GlenWyvis renewable heat assessment

27th September 2015

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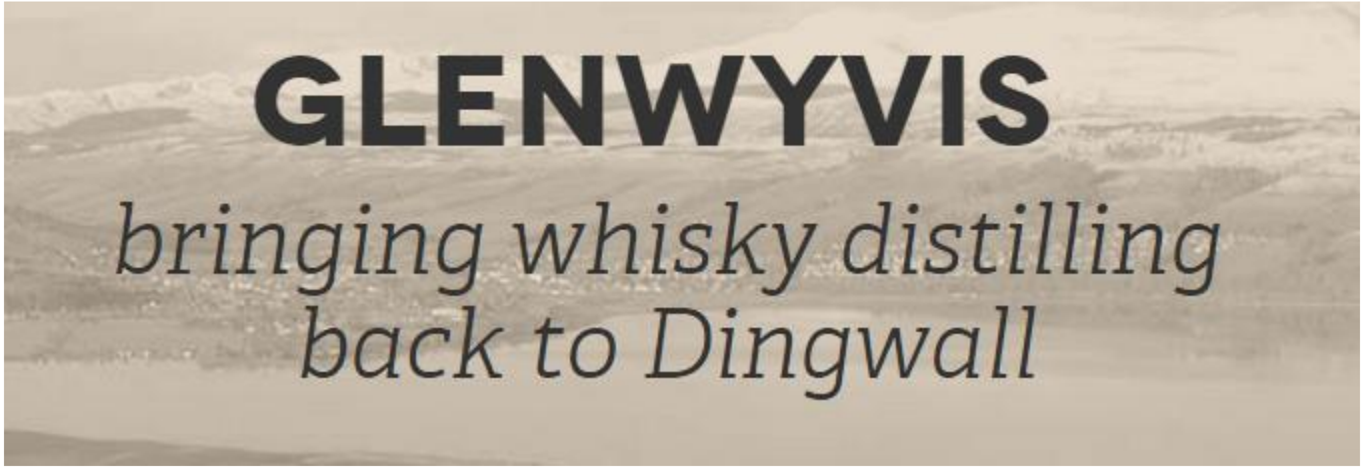
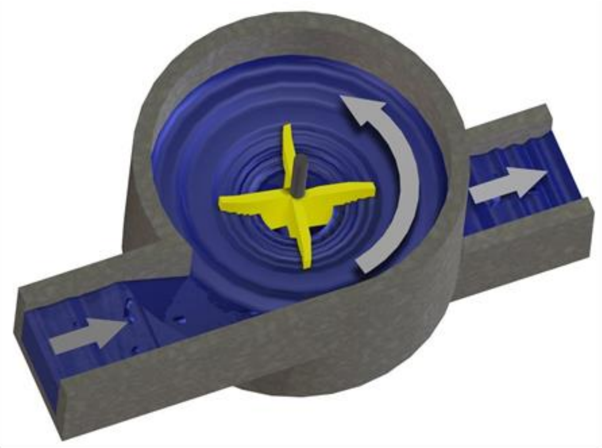
GlenWyvis builds on its history and unique resources



- The approved Dingwall farm site overlooks the areas of Ferintosh & Ben Wyvis, both steeped in distilling history from the 17th & 19th Century's
- The site boasts a unique impressive range of renewable energy technologies and hopes to capitalise on these to provide all the site's energy requirements from renewable means
- This locally financed project aim to be an example to other distilleries of similar size of how to produce whisky using local ingredients and green energy resources

Renewable energy has been used in a number of ways in the distilling industry to date






Renewable energy has been used in a number of ways in the distilling industry to date

- Scotch whisky association produced a guide for renewable energy options for whisky distilleries.
  - Thorough description of options but little focus on smaller craft distilleries
  - http://www.scotch-whisky.org.uk/media/41152/guide_for_distillers.pdf
- Anaerobic digestion
  - Implemented with varying degrees of success in larger distilleries
  - Lack of commercial solutions for craft size sites
- Biomass
  - Established technology in the food and drink sector using either wood chip or pellets
  - Dairy processing - Dairycrest Davidstow 2010
  - Distilling - Ardnamurchan Distillery 2014

Renewable energy has been used in a number of ways in the distilling industry to date

- Wind, Solar
  - Small electric to heat ratio has resulted on a focus on heat generation technologies to provide the highest CO_2 savings
  - Electricity is not competitive when compared to fossil fuel or biomass derived heat (see economic analysis)
- Heat pumps
  - Although this technology is maturing fast most the majority of units on the market are designed to produce heat at 60ºC which is not of particular use within the distilling process
- Solar thermal
  - Low temperature hot water can be used for mashing and re-heating of spirit but not for distilling
  - Low output in the winter months coincides with highest production demand

This study follows a project looking into the feasibility of renewable energy to provide mashing heat to craft distilleries

- The Scottish Biofuels Program set up a project to look at the options for using renewable energy on craft scale distilleries.
  - The project focused on providing mashing heat as steam generation was not seen as applicable for the heat loads associated with craft distilleries (<200kW demand)
  - Heat pumps, solar thermal, anaerobic digestion and biomass hot water were investigated
- Renewable Energy Solutions for craft Distillers - E4 Tech
- This project builds on this report to show how distilleries with a mash size of 0.5 tonnes can use biomass as their primary heat source for both mashing and distilling

GlenWyvis boasts a unique set of local renewable resources which can be used to help power the proposed site

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- GlenWyvis has a range of existing renewable energy generation on site including:
  - 12kW hydro electric turbine
  - 30kW solar farm with increased capacity of 10kW coming on line in August 2015
  - 11kW wind turbine (there is potential to replace the turbine with a larger unit)
  - 30kW log burner (providing heat for the existing buildings)
  - 3kW solar thermal (South facing site utilising maximum solar gain for current building)
  - A total of 96kW of local green energy sources
  - Electric car and charger
  - Dedicated water borehole

GlenWyvis boasts a unique set of local renewable resources which can be used to help power the proposed site

- Storage
  - Although storage is not currently economically viable expected reductions in cost will enable more locally generated electricity to be used at the site directly within the process
- Local community resources
  - There is a 250kW Cooperatively owned turbine in view across the valley from GlenWyvis which up to 400,000kWh of electricity can be sourced from although it will have to pass through the local distribution network before reaching GlenWyvis
  - It may be possible in the future to transfer electricity directly from this larger turbine to the GlenWyvis distillery

GlenWyvis boasts a unique set of local renewable resources which can be used to help power the proposed site

- Due to the time of electricity generation at GlenWyvis only a proportion of electricity generated would be directly used within the process with the rest being exported to the grid
  - 112,000 kWh of electricity generated per year through onsite renewables (5 – 10% is currently used by the farm and electric car leaving up to 100,000kWh for use by GlenWyvis). At £0.16/kWh (cost of green energy from the grid) this is worth £16,000 per year and rising
- Non thermal electricity demand has been estimated from Scotch Whisky Association benchmarks with a 30% increase applied to take into account the size of GlenWyvis (0.39 kWh electricity / lpa)
  - At 38,000 lpa the distillery will use approximately 15,000kWh for non heating energy (pumps, lighting, water treatment…) with this rising to 67,000 kWh with the maximum production of 172,000 lpa

A borehole and two other sources of natural water will save the business over £6,000/yr

- Enough water to satisfy the demands of the distillery at a maximum production of 172,000 lpa can be sourced from the local borehole (approved by SEPA in 2014), Tulloch spring and Dochary burn
  - http://www.scottishwater.co.uk/assets/domestic/files/you%20and%20your%20home/charges/swsoc1516.pdf
  - http://www.scottishwater.co.uk/assets/business/files/licensed%20provider%20portal/wholesalebilling/20150112part1wholesalechargesschemefor201516lpversion.pdf
  - Existing buildings projected annual water saving: £510/yr
  - New Master distillers projected annual water saving: £510/yr
  - Process and cooling water for distillery in initial years of production project annual water saving: £5,000/yr rising to approximately £23,000 for maximum production (cost avoided £1/m3)
  - Total projected annual water saving in initial production year: £6,020/yr rising to a maximum of 24,020m3 at maximum production

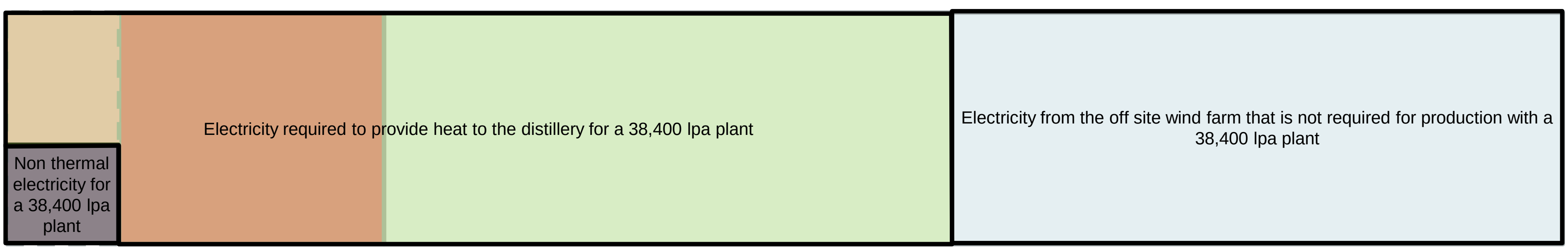
Both water and green energy resources available at Glenwyvis are worth up to £40,020 per year to the business

- Total water savings from local resources for initial business operation: £6,020 rising to a maximum of almost £24,000 at maximum production
- Value of all onsite generated renewable energy that can be supplied free of charge to the distillery: £16,000 (although only £2,400 worth is expected to be used for operation of the distillery the first year of operation at 38,400lpa)
- Total value of free resources to the distillery in year 1: £8,420
- Maximum value of free resources to the business: £40,020

GlenWyvis boasts a unique set of local renewable resources which can be used to help power the proposed site

- GlenWyvis is unique is its ability to provide the non-thermal electrical baseload (lighting, pumps, motors…) for the site directly from on-site renewables with at least 20kW baseload being constantly generated
- Electricity generation

- Electricity usage transparent overlay



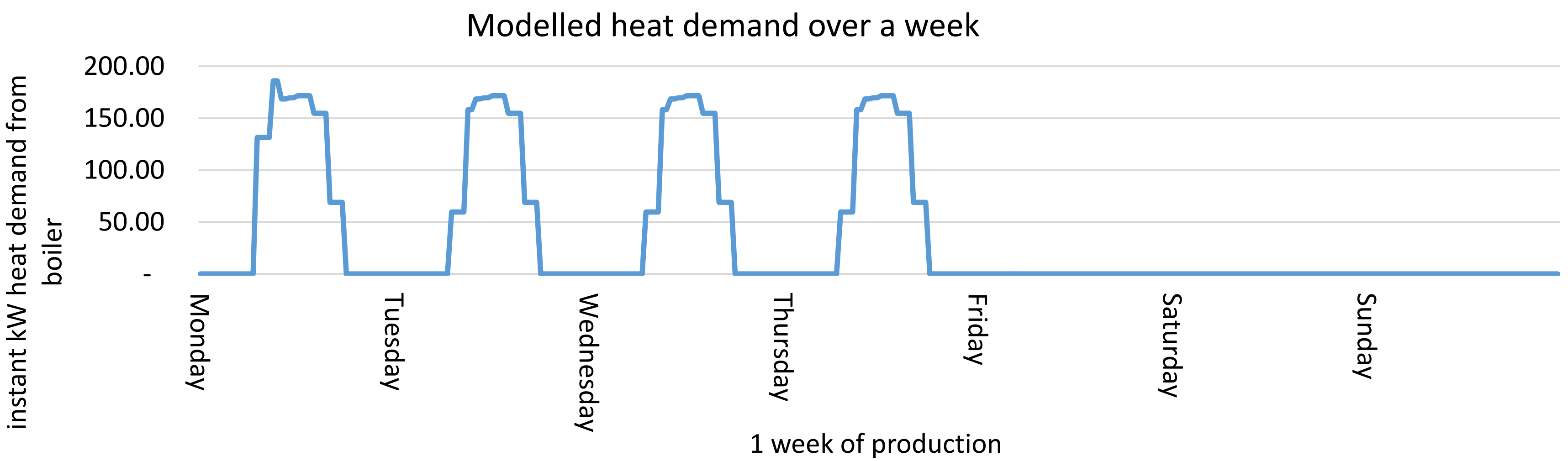
GlenWyvis boasts a unique set of local renewable resources which can be used to help power the proposed site

- The current electricity generating resources on site combined with the Dingwall community wind turbine will be able to support a production of approximately 60,000lpa (this figure will depending on the actual running demands of the plant) if electricity is used for the primary heat source

Heat load analysis

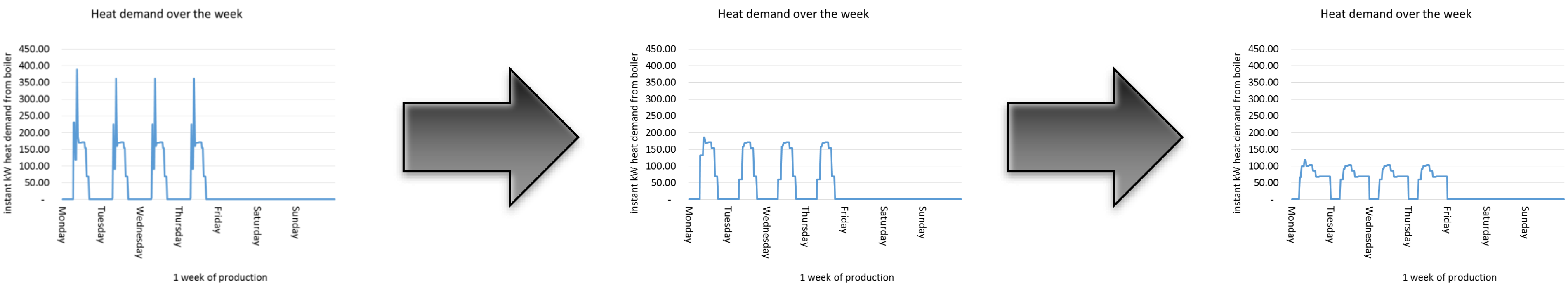
Heat loads for the proposed plant were modelled to help identify suitable heat generation equipment

- A distillery with similar processing equipment to that proposed at GlenWyvis was visited
  - Interviews with site operators
  - Thermal processes identified
  - Timings and quantities captured
- A model of the site's thermal demand over a week was produced (see below)



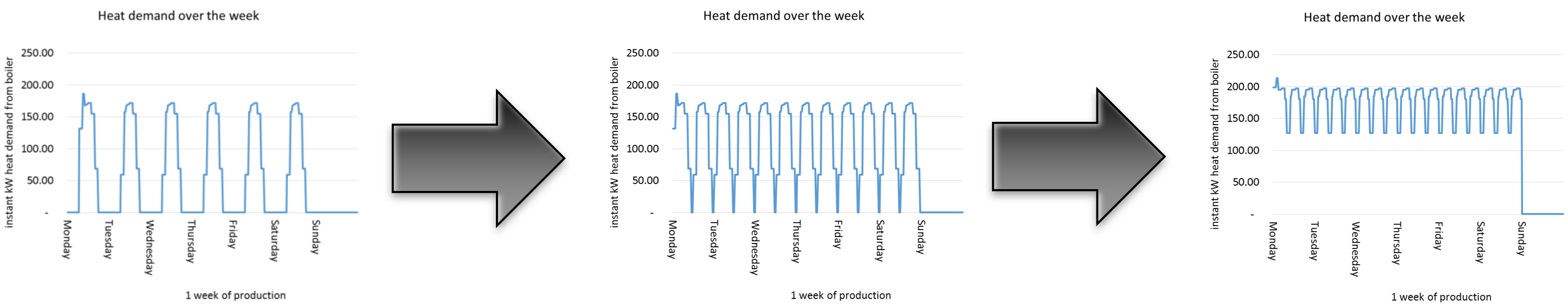
Alternative production patterns were produced to smooth out the heat demand profile

- Although the production profile at the sample site that we visited worked well with an oil fired boiler the majority of load was below 50% of peak demand
  - Oil or gas boilers can easily turndown to 25% of their operational peak
- Alternative production profiles were assessed to smooth out loads during operational hours, with average loading closer to peak demand
  - High load processes were identified (initial heat up in wash and spirit stills) and spread out over a longer time
  - Processes were staggered to reduce instantaneous loading



Maximum production profiles were explored to understand the impact of increased production on energy provision

- Increased weekly production to reduce the number of production weeks per year were also examined while exploring what production could be scaled to if longer shift patterns were employed
  - Production increased from four to six days a week, leaving Sunday for maintenance and wash-down
  - Though 24/7 operation two or three mashes could be processed each day
  - Maximum production capacity could be as high as 170,000 lpa



The increase operational hours associated with running a smoother heat load add considerable labour costs

- Estimated operator costs 38,400 lpa (196 mashes over 48 weeks)
  - Scenario 1 (modelled on sample site over 9.5 hours): £21,250
  - Scenario 2 (smoothed out heat loads over 11 hours): £25,500
- The difference between these labour costs could be brought down with automation of the initial start up periods in the morning and through learning to operate the site so that the boiler can run near full output for as much of the day as possible
- Scenario 2 estimates that the boiler will be run at an average of 60 – 70% loading and if this loading can be increase then so can the daily run times be reduced

Six Scenarios used for evaluation of technology options

- 1. Original - Sample distillery profile over 9.5 hours with four runs per week
- 2. Each run spread out over 11 hours with 4 runs per week
- 3. Each run spread out over 18 hours with 4 runs per week
- 4. Each run spread out over 11 hours with 6 runs per week
- 5. Each run spread out over 11 hours with 12 runs per week
- 6. Each run spread out over 8 hours with 18 runs per week

Six Scenarios used for evaluation of technology options

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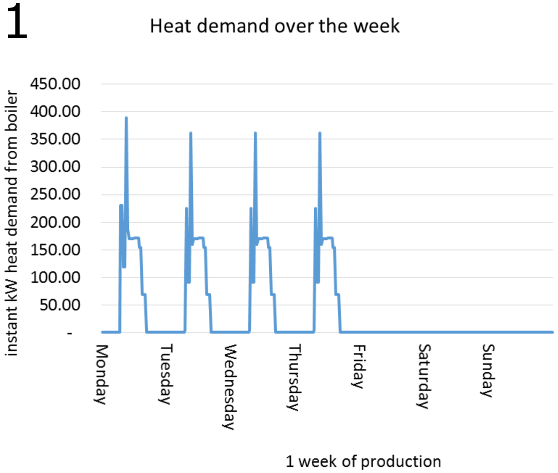

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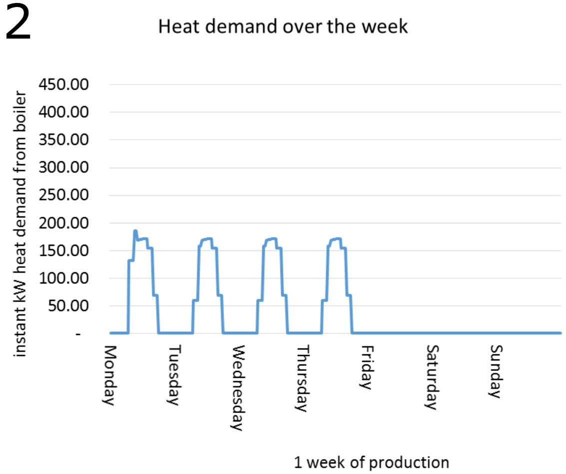

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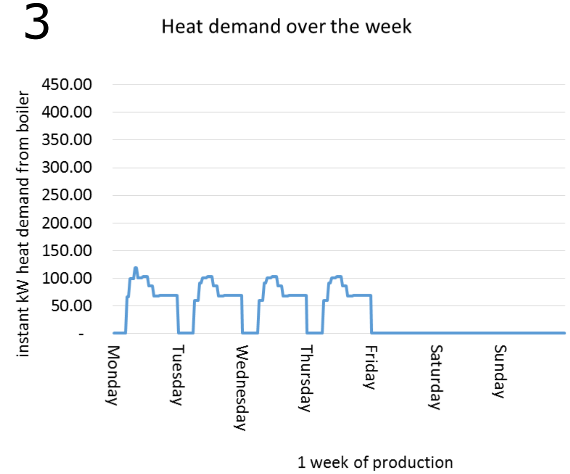

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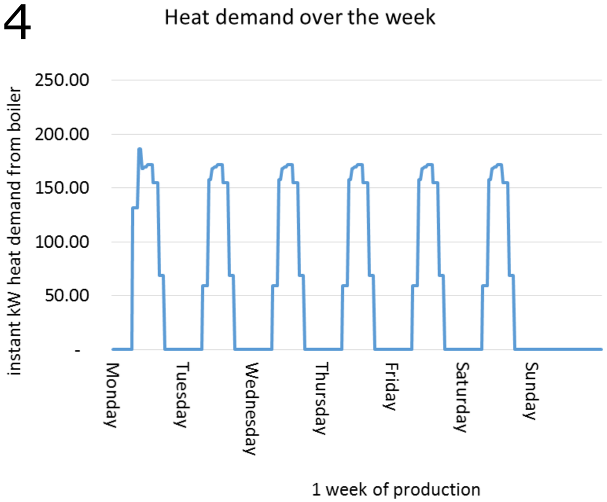

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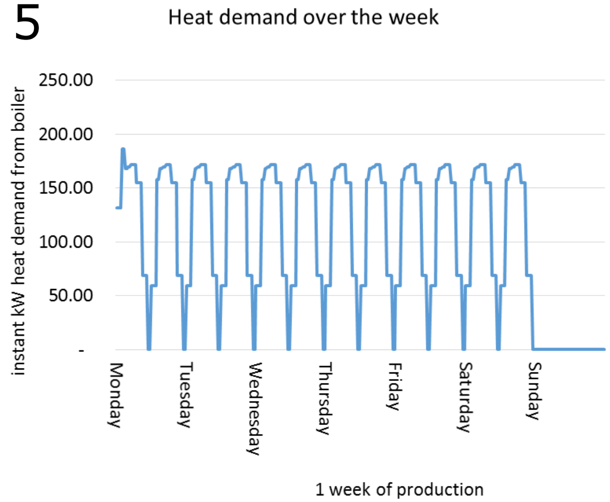

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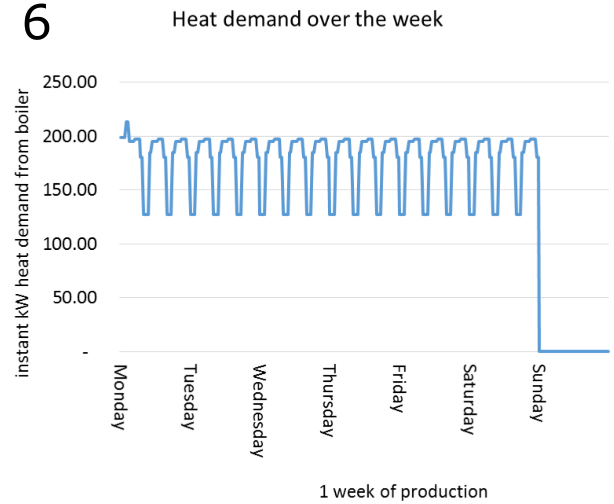
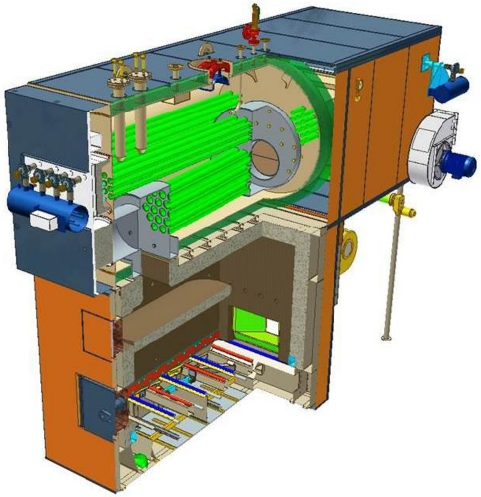


Heat producing technologies

Three technologies to provide heat to the distillery were assessed over the six different production scenarios

- When looking for the lowest CO_2 form of providing heat to the distillery three different heating technologies were assessed
  - Diesel oil boiler
  - Biomass boiler
  - Electric steam boiler



A diesel oil boiler was selected to form the baseline heating technology

- Byworth skid mounted boiler with integrated water treatment and hot well
  - 500kg/hr steam output
  - 25% turn-down
  - £40k CAPEX
  - £1.5k/yr maintenance
  - £0.045/kWh fuel cost, 80% running efficiency
- Bio-diesel could be used to improve the environmental credentials although a small amount of fossil fuel may be included in the fuel and special care needs to be taken when storing bio-fuels over long periods (Bio-diesel is currently being sold for approximately £0.06/kWh)

A biomass boiler can provide all the heat requirements for the site although usage patterns may need to be modified

- Schmid UTSR biomass boiler
  - 260 – 280kW of usable heat output
  - 50% minimum turn-down
  - £300k CAPEX (£290k for the boiler, water treatment and hotwell and £10k for the accumulator)
  - £1.5k - £6k/yr maintenance cost. (Range depends on how much site operators can be trained to carry out required weekly and monthly maintenance)
  - £0.0294/kWh fuel cost (3yr Stobart quote) and 72% running efficiency
- Several biomass boiler suppliers were approached but no others could offer a system small enough to provide steam at the required demand with experience in the distillery sector
- Using the smoothed out heat demand scenario will help with operational efficiency given that biomass boilers do not modulate as well as gas/oil boilers

To enable biomass heat generation additional supporting technology and practices may have to be employed

- A 10m^3 accumulator was suggested by the suppliers to help further smooth out the heat demands to the boiler, potentially decreasing the run times

- The distillery will need to be operated differently to those with oil or gas boilers, allowing time for warm up in the morning and stepping down processes in the evening in-line with end of day shut down of the boiler

- Imperative energy have installed a biomass system at Ardnamurchan which provides all of heat requirements to the distillery

  - Only biomass supplier to provide a system to a distillery that fully provides all of the heat requirements to the plant

  - Ardnamurchan has the same boiler to mash tun ratio (1.6tonnes of steam per hour for a 2 tonnes mash vessel) that has been suggested for Glenwyvis (400kg of steam for a 0.5 tonne mash vessel). Although there have been some complaints about the steam output from the biomass boiler much of this is perceived to be down to operator control and should be avoided through spreading the highest load processes over a longer period of time (see production profiles)

Wood chip is generally easier to source than wood pellets

- Stobart's supplied quote for G50 W35 Virgin wood chip
  - Stobart's are affiliated with Imperative energy, ensuring that the supply of fuel is appropriate for the supplied boiler
  - 3yr contract
  - Max area per chip of $5cm^2$
  - Moisture content between 30% and 35%
  - Storable within limits
  - 3.5kWh/kg @ 30% moisture
  - Approximately 480kg of biomass required per mash

An electric steam boiler could be entirely run on renewable energy, directly releasing no CO_2 emissions

- Fulton electric steam generator
  - 300 kW steam output
  - £44k CAPEX
  - £600/yr OPEX
  - £0.103/kWh electricity cost (Blended cost of grid electricity and on site renewables)
  - Near 100% running efficiency
- Lead acid, Lithium ion and flow batteries were investigated but at current costs only showed a marginal saving over the life time of the project (<1%)
- The price of storage is expected to drop as the sector expands and so the costs used in this model should be revised when making decisions on how heat is generated

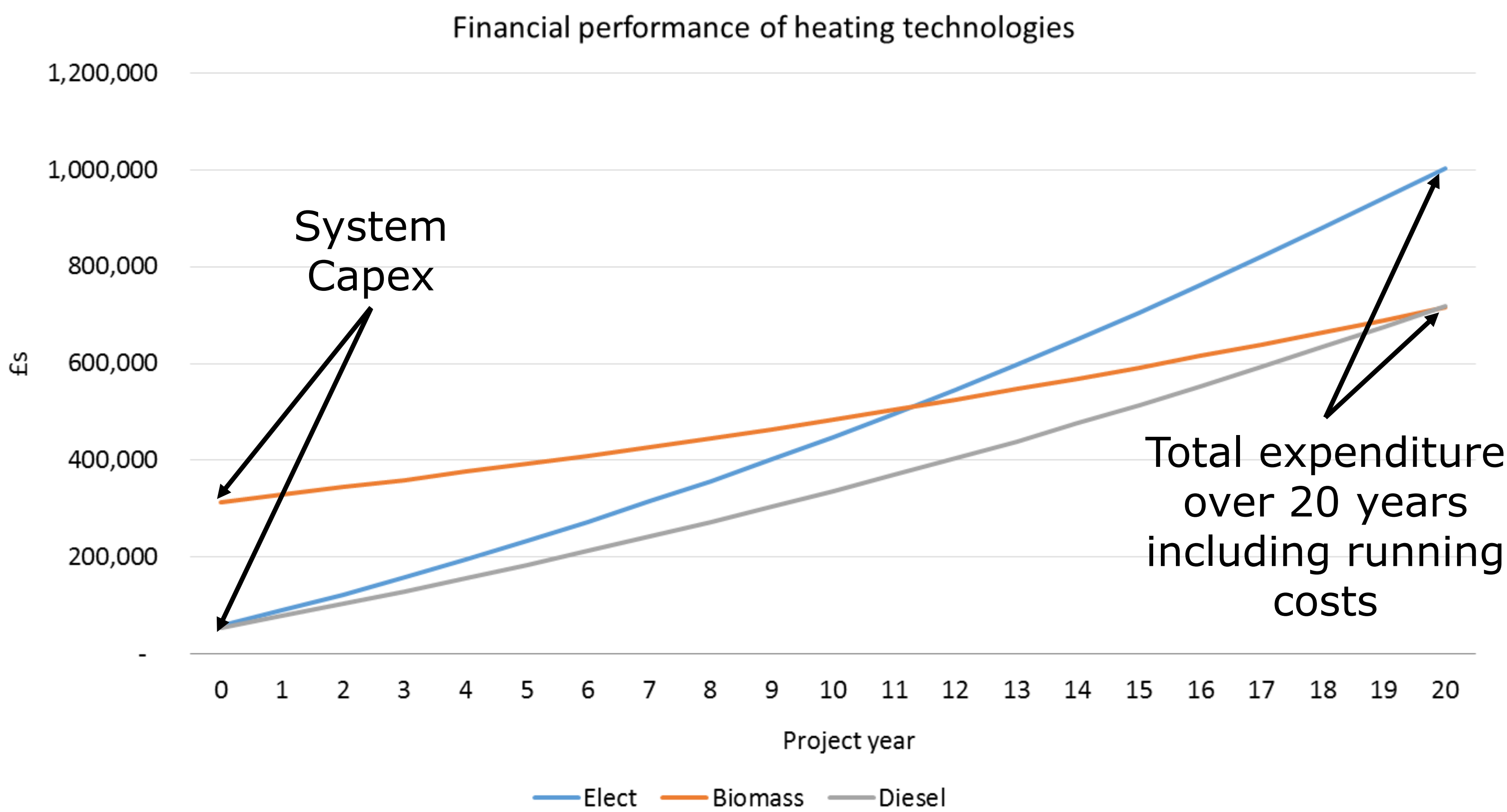
Economic analysis

Economic analysis was carried out on the options over a twenty year timeframe

- Financial model produced looking into running costs of different systems over a 20 year period (length of RHI for biomass)
- Electricity and fuel costs inflated in-line with DECC's predicted figures for electricity and gas (oil and woodchip assumed to track gas price)
- Year on year inflation set at 2.5%
- Labour costs for each production scenario have been included
- Scenarios 2, 4, 5 and 6 have been chosen as 1 is not compatible with biomass and 3 is not practical due to the increase labour costs

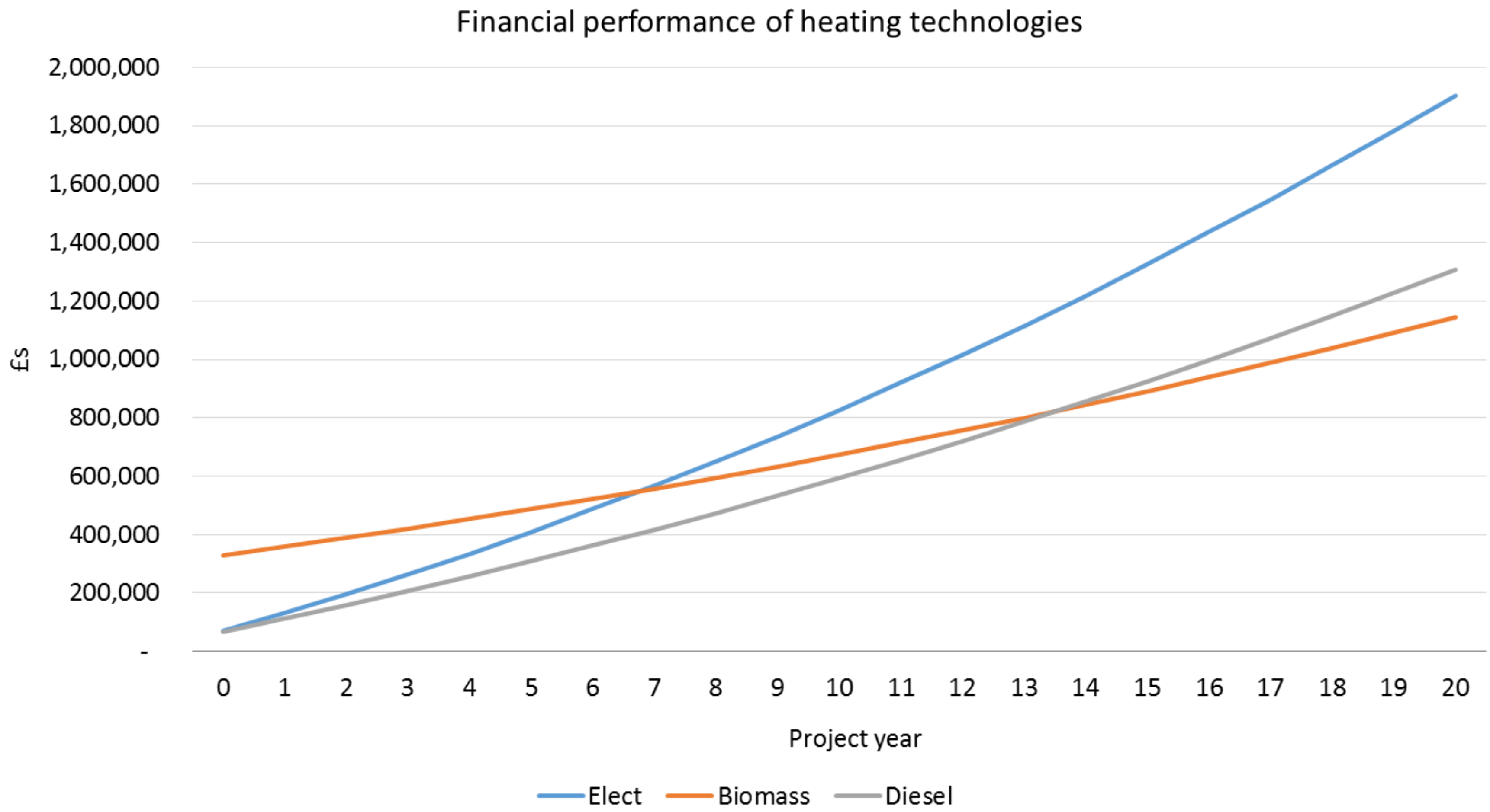
Economic analysis

- Scenario 2, 25 weeks of production, 20,000 lpa



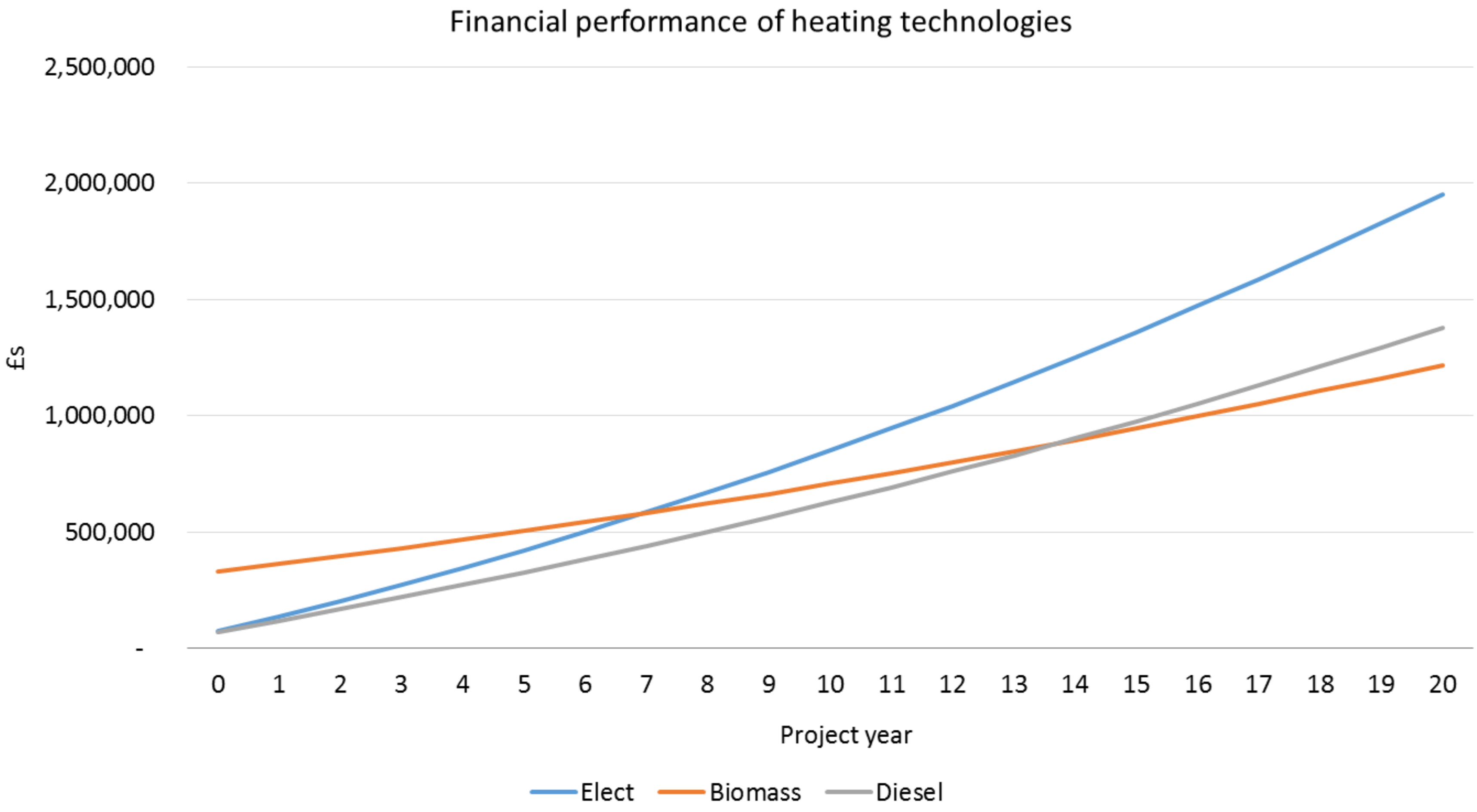
Economic analysis

- Scenario 2, 48 weeks of production, 38,400 lpa



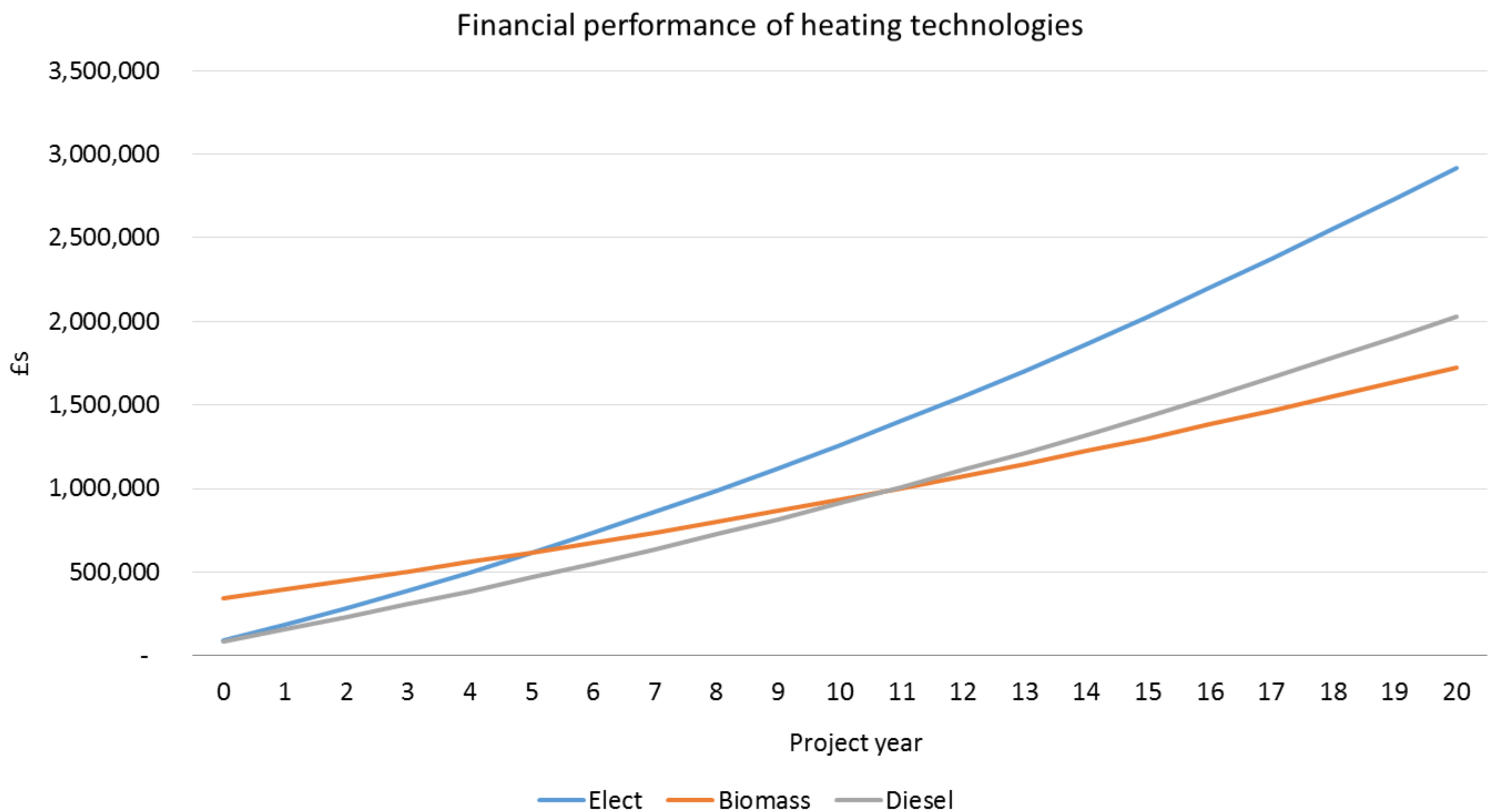
Economic analysis

- Scenario 4, 32 weeks of production, 38,400 lpa



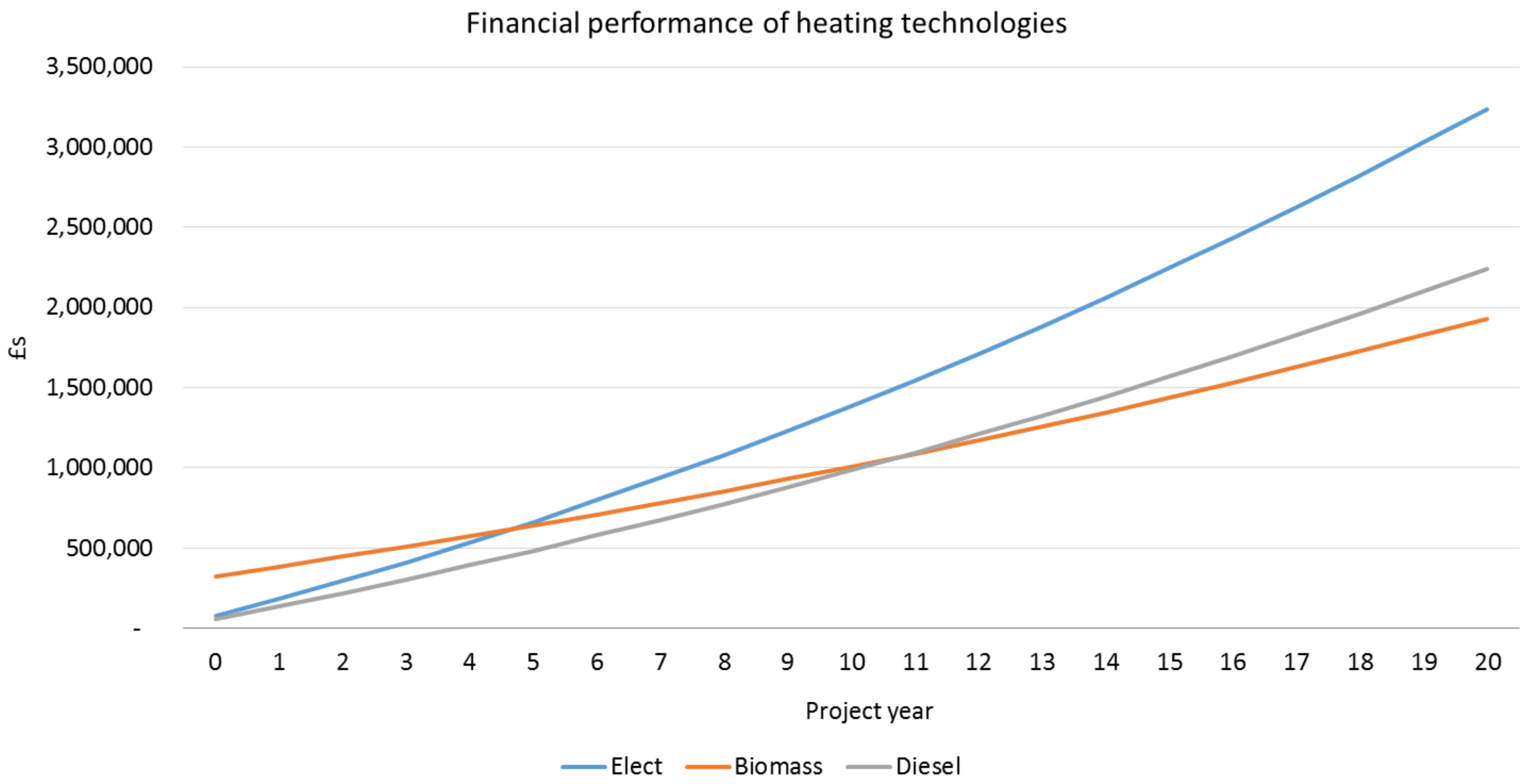
Economic analysis

- Scenario 4, 32 weeks of production, 57,600 lpa



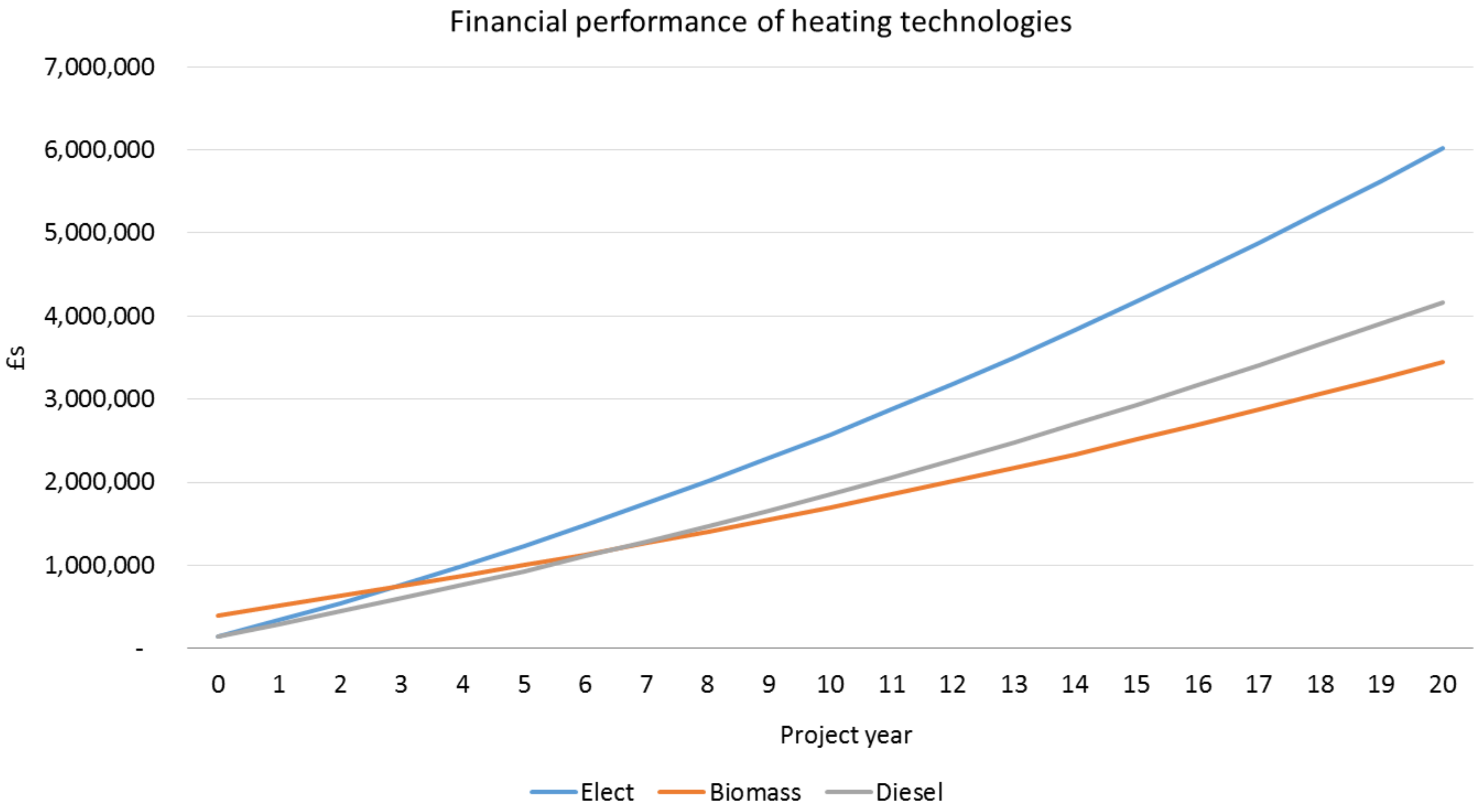
Economic analysis

- Scenario 5, 28 weeks of production, 57,600 lpa



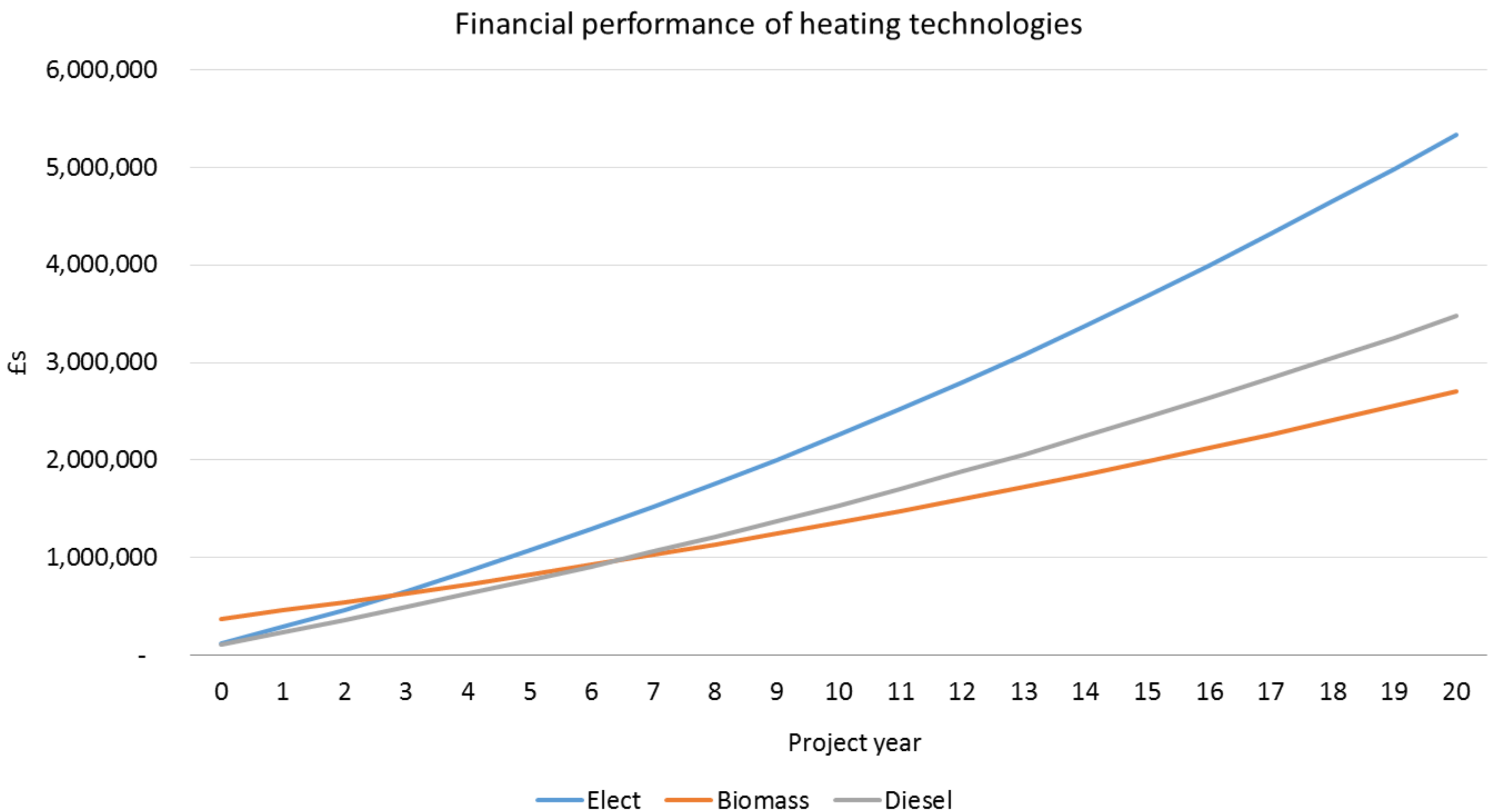
Economic analysis

- Scenario 5, 48 weeks of production, 115,200 lpa



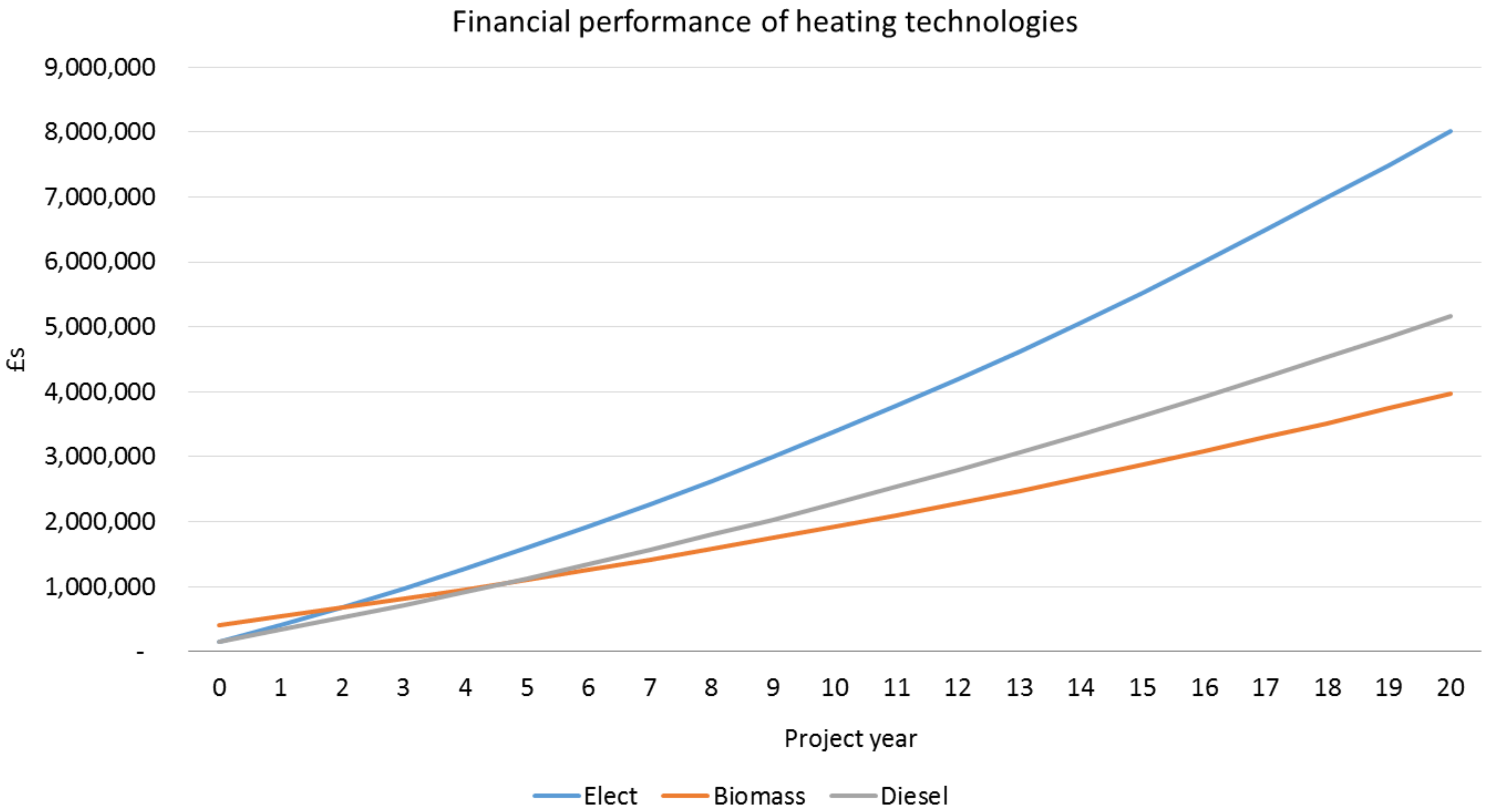
Economic analysis

- Scenario 6, 32 weeks of production, 115,200 lpa



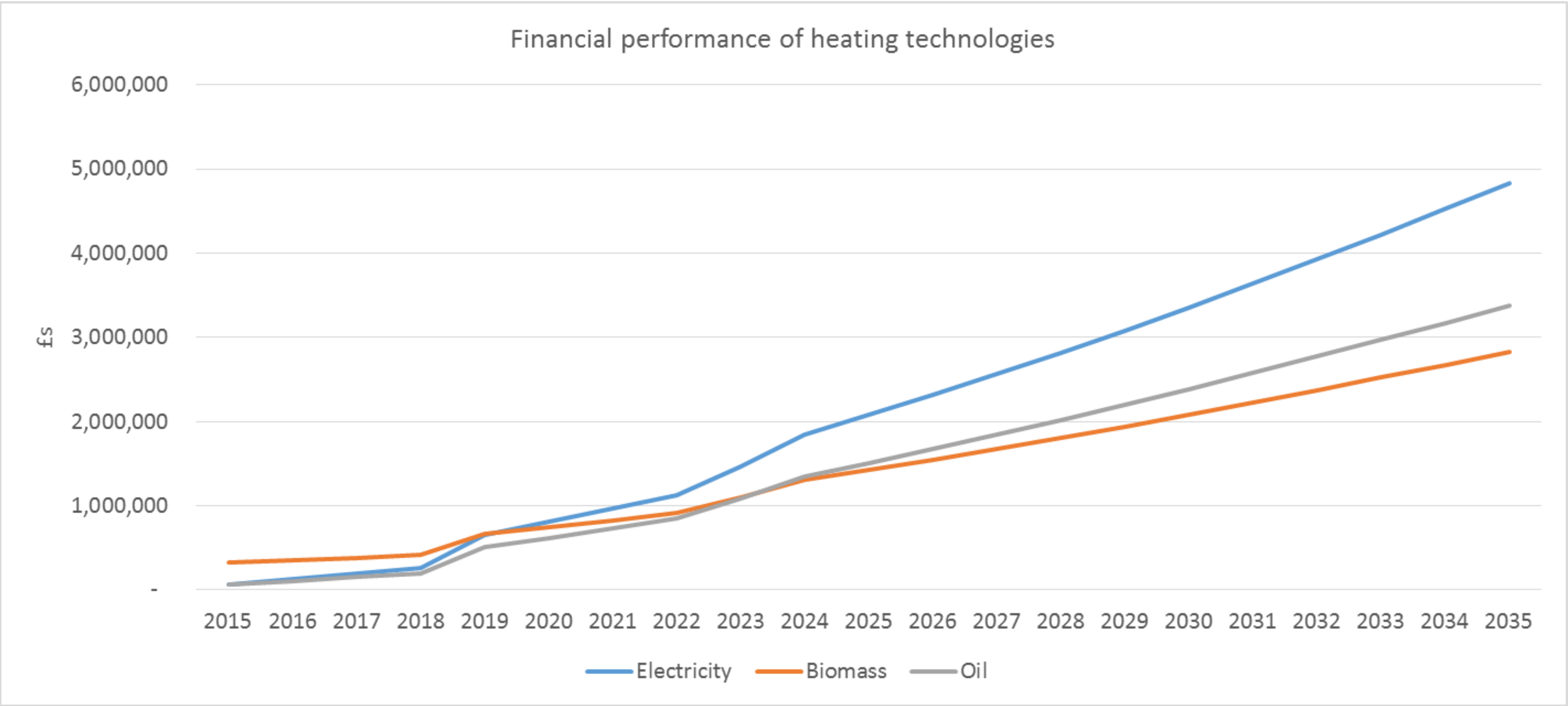
Economic analysis

- Scenario 6, 48 weeks of production, 172,800 lpa



Economic analysis

- Composite scenario using planning production profiles



Sensitivity analysis has been carried out to identify what variables will have the most impact on the project

- Sensitivity analysis carried out on scenario 2 and 38,400 lpa to assess the impact of varying key parameters and noting their impact on total lifecycle cost of each option

Biomass

Variable	Unit	Current value	Change increment	-2 change increments	-1 change increment	Current point	+1 change increment	+2 change increments
Boiler efficiency	%	72%	2%	1,164	1,153	1,143	1,134	1,124
Biomass cost	£/kWh	0.029	0.003	1,071	1,107	1,143	1,179	1,215
Opex cost	£/yr	1,500	500	1,117	1,130	1,143	1,156	1,169
RHI price	£/kWh	0.041	0.010	1,289	1,216	1,143	1,070	997
Biomass boiler capex	£	300,199	50,000	1,043	1,093	1,143	1,193	1,243

Oil

Variable	Unit	Current value	Change increment	-2 change increments	-1 change increment	Current point	+1 change increment	+2 change increments
Boiler efficiency	%	80%	2%	1,332	1,319	1,306	1,295	1,283
Oil cost	£/kWh	0.045	0.003	1,242	1,274	1,306	1,339	1,371
Opex cost	£/yr	1500	500	1,280	1,293	1,306	1,319	1,333
Oil boiler capex	£	39,268	5,000	1,296	1,301	1,306	1,311	1,316

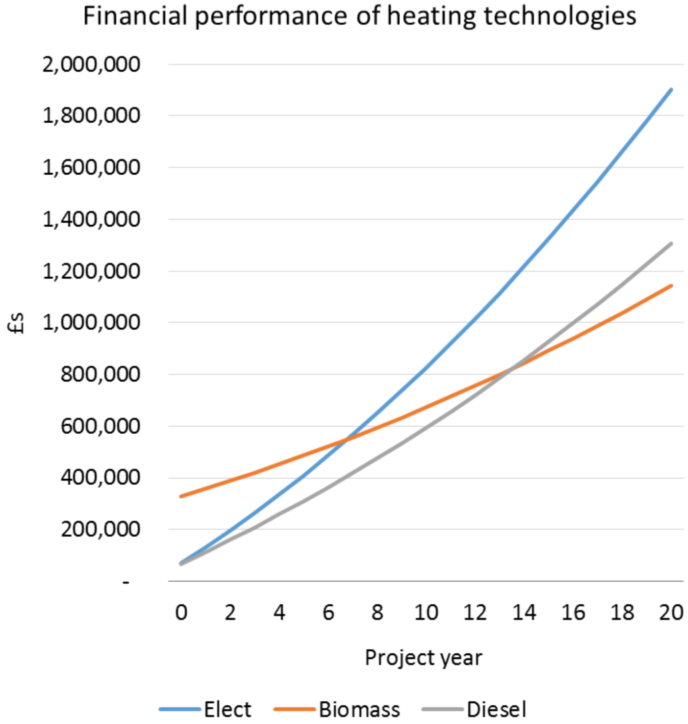
Electricity

Variable	Unit	Current value	Change increment	-2 change increments	-1 change increment	Current point	+1 change increment	+2 change increments
Electricity cost	£/kWh	0.106	0.010	1,694	1,798	1,901	2,005	2,108
Opex cost	£/yr	600	150	1,893	1,897	1,901	1,905	1,909
Electric boiler capex	£	44,240	5,000	1,891	1,896	1,901	1,906	1,911
Storage capex	£	-	5,000	1,891	1,896	1,901	1,906	1,911
Storage size	kWh	-	100	na	na	1,901	1,912	1,923

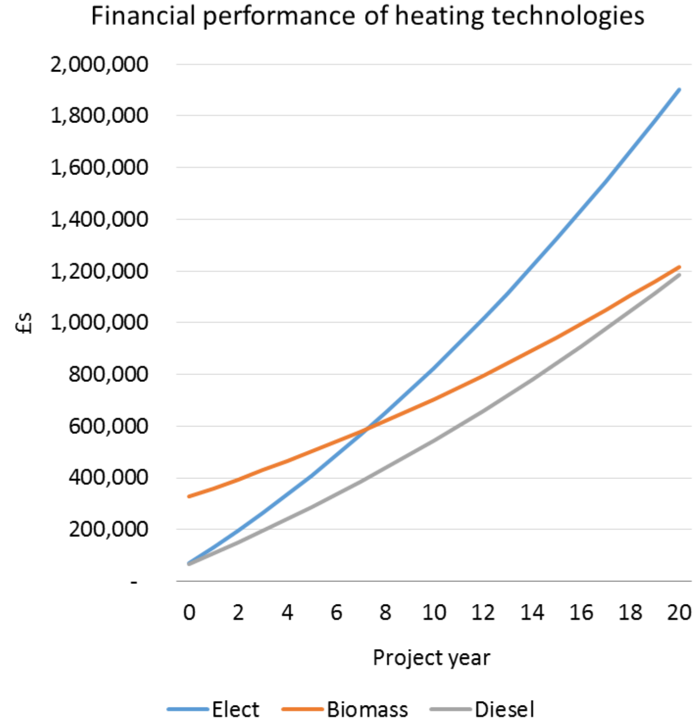
‘Worst case scenario’ with RHI degression kicking early with a further long term reduction in the oil price

- Scenario 4, 32 weeks of production, 38,400 lpa
- Base case compared against RHI degression of 25% and diesel price reduction of 25%

Base case



25% RHI degression and diesel price reduction



Increasing boiler size to increase site flexibility

Increasing boiler size will increase flexibility at the cost of overall efficiency and a marginal increase in Capex

- Conversations with distillery equipment manufactures highlighted that the load profiles first used would limit the flexibility of a plant especially when aiming for three shifts per day (up to eighteen mashes per week)
- Increasing the heat output by 75% (the next size up for Imperative energy) would only increase the capex by less than 10%
- The low turndown ratio (typically 50%) would mean that the efficiency of the system would drop unless the steam loads could remain high during each run. Special attention should be made to ensure that processes are arranged as to ensure that steam demand remains above this 50% threshold
- Increased boiler sizes would help to drop labour costs as operators can complete each mash in a shorter period

New scenarios for condensed runs with a larger boiler capacity

- Distilling was reduced from seven hours to five
- Initial heating up of stills reduced to one hour
- Assumed losses increased
- Over all production runs condensed to allow operators more time to carry out additional tasks between administering production

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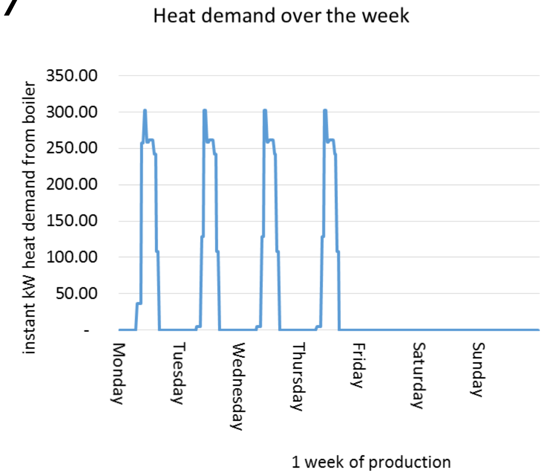

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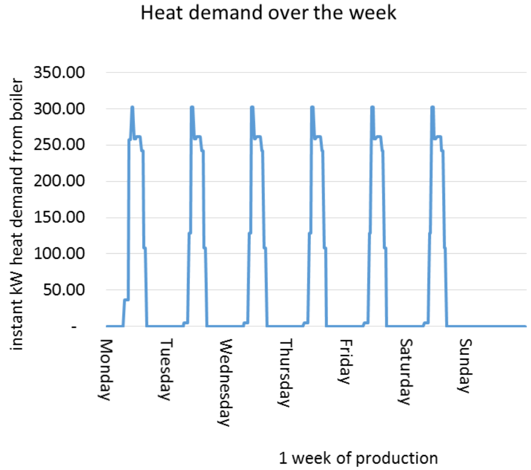

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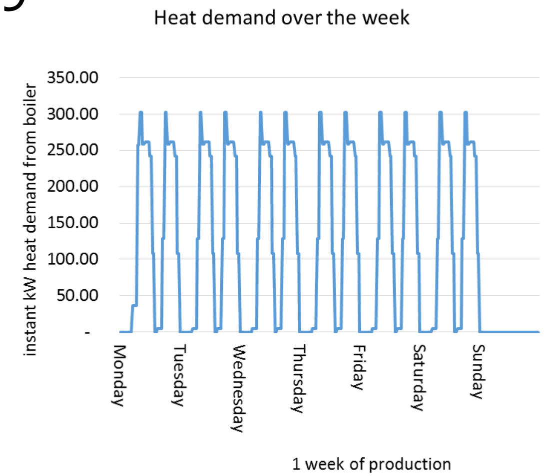

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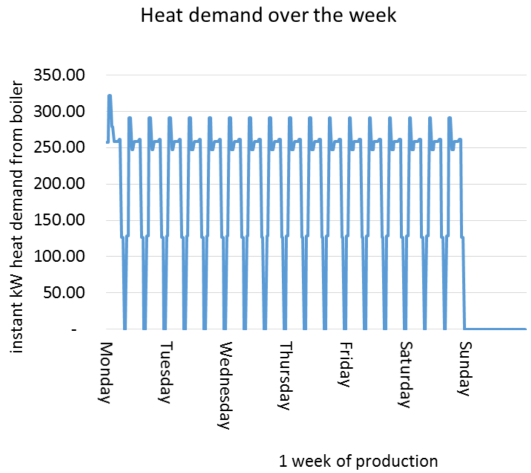
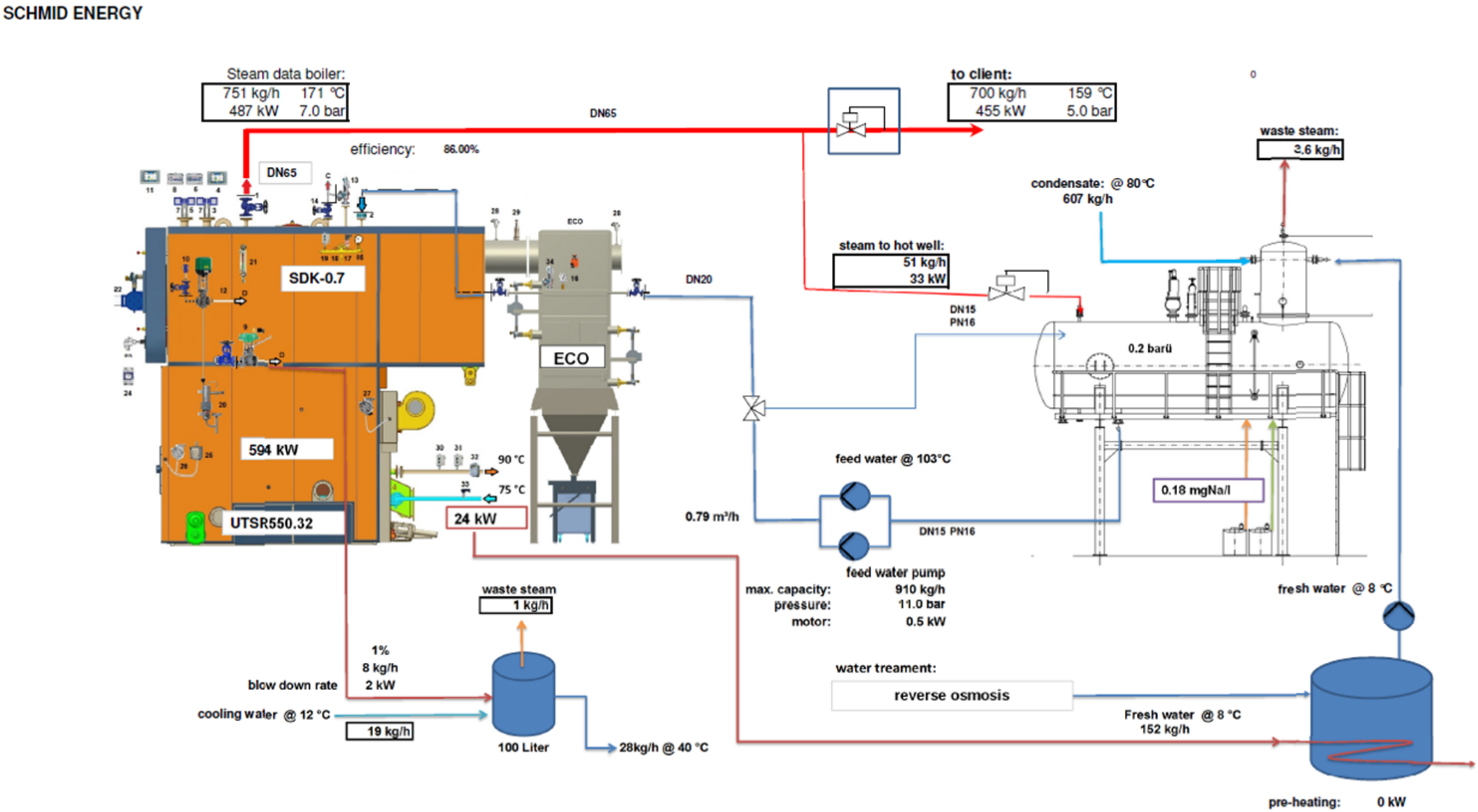


The next size up of boiler can produce 700kg/hr of steam with only approx £25k more capital outlay required

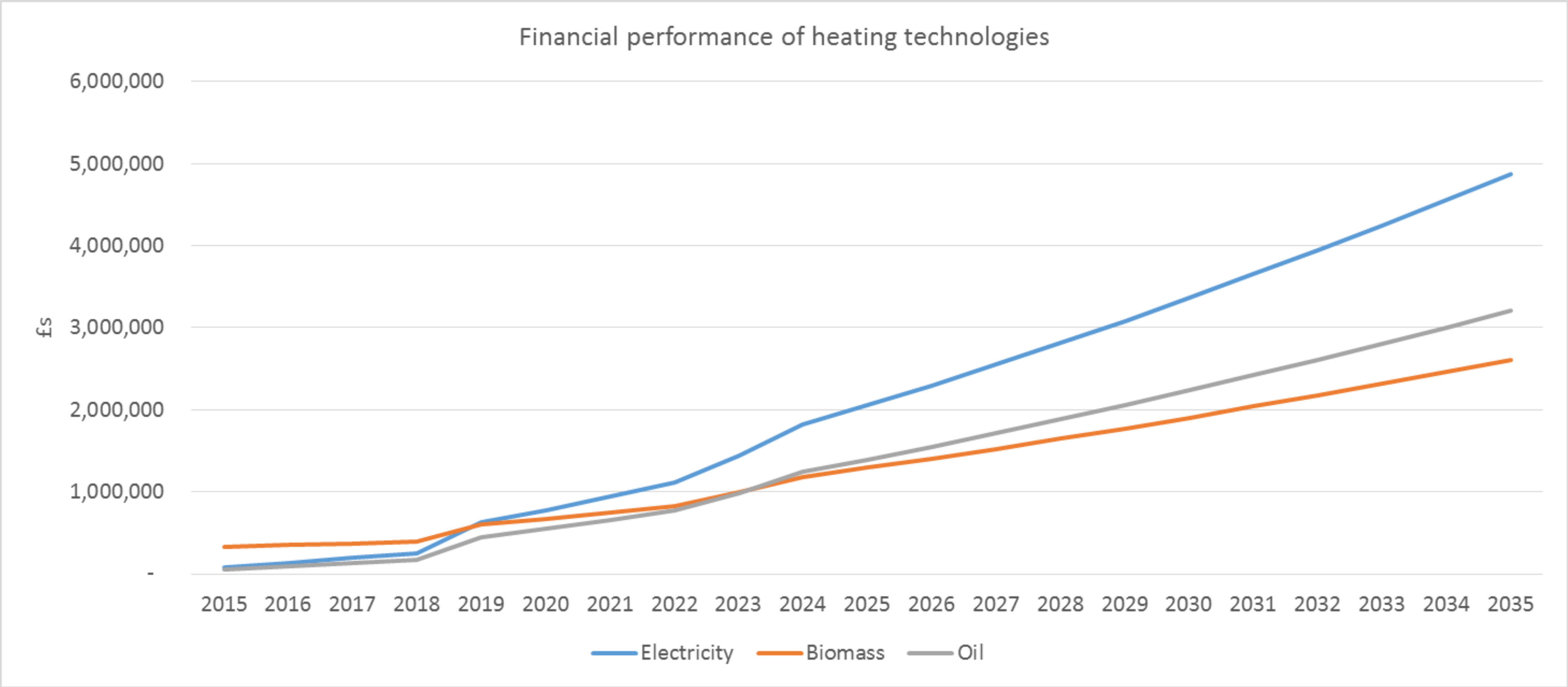
- Although the 400kg/hr steam boiler would be the more efficient at lower levels of production the next size up (700kg/hr) would offer more flexibility for larger production runs
- As the majority of the equipment is shared between both models the cost increase is less than 10%.
- Schmid UTSR biomass boiler
  - 455kW of usable heat output
  - 50% minimum turn-down
  - £325k CAPEX (£315k for the boiler, water treatment and hotwell and £10k for the accumulator)

Typical Schmid biomass boiler configuration for a 700kg/hr boiler



Economic analysis – increase boiler sizes and corresponding capex for all three systems

- Composite scenario using planning production profiles for a larger boiler size (little difference between previous options due to small increase in capex having little effect on total life cycle cost to business



Economic analysis – Sensitivity analysis for larger boiler systems

- Sensitivity analysis carried out on scenario 7 and 38,400 lpa to assess the impact of varying key parameters and noting their impact on total lifecycle cost of each option with the larger boiler parameters applied

Biomass

Variable	Unit	Current value	Change increment	-2 change increments	-1 change increment	Current point	+1 change increment	+2 change increments
Variable	Unit		Change increment	-2	-1	0	1	2
Boiler efficiency	%	67%	2%	1,005	991	978	966	954
Biomass cost	£/kWh	0.029	0.003	891	935	978	1,021	1,065
Opex cost	£/yr	1,500	500	952	965	978	991	1,004
RHI price	£/kWh	0.045	0.010	1,141	1,060	978	897	815
Biomass boiler capex	£	325,199	50,000	878	928	978	1,028	1,078

Oil

Variable	Unit	Current value	Change increment	-2 change increments	-1 change increment	Current point	+1 change increment	+2 change increments
Variable	Unit		Change increment	-2	-1	0	1	2
Boiler efficiency	%	80%	2%	1,213	1,198	1,185	1,172	1,159
Oil cost	£/kWh	0.045	0.003	1,112	1,149	1,185	1,221	1,257
Opex cost	£/yr	1500	500	1,158	1,172	1,185	1,198	1,211
Oil boiler capex	£	54,268	5,000	1,175	1,180	1,185	1,190	1,195

Electricity

Variable	Unit	Current value	Change increment	-2 change increments	-1 change increment	Current point	+1 change increment	+2 change increments
Variable	Unit		Change increment	-2	-1	0	1	2
Electricity cost	£/kWh	0.107	0.010	1,649	1,765	1,881	1,996	2,112
Opex cost	£/yr	600	150	1,873	1,877	1,881	1,885	1,889
Electric boiler capex	£	76,951	5,000	1,871	1,876	1,881	1,886	1,891
Storage capex	£	-	5,000	1,871	1,876	1,881	1,886	1,891
Storage size	kWh	-	100	na	na	1,881	1,891	1,902

Conclusions and proposed next steps

Economic analysis

- An oil fired system would have the lowest capital expenditure
- Using electrically generated heat from on and off site renewables will have the highest running costs and overall project costs despite an initial modest capital cost
- Over the 20 year life of the project biomass will have the lowest overall cost in all scenarios although the cross over point (point at which biomass is cheaper than diesel) can be as long as 17 years with lower levels of production and system utilisation
- Labour cost for the extended running hours can be reduced as operators learn how to get the most out the biomass boiler system
- Choosing to install a larger system would also give the flexibility to condense operator hours with shorter run times at the expense of a marginal decrease in overall system efficiency

Operating Considerations 1

- Using a biomass boiler will mean a change in the method of distillery operation from what has become the norm over the last half century. During this period it became normal practice to power the stills using steam generated from gas fired or oil fired boilers both of which heat up quickly and are responsive to changes in heat loads, neither of which the biomass boiler is
- With the low turn down ratio of the biomass boiler the most efficiency way to run the boiler is through a gradual start up and shut down with near constant operation above 50% of the design maximum heat output during production
- As a green energy & active farm site that already operates 365 days the required flexible distillery labour force & biomass heating system will integrate extremely well with the existing business attributes
- Although the majority of the maintenance of the biomass boiler can be delegated to the proposed site operators there will likely be more maintenance and downtime than with a oil or electric boiler

Operating Considerations 2

- The ideal method of operation of a biomass heat system is a constant 7 day, 24 hour working pattern although the additional labour costs may out way the efficiency benefits at smaller production scales
- This could require a more flexible workforce who are prepared to operate for periods of time on a 24 hour rotating shift pattern and at other times of the year work on continuous 5 day normal day shift doing non-production operations
- It is also likely to require an annual hours contract for employees rather than a regular hours per week and weeks per year contract

Project conclusions

- It follows from this study that GlenWyvis will benefit both environmentally and financially from utilising a Biomass boiler with the planned production for the site, outweighing the flexibility of a more traditional heating system such as oil
- Further more the site attributes and current links to the Coop wind turbine mean that a distillery of this size will have a secure source of future energy in the form of renewable electricity up to a certain production size
- Having such strengths in controlling the energy costs in distilling will position GlenWyvis to succeed in the short, medium and long term required for whisky
- There will need to be changes to working practices when compared to other distilleries but this should give a more flexible and involved team of workers
- This is turn should lead to many small improvements in efficiencies as the team implement learnings gained through this optimisation process

Next steps

- Invite suppliers of technology and fuel to site to provide formal quote based on site specifics
- Procure equipment and fuel supply contracts
- Go through accreditation process for RHI
- Start generating renewable heat for use within the Whisky manufacturing process

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