How “Green” is Electric Narrowboating?

A talk by Caroline Badger

Answer: It depends!

Factors affecting power use:

- How fast you cruise & canal/river conditions
- How much solar energy you can generate
- Battery type and size of battery bank
- How efficiently you use the generator (if you have one!)
- Correctly sized/matched propellor to hull & motor, & hull design
- How you heat your water and keep your cabin warm
- How much you cook & how toasty you like to keep your boat!

Answer: It depends!

Factors affecting environmental impact:

- Energy efficiency of equipment
- Emissions & carbon footprint of equipment
- Battery choice
- Types of fuel & power sources
- Noise and environmental disturbance
- Maintenance & longevity

Electric Narrowboats

Ideal vessel for electric propulsion:

- ✓Slow speed of travel
- ✓Weight not an issue
- ✓Large roof area for solar panels
- ✓Travel mainly through green spaces

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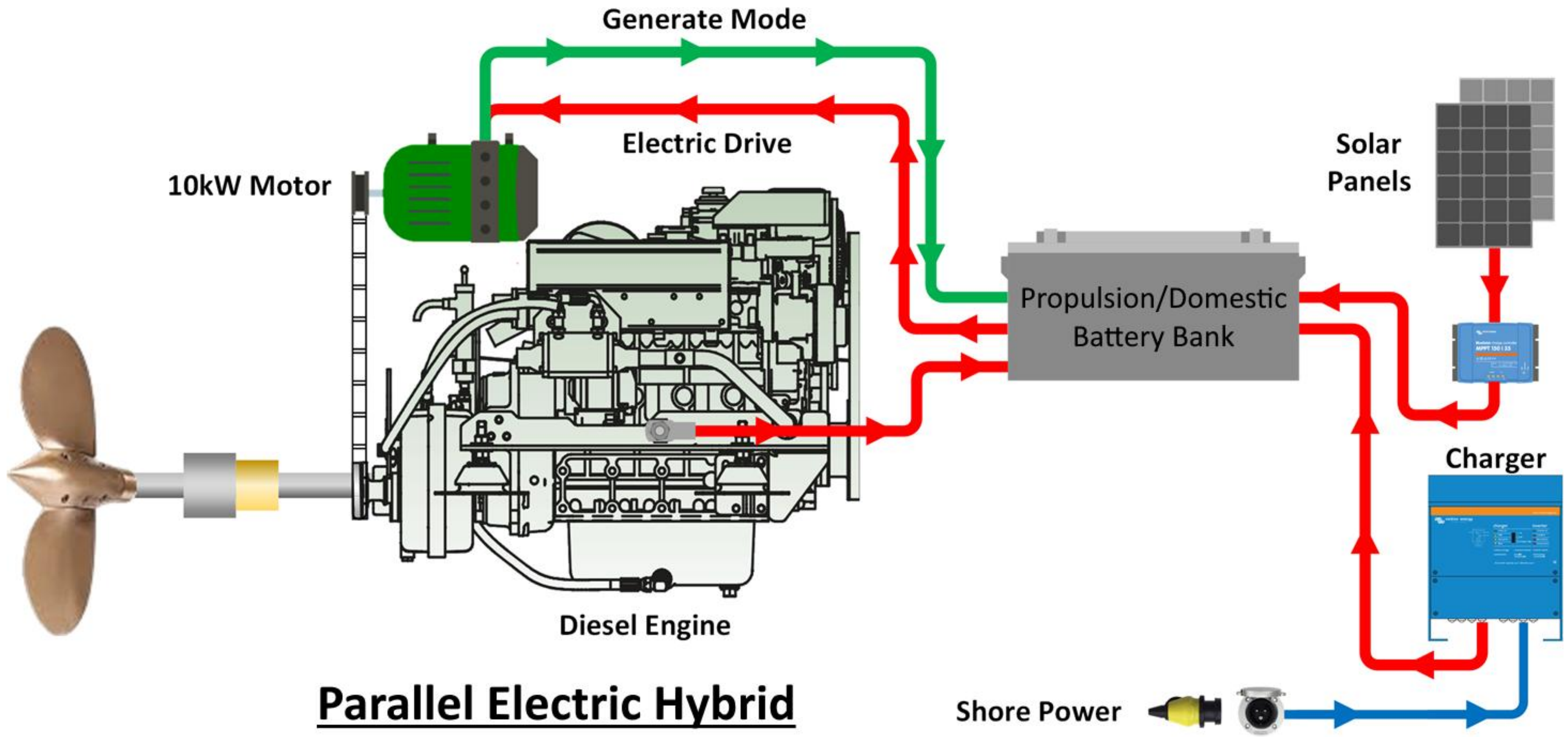
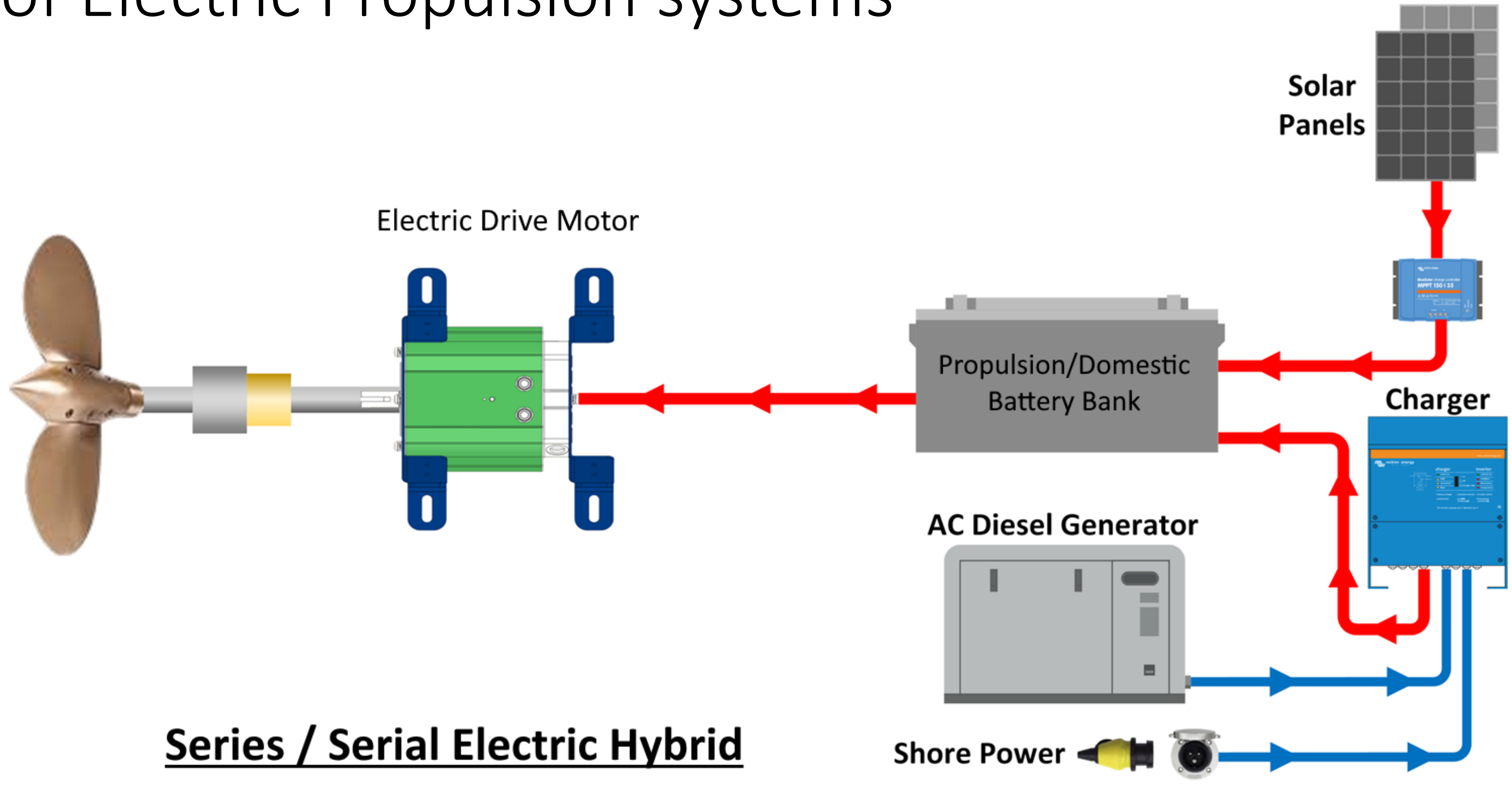
Types of Electric Propulsion systems



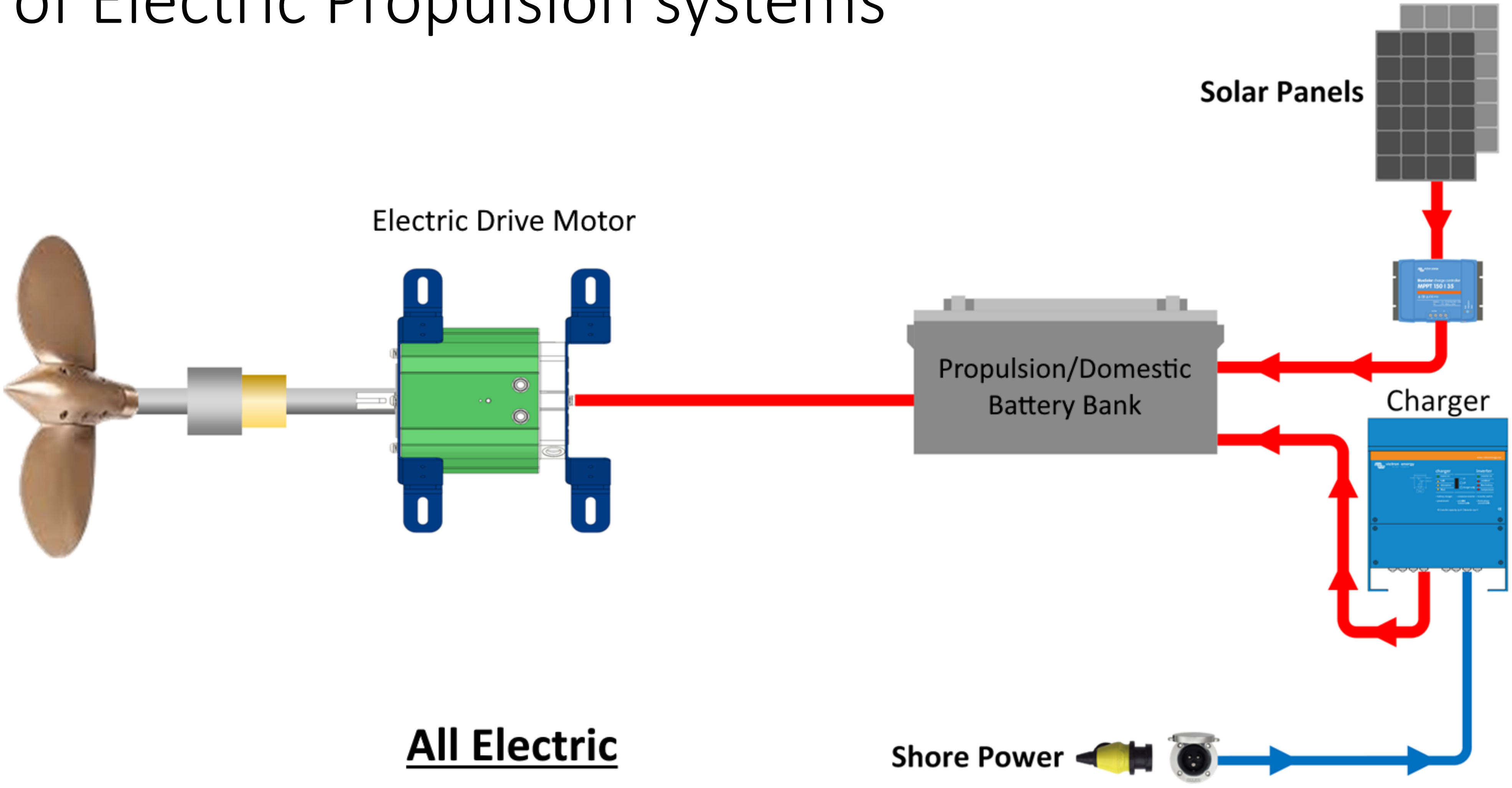
Parallel Electric Hybrid

Types of Electric Propulsion systems



Series / Serial Electric Hybrid

Types of Electric Propulsion systems



All Electric

Baseline Tailpipe Emissions – Diesel Powered Boat

Assumptions

1. **Engine Load**: Cruising at 2.5 mph typically uses **25–30% engine load**
2. **Fuel Consumption(25–30% Load)**: Beta 43 burns approx **1 to 1.5 l/hr** at this speed
3. **Diesel Energy and Emissions** (DEFRA / BEIS data 2023):
   1 litre of red diesel ≈ **2.68 kg CO_2**
   Other emissions (NO_x, PM, CO, HC) based on **marine diesel averages**

CO_2 Emissions

CO_2 = 7.2 litres × 2.68 kg/litre = 19.3 kg CO_2 per day

Other Exhaust Emissions

Using UK Maritime and European inland vessel emission factors and assuming:
At 30% load, the **engine is producing ~10 kW** (Beta 43 max = ~32 kW at full load)

Emission	Typical Factor (g/kWh)	Estimate @10kW for 6 hours
NO_x (oxides of nitrogen)	~9.0 g/kWh	540 g/day
PM (particulate matter)	~0.4 g/kWh	24 g/day
CO (carbon monoxide)	~1.5 g/kWh	90 g/day
HC (hydrocarbons)	~0.4 g/kWh	24 g/day

*These are **rough estimates**, assuming a non-aftertreated marine diesel engine*

Daily Diesel Consumption

Assuming **1.2 litres/hour** as a typical average at 25–30% load
Daily use = 1.2 litres/hour × 6 hours = 7.2 litres/day

Summary (Per 6-Hour Cruising Day at 2.5 mph)

Item	Estimate
Diesel used	~7.2 litres
CO_2 emissions	~19.3 kg
NO_x	~540 g
PM	~24 g
CO	~90 g
HC	~24 g

Notes

1. Real-world values vary with boat load, propeller efficiency, river current, and engine wear
2. Inland boats burning **red diesel** (10 ppm sulfur) emit more particulate matter than road engines
3. RCD 2013/53/EU only sets **moderate** emission limits for recreational boats, EU Stage V imposes much stricter standards for *commercial* inland waterway vessels, including limits on ultrafine particles
4. Beta 43 marine diesel engine used for reference does not carry approval under Stage V

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Emissions – Electrically Powered Boat

Assumptions

A 58 ft electric narrowboat at 2.5 mph typically uses:

1.5–2.5 kW average motor power

Assuming **2.5 kW total** average draw over 6 hours

Daily energy use

Energy use = 2.5 kW × 6 h = 15 kWh

Battery Charging via Shore Power (UK Grid Average)

Based on **UK government 2023 carbon intensity** of electricity:

UK grid average: **~160 g CO_2 per kWh**

Solar or other 100% renewable tariffs: **~0 g CO_2 per kWh**

CO_2 Emissions

CO_2 emissions = 15 kWh × 160 g = 2.4 kg CO_2 per day

Compared to **19.3 kg CO_2/day** for diesel = **87% reduction** using the UK grid

Other Exhaust Emissions

Electric motors have **zero tailpipe emissions**, so:

Pollutant	Diesel	Electric
NO_x	540 g	0 g
PM	24 g	0 g
CO	90 g	0 g
HC	24 g	0 g

Even with **grid electricity**, none of these pollutants are emitted onboard

That's crucial for air quality and user experience.

Summary: Diesel vs Electric (Per 6 Hr Cruising Day)

Metric	Diesel (Beta 43)	Electric (2.5 kW av)
Fuel / Energy	7.2 litres	15 kWh
CO_2 emissions	19.3 kg	2.4 kg (grid av)
CO_2 emissions (renewables)	19.3 kg	~0 kg
NO_x emissions	~540 g	0 g
PM emissions	~24 g	0 g
Noise & vibration	Moderate	Minimal

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Emissions – Series Hybrid Electric Powered Boat

Assumptions

1. **FP 8000x Generator:** Nominal output: 6.8kW Continuous (230VAC)
2. **Fuel Consumption:** **1 to 1.3 l/hr** under 30-40% load
3. **Runs at:** ~35% load (2.4kW) to cover propulsion **(1.2 l/hr)**
3. **Diesel Energy and Emissions** (DEFRA / BEIS data 2023):

   1 litre of red diesel ≈ **2.68 kg CO_2**

   Other emissions (NO_x, PM, CO, HC) as for diesel engine

CO_2 Emissions

CO_2 = 7.2 litres × 2.68 kg/litre = 19.3 kg CO_2 per day

IF generator runs entire 6 hrs whilst cruising

Customers of ours who have previously had diesel boats estimate that their diesel use is approx 30% of that used on a diesel boat

Daily Diesel Consumption

Assuming **runs for whole 6 hours (worst case)**

Daily use = 1.2 litres/hour × 6 hours = 7.2 litres/day

Advantages of the Hybrid Setup

Even though emissions on **cloudy/winter days** are similar to diesel cruising, the hybrid system offers key operational and environmental benefits:

1. Silent cruising

Generator runs intermittently (or in bulk charging mode)

Propulsion is electric = **quiet and smooth**

2. Higher overall efficiency

Diesel engine in the Beta 43 runs continuously even when not needed

Generator runs closer to optimal load for power generation

3. Solar offset

On sunny days, 100% propulsion from solar = **zero fuel use**

Average emissions over a season are **much lower** than diesel-only

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Real Life Data – Diesel Use

Fuel Comparison

Year	Arthur	Average over 33 weeks
2023	£1542	£47 pw
2024	£1880	£57 pw
2025 so far	£319	£29 pw

Arthur has consumed 44% less fuel per week in 2025 so far, compared to the average over 23/24

A straight comparison from 2025 against 2024 makes a 49% saving on fuel since Arthur became an electric hybrid

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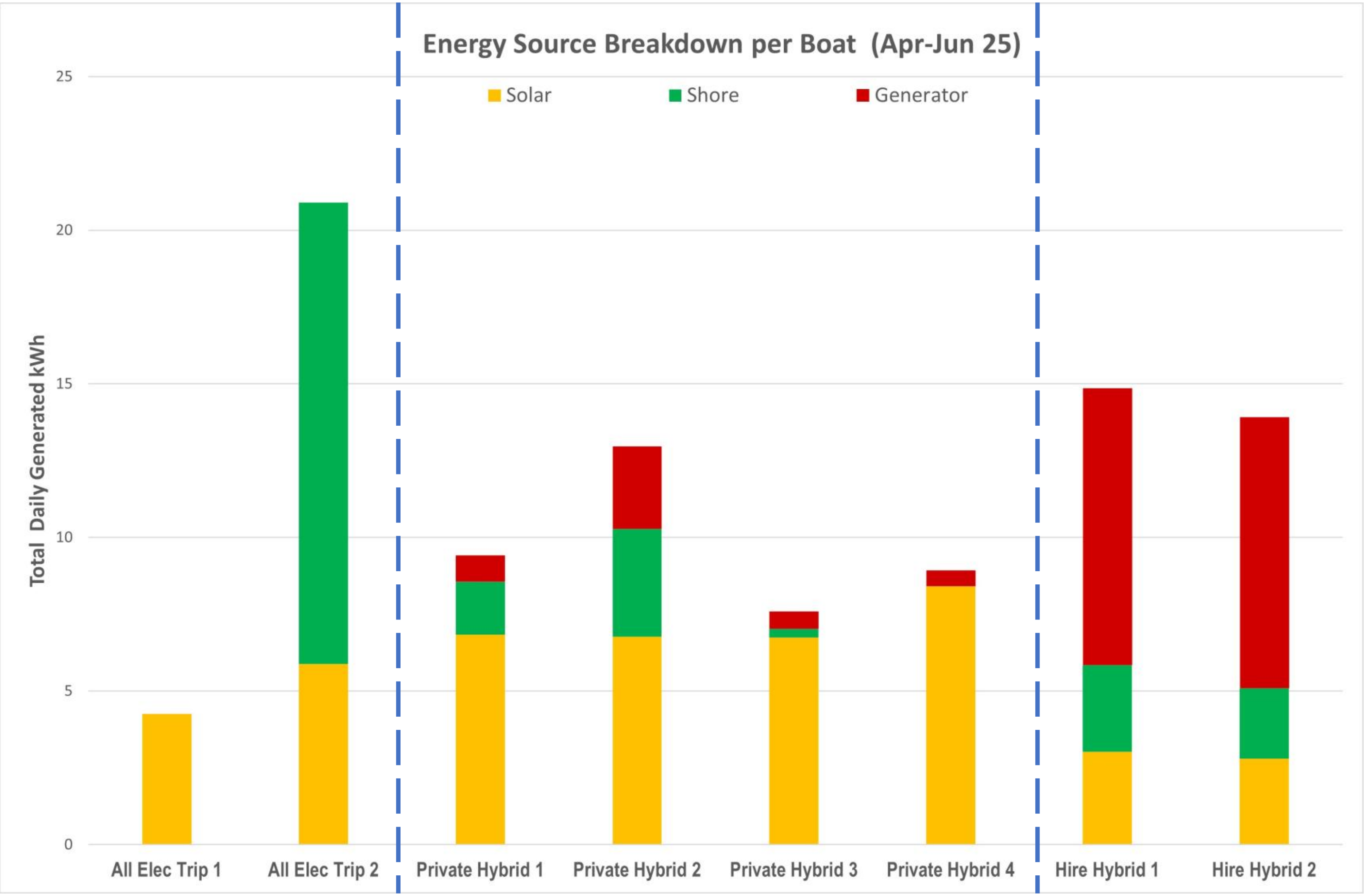
Real Life Data – April to June 2025



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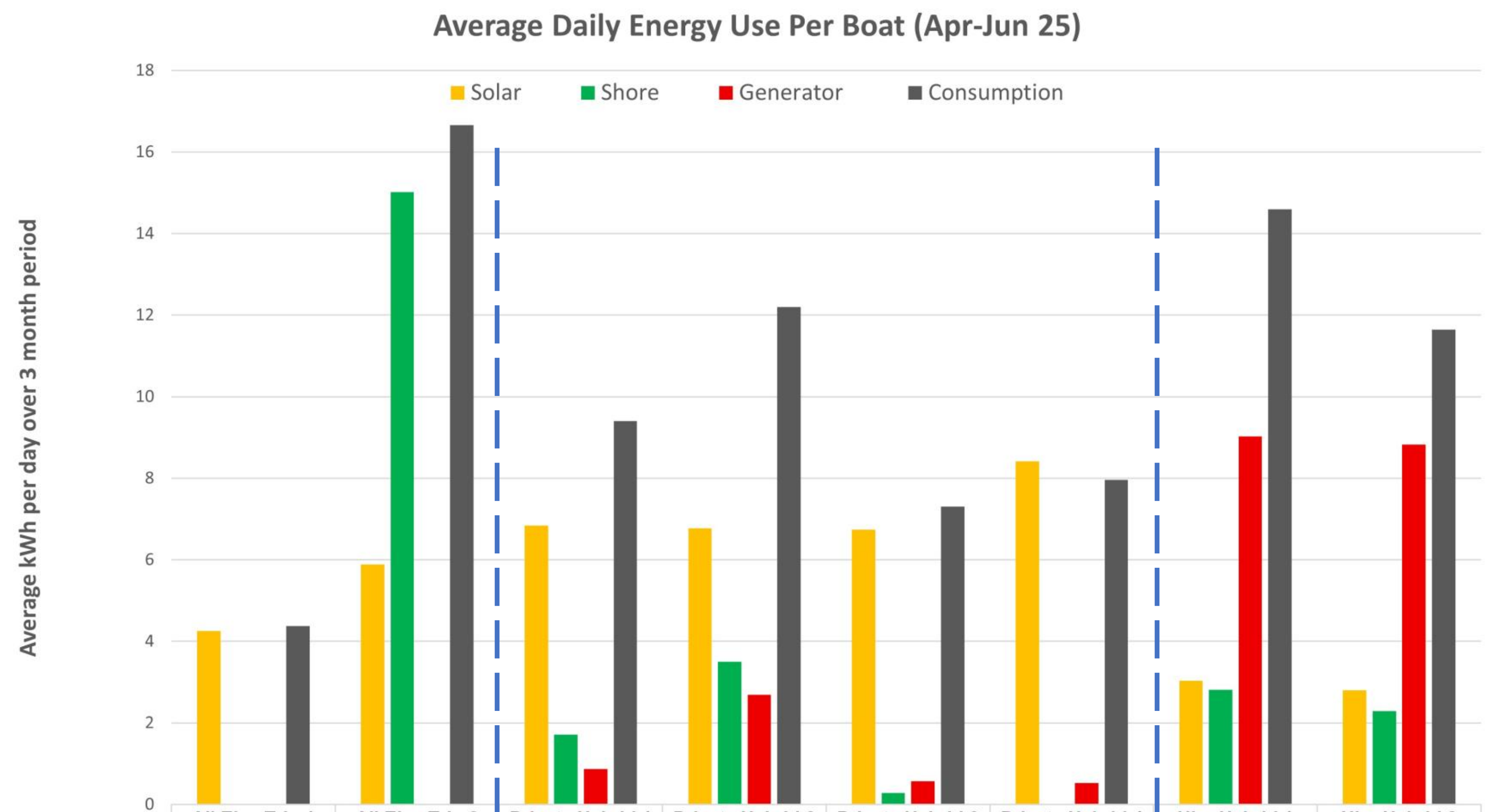
Real Life Data – April to June 2025



	All Elec Trip 1	All Elec Trip 2	Private Hybrid 1	Private Hybrid 2	Private Hybrid 3	Private Hybrid 4	Hire Hybrid 1	Hire Hybrid 2
Solar	4.25	5.88	6.84	6.77	6.74	8.41	3.03	2.8
Shore	0	15.02	1.71	3.5	0.28	0	2.81	2.29
Generator	0	0	0.87	2.69	0.57	0.52	9.02	8.83
Consumption	4.38	16.66	9.4	12.2	7.3	7.96	14.59	11.64

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Real Life Data – April to June 2025

Type	Launch Date	Solar Panel Array	Solar Yield since launch	Battery Type	Battery Bank Size	Miles Travelled	Locks	Notes
All Electric - Trip Boat 1	19/12/19	2.1 kW	6.3 mWh	Lead Carbon	1000Ahr (48kWh)	?	None	54ft Widebeam - solar power only 15 trips in period - av trip used 17kWh
All Electric - Trip Boat 2	13/05/21	1.92 kW	4.9 mWh	Lead Carbon	1000Ahr (48kWh)	796	None	64ft narrowboat - shore & solar cruises nearly every day - 82 day trips in 91 day period - av trip used 20kWh
Series Hybrid - Liveaboard 1	04/08/20	1.92 kW	6.1 mWh	$LiFePO_4$	600Ahr (28.8kWh)	64	22	Upgraded Battery Bank from Lead Carbon to LFP in March 2024
Series Hybrid - Liveaboard 2	10/12/20	1.92 kW	5.9 mWh	Lead Carbon	800Ahr (38.4kWh)	212	208	Original Batteries
Series Hybrid - Liveaboard 3	09/02/22	2.4 kW	4.6 mWh	Lead Carbon	800Ahr (38.4kWh)	158	110	Original Batteries
Series Hybrid - Liveaboard 4	04/06/24	2.8 kW	1.9 mWh	$LiFePO_4$	800Ahr (38.4kWh)	128	59	Largest Solar Array
Series Hybrid - Hire Boat 1	14/03/22	1.28 kW	1.9 mWh	$LiFePO_4$	400Ahr (28.8kWh)	534	?	Pushed hard by hirers
Series Hybrid - Hire Boat 2	11/03/25	1.2 kW	0.3 mWh	$LiFePO_4$	800Ahr (38.4kWh)	208	?	Pushed hard by hirers

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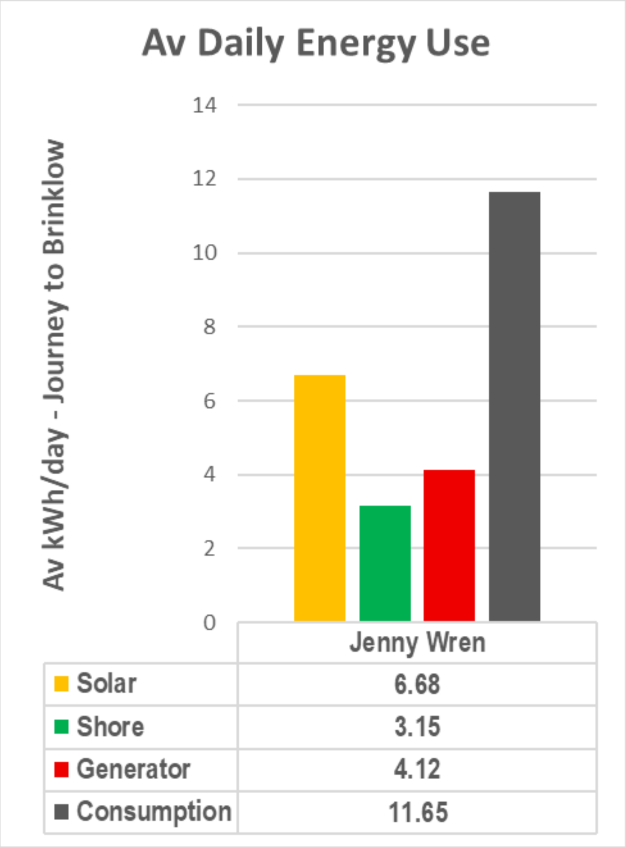
Jenny Wren – 20 Days to Brinklow from Droitwich



Launch Date	Solar Panel Array	Solar Yield since launch	Battery Type	Battery Bank Size	Miles Travelled	Locks
03/06/35	2.4 kW	0.2 mWh	$LiFePO_4$	1000Ahr (48kWh)	112	145

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Battery Choice – Environmental Impact

Comparison Table: Lifecycle Carbon Impact

Battery Type	Total Capacity (kWh)	Usable DoD	Effective kWh	Cycle Life	Replacements (15 yrs)	Production CO_2e (kg)	CO_2e per kWh Delivered
Flooded Lead Acid	38.4	50%	~19.2	~1,500	2–3 sets	5,800–6,500	**~2.5–3.5**
Lead Carbon	38.4	70%	~26.9	~2,200	1.5–2 sets	6,100–6,900	**~2.0–3.0**
$LiFePO_4$	38.4	95%	~36.5	~4,000+	1 set	9,600–11,500	**~0.8–1.5**

Conclusion:

- **$LiFePO_4$** has the highest up-front carbon cost but is the ***cleanest over its full lifecycle***
- **Lead Carbon** is a solid middle ground — better than Lead Acid on all fronts
- **Lead Acid** is the most carbon-intensive per kWh delivered, mostly due to lower DoD and shorter cycle life

Battery Choice – Efficency Factors

Flooded Lead Acid:

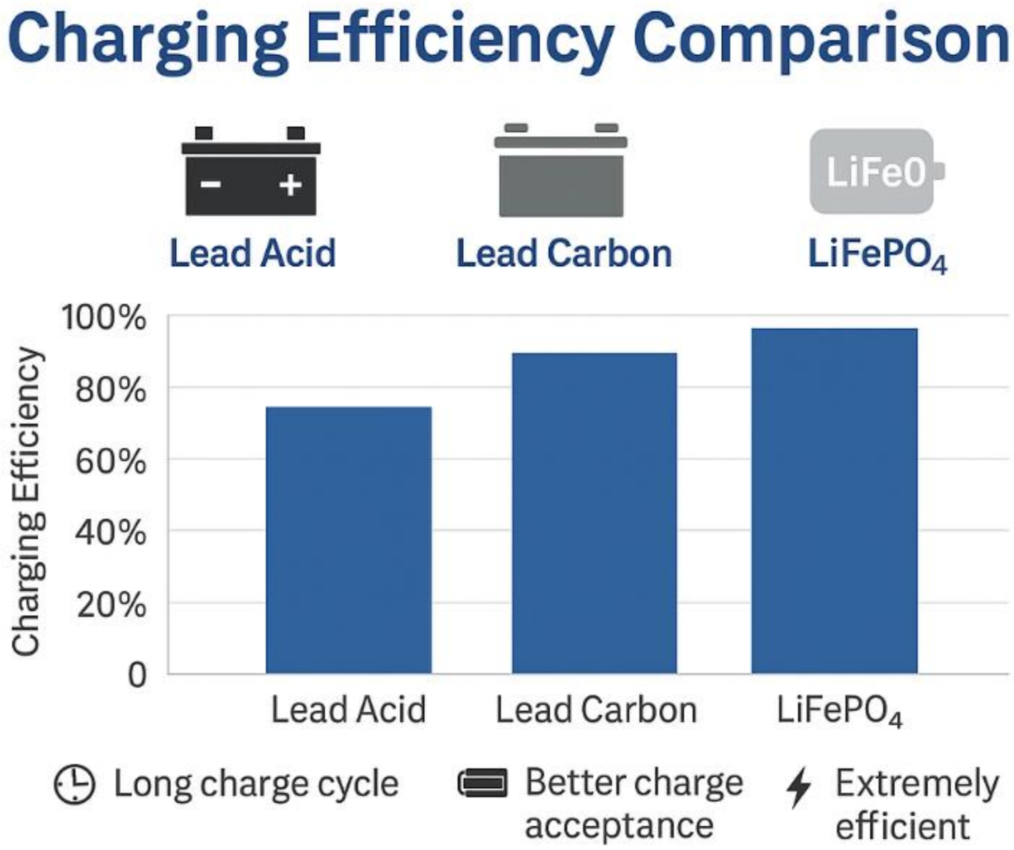
- Loses energy as heat & gassing during absorption phase
- Long charge cycle
- Poor partial SOC tolerance

Lead Carbon:

- More efficient than lead acid due to better charge acceptance and less sulphation
- Medium charge cycle
- Better partial SOC tolerance, but needs topping off

$LiFePO_4$:

- Extremely efficient with minimal losses
- Fast charge cycle
- Flat voltage curve allows smart charging
- Excellent partial SOC tolerance



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Battery Choice – Other Environmental Factors

Cradle to Grave Environmental Comparison

Factor	Lead Acid / Lead Carbon	$LiFePO_4$ (Lithium Iron Phosphate)
Key Materials	Lead, Sulfuric Acid, Carbon (for LC)	Lithium, Iron, Phosphate, Graphite, Copper
Mining Impact	Medium–High (toxic lead mining & smelting)	High (energy + water use in lithium/brine)
Toxicity	Very High (lead is a potent neurotoxin)	Low (non-toxic and cobalt-free)
Production Energy Use	Moderate	High
Current Recyclability	Excellent (~95–99%)	Low (~5–10%) but increasing
End-of-Life Risk	High if improperly recycled	Low–Moderate
Second-Life Potential	Low (not typically reused)	High (stationary storage after marine use)

Labour Exploitation and Lithium Batteries

- Not all Lithium Batteries are the same - safety-wise OR exploitation-wise
- There is *not* strong evidence of widespread child labour or forced labour in lithium mining

The Bigger Human Rights Issue: Cobalt

- **Cobalt** is used in many lithium-ion chemistries (like NMC or NCA) — ***but not in $LiFePO_4$***

Over **70% of the world's cobalt** comes from the **Democratic Republic of Congo (DRC) where there are documented serious human rights violations (child labour, unsafe mining conditions, lack of regulation and worker protection)**

Battery Choice – Safety

Battery Safety Comparison

Safety Feature	Flooded Lead Acid	Lead Carbon	$LiFePO_4$
Gassing Risk	High (needs ventilation)	Low	None (sealed, no gas)
Spill/Leak Risk	High (liquid acid)	Low	None (solid, sealed)
Explosion Risk	⚠ Medium (hydrogen buildup)	Low	Very Low
Fire Risk	Very Low	Very Low	Very Low
Thermal Runaway	Not applicable	Not applicable	Very Low risk
Maintenance Need	High (fluid checks, venting)	Moderate (less frequent)	None (sealed, BMS-managed)
Abuse Tolerance	Low (sulphation risk)	Better	Excellent

Battery Choice – Conclusion

- Lead-based batteries have lower initial environmental cost and are widely recycled, but they carry high human and ecological toxicity risks throughout their lifecycle.

- $LiFePO_4$ batteries have higher production impacts, but they are cleaner in use, non-toxic, and show long-term sustainability promise as recycling tech improves.

- If your budget allows, $LiFePO_4$ are the most sustainable choice of battery (of the types compared) for your electric narrowboat. Prices are reducing all the time, making them a more affordable option.

- Do not be put off by safety concerns – as long as you specify $LiFePO_4$ - do NOT be tempted to use second-life car batteries!

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HVO – Hydrotreated Vegetable Oil

TAKE ACTION
PROMOTE THE USE OF HVO

HVO
FOR LEISURE BOATERS
UP TO 90 % CO_2 REDUCTION

LET'S TALK ABOUT HVO

HYDROTREATED VEGETABLE OIL:
A sustainable fuel for your boat's diesel engine

INLAND WATERWAYS ASSOCIATION · RYA · BRITISH MARINE · CRUISING ASSOCIATION · Zemo Partnership – Accelerating Transport to Zero Emissions

To help increase demand, expand supply and stabilise the price of HVO to encourage the adoption of the biofuel in the leisure boating community. Please:

- ✓ Use HVO whenever you can get it.
- ✓ Inform your fuel suppler (marina, boatyard, hire base) that you would buy HVO if they stocked it.
- ✓ Lobby or write to your MP asking them to pressurise the Government to support our campaign to adopt policies that will make HVO available and affordable to leisure boaters.

HVO IS:

- Clear, colourless and odourless
- Cleaner than mineral diesel, with lower particle emissions
- More biodegradable than mineral diesel
- Suitable for use in any concentration with mineral diesel, from 1% to 100%
- Suitable for supply and distribution using the existing marine infrastructurediesel to a cleaner, greener, sustainable fuel known as HVO (Hydrotreated Vegetable Oil)
- It is not the 'FAME' biodiesel which is currently added at 7% to the mineral diesel you are probably buying (B7) and that causes problems in a marine environment.

MORE INFORMATION:

Visit: waterways.org.uk / ... hvo-joint-working-group

Join us to help ensure all recreational boating in the UK is more sustainable

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Reduce your carbon footprint on your boat

- ✓ Cruise slowly and steadily – the more energy you use to accelerate, the more you use to stop!
- ✓ Use shore power rather than generator when possible
- ✓ Work your generator hard – put washing machine, cooker, water heater, etc on while generator running
- ✓ Upgrade your batteries and/or solar array
- ✓ Solar – moor in the sun if you can! Keep panels cool, if batteries are full, turn on water heater, washing machine, cook dinner while sunny. Use eco-mode when on shore power (if available)
- ✓ Change your propeller?
- ✓ Heating – solid fuel stoves: burn eco friendly fuels
- ✓ Heating – diesel fired heaters: only use when absolutely necessary, turn thermostat down by a few degrees, use electric blankets & heated throws!
- ✓ Use HVO when you can – we all need to lobby Government!

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