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Global stocktake: Digital technologies for climate action



Green Digital Action

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Global stocktake: Digital technologies for climate action



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List of abbreviations

ADB	Asian Development Bank
ADEME	French Agency for Ecological Transition (Agence de la transition écologique)
AEDC	Abuja Electricity Distribution Company
AFD	French Development Agency (Agence française de développement)
AI	artificial intelligence
ANATEL	National Telecommunications Agency of Brazil (Agência Nacional de Telecomunicações)
ATM	air traffic management
AWS	Amazon Web Services
BEE	Bureau of Energy Efficiency (India)
BMS	building management system
BREEAM	Building Research Establishment Environmental Assessment Method
CAICT	China Academy of Information and Communications Technology
CBIT	Capacity-building Initiative for Transparency
CDP	CDP (formerly the Carbon Disclosure Project)
CIS	Commonwealth of Independent States
CNAS	China National Accreditation Service for Conformity Assessment
COP	Conference of the Parties
CST	Communications, Space and Technology Commission (Saudi Arabia)
CUE	carbon usage effectiveness
DESNZ	Department for Energy Security and Net Zero (United Kingdom)
EAGB	Electricity and Water Company of Guinea-Bissau
EBRD	European Bank for Reconstruction and Development
EGDC	European Green Digital Coalition
EPA	Environmental Protection Agency (United States)
EPR	extended producer responsibility
ERP	enterprise resource planning
ESCAP	Economic and Social Commission for Asia and the Pacific

(continued)

ESG	environmental, social, and governance
ETS	Emissions Trading System
EU	European Union
EV	electric vehicle
EVN	Vietnam Electricity
GbDT	Greening *by* Digital Technologies
GCF	Green Climate Fund
GDT	Greening Digital Technologies
GEF	Global Environment Facility
GHG	greenhouse gas
GHGRP	Greenhouse Gas Reporting Program (United States)
GIR	Greenhouse Gas Inventory and Research Center (Republic of Korea)
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GLAD	Global Land Analysis and Discovery
GSMA	GSM Association – representing mobile telecom network operators globally
GWCL	Ghana Water Company Limited
HVAC	heating, ventilation, and air conditioning
ICT	information and communication technology
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IMEO	International Methane Emissions Observatory
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication Standardization Sector
KONEPS	Korea ON-line E-Procurement System
LPG	liquefied petroleum gas
LTE	Long-Term Evolution (fourth-generation mobile standard)

(continued)

MARD	Ministry of Agriculture and Rural Development (Viet Nam)
MARS	Methane Alert and Response System
MIIT	Ministry of Industry and Information Technology (China)
MIMO	multiple-input multiple-output
ML	machine learning
MRI	magnetic resonance imaging
MRV	monitoring, reporting, and verification
NDC	nationally determined contribution
NEGK	National Electric Grid of Kyrgyzstan
OECD	Organisation for Economic Co-operation and Development
PACT	Partnership for Carbon Transparency
PaCT	Partnership for Cleaner Textile
PAS	Publicly Available Specification (British Standards Institution)
PAT	Perform, Achieve and Trade
PPA	power purchase agreement
PUE	power usage effectiveness
PV	photovoltaic
RE100	Renewable Energy 100
REF	Rwanda Renewable Energy Fund
SAGERS	South African Greenhouse Gas Emissions Reporting System
SBTi	Science Based Targets initiative
SCADA	supervisory control and data acquisition
SDEA	Swiss Datacenter Efficiency Association
SESAR	Single European Sky ATM Research
SMEs	small and medium-sized enterprises
SMS	short message service
TTL	China Telecommunication Technology Labs
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

(continued)

UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
UNITAR	United Nations Institute for Training and Research
VnSAT	Viet Nam Sustainable Agriculture Transformation Project
WBCSD	World Business Council for Sustainable Development
WEF	World Economic Forum
WTDC	World Telecommunication Development Conference
WTSA	World Telecommunication Standardization Assembly
WUE	water usage effectiveness

Units of measurement

CO_2e	carbon dioxide equivalent
tCO_2	tonnes of carbon dioxide
tCO_2e	tonnes of carbon dioxide equivalent
$MtCO_2e$	million tonnes of carbon dioxide equivalent
kWh	kilowatt-hour
MWh	megawatt-hour
GWh	gigawatt-hour
TWh	terawatt-hour
MW	megawatt
GW	gigawatt
GJ	gigajoule
PB	petabyte

Executive summary

Digital technologies are increasingly central to national climate strategies. Yet real-world evidence about how digitalization can cut emissions remains fragmented across different sectors, databases and geographic regions. As countries submit updated nationally determined contributions (NDCs) under the Paris Agreement, 103 out of the 140 NDCs with targets for 2035 that were submitted by July 2026 explicitly reference digital technologies as climate implementation tools,[1] up from roughly half of submissions in the previous cycle (2020-2021). This greater visibility reflects rising digital ambitions, as well as specific pressure to scale up green digital transformation plans. To pursue such aims, decision-makers need credible, independent evidence on what works, at what scale, and under what conditions.

At the same time, the energy and carbon footprint of artificial intelligence (AI) and digital infrastructure increases the urgency of documenting the sector's own progress on decarbonization, along with how digital technologies enable emission reductions in other sectors.

This report addresses that gap by assessing and scoring 150 documented real-world cases, deployed in 104 countries from major regions worldwide, to produce a global stocktake of digital technologies for climate action. The cases fall into two main domains: Greening *by* Digital Technologies, whereby digital technologies enable improvements in other sectors; and Greening Digital Technologies, addressing the sector's own impact. The two domains, furthermore, are anchored in two ITU standards: Recommendation ITU-T L.1480,[2] which measures the net greenhouse gas (GHG) impact of information and communication technology (ICT) solutions on other sectors; and Recommendation ITU-T L.1410,[3] which provides the lifecycle assessment methodology for ICT goods, networks, and services.

ITU's net-zero transition standard (L.1480), furthermore, defines "net climate impact" as the measurable emission reductions enabled by digital solutions in other sectors, minus the footprint of the digital technologies themselves.

What this stocktake covers

Greening *by* Digital Technologies covers the use of digital technologies to enable and unlock GHG mitigation and energy efficiency improvements in other sectors. These include energy systems, mobility and transport, buildings and homes, industry and manufacturing, and agriculture and forestry: the five sectors identified in Recommendation ITU-T L.1480. Public administration has been added as a sixth sector, given its growing role in digital-enabled GHG monitoring, reporting, and verification.

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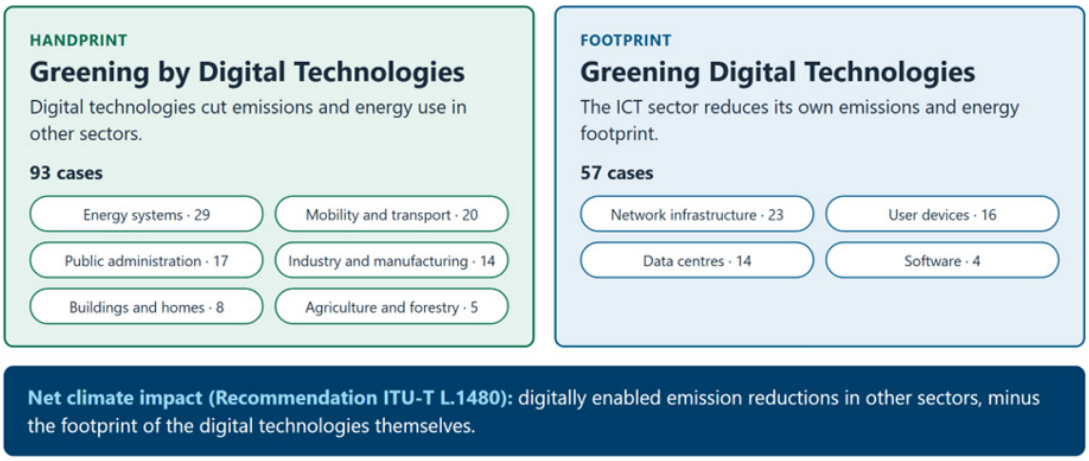
1 ITU, *Digital Technologies and NDCs: Digital Solutions in Support of NDC Implementation* (Geneva: ITU, 2026).

2 ITU, Recommendation ITU-T L.1480: *Enabling the Net Zero Transition: Assessing How the Use of Information and Communication Technology Solutions Impacts Greenhouse Gas Emissions of Other Sectors* (Geneva: ITU, 2025), https://www.itu.int/rec/T-REC-L.1480/en.

3 ITU, Recommendation ITU-T L.1410: *Methodology for Environmental Life Cycle Assessments of Information and Communication Technology Goods, Networks and Services* (Geneva: ITU, 2024), https://www.itu.int/rec/T-REC-L.1410/en.

Greening Digital Technologies entails reducing the ICT sector's own GHG emissions and energy footprint in network infrastructure, data centres, and user devices – the three sub-domains identified in ITU's digital sector emissions framework.[4] Software was added as a fourth sub-domain because software design and engineering choices directly affect energy consumption (Figure 1).

Figure 1: The two domains of the stocktake



Source: Figure prepared from stocktake case data (ITU, 2026).

The stocktake is structured around four research questions based on the findings from previous ITU studies:[5]

- Which digital solutions show documented, verifiable outcomes in GHG mitigation and energy efficiency across different economic sectors, and do those benefits remain positive after accounting for the footprint and rebound effects of the technologies involved?
- Which cases have reduced the energy consumption and GHG emissions of digital infrastructure, data centres, devices, and software?
- What are the main pathways through which digital technologies help meet climate and energy goals, and how are they combined?
- How can governments and other stakeholders incorporate proven digital solutions into their climate strategies?

This report does not endorse any specific company, vendor, or technology. Cases are included solely to surface documented examples of good practices and to illustrate digitalization opportunities for governments, development finance institutions, the private sector, international organizations, researchers, and other stakeholders working to advance digital technologies for climate action and sustainable development.

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4 ITU, *Digital Technologies in NDCs: Stocktake and Analysis* (Geneva: ITU, 2025), *p*. 5, https://www.itu.int/pub/S-GEN-GDA.002-2025.

5 ITU, *Digital Technologies in NDCs*; ITU and World Benchmarking Alliance, *Greening Digital Companies 2025: Monitoring Emissions and Climate Commitments* (Geneva and Amsterdam: ITU and WBA, 2025), https://www.itu.int/en/ITU-D/Environment/Pages/Publications/GDC-25.aspx.

Headline findings across the cases

All 150 cases are analysed based on the same four research questions. In every sector considered, the potential of digitally enabled climate solutions is clear. ITU-T L.1480 provides a rigorous methodology for assessing the net climate impact of digital technologies, accounting both for emissions reductions and energy savings enabled in other sectors and for the environmental footprint of the technologies enabling those, including rebound effects. To date, net impacts from digitalization have not been systematically documented, scaled, financed, or embedded in national policies. Yet the technologies in question are relatively mature and can be assessed for each use case based on widely recognized standards. What is still missing are institutional requirements and financial incentives to assess and verify net climate impacts.

The following findings summarize the main conclusions of the stocktake.

Finding 1: Digital technologies can deliver measurable, scalable climate benefits, but net impact reveals a more complex picture.

- Digitally enabled climate solutions show clear potential across every sub-domain of this stocktake: 45 of the 150 cases report a measured percentage cut in emissions or energy use. In the 21 where the cut can be credited to the intervention, the typical cut is 22%, and half of these cases fall between 8% and 52%. The strength of the evidence varies: 28 cases (19%) are Tier 1, checked by peer review, independent assurance, or independent evaluation, while 78 (52%) rest on the implementing organization's own reporting.
- Most cases report gross enabling benefits rather than verified net impacts. Only 15 of the 150 have been assessed with a net-impact method, and of the 14 that quantify the footprint of the digital infrastructure itself, 12 still show a net climate benefit, while in the other 2 the rebound scenarios reverse the result.
- Assessments also reveal trade-offs beyond climate impact: four of the five ADEME cases with a positive climate result add a net burden on mineral and metal resources, mainly from the equipment they install. Technologies and methodologies are available; one of the principal challenges is applying existing net-impact assessment methods more consistently.

Finding 2: Despite some well-documented efficiency gains, few organizations report whether their total energy use and emissions are falling.

- Reported efficiency gains can be large. By 2023, Nokia had cut the power use of its 5G massive multiple-input multiple-output (MIMO) base station by 50% per unit compared with 2019; Sony estimates that the PlayStation 5 uses 11% to 17% less energy per unit than the 2013 PS4 launch model; and New Relic estimates that, by July 2024, cloud workloads moved to more efficient processors emitted 37% less carbon dioxide or equivalent gases (CO_2e) per unit. Atos is one of the few firms to report changes in total consumption, with a 32% cumulative cut in energy use across its data centres and offices between 2019 and 2022.
- Only 30% of Greening Digital Technologies cases (17 out of 57) show changes in an organization's total energy use or emissions over time; three more cases give totals for a single year; and 37 only give per-unit figures or only cover energy intensity, energy efficiency, or avoided emissions.
- Intensity can fall much faster than total demand: AT&T's network energy intensity fell by 56% between 2020 and 2024 (our calculation from AT&T's chart values), while its total energy consumption fell only 14.3%. When reporting rests on intensity ratios, efficiency gains cannot be shown to reduce the sector's footprint.

- The kind of net assessment set out in ITU-T L.1480 cannot be completed without absolute figures for each element on either side of the equation. Network operators, data-centre owners, and device makers should therefore report their absolute energy use and emissions against a fixed baseline, alongside intensity metrics.

Finding 3: Large-scale impact depends more on programme design and enabling conditions than on technology choices.

- The largest independently evaluated outcomes come from national programmes that share a set of enabling conditions: national targets, financing tied to those targets, monitoring and evaluation built in from the outset, local institutional capacity, and multi-year funding cycles. In these programmes, digital tools are one part of a wider intervention.
- In Egypt, the industrial energy efficiency programme of the United Nations Industrial Development Organization (UNIDO) and the Global Environment Facility (GEF) saved 1 247 gigawatt-hours (GWh) and 358 000 tonnes of carbon dioxide (tCO_2) yearly. It trained more than 700 energy-efficiency consultants, supported ISO 50001 energy management and benchmarking in 70 companies, and made policy recommendations that were adopted in the national Industrial Innovation Strategy. Companies in the programme installed sub-meters and SCADA monitoring to track their energy performance.
- In Viet Nam, the GEF and United Nations Development Programme (UNDP) building energy code programme paired simulation software, metered monitoring of retrofitted buildings, and a national building energy database with compliance toolkits shared with all 64 provincial construction departments and training for officials and practitioners, saving 52 817 megawatt-hours (MWh) by project close.
- When digital tools are bundled with other components, their specific contributions may be obscured, with the exact share of efficiency gains or other outcomes to credit to digital investments remaining elusive.

Finding 4: Few solutions are codified for others to adopt, and only about a quarter are known to be replicated in other countries or sectors.

- The analysis shows that some digital climate solutions are being replicated, but few have been documented and institutionalized for independent adoption and scaling. Only 22 of the 150 cases (15%) document that their method has been codified so that others can adopt it without the original team: 11 publish their data, code, or method openly; 10 are written into law or regulation; and one case is an actual standard. MapBiomas, for example, publishes its land-use maps, methods, and code openly, and the EU Emissions Trading System is written into law. The one standard is the Partnership for Carbon Transparency (PACT) of the World Business Council for Sustainable Development (WBCSD), an open standard for exchanging product carbon footprints used by more than 5 000 companies and 48 software providers.
- A further 39 cases (26%) have been deployed in at least two countries or sectors, but their methods are not yet codified in a standard, open release, or regulation that others can adopt. The remaining 89 (59%) record a single deployment, suggesting significant opportunities for scaling up proven solutions.
- Wider adoption could be achieved by documenting methodologies more systematically and making them easier to transfer and implement across different countries, sectors, and organizations.
- Cost evidence is similarly thin. Only 35 of the 150 cases (23%) report any financial figure, 8 give the capital cost of the solution, 18 an operating saving, and only 4 a payback period. Governments and investors weighing adoption of existing digital solutions rarely have the cost data needed to make an informed decision.

Finding 5: Almost half of the cases analysed drive climate action in more than one way.

- The analysis identifies six distinct mechanisms or pathways for digital technologies to contribute to climate outcomes: Optimizing, Dematerializing, Amplifying, Accelerating, Connecting, and Monitoring. The six pathways vary widely in prevalence, evidence quality, and documented impact.
- About 45% of cases (67 out of 150) combine more than one pathway. Optimizing is the most common pathway, used in 98 cases, often in combination with Monitoring. Overall, cases that combine pathways do not achieve larger reductions than those that follow just one.
- Where a measured percentage reduction can be attributed to the intervention, Optimizing results in the largest reductions, with a median of 28% across 15 cases. This is followed by Monitoring, 18% based on 5 cases, where the reduction comes from acting on what is detected: patrols responding to deforestation alerts, utilities repairing leaks and grid faults.
- Amplifying, where digital tools spread an existing sustainability practice to more people, sites, or suppliers, is the hardest to credit: the cases report the total result of the practice, such as a company's emissions after switching to renewable power, not what the wider reach added. Only one of the seven measured reductions can be credited to the digital tool.
- Dematerializing produces comparatively strong evidence, with 5 of the 13 cases it leads at Tier 1, but the resulting reports of avoided emissions rest on modelled counterfactuals such as the trip not taken.
- Connecting and Accelerating are central to public-sector climate governance, but their impact remains under-documented. Such cases rarely involved measured emissions, instead focusing on achievements such as connections made, people reached, or finance mobilized.
- Stronger reference scenarios, evaluation design, and response chains would improve the credibility and comparability of all six pathways.

Finding 6: The methodology for measuring digitally enabled climate benefits exists, but the mechanisms needed to apply it at scale are missing.

- ITU-T L.1480[6] provides a methodology for assessing the net climate impacts of digital technologies, and sector-specific guidance is already available through initiatives such as the European Green Digital Coalition. However, the widespread use of these methodologies remains limited.
- What is missing are the policies, reporting mechanisms, procurement requirements, and financial incentives needed to make their use routine. Early mechanisms, such as the case-study programme of the European Green Digital Coalition (EGDC) and the IT4Green assessments of the French Agency for Ecological Transition (ADEME), show how this can work, but they remain small relative to the scale of adoption required.
- The policy ecosystem is far more developed for Greening Digital Technologies, with known and available reporting frameworks, standards, and incentives, including RE100, the Carbon Disclosure Project (CDP), the Science Based Targets initiative, and the EU Ecodesign Regulation. These mechanisms encourage organizations to measure, report, and improve their environmental performance.

[6] ITU, Recommendation ITU-T L.1480.

- Methodologies also exist for Greening *by* Digital Technologies, which accounts for 62% of this analysis, yet the supporting system for large-scale implementation remains limited. Closing that gap is an immediate priority.

Finding 7: Artificial intelligence (AI) features in one in four cases, but evidence on its net climate impact remains limited.

- AI or machine learning plays a role in 36 of 150 cases (24%), mostly improving the efficiency of existing systems: optimizing network energy use, managing district heating, and fine-tuning industrial processes.
- Against the AI technology types listed in ITU-T L.1801, case files name machine learning in 9 of the 36 cases and do not specify the technique in the rest.[7] No case describes generative AI or a large language model delivering a climate outcome.
- Only one of the 36 AI cases, SAWACO's AI-optimized desalination plant, breaks out the footprint of its AI component. ITU-T L.1801, providing guidelines for assessing the environmental impact of AI systems, was approved in February 2026 – too recently to influence the cases documented in this analysis.
- Wider use of ITU-T L.1801 could strengthen the credibility and comparability of AI-related climate claims, including where AI is referenced in national climate strategies and implementation plans.

Finding 8: The benefits of digitally enabled climate action are largely public goods, but the costs of assessing and verifying them fall on private actors who have no mechanism to recover that value.

- Assessment and verification costs discourage both investment in impact assessment and the use of rigorous measurement methodologies. Climate benefits enabled by digital technologies, such as avoided emissions in supply chains, reduced electricity losses in power grids, or lower agricultural emissions, accrue society-wide, as public goods, while the deploying organization captures only a small share of that collective value.
- Technology providers can benefit from selling a solution. However, neither the deploying organization nor the technology provider has a strong incentive to fund independent verification of the net impacts.
- Verified emission reductions often provide little additional commercial value because procurement systems rarely require independent net assessment, and financial instruments typically do not reward technology providers for the quality of their impact evidence. The cost of rigorous net-impact assessment falls on whoever commissions it, with no regulatory requirement and limited direct financial return.
- The result shows in the evidence base: 36 private-sector Greening *by* Digital Technologies cases in this stocktake document enabling benefits, but only 6 have been assessed with ITU-T L.1480-aligned net methods, one of them without quantifying the ICT footprint.
- Public implementers are in the same position: of the 32 government-led cases, the only 7 with a net assessment are ADEME's own modelled studies.
- The gap is widest outside Europe: 13 of the 15 net assessments cover European deployments, and none covers Africa or Asia-Pacific.
- Financial incentives to apply the existing methodologies could help close the assessment and verification gap for net climate impacts among digital companies and organizations worldwide.

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[7] ITU, Recommendation ITU-T L.1801: *Guidelines for Assessing the Environmental Impact of Artificial Intelligence Systems* (Geneva: ITU, 2026), https://www.itu.int/rec/T-REC-L.1801/en.

Findings by sector

Each target sector for Greening *by* Digital Technologies and each sub-domain for Greening Digital Technologies produces a clear takeaway with one documented example. Two patterns become evident. In cases of greening other sectors, what digital technologies deliver depends on the system they plug into: a known physical bottleneck, a management standard or market rule, a registry, or a land, input, or finance decision. Where that link is missing, the data is collected but emissions do not fall, so programmes need to pair each digital tool with the rule, standard, or decision it is meant to inform. Within the digital sector itself, efficiency gains are well documented, but few organizations report whether their total footprint is falling. Regular and transparent reporting of total footprints would show whether the gains achieved add up to net emissions reduction.

Greening by Digital Technologies

Greening *by* Digital Technologies is examined in six sectors where digital tools are widely deployed. In each, the climate benefit is either the aim of the intervention or a by-product of greater efficiency.

Public administration:

- Digital monitoring, reporting, and verification (MRV) platforms and satellite monitoring are what make many other climate outcomes countable. They let governments show that the measures in their NDCs are being carried out.
- The strongest systems link digital reporting to legal obligations and financial consequences. The EU Emissions Trading System is the most mature example: it covers emissions from more than 12 000 entities, and through its digital MRV system, operators responsible for over 99% of emissions from power generation, industry, and aviation met their legal obligations on time in 2024.
- Emissions from stationary installations fell 51% between 2005 and 2024, a fall the European Environment Agency attributes to carbon pricing, fuel switching, and climate policies; the digital system makes the cap enforceable and shows, sector by sector, where the reductions came from.
- Where satellite alerts and data feed finance, enforcement, or community action, they change decisions on the ground. For example, in Brazil, banks have used MapBiomas data to deny about USD 2 billion in credit to those who might have been involved in deforestation, according to the World Economic Forum. India's Perform, Achieve and Trade (PAT) scheme shows what monitoring delivers when it reports against targets: India's Bureau of Energy Efficiency reports energy savings of 25.78 million tonnes of oil equivalent.
- Digital government also brings climate co-benefits whose climate effect has yet to be quantified.

Energy systems:

- Digital tools deliver their largest results where they target known sources of emissions, such as electricity lost from power grids, and they make methane leaks from oil and gas sites visible. Acting on more of the leaks detected would turn that visibility into emission cuts.
- In grid programmes using smart meters, automated metering, or grid monitoring, the share of electricity lost fell from 10.2% to 8.0% in Saudi Arabia and from 9.7% to 7.0% in Armenia. Because grid programmes usually combine digital tools with new lines and

transformers, the digital share of the savings is rarely measured separately. The clearest result comes from Abuja, Nigeria, where AI-based grid mapping and outage detection helped cut the share of electricity lost on the distribution network from 44% to 26% within three months.

- Water utilities show the same pattern: smart meters and leak sensors help cut water losses, and smarter pumping, together with new pumps, cut pumping energy by 43% and by up to 60% at the two utilities assessed.
- Paying households and businesses to cut use at peak times also works at national scale: Great Britain's Demand Flexibility Service saved more than 3 300 MWh at peak times, a figure confirmed from market data.
- Digital payment and identity systems are also widening access to clean energy: M-KOPA has sold more than 1 million solar home systems through small daily mobile payments. BURN's cookstove project in Kenya has the only verified emission reductions among the five access cases: 52 405 tCO_2e verified under the Gold Standard for January to May 2025. A unique serial number on every stove prevents its carbon credits from being counted twice, and its metered electric stoves earn credits from the electricity use they record.

Mobility and transport:

- The clearest gains come when a digital service replaces a trip altogether, because the trip not taken can be counted, although most such figures are still modelled. Sanitas's digital hospital in Spain shows this at scale: a peer-reviewed study counts 640 122 digital appointments in 2020 and finds that in 90% of a sample of digital consultations no in-person visit to the same type of specialist followed within a week. It estimates that these appointments, together with 3.06 million digital report downloads, avoided a net 6 655 tCO_2.
- Fleet management systems also deliver measured net savings: in two of the fleet cases assessed with the EGDC net method, AI fleet management saves a net 169 tCO_2e a year across 85 buses in Mexico, and a digital transport management system saves a net 636 tCO_2e a year across 356 trucks in Europe.
- Routing and carpooling platforms report savings in the millions of tonnes, but these figures are modelled by the companies themselves. Because cheaper or easier travel can lead people to travel more or switch from public transport, their savings should account for this rebound before they are credited.

Industry and manufacturing:

- The best-evidenced energy savings come where digital tools support an existing energy management standard, audit programme, or regulatory target. In Morocco's ISO 50001 programme, participating companies cut their energy use by 9% on average, and several used smart meters, sensors, and real-time energy monitoring as part of their energy management.
- In Bangladesh, the International Finance Corporation (IFC) reports that the more than 450 textile and garment factories in its Partnership for Cleaner Textile cut emissions by 723 617 tCO_2e a year. Factories installed water, gas, steam, and electricity meters on the partnership's advice, alongside on-site resource-efficiency assessments, advice on low-cost and larger capital improvements, and low-cost financing through a USD 200 million Green Transformation Fund that the partnership helped create. The partnership also launched a web portal in 2020, designed to give factories real-time analytics on their water and energy use.
- AI and digital twins deliver larger percentage cuts at individual factories, such as 28% lower Scope 1 and 2 emissions at Siemens's Nanjing plant against 2022 figures.

- Supply-chain carbon platforms build the data that decarbonizing supply chains depends on: WBCSD's standard for exchanging product carbon footprints reaches more than 5 000 companies and reports more than 4 million product carbon footprints calculated, which lets buyers find emission hotspots and choose lower-carbon products. Measuring the resulting cuts in supplier emissions would show that effect directly.
- Carbon accounting is also moving into core business software: SAP has built it into the financial ledger of its enterprise resource planning system, generally available since 2024, so that companies can track emissions alongside costs.

Buildings and homes:

- Digital tools reliably cut energy use in buildings, and the gains grow with scale. How much a building saves depends on its starting point: a modelled building management system saves a large commercial building a net 468 tCO_2e a year compared with the basic building management system found in most office buildings, and 225 tCO_2e compared with a more capable system already in common use.
- Across building stocks the percentages are smaller: AI and Internet of Things (IoT) control of district heating, for example, cut heat use across more than 100 public buildings in Espoo, Finland, by 7% in 2021. In homes, smart meters cut electricity use by 3.4% and gas use by 3.0% in Great Britain's evaluation.
- Larger savings come when tools like these are applied across many buildings at once, to run a city's or an operator's building stock, or to enforce a national building code. Kiona's AI heating control shows this at portfolio scale: across 356 residential buildings in Sweden and Finland, an assessment of its 2022 operating data with the EGDC net method finds a net saving of 1 113 tCO_2e and 17 325 MWh of heat a year after deducting the footprint of the digital system, with heating energy down 7% on average.

Agriculture and forestry:

- Digital advice and monitoring deliver large reported effects when they change what happens on the ground: how land is used, how much fertilizer and fuel are applied, or whether forest loss is caught in time.
- Farmers who adopted the improved practices on 185 000 hectares of Viet Nam's Mekong Delta cut their pesticide costs by 48% and fertilizer costs by 35% on average and raised their net profits per hectare by 30% under a World Bank-supported low-carbon rice programme, which is modelled to cut emissions by 1.58 million tCO_2e a year. Customers of Brazil-based Solinftec's AI precision agriculture cut their fuel use by 15.4% on average in 2022, according to the Green Climate Fund. In Peru, communities whose trained monitors received satellite deforestation alerts lost an estimated 52% less tree cover in the first year than comparison communities.
- In each case the digital tool supplies the information, and the people and institutions that act on it deliver the result. The digital share is not yet measured separately, and apart from forest loss in the two satellite-alert cases, the effects are modelled or estimated rather than measured against comparison areas.

Greening Digital Technologies

Greening Digital Technologies concerns the sector's own footprint. As digital use grows, networks, data centres, devices, and software need to cut their own energy use and emissions, not only enable cuts elsewhere.

Network infrastructure:

- The largest savings come from taking equipment out of service or sharing it: replacing old copper networks with fibre, which lets operators switch off their copper exchanges, and operators sharing one network instead of each building their own.
- Telefónica reports that closing its first 1 000 copper exchanges and moving to fibre optic saved around 1 000 GWh, saying its fibre network has up to 94% lower environmental impact than copper for the same data use. China Telecom and China Unicom, which jointly built and share one 4G and 5G network with 1.375 million shared 5G base stations, report 24 900 GWh of electricity and more than 13 million tCO_2 saved a year.
- AI energy management also delivers significant savings within existing networks: e& (formerly Etisalat) in the United Arab Emirates reports that AI cut power use at its telecom sites and data centres by 15% to 20%, and an AI energy management system supplied by China Mobile Jiangsu saves one Chinese operator 171.7 GWh a year.
- Solar and hybrid power is replacing diesel and grid electricity at network sites: a case study by Huawei, Zain's technology partner, reports 150 000 tCO_2 avoided a year across more than 1 800 modernized Zain network sites.
- Most network results are calculated savings, compared with what would otherwise have been used, results at individual sites, or intensity figures, but 11 of the 23 cases also report how the operator's total energy use or emissions changed over time, which is what shows whether the footprint is falling.

Data centres:

- Data centres now report their energy efficiency well, and the most efficient run close to the practical limit: across the 10 cases in the stocktake that report a measured power usage effectiveness (PUE), the median is 1.24, meaning about 0.24 kWh goes on cooling, power conversion, and other overheads for every kWh used by the servers.
- The lowest values come from cooling with outside air or water instead of mechanical chillers, and from cutting losses in the power supply. These techniques do not work everywhere: data centres in hot, humid climates, where many low- and middle-income countries are, need more cooling, as the PUE of Amazon Web Services (AWS), 1.06 in Spain against 1.46 in Osaka, shows.
- Leading operators also use less water for each unit of electricity, measured as water usage effectiveness (WUE): AWS reports that its data centres' WUE has improved by 52% since 2021, and Microsoft's by 39%.
- Renewable electricity claims need closer reading, because most are annual totals: an operator that buys as much renewable electricity over a year, anywhere in the world, as it consumes can report a 100% match, even if its data centres run on fossil power at night or on grids with little clean generation. Google has matched 100% of its annual electricity use with renewable energy every year since 2017, but on the grids its data centres actually draw from, carbon-free energy averaged 64% of its electricity in 2023.
- Equinix matched 96% of its electricity with renewable sources in 2023, with 10 percentage points coming through power purchase agreements from specific renewable projects. Another 46 came from renewable energy certificates bought separately from the electricity: they show that renewable power was produced somewhere, but do not change the power the data centre actually uses. The remaining 40 came from certificates bundled with utility supply.
- PUE, WUE, and renewable matching are all rates or shares, not totals. Reporting how much electricity and water data centres use in total, and how much of their waste heat is reused, would show whether their overall footprint is falling as data centres expand.

User devices:

- Most of the carbon footprint of a smartphone, and likely of other portable devices, comes from making it, not using it: production accounts for an estimated 83% of the iPhone 15 Pro's 66 kg CO_2e lifecycle footprint and a modelled 85% of the Samsung Galaxy S23 Ultra's. The strongest levers therefore act before and after use.
- Keeping a device longer spreads its manufacturing footprint over more years: an assessment of the Fairphone 4 by the Fraunhofer IZM research institute finds a modelled 31% lower annual footprint when the phone is used for 5 years instead of 3, and 44% for 7 years with two battery replacements.
- Refurbishing a device avoids most of the footprint of making a new one: Swappie estimates a 78% lower footprint for each refurbished iPhone it sells. Refurbishment already operates at scale: Back Market reports more than 2 million tCO_2e avoided across 17 million customers.
- Cleaner manufacturing cuts emissions at the source: Apple reports that its supply-chain emissions reduction efforts on materials, electricity, and transport abated more than 2.7 million tCO_2e in 2023.
- For equipment that runs for long hours, use still matters: interventions on Xbox consoles, including more energy-efficient game code and optional energy saver modes, are estimated to have prevented over 1.2 million tCO_2e from fiscal years 2020 to 2023, compared with usage without them, and Sony estimates that the PlayStation 5 draws 80% less power than the PS4 in suspend mode. Most of these savings are modelled per device, and measuring how long people actually keep their devices, and whether a refurbished device replaces a new purchase, would confirm them.
- At end of life, only 22.3% of the world's e-waste was documented as properly collected and recycled in 2022, and digital systems that register producers and monitor their compliance, such as the one Rwanda is building, could help raise that share.

Software:

- Software can cut the carbon of computing without changing what users see, by running workloads on more efficient processors or at cleaner times of day. New Relic reports an estimated 37% lower CO_2e for the workloads it moved to more energy-efficient processors.
- In a UBS pilot, the grid carbon intensity for a sample batch job was 642 g CO_2e per kWh in the cleanest time window, against 710 g for a past run. Google moves tasks that can wait to the hours with the most low-carbon power across its data centres.
- Tools to measure these emissions are already in wide use: CodeCarbon, an open-source tool, has been downloaded more than 4 million times, and in a peer-reviewed study it measured 914 kWh and 340 kg CO_2e for 230 768 requests to the BLOOM large language model over 18 days. No case yet reports how the absolute emissions of AI and cloud workloads change as a result of a specific intervention.
- The cases still report in different units (per workload, per run, or per request), and the Software Carbon Intensity standard (ISO/IEC 21031) is designed to provide the common unit that will let them be compared.

Recommendations

The following recommendations address the principal gaps identified in this stocktake across both Greening *by* Digital Technologies and Greening Digital Technologies. The six recommended policy approaches focus on strengthening implementation, measurement, reporting, financing, and the use of international standards to support the responsible deployment of digital technologies for climate action. They are intended for governments,

development finance institutions, the private sector, international organizations, research institutions, and other relevant stakeholders.

1. Help countries and investors put ITU-T L.1480 into practice through technical assistance, capacity-building, and incentives for verified impact. ITU, development partners, and climate funds could support governments, particularly in least developed countries (LDCs) and small island developing States (SIDS), through targeted technical assistance and capacity-building programmes to apply ITU-T L.1480 within the national MRV frameworks they use to track and report progress on their NDCs. Such support could focus on practical implementation challenges, including defining system boundaries, identifying and collecting relevant data, documenting assumptions, selecting appropriate methodologies, and reporting results in a transparent and consistent manner. Implementation guidance and lessons learned from early applications of ITU-T L.1480, as well as insights from initiatives such as the European Green Digital Coalition, could further strengthen impact assessments.

Governments and development finance institutions could strengthen incentives to apply ITU-T L.1480. Results-based financing, eligibility for climate finance and voluntary carbon markets, procurement preferences, and requirements for transparent environmental reporting could reduce the costs associated with independent net-impact assessments. Crediting digitally enabled outcomes in carbon markets would, however, require careful treatment of additionality, attribution, double counting, and consistency with national and international accounting arrangements. Such measures would help create demand for rigorous measurement and reward organizations that invest in credible and verifiable impact evidence. Over time, governments could also consider moving from voluntary to required alignment with ITU-T L.1480 for net-impact assessments.

2. Design digitally enabled climate programmes to deliver impact, building in standards-based assessment and verification from the start. The largest independently evaluated outcomes in this stocktake come from national programmes, often supported by multilateral finance, that combine digital tools with national targets, financing tied to those targets, monitoring and evaluation built in from the outset, local institutional capacity, and multi-year funding cycles. Digitally enabled climate programmes should be designed with these conditions in place. Standards-based impact assessment and independent verification should be part of programme design and financing from the beginning, treated as a core component and funded accordingly rather than added as a post-project reporting requirement. Because digital tools are bundled with training, standards, and finance, programmes should also be designed so that the digital contribution can be separated, for example through a comparison group or an attribution analysis, and should state the baseline or reference system against which savings are measured.

Development finance institutions, climate funds, and implementing partners could encourage the use of internationally recognized methodologies such as ITU-T L.1480 by incorporating impact measurement and reporting requirements into project appraisal, monitoring, and financing frameworks. Results-based financing, funding eligibility criteria, and reporting requirements could help create stronger incentives for the generation of credible and verifiable evidence on the climate benefits of digital technologies.

3. Promote international standards for digital hardware procurement and sustainability reporting. ICT equipment manufacturers, operators, procurement bodies, and public authorities could be encouraged to use international standards as a common reference for sustainable ICT procurement and environmental reporting. This could include product environmental reports

aligned with standards such as ITU-T L.1410, as well as the use of existing guidance, standards, and training resources that support circular economy approaches, including device lifetime extension, refurbishment, reuse, and responsible end-of-life management.[8] [9]

National procurement authorities and regulatory frameworks could use international standards as technical references for sustainable procurement criteria, helping to generate comparable data on the environmental performance of digital equipment across procurement cycles while encouraging more circular, resource-efficient digital markets. Sustainability reporting by network operators, data-centre owners, and device makers should cover absolute energy use and emissions against a fixed baseline alongside intensity metrics, and the values measured over a year of operation rather than the values modelled at the design stage.

4. Promote evidence-based platforms for digital climate solutions. Platforms and initiatives that showcase digital technologies for climate action could encourage the use of quantified impact evidence aligned with internationally recognized methodologies, such as ITU-T L.1480. This would help improve the comparability, credibility, and transparency of climate-impact claims while making it easier for governments, development finance institutions, and project developers to identify promising solutions.

Greater visibility of solutions supported by credible impact evidence could also help connect technology providers with implementation opportunities, financing mechanisms, and advisory support, particularly in LDCs, SIDS, and other developing countries where access to independently verified solutions remains limited. Evidence expectations could be applied in proportion to an organization's size, context, and implementation maturity, while stronger claims would still need stronger evidence.

5. Strengthen primary footprint data, standardized telemetry, and net-effects assessment as sources of evidence on digital climate impact. Future evidence-gathering efforts should prioritize the collection of primary data on the energy use and environmental footprint of digital systems associated with high-impact digital climate solutions. This would make it possible to move beyond estimates of enabling benefits and undertake verified net-impact assessments that account for both the climate benefits delivered and the footprint of the digital technologies involved. Net assessments should also cover rebound effects and resource use, such as minerals and metals.

The main obstacle is data: only 15 of the 150 cases include a net-effects assessment, and the source documentation for the other 135 does not contain all the data needed for one, in particular primary data on the energy use of the digital system itself. Technology providers, programme designers, and funders could close this gap by building energy and emissions monitoring into digital solutions from the start rather than adding it later. Guidance is also needed for shared digital infrastructure, such as fibre networks and data centres: methods such as ITU-T L.1410 can assess its own footprint, but there is no agreed way to attribute to it a share of the climate benefits of the services it carries.

6. Promote ITU-T L.1801 as a practical tool to measure AI's environmental footprint. AI is increasingly cited in NDCs: 12% of the 140 NDCs analysed explicitly reference AI to be

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8 ITU, *Circular and Sustainable Public Procurement: ICT Equipment Guide* (Geneva: ITU, 2023), https://www.itu.int/hub/publication/d-hdb-guidelines-04-2023/.

9 ITU Academy, *Circular and Sustainable Public Procurement for ICTs (e-learning course)* (ITU, n.d.), https://academy.itu.int/training-courses/full-catalogue/circular-and-sustainable-public-procurement-icts-0.

deployed, for example in early warning systems, predictive monitoring of energy infrastructure, and resource management in agriculture.[10] However, the environmental footprint of AI systems is rarely measured or reported in a consistent manner. ITU-T L.1801, approved in February 2026, provides guidelines for assessing the environmental impact of AI systems. Climate finance institutions and development partners supporting AI-for-climate programmes could require L.1801-aligned footprint disclosure as a condition for crediting AI-enabled climate benefits. The aim is not to question the operational benefits that AI cases in this stocktake document, but to confirm that AI-enabled climate benefits remain once the footprint of the AI systems themselves is counted.

Modelled assessments or gross estimates of AI-enabled climate impact can be differentiated from independently verified net outcomes in national climate plans. Countries aiming to fulfil a climate pledge can then strengthen their evidence progressively in line with ITU-T L.1801 and ITU-T L.1480. Countries with AI applications in their NDC targets for 2035 might need technical assistance to commission such assessments before the next NDC review cycle.

[10] ITU, *Digital Technologies and NDCs*. https://www.itu.int/initiatives/green-digital-action/ndcs-stocktake/.

1 Introduction

1.1 Background and mandate

Digital technologies occupy a paradoxical position in the global climate agenda. Their own footprint is a growing and material share of global greenhouse gas emissions. It comes from the energy used by data centres, networks, and user devices, and from the emissions of making, replacing, and disposing of equipment, and it is rising as artificial intelligence (AI), video streaming, and more devices drive up demand. At the same time, digital technologies are now recognized as scalable tools for decarbonization across other sectors: smart grid management, precision agriculture, industrial process optimization, demand-side energy management, and digital public administration each offer documented pathways to energy savings and emissions reductions. The central challenge is that this enabling potential has been systematically under-documented, with claimed benefits inconsistently quantified, geographically uneven, and difficult to compare across jurisdictions and sectors. The geographic unevenness partly reflects differences between regions in reporting maturity and the availability of evidence, not only differences in deployment. This stocktake addresses that gap.

This stocktake of global best practices in Greening Digital Technologies and Greening *by* Digital Technologies is part of ITU's ongoing work to support Member States, sector members, and associates in integrating environmental sustainability into digital infrastructure planning and information and communication technology (ICT) policy. The engagement responds to growing demand for a structured, evidence-grounded overview of what has demonstrably worked across diverse geographies and governance contexts in reducing the environmental footprint of the digital sector itself and in harnessing digital technologies as an enabling force for sustainability across other sectors.

The work is conducted under the Green Digital Action initiative[11], a multi-stakeholder platform convened by ITU with over 50 partner organizations from government, industry, and civil society, launched at the 28th United Nations Climate Change Conference (COP28) in Dubai in December 2023 and formally recognized at the 29th conference (COP29) in Baku through the first-ever UN Climate Conference Digitalization Day and the COP29 Green Digital Action Declaration.

The work also builds on ITU's standardization activities to support evidence-based digital transformation and climate action. In particular, Recommendations ITU-T L.1480, L.1410, and L.1801 provide internationally recognized methodologies for assessing digitally enabled climate impacts, the environmental footprint of ICT systems, and the environmental footprint of AI. These standards offer a common framework for measuring, reporting, and comparing impacts across countries, sectors, and technologies, helping bridge the gap between innovation, implementation, and accountability. This stocktake contributes to those efforts by identifying practical applications, implementation experiences, and evidence gaps that can inform the uptake and future development of these standards.

This stocktake follows directly from the prior ITU publication: *Digital technologies in Nationally Determined Contributions (NDCs): Stocktake and Analysis,*[12] which mapped how Member States are integrating digital technologies into their climate commitments and highlighted the

[11] ITU, *Green Digital Action* (Geneva: ITU, 2023), https://www.itu.int/initiatives/green-digital-action/.
[12] ITU, *Digital Technologies in NDCs*.

need for more robust measurement of digitalization's climate impacts and benefits to enable evidence-based replication of proven solutions, as well as enhanced approaches to financing and technology transfer. This analysis was further complemented by the ITU-TEC report: Digital technologies and NDCs: Digital solutions in support of NDC implementation, which expanded the analysis to include 140 NDCs with 2035 targets from those submitted between 1 January 2024 and 31 July 2026.

These and other prior studies, including the yearly *Greening Digital Companies* report[13] and the *Green Data Centers* practitioners' guide,[14] identified a shared evidence gap: a curated, verified, and geographically balanced record of real-world cases demonstrating Greening Digital Technologies and Greening *by* Digital Technologies best practices, assessed against a common evidence standard. This stocktake addresses that gap. The questions it is designed to answer are:

- Which digital solutions show documented, verifiable outcomes in greenhouse gas (GHG) mitigation and energy efficiency across different economic sectors, and do those benefits remain positive after accounting for the footprint and rebound effects of the technologies involved?
- Which cases have reduced the energy consumption and GHG emissions of digital infrastructure, data centres, devices, and software?
- What are the main pathways through which digital technologies help meet climate and energy goals, and how are they combined?
- How can governments and other stakeholders incorporate proven digital solutions into their climate strategies?

The stocktake is descriptive and analytical rather than prescriptive. It does not rank countries, recommend specific vendors, endorse specific technologies, or produce economy-wide aggregation of avoided emissions. Its value lies in the systematic identification and structured comparison of practices that have produced documented climate action outcomes, and in making that evidence base accessible for policy dialogue and further research, while identifying critical gaps.

Research for this stocktake was conducted between May and July 2026 using the protocol documented in Chapter 2. This resulted in a research base of 500 documented cases from 139 countries, of which 150 meet the quality threshold and form the stocktake for this report; these 150 cases cover 104 countries.

1.2 Structure of this report

Chapter 2 (Methodology) describes the search protocol including multilingual waves and regional quota targets, the evidence-tier framework, the criteria rubric, and the expert scoring process. It also presents the composition of the evidence base, including the distribution of evidence tiers, geographic coverage across the six ITU regions, sector representation, and organizational type.

Chapter 3 (Cross-cutting findings) synthesizes findings across the 150 cases and answers the four core research questions. It touches on the net-effects evidence gap, the scale differential

[13] ITU and World Benchmarking Alliance, *Greening Digital Companies 2025*.
[14] ITU and World Bank, *Green Data Centers: Towards a Sustainable Digital Transformation - A Practitioner's Guide* (Geneva; Washington, DC: ITU; World Bank, 2023), https://www.itu.int/pub/D-THEM-32-2023-01.

between multilateral and private-sector programmes, the replicability-to-codification gap, the enabling pathway distribution, the accountability framework gap for Greening *by* Digital Technologies, the implementation and uptake of relevant international standards, and the role of AI across the evidence base.

Chapter 4 (Greening *by* Digital Technologies) and Chapter 5 (Greening Digital Technologies) provide thematic synthesis organized by sector cluster, with policy-relevant observations for each domain. These chapters draw on selected case studies and examples.

Chapter 6 (Findings and recommendations) draws policy implications, identifies evidence gaps, and proposes directions for strengthening the evidence base in future cycles.

1.3 Scope and thematic boundary

This stocktake treats Greening *by* Digital Technologies and Greening Digital Technologies as analytically distinct: each involves a different causal mechanism, evidence standard, and policy implication. They are closely linked nonetheless: a digital solution that enables emissions reductions in another sector should also minimize its own environmental footprint, through energy-efficient infrastructure, renewable energy use, longer device lifecycles, and low-carbon procurement, so that its net benefit is not undermined by the infrastructure delivering it.

Greening *by* Digital Technologies (GbDT) covers the positive handprint: the use of digital technologies to enable and unlock GHG mitigation and energy efficiency improvements in other sectors. These include energy systems, mobility and transport, buildings and homes, industry and manufacturing, and agriculture and forestry: the five sectors identified in Recommendation ITU-T L.1480.[15] Public administration has been added as a sixth sector, given its growing role in digital-enabled GHG monitoring, reporting, and verification.

Greening Digital Technologies (GDT) covers the reduction of the digital sector's own GHG emissions and energy footprint, across three sub-domains identified in ITU's digital sector emissions framework:[16] network infrastructure, data centres, and user devices. Software is added as a fourth sub-domain, because software design and engineering choices have a direct and material effect on the energy consumption of the hardware that runs them.

The two domains are assessed against different but complementary ITU-T standards. Greening *by* Digital Technologies cases are considered with reference to Recommendation ITU-T L.1480,[17] which provides the framework for measuring the net balance between ICT's enabling benefits in other sectors and its own environmental footprint. Greening Digital Technologies cases are considered with reference to Recommendation ITU-T L.1410,[18] which provides the lifecycle assessment methodology for ICT goods, networks, and services.

1.4 Target audience and policy relevance

This report is intended for the broad ecosystem of stakeholders involved in financing, implementing, assessing, and scaling digital technologies for climate action. For governments, regulators, national ICT authorities, and procurement bodies, it supports the use of digital

15 ITU, Recommendation ITU-T L.1480.
16 ITU, *Digital Technologies in NDCs, p*. 5.
17 ITU, Recommendation ITU-T L.1480.
18 ITU, Recommendation ITU-T L.1410.

technologies in climate strategies, NDCs, and national development plans, and the inclusion of climate goals in national digital strategies. For multilateral and bilateral development finance institutions and international organizations, it can inform digital and climate investment decisions. For private-sector stakeholders, including network operators, equipment vendors, hyperscalers, platform companies, and solution providers, it shows which solutions have documented results and how to measure these. The findings here may also encourage standards bodies, research institutions, and partners applying international standards (including ITU-T Recommendations) to support evidence-based Green Digital Action.

This stocktake is timed to inform several converging policy processes. The most immediate is the NDC 3.0 cycle: under the Paris Agreement[19] ratchet mechanism, countries are submitting revised nationally determined contributions for the 2035 target period. ITU's 2026 analysis of NDCs[20] found that 103 out of 140 NDCs with 2035 targets submitted by July 2026 explicitly reference digital technologies as climate implementation tools. This report provides the evidence base that should underpin those commitments: documented cases, outcomes of varying evidence strength, each assigned an evidence tier, and the methodological standards against which claims can be assessed.

At the ITU level, this stocktake supports ITU's mandate under Resolution 182 on the role of telecommunications/ICTs in relation to climate change and environmental protection, World Telecommunication Standardization Assembly (WTSA) Resolution 73 and World Telecommunication Development Conference (WTDC) Resolution 66 on ICT, environment, climate change and circular economy, as well as ITU Council Resolution 1429 on ITU's role in facilitating ICTs' contribution to sustainability and climate action.[21] The report also supports implementation of the Global Digital Compact and contributes to the objectives of the Pact for the Future by promoting evidence-based approaches to digital technologies for climate action and sustainable development.

19 UNFCCC, *The Paris Agreement* (Paris, 2015), https://unfccc.int/process-and-meetings/the-paris-agreement.

20 ITU, *Digital Technologies and NDCs*.

21 ITU, Resolution 182 (Rev. Bucharest, 2022), in Final Acts of the Plenipotentiary Conference (Bucharest, 2022) (Geneva: ITU, 2022), https://www.itu.int/dms_pub/itu-s/opb/conf/S-CONF-ACTF-2022-PDF-E.pdf; ITU, Resolution 73 (Rev. New Delhi, 2024), World Telecommunication Standardization Assembly (Geneva: ITU, 2024), https://www.itu.int/dms_pub/itu-t/opb/res/T-RES-T.73-2024-PDF-E.pdf; ITU, Resolution 66 (Rev. Kigali, 2022), in Final Report of the World Telecommunication Development Conference (Kigali, 2022) (Geneva: ITU, 2022), https://www.itu.int/dms_pub/itu-d/opb/tdc/D-TDC-WTDC-2022-PDF-E.pdf; ITU Council, Resolution 1429: ITU Role in Facilitating ICTs' Contribution to Sustainability and Climate Action, Document C24/142 (Geneva: ITU, 2024), https://www.itu.int/md/S24-CL-C-0142/en.

2 Methodology

2.1 Climate action outcome scope

This stocktake assesses climate impacts using two primary measurement categories.

The first is **greenhouse gas emissions**: emissions reduced or avoided through digital technologies, directly or indirectly, reported in tCO_2e per year or as percentage reductions in emissions intensity. The second is **energy consumption and efficiency**: reductions in energy use in information and communication technology (ICT) operations themselves (Greening Digital Technologies) and digitally enabled energy savings in other sectors (Greening *by* Digital Technologies), reported in kWh or GJ per year, or sector-specific intensity metrics.

Cases addressing other environmental dimensions (biodiversity, water quality, land degradation) are included only where they also document quantifiable greenhouse gas (GHG) or energy-related outcomes, to ensure consistency and comparability across the cases included in the stocktake. While considering all environmental dimensions and their interlinkages is important, doing so would have gone beyond the scope of this report. The assessment covers the climate outcomes documented for each case. For most cases these are gross enabling benefits; a net assessment, deducting the footprint of the ICT system and considering rebound effects, is available for a defined subset of 15 cases.

2.2 Design objectives

Within this scope, the stocktake methodology was designed to achieve five objectives:

1) Compile a diverse, geographically balanced sample of Greening Digital Technologies and Greening *by* Digital Technologies practices from all six ITU regions (Africa, the Americas, the Arab States, Asia-Pacific, the Commonwealth of Independent States, and Europe) covering both high-income and lower- and middle-income country contexts during the period 2020 to 2026.
2) Apply a structured evidence-quality framework (Tiers 1 to 3) as defined for this stocktake and described in Section 2.6 to distinguish independently verified from self-reported impacts, and to make the quality of the underlying evidence transparent to users.
3) Assemble a panel of international experts to score cases against three criteria (impact, replicability, and scalability) using a common rubric with defined score levels (see Section 2.7).
4) Identify cross-cutting patterns, limitations, and evidence gaps to inform ICT sustainability policy and future monitoring frameworks.
5) Produce a reusable, version-controlled knowledge base to support future stocktaking cycles and comparison against this baseline.

2.3 Case identification and search protocol

Cases were identified through a multi-wave search protocol designed to minimize English-language selection bias, ensure geographic coverage across all six ITU regions, and maintain an auditable record of inclusion and exclusion decisions. Searches were executed in the six UN official languages.

The protocol operated through successive waves, each addressing a gap identified in the preceding wave's geographic or sectoral coverage. The first waves established a broad cross-regional baseline by systematically canvassing academic databases, multilateral repositories, digital technology databases, corporate sustainability reports, and grey literature channels. Subsequent waves addressed under-represented regions and sectors.

A dedicated wave sought programmes that implement or reflect the spirit of Recommendation ITU-T L.1480 by assessing the net balance between the second-order enabling benefits of a digital solution and its first-order direct footprint costs. Two principal frameworks were identified. First, the European Green Digital Coalition (EGDC) Net Carbon Impact Assessment Methodology,[22] applied in a series of sector deployment case studies, eight of which are included in this stocktake (Box 1). Second, the French Agency for Ecological Transition (ADEME) IT4Green study,[23] which applied a consequential net impact method, compliant with ADEME's "Empreinte Projet" method and ITU-T L.1480, to nine digital use cases in France, seven of which are included in this stocktake.

Box 1: The European Green Digital Coalition (EGDC)

The European Green Digital Coalition (EGDC) is a voluntary initiative of major European ICT companies committed to making the digital sector a driver of the green transition. In 2024, EGDC published a Net Carbon Impact Assessment Methodology that operationalizes the accounting framework defined in ITU-T L.1480, providing sector-specific guidance for measuring the net climate benefit of ICT-enabled solutions.

The methodology requires three elements for each assessed deployment: a defined functional unit specifying the quantity of service delivered by the ICT solution; a defined reference scenario representing the environmental state without the intervention; and a net GHG impact expressed in tCO_2e, calculated by deducting the first-order footprint of the ICT infrastructure from the second-order enabling benefit it delivers. This approach directly addresses the most common limitation of ICT-enabled climate claims: that reported benefits represent gross enabling effects rather than verified net outcomes. EGDC applied the methodology across six sectors (energy and power, construction and buildings, agriculture, manufacturing, transport, and smart cities). Eight of its deployment cases are included in this stocktake.

ITU also issued an open call for case submissions. Through this route, 16 cases were submitted and assessed under the standard inclusion criteria.

Across all waves, 500 candidate cases documented in sources published between 2020 and 2026 were identified and screened (a few report results from earlier years). From these, 150 cases were selected, aiming for a balance across regions, sectors, technologies, and stakeholder groups. Each selected case can be classified under Greening *by* Digital Technologies or Greening Digital Technologies and documents a quantified outcome in an archived primary source. The exceptions are four cases without a verified outcome: three early-stage cases (case-099, case-278, and case-575), kept as examples of approaches still in development, and

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22 European Green Digital Coalition, *Net Carbon Impact Assessment Methodology for ICT Solutions (Brussels: European Green Digital Coalition, 2024),* https://www.greendigitalcoalition.eu/assets/uploads/2024/04/EGDC-Net-Carbon-Impact-Assessment-Methodology-for-ICT-Solutions.pdf.

23 Camps et al., *Direct and Indirect Environmental Quantification of Digital Impacts in Use Cases: Digitalisation of Nine Use Cases* (ADEME, 2026), https://librairie.ademe.fr/index.php?controller=attachment&id_attachment=9273.

one (case-586) whose submitted figures could not be verified. They are marked as having no outcome yet in the case tables and are not used in any outcome range or median.

Each outcome is recorded as measured (observed for a real deployment or period) or modelled (a model result, estimate, projection, or design value stated by the source). Only measured outcomes are used in the outcome ranges and medians in this report; modelled figures are labelled as modelled or projected wherever they appear.

2.4 Methodological approach and international standards

ITU-T L.1480[24] organizes the environmental effects of ICT solutions into three categories. **First-order (direct) effects** are the environmental footprint of the ICT solution itself: the energy consumed by devices, networks, and data centres during operation, and the embodied carbon from manufacturing, transport, and end-of-life disposal of ICT hardware. **Second-order (enabling) effects** are the environmental benefits that the ICT solution enables in other sectors: energy saved when smart grid management optimizes load dispatch, emissions avoided when a precision agriculture platform reduces fertilizer and water use, or travel eliminated when a digital service substitutes a physical transaction. **Higher-order (systemic) effects** are the broader structural changes induced by widespread ICT adoption, including **rebound effects** where efficiency gains stimulate increased consumption that partially offsets savings, and network and macro-economic shifts enabled by digital infrastructure at scale.

For Greening *by* Digital Technologies, this stocktake primarily documents **second-order (enabling) effects**, as defined in ITU-T L.1480.[25] Each case is evaluated within its stated system boundary, quantifying the reductions in energy use and GHG emissions that the ICT solution enables in the target sector. For the 78 Greening *by* Digital Technologies cases outside the 15 net-assessed cases, the first-order effect of the ICT solution itself has not been deducted from the enabling benefit to produce a net figure, and higher-order systemic and rebound effects are not systematically assessed. Two distinct constraints apply. For most cases, primary ICT footprint data is not publicly available. For multi-actor deployments (smart grid management, telemedicine platforms, digital trade facilitation systems), the constraint is methodological: no agreed allocation rule exists to separate the ICT solution's enabling contribution from the contributions of co-actors such as grid operators, healthcare providers, or customs authorities. Both gaps reflect current limitations in ITU-T L.1480 operationalization, not a finding about the direction of net effects.

For the remaining 15 cases (eight assessed under the European Green Digital Coalition net carbon methodology[26] and seven under the ADEME IT4Green study),[27] a net calculation has been applied under ITU-T L.1480 procedures, deducting first-order ICT costs from enabling benefits in 14 of them (the EGDC smart port logistics case does not quantify the footprint); one ADEME case, solar photovoltaic (PV) monitoring, uses a simplified rather than a full analysis. Rebound effects were assessed in all 15 cases: quantified in six of the seven ADEME IT4Green assessments, and assessed qualitatively in the eight EGDC assessments. These cases are identified explicitly in the case profiles and synthesis chapters.

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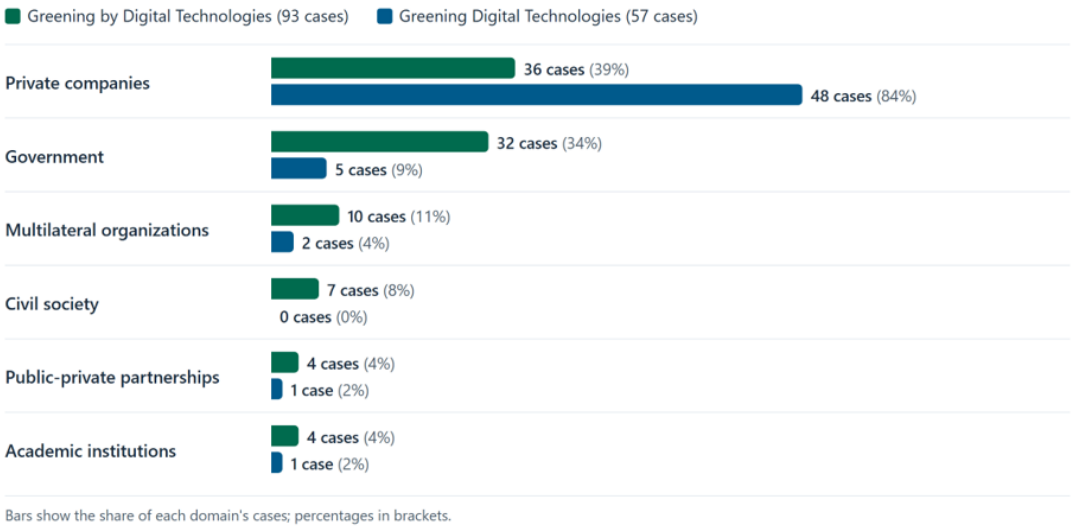
24 ITU, Recommendation ITU-T L.1480.
25 ITU, Recommendation ITU-T L.1480.
26 European Green Digital Coalition, *Net Carbon Impact Assessment Methodology for ICT Solutions*.
27 Camps et al., *Direct and Indirect Environmental Quantification of Digital Impacts in Use Cases*.

For Greening Digital Technologies, this stocktake focuses on measures that reduce the environmental footprint of ICT infrastructure, devices, networks, and services. The primary methodological reference is Recommendation ITU-T L.1410, which provides the lifecycle assessment methodology for ICT goods, networks, and services, aligned with ISO 14040[28] and ISO 14044[29]. Cases are evaluated within the system boundary declared by the implementing organization; second-order enabling benefits are not included unless separately attributed. Where a full cradle-to-grave lifecycle assessment has been applied, this is noted in the case profile.

2.5 Composition of the stocktake

Of the 150 cases, 38% address the environmental footprint of digital technologies (Greening Digital Technologies) and 62% use digital technologies to enable and unlock sustainability improvements in other sectors (Greening *by* Digital Technologies). The 38/62 split reflects the higher number of sector domains used for Greening *by* Digital Technologies (six sector domains against four Greening Digital Technologies sub-domains). Figure 2 depicts cases by lead organization type and Figure 3 shows the breakdown of cases by ITU region.

Figure 2: Cases by lead organization type, by domain

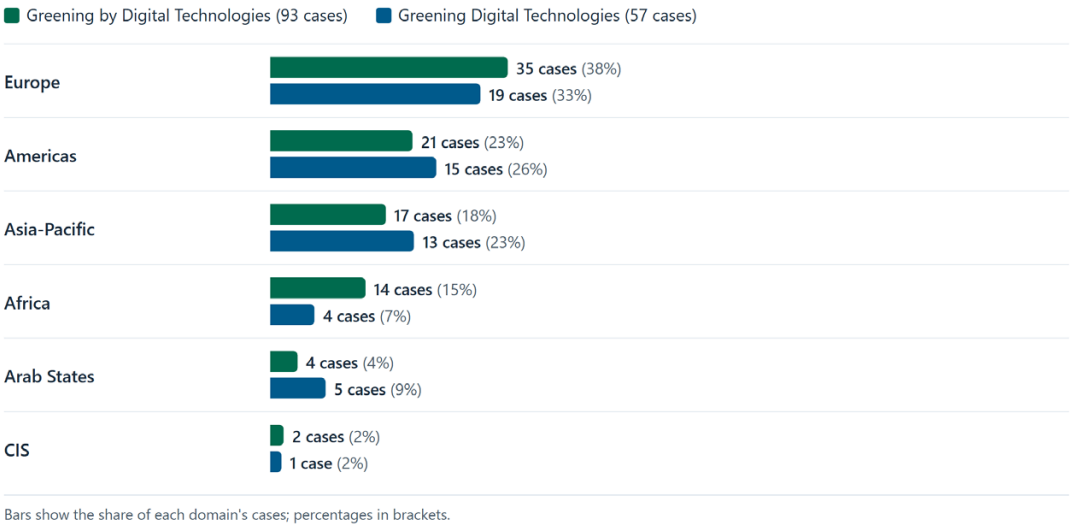


Source: Figure prepared for this report from the stocktake case data (ITU, 2026).

[28] International Organization for Standardization, ISO 14040:2006 *Environmental Management: Life Cycle Assessment: Principles and Framework* (Geneva: International Organization for Standardization, 2006), https://www.iso.org/standard/37456.html.

[29] International Organization for Standardization, ISO 14044:2006 *Environmental Management: Life Cycle Assessment: Requirements and Guidelines* (Geneva: International Organization for Standardization, 2006), https://www.iso.org/standard/38498.html.

Figure 3: Cases by ITU region, by domain



Source: Figure prepared for this report from the stocktake case data (ITU, 2026).

The European concentration of cases reflects mature sustainability reporting frameworks and the body of assessments produced by the EGDC[30] and ADEME[31]. This distribution is also a function of the available evidence base in public documentation, not a finding about the geographic distribution of digital sustainability practice.

2.6 Evidence tiers

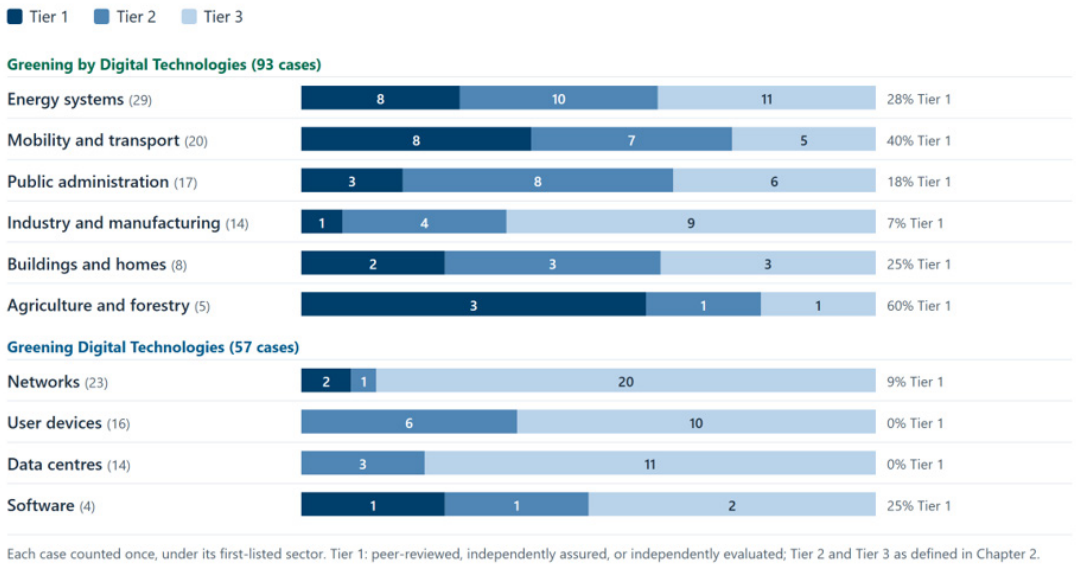
Each case carries an evidence tier classification reflecting the credibility of its environmental claim.

- **Tier 1** applies where the central impact claim has been checked independently in one of three ways. Peer-reviewed: the claim is published in a peer-reviewed venue, in a study of this intervention or programme. Independently assured: a named third party has issued a public assurance statement whose scope covers the outcome figures; scheme-level accredited verification of every operator's data also counts. Independently evaluated: an independent evaluation office or external evaluators have assessed the outcomes with published methods.
- **Tier 2** applies where the central claim comes from structured institutional reporting without an independent check of the outcome, such as implementer completion reports, official statistics, government or multilateral programme reports, and industry-coalition case studies.
- **Tier 3** applies where the central claim derives from the implementing organization's own reporting, such as press releases, company case studies, and unassured corporate reports.

Of the 150 cases, 19% are Tier 1, 29% are Tier 2, and 52% are Tier 3 (Figure 4 shows the split by sector). The predominance of Tier 3 evidence reflects the practical difficulty of obtaining peer-reviewed, independently assured, or independently evaluated coverage of operational interventions.

[30] European Green Digital Coalition, *Net Carbon Impact Assessment Methodology for ICT Solutions*.
[31] Camps et al., *Direct and Indirect Environmental Quantification of Digital Impacts in Use Cases*.

Figure 4: Evidence tiers by sector



Source: Figure prepared for this report from the stocktake case data (ITU, 2026).

2.7 Criteria scoring

The panel comprised international experts, selected by ITU to represent a range of regional perspectives, sector domains, and institutional backgrounds. Cases were scored by experts with relevant domain expertise, and each case was scored by at least one expert. The final score for each criterion is the arithmetic mean of all assessments received.

To ensure impartiality, experts were prohibited from scoring any case on which they had worked directly. Each expert received the full scoring rubric and case evidence summary before scoring, and was invited to attach written comments.

Cases were assessed against three criteria (impact, replicability, and scalability), each scored on a 1 to 5 ordinal scale (1=low, 5=high).

- **Impact** measures the scale and significance of the real-world environmental benefit, considering how large the outcome is, how many people or systems are affected, and how transformative it is relative to business-as-usual.
- **Replicability** measures the degree to which the approach can be adopted in another country, sector, or organizational context without bespoke re-engineering of the core mechanism.
- **Scalability** measures the degree to which the approach can be expanded beyond its current scope, considering whether the technology, business model, and governance conditions support broader deployment.

Scores are derived from the case evidence as documented in source materials. The rubric was applied consistently across all 150 cases.

The expert review scores are used to identify the strongest-performing cases within each sector and sub-domain.

2.8 Limitations

Causal attribution. The stocktake documents associations between digital solutions and reported climate outcomes; it does not establish independent causal attribution. Outcomes are as reported by implementing organizations or third-party sources, with evidence quality classified on the three-tier scale described in this chapter.

Representative sample. The 150 cases are not a statistically representative sample of global Greening Digital Technologies and Greening *by* Digital Technologies practice; they are a quality-filtered selection designed to maximize geographic, sectoral, and organizational diversity within the evidence base that met the quality threshold.

Language and publication bias. Despite the multilingual protocol, English-language sources dominate the evidence base, and Tier-1 sources are particularly concentrated in English-language academic journals. This structural constraint means quality distribution across regions is uneven in ways tier counts alone do not capture.

Public documentation. All cases were evaluated based on existing public documentation. No additional interviews or calculations were conducted with the case organizations.

Geographic concentration within regions. Minimum quota targets were met for all six ITU regions, but within-region coverage skews toward larger organizations and countries with established sustainability disclosure infrastructure; smaller operators, small and medium-sized enterprises (SMEs), and subnational initiatives are under-represented in the available evidence base.

System boundary diversity. Greening *by* Digital Technologies cases report enablement claims within the implementing organization's stated system boundary, which varies materially across cases. This stocktake does not reconcile boundaries across cases or aggregate case-level claims to sector-wide avoided-emissions multipliers. Case-level figures should be read with the boundary definition as reported in the individual case profile.

Aggregation. Case-level climate outcomes are not aggregated into a global total; doing so would require consistent system boundaries, a shared counterfactual methodology, and deduplication of overlapping interventions.

Rebound effects. The large majority of cases in the stocktake do not quantify rebound effects. The EGDC methodology requires every identified rebound effect to be assessed, at least qualitatively. The ADEME IT4Green assessments quantified rebound in six of their seven cases, and the Cornell remote work study quantified rebound-type effects such as non-commute travel and home energy use. The near-universal absence of rebound quantification elsewhere is a methodological gap rather than a data constraint, and remains the most material limitation on aggregating case-level outcomes to sector or economy level.

3 Cross-cutting findings

This chapter answers the four research questions set out in Chapter 1, drawing on patterns across the 150-case stocktake rather than on individual cases. Individual cases that illustrate these patterns are treated in depth in Chapter 4 (Greening *by* Digital Technologies) and Chapter 5 (Greening Digital Technologies); this chapter focuses on what the stocktake shows in aggregate.

3.1 Research question 1: which digital solutions show documented, verifiable outcomes in GHG mitigation and energy efficiency across different economic sectors, and do those benefits remain positive after accounting for the footprint and rebound effects of the technologies involved?

Score distribution and evidence quality

The 93 Greening *by* Digital Technologies cases span six sector domains. Table 3.1 shows the distribution across those domains, the evidence tier breakdown within each, and the average scores for impact (I), scalability (S), and replicability (R). Tables 3.1 and 3.2 use primary-domain counting: where a case has multiple sector tags, it is counted once under its first-listed primary domain. Of the 150 cases, 41 carry more than one sector tag.

Table 3.1: Greening by Digital Technologies cases by sector domain, with evidence tier breakdown (n = 93)

Sector domain	Evidence tiers (1 / 2 / 3)	I	S	R	What works	Main challenge
Public administration 17 cases	3 / 8 / 6	3.82	3.59	3.82	MRV platforms and satellite monitoring make climate outcomes countable, and enforceable when linked to legal obligations	Evaluating the enforcement and response through which reported data become emission cuts
Energy systems 29 cases	8 / 10 / 11	3.17	3.48	3.62	Grid programmes with digital metering and monitoring cut the share of electricity lost, from 44% to 26% in one programme; paying households to shift peak use works at national scale	Separating the digital share of the savings from that of new lines and transformers, and acting on more of the methane leaks satellites detect

Table 3.1: Greening by Digital Technologies cases by sector domain, with evidence tier breakdown (n = 93) (continued)

Sector domain	Evidence tiers (1 / 2 / 3)	I	S	R	What works	Main challenge
Mobility and transport 20 cases	8 / 7 / 5	2.68	3.45	3.68	Replacing trips with digital services, which gives the clearest counterfactual, and fleet and traffic management in individual operations	Verifying platforms' self-reported figures and accounting for rebound from cheaper travel
Industry and manufacturing 14 cases	1 / 4 / 9	3.59	3.79	3.87	The best-evidenced savings come where digital tools support ISO 50001 or a regulatory target	Verifying company-reported factory figures, separating the digital share of programme savings, and measuring supplier emission cuts
Buildings and homes 8 cases	2 / 3 / 3	3.00	3.44	3.75	Reliable savings in each building, adding up across whole building stocks and building codes	Savings depend on each building's starting point, are smaller across whole building stocks, and are partly modelled
Agriculture and forestry 5 cases	3 / 1 / 1	3.06	3.44	3.34	Large reported effects where programmes change land, input, or finance decisions, with digital tools as one input	Separating the digital share of results that depend on land, input, or finance decisions, and measuring greenhouse gas effects, which are so far modelled or estimated
93 cases	**25 / 33 / 35**	**3.23**	**3.53**	**3.70**		

Average scores from the expert panel evaluation. Evidence tier definitions in Chapter 2. Expert scores cover I (Impact), S (Scalability), and R (Replicability).

Public administration receives the highest average impact score in the expert assessment (3.82), reflecting the reach of its systems: digital monitoring, reporting, and verification (MRV) platforms and satellite monitoring record emissions and deforestation across whole economies and make

outcomes in other sectors countable. Their own share of the reductions they record is harder to isolate, so measured evidence of their direct effect remains limited: 3 of the 17 cases are Tier 1.

Industry and manufacturing rests most on company reporting: private companies lead 10 of its 14 cases, 9 are Tier 3, the highest share of any Greening *by* Digital Technologies sector, and only 4 report a measured reduction that can be attributed to the intervention, too few to give a range.

Energy systems have the most measured evidence: 8 of the 29 cases are Tier 1, and 6 report a measured percentage reduction that can be attributed to the intervention, a median of 34%. Three of these are cuts in electricity losses, where digital metering often comes with new lines and transformers, so the digital share is rarely separated.

Mobility and transport has, with energy, the most Tier 1 cases (8 of its 20), but its measured reductions are smaller and mostly come from pilots and trials: fuel savings of 2% to 8% from tyre monitoring, fleet management, and arrival management for flights, with a larger cut on waste-collection routes where truck idling is avoided (54%). A port terminal reports a larger, modelled cut of 19%.

Buildings and homes has the thinnest measured base: 2 of its 8 cases are Tier 1, and the two measured reductions are 3.4% from smart meters in British homes and 7% from artificial intelligence (AI) heating control in Espoo's public buildings, as savings depend on each building's starting point.

Agriculture and forestry is small (5 cases) but the best evidenced, with 3 at Tier 1, including a randomized trial in Peru, where communities receiving satellite deforestation alerts lost an estimated 52% less tree cover in the first year than comparison communities.

Greening *by* Digital Technologies cases are led by a mix of actors: private companies lead 36 of the 93 (39%), governments 32 (34%), multilateral organizations 10 (11%), and civil society, academic institutions, and public-private partnerships the remaining 15. Digitally enabled improvements in energy systems, agriculture, or public services cross organizational and sector boundaries and typically require a policy mandate, concessional finance, or cross-sector coordination that private actors alone cannot provide.

Why some impacts are easier to verify than others

To attribute an emission reduction to a digital solution, an assessment compares the outcome with a reference scenario, also called the counterfactual: in the words of ITU-T L.1480, "the situation without the studied ICT solution applied", whose emissions form the baseline.[32] Attribution is strongest where the design of the assessment itself supplies that reference scenario rather than assuming it, either because the activity the solution replaces can be counted directly or because a comparison group that did not receive the solution shows what would otherwise have happened. Peer-reviewed studies of telehealth and remote work make the counterfactual explicit: the clinical trip or commute that did not occur, estimated from travel behaviour data (case-492, case-493). Satellite deforestation alerts evaluated against control areas make the counterfactual for deforestation explicit: forest loss in areas that did not receive alerts (case-186, case-317). In each instance, the evaluation design builds the reference scenario into its structure rather than relying on a comparison made after the fact.

[32] ITU, Recommendation ITU-T L.1480.

Cases where attribution is only directionally plausible lack this built-in reference scenario. Smart grid and demand response cases, for instance, document the volume of energy shifted or peak demand reduced without specifying, against a verifiable baseline, what grid emissions would have been without the intervention. The same holds for most network and data centre cases, which report intensity gains without a defined baseline (Section 3.2).

The practical implication is that energy systems and industrial optimization would benefit from better design for measurement and impact evaluation. Pre-registered baselines, absolute metrics, and pre-specified counterfactual scenarios would strengthen many Tier 2 cases and position them for Tier 1 assessment through peer review, independent assurance, or independent evaluation, without changing the underlying intervention.

Assessing net climate impacts and what the results show

The most challenging aspect of research question 1 is whether documented benefits are still valid after a full net calculation: do enabled savings in the target sector exceed the energy and carbon cost of the digital solution itself, including hardware lifecycle, use-phase electricity, and end-of-life?

Of 150 cases, only 15 have had this calculation applied (Figure 5): 8 cases assessed under the European Green Digital Coalition (EGDC)[33] net carbon methodology aligned with Recommendation ITU-T L.1480,[34] and 7 cases from the IT4Green study of the French Agency for Ecological Transition (ADEME)[35] applying an equivalent consequential lifecycle assessment.

Seven of the eight EGDC cases quantify the information and communication technology (ICT) system's footprint and all seven return positive net results; the eighth, smart port logistics, reports the enabled saving without quantifying the footprint.

The seven ADEME IT4Green cases present a more varied picture. Five return positive net climate results, while two show the impact of rebound effects. For example, the tyre-as-a-service freight case (case-568)[36] is reversed by a 1% rise in freight volumes induced by lower per-unit transport costs, which turns a modelled saving of 1.6 million tCO_2e into a modelled net burden of about 0.18 million tCO_2e. The connected street lighting case (case-566)[37] is the most analytically significant: the Smart Digital System scenario yields a modelled net cumulative saving of 65 tCO_2e before higher-order effects (2023 to 2035), but when ADEME's higher-order effects are applied (financial rebound from reinvested energy-bill savings and the induced deployment of smart-city sensors), the combined burden reverses the sign to a net cumulative climate cost of 28.8 tCO_2e.

ADEME also assesses resource use, and there the picture changes: four of the five with a positive climate result add a net burden on mineral and metal resources, mainly from the equipment they install, and the fifth, carpooling, has an uncertain result.

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33 European Green Digital Coalition, *Net Carbon Impact Assessment Methodology for ICT Solutions*.
34 ITU, Recommendation ITU-T L.1480.
35 Camps et al., *Direct and Indirect Environmental Quantification of Digital Impacts in Use Cases*.
36 *IT4Green: Environmental Quantification of the Tyre-as-a-Service Use Case (ADEME, 2025)*, https://librairie.ademe.fr/index.php?controller=attachment&id_attachment=8016; Camps et al., *Direct and Indirect Environmental Quantification of Digital Impacts in Use Cases*.
37 *IT4Green: Environmental Quantification of the Smart Public Lighting Use Case (ADEME, 2026)*, https://librairie.ademe.fr/index.php?controller=attachment&id_attachment=8013; Camps et al., *Direct and Indirect Environmental Quantification of Digital Impacts in Use Cases* (ADEME, 2026), https://librairie.ademe.fr/index.php?controller=attachment&id_attachment=9273.

The net case for digitally enabled climate benefits holds in most deployment contexts tested, but rebound can cancel or reverse it when efficiency improvements reduce unit costs enough to induce volume growth in a carbon-intensive activity or trigger indirect infrastructure effects. The 15 assessed cases are not a random sample: the EGDC cases were selected partly for their likely magnitude of impact, and the ADEME cases from solutions presented as reducing environmental impact, so the positive results in 12 of the 14 cases that quantify the ICT footprint should not be generalized to the non-assessed cases. Fuller treatment of all 15 L.1480-aligned cases appears in Chapter 4 (Greening *by* Digital Technologies).

Figure 5: Net results of the 15 net-assessed cases, with and without rebound effects

Case	Net result without rebound	Net result with rebound
EGDC (rebound assessed qualitatively)		
5G smart port logistics, Italy (case-402)	Enabled saving; footprint not quantified	Not quantified; assessed qualitatively
Truck fleet management software (case-403)	Net saving	Not quantified; assessed qualitatively
AI fleet maintenance, Mexico (case-404)	Net saving	Not quantified; assessed qualitatively
Dynamic line rating, Spain (case-405)	Net saving	Not quantified; assessed qualitatively
Building management system (case-447)	Net saving	Not quantified; assessed qualitatively
IoT smart waste collection, Cyprus (case-454)	Net saving	Not quantified; assessed qualitatively
Edge AI district heating (case-476)	Net saving	Not quantified; assessed qualitatively
AI seawater desalination, Saudi Arabia (case-478)	Net saving	Not quantified; assessed qualitatively
ADEME IT4Green (rebound quantified in scenarios)		
Dynamic line rating, France (case-567)	Net saving	Net saving
Carpooling platforms, France (case-571)	Net saving	Net saving
Telework, France (case-569)	Net saving	Net saving
Rooftop solar PV monitoring apps, France (case-573)	Net saving	Net saving
Acoustic water-leak detection, France (case-572)	Net saving	Not quantified
Connected street lighting, France (case-566)	Net saving	Burden (connected version); saving (simple dimming)
Tyre-as-a-service for freight, France (case-568)	Net saving	Net burden

Net result: enabled reduction minus the footprint of the digital system (Recommendation ITU-T L.1480). The tyre-as-a-service case becomes a net burden if freight volumes rise by 1%; the connected street-lighting case when financial savings are reinvested. Sources: EGDC case studies; ADEME IT4Green (2026).

Source: EGDC case studies; ADEME IT4Green (2026).

Scale and programme design

The largest documented outcomes come from national programmes rather than individual deployments due to the difference in scale. Private-sector deployments at site or company level document a median reduction of about 3 100 tCO_2e a year (11 cases; middle half about 1 400 to 30 000 tCO_2e), while national programmes operate at a different order of magnitude: Egypt's industrial energy efficiency programme with the United Nations Industrial Development Organization (UNIDO) and the Global Environment Facility (GEF) cut 358 000 tCO_2 a year, according to its independent terminal evaluation, and companies in the programme installed

sub-meters and SCADA monitoring as part of their energy management systems.[38] Similarly, the International Finance Corporation (IFC) reports that its Partnership for Cleaner Textile in Bangladesh cuts 723 617 tCO_2e a year, and factories in the partnership installed water, gas, steam, and electricity meters on its advice.[39] However, too few national programmes report a comparable annual figure to give a range. These differences largely reflect the size of the unit of intervention. In national programmes, digital tools such as metering and monitoring are one part of a wider intervention, combined with national targets, financing tied to those targets, monitoring and evaluation built in from the outset, local institutional capacity, and multi-year funding cycles, so their own contribution is rarely separated.

3.2 Research question 2: which cases have reduced the energy consumption and GHG emissions of digital infrastructure, data centres, devices, and software?

Score distribution and evidence quality

The 57 Greening Digital Technologies cases are distributed across four sub-domains covering the ICT sector's own environmental footprint. Table 3.2 shows the case count, evidence tier breakdown, and average evaluation scores for each sub-domain.

Table 3.2: Greening Digital Technologies cases by sub-domain, with evidence tier breakdown (n = 57)

Sub-domain	Evidence tiers (1 / 2 / 3)	I	S	R	What works	Main challenge
Network infrastructure 23 cases	2 / 1 / 20	3.74	3.94	3.72	Retiring copper and sharing networks save the most; AI energy management also cuts site power	Verifying operators' own estimates and reporting total network electricity use
Data centres 14 cases	0 / 3 / 11	3.86	3.86	3.89	Efficiency is close to its limit (median PUE 1.24), mainly through cooling without chillers, and water use per kWh is falling	Adding absolute electricity and water use to PUE, WUE, and annual renewable matching, which are rates, not totals

[38] Clean Energy Ministerial Energy Management Working Group, Global Energy Management System Implementation: Case Study, Egypt: ELARABY Company for Trading and Manufacturing (2018), https://www.cleanenergyministerial.org/content/uploads/2022/03/cem-em-casestudy-el-araby-egypt.pdf; Global Energy Management System Implementation: Case Study, Egypt: Ezz Al-Dekheila Steel Co. (EZDK) (2017), https://www.cleanenergyministerial.org/content/uploads/2022/03/ezdk-egypt.pdf; *Independent Terminal Evaluation: Industrial Energy Efficiency in Egypt, GEF ID 3742, UNIDO Project 100349* (UNIDO, 2019), https://www.unido.org/sites/default/files/files/2019-12/GEF%20ID-3742_GFEGY-100349%20TE%20Report_2018.pdf.

[39] *PaCT: Partnership for Cleaner Textile (IFC)*, https://www.textilepact.net/; *Cleaner Production Case Study: Installation of Flow Meters* (World Bank Group, 2021), https://documents1.worldbank.org/curated/en/581351627045343844/pdf/Cleaner-Production-Case-Study-Installation-of-Flow-Meters.pdf.

Table 3.2: Greening Digital Technologies cases by sub-domain, with evidence tier breakdown (n = 57) (continued)

Sub-domain	Evidence tiers (1 / 2 / 3)	I	S	R	What works	Main challenge
User devices 16 cases	0 / 6 / 10	3.51	3.64	3.91	Longer use, refurbishment, and cleaner manufacturing cut the footprint where it arises	Measuring the savings from longer use and refurbishment, which are mostly modelled per device
Software 4 cases	1 / 1 / 2	3.00	3.75	4.13	Processor choice and timing cut workload carbon, and measurement tools are widely used	Adopting a common reporting unit, such as the Software Carbon Intensity standard, and reporting how the absolute emissions of AI and cloud workloads change
57 cases	**3 / 11 / 43**	**3.65**	**3.82**	**3.84**		

Average scores from the expert panel evaluation. Evidence tier definitions in Chapter 2. Expert scores cover I (Impact), S (Scalability), and R (Replicability).

Greening Digital Technologies cases receive higher scores than Greening *by* Digital Technologies cases across all three evaluated dimensions: impact (3.65 vs. 3.23), scalability (3.82 vs. 3.53), and replicability (3.84 vs. 3.70). One driver may be that energy is a direct operating cost for network operators and data centre owners, which creates commercial incentives to deploy, measure, and document efficiency improvements.

Of the Greening Digital Technologies cases, 84% come from the private sector (48 of 57), compared with 39% of Greening *by* Digital Technologies cases. However, external verification remains limited: 75% of Greening Digital Technologies cases (43 of 57) are classified as Tier 3, indicating that most evidence comes from self-reported organizational data rather than third-party assessment. Figure 4 in Chapter 2 shows the evidence tiers by sector for both domains.

The intensity-versus-absolute measurement gap

The Greening Digital Technologies cases rely almost universally on intensity, efficiency, and resource-performance metrics: energy per terabyte for networks, power usage effectiveness (PUE) or water usage effectiveness (WUE) for data centres, energy per device for user equipment, renewable electricity coverage, waste heat recovery, or equipment reuse. Most network and data centre cases document improvements in these metrics over the programme period. Many also acknowledge, in their own reporting, that absolute consumption remained flat or grew during the same period because traffic, workload, or user base growth outpaced efficiency gains. Only 17 of the 57 Greening Digital Technologies cases (30%) report how an organization's total energy use or emissions changed over time; 3 more give a total for a single year, and 37 report only intensity, efficiency, per-unit, or avoided-emissions figures.

Intensity improvement is a genuine operational achievement, but the net-effects accounting that research question 1 and ITU-T L.1480 call for requires absolute figures on both sides of the equation. The Greening Digital Technologies evidence base, measured primarily through intensity metrics, cannot straightforwardly supply that denominator. Shifting at least some Greening Digital Technologies reporting to absolute metrics with verified baselines is a precondition for the broader net calculation. Detailed sub-domain analysis appears in Chapter 5 (Greening Digital Technologies).

These measurement observations feed directly into the enabling pathway analysis in research question 3: the ability to assess impacts against a defined baseline is not a property of the evidence tier alone, but of the specific ICT mechanism deployed, which is what the pathway framework captures.

3.3 Research question 3: what are the main pathways through which digital technologies help meet climate and energy goals, and how are they combined?

Six enabling pathways and their distribution

Across all 150 cases, every mechanism through which ICT produces environmental outcomes maps to one of six enabling pathways (Figure 6):

Figure 6: Six enabling pathways and the number of cases using each



Source: Figure prepared for this report from the stocktake case data (ITU, 2026).

Each pathway generates a characteristic measurement currency, as summarized in Figure 6. ITU-T L.1480[40] provides a framework for converting a pathway's native unit into a comparable

[40] ITU, Recommendation ITU-T L.1480.

tCO_2e net figure, provided that a functional unit, reference scenario, system boundary, and supporting emissions data are available. This is hardest where the native indicator measures reach, finance, or activity rather than an environmental outcome. Connecting and Accelerating cases document their results in these native units: for example, 340 704 people with new or improved off-grid electricity service in Rwanda (case-548), 168 256 people with better electricity services in Guinea-Bissau (case-520), 9.6 million platform-recorded carpooling trips a year in France (case-571), and dynamic line rating deployed on 20 transmission circuits in Spain, 13 of which were assessed (case-405). These figures measure different things and are not added together.

Each case is tagged with one or more of the six enabling pathways. These tags organize findings in the synthesis chapters; they are not scored and do not affect case status.

Of the 150 cases, 45 report a measured percentage reduction in greenhouse gas (GHG) emissions or energy use, and 21 of these can be attributed, at least in part, to the intervention; the other 24 are company-wide or national trends within which the case sits using a combination of digital and non-digital solutions. Counting each case once under its first-listed pathway, Optimizing cases show a median reduction of 28% across 15 cases and Monitoring cases 18% across 5. The other pathways have too few measured reductions that can be attributed to the intervention to compare, because they mostly report in other units. Efficiency gains within an existing system have a median of 9% (12 cases), and cuts in losses in grids and supply networks a median of 28% (5 cases); too few cases replace one system with another, or avoid an activity, to give a range.

Figure 6 also shows that the pathway distribution splits sharply between domains. Greening Digital Technologies relies primarily on Optimizing (in 70% of its cases), Amplifying (25%), and Dematerializing (23%), the three pathways that cover the ICT sector's own operational efficiency, renewable energy procurement, and hardware lifecycle (Figure 6).

Greening *by* Digital Technologies deploys all six pathways, with Optimizing and Monitoring (62% of cases each) as the two leading mechanisms: most Greening *by* Digital Technologies solutions either optimize resource use through ICT or use ICT to measure and verify environmental outcomes. Monitoring is overwhelmingly a Greening *by* Digital Technologies mechanism (91% of Monitoring pathway uses); Accelerating is exclusively Greening *by* Digital Technologies (100%).

The response chain gap: from digital output to environmental outcome

Across Monitoring, Connecting, and Accelerating pathway cases, the most common structural shortfall is not measurement error but a programme design gap: programmes document what the digital system produces (alerts issued, meters installed, data transmitted) without specifying what happens as a result. Who acts on the methane alert, under what obligation, and within what timeframe? What operational or regulatory mechanism translates a smart meter reading into a changed behaviour or demand response? This gap, the absence of a documented institutional pathway from digital output to verified environmental outcome, recurs across otherwise strong cases and may be one reason the impact of many Monitoring, Connecting, and Accelerating cases is under-documented relative to their real-world climate governance role.

This response chain gap is distinct from the counterfactual gap that constrains Optimizing cases. The counterfactual gap arises when there is no documented baseline against which improvement

can be measured. The response chain gap arises when a digital output is documented but no mechanism connects it to a behavioural, operational, or regulatory change that produces the environmental outcome. A monitoring system that fires an alert and one that fires an alert and triggers a verified mitigation response have identical digital specifications but different climate contributions. Programme designers could be encouraged to specify the institutional pathway from digital observation to verified environmental outcome as part of evaluation design and climate finance assessment.

3.4 Research question 4: how can governments and other stakeholders incorporate proven digital solutions into their climate strategies?

The institutional infrastructure gap for Greening by Digital Technologies

Greening Digital Technologies has a functioning institutional infrastructure for measurement, voluntary disclosure, and policy adoption: Recommendation ITU-T L.1410,[41] RE100,[42] the Science Based Targets initiative,[43] whose guidance for the ICT sector is built on Recommendation ITU-T L.1470,[44] the Carbon Disclosure Project (CDP),[45] and specific regulations such as the reporting duty for data centres under the EU Energy Efficiency Directive[46] and the EU ecodesign requirements for servers and data storage.[47] These frameworks (see Table 3.3) share a structural property: a named institution takes responsibility for the standard, a reporting platform aggregates disclosure, and credibility mechanisms create incentives for participation.

Greening *by* Digital Technologies has the standards but not yet the system around them. Its central standard is ITU-T L.1480,[48] the international standard for net carbon impact accounting of digitally enabled solutions, supported by ITU-T L.1451,[49] the EGDC net carbon methodology, and the World Business Council for Sustainable Development (WBCSD) Guidance on Avoided Emissions[50] (see Table 3.3). The EU Taxonomy already recognizes data-driven solutions for emission reductions as an enabling activity, provided that their lifecycle savings are verified by an independent third party.[51] What it does not yet have is the implementation ecosystem that makes

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41 ITU, Recommendation ITU-T L.1410.

42 Climate Group, *RE100: Large and Ambitious Businesses Committed to 100% Renewable Electricity* (London: Climate Group, 2025), https://www.theclimategroup.org/re100.

43 Science Based Targets initiative, *Science Based Targets initiative (SBTi): Corporate Net-Zero Standard* (London: Science Based Targets initiative, 2024), https://sciencebasedtargets.org/corporate-net-zero.

44 ITU, Work Programme item for the revision of Recommendation ITU-T L.1470: Greenhouse Gas Emissions Trajectories for the Information and Communication Technology Sector Compatible with the UNFCCC Paris Agreement (Geneva: ITU, n.d.), https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=22384.

45 CDP Worldwide, *CDP: The Global Disclosure System for Environmental Impacts* (London: CDP Worldwide, 2025), https://www.cdp.net/.

46 European Parliament and Council of the European Union, Directive (EU) 2023/1791 of 13 September 2023 on Energy Efficiency, Article 12 (Brussels: European Union, 2023), https://eur-lex.europa.eu/eli/dir/2023/1791/oj/eng; Commission Delegated Regulation (EU) 2024/1364 on the First Phase of the Establishment of a Common Union Rating Scheme for Data Centres (Brussels: European Commission, 2024), https://eur-lex.europa.eu/eli/reg_del/2024/1364/oj/eng.

47 European Commission, *Commission Regulation (EU) 2019/424 Laying down Ecodesign Requirements for Servers and Data Storage Products* (Brussels: European Commission, 2019), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R0424.

48 ITU, Recommendation ITU-T L.1480.

49 ITU, Recommendation ITU-T L.1451: *Methodology for Assessing the Aggregated Positive Sector-Level Impacts of ICT in Other Sectors* (Geneva: ITU, 2019), https://www.itu.int/rec/T-REC-L.1451.

50 World Business Council for Sustainable Development, Guidance on Avoided Emissions, Version 2.0 (Geneva: WBCSD, 2025), https://www.wbcsd.org/resources/guidance-on-avoided-emissions/.

51 European Commission, Commission Delegated Regulation (EU) 2021/2139, Annex I, Section 8.2: Data-Driven Solutions for GHG Emissions Reductions (Brussels: European Commission, 2021), https://ec.europa.eu/finance/docs/level-2-measures/taxonomy-regulation-delegated-act-2021-2800-annex-1_en.pdf.

these standards operational at scale: clear implementation guidance and tools, integration into national reporting workflows, platforms for aggregating and comparing results across deployments, integration into accounting frameworks for nationally determined contributions (NDCs), and climate finance conditions beyond the EU Taxonomy that require ITU-T L.1480-aligned assessment for digitally enabled emissions reduction claims. This gap is the stocktake's clearest answer to research question 4: the 15 net-assessed EGDC and ADEME IT4Green cases in Chapter 4 show what applying the standard looks like in practice.

Table 3.3: Maturity of the supporting system in the two domains

	Greening Digital Technologies	Greening *by* Digital Technologies
Measurement standards	ITU-T L.1410 (lifecycle assessment of ICT goods, networks, and services) and ITU-T L.1470 (sector emission trajectories)	ITU-T L.1480 and L.1451, the EGDC net carbon methodology, and the WBCSD Guidance on Avoided Emissions
Commitments and reporting	RE100, Science Based Targets initiative (ICT guidance built on ITU-T L.1470), CDP reporting	No common mechanism for sector-wide reporting
Regulation	EU ecodesign requirements for servers and data storage; data centre reporting and rating under the EU Energy Efficiency Directive	No requirement to assess; EU Taxonomy activity 8.2 sets voluntary criteria
Verification and finance	Increasingly audited disclosure	Third-party verification required under EU Taxonomy activity 8.2 and for public claims under ITU-T L.1480; recognition in climate finance beyond the EU Taxonomy remains limited

From replication to codification

Some solutions are being replicated, but few are codified so that others can adopt them. Of the 150 cases, 22 (15%) document that their method has been codified so that others can adopt it without the original team (published openly, 11; written into law or regulation, 10; a standard, 1),[52] as with the Partnership for Carbon Transparency (PACT) of the WBCSD or MapBiomas. A further 39 cases (26%) have been deployed in at least two countries or sectors but have not crossed this threshold, and the remaining 89 (59%) document a single deployment. For adoption by governments and other stakeholders, these 39 cases are the near-term opportunity: proven, replicating across contexts, and one institutional step from wider uptake. Cost evidence is thinner still: only 35 of the 150 cases (23%) report any financial figure, 8 give the capital cost of the solution, 18 an operating saving, and only 4 a payback period, so governments and investors weighing adoption rarely have the cost data they need.

[52] Counted from the case files and archived sources, not from the expert scores. A case counts as codified only when its own method or tool is itself a standard, is published openly, or is written into law or regulation, and as replicated when the same solution is documented in at least two countries or sectors.

The AI measurement challenge

AI or machine learning plays a role in 36 of the 150 cases (24%), mostly as an efficiency layer on existing systems: optimizing network energy use, controlling district heating, fine-tuning industrial processes, and supporting deforestation monitoring. Against the AI technology types in Recommendation ITU-T L.1801, the case files name machine learning in 9 of the 36 cases and do not specify the technique in the rest; none describes generative AI or a large language model delivering a climate outcome.

On measured evidence, AI does not yet stand out in the Optimizing pathway: none of the 32 Optimizing cases that involve AI is Tier 1, and the 6 that report a measured percentage reduction attributable to the deployment show a median of 19%, against 43% for the 11 Optimizing cases without AI (counting every case that uses Optimizing, not only those it leads). The difference lies in evaluation design and deployment context rather than in what AI can do: few AI deployments are assessed against what would have happened without them. The AI cases that report against a stated baseline, such as Siemens's Nanjing factory (Chapter 4), remain company-reported.

The footprint of the AI systems themselves is rarely assessed. Only one case, the AI-optimized desalination plant of the Saudi operator SAWACO (Chapter 4), reports the AI component separately: a one-off model training run on a standard computer, 0.005 tCO_2e, against savings of 157.6 tCO_2e a year. No case quantifies dedicated AI infrastructure, such as specialized processors, data centre capacity, or faster hardware replacement, against the savings it enables. ITU-T L.1801, approved in February 2026, provides guidelines for this assessment, but it is too recent to have been applied in any deployment documented here (Recommendation 6).

The NDC relevance is direct: ITU's 2026 analysis of NDCs[53] finds that 103 out of 140 NDCs with 2035 targets submitted by July 2026 explicitly reference digital technologies as climate implementation tools, and that 12% explicitly reference AI to be deployed.

How the regions differ

The two domains of this stocktake distribute unevenly across the six regions and cannot be read as a single gradient. Figure 7 shows how often each region's cases use each pathway.

[53] ITU, *Digital Technologies and NDCs*.

Figure 7: Share of each region's cases using each enabling pathway, by domain

Greening by Digital Technologies (93 cases)

Region	Cases	Share of cases using each pathway: Optimizing	Monitoring	Dematerializing	Amplifying	Connecting	Accelerating
Europe	35	83%	54%	9%	0%	6%	3%
Americas	21	43%	67%	14%	5%	10%	5%
Asia-Pacific	17	53%	59%	24%	18%	0%	12%
Africa	14	36%	71%	0%	14%	36%	21%
Arab States	4	100%	75%	0%	0%	0%	0%
CIS	2	100%	100%	0%	0%	0%	0%

Greening Digital Technologies (57 cases)

Region	Cases	Share of cases using each pathway: Optimizing	Monitoring	Dematerializing	Amplifying	Connecting	Accelerating
Europe	19	68%	5%	32%	11%	0%	0%
Americas	15	67%	13%	20%	20%	0%	0%
Asia-Pacific	13	85%	8%	8%	23%	0%	0%
Africa	4	50%	25%	25%	25%	25%	0%
Arab States	5	80%	20%	20%	80%	0%	0%
CIS	1	0%	0%	100%	100%	0%	0%

The six pathway columns show the share of each region's cases that use each pathway; a case can use more than one, so a region's shares add up to more than 100%. Regions with fewer than five cases in a domain are shown but should be read with care.

Source: Figure prepared for this report from the stocktake case data (ITU, 2026).

The regional distribution of cases (Figure 3) is a finding about evidence availability, not deployment opportunity. Africa and Asia-Pacific likely contain major deployment opportunities given population, infrastructure growth, and climate vulnerability, but they are under-represented in the evidence base. The skew is sharpest in Greening Digital Technologies: sustainability reports follow corporate headquarters, not infrastructure locations. A European operator's efficiency programme covering infrastructure across multiple continents is counted in Europe because that is where the assurance statement originates. The infrastructure whose decarbonization matters most for developing economies remains largely absent from this evidence base.

What the multi-pathway complexity in lower-income regions signals

Africa has the highest multi-pathway rate of any region with a substantial number of cases: 64% of its Greening *by* Digital Technologies cases involve more than one pathway, with an average of 1.8 pathways per case. Connecting and Accelerating both appear more often in Africa than in any other region (in 36% and 21% of these cases), usually alongside Monitoring, which appears in 71%. Connectivity extends the reach of measurement, and operational improvements build on both.

This structural observation has a direct implication for replication design. Programmes designed for connectivity-mature environments, where connectivity is assumed and the solution concentrates on what the connection enables, cannot be transplanted to connectivity-constrained environments without incorporating the Connecting layer. Replication guidance developed for connectivity-mature contexts may require adaptation for deployments where foundational connectivity forms part of the intervention itself.

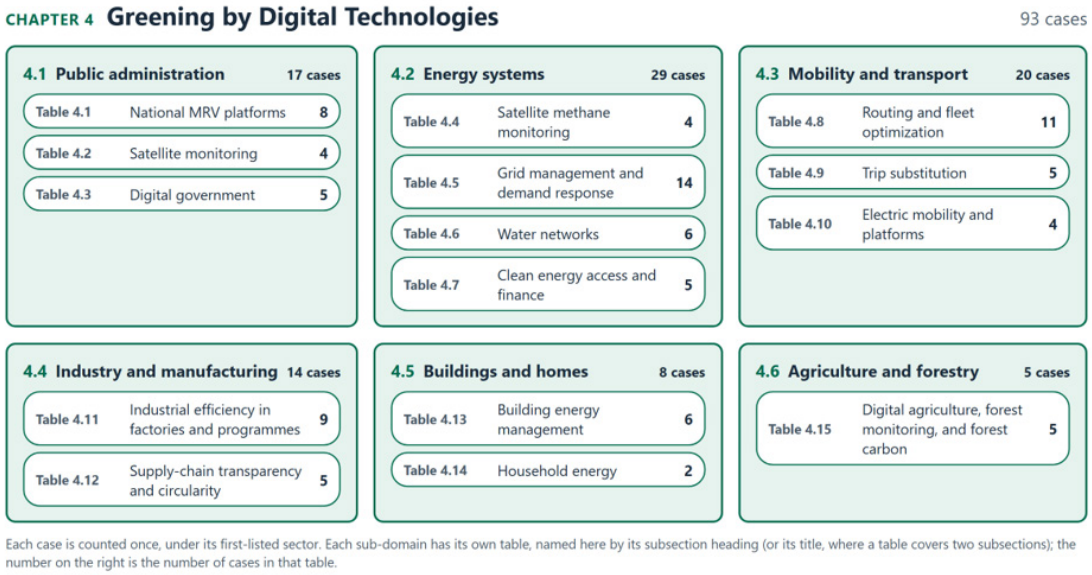
4 Greening *by* digital technologies

This chapter examines the 93 Greening *by* Digital Technologies cases where digital technology enables and unlocks measurable climate or energy outcomes outside the digital sector itself. Each case is counted once, under its first-listed sector: public administration (17 cases), energy systems (29), mobility and transport (20), industry and manufacturing (14), buildings and homes (8), and agriculture and forestry (5).[54]

The purpose of this chapter is to show what digitally enabled climate action looks like in the real economy. Chapter 3 established the cross-cutting findings: the net-effects gap, the replication-to-codification gap, the challenge of establishing a credible baseline for impact measurement, the six enabling pathways, and the institutional infrastructure missing around Recommendation ITU-T L.1480. This chapter sets out documented cases in which digital technologies contribute to climate change mitigation, energy-efficiency, and climate-governance outcomes, with evidence of varying strength, and the enabling conditions that make those outcomes credible and replicable.

Each section opens with its main finding, followed by its sub-domains, each with a summary table (see Figure 8). Section 4.1 begins with public administration, because its monitoring, reporting, and verification (MRV) platforms and satellite monitoring are what make outcomes in the other sectors countable.

Figure 8: The 93 Greening by Digital Technologies cases by sector and sub-domain



Source: Figure prepared for this report from the stocktake case data (ITU, 2026).

4.1 Public administration and digital governance

The 17 public-administration cases make this the third-largest sector among the Greening *by* Digital Technologies cases. They fall into three groups: national MRV and greenhouse gas (GHG) inventory platforms, satellite monitoring, and digital government. Monitoring is the dominant

[54] Each case is counted once, under its first-listed sector, as in Table 3.1 of Chapter 3. Cases tagged with more than one sector are discussed wherever they are relevant.

pathway, appearing in 12 of the 17 cases, followed by Dematerializing (4), Accelerating and Amplifying (3 each), and Optimizing (2). This sector is less about optimizing a single physical process and more about enabling climate governance.

Main finding: Digital MRV platforms and satellite monitoring make climate action countable and let governments show that the measures in their nationally determined contributions (NDCs) are being carried out. Where digital reporting carries legal and financial weight, as in the European Union Emissions Trading System (EU ETS), it shows sector by sector where emissions fell, offering important feedback on policy effectiveness. Where satellite data feed finance or enforcement, they can change decisions on the ground. India's Perform, Achieve and Trade (PAT) scheme shows what monitoring delivers when it reports against targets: the Bureau of Energy Efficiency (BEE) reports savings of 25.78 million tonnes of oil equivalent. Most other monitoring cases track emissions and inform decisions, which is the groundwork that measured reductions build on. Digital government also brings climate co-benefits, such as cleaner cooking fuel, whose climate effect has yet to be quantified, and paperless trade, whose saving has so far only been estimated.

National MRV platforms

Digital MRV platforms are a foundational component of the Paris Agreement transparency and compliance architecture. The eight cases in the stocktake cover five types of systems: mandatory emissions reporting, mandatory energy-saving targets, national inventory building, monitoring from electricity data, and NDC preparation support (Table 4.1).

Each system's design determines what it can measure and the level of confidence. Systems that make emissions reporting mandatory, such as the EU ETS, the Republic of Korea's Greenhouse Gas Inventory and Research Center (GIR), the United States Greenhouse Gas Reporting Program (GHGRP), and the South African Greenhouse Gas Emissions Reporting System (SAGERS), can show reported emissions and their change over time. In the 2024 EU ETS compliance cycle, operators responsible for over 99% of emissions from power generation, industry, and aviation met their legal obligations on time. That verified reporting makes the cap enforceable and shows, sector by sector, where the 51% fall in emissions from stationary installations between 2005 and 2024 came from, a fall the European Environment Agency attributes to carbon pricing, fuel switching, and climate policies. This gives EU policymakers the feedback they need to judge policy effectiveness.

The other systems show what different designs can measure. India's PAT scheme also uses mandatory digital reporting, but against energy-saving targets, which is why BEE can report savings of 25.78 million tonnes of oil equivalent. Rwanda's Capacity-building Initiative for Transparency (CBIT) platform is building the national inventory itself, so what it can show so far is eight country-specific emission factors that allow more precise Intergovernmental Panel on Climate Change (IPCC) Tier 2 estimates and a first Biennial Transparency Report. In Sichuan, China, the provincial power company links the electricity use of polluting enterprises to their pollution and carbon emissions for regulators.

Support for NDC preparation works before any of these systems are in place: it builds the capacity that measurement systems later depend on. The Climate Promise of the United Nations Development Programme (UNDP), for example, has supported 106 developing countries in preparing their NDCs, and in its first round, in 2019, over 90% of the countries it supported

raised the mitigation ambition of their NDCs. Its results are reported for the programme as a whole, however, so the contribution of its digital tools is not measured separately.

Table 4.1: MRV platform cases

Type of system	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Mandatory emissions reporting	EU Emissions Trading System (ETS) MRV platform[55] case-538	Over 12 000 entities across the 27 EU Member States, Iceland, Liechtenstein, and Norway	Supports verified emissions reporting and compliance; emissions from stationary installations fell 51% between 2005 and 2024, supported by carbon pricing, fuel switching away from coal, and renewable energy policies *Measured*	Tier 1	13.0
	US EPA Greenhouse Gas Reporting Program (GHGRP) [56] case-537	7 544 facilities reporting direct emissions, about half of US emissions (85% to 90% including suppliers)	Direct emissions of 2.58 billion tCO_2e reported in 2023, 4.4% lower than in 2022; every report checked electronically *Measured*	Tier 2	11.0
	The Republic of Korea's Greenhouse Gas Inventory and Research Center (GIR) [57] case-540	735 entities in the Korea Emissions Trading Scheme (2023)	Verified emissions of 549.9 $MtCO_2e$ in 2023, 3.9% lower than in 2022; all covered entities met their surrender obligations *Measured*	Tier 1	10.0

[55] Monitoring, Reporting and Verification (European Commission, n.d.), https://climate.ec.europa.eu/eu-action/carbon-markets/eu-emissions-trading-system-eu-ets/monitoring-reporting-and-verification_en; Greenhouse Gas Emissions Under the EU ETS (European Environment Agency, 2025), https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-under-the; Carbon Market Report 2025, COM(2025) 735 (European Commission, 2025), https://climate.ec.europa.eu/document/download/ddc1b1de-652b-49ed-8f15-d9fa8badd39f_en?filename=com_2025_735_en.pdf.

[56] *GHGRP Reported Data 2023* (US Environmental Protection Agency, 2024), https://www.epa.gov/ghgreporting/ghgrp-reported-data; *GHGRP Emissions Trends* (US Environmental Protection Agency, 2024), https://www.epa.gov/ghgreporting/ghgrp-emissions-trends.

[57] Web-based GHG Management System of the Republic of Korea (Partnership on Transparency in the Paris Agreement, n.d.), https://transparency-partnership.net/gpd/web-based-ghg-management-system-republic-korea; Korea ETS: ICAP Status Report (International Carbon Action Partnership, 2024), https://icapcarbonaction.com/en/ets/korea-emissions-trading-system-k-ets.

Table 4.1: MRV platform cases (continued)

Type of system	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	South African Greenhouse Gas Emissions ReportingSystem (SAGERS)[58] case-542	Web platform on which major emitters register and submit GHG data under the GHG Reporting Regulations	Facility data for the energy and industrial process sectors of the national inventory, which puts 2022 emissions at 478.3 $MtCO_2e$ excluding land use, 2.2% below 2000 *Measured*	Tier 2	7.0
Mandatory energy-saving targets	India's Perform, Achieve and Trade (PAT) scheme and Bureau of Energy Efficiency (BEE), PATNet portal and electronic Energy Saving Certificates [59] case-541	1 333 designated consumers representing 55% of industrial energy use	Energy savings of 25.78 million tonnes of oil equivalent across 1 333 energy-intensive industries *Measured*	Tier 1	11.0
National inventory building	Rwanda's GEF Capacity-building Initiative for Transparency (CBIT) platform [60] case-535	National capacity-building initiative	Eight country-specific emission factors across energy, industry, agriculture and land use, and waste, allowing Tier 2 reporting in Rwanda's first Biennial Transparency Report (2024); more than 300 people trained in MRV *Measured*	Tier 2	9.0

58 National GHG Inventory Document South Africa 2000 to 2022 (Republic of South Africa / UNFCCC, 2024), https://unfccc.int/sites/default/files/resource/National%20Inventory%20Document%20of%20South%20Africa%202000-2022.pdf.

59 *Perform Achieve and Trade (PAT) Scheme* (Bureau of Energy Efficiency, Ministry of Power, India, 2024), https://beeindia.gov.in/show_content.php?lang=1&level=2&ls_id=918&lid=752.

60 *Progress Report on the Capacity-Building Initiative for Transparency (CBIT)* (Global Environment Facility (GEF), 2025), https://www.thegef.org/sites/default/files/documents/2025-11/EN_GEF.C.70.Inf_.13_Progress%20Report%20on%20the%20CBIT.pdf.

Table 4.1: MRV platform cases (continued)

Type of system	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Monitoring from electricity data	State Grid Sichuan Electric Power Research Institute, power big data monitoring of enterprise pollution and carbon, China[61] case-586	Electricity use of polluting enterprises in Sichuan province linked to their pollution and carbon emissions for regulators	Submitter reports about 31 000 enterprises monitored and about 31 400 inspections replaced a year (unverified; the same form says the platform is not yet deployed) *No outcome yet*	Tier 3	11.0
NDC preparation support	UNDP, Climate Promise, global[62] case-557	Support to developing countries in preparing their NDCs, including digital planning and tracking tools	106 countries supported (2025); over 90% of countries supported in the first round (2019) raised the mitigation ambition of their NDCs *Measured*	Tier 2	13.0

Satellite monitoring

Satellite-based environmental monitoring adds an independent layer of observation, from national land-cover mapping and commodity supply chains to economy-wide and city-level emissions tracking, that complements national reporting and strengthens accountability. The four cases illustrate how these tools work across different scales and governance contexts (Table 4.2).

Satellite monitoring produces climate value when its information reaches a decision and leads to action. MapBiomas has mapped land use and land cover across all of Brazil every year since 1985, and its validated deforestation alerts now feed lending and enforcement decisions: banks have used its data to deny about USD 2 billion in credit to those who might have been involved in deforestation.

The other cases track emissions and supply chains rather than the reductions that monitoring brings about. Climate TRACE, a coalition that uses artificial intelligence (AI) and machine learning to analyse data from more than 300 satellites and more than 11 000 sensors, publishes an independent, open inventory that summarizes 744 678 997 assets into 2.77 million emission sources. Its value lies in checking national self-reporting: for the fourth year in a row, its estimates put oil and gas emissions from production and transport at three times the reported level.

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61 *Smart Governance for Pollution and Carbon Reduction via Power Big Data*, State Grid Sichuan Electric Power Research Institute, submission to ITU Green Digital Action, 2026.

62 Climate Promise 2025 (UNDP), https://climatepromise.undp.org/what-we-do/flagship-initiatives/climate-promise-2025; How Developing Countries Are Taking Climate Action Forward (UNDP), https://climatepromise.undp.org/news-and-stories/how-developing-countries-are-taking-climate-action-forward.

Another platform, Trase, links commodity exports to the places that produced them, connecting 16 038 trading companies to 5 280 subnational production regions, so that the deforestation linked to a trader's sourcing can be traced to where it occurred. Between 2021 and 2024, its data informed more than 150 company initiatives to tackle deforestation and more than 200 actions by financial institutions on due diligence, portfolio screening, and environmental, social, and governance (ESG) reporting.

Monitoring can also track how a city's emissions change over time. In Chengdu, the State Grid Sichuan Electric Power Research Institute combines satellite, drone, ground-station, and electricity data into gridded CO_2 estimates, which show the city's industrial CO_2 falling 16.5% and its transport CO_2 10.9% between 2017 and 2022.

Table 4.2: Satellite monitoring cases

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
National land-cover monitoring	MapBiomas[63] case-544	All of Brazil, with annual maps from 1985; network includes organizations in 14 other countries	About USD 2 billion of credit denied to those who might have been involved in deforestation (cumulative, World Economic Forum, 2023); Amazon deforestation down 23.5% in 2025 against 2024 (MapBiomas; its own contribution not isolated) *Measured*	Tier 3	14.0
Supply-chain transparency	Trase[64] case-472	16 038 trading companies and 5 280 production regions; covers all of Brazil's soy deforestation	More than 150 company deforestation initiatives and more than 200 financial-institution actions using Trase data (cumulative, 2024) *Measured*	Tier 3	12.0

[63] *These Maps Show Deforestation and Much More across Latin America: Here's How They Can Help Counter the Climate Crisis* (World Economic Forum (WEF), 2023), https://www.weforum.org/stories/2023/09/mapbiomas-climate-crisis-deforestation-brazil/; *MapBiomas Alerta RAD2024: Deforestation Fell in All Brazilian Biomes in 2024* (MapBiomas Brasil, 2025), https://brasil.mapbiomas.org/mapbiomas-desmatamento-caiu-em-todos-os-biomas-brasileiros-em-2024/; *Amazon Deforestation Declines as Brazil Reduces Forest Loss Nationwide* (Mongabay, 2026), https://news.mongabay.com/short-article/2026/06/amazon-deforestation-declines-as-brazil-reduces-forest-loss-nationwide/.

[64] *What Is Trase?* (Stockholm Environment Institute (SEI), 2024), https://trase.earth/about.

Table 4.2: Satellite monitoring cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Econo-my-wide emissions tracking	Climate TRACE[65] case-165	Global: 2 765 771 emission sources	Independent inven-tory covering 2.77 million emission sources *Measured*	Tier 3	13.0
Urban emis-sions tracking	State Grid Sichuan Elec-tric Power Research Insti-tute, MDCAT urban CO_2 monitoring, China[66] case-581	Chengdu and all 183 coun-ty-level units of Sichuan prov-ince	Satellite, drone, ground-station, and electricity data combined into gridded CO_2 esti-mates. Chengdu industrial CO_2 down 16.5% and transport CO_2 down 10.9% between 2017 and 2022, from the system's monitoring data *Measured*	Tier 3	9.0

Digital government

Digitalization of government transactions and services produces GHG reductions as a co-benefit of administrative modernization. The five cases digitize subsidy payments, trade procedures, internal administration, and public procurement, as well as provide connectivity for climate alerts. They establish their carbon effect in different ways, from no emissions estimate to the source's own estimate of the saving (Table 4.3).

Some of these programmes reach very large numbers of people, which makes their climate effect worth measuring in detail. India's PAHAL scheme pays cooking-gas (LPG) subsidies directly into bank accounts, and it carries the subsidy behind the country's shift from traditional biomass to cleaner cooking fuel: about 1.94 billion LPG refills were delivered in the 2024/25 financial year, and the linked Ujjwala scheme has given LPG connections to 103.3 million poor households. Moving these households off wood and other biomass reduces household air pollution and can ease pressure on forests. Digital targeting keeps the subsidy on course: 40.8 million duplicate, fake, or inactive connections had been blocked by July 2025. The climate effect of the switch has not yet been quantified.

In Vanuatu, the electronic Single Window built by the United Nations Conference on Trade and Development (UNCTAD) made two trade procedures fully paperless, which the source estimates cut 5 827 kg of CO_2, and modelling by the Economic and Social Commission for Asia

[65] *About the Coalition* (Climate TRACE Coalition, n.d., accessed 21 October 2026), https://climatetrace.org/about; *Climate TRACE Data Reveal High-Impact Opportunities for Cutting Greenhouse Gas Emissions* (Climate TRACE Coalition, 2025), https://climatetrace.org/news/climate-trace-data-reveal-high-impact-opportunities-for.

[66] Urban-Scale CO_2 Emission Monitoring, Inversion and Scenario Projection System: Chengdu/Sichuan Demonstration, State Grid Sichuan Electric Power Research Institute, 2026.

and the Pacific (ESCAP) of the paper, ink, and fuel that paperless trade avoids puts the saving at 32 to 86 kg of CO_2e per fully digital transaction. Jammu and Kashmir measures the printed pages avoided but only estimates the emissions saved (10 294 tCO_2 a year).

The Republic of Korea has required public bodies to buy green products where possible since 2005, and publishes its green procurement through the Korea ON-line E-Procurement System (KONEPS). Green products have made up a stable share of more than 16% of public product purchases since 2014, with 17.9% in 2023, worth about KRW 6 trillion. An official estimate for 2017 puts the cut from green purchases at 665 000 tCO_2e.

Governments can also apply these tools to their own digital estate: the UK Government reports the footprint of its information and communication technology (ICT) across 19 ministerial departments (69 bodies) (Chapter 5, Box 3).

In Brazil, the Defesa Civil Alerta system sends climate alerts to mobile phones by cell broadcast and has been demonstrated in 28 municipalities in the North region. Connectivity in the region is also expanding: the Norte Conectado programme is building a 12 000 km fibre-optic network along the beds of Amazon rivers, which the Ministry of Communications says will connect 59 municipalities and benefit 10 million people while avoiding deforestation, because the cable runs along riverbeds.

Table 4.3: Digital government service and transaction cases

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Subsidy payments	Ministry of Petroleum and Natural Gas, PAHAL Aadhaar-linked direct LPG subsidy transfer, India[67] case-543	India, nation-wide; launched in 54 districts in November 2014 and extended to all remaining districts in January 2015	125.7 million households receiving transfers (2015); 40.8 million duplicate, fake, or inactive connections blocked (2025) *Measured*	Tier 2	12.0
Paperless trade	UNCTAD and Government of Vanuatu, electronic Single Window[68] case-170	Vanuatu; two trade procedures automated through an electronic Single Window	Modelled reduction of 5 827 kg CO_2 from fully digitizing the two procedures (2021) *Modelled*	Tier 2	14.0

[67] *PAHAL-Guinness World Record* (Press Information Bureau, Government of India, 2015), https://www.pib.gov.in/newsite/PrintRelease.aspx?relid=132587; *Government Strengthens LPG Subsidy Transfers through PAHAL and Aadhaar Authentication* (Press Information Bureau, Government of India, 2025), https://www.pib.gov.in/PressReleasePage.aspx?PRID=2152413; *India: Prime Minister's Clean Cooking Scheme* (Pradhan Mantri Ujjwala Yojana, PMUY) (Global Alliance against Hunger and Poverty, 2025), https://globalallianceagainsthungerandpoverty.org/country-example/india-prime-ministers-clean-cooking-scheme-pradhan-mantri-ujjwala-yojana-pmuy/; *Cost-Effectiveness Analysis of the Pradhan Mantri Ujjwala Yojana (PMUY) in India: A Well-Being Perspective* (Observer Research Foundation, 2025), https://www.orfonline.org/research/cost-effectiveness-analysis-of-the-pradhan-mantri-ujjwala-yojana-pmuy-in-india-a-well-being-perspective.

[68] *Quantifying the Environmental Benefits from Paperless Trade Facilitation* (UNCTAD, 2021), https://etradeforall.org/news/quantifying-environmental-benefits-paperless-trade-facilitation.

Table 4.3: Digital government service and transaction cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Paperless administration	Government of Jammu and Kashmir, e-Office paperless administration platform, India[69] case-495	Union Territory of Jammu and Kashmir, India; 114 826 user accounts across the Secretariat, departments, and districts (July 2025)	405.7 million printed pages avoided since 2021; an estimated 10 294 tCO_2 a year avoided (2025) *Measured and modelled*	Tier 3	10.0
Green public procurement	Korea ON-line E-Procurement System (KONEPS), Republic of Korea[70] case-195	Integrated e-procurement platform for central and local government and public enterprises	Green public purchases estimated to have cut 665 000 tCO_2e in 2017 (official figures); 17.9% of public product purchases met minimum green criteria (2023) *Measured and modelled*	Tier 2	10.0
Climate alerts and connectivity	ANATEL and Government of Brazil, Norte Conectado fibre and Defesa Civil Alerta cell broadcast, Brazil[71] case-531	12 000 km of riverbed fibre being built to connect 59 municipalities in the Amazon; cell broadcast climate alerts	Alerts sent in 11 pilot municipalities (2024) and demonstrated in 28 municipalities in the North region (2025) *Measured*	Tier 2	12.0

[69] Shahid Iqbal Choudhary, *Green Governance: Evaluating the Environmental Gains of e-Office Transition*, Journal of Research in Environmental and Earth Sciences 11, no. 9 (2025), https://doi.org/10.35629/2532-11090107; *E-Office Saves 10,294 Tonnes of CO_2 Annually, 40 Cr Pages since 2021* (Rising Kashmir, 2025), https://risingkashmir.com/e-office-saves-10294-tonnes-of-co%E2%82%82-annually-40-cr-pages-since-2021/.

[70] *How South Korea Enables Its Green Transition through Green Public Procurement* (Open Contracting Partnership, 2024), https://www.open-contracting.org/2024/09/25/how-south-korea-enables-its-green-transition-through-green-public-procurement/; *Public Procurement Service Annual Report 2022* (Public Procurement Service, Republic of Korea, 2022), https://www.pps.go.kr/eng/bbs/view.do?key=00798&bbsSn=2310060005.

[71] *Defesa Civil Alerta: Sistema de Alerta por Broadcast Celular* (Anatel, 2025), https://www.gov.br/anatel/pt-br/dados/utilidade-publica/alertas-de-desastres/defesa-civil-alerta; *Norte Conectado é destaque por levar infraestrutura digital à Amazônia sem impactar o meio ambiente* (Brazilian Ministry of Communications, 2025), https://web.archive.org/web/20251126112037/https://www.gov.br/mcom/pt-br/noticias/2025/agosto/norte-conectado-e-destaque-por-levar-infraestrutura-digital-a-amazonia-sem-impactar-o-meio-ambiente.

4.2 Energy systems and clean energy access

The 29 energy cases, the largest group among the Greening *by* Digital Technologies cases, fall into four groups: satellite methane monitoring, grid management and demand response, water networks, and clean energy access and finance. Water utilities are included here because their climate effect comes through energy: pumping, treating, and desalinating water uses large amounts of electricity, and water lost from a network wastes the energy already spent on it. Household smart metering is discussed in Section 4.5. Optimizing and Monitoring dominate, appearing in 20 and 19 of the 29 cases: satellites and meters make emissions and losses visible, and AI dispatch and grid controls act on them.

Main finding: Digital tools deliver their largest results at known sources of emissions. In three grid programmes using smart meters, automated metering, or grid monitoring, the share of electricity lost fell from 44% to 26% in Abuja, Nigeria, from 9.7% to 7.0% in Armenia, and from 10.2% to 8.0% in Saudi Arabia. Because grid programmes also install new lines and transformers, the digital share of these savings is rarely measured separately. Water utilities show the same pattern: smart meters and leak sensors help cut water losses. Smarter pumping, together with new pumps, cut pumping energy by 43% and by up to 60% at the two utilities assessed, and net assessments find the ICT footprint small against the saving. Satellites now make methane leaks visible down to single facilities, so the gain for methane depends on acting on more of the leaks they detect. Paying households to shift or cut use at peak times already works at national scale: Great Britain's Demand Flexibility Service saved more than 3 300 MWh at peak times across 1.6 million households and businesses, a figure the system operator confirmed from market data. Digital payment and identity systems are already widening access to clean energy for households and small businesses that lenders could not otherwise reach, and BURN's cookstove project in Kenya has 52 405 tCO_2e of emission reductions verified under the Gold Standard.

Satellite methane monitoring

Satellites now detect methane from whole basins down to single facilities, but detection becomes mitigation only when someone acts on it. The four cases trace the chain from basin-wide estimates to facility-level detection and confirmed repairs (Table 4.4).

Response is the bottleneck. Since its launch, the Methane Alert and Response System (MARS) has sent more than 3 500 satellite-based alerts in 33 countries. The share of alerts that received a response rose from 1% in 2024 to about 12% in 2025, so most still go unanswered. In the year to the 2025 report of the United Nations Environment Programme (UNEP), the alerts led to 19 further confirmed mitigation cases, which together had been emitting 52 tonnes of methane an hour, and by April 2026 the total had reached 41 cases. Governments that receive alerts need an assigned authority and a procedure to notify operators and verify fixes, as guidance from the International Energy Agency (IEA) and the International Methane Emissions Observatory (IMEO) sets out.

The data themselves are no longer the limit. Kayrros uses satellite data to estimate methane across whole fossil fuel basins, against which national inventories can be checked. Its own estimates for 13 large coal, oil, and gas basins in nine countries show emissions 7% higher in 2023 than in 2020, even though six of those countries had signed the Global Methane Pledge to cut methane. GHGSat's commercial satellites work at the level of single facilities: they quantified 8.3 Mt of methane a year from 3 114 energy facilities in 2023. Carbon Mapper's Tanager-1 satellite does the same and publishes its data openly: in its first year it published 5

392 methane plumes on an open data portal used from 178 countries, so a leak can be traced to the site responsible.

Table 4.4: Satellite methane monitoring cases

Stage	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Basin estimates	Kayrros, Methane Watch satellite monitoring of oil and gas basins, global[72] case-313	13 large fossil fuel basins in nine producing countries	Methane emissions across 13 large fossil fuel basins up 7%, 2023 against 2020 (company analysis; detection method peer-reviewed) *Measured*	Tier 1	13.0
Facility detection, commercial satellites	GHGSat[73] case-187	Commercial constellation of 14 satellites launched since 2016, measuring methane at individual facilities	8.3 Mt of methane a year quantified from 3 114 energy facilities (2023) *Measured*	Tier 1	12.0
Facility detection, published openly	Carbon Mapper, Tanager-1 hyperspectral satellite, global[74] case-312	Global; one satellite launched in August 2024; 3 563 distinct emission sources in its first year, 2 800 of them methane; open data portal used from 178 countries	5 392 methane plumes published in the first year of operations (2025) *Measured*	Tier 3	14.0

[72] Irakulis-Loitxate et al., *Satellites Detect Abatable Super-Emissions in One of the World's Largest Methane Hotspot Regions*, *Environmental Science & Technology* 56 (2022), https://pmc.ncbi.nlm.nih.gov/articles/PMC9940854/; *Single-Blind Test of Nine Methane-Sensing Satellite Systems from Three Continents* (EGUsphere/Atmospheric Measurement Techniques, 2023), https://egusphere.copernicus.org/preprints/2023/egusphere-2023-1541/; *The Global Methane Pledge, Three Years On: Partial Progress Report* (Kayrros, 2024), https://www.kayrros.com/blog/the-global-methane-pledge-three-years-on-partial-progress-report/.

[73] *Global Energy Sector Methane Emissions Estimated by Using Facility-Level Satellite Observations* (Science (AAAS), 2025), https://www.science.org/doi/10.1126/science.adv3183.

[74] *Tanager-1: One Year in Space* (Carbon Mapper, 2025), https://carbonmapper.org/articles/tanager-1-one-year-in-space.

Table 4.4: Satellite methane monitoring cases (continued)

Stage	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Alert and confirmed response	UNEP International Methane Emissions Observatory (IMEO), Methane Alert and Response System (MARS), global[75] case-352	Global; launched at COP27 in November 2022; turns detections from more than 30 satellite instruments into notifications to governments	More than 3 500 alerts issued in 33 countries since launch (to 2025); response rate up from 1% (2024) to about 12% (2025); 19 further mitigation cases confirmed in the year to UNEP's 2025 report, together emitting 52 tonnes of methane an hour; 41 mitigation cases in total by April 2026 *Measured*	Tier 2	13.0

Grid management and demand response

Digital tools let existing grids carry more clean power without new wires: they shift demand to the hours when electricity is cheap and clean, cut the electricity lost between power plant and customer, and raise what existing lines can carry when the wind blows. Most of the 14 cases in Table 4.5 work in one of these three ways, and two smaller groups cover public street lighting and digital grid pilots.

Demand flexibility already works at large scale. A virtual power plant links many small devices, such as electric vehicles, heat pumps, and home batteries, so that the grid can call on them together as if they were one power station. Kraken, the software platform built by Octopus Energy, runs one of the largest: in 2025 it controlled about 2 GW across more than 500 000 devices in the United Kingdom and Germany, shifting charging and heating to the hours when power is cheaper and cleaner. Kraken also manages grid-scale battery storage and other utility-scale assets, and estimates that optimizing when they supply power saved 27 $MtCO_2$ in 2024.

In the United States, National Grid's ConnectedSolutions programme enrols customers' thermostats and home batteries in Massachusetts and Rhode Island in a virtual power plant run on EnergyHub's platform. In summer 2024, according to EnergyHub, its client utilities' virtual power plants shifted more than 44 GWh out of peak periods, and the company estimates that they avoided more than 16 500 tons of CO_2.

Paying people to cut their use at peak times also works at national scale. In winter 2022/23, Great Britain's Demand Flexibility Service paid 1.6 million households and businesses to reduce their

[75] *MARS Case Studies* (UNEP, 2026), https://www.unep.org/topics/energy/methane/mars-case-studies; *New Report Tracks and Informs Global Data-Driven Methane Reductions* (UNEP, 2025), https://www.unep.org/en/news-and-stories/technical-highlight/new-report-tracks-and-informs-global-data-driven-methane; *Responding to Satellite Notifications from the Methane Alert and Response System* (IEA, 2026), https://www.iea.org/reports/responding-to-satellite-notifications-from-the-methane-alert-and-response-system.

electricity use during 22 events, and together they saved more than 3 300 MWh at peak times, a figure the electricity system operator confirmed after checking market data. Households with a smart meter signed up through their supplier or a technology provider. When the operator expected the grid to be tight, it alerted these providers, which asked their customers to cut use and paid them for the reduction.

Loss reduction shows larger measured results. The digital part works by measuring where electricity goes: automatic meters replace less accurate electromechanical meters and estimated bills, and supervisory control and data acquisition (SCADA) systems report electricity flows in real time, so that faults and repair needs are found quickly. Seven grid programmes in Table 4.5 report on losses, and in three of them the fall can be attributed, at least in part, to the programmes that installed the digital tools. In a fourth, the Kyrgyz Republic, an independent validation attributes only a small share of the fall to the project.

The fastest result comes from Abuja, Nigeria, where the Abuja Electricity Distribution Company (AEDC) and the technology provider Beacon Power Services mapped 41 465 customers and the network and introduced tools that detect outages in real time. According to the French Development Agency (AFD), which supported the project, losses on AEDC's grid fell from 44% to 26% within three months. In Armenia, losses fell from 9.7% to 7.0% as 387 873 automatic meters were installed, and Saudi Electricity Company, with smart meters at all its customers and distribution automation raised from 4.0% to 36.4% of its network, cut distribution losses from 10.2% to 8.0% between 2020 and 2024. Both are whole-programme results, because the meters came with new lines and transformers or other measures.

The other four also show what is possible, but none of the seven isolates and measures the digital share. Vietnam Electricity replaced mechanical meters with 24.7 million electronic meters that report automatically, and national power losses fell from 12.23% in 2003 to 6.25% in 2022, a national trend over two decades. In the Kyrgyz Republic, distribution losses fell from 26% in 2009 to 12.7% in 2018, but the independent validation by the Asian Development Bank (ADB) attributes only 1.2 of those 13.3 percentage points to the project, which combined SCADA and metering with the rehabilitation of 118 substations. In Guinea-Bissau, a World Bank-financed project that installed 21 032 prepayment meters alongside 80 km of new or rehabilitated lines reports losses falling from 47% to 11%. Serbia's Elektrodistribucija Srbije (EDS) has installed 650 000 smart meters in a programme projected to save 68 000 tCO_2 a year.

Dynamic line rating adjusts the carrying capacity of existing power lines in real time to the weather, measured by connected weather stations, so that less wind power has to be curtailed. Two net assessments, which deduct the footprint of the ICT system, find net savings: Telefónica and Red Eléctrica's pilot in Spain saves a modelled net 50 094 tCO_2e a year, and the assessment by the French Agency for Ecological Transition (ADEME) of the solution of RTE, the French transmission system operator, a modelled net 43 912 tCO_2e over 2020 to 2035, although it adds a net burden on mineral and metal resources.

Street lighting shows that rebound can reverse a city-scale saving: in ADEME's representative town, connected lighting with remote dimming saves a modelled net 65 tCO_2e over 2023 to 2035 but becomes a modelled net burden of 28.8 tCO_2e once higher-order effects are included, such as reinvesting the savings and new telecom networks built on the lighting network. A simpler dimming design without network connectivity saves more and keeps a net saving with rebound.

Digital grid pilots are still small. In the first phase of the 3DEN initiative (Digital Demand-Driven Electricity Networks), run by UNEP and the IEA with Italian government support, four pilots each tested a different tool: digital districts offering flexible energy services in Brazil, demand response to keep the grid reliable in Colombia, a digital twin for operating a distribution grid in India, and digital monitoring of industrial energy use at a mineral water company in Morocco. Together they avoided nearly 3 800 tCO_2 a year, improved electricity reliability for more than 320 000 people, and deferred almost USD 60 million of grid investment. A second phase, begun in 2025, approved 14 projects from 93 applications.

Table 4.5: Grid and demand-side cases

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Demand flexibility	Octopus Energy and Kraken Technologies, Kraken AI platform, United Kingdom and Germany[76] case-487	United Kingdom and Germany; residential virtual power plant of EVs, heat pumps, solar panels, home batteries, and smart thermostats	2 GW of residential virtual power plant capacity across more than 500 000 devices (2025); an estimated 27 $MtCO_2$ avoided from dispatch of utility-scale assets, company-reported (2024) *Measured and modelled*	Tier 3	13.0
	National Grid and EnergyHub, ConnectedSolutions virtual power plants, United States[77] case-328	Massachusetts and Rhode Island; customer-owned thermostats and home batteries (159 000 devices enrolled across a north-eastern virtual power plant of National Grid and three other utilities, 2023)	More than 16 500 tons of CO_2 avoided across EnergyHub client virtual power plants (2024 summer season, company estimate; the source does not specify metric or short tons) *Modelled*	Tier 3	11.0

[76] *Kraken's Residential Virtual Power Plant (VPP) Reaches 2 GW Power Milestone* (Renewable Energy Magazine, 2025), https://www.renewableenergymagazine.com/miscellaneous/krakena-s-residential-virtual-power-plant-vpp-20250716; *Kraken's AI Grid Revolution: Powering a Clean Energy Future* (AI Magazine, 2025), https://aimagazine.com/articles/q-a-with-krakens-infraflex-gm-on-ai-ml-and-energy-demand.

[77] *EnergyHub Grows Client VPPs across North America, Breaking Resource Size and Deployment Records during the Hottest Summer Ever Recorded* (EnergyHub via PR Newswire, 2023), https://www.prnewswire.com/news-releases/energyhub-grows-client-vpps-across-north-america-breaking-resource-size-and-deployment-records-during-the-hottest-summer-ever-recorded-301975906.html; *Peak Performance: EnergyHub Clients Achieve Record-Breaking Flexibility with VPPs in 2024* (EnergyHub, 2024), https://www.energyhub.com/news/energyhub-2024-rewind.

Table 4.5: Grid and demand-side cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	National Energy System Operator, Demand Flexibility Service, Great Britain[78] case-011	1.6 million households and businesses; 22 events (winter 2022/23)	More than 3 300 MWh saved at peak times across events, confirmed from market data *Measured*	Tier 2	11.0
Grid loss reduction	Abuja Electricity Distribution Company (AEDC) and Beacon Power Services, AI grid mapping and outage detection, Nigeria[79] case-160	AEDC network, Abuja; 41 465 customers, 24 764 buildings, and close to 12 000 infrastructure elements mapped (2022)	Distribution losses down from 44% to 26% within 3 months; an estimated 31 000 tCO_2 avoided (company figure reported by investor Proparco, no published method) *Measured and modelled*	Tier 2	9.0
	Vietnam Electricity (EVN), electronic meters with automatic data collection[80] case-523	National grid of Viet Nam; electronic meters covering 81% of all meters (2022)	National power loss down from 12.23% (2003) to 6.25% (2022) alongside 24.7 million electronic meters *Measured*	Tier 2	10.0

78 *Demand Flexibility Service Delivers Electricity to Power 10 Million Households* (NESO), https://www.neso.energy/news/demand-flexibility-service-delivers-electricity-power-10-million-households; *Q&A: How Great Britain's 'Demand Flexibility Service' Is Cutting Costs and CO_2 Emissions* (Carbon Brief, 2023), https://www.carbonbrief.org/qa-how-great-britains-demand-flexibility-service-is-cutting-costs-and-co2-emissions/.

79 *Beacon Power Services: Harnessing Data to Drive Africa's Energy Transition* (Proparco, 2026), https://www.proparco.fr/en/news/beacon-power-services-harnessing-data-drive-africas-energy-transition; *Digital Energy Challenge: Innovative Projects Paving the Way for Africa's Energy Transition* (AFD, 2024), https://www.afd.fr/en/actualites/digital-energy-challenge-africa-energy-transition.

80 *What's Outstanding About AMI Smart Electricity Meter?* (Vietnam Electricity (EVN), 2023), https://en.evn.com.vn/d6/news/Whats-outstanding-about-AMI-smart-electricity-meter-66-163-3429.aspx; *Challenges in Reducing Power Loss on the Vietnamese Grid* (Vietnam Electricity (EVN), 2023), https://en.evn.com.vn/d6/news/Challenges-in-reducing-power-loss-on-the-Vietnamese-grid-66-163-3635.aspx.

Table 4.5: Grid and demand-side cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	Asian Development Bank and Electric Networks of Armenia, smart metering and network rehabilitation[81] case-388	387 873 automatic meters installed nationwide (2016 to 2020)	Distribution losses down from 9.7% (2016) to 7.0% (2020); 64 948 tCO_2e a year *Measured*	Tier 1	10.0
	National Electric Grid of Kyrgyzstan (NEGK) and ADB, SCADA and automated metering[82] case-461	Northern transmission grid of the Kyrgyz Republic; 190 substations on automated metering and 8 on SCADA	System-wide distribution losses down from 26% to 12.7%; ADB attributes 1.2 percentage points to the project and re-estimates 25 400 tCO_2e a year *Measured and modelled*	Tier 1	10.0
	Electricity and Water Company of Guinea-Bissau (EAGB) and World Bank, prepayment metering and line upgrades[83] case-520	National utility; 21 032 prepayment meters installed by the project and 80 km of distribution network built or rehabilitated	Transmission and distribution losses down from 47% (2016) to 11% (2024), a dashboard figure the completion report calls not adequate *Measured*	Tier 2	10.0

81 *Performance Evaluation Report: Armenia, Electric Networks of Armenia Rehabilitation (Loan 3540)* (Asian Development Bank, Independent Evaluation Department, 2023), https://www.adb.org/sites/default/files/Evaluation%20Document/821596/files/pper-arm_ena-redacted.pdf.

82 *Power Sector Improvement Project: Completion Report* (Asian Development Bank, 2020), https://www.adb.org/sites/default/files/project-documents/43456/43456-023-en.pdf; *Validation Report: Kyrgyz Republic, Power Sector Improvement Project, PVR-729* (Asian Development Bank Independent Evaluation Department, 2020), https://www.adb.org/sites/default/files/evaluation-document/659021/files/pvr-2671a.pdf.

83 *Implementation Completion Report Review, Guinea-Bissau Emergency Water and Electricity Services Upgrading Project (P148797)* (World Bank Independent Evaluation Group, 2025), https://documents1.worldbank.org/curated/en/099062425114039741/pdf/P148797-a11faecf-6d3e-4809-ac6c-f070d9271000.pdf.

Table 4.5: Grid and demand-side cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	Saudi Electricity Company, smart meters and distribution automation[84] case-524	National distribution network; smart meters at all customers; distribution automation from 4.0% (2020) to 36.4% (2024)	Distribution losses down from 10.2% (2020) to 8.0% (2024) *Measured*	Tier 3	9.0
	Elektrodistribucija Srbije (EDS) and EBRD, national smart metering, Serbia[85] case-525	3.7 million consumers; grid losses of 11% (2019); first phase financed by an EBRD loan	650 000 smart meters installed (2025); 68 000 tCO_2 a year projected for the full programme *Measured and modelled*	Tier 2	10.0
Grid capacity	Telefónica and Red Eléctrica, dynamic line rating for power transmission, Spain[86] case-405	533 km of high-voltage lines on 13 circuits, mainland Spain (pilot)	Modelled net saving of 50 094 tCO_2e a year on a transmission pilot, after deducting the ICT lifecycle footprint (EGDC) *Modelled*	Tier 2	11.0
	RTE, dynamic line rating for renewable grid integration, assessed by ADEME IT4Green, France[87] case-567	French high-voltage transmission lines; assessment period 2020 to 2035	Modelled net saving of 43 912 tCO_2e over 2020 to 2035 *Modelled*	Tier 1	9.0

[84] *Saudi Electricity Company FY2024 Results Presentation* (Saudi Electricity Company, 2025), https://www.se.com.sa/-/media/sec/Investors/Financial-Results/sec-fy-2024-results-presentation-english.ashx.

[85] *EDS Smart Metering Expansion (Project 51299)* (European Bank for Reconstruction and Development, 2024), https://www.ebrd.com/home/work-with-us/projects/psd/51299.html; *Croatia Installs One Million Smart Meters, Serbia Reaches 650 000* (Balkan Green Energy News, 2025), https://balkangreenenergynews.com/croatia-installs-one-million-smart-meters-serbia-reaches-650000/; *Serbia's DSO Elektrodistribucija Srbije Announces Smart Metering Rollout* (Balkan Green Energy News, 2021), https://balkangreenenergynews.com/serbias-dso-elektrodistribucija-srbije-announces-smart-metering-rollout/.

[86] European Green Digital Coalition et al., *EGDC Case Study: Telefónica Dynamic Line Rating Platform: Case Study Methodology* (Brussels: European Green Digital Coalition, 2024), https://www.greendigitalcoalition.eu/assets/uploads/2024/04/EGDC-Case-Study-Meth.-Telefonica-DLR.pdf.

[87] *IT4Green: Environmental Quantification of the Dynamic Line Rating Use Case (ADEME, 2026)*, https://librairie.ademe.fr/index.php?controller=attachment&id_attachment=8015.

Table 4.5: Grid and demand-side cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Public street lighting	ADEME IT4Green, connected street lighting with remote dimming, France[88] case-566	Fictitious but nationally representative French town of about 50 000 inhabitants; assessment period 2023 to 2035	Modelled net saving of 65 tCO_2e before higher-order effects, reversing to a modelled net burden of 28.8 tCO_2e when they are included (cumulative, 2023 to 2035); a non-connected dimming design saves more (83 tCO_2e) and keeps a net saving with rebound (45 tCO_2e) *Modelled*	Tier 1	9.0
Digital grid pilots	UNEP and IEA, 3DEN digital demand-driven electricity network pilots, Brazil, Colombia, India, and Morocco[89] case-181	Four pilots in the first phase (2020 to 2024)	Nearly 3 800 tCO_2 avoided a year; electricity reliability improved for over 320 000 people *Measured*	Tier 2	10.0

Water networks

Water utilities apply the same logic to treated water and pumping energy: the six cases cut the water lost from networks or the energy used to pump and treat it (Table 4.6).

Water networks lose energy too, because water that leaks has already been treated and pumped. In Malaysia, Air Selangor's network of 1 600 hydrophone and pressure sensors had found 295 leaks and bursts by January 2021, and in Ghana, non-revenue water at Ghana Water Company Limited (GWCL) fell from 54% to 40% between 2018 and 2024 after it introduced 112 000 ultrasonic smart meters and pressure management. Neither source measures the energy saved: GWCL reports "considerable energy savings" without a figure, and non-revenue water also includes billing losses, which the meters address. Smarter pumping cuts the energy directly: Scottish Water reports energy use up to 60% lower at 200 wastewater pumping stations with new pumps and digital control, and GWiK Goleniów in Poland 43% lower pumping energy from demand-driven pressure control and new pumps.

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88 *IT4Green: Environmental Quantification of the Smart Public Lighting Use Case* (ADEME, 2026), https://librairie.ademe.fr/index.php?controller=attachment&id_attachment=8013.

89 *3DEN Initiative: Digital Demand-Driven Electricity Networks* (UNEP / IEA, 2026), https://3den.energy-base.org/.

Net assessments of water cases show that the ICT footprint is small against the saving. The AI tool of the Saudi operator SAWACO for its desalination plant in Jeddah, which reads data from the plant's existing control system and recommends settings such as pump pressure and brine flow to operators, saves a net 157.6 tCO_2e a year, while training its AI system emitted 0.005 tCO_2e. ADEME's model of acoustic leak detection finds a net climate saving of 27.9 tCO_2e and 1.02 million m^3 of water no longer lost, although it adds a net burden on mineral and metal resources.

Table 4.6: Water network cases

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Leak detection and loss reduction	Air Selangor and Xylem, IoT leak detection in water networks, Malaysia[90] case-113	Major Malaysian water utility serving 8.4 million residents; 1 600 hydrophone and pressure sensors (2021)	295 leaks and bursts detected (to January 2021) *Measured*	Tier 3	12.0
	ADEME IT4Green, IoT acoustic leak detection in water networks, France[91] case-572	Representative French city of 50 000 inhabitants; 13-year analysis period	Modelled net climate saving of 27.9 tCO_2e and 1.02 million m^3 of water no longer lost *Modelled*	Tier 1	9.0
	Ghana Water Company Limited (GWCL) and Kamstrup, ultrasonic smart water meters[92] case-534	112 000 of more than 950 000 connections fitted with smart meters by 2024, with pressure management	Non-revenue water down from 54% (2018) to 40% (2024) *Measured*	Tier 3	10.0
Pumping and treatment energy	Scottish Water and Xylem, intelligent wastewater pumping, United Kingdom[93] case-441	200 wastewater pumping stations	Energy use up to 60% lower; 160 tCO_2e a year avoided through fewer maintenance callouts (2023) *Measured*	Tier 3	8.0

[90] *Xylem's Analytics Solution in Malaysia Detects Leaks, Bursts and Pressure Surges in Real Time* (Xylem, 2022), https://www.xylem.com/en-us/making-waves/water-utilities-news/xylems-analytics-solutions-in-malaysia/.

[91] *IT4Green: Environmental Quantification of the Water Leak Detection Use Case (ADEME, 2026)*, https://librairie.ademe.fr/index.php?controller=attachment&id_attachment=9277.

[92] *Reducing Water Loss through Smart Metering in Ghana* (Smart Water Networks Forum (SWAN), 2024), https://swan-forum.com/case-studies/reducing-water-loss-through-smart-metering-in-ghana/.

[93] *Scottish Water Cuts Energy by 60% with Flygt Concertor Intelligent Pump System* (Xylem, 2023), https://www.xylem.com/en-029/resources/case-studies/scottish-water-cuts-energy-by-60-with-flygt-concertor-intelligent-pump-system/.

Table 4.6: Water network cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	GWiK Goleniów and Grundfos, demand-driven pressure control, Poland[94] case-444	Largest pumping station of a utility serving over 30 000 people; new high-efficiency pumps	Pumping energy 43% lower (194 000 kWh a year); non-revenue water down 3.2 percentage points (2022) *Measured*	Tier 3	8.0
	SAWACO, AI setpoint optimization for seawater desalination, Saudi Arabia[95] case-478	One seawater desalination unit, Jeddah	Net saving of 157.6 tCO_2e a year from 286 482 kWh a year of electricity savings (EGDC, 2024) *Measured*	Tier 2	8.0

Clean energy access and finance

Digital payment, identity, and data systems make distributed clean energy financeable for households and small businesses that lenders and subsidy programmes could not otherwise reach. The five cases use different delivery models (pay-as-you-go credit, a results-based subsidy, a green bond, carbon finance, and an app for waste-to-energy collection), and in four of them the digital layer lowers the cost of reaching, collecting from, or verifying many small customers (Table 4.7).

Each delivery model reaches customers that conventional finance would miss, and the digital layer does a different job in each. M-KOPA, in Kenya and four other African countries, combines connectivity in its products with mobile money: customers take a solar home system home after a small deposit and pay in small daily instalments, and each payment builds a credit history that unlocks further products such as smartphones and digital loans. It has sold more than 1 million solar home systems. M-KOPA reports a modelled estimate of more than 2 million tCO_2 displaced since it began.

In Rwanda, the digital element is targeting. A results-based subsidy for poorer households uses an eligibility tool that checks buyers at the point of sale against the national ID database, which holds household welfare categories, and against records of households already connected. The subsidy is paid only once installation and after-sales service are verified, and the project had given 340 704 people new or improved electricity service by November 2021, up from 2 853 in March 2020.

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94 *How Optimal Pressure Management Led to Energy Savings of 43 Percent and Reduced Water Losses* (Grundfos, 2022), https://www.grundfos.com/about-us/cases/how_optimal_pressure_management_led_to_energy_savings_of_43_percent_and_reduced_water_losses.

95 European Green Digital Coalition and SAWACO, EGDC Case Study: SAWACO, the AI Digital Platform for SWRO (Brussels: European Green Digital Coalition, 2026), https://www.greendigitalcoalition.eu/assets/uploads/2026/04/SAWACO-Case-Study-Methodology-1.pdf.

Two other models use digital tools more narrowly. The International Finance Corporation (IFC) and SIMA solar green bond pools development, philanthropic, and corporate capital to lend to small and medium-size solar developers. It has financed 51 MW of rooftop and on-site solar, which replaced 2.21 million litres of diesel, and the fund estimates that its projects have avoided 45 000 tCO_2 so far and will avoid 4 million tCO_2 over the life of the assets. In Freetown, Sierra Leone, the city collects only about 30% of its waste, and waste accounts for 29% of the city's greenhouse gas emissions. There, the DortiBox app connects households with 346 waste collectors, and in the pilot the 11.85 tonnes of organic waste they kept out of landfill fed the pilot biodigester at the Aberdeen Women's Centre, which generated 12 205 kWh of electricity. No source reports the emissions this avoided.

BURN's Kenya cookstove project has the only verified emission reductions in the group: 52 405 tCO_2e under the Gold Standard for January to May 2025. Its digital tools support the crediting: every stove carries a unique serial number, which prevents double counting, SIM-enabled stoves add traceability, and its metered electric stoves earn credits under the Gold Standard's Metered Methodology from the electricity use they record. For its charcoal and wood stoves, use is still verified through household surveys.

Table 4.7: Clean energy access and finance cases

Delivery model	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Pay-as-you-go credit	M-KOPA, pay-as-you-go solar via mobile money, Kenya and other sub-Saharan African countries[96] case-367	Kenya, Uganda, Nigeria, Ghana, and South Africa; households without a formal credit history	More than 1 000 000 solar home systems sold (2021); more than 2 000 000 tCO_2 displaced since inception (2024, company-reported, not independently verified) *Measured and modelled*	Tier 3	11.0

[96] *M-KOPA Annual Impact Report 2021* (M-KOPA, 2022), https://www.m-kopa.com/newsroom/m-kopa-releases-annual-impact-report; *M-KOPA Impact Report 2024: Pathways to Progress* (M-KOPA, 2024), https://cdn.prod.website-files.com/66dc00a653080e6802168f64/66f4696da9ef16dfd2e9457e_2024%20M-KOPA%20Impact%20Report_Pathways_To_Progress_oniline.pdf.

Table 4.7: Clean energy access and finance cases (continued)

Delivery model	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Results-based subsidy	Rwanda Renewable Energy Fund (REF) and Ministry of Infrastructure, results-based off-grid solar subsidies with digital eligibility checks linked to the national ID database, Rwanda[97] case-548	Rwanda, households in the lowest income categories; subsidy window of USD 15 million launched in October 2020	340 704 people with new or improved electricity service by November 2021, up from 2 853 in March 2020 *Measured*	Tier 2	10.0
Blended green bond	IFC and SIMA Funds, Solar Green Bond for productive-use solar, sub-Saharan Africa[98] case-090	Africa; rooftop and on-site solar projects of small and medium-size local developers, some offering energy monitoring and controls	USD 131 million first close; 51 MW installed (2024); projected 4 000 000 tCO_2 avoided over asset lifetime *Measured and modelled*	Tier 3	10.0
Carbon finance with digital tracking	BURN Manufacturing, clean cookstoves with serial tracking and an electronic stove database, Kenya[99] case-385	Kenya Gold Standard project GS 5642; 4 million stoves distributed across Africa (2023)	52 405 tCO_2e of emission reductions verified for 31 January to 5 May 2025 (Gold Standard) *Measured*	Tier 1	11.0

[97] *Rwanda: Engaging the Private Sector in Off-Grid Solar Electrification* (Climate Investment Funds, 2022), https://www.cif.org/news/rwanda-engaging-private-sector-grid-solar-electrification; *Rwanda Renewable Energy Fund Project: Engaging the Private Sector in Off-Grid Solar Electrification (Climate Delivery Initiative Series: Case Study)* (Climate Investment Funds, 2022), https://www.cif.org/sites/cif_enc/files/knowledge-documents/cdi_rwanda.pdf.

[98] International Finance Corporation, IFC and SIMA Launch $150 Million Solar Green Bond for African Solar Developers alongside Finland and GEAPP (IFC, 2024), https://www.ifc.org/en/pressroom/2024/ifc-and-sima-launch-150-million-solar-green-bond-for-african-solar-developers-alongside-finland-and-geapp; SIMA's 2024 Impact Report (Social Investment Managers and Advisors, 2025), https://simafunds.com/wp-content/uploads/2025/09/Impact-Report-2024.pdf.

[99] *Gold Standard verification report, Burn Stoves Project in Kenya (GS 5642), monitoring period 31 January to 5 May 2025* (VKU Certification, 2025), Gold Standard assurance platform, https://assurance-platform.goldstandard.org/project-documents/GS5642; *Africa Go Green (AGG) Funds $10m Joint Project with BURN for Efficient Cookstove Distribution in Mozambique, Nigeria and DRC* (Cygnum Capital, 2023), https://www.cygnumcapital.com/news/africa-go-green-agg-funds-10m-joint-project-with-burn-for-efficient-cookstove-distribution-in-mozambique-nigeria-and-drc.

Table 4.7: Clean energy access and finance cases (continued)

Delivery model	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Waste-to-energy collection	Freetown Waste Transformers, DortiBox app for organic waste collection and biogas power[100] case-578	Freetown; 346 active waste collectors; 46 552 residents benefited (collection, income, or electricity)	11.85 tonnes of organic waste diverted and 12 205 kWh of electricity generated (pilot, 2024) *Measured*	Tier 3	7.0

4.3 Mobility and transport

The 20 mobility and transport cases fall into three groups: routing and fleet optimization, trip substitution, and electric mobility and platforms. The dominant pathway is Optimizing, in 16 of the 20 cases: fleet routing, port logistics, rail signalling, and air traffic management reduce the energy intensity of travel that still occurs. A Dematerializing cluster of five cases (remote work and telehealth) offers cleaner counterfactuals in principle, although most of their figures are modelled.

Main finding: Digital services that replace a trip give transport its clearest counterfactual, because the trip not taken can be counted, although most of their figures are still modelled. At Sanitas in Spain, 90% of sampled digital consultations were not followed by an in-person visit to the same type of specialist within a week. Fleet and traffic management delivers measured savings in individual operations: AddSecure's system for truck fleets, PortXchange's coordination of ship port calls, and Nicosia's waste collection routes, planned from bin fill-level sensors. ADEME's net assessments show how fragile such savings can be: in its modelled tyre-as-a-service case, a 1% rise in freight transport wipes out the gain. Routing and mobility platforms such as Google Maps and BlaBlaCar work at far larger scale, with savings in the millions of tonnes, but these figures are modelled by the companies themselves. Platform savings like these need explicit rebound treatment before they can be credited in NDC accounting, because cheaper or easier travel can lead people to travel more or to switch from public transport.

Routing and fleet optimization

Routing and fleet optimization produces the largest transport figures in the stocktake, from a global software feature to individual truck, bus, and waste collection fleets, and the net assessments show measured savings at fleet level (Table 4.8).

The fleet cases assessed under the European Green Digital Coalition (EGDC) methodology show what routing and fleet software saves once the footprint of the ICT system is deducted. AddSecure's transport management system plans routes that cut the distance trucks drive

[100] *Digitising Waste Collection: Freetown Waste Transformers' DortiBox App in Sierra Leone* (GSMA Mobile for Development, 2024), https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-for-development/blog/digitising-waste-collection-freetown-waste-transformers-dortibox-app-in-sierra-leone/; *Scaling Urban Innovation: Lessons from the GSMA Accelerated Growth Round* (GSMA Mobile for Development, 2025), https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-for-development/blog/scaling-urban-innovation-lessons-from-the-gsma-accelerated-growth-round/.

without freight and flags wasteful driving such as excessive idling, and saved a net 635.78 tCO_2e a year across 356 trucks of two European fleet customers. The PREDRI system developed by the University of Valencia uses on-board monitoring of 85 buses in Santiago de Querétaro, Mexico, to optimize routes, encourage efficient driving, and replace parts only when needed, and saved a net 169 tCO_2e a year. At the Livorno container terminal, Ericsson's 5G logistics system registers goods in real time and optimizes forklift movements, but its modelled 111 tCO_2e a year is an enabled saving only, because the ICT footprint was not quantified.

The largest figures show how far routing can reach, although they are modelled or projected rather than measured. Google's 2.7 million tCO_2e from fuel-efficient routing in 2024 is a self-reported estimate, and the Single European Sky ATM Research (SESAR) programme's 1.4 million tCO_2 a year is a projection for 2030. Set against the measured fleet results, which run to hundreds of tonnes a year per operator, they mark the gap between what routing could deliver at scale and what has so far been measured.

At sea, just-in-time port calls coordinated through PortXchange saved an average of 12.6 tonnes of fuel and 39.56 tCO_2 per port call across more than 1 000 calls, and NAPA's voyage optimization cut modelled fuel use by up to 7.3% when a bulk carrier fleet's 2021 voyages were re-simulated. On land, Google's Green Light uses AI and Google Maps driving trends to recommend traffic signal timing changes to city engineers, and is live in 20 cities. On the railway, Network Rail estimates that replacing lineside signals with in-cab digital signalling on the southern East Coast Main Line will save around 39% of whole-life carbon over 60 years compared with conventional signalling, a modelled figure.

Municipal fleets save fuel in the same way. In Nicosia, fill-level sensors let waste collection trucks stop only at bins that need emptying, which cut idling emissions by 54% at its underground bins. Assessed net of the ICT system's own footprint, the saving is 1.92 tCO_2e a year across 42 bins, although on the 17 glass recycling bins the sensors' footprint slightly exceeds the saving.

Net assessment also shows when a fleet saving holds and when changes in demand outweigh it. In ADEME's tyre-as-a-service case, the service monitors tyre pressure, temperature, and wear and sends real-time alerts, so tyres are kept at the right pressure and serviced before problems build up, because under-inflated tyres raise rolling resistance and fuel use. Across the French freight fleet, this saves a modelled net 1.6 $MtCO_2e$ over 2024 to 2035. But better-maintained trucks are also cheaper to run, and lower operating costs encourage more transport. Because the saving is a small share of each truck's fuel use, a small rise in total driving is enough to cancel it: if freight-kilometres grow by 1%, the result becomes a net burden of 0.18 $MtCO_2e$.

Table 4.8: Routing and fleet optimization cases

Deployment level	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Software platform	Google, Maps fuel-efficient route suggestions, global[101] case-417	Global; fuel-efficient route suggestions in Google Maps since October 2021, globally available since January 2025, with no roadside or in-vehicle hardware	Modelled 2 700 000 tCO_2e enabled in 2024 (self-reported estimate) *Modelled*	Tier 3	12.0
	Google Research, Green Light AI traffic signal timing, global[102] case-420	Live in 20 cities (2025); timing recommendations to city traffic engineers	3 000 tCO_2e attributed in 2024 (company estimate) *Modelled*	Tier 3	8.0
Transport infrastructure	SESAR Deployment Manager, digital air traffic management, Europe[103] case-475	European airspace; airport collaborative decision-making at 17 airports; Common Project One deployment across Europe to 2030	102 700 tCO_2 a year from airport collaborative decision-making; projected 1 400 000 tCO_2 a year by 2030 *Measured and modelled*	Tier 2	12.0
	Network Rail, East Coast Digital Programme in-cab signalling, United Kingdom[104] case-324	Southern East Coast Main Line, London King's Cross to the Stoke Tunnels near Grantham; assessed over 60 years	Estimated 39% whole-life carbon saving against conventional signalling renewal *Modelled*	Tier 3	10.0

[101] *Google 2025 Environmental Report* (Google, 2025), https://www.gstatic.com/gumdrop/sustainability/google-2025-environmental-report.pdf.

[102] *Green Light* (Google Research, n.d.), https://sites.research.google/gr/greenlight/; Google, *Google 2025 Environmental Report*.

[103] EUROCONTROL, *Think Paper #10: The Perfect Green Flight* (2021), https://www.eurocontrol.int/sites/default/files/2021-04/eurocontrol-think-paper-10-perfect-green-flight.pdf; European Aviation Environmental Report (SESAR Deployment Manager, 2022), https://www.sesardeploymentmanager.eu/news/european-aviation-environmental-report.

[104] *East Coast Digital Programme: Network Rail* (Network Rail, 2024), https://www.networkrail.co.uk/our-work/our-routes/east-coast/east-coast-digital-programme/; *East Coast Digital Programme Hits Major Milestone as Section Commissioned* (Network Rail Media Centre, 2024), https://www.networkrailmediacentre.co.uk/news/east-coast-digital-programme-hits-major-milestone-as-section-commissioned.

Table 4.8: Routing and fleet optimization cases (continued)

Deploy-ment level	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	PortXchange, Synchronizer just-in-time port call coordination, Netherlands[105] case-369	More than 1 000 port calls in Rotterdam, Felixstowe, and Algeciras	12.6 tonnes of fuel and 39.56 tCO_2 saved per port call on average (2022) *Measured*	Tier 2	11.0
Commercial fleets	AddSecure, Logic transport management system for truck fleets, Germany[106] case-403	356 diesel trucks of two EU fleet customers; 15.7 million km driven over 20 months	Net saving of 635.78 tCO_2e a year (EGDC, 2024) *Measured*	Tier 2	10.0
	University of Valencia (PREDRI), AI fleet management and predictive maintenance for buses, Mexico[107] case-404	85 diesel buses of one operator, Santiago de Querétaro (2021 to 2023)	Net saving of 169 tCO_2e a year (EGDC, 2023) *Measured*	Tier 2	7.0
	Ericsson, 5G smart port logistics management, Italy[108] case-402	One container terminal (Lorenzini terminal), Port of Livorno (2017 to 2021)	Enabled saving of 111 tCO_2e a year from forklift operations; ICT footprint not quantified (EGDC, 2021) *Modelled*	Tier 2	9.0
	NAPA and ClassNK, voyage optimization for Marubeni's bulk carriers, Finland and Japan[109] case-467	Re-simulation of all 2021 voyages of a group of Marubeni bulk carriers	Modelled reduction of up to 7.3% in fuel use and CO_2 (2023 study) *Modelled*	Tier 3	10.0

[105] *First-of-Its-Kind Study Finds JIT Dramatically Cuts Emissions* (Hellenic Shipping News, 2022), https://www.hellenicshippingnews.com/first-of-its-kind-study-finds-jit-dramatically-cuts-emissions/.

[106] European Green Digital Coalition et al., *EGDC Case Study: AddSecure Logic TMS: Case Study Methodology* (Brussels: European Green Digital Coalition, 2024), https://www.greendigitalcoalition.eu/assets/uploads/2024/04/EGDC-Case-Study-Method.-AddSecure-Logic-TMS.pdf.

[107] European Green Digital Coalition et al., *EGDC Case Study: PREDRI: Failure Prevention and Driving Optimisation: Case Study Methodology* (Brussels: European Green Digital Coalition, 2024), https://www.greendigitalcoalition.eu/assets/uploads/2024/04/EGDC-Case-Study-Method.-PREDRI.pdf.

[108] European Green Digital Coalition et al., *EGDC Case Study: Ericsson 5G: Case Study Methodology* (Brussels: European Green Digital Coalition, 2024), https://www.greendigitalcoalition.eu/assets/uploads/2024/04/EGDC-Case-Study-Meth.-Ericsson-5G.pdf.

[109] Joint NAPA-ClassNK Research with Marubeni Finds That Voyage Optimization Can Reduce Emissions by 7.3% (NAPA, 2023), https://www.napa.fi/news/impact-of-weather-routing-on-cii-rating-case-marubeni-fleet/.

Table 4.8: Routing and fleet optimization cases (continued)

Deploy-ment level	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	ADEME IT4Green, IoT tyre monitoring and tyre-as-a-service, France[110] case-568	French road freight vehi-cles; modelled national deploy-ment, 2024 to 2035	Modelled net saving of 1.6 $MtCO_2e$ before rebound, reversed to a net burden of 0.18 $MtCO_2e$ with a 1% increase in freight-km (2024 to 2035) *Modelled*	Tier 1	9.0
Municipal fleets	Nokia and Municipality of Nicosia, IoT sensor smart waste collection, Cyprus[111] case-454	Municipality of Nicosia, Cyprus; fill-level sensors on 42 bins (25 underground and 17 glass recycling bins)	Net saving of 1.92 tCO_2e a year after deducting the ICT system footprint (EGDC, 2022); on the 17 glass recy-cling bins alone the ICT footprint slightly exceeds the saving *Measured*	Tier 2	9.0

Trip substitution

Replacing trips with digital services offers the clearest counterfactual in transport, the trip not taken, although most of the figures are modelled. The five cases cover two services that replace a trip: remote work and telehealth (Table 4.9).

In peer-reviewed national studies, Cornell University and Microsoft found that fully remote workers have a 54% lower footprint than on-site workers, and UCLA Health Sciences and the University of Michigan estimated that telehealth in the United States avoided 21.4 to 47.6 million kg CO_2 a month. Both figures are modelled. Telehealth programmes also give the most direct evidence, because they count the consultations themselves: in northeast Brazil 86.6% of 4 642 teleconsultations replaced an in-person referral, and at Sanitas 90% of sampled digital consultations were not followed by an in-person visit to the same type of specialist within a week. ADEME's net assessment of teleworking in France shows the other side: heating or cooling homes during working hours offsets part of the commuting saving, leaving a modelled net 2 to 12 kg CO_2e per resident a year, 0.4% to 1.3% of the areas' annual emissions.

[110] Camps et al., *Direct and Indirect Environmental Quantification of Digital Impacts in Use Cases: Digitalisation of Nine Use Cases* (ADEME, 2026), https://librairie.ademe.fr/index.php?controller=attachment&id_attachment=9273.

[111] European Green Digital Coalition et al., *EGDC Case Study: Nokia Smart Waste Management: Case Study Methodology* (Brussels: European Green Digital Coalition, 2024), https://www.greendigitalcoalition.eu/assets/uploads/2024/04/EGDC-Case-Study-Meth-Nokia-Smart-Waste-Management.pdf.

Table 4.9: Trip substitution cases

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Remote work	Cornell University and Microsoft, carbon footprint study of remote work, United States[112] case-492	United States; survey data from Microsoft, the American Time Use Survey, the National Household Travel Survey, and the Residential Energy Consumption Survey	Modelled 54% lower footprint for fully remote workers than for on-site workers, and 11% to 29% lower for hybrid workers at home 2 to 4 days a week (peer-reviewed) *Modelled*	Tier 1	12.0
	ADEME IT4Green, digital teleworking net assessment, France[113] case-569	Three French functional urban areas (small, medium, and large); 2023 to 2035	Modelled net saving of 2 to 12 kg CO_2e per resident a year in the trend scenario, depending on urban area size *Modelled*	Tier 1	9.0
Telehealth	UCLA Health Sciences and University of Michigan, national telehealth emissions study, United States[114] case-493	United States; 1 481 530 telehealth visits a month from a database of 44.7 million insured adults, extrapolated to all insured adults (April to June 2023)	Modelled 21.4 to 47.6 million kg CO_2 a month avoided nationally (peer-reviewed) *Modelled*	Tier 1	11.0

[112] Yanqiu Tao et al., *Climate Mitigation Potentials of Teleworking Are Sensitive to Changes in Lifestyle and Workplace Rather Than ICT Usage*, Proceedings of the National Academy of Sciences 120, no. 39 (2023), https://doi.org/10.1073/pnas.2304099120.

[113] Clément Camps et al., *Quantification environnementale des effets directs et indirects du numérique pour des cas d'usage: Évolution du télétravail, Rapport étape 2 (Angers: ADEME*, 2025), https://librairie.ademe.fr/index.php?controller=attachment&id_attachment=8012.

[114] *Impact of Telemedicine Use on Outpatient-Related CO_2 Emissions: Estimate From a National Cohort* (American Journal of Managed Care, 2025), https://pmc.ncbi.nlm.nih.gov/articles/PMC13075377/.

Table 4.9: Trip substitution cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	Northeast Brazil primary care network, specialist tele-consultations[115] case-497	Northeast Brazil; 4 642 telecon-sultations with 4 106 patients across 13 specialties (June 2022 to Novem-ber 2023)	86.6% of telecon-sultations replaced in-person referrals; modelled 21.93 tCO_2e over 17 months (peer-re-viewed) *Measured and modelled*	Tier 1	8.0
	Sanitas, digital hospital appoint-ments and report downloads, Spain[116] case-442	640 122 digital appointments and 3.06 million report down-loads (2020)	Modelled 6 655 tCO_2 avoided net in 2020 (peer-re-viewed); 90% of sampled digital consultations not followed by an in-person visit to the same specialty within a week *Measured and modelled*	Tier 1	11.0

Electric mobility and platforms

Platform-based mobility can lower emissions, but only a net assessment shows whether the saving survives changes in demand. The four cases cover electric motorcycle fleets in Kenya, two carpooling platforms, and the urban climate effect of electrification. ADEME's net assessment of carpooling shows how far changes in demand can shrink a gross saving, while the Kenya figure is a company estimate (Table 4.10).

BlaBlaCar's platform matches drivers who have empty seats with passengers who share the cost of a long-distance trip. The company reports that its members filled more than 70 million empty seats in 2024 and avoided 2.5 $MtCO_2e$. The figure is modelled from the company's trip data, using what it describes as a lifecycle approach that includes side effects, but the method is not published in detail.

ADEME's assessment of short-distance carpooling platforms in France shows what remains of a platform's saving once two effects are deducted: trips by people who already carpooled informally and simply moved to the platform, and trips that replaced public transport, walking, or cycling rather than driving alone. What is left over 2022 to 2035 is a modelled net saving of 1 182 tCO_2e in Bordeaux, where the platform operates on its own, and 5 087 tCO_2e in Strasbourg, where the local mobility authority co-finances it, or about 84 and 363 tCO_2e a year.

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[115] Sabrina Dalbosco Gadenz et al., *Impact of Telemedicine on Reducing Travel-Related CO_2 Emissions in Chronic Disease Care: A Cross-Sectional Study in Northeast Brazil*, BMJ Open 15, no. 10 (2025), https://pmc.ncbi.nlm.nih.gov/articles/PMC12506095/.

[116] *Morcillo Serra et al., Impact on the Reduction of CO_2 Emissions Due to the Use of Telemedicine, Scientific Reports 12* (2022), https://pmc.ncbi.nlm.nih.gov/articles/PMC9307763/.

Strasbourg saves four times as much despite its smaller population, because the co-financing scheme brings far more trips. ADEME judges both gains marginal against France's targets for cutting transport emissions.

Motorcycle taxis play a large part in Kenya's public transport, and more than 2 million combustion-engine motorcycles are registered in the country. Roam builds electric motorcycles in Nairobi, runs charging and battery rental hubs, and since 2026 has connected its vehicles to its Roam Explorer platform. The platform tracks battery health, location, and use in real time, uses AI to predict maintenance, and works over 2G networks and short message service (SMS) where connectivity is weak. The company estimates that each motorcycle avoids about 3 tCO_2 a year, or about 12 000 tCO_2 a year across some 4 000 on the road. Bloomberg reported the figure, but it has not been independently verified, and the saving comes from electrification rather than from the platform itself.

Digital modelling can also show what electrification does beyond emissions. The Cooling Singapore project combined detailed inventories of the heat released by traffic with a 3D model of every building in the city and an urban climate model. A peer-reviewed study using it found that replacing all of Singapore's combustion vehicles with electric ones would lower near-surface air temperature by up to 0.6 °C, most strongly during the morning rush hour, because electric vehicles release less exhaust heat.

Table 4.10: Electric mobility and platform cases

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Electric fleet management	Roam (ROAM Electric), AI fleet management with solar charging hubs, Kenya[117] case-381	Nairobi, Kenya; Roam Hubs charging stations and the Roam Explorer fleet platform (launched 2026) over 2G, 3G, and 4G networks	About 12 000 tCO_2 a year across about 4 000 motorcycles, about 3 tCO_2 each (company estimate reported by Bloomberg, not independently verified) *Modelled*	Tier 3	10.0
Carpooling platforms	BlaBlaCar, long-distance carpooling platform, global[118] case-498	Global; 27 million active members (2023)	Modelled 2.5 $MtCO_2e$ avoided in 2024 (company-reported) *Modelled*	Tier 2	9.0

[117] Kenya Demonstrator (ENERGICA, n.d.), https://energica-h2020.eu/demonstration-sites/kenya-demonstrator/; Kenya E-Motorcycle Company Plugs Into Carbon-Offsets Trade (Bloomberg, 2025), https://www.bloomberg.com/news/articles/2025-11-19/kenya-e-motorcycle-company-plugs-into-carbon-offsets-trade.

[118] *2 Million Tonnes of CO_2 Saved: BlaBlaCar Publishes Its 2023 Sustainability Report* (BlaBlaCar, 2024), https://newsroom.blablacar.com/news/2-million-tonnes-of-co2-saved-blablacar-publishes-its-2023-sustainability-report; *2.5 Million Tonnes of CO_2 Avoided: BlaBlaCar Publishes Its 2024 Sustainability Report* (BlaBlaCar, 2025), https://newsroom.blablacar.com/news/sustainability-report-2024.

Table 4.10: Electric mobility and platform cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	ADEME IT4Green, digital short-distance carpooling platforms, France[119] case-571	France, two urban contexts (Bordeaux, platform only; Strasbourg, with public co-financing); 800 000 people carpool through digital platforms nationally (2023)	Modelled net saving of 1 182 tCO_2e without and 5 087 tCO_2e with public co-financing (cumulative, 2022 to 2035) *Modelled*	Tier 1	8.0
Urban climate modelling	Singapore-ETH Centre and partners, Cooling Singapore urban climate model, Singapore[120] case-559	City-wide model of traffic heat emissions and urban climate	Complete electrification of the vehicle fleet modelled to cut urban air temperature by up to 0.6 °C (peer-reviewed, 2022) *Modelled*	Tier 1	11.0

4.4 Industry and manufacturing

The 14 industry and manufacturing cases fall into two groups: industrial efficiency in factories and programmes, where sensors, AI, digital twins, energy management systems, or process control reduce energy and emissions intensity, and supply-chain transparency and circularity, where digital standards and platforms make product or corporate emissions visible. Optimizing appears in 12 of the 14 cases and Monitoring in 9, usually together: in most efficiency cases, digital tools measure energy use and then help optimize it.

Main finding: In industry, the best-evidenced energy savings come where digital tools support an existing energy management standard, audit programme, or regulatory target, such as ISO 50001. Egypt's industrial energy efficiency programme with the United Nations Industrial Development Organization (UNIDO) and the Global Environment Facility (GEF) saved 1 247 GWh a year across 70 companies, according to its independent terminal evaluation, and companies in the programme installed sub-meters, SCADA monitoring, and energy-tracking tools provided by UNIDO. In Morocco's ISO 50001 programme, participating companies cut their energy use by 9% on average, and several installed smart meters and real-time energy monitoring. These savings belong to the whole programme, not to the digital tools alone. Factory AI and digital twins report larger percentage cuts, such as 28% lower Scope 1 and 2 emissions at Siemens's Nanjing plant, although mostly at single sites and as company figures. Supply-chain carbon platforms are building the data that buyer-driven decarbonization depends

[119] *IT4Green: Environmental Quantification of the Carpooling Platform Use Case (ADEME, 2026)*, https://librairie.ademe.fr/index.php?controller=attachment&id_attachment=9276.

[120] Mussetti et al., *Do Electric Vehicles Mitigate Urban Heat? The Case of a Tropical City*, Frontiers in Environmental Science (2022), https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2022.810342/full.

on, although the resulting cuts in supplier emissions are not yet measured. No industry case has yet been assessed for net impact under the EGDC or ADEME IT4Green methods.

Industrial efficiency in factories and programmes

Digital tools cut industrial energy use in two ways: AI and process control inside individual plants, and metering and monitoring within national energy management programmes (Table 4.11).

Inside plants, AI and digital twins report large cuts. Siemens's Nanjing factory, which deployed digital twins across production and more than 50 AI applications, lowered its Scope 1 and 2 emissions by 28% against 2022, although its sources do not say which measures produced the cut. Holcim's Industry 4.0 applications, which have cut more than 400 000 tCO_2 across its cement sites (period not stated), include machine learning that predicts equipment failures and AI sensors that help kiln operators control burning and use more alternative fuels. Single-plant systems report smaller, specific savings. Metron's platform, which tracks more than 150 production variables on two glass furnaces in France, avoids 1 973 tCO_2 a year, and AspenTech reports that optimizing hydrogen flaring at CEPSA's La Rábida refinery in Spain saves about 1 400 tCO_2 a year. At Novelis's Uhrichsville plant in the United States, data analytics, scrap sorting, and scrap procurement together raise recycled content to 97% in its 3105 alloy and bring emissions to 1.1 tCO_2e per tonne of aluminium, against an industry average of 5.8. Most of these figures are company-reported, and Wuhan's 35 000 tCO_2 a year is a calculation in a national technology guide.

National programmes work across many companies at once. In Bangladesh, more than 450 textile and garment factories in the Partnership for Cleaner Textile (PaCT) of IFC cut 723 617 tCO_2e a year, and Egypt's industrial energy efficiency programme with UNIDO and GEF, covering 70 companies in 10 industrial sectors, saved 1 247 GWh and 358 000 tCO_2 a year. In these programmes, metering and monitoring support the energy management systems. PaCT factories installed water, gas, steam, and electricity meters on the partnership's advice. In Egypt, companies installed sub-meters and SCADA monitoring and tracked their energy performance with tools provided by UNIDO. In Morocco's ISO 50001 programme, companies installed smart meters, real-time energy supervision, and remote management of energy use. The savings belong to each programme as a whole, not to the digital tools alone.

Table 4.11: Industrial efficiency cases

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
AI and digital process control in plants	Siemens Numerical Control, AI lighthouse factory with digital twin, Nanjing, China[121] case-129	One 73 000 m^2 high-mix manufacturing plant, Nanjing; more than 50 AI use cases	28% lower Scope 1 and 2 emissions against a 2022 baseline (2024, company-reported) *Measured*	Tier 3	15.0

[121] *Siemens' AI-Powered Nanjing Facility Named World Economic Forum Global Lighthouse Factory* (Siemens AG, 2026), https://press.siemens.com/global/en/pressrelease/siemens-ai-powered-nanjing-facility-named-world-economic-forum-global-lighthouse.

Table 4.11: Industrial efficiency cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	Holcim, Plants of Tomorrow (Industry 4.0 applications in cement plants), global[122] case-453	140 cement sites worldwide; 1 600 Industry 4.0 applications (2023)	More than 400 000 tCO_2 reduced across the programme's sites (period not stated; company-reported, 2023) *Measured*	Tier 3	14.0
	Metron, EMOS furnace energy optimization, France[123] case-532	Two glass furnaces at one pharmaceutical hollow glass plant, France; more than 150 variables influencing production, about 1 000 data points per second per furnace	1 973 tCO_2 avoided a year (company-reported) *Measured*	Tier 3	11.0
	CEPSA, La Rábida refinery hydrogen network optimization with Aspen GDOT, Spain[124] case-410	One refinery, Huelva, Spain; hydrogen network optimized in two phases (2011 and 2018)	1 400 tCO_2 a year; a further 2 800 tCO_2 a year estimated if hydrogen supply were not limited *Measured and modelled*	Tier 3	9.0
	Novelis, digital scrap analytics in aluminium recycling, Uhrichsville, United States[125] case-464	One rolling and recycling plant; World Economic Forum Global Lighthouse Network	1.1 tCO_2e per tonne of aluminium against an industry average of 5.8, with 97% recycled content in its 3105 alloy (2024) *Measured*	Tier 2	14.0

[122] *Holcim Launches World's First Cement Plant Digital Twin* (Holcim Ltd, 2023), https://www.holcim.com/media/company-news/first-cement-plant-digital-twin.

[123] *Energy Performance Leads to the Optimization of Equipment and Industrial Production* (Metron (METRON SAS), 2020), https://www.metron.energy/blog/use-case-improvement-energy-performance/.

[124] *CEPSA Minimizes Hydrogen Losses and Reduces CO_2 Emissions by Optimizing Refinery Hydrogen Network* (AspenTech, 2022), https://www.aspentech.com/en/resources/case-studies/cepsa-minimizes-hydrogen-losses-reduces-co2-emissions-by-optimizing-refinery-hydrogen-network; Make the Big Pivot (Control Global, 2023), https://www.controlglobal.com/manage/sustainability/article/33000139/make-the-big-pivot.

[125] *Novelis Recognized by World Economic Forum as a Leader in Sustainable Manufacturing* (Novelis Inc., 2025), https://investors.novelis.com/news-events/press-releases/detail/1379/novelis-recognized-by-world-economic-forum-as-a-leader-in-sustainable-manufacturing.

Table 4.11: Industrial efficiency cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	Wuhan Iron and Steel (Baowu Group), 5G and industrial Internet environmental controls, China[126] case-433	One integrated steelworks, Wuhan; dust removal systems in ironmaking and steelmaking that use 804 000 MWh a year	An estimated 35 000 tCO_2 a year, from a calculation in China's 2024 national technology guide *Modelled*	Tier 2	14.0
Energy data in management programmes	IFC, Partnership for Cleaner Textile (PaCT), Bangladesh[127] case-332	Bangladesh garment and textile sector; web portal to help calculate resource consumption in the readymade garment industry	723 617 tCO_2e and 3 800 000 MWh saved a year across participating factories (2024) *Measured*	Tier 2	9.0
	UNIDO and GIZ, Accelerating Industrial Energy Efficiency in Morocco (ISO 50001), Morocco[128] case-211	38 companies, some with smart meters and real-time energy monitoring; 208 local experts trained	Average energy use down 9% per participating company (2024; baseline not published) *Measured*	Tier 2	12.0

126 *National ICT Domain Energy Conservation and Carbon Reduction Technology Application Guide and Cases (2024 Edition), Part 9: Digital-Green Coordinated Transformation Technology* (Ministry of Industry and Information Technology (MIIT), Energy Conservation Division, 2024), https://gxt.shaanxi.gov.cn/cyfz/jnly/202406/t20240629_3328404.html.

127 International Finance Corporation, *Bangladesh's Textile Sector Weaves a Clean, Sustainable Future* (Washington, DC: International Finance Corporation, 2018), https://www.ifc.org/en/stories/2010/clean-sustainable-bangladesh-textile; Dalberg Advisors, *Evaluating the Partnership for Cleaner Textiles Bangladesh* (Geneva: Dalberg, 2020), https://dalberg.com/our-experience/evaluating-partnership-cleaner-textiles-bangladesh/; *IFC-Led PaCT Programme Drives Sustainable Transformation in Bangladesh Textile Industry* (Apparel Views, 2024), https://www.apparelviews.com/ifc-led-pact-programme-drives-sustainable-transformation-in-bangladesh-textile-industry/; *IFC Launches Web Portal to Monitor Resource Usage in Bangladesh's Garments Sector* (IFC, 2020), https://www.ifc.org/en/pressroom/2020/ifc-launches-web-portal-to-monitor-resource-usage-in-bangladeshs; *Cleaner Production Case Study: Installation of Flow Meters* (World Bank Group, 2021), https://documents1.worldbank.org/curated/en/581351627045343844/pdf/Cleaner-Production-Case-Study-Installation-of-Flow-Meters.pdf.

128 *Accelerating Industrial Energy Efficiency in Morocco (AEEIM): Programme Summary* (UNIDO Industrial Decarbonization Platform, 2025), https://decarbonization.unido.org/resources/accelerating-industrial-energy-efficiency-in-morocco/; *Étude de cas: PESCASUD, Production d'huile et farine de poisson* (in French) (UNIDO Industrial Decarbonization Platform, 2026), https://decarbonization.unido.org/wp-content/uploads/2026/01/morocco-case-study-pescasud.pdf; *Étude de cas: GPC Papier et Carton, Fabrication d'emballages en carton ondulé* (in French) (UNIDO Industrial Decarbonization Platform, 2026), https://decarbonization.unido.org/wp-content/uploads/2026/01/morocco-case-study-gpc-papier-et-carton.pdf; *Étude de cas: AKKA Golden Mining, Groupe Managem (AGM), Exploration et exploitation minière* (in French) (UNIDO Industrial Decarbonization Platform, 2026), https://decarbonization.unido.org/wp-content/uploads/2026/01/morocco-case-study-akka-golden-mining-groupe-managem-agm.pdf.

Table 4.11: Industrial efficiency cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	UNIDO and GEF, Industrial Energy Efficiency programme, Egypt[129] case-107	Egypt; 70 companies in 10 industrial sectors, including iron and steel, cement, and fertilizers (2012 to 2018); sub-metering and energy monitoring software at some companies	1 247 GWh a year and 358 000 tCO_2 saved a year (independent terminal evaluation) *Measured*	Tier 1	11.0

Supply-chain transparency and circularity

Supply-chain transparency platforms work through procurement leverage: they create the data layer for buyer-driven decarbonization, whose effect on supplier emissions is still to be documented. The five cases cover product carbon data exchange, corporate carbon accounting, and remanufacturing (Table 4.12).

The World Business Council for Sustainable Development (WBCSD) Partnership for Carbon Transparency (PACT) addresses the first problem buyers face: suppliers' carbon data are rarely comparable. PACT provides an open methodology and data standard so that suppliers can calculate the carbon footprint of a product and share it with their customers in the same format. More than 5 000 companies use it, 48 software providers have built it into their platforms, 11 industry frameworks have fully or partially aligned their methods with it, and more than 4 million product footprints have been calculated. How many of these companies already exchange data automatically is not reported, and the intended effect, lower supplier emissions, is still to be quantified.

Corporate carbon accounting platforms work at the level of the whole company. Watershed helps large firms such as Walmart and FedEx, and four of the six biggest US banks, account for their Scope 1, 2, and 3 emissions: by August 2024 it had 1 $GtCO_2e$ of corporate emissions under management, and its co-founder says that every customer so far has passed an audit of its carbon accounting statements. Salesforce Net Zero Cloud tracks the Scope 1, 2, and 3 emissions of TELUS, whose Scope 1 and 2 emissions fell from 209 642 tCO_2e in 2023 to 186

[129] *How an Industrial Energy Efficiency Revolution Was Ignited in Egypt* (UNIDO Decarbonization / Industrial Energy Accelerator, 2020), https://decarbonization.unido.org/news/how-an-industrial-energy-efficiency-revolution-was-ignited-in-egypt/; *Independent Terminal Evaluation: Industrial Energy Efficiency in Egypt, GEF ID 3742, UNIDO Project 100349* (UNIDO, 2019), https://www.unido.org/sites/default/files/files/2019-12/GEF%20ID-3742_GFEGY-100349%20TE%20Report_2018.pdf; *Clean Energy Ministerial Energy Management Working Group, Global Energy Management System Implementation: Case Study*, Egypt: ELARABY Company for Trading and Manufacturing (2018), https://www.cleanenergyministerial.org/content/uploads/2022/03/cem-em-casestudy-el-araby-egypt.pdf; *Global Energy Management System Implementation: Case Study*, Egypt: Ezz Al-Dekheila Steel Co. (EZDK) (2017), https://www.cleanenergyministerial.org/content/uploads/2022/03/ezdk-egypt.pdf; *Global Energy Management System Implementation: Case Study*, Egypt: Sidi Kerir Petrochemicals Co. (SIDPEC) (2016), https://www.cleanenergyministerial.org/content/uploads/2022/03/sidpec-egypt.pdf.

512 tCO_2e in 2024. The SAP Green Ledger, generally available since December 2024, builds the same accounting into SAP's financial system, allocating emissions to individual transactions. These figures measure how much is accounted for, not how much is reduced.

Renault Trucks shows the circular end of the chain. Its Limoges plant remanufactures engines, gearboxes, injectors, and particle filters, and under its Restart programme used trucks are renovated and given a software update so that they can serve the same haulier for another 3 years. The company reports about 1 900 tCO_2 avoided through remanufactured parts in 2022, and estimates savings of 7.3 tCO_2 per reconditioned truck.

Table 4.12: Supply-chain transparency and circularity cases

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Product carbon data exchange	WBCSD, Partnership for Carbon Transparency (PACT), global[130] case-445	Global; more than 5 000 companies and 48 software providers using the standard (2025)	4 000 000 product carbon footprints calculated; effect on supplier emissions not yet independently quantified *Measured*	Tier 3	13.0
Corporate carbon accounting	Watershed, enterprise carbon accounting platform, United States[131] case-276	Fortune 500 and other enterprise customers, including Walmart and FedEx; Scope 1, 2, and 3 accounting	1 $GtCO_2e$ of corporate emissions under management (2024, company-reported) *Measured*	Tier 3	9.0
	Salesforce Net Zero Cloud used by TELUS, Canada[132] case-277	TELUS company-wide; 300 000 data records a year from fuel, power, remote operations, and compliance sources	Scope 1, 2, and 3 tracking; TELUS Scope 1 and 2 emissions 209 642 tCO_2e (2023) and 186 512 tCO_2e (2024) *Measured*	Tier 3	9.5

[130] *Partnership for Carbon Transparency (PACT): Action Page* (World Business Council for Sustainable Development (WBCSD), 2025), https://www.wbcsd.org/actions/partnership-for-carbon-transparency-pact/.

[131] *One Gigaton of Emissions Under Management* (Watershed Technology Inc., 2024), https://watershed.com/blog/one-gigaton.

[132] Salesforce, Canadian Technology Company TELUS Taps Salesforce Net Zero Cloud for Emissions Reporting, https://www.salesforce.com/news/stories/telus-taps-salesforce-net-zero-cloud/; TELUS Corporation, *TELUS 2024 ESG Data Sheet*.

Table 4.12: Supply-chain transparency and circularity cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	SAP, SAP Green Ledger, Germany[133] case-278	Carbon accounting built into SAP's ERP financial system, allocating emissions to economic activities and transactions; generally available since December 2024	No emissions result reported yet (general availability, 2024) *No outcome yet*	Tier 3	8.0
Remanufacturing	Renault Trucks, remanufactured parts and software-updated regenerated trucks, France[134] case-499	Limoges remanufacturing plant and the Renault Trucks repair network, France	About 1 900 tCO_2 avoided from remanufactured parts in 2022 (company-reported) *Measured*	Tier 3	9.0

4.5 Buildings and homes

The eight buildings cases fall into two groups: building energy management, from single buildings to city building stocks and a national building code, and household energy, covering smart meters and rooftop solar monitoring. Optimizing is the dominant pathway, in seven of the eight cases, usually alongside Monitoring (five). The sector's defining feature is that buildings are slow physical assets: digital technologies improve operation, but the magnitude depends on the baseline efficiency of the building stock and the authority to act on data.

Main finding: Digital tools reliably cut energy use in buildings, and the gains grow with scale. How much a building saves depends on its starting point. Schneider Electric's modelled building management system saves a large commercial building a net 468 tCO_2e a year compared with the basic building management system found in most office buildings, and 225 tCO_2e compared with a more capable system already in common use. Kiona's AI heating control shows the same pattern: emissions fell by 11% in buildings built between 1920 and 1944, but by 4% in triple-glazed buildings built since 1995, which already have more efficient heating systems. Across whole building stocks the percentages are smaller but add up: AI and Internet of Things (IoT) control of district heating cut heat use across more than 100 public buildings in Espoo, Finland, by 7% in 2021, and in homes, smart meters cut electricity use by 3.4% and gas use by 3.0% in Great Britain's evaluation. Kiona's AI heating control saves a net 1 113 tCO_2e and 17 325 MWh of heat a year across 356 residential buildings in Sweden and Finland, after deducting the footprint of the digital system, and Viet Nam's building energy code programme saved 52

[133] *SAP Announces General Availability of SAP Green Ledger* (SAP News Center, 2024), https://news.sap.com/2024/12/sap-green-ledger-general-availability/.

[134] *The Good Move 6: Regenerated Renault Trucks* (Renault Trucks, 2023), https://www.renault-trucks.com/sites/corporate/files/2023-11/GoodMove%206_REGENERATED%20RENAULT%20TRUCKS_EN.pdf.

817 MWh by project close, as reported in its independent terminal evaluation, with savings in new buildings estimated from the measured retrofit rate.

Building energy management

Digital building energy management works at every scale, from a single building to a national building code, and the savings grow with the number of buildings it reaches (Table 4.13).

Schneider Electric's modelled building management system cuts a large commercial building's electricity use by 13% and its gas use by 29% compared with the basic building management system found in most office buildings, a net 468 tCO_2e a year, or 225 tCO_2e compared with a more capable system already in common use, so the result depends on what it replaces. In a Dublin office, monitoring-based commissioning with IES's analytics found control faults, such as a boiler return water temperature set-point that was too high, and after they were fixed, energy use fell by up to 69% in the first 2 weeks, partly because of COVID lockdowns.

Across portfolios, SensorFlow reports 23.1 GWh saved, cumulatively, in its customers' hotels. Kiona's AI heating control sets each building's heating water temperature using indoor sensors and forecasts of weather, wind, and sun. Across 356 residential buildings, it saves a net 1 113 tCO_2e and 17 325 MWh of heat a year after deducting the footprint of the digital system, with heating energy down 7% on average and the largest emissions cut (11%) in buildings from 1920 to 1944. Espoo reports 7% (4 500 MWh) less district heating in its public buildings in 2021, using a self-learning system that adapts heating to each building, for example lowering temperatures at night in buildings used only by day.

At national scale, Viet Nam's building energy code programme saved 52 817 MWh by project close, as reported in its independent terminal evaluation, with savings in new buildings estimated from the measured retrofit rate.

Table 4.13: Building energy management cases

Deploy-ment level	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Single build-ing	Schneider Electric, high-perfor-mance building management system, Europe[135] case-447	Commercial buildings simu-lated for several European climate regions; large, medium, and small commercial archetypes	Modelled net saving of 468 tCO_2e a year per large commercial building against a standard BMS, and 225 tCO_2e against an advanced BMS *Modelled*	Tier 2	11.0

[135] European Green Digital Coalition et al., *EGDC Case Study: Schneider Electric High-Performance BMS: Case Study Methodology* (Brussels: European Green Digital Coalition, 2024), https://www.greendigitalcoalition.eu/assets/uploads/2024/04/EGDC-Case-Study-Meth.-SE-High-Per.-BMS.pdf.

Table 4.13: Building energy management cases (continued)

Deploy-ment level	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	IES and Savills, monitor-ing-based commissioning with iSCAN BMS data analytics at 1 George's Quay, Ireland[136] case-307	One 14 000 m^2 office building in Dublin	Energy use up to 69% lower in the first 2 weeks after control fixes, partly due to COVID lock-downs; 143.5 tCO_2 (electricity) and 159.4 tCO_2 (gas) a year projected (2021) *Measured and modelled*	Tier 3	8.0
Operator portfolio	SensorFlow, wireless IoT occupan-cy-based hotel room energy management, Southeast Asia[137] case-116	Hotels in Southeast Asia, including Singa-pore, Indonesia, and Cambodia; wireless retrofit with no hard-wired installation	23 114 322 kWh of energy saved and 11 636 tCO_2 avoided, cumula-tive across hotel customers (compa-ny-reported) *Measured*	Tier 3	11.0
	Ericsson and Kiona, edge AI heating opti-mization for district-heated residential build-ings, Sweden and Finland[138] case-476	356 district-heated residential build-ings, Sweden and Finland; 1 year of oper-ational data (2022)	1 113 tCO_2e net carbon saving and 17 325 MWh of heat saved a year across the buildings (EGDC, 2022) *Measured*	Tier 2	9.0
City	Danfoss Lean-heat and City of Espoo, AI and IoT district heat-ing optimization, Finland[139] case-370	City of Espoo, Finland; more than 100 public buildings and nearly 15 000 apartments on district heating	7% (4 500 MWh) less district heating in the city's public buildings in 2021 *Measured*	Tier 3	11.0

[136] *Monitoring Based Commissioning Saves Energy at George's Quay* (Integrated Environmental Solutions (IES), 2023), https://www.iesve.com/discoveries/view/28180/monitoring-based-commissioning-georges-quay; *1 George's Quay: Monitoring Based Commissioning* (Integrated Environmental Solutions (IES), n.d.), https://www.iesve.com/services/projects/28168/monitoring-based-commissioning-georges-quay.

[137] *Smart Energy Hotel Management Made Easy: SensorFlow* (SensorFlow, 2026), https://www.sensorflow.co/.

[138] European Green Digital Coalition, *EGDC Case Study: Kiona Edge AI Steering Function by Ericsson & Kiona* (Brussels: European Green Digital Coalition, 2026), https://www.greendigitalcoalition.eu/assets/uploads/2026/05/Case-study-methodology-Ericsson-Kiona-Edge-AI-Solution-Mar26.pdf.

[139] *Leanheat Building Helps City of Espoo Save EUR 200 000 in Energy Costs* (Danfoss, 2022), https://www.danfoss.com/en/service-and-support/case-stories/dcs/leanheat-building-helps-city-of-espoo-save-eur-200-000-in-energy-costs/.

Table 4.13: Building energy management cases (continued)

Deploy-ment level	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
National building code	GEF and UNDP, Energy Efficiency Building Code with building energy simulation software and compliance toolkits, Viet Nam[140] case-458	Viet Nam; 23 demonstration buildings, 14 of them retrofitted existing buildings and 9 new; compliance toolkits for provincial Departments of Construction	52 817 MWh of energy saved by project close (terminal evaluation; new-building savings estimated from the measured retrofit rate); 70% of provincial Departments of Construction reference the compliance toolkits (survey); modelled cumulative reduction of 32 552 tCO_2e by project close (2021) *Measured and modelled*	Tier 1	9.0

Outcomes are as reported by each source and are not comparable across rows.

Household energy

In the evaluation of Great Britain's roll-out, a pooled analysis of seven supplier studies found smart meters cut household electricity use by 3.4% and gas use by 3.0%, above the government's assumptions of 3.0% and 2.2%, and a national analysis of 1.7 million installations found median first-year savings of 2.5% and 2.0%. By the end of 2023, almost 35 million smart and advanced meters had been installed in homes and small businesses. The government expects the savings to come from in-home displays that show households their near-real-time use in pounds and pence, from more accurate bills, and from energy advice at installation. The national evaluation of Great Britain's smart meter roll-out sits alongside ADEME's assessment of apps for monitoring rooftop solar (Table 4.14).

Households with rooftop solar can also monitor their own production: ADEME assessed the mobile apps sold with these systems. A clamp meter fitted in the home measures how much electricity the panels produce and how much the household uses, and the app alerts the owner when output drops, whether from a breakdown or from leaves, pollen, or dust on the panels. Spotting these problems sooner means fewer hours of lost solar production: early detection of dirt on the panels accounts for two thirds of the gain, and of breakdowns for one third. For a typical household system, ADEME finds a modelled net saving of 535 kg CO_2e per installation over 2023 to 2035, before rebound effects. The clamp meter adds a burden on metals and minerals that this small gain does not offset.

[140] *Terminal Evaluation Report: Energy Efficiency Improvement in Commercial and High-Rise Residential Buildings (EECB) Project, Viet Nam (PIMS 5245)* (UNDP Viet Nam, 2021), https://erc.undp.org/evaluation/documents/download/19231.

No case measures household energy savings from combining smart meters with dynamic tariffs; the demand flexibility cases in Section 4.2 measure demand shifted, not energy saved.

Table 4.14: Household energy cases

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Household energy feedback	Great Britain smart meter roll-out (DESNZ, evaluated by the Behavioural Insights Team), United Kingdom[141] case-012	Great Britain; almost 35 million smart and advanced meters installed by the end of 2023; the national analysis covers 1.7 million electricity and 1.5 million gas meters installed from 2015 to 2018	3.43% less electricity and 2.97% less gas than comparable households without smart meters (pooled analysis of supplier studies) *Measured*	Tier 1	10.5
Household solar monitoring	ADEME IT4Green, mobile apps for rooftop solar PV monitoring, France[142] case-573	Residential rooftop solar installations, France; assessment period 2023 to 2035	Modelled net saving of 535 kg CO_2e per installation before rebound effects (cumulative, 2023 to 2035) *Modelled*	Tier 2	12.0

Outcomes are as reported by each source and are not comparable across rows.

4.6 Agriculture and forestry

The five agriculture and forestry cases are fewer than in the other sectors but highly policy-relevant: digital agriculture and forestry monitoring appear frequently in NDCs and development-finance pipelines. Monitoring appears in all five cases: satellite or field data reveal conditions, and the outcome depends on whether advice, finance, or enforcement acts on them. The section covers two groups: agricultural programmes and forest carbon mapping, and satellite deforestation alerts (Table 4.15).

Main finding: Digital advice and monitoring deliver large reported results when they change what happens on the ground: how land is used, how much fertilizer and fuel are applied, or

[141] *Monitoring Smart Meter Energy Savings Using the National Energy Efficiency Data-Framework* (UK Department for Energy Security and Net Zero, 2024), https://assets.publishing.service.gov.uk/media/672df39f5437e298ae64ce94/monitoring-smart-meter-energy-savings-using-NEED.pdf; *Do Smart Meters Reduce Households' Energy Consumption?* (Behavioural Insights Team, 2023), https://www.bi.team/blogs/do-smart-meters-reduce-households-energy-consumption/; *Impacts of Smart Metering Roll-Out on Household Energy Use* (UK Department for Energy Security and Net Zero, 2023), https://www.gov.uk/government/publications/impacts-of-smart-metering-roll-out-on-household-energy-use.

[142] *IT4Green: Environmental Quantification of the Solar PV Self-Production Monitoring Use Case (ADEME, 2026)*, https://librairie.ademe.fr/index.php?controller=attachment&id_attachment=9281.

whether forest loss is caught in time. Farmers who adopted Viet Nam's low-carbon rice practices cut their fertilizer costs by 35% on average and raised their net profits per hectare by 30%, and in Peru, communities whose trained monitors received satellite alerts lost an estimated 52% less tree cover in the first year than comparison communities. The digital tool supplies the information, and the result depends on the people and institutions that act on it. The digital share is not yet measured separately, the greenhouse gas figures are modelled or estimated, and the only effects measured against comparison areas are on forest loss, in the two satellite-alert cases.

Agricultural programmes and forest carbon mapping

Agriculture's quantified outcomes come from programmes and funds in which digital tools are one input among several, so the digital contribution is not measured separately. Translating input savings into GHG figures also requires a credible emissions factor for the avoided input, established in some source methodologies but not others. The first three cases in Table 4.15 are a national rice programme, a climate fund investing in precision agriculture, and a forest carbon mapping pilot with no outcome yet.

The largest figure is modelled: the Viet Nam Sustainable Agriculture Transformation (VnSAT) project estimates that low-carbon rice practices on 185 000 hectares cut emissions by 1 582 299 tCO_2e a year. Farmers used less seed, fertilizer, and pesticide, and on two thirds of that area also used certified seed, alternate wetting and drying of fields, and combine harvesting. Farmers who adopted the practices cut pesticide costs by 48% and fertilizer costs by 35% on average and raised net profits per hectare by 30%. Its digital elements, Internet of Things water-management pilots in Mekong Delta rice whose results the project scaled up and a smart irrigation pilot with 44 coffee households, are indirect, and neither the World Bank's completion report nor its independent review separates them from extension services, training, and investment. A separate mobile app, introduced to rice farmers in the Mekong Delta, gives localized advice, and its farm diaries can support carbon credit verification.

Solinftec's platform and solar-powered robots monitor fields plant by plant and guide planting, spraying, and harvesting decisions, helping farmers manage their fuel and input use. The Green Climate Fund, an investor in Solinftec, attributes the company's emission cuts mainly to lower fuel use and less ammonia-based fertilizer and crop protection chemicals. Its customers' 15.4% lower fuel use is measured, while its 385 114 tCO_2e avoided is an estimate. In Senegal, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and its partner data354 have built Carbon Lens, which combines satellite imagery with forest inventory data and has produced a first map of predicted above-ground carbon stock across Senegal, designed to support the country's NDC reporting.

Satellite deforestation monitoring

Satellite-based deforestation monitoring can strengthen the evidence base for enforcement by providing an independent layer of observation that complements self-reported information, but it produces a documented GHG outcome only where enforcement action has been independently evaluated against a verified counterfactual. Two cases meet that standard, measuring the effect on forest loss against comparison areas. MapBiomas, which maps all land cover in Brazil, is discussed in Section 4.1, because its documented results are credit and enforcement decisions rather than measured forest loss.

In Peru, communities whose trained monitors received satellite alerts through the Geobosques platform lost an estimated 52% less tree cover in the first year than comparison communities, and in African countries that subscribed to Global Forest Watch alerts, the probability of deforestation was 18% lower.

Table 4.15: Digital agriculture, forest monitoring, and forest carbon cases

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Low-carbon rice farming building on IoT pilots	Ministry of Agriculture and Rural Development (MARD) and World Bank, Sustainable Agriculture Transformation Project (VnSAT), Viet Nam[143] case-087	Mekong Delta, Viet Nam; 185 000 hectares of rice under low-carbon practices; IoT smart irrigation piloted with 44 coffee households	Modelled reduction of 1 582 299 tCO_2e a year from low-carbon rice farming; farmer pesticide costs down 48% and fertilizer costs down 35%; farmer net profits per hectare up 30% (2022) *Measured and modelled*	Tier 1	12.7
AI precision agriculture with climate finance	GCF CRAFT fund and Solinftec, AI precision agriculture, Brazil[144] case-418	Brazil; GCF investment through the CRAFT fund (FP181), which targets six countries in Latin America, the Caribbean, and Africa	15.4% lower customer fuel use (2022); an estimated 385 114 tCO_2e avoided since GCF's investment *Measured and modelled*	Tier 2	7.5

[143] World Bank, *Greening Viet Nam's Rice Bowl*; World Bank, *Vietnam Sustainable Agriculture Transformation Project: Implementation Completion and Results Report* (2023), https://documents1.worldbank.org/curated/en/099051123091518844/pdf/BOSIB02c6d17970450bc81069953a0323ea.pdf; *ICR Review: Vietnam Sustainable Agriculture Transformation (P145055)* (World Bank Independent Evaluation Group (IEG), 2023), https://documents1.worldbank.org/curated/en/099102023111514489/pdf/P1450 5508f0bf6012083a80425fb16de86d.pdf.

[144] *Mobilising Financing for Agricultural Technologies: Seeding a Climate Resilient and Food-Secure Future* (Green Climate Fund, 2024), https://www.greenclimate.fund/about/news-and-updates/stories/mobilising-financing-agricultural-technologies-seeding-climate-resilient-and-food-secure.

Table 4.15: Digital agriculture, forest monitoring, and forest carbon cases (continued)

Function	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Forest carbon mapping for NDC reporting	GIZ and data354, Carbon Lens AI forest carbon mapping, Senegal[145] case-575	Senegal; open satellite data combined with 167 forest inventory plots surveyed from 2024 to January 2026	No quantified outcome yet; a first map of predicted above-ground carbon stock across Senegal, designed to support NDC reporting (2026) *No outcome yet*	Tier 3	8.0
Deforestation alerts	Peru Geobosques[146] case-317	76 indigenous communities in the Peruvian Amazon, 39 of them in the programme (randomized trial)	52% less tree cover loss in the first year and 37% over 2 years in communities assigned to monitoring (randomized trial; estimates imprecise) *Measured*	Tier 1	9.0
	Global Forest Watch GLAD[147] case-186	Alert subscriptions in 22 tropical countries; effect found in Africa	Probability of deforestation 18% lower in African countries subscribing to alerts, against 2011 to 2016 levels *Measured*	Tier 1	12.0

[145] *From Motorbikes to Satellites: Senegal's New AI Approach to Forest Protection* (BMZ Digital Global, 2025), https://web.archive.org/web/20260611071908/https://www.bmz-digital.global/en/from-motorbikes-to-satellites-senegals-new-ai-approach-to-forest-protection/; Koné, Kouassi and Fonlladosa, *Carbon Lens-Senegal: A Multi-Source Machine Learning Approach for Forest Biomass Estimation in Tropical West Africa* (ITU Kaleidoscope, 2026), https://www.itu.int/en/ITU-T/academia/kaleidoscope/2026/Documents/Presentations/P4-presentation.pdf.

[146] Tara Slough, Jacob Kopas, and Johannes Urpelainen, *Satellite-Based Deforestation Alerts with Training and Incentives for Patrolling Facilitate Community Monitoring in the Peruvian Amazon*, Proceedings of the National Academy of Sciences 118, no. 29 (2021), https://pmc.ncbi.nlm.nih.gov/articles/PMC8307376/.

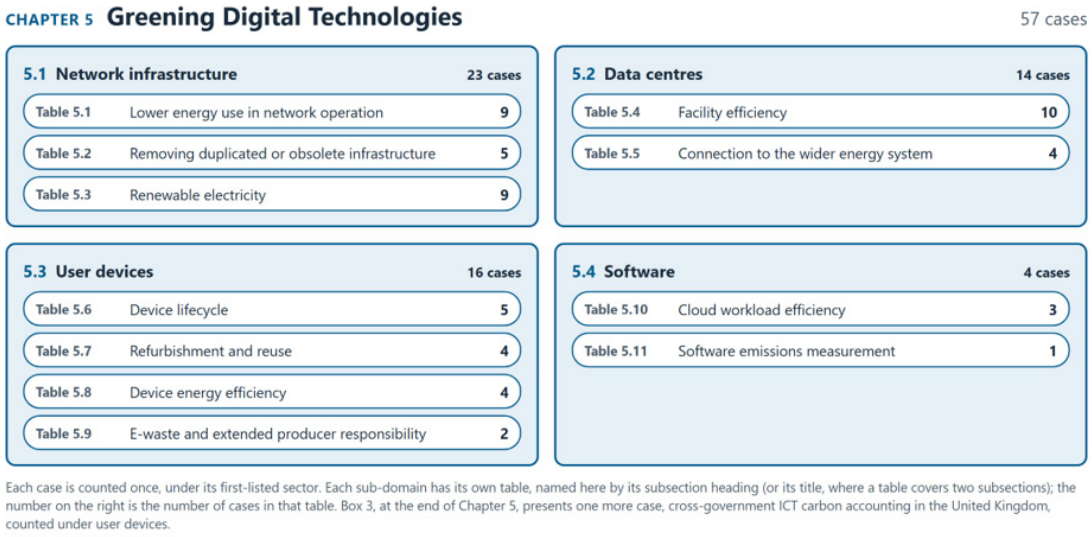
[147] *Moffette et al.,"The Impact of Near-Real-Time Deforestation Alerts Across the Tropics*, Nature Climate Change (2021), https://www.nature.com/articles/s41558-020-00956-w.

5 Greening digital technologies

This chapter examines the 57 Greening Digital Technologies cases in which the primary climate action outcome is a reduction in the digital sector's own energy use, greenhouse gas emissions, or embodied carbon. The cases are organized into four sub-domains: network infrastructure (23 cases), data centres (14), user devices (16), and software (4). Device lifecycle, product circularity, and network-equipment embodied-carbon evidence is integrated within the relevant sub-domain rather than treated as a separate category. Because most Greening Digital Technologies cases use the same pathway, Optimizing (40 of the 57), the pathways say little about how these cases differ. Each section therefore describes the levers its cases use (the practical means of cutting the footprint) and relates them to the six enabling pathways defined in Chapter 3.

This chapter shows which approaches to reducing the energy use, greenhouse gas emissions, and embodied carbon of information and communication technology (ICT) are already operational, and where the strongest evidence exists. Each section opens with its main finding, followed by its sub-domains, each with a table (see Figure 9).

Figure 9: The 57 Greening Digital Technologies cases by sector and sub-domain



Each case is counted once, under its first-listed sector. Each sub-domain has its own table, named here by its subsection heading (or its title, where a table covers two subsections); the number on the right is the number of cases in that table. Box 3, at the end of Chapter 5, presents one more case, cross-government ICT carbon accounting in the United Kingdom, counted under user devices.

Source: Figure prepared for this report from the stocktake case data (ITU, 2026).

5.1 Network infrastructure

The 23 network infrastructure cases work through three main decarbonization levers: reducing the energy intensity of network operation, eliminating duplicated or obsolete infrastructure, and replacing grid or diesel electricity with renewable electricity. The levers often appear together, but they differ analytically. For example, AI radio sleep modes and traffic-aware optimization reduce energy per unit of service. Network sharing, copper switch-off, and equipment reuse reduce the physical infrastructure required to deliver connectivity. Renewable procurement changes the emissions factor of remaining consumption. In pathway terms, the first lever is Optimizing, which appears in 17 of the 23 cases. The second is split between Optimizing and Dematerializing (4 cases), and the third is Amplifying (11 cases), as operators scale renewable supply across their sites.

Main finding: The largest savings come from operators sharing one network instead of building two, and from replacing copper with fibre optic. The network that China Telecom and China Unicom share saves 24 900 GWh of electricity a year, and Telefónica reports that closing its first 1 000 copper exchanges in favour of fibre optic lines saved around 1 000 GWh. AI energy management also delivers significant savings within existing networks, 171.7 GWh a year in one Chinese operator's network. Solar and hybrid power is replacing diesel and grid electricity at individual sites. Most network results are calculated savings, compared with what would otherwise have been used, results at individual sites, or intensity figures, although 11 of the 23 cases also report how the operator's total energy use or emissions changed. AT&T shows why totals matter: its network energy intensity fell by 56% between 2020 and 2024 (our calculation from AT&T's chart values), while its total energy consumption fell only 14.3%.

Lower energy use in network operation

AI-driven radio sleep modes and traffic-aware scheduling are in commercial use, from radio equipment at selected sites to company-wide programmes (Table 5.1). The systems use AI to predict traffic and switch off radio capacity, or whole pieces of equipment, in hours when traffic is low, waking them again when demand returns. Site-level results show what the technology can save, and company-wide figures show whether a company's total energy use falls.

Most cases report savings or site-level gains, and AT&T also reports how its total energy use changed over time. Its figures show the gap between the two measures: network energy intensity fell by 56% between 2020 and 2024 (our calculation from AT&T's chart values), from 123.6 to 54.6 MWh per petabyte, while total energy consumption fell only 14.3%. In other words, each petabyte now takes less than half the energy to carry, but the company's total energy use has fallen far less, so the efficiency gains have reduced its footprint much less than the intensity figure suggests.

Equipment-level savings can be large, such as the 171.7 GWh a year saved in one Chinese operator's network by the system China Mobile Jiangsu supplied. The Three UK figure of up to 70% is a maximum at selected sites, not a network average. Orange Egypt manages the energy of its offices and network sites under an ISO 50001 energy management system: connecting diesel-powered sites to the grid cut its Scope 1 emissions by 37%, although the source gives no baseline, and its offices saved 8 500 MWh of electricity. Across the whole Orange Group, in 26 countries, Scope 1 and 2 emissions fell 38.6% between 2015 and 2024 on a comparable basis, and 75% of the electricity used in its networks and buildings was low-carbon in 2024, including 48% from renewable sources.

In Qatar, Ooredoo's trials of hybrid diesel and battery power management cut daily generator runtime by up to 66% and fuel use per site by up to 55%, maximum trial results. Ericsson reports that energy-saving software features on Ooredoo's radio network, such as cell sleep and MIMO sleep modes, cut its energy consumption by 16% to 40%, although it gives no method. Two operators combine AI network controls with solar power. Advanced Info Service in Thailand reports 38 321 MWh of electricity saved and 19 157 tCO_2e avoided a year by AI optimization at its base stations, and a further 30 047 tCO_2e a year avoided by renewable power at 13 482 locations. Bharti Airtel, which launched a Green 5G programme with Nokia in India in October 2024, had by then classified more than 58% of its network sites as green and cut tower diesel use by more than 2 million litres a month while adding more than 75 000 sites in 2 years.

Table 5.1: Network energy efficiency cases

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
AI radio energy manage-ment	China Mobile Jiangsu, AI collaborative energy manage-ment for 4G and 5G base stations, China[148] case-432	One telecom operator's 4G and 5G radio network, China, with China Mobile Jiangsu as technology provider	171.7 GWh saved a year (2022) *Measured*	Tier 2	14.0
	Three UK, Vodafone UK, and Ericsson, AI radio energy management, United King-dom[149] case-169	Selected Three UK sites after an 18-month network modernization (2024); Vodafone UK trial sites in London (2025)	Network energy efficiency up to 70% higher at selected Three UK sites (2024); daily 5G radio unit power use up to 33% lower at Vodafone UK trial sites (2025) *Modelled*	Tier 3	11.3
	ZTE, 5G base station hiberna-tion, China[150] case-584	More than 350 000 5G active antenna units in China, enabled through a soft-ware upgrade (2023)	75 GWh saved a year compared with deep sleep mode (2023) *Measured*	Tier 3	11.0

148 Ministry of Industry and Information Technology, *National Guide to Energy-Saving Technology Applications in the Information Sector, 2022 Edition, Vol. 6: Energy Efficiency Technologies for Telecommunications Networks (Base Station Energy Efficiency) (Ministry of Industry and Information Technology / China Electronics Society, 2022),* https://www.cie.org.cn/list_42/11098.html.

149 *Three UK and Ericsson Set the Standard for Smart and Sustainable Networks* (Ericsson, 2024), https://www.ericsson.com/en/press-releases/3/2024/three-uk-and-ericsson-set-the-standard-for-smart-and-sustainable-networks; *Vodafone UK and Ericsson Trial AI Solutions for Improved 5G Energy Efficiency (Vodafone UK News Centre*, 2025), https://www.vodafone.co.uk/newscentre/press-release/ericsson-trial-ai-for-improved-5g-energy-efficiency/.

150 *ZTE Hibernation in 5G Base Stations* (GSMA (Climate Action: External Affairs), 2023), https://www.gsma.com/solutions-and-impact/connectivity-for-good/external-affairs/climate-action/case-studies/zte-hibernation-in-5g-base-stations/.

Table 5.1: Network energy efficiency cases (continued)

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Network-wide efficiency programmes	AT&T, network energy management and copper-to-fibre transition, United States[151] case-254	AT&T's national network, United States; efficiency programme running since 2015, with cell site sleep functions on LTE being extended to 5G	Network energy intensity down 56%, from 123.6 to 54.6 MWh per petabyte, and total energy consumption down 14.3% (2020 to 2024) *Measured*	Tier 3	10.0
	Orange Group, Green ITN programme, France and 25 other operating countries[152] case-079	Orange networks and IT systems in 26 countries across Europe, Africa, and the Middle East; programme running since 2015	Scope 1 and 2 emissions down 38.6% from 2015 to 2024 (comparable basis); 75% low-carbon electricity, 48% renewable (2024) *Measured*	Tier 1	11.0
AI network controls with solar power	Advanced Info Service (AIS), AI network optimization and solar roll-out, Thailand[153] case-062	Base stations nationwide, Thailand; solar and other renewable sources at 13 482 locations (2025)	38 321 MWh a year saved and 19 157 tCO_2e avoided a year by AI optimization, plus 30 047 tCO_2e a year avoided by solar (2025) *Measured*	Tier 3	10.0

[151] *AT&T, Connecting People to Greater Possibility: 2024 Sustainability Update (AT&T Inc., 2024), p. 15,* https://sustainability.att.com/Media/AT&TSustainabilityUpdatereport.pdf*; AT&T Corporate Responsibility: Energy Management* (AT&T Inc., 2026), https://sustainability.att.com/priority-topics/energy-management. The 56% is calculated from the two intensity values in the source.

[152] *Orange, 2024-2025 Integrated Annual Report (Orange, 2025),* https://web.archive.org/web/20250727110124/https://rai.orange.com/wp-content/uploads/sites/54/2025/06/integrated-annual-report-2024-2025.pdf*; Orange s.a. Sustainability: GHG Emissions and Green ITN Programme Data* (The Sustainable Innovation, 2026), https://thesustainableinnovation.com/orange-sustainability/.

[153] *Climate Actions: Act on Climate: Sustainability Priorities: AIS* (Advanced Info Service Public Company Limited (AIS), 2026), https://sustainability.ais.co.th/en/sustainability-priorities/act-on-climate/climate-actions.

Table 5.1: Network energy efficiency cases (continued)

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	Bharti Airtel and Nokia, Green 5G programme, India[154] case-258	National mobile network, India; around 42 000 network sites with solar access (May 2026)	Over 58% of network sites classified as green, and diesel use cut by over 2 million litres a month while sites were added (2024) *Measured*	Tier 3	12.0
Certified energy management	Orange Egypt, ISO 50001 energy management of buildings and network sites, with automated building management, Egypt[155] case-191	Orange Egypt's offices and network; almost 1 200 network sites converted to indoor-outdoor cooling	Scope 1 emissions down 37% by connecting diesel-powered sites to the grid (baseline not stated); 3 800 tCO_2 avoided, equivalent to 8 500 MWh of electricity saved, through building energy optimization (2023) *Measured*	Tier 3	11.0
Hybrid site power management	Ooredoo Qatar and Ericsson, Smart Connected Site trials, Qatar[156] case-057	Trial sites in Qatar with hybrid diesel generator and lithium-ion battery power management (2023)	Fuel consumption per site down by up to 55% in trials (2023, maximum trial result) *Measured*	Tier 3	11.0

Removing duplicated or obsolete infrastructure

Removing duplicated or obsolete infrastructure produces the largest absolute savings among the network cases, and equipment reuse extends the same logic to manufacturing. The cases cover network sharing, the retirement of legacy copper, equipment reuse, and lower-carbon equipment (Table 5.2).

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154 *Over Half of Airtel's Network Sites Are Now Green* (TelecomTalk / Bharti Airtel, 2024), https://telecomtalk.info/over-half-of-airtel-network-sites-green/986784/; Airtel, *Indus Towers Step Up Push to Reduce Diesel Dependence at Telecom Sites* (TelecomTalk, 2026), https://telecomtalk.info/airtel-indus-reduce-diesel-dependence-telecom-sites/1007569/.

155 Orange Egypt ESG Report (Orange Egypt Telecommunications S.A.E., n.d.), https://www.orange.eg/ar/documents/oeg-esg-report.pdf; Climate and Environment: Orange Engage for Change (Orange Egypt / Orange Group, 2024), https://engageforchange.orange.com/en/programs/67569e73-a8de-4f80-a082-515fd68aae3b.

156 *Ooredoo Qatar Deploys Ericsson Smart Connected Site Solution to Reduce Carbon Emissions* (Ericsson, 2023), https://www.ericsson.com/en/press-releases/5/2023/ooredoo-qatar-deploys-ericsson-smart-connected-site-solution-to-reduce-carbon-emissions; *Pioneering Sustainable 5G Rollout for Climate Action and Digital Transformation in Qatar* (Ericsson, 2023), https://www.ericsson.com/en/blog/middle-east-africa/2023/pioneering-sustainable-5g-rollout-for-climate-action-and-digital-transformation-in-qatar.

Sharing one network instead of building two gives the largest figure in the network cases: China Telecom and China Unicom, which jointly built and share one 4G and 5G network, save 24 900 GWh of electricity a year. Retiring copper works the same way, because fibre needs less equipment: one fibre exchange serves as many lines as four copper exchanges. Telefónica reports that closing its first 1 000 copper exchanges saved around 1 000 GWh, and that fibre has up to 94% lower environmental impact than copper.

Reuse avoids making new equipment: Vodafone's internal marketplace lets its operating companies in 22 markets reuse network equipment instead of buying new, and more than 26 000 items were reused between 2020 and 2023, avoiding an estimated 1 100 tCO_2e.

Equipment makers can also cut emissions in use and in manufacturing. Nokia halved the power use of its 5G massive multiple-input multiple-output (MIMO) base station against 2019, and its total emissions fell 28%, a figure under independent assurance; part of that fall came from lower sales, because most of Nokia's emissions come from the use of the equipment it sells. Flex's factory in Tczew, Poland, which makes network equipment for Ericsson, including units shipped to BT, is estimated to have cut the Scope 2 emissions of its production for Ericsson by 11 000 tCO_2e in 2022 by switching to renewable electricity.

Table 5.2: Network technology migration and reuse cases

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Network sharing	China Telecom and China Unicom, shared 4G and 5G network co-construction, China[157] case-562	China; jointly built and operated shared radio access network with 1.375 million shared 5G base stations (2024)	Electricity savings of 24 900 GWh a year and more than 13 000 000 tCO_2 a year avoided (2025, operator-reported) *Measured*	Tier 3	15.0

[157] *China Telecom's AI Initiatives Driving Sustainable Connectivity* (AI for Good, n.d.), https://aiforgood.itu.int/china-telecoms-ai-initiatives-driving-sustainable-connectivity/; *China Telecom Corporation Limited 2025 Sustainability (ESG) Report* (China Telecom Corporation Limited, 2026), https://www.chinatelecom-h.com/en/ir/report/esg2025.pdf; *China Telecom Corporation Limited 2024 Sustainability (ESG) Report* (China Telecom Corporation Limited, 2025), https://www.chinatelecom-h.com/en/ir/report/esg2024.pdf.

Table 5.2: Network technology migration and reuse cases (continued)

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Legacy network retirement and equipment reuse	Telefónica, copper switch-off, Spain[158] case-262	Spain; switch-off of 8 532 copper exchanges begun in 2014, which Telefónica announced in April 2023 it would complete by April 2024, with retail customers moved to fibre-to-the-home	1 000 GWh saved and some 355 000 tCO_2 avoided from closing the first 1 000 copper exchanges (to 2021); fibre network up to 94% lower environmental impact than copper for the same data use (company figure, no published method) *Measured and modelled*	Tier 3	14.0
	Vodafone, internal asset marketplace for network equipment, United Kingdom[159] case-496	Internal digital marketplace across Vodafone's 22 markets, launched in January 2020	More than 26 000 network equipment items reused group-wide (2020 to 2023), with an estimated 1 100 tCO_2e avoided *Measured and modelled*	Tier 3	11.0
Lower-carbon network equipment	Nokia, AirScale 5G base stations and value-chain emissions, Finland[160] case-502	Global telecom equipment maker; total emissions across Scopes 1, 2, and 3, most of them from the use of sold products	Total GHG emissions down 28% in 2024 (assured, partly from lower sales); 5G massive MIMO base-station power use down 50% against 2019 (2023, company-reported) *Measured*	Tier 1	14.0

158 Telefónica S.A., *The Gradual Farewell to Copper Plants*, https://www.telefonica.com/en/communication-room/news/the-gradual-farewell-to-copper-plants/; Telefónica S.A., *Telefónica Closes All Its Copper Central Offices*.

159 *Tackling e-Waste and Enabling a Circular Economy* (Vodafone Group, 2020), https://www.vodafone.com/news/newsroom/protecting-the-planet/tackling-e-waste-and-enabling-circular-economy-electronic-products.

160 *Nokia's People and Planet 2023 Report Underlines the Importance of Digital in Creating a More Sustainable Future* (Nokia / GlobeNewswire, 2024), https://www.globenewswire.com/news-release/2024/03/07/2841958/0/en/Nokia-s-People-and-Planet-2023-report-underlines-the-importance-of-digital-in-creating-a-more-sustainable-future.html; *Nokia in 2024: Annual Report 2024, Including the Sustainability Statement* (Nokia Corporation, 2025), https://www.nokia.com/system/files/2025-04/nokia-annual-report-2024_1.pdf.

Table 5.2: Network technology migration and reuse cases (continued)

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	Ericsson, Flex, and BT, renewable-powered manufacturing of network equipment, Poland[161] case-503	Flex factory in Tczew making about 1.1 million products a year for Ericsson; 1 401 baseband units shipped to BT (2022)	Scope 2 emissions 11 000 tCO_2e lower for Ericsson's production at Tczew, and 14 tCO_2e less embodied carbon in the units shipped to BT (2022) *Modelled*	Tier 3	8.0

Renewable electricity

Renewable power reaches network operations in two ways: solar and hybrid systems at individual sites, and renewable generation and purchase agreements at national scale. Five cases put power at individual sites, and four cover whole networks (Table 5.3).

At individual sites, the largest programme is Zain's, which reports 150 000 tCO_2 avoided a year across more than 1 800 modernized network sites, while MTN Ghana (3 325 tCO_2e in 2024) and stc's TAWAL towers (3 096 tCO_2 a year) report smaller site programmes. e& reports 40% lower power use at mobile sites using solar, and 15% to 20% lower power use from AI at its telecom sites and data centres. Jazz's 15 000 tCO_2 a year from 1 000 solar sites in Pakistan is projected.

At national scale, renewable generation and purchase agreements cover whole networks: Claro reports more than 500 000 tCO_2 avoided since 2017 from 200 MW of distributed generation in Brazil. Telenor's wind power agreement is projected to supply 330 GWh a year, more than 86% of the power use of its Norwegian operations, and Movistar Chile's agreement with ACCIONA is projected to supply 108 GWh a year. NBN Co has contracted 80 GWh a year of renewable electricity under a power purchase agreement, and its energy-saving feature cut Fixed Wireless network power use by 5%.

[161] Uniting for Climate Action: BT Group, *Ericsson and Flex's Journey towards Net Zero in the Telecommunications Ecosystem* (Ericsson, 2023), https://www.ericsson.com/en/blog/europe/2023/9/uniting-for-climate-action-bt-group-ericsson-and-flexs-journey-towards-net-zero-in-the-telecommunications-ecosystem; *Building the Next Generation of Communication Networks and a More Sustainable Future* (Flex, 2025), https://flex.com/resources/building-the-next-generation-of-communication-networks-and-a-more-sustainable-future.

Table 5.3: Network renewable energy cases

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Solar and hybrid power at network sites	Zain Group, Green Target Network, Kuwait[162] case-056	Network sites in Kuwait, Saudi Arabia, and other countries, developed with Huawei	150 000 tCO_2 avoided a year across more than 1 800 modernized network sites (2024) *Measured*	Tier 3	13.0
	MTN Ghana, Project Zero solar network sites, Ghana[163] case-138	Ghana; 2.4 MW of solar capacity at switching centres and 39 base station sites (2024)	3 325 tCO_2e avoided in 2024 *Measured*	Tier 3	8.0
	stc Group and TAWAL, solar-powered telecom towers, Saudi Arabia[164] case-006	370 TAWAL tower sites running mainly on renewable energy and 959 on hybrid energy, in Saudi Arabia and abroad (2024)	3 096 tCO_2 avoided a year (2024) *Measured*	Tier 3	11.3
	e& (formerly Etisalat), solar-powered mobile sites, United Arab Emirates[165] case-059	e& mobile sites in the United Arab Emirates using on-site solar and AI-driven power management	Power consumption at mobile sites using solar down 40% (2024); AI cut power use at telecom sites and data centres by 15% to 20% (company-reported) *Measured*	Tier 3	11.3

[162] *Green Target Network Helps Zain Reduce Carbon Emissions and Mitigate Climate Change Impacts* (Huawei Digital Power, 2024), https://digitalpower.huawei.com/en/cases/site-power-facility/green-target-network.

[163] *Project Zero: Transforming Green Energy in Ghana* (MTN Group, 2025), https://www.mtn.com/case-study/project-zero-transforming-green-energy-in-ghana/.

[164] *stc Group Sustainability Report 2024: Environmental Section* (stc Group (Saudi Telecom Company), 2024), https://www.stc.com.sa/content/dam/groupsites/stc-sustainability-report-2024/assets/img/pdfs/Environmental_performance_and_climate.pdf.

[165] *Sustainability Report 2023* (e&, 2024), https://www.eand.com/content/dam/eand/assets/docs/latest-announcements/2024/eandSR23-English-compressed.pdf; e& Group, *GSMA Reports GCC Sustainability Innovation Hub's Renewables and Decarbonisation Progress*, https://www.eand.com/en/news/12-nov-gsma-reports-gcc-sustainability-innovation-hub-s-renewables-and-decarbonisation-progress.html.

Table 5.3: Network renewable energy cases (continued)

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	Jazz (VEON) and Huawei, solar power at network sites, Pakistan[166] case-437	1 000 telecom sites across Pakistan; deployment completed in April 2026	13 MW of solar capacity installed; projected 15 000 tCO_2 avoided a year *Measured and modelled*	Tier 3	12.0
Renewable generation and purchase agreements	Claro, distributed renewable generation programme, Brazil[167] case-051	85 renewable plants in 14 states, Brazil (mid-2023)	More than 500 000 tCO_2 avoided since 2017 from 200 MW of distributed generation (2023) *Measured*	Tier 3	14.0
	Telenor Norway and Hydro, wind power purchase agreement, Norway[168] case-080	Telenor's Norwegian operations; 10-year agreement signed in 2022 for power from the 42-turbine Stor-Skälsjön wind park in Sweden	Projected 330 GWh a year under the agreement, covering more than 86% of the power use of Telenor's Norwegian operations at signing *Modelled*	Tier 3	12.0
	Movistar Chile and ACCIONA, renewable power purchase agreement, Chile[169] case-439	Movistar Chile's telecommunications network	108 GWh a year of renewable electricity contracted, projected to avoid 42 400 tCO_2 a year (2021) *Modelled*	Tier 3	5.0

[166] *Jazz Powers 1,000 Sites with Solar in Collaboration with Huawei, Advancing Green Connectivity in Pakistan* (Huawei Technologies / VEON, 2026), https://www.huawei.com/en/news/2026/4/solar-jazzworld.

[167] *Energia da Claro: Programa de Geração Distribuída de Energia (Prêmio ECO AMCHAM 2023 Submission)* (Claro S.A. / AMCHAM Brasil Prêmio ECO, 2023), https://www.premioeco.com.br/projeto/energia-da-claro-programa-de-geracao-distribuida-de-energia/; *Claro alcança 200 MW em programa de geração de energia renovável* (Teletime, 2023), https://teletime.com.br/29/05/2023/claro-alcanca-200-mw-em-programa-de-geracao-de-energia-renovavel/.

[168] *Telenor and Hydro Sign Agreement for the Supply of Renewable Energy* (Telenor Group, 2022), https://www.telenor.com/media/newsroom/announcement/telenor-and-hydro-sign-agreement-for-the-supply-of-renewable-energy/.

[169] *ACCIONA to Supply Clean Energy to Movistar Chile* (Power Technology, 2021), https://www.power-technology.com/news/acciona-movistar-chile/.

Table 5.3: Network renewable energy cases (continued)

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	NBN Co, Fixed Wireless network optimization and renewable electricity target, Australia[170] case-063	Australia's national broadband network; energy-saving feature on 2 400 Fixed Wireless towers	80 GWh a year of renewable electricity contracted under a power purchase agreement (2023); Fixed Wireless network power use down 5%, estimated to avoid 850 tCO_2 a year (2024) *Measured and modelled*	Tier 3	12.0

5.2 Data centres

The 14 data centre cases work through two levers: making the facility itself more efficient, through cooling, power design, and water use, and connecting it to the wider energy system, through waste heat recovery, renewable power supply, and grid integration. Data centre efficiency metrics, such as power usage effectiveness (PUE) and water usage effectiveness (WUE), are among the most mature in the Greening Digital Technologies cases. Both are ratios, so the field is moving toward total measures: absolute energy and water use, the reuse of waste heat, and the share of renewable electricity, with server utilization, e-waste, and embodied carbon also increasingly in view. All 14 cases use the Optimizing pathway, and no other: each improves how a data centre uses energy or water, including the cases that reuse waste heat or buy renewable power.

Main finding: Data centre energy efficiency is now well reported and close to its practical limit. The lowest values come from cooling with outside air or water instead of mechanical chillers, and from cutting losses in the power supply. Across the 10 cases in the stocktake that report a measured PUE, the median is 1.24, meaning about 0.24 kWh goes on cooling, power conversion, and other overheads for every kWh used by the servers, with the middle half of cases between 1.16 and 1.30.[171] Water efficiency is improving too: Microsoft and Amazon Web Services (AWS) report water use per unit of electricity 39% and 52% better than in 2021. Saving water can raise energy use, and data centres in hot, humid climates, where many low- and middle-income countries are, need extra cooling: AWS's PUE ranges from 1.06 in Spain to 1.46 in Osaka. PUE, WUE, and renewable matching are rates or shares, so they cannot show whether

[170] *NBN Co Announces 100 Percent Renewable Electricity Target and Towards Zero Carbon Ambition* (NBN Co Limited, 2021), https://www.nbnco.com.au/corporate-information/media-centre/media-statements/nbn-co-announces-100-percent-renewable-electricity-target-and-towards-zero-carbon-ambition; *NBN Co Cuts Energy Use on Fixed Wireless Network by the Equivalent of Powering 200 Homes* (NBN Co Limited, 2024), https://www.nbnco.com.au/corporate-information/media-centre/media-statements/nbn-co-cuts-energy-use-on-fixed-wireless-network.

[171] The 10 cases and their PUE values, each the latest measured value, or the median of a case's sites: Digital Realty, ZUR2 Zurich, 1.10 (2026, case-241); Google, fleet average, 1.10 (2023, case-275); AWS, 1.15 (2024, case-511); Microsoft, 1.17 (fiscal year 2025, case-510); Hoyinn, 1.229 (2024, case-565); TELUS, 1.25 (2024, case-277); Huawei, Dongguan, 1.28 (2021, case-428); Africa Data Centres, 1.30 (2024, case-251); Equinix, 1.39 (2024, case-232); and Atos, 1.42, the median of Longbridge 1.16, Fürth 1.42, and Birmingham 1.508 (2022, case-150). Design values (Cobalt 1.12, Nautilus 1.15) are not included.

a data centre's total energy and water use is falling. Annual renewable matching has a further limit: it can hide the hours and places where data centres still run on carbon-intensive power. Reporting absolute electricity and water use and the reuse of waste heat on a comparable, measured basis, alongside hourly matching such as Google's, would show whether the footprint is falling.

Facility efficiency

Data centres now report PUE values close to 1.1 and near-zero water use. The best values come from single facilities or designs: Digital Realty's ZUR2 facility in Switzerland has a certified PUE of 1.1 and a WUE of 0 L/kWh, and Nautilus's floating data centre is designed for a PUE of 1.15 and an estimated WUE of 0 L/kWh. Across whole fleets the figures are higher but still low: AWS reports a PUE of 1.15 (2024) and a WUE of 0.12 L/kWh (2025), and Microsoft a PUE of 1.17 and a WUE of 0.27 L/kWh in its 2025 financial year (Table 5.4).

Cooling can account for more than 40% of the energy used by large data centres, and more in smaller ones,[172] and in these cases the lowest values come from cooling without mechanical chillers. Cobalt's design value of 1.12 rests on indirect air cooling, and Nautilus cools its servers with water drawn from the San Joaquin River through a heat exchanger and returned to it. AWS uses outside air about 90% of the time, has raised the operating temperature of its data centres to 85 °F (about 29 °C), and switches to evaporative cooling when temperatures rise.

Saving water and saving energy can pull against each other. Evaporative cooling consumes water, and Microsoft notes that replacing evaporative systems with mechanical cooling will increase its PUE. Since August 2024, all its new data centre designs circulate water in a closed loop to cool chips directly, consuming no water for cooling, and their warmer operating temperatures help limit the extra power use. Iron Mountain's AZP-2 data centre in Phoenix, Arizona, the first in North America with Building Research Establishment Environmental Assessment Method (BREEAM) design certification, is designed to use more than 50% less water than a conventional design. Location matters as well. Many low- and middle-income countries are in hot, humid climate zones, which need extra cooling and where some techniques, such as cooling with cold outside air, are not available.[173] AWS's figures for 2025 show a PUE of 1.11 across its European data centres and 1.25 across Asia Pacific (excluding China), with individual regions ranging from 1.06 in Spain to 1.46 in Osaka, and its highest WUE values are in Singapore (1.57 L/kWh) and Jakarta (2.85 L/kWh).

The power supply is the second source of savings: Alibaba Cloud's direct current (DC) uninterruptible power supply, rated above 97.5% efficiency as a complete unit, saves 8 514 MWh a year compared with a conventional supply.

The third source is tighter control of how the facility runs. Atos reached a PUE of 1.16 at Longbridge by applying 92 best practices from the European Code of Conduct for Data Centre Energy Efficiency, including using cold outside air to assist cooling, and its sites use AI to optimize cooling and keep the cold air supplied to servers separate from the hot air they expel (cold aisle containment). Huawei's AI system sets the cooling policy in real time, and Africa Data Centres uses a digital twin to find the server configurations that use the least power.

[172] ITU and World Bank, *Green Data Centers*.
[173] ITU and World Bank, *Green Data Centers*.

The building itself can also be lower-carbon. For its Dongguan data centre, Huawei had the core modules and systems built and tested in a factory and then assembled on site, which it reports cut carbon emissions during construction by 90%, and water use and construction waste by 80%.

These values rest on different evidence. Atos (Eviden) self-reports 1.16 at its best site, Huawei's modular data centre 1.28, and Africa Data Centres 1.3, while Digital Realty's ZUR2 facility has a certified 1.1, and Cobalt's 1.12 and Nautilus's 1.15 are the values their facilities were designed to achieve, not measured in operation. Accredited testing bodies, such as the China Telecommunication Technology Labs of the China Academy of Information and Communications Technology (CAICT), can give such figures an independent basis (Box 2).

Table 5.4: Data centre facility efficiency cases

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Cooling	Cobalt Data Centre 3, BREEAM Outstanding facility, United Kingdom[174] case-515	One data centre on the Cobalt campus in Newcastle, United Kingdom; the campus has an IT capacity of 15 to 20 MW	BREEAM Outstanding certification; design-stage estimated PUE 1.12 *Measured and modelled*	Tier 2	12.0
	Nautilus Data Technologies, floating data centre with river-flow cooling, United States[175] case-513	One floating data centre on a barge on the San Joaquin River, Port of Stockton, California (2021)	Design PUE 1.15 and WUE 0 L/kWh (estimated, 2021) *Modelled*	Tier 3	9.0
	Amazon Web Services, global data centre fleet, United States[176] case-511	AWS global data centre fleet; recycled water used for cooling at 24 data centres (2025)	Fleet WUE 0.12 L/kWh (2025), 52% better than in 2021; PUE 1.15 (2024) *Measured*	Tier 3	10.0

[174] *Cobalt Data Centre Obtains BREEAM 'Outstanding' Award* (BRE Group (Building Research Establishment), 2022), https://bregroup.com/case-studies/cobalt-data-centre-3-breeam-outstanding; *Cobalt Cements Greenest Data Centre Accolade with Prestigious BREEAM Award* (Digitalisation World, 2013), https://web.archive.org/web/20260412163807/https://digitalisationworld.com/news/26468/cobalt-cements-greenest-data-centre-accolade-with-prestigious-breeam-award.

[175] *Stockton Data Center: Nautilus Data Technologies* (Nautilus Data Technologies, 2021), https://nautilusdt.com/stockton-data-center/.

[176] *Water Stewardship, Amazon Sustainability* (Amazon, 2025), https://sustainability.aboutamazon.com/natural-resources/water; *Amazon Web Services, AWS Cloud: Sustainable Cloud Computing*; *Amazon Claims Its Data Centers Are 7x More Water-Efficient Than the Industry Average* (Network World, 2026), https://www.networkworld.com/article/4184250/amazon-claims-its-data-centers-are-7x-more-water-efficient-than-the-industry-average.html.

Table 5.4: Data centre facility efficiency cases (continued)

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	Microsoft, global data centre fleet, United States[177] case-510	Microsoft's global data centre fleet; zero-water cooling design to be piloted in Phoenix, Arizona, and Mt. Pleasant, Wisconsin, in 2026	Fleet PUE 1.17 and WUE 0.27 L/kWh (financial year 2025); WUE 39% below the 2021 baseline by 2024 *Measured*	Tier 3	12.0
Power supply	Alibaba Cloud, 10 kV AC-input DC uninterruptible power supply, China[178] case-429	One new-build cloud data centre in East China with 1 000 racks at a design load of 12 kW per rack	8 514 MWh saved a year in an East China cloud data centre (2021) *Measured*	Tier 2	15.0
Whole-facility programmes and design	Atos (Eviden), data centres, United Kingdom and Germany[179] case-150	Atos data centres and offices; Longbridge and Birmingham (United Kingdom) and Fürth (Germany) facilities; 92 best practices applied at Longbridge	32% cumulative energy reduction (2019 to 2022); PUE 1.16 at Longbridge, 1.42 at Fürth, and 1.508 at Birmingham (2022) *Measured*	Tier 3	14.0

[177] *Measuring Energy and Water Efficiency for Microsoft Datacenters* (Microsoft Corporation, 2025), https://datacenters.microsoft.com/sustainability/efficiency/; Microsoft Corporation, *Sustainable by Design: Next-Generation Datacenters Consume Zero Water for Cooling* (2024), https://www.microsoft.com/en-us/microsoft-cloud/blog/2024/12/09/sustainable-by-design-next-generation-datacenters-consume-zero-water-for-cooling/.

[178] *National Communications Industry Energy-Saving Technology Products Application Guide and Cases (2021), Part 3: High-Efficiency Power Distribution for Green Data Centers* (Ministry of Industry and Information Technology (MIIT), 2021), https://www.miit.gov.cn/jgsj/jns/gzdt/art/2021/art_f601a266dba44fddb0be2e01bff336b2.html.

[179] *Atos Awarded by the European Union for the Energy Efficiency of Its Data Centers in the UK and Germany* (Atos SE / Eviden (atosgroup.com), 2023), https://www.atosgroup.com/en/press/atos-awarded-by-the-european-union-for-the-energy-efficiency-of-its-data-centers-in-the-uk-and-germany; *The EU Code of Conduct for Data Centres: Towards More Innovative, Sustainable and Secure Data Centre Facilities* (European Commission Joint Research Centre, 2023), https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/eu-code-conduct-data-centres-towards-more-innovative-sustainable-and-secure-data-centre-facilities-2023-09-05_en.

Table 5.4: Data centre facility efficiency cases (continued)

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	Africa Data Centres, IoT digital twin and solar power purchase agreement, South Africa[180] case-251	South African facilities of an operator that also runs data centres in Kenya and Nigeria; long-term solar power purchase agreement with Distributed Power Africa	PUE 1.3 at one facility (2024, company-reported); solar agreement for a projected 12 MW (2023) *Measured and modelled*	Tier 3	9.0
	Huawei, prefabricated modular data centre with AI cooling control, China[181] case-428	One cloud data centre, Dongguan T1, China, in operation since 2019	Annual PUE 1.28 (2021); construction-phase carbon emissions 90% lower *Measured*	Tier 3	14.0
	Digital Realty, ZUR2 data centre, Switzerland[182] case-241	One data centre, ZUR2 in Glattbrugg; first data centre globally to receive SDEA Platinum Plus certification (May 2026)	Certified PUE 1.1, CUE 0.02 kg CO_2e/kWh, and WUE 0 L/kWh (2026); global renewable coverage 75% (2024) *Measured*	Tier 3	13.0
	Iron Mountain, AZP-2 data centre with BREEAM design certification, United States[183] case-514	One 48 MW data centre in Phoenix, Arizona, the first in North America with BREEAM design certification (2022)	BREEAM Excellent design; water use more than 50% below a conventional design (2022) *Modelled*	Tier 3	10.0

[180] *How Data Centres Are Battling South Africa's Energy Crisis* (TechCentral, 2024), https://techcentral.co.za/data-centres-south-africa-energy-crisis/239869/; *Africa Data Centres and Distributed Power Africa Work Together to Reach Sustainable Development Goals* (Africa Data Centres, 2023), https://www.africadatacentres.com/africa-data-centres-and-distributed-power-africa-work-together-to-reach-sustainable-development-goals/.

[181] *Huawei Dongguan Cloud Data Center Is Selected as a Typical Application Case of Key Energy-Saving Technologies* (Huawei Digital Power, 2022), https://digitalpower.huawei.com/en/news/data-center-facility/265.

[182] *Platinum Plus Certification for Data Center ZUR2 from Digital Realty* (Organisator, 2026), https://www.organisator.ch/en/operational-excellence/2026-05-11/platinum-plus-zertifizierung-fuer-rechenzentrum-zur2-von-digital-realty/; Digital Realty Published 2024 Impact Report, *Highlighting Advancements in Sustainability Goals* (Digital Realty Trust (PR Newswire), 2025), https://www.prnewswire.com/news-releases/digital-realty-published-2024-impact-report-highlighting-advancements-in-sustainability-goals-302494776.html.

[183] *Iron Mountain Advances Sustainable Data Centers with BREEAM Certifications* (BRE Group, 2025), https://bregroup.com/case-studies/iron-mountain-advances-sustainable-data-centers-with-breeam-certifications.

Box 2: China Telecommunication Technology Labs of CAICT: testing and verification for green ICT

The China Academy of Information and Communications Technology (CAICT), formerly the Telecommunication Research Institute of the Ministry of Industry and Information Technology (MIIT), runs the China Telecommunication Technology Labs (CTTL). Its System Laboratory, set up in 2014, is accredited by China's national accreditation body (CNAS) to ISO/IEC 17025, 17020, and 17043, and is authorized by China's market regulator as a statutory metrology body: it serves as the national communications metrology station, the telecommunications industry's highest-level laboratory for calibrating and verifying measuring instruments. Its testing covers ICT equipment, networks and applications, and new energy, including energy-saving and environmental assessment.[1]

For green ICT, CTTL-systems offer green data centre evaluation, data centre energy-saving assessment, and testing of power supply, battery, photovoltaic, and air-conditioning equipment. CAICT carried out an MIIT study of the energy-saving potential of the information and communications sector during the 14th Five-Year Plan period, and it led the ITU-T work item on best practices for ICT technologies that promote carbon neutrality.[2]

Why it matters: accredited testing and assessment give governments and buyers an independent basis for checking the energy and carbon claims that most cases in this stocktake report themselves. Although CAICT's testing platform is not one of the 150 cases, the capabilities can progress sophisticated improvement for both green digital solutions as well as greening *by* digital solutions.

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1 CAICT, *China Telecommunication Technology Labs (in Chinese, n.d.)*, https://www.caict.ac.cn/wygk/zzjg/201804/t20180428_161091.htm (retrieved 9 October 2026).
2 CAICT TTL, *China Telecommunication Technology Labs brochure (in Chinese)* (2022).

Connection to the wider energy system

Data centres can also act as energy-system assets, by supplying waste heat to district heating networks, buying renewable power, and integrating with the grid. PUE does not capture these roles, because they reach beyond the facility it measures (Table 5.5).

Renewable matching needs the closest reading, because most claims are annual totals. Of Equinix's 96% coverage in 2023, 10 percentage points came through power purchase agreements, 46 from renewable energy certificates bought separately from the electricity, and 40 from certificates bundled with utility supply. So most of the 96% rests on certificates, which show that renewable power was produced somewhere but do not change the electricity the data centres draw from the grid. Google has matched 100% of its annual electricity use with renewables since 2017, but on the grids its data centres draw from, carbon-free energy averaged 64% in 2023.[184] The rest came from other sources of grid power, even though the annual total was matched. Hoyinn instead reports an absolute figure: 262 352 MWh of renewable electricity and certificates in 2024, 18.25% of its supply. Absolute figures like this show how much of the electricity used is clean, and how much is not.

Waste heat can become a local energy supply. LUMI, one of the world's most powerful supercomputers, at the CSC data centre in Kajaani, Finland, recovers its heat through liquid cooling, and heat pumps raise the water temperature for the town's district heating network;

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184 *Google's 2024 Environmental Report* (Google, 2024), https://blog.google/company-news/outreach-and-initiatives/sustainability/2024-environmental-report/.

CSC expected it to supply about 20% of Kajaani's district heat. DigiPlex shows that an operating data centre can be adapted: its Stockholm facility, cooled by indirect air, was, according to DigiPlex, the first operational data centre with this type of cooling to undertake a heat-recovery retrofit on such a large scale, under a 2018 agreement designed to heat 10 000 households. In Stockholm Exergi's model, heat pumps cool the data hall instead of a cooling machine, so the heat goes into the district heating network rather than a cooling tower.[185]

Table 5.5: Data centre energy-system connection cases

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Waste heat recovery	CSC, LUMI supercomputer waste heat for district heating, Finland[186] case-380	One supercomputer at the CSC data centre in Kajaani, Finland, feeding the district heating network of the local energy company	Projected to supply 20% of local district heat and cut the town's carbon footprint by 12 400 tCO_2e a year *Modelled*	Tier 3	11.5
	DigiPlex, data centre waste heat for district heating, Sweden and Norway[187] case-237	Data centres in Stockholm (an operating facility being retrofitted for heat recovery with Stockholm Exergi) and Oslo (Ulven campus, with Fortum Oslo Varme)	Heat recovery designed to heat 10 000 households in Stockholm and 5 000 apartments in Oslo (2018 agreements) *Modelled*	Tier 3	10.0

[185] *Heat Recovery* (Stockholm Exergi, 2024), https://www.stockholmexergi.se/en/heat-recovery/.

[186] *LUMI One of the Greenest Supercomputers in the World* (CSC, IT Center for Science Ltd, 2022), https://lumi-supercomputer.eu/lumi-one-of-the-greenest-supercomputers-in-the-world/.

[187] *DigiPlex Data Center to Heat 10 000 Stockholm Households* (Stockholm Data Parks, 2018), https://stockholmdataparks.com/2018/03/12/digiplex-data-center-heat-10000-stockholm-households/; *DigiPlex Data Center Will Help Keep Oslo Warm* (Data Center Dynamics, 2018), https://www.datacenterdynamics.com/en/news/digiplex-data-center-will-help-keep-oslo-warm/; *DigiPlex Innovative Heat Reuse Solution Named Renewable Technology of the Year at Energy Awards* (DigiPlex, 2018), https://www.prnewswire.com/news-releases/digiplex-innovative-heat-reuse-solution-named-renewable-technology-of-the-year-at-energy-awards-300761872.html.

Table 5.5: Data centre energy-system connection cases (continued)

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Renewable power and grid integration	Equinix, global data centre portfolio, United States[188] case-232	Global colocation portfolio; power purchase agreements totalling 1 472 MW (2025)	Global average PUE 1.39 (2024); renewable coverage 96% (2023); of the 96 percentage points, 10 through power purchase agreements, 46 from certificates bought separately from the electricity, and 40 from certificates bundled with utility supply (2023) *Measured*	Tier 2	14.0
	Hoyinn Technologies, generation-grid-load-storage integration at the Huailai campus, China[189] case-565	Huailai campus in Zhangjiakou, Hebei; about 500 MW of data centre load built by 2024	Company-wide (data centre area and Beijing office): 262 352 MWh of renewable electricity and certificates consumed, a green electricity share of 18.25% (2024); average annual PUE 1.229 (2024) *Measured*	Tier 3	9.0

5.3 User devices

The 16 user device cases address the two sources of a device's footprint: the energy it uses in operation, and the emissions from manufacturing it. For smartphones, and probably other portable devices, manufacturing is the larger share, so the levers that act on manufacturing come first.

The first is to keep devices in use for longer, through repair, refurbishment, and reuse, which spreads each device's manufacturing emissions over more years. A device that is slightly more efficient but replaced sooner may therefore have a larger lifetime footprint than a less efficient one kept longer. The second is to cut manufacturing emissions directly, by disclosing lifecycle impacts and helping suppliers switch to clean energy. Energy efficiency in use matters most for equipment plugged in for many hours a day, such as displays, game consoles, and medical

[188] *Equinix Releases Annual Sustainability Report, Highlighting Advancements in Environmental, Social and Governance (ESG) Goals* (Equinix, 2024), https://investor.equinix.com/news-events/press-releases/detail/1037/equinix-releases-annual-sustainability-report-highlighting; Equinix, *Equinix 2025 Sustainability Data Summary*, https://delivery-p112322-e1154416.adobeaemcloud.com/adobe/assets/deliver/urn:aaid:aem:39ee2b33-ca04-460f-a97b-1e92ef62ec05/Equinix-Inc_2025_Data-Summary.pdf.

[189] *Hoyinn 2024 Sustainability Report (TÜV Rheinland AA1000AS V3 Assured)* (Beijing Hoyinn Technologies Co., Ltd., 2025), https://www.hoyinn.com/nci/template/pdf/Hoyinn-Sustainability-Report2024.pdf.

imaging systems, where use is still a large share of the footprint. Collection and recycling deal with devices at the end of their life.

The cases fall into four groups: device lifecycle, refurbishment and reuse, device energy efficiency, and e-waste and extended producer responsibility. Keeping devices in use longer is Dematerializing, which appears in 8 of the 16 cases because it avoids making new devices, and Optimizing appears in 6 (cases can use more than one pathway).

Main finding: Manufacturing, not use, dominates the footprint of smartphones, and likely of other portable devices, so the strongest levers act before and after use, through cleaner manufacturing, longer lifetimes, and refurbishment. Apple reports that its supply-chain emissions reduction efforts on materials, electricity, and transport abated more than 2.7 million tCO_2e in 2023, using the Fairphone 4 for 5 years instead of 3 gives it a modelled 31% lower annual footprint, and Swappie estimates a 78% lower footprint for each refurbished iPhone. Refurbishment already operates at scale: Back Market reports more than 2 million tCO_2e avoided across 17 million customers. Use-phase efficiency still matters for equipment that runs for long hours, such as consoles and displays: interventions such as more energy-efficient game code and energy saver modes on Xbox consoles are estimated to have avoided over 1.2 million tCO_2e from fiscal years 2020 to 2023. Most reported device savings are modelled, many from per-device lifecycle estimates, and refurbishment savings rest on two assumptions that sales figures cannot show: how long the device is used, and whether it replaces a new purchase. Less than a quarter of the world's e-waste, 22.3% in 2022, was documented as properly collected and recycled. Digital systems that register producers and monitor their compliance, such as the service being developed in Rwanda to monitor extended producer responsibility (EPR), could help raise that share, but no case has yet measured their effect on collection.

Device lifecycle

Lifecycle assessments show where a device's carbon comes from, and the cases in this group act on the largest part: they keep devices in use for longer, or cut the emissions of manufacturing them, including through clean energy for suppliers (Table 5.6).

The lifecycle assessments in this group agree on where the carbon is: production accounts for an estimated 83% of the iPhone 15 Pro's footprint and 85.3% of the Galaxy S23 Ultra's 70.6 kg CO_2e. That is why the Fairphone 4 assessment finds a modelled 31% lower annual footprint from 5 years of use instead of 3. All three are per-device models, built on assumed device lifetimes rather than observed ones.

Apple's more than 2.7 million tCO_2e abated through its supply-chain reduction efforts in 2023 is measured and company-reported. Apple attributes its emission reductions to more renewable electricity in its supply chain and more recycled content, and reports that it and its suppliers have worked to triple the renewable electricity in its supply chain. Samsung reports that renewable energy covered 31.4% of its consumption in 2024, and 93.4% in its device division.

Table 5.6: Device lifecycle cases

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Lifespan extension	Fairphone, Fairphone 4 lifecycle assessment by Fraunhofer IZM, Netherlands[190] case-023	One smartphone model (Fairphone 4); use periods of 3, 5, and 7 years compared	Modelled 31% lower annual carbon footprint from 5 instead of 3 years of use, and 44% from 7 years with two battery replacements *Modelled*	Tier 2	10.5
Product lifecycle disclosure	Apple, iPhone 15 Pro product environmental report, United States[191] case-500	One smartphone model (iPhone 15 Pro, 128 GB) and the iPhone 15 lineup; cradle-to-grave assessment under ISO 14040/44	Estimated 83% of the lifecycle footprint from production; iPhone 15 lineup an estimated 5.6 kg CO_2e per device lower than the iPhone 14 series (2023); lifecycle footprint of 66 kg CO_2e (iPhone 15 Pro, 128 GB) *Modelled*	Tier 3	10.5
	Samsung, Galaxy S23 Ultra PAS 2050 lifecycle footprint, Republic of Korea[192] case-501	Galaxy S23, S24, and S25 Ultra smartphone models; Carbon Trust PAS 2050 assessments for the S23 and S24 Ultra, and Samsung's own ISO 14067 assessment for the S25 Ultra	Modelled lifecycle footprint of 70.6 kg CO_2e, 85.3% from production (2023); 48.9 kg CO_2e for the Galaxy S25 Ultra (2025), under a different method, so not directly comparable *Modelled*	Tier 2	11.0

[190] *Keeping Phones for 5 Years Cuts Yearly Impact on Global Warming* by Around 31% (Fraunhofer IZM, 2022), https://www.izm.fraunhofer.de/en/news/keeping-phones-for-5-years-cuts-yearly-impact-on-global-warming.html.

[191] *iPhone 15 Environmental Report Reviewed* (Compare and Recycle, 2023), https://www.compareandrecycle.co.uk/blog/iphone-15-environmental-report; *iPhone 15 Pro and iPhone 15 Pro Max Product Environmental Report* (Apple Inc., 2023), https://www.apple.com/environment/pdf/products/iphone/iPhone_15_Pro_and_iPhone_15_Pro_Max_Sept2023.pdf.

[192] *Samsung Galaxy S23 Series Sustainability Efforts Taken to New Heights* (Hitech Century, 2023), https://hitechcentury.com/samsung-galaxy-s23-series-sustainability/; *Galaxy S23 Ultra Product Environmental Report* (Samsung Electronics, 2023), https://www.samsung.com/global/sustainability/media/pdf/Galaxy_S23_Ultra_Environmental_Report_EN_230201.pdf; *Galaxy S25 Ultra Product Environmental Report* (Samsung Electronics, 2025), https://www.samsung.com/global/sustainability/landing_hub-file/AZUXQdtKImgALYMV/Galaxy_S25_Ultra_Environmental_Report_EN_2503.pdf; *Galaxy S24 Ultra Product Environmental Report* (Samsung Electronics, 2024), https://www.samsung.com/global/sustainability/media/pdf/Galaxy_S24_Ultra_Environmental_Report_EN.pdf.

Table 5.6: Device lifecycle cases (continued)

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Cleaner manufacturing	Apple, Supplier Clean Energy Program, United States[193] case-507	Apple's manufacturing supply chain; clean energy commitments cover 90% of direct manufacturing spend (2023)	More than 2.7 $MtCO_2e$ of supply-chain emissions abated through Apple's supply-chain reduction efforts on materials, electricity, and transport (2023, company-reported) *Measured*	Tier 3	12.0
	Samsung Electronics, renewable energy in electronics manufacturing, Republic of Korea[194] case-067	Samsung Electronics' global operations, including semiconductor and device manufacturing	Renewable energy 31.4% of total consumption company-wide and 93.4% in the device division (2024) *Measured*	Tier 3	11.7

Refurbishment and reuse

Refurbishment keeps devices in use for longer by giving them a second owner, and it now operates at scale through marketplaces, specialist refurbishers, and mobile operators. The room to grow is large: in Europe, only 25% of pre-owned smartphones are resold, according to the European Investment Bank[195] (Table 5.7).

Back Market, a marketplace for refurbished electronics, reports more than 2 million tCO_2e avoided to 2025 across 17 million customers in 17 markets. Swappie, Europe's largest iPhone refurbisher, estimates that a refurbished phone has a 78% lower carbon footprint than a new one, and that its customers avoided 23 550 tCO_2e in 2021. In South Africa, Vodacom sold more than 60 000 refurbished devices in 2023 through its Good as New programme, which also aims to make mobile devices more affordable, and in the Russian Federation, MTS restored 440 800 customer devices in 2023 with its partner SuperWave. Trust is what lets the market grow: Swappie offers warranties of as long as 3 years because, its founder says, most people do not trust refurbished phones, and Vodacom vets and certifies its partners, regularly tests the devices they supply, and sells its Good as New devices with a warranty.

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193 *More Than 300 Apple Suppliers Have Committed to Clean Energy* (Supply Chain Dive, 2023), https://www.supplychaindive.com/news/apple-suppliers-clean-energy-scope-3-carbon-neutral-products/693980/ ; Lamar Johnson, *Apple Reports It's Halved Emissions Since 2015 for Goal of Carbon Neutrality by 2030* (ESG Dive, 2024), https://www.esgdive.com/news/apple-2023-environmental-reports-emissions-halved-since-2015-carbon-neutral-esg/713873/.

194 *Climate Action* (Samsung Electronics, 2026), https://www.samsung.com/global/sustainability/planet/climate-action/.

195 *Finnish Company Refurbishes Smartphones to Cut Carbon Emissions* (European Investment Bank, 2024), https://www.eib.org/en/stories/finland-refurbishing-smartphone-critical-raw-materials.

Digital product passports could strengthen that trust further. Recommendation ITU-T L.1071, approved in 2024, sets out a model for the sustainability and circularity information that a digital product passport carries;[196] ITU's guide to circular public procurement of ICT equipment suggests that buyers specify product data sheets or digital product passports where available.[197] By giving buyers verified information about a device, such passports could become a key tool for trust in second-life devices.

Table 5.7: Device refurbishment and reuse cases

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Operator refurbishment programme	Vodacom, Good as New refurbished devices, South Africa[198] case-576	South Africa and other Vodacom markets; refurbished smartphones, modems, routers, tablets, and notebooks	More than 60 000 Good as New products sold (2023); an ADEME study cited by GSMA estimates that a refurbished phone used for 2 years emits 24.6 kg CO_2e a year less than a new phone used for 3 *Measured and modelled*	Tier 3	10.0
	MTS, device refurbishment and e-waste recovery, Russian Federation[199] case-069	MTS Group facilities; customer equipment restored with its partner SuperWave	440 800 customer devices restored and over 1 800 tonnes of recyclables collected for processing (2023) *Measured*	Tier 3	10.0
Refurbished device marketplaces	Back Market, refurbished electronics marketplace, France[200] case-474	Online marketplace founded in Paris in 2014, selling certified refurbished smartphones, laptops, desktops, and tablets	More than 2 000 000 tCO_2e avoided cumulatively to 2025 (estimated), using ADEME per-device lifecycle factors (company-reported) *Modelled*	Tier 3	12.0

196 ITU, Recommendation ITU-T L.1071: *A Model for Digital Product Passport Information on Sustainability and Circularity* (Geneva: ITU, 2024), https://www.itu.int/rec/T-REC-L.1071-202411-I.

197 ITU, *Circular and Sustainable Public Procurement*.

198 *Vodacom 'Good as New' Devices Program: Raising Awareness in Africa* (GSMA, 2023), https://www.gsma.com/solutions-and-impact/connectivity-for-good/external-affairs/gsma_study/vodacom-good-as-new-devices-program-raising-awareness-in-africa/.

199 *MTS PJSC Annual Report 2023: ESG and Sustainable Development* (MTS PJSC, 2023), https://storage.ir.mts.ru/mts-ir/images/documents/4%20Annual%20Report_2023.pdf.

200 *Back Market Enters New Phase of Growth as Demand for Sustainable Tech Accelerates (Back Market, 2025),* https://www.backmarket.com/en-us/c/press-release/2025-business-growth; ADEME, *Assessment of the Environmental Impact of a Set of Refurbished Products* (ADEME, 2022), https://librairie.ademe.fr/economie-circulaire-et-dechets/5833-assessment-of-the-environmental-impact-of-a-set-of-refurbished-products.html.

Table 5.7: Device refurbishment and reuse cases (continued)

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
	Swappie, refurbished iPhones, Finland[201] case-152	Refurbished iPhones sold by a Finnish refurbisher operating since 2016	Estimated 78% lower footprint per refurbished iPhone than a new one, and 23 550 tCO_2e avoided in 2021 (estimated); assuming that about 60% of sales replaced a new purchase *Modelled*	Tier 3	11.7

Device energy efficiency

Energy efficiency in use is the main lever for displays, game consoles, and other equipment plugged in for many hours a day, where use remains a large share of the footprint. It works through mandatory standards and through product design. The EU Ecodesign and Energy Labelling measures for electronic displays are the only efficiency standard among the device cases, and the console makers and Philips show what product design can do (Table 5.8).

The European Commission estimates that the EU Ecodesign and Energy Labelling measures saved 20 terawatt-hours (TWh) of electricity in 2020 across about 522 million displays in use in the EU, rising to a projected 51 TWh in 2030. Both are the European Commission's modelled estimates, not measured savings. The savings are expressed in electricity, not carbon, so they cannot be set against the tCO_2e results in the other device tables.

Product design also cuts the energy devices use. Sony estimates that PlayStation 5 uses about 80% less power in suspend mode than PS4 models, and Philips estimates that its AI-accelerated magnetic resonance imaging (MRI) scanning cuts power use per patient scan by 32% on average on two scanner models. Microsoft estimates that energy-saving measures on Xbox consoles avoided over 1.2 million tCO_2e from fiscal years 2020 to 2023, compared with use without them. Game studios used the Xbox Sustainability Toolkit, whose power dashboards and console telemetry show developers how much energy their games use, to cut that use in ways players do not notice, as in Halo Infinite and Call of Duty, while players opted into an energy-saving shutdown mode. Since 2023, Xbox consoles have also been carbon aware: when regional carbon intensity data are available, a console in energy-saving mode downloads game, app, and system updates at the point in its nightly maintenance window when the local grid has the highest share of low-carbon electricity, rather than at a random time.

[201] *Swappie Environmental Impact Report 2021* (Swappie, 2021), https://assets.swappie.com/Swappie_Environmental_Impact_Report_2021.pdf.

Table 5.8: Device energy efficiency cases

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Mandatory standards	European Commission, Ecodesign and Energy Labelling for electronic displays, European Union[202] case-468	EU27 market; an estimated 522 million electronic displays in use (2020)	Estimated electricity savings of 20 TWh a year in 2020, projected to reach 51 TWh a year by 2030 *Modelled*	Tier 2	13.0
Product design	Sony Interactive Entertainment, PlayStation 5, Japan[203] case-371	PlayStation 5 consoles sold worldwide since November 2020	Suspend-mode power an estimated 80% lower than PS4 models; overall energy use an estimated 11% to 17% lower than the 2013 PS4 launch model *Modelled*	Tier 3	11.0
	Philips, AI-powered SmartSpeed MRI, Netherlands[204] case-182	Philips MRI systems worldwide; more than 1 500 BlueSeal installations (2025)	Estimated average power reduction per patient scan of 32% (2025) *Modelled*	Tier 3	9.0
	Microsoft, carbon-aware Xbox consoles, United States[205] case-024	Xbox consoles in use, FY2020 to FY2023; carbon-aware downloads and energy saver modes	Over 1.2 $MtCO_2e$ avoided from FY2020 to FY2023 compared with usage without interventions (company-reported) *Modelled*	Tier 3	11.5

[202] European Commission, *Electronic Displays: Energy Efficient Products Portal*https://energy-efficient-products.ec.europa.eu/product-list/electronic-displays_en; European Commission, *Commission Regulation (EU) 2019/2021 of 1 October 2019 Laying down Ecodesign Requirements for Electronic Displays* (Brussels: European Commission, 2019), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R2021.

[203] *PlayStation 5 and Its Energy Efficiency* (Sony Interactive Entertainment (SIE), 2021), https://sonyinteractive.com/en/news/blog/playstation-5-and-its-energy-efficiency/.

[204] *Philips Accelerates Precise Imaging with Unique AI Technologies in MRI to Improve Patient Outcomes* (Philips, 2025), https://www.philips.com/a-w/about/news/archive/standard/news/press/2025/philips-accelerates-precise-imaging-with-unique-ai-technologies-in-mri-to-improve-patient-outcomes.html; *Sustainability in MR* (Philips USA, 2026), https://www.usa.philips.com/healthcare/technology/sustainability-in-mri.

[205] Microsoft Game Dev, *A Progress Update on Our Carbon Reduction Goals at Xbox*; *Xbox Is Now the First Carbon Aware Console, Update Rolling Out to Everyone Soon* (Xbox/Microsoft, 2023), https://news.xbox.com/en-us/2023/01/11/xbox-carbon-aware-console-sustainability/.

E-waste and extended producer responsibility

EPR makes the companies that sell electronics responsible for financing the collection, recycling, and disposal of their products at end of life, and digital registration and compliance systems make it workable. The Global E-waste Monitor 2024 measures the scale of the task: 62 million tonnes of e-waste were generated in 2022, only 22.3% was documented as properly collected and recycled, and formal management avoided an estimated 93 million tonnes of CO_2e (Table 5.9).

Rwanda shows how such a system is built. The country generated 10 000 tonnes of e-waste in 2022, of which only 20% was formally collected and recycled. Under a project with the Government of Rwanda and Saudi Arabia's Communications, Space and Technology Commission (CST), ITU is helping to set up a producer responsibility organization, run by the Business Research Council of the Private Sector Federation, through which the country's roughly 2 500 electronics producers (importers and distributors) meet their obligations together. The collection and recycling system is already in place: Enviroserve Rwanda, which runs 27 collection points across the country, reports more than 8 500 tonnes of e-waste collected and recycled since 2018, which it estimates prevented over 7 300 tonnes of CO_2 emissions, and about half of the 10 000 computers it processes each year are refurbished, mainly for schools, which have received more than 5 000 so far.

Table 5.9: E-waste and extended producer responsibility cases

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
E-waste monitoring and statistics	ITU and UNITAR, Global E-waste Monitor 2024, global[206] case-021	Global; e-waste generation and formal collection statistics for 2022, with projections to 2030	22.3% of e-waste formally collected and recycled in 2022; formal management avoided an estimated 93 $MtCO_2e$ *Measured and modelled*	Tier 2	10.0
Digital extended producer responsibility	ITU, Saudi Arabia's CST, and national partners, digital EPR compliance monitoring, Rwanda[207] case-099	Rwanda, one of three project countries; 10 000 tonnes of e-waste generated a year (2022 baseline)	Digital EPR services planned, not yet in use, so no outcome yet; Enviroserve has collected and recycled more than 8 500 tonnes of e-waste since its establishment *No outcome yet*	Tier 2	11.0

[206] International Telecommunication Union and United Nations Institute for Training and Research, *Global E-waste Monitor 2024*https://ewastemonitor.info/the-global-e-waste-monitor-2024/.

[207] *Actively Engaging Rwanda's Private Sector in e-Waste* Management: ITU Digital Impact Unlocked; Rwandans Urged to Stop Storing E-waste at Home as Health Risks Mount (Top Africa News, 2026), https://www.topafricanews.com/2026/05/01/rwandans-urged-to-stop-storing-e-waste-at-home-as-health-risks-mount/.

5.4 Software

Software determines how efficiently physical infrastructure is used. The four software cases work through two levers that mostly use existing infrastructure and need little capital investment from the user. The first is changing where and on what hardware workloads run, through carbon-aware scheduling (moving work that can wait to the hours when electricity is cleaner) and ARM-architecture processor migration. The second is measuring the emissions of workloads, which is the precondition for managing them. In pathway terms, the first lever is Optimizing, which appears in three of the four cases, and the second is Monitoring (one).

Main finding: Software can cut the carbon of computing without changing what users see, through the choice of processor and the timing of workloads. New Relic, the one case that reports a reduction for the workloads it changed, estimates 37% lower CO_2e for the more than 700 services it moved to Graviton, the energy-efficient server processors that Amazon Web Services designs for its cloud. Timing also matters: in a UBS pilot, the grid carbon intensity for a sample batch job was 642 g CO_2e per kWh in the cleanest time window, against 710 g for a past run, and Google schedules flexible tasks to the hours with cleaner power across its data centres. The tools to measure software emissions already run at production scale: CodeCarbon has been downloaded more than 4 million times, and in a peer-reviewed study it measured 914 kWh and 340 kg CO_2e for 230 768 requests to the BLOOM large language model. Two gaps remain: no case yet reports how the absolute emissions of AI and cloud workloads change as a result of a specific intervention, separately from other changes, and the cases use different units, which the Software Carbon Intensity standard (ISO/IEC 21031) is designed to replace with a common one.

Cloud workload efficiency

Choices made by software teams, such as which processor architecture a workload runs on and when it is scheduled, can cut the carbon of cloud computing without the customer buying new hardware. Of the three cases, one reports a reduction for the workloads it migrated, one shows the effect on a sample run, and one reports its company-wide clean energy share (Table 5.10).

Each result has a defined scope. New Relic's 37% lower CO_2e applies to the more than 700 services, 64% of its workloads, that it moved to Graviton. Each day, Google's Carbon-Intelligent Computing System compares a forecast of the local grid's hourly carbon intensity with a forecast of each data centre's computing demand, and moves tasks that can wait, such as YouTube video processing or adding words to Google Translate, to the hours with the most low-carbon power. It needs no extra hardware and does not affect services such as Search and Maps. Google has published the method but not yet the resulting emission reduction, and its 64% hourly carbon-free energy reflects all of its clean energy measures. Xbox applies the same idea to home consoles, scheduling updates for the hours with the cleanest power (Section 5.3). The UBS pilot found 642 g CO_2e/kWh in the cleanest time window for one sample batch job, against 710 g for a past run, and the jobs themselves were not yet being delayed. The absolute emissions of the affected workloads, not yet reported by any of the three, would show the full effect.

Table 5.10: Cloud workload efficiency cases

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Processor architecture migration	New Relic, migration to AWS Graviton processors, United States[208] case-272	More than 700 services migrated over 15 months, 64% of workloads by July 2024	37% lower CO_2e for migrated workloads (2024, estimated) *Modelled*	Tier 3	11.0
Carbon-aware workload scheduling	Google, Carbon-Intelligent Computing System, global[209] case-275	Google's global data centre fleet; shifts temporally flexible tasks such as YouTube video processing, Google Photos filter features, and Google Translate updates	A global average of 64% carbon-free energy across Google's operations (2023), reflecting all of Google's clean energy measures, not this system alone *Measured*	Tier 3	10.5
	UBS and Green Software Foundation, carbon-aware time-shifting of Azure batch workloads, Switzerland[210] case-188	Azure Batch workloads at UBS; minimum viable product identifying the lowest-carbon time within a 24-hour window, with jobs not yet delayed	Grid carbon intensity of a sample workload from 710 g CO_2e/kWh to 642 g CO_2e/kWh in the optimal window (2023) *Measured*	Tier 2	8.0

Software emissions measurement

Before the emissions of software can be cut, they have to be measured, and open-source tools now do this for AI and other computing workloads (Table 5.11).

CodeCarbon, an open-source Python library developed by Mila, DataForGood, BCG GAMMA, Comet.ml, and Haverford College, runs alongside a programme and estimates its emissions while it runs: it tracks the power drawn by the processors, graphics processors, and memory, and multiplies it by the carbon intensity of the electricity grid where the computing takes place. It has been downloaded more than 4.29 million times since its launch in December 2020, including 144 678 times in the 30 days to 7 October 2026. In an independent peer-reviewed comparison, its estimates came closest to wattmeter readings among the tools tested, at 80%

208 *New Relic Powers Sustainable Observability with AWS* (Amazon Web Services, 2024), https://aws.amazon.com/blogs/apn/new-relic-powers-sustainable-observability-with-aws/.

209 Ana Radovanovic et al., *Carbon-Aware Computing for Datacenters*, arXiv:2106.11750 (2021), https://arxiv.org/abs/2106.11750; *Google, Google's 2024 Environmental Report*https://blog.google/company-news/outreach-and-initiatives/sustainability/2024-environmental-report/.

210 *Carbon-Aware Computing Whitepaper: How UBS Succeeded in Measuring and Reducing Carbon Emissions of Their Core Risk Platform* (Green Software Foundation, 2023), https://greensoftware.foundation/articles/carbon-aware-computing-whitepaper-how-ubs-succeeded-in-measuring-and-reducing-car/.

to 102% of the measured value, although another study found it reported values almost twice as high on processor benchmarks. Researchers have also used it to measure the BLOOM language model, with 176 billion parameters, as it answered 230 768 requests over 18 days on 16 graphics processors: 914 kWh of electricity and 340 kg CO_2e. The tool does not model cooling, data transfer, or storage, so its figures leave out part of the footprint.

Results from such tools are still reported in different units, per workload, per run, or per request. The Software Carbon Intensity standard (ISO/IEC 21031) is designed to provide a common unit that would let them be compared.

Table 5.11: Software emissions measurement cases

Lever	Example	Scale	Primary outcome	Evidence tier	Score (of 15)
Workload emissions measure-ment	CodeCarbon, open-source Python library, Canada[211] case-390	Open-source library with 4 295 400 down-loads since December 2020; BLOOM study covered 18 days of inference	Estimates at 80% to 102% of watt-meter readings in an independent peer-reviewed test (2023); BLOOM inference study tracked 914 kWh and 340 kg CO_2e across 230 768 requests (2022) *Measured*	Tier 1	14.0

Absolute reporting, which most Greening Digital Technologies cases lack, can be done for a whole organization. Box 3 shows how the UK Government reports the footprint of its ICT across 19 ministerial departments and 69 bodies; the case spans several sub-domains and is counted under user devices, its first-listed sub-domain.

Box 3: Cross-government ICT carbon accounting in the United Kingdom

The UK Government's Greening Government ICT programme reports each year on government ICT. In 2023 to 2024 it covered 19 ministerial departments, with 69 departments, agencies, and government bodies, across end-user devices, peripherals, servers, networking, and printers and scanners. It estimates 340 285 tCO_2e across government ICT and digital services in 2023 to 2024, 33 502 tCO_2e (9%) less than in 2022 to 2023.

Why it matters: it shows that ICT carbon accounting across all categories can be done for a whole government, the kind of absolute reporting that few organizations in the Greening Digital Technologies cases provide.

[211] Luccioni et al., *Estimating the Carbon Footprint of BLOOM, a 176B Parameter Language Model*; pepy.tech, *CodeCarbon: PyPI Download Statistics*, https://pepy.tech/projects/Codecarbon; Bouza, Bugeau and Lannelongue, *How to Estimate Carbon Footprint When Training Deep Learning Models? A Guide and Review, Environmental Research Communications 5* (2023), https://doi.org/10.1088/2515-7620/acf81b; Jay et al., *An Experimental Comparison of Software-Based Power Meters: Focus on CPU and GPU* (IEEE CCGrid, 2023), https://doi.org/10.1109/CCGrid57682.2023.00020; *CodeCarbon, software record* (Zenodo, n.d.), https://doi.org/10.5281/zenodo.4658424.

6 Findings and recommendations

This stocktake's primary mode of impact is institutional: by establishing an evidence-screened base for digital enabling benefits, it creates the conditions under which net-carbon accounting aligned with Recommendation ITU-T L.1480 can be embedded in processes for nationally determined contributions (NDCs), climate finance conditionality, and procurement standards. Eight findings emerge from the evidence, and six recommendations translate them into actions.

6.1 Findings

Finding 1: Digital technologies can deliver measurable, scalable climate benefits, but net impact reveals a more complex picture

Proven technologies with documented climate benefits exist across every sub-domain covered by this stocktake. Evidence from both Greening Digital Technologies and Greening *by* Digital Technologies demonstrates reductions in energy consumption, greenhouse gas emissions, and resource use across networks, data centres, devices, software, industry, agriculture, and land-use applications. Of the 150 cases, 45 report a measured percentage cut in emissions or energy use. In the 21 where the cut can be credited to the intervention, the typical cut is 22%, and half of these cases fall between 8% and 52%. The strength of the evidence varies: 28 cases (19%) are Tier 1, checked by peer review, independent assurance, or independent evaluation, while 78 (52%) rest on the implementing organization's own reporting.

Only 15 cases in the stocktake have been assessed with a net-impact methodology, 14 of them with the information and communication technology (ICT) footprint quantified. Among those 14, 12 show a positive net climate benefit. In the other 2, the rebound scenarios of the French Agency for Ecological Transition (ADEME) reverse the result: a tyre-management service modelled to save 1.6 million tonnes of CO_2e over 2024 to 2035 becomes a net burden of about 0.18 million tonnes of CO_2e with a 1% increase in freight transport, and a connected street-lighting system becomes a net burden when the financial savings are reinvested and new sensor networks are added, although a simpler dimming version remains positive. These 15 cases are not a random sample: the European Green Digital Coalition (EGDC) cases were selected partly for their likely magnitude of impact, and the ADEME cases from solutions presented as reducing environmental impact, so this result should not be read as a general success rate for digitally enabled climate interventions. The findings confirm that ICT footprints and rebound effects can materially reduce apparent benefits and, in some circumstances, completely offset them. The ADEME assessments also look beyond carbon: four of the five ADEME cases with a positive climate result add a net burden on mineral and metal resources. This stocktake demonstrates that there is a benefit baseline. Whether it survives the net-effects test at scale requires a different kind of study than this one.

A key constraint is not technology readiness. Technologies capable of delivering climate benefits already exist across all sub-domains. The challenge is the lack of measurement, verification, and reporting frameworks needed to quantify, validate, and account for these benefits. Without such systems, governments cannot reliably include digitally enabled reductions in NDCs, climate finance institutions cannot value the resulting climate outcomes, and external verification remains difficult.

Finding 2: Despite some well-documented efficiency gains, few organizations report whether their total energy use and emissions are falling

Reported gains can be large. By 2023, Nokia had cut the power use of its 5G massive multiple-input multiple-output (MIMO) base station by 50% compared with 2019. Sony estimates that the PlayStation 5 uses 11% to 17% less energy than the 2013 PS4 launch model, and New Relic estimates that, by July 2024, cloud workloads moved to more efficient processors emitted 37% less CO_2e. All three are per-unit figures. Atos, which reports a 32% cumulative cut in energy use across its data centres and offices between 2019 and 2022, is one of the few to report a change in total consumption. Only 17 of the 57 Greening Digital Technologies cases (30%) report how an organization's total energy use or emissions changed over time, 3 more give a total for a single year, and 37 report only intensity, efficiency, per-unit, or avoided-emissions figures (our analysis of the case files). Intensity can fall much faster than total demand: AT&T's network energy intensity fell by 56% between 2020 and 2024 (our calculation from AT&T's chart values), while its total energy consumption fell only 14.3%. Growth in demand for connectivity and compute can partly or fully offset efficiency gains in absolute terms, a rebound-like volume effect (see Section 2.8).

As long as reporting rests on intensity ratios, efficiency gains cannot be shown to reduce the sector's footprint, and the net assessment set out in ITU-T L.1480 cannot be completed, because it needs absolute figures on both sides. Network operators, data-centre owners, and device makers should report absolute energy use and emissions against a fixed baseline alongside their intensity metrics, as Recommendation 3 sets out.

Finding 3: Large-scale impact depends more on programme design and enabling conditions than on technology choices

The largest documented outcomes come from interventions that operate at system scale. Private-sector deployments at site or company level document a median reduction of about 3 100 tCO_2e a year (11 cases; middle half about 1 400 to 30 000 tCO_2e). National and multi-country programmes reach far larger figures: Viet Nam's World Bank-financed low-carbon rice programme reports a modelled estimate of about 1.6 million tCO_2e a year, and the resource-efficiency programme of the International Finance Corporation (IFC) for garment factories about 0.7 million. In both, digital tools are one part of a wider programme, and the sources do not separate the digital contribution. These differences largely reflect the size of the unit of intervention (see Chapter 3). Global digital platforms report larger, modelled figures, such as Google Maps' fuel-efficient routing (a modelled 2.7 million tCO_2e in 2024) and BlaBlaCar's carpooling (a modelled 2.5 million tCO_2e in 2024), but these are company-reported, and the sources do not show that the avoided-emissions calculations have been independently verified. Where large outcomes are independently monitored and sustained, they are associated with programme design and enabling conditions: national targets, financing tied to those targets, independent monitoring and evaluation built in from the outset, local institutional capacity, and multi-year funding cycles. In Egypt, for example, the industrial energy efficiency programme of the United Nations Industrial Development Organization (UNIDO) and the Global Environment Facility (GEF), which saved 1 247 GWh and 358 000 tCO_2 a year, combined training, ISO 50001 energy management, and policy reform, with companies installing sub-meters and SCADA monitoring to track their energy performance. Meanwhile, Viet Nam's building energy code programme with the GEF and the United Nations Development Programme (UNDP) paired simulation software and monitoring with compliance toolkits and training leading to 52 817

MWh saved by project close. Transformative scale is therefore shaped less by the type of technology deployed than by whether the programme architecture sets national targets, funds independent evaluation, builds local institutional capacity, and runs across multi-year cycles that allow outcomes to compound.

Finding 4: Few solutions are codified for others to adopt, and only about a quarter are known to be replicated in other countries or sectors

Of the 150 cases, 22 (15%) document that their underlying method has been codified so that any government or operator can adopt it without access to the original team: 11 publish their data, code, or method openly, 10 are written into law or regulation, and 1 is itself a standard. MapBiomas, for example, publishes its land-use maps, methods, and code openly, and the EU Emissions Trading System is written into law. The one standard is the Partnership for Carbon Transparency (PACT) of the World Business Council for Sustainable Development (WBCSD), an open standard for exchanging product carbon footprints used by more than 5 000 companies and 48 software providers. A further 39 cases (26%) have been deployed in at least two countries or sectors but have not crossed this institutional threshold: no institution has formally taken responsibility for the methodology's continued development and transferability. The barrier is not technical: these solutions work and have been deployed repeatedly. It is institutional: the private actor who builds and operates the solution captures the commercial value, while the public-good value of making it openly replicable goes uncaptured and therefore uninvested. Initiatives such as the World Economic Forum (WEF) Global Lighthouse Network[212] and the Digital Public Goods Alliance show what becomes possible when that threshold is crossed, though most codified frameworks still lack any requirement to report net climate benefits. The EGDC net carbon methodology and the ADEME IT4Green study are the exceptions. The 39 cases that have been replicated but whose methodology is not yet embedded in a standard, open-source platform, or governance framework that others can adopt are a near-term scaling opportunity in the stocktake: proven, replicating across contexts, and separated from population-scale reach by a single institutional step. Cost evidence is thinner still: only 35 of the 150 cases (23%) report any financial figure, 8 give the capital cost of the solution, 18 an operating saving, and only 4 a payback period, so governments and investors weighing adoption rarely have the cost data they need.

Finding 5: Almost half of the cases analysed drive climate action in more than one way

The six enabling pathways vary significantly in both prevalence and documented impact. Optimizing appears in 98 of the 150 cases (65%) and leads 81 of them, Monitoring appears in 64 and leads 36, and Dematerializing appears in 23, Amplifying in 20, Connecting in 10, and Accelerating in 7. Almost half of the cases, 67 (45%), combine more than one pathway, most often Monitoring with Optimizing (36 cases): measurement, followed by the operational improvement it makes possible. Counting each case once, under its first-listed pathway, and only measured reductions that can be attributed to the intervention, Optimizing cases show the largest, a median of 28% (middle half 9% to 54%, 15 cases), followed by Monitoring (18%, 5 cases). Six of the seven Amplifying figures are company-wide emission or energy trends rather than the effect of the digital tool, so Amplifying has too few attributable figures to compare.

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[212] *Global Lighthouse Network: The Mindset Shifts Driving Impact and Scale in Digital Transformation* (World Economic Forum, 2025), https://reports.weforum.org/docs/WEF_Global_Lighthouse_Network_2025.pdf.

Cases that combine pathways do not show larger reductions than those that use one (a median of 15% across 11 cases, against 36% across 10), so the value of combining pathways lies in linking measurement to action rather than in larger percentage cuts. Dematerializing offers the clearest counterfactual, the trip not taken or the device not manufactured, and 5 of the 13 cases it leads are Tier 1, but none of them measures avoided emissions directly or reports a measured percentage reduction. Connecting (10 cases) and Accelerating (7 cases) are the rarest pathways and report no measured percentage reductions. Most are led by governments or multilateral organizations, but private companies lead 4 of the Connecting cases and 3 of the Accelerating cases.

The structural implication is direct: of the 98 cases deploying the mechanism used most often by ICT operators and programme managers, only 5 document that their method has been codified (published openly or written into regulation), and none of these is an ADEME IT4Green case. The Monitoring cases that show an emissions or land-use outcome, rather than an activity, share one property: an evaluation design that closes the chain from digital observation to a measured outcome, such as the randomized trial of Peru's Geobosques alerts or the peer-reviewed study of Global Forest Watch alert subscriptions. These designs remain rare, and Connecting and Accelerating cases rarely measure emissions: none of the 10 Connecting cases and only 2 of the 7 Accelerating cases has a measured emissions figure, so their impact is under-documented relative to their real-world significance.

Finding 6: The methodology for measuring digitally enabled climate benefits exists, but the mechanisms needed to apply it at scale are missing

Greening *by* Digital Technologies does not yet have an equivalent, widely adopted institutional ecosystem for sector-wide reporting and independent verification of digitally enabled reductions across agriculture, industry, mobility, buildings, or public administration. Rebound effects are a case in point: they are assessed when a methodology requires it, and quantified only where data allow (see Section 2.8). As a result, the digitally enabled contribution represented by the 93 Greening *by* Digital Technologies cases (62% of the stocktake) is generally not separately visible or attributable within existing greenhouse gas (GHG) accounting and climate finance frameworks, or in the mechanisms that allocate public investment toward verified high-impact solutions. By contrast, Greening Digital Technologies has a mature institutional accountability mechanism: RE100, the Science Based Targets initiative, Carbon Disclosure Project (CDP) reporting, the EU Ecodesign Regulation, and the Energy Efficiency Directive create systematic, comparable, and increasingly audited disclosure for the ICT sector's own operational footprint. ITU-T L.1480 provides a methodology for assessing the net climate impacts of digital technologies, and sector-specific guidance is already available through initiatives such as the European Green Digital Coalition. Integration into GHG accounting obligations, procurement requirements, a reporting platform, and climate finance conditionality tied to verified net-effects claims could operationalize them at scale.

Finding 7: Artificial intelligence (AI) features in one in four cases, but evidence on its net climate impact remains limited

AI or machine learning plays a role in 36 of 150 cases (24%), principally as an efficiency layer on existing systems: optimizing network energy management, controlling district heating, fine-tuning industrial processes, and supporting deforestation monitoring. Against the AI technology types in Recommendation ITU-T L.1801, the case files name machine learning in 9 of the 36 cases

and do not specify the technique in the rest; none describes generative AI or a large language model delivering a climate outcome. What has not been assessed is whether those benefits survive the net-effects test applied to the system as a whole: whether the energy consumption of AI training and inference, the data centre infrastructure required to run these models at scale, and the device replacement cycles induced by AI-capable hardware requirements cancel any portion of the enabling benefits attributed to AI deployment.

The eight EGDC cases represent the closest approximation to this test available in the stocktake. Seven of the eight quantify a first-order ICT system footprint as part of the net carbon calculation. Four involve AI as a core component. In the six cases that publish an explicit first-order figure, the total ICT carbon footprint ranges from under 0.001% to about 15% of enabled savings, and in all six the net balance remains positive. However, none of these cases disaggregates the AI component from the broader ICT footprint. Only one case in the entire stocktake, the AI-optimized desalination plant of the Saudi operator SAWACO, assessed under the EGDC methodology (case-478), breaks out the AI component as a distinct line item: model training on a standard computer for about 72 hours, costing 0.005 tCO_2e, against annual operational savings of 157.6 tCO_2e. This is the only case where the AI footprint calculation can be separately verified. The ITU Green Digital Action Green Computing group has identified this measurement gap directly in its Measuring What Matters report[213]. ITU-T L.1801, approved in February 2026, provides guidelines for assessing the environmental impact of AI systems. It is too recent to have been applied in any deployment documented in this stocktake.

Finding 8: The benefits of digitally enabled climate action are largely public goods, but the costs of assessing and verifying them fall on private actors who have no mechanism to recover that value

All 15 net-assessed cases come from two publicly supported programmes: the European Green Digital Coalition case studies, prepared under a European Parliament pilot project funded by the European Commission, and ADEME's lifecycle assessments for the French government. No other case in the stocktake reports a net assessment. The EGDC pilot was funded as a coalition exercise by the European Commission and assessed by Carbon Trust and Deloitte; the ADEME IT4Green study was publicly commissioned. This is not incidental. The carbon savings enabled by digital technologies accrue as public goods: avoided emissions in a client's supply chain, reduced grid losses in a distribution network, lower fuel use in precision agriculture. The ICT provider that enables these savings benefits from selling the solution but has no financial incentive to fund independent verification of the net impact, because verified savings carry little or no commercial premium over unverified claims: procurement systems do not currently require net assessment as a condition of eligibility, and financial instruments typically do not reward technology providers for the quality of their impact evidence.

The result shows in the evidence base: this stocktake documents 36 private-sector Greening *by* Digital Technologies cases, but only 6 of them have been assessed with ITU-T L.1480-aligned net methods, one of them without quantifying the ICT footprint. Public implementers are in the same position: of the 32 government-led cases, the only 7 with a net assessment are ADEME's own modelled studies. The gap is widest outside Europe: 13 of the 15 net assessments cover European deployments, and none covers Africa or Asia-Pacific. While methodologies exist, putting in place financial incentives to apply them might help close this gap. The cost of rigorous

[213] *Measuring What Matters: How to Assess AI's Environmental Impact* (ITU, 2025), https://www.itu.int/pub/S-GEN-GDA.001-2025.

net-impact measurement falls on whoever commissions it, with no regulatory requirement and limited direct financial return. This market failure has a second-order consequence: it suppresses the evidence base on which climate finance, NDC accounting, and procurement standards depend. Investments that are not measured are not counted; benefits that are not counted are not financed. The systematic under-investment in measurement is therefore not a reporting problem but a resource allocation problem that will persist until a financial mechanism corrects it.

6.2 Recommendations

These six recommendations are ordered by institutional scope, not by implementation sequence. They focus on strengthening implementation, measurement, reporting, financing, and the use of international standards to support the responsible deployment of digital technologies for climate action and sustainable development.

Recommendation 1: Help countries and investors put ITU-T L.1480 into practice through technical assistance, capacity-building, and incentives for verified impact.

ITU, development partners, and climate funds could support governments, particularly least developed countries and small island developing States, through targeted technical assistance and capacity-building programmes to apply ITU-T L.1480 within the national monitoring, reporting, and verification frameworks they use to track and report progress on their NDCs. Such support could focus on practical implementation challenges, including defining system boundaries, identifying and collecting relevant data, documenting assumptions, selecting appropriate methodologies, and reporting results in a transparent and consistent manner. Implementation guidance and lessons learned from early applications of ITU-T L.1480, as well as relevant experiences from initiatives such as the European Green Digital Coalition, could support these efforts.

To encourage wider uptake of verified impact assessment, governments, development finance institutions, and other stakeholders could strengthen incentives for the application of ITU-T L.1480. Results-based financing for digitally enabled climate projects, eligibility for climate-finance programmes and voluntary carbon market mechanisms, procurement preferences, and transparency requirements in environmental reporting could help reduce the cost barrier associated with independent net-impact assessment. Crediting digitally enabled outcomes in carbon markets would, however, require careful treatment of additionality, attribution, double counting, and consistency with national and international accounting arrangements. Such measures would help create demand for rigorous measurement and reward organizations that invest in credible and verifiable impact evidence. Over time, governments could also consider moving from voluntary encouragement toward requirements for ITU-T L.1480-aligned net-impact assessment.

Recommendation 2: Design digitally enabled climate programmes to deliver impact, building in standards-based assessment and verification from the start.

The largest independently evaluated outcomes in this stocktake come from national programmes, often supported by multilateral finance, that combine digital tools with national targets, financing tied to those targets, monitoring and evaluation built in from the outset, local institutional capacity, and multi-year funding cycles. Digitally enabled climate programmes

should be designed with these conditions in place. Standards-based impact assessment and independent verification should be part of programme design and financing from the beginning, treated as a core component and funded accordingly rather than added as a post-project reporting requirement. Because digital tools are bundled with training, standards, and finance, programmes should also be designed so that the digital contribution can be separated, for example through a comparison group or an attribution analysis, and should state the baseline or reference system against which savings are measured.

Development finance institutions, climate funds, and implementing partners could encourage the use of internationally recognized methodologies such as ITU-T L.1480 by incorporating impact measurement and reporting requirements into project appraisal, monitoring, and financing frameworks. Results-based financing, funding eligibility criteria, and reporting requirements could help create stronger incentives for the generation of credible and verifiable evidence on the climate benefits of digital technologies.

Recommendation 3: Promote international standards for digital hardware procurement and sustainability reporting.

Equipment manufacturers, operators, procurement offices, and public authorities could be encouraged to follow recognized international standards as a common reference for sustainable digital technology procurement and environmental reporting. This could include product environmental reports aligned with standards such as ITU-T L.1410, as well as the use of existing guidance, standards, and training resources that support circular economy approaches, including device lifetime extension, refurbishment, reuse, and responsible end-of-life management.[214] [215]

National procurement authorities and regulatory frameworks could use international standards as technical references for sustainable procurement criteria, helping to generate comparable data on the environmental performance of ICT equipment across procurement cycles while encouraging more circular, resource-efficient ICT markets. Sustainability reporting by network operators, data-centre owners, and device makers should cover absolute energy use and emissions against a fixed baseline alongside intensity metrics, and the values measured over a year of operation rather than the values modelled at the design stage.

Recommendation 4: Promote evidence-based platforms for digital climate solutions.

Established platforms that curate and promote digital technologies for climate action could encourage quantified impact evidence aligned with an internationally recognized methodology such as ITU-T L.1480, moving these platforms from curated showcases toward verified impact registries. This could create market incentives for rigorous measurement without new regulatory infrastructure, leverage existing platform reach and credibility, and build a verified solution pipeline that climate finance institutions and Member States can reference with confidence.

A curated pipeline of standards-aligned solutions, supported by advisory services and appropriate financing instruments, could help connect technology providers with deployment opportunities in least developed countries, small island developing States, and other developing countries

[214] ITU, *Circular and Sustainable Public Procurement*, https://www.itu.int/hub/publication/d-hdb-guidelines-04-2023/.
[215] ITU Academy, *Circular and Sustainable Public Procurement for ICTs*.

where access to independently verified solutions remains limited. Evidence expectations could be applied in proportion to an organization's size, context, and implementation maturity, while stronger claims would still need stronger evidence.

Recommendation 5: Strengthen primary footprint data, standardized telemetry, and net-effects assessment as sources of evidence on digital climate impact.

Future evidence-gathering efforts should prioritize the collection of primary data on the energy use and environmental footprints of ICT systems associated with high-impact digital climate solutions. This would make it possible to move beyond estimates of enabling benefits and undertake verified net-impact assessments that account for both the climate benefits delivered and the footprint of the digital technologies involved. These assessments should also cover rebound effects and resource use, such as minerals and metals, which can reduce or reverse a positive carbon result. The structural bottleneck preventing this is data availability: only 15 of the 150 cases include a net-effects assessment, and the source documentation for the other 135 does not contain all the data needed for one, in particular complete primary data on the ICT system's own energy use. Removing that constraint requires telemetry to be built in rather than added on. Guidance is also needed for shared digital infrastructure, such as fibre networks and data centres. Methods exist to assess its own footprint, for example ITU-T L.1410, but there is no agreed way to attribute to it a share of the climate benefits of the services it carries, as ITU-T L.1480 and the EGDC methodology do for individual digital solutions.

Recommendation 6: Promote ITU-T L.1801 as a practical tool to measure AI's environmental footprint.

AI is increasingly cited in 2035 NDCs, with 12% of the 140 NDCs analysed explicitly referencing AI to be deployed, for example in early warning systems, predictive monitoring of energy infrastructure, and resource management in agriculture,[216] yet verified evidence that AI-enabled benefits survive the net-effects test remains very limited. Such evidence would show that the reductions enabled exceed the energy and emissions cost of AI infrastructure, data centre build-out, and accelerated device refresh cycles.

Parties may wish to distinguish modelled or gross AI-enabled estimates from independently verified net outcomes, and to strengthen the evidence progressively using approaches aligned with ITU-T L.1801 and ITU-T L.1480. Countries with AI applications in their 2035 NDC targets could be offered technical assistance to commission those assessments before the next NDC cycle review.

ITU-T L.1801 provides guidelines for assessing the environmental impact of AI systems. Its wide use could help strengthen the credibility and comparability of AI-related climate claims, including where AI is referenced in national climate strategies and implementation plans. Climate finance institutions and development partners supporting AI-for-climate programmes could, for example, require ITU-T L.1801-aligned footprint disclosure as a condition for crediting AI-enabled climate benefits. The aim is not to question the operational benefits that AI cases in this stocktake document, but to confirm that AI-enabled climate benefits remain once the footprint of the AI systems themselves is counted.

[216] ITU, *Digital Technologies and NDCs*.

6.3 Closing note

This stocktake presents evidence-screened findings from 150 cases spanning all six ITU regions and 10 sector domains and sub-domains, covering both the ICT sector's own footprint and the climate benefits that digital technologies enable in other sectors. The cases were selected from a research base of 500 cases and documented from archived sources, searched between May and July 2026 and retrieved and verified until October 2026, applying a consistent evidence tier classification, scoring rubric, and outcome verification protocol, and distinguishing measured from modelled outcomes.

The collection demonstrates that Greening Digital Technologies and Greening *by* Digital Technologies outcomes are operational and measurable in all six ITU regions, a present reality across sectors and geographies documented in peer-reviewed literature, multilateral evaluation reports, and independently assured corporate disclosures.

It also demonstrates, with equal clarity, where the evidence base remains incomplete. Intensity improvements are more reliably documented than absolute reductions, and the highest-quality evidence is concentrated in member countries of the Organisation for Economic Co-operation and Development (OECD) and in multilateral-finance contexts. Rebound effects are widely acknowledged but quantified in only a small minority of cases, and the two ITU-T standards most directly applicable to this domain (ITU-T L.1480 and ITU-T L.1410) are validated in parts but not yet deployed together as the complete accounting architecture they were designed to constitute.

The strategic case for ICT as a net-positive climate force holds where efficiency gains outpace absolute demand growth. The 15 EGDC and ADEME IT4Green assessed cases provide encouraging evidence of positive net benefits across most of their deployment contexts, while further representative assessment is needed before generalizing across the wider stocktake. The net-positive case is not yet verified for AI infrastructure or 5G densification at scale, where workload and traffic volume growth are outpacing measured efficiency gains. That condition should be named explicitly: the findings in this report are accurate for the cases assessed, and the scope boundary is stated. Expanding the scope to cover the demand-growth denominator is a task for the next cycle. A second task is to understand why uptake of ITU-T L.1480 and the EGDC methodology remains limited despite their demonstrated value, and which incentives would change that.

The path from this stocktake to the next one runs through institution-building rather than technology development. The standards are written. The methodologies are demonstrated. Where the calculation has been applied, most cases show positive net benefits, although two become net burdens once rebound is included. The institutional step is connecting voluntary practice to accountable measurement: ITU-T L.1410, ITU-T L.1480, and ITU-T L.1801 adopted in procurement frameworks, in NDC reporting methodologies, in development finance conditionality, and in the national inventory systems that ultimately determine whether digitally enabled climate contributions are visible, countable, and credible. That institutional step will be supported by ITU in the months and years ahead.

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