EcoInternet_Index

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https://ecointernet.asia

EcoInternet Pilot Study Report 2021

Executive Summary

The COVID-19 pandemic unequivocally demonstrated that the Internet is and will likely continue to be the core and critical infrastructure for human cooperation and communication globally. The lockdowns around the world during the pandemic, has also shown that on one hand, as physical mobility was curtailed, global CO_2 emissions experienced the largest decline ever recorded, but on the other hand, digital mobility became imperative, carbon footprint of the Internet becomes an essential topic of consideration.

Beginning in 2020, DotAsia and APNIC Foundation have been exploring ways to advocate for multistakeholder discussions about the matter of Internet's impact on climate change, among the Internet Governance community and beyond. In 2021, with funding by Heinrich Boell Stiftung Hong Kong, this research project began with a pilot study on the carbon footprint of the Internet and its impact on the environment. We are at a critical time for digital communities to reflect on and monitor the expansion of the Internet, connecting with carbon footprint initiatives to develop concepts, tools and Internet governance policies, in order to tackle climate change and recovery plans. There is a strong need to increase awareness and proactivity among policymakers and developers and it is crucial to urge governments and the industry to prioritize the imperatives of climate change and environmental sustainability in future planning. Effective measures by multiple sectors on curbing digital carbon footprint are necessary to make a difference in global scale.

Based on data and literary research, along with discussions at various workshops and feedback from a distinguished group of advisors, this report introduces a multi-dimensional scalable framework for an EcoInternet Index (EII) which will allow comparative studies between the pilot countries and

jurisdictions. Beyond simply considering the carbon emission of the Internet, the findings understood that an appropriate narrative for addressing the issue must include not only the advocacy for carbon conscious consumers, but also how Internet activities replace more carbon intensive activities, that the energy that supports the power grid is of crucial importance, and that the optimization of Internet infrastructure capacity are all important dimensions that should be considered at the same time. The narrative which EII advances, in summary, is to "do more, waste less." Do more with the Internet and the infrastructure, and become more efficient with its use and with renewable energy sources. The EII is designed to model this approach towards a greener Internet that supports sustainable growth without compromising the environment.

The EII is thus designed around three axes: 1. the *Economy* axis will consider the relative carbon emission factor of Internet usage in relation to the digital economy advantage; 2. the *Energy* axis models the grid emission factor with consideration of renewable energy sources; and, 3. the *Efficiency* axis takes into account the Internet infrastructure capacity, the speed of connectivity as experienced by users and the variance or optimality of the utilization of available bandwidth. Together, the model provides a composite index that allows for the comparison of the eco-friendliness of the Internet infrastructure between large and small regions.

Although this pilot study included only six jurisdictions in Asia Pacific, the results suggest that the EII framework provides a scalable and reasonable composite set of indicators to consider the eco-friendliness of the Internet infrastructure across jurisdictions. This opens the door for future development of the EII to include other countries and economise in Asia Pacific as well as other regions around the world.

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1. Introduction

Sustainability is at the forefront of almost every agenda from local calls to action, industry going greener, to the United Nations' Sustainable Development Goals for 2030. At the COP26 that concluded mid-November 2021 in Glasgow, the nations took a range of decisions in the collective effort to limit global temperature rise to 1.5 degrees, adopted the Glasgow Climate Pact[1] and consensus was reached on key actions[2] to address climate change.[3]

Global emissions of carbon dioxide have been rising steadily by about 1% per year for decades. In 2020, in association to population confinement and economic activity slowdown due to the COVID-19 pandemic, the world has seen a decrease of 5.8% in 2020,[4] or almost 2 Gt CO2 – the largest ever decline and almost five times greater than the 2009 decline that followed the global financial crisis, which is the largest annual decline on record; daily global CO_2 emissions have decreased by 17% by early April 2020 compared with the figures of 2019.[5]

Although there was a significant decline in carbon emissions in 2020, it was obviously a result from population confinement and economic slowdown. Experts forecast that carbon emissions will rapidly bounce back, because digital activity has been accelerated by the pandemic, for example through online learning, home office, online shopping, and other social and entertainment activities. Estimates show that Global carbon dioxide (CO_2) emissions from fossil fuels and cement have rebounded by 4.9% in 2021. The Global Carbon Project (GCP)[6] projects that fossil emissions in 2021 will reach 36.4bn tonnes of CO_2 ($GtCO_2$), only 0.8% below their pre-pandemic high of 36.7 $GtCO_2$ in 2019. International Energy Agency just release the latest report in March 2022, showing CO_2 emissions rose to a record high in 2021.[7]

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[1] Glasgow Climate Pact: https://unfccc.int/process-and-meetings/the-paris-agreement/the-glasgow-climate-pact-key-outcomes-from-cop26

[2] Outcomes of the Glasgow Climate Change Conference: https://unfccc.int/process-and-meetings/conferences/glasgow-climate-change-conference-october-november-2021/outcomes-of-the-glasgow-climate-change-conference

[3] UN Press Release 13 November, 2021: https://unfccc.int/news/cop26-reaches-consensus-on-key-actions-to-address-climate-change

[4] IEA Global Energy Review: CO2 emissions: https://www.iea.org/reports/global-energy-review-2021/co2-emissions

[5] "Daily global CO2 emissions decreased by –17% (–11 to –25% for ±1σ) by early April 2020 compared with the mean 2019 levels, just under half from changes in surface transport. At their peak, emissions in individual countries decreased by –26% on average. The impact on 2020 annual emissions depends on the duration of the confinement, with a low estimate of –4% (–2 to –7%) if pre-pandemic conditions return by mid-June, and a high estimate of –7% (–3 to –13%) if some restrictions remain worldwide until the end of 2020." https://www.nature.com/articles/s41558-020-0797-x

[6] Global Carbon Project https://www.globalcarbonproject.org/

[7] IEA press release: Global CO2 emissions rebounded to their highest level: https://www.iea.org/news/global-co2-emissions-rebounded-to-their-highest-level-in-history-in-2021

In 2016, upon the launching of the United Nations Sustainable Development Goals (SDGs), DotAsia launched the Ajitora (www.ajitora.asia) project, an awareness program to promote the SDGs and its relation with Internet development. Since 2020, DotAsia has been working with APNIC Foundation (https://apnic.foundation/) to explore how best to foster and support the discussion about Internet's carbon footprint and impact on climate change to the Internet governance community. This study is supported by Heinrich Böll Stiftung Hong Kong to collect data and analyse the possible impact of data exchange on carbon emissions, and to consider a way to study the comparative impact of the Internet infrastructure among different jurisdictions and countries, especially for the Asia Pacific region (but a methodology that may also be applicable for other regions also). In this report, we present the research findings of this pilot study, which begins with investigating ways to measure the impact of digital activities on carbon emissions, leading to the discussion on how to consider the impact of digitalisation on global warming. In our research, we will analyze data from consumer usage of the Internet, as well as from Internet exchanges and relate it to carbon emissions, to investigate the relationship between them and to identify if there are problems and how best to consider industry policies to address them.

2. Carbon Footprint of the Internet

According to the Intergovernmental Panel on Climate Change Global Warming (IPCC), emissions of greenhouse gases from human activities are responsible for approximately 1.1°C of warming since 1850-1900 and "unless there are immediate, rapid and large-scale reductions in greenhouse gas emissions, limiting [global] warming to close to 1.5°C or even 2°C will be beyond reach."[8]

However, large-scale reductions are hard to achieve when the biggest CO_2 emitters are states that use mostly fossil fuels, and it is difficult to look at sustainability and cut down emissions when there is a heavy reliance on fossil fuels. When we look at sustainability, especially in the context of our increased online activities the past two years during the pandemic lockdowns, it is important to look at the actual carbon footprint of the Internet.

As of October 2021, there are 4.88 billion active Internet users across the globe, totaling almost 62% of the world's population, and in the last 12 months alone, 222 million new users came online.[9] We are living in an increasingly digital world, the Information and Communications Technology (ICT) sector remains at around 2% to 3%[10] of overall global emissions. Its carbon footprint could be reduced by a staggering 80% if the electricity it consumed came from renewable energy sources instead of fossil fuels.[11] Even though we are talking about a small slice of total global emissions, the fact that there is a large opportunity for improving sustainability, and the increasing growth of the digital economy makes it all the

[8] A Report of the Intergovernmental Panel on Climate Change, Synthesis Report of the Sixth Assessment Report https://www.ipcc.ch/ar6-syr/

[9] Data from Hootsuite via https://datareportal.com/global-digital-overview

[10] The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations: https://www.sciencedirect.com/science/article/pii/S2666389921001884

[11] A quick guide to your digital carbon footprint - Deconstructing Information and Communication Technology's carbon emissions https://www.ericsson.com/en/reports-and-papers/industrylab/reports/a-quick-guide-to-your-digital-carbon-footprint

more imperative that we make multiple layers of effort from policy level (ICT policy directives, renewable energy goals) to individual actions to address the situation.

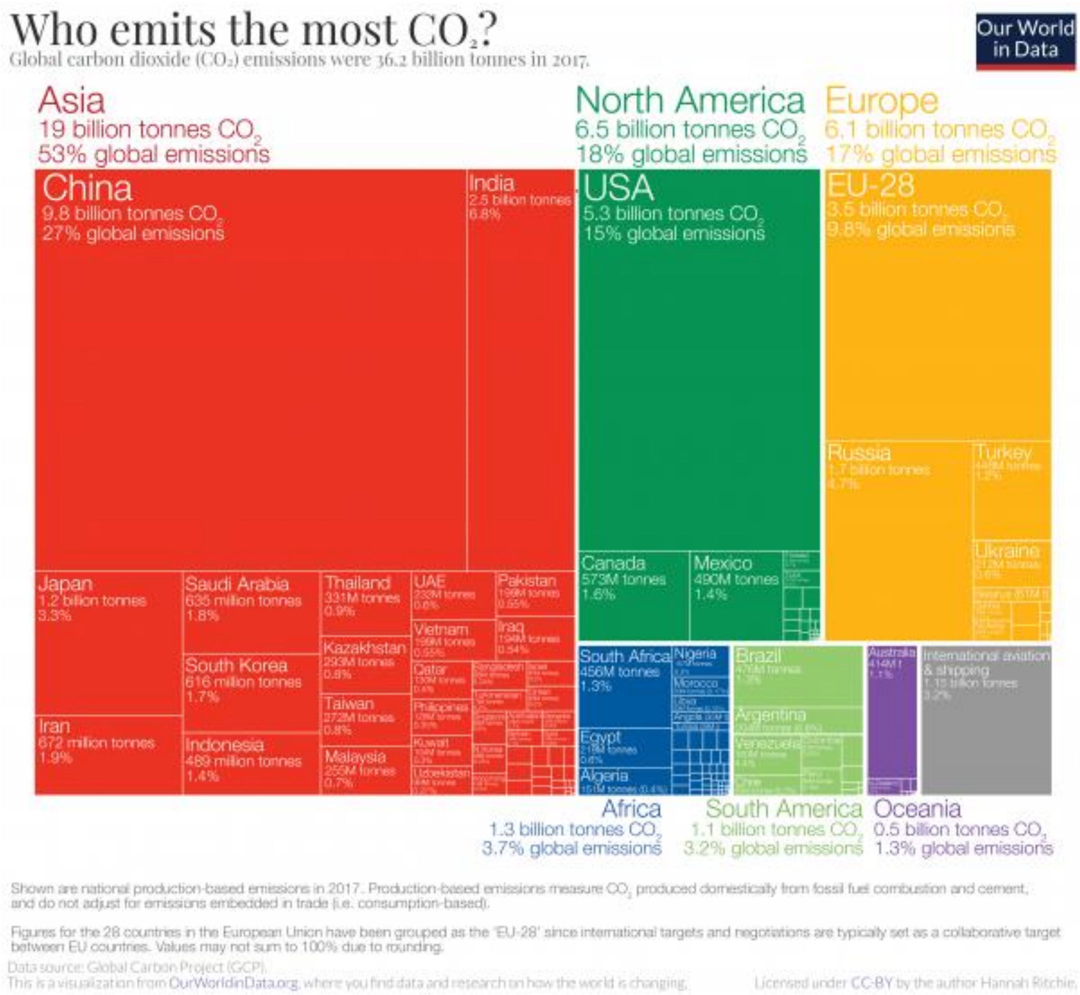


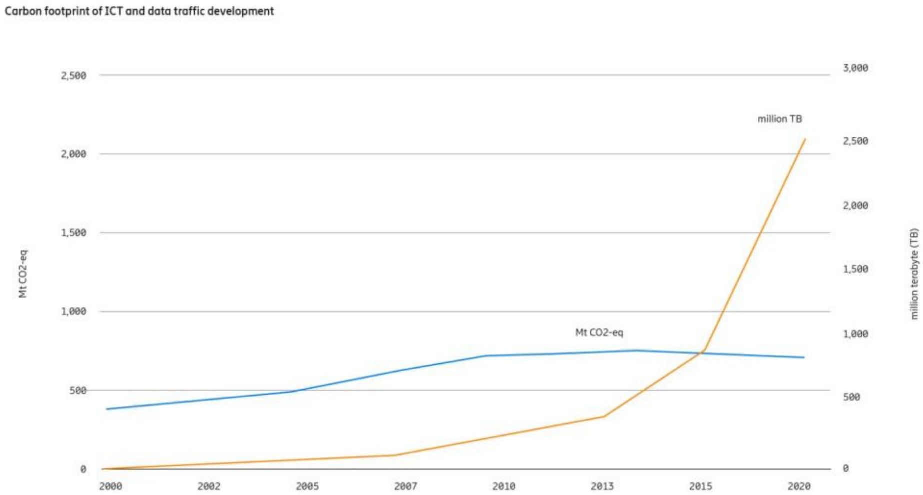
Figure source: https://ourworldindata.org/co2-emissions

When we look at calculating the carbon footprint of the Internet, there are variables that affect the outcome depending on what you include in the calculations. How much electricity is used for the manufacture and shipping of the infrastructure, hardware and devices of the Internet, the powering and cooling of these devices, the storage of data, etc. This study will focus on the data we use as a proximate measure for comparative study.

Internet traffic has tripled in only the past five years and around 90% of the data in the world today were created over the past two years[12]. In 2020, data creation was approximately 59 zettabytes (1 ZB/zettabyte = 1 trillion gigabytes). U.S. research firm IDC now notes that by 2025, newly created data will be 175 ZB.[13] Despite this rising demand for data, ICT's electricity is currently staying relatively flat, as increased internet traffic and data loads are countered by increased efficiencies[14]. Data centers consume around 1% of global electricity use even with the increased service demand. This suggests also that incremental data usage is not the key

[12] https://www.iea.org/reports/digitalisation-and-energy
[13] https://www.usitc.gov/publications/332/executive_briefings/ebot_data_centers_around_the_world.pdf
[14] Factcheck: What is the carbon footprint of streaming video on Netflix, George Kamiya https://www.carbonbrief.org/factcheck-what-is-the-carbon-footprint-of-streaming-video-on-netflix

power consumption of the Internet infrastructure, but rather the network capacity itself, i.e. the maintenance of the infrastructure itself represents a more important part of power usage of the Internet. This demand nevertheless is expected to continue to grow strongly, and energy use will continue to be determined largely by the pace of energy efficiency gains[15].



Carbon footprint of ICT and data traffic development
Credit: Ericsson: Deconstructing Information and Communication Technology's carbon emissions[16]

Many big tech companies have pledged to green their cloud, including the three largest cloud providers Amazon, Microsoft[17] and Google, which together comprise almost two-thirds of rentable cloud computing services[18]. The three metrics to look at to make this assessment are: the efficiency of a data center's infrastructure, the efficiency of its servers, and the source of its electricity. Optimization of efficiency for both infrastructure and servers have been streamlined for all three companies, the most critical measure remains the energy source. Amazon[19], Microsoft and Google[20] have lead the way in power purchase agreements (PPAs) from the tech sector (31 GW of PPAs for 2021). Even though PPAs directly contributes to the financing and investment in the production of new renewable energy, the Tech giants are still connected to grids the use fossil fuels, and more needs to be done in the progression to net-zero.[21]

2.1 User Activities Online

It is difficult for many of us to imagine not using the Internet as part of our daily activities. Each activity, an email, a search, sending a photo or a meme comes at the cost

[15] International Energy Agency (IEA) Report on Data Centres and Data Transmission Networks https://www.iea.org/reports/data-centres-and-data-transmission-networks
[16] https://www.ericsson.com/en/reports-and-papers/industrylab/reports/a-quick-guide-to-your-digital-carbon-footprint
[17] https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/
[18] https://www.wired.com/story/amazon-google-microsoft-green-clouds-and-hyperscale-data-centers
[19] https://aws.amazon.com/tw/blogs/industries/advancing-corporate-energy-goals-through-flexibility-management-for-renewable-energy-portfolios/
[20] https://sustainability.google/progress/projects/ppa/
[21] https://www.datacenterdynamics.com/en/news/google-and-amazon-are-top-ppa-buyers-but-their-net-zero-claims-are-greenwash/

of a few grams of CO_2 from the energy used to power the devices, the energy needed to power the networks and the servers hosting the content.[22] Each individual action may be small, but when aggregated by the 4.88 billion Internet users it becomes significant.

Any kind of online activities such as streaming, online gaming or even sending an instant message involves the transfer of data. There are many estimations in different analyses on the amount of electricity being consumed by data transfer i.e. energy intensity. Different methodologies and approaches will lead to a considerable variance in this number. In the research of carbon impact of video streaming by Carbon Trust[23], they used 0.0065 kWh/GB as the factor of fixed network energy intensity, and 0.1kWh/GB for mobile network. In this pilot study, we use 0.015 kWh per GB as the general energy intensity factor.[24] By calculation, streaming a 2-hour movie will use approximately 0.06kWh (depending of course on many other factors), which emits less than 6g of CO_2e - this does not include the electricity used to power the device. This presents a challenge for trying to definitively measure the carbon footprint of the Internet. Furthermore, in comparison, driving 2km to a cinema (to watch that same movie you would otherwise stream) emits roughly 240g of carbon emissions. In this context, we can argue that the Internet improves significantly upon some traditional activities or industries that may be more carbon-heavy. Which means an absolute measure of the Internet's carbon footprint, even as it naturally increases as usage increases, is not a meaningful measure of the eco-friendliness of the Internet infrastructure. Usage data must therefore be pitted against the digital transformation, i.e. the physical commercial activities that it replaces, for it to be a meaningful measure.

As the pandemic places over a quarter of the world's population under lockdown in 2020, millions of people go online for entertainment and more, total Internet hits have surged by between 50% and 70%, according to preliminary statistics and estimates show that streaming has also jumped by at least 12%.[25]

2.2 Pilot Study

This pilot study was conducted between April and December 2021 with the funding support by Heinrich Böll Stiftung Hong Kong. 6 major economies in the Asia Pacific region have been chosen for this pilot study based on their respective high percentage of carbon emissions and a considerably high percentage of Internet users in their populations, as well as readily available data for analysis.

The choice of the jurisdictions also reflects the interest to investigate the comparability of a model to consider the Internet's impact on climate change across economies of different size and advancement. China and India being large and developing countries, Hong Kong and Singapore being small cities, as well as Japan and Australia being more

[22] https://www.bbc.com/future/article/20200305-why-your-internet-habits-are-not-as-clean-as-you-think
[23] https://prod-drupal-files.storage.googleapis.com/documents/resource/public/Carbon-impact-of-video-streaming.pdf
[24] Calculating the Pollution Effect of Data by Gerry McGovern (16 March 2020) https://www.cmswire.com/digital-experience/calculating-the-pollution-effect-of-data/
[25] COVID-19 Pushes Up Internet Use 70% And Streaming More Than 12%, First Figures Reveal, Mark Beech https://www.forbes.com/sites/markbeech/2020/03/25/covid-19-pushes-up-internet-use-70-streaming-more-than-12-first-figures-reveal/

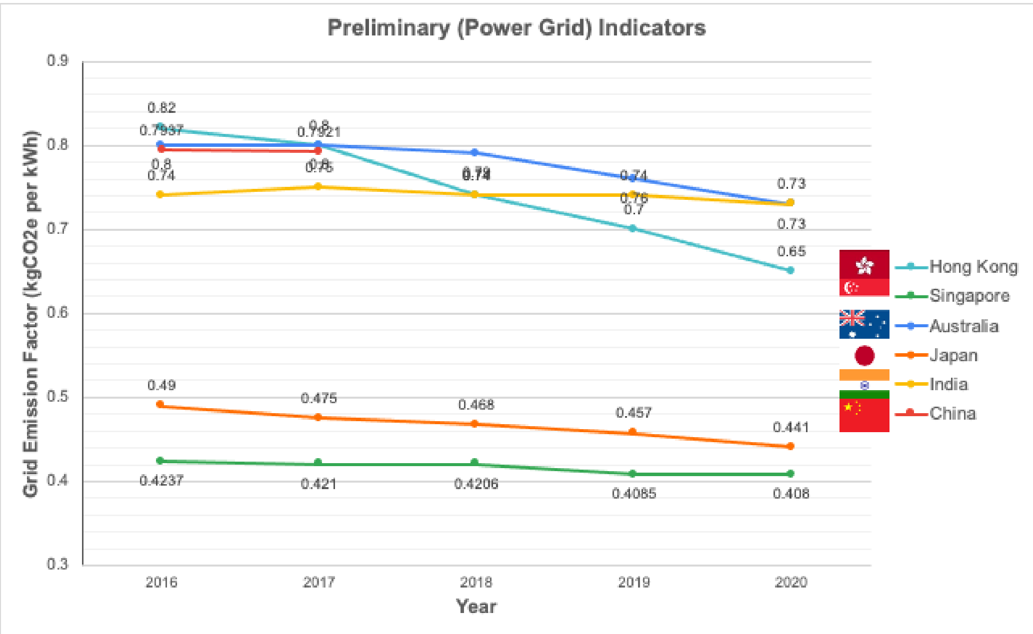
advanced economies. A framework that would allow comparison between such disparate jurisdictions will be important for a useful index.

Internet Usage (in Million-Hrs)	2016	2017	2018	2019	2020	% of Global	Acceleration (hrs)	Acceleration (% share)
Hong Kong	37	43	43	43	50	0.16%	16.28%	9.76%
Singapore	31	35	35	35	43	0.13%	22.86%	15.96%
Australia	113	121	110	127	142	0.44%	-3.16%	-8.59%
Japan	483	498	446	509	519	1.61%	-10.66%	-15.67%
India	3696	3428	4357	4469	4118	12.81%	-10.16%	-15.20%
China	4642	4882	4692	4982	5047	15.70%	-4.59%	-9.94%
Global Total	24430	27364	29852	30100	32154			

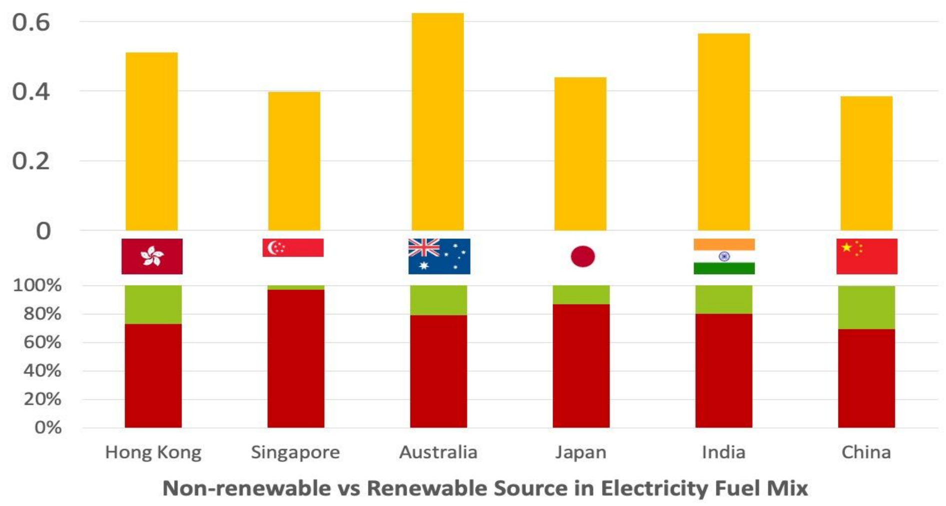
See Appendix B for further breakdown into time spent on individual activities for each jurisdiction.

2.3 Grid Emission Factor

As established above, the energy source is the most critical factor in determining greenness of the power grid. To be able to make meaningful comparisons across the 6 territories, we have to look at the Grid Emission Factor of each. The Grid Emission Factor (GEF) measures average CO_2 emission emitted per MWh of electricity. It is calculated using the generation-weighted average CO_2 emissions per unit net electricity generation of all generating power plants serving the system.



Can we infer that the more renewable energy a power grid uses, the lower the GEF? Taking a closer look at the renewable versus non-renewable energy source breakdown for each 6 territories, Singapore has a low GEF compared to the other 5 territories, however renewables make up just a fraction of their electricity generation fuel mix. This is because Singapore relies heavily (over 90%) on natural gas[26] to generate the electricity in their grid, and natural gas emits 50 to 60 percent less carbon dioxide (CO2) than regular oil or coal-fired power plants. It also emits greenhouse gases with a lower life cycle into the atmosphere. However this does not address sustainability concerns nor does it address climate change as natural gas may be a much 'dirtier' energy source than previously expected.[27]



See Appendix A: Grid Emission Factor Data for further details.

2.4 Internet Exchange Points

Section 2.1 above has already established the trend of our increasing hours spent online. But like traffic on the road, as well as electricity usage in the power grid, the data traffic of the Internet also ebbs and flows through peaks and troughs. To make sense of this pattern, of the overall peak and off-peak times for the global Internet, we investigated the public data available from the Internet Exchange Points (IXPs) from the pilot territories.

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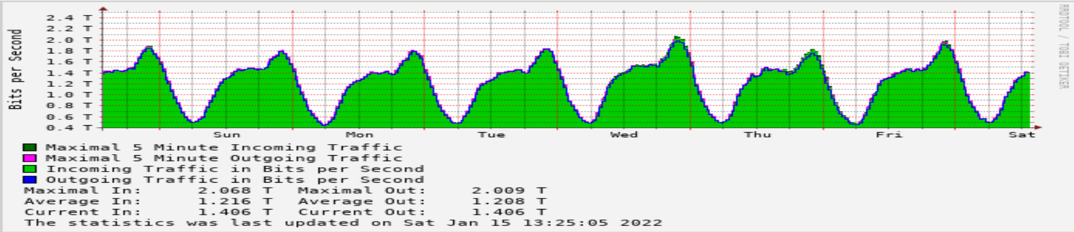
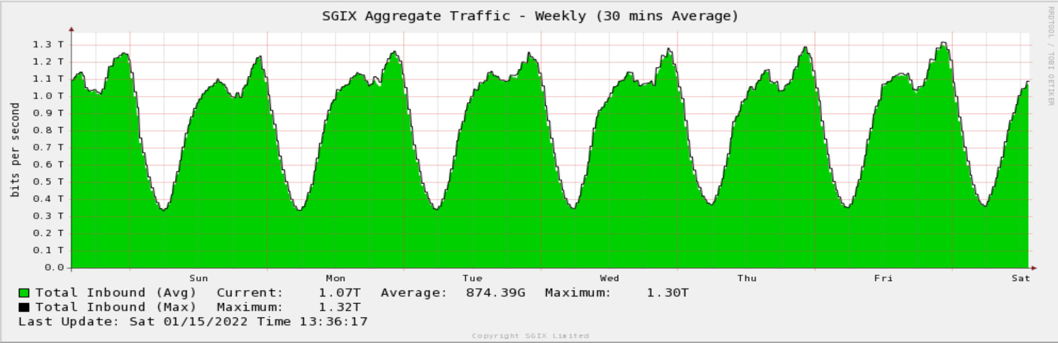
[26] https://www.ema.gov.sg/singapore-energy-statistics/Ch02/index2

[27] Methane's atmospheric concentrations have increased by at least 150 percent since the Industrial Revolution. Because of its potency, the more of it there is in the air the harder it will be to keep the planet's temperatures from soaring past global climate goals. https://www.nationalgeographic.com/science/article/super-potent-methane-in-atmosphere-oil-gas-drilling-ice-cores

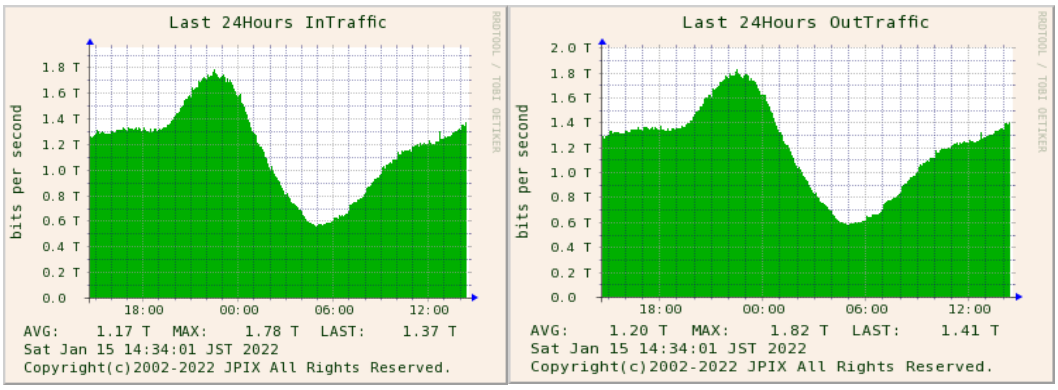
HKIX - https://www.hkix.net/hkix/stat/aggt/hkix-aggregate.html



SGIX - https://www.sgix.sg/services/traffic-statistics/



JPIX - https://www.jpix.ad.jp/en/technical_traffic.php



What is immediately observable is that there is a large fluctuation between the peak and troughs as well as, more importantly, the somewhat predictable pattern. Traffic during peak times is growing faster than average, in large part due to growing video-streaming and related traffic during these times[28] as well as all the business-related Internet traffic during the work-day. Off-peak troughs are in the late evening/early morning hours local time.

Given the pattern and the understanding that incremental data within the capacity of a network infrastructure, it is possible to design technical processes to make the Internet more power efficient, as in, being able to carry more data without incurring a more taxing power consumption. More specifically, for example, strategically timing data intensive processes and to distribute them to the edges during off-peak times would effectively allow more data to be processed, hence growth of Internet and digital

[28] https://www.sciencedirect.com/science/article/pii/S2214629618301051#sec0045

economy, without incurring proportionate consumption of energy, hence carbon footprint of the Internet.

2.5 The SDGs and Net Zero Goals

The evolution of the Internet and its applications has facilitated the development of the digital economy and substantial advancement in science, agriculture, health and education. It is critical that these technological advancements are used to facilitate the present requirements as well as consider future environmental, human and social requirements for a sustainable world. Strong, ethical, democratic and sustainable governance of the Internet will in turn render the Internet better able to support the Sustainable Development Goals and rights of all people. Sustainability is crucial in national, regional and sectoral planning of the global effects and outcomes of technology and its innovations. Awareness about the environmental impact of the increasing demand for electricity and electronic devices using the Internet could support the necessary sustainable transformation of our societies.

Of the 17 United Nations Sustainable Development (SDG) goals,[29] SDG 7 (Clean and Affordable Energy), SDG 9 (Industry, Innovation and Infrastructure), and in particular SDG 13 (Climate Action) directly call for action on combating climate change and its impacts and is intrinsically linked to all of the other Goals of the 2030 Agenda for Sustainable Development.

The Paris Agreement[30] was the landmark outcome of COP 21 in 2015, and since June 2020, 195 signatories and 189 countries have joined[31]. The goal of this legally binding international treaty is to limit temperature rise to well below 2°C, maybe even 1.5 °C and brings nations together to undertake ambitious and substantial efforts to combat climate change. At the heart of implementation are the Nationally Determined Contributions (NDCs)[32] which requires nations to submit their plans for climate action every 5 years towards (2020, 2025 etc.). Of the 195 parties to the Paris Agreement, 110 have so far submitted a new or updated national action plan – called Nationally Determined Contributions (NDCs) – as required by the agreement. However, their planned combined emissions reductions by 2030 still fall far short of the level of ambition needed to achieve the 1.5 °C goal[33].

Most emissions come from just a few countries. The top three greenhouse gas emitters: China, the United States and the European Union, contribute 41.5% of total global emissions, while the bottom 100 countries only account for only 3.6%. Collectively, the top 10 emitters account for over two-thirds (68.7%) of global GHG emissions[34]. Big tech has also pledged their part towards Net Zero Goals. Apple and Google have both announced that their businesses run on 100% renewable energy, yet as we have mentioned above, the reason these companies are able to make these claims is because they purchase enough renewable energy in the form of RECs to offset its global energy

[29] UN Sustainable Development Goals https://sdgs.un.org/goals
[30] Paris Agreement https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[31] https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-7-d&chapter=27&clang=_en
[32] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[33] Net Zero Coalition https://www.un.org/en/climatechange/net-zero-coalition
[34] https://www.wri.org/insights/interactive-chart-shows-changes-worlds-top-10-emitters

consumption and these calculations only covers direct operations and not their vast supply chains.

Still, Apple has committed to be 100% carbon neutral for its supply chain and products by 2030.[35] Microsoft has pledged to become carbon negative by 2030 and offset all carbon that it has emitted since its founding in 1975 by 2050.[36] Google has offset their historic carbon emissions as of the end of 2020, and aims to be operating on carbon-free energy 24/7 by 2030.[37] Facebook has reached net zero in operational GHG emissions in 2020 by reducing emissions by 94 percent (from 2017) and supporting carbon removal projects, and plan to reach net zero emissions in their value chain in 2030.[38] Amazon, one of the world's largest carbon emitters, has also set 2030 as the deadline to run on 100 percent renewable energy, and net zero carbon across all operations by 2040.[39]

Even as COP26 reaffirmed the Paris Agreement goals in the form of the Glasgow Climate Pact[40] more ambitious action needs to be taken to reach the 1.5 °C goal. Of the 74 parties with long-term mitigation visions, strategies and targets, will be contributing to the 5% reduction in GHG emissions by 2030, but the world will need 45% emissions reductions to keep warming to no more than 1.5 °C[41].

3. Community Engagement

As part of this pilot study, the team has engaged an advisory group of distinguished individuals and subject matter experts, as well as conducted two workshops at the Asia Pacific Regional Internet Governance Forum (APrIGF – https://www.aprigf.asia) and the United Nations Internet Governance Forum (IGF – https://www.intgovforum.org) in 2021 respectively. Preliminary findings of the study were presented to form the basis of the discussions at each of the workshops.

3.1 Research Advisory Group

The EII Research team comprises Edmon CHUNG (CEO, DotAsia), Christine OR (Project Manager) and Jennifer CHUNG (Director of Corporate Knowledge).

We would like express our sincere gratitude and thanks to our Advisory Group: Cassian DREW - Managing Director, Inclusive Growth, Advisor on COVID-19 Economic Recovery, UNDP; David JENSEN - UNEP Head of Environmental Peacebuilding; Desiree MILOSHEVIC - International Affairs and Policy Adviser at Afilias, Former Special Advisor to the Chair of the UN IGF MAG; Anna MOORE - Sustainability Consultant and Partnerships Manager,

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[35] https://www.apple.com/newsroom/2021/10/apple-charges-forward-to-2030-carbon-neutral-goal-adding-9-gigawatts-of-clean-power-and-doubling-supplier-commitments/
[36] https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/
[37] https://blog.google/outreach-initiatives/sustainability/our-third-decade-climate-action-realizing-carbon-free-future/
[38] https://sustainability.fb.com/
[39] https://sustainability.aboutamazon.com/
[40] https://unfccc.int/process-and-meetings/the-paris-agreement/the-glasgow-climate-pact-key-outcomes-from-cop26
[41] https://unfccc.int/news/cop26-update-to-the-ndc-synthesis-report

Eco-Business; Kathryn SFORCINA - Global Head of Strategy, IV.AI Co- Chair, UN IGF Policy Network for Environment and Digital; and, Sang Min SHIM - Visiting Research Fellow, Sejong Institute

3.2 Asia Pacific Regional Internet Governance Forum (APrIGF)

Workshop session titled: Critical Times: Impact of Digitalisation on Climate Change was held at the APrIGF on Sep 28, 2021. Speakers at the workshop included: Edmon Chung, Chief Executive Officer of DotAsia; Kathryn Sforcina, Global Head of Strategy at IV.AI; and, Sang Min Shim, Visiting Research Fellow at Sejong Institute; and the session was moderated by Lucia Siu, Programme Manager, Heinrich Boell Stiftung Hong Kong.[42]

At the workshop, participants discussed the Internet's impact on the environment, what has been done so far to reduce that impact, its resilience, the role that Internet-related technologies play to help to achieve the Sustainable Development Goals, the role that different stakeholders play in creating a sustainable world, as well as the policies put in place that remedy the damage caused to the environment preventing further deterioration.

In the discussion of the impact of digitalization on climate change, the following recommendations were made for possible implementation through policy and regulations that can ensure a green economy for the Asia Pacific region:

- Raising public awareness regarding carbon footprints and climate change
- Collaboration on policy dialogue among the nations for creating the green economy together
- Developing Green ICT policies for ICT sustainability
- Sustainability of the Internet's core infrastructure

3.3 United Nations Internet Governance Forum (IGF)

Workshop (WS#50) session titled: Critical Times: Impact of Digitalization on Climate Change was held at IGF on Dec 10, 2021. Speakers at the workshop included: Edmon Chung, Chief Executive Officer of DotAsia; Daphne Mah, Director of Asian Energy Studies Centre at Hong Kong Baptist University; and, Teddy Woodhouse, Senior Research Manager, A4AI at World Wide Web Foundation; and the session was moderated by Jennifer Chung, Director of Corporate Knowledge at DotAsia.[43]

Building on the preliminary findings of this EcoInternet pilot study, further discussion of smart grids and how it contributes to addressing climate change and policy recommendations regarding energy and Internet access were presented by the speakers. It was raised that implementation of smart grids requires trust in the society and that cases of backlashes were experienced, so data that can build trust through multi-sector and multistakeholder collaborations are important.

[42] https://proposals.aprigf.asia/proposal_details.php?id=5000731903893927751
[43] https://www.intgovforum.org/en/content/igf-2021-ws-50-critical-times-impact-of-digitalization-on-climate-change

On the issue of promoting Internet connectivity and digital inclusion, government policies and their implementation play an important role in influencing carbon emissions and climate change solutions e.g. active policies to build fewer and promote shared towers, connecting towers to an electricity grid rather than diesel powered; highlighting that as more people are online, the cost per user will be lower, and it brings greater benefits to a broader population and a greater social justification.

The key takeaways from the sessions included:

- Shareable resources are the key to an Eco Internet, for instance, shared Internet infrastructure and open data, as well as the use of renewable energy.
- The achievement of an efficient and environmental-friendly Internet relies on the close cooperation between different stakeholders.
- Both the carbon footprint and benefits of digital technologies need to be considered. Extensive use of the Internet generates increasing carbon footprint but it also replaces many activities which create much greater climate impact.

Call to Action:

- To urge the collaboration of multi stakeholders especially government and private sectors to prioritise the environmental issue with accelerating digitalisation and implement effective policies.
- To develop standardised measurements and data transparency which can be used universally including developing countries.

4. Insights Towards an Eco-Friendly Internet (EcoInternet)

Based on the studies and discussions explained above, it is understood that definitively identifying the carbon footprint of the Internet in a particular jurisdiction may be very complicated and open to much contention. Most importantly, such undertaking and data may not be fruitful in the sense of providing useful data for informed policy directives and decisions. Simply looking at the absolute size of the carbon footprint of the Internet does not give a complete picture of the carbon footprint of the digital activities of society as a whole.

Hence, it may not be useful to develop narratives that are focused on reducing the usage of the Internet, or along the lines of the traditional call to action of environmental campaigns, to “reduce, reuse and recycle.” Inasmuch as the Internet’s carbon footprint expands, it is important to also consider what activities such increased Internet usage may have replaced. For example, watching a movie online does incur a relatively heavier carbon footprint than, say, simply browsing the web or sending an email. Nevertheless, it may compare well against the carbon footprint of the alternative, that is, driving a car to the cinema to watch the film (see section 2.1 above). What is important therefore is to look at how the Internet drives digital economy, that is, to consider the increased usage of the Internet (hence the increase of Internet’s carbon footprint, with all things being equal) in relation to the growth in digital economy as a percentage of the overall industrial production and enrichment to society.

Another important aspect to consider is the efficient use of the Internet infrastructure. Noting that the per user carbon emissions of a network infrastructure reduces as more users are added (see discussion in section 3.3),[44] providing an economy of scale so to speak, it can be well deduced and understood that the maintenance of the overall network infrastructure represents an important part of the power consumption of the network (see also section 2.4).

4.1 Becoming a Carbon Conscious User

Even though "reduce" does not appear to be an appropriate narrative for addressing the issue, it is still important first and foremost to advocate to general users the awareness that the Internet does have a carbon footprint, and that it is growing rapidly as our reliance and usage of the Internet increases.

It is important to educate users to become carbon conscious. To realize that different online activities, or more importantly, different usage patterns do make a difference in the resulting carbon footprint. Also, to know that the key issue to consider is the energy that is powering your Internet. In other words, the power grid that is supporting the local Internet infrastructure as well as that supporting the Internet servers. On this front, grassroots movements can consider two avenues of advocacy: 1. Efforts targeted towards larger Internet platform and content providers to switch over to cleaner energy to power their server farms and operations; and, 2. Champion for government policies to support the utilization of cleaner energy and renewable sources for the power grid, as well as directives to encourage local Internet infrastructure providers to adopt greener backup power supply options.

In terms of being carbon conscious, it is not about writing shorter emails or watching less videos online, but rather, consider the times of your activities in relation to the peak hours for the power grid as well as for Internet traffic, as well as to understand what and how your Internet usage replaces or reduces otherwise more carbon-heavy activities. For example, consider activities such as data backup or data intensive activities to be scheduled in off-peak times, to select software applications and services that allow you to do so, and understanding how your utilizing of different transport options or navigation routes may or may not have an impact on the carbon footprint of a transit journey. On the aspect of the timing of backup and data intensive activities, it could also be further advocated to the industry through policy or guidelines that encourage data intensive operations to be conducted off-peak, as well as to offer services to customers and end users that may support pre-downloading or caching of content and data during off-peak hours.

User and industry decisions are both important and can make a difference for the EcoInternet.

4.2 The Grid that Powers Your Internet

The key issue towards an EcoInternet is to develop a greener and more sustainable power grid that supports the operation of the Internet. This includes both the local Internet infrastructure, as well as the global services that users connect to. Most

[44] Alliance for Affordable Internet (A4AI) Sustainable Access Report: https://a4ai.org/research/sustainable-access-report/

importantly this highlights the interdependence and cross boundary nature of the Internet.

While the section above explains the direct impact of the power grid on the carbon footprint of the Internet, the inter-relatedness goes deeper. In particular, the peak power consumption hours and the peak-trough patterns between the Internet infrastructure, as seen by data transfer follows the power grid patterns as well, which means that the consideration of such capacity utilization would very likely complement and support the efficient utilization of the power grid also.

The critical aspect for the power grid is the carbon emission per unit of electricity generated (usually measured in KgCO2/KWh). This includes the consideration for the composition of the respective percentage of electricity output produced from different energy sources, such as from coal, natural gas, hydro, wind, etc. Related to this would be the percentage of electricity output produced from renewable energy sources. Both of these dimensions are important factors for considering the eco-friendliness of the power grid, which in turns power the Internet, thus determining the eco-friendliness of the network.

Policy directives are critical to encourage increasing use of renewable energy in fueling the local power grid for an EcoInternet.

4.3 The Digital Advantage & Network Efficiency

As mentioned above, it appears that there is a mutual reinforcement between the efficient use of the power grid and the efficient use of the Internet infrastructure. An important aspect of an EcoInternet regardless, is to promote more efficient use of the network capacity. Understanding that the base power consumption of the network for maintaining the bandwidth and availability in fact contributes to a large part of energy use, it is important to better utilize the network capacity off-peak. Rather than throttling the growth of Internet usage by limiting peak usage, it is possible to in fact do more with the Internet by optimizing the off-peak usage of the network.

More importantly however is to ask the question whether the Internet replaces a more carbon intensive alternative. In general, that is a more likely case than not, especially when considering the Internet replacing paper use and other more carbon intensive industries in the economic industrial composition of a country or jurisdiction. This is the idea of the “Digital Advantage”. Instead of advocating for users to reduce usage, the pertinent question for an EcoInternet is whether the digital advantage is best realized.

In terms of policy intervention, it may be useful to consider the development of industry guidelines and incentives to better utilize network capacities, such as, as mentioned above, to encourage data intensive and not time sensitive activities, such as data backup and synchronization, etc., to be conducted in off-peak hours.

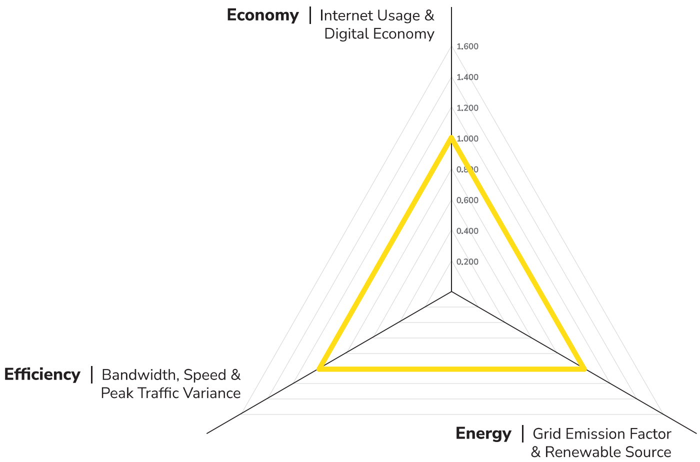
In short, the core narrative for an EcoInternet is to “Do more, waste less.” Do more with the Internet and waste less by promoting more efficient use of the network infrastructure capacity, and with more renewable energy source.

5. The Eco-Internet Index (EII)

Building on the insights above, this report proposes a framework for an EcoInternet Index (EII). Given the importance of multiple aspects in considering the eco-friendliness of the Internet, the EII is conceptualized as a multi-factor indicator modeled to allow comparative studies between countries and jurisdictions. To allow for meaningful comparison between jurisdictions, it is important both to have reasonably consistent data across the different jurisdictions, as well as to design the model taking into account the large differences between the population and Internet user numbers across Asia.

5.1 Methodology & Framework

The design of the EII framework will be built around three axes:



The Economy axis will include considerations for Internet usage patterns and their respective carbon emission factor to look into the relative carbon footprint of the Internet which approximates the comparative level between jurisdictions rather than attempting to estimate the actual carbon footprint of all Internet activities end-to-end. This will be juxtaposed with consideration of the proportion that the digital economy occupies with respect to the overall economy, again, also by identifying indicator that reflects or approximates the relative comparison between jurisdictions.

The Energy axis will draw on the grid emission factor, and will add consideration of renewable sources. The emphasis on renewable energy source aligns with the net zero goals, and a longer term view for the EcoInternet.

The Efficiency axis will model Internet usage in a different dimension, starting from the provider capacity, but placing emphasis on the speed of Internet connectivity as experienced by users. This is further moderated by the variance, or the optimality of the utilization of the bandwidth capacity based on traffic patterns observed (in particular at internet exchange points).

From the description above it may be observed that the two key aspects – Internet usage and the power grid – are repetitively included in two out of the three axes to place stronger weight for their consideration in the resulting index. For Internet usage, a different perspective is used, one starting from user behavior (in the Economy axis), and the other starting from provider capacity (in the Efficiency axis), but considered on a per-user basis (further details in section 5.4 below).

Another important consideration for the methodology is to construct a simple model that gives a reasonable indicator that describes the overall condition of the Internet vis-à-vis the ecosystem, rather than attempting to represent precise actual measuring of the Internet's carbon footprint and be entangled in the difficulties of definition and precision given the dynamic and changing environment. The EII proposes the use of a broad-stroke approach, drawing on indicators that give a sketch of local situations, but also one that allows comparison across jurisdictions, i.e. to produce a composite index that allows comparison between large and small countries alike.

5.2 Economy

To calculate the composite indicator for describing the Economy axis, the reported times spent on video, social media, music and gaming are considered against the respective Gigabyte (GB) per hour estimation as presented in Section 2.1 above and included in Appendix B: Carbon Footprint of the Internet as a Percentage of Total Carbon Footprint. A uniform conversion rate of 0.015 kilowatt per GB (kWh) is applied, as explained also in Section 2.1 above, across the different jurisdictions in this study. A base usage factor utilizing "other uses" is applied to the total time spent online with the assumption that there is a base level usage, such as background website refresh and other data activities even as a user is engaged in watching video or listening to music. This per user usage is multiplied by the number of Internet users in the particular jurisdiction, as well as 365 days per year to arrive at a total carbon footprint for Internet usage from a user perspective.

This is then compared with the total carbon emission for the particular jurisdiction, arriving at the percentage of the Internet usage carbon footprint in relation to total carbon footprint. This percentage is then compared with the percentage of digital economy, that is, to model the Internet's carbon footprint as a percentage of the total carbon footprint against the digital economy as a percentage of total economy.

$$\frac{\frac{Carbon\ Footprint\ of\ Internet\ Activities\ (kgCO_2)}{Total\ Carbon\ Emission\ (kgCO_2)}}{ICT\ Services\ as\ \%\ of\ Total\ Trade\ in\ Services\ (Export + Import)}$$

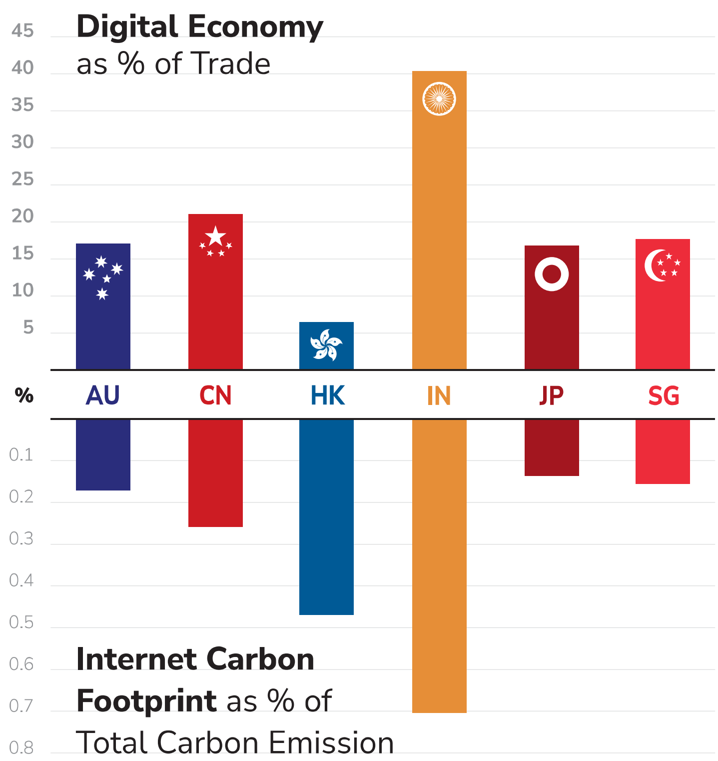
Based on the proposed model, the higher the score the larger impact (i.e. carbon footprint) the Internet has relatively for the given jurisdiction. Individually, the higher the carbon footprint of Internet activities are, as a percentage of total carbon emissions, the worse, or the higher the environmental impact is, whereas the higher the percentage of digital economy as a percentage of total trade is, the more worthwhile it is to "expend" the carbon cost of the Internet.

The data sets used for calculating the Economy axis score includes:

- Local energy authorities and provider reported data (Grid Emission Factor in $kgCO_2/kWh$)[45]
- We Are Social and Hootsuite Digital 2021 Reports (Internet usage hours per activity) [46]
- United Nations Conference on Trade and Development (UNCTAD) – Digital economy: Share of ICT goods as percentage of total trade, annual (Import and Export)[47]

Note that whereas the Internet usage carbon footprint is estimated based on end user usage data[48], it should provide a reasonable indicator for Internet activity in the respective jurisdiction. Likewise, the UNCTAD indicator used reports the share of ICT goods as a percentage of total trade. Even though this is not the absolute number for the Digital economy's contribution to GDP or overall economy, it should provide a consistent and comparable indicator for the purpose. Note also that in general, data for the year 2020 is utilized for the calculations in this pilot study, and for jurisdictions where data is not available for 2020, data from the latest year is used.[49]

The following chart summarizes the respective scores for the digital economy as percentage of trade, and Internet carbon footprint as percentage of total carbon emission:



[45] See Appendix A: Grid Emission Factor Data
[46] https://www.hootsuite.com/resources/digital-trends See Appendix B for further details
[47] https://unctadstat.unctad.org/EN/BulkDownload.html
[48] For future development, it is possible to utilize proprietary industry traffic data for this component of the index, rather than user generated usage hours, however, for the purposes of this pilot study we will be looking at publicly available data for the EII.
[49] For Share of ICT goods as a percentage of total trade, 2019 data is used for Import in China and Hong Kong, and for Export in Hong Kong. For Grid Emission Factor, the latest data point for China is found for 2017.

5.3 Energy

To calculate the composite indicator for describing the Energy axis, the Grid Emission Factor is divided by the percentage of renewable electricity output as part of the total electricity output for a jurisdiction.

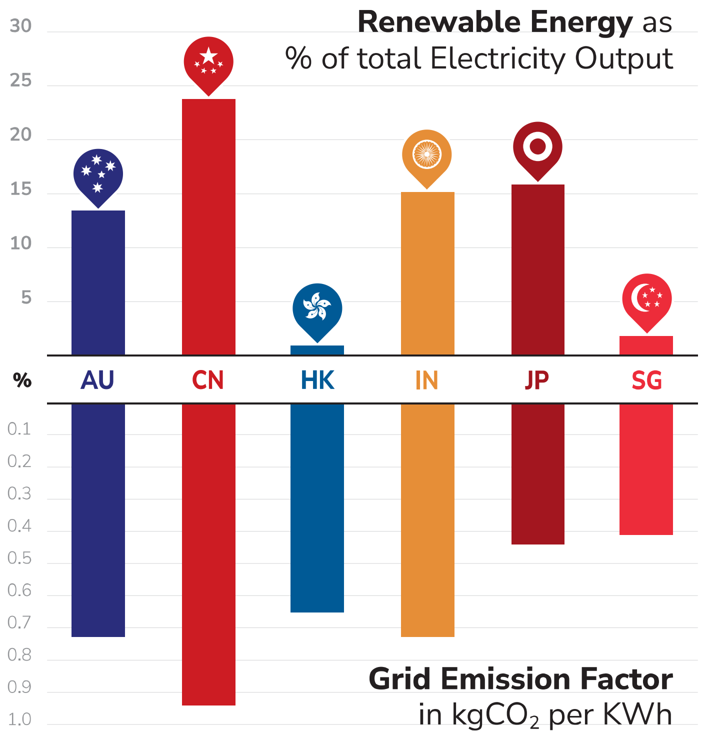
$$\frac{Grid\ Emission\ Factor\ (kgCO_2/kWh)}{Renewable\ Electricity\ Output\ (\%\ of\ Total\ Electricity\ Output)}$$

In alignment with the Economy axis, the higher the score for the Energy axis the larger impact (i.e. carbon footprint) the Internet has relatively for the given jurisdiction.

The data sets used for calculating the Energy axis score includes:

- Local energy authorities and provider reported data (Grid Emission Factor in $kgCO_2/kWh$)[50]
- World Bank Climate Change indicators: Renewable electricity output (% of total electricity output)[51]

The following chart summarizes the respective scores for renewable energy as percentage of total electricity output and Grid Emission Factors for the jurisdictions included in this pilot study:



[50] See Appendix A: Grid Emission Factor Data

[51] https://data.worldbank.org/indicator Note that the World Bank Climate Change indicators are only reported up to 2018 at the time of this report

5.4 Efficiency

To calculate the composite indicator for describing the Energy axis, three component indicators are utilized. The International Internet bandwidth per user (Mbps) is divided by the experienced Connectivity Speed (Mbps), and then multiplied by a Traffic Variance Factor. The Traffic Variance is estimated as a simple ratio of the mean traffic volume over the observed maximum traffic throughput (i.e. peak utilization) estimated by the data obtained within the observation period. Conceptually, it is understood that the quotient of mean/max traffic volume would provide a reasonable indicator of whether the capacity is well utilized and optimized.

More specifically, the closer the mean traffic volume is to the max (i.e. peak) traffic volume, the smaller the variance is and thus the capacity is better utilized. This ratio is then inverted, that is, such that it aligns with the design of the overall scoring approach whereby the higher the score the larger the impact is on the environment, i.e. the less favorable it is.

$$\frac{International\ Internet\ Bandwidth\ (Mbps\ per\ user)}{Connectivity\ Speed\ (Mbps)} \times \frac{Traffic\ Volume_{MAX}}{Traffic\ Volume_{MEAN}}$$

The data sets used for calculating the Efficiency axis score includes:

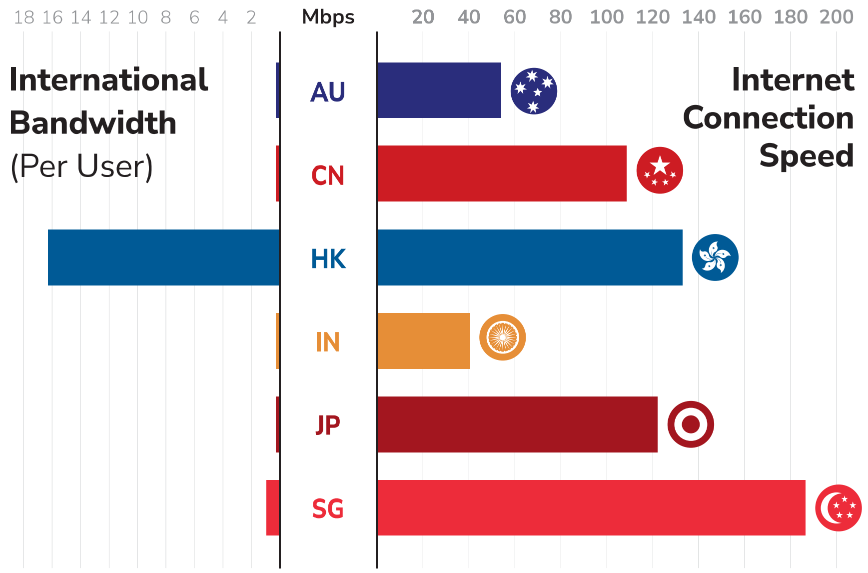
- International Telecommunications Union (ITU) ICT Indicators Database: Int'l Internet bandwidth per user[52]
- Internet connection speed by country, ranked by Speedtest.net data for April 2021, M-Lab data for May 2020 and SpeedTestNet.io data for March 2021[53]
- Local Internet exchanges (IX) metrics and statistics[54]

[52] https://www.itu.int/en/publications/ITU-D/pages/publications.aspx?parent=D-IND-WTID.OL-2021&media=electronic Note that the 2020 International Internet Bandwidth per user data is not available for AU, IN, JP and SG, the 2020 International Internet Bandwidth (total) is used and divided by the total number of Internet users in the particular jurisdiction for the calculations.

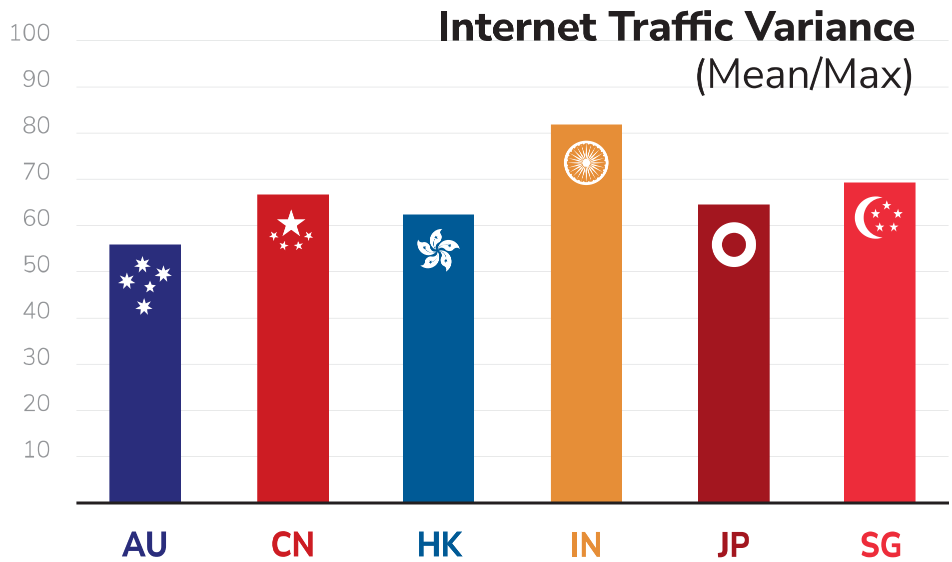
[53] Average of the 3 sources is used for the calculations: https://www.speedtest.net/global-index, https://s3-eu-west-1.amazonaws.com/assets.cable.co.uk/broadband-speedtest/worldwide-broadband-speed-league-2020-press-releases.pdf, http://speedtestnet.io/ included in the Wikipedia article on Internet Connection Speeds (https://en.wikipedia.org/wiki/List_of_countries_by_Internet_connection_speeds)

[54] See Appendix C for details

The following chart summarizes the respective levels of International Internet Bandwidth per user relative to connectivity speed experienced by users:



The following chart summarizes the variance factor calculated for the different jurisdictions in the pilot study:[55]



5.5 EcoInternet Index (EII) Composite Score

The EII Composite score is composed of the normalized score of the three axes. Each of the axes scores: Economy, Energy and Efficiency, will be normalized to a score between 1-5 based on the relative spread of the calculation results, and then combined by

[55] This graph shows the Mean/Max value to better illustrate that the lower the variance the better the score should be. Nevertheless, in the calculations Max/Mean is used to model that the higher the calculated result the larger the "footprint" is and thus a higher score represents less favourable conditions.

calculating the area of the resulting triangle plotted in the radio chart (as demonstrated in Section 5.1 above).

$$\frac{Score_{Economy} \times Score_{Energy} \times \sin 120°}{2} + \frac{Score_{Energy} \times Score_{Efficiency} \times \sin 120°}{2} + \frac{Score_{Efficiency} \times Score_{Economy} \times \sin 120°}{2}$$

The resulting final EII scores for this pilot study is as follows:

	Economy		**Energy**		**Efficiency**		**EII Score**	
	Normalized Score	*Rank*	*Normalized Score*	*Rank*	*Normalized Score*	*Rank*	*Composite Score*	*Rank*
AU	1.094	3	1.045	4	1.040	4	0.977	2
CN	1.209	4	1.020	2	1.006	2	1.009	3
HK	5.000	6	5.000	6	5.000	6	21.773	6
IN	1.466	5	1.034	3	1.030	3	1.188	4
JP	1.000	1	1.000	1	1.000	1	0.871	1
SG	1.037	2	1.341	5	1.143	5	1.193	5

In line with the axes scores, the larger the composite EII Score means the larger the impact on the environment, i.e. less favourable.

6. Analysis, Findings & Future Enhancements

In developing the EcoInternet Index (EII), an approach of simplicity is being used. A minimum number of indicators are used to suggest a comparable level, rather than attempting to integrate an extensive set of indicators. More specifically, the methodology is closer to the approach of the Human Development Index,[56] which utilizes just 4 indicators for its model, rather than that for the World Competitiveness Report,[57] which is compiled from over 110 indicators. Considering the availability, reliability and consistency of data, and the goal of developing a methodology that allows for meaningful comparison between jurisdictions, the EII was designed such that a minimum amount of data points be used that would be indicative of the state of the Internet and its footprint on the environment.

It is important to note that as an "index" the EII does not purport to represent actual carbon footprint generated by Internet activity, which would itself be difficult to quantify consistently and across different jurisdictions, but more importantly, would not be a useful measure to be useful for considering policy interventions and comparison between populous and smaller countries and jurisdictions. It is also important to note that this EII pilot study included only 6 jurisdictions and utilizes a normalization approach, thus the exact absolute scores are not so much a matter of interest, because it is designed for comparison, both comparison between jurisdictions as well as year-over-year comparisons (when the index is consistently and annually calculated).

[56] http://hdr.undp.org/en/content/human-development-index-hdi
[57] https://www.weforum.org/reports/the-global-competitiveness-report-2020

Nevertheless, the pilot study does provide a good glimpse of how different jurisdictions stack up against each other in terms of the eco-friendliness of their Internet infrastructure. For example, interestingly, we see China and India score ahead of Australia in both the Energy and Efficiency axes, which when considering that Australia still uses a significant amount of coal to generate its power supports the observation. It will be interesting to see, given Australia's commitment towards switching over to renewable energy,[58] if that position changes over time. Another interesting observation is about Japan. Known to be a highly efficient and clean country, while not being spectacular (or disastrous) in any of the indicators, comes out on top in all three axes. This is after all a pilot study, and further work should be done on analysing anomalies and sensitivities of the data, as well as to expand the collection of data across more jurisdictions before more meaningful and in-depth comparative analysis can be done.

6.1 Outliers & Sensitivity Analysis

From the results of this pilot study, it is clear that the scoring for Hong Kong appears to exhibit an anomaly. Thus, further analysis may be necessary to see if the anomaly reflects a reasonable comparative position vis-à-vis other jurisdictions in terms of modeling for the outlook for an ecologically friendly Internet infrastructure. Looking at the data from this report nevertheless, it appears that, at least, the resulting score reflects deficiencies and concerns as shown by reported numbers in Hong Kong.

On the Economy axis, Hong Kong's scoring is off the charts due to the high usage of the Internet coupled with a very low percentage occupied by the digital economy.

$$\frac{\frac{0.147\ MtCO_2}{31.24\ MtCO_2}}{5.268\%} = \frac{0.437\%}{5.268\%} = 0.089$$

While it may be possible that the indicator used, i.e., share of ICT goods as a percentage of total trade is not reflective of the Hong Kong situation, placing the percentage at only 5.7% in 2019. Nevertheless, this reconciles with the estimated contribution of the digital economy as a percentage of GDP as quoted by the government and the industry, which is between 5-6% in 2016 and 2017.[59]

This is not surprising given the structure of Hong Kong's economy which remains heavy on the trade of goods, logistics and other old economy operations, along with an even heavier weight on the financial sector, while Hong Kong's digital economy remains small because it has not expanded too much beyond its city boarders. As such, the EII score for Hong Kong in the Economy axis reflects that situation. For further study, perhaps what may be useful to consider is if the financial sector is included as part of the digital economy output, how that may change the outlook for Hong Kong. Nevertheless, this needs to be balanced with whether such inclusion is useful because it does not displace higher carbon footprint industries, although including it would provide a baseline position, i.e. for economies that rely heavily on the finance sector it is already relatively

[58] https://www.smh.com.au/politics/federal/renewable-energy-to-drive-down-household-power-bills-over-next-three-years-20211124-p59bnv.html
[59] https://hongkongbusiness.hk/information-technology/commentary/how-can-hong-kong-be-apacs-digital-leader and http://www.stats.gov.cn/english/pdf/202011/P020201103358487019447.pdf

eco-friendlier so to speak. How one considers the financing of, for example, fossil fuel companies and other high carbon footprint industries nevertheless potentially balances out the advantage or usefulness in carving out the finance sector. Given these considerations and an approach for simplicity and consistency in the EII design overall, it appears that adding the financial sector data may not be helpful.

As for the Energy axis, Hong Kong's score is again an outlier due to the very low percentage of renewable energy that is supporting the power grid. This is also supported by official report from the government, and, like Australia it appears that Hong Kong also has a plan to introduce more renewables in its power grid composition. The data point for Hong Kong's per user Internet capacity, i.e. International bandwidth per user, is again another outlier, which appears to be 20 to more than 100 times more than other jurisdictions. Whether this is due to erroneous reporting to the ITU by Hong Kong authorities may need to be investigated further (although the data had been consistently reported and consistently high across the years).

Furthermore, general sensitivity analysis can be done to see if small errors of data can lead to significant changes in scoring and ranking to understand the robustness of the framework. In this pilot study, a constant of 0.015 kWh/GB is used for the traffic to power consumption conversion formula, however this may be different depending on the infrastructure actually in place. Consideration perhaps for mobile or fixed broadband Internet usage may be included to explore if the sensitivity on the resulting calculations would be significant.

6.2 Expandability, Data Accuracy & Availability

Besides further examining the outliers and sensitivity of the scoring, it is useful to understand the expandability of the framework to other jurisdictions around Asia as well as the world. To begin with, the utilization of the UNCTAD, World Bank and ITU data sets should ensure some level of expandability as well as consistency of data across most countries. Nevertheless, the EII methodology does utilize data from local authorities and providers. These include local Internet exchange traffic data and local authorities and electricity provider data on energy source composition, as well as user behaviour data and Internet speed.

Particularly for the last two, although this EII pilot report utilizes results from a global survey maintained annually for the Internet usage data and utilizes data from multiple platforms for the speed test, both of which are proprietarily produced and publicly published and the stability and availability of data may need to be further considered for future development of the EII. As for the first two, local energy official report as well as provider reports should likely be consistent, especially in light of the Sustainable Development Goals (SDGs) and related reporting of power grid data. The availability of Internet exchange data may also need further consideration. While most Internet exchanges do publish data publicly, this may or may not continue, and also not all jurisdictions do have Internet exchanges that can provide relevant data for the component.

As mentioned in the brief analysis of the results for Hong Kong above, it may be useful to also analyse the reliability of the data sets, even as they are provided by official sources. Another consideration for further work is the timeliness of data obtained from the major data sets. For example, in this EII study, some of the data used is unfortunately from earlier years due to their missing availability in the current data sets from UNCTAD, World Bank and ITU respectively. For example, the percentage of total trade in services data is only available for Hong Kong up to 2019, and the international bandwidth data from ITU ranges from 2017 to 2020, likewise for grid emission factor, the data from China is only available up to 2017. In each case, the latest data available is used for this pilot study. If this is expected to continue to be the case for an annual compilation of EII, some consideration should be made on whether to take the latest data available or to produce some projection based on observed trends from the data set.

6.3 Future Development

Overall, the resulting data and scores seem to support that the EII model provides a useful comparison framework to consider the eco-friendliness of the Internet infrastructure across different jurisdictions. Each of the axes highlight the relevant relationships that makes for a balance between the positive aspects of the growth of the Internet along with the negative impacts on the Internet's carbon footprint and hence on the issue of climate change.

The quantification of observations through data into the EII does not replace the need for contextual understanding and evaluation of appropriate interventions to drive towards eco-friendlier Internet infrastructure in respective jurisdictions. Nevertheless, the EII proposes a reasonably simple yet reflective model to consider the issue of the Internet's impact on climate change.

Most importantly, it is hoped that the EII approach advocates the idea that the growth of Internet usage inevitably consumes more power and energy, however, what is important for ecological and policy considerations is not so much in curbing the use of the Internet, but in understanding the composition of the grid that powers the Internet, as well as trade and economic activities, which have a heavier carbon footprint, that the Internet replaces. The narrative which EII advances, in summary, is to "do more and waste less." Do more with the Internet and the infrastructure, and become more efficient with its use and with renewable energy sources. The EII is designed to model this approach towards a greener Internet that supports sustainable growth without compromising the environment.

Appendices

Appendix A: Grid Emission Factor Data .... **Error! Bookmark not defined.**
Appendix B: Carbon Footprint of the Internet as a Percentage of Total Carbon Footprint .... **Error! Bookmark not defined.**
Appendix C: EcoInternet Index Pilot Study Calculations.......................... **Error! Bookmark not defined.**

Appendix A: Grid Emission Factor Data

Australia

	2016	2017	2018	2019	2020	Changes %
Grid Emission Factor (kgCO2e per kWh)	0.80	0.80	0.79	0.76	0.73	-8.75%

https://www.industry.gov.au/sites/default/files/August%202021/document/national-greenhouse-accounts-factors-2021.pdf

China

	2014	2015	2016	2017	(2014-2017) Changes %
Northeast China - Grid Emission Factor (kgCO2 per KWh*)	1.1291	1.1082	1.0925	1.0826	-4.12%
East China - Grid Emission Factor (kgCO2 per KWh*)	0.8112	0.8046	0.7937	0.7921	-2.35%

https://www.mee.gov.cn/ywgz/ydqhbh/wsqtkz/
*Emissions of CO2 equivalent e.g. CH4, N2O are not included.

Hong Kong

	2016	2017	2018	2019	2020	Changes %
Carbon dioxide emissions intensity of CLP Group's generation and energy storage portfolio (kgCO2e per kWh)	0.82	0.80	0.74	0.70	0.65	-20.73%

https://sustainability.clpgroup.com/en/2020/standard-esg-disclosures/key-performance-metrics#data-table

India

	2016	2017	2018	2019	2020	Changes %
Grid Emission Factor (kgCO2 per KWh*)	0.74	0.75	0.74	0.74	0.73	-2.44%

https://cea.nic.in/wp-content/uploads/baseline/2021/06/User_Guide_ver_16_2021-1.pdf
*Emissions of CO2 equivalent e.g. CH4, N2O are not included.

Japan

	2016	2017	2018	2019	2020	Changes %
Grid Emission Factor (kgCO2e per kWh)	0.490	0.475	0.468	0.457	0.441	-10.00%

https://www.tepco.co.jp/en/corpinfo/illustrated/environment/emissions-co2-e.html

Singapore

	2016	2017	2018	2019	2020	Changes %
Grid Emission Factor (kgCO2e per kWh)	0.4237	0.4210	0.4206	0.4085	0.4080	-3.71%

https://www.ema.gov.sg/singapore-energy-statistics/Ch02/index2

Appendix B: Carbon Footprint of the Internet as a Percentage of Total Carbon Footprint

Internet usage data is taken from the Wearesocial survey and "others" is included based on the total time spent online as a base level of traffic. Data from the 2021 survey for 2020 usage pattern is used. A uniform rate of 0.015 kWH/GB is used for conversion (see discussions in Sections 2.1 & 5.2).

Australia

Time Online (Daily)	**Hours**	**Minutes**	**No. of Hours**	**GB/H**	**Usage**	**Unit**
Time on Video (broadcast & streaming)	3	30	3.500	2	7.000	GB
Time on Social Media	1	46	1.767	0.05	0.088	GB
Time on Music/Audio	2	2	2.033	0.042	0.085	GB
Time on Gaming	0	54	0.900	0.02	0.018	GB
Others	6	13	6.217	0.018	0.112	GB
No. of Internet Users	22.82 million			**Total:**	162,763	TB/day
https://wearesocial.com/au/blog/2021/01/digital-2021-australia/						
Conversion to Kilo-Watt Hours	**0.015**	**kWh/GB**	https://www.cmswire.com/digital-experience/calculating-the-pollution-effect-of-data/			
Energy Consumption per Day	2,500,033.69	kWh				
Carbon Footprint per kWh	0.73	kgCO2-e/kWh				
Carbon Footprint of per Year	666,133.98	tCO2-e	1000 kg = 1 metric ton			
Total Carbon Emission of Australia	391.89	MtCO2-e	https://ourworldindata.org/co2-emissions			
% of Carbon Footprint of Data Traffic of Online Activities	0.17%					

China

Time Online (Daily)	**Hours**	**Minutes**	**No. of Hours**	**GB/H**	**Usage**	**Unit**
Time on Video (broadcast & streaming)	3	12	3.200	2	6.400	GB
Time on Social Media	2	4	2.067	0.05	0.103	GB
Time on Music/Audio	2	46	2.767	0.042	0.116	GB
Time on Gaming	1	21	1.350	0.02	0.027	GB
Others	5	22	5.367	0.018	0.097	GB
No. of Internet Users	939.8 million			**Total:**	6,188,669	TB/day
https://wearesocial.com/cn/blog/2021/01/digital-2021-china/						
Conversion to Kilo-Watt Hours	**0.015**	**kWh/GB**	https://www.cmswire.com/digital-experience/calculating-the-pollution-effect-of-data/			
Energy Consumption per Day	95,057,950.60	kWh				
Carbon Footprint per kWh	0.7921	kgCO2-e/kWh	Data of East China from 2017 is used in calculation because it is the most recent report published and East China has the highest Internet usage.			
Carbon Footprint of per Year	27,482,821.97	tCO2-e	1000 kg = 1 metric ton			
Total Carbon Emission of China	10,670.00	MtCO2-e				
% of Carbon Footprint of Data Traffic of Online Activities	0.26%					

Hong Kong

Time Online (Daily)	Hours	Minutes	No. of Hours	GB/H	Usage	Unit
Time on Video (broadcast & streaming)	2	50	2.833	2	5.667	GB
Time on Social Media	1	57	1.950	0.05	0.098	GB
Time on Music/Audio	1	24	1.400	0.042	0.059	GB
Time on Gaming	1	0	1.000	0.02	0.020	GB
Others	7	15	7.250	0.018	0.131	GB
No. of Internet Users	6.92 million			**Total:**	40,368	TB/day
https://wearesocial.com/hk/blog/2021/01/digital-2021-hong-kong/						
Conversion to Kilo-Watt Hours	**0.015**	**kWh/GB**	https://www.cmswire.com/digital-experience/calculating-the-pollution-effect-of-data/			
Energy Consumption per Day	620,045.84	kWh				
Carbon Footprint per kWh	0.65	kgCO2-e/kWh				
Carbon Footprint per Year	147,105.88	tCO2-e	1000 kg = 1 metric ton			
Total Carbon Emission of Hong Kong	31.24	MtCO2-e	https://ourworldindata.org/co2-emissions			
% of Carbon Footprint of Data Traffic of Online Activities	0.47%					

India

Time Online (Daily)	Hours	Minutes	No. of Hours	GB/H	Usage	Unit
Time on Video (broadcast & streaming)	3	16	3.267	2	6.533	GB
Time on Social Media	2	25	2.417	0.05	0.121	GB
Time on Music/Audio	3	1	3.017	0.042	0.127	GB
Time on Gaming	1	20	1.333	0.02	0.027	GB
Others	6	36	6.600	0.018	0.119	GB
No. of Internet Users	624 million			**Total:**	4,220,734	TB/day
https://datareportal.com/reports/digital-2021-india						
Conversion to Kilo-Watt Hours	**0.015**	**kWh/GB**	https://www.cmswire.com/digital-experience/calculating-the-pollution-effect-of-data/			
Energy Consumption per Day	64,830,480.00	kWh				
Carbon Footprint per kWh	0.73	kgCO2-e/kWh				
Carbon Footprint of per Year	17,173,460.87	tCO2-e	1000 kg = 1 metric ton			
Total Carbon Emission of India	2,440.00	MtCO2-e	https://ourworldindata.org/co2-emissions			
% of Carbon Footprint of Data Traffic of Online Activities	0.70%					

Japan

Time Online (Daily)	Hours	Minutes	No. of Hours	GB/H	Usage	Unit
Time on Video (broadcast & streaming)	2	21	2.350	2	4.700	GB
Time on Social Media	0	51	0.850	0.05	0.043	GB
Time on Music/Audio	0	39	0.650	0.042	0.027	GB
Time on Gaming	0	34	0.567	0.02	0.011	GB
Others	4	25	4.417	0.018	0.080	GB
No. of Internet Users	117.4 million			**Total:**	557,264	TB/day
https://wearesocial.com/jp/blog/2021/01/digital-2021-japan/						
Conversion to Kilo-Watt Hours	**0.015**	**kWh/GB**	https://www.cmswire.com/digital-experience/calculating-the-pollution-effect-of-data/			
Energy Consumption per Day	8,559,575.30	kWh				
Carbon Footprint per kWh	0.441	kgCO2-e/kWh				
Carbon Footprint of per Year	1,377,792.04	tCO2-e	1000 kg = 1 metric ton			
Total Carbon Emission of Japan	1,030.00	MtCO2-e	https://ourworldindata.org/co2-emissions			
% of Carbon Footprint of Data Traffic of Online Activities	0.13%					

Singapore

Time Online (Daily)	Hours	Minutes	No. of Hours	GB/H	Usage	Unit
Time on Video (broadcast & streaming)	2	47	2.783	2	5.567	GB
Time on Social Media	2	17	2.283	0.05	0.114	GB
Time on Music/Audio	1	57	1.950	0.042	0.082	GB
Time on Gaming	0	49	0.817	0.02	0.016	GB
Others	8	7	8.117	0.018	0.146	GB
No. of Internet Users	5.29 million			**Total:**	30,610	TB/day
https://wearesocial.com/sg/blog/2021/01/digital-2021-singapore/						
Conversion to Kilo-Watt Hours	**0.015**	**kWh/GB**	https://www.cmswire.com/digital-experience/calculating-the-pollution-effect-of-data/			
Energy Consumption per Day	470,161.98	kWh				
Carbon Footprint per kWh	0.4080	kgCO2-e/kWh				
Carbon Footprint per Year	70,016.52	tCO2-e	1000 kg = 1 metric ton			
Total Carbon Emission of Singapore	45.50	MtCO2-e	https://ourworldindata.org/co2-emissions			
% of Carbon Footprint of Data Traffic of Online Activities	0.15%					

Appendix C: EcoInternet Index Pilot Study Calculations

Calculations are based on the methodology presented in Section 5 for the 6 jurisdictions included in this pilot study.

Economy Axis:

$$\frac{\frac{Carbon\ Footprint\ of\ Internet\ Activities\ (kgCO_2)}{Total\ Carbon\ Emission\ (kgCO_2)}}{ICT\ Services\ as\ \%\ of\ Total\ Trade\ in\ Services\ (Export + Import)}$$

Carbon Footprint:

	Carbon Footprint of Internet ($tgCO_2$-e)[1]	Total Carbon Emission ($MtCO_2$-e)	Total (%)	Remarks
AU	666,133.977	391.890	0.170%	
CN	27,482,821.975	10,670.000	0.258%	
HK	147,105.876	31.240	0.471%	
IN	17,173,460.866	2,440.000	0.704%	
JP	1,377,792.038	1,030.000	0.134%	
SG	70,016.521	45.500	0.154%	

Digital Economy:[2]

	Percentage of total trade in services (ICT Services, Import)	Percentage of total trade in services (ICT Services, Export)	Total (%)	Remarks
AU	9.784	7.370	17.154%	
CN	21.036		40.029%	*Export Data not included*[3]
HK	2.343	2.925	5.268%	*Data taken from 2019*
IN	6.808	33.452	40.260%	
JP	10.880	5.864	16.744%	
SG	9.604	7.984	17.588%	

Economy Axis Normalized Score

	Carbon Footprint (%)	Digital Economy (%)	Economy Axis Score	Normalized Score
AU	0.170%	17.154%	**0.991**	1.094
CN	0.258%	40.029%	**1.224**	1.209
HK	0.471%	5.268%	**8.939**	5.000
IN	0.704%	40.260%	**1.748**	1.466
JP	0.134%	16.744%	**0.799**	1.000
SG	0.154%	17.588%	**0.875**	1.037

[1] See Appendix B for detailed calculations

[2] Digital Economy: Share of ICT goods as percentage of total trade, annual (<500KB) https://unctadstat.unctad.org/EN/BulkDownload.html

[3] Data for China reported for 2020 appears to be an anomaly (the Export data is missing and the Import data is significantly increased. Therefore only the "Import" data is used and understood as the aggregate Import + Export data:

	2015	2016	2017	2018	2019	2020
Import	2.5784	2.78227	4.10106	4.52725	5.36483	21.03633
Export	11.79318	12.66231	12.17388	17.33559	18.99235	
Total	14.37158	15.44458	16.27494	21.86284	24.35718	

Energy Axis:

$$\frac{Grid\ Emission\ Factor\ (kgCO_2/kWh)}{Renewable\ Electricity\ Output\ (\%\ of\ Total\ Electricity\ Output)}$$

Energy Axis Normalized Score

	Grid Emission Factor[4]	Renewable electricity output (% of total electricity output)[5]	Energy Axis Score	Normalized Score
AU	0.730	13.638%	**0.054**	1.045
CN	0.937	23.927%	**0.039**	1.020
HK	0.650	0.279%[6]	**2.332**	5.000
IN	0.726	15.343%	**0.047**	1.034
JP	0.441	15.985%	**0.028**	1.000
SG	0.408	1.821%	**0.224**	1.341

Efficiency Axis:

$$\frac{International\ Internet\ Bandwidth\ (Mbps\ per\ user)}{Connectivity\ Speed\ (Mbps)} \times \frac{Traffic\ Volume_{MAX}}{Traffic\ Volume_{MEAN}}$$

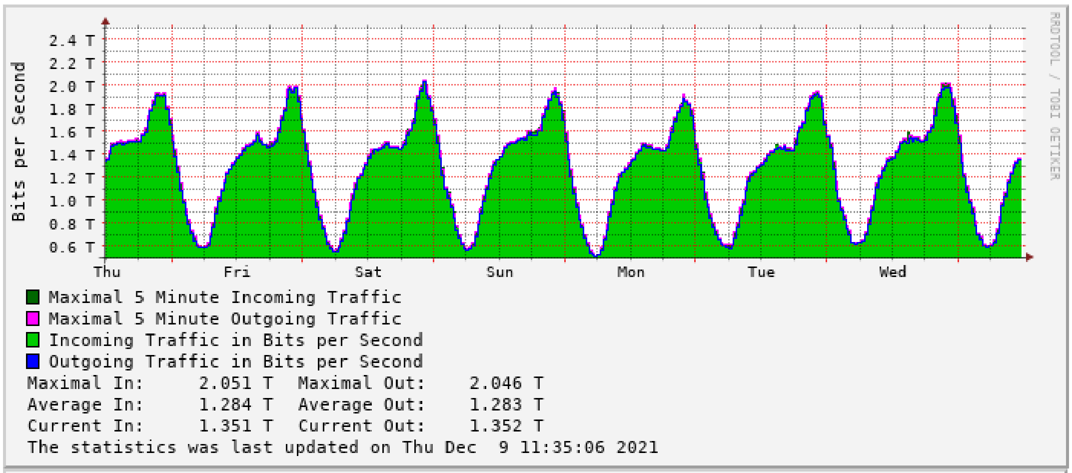
Internet Bandwidth & Connectivity Speed

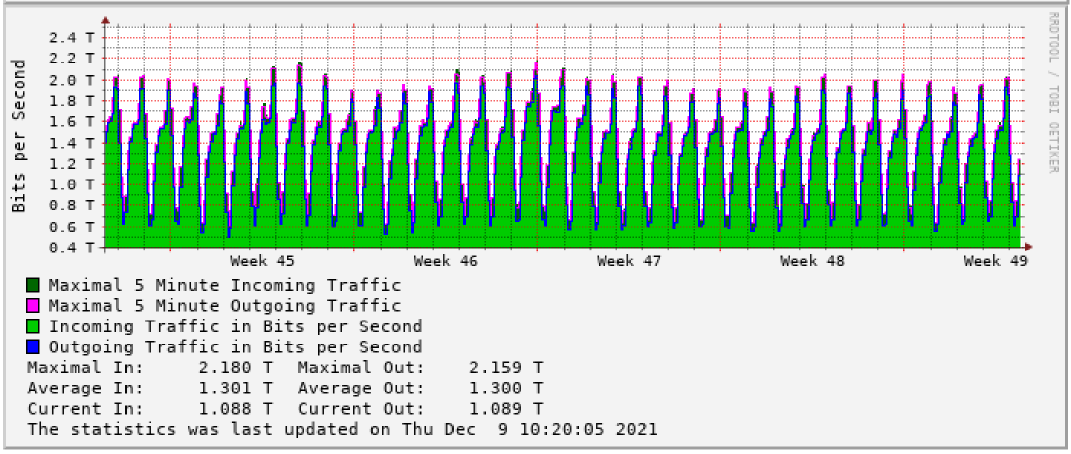
	International Internet bandwidth (Mbps / user)[7]	Ookla	M-Lab	Speedtest	Average (Mbps)[8]	Capacity / Speed Observed
AU	67.209	77.88	25.65	60.25	54.593	0.012
CN	43.314	172.95	2.08	153.49	109.507	0.004
HK	16,398.097[9]	240.83	105.32	53.27	133.140	1.232
IN	58.857	55.76	13.46	52.25	40.490	0.015
JP	24.796	167.18	54.61	147.19	122.993	0.002
SG	954.244	245.5	72.74	242.17	186.803	0.051

For the estimation of variance of Internet traffic, the data from different Internet eXchange Points (IXP) were taken (Snapshot data was taken on Dec 9, 2021 and the following graphs summarizes the data taken and used for this pilot study calculations):

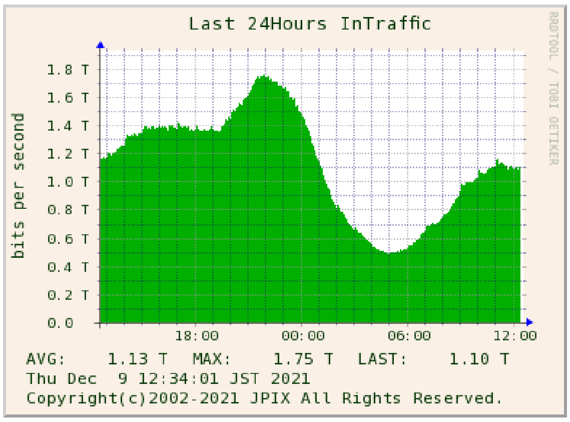
[4] See Appendix A for detailed calculations
[5] https://data.worldbank.org/indicator/EG.ELC.RNEW.ZS
[6] This extremely low data point causes some skewing of the data, nevertheless, the normalized score provides a reasonable comparison between other jurisdictions considered
[7] https://www.itu.int/en/publications/ITU-D/pages/publications.aspx?parent=D-IND-WTID.OL-2021&media=electronic see section 5.4 for methodology
[8] Average of the 3 sources is used for the calculations: Ookla (https://www.speedtest.net/global-index), M-Lab (https://s3-eu-west-1.amazonaws.com/assets.cable.co.uk/broadband-speedtest/worldwide-broadband-speed-league-2020-press-releases.pdf), and SpeedTestNet.io (http://speedtestnet.io/) included in the Wikipedia article on Internet Connection Speeds (https://en.wikipedia.org/wiki/List_of_countries_by_Internet_connection_speeds)
[9] This extraordinarily high data point causes some skewing of the data.

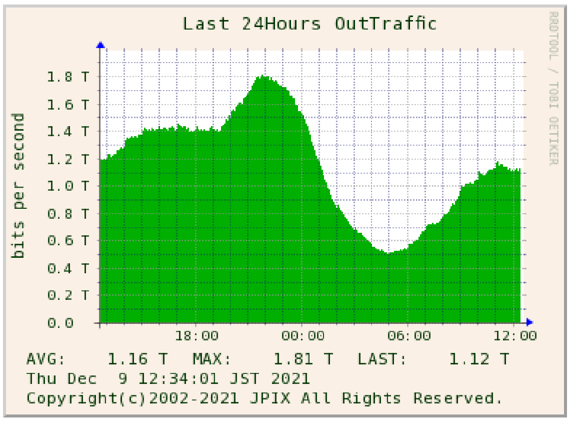
HKIX (HK): https://www.hkix.net/hkix/stat/aggt/hkix-aggregate.html

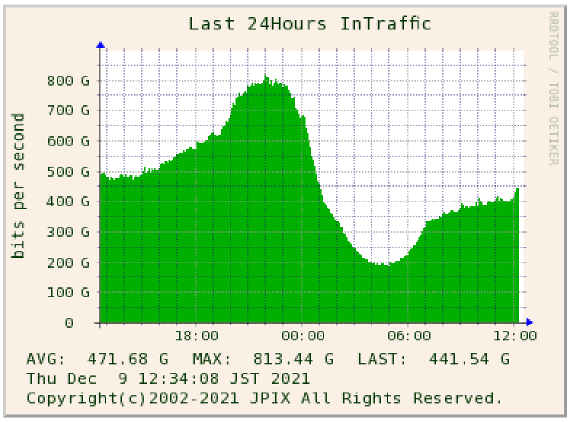


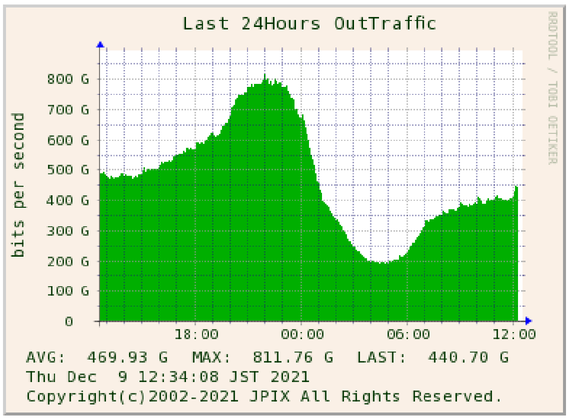


JPIX (JP): https://www.jpix.ad.jp/en/technical_traffic.php

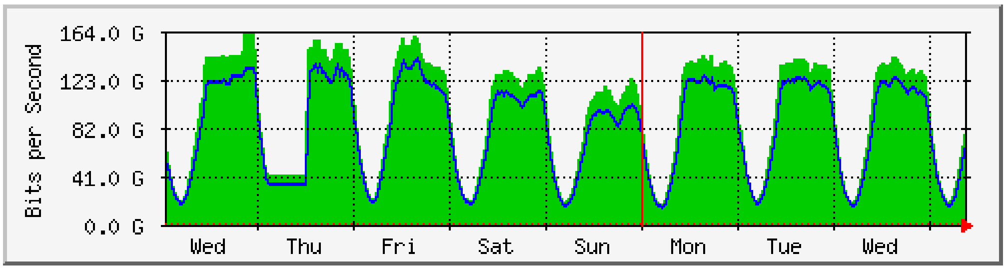


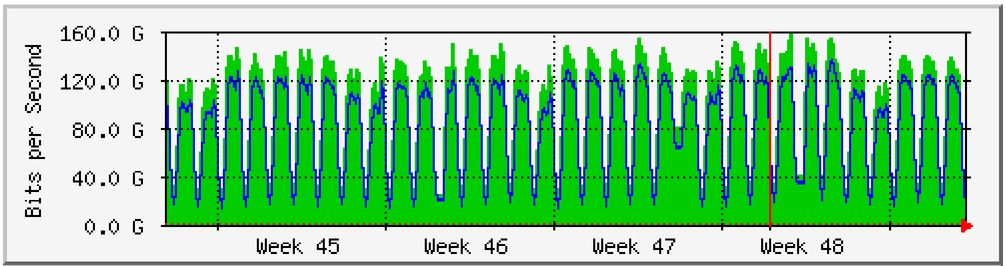


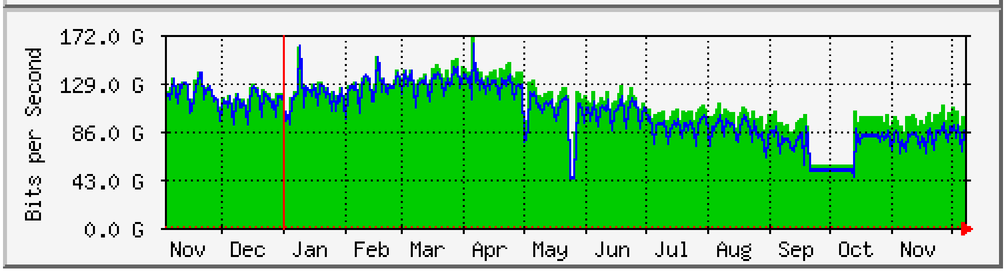




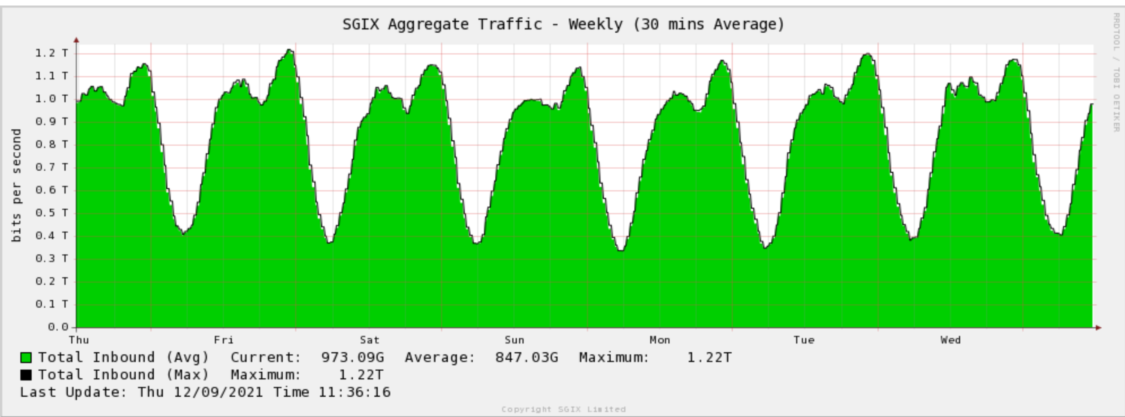
NIXI (IN): http://mrtg.nixi.in/mrtg.html

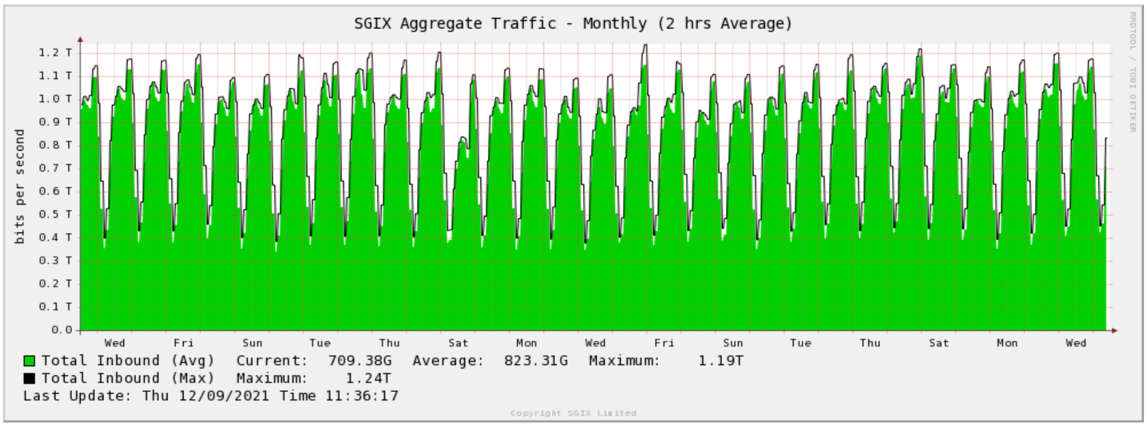






SGIX (SG): https://www.sgix.sg/services/traffic-statistics/





Data for ASN AU (https://metrics.ix.asn.au/d/000000053/ix-aggregates?orgId=2&refresh=1m&kiosk&inspect=24&inspectTab=data) was taken on Dec 8, 2021, and the average over 6 IXPs are included: NSW-IX, VIC-IX, WA-IX, QLD-IX, SA-IX and ACT-IX:

Gbps	NSW-IX	VIC-IX	WA-IX	QLD-IX	SA-IX	ACT-IX
Max	4068.440	1507.541	1102.006	977.994	252.719	18.245
Mean	2626.133	955.461	609.042	509.188	158.369	6.862
Max/Mean	1.549	1.578	1.809	1.921	1.596	2.659
Average						1.852

IXP Data for China was not found and an average of the above is used to offset the factor applied for the calculations of the score for China.

Efficiency Axis Normalized Score

	Capacity / Speed Observed	Internet Traffic Variance			Efficiency Axis Score	Normalized Score
		Max	Mean	Max/Mean		
AU	0.012			1.852	0.023	1.040
CN	0.004			1.531	0.006	1.006
HK	1.232	2.051	1.284	1.597	1.967	5.000
IN	0.015	0.937	0.769	1.218	0.018	1.030
JP	0.002	1.750	1.130	1.549	0.003	1.000
SG	0.051	1.220	0.847	1.440	0.074	1.143

EcoInternet Index (EII) Composite Score:

	Economy		Energy		Efficiency		EII Score	
	Normalized Score	*Rank*	*Normalized Score*	*Rank*	*Normalized Score*	*Rank*	*Composite Score*	*Rank*
AU	1.094	3	1.045	4	1.040	4	0.977	2
CN	1.209	4	1.020	2	1.006	2	1.009	3
HK	5.000	6	5.000	6	5.000	6	21.773	6
IN	1.466	5	1.034	3	1.030	3	1.188	4
JP	1.000	1	1.000	1	1.000	1	0.871	1
SG	1.037	2	1.341	5	1.143	5	1.193	5