Security via Decentralized Energy

Energy Security, Climate Change & Decentralized Energy

WADE

WORLD ALLIANCE FOR DECENTRALIZED ENERGY

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About WADE

The World Alliance for Decentralized Energy (WADE) was established in 1997, as a non-profit organization, to accelerate the worldwide development of high efficiency decentralized energy systems that deliver substantial economic and environmental benefits. WADE represents the interests of those involved in the entire value chain of combined heat and power (CHP) and renewable decentralized energy (DE) systems.

WADE believes that the wider use of DE is a key solution to bringing about the cost-effective modernization and development of the world's electricity systems. WADE's goal is to increase the overall proportion of DE in the world's electricity generating mix. To work towards its goal WADE undertakes a growing range of research and programs on behalf of its supporters and members:

- Cutting-edge research and analysis on energy and the environment;
- Global advocacy of policies and programs designed to level the playing field for DE;
- Organization of events and activities designed to promote and advance the market for DE technology and showcase member product offerings;
- Communications and public relations that delivers the DE message to policy-makers and the general public;
- Dissemination of market intelligence and breaking news to keep members informed of the latest developments in the global DE marketplace.

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Prologue

Based on a quick internet search one might be forgiven for thinking that squirrels were the number one threat to a nation's energy security. Typing in "squirrel", along with keywords such as "outage" and "failure", into the search engine generates thousands of news stories with bonechilling headlines such as:

"Squirrel Sets Off Outage - Thousands Affected"
"Blackout Traced to Squirrel"
"Power Failure Triggered By Squirrel"
"Stray Squirrel Shuts Down NASDAQ"

As real as the threat from squirrels to electricity infrastructure is, sadly it is the antiquated design of the current power system that is the real problem, and far more ominous threats will increasingly steal the headlines from our friends the squirrels.

Introduction

The need for energy and stability are two common desires which unite all communities in the world be they financial workers in high-tech businesses of the world's cosmopolitan centers or nomadic tribesman raising livestock in remote steppes. The geopolitical balance in the world is changing as powerful new economic forces are emerging. As the economies of China and India continue their impressive growth, and other major economies surface, competition for scarce energy resources is becoming of increasing strategic relevance. There are new bidders in the energy game and the drive to quench the ever increasing thirst for coal, oil, gas, uranium and electricity is propelling energy prices to new heights. New competition for resources is also leading to heightened political tensions and new strategic alliances as nations jostle to secure supplies and protect energy assets. At the same time the issue of climate change continues to rise on the agendas of governments around the world – a challenge which exacerbates energy insecurity. In short, energy security is becoming of increasing paramount. The two pillars of energy security (ensuring reliable fuel supplies and protecting energy infrastructure) are of increasing political currency.

In terms of ensuring timely fuel availability, supply networks, however important, are only one side of the energy security equation. Increasing supply of energy and reducing the need for energy per unit output (productivity, comfort, distance traveled etc) are two means to the same end. Smart nations are making the other side of the coin a strategic priority: approaches to reduce the demand for energy- primarily by using each unit of energy more efficiently. On average, a phenomenal two thirds of each unit of fuel burned to make electricity is wasted- the majority of each unit of fuel is vented up smoke stacks as waste heat. Once the power has been generated an additional 5-10% of the energy is lost in the form of 'line losses' as it is delivered to end users. So potential for reducing need for new supplies via improved energy conservation and efficiency is great. Decentralized energy (DE) is one important part of the demand-side equation and is the focus of this paper. DE is defined as: "electricity production at or near the point of use, irrespective of size, technology or fuel used - both off-grid and on-grid." It can include, on-site renewable energy, high efficiency cogeneration or combined heat and power (CHP) and industrial energy recycling and on-site power. Because DE installations are more numerous than conventional generators and, by definition, are located close to where the energy is required energy infrastructure is also much less vulnerable to natural threats and sabotage. DE increases efficiency thus relieving supply shortages and creates a more robust grid thereby reducing infrastructure vulnerability.

All nations have something to gain from DE. The solar panels on Mongolian yurts, the cell phone chargers in remote Kenyan villages, the fuel cells supplying secure power to research labs in the silicon valley and the massive heat recovery steam generators in Indian steel mills all fall under the banner of DE. DE is a cheaper path to global security and peace than efforts to guarantee larger and larger strategic reserves and build expensive, redundant, wasteful central power stations. The efficiency benefits obtainable via increased investment in DE will pay much higher dividends than equal investment in trying to increase supply through conventional means.

Increasing Relevance of Security

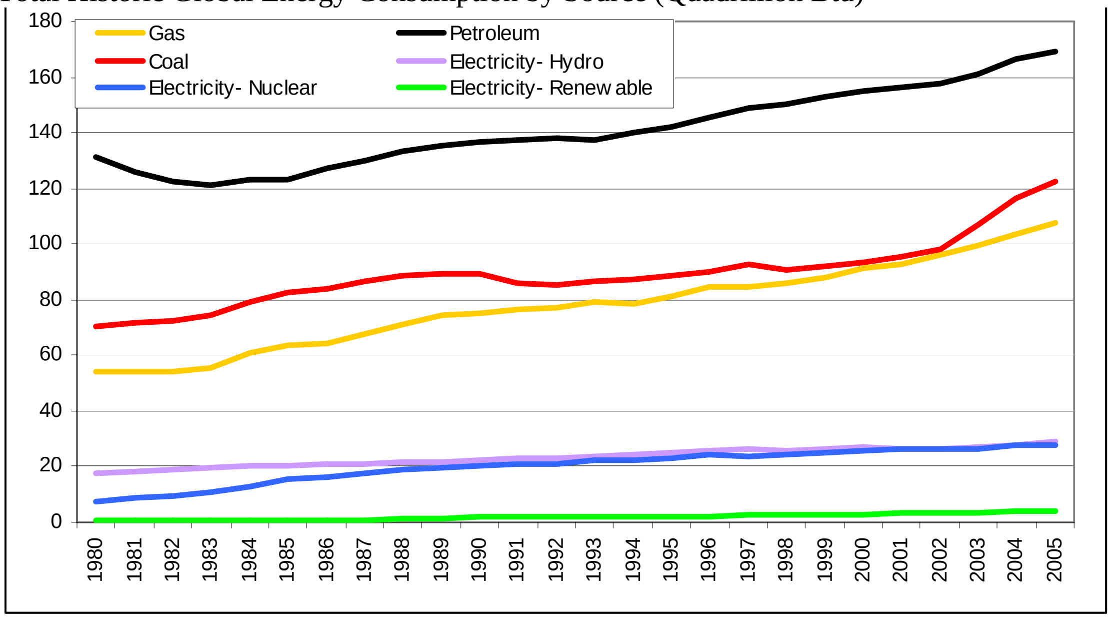
Energy Basis for Economic Activity

Energy is the basis for all economic activity, be it traditional fuels for cooking in palm huts, or the '5-nine' electricity reliability demanded by state of the art computer chip manufacturing facilities. There are many examples of power interruptions resulting in lost onomic productivity. It was estimated that as a result of rolling blackouts in California in 2001, the state suffered $21.8 billion in lost productivity, reduced household income of $4.5 billion and 135,000 lost jobs.[1] According to the Final Report of the Joint Power System Outage Task Force Report[2] the 2003 blackout in Northeast North America resulted in between 4 and 10 $US billion in the United States alone. In Canada, gross domestic product dropped 0.7% that month as a result of the blackout, there was a net loss of 18.9 million work hours, shipments of manufactured goods in Ontario were down $CAN 2.3 billion. When Russia shut off natural gas supplies to the Ukraine in 2006 many manufacturing facilities were forced to shift from gas to domestic coal in order to maintain production levels.[3] Although no official estimate exists as to lost productivity resultant in the Ukraine, or the Western European countries affected by the shortage, the interruption highlighted the danger of wasting more than half of each unit of gas imported from Russia that is consumed by centralized electricity plants without heat recovery. Each year in India rolling blackouts result in massive economic losses to private entrepreneurs and force businesses of all sizes to buy private generators to sustain business. The practice is so prevalent that the Indian Sub-continent has coined its own term for the practice. There it is referred to as "captive power". Power shortages are similarly prevalent in China costing Chinese industry millions of hours of lost productivity every year and jeopardizing international competitiveness in many cases. Developing nations from Afghanistan to Zambia consistently cite power shortages as a major impediment to economic and social development. In short, reliable energy is required, around the world in order to build and maintain economic activity and social stability. The need for reliable power is particularly acute in nations relying heavily on secondary industry (manufacturing) and tertiary industry including banking, retail, healthcare, education, media and other sectors that rely heavily on computing and communications. There is therefore a high correlation between energy use and economic prosperity as measured in GDP. The correlation is imperfect however – the energy intensity of the Canada in 2004 was comparable to that of Jamaica. Japan (typically seen as a leader in the field) was comparable to Nigeria. This means that per unit energy Nigeria is far more productive than Canada even though the United Nations gives Canada and Japan a higher "development" score. Despite this seeming contradiction in statistics one thing remains true: as a county's economy shifts to secondary and tertiary industries away from sustenance agriculture, the need for reliable energy, regardless of how efficiently that energy is used, increases.

Trends of Increasing Fuel and Electricity Use

Despite enormous gains in some countries around the world in terms of energy conservation (some, such as Denmark or Japan, have made huge gains in terms of reducing energy used to produce a unit of GDP) increasing energy use is the norm both nationally and from a global perspective. Figure 1 shows the increasing demand for energy resources around the world to meet industrial, commercial residential and transportation needs, or perceived needs.

Figure 1
Total Historic Global Energy Consumption by Source (Quadrillion Btu)

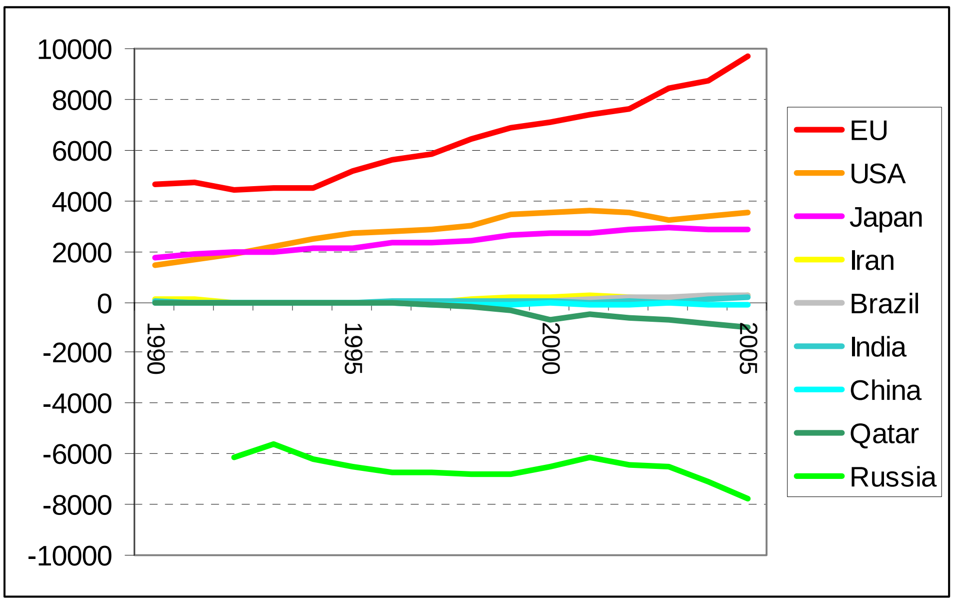


Source:WADE based on the US Energy Information Administration, International Energy Annual 2005

Increased Import Dependence Around the World

Because demand for energy is steadily increasing as conventional energy supplies dwindle it is only natural that renewed competition for scarce resources emerges. Record high energy prices attest to new competition. Figure 2 below illustrates that global economic power may be shifting from traditional centers. Even as total demand for gas grows around the world an increasing number of nations are relying more and more heavily on gas imports to meet demands- including Iran, the nation with the third largest gas reserves in the world. China on the other hand, although soon to be the world's largest economy, is still a net exporter of both gas and coal. One trend is certain: increased competition for scarce resources, especially from emerging economies. As the chief economist for CIBC World Markets investment banking firm, recently put it "domestic demand growth of as much as 5 percent per year in key oil producing countries is already beginning to cannibalize exports and will increasingly do so in the future as production plateaus or declines in many of these countries".[4]

Figure 2
Net Annual Natural Gas Import Dependence for Select Nations Over Time
(billion cubic feet)



Source: WADE 2007

Climate Change and Energy Security

The topic of climate and climate change deserves a special place in any discussion involving energy and energy security. The most recent report of the Intergovernmental Panel on Climate Change has demonstrated global scientific consensus that the world's energy consumption patterns are unsustainable and are contributing to the destabilization of the world's climate.[5]

At the same time however, the changing global climate is causing changes in energy production and consumption patterns around the world. Climate change is thus simultaneously a cause of energy insecurity and a result of the unsustainable use of energy that is the root of insecurity. As the US envoy to the UN recently put it: "Climate change presents a chicken and the egg paradox in the context of energy security. Climate change seriously exacerbates energy security woes and wasteful energy use in turn exacerbates climate change".[6]

Climate Change Insecurity- Roots in Unsustainable Energy

Electricity production is the single most important contributor to greenhouse gas emissions and is therefore a leading cause of climate change. The inefficient combustion of oil, gas, and especially coal, to generate electricity is therefore complicit for the destabilizing of the climate. There is no shortage of evidence that climate change results in widespread insecurity. Climate change has been linked to increased temperatures causing droughts, famines, insect infestations, the witness of new diseases, surges in existing maladies, and fires; floods and widespread human displacements; violent storms resulting great human suffering; unseasonable blizzards and cold temperatures and almost every other type of weather imaginable. The inefficient generation of electricity in centralized plants is therefore a major cause of climate change and the resulting conflict and insecurity that is resultant from it.

Climate Change- Exacerbating Insecurity

Just as energy use results in climate change, climate change perpetuates energy insecurity. A growing number of actors are recognizing the intimate interrelationship between climate change and security. A 2007 report released by the German Advisory Council on Global Change concluded that climate change is a major threat to international security.[7] If the international community cannot come together to tackle the problem of climate change, the report states, "climate change will draw ever-deeper lines of division and conflict in international relations, triggering numerous conflicts between and within countries over the distribution of resources, especially water and land, over the management of migration, or over compensation payments between the countries mainly responsible for climate change and those countries most affected by its destructive effects." The Federal Police Commissioner of Australia said in September 2007: "climate change is going to be the security issue of the 21st century." Also, in 2007 a diverse group of retired senior admirals and generals in the United States highlighted the threat to US national security arising from climate change.[8] Climate change threatens both the reliable supply of energy and the critical infrastructure needed to deliver and use the energy.

Reliable energy supplies are at risk from a variety of natural causes however the most obvious is weather. In fact, by far the most common cause of energy interruptions and power outages are weather incidents. Around the world minor power interruptions related to storms and routine weather are a daily event. Winds knocking trees or branches in to power lines, rains eroding the foundation from under power lines, freezing rain and snow weighing down power lines and heat waves causing cables to overheat- thereby increasing power losses- are some examples of phenomena that cause sporadic and unreliable energy availability. However these routine interruptions are so common that they rarely even make the headlines outside of the affected area. Occasionally a weather related incident causes much wider spread interruptions either causing major supply shortages or damaging critical infrastructure.

The centralized power system on which we have grown dependent is especially vulnerable to interruptions from extreme weather.

In the summer of 2005 a heat wave in France caused several major nuclear generating plants to be forced offline due to chronic water shortages. The unusual heat resulted in insufficient cooling water being available to safely operate the plants.[9] In various countries around the world unseasonably low precipitation has resulted in major power shortages. Hydro reservoirs were not sufficiently filled as a result of the droughts and this translated into either brownouts or need to import expensive fossil generated electricity form neighboring jurisdictions. The consensus in the scientific community is that these types of climate related interruptions of the energy economy are likely to increase - both in frequency and in severity. As the average world temperature increases as a result of climate change it is also likely that demand for electricity will concurrently be inflated. Higher temperatures will drive demand for air conditioning and cause increased demand for power even as supplies are tightened.

Climate change can also, of course, result in catastrophic damage to energy infrastructure. In 1999 freezing rain caused power interruptions for weeks in Eastern Canada and great discomfort was caused as temperatures plunged. Grid infrastructure simply collapsed under the weight of the ice. The 2003 blackout in the United States, caused by a branch falling on a wire thousands of kilometers away, resulted, among other things, in 145 million gallons of raw sewage being released from a Manhattan pumping station into the East River.[10] Hurricane Katrina knocked a third of US refining capacity which resulted in domestic US fuel reserves being drawn upon and corresponding upward motion for energy prices around the world. Although none of the above examples can be tied indisputably to climate change, because climate change will lead to more and more such events the above examples nevertheless illustrate how a changing climate will impact energy infrastructure.

Two Types of Vulnerability

Energy security can be framed in the context of either guaranteeing supplies of fuels or protecting critical energy infrastructure such as generating stations, transmission lines and distribution networks. The current international energy economy, based largely on the centralized electricity paradigm, is particularly vulnerable to both fuel supply disruptions and infrastructure failure from natural and human threats.

Supply Vulnerability

All major power sector technologies and fuels are subject to vulnerability of fuel supply interruptions, especially when fuels must be imported. Supply interruptions can be as a result scarcity due to high demand, temporal interruptions, economic sanctions from main fuel importing countries or simply being outbid by a competitor for the resource. Both threats and international responses to interruptions of fuel supply tend to be transnational in scope. Examples of conflicts involving supply interruptions are numerous.

Labour Disagreements

Domestic or inter-national labour strikes are one example of how the power sector is susceptible to energy price volatility. Although a major two-day walkout in the Nigerian oil sector in 2005 did not noticeably disrupt international oil prices the action did highlight vulnerabilities to non-violent direct action in the energy sector. Major labour strikes in the Venezuelan oil industry in 2002, on the other hand, did cause ripples around the world pushing oil prices to new heights as international oil reserves tightened.[11] In the UK, electricity production was affected during major coal miners strikes in 1984-85. Major coal strikes have also been carried out more recently in India in 2001 and in South Africa in 2007 where 'a drawn-out strike could have put further pressure on the country's frail electricity network'.[12]

Political and Economic Motivated Supply Interruptions

Natural gas, due to its relatively low emissions and the flexibility it offers operators, represents the fastest growing fossil portion of the power sector. In order for gas to reach end users it must either be shipped or piped- both of which pose unique security challenges. In its 2007 Natural Gas Market Review the IEA Concluded that "Gas Security is Deteriorating" even as gas continues to grow in popularity as a power generation fuel. In October 2007 the Chilean Chamber of Deputies approved a law to promote renewable energy citing uncertainty of continued imports of natural gas as a concern: "this is an efficient way of diversifying our energy matrix and it will help to substitute the absence of the Argentinean natural gas". Argentina, Chile's main supplier of gas, is using a higher proportion of gas to meet domestic needs which has caused Chile to re-evaluate the security of its energy supply. A similar example in early 2006 garnered much international attention. Russia's move to interrupt gas supply to the Ukraine as a result of an unresolved price dispute highlighted Western Europe's dependence on imported gas. Because the EU is expected to be increasingly dependent on foreign gas (Eurogas expects that the EU will import up to 75 percent of its natural gas requirements by 2020[13]) it will remain highly dependent on Russia, the number one gas exporter in the world (see figure 2). Currently Russia supplies more than 40% of the EU's gas.[14] Although in both these cases disruptions were not as serious as they could have been, they nevertheless underscore the vulnerabilities resultant from supply disruptions. Perhaps the best example in modern history of a nation suffering from being cut off from energy supplies is the case of Cuba in the early 1990s. With the collapse of the Soviet Union Cuba lost its access to heavily subsidized petroleum overnight and the island plummeted immediately into a major recession. The resultant "special period", as it became known, witnessed heavily weakened transportation networks, widespread electricity shortages and rationing of food and other basic commodities. The power sector gaming that transpired during the 2001 California blackouts is another example of how energy supply is vulnerable to manipulation and circumstance.

Malicious Interruptions

As expanded upon in the next section, deliberate targeting of weak links in supply chains is another danger to ensuring a continued supply of energy resources. Energy infrastructure such as pipelines, for example, because of their vulnerability, is a preferred target of terrorists and saboteurs. Examples of gas and oil pipelines being targeted will ruinous results are easy to come by, with recent incidents in areas as disparate as Canada[15], Ecuador[16] Georgia.[17, 18] [17]Mexico[19,20,21] and the Ukraine[22]. Disrupting pipelines, however, is not the only means for those with ill intentions to cause supply interruptions. Shipping lanes, for example, as illustrated by recent surges in international piracy, make energy commodities dependent on marine transport, such as LNG equally as vulnerable.

Increasing Competition and International Geopolitics

Energy supply disruptions are arguably the single biggest issue in global geopolitics and various consortiums of nations have been formed over the years to influence energy supplies both at home and abroad. OPEC is perhaps the most famous example- a group which formed in 1960 "in order to secure fair and stable prices for petroleum producers and an efficient, economic and regular supply of petroleum to consuming nations". OPEC, no doubt carries significant international influence on energy supplies around the world. The International Energy Agency (IEA), established in 1973, in turn "acts as energy policy advisor to 26 member countries in their effort to ensure reliable... energy for their citizens". New emerging consortiums emphasize the growing importance of energy supply security on the global stage. The founding of the Shanghai Cooperation Organization in 1996 illustrates the increasing global nature of energy security. The six member countries (China, Russia, Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan) have been cooperating since 2001 to improve regional security and access to energy. In August 2007 the group signed a treaty agreeing to a "unified energy market" stressing that energy is "the basis for continued economic growth and security". Other similar groups around the world also have strong mandate to guarantee energy supply for their members including the Association of Southeast Asian Nations, in Asia, Petrocaribe, in Latin America, etc.

Critical Infrastructure Vulnerability

Very closely related to vulnerability of supply, is vulnerability of physical infrastructure, the more tangible pillar of energy security. Infrastructure failure can be as a result of deliberate interruptions such as sabotage or terrorism, misuse of infrastructure, natural decay result from outdated equipment, natural disasters, evolving climate and day to day weather.

Natural Threats

A multitude of natural phenomenon threaten infrastructure. Extreme weather events as described in the above section are the most common stresses but there are also others. Landslides, natural erosion and decay and earthquakes are some examples. One illustration was an earthquake in 2003 in California that knocked out a 1000MW gas-fired plant, resulting in major blackouts.[23] Of significance was that the local gas distribution infrastructure was unaffected. An example relevant to many, if not most, countries is aging electricity infrastructure including natural decay of both generation and grid. Aging infrastructure is not only often technologically obsolete but is also more susceptible to interruptions than newer investments.

Military Targets

A centralized power system, with major plants in prominent locations, and key infrastructure easily catalogued on a piece of paper make a much more convenient military target than a highly decentralized network of generators. It is no coincidence that the Iraqi electricity infrastructure was one of the first targets in Allied Forces military attacks during the Persian Gulf War in 1990-91. The third and largest phase the Allied air campaign targeted facilities useful for both the military and civilians including electricity production facilities.[24] As a result of allied bombing the end of the Persian Gulf War, electricity production was estimated to be at four percent of its pre-war levels. Nor is it a coincidence that power infrastructure remains a key target of Iraqi guerrillas today even as attempts are made to rebuild the Iraqi power sector. Hundreds of incidences of sabotage targeting electricity infrastructure have been documented since efforts to rebuild the power infrastructure have got underway.[25] Army

Col. Michael Moon, director of electrical sector development for the U.S. Army Corps of Engineers' Gulf Region Division, in a 2007 interview stated "It's so easy to disrupt the electrical system. It's so easy to pull down a tower and … cause a blackout across the country".[26]

Sabotage

Electricity infrastructure is increasingly becoming a preferred targets of insurgents, rebels and guerrilla fighters around the world. In 2007 it was reported that over 1.5 billion Rupees ($ 24.8) worth of damages were experienced to electricity infrastructure in South-west Pakistan alone- largely as result of pro-Taliban guerillas. Headlines such as "Karachi bomb blast damages electricity pylon"[27] are not uncommon. Meanwhile a spree of attacks on Mexican energy infrastructure, including powerlines, by guerillas has put the economic well being of some states in jeopardy, forcing major industries to close.[20]

In a sign that sabotage of electrical infrastructure is becoming more of a concern, the Chinese government, in August 2007, announced that any individuals convicted of damaging the electrical infrastructure "causing direct economic losses over $131,500" are subject to the death penalty.[28] The following month the Nigerian President announced that the government would "deal much more severely[29]" with individuals found guilty of sabotaging electrical infrastructure. "No matter how hard we try to fix the energy problem, particularly power, if sabotage persists, we will not solve the power problem and our economy will never develop" announced the Nigerian Minister of State for Power. Remote electricity plants and their corresponding grid provide a easy target and disrupting power infrastructure can also be a means of displacing other energy trade. For example power shortages in Iraq have resulted in reduced oil production.[30]

Emerging Threats

There is a growing range of weapons that are designed specifically to immobilize electricity infrastructure. The 'Graphite bomb' for example, also known as a 'blackout bomb', showers an area in fine carbon filaments which interfere with electrical components. A version of the graphite bomb was used by NATO forces against Serbia in May 1999, disabling 70% of that country's power grid.[31]

E-bombs, a related weapon, are similarly designed to target electrical infrastructure. High power microwaves bombs (HPM e-bombs), flux compression generator bombs (FCGs), and nuclear E-bombs are some of the weapons in the arsenal aimed at incapacitating electrical infrastructure and electronics. The weapons are attractive partly because they can seriously damage someone's ability to fight without any direct harm to living things, however a serious e-bomb attack could very dangerous indeed- imperiling critical services such as medical servies, communications, water and sanitation, etc.

Another emerging threat, less obvious, but ominous nevertheless, is the silent, looming threat of cyber attacks. In April 2007, Russian hackers shut down overnight the economy of neighboring Estonia.[32] Using a technique known as a "distributed denial of service attack (DDoS)" the perpetrators overwhelmed Estonian servers en mass using armies of "zombie computers" from countries around the world including those as diverse as Egypt, Vietnam and Peru. The attacks rocked the nation, shutting down the major newspaper, shutting down electronic banking and automatic tellers as well as the internet. Although the power system was not targeted in this attack, it shows how a coordinated attack, in this case allegedly the work of volunteer pranksters, can have very real affect. The centralized power system is extremely vulnerable to cyber attacks. In a recent experiment designed to test the vulnerability of power systems to attack in the United States, the US Department of Energy's Idaho National Laboratory showed it was possible to successfully hack into the control system of a major power plant and shut down operations.[33] In 2006 a US security expert successfully hacked into a nuclear power plant control room, which controlled cooling of reactor core.[34] The implications are obvious. These tests shows the real potential for economies, and people, to be affected by cyber attacks. Indeed, according to a 2002 US Government Accountability Office report, 70% of energy and power companies had experienced some kind of severe cyber attack[35] and the frequency and sophistication of attacks is growing by all accounts. In response the National Electric Reliability Corp. (NERC) has put forward a number of new cybersecurity requirements that it is recommending be adopted by large scale power plants, standards that were attacked as inadequate by cyber experts. Various national administrations around the world have been publicly suspected of state-sponsored attacks on foreign critical security systems, for example, Germany, the United States and India have all identified China as a possible source of attacks, even though China has denied the allegations.[36,37]

The Costs

The human costs of failing energy systems are often immeasurable. Some estimates of economic costs resultant past or foreseen tragedies can provide an indication of the scale of impact electricity disruptions can have. For example Iraqi Finance Minister, Bayan Jabor, said in an August 2007 interview: “The country is devastated and we are in need of at least $100bn to $150bn to restore infrastructure - from sewerage to water to electricity to bridges and basic needs of the country”. One study looking at the possible economic implications of a terrorist attack in the US found that terrorists shutting down the LA port, the 5th busiest in the world, would result in $20 billion in costs in the first month alone. Another study found that an extended blackout in the LA region would similarly result in $20.5 billion of lost business but with proper planning and resilience the potential reduction could be reduced by over 85%. “Onsite electricity generation” is explicitly identified as one important measure for reducing vulnerability.

The Solution?

Strong arguments exist that suggest a system based on decentralized energy is much more resilient to dangers in any of the above forms. Headlines like “Standoff with Taliban leaves big Afghan dam project in limbo[38]” may be increasingly common but it is unlikely that we will be reading anytime soon “Al Qaeda Suspected in Bombing of Roof-top Solar Panel” or “Terrorists Target Small Power Plant in Supermarket Basement”. The next section outlines some of the reasons why decentralized energy can be used around the world as a means of protecting people from natural and malicious threats.

The Decentralized Energy Paradigm

In his state of the union address in January 2006 United States President now famously stated: "America is addicted to oil, which is often imported from unstable parts of the world. The best way to break this addiction is through technology".[39] America is not the only country addicted to fossil fuel energy. The list of nations knowingly and unknowingly being crippled with the dependency is on the rise. Although not referred to explicitly by the president, decentralized energy is one of the most practical and politically feasible "technologies" to reduce the destructive habit of energy waste in countries around the world.

Decentralized energy is neither a new nor an unfamiliar concept. The very first commercial electricity plant in the world, installed in 1882 in New York City at Pearl Street Station, was a combined heat and power plant. In different parts of the world and in different circles DE in known by names as diverse as distributed generation, on-site power, embedded generation, captive power, backup generation, uninterruptible power, cogeneration, district energy, etc. Although some may debate about the similarities between the various terms what they all share in common is that they are generating electricity where it is needed.

DE Benefits

The benefits of decentralized energy are numerous and are attracting more and more adherents every day. If venture capitalists are any indication we are in the process of witnessing a flood of interest in the clean tech sector- which includes clean DE.[40,41] Recent WADE research corroborates this suggestion- based on WADE research approximately 36% of electricity generated from generation capacity added in 2006 can be attributed to DE capacity.[42] Why the popularity? DE offers; substantial economic savings via reduced capital requirements, increased fuel efficiency, significantly reduced pollution including fewer climate destabilizing green house gases, and health debilitating criteria air contaminants, a smaller land use footprint, heightened power reliability, free grid services such as voltage support and operating reserves and is often the most affordable option for bringing power to communities without modern grid. Of most relevance to this discussion however is that DE can increase the energy security outlook of the regions in which it is employed both in terms of reduced infrastructure vulnerability and reduced fuel import dependence.

Reduced Supply Vulnerability

The Case of Azerbaijan

The case of Azerbaijan illustrates how a more decentralized approach can make for a grid infrastructure more resilient to both natural and human threats while simultaneously reducing dependency on fuel imports. The nation, bordering Russia to the North and Iran to the South, lies in a relatively politically volatile region of the world. Although neighboring Georgia has a smaller population and relies more heavily on hydro for its power needs, comparing the two nations provides an interesting contrast. Table 1 shows that the two nations have much in common. Georgia has to date continued on its historic path of providing thermal electricity based on a centralized model. Whereas Georgia has chosen to invest in upgrading its existing thermal power plants, thanks to financing from the World Bank and the EBRD[43], build new CCGT plants and mew high voltage transmission lines[44], Azerbaijan has chosen instead a more decentralized development model.

Table 1.
Basic Statistics of Georgia and Azerbaijan

	Georgia	Azerbaijan
Population (million people)	4.5	8.5
Area (km2)	69,700	86,600
$ PPP/capita	$3,800	$6,171
Electricity production	6.8 billion kWh (2004)	20.4 billion kWh (2004)
Electricity consumption	8.5 billion kWh (2004)	20.6 billion kWh (2004)
Natural gas - production:	20 million cu m (2004 est.)	5.0 billion cu m (2004 est.)
Natural gas - consumption:	1.5 billion cu m (2005 est.)	9.9 billion cu m (2004 est.)
	333 m3 per person	1170 m3 per person
Gas Imports	1.5 billion cu m (2005 est.)	4.9 billion cu m (2004 est.)
Gas Imports per capita m3/person/year	333	580

Source: WADE compilation based on CIA World Factbook

To meet its thermal generation capacity Georgia must rely on gas imports but because, its main plant, the Gardabani plant, does not recover heat, 40-60% of each unit of imported gas is lost in the form of waste heat and an additional 16% of the electrical energy is lost in the form of line losses.[45] Because the plant is some distance from Tblisi recovering heat is impractical and increased losses are unavoidable. In the event of a plant shut down (be it as a result of scheduled or unscheduled maintenance or sabotage) Georgia is fortunate enough to have Hydro backup but the difference in generation must either be met entirely from expensive imports or the nation is forced to rely on rolling blackouts. In January 2006 a series of terrorist attacks on Georgian energy infrastructure, including gas pipelines and electrical grid infrastructure, incapacitated the Georgian economy and left almost the entire population of 4.5 million without out heat at the same time the nation was experiencing the coldest weather in 20 years.[18]

The path that Azerbaijan has chosen is not only more amenable to waste heat recovery (which nearly doubles fuel use efficiency and reduces import dependency) but is also much less vulnerable to attack. In 2005, due to increasing need for power as a result of continued economic growth in Azerbaijan, a means was needed to ease tight supplies. Upon examining the various options available to meet the anticipated demand the Azerbaijani administration decided that a decentralized energy infrastructure was better able to meet requirements that the conventional approach of building a large centralized power plant. It was therefore decided that 5 smaller plants would be built in strategic locations of high energy demand.[46] Each plant was to be composed of 10 identical 9MW gas engines making for a total addition of 5 x 10 x 9 or 450MW. Because the plants were sited where the power was needed no additional transmission capacity was required and also, because power did not have to be moved large distances across the grid 16% less generation capacity could be built in order to meet the same demand (ie additional power did not have to be generated to make up for grid losses).

In Februray 2006, just 10 months after the original order was placed, the first of the five plants was up and running. Now all five of the plants are in operation, producing reliable electricity where it is needed.[47] Furthermore in three of the locations waste heat is being captured in the wintertime in order to heat greenhouses in order to produce value-added crops for export (a technique pioneered in the Netherlands). Using the power plants in such cogeneration applications greatly improves the fuel efficiency reducing the need for additional fuel imports. Currently the Azerbaijan engineers are looking at ways to further use waste heat at the remaining plants. The project has been so successful that a sixth and seventh plant of have been commissioned which plan to make further use of waste heat using absorption chillers for cooling in the summer time and heating of greenhouses in the winter.[48]

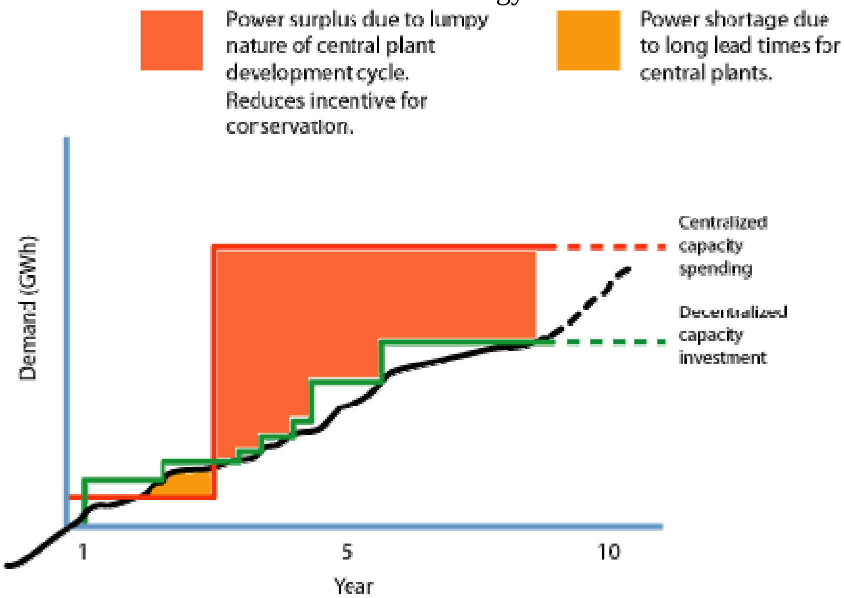
The decentralized model being employed in Azerbaijan has a multiplicity of security benefits. Data is not yet available on total fuel savings resultant from the approach but using the conservative estimate that fuel efficiency has been improved by 25% would translate into 25% less gas that would have to imported for power generation, decreasing significantly the bargaining power of nations on which Azerbaijan relies for gas (i.e Russia). Reduced imports also translated into significant economic savings and allowed scarce budgetary resources to be allocated elsewhere. Capital cost savings were also realized via the elimination of both the need to build extra capacity to meet peak demand and additional new grid capacity to move power to end users.

In addition, the vulnerability of Azerbaijan's power system to deliberate attack or natural disaster has been reduced considerably. In order for Azerbaijan to lose even 50MW all ten engines at one of the plants would have to fail at once. In order for a larger act of sabotage to be effective terrorists would have to coordinate 5 simultaneous attacks and each attack would have to be successful – perhaps not impossible but considerably more challenging than targeting a single, larger, plant. Robustness of the system is similarly improved from a perspective of natural disasters, water shortages (which make cooling difficult), etc.

A Modular Approach

One of the main drawbacks of centralized power plants is the fact that there is such a lag between when the perceived need for a plant is identified and when the plant is finally up and running and delivering actual power. In many cases the planning, design, construction and commissioning of a large coal, nuclear or hydro plant can span decades. In the case of decentralized energy a small plant can be up and running in months or even days. For example when the construction of the Comanche Peaks nuclear plant in Texas was delayed Texas Utilities contracted with several CHP facilities to provide firm capacity in the mean time.[49] Because of the greater flexibility and ease of in siting and constructing DE plants they can more easily match incremental load growth and are therefore a much more secure financial investment. Figure 3 below shows the two-fold benefits of a decentralized energy approach: reduced power shortages and closer match to actual demand. A misplaced bolt found inside the generator at Koeberg nuclear power plant in South Africa December 2005 required the replacement of much of the generator.[50] However, long lead times for repairing the 900MW unit including difficulty finding spare parts, meant the incident resulted in rolling blackouts for much of 2006 until it was repaired in May. As the case of Azerbaijan illustrates a nation can get more power, faster, by investing in DE rather than conventional centralized plants. When contrasted with the problems Iran is having developing civilian nuclear energy, or indeed the groundswell of public opposition to new nuclear build in the UK, you can see that DE is also much more politically palatable option- which makes in more practical.

Figure 3
Two-fold Benefits of Decentralized Energy



Source: WADE

Reduced Critical Infrastructure Vulnerability

Islands of Reliability

The benefit of the decentralized model in terms of resistance to natural disasters can be illustrated by a multitude of case studies. Most of New York City's 58 hospitals experienced backup power failures during the Northeast blackout of 2003- leading to obvious undesirable results.[51] There are numerous examples that suggest decentralized energy was the one shining light during the blackout however. At the South Oaks Hospital, for example, the staff were not even aware of the blackout plaguing their neighbors until a phone call from the local police.[52] The perfect transfer to CHP system allowed the hospital to be fully operational throughout the duration of the outage. Similar stories are common wherever disaster strikes. Shortly after the Northeast blackout Italy witnessed a blackout which plunged almost the entire nation, more than 56 million people, into darkness. Yet again however the lights of at least one hospital, equipped with a CHP plant, emerged a glowing example of how decentralized energy ensures reliability.[53] The Padua City Hospital ("*Azienda Ospedaliera di Padova*"), equipped with a modern onsite power system, handled the blackout without difficulties, exhibiting a seamless transition from grid power to fully autonomous operation.

Hurricane Katrina, in August 2005, knocked out power to millions of people in and around the Gulf of Mexico. Jackson Mississippi was one of the many cities affected. Again, a hospital with a cogeneration plant was the sole clear spot radiating in the surrounding gloom.

The Mississippi Baptist Medical Center in Jackson managed to stay operational for the duration of the emergency thanks to its onsite system.

Of course hospitals are not the only structures affected by blackouts, nor are they the only ones that benefit from decentralized energy during times of emergency. It has been documented that over 9.7GW of CHP capacity was operational within the region affected by the blackout in the United States in August 2003. Table 3 shows the diversity of applications that benefited from onsite power during blackout (the data does not included emergency generators that had to be started at the time- only onsite power applications that are running on a day to day basis).

Table2

Sites Identified with CHP within the area Affected by the Blackout by Application

Application	# of Sites	Capacity (MW)	Application	# of Sites	Capacity (MW)
Agriculture	3	71	Machinery	4	9
Air Transportation	2	10	Military	4	389
Amusement/ Rec.	23	103	Misc Manufacturing	6	182
Apartments	51	91	Nursing Homes	35	4
Chemicals	46	1556	Paper	32	1279
Coal Mining	1	33	Petroleum Refining	3	886
Colleges/Univ.	26	346	Primary Metals	11	1555
Commercial Building	9	24	Publishing	3	4
Communications	2	6	Rubber	6	389
Communty Services	4	1	Schools	19	3
Courts/Prisons	2	5	Services NEC	12	7
Crude Oil	2	1	Solid Waste Facilities	10	841
District Energy	3	94	Stone, Clay, Glass	2	31
Electrical Equipment	1	1	Technical Instruments	2	56
Fabricated Metals	5	58	Textile Products	1	1
Food	26	269	Transportation Equip	12	1118
Food Stores	5	1	Unknown	3	3
Furniture	1	1	Utilities	7	85
Government Fac.	1	1	Wastewater Treatment	3	14
Ground Transportation	1	10	Wholesale/Retail	4	12
Hospital/Healthcare	37	185	Wood Products	2	5
Hotels	8	1	Zoos/Museums	2	4
Laundries	4	1			

Source: WADE based on: Assessing the Benefits of On-Site Combined Heat and Power during the August 14, 2003 Blackout. June 2004. Energy and Environmental Analysis, Inc

Some of the success stories documented in the report include a bakery, a pharmaceutical plant and a chemical plant as well as various hospitals, and apartment buildings, one including a major supermarket. All were able to operate for the duration of the event even as their neighbors/competitors were forced to wait for the utilities to get power up and running.

The Swedish city of Malmö, a major commercial centre of southern Sweden, has attained a high level of self-sufficiency through heavy investment in a diverse portfolio of energy generation sited in the heart of the city. Energy technologies applied include solar/PV, wind, geothermal, biomass cogeneration, etc. The energy sources are largely connected and integrated in the buildings, which are in turn connected to the district heating network and therefore benefit the surrounding community ensuring constant supply of heat and electricity. The end result is that the community is largely energy self sufficient and few imports are required to meet local demands. The city has in effect created a cocoon for itself which protects it from energy price volatility and other whims of international energy markets.

Improved Resilience to Climate Risk

There is consensus in the scientific community that climate change is causing more extreme weather that poses danger to vulnerable infrastructures. As illustrated in the above examples DE offers communities a reliable source of energy when faced with climate induced extreme weather. DE is an effective means for communities to adapt to climate change even as DE helps mitigate the climate destabilizing effects of electricity production. The transmission and distribution system tends to be particularly vulnerable to weather and extreme weather. Central generation is wholly dependent on the grid. The collapse of one tower can result in none of a central generators power being accessible. A shift to more DE on the grid reduces the relative importance of any single tower or pole in supplying reliable power because power is being generated on both sides of it. A diverse portfolio comprised of hundreds of generators of various kinds also provides communities a buffer from fuel price volatility and fuel supply interruptions.

Improved Resilience to Emerging Threats

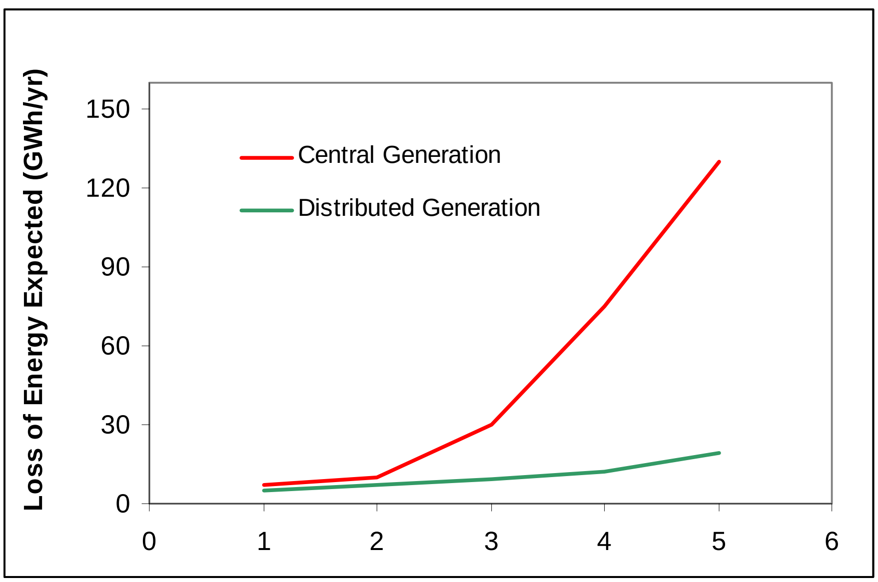
Today the world’s power system faces new threats and we need new solutions to face them. DE is one such solution. In the context of violent conflict the asymmetric nature of today’s clashes demand a new response that conventional defense strategies cannot offer. As conflicts shift from easily identified enemies to the new style of stealthy guerilla tactics traditional defenses aimed at protecting large power plants and other energy infrastructure become moot. Only by adapting the energy system to new realities such as creating a distributed network of intelligent and interconnected yet autonomous generators can resilience in the grid be maintained.

Because graphite bombs and E-bombs tend to have limited ranges a decentralized energy model is far more resilient to such weapons. A single blast from one of the above could shut down a major power plant, in effect cutting power in the order of hundreds or thousands of megawatts capacity- enough to power a small city. In order to cause similar havoc on a system based largely on decentralized model, a coordinated attack on hundreds or thousands of individual plants would be required. A successful attack on only a fraction of the plants would have limited local affects as neighboring plants, using smart meters and communications, could seamlessly make up for the difference. Cyber attacks too would prove comparatively ineffective to a decentralized network. As explained above shutting down a single multi-GW capacity coal, nuclear or hydro plant would affect millions of people. With a system of hundreds of smaller plants supplying the same people hundreds of security systems of varying sophistication would have to be breached in tandem- a far more unlikely, and labour intensive possibility. This is to say nothing of the possible disastrous consequences of a successful attack on a nuclear power plant- risks that need not come into the equation in the case of distributed generation.

The Research Evidence

The security benefits of DE have been documented in various academic and industry studies around the world. Recent work from Carnegie Mellon University in the United States concludes that as stress levels (such as lack of maintenance or incidents of sabotage) in a grid increase, distributed systems prove less vulnerable than centralized ones.[54] The reasons identified include the fact that, using a distributed system the need for reserve margins required in a central configuration can be nearly eliminated without a reduction in delivered energy and the reliability (measured in susceptibility to outages) of distributed systems is generally higher for distributed systems. Cost was another benefit of DE identified in the study. A follow up study following the 11 September attacks, suggested that "systems based more on gas-fired distributed generation plants may be up to five times less sensitive to the effects of systematic attack" than a central power systems.[55] The study used computer models to estimate loss of energy expected from strategic targeting of a distributed model containing 284 smaller gas-fired cogeneration systems totaling 3.5GW versus the standard system used by the IEEE to test reliability (which included 32 units totaling 3.5GW). One of the exercises undertaken showed that, based on known repair times, systems reliant on distributed generation would result in much lower energy losses as repair times were increased (see Figure 4).

Figure 4.
Estimated loss of energy resultant from simulated attack- Comparison of Distributed versus Central Systems



Source: Cogeneration and Onsite Power Production Magazine, Vol 3 Issue 1, Jan-Feb 2002

A study from 2003 looking at infrastructure security in the USA and the UK identified electricity as the second "most critical infrastructure" after only telecommunications.[56] The same study explicitly concluded that an energy system can be made more resilient to attack by "increasing the number of potential target points on which the attacker can expend resources". An earlier US study by the President's Commission on Infrastructure Protection produced similar conclusions.[57] Another study, in 2005, quantified the benefits arising from a DE approach in New England.[58] The study concludes that it is possible to measure very real economic benefits from configuring a grid with multiple smaller CHP installations rather than a single large central plant.

Reduced Costs

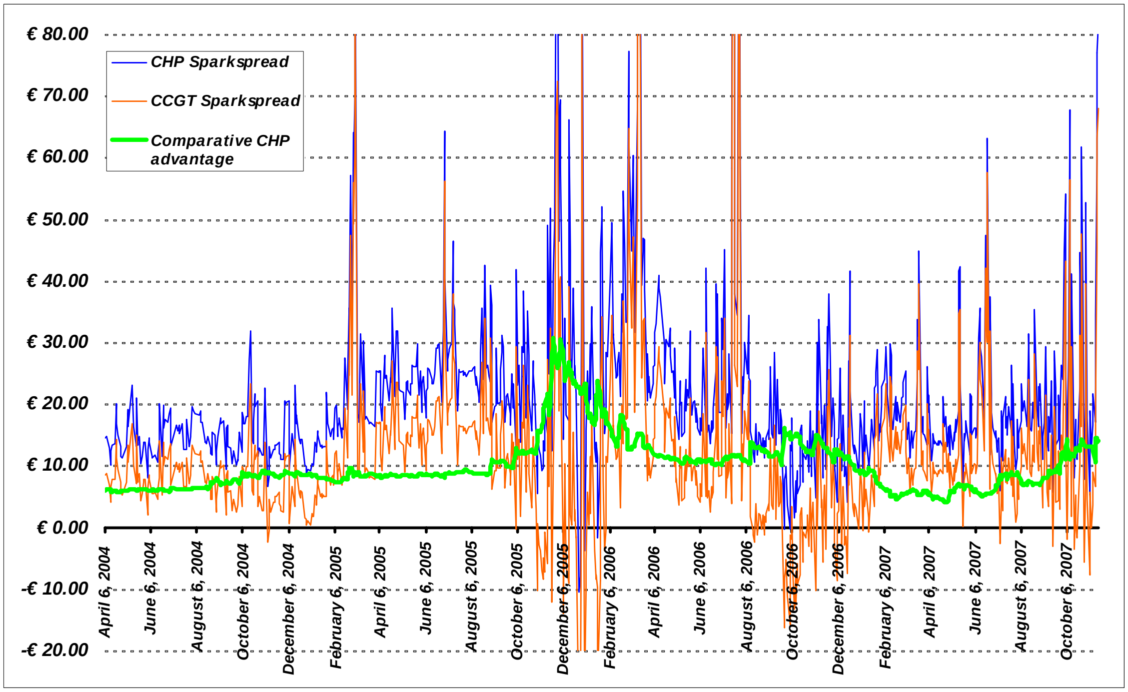
WADE research shows that on top of direct security benefits considerable cost savings arise from a shift to a more decentralized model. WADE demonstrated in a report commissioned in the UK that Britain could save about £UK 1.4 billion of avoided capital costs (~27% lower than the central alternative) and reduced delivered energy cost of 0.38 pence/kWh by using DE to meet demand rather than central plant- largely as a result of reduced need for expensive high voltage transmission.[59] Savings of a similar magnitude were witnessed in fuel use and climate change inducing carbon emissions would be reduced 17% along with a reduction in many other pollutants. A synthesis of similar WADE research from around the world shows that a shift from investment in centralized power generation to decentralized generation typically saves anywhere between 15% and 40% of total delivered energy costs by displacing the need for generation capacity to meet peak electricity demand as well as grid capacity to transport the displaced power.[60] Independent research reinforces these findings. Work by IEA, for example, estimates savings in excess of $125 billion as a result of increased global DE investment between now and 2030.[61]

Of course cost savings are a different issue than security; but, the above research neatly deflects allegations that improving security via decentralized energy need be a costly endeavor. Indeed, the evidence suggests that decentralized energy could create security benefits surpassing that offered by military hardware for a price tag comparable to a fraction of the military budget of many nations. Even compared to the costs of securing existing central infrastructure – not including new build- the costs to build new secure DE plants can seem modest. For example the International Atomic Energy Agency has estimated that "hundreds of millions of dollars would have to be spent around the world to improve construction and operating standards and enhance emergency response procedures" of existing nuclear plants.

Reduced Risk

One major investment criteria in appraising investment opportunities in natural gas –fired generators is spark spread (the ratio between input gas prices and output electricity prices). Research by WADE and others has demonstrated that decentralized generators fired by natural gas have a considerable economic advantage over large scale power only gas plants as spark spreads widen. Figure 4, below, shows the comparative advantage over time of CHP over CCGT in the UK.

Figure 4.
UK Spark Spreads for a 10 MW CHP Plant and a CCGT Power-Only Plant



Source: Delta Energy and Environment

The risk advantages of DE will be further heightened as it becomes more and more common practice to also consider greenhouse gas production in investments. "Clean spread" (for example by calculating the sparkspread and then adjusting for the cost of carbon credits required to meet legal requirements in the jurisdiction in question) will be an increasingly important investment metric. As demand increases around the world for clean technology, market forces will require investors opt for CHP because of the efficiency gains it offers. The public will demand CHP over CCGT as a better understanding of energy issues seeps into the general consciousness.

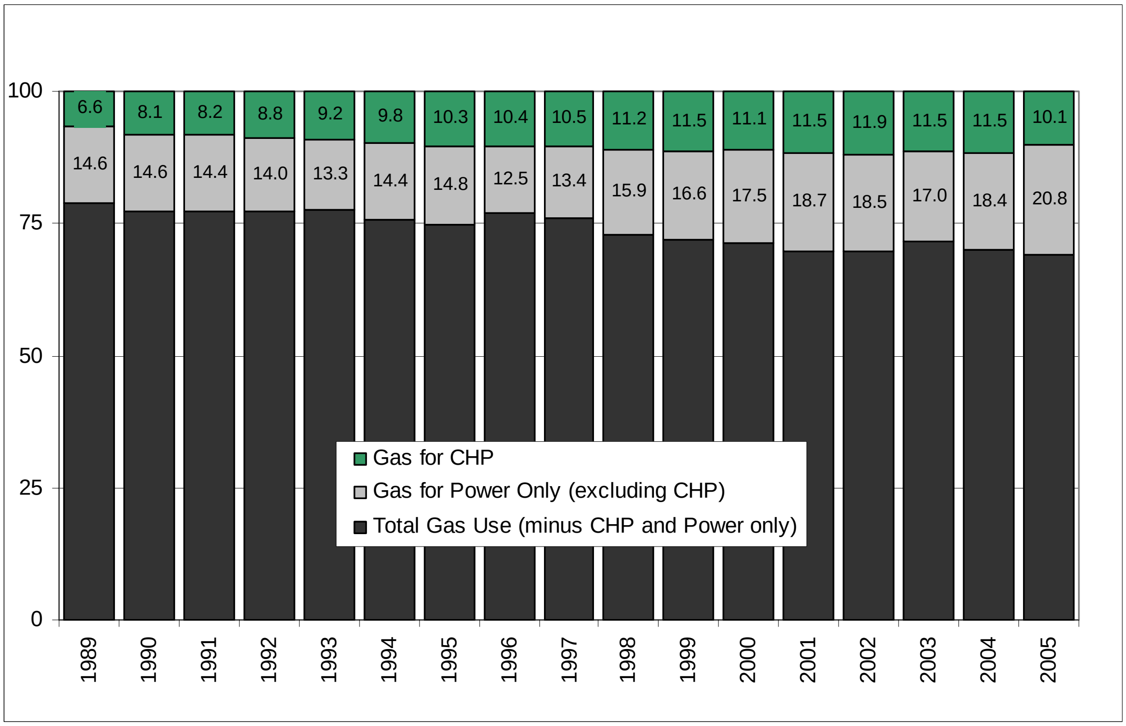
Local gas distribution companies can further reduce risk because most gas-fired onsite power projects flow through their meter, whereas larger gas power-generation projects (such as CCGT plants) flow through the meters of gas wholesalers. This means that by investing in DE gas companies will be able to enter strategic new markets, while improving the security of general gas use.

A Shift is Possible

In the mid eighties Denmark realized the enormous benefits of DE and mandated a large scale and rapid shift to more decentralized energy including combined heat and power plants connected to community energy grids. Now Denmark enjoys the benefits of an energy system more than 50% decentralized energy. Figure 5 shows that the United States almost doubled its CHP capacity between 1989 and 1999 without the kind of explicit policy support witnessed in

Denmark. Unfortunately the proportion has since dwindled. The data shows that given sufficient political will it is possible to quickly shift to a more decentralized energy paradigm.

Figure 5
Percentage of Total US Gas Used for CHP and Power Only Over Time



Source: WADE, 2007, based on data from EIA

Some commentators have argued that infrastructure rebuilding efforts in conflict ridden areas such as Iraq or Lebanon should focus on decentralized energy rather than the typical centralized approach. As one of Iraq's leading power sector experts put it, in reference to efforts to rebuild Iraq's power sector after the US offensive: "Had the bulk of the funds allocated for electricity works been devoted to installing smaller plants dispersed nearer load centers, full load demand could well have been met. The increasingly common power cuts could well have been substantially reduced, if not eliminated, country wide. Furthermore, the effects of sabotage or looting of transmission assets in the wake of the 2003 war would have been considerably lessened".[62]

Conclusions

As conventional energy sources dwindle and demand for energy is increasing around the world, the need for increased energy security is becoming more apparent. Decentralized energy technologies, including fuel cells, microturbines, reciprocating engines large and small, gas turbines large and small, plug-hybrid vehicles, photovoltaics, onsite wind, biogas digesters and a host of other technologies offer enormous security benefits. By reducing a region's vulnerability to energy supply interruptions and threats to critical electricity infrastructure, both natural and human, DE can offer great comfort at a low comparative cost.

DE is a practical way of mitigating risks associated with energy and climate insecurity while simultaneously allowing communities to adapt to energy interruptions from disrupted supply chains and damaged infrastructure alike. As the cultural and natural climate of the earth continue to change in the coming decades DE is the logical means of ensuring safe, secure energy to people from around the world.

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