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  • Fuels derived from waste
> To produce:
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How Oxfordshire County (UK) Managed to Close Its Landfill
with a Successful Association of *Material-from-Waste* and
*Energy-from-Waste* Solutions

Christophe Cord’homme

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1. Introduction

After Paris COP21, greenhouse gas effect and global warming are now recognized as worldwide challenges. A much older problem should also become a global challenge for humanity: municipal waste management. Solid waste management is an essential utility service, but it doesn’t appear in general to be in top priority for political managers. Open dumping is still being practiced, as the dominant method for waste disposal, in both low-income and upper middle-income countries.

The International Solid Waste Association (ISWA) has indicated in their report Wasted Health – The Tragic Case of Dumpsites that uncontrolled open dumping sites receive roughly 40% of the world’s waste and they serve about 4 billion people.

They present huge public health and environmental impacts with severe land pollution, freshwater, groundwater and sea pollution, local air pollution with open burning and also climate change major contribution.
ISWA has also published a roadmap for closing waste dumpsites. It is indicating that the World's most polluted places are the 50 biggest dumpsites, which affect the daily lives of 64 million people, a population the size of France.

As an example, let’s remember the recent catastrophe in Ethiopia; on Saturday 11th March 2017, a huge garbage dump landslide at the Koshe landfill in Addis Ababa killed at least 115 people, most of them women and children.

Figure 1: Landfill catastrophe in Addis Ababa (Etiopia) 3/2017

Today, this disastrous practice of waste disposal tends to be eliminated in most economically advanced countries, after taking decades and billions of euros in expenditure to achieve. It has allowed to reduce these direct health risks to their populations. Other priorities and initiatives are now relevant for developed countries, refer for instance to Circular Economy and Energy Transition. But as municipal solid waste per capita increases with income level, it is essential for our sustainable development to continue these efforts about waste treatment. With state-of-the-art techniques, Europe is paving the way for this responsible waste management.

2. European context for waste management

In the last decades, European Union has managed to put in place a complete legal framework for sustainable waste management.

2.1. European key principles

Let’s remind some of the EU waste management key principles:

- **Self-sufficiency principle**
  * Each Member State should have enough installations for its waste disposal

- **Proximity principle**
  * Waste disposal should be dealt with as close as possible to its generation

- **Polluter pays**
  * Producer of the waste should pay for its disposal costs

- **Producer responsibility**
  * Producer of product responsible for generated waste
2.2. European waste treatment hierarchy

In 2008, the Waste Framework Directive (WFD) 2008/98/EC has also given the following waste treatment hierarchy for the different types of process.

According to this hierarchy introduced by this directive, the worst destination for municipal waste is landfill or disposal without any recovery of available resources in the waste, such as material and energy.

2.3. Circular economy concept

Developed countries are now engaged in a new dynamic of re-discovering recycling and efficient resource use, driven by growing concerns about global warming, virgin resource depletion and resource scarcity. The diversion of waste from landfill is urgently required to minimize methane emissions to the atmosphere as part of efforts to reduce climate change gases.

In a circular economy, business designs materials for recovery and re-use. Goods are either a source for raw materials that can be recovered and re-used with Material-from-Waste facilities or for energy to avoid primary fossil fuels consumption with Energy-from-Waste plants (EfW). Nothing is wasted and when raw materials can no longer be reused, the energy they contain is recovered to replace virgin fuels.

With Circular Economy concept, resource management in the waste sector has the high level goal of saving natural resources. The challenge is to generate value from waste in terms of saved natural resources ranging from primary energy resources through minerals and metals to rare earth elements. Material recovery is higher in hierarchy than energy recovery in this respect when it comes to sorted, pure and homogenous high-value materials that are easily recovered such as some packaging, glass or metals.

Energy recovery has, however, its place when it comes to materials that are not easily recycled such as soiled or contaminated materials, composite materials and materials with a quality not suited for recovery, for example, due to deterioration of quality after several recycling sequences. Energy recovery may also be the better choice for low-
value materials such as wood and materials that require disproportionate resources to collect, treat and recover in a separate process system.

As EfW process replaces fossil fuels and allows to recover also materials such as aggregates or metals from bottom ashes, it serves the same high level purpose as many recycling activities. It is therefore regarded as an integrated part of the circular economy as illustrated in Figure 3 from ISWA Circular Economy report.

![Circular Economy diagram](image)

Source: ISWA Energy and Fuels report

2.4. EU circular economy package

To promote this waste treatment hierarchy and also the circular economy principle, in December 2015, the European Commission adopted an ambitious Circular Economy Package, which includes revised legislative proposals on waste to stimulate Europe's transition towards a circular economy which will encourage sustainable economic growth.

Key elements of the revised waste proposals include:

- A common EU target for recycling 65 % of municipal waste by 2030;
- A common EU target for recycling 75 % of packaging waste by 2030;
- A binding target to reduce landfill to maximum of 10 % of municipal waste by 2030;
- A ban on landfilling of separately collected waste;
Compared to the 28% figure in 2014 of Municipal Waste sent to landfill in EU in average, these measures set a clear strategy to discourage landfilling in Europe.

Closing Landfills could be obtained by closing the loop of Circular Economy with an association of Material from Waste combined with Energy from Waste solutions.

3. United Kingdom situation

In United Kingdom, the waste management situation was far away of these European objectives beginning of 2000’s.

For example, in 2004, more than 25 million of tonnes of MSW were landfilled on a total of around 36 millions of tonnes produced. Figure 4 showing approximately 70% landfilled.

3.1. UK landfill tax

By launching a Waste Strategy program, the United Kingdom (which was still in the European Union at this time), put in place a voluntary policy of reducing landfill volume and developing recycling. A strong political decision has been taken in order to divert municipal solid waste from landfilling in priority.

Landfill Tax was first introduced in 1996 to encourage waste producers and the waste management industry to switch to more sustainable alternatives for waste disposal. The UK Budget planned that the standard rate of Landfill Tax would rise by 8 GBP per tonne since 2007 each year up to and including 2014. It also announced a floor under this standard rate so that the tax would not fall below 80 GBP per tonne from 2014 to at least 2020 increasing each year in line with inflation.

It also announced the intention to provide further long-term certainty. End 2015, the landfill tax reached a level of 82.6 GBP/t corresponding to 120 EUR/t with the exchange rate at this time (pre Brexit).

Since April 2017, the landfill tax is now 86.1 GBP/t, but it represents only 94 EUR/t due to Brexit impact on Sterling value versus Euro.
As shown on the curve, it has given a long term visibility for councils and waste managing companies about the increase of costs of landfilling with this long-term planning. This point is crucial for the bankability of private projects which are the usual way of building infrastructure in UK. This measure changed also the competition panorama between the different types of treatment. Resource recovery (material and energy) have become more competitive compared to landfilling costs plus tax (see after).

### 3.2. Easy solution: Ask your neighbours

In reaction to this legislative measure, some UK councils have chosen the *easy* solution, which is to avoid to build any new infrastructure: they asked their neighbours to treat their problems of waste management.

For example, the Norfolk County Council presented during the 2016 World Waste to Energy Summit in London that they concluded an agreement with Suffolk County to export 20% of the Norfolk MSW to the new Suffolk Energy from Waste EfW plant and the rest was exported abroad on the continent under Refuse Derived Fuel (RDF) form. Of course, it is not respecting the proximity principle and this 100% export solution doesn’t give any real long term certainty. Nevertheless, Norfolk announced the fulfilment of their objective of *zero waste to landfills* by this mean.

Because of competitive price on the continent for the treatment in existing EfW facilities, this solution of waste export appeared often more competitive towards *domestic* solutions and has been chosen by several waste managers as shown by the following curve with the increase of MSW export in parallel with the tax increase. Note that for export, it is generally required an important waste preparation and pre-treatment to obtain a fuel product named RDF (Refuse Derived Fuel). Its quality should be in conformity with the requirements of the final treatment facility (the importer).
CEWEP organisation statistics has indicated that 2.94 million tonnes of RDF were exported in 2015 from UK to Netherlands, Germany and Sweden. The relative low price in these countries for RDF combustion is mainly due to present district heating high demands and revenues in large existing EfW plants, which are amortized.

Today the BREXIT has already had an impact of the Sterling value versus Euro. Therefore, this export solution doesn’t appear to be so competitive and the rate of export has decreased in the last months. This is showing the fragility of this easy solution: ask your neighbours to solve your problem.

4. Real long term solution: Do it yourself – Oxfordshire case
4.1. Oxford situation

Oxford City is around 100 km North West of London. This city is worldwide well known for its University and its annual rowing race against Cambridge University team.

But Oxfordshire County is also performing in waste management since a long time. In addition with selective collection, this community installed 7 waste recycling centers and 3 food waste biological treatment facilities with Composting and Anaerobic Digestion in addition with home composting.

These infrastructure allows Oxfordshire to be one of the best performing councils in UK at recycling and composting. But still a substantial amount of residual waste has to be disposed of.

This means that as well as reducing, reusing and recycling, Oxfordshire also needs to treat residual waste rather than landfill it.

4.2. Residual waste treatment – how they proceed?

In 2006, Oxfordshire has carried out a study considering the different alternative ways of treating residual waste and their costs compared with doing nothing.

One year later, Oxfordshire Joint Municipal Waste Strategy was agreed which following targets:

- Reduce waste growth to 0 % per person by 2012
- Increase recycling and composting rates to at least 55 % by 2019/20 (compared to 43 % in average in England).
- Build new waste treatment facilities to reduce the amount of landfilled waste
- Require technology safe for the environment and human health and recovering value from the waste

In 2007, they started a tender procedure with Private Finance Initiative for a concession. This type of procedure has been very common in UK. This tender was asking for a contract for residual waste treatment alternatives to landfill without any technologies restriction. 14 companies submitted their pre-qualification questionnaires. 8 were pre-qualified. These bidder companies submitted first proposals for outline solutions with a range of technologies. But all proposed Energy-from-Waste (EfW) as the best solution to treat Oxfordshire’s residual waste.

In 2008, Oxfordshire sent an invitation to submit detailed solutions (ISDS) at 2 selected companies on their 2 different sites. In 2009, after the Call for final tenders (CFT), the selection of preferred bidder was done in September. The Council Cabinet decision was finally announced in 7/2010 and the contract signed in 3/2011.

These final delays were mainly explained by the planning permission procedure for the facility with challenge process. It began in 2009 with the refusal of the 1st permission and appeal to the planning inspectorate with public inquiry. In September 2010, the
environmental permit was granted by the Environment Agency and the Planning and Regulation Committee approved the revised planning permission application the same year. In February 2011 the Secretary of State granted planning permission but a legal challenge against this decision was undertaken by a local resident’s group but it was finally dismissed by the high court in July 2011.

4.3. Oxfordshire municipal waste management strategy

The Oxford Waste and Recycling Strategy 2013-2020 plan has announced now that they have chosen to deliver the most sustainable option for managing Oxford’s MSW:

- **with the highest quality services,**
- **with reasonable cost**
- **with minimal negative impact on the environment.**

They also reminded that the objectives of this strategy is to:

1. **Reduce residual waste in Oxford.**
2. **Maximise the amount of resources re-used in Oxford.**
3. **Maximise the amount of waste recycled in Oxford.**
4. **Reduce the carbon impact of waste management in Oxford.**

New infrastructure will treat residual waste to further recover value and to minimise the environmental impact of managing Oxfordshire waste streams.

5. Oxfordshire residual waste treatment contract and construction

5.1. Delegation contract

In March 2011, was signed this Public Private Partnership (PPP) 25 years contract between Oxfordshire County Council and Viridor, a UK global waste management company, for landfill diversion and treatment of non-recyclable municipal waste. It included the financing, construction and operation of a new Energy Recovery Facility (ERF).

**Capital investment:** 205 million GBP for a 300,000 tpy plant

**Owner (PPP contract):** Viridor Oxfordshire Limited

**Plant location:** Ardley site, Oxfordshire, sitting low a landfill

Ardley quarry, is also famous in Europe for its fossilised dinosaur trackways which inspire the Architect’s vision for the ERF.

**Construction contract:** Viridor has signed a Turnkey Design and Build contract with CNIM. This EPC (Engineering, Procurement and Commissioning) contract was done in Joint venture with Clugston, for Civil Works.
Energy from Waste experience

CNIM is an international specialist in the treatment and energy recovery of waste and the company accompanies the public service delegates, the operators and also the local authorities. Its teams design, build and operate turnkey plants to treat household, industrial, non-hazardous waste. It delivers turnkey waste-to-energy units to local authorities or their delegated operators.

The group is committed to the energy performance of its equipment that meets the strictest environmental standards. At the head of a proven portfolio of proprietary technologies, CNIM, a European specialist in the sector, is very active throughout the world. With 26 references in British Islands, it has an historical strong leading position in this area.

5.2. Oxfordshire energy recovery facility technical characteristics

Annual capacity: 300,000 tonnes per year of residual Municipal Solid Waste
- 2 Combustion lines with reverse-acting Grates at design: 2 x 19.2 t/h NCV 9.7 MJ/kg
- 2 Steam Boilers: 52 MWth 60 bar (870 psia), 400 °C (752 °F)
- 1 Steam Turbine Generation Set rated at 24 MWe
- CHP-enabled (Combined Heat and Power)
- 2 Flue Gas Cleaning lines: SECOLAB + SNCR deNOx
- Bottom Ash processing facility

Figure 8 is showing the cross section of this facility.

Figure 8: Oxfordshire cross section

This plant is using Best Available Techniques. They have long and performing track records. These efficient and performing technologies guarantee the business plan fulfilment with high availability and reliability obtaining. One of the core process technology is related to the Reverse-acting grate combustion: efficient, flexible versus waste quality and reliable.

This process allows to divide waste volume by 100, destroy organic pollutants and produce green energy. It can treat easily without any modification both Residual Municipal Waste or Refuse Derived Fuel despite of important differences in calorific values.
The grate combustion process has obtained 90.7 % of the capacity breakdown of the Worldwide Thermal Treatment Plants awards in 2008-2016 [21]. During this period, this capacity is representing the equivalent of the building of 467 EfW plants of Oxford size. Fluidized bed technology represented 5.3 % and Alternative Thermal Treatment such as pyrolysis or gasification only obtained 3.8 % of this amount.

5.3. Oxfordshire ERF key dates

- 3/2011 – Contract signature
- 11/2011 – Notice to proceed
- 1/2013 – First boiler lift
- 4/2013 – Bunker completed
- 6/2013 – Boiler Pressure tests
- 7/2013 – Turbine delivered and Flue Gas Treatment erected
- 4/2014 – 1st waste fire
- 8/2014 – 1st electricity export
- 11/2014 – Take over
- 3/2016 – Availability test end

Figure 9: Architect view

Figure 10: Oxford plant after completion

Figure 11: Ardley plant construction
5.4. Oxfordshire Ardley health and safety on site

This working site has obtained a Top safety record with 1,8 Million man hours (equivalent to 205 years) without any lost time accident.

This was obtained with over 550 employees on site.

The Accident Frequency Rate AFR on Ardley site was much better than the Gold Standard’ AFR required for Olympic Delivery for London Olympic Games, which was also much lower than the average Construction industry AFR.

6. Oxfordshire energy recovery facility operation

6.1. Ardley technical performance results: an efficient ERF

This facility is based on most modern ‘Best Available Techniques’ for excellent combustion, removal of the hazardous substances of waste, high energy recovery efficiency and low environmental impact. This process is recognized as Recovery as the energy efficiency factor R1 is over 0.65. ARDLEY Energy Recovery Facility (ERF) is now fully operational.

All the guaranteed values have been reached after commissioning:

- The Waste throughput in operation was 3 % higher than the nominal value, whereas the energy production was 10 % higher than the guaranteed value.
- The pollutants emissions levels at stack were much lower than the guaranteed values as shown in Figure 13.

![Figure 13: Pollutants emissions values at stack versus guaranteed values](image-url)
- The reagent consumption was 10% lower in average compared to guarantee whereas the Air Pollution Control (APC) residues amount were 20% lower.
- The availability after 1 year test was 3% higher than the guarantee.

After first year of commercial operation, no significant corrosion was noticed on superheaters, on convective banks or on radiative surfaces.

6.2. Oxfordshire, environmental frontrunner

The official opening was realized on June 11, 2015 by HRH the Duke of Gloucester. John Sanders, chairman of Oxfordshire county council has declared during this ceremony: "Oxfordshire has the best recycling and composting rate of any county council in the country – last year we delivered a rate of over 61%.

This modern and well run energy recovery facility will treat almost all the waste left after recycling and composting … Diverting waste away from landfill and generating valuable electricity brings real environmental benefits to the people of Oxfordshire and nationally.

Ian McAulay, Viridor CEO completed:

It’s great to see Viridor’s latest ERF at Ardley already providing a 1st class service to our local authority and business customers. …I thank everyone for their hard work in delivering this world-class project.

6.3. Oxfordshire ERF for education and landscape

The plant operator is using a state-of-the-art visitor centre to teach children and interested adults about sustainable waste management.

In November 2016, Ardley ERF has also obtained the Oxford Preservation Trust Award for landscape. It was indicated that: Pitted against a host of University buildings, churches …, the Energy Recovery Facility (ERF) was recognised for its contribution to Oxfordshire’s landscape.

The reference to the ancient dinosaur activity on the site was also noticed.

As mentioned above, the ERF architect has chosen the outline of the dinosaur tracks discovered on Ardley quarry site for the silhouette of the facility as you could see in Figure 15.

This dinosaur activity was also reminded at the entry of the facility with the model of the Megawattasaurus dinosaur, all made from re-used materials.
7. Oxfordshire residual waste treatment result

7.1. ERF operation impact for Oxfordshire County

As indicated in recycleforoxfordshire.org.uk web page, Ardley Energy Recovery Facility (ERF) is now fully operational with a capacity of 300,000 t/y:

- sufficient to treat all of Oxfordshire's residual municipal waste
- diverts at least 95% of MSW from landfill
- generates enough electricity for about 38,000 homes
- reduces greenhouse gas emissions by approximately 56,800 tonnes of CO₂ equivalent per year (compared to landfill)
- provides a value for money solution for managing the residual waste compared to continuing to landfill

The residual waste treatment contract has no minimum tonnage which means this is not a barrier to their continuing efforts to reduce, re-use, recycle and compost more of their waste.
7.2. Landfill closing

A few months after take-over of the ERF (but almost one year before the end of the ERF availability test period), the Oxfordshire neighbour landfill has been closed in April 2015 after 35 years of operation. This is demonstrating therefore how the diversion of residual waste from landfill is possible with the help of this new infrastructure of Energy Recovery.

![Figure 17: Oxfordshire Landfill closure after Ardley ERF commissioning](https://blog.viridor.co.uk/2015/04/10/viridor-landfill-closures-confirmed)

7.3. Oxfordshire best recycling rate in UK in 2015

As required by EU waste hierarchy, an effort has continued to be done on waste reduction; Oxfordshire citizens produce less waste per person than any other County Council in England.

The recycling rates continued to improve, making Oxfordshire with the highest performing areas in the country. Table 1 is showing the total household waste recycling, composting and reuse rate for English local authorities listed in overall performance order for 2014/15.

This is a demonstration that Energy Recovery solution does not affect the recycling on the contrary of some rumour and fake news. Material-from-Waste and Energy-from-Waste goes hand in hand as complementary solutions to divert municipal waste from landfilling.

![Table 1: Recycling rates for local authorities in England 2014/2015](www.letsrecycle.com)

8. UK MSW treatment situation with landfill tax impact

As indicated on this curve from Ecoprog, it appears that the UK policy has been very successful towards the European strategic demand. In 10 years from 2004 to 2014 corresponding to the landfill tax increase period, the amount of landfilled waste in UK has dropped from 25 Mt in 2004 to 10 Mt in 2014 corresponding to a 60% reduction.

From a bad situation with 70% landfilling, UK has managed to catch up as its landfilling share is now very similar to the average in EU with 34%. This curve is also showing that this good result has been obtained by a well-balanced mix of solutions between...
Material-from Waste, organic recovery and Energy-from-Waste. By 2020, 6% of total UK electricity will be supplied by EfW.

Approximately half of this EfW annual capacity in UK has been supplied by CNIM.

![Figure 18: Evolution of shares of municipal waste treatment technologies in UK in 2004–2013](image)

Source: Eurostat

**Residual MSW treatment gate fees in UK**

Table 2 is giving the actual costs for gate fees for mixed waste supplied to large energy from waste plants, but also for landfill and its tax and RDF export (without its preparation cost). Gate-fees will vary in terms of the volume of material supplied, contract length and location.

**Table 2: Typical gate fees in UK in 2017**

<table>
<thead>
<tr>
<th>2017: GBP per tonne (costs)</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>EfW</td>
<td>70 – 105</td>
<td>70 – 105</td>
<td>70 – 105</td>
<td>75 – 105</td>
<td>75 – 105</td>
<td>75 – 105</td>
</tr>
<tr>
<td>RDF</td>
<td>80 – 90</td>
<td>80 – 90</td>
<td>80 – 90</td>
<td>80 – 90</td>
<td>80 – 90</td>
<td>80 – 90</td>
</tr>
</tbody>
</table>

Source: www.letsrecycle.com

**9. European situation**

At last, the evolution of the situation in Europe during this period presented on this CEWEP curve is also showing an important decrease of landfilling between 2004 in...
2014 from 49 % to 28 % share. This has been obtained with the association between Material-from-Waste and Energy-from-Waste facilities.
By this voluntary and efficient policy, UK has now managed to join now the *medium pack* of European countries instead of the *bad* pack, where it was before these decisions. The starting level of landfill share was much higher in UK (70 % instead of 49 %), but the rate of decrease of landfilling has been also much higher in UK, as they wanted to catch up their bad situation.

10. Conclusion

*Zero Waste to Landfills* is an important objective to reach in the Circular Economy strategy. Once the level of quality material recycling has been optimized, residual Municipal Solid Waste (MSW) is a resource of local renewable energy. The association between *Material from Waste* and *Energy from Waste* is the only scheme to avoid the use of landfills and close the Circular Economy loop at the level of Municipal Waste.

The case of Oxfordshire County is presented as an example to illustrate this waste management strategy. This county has the best results in UK in the waste hierarchy in waste reduction and *Material-from-Waste* Recycling. To close the loop in Circular Economy, they decided to build a modern and reliable *Energy-from-Waste* (EfW) facility. This successful case of this EfW building allowed them to close their landfill after this EfW plant commissioning. Energy Recovery solution does not affect the recycling. *Material-from-Waste* and *Energy-from-Waste* goes hand in hand as complementary solutions to divert municipal waste from landfilling.

Based on United Kingdom market successful story to reduce drastically their MSW landfilling, this paper shows the type of waste management solutions proposed and installed in line with *Zero waste to landfills* in a Circular Economy policy.

Landfill tax policy has been a very efficient tool to drive this landfill diversion strategy. By this voluntary and efficient policy, UK has now managed to join now the *medium pack* of European countries instead of the *bad* pack, where it was before these decisions.

Aknowledgements

Thank you to Viridor and to Morgane le Coguic for her support.

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