Gigaton Goal - 2024 Progress Update

March 2025

Progress summary

AT&T has long understood that AT&T connectivity such as fiber, 5G and the Internet of Things (IoT) can enable our customers to reduce greenhouse gas (GHG) emissions. In 2021, we announced the AT&T Gigaton Goal to enable customers to reduce a gigaton (1 billion metric tons) of GHG emissions through the use of AT&T connectivity by 2035.

We measure our progress against this goal by calculating the cumulative impact of emissions reduction starting in 2018, when we first calculated our emissions reduction enablement, until the end of 2035. Progress against this goal is reported annually. At the end of 2024, we calculated cumulative emissions reductions of 227.2 million metric tons of CO2e.

Enabled Emissions Reduction in millions of metric tons of CO2e:

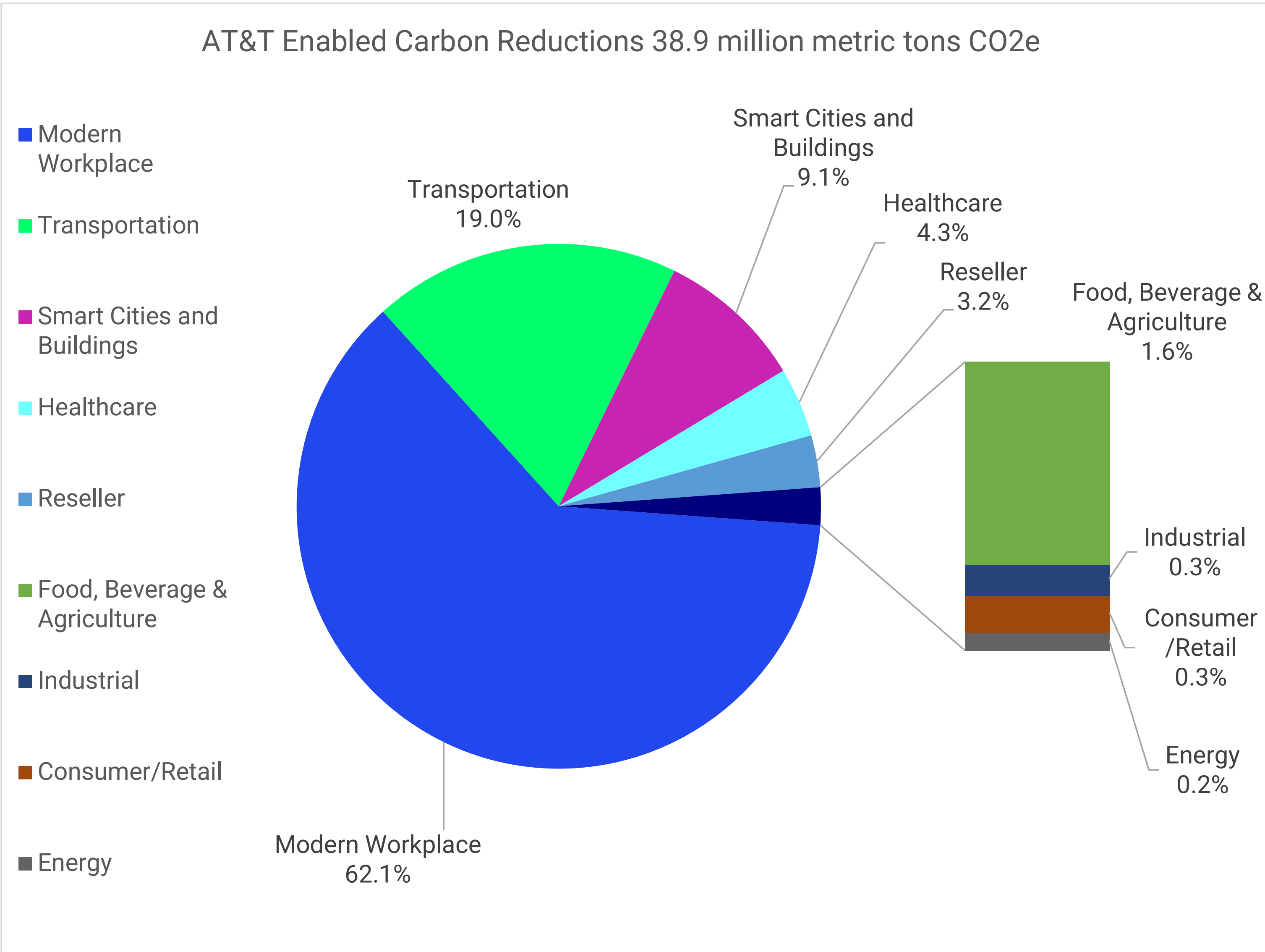
	2018	2019	2020	2021	2022	2023	2024
Annual	17.1	24[1]	31.3	37.9	38.9	39.1	38.9
Cumulative	17.1	41.1	72.4	110.3	149.2	188.3	227.2

Summary of impact areas

We have identified nine key impact areas where AT&T connectivity can play a fundamental role in reducing emissions. Here is a summary of their relative impact in 2024:

Impact Area	Carbon avoided (tCO_2e) (rounded)	Percentage of total
Modern Workplace	24,148,926	62.1%
Transportation	7,371,108	19.0%
Smart Cities and Buildings	3,529,949	9.1%
Healthcare	1,664,077	4.3%
Reseller	1,242,099	3.2%
Food, Beverage & Agriculture	626,648	1.6%
Consumer/Retail	113,679	0.3%
Industrial	99,245	0.3%
Energy	61,136	0.2%
Total	**38,856,865**	**100%**

[1] Note: In the early days of this work, we calculated avoided emissions every 2 years, so we used the average of 2018 and 2020 for 2019 avoided emissions


AT&T Enabled Carbon Reductions 38.9 million metric tons CO2e
Modern Workplace
Transportation
Smart Cities and Buildings
Healthcare
Reseller
Food, Beverage & Agriculture
Industrial
Consumer/Retail
Energy
Transportation 19.0%
Smart Cities and Buildings 9.1%
Healthcare 4.3%
Reseller 3.2%
Food, Beverage & Agriculture 1.6%
Industrial 0.3%
Consumer /Retail 0.3%
Energy 0.2%
Modern Workplace 62.1%

Overview of carbon abatement factors by impact area

We've identified a collection of activities for each impact area and worked with Carbon Trust to develop abatement factors that represent the average emissions reduction possible when using an AT&T-enabled solution compared to a reference baseline scenario. Below is a summary of those activities, their abatement factors and the relative impact of each activity.

Modern Workplace

Activity	Item units	Abatement factor (kg CO_2e/unit/year)
Telecommuting - Remote working	Residential internet connections	**1,239.04**
Videoconferencing - Desk-based	Videoconferencing seats	**5,600.00**
Office @ Hand	Videoconferencing seats	**5,600.00**
Flexware	Number of connections	**501.06**
Video Optimizer	Number of users	**0.0056**

Transportation

Activity	Item units	Abatement factor (kg CO_2e/unit/year)
Fleet Management	Connected vehicles	**574.28**
Fleet Management (Traxen)	Connected vehicles	**12,197.34**
EV Charging (ChargePoint)	Connected charging stations	**3,814.03**
Smart Pallets	Number of composite pallets	**71.60**
Carsharing (Zipcar)	Number of cars	**40,302.81**

Healthcare

Activity	Item units	Abatement factor (kg CO_2e/unit/year)
Remote Patient Monitoring	Connected remote monitoring devices	**444.61**

Smart Cities and Buildings

Activity	Item units	Abatement factor (kg CO_2e/unit/year)
Building Energy Efficiency-as-a-Service (Redaptive)	Number of sites	**160,678.42**
Building Energy Management Systems	Connected building management systems	**11,638.05**

Smart parking	Parking service connections	**269.06**
Street lighting	Streetlights	**20.99**
Advanced Water Metering Infrastructure	Number of houses	**0.89**
Efficient cooling towers (NALCO)	Number of units	**1,553.85**
Water Leak Monitoring (Badger Meter)	Number of domestic leaks	**0.0011**

Industrial

Activity	Item units	Abatement factor (kg CO_2e/unit/year)
Concrete Management (GCP)	Cubic meters of concrete	**4.52**

Consumer/Retail

Activity	Item units	Abatement factor (kg CO_2e/unit/year)
Smart Landscape Irrigation	Number of sites	**901.84**

Food, Beverage, and Agriculture

Activity		Abatement factor (kg CO_2e/unit/year)
Food Waste to Energy (Grind2Energy)	Number of sites	**84,408.30**
Durable Ag Sensors (Soiltech)	Number of connections	**11,534.59**

Energy

Activity	Item units	Abatement factor (kg CO_2e/unit/year)
Residential Smart Meters	Connected residential smart meters	**174.49**
Solar PV Optimization	Number of systems	**4.29**

Reseller

Activity	Item units	Abatement factor (kg CO_2e/unit/year)
Reseller	Number of connections	**540.98**

Methodology summary

In this section, we define the type of data collected and the research used to calculate the carbon abatement factor for each activity.

The calculations of abatement factors and the cumulative emissions avoidance are in line with the 2025 update to the AT&T Gigaton Goal Methodology. The numerical value associated with an abatement factor may change each year depending on annual updates in data source inputs that reflect the most recent year.

Emission factors from the following sources are used throughout the calculations to develop the carbon abatement factors:

- eGrid 2023
- DESNZ 2024[2]
- EPA
- IEA 2024
- EcoInvent 3.11

Detailed in the tables below are the references and assumptions used specifically for each activity.

[2] This dataset was previously referred to as "BEIS" – in reference to the UK Government's Department for Business, Energy and Industrial Strategy. In 2023, BEIS was split into different government departments, with DESNZ (Department Energy Security and Net Zero) taking its place in the role of publishing this annual dataset.

Modern Workplace

Telecommuting - Remote working	
Solution Description	AT&T connectivity provides domestic internet access, enabling customers to work from home without the need to physically travel to an office or place of work. Enabling remote working to occur reduces the usage of transportation required for physical commuting. AT&T also provides hosted voice solutions (e.g. Office@Hand) which provide a communications platform for remote working and therefore also contribute to instances of telecommuting when an employee is using a hosted voice solution to work remotely, even when not via an AT&T enabled network.
Implementation context	The implementation context is employees needing to collaborate at work and relates to all of AT&T's fixed broadband connections and sale of hosted voice solutions which are utilised by telecommuters within the USA in 2024.
Baseline Scenario	The baseline scenario is where employees are required to commute to their workplace every working day, even if their work can be effectively performed remotely.
ICT Solution Scenario	The solution scenario is a representation of the reality where AT&T offers connectivity via fixed broadband connections. For all employees with remote-capable roles, the average number of days per week with work-related travel between their homes and workplaces decreases.
Methodology	Emissions savings are calculated based on the difference in miles travelled between the 'baseline scenario' and the 'ICT solution scenario.' This calculation considers: • The number of telecommuters in the US • The average number of telecommuters work from home • The proportion of the total US fixed broadband market that AT&T holds • The percentage of the total US Hosted Voice market where users of voice/collaboration solutions are not already on AT&T fixed broadband, • The weighted average of various modes of commuting transportation, and average commuting distance. The resulting net carbon impact is based on the total transportation distance avoided and the emissions associated with the fuel from the avoided transportation.

Effects	**First Order Effects** First Order Effects were not considered in original assessment and are not factored into the calculation. These would relate to the lifecycle emissions associated with equipment required to run a fixed network and hosted voice solutions. **Second Order Effects** Second Order Effects are the emissions savings relating to the reduction in fuel combustion in from commuting transportation. **Higher Order Effects** No Higher Order Effects were identified/included.
Assumptions	It is assumed that: • The employed labour force work 47 weeks per year. • The proportion of AT&T fixed broadband connections in the US applies to the market of hosted voice solution users. • The secondary data sources that have been used to compute average commuting trends and remote working behaviour are representative for the pool of telecommuters covered by AT&T's telecommuting solutions.
Data sources	**Primary Data** • Number of AT&T fixed broadband connections in 2024. • Percentage of total US Hosted Voice market (inc. Office@Hand sales and resale of third-party solutions e.g. Zoom, Webex etc.). **Secondary Data** Total employed in the US: Labor Statistics Employed 2024 and Labor Force Statistics 2024 Total US fixed broadband subscriptions: ITU 2023 Percentage of people sometimes working remotely and percentage of remote-capable employees: Global Indicator: Hybrid Work - Gallup Distance commuted: US Department of Transportation, Bureau of Transportation Statistics, Omnibus Household Survey Forms of commuting and vehicle occupancy: Bureau of Transportation Statistics, Principal Means of Transportation to Work (Table 1-41) 2023 UK Government 2024 emission factors for motor cycle, regular taxi, public transport (average); EPA and DESNZ 2024 for typical passenger car (with adjustment for EVs based on IEA 2023 projections)
Exclusions	First Order Effects including embedded and operational emissions from necessary network equipment were excluded.

Videoconferencing - Desk-based	
Solution Description	AT&T sell videoconferencing services that enable connected video/audio such that business meetings can be conducted virtually rather than in-person.
Implementation context	The implementation context is employees being required to attend business-related meetings. The assessment boundary comprises of all videoconferencing services sold by AT&T in 2024 and the associated workers who were able to avoid attending in-person meetings due to having access to a videoconferencing service.
Baseline Scenario	The baseline scenario is where employees are required to travel in-person via road or air transportation for all business meetings.
ICT Solution Scenario	The solution scenario represents the reduction in business miles travelled per year (across road and air transportation) through the avoidance of in-person meetings due to AT&T connected videoconferencing services enabling discourse to occur remotely.
Methodology	An annual figure of 'typical equivalent travel distance to physical meetings if these had taken place instead of video calls' was calculated from data collected by a provider of videoconferencing and based on the use of a managed videoconferencing service over the period of a year. The case study considered the number of people involved in the videoconferences and their locations. It also assumed that 4% of the travel distance was by car, and 96% was by air. The avoided emissions per videoconferencing service was calculated by weighting the travel miles by road or air and multiplying by an appropriate emission factor for road or air travel.
Effects	**First Order Effects** First Order Effects were not considered in original assessment and are not factored into the calculation. These would relate to the lifecycle emissions associated with the videoconferencing services. **Secon Order Effects** Second Order Effects are the emissions savings relating to the reduction in fuel combustion in from business travel transportation (i.e. cars and planes). **Higher Order Effects** No Higher Order Effects were identified/included.
Assumptions	The assumptions made in the case study from a videoconferencing provider apply. It is assumed that: • All avoided air travel business trips could be characterised best by an emission factor for 'long-haul economy' flights. • All avoided road travel business trips could be characterised best by an emission factor for 'upper medium, petrol' cars (with adjustment made to account for the US stock of EV cars to prevent overestimation of impact).

Data sources	**Primary Data** Avoided miles of travel per service (videoconferencing provider case study) **Secondary Data** Meeting avoidance factor of 32%: Cisco research quoted by BT (no longer published online) DESNZ 2024 for long-haul air travel and car travel (with adjustment for EVs based on IEA 2023 projections)
Exclusions	First Order Effects including embedded and operational emissions from necessary network equipment were excluded.

Office@Hand	
Solution Description	The solution uses the same methodology and same abatement factor as Videoconferencing. Videoconferencing and Office@Hand were previously reported together; they are now reported separately but still use the same abatement factor and methodology.

FlexWare	
Solution Description	The AT&T FlexWare device enables the replacement of multiple purpose-built hardware devices with a single hardware device capable of delivering several network functions.
Implementation context	The implementation context is end-users needing certain functionality from their network infrastructure and relates to businesses using Flexware to deploy multiple network functions on a single device.
Baseline Scenario	The baseline scenario is the energy associated with use of multiple traditional purpose-built hardware such as routers, wan accelerators and firewalls.
ICT Solution Scenario	The ICT solution scenario is the energy associated with the use of the AT&T Flexware device.
Methodology	Estimated savings per device were estimated based on the average power of a typical router, firewall, and WAN accelerator devices on the market at the time of research. Net savings were calculated by subtracting the FlexWare power requirements from the total power requirements of the devices listed above, before applying energy savings associated with avoided cooling requirement, estimated to be an additional 30% of the energy savings. The electricity saving was converted to a carbon saving using the EPA eGRID average emission factor for the US plus upstream and transmission and distribution (T&D) losses from the IEA.
Effects	**First Order Effects** First Order Effects were not considered in the original assessment and are not factored into the calculation. These would relate to the lifecycle emissions associated with the FlexWare hardware. **Second Order Effects** The AT&T FlexWare device allows customers to save electricity and reduce their carbon emissions. Using one device, rather than multiple devices, to perform the same functions, lowers cooling requirements and reduces the demand for the production of multiple purpose-built devices and the associated embedded carbon emissions. **Higher Order Effects** Server virtualization relies on cloud computing to update/install software, which has its own electricity demands that are difficult to attribute to individual users. These have not been accounted for within this carbon impact assessment.

Assumptions	It was assumed that: • Implementation of FlexWare will always result in the replacement of three devices (router, firewall, and WAN accelerator) with a single FlexWare device. • Devices are in operation 24 hours, 365 days per annum. • Savings from decreased cooling requirements are assumed to be 30% of calculated energy savings. The 30% HVAC energy saving figure is based on the ASHRAE2 guidelines that 30 to 35 watts of cooling is required to offset the heat output for every 100 watts used. • We have assumed that the majority of FlexWare devices are installed in the U.S.
Data sources	**Secondary Data** Replaced device specifications available on respective vendor's website eGrid 2023 and IEA 2024 for derivation of electricity full lifecycle emissions
Exclusions	The embedded emissions of the AT&T FlexWare device and the replaced devices, as well as the power required to run cloud computing services were excluded.

Video Optimizer	
Solution Description	AT&T Video Optimizer is an open-source software tool that helps app developers and testers to optimize apps with video by catching errors and identifying areas consuming both unnecessary amounts of data and airtime. By reducing the amount of data consumed and airtime, AT&T Video Optimizer decreases the energy needed to run the network equipment that transmits the videos and can help extend battery life of the mobile devices using the app. This results in lower electricity usage and lower associated GHG emissions.
Implementation context	The implementation context is end-users engaging with mobile apps to play video content. The video optimizer tool helps developers to optimize the performance of their apps on mobile networks, helping to extend the battery life of devices, reduce charging need and resulting in lower electricity usage. It also helps to reduce the amount of data consumed to run video
Baseline Scenario	The baseline scenario is the use of apps and video content without optimization.
ICT Solution Scenario	The ICT solution scenario is the use of apps that have been optimized using the AT&T video optimizer, helping video content distributors use less bandwidth and improving the customer experience whilst reducing energy, emissions and associated costs.
Methodology	The total data savings and airtime savings on AT&T's network from the use of AT&T's Video Optimizer on a select number of apps were collated between 2012 and 2019 and used to calculate network and battery energy savings, respectively. Network Savings: • To calculate Network Savings, annual data savings on AT&T's network was multiplied by the respective year's energy intensity, to produce kWh savings between 2012 and 2019. The cumulative annual energy savings was then divided by AT&T's total mobility subscribers, to provide the energy savings per connection for 2019. • Using ITU data, this factor was multiplied by the number of mobile broadband connections in the US and globally, to provide total kWh saved for both the US and globally. The ITU figures were adjusted using an assumed adoption rate of 100% in the US and 50% globally to reflect the use of the apps in the respective areas. • kWh savings were converted into carbon savings by multiplying the US and global figures by the US eGRID electricity emissions factor and the IEA & DESNZ global electricity emission factor respectively. Battery Savings:

	• To calculate device battery savings, 2019 cumulative annual airtime savings on AT&T's network was multiplied by the average power consumption of the GSM radio module of a mobile phone to produce the annual kWh savings. This kWh savings figure was subsequently divided by AT&T's total mobility subscribers, to calculate the kWh savings per mobile subscriber for 2019. • Using ITU data, this factor was multiplied by the number of mobile broadband connections in the US and globally, to provide total kWh saved for both the US and globally. The ITU figures were adjusted using an assumed adoption rate of 100% in the US and 50% globally to reflect the use of the apps in the respective areas. • kWh savings were converted into carbon savings by multiplying the US and global figures by the US eGRID electricity emissions factor and the IEA & DESNZ global electricity emission factor respectively. These values were subsequently converted into gallons of gasoline using the EPA equivalency factors.
Effects	**First Order Effects** First Order Effects were not considered in the original assessment and are not factored into the calculation. There are no embedded emissions associated with the Video Optimizer tool on each device but there may be lifecycle emissions from equipment to run the overall software; these are not currently accounted for. **Second Order Effects** The AT&T Video Optimizer tool helps optimize video apps, decreasing data usage and device battery drainage, which in turn leads to lower electricity consumption and lower associated GHG emissions. **Higher Order Effects** Increased use of video apps due to improved user experience may have contributed to increased energy usage and higher emissions. This tool does not appear to create other outsized or irreparable environmental or social impacts.
Assumptions	It was assumed that: • There was a 100% adoption rate for US and a 50% adoption rate for global subscriptions (based on subscriptions/number of users of the selected apps in both the US and globally) • Apps will be used on smartphones while using mobile or fixed broadband

Data sources	**Primary Data** • AT&T Data Savings data from selected apps (2012-2019) • AT&T Airtime Savings data from selected apps (2012-2015, 2017) **Secondary Data** • EPA Equivalences (EPA Greenhouse Gas Equivalencies Calculator) • eGrid 2023 and IEA 2024 for derivation of electricity full lifecycle emissions • ITU Statistics: Number of Fixed and Mobile Broadband Subscriptions (https:// www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx) • Power Consumption of GSM radio module of a mobile phone (https://www.usenix.org/legacy/event/atc10/tech/full_papers/Carroll.pdf; https://arxiv.org/ftp/arxiv/papers/1312/1312.6740.pdf) • AT&T Domestic Broadband Connections and Mobility Subscribers: AT&T Inc. 2019 Annual Report
Exclusions	No First Order Effects or Higher Order Effects were quantified or included in the assessment.

Transportation

ChargePoint (EV Charging)	
Solution Description	AT&T's IoT connectivity enables the remote control and monitoring of ChargePoint's network of EV charging stations. Specifically, this allows for remote software updates and enhancements, provides monthly and quarterly reports of the station's performance metrics, enables proactive dispatch of station repair technicians when required, processes financial transactions, and monitors station efficiency 24/7 to improve queue management. This creates an integrated EV charging experience for businesses and drivers, providing both with useful and timely information and support services, facilitating the overall transition towards more sustainable forms of transport.
Implementation context	The implementation context is vehicles needing to be provided with power in the US and relates to businesses installing ChargePoint EV charging stations at their sites, which provide not only charging for customers, but useful and timely information to both station operators and EV drivers.
Baseline Scenario	Businesses do not install any EV chargers at their sites, effectively encouraging the continued use of internal combustion engine (ICE) Vehicles.
ICT Solution Scenario	Businesses install the IoT connected ChargePoint charging stations, helping support the EV transition and providing useful information to drivers of EVs to optimize their use.
Methodology	The total electricity dispensed across ChargePoint's AT&T enabled charging stations, the top 3 charged vehicle models, and number of AT&T enabled charging stations was collected for the calendar year 2019. • To calculate the kgCO2e per charging point from the electricity used by EVs, the kWh dispensed per charging point was multiplied by the eGrid 2023 US average electricity emission factor (EF). • Average kWh/mile was calculated using specific data for the top 3 vehicle models and information derived from various studies. This factor was then converted into miles/kWh. • Total distance travelled by cars recharged, per charging point was calculated by multiplying the 'kWh dispensed per charging point' by the 'miles per kWh' factor. This distance was subsequently used to calculate the kgCO2e from the average car (using average car EF) per charging point. • The difference between the two calculated values gives kgCO2e savings per charging station.
Effects	**First Order Effects** First Order Effects were not considered in the original assessment and are not factored into the calculation. These would relate to emissions associated with the lifecycle of any hardware necessary for the operation of the ChargePoint solution. **Second Order Effects** AT&T connected charging stations lead to carbon savings by enabling the use of electric vehicles rather than ICE vehicles.

	Higher Order Effects An improvement in the implementation and usability of EV charging stations can increase the proportion of drivers using electric vehicles, reducing emissions derived from vehicle fossil fuel consumption. This increase in demand can subsequently lead to greater investment into efficient electric vehicles and batteries, having knock-on effects for decarbonization in other industries in the long term. In the short term, a large shift from fossil ICE vehicles might lead to a greater overall quantity of manufactured cars than would have otherwise been made. This may create a disuse of petrol/diesel vehicles before their end of life and increases emissions in manufacturing and resource use. The technology does not appear to create other outsized or irreparable environmental or social impacts
Assumptions	• The case study assumes that the top 3 vehicle models are representative for all EVs using ChargePoint's AT&T enabled charging stations. • If the kWh/mile figure provided for each vehicle model did not include charging losses, an average charging loss factor of 23% was assumed. These charging losses account for the energy lost during the AC to DC conversion and energy consumed in surpassing battery resistance to charging.
Data sources	**Primary Data** • The most common vehicles come from ChargePoint primary data, as do the total number of connected charging stations and the total kWh. **Secondary Data** • eGrid 2023 and IEA 2024 for derivation of electricity full lifecycle emissions • Emissions factors used for ICE passenger cars come from the US EPA, with upstream (well-to-tank) emissions factors from DESNZ 2024 • The vehicle ranges and the Wh per mile come from manufacturer or 3rd part websites such as https://insideevs.com/ or https://ev-database.org/
Exclusions	First Order Effects and Higher Order Effects related to an increase in the overall electricity demand and an increase in emissions from EV manufacturing were not included.

Fleet Management	
Solution Description	This solution is a vehicle telematics system for large goods vehicle (LGV) fleets, which provides insights on driving styles and the selected routes taken to support optimising these to improve fuel efficiency. AT&T provides the connectivity that supports data collection on driving styles and routes taken to support the optimisation.
Implementation context	The implementation context for fleet management telematics solutions is fleet operators who are looking to maximise the operational efficiency of their existing fleet.
Baseline Scenario	Operating a vehicle fleet without the use of a telematics system.
ICT Solution Scenario	Fleet operators implementing a telematics system which provides insight on driving styles and routes taken, enabling targeted measures to increase fuel economy and reduce driver mileage.
Methodology	The methodology for ICE vans takes an industry average annual fuel consumption for LGVs and multiplies this by an emissions factor for gasoline from the EPA. This is then multiplied by a secondary source that identifies the typical fuel savings from the use of fleet management telematics solutions (10%). For battery electric vehicle (BEV) vans, a similar approach is taken where the average kWh per mile from a range of common electric LGV's is used and multiplied by a US Grid emission factor and the same secondary source that identifies savings. The overall savings are then split between ICE and BEV vehicles using data on the percentage of ICE vs BEV vans from the IEA to calculate the overall savings.
Effects	**First Order Effects** The lifecycle emissions (embedded and energy associated) emissions of the telematics solution would be the first order effect in this scenario. This was not calculated as part of the case study **Second Order Effects** Reduced fuel consumption or EV charging and the associated emissions from these activities due to more efficient driving or routing. **Higher Order Effects** There is a potential that savings from the use of a telematics solution may encourage fleet operators to increase their overall vehicle numbers. This effect has not been quantified. Technology does not appear to create other outsized or irreparable environmental or social impacts.
Assumptions	The case study assumes that LGVs within the fleet are aligned with the average values used (annual fuel consumption or kWh per mile). The case study assumes savings from telematics solutions are consistent with the secondary source used.
Data sources	**Secondary Data** Energy Savings Trust: A Guide to Telematics – typical fuel savings of between 5% and 15%. A figure of 10% fuel saving was used in the calculations. EPA: Greenhouse Gases Equivalencies Calculator – emission factor for gasoline

	Bureau of Travel Statistics: Light Duty Vehicle, fuel consumption and travel – average fuel consumed per vehicle per year (with adjustment for EVs based on https://www.iea.org/articles/global-ev-data-explorer
Exclusions	The lifecycle emissions of the telematics solutions are excluded from this case study.

Fleet Management (Traxen)	
Solution Description	Traxen is a fleet management solution for truck fleets which provides insights on driving styles and the selected routes taken to support optimising these to improve fuel efficiency. AT&T provides the connectivity which supports data collection on driving styles and routes taken to support the optimisation.
Implementation context	The Traxen implementation context is truck fleet operators who are looking to maximise the operational efficiency of their existing vehicle fleets.
Baseline Scenario	Operating a vehicle fleet without the use of a telematics system
ICT Solution Scenario	Fleet operators implementing a telematics system which provides insight on driving styles and routes taken, enabling targeted measures to increase fuel economy and reduce driver mileage.
Methodology	The methodology uses case study data from Traxen, which calculates an average fuel savings across all the trucks in a specific fleet. This average fuel savings is then calculated as an emissions savings using the DESNZ emissions factor for diesel fuel. Embedded emissions for the telematics solution are then subtracted to get an average annual net emissions saving per truck.
Effects	**First Order Effects** The embedded emissions of the telematics solution are included in the assessment and comprise of 3 components: • Controller (ECU) • Front Sensor • Samsung tablet **Second Order Effects** Traxen's solution contributes an average of 9% fuel savings across the fleet in the iQ Cruise case study. This is a per truck fuel saving of 1,041 gallons of gasoline. **Higher Order Effects** There is a potential that savings from the use of a telematics solution may encourage fleet operators to increase their overall vehicle numbers. This effect has not been quantified. Technology does not appear to create other outsized or irreparable environmental or social impacts.
Assumptions	System assumptions: 1. Controller (ECU) – assumed penetration rate of ECU is 100% 2. Radar/front sensor – assumed penetration rate is 50% 3. Samsung Tablet – assumed penetration rate is 10% It is assumed that the 9% fuel efficiency improvement is a representative average of the tests which were conducted.
Data sources	**Primary Data** • Case study data from Traxen Eaton FEI Test results **Secondary Data** • DESNZ 2024 emissions factor for diesel fuel • Embedded emissions are calculated using EcoInvent 3.11 data

Exclusions	It is assumed that any electricity consumption needed to power the controller and sensor components of the solution system will be negligible in emissions impact and can therefore be excluded. No Higher Order Effects have been deemed material or quantifiable in this study.

Smart Pallets	
Solution Description	AT&T connectivity enables traceability of the pallets, reducing pallet losses. This enables a business model supporting reuse of higher value pallets that are lighter in weight, more durable, and can withstand greater load capacity.
Implementation context	The implementation context is the current global logistics and shipping system.
Baseline Scenario	The baseline scenario is the use of traditional wooden shipping pallets with no IoT enabled tracking.
ICT Solution Scenario	The ICT Solution scenario is the use of the highly durable RM2 BLOCKpal pallets which have AT&T connectivity to enable tracking.
Methodology	The LCA study covered the cradle-to-grave life cycle of the RM2 composite pallet and a typical wood block pallet. The life cycle was divided into the following stages: • Material Production: The acquisition of raw materials such as silica and wood, and the processing of raw materials into intermediate materials used in the pallets, such as glass fiber, and lumber. • Component Manufacturing: The manufacture of pallet components that are purchased by the pallet manufacturers, such as screws, nails, and leg inserts. • Component Transport: The transportation of materials (i.e. glass fiber roving, lumber) and components (screws, nails) to the manufacturing facility. • Pallet Manufacturing: The manufacturing and final assembly of the pallets. • Distribution: Transportation of the finished pallet to the initial customer or user. • Use – Loaded: The transportation of the pallet during use when it is loaded with product. • Use – Disposal of Lost Pallets: The disposal of pallets that are lost during use. • Use – Repair: The repairing of damaged pallets. • Use – Backhaul: The transportation of the pallet during use when it is not loaded with product (e.g., transport to the service center and/or the next user). • End of life (EOL): Transport to landfill of non-recycled pallets at end of useful life.
Effects	**First Order Effects** Embedded emissions of the connected pallets are higher than a traditional wooden pallet, but lower over the lifetime of the product based on the overall number of trips taken. **Second Order Effects** Over its lifetime, each pallet avoids 72 kgCO2e due to net effects of reusability. Beyond this, the greater load carrying capacity of the pallet allows additional product to be carried per load, reducing the number of trips required. This effect was not quantified as the range and variety of products shipped make it impractical. **Higher Order Effects** No rebound effects were identified

	This technology does not appear to create other outsized or irreparable environmental or social impacts
Assumptions	• Pallet weight: 22.2 kg (composite), 29.5 kg (wood) • Number of lifetime trips per pallet: 162 (composite), 30 (wood) • Loss rate of pallets per trip: 0.5% (composite), 2% (wood) • Number of pallets required for 100,000 pallet trips: 899 (composite), 4400 (wood) • Distance from pallet manufacturer to first user: 600 miles • Distance from user to distribution center: 525 miles • Distance to next user: 100 miles. (For the wood pallet this is modeled as two transport legs of 50 miles via a service center) • Distance to landfill for disposal of pallets: 30 miles
Data sources	**Primary Data** • LCA study conducted by Pure Strategies for RM2 • RM2 primary data • Independent pallet use testing **Secondary Data** • LCA study performed by Franklin Associates (2009)
Exclusions	Removals and emissions of biogenic carbon from the wood pallets were excluded from the study (taking a net “carbon neutral” approach for biogenic carbon). Sequestration (storage of carbon) for the pallets is likely to be minimal, and end-of-life emissions from the wood are considered to be balanced by the CO2 absorbed by the trees during their life.

Car Sharing (Zipcar)	
Solution Description	AT&T connectivity provided to carsharing platforms like ZipCar allows members of their platform to search for, book and unlock cars and vans to use when they need, rather than owning their own vehicle. In 2023, 50% of members postponed purchasing or leasing a car because of ZipCar and 82% of members did not own a car.
Implementation context	The implementation context for ZipCar is the current use of vehicles for commuting and other journeys in the USA.
Baseline Scenario	The baseline scenario is that 100% of journeys taken by ZipCar would instead be taken by privately owned or leased vehicles
ICT Solution Scenario	ZipCar allows its members to book and unlock cars and vans where and when they need to, rather than owning their own vehicle for the journeys they take.
Methodology	Zipcar estimates the reduction in footprint per member. This is corroborated via a similar estimation within a research paper of average emissions savings due to a household participating in car sharing. It is assumed that one household is equivalent to one ZipCar member. The saving per household is multiplied by the number of members that are served by a single ZipCar during a year to calculate a total annual emissions savings. This value is adjusted for the current reporting year by accounting for the proportion of electric vehicles on the road, and the lower emissions impact of this vehicle types.
Effects	**First Order Effects** The First Order Effects would be the embedded emissions of the vehicles used by ZipCar. The overall emissions impact of this is positive as members would likely own or lease a vehicle each in the baseline scenario, rather than the average 50-90 members served per ZipCar. **Second Order Effects** Members who join Zip Car find that they drive 40% fewer miles than they did when they privately owned a vehicle **Higher Order Effects** No rebound effects are identified No trade-offs or negative effects were identified
Assumptions	Each individual household is assumed to be 1 ZipCar member An average of 70 members per car is used
Data sources	**Secondary Data** https://www.researchgate.net/publication/224247227_Greenhouse_Gas_Emission_Impacts_of_Carsharing_in_North_America 2023-Zipcar-Impact-Report.pdf (zipcar-drupal-prod.s3.amazonaws.com) Adjustment for EVs based on IEA 2023 projections
Exclusions	First Order Effects have not been quantified or included in the assessment.

Healthcare

Remote Patient Monitoring	
Solution Description	AT&T provides connectivity to digital healthcare monitoring solutions which enables patients with chronic conditions to be monitored remotely, reducing the number and length of hospital stays for this type of patient.
Implementation context	The implementation context is the current healthcare system in the US.
Baseline Scenario	Those with diagnosed chronic health conditions are not monitored and utilise hospital services whenever needed.
ICT Solution Scenario	Those with diagnosed chronic health conditions are monitored remotely and whether hospitalisation is required can be assessed via remote patient care.
Methodology	The percentage researched reduction in hospital admissions and hospitals stays as a result of remote patient monitoring for those with chronic conditions is used to calculate the reduction in the number of days spent in a hospital per year per patient. The emissions associated with a patient spending a day in a hospital is researched and multiplied by the reduction in number of days to calculate the emissions reduction.
Effects	**First Order Effects** First Order Effects were not considered in original assessment and are not factored into the calculation. These would relate to the lifecycle emissions associated with equipment required to monitor patients remotely. **Second Order Effects** The savings calculated derive from reduction in hospital emissions due to reduced hospital stays and reduced need to travel to hospital. **Higher Order Effects** No Higher Order Effects were identified.
Assumptions	The case study assumes that remote patient monitoring is only used on those with chronic health conditions. It is also assumed that secondary data from research on hospital admissions, distance from patients, hospital emissions and percentage reductions in admissions/length of stay is uniformly applicable. Trips to a hospital are assumed to be taken in an average car.
Data sources	**Secondary Data** Average of 1.5 of hospital admissions per year – Focus on: Hospital admissions from care homes Average of 5.9 days per hospital stay – OECD: Length of Hospital Stay Average 138 kgCO_2e per day per hospital stay – Environmental footprint of regular and intensive inpatient care in a large US hospital | The International Journal of Life Cycle Assessment Average 10.62 km journey to hospital – Methods for Calculating Patient Travel Distance to Hospital in HCUP Data

	Percentage reduction in hospital admissions and stays due to remote patient monitoring - Does remote patient monitoring reduce acute care use? A systematic review Ratio of length of hospitalisation for patients with chronic conditions versus average for all patients - The burden of chronic disorders on hospital admissions prompts the need for new modalities of care: A cross-sectional analysis in a tertiary hospital EPA and DESNZ 2024 for typical passenger car.
Exclusions	First Order Effects were not quantified or included in the assessment

Smart Cities and building

Building Energy Efficiency-as-a-Service	
Solution Description	The carbon savings described in this case study are a result of the Redaptive efficiency -as-a-Service (EaaS) business model that enables installation of energy-efficient lighting and mechanical equipment, combined with the use of AT&T's IoT technology. Both AT&T and Redaptive play a fundamental role in enabling the environmental benefits of the EaaS program. New energy-efficient lighting equipment allows users to save energy and reduce their carbon emissions without the need for upfront capital spending.
Implementation context	The implementation context is the energy consumption within building equipment. This use case applies to managers of these buildings who recognize the need to upgrade their building equipment to more efficient equipment but who don't have budget available to make the needed investments.
Baseline Scenario	In the baseline scenario, facility managers recognize that current building equipment isn't efficient, but they lack the budget to upgrade the inefficient equipment.
ICT Solution Scenario	In the ICT solution scenario, AT&T IoT connectivity provides near real-time energy usage data that can be used by an EaaS platform to create a financial model whereby the building manager does not need to make the upfront investment in new equipment, rather shares the financial savings from the new equipment with the EaaS provider.
Methodology	Energy savings are calculated using metered energy consumption and estimated based on a kWh square footage savings for the future sites. The kWh reductions are then converted into carbon savings using average eGrid emission factors. Savings from decreased cooling requirements are assumed to be 30% of metered energy savings.
Effects	**First Order Effects** Not calculated as part of this case study, but the embedded emissions of installed IoT sensors would be the First Order Effect. **Second Order Effects** Per site, the annual energy savings are approximately 208 MWh across the 615 facilities assessed. **Higher Order Effects** Increased efficiency and therefore saving on energy bills may contribute to increased usage of equipment due to lower costs to run. This effect has not been quantified No trade-offs or negative effects were identified
Assumptions	Energy savings are assumed to be consistent year on year and applicable to all facilities using this solution with AT&T connectivity.
Data sources	**Primary Data** Energy savings calculated from metered energy consumption and estimated based on a kWh square footage savings for future sites. **Secondary Data** eGrid 2023 and IEA 2024 for derivation of electricity full lifecycle emissions
Exclusions	First Order Effects and Higher Order Effects are excluded from this calculation.

Building Energy Management Systems	
Solution Description	Using IoT connectivity for data aggregation and data management of Building Management Systems (BMS) enables AT&T to proactively monitor energy use and equipment performance. This allows preventative maintenance and more timely responses to equipment malfunctions that result in improved energy use of building infrastructure equipment.
Implementation context	The implementation context for this solution is commercial buildings and office that use a range of equipment to manage the climate of their buildings.
Baseline Scenario	For equipment performance, the baseline scenario is scheduled maintenance and human equipment inspection.
ICT Solution Scenario	In the ICT enabled scenario, equipment performance is monitored by sensors which detect faults and run diagnostics. This helps to inform and prioritise maintenance, leading to reduced energy consumption at the building level.
Methodology	The system identifies a number of 'facility improvement measures' (FIMs), which engineers can respond to, and which may result in electricity and GHG emission savings. The FIMs for 2017 were analyzed and classified into the following categories: chiller setpoints, economizers, fans and variable frequency drives (VFDs), air reset controls, water reset controls, and freeze protection. The system also automatically monitors run-hours for the different equipment, thus allowing an estimate of electricity savings. Additionally, the system can capture estimate kWh and savings against each FIM. The total savings are summed up for all the categories. This method will likely underestimate the savings, as not all of the savings are captured using this approach. (For example, savings outside of the above categories would not have been captured).
Effects	**First Order Effects** The First Order Effects would be the embedded emissions of the IoT sensors installed on equipment. These were excluded from the calculation **Second Order Effects** • Energy savings of approximately 24,500 kWh per site per year. **Higher Order Effects** There is a potential economic rebound effect with this solution, where the financial savings from reduced energy encourage increased use of some equipment (e.g. heating and cooling) No trade-offs or negative effects were identified
Assumptions	Detailed saving figures were derived based on expert opinion and then aggregated by system reports.
Data sources	**Primary Data** FIM and site data provided from the system by AT&T **Secondary Data** eGrid 2023 and IEA 2024 for derivation of electricity full lifecycle emissions
Exclusions	First Order Effects and Higher Order Effects are excluded from this calculation. Smaller sites were not included as they are on a different system with less accessible data. Reduced engineer trips to site were not included due to the difficulty of reliably capturing the required information.

Smart Parking	
Solution Description	The solution enables drivers to find an appropriate parking space more efficiently, by providing the necessary information to drivers to identify and reach the space using as little fuel as possible. AT&T connectivity allows the smart parking meters to communicate the parking occupancy on a street or in a car park and adjust prices based on this, helping drivers to identify parking spaces or garages and reducing the distance they drive before finding a space.
Implementation context	The implementation context for this solution is an urgan setting like the city of San Francisco in California.
Baseline Scenario	In the baseline scenario, drivers park as they always have done, driving around until they find a space, often circling a block multiple times.
ICT Solution Scenario	In the ICT scenario, the smart parking meters have an improved interface and demand-responsive pricing to help drivers pay for parking more easily and avoid fines. They also contribute to improved information provision for drivers by providing real-time parking availability information and direction to garages with parking to make finding space easier.
Methodology	The calculation of avoided emissions is based on the SFpark case study conducted by the SFMTA. The case study compares 'before' and 'after' studies of emissions impact where smart parking was piloted in the 'after' scenario. The same analysis was conducted for control areas where traditional parking occurred in both scenarios. The case study identified that drivers in the pilot areas achieved an emissions reduction after the implementation of the solution, even when adjusting for any independent changes that occurred in the control areas. This difference in distances, and primary data on greenhouse gases in both pilot and control areas is used to calculate the emissions saving per parking meter per year. Using data from the IEA relating to EV stock in the US, these savings figures are then further adjusted to account for increasing usage of electric vehicles, which have lower emissions impact.
Effects	**First Order Effects** The First Order Effects would include the embedded emissions of new parking meters. These would likely be minimal in this case study and not included in the calculation. **Second Order Effects** The emissions saving avoided per parking meter per year is calculated from observation of a 30% drop in vehicle miles in the pilot area compared to 6% in the control area. **Higher Order Effects** Longer term, improved access to parking and lower prices may encourage more driving into these areas and increase emissions. This effect has not been quantified.
Assumptions	**Secondary Data** This case study assumes all data from the SFMTA case study remains consistent between years. Additionally, it is assumed that the case study areas are representative of the broader city of San Francisco.
Data sources	Adjustment for EVs based on IEA 2023 projections SFMTA – Case study data for the SFpark pilot project (sfpark_pilot_project_evaluation.pdf)

	Comparative emissions impact of EVs vs petrol cars from EDF Energy (https://www.edfenergy.com/for-home/energywise/electric-cars-and-environment#:~:text=Research%20by%20the%20European%20Energy,low%20carbon%20electricity%20is%20used.)
Exclusions	First Order Effects and Higher Order Effects are excluded from this calculation.

Smart Street Lighting	
Solution Description	Smart street lights use LED bulbs that reduce energy usage compared with traditional incandescent lighting. They can generate additional savings by adjusting the lighting output as needed based on ambient light conditions. AT&T connectivity supports this adjustability of lighting, which creates the energy efficiency gain.
Implementation context	The implementation context is any city or municipal area that uses street lighting.
Baseline Scenario	In the baseline scenario, lighting is delivered by incandescent lighting that turns on and off via timer and has only one light setting.
ICT Solution Scenario	The ICT solution scenario is the use of smart street lighting, which turns on when it senses that lighting is required and can adjust the light levels to suit the required level of lighting.
Methodology	The baseline scenario emissions are calculated using data on average kWh consumption of traditional street lighting from the World Lighting Council and US Department of Energy. This is then multiplied by the US average grid emissions factor from the US EPA eGRID dataset. Savings are calculated using data from an Intel smart lighting case study which identified a 20% saving in energy consumption through the use of smart streetlights. This saving percentage is multiplied by the emissions from traditional street lighting to calculate the avoided emissions per street light per year.
Effects	**First Order Effects** These were not calculated as part of the case study. There will however be embedded emissions related to new equipment such as the sensor system. **Second Order Effects** There is an assumed reduction in energy consumption of 20% with implementation of the solution. **Higher Order Effects** There are no rebound effects, trade-offs or negative effects associated with this solution
Assumptions	• The case study assumes that the existing split between incandescent and LED lighting will be consistent across all implementation contexts. As a result, it also assumes that the kWh per street light per year are consistent. • The case study assumes that the 20% saving from smart street lights is consistent across all contexts
Data sources	**Secondary Data** Average yearly consumption: ~221 kWh / year based on World Lighting Council Report on Incandescent vs LED lights and US Energy Department Report Assumed carbon reduction based on Intel report: Smart Street Lights for Brighter Savings and Opportunities
Exclusions	First Order Effects are excluded from this calculation.

Advanced Water Metering Infrastructure	
Solution Description	A pilot project with 502 houses, assessing impact of advanced metering infrastructure (AMI) with AT&T connectivity. The internal case study found that by allowing for increased visibility of the performance of water utilities, improving water safety, reducing water leakages, this AMI reduced water-related waste, emissions and costs.
Implementation context	The implementation context for this water metering solution is within households to monitor for leaks.
Baseline Scenario	The baseline scenario for this solution is the water that leaks or is lost from homes before the implementation of the metering solution.
ICT Solution Scenario	The ICT Solution scenario is a water infrastructure that is monitored on a near real-time basis, enabling the utility to quickly identify and repair leakages.
Methodology	Water savings as a result of the AMI pilot were calculated by comparing the Initial Phase average loss (kgallons) to the Phase II average loss (kgallons). This difference was then extrapolated to cover a full year and also scaled up to estimate the potential water savings impact if this technology were to be implemented in all houses in the county. To calculate carbon emissions savings as a result of water savings, it was necessary to determine the average life cycle emissions intensity of the water. A factor for kgCO2e per gallon of saved water was calculated as part of the Badger Meter case study (see description below). This included consideration of the emissions associated with energy consumed from water pumping and production of sodium hypochlorite and alum, used typically in water purification.
Effects	**First Order Effects** The first order effects consist of the embedded emissions of the IoT devices, and the Qualcomm and Jacobs equipment, as well as the emissions derived from the installation, use, and maintenance of the AMI system. These have not been considered as part of the case study. **Second Order Effects** The implementation of AT&T enabled AMI systems delivers significant water, energy and cost savings. It decreases water consumption by monitoring for leaks, having allowed the water utility to identify and address several water leaks and safety issues that previously would have gone undetected. It thereby also decreases the energy usage required for processing and pumping the water and the associated GHG emissions. Lastly, there are also direct cost savings associated with reducing water consumption. **Higher Order Effects** There are no identified rebound effects, trade-offs or negative effects associated with this solution
Assumptions	The testing period between 1 May and 20 June 2018 is assumed to be representative of water loss with and without the AMI. The following assumptions were made on the levels of water and wastewater treatment to determine the embedded emissions of the region’s water: The energy intensity of water treatment and pumping is assumed to be consistent across the mainland US, such that the data collected as part of the Badger Meter

	case study is a suitable proxy to use to generate an emissions intensity factor for water savings from this advanced water metering infrastructure. The energy required to process the water was assumed to come from the local electricity grid. Some utilities may use fuel-powered pumps or systems, which are more carbon intensive than the grid. Likewise, they could also use electricity with a renewable energy guaranteed source of origin for all their operations, which would nullify the carbon intensity of the water. Having reviewed the energy usage of water utilities in the UK (which can be found in annual reports), it was apparent that using electricity from the grid is normal practice in water processing. Therefore, this assumption is reasonable, and a more granular approach is not necessary. The amount of water consumed (i.e., deferred from treatment) was calculated using FAO data, which published figures for the total municipal water withdrawal in the United States and the amount of treated municipal wastewater. This figure was used to determine the percentage of water supplied that was treated after use in municipal wastewater facilities. According to the Compendium of Sanitation Systems and Technologies, 2nd revised edition by eawag, wastewater includes used water from agricultural activities, surface runoff or storm water.
Data sources	**Primary Data** • Gwinnett 502-house Pilot: District Measured Area metered flow and volume from 1 May and 20 June 2018 Gwinnett 502-house Pilot: Total metered **Secondary Data** • Badger Meter: kWh per gallon water, sodium hypochlorite and alum concentration in purified water. • EcoInvent 3.11 for Market for aluminium sulfate, powder (RoW); Market for sodium hypochlorite • eGrid 2023 and IEA 2024 for derivation of electricity full lifecycle emissions • Molly A. Maupin, J. F. (2014). Estimated Use of Water in the United States in 2010. Virginia. Retrieved from https://pubs.usgs.gov/circ/1405/pdf/circ1405.pdf • Elizabeth Tilley, L. U. (n.d.). Compendium of Sanitation Systems and Technologies. eawag. Retrieved from http://www.iwa-network.org/wp-content/uploads/2016/06/Compendium-Sanitation-Systems-andTechnologies.pdf • Stanford Woods Institute, B. L. (2013). Water and Energy Nexus: A Literature Review. Water in the West. Retrieved from http://waterinthewest.stanford.edu/sites/default/files/Water-Energy_Lit_Review.pdf • Centers for Disease Control and Prevention. (2015, January 20). Retrieved from https://www.cdc.gov/healthywater/drinking/public/water_treatment.html
Exclusions	The embedded emissions of the IoT devices, and the Qualcomm and Jacobs equipment, as well as the emissions derived from the installation, use, and maintenance of the AMI system are not included in this study.

Efficient Cooling towers (EcoLab)	
Solution Description	The solution uses 3D TRASAR technology to provide around-the-clock monitoring and control of chemical-performance technology to optimize water strategy effectiveness, manage and reduce maintenance requirements and aid the reuse of water. AT&T connectivity supports the delivery of data required for around the clock monitoring.
Implementation context	The implementation context for this solution is within water cooling towers, which have a wide variety of industrial uses.
Baseline Scenario	Water cooling towers are used with a lack of visibility, measurement and monitoring of water use.
ICT Solution Scenario	In the ICT solution scenario, water usage is reduced through use of 3D TRASER Technology which provides around-the-clock monitoring and control of chemistry performance - the technology helps to provide water strategy effectiveness. For example, it reduces the need for maintenance and aids water reuse.
Methodology	EcoLab update their annual GHG savings on their own website, which can be found here eROI Customer Impact Counter | Ecolab. The abatement factor per TRASAR unit is calculated by using the carbon savings and total number of installed TRASARs from a specific case study in a 2019 reference year. The total number of TRASAR units in the current reporting is then derived by dividing the total annual saving for this year, as provided by EcoLab, by the calculated abatement factor.
Effects	**First Order Effects** First Order Effects would include the embedded emissions of a TRASAR monitoring unit, however these have not been calculated and included as part of this case study. **Second Order Effects** Per Trasar unit, the emissions savings are 1,554 kgCO2e per year. In total for 2024, EcoLab avoided 2,259,068 tCO2e **Higher Order Effects** There is a potential economic rebound effect related to this solution, where savings on water as a result of the TRASAR solution encourage increased water usage overall. This effect has not been quantified. There are trade-offs or negative effects associated with this solution
Assumptions	The case study assumes that the calculation published by EcoLab annually is complete and accurate. The case study also assumes no meaningful improvements to the TRASAR solution which would significantly impact the savings of water, energy or emissions have been made.
Data sources	**Secondary Data** eROI Customer Impact Counter | Ecolab. Case study - Emissions savings per unit: Calculated from EcoLab: Partners for Greater Purpose, Sustainability Report 2019
Exclusions	First Order Effects and Higher Order Effects are excluded from this calculation.

Water Leak Monitoring (Badger Meter)	
Solution Description	Badger Meter's home monitoring system, referred to as BEACON, uses AT&T cellular connectivity to monitor and report on water pressure within a system in real time to identify where leaks are occurring and notifying customers of these leaks so they can be resolved quicker than traditional automated meter readings (AMR)_ monitoring or customers noticing potential leaks when their water consumption increases on their bill.
Implementation context	The implementation context for Badger's solution is the range of municipal water systems which Badger operates in.
Baseline Scenario	The baseline scenario is the resulting water that leaks in a system that is monitored solely by manual meter readings (MMR) and/or AMR.
ICT Solution Scenario	The ICT Solution scenario is the resulting water that leaks in the system that is monitored by Badger Meter's monitoring solution, referred to as advanced metering infrastructure (AMI), which allows for automated meter reads and leak detection using cellular connectivity to communicate when and where leaks occur.
Methodology	**Water pumping and chemical savings from domestic leaks** 1) The water pumping savings calculation takes the average hourly leak rate within a home from a weighted average calculated from Badger's BEACON data, which is used in both the reference and the solution scenario. 2) The time to detect a leak in the baseline scenario was calculated by combining the weighted average time to fix a leak from the Badger Data, and the earliest time that a customer would be able to notice an increase in their water consumption from AMR or manual reads (i.e. when they receive their bill. The shortest frequency of possible bill delivery would be monthly, and assuming leaks occur randomly, and that leaks are always detected as soon at the first instance of a bill of abnormal consumption - this is a very conservative assumption - it would take between 10-40 days for a leak to be detected). 3) In the solution scenario, the detection and repair time of 10-40 days (average 25 days), with this difference in time multiplied by the average leak rate to determine the total volume of water saved. This is then multiplied by the kWh/gallon pumping figure provided by badger, before being multiplied by an "Average US" Grid Emissions factor to calculate avoided emissions. 4) This total water saved value is also used to calculate emissions savings from chemicals, with the defined concentrations of chemicals converted to weights and multiplied by the relevant emission factors for their manufacture. **Truck roll savings from Customer call outs** 1) The avoided number of truck rolls per 1000 AMI connections and the average distance per truck roll is provided from case study data from a range of Badger Meter case studies. 2) This distance avoided is multiplied by the avoided number of truck rolls to capture a total distance. 3) This in turn is then multiplied by the average emissions factor for a van from the 2024 DESNZ conversion factor set to capture avoided emissions. **Truck rolls from reduced manual and drive-by meter reads**

	4) The total number of truck rolls per month avoided from driving to collect meter readings was provided by Badger Meter from case study data, as was the total number of metered connections. 5) The average distance per truck roll was gathered from a secondary source from the US department of Energy. 6) The provided data was scaled to calculate the total avoided truck rolls per 1000 AMI monitoring solutions per month and the total distance. Which is then multiplied by the same van emissions factor from DESNZ as above. 7) This is then scaled to an annual saving per 1000 AMI connections.
Effects	**First Order Effects** Embedded emissions of the ORION endpoints, including the following components, were accounted for: • Standard modem • Battery - D cell battery • PCB • Plastic housing • Epoxy **Second Order Effects** Resource savings • 524,302 gallons of water per 1000 AMI connections • 1,923 kWh per 1000 AMI connections • 24.3 kg of Alum savings per 1000 AMI connections • 4.9 tonnes of sodium hypochlorite savings • A total annual distance of 1,791,133 km of truck rolls avoided from customer call outs and 1,524,759 km from meter reads annually, resulting in associated fuel savings **Higher Order Effects** Some research was done to consider the Higher Order Effects also. There is a quantifiable increase in energy consumption from the need to treat more water at wastewater treatment facilities due to the reduction in leaks. However, the potential increase in emissions that would occur from allowing wastewater into the natural environment is assumed to exceed the impact of treating this water. Economic rebound effect may occur due to more efficient leak detection and repair, meaning customers are likely to save money on bills and could consume more water to offset their savings. However, as the savings for each individual are small, they are unlikely to cause this rebound effect on a material scale.
Assumptions	• The volume and concentration of chemicals used in water treatment is consistent across the mainland US. • Average truck rolls avoided per callout and the average distance avoided is consistent across all areas that Badger operates in. • Truck roll distances for customer callouts and AMR monitoring are taken from customer case studies and a US Department of Energy study, respectively. These figures appear low compared to other case studies, but we have used these distances to be conservative due to a lack of primary (telematics) data.

	• Detection in the baseline scenario has a lag related to the time it takes for customers to receive their bills. • The data provided on the embedded emissions per radio unit is complete and accurate. • BEACON system data used in calculated weighted average leak rate and detection time is accurate. • The energy required for pumping 1 gallon of water provided by Badger is accurate and consistent across US water systems. • Average diesel trucks are used for callouts and monitoring, using the DESNZ "Average Van - Diesel" EF for calculations. • Under the assumption that Badger Meter's connected AMI network solution allows leaks to be detected instantaneously as they arise, the provided data implies that after detection, it takes leaks 48.5 days to be fixed, on average. • The shortest frequency of possible bill delivery would be monthly, and assuming leaks occur randomly, and that leaks are always detected as soon as the first instance of a bill of abnormal consumption (this is a very conservative assumption), it would take between 10-40 days for a leak to be detected (assuming a bill takes 10 days to be received and that there are 30 days in a month)
Data sources	**Primary Data** • Badger advised data points including: water pumping energy requirement, domestic leak rate, chemical concentrations. • Badger BEACON leak data • ORION endpoint specifications and radio production emissions estimates (from Badger) • Case study data from Columbia S.C. and Aurora, Colorado **Secondary Data** • EcoInvent 3.11 for Market for aluminium sulfate, powder (RoW); Market for sodium hypochlorite • eGrid 2023 and IEA 2024 for derivation of electricity full lifecycle emissions • DESNZ 2024 for Average Van – Diesel • Monitoring for truck rolls distance - US Department of Energy: https://www.energy.gov/sites/prod/files/2016/12/f34/AMI%20Summary%20Report_09-26-16.pdf
Exclusions	The potential rebound effect of increased water volumes requiring treatment is excluded due to a lack of data. We assume the net carbon impact of this is mitigated via the emissions savings related to the broader environmental impact of reduction in untreated water leaving the water system through leaks. First Order Effects related to increased energy consumption have not been included in this assessment due to a lack of data. These increases are likely to be de minimis.

Industrial

Concrete Management (GCP)	
Solution Description	AT&T's connectivity enables the operation of internet-connected sensors which are utilised by GCP's solution 'Verifi' to monitor concrete composition when in-transit. Having real-time measurement of concrete mixes allows customers to meet specification requirements accurately and efficiently, reducing unnecessarily added excess material and truck idling times.
Implementation context	The implementation context for this case study includes GCP's customers that have purchased Verifi to assist with concrete management within the construction of built infrastructure.
Baseline Scenario	Commonly, producers of concrete use a higher proportion of cement than is required in concrete mixes. Concrete has minimum strength specifications that must be adhered to but, without visibility on the composition, producers often vastly 'overdesign' mixes. The baseline scenario is based on having no visibility of the concrete composition when in transit and, once it reaches the destination, adjusting by adding cement until it is fit for purpose.
ICT Solution Scenario	Verifi allows users to know exactly how much cement must be added to a mix to meet specification and, therefore, reduces surplus waste. Verifi also enables the reduction of time spent idling by concrete mixer trucks. This is because the AT&T connectivity allows the user to monitor and regulate the composition of the concrete mix from when it is first received, through transit and up to delivery. As the correct composition can be met and maintained more quickly than if mixes were tested manually, the time during which the truck is using fuel, is decreased.
Methodology	Three case studies of Verifi implementation were used to calculate an average value of cement reduced per kilogram of concrete delivered. This was based on data provided for the total cement used and total concrete volume delivered per case study, each with an unmanaged baseline scenario compared against a Verifi-managed scenario. Emissions associated with the cement production and all upstream activities (mineral extraction, delivery, processing etc.) were calculated using US-specific emission factors from Ecoinvent 3.11. Datasets containing records on idling time and drum revolutions were provided for Verifi customers for the scenario before usage of Verifi and for the scenario after Verifi implementation. The difference between the average time spent idling between loading completion and truck leaving the plant was calculated for each scenario. The average idling time saved due to Verifi was multiplied by a factor for diesel consumption per hour for a typical delivery truck to calculate the volume diesel saved. The emissions associated with this diesel reduction were calculated using a DESNZ emission factor for average biofuel blend diesel. The average number of concrete mixer drum revolutions between truck arrival at site and start of concrete discharge was also calculated for each scenario. A value for volume of truck fuel consumption per drum revolution was provided by GCP and this was used to calculate associated diesel and emissions saved in the same way as with the idling time reduction calculations. The emissions reduction (for both cement and diesel reductions) directly attributable to the use of Verifi was calculated by multiplying the calculated emission change by a percentage multiplier representative of the fraction of time during which Verifi was active and the savings could be attributed to the use of the solution.
Effects	**First Order Effects**

	Embedded emissions associated with the internet-connected sensors used in the Verifi solution were not considered in this case study. **Second Order Effects** • Reduced cement per cubic metre of concrete produced. • Reduced idling time of concrete mixer delivery trucks per cubic metre of concrete produced. • Reduced drum revolutions of the concrete mixer delivery trucks per cubic metre of concrete produced. **Higher Order Effects** There are no rebound effects, trade-offs or negative effects associated with this solution.
Assumptions	• It is assumed that the average cement composition is 25% Portland cement and 75% pozzolana and fly ash. • The fuel type of all concrete delivery trucks is assumed to be diesel, corresponding to the DESNZ emission factor for 'Diesel (average biofuel blend)'. • It is assumed that the average fuel consumption of a delivery truck whilst at idle is 0.84 US Gallons per minute, based on the value reported by Argonne National Laboratory for a delivery unloaded heavy truck (to be conservative in the estimate of amount of truck fuel saved, the truck was assumed to be unloaded although loading actually varies through operation). • It is assumed that the average fuel consumption of a delivery truck is 0.01 litres per drum revolution based on GCP guidance. • To attribute savings to Verifi based on active 'uptime' of the solution, it is assumed the reduction in emissions that has occurred between before and after implementation of Verifi occurred uniformly through time (a conservative approach to estimating the direct impact of Verifi on reducing emissions).
Data sources	**Primary Data** • Quantity data relating to total cement used and total concrete delivered for Verifi customers. • Quantity data relating to idling time and drum revolutions for Verifi customers. • A GCP 'uptime' report, measuring the proportion of time during December 2022 when the Verifi solution was active for each customer. Values advised by GCP: • Concrete produced by Verifi customers – 2021. • Typical case study cement reduction. • Fuel consumption per truck drum revolution. **Secondary Data** Ecoinvent 3.11 EFs: • Cement Production, Portland • Cement production, Pozzolana Portland DESNZ 2024 EFs: • Diesel (average biofuel blend). Argonne National Laboratory. *Vehicle Idle Reduction Savings Worksheet*. https://www.anl.gov/sites/www/files/2018-02/idling_worksheet.pdf

	• US Gallons per minute, diesel, delivery truck.
Exclusions	Verifi can also enable other components of a typical concrete mix to be reduced. Other factors that have been excluded from this study due to the lack of available data include: • Reduced water (replaced by Admix solution). • Reduced Admix solution (replaced by sand). • Reduced number of rejected concrete loads. First Order Effects are excluded from this calculation.

Consumer/Retail

Smart Landscape Irrigation	
Solution Description	AT&T connectivity enables real-time 24/7 leak notification and communication of more complete weather data to irrigation controllers. This lets customers track and manage their water usage with greater speed, precision and simplicity using cloud-based water management systems.
Implementation context	For irrigation controllers used in commercial settings, the HydroPoint solution allows them to monitor for leaks and determine more precisely where and when to water. Reducing water consumption by being more precise and reducing associated water pumping energy emissions.
Baseline Scenario	In the baseline scenario, watering of landscaping is not targeted and irrigation occurs regardless of expected weather conditions.
ICT Solution Scenario	With enhanced weather and field monitoring through HydroPoint, irrigation controllers can more precisely determine where and when to water, reducing water consumption and associated emissions. The monitoring solution can also support leak detection further reducing water consumption and emissions.
Methodology	To calculate carbon emissions savings due to water savings, it was necessary to determine the life cycle emissions intensity of the water used at each site. The emissions intensity of a public water supply varies depending on the source of the water (e.g. ground source vs. surface), the topography of the land over which it is distributed (i.e. steep terrain requires more electricity to pump the water), the level of the water and wastewater treatment and the carbon intensity of the electricity grid that powers the water processing and pumping. State level data covering grid emissions factors (including transmission and distribution (T&D) losses)[3] and water source breakdowns for public supply was used with assumptions of water levels and wastewater treatment which were based upon the standard practice of public water utilities in the U.S. Energy usage figures for water distribution and Well to Tank (WTT) emissions were included in the calculation.
Effects	**First Order Effects** Embedded emissions associated with the electronic equipment and energy consumption of these devices were not considered as part of this case study **Second Order Effects** • Water savings resulting from implementation of Hydropoint solution • Associated GHG savings from reduced energy consumption for processing and pumping water. • **Higher Order Effects** There are no rebound effects, trade-offs or negative effects identified as part of this case study.
Assumptions	The following assumptions were made on the levels of water and wastewater treatment to determine the embedded emissions of the water at each site: • The energy intensity of water treatment included coagulation, flocculation, filtration, microfiltration and disinfection. All of these processes are considered standard for a public water supply.[3]

[3] EPA. (2016). Emissions & Generation Resource Integrated Database (eGrid). Retrieved from https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

	• Tertiary wastewater treatment was assumed, as it is the most common degree of wastewater treatment.[4] Figures for the energy intensity (EI) of total water supply and wastewater treatment (including treatment and distribution) were calculated using data (given in kWh/MG) taken from a California Public Utilities Commission study.[4] Figures were given in this study for the EI of supply and conveyance from various sources, different degrees of water and wastewater treatment and water distribution. Although data from the study is state specific, we believe it is reasonable to assume that water supply and wastewater treatment practices are largely consistent across the US. In order to be conservative, where ranges in energy intensity of water treatment, wastewater treatment, conveyance etc. were given, lower bounds of these ranges were taken. All energy required to process the water used at each site was assumed to come from the local electricity grid. Some utilities may use fuel-powered pumps or systems, which are more carbon intensive than the grid. Likewise, they could also use electricity with a renewable energy guaranteed source of origin for all their operations, which would nullify the carbon intensity of the water. Having reviewed the energy usage of water utilities in the UK (which can be found in annual reports), it was apparent that using electricity from the grid is normal practice in water processing. Therefore, this assumption is reasonable, and a more granular approach is not necessary.
Data sources	**Secondary Data** California Public Utilities Commission. (2010). Embedded Energy in Water Studies, Study 2: Water Agency and Function Component Study and Embedded Energy - Water Load Profiles. GEI Consultants/Navigant Consulting. Retrieved from: ftp://ftp.cpuc.ca.gov/gopher-data/energy%20efficiency/Water%20Studies%202/Study%202%20-%20FINAL.pdf
Exclusions	• The embedded carbon emissions of the electronic equipment (i.e. manager and member controllers within the irrigation system) and electricity usage of these devices. • Reductions in the emissions from site vehicles which are no longer required to physically visit control valves and controllers used by the irrigation system.

[4] Stanford Woods Institute, B. L. (2013). Water and Energy Nexus: A Literature Review. Water in the West. Retrieved from: http://waterinthewest.stanford.edu/sites/default/files/Water-Energy_Lit_Review.pdf

Food, Beverage, and Agriculture

Food Waste to Energy (Grind2Energy)	
Solution Description	Grind2Energy is a solution for large food waste generators like supermarkets or hotels. The system turns food scraps into a liquid slurry than is transported to local anaerobic digestion facilities, preventing methane emissions and reducing the number of waste pick ups. The system is enabled by IoT connectivity, provided by AT&T which supports remote monitoring that enables improved pump out scheduling, optimises uptime and supports predictive maintenance.
Implementation context	The implementation context for grind to energy is a range of large food waste producers, this includes businesses such as supermarkets, hotels, casinos and sports arenas.
Baseline Scenario	In the baseline scenario, food waste from these businesses is sent to landfill to decompose, producing methane gas.
ICT Solution Scenario	In the ICT solution scenario, food waste in converted to slurry which is transported to an anaerobic digestion facility once the IoT monitoring identifies that the holding tank is full. In the anaerobic digestion facility, methane emissions are captured in a controlled environment and converted to renewable energy rather than being released into the atmosphere.
Methodology	The GHG emissions reductions are the sum of the emissions reduction from: • Reduced methane emissions from diverting food waste from landfill • Replacing carbon intensive fuel with generation of low-carbon bio-fuel • Reduced pick-ups The reduced methane emissions are calculated in combination with the replacement of carbon intensive fuel with low-carbon energy generated from food waste. First the methane emissions from food waste going to landfill are calculated using emission factors from the EPA Waste Reduction Model (WARM). Second, the emission savings are calculated from sending food waste to anaerobic digestion, which is then added to the reduced methane emissions from diverting food waste from landfill. The emission reduction resulting from a reduction in waste pick-ups were calculated by comparing the pick-ups post and pre-implementation across all of sites. The number of pick-ups pre-implementation were estimated based on the average visits per site per month and applied to the total number of sites post-implementation. The total reduction of pick-ups were then multiplied by an average return distance for a pick-up and converted into emissions using an emission factor for LVGs.
Effects	**First Order Effects** Embedded emissions associated with the IoT sensor technology, and the embedded and in-use emissions of the food grinder equipment used in the Grind2Energy solution were not considered in this case study. **Second Order Effects** • Reduced Methane emissions from reduced waste to landfill • Reduced truck rolls due to a reduced number of food waste pick-ups. **Higher Order Effects** There are no rebound effects, trade-offs or negative effects associated with this solution.
Assumptions	▪ It was assumed that the 4 months' food waste data is representative of the full year (and also similarly for the number of pick-ups).

	▪ It is assumed that the baseline for all customers (prior to use of the InSinkErator) was to send the food waste to landfill. ▪ The following assumptions have been made to obtain the landfill and anaerobic digestion emission factor for food waste from the WARM model: • National average grid electricity emission factor used to account for the avoided electricity-related emissions during the landfilling process • National average moisture conditions at landfill • Wet digestion anaerobic digestion process • No curing of digestate after digestion • Digestate land application • Default distances that occur during the transportation of materials to the management facility. ▪ It was assumed that all food waste consists of the WARM model's typical food waste mix (Beef 9%, Poultry 11%, Grains 13%, Fruits and Vegetables 49%, Dairy Products 18%) ▪ It is assumed that the average one-way distance for a waste pick-up is 15 miles and it was assumed that the trucks are 0% laden on the way to pick-up the waste and 100% laden on the return trip.
Data sources	**Primary Data** ▪ Food waste data from Grind2Energy ▪ Pick-up data from Grind2Energy **Secondary Data** ▪ WARM Model version 14, food waste anaerobic and landfill emission factors[5] ▪ DEFRA 2017 emission factors for an average LGV vehicle
Exclusions	▪ The embedded and in-use emissions of the food grinder equipment (previous measurement of the energy used by the food grinders showed this to be negligible) are not considered in this calculation. ▪ Water consumption and the associated emissions of the food grinder equipment (water use is minimal) were also excluded. ▪ Emissions from the use of fertilizer that has been generated (assumed that these would have been generated anyway by the fertilizer that is being replaced) were also excluded.

[5] Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM ver14), Tables 1-10 and 1-36; https://www.epa.gov/sites/production/files/2016-03/documents/warm_v14_organic_materials.pdf and WARM model ver14; https://www.epa.gov/sites/production/files/2018-03/warm_v14_march13_2018.xls

Agriculture Sensors (Soiltech)	
Solution Description	AT&T connectivity enables Soiltech sensors that monitor soil moisture, temperature, humidity, location and impacts that may create bruising while crops are being transported. These sensors can be used during the stages of growth, transportation and storage for a variety of crops. This technology helps increase yield, reduce spoilage, decrease water consumption in irrigation, and decrease farm vehicle fuel consumption by reducing need to drive for in-person monitoring of fields. Soiltech sensors also lead to a reduction of fertilizer use, though this is currently not being accounted for in the case study.
Implementation context	Farmers can use Soiltech sensors to monitor soil; storage conditions and bruising for a wide range of crops, including potatoes, onions, sugar beets and barley. This can reduce spoilage of crops; increase water efficiency; reduce fuel consumption related to visual inspection of crops; reduce fertiliser use; and increase crop quality and yield.
Baseline Scenario	The baseline scenario is the use of traditional farming methods, relying primarily on visual inspection to identify when to irrigate, apply fertiliser; or cultivate crops.
ICT Solution Scenario	In the ICT solution scenario, Soiltech's durable sensor is planted with the seed during an agricultural cycle to inform on and monitor the soil type; moisture levels; bruising via impacts during harvest, trucking sorting, offloading, etc; monitor storage humidity and temperature. The sensor can then be recharged and re-used for the next cycle.
Methodology	The GHG emissions reductions are the sum of the emissions reductions from: • Reduced emission intensity due to increased yield • Reduced use of irrigation water, resulting in less pump energy used • Reduced spoilage of crops, avoiding the farmer having to use additional water, land, fuel, and fertilizer to achieve the contracted level of production • Reduced emissions from farm vehicles The reduced emissions intensity due to increased yield was calculated on the basis that the use of Soiltech sensors results in an increase of 1 metric ton of potato crop per acre. This value is based on data collected at the BHF Farm, comparing previous year's yield in the same field (without Soiltech sensors). The new yield of potato crop per acre was multiplied by the average emission factor for potato production, and divided by the previous yield, to calculate the lower emissions intensity of the potato crop using Soiltech sensors. Subsequently, the previous yield was multiplied by the average emission factor for potato production and the new yield was multiplied by the new emissions intensity factor – the difference between these values gives us the total emissions savings per acre (tCO_2e per acre). The GHG emission savings from reduced use of irrigation water was calculated using data from the MLC Farm (2,550 acres). By using Soiltech sensors, a total reduction of 140,000,000 gallons of water was achieved. This total was divided by the number of acres in this farm to calculate the gallons of water saved per acre. To then calculate water emissions savings, an average US energy factor for ground water pumping (average kwh per million gallon of water pump) was used to estimate energy use and the US electricity grid was applied to convert this total into emissions. The GHG emission savings from reduced spoilage was calculated from the recorded 30% decrease of spoilage through the use of Soiltech sensors, at the MLC Farm. Using an assumed average yield of 25 metric tons of potato per acre

	with a 5% spoilage rate as the baseline, a 30% reduction was applied to the 5% spoilage rate to calculate the new total potato crop output with acre. The difference in output represents the metric tons of spoilage avoided. To calculate the total tCO2e avoided per acre, a US average emission factor for potato production was used. The GHG emission savings from reduced fuel was calculated using an estimated average of 100 driving miles avoided per day over 100 days out of a year, derived from estimates recorded at the BHF Farm. This average was deemed to be reasonable as the farm covers over 10,000 acres, with fields as far apart as 300 miles. The 100 days reflects the average growing period for potatoes. Total miles avoided (miles avoided per day * 100 days) was multiplied by the emission factor for a dual purpose 4x4 to give us total avoided emissions in tCO2e.
Effects	**First Order Effects** The embedded emissions of Soiltech's sensor constitute the first order effects of this solution. These emissions were not calculated or considered as part of this study **Second Order Effects** Carbon savings from Soiltech come from four main areas: • Reduced emission intensity due to increased yield. • Reduced consumption of irrigation water, resulting in less pump energy used and therefore fewer GHG emissions • Reduced spoilage of crops, avoiding the farmer having to use additional water, land, fuel, and fertilizer to achieve the contracted level of production • Reduced emissions from farm vehicles, as the remote monitoring reduces the need to physically visit the fields to check moisture levels **Higher Order Effects** There are no rebound effects, trade-offs or negative effects associated with this solution.
Assumptions	It is assumed that the savings monitored are a sole result of Soiltech's sensors.
Data sources	**Secondary Data** • Potato emission factor (EcoInvent 3.5) • BHF and MLC Farms data (annual yield increase, spoilage reduction, mileage reduction, and water reduction) provided by Soiltech • Petrol dual purpose 4x4 emission factor (DEFRA 2019) • Water pumping emission factor (Food and Agriculture Organization of the United Nations (FAO) Aquastat & eGrid)
Exclusions	• Embedded carbon emissions of the sensors • Emission reductions from reduced fertilizer use

Energy

Solar PV Optimisation	
Solution Description	Solar photovoltaic (PV) with AT&T's IoT connectivity enables users to monitor, troubleshoot, and improve the performance of installed solar systems. This visibility was found to decrease emissions by reducing the need for a technician to visit site (reducing travel emissions) and increasing uptime in electricity generation (generating additional renewable electricity that can be introduced into the grid).
Implementation context	The implementation context for IoT connected solar is any installed solar PV system.
Baseline Scenario	In the baseline scenario, solar PV systems would require a technician to visit site to diagnose if there are any issues or respond to outages from the system.
ICT Solution Scenario	In the ICT solution scenario, solar PV systems are monitored by IoT enabled connectivity, meaning monitoring of output and troubleshooting issues can be done remotely before dispatching technicians to the installation.
Methodology	**Reduced truck rolls** The reduced truck rolls are calculated by identifying the number of solar PV systems that would require truck rolls in the baseline scenario. This is then multiplied by the distance driven per truck roll from an Enphase case study. This distance then multiplied by the emissions factor from DESNZ for an average truck to calculate the overall emissions saving from truck rolls and the savings per solar PV system. **Increased uptime in electricity production** The total number of microinverters that would fail each year is calculated using the typical system size and the percentage that are out of action at any one point in time due to failures. This is scaled by the number of microinverters at connected sites to calculate how many would fail each year if they were not connected. This figure is then multiplied by the average annual power generation per microinverter per year (based on 3 different models and their percentage deployment) to calculate the amount of additional renewable energy generated. This figure is then multiplied by the US EPA eGRID emission factor and the upstream emissions factors related to generation and transmission from the IEA, as this would represent the emissions if all the additional energy was generated by the grid.
Effects	**First Order Effects** The First Order Effects for solar PV optimisation would be the embedded emissions associated with the IoT connectivity solution. These were not calculated as part of the case study. **Second Order Effects** Emissions impact is decreased via a combination of a reduction of truck rolls, equating to 1.6 miles per cellular system, and a reduction in the energy consumption of microinverters, equating to 7.3 kWh per cellular system. **Higher Order Effects** There are no identified rebound effects, trade-offs or negative effects associated with this solution.

Assumptions	This case study assumes that the total number of systems reporting via IoT and not reporting via IoT remain consistent. The case study also assumes that the typical microinverter systems and their power generation have remained consistent since the case study year.
Data sources	**Primary Data** • Enphase case study on the impact of IoT monitoring on Solar PV **Secondary Data** • eGrid 2023 and IEA 2024 for derivation of electricity full lifecycle emissions • DESNZ 2024 factor for average truck emission factor
Exclusions	The embedded emissions of the IoT connectivity solutions are excluded from the calculation The increased adoption of solar sales was excluded from the savings total due to uncertainty.

Residential smart meters	
Solution Description	Smart meters utilise connectivity to monitor and inform households of their energy usage, helping individual households to identify where/when they are using energy and potentially identify areas where they could reduce this.
Implementation context	The implementation context for residential smart meters is within US homes.
Baseline Scenario	The baseline scenario is the use of electricity with no monitoring of consumption beyond monthly bills and meter reads.
ICT Solution Scenario	The ICT solution scenario is the constant monitoring of energy consumption through the use of the smart meter.
Methodology	The case study relies on secondary data, multiplying the average annual electricity consumption per US Household from the EIA by the electricity saving per smart meter from a range of case studies as aggregated here: Do smart meters reduce households' energy consumption? | BIT
Effects	**First Order Effects** The embedded emissions of the smart meter would be the First order effect. These were not calculated as part of the case study. **Second Order Effects** The calculated second order effect are emissions savings of 169.78 kgCO2e/device/year **Higher Order Effect** There is a potential economic rebound effect with this solution, where the financial savings from reduced energy encourage increased use may encourage less frugal domestic consumption.
Assumptions	The energy savings and energy consumption per household are assumed to be consistent
Data sources	US EIA domestic electricity consumption: https://www.eia.gov/tools/faqs/faq.php?id=97&t=3 Smart meter energy reduction percentage: Do smart meters reduce households' energy consumption? | BIT US EPA eGrid + upstream factors (eGRID 2023 and IEA 2024)
Exclusions	First Order Effects and Higher Order Effects are excluded from this calculation.

Reseller

Value Added Reseller (VAR)	
Solution Description	Value added reseller connections are AT&T IoT connections which are sold for use within connected solutions via a third party.
Methodology	The purpose of this abatement factor calculation is to approximate the impact of AT&T's VAR connections, using the average abatement factor of AT&T IoT enabled solutions (known to be included in the reseller solutions) as a proxy. The choice of solutions that were included in this average is based on a knowledge of the broader market provision of connectivity to solutions. Fleet Management, EV Charging, Smart Pallets, Remote Patient Monitoring, Building Energy Efficiency as a Service, Building Energy Management System, Smart Parking, Smart Street Lighting, Residential Smart Meters, Durable Ag Sensors, Advanced Water Metering Infrastructure, Solar PV Optimisation, Efficient Cooling Towers, Carsharing, Fleet Management (Traxen) and Water Leak Monitoring (Badger Meter). A weighted average abatement factor is created based on the number of connected units for each solution and the respective abatement factor. The total connection count for each of the solutions included in the average is divided by the total number of AT&T IoT connections sold in the reporting year to approximate the proportion of sold reseller connections that would result in abatement. This proportion is multiplied by the total number of value added reseller connections and the weighted average abatement factor to calculate the annual abatement.
Assumptions	This calculation is based on the key assumption that reseller connections are sold to same type of solutions in exactly the same proportion as AT&T's own direct sales of IoT connections. It is also based on the premise that the abatement factors calculated for AT&T's own direct customers are, on average, equally applicable to solutions of the same type which are provided with connectivity by reseller connections.