Strengthen electricity grid at key points

1. EXECUTIVE SUMMARY

1.1. Decarbonisation of the heating and transportation sectors on the Isle of Man will involve accelerated deployment of heat pumps (HPs) and electric vehicles (EVs) respectively. The increased electricity consumption and maximum demand will require major reinforcement of the Island's transmission and distribution system in the long term to 2050 if an accelerated strategy to net zero emissions is adopted. However for the next decade, current studies by a reputable UK consultancy – EA Technology - have indicated that modest investment costs are required to accommodate a 'zero carbon' trajectory comprising 10,000 EVs and 5,700 HPs by 2030. Moreover fully leveraging innovative adoption of principally dynamic tariff pricing structures and load management capabilities could reduce the potential cost of network investment. This is partly attributable to the 'loss' of electricity retail sales since 2009 providing some headroom both in electricity supply and transmission/distribution capacity to meet the majority of the increased load anticipated from the relatively high volumes of potential EVs and HPs over the next decade.

1.2. Widespread energy efficiency measures and structural changes in the Island economy has resulted in surplus generation from the existing Combined Cycle Generation Turbine (CCGT) plant and increased distribution network capacity at key strategic substations around the Island. Therefore the incremental electricity supply and network capacity requirements to accommodate aggressive EV and HP projections over the next decade to 2030 are expected to be met with minimum network expenditure.

1.3. In the longer term from 2030 to 2050 the impact on network reinforcement costs is anticipated to significantly increase due to the increased electrical load from a potentially exponential expansion in the deployment of EVs and HPs Island wide. However based on UK forecasts this is expected to be partly mitigated by a combination of alternative heating and transportation technologies and load management services offering system flexibility to defray substantial incremental network investments. Increased levels of domestic and commercial solar PV and thermal/battery storage – as the latter's prices continue to fall – will delay the need for major network reinforcement. Further support will originate from low carbon hybrid heating alternatives such as HP/'green gas' boiler systems, increased potential of vehicle to grid/home capabilities to facilitate aggregated load management services and dynamic electricity pricing tariffs to encourage usage at off-peak periods or times of surplus renewable generation.

2. THE CHALLENGE

Introduction

2.1. The transition to a low carbon economy will involve the replacement of conventional fossil-fuelled heating and 'internal combustion engine (ICE)' transportation with a combination of low and zero emission alternatives such as air source heat pumps (HPs) and electric vehicles (EVs). Depending on the time frames and speed of this transition, this will require investment in the network to accommodate both the associated increase in electricity demand, and to mitigate the impact on winter peak demands. However in the medium to long term, falling costs of embedded generation such as solar photo-voltaic (PV) panels, widespread rollout of smart metering enabling the introduction of dynamic tariffs, advances in battery storage technologies and smart load management measures will all contribute to reducing the overall costs of network reinforcement and operation.

Current carbon emission status of transport and heating on Island

2.2. Isle of Man Government 2016 carbon emission statistics show that residential heating's contribution is c. 286,000 tonnes (34%) whilst that of transport is 158,000 tonnes CO_2 (19%). Therefore an accelerated deployment of both HPs and EVs will make a substantial contribution to the Island's net zero emissions target by 2050 especially post 2035 when the majority of MU's generation mix is planned to be sourced from renewable generation.

2.3. Based on Isle of Man Government's Climate Mitigation Challenge 1 and National Grid's most optimistic 'Two Degrees' Future energy scenario 2, it is anticipated that c. 10,000 EVs and over 5,700 HPs will need to be accommodated by 2030 to comply with the long term net zero emission trajectory for the Island. There are currently around 41,000 households with conventional oil or natural gas/LPG boilers, 5,000 small to medium businesses, c. 65,000 standard cars and over 7,000 commercial/public sector vans and HGVs registered on the Island. As of September 2019, there are presently only c. 200 HPs installed either privately or in social housing and c. 300 of both EVs and Plug-in Hybrids on the island. Compound annual growth rates of over 40%/annum in both the heating and transportation sectors respectively will need to be achieved over the next decade to deliver the 2030 EV and HP targets.

EA Technology Report

2.4. EA Technology (EA Technology, 2019) have recently been commissioned by Manx Utilities Authorities (MUA) to determine the impact on the main network costs of accommodating the 2030 targets for EVs and HPs using techno-economic modelling. In their worst case scenario assuming minimum mitigation from future smart charging and load management capabilities, EAT have forecast a requirement for transmission and low voltage distribution network investment costs of c. £760,000.

However maximum exploitation of the smart meter rollout programme to facilitate off-peak charging for both EVs and HPs in combination with advanced load management services is expected to halve this cost. Post 2025, major advances in vehicle to grid technologies from EV batteries will contribute towards a demand management response – together with load control of HPs particularly where thermal storage can play a dominant role in riding through winter peak electricity demands – will further mitigate the upfront investment costs of having to strengthen MUA's network. EAT have forecast future network reinforcement costs to potentially to reduce to c.£365,000 and also allows for a range of technological solutions such as contracting system flexibility at the Low Voltage (LV) network from third party commercial organisations utilising large scale battery storage facilities. Other mitigating cost factors include meshing of LV urban networks and using LV ground mounted transformers.

Specific challenges imposed by heat pumps

2.5. Key challenges presented by HPs is their seasonality with additional electricity, specifically demanded during the winter months adding to the increased lighting loads experienced as daylight hours reduce. Delta Energy & Environment (2019) Consultancy examined this phenomenon for a major UK Distribution Network Operator, Electricity North West (ENW) in June 2016 and used a building physics model to generate half-hourly load profiles for various heat pumps in different house types operating at different outside temperatures. Figure 1 highlights the increased electricity demand envisaged for a severe 1 in 20 winter compared to the average ENW electricity peak particularly the key time periods in the early morning and late afternoon/early evening.

2.6. Electrification of heating using Heat Pumps could potentially increase winter electricity demand from 2.5 kW to 5.5 kW per household. Consequently 10,000 HPs (equivalent to 22% share of domestic homes with HPs) by 2030 could result in an increased winter electrical demand ranging from of 25 MW to 55 MW on the Isle of Man.

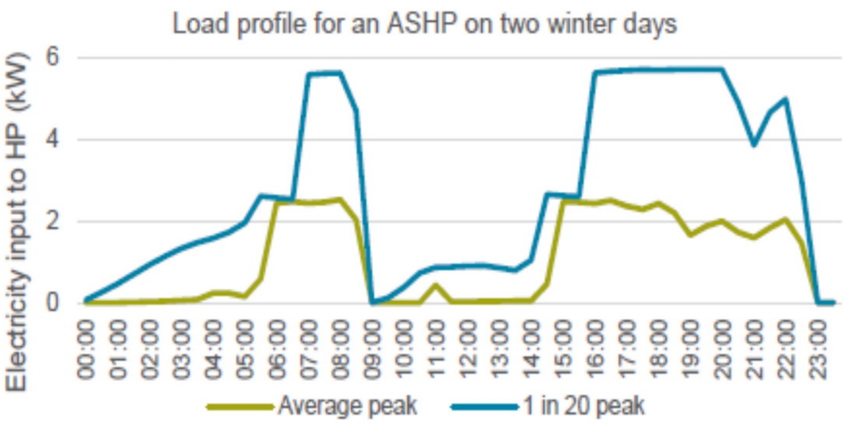

Figure 1: Electricity Load Profile for an Air Source Heat Pump (ASHP) on two Winter Days, Extract from Delta Energy & Environment (2019).

2.7. Delta Energy & Environment (2016) also conducted detailed granular analysis of types of heat pumps in the Electricity North West region which concluded that peak loads could increase to c. 250 MW for an average winter peak to as much as 3.5 GW by 2050 – as seen in Figure 2 below:

Scenario	Share of homes with a heat pump	Additional network load on an 'average' winter peak	Additional network load on a '1 in 20' winter peak
Low	~5%	200 – 300 MW	400 – 500 MW
Reference	~20%	800 – 900 MW	1,400 – 1,500 MW
High	~50%	~2,500 MW	~3,500 MW

Figure 2: Impact of different penetration levels of heat pumps on peak electrical demand. Extract from Delta Energy & Environment (2016).

2.8. The report determined that diversity amongst HP operation will be low and estimated this at only 10-15% for an average winter – and even lower for a 1-in 20 winter. They used EA Technology's Transform Model to forecast costs of £150 million to £3.3 billion necessary to be invested in additional capacity on the ENW Low Voltage (LV) network across the three scenarios viz 5, 20 and 50% shares of homes with a heat pump and assuming the worst case winter scenario of a 1-in-20 winter.

2.9. Further work by Imperial College (2018) modelled the national system to incorporate the potential flexibility of heat pump operation demonstrated that at times of low electricity prices, flexibility could increase peak loads by on average 5-15% on 'average' peak winters.

2.10. UK Government's strategy to decarbonise heat will consider a number of alternative low carbon and zero emission heating solutions including heat pumps, biomass boilers, localised district heating networks, domestic micro-combined heating and power (CHP) plant and hybrid heat pump/gas boiler combinations. The boiler for the latter option could eventually be designed to operate on 'green'/bio-gases and possibly hydrogen in the long term as surplus renewables are used to cost effectively produce hydrogen by electrolysis. However the cheapest solution to reduce heating demand is to substantially improve the insulation level of domestic households to reduce the capacity of heat pumps required and future operating costs for prospective owners.

2.11. For the Isle of Man, there has been a c. 10% reduction in total electricity usage and peak demand since the 'financial crash' of 2009 due to a combination of factors including: the advent of smart LED lighting systems in both domestic and all business sectors; more energy efficient domestic appliances and consolidation of business/Government operations across the Island. This is expected to continue over the next decade providing both surplus generation output to meet future electricity requirements for the 'Two degree' energy scenario – 10,000 EVs and 5,700 HPs by

2030 – and surplus substation and transmission network capacity to minimise incremental spend on network reinforcement.

2.12. However a combination of mitigating factors is expected to reduce the severity of increased electrical winter peak demand comprising:

- Proactively engaging with customers to reduce peak loads resulting from heating through adoption of measures such as thermal efficiency improvements (a combination of loft and underfloor lagging, cavity wall insulation and enhanced glazing) and therefore encouraging the installation of more efficient and smaller sized heat pumps;
- dynamic electricity heating tariffs which encourage off-peak usage and 'penalise' (or incentivise load reduction) electricity consumption at critical winter peak times;
- encourage thermal storage schemes in parallel with HP installations incorporating load control mechanisms that provide the necessary hot water/space heating requirements during winter peaks and allow heat pump to be temporarily switched off;
- bivalent combinations of base load heat pumps with 'green gas'/hydrogen fired boilers supplementing heating requirements during exceptionally cold winters;
- use of self-generation from solar PV in combination with electricity battery storage to run heat pumps during winter peaks;
- future developments of vehicle–to-grid technologies allow discharge of EV batteries to supplement operation of heat pumps;
- third parties establishing community energy schemes that avoid the need for individual heat pumps;
- micro CHPs installed alongside heat pumps;
- load management incentives which encourage shifting of HP operation via inbuilt control mechanisms.

Specific challenges imposed by EVs

2.13. In addition, EVs tend to be regarded as a challenge to peak winter demand due to both their increasing battery capacity – with new models approaching 40 kWh - and the possibility of EV owners charging their vehicles immediately on returning from work. Given the short commuting distances on the Island this may result in charging commencing from 17:30 despite the financial incentives offered by MUA with their EV electricity tariff to charge their EVs from midnight -7am at almost half the standard electricity tariff rate (9.1p/kWh v 16.7p/kWh).

2.14. National Grid (2019) has examined the EV charging profile trend from a large sample of EV owners in the UK which has taken into account the benefits of workplace and public charging facilities. Figure 3 indicates a residential charging peak at around 8pm and therefore avoids the usual system electricity demand observed historically during the winter months between 5-6pm. On the Island, MUA's system peak is around the same time as that of the UK but the shorter travelling times may result in the residential EV charging peak coinciding with the system peak and therefore necessitating system reinforcement. However the accelerated rollout of LED lighting schemes in domestic households, businesses, Government offices and local authorities' street lighting schemes has significantly reduced MUA's systems maximum demand during the last decade.

Figure 3: Impact of EV charging on UK's system peak demand

2.15. Further expansion into smart LED lighting schemes and an acceleration in hybrid solar PV self–generation and battery storage schemes is expected to provide further 'headroom' in substation capacity and consequently delaying any immediate need for network reinforcement in the short to medium term. However with a parallel objective to accelerate the transition to low carbon heating in the form of heat pumps may exacerbate network impacts especially during exceptionally cold winter days. Widespread adoption of thermal and battery storage, dynamic electricity tariffs that encourage off-peak electricity usage and penalise consumption at 'super-peak' and load management services will substantially contribute to delaying network reinforcements in the medium term.

3. THE OPPORTUNITY

Post Combined Cycle Gas Turbines (CCGT)

3.1. Marginal carbon savings can be achieved in the low emission transportation and heating sectors during the next decade as the majority of electricity generation will be sourced from the existing gas fired generation plant. However these carbon savings will be materially enhanced once the transition to wholly renewable generation occurs post 2030-35 following the re-purposing of the existing CCGT to either operating on 'green' gases or simply acting as a form of grid security back-up in the event of reduced power output from new renewable generation plant.

Carbon Tax

3.2. Due to the combination of the European Union Emission Trading System (EU-ETS) carbon tax which is currently in the order of €25/tonne of CO_2 and the UK's sterling denominated Carbon Support Price of £18/tonne CO_2 equivalent, UK coal plant face an onerous total carbon tax of the order of £36/MWh on their generation unit costs whilst gas fired plant face an accumulative penalty cost of c. £16 / MWh. This has achieved the desired result of ensuring that it is uneconomical for coal plant to operate with only about 5 stations expected to remain operating beyond 2020. The latter are expected to be completely closed by 2025. The combined carbon prices are incorporated in the UK's wholesale electricity prices and therefore provide a profitable wholesale margin for MUA for their exports from their CCGT.

Generation Capacity on Isle of Man

3.3. In the event that there is a large scale transition to both EVs and HPs, MUA has sufficient generation capacity to accommodate the increase electricity demand (to at least 2030 based on the figures outlined in the Government's Climate Mitigation Action plan) with wholesale exports simply being displaced with incremental retail electricity sales. Figure 4 highlights the level of exports (in red) on a daily basis from the CCGT to the UK which is expected to amount to over 160 GWh in electricity volumes in 2019/20.

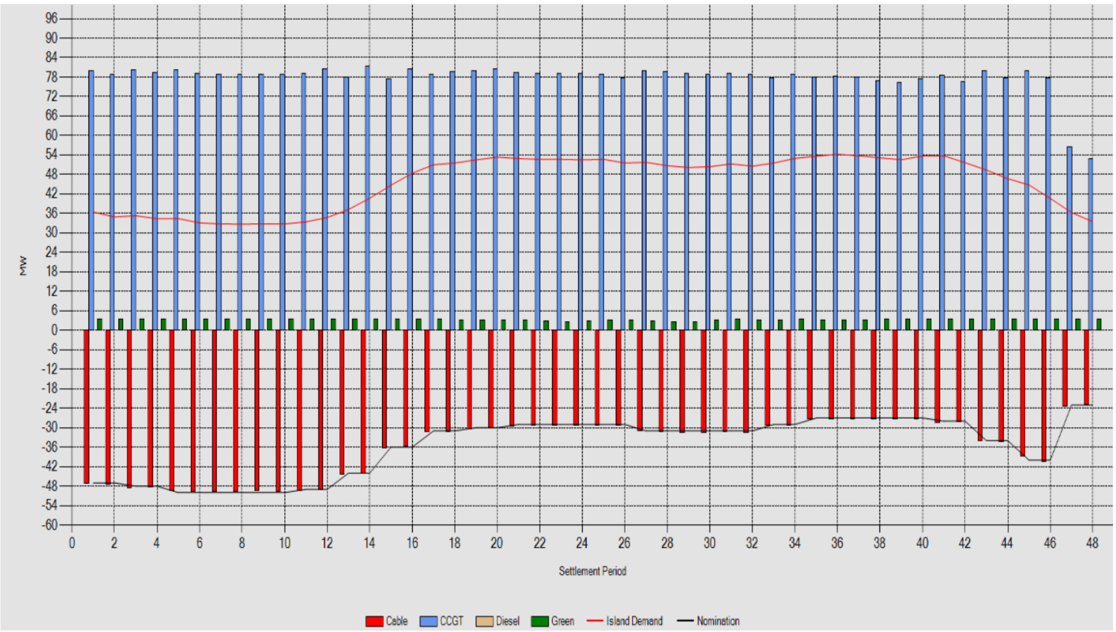

Figure 4: Isle of Man Retail Demand and Wholesale exports to the UK – 17 Sept/19

3.4. In electricity consumption terms, 10,000 EVs and c. 6,000 HPs are estimated to represent only c. 60 GWh of additional electricity demand and therefore easily accommodated by the target year of 2030. However the worst case scenario for EVs is the potential impact on MUA's peak electrical demand at 5pm on a cold winter's day in the event that all 10,000 EVs decide to charge their batteries at the standard

EV charging station rate of 7kW (per hour) which would represent a potential aggregated incremental demand of 70MW. However focus should be on the following:

- Encouraging workplace (as exemplified by the Island's Mountain View Innovation Centre) , public and destination charging;
- innovative EV tariff structures encouraging charging during off-peak times of the day (presently there are 168 domestic customers benefiting from MU's price advantageous EV tariff equivalent to c. 65% of total EV owners);
- domestic and commercial self–generation in the form of solar PV and in combination with domestic behind-the-meter (BTM) battery storage and other innovative load management initiatives are expected to substantially reduce this peak electrical demand; and
- increased levels of smart low wattage LED lighting.

3.5. Together; these are all anticipated to collectively reduce electricity peak demands and further delay the need to carry out major investments to reinforce MU's existing network infrastructure.

EA Technology Report results

3.6. The main conclusions of the EA Technology (EAT) (2019) report was that an additional £757,000 would need to be spent on MUA's transmission and distribution network if we were to accommodate 10,000 EVs and c. 5,700 HPs by 2030 on a business-as-usual scenario assuming minimum investment in new and innovative technologies. They also added that by capitalising on 'smart' solutions, network investments can almost halve the discounted totex (combining capex and opex) to c. £365,000. The Transform model used by EAT assumed a general Island-wide perspective and did not take into account specific network investments required to strengthen distribution feeders into some rural areas where a 'cluster' of EV and HPs may demand additional reinforcements to accommodate their installation and future operation. MUA acknowledge that there are likely to be 'hot spots' predominantly in rural and semi-rural locations around the Island where incremental network spend is required to 'future-proof' the distribution system and avoid more costly upgrades as EVs and HPs become mainstream household requirements.

3.7. In addition AET will not have factored into account the costs of providing localised EV public charging stations which on average can cost from £5k-£7k/Charge point (CP) depending on location, requirement for major civil works, availability of substation capacity, rate of charging, etc. Using a conservative ratio of 10 EVs/Charge point socket, the 'Two Degrees' energy scenario and IoM Climate Challenge Mitigation strategy of 10,000 EVs by 2030, it has been estimated that close to 500 EV Charge point stations (assuming each CP comprises a twin socket) will be required at a 'worst case scenario' capital cost ranging from £2.5 - 3.5 million.

4. THE ACTIONS

Necessary ambition plus tabulation

4.1. Using National Grid's 2017 Future Energy Scenarios, the 'Two Degrees' scenario is the only relevant trajectory that has to be adopted to achieve net zero emissions by 2050. Normalising UK's future EV and HP projections to reflect household and car registrations statistics on the Isle of Man, the following tables have been produced:

Table 1: Heat Pump numbers and Carbon saving projections from 2030 to 2050

	2030	2040	2050
	Nos of HPs		
STEADY STATE	1,128	1,362	1,453
SLOW PROGRESSION	1,348	1,710	1,884
CONSUMER POWER	1,513	1,723	1,833
TWO DEGREES	5,776	8,606	23,144
Carbon savings	tonnes of CO_2 eq		
STEADY STATE	1,211	2,943	3,140
SLOW PROGRESSION	1,448	3,694	4,072
CONSUMER POWER	1,625	3,723	3,962
TWO DEGREES	6,204	18,598	50,014

Table 2: Electric Vehicle numbers and carbon savings from 2030 to 2050

Nos of EVs	2030	2040	2050
STEADY STATE	1,773	3,915	5,989
SLOW PROGRESSION	3,759	11,176	31,677
CONSUMER POWER	2,398	17,488	40,973
TWO DEGREES	10,027	30,250	47,620
Carbon Savings	tonnes of CO_2 eq		
STEADY STATE	2,101	6,890	7,097
SLOW PROGRESSION	4,455	19,669	55,752
CONSUMER POWER	2,842	30,778	72,113
TWO DEGREES	11,882	53,240	83,811

High Ambition plus tabulation

4.2. The High Ambition option will involve rapid acceleration of HP and EV numbers to achieve the '2050' targets a decade earlier and assumes that the standard zero carbon heating and transportation technology is predominantly HPs and EVs. Hybrid solutions predicated over the transition period will have to disregarded and clear targeting of pure EV and HP solutions made a prerequisite.

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