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Reliable Recovery - benefits of stored passive flue gas heat recovery for UK homes and the wider economy

July 2017

As the residential heating and energy efficiency industry has innovated over the past 10 years, government has an opportunity to craft new legislation which reflects the opportunities for consumers and the UK as a whole to save resources and energy from the use of new technologies. This paper updates the literature on the benefits of stored Passive Flue Gas Heat Recovery (PFGHR) which delivers:

- An increase to domestic hot water efficiency of 31%, which equates to an annual gas bill reduction of £34 for a typical household.
- Up to 50% hot water efficiency savings in winter, given approximately 9% improvement in summer. This results from the additional space heating energy recovery in the winter, and helps reduce consumption at a time of year when energy systems are most strained.
- Other utility bill savings from the reduction in rejected lukewarm water consumption. Stored PFGHR provides instantaneous hot water and therefore reduces water waste by approximately. We estimate this benefit to be £66 a year for a typical household.
- Given current costs of installation, stored PFGHR has a payback period of less than 5 years. With the potential for cost down as deployment scales, we project that this payback period can be reduced to just over 2 years. This is provided some initial government support which can help tackle barriers to take up.

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1. Context – unlocking home energy saving

Over the last 10 years, average gas and electricity bills in the UK have risen in real terms by 31% and 37% respectively[1], at a time of economic difficulty and stagnating real wages. The benefits of technologies which save energy are evident, both in addressing the rising cost of living, and also by helping the UK reduce greenhouse gas (GHG) emissions and tackle dangerous climate change.

Concurrently, innovation in building-level heating technologies have created an opportunity to review policy and building regulations, to better support the latest and most-effective measures. The 2005 revision to energy performance standards had a dramatic and positive impact on the market, carbon emissions, and consumers - who now enjoy lower fuel bills as a result of the regulation changes.

Since 2005 the heating industry has developed a number of new technologies which, when installed and operated in the home, provide energy consumption savings over and above those provided by condensing boilers. However, there are a number of behavioural barriers – internalities – which prevent user uptake, despite the long-run benefit. These include a lack of good information on the technologies involved and a preference for the *status quo* ('bounded rationality'). Government has a role to play in helping deliver better market outcomes for consumers.

Whilst all the measures proposed in the *Future of Heat* consultation[2] provide energy savings under optimal usage, a challenge is to support measures which will provide energy savings under real-use conditions. Some measures have to be used by consumers appropriately to deliver energy efficiency gains, and this can be problematic for many homes who do not have the knowledge to use measures optimally.

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[1] BEIS (2017) *Domestic energy price statistics*. Available from: https://www.gov.uk/
[2] BEIS, 2016. Heat In Buildings. The Future Of Heat: Non-Domestic Buildings. Consultation.

PFGHR devices recover heat from flue gas emissions of a combination boiler to pre-heat the property's hot water. The system works independently and requires no maintenance or user knowledge. Like the introduction of the Condensing boiler regulations in 2005, this technology can have a demonstrable positive and lasting impact on the efficient running of home heating systems, thereby lowering energy consumption for consumers and UK GHG emissions.

With over 23 million homes heated by natural gas and an increasing penetration of combination boilers (see Figure 1), PFGHR is one of a number of measures which can play a crucial role in boosting energy efficiency in the UK.

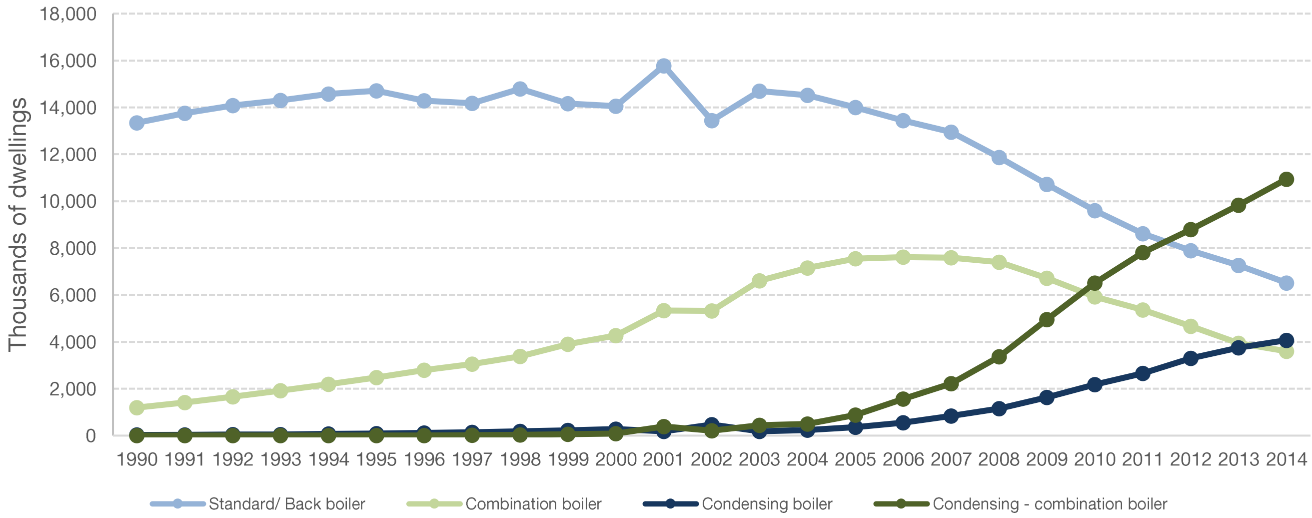

Figure 1 - Boiler types in the UK (BEIS, 2017)

2. Consumer benefit from PFGHR

PFGHR systems are categorised into two types:

01 Devices without thermal storage – only recover flue heat energy during hot water production. This is the direct energy saving;

02 Devices with thermal storage – can also store energy from the flue when the boiler is heating the home. This is the *indirect* energy saving.

PFGHR systems with storage can provide both direct energy savings (recovered energy from the flue to be used instantly for hot water), and indirect energy savings (recovered energy used for hot water at a later point in time).

According to the *Evidence Gathering: Passive Flue Gas Heat Recovery Technologies*[3] consultation carried out by BEIS in 2016, PFGHR devices save an average of 9% (PFGHR devices without a thermal storage) to 31% (PFGHR devices with a thermal storage) of the gas used to heat domestic hot water (DHW) in a typical house. This is equivalent to a boiler efficiency improvement of around 1 to 5 percentage points of the total energy required for heating purposes.

[3] BEIS, 2016. Evidence Gathering: Passive Flue Gas Heat Recovery Technologies. Consultation.

Stored PFGHR gas saving

Given a typical heat demand profile (12,000 kWh space heating and 2,000 hot water)[3], a stored PFGHR system would deliver 847 kWh of gas savings per year – based on a 31% annual hot water efficiency figure. As illustrated in Table 1, this is equivalent to about 5% of a typical home's heating demand - and when monetised with an average retail gas price[4], equates to around £34 worth of energy bill savings per year.

This average figure masks the varying seasonal efficiency of the technology. In summer months, the stored PFGHR provides no additional benefit over a non-storage system, as we assume that there is no space heating demand and therefore no opportunity for storage of recovered energy from this source. The 2016 BEIS report uses an efficiency figure of 9% for non-stored PFGHR unit.

It is in the colder months when space heating is required that the stored system provides additional benefit, by recovering and storing energy for hot water use. We calculate that in winter months stored PFGHR can deliver hot water efficiency savings of up to around 50%. This is at a time of year when energy systems are most strained with tight supply margins, and therefore efficiency savings are most valuable. This is explored further in Section 3.

[4] BEIS, 2017. Data tables 1-19 supporting the toolkit and the guidance. Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal.

Indeed, the efficiency achieved by stored PFGHR can vary significantly depending on the volume of the thermal store, space heating demand, usage patterns[3] (which depend on building size and age), as well as the test protocol used to assess the efficiency of a PFGHR device. For example, a PFGHR system in a larger building with a higher gas requirement for heating will be able to store more recovered heat.

Over time, new properties have been built to increasingly improved fabric efficiency standards. This means that DHW consumption – which remains relatively unchanged - accounts for an increasingly dominant proportion of the total gas bill. Consequently, installing a PFGHR device provides greater total efficiency savings, whereas the total amount of recovered heat may decrease with reduced heating demand over time. This has been illustrated in the Figure 2 below.

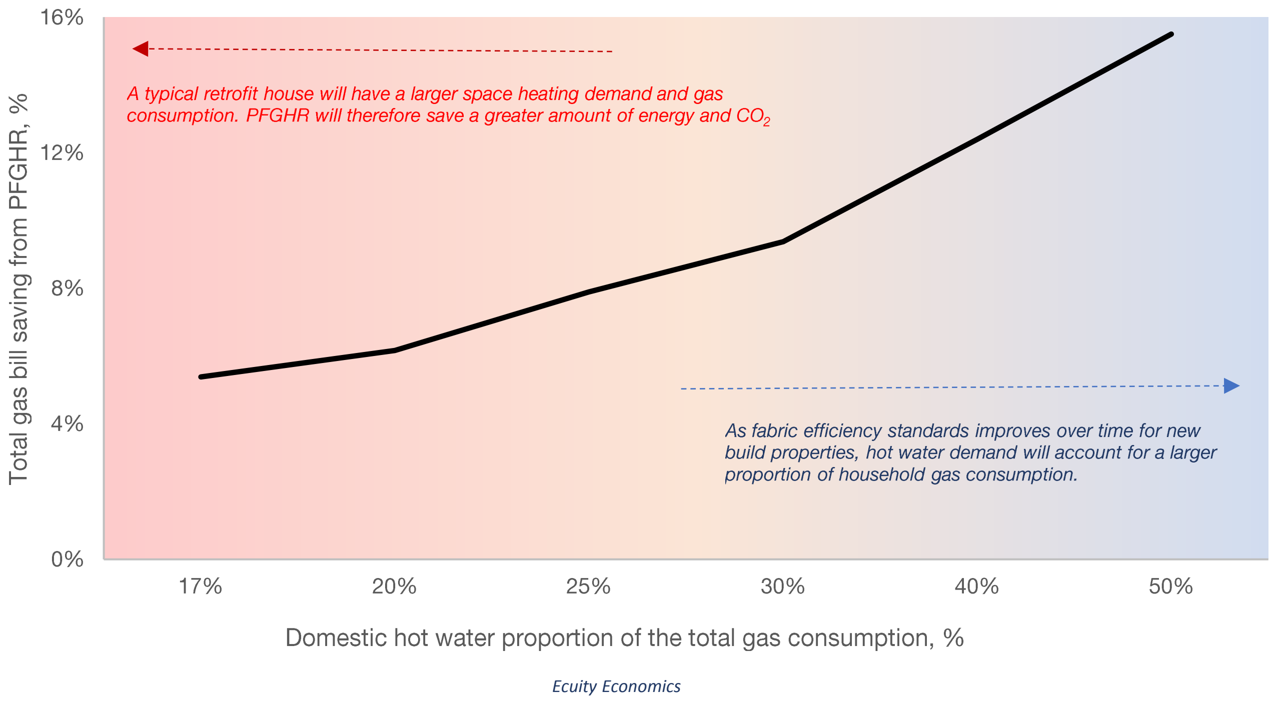

Figure 2 – Total gas bill savings from PFGHR with respect to the proportion of DHW consumption

Whilst PFGHR systems deliver dependable efficiency savings over their lifetime, the system does have an upfront cost. We concur with BEIS' estimate of £460[5] for a device with thermal storage - though, as demonstrated in Section 4, consider that this will fall over time with scale, innovation and deployment.

[5] BEIS, 2016. Domestic Heating Replacement Regulations. Impact Assessment. Available from: https://www.gov.uk/

	Impact	Cost	Source	User interaction
Weather Compensators	1.1% reduction in heat demand	Central: £80	BEIS	Medium
TRVs	3% reduction in heat demand	Central: £350	BEIS	Medium
PFGHR (BEIS Future of Heat)	2.9% reduction in heat demand	£460 in year 1, reducing to £200 with mass production in year 2	BEIS	Low
Stored PFGHR	5.4% reduction in heat demand	£460 in year 1, reducing to £200 with mass production in year 2	Report	Low
Learning Thermostats	4% reduction in heat demand, including 1.1% impact of weather compensators	£210, including integrated weather compensator	BEIS	High

Table 1 - Cost and impact of measures covered in Future of Heat BEIS (2016) policy with report's PFGHR assumptions

Additional water bill savings for consumers

Residential water consumption falls into 3 categories: useful cold water usage (for drinking and flushing of toilets etc.), useful hot water usage (for heating and showers etc.), and additionally unwanted lukewarm water. Typically, when running a hot water tap, it takes some time for the water to reach useful temperatures. During this process, lukewarm water is rejected which is a cost to consumers, and also generally a waste of resources for the UK economy (discussed further in Section 3).

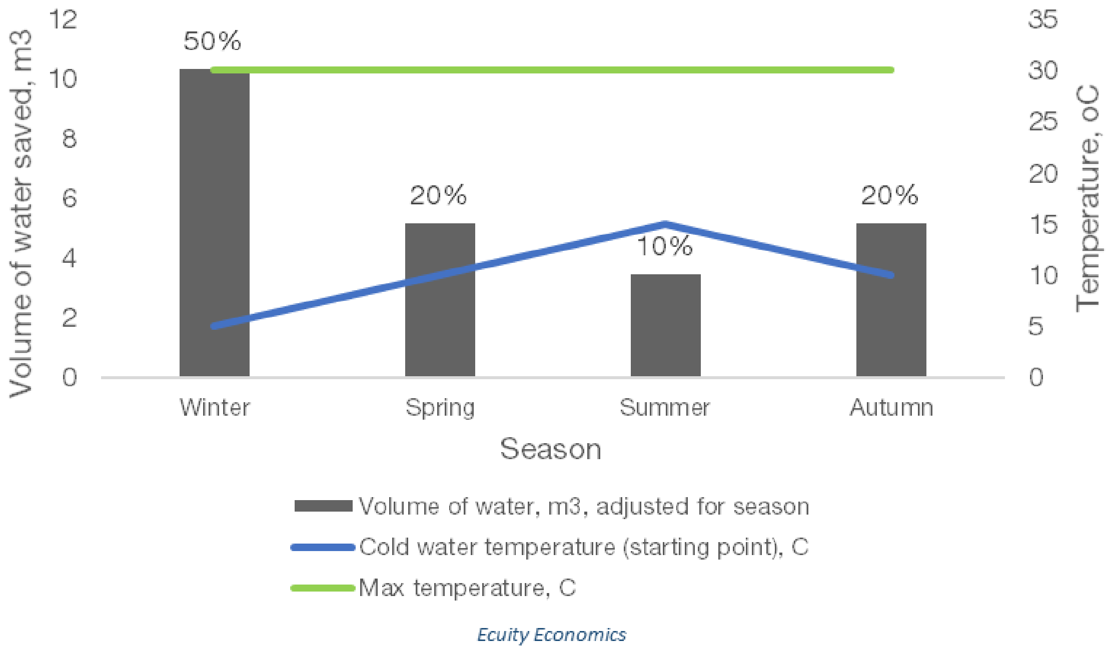

Figure 3 – Lukewarm water savings per season with respect to cold water temperatures and SAP boiler penalty of 600 kWh (percentage denotes the assumed proportion of DHW demand in the respective season).

Stored PFGHR provides the home with instantaneous hot water, which reduces the amount of rejected lukewarm water wasted by the home. SAP 2012 penalises condensing gas boilers by 600 kWh on account of the energy needed to warm rejected water. Our analysis uses this figure to estimate the potential water saving benefit of the technology. We assume that stored PFGHR recovers enough energy to remove this penalty (see the 847 kWh estimate above), and therefore saves the lukewarm water that would otherwise be rejected.

The temperature of water supplied to homes varies throughout the year from 5-15°C depending on season (Figure 3). Assuming that the temperature for useful water is 30°C, this SAP 2012 figure equates to 20,640-34,400 litres of rejected water per year. A reasonable assumption was made that cold water is used more than hot water during the summer, and hence most of the DHW consumption occurs during the heating season (50% in the winter, and 20% in both spring and autumn, and 10% in the summer). Adjusting the water consumption figure derived from the SAP score for seasonality, the total water saving thorough the year is 24.08 m^3. This is 20-33% of the annual water consumption of a typical house.

This demonstrates that PFGHR should not just be conceived narrowly as a gas saving technology, but as a resource saving technology. Whilst the *Future of Heat* domestic policy consultation has an objective to consider measures which improve the efficiency of residential heating systems, it is understandable that the metrics and benefits considered focus on energy consumption and bills. However, this approach underestimates the total benefit of PFGHR to consumers, which should be considered by government when developing regulations which impact such measures.

Moreover, the installation of a PFGHR device with thermal storage and the energy efficiency savings made, mean that users could install smaller sized, lower cost boilers to meet underlying heat demand. The reduced heat input requirement provides the scope for further savings as smaller boilers can be installed.

Table 2 brings together both the gas and water consumption savings from a typical house utilising a stored PFGHR system with their combination boiler. As shown, our estimate of the value of the water bill savings exceeds that of the gas reduction, and the total utility bill saving of £100[6] per year is attractive. The water bill savings by region vary between £57-£132 (Table 3).

Given a stored PFGHR upfront cost of £460 - as represented in the *Future of Heat* consultation - this yearly utility bill saving gives consumers an attractive payback of less than 5 years. In addition, we anticipate that this capital cost will reduce further given scale and volume over time. This is explored further in Section 4.

	Additional Upfront Costs	*Bill savings per year*	*Payback period, years*	*Source*
Weather comp	£80	£6	13	BEIS
Stored PFGHR	£460	£100, comprised of: - £66 water (a saving of 24.08 m^3) - £34 gas (a saving of 847 kWh)	4.6	Report
Learning thermostats	£130	£16	8	BEIS
TRVs	£350	£16	22 (unlikely to payback)	BEIS

Table 2 - Bill savings in a typical house: stored PFGHR and BEIS – Future of Heat data as comparison

6 Water price calculated from weighted averages of water and sewerage tariffs from the main water companies (Anglian Water, Welsh Water, Northumbrian Water, Severn Trent Water, Southern Water, South West Water, Thames Water, Wessex Water, Yorkshire Water, Northern Ireland Water, and United Utilities).

	Water and sewerage (metered) price, £/m³	*Bill savings per year*
Anglian Water	3.1967	£77
Welsh Water	2.9942	£72
Northumbrian Water	2.3744	£57
Severn Trent Water	2.3475	£57
Southern Water	3.5870	£86
South West Water	5.4879	£132
Thames Water	2.0780	£50
United Utilities	2.9720	£72
Wessex Water	4.0169	£97
Yorkshire Water	2.8993	£70
Northern Ireland Water	2.7400	£66

Table 3 – Water bill savings in a typical house by region (2017 prices accurate as at June 2017 and available online)

3. Wider Benefits of PFGHR

Reducing the costs of providing water

The supply and treatment of water used in residential properties – including rejected lukewarm water – requires a significant use of electricity. The water industry is energy intensive, and uses 448.4 ktoe (5.2 TWh) of energy for collection, treatment and supply annually[7]. This is used to supply around 6,205 billion litres of water and to treat 5,840 billion litres of wastewater annually.[8]

Our analysis estimates that the current stock of PFGHR saves up to (if stock consisted of stored systems) 2.4 billion litres of water per year, which – assuming a linear relationship between water supply and energy demand – would equate to 2.06 GWh of electricity. This is enough electricity to power 589 houses for a year.

Given a total gas combination boiler market size of 14,542,000[7], the savings potential is 350 billion litres of water and 300 GWh (6%) of electricity in the water industry per year. This is equal to more than twice the annual output of the average-sized onshore wind farm as supported under Contracts for Difference round 1[9], and the amount of water consumed if every person in the UK had a daily shower for three months[10].

As a resource, electricity is most valuable during the peak hours of demand when margins are tightest, which normally coincides with higher than average consumption of hot water. In addition, both hot water and electricity demand follow a similar seasonal pattern, as the demand is higher in the heating season. PFGHR reduces water consumption during the winter 'peak hours,' typically in the mornings and evenings when consumers are demanding hot water, space heating and use other household appliances. Reducing the consumption of water during these periods would logically have a positive impact on water industry revenues, as it reduces the supply of units of water which are sold for the same retail price (marginal benefit), but have a very high marginal cost of production. This is illustrated below in Figure 4 which shows a fixed price for water against the variable cost of power. This peak shaving and reduction in power demand can benefit the National Grid.

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[7] BEIS, 2016. Energy consumption in the UK (ECUK) 2016 Data Tables. National Statistics. Available from: https://www.gov.uk/government/statistics/energy-consumption-in-the-uk

[8] Water UK, 2017. Available from: http://www.water.org.uk/consumers/what-water-companies-do

[9] Calculated using BEIS (2017) load factor 31.6%, and based on an average onshore wind farm capacity of 49.9MW

[10] Equal to 86 showers. Calculated using Waterwise data. Waterwise, 2011. Showers vs. Baths: facts, figures and misconceptions.News. Available from: http://www.waterwise.org.uk/news.php/11/showers-vs.-baths-facts-figures-and-misconceptions

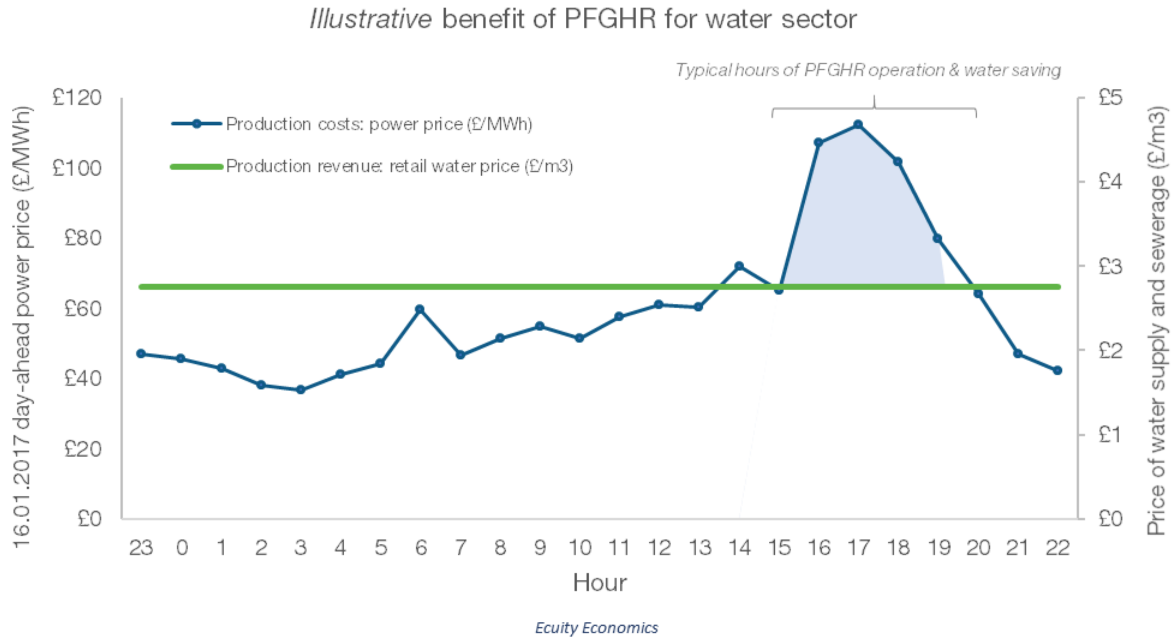

Figure 4 - Value of reduced water consumption at peak power periods - indicative (source: Nordpool & Ecuity research)

Moreover, additional to an improved economic position for the water industry, lowering electricity consumption lowers the sector's carbon emissions. In terms of GHG emissions, BEIS estimates that the supply and treatment of water accounts for 0.344 kg CO_2e/m^3 and 0.708 kg CO_2e/m^3 respectively. Assuming water is both supplied and treated together, this gives a carbon intensity factor for the water sector[11] of 1.052 kg CO_2e/m^3. For 24.08 m^3 of water saved per household aggregated over the total number of households with PFGHR (~100,000), we estimate that PFGHR reduces the amount of CO_2e produced from water supply and treatment by 2,533 tCO_2e (increasing up to 368,384 tCO_2e, if PFGHR would be available in all of the combination boiler population) in addition to 15,584 tCO_2e saved on the household level.

Customers	**Number of combination boilers**	14.5 million
	Aggregate cost of stored PFGHR installation	£6.7 billion
	Aggregate customer bill savings per year	£1.45 billion
	Water savings per year	350 billion litres
	Gas savings per year	12.3 TWh
	CO_2e savings per year	2,266 $KtCO_2e$
Water industry		
	Electricity savings per year	300 GWh
	CO_2e savings per year	368 $KtCO_2e$

Table 3 - Wider benefits of potential deployment of PFGHR devices

[11] BEIS, 2016. UK Government GHG Conversion Factors for Company Reporting. Greenhouse gas reporting - Conversion factors 2016. Conversion factors 2016 - Full set (for advanced users).

4. Scope for future uptake and cost down

There are currently around 100,000 PFGHR systems operating in the UK[3]. The technology complements a combination boiler and increases the efficiency of the heating system. Given this, PFGHR and combination boilers could be considered as complimentary goods, with an increase in demand for combination boilers boosting the potential for PFGHR deployment.

Figure 5 below provides an overview of the current deployment of condensing combination boilers and condensing system boilers, and forecasts forward based on these historic trends (with the shaded area providing the 95% confidence interval). In 2014, the BEIS data[7] suggests that there were over 10.9 million condensing combination boilers, and a shrinking 3 million non-condensing combination boilers.

Given consumer trends over the previous decade, the condensing combination boiler will become more dominant over the coming years, with our forecast seeing deployment increase up to 17.5 million by 2020. This rate of take up exceeds that of condensing system boilers, and suggests a greater potential market for PFGHR over time.

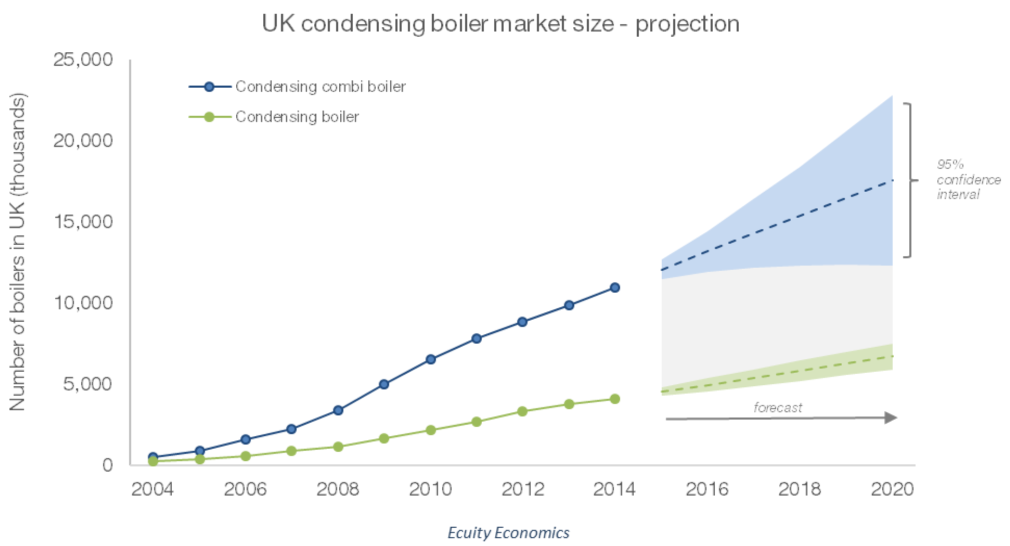

Figure 5 - Boiler types in the UK (BEIS, 2016), Ecuity forecast

Government support for PFGHR would help address the behavioural barriers which stunt uptake of energy saving measures. This is key for PFGHR which currently is deployed in around 1% of properties which have combination boilers installed.

Based on BEIS' *Evidence Gathering: Passive Flue Gas Heat Recovery Technologies* paper we have developed the following representation of the cost-down potential for stored PFGHR systems, given economies of scale. Figure 6 below details this, and uses the BEIS report to amend our current cost of installation for the projected impact of economies of scale.

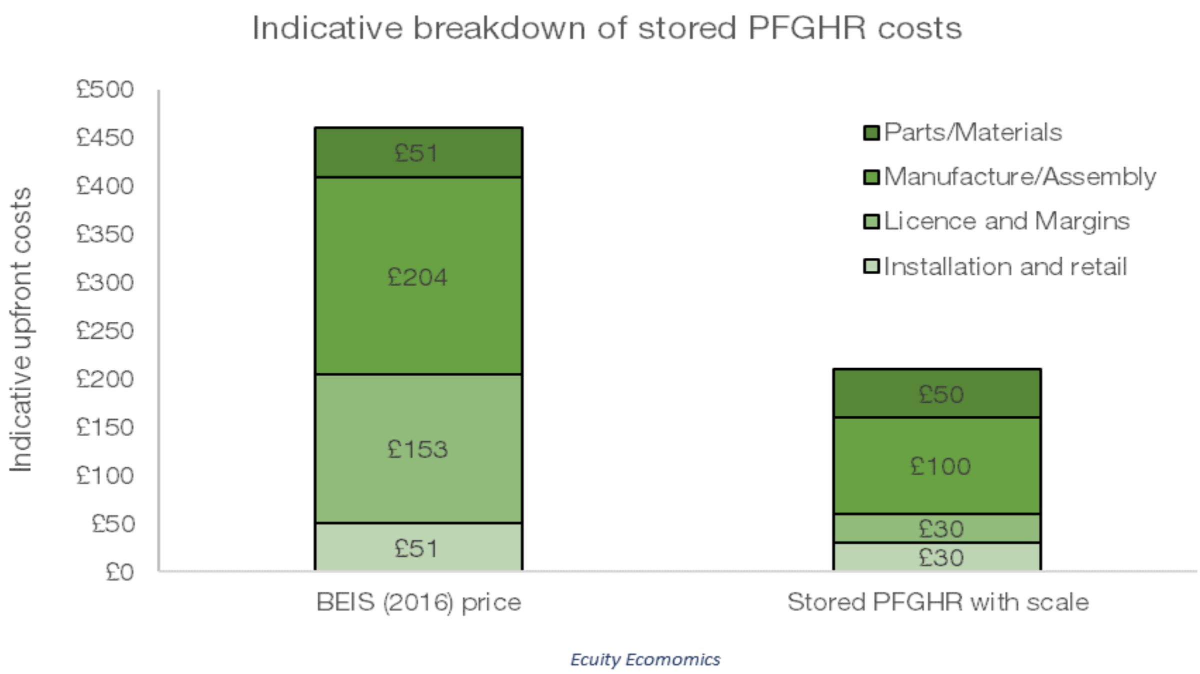

Figure 6 - Indicative cost breakdown of stored PFGHR using BEIS (2016) report data

This cost reduction would reduce the payback period from 5 years to approximately 2 years. Even when taking account of consumer's discount rate – the time value of money or preference for consumption today rather than tomorrow – the stored PFGHR pays back in under 3 years (using an 11% discount rate from Newell & Siikamäki – *Individual Time Preferences and Energy Efficiency*[12]).

Enacting policy which requires PFGHR to be installed as a mandatory measure, or one of a group of required measures with a new boiler, would present significant opportunities for greater deployment and economies of scale. Indeed, with the annual combination boiler take up rate at approximately 1.2 million, if 5% of these systems had PFGHR systems installed then the number of installed PFGHR units would more than double in 2 years. This would provide ample opportunity for economies of scale and cost down.

[12] Newell & Siikamäki, 2015. Individual Time Preferences and Energy Efficiency. American Economic Review 105(5), pp. 196-200.

5. Summary – the case for supporting PFGHR

This paper has demonstrated the multiple benefits and the cost of installing stored PFGHR systems. In an average home with the DHW demand of 2000 kWh, a stored PFGHR device saves around £100 on water and gas bills annually, providing a payback in just under 5 years. For a stored PFGHR population of 100,000 devices, the annual bill savings are in the region of £6.6mn for water and £3.4mn for gas – a total of £9.9mn. In other terms, it would annually save an amount of gas sufficient to supply 5.4 thousand additional households and water enough to fill 300 baths per household[10].

The installation of PFGHR devices with thermal storage generates significant benefit both for the consumer as well as the water industry, outweighing the capital cost of the installation and offsetting a total of 181 kgCO_2e per household – the equivalent of a round trip from Brighton to Edinburgh in a newly registered (2016) car.

Currently, less than 1% of homes have PFGHR installed – approximately 100,000 properties (BEIS, 2016). There is a potential to increase the deployment to the whole population of combination boilers (14,542,000 in total), which would consequently generate a total of £1,452mn in savings for customers annually. Additionally, it would offset 368,384 tCO_2e (Table 4), which is equivalent to the amount of emissions generated by 107,715 return flights from London to Melbourne.

	Cost	*Annual benefit*	*Net present value of supporting 14.5 million stored PFGHR devices*
Consumers	£6.69 billion	£1.48 billion	£9.99 billion

Table 4 - Costs and benefits of installing a stored PFGHR system.

As the penetration of condensing combination boilers increases over coming years, the case for a greater deployment of stored PFGHR strengthens. Indeed, the technology requires little interaction with the consumer, and will consistently provide gas bill and water bill savings over its lifetime.

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