SALT LAKE COUNTY
PLANNING & TRANSPORTATION

SALT LAKE COUNTY
REGIONAL SOLUTIONS
FALL 2022

CLEAN AIR COMMUNITIES

Rethinking Land Use to Facilitate Cleaner Air

Air quality in the Salt Lake Valley is a complex problem and has repeatedly been shown as a top concern for Utah residents. Many people with different expertise are researching air quality in order to create and implement more solutions across all scales. Some solutions for improving air quality come from an upper level of required regulation. Solutions on the other end may entail an individual household's self-regulation. A need for change at all levels is being more widely recognized and accepted.

Recognizing the long-term impacts that the built environment can have on air quality, developers, planners, governments, and citizens should start looking at investments in land uses, development patterns, and buildings that are focused on reducing poor air quality in our communities now and into the future. Recognizing the immense leverage that both community partners and public desire can have on air quality, the intent of this report is to summarize the biggest issues and generate new ideas to move Salt Lake County's long-term air pollution in a positive direction.

We hope that those reading this report will inspire others to think outside of the box within the communities they serve and live in to make positive long-term changes to where and how we build places so future generations will have cleaner air and better health outcomes.

CLEAN AIR COMMUNITIES

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Executive Summary

Each of the areas that are focused on in this report were identified based on the understanding that buildings and vehicles are both large sources of pollution within Salt Lake County.

First, an overview of the larger picture of air quality in Utah and why it is a problem is laid out.

Understanding larger industrial source pollution and its potential harm is a good baseline to make land-use decisions that protect the public's health, safety, and well-being.

Cities have the power of laying the foundational groundwork in how land use is planned, but the public, developers, contractors, and financial institutions are often those on the ground making development happen.

Cities can adopt more sustainable building codes, but contractors may need to act as part of a greater good, recognizing that the physical buildings they create will have long-term impacts on air quality.

Beyond buildings, good community design can drive improvements in air quality on a large scale while also improving other quality of life factors.

01
The Air Quality Problem

Figure 1. Photo by Michael Tuszynski on Unsplash

Indigenous people of Utah documented poor air quality prior to 1847. They noted a "blue smoke" hanging on the top of the Salt Lake valley, providing evidence that Utah's bad air quality existed and was known about for more than one century.

Municipal regulation of the nuisance of smoke was suggested later in 1881 to control business smoke discharge and reduce outdoor air pollution. Salt Lake City passed the first air quality ordinance in 1891, which put a daily fine for excessive smoke into place. However, Salt Lake Telegram pointed out in 1912 that the health impact due to air quality pollution was not truly being paid for by the fines within the air quality ordinance regulations.[1]

The first research to study the effect of air pollution and health impact did not occur until the 1920s and temperature inversions that were trapping pollution during the winter was not discovered until research in the 1950s. An air inversion occurs when a layer of cold air is trapped underneath a layer of warmer air in the atmosphere during Utah's winter. Research has continued over time to better understand the relationship between air pollution and meteorology.[2]

[1] Williams, "'It's Not a New Problem.'"

[2] Williams.

Utah's geography sets it up for air inversions to occur as mountains increase the strength of inversions. During the winter season, less cold and warm air mix as the ground stays cold for an extended time. Inversions frequently occur after snowstorms as sunlight is reflected off the snow and warms the atmosphere while the ground itself and the air near it stays cold. The warmer air higher in the atmosphere traps the cooler air near the ground, causing a temperature inversion.[3] In summer, air pollution is caused by ozone. Ozone is a haze of microscopic particles, classified by their size: 2.5 microns. These PM2.5 particles are formed through chemical and photochemical reactions rather than direct emission in the atmosphere. Nitrogen Oxide (NOx), volatile organic compounds (VOCs), Sulfur Dioxide (SO2), and Ammonia (NH3) emitted into the environment from vehicles, buildings, and other sources are a precursor to PM 2.5 increasing.[4] Today, the Utah Department of Environmental Quality's subdivision of the Department of Air Quality is the primary department that reports current air conditions for different counties. Air quality monitoring includes PM 2.5, Ozone, temperature, and wind. With air quality changes throughout the day, the air quality index (AQI) is used to indicate current air quality.[5]

Air quality is measured with a network of sensors of various grades. EPA certified sensors are less prevalent but are the most accurate and scientifically-sound monitors. Community level sensors such as Purple Air and AirU sensors fill in gaps in the air quality network and are commonly hosted at individual homes and businesses. These do not produce reliable scientific data as they can be placed in locations or have sensor issues that do not produce accurate data, but they are still an important and useful part of the air quality network. Altogether, thousands of air sensors are constantly monitoring real-time changes, providing residents with important air-quality data. The Real-Time Air Quality Index Visual Map is an excellent example to access the location of sensors.[6] Most of the scientific EPA level sensors are located close to freeways, major construction, or mining sites. These high-quality sensors don't have a wide disbursement to capture air quality in many of the residential communities in Utah.[7] The built environment, consisting of buildings and homes, creates a large area source, which is the second most significant air pollution source in Utah. It is necessary to pay more attention to this source of pollution as it will have long term impacts on air quality.

Air pollution has been shown to have a significant impact on human health. Vehicle emissions, oil burning, natural gas fuel, coal fuels, and chemical products used in industries such as paint and pesticides are all anthropogenic air pollution sources. In Utah, wildfire smoke from large fires in California has recently been notable to atmospheric researchers, who began looking at the ways which smoke traveled and how it affected local air quality beyond when fires were extinguished. They found that smoke from wood, wildfire, and fireworks has greater impacts on health as the particles are physical in nature in nature instead of chemical and are more likely to enter homes and affect indoor air quality. [8]

In 1993, a NIEHS study was the first to establish an association between fine particulate matters and mortality. The study found that primary health problems caused by air pollution are respiratory diseases, including early lung development, emphysema, asthma, chronic obstructive pulmonary disease, and bronchitis. Due to fine particles mainly being suspended in air, they also impact the cardiovascular systems. Impaired blood vessel function, artery calcification, hemorrhagic stroke, and decreased high-density lipoprotein have been proved to correlate with PM. In worst cases, exposure to methylene chloride in the air may increase the chance of breast cancer. The most vulnerable populations affected by air pollution are the elderly, children, pregnant women, and the immunocompromised population.[9]

Due to the microscopic size of PM 2.5, particles get trapped deep in the lungs, increasing asthma, especially in children, since children breathe faster than adults.[10] Pneumonia is a common disease in older adults who suffer from the effects of poor air quality. In most cases, they initially develop pneumonia, and will the die from

[3] Utah DEQ, "Inversions."
[4] Utah DEQ.
[5] Utah DEQ, "Utah DAQ: Trend Charts."
[6] The World Air Quality Index, "Air Pollution in Utah."
[7] "Air Quality Laws and Rules - Utah Department of Environmental Quality."
[8] Mendoza, Benney, and Boll, "Long-Term Analysis of the Relationships between Indoor and Outdoor Fine Particulate Pollution."
[9] NIEHS, "Air Pollution and Your Health."
[10] "Recess Guidance Protects Kids During Poor Air-Quality Days."

pneumonia once in the hospital.[11] Research shows that air pollution can cause premature death in Utah up to 8000 each year and average life expectancy decreases between 1.1 to 3.6 years.[12] By controlling air pollution, Utah will save 500 million per year by 2030.[13]

Utah Air Quality Board created the Utah Air Conservation Act based on Title 19, Chapter 2 of the Utah Code. The UAQB also has administrative rules to inform public. Utah citizens have opportunities to influence law making related to air quality by mailing comments to state agencies. Current air quality rules including index of all air quality rules, state implementation plan, and Utah division of air quality rules. All Utah air quality rules will be reviewed every five years. All public comments will be considered to make changes.[14]

As Utah's air quality does not meet federal standards as determined by the EPA, additional regulations have been implemented to bring problem areas into attainment. Regulations are tighter in EPA non-attainment areas and areas are rated on eight levels from "marginal" to "extreme."[15] As of April 15, 2022, the EPA was looking at changing Northern Wasatch Front's non-attainment status from "marginal" to "moderate" due to failure to meet the 2015 air quality standards by 2021.[16]

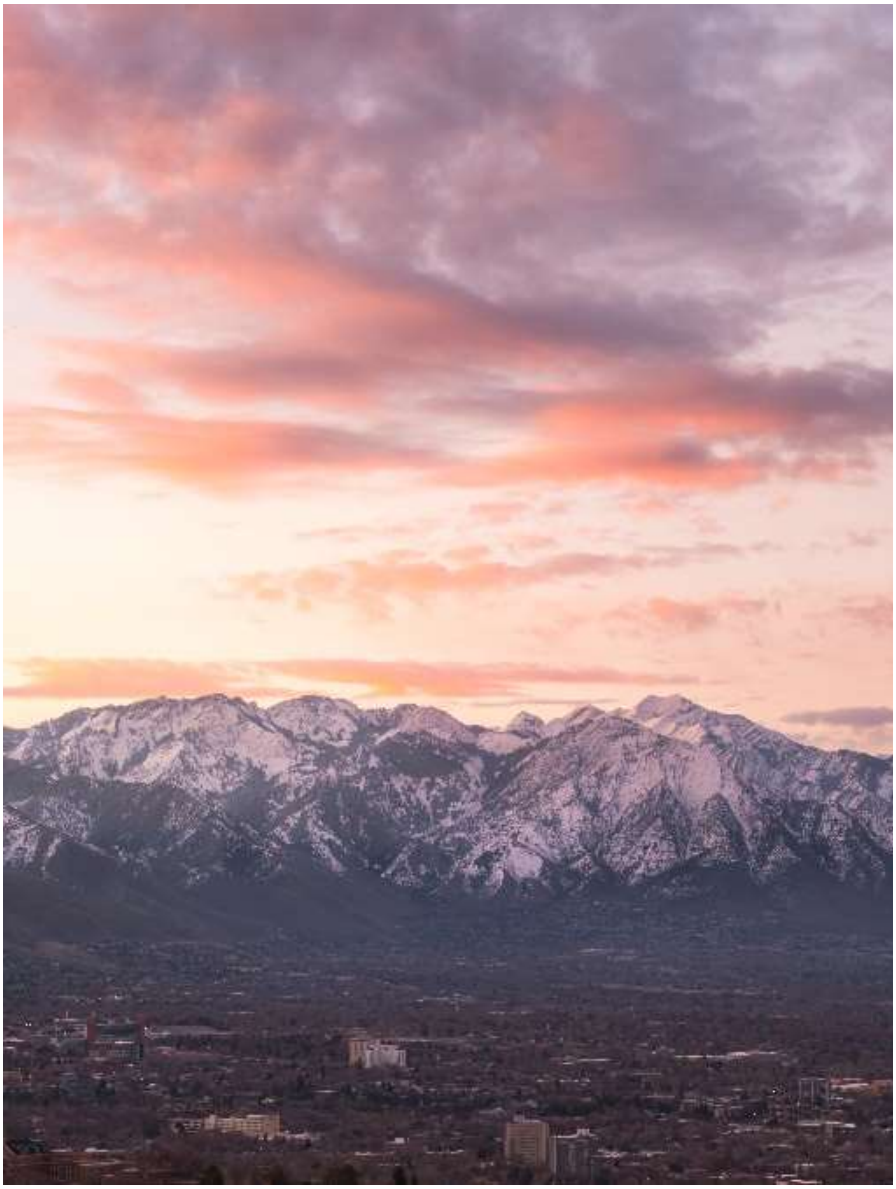

Figure 2. Photo by Jake Weirick on Unsplash

[11] Pirozzi, "Bad Air Quality along Utah's Wasatch Front Causes More than 200 Pneumonia Cases Each Year."
[12] Errigo et al., "Human Health and Economic Costs of Air Pollution in Utah."
[13] Errigo et al.
[14] "Air Quality Laws and Rules - Utah Department of Environmental Quality."
[15] US EPA, "Ozone Designation and Classification Information."
[16] Cobabe and KSLNewsRadio, "Proposed EPA Action on Utah Air Quality Applauded by Advocates."

02

Industrial Pollution

Figure 3. Photo by Patrick Hendry on Unsplash.

Industrial source pollution is a type of point, non-mobile pollution that can contribute to poor air quality. Industrial sources of pollution can include both small PM2.5 particulates and larger PM10 particulates. Industrial sources of pollution may also include additional chemicals that are harmful to human health present in the emissions.

Examples of point-sources are oil refineries, power production, and chemical processing plants.[17]

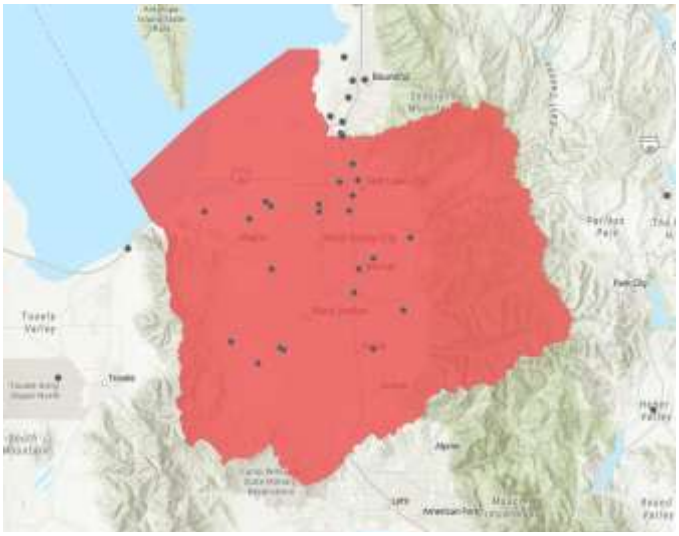

Figure 4. Map of point sources categorized as "major" on the EPA registry.

[17] Sells, "Taking Stock of Emissions in Utah."

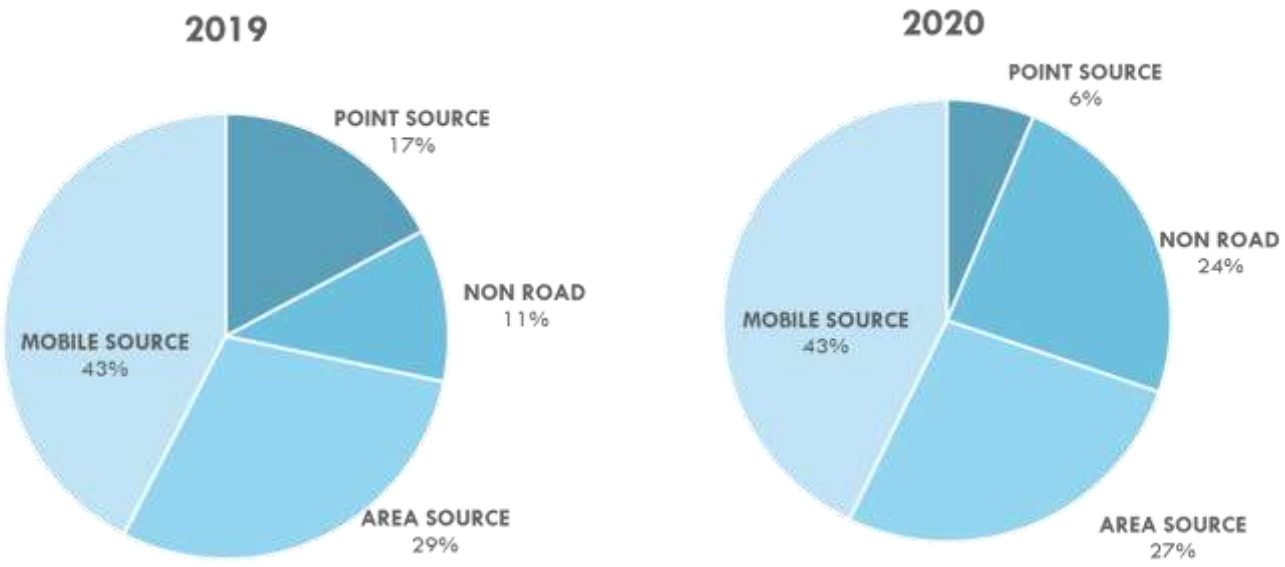

Figure 5. Wasatch Front Sources of Air Pollution 2019 and 2020.

Considering the negative impacts industrial sources of pollution can have on human health, awareness around where major industrial sources of pollution are located does and should continue to influence land development and where we choose to build communities.

Rio Tinto Kennecott

Kennecott Copper has long been a large pollution emitter in Salt Lake County, but regulations and technology have improved the pollution they are emitting over time. In 1995, Kennecott converted their smelting process to a flash smelter, which dramatically reduced emissions, as seen in this chart from Metso: Outotec (see Figure 6).

Data from the Utah DAQ in 2017 shows that Rio Tinto Kennecott contributed more than half of all sulfur dioxide emissions in the Wasatch Front at that time, though this has certainly decreased after retiring the last coal powered plant in 2019.

Figure 6. Smoke from Kennecott Smelter 1936. Source: Utah Historical Society.

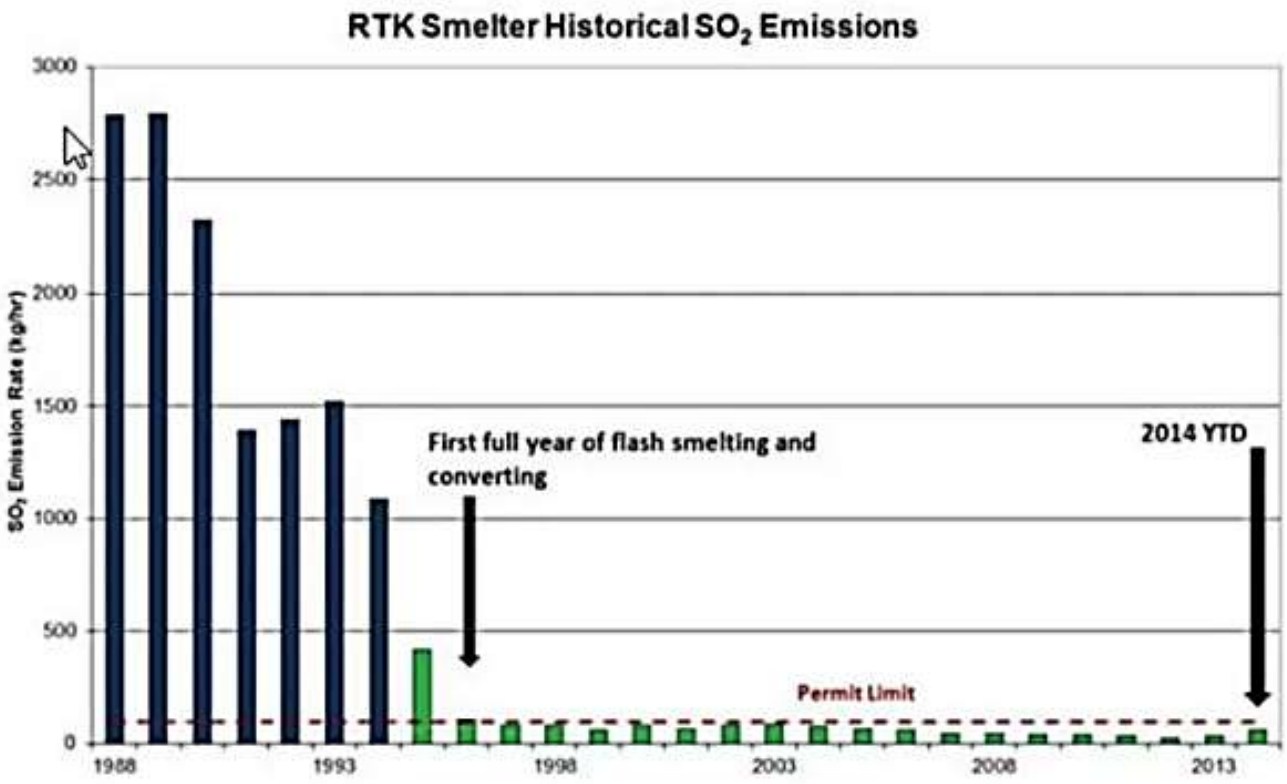

Figure 7. Historical SO2 Emissions from the Rio Tinto Kennecott Smelter.

After an argument to the Utah Air Quality Board by Western Resources Advocates that the Clean Air Act required Kennecott to stop burning coal year-round instead of just in the winter, Rio Tinto decided to shut down their last coal-fired plant as of May 2019. This move cut emissions by 6,000 tons and reduced Rio Tinto Kennecott's carbon footprint by 65% annually, which is "equivalent to 2,218,055,501 miles driven by an average passenger vehicle."[18] Rio Tinto has continued to transition to clean and renewable energy, using certified clean energy from Rocky Mountain and natural gas power generation becoming one of the industry's cleanest. In addition to cleaner power sources, Rio Tinto Kennecott also has increased power efficiency by using a combined heat and power system and is working toward a net-zero emissions goal. [19]

Refineries and Tier 3 Gas

Refineries as a group are the 2nd largest industrial source of pollution after RTK. They are subject to regulation on a federal and state level and must have a SIP.

Tier 3 gas is a low sulfur gas that reduces NOx and VOC, reducing air pollution outputs both in its production at refineries and for vehicles using it. While Tier 3 gas substantially reduces emissions in all vehicles, vehicles made in 2017 or later are optimized for Tier 3 gas and emissions are reduced by 80% in these cars.

Local refineries started producing Tier 3 gas in 2019, and four of the five refineries in the Wasatch Front have currently upgraded to Tier 3 gas production. Tier 3 gas is reliably found at specific gas stations who use gas produced by these four refineries. Retailers that purchase a mix of gas from all five refineries cannot state that they consistently have Tier 3 gas available. The

[18] Walker, "Kennecott Utah Copper Shuts Down Its Last Coal-Fired Plant"; Roth, "Utah's Polluters: Miners and Refiners."

[19] Copper Alliance, "Rio Tinto Advances Clean Energy at Kennecott - Copper Alliance."

remaining refinery, Big West Oil, is beginning its process of conversion to Tier 3 standard as of November 2021.[20] With all refineries in Utah producing tier 3 gas, there will be more consistent/reliable tier 3 gas use. Tax incentives passed by the Utah legislature were key to this transition.

Local governments are setting an example and taking action to make an impact as seen by Salt Lake County requiring the use of Tier 3 gas in all county vehicles as of Oct. 2021.[21] With other organizations acting similarly, this can have a wide-scale impact as it involves a large number of vehicles. As all refineries are converted and Tier 3 gas becomes standard at all gas stations, the impact will further multiply. Taking action now before Tier 3 is universally available is a simple action that organizations and individuals can make every time they fill up their gas tank.

Today, we recognize that refineries should not be located in populated areas and acknowledge that if we were building refineries today, that they would not be located where they are today because of the impacts of large-scale pollution on human health. The amount of monetary investment in the infrastructure of refineries makes it cost-prohibitive to relocate them. Future land use decisions may incentivize the relocation of refineries over expansion.

As the population expands and more people are within the 30-mile radius of refineries where they are at an increased risk of cancer and other health impacts, the cost of relocation may become a higher priority over increasing regulation.[22]

Other Mining: Gravel and Construction Materials

Gravel and construction materials are prevalent throughout Utah and the Wasatch Front. Gravel and sand materials are deposits from ancient oceans, Lake Bonneville, uplift, and glaciation.[23]

This type of mining and crushing operation creates large amounts of dust (PM10), which can be exaggerated by Utah's dry, arid, climate. Mitigation measures are taken to reduce fugitive dust and mining companies must operate within permitted amounts. Regulations for mining operations are controlled by the Utah Division of Air Quality (DAQ), which requires that any dust clouds that leave the property do not have an opacity density (amount of light that can pass through) of more than 10%.[24]

Many groups involved in public health and air quality have questioned why gravel and rock mining industries need to be located in close proximity to where the majority of the population in the state lives.[25] Leaders argue that they need to be close to population centers where construction is occurring to save on transportation and other costs. In 2019, the state legislature created protections for the expansion of "critical infrastructure materials" operations and limited what cities and counties can include in their ordinances with HB 288. These protections extend to mining operations specifically for "critical infrastructure materials" that are already established or have a vested right due to the submission of a conditional use permit.

Recognizing a potential for new mining or gravel operations in the Wasatch Mountains, Salt Lake County council voted on April 5th, 2022, to update their land ordinances to not allow mining on lands in the Forest and Recreation (FR) zones.[26]

Industrial Clean Energy Transition Example

Rio Tinto Kennecott and the local refineries are both examples of how improvements can be made for cleaner air within our local airshed, other communities are seeing improvements in point source pollution reduction as well.

Using systems thinking can refine processes to better harness waste energy and make that energy usable. Systems that reduce waste and create a smaller closed system processes are more efficient and create less pollution.

[20] "Big West Oil Proceeds with Honeywell to Revamp Alkylation Unit."
[21] "Cleaner Burning Gas Now Used by All Salt Lake County Government Vehicles."
[22] Williams et al., "Proximity to Oil Refineries and Risk of Cancer."
[23] "Glad You Asked."
[24] Utah Office of Administrative Rules.
[25] Gillie, "House Considers New Bill to Protect Sand, Gravel and Rock Operations."
[26] "Salt Lake Co. Council Bans Mining in Canyons, Foothills."

International Example

Throughout western Europe, waste product including tires, wood, plastics, chemicals, treated municipal solid waste, and other types of waste are co-combusted in cement kilns in large quantities. Cement kilns are well-suited for waste combustion because of their high process temperature and because the materials needed (clinker and limestone) act as gas-cleaning agents. In this process, fossil fuels are replaced with alternative fuels that otherwise would have been incinerated or landfilled, contributed to lower overall CO2 emissions.[27]

Regulation

Point sources are large enough contributors to pollution that they are monitored and regulated by the state and federal government and are required to submit information about their emissions. Regulation is an essential first step to addressing industrial pollution. Regulation occurs at both federal and state scales and has been a key tool in reducing pollution by putting limits on industrial outputs.

Industrial sources create a large amount of pollution among few actors (as compared to many individual actors creating a large area source), and regulating these sources is an important piece in making substantial positive movement toward cleaner air.

Overall, large industry in Utah has reduced emissions by 47 percent since 1995 as a result of state and federal requirements.[28] The State has been working on State Implementation Plans (SIPs) for the last decade.[29] SIPs require significantly reduced emissions from a variety of small and large sources, including industry, household chemicals, paints, and other ambient area sources.[30] SIPs will continue to decrease pollution from industrial sources.

Areas that could use more regulation and reporting is on methane gas leakage as 2017 research shows leaks at both power plants and refineries have been shown to leak at higher rates than previously thought.[31] As other sources of pollution are better understood, it is imperative that they are looped into state regulations and SIPS so that they can be addressed.

Recommendations

Moving forward, there are actions that can be taken to continue to reduce industrial sources of pollution and mitigate its effects. Overall, reducing emissions from their source is far better than trying to mitigate the effects.[32]

The World Green Building Council has made recommendations for addressing industrial sources of pollution in cities.[33]

These include:

1. Requiring all commercial and industrial processes to use ultra-low sulfur diesel
2. Retrofitting and controlling emissions from existing power plants with the shift away from coal and requiring new power plants to use cleaner fuel such as natural gas, or hydrogen.
3. Incentivizing local power companies to promote the development of renewable energy for generating electricity

As noted in the recommendations by the World Green Building Council, there are multiple changes that Industry itself can take on. As communities move toward cleaner energy and reduce their reliance on coal power, decreases in major sources of pollution will continue to decline. Using cleaner energy sources can have a significant impact, as was seen when Rio Tinto Kennecott moved to natural gas from coal.

AltEnergyMag outlined three additional strategies for industrial manufacturing beyond moving to clean energy that are applicable to industrial pollution in general.[34]

These include:

- Using technology to eliminate pollution at the source with the use of Catalytic oxidizers, regenerative thermal oxidizers (RTOs), and rotary concentrators.
- Choosing non-toxic materials to produce goods

[27] "Clean Energy Solutions Center | Renewable Energy in Industrial Applications: An Assessment of the 2050 Potential."
[28] Call, "Understanding the Sources and Causes of Utah's Air Pollution."
[29] ABC4 Utah, "Utah's Air Quality May Not Be as Bad as You Think."
[30] Envision Utah, "Your Utah, Your Future - Background."
[31] Lavoie et al., "Assessing the Methane Emissions from Natural Gas-Fired Power Plants and Oil Refineries."
[32] "Improving Air Quality in High Density Cities."
[33] "Improving Air Quality in High Density Cities."
[34] Huntington, "Readers Choice 2020."

- Use more effective and efficient enterprise planning to better balance supply and demand as manufacturing goods that are not needed contribute to air pollution.

The EPA and state could increase regulations on industrial sources of pollution directly as well. California's population density has pushed them to have more regulations to reduce air pollution than other states may have. Market based approaches like cap and trade that were initially used in California were imbalanced. Direct regulation has shown to have a much larger impact and have been key to reducing air pollution in California, at the source.[35]

State legislation can also use regulatory power and/or incentives/disincentives to move industry toward making changes that reduce air pollution, as seen in the state's incentives for refineries moving to Tier 3 gas.

On a community scale, cities can ensure to maintain appropriate buffers and transitions between land uses to ensure that people are not living within close proximity to highly concentrated industrial pollution sources. Implementation of buffers between land uses can become increasingly difficult for cities as development pressure for limited amounts of land increases.

As more people live near industrial sources of pollution, it can create pressure to relocate those industries to less populated areas.

Stericycle, a medical waste incineration facility in North Salt Lake, has faced public pressure to relocate in addition to fines and additional oversight due "exceeding its emissions limits and rigging its stack tests."[36] Public awareness and involvement can serve as a type of grassroots regulation and monitoring, making it harder for polluters to attempt to side-step air quality regulations. Several advocacy groups within Utah continuously advocate for action to address cleaner air.

Salt Lake County's West General Plan includes several goals and strategies to mitigate the impacts between incompatible land uses (i.e. between industrial uses/sources of pollution and residential areas). These include:

- Establish vegetation buffers
- Use appropriate zoning and setbacks
- Consider impacts of mining on roads
- Communicate with mining companies on reclamation
- Use dust suppression techniques

Counties and cities can examine their ordinances and make changes to address air pollution caused by industrial sources. Zoning and planning are ways in which air pollution in general and industrial pollution sources specifically can be addressed. Millman Land highlights that in 2016, Newark, NJ passed an ordinance requiring industrial and commercial developments to submit an environmental checklist with their application. And in Commerce, California, a Green Zones Policy was established that "prohibits specific industrial uses in proximity to sensitive or residential areas."[37] Addressing air pollution can certainly be an issue that would fall under public health, safety, and welfare.

Overall, a collective drive by government, industry, and citizens toward reducing toxic outputs at all scales are good goals to actively work toward.

Figure 8. The Great Salt Lake; Photo by Adam Thomas on Unsplash

[35] The Times Editorial Board, "Editorial: Regulators Must Force Oil Refineries to Cut Smog - Los Angeles Times."

[36] "Medical Waste Incinerator Agrees to Pay $2.6M to Resolve Alleged Clean Air Violations."

[37] Land, "How Zoning Laws Can Help Reduce Pollution."

03

Residential and Commercial Buildings

Figure 9. Salt Lake City; Photo by Brent Pace on Unsplash

Outdoor / Ambient Air Quality

Health-Related Air Quality

Today 27% of ambient air pollution in Utah is tied to buildings, the second-largest categorical source, only behind vehicles. However, by 2050 it is expected to more than double to 56%, to become far and away from the largest point source category (see Figure 9).[38] This is good and bad news. The good - this comes largely through policy and regulation that target other sources of pollution like vehicles and industrial sources, and through better land-use planning. The bad - there is very little policy regulation for building design and construction practices. Additionally, with the State population expected to close to double by 2050, development and construction must work hard

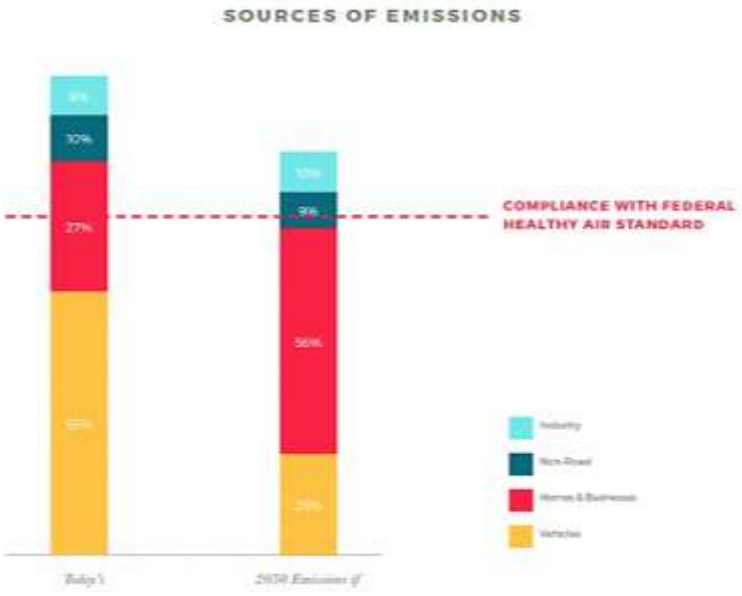

Figure 10. Current and future sources of emissions in Utah from Envision Utah, "Your Utah, Your Future".

[38] Envision Utah, "Your Utah, Your Future - Background."

to keep up, leaving less ability or incentive to reduce air pollution impacts.

Within building operations, nearly all the air quality emissions occur due to the building's energy usage, some of which have impacts on local air quality. Seventy million homes and businesses across the US use combustion-based energy to power furnaces, water heaters, and gas stoves. Combustion of natural gas and biomass will release carbon dioxide, particulate matter (PM 2.5 and 10), and volatile organic compounds among other pollutants. These emissions can create localized point sources for pollutants throughout our cities that lead to health impacts and even death. Based on a research paper from Harvard, building-sourced particulate matter resulted in at least 17,000 premature deaths across the US in 2017. Thankfully, Utah was a lot better off than most states with only 32 premature deaths (see Figure 10).[39]

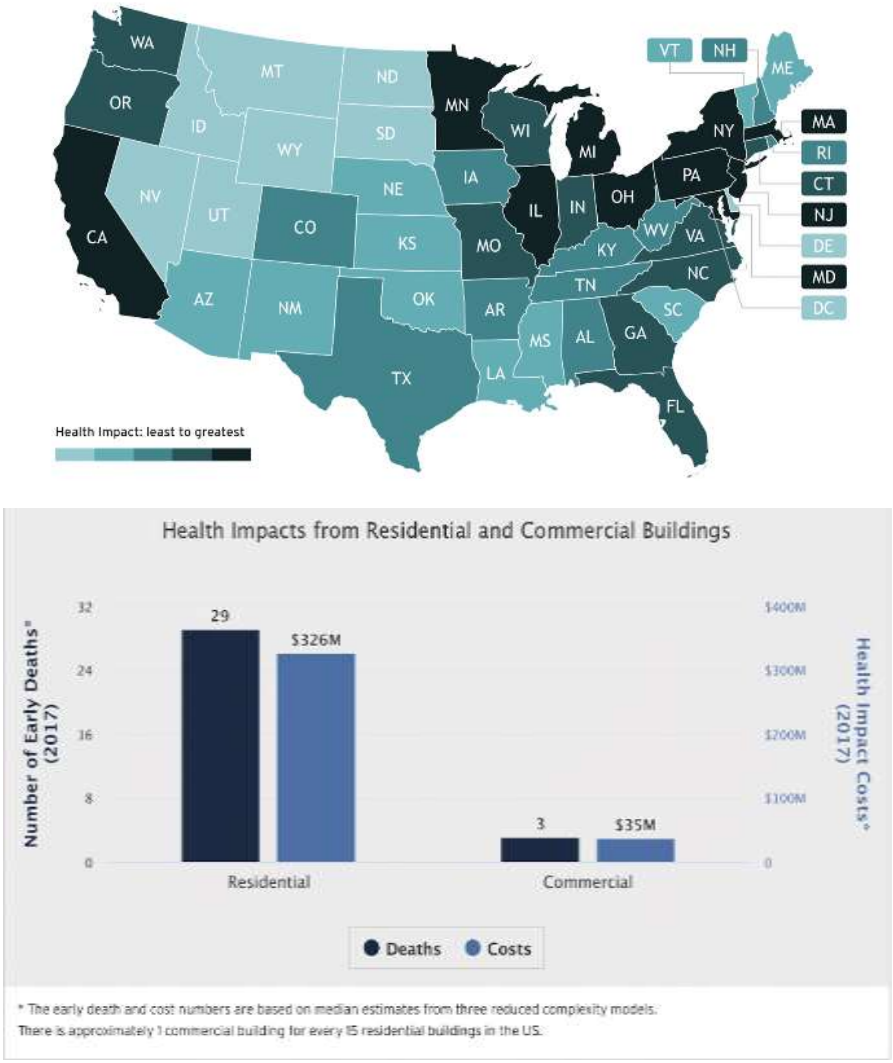

Figure 11. Harvard research showing the health impacts, deaths, and costs of air pollution produced by buildings and homes.

Building construction too has significant impacts on ambient air quality during all stages in the process: demolition, excavation, construction, and renovations. Particulate matter especially is impacted with a measurable impact tied to construction for areas closer to the site. For example, researchers found that the demolition of three high-rise public housing sites in Chicago resulted in a 74% increase in PM10 levels measured 100 meters downwind of each site.[40] Other research has shown that the increase in PM10 measured around a construction site corresponds to an increase in respiratory disease risk.[41] Within growing major cities there are often several of these construction projects occurring simultaneously, which can have a significant impact at the city scale. For example, the London Atmospheric Emissions Inventory (LAEI) estimated that construction related activities accounted for 1.4% of total PM10 levels for the city as a whole in 2010.[42]

Greenhouse Gas Emissions

In addition to health impacted air quality, those listed as NAICs, greenhouse gasses like CO2 are another intensive impact from our buildings. Buildings present important

[39] Buonocore et al., "A Decade of the U.S. Energy Mix Transitioning Away from Coal."
[40] Dorevitch et al., "Demolition of High-Rise Public Housing Increases Particulate Matter Air Pollution in Communities of High-Risk Asthmatics."
[41] Bansal, Singh, and Sawhney, "Effect of Construction Materials on Embodied Energy and Cost of Buildings—A Case Study of Residential Houses in India up to 60 M2 of Plinth Area."
[42] Azarmi and Kumar, "Ambient Exposure to Coarse and Fine Particle Emissions from Building Demolition."

point sources of carbon emissions, particularly through gas, oil, or propane-powered appliances. 39% of CO2 emissions globally are attributed to buildings. This produces approximately 600 million tons of CO2 and accounts for one-tenth of all US CO2 emissions.[43] Although not an important factor in health-related air quality, CO2 plays an important role as a greenhouse gas with climate change impacts.

The larger share, 28%, comes from building operation which includes air conditioning, heating, lighting, and any other energy usage of houses and buildings. Air conditioning especially is expected to see huge growth in the future. With a warmer global climate and increasing demand in the developing world nations, the IEA predicts that by 2050 the total number of air conditioners will more than double from 2 trillion units to 5.5 trillion units (see Figure 11).[44]

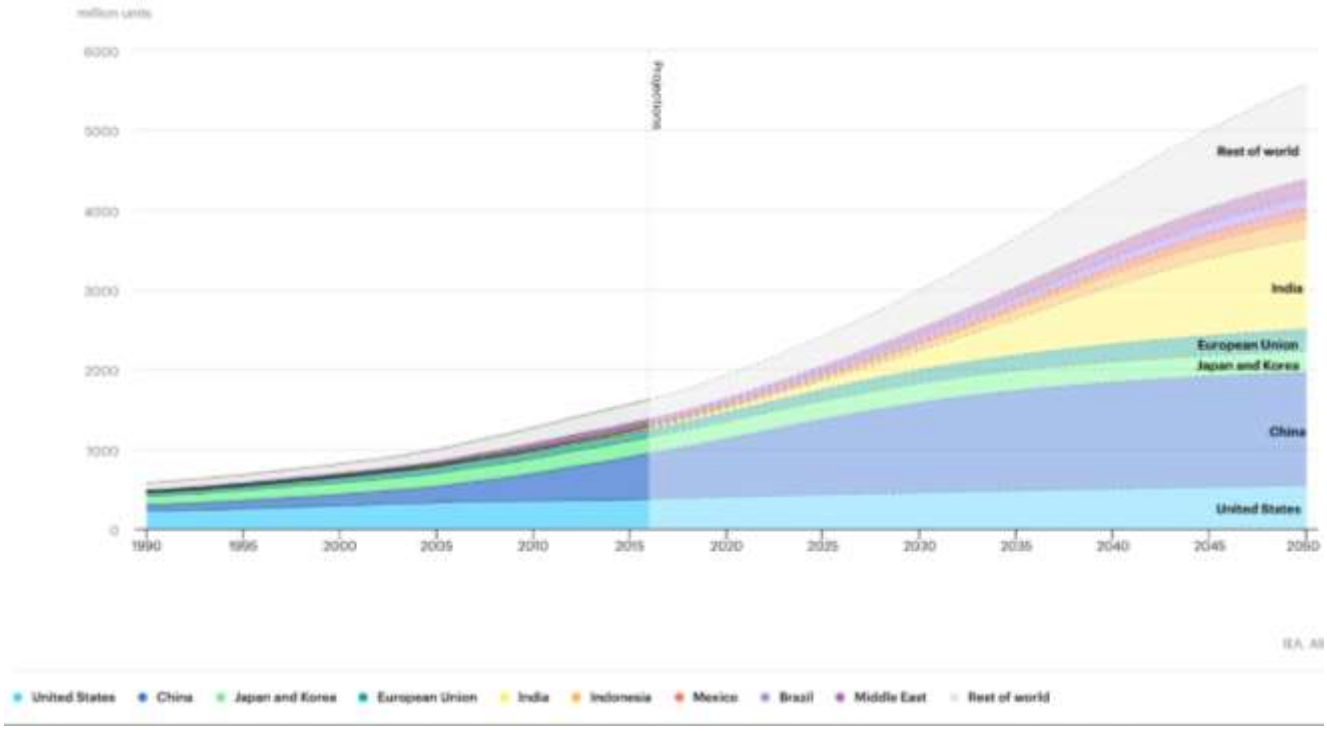

Figure 12. Global share of air conditioning units by country. Source: IEA

The other 11% of buildings as a share of global carbon emissions is a result of construction, demolition, and renovation of buildings. While this has only one-time impacts, the scale of development creates a nearly continuous process fed by growth. All parts of the construction process have impacts from excavation and drilling, which kick up the particulate matter, the use of combustion-powered heavy machinery and vehicles throughout, renovation, and demolition which creates waste materials- involving dust and hazardous materials.[45]

Policy Recommendations

Wood Stove and Fireplace Replacement Program

Wood burning stoves and fireplaces have the most significant local impact out of any air quality concern. Thankfully, they are somewhat infrequent in major cities in the US, largely in the more rural and remote areas without energy connectivity. However, some older homes still utilize wood-burning on-site for heating. Salt Lake County has already created a rebate program to help convert these wood-burning fireplaces to gas or electric. We would push harder toward electric fireplaces than gas, but either option represents a positive step forward in reducing emissions.

[43] "Health Air Quality Impacts of Buildings Emissions."
[44] "Global Air Conditioner Stock, 1990-2050 – Charts – Data & Statistics - IEA."
[45] Azarmi and Kumar, "Ambient Exposure to Coarse and Fine Particle Emissions from Building Demolition."

Electric Appliances

One of the strongest methods to reduce the effect of building ambient air quality impacts is through appliance upgrade rebate programs. Many cities provide a rebate program to help encourage when the appliance breaks it is replaced with a more energy-efficient version. Salt Lake City specifically has a program run in a partnership with Dominion Energy, the local natural gas provider, to replace gas appliances with more energy-efficient gas appliances, with a few hundred dollars provided as a rebate according to the appliance energy star rating.[46]

While energy efficiency upgrades are a good start, a more complete solution would be to encourage a transition to electric appliances, again through a rebate program. This would remove 100% of the building operation air quality impacts, and given an electricity system transition toward renewable energy, mean lower greenhouse gas impacts. This also means partnering with the electric provider instead of natural gas to administer the rebate program.

Renewable Energy Tax Credit

Both the State of Utah and the Federal Government administer a tax-incentive program for renewable energy projects. While these extend to other renewable energy projects, for most building owners these are used for rooftop solar. The Federal Income Tax Credit will cover 26% of the qualified renewable energy project costs accrued in 2022, or 22% in 2023. The tax credit has been in the process of ramping down from a 30% credit in 2019 and is set to expire in 2024 unless extended.[47] Qualified projects include "solar electric property, solar water heaters, geothermal heat pumps, small wind turbines, fuel cell property, and qualified biomass fuel property."[48]

Utah's residential Renewable Energy Systems Tax Credit too is in the process of winding down from 2020 and expiring in 2024. Presently, it offers 25% of project costs capped at $800 work installations during 2022 and a $400 cap in 2023. Commercial buildings are eligible for the Commercial Investment Renewable Energy Tax Credit instead. This program offers 10% off a qualified renewable energy project cost up to $50,000, with no set program expiration date.[49]

First, we recommend putting pressure on the state and federal governments to continue renewable energy tax credit programs. Short of a program renewal from the state or federal government, however, there may be an opportunity for local governments at the county or city level to provide similar incentive programs through rebates and partnerships with renewable energy contractors and electricity providers.

Construction Best Practices

While there are generally understood best practices in construction that focus on ambient air quality impacts it is very little in terms of regulation and enforcement. The two key areas of particulate matter mitigation include dust suppression practices and monitoring the local wind speed, direction, and humidity at the site. Many construction companies follow a set of best practices standards but creating and enforcing a set of standards that must be followed for construction in your city, county, state, or nationally would go a significant distance in limiting the downwind impact of building construction on ambient air quality.

Indoor Air Quality

Americans on average spend around 90% of their life indoors therefore it is worthy of much of our attention when it comes to air quality.[50] Importantly too, without proper ventilation, indoor air pollution can concentrate to 2 to 5 times that of ambient air.[51] To further complicate things, indoor air quality relates to a combination of both outdoor air pollution entering the building and the sources of air pollution that exist within our buildings.

Indoor Point Sources

Within our buildings the primary sources of air pollution are combustion sources, cleaning supplies, and building materials:

[46] "ThermWise | Utah | Dominion Energy."
[47] "Renewable Energy Systems Tax Credit - Office of Energy Development."
[48] "Renewable Energy Systems Tax Credit - Office of Energy Development."
[49] "Renewable Energy Systems Tax Credit - Office of Energy Development."
[50] US EPA, "Indoor Air Quality."
[51] "The Total Exposure Assessment Methodology (TEAM) Study: An Analysis of Exposures, Sources, and Risks Associated with Four Volatile Organic Chemicals - Lance A. Wallace, 1989."

Any combustion source within a home can negatively impact indoor air quality through the release of carbon monoxide, particulate matter, nitrous oxides, and volatile organic compounds.[52] Common forms of combustion within a building include, cigarettes, candles, and wood, coal, and gas-powered fireplaces, stoves, and appliances for heating and cooking. These sources release carbon monoxide, particulate matter, and volatile organic compounds. While it has long been understood that wood burning within homes releases hazardous air quality pollutants, natural gas, particularly stoves, is a newly understood indoor air pollution point source. Gas stoves produce twice the particulate matter as electric stoves.[53] In addition, it produces nitrogen oxides, carbon monoxide, and formaldehyde, all hazardous pollutants to human health.

Secondly, there are many commonly used household chemical products that are hazardous in a variety of contact with humans including in releasing harmful volatile organic compounds. These include cleaning supplies, paints, and insecticides.

Third, the building materials themselves are potential sources of indoor air pollution. Most famously this has included asbestos insulation material, a very hazardous source for particulate matter. There are an array of other materials including composite wood products, flooring, adhesives, and through mold and pet dander, as VOC pollutant sources.[54] Older buildings may be especially at risk as lead paint was only banned in 1978 and asbestos insulation in 1989. 47 percent of existing structures in Salt Lake County were built before 1980, and 59 percent by 1990, or just after lead paint and asbestos insulation were banned respectively.[55] This leaves a large part of the population potentially at risk in their homes or workplaces, unless sufficient mitigation measures were made.

Outdoor Point Sources

Until recently public perception was that generally regardless of outdoor air pollution, if you go inside, you are safe. Unfortunately, this is not as true as we would like to believe for three main reasons: infiltration, failure to follow filter replacement guidance, and extra fine particulate matter from wildfires and fireworks.

Infiltration or a "draft" is when air can enter a building without passing through an intake system and a filter. There may be gaps around windows and doors, joining for walls and floors and ceilings, or other openings like a dryer vent or similar.[56] Older and less well constructed buildings typically have more infiltration; however, this can be remedied through retrofits and mitigation. When ambient air quality is poor this infiltration allows unfiltered polluted air into the home. On the other hand, it can allow air polluted from indoor point sources to escape before it concentrates.

Central air systems can solve both infiltration and indoor point sources to a large degree. Both indoor and outdoor air is filtered as it passes through the system. Filters come in a range of different Minimum Efficiency Reporting Values (MERV) ratings, based on its ability to trap particulate matter between 0.3 and 10 microns (µm). The higher the MERV rating the higher percentage

Figure 13. Photo by Craventure Media on Unsplash

[52] US EPA, "Indoor Air Quality."
[53] Hu, Singer, and Logue, "Compilation of Published PM2.5 Emission Rates for Cooking, Candles and Incense for Use in Modeling of Exposures in Residences."
[54] Mitchell and Sep 01, "Building Materials Can Be a Major Source of Indoor Air Pollution -."
[55] US Census Bureau, "American Community Survey 5-Year Data (2009-2020)."
[56] US EPA, "Indoor Air Quality."

and finer the PM that is trapped. While it's important that buildings use a higher MERV rated filter, equally important is that they are replaced as recommended, something many building owners and homeowners do not do. One survey found only 18% of Americans replace their air conditioner filter monthly, and that 29% don't replace them at all. Of those that do change their filter most, 31% do it every few months.[57]

Recent research from the University of Utah has indicated that while filtered central air systems are effective at largely reducing particulate matter during poor air quality events linked to inversion, they are not nearly as effective at filtering out particulate matter sourced by wildfires and fireworks.[58] These events produce very fine particulate matter, which can stay suspended in the air for significantly longer and is not as easily trapped by typical building air filtration. Wildfires are becoming especially common during the summers in the Western US, affecting locations far downwind of the fire, including Salt Lake County, like we saw in 2021.

MERV Rating	Average Particle Size Efficiency in Microns
1-4	3.0 - 10.0 less than 20%
6	3.0 - 10.0 49.9%
8	3.0 - 10.0 84.9%
10	1.0 - 3.0 50% - 64.9%, 3.0 - 10.0 85% or greater
12	1.0 - 3.0 80% - 89.9%, 3.0 - 10.0 90% or greater
14	0.3 - 1.0 75% - 84%, 1.0 - 3.0 90% or greater
16	0.3 - 1.0 75% or greater

Figure 14. Summary table of MERV ratings by the US EPA.

Recommendations

Ventilation, Filtration, and Building Standards

There are no set requirements for ventilation for buildings in the United States, both in terms of ventilation rates and filtration. Instead, it is left up to local governments for regulation. The State of Utah requires mechanical ventilation with a minimum of five air changes per hour but does not set filtration standards. This leaves building owners to voluntarily choose to follow set standards produced by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). The two most common standards are 62.1 (2004) and 62.2 (2010) although a newer 90.1 was released. ASHRAE 62.2 recommends 0.35 air changes per building per hour and a MERV rating of 8 for homes. A MERV rating of 8 is effective for larger PM but does little to catch fine particulates (PM 2.5). In comparison, ASHRAE 90.1 their 2019 recommendation, upped their recommendation to a MERV rating of 13 or higher.[59] Included is a summarization table for MERV ratings provided by the US EPA (see Figure 13).[60]

In comparison, the European Union has a committee named the "European Committee for Standardization" which establishes recommended building ventilation requirements.[61] Several European nations have adopted these or even more stringent standards and enforce them through regulation. Generally, these require minimum rates of air exchange of 0.5 building volume per hour and filtration rates of 98% of 0.4 µm particles. These standards are much stronger than ASHRAE 62.2 the US equivalent and can carry regulatory weight.

In the US there are two primary certification programs for buildings, LEED and WELLS. Again, these are voluntary programs, where buildings can be certified to follow a set of required checklists for human health and safety and energy efficiency standards.[62] According to their stated vision, "LEED certified buildings are proven to save money, improve efficiency, lower carbon emissions and create healthier places for people." We recommend that local governments should incorporate ASHRAE 90.1 (MERV 13+) and components of LEED and WELLS building certifications into minimum building

[57] "Air Filter Survey."
[58] Mendoza, Benney, and Boll, "Long-Term Analysis of the Relationships between Indoor and Outdoor Fine Particulate Pollution."
[59] ASHRAE, "Standards 62.1 & 62.2."
[60] US EPA, "What Is a MERV Rating?"
[61] "EN 16798-1."
[62] "LEED Rating System | U.S. Green Building Council"; "WELL | IWBI."

code requirements. These will preserve indoor air quality both to protect against indoor and outdoor sources of air pollution.

Replace Wood Stoves and Appliances

We recommend reducing the use of wood burning within homes, echoing a point made in the previous section detailing the ways to reduce the impacts of buildings on ambient air quality more broadly. This can be done through a rebate program to replace appliances especially wood burning stoves and fireplaces with gas or electric alternatives. Similarly local governments can offer a rebate program for more efficient and cleaner gas furnaces. Both these ideas are discussed in greater detail in the previous section. New research shows that even modern gas stoves can elevate nitrogen dioxide and carbon monoxide within homes, affecting indoor air quality and causing health issues. Gas stoves can have nitrogen dioxide concentrations that are 50–400 percent higher than homes with electric stoves and children within homes are especially susceptible to the risks of gas stove pollution.[63] Cities are taking action against polluting appliances such as wood burning stoves and old or gas appliances by not allowing them in new buildings through ordinances or building codes.

Figure 15. Recommendation to replace wood burning appliances with electric options. Photo by Andrea Davis on Unsplash

Figure 16. Photo by Michael Tuszynski on Unsplash.

[63] Seals, "Indoor Air Pollution."

04
Land Use

Figure 17. Salt Lake County from space. Public Domain, https://commons.wikimedia.org/w/index.php?curid=69950

Currently, most pollution comes from vehicle emissions which are expected to change by 2050 where the most dominant sources of pollution will be homes, commercial buildings, offices, and other structures (see Figure 18).[64]

There are many different forms of land use that affect air quality contributing to air pollution. In many developed places, suburbanization contributes to poor air quality because of heavy vehicle use and land development. According to the Environmental Protection Agency (EPA), increased air pollution due to vehicle use results in higher concentrations of certain air pollutants in developed areas that may exacerbate human health problems such as asthma.[65]

As stated by the EPA, there are many different sources of air pollution, including naturally occurring sources such as windblown dust, and

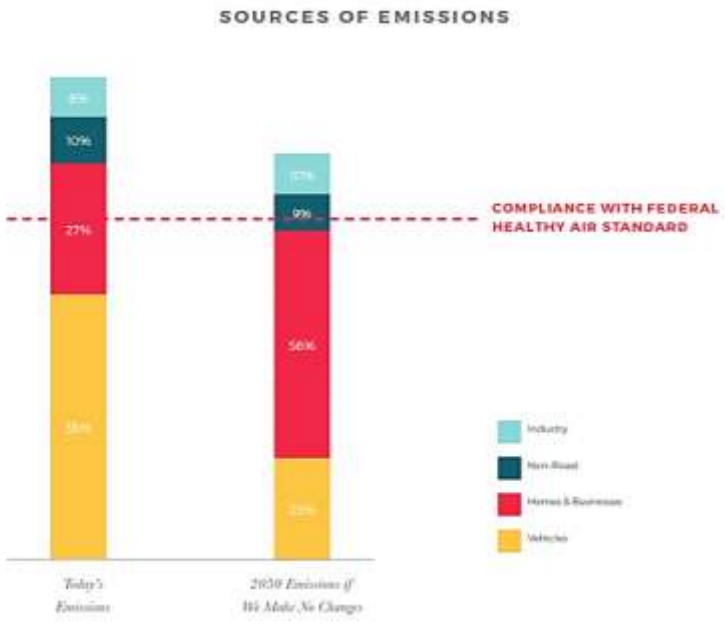

Figure 18. Current vs. future emission sources from Envision Utah.

[64] Envision Utah, "Your Utah, Your Future - Background."

[65] US EPA, "Land Use."

man-made sources such as factories, and power plants that come from these stationary sources, as well as transportation sources like cars, buses, planes, trucks, and trains.

Impact of the Stay Safe, Stay Home Directive on Vehicle Emissions

Vehicle emissions have a great impact on air quality, evidence during the COVID-19 lockdown shows that there was a significant vehicle emission reduction of NO2 and CO than other pollutants which coincide with reduced transportation and utility demands.[66] Land use as it relates to vehicle emissions during the COVID-19 lockdown shows the impact of vehicle emissions on air quality, making the case for land use strategies such as developing a robust public transportation network system to reduce the number of cars on the road. Research findings show the following benefits of having fewer cars on roads:[67]

- Nitric oxide (NO) levels were 57% lower than the average March, and nitrogen dioxide (NO2) was 36% lower than average.
- O3 (ozone) is about the same as usual at midday but slightly elevated at night. This is characteristic evidence of less NOx in the air and less reaction between NOx and ozone at night. It's consistent with what scientists think urban air would look like with decreased NOx emissions.
- PM2.5 (particulate matter) is down by 59%, particularly at night. It's not clear yet whether that's due to reduced overall particulate matter emissions or reduced formation of particulate matter through atmospheric chemistry.
- CO2 (carbon dioxide) levels are at 19% and 33% lower than average at the Sugarhouse and U stations, respectively.
- SO2 (sulfur dioxide) is around typical levels. Mitchell says this isn't surprising, as there aren't many SO2 sources in the Salt Lake valley

The graph below shows traffic trends during the COVID-19 lockdown in Salt Lake County (see Figure 19).[68]

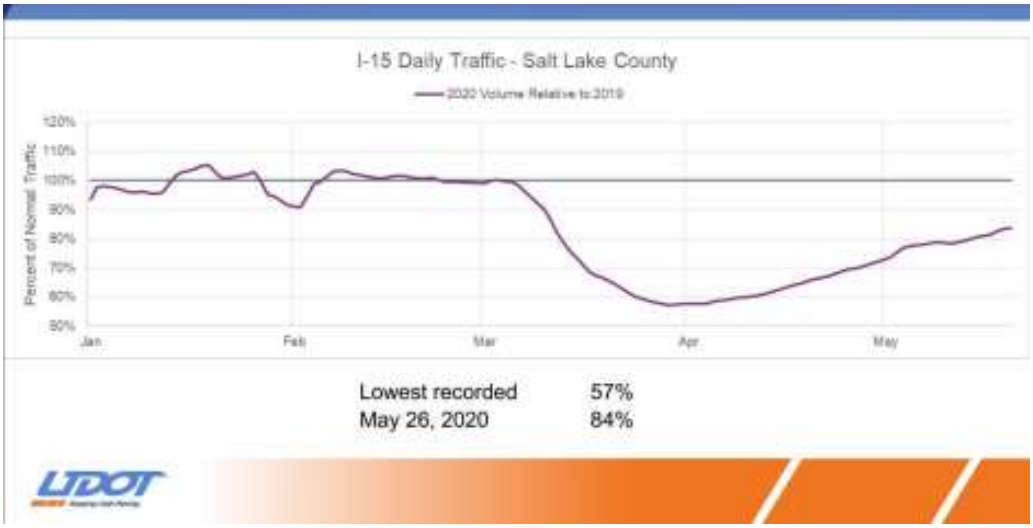

Figure 19. UDOT traffic counts showing the impact of COVID on daily traffic.

Though vehicle emissions are a major cause of concern when it comes to air quality, according to *Breathe Utah,* there are approximately 750,000 buildings in Utah's urban areas. These buildings emit approximately 12 tons of emissions from natural gas heating on an average winter day. Buildings in Utah waste an estimated 20-30% of the energy they consume, which equates to over four million tons of CO2 emissions every year. This is equivalent to adding over 750,000 new passenger vehicles to Utah roads.[69]

Policy Recommendations

- Infill development: According to the EPA, encouraging pedestrian and transit travel by

[66] Chen, et al, "Nonuniform Impacts of COVID-19 Lockdown on Air Quality over the United States - ScienceDirect."
[67] Mendenhall, "Impacts on Air Quality During COVID-19 - News."
[68] UDOT, "Recent Trends With Road Usage."
[69] Breathe Utah, "Breathe Utah - Air Quality."

locating new development in already developed areas, to group activities closer together, and making use of previously built land through remediation and redevelopment. Both of these options help reduce the pollution that comes with land development[70]

- Educating the public: there are many ways we can all individually help improve air quality. Providing effective manageable steps everyone can take will contribute to improving our overall air quality. This can be done by educating people similarly to the TravelWise initiative by UDOT that educates and advocates for measures such as carpooling and utilizing public transportation, teleworking, and others[71]
- Green space and its natural ability to filter pollution from the air: focusing on greening developed buildings can help filter air pollution. A 2011 study found air pollution removal through the intensive application of green roofs is comparable to mitigation effects of urban forests. For example, adoption of green roofs by 20 percent of "ready" buildings in Washington, D.C., was estimated to remove the same amount of air pollution as 17,000 street trees, and an estimated 20 per cent conversion of all industrial and commercial roofs to green roofs in Detroit, Michigan, would remove over 800,000 kilograms (889 tons) per year of NO2[72]
- Investing in public transportation networks would greatly improve air quality. Making public transportation efficient and convenient[73]

Figure 20. UTA Trax. Photo by Saul Flores on Unsplash

Figure 21. Walkable city example. Photo by Tobi on Unsplash

- Designing more walkable cities: Cities with improved air quality have two things in common, walkability and robust public transportation networks that improve access throughout the city. Walkable neighborhoods (and also neighborhoods served by mass transit) may allow people to reduce their daily travel distance, thereby decreasing vehicle emissions of NO and other O3 precursors[74]
- Intentionally developing the land while considering air quality has led to creative and innovative ways to reduce pollution such as green spaces, green roofing so that there are diverse land development strategies to mitigate the effects of urban heat islands and use green spaces as a carbon sink.[75]

[70] United States. Environmental Protection Agency, "EPA Guidance."
[71] Utah DOT, "TravelWise Utah."
[72] Getter et al., "Seasonal Heat Flux Properties of an Extensive Green Roof in a Midwestern U.S. Climate"; Tara Zupancic, Claire Westmacott, Mike Bulthuis, "The Impact of Green Space on Heat and Air Pollution in Urban Communities."
[73] United States. Environmental Protection Agency, "EPA Guidance."
[74] Marshall, Brauer, and Frank, "Healthy Neighborhoods."
[75] Getter et al., "Seasonal Heat Flux Properties of an Extensive Green Roof in a Midwestern U.S. Climate."

05
Community Design

Figure 22. Daybreak Utah; By Egray Daybreak - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=98890729

According to the CDC, "public health problems in the United States, such as…breathing and heart problems related to air pollution, are all influenced by the design of our communities. Designing communities that encourage healthy choices is critical to improving the health and quality of life of community members."[76] The Utah Department of Health acknowledges that "urban sprawl, inadequate public transportation, and energy inefficient buildings affect human health and have an impact on climate change."[77]

According to Frank et al. (2006), "single-use, low-density land development, and disconnected street networks are positively associated with auto dependence and negatively associated with walking and transit use."[78] The problem to be addressed is suburban sprawl; this is often characterized as not compact, single-use zoning. Where most streets are loops or cul-de-sacs and are disconnected from other amenities. An increase in vehicular travel will increase per capita vehicle emissions.

Per capita vehicle miles of travel are also positively associated with per capita emissions of oxides of nitrogen (NOx) and volatile organic compounds (VOC). These two pollutants form harmful ground-level ozone (Frank, 2006). Additionally, Ewing et al. found the connection between sprawl and ozone levels was strong enough that some regions which do not currently meet

[76] "Community Design | Tracking | NCEH | CDC."
[77] "UT-EPHT - Community Design."
[78] Frank et al., "Many Pathways from Land Use to Health."

federal ozone standards would meet them if they were compact.[79]
When considering air pollution and community design, one must differentiate between emissions and concentration.

Emissions: the amount of pollution released from a source, such as a tailpipe or a smokestack

Concentration: the amount of ambient pollutants in the air in a particular location

Even though compact urban form does lower emissions, Schweitzer et al. (2010) argue that compact urban forms may not improve urban respiratory health. This is because while the amount of pollution may be lowered, emissions still react and disperse and can produce high concentrations in particular places, thus affecting human exposure unevenly. Thoughtful considerations should be discussed as higher population densities achieved through infill development may locate more people in areas where air quality is poor.[80] However, methods such as mixed land-use, higher density, and greater street connectivity are associated with significantly lower per capita emissions.

A study conducted in the upper Midwestern United States found that replacing short automobile trips with bicycle transport yielded health benefits through improved air quality and increased physical activity.[81] The study estimated changes in regional emission and air quality as well as the resulting health benefits. According to their findings, in a study region of 31.3 million, they "estimated that eliminating short car trips and completing 50% of them by bicycle would result in mortality declines of 1,295 deaths/year, (608 fewer deaths due to improved air quality and 687 fewer deaths due to increased physical activity)."

The estimated combined economic benefit from improved air quality and physical fitness for the region would exceed $8.7 billion/year, which is equal to 2.5% of total cost of health care for the five midwestern states in 2004 as "changes in PM2.5 and ozone would result in net health benefits of $4.94 billion/year. Completing 50% of short trips by bicycle would yield $3.8 billion/year in savings, about $1.5 billion less in savings than from reductions in air pollution." (see Figure 23).[82]

This research is critical to contributing evidence that providing well connected bicycle and walking infrastructure does indeed return on the investment. They also prove that although the configuration and historical growth patterns in America differ when

Figure 23. Costs associated with commute. Source: Discourse Media with data from George Poulos.

[79] Ewing, Pendall, and Chen, "Measuring Sprawl and Its Transportation Impacts."
[80] Schweitzer and Zhou, "Neighborhood Air Quality, Respiratory Health, and Vulnerable Populations in Compact and Sprawled Regions."
[81] Grabow et al., "Air Quality and Exercise-Related Health Benefits from Reduced Car Travel in the Midwestern United States."
[82] Grabow et al.

compared to more walkable European cities, it is still feasible for similar travel distances in midsized American cities of similar densities to promote greater active transportation which need not be limited to areas of high density.

In 2019, Salt Lake County hosted keynote speaker Jeff Speck for the regional solutions annual event which focused improving regional transportation. He focused on walkable communities and strategies which could be implemented in Salt Lake City.[83]

Speck's General Theory of Walkability touches on the key factors that need to be present to encourage more people to walk places. The walk needs to be 1) useful, 2) safe, 3) comfortable and 4) interesting.

Another key takeaway from his lecture was considering the social cost of transportation. Economists estimate that 40% of and individual's income is spent on transportation. However, what is the societal cost of various transportation modes? The above graphic shows that while the individual may only pay $1 across different transportation modes, the societal cost for personal vehicles is significantly more than walking, bicycling, or buses.

There are also environmental and public health impacts to consider. As climate change continues to accelerate, according to the Intergovernmental Panel on Climate Change (IPCC) in Sixth Assessment Report published in 2021, human influence on the climate system is now an established fact.[84] Therefore, planners, developers, elected officials, and decision makers, must be informed and educated about the tactics to successfully plan for the future with climate change and resilience in mind. By prioritizing developments that are within walking distance to transit, and increasing transit efficiency, communities can decrease the dependence of personal vehicles, thus decreasing vehicle emissions.

Lastly, as previously mentioned, air pollution is a public health concern. In the book, *Community Design and Air Quality* by Jonathan M. Samet states "high-income countries, air pollution remains a public health threat to urban dwellers." Worldwide, air pollution is an ever-greater threat as population concentrations increase, industrialization rises, and vehicle fleets expand.[85]

His key points include:

- Urban environments will continue to grow, and their design needs to address exposure to traffic and industrial pollution
- Air quality management involves a diverse mix of strategies that extend from local to national levels.
- Transport of pollution goes across jurisdictional boundaries; therefore, coordination involving stakeholders and cross-regional collaboration is crucial to magnify efforts. Agreements between governments may be necessary.
- Residencies need to be sited away from major roadways, and the design of urban areas needs to preserve open space, offer walkable routes, and reduce sprawl.

Current Community Design Examples

Salt Lake City- Sugar House

The downtown urban core of Salt Lake City has large blocks (600 ft), creating an unwalkable city. However, particular neighborhoods within Salt Lake City, such as Sugar House is an existing example of a more walkable community. Areas such as Salt Lake City's 9th district, Holladay town center, and 15th district emulate the Congress of New Urbanism concepts such as mixed-use zoning, high density, and bicycle infrastructure, thus attracting residents and visitors to these places.

The Sugar House Future Land Use Plan incorporates the following land uses to allow residential and small businesses to provide community-level commercial activities to residents.[86]

- *Neighborhood Business Land Use:* provide small-scale services within close proximity to residential neighborhoods. Businesses must be compatible with the land uses and architectural features

The intent of mixed-use zoning is to support more walkable community development patterns located near transit lines and stops. Within both mixed-use zones, uses must be compatible with surrounding uses and architectural features.

[83] *Jeff Speck - Salt Lake County Walkable Communities - YouTube*.
[84] "Special Report on Climate Change and Land — IPCC Site."
[85] Samet, "Community Design and Air Quality."
[86] Salt Lake City, "Sugarhouse Master Plan."

- *Low-intensity Mixed Land Use:* integration of residential with small business uses at ground floor levels. Height limits are generally 1-2 story structures.
- *High-Intensity Mixed Land Use:* integration of residential with small business uses at ground floor levels. Height limits are generally 2-4 story structures.

South Jordan- Daybreak

The best existing example of a walkable community within Salt Lake County is Daybreak, located in South Jordan, UT. One of the greatest highlights in Daybreak is the well-designed street network that promotes connectivity and outstanding pedestrian and bicycle infrastructure.[87] This development was an outcome of Envision Utah's influential public-private initiative and "stands as one of the largest traditional neighborhood developments in the country."[88] The development spans 4,100 acres and has incorporated mixed-use zoning in their town center filled with shops, restaurants, homes, and activity centers. Furthermore, Daybreak is an example of a transit-oriented development (TOD) as it is connected to the light rail UTA TRAX red line which allows residents another transportation option to travel to Salt Lake City downtown, the University of Utah, the airport, and other destinations throughout the Salt Lake region.

According to Congress for the New Urbanism, Daybreak has a growing town center with parks, schools, churches, and employment. The urban center of 60,000 people also has 15 million square feet of commercial space. Furthermore, Daybreak is a leading example of implementing green infrastructure or low-impact development to utilize ecological systems to manage stormwater runoff. Daybreak serves as a model for sustainable growth and provides six key lessons for developers in the Salt Lake area:

1. Provide a wide range of housing options to meet people's needs throughout their lives
2. Move jobs and shopping closer to homes to shorten commutes and improve air quality.
3. Build efficient and cost-effective infrastructure to give people a choice in how they move around
4. Deliver more tax revenue per unit of infrastructure so the government will have more resources to maintain that infrastructure
5. Build for energy efficiency and preservation of water resources
6. Preserve key parks and open space areas in close proximity to residents.

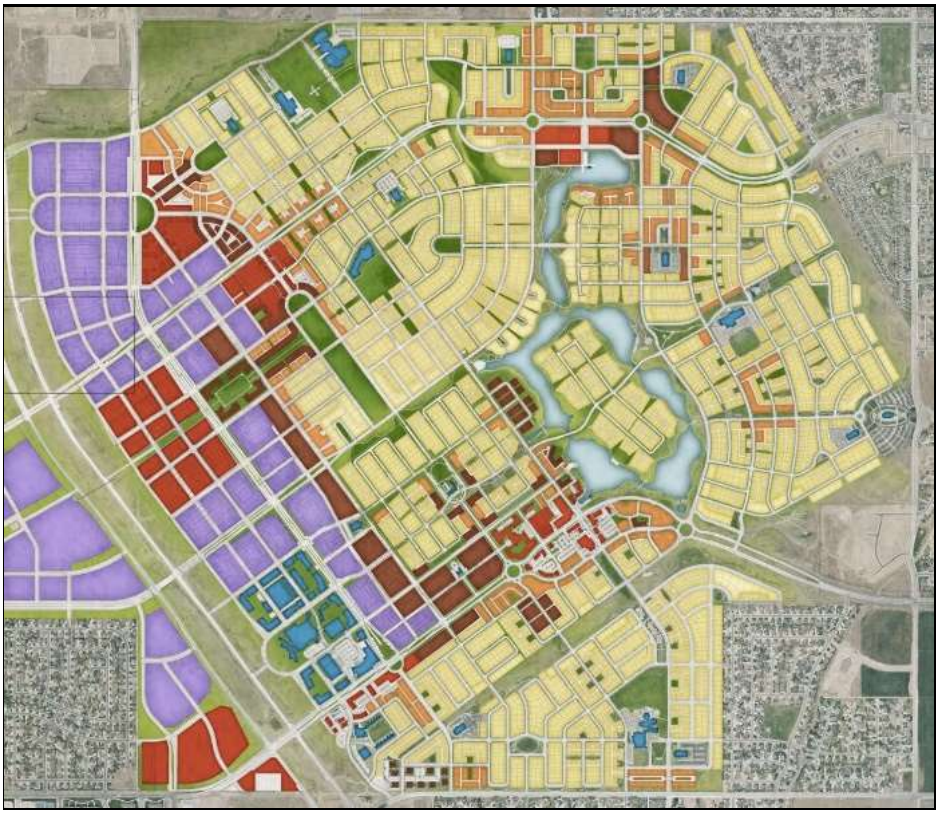

Figure 24. Site plan for the Daybreak Master Planned Community.

[87] Salt Lake County Regional Planning and Transportation, "Salt Lake County Street Connectivity Map."

[88] "Daybreak | CNU."

Figure 25. Energy efficient homes by Garbett Homes in Daybreak Utah.

National and International Examples

According to the United States Environmental Protection Agency (EPA), practicing principles of smart growth within communities can promote walkable communities. One example within the United States is Northwest Landing, DuPont Washington.[89] This neighborhood was developed with the intent to design a community where residents did not need to drive for every trip. It is built on 3,000-acre site of former explosives factory and incorporates a grid of streets and sidewalks to promote walking. Twelve miles of paths maintain pedestrian connections through 550 acres of preserved open space.

Figure 26. A park in Northwest Landing in Dupont, Washington. Source: US EPA

Most of the homes in the Northwest Landing neighborhood are within walking or bicycling distance to major companies, shopping centers, main street, as well as an elementary school. Housing stock include a variety of options including apartments, condominiums, single-family cottages, medium and large-lot homes. This mix of housing types allows for diversity among residents. Narrow streets and house designs encourage walking and are effective traffic calming measures. Garages are located on back alleys to reduce vehicle-pedestrian collisions and a park-and-ride facility for commuter bus service to Tacoma and Seattle is adjacent to Northwest Landing downtown.

The intentional and good community design has led Northwest Landing to be named one of the most walkable communities in the United States in 1997.

Another study conducted in Seoul, South Korea provides insights of understanding urban regeneration projects using examples of creating walkable spaces with natural green elements, and their potential to improve a city.[90] The following table is taken from this study and illuminate the positive and negative arguments to consider when planning or creating walkable spaces within a community (see Figure 27).

They identified four elements which should be incorporated when creating walkable places such as

[89] US EPA, "Create Walkable Neighborhoods."

[90] Shafray and Kim, "A Study of Walkable Spaces with Natural Elements for Urban Regeneration."

Table 3. Positive arguments and negative arguments.

Positive Arguments	
(+) Reduction of congestion and car dependency in terms of transportation, although it is difficult to retrofit existing built-up areas	Southworth (2005) [2];
(+) Enhancement of a healthy life style by facilitating outdoor walking & exercise	Smith et al. (2008) [25]; Leslie et al. (2007) [26]; Lee & Moudon (2008) [27];
(+) Promotion of social interaction through "face-to-face collaboration"	Speck (2012) [23]
Negative Arguments	
(−) Physical activity in polluted air has a negative impact on health condition associated with several adverse health outcomes;	Marshall et al. (2015) [28]; Saelens (2003) [29],
(−) Low visibility (caused by smog, yellow dust, etc.) reduces the visual quality of place; reduced pleasure from walking	"ecological aesthetics" Gobster et al. (2007) [30];
(−) Long-term exposure and multi-factorial relationships	Shin (2007) [31]

Figure 27. Positive and negative arguments for creating walkable spaces within a community.

located near water, increased greenery, far distance from industrial production and transport pollution, and technical protection measures (see Figure 29). [91]

These elements should be considered in projects throughout Salt Lake County to create more enjoyable walkable spaces throughout communities. Furthermore, Table 13 from this study covers ways to improve the local air quality using natural elements. Simple measures such as providing more pocket parks and trees can both alleviate urban heat island effect by shading buildings, thus reducing dependence on air conditioning, removes greenhouse gas pollutants, and contribute to impacting the microclimate of a community (see Figure 30).[92]

Shafray et al. determined, "there is a need for inclusive urban planning with a detailed consideration of environmental issues." While these strategies may apply and work well in Seoul, they must be critically analyzed for the Salt Lake Region with the limitation of water as a key consideration. As stated in this study, "green elements can decrease local air pollution in the area and facilitate the restoration of the natural environment and increase ecological special richness." However, cross-

Figure 29. Photo by AZGAN MjESHTRI on Unsplash.

Table 4. Nature-based elements and features that are important for urban walkable places.

	Location Near Water: *Availability:* River/Water stream/Lake/etc.
	Increased Area of Greenery: *Availability:* Landscape and evergreen trees/Landscape shrubs/Perennials/Annuals/etc.
	Far Distance from Industrial Production & Transport Pollution: *Availability:* Urban points of attraction located far from hazardous industries/etc.
	Technical Protection Measures: *Availability:* Cleaning of drains/Air quality control/Protection of ecology and fauna/etc.

Figure 28. Table 4 showing what nature-based elements are important for walkable places.

[91] Shafray and Kim.

[92] Shafray and Kim.

Table 13. Ways to Improve Air Quality Locally with the Use of Natural Elements.

Ways to Improve Air Quality Locally
• Affecting microclimate: human comfort, building energy budgets, and heat islands [74]
• Young trees and mature trees absorb CO_2 (13 lbs/year and 48 lbs/year) and release oxygen (enough for two persons) [74–76]
• Trees alleviate the greenhouse effect by shading buildings (reducing the need for air-conditioning by 30%) [75]
• Trees remove other gaseous pollutants with normal air components, for example, sulfur dioxide (SO_2), ozone (O_3), nitrogen oxides (NO_x), and particulates [75]

Sources: [69–71], Authors (2017).

Figure 30. Using natural elements to improve air quality.

disciplinary collaboration must occur to ensure the success of establishing native plants and trees in a sustainable manner in the local context.[93]

Recommendations and Best Practices

According to Jeff Speck, to support healthy living and healthy community design there are a few places to start; first, conduct a walkability study and lane inventory. In order to build better infrastructure and improve community design, each community within Salt Lake County must accurately understand the existing conditions.

Second, design dictates behavior, so the wide the lane, the faster cars will drive. To improve the safety for pedestrians and bicyclists, narrowing lanes by restriping can be a cost effective. He emphasized that we don't need to rebuild, just start by restriping.

Next, the Utah Department of Health recommends the following for healthy community design:[94]

- Lower vehicle dependence by building homes, businesses, schools, churches, and parks closer together to encourage walking and biking
- Provide opportunities for people to be active and social close to home. This can improve physical and mental health
- Allow people to age in a community that reflects changing lifestyles and physical capabilities

Additionally, the Congress of New Urbanism promotes creating and designing the "Traditional Neighborhood."[95] This includes communities compact, diverse uses, and walkable communities where the daily needs are met within a walking distance. Ideally, streets are well connected, and a 5-minute walk allows a person to go from the edge to the center of the community.

Lastly, according to the EPA, the following smart growth and transportation principles are known to be the best practices when considering sustainable community design. As transportation and land use patterns are inextricably connected, prioritizing and incorporating smart growth principles will improve the quality of life by reducing greenhouse gas emissions and improving air quality.[96]

Below are the main smart growth principles to consider for each new development:

- Mixed land uses
- Compact building design
- Range of housing choices
- Walkable neighborhoods
- Distinctive and attractive places
- Preserve open space and farmland
- Direct development toward existing communities
- Variety of transportation choices
- Predictable, fair, and cost-effective decision-making
- Community and stakeholder participation

[93] Shafray and Kim.
[94] "UT-EPHT - Community Design."
[95] Congress for the New Urbanism, "Daybreak."
[96] US EPA, "Smart Growth and Transportation."

Transit-oriented development (TOD) create walkable communities of all ages and incomes and provides more transportation and housing options. The EPA defines TOD as, "compact development built around a transit station or within easy walking distance (typically a half-mile) of a station and containing a mix of land uses such as housing, offices, shops, restaurants, and entertainment."[97] However, a TOD must be matched with a connected neighborhood. This type of development need to be places to live, work and play. They are very beneficial as they can boost public transit ridership, reduce greenhouse gas emissions, and air pollution, spur economic development, and make housing more affordable.

Due to the large block sizes found within Salt Lake City, Speck also recommended designing more intricate passages with a secondary network for pedestrians, bicycles, and cars to cut through. One example found within Salt Lake City is Regent Street located near City Creek Shopping Center. Additionally, City Creek Shopping Center is an example of a pedestrian network that cuts through the middle of the block.

Lastly, to encourage and support bicycling throughout Salt Lake County, communities must create protected bike lanes. Again, since Salt Lake City blocks are so wide, there is enough asphalt to reallocate space for safer bicycle lanes. Planners, communities, and decision makers must choose to invest in well-connected bicycle infrastructure.

Policy Recommendations

- Don't require parking for individual businesses- give parking the right price
- Decrease Vehicular speed (20-25 mph)
- Traffic calming measure - slow cars down by creating narrow roads/smaller block size
    - Bulb outs, chokers
    - Landscaping ordinance
    - Pedestrian islands
- Mixed-use zoning - When designing new places, we have choices i.e. The Point
- Center-based planning in general plans and implemented into planned community zones, overlay zones, or new zoning districts.

Additional Resources

- Smart Growth and Transportation | US EPA
- Urban Bikeway Design Guide | National Association of City Transportation Officials
- Urban Street Design Guide | National Association of City Transportation Officials
- Street Design Elements | National Association of City Transportation Officials
- Green Infrastructure | National Association of City Transportation Officials
- Designing Streets for Kids Guide | Global Designing Cities Initiative
- Superblock (Superilla) Barcelona—a city redefined. Public Realm

Related Maps

- WFRC Active Transportation Story Map
- SLCo Active Transportation Implementation Plan (Interactive Web Map)
- Wasatch Choice Map
- SLCo Street Connectivity Map
- SLCo Residential Zoning Map
- SLCo Combined Zoning Map

Figure 31. Park City Main St. Photo by Olivia Hutcherson on Unsplash.

[97] US EPA.

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