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Transitioning to Eco-Cities: Reducing Carbon Emissions while Improving Urban Welfare

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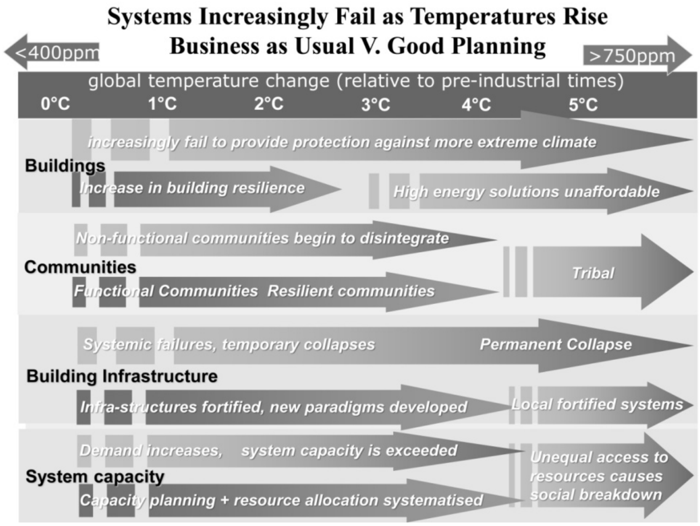
Introduction

We live in a world where rapid change and unmanaged growth is driving the collapse of established systems, be they top-down macroeconomic failures of the economies such as those of Greece and Spain in 2012, the bottom-up collapse of the housing markets in the United States in 2007–2010, or the escalating failure of infrastructures and buildings to provide adequate shelter during extreme weather events (see Figure 1). While seeking to avoid such collapses, we must understand where economic weaknesses and related breaking points exist and how to measure them. In rapidly evolving systems, we must efficiently draw on experience to grow in successful directions. This chapter tackles the challenges of creating such measures and explores the form they might take, using case studies from Arizona and the city of Dundee in Scotland.

The chapter is divided into four parts. The first deals with concepts of resilience and adaptive capacity of individuals and populations within that built environment. Part two presents a case study of the failure of the Arizonan housing market in 2007–2010. This details the problem of asymmetric information, the ignorance by the majority of the potentially catastrophic impacts of rising energy, transport and water prices on their own household budgets, and raises the question of how this was allowed to happen in a so-called "responsible" society. Part three introduces the second case study of the city of Dundee in Scotland and a consideration of the role that solar technologies might play in alleviating

Figure 1
The Warming of the Climate Will Exacerbate the Nature and Rate of Collapse of the Whole Gamut of Our Social and Physical Systems within the Built Environment. Strengthening of These Systems Is Essential to Improve Their Adaptive Capacities and Resilience to Collapse



Source: Roaf et al. 2009.

fuel poverty in that city. The fourth and final part discusses the development of standardized metrics and indicators for describing the adaptive economic capacity of a population and testing the sensitivities of a group to a range of hazards that may threaten to cause the socioeconomic systems within which they operate to collapse. Such metrics and indicators would provide decision makers with the critical ability of testing policies and strategies against the capacity of the system to absorb stress and its breaking points under a range of different conditions. While so doing, such metrics can be used to inform successful adaptation strategies for different populations.

The conclusions clearly point to the social and economic benefits of moving toward facilitating the adoption of wide-scale use of solar energy for domestic populations to reduce economic stress upon them and prevent the collapse of regional housing markets and with them their attendant communities.

Resilience

Systems all around us are beginning to very visibly fail, some in response to extreme weather events, some because of aging and poor infrastructures, and some because the capacity of those systems are being pushed beyond their limits by physical pressures and/or, by mismanagement and a lack of planning. The growing human and economic costs of system failures, be they local power outages or the tripping out of a grid feeding 700 million people in northern India, is driving the political imperative to build more "resilience" into the lives, landscapes, infrastructures, communities, and businesses of citizens around the world. Resilience is now a headline issue that sells popular books at airports[1] and is stimulating a new generation of resilience research and thinking. If so many clever people are putting their minds into the subject, why does the rate and scale of the collapse of systems around us continue to increase so alarmingly? This is a key question addressed in this paper in relation to housing and the energy used to run it.

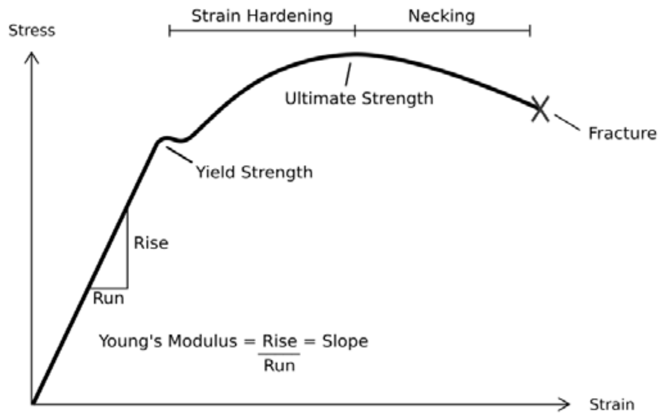
Resilience is described differently by engineers, ecologists, or system scientists. It is, however, an attribute of social and physical systems that is increasingly sought by planners, architects, engineers, and politicians alike. The technical definition of resilience for material scientists *is the property of a material to absorb energy when it is deformed elastically and then, upon unloading, to have this energy recovered*—the ability to bounce back to normal after a testing event.

The amount of resilience is defined by material scientists as the maximum energy (stress) that can be absorbed per unit volume without creating a permanent distortion as can be calculated for metals, for instance, by integrating the stress–strain curve from zero to the elastic limit.[2] One premise of this paper is that we need to be able to define the amount of stress that can be absorbed in the housing sector before it begins to yield to that pressure. Another challenge is to develop methods for defining the bandwidth of the adaptive opportunities available for households to take the extra strain before the system collapses and does not "bounce back" and therefore suffers permanent distortion. Without being able to define those three properties of the system: yield behaviors of the system, adaptive capacity bandwidths and fracture points, planners, designers, and politicians have insufficient information to be able to act accordingly to maximize the adaptive capacity of the system and avert fracture and system collapse.

Figure 2 shows the characteristics that are involved in this definition. Stress is placed on the material that reaches a yield point; then, the bandwidth of strain is a range over which the material can absorb stress before it reaches its maximum strength and then fractures. In a metal, as with socioeconomic systems, the fracture points also change with the temperature of the material.

The rate at which stress is applied to an inanimate, non-learning metal does not affect the strain at which it fractures because the metal simply mechanically performs to its limits. In "learning" ecological systems, the rate of change, a product of the rise (scale of the stress) and run (scale of the strain) of the process over time, can be significant. Berkes et al.[3] point out that in a rapidly changing world, socioecological systems either evolve or do not survive. The function of this evolution is to increase the strain the system can absorb before collapse occurs.

Figure 2
The Metallurgists Definition: Resilience is the Area under the Linear Portion of a Stress-Strain Curve



Source: Campbell, 2008.

The capacity, or maximum strength or ability to do work, of the whole system is obviously key in relation to the demands placed upon it. Authors have been warning of the risks posed by growing populations within the limited ecosystems of the planet for four decades.[4,5] However, the rate of change in the system is obviously also critical in "learning" systems, and Donella Meadows[6] argued that the buffeting of our socioeconomic systems by multiple stresses today makes it difficult to react "in time" to threats because the complex behaviors of systems that are dependent on the relative strengths of the multiple feedback loops in the system causing a chain of loops to dominate behaviors. The critical issue here is how confounding this complexity is.

Clarity is sought by some who believe that answers can be reached through disaggregation of the problem. "If resilience is to be measured operationally it must be in relation to a potential and specific change in the system."[7] The risk of a system breaking in relation to climate change in the built environment has been disaggregated and characterized by David Crichton as having three vectors:[8,9]

- *Hazard*: how bad is it going to get? How large is the stress placed on the system?
- *Exposure*: where are people situated in relation to that Hazard? How exposed is the system to the hazard and how likely is it to happen, how often and how hard?
- *Vulnerability*: how likely is the combination of the above to prove lethal? What strain can the system take? What are the adaptive opportunities and potentials of the system?

The impacts of resilience building actions must also be taken into account to ensure that the reinforcing of one part of the ecosystem in the short term does not threaten the survival of the whole ecosystem over time. "Resilience is the potential to sustain development by responding to, and shaping change in a manner that does not lead to the loss of future options. Resilient systems also provide capacity for renewal and innovation in the face of rapid transformation and crisis."[10] Here, the idea of innovation being a key tool for those trying to build resilience into the system is important, but where perhaps innovation is most needed is not in the development of physical innovations and "product" based approaches but in the resetting of the way in which we view the problem, and importantly the language in which we describe it.

Geoff Wilson[11] defined resilience as follows: "The capacity of a system to absorb disturbance and reorganize while undergoing change to still retain essentially the same function, structure and identity, and feedbacks . . . resilience is measured by the size of the displacement the system can tolerate and yet return to a state where a given function can be maintained." Perhaps, the presumption that the same functions, structures, and identities are to be maintained threatens the survivability of the structure. It does appear to presume that the way things were done before is how they should be done in the future, which is a counter-intuitive assumption in a system that has already failed in a rapidly changing world. C. S. Holling[12] noted that "Placing a system in a straitjacket of constancy can cause fragility to evolve," and all too often in recent years this fragility, or brittleness, of the fabric of the built environment has proved lethal in terms of the thousands of lives and buildings lost to flood, heat, cold, or winds as well as proving catastrophic for the livelihoods and communities involved.

Ecosystems today do have to evolve rapidly to survive but perhaps we should be more radical in the way we re-imagine our futures. Business-as-usual interests and thinking are, according to some, providing a damaging straitjacket to the evolution of systems. Ironically, market liberalization and programs of deregulation led by the Chicago School of Economics and their advocates, such as Milton Friedman and his adherents Margaret Thatcher and Ronald Regan, weakened the built environment by allowing the "lowest common denominator" solutions to prevail. For instance, in the building industry, this resulted in the prevalence of the cheapest and most brittle building types despite the apparent move in the United Kingdom toward more stringent regulations. An example is the Shard building in London, just completed, that is a tall, all glass, and steel tower with appalling environmental building performance and embodied energy costs that are many times those of a modest office block that will be refused planning permission because it is naturally ventilated. There is one rule for the rich here and one for the poor. Joseph Stiglitz[13] rails against the chronic damage done by those who have undermined the public sector, plundered financial markets, and been "seduced and neutered by lobbyists and their own avarice."

Garrett Hardin[14,15] developed the idea of the Tragedy of the Commons to describe the dilemma that arises from the situation in which multiple individuals acting independently and rationally consulting their own self-interest will ultimately deplete a shared limited resource, even when it is clear that it is not in anyone's long-term interest for this to happen. His ideas were taken up by many attempting to rationalize why, in the face of our growing knowledge base, decisions were being made that appeared to push progress into socially, environmentally damaging directions. All of us wanting and having more would inevitably push local ecosystems, and in turn, economies, beyond their capacities. Stiglitz[16] highlighted the profound dangers of "asymmetric information" where some individuals have access to privileged information that others don't causing unfair advantage that can result in system collapse in itself. Increasing numbers of authors suggest that the internal mechanisms of neoliberal and turbo-capitalism, which are devoid, in such ways, of values of fairness, trust, and civil responsibility, are to blame and will inevitably take us to the cliff edge highlighted by Hardin and Stiglitz.[17,18]

Many authors point to the confounding nature of the high level of complexity of the systems in play and their feedback loops, and the problems associated with our reliance on trend extrapolating models in forecasting and predicting the performance of systems. Robert Ayres[19] specifically points out that to forecast "turning points," it is necessary to get away from trend-based models as used in extrapolation but goes on to point out the weakness of trying to characterize too many complex nonlinear interactions with limited differential equations such as those used since the early year of Ecological modeling and in the original Limits to Growth model by Meadows et al.[20]. Ayres claimed that simple quantifiable models will not be adequate to identify timings and other attributes of Turning Points but that "*naive intelligence and intuition may be the best tool for coping with a very complex and non-deterministic future*."

Adaptive Capacity

In the background documents for the third report of the International Panel on Climate Change,[21] the concept of adaptive capacity was developed in relation to the vulnerability of populations. At a national level, vulnerability is determined by factors such as economic wealth, technological opportunities and infrastructural resilience, information and knowledge, and equity and social capital. Both determinants of, and indicators of, adaptive capacity are typically given at a national level, rather than in relation to the risk level of an individual sector, person, or household,[22] and definitions of key adaptation terms are not often associated with methods for their quantification.[23,24,25] Key data collection and analysis methods for adaptation typically deal, on one hand, with high-level measures such as gross domestic product (GDP), or are specific to local community-level factors.[26]

While adaptive capacity can cushion the impacts of climate hazards, Lea Berrang-Ford et al.[27] and others have noted that adaptive capacity does not necessarily translate into adaptation not least because of the "wicked" complexity of the issues involved. The role of a wild card such as background temperatures at which a particular hazard manifests itself for a set exposure and vulnerability level may prove to be a determining factor in system collapse, an idea that is developed in the Arizonan case study described below. The speed at which catastrophic events occur can inhibit effective action being taken in time and the routes between data collection, analysis to strategy development, and action may not exist or be difficult and slow to functionalize, and the inappropriate scale of available data in relation to the available policy tools for implementation is an issue. So, the actual scale, or grain, of available data in relation to the scale of the data requirements for policymaking and implementation are critical factors and need to be compatible.

The following case study sets out to look at the operational bandwidths for adaptive economic capacity of typical households in Phoenix, Arizona, which were crossed over the course of the catastrophic collapse of the Arizonan housing market in 2007–2008. The idea that Ayres' "naive intelligence and intuition," or perhaps "common sense" might have been applied to inform a more resilient development model for Arizona Valley is proposed.

Arizona: A Case Study of Housing Market Collapse

This case study arose from a period the author spent as visiting Research Fellow in the Herberger Institute Research Centre with Professor Harvey Bryan and Janet Holston at Arizona State University (ASU) in Tempe in the spring and summer of 2007. Having recently completed a book on climate change,[28] it appeared that Arizonans were potentially a) exposed and b) vulnerable to both oil shocks and spikes in oil prices and extreme weather events in the hot, dry desert climate for which Arizona is famous. At ASU, it became clear that the individuals and their families were often sitting on a financial fence where pressures in each direction could unbalance their monthly budgets for better or worse. Unstable oil prices at the time were particularly problematic.

The Peak Oil issue has been widely discussed for decades. Interest in the phenomenon of Peak Oil started with the work of M. King Hubbert in the 1950s.[29] By the 1990s, the related movement was a growing force.[30] The potential scale of the related impacts for keeping buildings and cities[31] comfortable during extreme weather events were beginning to surface, and by 2005/6, credible studies began to predict that the point of global maximum oil production was approaching.[32] Colin Campbell of the Association for Peak Oil (ASPO) had predicted a 2007/8 peak for global oil production, which was subsequently acknowledged as credible by a number of authorities.[33] By the turn of the millennium, this oil peak was being associated with the potential for "oil shocks" within the global economy.[34]

Teaching a course in the Global Institute of Sustainability (GIOS) at ASU in its inaugural year offered an opportunity to explore different aspects of the "sustainability" of communities across the valley with student groups. One such community was that of the new, idealized, out of town "sustainable" community of Verrado, which is part of the larger town of Buckeye.[35]

Verrado is a new master-planned community on 8,800 acres of land owned by Caterpillar, which in the mid 1990s went into partnership with the developer DMB to create the new town. The area was zoned for up to 14,080 homes. Since the 2008 housing crash, the planned numbers were scaled back to eleven thousand home sites. In reality, only around two thousand homes have been completed to date. The 2004 opening of the first homes was at the peak of the Arizona housing boom and at the top of the market; DMB claimed to be selling a hundred homes a week. DMB constructed parks, roads, a village center, a golf course, health club, and schools and wrote its own development and zoning codes that permit mixed use. There was a high ambition for this to be a truly "sustainable" community, a concept with many different definitions.[36] Designers applied the philosophy of New Urbanism to the town and included medium urban densities, walkable destinations, mixed-use buildings, and a traditional village center with pedestrian ways through connective parks, schools, and job centers. Students identified the following properties of the development:

Strengths

- Diverse land use within community
- Hundred year water rights secured
- Well-engineered wastewater reclamation system

Weaknesses

- Poor initial plant selection in common areas
- Overall local increasing demand on Colorado River water

Recommendations

- Replace common area plants with more suitable species.
- Realize reduced water and energy consumption.

In hindsight, these recommendations appeared toothless and reflected the prevailing mindset of "everything is alright" despite huge cracks already being visible in the developer model that was reshaping Arizona Valley.

The GIOS study did identify the problem of covering large distances to travel for work, amenities, or recreation, and in fact, the location of Verrado may well prove the most challenging obstacle it has to overcome in its future. It is located in an area with very few local jobs, 40 miles from Phoenix and 45 miles from Tempe and Scottsdale, the three largest local areas of employment. Some websites claim Verrado is only 25 miles from Phoenix making commuting appear more attractive and affordable. More credible sites claim the higher figure. The difference between the two mileage estimates for someone who, for instance, worked at ASU in Tempe, lives in Verrado, and drives a 20 mile per gallon SUV would be around 200 miles a week. At $4 a gallon of gas, this equates to an extra cost of around $40 a week and $150–$200 a month difference in commuting costs. A desire to manage information on this issue by developers wanting to sell homes is understandable. Here is a good example of "asymmetric information."

Buckeye is also in an area with extremely limited freshwater rights despite house purchasers being told that it has hundred years of water rights. Again—"asymmetric information." The high cost of domestic water supplies has proved an additional, often unforeseen, cost in moving to the town. Monthly water rates were always high, but in 2012, the Arizona American Water Company sought an immediate 83 percent increase in water rates, translating to roughly $25.00 per month more for the average water customer in Verrado and other communities. After much negotiation, a settlement was reached to phase-in annual increases that totaled 58 percent by the third year. Average water users could expect the following on their monthly water from April to July 2012: no increase; a $12.95 increase on monthly bills in July 2012 followed by a $3.09 increase in July 2013; and a further $3.09 increase in July 2014 (www.verrado.net).

The subject of water provision and rights in Arizona is an enormously complex one and well-covered by experts such as Robert Glennon[37,38] and James Powell,[39] who have written eloquently of the problems in books on America's water crisis and the excessive use of the finite ground water to spur on development growth. Water literacy will not only increasingly become a part of local, state, and national election cycles, but it is also clear from blogs for buyers wanting to buy homes in Verrado that the cost of water is creeping up their lists of priorities. People are now requesting information on the local water rates from estate agents as they consider property purchases. In 2007, researchers at ASU knew that Buckeye did not have the claimed adequate hundred years of fresh water rights, but they were not allowed to go public on such facts because of the power of the developers in the state. How the Arizona government, which had all the facts on hand, let this happen remains to be explored, although Andrew Ross[40] clearly describes the conspiracy of the influential in Arizona to promote unsustainable growth to the detriment of the masses and the enrichment of those with power. In addition, new legislation was introduced in 2007 to liberalize rules on the allocation of water to promote the interests of housing developers with prices for water per gallon set at half that of rainy Seattle where water use per person was half that of Arizona.

The energy–water nexus is the most hidden actor in the affordable housing crisis. Water, Glennon argued[41], is more important than oil in our society, since nearly every economic activity and production cycle requires water. Energy companies cannot produce electricity without water. The energy industry depends on water to process and transport petroleum, coal, natural gas, and other fuels like ethanol. Municipalities need this energy to pump water through distribution systems, treat drinking water, and manage storm water. As such, Glennon argues that sustainable water, energy, and economic policy should not be separated but are currently negotiated independently. But what in fact became the nemesis of such settlements as Verrado in 2007/8 was not the predicted and catastrophic collapse of water supplies[42] but an unparalleled spike in the price of oil.

The pressures faced by ordinary Arizonan families in paying monthly bills seemed clear to my common-sense view of the world, and on April 27, 2007, I presented the following tables at the Livability Summit organized by Valley Forward, a group of five hundred of the leading companies in Arizona Valley. With the rather imperfect tables for single-person outgoings in Verrado and Garfield, we tried to point out the vulnerability of the ordinary household to rising energy prices. They do clearly, if crudely, show the impacts that a doubling of energy prices would have on monthly and annual outgoings, and I suggested then that this might well happen by the year 2020, which is why the predicted mortgage costs—in the pre-bust markets—rose for both communities. The price of oil in fact doubled by July 2007. Table 1 shows a sketchy list of what a young professional with a well-paid job might pay per month living a baseline "American Dream" lifestyle in a three-bedroom home in Verrado in April 2007 and what they would have to pay if the price of energy across the board doubled. Altering the cost of the mortgage and doubling the energy and water costs has a profound effect on the income requirements. A required basic salary of $71,488 leaps to $93.756 in what proved to be a devastating difference for many ordinary families in Arizona Valley.

Table 1
Rough Calculation Done in April 2007 of What a Single Young Professional with a Well-Paid Job Might Pay Per Month, and Over a Year, Living in a Three Bedroom Home in Verrado and What They Would Have to Pay if the Price of Energy Doubled Across the Board

Single person	**VERRADO 2007**		**VERRADO 2020**	
2020 = x 2 energy prices Without water trucking prices	**$ per month**	**$ per year**	**$ per month**	**$ per year**
Mortgage	2000	24000	2800	33600
Property Tax	500	6000	500	6000
Water + sewer	80	960	160	1920
Energy	300	3600	600	7200
Car purchase	300	3600	300	3600
Gas / petrol	250	3000	500	6000
House insurance	100	1200	100	1200

(*Continued*)

Table 1 (*Continued*)

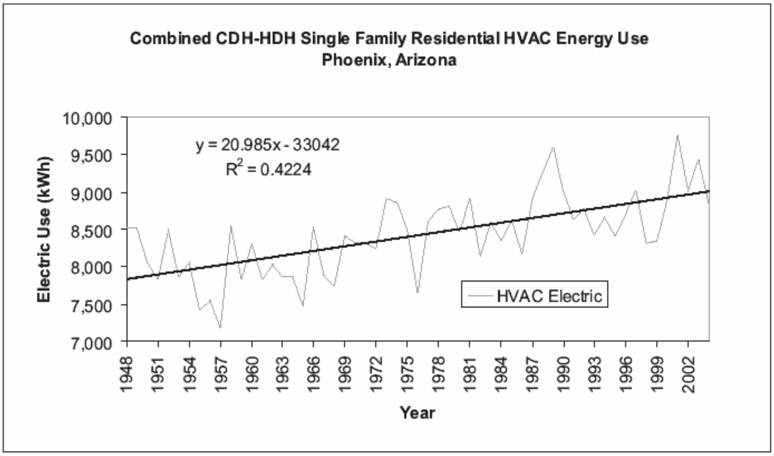
Single person	**VERRADO 2007**		**VERRADO 2020**	
2020 = x 2 energy prices Without water trucking prices	**$ per month**	**$ per year**	**$ per month**	**$ per year**
Car insurance	100	1200	100	1200
Telephone, internet, mobile	100	1200	100	1200
Cable	50	600	50	600
Health insurance	200	2400	200	2400
Extras	100	1200	100	1200
Groceries	300	3600	300	3600
Credit Cards	200	2400	200	2400
TOTAL	**4,580**	**54,960**	**6,010**	**72,120**
& 30% TAX		16488		21636
Annual salary		**$71,488**		**$93,756**

Source: Sue Roaf.

In contrast, the "sustainability" concerns of residents of the Phoenix inner city suburb of Garfield[43] centered around the community-led initiatives to reduce gang crime in their area to which they had considerable success. Garfield inhabitants paid much less for commuting to work and for water, but they had a different additional expense to deal with in 2007: the extra cost of air-conditioning owing to the heat island effect. The climate of Phoenix has been particularly well-studied, and the city has one of the USA's Long-Term Ecological Research (LTER) centers. Thomas Karl[44] demonstrated a clear correlation between growing urban populations and increasing urban temperatures, and there has been extensive subsequent work on the magnitude and workings of the Urban Heat Island (UHI). In 2000, A. J. Brazel et al.[45] published a detailed, comparative study of the UHI in Phoenix and Baltimore and showed that the long-term urban UHI temperatures had increased in both cities in line with Karl's[46] graph, showing a clear correlation between rising UHI temperature and growing populations.

Darren Ruddell et al.[47] built on this work in a study looking at the relationship between health and the UHI. The 1995 heat wave in Chicago had shown that those most likely to suffer and die during such events are the poor, the elderly, and some ethnic minorities.[48] The 2003 heat wave in Europe, during which around fifty-two thousand excess deaths from heat occurred,[49] showed the potential scale of heat related disasters. Ruddell et al. showed that when it gets so hot, the whole city is affected but some areas can provide more cooling protection. Parks, shade, trees,

Figure 3
Retrospective HVAC Energy Use Analysis (over fifty years) for a 2000 square foot Single Family Home in Phoenix, Arizona. The Increase in Energy Use Shown is Solely Due to Phoenix's Increasing Average Summer Minimum Low Night-Time Temperatures Resulting from the Urban Heat Island



Source: Harvey Bryan and ASU's SMART Program.

and vegetation play a significant role in reducing temperatures locally. Building on such science, ASU academics, including Jay Golden and Harvey Bryan, were able to plot the increase in energy use for air-conditioning, which is due to Phoenix's increasing average summer minimum low night-time temperatures alone. This is the additional energy penalty paid by the ordinary families of Phoenix solely as a result of the city's UHI. Again, the lower-income families who have the cheaper and less efficient cooling systems will pay more in running costs, as they do for driving the cheaper, older, and less-efficient vehicles and living in areas where there are no verdant gardens around their homes.

In a new city in Columbia Table 2 shows that a lower salary will support the minimal "American Dream" standard of life in Garfield but that energy for increased air conditioning use in Phoenix has the potential over time to drive up the monthly bill in a hot summer. The Arizonan developer has a lot to answer for simply pushing people into larger and larger poorly insulated, often unshaded homes in gardenless lots further from work in the name of profit. Stiglitz[50] highlights the "price of inequality" when he promotes the idea of doing well by others and the "common welfare" as being a prerequisite for improving one's own position. The untrammeled greed of the Arizonan house builders and their friends in power at all levels of Arizonan society actually destroyed their own industry, businesses, and credibility in many cases.

Table 2
Rough Calculation Done in April 2007 of What a Single Young Professional with a Well Paid Job Might Pay Per Month, and Over a Year, Living in a Three Bedroom Home in Garfield and What They Would Have to Pay If the Price of Energy Doubled Across the Board

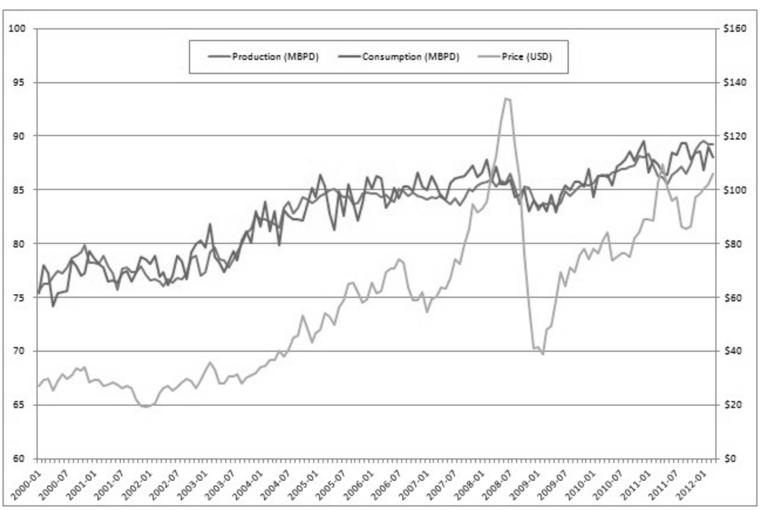
Single person	**GARFIELD 2007**		**GARFIELD 2020**	
2020 = x 2 Energy Prices Without heat island rises	**$ per month**	**$ per year**	**$ per month**	**$ per year**
Mortgage	1,400	14,400.00	2,000.00	24,000
Property Tax	500	6,000.00	500.00	6,000
Water + sewer	80	960.00	160.00	1,920
Energy	200	2,400.00	400.00	4,800
Car purchase	300	3,600.00	300.00	3,600
Gas / petrol	100	1,200.00	200.00	2,400
House insurance	100	1,200.00	100.00	1,200
Car insurance	100	1,200.00	100.00	1,200
Telephone, internet, mobile	100	1,200.00	100.00	1,200
Cable	50	600.00	50.00	600
Health insurance	200	2,400.00	200.00	2,400
Extras	100	1,200.00	100.00	1,200
Groceries	300	3,600.00	300.00	3,600
Credit Cards	200	2,400.00	200.00	2,400
TOTAL	**3,730**	**42,360.00**	**4,710.00**	**56,520**
& 30% TAX		12,708.00		16,9561
Annual salary		**$55,068.00**		**$73,476**

Source: Sue Roaf.

In April 2007, oil prices hovered at an all time high of around $65 a barrel. At the "Livability" Summit of the Valley Forward organization in Phoenix, I wanted to promote the need to understand oil dependence as a key vulnerability of their development model, and I urged them to consider building smaller homes that run largely on solar energy. I would classify the audience at the event as neutral to hostile. Within a year, Figure 4 shows that the "2020" scenario in Tables 1 and 2 had been reached. By September 2007, oil was at $80, and by July 2008, the price spiked at $147 a barrel. The thirteen-year time frame I had put on the doubling of the price of a barrel of oil occurred in thirteen months. In its wake, the fuel-poor of Arizona fell victim to this energy price shock. The ordinary

American dream lifestyle suddenly became a lot more expensive. People had to make choices. They had to keep their children cool in the heat-wave summers of 2007 and 2008; they had to buy gas to get to work, health insurance, food, energy for cooling, credit card bills, and other basic living expenses including water. Further down the line of essential payments were the mortgage repayments. Many residents had leveraged their salaries to be able to buy in aspirational developments, and by the end of 2007, more than six hundred Verrado lots had gone into foreclosure.[51] The 2010 Census in Arizona shows that ninety-one thousand homes in the city of Phoenix were vacant and 261,000 in surrounding Maricopa County. One in seventeen homes in Arizona had been in foreclosure that year. Arizona was the "domino" state in America after which many others fell, triggering a US and then a global economic meltdown in 2007/8. Phoenix was one of the worst-hit cities in the global recession with house prices in the city falling 57 percent between 2006 and mid-2011. Only time will tell how much of Verrado eventually does get built, but even now, if one mentions such concerns, there is a tendency among local people to not wanting to be aware, perhaps to protect those people still hanging on in such suburbs or because the reality may shed light on their own housing predicament. Stiglitz may agree here that the sooner the facts are known to the majority, the sooner the adaptive corrections can be made to the system and the safer it will be as a result. The rich can always move state.

Figure 4
Global Oil Production, Consumption, and Price 2001–2012



Source: US Energy Information Administration

Dundee Solar City Case Study

Dundee is a cool, wet city on the east coast of Scotland (Latitude: °N56°45' N), and the fuel poverty that led to the collapse of the Arizonan housing market is prevalent in Dundee too as it is in the rest of the United Kingdom. A UK household is currently said to be fuel-poor if it needs to spend more than 10 percent of its income on fuel to maintain an adequate level of warmth.[52] The adequate standard of warmth for a UK home is usually defined as 21 °C for the main living area, and 18 °C for other occupied rooms. Fuel poverty is therefore based on modelled spending on energy, rather than actual spending. Although the emphasis in the definition is on heating the home, modelled fuel costs in the definition of fuel poverty also include spending on heating water, lights, and appliance usage, and cooking costs.[53]

Table 3 below shows the number of fuel-poor households in England in each year it has been measured. The Department of Energy and Climate Change (DECC)[54,55] gives a range of reasons for the fluctuation in numbers of fuel-poor households year on year in the United Kingdom, but again, the rising cost of domestic energy, oil prices, and the dips in the United Kingdom and global economies, as with Arizona, were seen as key.

Note the clear jump in fuel poverty from 2005 to 2006. Domestic energy prices have been continually rising since then in the United Kingdom, and in

Table 3
Number of Fuel-Poor Households in England

Year	No. of fuel poor households (million)
1996	5.1
1998	3.4
2001	1.7
2002	1.4
2003	1.2
2004	1.2
2005	1.5
2006	2.4
2007	2.8
2008	3.3
2009	4.0
2010	3.5

Source: DECC

2011, domestic fuel prices rose a further 20 percent pushing more people into fuel poverty. On average, an additional twenty-seven thousand people die in England and Wales a year[56], many of whom will have been suffering from the debilitating effects of fuel poverty. As extreme weather events increase, more deaths are predicted with many being attributable to cardiovascular and respiratory diseases caused by excess cold and fuel poverty.[57]

Significant differences in fuel poverty levels exist across Britain, with one in fourteen households in England, one in nine in Wales, and one in four in Northern Ireland being in fuel poverty by 2008.[58] Recent estimates by the Scottish government put this figure at over a third of Scottish households. In some areas of Scotland, this figure is even higher with 45 percent of rural households deemed to be fuel-poor in 2009 and 20 percent in extreme fuel poverty, while only 30 percent of urban households in Scotland are fuel-poor and 8 percent of those in extreme fuel poverty.[59]

Scotland also has ambitious targets for renewable energy production and for more independence from fossil fuels by 2020, as legislated under the radical 2009 Climate Change Act.[60,61] The Scottish government aims to produce 20 percent of its energy from renewables by 2020 and 80 percent by 2050, but these energy targets are currently not linked to the fuel poverty issue.[62] The key elements in determining whether a household is fuel poor or not are considered to be:

- Income
- Fuel prices
- Fuel consumption (dependent on the lifestyle of the household and the dwelling characteristics)

Households living in older dwellings are also more likely to experience fuel poverty, with around a third of households in Scotland living in dwellings built before 1919 being fuel poor, compared to less than a fifth of households living in dwellings built after 1982.[63] Fuel poverty is a complex issue and government policies to address income poverty, and by extension fuel poverty, have tended to focus on financial subsidies and incentives around children, older people, and the unemployed, whilst deprivation-related policies have focused almost exclusively on regenerating deprived urban areas.

There is a clear need for government policy makers to understand that progress on fuel poverty will be limited unless the government commits to understanding the complex range of issues and drivers in which it operates. One of the initial flawed assumptions is that people live in homes with living rooms at 21 °C. Will Anderson and Vicki White[64] conducted in-depth interviews about real energy habits and found that a wide and diverse range of market behaviors occur as people actively engage in reducing consumption. Nearly half (47 percent) of the low-income households said their homes had been colder and 18 percent said their homes had been much colder than they wanted during the previous winter resulting in various consequences such as controlling systems, damp, or condensation, which would have knock-on effects on health. The low-income households who experienced cold homes reported adverse impacts on their mental health, physical health, and social lives. Nearly half (47 percent) said the cold had made them feel anxious or depressed, 30 percent said an existing health problem had worsened, and 17 percent could not invite friends or family over to the house.

These families were reaching the end of their "adaptive opportunities and capacity" and approaching breaking point. The majority could not, or did not, switch to cheaper suppliers because of ignorance or fear of consequences if it did not turn out well for them. Such families have no tolerance for things to go wrong. If all their actions failed to keep them safe and warm in their own homes, then they have one further conscious action available—to move. Their ecological niche had then collapsed and they could not bounce back in that environment. That is exactly what happened in Arizona. The fracture had occurred.

The Solar Solution for Fuel Poverty in Dundee

Solar Energy is a form of renewable energy whose integration into the fabric of a building, and in turn a city, is the easiest, and it is capable of providing a significant amount of the necessary electricity, heat, and hot water for the comfortable operation of a building over a year. Building-integrated PV and solar thermal (BIPV and BIST) can inform architectural features and aesthetics in forms such as passive solar sun spaces into the design language of the building envelope. They are clean, quiet, robust, energy-neutral to operate and can result in avoided costs of construction if used as rain screen cladding. They may require occasional cleaning over time depending on the climate and air pollution levels where they are located.

People like solar energy in their cities and on their own homes. For many years, we have known this. H. M. Chadwick et al.[65] studied the acceptability of different renewable energy technologies by the local community, as perceived by planners, and found that in comparison to large-scale wind installations and waste incineration, solar energy technologies in the form of passive solar, solar PV, and solar heating are likely to be favorably viewed by local people. The use of solar design in buildings since the earliest times is linked with an embedded cultural appreciation of the power and importance of the sun to human civilizations over millennia.[66] Around 80 percent of people in a recent UK survey said they supported renewable energy for providing electricity, fuel, and heat[67] largely because of the rising price of domestic energy bills.

The Solar City Solution

What happens if we actually try and run whole cities on solar energy? At the turn of the millennium, a new solar movement grew to promote the idea of a city-level integration of solar energy systems. The solar potential of cities lies in not only reducing fossil fuel energy use in, and carbon emissions from, cities but also improving local businesses and the economy, and by doing so while improving the lot of the ordinary citizen. It can be a win-win technology. Roaf and Rajat Gupta[68] demonstrated that with the energy saving measures and low-carbon technologies, BIPV and BIST, around 70 percent of domestic emissions from heating, lighting, and hot water could be eliminated from UK homes at a cost of around £100 billion in 2007. In 2007–2008 alone, the UK government committed some £70 billion to cleaning up and detoxifying existing nuclear power stations in Britain. Since then, the cost of installing a 4 kWp PV system in a high-volume project has fallen by three quarters from around £20,000 a system to £5,000.

That study looked at barriers and influences of solar ordinances, grid configuration issues and markets, planning law, local authority programs, government-level fiscal incentive schemes, and citizen-action programs. The question in Dundee was one of resilience with a focus on questions of the contribution of building integrated solar energy to the resilience of the ordinary citizen in terms of their ability to lead an adequately decent, healthy, and comfortable lifestyle, while living within their means. Could building integrated solar energy systems take citizens out of fuel poverty?

Dundee joined the Solar City movement in 2006 and by 2009 won significant support from the Scottish government for its programs to educate its citizens in energy efficiency and the benefits of using solar systems (www.dundeesuncity.org.uk and www.solarcitiesscotland.org.uk). Scotland patently does not have the best global climate for solar energy, and historically, people have considered the weather as a barrier to solar markets. However, the radiation incidence available is more than adequate and an appropriately sized PV and SWH system on a typical house in Scotland can meet more than 50 percent of the annual needs of a Scottish household for either electricity or hot water. Dundee, like many other Solar Cities around the world, was experimenting with a range of social, fiscal, and commercial incentives to increase the uptake of solar systems in the area. The most effective policy was the UK government's Feed-in Tariff (FIT), a generous rate-based incentive that paid people who installed systems up to 41.5p per kW generated by their systems.

Over 1 GW of PV installations were installed in the United Kingdom as a result of FIT in 2009–2011 alone. The success of the program was responsible for its own demise. Politicians no doubt took stock of the fact that as more people generated their own energy, the need for major new investment in large scale nuclear and a new generation of gas plants diminished. A key objection mooted for its termination was that the poor were subsidizing the middle classes in getting systems fitted, but citizens of the United Kingdom across the board have been heavily subsidizing the clean-up of nuclear plants for generations and that is not considered a reason to stop the program of a new nuclear build in Britain, which will allegedly require £250 billion of support from the UK government over the next forty years. That is enough money to give every home in the United Kingdom £10,000 each for efficiency measures and solar systems, an investment that could preclude the need for new nuclear power stations at all and lay the foundations for a safe renewable energy economy for all coming generations.

With our concern about the increasing numbers of citizens in Dundee in fuel poverty, and the case study of Phoenix Arizona in mind, Andreadis et al.[69] undertook a study for Dundee, a city with very high levels of social deprivation, to explore the potential role for building-integrated solar technologies together with the adoption of some basic energy efficiency measures as a successful and lasting solution for the elimination of fuel poverty in the city.

The Scottish Index of Multiple Deprivation (SIMD) classifies the areas of Scotland according to how deprived the population of areas are. Bailey et al.[70] quote Townsend's definition "*People are relatively deprived if they cannot obtain, at all or sufficiently, the conditions of life—that is, the diets, amenities, standards and services—which allow them to play the roles, participate in the relationships and follow the customary behaviour which is expected of them by virtue of their membership of society. If they lack or are denied resources to obtain access to these conditions of life and so fulfil membership of society, they may be said to be in poverty*." The term "multiple" has been used to include all the types or domains of deprivation which the SIMD examines which are: Current Income, Housing, Health, Education Skills and Training, Employment, Geographic Access to Services, and Crime.[71,72] The Georgios Andreadis et al.[73] found that the domains that were taken into account are those of income, housing, and employment. They found that 72,329 citizens lived centrally in the city out of a total population in Dundee of 143,090 in 2003. SIMD analysis showed significant concentration of deprivation in the chosen area of 88 data zones in which a third were in the 20 percent most-deprived households in Scotland. It was not possible to identify how many people are under the fuel-poverty threshold; however, they applied some common sense to arrive at his estimate for the fuel-poor of the city. Around 20 percent of the population were income-deprived, 14 percent had no central heating, and 11 percent were out of work.

It was found that there are about 1,300 domestic buildings suitable for solar integration, all of which have tilted roofs with a maximum deviation of ±30° from South. It has also been estimated that there are about three hundred more suitable buildings in the rest of the city. The City Council of Dundee has made a different investigation and concluded that this number is 1,500 for the whole city, and therefore, the two estimations concur. The 1,300 buildings reported here do not correspond to same numbers of households because there were many blocks of flats included, whose roofs seemed suitable for solar integration. The total roof area was found to be 88,313 m^2 which can receive 97,914,848 kWh of the total solar radiation per annum. This gives a 9.6 MW_p total PV capacity and 9,380,242 kWh per year of net electrical energy. The current energy consumption in the city was calculated using the typical annual electricity consumption of Scottish households reported on by Robert Currie et al.[74] being 3,084 kWh for a single person, 4,117 kWh for a working couple and 5,480 kWh for a four-member family (parents at work and children at school). According to another study by DECC,[75] the average annual household electricity consumption in thirty-two zones is 3,601 kWh for the ordinary domestic and 5,697 kWh for the Economy 7 off-peak tariff. If these two averages are combined according to their weights (percentage of the total), the annual average of 4,052 kWh for a dwelling in the city of Dundee is derived. The installed BIPV could thus cover the energy needs of 5,500 four-member households, 12.5 percent of the homes in Central Dundee.

Andreadis et al.[76] also suggested that the unsuitable parts of the roof areas can become usable if solar thermal collectors are installed: another 8 percent of the estimated roof area can be usable for BIST systems bringing in around 2,500,000 kWh of solar hot water and increasing usefully the total solar contribution in Table 5. The total of 11,880,242 kWh of free solar energy potentially installable would provide an additional benefit of 4,443,781 kg of CO_2 emission reduction savings annually from the city.

Energy-efficiency measures were included for five thousand of the worst (most fuel poor) households installing new 24 kW_{th} gas condensing boilers at £725 each; internal insulation of solid walls cost £5,500–£8,500; with the costs of low-energy lighting and retro-fitting selected properties being included, the total average cost per house was around £7,500. The basic cost of this efficiency program would be around £37,500,000. Adding up the total costs for BIPV and BIST solar systems and energy-efficiency measures, the total budget of the suggested solar plan for Dundee would be £67 million. This would then take vulnerable families in Dundee out of fuel poverty, but it would also have a range of additional benefits. Also, £67 million is what will be spent on the new Victoria and Albert Museum waterfront development in Dundee and a quarter of the cost of the new 28-mile Aberdeen Bypass that is being fought by Aberdonians in the courts.

The solar industry in Scotland includes both large scale installers and small local companies who have rapidly grown in numbers in the wake of the FITs bonanza, which ended abruptly in December 2011 when the UK government shut it down with little warning. Energy-efficiency work can again be undertaken by local companies or by larger players in the market. A number of studies have estimated jobs potentially accruing to these “green” industries in the United Kingdom and the United States.

Jonathan Neale[77] argues that the transition to an inclusive green economy will require new metrics that go beyond the prevailing narrow focus on income poverty and gross domestic product (GDP) to a broader way of tracking economic, social, and environmental progress and well-being. Making an inclusive “green economy” work for the poor too is vital for a resilient future, but it needs government commitment. Safeguarding the poor against any adverse impacts during the transition process and functionalizing a system that maximizes the opportunities and benefits for all is key. He sets out the route to building a million new jobs in that new green British economy.

Jacob Kirkegaard et al.[78] in the United States did an extremely useful working paper on issues around "solar employment." They covered in detail the PV industry's recent growth patterns, industry cost structure, trade and investment patterns, government support policies, and employment generation potential. In conclusion, they stressed the need for governments to provide sufficient and predictable long-term support to solar energy deployment. Such long-term frameworks bring investments forward and encourage cost cutting and innovation so that government support can decrease over time. They point out that it is not just the manufacturing jobs in the solar industry that are important but the total number of jobs that could possibly be created including those in research, project development, installation, operations, and maintenance. Their call for a "broader" view of the benefits of a solar economy are welcome in a world where we have seen the prices of energy, food, and water tip systems into freefall. We saw this in the Arab Spring, in the "Occupy" movements around the world and in the violent riots on the streets of Britain in the summer of 2010. We saw it in the Arizonan housing case study and we can clearly calculate the costs, and assess the benefits, of acting locally to build a solar future in a city like Dundee.

Since 2008, the Joseph Rowntree Foundation has published reports on the Minimum Income Standard (MIS) for the United Kingdom, in which they have tracked what members of the public think people need to have a socially acceptable standard of living and how much money different households need to reach this standard. They have achieved this by holding in-depth discussions with people on this subject since 2006 and, although people are aware that times are tougher, people's perception about what this minimum should include has not fundamentally changed. However, , there are some instances where people are clearly thinking hard about how they meet their needs in more economical ways like not going out so often or buying cheaper goods and presents.[79] These trends and attitudes are well-captured in the MIS and people can estimate on the MIS website what their own minimum income standards are and test the sensitivity of their MIS to changes in the prices of different good and services. What we can clearly see in the annual MIS reports is the evolution of behaviors and perceptions in a changing economic background. What we don't see is clear evidence of what happens to families when they fall significantly below their own MIS level and what the consequences of that failure might be.

In order to turn the MIS into a standard measure, and indicator, of the resilience of a population, a second measure of how well an individual household meets that standard is needed. The MIS demonstrates the minimum level of income required to pay for a bare minimum standard of living. The second measure required for a typical household figure is how much income is actually coming into households. This represents an individual domestic product (IDP), the total income to one household including multiple wages, benefits, and other incomes. These two measures would provide an alternative finer grained indicator of the relative success or stress of households within different populations of a larger economy providing much more effective policy indicators than the coarse grained instrument of the GDP and average income figures. Stiglitz[80] points out that in the five years after 2007, the top 1 percent seized more than 65 percent of the gain in the US national income, and by 2010, their share was 93 percent. GDP figures and average incomes mask this inequality. The gap between the rich and the poor is increasingly recognized as an indicator of the general success of an economy across multiple factors and populations showing wide gaps fare significantly worse than those in less unequal societies.[81]

The difference between the MIS and the IDP of a population is a proxy for their "adaptive capacity" indicating how much extra strain their own economic system can tolerate. Another modifying factor in a "learning" population would have to be included for the rate of change of the system. Using an MIS/IDP measure, the sensitivities of the system to factors such as the increase in energy or water prices could be tested, and short, medium, and long-term policies developed to avoid system collapse by exploitation of the potentials of adaptive opportunities and maximization of adaptive bandwidths. This need for a revisit on how we measure fuel poverty has recently been addressed in a detailed review of fuel poverty in the United Kingdom by John Hills,[82] who clearly elaborates the need for a more sophisticated approach to the subject than simply defining fuel poverty with 10 percent of the income figure.

What is clear is that we need a simple calculation for the household income minus household outgoings for individual populations, which gives a clear handle on the exposure and vulnerability of a family, or a population, to the hazard of fuel poverty. The vulnerabilities of a family revolve around variables such as the quality of construction and design of their home, location, climate, household funding model, etc. Secondary vulnerabilities that are in turn influenced by those factors include the price of food, water, and other costs. John Hills[83] recommends that such indicators (he defined one as the LIHC—the Low Income High Costs indicator) should be used as the basis for operational target-setting and to develop policies that a) benefit the individual household not the economy as a whole and b) alert decision makers when populations approach an economic fracture point.

The New American Dream: The Solar Solution for Arizona

Table 4 was drawn up way back in 2007 for a "Valley Forward" audience of business people to show what might have been if, instead of building 4,500 square foot chipboard mansions across the desert, developers had built smaller, more robust, well-insulated, and shaded homes, running on solar energy with a high thermal capacity construction to store heat and cool. Such homes could also have powered solar electric cars, bikes, and scooters that might have taken them to the shaded parking lot of their local branch station of the electric Arizona Rail system. The smaller ecohomes would have cost the same to build with their installed efficiency measures and solar systems as the larger ones, but the running

Table 4
Table Showing a Rough Estimate of the Impact on Household Bills of an Increased Use of Solar Energy to Run the Home and Transport for Verrado and Garfield with Garfield Residents Walking, Using Bicycles, or the Bus and Verrado Residents Using Electric Vehicles and the Arizona Rail System to Commute. The Figures Include Increased Mortgage and Water Costs and the Original Price Increase with Fossil Fuel Energy is Included in Brackets above the Annual Total

Single person	**GARFIELD 2007**		**SOLAR GARFIELD 2020**		**VERRADDO 2007**		**SOLAR VERRADO 2020**	
	Monthly	**Annually**	**Monthly**	**Annually**	**Monthly**	**Annually**	**Monthly**	**Annually**
Mortgage	1,400	14,400	2,000	24,000	2,000	24,000	2,800	33,600
Property Tax	500	6,000	500	6,000	500	6,000	500	6,000
Water + sewer	80	960	160	1,920	80	960	160	1,920
Energy	200	2,400	50	600	300	3,600	50	600
Car purchase	300	3,600	300	3,600	300	3,600	300	3,600
Gas / petrol	100	1,200	0	0	250	3,000	100	1,200
House insurance	100	1,200	100	1,200	100	1,200	100	1,200
Car insurance	100	1,200	100	1,200	100	1,200	100	1,200
Telephone	100	1,200	100	1,200	100	1,200	100	1,200
Cable	50	600	50	600	50	600	50	600
Health insurance	200	2,400	200	2,400	200	2,400	200	2,400
Extras	100	1,200	100	1,200	100	1,200	100	1,200
Groceries	300	3,600	300	3,600	300	3,600	300	3,600
Credit Cards	200	2,400	200	2,400	200	2,400	200	2,400
	3,730	42,360	4,160	49,920	4,580	54,960	5,060	60,720
30% TAX		12,708		14,976		16,488		18,216
Annual salary		**$55,068**		**($73,476)** **$71,488**		**($93,756)**		**$64,896** **$78,936**

cost is significantly less and these homes have not been susceptible to extreme spiking of energy costs, as once installed, solar energy is not only clean, but also free, and if properly installed, can also provide a further heat insulating barrier for the roof in turn lowering the cooling loads of the building. The impact of a solar lifestyle is the greatest on the expenditure for the home owners of Verrado. The simple point here is that if Arizonans had built such ecohomes[84] with less expensive and carefully zoned air-conditioning systems and PVs, then in the summer of 2007, many of them could have cooled their homes, eaten and paid their mortgages, and remained in their homes, not left on the streets where many of them found themselves, or moved state. Instead, Arizona was a tipping state that helped to topple the US and then the global economy system with such dire consequences for us all.

Conclusions

In our search for socioeconomic resilience in a rapidly changing world, both measures and motivations matter enormously. There is a need for a deeper understanding of where populations stand in relation to economic stress, their "adaptive capacity," how much extra economic strain they can tolerate in the real context of their own societies, economies, and environments. A vital factor to determine is at what point their whole economic system fractures, and what factors functionalize the breaking points inherent in those systems.

The MIS/IDP or LIHC indicator approach could be developed to achieve this and to test system sensitivities. When governments need to ratify spending hikes by private and public bodies such as 5–10 percent hikes in transport, water, or energy costs, the figures would be run through the MIS/IDP model to examine the extent to which such price hikes will push a population over the fracture cliff. It is not difficult to see that the Solar City model will fare much better in targeting investment to where it will help reduce economic inequality and take ordinary citizens out of fuel poverty forever. However, we know from Stiglizt[85] and Lazarus[86] that such end points may not be in the interests of the ruling classes, and their lobbyists, in too many countries. But perhaps, this is the exact time when even vested interests must bring about a paradigm shift, developing strategies and measures that enable populations to withstand the growing stresses and strains in our economic systems, in order to ensure the continuation of their own interests.

This exploratory chapter has identified that we need to understand, functionalize, and maximize our adaptive capacity and to identify fracture points in our socioeconomic systems in order to simply survive in an evolving form. It has also highlighted the fact that potentially a solar-powered society is a more resilient society, one with a far larger adaptive capacity to resist the inevitable soaring of fossil fuel prices in the future, as well as its increasingly extreme climates. A solar-powered society can be a safer society, but one in which the "one percent" might not make as much money. It's a choice we all have to make, of who matters to our own best interests in the long run. The real question is who actually makes the decision? *Quis custodiet ipsos custodes*? Who guards the guardians? Perhaps, after all, we all do.

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