FARMPOWER

Exploring the Size of the Prize

FARMPOWER
Putting Agriculture on the Grid

Our vision for Farm Power in 2020

By 2020, UK farms and rural communities will be making a significant contribution to a resilient, low-carbon energy system.

We believe that:

- Despite the pioneering efforts of some, the considerable potential of farms and rural communities to contribute to the energy system remains largely untapped;
- This potential can be realised in a manner that ***enhances*** food production and a variety of other societal goals, including:
  - the provision of essential ecosystem services, such as improved carbon, biodiversity, water and land management; and
  - job creation and rural economic development;
- These broader goals – and the potential for energy investments to support them – must be explicitly factored into decision-making around the UK's energy future (yet are currently largely ignored);
- The income provided by energy production will increase the economic resilience of farms – and thus the UK food system;
- Farm-based energy provides an opportunity to strengthen the relationship between farmers and their communities through mechanisms such as shared ownership and jointly-constructed community energy plans;
- Investment in sustainable farm-based energy is a means to kick-start the inevitable transition to a smart, dynamic, and increasingly decentralised, energy system.

To achieve this vision, the *Farm Power Coalition* will:

- Help farmers make informed choices about the best technologies and options for their businesses.
- Work with Government and business to:
  - Break-down the barriers that are stifling investment in sustainable farm-based energy;
  - Put in place a supportive regulatory, planning and financial environment;
  - Ensure that energy assets are located appropriately, and are designed to maximise co-benefits;
- Strive to create markets for sustainable farm-based energy, both within local communities, and along the corporate agricultural supply chain (and beyond).
- Work to ensure that farms and rural communities have easy, fair and affordable access to the grid.

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1 Executive summary

Many studies have explored the potential of different technologies to contribute to the UK energy system – albeit with widely varying results – but few have explicitly considered the potential role that sustainable *farm-based* energy could play. This report represents an attempt to explore that role head-on.

A key driver in producing this report is our belief that, despite the pioneering efforts of some, the considerable potential of farms and rural communities to contribute to the energy system remains largely untapped. Farm-based energy doesn't get the attention, or the support, it deserves – and farmers are finding ways to invest in renewables *despite* the system, rather than *because* of it. We hope this report helps to change that.

There are different ways to estimate the potential of farm-based power in the UK. In this report we have:

- Extrapolated out the results from the June 2013 *Farmers Weekly* survey that launched the *Farm Power* project;
- Built out simple scenarios on the basis of some reasonable – yet ambitious – assumptions on how much renewable energy technology farms could potentially host; sense-checked against case studies of real farms;
- Considered a number of projections for the potential renewables capacity in the UK, and then explored the potential for farms to contribute to these.

Regardless of which approach is used, it's easy to find at least 10GW – and quite possibly 20GW – of unmet potential across British farms. Our scenarios, for example, play out as follows (in terms of total installed capacity):

Technology	Capacity (low-end scenario)	Capacity (high-end scenario)
Solar PV (ground)	5.9 GW	14 GW
Solar PV (rooftop)	1.4 GW	1.4 GW
Farm-scale wind	2.5 GW	3.6 GW
Anaerobic digestion	0.1 GW	1 GW
Total (rounded to the nearest 0.5GW)	10 GW	20 GW
% of UK Total (2013)	10.5%	21%

Sustainable farm-based energy not only has the potential to contribute significantly to the UK energy system, but can *complement* food production – whether that's by:

- providing additional income to farmers and helping them become more resilient (and thus able to provide food);
- combining sheep/poultry/other food production with energy;
- providing space for the pollinators upon which much food production depends.

It also provides multiple co-benefits, from increasingly rare manufacturing jobs in the UK through to carbon savings and slurry management – and we therefore need to find ways to better understand and reward the *non-energy* benefits of farm-scale energy systems.

In sum, the potential benefits of sustainable farm-based energy are huge. To realise this potential, however, will require coordinated effort to tackle the many barriers that currently prevent farmers from fully grasping this opportunity.

2 Introducing Farm Power

2.1 Participants

Farm Power is a collaborative project, initially conceived by Forum for the Future, Farmers Weekly and Nottingham Trent University, and now overseen by a Steering Group comprised of:

- Business in the Community
- Endurance Wind Power
- The Farm Energy Project
- Farmers Weekly
- Forum for the Future
- George Thompson Ltd
- Lely
- Lightsource Renewable Energy
- National Grid
- NFU
- Nottingham Trent University
- United Utilities

The project has received financial support from the Ashden Trust and the Esmee Fairbairn Foundation, as well as the corporate members of the Steering Group.

Our *Vision for Farm Power in 2020* is being launched alongside this report, and we have now started building a broader coalition of organisations in support of that vision.

2.2 Aims of the project

Farm Power aims to bring about a step-change in the uptake of sustainable farm-based energy across the UK, by:

- Exploring and outlining the potential role that farms/rural communities could and should play in a sustainable energy system;
- Identifying and understanding barriers to the uptake of sustainable farm-based energy, as well as potential drivers of change;
- Creating a diverse and effective coalition (united by a common vision), and a series of targeted workstreams, to tackle these barriers.

2.3 The purpose of this report

Many studies have explored the potential of different technologies to contribute to the UK energy system – albeit with widely varying results – but few have explicitly considered the potential role that sustainable *farm-based* energy could play. This report represents an attempt to explore that role head-on.

A key driver in producing this report is our belief that, despite the pioneering efforts of some, the considerable potential of farms and rural communities to contribute to the energy system remains largely untapped. Farm-based energy doesn't get the attention, or the support, it deserves – and farmers are finding ways to invest in renewables *despite* the system, rather than *because* of it.

We hope this report helps to change that.

We would be delighted to receive feedback and further data, whether that supports or refutes our findings. *Farm Power* is an ongoing project that intends to show the potential of sustainable farm-based energy production and what it could achieve in a supportive environment – and we will continue to explore many of the issues raised in this report over the next year or so.

2.4 Acknowledgements

The research within this report has been a collaborative effort. Most of the data have been compiled by Matt Harper, a researcher at Nottingham Trent University, and we have drawn on the insights and contributions of our Steering Group in developing and finalising our scenarios. A June 2013 survey undertaken by *Farmers Weekly* has played a key role, and Fisher German has provided estimates of the financial implications and benefits of investing in farm-based renewables. The Anaerobic Digestion and Bioresources Association, the National Farmers' Union, and RenewableUK have also contributed data and insight that have informed our thinking. The report itself has been collated and written by Forum for the Future.

3 Exploring the size of the prize

3.1 Approach

There are different ways to estimate the potential of farm-based power in the UK. In producing this report, we have:

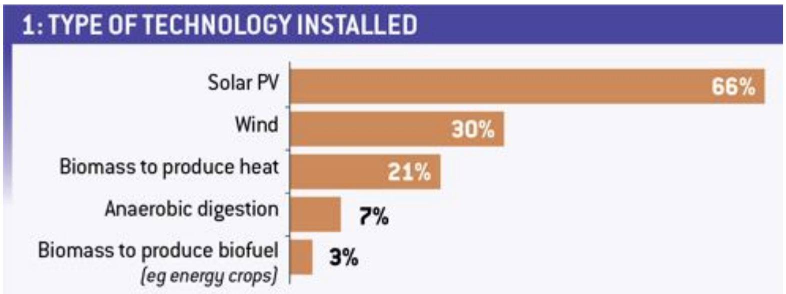
- Extrapolated out the results from the June 2013 *Farmers Weekly* survey that launched the *Farm Power* project;
- Built out simple scenarios on the basis of some reasonable – yet ambitious – assumptions on how much renewable energy technology farms could potentially host; sense-checked against case studies of real farms;
- Considered a number of projections for the potential renewables capacity in the UK, and then explored the potential for farms to contribute to these.

By exploring the latter, we have also considered what might comprise a reasonable land 'take' for energy – although having undertaken this research, one of the key assumptions we wish to challenge is the idea that energy production requires turning land over *exclusively* to energy: we would argue that energy production can be compatible with food production, or indeed with other uses of land that are beneficial to society.

Our research has focused on exploring the potential for solar PV, wind and anaerobic digestion. There is also potential for farmers and rural communities to invest in sustainable biomass and small-scale hydro-electric schemes – so the overall potential of farms to contribute to the UK's energy system is likely even greater still than that implied in this report.

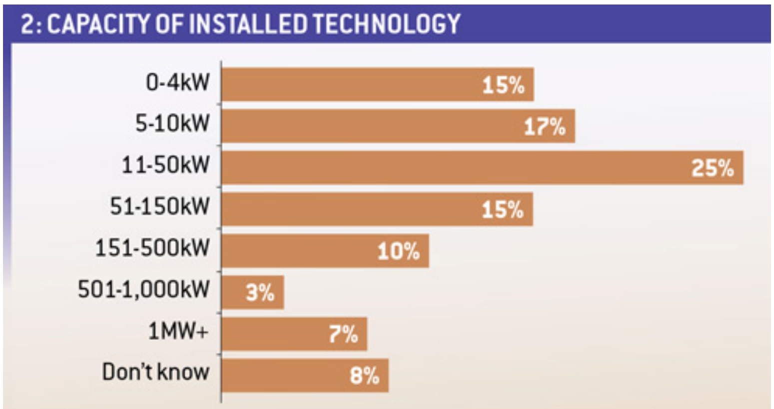
3.2 Extrapolating out the results from the June 2013 *Farmers Weekly* survey

In June 2013, *Farmers Weekly* published a survey that gathered opinion on farm-based renewable energy from nearly 700 farmers across the UK[1]. Of the 693 farmers that responded to the survey, 38% had invested in renewables, with the most popular technology types being solar PV (66%), wind (30%) and biomass for heat (21%):



1 http://www.fwi.co.uk/business/survey-shows-great-potential-for-on-farm-renewables.htm#.Ucwwdr5wZMs

In terms of installed capacity, the survey revealed the following breakdown:



If these results were extrapolated out across all 220,000 farms in the UK (with every farm installing the capacity at the top end of each band), the resulting installed capacity would be 41.2 GW[2]:

Extrapolation	Resulting installed capacity
If 15% of total UK farms (33,000) installed 4kW	0.13GW
If 17% of total UK farms (37,400) installed 10kW	0.37GW
If 25% of total UK farms (55,000) installed 50kW	2.75GW
If 15% of total UK farms (33,000) installed 150kW	4.95GW
If 10% of total UK farms (22,000) installed 500kW	11GW
If 10% of total UK farms (22,000) installed 1MW	22GW
TOTAL	41.2GW

Even if we limit our extrapolation to those farms in the UK that are larger than 20 hectares (116,565 according to Defra[3] – rounded to 115,000 in this instance) the resulting installed capacity still reaches a substantive 21.55 GW:

Extrapolation	Resulting installed capacity
If 15% of these farms (17,250) installed 4kW	0.07GW
If 17% of these farms (19,550) installed 10kW	0.2GW
If 25% of these farms (28,750) installed 50kW	1.44GW
If 15% of these farms (17,250) installed 150kW	2.59GW

2 At the end of 2013, total UK installed capacity (across all technologies) was 94.1GW
3 DEFRA; UK Agricultural Statistics, 2014

If 10% of these farms (11,500) installed 500kW	5.75GW
If 10% of these farms (11,500) installed 1MW	11.5GW
TOTAL	21.55GW

3.3 Our scenarios

21.55 GW is an impressive figure, and we therefore wanted to test this against some simple scenarios, informed by some reasonable – yet ambitious – assumptions on how much renewable energy technology farms could potentially host. To ground these scenarios in the experience of real farmers, we have sense-checked them against a small number of case studies (see appendix 1).

The scenarios we developed are as follows:

SOLAR

Our low-end solar scenario assumes that every farm greater than 20ha installs a 50kW ground-mounted solar array. A 50kW ground mounted solar array requires approximately 750m² (assuming 15 m²/kW), representing less than 0.5% of the land area of a 20ha farm. The total land 'take' across the UK in this scenario is 8,750 ha (it would rise to 14,560 ha if we assumed 25 m²/kW).

Our research suggests that this amount of land is available on a farm without any impact on land used for food production. One of our case study farms, for example, has 60kW of solar located adjacent to farm buildings on a redundant horse paddock, on land that the farmer does not consider suitable for cultivation.

Our high-end solar scenario assumes that every farm greater than 20ha installs ground-mounted solar PV, but sees the size of the installation scaling with the size of the farm – although still representing less than 0.5% of the land area of each farm. The total land 'take' across the UK in this scenario is 20,700 ha (rising to 34,500 ha if we assumed 25 m²/kW).

Both solar scenarios assume that all farms in the UK, regardless of size, install a 4kW rooftop solar PV system. And both also assume that the 116,609 agricultural buildings across the UK that are considered to have 'conversion potential'[4] install a 4kW rooftop solar PV system. We have assumed that if these buildings have conversion potential, then they also have the structural potential to host solar PV.

With regard to roof-top solar, these scenarios are obviously bullish in terms of the number of farm buildings that can host rooftop PV, but conservative in terms of the size of the system embraced (one of our case-study farms had 70kW of rooftop solar PV installed, for example).

WIND

Our wind scenarios assume that 15% of farms are suitable for wind, with the size of turbine installed scaling with the size of the farm (on the basis that a larger farm is not only more likely to have a suitable location for a larger wind turbine, but also that any barriers regarding the proximity of a turbine to neighbouring properties are reduced as the size of the farm increases).

Our low-end estimate involves 2,100 farms (5% of farms in the 100ha+ range) installing 500kW turbines, while our high-end estimate involves those same farms installing 1MW turbines.

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[4] This estimate is based on extrapolating out results from the 2012 Defra Farm Practises Survey, which found that 41% of respondents had buildings with potential for conversion to commercial use.

ANAEROBIC DIGESTION

Our low-end AD scenario assumes that all 7,242 dairy farms across the UK with 100+ cows install a 15kW AD plant – and that this is fed solely by manure and cattle slurry.

In calculating the 'avoided methane emissions' associated with this scenario, we have assumed that each dairy farm 'produces' 2,555 tonnes of manure per year, and that all of this can be captured (resulting in a total of 18,503,310 tonnes processed per year). 2,555 tonnes represents the expected production of slurry by 100 cows over the course of a year, and given that most UK dairy farms are larger than this, it is a conservative estimate of the total available slurry. However, given that year-round housing of cattle (and thus capture of slurry) is not typical in the UK, the conservatism of this estimate is balanced by our assumption that all of this slurry could be processed via AD.

Our high-end AD scenario draws from the Anaerobic Digestion and Bioresources Association (ADBA) calculations that assume:

- A 1% annual increase in livestock numbers between 2014 and 2030, building from a current 'capturable' availability of 68 million wet tonnes of manure (*and* associated animal bedding) per year;
- 240,000 ha of land made available for AD feedstock;
- 1,800 farms install 500kW AD systems to utilize these feedstocks.

Technology	Scenario assumption	Total installed capacity	Associated generation*	Carbon savings**
Solar				
Ground-based (low)	• If every agricultural holding of 20ha or more (116,500) installed a 50kW ground mounted solar array.	5.85 GW	4,439 - 5,243 GWh/yr	1,909,000 - 2,254,000 tCO_2e/yr
Ground-based (high)	• If every agricultural holding of 20-50ha (42,000) installed a 50kW ground mounted solar array. • If every agricultural holding of 50-100ha (33,000) installed a 100kW ground mounted solar array. • If every agricultural holding of 100ha+ (42,000) installed a 200kW ground mounted solar array.	13.80 GW	10,517 - 12,420 GWh/yr	4,522,000 - 5,341,000 tCO_2e/yr
Farmhouse rooftop	• If every farm in the UK (220,000) deployed a 4kW roof mounted array.	0.88 GW	671 - 770 GWh/yr	288,000 - 331,000 tCO_2e/yr
Agricultural buildings	• If every agricultural building with conversion potential (116,609) had a 4kW roof mounted array.	0.47GW	355 - 408 GWh/yr	153,000 - 175,000 tCO_2e/yr
Wind				
15% uptake, scaling to 500kW	• If 15% of holdings in the 20-50ha range (6,300 farms) installed a 15kW turbine • If 15% of holdings in the 50-100ha range (4,950 farms) installed a 85kW turbine • If 10% of holdings in the 100ha+ range (4,200 farms) installed a 225kW turbine • If 5% of holdings in the 100ha+ range (2,100 farms) installed a 500kW turbine	2.51 GW	5,651 - 6,952 GWh/yr	2,430,000 - 2,989,000 tCO_2e/yr
15% uptake, scaling to 1MW	• If 15% of holdings in the 20-50ha range (6,300 farms) installed a 15kW turbine • If 15% of holdings in the 50-100ha range (4,950 farms) installed a 85kW turbine • If 10% of holdings in the 100ha+ range (4,200 farms) installed a 225kW turbine • If 5% of holdings in the 100ha+ range (2,100 farms) installed a 1MW turbine	3.56 GW	8,015 - 9,262 GWh/yr	3,447,000 - 3,983,000 tCO_2e/yr

Technology	Scenario assumption	Total installed capacity	Associated generation*	Carbon savings*
AD				
Dairy slurry only	• If all the 7,242 Dairy farms across the UK with 100+ cows deployed a 15kW AD plant fed solely by manure and cattle slurry	0.1 GW	541 – 869 GWh/yr	233,000 - 374,000 tCO_2e/yr *(Plus, some 600,000* tCO_2e/yr *in avoided methane emissions)****
All slurries, and 240,000 ha of crop	• If 1,800 farms installed 500kW AD systems	0.9 GW	4,486 - 7,200 GWh/yr	1,929,000 - 3,096,000 tCO_2e/yr *(Plus, some 1,600,000* tCO_2e/yr *in avoided methane emissions)****

Notes:

* The range of electricity generation figures (and thus the carbon 'savings' as well) in the above table derive from using two different approaches to determine expected generation from the stated installed capacity.

The lower figure in the range derives from using DECC's recommended load factors (based on five year unchanged mean figures published in DUKES, 2013). These recommended load factors are as follows: solar = 8.7; wind = 25.7; AD = 56.9.

The higher figure in the range derives from applying industry expectations regarding the performance of equipment in the field (such that solar PV generates 900kWh per kW of installed capacity; wind turbines perform as expected and experience an annual average wind speed of 6m/s; and that a 500kW AD system will result in (gross) generation of 4,000 MWh/yr).

** We have used DECC's figure of 430g/kWh to calculate carbon savings arising from the production of renewable electricity.

*** Regarding avoided methane emissions, RASE have calculated that the estimated GHG potential of the UK's animal slurries is three million tonnes of CO2e per year[5]. Our 'low' AD scenario involves some 19% of total slurries being used, with an estimated annual GHG potential of 600,000 tCO_2e, and our 'high' AD scenario involves some 53% of total slurries being used, with an estimated annual GHG potential of 1.6 million tCO_2e

The range of potential installed capacity realised under these scenarios can be summarised as follows:

Technology	Capacity (low-end scenario)	Capacity (high-end scenario)
Solar PV (ground)	5.9 GW	14 GW
Solar PV (rooftop)	1.4 GW	1.4 GW
Farm-scale wind	2.5 GW	3.6 GW
Anaerobic digestion	0.1 GW	1 GW
Total (rounded to the nearest 0.5GW)	10 GW	20 GW
% of UK Total (2013)	10.5%	21%

5 http://www.fre-energy.co.uk/pdf/RASE-On-Farm-AD-Review.pdf

With some judicious rounding of figures, our scenarios look like this (the generation and carbon savings numbers in these tables are derived from using DECC's recommended load factors and are therefore at the conservative end of the ranges listed above):

The 10GW scenario

Technology	Capacity	Generation	Carbon savings
Solar PV (ground)	6 GW	4,500 GWh/yr	2,000,000 tCO_2e/yr
Solar PV (rooftop)	1.4 GW	1,000 GWh/yr	500,000 tCO_2e/yr
Farm-scale wind	2.5 GW	5,500 GWh/yr	2,500,000 tCO_2e/yr
AD	0.1 GW	550 GWh/yr	850,000 tCO_2e/yr
Total	10 GW	11,550 GWh/yr	5,850,000 tCO_2e/yr
UK Total (2013)	94.1GW	351,800 GWh	
Potential farm contribution	10.5%	3.3%	

The 20GW scenario

Technology	Capacity	Generation	Carbon savings
Solar PV (ground)	14 GW	10,500 GWh/yr	4,500,000 tCO_2e/yr
Solar PV (rooftop)	1.4 GW	1,000 GWh/yr	500,000 tCO_2e/yr
Farm-scale wind	3.6 GW	8,000 GWh/yr	3,500,000 tCO_2e/yr
AD	1 GW	4,500 GWh/yr	3,500,000 tCO_2e/yr
Total	20 GW	24,000 GWh/yr	12,000,000 tCO_2e/yr
UK Total (2013)	94.1GW	351,800 GWh	
Potential farm contribution	21%	6.8%	

These scenarios give us the confidence to state that there's at least 10GW – and quite possibly 20GW – of untapped capacity across UK farms.

We undertook this research hoping to confirm that farms had the potential to deliver "a chunk, rather than a sliver," of the UK's energy needs (and that farm-based energy therefore demanded much greater attention and support). With these scenarios, we are confident that we've done just that.

However, given that these scenarios do not consider the potential for sustainable biomass, or small-scale hydro, it's entirely reasonable to assume that farms could in fact play an even more substantial role in our energy system.

Indeed, if we look to some of the more ambitious projections for the future of solar and wind in the UK, these suggest that there might even be a greater role for farm-based solar and wind than our scenarios imply – particularly if we collectively embrace ground-based solar PV.

3.4 Exploring broader projections for renewables in the UK

Estimates of future solar capacity in the UK

A number of studies have explored the overall contribution that renewables could make to the UK's energy system. The table below outlines DECC's stated goal for solar PV, alongside two of the more 'bullish' estimates that we have found regarding the potential contribution of solar – and outlines the likely land requirement if this capacity was to be met through ground-based solar (using the assumption that 1kW of solar capacity requires 25 m² (or that 1MW requires 2.5 ha of land).

	DECC (High) Projection[6]	Kombikraftwerk[7]	Zero Carbon Britain[8]
Proposed capacity (GW)	20	37	75
Area required (ha) if 100% of this capacity is ground-based	50,000	92,500	187,500
% of UK 'Utilised Agricultural Area'	0.23	0.43	0.87
Area required (ha) if 50% of this capacity is ground-based	25,000	46,250	93,750
% of UK 'Utilised Agricultural Area'	0.12	0.21	0.43

The largest proposed role for solar that we have found is the 75GW of installed capacity included in the Centre for Alternative Technology's (CAT) *Zero Carbon Britain* analysis. CAT calls for this capacity to be installed on Britain's roofs (suggesting that 10-15 % of the UK's roof area would be required to host this amount of PV).

But we wanted to consider the potential implications of installing this much solar PV on Britain's farms.

If 75GW of solar PV was to be installed on the ground, the land required to host this amount of PV would be 187,500ha. But to provide another rooftop comparison, there are an estimated 250,000 ha of south facing commercial roofs in the UK[9]. So why should we even consider installing significant amounts of ground-based solar PV?

Firstly, because it's the most thriving and cost-competitive part of the market. Secondly, because it can provide valuable income to farmers and rural communities alike. And thirdly, because ground-based solar does not require the exclusive use of the land on which it sits. It is quite compatible with livestock and poultry production, for example (we have even heard anecdotal stories of lambing success *improving* after

6 http://offlinehbpl.hbpl.co.uk/NewsAttachments/RLP/uk_solar_pv_strategy_part_2.pdf
7 http://www.nature.com/nmat/journal/v11/n11/full/nmat3466.html?message-global=remove
8 http://zerocarbonbritain.com/
9 UK Solar PV Strategy Part 2: Delivering a Brighter Future (April 2014)

the introduction of solar PV, on the basis of the increased shelter from adverse weather and airborne predators provided by the panels).

Ground-based solar is also compatible with flower-rich meadows[10], and with the UK having experienced a 97% reduction in such habitat since the 1930s[11], ground-based solar could potentially make it economically viable for farmers to help restore this critical habitat. There are now fewer than 100,000 ha of flower-rich meadow left in the UK. If we wanted to double the 100,000 ha of flower-rich meadow left in the UK, using ground-based solar PV as the means to pay for the associated change in land-use, we would gain some 40 GW of installed capacity at the same time.

Flower-rich meadows also happen to provide excellent habitat for bees and other pollinators and, given the importance of 'pollination services' to food production, an argument could therefore be made that ground-based solar PV could in fact bolster the production of food.

Just how big is 100,000 hectares (or indeed 187,500 ha)? Well, there are currently 150,000 hectares of uncropped arable land (covering bare fallow and arable land not in production) in the UK[12]. Golf courses are estimated to take up 270,000 hectares[13]; and the UK's horse population has been estimated to require as much as 600,000 hectares[14].

When compared to other uses of land, therefore, 100,000-187,500 hectares is not that significant. But it is also crucial for us to stop thinking about energy production as being incompatible with other land-uses. We need to move beyond 'either/or' thinking when it comes to land-based decision-making. The food vs energy debate (or food vs biodiversity; or energy vs flood control; or, indeed, any such binary take on land use) reduces complex land use choices into a massively-simplified trade-off. If we get farm-based energy *right*, we have both energy and food!

Estimates of future wind capacity in the UK

Current Government attitudes towards onshore wind notwithstanding, it remains, for now, the cheapest renewable option, and plays a key role in most forward projections of the UK's energy system:

There is currently 7.5GW of onshore wind in the UK (and 3.7GW of offshore wind)[15], and projections suggest that total onshore capacity could, under certain conditions, grow to as much as 36GW (under National Grid's 'Gone Green' scenario) by 2030. Other projections – even at the high end – are less bullish, but still suggest between 19-24GW by 2030[16]:

	Gvmt (High)	Arup (High)	National Grid (Gone Green)	Poyry (High)	RA Eng GtF
Proposed capacity in 2020 (GW)	19	14.1	12.1	15	13.5
Proposed capacity in 2030 (GW)		23.6	36.0	21	18.5

We have found it difficult to determine how much of this might be located on farms. It seems entirely reasonable to assume that any substantive future onshore capacity will be located in *rural* areas, but

10 See http://www.bre.co.uk/filelibrary/pdf/Brochures/NSC-Biodiversity-Guidance.pdf
11 Bees and other pollinators: their value and health in England Review of policy & evidence, July 2013
12 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/343443/structure-jun2014provcrops-eng-14aug14.pdf
13 http://www.insidehousing.co.uk/home/blogs/home/blogs/golf-and-gaff/6529332.blog
14 http://www.insidehousing.co.uk/horse-and-house/6527588.blog
15 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/338750/DUKES_2014_printed.pdf
16 http://www.raeng.org.uk/news/publications/list/reports/wind_report.pdf

determining how much of this is likely to sit on farms, as opposed to rural estates, or the countryside more broadly, has proven difficult.

In our own scenarios, we have assumed that farms are more likely to embrace small- and medium-scale wind (rather than large-scale turbines and/or wind farms) and this presents some interesting questions:

- Is onshore wind more or less acceptable to the public (and/or Government) if it appears in smaller 'farm-scale' installations/clusters, rather than at landscape-scale?
- Is a farmer -owned approach to wind more palatable to the public than the utility-owned norm?

4 Benefits to farmers (and society more broadly)

Sustainable farm-based energy not only has the potential to contribute significantly to the UK energy system, but also to build resilience in the UK's food system. By providing additional income to farmers, energy production can be an essential component of farm economic viability and success – and therefore critical if we want farms to continue to be able to provide us with food.

Farm income is obviously dependent on many variable factors (not least weather and yield) and varies year to year. Nevertheless, the average farm income in the UK in 2013/14 was £43,000[17] and, as our case studies (and the tables below) demonstrate, energy has the potential to be a significant contributor to farm income (providing over 50% of income in one example). The following tables, produced by Fisher German, offer some insights into the expected financial performance of different technologies at different scales:

Solar	4kW	50kW	150kW	250kW
Expected generation (assuming 900kWh/kW)	3.5 MWh/yr	45 MWh/yr	135 MWh/yr	225 MWh/yr
Typical capital cost	£6,500	£55,000	£155,000	£250,000
Income from FITs (assuming 100% of electricity is exported)	£586/yr	£7,605/yr	£20,398/yr	£32,985/yr
Value of electricity if 100% used/sold on site (10p/kWh)	£350/yr	£4,500/yr	£13,500/yr	£22,500/yr

Wind	50kW	225kW	500kW
Expected generation (at 6m/s wind speed)	165 MWh/yr	440 MWh/yr	1600 MWh/yr
Typical capital cost	£250,000 - £270,000	£580,000 - £630,000	£1,200,000 - £1,400,000
Income from FITs (assuming 100% of electricity is exported)	£34,270/yr	£79,684/yr	£289,760/yr
Value of electricity if 100% used/sold on site (10p/kWh)	£16,500/yr	£44,000/yr	£160,000/yr

17 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/373091/agindicator-b6-11nov14.pdf

AD	250kW	500kW
Expected generation (gross)	2,000 MWh/yr	4,000 MWh/yr
Typical capital cost	£1,400,000	£2,200,000
Income from FITs (assuming 100% of electricity is exported)	£225,000/yr (NB. Does not include potential RHI income)	£417,000/yr (NB. Does not include potential RHI income)
Value of electricity if 100% used/sold on site (10p/kWh)	£181,000/yr	£362,000/yr

As well as providing a potential income stream to farmers, sustainable farm-based energy also provides a number of broader benefits to society.

At least 15 companies are manufacturing small- to medium-scale (0.5kW-500kW) turbines in the UK, all providing employment, and the solar industry supported 14,000 jobs in the UK in 2013[18].

The carbon savings outlined in our scenarios earlier are substantive and, in the case of anaerobic digestion (provided animal slurries are utilised as feedstocks), are boosted by significant additional savings arising from avoided methane emissions.

But the 'co-benefits' of farm-scale energy systems are many and varied. Farm-scale anaerobic digestion serves as a perfect example. While it, in isolation, will likely remain a relatively small contributor to the UK's overall energy system, it deserves support given its multiple non-energy benefits – from slurry treatment and reduced carbon emissions; through to water pollution prevention and fertiliser production. Yet, as things stand, the only support mechanisms anaerobic digestion can tap into are those geared towards energy production.

We therefore need to reward the *non-energy* benefits of farm-scale energy systems. Until we find a way to value and support such technologies on the basis of the range of benefits they provide, brilliant solutions such as small-scale anaerobic digestion will continue to struggle.

18 BRE National Solar Centre

5 Conclusions

There are different ways to estimate the potential of farm-based power in the UK. In this report we have:

- Extrapolated out the results from the June 2013 *Farmers Weekly* survey that launched the *Farm Power* project;
- Built out simple scenarios on the basis of some reasonable – yet ambitious – assumptions on how much renewable energy technology farms could potentially host; sense-checked against case studies of real farms;
- Considered a number of projections for the potential renewables capacity in the UK, and then explored the potential for farms to contribute to these.

Regardless of which approach is used, it's easy to find at least 10GW – and quite possibly 20GW – of unmet potential across British farms.

This potential can be met in a manner that *complements* food production – whether that's by:

- providing additional income to farmers and helping them become more resilient (and thus able to provide food);
- combining sheep/poultry/other food production with energy;
- providing space for the pollinators upon which much food production depends.

Indeed, the idea that energy production requires turning land over *exclusively* to energy needs to be challenged.

And decision-makers need to consider and reward the *non-energy* benefits of different energy technologies.

Appendix 1: Case studies

These case studies were used to sense-check our scenarios ("did our scenarios feel plausible given the experience of farmers on the ground?") and to provide insights into the financial viability and performance of farm-based energy.

Installed capacity per farm	Insights
8.9kW 50ha livestock farm in Dumfries.100% small-scale hydro.	Energy-related income = 30% of farm income
50 kW 40ha mixed (Market Gardens, Livestock, Poultry) farm in Derbyshire. 100% wind	
60 kW 120ha mixed (Arable & Fruit) farm in Essex. 100% ground-based solar PV	Solar located on redundant horse paddock adjacent to farm buildings (land not considered suitable for cultivation). Grass between panels allowed to 'go rough' – and increase in finch numbers noted
85 kW 220ha mixed (Beef/Arable) farm in Herefordshire. 15kW wind (5yr payback), 70kW roof-based solar PV (20yr payback)	Annual production from solar 18% higher than predicted, whereas production from wind has only been 20% of what was predicted – putting wind in the right place matters! 70kW roof-based PV suggests potential of farm buildings could be higher than noted in scenarios
170kW 220ha mixed Use (Dairy, arable and cheese-making) farm in Norfolk. 170kW AD, (expecting 8 year payback)	Feedstock all sourced on-farm (involving a switch to purpose-grown crops) Energy-related income = 19% of farm income
300kW 1,900ha livestock (sheep and cattle) hill farm in Dumfries. 100kW wind; 52kW hydro; 150kW biomass; 4kW roof-based solar	Micro-hydro systems payback = 3 years Energy-related income = 52% of farm income
1000kW Poultry (820,000 Chickens) farm in Norfolk. 2x500kW Biomass units (7 year payback)	Units run exclusively on poultry litter. Energy related income = 1.4% of overall farm income, but 2,500 tonnes of litter (1/3 of total produced) with a fertiliser value of £12 a tonne (total value £30,000) is converted into 200 tonnes of ash with a value of £160/tonne (total value £32,000)
1075kW 200ha arable farm in Berwickshire. 950kW biomass, 75kW wind, 50kW ground-based solar (7 year payback)	Inputs used in biomass unit are typically wheat or rape straw (but unit is flexible). All feedstocks sourced on-farm

Appendix 2: Agricultural statistics

We have made use of the following statistics and assumptions in this report (unless otherwise stated):

General Agricultural Statistics (all taken from DEFRA; UK Agricultural Statistics, 2014 unless stated).

- There are a total of 222,000 agricultural holdings, covering 17.3 million ha in UK.
- 116,565 agricultural holdings are greater than 20 ha in size.
- Number of farms in the UK by size:

Farm size (ha)	Number of farms
<20	106,000
20-50	42,000
50-100	33,000
100+	42,000
Total	220,000

- Total croppable area in the UK: 6.3 million hectares.
- Total permanent grassland in the UK: 9.7 million hectares.
- 4,500 holdings with 100+ dairy cows in England.
- 149 holdings with 100+ dairy cows in Northern Ireland (The Agricultural Census in Northern Ireland, Results for June 2013).
- 1,079 holdings with 100+ dairy cows in Wales (Welsh Agricultural Statistics, 2011).
- 1,514 holdings with an average of 120 cows in Scotland (Economic Report on Scottish Agriculture 2013).

Carbon savings

- DECC's carbon factor of 430gCO_2/kWh is used to calculate 'carbon savings' resulting from the production of renewable electricity.

Capacity factors of different technologies:

Load factor (sometimes called capacity factor) is a measure of the actual electrical output from a piece of energy generation technology compared to its maximum potential output:

$$\frac{\text{Annual generation}}{(365\text{ days/year}) \times (24\text{ hours/day}) \times \text{Capacity}} = \text{Load factor}$$

The load factors used in this report are based on five year unchanged mean figures published in DUKES, 2013:

	Solar PV	Wind	Anaerobic digestion
2009	9.3	26.5	46.9
2010	7.6	21.5	58.8
2011	5.1	27.2	57.6
2012	11.2	25.6	60.5
2013	10.2	27.9	60.7
Average	8.7	25.7	56.9

About Forum for the Future

Forum for the Future is an independent non-profit that works globally with business, government and other organisations to solve complex sustainability challenges.

We aim to transform the critical systems that we all depend on, such as food and energy, to make them fit for the challenges of the 21st century. We have 18 years' experience inspiring new thinking, building creative partnerships and developing practical innovations to change our world. We share what we learn from our work so that others can become more sustainable.

System innovation is at the heart of our strategy. One of our key approaches is creating innovation coalitions, bringing together groups to solve bigger sustainability challenges - including those that work across whole value chains. Another of our approaches is helping pioneering businesses go further, faster.

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