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The Socio-Economic Value of Radio Spectrum used by Utilities in support of their operations

Report by the Joint Radio Company Ltd

on behalf of the

European Utilities Telecommunications Council

13 January 2012

Release 1.1

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CONTENTS

EXECUTIVE SUMMARY

0.1 When commercial entities are faced with decisions on whether or not invest in assets, their decisions are based purely on an economic assessment of the value of such assets to the entity. Where those assets also have a social value, it is for society, through the proxy of government, to assess any additional societal benefits and attribute a financial value to them.

0.2 Public safety organisations and elements of the critical national infrastructure have traditionally used radio communications to underpin their operations. The allocation of this spectrum has historically been made by governments who have implicitly taken into account the socio-economic value in making allocations of spectrum to these sectors.

0.3 With the modern tend towards the application of market mechanisms for the award of spectrum to all entities, including the public sector, utilities will assess the economic value of radio spectrum to them in judging the amount of money to commit to spectrum access in any competitive award process, and the associated business risks. Any societal value will thus be ignored.

0.4 The purpose of this study was to investigate whether there might be an element of socio-economic value attributable to radio spectrum deployed by utilities in the conduct of their business; and if this is the case, to place an indication of the amount of socio-economic value which might thus be overlooked if an award is made purely on the basis of the economic value of the radio spectrum to the utilities concerned.

0.5 There are limitations due to the sources of data used in the report. The data is mainly based around research in the UK and USA and relates to power interruptions to electricity networks stretching back several decades in some cases.

0.6 More study is required on the socio-economic value of radio spectrum used to support utility operations in Europe. This new study should look forward to valuations based on Smart Grid Deployment to facilitate renewable energy generation, greenhouse gas reduction and enhance security of supply.

- **" … societal benefit of spectrum used by the electricity industry to ensure reliable operation of the electricity supply network may have a societal benefit 50 to 150 times the economic value of the electricity itself."**
- **Utilities need to be able to apply innovative ICT solutions to increase their efficiency.**
- **Access to radio spectrum will enable utilities to respond to the changing regulatory environment more quickly, efficiently and cost effectively.**

0.7 On the basis of the available data, the report concludes that the societal benefit of spectrum used by the electricity industry to ensure reliable operation of the electricity supply network may have a societal benefit 50 to 150 times the economic value of the electricity itself.

0.8 Within the resources available for the study, it has not been possible to produce equivalent figures for the gas and water utilities, although it is probable that a similar situation pervades these industries. The impact of disruption to these industries is most probably at the lower end of the multiplier ratio due to much less economic impact from disruption to gas and water supplies, although the social impact of loss of gas and water may be greater under certain climatic conditions.

0.9 On the basis of the analysis of this report and work in the USA, radio regulatory authorities should review their spectrum allocation mechanisms to ensure that this socio-economic value of spectrum is not overlooked when formulating spectrum policy. This becomes especially important as utilities face challenging energy policy objectives and apply innovative ICT solutions to the networks to benefit European citizens, commerce and industry.

1. INTRODUCTION

1.0.1 Historically, national administrations allocated radio spectrum under a 'command and control' mechanism whereby governments decided who would have access to the radio spectrum, and the price to be paid for access. This price was usually determined by the administrative cost of managing the radio spectrum.

1.0.2 During this era, radio spectrum was recognised for its value as 'wire-less communication' ie communicating with moving objects or people (eg transport), addressing large numbers of people or items simultaneously (eg broadcasting) and long range communication (eg short wave radio). Utilities were early adopters of radio because it enabled control rooms to talk to a mobile workforce undertaking emergency repairs, and control remote infrastructure independently of the fixed wire-line system which might fail under the same conditions as the utility structures themselves (eg severe weather).

1.0.3 In the 1980s as mobile phone technology developed, governments recognised that radio spectrum had an increasing economic value, leading to conflicts and controversy over the best allocative mechanisms to be deployed to determined who might be granted access to an increasingly valuable commercial resource, and the appropriate price to be levied for access to this scarce natural resource.

1.0.4 By the 1990s, economic doctrines started to pervade spectrum management, with governments deriving large sums of money through auctions granting rights to spectrum, stimulated principally by massive growth in demand for mobile phones, but also recognising the enormous value of radio spectrum used for broadcasting as well. It was also apparent that demand was vastly exceeding supply, hence the application of economic principles to spectrum management was a logical development.

1.0.5 However, the application of rigid market economics for access to spectrum by non-telecommunications organisations has always been fiercely contested. Such use includes non-commercial services such as radio amateurs, radio astronomy, scientific research, low power devices such as car key fobs and garage door openers, and Wi-Fi. In parallel with such use, internationally co-ordinated services such as aeronautical and maritime communications and radio navigation were deemed 'safety of life', and thus largely excluded from market mechanisms.

1.0.6 National safety of life services and radio services used to support the critical national infrastructures have remained largely immune from having to seek access to spectrum via market based mechanisms as the spectrum allocated to them under previous 'command and control' principles has been adequate to meet their needs, and the impact has been largely confined to them having to pay a market related cost for the spectrum they use.

1.0.7 With the explosive growth in data communications, especially mobile broadband communications, these critical national infrastructure industries are looking towards applying technological innovation to improve their operational efficiency. These critical national infrastructure industries also face new operational challenges, all of which lead to a need for access to additional radio spectrum to meet their changing operational requirements.

1.0.8 In the case of utilities, especially the electricity transmission and distribution industries, these requirements are being driven by energy policy goals which require accelerated removal of carbon from the energy supply, allied to increased security whilst simultaneously seeking to contain costs – the **energy *triologue* of carbon reduction, security of supply and cost reduction.**

1.0.9 It is now widely recognised that the means whereby these energy policy objectives will be met is a rapid expansion in renewable energy supply, complemented by a more intelligent and interactive electricity network, commonly known as a ***Smart Grid.***

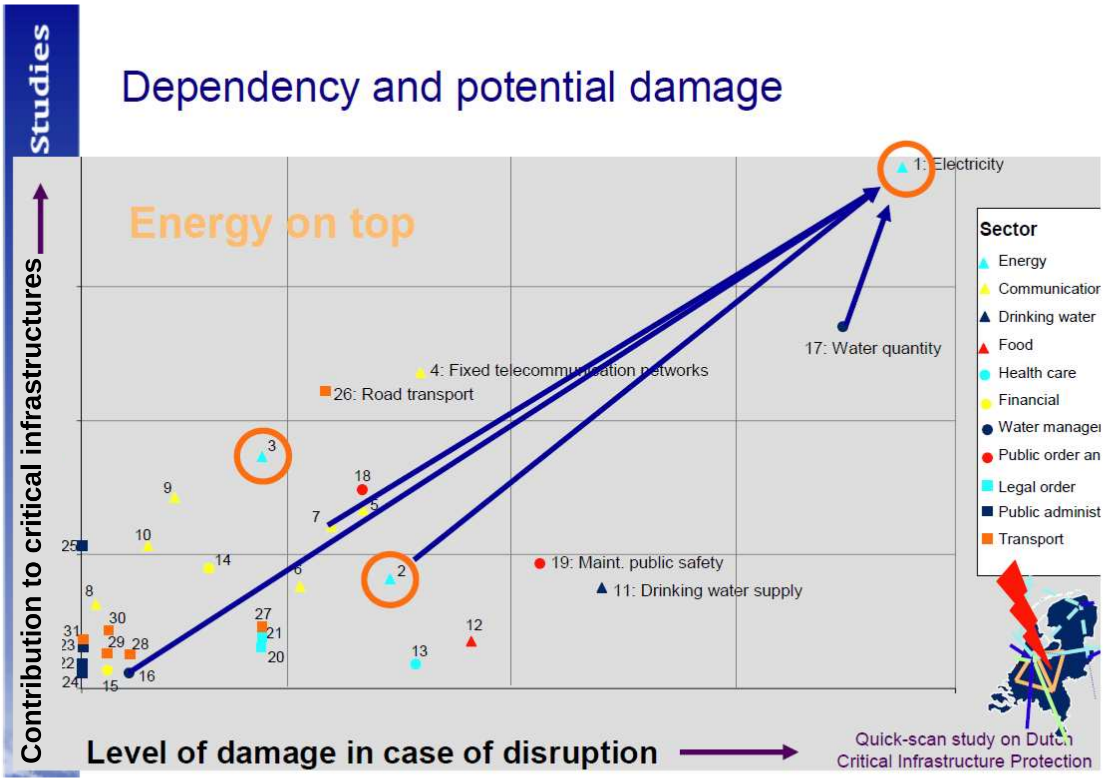
1.0.10 The achievement of these objectives will require a massive increase in the application of Information and Communication Technologies (ICT) to the existing electricity infrastructure, and to achieve these objectives on the timescale envisaged will require application of radio-based technologies in many cases.

1.0.11 As well as energy policy objectives impacting on the energy transmission and distribution systems, more stringent economic regulation has pushed these energy systems towards higher levels of utilitisation to reduce unit costs, and two way energy flows through the systems to enhance energy trading. This reduces the spare capacity and margin of error available to accommodate unforeseen circumstances and situation.

1.0.12 In parallel with the changing requirements on the utilities themselves, society has become more dependent on the services delivered by the utilities. There is then interdependence between elements of the critical national infrastructure on one another. This is illustrated graphically by a study undertaken by the Hague Centre for Strategic Studies (chart shown on next page). This tracks the interdependencies of the various identified elements of critical national infrastructure, but what emerges is that all elements of the critical national infrastructure have a dependence on electricity.

> *"Probably the most extreme … scenario in this section … is the nationwide loss of electricity. … because of our reliance on electricity for so many aspects of our lives, even localised losses of electricity can have a significant impact on those affected."*
>
> *There are comprehensive plans in place for handling both a complete national outage and regional outages. In the event of a national outage … the objective would be to restore supplies throughout Great Britain within three days."*
>
> Source: UK Cabinet Office, 2010 National Risk Register

1.0.13 This crucial dependency on a reliable supply of electricity emerges later in the report as a large socio-economic benefit from a reliable supply of electricity, and by extension other utilities; and then onto the role of radio spectrum in supporting these operation.



No.	Sector	Product or service
1	Energy	Electricity
2		Natural gas
3		Oil
4	Telecommunications	Fixed telecommunication networks services
5		Mobile telecommunication services
6		Radio communication and navigation
7		Satellite communication Incl. GPS & navigation
8		Broadcast services
9		Internet access
10		Postal and courier services
11	Drinking water	Drinking water supply
12	Food	Food supply and food safety
13	Health	Health care *
14	Financial	Financial services and financial infrastructure (private)
15		Financial transfer services (government)
16	Retaining and managing surface water	Management of water quality
17		Retaining and managing water quantity
18	Public Order and Safety	Maintaining public order
19		Maintaining public safety
20	Legal order	Administration of justice and detention
21		Law enforcement
22	Public administration	Diplomacy
23		Information provision by the government
24		Armed Forces / Defence
25		Public administration
26	Transport	Road transport
27		Rail transport
28		Air transport
29		Inland navigation
30		Ocean shipping
31		Pipelines

The chart shows the dependency of all constituent parts of the critical national infrastructure on a reliable and dependable source of electrical energy.

Source: Critical Infrastructure Protection Energy Security, The Hague Centre for Strategic Studies, a TNO Initiative, Eric Luiijf MSc, 10 July 2007.

1.1 RADIO TECHNOLOGIES EMPLOYED

1.1.1 Utilities employ a wide variety of both private and public telecommunications technologies. Fixed networks use fibre optic cables; copper cables in the form of conventional commercial telecommunications cables and 'pilot' copper telecommunications cables originally installed at the same time as the supply cables; plus 'power line communications' where telecommunications signals are superimposed on the supply cables. In the radio domain, commercial microwave spectrum is used by many companies for back-haul and trunk communications, plus large number of mobile phone connections. In some cases, especially for smart metering, deregulated spectrum may be employed; and occasionally, broadcasting spectrum is used as in the case of the 'radio teleswitch' service in the UK which utilises the BBC Radio 4 transmitter on 198 kHz for wide area load control.

1.1.2 However, for critical operations and communications with their mobile work force, utilities have traditionally relied on self-provided radio communications, using radio spectrum licensed by national spectrum regulators.

1.1.3 The radio technologies used by utilities for private network provision do not align directly with the standard classification of radio services used by administrations, falling mainly into the categories designated 'mobile' and 'fixed' services. However, the main technologies used to support critical utility operations are 'private mobile radio' and 'point-to-multi-point' radio systems, various classed as 'fixed' or 'mobile' by different administrations.

1.1.5 To facilitate use of published statistics, the majority of which are derived from the UK or USA, for convenience, this report uses a generic term **'business radio'** to refer to these services.

1.2 SPECTRUM ACCESS

1.2.1 The issue now arises that with the application of economic principles for spectrum access to the next generation of radio communications systems for utility use – especially for telecommunications in support of the Smart Grid – utilities are faced with the prospect of competing for spectrum access using commercial mechanisms, principally auctions.

1.2.2 Participation in spectrum auctions and other market access mechanism is problematic for utilities and other public safety organisations for a number of reasons, including:

- Market mechanisms provide no guarantee of access on a timescale commensurate with utility requirements.
- Utility regulatory timescales do not necessarily align with spectrum release dates.
- Financing mechanisms for utilities are tightly regulated and transparent, exposing the potential bid position of utilities taking part in auctions to non-utility participants.
- The size and geographic distribution of spectrum blocks is unlikely to align with utility requirements, requiring utilities participating in auctions to obtain excess spectrum. This would oblige utilities to trade on unwanted spectrum which creates uncertainty and financial risk that ought not to fall on energy consumers.

1.2.3 In contemplating participation in a spectrum auction, utilities will view spectrum purely as an input cost: a commercial utility will only reflect in an auction bid the economic value of the spectrum to that organisation, not the true value to society. A commercial entity has no incentive to reflect the social cost of that spectrum.

1.2.4 The purpose of this study is to determine if there is a socio-economic value to spectrum used by utilities to support their operations; and if this is the case, to postulate a value which includes public benefit.

1.3 DATA SOURCES

1.3.1 Although the remit of the report was to focus on utility applications in Europe, it has proven difficult to obtain relevant data. The main source of data has been the UK, with a surprising amount of data and in-depth of analysis from the USA. It is not clear if this is a language issue (in that it was difficult in the context of this introductory study to access non-English language research); or whether there is genuinely more research undertaken in the US on the socio-economic impact of failure of utility supplies than in Europe.

1.3.2 The study focuses on published data, which by its nature is historic, and in some cases quite dated in a fast moving technological field where society is far more dependent on reliable electricity supplies than even 10 years ago. The main source of data is thus major losses of electricity supply which have stimulated rigorous economic analysis. It had been hoped that the study could draw some conclusions looking forward towards to a situation where a social value could be placed on greenhouse gas reduction and avoidance or reduction in climate change consequences, but the uncertainty and contested nature of these figures has precluded reliable analysis in the time available.

1.4 BASIS OF ECONOMIC ANALYSIS

1.4.1 Business Radio communications, also referred to as Business Radio or Professional Radio, is used extensively through-out the UK economy to aid firms in pursuing efficiencies and maintaining a competitive advantage in international markets. The UK Federation of Communications Services (FCS) Business Radio Group, who represent firms and industries with interest in business radio[1], see these radio communications as integral parts of modern businesses. Users need Business Radio "...not only [to] gain efficiency benefits but they also have to have the unique functionality provided by Business Radio to meet increasingly stringent Health and Safety and other legislative requirements."[2]

[1] "The Business Radio Group represents the interests of businesses and organisations involved in the manufacture and distribution of business radio products and services, organisations using business radio systems, spectrum licensees, spectrum managers, and applications providers. The group has been active in supporting the business radio community since 1982."
Federation of Communications Services, Business Radio Group, http://www.fcs.org.uk/MemberGroups/Business-Radio/BusinessradioHome.aspx

[2] Federation of Communications Services, 2007. *The Importance of Business Radio to the UK.* [online] London: FCS (Published 2007) Available at: <http://www.fcs.org.uk/my%20files/07-10-

1.4.2 The use of Business Radio by non-telecoms operators is not immediately noticeable to observers due to its function as part of the support infrastructure rather than as a direct generator of revenue. However, it is an industry of itself and should be treated as such rather than merely as part of an indiscriminating, non-differentiated 'Radio Spectrum' market.

1.4.3 A clear definition of the types of radio spectrum is therefore important if applying economic theory. Assigning a 'one-size-fits-all' market approach to non-homogenous goods can potentially be damaging to the total welfare a society gains from that resource.

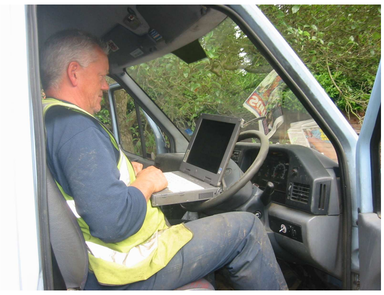
1.4.4 When applying economic theory, it is essential that the good is defined correctly. Goods can be defined as a private good, club good (natural monopoly), common resource or public good. Although a more in-depth analysis will be taken, Business Radio shares many characteristics with a public good when applied to industries where the marginal social benefit it creates through indirect 'ripple' effects are un-costed in the traditional market mechanism. Intervention is required if such market failure is the case – where the market mechanism fails to provide what society actually demands.

1.4.5 This paper's objective is to ultimately investigate whether market failure has taken place, with Business Radio providing a socio-economic value which is not realised by the classic market mechanism, leading to the mis-allocation of resources from their most efficient use. It is imperative to identify what are the technical and economic characteristics of Business Radio and the impact of Business Radio on industries providing indispensible public goods and services – the Critical National Infrastructure[3]. From existing studies of the socio-economic value of Business Radio and the application of established methodology, a range of values for the UK can be obtained, allowing conclusions to be drawn as to whether Business Radio produces a marginal benefit to the UK economy greater than the private benefit and if there would be clear benefits from the use of an alternative allocation method to that currently used.

1.4.6 Since to a first level of approximation, the UK market is similar to other European Countries, and the regulation of both utilities and telecoms across the European Union is becoming ever more closely aligned, any multiplier effects demonstrated in the UK market are applicable across the Community.

1.4.7 Although initial examination suggests that there is a much greater socio-economic value to be gained from the allocation of Business Radio to providers of public goods and services, this paper aims to provide credible estimates as to the level of disparity and whether this merits any further action.

2. BUSINESS RADIO



2.0.1 The majority of UK industries today require communications systems to transfer data between workers and departments so as to provide the best possible service in highly competitive markets. Public telecommunications, such as mobile phones, fax, internet, and landline networks and so on, utilising fixed communications, GSM or 3G networks are used as they are readily available and, for the most part, simple.

19%20brc%20value%20of%20business%20radio-public.pdf> pg 3
[Accessed 03 August 2011].

[3] This paper will be mostly focused on the effects to Utilities providers as data is more readily available and the issues surrounding the use of Business Radio can be observed with relative ease compared to other areas of the Critical National Infrastructure such as Emergency Services.

2.0.2 However, some industries require specifications beyond the capabilities of public telecommunications. Industries used in emergency scenarios and disaster response or which require resilient, dedicated communications to ensure operational efficiency on a day-to-day basis can only be supported by the use of Business Radio communications. The FCS has previously constructed a brief list[4] of some UK industries that use Business Radio:

- Aerospace
- Airports
- Banking
- Broadcasting
- Chemicals
- Construction
- Defence
- Distribution Logistics
- Electronic
- Emergency Services
- Entertainment
- Environmental
- Events
- Finance
- Healthcare
- IT Sector
- Lifeboats
- Local Government
- Manufacturing
- Marine
- National Government
- Oil Industries
- Petroleum Terminals
- Pharmaceuticals
- Prisons
- Ports
- Public Safety
- Retail Stores
- Retail Centres
- Security
- Sport
- Telecoms
- Transport
- Utilities

[4] Federation of Communications Services, 2010. *The Importance of Business Radio to the UK.* [online] London: FCS (Published 2010) Available at: http://www.fcs.org.uk/my%20files/fcs_pdfs/member%20groups/business%20radio/10-06-28_fcs_contribution_on_sfbr_publication_version.pdf pg 10-11
[Accessed 03 August 2011].

2.0.3 Whilst this list is by no means all encompassing, it shows clearly that Business Radio is used throughout the UK economy. Business Radio has clear operational benefits over other available forms of communications which users demand to provide a safe and efficient service.

2.1 TECHNICAL REQUIREMENTS

2.1.1 The communications systems facilitate a 'fast call' mechanism, requiring only a single button to communicate. The system can also be used to 'group call', allowing one-to-many and many-to-one communications as well as one-to-one use. Data and voice can both be used on a single channel, unlike public communications. Furthermore, calls made can be ranked on importance rather than on the order they join the queue. This ranges from routine traffic to priority calls to emergency calls.

2.1.2 The networks, being controlled 'in-house' are not reliant on third party management and so can be made to be highly resilient (reserve power, rural coverage, flood resistant, working underground, etc.), ensuring the service is always available and secure. For some industries therefore, Business Radio is not just preferred, but essential.

2.1.3 The capital equipment too is built for the difficult environments they will be used in. Handheld terminals and base stations are robust and cheap to replace. An element of certainty about the running costs also exists as they are not based upon the whims of public network providers.

2.1.4 Other features of the Business Radio systems which have made them so desirable for these industries include:

- People Tracking
- Links to alarm systems
    - Ability to operate alarms
- Accessing other radio communication systems
- 'Man Down'
    - Measures response time of workers so that incapacitated workers can be discovered.

2.1.5 Public networks in comparison offer no such guarantees of service, especially in harsh environments or times of high traffic, and are limited in their abilities to communicate in such diverse ways. It is vital then to differentiate between Business Radio and public networks as they are entirely different services.

2.1.6 Sometimes, as alluded to earlier, these differences go beyond being merely a convenience to the firm. Business Radio can be essential to providing the service. Critical National Infrastructure is one area where providers rely upon Business Radio communications systems both daily and to prevent disasters, which would lead to drastic economic damage, damage to society or loss of life well beyond those agents responsible.

> **Opportunity Cost**: Whatever must be given up to obtain some item.
>
> **Source:** Mankiw, N. and Taylor, M. (2010) *Economics: Special edition* Andover: Cengage Learning EMEA , P. 6

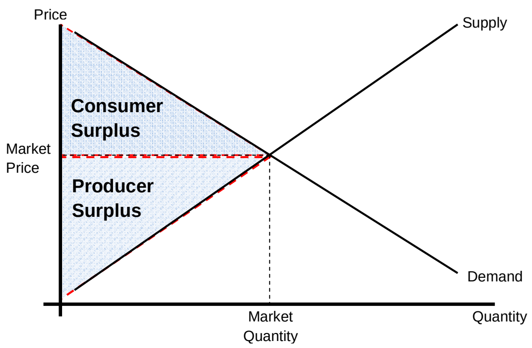
2.1.7 As stated by the FCS, Business Radio enables firms to abide by "stringent Health and Safety and other legislative requirements."[5] London Underground and the Channel Tunnel could not run safely without Business Radio. Dartford Tunnel and the Over ground Trains would have to run at reduced rates, making them financially unviable. The 'Lone Worker' scenario covered by The Health and Safety at Work etc Act 1974 and the Management of Health and Safety at Work Regulations 1999 would require Police and Security Guard services to have crews of at least 2 members of staff rather than 1 member with a radio set, increasing costs and response times.

2.1.8 Although not all functions would grind to an absolute halt without Business Radio, the opportunity cost of using the next best alternative would be of such magnitude that it realistically cannot be considered if at all avoidable.

2.2 SOCIO-ECONOMICS OF BUSINESS RADIO

2.2.1 In conducting a socio-economic evaluation of Business Radio, understanding of the type of good and what economic theories are then applicable is key as it enabling greater understanding of consumers and producers incentives. This should be the foundation of any analysis as without it, results may be misleading and fail to observe crucial points.

Consumer Surplus



The area labelled '**Consumer Surplus**' is the aggregate surplus of consumers in the market up to the final consumer (at market quantity) where they pay their willingness-to-pay for the good or service. Beyond this point, a consumer would pay more for the good or service than the surplus they would achieve from its consumption and so do not pay for it.

'**Producer Surplus**' is the difference between the cost of producing the good or service (the supply curve) and the price they receive from the sale of the good or service (the market price).

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[5] Federation of Communications Services, 2007. *The Importance of Business Radio to the UK.* [online] London: FCS (Published 2007) Available at: http://www.fcs.org.uk/my%20files/07-10-19%20brc%20value%20of%20business%20radio-public.pdf pg 3
[Accessed 03 August 2011].

2.2.2 A good or service in economics can be usually defined as a private good, club good (natural monopoly), common good or public good depending on the ability to exclude consumption and whether use by one consumer prevents another's use – Excludable and Rival. Examples of the types of good are in the 'Type of Economic goods' box below.

2.2.3 These definitions show who derives surplus from the consumption of the good or service in relation to who actually paid for it.

2.2.4 Consumer surplus is a measure of the difference between what a customer is willing to pay and the actual price of the product. Consumer surplus was formally explained by Alfred Marshall in his Principles of Economics. It can be defined as the excess utility (or surplus) above the price actually paid. In Marshall's words: "the price which a person pays for a thing can never exceed and seldom comes up to that which he would be willing to pay rather than go without it: so that the satisfaction which he gets from its purchase generally exceeds that which he gives up in paying away its price; and he thus derives from the purchase a surplus satisfaction. The excess of the price which he would be willing to pay rather than go without the thing, over that which he actually does pay, is the economic measure of this surplus satisfaction."[6]

2.2.5 With a private good, where a good is both rival and excludable, the consumer who purchases the good derives the entire consumer surplus and thus the normal market structure provides an allocative efficient outcome. At the equilibrium price level, consumers will derive the consumer surplus – the aggregate difference between the price each is willing to pay and what they did actually pay – and the suppliers will derive the entire producer surplus – the aggregate difference between the cost of producing each unit and that revenue they actually received from its sale. This normal market structure provides an incentive to each agent, the surplus they receive, which those willing to act in the market receive and those who don't do not.

Types of Economic Goods

Excludability: The property of a good whereby a person can be prevented from using it.

Rivalry: The property of a good whereby one person's use diminishes other people's use.

		Rival? Yes	Rival? No
Excludable?	Yes	Private Goods - Clothing - Congested toll roads	Natural Monopolies (Club Goods) - Cable TV - Uncongested toll roads
Excludable?	No	Common Resources - Fish in the Ocean - The Environment - Congested non-toll roads	Public Goods - Flood-control dams - National Defence - Uncongested non-toll roads

Source: Mankiw, N. and Taylor, M. (2010) *Economics: Special edition* Andover: Cengage Learning EMEA , P. 208

2.2.6 A public good exists where the good is non-excludable and non-rival. In this situation, the market will fail to provide the optimum solution because of the Free Rider Effect. The Free Rider Effect exists where consumers can consume the good and gain benefit without paying. Non-excludable goods cannot prevent those who do not pay for the use of the good from using it, thus removing the incentive to reveal a consumer's true willingness-to-pay to have the good or even to pay for it at all. This means that, despite being demanded, it will not be supplied. This is allocative inefficiency (Pareto Inefficiency) where potential surplus is lost. This is called Dead Weight Loss. A classic example is for National Defence.

> **Free Rider**: A person who receives the benefit of a good but avoids paying for it.
>
> **Source:** Mankiw, N. and Taylor, M. (2010) *Economics: Special edition* Andover: Cengage Learning EMEA , P. 209

> **National Defence**
>
> The defence of the country from foreign aggressors is a classic example of a public good. Once the country is defended, it is impossible to prevent any single person from enjoying the benefit of this defence. Moreover, when one person enjoys the benefit of national defence, he does not reduce the benefit to anyone else. Thus, national defence is neither excludable nor rival.
>
> National defence is also one of the most expensive public goods. In the UK in 2002 it accounted for about £25 billion of government expenditure – the fourth largest category (behind social security, the National Health Service and education). People disagree about whether this amount is too small or too large, but almost no one doubts that some government spending on national defence is necessary. Even economists who advocate small government agree that the national defence is a public good the government should provide.

2.2.7 These public goods are generating positive externalities – where consumers who have not paid for the good benefit from consumption by another consumer. This means that the benefit created by each unit consumed – marginal social benefit (MSB) – is greater than the benefit created for the individual in the society who paid for that unit – marginal private benefit (MPB). As people do not need to buy the good to benefit from it, this leads to the market under supplying and under demanding the good.

2.2.8 Through licensing, Business Radio is a private good. Electromagnetic spectrum can also be a common good, as exemplified by 'licence exempt' or 'unlicensed' spectrum. With licensed spectrum, one person's use prevents use by another and others can be excluded from use.

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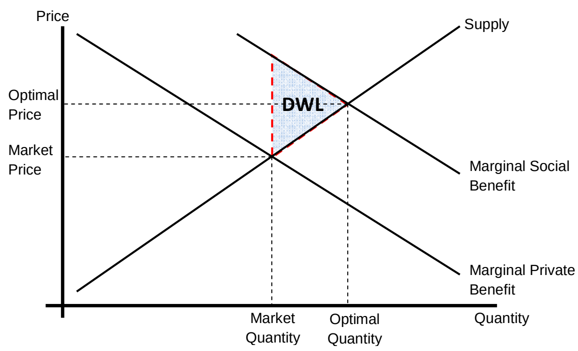
[6] Marshall, A. (1890). *Principle of Economics.* London: Macmillan and Co., Ltd. cited in Economic Aspects of Spectrum Management (2010). *International Telecommunication Union*. Retrieved August 25, 2011 from http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2012-3-2010-PDF-E.pdf p. 34

Marginal Private Benefit and Marginal Social Benefit



In markets for public good, there is a disparity between the benefit received by the individual (private benefit) and the benefit received by society (social benefit). This generates Dead Weight Loss (DWL) as, if it were a normal good, the benefits would be realised, leading to higher consumption, higher prices and higher total surplus.

2.2.9 Whilst some services, such as banking and distribution logistics, are excludable, emergency services, utilities and public transport use Business Radio to distribute services with unaccounted social benefits. While they are not entirely public goods like national defence, clean air, the environment, etc. because they are partially excludable (utilities bills, train tickets, etc.), it is not possible for all social benefits to be excluded, making them a quasi-public good. Someone who does not pay for a train ticket will still benefit from reduced congestion, cleaner air, reduced pollution and increased productivity by society generally. Therefore, when looking at the socio-economic value of Business Radio, it is the use to which it is put and how that increases benefits to society that should be evaluated rather than the spectrum itself.

3. THE UNITED KINGDOM'S CRITICAL NATIONAL INFRASTRUCTURE.

3.0.1 When looking at where large, unobserved social benefits may be gained, the UK National Infrastructure becomes the prime candidate. The services have large ripple effects on the economy which are not represented. This has caused many countries to partially or entirely nationalise these industries as they would fail to provide services at Pareto Efficient levels in the free market.

3.0.2 The Centre for the Protection of the National Infrastructure (CPNI) define the United Kingdom's National Infrastructure as "...the facilities, systems, sites and networks necessary for the delivery of the essential services upon which daily life in the UK depends"[7]. Nine sectors are considered by The CPNI to meet this definition:

- Communications
- Emergency Services
- Energy
- Finance
- Food

[7] CPNI Website (2010). *Centre for the Protection of National Infrastructure*. Retrieved August 25, 2011 from http://www.cpni.gov.uk/about/cni/

- Government
- Health
- Transport
- Water

3.0.3 Although these are all important services, the loss of some would have immediate drastic consequences – these are considered to be the Critical National Infrastructure. Whilst sectors are not named, the Critical National Infrastructure is deemed by the CPNI to be "the sectors there are certain 'critical' elements of infrastructure, the loss or compromise of which would have a major, detrimental impact on the availability or integrity of essential services, leading to severe economic or social consequences or to loss of life."[8] This may refer to physical assets, such as buildings and sites, or logical assets, such as computer systems or radio systems.

3.0.4 Naturally, these 'critical elements' do not command a price to fully cover the benefits to society they provide. However, government intervention is required to ensure that the services remain to be provided, usually through subsidisation or regulation.

3.0.5 When looking at the use of Business Radio in the Critical National Infrastructure, the industries which this paper would recommend be classified as part of the Critical National Infrastructure are those where the opportunity cost of the next best alternative is greatest – where the consequences of substituting Business Radio for the next best alternative would be most dire. In these industries, there is no prospect of substituting Business Radio for any other alternative without '...severe economic or social consequences or to loss of life'.

3.0.6 In the United Kingdom, the elements of the National Infrastructure which are in a position where Business Radio is non-substitutable are Emergency Services, Utilities (Energy Providers) and Public Transport. Although this paper focuses on the arguments for Utility providers, all these Critical National Infrastructure industries are reliant on stable Business Radio communication systems to provide their critical services.

3.0.7 Although a numerical value has not been definitively assigned as it is highly complex and almost certainly inaccurate, many other papers agree that these sectors demand Business Radio to provide services on a national scale efficiently. The national systems require complex co-ordination and interconnectivity to provide the best possible outcome.

3.0.8 An obvious use of Business Radio is with Emergency Services to provide their radio communications. The Emergency Services also demonstrates the variance between socio-economic and market values and that government intervention is sometimes needed for a market to succeed in providing social benefit. While the Fire Service in the UK was a private sector industry operated by insurance companies until 1865, its social value was better realized through government intervention in the market. Nowadays, no-one would consider such a system and while some medical services are still privately run, governments often intervene in the market in some form.

[8] CPNI Website (2010). *Centre for the Protection of National Infrastructure*. Retrieved August 25, 2011 from http://www.cpni.gov.uk/about/cni/

3.1 USE AND COSTS OF BUSINESS RADIO BY THE CRITICAL NATIONAL INFRASTRUCTURE

3.1.1 In the UK, Emergency Services use radio to communicate between colleagues and central command centres. Police systems are used in all environments to send officers to jobs, to co-ordinate responses to incidences and to call for assistance. Ambulance services use radio communications to different units of care so that patients can receive critical care as quickly as possible. Fire Services use radios to maintain safety cordons and to ensure the safety of their operatives in dangerous environments. Utilities similarly use it in dangerous environments to ensure safety during operations and to maintain as much of the national grid as possible whilst transport use radio to maximize the functioning of the transport networks. The use of radios is primarily to co-ordinate units quickly so they can be used most efficiently. Without radio systems, public networks or even runners would have to be used, as in the 7/7 bombings, dramatically limiting the speed and efficiency of responses.

3.1.2 The social cost of a lack of efficient radio systems can be easily seen. 'The Strategic future of Business Radio' by the FCS considers "the cost to the UK of additional deaths were professional radio facilities taken away" from Police units responding to Road Traffic Incidents, resulting in "a modest rise of around 5% increase in the number of fatalities and serious injuries resulting from the police not being able to reach an accident in time stop further accidents." Working with figures from the Department of Transport, the costs would be £560 million per annum[9]. Other costs include the increase in workers required to comply with the Lone worker Health and Safety regulation and the losses caused by inefficiency in ambulance response time and increased fire damage, which measured £1.3 billion in 2008.[10].

3.1.3 The utilities sector use Business Radio to great effect throughout the industry. On a daily basis, it is used to monitor some facilities, to co-ordinate security at key installations and for routine maintenance of the network. There is a greater need for spectrum in the utilities sector in the future if the government and European Commission want to implement Smart Grids to meet the Green Agenda. Smart Grids will require communications to monitor load on the network and maintain the large number of facilities which will be needed for the network to function. The management of the grid in such a way reduces the reliance on fossil fuel generation as local green energy will be better accommodated.

3.1.4 However, Business Radio is also needed in time critical incidents. Whether caused by deliberate sabotage, the failure of components or environmental conditions, utilities networks would rely on resilient Business Radio systems to rectify the problems immediately. In a Black start, which can occur in less than 3 minutes, the procedure to restart the grid would require a 72 hour operation – 71 hours and 40 minutes longer than a public network system with working backup systems can remain

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[9] The Strategic Future of Business Radio (2010). *Federation of Communication Services Business Radio Group*. Retrieved August 25, 2011 from http://www.fcs.org.uk/my%20files/fcs_pdfs/member%20groups/business%20radio/10-06-28_fcs_contribution_on_sfbr_publication_version.pdf P. 15-16

[10] Association of British Insurers: Record rise in the costs of fire damage (2009). *Association of British Insurers*. Retrieved August 25, 2011 from http://www.abi.org.uk/Media/Releases/2009/12/Record_rise_in_the_costs_of_fire_damage.aspx

standing without power. These kinds of incidents, including sabotage of nuclear facilities, cannot have a calculated economic value with any credibility. Not having Business Radio is not an option.

3.1.5 The transport system, although not necessarily posing the greatest direct threat to human life, has the potential to cause great economic disruption and damage without Business Radio. Railway networks are especially reliant on these systems as they need to co-ordinate networks over great distances. Buses, trams and other public transport systems are dependent on these systems to a lesser extent. Over ground trains use the networks not only to ensure disruptions are minimized on a daily basis, but also as the safety system to prevent collisions and deal with obstacles on the tracks. The Cowden inquiry into the crash in 1994 which killed 5 people concluded "had cab secure radio been available this accident could have been prevented."[11]

3.1.6 Business Radio on Underground trains in the UK, following the 7/7 inquiry, is compulsory. Without full radio contact, no Underground trains are allowed to run. The FCS strategic review didn't attempt to calculate economic losses as "London would cease to function and the economic impact would be vast."[12]

3.1.7 It is clear that these sectors can clearly be included as part of the Critical National Infrastructure and that, without Business Radio communications systems, they would cease function, as Business Radio is either non-substitutable or at such a cost that it is not realistically possible for them to offer the same service. With the future development of Smart Grids planned for Europe, this problem will become more acute for utilities as the network cannot hope to function unless the necessary data can be accessed and acted upon.

3.2 AUCTION ALLOCATION

3.2.1 In the UK, all radio spectrum is sold through an auction market mechanism, excluding internationally co-ordinated spectrum for maritime, aeronautical, Ministry of Defence and unlicensed non-commercial spectrum. Originally, it was proposed that the Defence sector would have to acquire spectrum through auctions to encourage efficiency savings, but the current approach is to encourage the Ministry of Defence to release some of its existing spectrum inventory using financial incentives. When using the auction allocation method, there are limitations on its effectiveness to meet social obligations for the Critical National Infrastructure Sectors. These limitations manifest due to the legal technicalities of governments intervening in markets as well as the lack of incentives in quasi-public good markets.

3.2.2 The issue of government intervention exists for bidders at auction who receive funding from government, such as the Emergency Services. Revenues raised from spectrum auctions are collected by the Treasury. Therefore, the FCS points out, it is perverse for public sector bodies to compete in

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[11] Railway Accident at Cowden (1995). *Health & Safety Executive*. Retrieved August 25, 2011 from Health and Safety Executive, HM Railway Inspectorate Web site: http://www.railwaysarchive.co.uk/documents/HSE_Cowden1994.pdf P. 30, paragraph 119.

[12] The Strategic Future of Business Radio (2010). *Federation of Communication Services Business Radio Group*. Retrieved August 25, 2011 from http://www.fcs.org.uk/my%20files/fcs_pdfs/member%20groups/business%20radio/10-06-28_fcs_contribution_on_sfbr_publication_version.pdf P. 13

auctions with privately funded bodies when the proceeds of the auction will be returned to the public exchequer. Furthermore, as the bidder will need to apply for money from the treasury, the bid amounts will be in the public domain, allowing competitors to work out their maximum bids before the auction. Conversely, since no money flows from the government other than administration fees, the Treasury indirectly determines the outcome of the auction.

3.2.3 The FCS also points out that the process could then be “subject to challenge from the other participants and so would not get the spectrum then even though they ‘won’ at auction”[13] unless they could justify it. Thus auctions have many shortcomings and it could be argued that a more efficient allocation could be made without the auction.

3.2.4 The incentive problem exists for suppliers of public goods as well. As the revenue received for a quasi-public good is not equal to the amount that society truly would pay for the quantity they actually demand, the financial capital does not exist to make the desired investment in networks, such as Smart Grids - which industry created in response to government calls for action on climate change, increased security of supply and affordability. Furthermore, auctions create uncertainty. The lack of confidence would limit how much firms will invest as, even if they created better networks, they would not be able to guarantee spectrum for the network. As had been noted in a number of countries in relation to the energy sector, long-term investment and innovation often suffers in regulated competitive markets.

3.2.5 One way to encourage firms to invest would be for the government to introduce a standard or fines for failure to supply which had penalties which makes the investment attractive to avoid fines. This is particularly relevant to the utilities sector. However, an effective incentive regime would be extremely complex due to the number of variables involved, some beyond the utilities control (eg short and long term weather incidents),. Determining the level of the fines would also have an element of randomness because the impact is highly dependent on the time of day, season and duration of the incident.. Furthermore, if the penalties are too great, the possibility of bankruptcy would lead to participant leaving the market or increasing prices to increase financial reserves.

3.2.6 It is clear that auction market mechanisms lack sufficient incentives to achieve Pareto efficient outcomes with quasi-public goods and the Business Radio Spectrum allocation. This needs to be addressed for these Critical National Infrastructure sectors for the socio-economic value of Business Radio to be realised.

4. EXISTING SOCIO-ECONOMIC ANALYSIS OF THE UTILITIES SECTOR

4.0.1 There are already existing reports which have studied the socio-economic value of electricity, largely in The United States of America. When looking at Critical National Infrastructure, the studies can be used to evaluate the marginal benefit of a Business Radio

[13] The Strategic Future of Business Radio (2010). *Federation of Com*
Retrieved August 25, 2011 from
http://www.fcs.org.uk/my%20files/fcs_pdfs/member%20groups/b
28_fcs_contribution_on_sfbr_publication_version.pdf P. 38

system to the Utilities Sector. The reports mainly look around the disparity between the social benefit and the private benefit and the consequence of this when looking at market prices. The magnitude of this difference determines the potential Pareto improvement which is achievable using a Business Radio System and, therefore, if the allocation system currently used is optimal.

4.0.2 The reports which have been used for evidence in this report have been selected as they provide both extended analysis from historical evidence with recent reports which have focused on recent events. The scope of this report has largely dictated the amount of data which can be processed and so the figures used are general rather than specific to individual outages, which would require much greater data processing.

4.1 'THE ECONOMIC COST OF THE BLACKOUT: AN ISSUE PAPER ON THE NORTHEASTERN BLACKOUT, AUGUST 14 2003

4.1.1 The ICF Consulting paper 'The Economic Cost of the Blackout' looks at the direct and indirect effects of the North-eastern United States Blackout – The New York power outage on 14th August 2003 for 25 hours. ICF Consulting "conceive and implement solutions and services that protect and improve quality of life"[14] – finding technical solutions to problems for governments, major corporations and multilateral institutions. This particular report was created to investigate the repercussions of a potential co-ordinated attack on the Californian Transmission Grid.

4.1.2 ICF Consulting's analysis was based around "consumer's willingness-to-pay to avoid such outages". The difference represents how much a consumer is willing to pay to insure against the costs that they would face in the event power is lost. Using figures collected from the 1977 outage in a Congress Report by the Office of Technology Assessment, which will also be examined, the Willingness-to-pay was 100 times the retail price of electricity (retail price = $34/MWh = $0.034/kWh). Direct costs had an economic cost, which includes the social and private benefit, of $0.66/kWh and the Indirect costs were $3.45/kWh. Therefore, the total economic cost calculated by ICF Consulting of the outage was $4.11/kWh, equivalent to around $4000/MWh or 100 times the given retail price.

4.1.3 In modifying to approximate cost ratios today, they have used a multiplier effect with a range of 80-120 times the retail price to form lower and upper boundaries. The retail price of electricity is quoted from August 2002 at $93/MWh. Over the 72 periods the outage occurred, a total of 918,800 MWh were lost. At $93/MWh, this amounts to $85,448,400 revenue lost to the energy provider. However, the total economic cost of the blackout, using their willingness-to-pay range of 80-120, is in the range of $7 to $10 billion.

4.1.4 If a comprehensive radio-based telemetry and telecontrol system had been in place to monitor the network infrastructure, the growing instability of the network could have been detected, and it is highly likely the incidence would have been prevented. The ability to provide resilience in this kind of incident or restore all power in less than 72 hours would be greatly reduce the total economic cost to the nation without increasing the operating cost of the network to a material degree.

[14] Our Purpose and Vision (2011). *ICF International*. Retrieved August 25, 2011 from Web site: http://http://www.icfi.com/about/our-purpose-and-vision

Total Economic Cost of New York 14th August 2003

Approximate Start Time	Approximate End Time	Lost Megawatt	Duration		Cost of Blackout ($ Billion)	
		MW	Hour	MWh	Lower Bound	Upper Bound
8/14 - 4 PM	8/14 - 8 PM	61,800	4	247,200	$1.8	$2.8
8/14 - 8 PM	8/15 - 6 AM	30,900	10	309,000	$2.3	$3.4
8/15 - 6 AM	8/15 - 10 AM	15,450	4	61,800	$0.5	$0.7
8/15 - 10 AM	8/16 - 12 AM	13,200	14	184,800	$1.4	$2.1
8/16 - 12 AM	8/16 - 10 AM	6,600	10	66,000	$0.5	$0.7
8/16 - 10 AM	8/17 - 6 AM	2,000	20	40,000	$0.3	$0.4
8/17 - 6 AM	8/17 - 4 PM	1,000	10	10,000	$0.1	$0.1
Total Economic Cost					**$6.8**	**$10.3**

Source: The Economic Cost of the Blackout: An issue paper on the Northeastern Blackout, August 14, 2003 (2004). ICF CONSULTING. Retrieved August 25, 2011 from http://www.solarstorms.org/ICFBlackout2003.pdf p. 2

4.2 'THE IMPORTANCE OF BUSINESS RADIO TO THE UK' FEDERATION OF COMMUNICATIONS SERVICES REPORT

4.2.1 The FCS Business Radio Group report 'The Importance of Business Radio to the UK' observes that:

- In the public sector the ration of business radio investment to organisation turnover is approximately 1:30; and
- For a major construction project valued at £5 billion, the cost of the radio communications system over 6 years is £2 million.

4.2.2 As well as its role in preventing harm or loss of life, the FCS notes "the value of Business Radio to the economy is up to 2000 times the cost of Business Radio Infrastructure systems and terminals"[15]. This places the total economic value to society of the £1-2 billion per annum Business Radio Industry as calculated by the FCS and the Radiocommunications Agency close to £2000 billion each year. This estimates the cumulative benefit of Business Radio through applications in the UK economy, including utilities' use in telemetry and telecontrol.

[15] The Importance of Business Radio to the UK (2007). *Federation of Communication Services Business Radio Group*. Retrieved August 25, 2011 from http://www.fcs.org.uk/my%20files/07-10-19%20brc%20value%20of%20business%20radio-public.pd P. 14

4.3 'ECONOMIC ASPECTS OF SPECTRUM MANAGEMENT'- INTERNATIONAL TELECOMMUNICATION UNION (2010)

4.3.1 The International Telecommunication Union is "The United Nations specialised agency for information and communication technologies"[16] and aim to promote improved use of ITC. It also recognises the need to cater for Critical National Infrastructure sectors: "Belonging as it does to the public domain of the state, the spectrum must be managed in the interests of the national community as a whole."[17]

4.3.2 The ITU acknowledges the importance of Cost-Benefit Analysis in making these decisions in their report 'Economic aspects of Spectrum Management' stating that "assessment of the economic benefit arising from the use of the radio spectrum is useful in making spectrum planning decisions. If quantifications of these benefits is required for spectrum planning and strategic development then suitable methodologies must be identified"[18]. They also highlight the importance of realising that there are firms which rely on radio communications beyond those where it forms part of the core business.[19]

4.3.3 Whilst the report itself does not formulate ranges of values as part of a socio-economic study, it does analyse the methodologies predominately used by a Cost-Benefit Analysis to calculate the projects contribution – Total Surplus and GDP and employment. The ITU claim such methods can be used to estimate the benefits from "the provision of a single end-user service"[20].

4.3.4 The GDP and Employment method estimates the contribution the introduction of a radio system makes towards economic activity. This total contribution is a result of the Direct Effect, Forward Linkage, Backward Linkage, Displacement Effect and the Multiplier Effect [Total Contribution = Multiplier Effect(Direct Effect + Forward Linkage + Backward Linkage – Displacement Effect)][21].

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[16] Overview (2011). *International Telecommunications Union*. Retrieved August 25, 2011 from http://www.itu.int/en/about/Pages/default.aspx

[17] Economic Aspects of Spectrum Management (2010). *International Telecommunication Union*. Retrieved August 25, 2011 from http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2012-3-2010-PDF-E.pdf p. 13

[18] Economic Aspects of Spectrum Management (2010). *International Telecommunication Union*. Retrieved August 25, 2011 from http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2012-3-2010-PDF-E.pdf p. 30

[19] "These improvements may include: increased productivity, increased exports, reduced operating costs and increased employment. Improvements in the performance of a business are not only found where radio forms part of the core business (e.g. a telecommunications service provider, radio equipment manufacturer), but also where it is used as a way to support the core business (e.g. a water supply company using telemetry and telecommand to remote reservoirs, a taxi company using mobile radio to pass passenger details to taxis" Economic Aspects of Spectrum Management (2010). *International Telecommunication Union*. Retrieved August 25, 2011 from http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2012-3-2010-PDF-E.pdf p. 31

[20] Economic Aspects of Spectrum Management (2010). *International Telecommunication Union*. Retrieved August 25, 2011 from http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2012-3-2010-PDF-E.pdf p. 31

[21] Economic Aspects of Spectrum Management (2010). *International Telecommunication Union*. Retrieved August 25, 2011 from http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2012-3-2010-PDF-E.pdf p. 33

4.3.5 The Direct Effect represents GDP and employment realised by the use of ICT. Forward Linkage is the "provision by one firm or industry of produced inputs to another firm or industry"[22] whilst Backward Linkage is "the use by one firm or industry of produced inputs from another firm or industry"[23]. The Displacement Effect is a downward revision based on the opportunity cost – If this radio was not being used for this use, it would instead be used in the next best alternative, which would provide GDP. By removing the value of the next best alternative (also known as the transfer earning – "the amount which could be paid for an Factor of Production as it is currently being used to prevent it being used by someone else"[24]), the value of the best alternative above the second best is left (economic rent – "Amount paid above the level of transfer earnings"[25]). The multiplier effect is the GDP generated as wages and profits generated from the use of radio are spread through the economy, which the ITU estimates be a factor of 1.4 times[26].

4.3.6 This total will account for linkage and induced effects. Linkage effects are found in the supply and distribution of goods functioning on Business Radio, which is dependent on demand levels, whilst induced effects are the ripple effects caused by the multiplier effect. The ITU advises the best method to observe the sector level change is using Input-Output tables.

4.3.7 The measurement of total surplus, producer and consumer, measures the aggregate surplus the good or service will achieve, using Alfred Marshall's definition. By measuring the difference between what people would be willing to pay and what they actually pay, the difference between the demand curve and the price, surplus can be accounted – as seen on the 'Consumer Surplus' box. For a good with spillover social benefits, this requires the private benefit curve and social benefit curve to be known as well as the supply curve.

4.3.8 Both methods have advantages and disadvantages described in the ITU report which will be included further on in this report. The ITU does provide a brief evaluation of the use of the different methodologies:

4.3.9

> "GDP is better for assessing the value of multiple uses of radio within a country, or for comparison between individual uses/services, whereas consumer surplus provides more detailed information that may be used, for example, in determining licence fees or reserve auction prices"[27]

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[22] What is forward linkage? Definition and meaning (2011). *Economics-Dictionary.com*. Retrieved August 25, 2011 from http://www.economics-dictionary.com/definition/forward-linkage.html

[23] What is backward linkage? Definition and meaning (2011). *Economics-Dictionary.com*. Retrieved August 25, 2011 from http://www.economics-dictionary.com/definition/backward-linkage.html

[24] What is transfer earnings? Definition and meaning (2011). *Economics-Dictionary.com*. Retrieved August 25, 2011 from http://www.economics-dictionary.com/definition/transfer-earnings.html

[25] What is transfer earnings? Definition and meaning (2011). *Economics-Dictionary.com*. Retrieved August 25, 2011 from http://www.economics-dictionary.com/definition/transfer-earnings.html

[26] Economic Aspects of Spectrum Management (2010). *International Telecommunication Union*. Retrieved August 25, 2011 from http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2012-3-2010-PDF-E.pdf p. 32

[27] Economic Aspects of Spectrum Management (2010). *International Telecommunication Union*. Retrieved August 25, 2011 from http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2012-3-2010-PDF-E.pdf p. 36

4.3.10 While the ITU report does advocate the use of Cost-Benefit Analysis in allocation decisions, it does also realise "... for some assignment decisions cultural/social aspects may be another factor"[28]. Whilst this report is an economic paper and so is concerned solely with justification on economic (but not just monetary) grounds, it is not say there may be other valid justifications, such as income equality, Smart Grids or the green agenda. However, this report focuses on justification of decisions purely on economic grounds.

4.4 'PHYSICAL VULNERABILITY OF ELECTRIC SYSTEMS TO NATURAL DISASTERS AND SABOTAGE')

4.4.1 The 1990 report 'Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage' by The US Office of Technical Assessment has provided the greatest analysis of economic costs arising from blackouts and has been greatly influential in the figures and methodology of this report.

4.4.2 The report clearly outlines that, despite the measures taken by utilities companies, "the consequences of a major, long-term blackout are so great that there is a clear national interest involved. Steps that may not be worthwhile for individual utilities could make sense from the national perspective"[29]. This realises that the market mechanism for utilities, being a quasi-public good, does not provide the incentives for firms to prevent long blackouts which would have greater social impact than private impact because of market failure.

4.4.3 Focusing on the 1977 New York blackout, the report's summary is below, it produces a list of some Direct and Indirect costs of the blackout with cost estimations[30], although it is clearly not comprehensive due to the time and monetary constraints of surveys. It further compiles a list of the components of direct and indirect costs which can be valued for residential, industrial, commercial, agricultural, infrastructure and public service users[31]. There is sectoral impact analysis for Industrial, Commercial, Agriculture, Residential, Transportation, Telecommunication, Emergency Services and Public Services[32].

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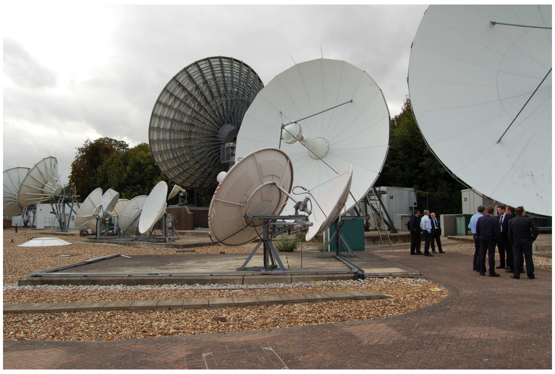
[28] Economic Aspects of Spectrum Management (2010). *International Telecommunication Union*. Retrieved August 25, 2011 from http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2012-3-2010-PDF-E.pdf p. 37

[29] Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage (1990). *Office of Technical Assessment*. Retrieved August 25, 2011 from Congress of the United States, Web site: http://www.fas.org/ota/reports/9034.pdf p. 1

[30] **Table 1 at the bottom of the Report**

[31] **Table 3 at the bottom of the Report**

[32] Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage (1990). *Office of Technical Assessment*. Retrieved August 25, 2011 from Congress of the United States, Web site: http://www.fas.org/ota/reports/9034.pdf p. 23 - 29



4.4.4 The paper calculates a 'Hypothetical Outage Cost Estimate' of $1 - $5 per kWh (using 1990 prices) for blackouts, recognising a large variation in the true economic cost which is dependent on variables such as "type of customer, the conditions of the outage [and] the length of the outage"[33]. It also recognises that some activities are not lost, but merely displaced in time. Unrecovered costs for commercial firms are 20% and 30% for industrial firms. Actual Outage cost estimates are provided from various sources, seen in Table 4[34]. The figures collected use a range of methods which can be re-calculated for UK utilities providers: Wages paid, Gross National Product per kWh, Gross Regional Product per kWh, Cost-Benefit Analysis, Market research data and Survey data. This yielded lower bound estimates of direct costs of $0.66/kWh and indirect costs of $3.45/kWh.

4.4.5 As these reports were conducted by large economic groups over extended periods of time, it is impossible to replicate the level of detail in this report. Cost-Benefit Analysis, Survey data and Market Research data particularly cannot be compiled as completely and therefore could produce meaningless ranges. However, the methods which simplify calculations by introducing assumptions such as equating the damages to regional Gross Domestic Product can be re-calculated and GDP deflators can be applied to the previous figures to create a possible range (GDP deflator is preferable to the Consumer Price Index as it uses a spread of all goods in the economy, including capital goods, and does not count imports, whose production would not have been affected), which can be used against the re-calculated values to evaluate the accuracy.

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[33] Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage (1990). *Office of Technical Assessment*. Retrieved August 25, 2011 from Congress of the United States, Web site: http://www.fas.org/ota/reports/9034.pdf p. 21

[34] **Table 4 at the bottom of the Report**

Box C—New York City Blackout

On July 13, 1977, at approximately 9:41 p.m., New York City plunged into total darkness. The blackout was caused by a series of lightning strikes compounded by improperly operating protective devices, inadequate presentation of data to system dispatcher, and communication difficulties. These combined factors created conditions that cascaded to the point of total collapse of the Consolidated Edison (Con Ed) system.[1]

On this day, Con Ed was providing approximately 5,860 MW of electricity to its New York City customers over 345- and 138-kV transmission lines and cables. Approximately half of the electricity was being generated by plants located in Brooklyn, Manhattan, Queens, and Staten Island; the remaining load was supplied by Con Ed generators outside the city, and purchased from utilities in upper New York State and Canada. Con Ed also was wheeling 240 MW to the Long Island Lighting Co. (LILCO) and approximately 200 MW of emergency power to the Pennsylvania-Jersey-Maryland Pool.

At 8:37 p.m. lightning hit two 345-kV lines supplying 1,200 MW of electricity from the Indian Point No. 3 and the Bowline and Roseton generating units to the City. The resulting short circuit caused the protective relays, located at the Millwood West and Buchanan South substations, to open the circuit breakers and disconnect the lines. This interrupted the supply (870 MW) from Indian Point No. 3, which then shut down automatically. Isolating the generator at Indian Point No. 3 caused one of the 345-kV transmission lines between Pleasant Valley and Millwood West to increase load above its normal capacity rating (825 MW), although it remained within its long-term emergency rating (860 MW). This caused operators to reduce voltage by 8 percent. The Con Ed system operator requested all generators within the city to increase power production to replace the loss and relieve loading on the 345-kV line. However, by 8:55 p.m. the in-city generation had increased (550 MW) only enough to compensate for the two-thirds of the power lost.

Nineteen minutes later, another bolt of lightning hit with a devastating effect. This bolt hit one of the remaining large, heavily loaded 345-kV lines bringing power to the city. Normally, the strike should have caused relays to temporarily isolate the line for mere moments-just long enough to dissipate the lightning's energy. However, one circuit breaker failed to operate properly, causing other relays to isolate the line entirely. This loss of transmission capacity overloaded remaining lines, resulting in their isolation.

With the now inadequate supply of power, Con Ed had no choice but to shed load, blacking out parts of Westchester County. Simultaneously, LILCO's spinning reserves automatically increased output. However, the cables connecting LILCO and Con Ed were overloaded as a result, and LILCO disconnected itself from Con Ed, eliminating a further source of power.

At 9:27 p.m., still another lightning bolt struck a power line. When this happened, the remaining Con Ed generators could not maintain the load and were shut off automatically. At the same time, Public Service Electric & Gas Co. disconnected from the Con Ed system severing Con Ed's remaining ties to the north. At approximately 9:41 p.m. the 1977 New York City blackout began.

Full power was restored in about 25 hours. Many protective circuit breakers had to be individually examined and reset. The city was powered up one section at a time, carefully balancing the added loads with supply, as described in chapter 5.

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[1]Systems Control, inc., *Impact Assessment of the 1977 New York City Blackout,* prepared for the U.S. Department of Energy, July 1978, p. 13.

Source: Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage (1990). *Office of Technical Assessment*. Retrieved August 25, 2011 from Congress of the United States, Web site: http://www.fas.org/ota/reports/9034.pdf p. 22

4.5 EVALUATION

4.5.1 With the limited data set available, it is difficult to discern a representative figure of any credible precision. The Office for Technical Assessment estimated the economic cost of a reduction of electricity supply to 80% peak capacity in Florida in 1978 for 25 days in July/August to be 50 times retail price of electricity[35] but around 120 times retail price for the 1977 outage which lasted just 25 hours[36]. ICF Consulting estimate the effects generally to be around 80 – 120 times the retail price today[37] based upon the calculations in the Office of Technical Assessment whilst the original Office of Technical Assessment estimation was 15 – 75 times based upon consensus among utility analysts at the time.[38]

4.5.2 However, the actual costs shown in table 4 reveal much larger deviation than these ranges for the ratio between the economic cost and the retail price of electricity as shown in the 'Economic costs of Outages' box. If a geometric mean is taken, it doesn't fall near the range, showing a ratio of around 250 times the price. Even the median, which negates outliers more effectively, measures around 150, with a semi inter-quartile range of around 650.

4.5.3 This variation is likely to have been caused not only be the variations described by the Office for Technical Assessment's Report but also due to large changes in society which affect consumers' demand for electricity. Since 1971, when the first figure was taken, economies have become far more dependent on their utilities, increasing the range of the result over such long periods of time. When combined with the inaccuracies caused by asking people to estimate their willingness-to-pay with little actual data to base answers on, the variation is not a surprise. With the further variations of location and time of year, an exceptionally large sample would have to be collected, well beyond the scope of this report – for a confidence interval with 95% confidence to calculate the ratio between economic cost and retail price with the current standard deviation, the sample would have to measure over 30,000 incidents.

4.5.4 To calculate the socio-economic value of Business Radio in reliable electricity supplies is contentious. The most appropriate method may be, rather than calculating an imprecise representative value, to find the minimum ratio at which a Business Radio system, assuming that it would prevent 75%, 50% and 25% of kWh in an outage, would have a positive socio-economic value.

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[35] Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage (1990). *Office of Technical Assessment*. Retrieved August 25, 2011 from Congress of the United States, Web site: http://www.fas.org/ota/reports/9034.pdf p. 23

[36] 'The costs of the 1977 New York City blackout have been studied more extensively than other outages... Based on these figures, the direct cost of unserved energy was $0.66/kWh and the indirect cost was $3.45/kWh.' If the $0.034/ kWh retail price is assumed.
Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage (1990). *Office of Technical Assessment*. Retrieved August 25, 2011 from Congress of the United States, Web site: http://www.fas.org/ota/reports/9034.pdf p. 21

[37] The Economic Cost of the Blackout (2004). *ICF Consulting*. Retrieved August 25, 2011 from http://www.solarstorms.org/ICFBlackout2003.pdf p. 2

[38] '...system outage costs can be valued at something between $1 and $5 per kilowatt-hour(kWh)...' with 1990 retail price of electricity $0.0657/ kWh
Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage (1990). *Office of Technical Assessment*. Retrieved August 25, 2011 from Congress of the United States, Web site: http://www.fas.org/ota/reports/9034.pdf p. 21

4.5.5 The implementation of Business Radio communications systems to support Smart Grids could be optimal in providing resilience and preventing outages. As the radio communications system can monitor all facilities on the network and issue commands to prevent imbalances in networks, it allows the impact of any outage to be minimised and supplies to be restored more quickly than would be the case without private radio systems. As it also incurs benefits not accounted for such as in the positive environmental impacts, green energy production etc. The environmental benefits will remain active at all times as an element of gas turbine generation or coal generation will be averted through better generation management.

5. EXAMINING THE SOCIO-ECONOMIC VALUE OF BUSINESS RADIO IN THE UTILITIES SECTOR

5.0.1 As outlined in the ITU report on the economic aspects of spectrum management, the economic analysis can be made using two methods: surplus or GDP. There are advantages and disadvantages to both which determine the extent to which they can and should be applied to this analysis.

5.0.2 GDP methodologies have the advantage that they provide a monetary equivalent of all added-value services to the product. It is also easily calculated as it is the expenditure needed to obtain the final good, which can be seen at market or through firm records. This should account for all expenditure on the factors of production needed to produce the good. Furthermore, these figures can be compared to other expenditure to provide an opportunity cost of one project against another.

5.0.3 However, this simplistic approach negates non-marketable spill over effects such as environmental damage, income inequalities, health effects, education or other affects on standards of living. With public goods especially, this unaccounted value is where most of the benefit of the good is to be found – discounting this ripple effect grossly underestimates the true value of the good. Furthermore, GDP is a measure of expenditure within an economy in a period of time. By altering GDP from using existing market values to theoretical market values, including non-marketable benefits, it no longer measures GDP unless these theoretical market values become the existing market values through market intervention.

5.0.4 Conversely, surplus measurements will account for the ripple effect and the benefits to society provided from this use against its next best alternative. It also differentiates between the demand and supply of the good at varying quantity levels more effectively as it observes the rate of change across the whole curve rather than just around the equilibrium.

5.0.5 However, this raises large issues in the calculations. The procedure to calculate the supply curve is relatively straight forward, taking the marginal cost of producing each additional unit, if time consuming. The act of calculating the demand curve, finding the average price people would be willing to pay or each combination of units on the market, is not only time consuming but, in many markets, incredibly complex and imprecise. Without the demand curve, it becomes even less accurate and as surplus is not easily comparable with GDP, further calculations are required with more assumptions, reducing its accuracy and precision considerably.

5.1 CALCULATIONS

5.1.1 When calculating the contribution of a Business Radio system, it would be best to use figures and methodologies established in existing reports which have the benefit of much greater levels of research and data available to them. This would avoid exacerbating some of the issues that the ITU report raised about the use of surplus calculations: “time consuming... assumptions have to be used and these may distort results... consumer surplus is not easily comparable with GDP"[39]. Work by the economists who wrote the existing reports will have provided reliable indications of the value of the social benefit in measurements comparable to GDP, making it possible to compare these benefits against the cost of Business Radio investments.

5.1.2 In providing current approximations of social benefit from reliable utility supplies, social benefit figures need to be updated from previous prices to current prices. This will lead to approximations which can be examined against the ratios stated by ICF Consulting and the Office for Technical Assessment. This will hopefully provide any claims are at least partially valid.

5.1.3 After a credible range of values have been identified, the cost of a Business Radio Communications system (cost per kWh) over a period of time can be compared to the range. As it is unlikely that a Business Radio Communication system will prevent all outages, which may still occur from storms, ice, felled trees, vandalism or terrorism, the cost of a Business Radio system will be calculated per kWh weighed against percentage of resilience provided. The weightings will be 75%, 50% and 25% resilience, representing the amount of kWh that the Business Radio system would provide resilience for. As resilience is needed day-to-day, rather than just when an outage occurs, resilience should be measured against all kWh provided (This is the classic argument that you wouldn't get rid of the army just because there is no war at the moment). There is also the day-to-day use of maintenance and safety.

Pareto efficiency: Pareto efficiency, or Pareto optimality, is a concept in economics named after Vilfredo Pareto.

Given an initial allocation of goods among a set of individuals, a change to a different allocation that makes at least one individual better off without making any other individual worse off is called a Pareto improvement. An allocation is defined as "Pareto efficient" or "Pareto optimal" when no further Pareto improvements can be made.

Pareto efficiency does not necessarily result in a socially desirable distribution of resources: it makes no statement about equality, or the overall well-being of a society.

Sources: Barr, N. (2004). Economics of the welfare state. New York, Oxford University Press (USA).

Sen, A. (1993). Markets and freedom: Achievements and limitations of the market mechanism in promoting individual freedoms. Oxford Economic Papers.

5.1.4 Potential Pareto improvements can be evaluated against these ranges. Although the figures are approximate in of limited precisions, the general rule would be that if the economic cost (per kWh) of reliable energy supplies is greater than the weighted cost of the Business Radio Communications systems (per kWh), there is potential Pareto efficiencies to be gained. This means that there is an economic argument for investments to be made to increase social benefit, although the argument for the investment based on private benefit is not necessarily present - especially for public goods. If they are equal, there is no potential improvement and if the cost of the Business Radio system is more than the socio-economic

[39] Economic Aspects of Spectrum Management (2010). *International Telecommunication Union*. Retrieved August 25, 2011 from http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2012-3-2010-PDF-E.pdf p. 36

value, it cannot be justified on grounds of economic benefit. With the weighting system, investments may only be justifiable if it provides a certain level of resilience – the 'critical level'.

5.1.5 The value for this 'critical level' at which a Business Radio Communications System represents a potential Pareto improvement can be compared to the economic cost figures suggested by the reports.

5.2 ESTIMATING THE ECONOMIC COST

5.2.1 to validate the critical economic cost on which conclusion can be based, a range of estimate values needs to be created. This can be done by updating the figures in the Office of Technical Assessment report and comparing the levels to the current retail price of electricity.

5.2.2 To adjust the Office of Technical Assessment figures to its equivalent sterling value today. Purchasing Power Parity exchange rates have been used (Purchasing Power Parity assumes that the relative price of a good in the USA and UK is the same). [See table on next page.] The results reveal a very wide range of values, which is mostly due to the large number of variables which can affect the cost for individual outages beyond merely the length of the outage in question. It does reveal that the lowest figure in the Office of Technical Assessment's report is equivalent to £0.8522/kWh in today's prices for the 1973 New York State blackout. Using the ratio from the period between the economic cost per kWh and the retail price at the time, the minimum ratio of the socio-economic value to the retail price is 16 times. However, the Office of Technical Assessment recommends 'outage costs can be valued at something between $1 and $5 per kilowatt-hour (kWh) for the types of outage commonly experienced'[40]. With the retail price of electricity in 1990 at $0.0657[41], this is a ratio between 15 and 75. This figure encompasses the majority of the data, although there are values above the range too.

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[40] Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage (1990). *Office of Technical Assessment*. Retrieved August 25, 2011 from Congress of the United States, Web site: http://www.fas.org/ota/reports/9034.pdf p. 10

[41] Table 8.10 Average Retail Prices of Electricity, 1960-2009 (2009). United States Energy Information Administration. RETRIEVED AUGUST 25, 2011 FROM, United States Energy Information Administration Web site: http://www.eia.gov/emeu/aer/txt/ptb0810.html

Economic Costs of Outages

Date	Geographic Scope	Estimated Cost$_1$	Inflated figure (2009)$_2$	Equivalent Euros (2009 Value)$_3$	Rate (cost per..)	Retail Price ($/kWh)$_4$	Deflated figure (2009)$_2$	Equivalent Euros (2009 value)$_3$	Ratio
1971	United States	$0.60	$2.68	€1.97	kWh	$0.02	$0.08	€0.06	33
1973	New York State	$0.33	$1.33	€0.98	kWh	$0.02	$0.08	€0.06	17
1976	United States	$2.68	$9.02	€6.64	kWh	$0.02	$0.07	€0.05	122
1976	United States	$7.21	$24.26	€17.87	kWh	$0.04	$0.12	€0.09	195
1977	Canada	$60.00	$184.43	€135.85	kWh	$0.03	$0.10	€0.08	1765
1977	Canada	$91.00	$279.71	€206.04	kWh	$0.03	$0.10	€0.08	2676
1983	Pacific Gas & Electric Power (PG&E)	$6.72	$13.28	€9.78	kWh	$0.07	$0.14	€0.10	96
1983	PG&E	$2,126.00	$4,200.51	€3,094.16	kWh	$0.07	$0.14	€0.10	30371
1986	PG&E	$2.93	$5.06	€3.73	kWh	$0.07	$0.13	€0.09	39
1986	PG&E	$14.61	$25.22	€18.58	kWh	$0.07	$0.13	€0.09	197

The cost of outages adjusted to current Euro equivalent values and the ratio of the Total Economic Cost of the outage to the retail price of electricity at the time. Current GBP figures calculated by use of GDP deflator on values from Office of Technical Assessment Table 4 and then 2009 average exchange rate is applied to convert currency.

Sources: [1]Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage (1990). OFFICE OF TECHNICAL ASSESSMENT. Retrieved August 25, 2011 from Congress of the United States, Web site: http://www.fas.org/ota/reports/9034.pdf p. 21

[2]Historical GDP Deflators for Baseline Countries/Regions (in percent) 1969-2010 (2010). *United States Department of Agriculture*. Retrieved August 25, 2011 from United States Department of Agriculture, Web site: http://www.ers.usda.gov/data/macroeconomics/Data/HistoricalGDPDeflatorValues.xls

[3]Foreign Currency Units per 1 U.S. Dollar, 1948-2009 (2009). PACIFIC EXCHANGE RATE SERVICE. Retrieved August 25, 2011 from The University of British Columbia, Sauder School of Business Web site: http://fx.sauder.ubc.ca/etc/USDpages.pdf Exchange rate pounds sterling to Euros 0.86774: European Central Bank rate average January – July 2011

[4]Table 8.10 Average Retail Prices of Electricity, 1960-2009 (2009). UNITED STATES ENERGY INFORMATION ADMINISTRATION. Retrieved August 25, 2011 from, United States Energy Information Administration Web site: http://www.eia.gov/emeu/aer/txt/ptb0810.html

5.2.3 If the view is taken that a Business Radio Communication System is only provided to prevent outages, and thus its value should only be judged against this, the National Energy Technology Laboratory for the US Department of Energy identifies annual costs to the US economy from power disturbances which might be prevented by the deployment of a private radio system.

5.2.4 Events such as the outage in New York on 14th August 2003 have large socio-economic costs. That event cost the economy $10 billion[42]. The National Energy Technology Laboratory report also states 'the annual cost of power disturbances to the US economy is enormous (of the order of $100 billion according to EPRI)'[43] which more advanced Business Radio systems could drastically reduce. Although the economies have difference facets, this translates to roughly £60 billion a year to the UK economy[44]. If this is converted to kWh, with National Grid stating 314.7 TWhrs was generated in 2010/11 (weather adjusted)[45], it is equivalent to £0.1906/kWh. Although this is of a similar order to the current retail price of electricity, providers are not willing to invest greatly in systems which prevent these loses as they do not incur the full socio-economic cost of outages, and would therefore not reap the benefits of any savings.

5.2.5 Currently existing Business Radio systems, although not comprehensively deployed around the New York outage in 2003, can contribute to mitigating outages. A system for the UK would cost around £100 million for a 10 year working life. Without accounting for growth of demand in electricity, and thereby assuming consumption of 314.7 TWh a year, the amortised cost of the system on a simplistic basis would be £10 million per annum, or £0.0000318/kWh. This needs to be adjusted for the amount of resilience that the system would provide – the London 2003 outage proves that current systems are not without fault. This equates to £0.0000424/kWh, £0.0000636/kWh and £0.000127/kWh for 75%, 50% and 25% resilience respectively. This demonstrates that Business Radio represents a Pareto improvement and is economically viable.

5.2.6 Systems using similar technology are used by National Grid, although they carry communications by fibre optic cables threaded through the earth wire running along the top of the pylons, rather than radio-based systems. Distribution companies also have limited access to fibre optic cables installed when power cables are renewed, together with copper pilot cables installed with the original electricity conductors. However, distribution companies do not have a sufficiently comprehensive network of fibre optic or copper telecommunications cables to be able them to monitor and control the networks without access to third-part telecommunications networks or self-provided radio links.

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[42] Modern Grid Benefits (2007). *National Energy Technology Laboratory Modern Grid Initiative*. Retrieved August 25, 2011 from United States Department of Energy, Office of Electricity Delivery and Energy Reliability Web site:
http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/Modern%20Grid%20Benefits_Final_v1_0.pdf p. 6

[43] Modern Grid Benefits (2007). *National Energy Technology Laboratory Modern Grid Initiative*. Retrieved August 25, 2011 from United States Department of Energy, Office of Electricity Delivery and Energy Reliability Web site:
http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/Modern%20Grid%20Benefits_Final_v1_0.pdf p. 4

[44]Exchange rate $1 = £0.605179 Retrieved August 24, 2001 from Web Site:
http://www.xe.com/ucc/convert/?Amount=1&From=USD&To=GBP

[45] National Electricity Transmission System (NETS) Seven Year Statement (2011). *National Grid*. Retrieved August 25, 2011 from, Web site: http://www.nationalgrid.com/NR/rdonlyres/D4D6B84C-7A9D-4E05-ACF6-D25BC8961915/47015/NETSSYS2011Chapter2.pdf p. 11

5.2.7 Although distribution companies will usually install fibre optic cables within electricity supply cables when renewing assets, it is not feasible to install fibre optic cabling within existing underground electricity cables; and difficult to cost justify to retrofit on overhead lines or ducted cables. With an asset life of the order of 50 years, it is not cost justifiable to replace an electricity cable simply to add a telecommunications capability. Furthermore, where a communications facility is damaged or fails, it is not usually feasible to repair the telecommunications facility without causing disruption to the electricity supply, a situation often not acceptable to consumers, necessitating installation of a radio link to circumvent the breakage. In addition, where only a section of electricity cable is replaced, there will be no connectivity for an accompanying fibre optic cable if installed only on the new section of cabling; and hence no immediate business case for installing a fibre in the new section of cable.

5.2.8 There can also be an issue with the additional cost of a fibre where a communications facility is damaged or fails. It is not usually feasible to repair the telecommunications facility without disruption to the electricity supply, a situation often not acceptable to consumers. In addition, where only a section of electricity cable is replaced, there will be no connectivity for an accompanying fibre optic cable if installed only on the new section of cabling.

5.2.9 Thus, distribution companies need access to radio systems for network monitoring and control as commercial telecommunications systems and self-provided fixed telecommunications circuits are not always a viable option for controlling the network infrastructure.

5.2.10 The benefit of robust automatic control systems has been empirically proven, for example, comparing the outage in London in 2003 with the New York outage in 2003. As a further example, informed monitoring enabling rapid intervention by control engineers in the UK on 27 May 2008 prevented a cascade failure following the unrelated failure of two major sources of generation in the British National Grid. However, with local generation increasing and increasing uncertainty of load on the grid, these events may start to become more common in the future as the present infrastructure becomes further and further out of date. For 21st century generation, a new grid architecture needs to be devised. This is commonly referred to as Smart Grids.

5.3 SMART GRID

Changing Conditions That Affect System Reliability

Previous Conditions	Emerging Conditions
Fewer, relatively large resources	Smaller, more numerous resources
Long-term, firm contracts for energy supply	Energy contracts shorter in duration, and subject to trading; more non-firm transactions, fewer long-term firm transactions
Bulk power transactions relatively stable and predictable	Bulk power transactions relatively variable and less predictable
Assessment of system reliability made from stable base (narrower, more predictable range of potential operating states)	Assessment of system reliability made from variable bass (wider, less predictable range of potential operating states)
Limited and knowledgeable set of utility players	More players making more transactions, some with less interconnected operation experience; increasing with retail access
Unused transmission capacity and high security margins	High transmission utilisation and operation closer to security limits
Limited competition, little incentive for reducing reliability investments	Utilities less willing to make investment in transmission reliability that do not increase revenues
Market rules and reliability rules developed together	Market rules undergoing transition, reliability rules developed separately
Limited wheeling (ie dynamic system changes)	More system throughput

Source: Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations (2004). U.S.-CANADA POWER SYSTEM OUTAGE TASK FORCE. Retrieved August 25, 2011 from, Web site: http://www.doe.gov/sites/prod/files/oeprod/DocumentsandMedia/BlackoutFinal-Web.pdf p. 104

5.3.1 The current grid system has several conditions emerging which are root causes of recent blackouts and, as the network expands, will continue to become even bigger problems with increased, sporadic load and local generation.

5.3.2 The US-Canada Power System Outage Task Force lists the causes of recent US power outages, which largely comprises of increasing imbalances, operating procedure and human error.[46] The system reliability issues which lead to such events are mostly because the out-dated grid networks cannot cope with current conditions, which differ from when the grid was created, as seen in the box above. Recommendations by the report call for updated resilience in the network to reduce vulnerabilities.[47]

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[46] Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations (2004). U.S.-CANADA POWER SYSTEM OUTAGE TASK FORCE. Retrieved August 25, 2011 from, United States Department of Energy Web site: http://www.doe.gov/sites/prod/files/oeprod/DocumentsandMedia/BlackoutFinal-Web.pdf p.104

Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations (2004). U.S.-CANADA POWER SYSTEM OUTAGE TASK FORCE. Retrieved August 25, 2011 from, United States Department of Energy Web site: http://www.doe.gov/sites/prod/files/oeprod/DocumentsandMedia/BlackoutFinal-Web.pdf Chapter 10: p. 139-170

5.3.3 The National Energy Technology Laboratory for the US Department of Energy sees Smart Grids as the way to address these needs at a cost efficient level. Features of the new grid, such as self-healing through continuous assessment and analysis, greater resilience and better power quality virtually eliminate the possibility of cascade outages and have environmental benefits from reduced loses in transmission and better allocation of green energy.[48]

5.3.4 The socio-economic argument in the National Energy Technology Laboratory report appears to be strong, claiming social benefits of $638-802 billion compared to the $165 billion cost over 20 years and a cost-benefit ratio of 4 to 1.[49] The report sees the grid as having the potential to save $40 billion per annum[50] and reduce the 1000 fatalities and 7000 flash burn injuries which occur in the US each year[51]. The main benefit to European economies comes from the ability to better accommodate local green energy production and increase resilience, preventing green energy provision from tripping the grid. With less reliance on fossil fuels, there should be reductions in CO_2, NO_X and SO_X emissions[52].

5.3.5 As well as more extensive application of existing technologies, new technologies are emerging offering the prospect of more efficient management using demand-side management techniques to balance supply and demand on a more dynamic basis.

5.3.6 A low latency wide area measurement capability will provide real-time and historical information about the state or predicted behaviour of the transmission grid using a network of precisely timed monitoring devices variously called synchrophasors or phasor measurement units.

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[48] Modern Grid Benefits (2007). *National Energy Technology Laboratory Modern Grid Initiative*. Retrieved August 25, 2011 from United States Department of Energy, Office of Electricity Delivery and Energy Reliability Web site: http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/Modern%20Grid%20Benefits_Final_v1_0.pdf p. 2

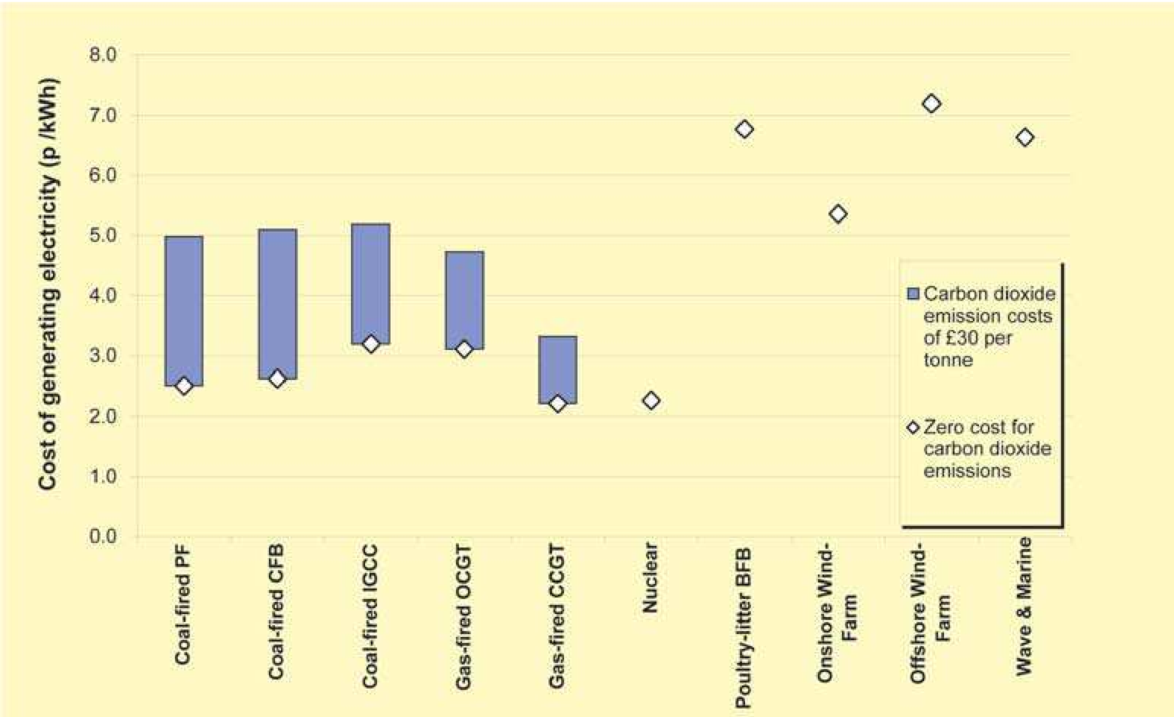
[49] Modern Grid Benefits (2007). *National Energy Technology Laboratory Modern Grid Initiative*. Retrieved August 25, 2011 from United States Department of Energy, Office of Electricity Delivery and Energy Reliability Web site: http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/Modern%20Grid%20Benefits_Final_v1_0.pdf p. 14

[50] Modern Grid Benefits (2007). *National Energy Technology Laboratory Modern Grid Initiative*. Retrieved August 25, 2011 from United States Department of Energy, Office of Electricity Delivery and Energy Reliability Web site: http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/Modern%20Grid%20Benefits_Final_v1_0.pdf p. 15

[51] Modern Grid Benefits (2007). *National Energy Technology Laboratory Modern Grid Initiative*. Retrieved August 25, 2011 from United States Department of Energy, Office of Electricity Delivery and Energy Reliability Web site: http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/Modern%20Grid%20Benefits_Final_v1_0.pdf p. 8

[52] Modern Grid Benefits (2007). *National Energy Technology Laboratory Modern Grid Initiative*. Retrieved August 25, 2011 from United States Department of Energy, Office of Electricity Delivery and Energy Reliability Web site: http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/Modern%20Grid%20Benefits_Final_v1_0.pdf p. 13

Cost of Energy Generation in the UK



The graph shows the cost of electricity generation with the additional cost of the carbon tax applied to generation which produces Carbon Dioxide of £30 per tonne of Carbon Dioxide emitted.

Source: The Cost of Generating Electricity (2004). *The Royal Academy of Engineering*. Retrieved August 26, 2011 from, United States Department of Energy Web site: http://www.raeng.org.uk/news/publications/list/reports/Cost_of_Generating_Electricity.pdf p. 11

5.3.7 Synchrophasors are devices which enable the phase relationships across a distribution or transmission network to be monitored, ultimately offering the possibility of real-time comparisons of these phase relationship to enable control of the networks to enhance stability. This will enable a distribution network operator to steer their network more precisely in response to transmission operator requirements. This reduces the likelihood of major cascading blackouts.

5.3.8 If a Smart Grid was applied to the UK at the same cost as in the US, the $165 billion cost of Smart Grid over 20 years would cost around £100 billion. The report ‘Energy consumption in the UK’ by the department of trade and industry place energy consumption growth between 1990 and 2001 at 1% a year after being adjusted for temperature and, other the 20 year period, this provides a total of 6929.38 TWh. At a cost of £100 billion over these 20 years, an estimated cost would be £0.0144/kWh. Discounting this figure by 75%, 50% and 25% presents estimated costs of £0.0192/kWh, £0.0289/kWh and £0.0577/kWh respectively.

5.3.9 This cost is considerably lower than the retail price of electricity and so lower than people’s willingness-to-pay for reliable energy supplies. It is also less than the losses companies face each year from the outages. However, depending on the generation source and the resilience it provides, it can be as expensive as the cost of generation, as shown in the 'Cost of Energy Generation in the UK' box, and, with existing Business Radio systems providing resilience at a much lower cost due to its compatibility with existing infrastructure, it is clear why companies are reluctant to make such investments as part of a business plan. However, the socio-economic argument says that even if a Smart Grid only provided 10% resilience against losses caused by outages only, albeit based upon crude calculations and assumptions, it would still yield a potential Pareto improvement for the UK economy.

5.3.10 In addition to the resilience benefits of enhanced communications in the electricity networks, research in the UK demonstrates that optimising responsive demand has the potential to reduce the system peak and the need for system reinforcement by a very considerable amount. At the national level, full penetration of Electric Vehicles and Heat Pumps could increase the present daily electricity consumption by about 50%, while doubling the system peak (requiring in turn significant generation and network reinforcements). However, by optimising demand response the peak increase could be restricted to only 29%, resulting in massively improved utilisation of generation and network capacity, and significantly reduced network investment. At the local distribution network level, significant benefits of optimising demand response in relation to the network capacity are observed even for very low levels of penetration of electric vehicles and heat pumps.[53]

6. CONCLUSIONS

6.0.1 Whilst energy providers may remain cautious about the business benefits of investing in next generation grid infrastructure, there is a clear socio-economic argument for the wider application of currently available wireless-based communications systems into utility networks based on the analysis contained within this report.

6.0.2 Furthermore, there are even greater socio-economic benefits to be had from the introduction of next generation infrastructure using business radio communication systems as part of a smart grid, but their economic characteristics as a quasi-public good means that providers will be unwilling to invest as the private benefit is not sufficient. Commercial organisations have a primary duty to protect the interests of their shareholders, not to act as a support mechanism for a quasi-public good.

6.0.3 In addition to the economic arguments around business radio communication systems, there are also great daily environmental, efficiency and safety benefits to be had from the implementation of advanced radio systems as well as their contribution to avoiding outages and the associated economic damage which has been observed in the reported incidents.

6.0.4 In addition to evaluating business radio communications systems, this report has aggregated some of the existing data to be found on the value of utilities to society and, on a broader scale, the need for government to provide tailored support to Critical National Infrastructure sectors to enable the realisation of potential Pareto improvements in the economy.

6.0.5 Whilst this report has not specifically identified alternative market mechanisms (which is outside its scope), there are drawbacks in auction market mechanisms when long term investment is concerned.

6.0.6 All industries face risks in a competitive climate, but government must provide a degree of certainty where substantial social benefit is involved, such as in Critical National Infrastructure sector markets.

[53] "Benefits of Advanced Smart Metering for Demand Response based Control of Distribution Networks", Centre for Sustainable Electricity and Distributed Generation, Imperial College, London UK, 2010

6.0.7 The study into socio-economic values for Business Radio has found that figures for its value range considerably as they are dependant on a vast array of variables, some independent and some dependent. However, the socio-economic value of reliable electricity supplies which business radio systems support can be said to have a minimum range of values between 50 – 150 times the retail price of the electricity supplied. Furthermore, GDP figures alone do not fully reflect societies true demand for resilient supplies as established by Cost-Benefit Analysis or surveys due to the 'Free-Rider Effect' in (quasi)public good markets.

6.0.8 Nevertheless, business radio communications systems can be justified on economic grounds to provide resilience. However, firms may need government assistance to accelerate the implementation of smart grid systems. As well as needing confidence that the spectrum they need will be available to them, the costs of the systems may have an impact. These costs are significant compared to existing technology and, with restrictions on utilities bills, this would make firms reluctant to upgrade existing networks. A role of government, as well as creating market conditions to stimulate investment, would be to ensure that firms can recover the costs of the investment.

6.0.9 In researching the socio-economic value of business radio communications systems, particularly pertaining to the utilities markets, facets about existing research have also come to light. It appears that many Critical National Infrastructure representative bodies have been highlighting potential vulnerabilities in their networks, compromising resilience for the last 20 years. Having realised the elements of market failure which were preventing firms investing – the Free Rider Effect – government action has formed parts of recommendations made. The US-Canada Power System Outage Task Force 'Final Report on the August 14, 2003 Blackout in the United States and Canada' and The Office of Technical Assessment 'Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage' are just two examples.

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EUROPE THE INDEPENDENT 19

Europe suffers worst blackout for three decades

By Stephen Castle
Europe Correspondent

One of the worst and most dramatic power failures in three decades plunged millions of Europeans into darkness over the weekend, halting trains, trapping dozens in lifts and prompting calls for a central European power authority.

The blackout, which originated in north-western Germany, also struck Paris and 15 French regions, and its effects were felt in Austria, Belgium, Italy and Spain. In Germany, around 100 trains were delayed, and in the French capital firemen responded to 40 calls from those trapped in lifts late on Saturday night. However, the Eiffel Tower and other monuments remained illuminated, the metro kept running and there were no reports of injuries.

The power loss came about when Germany's network became overloaded, probably as a result of a routine shut down of a high-voltage transmission line under the Ems river to allow a ship to pass by safely.

The fallout from the incident, said to be one of the worst since the 1970s, left engineers and politicians aghast, and underlined the interdependence of European countries' electricity grids.

Parts of western Germany, including the Ruhr region, were without power for half an hour, delaying scores of trains for up to two hours.

In France, five million people were left without electricity, including many in Paris.

In Italy, while the main effects were concentrated in Piedmont and Liguria in the north-west, the blackout even touched Puglia, in the country's south-east.

Belgium was affected, with the cities of Antwerp, Ghent and Liege among the areas hit. Meanwhile, the Spanish network Red Electrica said parts of Madrid, Barcelona, Zaragoza and the region of Andalucia suffered power loss too.

Work was under way yesterday to try to identify why such a routine operation provoked such a massive power failure.

Romano Prodi, the Italian premier, said from his native city of Bologna that the incident suggested that Europe needed to strengthen its co-ordination of power supplies. "My first impression is that there is a contradiction between having European [power] links and not having one European [power] authority," he said. "We depend on each other with being able to help each other, without a central authority."

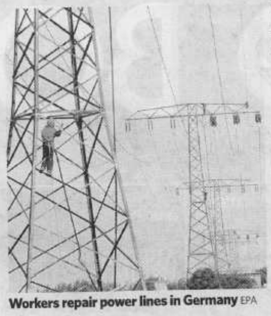
The likely Socialist candidate in France's presidential elections, Ségolène Royal, also called for the creation of a centralised European electricity authority. "One of the things at stake in the relaunching of Europe will be big policy areas like energy," she said.

Energy has become a priority area for EU policymakers during the past year. A summit last month in Finland was dominated by discussions with Russia's President Vladimir Putin on energy security.

The European Commission is investigating the structure of the EU's power market and whether the Continent's giant firms need to be broken up to encourage greater competition.

Meanwhile, the inquest into the latest incident has begun. The German power giant E.On said it had shut down transmission lines in the past without causing problems, and was investigating why this operation went so badly wrong.

Theo Horstmann, of RWE AG, another German power firm, said the shortage had caused substations across Europe to shut down automatically to prevent further damage.



Workers repair power lines in Germany EPA

Blackout zone

Areas affected by the power cut

6.0.10 While there are also social, cultural and environmental arguments to be debated around the application of radio communications in Critical National Infrastructure, this report is solely devoted to the economic arguments. The objective is to investigate the socio-economic value of business radio and whether the costs involved can be justified as they provide a potential Pareto improvement, benefiting society. Based upon the figures provided, there is an argument that such systems would be of great benefit based upon their socio-economic value. However, it is worth noting that it will require government intervention in the market to provide industries with certainties about the availability of spectrum and the collection of revenue. Despite this, present evidence suggests a large socio-economic value for business radio in quasi-public good markets, such as the market for electricity where business radio supports provision of resilient supply with a social benefit 50 to 150 times the private benefit.

6.0.11 As this report relies on historic data, and western society becomes increasingly dependent on a reliable electricity supply to sustain its standard of living, the societal benefit ratio is likely to be moving towards the higher end of the ratio, possibly exceeding 150 times in the current position.

6.0.12 The report draws mainly on work undertaken in the UK and USA. More research is necessary to determine how much equivalent work is available for other European countries; and if insufficient research has been undertaken, additional work commissioned to understand how the socio-economic value of spectrum varies across the EU.

6.0.13 Further research is also necessary to look forward into a world increasingly dependent on a reliable supply of electricity to sustain its lifestyle; and to explore the impact of new policy imperatives associated with climate change, greenhouse gas reduction and security of supply on the socio-economic value of spectrum used by utilities in support of their operational requirements.

7. ACKNOWLEDGEMENTS

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Table 5 – Cost of the New York City Blackout – 1977[a]

Impact Areas	Direct ($M)		Indirect ($M)	
Businesses	Food spoilage…	1.0	Small Businesses	155.4
	Wages lost…	5.0	Emergency aid (private sector)…	5.0
	Securities Industry…	15.0		
	Banking Industry…	13.0		
Government (Non-public services)			Federal Assistance Programs…	11.5
			New York State Assistance Program…	1.0
Consolidated Edison	Restoration costs…	10.0	New capital equipment (Program and installation)…	65.0
	Overtime Payments…	2.0		
Insurance[b]			Federal crime Insurance…	3.5
			Fire Insurance…	19.5
			Private property Insurance…	10.5
Public Health Services			Public hospitals-Overtime, emergency room charges…	1.5
Other public services	Metropolitan Transportation Authority (MTA) revenue: Losses…	2.6	MTA vandalism…	0.2
			MTA new capital equipment required…	11.0
	MTA overtime and unearned wages…	6.5	Red Cross…	0.01
			Fire Department overtime and damaged equipment…	0.5
			Police Department overtime…	4.4
			State Courts overtime…	0.5
			Prosecution and correction…	1.1
Westchester County	Food spoilage…	0.25[c]		
	Public services: equipment damage, overtime payments…	0.19		
Totals…		**$55.54**		**$290.16**

[a]Based on aggregate data collected as of May 1,1978.
[b]Overlap with business losses might occur since some are recovered by insurance.
[c]Looting was included in this estimate but reported to be minimal.
NOTE: These data are derivative, and are neither comprehensive nor definitive
SOURCE: Systems Control, Inc., Impact Assessment of the 1977 New York City Blackout, prepared for the U.S. Department of Energy, July 1978, p. 3

Source: Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage (1990). *Office of Technical Assessment*. Retrieved August 25, 2011 from Congress of the United States, Web site: http://www.fas.org/ota/reports/9034.pdf p. 23

Table 3—Direct and Indirect Costs

Primary electricity user	Direct cost components (costs to household, firm, institution, etc.)	Indirect rests	Remarks
Residential……………	a. Inconvenience, lost leisure, stress b. Out-of-pocket costs —spoilage —property damage c. Health and safety	a. Costs on other households and firms b. Cancellation of activities c. Looting/vandalism	Indirect costs are a minimal, if not negligible, fraction of total (direct and indirect) costs of a Curtailment.
Industrial, commercial, and agricultural firms……………	a. Opportunity costs of idle resources —labour —land —capital —profits b. Shutdown and restart costs c. Spoilage and damage d. Health and safety effects	a. Cost on other firms that are supplied by impacted firms (multiplier effect) b. Costs on consumers if impacted firm supplies a final good c. Health and safety-related externalities	Indirect effects are likely to be minimal for most capacity-related interruptions, but can be significant component of total costs for longer duration energy shortfalls.
Infrastructure and public Service……………	a. Opportunity cost of idle resources b. Spoilage and damage	a. Costs to public users of impacted services and institutions b. Health and safety effects c. Potential for social costs stemming from Looting and vandalism	Indirect costs constitute a major portion of total costs of curtailment.

SOURCE: M. Munasinghe and A. Sanghvi, "Reliability of Electricity supply, Outage Costs and Value of Service: An Overview," The Energy Journal, vol. 9, 19s8, p. 5.

Source: Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage (1990). *Office of Technical Assessment*. Retrieved August 25, 2011 from Congress of the United States, Web site: http://www.fas.org/ota/reports/9034.pdf p. 20

Table 4—Comparison of Cost Estimates for Power Outages[1]

Date	Geographic scope	Estimated cost
1971	New York State	$2.17 million/hr[a]
1971	New York City	$2.5 million/hr[a]
1971	United States	$0.60/kWh[b]
1973	United States	$0.33/kWh[c]
1976	United States	$1 kWh[d]
1976	United States	$2.68/kWh (industrial) $7.21/ kWh (commercial)
1977	Canada	$15/kW (15-minute outage) $91/kW (1 –hour outage)
1978	New York City	$4.1 kWh
1983 [2]. . . .	PG&E service area	$14.87 to reduce outages to a minimum[e] -$26.41 to tolerate 1,400 hours additional outages
1983 [3]. . . .	PG&E service area	$6.72/kWh (one 1-hr outage, summer afternoon)[f] $2,126/kWh (eight 48-hr outages, summer afternoon)
1986 [4]. . . .	PG&E service area	$1.35/outage/year (momentary)[g] $39/outage/year (12 hrs, winter morning)
1986 [5]. . . .	PG&E service area	$2.93/kWh (4hrs, winter morning, 3.15 kWh unserved)[h] $14.61/kWh (1 hr, winter evening. 0.75 kWh unserved)

[a]Based on wages paid.

[b]Based on GNP/kWh ratio.

[c]Based on GRP/KWh ratio.

[d]Based on cost-benefit analysis.

[e]Residential, based on market research data.

[f]Commercial, based on survey data. Reflects total direct cost range of $3,515 to $1,112,092.

[g]Residential, based on customer survey data.

[h]Residential, based on contingent valuation data.

SOURCES:

[1] Unless otherwise noted, the material in this table is from William T. Miles, Jane Corwin, and Peter D. Blair, "Cost of Power Outages-The 1977 New

York City Blackout," paper presented at the IEEE 1979 Annual Meeting, Seattle, WA, May 14-17, 1979, and sources cited therein.