societies

Communication

Could 79 People Solarize the U.S. Electric Grid?

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Abstract: Although wealth inequality has many established negatives, this study investigates a potential positive, unprecedented wealth concentration makes it possible for solutions to large and seemingly intractable problems to be deployed by convincing a relatively small number of individuals to invest. In order to probe this potential outcome of inequality, this study quantifies the number of people necessary to radically reduce the greenhouse gas emissions responsible for global climate destabilization from the U.S. electric grid, which is one of the largest sources of emissions. Specifically, this study determined that 1544 GW of solar photovoltaic (PV) technology must be deployed to eliminate the use of fossil fuels on the U.S. electric grid, if PV is conservatively deployed as a function of population density. The results showed that only 79 American multi-billionaires would need to invest in PV. This investment would still leave each investor with a billion dollars of liquid assets as well as substantial long-term profits from PV. The analysis also concluded that 79 people is a conservative upper estimate of those that would need to be convinced of the usefulness of moving to a solar U.S. grid and that this estimate is likely to decrease further in the future.

Keywords: income inequality; electrical grid; philanthropy; photovoltaic; renewable energy; solar energy; wealth distribution; wealth inequality; wealth gap; solarize

1. Introduction

By the 1990s in most publicly held companies, the compensation of the highest-paid employees (e.g., top executives) was virtually independent of their job performance [1,2]. Simultaneously, income inequality has risen as the value provided to society by these top earners has become divorced from their earnings.[1] Despite the relatively extreme income inequality observed in the U.S., the distribution of wealth is far more concentrated [5–7]. In 2017, the distribution of wealth has become clearly unequal, with the lower-income half of the American population owning about 1.1% of the total wealth, while the wealthiest 1% possessing about 35.5% of the wealth [8]. It is well known that much of this wealth is inherited and that the transmission of capital down the generations is an extremely important determinant of an individual's or a household's wealth [9–13]. For all of these extremely wealthy people, income is dominated not by their efforts (work), but by their investments

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[1] In the U.S. in 2018, the average CEO of the S&P 500 Index firms was paid 361 times the wages earned by the average worker [3]. Interestingly, CEOs are often rewarded economically, even when the are objectively ineffective, with pay, bonuses, and "golden parachutes" worth on average $48 million (e.g., the roughly 40% who were the top 25 highest paid in 20 years whose companies failed, went bankrupt, paid millions of dollars in fines for fraud, or received taxpayer bailouts [4]). It should be pointed out that there is no evidence that even the 60% of top paid executives, who were not objective failures, were able to provide material value to their companies or society from the work they performed (e.g., analysis and decision making from themselves, not their subordinates) equivalent to the value of their remuneration.

(e.g., rental income, capital gains, dividends, interest, etc.). As, for example, the higher one's income the greater the share of that income is dominated by capital gains [14]. In addition, U.S. tax law for capital gains has an effective tax rate of less than half of those whose income is based on labor [15] and decreases in taxes are evident as the rich become super rich [16]. This tax policy was one of the factors that has further concentrated wealth over time.

The majority of the literature negatively views wealth inequality as studies show that wealth inequality leads to high social costs [17]. Here, this literature will be summarized to put the potential benefit of inequality discussed in this paper into context. Inequality does not generate optimal outcomes for society if the incentives rest on rents [18]. Inequality can cause individuals to divert effort to securing favor from the wealthy because they possess the preponderance of capital, resulting in resource misallocation, corruption, nepotism, and the expected sub-optimal economic, social, and environmental consequences [17–29]. It has already been well-established that income inequality negatively affects economic growth in the future [19–21], in part because lower income households cannot stay healthy and accumulate physical and human capital [22,23] (e.g., poor, smart, young people cannot go on to college because of access to funding or perceived unacceptable debt burden, which reduces overall labor productivity [18]). This inequality also contributes to lower intergenerational mobility (e.g., less earnings mobility across the generations) [24] and increases the probability of political conflict [25]. Simultaneously, income inequality generally creates sub-optimal policy [26], which reduces the public good to help economic growth and creates an inequality of opportunities for the poor (e.g., access to education, credit, infrastructure, public decision making, etc.) [27]. In extreme situations, a preponderance of inequality can drive a global financial crisis [28] and policies that further inequality are formalized into law because of lobbying [29].

Although inequality has these established negatives, there is a positive to inequality that concentrates wealth for a few individuals, as follows: For solving large and capital-intensive problems, the number of individuals necessary to invest has grown smaller over time and may be approaching a point where the individuals could conceivably all know each other as they already preferentially associate with one another [30]. This association is important as it would make it possible for solutions to large and seemingly intractable problems to be deployed by convincing a relatively small number of individuals to invest within their social circle. In order to probe this potential benefit for inequality and wealth concentration, this study quantifies the number of billionaires necessary to reduce the greenhouse gas emissions responsible for climate destabilization in areas across the globe [31]. Specifically, it investigates elimination of carbon emissions from one of the largest sources—combustion of fossil fuels for the U.S. electric grid (e.g., the three grids made up of the Western interconnection, Eastern interconnection, and ERCOT (Electric Reliability Council of Texas), which are loosely connected, that service the continental U.S.) [32]. This study will determine the amount of solar photovoltaic (PV) technology that must be deployed to convert the U.S. electric grid, which is currently 1.2% solar [33], to eliminate all existing fossil fuels. Then, it will estimate the costs for that conversion and the number of billionaires that would be able to maintain billionaire status while still completing the conversion. The results will be presented and discussed in the context of leveraging wealth concentration by focusing excess capital from the wealthiest individuals to partially solve global climate destabilization from greenhouse gas (GHG) emissions that threaten everyone throughout all global societies.

2. Materials and Methods

Data on U.S. population and solar flux was collected and geolocated. Three databases were obtained to analyze the ratio of population-adjusted solar flux for each state, as follows: (1) A shapefile of the United States was obtained from the ArcGIS database [34], (2) a shapefile of normal direct solar irradiance was obtained from the National Renewable Energy Laboratory database [35], and (3) the population density throughout the U.S. was obtained from the U.S. Census [36]. The ratio of population-adjusted solar flux in each state was transcribed to a map utilizing ArcMap version 10.6.1.

Population-adjusted solar flux is needed to determine a practical PV deployment density over the U.S. and prevent unnecessarily costly adaptations of the electric grid for the placement of large PV systems in high solar flux areas. Thus, the calculations here are based on providing solar power where the people are located, which has the benefits of distributed generation.

In order to obtain the average population-adjusted solar flux for the U.S., $\mathrm{F_{USA}}$ in kWh/m^2/day, the following equation was developed here and used the fraction of solar flux multiplied by the population of each state for the whole country:

$$F_{USA} = \sum_{s=1}^{50} \left(\frac{F_s p_s}{\sum_{s=1}^{50} (F_s p_s)} \right) F_s \left[\mathrm{kWh/m^2/day} \right] \tag{1}$$

where F_s is the average kWh/m^2/day of solar irradiation in each state, s; and p_s is the population of state, s. Thus, a ratio is determined of the population adjusted solar flux for each state in the large bracket. By summing this ratio, times the solar flux for the state, the average solar flux for the whole U.S. is determined.

The list of 2,123 individuals that have more than a billion U.S. dollars in assets, maintained by Forbes [37], was first screened for Americans, which reduced the number to 568 individuals listed in Appendix A. In order to ensure that each individual maintained US$1 billion in wealth if they decided to invest in solarizing the U.S., the aggregate potential capital was calculated by:

$$C = \sum_{n=1}^{n=T_c} w_n - \$1b \ [\mathrm{US\$}] \tag{2}$$

where w_n is the individual wealth for each person and T_c is the total number of individuals needed to meet a capital investment goal. So, for example, for all 568 Americans, C is equal to US$2511.7 billion.

U.S. Energy Information Administration data for 2017 [38] was used to calculate the energy needing to be resourced. The U.S. used 4.034 trillion kWh/year in 2017 in total, but fossil fuels, which all contribute to climate change, were only responsible for 2.536 trillion kWh/year [38]. So, this latter value was used. The National Renewable Energy Laboratory estimates [39] that the total installed system cost, which is one of the primary inputs used to compute the levelized cost of electricity (LCOE) [40], has declined to US$2.80 per direct current watts (Wdc) for residential systems, US$1.85 Wdc for commercial, US$1.03 Wdc for fixed-tilt utility-scale systems, and US$1.11 Wdc for one-axis tracking utility-scale systems. The value of US$1.03 Wdc for fixed-tilt utility-scale systems is used in the final analysis because previous learning rates [41–45] for the global PV industry has resulted in continuous and aggressive reduction in the costs of solar modules [46,47]. As of January 2019, the spot price of the lowest cost PV modules has dropped below US$0.20/W [48]. Technical improvements, like moving to black silicon, are expected to drop those costs further [49] and the International Renewable Energy Agency (IRENA) predicts that the prices will fall by 60% in the next decade [50]. Thus, it is within reason that the PV prices that have already been obtained in the U.S. on the large scale could be met on the small, distributed scale in the near future, with a massive scale up of the industry as analyzed here.

3. Results

The ratio of population-adjusted solar flux in each state is shown in Figure 1.

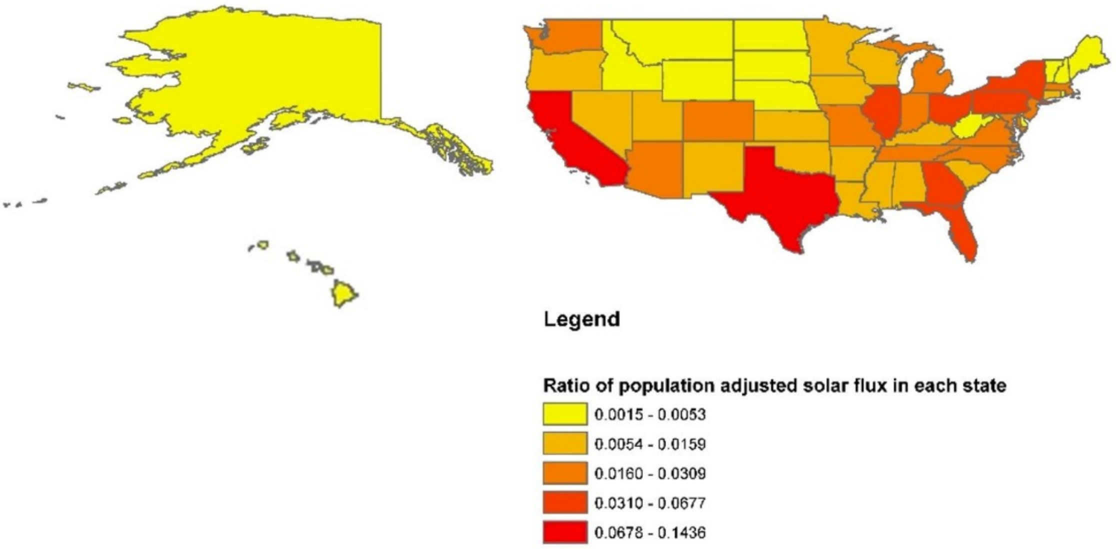

Figure 1. Ratio of population-adjusted solar flux in each U.S. State.

Using Equation (2) and the data shown in Figure 1, the F_{USA} was found to be 4.499 $kWh/m^2/day$. Using the conservative assumption that solar PV is deployed as a function of population and not optimal solar flux, this 4.499 $kWh/m^2/day$ demands that 1544 GW of installed PV. This amount of PV would produce the $2.536x10^{12}$ kWh needed to replace all fossil fuels for electricity production within the U.S. At $1.03/Wp (per peak Watt), this would entail an investment of US$1.59 trillion. Historically, US$1.59 trillion would be considered a substantial sum of capital, however, as discussed in the above, a relatively small number of people (568) in America now control more than this quantity of capital. After assuming that each multi-billionaire in the U.S. would dedicate their wealth in excess of $1 billion to solarization, the cumulative sum of Equation (2) was calculated and is shown in Table 1.

Table 1. Cumulative American multi-billionaires necessary to reach investment goals of complete replacement of all of the fossil fuel-based electricity generation in the U.S. with solar.

Cumulative Number of Investors	American Multi-Billionaires	Wealth Total -$1B [B US$]	Cumulative Excess Wealth [B US$]
1	Jeff Bezos	111	111
2	Bill Gates	89	200
3	Warren Buffett	83	283
4	Mark Zuckerberg	70	353
5	Charles Koch	59	412
6	David Koch	59	471
7	Larry Ellison	57.5	528.5
8	Michael Bloomberg	49	577.5
9	Larry Page	47.8	625.3
10	Sergey Brin	46.5	671.8
11	Jim Walton	45.4	717.2
12	S. Robson Walton	45.2	762.4
13	Alice Walton	45	807.4
14	Sheldon Adelson	37.5	844.9
15	Steve Ballmer	37.4	882.3
16	Phil Knight	28.6	910.9
17	Jacqueline Mars	22.6	933.5
18	John Mars	22.6	956.1
19	Michael Dell	21.7	977.8
20	Paul Allen	20.7	998.5
21	Thomas Peterffy	19.3	1017.8
22	Len Blavatnik	19.2	1037

Table 1. *Cont.*

Cumulative Number of Investors	American Multi-Billionaires	Wealth Total -$1B [B US$]	Cumulative Excess Wealth [B US$]
23	James Simons	19	1056
24	Elon Musk	18.9	1074.9
25	Laurene Powell Jobs	17.8	1092.7
26	Ray Dalio	16.7	1109.4
27	Carl Icahn	15.8	1125.2
28	Donald Bren	15.3	1140.5
29	Abigail Johnson	14.9	1155.4
30	Lukas Walton	14.9	1170.3
31	Rupert Murdoch	14	1184.3
32	Harold Hamm	13.1	1197.4
33	Steve Cohen	13	1210.4
34	Dustin Moskovitz	13	1223.4
35	Charles Ergen	12.4	1235.8
36	Eric Schmidt	12.4	1248.2
37	Philip Anschutz	12	1260.2
38	Jim Kennedy	12	1272.2
39	Blair Parry-Okeden	12	1284.2
40	Leonard Lauder	11.9	1296.1
41	Stephen Schwarzman	11.6	1307.7
42	Donald Newhouse	11.3	1319
43	Andrew Beal	10.6	1329.6
44	John Menard, Jr.	10.5	1340.1
45	David Tepper	10	1350.1
46	Pierre Omidyar	9.5	1359.6
47	Ronald Perelman	8.8	1368.4
48	Micky Arison	8.7	1377.1
49	Thomas Frist, Jr.	8.6	1385.7
50	Charles Schwab	8.4	1394.1
51	Herbert Kohler, Jr.	8.3	1402.4
52	Jan Koum	8.1	1410.5
53	James Goodnight	8	1418.5
54	Ken Griffin	8	1426.5
55	James Chambers	7.7	1434.2
56	Katharine Rayner	7.7	1441.9
57	Margaretta Taylor	7.7	1449.6
58	Gordon Moore	7.5	1457.1
59	Stanley Kroenke	7.3	1464.4
60	John Malone	7.1	1471.5
61	Carl Cook	7	1478.5
62	David Geffen	7	1485.5
63	George Soros	7	1492.5
64	Edward Johnson, III.	6.9	1499.4
65	David Duffield	6.8	1506.2
66	George Kaiser	6.8	1513
67	Patrick Soon-Shiong	6.8	1519.8
68	Stephen Ross	6.6	1526.4
69	Pauline MacMillan Keinath	6.4	1532.8
70	Eli Broad	6.3	1539.1
71	Sun Hongbin	6.3	1545.4
72	Christy Walton	6.3	1551.7
73	Shahid Khan	6.2	1557.9
74	John Doerr	6.1	1564
75	David Green	5.8	1569.8
76	Hank & Doug Meijer	5.8	1575.6
77	Brian Acton	5.6	1581.2
78	Ann Walton Kroenke	5.6	1586.8
79	Leon Black	5.5	1592.3

As can be seen in Table 1, only 79 American multi-billionaires would need to invest to convert all of the U.S. to solar from fossil fuels. This investment would still leave each investor with a billion dollars to use in any way they please.

4. Discussion

The results of this study indicate that a relatively small number of America's wealthiest individuals could completely convert the U.S. electric grid away from fossil fuels by replacing the remaining fossil fuel generation with solar. Seventy-nine Americans would need to give up some of their wealth to make this conversion possible and although they would each remain a billionaire, there are three areas that need to be discussed in the next three subsections, as follows:

1. Why might multi-billionaires want to voluntarily give up their wealth to solarize the U.S.?
2. What is the probability that multi-billionaires would be willing to make the required investment in solar even if they found the reasoning compelling?
3. What are the primarily limitations of the methodology and assumptions made here that resulted in such a low number of individuals needing to give up their wealth to radically remake the U.S. electric grid?

4.1. Why Would a Multi-Billionaire Want to Invest in Solarizing the U.S.?

Both global GHG emissions [31] and global atmospheric carbon dioxide (CO_2) concentrations are increasing rapidly [51], which creates an enormous urgency to cut emissions [52]. The resultant climate change is well-established with a high confidence as are the negative impacts on natural and socio-economic systems [53,54] including the following:

(i) Higher temperatures and heat waves that result in thousands of deaths from hyperthermia and are expected to increase [55–57],
(ii) other adverse effects on human society and health [58],
(iii) crop failures [59,60] that aggravate global hunger and food insecurity [61–63],
(iv) electric power outages [64,65],
(v) rising sea levels that cause low-lying coastal areas throughout the world to submerge gradually, as well as erosion of shorelines [66,67],
(vi) increased risk of flooding [68] and saltwater intrusion [69], as well as severe storms that cause more damage to coastal environments [70],
(vii) risks to forests [71–74],
(viii) droughts [75] and
(ix) fire [71,76,77].

These negative externalities have been shown to be due to human activities, with a confidence level of 95% (primarily combustion of fossil fuels, which is the dominant cause of global warming from 1951 to 2010) [78,79]. Climate change is widely viewed as one of the greatest challenges of our age [80] and GHG emissions from electricity generation is one of the largest contributors to the problem in the U.S. (in 2016 transportation surpassed electric generation for the first time) [32]. Some of the billionaires shown in Table 1 have already discussed what a large problem climate change is and have begun to contribute to energy solutions by investing in Breakthrough Energy Ventures, which is a billion-dollar fund backed by some of the world's top entrepreneurs and investors, including the following: Jeff Bezos, Bill Gates, Mark Zuckerberg, and Michael Bloomberg [81]. Bill Gates, for example, has thought hard about not only the solution to climate change, but others as well [82]. Other multi-billionaires on the list, like Elon Musk, the Tesla founder, said sustainable energy solutions are technologically viable and have been working aggressively for their success [83]. In addition, many of the companies that American multibillionaires control have made substantial investments in solar; so, they are familiar with the technical and economic potential of the technology. For example, Larry Page and Sergey

Brin's Google officially hit its 100% renewable energy target in 2018 [84] and the Walton's Walmart has made a public commitment to solar [85], with the second most onsite PV of any company in the world [86]. Despite this promise, there are a minority on the list in Table 1 who are heavily invested in fossil fuels and would find the transition more challenging. For these individuals, as the potential liability for climate change becomes more serious [87], they might also be convinced to convert for the good of the companies they helped develop. As of this writing, no lawsuits have been won to make a corporation that is a GHG emitter liable for emissions. There are, however, multiple such lawsuits pending and, as the potential liability is so large that it could easily bankrupt most companies, converting to renewable energy could be used as a hedge against this risk [87].

Alternatively, these individuals may be interested in solarizing the electrical grid using a distributed generation model, proposed here, by following the largely successful securitization of PV assets [88–91] due to the purely economic advantages of PV. PV is made even more profitable by the plethora of tax incentives available, which result in large economic returns on investment. First, the renewable energy tax credit allows the system owner to effectively reduce system costs by 30% [92] and the systems are eligible for MACRS (Modified Accelerated Cost Recovery System) 5-year accelerated depreciation. It should be noted here that these tax credit and depreciation factors were conservatively not used in the financial estimates made in the results to eliminate any risk due to policy changes at the U.S. federal level, which would make the estimates inaccurate. Using these mechanisms could make the PV investments discussed in the results substantially profitable for the investors. It is noted that this profitability would need to be weighed against other potential sources of profits for the multi-billionaires, as well as their personal stake in the moving society towards sustainability.

As of this writing, the federal investment tax credit is available at 30% through 2019 and steps down to 26% in 2020, 22% in 2021, and 10% for commercial and industrial systems thereafter [93]. Business owned systems are also eligible for MACRS 5-year accelerated depreciation. The 2017 tax law allows for 5 years of 100% bonus depreciation for systems installed after September 27, 2017 [94]. The term 100% bonus depreciation means that the whole project's applicable tax depreciation is accelerated to the first year of the system's commissioning [95]. This is especially significant for investors in higher income tax brackets, as they see comparatively more value because electricity expenses are paid with after-tax dollars—they are not tax deductible. Different states offer solar energy property tax incentives, providing various amounts of tax exemptions on residential, commercial, and industrial solar PV systems [96]. A final tax incentive opportunity is the creation of Opportunity Zones [97]. This is an investment vehicle that attempts to match economic need with private investment. Qualified opportunity zone property includes any qualified opportunity zone stock, any qualified opportunity zone partnership interest, and any qualified opportunity zone business property [97]. Solar PV systems are well within the defined qualified business property. First, it allows for the temporary deferral of including gross income for gains that are reinvested in a qualified opportunity fund [97]. Second, it allows for *exclusion* of up to 15% of the gain on the original investment, that is deferred by the investment in the qualified opportunity fund if held for seven years [97]. Third, the taxpayer may elect to *exclude* the post-acquisition gains on investments from gross income in qualified opportunity funds that are held for at least ten years [97]. As an added bonus, opportunity zone tax benefits can be layered on top of the Renewable Energy Investment Tax Credit and accelerated depreciation to make an even better investment.

4.2. Probability of Solar Investment

Many of those on the list in Table 1 are already familiar with solar and are investing in it. With the potential to be in a group of the elite that would be potentially credited with "saving the world", there is a non-zero probability that convincing all of these 79 individuals to make the investment is possible. This hypothesis is further supported by the number of multi-billionaires pledging to give away much of their fortunes before they die. This is formally being done in the Giving Pledge, which is a commitment by the world's wealthiest individuals and families to dedicate the majority of their wealth to giving back to the rest of society through philanthropy [94]. At the end of 2018, the pledge had 187 pledgers including several on the list in Table 1, including Warren Buffett, Larry Ellison, James Simons, George Kaiser, and George Lucas [98]. None of these pledges were factored into the analysis here. In academia, there has been an enormous debate raging about inequality [19,99–108] but there appears to be a potential consensus forming among the world's economic elite that their wealth should be used for the betterment of society. Future work is needed to quantify these consensuses and the probability that a relatively small group would collaborate on such a major project. It should also be noted that some of those on the list (e.g., Charles (5) and David (6) Koch) are heavily invested in fossil fuel industries, as well as climate denial activities [109]). However, as noted above, if even a single GHG emissions liability case is won, all investors in fossil fuel industries would financially benefit from immediate renewable energy investment to mitigate climate change-related liability. In addition, all of the analysis presented here assumed conventional economics (e.g., no value was assigned to environmental externalities). However, as the costs of climate change continue to mount [54,110,111], the discipline of green economics [112–114] may gain prominence over conventional economics, which would have the effect of making solar PV even more economically profitable.

4.3. Limitations

This study has several limitations. First, this study assumed that there was more than enough non-shaded optimal surface area to allow for distributed generation with PV, but it did not explicitly calculate siting for the 1544 GW of PV necessary to replace all of fossil fuel electricity production in the U.S. The nuances of territory and siting at both the large scale for PV output [115], as well as DG benefits [116,117] and roof top [118–122] as well as façade [123] locations have been covered extensively. Here, the conservative assumption about locating the PV systems was based on a distributed generation model where the PV would be located following population density in each state across the U.S. There are far more than enough optimal locations (surface area) to install PV in each region to cover more than 100% of the entire U.S. electricity use (let alone the 63% needed here) [124]. A more granular analysis is left for future work. Second, this study did not look at past investments nor to future investments that would reduce the need for the full 1544 GW of PV. The calculations for the PV necessary to completely eliminate fossil fuels from U.S. electric generation are only for the new solar investments necessary. All previous investments and investments in other renewable energy technologies, like wind power, are not considered. It also did not attempt to quantify profitable investments in energy efficiency and conserving technologies (e.g., lighting [125], moving from resistive electricity-based heating to heat pumps [126], buildings [127], and electric motors and drives [128]). It is highly likely that there will continue to be investments in energy efficiency and other renewable energy technologies. Thus, it is highly likely that the value of PV needed, calculated here, is an overestimate. Determining the degree of that overestimate is left for future work. Third, this study assumed modern PV technology. Again, the learning rate in PV production and the efficiency of the technologies can be expected to continue to climb, thus reducing PV costs further [48,49]. This again was taken as a conservative assumption, the correction of which is left for future work.

This study only looked at the generation component of electricity and did not take into account load balancing, efficiency, storage, power quality factor, or transmission. With the solar slated to be put in place, the investment in storage and transmission and other technologies to maintain operation of the grid would be expected to be provided using the conventional utility models. There is recent evidence that this assumption is valid in Germany, where renewables have been able to cover 100% of power for the first time as of January 2018 [129]. Critics may demand that the 79 billionaires must also pay for storage to regulate the grid. This study does not consider this additional investment for the following complexities related to the structure of the U.S. electric utilities, that would both increase as well as decrease costs that will be briefly summarized here. First, only roughly 63% of the power sources on the U.S. grid would need to be converted to solar to replace the existing fossil fuels. The solar specifically investigated here is for use in distributed generation (DG—the assumption based on population density-based deployment). It is well established that DG can postpone investments in generation, transmission, and distribution as electrical power demand grows and, at a large enough scale, eliminate them [130]. DG also reduces transmission losses [131]. Elimination of these losses would result in cost savings of about 10–15% [132]. Other DG benefits include decreased pollution and greenhouse gas emissions [133] and their concomitant potential reductions in mortality by converting to solar [134]. For coal replacement in particular, these premature deaths prevented can be substantial to the point that they number more per year than the current total coal mining employment [135]. In addition, DG provides transmission congestion relief, increased reliability, and ancillary services [131,136]. The economic impacts of these details are highly dependent on the potential for changes in laws revolving around electric utilities and green economics and are left for future work to ensure a smooth transition from fossil fuel generation to solar.

Another limitation is addressing the variations in the PV power that exist in a high PV penetration scenario, like the one discussed in this study is due to (i) the night/day cycle, (ii) the yearly cycle, and (iii) fluctuating cloud conditions. Variations (i) and (ii) will be addressed by changes in the grid and investments by conventional utilities as more PV is deployed and storage becomes necessary. However, reason (iii) (of fluctuating cloud conditions and thus rapidly changing PV power) is the largest problem that needs to be addressed at high penetration rates immediately. However, cloud variations can be largely mitigated using the deployment recommended in this study (e.g., DG). Specifically, by deploying solar PV systems over a larger geographic area, any specific clouds have only a small effect on the overall grid. For example, if a network of PV installations is dispersed throughout a 100 km^2 area, the tolerable acute penetration for PV will increase to 18.1% and if the area expands to 1000 km^2, the limit for PV penetration is 35.8% [137]. It should be noted that, in the solar PV, penetration level is the real time percentage (not the overall percentage of PV electricity generation), which would of course be considerably less as peak sun hours are only available for a few hours each day. Effectively, this means that a PV penetration many times the current value could be tolerated from the grid before any changes are necessary. As an increasing penetration of PV is made, if it is deployed with DG strategies, the penetration level can get to about a third before significant changes have to be made. Some existing policies and pricing methods will help make these changes less challenging. In many cases, this will mean using existing techniques for load shedding, load temporal displacement, and the usage of more storage. For example, time of use metering (TOU), which currently favors using electricity at night, will be reversed so that using electricity in the middle of the day will be the least costly when PV is at full output. As the goal of elimination of fossil fuel production for the grid is approached, utilities would need to invest in storage and other technologies to ensure normal operation and they would do it following the same basis that they currently do to make capital investments for generation that would no longer be necessary. The details of this arrangement and the timeline are left for future work.

Overall, this study is overly conservative in the number of billionaires needed to solarize the U.S. because it made the assumption that solar would be distributed based on population density and that current PV prices would be used. There is an expectation of cost decreases based on deployment of known technologies, as well as the scale, as society approaches a sustainable future [138]. The following effects would be expected after 79 of the wealthiest Americans began to invest all but US$1 billion in conversion of the U.S. electric grid away from fossil fuels. First, the price of solar, after the first shock to supply by the rapidly increased demand, would be decreased. Similar drops would be expected in the balance of systems components (i.e., racking, electronics) as well as, eventually, storage. In addition, less PV would be necessary if it were strategically located in high solar flux areas in certain utility regions. Similarly, the growth of other renewable energy sources, like wind, which currently costs less than fossil fuel generation, is expected to continue and would also reduce the demand for solar. Likewise, with the surge in demand from the proposed solar replacement of all fossil-fuel generation in the U.S., the price per unit solar would be expected to drop considerably. At the same time, the concentration of wealth continues to increase in the U.S. [139–141], and globally (the richest 26 globally own more wealth than the bottom 50% of humanity [142]). All of these factors combine to mean less and less individuals will need to be convinced as time goes forward. For these reasons, it can be comfortably concluded that 79 is a conservative estimate on the number of American multi-billionaires that would need to be convinced of the usefulness of moving to a solar U.S. grid in order to make it a reality. Finally, this analysis can be expanded beyond the U.S. to globally reduce greenhouse gas emissions, while accounting for the life cycle of greenhouse gas emissions of various types [143], as well as the impact on emissions as a function of growth of PV [144].

5. Conclusions

Although wealth inequality has many established negatives, this study has shown the potential positive that, when solving large capital-intensive problems, the number of individuals that need to be convinced to act has become small and manageable. Here, we have investigated the potential to reduce greenhouse gas emissions, responsible for climate destabilization in areas across the globe, in the U.S. electric grid by first determining the amount of solar PV technology that must be deployed to eliminate all fossil fuels from the U.S. electric grid, the costs for that conversion, and the number of multi-billionaires that would be able to maintain billionaire status while still completing the conversion. The results show that only 79 American multi-billionaires are needed. The analysis also concludes that this is a conservative estimate on the number that would need to be convinced of the usefulness of moving to a solar U.S. grid and that upper estimate is likely to decrease even further in the future.

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Appendix A

2018 RANKING REAL TIME RANKING			
2018 World Rank	**American Multi-Billionaires**	**Wealth (B US$)**	**Source of Wealth**
#1	Jeff Bezos	112	Amazon
#2	Bill Gates	90	Microsoft
#3	Warren Buffett	84	Berkshire Hathaway
#5	Mark Zuckerberg	71	Facebook
#8	Charles Koch	60	Koch Industries
#8	David Koch	60	Koch Industries
#10	Larry Ellison	58.5	software
#11	Michael Bloomberg	50	Bloomberg LP
#12	Larry Page	48.8	Google
#13	Sergey Brin	47.5	Google
#14	Jim Walton	46.4	Walmart
#15	S. Robson Walton	46.2	Walmart
#16	Alice Walton	46	Walmart
#21	Sheldon Adelson	38.5	casinos
#22	Steve Ballmer	38.4	Microsoft
#28	Phil Knight	29.6	Nike
#34	Jacqueline Mars	23.6	candy, pet food
#34	John Mars	23.6	candy, pet food
#39	Michael Dell	22.7	Dell computers
#44	Paul Allen	21.7	Microsoft, investments
#47	Thomas Peterffy	20.3	discount brokerage
#48	Len Blavatnik	20.2	diversified
#52	James Simons	20	hedge funds

2018 RANKING REAL TIME RANKING			
2018 World Rank	**American Multi-Billionaires**	**Wealth (B US$)**	**Source of Wealth**
#54	Elon Musk	19.9	Tesla Motors
#58	Laurene Powell Jobs	18.8	Apple, Disney
#67	Ray Dalio	17.7	hedge funds
#73	Carl Icahn	16.8	investments
#80	Donald Bren	16.3	real estate
#83	Abigail Johnson	15.9	money management
#83	Lukas Walton	15.9	Walmart
#94	Rupert Murdoch	15	newspapers, TV network
#100	Harold Hamm	14.1	oil & gas
#102	Steve Cohen	14	hedge funds
#102	Dustin Moskovitz	14	Facebook
#106	Charles Ergen	13.4	satellite TV
#106	Eric Schmidt	13.4	Google
#108	Philip Anschutz	13	investments
#108	Jim Kennedy	13	media
#108	Blair Parry-Okeden	13	media, automotive
#113	Leonard Lauder	12.9	Estee Lauder
#117	Stephen Schwarzman	12.6	investments
#121	Donald Newhouse	12.3	media
#132	Andrew Beal	11.6	banks, real estate
#134	John Menard, Jr.	11.5	home improvement stores
#138	David Tepper	11	hedge funds
#145	Pierre Omidyar	10.5	eBay
#152	Ronald Perelman	9.8	leveraged buyouts
#154	Micky Arison	9.7	Carnival Cruises
#158	Thomas Frist, Jr.	9.6	health care
#162	Charles Schwab	9.4	discount brokerage
#164	Herbert Kohler, Jr.	9.3	plumbing fixtures
#170	Jan Koum	9.1	WhatsApp
#172	James Goodnight	9	software
#172	Ken Griffin	9	hedge funds
#178	James Chambers	8.7	media, automotive
#178	Katharine Rayner	8.7	media, automotive
#178	Margaretta Taylor	8.7	media, automotive
#181	Gordon Moore	8.5	Intel
#183	Stanley Kroenke	8.3	sports, real estate
#186	John Malone	8.1	cable television
#190	Carl Cook	8	medical devices
#190	David Geffen	8	movies, record labels
#190	George Soros	8	hedge funds
#196	Edward Johnson, III.	7.9	money management
#198	David Duffield	7.8	business software
#198	George Kaiser	7.8	oil & gas, banking
#198	Patrick Soon-Shiong	7.8	pharmaceuticals
#205	Stephen Ross	7.6	real estate
#207	Pauline MacMillan Keinath	7.4	Cargill
#211	Eli Broad	7.3	investments
#211	Sun Hongbin	7.3	real estate
#211	Christy Walton	7.3	Walmart
#217	Shahid Khan	7.2	auto parts
#222	John Doerr	7.1	venture capital
#242	David Green	6.8	retail
#242	Hank & Doug Meijer	6.8	supermarkets

2018 RANKING REAL TIME RANKING			
2018 World Rank	**American Multi-Billionaires**	**Wealth (B US$)**	**Source of Wealth**
#251	Brian Acton	6.6	WhatsApp
#251	Ann Walton Kroenke	6.6	Walmart
#261	Leon Black	6.5	private equity
#261	John Paulson	6.5	hedge funds
#265	David Shaw	6.4	hedge funds
#265	John A. Sobrato	6.4	real estate
#274	Daniel Gilbert	6.3	Quicken Loans
#281	Richard Kinder	6.2	pipelines
#281	Robert Kraft	6.2	New England Patriots
#281	Ralph Lauren	6.2	Ralph Lauren
#287	Les Wexner	6.1	retail
#289	Whitney MacMillan	6	Cargill
#296	Marijke Mars	5.9	candy, pet food
#296	Pamela Mars	5.9	candy, pet food
#296	Valerie Mars	5.9	candy, pet food
#296	Victoria Mars	5.9	candy, pet food
#305	Nancy Walton Laurie	5.8	Walmart
#305	Tom & Judy Love	5.8	retail & gas stations
#305	Robert Rowling	5.8	hotels, investments
#305	Dennis Washington	5.8	construction, mining
#315	David Sun	5.7	computer hardware
#315	John Tu	5.7	computer hardware
#321	Jensen Huang	5.6	semiconductors
#321	Charles Johnson	5.6	money management
#321	Jerry Jones	5.6	Dallas Cowboys
#321	Richard LeFrak	5.6	real estate
#321	Steven Rales	5.6	manufacturing
#334	Dannine Avara	5.5	pipelines
#334	Scott Duncan	5.5	pipelines
#334	Milane Frantz	5.5	pipelines
#334	Diane Hendricks	5.5	roofing
#334	Gabe Newell	5.5	videogames
#334	Randa Williams	5.5	pipelines
#351	Richard DeVos	5.4	Amway
#351	George Roberts	5.4	private equity
#351	Edward Roski, Jr.	5.4	real estate
#365	Jim Davis	5.3	New Balance
#365	David Filo	5.3	Yahoo
#365	Henry Kravis	5.3	private equity
#372	Israel Englander	5.2	hedge funds
#372	Marian Ilitch	5.2	pizza, sports team
#372	Bruce Kovner	5.2	hedge funds
#372	George Lucas	5.2	Star Wars
#372	Robert Rich, Jr.	5.2	frozen foods
#382	Bernard Marcus	5.1	Home Depot
#382	Fred Smith	5.1	FedEx
#382	Ronda Stryker	5.1	medical equipment
#388	Martha Ingram	5	book distribution, transportation
#388	Karen Pritzker	5	hotels, investments
#404	Robert Bass	4.9	oil, investments
#404	Marc Benioff	4.9	business software
#404	Charles Dolan	4.9	cable television
#404	Ray Lee Hunt	4.9	oil, real estate
#404	John Overdeck	4.9	hedge funds

2018 RANKING REAL TIME RANKING			
2018 World Rank	**American Multi-Billionaires**	**Wealth (B US$)**	**Source of Wealth**
#404	Sumner Redstone	4.9	media
#404	Reinhold Schmieding	4.9	medical devices
#404	David Siegel	4.9	hedge funds
#404	Sam Zell	4.9	real estate, private equity
#422	Bubba Cathy	4.8	Chick-fil-A
#422	Dan Cathy	4.8	Chick-fil-A
#422	Rupert Johnson, Jr.	4.8	money management
#422	Travis Kalanick	4.8	Uber
#422	Trevor Rees-Jones	4.8	oil & gas
#422	Jeff Skoll	4.8	eBay
#422	Daniel Ziff	4.8	investments
#422	Dirk Ziff	4.8	investments
#422	Robert Ziff	4.8	investments
#441	Stanley Druckenmiller	4.7	hedge funds
#441	Ted Lerner	4.7	real estate
#441	Gwendolyn Sontheim Meyer	4.7	Cargill
#441	J. Christopher Reyes	4.7	food distribution
#441	Jude Reyes	4.7	food distribution
#441	Sheldon Solow	4.7	real estate
#456	Jeremy Jacobs, Sr.	4.6	food service
#456	Chris Larsen	4.6	cryptocurrency
#466	Paul Tudor Jones, II.	4.5	hedge funds
#466	John Sall	4.5	software
#466	Leonard Stern	4.5	real estate
#480	Tamara Gustavson	4.4	self-storage
#480	John Morris	4.4	sporting goods retail
#480	Robert Smith	4.4	private equity
#480	Russ Weiner	4.4	energy drinks
#499	Rocco Commisso	4.3	telecom
#499	Tilman Fertitta	4.3	Houston Rockets, entertainment
#499	Terrence Pegula	4.3	natural gas
#499	Robert Pera	4.3	wireless networking gear
#499	Gary Rollins	4.3	pest control
#499	Randall Rollins	4.3	pest control
#499	Alejandro Santo Domingo	4.3	beer
#499	Andres Santo Domingo	4.3	beer
#499	Roger Wang	4.3	retail
#514	Stephen Bisciotti	4.2	staffing, Baltimore Ravens
#514	Austen Cargill, II.	4.2	Cargill
#514	James Cargill, II.	4.2	Cargill
#514	Archie Aldis Emmerson	4.2	timberland, lumber mills
#514	Marianne Liebmann	4.2	Cargill
#514	Bobby Murphy	4.2	Snapchat
#514	Igor Olenicoff	4.2	real estate
#514	Walter Scott, Jr.	4.2	utilities, telecom
#514	Clemmie Spangler, Jr.	4.2	investments
#527	Arthur Blank	4.1	Home Depot
#527	Jack Dangermond	4.1	mapping software
#527	James Jannard	4.1	sunglasses
#527	Isaac Perlmutter	4.1	Marvel comics
#527	H. Ross Perot, Sr.	4.1	computer services, real estate
#527	Thomas Pritzker	4.1	hotels, investments
#527	Julian Robertson, Jr.	4.1	hedge funds
#527	Evan Spiegel	4.1	Snapchat

2018 RANKING REAL TIME RANKING			
2018 World Rank	**American Multi-Billionaires**	**Wealth (B US$)**	**Source of Wealth**
#527	Kelcy Warren	4.1	pipelines
#550	Ben Ashkenazy	4	real estate
#550	Dagmar Dolby	4	Dolby Laboratories
#550	Dan Friedkin	4	Toyota dealerships
#550	Ronald Lauder	4	Estee Lauder
#550	Michael Moritz	4	venture capital
#550	Richard Schulze	4	Best Buy
#550	Jeff Sutton	4	real estate
#572	Rick Caruso	3.9	real estate
#572	Tom Gores	3.9	private equity
#572	Stewart and Lynda Resnick	3.9	agriculture, water
#572	Jerry Speyer	3.9	real estate
#572	Harry Stine	3.9	agriculture
#572	Steven Udvar-Hazy	3.9	aircraft leasing
#588	Nathan Blecharczyk	3.8	Airbnb
#588	Brian Chesky	3.8	Airbnb
#588	Joe Gebbia	3.8	Airbnb
#588	Jeff Greene	3.8	real estate, investments
#588	Robert McNair	3.8	energy, sports
#588	Ira Rennert	3.8	investments
#588	Henry Samueli	3.8	semiconductors
#606	Nick Caporella	3.7	beverages
#606	Mark Cuban	3.7	online media
#606	Ken Fisher	3.7	money management
#606	H. Fisk Johnson	3.7	cleaning products
#606	Imogene Powers Johnson	3.7	cleaning products
#606	S. Curtis Johnson	3.7	cleaning products
#606	Helen Johnson-Leipold	3.7	cleaning products
#606	Winifred Johnson-Marquart	3.7	cleaning products
#606	Michael Milken	3.7	investments
#629	Jeffery Hildebrand	3.6	oil
#629	Edward Johnson, IV.	3.6	money management
#629	Elizabeth Johnson	3.6	money management
#629	Peter Kellogg	3.6	investments
#629	Rodger Riney	3.6	discount brokerage
#629	Steven Spielberg	3.6	Movies
#629	Anita Zucker	3.6	chemicals
#652	Judy Faulkner	3.5	health IT
#652	Joshua Harris	3.5	private equity
#652	Douglas Leone	3.5	venture capital
#652	Anthony Pritzker	3.5	hotels, investments
#652	J.B. Pritzker	3.5	hotels, investments
#652	Mitchell Rales	3.5	manufacturing, investments
#652	Bernard Saul, II.	3.5	banking, real estate
#652	Donald Sterling	3.5	real estate
#679	Riley Bechtel	3.4	engineering, construction
#679	Stephen Bechtel, Jr.	3.4	engineering, construction
#679	Jimmy Haslam	3.4	gas stations, retail
#679	Min Kao	3.4	navigation equipment
#679	Steve Wynn	3.4	casinos, hotels
#703	John Arnold	3.3	hedge funds
#703	Sid Bass	3.3	oil, investments
#703	John Brown	3.3	medical equipment
#703	Charles Cohen	3.3	real estate
#703	Rakesh Gangwal	3.3	airline

2018 RANKING REAL TIME RANKING			
2018 World Rank	**American Multi-Billionaires**	**Wealth (B US$)**	**Source of Wealth**
#703	Reid Hoffman	3.3	LinkedIn
#703	Amos Hostetter, Jr.	3.3	cable television
#703	Ken Langone	3.3	investments
#703	George Lindemann	3.3	investments
#703	Mary Alice Dorrance Malone	3.3	Campbell Soup
#703	Henry Nicholas, III.	3.3	semiconductors
#703	Pat Stryker	3.3	medical equipment
#729	Neil Bluhm	3.2	real estate
#729	Andrew & Peggy Cherng	3.2	restaurants
#729	Scott Cook	3.2	software
#729	Leon G. Cooperman	3.2	hedge funds
#729	John Paul DeJoria	3.2	hair products, tequila
#729	Tom Golisano	3.2	payroll services
#729	Daniel Loeb	3.2	hedge funds
#729	Daniel Och	3.2	hedge funds
#729	Marc Rowan	3.2	private equity
#729	Haim Saban	3.2	TV network, investments
#729	Lynn Schusterman	3.2	oil & gas, investments
#729	Mark Shoen	3.2	U-Haul
#729	Meg Whitman	3.2	eBay
#766	John Catsimatidis	3.1	oil, real estate
#766	Do Won & Jin Sook Chang	3.1	fashion retail
#766	Barry Diller	3.1	online media
#766	Jack Dorsey	3.1	Twitter, Square
#766	Allan Goldman	3.1	real estate
#766	Jane Goldman	3.1	real estate
#766	Amy Goldman Fowler	3.1	real estate
#766	Diane Kemper	3.1	real estate
#766	James Leprino	3.1	cheese
#766	Richard Sands	3.1	Food & Beverage
#766	Donald Trump	3.1	television, real estate
#766	Romesh T. Wadhwani	3.1	software
#791	Clifford Asness	3	Investment Management
#791	Tom Benson	3	New Orleans Saints
#791	Jim Breyer	3	venture capital
#791	Valentin Gapontsev	3	lasers
#791	Johnelle Hunt	3	trucking
#791	John Middleton	3	tobacco
#791	Jorge Perez	3	real estate
#791	Jean (Gigi) Pritzker	3	hotels, investments
#791	Michael Rubin	3	online retail
#791	Robert Sands	3	Food & Beverage
#791	Herb Simon	3	real estate
#791	Don Vultaggio	3	AriZona Beverages
#822	Chuck Bundrant	2.9	fishing
#822	Gerald Ford	2.9	banking
#822	Joseph Grendys	2.9	poultry processing
#822	Randal Kirk	2.9	pharmaceuticals
#822	Jeff Rothschild	2.9	Facebook
#822	Thomas Siebel	2.9	business software
#822	Paul Singer	2.9	hedge funds
#822	Jon Stryker	2.9	medical equipment
#822	Vincent Viola	2.9	electronic trading
#859	William Conway, Jr.	2.8	private equity
#859	Daniel D’Aniello	2.8	private equity

2018 RANKING REAL TIME RANKING			
2018 World Rank	**American Multi-Billionaires**	**Wealth (B US$)**	**Source of Wealth**
#859	Jim Davis	2.8	staffing & recruiting
#859	Doris Fisher	2.8	Gap
#859	John Fisher	2.8	Gap
#859	Kieu Hoang	2.8	medical products
#859	H. Wayne Huizenga	2.8	investments
#859	Osman Kibar	2.8	biotech
#859	Penny Pritzker	2.8	hotels, investments
#859	David Rubenstein	2.8	private equity
#859	Mark Walter	2.8	finance
#859	William Wrigley, Jr.	2.8	chewing gum
#859	Mortimer Zuckerman	2.8	real estate, media
#887	Ray Davis	2.7	pipelines
#887	Edward DeBartolo, Jr.	2.7	shopping centers
#887	Bennett Dorrance	2.7	Campbell Soup
#887	Don Hankey	2.7	auto loans
#887	Reed Hastings	2.7	Netflix
#887	James Irsay	2.7	Indianapolis Colts
#887	Bob Parsons	2.7	web hosting
#887	Phil Ruffin	2.7	casinos, real estate
#887	Howard Schultz	2.7	Starbucks
#887	E. Joe Shoen	2.7	U-Haul
#887	Frank VanderSloot	2.7	nutrition and wellness products
#887	Ty Warner	2.7	real estate, plush toys
#887	Oprah Winfrey	2.7	TV shows
#924	David Bonderman	2.6	private equity
#924	Phillip Frost	2.6	pharmaceuticals
#924	B. Wayne Hughes	2.6	self-storage
#924	Stephen Mandel, Jr.	2.6	hedge funds
#924	Sean Parker	2.6	Facebook
#924	Jay Paul	2.6	real estate
#924	Patrick Ryan	2.6	insurance
#924	Thomas Secunda	2.6	Bloomberg LP
#924	Warren Stephens	2.6	investment banking
#924	Glen Taylor	2.6	printing
#924	Jerry Yang	2.6	Yahoo
#965	Edward Bass	2.5	oil, investments
#965	Lee Bass	2.5	oil, investments
#965	Bert Beveridge	2.5	vodka
#965	George Bishop	2.5	oil & gas
#965	Norman Braman	2.5	art, car dealerships
#965	Kenneth Feld	2.5	circus, live entertainment
#965	Noam Gottesman	2.5	hedge funds
#965	Jonathan Gray	2.5	investments
#965	John Henry	2.5	sports
#965	Aerin Lauder	2.5	cosmetics
#965	Jane Lauder	2.5	cosmetics
#965	Jeffrey Lorberbaum	2.5	flooring
#965	Joe Mansueto	2.5	investment research
#965	C. Dean Metropoulos	2.5	investments
#965	Arturo Moreno	2.5	billboards, Anaheim Angels
#965	Richard Peery	2.5	real estate
#965	Larry Robbins	2.5	hedge funds
#965	Charles Simonyi	2.5	Microsoft
#965	Mark Stevens	2.5	venture capital
#965	Peter Thiel	2.5	Facebook, Palantir

2018 RANKING REAL TIME RANKING			
2018 World Rank	**American Multi-Billionaires**	**Wealth (B US$)**	**Source of Wealth**
#965	Elaine Wynn	2.5	casinos, hotels
#965	Denise York	2.5	San Francisco 49ers
#965	David Zalik	2.5	financial technology
#1020	George Argyros	2.4	real estate, investments
#1020	John Arrillaga	2.4	real estate
#1020	Peter Buck	2.4	Subway sandwich shops
#1020	Drayton McLane, Jr.	2.4	Walmart, logistics
#1020	Daniel Pritzker	2.4	hotels, investments
#1020	John Pritzker	2.4	hotels, investments
#1020	Eric Smidt	2.4	hardware stores
#1020	Alexander Spanos	2.4	real estate, Los Angeles Chargers
#1070	David Gottesman	2.3	investments
#1070	Bill Haslam	2.3	truck stops
#1070	W. Herbert Hunt	2.3	oil
#1070	Bradley Jacobs	2.3	logistics
#1070	Brad Kelley	2.3	tobacco
#1070	Vinod Khosla	2.3	venture capital
#1070	Clayton Mathile	2.3	pet food
#1070	J. Joe Ricketts	2.3	TD Ameritrade
#1070	Dan Snyder	2.3	Washington Redskins
#1070	John Tyson	2.3	food processing
#1103	Ron Baron	2.2	money management
#1103	Timothy Boyle	2.2	Columbia Sportswear
#1103	Chase Coleman, III.	2.2	hedge fund
#1103	Jim Coulter	2.2	private equity
#1103	Frank Fertitta, III.	2.2	casinos, mixed martial arts
#1103	Lorenzo Fertitta	2.2	casinos, mixed martial arts
#1103	Ernest Garcia, II.	2.2	used cars
#1103	Stanley Hubbard	2.2	DirecTV
#1103	Thomas Lee	2.2	private equity
#1103	Eric Lefkofsky	2.2	Groupon
#1103	Phillip T. (Terry) Ragon	2.2	health IT
#1103	Stewart Rahr	2.2	drug distribution
#1103	T. Denny Sanford	2.2	banking, credit cards
#1103	Julio Mario Santo Domingo, III.	2.2	beer
#1103	Ted Turner	2.2	cable television
#1103	William Young	2.2	plastics
#1157	Leslie Alexander	2.1	sports team
#1157	Todd Christopher	2.1	hair care products
#1157	Gordon Getty	2.1	Getty Oil
#1157	Alec Gores	2.1	private equity
#1157	Catherine Lozick	2.1	valve manufacturing
#1157	David Murdock	2.1	Dole, real estate
#1157	H. Ross Perot, Jr.	2.1	real estate
#1157	Tor Peterson	2.1	commodities
#1157	Kavitark Ram Shriram	2.1	venture capital, Google
#1157	David Walentas	2.1	real estate
#1157	Ronald Wanek	2.1	furniture
#1215	S. Daniel Abraham	2	Slim-Fast
#1215	Ron Burkle	2	supermarkets, investments
#1215	James Clark	2	Netscape, investments
#1215	Christopher Cline	2	coal
#1215	Alexandra Daitch	2	Cargill
#1215	Glenn Dubin	2	hedge funds
#1215	Robert Duggan	2	pharmaceuticals

2018 RANKING REAL TIME RANKING			
2018 World Rank	**American Multi-Billionaires**	**Wealth (B US$)**	**Source of Wealth**
#1215	Thomas Hagen	2	insurance
#1215	Bruce Karsh	2	private equity
#1215	Henry Laufer	2	hedge funds
#1215	Jeffrey Lurie	2	Philadelphia Eagles
#1215	Sarah MacMillan	2	Cargill
#1215	Howard Marks	2	private equity
#1215	Jonathan Nelson	2	private equity
#1215	Peter Peterson	2	investments
#1215	Antony Ressler	2	finance
#1215	Rodney Sacks	2	energy drinks
#1215	Brian Sheth	2	investments
#1215	Lucy Stitzer	2	Cargill
#1215	Katherine Tanner	2	Cargill
#1215	Amy Wyss	2	medical equipment
#1215	Jon Yarbrough	2	video games
#1215	Charles Zegar	2	Bloomberg LP
#1284	James Dinan	1.9	hedge funds
#1284	Bill Gross	1.9	investments
#1284	Jeffrey Gundlach	1.9	investments
#1284	Jennifer Pritzker	1.9	hotels, investments
#1284	Alan Trefler	1.9	software
#1284	Evan Williams	1.9	Twitter
#1339	Nicolas Berggruen	1.8	investments
#1339	James France	1.8	Nascar, racing
#1339	Stewart Horejsi	1.8	Berkshire Hathaway
#1339	Hamilton James	1.8	investments
#1339	John Kapoor	1.8	healthcare
#1339	William Lauder	1.8	Estee Lauder
#1339	Linda Pritzker	1.8	hotels, investments
#1339	Brian Roberts	1.8	Comcast
#1339	William Stone	1.8	software
#1394	Herbert Allen, Jr.	1.7	investment banking
#1394	John Farber	1.7	chemicals
#1394	Robert Fisher	1.7	Gap
#1394	William Fisher	1.7	Gap
#1394	Timothy Headington	1.7	oil & gas, investments
#1394	Jim Justice, II.	1.7	coal
#1394	William Koch	1.7	oil, investments
#1394	Marc Lasry	1.7	hedge funds
#1394	David Lichtenstein	1.7	real estate
#1394	Craig McCaw	1.7	telecom
#1394	Miguel McKelvey	1.7	WeWork
#1394	Vincent McMahon	1.7	Entertainment
#1394	Gary Michelson	1.7	medical patents
#1394	Jerry Moyes	1.7	transportation
#1394	Charles Munger	1.7	Berkshire Hathaway
#1394	Nelson Peltz	1.7	investments
#1394	Roger Penske	1.7	cars
#1394	Henry Swieca	1.7	hedge funds
#1394	Todd Wagner	1.7	online media
#1477	Bill Austin	1.6	hearing aids
#1477	Louis Bacon	1.6	hedge funds
#1477	William Berkley	1.6	insurance
#1477	Aneel Bhusri	1.6	business software
#1477	O. Francis Biondi	1.6	hedge funds

2018 RANKING REAL TIME RANKING			
2018 World Rank	**American Multi-Billionaires**	**Wealth (B US$)**	**Source of Wealth**
#1477	David Booth	1.6	mutual funds
#1477	Steve Conine	1.6	online retail
#1477	Stephen Feinberg	1.6	private equity
#1477	Paul Foster	1.6	oil refining
#1477	Mario Gabelli	1.6	money management
#1477	Christopher Goldsbury	1.6	salsa
#1477	Brian Higgins	1.6	hedge funds
#1477	Michael Jordan	1.6	Charlotte Hornets, endorsements
#1477	Edward Lampert	1.6	Sears
#1477	Thai Lee	1.6	IT provider
#1477	Billy Joe (Red) McCombs	1.6	real estate, oil, cars, sports
#1477	Manuel Moroun	1.6	transportation
#1477	Sheryl Sandberg	1.6	Facebook
#1477	Niraj Shah	1.6	online retail
#1477	Ben Silbermann	1.6	Pinterest
#1477	Thomas Steyer	1.6	hedge funds
#1477	Charlotte Colket Weber	1.6	Campbell Soup
#1561	Bill Alfond	1.5	shoes
#1561	Susan Alfond	1.5	shoes
#1561	Ted Alfond	1.5	shoes
#1561	Carol Jenkins Barnett	1.5	Publix supermarkets
#1561	Martha Ford	1.5	Ford Motor
#1561	Richard Hayne	1.5	Urban Outfitters
#1561	Seth Klarman	1.5	investments
#1561	Eren Ozmen	1.5	aerospace
#1561	Fatih Ozmen	1.5	aerospace
#1561	Mark Pincus	1.5	online games
#1561	Kevin Plank	1.5	Under Armour
#1561	Nicholas Pritzker, II.	1.5	hotels, investments
#1561	Fayez Sarofim	1.5	money management
#1561	Kevin Systrom	1.5	Instagram
#1561	Jim Thompson	1.5	logistics
#1561	Jonathan Tisch	1.5	insurance, NFL team
#1561	Kenneth Tuchman	1.5	outsourcing
#1650	Herb Chambers	1.4	car dealerships
#1650	John Edson	1.4	leisure craft
#1650	David Einhorn	1.4	hedge funds
#1650	Victor Fung	1.4	trading company
#1650	Alan Gerry	1.4	cable television
#1650	J. Tomilson Hill	1.4	investments
#1650	George Joseph	1.4	insurance
#1650	Michael Krasny	1.4	retail
#1650	James Leininger	1.4	medical products
#1650	Gary Magness	1.4	cable TV, investments
#1650	Forrest Preston	1.4	health care
#1650	Jerry Reinsdorf	1.4	sports teams
#1650	Evgeny (Eugene) Shvidler	1.4	oil & gas, investments
#1650	Peter Sperling	1.4	education
#1650	Kenny Troutt	1.4	telecom
#1650	Dan Wilks	1.4	natural gas
#1650	Farris Wilks	1.4	natural gas
#1650	Richard Yuengling, Jr.	1.4	beer
#1756	Edmund Ansin	1.3	television
#1756	Steve Case	1.3	AOL
#1756	Darwin Deason	1.3	Xerox

2018 RANKING REAL TIME RANKING			
2018 World Rank	**American Multi-Billionaires**	**Wealth (B US$)**	**Source of Wealth**
#1756	Jamie Dimon	1.3	banking
#1756	Anne Gittinger	1.3	Nordstrom department stores
#1756	Irwin Jacobs	1.3	semiconductors
#1756	Mitchell Jacobson	1.3	industrial equipment
#1756	Alexander Karp	1.3	software firm
#1756	Sidney Kimmel	1.3	retail
#1756	Rodney Lewis	1.3	natural gas
#1756	Cargill MacMillan, III.	1.3	Cargill
#1756	John MacMillan	1.3	Cargill
#1756	Martha MacMillan	1.3	Cargill
#1756	William MacMillan	1.3	Cargill
#1756	Craig Newmark	1.3	Craigslist
#1756	Bruce Nordstrom	1.3	Nordstrom department stores
#1756	Alexander Rovt	1.3	fertilizer, real estate
#1756	Leonard Schleifer	1.3	pharmaceuticals
#1756	Wilma Tisch	1.3	diversified
#1756	Jayshree Ullal	1.3	computer networking
#1756	Stephen Winn	1.3	real estate services
#1867	Marc Andreessen	1.2	venture capital investing
#1867	Thomas Bailey	1.2	money management
#1867	Charles Brandes	1.2	money management
#1867	Henry Engelhardt	1.2	insurance
#1867	Donald Foss	1.2	auto loans
#1867	Robert Friedland	1.2	mining
#1867	Donald Friese	1.2	manufacturing
#1867	Ryan Graves	1.2	uber
#1867	B. Wayne Hughes, Jr.	1.2	storage facilities
#1867	Thomas James	1.2	finance
#1867	Gail Miller	1.2	basketball, car dealers
#1867	Michael Price	1.2	investments
#1867	Lynsi Snyder	1.2	In-N-Out Burger
#1867	Thomas Tull	1.2	movies
#1867	Alfred West, Jr.	1.2	money management
#1999	William Ackman	1.1	hedge funds
#1999	J. Hyatt Brown	1.1	insurance
#1999	Bharat Desai	1.1	IT consulting
#1999	Joseph Edelman	1.1	hedge funds
#1999	Paul Fireman	1.1	Reebok
#1999	J. Christopher Flowers	1.1	investments
#1999	Drew Houston	1.1	cloud storage service
#1999	Richard Kayne	1.1	investments
#1999	Isaac Larian	1.1	toys
#1999	Frank Laukien	1.1	scientific equipment
#1999	Nancy Lerner	1.1	banking, credit cards
#1999	Norma Lerner	1.1	banking
#1999	Randolph Lerner	1.1	banking, credit cards
#1999	William Macaulay	1.1	energy investments
#1999	John Martin	1.1	pharmaceuticals
#1999	Andrea Reimann-Ciardelli	1.1	consumer goods
#1999	Chris Sacca	1.1	venture capital investing
#1999	Michael Steinhardt	1.1	hedge funds
#1999	Laurie Tisch	1.1	insurance, NFL team
#1999	Steven Tisch	1.1	insurance
#1999	James Truchard	1.1	software
568 people	**Billions total in wealth**	**3079.7**	

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