Supporting Local Energy Efficiency as an Alternative to Network Reinforcement

June 2015

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Delivering innovative energy saving solutions

Foreword by Jenny Saunders, National Energy Action

National Energy Action is a leading fuel poverty charity working across the UK. National Energy Action undertakes a range of activities, including research and analysis into the causes and extent of fuel poverty; campaigning for strategic action to make homes warmer and energy bills lower for the poorest and most vulnerable; local demonstration projects and developing and delivering national training and qualifications to improve the quality of energy advice and services to vulnerable households. National Energy Action has developed partnership arrangements and delivery projects with both gas distribution networks and distribution network operators and worked with Northern Powergrid on the Customer Led Network Revolution project. We have been delighted to work with AgilityEco and Northern Powergrid on this collaborative study investigating the potential for distribution network operators to make alternative investments such as domestic energy efficiency to avoid network reinforcement costs.

We hope the results present some tangible opportunities to combine environmental, social and economic imperatives whilst delivering lasting benefits for Northern Powergrid's customers. I know from my work on Northern Powergrid's Social Issues Expert Group and our previous work together that this is a growing priority within your business. I am confident you will give careful consideration to the research outcomes and to proactively take forward the opportunities identified. We will also continue to support a suitable regulatory framework that incentivises and recognises the benefit and cost effectiveness of alternative investments across all network companies. We also note that this will require the willingness of a range of players to engage with you and we therefore highlight how projects can be developed to meet the shared objectives of a number of parties.

Finally, we would like to thank all those at Northern Powergrid that have invested their time and energy into this study. We would not have been able to complete this investigation without you and we are grateful for your enthusiastic support.

Jenny Saunders OBE
Chief Executive

National Energy Action (NEA)

Foreword by John Barnett, Northern Powergrid

National Energy Action is a key partner of Northern Powergrid. Our collaboration challenges and influences our social responsibility plans and ambitions. National Energy Action recently lobbied Ofgem and government, arguing that distribution network operators should maximise their social reach by considering their investment in the network in the wider context of fuel poverty alleviation. Northern Powergrid is pleased to respond to that challenge.

In the context of our customers sending us strong signals to improve our service whilst keeping prices down, it is important that we remain open to opportunities to invest even more efficiently. New ideas and projects such as the one investigated in this report will help us achieve this goal.

We have partnered with National Energy Action in order to explore the premise that in some cases, permanently reducing peak energy demand is socially, financially, and environmentally better than creating extra capacity in the network to cope with increased peak demand. This report explores parts of that premise.

AgilityEco has produced a report that will shift the nature of the discussion from the abstract to the factual. It starts exploring some of the questions that spring to mind while considering this idea, and creates a stepping stone for further work. Some uncertainty remains, and the onus is now on ourselves and our partners to do more work in depth to understand better the constraints and opportunities identified in this report for distribution network operators to help alleviate fuel poverty.

John Barnett
Commercial Director

Northern Powergrid

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About Northern Powergrid

Northern Powergrid runs the only major electricity distribution network that provides power to customers in the Northeast, Yorkshire and north Lincolnshire.

We move electricity to and from homes and businesses over our network – we don't sell electricity, neither do we operate power stations. We take electricity from National Grid's transmission network (which connects the larger power stations) and from smaller generators (such as wind farms) that are directly connected to our network.

Our network consists of 61,000 substations, and around 91,000 km of overhead wires and cables. We distribute power to some 3.9 million properties. We operate as one company but we are regulated by the energy regulator, Ofgem (the Office of Gas and Electricity Markets), as two licensed businesses: Northern Powergrid (Northeast) Ltd and Northern Powergrid (Yorkshire) plc.

We are amongst the larger businesses in our region. We directly employ over 2,200 people, and also engage contractors and their staff who work with us to keep the lights on in our part of the country.

Contact: yourpowergrid@northernpowergrid.com

About National Energy Action

National Energy Action is a leading fuel poverty charity working across the UK. We undertake a range of activities, including research and analysis into the causes and extent of fuel poverty; campaigning for strategic action to make homes warmer and energy bills lower for the poorest and most vulnerable; local demonstration projects and developing and delivering national training and qualifications to improve the quality of energy advice and services to vulnerable households.

We have developed partnership arrangements and delivery projects with both gas distribution networks and distribution network operators and worked with Northern Powergrid on the Customer Led Network Revolution project. We have been delighted to work with AgilityEco and Northern Powergrid on this collaborative study investigating the potential for distribution network operators to make alternative investments such as domestic energy efficiency to avoid network reinforcement costs.

Contact: info@nea.org.uk

About AgilityEco

AgilityEco provides a range of professional services to clients in both the public and private sectors in the area of energy efficiency. First and foremost we offer unrivalled knowledge of residential carbon reduction policy in the UK. We use this to help our clients unpick complex support mechanisms so that they can unlock funding opportunities for energy efficiency projects. With a wealth of experience in the energy sector, both within major energy utility and energy efficiency delivery businesses, we also have the knowledge, experience and contacts to deliver advisory and consultancy assignments across the energy, energy efficiency and low carbon sectors.

Contact: enquiries@agilityeco.co.uk

Executive Summary

Project rationale and methodology

Fuel poverty is a major social issue in the UK, because of the amount of people affected, and of the way it affects people[1].The report investigates the potential for electricity network operators to make a direct contribution to preventing fuel poverty, by investing in domestic energy efficiency[2] improvements.

The benefits to the network are identified in the following way: improved energy efficiency may lead to permanent demand reduction, which may in turn lead to reduced peak demand, which may offset the need for network reinforcement. Based on this premise, NEA is asking if there a possibility to divert any part of the budget allocated to load-related network upgrade schemes into local schemes that improve energy efficiency for those who need it the most. This idea is referred to as Alternative Investment Strategy (AIS).

Current practices of network planning ensure that reinforcement investment is done on a need basis, and once alternative, cheaper solutions (such as circuit reconfiguration) have been explored. However, the AIS idea challenges current network planning processes and its viability within the electricity infrastructure world is dependent on many factors. This report seeks to explore a few by answering three key questions:

- “Size of the Prize”: What proportion of Northern Powergrid’s core investment budget could be spent towards domestic energy efficiency under the AIS premise?
- “Economic Feasibility”: how competitive is investment in local energy efficiency likely to be compared to conventional network reinforcement?
- “Practical Feasibility”: how feasible would it be for Northern Powergrid to identify and financially support the required local energy efficiency initiatives?

Results

Our investigation of the “**Size of the Prize**” consisted in analysing the past and future expenditure made by Northern Powergrid, in order to record the load- related line items that could theoretically be spent towards energy efficiency as an alternative to increasing capacity of the network. The potential prize adds up to £5.2m per year, or 1.4% of the capital investment of Northern Powergrid. There are several pre-requirements for a network reinforcement scheme to be replaced by an energy efficiency improvement scheme, so this represents the maximum that the DNO (including customer contribution to customer-driven reinforcement) could spend per year in energy efficiency. It is a significant amount.

From our investigation of the **economic feasibility** of AIS, we concluded on the basis of a relatively simplistic analysis that there are measures (such as low energy lighting and water heating time switching) which may be competitive on cost-effectiveness

[1] The National Energy Action estimate that at least 30,000 have perished prematurely in the last five years due to an inability to adequately heat their homes, and over 100,000 British citizens could die in the next 15 years for the same reason.

[2] Energy efficiency is a way of managing and restraining the growth in energy consumption. Something is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input. Demand reduction delivered from energy efficiency gain differs from demand-side response, which delivers temporary load reduction, or “peak-shifting”.

grounds for AIS without further subsidy. However, projects involving low energy lighting alone are unlikely to deliver sufficient peak winter demand reduction to be an alternative for low voltage reinforcement projects, which tend to affect small numbers of households. Furthermore, due to constraints on time and resource, this analysis did not take into account issues such as the impact of “diversity” or the rate of take-up of low carbon grid technologies. This more rigorous analysis will need to be carried out in future research work.

A variety of government schemes provide subsidy for energy efficiency measures, supplementing the potential AIS support and enabling these measures to compete with conventional reinforcement expenditure – in these cases AIS could act as “gap-funding”, enabling projects that are not feasible with funding only from these government schemes to become feasible. We noted in particular that measures affecting the efficiency of electrically heated homes are worthy of strong consideration for AIS, in particular insulation and heating improvements/replacement. These measures may be key at the low voltage level, where a high impact per home is needed to deliver on a scale that benefits the network.

From our analysis of **practical feasibility,** we concluded that the most acute need for energy efficiency improvement is located, generally speaking, in similar locations to those places where Northern Powergrid has a track record of investing in reinforcement. This geographical overlap indicates that there are likely to be various options to put AIS into practice, including AIS which only requires gap-funding by Northern Powergrid. Some areas may provide more opportunities than others for AIS. For example, Leeds, which has a high concentration of Northern Powergrid investment, is likely to provide many opportunities due to relatively high population density, high deprivation and high penetration of electrically heated housing.

Case studies show that within a wide variety of outcomes, excellent peak winter demand reductions can be achieved at relatively low cost, particularly where this is an explicit aim of the project. This creates a positive background for developing the idea of AIS further.

Our investigation of the regulatory environment shows no barriers, although clarification of statements at European level could be helpful to pave the way for a more active DNO role through AIS.

This project represents a first step to identifying the opportunity and understanding the feasibility of DNOs investing in local energy efficiency. **We believe that we have demonstrated that a small but nonetheless meaningful opportunity may exist.** However, further follow-on work will be required in advance of any such investment taking place.

We recommend that Northern Powergrid should build on the work described in this report in a number of specific areas in order to fully quantify the opportunity and prepare for AIS investment becoming part of its network design toolkit:

- **Detailed cost-effectiveness analysis**: Further, more rigorous analysis of the relative cost effectiveness of AIS by comparison to conventional network reinforcement, take into account issues such as the impact of diversity, of the rebound effect, and of the rate of take-up of low carbon technologies, is required to rigorously test the findings of our simplistic cost-effectiveness analysis.

- **Site-specific feasibility studies**: We suggest that Northern Powergrid commission a small number of feasibility studies of potential AIS investments in areas where significant network reinforcement is planned in future years. These studies should investigate the housing types, heating types, levels of deprivation and potential for partnership with energy efficiency providers and Local Authorities and Housing Associations. Ideally these studies should identify particular AIS projects to clarify both the technical aspects; and the financial aspects of AIS.
- **Regulation and policy study**: In order to put AIS into practice, Northern Powergrid will need to understand how to engage in AIS in practice, and how this fits with its regulatory mechanisms. This work should cover areas such as project selection, evidence requirements, and treatment of AIS within price controls.
- **Pilot projects**: Once these steps are undertaken, in order to gain practical confidence in AIS, it would then make sense for Northern Powergrid to undertake a small number of practical pilots to demonstrate both that AIS can be deployed in practice and that the desired peak demand reductions are delivered in a sustained and cost effective manner. This would build on the growing research work undertaken by other DNOs (such as Western Power Distribution's Less Is More, and Electricity North West's Power Saver Challenge).

Project Background

Fuel poverty is an important issue. Government's new target on minimum standards for home energy efficiency introduced by the recent fuel poverty strategy[3] indicate that it is a problem that deserves more attention and better solution than it has been given until now by national government. This message has been broadcast by many organisations, such as NEA and Fuel Poverty Advisory Group for some time[4]. Improved energy efficiency of heating appliances and better insulation of homes are part of the toolkit that can address a problem that has negative consequences on people's bills, health and life ability (see box 1 for more information on fuel poverty).

Box 1: The problem of fuel poverty
The "Manifesto for Warmth" published by National Energy Action explains the size of the fuel poverty problem. Cold homes affect some of the frailest members of our society. National Energy Action estimate that at least 30,000 vulnerable people have perished prematurely in the last five years due to an inability to adequately heat their homes and over 100,000 British citizens could die unnecessarily within the next 15 years for the same reason. That is 5,300 in the North East, and 10,800 in Yorkshire and Humber. Millions more low-income and vulnerable households are in significant personal debt and have to ration their energy use. As well as causing acute personal suffering, this also reduces economic activity within deprived areas and leaves the NHS currently bearing a yearly burden of approximately £1.5bn treating cold-related illnesses every winter.

From a strict regulatory point of view, there are mainly two reasons why a DNO would take an active role in deploying this toolkit: the efficiency incentive and its social obligations which feature in the RIIO-ED1 framework.

The price control framework that regulates all DNOs activities has an element where efficiencies gained by the DNO through deploying more cost efficient methods than those agreed at the beginning of the price control are shared between the business and its customers. This is the "efficiency incentive". It is a rule which allows DNOs to keep a share of the savings that result from their effort to invest at lesser costs than originally planned. Theoretically, this rule creates a financial logic, whereby any investment that costs less than forecast investment will be undertaken by DNOs, so long as it doesn't compromise their ability to deliver the predefined outputs. In a publication dated from October 2013, the regulator Ofgem concluded[5]: "*Consequently, if energy demand reduction measures represent the most efficient means of resolving constraints on the network, then DNOs will be incentivised to use them and make gains against their allowances under the efficiency incentive*."

In parallel, the new price control framework, RIIO-ED1, is incentivising the DNOs to investigate new and alternative operational solutions, outside of the traditional duty

[3] https://www.gov.uk/government/publications/cutting-the-cost-of-keeping-warm
[4] The latest manifesto from these organisations on the topic can be found respectively on: http://www.actionforwarmhomes.uk/ and https://www.gov.uk/government/publications/fuel-poverty-advisory-group-for-england-12th-annual-report-2013-14
[5] Source: https://www.ofgem.gov.uk/publications-and-updates/role-distribution-network-operators-dnos-relation-energy-demand-reduction

of delivering electricity to its customers. One such new area is labelled "Social obligations", and dictates that DNOs should assume a greater responsibility towards helping the fuel poor and vulnerable customers[6]. Northern Powergrid has embraced this mandate as an opportunity "to support the wider social agenda"[7] .

Under the effect of both regulatory drivers, DNOs across Britain have indeed started to broaden their thinking, and are testing the network benefit of permanent peak load reduction achieved through energy efficiency improvements (see box 2 for a sample of projects). However, this idea remains complex for DNOs in so far as it requires investigating customer-led initiatives, which traditionally the DNOs have not done.

Groups lobbying for action against fuel poverty have pushed forward the idea on several occasions[8] Northern Powergrid engaged AgilityEco in partnership with NEA, to investigate the idea further. The work contributes to the research carried out by other DNOs on the theme.

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[6] The 'Strategy decision for the RIIO-ED1 electricity distribution price control' document published by Ofgem in 2013 states: "We want to encourage DNOs to maximise their role in understanding, identifying and dealing with consumers in vulnerable situations. We recognise that for DNOs to fulfil this role they will need to undertake a major cultural and behavioural shift".

[7] As laid out by the commitments made in the business plan for 2015-23, available on: http://www.yourpowergridplan.com/#!social_obligations

[8] An example of where the AIS idea has been circulated is the Energy Efficiency sub-group of Work Stream 6 of the Smart Grid forum.

Box 2: DNO-led projects aiming at reducing peak load as an alternative to network reinforcement

In seeking to balance new social obligations with the task of delivering value for money, DNOs are broadening their thinking about possible new investment models. We report here on initiatives that study the use of energy efficiency measures as a solution to network issues, and as a mean to reduce peak load permanently. The present report will add to this pipeline of research initiatives and contribute to the industry's learnings.

Less is More

Western Power Distribution partnered with the Centre for Sustainable Energy to help communities reduce their electricity demand, especially at peak times so that less money was spent on upgrading substations, to cope with rising demand. The project encouraged ten communities, "attached to" a monitored substation to consider their electricity use and find ways to reduce it and/or shift it to off-peak times, in return for up to £5,000. The project was presented as a solution to create savings for everyone, with reduced bills and reduced upgrade costs.

Project duration: January 2014 to April 2015

Power Saver Challenge

The project is to extend the life of the existing assets by working with customers to reduce the amount of electricity they use, in return of a reward. Electricity North West Ltd is working with NEA in Stockport on a proof-of-concept, gathering 10 teams in a competition, to aim for the challenge of a 10 per cent reduction in winter peak electricity compared to the previous year, and with the help of advice and energy-saving equipment. The aim is to test the feasibility of avoiding investment in an urban primary substation and extend the life of the existing asset.

Project duration: October 2013 to April 2015

Solent Achieving Value from Efficiency (SAVE)

Led by Scottish and Southern Energy Power Distribution in the Solent and surrounding area, the project aims to establish to what extent energy efficiency measures can be considered as a cost effective, predictable and sustainable tool for managing peak demand as an alternative to network reinforcement.

The trial will compare the effectiveness of four energy efficiency measures (LED installation, data-informed engagement campaign, DNO price-signals direct to customers plus data-informed engagement, and community coaching) and produce an investment decision tool that introduces the deployment of energy efficiency measures as a solution to network constraints.
Project duration: January 2014 to June 2018

More about these projects on:
http://www.lessismore.org.uk/
http://www.powersaverchallenge.co.uk
https://www.ssepd.co.uk/save/

Project Rationale

The report investigates the potential for electricity network operators to make a direct contribution to preventing fuel poverty, by investing in domestic energy efficiency (see Box 3 for a definition) improvement.

The benefit to the network is identified in the following way: improved energy efficiency may lead to permanent demand reduction, which may in turn lead to reduced peak demand, which may offset the need for network reinforcement. Based on this premise, the NEA is asking if there a possibility to divert the budget allocated to load-related network upgrade schemes, into local schemes that improve energy efficiency for those who need it the most. This idea is referred to as Alternative Investment Strategy (AIS).

Box 3: Energy efficiency defined

Energy efficiency is a way of managing and restraining the growth in energy consumption. Something is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input. For example, when a compact florescent light (CFL) bulb uses less energy (one-third to one-fifth) than an incandescent bulb to produce the same amount of light, the CFL is considered to be more energy efficient (source: International Energy Agency*).

Within studies of the energy system, energy efficiency is a type of "demand side measure", which delivers permanent demand reduction. In the context of this report, we refer to energy efficiency as a way to reducing peak electricity demand more particularly. Given that Northern Powergrid is motivated in part by its social obligations, this report has placed specific emphasis on domestic energy efficiency, rather than energy efficiency in other areas such as industry, public sector or street lighting.

To clarify, demand reduction delivered by energy efficiency measures differs from demand-side response, which delivers temporary load reduction, and which, when applied to large customers, is sometimes referred to in the DNO jargon as "constraint connection".

* www.iea.org/topics/energyefficiency

Some aspects of the context for AIS plays in favour of the idea:

- There remains a significant (and in many case a largely untapped) potential for electrical energy efficiency gain. For example, this report contains data showing that up to 11% of homes in parts of Northern Powergrid's service areas is electrically heated, which is recognised to be a lesser effective way to heat. In addition, government research also shows that 40% of lighting in living rooms and bedrooms is from inefficient tungsten bulbs, and that almost half of all households use inefficient supplementary heating in one or more rooms9

[9] https://www.gov.uk/government/statistics/energy-follow-up-survey-efus-2011

- The costs of more efficient technologies such as low energy lighting10 and solar panels11 are falling, in some cases rapidly
- There are, in some cases, existing sources of funding that will cover a significant part of the cost of more efficient alternatives. These include Energy Company Obligation, Renewable Heat Incentive, Feed In Tariffs, and Green Deal Home Improvement Fund, that may considerably leverage the funding by DNOs, such that the DNO funding becomes “gap-funding”. These further funding sources are discussed further in this report
- In Northern Powergrid, the standard approach to managing the increases in load-related risks on high-voltage and low-voltage network is already to utilise a range of solutions12, including demand-side measures.

Similarly, some other aspects of the context for AIS play against it. The report addresses a selection of four of them:

- Many network reinforcement investments are timed to “piggyback” on end-of-life network asset replacements, so the incremental cost of providing extra capacity is sometimes only a minor part of the network investment cost. This maximises the cost efficiency of network investment, and as such is beneficial to the electricity customer, but it affects the cost competitiveness of AIS as a network solution.
- Reinforcement and customer-driven investment itself is limited. It represents only a relatively small part of Northern Powergrid’s total costs and some of this is paid by the customer requesting work (8% of the total costs put forward in the RIIO-ED1 business plan, which equals to £326.3 million over the period 2015-2023[13]). Many other spend categories (such as asset replacement, diversions, flood defences, Information Systems, etc.) are clearly not candidates for AIS
- The reinforcement budget is underpinned by an established methodology which balances Northern Powergrid’s security of supply obligations[14] with financial efficiency imperatives. A key success factor to AIS is to be demonstrably the most economical solution. Whilst network reinforcement investments are proven, and deliver a highly predictable outcome for DNOs, there may be less certainty that efficiency investments will deliver the expected outcome. For example, improvements in energy efficiency have been shown in some cases to result in “comfort taking”, i.e. increasing energy consumption to improve quality of life, which may partly offset any peak load reduction from efficiency gains. This phenomenon is known as the “rebound effect”. It reduces the lifetime of the viability of AIS for a given project and creates a situation where reinforcement may be required later, on top of AIS

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[10] http://www.greentechmedia.com/articles/read/A-Shift-in-Lighting-LED-Bulbs-Fall-to-Under-8

[11] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/302049/uk_solar_pv_strategy_part_2.pdf

[12] “Annex 1.29 Additional justification for our reinforcement forecast for 2015-23” published by Northern Powergrid, March 2014

[13] “Our business plan 2015-23, Executive Summary”, published by Northern Powergrid, in March 2014.

[14] The security of supply obligations are dictated by:

- the Distribution Code, which obliges DNOs to be compliant with the distribution network security of supply standard, ENA Engineering Recommendation P2/6
- the Electricity Act 1989, which requires DNOs to ‘develop and maintain an efficient, co-ordinated and economical system of electricity distribution’
- the ESQC Regulations 2002,which imposes a general requirement that the distribution system is ‘sufficient for the purposes for and the circumstances in which it is used’

- It is unproven that there will be a strong correlation between the locations in which reinforcement investments are required and the locations where significant energy efficiency investment opportunities exist. However, the fact that both are likely to be linked to areas of high population density would suggest that this will be the case.

This project has been designed to have a specific scope, and aims only to develop some early evidence on the size and feasibility of the opportunity. It does not intend to address conclusively the following points:

- Regulatory barriers:
  - Does the current British and European regulatory regime allow it?
  - How would such costs be treated in the regulatory framework?
- Information barrier:
  - How can DNO gain visibility on local projects that aim at deploying energy efficiency?
  - How can DNO quantify with confidence the peak load reduction delivered by energy efficiency projects?

A list of suggested further work that would capture these points is provided at a later stage in this report. Such work would help progress the deployment of the AIS that this report demonstrates to be possible.

It should be noted that energy efficiency investments will deliver a range of other positive outcomes of relevance to the DNOs' corporate social responsibility goals and social obligations regulated outputs. Box 4, reproduced from NEA's Manifesto for Warmth[15], outlines some of the ancillary benefits of improved energy efficiency as a means of alleviating fuel poverty.

Box 4: The recognised benefits of acting to alleviate fuel poverty

1. Reductions in bills and energy arrears can increase spending within poorer communities and local economies
2. Better living conditions and significant positive impacts on health
3. Increased internal temperatures will lead to fewer premature winter deaths
4. Reductions in bills can lead to less stress and better mental health for occupants
5. Less damp and mould growth within homes reduces respiratory problems
6. Local employment from a more buoyant energy efficiency industry will create more demand for local low and medium-skilled labour
7. Better local air quality.

[15] http://www.nea.org.uk/Resources/NEA/Publications/2013/MANIFESTO%20FOR%20WARMTH%20(LO%20RES)%20CS6.pdf

Project Approach and Methodology

Northern Powergrid's approach to investment is to keep costs as low as possible. They are a leading performer on a range of comparative efficiency measures. This good value for money is a top priority for their stakeholders, including investors, Ofgem and customers who want affordable bills. In 2015-23, they plan to spend 3.1% less than in the previous 2010-2015 period on a like-for-like basis, and this is driven by tighter control over investment costs. There is a projected 9% reduction in annual like-for-like investment costs in the 2015-23 period, while delivering improved output[16].

In driving down costs, Northern Powergrid consider the investment they need to meet their licence obligation relating to running an economical, efficient, and coordinated system, and to comply with Ofgem's incentives relating to customer service. Delivery commitments include for example a reduction in the number and duration of power cuts, and an end-to-end improvement in time for connections.

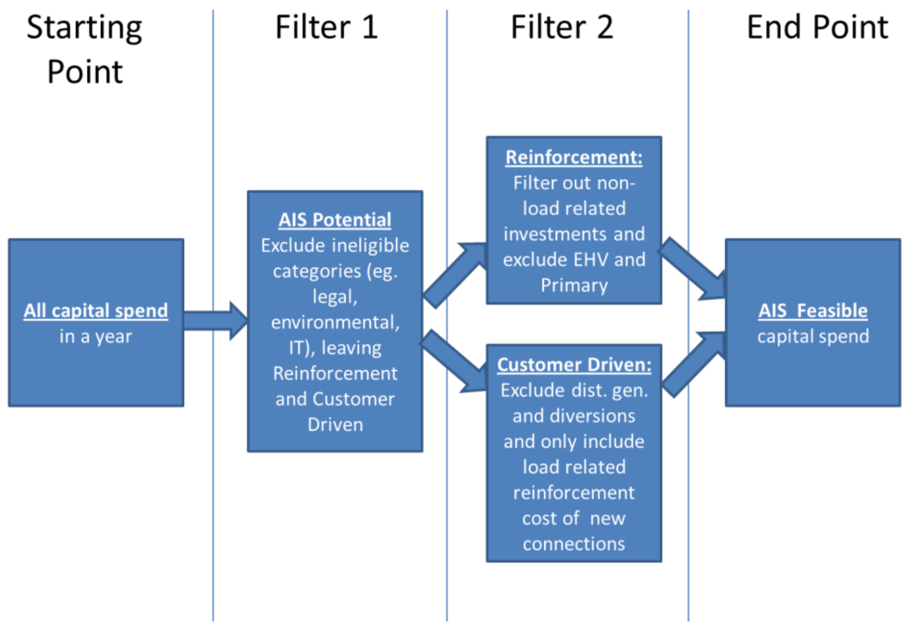
To meet their overarching objective of a downward pressure on costs, Northern Powergrid invest only where there is a clear and specific need for improvements or where they can be delivered within existing costs.

Northern Powergrid are continuously looking for alternative feasible ways to deliver their required service levels. For example they look at trading off maintenance and repair with replacement, to ensure the best value total cost-option. This report uses the same overall approach, to test whether and to what extent AIS can deliver the same network benefit as those investments set out in the 2015-23 business plan, for the same, or less cost.

Size of the Prize

Our approach to understanding the total sum available for substitution by AIS is represented in Figure 1, below.

Figure 1: Project approach to estimating the "Size of the Prize"



[16] "Our business plan ,2015-2023", published by Northern Powergrid, March 2014

With support of experts from within Northern Powergrid's Investment Planning, and System Design teams and using spreadsheet data provided by Northern Powergrid, AgilityEco carried out a detailed "screening" analysis of each of the last five year's system improvement expenditure and the projected investment spend for the eight-year RIIO period.

Our first stage was to screen out categories of investment which were not suitable for substitution by AIS. The second stage was to produce an analysis at the subcategory level of investment, to find which were driven by load and most likely to be suitable for AIS.

Building on this initial breakdown provided insight into the likely overall size of the opportunity within Northern Powergrid's capital expenditure going forward.

Economic Feasibility

This second stage of the work investigated a sample of past Northern Powergrid reinforcement projects to identify an indication of the range of unit capital cost, expressed in £ spent per kilowatt of peak winter capacity required, again supported ably by Northern Powergrid's experts.

We then looked at alternative local energy efficiency investments, expressing their cost in £ spent per kilowatt of peak winter demand reduction. We then compared the cost effectiveness of these alternative investments with the cost effectiveness of conventional reinforcement investment, expressed in £ spent per kilowatt of peak winter capacity created.

This work also considered other sources of funding available for energy efficiency investment which would help subsidise the cost of these investments, thereby increasing the cost effectiveness of the DNO's investment.

Practical Feasibility

We then considered a number of practical aspects associated with AIS to gain insights into its feasibility. These comprised:

- Analysis of the geographical clustering of investments suitable for substitution by AIS and the coincidence of these "hotspots" with areas of high population density and a consideration of deprivation and housing types. The greatest numbers of AIS opportunities will arise where there are most dwellings.
- Commentary on a number of broader case studies to provide insight into how these can be implemented in practice.
- Consideration of regulatory issues associated with DNOs pursuing AIS.

Size of the Prize

This section seeks to quantify, within Northern Powergrid's annual capital budget, the proportion which could be earmarked for identification of potential opportunities for substitution by local energy efficiency through an alternative investment strategy (AIS):

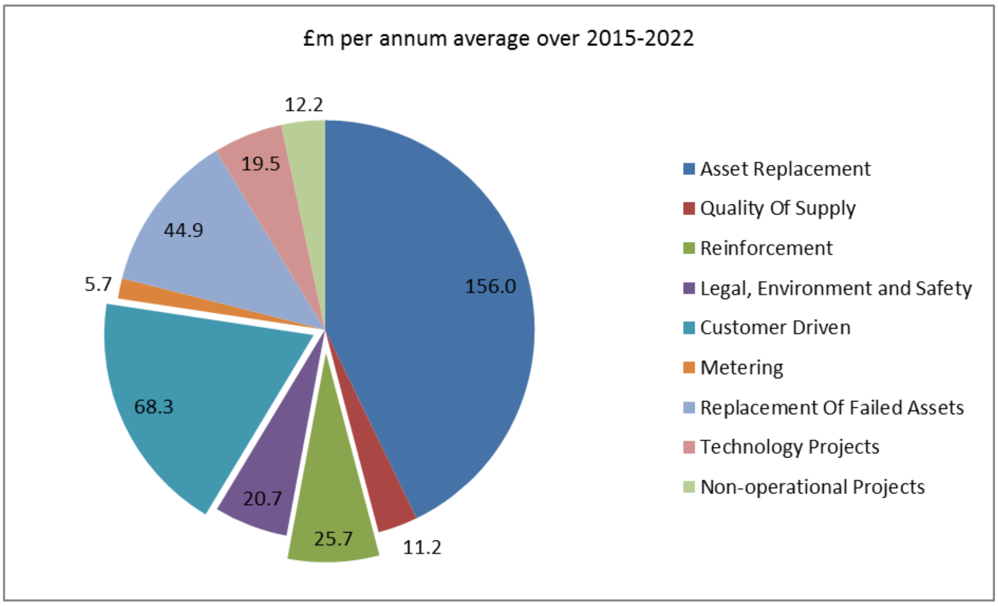
- What is the total annual budget (£) of projects eligible to AIS and why this is only a subset of overall capital investment?
- What is the total demand reduction that needs to be delivered by AIS projects to avoid the investment (peak kW avoided)?
- What is the hurdle that AIS projects would need to clear in order to be considered (£/kW)?

Overall, Northern Powergrid net costs (including operating expenditure) average of £492.1m per year in the last price control period, known as DPCR5. Projecting forward, the total projected net costs for the RIIO-ED1 period of 2015-23 is £4,076bn, or £509.5m per year[17].

In this analysis, we utilise the capital investment plan of Northern Powergrid, which aligned to the plan submitted to the regulator Ofgem in March 2014. The investment plan provides the ability to drill down to allow a closer insight into the driver for investment. The plan is a sub-segment of the regulatory plan and is based on a calendar year end and uses the classification of investment costs Northern Powergrid utilise to run the business, the costs are before (gross of) any customer contribution towards the work. They also exclude operating expenditure and efficiencies required by the regulator. The plan costs are in nominal or outturn terms, rather than 2012-13 real prices.

Figure 2 shows the allocation of the capital budget by investment driver, for eight calendar years, from 2015 to 2022.

Figure 2: Breakdown of Northern Powergrid's Capital Investment Plan



[17] Section1 of "Our Business Plan 2015-23", published by Northern Powergrid, March 2014. Costs are expressed in 2012-13 prices.

Filter 1: Investment Categories with Potential for AIS

Investment was categorised using the Northern Powergrid investment drivers, and considered for its suitability for substitution by AIS as follows:

1. **Asset Replacement.** This category of investment accounts for around 40 per cent of all investment. Most of this expenditure is driven by the age and condition of the assets, which are replaced as they reach their end of life. This category of investment is not driven by load. Northern Powergrid's network underwent significant expansion in the 1950s and 1960s. Given the typical useful life of assets installed at that time, Northern Powergrid has been in a period of relatively high renewal requirements in DPCR5, to maintain the overall condition, health and reliability of the network, balancing options across replacement, refurbishment, rationalisation, and managed deferral of expenditure. Overloading assets does tend to reduce life expectancy of an asset, but currently, overloads occur only rarely, under situations where it is necessary to run the network with a reduced number of assets in service[18]. These situations arise due to asset failures or planned work on the network**.**
2. **Quality of Supply.** In general, work in this category has no effect on network capacity. Mostly, it is carried out to minimise Customer Interruptions (CI) and Customer Minutes Lost (CML), and to install and replace remote controls which speed up restoration times when faults occur. We considered whether work to keep the numbers of customers below a level on each part of the network might free up investment in AIS, but we concluded that this would require Ofgem to take a very different approach towards its quality of supply and incentive measures. In any case, investment cannot easily be switched across and still prove value for money. Investment in AIS would therefore not reduce the requirement for this category of investment and therefore we have excluded it from the AIS scope.
3. **Reinforcement.** This was considered the category of investment most suitable for substitution by AIS. Reinforcement at 20kV and below was considered the easiest category to substitute, because 33kV, 66kV and 132kV networks introduce the challenge of scale (i.e. size of deployment of AIS).
4. **Legal, Environment and Safety.** This work has no effect on network capacity, it is carried out to meet legal obligations and to ensure that the Northern Powergrid network operates in a safe manner. Examples include improving security against metal theft, reducing noise pollution, and work to mitigate the risk of asbestos hazards.
5. **Customer-driven.** This investment ensures Northern Powergrid meets their obligation to provide customers with a connection or diversion where required. In accordance with the regulatory framework that relate to customer contributions, the majority of capital expenditure is reclaimed from the customer requesting the work. Where load-related reinforcement work has been carried out alongside the connection investment, this has been considered.
6. **Metering.** This capital expenditure ensures Northern Powergrid meets its obligations to provide appropriate metering on the network but provides no additional capacity. This has therefore been excluded from the analysis.
7. **Replacement of failed assets.** This ensures that the network is reinstated in the event of a fault or incident – this accounts for around 10 per cent of total investment, and is clearly unsuitable for replacement by AIS.

[18] See section 2.8.2 of "Our business plan, 2015-23"published by Northern Powergrid, March 2014.

8. **Technology Projects.** These provide no additional network capacity (though they do contain some projects with an environmental aim). These have not been considered for AIS.
9. **Non-operational projects.** These are projects such as updating IT or telecoms, provide no new network capacity and have thus been excluded.

In addition Northern Powergrid's investment budget must cover business overheads which are clearly not suitable for replacement by AIS.

In summary, the budget categories considered to be ***potentially*** suitable for AIS are: Reinforcement and Customer-Driven. Figure 2 shows that this represents £94m per annum in average, over the RIIO-ED1 period. This is approximately 26% of total planned capital investment.

Filter 2: Investment Sub-Categories Likely to be Suitable for AIS

Step two of the methodology consisted of a more detailed analysis of the investment categories retained from Filter 1, with a view to determine what proportion is ***likely*** to be suitable for AIS.

Reinforcement capital investment is sub-categorised as follows:

- Reinforcement Load Related (LR) Grid (132kV) (16% of reinforcement spend)
- Reinforcement LR Primary (66kV and 33kV) (11%)
- Reinforcement LR 20kV & below (44%)
- Fault Level (7%)
- Major System Risk (22%)

Sub-categories related to fault level and major system risk were not considered suitable for substitution by AIS, as these categories generally independent of load.

As a main priority, Northern Powergrid must ensure that they have sufficient capacity to meet their licence obligations that also includes general background increase in load.

At the EHV level, there is little opportunity for AIS opportunities as the diversified consumption is accounted for and the suitability of energy efficiency as a solution to network issues is greatly reduced. For example, in the North East, slow load growth caused by industrial decline, population reduction and the roll-out of energy efficient white goods, combined with recent investment in that area, has reduced the requirement for Northern Powergrid to invest in reinforcement. In Yorkshire there are a small number of pockets of growth which require investment in EHV. Such projects are costly and have a big impact. At these levels of demand, the security of supply and resilience standards mean[19] that larger energy efficiency schemes are needed. To mitigate the reinforcement at this level it may be necessary for the demand to be reduced by a significant level at the scale of an entire town or city. Therefore, in the case of Northern Powergrid, given the combination of a very small number of projects and these projects being very large scale, EHV investments have been deemed as

[19] These considerations are in line with the Engineering Recommendation (ER) P2/6, "Security of Supply", the current distribution network planning standard. DNOs have a licence obligation to plan and develop their systems according to ER P2/6.

unsuitable for AIS and thus eliminated. This conclusion may not be true for other network operators and should be examined on a case-by-case basis.

At the HV and LV level, the reinforcement requirement is based on average customer demands and expected peak demands. Informed assumptions are supplemented by actual demand figures from the local area prior to any investment taking place. The load requirements and network capability are monitored to determine whether reinforcement is required on a site-specific basis. Due to slow demand and low load growth, it is a relatively reactive activity, which takes the form of specific solutions to address specific issues. This creates an ideal context for AIS, i.e. a solution to be deployed on a case-by-case basis.

A few projects in the load related Primary category – again, longstanding, planned projects – also have the potential for substitution by demand reduction, but are difficult to substitute as they are already in an advanced state of planning and due to be implemented shortly. In the case of Northern Powergrid, many of the load-related primary projects are actually works intrinsically linked to the large EHV projects and are thus unsuitable. The remaining projects were examined on a case-by-case basis and a small subset (approximately 5%) deemed potentially suitable for AIS. Of a total of £2.7m per annum average forecast spend during the RIIO ED1 period (in 2015 prices), £0.1m per annum was deemed potentially suitable for AIS.

To explore the AIS opportunity contained in the “Reinforcement LR 20kV & below” category, we have proceeded in two steps: studying first a sample of historical investments, and then applying the results to the investment forecast. The outcome is shown in Figure 3.

The sample of historical investments used in the analysis consists of all low-voltage and high-voltage reinforcement works (known as WP06 projects in NPg internal business plan), for DPCR5-to-date, in the Yorkshire licence. We call it Sample A. This category is sub-divided into a number of work programmes, each of which was assessed on a case-by-case basis. Some of these work packages were eliminated altogether (such as investments to deal with voltage complaints, or investments to deal with fault levels in excess of asset ratings), others were included in whole (particularly investments to deal with overloaded transformers) and others were included in part, based on a detailed analysis of a large sample of historical investments in that work package. The outcome of this analysis was that approximately one third of 20kV and below was load related investment and may be suitable for AIS.

Figure 3: Eligibility Analysis of Load-Related “20kV and Below” Investments

	Suitability based on analysis produced on a sample A	RIIO ED1, year average (£m)	Suitable for AIS (£m)
WP06-01 - P2/6 Non Compliance	0%	1.15	-
WP06-02 - Overloaded GM HV Transformer	100%	0.42	0.42
WP06-03 - Overloaded PM HV Transformer	100%	0.21	0.21
WP06-04 - LV Network with High Earth Fault Loop Impedance	0%	-	-
WP06-05 - Voltage Complaint (split into 12 & 13 from 2013)	0%	-	-
WP06-06 - Insufficient HV Interconnection	43%	2.51	1.08
WP06-07 - Insufficient LV Interconnection	47%	1.96	0.92
WP06-08 - Fault Level in Excess of Asset Rating	0%	0.11	-
WP06-09 - Load Transfers	0%	0.51	-
WP06-10 - Opportune System Improvement	0%	0.93	-
WP06-11 - Overloaded LV Cables	61%	1.25	0.76
WP06-12 - HV Voltage Complaint (inc in 05 pre 2013)	0%	1.03	-
WP06-13 - LV Voltage Complaint (inc in 05 pre 2013)	0%	1.01	-
WP06 - System Reinforcement HV & LV		11.10	**3.40**

Note: The RIIO-ED1 investment numbers correspond to the Capital investment plan, based on the regulatory plan submitted by Northern Powergrid in March 2014, and using nominal prices.

In summary, of the reinforcement capital budget, a portion of the investment relating to “Reinforcement LR Primary” and to a larger extent, to “Reinforcement LR 20kV & Below” were considered to be likely candidates.

In parallel to running this filtering exercise, we note that the size of the reinforcement budget suitable for replacement by AIS will be sensitive to a number of factors:

- In future years, network investment will be a mix of conventional and smart solutions. This is in contrast with past years, when investment was made towards conventional solutions. Smart solutions are typically cheaper. Northern Powergrid, like the rest of the DNOs, has planned to use that type of technology[20]. This new mix may improve the competiveness of network reinforcement compared to that of energy efficiency (which is discussed in the following section).

- Investment in network reinforcement at low voltage is particularly reactive and the budget, like any forecast, is likely to vary in order to adapt to changing external factors. The impact of the recession and of energy efficiency improvements over the period has been to slow down the rate of growth, leading Northern Powergrid to assume a 0.5% per annum growth in peak demand. If demand rises more slowly than projected, whether due to slower regional or national economic or population growth, successful energy efficiency measures, slower take-up of low-carbon, and other electricity dependent technologies such as electric cars then there is less pressure to invest in network reinforcement, and hence less available to switch to specific energy demand reduction alternatives. However, faster demand from higher economic or population growth, less successful energy efficiency measures, or faster take-up of low-carbon, and other electricity dependent technology, will add to the pressure to reinforce the network and mean that more investment is potentially available to shift to AIS.

[20] For more detail, refer to the chapter about smart technology in the Expenditure section of “Our business plan 2015-23”, published by Northern Powergrid, March 2014.

The **customer-driven** capital expenditure is sub-categorised into:

- Diversions (direct cost) (22% of customer driven spend)
- Distributed Generation (direct costs) (20%)
- Connections (direct costs) (58%)

Diversions (moving network assets to accommodate building or infrastructure changes) are clearly not suitable for substitution by AIS. Similarly, network reinforcement to enable new local power generation assets to be connected is unlikely to be suitable for AIS. Much of this reinforcement is to mitigate the effect of reverse power flow upstream on the network. Any AIS would exacerbate rather than alleviate the problem, leading to more reverse power flow.

Northern Powergrid has an obligation to provide customers with a connection where queried to do so. Northern Powergrid's projections for customer-driven activity are built on analysis of historical trends plus a view of how the market will change in the future. Much of the direct cost of this customer-driven activity is borne directly by the customer, and it is only the cost of consequential reinforcement that is potentially suitable for AIS.

Here again, the methodology used was extrapolation based on a sample. Sample B consists of the customer-driven reinforcement work, quoted for and accepted during the regulatory year 2013/14 in the Yorkshire licence area. Sample B shows that out of the £1.9m spent by Northern Powergrid on reinforcements linked to customer-driven activity, just £0.58m was load-related.

Assuming that the developer is agreeable to the idea of AIS (most likely because reducing the predicted load costs cheaper than the reinforcement work), and so that load-related reinforcement costs that are borne by connections customers could also be diverted to AIS, we may add customer contributions in relation to this reinforcement, which, in the sample, increases the size of the prize to £0.84m.

It was not possible given time and resource constraints for this analysis to be replicated for multiple years or for the North East, so for the present we assumed that this year was typical and that the distribution of projects in Yorkshire is the same as the North East. So, for simplicity, we assumed that this total AIS potential in 2013/14 (£0.84m) as a share of overall customer driven expenditure (£34.1m), or 4.1%, will apply in future years, across both licence areas. These assumptions should be tested in a future phase of work by investigating multiple years, covering both the Yorkshire and North East networks.

Applying this percentage to the average annual spend on customer-driven connections over the RIIO ED1 period (£39.2m) suggest an average annual spend of £1.6m which is ***likely*** to be suitable for AIS (see Figure 4).

Key Conclusions on Size of the Prize

Combining the subset of investment activities in the Reinforcement and Customer-driven categories that were deemed likely to be suitable for AIS, the "size of the prize" is established to be £5.2m per year, or 1.4% of the capital annual investment over the RIIO-ED1 period. This is summarised in Figure 4.

Based on this report, this amount represents the maximum amount that Northern Powergrid (including customer contributions to customer-driven costs) could invest per year in energy efficiency improvement work, in order to pursue the AIS idea. It is however likely to vary in accordance to the trend of load growth in its licence area.

Figure 4: Summary of maximum AIS Size of the Prize

	RIIO ED1, year average (£m)	Filter 2	Suitable for AIS (£m)
Reinforcement load-related grid	4.3	0%	-
Reinforcement load-related Primary	2.7	5%	0.1
Reinforcement load-related 20kV & below	11.1	see Figure 3	3.4
Fault level	1.9	0%	-
Major System Risk	5.8	0%	-
Total Reinforcement	**25.7**		**3.5**
Diversions	15.4	0%	-
DG	13.8	0%	-
Connections	39.2	4.1%	1.6
Total Customer-driven	**68.3**		**1.6**
TOTAL Capital Investment			**5.2**

Note: The RIIO-ED1 investment numbers correspond to the Capital investment plan, built on the regulatory plan submitted by Northern Powergrid in March 2014, and using nominal prices.

Further Work

This investigation work has highlighted areas that will require further clarification:

- The scope for load-related primary (66kV and 33kV) investments to be substituted by large-scale ambitious AIS projects. This will be particularly important if the methodology herein is being considered in other parts of the country with different high voltage investment plans.
- At a later point a more rigorous analysis of the customer connections investment area, where for reasons of time and resource a relatively simplistic approach was adopted.

Economic Feasibility

In order for Alternative Investment Strategy not to be disruptive of a DNO's services and of the standard level of electricity distribution, it would need to fulfil strict criteria:

- Economic - cost no more than the planned reinforcement work measured on the same basis.
- Reliable - reliable at times of pressure, in particular at times of peak winter demand.
- Practical - able to take place in the specific local areas where network reinforcement is currently planned to take place in a timely manner.

This section explores the first and second point. The practicality point is studied in the next section.

First, we compare the cost effectiveness of AIS (in £ per kW of winter peak demand reduction) compared to that of network investments (in £ per kW of winter peak capacity created). This helps address the question: "of the proportion of the budget that we have categorised as ***likely*** to be suitable for AIS, how ***competitive*** is investment in local energy efficiency likely to be compared to conventional network reinforcement?"

Cost-effectiveness of Network Investment Based on Northern Powergrid's Past Investment

With support from Northern Powergrid, we looked closely at a sample of historical individual investment projects in the sub-categories considered likely for AIS, in order to learn about the range of cost effectiveness of network investments. In this case, cost effectiveness is understood as: £ spent to create one extra kilowatt of capacity on the network.

A sample of 77 load related LV and HV work programmes, completed in Yorkshire between 2004 and 2014 was isolated with the help of the System Design team from Northern Powergrid, and assumed to be representative of the total portfolio of reinforcement programme in these 10 years. The sample is referred to as Sample D[21].

Sample D was used to support this next analysis. Figure 5 shows the cost of these 77 network reinforcement projects, ranked in the order of highest to lowest, against the resultant cost per kW required to be produced by that investment.

[21] An initial sample, Sample C, of 156 load related LV and HV work programmes completed in the Yorkshire licence area between 2004 and 2014 was provided by Northern Powergrid. Of this sample, only 77 had sufficient data on cost and capacity expansion to allow a cost-effectiveness analysis. These projects form Sample D. Discussion with the Northern Powergrid team gave a certain degree of confidence that Sample D is representative of customer-driven investments and of the North East work programmes. In future work, we recommend that this assumption is tested, and in particular that: the reduction from 156 to 77 projects did not create a bias in the data; the distribution of cost effectiveness of investments in the North East is similar to that in Yorkshire; and the distribution of cost-effectiveness has not changed significantly since 2004, nor will it change significantly in the RIIO-ED1, compared to this earlier period.

Figure 5: Cost-effectiveness of 77 "Sample D" projects in Yorkshire 2010-2014

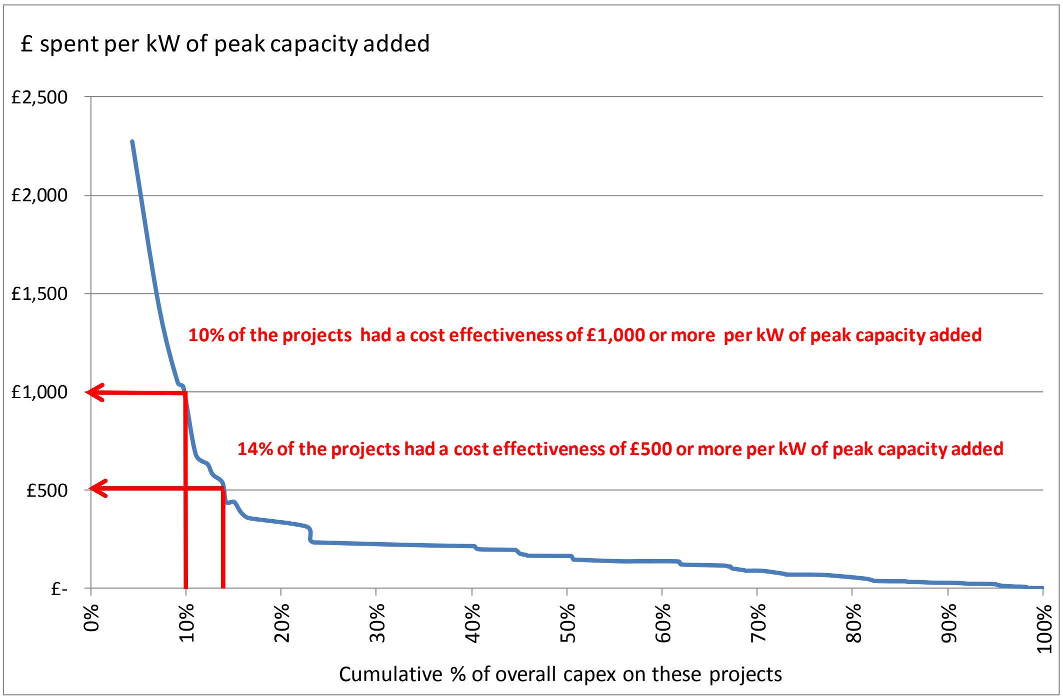


Figure 5 highlights that within Sample D, there are a few projects that have a very high cost for each additional kW of peak capacity delivered. These projects are easiest to substitute for AIS. For example, about 14% (by cost) of network reinforcement projects have a cost effectiveness of £500 per kW required or above.

About 10% (by cost) of network reinforcement projects in this sample have a cost effectiveness of £1,000 per kW or above – noting however that this is just four costly projects.

There is also a long tail of projects with a low cost per kW required. These are likely to be shown in our next analysis (cost-effectiveness of energy efficiency), to have a low propensity for replacement by AIS, as the corresponding energy efficiency scheme would have to be relatively cheaper for the amount of demand reduction it would deliver.

Figure 6: Cost-effectiveness of 77 "Sample D" projects in Yorkshire 2010-2014, focusing on price range £0 to £500

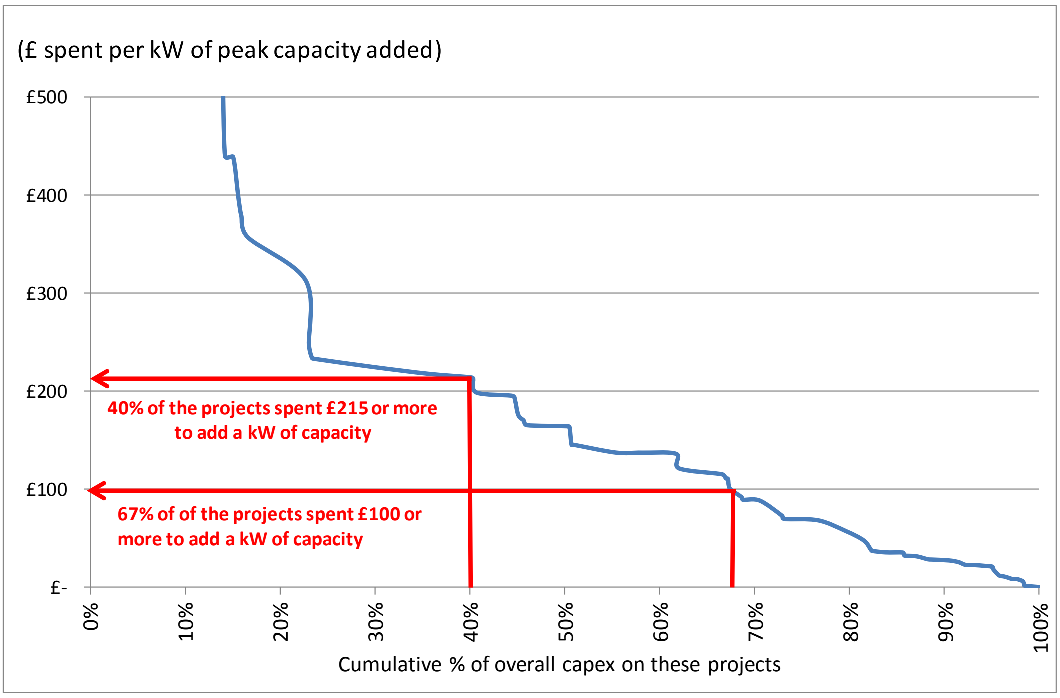


Figure 6 is a sub-set of Figure 5, with a focus on the price range £0 to £500. It shows that approximately 40% (by cost) of reinforcement works have a cost effectiveness of about £200 per kW or above, and two thirds have a cost effectiveness of £100 per kW or above.

Cost-effectiveness of Individual Network Reinforcement Options

The unit costs from Sample D, shown in Figures 5 and 6, represents a mix of options (i.e. substations and cables upgrades), deployed in each of the different projects deployed in the past.

An alternative set of reference that has relevant to this analysis, is the unit cost of substation reinforcement, as derived from Northern Powergrid's investment forecast[22]. The source that we have used is the Ofgem model, provided in the Final Determination for RIIO-ED1, November 2014.

Figure 7: Cost-effectiveness of Substation Reinforcement

Substation reinforcement	Primary Voltage	Secondary Voltage	NPgY £k/MVA of capacity released	NPgN £k/MVA of capacity released
Secondary network	LV	LV	143	18
Secondary network	HV	LV	33	32
Secondary network	HV	HV	88	83
Primary network (n-1)	EHV	HV	4	135
Primary network (n-1)	132 kV	EHV	106	n/a

Figure 7 shows the occurrence of a large spread of unit costs across the two licence areas. This is explained by the fact that the work scheduled covers a large variety of situations and requirements. It introduces the idea that the reinforcement work programmes which may be considered for substitution by AIS, are likely to have a similarly wide variety of unit cost (as is the case for those shown in Figure 5 and 6).

We conclude that the comparison between the cost-effectiveness of network reinforcement and cost-effectiveness of energy efficiency improvement is not a "one-size fits all", and that the competiveness of energy efficiency over network reinforcement will vary on a case-by-case basis.

[22] These unit costs are derived from Northern Powergrid's investment forecast provided in the RIIO-ED1 Final Determination, in November 2014.

Cost-effectiveness of Energy Efficiency

In the spirit of exploring the AIS issue, rather than providing an accurate answer to the question, this report has taken a simplistic approach on some aspect of cost effectiveness, and leaves the more rigorous analysis to future research works:

- A network is designed to cope with total peak demand, which is assessed based on a series of assumptions, modelled regularly by the Asset Management team. These assumptions include: average household consumption (which accounts for expected gain in energy efficiency driven by laws such as product labelling), the principle of diversity[23], and take up rate of low-carbon technology. This report adopts the simplistic view that the reduction in electricity demand delivered by the energy efficiency measures affect directly and in its entirety the total peak demand. This allows putting aside the complexity of how each measure would impact on each of the variables of the forecasting model.
- The price control framework that the DNOs operate by applies a degree of rigour to the estimation of cost efficiency that this report does not use. As part of the regulatory process, investment are compared and selected thanks to a cost-benefit analysis model, which includes considerations about network losses.

The main uses of household consumption of electricity are, in order of use:

- Space heating in electrically heated homes
- Water heating in electrically heated homes
- Cold appliances
- Consumer Electronics
- Cooking
- Lighting
- Wet appliances

To deliver AIS with the scale and reliability required to make a meaningful contribution, it makes sense to consider energy efficiency choices in order, namely investment in:

- more efficient space heating or insulation in electrically heated homes
- more efficient water heating in electrically heated homes
- more efficient electricity usage overall, or more efficient appliances or lighting

Figure 8 has been produced by the NEA. It compiles the cost effectiveness of a variety of AIS investment types. These have been calculated in terms of cost per household, for each kW of demand reduction at peak time.

Note that in Figure 8, all costs before any reduction from other sources, prices not converted in 2015 prices[24]. Our analysis only covers domestic AIS, and there may be non-domestic AIS which would be suitable for substitution.

[23] Diversity is the term used to describe the fact that customers use energy at different times, i.e. not all electrical load is on all at once. From a network modelling perspective this means that as the number of customers on the feeder increases, the maximum demand calculated for a feeder is not the sum of the maximum demands of each customer.

[24] Prices have not been converted into 2015 money as the costs of energy efficiency measures have fallen over the period.

Box 5: The rebound effect

A known risk that affects the performance of energy efficiency measures is "the rebound effect". This is where the reduction in energy consumption (in this case electricity consumption) caused by a new measure is wholly or partially offset by a change in behaviour because of a combination of:

- An income effect, e.g. a reduction in electricity bills from one source means that there is more to spend on other consumption which uses more electricity.

- A price effect, e.g. a reduction in electrical heating costs means that households feel able to heat their home to a higher temperature, taking the benefit as more heat rather than lower bills.

The rebound effect varies from measure to measure, and also depends on household circumstances. A household in fuel poverty, and likely to be under-heating their home, is more likely to take a heating efficiency gain as heat, than a household that is already heating their home adequately. Ofgem allows for rebound effects in the residential sector by assuming that 15% of the energy saved by insulation is "taken back" by improved comfort in the form of higher temperatures. This figure is assumed to be 40% for people living in fuel poverty[25]. The rebound from switching inefficient electrical heating to cheaper gas or district heating will not have any impact on the initial electricity saving. There is less rebound from more efficient water heating and from switching a well-used light bulb to a more efficient make. This is unlikely to result in more water being heated or in that part of the home being lit for longer.

Although there has been much research on the rebound effect in general, there is more limited data on its impact on peak electricity demand. Therefore this report uses a conservative approach where demand impacts are scaled down by a "confidence level" which varies depending on the measure itself and the risk of rebound.

[25] DECC, 2010, Estimated Impacts of Energy and Climate Change Policies on Energy Prices and Bills

Figure 8: Alternative Investment Strategies and Their Impact

Category	Energy Efficiency Measure	Cost per household (£)	Peak reduction per household (kW)	Cost Effectiveness (£/kW)	Confidence Level (%)	Adjusted Cost Effectiveness (£/kW)	Approx Annual Saving for resident (£)
Heating Electrically Heated Homes	Electricity to gas conversion (old storage to gas or biomass)	£3,500	2	£1,750	95	£1,838	£445
	Upgrading electric heating (old Storage to new generation storage)	£3,250	1.3	£2,500	90	£2,750	£120
	Electric heating to community heating (in block)	£10,000	1.3	£7,692	90	£8,462	£400
	MicroCHP (Baxi EcoGen)	£6,000	1	£6,000	95	£6,300	N/K
	MicroCHP (BLUEGen)	£18,000	2	£9,000	95	£9,450	£2,000
Elec Water Heating (gas heated homes)	Fit timer (if storage tank)	£60	1	£60	50	£90	£0
Lighting	Replace indicative 3 X 60w incandescent with 3 X 15w compact fluorescent	£12	0.135	£89	95	£93	£20
	Replace indicative 3 X 60w incandescent with 10w LED	£27	0.15	£180	95	£189	£22
	Replace indicative 3 X 50w GU10 to 6w LED direct lamp replacement	£18	0.132	£136	95	£143	£20
	Hybrid - 3 X 60wincandescent to CFLs & 5 X 35w GU10 halogen tungsten filament lamps 6w LED	£34	0.28	£121	95	£128	£35
	District wide street lighting upgrade	*£555*	*0.037*	*£15,000*	*100*	*£15,000*	*NIL*
Building Improvements - Electric Heating	Cavity wall insulation	£415	0.4	£1,038	75	£1,297	£145
	Loft Insulation (None - 270mm)	£170	0.4	£425	75	£531	£150
	Solid wall insulation	£10,000	0.8	£12,500	75	£15,625	£270
	Community ECO insulation scheme (High Rise)	£10,000	1.15	£8,696	50	£13,043	£400
Appliance	Voltage Power Optimisation (VPO)	£300	0.025	£12,000	95	£12,600	£23
	Inefficient appliance swappage scheme	£165	0.041	£4,024	75	£5,030	£50
Behaviour	Dedicated behaviour change programme and support	£400	0.16	£2,500	45	£3,875	£41
Hybrid (Gas Heated)	External wall insulation with PV and behaviour change programme	£12,000	1	£12,000	75	£15,000	£400

Reliability of Energy Efficiency Improvement as a Network Solution

The adjustment, “confidence level”, used in Figure 8 is a judgement made by the NEA project team that reflects the certainty placed in the various energy efficiency measures, to achieve the peak load saving, in the context of a diverse population of customers. The number provided is based on industry research[26], and calculated by considering average engagement levels of households in a population[27], their receptiveness to a change of behaviour[28], the ability and desire to use technology to best effect, and any rebound effect[29] likely in that population as discussed above.

Certainty in load reduction is a crucial point. The service level standard that a DNO is required to guarantee leaves little space for speculation on the ability of a solution to a network problem to deliver. Current traditional methods of asset upgrades deliver a certainty nearing 100%, because the extra capacity created is a known factor, and this is an aspect on which AIS will have to compete against. In this report, we accept the judgement of the NEA experts as a valid reference point. Further research, including that already undertaken by other DNOs (for example the SAVE project), will help explore this point.

The figure shows that behaviour change programmes cost £2,500 per kW reduction. However, because of the diversity of a population within a defined project area within the scope of a potential AIS project (area served by plant), the confidence level is relatively low. This gives an adjusted cost of £3,875 per kW reduction. Case studies and references (which appear in Appendix 1) have shown behaviour change can respond to programmes and community competitions, to account for significant drops in demand, including at peak times.

For Northern Powergrid to be able to divert investment into energy efficiency measures, the long term benefit of energy efficiency – minus the rebound effect – need to be known to a satisfactory degree. However, there is less data on the lasting impact of such programmes. More significant demand reduction occurs when changes are made which combine measures such as insulation and more efficient appliances with behaviour change programmes to minimise rebound effects. To gain maximum impact of any AIS solution, behaviour change and household engagement is an essential part of a project, and should not be underestimated. Several recent reports focus on the importance of this activity within energy related projects[30].

Some measures provide a good reduction in overall electricity use, but do not reduce peak winter demand use. More efficient storage heating would of itself provide little

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[26] NEA Report “Technical Feasibility Study for Electricity NW Ltd into Electricity demand Reduction in Heaton Norris and Heaton Mersey areas of Stockport” May 2013 [unpublished]

[27] City-Scale Domestic retrofit Schemes: Learning from the early adopters http://www.tandfonline.com/doi/abs/10.1080/09640568.2014.965299#.VNnL1vmsU9Y

[28] What Works in Changing Energy Behaviours in the Home? – A Rapid Evidence Assessment – DECC Final Report https://www.gov.uk/government/publications/what-works-in-changing-energyusing-behaviours-in-the-home-a-rapid-evidence-assessment

[29] BRE Energy Follow Up Survey 2013 https://www.gov.uk/government/statistics/energy-follow-up-survey-efus-2011

[30] The Missing Quarter – Integrating Behaviour change with Low Carbon retrofit http://www.svha.co.uk/downloads/svha_downloads/behaviour%20change%20report.pdf
Behaviour Change & Energy Use – The Cabinet office https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/60536/behaviour-change-and-energy-use.pdf
What Works in Changing Energy Using Behaviours in the Home? A rapid Evidence Assessment DECC https://www.gov.uk/government/publications/what-works-in-changing-energyusing-behaviours-in-the-home-a-rapid-evidence-assessment [Accessed 01/03/2015]

benefit to peak demand, as the use of electricity to charge storage heating units occurs outside the peak. However, here, our calculations take account of the behaviour of those with inefficient storage heating, who commonly use additional and very electricity-intensive forms of heating (most notably portable electric room heaters) in the peak evening period to top-up their inadequate storage heating. Figure 8 does not cover more efficient gas heating or insulation where there is gas heating as these impact on the demand for gas rather than electricity.

Figure 8 also shows that there is a cluster of measures costing below £200 per kW. These are largely based around lighting and the replacement of inefficient light bulbs. These lighting measures are very reliable, as would be expected from a straightforward substitution of forms of light. Also in this cheaper category comes the measure of fitting a timer to an electrically heated water tank.

Other measures have a much higher cost per kW, and would not be economic alternatives based on these calculations, and Figures 6 and 7.

In comparing the cost-effectiveness of AIS with the cost-effectiveness of conventional network capital investment, no account has been taken of the typically shorter lifetime of AIS investments. This will vary: product standards are improving so a subsequent replacement by a consumer is unlikely to mean that peak demand reverts to previous levels. In other cases, a switch, e.g. from electrical heating to gas, will tend to be permanent.

The principle of diversity will also affect the theoretical Peak reduction shown in Figure 8, and thereby the cost-effectiveness of the measures. In the same way that diversity affects the aggregation of maximum demand linked to a feeder, it is likely to affect the aggregation of demand reduction by as much as 80% (i.e. reduce the peak reduction, and increase the cost effectiveness by as much).

Because of these considerations comparing Figures 6 and 8 will only provide an approximate indication of the cost-competitiveness of AIS.

Box 6: Scale considerations and the importance of local housing types

Cost-competiveness of energy efficiency measures on a kW basis is insufficient. It is also important to consider whether these measures can deliver on a scale required to avoid the need for reinforcement. The ability to achieve scale depends on:
- The number of customers taking part
- The current level of energy efficiency, and housing stock
- The impact of the energy efficiency measure deployed

Half of the projects in Sample D required an increase in capacity of 300kW or less, and the average requirement was for around 200kW. Reinforcement work will impact on varying numbers of customers depending on whether it is the high voltage or low voltage level that requires reinforcement. For example high-voltage feeders will impact on average 2,000 customers. Delivering 200kW of demand reduction from that population may sound feasible, but the benefit to the network is less significant. Similarly, low voltage feeders impact on an average of 100 customers, which will deliver 200kW of peak demand with more difficulty, but to a higher benefit to the network.

Sample D provided little information on the numbers of customers served by the reinforcement investment projects: just 22 of our 77 sample projects held this data. It was divided almost evenly between customer numbers over 2,000 and those under 500, though there was very limited data on the projects costing over £200/kW and these appeared to be more biased towards serving fewer customers. As a result, we focused the analysis on two examples, with a view to find out if they could provide a reduction of 200kW.

A **hybrid example**[31] (replacing a mix of lights with more efficient substitutes) brings the cost per kW of reduced demand is £128. Figure 6 tells us that at this cost, it is a candidate for AIS in around 60 per cent (by cost) of reinforcement investments. This delivers a peak reduction per household of around 0.28kW a year. Delivering 200kW just through this hybrid lighting replacement scheme would require 714 households to adopt the measures.

Moving to the scenario of **fitting a timer to electrically heated water storage tanks**, the cost per kW of reduced demand is £120, making it a cost-competitive candidate for AIS in around two-thirds (by cost) of reinforcement investments (based on Figure 6). This delivers peak reduction per household of around 1kW a year. Delivering 200kW by fitting timers would require 200 households to adopt measures, which, according to the spread of Sample D, qualifies the majority of the reinforcement projects.

The additional key condition to consider is the existence of houses that can house such energy efficiency measures, and that lend themselves best to the strategy. This is explored in the next section practical feasibility.

The combined challenges create a set of multiple pre-requisites to AIS, which the DNO will have to find the right partners to tackle, and which points to the fact that AIS is locality-specific solution rather than one that could be deployed across the entire DNO licence area.

[31] Three 60w incandescent bulbs changed to CFLs and five 35w GU10 halogen tungsten filament lamps to 6w LED

Leveraging Other Sources of Funding – AIS as "Gap-Funding"

In addition to the network reinforcement budget, it is possible to take account of the other sources of funding towards energy efficiency measures. In this context, the investment brought in by the DNO becomes "gap funding", i.e. it contributes to a wider pot of funds. This wider pot of funds will cover a significant part of the cost.

From the point of view of the DNO, this may be even more beneficial as it will gain from the demand reduction, in return for a much reduced investment outlay. From the point of view of other funders, they are being supported to meet their obligations at a reduced cost.

Figure 9 shows that while there are a variety of schemes which place obligations or incentives for energy efficiency measures, they do not incentivise all types of energy conservation measure, which may lead to which might reduce peak winter electricity demand. For example, they do not generally include support towards more energy efficient appliances. They also support a range of measures which do not impact on peak winter demand. However, there is sufficient overlap to indicate that many measures considered above could become economic to consider as suitable AIS. In addition to the lighting and water heating options already considered, they are likely to bring within acceptable investment limits heating and insulation measures for electrically heated housing including:

- new generation electrical storage heating
- micro CHP such as Baxi and BlueGEN
- biomass conversion
- community heating
- insulation for loft, cavity and solid walled electrically heated properties

Heating upgrades provide a very high reduction in kW per electrically heated household (1-2kW per household) and to a lesser extent (0.4-1.15kW per household) for insulation projects[32]. Bringing these measures within an acceptable cost per kW of peak winter demand reduction will be key to delivering AIS for at the low voltage level.

In addition to the schemes outlined above, Gas Distribution Network (GDN) companies are incentivised to connect fuel poor households to the gas network following an economic assessment model and it is anticipated that 77,000 households will be connected to the network over the next 8 years[33]. This means that there may be instances where heating demand from electrically heated homes could be removed from the electricity network for their heating and water heating needs at little/no cost to DNOs through co-operation with GDNs, potentially gap-funding gas connection projects.

Many local authorities and social housing providers will also contribute towards schemes, in particular community heating schemes affecting social housing.

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[32] This data has been sourced from the case studies in Appendix 1

[33] Fuel Poor Network Extension Scheme: https://www.ofgem.gov.uk/ofgem-publications/89315/fpnesconsultletter140814issued.pdf

Figure 9: Examples of Sources of Funding Towards Energy Efficiency, as a Complement to AIS

Scheme	Who bears obligation/ incentive to fund?	Electricity demand reduction measures covered	Impact on £/kW of AIS
Energy Company Obligation (ECO)	Energy Suppliers are required to achieve energy savings, and they offer free or subsidised measures to achieve this.	For those on certain benefits, help towards ◦ loft or cavity wall insulation ◦ boiler repairs or replacements	ECO covers the full cost of many energy savings, but AIS gap funding could make the difference for more expensive measures, e.g. solid wall insulation.
Renewable Heat Incentive (RHI)	Domestic or non-domestic customers produce renewable heat and receive a payment from the Government for their generation.	Money towards: ◦ biomass boilers ◦ solar water heating ◦ certain heat pumps	Solar measures and air source heat pumps are unlikely to be good candidates for AIS as they do not impact sufficiently on peak winter demand and may exacerbate it. Biomass heat substituting for electrical heating will reduce peak winter demand and could be a good candidate for AIS gap funding.
Feed-in-Tariff (FiT)	Domestic or non-domestic customers produce renewable electricity and receive a payment from the Government for their generation.	Money towards: ◦ solar panels ◦ wind turbines ◦ hydroelectricity ◦ micro combined heat and power systems	Solar measures are unlikely to be good candidates for AIS as they do not impact sufficiently on peak winter demand. Micro CHP should reduce peak winter demand and could be a good candidate for AIS gap funding.
Green Deal Home Improvement Fund	Domestic customers apply for a subsidy towards energy efficiency measures carried out under the Green Deal process. At times when the subsidy is not available, domestic customers may pay for works carried out through a reduction in their energy bills.	Up to £1,000 towards the cost of installing any two of the following: ◦ a condensing gas boiler on mains gas ◦ double, triple or secondary glazing ◦ energy efficient replacement external doors ◦ cavity wall insulation ◦ floor insulation ◦ flat-roof insulation ◦ insulation for a room in the roof ◦ a replacement warm air unit ◦ fan-assisted storage heaters ◦ a waste water heat recovery system	Green Deal and the Green Deal Home Improvement Fund will only pay for measures which pay for themselves through energy bill reductions. A DNO AIS could offer an additional incentive, targeted at measures that have most impact on electricity demand. This could be at relatively low cost per household.

Key Conclusions on Economic Feasibility

In summary, the assumptions made in this research allow us to draw some initial conclusions on the economic feasibility of AIS:

- Cost-effectiveness of network reinforcement, and of energy efficiency, defined respectively as the cost of adding one kW of capacity on the network, and reducing peak demand by one kW, varies substantially from one solution to another. In addition, because solutions are deployed in practice as a mix of options, it is difficult to draw general conclusions from a simple comparison, outside of any context.
- Comparing their cost-effectiveness shows that there is a relatively small subset of energy efficiency measures (in particular low energy lighting and water heating timers) which may be cost-competitive compared with network reinforcement. There are a larger number of energy efficiency measures (including heating replacement, insulation and energy efficient appliances) which are in general less cost effective than conventional network reinforcement.
- Outside of cost considerations, energy efficiency measures need to guarantee a certain level of certainty of result in order to compete with network reinforcement as a network solution. This means beating the rebound effect, delivering on a sufficient scale after taking into account the diversity principle, and for the long-term.
- A variety of government schemes provide funding for energy efficiency measures which, when combined with AIS investment, substantially boosts the competitiveness of cost-effectiveness of energy efficiency, against that of conventional reinforcement.

Further Work

The work in this section has highlighted areas that will require further investigation to confirm these conclusions:

- The quantity and the longevity of the peak demand reduction delivered by improved energy efficiency are the measures of the benefit delivered to the network. The measures used in this report are assumptions based on a variety of case studies, so further work is required to introduce statistically valid values, with a higher degree of certainty.
- It should be noted that these solutions are dependent on appropriate target communities containing the appropriate housing, tenure and technologies to enable retrofit and behaviour change actions (AIS) to be deployed with predictable results. A number of case studies would help to establish whether the scale of peak demand reduction can be achieved on a cost effective basis to deliver peak load reductions and network benefit sufficient to cancel the need for conventional reinforcement investment.
- Diversity has not been taken into account in this analysis, but its consideration may have a detrimental impact on the cost-effectiveness of AIS. Future work would need to investigate the specific impact of diversity on the relative attractiveness of AIS for the types of AIS measures considered in this report.

Practical Feasibility

In this section we consider the likelihood of simultaneity of location between energy efficiency opportunities and planned network reinforcement (used as an indicator for the location of network constraints). Coincidence of location is indeed a key condition to the feasibility of AIS. The study focusses on several questions:

- Can we learn more from the geographical distribution of projects?
  - Are projects located in areas which are more likely to provide sufficient households for the measures?
  - Do these areas contain the sort of housing which provides opportunities for AIS?
  - Do they house deprived populations which will attract greater funding under ECO?
- What do existing case studies of energy efficiency projects tell us?
- Are there any regulatory barriers to DNO AIS?

The availability of information to DNO is a barrier to AIS, because DNOs are not routinely kept informed of local projects that deploy energy efficiency measures. Solution to this barrier is not in the scope of this report. The Energy Technologies Institute's Smart Systems and Heat project may deliver best practice on the topic and progress the knowledge in how to make local infrastructure investment decision with confidence[34].

Geographical Distribution of Northern Powergrid Projects

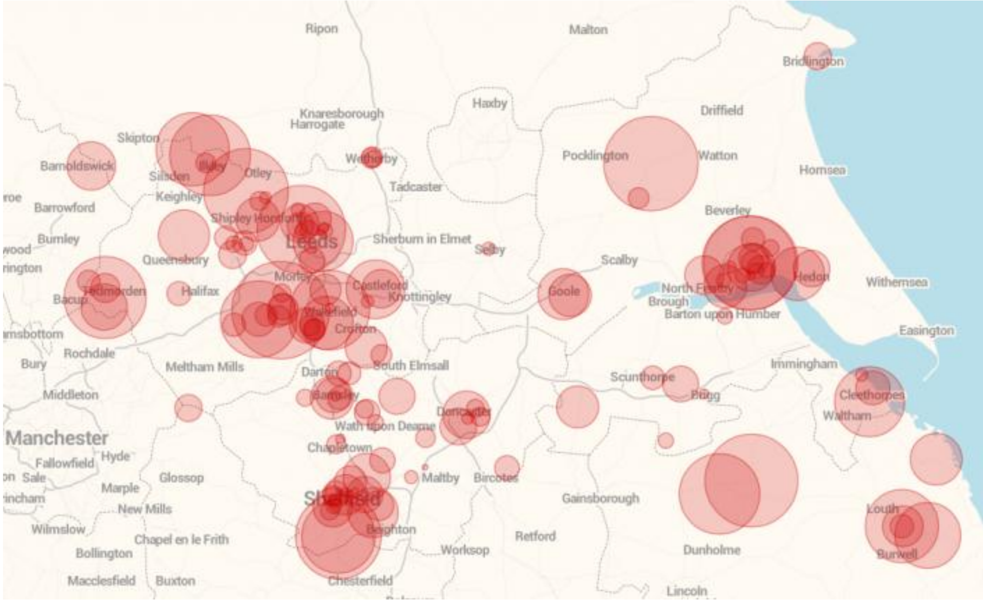
Populations cluster, as do reinforcement projects. Sample C of 156 Yorkshire-based projects from the Economic Feasibility section was used to build the following map. The map displays the geographical spread of the reinforcement projects, based on the location data in the sample. The "clustering" of these projects is shown in Figure 10.

Projects appear to concentrate loosely down the M1 corridor from Leeds, through Wakefield/Dewsbury to Sheffield and further west in Hull.

According to the 2011 census, much of this area is 7,900-23,700 population per km^2, with Hull at above 23,700 population per km^2.However there are significant projects, such as around Louth to the South-East of the map, where population density is relatively low, at around 1.3-3.3 population per km^2.

[34] http://www.eti.co.uk/programme/smart-systems/

Figure 10: Concentration and Size of Sample C projects



Note: the size of the bubble denotes scale of the project.

Geographical Distribution of Economic Deprivation

In investigating the scope for AIS, locating deprivation can be used as a proxy for locating fuel poverty and energy efficiency projects

- Many of the alternative sources of funding for energy efficiency projects and fuel poverty projects, notably ECO, are focused on deprived areas. In addition, local authorities and other agents tend to focus their social programmes on the most deprived localities.
- Given that potential pursuit of AIS by Northern Powergrid is driven by its desire to deliver social outcomes as well as cost effective network management, the potential to deliver AIS in areas of deprivation is desirable.

Carbon Saving Communities Obligation Areas (CSCO) are those where the bottom quartile of families are on the "Index of Multiple Deprivation", a Government composite measure of deprivation comprised of seven individual indicators[35]. Much energy efficiency subsidy at present is focused on these areas. This will remain the case until March 2017 (when the current ECO period ends), and it is likely to remain the case beyond the end of the current ECO period, given the policy positions of the main political parties.

Figure 11 shows the incidence of Carbon Saving Communities Obligation Areas across Northern Powergrid's service area – shown in maroon.

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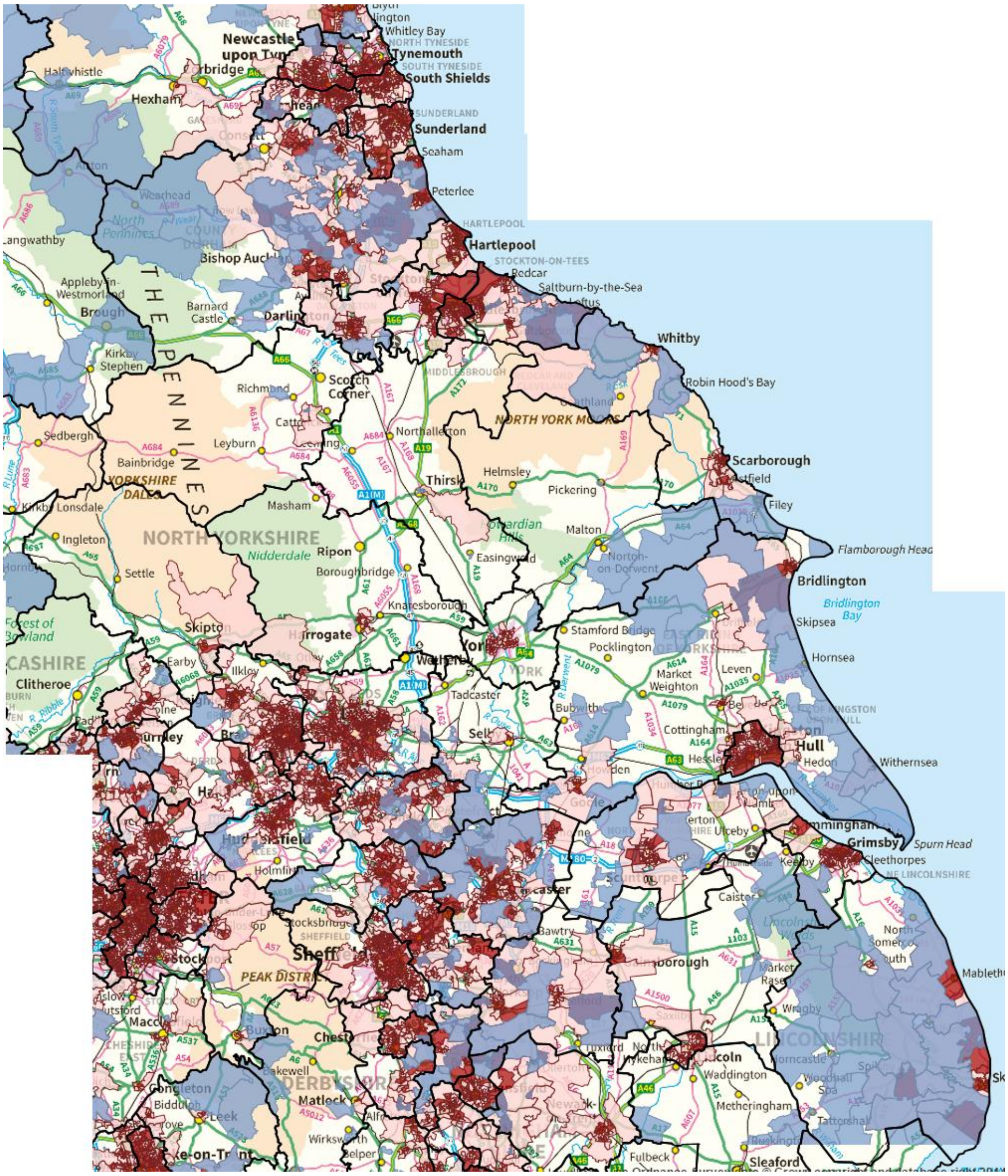
[35] These relate to income deprivation, employment deprivation, health deprivation and disability, education skills and training deprivation, barriers to housing and services, living environment deprivation, and crime which reflect the broad range of deprivation that people can experience. See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/6320/1870718.pdf

Figure 11: CSCO Areas, Adjacent Areas, and Rural Areas in Yorkshire and the North East



Legend: CSCO Areas: maroon, Adjacent Areas: salmon pink, Rural Areas: light blue

Figure 11 shows that there is a very high incidence of CSCO areas right across Northern Powergrid's service area, particularly in the areas of high density of population. This also coincides with the areas of high reinforcement expenditure shown in Figures 10.

This coincidence of location suggests that there will be opportunities to supplement investment in AIS by network companies with other sources of funding (in this case ECO), an opportunity we have described previously as "gap funding".

Current legislation (running to 2017) allows one energy efficiency improvement to be installed in a CSCO Adjacent Area for every four installed in a CSCO Area. CSCO Rural is the bottom quartile of rural LSOAs on the Index of Multiple Deprivation. 15% of all CSCO needs to be delivered in CSCO Rural Areas. The inclusion of these further categories includes further large parts of the Northern Powergrid service area, making it even more likely that opportunities exist or could be created to gap-fund AIS.

Distribution of Housing Types

We have also looked in greater detail at available data for housing in areas of Yorkshire with a view to gain insight into the availability of AIS measures and the cost effectiveness of conventional reinforcement spend in these areas.

Figure 12: Housing types in Local Authorities of Yorkshire[36]

Local Authority	Average £/kW of completed schemes (where data available)[37]	Solid Wall	Std Cavity	High rise	Mobile residential Homes	PERCENTAGE Households with no Central heating	PERCENTAGE Households with Electric Central Heating
Hull	£283	✓	✓	✓	✓	4	7
Sheffield	£101	✓	✓	✓	✓	2	7
Bradford	£90	✓	✓	✓	✓	6	7
Leeds	£552	✓	✓	✓	✓	5	11
Wakefield	£34	✓	✓	✓	✓	2	6
Barnsley	£123	✓	✓	✓	X	1	2
Yorkshire & Humber					**5,278**	3	6
England					**88,918**	3	9

Figure 12 shows a wide variety of housing types in each of the local authorities. For example, Leeds is shown to have a relatively high proportion of electrically heated properties. This is important: as was demonstrated in the Economic feasibility section, it is by providing electrically heated homes with insulation and/or alternative heating, that the highest peak demand reductions per household can be achieved.

From our knowledge of the Leeds area, we believe that the relatively high number of high-rise flats, which are electrically heated and house deprived communities, could make this a highly suitable area for AIS: the concentration of electrically heated homes which should attract high levels of ECO should provide more opportunities to support demand reduction. In addition, the relatively high current investment costs should support a wider variety of measures.

Of course Leeds is not unique in this respect – Figure 12 also shows that all of the other local authority areas with the exception of Barnsley have relatively high penetration of electrical heating. Previous discussions held by Northern Powergrid and AgilityEco with Your Homes Newcastle and Gateshead Council also revealed high numbers of electrically heated homes, particularly in tower blocks.

[36] All data from Office of National Statistics – Neighbourhood Statistics Data https://neighbourhood.statistics.gov.uk/dissemination/ except see footnote 36.
[37] Source: Northern Powergrid sample of 77 Yorkshire based projects. Figures in current prices. Given the small sample size this column should not be relied upon.

Case Studies of Project Supporting Local Energy Efficiency

In order to test the feasibility further in terms of the realism of cost estimates and likelihood of projects which match against investment requirements, NEA reviewed cases where local energy efficiency could be shown to have reduced on peak winter demand. Key data from four case studies, set out in full in Appendix 1, are presented in figure 13 below.

Figure 13: Data from case studies of projects supporting local energy efficiency

	Case Study 1 Heaton and Norris Towers, Stockport	Case Study 2 ERDF social housing energy management project	Case Study 3 North Leigh Energy Efficiency Project	Case Study 4 Repower Bainbridge
Estimated peak Winter demand savings per household	1.17kW	0.23kW	0.16kW	1.4kW
Total estimated or actual cost per kW saved	£8550/kW	£16,000/kW	N/K	£300/kW
Total estimated cost to a DNO partner	£125/kW	Nominal (project was funded from existing sources)	£770/kW	Under £300/kW (depending on availability of other funding

Note: all data sources cited in Appendix 1

These case studies show wide differences in outcomes. Peak winter demand saving per household was an impressive 1.4kW in Bainbridge, where an island of 6,800 households was "targeted". This is clearly higher than the peak saving quoted in the previous section, driven in large part by behaviour change. Less than a third of households had heating improvements and the rest of the reduction depended on intensive behaviour change measures, delivered at relatively low cost. The impressive peak winter demand outcome may also have been because it was peak winter demand that was specifically targeted, rather than overall energy or energy cost savings. It shows how AIS can make a significant difference over a large area.

The ERDF project rested on insulation and renewable energy fitted to a smaller number of homes. The reductions in peak winter demand were relatively costly. Similarly the Heaton and Norris project insulated and fitted renewable energy to two tower blocks. Close proximity with other residents and smaller surface areas of walls interfacing with the outdoor environment reduced the savings, but the peak load was relatively high because the heating was electrical.

These projects show that good results can be achieved in specific local areas, which contain housing in need of particular AIS measures.

The Regulatory Framework in Great Britain and Europe

So far, this report has considered the economic aspects of the suitability of AIS. However, an important consideration which must be addressed is whether the regulatory framework supports these non-traditional approaches and whether any barriers can be identified to a DNOs investment or involvement in these models.

As noted in the introduction, within the strategy decision overview for RIIO-ED1[38] and within the latest report produced by the Government's Fuel Poverty Advisory Group in England[39], Ofgem state that DNOs are incentivised through an "efficiency incentive" to deliver outputs as efficiently as possible. The effect of the efficiency incentive should mean that where a DNO makes a saving in the cost of their investments, it gets to keep a proportion of the saving, with the remainder returned to consumers. Provided the contribution by the DNO to the cost of AIS is lower than the cost of the network reinforcement, we have highlighted how, in some instances, DNOs can look to this mechanism to incentivise the installation of alternate heating technologies or in-home energy efficiency to offset the need for wider network reinforcement[40]. We have also highlighted that it is not always possible to keep the costs of AIS lower than network reinforcement and therefore, justifiably, the generic efficiency incentive would not provide a reward.

As identified above, it is critically important to understand how the regulatory regime could impact on a DNO being able to identify complementary energy efficiency activity that is already being planned or developed within an area, to enable them to 'piggyback' a DNO investment on top of third party finance instead of making the investment entirely independently. Capturing this opportunity requires:

- the DNO to have a positive incentive to undertake this additional investigation
- the willingness of a third party (or parties) to engage with a DNO and a regulatory regime which does not prohibit this co-ordination, and
- an alternative project that meets the shared objectives of all parties.

Within RIIO-ED1 Ofgem have increased the value of reward available under Stakeholder Engagement Incentive so that Ofgem can specifically assess and reward the steps DNOs take in response to social challenges[41]. In order to develop AIS alongside other third party funds instead of making the investment entirely independently, there is a clear need to engage with a wide range of stakeholders such as local authorities, housing associations, obligated energy suppliers, other energy distributors (both gas) and potentially other utility providers. As long as the Stakeholder Engagement Incentive is large enough to cover the overheads associated with identifying these third party opportunities, this should be a sufficient incentive undertake this additional investigation.

Gas Distribution Network (GDN) companies are incentivised to connect fuel poor households to the gas network following an economic assessment model and it is anticipated that nearly 80,000 households will be connected to the network over the

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[38] Strategy decision for the RIIO-ED1 electricity distribution price control, Ofgem, 04 March 2013.
[39] FPAG 12th Annual Report, February 2015, p 24.
[40] Ofgem have also set out some clear requirements to improve the quality of information DNOs (or other parties) have access to about vulnerable consumers and request that there is a clear explanation of how this information will be used
[41] RIIO-ED1 Stakeholder Engagement and Consumer Vulnerability (SECV) incentive consultation, Ofgem, 16th Dec 2014.

next 8 years. The report has highlighted how this provides an opportunity to DNOs for joint working.

Ofgem has also recently set out its requirement for the Gas GDNs Discretionary Reward Submission (DRS) under the RIIO GD1 framework[42]. For the first time the regulator is asking for a collaborative approach to the submission with the four GDNs putting a joint submission as well as their own supporting evidence. The submission covers Fuel Poverty, Carbon Monoxide Awareness and wider environmental impacts. The GDNs have been working collaboratively and sharing best practice. They are currently working to review what they and others are doing in this area and deciding where to best allocate their focus and resource in the future. These developments highlight how the current or emerging regulatory regime could help create some clear synergies between DNOs and GDNs which could help support AIS.

One final consideration of whether AIS can meet shared objectives is to briefly highlight the potential for DNOs to work with obligated energy suppliers to co-fund in-house measures. Following previous GB-wide supplier funded initiatives like the Carbon Emissions Reduction Target and the Community Energy Saving Programme, the Energy Company Obligation (ECO) is delivered by obligated parties across England, Scotland and Wales[43]. Whilst the programme can be challenging to access and leverage due to an ability to guarantee assistance for eligible households, it does provide energy efficiency measures for low income and vulnerable households and has been extended from March 2015 until March 2017. A complimentary regulatory regime could create some clear synergies between DNOs and another party.

Finally, an important consideration is how conducive the regulatory framework is at European level at supporting these non-traditional approaches and whether any barriers can be identified which prohibit a DNOs involvement in these models. In this context, the EU Energy Efficiency Directive[44] states that by 30 June 2015 Member States shall ensure that:

> (a) an assessment is undertaken of the energy efficiency potentials of their gas and electricity infrastructure, in particular regarding transmission, distribution, load management and interoperability, and connection to energy generating installations, including access possibilities for micro energy generators;
>
> (b) concrete measures and investments are identified for the introduction of cost-effective energy efficiency improvements in the network infrastructure, with a timetable for their introduction.

According to the UK National Energy Efficiency Action Plan[45] the UK will transpose the requirements in Article 15(2) through secondary legislation under section 2(2) European Communities Act 1972 by placing a requirement on Ofgem to ensure the assessment is undertaken and that concrete energy efficiency improvements are identified. A further requirement is to stipulate a clear timetable for their introduction.

[42] Decision on arrangements for the first Gas Discretionary Reward Scheme (DRS) under RIIO-GD1, Ofgem, 12th December 2014.
[43] Following termination of the Warm Front scheme in January 2013, England continues to be the only UK nation without a Government-funded energy efficiency programme targeted at fuel poor households. In contrast, Scotland and Wales have continued to expand funding for their own national programmes at these could be used for DNOs who operate in these countries.
[44] The Energy Efficiency Directive was agreed in October 2012, please read the text here.
[45] UK National Energy Efficiency Action Plan: DECC, April 2014.

Whilst it is anticipated that the requirements of the Directive are to investigate network infrastructure efficiency and losses, this assessment could also include a consideration of the potential for in-home energy efficiency measures, such as the AIS identified within this report.

This development is however contradicted by a more recent consultation by the Council of European Energy Regulators investigating the Future Role of DSOs[46] (here called DNOs). Whilst the paper acknowledges that contributions to improved energy efficiency can be delivered across distribution network and DNOs should have a role in delivering activities related to energy efficiency, they imply this role should be limited to activities to improve energy efficiency of the network and there are tensions to balance in 'reaching beyond-the-meter'. However, later in the paper it acknowledges that there may be value for the network from consumer energy efficiency measures that avoid network reinforcement and consumers could benefit for this.

Given that this ambiguity could act to deter AIS, it would be helpful for interested parties to seek clarity from the Council of European Energy Regulators and ensure that the Council understands and recognises the value in promoting outcomes that can lead to greater economic, environmental and social outcomes whilst not impacting on the overall goals of the Electricity and Gas Directives[47]. This would help the EU deliver its overall goal of European energy policy is to ensure "safe, secure, sustainable and affordable energy for all businesses and consumers alike"[48].

In conclusion, while there is no bespoke regulatory framework covering DNOs in Great Britain to support the development of alternative investment strategies, the existing regulatory framework could reliably support DNOs to undertake AIS and work with third parties to meet their statutory duties in this area. In Europe, the story is more mixed. Whilst it appears the transposition of the requirements of the Energy Efficiency Directive in the UK could support DNOs' efforts, it would be helpful if lobbying efforts could support a clarification of the ambiguous interpretation of the Council of European Energy Regulators of the role of DNOs on energy efficiency and the need to balance this with the establishment of a European Competitive Energy Market and, in particular, Member States' response to the high-level requirements of the Third Energy Package.

[46] The Future Role of DSOs - A CEER Public Consultation Paper, CEER, 16 December 2014.
[47] The Directive can be found here.
[48] Towards a new Energy Strategy for Europe 2011-2020, EU Council, 2011

Key Conclusions on Practical Feasibility

In summary our analysis of the practical feasibility of AIS leads us to conclude that:

- Overall, overlaying the geographical distribution of projects with a map of deprivation indices demonstrates coincidence of location. This implies that there are future opportunities for AIS, including AIS for which Northern Powergrid could "gap-fund".
- Although AIS is a solution to a network problem which can only be deployed on a case-by-case basis, some combination of factors act as an indicator for where opportunities are likely to occur. For example, Leeds, which concentrates a high level of Northern Powergrid investment, is likely to provide many opportunities due to relatively high population density, high deprivation and high electrically heated housing.
- Case studies show that significant peak winter demand reductions can be achieved at relatively low cost, particularly where: (a) behaviour change is targeted alongside physical measures; and (b) where peak demand reduction is a specific aim of the project.
- Our investigation of the regulatory environment shows no explicit barriers, although as explained below, clarification of statements at European level could be helpful to pave the way for a more active DNO role in AIS.

Further Work

The investigation work has highlighted areas that will require further clarification:

- Although the research did indicate that reinforcement expenditure takes place mostly in dense urban areas where the scope for AIS is highest, once AIS is taken forward to potential trial projects, this analysis will need to be tested in more detail – are there actual AIS opportunities of the size and scale available to offset a planned grid investment. This could be found out for instance through further stakeholder engagement.
- Although the regulatory analysis highlights no explicit barriers, we suggest that clarification from the Council of European Energy Regulators is sought in relation to the potential role of DNOs "reaching beyond the meter".

Further Work

This report represents a first step to identifying the opportunity and understanding the feasibility of DNOs investing in local energy efficiency. **It suggests that a relatively small but nonetheless meaningful opportunity may exist**.

However, as highlighted in earlier sections, further follow-on work will be required in advance of any such investment taking place:

- The scope for load-related primary (66kV and 33kV) investments to be substituted by large-scale ambitious AIS projects
- A more rigorous analysis of the customer connections investment area, where a simplistic approach was taken
- The quantity and the longevity of the peak demand reduction delivered by energy efficiency gains, and in comparison with network investments
- case studies to help establish whether the required scale of peak demand reduction can be achieved on a cost effective basis to deliver peak load reductions
- the impact of diversity on the relative economic attractiveness of AIS
- more detailed analysis of whether AIS opportunities of the size and scale available to offset a planned grid investment are exist
- clarification from the Council of European Energy Regulators in relation to the potential role of DNOs “reaching beyond the meter”.

The empirical evidence found in other DNOs projects, such as Less is More, and the Power Saver projects may provide answers to some of the questions that remain open in this report.

Once Northern Powergrid is satisfied that these issues have been satisfactorily clarified, we recommend that a number of site-specific feasibility studies are carried out. These should identify a number of locations where reinforcement works are identified as required in the future. It should investigate the housing types (in particular the heating-types, levels of economic deprivation and potential for partnership work with ECO suppliers and the local authority).

Out of this work might come further insights into the mechanism for such investments taking place (regulatory aspects, project selection, evidence requirements, etc); the technical aspects (quantifying the peak load reduction, project evidence requirements); and the financial aspects (treatment within price control, price offered, leveraging existing funding mechanisms, etc).

Other questions that remain unanswered and were not included in the scope of this report are listed below.

Regulation and Policy

- How would this work financially within DNO price control mechanism?
- How would DNO network design policy be modified to accommodate a new investment class/model?
- How can this work integrate with existing workstreams such as Smart Grid Forum Workstream 3 (“Developing Networks for Low Carbon—The Building Blocks for Britain’s Smart Grids”)?

Information

- How can DNO gain visibility on local projects that aim at deploying energy efficiency?
- How can DNO quantify with confidence the peak load reduction delivered by energy efficiency projects?

Selection and Pricing

- How would DNO select which project(s) to invest in as alternative to reinforcement – seek proposals via an auction, aim to identify relevant loads (eg electrically heated tower blocks) from its own records and offer funding support to owners, etc?
- Push vs Pull: Ongoing evaluation of approaches made by developers vs requesting proposals at times when reinforcement investment is being planned?
- How to maximise the leverage obtained by ensuring DNO investment complements other existing funding streams (such as ECO, and RHI)
- How does DNO demonstrate to the regulator that it has secured value for money?

Appendix 1 - Supporting Local Energy Efficiency as an Alternative to Network Reinforcement – Learning from Four Projects

1. Heaton and Norris Towers in Stockport[49]

Heaton Norris and Heaton Towers are two tower blocks in close proximity to one another, and contain a total of 136 flats. They house a mixture of individuals, families and retired people. In 2012-13 the tower blocks were improved by the installation of external wall insulation – funded through the Community Energy Saving programme (CESP) which preceded the current Energy Company obligation (ECO) funding. In addition to insulation improvements, a replacement heating system was installed which moved the residents from electric storage heating to a “wet” biomass fuelled community heating solution. Flats were provided with radiators, heat meters and modern controls.

The Biomass supply company modelled pre-improvement energy use, and directly measured energy use post improvement. The company estimated an electrical energy reduction of 3,500kWh per year per flat. Direct measurement of heat demand over the period between December and mid-May 2013 revealed that the mean heat usage was c.1,930kWh/flat (and a median of 1,570kWh).

Resident interviews within a sample of flats revealed that prior to the works, 80% of residents used supplementary heating in the evening, as the storage heating was felt to be as inadequate later in the day, and controllability was almost non-existent.

The modelling carried out by the company demonstrated that an estimated 1.17kW per flat could be saved from peak load by carrying out the heating improvements. The capital cost of the district heating works for this project was typically in the range of £8 - £12k (average £10k) per flat. On the basis of a cost per kW achieved through the capital outlay, £8,550 per kW peak load reduced would be required to fund the scheme.

However, these projects are not implemented with the prime objective of reducing peak electrical load, they are to improve housing, reduce heating costs (and fuel poverty), improve the health and wellbeing of the community and improve the “look and feel” of neighbourhoods[50]. ECO can provide funding for the implementation of these schemes in appropriate circumstances, so a relatively small contribution towards any shortfall, may be required from a partner DNO, to support or catalyse a retrofit scheme in an appropriate area. For example, a DNO could fund the behaviour change advice to residents to improve and maintain the savings to the network. This support to residents would cost around £20,000, giving a cost of £125.00 kW of peak load reduction.

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[49] NEA Report “Technical Feasibility Study for Electricity NW Ltd into Electricity demand Reduction in Heaton Norris and Heaton Mersey areas of Stockport” May 2013 [unpublished] with data provided by British Gas New Energy.

[50] http://www.nottinghamcityhomes.org.uk/documents/modern_warm_secure/impact_studies/Final_report_Mar_2012.pdf [Accessed 28/01/2014]

2. European Regional Development Fund Social Housing Energy management Project[51]

This project involved three partners, the local council and two separate social housing providers in the NE of England. The project involved retrofitting low carbon technologies to 322 “hard to treat and heat” properties owned by the housing providers’ 268 non-standard build homes and one tower block containing 55 flats.

External wall insulation was fitted to all three main property types, along with complimentary solar photovoltaic panels, and energy advice aiming at maximising usage of the “free” energy produced in the 268 houses. Significant social benefits were realised in the communities, with improved resident comfort, health and reduced energy bills being cited by householders.

In these homes, electricity use reduced by an average of 44% in the 132 poorest energy performing homes, and 19% in the 55 moderate performing homes, equating to an annual saving of 2,268kWh and 1,144kWh respectively. Additionally, residents reported a reduction in the use of additional electric fires from 40% using the fires prior to improvements, to 13% after improvements. These are likely to be used in the early evening.

It is estimated that the properties have reduced peak electricity loading by around 75kW. An investment of £1,200,000 provided an indicative saving of **£16,000 per kW**. There was no DNO contribution.

[51] https://ore.catapult.org.uk/documents/10619/127231/Social+Housing+final+report/6ca05e01-49cc-43ca-a78c-27fe0e2dd239

3. SSE[52][53] - the North Leigh Energy Efficiency Project

The Electricity Demand Reduction Project (EDRP) was a major research project investigating the impact of a wide range of interventions on domestic energy consumption, in around 60,000 homes in England, Scotland and Wales.

The trials were launched in July 2007 and were managed by Ofgem on behalf of DECC. Government provided a total of **£9.75m** towards the trials which was match-funded by the participating suppliers. The final analysis of the trials has now been published at www.ofgem.gov.uk. One case study is presented below - **the North Leigh Energy Efficiency Project** - which was conducted by SSE. No publically available data is available as to the actual cost of this project.

This project operated in the North Leigh area of Oxfordshire in 2005 with the Thames Valley Energy centre. The strategic aim of the project was to identify what works in motivating people to save energy. The community was given the target of reducing their electricity use by 10% for at last three months of 2009 compared with the same period in 2008. Substation loading was monitored to provide the data. If the reduction was met, a community prize of £20K was offered by SSE to install PV on the village hall. 800 households were involved in the project, and worked with the North Leigh Energy Efficiency Project to achieve the goals.

Supported by community events, door to door advice and weekly surgeries, the project did result in the achievement of the 10% target, within the timeframe. The prize money was awarded.

Resources were provided to assist householders achieve the goal included thermal imaging of individual homes, provision of in home displays (SSE branded Eco Eye / Owl Meter style devices), free cavity wall and loft insulation (funded through SSEs CESP commitment), £25 vouchers for low energy light bulbs, and £500 vouchers towards the purchase of A+ rated "white goods". Some promotional material was produced in the form of T-shirts, indoor thermometers, a website, and numerous community events. SSE funded these resources and activities.

The following specific interventions were recorded:

- 214 smart meter households served by SSE at the start of the project (189 still served at the end)
- 431 real time displays provided to both SSE and non-SSE customers (348 were set up with 82 requiring re-setting). During visits, assistance was given with installation and advice on use
- 607 infrared surveys carried out, with the results mailed directly to the household, along with an Energy Performance Certificate rating (estimated from the infrared data) and an insulation offer. No households took up the offer of insulation via this promotion
- 409 energy advice booklets given out
- 405 individual requests were made for the VoEVT member of staff to re-visit to provide further advice

[52] http://www.sustainabilityfirst.org.uk/docs/2014/Sustainability%20First%20-%20Paper%2010.%20Annex%202.%20-%20EDRP%20Community%20Demand%20Reduction%20Competition.%20Megan%20McMichael%20-%20January%202014.pdf

[53] Energy Demand Research project: Final Analysis Available at https://www.ofgem.gov.uk/ofgem-publications/59110/edrp-appendix-d-sse-community-trials.pdf

- 96 compact fluorescent lights (CFLs) handed out by VoEVT
- 95 thermometer cards provided
- 50 smart meter requests made via VoEVT
- 30 standby savers handed out
- 21 cavity wall and loft insulation measures were installed (47 enquiries were made and 26 jobs were cancelled)
- 1,300 CFLs were purchased utilising a £25 voucher supplied by SSE (£32,500)
- Events (SSE Sponsored)
- £20,000 community prize sponsored by SSE.

The funding was provided through a combination of Energy Saving Trust established sponsorship (before the EDR project started), and through Ofgem, match funded directly by SSE.

For a partner project where the DNO funds the community events, booklets, publicity materials, prize money and vouchers, and investment of £100,000 and working with established partners (such as in a transition town), there is a potential to reduce the peak load by 10% as achieved here. It is likely that this would equate to around 130kW peak load reduction, making this an investment of **£770 per kW** for the DNO.

4. RePower Bainbridge[54]

RePower Bainbridge (RePower) was a three-year project on Bainbridge Island, Seattle, United States of America, aimed at reducing energy demand, eliminate a peak load capacity challenge, complete home energy assessments, upgrade Island homes, promote renewable and clean energy systems, educate homeowners and create green jobs.

Bainbridge Island is home to approximately 6,800 households. The project was intended to be a community-focused residential energy efficiency model for adoption by communities worldwide. RePower's energy-efficiency efforts are based on conservation efforts including energy assessments with direct installations of energy-efficient lighting and showerheads, building envelope improvements, heating system upgrades, fuel conversions, renewable energy systems, and implementing a demand response system backed up by a comprehensive community education and engagement programme.

The aims were to reduce peak time energy demand on the island by completing:

- 5,000 home energy assessments
- 2,000 home energy upgrades

Outcomes included:

- Creating 65 new jobs directly, and 252 jobs indirectly
- Reducing carbon emissions by more than 6,904 tonnes
- 15% energy savings in each participating home.

Positive Energy monitored weather conditions and, when temperatures were expected to drop below freezing on cold winter mornings and cause peak demand, used e-mail, Facebook, and twitter to ask people to power down appliances and curtail their energy usage. They also worked with partners to create a digital dashboard, showing people in real time exactly how much energy the island was using. Energy displays were erected in over 10 prominent public spaces around the island.

This project resulted in a reduction of **peak load** power by **10 MW** during the winter of 2010-2011 - the first winter of this voluntary citizen engagement program. No one expected such a significant response.

In terms of a cost for the project, this was a partnership project drawing in funds from a variety of funders. RePower paid $345,955 (≈ £228,000) to the project in the form of incentives, and the project overall cost $4,572,955 (≈ £3m), much of which was private funding from home owners and government support through the American Recovery and Reinvestment Act (ARRA) through the U.S. Department of Energy Better Buildings program.

If a UK based DNO funded the entire replicated project of £3m, the cost per kW peak load reduced is **£300 per kW**, although ECO funding could provide contribution to some eligible "building envelope improvements", improving the take up and impact of the project in the UK.

[54] Available at http://repowerkitsap.org/documents/DOE%20Handbook_FINAL.pdf

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