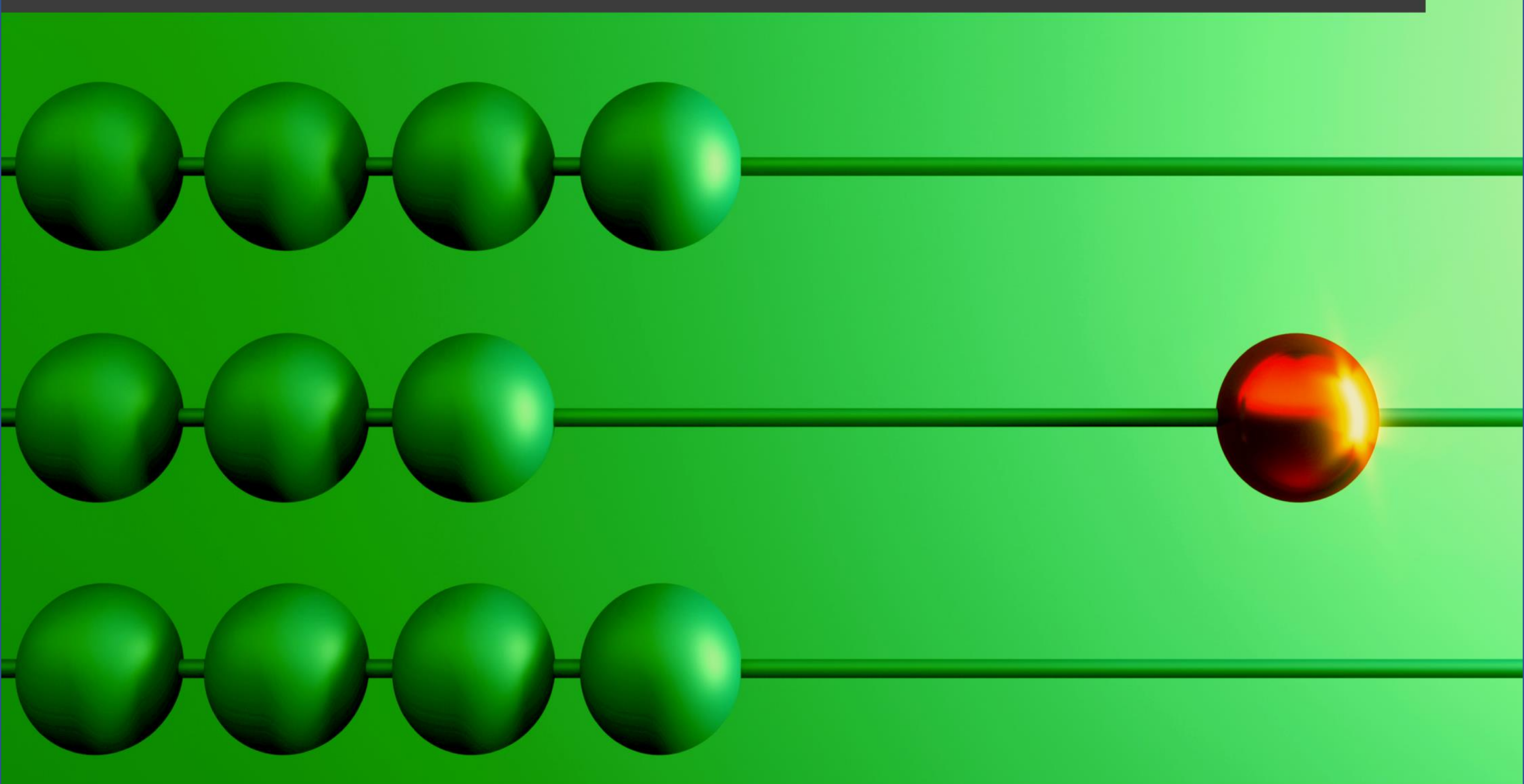
Sustainable IT Playbook for Technology Leaders

Design and implement sustainable IT practices and unlock sustainable business opportunities



Niklas Sundberg

Foreword by Hélène Barnekow, Partner at Ascension AS and Board Member

Preface

To get the most out of this audiobook.

No software is required to get the most out of this audiobook. There is a website accompanying the audiobook, www.sustainableitplaybook.com, where you will be able to download additional book resources in PowerPoint or Excel format. The audiobook resources can be accessed behind a password-protected site. The password is `MySustainableITJourney`.

Chapter 1

Images

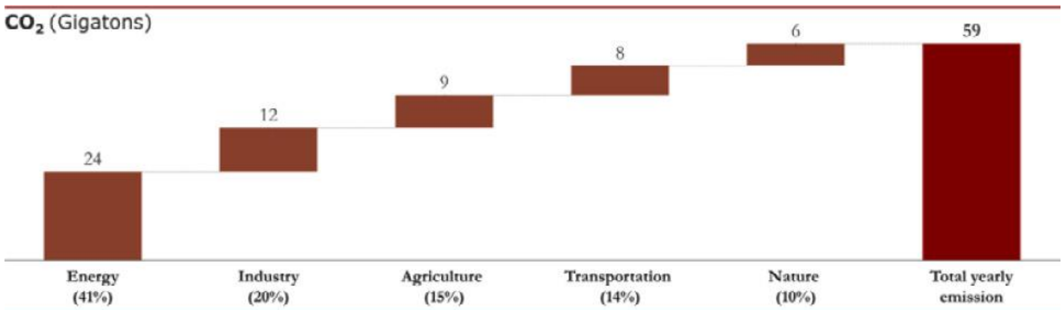


Figure 1.1 – How GHG emissions add up

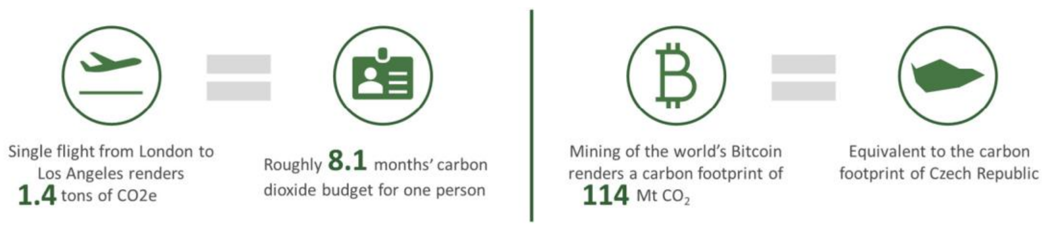


Figure 1.2 – Carbon emission comparison between common use cases

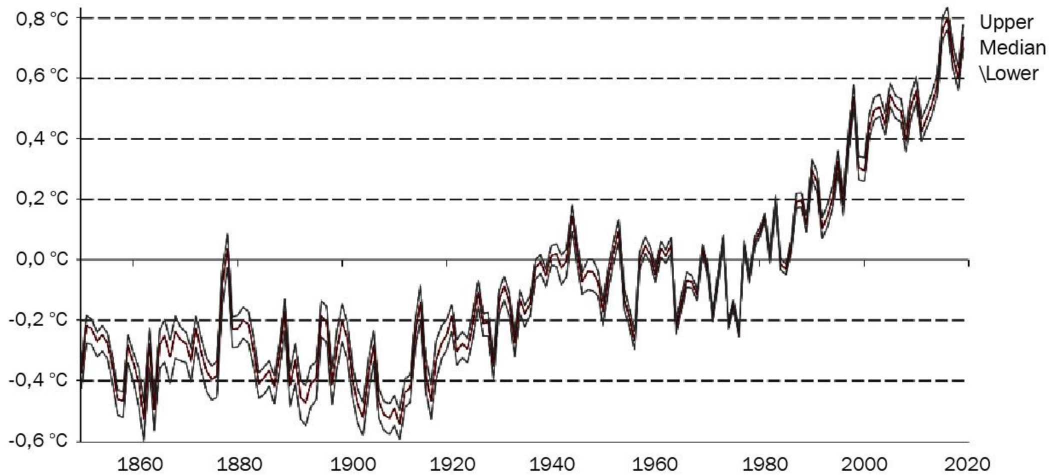


Figure 1.3 – Indicating a 0.7°C rise in global temperatures. The upper and lower gray lines represent the upper and lower confidence intervals, whereas the red line demonstrates the average annual temperature trend:

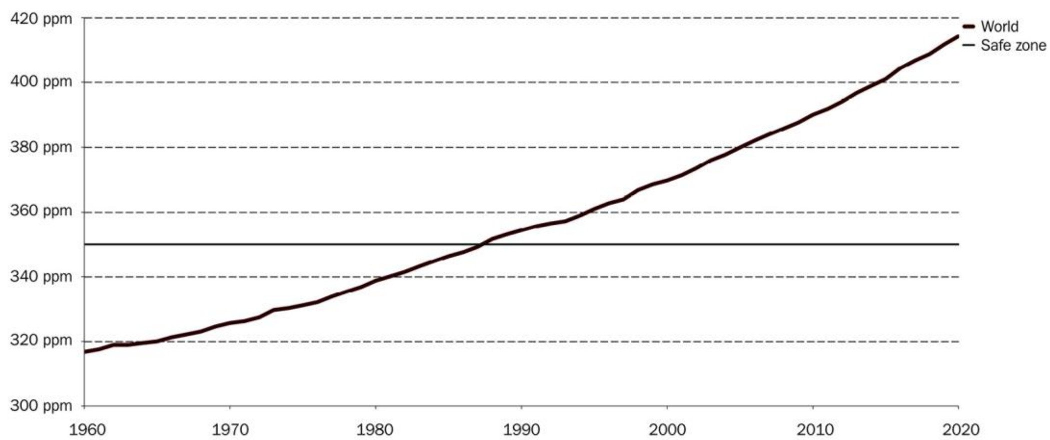


Figure 1.4 – Atmospheric concentrations of CO2 continue to rise

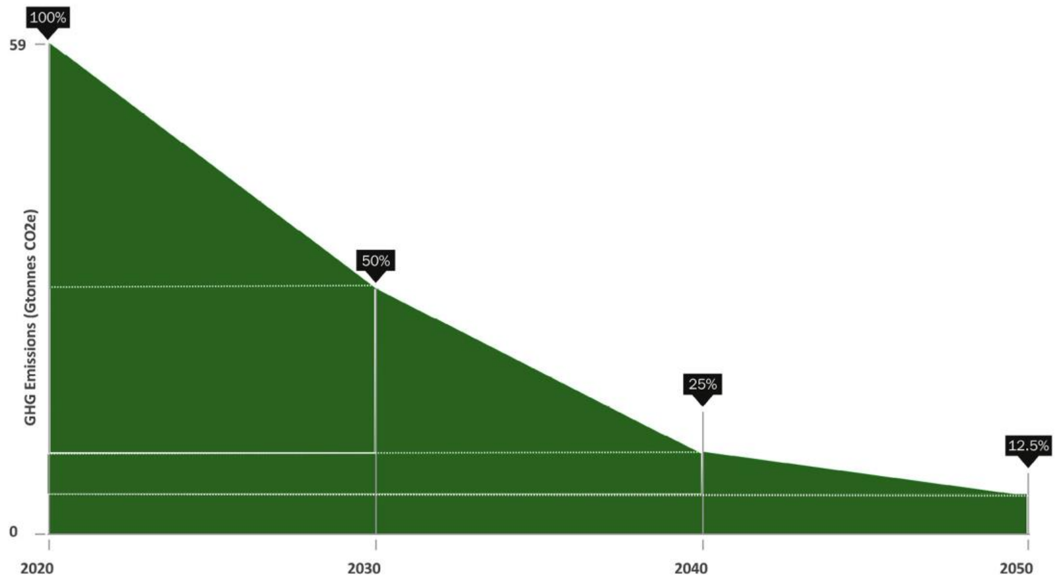


Figure 1.5 – Carbon Law; we need to halve our CO2 emission every decade until 2050

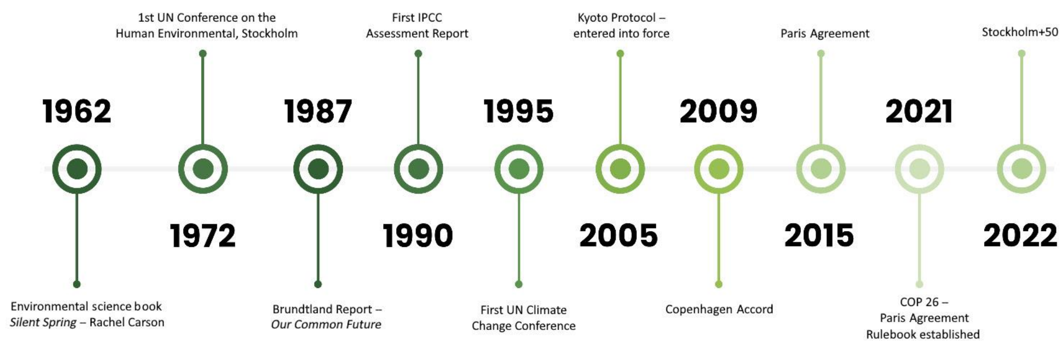


Figure 1.6 – History of climate action and policy change

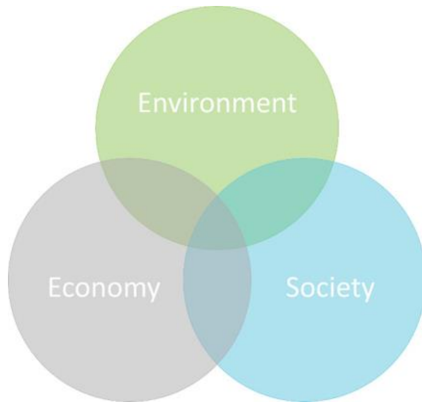


Figure 1.7 – Three pillars of sustainability: Environment, Society, and Economy

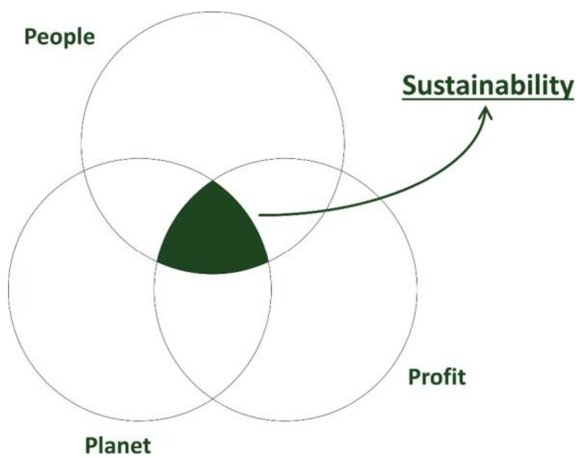


Figure 1.8 – 3Ps of the triple bottom line

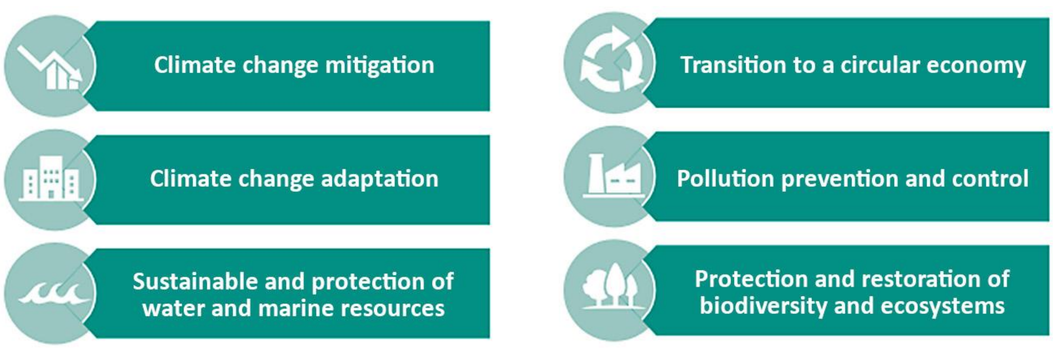


Figure 1.9 – The EU Taxonomy–six environmental objectives

Figure 1.10 – EU Taxonomy – schedule

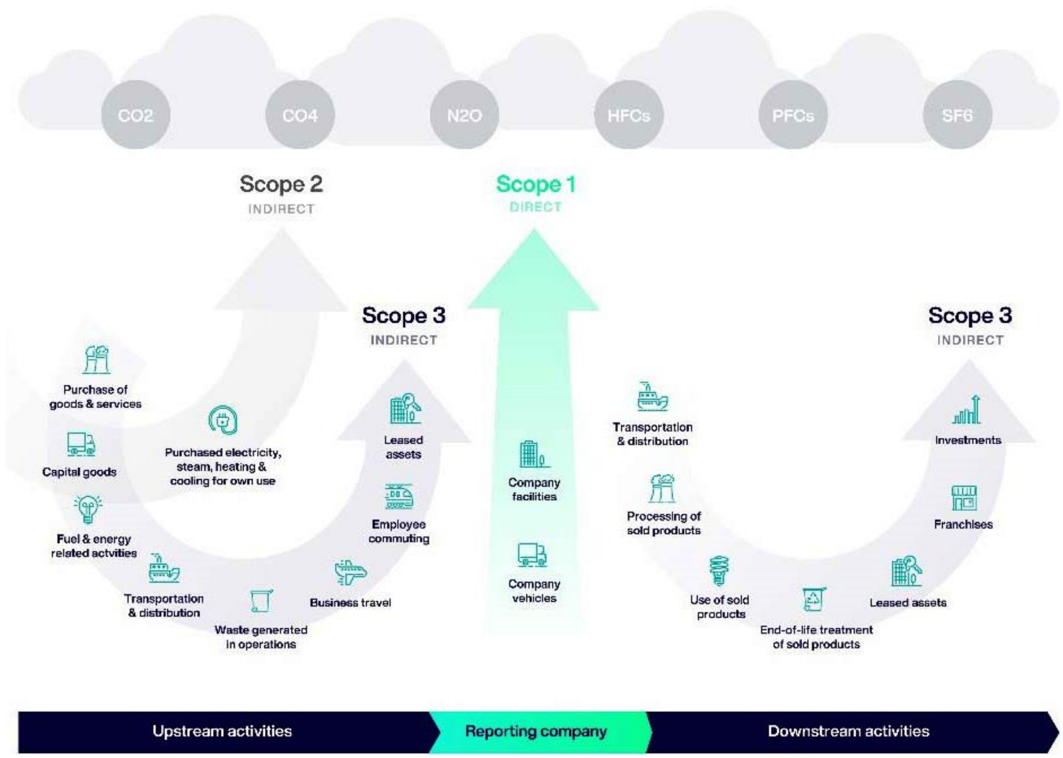


Figure 1.11 – The three scopes of GHG emissions (World Resource Institute n.d.)

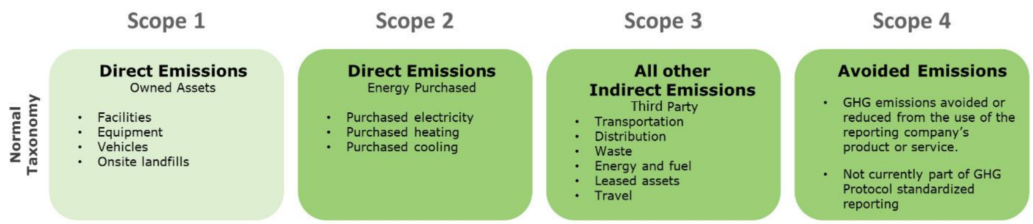


Figure 1.12 – Carbon emission scope classification

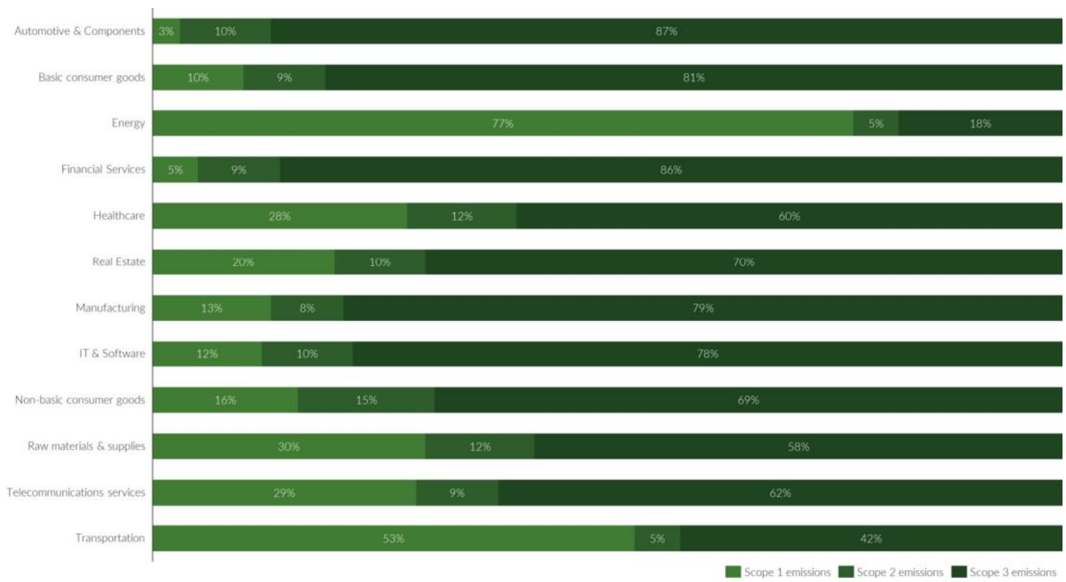


Figure 1.13 – Scope emissions by industry

A dramatically different top 12

Top 12 in 2022	Market CAP ($B)	Top 12 in 2015	Market CAP ($B)	Top 12 in 2000	Market CAP ($B)
Apple	$2 652	Apple	$710	General Electric	$474
Microsoft	$2 222	Alphabet/Google	$449	Exxon Mobil	$302
Alphabet/Google	$1 951	Microsoft	$368	Pfizer	$290
Amazon	$1 446	Exxon Mobil	$334	Citigroup	$287
Meta/Facebook	$843	Wells Fargo	$297	Cisco	$275
Berkshire Hathaway	$682	Johnson & Johnson	$274	Wal-Mart Stores	$287
Tencent	$573	Facebook	$272	Microsoft	$231
Johnson & Johnson	$434	General Electric	$259	AIG	$229
JP Morgan Chase	$427	JP Morgan Chase	$255	Merck	$216
Wal-Mart Stores	$388	Amazon	$247	Intel	$202
Alibaba	$344	Wal-Mart Stores	$230	Johnson & Johnson	$181
Exxon Mobil	$307	Proctor & Gamble	$218	Coca-Cola	$164

Data: https://companiesmarketcap.com/ 2022 valuations as 1/28/22

Figure 1.14 – Market cap development on S&P 500

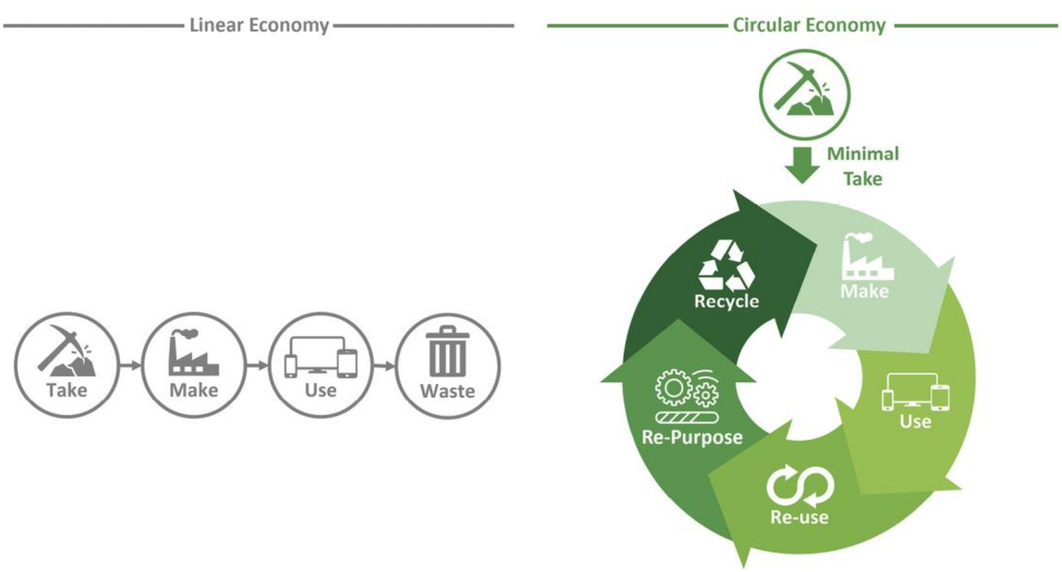


Figure 1.15 – From a linear economy to a circular economy

Further resources

- Intergovernmental Panel on Climate Change (IPCC): https://www.ipcc.ch/
- United Nations – Sustainable Development Goals (SDG): https://sdgs.un.org/goals
- Polman, P and Winston, A. (2021) *Net Positive: How Courageous Companies Thrive by Giving More Than They Take*, Harvard Business Review Press
- Gates, B. (2021) *How to Avoid a Climate Disaster*, Allen Lane
- Doerr, J. (2021) *Speed & Scale*, Penguin Random House UK

Bibliography

- 2020. *Apple 12 Product Environmental Report*. October 13. Accessed March 13, 2022. https://www.apple.com/environment/pdf/products/iphone/iPhone_12_PER_Oct2020.pdf
- Banerjee, Neela, Lisa Song, and David Hasemyer. 2015. *Exxon's Own Research Confirmed Fossil Fuels' Role in Global Warming Decades Ago*. Inside Climate News. September 16. Accessed January 28, 2022. https://insideclimatenews.org/news/16092015/exxons-own-research-confirmed-fossil-fuels-role-in-global-warming/
- Bay, Stephen. 2020. *With the rise in home working, we need a scope 4 for GHG emissions*. December 9. Accessed May 22, 2022. https://www.reutersevents.com/sustainability/rise-home-working-we-need-scope-4-ghg-emissions
- n.d. *Carbon Disclosure Project*. https://www.cdp.net/en
- 2021. *CDP - Disclosure Insight Action*. October 14. CDP reports record number of disclosures and unveils new strategy to help further tackle climate and ecological emergency

- 2020. *Circular economy action plan*. European Commission. March. Accessed January 29, 2022. https://ec.europa.eu/environment/strategy/circular-economy-action-plan_en
- February 27th, 2022. *Climate Change 2022 Impacts, Adaption and Vulnerability Summary for Policymakers*. IPCC.ch
- n.d. *Companies taking action*. Science Based Targets. Accessed March 05, 2022. https://sciencebasedtargets.org/companies-taking-action
- Dean, Brian. 2022. Zoom User Stats: *How Many People Use Zoom in 2022?* Zoom Inc. January 06. Accessed January 25, 2022. https://backlinko.com/zoom-users
- 2021. *Dell Latitude 7420*. January. Accessed March 17, 2022. https://www.dell.com/sv-se/dt/corporate/social-impact/advancing-sustainability/sustainable-products-and-services/product-carbon-footprints.htm#tab0=1&pdf-overlay=//www.delltechnologies.com/asset/sv-se/products/laptops-and-2-in-1s/technical-support/latitud
- Delworth, T., F. Zeng, G. Vecchi, and et al. 2016. "The North Atlantic Oscillation as a driver of rapid climate change in the Northern Hemisphere." *Nature* 509–512. https://doi.org/10.1038/ngeo2738
- n.d. *Digiconomist.net*. Accessed March 02, 2022. https://digiconomist.net/bitcoin-energy-consumption
- Doerr, John. 2021. *Speed & Scale – A Global Action Plan for Solving Our Cimate Crisis Now*. UK: Penguin Business.
- 2021. *European Commission*. 07 01. https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en
- Fankhauser, S., S. M. Smith, M. Allen, and et al. 2021. *The meaning of net zero and how to get it right*. Natural Climate Change.

- Finch, Caleb. 2019. *History of Companies and Industries Listed on the S&P 500*. QAD.com. October 03. Accessed March 05, 2022. https://www.qad.com/blog/2019/10/sp-500-companies-over-time
- Ginér, Gabrielle, Katie Schindall, Melanie Kubin-Hardewig, Pia Tanskanen, Ramon Fernandez, Maha Alnuhait, Enrique Blanco, and Sara Nordbrand. 2022. *Strategy Paper for Circular Economy: Network Equipment*. GSMA. March 01. Accessed March 05, 2022. https://www.gsma.com/betterfuture/resources/strategy-paper-for-circular-economy-network-equipment
- n.d. *Global Compact Network Germany*. Accessed January 25, 2021. https://www.globalcompact.de/en/
- 2022. *Global Footprint Network*. March 03. https://www.footprintnetwork.org/our-work/ecological-footprint/
- IPCC. 2013. *Climate Change 2013: The Physical Science Basis*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.
- 2022. *ipcc.ch*. https://www.ipcc.ch/report/sixth-assessment-report-cycle/
- 2021. *ipcc.ch*. August. https://www.ipcc.ch/report/ar6/wg1/
- ISWA. 2020. *Global E-waste Surging: Up 21 Percent in 5 Years*. United Nations Institute for Training and Research. July 2. Accessed January 27, 2022.
- Jensen, Henrik Hvid. 2022. *5 circular economy business models that offer a competitive advantag*e. World Economic Forum. January 27. Accessed January 29, 2022. https://www.weforum.org/agenda/2022/01/5-circular-economy-business-models-competitive-advantage?utm_source=linkedin&utm_medium=social_scheduler&utm_term=Circular+Economy&utm_content=29/01/2022+05:00
- Johnson, John, and Steven Steutermann. 2019. "Preparing for 2029, When Consumer Product Supply Chains Cannot Produce Waste." August 08. Accessed January 29, 2022. https://www.gartner.com/en/documents/3956095

- Lacis, A. A., G. A. Schmidt, D. Rind, and R. A. Ruedy. 2010. “Atmospheric CO2: Principal control knob governing Earth’s temperature.” *Science, 330(6002)* 356–359.
- McCarthy, Niall. 2014. *Europe is Highly Dependent on Russian Gas*. July 23. Accessed May 22, 2022. https://www.statista.com/chart/2485/europe-is-highly-dependent-on-russian-gas/
- Mendiluce, Maria. 2022. “*Setting Science-Based Targets to Combat Climate Change*.” Harvard Business Review. February 02. Accessed March 04, 2022. https://hbr.org/2022/02/setting-science-based-targets-to-combat-climate-change
- 2020. “*Netflix Environmental Social Governance*.” Netflix. February 2. Accessed January 25, 2022. https://s22.q4cdn.com/959853165/files/doc_downloads/2020/02/0220_Netflix_EnvironmentalSocialGovernanceReport_FINAL.pdf
- Obringer, Renee, Benjamin Rachunok, Debora Maia-Silva, Maryam Arbabzadeh, Roshanak Nateghi, and Kaveh Madani. 2021. “The overlooked environmental footprint of increasing Internet use.” *Resources, Conservation & Recycling* 167 (105389). https://pub-victoria.escribemeetings.com/filestream.ashx?DocumentId=63876#:~:text=Considering%20that%20a%20number%20of,until%20the%20end%20of%202021
- Ollagnier, Jean-Marc, Sytze Dijkstra, and Robinson Matthew. 2021. *Strategy & Consulting*. October 21. Accessed May 22, 2022. https://www.accenture.com/hk-en/insights/consulting/reaching-net-zero-by-2050
- n.d. *Our world is now only 8.6% circular*. CGR. Accessed March 04, 2022. https://www.circularity-gap.world/updates-collection/circle-economy-launches-cgr2020-in-davos
- Price, Tim. 2018. “Generation Green: how millennials will shape the circular economy.” *Environmental journal*.

- 2021. *Reuse and recycle: Google, Microsoft & Dell join forces to tackle e-waste crisis by 2030*. March 19. Accessed March 17, 2022. https://economictimes.indiatimes.com/magazines/panache/reuse-and-recycle-google-microsoft-dell-join-forces-to-tackle-e-waste-crisis-by-2030/articleshow/81585724.cms
- n.d. *Road to Zero Emissions*. As You Sow. Accessed March 05, 2022. https://www.asyousow.org/report-pages/2022/road-to-zero-emissions
- Rockström, J et al. 2017. "A roadmap for rapid decarbonization." *Science* 355.6331, 1269–1271.
- Rockström, Johan, and Mattias Klum. 2012. *The Human Quest: Prospering Within Planetary Boundaries*. Langenskiöld.
- Rockström, Owen Gaffney and Johan. 2021. *Breaking Boundaries – The Science of Our Planet*. London: Penguin Random House.
- SEC. 2022. *SEC Proposes Rules to Enhance and Standardize Climate-Related Disclosures for Investors*. March 21. Accessed May 22, 2022. https://www.sec.gov/news/press-release/2022-46
- Spangler, Todd. 2020. *Netflix Adds 8.8 Million Subscribers in Q4, Cites Competition for Lower U.S. Gain*s. Variety. January 21. Accessed January 25, 2022. https://variety.com/2020/digital/news/netflix-q4-2019-earnings-results-1203474435/
- Takahashi, Paul . 2021. *Over 100 oil and gas companies went bankrupt in 2020*. Houstin Chronicle. January 21. Accessed March 06, 2022. https://www.houstonchronicle.com/business/energy/article/More-than-100-oil-and-gas-companies-filed-for-15884538.php
- 2018. *Think with Google*. Google. June. Accessed January 25, 2022. https://www.thinkwithgoogle.com/marketing-strategies/search/global-youtube-mobile-watch-time-statistics/

- UNEP DTU Partnership. 2020. *Emissions Gap Report*. United Nations Environment Programme.
- Viguerie, S. Patrick, Ned Calder, and Brian Hindo. 2021. "2021 Corporate." May. Accessed March 05, 2022. https://www.innosight.com/wp-content/uploads/2021/05/Innosight_2021-Corporate-Longevity-Forecast.pdf
- n.d. *What is circular economy?* Ellen Macarthur Foundation. Accessed March 05, 2022. https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview
- 2020. *Why your internet habits are not as clean as you think*. BBC. March 05. Accessed January 26, 2022. https://www.bbc.com/future/article/20200305-why-your-internet-habits-are-not-as-clean-as-you-think
- Winston, Andrew. 2021. *Sustainable Business Went Mainstream in 2021*. Harvard Business Review. December 27. Accessed March 05, 2022. https://hbr.org/2021/12/sustainable-business-went-mainstream-in-2021.
- n.d. *World Resource Institute*. Accessed March 04, 2022. https://www.wri.org/.

Chapter 2

Images

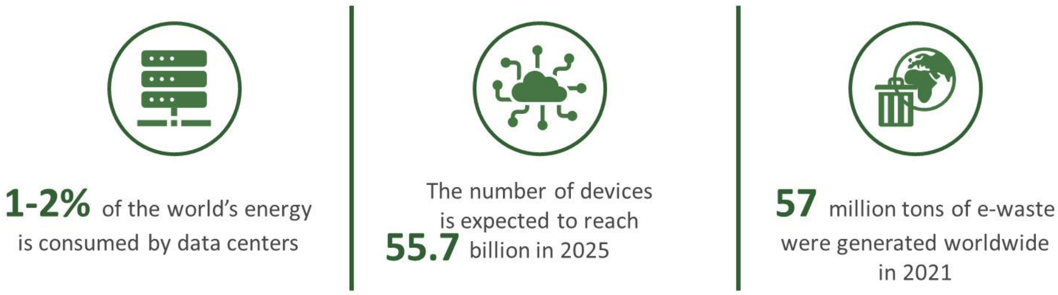


Figure 2.1 – Leading examples of IT's impact on the environment

Figure 2.2 – Sustainability in IT, sustainability by IT, and IT for society

Figure 2.3 – Sustainability in IT examples (direct CO2 emission reduction)

Figure 2.4 – Sustainable by IT (indirect CO2 emission reduction)

Figure 2.5 – Examples of key focus areas in IT for society

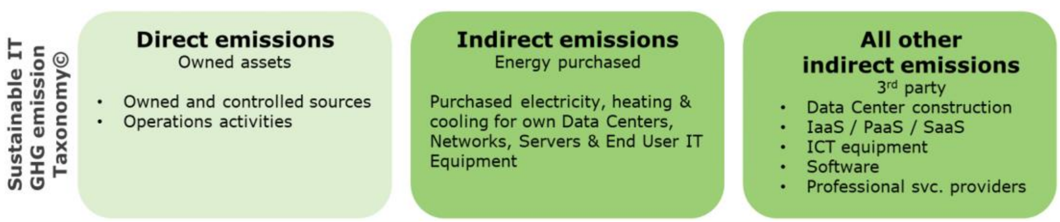


Figure 2.6 – The Sustainable IT Greenhouse Gas Emission Taxonomy© (Sundberg, Sustainable IT Greenhouse Gas Emission Taxonomy 2021)

Figure 2.7 – The top four main business drivers for sustainable investments

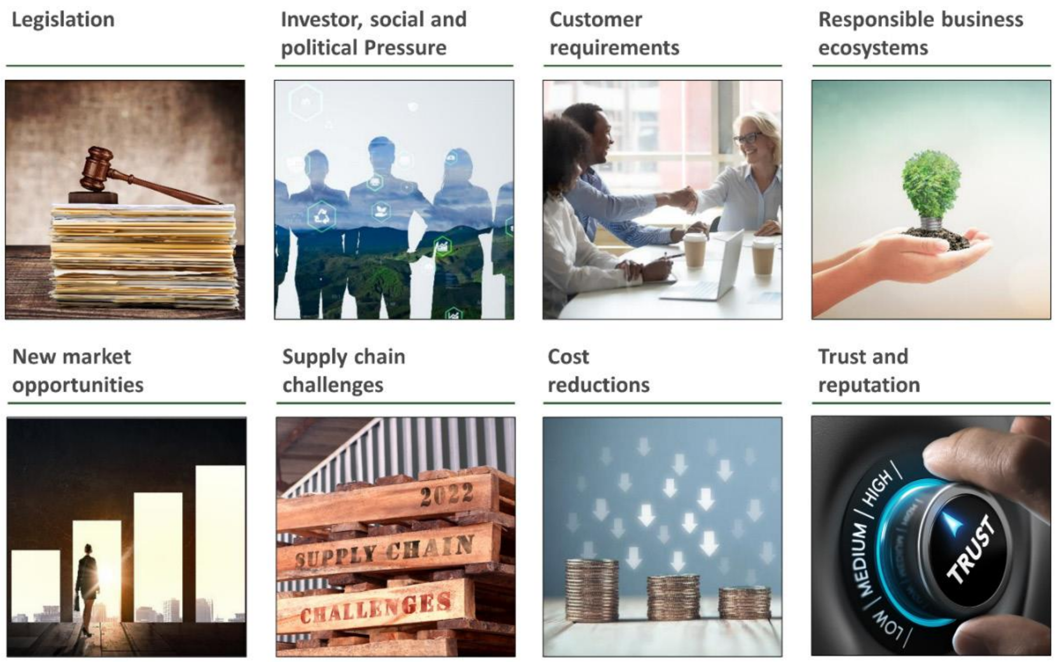


Figure 2.8 – The drivers for a corporate sustainability plan

Figure 2.9 – ESG considerations for IT

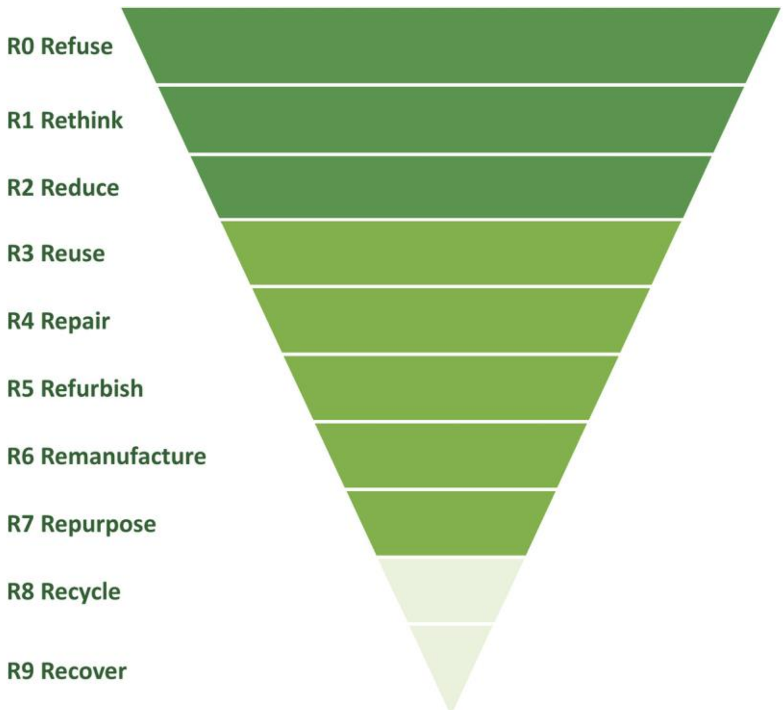


Figure 2.10 – A zero-waste hierarchy

Bibliography

- 2016. “2016 Cone Communications Millennial Employee Engagement Study.” *Cone Communications*. Accessed March 25, 2022. https://www.conecomm.com/research-blog/2016-millennial-employee-engagement-study
- 2022. “Allianz Risk Barometer 2022.” *Allianz*. January. Accessed March 25, 2022. https://www.agcs.allianz.com/news-and-insights/reports/allianz-risk-barometer/download.html
- Beals, Monique. 2021. *McKinsey employees angered over firm’s work with world’s top polluters*. October 27. Accessed March 30, 2022. https://thehill.com/business-a-lobbying/578802-mckinsey-employees-angered-over-firms-work-with-worlds-top-polluters

- n.d. *Bitcoin Mining Map*. University of Cambridge. Accessed March 16, 2022. https://ccaf.io/cbeci/mining_map
- BSR/GlobeScan. 2019. *The 2019 BSR/GlobeScan State of Sustainable Business Survey*. BSR/GlobeScan. November 12. Accessed March 29, 2022. https://globescan.com/2019/11/12/2019-state-sustainable-business-survey/.
- Crowell, Chris. 2019. *Survey: Employees want to work at companies with sustainability programs*. Solar Builder Magazine. February 18. Accessed March 29, 2022. https://solarbuildermag.com/news/survey-employees-more-likely-to-work-for-company-with-sustainability-programs/
- Deloitte. 2020. 2*020 Global Technology Leadership Study*. Deloitte. Accessed March 29, 2022. https://www2.deloitte.com/br/en/pages/technology/articles/global-techleadership-survey.html
- European Commission. n.d. *A European Green Deal*. European Commission. Accessed March 29, 2022. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
- —. 2019. *Special Eurobarometer 490: Climate change*. European Commission. October. Accessed March 29, 2022. https://data.europa.eu/data/datasets/s2212_91_3_490_eng?locale=en
- Gartner. 2021. *Gartner Says Four Trends Are Shaping the Future of Public Cloud*. Gartner Inc. August 2. Accessed January 31, 2022. https://www.gartner.com/en/newsroom/press-releases/2021-08-02-gartner-says-four-trends-are-shaping-the-future-of-public-cloud?spm=a2c65.11461447.0.0.964e28c6a8EcQ2#:~:text=Gartner%20forecasts%20end-user%20spending,less%20than%2017%25%20in%202021
- 2020. *Global E-waste Surging: Up 21 Percent in 5 years*. United Nations institute for Training and Research. July 2. Accessed January 27, 2022.
- 2022. “Global Risks Report 2022.” *World Economic Forum*. January 11. Accessed March 25, 2022. https://www.weforum.org/reports/global-risks-report-2022

- Google. 2019. *Google Environmental Report 2019*. Google. Accessed March 29, 2022. https://sustainability.google/reports/environmental-report-2019/
- —. December 2016. *Machine learning finds new ways for our data centers to save energy*. Google. Accessed March 29, 2022. https://sustainability.google/progress/projects/machine-learning/#:~:text=Our%20data%20centers%20employ%20advanced,distributed%20to%20minimize%20energy%20loss
- —. n.d. *Operating on 24/7 Carbon-Free Energy by 2030*. Google. Accessed March 29, 2022. https://sustainability.google/progress/energy/
- Greenpeace. 2020. *Oil in the Cloud - How Tech Companies are Helping Big Oil Profit from Climate Destruction*. Greenpeace. May 19. Accessed March 29, 2022. https://www.greenpeace.org/usa/reports/oil-in-the-cloud/
- Howarth, Josh. 2022. *The 6 Biggest Sustainability Trends In 2022*. January 20. Accessed March 30, 2022. https://explodingtopics.com/blog/sustainability-trends
- IDC. 2021. *Cloud Computing Could Eliminate a Billion Metric Tons of CO2 Emission Over the Next Four Years, and Possibly More, According to a New IDC Forecast*. IDC. March 08. Accessed January 31, 2022. https://www.idc.com/getdoc.jsp?spm=a2c65.11461447.0.0.964e28c6a8EcQ2&containerId=prUS47513321
- —. 2020. *IoT Growth Demands Rethink of Long-Term Storage Strategies*. IDC. July 27. Accessed March 26, 2022. https://www.idc.com/getdoc.jsp?containerId=prAP46737220
- —. 2021. "The C-Suite Sustainability Imperative 2021." *Servicenow.com*. October. Accessed March 25, 2022. https://www.servicenow.com/content/dam/servicenow-assets/public/en-us/doc-type/resource-center/infographic/info-csuite-sustainability-imperative-2021.pdf

- IEA. 2019. *Global trends in internet traffic, data centre workloads and data centre energy use, 2015-2021*. IEA. November 25. Accessed March 26, 2022. https://www.iea.org/data-and-statistics/charts/global-trends-in-internet-traffic-data-centre-workloads-and-data-centre-energy-use-2015-2021
- IPCC. 2018. *Special Report: Global Warming of 1.5 C*. IPCC. Accessed March 29, 2022. https://www.ipcc.ch/sr15/download/

Chapter 3

Images

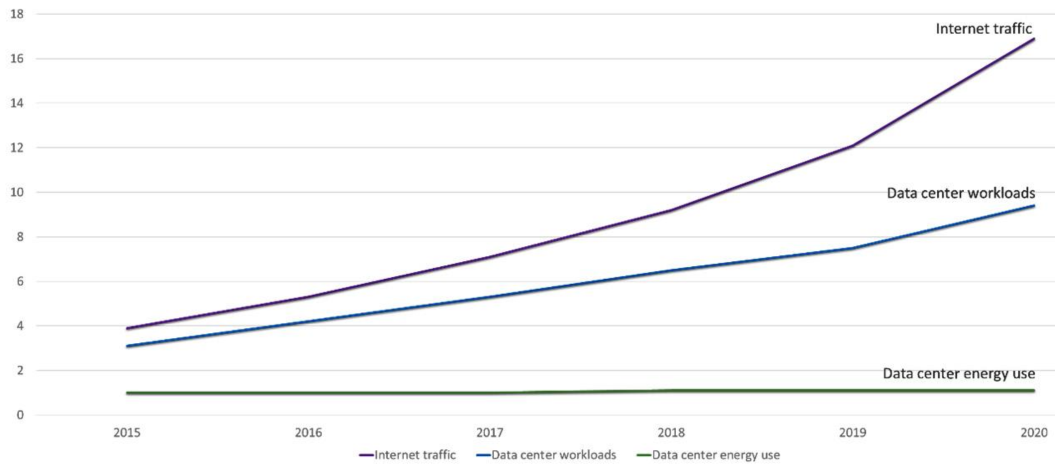


Figure 3.1 – Increase in internet traffic, data center workloads, and data center energy use, 2010–2020 (IEA 2021)

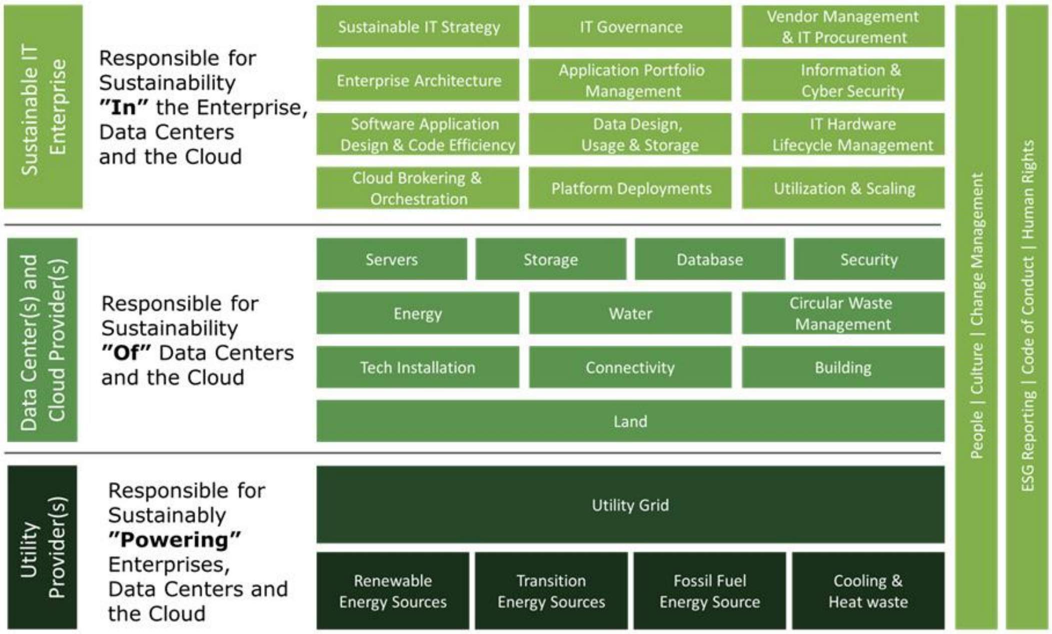


Figure 3.2 – Sustainable IT reference model

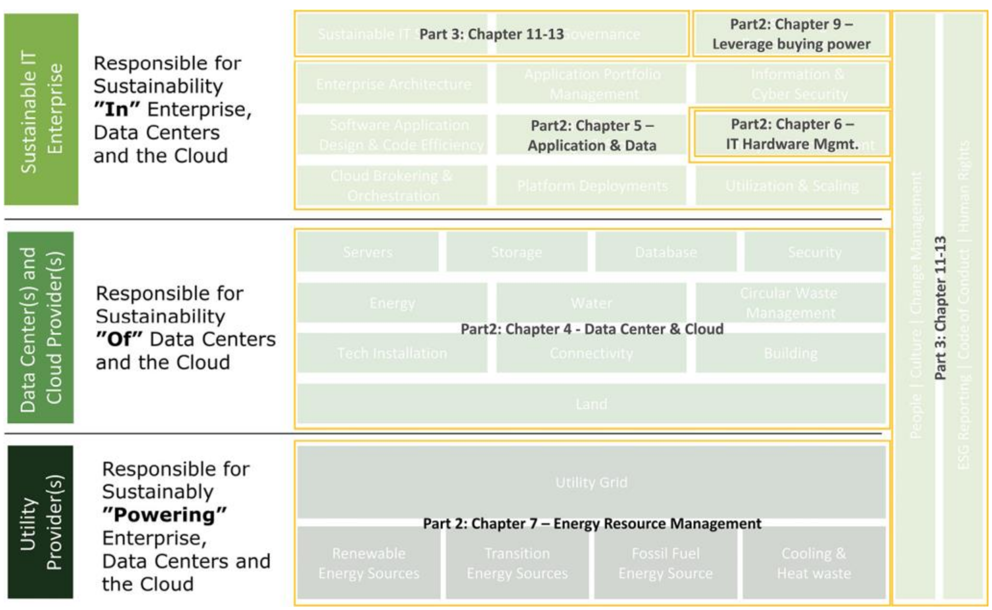


Figure 3.3 – Chapters interlinked with the reference model

Bibliography

- Grotty, James, and Ivan Horrocks. 2017. “Managing legacy system costs: A case study of a meta-assessment model to identify solutions in a large financial services company.” *Applied Computing and Informatics* 13 (2): 175–183. Accessed April 05, 2022. Managing legacy system costs: A case study of a meta-assessment model to identify solutions in a large financial services company
- IEA. 2021. *Global trends in internet traffic, data centres workloads and data centre energy use, 2010–2020*. November 03. Accessed April 01, 2022. https://www.iea.org/data-and-statistics/charts/global-trends-in-internet-traffic-data-centres-workloads-and-data-centre-energy-use-2010-2020
- Infosys. 2018. “Case study: SAP success stories life sciences.” *Infosys*. Accessed April 05, 2022. https://www.infosys.com/industries/life-sciences/case-studies/Documents/SAP-success-stories-life-sciences.pdf
- Kamiya, George. 2021. *Data Centres and Data Transmission Networks*. November. Accessed April 1, 2022. https://www.iea.org/reports/data-centres-and-data-transmission-networks
- TCO Certified. 2022. *Circularity in practice: How to manage notebook computers responsibly*. March 08. Accessed April 05, 2022. https://tcocertified.com/news/circularity-in-practice-how-to-manage-notebook-computers-responsibly/?utm_campaign=5e7df1e6d4732700014a04a5&utm_content=6244037a70a1440001c8c29e&utm_medium=smarpshare&utm_source=linkedin#4035724c6ae116b3a
- UN Environment Programme. n.d. “Greenhouse gas emissions in the ICT sector – Trends and methodologies.” *UN Environment Programme*. Accessed April 01, 2022. https://c2e2.unepdtu.org/wp-content/uploads/sites/3/2020/03/greenhouse-gas-emissions-in-the-ict-sector.pdf

- UN. 2015. *Water and Energy*. March 13. Accessed April 05, 2022. https://www.un.org/waterforlifedecade/water_and_energy.shtml

Chapter 4

Images

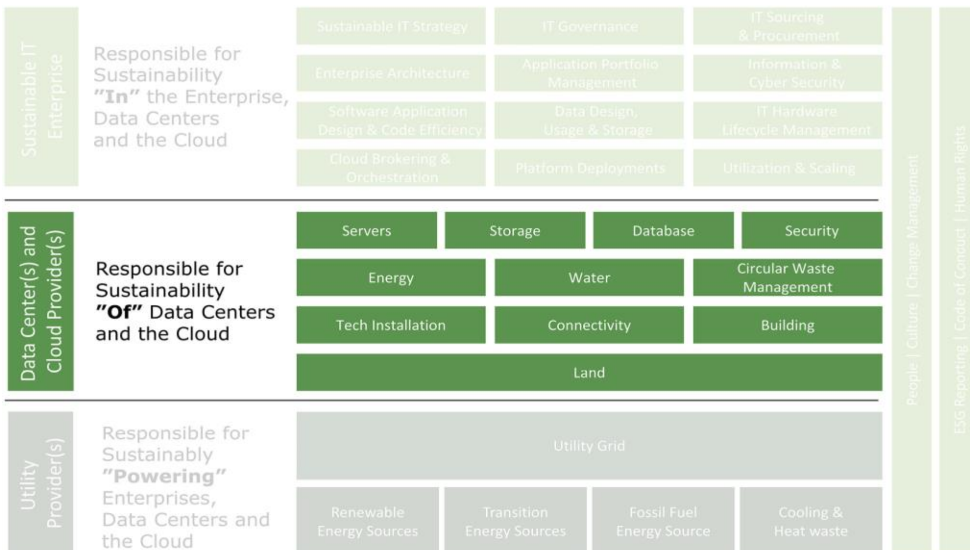


Figure 4.1: The sustainable IT reference model – Chapter 4 focus

Figure 4.2: Definition of cloud computing (NIST 2011)

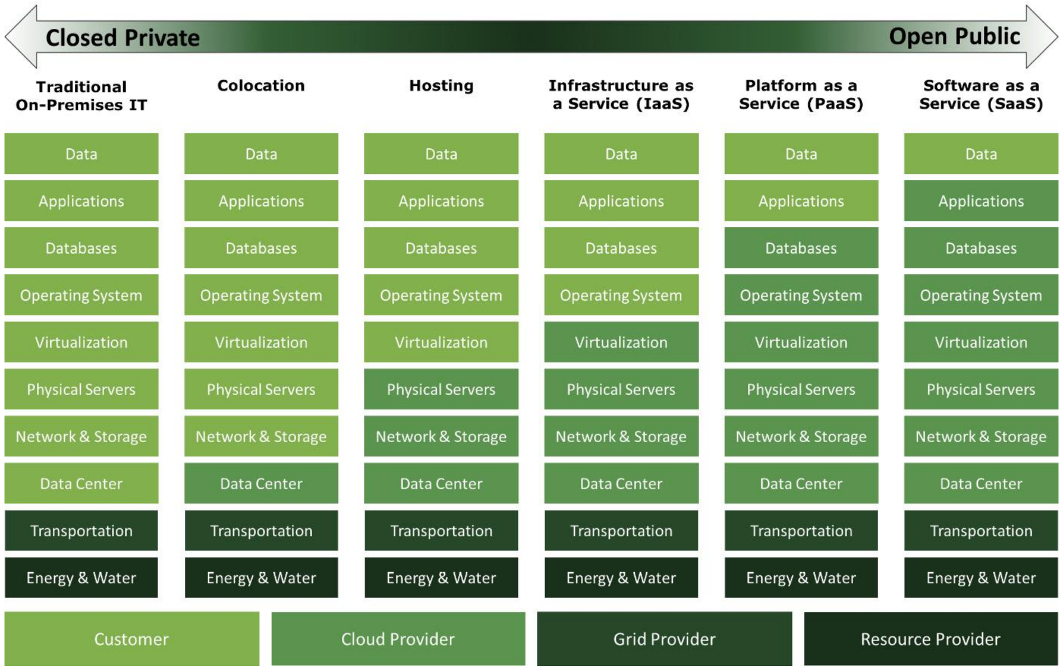


Figure 4.3: Areas of responsibility within the cloud services

Figure 4.4: The value that the cloud can bring

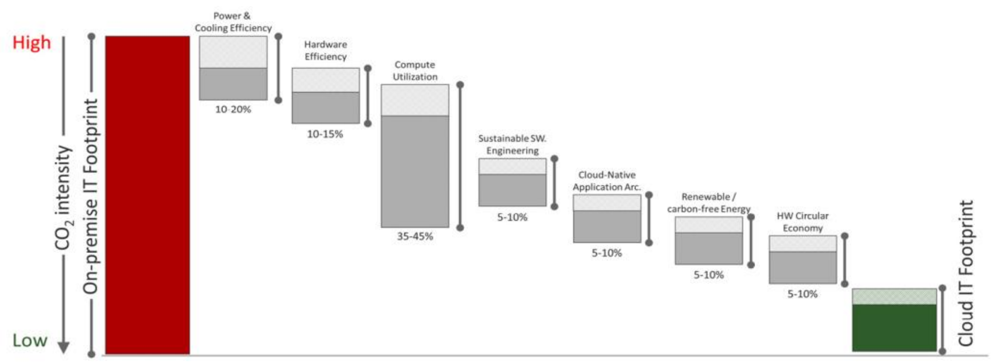


Figure 4.5: Carbon emission reduction potential by moving from on-premises to the cloud (Lacy, et al. 2020)

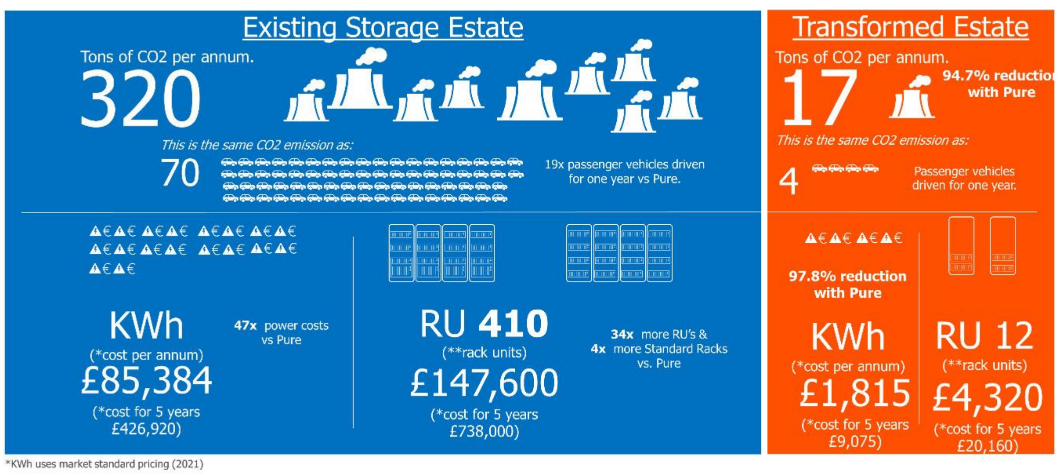


Figure 4.6: Environmental impact through tech modernization

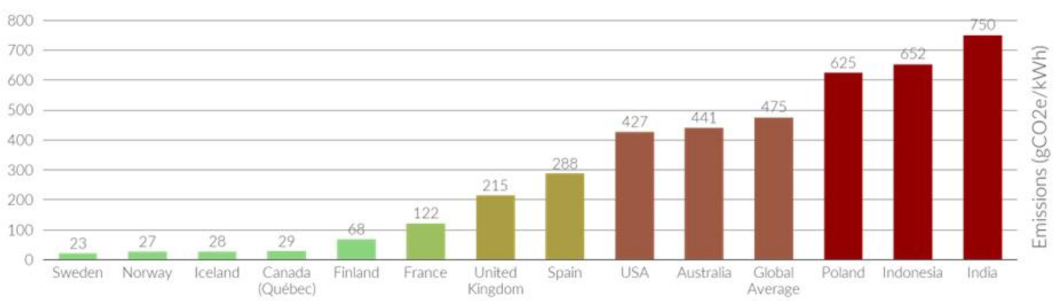


Figure 4.7: Placement of the workload impacts your CO2e significantly (Electricitymap 2022)

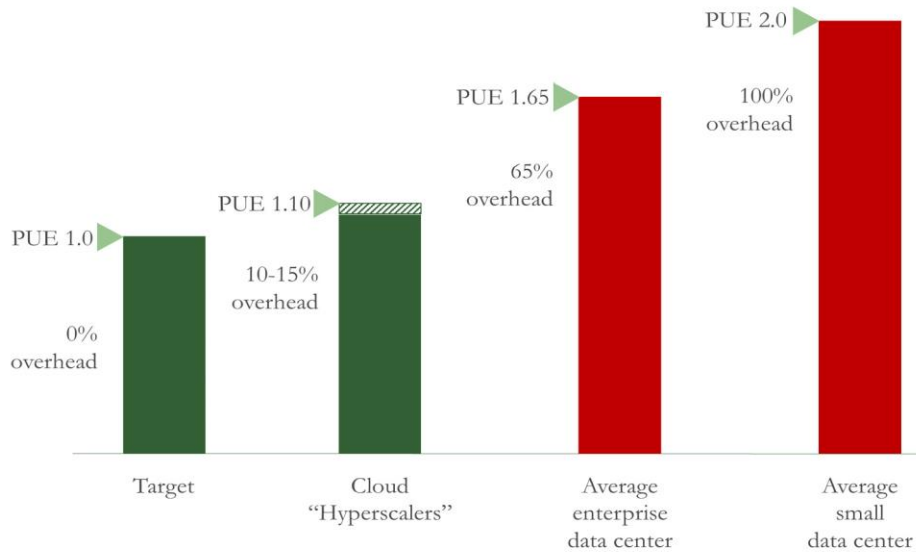


Figure 4.8: PUE comparison

Description	Metric	General Requirement	United Nations Sustainable Development Goals Alignment
Energy Consumption	GWh mtCO2e	**CUE** Carbon Usage Effectiveness	7. Affordable and Clean Energy 13. Climate Action
Renewable Energy	%	**REF** Renewable Energy Factor	9. Industry, Innovation and Infrastructure 12. Responsible Consumption and Production
Power Usage Effectiveness	PUE	**PUE** Power Usage Effectiveness	12. Responsible Consumption and Production 13. Climate Action
Sustainable Water	WUE	**WUE** Water Usage Effectiveness	6. Clean Water and Sanitation
Waste Management	Ton %	**ERF - EDE** Energy Reuse Factor Electronics Disposal Efficiency Reduce – Reuse - Recycle	12. Responsible Consumption and Production

Figure 4.9: A data center sustainability score card

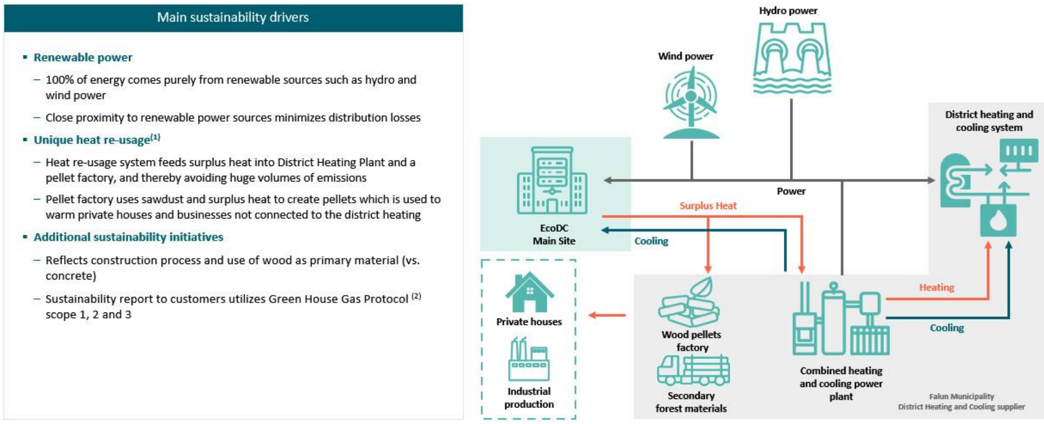


Figure 4.10: The EcoDataCenter ecosystem with Falun municipality district heating and cooling (Image courtesy of EcoDataCenter)

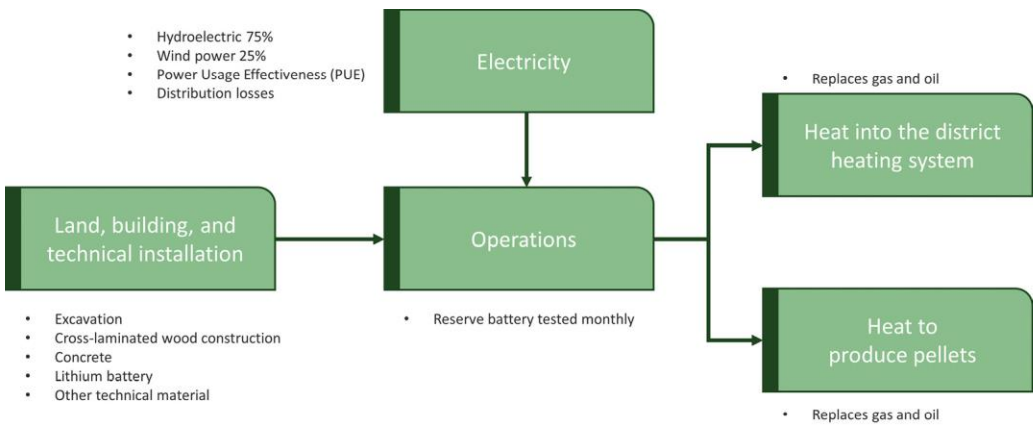


Figure 4.11: EcoDataCenter's emissions flow

Company	2020 Carbon Footprint (MtCO2e)	Carbon Neutral Target	Net-Zero Carbon Emission Target	Renewable Energy Target	Water Target	Waste Target
Microsoft	13.8	2012	2030	2025	2030	2030
Google	10.3	2007	2030	2030	2030	2030
AWS	60.6	2040	-	2025	-	-
Alibaba	9.51	2030	-	-	-	-
Oracle	80.9	-	2050	2025	-	-
Tencent	5.1	2030	-	2030	-	-
IBM	132.5	-	2030	2030	-	-

Figure 4.12: Cloud service provider sustainability commitment comparison

Figure 4.13: Examples of external green and eco-sustainability agencies

Tables

Organization	**PUE value**
Google	1.12
Microsoft	1.12
HP	1.19
Facebook	1.08
Yahoo!	1.08
eBay	1.45

Alibaba	1.08
Tencent	1.12
IBM	1.53

Table 4.1: The PUE values of different companies (Khaliq uz Zaman, et al. January 2019) (IBM 2021)

Emissions per kWh	Greenhouse Gas Protocol (GHG)			Total	Avoided emissions	Total
Scope	I	II	III		IV	
Land	-	-	0,0	**0,0**	-	**0,0**
Building	-	-	0,1	**0,1**	-	**0,1**
Tech installation	-	-	1,1	**1,1**	-	**1,1**
Operations	1,3	-	0,9	**2,2**	-	**2,2**
Power	-	10,5	0,0	**10,5**	-	**10,5**
Heat re-usage	1,7	-	-	**1,7**	-48,9	**-47,2**
TOTAL	**3,0**	**10,5**	**2,1**	**15,6**	**-48,9**	**-33,3**

Table 4.2: The CO2 equivalent calculation

Formulas

Formula 4.1: PUE

$$PUE = \frac{Total\ facility\ energy}{IT\ equipment\ energy}$$

Further reading

- NIST Definition of Cloud Computing: https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-145.pdf
- *Minimising Data Centre Environmental Impact – Beyond Energy Efficiency, Flucker et al. CIBSE*
- *Data Center Sustainability Index*, Tozer et al. ASHRAE 2018
- Ecodesign Regulation on servers and data storage products:

https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/energy-efficient-products/servers-and-data-storage-products_en

- Code of Conduct for Energy Efficiency in Data Centres: https://joint-research-centre.ec.europa.eu/energy-efficiency/energy-efficiency-products/code-conduct-ict/code-conduct-energy-efficiency-data-centres_en
- Development of the EU Green Public Procurement (GPP) Criteria for Data Centres, Server Rooms, and Cloud Services:

  https://publications.jrc.ec.europa.eu/repository/handle/JRC118558
- Data Center Handbook: Plan, Design, Build, and Operations of a Smart Data Center, Hwaiyu Geng, April 2021: https://www.wiley.com/en-us/Data+Center+Handbook%3A+Plan%2C+Design%2C +Build%2C +and+Operations+of+a+Smart+Data+Center%2C+2nd+Edition-p-9781119597551
- Stockholm Innovates District Heating with New Solutions and Renewable Sources: https://smartcitysweden.com/best-practice/401/stockholm-innovates-district-heating-with-new-solutions-and-renewable-sources/
- EcoDataCenter, CO2 equivalent calculation: http://www.ecodatacenter.se/
- Climate Neutral Data Centre Pact: https://www.climateneutraldatacentre.net/
- The European platform for the creation of a sustainable digital economy: https://sdialliance.org/
- The **Open Computer Project Foundation** (**OCP**): https://www.opencompute.org/

Bibliography

- Andrae, Anders S.G. 2020. “New perspectives on internet electricity use in 2030.” ResearchGate. June. Accessed on 10 April 2022.

https://www.researchgate.net/publication/342643762_New_perspectives_on_internet_electricity_use_in_2030

- 2018. Apple. 9 April. https://www.apple.com/newsroom/2018/04/apple-now-globally-powered-by-100-percent-renewable-energy/
- AWS. 2022. https://aws.amazon.com/architecture/well-architected/?wa-lens-whitepapers.sort-by=item.additionalFields.sortDate&wa-lens-whitepapers.sort-order=desc. Accessed on 25 July 2022 . https://aws.amazon.com/architecture/well-architected/?wa-lens-whitepapers.sort-by=item.additionalFields.sortDate&wa-lens-whitepapers.sort-order=desc.
- Bala, Raj, Bob Gill, Smith Dennis, och David Wright. 2021. "Magic Quadrant for Cloud Infrastructure and Platform Services." Gartner. July. Accessed on 21 04 2022. https://www.gartner.com/doc/reprints?id=1-271OE4VR&ct=210802&st=sb
- 2020. BBC. 14 September. https://www.bbc.com/news/technology-54141899
- BloombergNEF. 2021. 2H 2021 Corporate Energy Market Outlook. Accessed on 01 April 2022. https://about.bnef.com/new-energy-outlook/
- Brady, G., N. Kapur, J. Summers, och H. M. Thomson. 2013. "A case study and critical assessment in calculating power usage effectiveness for a data centre." Energy Conversion and Management 76 155–161.
- CNDCP. 2020. "Home Page." Climate Neutral Data Centre Pact. Accessed on 23 April 2022. https://www.climateneutraldatacentre.net/
- Condon, Stephanie. 2022. Record-breaking heatwave causes cloud-computing problems. 19 July. Accessed on 29 July 2022. https://www-zdnet-com.cdn.ampproject.org/c/s/www.zdnet.com/google-amp/article/the-uk-heat-wave-brings-down-some-oracle-and-google-cloud-data-centers/
- Electricitymap. 2022. Climate impact per region. 29 July. Accessed on 29 July 2022. https://app.electricitymaps.com/map

- Equinix. 2022. Green by design. Accessed on 25 July 2022. https://www.equinix.com/data-centers/design/green-data-centers?ls=Advertising%20-%20Web&lsd=22q1_enterprise_digital-infrastructure+digital-infrastructure_/data-centers/design/green-data-centers_dm_obility_paid-search_google_us-en_AMER_Brand_demand-gen&utm
- European Commission. 2022. REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition. 18 May. Accessed on 29 July 2022. https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131
- Ferguson, Iain. 2022. Going Green with Cloud: How to Achieve Your Sustainability Objective. Alibaba Cloud. 26 January. Accessed on 31 January 2022. https://www.alibabacloud.com/blog/going-green-with-cloud-how-to-achieve-your-sustainability-objectives_598517
- Gartner. 2021. Gartner Says Four Trends Are Shaping the Future of Public Cloud. Gartner Inc. 2 August. Accessed on 31 January 2022. https://www.gartner.com/en/newsroom/press-releases/2021-08-02-gartner-says-four-trends-are-shaping-the-future-of-public-cloud?spm=a2c65.11461447.0.0.964e28c6a8EcQ2#:~:text=Gartner%20forecasts%20end-user%20spending,less%20than%2017%25%20in%202021
- Google. 2022. Carbon free energy for Google Cloud regions. Accessed on 26 07 2022. https://cloud.google.com/sustainability/region-carbon
- —. 2021. Google Masterclass. Accessed on 25 07 2022. https://sustainableitdecoded.withgoogle.com/en-gb/dashboard
- IBM. 2021. "2021 ESG Report." IBM. Accessed on 22 April 2022. https://www.ibm.com/impact/files/reports-policies/2021/IBM_2021_ESG_Report.pdf
- IDC. 2021. Cloud Computing Could Eliminate a Billion Metric tons of CO2 Emission Over the Next Four Years, and Possibly More, According to a New IDC

Forecast. IDC. 08 March. Accessed on 31 January 2022. https://www.idc.com/getdoc.jsp?spm=a2c65.11461447.0.0.964e28c6a8EcQ2&containerId=prUS47513321

- 2020. IoT Growth Demands Rethink of Long-Term Storage Strategies. IDC. 20 July. https://www.idc.com/getdoc.jsp?containerId=prAP46737220
- Kamiya, George. 2021. Data Centres and Data Transmission Networks. November. Accessed on 1 April 2022. https://www.iea.org/reports/data-centres-and-data-transmission-networks
- Khaliq uz Zaman, Sardar, Atta ur Rehman Khan, Junaid Shuja, Tahir Maqsood, Faisal Rehman, och Saad Mustafa. January 2019. "A Systems Overview of Commercial Data Centers: Initial Energy and Cost Analysis." International Journal of Information Technology and Web Engineering.
- Khan, A. R., M. Othman, och A. N. Khan. 2013. "A Novel Application Licensing Framework for Mobile Cloud." International Conference on Future Trends in Computing and Communication Technologies 127-131.
- Lacy, Peter, Paul Daugherty, Pavel Ponomarev, och Kishore Durg. 2020. The green behind the cloud. Accenture. 22 September. Accessed on 31 January 2022. https://www.accenture.com/_acnmedia/PDF-135/Accenture-Strategy-Green-Behind-Cloud-POV.pdf
- Microsoft News Center. 2018. The Microsoft Cloud can save customers 93 percent and more in energy and carbon efficiency. Microsoft. 17 May. Accessed on 27 January 2022. https://news.microsoft.com/2018/05/17/the-microsoft-cloud-can-save-customers-93-percent-and-more-in-energy-and-carbon-efficiency/#:~:text=%E2%80%94%20May%2017%2C%202018%20%E2%80%94%20A,issued%20Thursday%20by%20Microsoft%20Corp.&text=These%20gains%2C%20as%
- Moss, Sebastian. 2021. Google shifts "moveable" compute tasks between data centers to use regional renewable energy. 21 May. Accessed on 25 07 2022.

https://www.datacenterdynamics.com/en/news/google-shifts-moveable-compute-tasks-between-data-centers-to-use-regional-renewable-energy/

- NIST. 2011. “The NIST Definition of Cloud.” National Institute of Standards and Technology. September. Accessed on 10 April 2022. https://nvlpubs.nist.gov/nistpubs/legacy/sp/nistspecialpublication800-145.pdf
- Nolan, Maggie, och Mylissa Tsai. 2020. Cloud Migrations Can Reduce CO2 Emissions by Nearly 60 Million tons a Year, According to New Research from Accenture. Accenture. 22 September. Accessed on 31 January 2022. https://newsroom.accenture.com/news/cloud-migrations-can-reduce-co2-emissions-by-nearly-60-million-tons-a-year-according-to-new-research-from-accenture.htm?spm=a2c65.11461447.0.0.964e28c6a8EcQ2#:~:text=22%2C%202020%20%E2%80%93%20Migration%20to%20the,Accen
- Reuters. 2022. China aims to build 450 GW of solar, wind power on Gobi desert. 05 March. Accessed on 26 July 2022. https://www.reuters.com/world/china/china-aims-build-450-gw-solar-wind-power-gobi-desert-2022-03-05/
- Ritchie, Hannah, och Max Roser. 2020. Electricity Mix. ourworldindata.org. Accessed on 26 May 2022. https://ourworldindata.org/electricity-mix#citation
- Roach, John. 2020. Microsoft finds underwater datacenters are reliable, practical and use energy sustainably. 14 September. Accessed on 25 July 2022. https://news.microsoft.com/innovation-stories/project-natick-underwater-datacenter/
- Sethi, Satinder. 2021. Advancing Sustainability Objectives with IBM Cloud. IBM. 4 November. Accessed on 31 January 2022. https://www.ibm.com/cloud/blog/advancing-sustainability-objectives-with-ibm-cloud
- Smart City Sweden. 2022. Stockholm Innovates District Heating with New Solutions and Renewable Sources. Accessed on 25 July 2022.

https://smartcitysweden.com/best-practice/401/stockholm-innovates-district-heating-with-new-solutions-and-renewable-sources/

- SVT Nyheter. 2022. I Boden ska man odla i spillvärme från datacenter – mitt i smällkalla vintern. 2 July. Accessed on 25 July 2022. https://www.svt.se/nyheter/lokalt/norrbotten/ett-steg-narmare-att-odla-i-spillvarme-fran-datacenter
- Tencent. 2022. "Tencent Carbon Neutrality Target and Roadmap Report." Tencent. February. Accessed on 21 April 2022. https://static.www.tencent.com/attachments/TencentCarbonNeutralityTargetandRoadmapReport.pdf
- Verdict. 2022. Data centers must adapt to climate crisis. den 20 July. Accessed on 29 July 2022. https://www.verdict.co.uk/data-centers-global-warming/
- Wingren, Anrdeas. 202. Idag öppnar Microsofts hållbara datacenter i Sverige – skapar nya möjligheter för Sverige genom hållbar digitalisering.21 November. Accessed on 26 07 2022. https://news.microsoft.com/sv-se/2021/11/16/idag-oppnar-microsofts-hallbara-datacenter-i-sverige-skapar-nya-mojligheter-for-sverige-genom-hallbar-digitalisering/
- Wipro. 2021. "Wipro Selected as Dow Jones Sustainability World Index (DJSI) Member for the 12th Consecutive Year." Wipro.com.23 November. Accessed on 23 April 2022. https://www.wipro.com/newsroom/press-releases/2021/wipro-selected-as-dow-jones-sustainability-world-index-djsi-member-for-the-12th-consecutive-year/
- Andrae, Anders S.G. 2020. "New perspectives on internet electricity use in 2030." *ResearchGate*. June. Accessed on 10 April 2022. https://www.researchgate.net/publication/342643762_New_perspectives_on_internet_electricity_use_in_2030
- 2018. *Apple*.9 April. https://www.apple.com/newsroom/2018/04/apple-now-globally-powered-by-100-percent-renewable-energy/

- Bala, Raj, Bob Gill, Smith Dennis, och David Wright. 2021. "Magic Quadrant for Cloud Infrastructure and Platform Services." *Gartner*. July. Accessed on 21 04 2022. https://www.gartner.com/doc/reprints?id=1-271OE4VR&ct=210802&st=sb
- 2020. *BBC*.14 September. https://www.bbc.com/news/technology-54141899
- Brady, G., N. Kapur, J. Summers, och H. M. Thomson. 2013. "A case study and critical assessment in calculating power usage effectiveness for a data centre." *Energy Conversion and Management 76* 155–161.
- CNDCP. 2020. "Home Page." *Climate Neutral Data Centre Pact*. Accessed on 23 April 2022. https://www.climateneutraldatacentre.net/
- Ferguson, Iain. 2022. *Going Green with Cloud: How to Achieve Your Sustainability Objective*. Alibaba Cloud.26 January. Accessed on 31 January 2022. https://www.alibabacloud.com/blog/going-green-with-cloud-how-to-achieve-your-sustainability-objectives_598517
- Gartner. 2021. *Gartner Says Four Trends Are Shaping the Future of Public Cloud*. Gartner Inc.2 August. Accessed on 31 January 2022. https://www.gartner.com/en/newsroom/press-releases/2021-08-02-gartner-says-four-trends-are-shaping-the-future-of-public-cloud?spm=a2c65.11461447.0.0.964e28c6a8EcQ2#:~:text=Gartner%20forecasts%20end-user%20spending,less%20than%2017%25%20in%202021
- IBM. 2021. "2021 ESG Report." *IBM*. Accessed on 22 April 2022. https://www.ibm.com/impact/files/reports-policies/2021/IBM_2021_ESG_Report.pdf
- IDC. 2021. *Cloud Computing Could Eliminate a Billion Metric tons of CO2 Emission Over the Next Four Years, and Possibly More, According to a New IDC Forecast*. IDC.08 March. Accessed on 31 January 2022. https://www.idc.com/getdoc.jsp?spm=a2c65.11461447.0.0.964e28c6a8EcQ2&containerId=prUS47513321

- 2020. *IoT Growth Demands Rethink of Long-Term Storage Strategies*. IDC.20 July. https://www.idc.com/getdoc.jsp?containerId=prAP46737220
- Kamiya, George. 2021. *Data Centres and Data Transmission Networks*. November. Accessed on 1 April 2022. https://www.iea.org/reports/data-centres-and-data-transmission-networks
- Khan, A. R., M. Othman, och A. N. Khan. 2013. "A Novel Application Licensing Framework for Mobile Cloud." *International Conference on Future Trends in Computing and Communication Technologies* 127–131.
- Lacy, Peter, Paul Daugherty, Pavel Ponomarev, och Kishore Durg. 2020. *The green behind the cloud*. Accenture.22 September. Accessed on 31 January 2022. https://www.accenture.com/_acnmedia/PDF-135/Accenture-Strategy-Green-Behind-Cloud-POV.pdf
- Méndez-Villamil, Marta Mu¨noz. 2021. *Google Masterclass*
- Microsoft News Center. 2018. *The Microsoft Cloud can save customers 93 percent and more in energy and carbon efficiency*. Microsoft.17 May. Accessed on 27 January 2022. https://news.microsoft.com/2018/05/17/the-microsoft-cloud-can-save-customers-93-percent-and-more-in-energy-and-carbon-efficiency/#:~:text=%E2%80%94%20May%2017%2C%202018%20%E2%80%94%20A,issued%20Thursday%20by%20Microsoft%20Corp.&text=These%20gains%2C%20as%
- NIST. 2011. "The NIST Definition of Cloud." *National Institute of Standards and Technology.* September. Accessed on 10 April 2022. https://nvlpubs.nist.gov/nistpubs/legacy/sp/nistspecialpublication800-145.pdf
- Nolan, Maggie, och Mylissa Tsai. 2020. *Cloud Migrations Can Reduce CO2 Emissions by Nearly 60 Million tons a Year, According to New Research from Accenture*. Accenture.22 September. Accessed on 31 January 2022. https://newsroom.accenture.com/news/cloud-migrations-can-reduce-co2-emissions-by-nearly-60-million-tons-a-year-according-to-new-research-from-

accenture.htm?spm=a2c65.11461447.0.0.964e28c6a8EcQ2#:~:text=22%2C%20 2020%20%E2%80%93%20Migration%20to%20the,Accen

- Sethi, Satinder. 2021. *Advancing Sustainability Objectives with IBM Cloud*. IBM.4 November. Accessed on 31 January 2022. https://www.ibm.com/cloud/blog/advancing-sustainability-objectives-with-ibm-cloud
- Tencent. 2022. "Tencent Carbon Neutrality Target and Roadmap Report." *Tencent*. February. Accessed on 21 April 2022. https://static.www.tencent.com/attachments/TencentCarbonNeutralityTargetandRoadmapReport.pdf
- Wipro. 2021. "Wipro Selected as Dow Jones Sustainability World Index (DJSI) Member for the 12th Consecutive Year." *Wipro.com*.23 November. Accessed on 23 April 2022. https://www.wipro.com/newsroom/press-releases/2021/wipro-selected-as-dow-jones-sustainability-world-index-djsi-member-for-the-12th-consecutive-year/

Chapter 5

Images

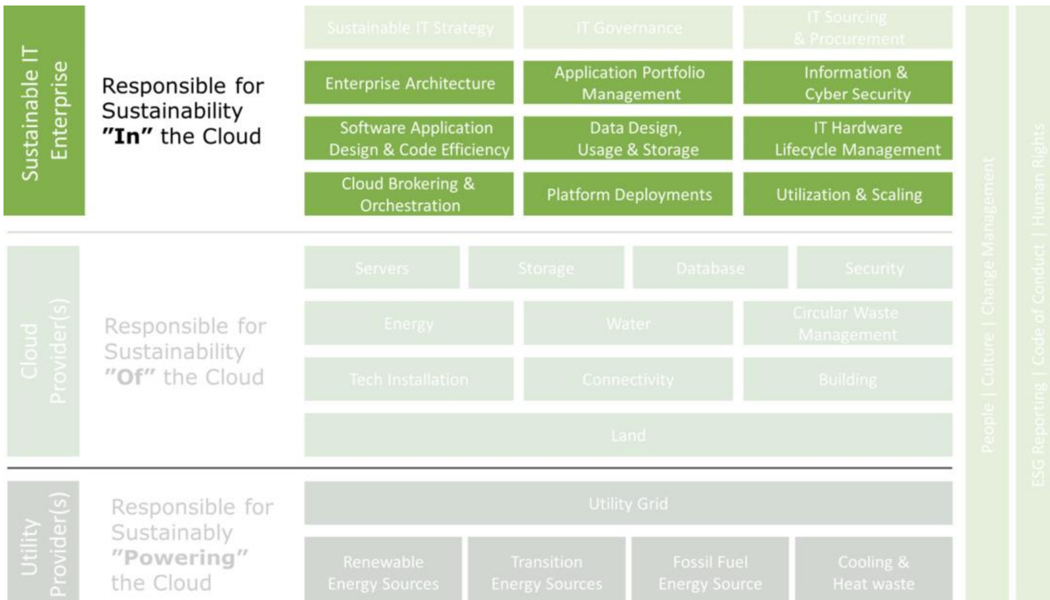


Figure 5.1 – Sustainable IT reference model – Chapter 5's focus

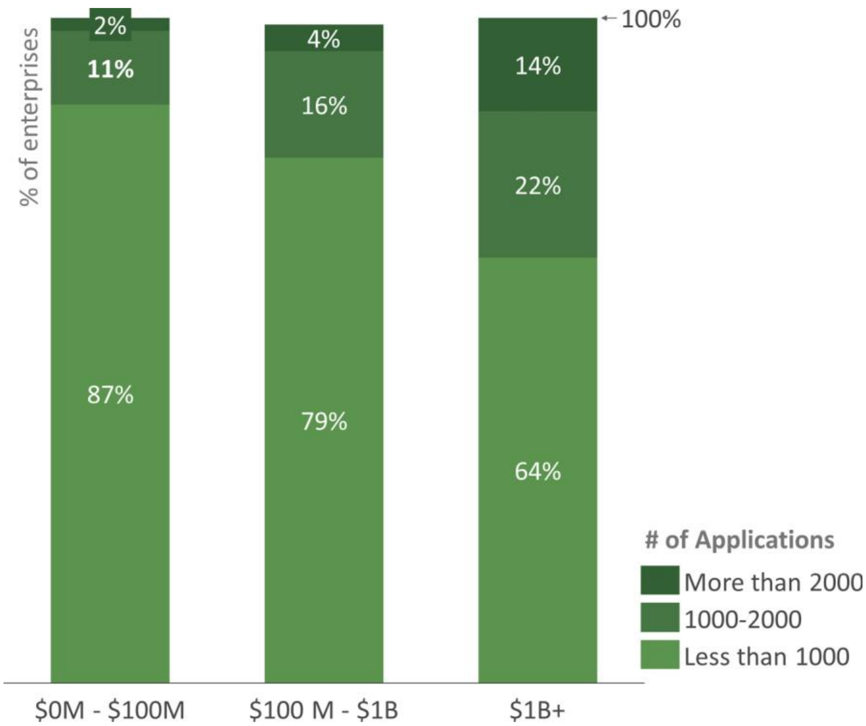


Figure 5.2 – Breakdown of the number of applications per enterprise size

Figure 5.3 – Breakdown of the number of applications per enterprise size

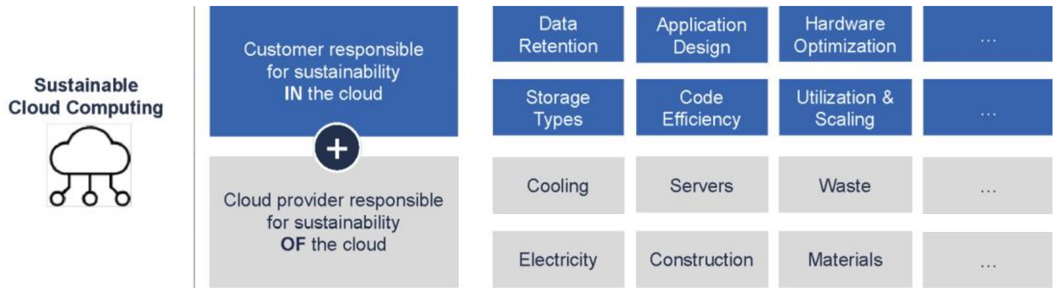


Figure 5.4 – Shared responsibility model for sustainable cloud computing

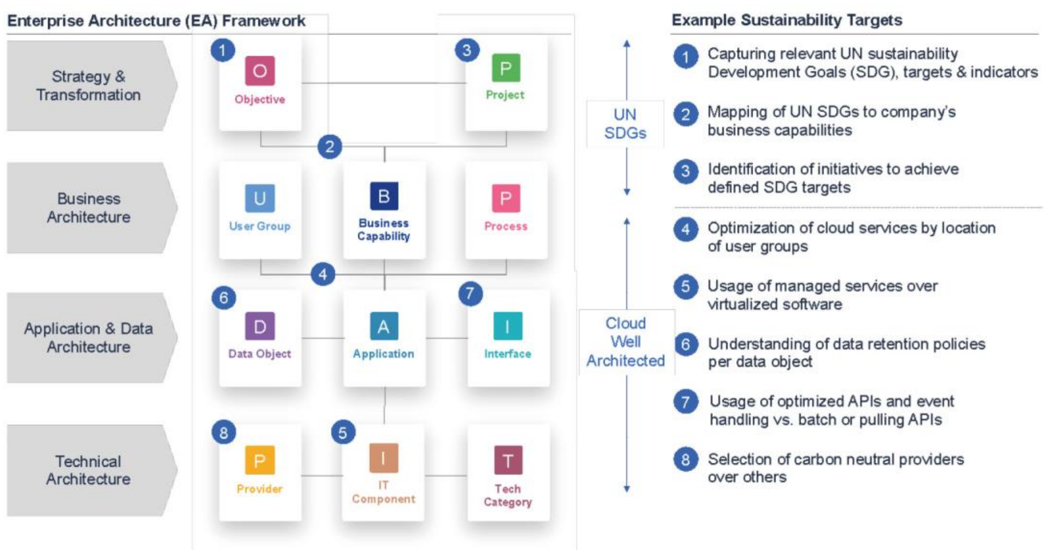


Figure 5.5 – Tracking sustainability targets in an EA framework

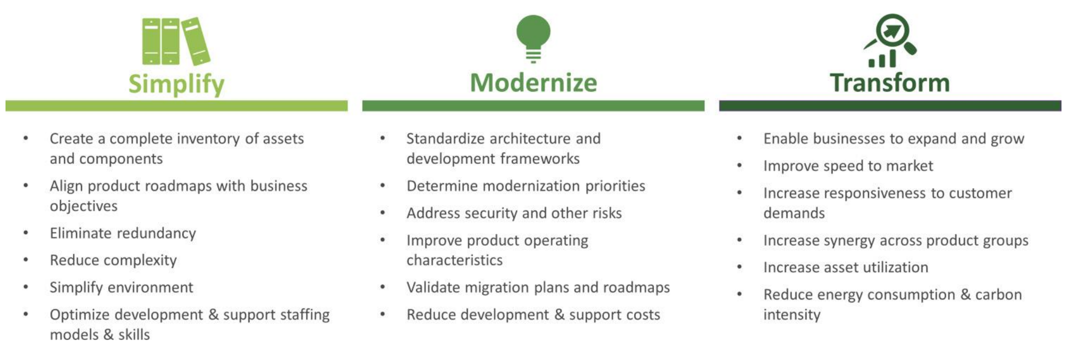


Figure 5.6 – Application portfolio optimization objectives

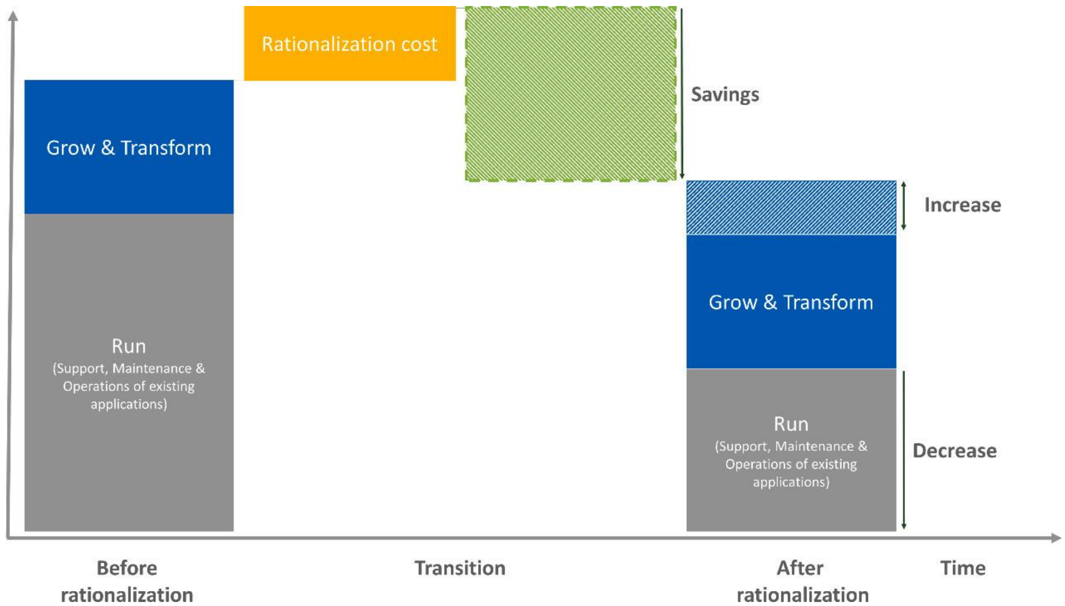


Figure 5.7 – Application rationalization before and after cost benefits comparison

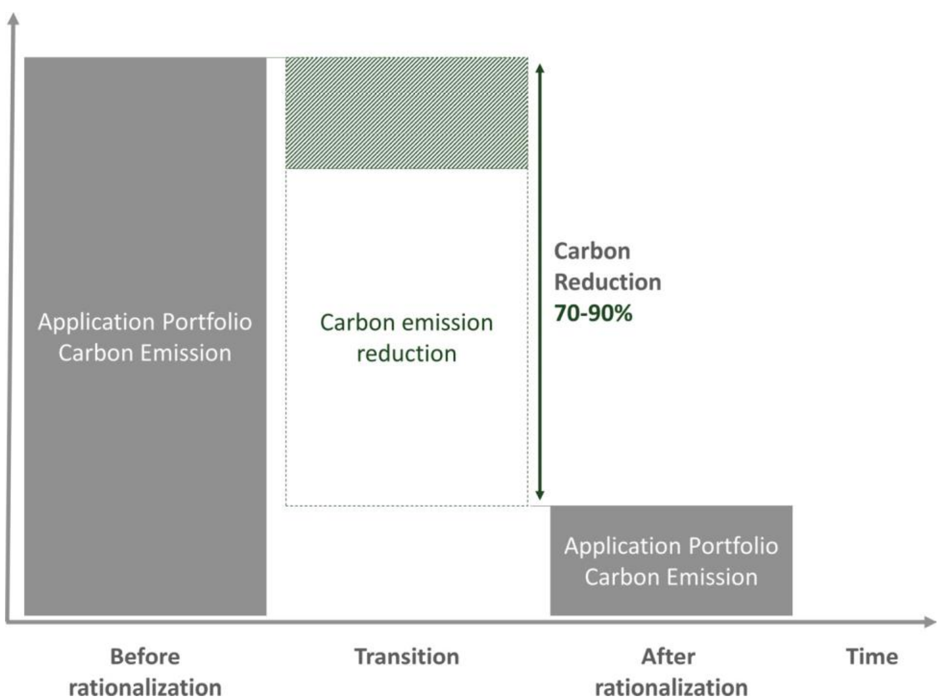


Figure 5.8 – Application rationalization before and after carbon emission reduction comparison

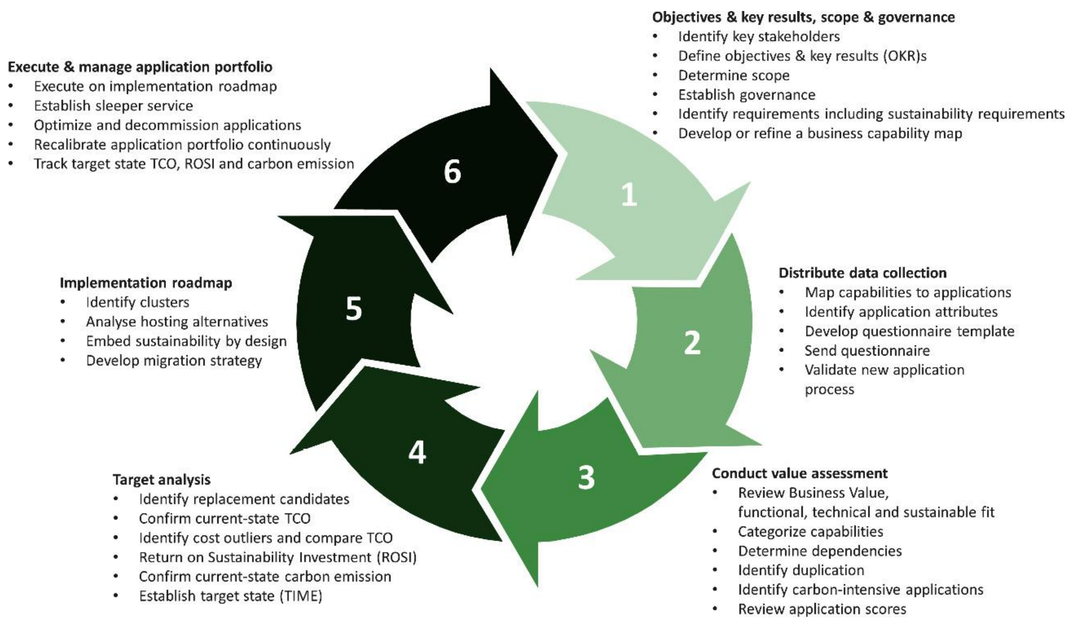


Figure 5.9 – Sustainable IT application rationalization six-step process

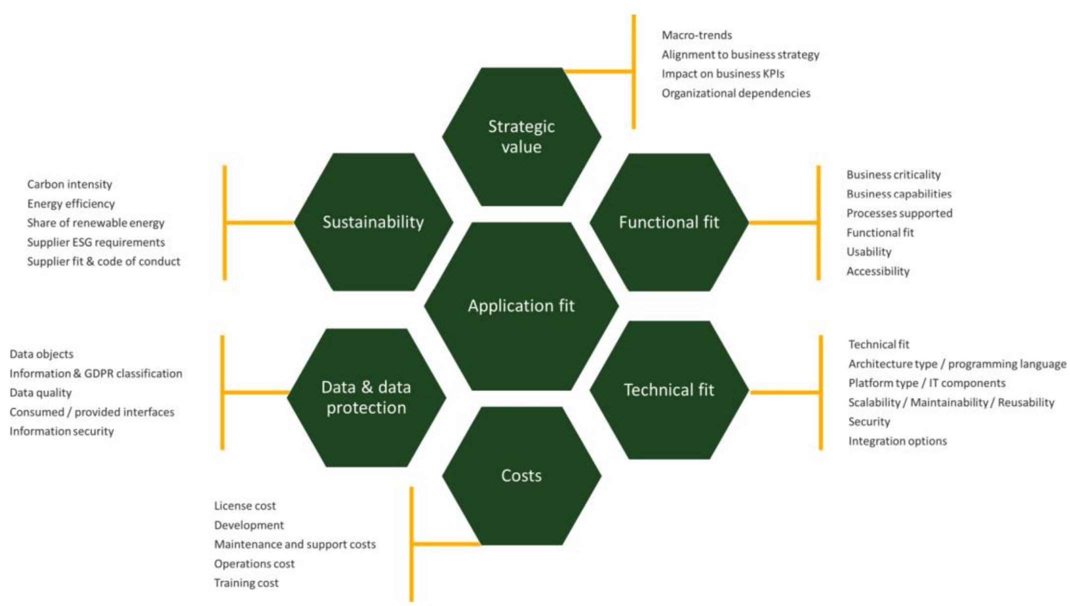


Figure 5.10 – Application assessment criteria

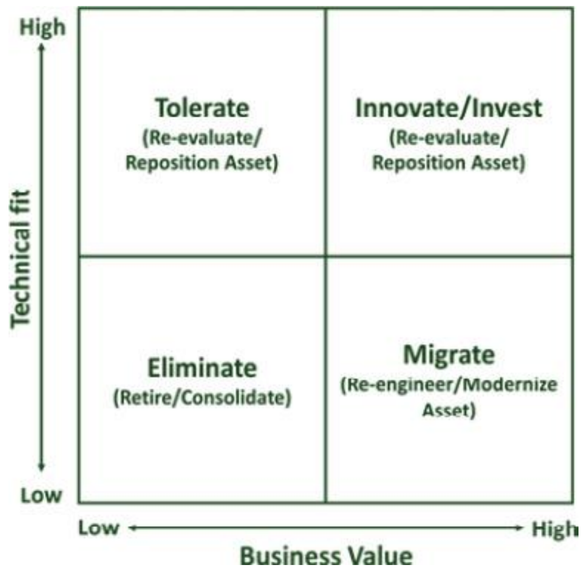


Figure 5.11 – TIME analysis quadrant

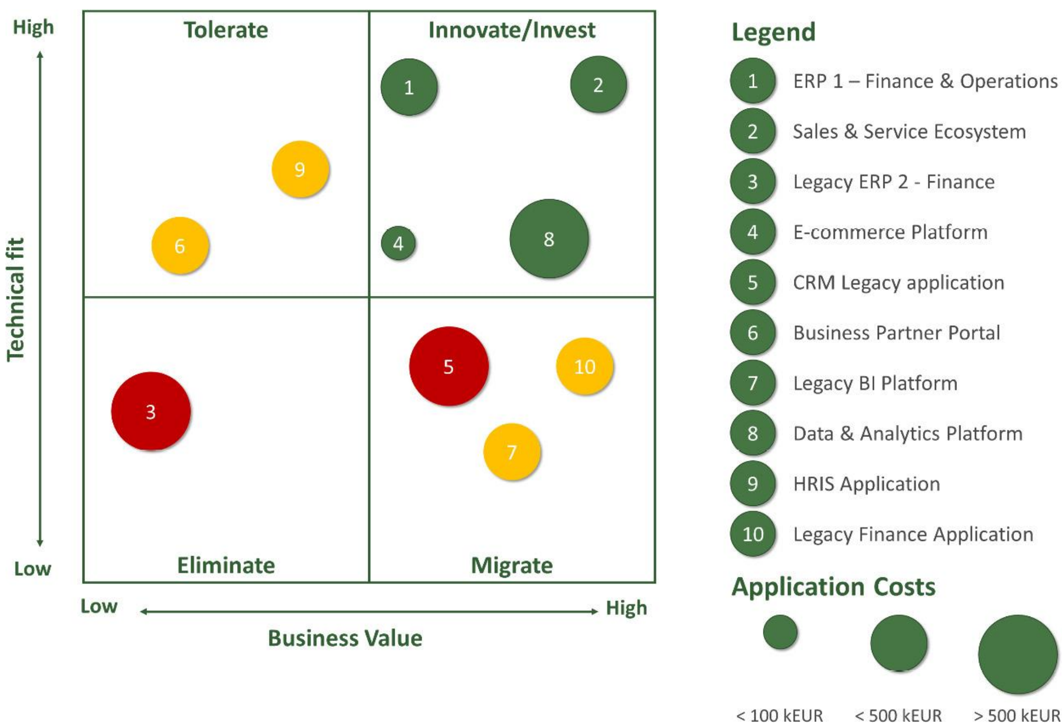


Figure 5.12 – TIME analysis application cost

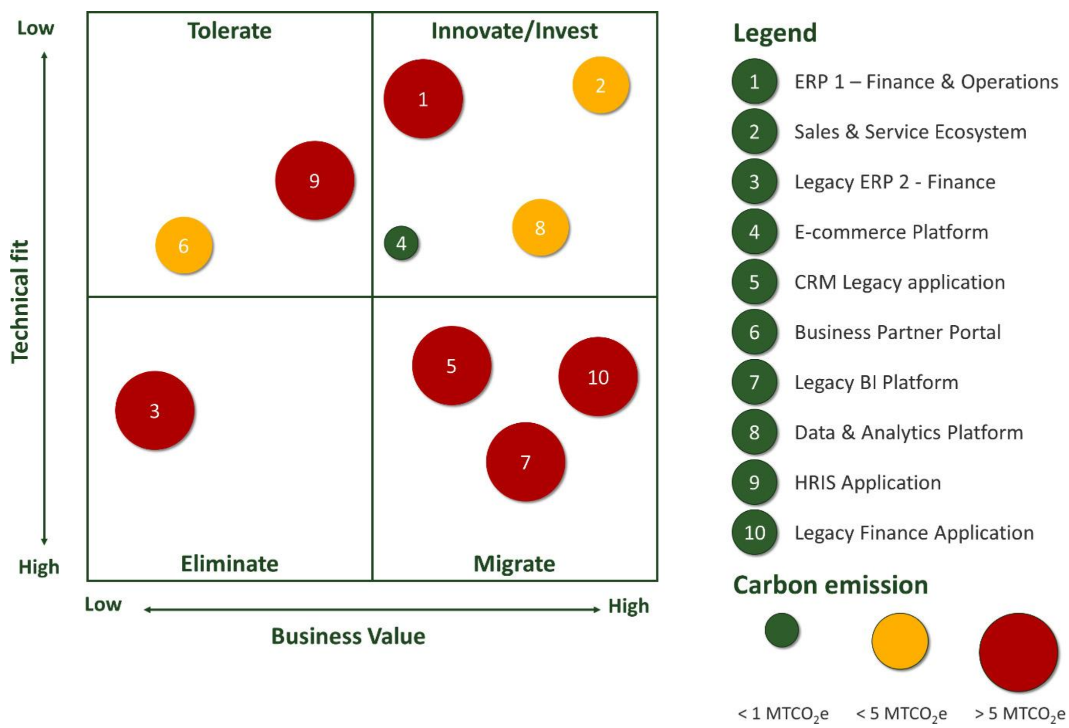


Figure 5.13 – TIME analysis of carbon emissions

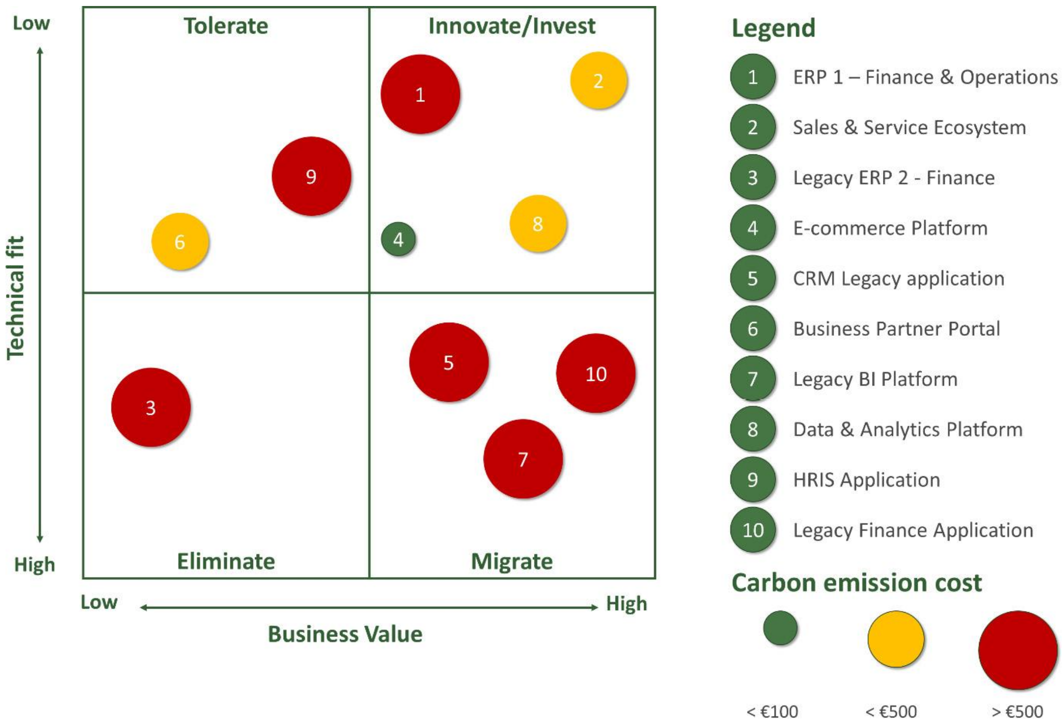


Figure 5.14 – TIME analysis of carbon costs

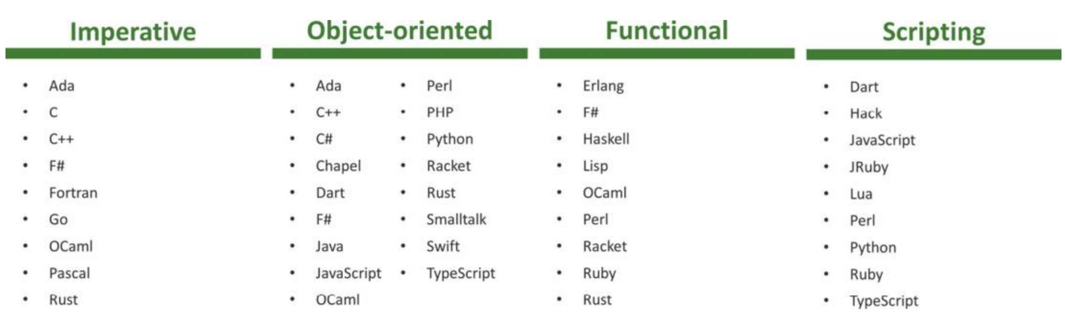


Figure 5.15 – Programming language paradigms (Pereira, et al. 2017)

<table>
<tr><th>Time & Memory</th><th>Energy & Time</th><th>Energy & Memory</th><th>Energy, Time & Memory</th></tr>
<tr><td>C | Pascal | Go</td><td>C</td><td>C | Pascal</td><td>C | Pascal | Go</td></tr>
<tr><td>Rust | C++ | Fortran</td><td>Rust</td><td>Rust | C++ | Fortran | Go</td><td>Rust | C++ | Fortran</td></tr>
<tr><td>Ada</td><td>C++</td><td>Ada</td><td>Ada</td></tr>
<tr><td>Java | Chapel | Lisp | OCaml</td><td>Ada</td><td>Java | Chapel | Lisp</td><td>Java | Chapel | Lisp | Ocaml</td></tr>
<tr><td>Haskell | C#</td><td>Java</td><td>OCaml | Swift | Haskell</td><td>Swift | Haskell | C#</td></tr>
<tr><td>Swift | PHP</td><td>Pascal | Chapel</td><td>C# | PHP</td><td>Dart | F# | Racket | Hack | PHP</td></tr>
<tr><td>F# | Racket | Hack | Python</td><td>Lisp | OCaml | Go</td><td>Dart | F# | Racker | Hack | Python</td><td>JavaScript | Ruby | Python</td></tr>
<tr><td>JavaScript | Ruby</td><td>Fortran | Haskell | C#</td><td>JavaScript | Ruby</td><td>TypeScript | Erlang</td></tr>
<tr><td>Dart | TypeScript | Erlang</td><td>Swift</td><td>TypeScript</td><td>Lua | JRuby | Perl</td></tr>
<tr><td>JRuby | Perl</td><td>Dart | F#</td><td>Erlang | Lua | Perl</td><td></td></tr>
<tr><td>Lua</td><td>JavaScript</td><td>JRuby</td><td></td></tr>
<tr><td></td><td>Racket</td><td></td><td></td></tr>
<tr><td></td><td>TypeScript | Hack</td><td></td><td></td></tr>
<tr><td></td><td>PHP</td><td></td><td></td></tr>
<tr><td></td><td>Erlang</td><td></td><td></td></tr>
<tr><td></td><td>Lua | JRuby</td><td></td><td></td></tr>
<tr><td></td><td>Ruby</td><td></td><td></td></tr>
</table>

Figure 5.16 – Program language efficiency based on variable combinations (Pereira, et al. 2017)

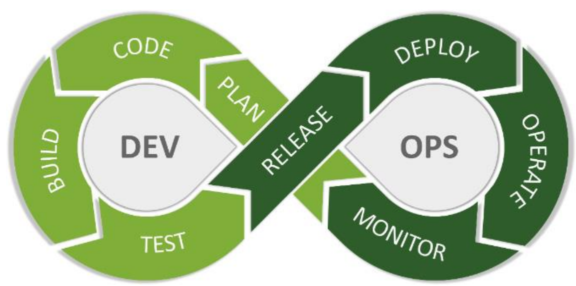
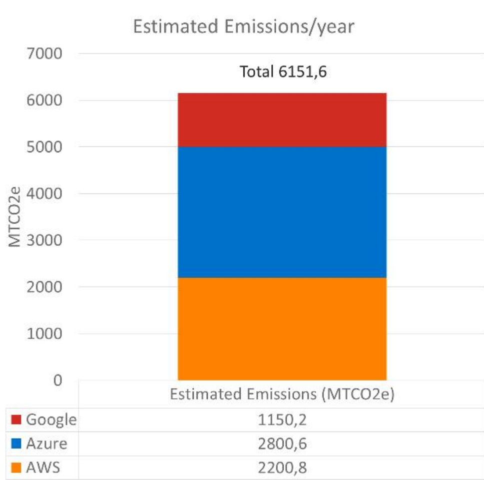
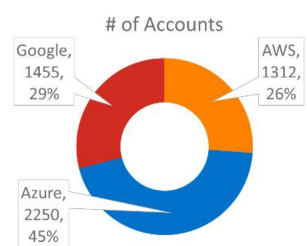


Figure 5.17 – DevOps life cycle





Emission Intensity per Account

Provider	Emissions (MTCO2e)	# of Accounts	Emission Intensity / Account
AWS	2200,8	1312	1,68
Azure	2800,6	2250	1,24
Google	1150,2	1455	0,79

Figure 5.18 – Cloud provider CO2 emission sample report

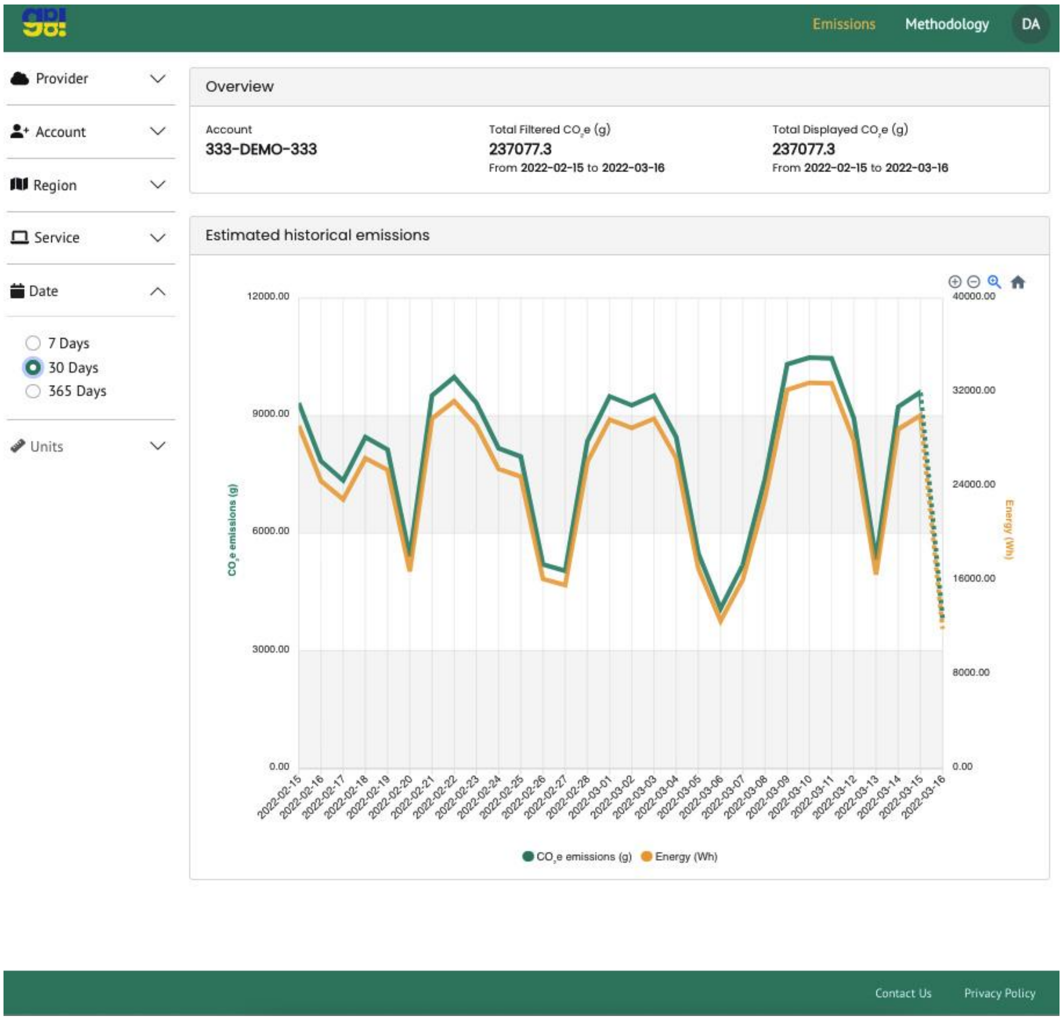


Figure 5.19 – Gaia Generation emission dashboard (image courtesy of Gaia Generation)

Tables

Application ID	1	2	3	4	5
Application Name	ERP 1 – Finance & Operations	Sales & Service Ecosystem	Legacy ERP 2 - Finance	E-Commerce Platform	CRM Legacy application
Business criticality	Business critical	Business operational	Business operational	Mission critical	Administrative service
Business capabilities	Finance, manufacturing & logistics	Sales, marketing, customer service & field service	Finance	Sales & customer service	Sales
Processes supported	Order to cash, procure to pay, forecast to plan, plan to produce, record to report & acquire to retire	Quote to cash & service to cash	Record to report & acquire to retire	Quote to cash	Quote to cash
Functional fit	Perfect	Appropriate	Unreasonable	Appropriate	Insufficient
Usability	Appropriate	Perfect	Unresonable	Appropriate	Insufficient
Accessibility	Appropriate	Appropriate	Insufficient	Appropriate	Insufficient

Table 5.1 – Application registry – functional fit

Application ID	1	2	3	4	5
Application Name	ERP 1 – Finance & Operations	Sales & Service Ecosystem	Legacy ERP 2 - Finance	E-Commerce Platform	CRM Legacy application
Application Type	SaaS	SaaS	Client Server	Client Server	Client Server
Application Platform	SAP S/4 Hana	Salesforce	ECC 4.0	IBM WebSphere Commerce 7.0	CRM Dynamics 2011
Database	N/A	N/A	Oracle DB	IBM DB2	MSSQL 2008 R2
Middleware	N/A	N/A	Oracle SOA Suite	BizTalk 2016	BizTalk 2016
Operating System	N/A	N/A	Suse Linux	Suse Linux	Windows Server 2011
Hardware	N/A	N/A	Dell XPS, i7 2-core	Dell PowerEdge M640P	Dell XPS, i7 2-core
Cloud Provider	Community Cloud	Community Cloud	Private Cloud	Private Cloud	Private Cloud

Table 5.2 – Application registry – technical fit

Application ID	1	2	3	4	5
Application Name	ERP 1 – Finance & Operations	Sales & Service Ecosystem	Legacy ERP 2 - Finance	E-Commerce Platform	CRM Legacy application
Carbon intensity	High	Medium	High	Medium	High
Energy efficiency	Appropriate	Appropriate	Unreasonable	Insufficient	Unreasonable
Share of renewable energy	100%	100%	0%	100%	0%
Supplier fit	Strategic	Strategic	Exit	Tactical	Exit
Code of conduct	Signed	Signed	Not signed	Signed	Not signed
ESG requirements met	Partially	Met	Not met	Partially	Not met

Table 5.3 – Application registry – sustainability

	Amazon Web Services (AWS)	Microsoft Azure	Google Cloud Platform
The company targets carbon reduction.	AWS aims to power operations with 100% renewable energy by 2025 and drive toward net-zero carbon by 2040	Today, Microsoft Azure is carbon neutral and committed to reaching 100% renewable energy by 2025 and being carbon negative by 2030	Google is carbon neutral today and aims to run on carbon-free energy by 2030
Sustainability resources	Sustainability Pillar of the AWS Well-Architected framework contains six design principles for sustainability in the cloud	Emission savings estimator	Low CO_2 indicator, Unattended project recommender, Recommendations to reduce carbon footprint
Reporting Solution	AWS Carbon Footprint (generally available)	Emissions Impact Dashboard (generally available)	Carbon Footprint (public preview)
Methodology	**Scope 1 and 2** are based on ISO ISO 14064 and GHG **Market-based** approach for scope 2 while considering renewable energy purchases	**Scope 1,2, and 3** are based on ISO 14064 and GHG Energy consumption **calculated** on machine specifications Grid carbon intensity factors from various sources (EPA, eGRID, IEA, and so on) Region-specific factor calculated by Microsoft	**Scope 2** reported (GHG) **Location-based** reporting based on GHG Energy consumption **measured** at the machine level Grid carbon intensity factor from electricitymap.org or International Energy Agency (IEA) Renewable power purchases excluded Not all services are covered yet
Metrics	Estimated Emissions (MTCO2e) Saving compared to on-premise (MTCO2e) Savings from renewable energy (MTCO2e) Savings using AWS services (MTCO2e)	Emissions (MTCO2e) Usage (hours) Carbon Intensity (MTCO2e/usage)	Emissions (kgCO2e)
Granularity	Geographical grouping, service (EC2, S3, Other), year, and month	Subscription, region, service, year, and month	Billing account, project, service, location, year, and month
Frequency	Monthly (with a delay of up to 3 months)	Monthly (on the 14th day of the previous month)	Monthly (up to 21 days of the previous month)
Costs	Free	Free/license fees for PowerBI Pro	Free/minimal fees for exporting with BigQuery

Table 5.4 – Cloud provider carbon footprint tool comparison

Further reading

To learn more about the topics that were covered in this chapter, take a look at the following resources:

- The Application Rationalization Playbook: https://www.cio.gov/assets/files/Application-Rationalization-Playbook.pdf.
- Awesome green software – research, tools, code, libraries, and training for building applications that emit less carbon into our atmosphere: https://github.com/Green-Software-Foundation/awesome-green-software.
- Cloud Carbon Footprint, an emissions measurement and analysis tool. Free and open source: http://www.cloudcarbonfootprint.org/.
- Computer benchmark game: https://benchmarksgame-team.pages.debian.net/benchmarksgame/index.html.
- The Green Software Foundation: https://greensoftware.foundation/
- Gaia Generation: https://www.gaiagen.eu/
- AWS Carbon Footprint tool: https://docs.aws.amazon.com/awsaccountbilling/latest/aboutv2/what-is-ccft.html
- Microsoft Azure Emissions Impact Dashboard: https://www.microsoft.com/en-us/sustainability/emissions-impact-dashboard?activetab=pivot_2:primaryr12
- Google Cloud Carbon Footprint: https://cloud.google.com/carbon-footprint

Bibliography

- Calero, Coral, and Mario Piattini. 2015. *Introduction to Green Software Engineering*. Springer International Publishing.

- Carlsson, Rebecka. 2021. *Exponentiell klimatomställning*. Stockholm: Lava förlag.
- Elizabeth, Jane. 2017. *Java is one the most energy efficient languages, Python among the least energy efficient*. September 18. Accessed May 05, 2022. https://jaxenter.com/energy-efficient-programming-languages-137264.html#:~:text=However%2C%20Java%20is%20one%20of,majority%20of%20the%20energy%20consumed.
- Gartner. n.d. "Glossary." *Gartner*. Accessed April 30, 2022. https://www.gartner.com/en/information-technology/glossary/application-program.
- Grotty, James, and Ivan Horrocks. 2017. "Managing legacy system costs: A case study of a meta-assessment model to identify solutions in a large financial services company." Applied Computing and Informatics 13 (2): 175-183. Accessed April 05, 2022.
- IDC. 2021. *Cloud Computing Could Eliminate a Billion Metric Tons of CO2 Emission Over the Next Four Years, and Possibly More, According to a New IDC Forecast.* IDC. March 08. Accessed January 31, 2022. https://www.idc.com/getdoc.jsp?spm=a2c65.11461447.0.0.964e28 c6a8EcQ2andcontainerId=prUS47513321.
- IEA. 2019. *Emissions*. Accessed July 06, 2022. https://www.iea.org/reports/global-energy-co2-status-report-2019/emissions.
- Infosys. 2018. "Case study: SAP success stories life sciences." *Infosys*. Accessed April 05, 2022. https://www.infosys.com/industries/life-sciences/case-studies/Documents/SAP-success-stories-life-sciences.pdf.
- Lacy, Peter, Paul Daugherty, Pavel Ponomarev, and Kishore Durg. 2020. The green behind the cloud. Accenture. September 22. Accessed January 31, 2022. https://www.accenture.com/_acnmedia/PDF-135/Accenture-Strategy-Green-Behind-Cloud-POV.pdf.

- LeanIX. 2022. “Enterprise Architects on IT Priorities for 2022.” Leanix.net. Accessed June 01, 2022. https://www.leanix.net/en/download/enterprise-architects-on-it-priorities-2022.
- —. 2019. “Enterprise Architecture Insights Report.” Accessed March 24, 2022. https://www.leanix.net/en/download/enterprise-architecture-insights-report-2019.
- —. 2019. “How Application Rationalization Contributes to the Bottom Line - and a Guide to Do it.” LeanIX. February 19. Accessed April 30, 2022. https://www.leanix.net/en/blog/how-application-rationalization-contributes-to-the-bottom-line-part-one.
- Microsoft News Center. 2018. *The Microsoft Cloud can save customers 93 percent and more in energy and carbon efficiency*. Microsoft. May 17. Accessed January 27, 2022. https://news.microsoft.com/2018/05/17/the-microsoft-cloud-can-save-customers-93-percent-and-more-in-energy-and-carbon-efficiency/#:~:text=%E2%80%94%20May%2017%2C%202018%20%E2%80%94%20A,issued%20Thursday%20by%20Microsoft%20Corp.andtext=These%20gains%2C%20as%.
- MSCI. 2022. *Who cares about the UN Sustainable Development Goals?* Accessed July 06, 2022. https://www.msci.com/who-cares-about-the-un-sustainable-development-goals.
- Pereira, Rui, Marco Couto, Francisco Ribeiro, Jácome Cunha, Joâo Paulo Fernandes, and João Saraiva. 2017. “Energy Efficiency across Programming Languages - How Does Energy, Time, and Memory Relate?” https://greenlab.di.uminho.pt. September. Accessed May 05, 2022. https://greenlab.di.uminho.pt/wp-content/uploads/2017/09/paperSLE.pdf.
- Taina, Juha. 2011. *Good, Bad, and Beautiful Software - In search of Green Software Quality Factors*. CEPIS UPGRADE.

- U.S. Federal CIO Council. 2020. “The Application Rationalization Playbook - An Agency Guide to Portfolio Management.” cio.gov. Accessed April 30, 2022. https://www.cio.gov/assets/files/Application-Rationalization-Playbook.pdf.

Chapter 6

Images

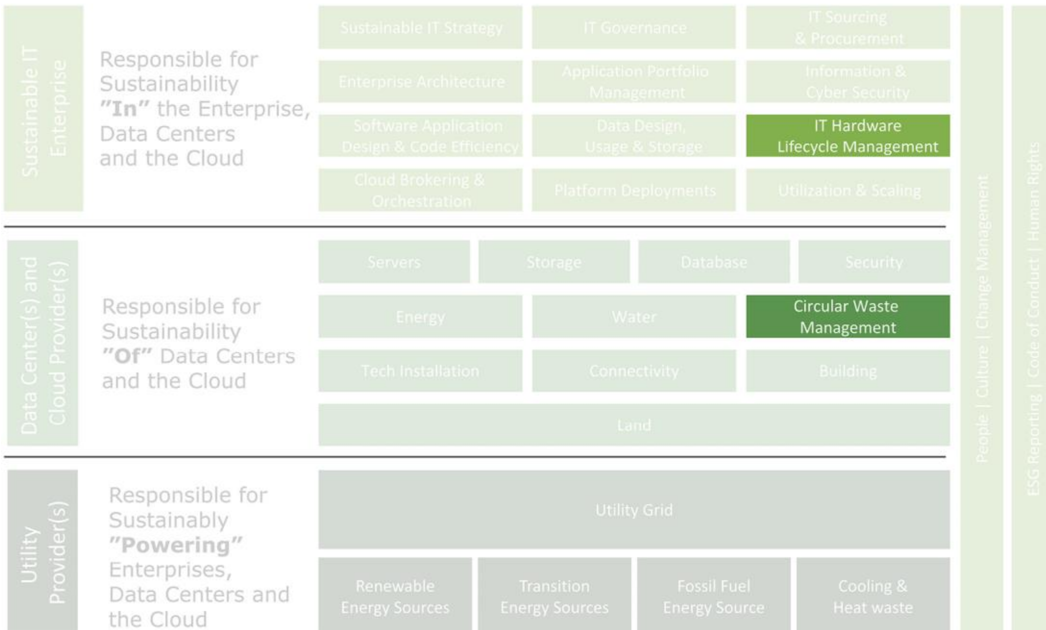


Figure 6.1 – Sustainable IT reference model – Chapter 6 focus

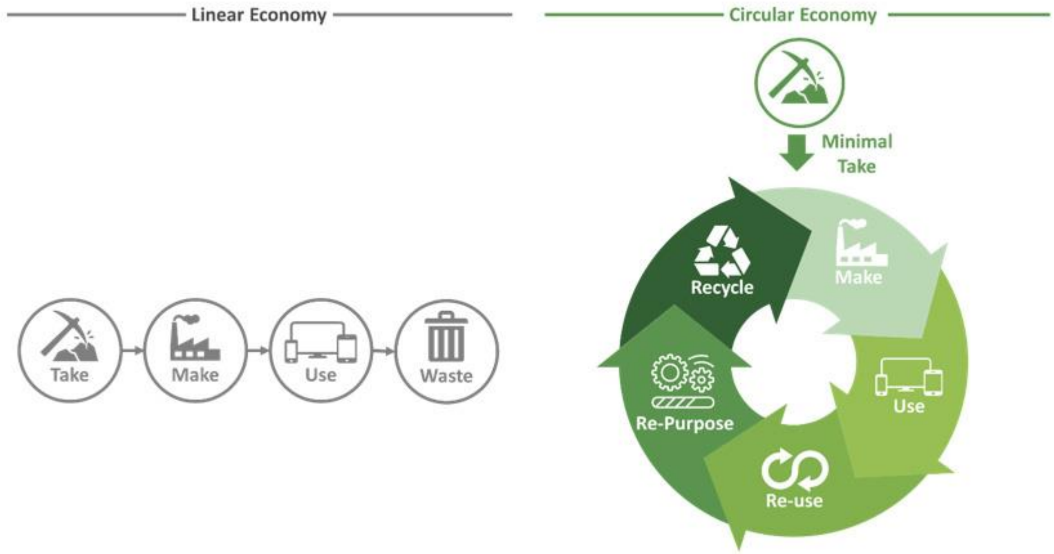


Figure 6.2 – From a linear to a circular economy

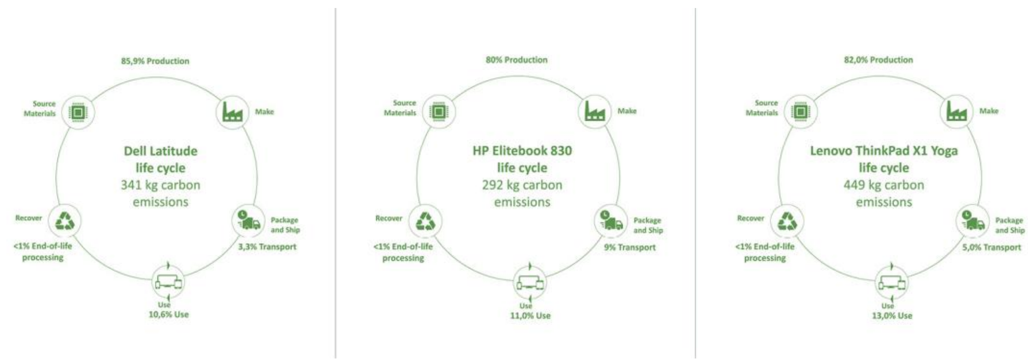


Figure 6.3 – Notebook product CO2 life cycle emission comparison

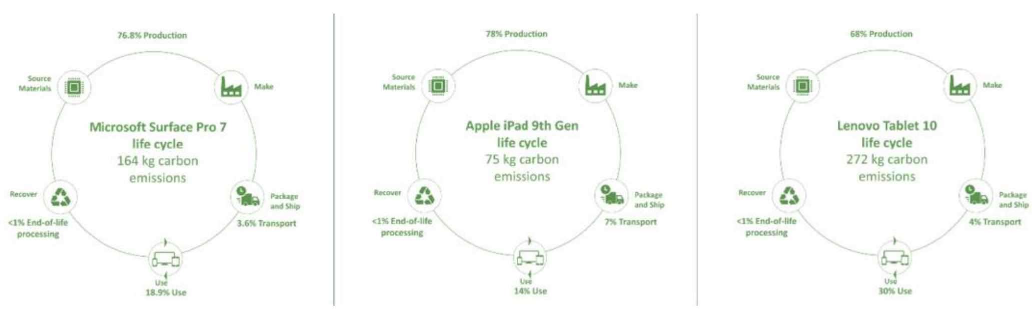


Figure 6.4 – Tablet product CO2 life cycle emission comparison

Figure 6.5 – Smartphone product CO2 life cycle emission comparison

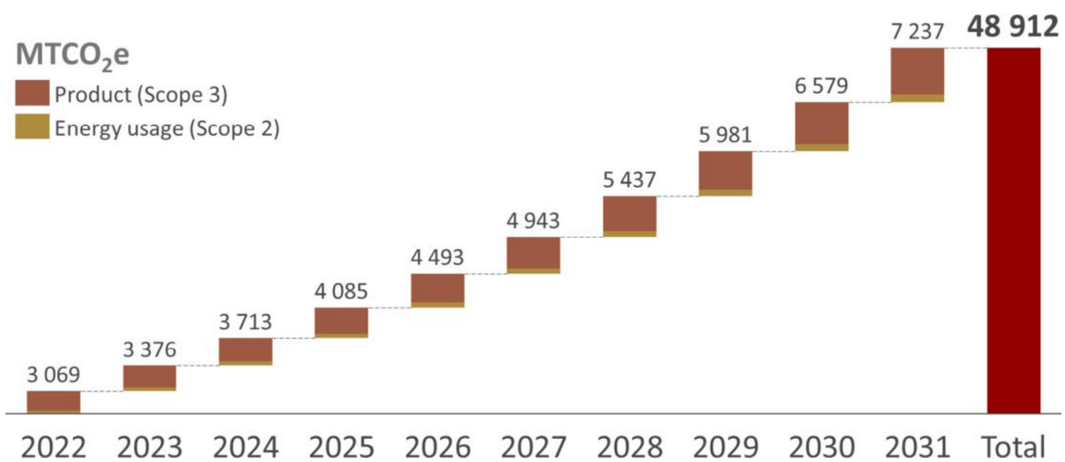


Figure 6.6 – Global manufacturing model company computer GHG emissions

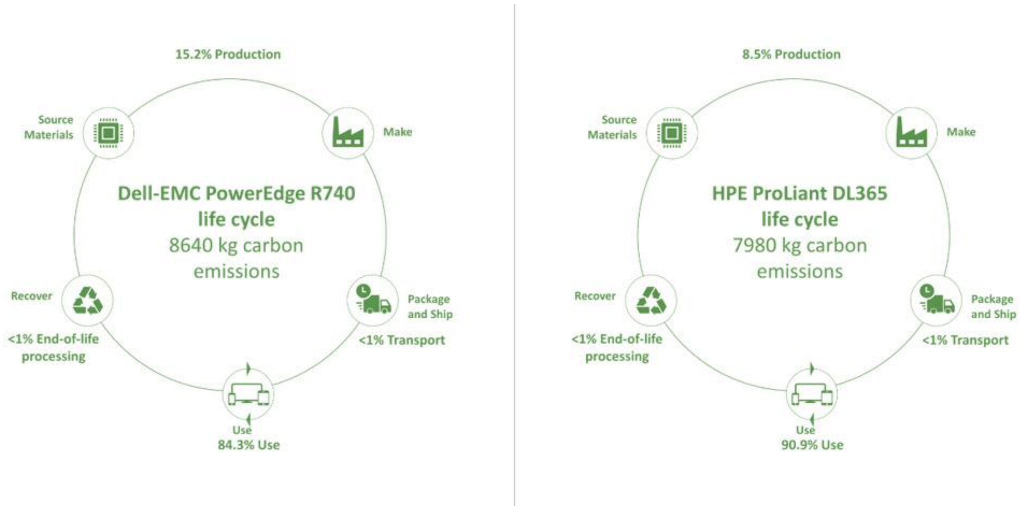
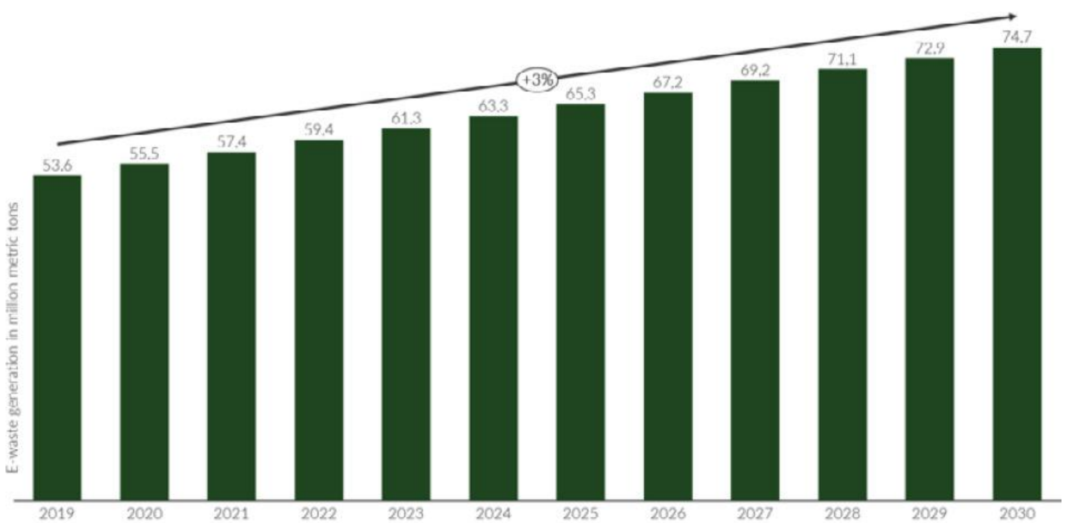


Figure 6.7 – DELL-EMC and HPE server production carbon footprint life cycle distribution



Source: Statista 2022

Figure 6.8 – Projected electronic waste generation worldwide from 2019 to 2030 (in a million metric tons)

Figure 6.9 – E-waste and recycling rate per continent (ISWA 2020)

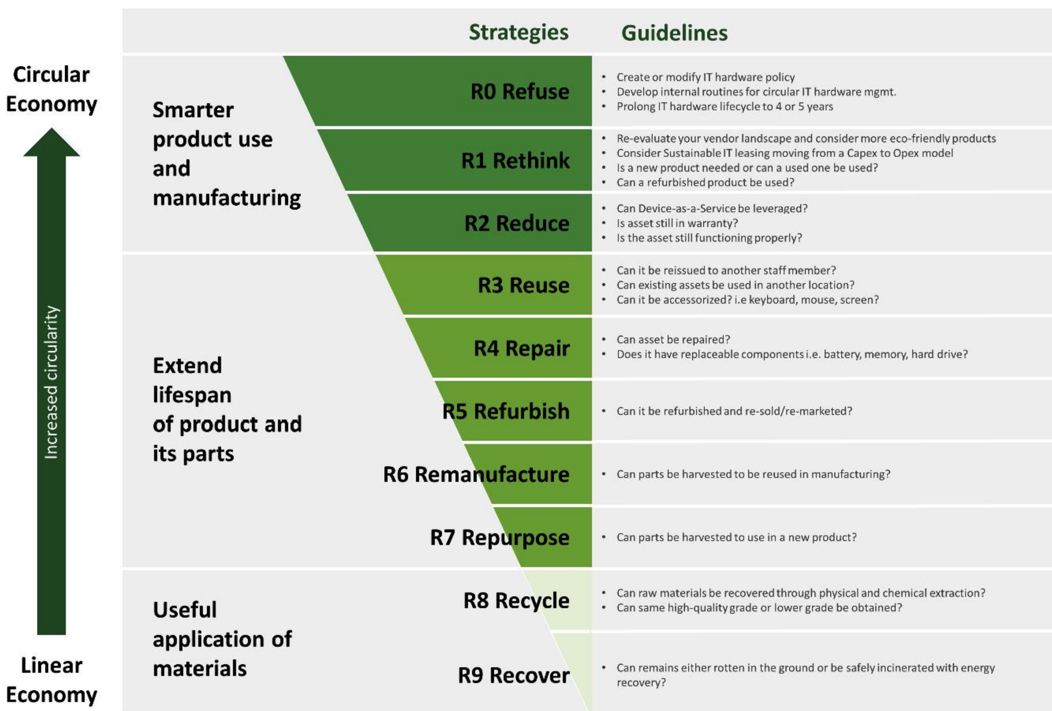


Figure 6.10 – 9R framework circular economy

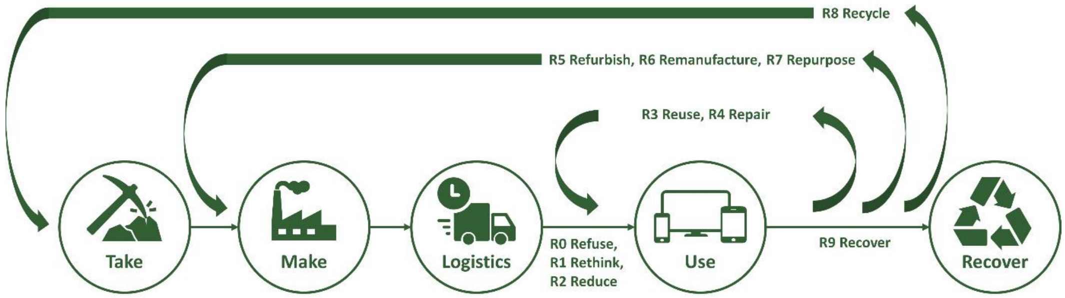


Figure 6.11 – Circular economy approach to the 9R framework

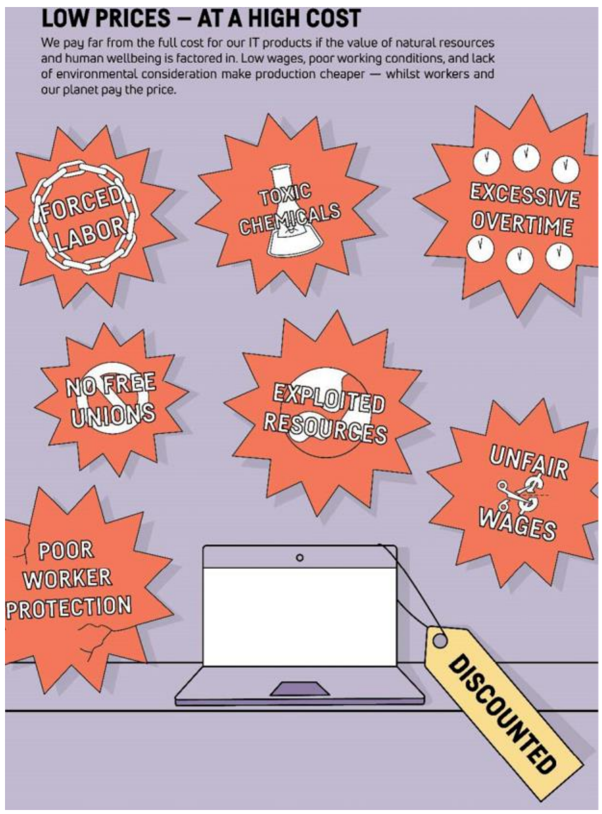


Figure 6.12 – Low prices – at a high cost (image courtesy of TCO Certified)

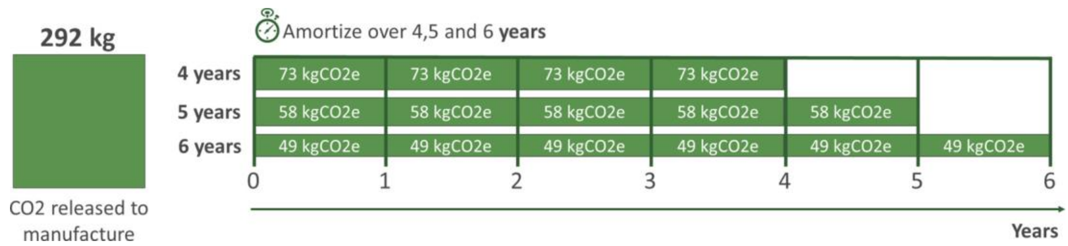


Figure 6.13 – Amortizing a laptop's carbon emission over 4, 5, and 6 years

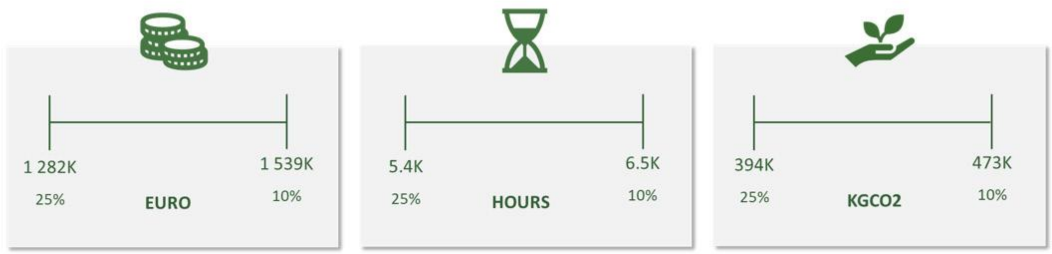


Figure 6.14 – Business case for change – summary of cost savings, efficiency gains, and GHG emission reduction

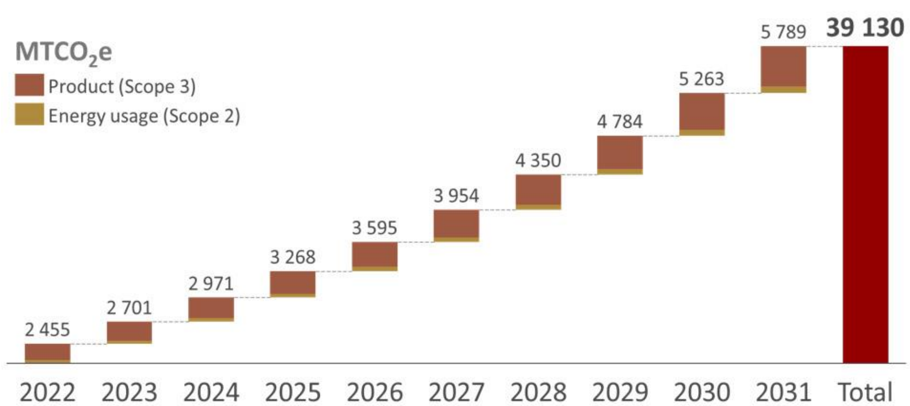


Figure 6.15 – Changing the product life cycle's global manufacturing model company computer GHG emissions

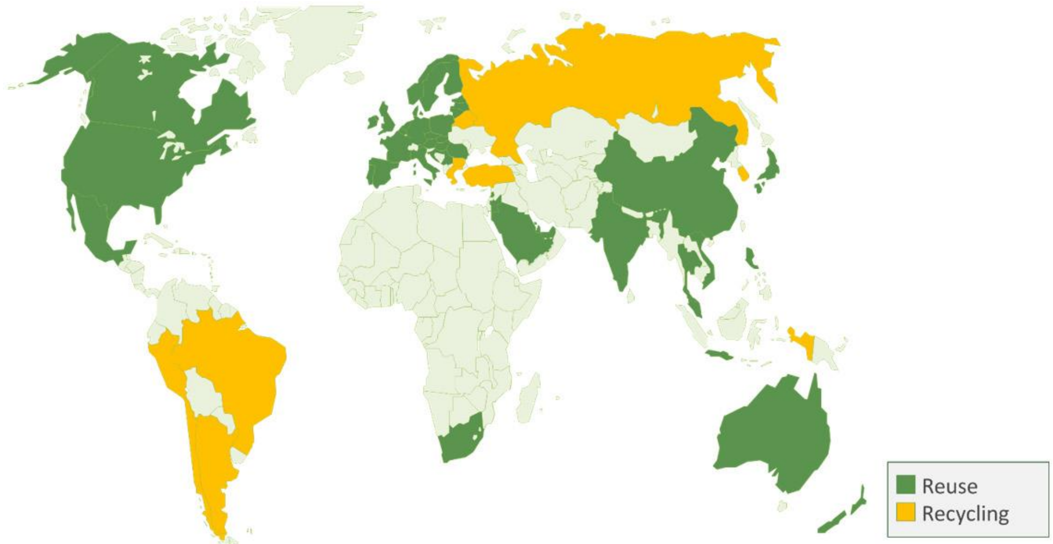


Figure 6.16 – Global ITAD footprint and service availability

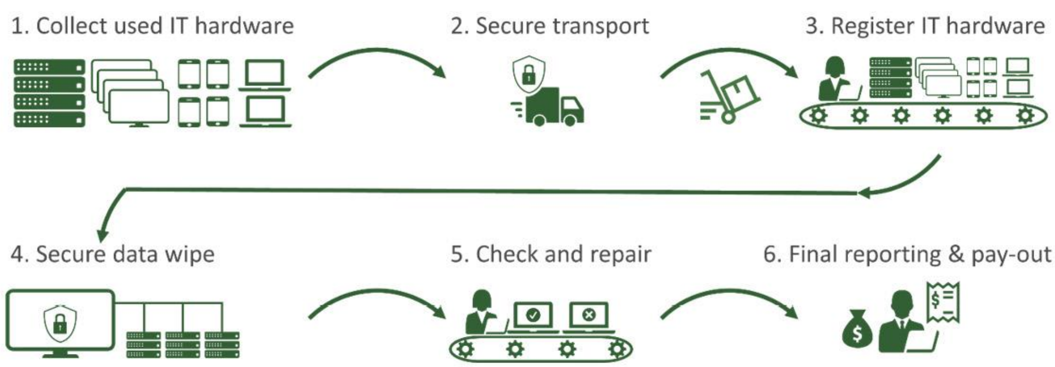


Figure 6.17 – IT asset disposition process

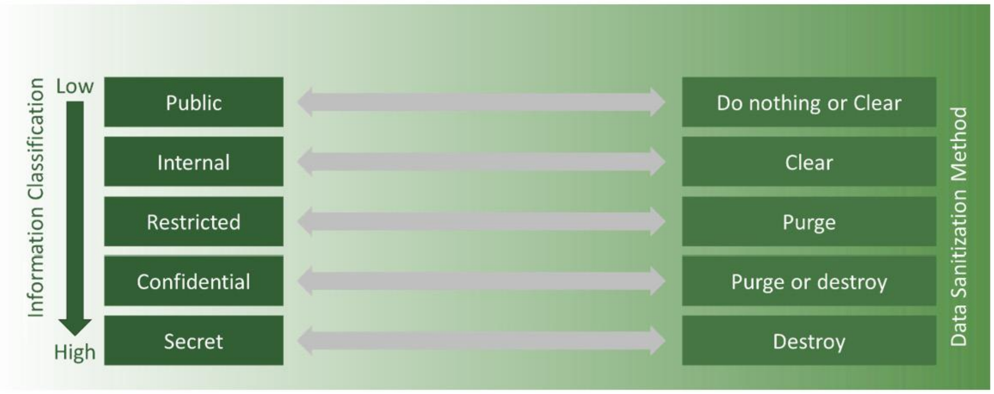


Figure 6.18 – Mapping information classification versus data sanitization

Company	2020 Carbon Footprint (MtCO2e)	Carbon Neutral Target	Net-Zero Carbon Emission Target	Renewable Energy Target	Water Target	Waste Target
Lenovo	150	-	2050	-	-	-
HP	44.9	2025	2040	2040	-	2025
Dell	298.5	-	2050	2040	-	-
Apple	22.6	2020	2030	2020	-	-
Acer	12.2	-	2050*	2025	-	-
Asus	1,221.3	-	-	2035	-	-

Scope 1 & 2 only, *80 percent by 2050

Figure 6.19 – IT hardware sustainability commitment comparison

Description	Metric	General Requirement	United Nations Sustainable Development Goals Alignment
Equipment lifetime	Years	Equipment lifetime years	12. Responsible Consumption and Production 13. Climate Action
Renewable energy	%	**REF** Renewable Energy Factor	9. Industry, Innovation and Infrastructure 12. Responsible Consumption and Production
Circular economy reuse and repair	%	**Reuse and Repair** % equipment reused	12. Responsible Consumption and Production 13. Climate Action
Zero waste to landfill	WUE	**Recycle** % equipment reused	12. Responsible Consumption and Production 13. Climate Action
Hazardous substances	%	**Hazardous Substances** % equipment with hazardous substances	12. Responsible Consumption and Production 13. Climate Action

Figure 6.20 – IT hardware sustainability scorecard

Tables

		Computer Cost	Efficiency	Sustainability
	Assets	**Cost - EUR**	**Cost - EUR**	**KGCO2**
	36 000	**950**	**4**	**292**
4 year Lifespan Volume		34 200 000	144 000	10 512 000
Current 4 year model - Yearly Lifespan Volume	**4**	8 550 000	36 000	2 628 000
Proposed 5 year model - Yearly Lifespan Volume	**5**	6 840 000	28 800	2 102 400
Yearly savings		-1 710 000	-7 200	-525 600
Net yearly savings @ replacement contingency 10%	**10%**	**-1 539 000**	**-6 480**	**-473 040**
Net yearly savings @ replacement contingency 25%	**25%**	**-1 282 500**	**-5 400**	**-394 200**

Table 6.1 – Business case for change – end user computing

Rank	**Manufacturer**	**Market Share**
1	Lenovo	24.7%
2	HP	21.8%
3	Dell	17.6%
4	Apple	7.6%
5	Acer	7.2%
6	Asus	6.4%
7	Other	14.7%

Table 6.2 – Top six vendors by number of units shipped in 2021

Further reading

To learn more about the topics that were covered in this chapter, take a look at the following resources:

- Basel action network: https://www.ban.org/
- WEEE forum: https://weee-forum.org/who-we-are/
- Impacts and Insights: Circular IT management in practice. Report on circularity in the IT sector, including 33 hands-on tips on how your organization can move in a circular direction: https://tcocertified.com/2020-impacts-and-insights/
- The circular economy — an opportunity for more sustainable IT products: https://tcocertified.com/circular-economy/
- Social responsibility is a challenge in the IT product supply chain: https://tcocertified.com/social-responsibility/
- Sustainable Electronics Recycling International (SERI): https://sustainableelectronics.org/
- E-Stewards: https://e-stewards.org/

Bibliography

- Acer. 2021. "Acer Earthion: our long-term commitment to the environment." *acerforeducation.acer.com*. June 04. Accessed May 18, 2022. https://acerforeducation.acer.com/experiences/projects/earthion-commitment-environment/#:~:text=%E2%80%9CAcer%20joins%20over%20300%20of,the%20RE100%20Key%20Collaborator%20Award
- —. 2021. "Acer Expands Lineup of Eco-friendly Vero Products." *news.acer.com*. October 13. Accessed May 18, 2022. https://news.acer.com/acer-expands-lineup-of-eco-friendly-vero-products
- —. 2021. "Acer Listed on Dow Jones Sustainability Indices (DJSI) for Eighth Straight Year in 2021." *news.acer.com*. November 18. Accessed May 18, 2022. https://news.acer.com/acer-listed-on-dow-jones-sustainability-indices-djsi-for-eighth-straight-year-in-2021

- 2018. *Apple*. April 9. https://www.apple.com/newsroom/2018/04/apple-now-globally-powered-by-100-percent-renewable-energy/
- 2020. *Apple 12 Product Environmental Report*. October 13. Accessed March 13, 2022. https://www.apple.com/environment/pdf/products/iphone/iPhone_12_PER_Oct2020.pdf
- Apple. 2022. "Apple Environmental Progress Report 2022." *Apple*. Accessed May 15, 2022. https://www.apple.com/environment/pdf/Apple_Environmental_Progress_Report_2022.pdf
- —. 2022. "Apple expands the use of recycled materials across its products." *Apple.com*. April 19. Accessed May 16, 2022. https://www.apple.com/newsroom/2022/04/apple-expands-the-use-of-recycled-materials-across-its-products/
- Asus. 2020. "Operational Footprint | Climate Action." *csr.asus.com*. Accessed May 18, 2022. https://csr.asus.com/english/article.aspx?id=1729
- Capgemini. 2021. *Sustainable IT - Why it's time for a Green revolution for your organization's IT*. Capgemini research institute.
- Carlsson, Rebecka. 2021. *Exponentiell klimatomställning*. Stockholm: Lava förlag.
- Cunnie, Shawn. 2022. *IT Asset Disposition is Critical to Sustainability Goals*. January 21. Accessed May 21, 2022. https://www.missioncriticalmagazine.com/articles/93937-it-asset-disposition-is-critical-to-sustainability-goals
- 2021. *Dell Latitude 7420*. January. Accessed March 17, 2022. https://www.dell.com/sv-se/dt/corporate/social-impact/advancing-sustainability/sustainable-products-and-services/product-carbon-footprints.htm#tab0=1&pdf-overlay=//www.delltechnologies.com/asset/sv-se/products/laptops-and-2-in-1s/technical-support/latitud

- Dell. 2019. “Life Cycle Assessment of Dell PowerEdge R740.” *Dell.com*. Junie. Accessed May 15, 2022. https://www.dell.com/sv-se/dt/corporate/social-impact/advancing-sustainability/sustainable-products-and-services/product-carbon-footprints.htm#scroll=off&tab0=3&pdf-overlay=//www.delltechnologies.com/asset/sv-se/products/servers/technical-support/lca_powe

- —. 2022. “Progress made real FY21 ESG Report.” *Dell*. Accessed May 15, 2022. https://www.dell.com/en-ie/dt/corporate/social-impact/reporting/fy21-progress-made-real-report.htm#pdf-overlay=//www.delltechnologies.com/asset/en-ie/solutions/business-solutions/briefs-summaries/delltechnologies-fy21-progress-made-real-report.pdf

- —. n.d. “Social impact.” *Dell.com*. Accessed May 15, 2022. https://www.dell.com/sv-se/dt/corporate/social-impact.htm#:~:text=By%202030%20we%20will%20cut,2%20and%203%20by%202050

- EU Parliament. 2011. “Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment Text with EEA relevance.” *eur-lex.europa.eu*. June 8. Accessed May 18, 2022. https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32011L0065

- —. 2011. “RoHS Directive.” *cemarking.net*. June 8. Accessed May 18, 2022. https://cemarking.net/eu-ce-marking-directives/rohs-directive/

- European Environmental Bureau. 2019. “Coolproducts don’t cost the Earth.”

- Exittechnologies. 2021. *IT Asset Disposition: A Review of the Services, Market, and Considerations*. September 27. Accessed May 21, 2022. https://www.exittechnologies.com/blog/data-center/it-asset-disposition-overview/

- Gartner. 2022. *Gartner.com*. January 12. Accessed May 15, 2022. https://www.gartner.com/en/newsroom/press-releases/2022-01-12-gartner-says-worldwide-pc-shipments-declined-5-percent-in-fourth-quarter-of-2021-but-grew-nearly-10-percent-for-the-year
- Gill, Victoria. 2021. "Waste electronics will weigh more than the Great Wall of China." *bbc.com*. October 13. Accessed May 16, 2022. https://www.bbc.com/news/science-environment-58885143
- Greenpeace. 2017. "Guide to Greener." *greenpeace.org*. Accessed May 18, 2022. https://www.greenpeace.org/usa/wp-content/uploads/2017/10/Guide-to-Greener-Electronics-2017.pdf
- —. 2017. "HP report card." *greenpeace.org*. Accessed May 18, 2022. https://www.greenpeace.org/usa/wp-content/uploads/2017/10/GGE2017_HP.pdf
- —. 2017. "Lenovo report card." *greenpeace.org*. Accessed May 18, 2022. https://www.greenpeace.org/usa/wp-content/uploads/2017/10/GGE2017_Lenovo.pdf
- HP. 2020. "HP 2020 Sustainable Impact Report." *HP.com*. Accessed May 15, 2022. https://www8.hp.com/h20195/v2/GetPDF.aspx/c07539064.pdf
- HP Inc. 2021. "HP Inc. Announces Ambitious Climate Action Goals." *HP.com*. April 20. Accessed May 15, 2022. https://press.hp.com/us/en/press-releases/2021/hp-inc-announces-ambitious-climate-action-goals.html
- ISWA. 2020. *Global E-waste Surging: Up 21 Percent in 5 years*. United Nations institute for Training and Research. July 2. Accessed January 27, 2022.
- IT-recycling. 2022. "Environmentally-harmful substances in old computers and computer waste." *it-recycling.nl*. Accessed May 16, 2022. https://www.it-recycling.nl/en/it-recycling/computer-components-contain-toxic-substances/
- Kirchherr, Julian, M.P. Hekkert, and Reike Denise. 2017. "Conceptualizing the Circular Economy: An Analysis of 114 Definitions." *Researchgate.net*

September. Accessed May 12, 2022. https://www.researchgate.net/publication/320074659_Conceptualizing_the_Circular_Economy_An_Analysis_of_114_Definitions

- Lenovo. 2020. "Lenovo Sustainability Combatting Climate Change: Performance." *www.lenovo.com*. Accessed May 18, 2022. https://www.lenovo.com/us/en/sustainability-climate-change-performance/
- Market Research Future. 2021. "IT Asset Disposition Market with COVID-19 impact Analysis By Service Type, Asset Type, Organization Size, End User (Banking, Financial Services, and Insurance (BFSI), IT and Telecom, Healthcare), and Region - Global Forecast to 2026." *www.researchandmarkets.com*. April. Accessed May 2022, 2022. https://www.researchandmarkets.com/reports/5318361/it-asset-disposition-market-with-covid-19-impact?utm_source=GNOM&utm_medium=PressRelease&utm_code=h3l493&utm_campaign=1535256+-+Global+IT+Asset+Disposition+Market+(2021+to+2026)+-+Strategic+Partnerships+a
- Mendoza, N.F. 2020. "Global e-waste is up 21% in 5 years, causing serious environmental harm." *techrepublic.com*. July 14. Accessed May 21, 2022. https://www.techrepublic.com/article/global-e-waste-is-up-21-in-5-years-causing-serious-environmental-harm/
- Microsoft. 2021. "Ecoprofile Surface Pro 8." *Microsoft*. Accessed May 12, 2022. https://www.microsoft.com/en-us/download/confirmation.aspx?id=55974&6B49FDFB-8E5B-4B07-BC31-15695C5A2143=1
- Morgan, Blake. 2020. *Forbes*. November 9. https://www.forbes.com/sites/blakemorgan/2020/11/09/10-most-sustainable-consumer-tech-companies/?sh=32ee43c549a8

- Murray, James. 2012. “EU revamps e-waste rules with demanding new recovery targets.” *theguardian.com*. Aug 14. Accessed May 21, 2022. https://www.theguardian.com/environment/2012/aug/14/eu-waste
- 2020. *NO TURNING BACK. How the Pandemic as Reshaped Digital Business Agendas. Google Cloud*. IDG Communications, Inc.
- Page Motes. 2022. “Repair, Reuse, Recycle: The Circular Economy in Action.” *Dell.com*. Feburary 22. Accessed May 15, 2022. https://www.dell.com/en-us/blog/repair-reuse-recycle-the-circular-economy-in-action/
- Potting, José, Marko Hekkert, Ernst Worrell, and Aldert Hanemaaijer. 2017. “Circular Economy: Measuring Innovation in the Product Chain - Policy Report.” *PBL.nl*. January. Accessed May 12, 2022. https://www.pbl.nl/sites/default/files/downloads/pbl-2016-circular-economy-measuring-innovation-in-product-chains-2544.pdf
- Royal Society of Chemistry. 2022. “Meet the precious metals.” *rsc.org*. Accessed May 16, 2022. https://sustainability.rsc.org/meet-the-precious-elements/
- Ryder, Guy, and Zhao Houlin. 2019. *The world’s e-waste is a huge problem. It’s also a golden opportunity*. January 24. Accessed July 07, 2022. https://www.weforum.org/agenda/2019/01/how-a-circular-approach-can-turn-e-waste-into-a-golden-opportunity/
- The Guardian. 2019. *Fairphone 3 review: the most ethical and repairable phone you can buy*. The Guardian. September 19. Accessed January 27, 2022. https://www.theguardian.com/technology/2019/sep/18/fairphone-3-review-ethical-phone
- January 24, 2019. “The world’s e-waste is a huge problem. It’s also a golden opportunity.” *World Economic Forum*. Davos, Switzerland.
- Tiseo, Ian. 2021. “Apple’s GHG emission 2012-2020.” *Statista.com*. May 2021. Accessed May 15, 2022. https://www.statista.com/statistics/528604/carbon-emissions-from-apple-by-

segment/#:~:text=Apple%20Inc%20released%20approximately%2022.6,period%2C%20followed%20by%20product%20use

- Yale University. 2022. “Almost 1,000 Companies Have Curtailed Operations in Russia—But Some Remain .” som.yale.edu. May 22. Accessed May 21, 2022. https://som.yale.edu/story/2022/almost-1000-companies-have-curtailed-operations-russia-some-remain

Chapter 7

Images

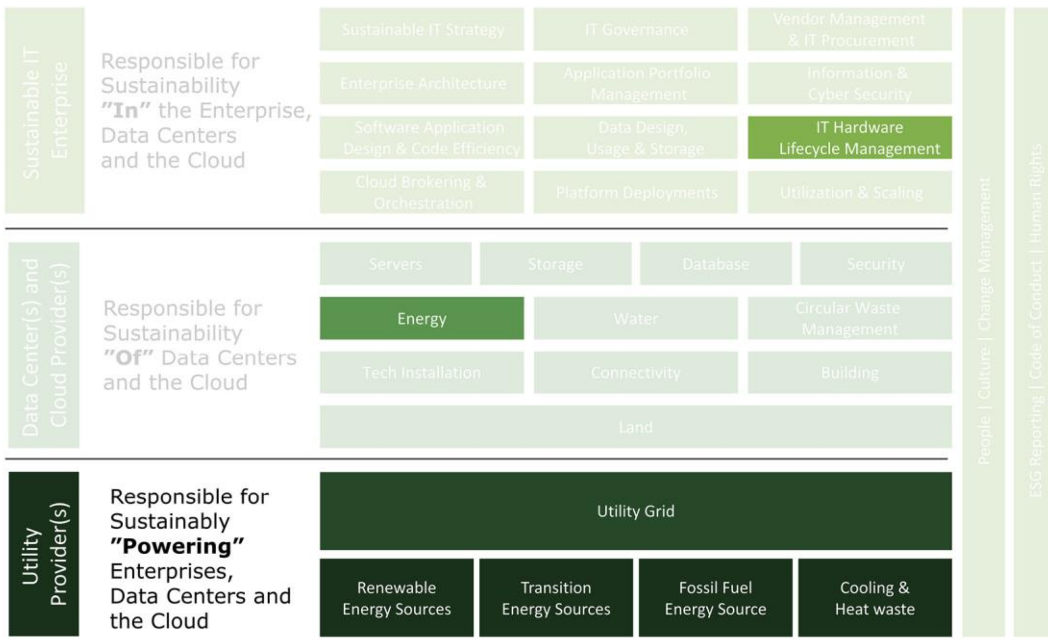


Figure 7.1 – Sustainable IT reference model – Chapter 7 focus

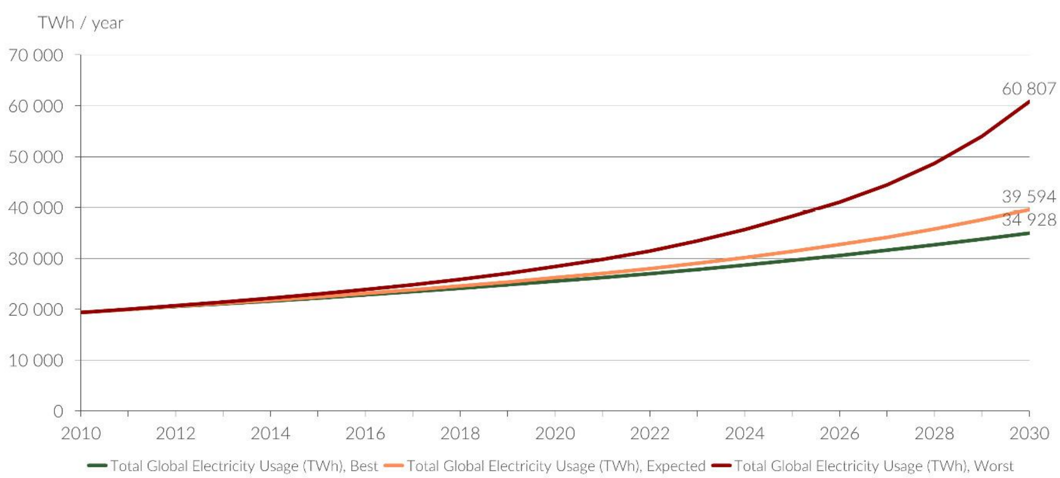


Figure 7.2 – Global electricity supply forecast (TWh) 2010-2030

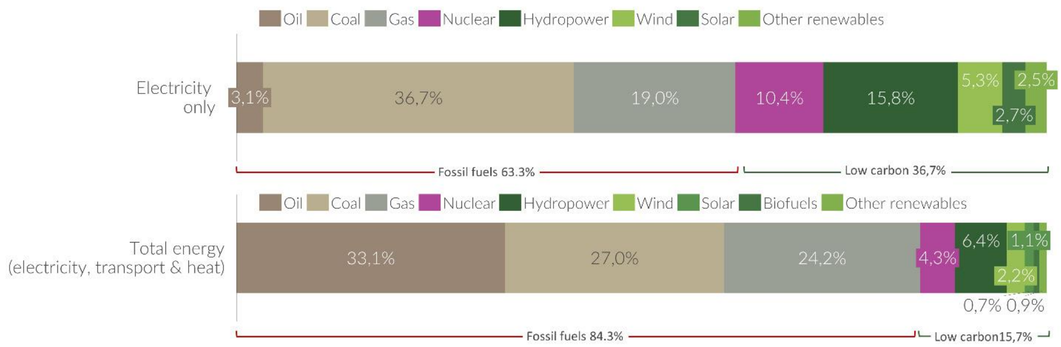


Figure 7.3 – Share of low-carbon sources in electricity and total energy

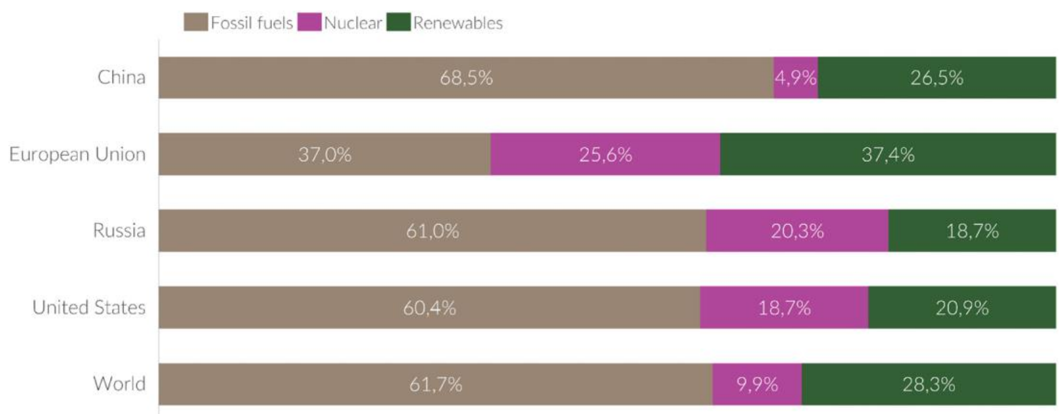


Figure 7.4 – Breakdown of per capita electricity from fossil fuels, nuclear, and renewables

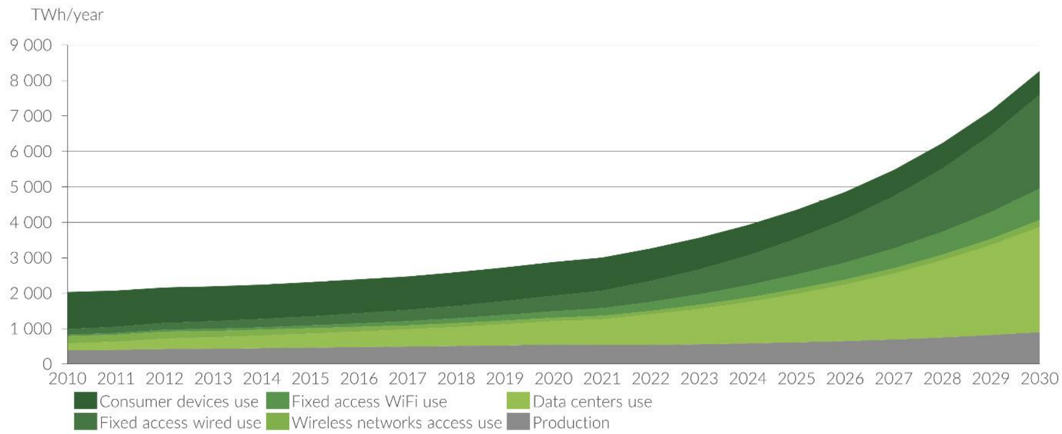


Figure 7.5 – Global ICT electricity supply forecast (TWh) 2010-2030

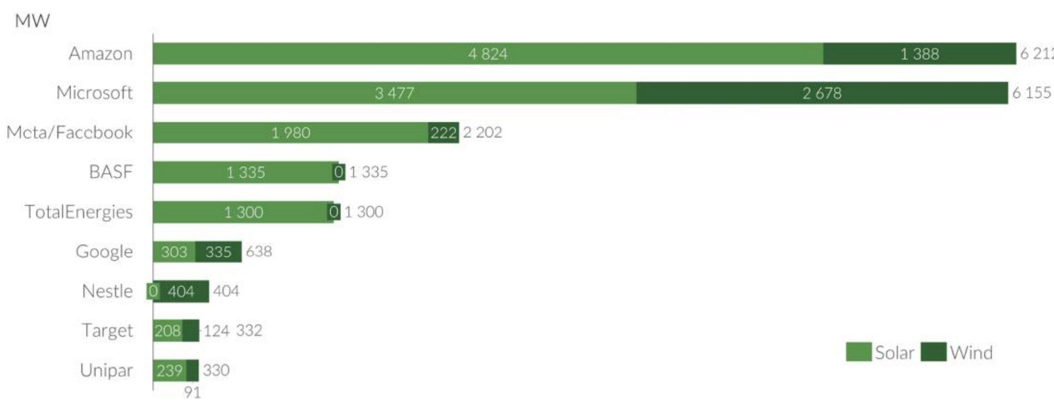


Figure 7.6 – Top corporate buyers of clean energy in 2021 (BloombergNEF 2022)

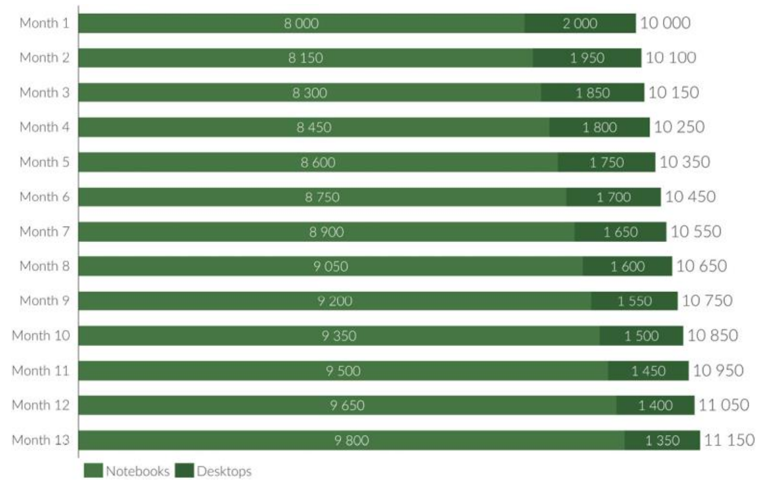


Figure 7.7 – Distribution of notebooks and desktops over a rolling 12-month cycle

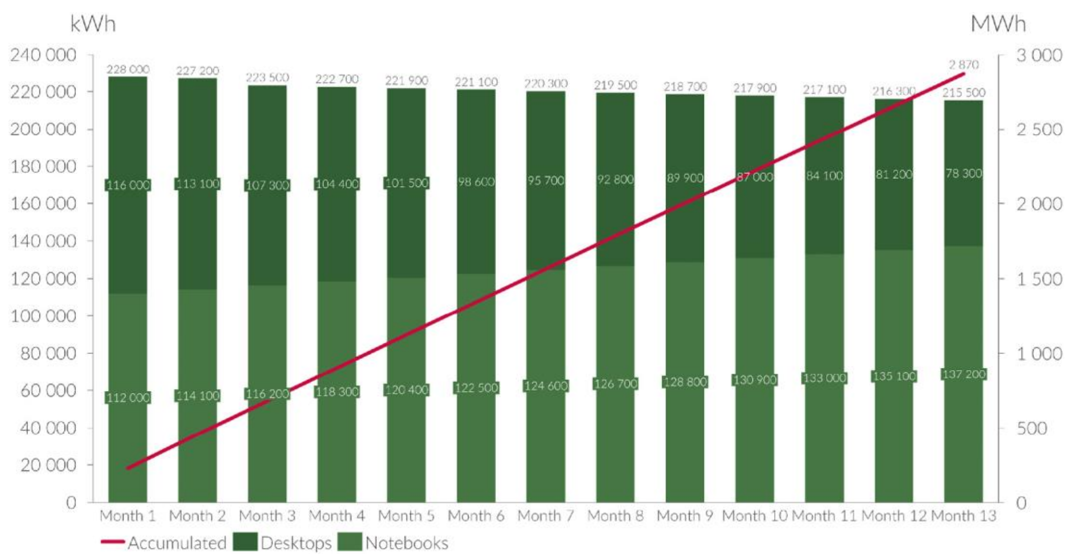


Figure 7.8 – Energy consumption over a rolling 12-month cycle

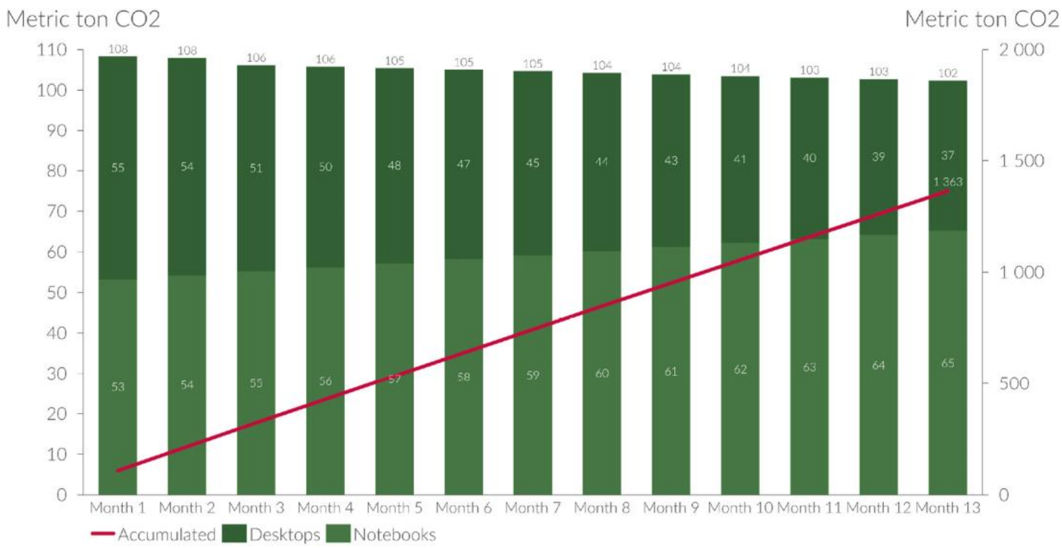


Figure 7.9 – Carbon dioxide emission 12-month rolling cycle

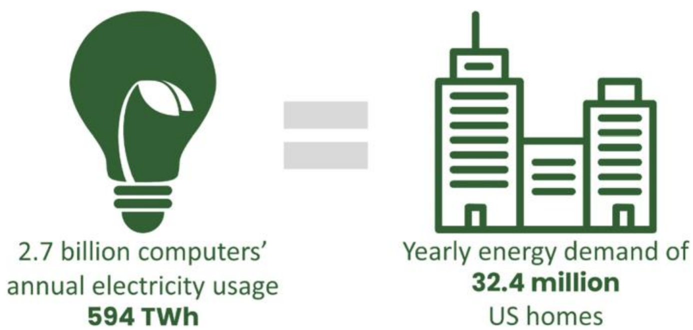


Figure 7.10 – Global energy consumption of the world’s computers equals hourly energy demand

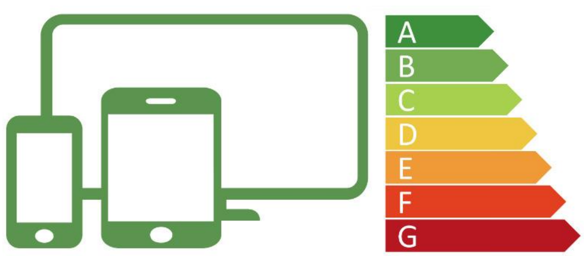


Figure 7.11 – Example of energy rating label

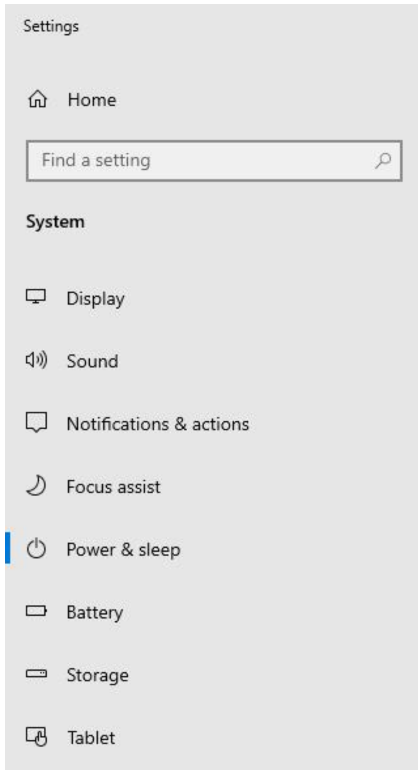


Figure 7.12 – Windows 10 power management settings

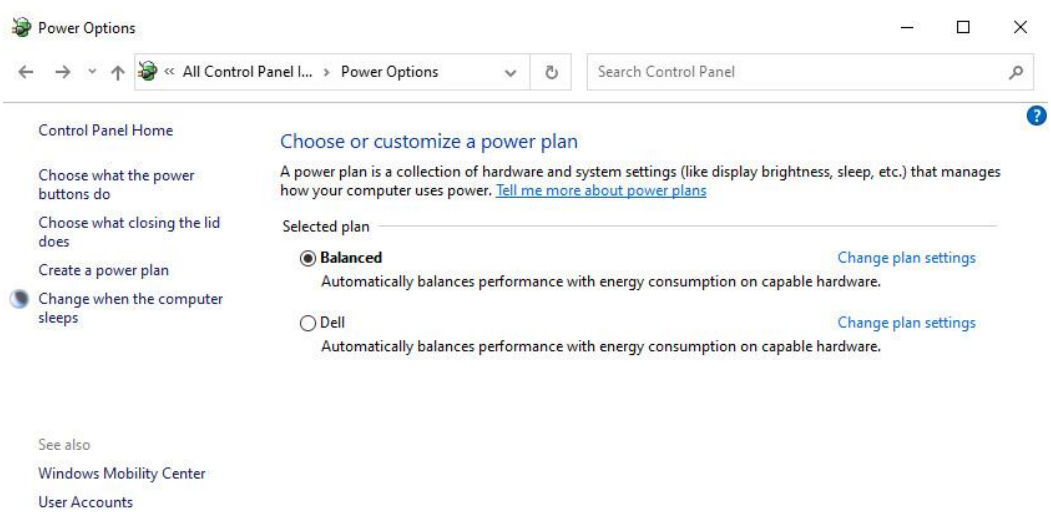


Figure 7.13 – Windows 10 Power Options settings

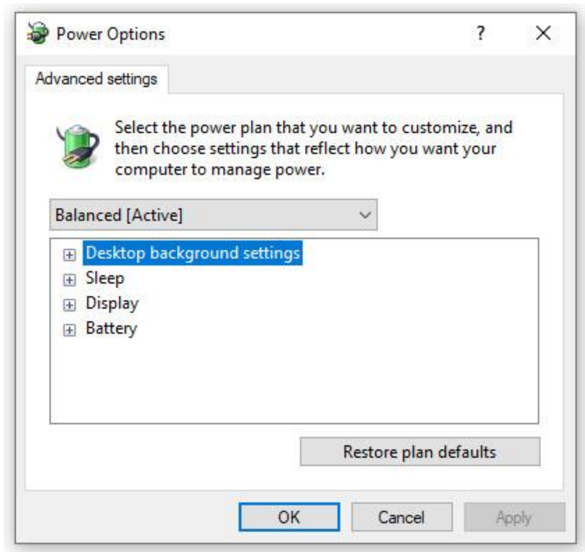


Figure 7.14 – Windows 10 Advanced power settings

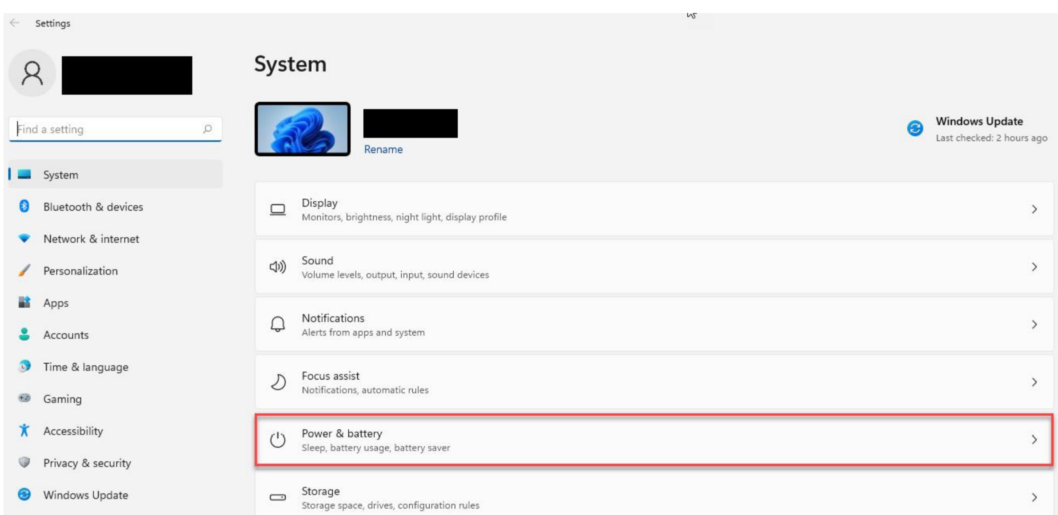


Figure 7.15 – Windows 11 system settings

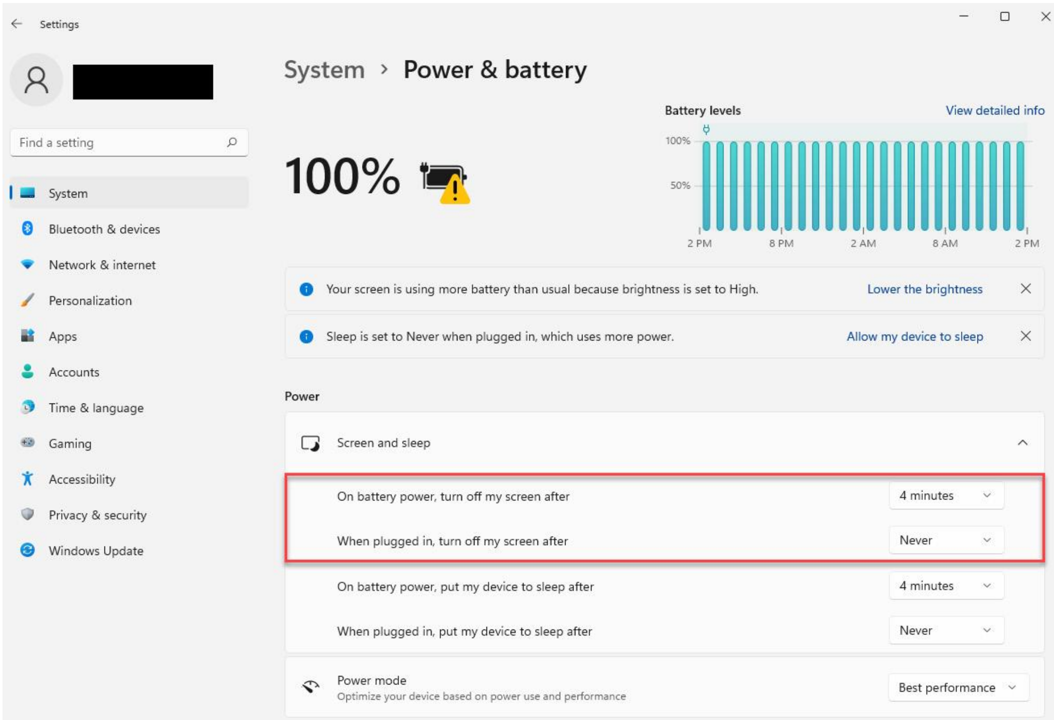


Figure 7.16 – Windows 11 Power & battery settings – changing the screen time setting

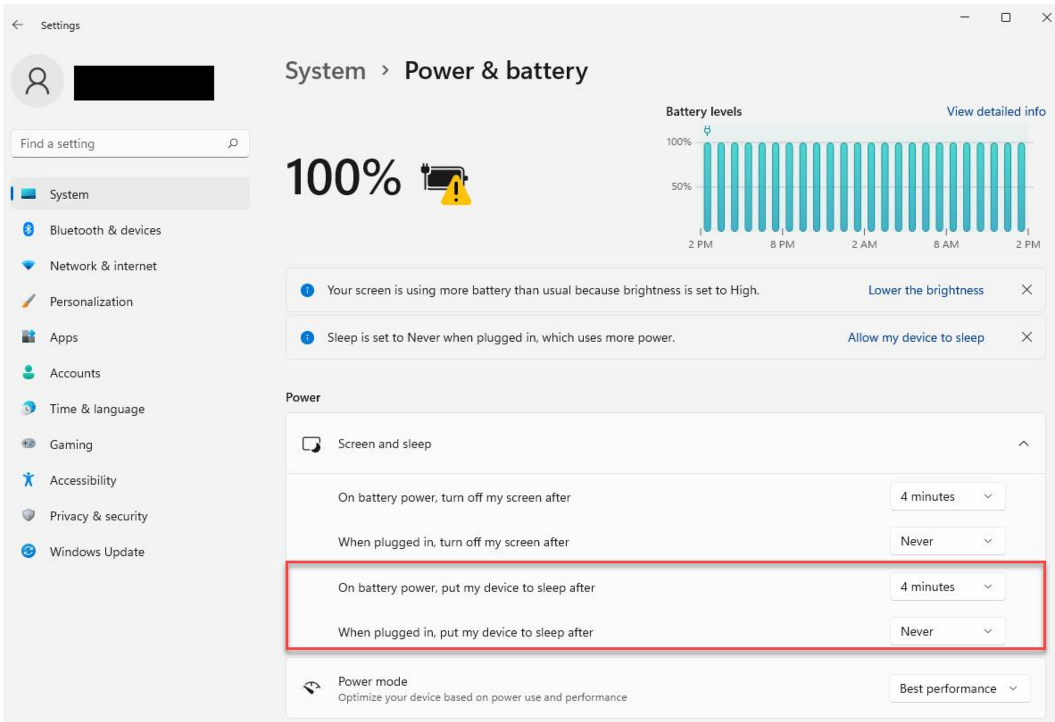


Figure 7.17 – Windows 11 Power & battery settings – changing the sleep mode setting

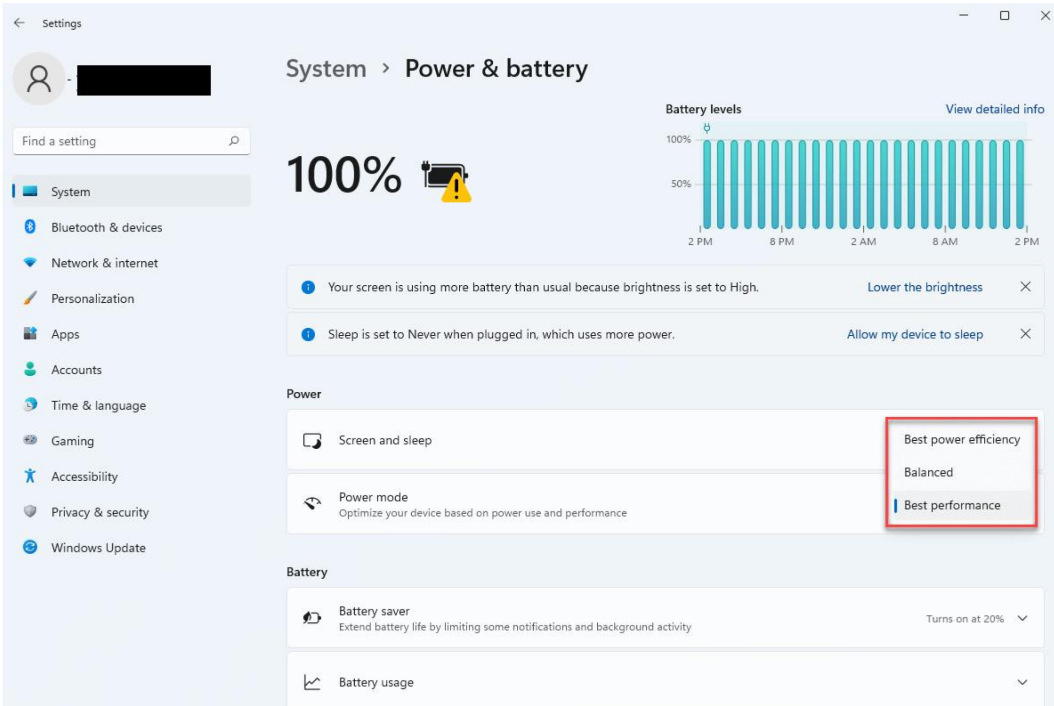


Figure 7.18 – Windows 11 Power & battery settings – changing power modes

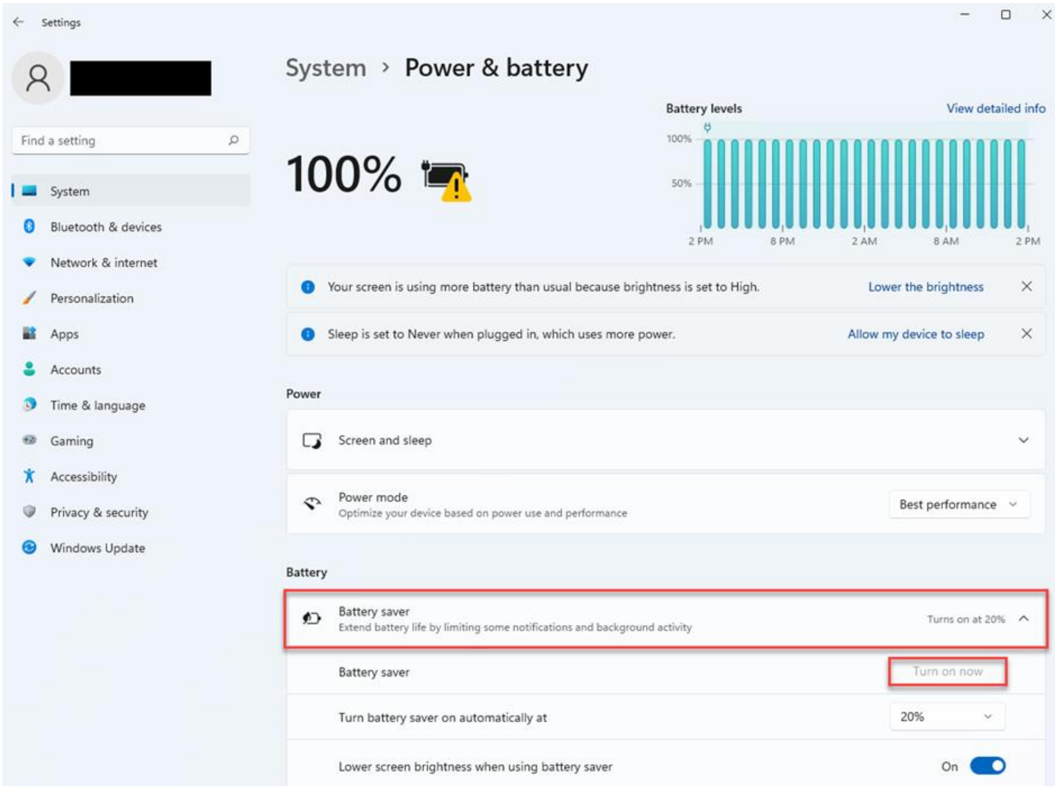


Figure 7.19 – Windows 11 Power & battery settings – enabling battery saver manually

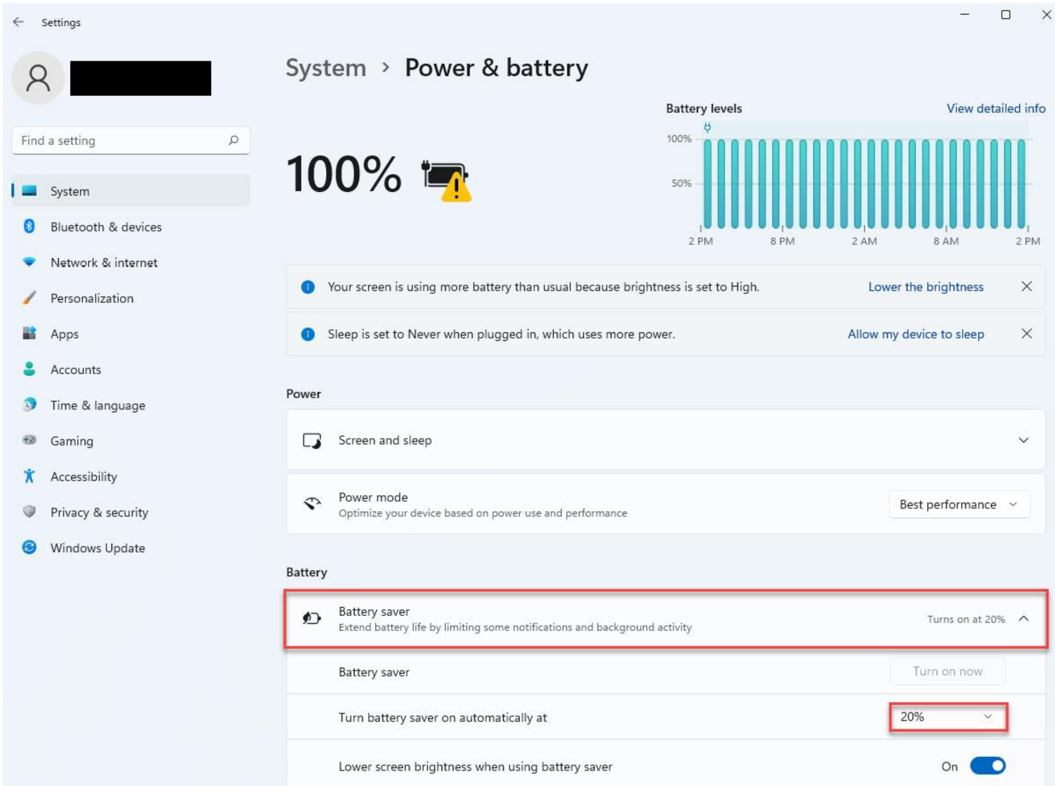


Figure 7.20 – Windows 11 Power & battery settings – enabling battery saver automatically

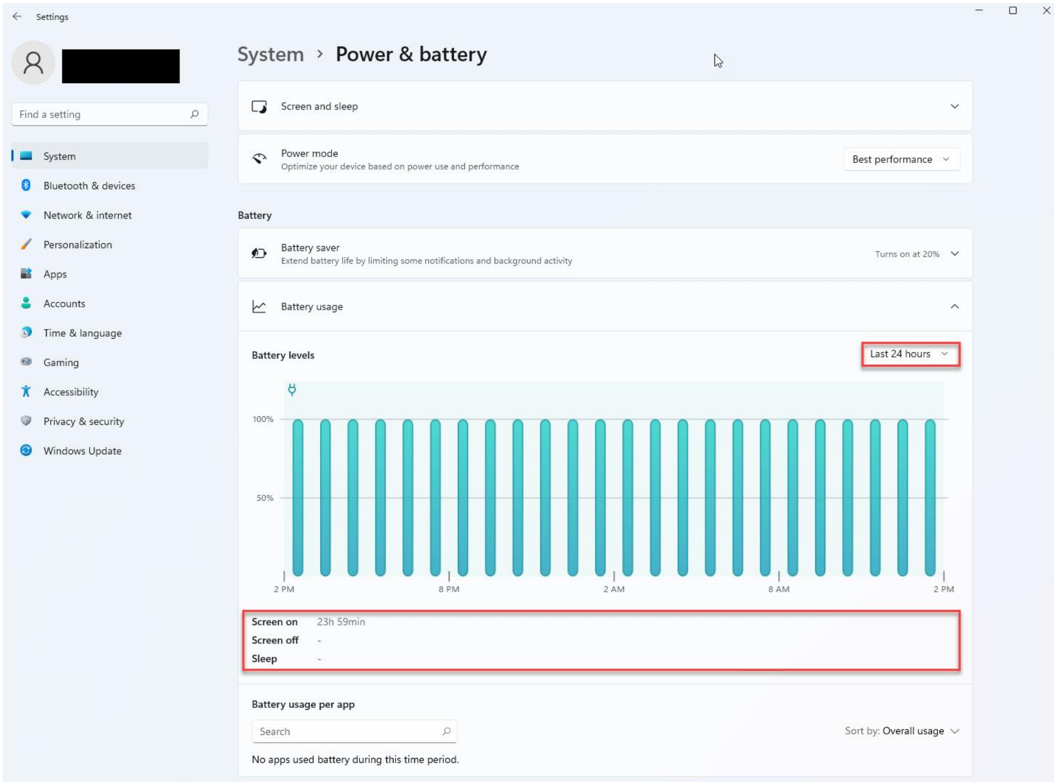


Figure 7.21 – Windows 11 Power & battery settings – battery usage

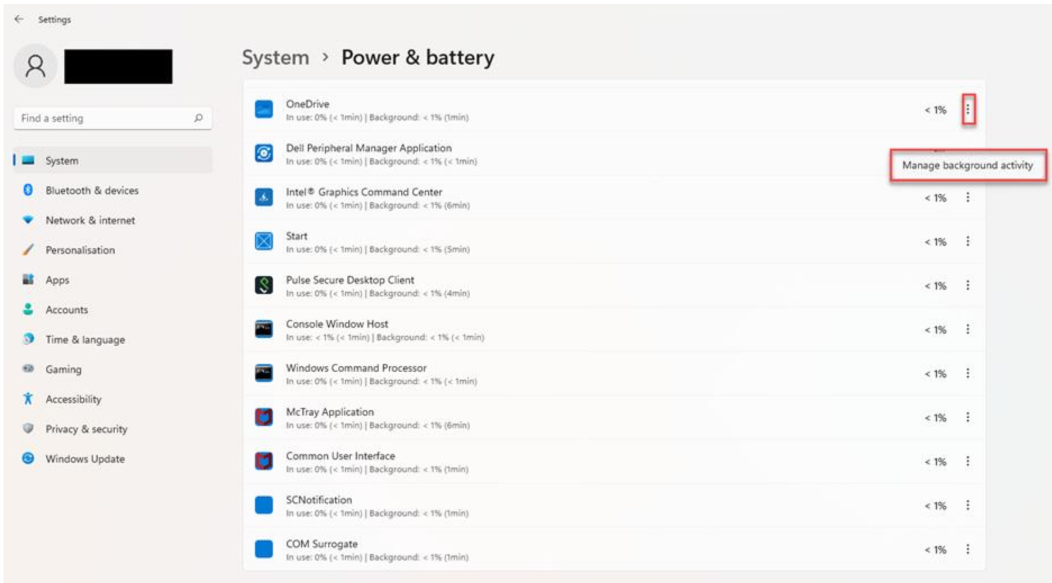


Figure 7.22 – Windows 11 Power & battery settings – managing apps background activities

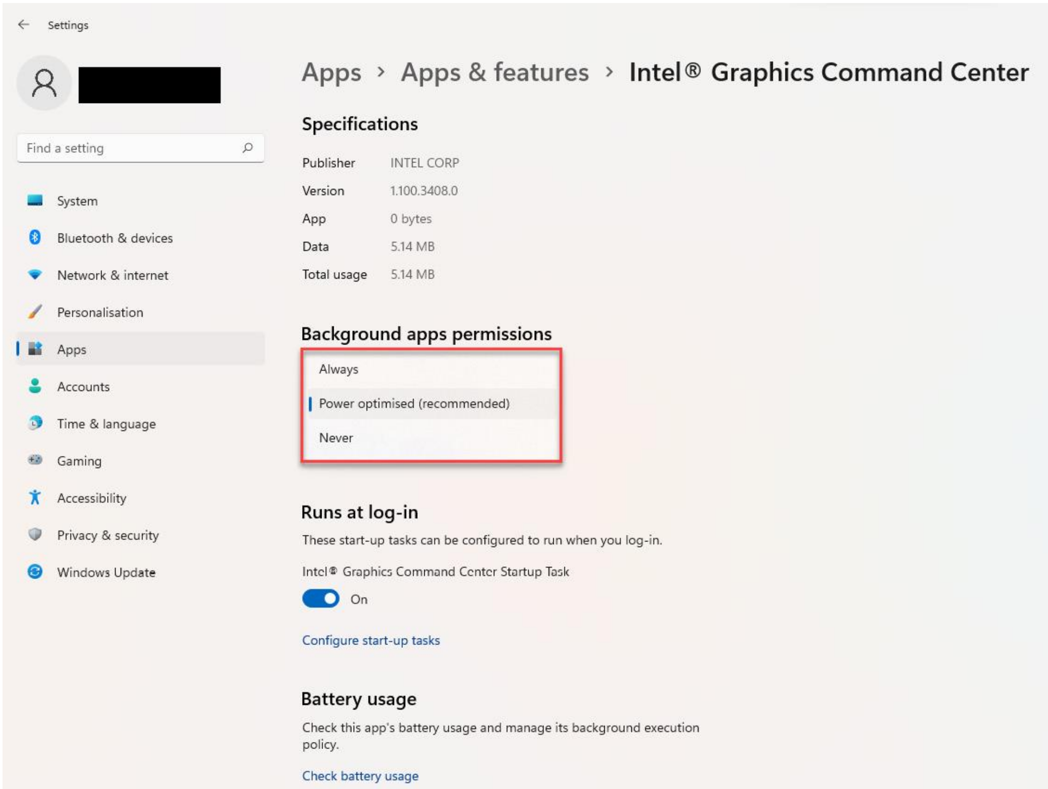


Figure 7.23 – Windows 11 Power & battery settings – managing background apps permissions

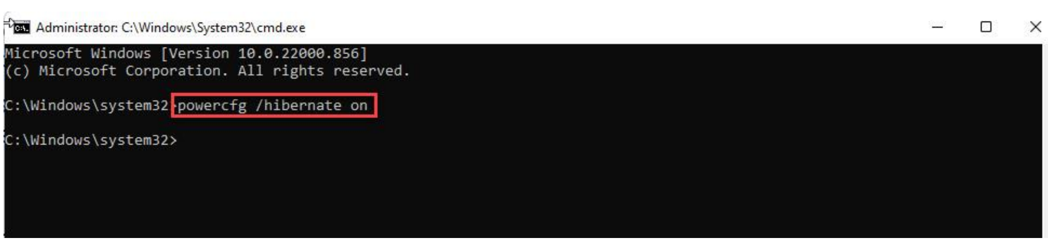


Figure 7.24 – Windows 11– Command Prompt – enabling hibernation

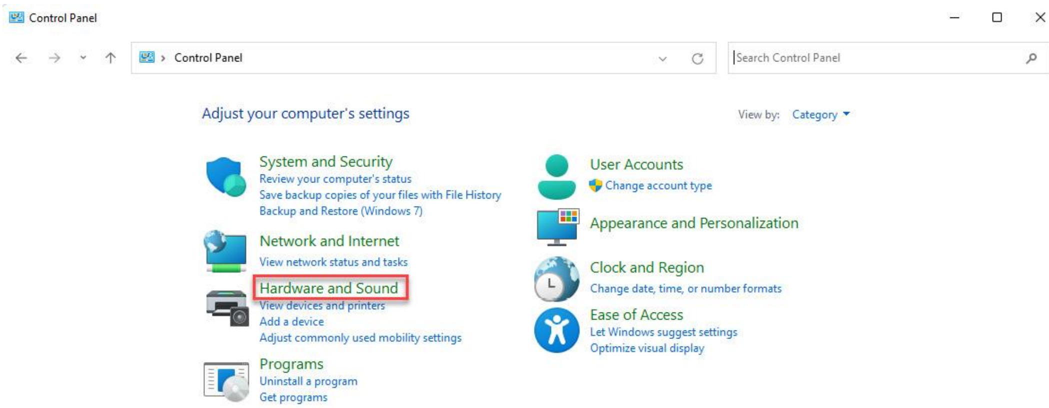


Figure 7.25 – Windows 11– Control Panel – Hardware and Sound

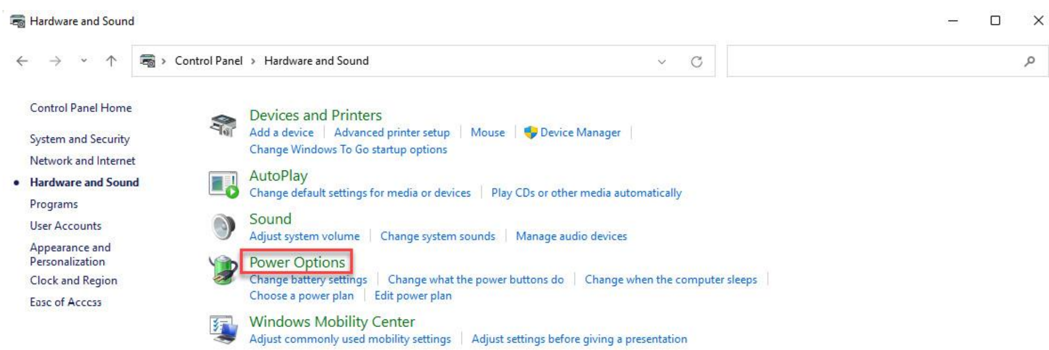


Figure 7.26 – Windows 11 – Control Panel – Hardware and Sound – Power Options

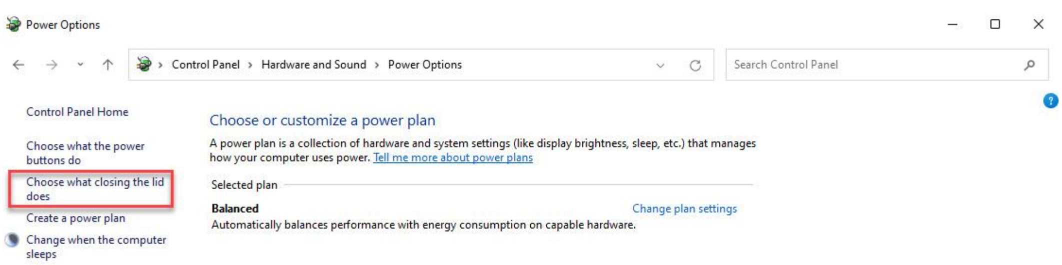


Figure 7.27 – Windows 11 – Control Panel – Hardware and Sound – Power Options – Choose what closing the lid does

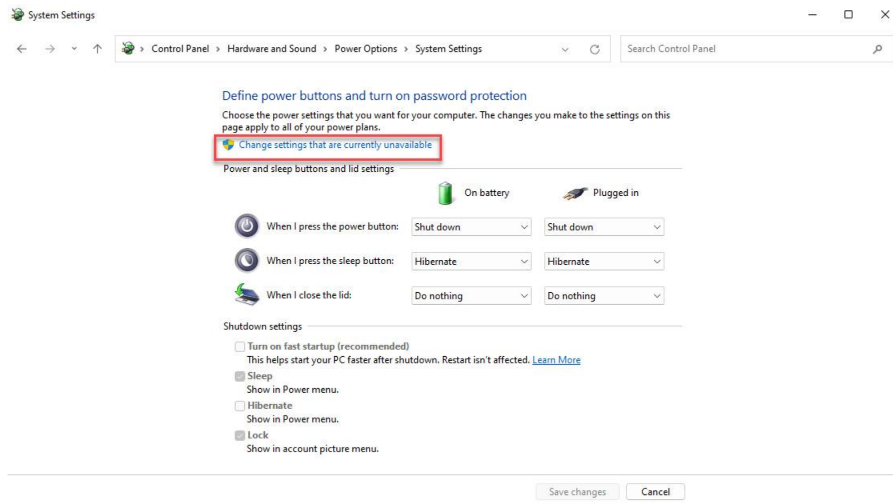


Figure 7.28 – Windows 11 – Control Panel – Hardware and Sound – Power Options – System Settings – Change settings that are currently unavailable

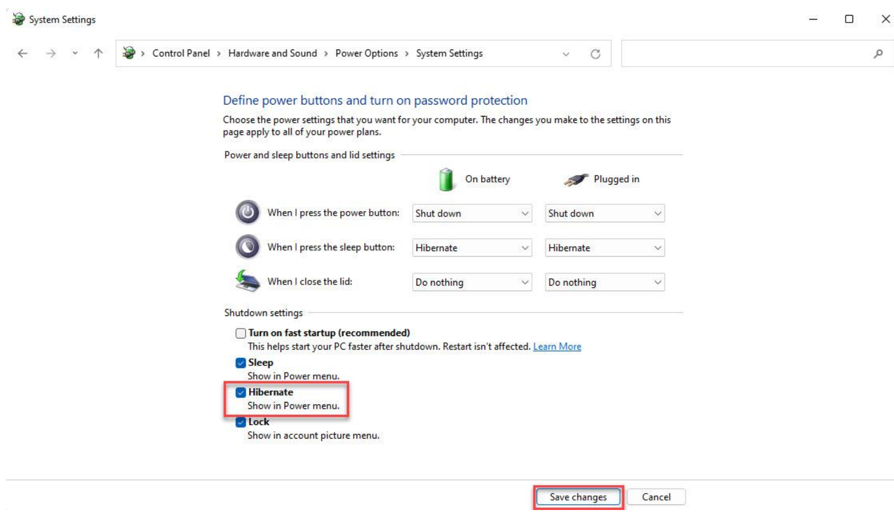


Figure 7.29 – Windows 11 – Control Panel – Hardware and Sound - Power Options – System Settings – Hibernate

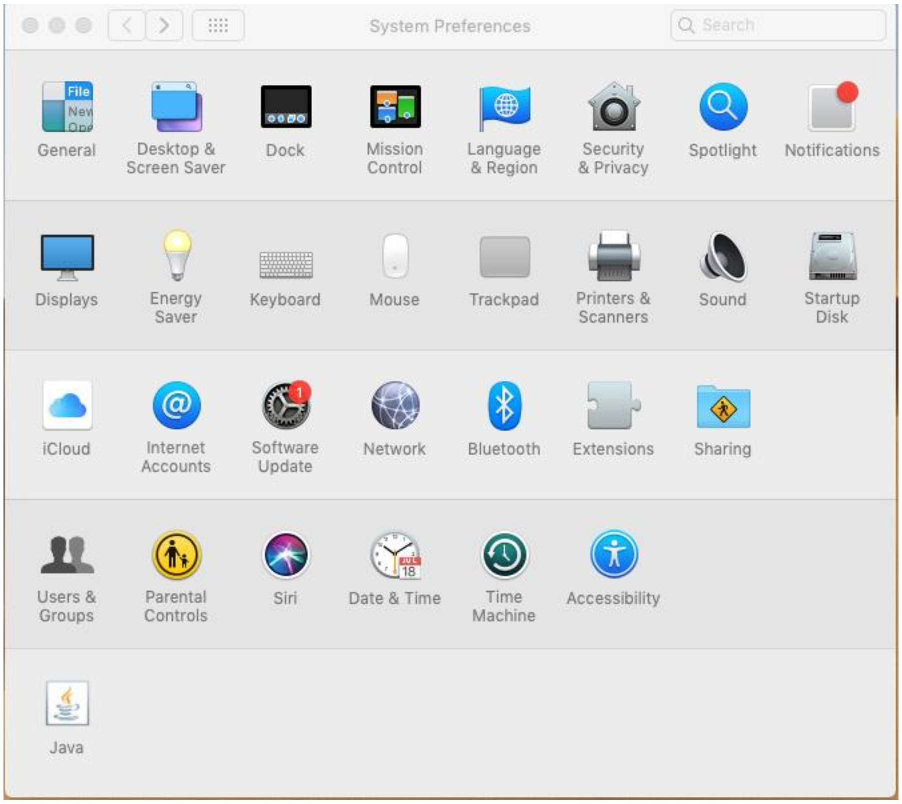


Figure 7.30 – macOS system preferences energy saver

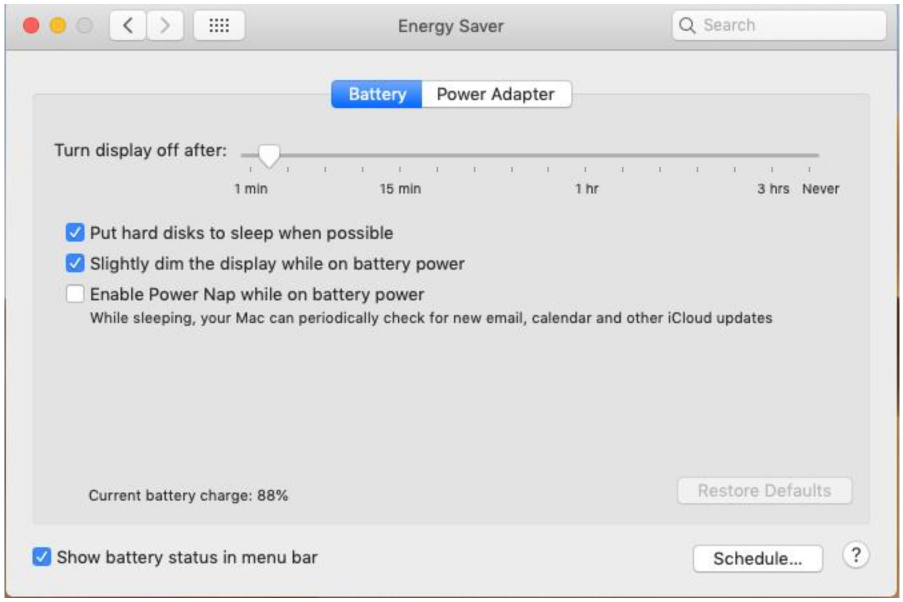


Figure 7.31 – macOS Energy Saver Battery

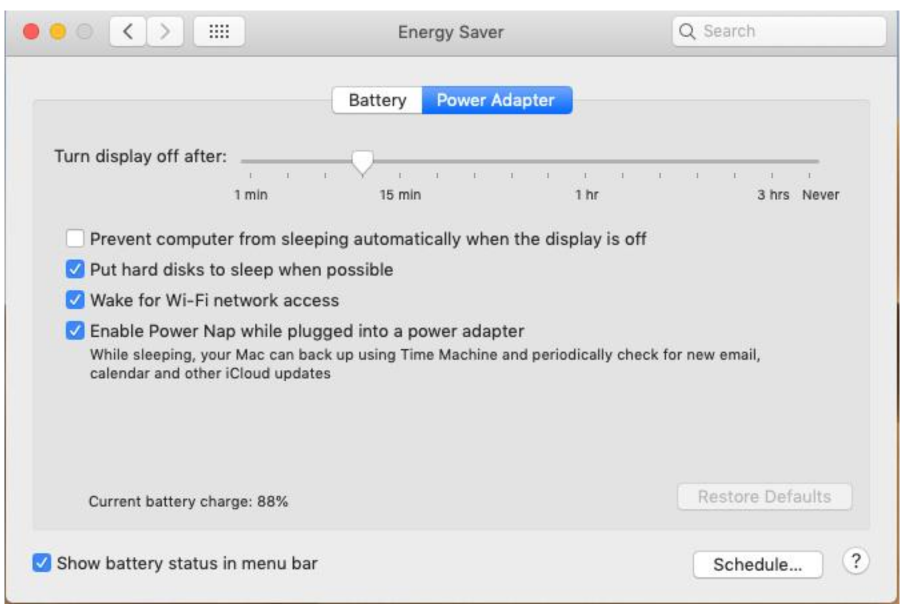


Figure 7.32 – macOS Energy Saver Power Adapter

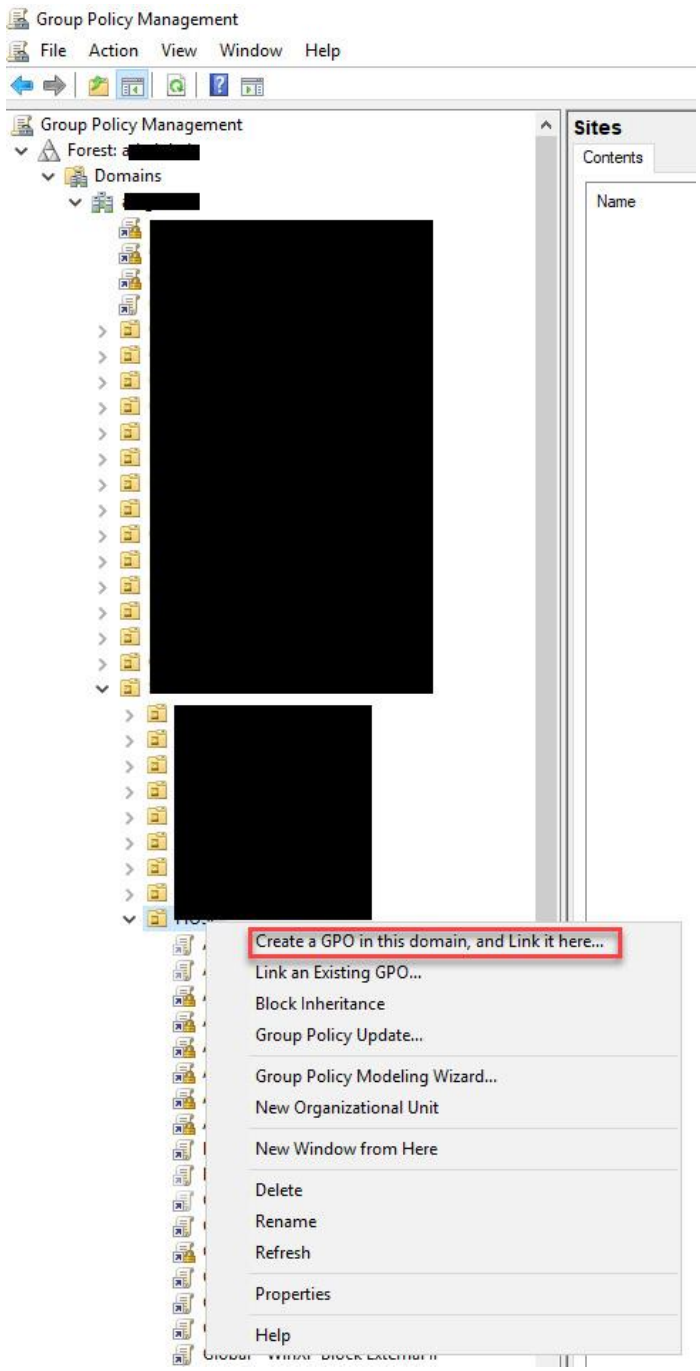


Figure 7.33 – Group Policy Management – Create a group policy object (GPO)

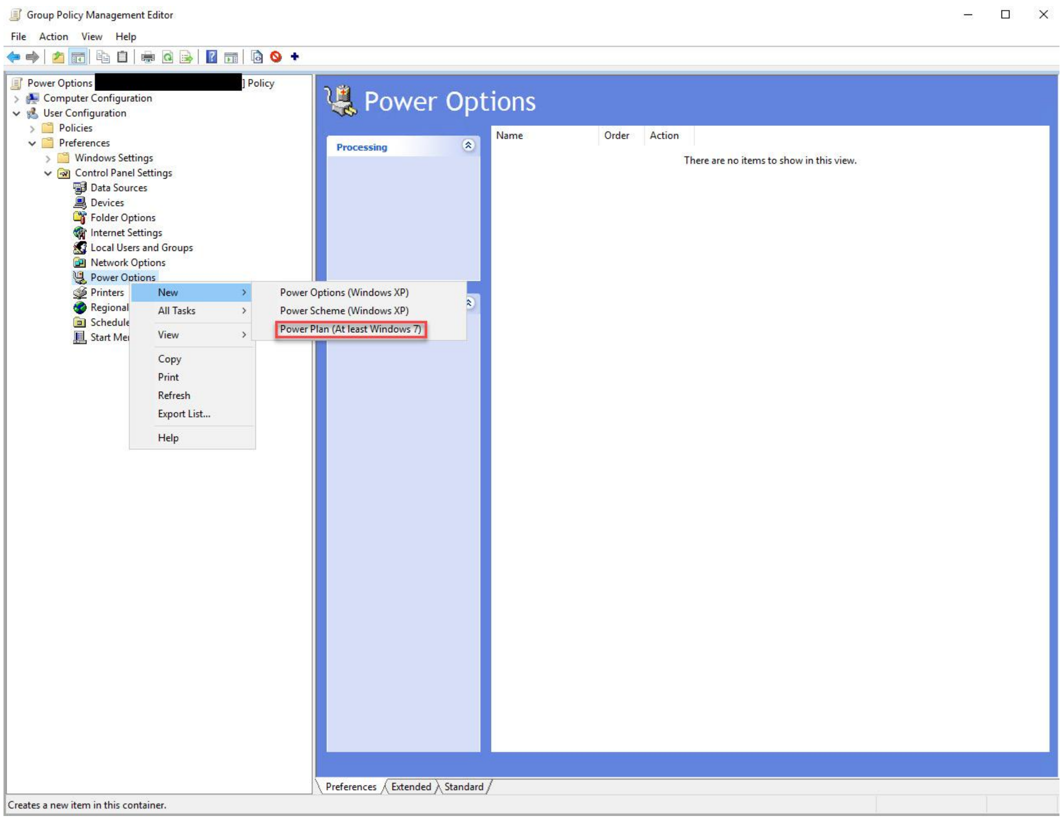


Figure 7.34 – Group Policy Management – Creating a power plan

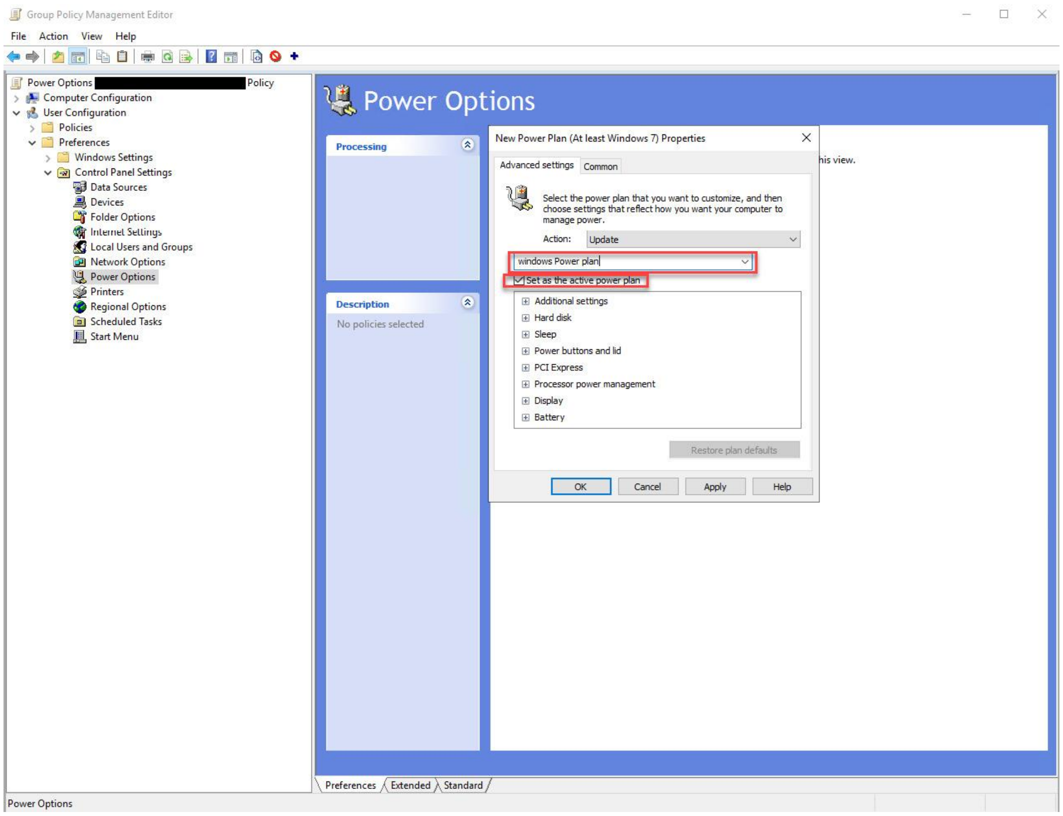


Figure 7.35 – Group Policy Management – Set as the active power plan

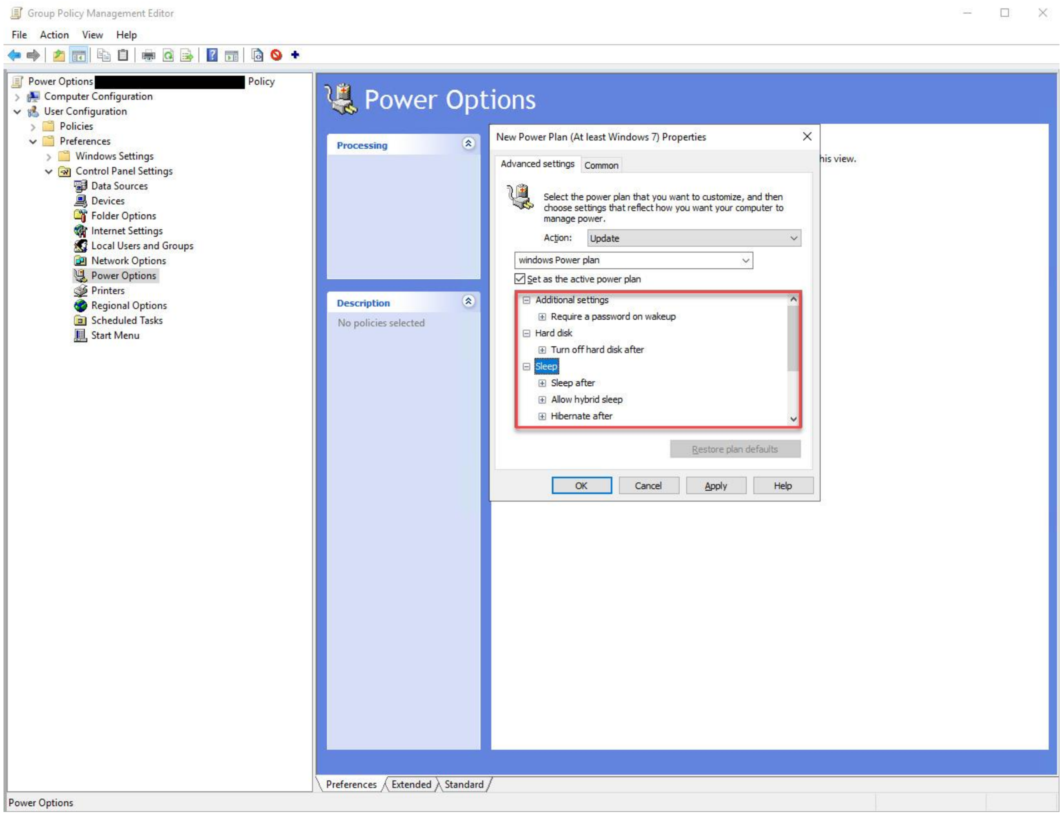


Figure 7.36 – Group Policy Management – Selecting desired power options

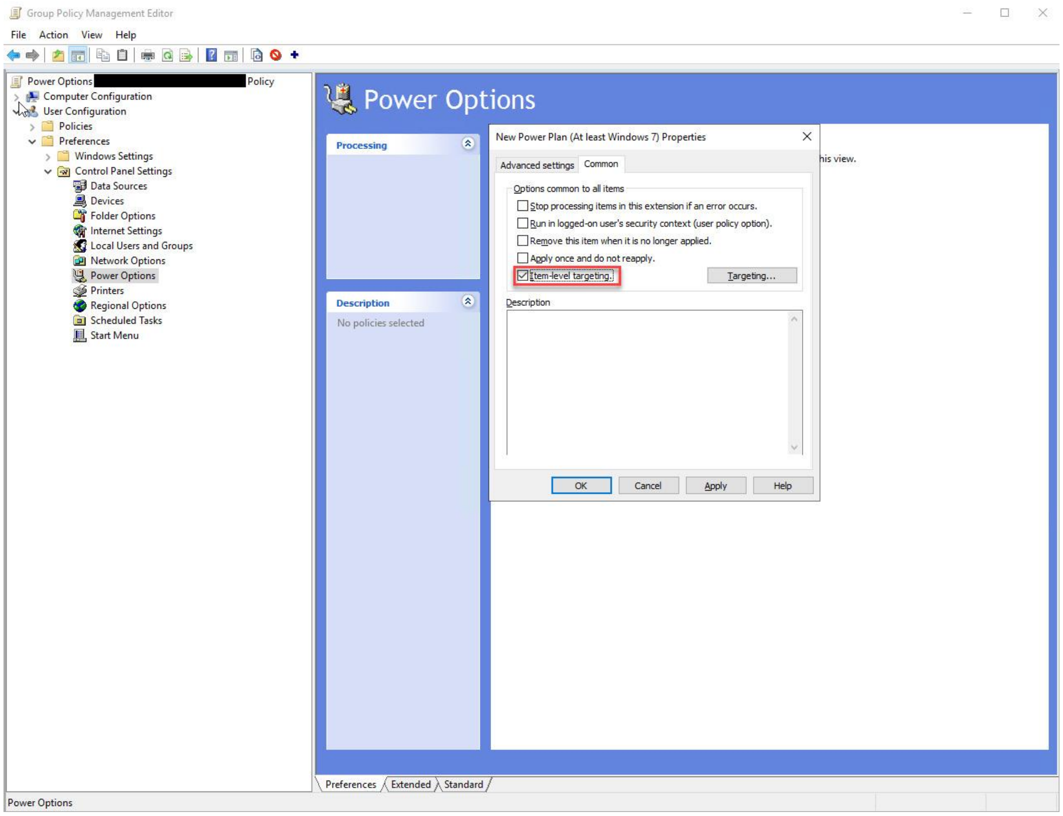


Figure 7.37 – Group Policy Management – Item-level targeting

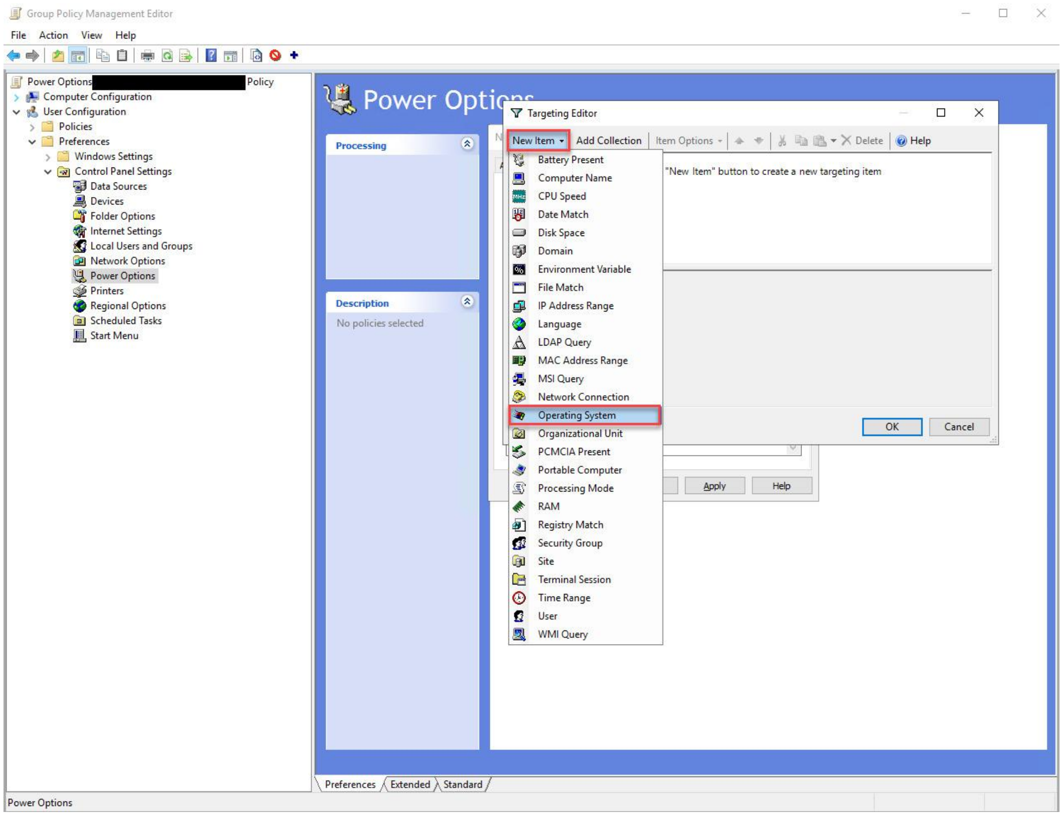


Figure 7.38 – Group Policy Management – Configuring operating systems

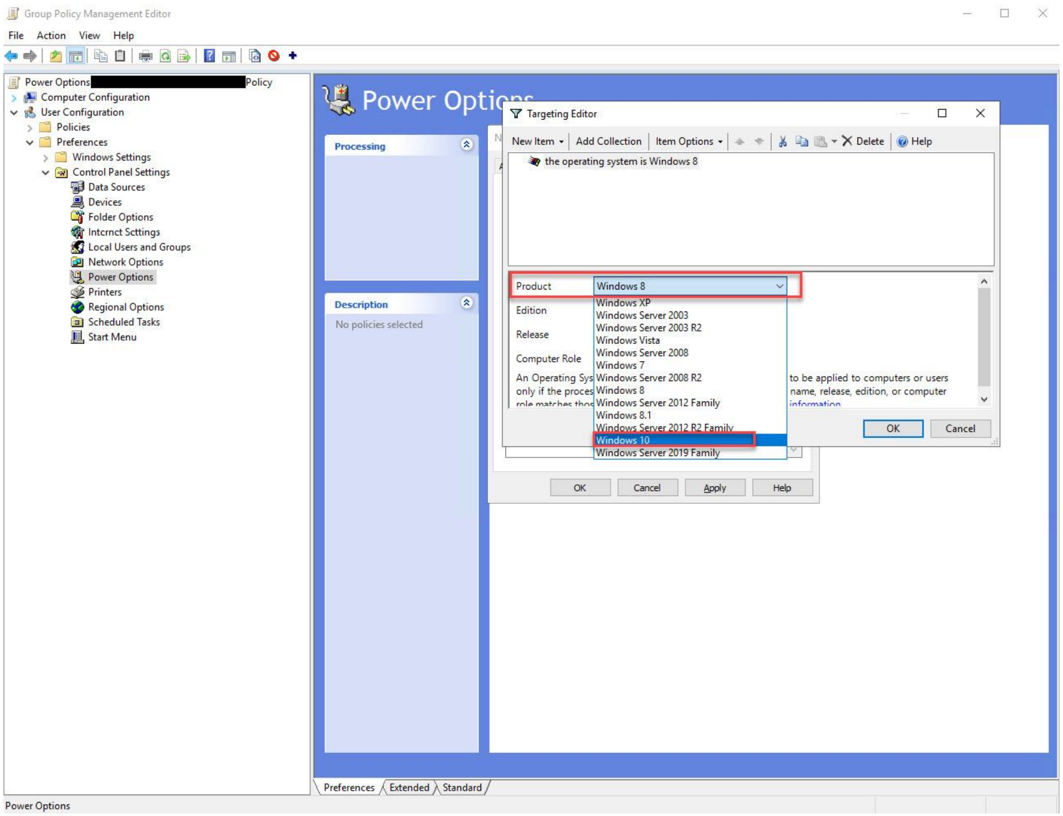


Figure 7.39 – Group Policy Management – Selecting operating systems

Tables

ICT Device	Energy Demand (Yearly TEC kilo-watt hour)
Desktop PC	58
Notebook/Laptop	14
Tablet PC	12
Smartphone	3.5
Home Gateway	7.2
Screens	56.5

Enterprise Server	1,760
Enterprise Storage	4,467

Table 7.1 – Annual consumption of a typical Energy Star-certified IT hardware in the use phase

ICT Device	Energy Consumption	Carbon Emission	Carbon sequestrian
	(kilo-watt hour)	(mega ton of CO2)	(trees)
Notebook (Low)	110 kilo-watt hour	0.05	4.5
Notebook (High)	220 kilo-watt hour	0.1	9
Desktop	440 kilo-watt hour	0.21	19
Server	2,102 kilo-watt hour	1.00	91

Table 7.2 – Summary of yearly energy consumption and carbon emission of ICT devices

ICT device	Turned on	Sleep mode
	kilo-watt hour/hour	kilo-watt hour/hour
Notebook	0.02	0.001
Desktop	0.07	0.003

Table 7.3 – IT hardware comparison between turned on and sleep mode

Formulas

Formula 7.1 - calculate the annual consumption of energy in kilo-watt hour

$$\left(\left[\frac{the\ capacity\ of\ appliance\ expressed\ in\ watt}{1000}\right]\right) \times [\#\ of\ hours'use] \times [\#\ of\ days'use] = \#\ of\ kWh$$

Formula 7.2 - calculate carbon emissions expressed in metric tons:

$$[number\ of\ kWh] \times [carbon\ intensity\ MTCO2/kWh] = carbon\ emission\ MtCO2$$

Formula 7.3 - calculate the number of trees per year:

$$\frac{Carbon\ emission\ MtCO2}{0.011\ MtCO2\ tree\ year} = \#\ trees\ per\ year$$

Formula 7.4 – Yearly energy consumption calculation of the world's computers

$$\left(\left[\frac{100}{1{,}000}\right]\right) \times [8] \times [275]\ \times 2{,}700{,}000{,}000 = 594{,}000{,}000{,}000\ \ kWh\ (kilowatt\ hours)$$
$$= 594{,}000{,}000\ MWh\ (megawatt\ hours)$$
$$= 594{,}000\ GWh\ (gigawatt\ hours) = 594\ TWh\ (terawatt\ hours)$$

Further reading

- *TCO Certified Product Finder*: https://tcocertified.com/product-finder/
- *Energy Star® Product finder*: https://www.energystar.gov/productfinder/
- *Energy Star Program Requirements for Computers*: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Computers%20Final%20Version%208.0%20Specification%20-%20Rev.%20April%202020_0.pdf
- *Energy Star Program Requirements for Servers*: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Computer%20Servers%20Program%20Requirements_0.pdf

Bibliography

- ACER. 2020. *Estimated number and diversity of supply sources 2020*. Accessed May 26, 2022: https://aegis.acer.europa.eu/chest/dataitems/214/view
- Akbari, H. 2002. "Shade trees reduce building energy use and CO2 emissions from power plants." *Environmental Pollution* 116: 119-126: https://www.sciencedirect.com/science/article/abs/pii/S0269749101002640
- Amazon. 2022. *Renewable Energy*. Accessed May 26, 2022: https://sustainability.aboutamazon.com/environment/sustainable-operations/renewable-energy?energyType=true

- Andrae, Anders S.G. 2020. “New perspectives on internet electricity use in 2030.” *ResearchGate*. June. Accessed April 10, 2022: https://www.researchgate.net/publication/342643762_New_perspectives_on_internet_electricity_use_in_2030
- Andrae, Anders S.G.; Edler, Tomas. 2015. “On Global Electricity Usage of Communication Technology: Trends to 2030.” *Challenges* 6: 117-157. Accessed May 30, 2022: https://www.researchgate.net/publication/275653947_On_Global_Electricity_Usage_of_Communication_Technology_Trends_to_2030
- BloombergNEF. 2021. *2H 2021 Corporate Energy Market Outlook*. Accessed April 01, 2022: https://about.bnef.com/new-energy-outlook/
- —. 2022. *Corporate Clean Energy Buying Tops 30GW Mark in Record Year*. January 31. Accessed May 26, 2022: https://about.bnef.com/blog/corporate-clean-energy-buying-tops-30gw-mark-in-record-year/
- Buchholz, Katharina. 2022. *Which European Countries Depend on Russian Gas?* 2022 Feb. Accessed May 26, 2022: https://www.statista.com/chart/26768/dependence-on-russian-gas-by-european-country/
- Carlsson, Rebecka. 2021. *Exponentiell klimatomställning*. Stockholm: Lava förlag.
- EIA. 2022. *Electric Power Monthly*. March. Accessed June 08, 2022: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a
- Energy Star. 2020. *ENERGY STAR® Program Requirements for Computers*. October 15. Accessed May 27, 2022: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Computers%20Final%20Version%208.0%20Specification%20-%20Rev.%20April%202020_0.pdf
- —. 2019. *ENERGY STAR® Program Requirements for Computer Servers*. June 19. Accessed May 26, 2022:

https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Computer%20Servers%20Program%20Requirements_0.pdf

- Google. 2022. *Environmental Report*. Accessed May 26, 2022: https://www.gstatic.com/gumdrop/sustainability/google-2021-environmental-report.pdf
- Griffin, Andrew. 2020. *More UK energy is coming from clean sources than fossil fuels for the first time, National Grid announces*. independent.co.uk. January 01. Accessed May 26, 2022: https://www.independent.co.uk/climate-change/news/clean-energy-fossil-fuels-national-grid-2019-statistics-latest-a9266116.html
- IEA. 2022. *Data and statistics*. International Energy Agency. May 26. Accessed May 26, 2022: https://www.iea.org/data-and-statistics/charts
- —. 2020. *Global EV Outlook 2020*. June. Accessed May 26, 2022: https://www.iea.org/reports/global-ev-outlook-2020
- —. 2021. *Renewable electricity growth is accelerating faster than ever worldwide, supporting the emergence of the new global energy economy*. December 01. Accessed May 26, 2022: https://www.iea.org/news/renewable-electricity-growth-is-accelerating-faster-than-ever-worldwide-supporting-the-emergence-of-the-new-global-energy-economy
- ITU. 2021. *Statistics*. Accessed June 06, 2022: https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx
- Johnson, Joseph. 2022. May 09. Accessed May 26, 2022: https://www.statista.com/statistics/617136/digital-population-worldwide/
- Markkanen, Aapo. 2021. *What Is Digital Sustainability and How Does It Drive ESG Goals?* November 04. Accessed May 26, 2022: https://www.gartner.com/en/articles/what-is-digital-sustainability-and-how-does-it-drive-esg-goals

- Microsoft. 2022. *2021 Environmental Sustainability Report*. Accessed May 26, 2022: https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE4RwfV
- Miller, Rich. 2022. *Cloud Titans Were the Largest Buyers of Renewable Energy in 2021*. February 11. Accessed May 26, 2022: https://datacenterfrontier.com/cloud-titans-were-the-largest-buyers-of-renewable-energy-in-2021/
- Müller-Kraenner, Sascha. 2007. *Energy security Re-measuring the World*. London: Earthscan.
- Ritchie, Hannah. 2020. *Sector by sector: where do global greenhouse gas emissions come from?* Our World in Data. September 18. Accessed March 30, 2022: https://ourworldindata.org/ghg-emissions-by-sector
- Ritchie, Hannah, and Max Roser. 2020. *Electricity Mix*. ourworldindata.org. Accessed May 26, 2022: https://ourworldindata.org/electricity-mix#citation
- United States Census Bureau. 2021. *QuickFacts United States*. Accessed June 06, 2022: https://www.census.gov/quickfacts/fact/table/US/HSD410220
- Vailshery, Lionel Sujay. 2021. *IoT and non-IoT connections worldwide 2010-2025*. 2021 March. Accessed May 26, 2022: https://www.statista.com/statistics/1101442/iot-number-of-connected-devices-worldwide/
- —. 2021. *IoT and non-IoT connections worldwide 2010-2025*. 2021 March. Accessed May 26, 2022: https://www.statista.com/statistics/1101442/iot-number-of-connected-devices-worldwide/

Chapter 8

Images

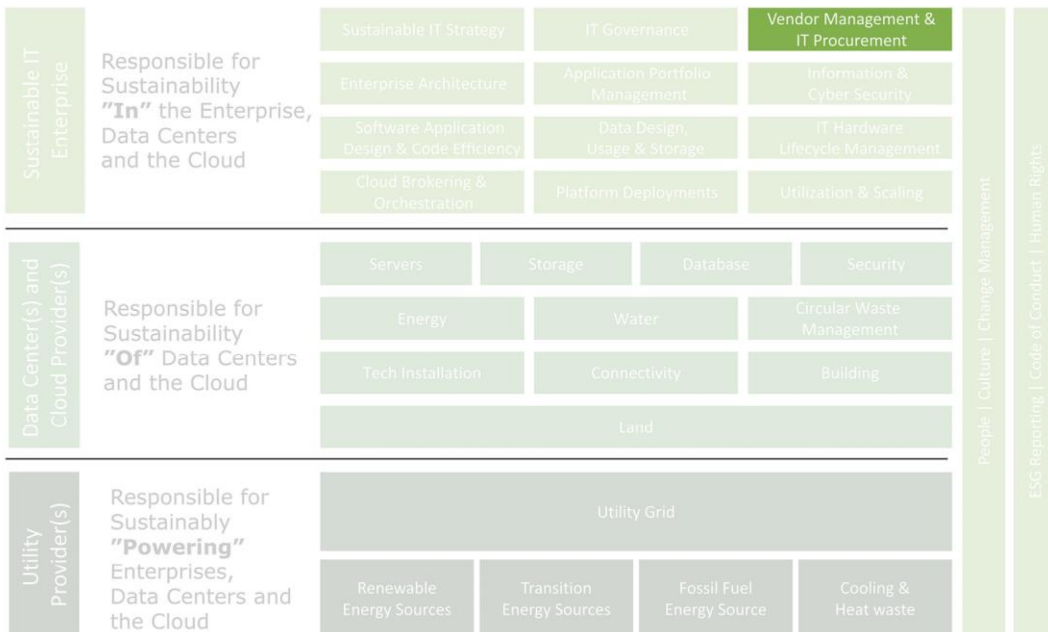


Figure 8.1 – Sustainable IT reference model – Chapter 8 focus

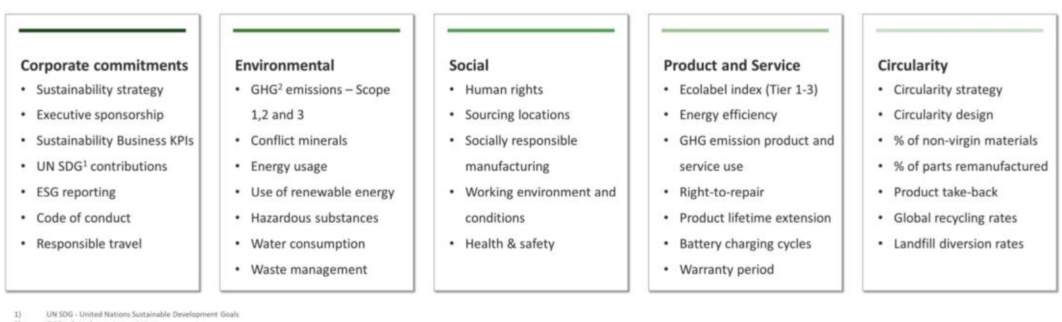


Figure 8.2 – Key IT sustainability requirements

Figure 8.3 – Sustainable IT procurement – a three-step process

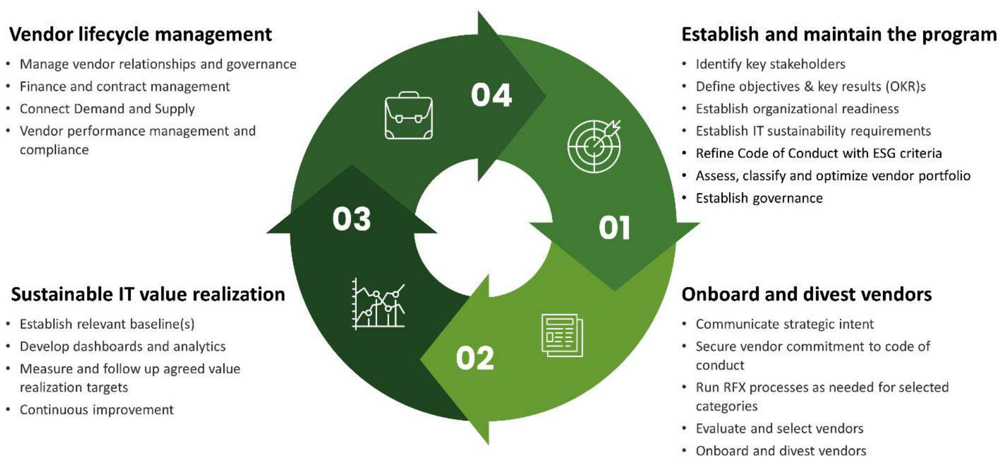


Figure 8.4 – Sustainable IT vendor management program

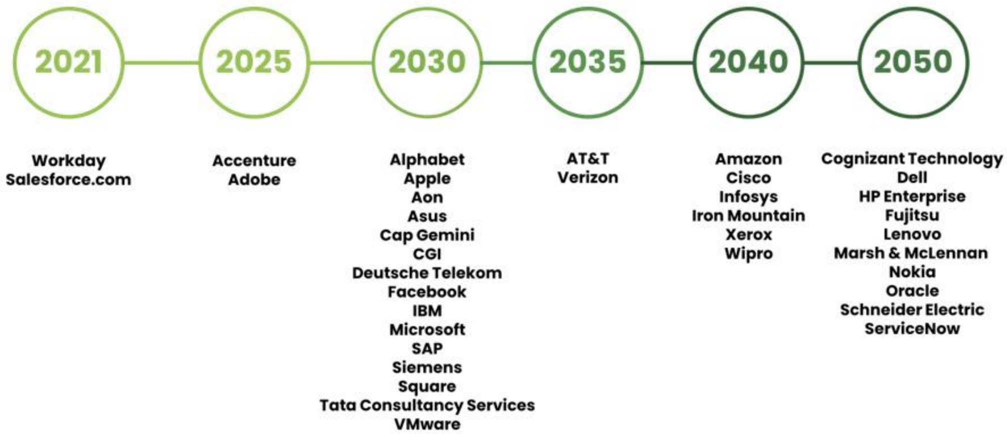


Figure 8.5 – Net-zero ambitions of major ICT companies

Description	Metric	General Requirement	United Nations Sustainable Development Goals Alignment
Energy Consumption	GWh mtCO2e	**CUE** Carbon Usage Effectiveness	7. Affordable and Clean Energy 13. Climate Action
Renewable Energy	%	**REF** Renewable Energy Factor	9. Industry, Innovation and Infrastructure 12. Responsible Consumption and Production
Power Usage Effectiveness	PUE	**PUE** Power Usage Effectiveness	12. Responsible Consumption and Production 13. Climate Action
Sustainable Water	WUE	**WUE** Water Usage Effectiveness	6. Clean Water and Sanitation
Waste Management	Ton %	**ERF - EDE** Energy Reuse Factor Electronics Disposal Efficiency Reduce – Reuse - Recycle	12. Responsible Consumption and Production

Figure 8.6 – Data center sustainability scorecard

Description	Metric	General Requirement	United Nations Sustainable Development Goals Alignment
GHG emissions	$kgCO_2$	Product Greenhouse gas emission	12. Responsible Consumption and Production 13. Climate Action
Equipment lifetime	Years	Equipment lifetime years	12. Responsible Consumption and Production 13. Climate Action
Renewable energy	%	**REF** Renewable Energy Factor	7. Affordable and clean energy 9. Industry, Innovation, and Infrastructure 12. Responsible Consumption and Production
Circular economy reuse and repair	%	**Reuse and Repair** % equipment reused	12. Responsible Consumption and Production 13. Climate Action
Zero waste to landfill	WUE	**Recycle** % equipment reused	12. Responsible Consumption and Production 13. Climate Action
Hazardous substances	%	**Hazardous Substances** % equipment with hazardous substances	12. Responsible Consumption and Production 13. Climate Action

Figure 8.7 – IT hardware sustainability scorecard

Further reading

To learn more about the topics that were covered in this chapter, take a look at the following resources:

- ASF Leadership for Change: https://www.atea.se/atea-sustainability-focus/leadership-for-change/
- Clean Electronics Production Network: http://www.centerforsustainabilitysolutions.org/clean-electronics
- Dutch **Sustainable Public Procurement** (**SPP**): https://www.mvicriteria.nl/en/webtool?cluster=1#//7/1//en
- Epeat: https://www.epeat.net/

- Energy Star: https://www.energystar.gov/
- European Union Green Public Procurement: https://ec.europa.eu/environment/gpp/index_en.htm
- European Union Data Centres Code of Conduct: https://e3p.jrc.ec.europa.eu/communities/data-centres-code-conduct
- UK Public Sector: Greening Government ICT and Digital Service Strategy: https://www.gov.uk/government/publications/greening-government-ict-and-digital-services-strategy-2020-2025
- International Labor Organization – Eight Fundamental Conventions: https://www.ilo.org/global/standards/introduction-to-international-labour-standards/conventions-and-recommendations/lang--en/index.htm
- **Responsible Business Alliance** (**RBA**): https://www.responsiblebusiness.org/
- TCO Certified: https://tcocertified.com/
- TCO Certified Accepted Substance List: https://tcocertified.com/industry/accepted-substance-list/
- United Nations Convention on the Rights of the Child: https://www.ohchr.org/en/instruments-mechanisms/instruments/convention-rights-child

Bibliography

- Capgemini research institute. 2021. *Sustainable IT - Why it's time for a Green revolution for your organization's IT*. Capgemini research institute.
- Circularity gap. 2020. *Our world is now only 8.6% circular*. CGR. Accessed March 04, 2022. https://www.circularity-gap.world/updates-collection/circle-economy-launches-cgr2020-in-davos
- Coeus Consulting. 2022. *CIO and IT Leadership Survey 2022 - The critical role of technology leaders in delivering on sustainability targets*. Accessed June 13,

2022.
https://f.hubspotusercontent10.net/hubfs/3969064/CIO%20&%20IT%20Leadership%20Survey%202022%20-%20Coeus%20Consulting.pdf?hsCtaTracking=702ec559-7a9a-4dd2-972d-bbbbd1cc4731%7C90eceb9c-6dd4-42b1-b891-8688d1b0dd70

- Kirchherr, Julian, M.P. Hekkert, and Reike Denise. 2017. "Conceptualizing the Circular Economy: An Analysis of 114 Definitions." *Researchgate.net*. September. Accessed May 12, 2022. https://www.researchgate.net/publication/320074659_Conceptualizing_the_Circular_Economy_An_Analysis_of_114_Definitions

- Tech Monitor. 2021. *Technology Leaders Agenda 2021*. Accessed 06 13, 2022. https://techmonitor.ai/whitepapers/technology-leaders-agenda-2021

Chapter 9

Images

Figure 9.1 – Sustainability by IT: 10 key areas for indirect carbon dioxide (CO2) emission reduction

Figure 9.2 – Moving from product-centric to subscription service-centric business model (Zoura 2022)

Figure 9.3 – Hack for Earth innovation process: Dream-Hack-Build

Further reading

If you would like to know more, please refer to the following resources:

- Decathlon sustainability: https://sustainability.decathlon.com/
- Zoura—Environmental Social Governance: https://investor.zuora.com/Environmental-Social-Governance/default.aspx
- Dream for Earth: https://dreamforearth.com/
- Dryad: https://www.dryad.net/
- Hack for Earth challenges: https://www.hackforearth.com/challenges
- Microsoft Cloud for Sustainability: https://www.microsoft.com/en-us/sustainability/cloud
- SAP Sustainability Control Tower: https://www.sap.com/products/sustainability-control-tower.html
- Salesforce Net Zero Cloud: https://www.salesforce.com/products/net-zero-cloud/overview/
- Cozero climate action platform: https://cozero.io/
- Sustain.Life sustainability platform: https://www.sustain.life/

- Normative carbon accounting engine: https://normative.io/
- SME Climate Hub—Free business carbon calculator, powered by Normative with support from Google.org: https://smeclimatehub.org/
- Climate Engine—Leverage satellite and sensor data to visualize environmental risk: https://climateengine.com/
- WGBC: https://www.worldgbc.org/

Bibliography

- *Circularity Gap. 2020. Our world is now only 8.6% circular*. *CGR*. Accessed March 4, 2022. https://www.circularity-gap.world/updates-collection/circle-economy-launches-cgr2020-in-davos
- *Decathlon. 2021. L'ÉVALUATION ENVIRONNEMENTALE DE NOS PRODUITS*. Accessed July 27, 2022. https://engagements.decathlon.fr/levaluation-environnementale-de-nos-produits
- *Decathlon. 2020. LE PLAN DE TRANSITION: Stratégie pour le développement durable de Décathlon 2020-2026 - version 3*. Accessed July 27, 2022. https://engagements.decathlon.fr/le-plan-de-transition-2020-2026-decathlon
- *Electrolux. 2022. Robovaccum painlessly*. Accessed July 3, 2022. https://purei9.electrolux.se/
- *Gartenberg, Chaim. 2022. Apple will reportedly sell the iPhone as a subscription service*. *March 24, 2022.* Accessed July 3, 2022. https://www.theverge.com/2022/3/24/22994814/apple-iphone-hardware-subscription-bundle-report
- *"Global Risks Report 2022". World Economic Forum. January 11, 2022.* Accessed March 25, 2022. https://www.weforum.org/reports/global-risks-report-2022
- *Husqvarna. 2017*. *Husqvarna pilots pay-per-use and brings chainsaws and hedge trimmers into sharing economy*. *May 10, 2017.* Accessed July 3, 2022.

https://www.husqvarnagroup.com/en/news/husqvarna-pilots-pay-use-and-brings-chainsaws-and-hedge-trimmers-sharing-economy

- *IEA. 2021. NetZero by 2050 - Flagship report*. *May 2021.* Accessed June 27, 2022. https://www.iea.org/reports/net-zero-by-2050
- *Martella, Roger. 2022. How businesses are taking the lead to get the world to net-zero*. *May 22, 2022.* Accessed June 26, 2022. https://www.weforum.org/agenda/2022/05/global-sustainability-corporations-lead-net-zero?utm_source=linkedin&utm_medium=social_video&utm_term=1_1&utm_content=26085_Google%27s_new_campus_+zero-carbon&utm_campaign=social_video_2022
- *Méndez-Villamil, Marta Munoz. 2021. Google Masterclass*.
- *Musaab Almulla, Samah El-Shahat, and Nan Zhou. 2022. What is 'materials transition' and why is it critical for a net-zero future? June 14, 2022*. Accessed June 28, 2022. https://www.weforum.org/agenda
- *ShoP Architects. 2022. Uber HQ.* Accessed June 23, 2022. https://www.shoparc.com/projects/uber-hq/
- *Tiseo, Ian. 2022. Distribution of fossil fuel CO2 emissions worldwide in 2020, by select country*. *June 22, 2022*. Accessed June 28th, 2022. https://www.statista.com/statistics/271748/the-largest-emitters-of-co2-in-the-world/
- *UBS. 2021. Investing in digital subscriptions*. *March 10, 2021*. Accessed July 27, 2022. https://www.ubs.com/global/en/wealth-management/our-approach/marketnews/article.1525238.html
- *Udvarlaki, Roland. 2022. Smartphone subscriptions are here, but should you care about it? June 16, 2022.* Accessed July 3, 2022. https://pocketnow.com/fairphone-smartphone-subscription

- *UK Gov. 2013. Environmental reporting guidelines: including Streamlined Energy and Carbon Reporting requirements*. *April 12, 2013.* Accessed June 28, 2022. https://www.gov.uk/government/publications/environmental-reporting-guidelines-including-mandatory-greenhouse-gas-emissions-reporting-guidance
- *Volvo Cars. 2022. Care by Volvo - The flexible car subscription*. Accessed July 3, 2022. https://www.volvocars.com/uk/care-by-volvo/
- *World Bank. 2021. Universal Access to Sustainable Energy Will Remain Elusive Without Addressing Inequalities*. *June 21, 2021*. Accessed June 23, 2022. https://www.worldbank.org/en/news/press-release/2021/06/07/report-universal-access-to-sustainable-energy-will-remain-elusive-without-addressing-inequalities#:~:text=Access%20to%20electricity.&text=As%20a%20result%2C%2090%20percent,fragile%20and%20conflict
- *Zoura. 2022. Evolving Your IT Architecture for a Subscription Business*. Accessed July 27, 2022. https://www.zuora.com/guides/evolving-architecture-subscription-business-model/
- *Zoura. 2022. Subscription Economy Index™*. Accessed July 27, 2022. https://www.zuora.com/resources/subscription-economy-index/
- *Zoura. 2020. Subscription impact report*. Accessed July 27, 2022. https://www.zuora.com/resource/subscription-impact-report/
- *Zoura. 2022. Termed and Evergreen Subscriptions*. Accessed July 27, 2022. https://www.zuora.com/resource/termed-and-evergreen-subscriptions/
- *Zoura. 2021. The End of Ownership*. Accessed July 27, 2022. https://fr.zuora.com/resource/the-end-of-ownership/
- *Zoura. 2022. Zuora, Subscribed, Subscription Economy, Powering the Subscription Economy, and Subscription Economy Index are trademarks or registered trademarks of Zuora, Inc*.

- *Zscaler. 2022. Work From Anywhere Trends Dashboard*. *June 24, 2022*. Accessed June 24, 2022. https://www.zscaler.com/threatlabz/work-from-anywhere-dashboard

Chapter 10

Images

Figure 10.1 – The sustainable IT maturity model©

Figure 10.2 – The five dimensions of the sustainable IT maturity model

Figure 10.3 – The path to sustainable IT

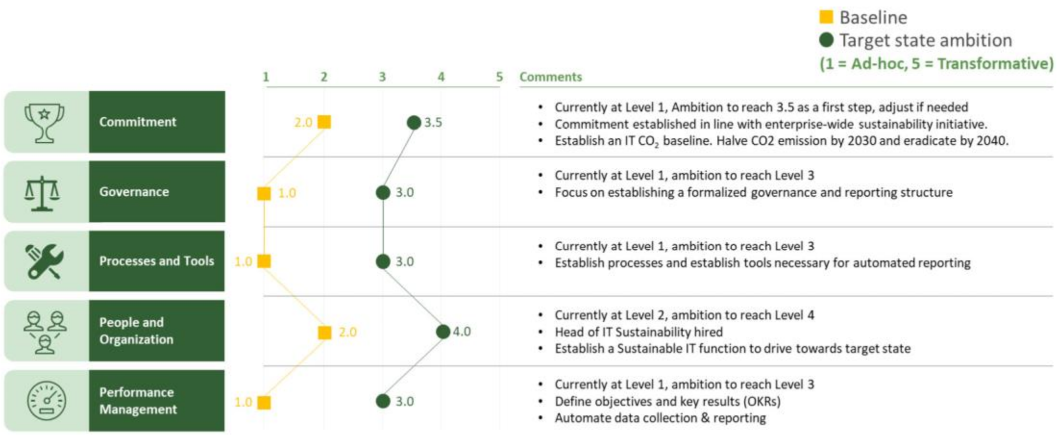


Figure 10.4 – Sustainable IT maturity model assessment example

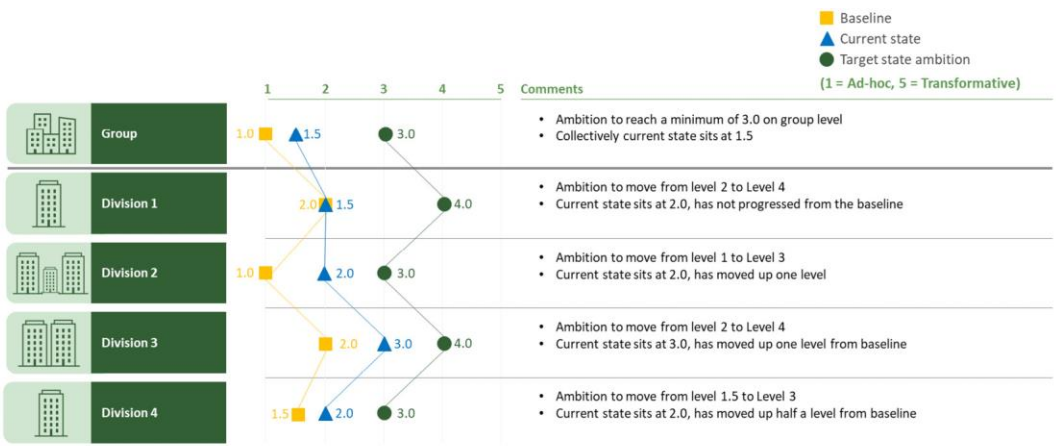


Figure 10.5 – Large corporation's sustainable IT maturity model assessment example

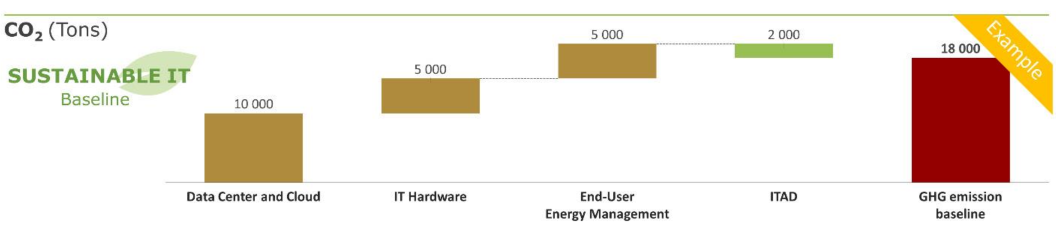


Figure 10.6 – GHG emissions baseline example

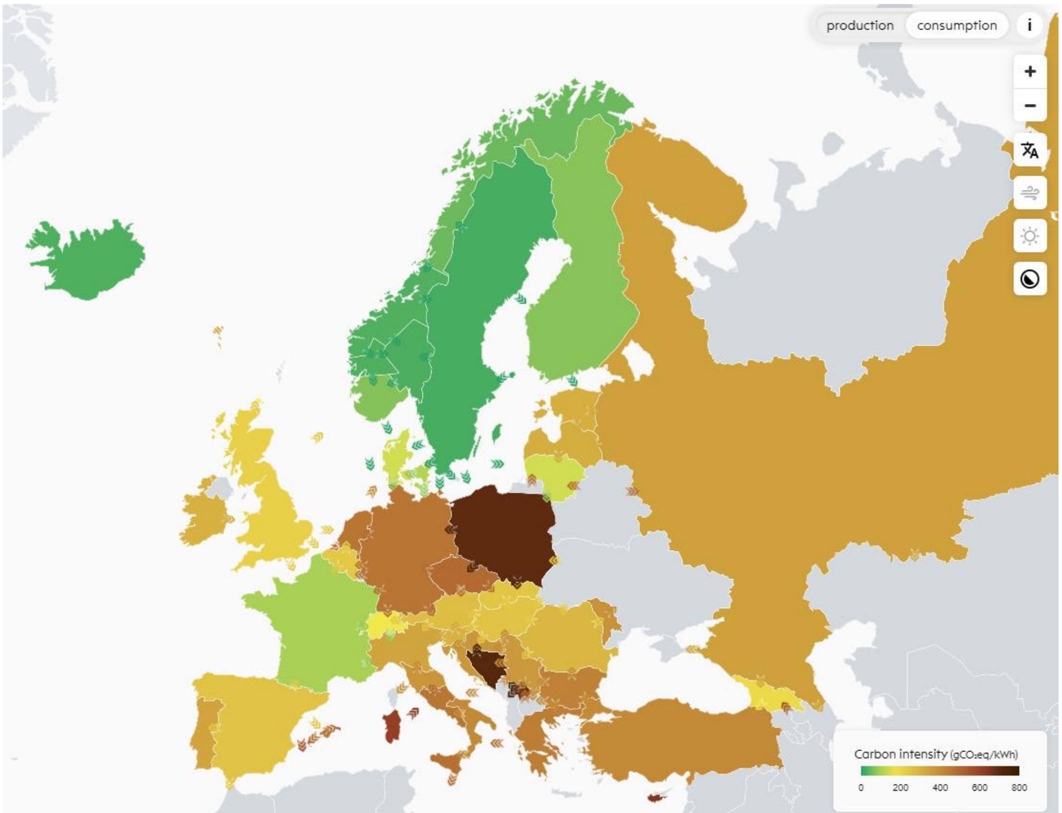


Figure 10.7 – Europe carbon intensity map snapshot courtesy of Electricitymaps.com

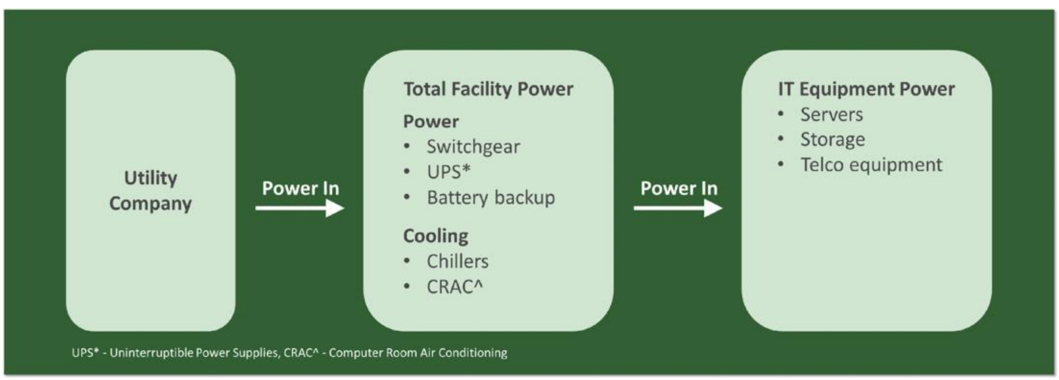


Figure 10.8 – Power Usage Effectiveness (PUE)

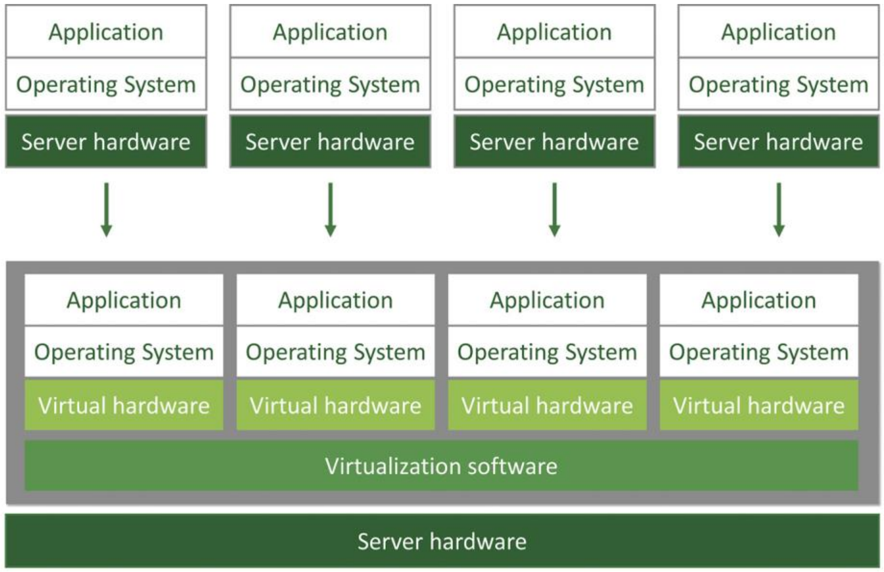


Figure 10.9 – From hardware to software virtualization

Figure 10.10 – Emission calculation – a seven-step process

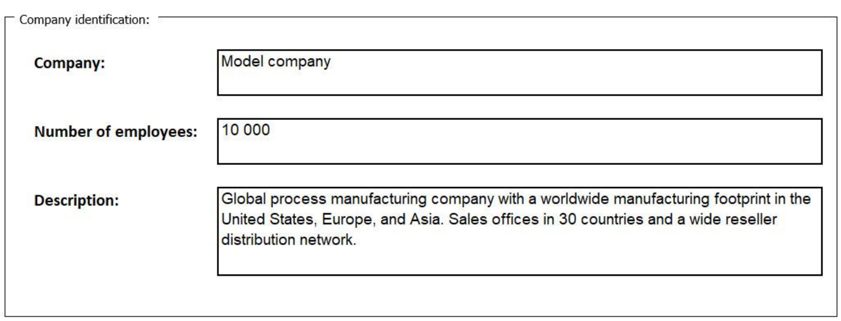


Figure 10.11 – Company identification

Company overview:

Business objectives:

To be the worldleader and most innovative company providing the best products within our industry.

Business sustainability ambition:

Climate change commitment through Science Based Target Initiative (SBTi). Ambition to halve greenhouse gas emissions no later than 2030 and become net positive by 2040.

Focus areas:
- Climate action
- Focus on social & economic inclusion
- Sustainable & responsible sourcing
- Employee health, safety & well-being

IT overview:

Global IT organization but a disparate and distributed IT landscape worldwide.
A mixture of servers on-premise in local data centers, outsourced global data centers, and in the cloud. The ambition is to migrate out of local on-premise data centers either to global data centers or the cloud.
Out of all employees, everyone has a company-issued computer and a smartphone.
IT asset disposition is not formalized and no CO2 emission recovery is tracked for recycling. Currently, only 10% of IT assets are properly managed.

Sustainable IT ambition:

Transition to a sustainable IT enterprise through sustainable innovation & technology

Focus areas:
- Climate action - reduce greenhouse gas emissions in line with corporate objectives
- Talent & teamship development
- Equity, Diversity & Inclusion
- Data security & privacy

Figure 10.12 – Company overview

Parameters:

Year:	**2022**
Energy efficiency improvement YoY:	**7%**
ITAD CO2 emission recovery percentage:	**30%**

Figure 10.13 – Parameters

Assumptions:

Data center and cloud:	Hybrid data center and cloud setup with servers in local on-premise data centers, global outsourced data centers and in the cloud.
Application and data:	Application and data are part of data center and cloud calculation. What is not included in the calculation is pure SaaS applications because at this time the software vendors are unable to provide this figure.
IT hardware:	Current IT hardware refresh cycle for computers are three years, two years for smartphones, three years for tablets and four years for monitors.
Energy management:	No energy management policies implemented nor enforced from the start.
IT asset disposition:	IT asset disposition is not formalized from the start and no CO2 emission recovery is tracked for recycling. Currently, only 10% of IT assets are properly recycled.
Network traffic	Network traffic not part of emission calculation.

Figure 10.14 – Assumptions

Category	Type	Description	Scope 1	Scope 2	Scope 3	Total	Unit
Data center & Cloud	Local data center - Low-carbon	Local on-premise emissions low-carbon power consumption	0	37	329	366	kg CO2
Data center & Cloud	Local data center - Average-carbon	Local on-premise emissions medium-carbon power consumption	0	836	329	1165	kg CO2
Data center & Cloud	Local data center - High-carbon	Local on-premise emissions high-carbon power consumption	0	1056	329	1385	kg CO2
Data center & Cloud	Global data center - Low-carbon	Global data center emissions from low-carbon power consumption	0	0	275	275	kg CO2
Data center & Cloud	Global data center - Average-carbon	Global data center emissions from medium-carbon power consumption	0	0	874	874	kg CO2
Data center & Cloud	Global data center - High-carbon	Global data center emissions from high-carbon power consumption	0	0	1039	1039	kg CO2
Data center & Cloud	Cloud - Low-carbon	Cloud emissions from low-carbon power consumption	0	0	183	183	kg CO2
Data center & Cloud	Cloud - Average-carbon	Cloud emissions from medium-carbon power consumption	0	0	583	583	kg CO2
Data center & Cloud	Cloud - High-carbon	Cloud emissions from high-carbon power consumption	0	0	693	693	kg CO2
IT Equipment	Computer - Notebook - Low Energy	Notebook computer - standard issue - Low energy consumption	0	50	200	250	kg CO2
IT Equipment	Computer - Notebook - High Energy	Notebook computer - standard issue - High energy consumption	0	100	200	300	kg CO2
IT Equipment	Computer - Desktop	Desktop computer - standard issue	0	180	329	509	kg CO2
IT Equipment	Monitor	Monitor - standard issue	0	32,5	380	412,5	kg CO2
IT Equipment	Smartphone	Smartphone - standard issue	0	3,3	60	63,3	kg CO2
IT Equipment	Tablet	Tablet - standard issue	0	3,3	150	153,3	kg CO2
IT Equipment	Printer usage-High	Printer - high energy usage	0	272	0	272	kg CO2
IT Equipment	Printer usage-Medium	Printer - medium energy usage	0	171	0	171	kg CO2
IT Equipment	Printer usage-Low	Printer - low energy usage	0	104	0	104	kg CO2
IT Equipment	Device-as-a-Service		0	25	0	25	kg CO2

Figure 10.15 – Emission table

Type	Year 2022	Comments
Cloud & Data Center - Server count	**3 000**	
Local data center - Low-carbon		
Local data center - Average-carbon		
Local data center - High-carbon	1 000	
Global data center - Low-carbon		
Global data center - Average-carbon		
Global data center - High-carbon	1 000	
Cloud - Low-carbon		
Cloud - Average-carbon		
Cloud - High-carbon	1 000	
IT Hardware - New purchase YoY	**13 250**	**Comments**
Computer - Notebook - High Energy	2 500	Refresh rate every 3 years
Computer - Notebook - Low Energy	340	Refresh rate every 3 years
Computer - Desktop	660	Refresh rate every 3 years
Monitor	3 750	Refresh rate every 4 years
Smartphone	5 000	Refresh rate every 2 years
Tablet	1 000	Refresh rate every 3 years
IT Hardware - Existing hardware	**39 680**	**Comments**
Computer - Notebook - High Energy	8 000	8/10 notebook
Computer - Notebook - Low Energy	-	
Computer - Desktop	2 000	2/10 desktops
Monitor	15 000	1,5 monitor per desktop and notebook
Smartphone	10 000	Every employee has a company issued smartphone
Tablet	3 000	1/3 of employees has a tablet
Printer usage -High	480	4 Printers per site for 120 locations
Printer usage -Medium	720	6 Printers per site for 120 locations
Printer usage -Low	480	4 Printers per site for 120 locations
IT Asset Disposition	**-**	**Comments**
Computer - Notebook - High Energy	-	Assume 0% asset recycling and carbon credit recovery year 1
Computer - Notebook - Low Energy	-	Assume 10% asset recycling and carbon credit recovery year 2
Computer - Desktop	-	
Monitor	-	
Smartphone	-	
Tablet	-	

Figure 10.16 – IT asset registry

Type	Scope 1	Scope 2	Scope 3	Total	Units
Cloud & Data Center	-	1 056 000	2 061 000	3 117 000	
Local data center - Low-carbon	-	-	-	-	
Local data center - Average-carbon	-	-	-	-	
Local data center - High-carbon	-	1 056 000	329 000	**1 385 000**	kg CO2
Global data center - Low-carbon			-	-	
Local data center - Average-carbon			-	-	
Global data center - High-carbon			1 039 000	**1 039 000**	kg CO2
Cloud - Low-carbon			-	-	
Cloud - Average-carbon			-	-	
Cloud - High-carbon			693 000	**693 000**	kg CO2
IT Hardware	-	-	2 539 500	2 539 500	**Units**
Computer - Notebook - High Energy			500 000	**500 000**	kg CO2
Computer - Notebook - Low Energy			-	-	kg CO2
Computer - Desktop			164 500	**164 500**	kg CO2
Monitor			1 425 000	**1 425 000**	kg CO2
Smartphone			300 000	**300 000**	kg CO2
Tablet			150 000	**150 000**	kg CO2
Energy Management EUC	-	1 994 000	-	1 994 000	**Units**
Computer - Notebook - High Energy		800 000		**800 000**	kg CO2
Computer - Notebook - Low Energy		-		-	kg CO2
Computer - Desktop		360 000		**360 000**	kg CO2
Monitor		487 500		**487 500**	kg CO2
Smartphone		33 000		**33 000**	kg CO2
Tablet		9 900		**9 900**	kg CO2
Printer usage-High		130 560		**130 560**	kg CO2
Printer usage-Medium		123 120		**123 120**	kg CO2
Printer usage-Low		49 920		**49 920**	kg CO2
Device-as-a-Service		-		-	kg CO3
IT Asset Disposition	-	-	-	-	**Units**
Computer - Notebook - High Energy			-	-	kg CO2
Computer - Notebook - Low Energy			-	-	kg CO2
Computer - Desktop			-	-	kg CO2
Monitor			-	-	kg CO2
Smartphone			-	-	kg CO2
Tablet			-	-	kg CO2
			-	-	
Total CO2 emission	**1**	**2**	**3**	**Total**	**Units**
	-	3 050 000	4 600 500	7 650 500	kg CO2
	-	3 050	4 601	7 651	tonnes CO2

Figure 10.17 – Emission baseline

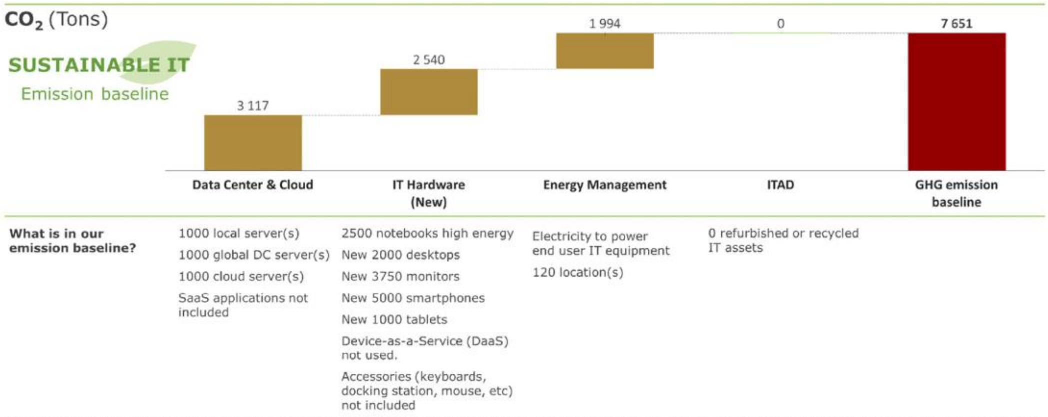


Figure 10.18 – Emission baseline aggregated view

Type	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Comments
Cloud & Data Center - Server count	**10 000**	**11 000**	**12 000**	**13 000**	**14 000**	**15 000**	**16 000**	**17 000**	**18 000**	**19 000**	
Employees	10 000	11 000	12 000	13 000	14 000	15 000	16 000	17 000	18 000	19 000	Employee growth 1000 per year
Cloud & Data Center - Server count	**3 000**	**2 900**	**2 800**	**2 700**	**2 600**	**2 200**	**2 200**	**2 200**	**2 200**	**2 200**	
Local datacenter - Low-carbon											
Local datacenter - Average-carbon											
Local datacenter - High-carbon	1 000	800	600	400	200	-	-	-	-	-	Move 200 servers to the cloud and decommission 50 per year.
Global datacenter - Low-carbon											
Global datacenter - Average-carbon											
Global datacenter - High-carbon	1 000	750	500	250	-	-	-	-	-	-	Move 200 servers to the cloud and decommission 50 servers per year.
Cloud - Low-carbon		550	1 100	1 650	2 200	2 200	2 200	2 200	2 200	2 200	Move servers to low-carbon region.
Cloud - Average-carbon											
Cloud - High-carbon	1 000	800	600	400	200	-	-	-	-	-	Move 200 servers per your to low-carbon region.
IT Hardware - New purchase YoY	**12 750**	**8 800**	**9 800**	**9 750**	**11 200**	**11 650**	**12 100**	**12 550**	**13 000**	**13 400**	**Comments**
Computer - Notebook - High Energy	2 500	500	500	500	250	250	250	250	250	250	Refresh rate shift from 3 years to 4 years
Computer - Notebook - Low Energy	-	1 500	2 000	1 500	3 000	3 000	3 000	3 000	3 000	3 000	Refresh rate shift from 3 years to 4 years
Computer - Desktop	500	500	500	500	250	250	250	250	250	250	Refresh rate shift from 3 years to 4 years
Monitor	3 750	1 500	1 500	1 500	1 500	1 500	1 500	1 500	1 500	1 500	Refresh rate shift from 4 years to 5 years
Smartphone	5 000	3 600	4 000	4 300	4 650	5 000	5 300	5 650	6 000	6 300	Refresh rate shift from 2 years to 3 years
Tablet	1 000	1 200	1 300	1 450	1 550	1 650	1 800	1 900	2 000	2 100	Refresh rate every 3 years (No change)
IT Hardware - Existing hardware	**39 680**	**43 110**	**46 960**	**50 760**	**54 610**	**58 460**	**62 260**	**66 110**	**69 960**	**73 760**	**Comments**
Computer - Notebook - High Energy	8 000	6 500	5 000	3 500	2 000	1 500	1 000	1 000	1 000	1 000	
Computer - Notebook - Low Energy	-	1 500	3 500	4 000	6 000	6 500	7 000	7 000	7 500	8 000	
Computer - Desktop	2 000	2 000	1 500	1 500	1 000	1 000	1 000	1 000	1 000	1 000	
Monitor	15 000	16 500	18 000	19 500	21 000	22 500	24 000	25 500	27 000	28 500	1,5 monitor per desktop and notebook
Smartphone	10 000	11 000	12 000	13 000	14 000	15 000	16 000	17 000	18 000	19 000	Every employee has a company issued smartphone
Tablet	3 000	3 650	4 000	4 300	4 650	5 000	5 300	5 650	6 000	6 300	1/3 of employees has a tablet
Printer usage - High	480	240	240	240	240	240	240	240	240	240	4 to 2 printers per site for 120 locations
Printer usage - Medium	720	480	480	480	480	480	480	480	480	480	6 to 4 printers per site for 120 locations
Printer usage - Low	480	240	240	240	240	240	240	240	240	240	4 to 2 printers per site for 120 locations
Device-as-a-Service	-	1 000	2 000	4 000	5 000	6 000	7 000	8 000	8 500	9 000	
IT Asset Disposition	**-**	**3 933**	**6 410**	**9 147**	**10 725**	**11 400**	**12 075**	**12 735**	**13 410**	**14 198**	**Comments**
Computer - Notebook - High Energy	-	800	975	1 000	788	450	338	225	225	225	Assume 0% asset recycling and carbon credit recovery year 1
Computer - Notebook - Low Energy	-	-	225	700	900	1 350	1 463	1 575	1 575	1 688	Assume 40% asset recycling and carbon credit recovery year 2
Computer - Desktop	-	200	300	300	338	225	225	225	225	225	Assume 60% asset recycling and carbon credit recovery year 3
Monitor	-	1 200	1 980	2 880	3 510	3 780	4 050	4 320	4 590	4 860	Assume 80% asset recycling and carbon credit recovery year 4
Smartphone	-	1 333	2 200	3 200	3 900	4 200	4 500	4 800	5 100	5 400	Assume 90% asset recycling and carbon credit recovery year 5
Tablet	-	400	730	1 067	1 290	1 395	1 500	1 590	1 695	1 800	

Figure 10.19 – Ten-year IT asset registry simulation

Type	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Units
	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	
Cloud & Data Center	**3 117 000**	**2 542 300**	**1 967 600**	**1 392 900**	**818 200**	**402 600**	**402 600**	**402 600**	**402 600**	**402 600**	
Local data center - Low-carbon	-	-	-	-	-	-	-	-	-	-	kg CO2
Local data center - Average-carbon	-	-	-	-	-	-	-	-	-	-	kg CO2
Local data center - High-carbon	1 385 000	1 108 000	831 000	554 000	277 000	-	-	-	-	-	kg CO2
Global data center - Low-carbon	-	-	-	-	-	-	-	-	-	-	kg CO2
Global data center - Average-carbon	-	-	-	-	-	-	-	-	-	-	kg CO2
Global data center - High-carbon	1 039 000	779 250	519 500	259 750	-	-	-	-	-	-	kg CO2
Cloud - Low-carbon	-	100 650	201 300	301 950	402 600	402 600	402 600	402 600	402 600	402 600	kg CO2
Cloud - Average-carbon	-	-	-	-	-	-	-	-	-	-	kg CO2
Cloud - High-carbon	693 000	554 400	415 800	277 200	138 600	-	-	-	-	-	kg CO2
IT Hardware	**2 539 500**	**1 530 500**	**1 669 500**	**1 610 000**	**1 813 750**	**1 849 750**	**1 890 250**	**1 926 250**	**1 962 250**	**1 995 250**	
Computer - Notebook - High Energy	500 000	100 000	100 000	100 000	50 000	50 000	50 000	50 000	50 000	50 000	kg CO2
Computer - Notebook - Low Energy	-	300 000	400 000	300 000	600 000	600 000	600 000	600 000	600 000	600 000	kg CO2
Computer - Desktop	164 500	164 500	164 500	164 500	82 250	82 250	82 250	82 250	82 250	82 250	kg CO2
Monitor	1 425 000	570 000	570 000	570 000	570 000	570 000	570 000	570 000	570 000	570 000	kg CO2
Smartphone	300 000	216 000	240 000	258 000	279 000	300 000	318 000	339 000	360 000	378 000	kg CO2
Tablet	150 000	180 000	195 000	217 500	232 500	247 500	270 000	285 000	300 000	315 000	kg CO2
Energy Management EUC	**1 994 000**	**1 749 819**	**1 579 608**	**1 430 686**	**1 277 092**	**1 218 428**	**1 156 827**	**1 108 780**	**1 070 412**	**1 024 133**	
Computer - Notebook - High Energy	800 000	617 500	450 000	297 500	160 000	112 500	70 000	65 000	60 000	55 000	kg CO2
Computer - Notebook - Low Energy	-	71 250	157 500	170 000	240 000	243 750	245 000	227 500	225 000	220 000	kg CO2
Computer - Desktop	360 000	342 000	243 000	229 500	144 000	135 000	126 000	117 000	108 000	99 000	kg CO2
Monitor	487 500	509 438	526 500	538 688	546 000	548 438	546 000	538 688	526 500	509 438	kg CO2
Smartphone	33 000	34 485	35 640	36 465	36 960	37 125	36 960	36 465	35 640	34 485	kg CO2
Tablet	9 900	11 443	11 880	12 062	12 276	12 375	12 243	12 119	11 880	11 435	kg CO2
Printer usage-High	130 560	62 016	58 752	55 488	52 224	48 960	45 696	42 432	39 168	35 904	kg CO2
Printer usage-Medium	123 120	77 976	73 872	69 768	65 664	61 560	57 456	53 352	49 248	45 144	kg CO2
Printer usage-Low	49 920	23 712	22 464	21 216	19 968	18 720	17 472	16 224	14 976	13 728	kg CO2
Device-as-a-Service	-	23 750	45 000	85 000	100 000	112 500	122 500	130 000	127 500	123 750	kg CO2
IT Asset Disposition	**-**	**- 246 540**	**- 399 780**	**- 565 530**	**- 662 951**	**- 699 503**	**- 740 408**	**- 780 638**	**- 821 543**	**- 869 198**	
Computer - Notebook - High Energy	-	- 48 000	- 58 500	- 60 000	- 47 250	- 27 000	- 20 250	- 13 500	- 13 500	- 13 500	kg CO2
Computer - Notebook - Low Energy	-	-	- 13 500	- 42 000	- 54 000	- 81 000	- 87 750	- 94 500	- 94 500	- 101 250	kg CO2
Computer - Desktop	-	- 19 740	- 29 610	- 29 610	- 33 311	- 22 208	- 22 208	- 22 208	- 22 208	- 22 208	kg CO2
Monitor	-	- 136 800	- 225 720	- 328 320	- 400 140	- 430 920	- 461 700	- 492 480	- 523 260	- 554 040	kg CO2
Smartphone	-	- 24 000	- 39 600	- 57 600	- 70 200	- 75 600	- 81 000	- 86 400	- 91 800	- 97 200	kg CO2
Tablet	-	- 18 000	- 32 850	- 48 000	- 58 050	- 62 775	- 67 500	- 71 550	- 76 275	- 81 000	kg CO2
Total CO2 emission	**Total**	**Total**	**Total**	**Total**	**Total**	**Total**	**Total**	**Total**	**Total**	**Total**	**Units**
	7 650 500	5 576 079	4 816 928	3 868 056	3 246 091	2 771 275	2 709 270	2 656 992	2 613 720	2 552 786	kg CO2
	7 651	5 576	4 817	3 868	3 246	2 771	2 709	2 657	2 614	2 553	tonnes CO2

Figure 10.20 – Ten-year carbon emission simulation

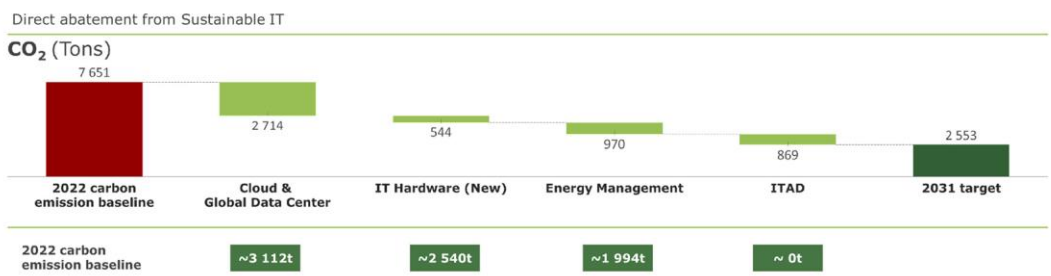


Figure 10.21 – Ten-year carbon emission waterfall summary

Tables

Category	Scope 1	Scope 2	Scope 3
Own on-premise or data center server	√	√	
Outsourced data center server			√

Cloud provider		√

Table 10.1 – Scope impact per category

Tables 10.2 and 10.3 are given as part of a larger section of text in the Formula section.

ICT Device	Energy Consumption (kWh)	Carbon Emission Low-Carbon (kgCO2/Year)	Carbon Emission High-Carbon (kgCO2/Year)
Notebook (Low)	110 kWh	2.3	50
Notebook (High)	220 kWh	4.6	100
Desktop	440 kWh	9.2	210

Table 10.4 – Summary of yearly energy consumption and carbon emissions of ICT devices

Formulas

Formula 10.1 – Formula for calculating PUE

$$PUE = \frac{Total\ facility\ energy}{IT\ equipment\ energy}$$

Formula 10.2

Yearly carbon emission from the production of servers:

$$\frac{Total\ Server\ Carbon\ Emission\ \times \%\ of\ Manufacturing}{Product\ Lifetime} = Yearly\ carbon\ emission\ from\ manufacturing$$

$$\frac{8649\ kgCO2e \times 15.2\%}{4} = 329\ \frac{kgCO2e}{year}$$

Server virtualization rate in the global data center:

As stated in the *Percentage of virtual CPUs* section, we assume that only 75% of server capacity is needed when running in a global data center setup:

$$Yearly\ carbon\ emission\ from\ manufacturing\ \times\ Percentage\ of\ virtual\ CPUs$$
$$=\ Global\ data\ center\ server\ yearly\ carbon\ emission\ from\ manufacturing$$

$$329\frac{kgCO2e}{year} \times 75\% = 247\frac{kgCO2e}{year}$$

Server virtualization rate in the cloud:

As stated in the *Percentage of virtual CPUs* section, we assume that only 50% of server capacity is needed when running in a cloud hyper-scaler setup:

$$Yearly\ carbon\ emission\ from\ manufacturing\ \times\ Percentage\ of\ virtual\ CPUs$$
$$=\ Cloud\ server\ yearly\ carbon\ emission\ from\ manufacturing$$

$$329\frac{kgCO2e}{year} \times 50\% = 165\frac{kgCO2e}{year}$$

We have now calculated the yearly carbon emissions for manufacturing the server, which are as follows:

- On-premise server from manufacturing: $329\frac{kgCO2e}{year} = 0.329\frac{tonCO2e}{year}$
- Global data center server from manufacturing: $247\frac{kgCO2e}{year} = 0.247\frac{tonCO2e}{year}$
- Cloud server from manufacturing: $165\frac{kgCO2e}{year} = 0.165\frac{tonCO2e}{year}$

Now, let us calculate the yearly carbon emissions to power the server. We know the yearly energy demand for the server is 1,760.3 kWh/year. We assume a carbon intensity of 21 gCO2/kWh for powering the server in a low-carbon environment. For a high-carbon environment, we assume the IEA global average carbon intensity of electricity generated is 475 gCO2kWh. If the location of your servers is known, it might be a good idea to reference the carbon intensity from https://app.electricitymaps.com/.

On-premise server emission from power consumption:

$$Server\ power\ consumption\ \left(\frac{kWh}{year}\right) \times Carbon\ intensity\ \left(\frac{gCO2e}{kWh}\right) = Carbon\ emission\ (\frac{gCO2e}{year})$$

Global data center server emission from power consumption:

As stated previously, we assume a 25% improvement in server utilization rate (CPU usage) for a cloud server and apply the factor to the formula:

$$Server\ power\ consumption\ \left(\frac{kWh}{year}\right) \times Carbon\ intensity\ \left(\frac{gCO2e}{kWh}\right) \times (100\% - 25\%)\ Server\ utilization\ rate\ improvement = Carbon\ emission\ (\frac{gCO2e}{year})$$

Cloud server emission from power consumption:

As stated previously, we assume a 50% improvement in a cloud server's server utilization rate (CPU usage) and apply the factor to the formula:

$$Server\ power\ consumption\ \left(\frac{kWh}{year}\right) \times Carbon\ intensity\ \left(\frac{gCO2e}{kWh}\right) \times (100\% - 50\%)\ Server\ utilization\ rate\ improvement = Carbon\ emission\ (\frac{gCO2e}{year})$$

On-premise server emissions from low-carbon power consumption:

$$1760.3\frac{kWh}{year} \times 21\frac{gCO2e}{kWh} = 36\ 966\frac{gCO2e}{year} = 37\frac{kgCO2e}{year} = 0.037\frac{tonCO2e}{year}$$

On-premise server emissions from average-carbon power consumption:

$$1760.3\frac{kWh}{year} \times 475\frac{gCO2e}{kWh} = 836\ 142.5\frac{gCO2e}{year} = 836\frac{kgCO2e}{year} = 0.836\frac{tonCO2e}{year}$$

On-premise server emissions from high-carbon power consumption:

$$1760.3\frac{kWh}{year} \times 600\frac{gCO2e}{kWh} = 1\ 056\ 180\frac{gCO2e}{year} = 1\ 056\frac{kgCO2e}{year} = 1.056\frac{tonCO2e}{year}$$

Global data center server emissions from low-carbon power consumption:

$$1760.3\frac{kWh}{year} \times 21\frac{gCO2e}{kWh} \times 75\% = 27\ 725\frac{gCO2e}{year} = 27.7\frac{kgCO2e}{year} = 0.0277\frac{tonCO2e}{year}$$

Global data center server emissions from average-carbon power consumption:

$$1760.3\frac{kWh}{year} \times 475\frac{gCO2e}{kWh} \times 75\% = 627\ 107\frac{gCO2e}{year} = 627\frac{kgCO2e}{year} = 0.627\frac{tonCO2e}{year}$$

Global data center server emissions from high-carbon power consumption:

$$1760.3 \frac{kWh}{year} \times 600 \frac{gCO2e}{kWh} \times 75\% = 792\,135 \frac{gCO2e}{year} = 792 \frac{kgCO2e}{year} = 0.792 \frac{tonCO2e}{year}$$

Cloud server emissions from low-carbon power consumption:

$$1760.3 \frac{kWh}{year} \times 21 \frac{gCO2e}{kWh} \times 50\% = 18\,483 \frac{gCO2e}{year} = 18 \frac{kgCO2e}{year} = 0.018 \frac{tonCO2e}{year}$$

Cloud server emissions from average-carbon power consumption:

$$1760.3 \frac{kWh}{year} \times 475 \frac{gCO2e}{kWh} \times 50\% = 418\,071.3 \frac{gCO2e}{year} = 418 \frac{kgCO2e}{year} = 0.418 \frac{tonCO2e}{year}$$

Cloud server emissions from high-carbon power consumption:

$$1760.3 \frac{kWh}{year} \times 600 \frac{gCO2e}{kWh} \times 50\% = 528\,090 \frac{gCO2e}{year} = 528 \frac{kgCO2e}{year} = 0.528 \frac{tonCO2e}{year}$$

If we summarize all nine calculations, we get the following table:

Category (kgCO2/Year)	Low-Carbon	Average-Carbon	High-Carbon
Own on-premise or data center server	37	836	1056
Global data center server	27.7	627	792
Cloud provider	18	418	528

Table 10.2 – Server emissions from power consumption

Now that we have calculated server emissions for yearly power consumption, we can conclude that there is a massive difference – a 22 times improvement between running in a low-carbon environment as opposed to running in an average-carbon environment and a 28.5 times improvement between running in a low-carbon environment as opposed to running in a high-carbon environment.

Finally, to calculate a server's total emission per year, we need to add the embodied emissions from manufacturing (Scope 3) and your power consumption (Scope 2 or Scope 3) together to get the total emissions per year. Here, we assume that all servers have been manufactured with the global average carbon intensity of 475 gCO2/kWh.

The total server emission can be calculated as follows:

$$CO2e\ from\ manufacturing\ \left(\frac{kgCO2e}{year}\right) + CO2e\ from\ power\ consumption\ \left(\frac{kgCO2e}{year}\right) = Total\ carbon\ emission\ \left(\frac{kgCO2e}{year}\right)$$

Note that from a carbon accounting perspective, it is essential to keep them separate; therefore, we must calculate our Scope 2 from power consumption and our Scope 3 embodied carbon separately:

Total on-premise emissions from low-carbon power consumption:

$$329\ \left(\frac{kgCO2e}{year}\right) + 37\ \left(\frac{kgCO2e}{year}\right) = 366\ \left(\frac{kgCO2e}{year}\right) = 0.366\ \left(\frac{tonCO2e}{year}\right)$$

Total on-premise emissions from average-carbon power consumption:

$$329\ \left(\frac{kgCO2e}{year}\right) + 836\ \left(\frac{kgCO2e}{year}\right) = 1165\ \left(\frac{kgCO2e}{year}\right) = 1.165\ \left(\frac{tonCO2e}{year}\right)$$

Total on-premise emissions from high-carbon power consumption:

$$329\ \left(\frac{kgCO2e}{year}\right) + 1056\ \left(\frac{kgCO2e}{year}\right) = 1385\ \left(\frac{kgCO2e}{year}\right) = 1.385\ \left(\frac{tonCO2e}{year}\right)$$

Total global data center emissions from low-carbon power consumption:

$$247\ \left(\frac{kgCO2e}{year}\right) + 27.7\ \left(\frac{kgCO2e}{year}\right) = 275\ \left(\frac{kgCO2e}{year}\right) = 0.275\ \left(\frac{tonCO2e}{year}\right)$$

Total global data center emissions from average-carbon power consumption:

$$247\ \left(\frac{kgCO2e}{year}\right) + 627\ \left(\frac{kgCO2e}{year}\right) = 874\ \left(\frac{kgCO2e}{year}\right) = 0.874\ \left(\frac{tonCO2e}{year}\right)$$

Total global data center emissions from high-carbon power consumption:

$$247\ \left(\frac{kgCO2e}{year}\right) + 792\ \left(\frac{kgCO2e}{year}\right) = 1039\ \left(\frac{kgCO2e}{year}\right) = 1.039\ \left(\frac{tonCO2e}{year}\right)$$

Total cloud emissions from low-carbon power consumption:

$$165\ \left(\frac{kgCO2e}{year}\right) + 18\ \left(\frac{kgCO2e}{year}\right) = 183\ \left(\frac{kgCO2e}{year}\right) = 0.183\ \left(\frac{tonCO2e}{year}\right)$$

Total cloud emissions from average-carbon power consumption:

$$165\left(\frac{kgCO2e}{year}\right)+418\left(\frac{kgCO2e}{year}\right)=583\left(\frac{kgCO2e}{year}\right)=0.583\left(\frac{tonCO2e}{year}\right)$$

Total cloud emissions from high-carbon power consumption:

$$165\left(\frac{kgCO2e}{year}\right)+528\left(\frac{kgCO2e}{year}\right)=693\left(\frac{kgCO2e}{year}\right)=0.693\left(\frac{tonCO2e}{year}\right)$$

In the following table, these calculations have been sorted and categorized into the proper scope and summarized:

Server Emissions Table (kgCO2e/Year)	**Scope 1**	**Scope 2**	**Scope 3**	**Total**
On-premise emissions, low-carbon power consumption		37	329	366
On-premise emissions, average-carbon power consumption		836	329	1,165
On-premise emissions, high-carbon power consumption		1,056	329	1,385
Global DC emissions, low-carbon power consumption			275	275
Global DC emissions, average-carbon power consumption			874	874
Global DC emissions, high-carbon power consumption			1,039	1,039
Cloud emissions from low-carbon power consumption			183	183
Cloud emissions from average-carbon power consumption			583	583
Cloud emissions from high-carbon power consumption			693	693

Table 10.3 – Server emissions table

Formula 10.3

$$Data\ transmission\ (MB) \times 0.0023 \left(\frac{kWh}{MB}\right) = Energy\ Consumption\ kWh$$

Formula 10.4:

$$1024\ Mb \times 0.0023 \left(\frac{kWh}{MB}\right) = 2.355\ kWh$$

Formula 10.5

$$2.355\ kWh\ \times 475\ \frac{gCO2e}{kWh} = 1\ 119\ gCO2e = 1.12\ kgCO2e$$

Bibliography

- 451 Research. 2019. *The Carbon Reduction Opportunity of Moving to Amazon Web Services*. October. Accessed August 04, 2022. https://sustainability.aboutamazon.com/carbon-reduction-aws.pdf
- Brady, G., N. Kapur, J. Summers, and H. M. Thomson. 2013. "A case study and critical assessment in calculating power usage effectiveness for a data centre." *Energy Conversion and Management* 76 155–161.
- Delforge, Pierre, and Josh Whitney. 2014. *Data Center Efficiency Assessment*. August. Accessed August 04, 2022. https://www.nrdc.org/sites/default/files/data-center-efficiency-assessment-IP.pdf
- 2021. *Dell Latitude 7420*. January. Accessed March 17, 2022. https://www.dell.com/sv-se/dt/corporate/social-impact/advancing-sustainability/sustainable-products-and-services/product-carbon-footprints.htm#tab0=1&pdf-overlay=//www.delltechnologies.com/asset/sv-se/products/laptops-and-2-in-1s/technical-support/latitud
- Dell. 2019. "Life Cycle Assessment of Dell PowerEdge R740." *Dell.com*. Junie. Accessed May 15, 2022. https://i.dell.com/sites/csdocuments/CorpComm_Docs/en/carbon-footprint-poweredge-r740.pdf

- Gill, Victoria. 2021. "Waste electronics will weigh more than the Great Wall of China." *bbc.com*. October 13. Accessed May 16, 2022. https://www.bbc.com/news/science-environment-58885143
- IEA. 2019. *Emissions*. Accessed July 06, 2022. https://www.iea.org/reports/global-energy-co2-status-report-2019/emissions
- Khaliq uz Zaman, Sardar, Atta ur Rehman Khan, Junaid Shuja, Tahir Maqsood, Faisal Rehman, and Saad Mustafa. January 2019. "A Systems Overview of Commercial Data Centers: Initial Energy and Cost Analysis." *International Journal of Information Technology and Web Engineering*.
- Microsoft News Center. 2018. *The Microsoft Cloud can save customers 93 percent and more in energy and carbon efficiency*. Microsoft. May 17. Accessed January 27, 2022. https://news.microsoft.com/2018/05/17/the-microsoft-cloud-can-save-customers-93-percent-and-more-in-energy-and-carbon-efficiency/#:~:text=%E2%80%94%20May%2017%2C%202018%20%E2%80%94%20A,issued%20Thursday%20by%20Microsoft%20Corp.&text=These%20gains%2C%20as%
- Ryder, Guy, and Zhao Houlin. 2019. *The world's e-waste is a huge problem. It's also a golden opportunity*. January 24. Accessed July 07, 2022. https://www.weforum.org/agenda/2019/01/how-a-circular-approach-can-turn-e-waste-into-a-golden-opportunity/

Chapter 11

Images

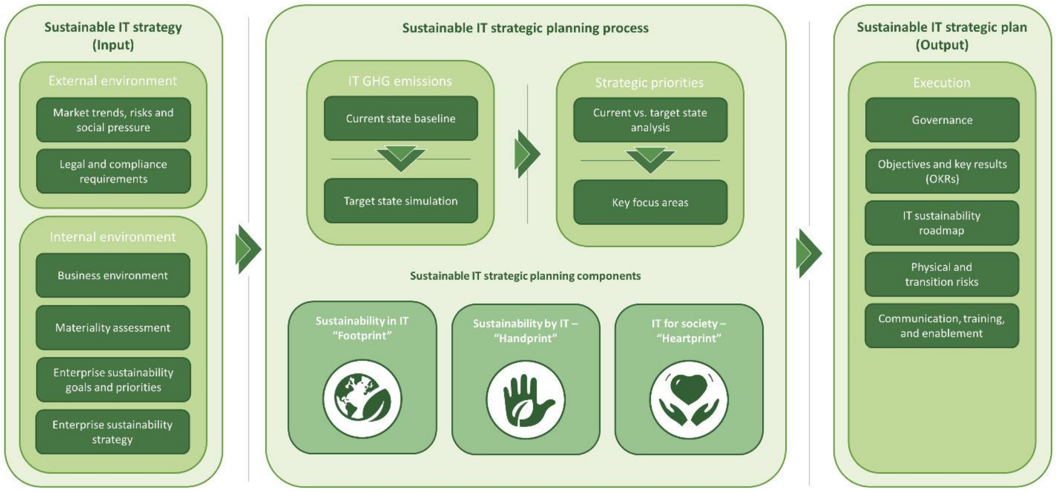


Figure 11.1 – Sustainable IT strategy framework

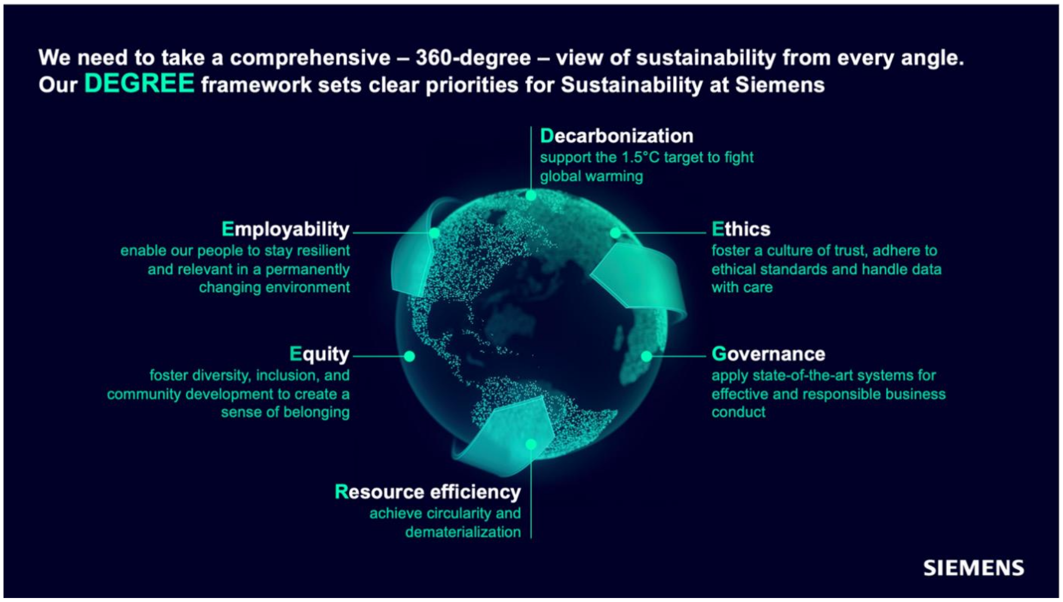


Figure 11.2 – Siemens DEGREE framework

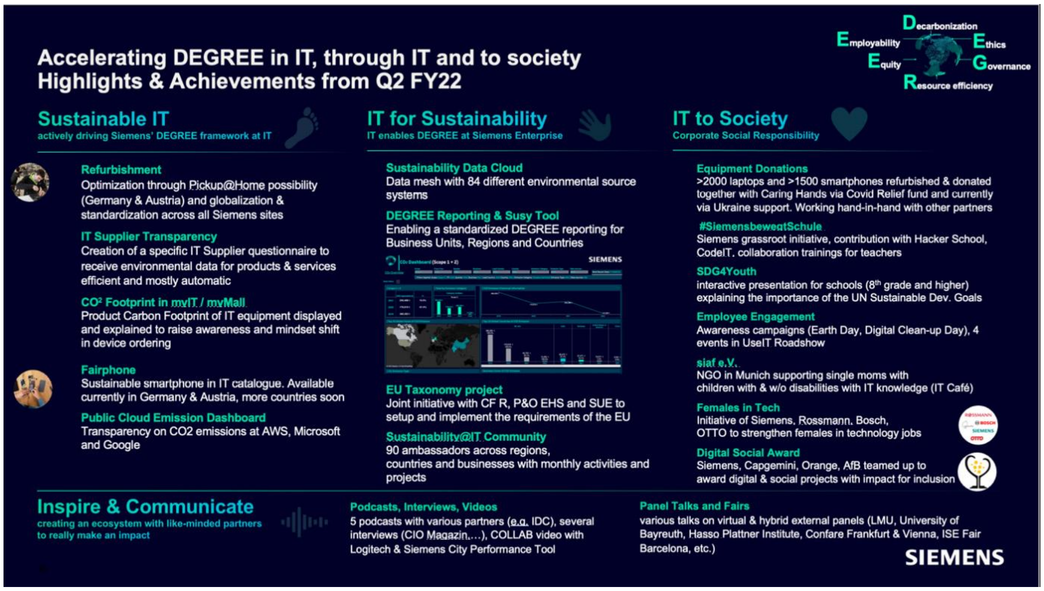


Figure 11.3 – Siemens accelerating DEGREE in IT, through IT, and to society

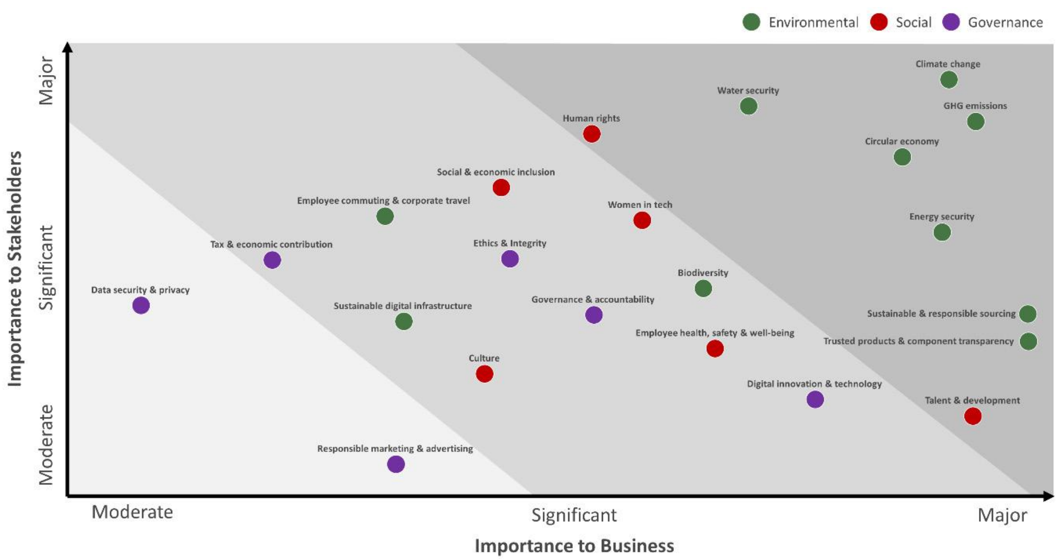


Figure 11.4 – Materiality assessment example

Figure 11.5 – ESG issues grouping example

Figure 11.6 – Sustainability strategy goals

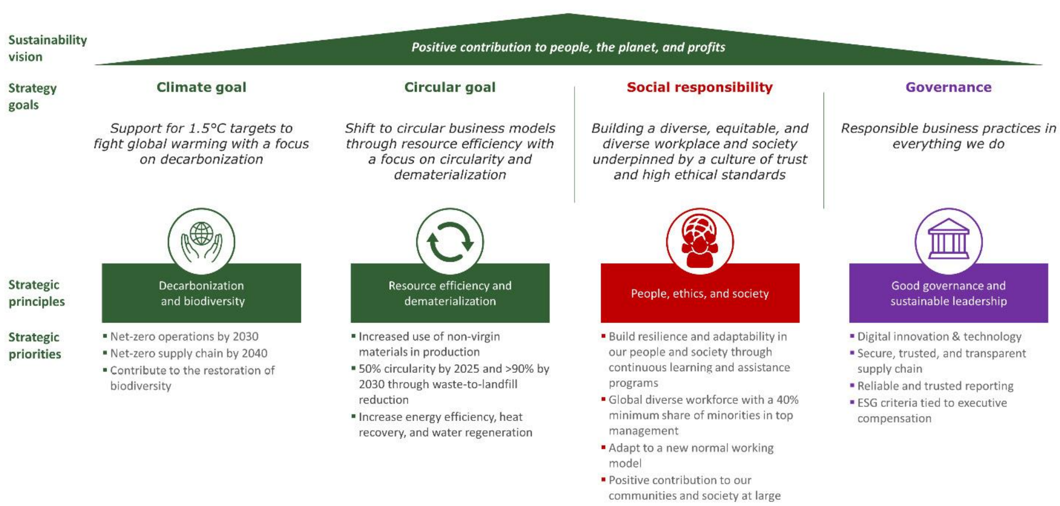


Figure 11.7 – Sustainability strategy house

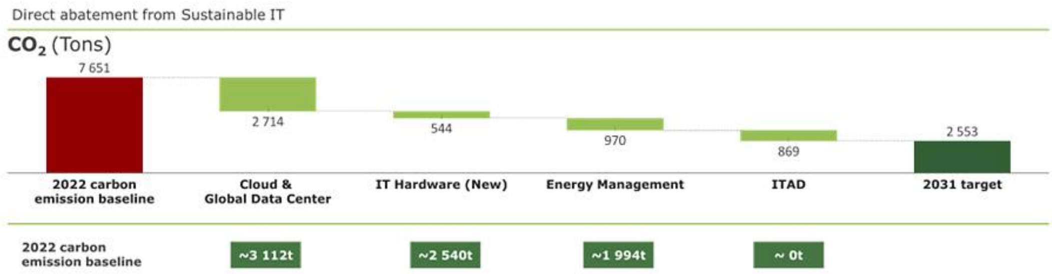


Figure 11.8 – 10-year carbon emission waterfall summary

Figure 11.9 – Sustainable IT value proposition

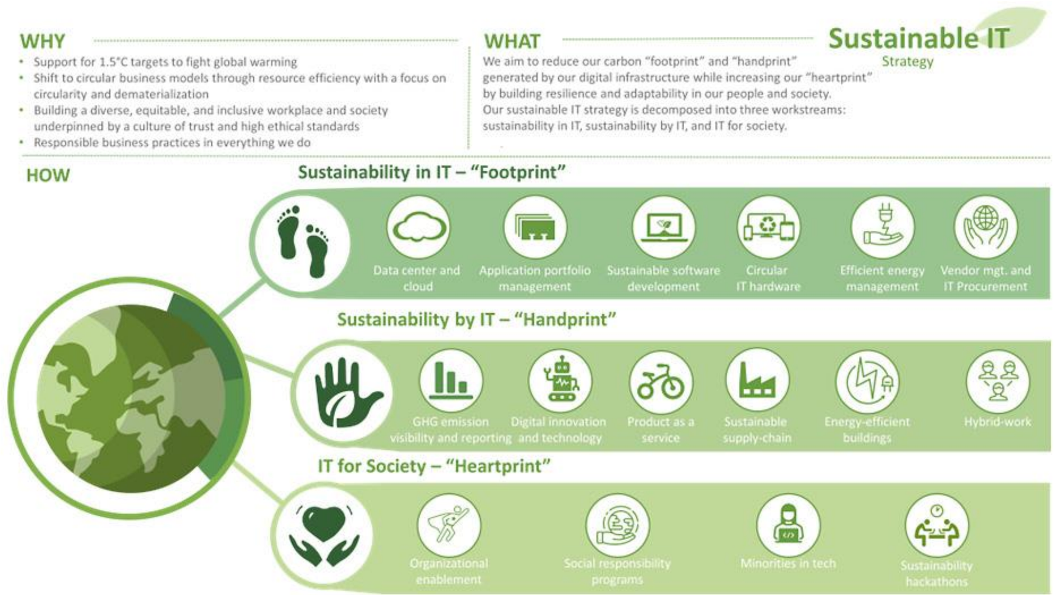
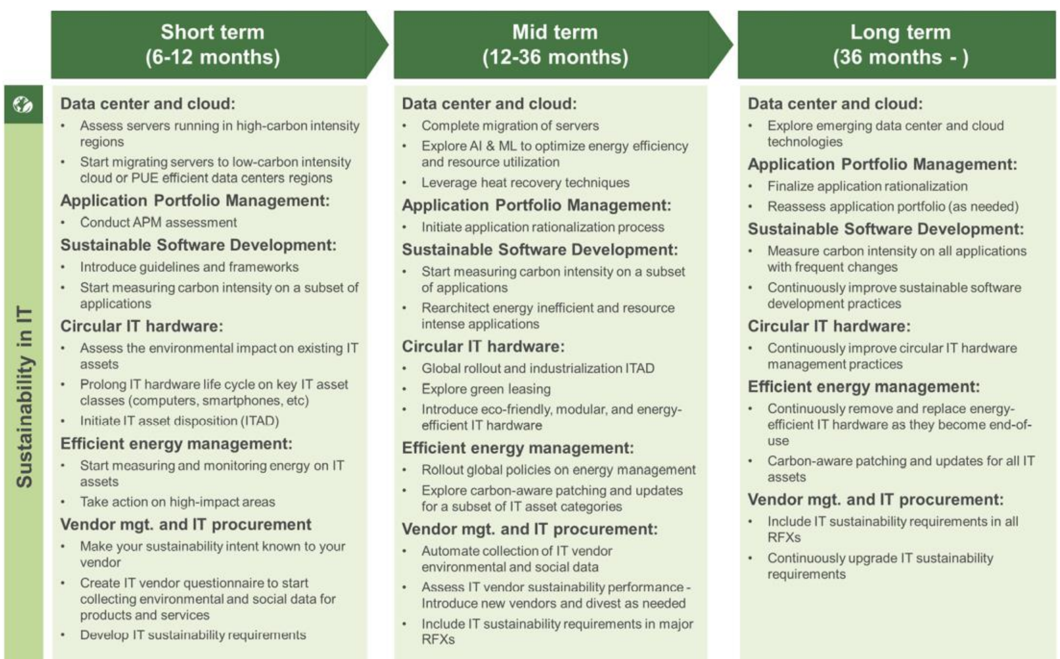


Figure 11.10 – Sustainable IT strategy on-a-page



Sustainability in IT

Short term (6-12 months)	Mid term (12-36 months)	Long term (36 months -)
Data center and cloud: • Assess servers running in high-carbon intensity regions • Start migrating servers to low-carbon intensity cloud or PUE efficient data centers regions **Application Portfolio Management:** • Conduct APM assessment **Sustainable Software Development:** • Introduce guidelines and frameworks • Start measuring carbon intensity on a subset of applications **Circular IT hardware:** • Assess the environmental impact on existing IT assets • Prolong IT hardware life cycle on key IT asset classes (computers, smartphones, etc) • Initiate IT asset disposition (ITAD) **Efficient energy management:** • Start measuring and monitoring energy on IT assets • Take action on high-impact areas **Vendor mgt. and IT procurement** • Make your sustainability intent known to your vendor • Create IT vendor questionnaire to start collecting environmental and social data for products and services • Develop IT sustainability requirements	**Data center and cloud:** • Complete migration of servers • Explore AI & ML to optimize energy efficiency and resource utilization • Leverage heat recovery techniques **Application Portfolio Management:** • Initiate application rationalization process **Sustainable Software Development:** • Start measuring carbon intensity on a subset of applications • Rearchitect energy inefficient and resource intense applications **Circular IT hardware:** • Global rollout and industrialization ITAD • Explore green leasing • Introduce eco-friendly, modular, and energy-efficient IT hardware **Efficient energy management:** • Rollout global policies on energy management • Explore carbon-aware patching and updates for a subset of IT asset categories **Vendor mgt. and IT procurement:** • Automate collection of IT vendor environmental and social data • Assess IT vendor sustainability performance - Introduce new vendors and divest as needed • Include IT sustainability requirements in major RFXs	**Data center and cloud:** • Explore emerging data center and cloud technologies **Application Portfolio Management:** • Finalize application rationalization • Reassess application portfolio (as needed) **Sustainable Software Development:** • Measure carbon intensity on all applications with frequent changes • Continuously improve sustainable software development practices **Circular IT hardware:** • Continuously improve circular IT hardware management practices **Efficient energy management:** • Continuously remove and replace energy-efficient IT hardware as they become end-of-use • Carbon-aware patching and updates for all IT assets **Vendor mgt. and IT procurement:** • Include IT sustainability requirements in all RFXs • Continuously upgrade IT sustainability requirements

Figure 11.11 – Sustainability in IT – short-term, mid-term, and long-term plans

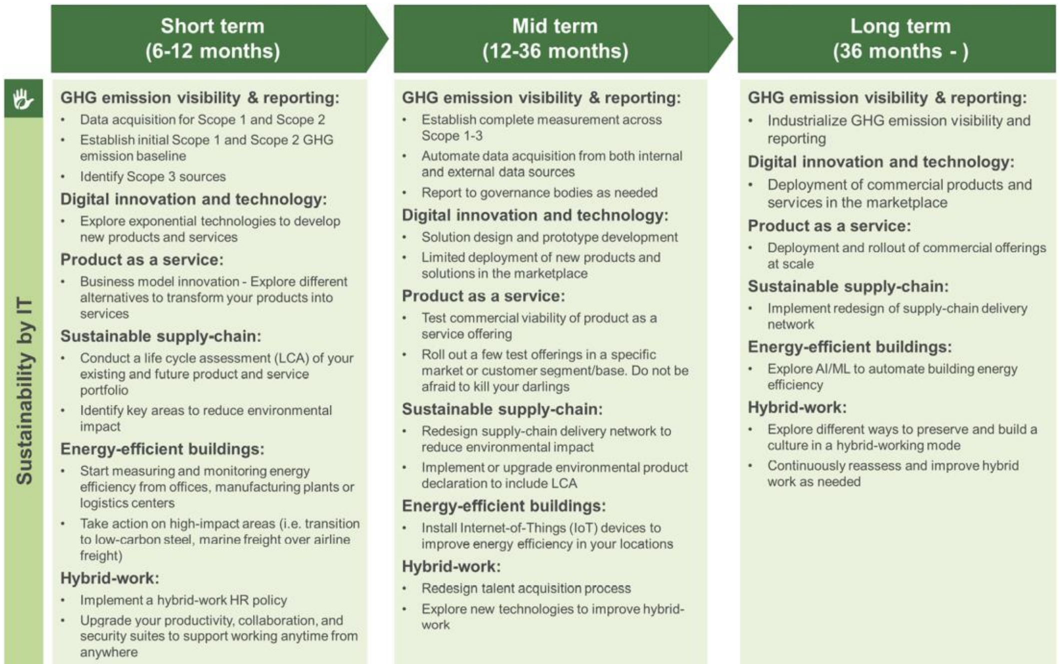


Figure 11.12 – Sustainability by IT – short-term, mid-term, and long-term plans

Figure 11.13 – IT for society – short-term, mid-term, and long-term plans

Expected results	
A flexible technology platform to support the company's future growth running on low-carbon intensity	
Objectives	**Activities**
■ Migrate existing server estate to a modern cloud computing platform ■ Cloud computing enables IT systems to be scalable and elastic ■ Increase share of the virtualization ■ Improve security and compliance ■ Retire old legacy technology platforms	■ Identify all infrastructure in scope to be migrated ■ Conduct analysis on viable migration options, limitations, risk, dependencies ■ Create a migration plan ■ Plan out-migration steps in detail ■ Prepare a communication plan and communicate continuously with stakeholders ■ Prepare a final cut-over plan ■ Conduct migration(s) ■ Verify migration results
Interdependencies/Risks	**Benefit**
■ Lack of cloud engineers ■ Migration of legacy systems	■ Provide a customer experience that is always on with no downtime and no service windows ■ Deliver IT services (software, platform, and infrastructure) to realize agility, scalability, reliability, resilience, cost optimization, and sustainability benefits ■ Decarbonize our digital infrastructure with a minimum of a factor of 20x
Initiative Manager	**Sponsor**
Digital infrastructure transformation manager	Chief Information Officer

Figure 11.14 – Sample initiative charter

Tables

Goal	Strategic Principle	Strategic Priorities
Climatel	Decarbonization and biodiversity	Net-zero operations by 2030
		Net-zero supply chain by 2040
		Contribute to the restoration of biodiversity
Circular	Resource efficiency and dematerialization	Increased use of non-virgin materials in production
		50% circularity by 2025 and >90% by 2030 through waste-to-landfill reduction
		Increase energy efficiency, heat recovery, and water regeneration
Social responsibility	People, ethics, and society	Build resilience and adaptability in our people and society through continuous learning and assistance programs

		A global, diverse workforce with a 40% minimum share of minorities in top management
		Adapt to a new normal working model
		Positive contribution to our communities and society at large
Governance	Good governance and sustainable leadership	Digital innovation and technology
		Secure, trusted, and transparent supply chain
		Reliable and trusted reporting
		ESG criteria tied to executive compensation

Table 12.1 – Enterprise sustainability strategy goals, principles, and priorities

	Challenges and Pain Points	Capabilities and Required Step-Change	Objectives and Key Results (OKRs)
Sustainability in IT – "Footprint"	• A large share of servers in high-carbon cloud and data centers • No sustainability is embedded into application portfolio management or software development • Limited energy management visibility and tracking • A high turnover rate of IT hardware, limited repair, and reuse • Limited sustainability requirements embedded within RF(X), contracts, and more	• Cloud and data center • Application portfolio management • Sustainable software development • Efficient resource management • Circular IT hardware management • IT asset disposition • Vendor management and IT procurement	• Reduce a minimum of 70% CO_2 emission from IT operations, including scope 3, by 2030 • Reduce CO_2 emissions from cloud and data center operations by 70% or more by 2050 • Prolong the lifespan of IT hardware • Increase share of **Device-as-a-Service** (**DaaS**) • Improve energy resource efficiency by 50% • Remove one ton of CO_2 emissions through ITAD per year by 2030
Sustainability by IT – "Handprint"	• Visibility of the current emissions baseline • **Life cycle assessment** (**LCA**) of the current product and service portfolio • New regional and national regulatory requirements • Limited sustainability innovation in products and services	• GHG emission visibility and reporting • Digital innovation and technology • **Product-as-a-Service** (**PaaS**) • Sustainable supply chain, including • product and services LCA visibility • Energy-efficient buildings • Hybrid-work	• Enable sustainable digital innovation and technology • Provide support for a single source of truth for environmental data across the enterprise • Support for supplier and scope 3 management

	Challenges and Pain Points	Capabilities and Required Step-Change	Objectives and Key Results (OKRs)
IT for Society – "Heartprint"	• 15% of minorities share in top management • Scarcity of trained sustainability professionals • Limited sustainability training available	• Organizational enablement • Social responsibility programs • Women in tech • Sustainability hackathons	• Awareness campaigns and formal training • Initiate IT hardware and employee time donation programs • Increase the share of minorities in IT roles by 30%

Table 12.2 – Sustainable IT value proposition

Bibliography

- Rare.org. 2022. *Eight Principles for Effective and Inviting Climate Communication*. Accessed September 04th, 2022. https://rare.org/report/eight-principles-for-effective-and-inviting-climate-communication
- Siemens. 2022. *Sustainability Figures*. Accessed August 17th, 2022. https://new.siemens.com/global/en/company/sustainability/sustainability-figures.html#!/siemens/en/our-degree-framework/
- Yale. 2021. *International Public Opinion on Climate Change*. June 28th. Accessed September 04th, 2022. https://climatecommunication.yale.edu/publications/international-public-opinion-on-climate-change/toc/3/#:~:text=Most%20respondents%20say%20they%20need%20more%20information
- —. 2022. *Yale Climate Opinion Maps 2022*. February 23rd. Accessed September 04th, 2022. https://climatecommunication.yale.edu/visualizations-data/ycom-us/

Chapter 12

Images

Figure 12.1 – The 5Cs for success

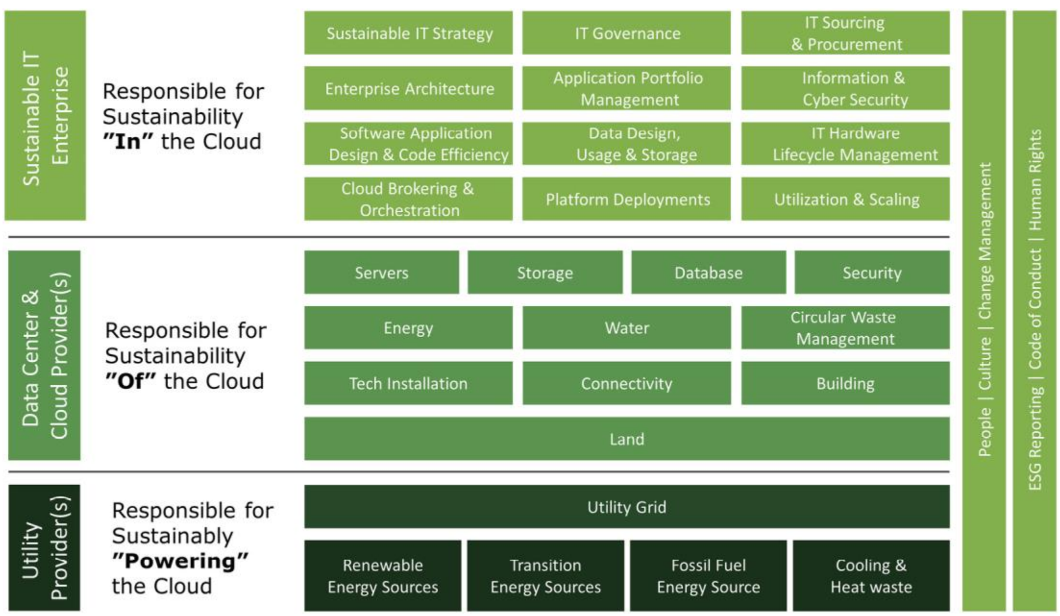


Figure 12.2 – Sustainable IT reference model

Figure 12.3 – Sustainable IT maturity model©

Figure 12.4 – Emission calculation – the seven-step process

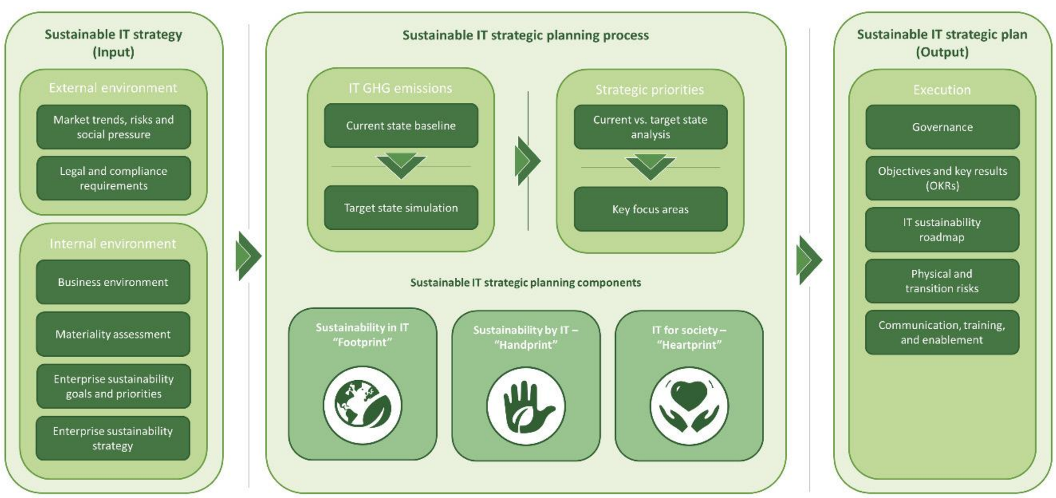


Figure 12.5 – Sustainable IT strategy framework

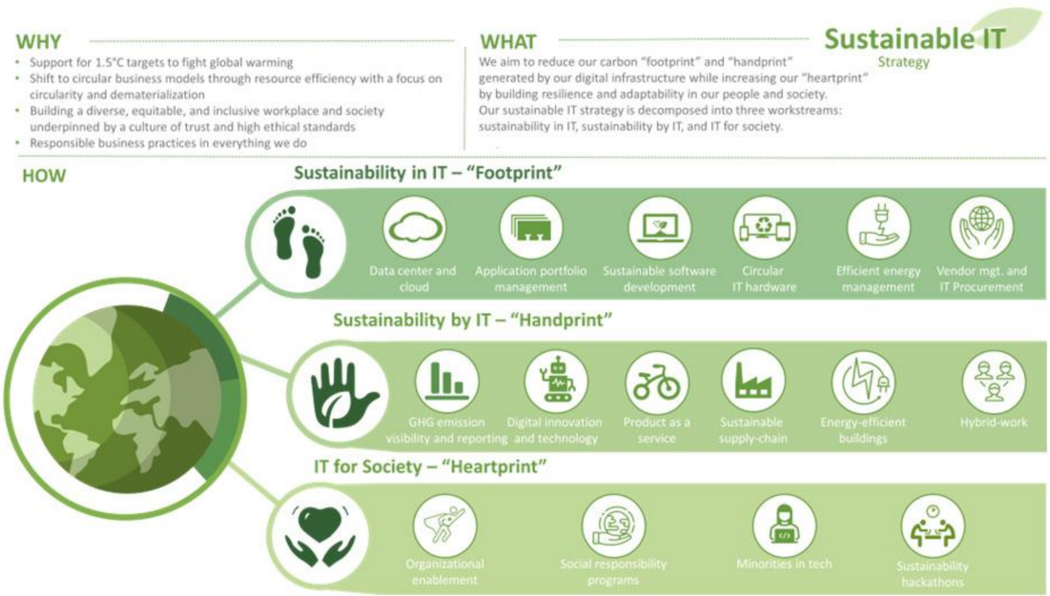


Figure 12.6 – Sustainable IT strategy on-a-page

Bibliography

- Accenture. 2021. *Accenture, GitHub, Microsoft, and ThoughtWorks Launch the Green Software Foundation with the Linux Foundation to Put Sustainability at the Core of Software Engineering*. May 25. Accessed September 21, 2022. https://newsroom.accenture.com/news/accenture-github-microsoft-and-thoughtworks-launch-the-green-software-foundation-with-the-linux-foundation-to-put-sustainability-at-the-core-of-software-engineering.htm
- —. 2022. *This finding is based on an analysis of 276 companies in our research whose ESG impact has been scored*. Accessed September 21, 2022. https://sray.arabesque.com/
- Deutsch, Anthony, Kirstin Ridley, and Simon Jessop. 2022. *Dutch airline KLM sued over 'greenwashing' ads*. July 6. Accessed July 6, 2022.

https://www.reuters.com/business/aerospace-defense/dutch-airline-klm-sued-over-greenwashing-ads-2022-07-06/

- Evans, Scarlett. 2022. *TotalEnergies sued for alleged greenwashing*. March 3. Accessed August 30, 2022. https://www.offshore-technology.com/news/totalenergies-sued-for-alleged-greenwashing/
- Gartner Inc. 2022. *Does Your Organization Need a Chief Sustainability Officer?* April 25. Accessed September 21, 2022. https://www.gartner.com/en/articles/does-your-organization-need-a-chief-sustainability-officer
- Gartner Inc. 2022 Q2. *Planning for the Never Normal*. Digital, Standord, CT: Gartner Inc.
- Kit Chellel; Wojciech Moskwa. 2022. *A Plastic Bag's 2,000-Mile Journey Shows the Messy Truth About Recycling*. March 29. Accessed 09 24, 2022. https://www.bloomberg.com/graphics/2022-tesco-recycle-plastic-waste-pledge-falls-short/?leadSource=uverify%20wall
- Roberts, Dan. 2022. *IT leadership: You gotta have H.E.A.R.T.* August 8. Accessed August 30, 2022. https://enterprisersproject.com/article/2022/8/it-leadership-you-gotta-have-heart
- United Nationals Global Compact & Accenture. 2021. *Climate leadership in the eleventh hour*. Accessed September 21, 2022. https://www.accenture.com/us-en/insights/sustainability/ungc#:~:text=Climate%20leadership%20in%20the%20eleventh%20hour,-The%20latest%20United&text=CEOs%20report%20that%20their%20businesses,to%20more%20sustainable%20business%20models
- Wicker, Alden. 2022. *H&M Is Being Sued for Greenwashing. What Does That Mean For Fashion?* August 19. Accessed August 30, 2022. https://www.thecut.com/2022/08/h-and-m-greenwashing-fashion.html