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Solutions

Battery arrays to reduce peak UK electricity demand by 17.5%

UK peak electricity demand can be reduced by 17.5% by investing £21 billion on a 6:1 10GW battery array. It will save 14.6 million tonnes of CO2 emissions annually.

An £8.4 billion investment in a smaller battery array would reduce peak demand by 7%.

Hinkley C will generate 7% of the UK's electricity at a cost of £26 billion.



UK-wide restrictions on green energy and battery array connections to the grid are bad for the environment.

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Green backup as well as green energy: the case for battery arrays

As the UK transitions to a green economy, we will need more electricity, and in particular green electricity, as gas and diesel cannot be green. The grid distributes the power that is generated and is operating at close to peak capacity, which means that in many parts of the country green energy connections to the grid are being refused or only sometimes allowed if the green energy provider pays an exorbitant fee to allow the connection of green energy to the grid¹.

There is a difference of around 12-Gigawatts of electrical requirement at any time during a 24-hour period. That very roughly translates into a demand for 40-Gigawatts of electrical power during the day and 28-Gigawatts of electrical power during the night². In line with Government policy, an increasing proportion of UK energy is provided by renewable energy sources.

However, there are periods during the day when electrical demand is much higher than others and this is currently dealt with by various forms of demand management, the majority of which fall back on fossil fuel and other CO2e emitting generating capacity³. Only a tiny part is provided by green storage solutions, the most compelling of which are grid level battery arrays. Ideally, these arrays should be working in tandem with non-renewable sources that by their nature have fluctuating output but this is not happening in large parts of the country.

Legislation out on 1st April 2023 might resolve some of the issues as the maximum that an ENA (Energy Networks Association) can charge for connection has been set at £1,720,000 per Megawatt¹. That is an approximate 17% increase in the price of a 1-Megawatt battery array which costs around £1 million but is a huge improvement on the up to £10 million that has been quoted for some connections to the grid. Evidence that green energy cannot be connected to the grid has been provided by the generators, Octopus Energy⁴, battery array providers and is highlighted by reports that hundreds of millions of pounds are being spent to pay wind farm operators to stop providing power to the grid, to prevent the grid from being overloaded⁵.

As we move to a green economy we will need more wind, more solar and more electric vehicles with batteries. The only sensible way to charge a lot of electric vehicle batteries at the same time, without bringing the grid down, is to have even bigger batteries storing energy to charge the smaller batteries in electric vehicles. In the long run, massive investment in the grid will be required and generation by gas and possibly even coal and nuclear energy will continue to be part of the mix. Increasing the importance of renewable or green energy sources is only possible if there are adequate storage solutions.

The country currently has approximately 2.1-Gigawatt⁶ of battery arrays, which is a small fraction of what is required. Probably the major reason for such a small amount is the refusal of connection to the grid, to prevent overloading, but battery arrays themselves will not overload the grid as the battery arrays are intelligent and can store the energy to be released at a time when the grid needs it.

A (6:1 10-Megawatt battery array) 10-Gigawatt battery array could provide 60-Gigawatt hours of energy. The batteries could be slowly recharged at night or when daytime demand is low and fast discharged at peak times. We are unlikely to be able to displace all the standby coal and gas generation, but might it be possible to displace 40% with battery arrays capable of storing and delivering 24-Gigawatt hours of energy?

This will not happen without significant investment, including private sector investment. However, currently if you buy power to fill your battery off-peak, you can only sell it for much less at peak time, which looks like a deliberate disincentive for investors. Is it possible that just changing the price mechanism as well as making grid connections a priority would accelerate the use of battery arrays, make the UK a greener economy faster, and help deliver the UK's Net Zero goals more efficiently?

Restriction on Green Energy Connection to the Grid

I want to be clear that my engagement is entirely public service. Neither I nor my business have any commercial interest in generating electricity, the Network or battery arrays.

Dr. Alex is one of the leaders in the field, but I am the one driving this, fundamentally for my grandchildren.

The purpose is to inform, and the ask is to present information to the right people so that the UK gets the green energy that it is the policy of the Government to deliver.

Ofgem have put in writing that battery arrays are generation, but yet they have also asked DNOs to provide battery arrays⁷.

Completely contrary to Government policy there are restrictions, UK-wide, on the distribution of green energy. This is not about whose fault anything is, but an understanding of the facts.

Fact: The DNO in Derby will not allow our business in Derby to connect solar energy to the grid.

Dr. Alex has advised me that in large parts of the UK there is a restriction on connecting green energy to the grid, in many cases the restrictions apply until 2030.

Dr. Alex provided me with proof in confidence about 2 separate denials to connect from the “National Grid” and which he may or may not wish to share. One from Coventry denied connection until 31st October 2028. Another from Northern Powergrid denied connection above 1MW until 2031.

Greg Jackson the CEO of Octopus has been recorded to claim that a wind farm can be built in a year but can take 6 to 7 years to connect to the grid⁸.

It is only important if it is both true and contrary to Government policy and if it is diminishing the ability to lessen the worst impacts of climate change.

Why Battery Arrays Matter

UK peak energy demand is approximately 40GW during the day and 28GW at night. A 6:1 10GW battery array would provide 60GWh and change daytime peak consumption to 30GW and increase night-time peak consumption to 33GW. The battery array would be quick release at peak demand during the day and slow re charge at other times.

The peak would then be 33GW and not 40GW, which is a reduction of 17.5% (100% less 33/40) and in theory would not require any increased investment in the grid, if in fact we had a national grid. The cost of the battery array would be circa £21 billion, against the projected £26 billion cost of Hinkley C to generate 7% of the total electricity demand for the UK.

Electricity cannot be stored in any other way apart from battery arrays. Less peak demand means less generation capacity or more likely the same generation capacity to deliver more electricity as we move from fossil fuels to green electricity.

Wind and solar are unpredictable generation and charging electric vehicles cannot come directly from the grid at peak demand times, so battery arrays are essential for a green electricity future. Even if only 40% of the peak demand could be stored and used to provide the same 7% as Hinkley C, the cost would be £8.4 billion for a smaller battery array instead of £26 billion for Hinkley C.

The point is that batteries are currently an essential part of delivering more green electricity, but not anywhere nearly as useful if they cannot be connected to the grid to manage peak demand. A failure to allow connection of battery arrays is both wasteful and leads to the unnecessary generation of more electricity to meet peak demand.

Why is refusal to connect to the grid important?

The Government has no money and according to one leading venture capitalist.

“We share your belief that dealing with the peaks is key. Indeed, the investment (and climate) opportunity from dealing with the peaks in power supply has been a core strand of our Infrastructure strategy for several years. We are not alone, and there appears to be plenty of capital to support that thesis. I would also expect to see more operating companies follow AES’s lead by investing in their own battery capacity. Better to do this than wait for Governments to work out what is necessary.”

If true there is plenty of capital available, but it has not been deployed if the peak demand to lowest demand gap for electricity has not changed in the last decade.

Small businesses can and would deploy their capital more readily if they could connect a battery array to the grid and benefit financially from the ability to buy and store energy at a sufficiently less cost than the price it could be sold for at peak times.

The Government cannot afford the capital outlay for the minimum 7% reduction in peak demand or increase of the 7% peak supply that a circa £8.4 billion battery array would provide. Venture Capital could provide the capital but have not invested, private businesses (wind and solar) or households would probably invest more in solar energy if they could have small battery arrays that they could connect to the grid.

Improving the business case for battery arrays requires connection to the grid and a fairer price for energy supplied.

The author does not know how generators and distribution networks are remunerated and that is the key to ensuring that energy storage becomes a significant part of the provision of more green energy.

P28 Compliance — Planning Limits for Voltage Fluctuations

The principle of taking energy when it is cheaper or when you need it and selling it when it is more expensive or when you have excess is a mechanism to increase generation/reduce demand or reduce generation/increase demand on the electricity grid and that can have consequences for the grid management and cause problems with grid voltage fluctuations.

The issue is that of the rapid change in voltage caused by the simultaneous swing of multiple BESS systems on a related part of the network. **To be clear this only applies to batteries that import and/or export power to the grid.**

A P28 study is carried out to determine whether or not a power system and any related equipment meets DNO requirements for voltage fluctuations.

The study must determine the maximum and minimum voltages that can be tolerated by electrical equipment without adversely affecting its performance.

According to the P28 Standard, the maximum permissible voltage dip is 3% for less than 10 minutes of energisation, and 1% for regular energisation.

Simply a BESS may impact on other connected users.

Many current GSP groups are closed to battery technology due to P28 compliance.

To fix the issue requires building more GSP groups and reconfiguring the network to bring the impedance down (expensive) or upgrading existing connections onto a higher voltage (very expensive).

This is a management issue that requires fixing through investment and the application of technology.

Are Batteries CO₂e Beneficial

It may or may not be true that there is widespread scepticism at “Westminster” that battery arrays are CO₂e beneficial after considering the CO₂e cost of production, use and disposal.

Under separate cover,⁹ I have provided the evidence that the 1.25MW battery array that AESSEAL® installed recently is good for the planet. The CO₂e cost, including disposal over the 15-year life cycle, is circa 112 tonnes and a CO₂e net benefit of 2415 tonnes over the same 15-year period.

On a macro level for £26 billion Hinkley C is reported to save 9 million tonnes of CO₂e annually and an £8.4 billion investment in a battery array to reduce peak demand by 7% would save approximately 5.84 million tonnes of CO₂e.

Battery Recycling

The environmental challenges of recycling batteries at end of life are being addressed. An example is Technology Minerals¹⁰ and its battery recycling business, Recyclus, who have just received Environment Agency (EA) approval to open the UK's first industrial scale lithium-ion battery recycling plant in Wolverhampton moving the UK nearer to a circular battery economy.

Once the commissioning phase is complete, Recyclus will be able to process up to 22,000 tonnes per year of lithium-ion batteries. Recyclus will receive revenues from the collection of lithium-ion batteries, and via the direct sales of material recovered from the batteries. This material, called 'black mass' contains large quantities of lithium, nickel, cobalt, and manganese which can then be extracted and re-used in new battery production.

This offers an environmentally friendly solution for end of life batteries and further addresses concerns which may be raised about the disposal of batteries. It also reduces the impact on the environment of the effects from mining.

The Problem with Hydrogen

Hydrogen is the lightest and most abundant element in the universe.

When hydrogen is combusted with oxygen it forms water. It may be possible therefore to use hydrogen as a low-carbon fuel source. Hydrogen can be combusted directly, or it can be used in a fuel cell to produce electricity.



Hydrogen Production

Over 95% of the world's hydrogen is produced using the "Steam Methane Reforming" process (SMR). In this reaction, natural gas is reacted with steam at an elevated temperature to produce carbon monoxide and hydrogen. A subsequent reaction — the "Water Gas Shift" reaction (WGS) then reacts additional steam with the carbon monoxide to produce additional hydrogen and carbon dioxide.

The Steam Methane Reforming reaction is:



The Water Gas Shift (WGS) reaction is:



It seems clear that the secret of producing hydrogen is that it is produced primarily from fossil fuels.

Hydrogen can also be produced by the electrolysis of water, but this is a more costly approach than the SMR route.

The Carbon Footprint of Steam Methane Reforming

The carbon footprint of hydrogen production via SMR can be broken down into two parts.

1. Firstly, as indicated by the SMR and WGS reactions, 100% of the carbon in the incoming methane is ultimately converted to CO₂. In the process of producing one molecule of CO₂, four molecules of hydrogen (H₂) are produced with the steam contributing the additional hydrogen. Thus, per 4 units of hydrogen produced from methane, 1 unit of CO₂ will be produced.
2. The second part is the carbon footprint associated with the individual process units ¹¹.

Linde, one of the world's largest producers of hydrogen, has broken down the carbon footprint associated with the individual process steps and have concluded that this converts to 9.3 kilograms (kg) of CO₂ produced per kg of hydrogen production ¹². One kilogram of hydrogen is the energy equivalent of one gallon of gasoline which produces 9.1 kg of CO₂ when combusted. This is the equivalent to 0.28 kg of carbon dioxide emissions associated with one kilowatt-hour of hydrogen production.

Of course, that is just the carbon footprint of hydrogen production. To use the hydrogen for power, it still must be compressed, transported, and either combusted or converted to electricity in a fuel cell. The fuel cells themselves must also be built, and there are carbon emissions associated with those construction processes.

For perspective the Energy Information Administration lists ¹³ the carbon footprint of electricity production from coal and natural gas as 1.0 kg/kWh and 0.42 kg/kWh respectively, but that is for the actual conversion into power and not just the energy content of the fuel.

It is likely that the conversion of hydrogen into power will have a carbon footprint greater than that of natural gas-fired power, but less than that of coal-fired power.

CCS

However, it is possible in theory to capture the carbon emissions generated in the SMR process and that is where the carbon capture and storage technology is being toted and the Government is putting its Net Zero aspirations in this basket. To power CCS a great deal of Net Zero power is required and that brings us back to the beginning.

For CCS to reduce emissions we need low carbon power and we do not have it.

Conclusion

Our electricity supply chain is not actually broken but battery arrays would make it greener, provide more green electricity capacity and connection to the grid is an essential component to accelerate the supply of battery arrays. Battery arrays will be essential to store unpredictable solar and wind power and to re charge E.V.s. It is also a fact that £8.4 billion spent on battery arrays will not scratch the surface of the longer-term requirement to generate, store and distribute more green electricity.

Yours sincerely,

Chris Rea, CBE, DL, BSc, CEng, HonFIMechE

On behalf of Betterworld.Solutions

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Contributors, who actually provided almost all of the detail: -

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APPENDIX 1

Connections delays reported as construction starts on major UK solar plant

Construction of “Project Fortress”, the UK’s largest solar and battery storage plant is under way in Kent as reported by the Financial Times on 24 April, 2023. This project is forecast to generate enough renewable power each year to meet the needs of about 100,000 UK homes.

However, in the FT article the trade body, Solar Energy UK, echoes the Betterworld Solutions report conclusion that the lack of grid-level battery storage is a major obstacle to progress on renewables.

They say that many projects have been told that they have a 10 to 15 year wait to get a connection, with one given a 2037 deadline. “Securing investment in reinforcing the UK’s electricity networks is priority number one for the solar industry.

“Many larger projects, whether solar farms or mounted on warehouse rooftops, are unable to connect to the grid and waiting times for upgrades can stretch long into the 2030s,” (Solar Energy UK, reported by the FT).

[\(read full article here\)](#)



APPENDIX 2

Octopus CEO says grid is “not fit for purpose”.

Octopus CEO says grid is “not fit for purpose”: At the Times Earth Business Summit CEO of Octopus, Greg Jackson, made comments on how building wind farms may only take 1-year worth of engineering but could lead to 6-7 years to get authorisation to connect to the grid.

In a quote, a National Grid representative said: “National Grid is one of the largest green investors in the FTSE & is investing £15 billion over the next 5 years to deliver the energy transition, which is the surest long-term route to energy affordability, resilience & independence.

“National Grid has to operate within a planning & regulatory framework which prevents investment in anticipation of generators requesting a connection to the grid. This needs urgent reform to allow faster connections to the grid.

“We’re working with the Government & regulator to push this forward at pace.”

Octopus CEO says grid is “not fit for purpose”.

[\(read full article here\)](#)



APPENDIX 3

Ofgem confirms approach to boosting green and smart investment in local grids

Ofgem has confirmed that its proposed 2023 price control for electricity distribution networks will:

- Require DNOs to grow their capacity using ‘flexible’ solutions where they can, such as battery storage or smoothing peaks in demand, before building expensive new network capacity.

[\(read full article here\)](#)



Ofgem launches review into local energy system operation

Ofgem has launched a review into how the energy system is planned and operated locally to ensure Great Britain is ready for a huge increase in green, more affordable home grown power.

This could result in the creation of new independent bodies separate from network companies to oversee local energy systems across the country.

[\(read full article here\)](#)



APPENDIX 4

Report from Environmental Research Institute

The Swedish IVL (Environmental Research Institute) released a report stating that CO₂ emissions from battery manufacture have been halved in recent years and range from 59 to 119 kg CO₂ per kWh of battery capacity. The higher value is where batteries are manufactured solely with the use of fossil fuels and is a worst-case scenario. Many organisations consider the mean of 89 kg CO₂ per kWh as a realistic value for calculating the CO₂ emissions.

Considering 1.25MWh (1,250 kWh) of battery multiplied by 89 = 111,250 kg CO₂ or 112 tonnes.

The annual savings are calculated from a combination of a reduction in grid usage and the mix between day and night-time generation and are typical as the usage and generation may vary with weather conditions.

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
CO ₂ e Footprint (tonnes)	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	112
CO ₂ e Savings (tonnes)	168	168	168	168	168	168	168	168	168	168	168	168	168	168	168	2527
																2415

APPENDIX 5

Update 02.03.2023 – Further evidence

Brits paying hundreds of millions to turn off wind farms as network ‘can’t cope’ with the power

[\(read full article here\)](#)



APPENDIX 6

Update 21.03.2023 – University of Sheffield

Battery energy management strategies for UK firm frequency response services and energy arbitrage

[\(read full article here\)](#)



APPENDIX 7

Update 21.03.2023 - Dynamic Containment

National Grid ESO launches new frequency control service. “... but battery storage is expected to make up the bulk of provision in the early stages”.

[\(read full article here\)](#)



APPENDIX 8

EA Approval for Lithium-ion Battery Recycling Plant

Robin Brundle, Chairman of Technology Minerals, says: “Given the global shift towards electrification and the growing demand for Li-ion batteries, we believe we have a compelling first mover advantage in this burgeoning market. Our aim is to establish enduring partnerships with businesses and organisations, both in the UK and internationally, offering them an environmentally friendly solution for their end-of-life batteries.

[\(read full article here\)](#)



APPENDIX 9

From: Solon Mardapittas

Sent: Monday, March 20, 2023 8:09 PM

To: Chris Rea

Subject: [EXT] Our Discussion

Dear Chris,

Good to speak to you, as promised please see a bit more detail on the topics we were discussing. Forgive me, I'm a technical person and I hope that I've managed to explain the 2 big questions raised by you in the call without too much Jargon/going too in depth. Happy to continue dialogue if anything is unclear.

1 – Failure to connect to the grid

ENAs and grid restrictions - We submit over 200 applications for battery schemes behind the meter, for I&C customers a year. In the last 6 months, over 60% of our applications have been returned with either complete rejections or prohibitive costs to connect relatively small assets (500kW to 2MW) – with some costs being seen beyond £10m/MW and/or with timescales for connection between 2028 to 2037. Some recent positive news has now capped this at maximum of £1,720 / KW (or £1,720,000 per MW see: <https://www.premierenergy.co.uk/blog/electricity-connection-charges-good-news-from-april-2023/>), however, this has not resolved (and may even increase) timescales observed above.

The major restrictions observed are caused by upstream substations not being able to deal with either additional generation, potential fault contribution from Inverter based systems (PV, BESS etc.) and network voltage rises/flickers. On the fault issues, the key here to note is that both PV and batteries use very similar technology to convert DC to AC, and although a batteries output is completely controllable, being able to limit based on setpoint and control export/import, the potential for the system to create a fault onto the network is treated identical as a PV system. In some areas in the country there are embargoes connecting any form of generation and unfortunately for the reasons above, this includes batteries.

2 – Price mechanism – DNO's reducing returns

Due to oversubscription of certain flexibility services (e.g., DM/DC/DFFR) by a mix of providers, the flexibility requirement from DNO's in some cases are being met already and in other cases are saturating, reducing the value of these services. As of the end of 2022, there was 2.1GW of installed battery storage – but one of the key new schemes named Dynamic Containment is approaching saturation as the total required capacity was around 1GW (DC – High and DC – Low together) – meaning one of the key revenues for battery storage has now begun to observe saturation and a fall in value.

Solon Mardapittas

Chief Executive Officer, Powerstar

DC = Dynamic Containment, DFFR is a continuously delivered service used to control the normal second-by-second grid frequency changes. Every storage provider must respond to changes in normal grid frequency by decreasing or increasing their import / export power.

APPENDIX 10

Connected Load (Batteries included) refused in some areas up to 2030.

Case Study 1

Below is the “business case” for a 0.5MW battery array which was installed in 2019.

Cost:	£381,000	
Revenue received:	£22,571	To provide grid services
Avoiding DUOS and BSUOS	£29,692	
Triad Savings from Transmission, i.e., not using energy at peak times.	£17,600	
Total annual revenue received	£69,863	18.33% return

As it is also a UPS this was also a very good financial idea. A UPS alone was quoted at £250K.

DUOS – Distribution Use of System

BSUoS – Balancing Services of system

Case Study 2

The grid could not refuse connection as we had permission but only for connected load which is 30% more than the incoming supply (at any time).

Upgraded battery array to 1.2MW. The payment scheme changed resulting in a price reduction.

Cost:	£1,051,545	
Total declines for next 3 years	£106,000	Return reduces to 10%
2993 Solar Panels energy export	£9,000	It is better to store and use than sell to the grid as the payment is pitiful
Grid Peak Energy Generating Reduction	£30,000	
Total annual revenue received (max)	£136,000	12.93% return

Case Study 3

Second battery to get around the connected load limitation.

Cost:	£702,842
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The only benefit is to the planet as we will generate more green energy for our own use. There is no return as we might get between £9,000 and £30,000. The circa £9,000 is the price gained for export to the grid and the circa £30,000 is the avoidance of buying as we have more self-generated capacity that we can store and use at will.

The reason to do this is both the ability to pay without a return, which is quite unusual and the annoyance that we would otherwise have been prevented from generating more green energy.

Summary – the grid refuses connections even of batteries to prevent overload in the grid or it is to prevent them from investing in the grid?

Batteries could give and take energy to reduce peak demand, but the grid is actively seeking to prevent that.

In short, absent Government action, batteries will not become a part of the Climate Change Solution.

There are already peak selling prices for energy. Industrial customers get charged a lot more for peak energy consumption, but none of that principle is applied to peak energy reduction. There is no point in buying energy off-peak for 3 or 4 times more than you can sell it for so there is a missed opportunity to use battery arrays to reduce peak energy demand.

APPENDIX 11

[UK Battery Storage Project Database Report - Solar Media](#)

There is “a total pipeline of planned capacity of 57GW” of battery storage.

[\(read full article here\)](#)



APPENDIX 12

<https://www.energydashboard.co.uk/live>

This is a snapshot of peak energy for a single day and also the Generation Mix.

[\(read full article here\)](#)



APPENDIX 13

March 2023 – 428 pages

HM Government Budget Delivery Plan (for Net Zero) – 192 pages

[\(read full article here\)](#)



Powering up Britain – 30 pages

[\(read full article here\)](#)



Energy Security Plan – 80 pages

[\(read full article here\)](#)



The Net Zero Growth Plan – 126 pages

[\(read full article here\)](#)



The total of 428 pages mentions battery arrays twice.

APPENDIX 14

Estimating The Carbon Footprint Of Hydrogen Production

Forbes.com - Jun 6, 2020,06:00pm EDT

[\(read full article here\)](#)



APPENDIX 15

Hydrogen production

Linde - Making our world more productive

[\(read full article here\)](#)



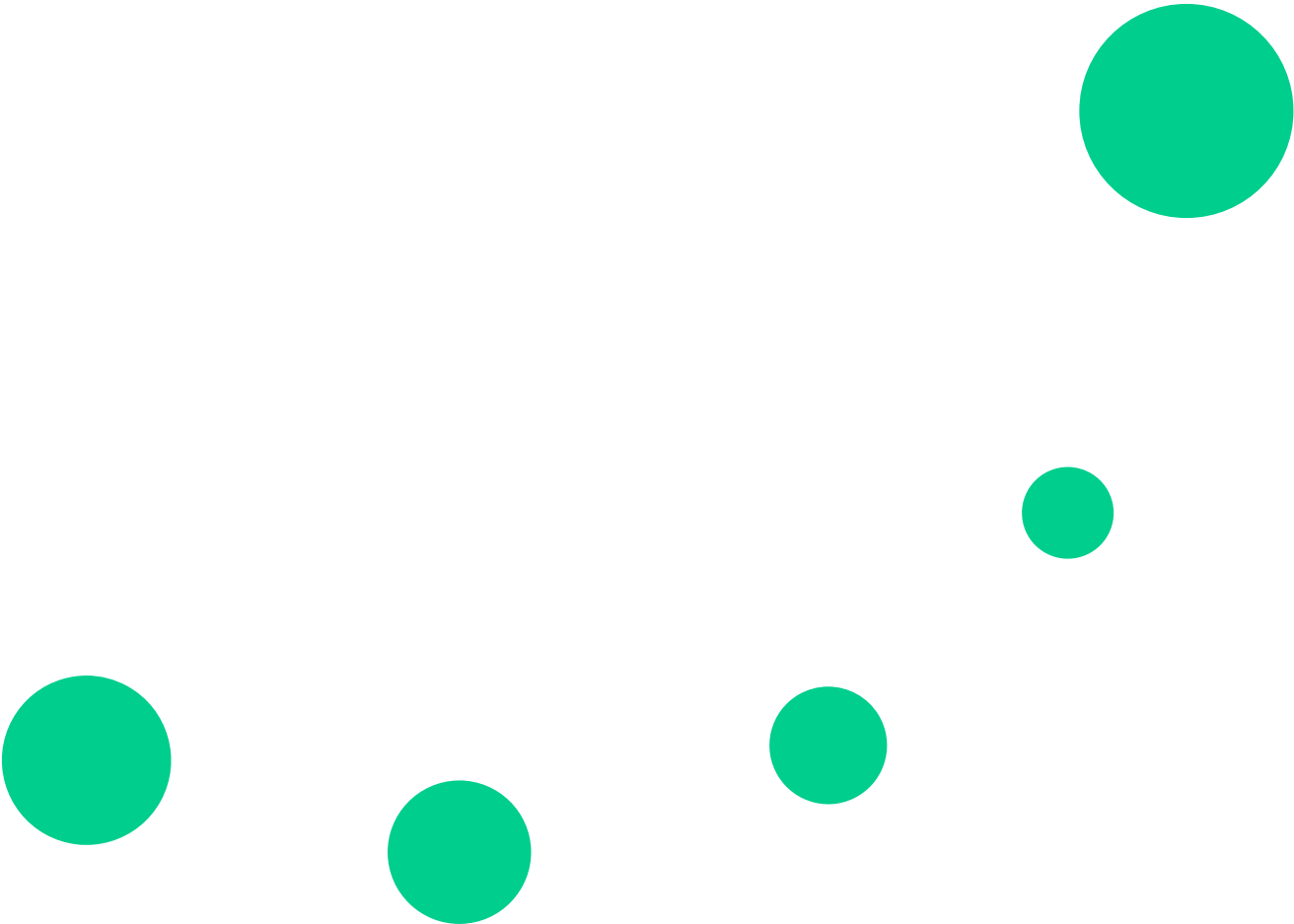
APPENDIX 16

How much carbon dioxide is produced per kilowatthour of U.S. electricity generation?

EIA - U.S. Energy Information Administration

[\(read full article here\)](#)





Chris Rea is the Managing Director of AES Engineering Ltd., a small semi-global business with operations in 40 countries.

Betterworld.Solutions is a philanthropic, best practice sharing organisation that seeks to encourage the Boards of companies worldwide to create an investment policy to prevent global warming. It is based upon the principal that more environmental projects would be funded if the decision makers knew that the opportunity existed.

For further information, visit <https://betterworld.solutions>



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