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Integrated on-farm renewable energy – optimisation and the road to Net Zero

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Integrated On-Farm Renewable Energy – Optimisation and the path to Net Zero

Abstract

The energy cost crisis is driving a strong interest in optimising integrated on-farm renewable energy. The British Farming Industry was granted access to a major resource to enhance productivity when rural electrification was delivered. In many cases the challenge now is to optimise renewables within the farm energy use, and in so doing embrace new control technologies on the farm and at the grid edge. The feed in tariff replacement, the smart export guarantee, pays for export not total generation, and is typically much more modest in its payment level. The farm scale challenge is a paradigm shift, from maximising the feed in tariff, to optimising the choice, size and integration of renewable generation with the farm consumption profile to reduce import costs. The objective of this article is to describe an approach to optimising the initial selection of renewable generation equipment, load, import and export tariffs, and electricity network connection at a specific location and farm type. Farmer interest in reducing energy costs, actively engaging towards Net Zero, and increasing resilience, are all ongoing and remain important production factors.

Introduction

The route to optimisation is enabled by making the right informed choices. The application of systems engineering & optimisation requires a knowledge of the constraining parameters and their associated values as outlined in the following table. This article focuses primarily on energy optimisation on the farm, and with the advent of advanced controller optimisation can also include the interface to the electricity network, or “Grid Edge” which is also discussed and in scope, and links to the wider challenge of optimising the grid itself. Figure 1 below summarises the main parameters to be optimised and a range of typical values each parameter can have in a farm situation. Effectively the main available choices are laid out, but the optimal combination depend on the farm in question and the prevailing parameters are discussed below.

Location & Enterprise	Site	Average Wind Speed	Sun Hours	Water Course	Biomass	Animal Waste	Other Anaerobic Digestion Feedstock
	Farm Type	Arable	Dairy	Pigs	Poultry	Mixed	Horticulture
	Electricity Network Connection	Existing Capacity	Constraints – Thermal Voltage Fault Level	Reinforcement 1 Phase PMT Upgrade Options	Reinforcement Split-Phase PMT Upgrade Options	Reinforcement 3 Phase PMT Upgrade Options	Reinforcement 3 Phase PMT & OHL Upgrade Options
	Electrical Equipment	Diversity	Energy Efficiency	Motors	Lighting	Heating	Cooling
Electricity Profile Characteristics	Electrical consumption profile	Load factor	Day vs Night consumption	Time of day	Weekday vs Weekend consumption	Monthly vs annual consumption	Seasonal vs annual consumption
	Electricity Flexibility	Maximum Demand Reduction	Move into night time consumption	Move within day	Move to weekend	Move to times of peak generation	External Response Services
	Storage	Heating Thermal Storage	Cooling Thermal Storage	Electrical Battery Storage	Hydrogen	Bio-Methane	
Bulk Heat and Derivative Fuels	Example Applications	Space Heating	Drying	Water Heating	Hydrogen Transport	Bio-Methane to Gas Grid Injection	Bio-Methane Tractors
Import/Export Commercial Arrangements	Import Supply Tariff	Tariff Prices	Contract Prices	Profile or Half Hourly Data	Fixed or variable	TNuos & Duos pass-through	Transparent
	Export Tariff	Smart Export Guarantee	Power Purchase Agreement	Managed Contract	Cooperative Group Export	Direct or Virtual Private Wire	Business Peer to Peer
Renewable Generator Type	Type	Wind	Hydro	Solar PV Solar Thermal	AD Plant	Biomass & Gasification	Hydrogen Production
Generator Sizing	Sizing Strategy	Within Existing Connection	Within incremental Network Upgrades	Maximise Resilience/self sufficiency	Maximise on premise use	Maximise Export	Optimise sizing against all factors
	Smart/ Intelligent Controllers	Generation Diverted to Storage	Static Export Limiter	Static Export Controller with Load damping	Dynamic Export Controller with Load Damping	Active Network Management Control of Generator	Combined premise and network control

Notes
PMT Pole Mounted Transformer
OHL Over Head Line
Energy Efficiency Measures – include for example Plate Coolers, Heat Recovery, Motor Speed Control, LED Lighting, Air/Ground source heat pumps and geothermal.
Where Heat and power is produced the utilisation of the heat is significant, as of course are any renewable heat incentive payments
Farm waste management benefits of some solutions need taking into account, and in the future value from CCS, and industrial crops.
Figure 1, line items not necessarily mutually exclusive
Figure 1 columns do not imply solution alignment
Hybrid renewable generator solutions additional to details in figure 1
Farm electrical resilience strategy under optimisation assumed to make use of existing network connection
Electricity network connection is part of optimisation challenge ie not off-grid
Complementary renewable generation to farming practice needs consideration eg PV & Sheep Grazing combination
Direct mechanical rather than electrical renewable drive not considered above but may have its application
CHP Combined Heat and Power
TNuos transmission network use of system
Duos distribution use of system

Figure 1 Optimisation Parameter Overview

Optimisation Benefits

Optimisation of farm energy use and renewable generation deployment has a range of targeted benefits available including;

- Lower farm energy costs
- Green benefit in reducing farm energy carbon footprint
- Better return on investment and reduced renewable scheme payback period
- More accepted renewable generation connection requests enabling smaller farms to benefit
- Greater proportion of renewable generation used on site
- Greater proportion of farm consumption provided by renewable generation
- Electricity reinforcement costs managed and better match to incremental capacity upgrades
- Opportunities for advanced controllers and developing the optimisation approach itself

Location & Farming Enterprises

The foundations of renewable generation choices are of course in the physical aspects of location which dictate the provision of natural resources such as wind speed, sunlight hours etc. and the associated tipping points between them for specific enterprise types. There are alignments between some enterprise types and types of renewable generator such as intensive livestock, or top fruit storage and solar PV, but for other combinations the alignment is less immediately apparent and needs careful assessment especially where multiple enterprise types are present on the same farm.

The existing electricity renewable connection process is dominated by “what do you want to connect/can I connect this?” rather than, “what could I connect” or “where can I connect what and when”. The percentage of quotations that progress to successful connection is low suggesting in many cases fundamental mismatches between proposed schemes and local network capability. The network companies are subject to the regulators Network Incentive on Connections Engagement (ICE) scheme but are not yet performance measured on the proportion of quotations successfully connected, only quotation provision within defined timescales.

Most farms are served with an HV line and Pole Mounted Transformer (PMT), with typical incremental upgrades including the option of swapping the transformer for the next size up without HV Over Head Line (OHL) change, however where only two wire HV OHL is present upgrading to three-phase can involve substantively more expense. There is also a step change to cost when an upgrade from pole mounted to ground mounted sub-station is required. Optimisation can usefully seek to utilise capacity up to these step changes in cost. Under G98 small scale renewable connections can be accepted without reinforcement, which prompts the question what could be accepted on an existing sole use PMT or its next size up. As the distribution companies move towards becoming Distribution System Operators their approach to planning assessing network connections is likely to evolve from a deterministic worst-case scenario approach to one with more probabilistic modelling and scope for using smarter controller devices.

The enterprise type will drive the existing range of electrical equipment and hours of use. Energy efficiency measures should be assessed and allocated their appropriate position in the intervention merit order. It needs to be borne in mind that the value and effect of subsequent interventions are affected by those previous implemented, a classic example being the trilema between Economy 7 bulk milk tank controller, plate coolers and heat recovery.

Farm Electricity Needs

The enterprise type and its portfolio of electrical equipment will drive a characteristic consumption

profile across each day of the year. The profile can be further enhanced by applying flexibility to load that can be time shifted to match renewable generation timing, or away from a high import tariff price timing. Storage can also be applied to arbitrage time of low prices or high generation output against actual time of use and to increase the proportion of own generation use on site.
Where both electricity and heat are produced the value and load factor utilisation of the heat is also important to scheme viability and economics including here the possible payments under the renewable heat incentive. Bio-Methane produced from anaerobic digestion can be used to produce electricity and heat (CHP), used in a boiler to directly produce heat, or where there is a connection, injected into the gas distribution system.

Commercial Arrangements

The competitive supply agreement price level and critically its pricing structure against the import consumption profile after generation, flexibility actions, energy efficiency measures, and any potential storage, will be key in managing this cost component. The double mantra of "use less and then pay less per unit for what is used" is a useful import cost reduction strategy. The deployment of smart meters should enable quarterly customers to access a wider choice of tariff structures including greater seasonality. Buying groups may also be able to use aggregation to secure competitive prices.
Where the farm has flexibility in rapidly reducing demand on a reasonable scale there are a range of ancillary services that National Grid and increasingly the network operators, as they transition to more proactive Distribution System Operators, are interested in contracting for. National Grid have an initiative branded "Power Responsive" specifically targeted at these response services.

On export, mention has been made of the feed in tariff replacement with the typically lower value smart export guarantee, and at the larger end of the market power purchase agreements continue in use along with managed contracts seeking to fully utilise the market. In seeking better returns for export locally farmers may be keen to explore future settlement changes that might enable peer to peer trading and developments such as direct or virtual private wire.

Renewable Choices

The foundation to optimisation is the renewable generator type as discussed, but in addition the consequent sizing strategy, running arrangements, and potential advanced control are also relevant to maximising returns. On generators, sizing strategies deserve greater scrutiny with a move required to take account of existing capacity and incremental network upgrades, coupled with the need to optimise the sizing for on premise use and take advantage of the advances in grid edge control technology that are gradually becoming available.

Advances in power electronic devices have already enabled domestic excess solar PV output to be diverted to water heating, static export limiters are already governed by engineering recommendation G100, wide-scale active network management schemes are being used now by the network operators to manage network constraints by constraining off large generators where required. On the farm there is the potential to advance and deploy control approaches to include the capability to damp down export by applying useful load before the generator is constrained off, and to do this initially statically and then dynamically. This approach has the potential to reduce reinforcement costs, increase the utilisation of renewable generation and reduce imports. Further in the future the controller could combine both premise and the wider network requirements into a control strategy at the grid edge. The network operator willingness to have control schemes that reach beyond the meter into the premise, and are more complex in the smaller customer sector, will in part determine uptake.

Optimisation

The main pathways to optimisation are shown in Figure 2. Renewable investment scenarios can be tested by assessing the interaction of the parameters shown. Foundation optimisation is about getting the traditional fundamental choices right for site, enterprise practices, and resultant energy profiles. Intermediate optimisation can be likened to “good house-keeping” with its consideration of energy usage, and supply contract commercials of import and export. The advanced area shows potential for further innovation to be applied and proven in the areas of controller development, the utilisation of storage and provision of response services. Foundation optimisation choices put projects on the right initial design alignment, with intermediate and advanced measures aimed at improving the design further and underpinning ongoing operational performance.

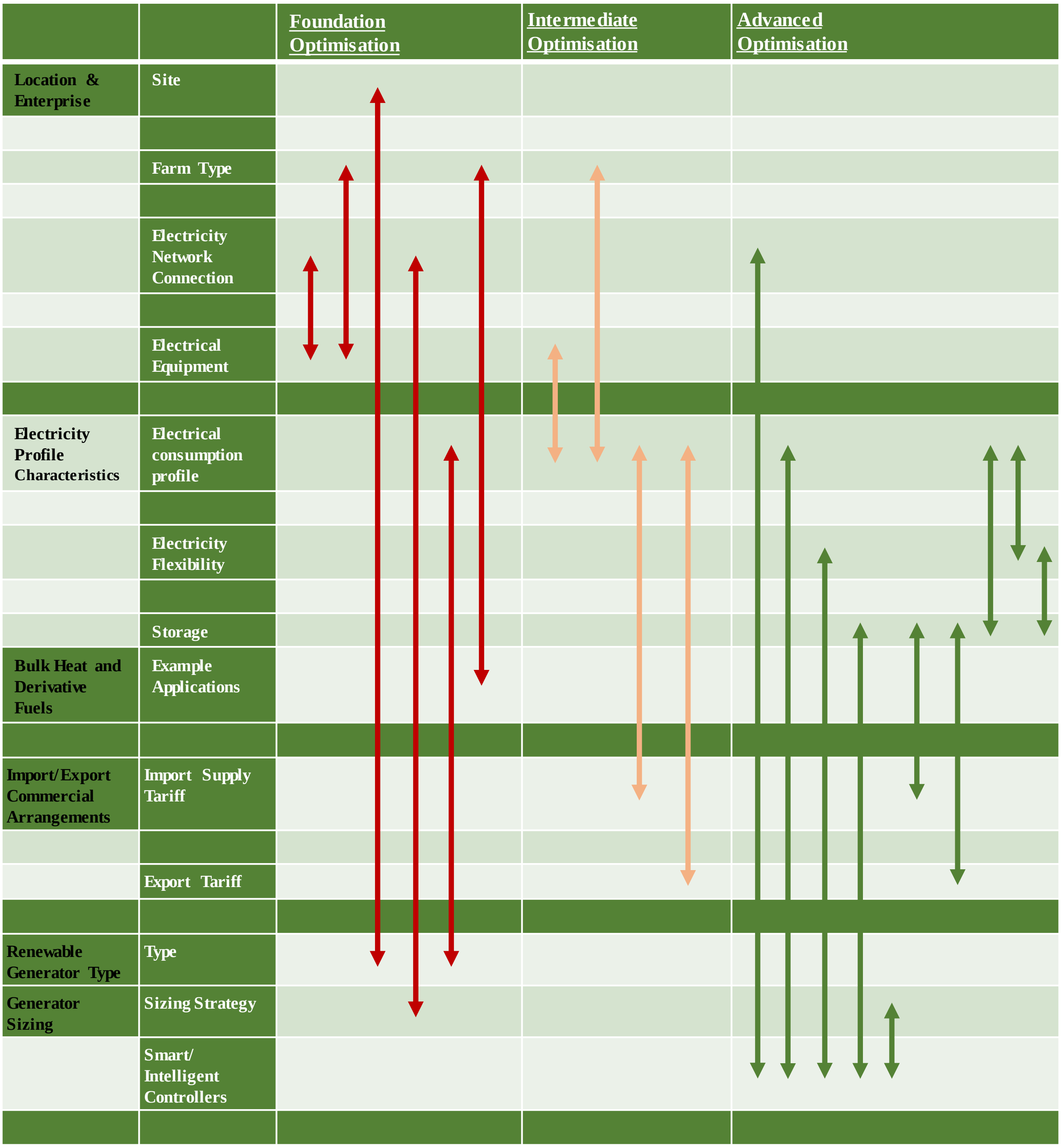

Figure 2 Optimisation Pathfinder

Key Performance Indicators

The case for optimisation is made and hopefully recognised, but how can it be measured? Optimisation key performance metrics can be developed and are likely to include;

- Generation load factor
- Proportion of renewable generation produced and productively used or stored for use on site
- Proportion of farm consumption provided by own renewable generation
- Carbon footprint
- Return on investment or payback period
- Average price of imported electricity
- Average price of exported electricity
- Amount by which own generation undercuts import prices with their embedded distribution and transmission costs.
- Utilisation of electricity network connection capacity
- Use of flexibility, energy efficiency measures and where appropriate storage.
- Are electricity and heat production fully utilised?
- Are advanced controllers utilised?

Conclusions

The withdrawal of the electricity Feed in tariff has created the challenge to optimise integrated on-farm renewable generation and energy use to ensure a sustainable and economic return. The network companies and other organisations have access to innovation funding with scope to encourage the development of enhanced solutions to the issues raised with possible opportunities for the farming industry to take an active part. Optimisation has the potential to make a real difference to individual farm businesses across the full spectrum of enterprise size and is targeted at on-farm integrated installations, rather than stand-alone large-scale developer projects. It is perhaps at the smaller enterprise where funds are not available for consultancy, but where the benefits of optimisation advice can deliver important savings and are most acutely felt. There is scope for greater agricultural representation in the innovation initiatives available and it is important for the future that this takes place.

The optimisation problem presented by integrated farm renewables crosses the agricultural engineering and electricity generation and distribution domains. Key support not yet fully available to address this challenge are;

- Farmer access to an independent expert/intelligent computer model for supporting informed optimisation decision making from project inception to operation, through the application of systems engineering.

- Data available from the field, on renewable installation key performance metrics as to the actual level of performance achieved, that can be used to provide updated best practice benchmarks, validate models, support decision making, and target operational performance enhancement.

- The need for cross domain innovation projects that target optimisation based on collaboration between agricultural and engineering disciplines utilising new technology.

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Brian is an independent chartered engineer with 40 years of experience from the electricity, ICT and agricultural industries. Recent activity included leading an international companies UK smart grid team and their involvement in a portfolio of innovation projects with the electricity distribution companies.

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