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A futures perspective of health, climate change and poverty in the United States

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ABSTRACT

Trend assessments suggest that poverty and health will worsen in the United States in the coming decades and that climate change will exacerbate these trends. An aging society, lack of affordable housing, and automation threaten the economic sustainability of millions of households. Despair, drug abuse, and unhealthy lifestyles have led to the first decline in life spans in the U.S. during a non-war period. Extreme weather events caused by climate change can be anticipated to disrupt economic activities and destroy homes and infrastructure, pushing millions of more Americans into poverty. A warming climate threatens vulnerable individuals, such as elders, with heat stress, increasing levels of air pollution, and increasing risks from new tropical diseases entering the country. It is anticipated that climate change will force tens of millions of Americans from their homes, creating The Great Migration (TGM) scenario. The welfare of the migrants will depend on what types of human settlements they migrate to. Seven different types of settlements are depicted within the TGM scenario, such as Willow Pond settlements that represent radical re-designs of suburbs to make them sustainable and resilient to climate change. Numerous recommendations are provided to foster positive outcomes with respect to TGM, including having the U.S. formally designate that the right to safe and adequate housing is a human right.

1. Introduction

It is widely recognized that climate change will adversely impact human health in many ways, from the debilitating impacts of extreme heat stress to fatalities caused by extreme weather events (U.S. Global Change Research Program, 2016). It is also widely acknowledged that economically disadvantaged households and communities will disproportionately suffer from the impacts of climate change (Chalupka et al., 2020). This paper studies relationships between climate change, health and poverty in the United States (U.S.) as they could unfold over the next several decades.

Section 2 articulates major trends that are anticipated to influence poverty in the U.S. in the mid- to long-term. These include an aging population on fixed incomes and reductions in funding for social service programs. Section 3 repeats this exercise with respect to health. Here again, the preponderance of trends seems to be working against improvements in health in the U.S. Section 4 explains how climate change can be anticipated to exacerbate the most negative driving forces with respect to poverty and health inequities.

Section 5 addresses two new issues that have emerged in the U.S. as this paper was being written: the coronavirus (COVID-19) pandemic and the Black Lives Matter (BLM) movement. The former poses substantial near-term risks to poverty and health, though could spur more positive actions with respect to health care and public health in the mid-to-long-term. BLM could positively transform

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the way U.S. society deals with systemic poverty and health inequalities, which then could reduce the negative impacts of the climate crisis.

The second half of the paper presents the results of our scenario exercise to explore potential poverty, health, and climate change futures of the U.S. Our scenario is driven by one major anticipation, that climate change will displace millions of Americans from their homes, leading to The Great Migration. This scenario is presented in Section 6. Section 7 describes the range of types of communities where the migrants might migrate to based on their urbanicity and ability to adapt to climate change. How poverty and health inequities play out in each community within the context of climate change and The Great Migration are addressed. There are many policy avenues open to U.S. society that could ameliorate the worst aspects of this scenario. These are addressed in Section 8.

2. Poverty

In the year 2018, the U.S. Census Bureau estimated that the poverty rate in the U.S. was 11.8 %, which translates into 38 million individuals[1]. This was the lowest poverty rate recorded after the Great Recession of 2008. The poverty rate by itself does not capture the full range of material deprivation and economic stresses felt by families across the U.S. For example, a study conducted by the U.S. Federal Reserve found that a full 40 % of U.S. households could not afford an unplanned, emergency expense of $400[2]. One reason given is that American households are heavily in debt. In 2019, it is estimated that the average personal debt was just over $90,000[3]. Conversely, over 50 % of individuals between the ages of 45 and 54 have no personal savings whatsoever[4]. Thus, economic insecurity is pervasive throughout the U.S.

This first set of trends suggests that poverty and economic insecurity will worsen in the coming years.

- Aging population on fixed income – By 2060, 95 million Americans will be over 65 years old, up from 56 million in 2020, which is an increase from 17 % to 23 % of the population[5]. Currently, the only income that 25 % of Americans over 65 years old have is Social Security, which at its inception was never designed to provide retirees with an adequate income[6]. On average, Social Security replaces only 38 % of pre-retirement income[7]. This trend is expected to worsen as the percentage of workers with defined retirement plans dwindles to a very low rate, many other alternative 401 K plans fall into dissolution, and low- to moderate income workers continue to be unable to save money for their retirements.
- Gentrification and the inner suburbs – Numerous major cities in the U.S. have undergone gentrification and are continuing to gentrify. This process has led to the dislocation of long-time residents with low-to-moderate incomes to the inner suburbs of the major urban centers. Being fiscally strapped, these suburbs do not have the resources to meet the social service needs of these forced migrants, which is leading to increasing material deprivation[8] and increases in poverty[9]. There are no signs that this trend will reverse itself over the coming decades.
- Lack of affordable housing and energy – Currently, the U.S. lacks 7 million affordable housing units (Center for American Progress, 2021). Virtually no households living on limited incomes can afford fair market rents (Aurand et al., 2020). One in three U.S. households find it difficult to pay their energy bills (U.S. Energy Information Administration, 2018). These trends do not appear to be reversible any time soon.
- Lack of living wage jobs – The economy of the U.S. is dominated by service sectors jobs; 71 % of the workforce have jobs in this sector (Pew Research, 2019). Unfortunately, a high percentage of these jobs are low-wage and are often part-time and lacking in benefits. Even more unfortunately, disruptive technologies, combined with the after-effects of the coronavirus pandemic (see Section 5.1) could end up reducing employment opportunities in the service sector. Additionally, automation will continue to reduce employment in the manufacturing sector[10] and the emergence of autonomous vehicles could decimate employment in the transportation sector (Center for Global Policy Solutions., 2017). All-in-all, for many Americans, prospects of jobs that pay living wages can be expected to diminish in the coming years.
- High levels of personal and household debt – As noted above, personal debt in the U.S. is already high. There are no signs that this situation will trend differently in the future for a substantial fraction of U.S. households.
- Lack of adequate funding for social services – Conservative administrations at all levels of U.S. government have succeeded in reducing funding for social service programs targeted to serve economically disadvantaged households and communities. For example, federal funding for many major block grant programs has fallen 26 % since the year 2000[11]. Turmoil caused by the

[1] https://www.census.gov/library/publications/2019/demo/p60-266.html.
[2] https://www.federalreserve.gov/publications/files/2017-report-economic-well-being-us-households-201805.pdf.
[3] https://www.bankrate.com/finance/debt/average-american-debt/.
[4] https://spendmenot.com/american-savings-statistics/.
[5] https://www.census.gov/data/tables/2017/demo/popproj/2017-summary-tables.html.
[6] https://www.cbpp.org/research/social-security/policy-basics-top-ten-facts-about-social-security.
[7] https://www.cbpp.org/research/social-security/policy-basics-top-ten-facts-about-social-security.
[8] https://www.citylab.com/equity/2019/04/gentrified-cities-neighborhood-change-displacement-poverty-data/586840/.
[9] https://www.brookings.edu/testimonies/the-changing-geography-of-us-poverty/.
[10] https://fortunly.com/statistics/automation-job-loss-statistics/.
[11] https://www.cbpp.org/research/federal-budget/funding-for-housing-health-and-social-services-block-grants-has-fallen.

coronavirus pandemic and BLM may turn this trend around, though skyrocketing federal debt attributed to programs to deal with the former may be an insurmountable barrier to restoring funding to social service programs.

Unless the political will of the U.S. becomes more amenable to helping the less fortunate, the combination of these trends could double the U.S. poverty rate over the next several decades. The only driving force that could counter the types of negative trends on poverty just listed is technology writ large. Instead of allowing disruptive technologies to continue to gut the middle class, the vision here is that disruptive technologies could actually be used to disrupt poverty. Households and communities could employ extremely affordable technologies to produce energy and food, and manufacture essentials. This vision is depicted in more detail in Sections 7.5 and 7.6, titled Willow Ponds and Islandias, respectively.

3. Health

One sign that the health of Americans is in the balance is the slight decline in life expectancy between 2014–2017[12], and then another as a result of the coronavirus pandemic (see Fig. 1). The opioid epidemic received most of the blame for this unprecedented outcome in a non-war period, along with unbalanced diets and sedentary lifestyles, and increasing rates of suicide[13]. According to the America's Health Ranking, in the past 30 years, obesity and diabetes have increased 166 % and 148 %, respectively[14]. American society is plagued by health disparities between the white and minority populations. More bacterial infections are becoming resistant to anti-bacterial treatments[15] while the anti-vaxxer movement is on the rise[16].

Other major trends impacting health include:

- Aging population – Older individuals have more health problems than younger individuals. Cognitive issues such as Alzheimer's and Parkinson's Disease can be expected to inflict increasing numbers of Americans.
- Worsening Mental Health – Increasing numbers of Americans are experiencing mental health issues[17]. Causes include pathologies of social media, physical isolation, economic despair, worries about climate change, and the accumulation of stresses that modern American society inflicts upon individuals. Partisan politics and on-going culture wars only adds to mental stress. These issues will probably worsen over time.
- Resistance to anti-biotics – It is a cruel unintended consequence that germs like bacteria and fungi are becoming increasingly resistant to modern medicines[18]. Increasing numbers of people will die unless modern medicine can regain its advantages over microbial infections.
- Health Insurance Poverty – Increasing costs and decreasing availability of health insurance both work to reduce access to high quality health care in the United States.
- Worsening outdoor air quality and other environmental issues – Separate from climate change, deregulatory efforts and lack of funding for environmental programs is leading to worsening air and water quality[19].

Poverty negatively impacts human health. The Healthy People Program of the U.S. Department of Health and Human Services defines social determinants of health (SDOH) as "conditions in the environments in which people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks[20]." The five pillars of SDOH are neighborhood and the built environment, economic stability, education, social and community context, and health and health care. None of these pillars will be strong in the climate slums that will emerge in the poorer inner suburban of major cities. Thus, as a result, poverty levels will be quite high in these communities. The health impacts of climate change will also be correspondingly high.

Worse health can lead to increasing levels of poverty. The simplest link is that poor health results in more missed days of work for low-income workers. Since in the U.S. few low-income workers have paid sick leave, a missed day of work directly reduces their income[21]. Too many missed days of work could lead employers to fire workers. In more extreme cases, poor health could lead to becoming too disabled to work. The safety net is not robust enough to allow disabled workers to escape poverty. In fact, our research has found that near-elderly households (i.e., older but not yet at retirement age) suffer much higher levels of bad health, home conditions and household budget situations than other households (Tonn et al., 2021).

Changes in technology as opposed to changes in human behavior may be the key to ameliorating the host of negative trends on human health in the U.S. Researchers are continuing to improve treatments for a wide range of health problems, from Alzheimer's to

[12] https://www.cdc.gov/nchs/data/hestat/life-expectancy/life-expectancy-2018.htm.
[13] https://www.statista.com/statistics/1040079/life-expectancy-united-states-all-time/.
[14] https://assets.americashealthrankings.org/app/uploads/ahr_2019annualreport.executivehighlights.pdf.
[15] https://www.euro.who.int/en/health-topics/disease-prevention/antimicrobial-resistance/about-amr/global-trends-bacteria.
[16] https://www.healthline.com/health/vaccinations/opposition.
[17] https://www.ajmc.com/focus-of-the-week/mental-health-issues-on-the-rise-among-adolescents-young-adults.
[18] https://www.cdc.gov/drugresistance/about.html.
[19] https://www.climatecentral.org/news/climate-change-is-threatening-air-quality-across-the-country-2019.
[20] https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-of-health.
[21] https://www.epi.org/publication/work-sick-or-lose-pay-the-high-cost-of-being-sick-when-you-dont-get-paid-sick-days/.

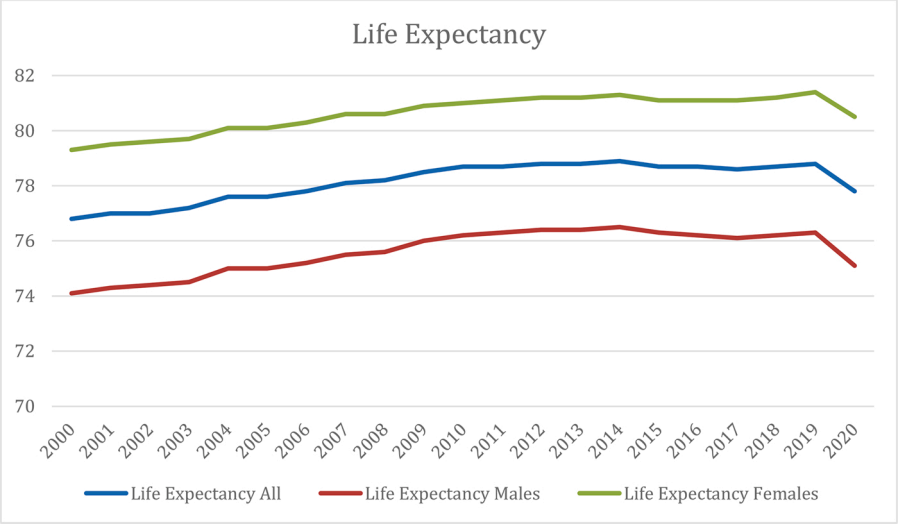

Fig. 1. Life Expectancy in the United States*.
*https://www.cdc.gov/nchs/data/vsrr/VSRR10-508.pdf

cystic fibrosis[22]. CRISPR gene editing technology is beginning to see clinical trials to combat cancer and blood disorders[23]. Health-related apps for digital devices are proliferating[24]. Advances in optical imaging, surgical robotics and remote surgery are revolutionizing this field of medicine[25]. Science is continuing to improve the nutritional value of food crops[26].

4. Climate change

The potential impacts of climate change on the U.S. are well known, numerous, and far-reaching. Warming of the atmosphere is anticipated to increase levels of tropospheric ozone, periods of drought, and wildfires. Hurricanes, tornados, and floods are expected to be more frequent and more extreme. Damages to urban infrastructures will be more crippling and expensive. The changing climate will impact agriculture and create new pathways for the invasion of tropical diseases and invasive species.

It is also clear that climate change will not be mitigated over the next several decades. Greenhouse gas emissions are still increasing. Even if movements towards electrification and renewable energy take hold, it may take centuries for the elevated levels of GHG in the atmosphere to abate. Thus, adaptation must be a key strategy for the U.S. and humanity moving forward. Unfortunately, in the U.S., adaptation efforts are hampered by an unwillingness to expend public funds to protect the public good in all but the direst of circumstances. This unenlightened perspective is exacerbated by fervent climate change deniers. Thus, for the most part, our study assumes that climate change's impacts on poverty and health will not be ameliorated without new policies.

Climate catastrophes directly influence disruptions (e.g. supply chains) and destruction (e.g. property) and increase health risks. Fig. 2 illustrates the devasting and interrelated impacts that catastrophic climate change can have on individuals' economic well-being, health, and quality of life.

Climate change is expected to lead to increases in these types of health problems:

- Bad allergy days may increase from longer growing seasons and increasing levels of pollens produced by noxious weeds and other plants that trigger seasonal allergies. Increased exposure to allergens not only could exacerbate the asthma epidemic in the U.S. but also weaken individuals' immune systems in general[27];
- Health impacts of heat stress will increase from hotter days and nights and more frequent and extended heat waves. It is anticipated that heat stress-related deaths in the U.S. will increase (Wu et al., 2014);
- Respiratory and cardiovascular issues from air pollution, such as tropospheric ozone, and hotter temperatures are expected to worsen as the climate warms;
- New water borne diseases may arise in the U.S. as the warming climate heats up surface water bodies[28];

[22] https://nypost.com/2019/11/18/the-most-amazing-medical-breakthroughs-of-2019/.
[23] https://www.sciencenews.org/article/crispr-gene-editor-first-human-clinical-trials.
[24] https://www.digitaltrends.com/mobile/best-health-apps/.
[25] https://www.staffcare.com/4-advancements-in-surgical-technology/.
[26] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4346933/.
[27] https://www.hsph.harvard.edu/c-change/subtopics/climate-change-and-allergies/.
[28] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5468171/.

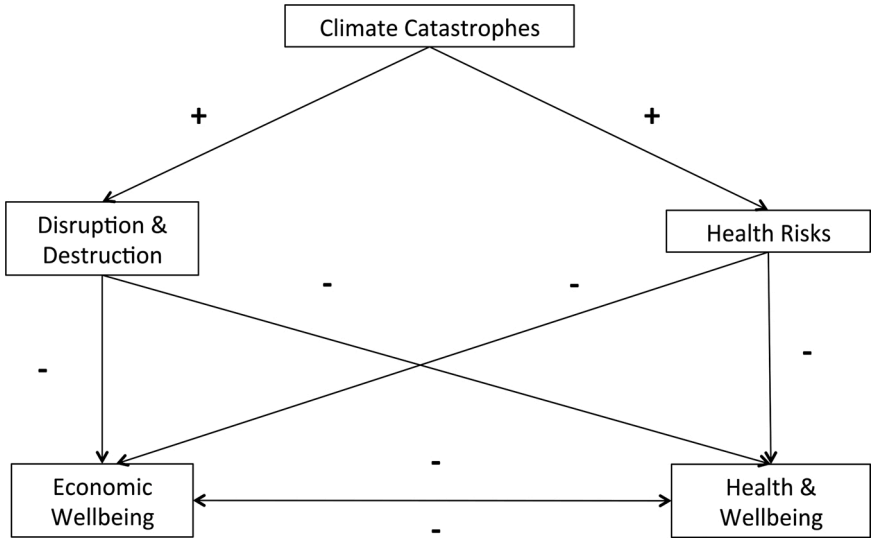

Fig. 2. Impacts of Climate Change on Poverty and Health.

- As the climate warms, tropical diseases new to the U.S. will migrate north into the U.S.[29];
- Injuries and deaths from extreme weather events, whether they be hurricanes or tornados or flash floods, can be expected to increase due to climate change[30];
- Extreme weather events will increase the frequency of power outages. Power outages may deprive individuals from the benefits of electrical medical equipment and refrigerated medicines resulting in increased morbidity and mortality (Hernandez, 2021);
- Household displacement and migration will adversely impact mental health (Siriwardhana and Stewart, 2013); and
- Frequency and intensity of droughts and heat waves will cause more wildfires that will result in injuries and fatalities and adversely impact health[31].

Climate change could exacerbate negative poverty trends in numerous manners, including:

- Disruptions of supply chains could raise the prices of most every product and service;
- Extreme weather events will increase the probability that families will face unexpected and unaffordable emergency expenditures (e.g., home repair, vehicle repair, high energy bill);
- Gentrification may increase as many affluent households find that cities are more resilient to climate change than are suburbs with respect to transportation, electricity, and water;
- Extreme weather events could disrupt employment to the degree that jobs are lost;
- Extreme weather events and drought/wildfires disproportionately destroy affordable housing, which will then not be rebuilt;
- Destruction of property will lead to displacement and increased poverty;
- Increased temperatures will increase energy burdens (Jessel et al., 2019);
- Increased extreme weather events will cause increased material deprivation due to disruptions in telecommunications and transportation systems; and
- Increased extreme weather events will increase power outages which will disrupt economic activities.

Increasing levels of poverty will reduce the resilience of households and homes to the adverse impacts of climate change and will negatively impact health. For example, households suffering from energy poverty may have to forgo food and prescriptions to pay their utility bills. Low-income workers' health may decline for various reasons due to climate change and then may miss more days of work. As mentioned previously, since most low-income workers in the U.S. do not have paid sick leave, their incomes will fall. Lower incomes may lead to increasingly worse health, feeding a downward spiral.

The negative impacts of climate could further increase poverty levels in the U.S. to around 30 % and lead to another period of decreases in estimated life spans.

[29] https://www.aacc.org/publications/cln/articles/2018/august/climate-change-is-shifting-the-course-of-infectious-diseases.
[30] https://www.niehs.nih.gov/research/programs/geh/climatechange/health_impacts/weather_related_morbidity/index.cfm.
[31] https://www.ucsusa.org/resources/climate-change-and-wildfires.

5. New driving forces: COVID-19 and Black Lives Matter

5.1. The coronavirus pandemic

As this piece is being written, the world is still in the midst of the COVID-19 pandemic[32]. It is anticipated that the virus will eventually infect hundreds of millions of individuals and result in the deaths of millions. Countries, states, and municipal governments reacted, to various degrees, by shutting down local economic activities and issued shelter-in-place orders to reduce the spread of the virus. The economic impacts of these actions have been devastating.

It will take some time to discern what lasting impacts the pandemic will have on economies and societies, thus COVID can certainly be considered a wildcard at present. However, here are some initial thoughts. First, it is likely that the economic contraction will greatly increase poverty rates in the U.S. Second, at this point in time, the economic contraction will adversely impact state and local revenue, which will exacerbate trends towards reductions in funding for social services. This impact will both hamper economic recovery and lead to increase of preventable health risks attributable to climate change. Third, revenue shortfalls will reduce expenditures on climate resilience programs.

Here is a list of near-term major impacts that can be anticipated from the pandemic:

- Increased poverty and loss of jobs;
- Diminished functioning of several thousand COVID-19 victims, many have/will have permanent medical conditions and disabilities as a result of the virus;
- Increased mortality rates from COVID-19;
- Increased morbidity and mortality rates due to other health issues;
- Increased rates of substance misuse, depression, anxiety, suicide, and violent crimes; and
- Though reduced economic activity may reduce the emissions of GHGs in the very short-term, this will also lead to a reduction in the prices of fossil fuels, which could possibly lead to increased consumption in the near-term.

Here is a list of longer-term impacts that can be anticipated from the pandemic:

- Increases in funding for public health programs;
- Acceleration of local self-sufficiency efforts; and
- Improvements in the resiliency of supply chains.

5.2. Black Lives Matter

The Black Lives Matter (BLM) was officially born on July 13, 2013, in a response of the Black and Brown community to police brutality[33]. BLM is an attempted intervention in a world where black and brown individuals are intentionally profiled and targeted. The heinous death of George Floyd at the hands of the Minneapolis, Minnesota police has recently led to a tremendous outpouring of support for BLM. The broader context is American society can still be characterized as racist and, many would argue, has not evolved substantially or meaningfully from its slave owning past.

With respect to the subject of this paper, health, climate change and poverty in the U.S. in the future, the question to address is: What will be the impact of the BLM movement writ large with respect to social justice, and health, climate, and income equalities? It will take some time to discern the impact of BLM on these aspects of society, so this is a legitimate wildcard.

Here is a list of potential impacts that BLM could lead to in the U.S.:

- Increased funding for social programs and social services;
- More proactive governance in the face of natural disasters and pandemics;
- Reduced health inequities;
- Increased economic productivity as human capital is better utilized;
- Improved educational outcomes for minority populations; and
- A better understanding of the movement to address climate change.

6. Major anticipation: The Great Migration (TGM)

The picture drawn of the U.S. in the year 2070 builds upon the trends just discussed and also upon this driver, which we take as given: *The Great Migration (TGM)*. Climate change will force the relocation of millions of Americans from it coasts, deserts, and, to a lesser extent, expanded flood plains. Forty percent of Americans, ~130 million people currently, live in a coastal county[34]. It is

[32] https://coronavirus.jhu.edu.
[33] https://blacklivesmatter.com/six-years-strong/.
[34] https://coast.noaa.gov/states/fast-facts/economics-and-demographics.html.

anticipated that these areas will experience sea level rise that will inundate large swaths of land, making them uninhabitable.[35] Additionally, the coasts can expect to be battered by more frequent and more powerful storms. Storm surges, extreme winds, and torrential rains will destroy property, some of which will not be rebuilt. Increasing prospects of risk to property and health will lead many to flee these areas before disaster strikes them personally.

The desert regions of the Southwestern U.S. are home to 15 million people[36]. It is anticipated that much of the Southwestern U.S. will become too hot to inhabit. As forecast for other parts of the world, the Southwest will experience temperature increases between 4 and 10 °F[37]. It is predicted that there will be more days where temperatures will exceed 104 °F that can prove deadly to people who must work outside[38]. Homes and offices will be barely inhabitable during these brutal heat waves. Water shortages will become worse, as droughts will become graver and more extended over time and as underlying groundwater supplies become completely exhausted.

The number of people estimated to be living in flood plains is 41 million[39]. Flood plain insurance is anticipated to disappear, which will drive a very large percentage of individuals from these areas.

Overall, at a minimum, we anticipate that at least 33 % of individuals living near the coasts, in the deserts, and in flood plains will be forced to internally migrate to other places in the U.S. The Great Migration could be 70 million strong. To accommodate TGM, the U. S. will need 25–30 million new housing units. Failure to build these new units will increase material deprivation and poverty.

Households in poverty and facing material hardships will compose a large portion of the displaced. Displaced households experiencing near-poverty and even those that could be considered middle income will also be at extreme risk of falling into poverty, depending in part on to where they are able to migrate. The multi-faceted scenario presented in the next section addresses where everyone may end up and how they may fare.

7. The United States circa 2070

Early in the 21st century, about 31 % of the U.S. population lived in urban areas, 55 % in suburban areas, and 14 % in rural areas[40]. We estimate that the 70 million participants of TGM will allocate themselves to these types of regions in a similar proportion: 20 million urban, 38 million suburban, and 12 million rural. They will be distributed in seven distinct groups of human settlements.

Fig. 3 plots the seven representative communities on a graph with how many displaced individuals may end up in them on the y-axis and how well each community will adapt to climate change on the x-axis. The seven types of settlements differ based on their urbanicity, how well the representative communities adapt to climate change, and what degree the representative communities are impacted by TGM and/or contribute indirectly to additional displacement of vulnerable populations. As depicted in Fig. 3, adaptation ranges from a very high level of adaptation to essentially no adaptation whatsoever. In-migration runs from no in-migration to very high levels. Fig. 4 presents a Sankey Diagram that indicates where the 60 million individuals dislocated by climate change and another 10 million dislocated by gentrification start from (origin) and where they end up with respect to the seven types of settlements (destination).[41] The balance of this section presents brief descriptions of each of these seven types of communities.

7.1. Sentient cities

Sentient Cities strive to be sustainable, resilient, and adaptable. They will be learning cities as well. The European Organization for Economic Cooperation and Development (OECD) defines a learning city as: *a city in which communities attempt to learn collectively as a means of changing their own futures* (Yang, 2015).

These cities will employ advanced information technologies to collect and analyze big data in real time to, for example, reduce GHG emissions and waste production, prepare for extreme weather events, explore changes to programs and policies, and evaluate current programs and policies. These technologies will fully interact with and engage local residents, businesses, government organizations, and non-governmental organizations. In this way, these cities can be described as being *sentient*.

Sentient cities will arise from proactive public sector investments and public-provide sector partnerships. Characteristics of sentient cities are most likely to arise in international cities that host major research universities and are global hubs for technology development. They will be homes for the world's symbolic analysts (Reich, 1992). One can imagine places like Boston, Palo Alto, and Austin, homes to leading universities, as emerging sentient cities in the U.S.

The impacts of sentient cities on poverty and human health in the age of climate change will be mixed. On the positive side, a sentient city will be well equipped to deal most effectively with the potential impacts of extreme weather. They will have hardened electrical grids dominated by more reliable micro-grids. More production will be local. For example, vertical farms will be commonplace in sentient cities. They are likely to devote more rather than fewer resources to public health and affordable housing. The quality of life of economically disadvantaged households already living in sentient cities can be anticipated to improve.

On the negative side, living expenses in these cities will be high. Opportunities to find plots of land to develop new housing will be

[35] A recent study estimated that 13 million Americans will be displaced due to sea level rise alone (Gopal, 2019).
[36] https://www.census.gov/library/visualizations/2019/demo/desert-southwest.html.
[37] https://www.nps.gov/articles/climate-change-in-the-southwest-potential-impacts.htm.
[38] https://www.nationalgeographic.com/news/2017/06/heatwaves-climate-change-global-warming/.
[39] https://e360.yale.edu/digest/41-million-americans-live-in-flood-zones-three-times-the-fema-estimate-finds-new-study.
[40] https://www.pewsocialtrends.org/2018/05/22/demographic-and-economic-trends-in-urban-suburban-and-rural-communities/.
[41] or the sake of argument, please assume that new migrants into the U.S. are also subsumed into The Great Migration.

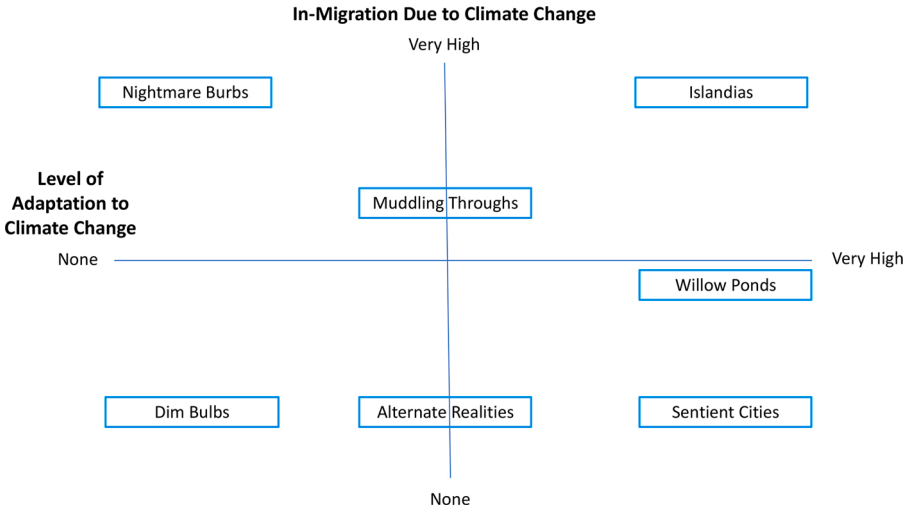

Fig. 3. Seven Representative Communities by Displacement and Adaptation.

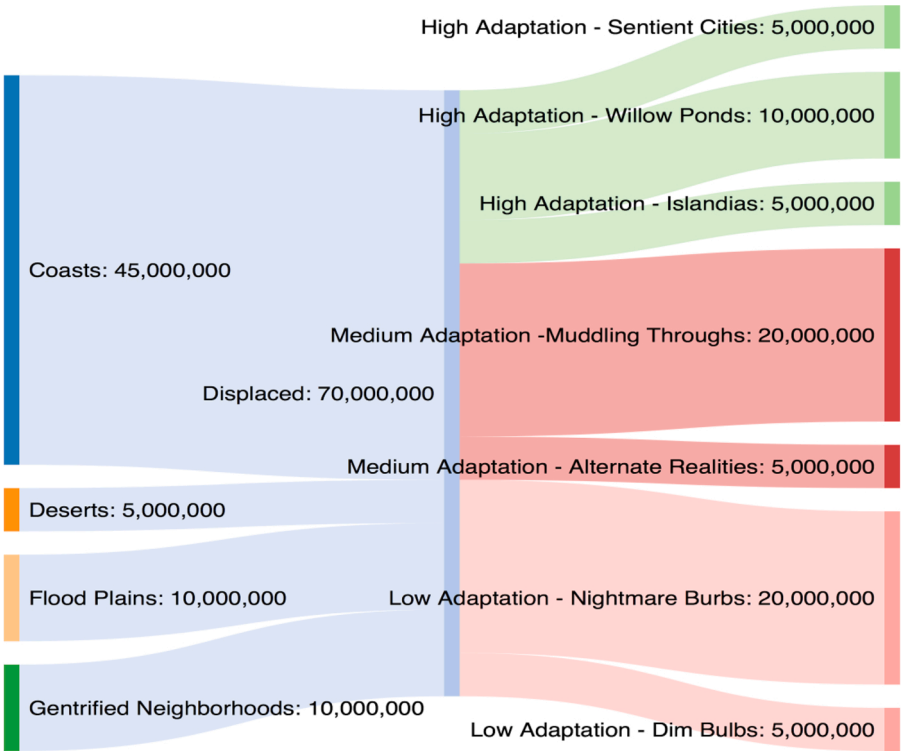

Fig. 4. Origin/Destination Diagram.

limited. Thus, it is unlikely that many if any low to middle income households involved in TGM will be able to afford to live in these cities. In-migration of low-income households into sentient cities will be relatively low.

7.2. Willow Ponds

Climate refuges will spring up in the vast suburban areas of the U.S. Previously, suburbs could be characterized as being completely lacking in self-sufficiency, given a strong definition of the word. They produced virtually no energy or food. Nothing was recycled locally. Water was not conserved.

Self-sufficient suburbs are the result of a convergence of factors: a need to reduce economic risks due to globalization, need for

resilience in the face of climate change, and the availability of a wide range of affordable distributed technologies. The typical suburban plot of land also allows some space for the cultivation of biomass and agricultural resources.

A paper previously published in *Futures* describes the self-sufficient, revitalized suburb called Willow Pond (Tonn and Stiefel, 2014). Driven by climate change, volatile food prices and supplies, volatile energy prices and supplies, economic globalization, frustration with politics, and technological convergence, the residents of Willow Pond created a self-sufficient infrastructure. Home systems feature photovoltaic skins, fuel cells, and artificially intelligent home management. Local manufacturing systems feature: only recyclable, reusable, and renewable materials; additive manufacturing; and sprawl farms. Willow Pond also boasts electric vehicles, immersive telecommunications, largely closed-loop water systems, redesigned community spaces, and central energy storage. Residential self-sufficiency challenges include shifting from a cash- to collaboration-based economy; managing community size to maximize efficiency; balancing technological versus human capital; and dealing with self-sufficient employment versus traditional jobs, among others (Tonn and Stiefel, 2014).

Willow Pond-type developments could be more amenable destinations for climate migrants than Sentient Cities. Zoning ordinances will need to radically change to allow residential properties and subdivisions to become production hubs. These changes could also allow innovations in affordable housing, which could include co-housing, accessory dwelling units, and even 3D printed homes. Every redesigned built structure will be resilient to climate change, which will improve health outcomes. Still, on the whole, these communities will be expensive to join, given their reliance on a panoply of advanced technologies.

7.3. Islandias

In the rural areas, we call these climate refuges *Islandias*. Islandia is the title of a utopian novel written by Austin Tappan Wright (1942). Mostly written in the 1920s, the novel is about a fictional rural island society called Islandia that employs the latest in agricultural science with an intricate socio-economic-political system to become completely self-sufficient and sustainable. Modern day Islandias will be similarly organized and will mostly likely need some external investments to take root and thrive (See Tonn and Ogle, 2002). Here is a vignette that captures the origins and spirit of a rural climate refuge.

Roberta and her two children count their blessings every new day in the climate refuge in Cherokee County, Iowa. This county has benefitted from the largess of the big five tech companies in the U.S., who invested in the infrastructure necessary to take in forty thousand climate migrants from around the United States, quadrupling its population and definitively stemming its steady population loss from decades earlier. Now the 580 square mile county has the most up-to-date broadband that supports a wide range of new employment opportunities in the county. Roberta's story is dramatic but not unusual for the new residents. Her home in Florida was washed away during a hurricane. Actually, the entire county was washed away. She and her kids managed to escape but spent the next two years slowly migrating up north. Because her former county no longer existed, there was no legal jurisdiction to enforce her alimony payments agreement. All of their prior medical records were also lost. Housing and employment instabilities impacted her health and her kids did poorly in school. One of her friends had made it to Cherokee County and had recommended her to Google to fill a new position as a YouTube video curator. She and her kids are enjoying their new lives and especially appreciate the organic cultural diversity of their climate refuge.

It is anticipated that Islandias will be attractive to climate migrants who were displaced from rural communities. Many of these migrants will also be escaping oppressively religious communities, as they finally come to believe the climate change is real. Overall, these communities will be resilient to climate change. They will not be high income but will have high levels of social capital. This will allow them to take care of the economically disadvantaged. Sophisticated health care facilities will still be lacking in rural areas, but telehealth services will improve tremendously.

7.4. Muddling throughs

A large portion of the U.S. will muddle through the impacts of climate change and TGM (Lindblom, 1959). These urban, suburban and rural communities are inland, with the majority being located in the non-coastal Mideast, Midwest, Great Plains and Southeast regions of the U.S. The political DNA of these communities will allow the allocation of only a modest amount of public resources to adapt to climate change. For example, efforts will be made to harden electric power systems to improve their resilience to extreme weather events but power outages will continue to plague these communities, as will flooding, and disruption of transportation and telecommunication services.

These communities will absorb a large portion of the TGM. How this will happen will be quite dependent on the characteristics of the destination communities. Many migrants will head to major cities, such as Denver and Minneapolis. Upper middle-class migrants that are able to maintain or find new employment will hasten the gentrification of these cities, thereby increasing a secondary migration of lower-income households out of the urban cores to older inner suburbs (see the Nightmare Burbs in Subsection 7.6). In this way, poverty levels will be increased over baseline levels seen today. Additionally, these communities will abandon development in what will be expanded flood plains. This will also force low-income households out of the cities to the Nightmare Burbs.

Some communities will be able to grow without displacing existing low-income residents. Here we are thinking of smaller urban centers that have only recently seen their populations increase, communities like Fargo, South Dakota, Jackson Hole, Wyoming and Boulder, Colorado.

Many new migrants will overwhelm existing populations of other communities. For example, Detroit will attract climate migrants because of its low land and housing prices and relative safety from climate catastrophes. In fact, this is already happening, and conflicts are already arising between the newcomers and long-term residents[42].

The cities and rural communities of Appalachia will also be a popular destination for climate migrants because of the mild climate and low probability of natural disasters. Culture wars will certainly ensure, as the newcomers may not appreciate nor make authentic attempts to adapt to the Appalachian way of life, having completely disregarded the indigenous pronunciation of the region. In some ways, there will be no time, as these mostly rural and economically disadvantaged counties will find themselves in a desperate race to build roads and sewer systems, increase police and fire departments, and build new housing which will seemingly springing to live during the night like mushrooms. Ironically, the health of the original inhabitants will increase as money will now be available to support full service hospitals, active family practices, and medical specialists. The new inhabitants will effectively shut down the pill mills that were feeding the opioid addiction crisis, too. Conversely, the health of the new comers will be somewhat worse, due to the stress of moving and pervasive increases in health risks to due climate change. But it will be better than it would have been had they stayed put to face the wrath of climate change.

Lastly, there will be some innovations in the Muddling Through communities that are worth mentioning. Since most of the major cities are located on major rivers and lakes, micro-communities of affordable and supportive housing and homeless shelters will spring up on abandoned boats and barges. These new living arrangements will essentially exist within flood plains and will be isolated from the remaining developments. They can be winched here and there depending on water levels and local governments' whimsies. After a while, it will be evident that these communities can be easily expanded and may eventually become destinations for tourists.

Poverty will still exist in the Muddling Through communities. Despite the BLM movement, they will still seek to allocate the minimum amount of public resources to social services, health care, housing, and public health. Low-income migrants will face overcrowded and unaffordable housing and very tight labor markets. Little progress will be made to ease the financial stresses of retirees living only on Social Security. Health risks attributable to climate change will increase, not decrease. In particular, we expect increasing levels of deaths due to thermal stress.

7.5. Alternate realities

These are upper-middle class and upper-class suburbs that will be particularly immune to driving forces related to poverty, health, and climate change. These suburbs' legacy includes exclusionary zoning, and high property values. They are economically-gated, if not also physically gated, communities that are unwelcome homes for the economically disadvantaged. Only the most well-off climate migrants will be able to find new homes in these communities. These communities may suffer from regional disruptions in electricity, transportation, and telecommunications from extreme weather events and these events may up-root trees and damage homes. However, on the whole, climate change will not impact health and will not lead to increases in poverty in these communities.

7.6. Nightmare burbs

For many, future lives in the suburbs will not resemble the American dream. As noted in Section 2, gentrification of U.S. cities is already resulting in out-migration of lower-income households to poorer inner suburbs. TGM, more gentrification and abandonment of flood plains will add even more population to these communities. These suburbs can be characterized in these ways: old and dilapidated housing, aging urban infrastructures, poor to non-existent public transportation systems, and low property values. The low property values lead to lower than average housing costs, which are taken advantage of by slum landlords. Evictions and overcrowding are common in these communities. Efforts to turn these communities around fail because the tax base cannot support adequate schools, hospitals or social services.

Poverty rates in these Burbs will exceed national averages. Health will correspondingly suffer. Adaptation to climate change will be minimal if at all. Power outages and flooding will be endemic. Heat waves will regularly threaten human health, especially the health of the elderly, disabled, and socially isolated. Disruptions of transportation and lack of reliable telecommunications systems will dim employment prospects.

7.7. Dim bulbs

Rural America will also continue to be the home of religious conservatives, known worldwide for their denial of climate change, racist tendencies, and aversion to social services for the economically disadvantaged. It can be expected that some climate migrants displaced from these types of communities will be attracted to settling in similar communities, which we call *Dim Bulbs*.

The Dim Bulbs will not adapt to climate change, obviously. Youth may move away but by-and-large, their populations will fossilize in place. Health care will be deficient. Poverty rates will be high and untended. Frequent power outages will be characterized by the literal dimming of their lightbulbs.

The Dim Bulb communities will, nevertheless, see a few innovations in lifestyles and employment. Here is a vignette from the Central Valley region of California.

[42] https://www.crainsdetroit.com/nonprofit/new-detroit-turns-focus-racial-inequities.

An unanticipated consequence of climate change was the dramatic reduction of undocumented migrant agricultural workers in the Central Valley of California. Simply put, the heat and drought has rendered the area almost totally uninhabitable and most certainly destroyed the agriculture in the Valley. Juan stayed on, though. Numerous businesses and families have hired him, albeit at a very low wage per job, to do the best he could to preserve the agricultural infrastructure in his 'territory' of the Valley in hopes, however dim, that the climate might become more favorable to agriculture in the region. The U.S. Bureau of Labor Statistics created a brand-new job category for people like Juan, Resource Shepherds. Juan rotates through his territory every two weeks or so in a Mad Max kind of vehicle. He calls in drones to help him deal with the occasional looter. He enjoys the solitary lifestyle and his health even improved over time.

7.8. Other wildcards

This paper sites numerous existing trends, identifies various new technologies that could influence health and poverty, and addresses two substantial emerging issues in the U.S., COVID and BLM, which can be viewed as wildcards because their impacts on society are quite uncertain. Two other wildcards deserve to be mentioned here. One is the failure of American democracy. Also as this paper was being written, individuals who were attempting to essentially overthrow the results of the national presidential election attacked the U.S. capitol. In addition to this violence, efforts are being undertaken by conservative, White politicians to restrict voters' rights and otherwise subvert democracy. If this happens, then one can anticipate efforts to combat climate change will dwindle, as will commitments to supporting health improvement and poverty reduction programs for low-income and minority populations. Those in need will increase in all of the human settlements described above.

A second wildcard to consider is geoengineering. One could argue that it is possible (thought maybe highly unlikely) that a successful geoengineering initiative could stop global climate change and all of its catastrophic impacts. In this case, The Great Migration would be forestalled. It could also be the case that the unintended consequences of geoengineering could also be catastrophic.

7.9. Summary

In summary, the U.S. can and ought to anticipate The Great Migration. Tens of millions of Americans will flow to very different destinations. Some may offer welcome refuge from climate change, such as Willow Ponds and Islandias. Some may not, such as the Nightmare Burbs and Dim Bulbs. Some may just be unfordable, such as the Sentient Cities, or inhospitable, such as the Alternate Realities. Some may not offer much of a respite from poverty, climate change and bad health, such as the Muddling Throughs. Aggregate changes in poverty and health depend upon which of these types of communities grows more and what types of policies might be enacted to improve the worst communities.

8. Policy recommendations

It is quite daunting to take on the plethora of policy recommendations needed to effectively address poverty and health in the U.S. This section limits the focus to housing issues associated with TGM.

Formally Declare the Right to Adequate Housing a Human Right. It is imperative that a sound, ethical foundation be adopted to guide the development of new and adequate housing in response to TGM. We believe that there is a human right to adequate housing. The United Nations sets out these principles[43]:

1 Legal security of tenure
2 Availability of services, materials and infrastructure
3 Affordable housing
4 Habitable housing
5 Accessible housing
6 Location
7 Culturally adequate housing

The most powerful recommendation would be to amend the U.S. constitution to formally set out that housing is a right to be enjoyed by every U.S. citizen. Failing this, the U.S. Congress could pass housing legislation, such as an Adequate Housing as a Human Right Act, to guide housing policy in the U.S.

Greatly Increase Affordable Housing Programs. By far the most straightforward approach to increasing affordable housing in the U.S. is to increase subsidies. These subsidies could take the form of reduced interest loans to developers or increases in the number and size of housing vouchers to income eligible households. Funding could also be increased for affordable housing retrofits, and the installation of energy efficiency, healthy breathing, and climate resilience measures. Adherence to the principles set out above will help to ensure that re-development of areas ravaged by climate change will benefit historically under-represented populations and not exacerbate the negative impacts of gentrification. For example, rebuilding in some areas of New Orleans from Hurricane Katrina exhibited gentrification as the neighborhoods became whiter and higher income (Aune et al., 2020).

[43] https://www.un.org/ruleoflaw/files/FactSheet21en.pdf.

Change local housing ordinances. New homes will need to be built quickly. They ought to be built to be sustainable and resilient. Traditional zoning ordinances and building codes should be revised to foster these goals. For example, zoning ordinances will need to be revised to allow the development of Willow Ponds in suburban areas and even Islandias in rural areas. Zoning should be revised to allow new housing units to be built on already occupied large lots. These are typically referred to as accessory dwelling units[44]. A whole host of changes in building codes are needed to allow in-home production of energy and even the construction of new homes by 3D printing[45].

Support Private-Public Sector Housing Innovations. Though urban planners have long been inspired by the Garden City idea of Ebenezer Howard (1902) and visions of urbanicity proposed by Le Corbusier[46], the housing sector is resistant to change and innovation. On the other hand, once an innovation can be proven to be marketable, the housing sector will work to provide those innovations to prospective customers. It is recommended that private-public sector partnerships be funded to develop pilot housing developments designed around the principles and using the new technologies set out above. The partnerships will reduce financial risks faced by the private sector and will hasten the learning processes that governments must address to providing new, innovative housing during TGM.

Consolidate City-County Governments. To address financial problems that are being faced by the poorer inner ring suburbs and that will be intensified by TGM, it is suggested that the federal and state governments provide incentives to consolidate city and county governments, including suburban governments, into larger administrative units[47].

Increase Access to Administrative Records. The impacts of climate change will not only displace millions of Americans but will also disrupt, at best, or destroy, at worst, public record keeping. When communities are destroyed by the impacts of climate change, so too will be their court houses, tax assessor offices, public deeds departments, schools, clinics and hospitals. Court decrees, property claims, school records, and health records could become lost forever, or at least functionally inaccessible to migrants. It is recommended that courts (Tonn et al., 2012) and other institutions work to protect these types of information and make them available to migrants and officials, health care organizations, schools, etc. wherever the migrants might land.

9. Conclusion

The overall conclusion we reach is that even in a developed country such as the U.S., the combined challenges to improving health and alleviating poverty in the face of climate change are enormous. Most trends in the U.S. suggest worsening poverty and health even without the influences of climate change. Disruption and destruction wrought by climate change will cause TGM and dramatically increase poverty rates. Climate change will also unleash a new tsunami of health risks on the U.S. population. Another pandemic would further increase poverty and destroy the health of individuals throughout the U.S.

Conversely, the climate crisis and TGM could also spur innovation in U.S. settlements. We envision the emergence of Sentient Cities, Willow Ponds, and Islandias as sustainable welcoming environments for climate migrants. The BLM movement could further enhance the experiences of low-income climate migrants of color moving into new homes and communities. Federal laws and regulations related to the right to adequate housing as a human right and financing more affordable housing could significantly mitigate the negative impacts of climate change on human health and poverty.

References

Aune, K., Gesch, D., & Smith, G. (2020). A spatial analysis of climate gentrification in Orleans Parish. *Environmental Research, 185*, Article 109384.

Aurand, A., et al. (2020). *Out of reach 2020*. National Low Income Housing Coalition. https://reports.nlihc.org/sites/default/files/oor/OOR_BOOK_2020.pdf.

Center for American Progress https://www.americanprogress.org/issues/green/reports/2019/08/01/473067/a-perfect-storm-2/.

Center for Global Policy Solutions. (2017). *Stick shift: Autonomous vehicles, driving jobs, and the future of work*. Washington, DC: Center for Global Policy Solutions.

Chalupka, S., Anderko, L., & Pennea, E. (2020). Climate change, climate justice, and children's mental health: A generation at risk? *Environmental Justice, 13*(1), 10–14.

Gopal, P. (2019). *America's great climate exodus is starting in the Florida keys*. Bloomberg News. Sept 20, https://www.bloomberg.com/news/features/2019-09-20/america-s-great-climate-exodus-is-starting-in-the-florida-keys?utm_campaign=news&utm_medium=bd&utm_source=applenews https://blogs.scientificamerican.com/observations/u-s-cities-need-to-plan-for-an-influx-of-internal-climate-migrants/.

Hernandez, D. (2021). Resilient power: A home-based electricity generation and storage solution for the medically vulnerable during climate-induced power outages. *Futures, 128*, Article 102707.

Howard, E. (1902). *Garden cities of to-morrow* (2nd ed.). London: S. Sonnenschein & Co.

Jessel, S., Sawyer, S., & Hernandez, D. (2019). *Energy, poverty, and health in climate change: A comprehensive review of an emerging literature* (Vol. 7, p. 357).

Lindblom, C. (1959). The science of "Muddling through". *Public Administration Review, 19*(2), 79–88.

Pew Research. (2019). *Ten facts about American workers*. https://www.pewresearch.org/fact-tank/2019/08/29/facts-about-american-workers/.

Reich, R. (1992). *The work of nations: Preparing ourselves for the 21st century capitalism*. New York: Vintage Books.

See Tonn, B., & Ogle, L. (2002). Gatlinforge: A vision of a future gateway community. *Futures Research Quarterly, 18*(3), 5–39.

Siriwardhana, C., & Stewart, R. (2013). Forced migration and mental health: Prolonged internal displacement, return migration and resilience. *International Health, 5*(1), 19–23.

Tonn, B., & Stiefel, D. (2014). Willow Pond: A decentralized low-carbon futures scenario. *Futures, 58*, 91–102.

Tonn, B., Hawkins, B., Rose, E., & Marincic, M. (2021). Income, housing and health: Poverty in the United States through the prism of residential energy efficiency programs. *Energy Research & Social Science, 73*, Article 101945.

[44] https://www.huduser.gov/portal/publications/adu.pdf.

[45] https://www.autodesk.com/redshift/3d-printing-building-construction/.

[46] https://en.wikipedia.org/wiki/Le_Corbusier.

[47] https://www.nlc.org/resource/cities-101-consolidations.

Tonn, B., Stiefel, D., Scheb, J., Glennon, C., & Sharma, H. (2012). Future of the courts: Fixed, flexible, and improvisational frameworks. *Futures, 44*, 802–811.
U.S. Energy Information Administration. (2018). *One in three U.S. households faces a challenge in meeting energy needs.* https://www.eia.gov/todayinenergy/detail.php?id=37072.
U.S. Global Change Research Program. (2016). *The impacts of climate change on human health in the United States: A scientific assessment*. Washington, DC. April.
Wright, A. (1942). *Islandia*. New York: Farrar & Rinehart.
Wu, J., et al. (2014). Estimation and uncertainty analysis of impacts of future heat waves on mortality in the Eastern United States. *Environmental Health Perspectives, 122*(1), 10–16.
Yang, J. (2015). *Building learning cities as a strategy for promoting lifelong learning* accessed February 2015 http://uil.unesco.org/fileadmin/workshops/en/pilot_cb/pres_ref/Day%2005/2.%20Jin%20Yang.pdf.