

# Broadband and Environmental Benefit Data and Literature Report

## SCAG Caltrans Broadband Grant Task 3:1: Review Broadband and Environmental Benefit Data and Literature

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# Summary

## A. Report Organization

The Broadband and Environmental Benefit Data and Literature Report is organized in the following sections:

### 1. Section 1:

#### **Foundational Reference Documents used for the Caltrans Broadband Grant**

The documents in this section are provided as reference as they create the foundation as to why SCAG, with CETF and Southern California Regional Broadband Consortia, are studying the relationship between improved broadband and reduced Vehicle Miles Traveled (VMT) and Greenhouse Gas Emissions (GHG).

The foundational documents help provide the context on why there should be a nexus found between improved broadband through the utilization of public road rights-of-way as a public investment and benefit for broadband users, especially in rural and disadvantaged communities, and reduced VMT and GHG which broadband service expansion is determined a legitimate, and even preferred, Transportation Demand Management (TDM) strategy to mitigate traffic and environmental impacts, and protect the public investment in state and local highways.

Ultimately, planning for broadband and including broadband conduit as an eligible project cost in public rights of way on interstates, state highways, bridges, regional roads, and local streets should be considered a standard TDM measure and be included in the modern concept of designing and building complete streets.

The foundational documents include groundbreaking work done by the California Emerging Technology Fund (CETF), the existing Smart Mobility Framework and Wired Broadband Guidelines from Caltrans, Corridor Plans done by Caltrans and the California Transportation Commission (CTC).

## **2. Section 2:**

### **California Specific Reports and Data addressing VMT, GHG, and Broadband**

This section includes the current draft of the California Broadband Council (CBC) Broadband Action Plan as it is a directive from the Governor's recent "Broadband for All" Executive Order.

Studies and reports from California based government and organizations flesh out this section with important work from SCAG and UC Davis, as well as additional Caltrans Reports that address technology, mobility, and reductions in VMT and GHG using a variety of methods, including internet-based solutions such as telecommuting.

Reference documents are included for context from the Governor's Office of Planning and Research (OPR) regarding CEQA's updated VMT standard and GHG standards for reviewing impacts of transportation projects, land-use developments, etc.

## **3. National Data, Articles, and Research**

Reports focusing on internet usage resulting in VMT and GHG reductions are included from national sources, including the Federal Highway Administration (FHWA), U.S. Department of Energy, Ohio Department of Transportation, US Ignite, and the American Consumer.

## **4. Industry Centric Information, covering Telecommuting, Telehealth, Distance Learning, and the Internet of Things (IoT)**

This section includes research from RAND, UC Davis, UC San Diego, San Jose State University Mineta Transportation Institute, Cornell University, Oregon Department of Transportation, and various academic and research journals.

In preparing this report, it is clear there are plenty of academic research and government agency reports about internet use leading to VMT and GHG reductions. In fact, this topic has been richly studied in California, nationally, and beyond for many years. The many studies include looking at the effect on VMT and GHG, as well as other environmental and community benefits from telecommuting, telehealth, and distance learning.

There has been interest in also studying potential benefits from the Internet of Things (IoT) concept related to components and services used in our everyday life becoming connected to the internet through the cloud via smartphone and other computer apps. E.g., security systems, cameras, speakers for two-way conversation, lighting switches, thermostats, appliances, banking, product, groceries, and meal delivery, etc.

As more routine, everyday items become automated, will there be a significant reduction of trips with associated reductions in GHG, or will there be an increase of delivery trips offsetting trip reduction?

The use of online services by government and the advent of more online shopping, meal delivery and services also could be quantified into potential reductions in VMT and GHG.

## **5. Online Data Tools**

A sample of online data tools is provided to show that there are agencies, including the California Transportation Authority, SCAG, and the County of Los Angeles are providing annual traffic data, GIS data, and VMT and GHG information.

There are numerous online calculators for determining how variables impact VMT and GHG. The Street Lights calculator is shown as it is a newly minted “Post-COVID-19 Climate Impact Calculator.”

## B. Findings, Identification of Information, and Data Gaps

Although, the majority of the research over the past 20 years concludes it is clear telecommuting, made possible from increased and higher quality internet service, will reduce traffic congestion, VMT, and GHG, the rate of telecommuting has been stable at about 5% of all workers, including the self-employed and farmers.

There are some recent studies that claim people who telecommute eventually add more driving into their routine due to their flexible schedule, such as errands and school-related trips, but these also minimize that those trips are most likely at non-peak hour, and errands may be grouped up into one longer errand trip. These studies almost appear to be done with a contrarian vein as there are studies over such a long period that confirm positive environmental benefits and reduced VMT and GHG from telecommuting.

It has been found that during the first peak of COVID-19, the workforce was telecommuting at around 40% with some reports much higher. Approximately 20% of the workforce will continue to telecommute, post-COVID-19, either all week, a few days a week, or even one day per week. There will need to be more reporting on the level of distance learning, telehealth, online government, and other online services post-pandemic.

Why were telecommute rates so low prior to COVID-19? It is not a lack of data, research, or the availability of internet service, that has kept the telecommuting percentage at 5% for so many years.

It appears more likely that study after study may be sitting on shelves and dormant in academic journals. The studies on this topic seem to have been used to create additional studies, without commensurate advances in public or private sector policy.

There is data and research available supporting the use of the internet based technologies to reduce VMT and GHG, yet there has been no significant rally from leadership, nor from business and government agencies, to strongly support or promote telecommuting, and other online services, as a high-value TDM method.

The average person is not hearing about new innovative TDM policies and programs that focus on telecommuting, telehealth, and distance learning based on technology advancements derived from higher internet service in order to reduce VMT, GHG and ultimately benefit climate change or other quality of life issues.

The studies are not being elevated to much in the way of public policy making. There is interest in broadband as a VMT mitigation strategy as a subject matter, but it seems to stay in the research phase and never get out the academia or government agency door.

Going through the documentation, data, and literature, rather than a research or data gap, it looks like there is more of a *leadership, policy, and action gap*, and a need for much more community outreach and education, when it comes to connecting the dots of improved broadband leading to reduced VMT and GHG as a viable TDM strategy.

Who knew the data and information is out there and available? What is missing is policy, programs and a strong community understanding of why internet based activities such as telecommuting, telehealth, and distance learning lead to reduced VMT and GHG, which in turn are good for the environment and climate change, as well as help sustain the transportation system.

Further, since the issue is being continually studied without action from the studies, the community is missing out on incentives to utilize internet-based solutions to reduce VMT and GHG as none are being pushed forward by policy makers and transportation leaders.

In addition, if leadership takes action and develops clear and understandable VMT and GHG reduction TDM strategies related to telecommuting, internet service providers (ISPs) would have more pressure to improve their service as they would be viewed as integral to reducing VMT and GHG, helping with climate change.

Transportation projects would be expected to consider broadband in their rights-of-way to further accelerate deployment, especially in underserved rural and disadvantaged communities. The cost of broadband planning and leveraging the transportation system for broadband deployment—systems that are owned by the public—would not be a big policy concern or question. It would be as simple as a complete street includes broadband planning to reduce VMT and GHG as a standard TDM strategy

The COVID-19 pandemic response has proved out that the technology and internet service for many does in fact exist at the level to be able to use telecommuting, telehealth, distance learning (not all education, but as an option), online government and services as a regular TDM strategy to reduce VMT and GHG. It has also shown where there are serious broadband service gaps, no service at all, and significant pricing issues that need to be addressed, especially if the internet is to become an important TDM strategy embraced within the community, including the disadvantaged.

COVID-19 shows the severe need for improved broadband policy, planning, deployment, access, and cost options in order to roll-out these TDM strategies in areas where internet service poor and suffer from the digital divide. Many more people and places are affected by the digital divide than was thought before the COVID-19 pandemic pulled the curtain back on just how many are unserved and underserved.

COVID-19 revealed that the broadband technology needs significant improvement for a massive online shift to telecommuting, telehealth, and distance learning. This information is helpful to show why pursuit of roadway rights-of-way at all levels in the State for broadband planning and deployment should be considered for transportation funding, especially in underserved, disadvantaged communities.

With COVID-19 pandemic hitting in early 2020, suddenly the only option for many to keep working, teaching, and learning was to move quickly to telecommuting and distance learning.

The health care sector also moved online, with the previous insurance payment barrier being removed at the federal level so that telehealth—phone and virtual appointments-- could quickly replace physical appointments. The medical community ramped up as fast as they could to roll out telehealth options, which became the only option for many seeking appointments with their healthcare providers.

The government also moved as many services as they could online, including public meetings, workshops, and conferences. Private industry also moved conferences and events to virtual platforms.

Online shopping and meal delivery services increased dramatically. It will be interesting to learn how VMT and GHG was affected by an increase in the service and delivery (logistics) sector during the COVID-19 pandemic, and if there are continuing trends from many changes made based upon use of available technology and broadband applications.

This one-time shift in behaviors, based upon the COVID-19 health crisis, to move so much online, revealed the good, the bad, and the ugly of the current internet system. This situation now provides a platform to support why broadband needs to be elevated in public policy. The increase in online usage derived from the health crisis will most likely result in many, who did not previously and were not planning to embrace online options for work, school, healthcare, and other services, to be interested in continuing on this path. To what level is not yet known.

The instant drain on broadband service from all of these sectors moving online so suddenly, even in areas that had been perceived as served somewhat adequately, brings attention to the need to pursue higher level broadband service, and to start outlining as many benefits as possible of doing so, including the reduction of VMT and GHG to improve traffic congestion and the environment.

It is therefore timely to be studying the concept of connecting broadband planning and deployment to transportation investments as a TDM strategy. It will be relevant to the community to be looking at how online activities such as telecommuting, telehealth, etc., that are possible through strong, reliable, and reasonably priced internet service, could be utilized as a robust TDM strategy resulting in reduced VMT and GHG.

The SCAG technical consultant, once on board, will be preparing a socio-economic analysis, as well as transportation system performance data analysis which will be the basis for the final Transportation Broadband Strategies to Reduce VMT and GHG Report. This analysis will be able to capture information on changed online behaviors and perceptions from the pandemic.

SCAG's technical consultant will review the information provided in this report and identify additional data that will be needed. It will most likely be information that SCAG and other government agencies have related to vehicle mile trip data and other data sets. The Regional Broadband Consortia will also provide data from their regions as needed.

Based upon consultation with SCAG's technical consultant, Regional Consortiums will pursue community engagement, stakeholder convenings, and focus group surveys that will also provide data about how the community perceives their internet service related to telecommuting, telehealth, distance learning, etc. and how they feel about the role their internet usage and behavior can play as a TDM strategy to reduce VMT and GHG to improve the environment.

## **Section 1 – Foundational Reference Documents for Caltrans Broadband Grant**

**1. Title:** **Broadband as a Green Strategy Policy Brief**

Source: California Emerging Technology Fund (CETF)

Reference: <https://www.cetfund.org/report/2012-broadband-as-a-green-strategy-policy-brief/>

Date: 2012

*Attachment:* “A1”

**Abstract:** Broadband (high-speed Internet access) is an essential 21<sup>st</sup> Century Infrastructure and a necessity for California’s future global competitiveness, prosperity, and high quality of life. The use of diverse broadband-driven applications also has the potential to reduce greenhouse gas (GHG) emissions and energy consumption, helping meet local, state, and federal air quality standards.

**2. Title:** **Broadband as a Green Strategy Report: Understanding How the Internet Can Shrink Our Carbon Footprint**

Source: CETF

Reference: <https://www.cetfund.org/report/green-benefits/>

<https://www.cetfund.org/report/broadband-as-a-green-strategy-understanding-how-the-internet-can-shrink-our-carbon-footprint/>

Date: 2014

*Attachment:* “A2”

**Abstract:** Broadband is part of the Information and Communication Technology (ICT) sector, which is a large consumer of energy and emitter of greenhouse gases (GHG). By 2020, the sector is projected to be responsible for 2.3 percent of total global emissions.

The proliferation of smart devices and cloud computing infrastructure, combined with the Internet becoming a foundation for the global economy, assures that power consumption and emissions of the ICT sector will continue to grow.

ICT is changing dramatically the way people work, learn, play, shop, connect, and mobilize.

Affordable, accessible broadband is critical for California to meet its GHG emissions goals to help reduce impacts on the environment and improve the quality of life for all.

**3. Title: California General Plan Guidelines**

Source: Governor’s Office of Planning and Research (OPR)

Reference: <https://opr.ca.gov/planning/general-plan/>

Date: 2017 and 2020

*Attachment:* “A3”

**Abstract:** Broadband and “Dig Once” policies are included in the 2017 Circulation Element and Healthy Communities Section Guidelines (Pages 81, 82 and 211 and the 2020 updated Environmental Justice Element (Page 22) to consider broadband for public facilities.

**4. Title: 2018 Comprehensive Multimodal Corridor Plan**

Source: California Transportation Commission (CTC)

Reference: <https://catc.ca.gov/programs/sb1/solutions-for-congested-corridors-program/comprehensive-multimodal-corridor-plan-guidelines>

Date: December 2018

*Attachment:* “A4”

**Abstract:** California’s Solutions for Congested Corridors Program was adopted in 2017 to fund projects that make specific performance improvements that are part of a comprehensive corridor plan designed to reduce congestion in highly traveled corridors by providing more transportation choices while preserving the character of the local community and creating opportunities for neighborhood enhancement projects.

The 2018 Comprehensive Multimodal Corridor Plan provides a unique opportunity for Caltrans and its partners to undertake collaborative planning to address strategic development of technology and other infrastructure needs.

The collaborative identification of strategic corridors to accommodate existing and future broadband internet needs and to further implementation of “Dig Once” policies facilitates the use of technology and broadband to reduce vehicle miles traveled, improve mobility, and reduce congestion.

Technologies such as real-time, web, and mobile enabled trip planning, and ride sourcing services are changing how people travel. The advent of connected autonomous, and electric vehicles will also transform the movement of people and freight. The corridor planning process offers an opportunity to leverage existing Information Technology Systems (ITS) and identify future technology needs.

**5. Title: Caltrans Corridor Planning Process Guide**

Source: Caltrans

Reference: <https://dot.ca.gov/programs/transportation-planning/multi-modal-system-planning/system-planning/corridor-planning-process-guide>

Date: February 2020

*Attachment:* "A5"

**Abstract:** Existing and expected land use and demographics should be summarized at the corridor level. This includes a brief description of the Place Types within the corridor area, as well as a general description of local and regional land use, demographic characteristics, broadband, environmental, and development plans.

A range of Place Types appropriate for description in Corridor Plans are listed within Caltrans Smart Mobility Framework.

**6. Title: Caltrans Incorporating Wired Broadband Facility on State Highway Right-of-Way User Guide**

Source: Caltrans

Reference: <https://dot.ca.gov/programs/design/wired-broadband>

Date: 2018

*Attachment:* "A6"

**Abstract:** California Assembly Bill 1549 (Wood, Chapter 505, Statutes of 2016) requires that Caltrans, during the planning phase of specified Caltrans-led highway construction projects, notify broadband deployment companies and organizations on its Internet Web site of transportation projects that involve construction methods suitable for the installation of broadband. Upon notification from Caltrans, companies or organizations working on broadband deployment may collaborate with Caltrans to install a broadband conduit as part of a project.

The bill also required Caltrans, in consultation with Broadband Stakeholders, to develop guidelines to facilitate the installation of broadband conduit on State highway right-of-way on or before January 1, 2018.

The Caltrans Wired Broadband Facility on State Highway Right-of-Way User Guide provides methodology for Internet Service Providers (ISPs) to access Caltrans facilities for broadband deployment.

**7. Title: Caltrans Smart Mobility Framework**

Source: Caltrans

Reference: <https://dot.ca.gov/programs/transportation-planning/office-of-smart-mobility-climate-change/smart-mobility-active-transportation/smart-mobility-framework>

Date: 2010

*Attachment:* "A7"

**Abstract:** Caltrans Smart Mobility Framework (SMF) is a planning guide that furthers integration of smart growth concepts into transportation planning in California. SMF responds to the transportation needs of the State's people and businesses, addresses climate change, advances social equity and environmental Justice, supports economic and community development, and reduces per capita vehicle miles traveled.

SMF helps achieve California's mandate to find solutions to climate change and the need to reduce greenhouse gas (GHG) emissions and per capita vehicle miles traveled (VMT).

Reduced per capita auto use will lower emissions of GHG gas and conventional pollutants, reduce petroleum consumption and associated household transportation costs, and minimize negative impacts on air quality, water quality, and noise environments.

Achieving the State's goals for reduction of GHG and VMT requires a positive and integrated approach to our transportation future.

## **Section 2 - California Specific Reports and Data (VMT, GHG, and Broadband)**

**1. Title: Draft California Broadband Action Plan**

Source: California Broadband Council (CBC)

Reference: <https://broadbandcouncil.ca.gov/action-plan/>

Date: 2020

*Attachment: "A8"*

**Abstract:** California Executive Order N-73-20 requires the development of a California State Broadband Action Plan. Outreach has been underway for a few months. The California Broadband Council will discuss the Draft Broadband Action Plan at its November and December meetings.

**2. Title: SCAG Connect SoCal Plan**

Source: SCAG

Reference: <https://www.connectsocal.org/Pages/Connect-SoCal-Final-Plan.aspx>

Date: September 2020

*Attachment "A9"*

**Abstract:** Connect SoCal is a long-range visioning plan that builds upon and expands land use and transportation strategies established over several planning cycles to increase mobility options and achieve a more sustainable growth pattern. It charts a path toward a more mobile, sustainable, and prosperous region by making connections between transportation networks, between planning strategies and between the people whose collaboration can improve the quality of life for Southern Californians.

**3. Title: COVID-19 Transportation Impact in the SCAG Region Power Point and Report**

Source: SCAG

Reference: <https://www.connectsocal.org/Pages/Connect-SoCal-Final-Plan.aspx>

Date: September 2020

*Attachment "A10"*

**Abstract:** Vehicle miles traveled (VMT) on the region's arterial and highway network declined by nearly 80 percent in early April (using January 2020 as benchmark). VMT on the freeway network alone dropped by nearly 50 percent in early April over prior year. VMT began increasing again by mid-April. Total VMT is now nearing pre-pandemic levels.

**4. Title: Caltrans Greenhouse Gas Emissions and Mitigation Report**

Source: Caltrans

Reference: <https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/office-of-smart-mobility-and-climate-change/ghg-emissions-and-mitigation-report-final-august-2-2020-revision9-9-2020-a11y.pdf>

Date: August 2020

*Attachment* "A11"

**Abstract:** Historically, Caltrans focused its investments towards expanding the highway system to meet the demands of a growing population and economy and increased vehicle ownership and use. Today, expansion of the highway system has slowed, and the focus has shifted to managing the system effectively. This paradigm calls for evaluating new highway projects in terms of their ability to move people rather than vehicles, and to support a multimodal system that offers travel choices and better reliability.

The shift in focus away from maximizing vehicle throughput is also reflected in the passage of SB 743, which calls for replacing vehicle delay and level of service as the mechanism for evaluating transportation impacts under the California Environmental Quality Act (CEQA). Because it plans, builds, and operates most of the state's highway system, Caltrans has some unique opportunities to influence on-road vehicle travel in the state.

These opportunities include the provision of multimodal transportation systems that provide viable alternatives to vehicle travel, roadway pricing and other approaches to manage demand, and avoiding new highway capacity additions that result in substantial induced vehicle travel, leading to higher VMT and GHG emissions. The phenomenon of induced vehicle travel is widely accepted and well documented, and it can often lead to an increase in VMT and GHG emissions when highway capacity is expanded, including through the addition of HOV and express lanes.

**5. Title: Technical Advisory on Evaluating Transportation Impacts in CEQA**

Source: California Governor's Office Planning and Research (OPR)

Reference: [https://opr.ca.gov/docs/20190122-743\\_Technical\\_Advisory.pdf](https://opr.ca.gov/docs/20190122-743_Technical_Advisory.pdf)

Date: December 2018

*Attachment:* "A12"

**Abstract:** This technical advisory serves professional planners, land use officials, and CEQA practitioners. OPR issues technical assistance on issues that broadly affect the practice of land use planning and the California Environmental Quality Act (CEQA). The purpose of this document is to provide advice and recommendations, which agencies and other entities may use at their discretion. This document does not alter lead agency discretion in preparing environmental documents subject to CEQA.

**6. Title: Future of Mobility White Paper – CA Transportation Plan 2050**

Source: Caltrans

Reference: [https://ctp2050.com/wp-content/uploads/2020/10/CTP2050\\_Future\\_of\\_Mobility\\_White\\_Paper.pdf](https://ctp2050.com/wp-content/uploads/2020/10/CTP2050_Future_of_Mobility_White_Paper.pdf)

<https://tsrc.berkeley.edu/future-mobility-white-paper>

Date: January 2018

Attachment "A13"

**Abstract:** Transportation is undergoing a transformative revolution. Trending technologies and competitive markets re accelerating innovation in the field at faster rates than previously predicted. As such, California is required to renew its long-range comprehensive transportations plan. Key broadband related points:

- Increasingly, as transportation networks rely on wireless services and technologies, equitable mobility will depend on access to broadband Internet, smartphones, and bank accounts.
- Information and Communications Technology (ICT), including current U.S. technology penetration levels and ICT's role in enabling shared mobility and automated vehicles.
- The use of Global Positioning System (GPS) applications, especially on mobile devices with access to mobile Internet services, has revolutionized real-time and on-demand transportation services. And the number of Internet-connected vehicles is expected to grow rapidly.

**7. Title: Cutting Greenhouse Emission Is Only the Beginning: A Literature Review of the Co-Benefits of Reducing Vehicle Miles Traveled.**

Source: National Center for Sustainable Transportation/UC Davis

Reference: <https://escholarship.org/content/qt4h5494vr/qt4h5494vr.pdf>

Date: March 2017

Attachment: "A14"

**Abstract:** Traditional evaluation of the transportation system focuses on automobile traffic flow and congestion reduction. However, this paradigm is shifting. In an effort to combat global warming and reduce greenhouse gas (GHG) emissions, a number of cities, regions, and states across the United States have begun to deemphasize vehicle delay metrics such as automobile Level of Service (LOS). In their place, policymakers are considering alternative transportation impact metrics that more closely approximate the true environmental impacts of driving. One metric increasingly coming into use is the total amount of driving or VMT.

**8. Title: A Framework for Projecting the Potential Statewide Vehicle Miles Traveled (VMT) Reduction from State-Level Strategies in California**

Source: National Center for Sustainable Transportation/UC Davis

Reference: <https://escholarship.org/uc/item/2z48105j>

Date: March 2017

Attachment: "A15"

**Abstract:** This white paper examines the evidence available and assumptions needed for projecting statewide Vehicle Miles Traveled (VMT) reductions for each category of strategies. The goal is to provide a framework for projecting the magnitude of reductions that the state might expect for the different strategies. This framework helps to illuminate the sequence of events that would produce VMT reductions and highlights important gaps in knowledge that increases the uncertainty of the projections. The evidence justifies state action on these strategies: the available evidence shows that the strategies considered in this paper are likely to reduce VMT if promoted by state policy.

**9. Title: Driving Change – Reducing Vehicle Miles Traveled in California**

Source: Public Policy Institute of California (PPIC)

Reference: <https://www.ppic.org/publication/driving-change-reducing-vehicle-miles-traveled-in-california/>

Date: February 17, 2011

Attachment: "A16"

**Abstract:** Senate Bill (SB) 375, adopted in 2008, calls on regional transportation planning agencies and local governments to develop strategies for reducing GHG from passenger vehicles by reducing per capita VMT. Specific strategies, traditionally used to reduce traffic congestion and improve air quality, are to be employed to help reduce emissions.

## **Section 3 - National Data, Articles, Research**

### **1. Title: Broadband Models for Unserved and Underserved Communities**

Source: US Ignite

Reference: [https://www.us-ignite.org/wp-content/uploads/2020/07/USIgnite\\_Altman-Solon\\_Whitepaper-on-Broadband-Models\\_FINAL\\_7-9-2020.pdf](https://www.us-ignite.org/wp-content/uploads/2020/07/USIgnite_Altman-Solon_Whitepaper-on-Broadband-Models_FINAL_7-9-2020.pdf)

Date: July 9, 2020

*Attachment:* "A17"

**Abstract:** A white paper from [US Ignite](#) and [Altman Solon](#), explores the various models that cities can employ to connect their residents and businesses.

The paper covers five approaches that communities can take to improve Internet access, from full private broadband to full municipal broadband with varying types of public-private partnerships in between. Of all the well-connected American cities (where 50% of residents have access to 250 Megabits per second broadband speeds), the paper finds that 8% are served a form of municipal network.

To help local government officials figure out which model is right for their community, US Ignite and Altman Solon include a number of helpful charts, decision trees, and other considerations.

### **2. Title: Innovate Ohio DOT Digital Infrastructure and Access Strategy**

Source: Ohio Department of Transportation (Ohio DOT)

Reference: <http://www.dot.state.oh.us/Divisions/ContractAdmin/Contracts/PurchDocs/601-20a.pdf>

Date: September 25, 2019

*Attachment:* "A18"

**Abstract:** Innovate Ohio, in partnership with the Ohio Department of Transportation, issued a 16-page broadband access report on September 24 – a report commissioned at the behest of Ohio Governor Mike DeWine (R) in June – to provide a strategic plan for “improving and expanding broadband” across the state. The key finding of that report is that the rights-of-way along state-owned interstate highways “hold considerable value” that can be “leveraged in order to expand broadband.”

**3. Title: Understanding Travel Behavior**

Source: Federal Highway Administration (FHWA)

Reference: [https://www.fhwa.dot.gov/policy/otps/travel\\_behavior\\_research\\_scan.pdf](https://www.fhwa.dot.gov/policy/otps/travel_behavior_research_scan.pdf)

Date: March 2016

*Attachment: "A19"*

**Abstract:** Travel behavior is undergoing a period of significant change in the United States, and this change is beginning to reveal itself in long-standing measures of transportation. While the United States is still heavily dependent on the personal automobile for mobility, changes in technology, demographics, economics, and attitudes are transforming how mobility is attained. At the same time, advances in information technology are opening new ways for transportation activity to be measured more comprehensively. These transformative trends are reshaping how we think about transportation policy, operations, and planning.

This report presents a research scan of the state of knowledge in transportation to enhance understanding of travel behavior and various influencing factors on future travel. It provides an overview of the current state of travel behavior as measured today, as well as background on the current understanding from literature in travel behavior research. It also explores what is known about the socio-demographic portrait of Americans and how demographics influence travel behavior.

The report discusses emerging information technology and its impact on new mobility options. It also presents emerging methodologies and new forms of data that show significant potential to improve the resolution and comprehensiveness of travel behavior information. Finally, it identifies gaps in understanding that could be addressed in the future with appropriate applications of emerging data and technological resources.

**4. Title: Addressing Effects of Travel Reduction and Efficient Driving on Transportation Energy Use and Emissions.**

Source: U.S. Dept of Energy

Reference: <https://www.nrel.gov/docs/fy13osti/55635.pdf>

Date: March 2013

*Attachment: "A20"*

**Abstract:** Numerous transportation strategies are directed at reducing energy use and greenhouse gas (GHG) emission by changing the behavior of individual drivers or travelers. These behavioral changes may have the effect of reducing travel, shifting travel to more efficient modes, or improving the efficiency of existing travel. This report reviews and summarizes the literature on relationships between these strategies and transportation-related energy use and GHG emissions. This report summarizes historical findings documented in existing literature, as well as recent efforts that had not previously been reported, and highlights and interprets that literature for information most relevant to an energy perspective.

**5. Title:      Broadband Services: Economic and Environmental Benefits**

Source:        The American Consumer Institute

Reference:     <https://www.theamericanconsumer.org/2007/10/broadband-services-economic-and-environmental-benefits/>

Date:          October 31, 2007

*Attachment:*   “A21”

**Abstract:**     The purpose of this paper is to investigate the use of advanced technologies, including broadband services and telecommunications technologies, and their specific effects on energy use and the environment. This study adds to the discussion of how to reduce greenhouse gas emissions by documenting the reductions that can be realized by the widespread delivery of broadband services in the U.S. Current carbon dioxide emissions in the U.S. hover around 7.9 billion tons and are growing.[2] This study finds that wide adoption and use of broadband applications can achieve a net reduction of 1 billion tons of greenhouse gas over 10 years, which, if converted into energy saved, would constitute 11% of annual U.S. oil imports.

## **Section 4 – Industry Centric Information**

### **Telecommuting**

1. **Title:** (Re)Awakening to the benefits and climate impacts of telework during COVID-19

**Source:** UC San Diego, A Capstone Project

**Reference:**

[https://escholarship.org/content/qt7nf8k2q6/qt7nf8k2q6\\_noSplash\\_30708910e19831fd3d84c41a96ad5050.pdf](https://escholarship.org/content/qt7nf8k2q6/qt7nf8k2q6_noSplash_30708910e19831fd3d84c41a96ad5050.pdf)

**Date:** June 12, 2020

*Attachment* “A22”

**Abstract:** During the COVID-19 pandemic, millions of employees have shifted to working from home, either full-time or part-time. Prolonged quarantine measures put in place in response to the current global health crisis have forced businesses, both essential and non-essential, to adapt to their workforces stuck at home and no longer able to come into the office.

In order to keep their workforce employed, engaged and productive in a prolonged quarantine environment, employers have adapted by enabling large portions of their previous in-office workforce to work remotely from home. The history of working from home, also commonly referred to as telework or telecommuting, is one of mixed success and mixed support; however, when left with few alternatives, businesses are embracing the potentials of a remote workforce.

The increase in employees working from home has directly impacted short-term environmental air quality and reduced greenhouse gas (GHG) contributions due to a reduction in employee transportation requirements. In short, people are driving less, and the environment is benefiting.

Additional potential benefits from the increase in employees working outside the office include reductions in office electricity consumption, water consumption, and waste generation, as well as cost savings due to potential reductions in total office footprint requirements.

This capstone explores the overall environmental impacts, long-term climate implications, return on investment and success strategies for an increasingly remote workforce.

**2. Title: The COVID-19 Pandemic and the Changing Nature of Work Lose Your Job, Show Up to Work, or Telecommute?**

Source: RAND

Reference: [https://www.rand.org/pubs/research\\_reports/RRA308-4.html](https://www.rand.org/pubs/research_reports/RRA308-4.html)

Date: June 2020

*Attachment:* "A23"

**Abstract:** Stay-at-home orders save lives, but the extent to which they threaten livelihoods depends on the nature of one's work. How much has the ability to work from home mitigated the economic effects of the coronavirus disease 2019 (COVID-19) pandemic? In the first week of May 2020, RAND researchers conducted a survey of more than 2,000 individuals in the nationally representative RAND American Life Panel (ALP) to find out how their lives changed as a result of the pandemic. The report focuses on 1,277 individuals who were working for pay or profit in February 2020.

**3. Title: US COVID-19 mitigation efforts resulting in significant decline in traffic, emissions, and fuel-tax revenues**

Source: UC Davis, Road Ecology Center

Reference: <https://www.greencarcongress.com/2020/05/20200502-ucd.html>

Date: May 2, 2020

*Attachment:* "A24"

**Abstract:** Findings were that total US vehicle miles traveled (VMT) at the county and state level declined by 61% to 90% following the various government stay-at-home orders in response to the COVID-19 pandemic. Using data from Street Light, the researchers estimated changes in daily VMT across the US before and after government shelter-in-place guidance. The difference amounted to a drop from 103 billion miles in early March to 29 billion miles during the second week of April. All states reduced their vehicle miles traveled by at least 60%.

The authors used the VMT data to calculate that emissions of US greenhouse gas (GHG) emissions were reduced by 4% in total and by 13% from transportation in the almost 8 weeks since many stay-at-home orders went into effect.

**4. Title: Caltrans Sustainability Director: What Benefits Telecommuting may bring are still very much unknown**

Source: California Streetsblog

Reference: <https://cal.streetsblog.org/2020/08/04/what-benefits-telecommuting-may-bring-are-still-very-much-unknown/>

Date: August 4, 2020

Attachment: "A25"

**Abstract:** Article quotes Ellen Greenberg who recently took the job of Sustainability Director for Caltrans, She is quoted as saying within Caltrans, there's been an amazing shift, and that before the pandemic, despite some encouragement, telecommuting had very low adoption rates among the almost 21,000 people who work for the Caltrans. "But we found that we could do this," and at one point almost 90% of Caltrans office employees – which are maybe two-thirds of their work force – were working from home.

In addition, Sam Speroni, a UCLA graduate student who is preparing a research review for Caltrans, has found little consistency among pre-COVID-19 research results. These have generally been based on limited data samples and usually focused on specific questions such as environmental benefits, worker productivity, or potential technologies. "I have been surprised at a number of things I've been learning," said Speroni. "One is how incoherent and inconsistent existing research is. You could find a study that comes to one conclusion, and a different one that says the opposite."

"New trip making habits are likely to emerge," said Greenberg, "so telework does not 'zero out' VMT." In general, people have a kind of mental travel budget – how much time they are willing to, or want to, spend traveling. For many years researchers who have studied this have pinned the "ideal commute" at about twenty minutes. That goes for car, transit, bike, or walking commutes – people generally seem to like about a twenty minute distance between home and work.

Also, "people are accustomed to using that time for driving," said Greenberg, and although not having to drive in rush hour traffic could be a huge stress reducer, it does not mean people do not want to drive at all. In fact, they may shift their driving to a different time. That has implications for traffic congestion, if it means lower peak-hour traffic volumes (and potentially higher off-peak traffic), which is not a bad outcome. But it means little for reducing VMT.

**5. Title: The “GO-Virtual Initiative”: Using Flexible Workplace Practices to Reduce Traffic Congestion, Increase Economic Development, and Provide More Access to Affordable Housing Choices in the South Bay Region of Los Angeles County**

Source: San Jose State University (SJSU)/Mineta Transportation Institute

Reference: [https://transweb.sjsu.edu/sites/default/files/1860-Prager-Flexible-Workplaces-South-Bay\\_0.pdf](https://transweb.sjsu.edu/sites/default/files/1860-Prager-Flexible-Workplaces-South-Bay_0.pdf)

Date: August 2019

Attachment: “A26”

**Abstract:** The “GO-Virtual Initiative”: Using Flexible Workplace Practices to Reduce Traffic Congestion, Increase Economic Development, and Provide More Access to Affordable Housing Choices in the South Bay Region of Los Angeles County Flexible workplace practices (FWPs) such as telework, flexible scheduling, and the use of co-working spaces have the potential to address problems of congestion, pollution, and lack of housing affordability in the South Bay region of Los Angeles County.

However, trends in the adoption of FWPs—especially of working from home—across the region do not appear to be increasing as much as expected, despite advances in technology, changing worker demands, and evolving workplace cultures. In the South Bay and Los Angeles, commute times and the proportion of residents driving alone to work have increased as the economy has grown. As alternatives to driving alone to work, employees appear to face the choices of using public transit if more accessible, or carpooling if the journey is longer; however, both of these modes of transportation have declined in usage in recent years.

Instead, the only alternative to driving alone that has increased in frequency in the South Bay and Los Angeles County in recent years is working from home, which is most likely concentrated among residents in locations with higher education levels or occupations that are more appropriate. Prior literature has provided numerous insights here, finding that conditions are region-specific, and that occupational and industry constraints combine with manager resistance and employee concerns over work-life balance to limit the expansion of FWP. The authors of this study contribute to the literature by focusing on the obstacles to expansion of FWP among South Bay organizations, as well as by comparing the projected impacts of potential government interventions in this space.

The authors explore these issues with methods innovative to the field, including a combination of surveys and expert elicitation focus groups that includes numerous types of FWP, especially the inclusion of co-working spaces as a strategy. Participants in the survey and focus groups perceived the major obstacles to expansion to be a combination of managerial and executive resistance, alongside occupational constraints. Participants perceived government subsidies and incentives as both having a good combination of costs and impacts, possibly to be used to encourage the use of private co-working spaces, which offer a market solution that balances the benefits of traditional at-home telework and collaborative workplaces. Telework remains a cost-effective approach to reducing commute-related emissions, and hence more aggressive programs, such as telework facilities exchanges, expansion of South Coast Air Quality Management District mandates, and incentives for workforce training and program implementation may be needed to achieve broader climate action and local pollution targets.

**6. Title: 5 Stats about Telecommuting’s Environmental Impact**

Source: Flexjobs

Reference: <https://www.flexjobs.com/blog/post/telecommuting-sustainability-how-telecommuting-is-a-green-job/>

Date: April 16, 2019

Attachment: “A27”

**Abstract:** Remote work is looked to for solving problems with work-life balance, employee retention, and productivity. But is it also a way to reduce negative impacts on the environment, and to create a more sustainable way to work?

These five stats about telecommuting’s environmental impact say it is.

1. Commuting contributes greatly to the second-largest sources of United States GHG.
2. Company offices are part of the fourth-largest contributor to GHG.
3. Remote workers today have the same impact on air quality as planting a forest of trees.
4. Remote work helps people avoid the personal health risks from environmental pollution.
5. Remote work positively impacts environment *and* bottom line of companies that allow it.

**7. Title: Employer Transportation Demand Management (TDM) Programs**

Source: Oregon Department of Transportation

Reference: <https://www.oregon.gov/ODOT/Planning/Documents/Mosaic-Employer-based-TDM-Programs.pdf>

Date: 2010

Attachment: “A28”

**Abstract:** Employer TDM programs help meet local goals for vehicle miles traveled (VMT) and congestion reduction, environmental stewardship, and quality of life.

An 82-program sample of employer TDM programs found the average empirically based estimate of site-specific vehicle trip reduction impacts for employer support programs alone is 4% to 5% vehicle trip reduction (VTR). Those TDM programs that provided transportation services were considerably more effective as a group in reducing vehicle trips (22% program VTR).

**8. Title: Does Telecommuting Reduce Vehicle Miles Traveled? An Aggregate Time Series Analysis for the U.S.**

Source: UC Davis

Reference: <https://escholarship.org/uc/item/74t9663f>

Date: July 2004

*Attachment:* "A29"

**Abstract:** This study examines the impact of telecommuting on passenger vehicle-miles traveled (VMT) through a multivariate time series analysis of aggregate nationwide data spanning 1966-1999 for all variables except telecommuting, and 1988-1998 for telecommuting. The analysis was conducted in two stages. In the first stage, VMT (1966-1999) was modeled as a function of conventional variables representing economic activity, transportation price, transportation supply and socio-demographics. In the second stage, the residuals of the first stage (1988-1998) were modeled as a function of the number of telecommuters.

We also assessed the change in annual VMT per telecommuter as well as VMT per telecommuting occasion, for 1998. The models suggest that telecommuting reduces VMT, with 94% confidence. Together with independent external evidence, the results suggest a reduction in annual VMT on the order of 0.8% or less.

Even with impacts that small, when informally compared to similar reductions in VMT due to public transit ridership, telecommuting appears to be far more cost-effective in terms of public sector expenditures.

**9. Title: Review of the Literature on Telecommuting and Its Implications for Vehicle Travel and Emissions**

Source: Resources for the Future

Reference: <https://media.rff.org/documents/RFF-DP-04-44.pdf>

Date: December 2004

*Attachment:* "A30"

**Abstract:** A review of 20 empirical studies of telecommuting, all of which focus on the trip reduction perspective. The studies include earlier ones with smaller datasets, such as some pilot studies of individual employers, and more recent studies based on broader surveys of both telecommuters and non-telecommuters. Focus is on the results of the studies with respect to participation and frequency of telecommuting, the effects on vehicle-miles-traveled (VMT) and trips, and in some cases, the impacts on emissions and air quality.

Most studies of VMT and trip reductions from telecommuting show that telecommuters significantly reduce both daily trips and VMT. Not only does commute VMT fall, but non-commute VMT appears to fall in some cases as well. The studies of VMT, however, tend to focus on the reductions for individual employees who choose to telecommute.

Although an individual telecommuter may experience a sharp reduction in VMT, total benefits depend on how many people are telecommuting, how often they are doing so, and the duration of telecommuting. More research is needed with larger and more broadly based datasets across employers that include both individual employee characteristics and employer and job characteristics. This would allow a better analysis of telecommuting choice and frequency as well as more reliable estimates of VMT and emissions impacts.

**10. Title: Employer Transportation Demand Management (TDM) Programs**

Source: Journal of the Air & Waste Management Association

Reference: <https://www.oregon.gov/ODOT/Planning/Documents/Mosaic-Employer-based-TDM-Programs.pdf>

Date: 1996

*Attachment:* "A31"

**Abstract:** Analysis of the travel diary data and the emissions model output supports the hypothesis that telecommuting has beneficial transportation and air quality impacts. The most important results are that telecommuting decreases the number of daily trips (by 30%), the vehicle-miles traveled (VMT) (by 63%), and the number of cold starts (by 44%), especially those taking place in early morning. These reductions are shown to have a large effect on daily emissions, with a 50% to 60% decrease in pollutants generated by a telecommuter's personal vehicle use on a telecommuting day.

These net savings are almost entirely due to the elimination of commute trips, as non-commute trips increased by 0.33 trips per person-day (9% of the total trips), and the non-commute VMT increased by 2.2 miles.

Telecommuting is one of many Transportation Demand Management (TDM) strategies being considered by policy makers to reduce congestion levels and improve air quality. As one of the first studies to directly measure the impacts of telecommuting on vehicle emissions levels, this research contributes to a new body of data on the air quality impacts of telecommuting.

The findings support the hypothesis that telecommuting benefits both air quality and congestion. The methodology presented may be applied to other TDMs to analyze the comparative impacts of each strategy. This information will help policy makers identify the most effective congestion reduction and air quality improvement approaches. As telecommuting adoption moves into the mainstream, its net impacts are still expected to be beneficial—a reduction in VMT and in emissions.

## **Telehealth**

### **11. Title: Virtual Intensive Outpatient Outcomes: Preliminary Findings**

Source: Hazelden Betty Ford Foundation/Butler Center for Research

Reference: <https://www.hazeldenbettyford.org/education/bcr/addiction-research/virtual-intensive-outpatient-outcomes>

Date: September 2020

*Attachment* “A32”

**Abstract:** Hazelden Betty Ford had piloted a telehealth addiction treatment prior to the COVID-19 pandemic with a one year timeline for implementation. Due to the virus, their timeline accelerated, and they pivoted the majority of their intensive outpatient (IOP) services from in-person to virtual at the beginning of the pandemic. In order to better understand what works in virtual services and for whom, they undertook an evaluation of the virtual IOP services. Overall, the preliminary findings indicate that virtual IOP services have been as effective as in-person IOP treatment.

### **12. Title: Broadband Internet Access Is a Social Determinant of Health**

Source: American Journal of Public Health (AJPH)

Reference: <https://mobroadband.org/wp-content/uploads/sites/44/2020/07/Broadband-Access-and-Social-Determinants-of-Health.pdf>

Date: August 2020

*Attachment* “A33”

**Abstract:** Now, more than ever, broadband Internet access (BIA) must be recognized as a social determinant of health. Disparities in access should be treated as a public health issue because they affect “the health of people and communities where they live, learn, work and play.” The COVID-19 pandemic demonstrates that lack of BIA influences each of the six social determinant of health domains defined by the American Medical Association. It also affects an additional domain, which is particularly pertinent during a pandemic—access to credible information. Reduced BIA, particularly during this pandemic, has the potential to exacerbate this country’s existing health disparities because it disproportionately affects those who are already vulnerable. Indeed, those who are older, are racial/ ethnic minorities, have lower incomes, are less educated, or live in rural areas may experience worse health outcomes under normal circumstances and are even less able to access health enhancing resources during social-distancing orders.

Without BIA, patients cannot fully use telehealth in all its forms: asynchronous messaging via patient portals, remote monitoring devices such as blood pressure monitors, or synchronous video connections to consult with a physician. Telephone calls are an alternative to video visits, but because they permit only audio communication, they limit possible interactions between patients and health care professionals. Variation in BIA reliability also presents challenges to technical visit quality. Some patients, even those with BIA, have declined to use these technologies because of difficulties with digital literacy or privacy concerns.

**13. Title: Eco-Friendly Benefits of Telehealth Visits**

Source: BioFriendlyPlanet.com

Reference: <https://biofriendlyplanet.com/green-ideas/eco-friendly/eco-friendly-benefits-of-telehealth-visits/>

Date: July 21, 2020

*Attachment* "A34"

**Abstract:** The current COVID-19 pandemic has forced everyone to change their usual routines, and the medical industry is no exception. Patients and providers have created and adapted to new systems so medical care can continue as safely as possible. One of those new systems is telehealth.

Patients can now see their providers over virtual appointments either with a video call or a typical voice call. Telehealth is a fantastic option, especially while going out and being in close proximity to other people is not advised, but other benefits to telehealth might be less obvious. This new technology is providing an excellent service, but it is also helping our planet.

**14. Title: Impact of the digital divide in the age of COVID-19**

Source: Journal of the American Medical Informatics Association

Reference: <https://academic.oup.com/jamia/article/27/7/1147/5826352>

Date: April 28, 2020

*Attachment* "A35"

**Abstract:** Due to COVID-19, by early March 2020, the need for an immediate adaptation of our clinical care delivery system was clear. Within a week, clinics had transitioned from in-person visits to telehealth involving telephone or video. Screening processes for COVID-19 were quickly made available on a free online platform through which at-risk individuals were directed to drive-through centers for in-person testing.

The problem was that many of our patients could not access the online system. In our roles as directors of free clinics, we have become intimately involved with the complexity inherent to the care of underserved populations, including how seemingly innovative programs can sometimes not meet their intended goals.

As our main hospital system was transitioning to telehealth-based care, we were rapidly trying to put measures into place at our free clinics that would ensure that our patients did not lose their access to health care. It quickly became apparent that the newly built telehealth systems created additional access hurdles for our free clinic patients, and we would soon learn that pockets existed within the larger population that were impacted by these barriers. As is often the case, those whose access was impeded were the most vulnerable to poor health outcomes related to COVID-19.

This was not unique to our community, and in fact it was repeated throughout the country when other hospital systems transitioned to telehealth as a sensible and efficient way to deliver health

care while implementing social distancing to combat the spread of COVID-19. Simultaneously, the diminished accessibility to technology based on various societal and social factors, sometimes referred to as the digital gap or digital divide, was being exposed at a critical time in a public health crisis. Frighteningly, there were no measures at the ready to address it.

Regarding the patient populations seen in our free clinics, our first concern was physical access to Internet services, defined largely by built environment factors. Our homeless population lacked reliable Internet access outside of the technology center at the clinic. About a third of those served at the rural CARES clinic site do not have Internet access in their homes. This is not unlike the Federal Communications Commission report in 2018 showing that within the United States, 31% of rural households still lack access to broadband Internet.

A combination of technology and in-person services has been found to help address some of this disparity, and in our case, a direct combination of the 2 types of service proved necessary.

## **Distance Learning**

**15. Title: School is starting – and the broadband gap will be a massive problem**

Source: CNET

Reference: <https://www.cnet.com/news/back-to-school-season-is-here-but-the-homework-gap-is-still-a-massive-problem/>

Date: August 26, 2020

*Attachment:* “A36”

**Abstract:** The digital divide means millions of American children do not have broadband connections at home, even as their schools hold virtual classes.

This shift online has shined a light on a long-standing problem that has only gotten more severe in the age of the coronavirus: the so-called homework gap. The country has wrestled with a digital divide for decades, but the pandemic has exposed some of the most vulnerable populations: Students from poorer urban areas and remote rural districts, with minorities disproportionately hurt by lack of access to connectivity.

Schools are being forced to tackle the digital divide problem in their districts, becoming experts in complex broadband options seemingly overnight. That is on top of grappling with how to make sure their low-income students are fed and healthy, and navigating archaic regulations controlling how they receive funding. Various schools around the country have relied on emergency relief funds from the CARES Act to purchase devices and hotspots for students, while others have begged the public and businesses for help funding equipment.

This article outlines the hardships that school districts are facing across all of California, and nationally.

**16. Title: Distance Learning is Good for the Environment: Savings in GHG Emissions**

Source: Online Journal of Distance Learning Administration/University of West Georgia

Reference: [https://www.westga.edu/~distance/ojdla/winter144/campbell\\_campell144.html](https://www.westga.edu/~distance/ojdla/winter144/campbell_campell144.html)

Date: 2011

*Attachment:* "A37"

**Abstract:** Distance learning is associated with a variety of benefits such as reduced use of campus facilities, increased accessibility, and control of disease transmission. In this study, we explore an additional benefit: mitigation of anthropogenic carbon dioxide emissions contributing to global climate change.

A survey was presented to 500 students enrolled in online courses on three college campuses. Students who commuted by personal car were asked to estimate whether taking the course online resulted in fewer driving trips to campus.

The environmental consequences of the estimated reduction in commute trips were assessed by calculating the CO<sub>2</sub> emissions savings associated with reduced consumption of gasoline.

The results indicate that offering a lower-division class of 100 students with an online format leads to reduced CO<sub>2</sub> emissions of 5-10 tons per semester, and knowledge of such an environmental benefit leads to enhanced student satisfaction with distance learning.

### **Broadband – Internet of Things**

**17. Title: Greening Internet of Things for Smart Everythings with A Green Environment Life: A Survey and Future Prospects**

Source: Cornell University

Reference: <https://arxiv.org/abs/1805.00844>

Date: May 2, 2018

*Attachment:* "A38"

**Abstract:** Tremendous technology development in the field of Internet of Things (IoT) has changed the way we work and live. Although the numerous advantages of IoT are enriching our society, it should be reminded that the IoT also consumes energy, embraces toxic pollution and E-waste. These place new stress on the environments and smart world. In order to increase the benefits and reduce the harm of IoT, there is an increasing desire to move toward green IoT.

Green IoT is seen as the future of IoT that is environmentally friendly. To achieve that, it is necessary to put a lot of measures to reduce carbon footprint, conserve fewer resources, and promote efficient techniques for energy usage. It is the reason for moving towards green IoT, where the machines, communications, sensors, clouds, and internet are alongside energy efficiency and reducing carbon emission. This paper presents a thorough survey of the current on-going research work and potential technologies of green IoT with an intention to provide some clues for future green IoT research.

## **Energy**

**18. Title:** Understanding the Impacts of COVID-19 on Global CO2 Emissions

Source: IEA Data, Global Energy Review

References: <https://www.iea.org/news/after-steep-drop-in-early-2020-global-carbon-dioxide-emissions-have-rebounded-strongly>

<https://www.iea.org/articles/global-energy-review-co2-emissions-in-2020>

Date: March 2, 2021

Attachment: "A39"

**Abstract:** After a steep drop in early 2020, Global Carbon Dioxide Emissions have rebounded strongly. Global energy-related CO2 emissions were 2% higher in December 2020 than in the same month a year earlier, according to IEA data, driven by economic recovery and a lack of clean energy policies.

The COVID-19 pandemic resulted in the largest-ever decline in global emissions. The COVID-19 pandemic and resulting economic crisis had an impact on almost every aspect of how energy is produced, supplied, and consumed around the world. The pandemic defined energy and emissions trends in 2020 – it drove down fossil fuel consumption for much of the year, whereas renewables and electric vehicles, two of the main building blocks of clean energy transitions, were largely immune. As primary energy demand dropped nearly 4% in 2020, global energy-related CO2 emissions fell by 5.8% according to the latest statistical data, the largest annual percentage decline since World War II. In absolute terms, the decline in emissions of almost 2 000 million tons of CO2 is without precedent in human history – broadly speaking, this is the equivalent of removing all of the European Union’s emissions from the global total. Demand for fossil fuels was hardest hit in 2020 – especially oil, which plunged 8.6%, and coal, which dropped by 4%. Oil’s annual decline was its largest ever, accounting for more than half of the drop in global emissions. Global emissions from oil use plummeted by well over 1 100 Mt CO2, down from around 11 400 Mt in 2019. The drop in road transport activity accounted for 50% of the decline in global oil demand, and the slump in the aviation sector for around 35%. Meanwhile, low-carbon fuels and technologies, in particular, solar PV and wind, reached their highest ever annual share of the global energy mix, increasing it by more than one percentage point to over 20%.

A common theme across all economies is the scale of the impact of the pandemic and lockdown measures on transport activity. The decline in CO2 emissions from oil use in the transport sector accounted for well over 50% of the total global drop in CO2 emissions in 2020, with restrictions on movement at local and international levels leading to a near 1 100 Mt drop in emissions from the sector, down almost 14% from 2019 levels. With various travel advisories and border restrictions, international aviation was the sector hardest hit in 2020, with global flight activity reaching a low in April 2020 of 70% below the level in the same month a year earlier. In contrast to pre-crisis levels, emissions from international aviation fell by almost 45% or 265 Mt CO2 across the year to a level last seen in 1999. This decline is equivalent to taking around 100 million conventional cars off the road.

## **Section 5 - Online Data Tools**

### **1. Title: Annual Miles Traveled**

Source: California Transportation Authority

Reference: <https://data.ca.gov/dataset/annual-miles-traveled>

**Abstract:** The Traffic Data Branch produces a Monthly Vehicle Miles of Travel (MVMT) report (often called the "Trend" report). This report estimates the number of vehicle miles that motorists traveled on California State Highways using a sampling of up to 20 traffic monitoring sites. Various roadway types are used to calculate VMT. The Monthly Vehicle Miles of Travel report for the California State Highway System gives the estimated vehicle miles driven and the resulting percentage changes in travel. The "Percentage of Change in Travel" charts are for driven over a three-year period.

### **2. Title: SCAG GIS Open Data Portal**

Source: California Transportation Authority

Reference: <https://gisdata-scag.opendata.arcgis.com/>

**Abstract:** SCAG collects and allows open access to a variety of data sets, including census, environment, land-use, transportation, planning, and modeling.

### **3. Title: Total & Average Daily per Capita Vehicle Miles Traveled in LA County**

Source: County of Los Angeles

Reference: <https://data.lacounty.gov/dataset/Total-and-Average-Daily-per-Capita-Vehicle-Miles-T/ba5z-qxm7>

**Abstract:** VMT Data in LA based on total and average daily vehicle traveled in LA, 2005 to 2017

### **4. Title: Special Report – Post COVID-19 Climate Impact Calculator**

Source: Street Light Data

Reference: <https://www.streetlightdata.com/special-report-post-covid-climate-impact-calculator/>

**Abstract:** Much has been made of the environmental-impact “silver lining” of the COVID-19 pandemic stay-home orders. Plummeting traffic volume has created lower carbon output and greenhouse gas emissions, with previously congested and smog-choked cities reporting cleaner air and more abundant wildlife.

Streetlight Data has been tracking reduced vehicle miles traveled (VMT) totals across the country since March. And as the Brookings Institution recently found when analyzing our data, VMT has not been this low since 1998.