Providing Non-food Needs if Industry is Disabled

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ABSTRACT: A number of risks could cause global electrical failure, including a series of high-altitude electromagnetic pulses (HEMPs) caused by nuclear weapons, an extreme solar storm, and a coordinated computer virus attack. Since modern industry depends on electricity, it is likely that much industry and machines would grind to a halt. The most challenging need to be met in these scenarios is likely to be food, and this is analyzed elsewhere in this conference. However, without industry, food cannot easily be shipped around the world, so one method to maintain the human population without electricity in an emergency is relocating people to the food sources. We find that this is possible even in the worst-case scenario by retrofitting ships to be wind powered. We also discuss solutions for non-industry inland transportation, water supply and treatment, and heating of buildings. We find that the nonfood needs could be met for nearly everyone in the short and medium term.

***Keywords*: high-altitude electromagnetic pulse, solar storm, computer virus, global catastrophic risk, existential risk, industry, electricity**

Acknowledgments: A. Ray Taylor, Allen B. Hundley, Lewis Dartnell and Joseph Geddes contributed helpful discussions. This paper represents views of the authors, and does not necessarily represent the views of the Global Catastrophic Risk Institute. Funding was provided by Tennessee State University.

1. INTRODUCTION

There are several human-caused and natural catastrophes that could result in global-scale temporary electrical grid and/or electronics failure. The loss of the grid and/or elimination of all non-shielded electronics would be expected to halt the majority of industries. A high-altitude electromagnetic pulse (HEMP) caused by a nuclear weapon could disable electricity over much of a continent. It is conceivable that multiple HEMPs could be created around the world, due to a world nuclear war or from suicidal terrorists co-opting nuclear weapons. This could destroy the majority of electrical grid infrastructure globally, and as fossil fuel extraction and industry is dependent on electricity, industry could also be disabled (Foster, 2008). Similarly, solar storms have destroyed transformers connected to long transmission lines (Board, 2008). There is evidence that within the last 2000 years, two solar storms occurred that were far more intense than modern society has endured (Mekhaldi et al., 2015). Though solar storms may last less than the 12 hours required to directly expose the entire earth, the earth's magnetic field lines redirect the storm to affect the opposite side of the earth (Board, 2008). Therefore, it is possible that an extreme solar storm could disable electricity globally, and therefore industry. Finally, Stuxnet was a computer virus that disabled Iranian centrifuges (Kushner, 2013). There is evidence that a computer virus disrupted electricity on a small scale (Goodin, 2016). It is possible that coordinated attacks on many electric grids could also disrupt industry globally.

The temporary or extended loss of industry would present many challenges. The first priorities of humanity's challenges are food, water, shelter and clothing as these are the basic necessities. With the loss of industry, provision of food is likely to be the greatest challenge, and this is addressed elsewhere (Cole et al., 2016). Additional challenges covered here include provision of sanitation, medicine, water treatment and transportation to food and water sources. Previous work has analyzed provisioning needs other than food in scenarios of the sun being blocked (Denkenberger and Pearce, 2014). In these scenarios, industry was assumed to be functioning (Denkenberger and Pearce, 2015), which allows the possibility of maintaining near-current levels of consumption of goods. In the present work, the collapse of industry makes this much more difficult. Therefore, we do not attempt to maintain present living locations and levels of consumption, but instead merely to provide a technical path to save nearly all human life in such a catastrophe. Ideally, this could be achieved even in the worst-case scenario where industry is disrupted over an extended period. We leave the actual recovery time (and mechanism) from various catastrophes for future work. HEMPs could disable vehicles, including ships (Foster, 2008). However, these detonations would not likely be over open oceans, which means that many ships may still be operational. However, it is possible that a series of super computer viruses could disable ships through the Internet or GPS links. In some of the less challenging scenarios, it may be possible to continue running the majority of machines on the fossil fuels that had previously been brought to the surface or from the use of microgrids or shielded electrical systems. Furthermore, natural gas would continue to bleed out of wells. In addition, it may be possible to run some machines on gasified wood (LaFontaine and Zimmerman, 1989). However, in the worst-case scenario, all existing un-shielded electronics would be destroyed, so to address this challenge we conservatively assume that no electrical/fossil fueled machines will function immediately after the catastrophe. Repairing these systems and re-establishing electrical infrastructure would be a goal of the long term and work would start on it immediately after a catastrophe. However, human needs would need to be met immediately (and continually) and here we focus on what is technically possible without the electrical infrastructure, leaving economics and politics for future work. This work helps to build resilience to global catastrophic risk, as was done for sunblocking catastrophes previously (Baum et al., 2015).

2. NON FOOD NEEDS

2.1 Water/Sanitation

Basic water supply is needed for drinking, cooking, and washing hands. There would need to be temporary relocation of some people so that they could carry this water to their living quarters. In wet areas, this relocation would be modest if needed at all and over relatively short distances. However, in dry areas, the distances would be longer. This relocation would generally require inland transport. In places with indoor plumbing, the water use is far greater than survival water requirements. Therefore, by going to minimum water use, storage in water towers would last a significant amount of time. Rainwater capture could also be increased at both household (Grady and Younos, 2008) and at the commercial scale (Chilton et al., 2000). On the other end of the spectrum, people who already carry water from natural sources would not be affected by the loss of industry. It is those people who carry water from spigots with water supply powered by industry (desalination and/or pumping) who would be in the most critical situation. If these people were near the ocean, it would be possible to improvise solar stills that evaporate water and condense it on the top glass (Pearce and Denkenberger, 2006). If the supply were surface water, people could move to it. If the supply were groundwater, it may be possible to mimic the traditional well system with a bucket let down into a shaft to retrieve water. This could be done by removing the system above the pipe going into the ground. Then a vessel could be lowered into the pipe to bring up water.

Water treatment could generally be achieved by bringing it to a boil with biomass fires or using passive solar techniques such as the SODIS method (Dawney and Pearce, 2012; Oates et al., 2003; Sommer et al., 1997). There are techniques to reduce biomass consumption for heating, and it is possible that more sophisticated solar water pasteurization could be performed (Denkenberger and Pearce, 2006).

Sanitation without running water can be provided by simple pit latrines. More advanced methods could allow the human waste to be pasteurized and fed to animals.

2.2 Clothing/Shelter

The current stock of clothing would last for a number of years. Regardless, traditional methods of using animal skins, silk, wool and cotton to make clothing would be feasible without industry.

Basic building heating can be achieved with open fires, as was done traditionally. However, breathing the smoke would cause many fatalities and so would fires getting out of control as is currently a problem in the developing world (Bruce et al., 2000). A number of homes have wood fireplaces and wood-burning stoves. Salvaged metal could be used to expand the density of stoves or less efficient would be the use of salvaged bricks to make additional fireplaces. Heating requirements could be dramatically reduced by consolidating families in a smaller number of buildings and then also consolidating building insulation to a subset of the rooms. Also, given the pervasive relocation, many more people per square meter would be present in the occupied houses, which would create more self heating. In these full houses, salvaged insulation could be added to the exterior walls. Before the above medium-term solutions can be implemented, there are short-term options such as wearing heavy winter clothing, camping indoors in sleeping bags, and consolidating in basements. A mattress could be filled with insulating material after the thermally conductive metal springs are removed. Layers of blankets and multiple people per mattress would be very beneficial. The combination of these techniques should be equivalent to high performance sleeping bags, which can be rated as low as -20 Celsius (Baregreen, 2016). For some cold areas these measures would not be feasible and may need to be evacuated using the same techniques as are discussed in the next section.

2.3 Medicine/Health

It is fairly straightforward to make soap with animal fat and wood ash (Dartnell, 2014). However, vaccines would not be feasible and even basic antibiotics take considerable processing (Dartnell, 2014). Therefore, there would likely be considerable mortality due to infectious disease. However, mortality will still be significantly lower than preindustrial times because of knowledge of the germ theory of disease and availability of soap. There would also be significant mortality associated with losing advanced medical techniques like life support.

The challenge of providing everyone's needs would be made easier over the longer term if birth control were available. Though the pill would not be feasible, condoms made from natural rubber would be (Frezieres and Walsh, 2000). Also, non-reproductive sex could be encouraged.

2.4 Transportation

The most efficient form of transportation without industry would be wind powered ships, although with typical winds, ship speeds will likely be lower than engine powered ones. Existing ships could be retrofitted with kites as sails (O'Rourke, 2006). In one example, a kite sail saved 10-15% of a ship's energy, with competitive speed (Sanderson, 2008). One such kite is made by Skysails GmbH a German company. Their largest model is the SKS C 320, which is rated as producing up to 2,000 kW of power. The SKS C 320 is winch launched from a telescoping pole, with the wires the kite attaches to being able to extend up to 500 m (SkySails, 2016). If the speed of the ship were one half as much as normal, this would require 1/4 as much force and 1/8 as much power. Therefore, the above kite alone could propel the ship at half its cruising speed (in reality even more, because a slower kite and ship speed means more force on the kite from the wind). The average speed of large ships is approximately 8.5 m/s (Fox and McDonald, 1998; Notteboom and Cariou, 2009). In order to travel upwind (tack), a keel is beneficial. However, even if it were not possible to retrofit one, the fact that ships used for shipping are long would mean they would not drift too far sideways from the ideal tacking path. Another retrofit that may be required is ventilation: fans could be human or animal powered.

A further retrofit required would be for the rudder. The power calculations assume that the rudder will realize its full range of motion (73 degrees) in a time frame of 30 seconds (Machinery Spaces, 2016). With a maximum rated torque of 1860 kilonewton meter (kNm) on the largest ship, the mechanical power required is approximately 60 kW (Royce, 2016) . Since the ship will only be traveling about half the normal speed, the force on the rudder would only be about one quarter, and the time to rotate could be twice as long for the same safety, yielding only 1/8 the required power. Since people can produce in excess of 1 kW for short periods of time (Bosco et al., 1983), this would require less than 10 people, which is quite feasible even assuming no electrical equipment. Steel could be cut with a hydrocarbon flame, potentially fueled by natural gas leaking from wells or plant oil that is heated to vaporize to provide the driving pressure (biogas and wood gas have low energy density values, so may not be able to exceed the melting temperature of steel).

Cargo ships spend approximately 20% of the time at dock for loading, unload and maintenance (Benson, 2016). If ships at sea are disabled, it may be feasible to recover many ships after the catastrophe hits, but we ignore this to be conservative.

The primary purpose of these ships would be to relocate people to where the food production is rather than attempt to transport the much larger volume and mass of food to people continuously. To make this task more feasible, food could be transported from the producing regions on the way to the population centers and offloaded to tide those population centers over. The current global shipping traffic is 53,000 billion tons moved 1 kilometer (Gt-km) (UNCTAD, 2009). This does not count the capacity of military and other vessels, which is conservative. With the slower speed and being full both directions, duty cycle would be higher. However, it will take longer to load and unload without industry, so we assume the same duty cycle. With only 20% of current ships and one half the speed of current ships (higher in good conditions and lower with low wind speeds or tacking), the capacity would be 5,300 Gt-km. We consider the typical transport distance as 12,000 km (Cole et al., 2016), and with a speed of 4.2 m/s, this would take 33 days. A straightforward way of moving many people is to put them in shipping containers with holes cut in the walls. The holes would both allow access and ventilation. A typical shipping container weighs 2.3 tons, has a floor area of 15 m^2 and a volume of 39 m^3 (Twenty-foot equivalent unit, 2016). We assume giving 2 m^2 per person so that people can lie down to sleep. We also estimate 0.5 kg per day of dry food and 3 kg per day of water (there would be some other supplies, but likely some fishing). Assuming 60 kg humans, the total is then 480 kg per person, dominated by the shipping container. On the return trip, sacks of grain could be carried into the shipping containers. However, in order to maximize grain transport, most of the shipping containers would need to be removed. This may be possible with human or animal powered cranes. This would mean that the shipping containers would generally be making one-way trips. However, because of the slower speed, minority of current ships involved, and greater capacity than required (see below), current shipping containers are likely to be sufficient (despite the loss of the containers associated with the ships lost at sea). If not, other methods of housing people on ships could be devised. If shipping containers are used and if the bulk density of the sacks of grain is 600 kg/m^3, the shipping container plus grain would be 91% grain by weight. Therefore, if the weight in both directions were equated, 440 kg of grain could be transported in the opposite direction per person traveling in the primary direction. Africa has roughly 2 months of food storage, while Europe has about 8 months (Cole et al., 2016).

The months of food for one person per person removed is:

$$t_r = \frac{Wk}{f} \qquad (1)$$

where W is the total weight required per person moved, k is the fraction grain by weight, and f is the amount of food required per person per month (15 kg). Equation 1 yields about 29 months with the numbers above. Since relocation may need to occur over a period of years, trips can be made every few months, and the retrofits could be performed within a few months, it is a good approximation to assume a linear reduction in population from the beginning of the crisis. Therefore, the percent excess population on average over the relocation period is 8% for Africa and 19% for Europe. If there were no influx of food, the time for relocation would simply be the months of food storage at current population divided by the percent excess population, yielding 22 months for Africa and 36 months for Europe. As the ships remove all the excess people, since the average excess people is only half as many as number of people who are removed, the food brought in lasts the remaining people an additional $2t_r$, or 58 months in this example. Therefore, adding to the time if there were no food influx, the total time to remove excess people is 80 months for Africa and 94 months for Europe.

With ~400 million people to be relocated for the pessimistic scenario of preindustrial agricultural productivity (Cole et al., 2016), this is approximately 60 million people relocated per year. However, the capacity for relocation is about 500 million people relocated per year, or nearly an order of magnitude greater than the requirement. This means there would be spare capacity to relocate draft animals, other essential cargo, and people to another part of a continent using the conservative assumptions above.

Over land transportation will also be required. People walking or human powered vehicles (e.g. bicycles) is very energy inefficient. The best freight and human transportation is likely barges pulled by kites. Tacking may be possible in large rivers. But even if this is not possible, when the wind is a favorable direction, some kite power would be feasible. The rest would be made up by animals consuming food unfit for humans. In areas where trees have grown back next to canals, labor intensive cutting down trees would be required. The next best would likely be railroad cars pulled by a combination of kites and animals. Then there would be road vehicles pulled by kites and animals.

3. ADDED VALUE FOR INTEGRATIVE RISK MANAGEMENT AND URBAN RESILIENCE

In the Hyogo Framework for Action, this work supports identifying risks and preparedness. But in order to be prepared, these solutions for the loss of industry must be disseminated (because of the loss of communication), so this is a gap in the Post 2015 Framework for Disaster Risk Reduction. Training for the scenarios considered here could be done at the same time that other training is done. Given the loss of industry, many people would need to move out of cities to the farmland. However, for those remaining, it is possible to provide non-food needs.

4. CONCLUSIONS/FUTURE WORK

Even if industry collapses due to temporary elimination of electrical infrastructure, the basic nonfood needs of nearly everyone could be met technically assuming global cooperation. The major source of mortality above the current level would likely be infectious diseases. Stockpiling of vaccines and antibiotics could solve this problem for a limited amount of time, possibly with natural cold storage. By providing for human needs, this allows humans the ability to protect biodiversity, as in the case of sunblocking catastrophes (Baum et al., 2016).

It would be preferable if the loss of industry could be prevented. This could be achieved by preventing the source of catastrophes such as HEMPS and cyber attacks, although it is not possible for solar storms. Another option is hardening the systems to the insults. This would be relatively straightforward in the case of solar storms as it is mainly about protecting transformers. Protecting against HEMPs would be much more expensive because the damage includes electronics connected to the grid and even vehicles (Foster, 2008). In a small part this can be done by improved electronics shielding to critical equipment and movement to distributed generation of hardened microgrids. Protecting against a coordinated cyber attack would also be difficult, although there is already a considerable literature on improving grid security and such an attack on a global scale would be highly non-trivial. Even if all this prevention and protection is feasible and justified, until it is all implemented, a backup plan is needed.

In order to save nearly everyone if industry collapses, people would need to know about how to provide their needs without industry. Depending on the catastrophe, there may be a window of opportunity to disseminate this information after a catastrophe, such as via emergency short message system (SMS) with cellular phone towers and cell phones relying on backup power. However, it would be preferable if this information were disseminated ahead of the catastrophes as some of them could halt the vast majority of electronic communication. Also, the actual relocation plans should be calculated ahead of time and ideally distributed ahead of time. This would reduce the chance of losing civilization, from which humanity might not recover. This reduced risk would benefit the far future of humanity, which has overwhelming importance (Beckstead, 2013).

Loss of industry locally is much more likely, caused by scenarios such as the breakdown of international cooperation and therefore trade. Many of these techniques could be applied to individual countries that lose industry temporarily.

Future research includes performing experiments on the ability to adapt to meet humanity's needs without the use of electricity and/or electronics. The results should be published freely following open hardware (OSHW, 2016) protocols so that everyone can use them. Such experiments could include retrofitting a ship to function without industry (using non-industrial steel cutting techniques), quantifying the thermal comfort of low-cost techniques for building heating and sleeping, testing methods of manually removing water from modern wells, and improvising a solar still and fishing equipment on a cargo ship.

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