl-2022-trends-in-global-co2-and_total-greenhouse-gas-emissions-2021-summary-report_4758.pdf

[55] Environmental Protection Agency. (n.d.). Historical GHG Emissions. EPA. Retrieved October 13, 2022, from https://www.epa.gov/climate-indicators/climate-change-indicators-global-greenhouse-gas-emissions

[56] Freitag, C., Berners-Lee, M., Widdicks, K., Knowles, B., Blair, G. S., & Friday, A. (2021, September 10). The real climate and transformative impact of ICT: A Critique of estimates, trends, and regulations. Patterns. Retrieved October 17, 2022, from https://www.sciencedirect.com/science/article/pii/S2666389921001884

[57] Lambrette, U. (2021, May 11). The Next Level Of Emission Reductions In Telecom Operators. Oliver Wyman . Retrieved October 17, 2022, from https://www.oliverwyman.com/our-expertise/insights/2021/may/next-level-of-emission.html

[58] RE100. (n.d.). RE100 Climate Group. Retrieved October 13, 2022, from https://www.there100.org/

[59] GSMA Association. (2020, March 5). *ICT industry agrees landmark science-based pathway to reach net zero emissions.* GSMA Newsroom. Retrieved October 17, 2022, from https://www.gsma.com/newsroom/press-release/ict-industry-agrees-landmark-science-based-pathway-to-reach-net-zero-emissions/#_edn1

[60] *#SMARTer2030 ICT Solutions for 21st Century Challenges* . United Nations Climate Change. (n.d.). Retrieved October 10, 2022, from https://gesi.org/research/smarter2030-ict-solutions-for-21st-century-challenges

[61] GSMA Association. (2019, December). *The Enablement Effect.* GSMA . Retrieved October 16, 2022, from https://www.gsma.com/betterfuture/wp-content/uploads/2019/12/GSMA_Enablement_Effect.pdf

[62] Fan , Y., & Liu , R. (2022, February 9). *PowerPilot: Enabling end-to-end Greener 5G Networks.* ZTE. Retrieved October 17, 2022, from https://www.zte.com.cn/global/about/magazine/zte-technologies/2022/1-en/Special-Topic/3.html

[63] International Energy Agency. (2022, September 1). *Data Centres and data transmission networks – analysis.* IEA. Retrieved October 14, 2022, from https://www.iea.org/reports/data-centres-and-data-transmission-networks

[64] Ding, Y., Duan, H., Xie, M., Mao, R., Wang, J. J., & Zhang, W. (2022, April 12). *Carbon emissions and mitigation potentials of 5G base station in China.* Resources, Conservation and Recycling. Retrieved October 14, 2022, from https://www.sciencedirect.com/science/article/abs/pii/S092134492200177X?via%3Dihub

[65] Nokia Corporation. (2020, December 2). *Nokia confirms 5G as 90 percent more energy efficient.* Nokia. Retrieved October 14, 2022, from https://www.nokia.com/about-us/news/releases/2020/12/02/nokia-confirms-5g-as-90-percent-more-energy-efficient/

[66] Williams, L., Sovacool, B. K., & Foxon, T. J. (2022, January 13). *The energy use implications of 5G: Reviewing whole network operational energy, embodied energy, and indirect effects.* Renewable and Sustainable Energy Reviews. Retrieved October 14, 2022, from https://www.sciencedirect.com/science/article/pii/S1364032121012958?via%3Dihub

[67] Tylenda, E., Lee , A., Duval, A., Chen , G., Meyer , M., Singer, B., Bingham, D. R., Jones , E., Corbett, B., & Aggarwal, R. (2022, August 16). *GS Sustain: Telecoms - the fibre & 5G Decarbonization debate.* Goldman Sachs. Retrieved October 14, 2022, from https://www.goldmansachs.com/insights/pages/telecoms-the-fibre-and-5g-decarbonisation-debate.html

[68] Ampd. (n.d.). Retrieved October 13, 2022, from https://www.ampd.energy/

[69] Kang, J. (2022, October 11). *Charging ahead: Hong Kong's AMPD Energy is on a global expansion drive to make construction sites greener.* Forbes. Retrieved October 17, 2022, from https://www.forbes.com/sites/johnkang/2022/10/11/charging-ahead-hong-kongs-ampd-energy-is-on-a-global-expansion-drive-to-make-construction-sites-greener/?sh=6bf8ec004570

[70] Hong Kong Science and Technology Parks Corporation. (2016, December 21). *HK start-up launches zero-pollution energy storage system.* HKSTP. Retrieved October 17, 2022, from https://www.hkstp.org/press-room/hk-start-up-launches-zero-pollution-energy-storage-system/

[71] Arbabzadeh, M., Sioshansi, R., Johnson, J. X., & Keoleian, G. A. (2019, July 30). The role of energy storage in deep decarbonization of electricity production. Nature News. Retrieved October 17, 2022, from https://www.nature.com/articles/s41467-019-11161-5

[7272][72] *About GK*. Green Koncepts Pte Ltd. (n.d.). Retrieved October 17, 2022, from https://www.greenkoncepts.com/content/8-about-gk

[73] *IOT platform helps Singapore decarbonise existing buildings*. Smart Cities World. (n.d.). Retrieved October 12, 2022, from https://www.smartcitiesworld.net/commercial-buildings/iot-platform-helps-singapore-decarbonise-existing-buildings-7948

[74] THE CLIMATE CHOICE UG. (2022, March 2). *Case study: O2 telefónica • the climate choice.* The Climate Choice. Retrieved October 16, 2022, from https://theclimatechoice.com/en/success-story-o2-telefonica/

[75] Corporate innovation index. APIB. (n.d.). Retrieved December 20, 2022, from https://exed.bschool.cuhk.edu.hk/cii-design-methodology/