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Suggested Reference

Matthewman, S. D., & Byrd, H. (2014). Blackouts: A Sociology of Electrical Power Failure. Social Space, 1-25. Retrieved from <http://socialspacejournal.eu/Sz%C3%B3sty%20numer/Steve%20Matthewman%20Hugh%20Byrd%20-%20Blackouts%20a%20sociology%20of%20electrical%20power%20failure.pdf>

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Blackouts: a sociology of electrical power failure

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Abstract

Electricity fuels our existence. It powers water purification, waste, food, transportation and communication systems. Modern social life is impossible to imagine without it. This article looks at what happens when the power goes off. It scrutinises the causes and consequences of accidental electrical power cuts. It begins by identifying the reasons for power failure. In doing so, power generation systems are identified as critical infrastructures. They are more fragile than is commonly supposed, and the argument is made that they are getting frailer. Irrespective of cause, blackouts display similar effects. These social patterns are identified. They include measurable economic losses and less easily quantified social costs. Financial damage, food safety, crime, transport issues and problems caused by diesel generators are all discussed. This is more than a record of failures past. It is contended that blackouts are dress rehearsals for the future in which they will appear with greater frequency and greater severity. Increasing numbers of blackouts are anticipated due to growing uncertainties in supply and growing certainties in demand. Supply will become ever more precarious because of peak oil, political instability, infrastructural neglect, global warming and the shift to renewable energy resources. Demand will become stronger because of population growth, rising levels of affluence and the consumer 'addictions' which accompany this.

Key words: accidents, blackouts, critical infrastructure, electricity

1. Introduction: accidental network failure

All other living creatures rely on a single source of energy – food. Humans have a specific problem in that they also require fuel for personal and collective well-being. Security of fuel supply is therefore a pressing social problem. A specifically

modern problem also presents: today life is sustained by complex critical infrastructures. These infrastructures, including those that generate power, are more fragile than is commonly supposed. In the case of electrical power they are also getting frailer. This has not gone unnoticed. For example the United Kingdom's Economic and Social Research Council (2004) urged that the project for 21st century social science should be to reckon with urban vulnerability and network failures. This paper makes a modest contribution towards such a project. It focuses upon one network failure, the accidental loss of electrical power referred to as blackouts. It follows Charles Perrow's (1984: 64) definition of accidents as unintended events that damage people, materials and systems. While many blackouts are caused by accidents best described as systems failures, network failures due to inadequate energy – whether it be depletion of resources such as oil and coal or the vagaries of the climate in the supply of renewable energy – also feature. Inadequate resource supply offers a glimpse into likely future trends for many countries. For those reliant upon fossil fuels to generate electricity, the peak production of resources such as coal is already evident. For example, the UK Government's incoming energy adviser stated in 2009 that '[t]here is a worry that in 2016 there might not be enough electricity' (MacKay quoted in Harrabin 2009). The Royal Academy of Engineering (2013: 3) has signalled its concern about the resilience of the system, which mirrors those of Ofgem (2013), National Grid (2013) and the Department of Energy and Climate Change (2012). All believe that the system's security could be seriously reduced by the winter of 2015/16. The World Bank (2010) called its analysis of energy in thirty countries in the former Soviet Union *Lights Out?* The American Society of Civil Engineers (2011) suggests that the United States' generation system will collapse by 2020 without significant infrastructural investment (they estimate a figure of 107,000,000,000 USD (78,000,000,000 EUR) or 732,000,000,000 USD (532,000,000,000 EUR) by 2040, although some believe that Texas could experience serious problems as early as 2014 (Smith 2012: A9).

Energy security remains an issue for those countries with access to significant renewable energy supplies. Weather is not always dependable and is likely to become less predictable with global warming. For instance, blackouts in Kenya (Burnham, Groneworld, 2010), India (BBC 2008b), Tanzania (BBC 2006) and Venezuela

(BBC 2010) were caused by shortages of rain for hydro dams. Indeed, the Executive Office of the President released a report prepared by the President's Council of Economic Advisers and the U.S. Department of Energy Office (2013: 3) which lists 'severe hurricanes, winter storms, heat waves, floods and other extreme weather events' as being increasingly likely due to anthropogenic climate change.

Understanding blackouts is more than a record of past failures. It is argued that current blackouts are dress rehearsals for the future in which they will appear with greater frequency and severity. The potential scale of the problem is alarming. On Thursday 14th August 2003 a blackout in the north-eastern United States and Ontario took power away from 50,000,000 people (Jacobs 2013), the Saturday 10th November 2009 blackout in Brazil and Paraguay affected 60 million people (McGowan 2009), while the blackout in India on Tuesday 31st July 2012 affected 20 of the country's 28 states, taking out three of its five grids, affecting as many as 600,000,000 (Energy Data 2012). Increasing numbers of blackouts are predicted due to growing uncertainties in supply and growing certainties in demand. Supply will become increasingly precarious because of peak oil, political instability, infrastructural neglect, global warming and the shift to renewable energy resources. Demand will become stronger because of population growth, rising levels of affluence and the consumer 'addictions' which accompany it.¹ In closing two such 'addictions' are considered: current air-conditioning use and potential future electric vehicle (EV) use.

2. Infrastructures and critical vulnerability

John McNeill reminds his readers that the complex infrastructures that frame our existence are historically novel. While they are an assumed aspect of our existence, humans have not been living with them for long. 'In 1870, most cities were held together by muscle and bone: people and horses carried or pulled all the food, water, goods, wastes, and information that circulated. By 1920, cities in the wealthy parts of the world (and a few elsewhere) were immensely complex systems of interlocking technical systems' (McNeill 2000: 290). Infrastructures permitted western cities to dig down, rise up and spread out.

¹ 'Addiction' is not used here in a strict clinical sense but it does signal notions of physical and psychological dependence.

Nigel Thrift (2005: 212-4) uses the term the 'technological unconscious' to refer to those invisible infrastructures that make life feasible while escaping notice. He is not the only one directing scholars to this domain. For Paul Edwards (2003: 185) these infrastructures are 'the invisible, unremarked basis of modernity itself'. Geoffrey Bowker and Susan Leigh Star (2000: 33) argue that infrastructural absence from the collective conscience is a function of use and size. The easier technologies are to use the less they are reflected upon. The better they work the less obvious they become. Modern technology fails to register except when it fails. Yet accidents are to be expected in complex hi-tech assemblages. This is because the potential exists for failures within the system to interact with each other in unanticipated and often incomprehensible ways. These will be particularly devastating in tightly coupled systems like the US and European energy grids, where processes are rapid, intimately linked and hard to stop. To use C. Perrow's (1984) word, they are normal.

Even when acknowledged, Paul Edwards (2003: 190) writes that our routine explanations for accidents fail us too. Electrical power blackouts are reported as human errors or as technological shortcomings. These are also the standard stories of the energy industries. The problem is either reduced to the level of individuals or to nuts and bolts. This binary of blame – people or hardware – obscures the *systemic* nature of accidents and network failures, which are the outcome of relations between people, technical systems, resources, institutions, regulatory frameworks, environmental conditions and social expectations (various causes of blackouts were identified and they are listed in the following section).

In the privileged west a continuous and stable supply of electricity is assumed. This assumption will be increasingly challenged. Electrical power generation and distribution rests on a complex vulnerable assemblage. Power does not consistently flow along the same predetermined path. When a supplier sends power to another it increases the power supply, while the receiver either reduces production or has increased demand. Power goes from 'source' to 'sink' along connecting paths. Shifts in generation and transmission anywhere within the system alter loads on generators and transmission lines at all other points, the consequences of which may

not be fully anticipated or managed. Delivery systems become more complex as distances and interconnectivity increases.

The normal way to guard against system failure is to ensure that power flows remain below the transmission line's capacity. When the capacity limit is transgressed the lines overheat. This may cause them to sag, generate unstable power supply or even fail. Longer power lines result in greater losses. Further vulnerabilities arise because AC power grids need the frequency and phase of all power generation to synchronise within tightly defined limits. Circuit breakers are used to remove generators from the system if their frequency fluctuates too greatly. However, when 'certain parts of the grid are carrying electricity at near capacity, a small shift of power flows can trip circuit breakers, which sends larger flows onto neighbouring lines to start a chain reaction failure' (Lerner 2003: 10).

Electrical power is not merely infrastructure. It meets the International Risk Governance Council's (IRGC) definition of *critical* infrastructure. Critical infrastructures are large-scale human-built systems that supply continual services central to society's functioning. They are the subject and source of numerous threats. These systems typically have no single owner, manager or controller meaning interests and operating procedures can diverge and conflict (Kröger 2005). This applies to electrical power, where the physics of the system is complicated by its administration. The North American power grid is a single machine, arguably the world's largest (Lerner 2003: 8), but this unified physical system is politically fragmented. It crosses a variety of borders, competing corporate spaces and regulatory zones. The American Society of Civil Engineers (2009: 134) notes that over 3100 electric utilities operate on it.

The vulnerability of the electricity system is demonstrated by a blackout which took place on Sunday 28th September 2003. This rapidly escalated into grid collapse. The event began when a falling tree broke an electrical power line in Switzerland's Lukmanier Pass. The nearby San Bernadino line subsequently overloaded. Twenty four minutes after the first tree flashover, a second tree came down in the Great St. Bernard Pass. Two important lines failing were too much for the system to bear. Moments later the overloads tripped the other interconnectors towards Italy, separating it from Europe's electricity network (UCTE 2004: 4-5). The low voltage level in the north of the country caused several Italian power plants to trip. All of It-

ally was left without power. It says something about the fragility, complexity and interconnectivity of the modern world when a nation is brought to a halt by two trees falling outside its territory.

The IRGC measures criticality by space, size and time: the geographical spread of failure, the severity of its effect and the speed with which it is felt. Failure in the electric power network is potentially international in scale, it can profoundly affect those within the afflicted area, and do so immediately (Kröger 2007: 10). Network failures of this type are as critical as it gets. Disruptions to critical infrastructures have rippling effects as they are dynamic and interdependent arrangements (on this see Bashan et al., 2013). Electricity powers, connects to and synchronises with other systems. Graham (2010: 5) argues that it is more apt to think of separate infrastructures as a complex single whole. Blackouts affect pumps, refrigeration, traffic lights, trains and cell phone towers. This has serious consequences for water, waste, food, transportation and communication systems. Modern social life is impossible to imagine without it.

The following section examines some patterns that emerge when the power goes out. This provides insights into what to expect in the future.

3. Patterns of network failure: the social effects of blackouts

3.1. General remarks

The unpredictable nature of blackouts and their aftermath limits the collection of field data. Inconvenienced populations do not need the additional inconvenience of having to interact with social science researchers. With these practical and ethical considerations in mind the data discussed in this section is derived from reputable media coverage of the events. Sometimes this is the only available source of data for the researcher. Almost 50 significant power-outage events were scrutinised across 26 countries, mostly over the last decade. Such convenience sampling does not claim to be scientific nor does it contain all possible data pertaining to such incidents. It is inevitably skewed by the selection criteria of mainstream news media. Nonetheless it highlights basic facts, trends and relationships. It helps us understand individual blackouts and it helps build up a qualitative summary of them.

In examining these blackouts numerous causes were reported, including: technical failure (BBC 1998b), extreme weather events (Aljazeera 2009), political spite (BBC 2011), deceiving the enemy during war (New Zealand Herald 2001), sabotage by narco-terrorists (Reuters 2013) or political opponents (Mogollan, Kraul, 2013), inadequate generation capacity (Iqbal 2010), financial problems (BBC 2001), corruption (Cist 2008), increased air-conditioning use (Vidal 2006), infrastructural neglect (Alic 2012), punishment for non-payment of power bills (Whaley 2013) and a lack of resources to generate electricity (Amos 2013). Resource lack applies to both fossil fuels (BBC 2008b) and renewable energy sources (Haviland 2009).

When blackout events happen the electrical supply industries are faced with establishing future mitigation systems. Research and risk analysis is carried out with the aim of producing resilient future supplies. For example, the electricity supply industry produced a book on improving supply security following the previously mentioned Italian power outage in 2003 (IEA 2005). Less research is carried out on the social impact of power outages (for an exception see Nye 2010). Irrespective of cause, the survey of media reports shows that patterns emerge whenever blackouts result. These include measurable economic losses and social costs that are harder to quantify. The main themes to emerge from media reports were: economic damage, food safety, crime, transport and the problems caused by diesel generators are looked at.

3.2. Economic costs

For several blackout events the direct monetary cost has been calculated. This is generally measured using an economic model such as loss of sales or production. The examples here show that losses vary considerably from minor inconveniences of ATM machine failure, as in the UK in 2009 when a major bank lost its power supply (Alexander 2009), all the way to major economic failures costing hundreds of millions of dollars. Power outages and quality disturbances are estimated to cause economic losses of between 25,000,000,000 USD (18,000,000,000 EUR) and 180,000,000,000 USD (131,000,000,000 EUR) per annum in America (ASCE 2009: 134). During Easter 2010 Venezuela's President extended the holiday period in order to reduce the country's electricity demand. Rolling blackouts were imposed on areas of

the country. The business community warned the president of a loss of production and food supply shortages (Guardian 2010). Friday 25th January 2008, the three largest gold mines and two biggest Platinum mines in South Africa were forced to shut down due to a blackout. Within minutes, the world price of these commodities rose by 5% (McGreal 2008b). Power cuts in Iran in September 2008 added to the economy's woes: 'Without electricity, the economy continues to self-destruct. In the scorching heat, offices cannot operate without air-conditioners and the little manufacturing done in Iran is threatened with even more disasters. Making deals with China necessitated the opening up of the Iranian market to cheap Chinese goods so at this rate the little of it done at home will be destroyed' (Cist 2008).

Beijing: in July 2004 rolling blackouts occurred as energy demand soared. To compensate, factories operated at night to save energy on air-conditioning use and the state press urged people to stop wearing suits as a means of keeping cool. Driven by an inadequate supply of resources, state governments introduced rationing of electricity with the logic of turning lights off in one place to keep them on in another (BBC 2004a). On Friday 15th August 2003 parts of Canada and the US were hit by blackout. Trading on the stock exchange was described as 'light', people struggled to get to work and ATM machines stopped functioning. Car manufacturing was hit hard with 12 General Motors and 24 Ford plants closing. Airports in the US and Canada were closed resulting in 500 flight cancellations and an estimated 'tens of millions of dollars' losses (BBC 2003a).

3.3. Food safety

Italy was crippled by a grid collapse in the month following the North American outages. The 18 hour blackout exposed the country to almost every aspect of dependency that comes with an addiction. Only a few hours into the blackout it was estimated that the loss of food sales amounted to 50,000,000 EUR with the loss of frozen food adding a further 70,000,000 EUR (BBC 2003b). Blackouts obviously severely impact upon foodstuffs. The need to preserve freshness through fridges and freezers is a priority. Inability to safely store food has a number of consequences. Economic loss is perhaps the most immediate and obvious. To take another example, in May 2008 traders in Zanzibar soon found their stock perishing. Meat went bad

due to blackouts. Shopkeepers looked to claw profits back by buying fresh meat at reduced prices, only to find that no market existed for it. Customers were equally reliant on electrical power. They had no means of cooking (BBC 2008a). Blackouts were so frequent in Kenya during 2010 that Nairobi's restaurants planned menus to accommodate them. With each blackout staff scrambled to get generators running to avoid food spoilage, but cooks never met demand due to the lack of stoves. Hosts noted the frustration of serving restricted offerings to customers while potentially poisoning them (Burnham, Groneworld, 2010). In 2010 authorities imposed electricity rationing to meet energy efficiency targets in Hebei Province, China. Tens of thousands of households were left without electricity for 22 hours out of three days with the consequent loss of refrigeration. Milk curdled and vegetables rotted as the domestic penalty for industries that exceeded energy consumption targets (Watts 2010). A more tragic consequence of a lack of refrigeration was felt in Pakistan in June 2010. Blackouts during a heat wave resulted in 12 hours a day without electricity. Numerous deaths were recorded from food poisoning as people ate bad food from freezers (Iqbal 2010).

3.4. Crime rates

When the lights go out, crime rates increase. Security systems fail without electricity. Blackouts provide opportunities for fraud, theft and exploitation (BBC 2009a; b). In South Africa in 2008 an increase in robbery occurred during times of blackouts including premeditated and violent robbery from cars returning home and being delayed in the street while electric gates were opened manually (McGreal 2008a). In Zanzibar, following four weeks of an electricity blackout it was announced that power had at last been restored. But not for many, as the opportunity for making money out of the scrap metal value of electricity cables was too tempting while the cables were not live (Boswell 2008). In 2006 in Tanzania the rains failed and the hydro dams ran almost dry. The Energy Minister realised the value of electricity: 'It is important to have light at night to curb crime' (BBC 2006). Auckland suffered a blackout for five weeks (BBC 1998a). The police adopted saturation policing, doubling patrols and using private security guards to prevent looting. It is the only example identified in which crime reportedly *reduced* during a blackout. The city centre

effectively closed down for weeks. Tourists left and the empty streets offered little opportunity for petty criminals. More typically, extended periods without electricity or intermittent periods of rolling blackouts lead to social unrest. In Pakistan it was estimated that 53% of the population went without power for eight hours of the day in 2009. The power cuts usually occur during hot summers. High temperatures and hikes in energy prices are a recipe for unrest. 'In Karachi and throughout the Punjab ... angry mobs went on a rampage and assailed power companies in frustration at the long daily power cuts that have brought modern life to a standstill' (Iqbal 2010).

3.5. Accidents and transportation

One of the most immediate and prevalent problems with blackouts comes from the loss of traffic lights. Traffic jams and accidents were a recurring theme in the enforced blackouts in China in 2010 (Watts 2011), Brazil in 2009 (Aljazeera 2009), Italy in 2003 (BBC 2003b) and California in 2001 (BBC 2001a). Similar issues with the South African blackouts of 2008 prompted the Government to consider replacing the electrical supply to traffic lights with solar-powered electricity (McGreal 2008b).

Public transport is another victim with the loss of subway trains below ground and rail systems above. Thousands of people were stranded in Brazilian cities after the world's largest power outage occurred in 2009 (Aljazeera 2009). It shut down the subway system in São Paulo's financial centre trapping thousands inside. In September 2003, underground trains in Italy stopped in the blackout trapping passengers inside for hours. 110 trains were halted, with an estimated 30,000 commuters affected (BBC 2003b). One month earlier, in New York, the subway stopped, trapping people inside. The Mayor warned non-essential workers against travel. Electric buses and underground railways also came to a halt in the Iranian blackout of 2001 (BBC 2001b). Air travel is also sensitive to these failures due to a loss of communication systems and a lack of runway lighting. Parking also becomes problematic. Security gates cease to operate causing issues for those stuck inside, and outside, secure parking areas.

3.6. Diesel generators

Given the problems detailed above, diesel-fuelled generators may appear as a lifeline to households, hospitals, businesses and states as they offset the deleterious effects of accidental blackouts. However complaints about noise and air pollution caused by generators are a common theme in blackouts. Furthermore, the cost of generators and their fuel make them prohibitive to all but the most privileged. Generators, then, also operate as symbols of wealth, emphasising the rift between rich and poor.

In June 2010, a combination of war, corruption and incompetency left Baghdad with electricity for only two hours per day. Residents complained of 'the din of a thousand diesel engines' (Gatehouse 2010). Small business owners suggested that as much as half of their income went on fuel and servicing costs for generators. In the Gansu province, China, in 2010, local government enforced rolling blackouts and factory shutdowns led to a surge in generator use. Competition for diesel fuel ensued between its traditional use for transport and the new use, causing queues for diesel at filling stations (Watts 2011). In Pakistan in June 2010 the combination of record-breaking temperatures (53°C) and hours a day without electricity made life without fans, fridges or air-conditioning more than just an inconvenience, it could make all the difference in the world. For those rich enough, a generator is an essential piece of equipment. 'The wealthy will switch on their generators to keep a running supply of power every time the electricity trips', wrote Nosheen Iqbal (2010), but 'the poor are simply left to swelter and suffer'.

After years of war, corruption and general neglect, Nepal's electricity supply was rationed in 2009. Reporters wrote of 'severe and unprecedented' power cuts, with around 16 hours a day of blackout (Haviland 2009). With this level of electricity interruption schools, businesses, private hospitals and households cease to function properly. To be able to maintain some level of normality, those who could afford it purchased a generator: 'the rich are buying generators and the poor are having to re-plan the patterns of their lives' (Haviland 2009). Blackouts in Zanzibar (BBC 2008c) and Tanzania in general (BBC 2006) had a similar impact with the noise of generators being heard throughout urban centres. Demand for generators in Zanzibar was so great that that they sold out. Buying them was one thing, running them another. Small businesses purchased generators but the fuel costs resulted in unsustainable

trading. One cafe owner estimated the running costs to be 100 USD (73 EUR) a day. Residents likened this daily cost to 'the equivalent to half a month's electricity bill' (BBC 2008c).

4. 'Addictions' present and future: air-conditioning and electrical vehicle demand

So far this article has cast light on an ordinary infrastructure, noted its critical nature and detailed some of the social consequences of its failure. Here it considers growing consumer demand for devices which increase our dependency upon electricity (IEA 2010: 77). The looming threat of blackouts cannot solely be blamed on the vulnerabilities inherent in electrical power generation. A crisis of overconsumption must also be considered. For example, average US household electricity usage increased 1,300% between 1940 and 2001 (Nye 2010: 144). While efficiency gains can potentially offset this; research reveals that demand routinely outstrips said gains. For example, in the period that refrigerator efficiency increased by 10%, refrigerator demand grew by double that. Similar figures apply to both heating and cooling technologies (Foster et al., 2010: 178).

While there are all manner of 'must-have' devices for the modern consumer here just two are discussed: current demand for air-conditioning and anticipated demand for EVs. Increased demand for such devices will place additional strains on already struggling systems of power generation, and in the case of air-conditioning there is the compounding factor of it having a disproportionate impact upon peak load (McNeill, Letschert, 2007: 1311).

Calling our relationship to air-conditioning an addiction might seem an overstatement, yet a number of scholars working in a range of geographical locations have noted our powerful attachment to it, sometimes using the term literally (Cândido et al., 2009; Chun et al., 2008; de Dear and Auliciems 1988; Prins 1992). Once acclimatised to air-conditioning people are reluctant to give it up.

Air-conditioners have affinities with diesel generators. Both offer solutions to private problems that simultaneously create larger collective ones. Generators generate more than electrical power, they also produce community envy, air and noise pollution. Air-conditioners cool and dehumidify domestic and commercial space, but in doing so they heat the environment and are linked to ozone depletion. With-

out a trace of irony PR Web (2008) could open its press release on predicted air-conditioner sales: 'Depletion of the ozone layer, El Niño effect, global warming, and rising population are all hot factors that are driving ahead the need for a cool world'. No causal link was inferred.

Currently, none can compete with the US, which Stanley Cox (2010: 32) describes as 'the undisputed champion' of air-conditioning. David Nye (2010: 109) singles out air conditioning use in America in the last few decades as '[t]he greatest factor in increased electrical consumption' and one of the greatest sources of systemic strain: from the 1990s onward blackouts tend to occur in summer rather than winter months (2010: 111-2). The statistics speak for themselves: air-conditioning accounts for 20% of US domestic electricity consumption and 13% of the commercial sector's figures which equal the entire African continent's overall electrical demand. The government expects cooling consumption to grow a further 22% over the next two decades in the commercial sector.

Growing demand will add an additional burden to utility companies that are being pressured to reduce greenhouse gas emissions. Electricity generation by American utilities currently produces 2,500,000 metric tons of CO₂ and 11,000,000 tons of SO₂ per year. In 2007 commercial and residential air-conditioning consumed 484,000,000,000 kilowatt hours of electricity, a number which Cox (2010: 37, 43) notes is not much lower than *total* US energy consumption in the mid-fifties. This could not be supplied by renewable sources, even if the entire nation's was harnessed.

But the US is now regarded as a saturated market, the real growth will occur elsewhere. The PR Web cited a Global Industry Analysts study which predicts sales of 85,400,000 units in 2012. Asia-Pacific was both the fastest growing and the most significant market. Air-conditioners already constitute 20% of overall Chinese electricity consumption (Teske 2010: 188), where household ownership of air-conditioners has tripled in the decade since 1997 (Cox 2010: 44). India shows a similar pattern of uptake: air-conditioner sales are growing at 20% per annum (McNeil and Letschert 2007: 1311). Michael Sivak (2013) has calculated that global air-conditioning demand has the potential to exceed that of the United States by a factor of 50.

In 2009 Morna Isaac and Detlef van Vuuren of the Netherlands Environmental Assessment Agency published the first planetary study of residential demand for domestic heating and cooling set within the context of global warming. Their work paints an alarming picture. According to their calculations world demand for heating rises until 2030 after which time it stabilises. By contrast, demand for air-conditioning will rise rapidly to 2100. This is mostly a function of rising prosperity. The shift from heating to cooling spells bad news for the climate, for in many countries (like the USA) cooling is more carbon intensive than heating. Moreover, demographic trends show that most people will live in the tropics, where cooling demand will increase along with its cost. They estimate the energy demand for cooling in 2100 to be 40 times greater than it was in 2000 (Isaac, van Vuuren, 2009: 513). An earlier, more limited, study suggested between 18-25 % less cold weather per annum four decades hence and 17-23% more hot weather. Population increases (which, as noted, will be greater in hotter regions) and global warming would make for a 65-72% increase in cooling demand (Stein and Lemke cited in Cox 2010: 31-2).

Gwyn Prins (1992: 251) described America's physical attachment to air-conditioning as that nation's 'most pervasive and least noticed [current] epidemic'. An epidemic, it should be noted, that is becoming a pandemic. Another suggestion to be made is that electric vehicles (EV) are shaping up to be a future 'addiction'. A 2010 consumer survey in major markets by Ernst & Young affirmed that serious demand for EVs already exists. A quarter of those questioned were interested in purchasing one (Shankar 2010). Ernst & Young's Global Automotive Leader forecast demand exceeding supply for the 2010/11 production runs. Richard Gilbert and Anthony Perl (2008) had already forecast growing demand for EVs relative to internal combustion engines as they are quieter, more energy efficient and less likely to require maintenance.

Vehicle producers have become increasingly interested in EVs. The International Energy Agency (IEA) (2010: 5) identified a single political 'megadrive' for this: G-20 and APEC pledges to eventually eliminate inefficient subsidies for fossil fuels, the total cost of which they estimated to be 312,000,000,000 USD (227,000,000,000 EUR) in 2009 alone. The World Bank's (2011: 1) view is broader. It highlights four supply and demand 'megatrends' driving vehicle electrification: the

aforementioned climate change policies aimed at reducing (vehicular) CO₂ emissions, concerns about the cost and security of oil supply, increasing congestion and attendant air pollution and impressive technological breakthroughs regarding batteries. Combined, they make mass markets for such vehicles possible.

The IEA's EV forecasts go to 2035. They offer a range of scenarios. Their best case one for EV sales is the 450 Scenario. This is named after the limitation of the long-term concentration of atmospheric greenhouse gases to 450 parts per million of CO₂ equivalent to ensure global temperature rises of no more than 2°C above pre-industrial levels. Assuming this strong policy orientation towards countering the effects of global warming, there would be sales of almost 65,000,000 EVs and plug-in hybrid electric vehicles (HEVs) by 2035 (IEA 2010: 433). The World Bank's EV forecasts only go out to 2020. In their estimation plug-in HEVs and EVs could total 10% of all new vehicle sales by then (World Bank 2011: 7). This would create an estimated EV value chain of over 250,000,000,000 USD (182,000,000,000 EUR). The figure factors in the cost of energy generation and distribution, fuelling and infrastructure, batteries, other components and the EV's themselves, but the calculation does not include advertising, branding and services.

Such demand would add 20,000,000,000 USD (15,000,000,000 EUR) in incremental electricity sales (World Bank 2011: 28). Gilbert and Perl (2008: 161) calculate that, *ceteris paribus*, 'converting the personal vehicle fleet to electric drives in a higher-income jurisdiction would increase the amount of electricity that has to be generated by 15–40%'. While the required generating capacity could be significantly lower than this figure if batteries are charged during off-peak periods, it nonetheless remains true that increased demand for EVs necessarily increases demand for electrical power. S. Cox (2010: 43) relates the discussion back to where it began in this section: 'If all household vehicles were to be replaced with highly efficient electric models, with no reduction in numbers, the new cars would still consume on the order of twice as much electricity as residential and commercial air-conditioning combined'.

The load shedding that occurred in Nepal in 2009 offers a glimpse of the vulnerability of one particular mode of electrically-powered transport that is likely to replace the internal combustion engine in many countries in the future. Nepal ob-

tains much of its energy from hydroelectricity and has numerous EVs. Kathmandu has about 700 battery-operated rickshaws, each capable of carrying 10 passengers. Power cuts meant there was insufficient time to recharge batteries daily. By the time the families of the rickshaw operators were factored in, the chairperson of the Electric Vehicles Association of Nepal estimated that at least 10,000 people had been adversely affected. That figure excluded passengers (Haviland 2009).

5. Conclusions

Grid supplies of electricity have democratised energy distribution in many countries across the world. This supply is generally taken for granted in western societies which have developed an 'addiction' to the tools and appliances that are driven by this form of energy. Modern societies have become dependent on air-conditioning, computers, lights, fridges and freezers that are, in turn, dependent on an uninterrupted supply of electricity. Such is our dependency that our comfort, security, communication systems, transport, health, food supply, businesses and social equity systems strain when electricity supplies are interrupted. The continuing sophistication and prevalence of electrical appliances only serves to increase our dependence. Here digitisation looms as a key factor. In the digital world interruptions and disturbances less than 1 cycle ($1/60^{\text{th}}$ second) can have catastrophic effects. Servers and computers crash, life support machines become their opposite, intensive care operations are compromised, as indeed are all manner of automated machines and micro-processor based devices (Galvin Electricity Initiative 2011).

Western societies now face a significant social problem. They are becoming ever more dependent upon electrical power yet supply will struggle to meet demand. Increasing numbers of people are living longer and enjoying rising living standards. This increases demand for electrical appliances (IEA 2010: 89). In 2008 the world's population was 6,700,000,000. This is predicted to rise to 8,500,000,000 by 2035. Across the same time period demand for electricity is estimated to grow by 80%. This will require an additional 5900 gigawatts of additional capacity (IEA 2010: 77). No one knows how this will be generated.

Even in the privileged west electrical supply is less robust than is commonly supposed. The US system works on the principle of 99.97% reliability. This means

that blackouts cost consumers about 150,000,000,000 USD (EUR 109,000,000,000 EUR) per annum. Consumers end up spending an additional 50 cents per dollar spent on electricity to ameliorate the costs of outages (Galvin Electricity Initiative 2011). And this system is getting frailer. S. Massoud Amin (2011) scrutinised the data sets of the US Department of Energy's Energy Information Administration and the North American Electric Reliability Corporation across three time periods: 1995–1999 2000–2004 and 2005–2009. These data sets showed that blackouts increased in frequency and severity across each five year period. For example, S. M. Amin found 147 separate outages over 100 megawatts between 2000 and 2004. This increased to 230 outages between 2005 and 2009. Assuming a two-percent growth in annual demand, power outages impacting upon 50,000 customers or more rose from 140 between 2000 and 2004 to 303 between 2005 and May 2009. More recently, a report authored for the Executive Office of the President (2013: 8) concedes that the incidence of major blackouts is increasing.

In the US deregulation and privatisation have created further systemic weaknesses as there is no economic incentive to maintain or improve the grid. Since deregulation electric utilities have reduced research and development spending on aggregate by 78.6% (Sanyal, Cohen, 2009: 41). Infrastructural investment in both the USA and Europe has been poor. Almost three quarters of the US grid's transmission lines and power transformers are more than twenty five years old, while the average age of a power plant is 30 years old. Almost three quarters of the coal-fired capacity is over 30 years old and 60% of circuit breakers are 30 years plus (American Society of Civil Engineers 2013: 18–19). Older transmission lines dissipate more energy than more modern ones. The grid also lacks automated sensors which could warn operators of mechanical failure (Executive Office of the President 2013: 7). The American Society of Civil Engineers' (2009: 134) *Report Card for America's Infrastructure* noted several alarming facts: demand for electricity has increased 25% since 1990 but construction of transmission facilities generally fell across three decades. It estimated that as much as 1,500,000,000,000 USD (EUR 1,100,000,000,000) will need to be invested in electric utilities by 2030 to meet demand (see also Nye 2010: 208). A study by Greenpeace International and the European Renewable Energy Council showed that a great number of power plants in the US, Europe and Japan are also nearing the

end of their days. Over half are two decades old or more. The same holds for the majority of the planet's nuclear reactors, many of which are now being pushed to double their intended life expectancy (Teske 2010: 36, 33). Power grids are consequently operating at close to capacity – S. M. Amin (2011) said that American 'grid operators should be praised for keeping the lights on' – but such conditions stop planned outages for routine maintenance increasing risks of blackouts. Other studies note a fairly obvious point: that complex systems running at a critical point are liable to cascading failure (Dobson et al., 2007).

Guaranteed electrical power is also under threat because of resource constraint: fossil fuel depletion and the transient nature of renewable energy sources. Peak oil and climate change are also causing an increase in the demand for electricity. The global preparations towards the widespread use of electric vehicles combined with the rapid spread of air-conditioning will create greater dependence on forms of energy with undependable supplies. In consequence blackouts will become more frequent. This means that serious questions will have to be asked at both the individual and collective level concerning what is wanted and what is needed, balancing what is good for individuals with what is good for others and ultimately what is good for the environment.

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wpłynęło/received 21.11.2013; poprawiono/revised 8.01.2014.