**Technical assessment for**

**Walkable Cities**

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# Acronyms and Symbols Used

* **E-Scooter** – Electric kick scooter
* **ICE** – Internal Combustion Engine
* **ITDP** – Institute for Transportation and Development Policy
* **ITF** – International Transport Forum
* **PDS** – Project Drawdown Scenario
* **PKM** – Passenger-kilometer (1 passenger moved 1 kilometer)
* **REF** – Reference Scenario (of Project Drawdown)
* **TAM** – Total Addressable Market
* **GHG** – Greenhouse Gas
* **GT** – Gigatons
* **ICT** – Information and Communication Technology
* **IEA** – International Energy Agency

# Executive Summary

The act of walking as a sustainable form of mobility is a relatively new concept. Walking is the neglected transport mode, which is the simplest, most sustainable and cheapest medium of locomotion. Currently we walk 1,334 billion kilometers, equivalent to around 200km (130 miles) per person per year or barely 7 minutes per day. We drive 7 times as much as we walk. Walkability is mostly associated with leisure and recreation in the majority of urban projects around the world; however, the notion of walking as a competitor in the area of sustainable urban mobility is increasing especially post covid.

The specialized literature that studies travel choices in cities across the world uses regularly an agreement of seven variables with words beginning with D to measure walkability: 1) Density: Computes an overall activity density per area unit. 2) Diversity: It measures the number of diverse land uses in a given area, 3) Design: It includes street network characteristics within an area. 4) Destination accessibility: It measures effortless access to trip attractions such as employment, which is measured by distance or time, 5) Distance to transit: This factor studies how far an area is from the nearest public transport stop or station, 6) Demand management: This variable studies parking supply (cars, bicycles, buses) and its cost, and 7) Demographics: While not part of the built environment, demographics is the seventh D because it influences patterns in travel choices based on the age of users.

Population density is one of the variables chosen to measure walkability on a global scale. It is a widely used metric globally for making a city walkable. The methodology uses annual variations of population density in cities from 2014 to 2050 in order to create one of the projections for the future.

The Reduction and Replacement Solutions (RRS) model was used to evaluate the impacts of increased walkable cities around the world from 2014 to 2060 with primary results being reported here for the period 2020-2050. The current adoption of walkable cities was found to be about 4.5% of the total addressable market (TAM) globally.

The model is based on three main sources for walking statistics: International Transportation Forum Transport Outlook (ITF), the Institute for Transportation and Development Policy’s (ITDP) Global High-Shift Cycling report and previously published methodology by Project Drawdown utilizing urban population density. These three sources yield an estimated current adoption of 1,334 billion passenger-kilometers (pkm) of walkable cities use around the world. The model then projects walkable city pkm to increase to over 3,409 billion pkm by 2050.

The results of the analysis show that walkable cities represent a net financial benefit for the individuals who use it, as well as a net greenhouse gas (GHG) benefit for the globe. Given the projections described above and the emissions factors of the conventional alternative, the predicted increase in the use of walkable cities over current levels could prevent the release of 4.47 cumulative gigatons of carbon dioxide-equivalents and save consumers $7,048 billion over the period studied.

# Literature Review

Globally, transport of people and goods produces 9.5 gigatons (Gt) of carbon dioxide-equivalent (CO2-eq) greenhouse gas emissions annually, equivalent to 23 percent of *energy-related* emissions, or 14 percent of *all* emissions (IEA, 2018)[[1]](#footnote-1). In individual countries, where transport is based on high-emission modes, transport can account for much higher shares. The sources of those 9.5 Gt are chiefly from cars and light trucks, which account for over 50% of all transport emissions. Heavy freight trucks and buses contribute an additional 26% and air transport and shipping each generate 10% of global transport emissions (IEA, 2018). Growth rates in emissions for some subsectors like air transport and shipping are very high, so the Transport Sector requires special focus to keep emissions from ballooning out of control, as some projections indicate. Transport, however, is a service derived from economic growth. Research shows that wealthier people travel more, locally and internationally, and demand more goods and services. So, as a country develops economically, movement of people and goods increases. Solutions generally can be classified using the “*avoid-shift-improve*” framework: *avoid* travel altogether, *shift* travel to low-carbon modes or *improve* modes to generate lower emissions.

## State of Walkable Cities

The act of walking as a sustainable form of mobility is a relatively new concept. As Dan Burden mentions, “walkability is a word that did not exist just 20 years ago; we made walking so unnatural that we had to create a word to pronounce what we were missing” (ARUP, 2016). A report from the International Transport Forum (ITF) has dubbed walking the neglected transport mode, which is the simplest, most sustainable and cheapest means of locomotion. (OECD/ITF, 2011). Walkability is associated mainly with leisure and recreation in the majority of urban projects around the world; however, the notion of walking as a mode choice in the area of sustainable urban mobility is increasing.

The evolution of human mobility originates with our feet. The historic configuration of cities has been dictated by the human capacity to walk. The Inca and Aztec civilizations sustained large empires for centuries on foot. In France, mechanical mobility equaled walking only during the 1920s (Ausubel et al., 1998). Pedestrian cities usually have a diameter no greater than 5 km (Marchetti, 1994). This is the average hourly speed of a healthy pedestrian (alternatively, 5 km/hour for males and 4 km/hour for females (Wigan, 1994)). When cars were introduced that traveled 6-7 times faster than a pedestrian, cities increased their connected area 6-7 times in linear terms. Walking 5km/hour for 1 hour provides a radius of 2.5 km and an area of 20km2. These are the distances that define a village globally. Even today the area that can be crossed in one hour with dominant modes of transport functionally defines a city (Marchetti, 1994).

The term ‘pedestrian’ often includes anyone walking or using a mobility aid such as a wheelchair (Lo, 2009). The non-work walking modal share differs in traditional and contemporary neighborhoods (or grid and cul-de-sac (Lindelöw, 2016)); the share for walking is 7% (automobiles 85%) in the traditional neighborhood, while for the contemporary non-dense neighborhood the share is 2% (automobiles 96%) (Cervero & Radisch, 1996). Even dissimilar cities such as Paris and Houston share a non-motorized transportation mode of less than 4% (Rode & Floater, 2014). In the United States, commuting by walking has decreased significantly from 9.9% in 1960 to 5.6% in 1980 and 2.6% in 2019 (U.S. Census, 2019). Despite the low share of walking in many cities located in North America and Europe, it has a high mode share in the global south. Most of Latin America is dense and urban, particularly Chile which has a walking mode share in its cities between 18.5% and 36 % (34.5% in Santiago which has 40% of the population (Herrmann-Lunecke et al., 2020).

The alteration in transport intensity between high- and low-density zones within a city can be more than 40% in vehicle-miles-travelled per capita (Ewing et al., 2008). Doubling densities within metropolitan regions can reduce vehicle kilometers-travelled (VKT) by up to 25% (Rode & Floater, 2014). In the context of Germany, a study modeled economic outcomes of policies that focused on the reduction of three negative environments in cities: traffic-related emissions of greenhouse gases, noise, and air toxins. The report discovered positive net effects from diminishing car use across different strategies. Actions to increase the share of walking and cycling would increase GDP by 1.11%, total employment by 1.37% and employment in transport by 4.14% by 2030 (Rode & Floater, 2014).

Instead of car-centric developments, walkable cities are growing and are in high demand (Center for Real Estate and Urban Analysis, 2019). Cities in the 21st century are witnessing a connection between urban design and non-motorized mobility. This pattern aims to create options that reduce car dependence. The idea of urban vitality is closely associated with pedestrian infrastructure. One of the most visible changes in the global urban landscape is related to the conversion of former roads that served motorized vehicles during the 20th century. The purpose of these transformations is to redesign those spaces as pedestrian oriented infrastructures. Among the most significant urban projects of this kind we can find contemporary examples in Seoul (Republic of Korea), Mexico City (Mexico) and New York (United States) among many others.

### Keys to Walkability in the Urban World

The specialized literature that studies travel choices in cities across the world uses regularly an agreement of seven variables with words beginning with D (Ewing & Cervero, 2010). This taxonomy provides researchers with order and conventional concepts. The original “three Ds” are density, diversity, and design (Cervero & Kockelman, 1997). They were followed later by destination accessibility and distance to transit. The last two variables are demand management, and demographics(Ewing et al., 2008; Ewing & Cervero, 2010). These seven variables are factors to measure walkable cities on a global scale. It is important to note that these are malleable classifications, with ambiguous boundaries that may change in the future. Dimensions such as diversity and destination accessibility overlap. The explanation is based on the document Travel and the Built Environment: A Meta-Analysis (Ewing & Cervero, 2010):

1. DENSITY. This variable computes an overall activity density per area unit. The area can be gross or net land area, and the activity variable can be population, employment, dwelling units, building floor area, or something else. Population and employment are sometimes summed to represent an overall activity density per area unit. The variable is useful to indicate potential trip origins and destinations.
2. DIVERSITY. It measures the number of diverse land uses in a given area. It focuses on the degree to which different land uses are located within proximity of each other, reducing the need to travel outside of the area for common trip purposes. Low values indicate single-use environments while higher values represent more varied land uses
3. DESIGN. It includes street network characteristics within an area. The characteristics could be noise, safety, visual interest, and weather protection. Measures comprise proportion of intersections and pedestrian crossings, average block size, and number of intersections per square mile or square kilometer. This factor considers variables that differentiate pedestrian-oriented environments from auto-oriented zones.
4. DESTINATION ACCESSIBILITY. It measures effortless access to trip attractions such as employment, which is measured by distance or time.
5. DISTANCE TO TRANSIT. This factor studies how far an area is from the nearest public transport stop or station. It is normally the average of the shortest street routes from the residences or workplaces in an area to the nearest rail station or bus stop.
6. DEMAND MANAGEMENT. The main purpose of this variable is the study of parking supply (cars, bicycles, buses) and its cost.
7. DEMOGRAPHICS. While not part of the built environment, demographics is the seventh D because it influences patterns in travel choices based on the age of users.

The following figures are examples of studies that have analyzed the role of population density in urban mobility. They have measured variables such as CO2 emissions per capita, energy use per annum, cost-effective transport, and regional patterns of mobility:

Chart, scatter chart

Description automatically generated

Figure . Average urban densities in large cities and average carbon emissions per capita. (Rode & Floater, 2014) from (Angel et al., 2011)

Chart, scatter chart

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Figure . Relationship between urban form and cost-effective public transport. (United Nations Human Settlements Programme, 2013)

Chart, bar chart

Description automatically generated

Figure . Average density, median density, and overall density in large cities in all world regions. (Angel et al., 2011)

Chart, bar chart

Description automatically generated

Figure . Urban population densities of 1366 cities, mean densities by region (2000-2010). (United Nations Human Settlements Programme, 2013)

Map

Description automatically generated

Figure . The average density of large cities in all countries (persons per hectare), 2000. (Angel et al., 2011)

### The Importance of Population Density

Walking is strongly related to land use diversity, residential and employment density, and the number of destinations within walking distance. Density congregates people and places close together. One of the most important factors for active mode choice is residential density (Molaei et al., 2021). Normal elasticity of vehicle-km travelled with respect to local density is –0.05 (Ewing & Cervero, 2010). In the context of United States, there are significant associations between percent walking and population density. Population densities need to exceed 13 residents per acre [3,212 persons per km2] for changes in walking trips. In shopping trips, for instance, once this population density was surpassed and until it reached 4,500 persons per km2, the share of single occupant vehicle decreased from 51% to 42%, and walking increased from 3.69% to 21%. For work trips, the increase of walking was from 3.37% to 10%. The correlation coefficients between population densities and the share of walking was 0.31 in shopping trips and 0.34 in work trips (LAWRENCE D & PIVO, 1994).

Similarly, residents tend to drive less in dense, compact cities than in sparse, sprawling urban areas. There are six variables that encourage this pattern in dense and compact urban environments: shorter trip distances, more congestion, higher car insurance bills, higher gasoline prices, less parking, better public transit, and a more pleasant walking environment. Long term data from thousands of cities with different varieties of incomes and geographic contexts suggest that there is a fundamental threshold of urban intensity (measured by residential and employment density) where automobile dependence is significantly reduced and other forms of mobility are incorporated. This threshold varies from 3,000 to 4,000 persons per km2 (Guerra, 2014).

No correlation was observed between household car use and residential population density below 1,500 per km2 in the United States. The relationship only became pronounced above 2,900 per km2 (Pickrell, 1999). A similar threshold of 3,500 jobs and people per km2 across fifty-eight high-income cities around the world was identified (Newman & Kenworthy, 2006). The effect of land use on travel demand in Montreal, Canada was modeled. The methodology included three types of clusters based on residential density. The automobile-oriented clusters presented a mean population density that ranged from 1,900 to 2,900 persons per km2. Transit-oriented clusters had a residential density of 4,400 to 8,600 persons per km2. Finally, exclusively pedestrian-oriented zones had density from 8,600 to 9,600 persons per km2. In the study, the gap between 2,900 to 4,400 persons per km2 was consistent with the numbers required to abandon cars and to use other forms of urban mobility, including walking (Harding et al., 2012).

Thus, declines in single-occupant vehicles use and increases in non-motorized mobility become substantial only at a threshold from 3,000 to 4,000 people or more per square kilometer. These densities are rarely observed in suburbs located in the United States and they are limited in Western Europe. However, they are often reached in Asia, Africa, and Latin America. For instance, in cities such as Mexico City, Bogota, Mumbai, Lagos and Sao Paulo, like most other developing-world metropolises, population density levels are higher than this minimum. The most peripheral neighborhoods in Mexico City had an average of 5,400 people per km2 in 2005. By 2016 nearly all of Mexico City’s residents will live in neighborhoods that are sufficiently dense to influence travel choices, encompassing walking (Guerra, 2014).

Map

Description automatically generated

Figure . The location of 3,646 large cities in the nine world regions, 2000. (Angel et al., 2011)

### Walkable Cities and Climate Change

Walking is the only zero emissions transportation mode (bicycling is zero emissions but the bicycle is manufactured) (TNMT, 2021) and is therefore a climate solution. Since 2104, Chile has set as a priority, walking as a mode choice to achieve climate goals (Herrmann-Lunecke et al., 2020). According to Wright and Fulton (2005), in a typical Latin American city a 5% increase in walking or cycling mode share can reduce CO2 emissions by 7%. In addition to health benefits, walking provides other benefits that help to prevent climate change such as lower congestion, improved air quality and less fuel consumption (Texas A&M Transportation Institute, 2016).

Chart, bar chart

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Figure . Emissions by Transport Mode Source: (TNMT, 2021)

## Adoption Path

The situation of non-motorized mobility (walking and cycling) as a regular choice of transportation is different throughout the world. In some cities, non-motorized mobility represents 40% of trips in Africa, 35% in South Asia, and 30% in Latin America (). In some African cities, walking and cycling still represent more than 70 per cent of trips. In many Chinese and Indian cities this form of transportation accounts for more than 50% and 33% respectively Rode & Floater, 2014. Urban inequalities shape the role of walkability as a transport mode. More than 2.2 billion people in the developing world walk on average 3.7 miles per day (6 kilometers) to get water to drink (Water Mission, 2021). While walkable environments are linked to leisure and recreation in rich countries, this form of mobility is a necessity in the developing world.

### Current Adoption

The current modal share of walkable cities is the percentage of urban pkm done through walking. Adoption projections are gathered from as many credible sources as possible. Sources include ITF (OECD/ITF, 2021), ITDP (UC Davis et al., 2015) and calculations made and previously published by the Drawdown team based on urban density and population . Each source is discussed below. Current modal share can be seen in Table ‎1.1.

The International Transport Forum (ITF) reports mode share of urban passenger transport in its Outlook report that it publishes every other year. The ITF reports urban passenger mode share for walking The ITF also provides mode share in three different scenarios. Walking is expected to increase in all scenarios. The most ambitious scenario assumes higher density transit oriented development and “15 minute cities” which includes a large increase in walking as a mode and also as a feeder to public transit (OECD/ITF, 2021). The ITF Outlook 2021 is the only model and report that is available that takes the 2020 global pandemic into consideration.

The Institute for Transportation and Development Policy (ITDP), in cooperation with the University of California, Davis, produced a comprehensive global estimate of transportation mode shares and pkm through 2050. In ITDP’s estimate of a high-shift to sustainable transportation, the portion of urban pkm travelled by walking increases steadily (UC Davis et al., 2015).

The share of urban pkm by walking is estimated based on the capacity to influence the walking portion of travel demand via the intensity of urban activity, which is measured by population density. Long term data from thousands of cities with different incomes and contexts suggest that there is a basic threshold of urban intensity (population density) where automobile dependence is significantly reduced and other forms of mobility are incorporated, including walking. This threshold varies from 3,000 to 4,000 persons per km2 (Ewing & Cervero, 2010; Guerra, 2014; Harding et al., 2012; LAWRENCE D & PIVO, 1994; Newman & Kenworthy, 2006; Pickrell, 1999). Once the minimum threshold is established, two values of walking share can be estimated. For dense cities, the average worldwide is between 6.5% and 7% (Cervero & Radisch, 1996; Rode & Floater, 2014). The estimation for non-dense city is between 2% and 2.8% (Cervero & Radisch, 1996; McKenzie, 2014).

A sample of almost 1,00 cities disseminated through 144 countries with a minimum population of 500,000 was used to calculate adoption. This database constitutes 51.4% of the urban population of the world in 2021. Variables such as city population and population density per city were extracted from the document Demographia World Urban Areas (Built-Up Urban Areas or Urban Agglomerations) 17th Annual Edition (Demographia, 2021).

The urban population projections from 2014 to 2050 were taken from the document Annual Urban Population at Mid-Year by Major Area, Region and Country, 1950-2050 United Nations, Department of Economic and Social Affairs, Population Division (UN, 2018). World Urbanization Prospects: The 2018 Revision. World population projections were consulted in the database World Population Prospects: The 2019 Revision from the United Nations, Department of Economic and Social Affairs, Population Division (UN, 2019).

Since population density shapes the adoption for walkable cities, the analysis incorporated realistic projections of urban density at the present time. These scenarios are inspired by the document The dimensions of global urban expansion: Estimates and projections for all countries, 2000–2050, (Angel et al., 2011) where a dataset was created that encompasses a sample of 3,646 named cities that had populations in excess of 100,000 in the year 2000. The conclusions of this work are in the same tenor with works such as The Spatial Organization of Cities: Deliberate Outcome or Unforeseen Consequence? (Bertaud, 2004). Based on historical evidence and geographical projections of urban land cover in the world towards 2050, a decreasing population density should be considered as one of the scenarios.

Table . Current Global Modal Share and Adoption of Walkable Cities in billion PKM

|  | **Percent (%)** | **Billion PKM** |
| --- | --- | --- |
| Current Adoption | 4.50% | 1,333.8 |

Table . Current Global Walkable City use by region

| **Region** | **Percent (%)** |
| --- | --- |
| OECD 90 | 10.5% |
| Eastern Europe | 5.2% |
| Asia (Sans Japan) | 50.6% |
| Middle East and Africa | 20.4% |
| Latin America | 13.3% |
| Total | 100% |

### Trends to Accelerate Adoption

#### Land Use and Transport Policies

The lockdowns from the global pandemic that began in 2020 brought huge increases in walking for recreation, commuting and shopping. This mode switch (also caused by health fears from public transit) will be permanent for some urban passengers. The quick policy changes for transport infrastructure that many cities (such as Boston, Brussels, Denver, Milan, Minneapolis, Oakland, Paris, Philadelphia and New York City among many others (Hickman, 2020)) enacted enabled this increase in walking by making pedestrians feel safer through slow streets, safe streets, closed streets and reduced speed limits for cars on most streets in the city (NACTO, 2020; Surico, 2021). Brussels (Brussels City Government, 2020) and Paris (France 24, 2021) are among the first to make a city-wide speed limit of 30 km/hr (19 miles/hr) permanent. Many cities are making these changes permanent and should be encouraged to do so (Times Editorial Board, 2021).

15-minute cities are an emerging policy trend that aims to give residents everything that they need within a 15-minute walk and are pedestrian focused. The C40 Cities Climate Leadership Group published guidelines in July 2020 and used examples from Portland, Barcelona, Houston, Paris, Shanghai, Guangzhou, Chendu, Melbourne, Ottawa, Madrid, Edinburgh, Seattle and Milan (C40 Cities, 2020). In Barcelona, in April 2020, the Manifesto was signed by 300 architects and 160 academics that is similar to a 15-minute city and aims to “replace commodification with centrality of life” (Paolini, 2020). Paris has committed to becoming a 15-minute city (Willsher, 2020).

#### ICT

Map apps on mobile phones have made walking as a mode much easier, efficient and productive (Nelson, 2020). It also allows tracking the amount of walking trips and the portion of walking on multi-modal trips improving data availability for planners and governments. The popularity of fitness tracker apps such as fitbit have led to increases in walking (DiFrancisco-Donoghue et al., 2018).

### Barriers to Adoption

#### Emerging modes

Electric kick scooters (e-scooters) are becoming popular all over the world and shared dockless systems are prevalent (Dias et al., 2021). While e-scooters do replace some car trips, they mostly replace walking (Carey, 2021; Sanders et al., 2020). This means that a zero emission mode is being replaced by a mode that has emissions from manufacturing and a little from charging, but they also have to be collected, charged, redistributed and maintained, typically by an internal combustion engine (ICE) van (ITF/OECD, 2020). Additionally, the first generation of shared e-scooters only had a lifetime of 28 days although some improvements have been made (ITF/OECD, 2020; Lekach, 2019). E-scooters potentially have a role in sustainable urban transportation but care must be taken to not take mode share from walking (perhaps through distance pricing schemes among other options) and should replace car trips.

#### City Exodus

It is too early to call it a permanent exodus. However, many people across the world left urban centers during the pandemic and some moves were temporary while others were permanent (Bowman, 2020). For example, as major cities such as Paris (Bhayat, 2021) and London (Marsh, 2020)emptied, and as residents fled dense Manhattan, the suburbs of the Hamptons and Greenwich boomed (Kolomatsky, 2021). However, these moves may end up making large urban centers less dense (but still a walkable city) while making secondary cities more dense (Gu & Rojanasakul, 2021; Ramani & Bloom, 2021) and more suitable to walking.

### Adoption Potential

The adoption potential for walkable cities is large. Cities are increasingly seeking to become more sustainable and to combat climate change. The trends towards 15-minute cities and slow/safe/closed streets brings high potential to increase walking as a mode choice. Even the barrier of city exodus can bring potential if the recipient cities plan properly. The adoption is limited by those that cannot or will not walk and also by weather and terrain. However, density brings more services (schools, shopping, etc.) in closer proximity which increases the adoption potential.

## Advantages and disadvantages of Walkable Cities

### Similar Solutions

Solutions that are similar to or can replace walkable cities are all other modes that serve the urban passenger market. These modes include car, public transit, e-bike, conventional bike, e-kick scooters and e-mopeds. All but the last two modes (which are considered motorized 2/3 wheelers) are current Drawdown Solutions (car use encompasses three solutions-electric, hybrid and sharing).

### Arguments for Adoption

Walkable cities is an important mode choice for sustainable urban passenger transit. It is the least emitting component of the mix of mode choices and has the ability to shift use from modes with higher emissions. The solution`s advantages and disadvantages are better understood when compared to the other available urban passenger mode choices. 2/3 wheelers are not currently Drawdown solutions and will not be evaluated as to whether the benefits outweigh the costs because there is no consensus and Drawdown has not yet modeled the results.

The municipal costs of building walkable cities are much lower than constructing car lanes, bike lanes or public transit and do not incur subsidies like most public transit.

The user costs and emissions of using the solution of walking are much lower than using a car or purchasing an e-bike.

Walking requires more physical activity than biking, car or public transit.

The space efficiency of walking is less than e-bikes and conventional bikes and significantly less than that of cars or public transit.

### Additional Benefits and Burdens

Additional benefits include health benefits. Active modes and particularly walking improve health and reduce obesity and diabetes (Brondeel et al., 2017; Texas A&M Transportation Institute, 2016). Residents of walkable neighborhoods weigh less (6-10 pounds) than residents of sprawling neighborhoods (Walk Score, 2021).

Pedestrians have the opportunity for awareness, attentiveness and interaction of and with the local environment and people (Texas A&M Transportation Institute, 2016) which brings about lower crime, more creativity and arts organizations and higher civic engagement (Florida, 2014).

Burdens of walkable cities are that sometimes the density needed makes housing in high demand and can reduce affordability (King & Clarke, 2015)

Table . Urban Passenger Mode Comparison

|  | **User Costs** | **Emissions** | **Speed** | **Physicality** | **Congestion** | **Space Efficiency** |
| --- | --- | --- | --- | --- | --- | --- |
| Walking. | Low | None | Low | High | Low | Low |
| E-Bike | Low | Low | High | Medium | Low | Low |
| Conventional Bike | Low | None | Medium | High | Low | Low |
| Car | High | High | Medium | Low | High | High |
| Public Transit | Low | Low | High | Low | Low | Medium |

# Methodology

## introduction

Project Drawdown’s models are developed in Microsoft Excel using standard templates that allow easier integration since integration is critical to the bottom-up approach used. The template used for this solution was the Reduction and Replacement Solutions (RRS) which accounts for reductions in energy consumption and emissions generation for a solution relative to a conventional technology. These technologies are assumed to compete in markets to supply the final functional demand, which is exogenous to the model, but may be shared across several solution models. The adoption and markets are therefore defined in terms of functional units, and for investment costing, adoptions are also converted to implementation units. The adoptions of both conventional and solution were projected for each of several scenarios from 2015 to 2060 (from a base year of 2014) and the comparison of these scenarios (for the 2020-2050 segment[[2]](#footnote-2)) is what constituted the results.

The functional unit[[3]](#footnote-3) of the analysis is the passenger kilometer (pkm); and the implementation unit[[4]](#footnote-4) the urban trip. The agency level used for the analysis is the city, as it is the agent that will make policies that influence density and thus walkability. Therefore we analyze these impacts on the perspective of the city rather than from the individual user.

The Total Addressable Market (TAM) covers all demand for the function provided by the solution. For walkable cities, the TAM is global demand for urban passenger travel including conventional and emerging solutions. Most reports available in the literature exclude non-motorized trips when calculating urban modal share. This was repeated here for two main reasons. First the modal share is calculated through pkm, and therefore the smaller trip distance of a non-motorized trip results to a much smaller share. Second, non-motorized trips are much harder to record and predict. Adjustments have been made to account for the non-motorized pkm. One should note however than walking trips are often complementary to public-transit trips, and so an increase in public transit adoption should lead to increased walking.

The Project Drawdown Scenarios, (PDS), estimate an annual increase of the modal share of walkable cities in urban environments as the total number of pkm grows. The increased number of walking trips will mainly come from newly generated trips, although some will come from existing private vehicle, non-motorized, or other mode trips and as a feeder to public transi.

The conventional technology in this model will be the private car, more specifically ICE cars. Since hybrid, electric, or other engine vehicles sum up to only a few percent of the global car fleet, they will not be considered in this approach.

As mentioned previously, the functional unit of the analysis is the passenger kilometer and the implementation unit the urban trip. Since the conventional technology and solution have different average trip lengths, estimations will be done using these figures. Average urban trip length for a private car is 9km (Department for Transport, 2020; UC Davis et al., 2015), which corresponds to 15.36 pkm (average car occupancy rate sources listed below). Average urban trip length for walking is 2 km (Department for Transport, 2020; US DoT, 2020).

## Data Sources

Data from multiple sources were compiled to construct this model, with an emphasis on recent, credible, and peer-reviewed methodology. The data sources used for the model have been divided in three main sections: Total Addressable Market (TAM), Adoption Projections and Variable Inputs.

### Total Addressable Market

The Total Addressable Market (TAM) covers all demand for the function provided by the solution. For the Walkable Cities solution, TAM is world urban passenger kilometers made by all modes. Global TAM was projected mainly using data obtained from (IEA, 2016; The International Council on Clean Transportation, 2012; UC Davis et al., 2015). Regional data come from ITDP-UC Davis (UC Davis et al., 2015).

### Adoption Projections

Adoption projections are gathered from as many credible sources as possible. Sources include (Demographia, 2021; OECD/ITF, 2021; UC Davis et al., 2015; UN, 2018, 2019). Regional data come from ITF (OECD/ITF, 2021)

### Variable Inputs

Variable inputs are used in the Variable Meta-Analysis and are updated to reflect current conditions at each update.

#### Financial Variables

Financial variables include first costs and operating costs for both conventional and the solution. Operating costs are variable and fixed and are derived from lifetime capacity and average annual use for conventional and solution.

There is no solution first cost data due to an inability to show comparable first costs for walkable cities due to lack of data and high variability of the costs of improving walkability in cities. Therefore there are no first costs for conventional or solution.

Conventional first costs are calculated and used for depreciation as an input to the operating cost per trip variable. These costs are mostly reported at the regional level and are based on (Carnext, 2019; Carview, 2019; Coren, 2019; Feijter, 2018a, 2018b; Gasnier, 2019; Hu, 2019a, 2019b; IEA, 2019; IEA & ICCT, 2019; ITDP, 2019; Lutney & Nicholas, 2019; Mock, 2018; Ning, 2018; Tate, 2019; Wang, 2017, 2018).

The conventional and solution lifetime capacity data and average annual use come from (Department for Transport, 2020; UC Davis et al., 2015; US DoT, 2020).

Conventional variable operating costs (in addition to depreciation) are regional and based on (AAA, 2019; Bartlett, n.d.; BTS, 2019; Hagman et al., 2016; Masson, 2018; Norman, 2021).

#### Emissions Reduction Variables

The conventional fuel consumed per pkm data is from (Bieker, 2020; ITF/OECD, 2020; Schäfer & Yeh, 2020; Wu et al., 2019) some of which have multiple data points for many countries.

Indirect emissions for conventional come from (ITF/OECD, 2020).

#### Additional Variables

Threshold city density for marked increase in walking data come from (Ewing & Cervero, 2010; Guerra, 2014; Harding et al., 2012; LAWRENCE D & PIVO, 1994; Newman & Kenworthy, 2006; Pickrell, 1999).

Walking mode share of dense cities is from (Cervero & Radisch, 1996; Rode & Floater, 2014).

Walking mode share of non-dense cities is from (Cervero & Radisch, 1996; McKenzie, 2014).

Average car lifetime data come from several sources such as (Hawkins et al., 2012; ITF/OECD, 2020; NHTSA, 2006; Zheng et al., 2019).

Average car occupancy comes from a variety of sources including (Center for Sustainable Systems University of Michigan, 2020; Environmental and Economic Policy Research Center of the Ministry of Ecology and Environment, 2018; ITF/OECD, 2020; Liu et al., 2017; McQueen et al., 2020; Schäfer & Yeh, 2020).

The household discount rate is based on data from (Koster & Pinchbeck, 2018; Li & Pizer, 2018, 2021; Martin et al., 2020).

## Total Addressable Market

The total addressable market is the total of functional transportation units provided to the world urban market by all modes. Data were obtained from the International Council on Clean Transportation (ICCT), Institute for Transportation and Development Policy (ITDP) and International Energy Agency (IEA). The values shown represent the average from all the sources (Table 2.1). Since most of the collected data report values in 5-year intervals, values for the in-between years were estimated with the use of data interpolation. Regional data come from the ITDP-UC Davis study, taken from their High Shift scenario. While the global TAM more than doubles throughout the study period, that the regional TAMs for OECD90 and Eastern Europe initially grow before returning to around 2015 levels. The growth comes mainly from Middle East and Africa region, where the TAM is almost 4 times bigger; and Asia, where the TAM more than doubles by 2050. In Latin America the TAM grows about 80%.

Table . Global and Regional TAM, in billion pkm

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Drawdown Region** | **2015** | **2030** | **2045** | **2050** |
| World | 26,539 | 38,473 | 51,468 | 56,606 |
| OECD90[[5]](#footnote-5) | 9,476 | 9,741 | 9,323 | 9,281 |
| Eastern Europe | 1,261 | 1,317 | 1,277 | 1,273 |
| Asia (sans Japan) | 9,459 | 15,411 | 20,582 | 22,091 |
| Middle East and Africa | 2,847 | 4,614 | 7,963 | 9,485 |
| Latin America | 2,715 | 3,863 | 4,721 | 4,943 |

## Adoption Scenarios

Two different types of adoption scenarios were developed: a Reference (REF) Case which was considered the baseline, where not much changes in the world, and a set of Project Drawdown Scenarios (PDS) with varying levels of ambitious adoption of the solution. Published results show the comparison of one PDS to the REF, and therefore focus on the change to the world relative to a baseline.

### Reference Case / Current Adoption

For most Project Drawdown solutions, the REF scenario assumes that the 2014 adoption of the solution is “frozen” for the study period. It uses the percentage of adoption in the base-year as the fixed percentage of TAM projecting forward which is 4.50%.

### Project Drawdown Scenarios

Three Project Drawdown scenarios (PDS) were developed for each solution, to compare the impact of an increased adoption of the solution to a reference case scenario. Three sources were used to make the PDS projections, the International Transport Forum (OECD/ITF, 2021), Institute for Transportation and Development Policy (ITDP), in cooperation with the University of California, Davis (UC Davis et al., 2015) and using previously published Project Drawdown estimates. The ITF reports walking pkms globally and regionally to 2050. ITDP reports a global estimate of transportation mode shares and pkm through 2050. The Project Drawdown team estimates are based on density and population projects from the United Nations and Demographia (Demographia, 2021; UN, 2018, 2019) and assumptions of walking modes from (Cervero & Radisch, 1996; McKenzie, 2014; Rode & Floater, 2014). Estimates of walkable cities share were made based on the proportion of walking pkms based on a meta-analysis of all modes made for integration of all solutions by Drawdown.

#### Plausible Scenario

This scenario assumes that walkable cities continue to grow without any major interventions and that most of the temporary covid measures to increase slow/safe/closed streets are reverted with a few exceptions. The baseline TAM and adoption cases are considered plausible.

#### Drawdown Scenario

In this scenario, most covid street measures are made permanent and cities around the world continue to build walkable city infrastructure and encourage walking. Transit oriented development and 15-minute cities remain a trend. The conservative TAM and adoption cases are part of a world focused on the target of achieving drawdown by 2050.

#### Maximum Scenario

This scenario assumes that the trend towards walking during lockdowns remains and goes further than the drawdown scenario in that in addition to transit oriented development and 15-minute cities, cities make zero emission zones and embrace circularity to make their city competitive and to attract residents and businesses thus increasing density. The ambitious TAM and adoption cases are part of a world focused on zero emission..

## Inputs

Many variables have been defined and calculated for this analysis. They are grouped by climate inputs, financial inputs and technical inputs. Each variable is described below. In the analysis, the agent that will decide whether to influence walkable cities is the city. Therefore, the impacts on the perspective of the city are analyzed.

### Climate Inputs

This section addresses the environmental inputs of the model. These can be either direct emissions, through fuel combustion or the electricity grid, or indirect, through the construction of the vehicles.

#### Direct Emissions

Direct emissions can come from fuel combustion or from electricity consumption. Certain assumptions regarding the technologies are made to calculate them. All conventional technology vehicles are ICE cars, therefore conventional has only fuel-combustion related emissions.

For ICE cars, the input required is the average liters of fuel required per pkm. This information has also been used for the calculation of the operational cost of cars. It is calculated by dividing the average fuel consumption fec by the average car occupancy AOc.

To calculate the reduction obtained by the solution technology, one estimates how much fuel would be saved (100%) by switching a car pkm to a walking pkm.

#### Indirect Emissions

Indirect emissions from vehicle manufacturing must also be taken into account. Figures from various sources, related with the CO2eq emissions generated to produce an ICE car are used to calculate these emissions per pkm.

Table . Climate Inputs

|  | **Units** | **Project Drawdown Data Set Range** | **Model Input** | **Data Points (#)** | **Sources (#)** |
| --- | --- | --- | --- | --- | --- |
| Fuel Consumed per Functional Unit - CONVENTIONAL | *Liter/ B PKM* | 54,333,961-116,690,930 | 85,512,446 | 8 | 4 |
| Indirect CO2 Emissions per CONVENTIONAL Functional Unit | *t CO2-eq/ B PKM* | 69,229-91,269 | 80,249 | 4 | 1 |

Note: Project Drawdown data set range is defined by the low and high boundaries which are respectively 1 standard deviation below and above the mean of the collected data points[[6]](#footnote-6).

### Financial Inputs

This section addresses the financial inputs of the model, by splitting them to first and operational cost. The costs have been converted to US$2014 based on inflation.

#### First Cost

Conventional first costs (purchase price of a car), is excluded as a variable from the model due to an inability to show comparable first costs for walkable cities due to lack of data and high variability of the costs of improving walkability in cities. Conventional first costs are calculated and used for depreciation as an input to the operating cost per trip variable. There are no solution first costs.

#### Operational Cost Factors

The conventional, ICE cars, in addition to depreciation, carry the additional fixed expense of insurance to the user and is calculated to a pkm basis and added to the operating costs.

There are no fixed operating costs for the solution.

The conventional variable operating costs are maintenance and fuel costs.

There are no variable operating costs for the solution.

#### Discount Rate

The household discount rate of 3.2% was used based on the average of 3 peer reviewed sources reporting global household discounting.

Table . Financial Inputs for Conventional Technologies

|  | **Units** | **Project Drawdown Data Set Range** | **Model Input** | **Data Points (#)** | **Sources (#)** |
| --- | --- | --- | --- | --- | --- |
| Fixed Depreciation and Insurance Costs (Conventional) | *US$2014/Person trip* | 1.10-2.18 | 1.64 | 36 | 20 |
| Variable Operation and Maintenance Costs (Conventional) | *US$2014/B Pkm* | 30,531,321-460,317,247 | 223,894,625 | 7 | 4 |
| Fuel Cost (Conventional) | *US$2014/B Pkm* |  | 88,561,479 |  |  |

### Technical Inputs

Besides only climate- and financial-oriented variables, some variables have been defined which apply to both climate and financial results. These are called Technical inputs and are described below.

#### Replacement Factors

The Conventional and Solution Implementation unit is only relevant for a defined number of pkms equal to one trip. The conventional and solution average annual use and the lifetime capacity are therefore the same and is one trip.

#### Technical Factors

Other variables were used in the calculations for the climate, financial and replacement factors. They are listed below.

Table . Technical Inputs

|  | **Units** | **Project Drawdown Data Set Range** | **Model Input** | **Data Points (#)** | **Sources (#)** |
| --- | --- | --- | --- | --- | --- |
| Average Car Occupancy | Persons/vehicle | 1.39-2.04 | 1.72 | 15 | 6 |
| Threshold City Density for Marked Increase in Walking | Person/km2 | 2,873-3,298 | 3,000 | 6 | 6 |
| Walking Mode Share of Dense Cities | Percent | 6.5-7.0 | 6.75 | 2 | 2 |
| Walking Mode Share of Non-Dense Cities | Percent | 2.0-2.8 | 2.4 | 2 | 2 |

## Assumptions

Six overarching assumptions have been made for Project Drawdown models to enable the development and integration of individual model solutions. These are that infrastructure required for solution is available and in-place, policies required are already in-place, no carbon price is modeled, all costs accrue at the level of agency modeled, improvements in technology are not modeled, and that first costs may change according to learning. Full details of core assumptions and methodology will be available at [www.drawdown.org](http://www.drawdown.org). Beyond these core assumptions, there are other important assumptions made for the modeling of this specific solution. These are detailed below.

1. All cars identified as a “convectional technology” use ICE;
2. Travel mode fuel efficiencies and fuel prices remain constant through 2050;
3. Average urban trip lengths with cars and public transit remain constant through 2050;
4. Mode Energy Usage: Urban bus and Mini bus use liquid fuel and electricity; Cars and BRT use only liquid fuel; Metro, Tram, and Commuter rail use only electricity.

## Integration

The complete Project Drawdown integration documentation (will be available at [www.drawdown.org](http://www.drawdown.org)) details how all solution models in each sector are integrated, and how sectors are integrated to form a complete system. Those general notes are excluded from this document but should be referenced for a complete understanding of the integration process. Only key elements of the integration process that are needed to understand how this solution fits into the entire system are described here.

Each solution in the Transportation sector (including Walkable Cities and Bike Infrastructure) was modeled independently and integration was performed to ensure consistency within the sector. Intra-sectoral integration of the transportation solutions was based on two main components:

* TAM/Adoption Consistency: Ensuring that all solutions that are in the same “market” use the same TAM data, use consistent market shares, and have projected adoptions that do not exceed the total projected demand
* Variable Consistency: Ensuring that all variables that are used in several solutions have the same values.

The total motorized and non-motorized transport demand (TAM) was collected and synthesized from several sources in functional units (mostly passenger-km and ton-km), then classified according to type (urban passenger, non-urban passenger, and all freight). The TAM was then assigned to each solution according to the service that the solution technology provides. The TAM served as the upper limit of the sum of adoptions of the modeled solutions. Additionally, some reasonable bounds that were lower than the TAM were placed on adoptions to represent the technologies not affected by the matrix of solutions of Project Drawdown (such as 2-wheelers, intercity bus, and conventional rail).

To determine the new mode shares as adoption grew independently in the models, a simplified approach was used. Solutions were prioritized according to their impact on the climate/environment and efficiency (in space, energy and cost terms). Higher priority solutions were allocated larger proportions of their total individual projected adoption than lower priority ones. Put another way, if the sum of all projected adoptions exceeded the limit discussed above, then in reverse order of priority, and until that was no longer the case, the projected adoption of each solution was reduced until either the relevant bound was no longer exceeded or the adoption was zero. In practice, this mostly affected the Hybrid Cars solution, and to a lesser extent Electric Vehicles which were (respectively) the lowest and second lowest priority solutions in the urban and non-urban passenger TAM’s. The adjusted adoption projections are then used in the individual solution models and in the technical report. Therefore, the adoptions shown in this report already account for integration.

For several variables, especially those relating to the conventional technology (ICE cars), discount rates, fuel prices, emissions factors, and mode shares, consistency across solutions was maintained by ensuring that the same values were used in different models needing those variables.

In addition to intra-solution integration within the transport sector, there was an integration process across the grid solutions and the electricity efficiency solutions (buildings, transport, materials etc.) which adjusted for the double counting. Double counting of emissions reduction was a factor of using the reference grid emissions factors for electricity-based solutions. As grid solutions (Utility-scale Solar PV and others) are adopted, the grid gets cleaner and the impact of efficiency solutions is reduced (where they reduce electricity demand) or increased (where they increase electricity demand[[7]](#footnote-7)). Grid solutions are adjusted to remove the double counting as described in the Project Drawdown integration documentation.

## Limitations/Further Development

Active mode urban travel is not reported widely on a global or regional basis partly due to the short trip distances. It is a growing area of research and global and regional estimates began being reported in 2016 from the ITF (OECD/ITF, 2021). Walking is also part of multi-modal trips. Direction apps such as CityMapper, Google Maps and Apple Maps (among others) have begun reporting data for walking trips and as part of multi-modal trips. Exercise apps such as Fitbit have begun reporting steps walked by country which can be transformed into distance and then mode share.

The covid street measures from the global pandemic lockdowns of 2020 are still reporting data. While the measures are mostly known, the data and also the ultimate fate of the measures is still being processed.

Urban population density was a surprisingly good fit when compared to modal share from ITF. The availability of urban employment density would provide more data with which to make estimates.

Regarding the different agency levels, it was decided to address the analysis from a city perspective. Another possible viewpoint is that of the individual user. In such an analysis, the costs would include first costs to purchase a car and also the financial and climate impacts of alternative modes such as public transit, bicycle infrastructure and e-bikes.

# Results

## Adoption

Below are shown the world adoptions of the solution in some key years of analysis in functional units and percent for the three Project Drawdown scenarios.

Table . World Adoption of the Solution

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Solution** | **Units** | **Current Year (2018)** | **World Adoption by 2050** | | |
| **Plausible** | **Drawdown** | **Maximum** |
| Walkable Cities | billion pass-km | 1,334.00 | 3,409.25 | 3,696.60 | 4,822.18 |
| *(% Market)* | 4.5% | 5.0% | 5.5% | 7.1% |

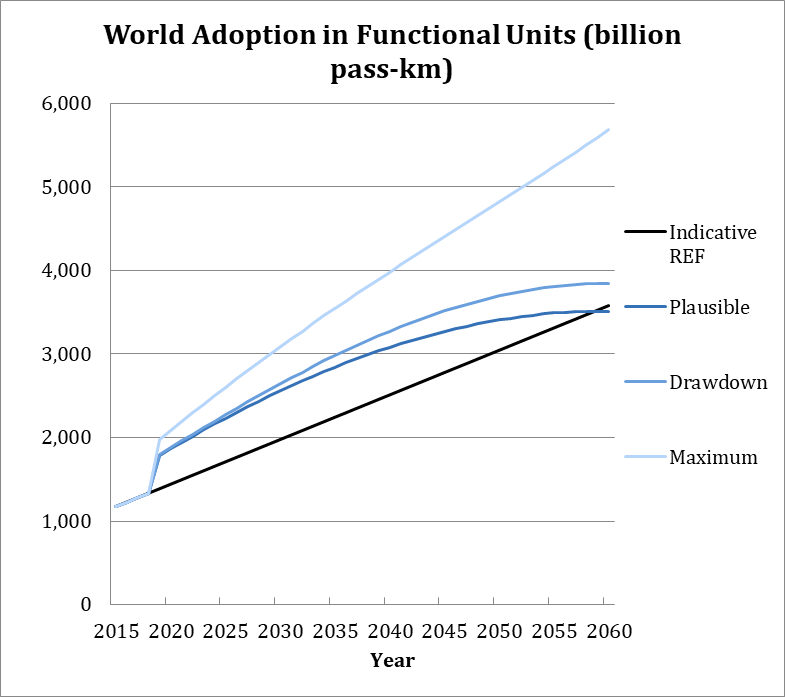


Figure . World Annual Adoption 2020-2050

## Climate Impacts

Below are the emissions results of the analysis for each scenario which include total emissions reduction, atmospheric concentration changes, and sequestration where relevant. For a detailed explanation of each result, please see the Glossary (Section 6).

Table . Climate Impacts

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scenario** | **Maximum Annual Emissions Reduction** | **Total Emissions Reduction** | **Emissions Reduction in 2030** | **Emissions Reduction in 2050** |
| *(Gt CO2-eq/yr.)* | *Gt CO2-eq (2020-2050)* | *(Gt CO2-eq/year)* | *(Gt CO2-eq/year)* |
| ***Plausible*** | 0.16 | 4.47 | 0.16 | 0.10 |
| ***Drawdown*** | 0.21 | 5.68 | 0.18 | 0.18 |
| ***Maximum*** | 0.49 | 10.79 | 0.31 | 0.49 |

The solution was integrated with all other Project Drawdown solutions and may have different emissions results from the models. This is due to adjustments caused by interactions among solutions that limit full adoption (such as by feedstock or demand limits) or that limit the full benefit of some solutions (such as reduced individual solution impact when technologies are combined).

Table . Impacts on Atmospheric Concentrations of CO2-eq

|  |  |  |
| --- | --- | --- |
| **Scenario** | **GHG Concentration Change in 2050** | **GHG Concentration Rate of Change in 2050** |
| *PPM CO2-eq (2050)* | *PPM CO2-eq change from 2049-2050* |
| ***Plausible*** | 0.35 | 0.00 |
| ***Drawdown*** | 0.45 | 0.01 |
| ***Maximum*** | 0.87 | 0.03 |

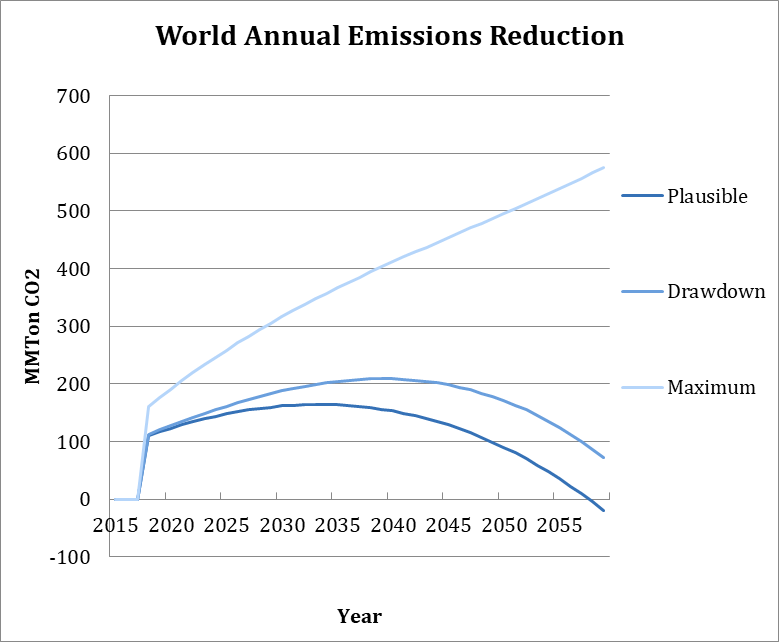


Figure . World AnnualGreenhouse Gas Emissions Reduction

## Financial Impacts

Below are the financial results of the analysis for each scenario. For a detailed explanation of each result, please see the glossary.

Table . Financial Impacts

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scenario** | **Cumulative First Cost** | **Marginal First Cost** | **Net Operating Cost Savings** | **Lifetime Operating Cost Savings** | **Lifetime Cashflow Savings NPV (of All Implementation Units)** |
| *2015-2050 Billion USD* | *2015-2050 Billion USD* | *2020-2050 Billion USD* | *2020-2050 Billion USD* | *Billion USD* |
| ***Plausible*** | 0.00 | 0.00 | 6,699.37 | 7,048.72 | 3,864.75 |
| ***Drawdown*** | 0.00 | 0.00 | 8,548.60 | 8,906.52 | 4,697.95 |
| ***Maximum*** | 0.00 | 0.00 | 16,321.86 | 16,839.80 | 8,497.18 |

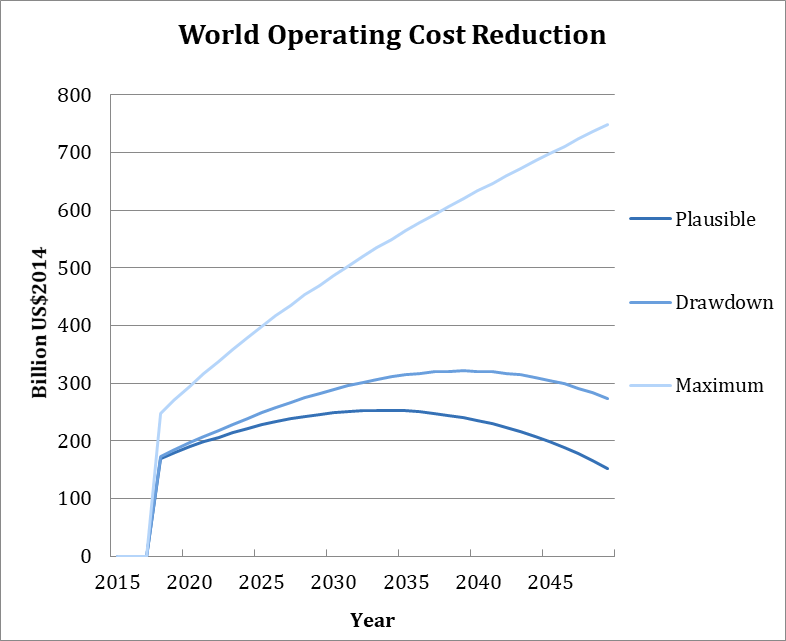


Figure . Operating Costs Over Time

# Discussion

Walkable cities is the only zero emission mode and is therefore a critical solution to achieve Drawdown. Currently it is estimated that 9.5 Gt CO2 eq was produced due to the transportation sector around the world in 2018 (IEA, 2018). The current estimates show that using walkable cities in place of the conventional mode can reduce CO2 eq per year by 0.16 Gt (on average for 2020-2050 in the Plausible Scenario) resulting in 4.47 Gt CO2 eq cumulatively from 2020-2050. In more aggressive scenarios, most covid street measures are made permanent and cities around the world continue to build walkable city infrastructure and encourage walking. Transit oriented development and 15-minute cities remain a trend. The decrease in car trips and increase in walking trips has the additional benefits of lower congestion, better air quality, less noise, lower GHG emissions and improved health.

The global pandemic that began in 2020 and resulted in lockdowns saw a shift towards walking for recreation, shopping and commuting and for replacing trips that would have been done using public transit. Cities began instituting measures to make slow/safe/closed to increase pedestrian safety. Some policy makers are trying to make this shift permanent

In addition to climate impacts, walkable cities have numerous other benefits. They are equitable because there are no costs to use this mode and it brings no harm to others (ITDP, 2020). Walkable cities are reliable and versatile making them resilient (ITDP, 2020). Active modes and particularly walking improve health and reduce obesity and diabetes (Brondeel et al., 2017; ITDP, 2020; Texas A&M Transportation Institute, 2016). Residents of walkable neighborhoods weigh less (6-10 pounds) than residents of sprawling neighborhoods (Walk Score, 2021). Walkable cities are good for the economy and society because pedestrians have the opportunity for awareness, attentiveness and interaction of and with the local environment and people (ITDP, 2020; Texas A&M Transportation Institute, 2016) which brings about lower crime, more creativity and arts organizations and higher civic engagement (Florida, 2014; ITDP, 2020).

The financial results presented in Table 3.4 show the NPV of the walkable cities solution to be $3,864 billion with a net operating savings of $6,699 billion from 2020 to 2050. Neither the walkable cities solution nor the conventional have first costs. The costs savings comes from switching from ICE vehicles which have depreciation, maintenance, insurance and fuel costs. Walkable cities is an easy to implement, cost-effective solution that has significant reductions in emissions.

Walking instead of driving a car not only improves the health of the rider, but also reduces the localized particulate emissions from internal combustion engines, thus improving air quality and health outcomes for non-walking urban passengers. Increasing walking in urban centers may seem like a difficult task, and it will require concerted efforts to design infrastructure that supports pedestrians. However, there are significant steps in this direction taking place throughout the world. For example, the city of Paris already has the highest mode share of walking in Europe but continues to enact policy to increase it. Policies have included banning cars and closing roads as part of implementing a “Paris for pedestrians” program and additionally, planning to become a 15-minute city. If these policies start spreading gloablly, the world will see large-scale benefits in a range of environmental, social, and economic areas.

Some improvements in the modeling could be expanding the scenarios to include the results of the achievement of more specified mode share goals (6%, 8% or 10%) by 2050 and more details on the results from the covid street measures.

## Limitations

Walkable cities is an important component for decarbonizing urban passenger transportation. However, some passengers are simply unable or unwilling to utilize walking as a mode and some geographical areas have climates and terrains that are not inviting for the use of walking. In some developing countries, car ownership is seen as a status symbol and walking is not. These obstacles can be overcome with the right type of walkable city matched to the place (15-minute city, transit oriented development, slow/shared/closed streets) and awareness campaigns and social agreements (Paris for Pedestrians).

## Benchmarks

As discussed above, adoption data is reported in different forms and requires adjustment for comparison. Therefore, it is difficult to find comparable (without adjustment) sources for benchmarking. Only one source reported adoption data that could be converted into percent of urban passenger travel and is benchmarked in Table 4.1.

Table . Benchmarks

| **Source and Scenario** | **Market Share in 2050 (%)** |
| --- | --- |
| (OECD/ITF, 2021) – Recover | 9.3% |
| (OECD/ITF, 2021) – Reshape | 12.1% |
| (OECD/ITF, 2021) – ReshapePlus | 12.2% |
| Project Drawdown – Plausible Scenario) | 5.0% |
| Project Drawdown – Drawdown Scenario | 5.5% |
| Project Drawdown – Maximum Scenario | 7.1% |

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# Glossary

**Adoption Scenario** – the predicted annual adoption over the period 2015 to 2060, which is usually measured in **Functional Units**. A range of scenarios is programmed in the model, but the user may enter her own. Note that the assumption behind most scenarios is one of growth. If for instance a solution is one of reduced heating energy usage due to better insulation, then the solution adoption is translated into an increase in use of insulation. There are two types of adoption scenarios in use: **Reference (REF)** where global adoption remains mostly constant, and **Project Drawdown Scenarios (PDS)** which illustrate high growth of the solution.

**Approximate PPM Equivalent** – the reduction in atmospheric concentration of CO2 (in **PPM**) that is expected to result if the **PDS Scenario** occurs. This assumes a discrete avoided pulse model based on the Bern Carbon Cycle model.

**Average Abatement Cost** – the ratio of the present value of the solution (**Net** **Operating Savings** minus **Marginal First Costs**) and the **Total Emissions Reduction**. This is a single value for each solution for each **PDS Scenario**, and is used to build the characteristic “*Marginal Abatement Cost*” curves when Average Abatement Cost values for each solution are ordered and graphed.

**Average Annual Use** – the average number of functional units that a single implementation unit typically provides in one year. This is usually a weighted average for all users according to the data available. For instance, total number of passenger-km driven by a hybrid vehicle in a year depends on country and typical number of occupants. We take global weighted averages for this input. This is used to estimate the **Replacement Time**.

**Cumulative First Cost** – the total **First Cost** of solution **Implementation Units** purchased in the **PDS Scenario** in the analysis period. The number of solution implementation units that are available to provide emissions reduction during the analysis period is dependent on the units installed prior to the analysis period, and hence all implementation units installed after the base year are included in the cumulative first costing (that is 2015-2050).

**Direct Emissions** – emissions caused by the operation of the solution, which are typically caused over the lifetime of the solution. They should be entered into the model normalized per functional unit.

**Discount Rate**- the interest rate used in discounted cash flow (DCF) analysis to determine the present value of future cash flows. The discount rate in DCF analysis takes into account not just the time value of money, but also the risk or uncertainty of future cash flows; the greater the uncertainty of future cash flows, the higher the discount rate. Most importantly, the greater the discount rate, the more the future savings are devalued (which impacts the financial but not the climate impacts of the solution).

**Emissions** **Factor**– the average normalized emissions resulting from consumption of a unit of electricity across the global grid. Typical units are kg CO2e/kWh.

**First Cost**- the investment cost per **Implementation Unit** which is essentially the full cost of establishing or implementing the solution. This value, measured in 2014$US, is only accurate to the extent that the cost-based analysis is accurate. The financial model assumes that the first cost is made entirely in the first year of establishment and none thereafter (that is, no amortization is included). Thus, both the first cost and operating cost are factored in the financial model for the first year of implementation, all years thereafter simply reflect the operating cost until replacement of the solution at its end of life.

**Functional Unit** – a measurement unit that represents the value, provided to the world, of the function that the solution performs. This depends on the solution. Therefore, LED Lighting provides petalumen-hours of light, Biopublic provides tera-watt-hours of electricity and high speed rail provides billions of passenger-km of mobility.

**Grid Emissions** – emissions caused by use of the electricity grid in supplying power to any operation associated with a solution. They should be in the units described below each variable entry cell. Drawdown models assume that the global electric grid, even in a Reference Scenario, is slowly getting cleaner, and that emissions factors fall over time resulting in lower grid emissions for the same electricity demand.

**Implementation Unit** – a measurement unit that represents how the solution practice or technology will be installed/setup and priced. The implementation unit depends on the solution. For instance, implementing electric vehicles (EV) is measured according to the number of actual EV’s in use, and adoption of Onshore Wind power is measured according to the total terawatts (TW) of capacity installed worldwide.

**Indirect Emissions** – emissions caused by the production or delivery or setup or establishment of the solution in a specified area. These are NOT caused by day to day operations or growth over time, but they should be entered into the model normalized on a per functional unit or per implementation unit basis.

**Learning Rate/Learning Curve** - Learning curves (sometimes called experience curves) are used to analyze a well-known and easily observed phenomenon: humans become increasingly efficient with experience. The first time a product is manufactured, or a service provided, costs are high, work is inefficient, quality is marginal, and time is wasted. As experienced is acquired, costs decline, efficiency and quality improve, and waste is reduced. The model has a tool for calculating how costs change due to learning. A 2% learning rate means that the cost of producing a *good* drops by 2% every time total production doubles.

**Lifetime Capacity** – this is the total average functional units that one implementation unit of the solution or conventional technology or practice can provide before replacement is needed. All technologies have an average lifetime usage potential, even considering regular maintenance. This is used to estimate the **Replacement Time**. and has a direct impact on the cost to install/acquire technologies/practices over time. E.g. solar panels generate, on average, a limited amount of electricity (in TWh) per installed capacity (in TW) before a new solar panel must be purchased. Electric vehicles can travel a limited number of passenger kilometers over its lifetime before needing to be replaced.

**Lifetime Operating Savings**–the operating cost in the PDS versus the REF scenarios over the lifetime of the implementation units purchased during the model period regardless of when their useful life ends.

**Lifetime Cashflow NPV**-the present value (PV) of the net cash flows (PDS versus REF) in each year of the model period (2015-2060). The net cash flows include net operating costs and first costs. There are two results in the model: Lifetime Cashflow NPV for a Single **Implementation Unit**, which refers to the installation of one **Implementation Unit**, and Lifetime Cashflow NPV of All Units, which refers to all **Implementation Units** installed in a particular scenario. These calculations are also available using profit inputs instead of operating costs.

**Marginal First Cost** – the difference between the **First Cost** of all units (solution and conventional) installed in the **PDS Scenario** and the **First Cost** of all units installed in the **REF Scenario** during the analysis period. No discounting is performed. The number of solution implementation units that are available to provide emissions reduction during the analysis period is dependent on the units installed prior to the analysis period, and hence all implementation units installed after the base year are included in the cumulative first costing (that is 2015-2050).

**Mode of Transport** – a type of transportation that is structurally unique such as car, bus, plane, or rail. Within each mode are several sub categories such as Bus Rapid Transit (BRT), High Speed Rail (HSR). There are some modes that are only used for passengers or freight and others that can be used by both.

**Net Annual Functional Units (NAFU)** – the adoption in the PDS minus the adoption in the REF in each year of analysis. In the model, this represents the additional annual functional demand captured either by the solution in the **PDS Scenario** or the conventional in the **REF Scenario**.

**Net Annual Implementation Units (NAIU)** – the number of **Implementation Units** of the solution that are needed in the PDS to supply the **Net Annual Functional Units (NAFU).** This equals the adoption in the PDS minus the adoption in the REF in each year of analysis divided by the average annual use.

**Net Operating Savings** – The undiscounted difference between the operating cost of all units (solution and conventional) in the **PDS Scenario** minus that of all units in the **REF Scenario**.

**Operating Costs** – the average cost to ensure operation of an activity (conventional or solution) which is measured in 2014$US/**Functional Unit**. This is needed to estimate how much it would cost to achieve the adoption projected when compared to the **REF Case**. Note that this excludes **First Costs** for implementing the solution.

**Payback Period** – the number of years required to pay all the **First Costs** of the solution using **Net Operating Savings**. There are four specific metrics each with one of **Marginal First Costs** or **First Costs** of the solution only combined with either discounted or non-discounted values. All four are in the model. Additionally, the four outputs are calculated using the increased profit estimation instead of **Net Operating Savings**.

**PDS/ Project Drawdown Scenario** – this is the high growth scenario for adoption of the solution

**PPB/ Parts per Billion** – a measure of concentration for atmospheric gases. 10 million PPB = 1%.

**PPM/ Parts per Million** – a measure of concentration for atmospheric gases. 10 thousand PPM = 1%.

**REF/ Reference Scenario** – this is the low growth scenario for adoption of the solution against which all **PDS scenarios** are compared.

**Regrets solution** has a positive impact on overall carbon emissions being therefore considered in some scenarios; however, the social and environmental costs could be harmful and high.

**Replacement Time**- the length of time in years, from installation/acquisition/setup of the solution through usage until a new installation/acquisition/setup is required to replace the earlier one. This is calculated as the ratio of **Lifetime Capacity** and the **Average Annual Use**.

**TAM/ Total Addressable Market** – represents the total potential market of functional demand provided by the technologies and practices under investigation, adjusting for estimated economic and population growth. For this solutions sector, it represents world and regional total addressable markets for electricity generation technologies in which the solutions are considered.

**Total Emissions Reduction** – the sum of grid, fuel, indirect, and other direct emissions reductions over the analysis period. The emissions reduction of each of these is the difference between the emissions that would have resulted in the **REF Scenario** (from both solution and conventional) and the emissions that would result in the **PDS Scenario**. These may also be considered as “emissions avoided” as they may have occurred in the REF Scenario, but not in the PDS Scenario.

**Transition solutions** are considered till better technologies and less impactful are more cost effective and mature.

**TWh/ Terawatt-hour** – A unit of energy equal to 1 billion kilowatt-hours

1. Non energy-related emissions include land use change emissions (including deforestation), and methane and F-gas release from agriculture, refrigeration, and industrial activity. [↑](#footnote-ref-1)
2. For most results, only the differences between scenarios, summed over 2020-2050 were presented, but for the net first cost, the position was taken that to achieve the adoptions in 2020, growth must first happen from 2015 to 2020, and that growth comes at a cost which should be accounted for, hence net first cost results represent the period 2015-2050. [↑](#footnote-ref-2)
3. The functional unit is the unit measuring the society function provided by the technology, in this case – mobility. [↑](#footnote-ref-3)
4. The implementation unit is the unit measuring installation of the technology. As the focus is on encouraging travelers to use existing systems, which are expected to provide an indication of value to public authorities as well as increased financial security, this would lead to improvements in service levels to match demand which in turn would lead to increased ridership resulting in a virtuous cycle. [↑](#footnote-ref-4)
5. The Organisation for Economic Cooperation and Development, with membership as at the end of 1990 (this was chosen to match the AMPERE model used by the IPCC and developed by the International institute for Applied Systems Analysis (IIASA). See [www.iiasa.ac.at](http://www.iiasa.ac.at) ) [↑](#footnote-ref-5)
6. In some cases, the low boundary is negative for a variable that can only be positive, and in these cases the lowest collected data point is used as the “low” boundary. [↑](#footnote-ref-6)
7. Some solutions such as Electric Vehicles and High-Speed Rail increase the demand for electricity and reduce the demand for fuel. [↑](#footnote-ref-7)