Cross-Pollination and Digitalization of Public Sector Data

Opportunities and Challenges

Energy Division
Institution for Development Sector

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Executive Summary

This report has been designed to aid governments in Latin America and the Caribbean in embracing the opportunities public sector data utilization and AI deployment can provide in achieving a circular economic model and the UN's Sustainable Development Goals (SDGs). To do this, the report provides a novel concept of sharing data between these key players that we have dubbed *data cross-pollination*. We have defined the concept as the process of exposing government actors to new ways of thinking by sharing knowledge, thus allowing them to make better decisions, provide better services, and design better policies. Drawing on this concept, it considers four SDGs, i.e., energy, sustainable food systems, reducing pollution, and smart cities, that could benefit from using and reusing data for data cross-pollination. Building on case studies and initiatives stemming from these four SDGs, the report highlights the main challenges and opportunities of utilizing data to achieve a circular economic model and sustainable development. It also looks into the potential of AI to enrich such data cross-pollination and focuses on potential applications of AI in circular innovation that can be transposed in the public sector.

The report's first chapter provides the reader with an overview of the data ecosystem and the main challenges governments face when leveraging data, i.e., data silos, data interoperability, data findability, accessibility, representativeness, quality, reusability, security, and literacy. It further provides a definition of data cross-pollination that is supplemented by the concepts of open data and data philanthropy.

The second chapter presents an overview of the data landscape in the energy sector (SDG 7) and how these data can be cross-pollinated with healthcare (SDG 3), agriculture and food security (SDG 2), and what opportunities and challenges may lie ahead. The third chapter highlights the opportunities and challenges that data cross-pollination trends present in the creation of sustainable food systems (SDG 2). Furthermore, the chapter outlines how the agricultural industry can realize its full digital potential by cross-pollinating its data with the energy sector (SDG 7) and the water sector (SDG 6).

The fourth chapter of the report gives an overview of the health and environmental toils governments across the globe are facing due to air pollution. It lays out the current applications of data analytics to curb its adverse effects and what opportunities and challenges lie in leveraging these data. The fifth chapter tackles the issues created by rapid urbanization by proposing data cross-pollination to create sustainable energy (SDG 7) and healthcare (SDG 3) environments within a smart city paradigm.

The sixth chapter of the report aims to provide the reader with an overview of how data from the sectors mentioned above can be pollinated with AI to enable Latin America and the Caribbean to shift to a circular economic model. The chapter further lays out the challenges of deploying AI, as well as good practices facilitating data sharing within the public sector.

List of Acronyms

4IR	Fourth Industrial Revolution
AI	Artificial Intelligence
AMI	Advanced Metering Infrastructure
API	Application Program Interface
AR	Augmented Reality
DDP	Development Data Partnership
DMCii	DMC International Imaging
ERTMS	European Rail Traffic Management System
ERNC	Energías Renovables No Convencionales
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GIS	Geographic Information Systems
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and Communication Technologies
IDB	Inter-American Development Bank
IMERG	Integrated Multi-Satellite Retrievals for Global Precipitation Measurement
IMF	International Monetary Fund
IoT	Internet of Things
IRENA	International Renewable Energy Agency
IT	Information Technology
LAC	Latin America and the Caribbean
LCA	Life Cycle Analysis
ML	Machine Learning
NREL	National Renewable Energy Laboratory
NRW	Non-Revenue Water
OGD	Open Government Data
PMU	Phasor Measurement Units
PPP	Public-Private Partnership
SDG	Sustainable Development Goal
SFS	Sustainable Food System
SWS	Smart Water System
SWT	Smart Water Technology
VR	Virtual Reality
WDS	Water Distribution System
WFP	Water Footprint
WSN	Wireless Sensor Network

1. Introduction

Data is no longer just a buzzword; it is imperative to develop our societies in the digital age. This new resource dubbed "the new oil" seeps into every pore of our lives and is beginning to find its use across sectors and industries, bringing about a new era of economic development and growth. Businesses have already started the race for digital transformation to capitalize on the extensive value data brings. This trend is no longer exclusive only to commercial operation models whose main goal focuses on earning profits by providing goods and services, developing and sustaining a competitive edge, and satisfying customers and other stakeholders by delivering value. Governments have begun to understand the importance of data in maintaining domestic tranquility, achieving sustainable development, securing their constituents' fundamental rights, and promoting general welfare and economic growth.

Governments no longer remain idle as they have begun to view data as an asset for more effective and efficient decision-making. Traditional decision-making processes in government take much longer due to the involvement of many diverse actors. Governments and government agencies are privy to vast amounts of data that they accumulate through implementing laws and regulations, public services, financial transactions, other interactions with citizens, and intragovernmental interactions. These developments have coaxed governments to explore avenues to transition and enable a data-led and data-informed circular economic model.[1]

However, governments must be cognizant of the general complexities of social issues, which are multifaceted and profoundly impact one another. Hence, navigating the new and emerging issues which are a byproduct of the ever-increasing generation of data through our daily use of online services will be paramount. If governments are to reap the benefits of digitalization and public sector data cross-pollination, they must introduce adequate checks and balances to ensure data privacy for their citizens. To ensure data privacy compliance, governments must impose data governance policies that ensure the data's availability, usability, integrity, and security. In order to be effective, data governance must ensure that data is consistent, trustworthy, and does not get misused.[2]

The effective use of data in government by the departments and agencies that underpin its operations is an integral part of public sector digitalization and digital transformation. Governments are becoming more aware of the benefits of the vigorous exploitation of personal information and data on social justice, citizen-centric government, and personalized services. As data cannot be depleted and can be reused indefinitely for an unlimited range of purposes, governments can use data to better understand and design services to fit the needs of their citizens better, deliver positive outcomes for the wider public, and promote the effective use of public resources, transparency, and accountability.[3] Furthermore, by cross-pollinating data, the benefits of using this data by governments can promote new business opportunities, sustainable development, innovation, and competition and cooperation within and across sectors.

[1] The circular economy is a model of production and consumption which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible.
[2] Stedman, C., Vaughan, J. (2020) What is Data Governance and Why Does it Matter?, at https://searchdatamanagement.techtarget.com/definition/data-governance
[3] Timmis, S., Heselwood, L., Harwich, E. (2018) Sharing the Benefits How to Use Data Effectively in the Public Sector, at https://reform.uk/research/sharing-benefits-how-use-data-effectively-public-sector

Despite the benefits of data analysis on making better decisions, improving policy design, and service delivery, data sharing among government departments and agencies presents multiple challenges. The use and sharing of public sector data pose several challenges: (i) data silos between different sectors and departments, (ii) data interoperability and interoperability of systems, (iii) data findability, accessibility, representativeness (non-biased data), quality, reusability, security, and literacy.

- ***Data silos***. A repository of data can be controlled by one department or business unit, isolating it from the rest of the organization, making the data siloed. Data silos hinder the application of big data analytics, Artificial Intelligence (AI), and Machine Learning (ML), as siloed data is neither readily accessible, coherent, or consistent. Government agencies and departments usually have large isolated databases which contain confidential and public information.[4] Data silos impact the very core of a government agency's operation. In many cases, the issues surrounding silos stem from the inability to separate confidential or sensitive data from data that could be shared within the government and data in the public domain. Much like the "Tower of Babel," these fragmented, disorganized systems keep data isolated, hindering the value that data sharing could create amongst government players.[5]
- ***Data interoperability***. Interoperability can allow different government entities to achieve a common objective by exchanging simple data items through interoperable software applications. This fusion of multiple data points can bring massive value for governments to make educated decisions, create better policies, and provide more efficient services. However, governments are faced with difficulties in sharing, integrating, and working with the wealth of data they possess as a result of (i) disparate protocols, technologies, and standards, (ii) divergent needs and capabilities of multiple internal and external constituencies, and (iii) fragmented data production and dissemination systems.[6]
- ***Data findability***. For governments to use and reuse data, data must be easy to find for humans and computers.
- ***Data quality***. With digital information expanding and becoming more complex, information management, organization, and processing are also becoming more complex. Sharing and organizing government data poses a challenge, as there is no cohesive format that allows for analytics in the legacy systems of different agencies. Despite most government data being structured rather than semi-structured or unstructured, collecting it from multiple channels and sources presents a further challenge. The lack of standardized solutions, software, and cross-agency solutions for extracting useful information from discrete datasets in various government agencies. Insufficient funding due to government austerity measures to develop and implement these solutions further exacerbate the problem.[7]
- ***Data security***. Much like players in the private sector, government entities are not immune to data breaches and cyber-attacks. Data security is the primary attribute of public sector big data, as collecting, storing, and using it requires special care. Hence, these government entities must strike a balance in protecting the data they collect while at the same time allowing it to be analyzed by data scientists in its protected form.

[4] Timmis, S., Heselwood, L., Harwich, E. (2018) Sharing the Benefits How to Use Data Effectively in the Public Sector, at https://reform.uk/research/sharing-benefits-how-use-data-effectively-public-sector
[5] Kim, G. H. (2014) Big Data Applications in the Government Sector: A Comparative Analysis Among Leading Countries
[6] UNESCAP (2019) Introduction to Data Interoperability Across the Data Value Chain, at https://www.unescap.org/sites/default/files/Session_4_Data_Interoperability_WS_National_SDG_10-13Sep2019.pdf
[7] Kim, G. H. (2014) Big Data Applications in the Government Sector: A Comparative Analysis Among Leading Countries

Furthermore, legal and regulatory frameworks are crucial to ensuring safe data sharing, privacy, security, and protection standards.

- ***Data literacy***. Government entities must ensure their employees are data literate, i.e., they have the ability to generate, process, analyze, and present meaningful information from data, and develop, use and apply algorithmic tools and strategies to guide informed, optimized, and contextually relevant decision-making processes.[8] Data literacy is increasingly considered a core skill, with some research suggesting that 90 percent of jobs in advanced economies already require a measure of data skills[9]. At the same time, less than a third of the population possesses adequate skills. In order to take advantage of the data economy, governments need to work quickly to close this gap, which is even wider in developing countries.

With digital information expanding and becoming more complex, information management, organization, and processing are becoming more complex. This poses a challenge in sharing and organizing government data, as it involves finding a cohesive format that would allow for analytics in the legacy systems of different agencies. Despite most government data being structured rather than semi-structured or unstructured, collecting it from multiple channels and sources presents a further challenge.

The use of big data has perpetuated a digital transformation that has significant impacts on multiple industries at an unprecedented speed and scale. Many developed countries have begun leveraging big data and AI to combat existing economic and social problems, improve policy design and service delivery, and make better decisions. Big data is a term that describes data sets made available through digitalization that are gigantic and complex and cannot be processed and analyzed through the use of conventional data processing techniques. Big data analytics uses advanced computational techniques to identify specific patterns, trends, and repetition in the data sets to extract meaningful data.

While the current use of big data is mainly confined to the private sector, governments around the globe are making significant efforts to incorporate big data analytics in the race to improve statistical capacity for evidence-driven decision making and tackle salient problems such as food insecurity, the spread of diseases, climate change, etc. Policymakers are beginning to realize the potential for channeling these massive data torrents into actionable information that can be used to identify

Big data was originally characterised by the 4 "V's", but is currently characterized as a 5 "Vs" concept including volume, velocity, veracity, variety and value. *Volume* refers to the large volumes of data that is generated on a daily basis from various sources. *Velocity* refers to both how fast the data is being collected and how fast the data is processed by big data technologies to deliver expected results, sometimes it's better to have limited data in real time than many data at a low speed. *Veracity* refers to the biases, noise and abnormality in data, or it can even be defined as the quality of the data. Social media, call detail records, sensors, web scraping and satellite imagery, to name a few, represent new sources of information that provide the opportunity to produce more and better-quality data for development. *Variety* refers to structured, unstructured, and semi-structured data that is gathered from multiple sources and theses sources of information varies depending on the nature of the business. Finally, *value* is the latest V and is at the top of the big data pyramid and refers to the ability to turn all "V"s into business and/or products for organization.

[8] https://www.dqinstitute.org/dq-framework/

[9] European Commission (2018) New Measures to Boost Key Competences and Digital Skills, As Well As the European Dimension of Education, at https://ec.europa.eu/digital-single-market/en/news/new-measures-boost-key-competences-and-digital-skills-well-european-dimension-education

needs, provide services, and predict and prevent crises for the benefit of the underserved, often unreachable by traditional methods, low-income populations. This enables experimental and agile regulatory and policy programming that adapts and reacts to dynamic and complex environments based on real-time data.

Digital technologies could be critical in enabling the tracking of the flow of products, components, and materials and making the resultant data available for improved resource management and decision-making across all stages of the industry lifecycle. Data, and big data, can facilitate several aspects of circular strategies. For example, data can be used to improve waste-to-resource matching in industrial symbiosis systems via real-time gathering and processing of input-output flows. Furthermore, data analytics could be used to predict product health and wear, reduce production downtime, schedule maintenance, order spare parts, and optimize energy consumption.[10]

As resource-related challenges to businesses and economies are mounting, transitioning to a circular economic model will enable key policy objectives such as generating economic growth, creating jobs, and reducing environmental impacts.[11] Transitioning to a circular economy and reaping the lasting benefits of a more innovative, resilient, and productive economic model relies on establishing efficient and productivity-enhancing circular strategies that heavily depend on innovation. The adoption of innovative solutions will not only transform business operations, supply, and logistics it will also support governments and policymakers to better align their economic development and growth with the UN 2030 Agenda for Sustainable Development.

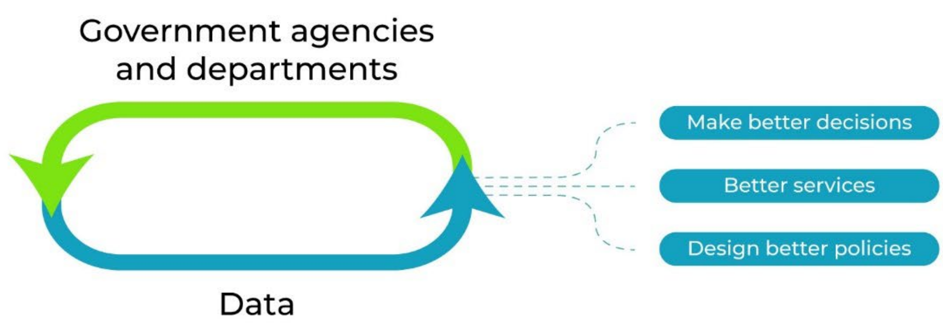
While simultaneously achieving the transition to a circular economy, the implementation of the UN's Sustainable Development Goals (SDGs) depends on increased investment, new technologies, data, and policy and institutional reform. Rapid advances in technology-based solutions spearheaded by the Fourth Industrial Revolution (4IR) are having profound effects on existing systems of production, management, and governments. As an umbrella term, the 4IR encompasses a range of emerging and disruptive technologies, such as Artificial Intelligence (AI), Big Data, the Internet of Things (IoT), Blockchain, Drones, Virtual and Augmented Reality (VR/AR). The broad and deep implications of their adoption are both positive and negative, as has been the case with each industrial revolution that has preceded the 4IR. How countries respond, embrace, and adapt to the digital transformation perpetuated and accelerated by these technological advances will play a key role in whether they achieve their SDGs. For the purposes of this paper, we will only focus on AI and big data solutions as part of the technological advancements falling under the auspices of the 4IR.

Governments and policymakers must explore cross-pollinating datasets from different government departments and agencies to reap the benefits of big data analytics. In nature, cross-pollination occurs when one plant pollinates a plant of another variety; thus, the genetic material of both plants merge, and the seeds produced include characteristics from both flowers. Similarly, cross-pollination of public sector data links and combines the information from different government departments and agencies, sprouting seeds for innovative governance solutions. For the purposes of this paper, we define data cross-pollination as a process of exposing government actors to new ways of thinking by sharing knowledge, thus

[10] Kristoffersen, E., Blomsma, F., Mikalef, P., Li, J. (2019) The Smart Circular Economy: A Digital-Enabled Circular Strategies Framework for Manufacturing Companies, at https://www.sciencedirect.com/science/article/pii/S0148296320304987
[11] Ellen MacArthur Foundation (2015) Delivering the Circular Economy: A Toolkit for Policymakers

allowing them to make better decisions, provide better services, and design better policies (Figure 1).

Figure 1. Data Cross-Pollination

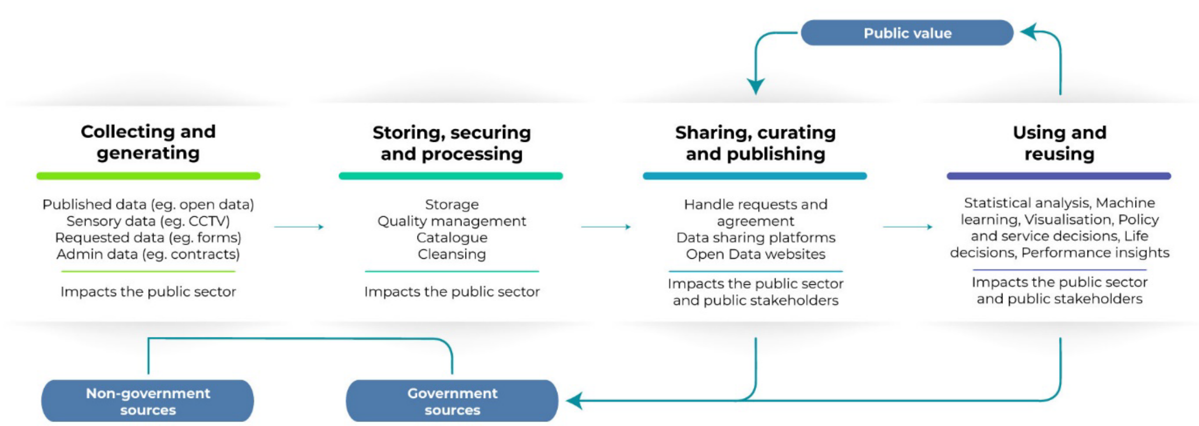


Source: Created by Authors

Data cross-pollination is a prerequisite for good governance

Through the application of data, governments have almost limitless potential for providing more efficient, effective, and trustworthy public services across sectors. Good data governance can contribute to setting a shared vision, enhancing coherent implementation and coordination, and strengthening the institutional regulatory capacity. Technical foundations to better control the data value cycle (Figure 2) to enhance trust deliver value.[12]

Figure 2. The government data value cycle



Source: Adapted from OECD (2019) The Path to Becoming a Data-Driven Public Sector

[12] OECD (2019) The Path to Becoming a Data-Driven Public Sector

The government data value cycle allows for the more efficient and effective government operation and the creation of new public value. This cycle encompasses four phases of data in government:

- ***Collecting and generating data***. In order for governments to start applying data, they must first generate and collect said data. Public servants access data that takes many forms and comes from a variety of sources. The data used can come from a third party's published dataset, whether as open government data (OGD) or through an application program interface (API), or the data could be produced as a result of government activity (creating government contracts). The data could be owned by private sector actors working in conjunction with the public sector in delivering goods and services. Although much of these data are generated by government activity, the first stage of the cycle may involve non-governmental sources, thus highlighting the importance of universal standards for collecting and handling data in private and public sectors. While the implications of data involved in this first stage are internal to the public sector and only influence internal decisions, good quality data aids in its reuse in subsequent stages. As these decisions shape the interactions through which data are collected and lay the foundations for future use, this phase of activity defines the citizen experience of government services.
- ***Storing, securing, and processing data***. Once these data are identified, collected, and generated, they must be kept, secured, and processed. To ensure that the data collected is useful, decisions must be taken about storing it, assessing its quality (including any issues around bias), cataloging it, and cleaning it. These steps are essential in ensuring citizens' confidence in the public sector's capacity to properly handle data and provide a solid basis for the subsequent phases of the cycle.
- ***Sharing, curating, and publishing data***. The third phase of the government data value cycle considers how the stored, secured, and processed data are shared, curated, and published. At this point, legal context and constraints may dictate how readily requests for access and agreements to share can be handled for data that are not openly available. There are explicit efforts to support sharing, curating, and publishing. The availability of data interoperability platforms and licensing those data available through open data websites should be a priority with the earlier stages of the cycle, thus ensuring the latent quality of the data.[13]
- ***Use and reuse of data***. The final phase of the government data value cycle focuses on using and reusing data and offers the most apparent opportunity for generating visible public value.

[13] OECD (2019) The Path to Becoming a Data-Driven Public Sector

The Open Data Concept

Governments should adopt the classical concept of open data on all important information for public use. The concept can be defined as " Open data is data that can be freely used, reused and redistributed by anyone - subject only, at most, to the requirement to attribute and share-alike."[14]

Open Data, as a philosophy, intends to encourage the comparison of data from different sources to create value and new applications. This involves some expenditure of public resources and effort, as data must be "refined" or otherwise transformed to realize its full potential. By making government data accessible and reusable, individuals, organisations, and even governments are able to innovate and collaborate in new ways.

For the public sector, there is a set of tests that can be performed to assess whether data can be considered open, consisting of 3 laws:[15]

- If it cannot be spidered or indexed, it does not exist;
- If it is not available in an open and machine-readable format, it cannot engage; and
- If a legal framework does not allow it to be repurposed, it does not empower.

These laws were proposed for open government data, but it can be said that they apply to open data generally, even outside government environments. For example, in private companies, civil society organizations, and international organizations. In this sense, there was also a consensus on the general lines and principles that open government data should follow as a good practice. For government data to be considered open, it must comply with the eight Open Government Data Principles (Figure 3).[16]

These principles require that the data be:

- ***Complete***, i.e., as public data is not subject to valid privacy, security, or privilege limitations, it can be made available.
- ***Primary***, the data must be collected at the source, with the highest possible level of granularity, and not in aggregate or altered forms.
- ***Timely***, requires the data are made available as quickly as necessary to ensure that the value of these data is preserved.
- ***Accessible***, i.e., the data is made available to the widest range of users for a very broad range of purposes.
- ***Machine processable*** requires that the data are reasonably structured to permit their automated processing.
- ***Non-discriminatory***, i.e., the data are made available to anyone, without prior requirements for registration to access said data.
- ***Non-proprietary*** requires that the data are made available in a format that is not exclusive to any entity.
- ***License-free***, i.e., the data are not subject to any copyright, patent, trademark, or trade secret regulation. Reasonable privacy, security, and privilege restrictions, however, may be allowed.

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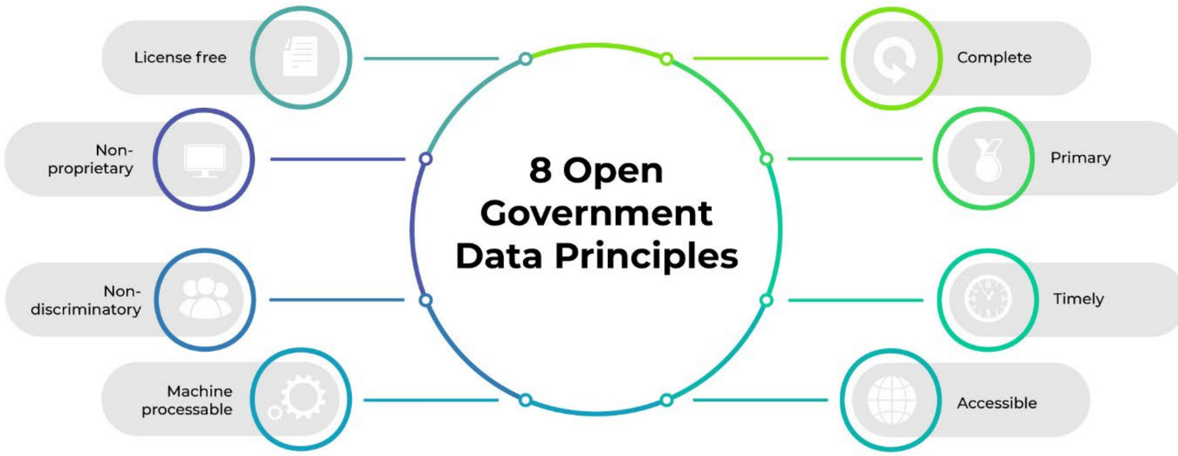
[14] Open Knowledge Foundation (2021) Open Data Handbook, at http://opendatahandbook.org/
[15] Harvard Kennedy School of Government - David Eaves (2009)
[16] Open Data (2007) The Annotated 8 Principles of Open Government Data, at https://opengovdata.org/

Figure 3. Principles of Open Government Data



Source: Created by Authors

The opening of data sets allows external stakeholders to generate public value based on these data. Still, equal weight and attention are given to the internal experience in a data-driven public sector. In order for public officials to increase their effectiveness by enhancing their data capabilities and subsequently generate greater public value, the management and application of data at each stage in this process must be improved. Generally speaking, the benefits of making data open include:

- ***Transparency***. Open data supports public oversight of governments and helps reduce corruption by enabling greater transparency. This monitoring of government activities is achieved by tracking public budget expenditures and impacts. Furthermore, it encourages greater citizen participation in government affairs and supports democratic societies by providing information about voting procedures, locations, and ballot issues.
- ***Public service improvement***. Open data provides citizens with the raw materials they need to engage their governments and improve public services, such as public planning or providing feedback to government ministries on service quality.
- ***Innovation and economic value***. As an essential resource for social innovation and economic growth, open data provides governments with new opportunities to collaborate with their citizens and evaluate public service delivery.
- ***Efficiency***. Open data makes it easier and inexpensive for government ministries to discover and access their data or data from other ministries, thus reducing acquisition costs, redundancy, and overhead. Furthermore, it can allow citizens to alert governments to gaps in public datasets, providing more accurate information.[17]

[17] Stankovic, M., Neftenov, N., et al (2021) Emerging Technology Trends: Artificial Intelligence and Big Data for Development 4.0, at https://www.itu.int/en/myitu/Publications/2021/05/04/12/23/Emerging-technology-trends-Artificial-intelligence-big-data-for-development-4?fbclid=IwAR0rQewEXWpHonRXL2_crXMHqyQ_Fa8tjT-TuAs0jVEDwwC1eZCY8kbIh5o

Data Philanthropy

Data philanthropy is a new and rapidly evolving concept, defined as the act of sharing private data assets to serve the public good. Governments are not the only stakeholders capable of making a change. In the digital age, most of the data generated are accumulated in private hands. The data is used to increase business efficiency and profitability and derive greater and more detailed insights about all types of activity. However, some companies are leveraging their data assets to improve public services and decision-making through the emerging field of data philanthropy.

The foundations of corporate data philanthropy were laid with the International Charter on Space and Major Disasters in 1999. This Charter gave a clear protocol to satellite companies, such as DMC International Imaging (DMCii), with a clear protocol on periodically sharing valuable imagery and to public actors in times of crisis. As a result, DMCii tasked its fleet of satellites on flooding in the United Kingdom, fires in India, floods in Zimbabwe, and snow in South Korea. The data gathered and visuals captured by DMCii was and can be requested by official crisis response departments and relevant UN departments to better assess damage and coordinate relief efforts.

While satellite imagery is an area of apparent societal value, data philanthropy holds even more significant potential on the ground. It is a well-established fact that the information revolution has helped the private sector speed ahead in data aggregation, analysis, and applications. By providing public actors with periodic access to their data, public actors could use real-time data to mitigate common challenges. This data could be used to promote more responsive cities and academic research.

Sharing economy companies could share their real-time housing, transit, and economic data with city governments or public interest groups to create more responsive cities. For example, they are combining 'Uber's bird's eye view " of every driver on the road in a city with an entire portfolio of real-time information. The Uber Movement is an initiative that addresses the increasing vulnerability of pedestrians and cyclists as they interact with cars and trucks. It does this by providing invaluable data for evaluating traffic safety to local governments. By providing this data, it allows cities and city planners to more deeply understand and address urban transportation challenges by identifying and measuring congestion in their jurisdiction, calibrate and validate travel demand models, measure the efficacy of policies and infrastructure investments, and build a so-called transportation scorecard for a city or across a region.[18] An early leader in this space is the City of Chicago's urban data dashboard – WindyGrid.[19] The dashboard aggregates an ever-growing variety of public datasets within city departments (such as police, fire, public health, streets, and sanitation). It combines it with weather data and tweets to allow for more intelligent urban management.

Similarly, data has been an integral part of creating more responsive cities across Latin America and the Caribbean (LAC) through the emergence of the phone app Waze. The app shows users the quickest, least congested route for getting around the heavily congested streets of cities across LAC. IDB has been an important partner that invests in transportation infrastructure

[18] https://movement.uber.com/?lang=en-US

[19] Stempeck, M. (2014) Sharing Data is a Form of Corporate Philanthropy, at https://hbr.org/2014/07/sharing-data-is-a-form-of-corporate-philanthropy

across LAC to help reduce poverty and increase sustainability in the region.[20] IDB partnered with Waze, which provides real-time geocoded data on traffic conditions and alerts reported by Waze users from across LAC in an attempt to improve urban mobility.[21] We are provided with a glimpse of how we could design responsive cities that react to this data through these pioneering examples. A responsive city is one where services, infrastructure, and even policies can flexibly respond to the rhythms of its residents in real-time. Private-sector data contributions could significantly accelerate these nascent efforts.

To further advance the concept of data philanthropy and facilitate the collaboration between the public and private sector, the Inter-American Development Bank (IDB), the World Bank, and the International Monetary Fund (IMF) founded the Development Data Partnership (DDP). The DDP is a new consortium that intends to provide the security, efficiency, and effectiveness of data partnerships for the public good to facilitate public-private partnerships (PPPs) for the public good at scale. It builds linkages between relevant public sector stakeholders and private sector data partners, such as the Bill and Melinda Gates Foundation, Facebook, Google, MapBox, and Veraset.[22] The DDP aims to promote responsible public-private sector data collaboration for policymaking and international development based on the following pillars:

- **Legal foundation** – template data license agreements and agreements between organizations save time and resources.
- **Responsible data use** – data governance principles guide best practices for responsible and ethical data use.
- **Multi-disciplinary teams** – working groups of data engineers, data scientists, domain experts, legal counsel, communications specialists, procurement specialists, and others across the member organizations make a complete platform possible.
- **Secure information technology (IT) architecture** – a web-based partnership management portal that ensures the value proposition for Data Partners is constantly met, facilitating seamless interactions between Partners and teams from multiple international development organizations.
- **Data goods** – managed, accessible repositories for derived data products and algorithms that broaden the impact of the DDP.[23]

Additionally, the benefits of data philanthropy have spillover potential in academia as well. Researchers face unfortunate barriers to entry when trying to access data. For example, Twitter has been selling access to a range of real-time application programming interfaces (APIs) to marketing platforms. However, the company's price points often exceed researchers' budgets. The result is that only researchers that are privy to specific data (such as full-volume social media streams) can analyze and generate knowledge from the compelling information contained in those data. To accelerate the pursuit of knowledge, Twitter piloted a Data Grants program that offered access to segments of their real-time global trove to a select group of researchers. Through this program, academics and other researchers can apply to receive

[20] Waze (2019) Traffic in Latin America? We're Looking at You, at https://medium.com/waze/traffic-in-latin-america-were-looking-at-you-f4ecdc55a143
[21] IDB Invest (2019) Here's One Example of How Big Data Helps Transportation in Our Region, at https://idbinvest.org/en/blog/transport/heres-one-example-how-big-data-helps-transportation-our-region
[22] IMF Connect (2020) Development Data Partnership: Bridging the Data Gap for Public Good, at https://www.imfconnect.org/content/imf/en/annual-meetings/calendar/open/2020/10/13/development_datapartnershipbridgingthedatagapforpublicgood_158127but.html?calendarCategory=T2ZmaWNpYWwvQnkgSW52aXRhdGlvbg==.UHJlc3M=.T3Blbg==
[23] https://datapartnership.org/

access to relevant bulk data downloads, such as a period of time before and after an election or a particular geographic area.[24]

2. Data cross-pollination in the energy sector

The electricity access problem is *described* by two components: (i) the identification of underserved populations, and (ii) the estimation of their connectivity through existing assets.

Once the description is in place, the *predictions* of cost and likelihood of project success can be used to help compare competing technologies.

Modern societies are heavily reliant on reliable and affordable energy services to function smoothly and develop equitably. Over a billion people still lack proper access to electricity, and almost three billion people use inexpensive and energy-dense fossil fuels, wood, coal, and dung, for cooking and heating.[25] The lack of energy access vastly impedes the quality of life, delivery of social services, and economic development. To ensure access to affordable, reliable, sustainable, and modern energy for all (SDG 7), a wide range of technology and business models must be deployed, including improved collection, storage, and analysis of data.

Despite the use of data analytics in the energy sector for decades, detailed data regarding energy consumption and the population's socioeconomic status are often scarce in remote low-income areas. However, vast amounts of interrelated data are being created daily as information and communication technologies (ICT) such as satellite imagery, mobile phones, and mobile systems that can be used and integrated into energy planning models. The collection of these datasets can aid in the description of the characteristics of the regions targeted for energy access expansion. This can offer more detailed energy access data from satellite images, deriving alternative creditworthiness scores and customer stickiness indicators from mobile payment history and indicating user mobility and urbanization trends from call detail records. This would also enable the making of predictions about future energy demand that will help in the selection of appropriate energy service alternatives.[26]

Developing countries grapple with the omnipresent challenge of providing sufficient access to energy to their citizens. Despite having an appropriate grid connection infrastructure, many developing countries cannot provide reliable energy access during peak hours when the grid may be overwhelmed. The deployment of big data and advanced analytics solutions has begun to transform energy distribution to alleviate this challenge through improved modeling of incentives and pricing.

To make energy more accessible, it is vital that relevant data is free to access, is machine-readable, and open for reuse. In many cases, stakeholders in the energy sector do not have the funding or capabilities necessary to collect and store these vast amounts of data. To circumvent this, an increasing number of stakeholders in this sector have begun to understand and promote the value of sharing their data. However, policymakers must ensure the regulation of sharing these data, taking into account open data principles.

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[24] Ibid

[25] World Bank (2017) Energy Analytics for Development: Big Data for Energy Access, Energy Efficiency, and Renewable Energy

[26] Hassani, H., et al (2019) Big Data and Energy Poverty Alleviation, at https://www.researchgate.net/publication/336038876_Big_Data_and_Energy_Poverty_Alleviation

To achieve SDG 7, the energy sector is integrating new technologies to improve the reliability and affordability of its services. Data, or rather data sharing, is a new frontier in which the energy sector can increase its value and improve energy access for all. With the integration of an advanced metering infrastructure (AMI), novel technical means to share information between consumers and utilities emerge. Developing countries have much to gain from these new solutions as they modernize their grid and promote utility reform initiatives. However, the real value addition and opportunities for developing countries lie in the data they are poised to collect by introducing smart meters and other sensors. For example, IBM Research-Africa is developing software applications to model rural electrification strategies and predict potential economic and social benefits. Such data-driven tools, built on a mix of open and big data, could assist local governments and donors design energy access expansion programs. For instance, the Earth Institute at Columbia University has also undertaken significant geospatial planning exercises over the past ten years in several countries in Africa, Asia, and Oceania, many of them related to World Bank activities. The Earth Institute recently implemented a World Bank-supported program in Nigeria, piloting geospatial least-cost planning in selected distribution zones while ensuring that the sector master plan is developed and updated in coordination with the distribution plan.[27]

If governments achieve the goals set in SDG 7 and transition to a circular economy, breaking through the constraints of data silos and promoting data interoperability and integration in the energy sector is paramount. Governments must strive towards data interoperability to overcome data silos, cross-pollinating electricity data to improve service offerings in other sectors, such as renewable energy for smart cities, healthcare, agriculture, and sustainable food systems.

Renewable energy data

Big data analytics can boost sustainable power generation by effectively forecasting the availability of renewable energies. For example, weather modeling and cloud imaging tools can be used to accurately predict the performance of solar and wind farms well in advance. With this technology, we can maximize and store electrical output to meet demand. Despite LAC being at the beginning of the process of datafication[28] of the energy sector, a few players have emerged that are leading the dialogue. The IDB has been one of the major players in promoting the energy transition in LAC in line with SDG 7. One of its recent pioneering initiatives highlighting the revolutionary impact of data in the energy sector is the LAC Energy HUB. The LAC Energy HUB is a digital platform developed by the IDB, the Latin America Energy Organization (OLADE), and the International Renewable Energy Agency (IRENA) that showcases innovative data visualizations seeking to foster energy policy innovation, research, and mutual collaboration. The HUB aims to concentrate information and promote the use and generation of data on energy in LAC in a single place, making it easily accessible, interactive, intuitive, comparable, and useful.[29] Another player in the Latin American renewable energy

[27] World Bank (2017) Energy Analytics for Development: Big Data for Energy Access, Energy Efficiency, and Renewable Energy

[28] Datafication refers to the process by which subjects, objects, and practices are transformed into digital data. Datafication renders a diverse range of information as machine-readable, quantifiable data for the purpose of aggregation and analysis. Southerton, C. (2020) Datafication, at https://link.springer.com/referenceworkentry/10.1007%2F978-3-319-32001-4_332-1#howtocite

[29] Florence School of Regulation (2020) Beyond the Data: the LAC Energy Hub, at https://fsr.eui.eu/beyond-the-data-the-lac-energy-hub/

sector is IRENA. In an effort to advance the energy transformation of LAC, IRENA and IDB signed a partnership in 2021 to support each other's initiatives, i.e., the LAC Energy HUB and IRENA's Climate Investment Platform.[30] The US Department of Energy's National Renewable Energy Laboratory (NREL) is currently conducting an initial assessment of the improvements needed in Guyana's grid infrastructure, controls, data, and management systems to support large-scale renewable energy penetration. Furthermore, NREL is developing a geospatial analysis tool which will be used to inform data-driven clean energy decision-making in Haiti and Peru.[31]

Healthcare (SDG 3) and the Energy Sector

Confronted with the implications of the rapid changes promoted by digitalization, both the energy and healthcare sectors face similar challenges that can motivate mutual learning. Traditionally both sectors have fallen into the trap of data silos and fragmented IT landscapes. Cross-domain, cross-border, and even cross-sector data processes have amplified the need to overcome these issues.

The need to develop new ways of delivering services is the catalyst that is transforming both sectors. As consumers in the energy sector and patients in healthcare are increasingly called in, this is of particular importance, making it necessary to recognize their needs and enable their involvement. However, both sectors are experiencing the same interoperability challenge – implementing citizens' right to access and sharing personal (health or energy metering) data.[32]

For a citizen-centered ecosystem to evolve and for data cross-pollination to occur and interoperability to be achieved, data silos must become an artifact of the past. The nature of data interoperability has only one universal commonality – change, making a "one size fits all" approach no longer viable.

Energy for Agriculture & Food Security (SDG 2)

Modern agriculture requires a considerable amount of energy throughout the entire cycle of agricultural production. The energy needs of the agriculture sector span from the direct use of energy for farm machinery, water management, irrigation, cultivation and harvesting, post-harvest energy used for food processing, storage, and transportation, to the indirect energy use for fertilizers, chemical pesticides, insecticides, and herbicides.

Energy availability has been crucial for much of the food security in the industrialized world. The process of "energizing" the entire food production chain has been an essential feature of agricultural development throughout recent history and is a chief factor in achieving food security. Despite the leaps developed countries have experienced, developing countries lag in modernizing their energy inputs to agriculture.

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[30] IADB (2021) IDB and IRENA Accelerate a Sustainable Energy Future in Latin America and the Caribbean, at https://www.iadb.org/en/news/idb-and-irena-accelerate-sustainable-energy-future-latin-america-and-caribbean

[31] https://www.nrel.gov/international/projects-latin-america-caribbean.html

[32] Florence School of Regulation (2021) Energy in the Digital Age: Disruptive Changes and New Governance Needs, at https://fsr.eui.eu/energy-in-the-digital-age-disruptive-changes-and-new-governance-needs/

Similar to the healthcare sector, data silos are a significant impediment to the cross-pollination of data for the agriculture sector. In terms of the energy needs of the agriculture sector, necessary data required for the energy inputs for food processing and transportation by agro-industries is excluded. This poses a challenge as the estimates of these activities range up to twice the energy reported solely in agriculture.

The absence of definitive energy data throughout the lifecycle of the stages of agricultural production, especially in developing countries, presents a significant problem for developing countries, making the analysis of the country's energy statistics impossible. Additionally, the data collected tends to conceal the effects of these energy inputs in improving agricultural productivity.[33]

Opportunities

Governments can champion open data principles on a national level. They could do this by developing regulations focusing on data ownership, best practices for data management, and access rights to data.

Investing in data infrastructure and analytics capacity should be imperative for utilities. This can improve their operational efficiency by exploring predictive maintenance, non-technical loss detection, and alternative payment options.

The involvement of international organizations as funders and conveners can help shape the dialogue for the digitalization of the energy sector. Considering the local technical capacities of energy utilities present themselves as a critical bottleneck, international organizations can provide technical assistance in developing in-country capabilities. International organizations could assist energy stakeholders in building a comprehensive digital infrastructure (software and connectivity infrastructure, such as integrated networks and sensors) and human capacities to collect, store, analyze, and share data through targeted training and skill-building programs.

Challenges

The integration of digital technologies and the use of data in the energy sector might not happen on its own. Even though leveraging big data and open data can have many benefits for the energy sector, significant challenges persist in their uptake and scale-up. These challenges range from the cost of data infrastructure upgrades and limited collection and dissemination of data due to poor connectivity to a lack of data standards which inadvertently create silos and underutilized data. Furthermore, the energy sector grapples with insufficient capacity to perform analytics, a lack of understanding of the potential data they possess, and a general resistance to the uptake of new technologies.

To enable and ensure accountability, public data releases must respect citizens' privacy while being sufficiently detailed at the same time.

Cybersecurity is another major challenge for the energy sector as a result of the ever-increasing integration of digital technologies and data into energy infrastructure. Digital technologies can

[33] http://www.fao.org/3/X8054E/x8054e05.htm

be used to control energy production, transmit information about energy consumption, and monitor demand, making the energy sector susceptible to an increasing number of cyber threats. A cyber-resilient energy delivery system is needed to ensure reliable energy delivery and services and tackle the sector's vulnerabilities regarding illegal data breaches. [34]

3. Data cross-pollination in sustainable food systems

Agriculture provides the direct livelihood for 2.5 billion people feeding the entire planet. With population growth and the evolution of dietary needs, the agriculture sector will be put under enormous strain to provide 49% more food than it did in 2012 by 2050. [35]

Food production is a resource-intensive activity, and with food demand experiencing an ever-increasing upward trajectory, humanity faces many challenges. The industry is responsible for 21-37% of all greenhouse gas emissions, consumes vast amounts of finite resources such as water and energy, thus contributing to climate change. Furthermore, the need for more arable land to sustain demand is the primary reason for land degradation and biodiversity loss.[36]

> A sustainable food system (SFS) is a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised. By being profitable throughout the entire lifecycle, an SFS will achieve economic sustainability, having broad-based benefits for society (social sustainability). In order for a food system to achieve environmental sustainability it must have a positive or neutral impact on the natural environment.

People's access to sufficient, safe, and nutritious food remains a serious global challenge. Current estimates show that nearly 690 million people are undernourished, or 8.9% of the world population.[37] Extreme hunger and malnutrition are massive barriers to achieving sustainable development, creating a trap that people cannot easily escape. As a result, the UN has set out an ambitious goal to end hunger, achieve food security, and improve nutrition (SDG 2) by 2030. To achieve this goal, the global food system needs to be reshaped to be more productive, more inclusive of poor and marginalized populations, environmentally sustainable and resilient, and deliver healthy and nutritious diets to all.[38]

Governments need to ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production to eradicate world hunger.

Due to the myriad of components, actors, and processes and their ability to constantly change, food systems are challenging to comprehend and predict. Significant strides have been made in improving the availability of food system-related data. Still, gaps persist across all food system components, including supply chains (especially post-farmgate), food environments, diets, and diverse health, livelihood, and sustainability-related outcomes. Data availability varies across geographic areas and income groups. Differences relate to the varying levels of

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[34] World Bank (2017) Energy Analytics for Development: Big Data for Energy Access, Energy Efficiency, and Renewable Energy
[35] http://www.fao.org/geospatial/en/
[36] European Commission (2020) Towards a Sustainable Food System, at https://ec.europa.eu/info/sites/default/files/research_and_innovation/groups/sam/scientific_opinion_-_sustainable_food_system_march_2020.pdf
[37] https://www.un.org/sustainabledevelopment/hunger/
[38] FAO (2018) Sustainable Food Systems Concept and Framework

resources available to invest in large, potentially expensive data collection and surveillance efforts and the different priorities countries may have regarding their food systems.[39]

The agricultural industry needs to build upon easily accessible and interoperable data infrastructure to realize its full digital potential. The capacity to create value in the food system or to create better policies using digital technologies depends not only on connectivity infrastructure (hard infrastructure), but also on the regulatory environment and institutional arrangements (soft infrastructure), which together govern access to and use of digital technologies and related data in the agriculture sector. These two elements together shape the creation of effective systems for digitalization in agriculture, often called the "data infrastructure" or "data ecosystem." The data infrastructure is the system enabling and governing the collection, access, and transfer of data (data governance), storage and analysis of farm data to produce knowledge and advice (actionable insights), and feedback loops to stakeholders in the agriculture sector, including farmers as well as policymakers. The rationale for improving access to government-held agricultural data is based on the following two premises:

- Farmers can better understand the environmental impacts of their decisions and how policies work, as well as learn from government-held information about the agriculture sector more generally;
- Using data infrastructures in agriculture, the private sector and *researchers* can develop and deliver better services for agriculture. [40]

[39] Marshall, Q., et al (2021) You Say You Want a Data Revolution? Taking on Food Systems Accountability
[40] OECD (2019) Chapter 5. Realising Digital Opportunities in Agriculture Requires a Data Infrastructure, at https://www.oecd-ilibrary.org/sites/d2fbead0-en/index.html?itemId=/content/component/d2fbead0-en&__cf_chl_jschl_tk__=581d1504f84eaade351603f47d466e146a27070d-1622302822-0-AZ1_UdVi7nQdUF_rRrtjr0b3QBPsJ94rLqmcB5NUL84sShoXDY7m8EYdebdxDvekinkQLyS3IUV56hGCL4235GemzyYXKQdcLGx8lZukIHasj3DhvyYF-i7Ra-8lkgmFRlRi9Ruls1ejsfwLMD1b3xYEru88lsUX_eNYM8Ee-iRLltxberOnH1DLF3R3YKyMGZYrXk5NmTucd6WD_4qRD4I4_KgqdODfxLGqEW2yvnmdstTToVThkLrBGP9R0Aj8eph9a8nNB2r1oXZ3BVMYmFkZUuetpy6jEcpl1tr6jEZTuDjMsFHat6txiXQwU5EwgAc4KWvrzy3B03M_JgxYHjFB6PEqzzgg-qQDzeouFvYuSdGH2u7qTxPBvea2XZw5_GHiuYm6aHQTLROb60lMXRX0i17Fe8tVDkyC2htQSgg7KQw3mE4mefCtLp6vc6KRWm-XrXv8zvkOIIBq1mjBTmZRlM76CYQ4Sh1ygRGEgWBW

Without good quality data, even the most refined algorithm will not be able to provide good information. For example, big data analytics can aggregate a large amount of data, but big data analytics only makes sense if it can be used to produce quality analysis. If bad quality data is used in automation, it can potentially have significant negative consequences. However, quality data and "fit for use" data can be expensive to produce.

Estonia e-government and the creation of a comprehensive data infrastructure for public services and agriculture policy implementation

This case study illustrates how digital technologies can be used to improve the administration of government systems and the provision of public services, including in relation to agriculture.

The Estonian government made two critical technology choices: a compulsory digital identity (ID-card, proof of concept and ecosystem built in 2004) allowing the real world to match the digital. The second choice was to develop the X-Road, the data management infrastructure based on an innovative decentralized linked government data infrastructure preventing data redundancy and using Blockchain technology to create transparency about data access.

Among a range of applications, this infrastructure is used for agriculture policy and regulations. The Estonian national paying agency has been using satellite imaging and remote sensing since 2005 and controls of mowing requirements under the EU CAP, attached to financial support from the European Commission, have been increasingly automatized from 2011. With remote sensing and automation of processes, the percentage of checks has gone from 5% on site to almost 100% performed remotely.

A range of digital services is also now available to farmers, including digital registers. For instance, whereas information was previously recoded using a paper-based system, farmers are now able to provide information via an e-register. As of August 2018, 64% of documents and 89% of notifiable animal events were submitted using the e-services register.

Sustainable food systems and the Energy Sector (SDG 7)

Food systems are intrinsically linked to and heavily dependent on energy in order to meet demand. This can be seen in the food sector's (agriculture, food production, transportation, and consumption) reliance on energy, consuming approximately 200 EJ per annum globally.[41] The current practices employed in food manufacture are considered unsustainable due to the sector's high energy intensity, which is linked to large levels of greenhouse gas emissions and depleting resources. In response, the food manufacturing sector has undertaken a vital transformation to meet long-term reduction goals on energy demand.

Data must be employed to identify energy consumption hotspots to achieve reductions in energy demand and sustainable food systems. At present, energy data corresponding to different food processes provides a general overview of food systems or focuses on food and energy and climate change. This presents itself as a problem for data cross-pollination as comprehensive consumption data or a variety of food products are scarce.

[41] Ladha-Sabur, A., et al (2019) Mapping Energy Consumption in Food Manufacturing, at https://www.sciencedirect.com/science/article/pii/S0924224417303394

Generally, data on energy use that focuses on food systems are grouped by chain or subsector, making it very fragmented, foodstuffs are processed to varying degrees, and production is not always continuous. Hence, cross-pollination of data in this sector has not yet occurred as data siloes still present a significant roadblock. However, data can play a crucial role in optimizing the whole food sector, allocating resources more effectively, and reducing waste and fossil fuel dependency, therefore transitioning to a sustainable food system capable of meeting global food demand.

The US National Soil Moisture Network (NSMN)

Two types of technologies are used for the monitoring of soil water content in the United States: direct in situ instruments and remote sensing. Each approach has strengths and weaknesses. Remote sensing has the advantage of allowing contiguous data coverage across the United States and progress in its precision has resulted in increasing use for agriculture services and policy implementation. However, data provided is still at a relatively coarse level of resolution. *In-situ* measurements group diverse types of networks. Some, such as wireless sensors networks (WSN), provide data at the farm level and can be integrated into decision systems for precision agriculture or water management. However, these are often private and systems are proprietary and focus on the farm level. In addition, the data belongs to either the farmers or the company providing the service and is therefore not easily accessible by other stakeholders, including researchers and the government.

Most data used by researchers is still mostly at the 30 km scale. These mesoscale networks, also called mesonet, have principally resulted from initiatives at the State level. As a consequence, they are distributed unevenly across the United States, with some geographic areas more densely covered than others. In addition, they are not always publicly accessible and some are protected by paywalls. While the mesonet is very useful for some applications, understanding a range of natural phenomenon requires broader coverage. In addition, understanding the dynamics of soil moisture in ways that can be useful for policy management and decision making requires more information than soil moisture data point estimates. Needed information—such as soil characteristics, composition across multiple soil depths, weather patterns, and land use information—is available but in disparate data networks and from different sources.

While a large amount of data exists and could support researchers and policy makers, it is not used to its full potential. This is due to a lack of technical capacity (data processing and management) but also to the independent and non-coordinated development of networks across the United States. The production of an accurate representation of soil moisture at an informative scale has therefore remained a challenge, and soil moisture observations have been poorly integrated into assessments of vulnerability, such as early warning systems for droughts and floods.

Water (SDG 6) and Sustainable Food Systems

Food production is strongly dependent on and affects the quality and availability of water, as boosting agricultural production can increase water withdrawals and worsen land and water degradation. Furthermore, achieving nutrition targets requires access to clean water and sanitation. Counteracting these potential trade-offs requires sustainable agricultural systems and practices and enhanced water governance to manage growing and competing demands on water resources.[42]

[42] International Council for Science, (2017). *A Guide to SDG Interactions: from Science to Implementation*

As water scarcity is a looming threat to the development of humanity and the entire global ecosystem, water management strategies based on data must be implemented in agriculture and food production.

With the advent of smart water technology (SWT), we can adequately manage and save water resources. These SWTs encompass a wide range of sensors, ICT to provide real-time monitoring of data (such as water flow, quality, moisture), thus enabling the creation of a smart water system (SWS). An SWS can detect any abnormalities, such as non-revenue water (NRW) losses, water contamination in the water distribution system (WDS), and improve water treatment plants and agriculture efficiency. For example, Senseye[43] is a UK-based company with a global reach providing evaluations of different sensor technologies that enable smart farming. Senseye does this by highlighting the capabilities of sensor technologies in delivering better revenue to farmers by suggesting crops best suitable for their field based on an environmental analysis that aims to reduce the water footprint necessary for crop production by predicting efficient watering timing.[44]

Opportunities

Government organizations that collect or store agricultural data could work together with data providers and data users to establish clear frameworks governing data access and use. It is important to emphasize that such frameworks should be coherent with broader policies governing such issues and underlying legislation authorizing government agencies to collect agricultural data.

In seeking to improve publicly-held agricultural datasets, data-collection agencies can explore how government organizations' burden of existing data collection can be lessened while maintaining or strengthening data collection through digital technologies, including considering how digital tools could be used to gather data via alternative pathways. Data management frameworks could also support the evaluation of data quality for data from alternative sources and planning. Finally, government organizations have a role in ensuring the longevity and robustness of these data sources.

Governments should also explore ways to incentivize the provision of private sector data for public use and agricultural research. This should include the consideration of providing incentives for farmers to allow their data to be shared for policy purposes. These options include monetary incentives (i.e., payments for data provision) and non-monetary incentives, such as the provision of regulatory safe-harbors for data providers or provision of services that use data that has been provided (e.g., benchmarking services).

While further work is needed to evaluate existing regulatory and governance frameworks, governments seem to have a role to help stakeholders clearly understand different available governance arrangements and provide clearly articulated underpinning regulatory frameworks that other users can build on.[45]

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[43] https://www.senseye.io/about-senseye

[44] Gupta, A. D., et al (2020) Smart Water Technology for Efficient Water Resource Management: A Review, at https://ideas.repec.org/a/gam/jeners/v13y2020i23p6268-d452399.html

[45] Ibid

Challenges

The variety of data and limitations of bandwidth in many farming communities presents itself as an issue for data management. Public remote sensing platforms generate vast amounts of data, leading to data archives that go beyond the exabyte (1018 bytes) levels. This has forced the public sector to invest in large data systems capable of serving a broad scientific community. Despite the benefits associated with their ability to disseminate data, these systems require wide-ranging and intricate knowledge of a variety of satellites and sensors, file formats, metadata standards, physics, etc. Hence, governments require considerable expertise to be able to gain any significant agricultural benefits from these systems.

Commercial satellite, aerial, and drone-based data systems continue to be fragmented due to competing interests, resulting in a variety of data formats. The velocity of data coming off these various platforms, coupled with the volume of the generated data, has led to a fragmented and siloed data management infrastructure for the sector.

The inherent spatial nature of agriculture and the remotely sensed data generated by geographic information systems (GIS) was initially thought of as an opportunity to minimize the occurrence of siloed data by providing a spatial context (maps) around data. However, despite the proliferation of GIS systems spanning topic areas well beyond remotely sensed data, additional silos of geospatial information have emerged.[46]

Small farmers in developing countries face a daunting task to take advantage of the endless amounts of available data and rapid-fire advancements in technology. These smallholder farmers in developing countries often make field decisions based on generic recommendations or historical information rather than scientific data. A persistent challenge for achieving precision agriculture[47] by these farmers is their lack of knowledge about data and limited access to technological advancements, which can inform best practices by simulating many scenarios. Furthermore, farmers in developing countries have limited access to capital to deploy data-enabled technologies.

4. Data cross-pollination and reducing pollution

The global consumption of biomass, fossil fuels, metals, and minerals is expected to double in the next 40 years, while the annual waste generation is projected to increase by 70% by 2050. Consumerist practices are expected to grow by 2050, with projections estimating that humanity will consume three times more than it does now. These unsustainable economic practices contribute to 7 million premature deaths as a result of air pollution each year. The cost of illness and death from air pollution globally exceeds $3 trillion per annum.[48] As we have yet to find a planet capable of supporting life, the UN Agenda for Sustainable Development has recognized air pollution as a pressing sustainability concern mentioned in two SDG targets,

[46] Delgado, J. A., et al (2019) Big Data Analysis for Sustainable Agriculture on Geospatial Cloud Framework, at https://www.frontiersin.org/articles/10.3389/fsufs.2019.00054/full
[47] Precision Agriculture is an approach to farm management that uses IT to ensure that crops and soil receive what they need for optimum health and productivity, thus ensuring profitability, sustainability and environmental protection.
[48] Cicero (n.d) One Solution for Air Pollution, at https://cicerogroup.com/big-data-one-solution-for-air-pollution/

i.e., sustainable reduction of health impacts from hazardous substances (SDG 3.9)[49] and reducing adverse effects of cities on people (SDG 11.6).[50]

In addition to the significant threats air pollution poses to human health, it also has a heavy toll on the environment, economy, and food security. Therefore, addressing crises arising from air pollution cannot be addressed in isolation, as they are closely linked to policies tackling issues such as energy, climate, transport, trade, agriculture, public health, and biodiversity. By designing well-thought-out air quality strategies, major co-benefits can be achieved in other policy goals. [51]

To achieve SDG 3.9 and SDG 11.6, governments have turned to innovative solutions based on data. This is due to data's ability to provide researchers, businesses, and governments with the best information possible, allowing them to see correlations they may have missed and make highly informed decisions, thus optimizing their resource use and conservation approach.

> Improving air quality through greater efficiency and increased deployment of renewable solutions goes hand-in-hand with the broader energy sector transformation and decarbonization commitments adopted with the Paris Agreement.

This air pollution data derives from models based on data collected from a limited number of stationary monitoring sites coupled with transportation, weather data, satellite imaging data, and other open data sources to estimate pollution in real-time for various locations.[52] However, more direct air quality data is needed to improve the accuracy of these models. In the hopes of improving air quality, governments, researchers, and businesses have deployed low-cost portable sensing devices connected via Wi-Fi networks that generate and gather vast amounts of data to inform visualizations of air quality from that data. These visualizations allow governments and researchers to draw connections between geography and data, thus identifying areas where air pollution has increased over time and identifying the potential underlying causes.[53]

Big data analytics can also help businesses and governments optimize their use of resources, cutting back on water and energy consumption. For example, networks of sensors can collect data on a buildings' water and energy use, allowing businesses to see where they may be inefficiently spending resources. In some buildings, heating, ventilation, and air conditioning (HVAC) systems are left running 24/7 or when not seasonally appropriate—like heating systems that continue to function through the summer or exhaust fans that run even when the building is unoccupied. With big data analytics, companies can pinpoint and cut back on unnecessary energy and water use. Some advanced systems can even automatically adjust building systems to optimize the use of energy. These systems can, for example, deactivate lighting when the system detects that no worker is using a certain room or corner of the office. [54]

In the case of LAC, poor air quality and climate change are considered major impediments to economic growth, disproportionately affecting vulnerable populations and ecosystems,

[49] https://sdgs.un.org/goals/goal3
[50] https://sdgs.un.org/goals/goal11
[51] Rafaj, P., Kiesewetter, G., Gul, T. (2018) Outlook for Clean Air in the Context of Sustainable Development Goals, at https://www.sciencedirect.com/science/article/pii/S0959378018304035#:~:text=Air%20pollution%20is%20recognized%20as,impacts%20of%20cities%20on%20people)
[52] Ibid
[53] Tsui, J. (2020) Using Big Data Technology for Environmental Protection, at https://eponline.com/articles/2020/03/25/using-big-data-technology-for-environmental-protection.aspx
[54] Environmental Protection (2020) Using Big Data Technology for Environmental Protection, at https://eponline.com/Articles/2020/03/25/Using-Big-Data-Technology-for-Environmental-Protection.aspx?Page=2

leading to premature deaths, crop losses, and ecosystem damage.[55] Despite pollution being considered a real threat to LAC, monitoring air quality in large cities across the region is not widespread. However, there is an example from Brazil's Telefonica. The company's big data unit LUCA combines cell phone data and open data from weather stations, air quality, and traffic sensors in an effort to analyze the air quality and predict traffic in certain locations in Sao Paolo. Telefonica provided insights to municipal officials with the intent to help policymakers better understand the correlation between population mobility in Sao Paolo. In addition to this, Telefonica provided policymakers with air quality data so as to facilitate evidence-based interventions to solve both problems.[56]

[55] FAO (2018) Efforts to Reduce Air and Climate Pollutants in Latin America Could Reap Immediate Health Benefits, at http://www.fao.org/in-action/agronoticias/detail/en/c/1127361/
[56] https://datacollaboratives.org/cases/using-big-data-to-combat-air-pollution-in-brazil.html

Health (SDG 3), Environmental Conservation and Reducing Pollution

Air pollution has been a worldwide concern that has a devastating impact on the population's overall health. Assessing the effects air pollution has on human health is vital in protecting individual health. In addition to pollution exposure, it is also essential to consider environmental factors, some of which may have an exacerbating effect, some others a mitigating one. Extreme temperatures and ultraviolet radiation, for instance, can exacerbate pre-existing health conditions such as cardiovascular and pulmonary diseases, as well as trigger new ones by aggravating exposure levels.[57] In order to tackle health issues as a result of air pollution, the employment of big data and data analytics is paramount. Data can provide valuable insights by estimating high-resolution air pollution concentrations, quantifying the health effects of single pollutant and pollutant mixtures, and designing personalized health advisory models based on individual characteristics and exposure information.[58]

> The power of data can be leveraged to strategically improve air quality by tracking and avoiding polluted air.
>
> IBM has already embarked on an ambitious new $160 billion project by installing state-of-the-art sensors throughout Beijing to observe pollutant emissions. By mapping the air quality data collected through these sensors with meteorological data, the city can then predict where harmful pollutants will spread 72 hours in advance, based on how disparate pollutant concentrates interact with other particulate matter. This information can be proactively communicated with residents to help them avoid specific geographic areas, divert traffic to less-congested, less-polluted areas, post information on electronic freeway signs, and even alter toll road costs in real time. Furthermore, predictive analytics offers leaders the opportunity to work with factories in planning and synchronizing production cycles, preventing air pollution before it accumulates.

Air pollution is one of the most persistent environmental issues in LAC, with exposure to air pollutants being associated with increased mortality and morbidity. Despite efforts to monitor air quality in large cities, environmental authorities' information on air quality has poor publicity and presentation, making it difficult to take action for critical air pollution episodes. Nevertheless, there are grassroots efforts to curb air pollution in LAC.[59] Mimasoft is a Chilean startup that has developed a proprietary software that uses AI to identify and solve environmental problems, such as air pollution and waste management. The software measures, monitors, and analyzes various sustainability variables, such as life cycle analysis (LCA), carbon and water footprints (WFP), air quality, and noise pollution levels.[60] Mimasoft's technology contributes to reducing carbon footprints by 40% and the global environmental impact of companies by 20% through identifying critical points of management. The startup has piloted its technology in the Sierra Gorda wind farm, where it aided in reducing the carbon footprint generated from the construction phase of the Energías Renovables No Convencionales (ERNC) generation plant by 47%.[61] Another example comes from the

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[57] Vitolo, C., et al (2018) Modeling Air Pollution, Climate, and Health Data Using Bayesian Networks: A Case Study of the English Regions, at https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017EA000326
[58] Chen, L., et al (2017) Big Data Analytic Based Personalized Air Quality Health Advisory Model, at https://ieeexplore.ieee.org/document/8256082
[59] https://mimasoft.cl/en/about-us/
[60] InduAmbiente (2021) Artificial Intelligence Made in Chile Helps Reduce the Carbon Footprint of Companies by Over 40%, at https://www.induambiente.com/actualidad/noticias/inteligencia-artificial-made-in-chile-ayuda-a-reducir-sobre-40-la-huella-de-carbono-a-empresas
[61] Ibid

Universidad Nacional Autonoma de Mexico, which is developing a low-cost wearable device (bracelet) that can measure atmospheric pollutants. The bracelet is connected to any network through an app and provides users with detailed and real-time data about the levels of environmental pollutants, such as carbon dioxide, carbon monoxide, and ozone. The bracelet further records temperature, humidity, and UV radiation levels so that users know the air quality in their vicinity.[62]

However, air pollution is not the only environmental and health crisis that LAC is facing. Even though LAC is home to about 30% of the world's freshwater sources, it has been silently combatting a water crisis, a crisis that has irreversible health effects on children's lives. At the heart of the crisis is the fact that approximately less than 40% of the region's water is left untreated for human consumption and use. Whereby polluted water sources are released into lakes, rivers, and oceans, which are then contaminated with human and animal waste, and transferred through water systems into many homes.[63]

In addition to having a negative impact on human health, air pollution poses exponential risks to the environment, manifesting itself as acid rain, eutrophication,[64] haze, ozone depletion, crop and forest damage, and global climate change.[65] Big data must now be harnessed for ecological forecasting to improve decision-making in the public and private sectors. Monitoring environmental change in near real-time can be beneficial if there is the capacity for action at a similar temporal scale, which is often not the case. However, useful applications are emerging.[66]

Opportunities

The acquisition and analysis of big data must be solution-focused and address sustainability challenges raised by pollution while engaging with decision-makers and those affected by such decisions. From documenting our planet's greenness to detecting where resources are being illegally harvested, big data analyses can now place detailed evidence of rapid environmental change resulting from pollution in the hands of entities capable of management action.[67]

Challenges

Existing complications among distinct data sets—such as different standards, formats, and structures—require long-term continuous commitments and collaborations among data

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[62] Universidad Nacional Autonoma de Mexico (2021) Dispositivo Que Mide la Calidad Del Aire, at https://www.comunicacionfi.unam.mx/mostrar_nota.php?id_noticia=2246
[63] Prashad, J. (2020) Latin America's Water Pollution Crisis and its Effects on Children's Health, at https://www.humanium.org/en/latin-americas-water-pollution-crisis-and-its-effects-on-childrens-health/
[64] Eutrophication is a condition in a water body where high concentrations of nutrients (such as nitrogen) stimulate blooms of algae, which in turn can cause large-scale fish deaths and loss of plant and animal diversity.
[65] https://www.mass.gov/doc/health-environmental-effects-of-air-pollution/download#:~:text=Air%20pollution%20can%20damage%20crops,(such%20as%20harsh%20weather).
[66] Runting, R. K., et al (2020) Opportunities for Big Data in Conservation and Sustainability, at https://www.nature.com/articles/s41467-020-15870-0
[67] Ibid

providers and stakeholders in the Earth science and health communities. Such partnerships may take years to develop and implement.

Integrating environmental and health data presents many challenges. First, even among Earth observations, different data sets are typically discipline-oriented and heterogeneous, with distinct formats and structures.

Each data file represents a snapshot or time average of environmental conditions in different dimensions with different spatial and temporal resolutions and coverage in satellite data sets. Data structures—the ways the data are organized, processed, stored, and retrieved—are often complex, depending on the types of instruments, data providers, and projects involved. Meanwhile, in situ measurement data are often unstructured: Photographs, video, and other formats, for example, are not easily reduced to numbers on a spreadsheet. The more such differences exist among data sets, the harder it becomes to unify them and look for correlations.

Another complication is that complex data structures and large numbers of data files can be challenging to extract long time series from environmental data sets for a given location. For example, the Integrated Multi-satellite Retrievals for Global Precipitation Measurement (IMERG) half-hourly precipitation data set contains more than 350,000 files, each about 10 megabytes in size and spanning from 2000 to the present. Extracting a time series of precipitation at a neighborhood in San Francisco from this data set would require a user to download all 350,000 files.

Health data relevant to disease outbreaks comprise clinical data and environmental, socioeconomic, and behavioral information pertinent to health and wellness. Like Earth observations, health data types are diverse and heterogeneous and can be structured or unstructured, further complicating integration efforts. In addition, health data are often not standardized, and records often reflect the health conditions of individuals. Because few environmental data sets provide comparable degrees of street-level detail, drawing inferences that integrate health and environmental data can be difficult.[68]

5. Data cross-pollination and smart cities

The trend of migration to urban areas has only seen an upward trajectory since the First Industrial Revolution. As cities and the metropolitan regions continue to act as powerhouses of economic growth (accounting for about 60% of global GDP), it is unsurprising that more than half of the world's population lives in urban areas, a share projected to rise to 60% by 2030. This rapid urbanization, which is the sole culprit for about 70% of global carbon emissions and over 60% of resource use, results in a growing number of slum dwellers, inadequate and overburdened infrastructure and services, worsening air pollution, and unplanned urban sprawl.[69] Because of these mounting issues, the UN has set out to make cities inclusive, safe, resilient, and sustainable (SDG 11) by 2030.

This mainly presents itself as an issue in the context of LAC, as rapid urbanization processes observed in the region during the last few decades posed multiple challenges and caused

[68] Liu, Z., Tong, D., et al (2021) Integrating Data to Find Links Between Environment and Health, at https://www.preventionweb.net/news/view/78082
[69] https://www.un.org/sustainabledevelopment/cities/

great contrasts in the quality of life within cities. More than 80% of the population lives in cities, and approximately 27% of the urban population still lives in informal settlements without proper access to basic urban services.[70]

With urban populations on the rise, the necessity to create a modern, sustainable living environment for urban citizens has become a significant area of interest for both the public and private sectors. Current modern cities are equipped with sensors generating vast amounts of data waiting to be tapped for "smart" decision-making. This data can provide city decision-makers with a holistic view of the scenarios of physical infrastructure, buildings, vehicles, and human flows in cities in real-time to have a timely response. By integrating emerging technologies, modern cities can be transformed into smart cities able to tackle problems arising from rapid urbanization, such as environmental pollution, traffic congestion, flood, waste disposal, water shortage, and rising healthcare and medical costs.[71]

> A smart city is a suite of smart applications bringing together technologies, governments and societies to enable characteristics, such as smart healthcare, smart transportation, smart home, smart building, etc. designed and developed to manage assets and resources more efficiently.

In this context, the concept of smart cities refers to the development of technology and data-based urban systems integrating ICT and data with various physical devices (sensors) that are interconnected, thus driving efficient city management and economic growth. This reliance on ubiquitous sensing capabilities of wirelessly connected sensors and actuators to observe, measure, reason, and act in the physical world creates valuable assets in the form of data.[72] These data can be collected, used, and analyzed to optimize city operations, manage resources, and improve the everyday life of citizens.

These sensor-generated data can have an impact on various sectors of a city, including:

- **Public Safety:** Smart cities must provide security for their citizens. Cities can use predictive big data analytics to identify which areas are prone to be hubs of crime and predict the exact crime location. Information like historical and geographical data helps cities create a much safer environment.
- **Transportation:** Traffic congestion is a significant problem in many cities since it can cost cities millions in revenue. Cities can manage transportation by analyzing data from transport authorities. The analyzed data can uncover patterns that help reduce traffic congestion and help authorities implement data-driven road optimization.
- **Cost Reduction:** Cities invest a lot of money in transforming a city into a smart city. These investments can be either for remodeling or renovation. Analysis of big data can suggest which areas require transformation and what kind of transformation. As a result, cities can make dedicated investments for needed areas.
- **Sustainable Growth:** Regular analysis of the growth of a smart city enables city officials to get continuous updates about needed changes. Constant updates are the key growth drivers of sustainability because they provide a clear idea regarding the required developments. Data plays a crucial role in determining the outcomes of development in a smart city.[73]

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[70] Bouskela, M., Elnir, H., (2018) Shaping Smart Cities in Latin America and the Caribbean, at https://blogs.iadb.org/ciudades-sostenibles/en/shaping-smart-cities-in-latin-america-and-the-caribbean/

[71] Raghavan, S., et al (2020) Data Integration for Smart Cities: Opportunities and Challenges, at https://link.springer.com/chapter/10.1007/978-981-15-0058-9_38

[72] Ibid

[73] Maayan, G. D. (2020) How Big Data Impacts Smart Cities, at https://www.dataversity.net/how-big-data-impacts-smart-cities/#

The emergence of big data has added a new aspect to conceptualizing digital technologies to deliver public services and digital governance. Practices associated with big data, especially around machine learning, automated decision-making, and predictive algorithms, are changing how public service decision-makers and providers envisage future technology solutions in all service areas, including smart city urban environments. Without neglecting the implementation of data analytics in governmental settings and realizing genuine benefits, the current discourse reflects a technocratic agenda based on scientific-technological rationality. Typically, urban public service delivery is aligned with commercial ambitions to harvest data from citizens. Public values such as transparency and fairness are outranked by attention to instrumental values such as efficiency, safety, and security. There is an alignment with a corporate discourse in terms of governance where the private sector represents the 'gold standard' of technological deployment to be replicated in the public sector. This approach neglects the integrity of the public sector, its institutional norms and values, and the public organization's uniqueness in safeguarding the rule of law, political neutrality, democratic control, accountability, and the assurance of other non-economic public values.[74]

Smart Cities and Energy (SDG 7)

The management of energy expenditure is a crucial issue in modern society. Countries across the globe have begun to propose strategies that guarantee increased access to energy resources at affordable costs for their citizens while at the same time ensuring the conservation of resources and the protection of the environment.

Effective energy management policies can only be implemented when innovative and emerging technology solutions are integrated into the smart city paradigm. The capabilities of monitoring, controlling, and managing energy consumption generate vast amounts of data capable of addressing key issues when implementing smart cities. Hence, data-driven solutions for optimal grid management through digital solutions are integral to achieving energy-efficient smart cities.

Furthermore, policymakers, governments, global industries, and the international community are under enormous pressure to deploy renewable energy sources and improve energy efficiency due to the looming threat of climate change. In an effort to comply with the need for cleaner energy, as well as economic and ecological demands, the electricity market structure has begun to gradually transition to a more decentralized and interactive approach where the emphasis is given to smart grid technologies, allowing energy consumers to play the role of prosumers who produce, sell, or share surplus energy.[75]

Considering that cities play a leading role in LAC's economic and demographic development, transitioning to a smart city paradigm would be most advantageous. Cities in LAC generate two-thirds of the gross domestic product (GDP) of countries in the region, yet they are the most unequal in the world. With expectations that primary energy demand in LAC will be at least 80% higher in 2040 than what it is today, cities in LAC must install smart meters and sensors and utilize the data they generate if they wish to transition to smart cities. At present, Brazil's

[74] Logfren, K., Webster, W. R. (2020) The Value of Big Data in Government: The Case of 'Smart Cities', at https://journals.sagepub.com/doi/pdf/10.1177/2053951720912775

[75] Bokolo, A., et al (2019) Big Data-Oriented Energy Prosumption Service in Smart Community Districts: A Multi-Case Study Perspective, at https://energyinformatics.springeropen.com/articles/10.1186/s42162-019-0101-3

application of smart metering and related smart grids has been confined to research and relatively isolated groups of consumer units.[76]

Energy Monitoring Devices in HengQin Island China

HengQin Island in Southern China has installed energy monitoring devices in factories and worksites, allowing analysts to immediately identify and address high levels of pollution or track energy waste. In monitoring these sites and equipment, big data has enabled HengQin to track emissions and energy consumption in real time, allowing for immediate results in a substantive decrease in energy costs and carbon emissions. By utilizing these energy monitoring devices, and the data they create, HengQin has experienced real traction in attaining its goal of cutting carbon emissions by 45% in 2020.

Healthcare (SDG 2) and Smart Cities

Smart city technologies can detect and mitigate public health crises, as evidenced by the current COVID-19 pandemic. The events that transpired with the spread of the virus have changed our perceptions of what a city is. Cities are living organisms that provide us with terabytes of data generated from different sources, such as lamp posts, buses, climatic stations, police vehicles, traffic lights, security cameras, automatized hospitals, universities, museums, and any other element that can be connected to a smart city macrocosm. The data generated played a pivotal role in government efforts to slow the spread of the virus.[77]

Social media data has also played a major role in offering clues by monitoring what residents post about themselves, noting breaks in routine. This has allowed smart city macro-systems to retrieve that information and store the health behaviors of their inhabitants, quickly detecting infected people and clusters. Despite using data generated by social media raising privacy concerns, these 'invasive' solutions have proven to be highly effective when trying to reduce the virus spread.[78] One such example can be seen in Uruguay with the rapid response to the COVID-19 crisis. The Uruguayan Agency for Electronic Government and the Information and Communication Society (AGESIC), with the help of a large number of private companies, developed the Coronavirus UY app. The app harnessed technology for social good by incorporating information on the state of the pandemic in Uruguay, allowed users to report symptoms, be alerted if they have been in close contact with a person who has contracted the virus, conduct telemedicine consultations,[79] and has recently expanded its services to act as a vaccination certificate.[80]

[76] Mutule, A., et al (2021) Implementing Smart City Technologies to Inspire Change in Consumer Energy Behaviour, at https://www.mdpi.com/1996-1073/14/14/4310/pdf
[77] Kanowitz, S. (2021) How Smart Cities Can Mitigate the Impact of Health Crises, at https://gcn.com/articles/2021/01/21/smart-city-health.aspx
[78] Ibid
[79] Ministerio de Salud Publica (2020) Nueva Version de la App Coronavirus UY con Alerta por Exposicion, at https://www.gub.uy/ministerio-salud-publica/comunicacion/noticias/nueva-version-app-coronavirus-alerta-exposicion?fbclid=IwAR14QAe7tk6ptNrHmI4D7e58OFjRsNUbmcG-SaCbxhnbdjnvPtDMHXgFEQI
[80] https://radiouruguay.uy/certificado-de-vacunacion-quedara-disponible-en-la-app-coronavirusuy-adelanto-jodal/

Data collection is only one element of enabling smart city response to health crises. Since smart cities provide massive amounts of uninterrupted data each second, highly efficient algorithms are necessary to transform those data into useful information.

Opportunities

Interoperable technologies and open data models have a far higher success rate since they grant superior flexibility and scalability and secure the ability to integrate a number of different devices and applications on the same infrastructure, scaling up and adding new functionalities when and where needed.

Several cities have begun to offer open data to citizens and businesses through open data portals. Open data portals allow data owners to publish and share either full data sets or metadata from multiple sources into huge, searchable databases or archives of different types of machine-readable media. The open data portal approach uses search tools that allow human users to filter and search the data relevant to their problems. It has been found that most of the current Open Data Initiatives are from the European Union member states. These open data portals serve as the platforms for smart city solution providers to access data with minimal costs to develop next-generation applications.[81]

Challenges

At present, most of the smart city sensor data are stored and secured in proprietary storage or in electronic devices, undisclosed to the public. Innovative solutions, which exploit these data to create better public services, are constantly being hampered by the lack of visibility, accessibility, and compatibility among these data. Smart city systems which work in "silos" are closed, designed, and developed by specific vendors using proprietary technologies and dedicated to a particular need of a home, a company, or a few persons rather than contributing to the common good of the cities. They cannot be easily combined or extended with third-party components or services due to the heterogeneity of structure and formats. Hence, there is an increasing need for a new tool or platform to facilitate the collection, integration, and assimilation of smart city data to support what a "smart" city could do.[82]

However, the existence of open standards does not automatically result in open systems due to the fact that the models require deliberate efforts by IoT system designers and developers to change their internal design and architecture to be aligned with the standards, but it does not address the legacy issues of existing systems which are already in place with its proprietary design. Furthermore, there are many different standards currently available for IoT systems. Without strict enforcement of any standards as the sole global one, the IoT scene remains inherently fragmented, with varying standards being adopted by different communities of practitioners or companies.[83]

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[81] Raghavan, S., et al (2020) Data Integration for Smart Cities: Opportunities and Challenges, at https://link.springer.com/chapter/10.1007/978-981-15-0058-9_38
[82] Ibid
[83] Ibid

6. The potential of Artificial Intelligence in data cross-pollination

In recent years, the rapidly growing presence of AI in virtually every aspect of life in the industrialized world has led to important questions on how AI can help achieve the SDGs. The conversations on AI in human development are nascent, with many exciting ideas being proposed. However, the discussions to date have been mainly abstract, with little specificity about where big data and AI can help. Indeed, there is a significant knowledge gap between the AI community and the development community, which needs to be closed to separate fact from hype and ensure resources are dedicated to initiatives with a significant likelihood of impact.

Use of AI in the energy sector

Conventional grid infrastructures—with centralized generation and widespread distribution—are too capital intensive for the governments of low-income countries. Recognizing the environmental cost of fossil fuels, many governments have begun shifting away from conventional electrification models.[84]

AI can cut energy waste, lower energy costs, and facilitate and accelerate the use of clean, renewable energy sources in power grids worldwide. AI can also improve the planning, operation, and control of power systems. Thus, AI technologies are closely tied to the ability to provide clean and cheap energy that is essential to development.

The use of AI in the power sector is now reaching emerging markets, where it may have a critical impact, as clean, cheap, and reliable energy is essential to development. The challenges can be addressed over time by transferring knowledge of the power sector to AI software companies. When designed carefully, AI systems can be particularly useful in the automation of routine and structured tasks, leaving humans to grapple with the powerful challenges of tomorrow.

The power sector has a promising future with the advent of solutions such as AI-managed smart grids. These are electrical grids that allow two-way communication between utilities and consumers. Smart grids are embedded with an information layer that allows communication between its various components so they can better respond to quick changes in energy demand or urgent situations. This information layer, created through the widespread installation of smart meters and sensors, allows for data collection, storage, and analysis.

Phasor measurement units (PMUs), or synchrophasors,[85] are essential for the modern smart grid. They enable real-time measurement and alignment of data from multiple remote points across the grid. This creates a current, precise, and integrated view of the entire power system, facilitating better grid management.

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[84] Buluswar, S. et al. (2018) Artificial Intelligence and Data Analytics for Human Development, at https://transformativetechnologies.org/insights/emerging-technologies/artificial-intelligence-and-data-analytics-for-human-development/

[85] A Phasor Measurement Unit, also called a PMU or a synchrophasor, is a key tool used on electric systems to improve operators' visibility into what is happening throughout the vast grid network. A PMU is a device that measures a quantity called a phasor.

Paired with powerful data analytics, these smart-grid elements have helped improve electricity transmission and distribution networks' reliability, security, and efficiency. Given the large volume and diverse structures of such data, AI techniques such as machine learning are best suited for their analysis and use. This data analysis can be used for a variety of purposes, including fault detection, predictive maintenance, power quality monitoring, and renewable energy forecasting.

The use of smart grids in developing countries lags advanced economies, but several developing countries have taken steps to adopt them, with various levels of development. These include Brazil, China, Gulf Cooperation Council (GCC) countries, Malaysia, South Africa, Thailand, and Vietnam, among others.

AI can also help with prediction issues in hydroelectricity production. Most countries have reliable hydrology data collected over 40 years, and in some cases, more protracted, that facilitates the prediction of hydrology using proven stochastic dual dynamic programming tools. However, in the past year, climate change has disrupted such predictions. Currently, the mathematical models underlying the operation of power production are approximately 30 years old and are generally incompatible with the current realities of the hydropower sector. The increasing uncertainty of parameters such as future precipitation levels or pricing is among the many challenges to optimizing production and profit.[86]

AI can help with fault prediction has been one of the key applications of AI in the energy sector, along with real-time maintenance and identification of ideal maintenance schedules. AI combined with sensors can monitor equipment and detect failures before they happen, thus saving resources, money, time, and lives. Preventive measures such as chemical agent spray to avoid turbine shutdowns are optimized (quantity, composition, and timing) using IoT and AI.[87]

AI can also facilitate maintenance. For instance, the United Kingdom's National Grid uses drones to monitor wires and towers that transmit electricity from power stations to homes and businesses. Due to their ability to cover vast geographical areas and challenging terrain and equipped with high-resolution still and infrared cameras. The drones cover 7,200 miles of overhead lines across England and Wales. AI is used to monitor power assets' conditions and determine when they need to be replaced or repaired.[88]

Energy Efficiency Decision Making. Smart devices, such as Google Home, Amazon Alexa, and Google Nest, enable customers to interact with their thermostats and other control systems to monitor their energy consumption. Automatic meters coupled with AI optimize energy consumption and storage. For instance, it can trigger devices to be turned off when power is expensive, electricity is stored via car and other batteries when power is cheap, or abundant solar rooftop energy. AI will play a pivotal role in using data, such as grid data, smart meter data, weather data, and energy use information, to study and improve building performance, optimize resource consumption, and increase comfort and cost-efficiency for residents.

For example, Suncast has implemented a generation prediction project in Chile, developing a high-precision model to predict solar photovoltaic power generation, with models based on machine learning and artificial intelligence techniques.[89] Claro Colombia presented solutions

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[86] IFC (2020) Artificial Intelligence in the Power Sector
[87] CBInsights (2018) "*5 Ways the Energy Industry is Using Artificial Intelligence.*" Research Briefs, March 8, 2018. https://www.cbinsights.com/research/artificial-intelligence-energy-industry/.
[88] Vaughan, A. (2018) "AI and Drones Turn an Eye Towards UK's Energy Infrastructure." theguardian.com, December 2, 2018. https://www.theguardian.com/business/2018/dec/02/ai-and-drones-turn-an-eye-towards-uks-energy-infrastructure.
[89] https://www.suncast.cl/?lang=en

based on its NB-IoT (Narrowband Internet of Things) network, which focuses on smart lighting solutions, aqueducts, and smart cities.[90]

The use of AI will entice the proliferation of so-called "prosumers." The spread of distributed generation means that consumers can contribute to power generation, effectively acting as producers (prosumers). AI can facilitate decision-making about optimal times for distributed generation to contribute to the grid rather than draw from it. AI can also help traditional producers and system operators who will now have to balance increased intermittent renewables, distributed generation including prosumers, and new demand-side trends such as the increase in electric vehicles.[91]

AI can also prevent losses caused by informal connections. AI could be deployed to identify discrepancies in usage patterns, payment history, and other consumer data and detect informal connections. When combined with automated meters, AI can improve energy consumption monitoring. It can also optimize costly and time-consuming physical inspections. For example, Brazil, which has been suffering from a high rate of non-technical losses, including informal connections and billing errors, has benefited from such solutions. The University of Luxembourg has developed an algorithm that analyzes information from electricity meters to detect abnormal usage. The algorithm has revealed problematic cases at a higher rate than most other tools when applied to information over five years from 3.6 million Brazilian households. The technology will be deployed across Latin America.[92]

[90] Smart Energy International (2021) Latin America's Innovation Outlook, at https://www.smart-energy.com/magazine-article/latin-americas-innovation-outlook/
[91] Ommid, S., Menes R. (2020) "Artificial Intelligence and the Future for Smart Homes." *EM Compass Note 78*, IFC, February 2020.
[92] Shah, Saqib. 2017. "Companies Will Use AI to Stamp Out Electricity Theft. "engadget.com, September 25, 2017. https://www.engadget.com/2017/09/25/companies-will-use-ai-to-stamp-out-electricity-theft/

AI can also guard against cyber-attacks aimed at critical energy infrastructure. A structured approach that applies AI solutions, communication, organizational, and process frameworks along with technical improvements in a few areas can significantly reduce cyber-related risks for utilities. Applying AI for monitoring and detecting cyber threats helps defenders create a unified picture of anomalous behavior and draw out actionable insights for defenders to make decisions and stop malicious cyber-attacks.[93]

Anti-Theft Technology in the Energy Sector of Brazil

Ampla, an electric power distribution subsidiary of Brazil's Enel Group operates in 66 municipalities of the State of Rio de Janeiro and serves nearly seven million inhabitants and 2.5 million customers. It is one of the largest power distributors in Brazil, responsible for 2.5 percent of the nation's energy turnover and 27.8 percent of the states. It serves an area of 32,608 square kilometers, some 73.3 percent of the state territory. The Ampla market has a residential profile, with 80 percent of its clients in low-density, high-complexity areas.

Ampla has long been plagued by loss of power due to fraud and theft, with more than half of it concentrate in five municipalities, all of which are populous favelas with high rates of urban violence and drug trafficking.

The high rate of non-technical losses (i.e., via theft) damages the quality of Ampla's services, the safety of the population, and also pushes national energy production above levels needed by the market and the formal economy, causing waste.

To address these theft and power-loss issues, Ampla deployed an Anti-Theft Machine Project for medium voltage customers. The system gathers all the elements of power use measurement through digital meters into a single device that connects to Ampla through a remote management system using cellular communication networks. The devices are intelligent modules with diverse functionalities, and once a day, they transmit accurate consumption information to Ampla for efficient remote management of supplies, disruptions, and reactivations. Artificial intelligence is used in the control center to identify unusual patterns relative to customer profiles located in similar areas.

This data is also used to anticipate consumer behavior and predict which customers are likely to have informal connections to the power grid. This information can then be used to curb such connections and cut waste.

Brazilian business magazine *Exame* named Ampla's antitheft system one of the top ten innovations of the last decade in Brazilian industry.

Use of AI in transportation

Transport in emerging markets often faces acute challenges due to poor infrastructure, growing populations, urbanization, and in some regions, rising prosperity, which increases vehicle traffic, cargo volumes, and pollution. Artificial intelligence offers new solutions to these challenges by making market entry more accessible and allowing countries to reach underserved populations, creating markets and private sector investment opportunities associated with them.

Urban mobility: Small-scale autonomous bus trials have been implemented worldwide, in places as diverse as Finland, Singapore, and China. Autonomous shuttles are already operational in Norway, Sweden, and France. One example is Olli, a self-driving electric shuttle by Local Motors, a US company powered by IBM Watson. Olli is the first AV to use IBM's Watson and its Internet of Things database to analyze the surrounding traffic and make decisions based on that data. Besides driving itself, Olli also provides its passengers with restaurant and

[93] Simonovich, L. (2020) Artificial Intellifence can Protect all Companies in the Energy Transition from Cyberattacks, at https://www.atlanticcouncil.org/blogs/energysource/artificial-intelligence-can-protect-all-companies-in-the-energy-transition-from-cyberattacks/

weather information. Olli has been tested in several US cities.[94] Ride-hailing and sharing platform Uber uses AI for driver and ride-matching, route optimization, and driver onboarding.

Traffic management operations: Many AI algorithms are well-suited to solving complex problems such as those posed by traffic operation, and they are being used around the world. One example is SurTrac from Rapid Flow Technologies, a Carnegie Mellon University spinoff, which provides solutions for intelligent traffic signal controls. It has coordinated traffic flows at a network of nine traffic signals in three major roads in Pittsburgh. Rapid Flow helped reduce travel times by over 25 percent on average and wait times declined by 40 percent during the trial. It also reduced stops by 30 percent and emissions by 20 percent.[95]

European rail traffic management system

In the EU, the first key step towards the introduction of ATO and AI solutions in rail transport is the deployment of the European rail traffic management system (ERTMS), which provides trains with a driver assistance system. The ERTMS aims to harmonize EU rail transport systems by deploying a single control, command, signaling and communication standard. It is composed of a European train control system, which enables beacons installed on the track to retrieve information and convey driving instructions to the vehicle, and a standard system for mobile radio communications on railways. In addition to ensuring technical compatibility between national rail systems, the ERTMS combined with ATO can reduce rail operators' costs and energy consumption, and increase rail speed (up to 500 km/h), punctuality, safety and line capacity.

Source: https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/635609/EPRS_BRI(2019)635609_EN.pdf

Logistics: Trucking is a key target for AI interventions, with cargo delivery as a potential early space for adopting AV technology worldwide. In 2015, Uber bought a driverless technology firm, Otto. It completed the first autonomous truck delivery year later, carrying 50,000 Budweiser beer cans over 120 miles from Fort Collins to Colorado Springs. Established players like Volvo and trucking firms like Starsky are also testing their prototypes.[96]

Logiety, a Mexican company, uses machine learning to streamline the international customs and taxing process by classifying and sorting products for import and export by material, size, and weight and matching them with their corresponding tariffs.[97]

Loggi, one of Brazil's newest unicorns, is a logistics startup that connects couriers to customers that need express last-mile delivery services. The company already uses an app to connect motorcycle delivery drivers and its clients in various sectors. To fund its expansion over the next five years, the company is looking to leverage AI and big data to optimize delivery routes and timeliness.[98]

Marine: Autonomous ships are one obvious application of AI in the shipping sector. Shipping companies like Nippon Yusen and Kongsberg are testing their prototypes, successfully testing an autonomous ship in Finland in 2018. But AI also provides the opportunity to optimize networks and routes, reducing fuel costs and emissions. In 2018, Hong Kong-based shipping line OOCL partnered with Microsoft's AI research center to optimize their network operations, a 15-week effort that generated savings of $10 million per year for OOCL.[99]

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[94] https://localmotors.com/meet-olli-3/

[95] Opdyke, H. (2019) Surtrac Allows Traffic to Move at the Speed of Technology, at https://www.cmu.edu/news/stories/archives/2019/october/traffic-moves-at-speed-of-technology.html

[96] Sage, A. (2016) Uber's Otto Hauls Budweiser Across Colorado in Self-Driving Truck, at https://www.reuters.com/article/us-uber-trucking-beer/ubers-otto-hauls-budweiser-across-colorado-in-self-driving-truck-idUSKCN12P13N

[97] https://logiety.com/

[98] https://www.loggi.com/en/

[99] IFC (2019) How Artificial Intelligence is Making Transport Safer, Cleaner, More Reliable and Efficient in Emerging Markets

Use of AI in sustainable food systems

Models utilizing AI can help meet rising global demand for food and support a more inclusive and sustainable food system by (1) enhancing the resilience of farming methods; (2) reducing the cost of quality inputs and services to underserved farmers; and (3) improving market access to facilitate smallholder farmer integration into regional and global supply chains. Although nascent in emerging economies, applications for artificial intelligence in agribusiness will increase as farmers' access to the Internet and adoption of smart devices increases across low-income countries.

Improvements in the productivity and sustainability of the global agricultural system and higher returns on investment for farmers are critical to meeting the SDGs. In emerging markets, food losses take place throughout the production, post-harvest handling, storage, and processing stages.

Another critical development challenge is that agriculture both contributes to and will be fundamentally affected by climate change. Land use, including agricultural practices, deforestation for arable land, and the forestry industry, account for 28 percent of net greenhouse gas emissions. At the same time, climate change affects the availability of, access to, and stability of the global food system. The challenge in meeting food demand and transporting food across markets sustainably cannot be solved through business-as-usual farming practices.

The adoption and diffusion of AI technology and precision agriculture into agtech business models promise to address these challenges. For instance, AI applications in financial services, knowledge, and capital can help improve the cost efficiency of agribusinesses by using inputs "intelligently" and increasing the quality of outputs. AI applications also promise to improve the sustainability of farming practices by reducing fertilizer and pesticide use, enhancing the accuracy of pest and disease detection, and facilitating the automated grading of crops. Additionally, combining data on soil characteristics, weather, and other climatic factors and interpreting them through machine learning software helps to plant, manage farm operations, and harvest. And AI technology can help enhance the transparency of global food supply chains, minimize food loss, and facilitate the monitoring of food quality standards.[100]

Space AG[101] from Peru offers a platform to digitalize farms by combining data captured by drones and satellite images, integrating and processing data from crops to create a digital map of the farms and generate alerts of anomalies related to irrigation and plant vigor, as well as more accurate harvest forecasts.

The company uses AI methods for correlating production data with chlorophyll concentration, leaf surface, and plant height and integrating them with other crop variables to develop harvest optimization models and plots to be harvested, harvest forecasting, resource-focused application, and early detection of anomalies.

[100] IFC (2020) Artificial Intelligence in Agribusiness is Growing in Emerging Markets
[101] www.spaceag.co

The company has also developed image recognition to identify harvest volumes, times and sites more accurately, and fruit anomalies, together with a series of sensors and telemetry to operate agricultural machinery.[102]

Challenges

Deployment of AI in the energy, transportation, and water and sanitation sectors will need an incremental renovation of existing infrastructure. For instance, intelligent trains will have to integrate external technologies developed for the automotive industry.

Common challenges concern financing digital and AI research, innovation activities, infrastructure, and new digital skills. A lack of reliable power sources and weak telecommunications networks is part of this obstacle. Countries that make few investments in technology research and hard infrastructure as a percentage of GDP may have a harder time harnessing the power of AI. Setting out the responsibilities of manufacturers, operators, and drivers depending on the level of automation is another important common challenge: finding appropriate answers to new legal issues concerning liability and ethics. Like any other industrial sector using automated control systems, railways will have a technical and human challenge to fight against cyber threats and protect their assets. But, according to experts, the most complicated common challenge by far will be the development of a new mindset. Sharing data, evolving the relatively rigid railways business model towards a more dynamic network that joins technological platforms, mobility providers, and customers, is a difficult task. This might prove more difficult than switching from electrical to digital instruments and devices or implementing autonomous or automated systems.

Good practices: Facilitating data sharing within the public sector

Lately, there has been a remarkable trend towards facilitating data sharing within the public sector. This trend is motivated by governments' commitment to become more data-driven and take advantage of technological trends such as big data and AI. Australia's data-sharing and release legislation (DS&R legislation)[103] and the United Kingdom's Data Ethics Framework and Centre for Data Ethics and Innovation[104] are examples that facilitate data sharing within the public sector.

Another example is Estonia's Information Sharing Data Sheet (X-Road) initiative. The objective of X-Road is to facilitate data exchange and linkage by inter-connecting the central national databases in Estonia. X-Road enables citizens, government agencies, and private-sector organizations to use most Europe-wide data registered in national registries securely. It is motivated by the "once-only" principle according to which public agencies should only collect

[102] IADB (2019) Agtech Innovation Map in Latin America and the Caribbean, at (https://publications.iadb.org/publications/english/document/AGTECH_Agtech_Innovation_Map_in_Latin_America_and_the_Caribbean_en.pdf
[103]https://pmc.gov.au/public-data/data-sharing-and-release-reforms#:~:text=The%20DS%26R%20Act%20could%20help,data%20safeguards%20are%20in%20place .
[104] https://www.gov.uk/government/organisations/centre-for-data-ethics-and-innovation

data that is not previously maintained in any other public-sector databases. In other words, if a company or an individual has already submitted data to the public sector, they should not be forced to do it twice. At the same time, X-Road allows verifying the quality of the data, which is possible because public and private-sector institutions can connect their information system to X-Road.[105]

[105] https://e-estonia.com/solutions/interoperability-services/x-road/

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