Incentives for Thermal Desalination in the UK

Authors: *Peter G. Nicoll and Stephen M. Othen*

Presenter: *Peter G. Nicoll*
Business Development Director – Fichtner Consulting Engineers Ltd – UK

Abstract

Is the climate right for thermal desalination plants in the UK?

Historically while the UK has in the past been pioneering in the development of seawater desalination, notably with the multi stage flash process, very few facilities have been installed in the UK.

A brief review is presented of the historical situation within the UK and of the current status where a number of installations are being considered for the production of municipal drinking water.

The drive for increased use of renewable energy, the reduction in greenhouse gas emissions and the UK's requirements to significantly reduce the amount of municipal solid waste sent to landfill may indirectly provide an opportunity for the application of thermal desalination within the UK at selected Energy from Waste (EFW) facilities. The incorporation of thermal desalination at these facilities may significantly reduce the 'gate fee' to receive waste (and/or increase profitability) as a result of them being classed as 'good quality' Combined Heat and Power (CHP) Schemes and therefore able to qualify for Renewable Obligation Certificates (ROCs), a tradable certificate for renewable energy.

Some of these new drivers for desalination are explored, including the recent change in the UK's Renewable Obligation, which as a result might lead to the conclusion that the production of potable water by thermal desalination is a 'green' process! A number of EFW and thermal desalination plant configurations of differing sizes are considered, together with simple plant economics, which clearly show that thermal desalination utilising the steam from Energy from Waste facilities may indirectly significantly reduce the cost of water production or increase the profitability of such a plant, in the UK context. In some instances the simple payback period for the desalination plant would be approximately seven months, based on the additional revenue from the electricity alone.

I. INTRODUCTION

Periodically within certain areas of the UK, desalination using reverse osmosis is considered for the supply of municipal water, generally after a long hot summer, when the use of hose pipes are banned or more severe drought measures are introduced. We can recall a similar situation within the Perth region of Western Australia some years ago, noting that now, as part of the solution, the new seawater reverse osmosis plant at Kwinana has been built.

The UK has historically depended on landfill as its primary means of waste disposal with very few residual waste treatment facilities. There are now significant economic and political pressures to reduce the amount of waste sent to landfill, with one key solution being the use of Energy from Waste plants.

An opportunity now exists facilitated by the economics of generating renewable electricity from a conventional Energy from Waste plant to cheaply produce desalinated water in certain instances. This is explored further in this paper.

II. HISTORICAL AND CURRENT STATUS OF DESALINATION IN THE UK

2.1 Historical perspective

The UK has a long history of being associated with the developed of desalination processes, notably the historical submerged tube process and more recently the multi stage flash process (MSF), with companies such as Aiton and Co., G and J Weir, Richardson's Westgarth and latterly Weir Westgarth, making significant contributions to the development of these processes. The vast majority of the plants produced have been located overseas.

There have been a number of small scale facilities [1], mostly associated with the production of water for industrial use. In terms of municipal water supply, thermal MSF plants were located on the islands of Guernsey (1961) and Jersey (1969), both of which have been decommissioned, and in more recent times, a very small seawater reverse osmosis plant (200 m^3/day) on the Isles of Scilly (1994) and a 4,500 m^3/day in Jersey (1997) on the site of the former MSF plant.

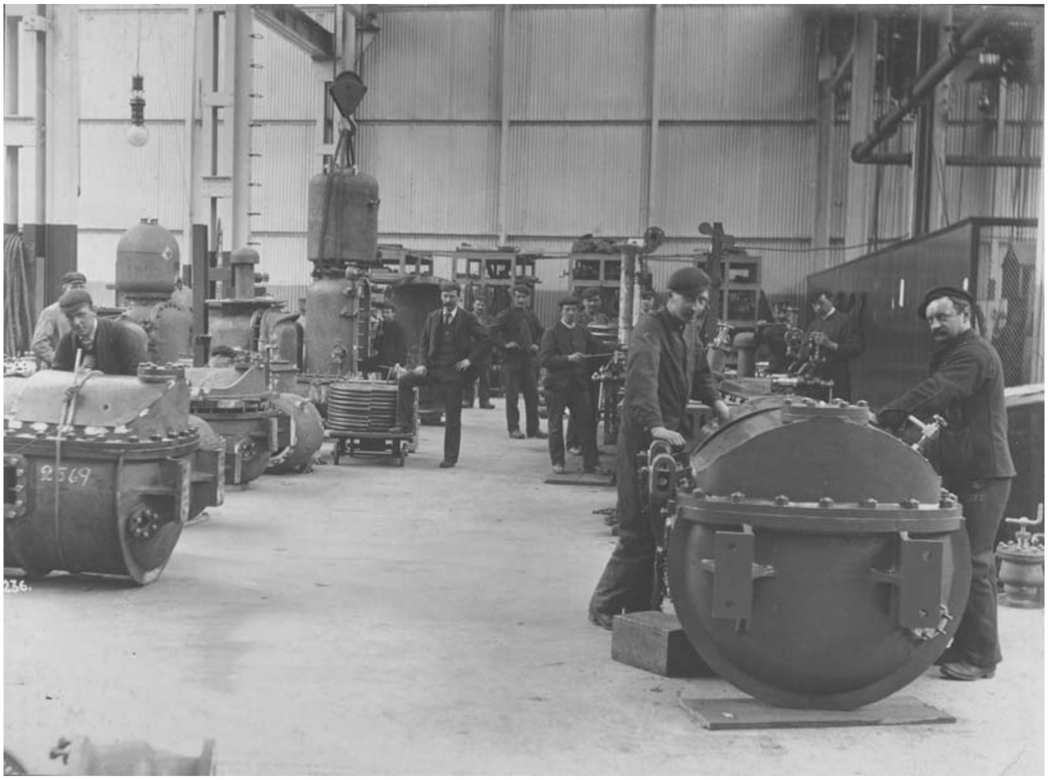

Figure 1: Submerged tube plant being assembled at G & J Weir's Glasgow facility in 1904.

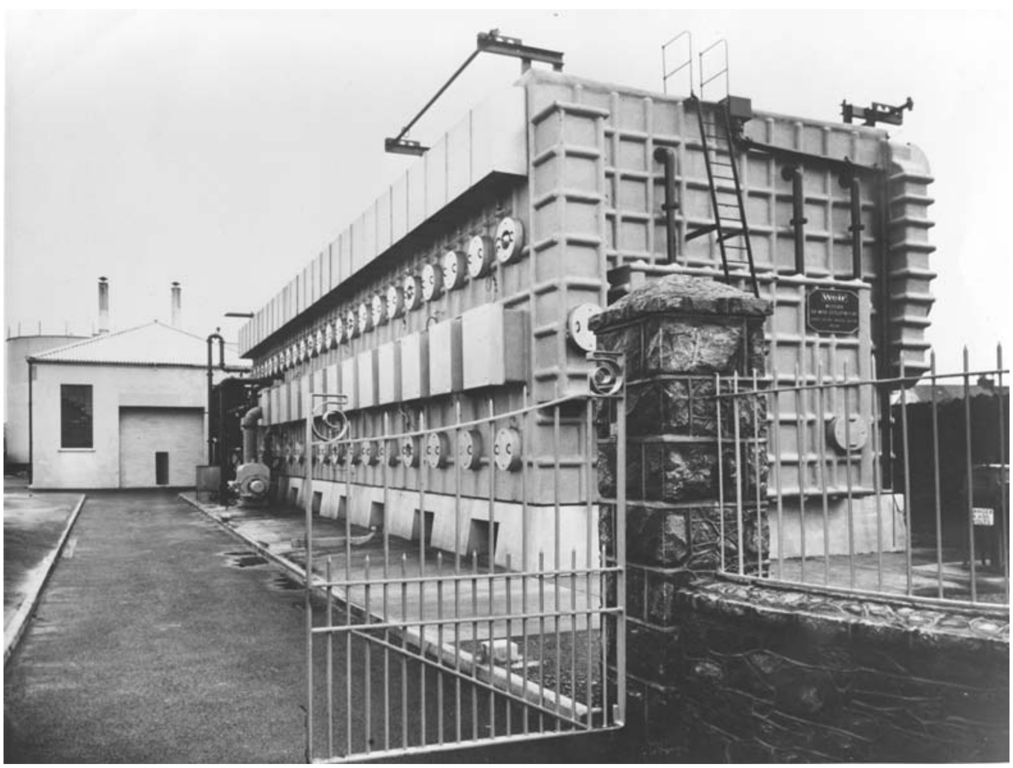

Figure 2: 40 stage MSF plant in Guernsey, operational in 1961

2.2 Planned desalination installations

We understand that all the current planned installations for municipal use are in the South East of England. It is also worthy of note, that it would appear that none of the Energy from Waste facilities in this area have suitable outlets for the waste heat produced, concentrating on the generation of electricity alone.

2.2.1 *Thames Water*

Thames Water has been in the process of developing the Thames Gateway Project, a 140,000 m^3/day brackish water reverse osmosis plant located on the tidal River Thames in London. The Mayor of London overturned the local planning authority's approval for the project, with objections that it did not deliver sustainable and efficient management of water supplies in London. This decision was rebuffed by Thames Water, who subsequently appealed and went to public enquiry, with the planning inspector's report going to DEFRA in September 2006. The outcome has recently been determined (July 2007) and planning permission has been granted [2]. It should be noted that the energy supply for the plant will be based on 100% renewable energy, a substantial portion of which will be electricity generated from bio-diesel.

Thames Water's 25 year resources plan identifies provision for a second plant in the 2020s. Cory Environmental are developing an Energy from Waste plant (550,000 tpa) on the opposite side of the river to the proposed Thames Gateway Project. This project has also been opposed by The Mayor of London, but is also now proceeding. We understand there are no current plans to utilise any of the heat for thermal desalination.

2.2.2 *South East Water*

Newhaven is located on the south coast of Britain, in an area which has historically had a number of periodic water supply restrictions. The water supply company for the area, South East Water (SEW), has undertaken a two year study into the supply of desalinated water. This has included pilot trials for an extended period using reverse osmosis as the chosen process. A recent announcement (3 April 2007) by South East Water, states that 'desalination is not yet the right solution for delivering extra water at peak times, or during extended dry periods' and 'desalination remains an expensive option in terms of operating and environmental costs when compared to developing additional resources'. SEW has also said that in the longer term desalination will be continued to be assessed.

Veolia Environment, have recently received planning permission for an Energy from Waste plant, to be located near to the proposed site of South East Water's Newhaven desalination plant on the same estuary. We understand there are no plans to utilise the waste heat from the facility.

2.2.3 *Others in the South East*

Folkestone and Dover Water plan a small desalination plant at Hythe in 2019 and Southern Water propose the development of a desalination plant in the 2020s.

2.3 Barriers

Clearly the widespread use of desalination processes using seawater in a UK context does not make economic sense given that in general there is a plentiful supply of potable water. The main issues associated with inhibiting the use of this process, on a municipal scale, are the perceptions that it is not economic, is very energy intensive and therefore not 'green' and the possible impact of the brine discharge on the environment.

There has been discussion in the past, normally in times of drought, about the use of desalination plants as a means to alleviate the problems. Then what inevitably happens is that it rains and any plans are dropped, one example being Southern Water who have considered desalination as an emergency measure in the past.

III. INCENTIVES FOR DESALINATION

3.1 Water Shortages

The South East of England is the area that is most prone to water shortages, with hose pipe bans, temporary drought orders and various other measures being put in place periodically with a view to conserve water supplies.

The UK Government also plans to build 500,000 new homes in the area, which would further increase the stress on the existing water resources. In the Kent region alone, there is a forecast shortfall of 125,000 m^3/day by 2035, based on a low population growth model.

There are significant planning and environmental obstacles to be overcome in the development of new water bodies for water storage, noting that there is no national network for water, such that the plentiful resources in the north of the country could be used elsewhere. The planning, permitting and implementation of a desalination plant may well be easier and quicker, in particular if its 'green' credentials are demonstrated.

The average British home uses 150 litres per person per day, whereas in Germany, Belgium and Holland the consumption is 130 litres. There are therefore some savings that could be made due to differing behaviours.

3.2 The UK's Renewable Obligation and 'Good Quality' Combined Heat and Power Schemes

The Renewables Obligation Order 2006 [3 ,4, 5], is a mechanism approved by the European Union for state aid, which obliges all electricity suppliers in Great Britain to ensure that a proportion of electricity supplied is produced from renewable sources of energy. The Suppliers can meet this obligation either by supplying power from renewable generating stations, by purchasing green certificates (Renewables Obligation Certificates - "ROC's") or by paying a buy-out price, collected by a fund and recycled to suppliers. ROC's were trading at £46 / MWh in July 2007.

The Obligation has been extended in April 2006 such that the electricity attributable to the biomass fuel content of mixed waste plants which use "good quality" Combined Heat and Power (CHP) [6], would be eligible for ROCs. This is a key element of the subject of this paper.

A plant burning waste must be a qualifying combined heat and power scheme certified by the CHPQA, and only the qualifying power is eligible for ROCs. To achieve full eligibility, the CHP scheme needs to be a 'Good Quality' scheme by achieving a design Quality Index (QI) of 105, and an annual operating QI of 100.

QI = X x power efficiency (GCV basis) + Y x heat efficiency (GCV basis)

In recognition of the difficulty of UK CHP schemes in achieving high efficiencies when burning waste or biomass, the current CHPQA system allows relatively relaxed factors to calculate the Good Quality Index. Currently, X = 400 and Y = 140.

3.2.1 *ROCs and 'Good Quality' CHP – the future*

The Department for Environment, Food and Rural Affairs (DEFRA) and the CHPQA are now considering the impact of the EU Cogeneration Directive (2004/8/EC) [7]. According to the CHPQA's interpretation, this has a significant impact on waste or biomass fired CHP schemes. To allow state aid , any CHP scheme should be high efficiency co-generation. A critical clause in the Directive is clause 12.2, which defines high efficiency cogeneration for units with an electrical capacity of more than 25MW as achieving an overall efficiency of 70%.

The other main criterion, and an overriding one as far as the EU is concerned, is that the Primary Energy Saving (PES) must exceed 10%. Annex III of the Directive defines how the PES is calculated. For biomass and waste, this is by comparison with reference efficiencies for stand-alone plants. According to the CHPQA, for waste and biomass, the reference efficiency for power is 25% (NCV basis) and for heat is 80% (NCV basis).

To comply with the Cogeneration Directive, the CHPQA has initially proposed that the X and Y values in the Quality Index be reduced. This would require an energy-from-waste plant to operate with a higher electrical and power efficiency than is currently the case. However, this approach has not yet been agreed. Any changes to the Quality Index, or any alternative approach to determining eligibility for ROCs for EfW plants, would naturally have an impact on the economics of EFW with thermal desalination.

This review by DEFRA and CHPQA is significant, with a direct affect on the incentives to utilise the heat from Energy from Waste plants.

IV. ENERGY FROM WASTE

4.1 UK Background

The UK has historically relied on landfill for waste disposal and currently has limited waste treatment capacity. A number of Government initiatives and the EU Landfill Directive [8] have forced the UK to go through a recent period of step change. This process has started, largely with a focus on increased recycling and composting. The UK has implemented a trading scheme (the Landfill Allowance Trading Scheme) in order to achieve the reductions in waste sent to landfill required by the Landfill Directive and this scheme includes potentially punitive fines (£150 per tonne) on the waste disposal authorities. This means that the UK will need to develop significant new waste treatment facilities and in particular EFW capacity in the coming years.

The UK currently produces around 35 million tonnes per annum (Mt/a) of municipal solid waste (MSW), of which about 4.5 Mt/a is currently burnt in EFW plants. Of this, approximately 5% of the EFW capacity is used to burn refuse derived fuel (RDF). A further 0.4 Mt/a of capacity is under construction, which will raise the total EFW capacity in the UK to nearly 5 M t/a. A further 2 M t/a capacity has been identified, which is currently under development in the UK.

Assuming that all the planned EFW capacity is built and that recycling reaches an optimistic level of 30% in 2010, rising to 40% by 2020, the UK will require waste diversion from landfill of a further 2.6 Mt/a of residual waste to achieve the Landfill Directive targets in 2010, rising to 14.3 Mt/a in 2020. There is currently much debate as to whether this diversion should be achieved with biological or thermal treatment methods.

There has been a recent increase in the number of mechanical biological treatment (MBT) plants under development and construction. These will pre-treat the raw waste, but lead to large amounts of refuse derived fuel (RDF) being produced. If the shortfall in residual waste treatment capacity is met by MBT plants, about 5 Mt/a of RDF will be produced by 2020 (depending on the design of the MBT facility).

Currently the UK has few outlets for RDF. The possibilities are:

- Cement kilns. Some of these are under development, but the total RDF capacity of the UK kilns is unlikely to exceed 400,000 t/a.
- Coal-fired power stations. Due to new emissions legislation and the current state of the UK power industry, it is extremely unlikely that UK coal-fired power stations will be developed to enable them to burn RDF before 2016 when they will have to comply with the stricter emission limits in the Large Combustion Plant Directive [9] and could be operated to comply with the co-incineration requirements of the Waste Incineration Directive (WID) [10].
- Purpose built plants. A few small plants exist, but an increase in capacity would require significant investment. A major advantage of an RDF plant is that it is not necessary to locate the plant close to the source of the waste. However, the economics of an RDF plant will not compare well with an equivalent mass burn plant due to the additional costs of producing the RDF.

Whilst there is a move towards MBT and RDF production in the UK, local authorities are becoming increasingly aware of the problems associated with developing outlets for this material. Consequently, there is interest in conventional mass burn facilities if appropriately scaled to allow scope for increased recycling.

One of the biggest challenges in developing EFW facilities in the UK is to find suitable sites where:

- It will be possible to achieve planning consent;
- Sufficient waste is available locally to ensure gate fees are adequate; and,
- The location is satisfactory in terms of the costs of the land and for connections to external services, particularly the electrical connection.

These challenges have led to significant delays in the development of a number of facilities in recent years.

Landfill tax is increasing (£32 in 2007 rising to £48 in 2010), which will be a driver in itself, providing a stimulus for waste treatment facilities. Facilities incorporating energy recovery, with ‘green power’ credentials will be economically favoured because of the significant contribution of ROCs.

4.2 Economics of Energy from Waste with Desalination

Given the current market prices and the sizing of desalination plant, the most economic technology making use of the waste heat would be the multiple effect process with or without thermal compression. Multi stage flash in terms of capital and operating costs is now recognised as the most expensive option.

Reverse osmosis would require a plant configuration, where steam driven high pressure pumps were used. The problem with this option is that the steam used to drive the turbine is not treated as a heat export under the CHPQA scheme. Instead, the power consumption avoided is treated as an additional power output. This means that the plant would not be exporting heat and so could not be defined as a Good Quality CHP Scheme, hence would not attract ROCs. Therefore, there is no economic benefit in using reverse osmosis in this configuration.

Hence two different plant configurations were considered:

a. Case A. Using extraction steam (10 bara) from the turbine to supply steam via a steam exchanger to a multiple effect plant using thermo compression.

b. Case B. A back pressure turbine, with the exhaust steam system connected to a steam exchanger, with a supply steam to the MED plant at 60 deg. C saturated.

In each case the plant was thermodynamically modelled using Fichtner’s thermal cycle analysis software, KPRO.

4.2.1 *Case A – Multiple Effect Distillation with Thermocompression*

This is based on a condensing turbine, extracting steam to provide the heat driving force for a desalination plant. Four sub-cases were considered.

1) Base case – no desalination plant.
2) Minimum case – minimum heat extraction required to achieve a QI (Quality Index) of 100.
3) Realistic case – QI of around 110 for comfort.
4) Maximum case – maximum practical heat extraction.

Each case was run for 200,000 tpa municipal solid waste with a net CV (calorific value) of 9.2 MJ/kg.

The Desalination plant was assumed to have the following requirements per cubic metre of water per hour:

- Gain Output Ratio (GOR) of 8, equivalent to 0.125 tonnes of steam per hour (saturated steam at 10 bar-a).
- 2 kWh of electricity per hour.

The income figures are based on power exported at £33 per MWh, ROC income of £40 per MWh and Desalination income of 80p per cubic metre.

Case	Power Exported (kW)	Desal capacity (m^3/hr)	QI	Income (£/hr)	Income (£/te waste)	Change from base (£/te)
A1	16,070	0	96	530.31	21.21	
A2	14,867	56	100.3	1,130.09	45.20	23.99
A3	12,289	176	109.7	1,037.90	41.52	20.30
A4	7,478	400	127.3	865.89	34.64	13.42

Table 1

4.2.2 *Case B*

This is based on a back pressure turbine, providing heat to the desalination plant by generating saturated steam at 60°C. This requires a turbine back pressure of 0.312 bara. Four sub-cases were considered.

1) Base case – for reference only, as the actual base case is case A1 from earlier – you would never in practice design a plant with such a high back pressure.
2) Minimum case – minimum heat extraction required to achieve a QI of 100.
3) Realistic case – QI of around 110 for comfort.
4) Maximum case – maximum practical heat extraction, based on 90% of exhaust steam being used for desalination.

The Desalination plant was assumed to have the following requirements per cubic metre of water per hour:

- 0.125 tonnes of steam per hour (60°C, about 0.21 bara). i.e. GOR = 8.
- 2 kWh of electricity per hour.

Case	Power Exported (kW)	Desal capacity (m^3/hr)	QI	Income (£/hr)	Income (£/te waste)	Change from case A1 (£/te)
B1	13,815	0	83.7			
B2	13,807	88	100.2	1,078.31	43.13	21.92
B3	13,695	144	110.2	1,114.94	44.60	23.39
B4	13,135	424	159.8	1,298.06	51.92	30.71

Table 2

4.2.3 *Optimum solution*

Given the analysis results summarised above, there are two conclusions:

1. To maximise the electricity income, with minimal investment in the desalination plant then a multiple effect distillation plant with thermal compression, utilising sufficient steam to meet the requirements of the CHPQA scheme is the most economic option.

2. A MED plant configured with a back pressure steam turbine utilising as much of the exhaust steam as possible, provides a plant that maximises the income from the sale of electricity and water.

It is clear that the solution proposed depends on what the drivers are for power and water, but it is far more likely that the income from power will be the primary driver.

It should be noted that the desalinated water produced could not simply be dumped back into the sea, otherwise it may not be treated as a 'good quality' CHP Scheme. It could however be used on the EFW plant for process use (typically 120 m^3/day required for a 200,000 tpa EFW plant), tb this is not sufficient to use the minimum quantity produced with a GOR of 8. It is therefore highly likely that the water produced would have to be exported from the facility.

4.2.4 *Payback Period*

In order to demonstrate, simply, the significant impact on the income associated with meeting the requirements of a 'good quality' CHP scheme and the substantial additional income associated with ROCs, the payback period is worthy of consideration.

If we consider what is termed the optimum solution (A2), with a small MED plant with thermo compression (GOR = 8, 1,344 m^3/day) this may cost around £2 million, including civil works and installation. The payback period based on only the additional electricity income from ROCs, based on waste with a 65% biomass content would be approximately 7 months. Clearly if a plant with a lower GOR was used then the payback period would be even shorter.

Under the PPC Regulations the desalination installation EFW plant would be required to demonstrate Best Available Technology (BAT), which might imply using a high GOR of say 8. However it would appear that the PPC Regulations do not apply to thermal desalination plants in the UK, nor does there appear to be a requirement to undertake an environmental impact assessment (EIA).

There will be a requirement for planning permission, discharge consents and possibly input from the Environment Agency, who has a duty to secure the proper and efficient use of water resources. Hence a high GOR plant may still be preferable. The politics are such that it would clearly be desirable to put forward a high efficiency plant, thus demonstrating its 'green' credentials.

As discussed earlier, the calculation of the Quality Index may change in the future such that higher electrical and power efficiencies would be required to qualify for ROCs. This would affect the payback period. However, it is noticeable that much higher efficiencies are achievable if the quantity of desalinated water is increased, so that it should still be possible to qualify for ROCs.

V. A CHALLENGE TO THE UK WATER AND WASTE INDUSTRIES

The question that needs to be asked is why has this significant new opportunity in utilising the 'good quality' CHP Scheme to obtain the significant additional revenue associated with the generation of 'green' electricity not been exploited?

There are several businesses operating in the UK market, with both waste and water supply businesses, for instance:

- The Pennon Group plc, which owns South West Water and Viridor Waste Management has interests in both the waste and water sectors. Viridor has interests in the EFW sector.
- United Utilities has a regulated water supply and waste water treatment business located in the North West of England. It clearly has ambitions in municipal waste treatment having been recently short-listed (1 of 2) for the Derbyshire waste PFI contract and has also just been pre-qualified for the Cheshire waste PFI contract.
- Veolia and Suez have a very significant presence in the UK waste market and also operate in the UK water supply sector. Veolia in particular, even with its strong track record in the MED field through Sidem and Entropie, does not appear to have any published plans to utilise the waste heat at their proposed Newhaven EFW facility. Noting, that South East Water, following pilot RO trials, decided that desalination was too expensive on an adjacent site.

It can be concluded that there is no shortage of potential players in the UK market who are actively involved in both the waste and water supply sectors, yet none of them appear to have any published plans to pursue the EFW and thermal desalination option.

Perhaps it will be a power generation or industrial sector player that will be the first to exploit this new opportunity. The development of these facilities by these businesses may be constrained by public perception and perhaps their wish not to be associated with EFW plants, although perhaps the use of RDF as a fuel source might be considered a softer option.

One element of the equation that should not be forgotten in exploiting the 'good quality' CHP Scheme, as part of a new project development utilising project finance, is the long term security of the heat off-take. If the off-take is for process use in an adjacent facility, there may be issues with the 'bankability' of the scheme depending on the reliance of the project on ROC income. It is important to remember that the export of water is normally much more secure than the export of steam, which might make project finance easier.

The question now is by whom, when and where will the first thermal desalination plant in modern times be built in the UK?

V. CONCLUSIONS

The UK has historically been slow to adopt Energy from Waste (EFW) as a means for disposal of municipal solid waste, unlike much of continental Europe and elsewhere. The introduction by the Government of The Renewables Obligation Order 2006 and in particular the changes made to include EFW in a combined heat and power mode that meets the requirements of the Good Quality CHP Scheme has opened up the significant possibility of utilising the heat for desalination, the main driver being the significant additional electricity revenue from Renewable Obligation Certificates (ROCs). The most suitable process from an economic perspective is multiple effect distillation, as this minimises the parasitic power load compared to multi stage flash. The reverse osmosis process, using steam driven high pressure pumps, would not qualify under the CHPQA Scheme and therefore would have no economic merit.

The CHPQA Scheme is currently being reviewed to take more account of the EU Cogeneration Directive, which may make it more difficult to obtain ROCs. This situation needs to be monitored.

The optimum plant configuration, from an economic perspective, is based on the use of medium pressure extraction steam with a low GOR based MED plant, producing water for the EFW's own onsite use. Such a facility meets the requirements of the CHPQA, minimises the capital investment in the desalination plant and maximises the income from ROCs, although from an environmental perspective it does not maximise the benefits of the use of renewable energy, in this case the biodegradable content of the waste used in the incineration facility.

The recent increases in Landfill Tax, may also significantly increase the opportunities for the use of waste treatment technology (incineration or mechanical biological treatment of both municipal solid waste (MSW) and commercial waste). This measure will further increase the potential for building incinerators using waste or refuse derived fuel as a feedstock.

The use of a desalination plant with a suitable off-take agreement is more likely to be 'bankable' than a CHP scheme that relies on a variety of industries in close proximity for the use of the heat. It is far easier to export water than it is to export heat!

It will be interesting over the next few years, to see whether this opportunity presented by The Renewables Obligation, the significant increase in Landfill Tax, the pressures in the south east of England with increased population and water scarcity, may facilitate an increase in the number of energy from waste plants and their coupling with thermal desalination in the UK.

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