Waste and Water Minimisation Audit Review

for

International Rectifier, Newport (IRN)

INTRODUCTION

This document is provided to satisfy the requirements of EPR Permit No: BV7460ID condition 2.4.1.2; that is to carry out a waste minimisation and water use efficiency audit and submit to the Agency at least every four years a review of said audits and progress made against the action plan.

RAW MATERIALS

The operator should maintain a list of raw materials and their properties

IRN, in the execution of its operations, retains and maintains vast quantities of information pertaining to the raw materials it uses and their properties; internal systems employed within IRN provide the mechanisms of data capture. Where possible, environmental impacts for all operations undertaken at IRN have been assessed. To ensure adequacy of ongoing maintenance of its systems and continuous improvement, audits of the systems employed at IRN are completed to ISO 9001:2008, TS 16949:2009 and ISO 14001:2004 2nd Edition, ISO 50001 and OHSAS 18001. IRN has also recently achieved the Carbon trust Waste standard and Carbon Trust water standard.

For the purposes of this audit report, and in the interests of practicality, only selected information is included as appendices to this audit report, this information chosen specifically due to its potential for environmental impact, however, further supporting information is available on site.

The site holds a full and extensive 'live' site materials inventory and quantities, which is available for review on site only, upon request.

All materials, where appropriate, are supported by their Material Safety Data Sheets (MSDS), copies of which are maintained by on-site subcontract gas and chemical management vendors and held in soft copy within IRN's electronic document control system; these are available for inspection upon application to IRN's HS&E department.

The IRN site is classified a Lower Tier COMAH site, and hence a further detailed list classifying all hazardous chemicals as defined within the COMAH regulations is held on site, and reviewed and updated, as a minimum, annually.

The operator should have procedures for the regular review of new developments in raw materials and for the implementation of any suitable ones with an improved environmental profile

IRN's specification No 42-9015 "Supply Chain Review Board" demonstrates IRN's systemised approach to the regular review of developments in raw materials and provides the controlling mechanism for the implementation of proposed materials change.

Part of the materials approval process incorporates an Environmental Health & Safety Material Review Process No 02-5444 which includes consideration of materials with improved environmental profiles which may be alternately deployed.

IR COP 1000-01 "Banned and Controlled Substances Policy" defines IR's compliance standard for its products with respect to banned and restricted substances to meet existing and anticipated legal requirements and market demands. Its scope includes all raw materials, parts, components or products that are incorporated into the product that International Rectifier manufactures. For out-source manufacturers, this includes products produced by the manufacturer on behalf of International Rectifier. Due to the acquisition of the company by Infineon Technologies, IRN is developing its own policy to replace the American- and German-centric documents held at corporate level. This work is progressing with the assistance of external consultants.

Please note: all cross referenced documentation within this specification is omitted from inclusion within this audit report for reasons of clarity and retention of business sensitive/confidential material, but may be inspected on site via application and approval of IRN's General Manager.

The operator should have quality assurance procedures for controlling the impurity content of raw materials.

At the highest level, IRN's approach to quality assurance is governed by the requirements of IRN Specification No 42-9104 "IR Newport Quality Assurance Manual".

To ensure the quality of raw materials utilised directly by IRN in the manufacture of its products all are subject to incoming inspection (IRN specification 22-5906 "Materials Incoming Inspection"). In addition, due to the stringent nature of requirements within the raw materials for product cleanliness and quality, statistical methods are employed to validate the quality of the materials received from qualified suppliers against IRN product material specifications.

> *The operator should complete any longer-term studies needed into the less polluting options and should make any material substitutions identified*

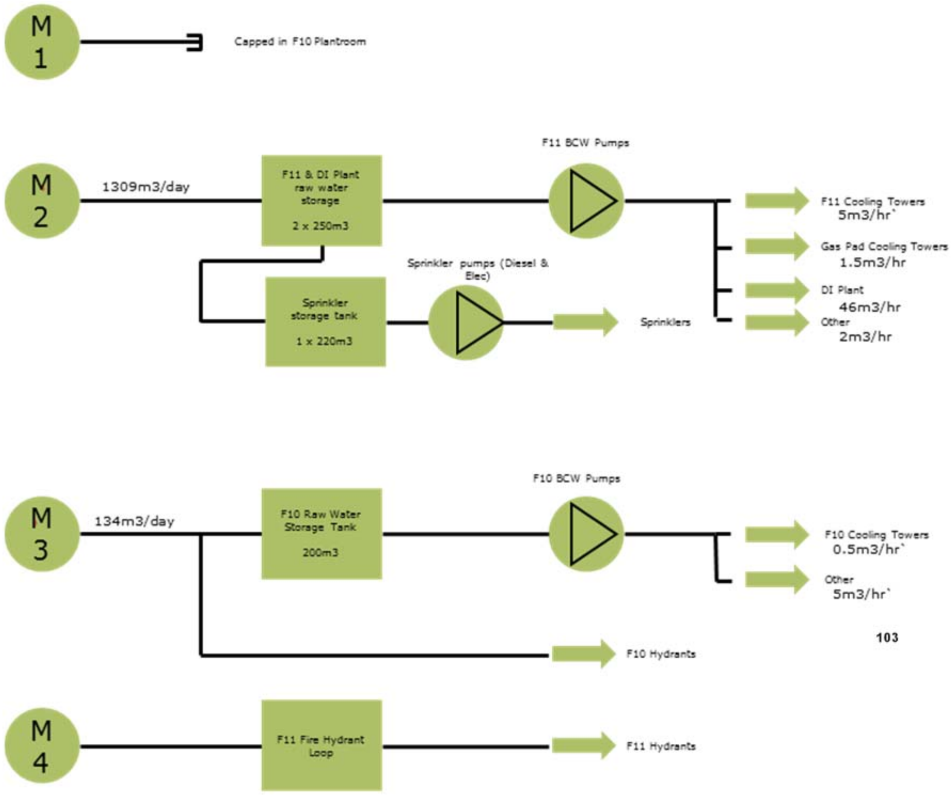
Similarly to the requirements of 2.4.1, Raw Materials Selection, and IRN's internal specifications for supply chain review, Environmental Health and Safety review, any identified changes to raw materials used are subject to a rigorous procedure prior to their introduction. This is undertaken via the Process Change Review Board (Specification No 62-0163 "Process Change Procedure"). The requirements of the process change procedure require advance consideration and longer term study of the effects of proposals/changes made to site materials prior to use, during and post process changes. However, where it is possible to substitute materials for less polluting options, IRN give these a high priority.

For example, over the last few years the use of R22 refrigerant has gradually been tightened (no virgin material to be used, to no recharging at all). To ensure we remained not only compliant but planned ahead for a potential total ban, we reviewed the materials used within our cooling systems, bringing in specialist contractors AND their advisors from the trade body to discuss. We are now on a rolling program to change systems to charge with gasses with improved environmental credentials (R134A).

WATER DATA

Overall Water Balance

Flow diagrams and water mass balances for the activities should be produced.



Water Flow Diagram

Site Water Storage Capacities:

- F11 & F10 Sprinkler Feed Tank 220 m^3
- F10 Raw Water 200 m^3
- F11 Raw Water 250 m^3x2

Services Fed from F11 Raw Water:

F11 DI Plant (Servicing F10 & 11)

F11 Energy Centre Cooling Tower Make-up

Closed Water Circuit Pressurisation Units

BOCE Gas Plant Cooling Towers

Toxic Extract Scrubbers

Safety Showers

Wet Bench Drain Aspirators

Wet Bench Actuators

Probe Back grinders

Wet fire systems

Details of F10 & 11 Site DI Production / Circulation:

DI Water Generation – Reverse Osmosis (RO) Feed Water

- RO Membranes 76.6% efficiency
  (improved from 73.3% following membrane upgrade)

- Feed Water Volume 46 m^3/hr
  (reduced from 80 m^3/hr due to RO membrane change, RO reject recovery, and site facilities rationalisation)

F10N / F10S DI

- Circulation 36 m^3/hr
  (reduced from 72 m^3/hr due to facilities rationalisation)

- Usage 15 m^3/hr
  (reduced from 30.5 m^3/hr due to facilities rationalisation)

F11 DI

Note: during the period under review, production capacity has been transferred from Fab10 to Fab11. The equipment in the latter uses water more efficiently thus while total manufacturing output has increased the quantity of water has remained largely static; this is reflected in the figures below. Please see also graphs for water versus silicon later in this report.

- Circulation 55 m^3/hr (was 57 m^3/hr)
- Usage 27 m^3/hr (was 26.5 m^3/hr)

Total Site DI Usage

- Total Usage 43 m^3/hr
  (reduced from 57 m^3/hr. This figures also includes water used in air handlers not itemised above)

RO Storage Capacity	50 (60) m^3	x3 off
F10 UHP Water Storage Capacity	50 (60) m^3	x1 off
F11 UHP Water Storage Capacity	50 (60) m^3	x2 off

NB: UHP water storage for F10 / 11 can be cross-coupled. Figures in bracket represent maximum theoretical storage, stated figures represent actual usable storage volumes.

Services Fed from F10 Raw Water:

F10 BCW

- Cooling Tower Make-up
- Closed Water Circuit Pressurisation Units
- Safety Showers
- Wet Bench Drain Aspirators
- Probe Back grinders

Combined Site Raw Water Usage:

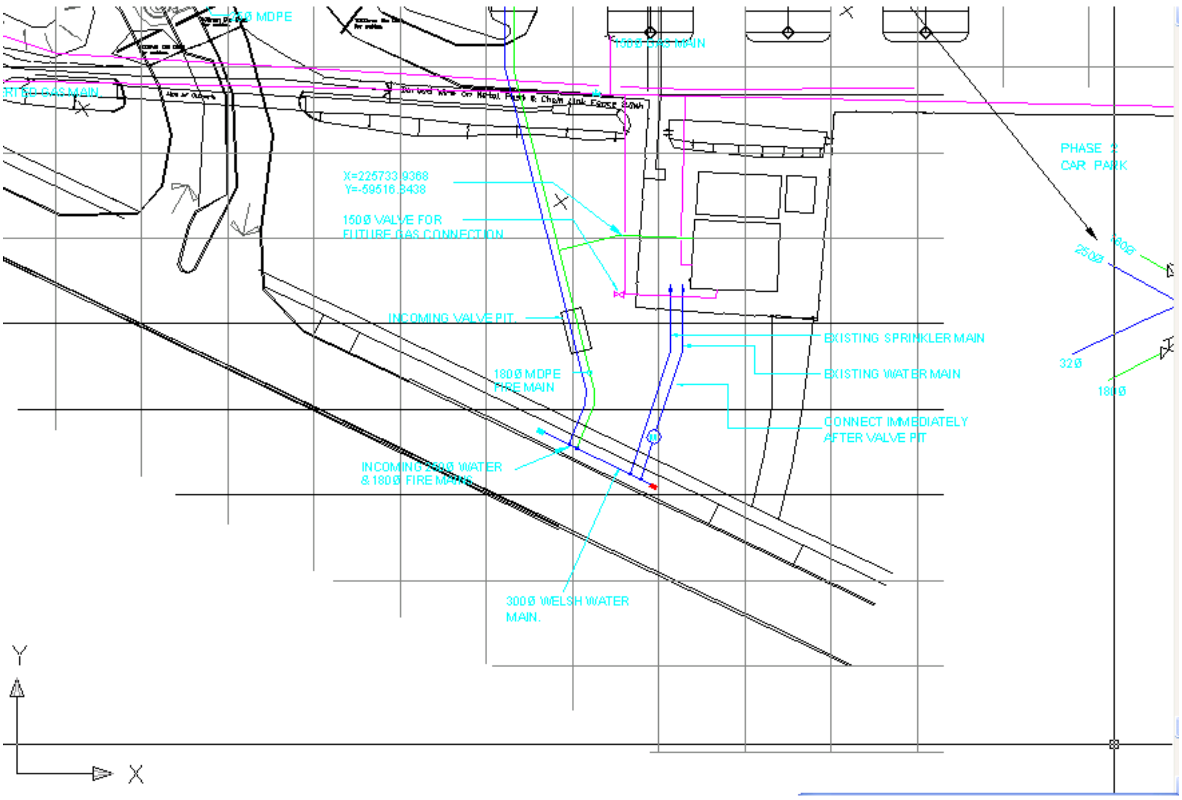
F10N&S	134 m^3/24 hr (was 251 m^3/24 hr)
F11	1309 m^3/24 hr (was 2221 m^3/24 hr)
Average Site Usage	60 m^3/hr (was 103 m^3/hr)

Site Water Mass Balance:

Cooling Tower Losses:

- F10N Cooling Towers (x3 off) — 0.5 m^3/hr
  (Loss stated is combined average. Was 6 m^3/hr)
- BOCE Gas Pad Cooling Towers (x2 off) — 1.5 m^3/hr
  (Loss stated is combined average. Was1 m^3/hr)
- F11 Cooling Towers (x3 off) — 5.0 m^3/hr
  (Loss stated is combined average. Was4 m^3/hr)

DI Production (RO Feed Water)	46 m^3/hr (was 80 m^3/hr
Other process usage (F10 & 11 Other)	7 m^3/hr (was 12 m^3/hr)
Total	60 m^3/hr (was 103 m^3/hr)



Site Water Meters Diagram

Water-efficiency objectives should be established, with constraints on reducing water use beyond a certain level being identified (which usually will be installation specific).

Targets are set annually to reduce the volume of water consumed measured against the quantity in metres squared of finished product (silicon) shipped. Performance is tracked through the EMS review process.

In 2015 IRN achieved ISO50001 certification for which energy performance against predicted usage is tracked. Now in the second full year of this process, IRN aims to extend the scope of the EnMS to include water metrics. Currently, the intention is to run this in parallel with the EMS review process noted above.

Over the last year the site has also undertaken (and been awarded) Carbon Trust standards for both waste and water. We believe that this reinforces the site's commitment to ongoing waste and water minimisation and its maximisation of environmental responsibility.

Measures should be in place to minimise the risk of contamination of surface waters or ground water by fugitive releases of liquids or solids.

A Site Protection and Monitoring Programme (SPMP) is in place and is incorporated into ISO14001 to ensure auditing and compliance are tracked. The SPMP monitors those areas at risk (although already accepted as low) to ensure the site surfaces, secondary containment and tertiary containment systems are fully inspected and monitored for effective containment against accidental release of fugitive release of solids or liquids.

In 2016 IRN also started a review process for COMAH with respect to Environmental Risk Assessments. This has progressed and is currently in phase 2 of the CDOIF type assessments which we believe should give extra clarity for any potential risk areas.

This review is also proposed to be issued to NRW for update for our COMAH control and compliance.

Surface water is effectively segregated from all effluent on site via a complex drainage system, which is held up on an onsite lagoon (pond supporting life) for use as firewater should an emergency situation occur. Due to the exceptionally high quality water required for processing within the installation, surface water cannot be reused in the main process nor in cooling systems in case of cross contamination.

PROJECTS

Following discussion with NRW, we are broadening the scope of this review to cover not just water usage but energy usage as a whole. As noted above, targets are set and tracked through the EMS (electricity, water and waste) and EnMS (electricity and natural gas, plus water from 2017 onwards). Supporting documentation including the procedures for targeting and tracking are held on site and are available for review on site.

Details of projects undertaken for energy and water efficiency improvements can be found in Appendix 3.

WASTE DATA

The onsite waste contractor provides detailed analysis of the waste produced on site and its disposal route. IRN sets annual targets for increasing the percentage of waste recycled and tracks the total volume against product shipped (silicon metres squared).

> *A system should be in place and maintained which records the quantity, nature and origin of any waste that is disposed of or recovered – and also, where relevant, the destination, frequency of collection, mode of transport and treatment method for those wastes.*

The system employed by IRN to record the quantity, nature, origin and disposal of waste, is defined within the Waste Management Service Level Agreement IR Newport document number 22-0152.

This service level agreement or SLA, describes the management of collection, handling, sorting and disposal of site waste by a waste management service provider. The current waste management service provider is Biffa UK Ltd who has two permanent waste technicians on site handling all on-site waste movements.

The contractual requirements of the SLA ensure the quantity, nature and, where applicable, origin of waste is recorded and reported on a monthly basis. This is further enhanced by a contractual requirement for the waste service provider to further recover or recycle waste streams wherever possible to enable the site environmental targets for recycling to be achieved.

A summary of waste streams, frequency of collection, mode of transport and treatment is provided in Table 1.

* *Average frequency of collection*

Table 1. Summary of Waste Streams (Sept-2016)

WASTE STREAM	FREQUENCY OF COLLECTION *	DESTINATION	MODE OF TRANSPORT	TREATMENT	RECOVERY OR RECYCLING
Process inorganic chemicals	Continuous	Welsh Water treatment plant	Effluent sewer	Neutralization	No
Inorganic chemical emissions (air)	Continuous	Welsh Water treatment plant via fume scrubber plant	Effluent sewer	Fume scrubbers and neutralization	No
Organic (VOC) emissions (air)	Continuous	Atmosphere	Solvent extract	Pyrophoric abatement	Not applicable
Canteen waste	Weekly	Bulking – then AD	Mobile compactor	Anaerobic digestion	Yes
Wood	Monthly*	CS waste	26.8 M^3 Open skip	Chipping - Bio fuel	Yes
Metal (Ferrous)	Monthly*	Griffiths Stringer	26.8 M^3 Open skip	Recycle (splitting) Removal of any non-metallic materials	Yes
Plastic	Monthly*	Envira	26.8 M^3 Open skip	Washed to remove trace contamination – Crushed and pelletized	Yes
Aluminum	Monthly*	Griffiths Stringer	15 M^3 skip	Recycle (splitting) Removal of any non-metallic materials	Yes
Cardboard	Monthly*	Envira	Pallets	Paper mill / pulped	Yes
Solvents and organic liquids	Fortnightly	Tradebe Solvent Recoveries Fawley	Road tanker	Incineration/ furnace pre-heat	Yes
Glass	Monthly*	Bulking – then recycle	Mobile compactor	Crushed / Recycle	Yes
Paper(confidential)	Monthly	Licensed waste subcontractor Recycling Centre Cardiff	Via road	Shredding / cross cut - Recycle	Yes
General Dry Waste	Monthly*	Atlantic	26.8 M^2 Open skip and 26.8 M^2 compactor	RDF	Yes
Hazardous waste	Monthly	Biffa - Cardiff - Licensed waste subcontractor Via waste Transfer & Bulking station	1000 L^3 waste safes	Multiple, neutralization then- disposal	No
Batteries (lead acid & alkaline)	6 months*	Biffa - Cardiff - Licensed waste subcontractor Via waste Transfer & Bulking station	100 L^3 Mini Waste safe	Recycle	Yes
IT and electronic scrap	Quarterly*	Biffa - Cardiff - Licensed waste subcontractor Via waste Transfer & Bulking station	Pallet box	Segregation and Recycle	Yes
Ink and toner cartridges	Quarterly *	Clover Environmental Solutions	Via road	Reuse	Yes
Polishing waste (slurry)	Daily	Welsh Water treatment plant	Effluent sewer	Neutralization	No

Wastes should be segregated wherever practicable, and the disposal routes identified. Disposal should be as near to the point of generation as practicable.

Processes have been developed and documented to ensure the primary waste generating areas, Fab 10 and Fab 11, segregate their waste streams and that they are correctly identified, defined within IR Newport document; 02-5610 Manufacturing Waste Disposal Procedure.

Segregated waste streams generated within the site are collected by the onsite Waste Technicians and disposed of via the correct disposal routes. The documented process for waste disposal is defined within IR Newport document; 02-5681 Waste Disposal Control Procedure.

Records should be maintained of any waste sent off-site (Duty of Care).

All movement of waste off-site is controlled by a licensed waste subcontractor, currently, Biffa UK Ltd. They maintain comprehensive records of waste transfers (Transfer Notes). These records are retained by on site and are subject to scheduled audits by both internal and external auditors.

Waste that is classified hazardous i.e. waste that is toxic, corrosive or environmentally hazardous, requires approval via a Section 62 document issued by the Environmental Agency a minimum of 3 days prior to the waste being shipped. These records (section 62 copies) are retained on site and are also subject to scheduled audits by internal and external auditors.

Appropriate steps should be taken to prevent all emissions from waste storage and handling (eg: liquid or solid spillage, dust or VOC emission)

Strict guidelines have been documented for the handling and storage of all waste streams encountered onsite. These are contained within: 02-5681 Waste Disposal Control Procedure.

These guidelines (above) ensure that hazardous waste is safely collected daily from defined collection points across the site and moved to the waste compound where it is sorted and placed in designated containers. Containment of waste is ensured by the use of double bagging. Waste storage containers are primarily Waste Safes ™ or steel drums situated in the bunded waste building. Organic liquid waste is piped from the manufacturing areas into bunded holding tanks for collection and recovery by the Waste Contractor’s road tanker.

Waste should be recovered, unless it is technically or economically impractical to do so

All the current waste streams identified in Table 1 have been subjected to an assessment to identify technically and financially viable improved environmental options for waste disposal.

The assessments, summarized in Table 2, found that all current waste streams are either 100% recycled, reused or disposed of using best available environmental practices.

As part of the site’s ongoing waste minimisation activities we are actively implementing the waste hierarchy – waste minimisation targets are set in our annual EMS (Environmental Management System) report and have allowed us to show a sustained and significant improvement in this stream. A number of opportunities have been pursued, including:

RDF – Refuse Derived Fuel:
This has allowed a marked improvement in our overall waste disposal and has seen us go from a situation pre-2014 where 50% of our non-hazardous waste had a disposal route that was landfill to a typical landfill disposal quantity of < 10% during 2014 and < 2% in 2015. At the time of writing, our rate of non-hazardous waste to landfill is zero.

The employment of a second onsite waste operative has enabled us to introduce further specialist segregation for materials resulting in a reduction in overall waste generation and enabling better reuse/ recycle options to be explored.

Waste targets and projects are identified and tracked through the annual EMS review process.

Table 2 Waste Assessments

WASTE STREAM	CAN THIS WASTE PROCESS BE ELIMINATED	CAN THIS WASTE PROCESS BE SUBSTITUTED	CAN THE RAW MATERIALS BE SUBSTITUTED	CAN THIS WASTE BE RECYCLED OR REUSED
Process inorganic chemicals	Process chemicals consist primarily of acids (HCL, HF, H2SO4, H3PO5, HNO3) bases (NH4OH) and oxidisers (H2O2). These are blended or diluted by automated wet processing equipment to produce etchants and cleaning reagents used at critical manufacturing process steps. Removal of these steps would not allow manufacturing of semiconductors	Etching using wet chemicals has diminished during the last 20 years due to the introduction of alternative techniques such as plasma etchers. The current etching process steps have currently no available chemical alternative. Cleaning process steps using various chemical blends are used to remove organic residues and particles from product surfaces. Substitute non proven techniques may become available such as Carbon dioxide crystal (dry ice) blasting, ozone and dilute chemistries at high capital investment and require investigation.	The current manufacturing processes use technologies and techniques that are require these chemical agents. Semiconductor processing throughout the industry uses these process steps, which have been developed to give the most effective process yields and product reliability.	The inorganic process chemicals used are the purest available (< 1ppb impurities) and filtered to 0.2 micron to eliminate particles. Once used within the process in is not possible to unblend these chemicals and remove impurities to < 1ppb using currently available technologies
Inorganic chemical emissions (air)	Inorganic chemical emissions to air result from the operations described above therefore elimination from current manufacturing processes is not possible. Chemical emissions are minimised to meet environmental regulations by the use of fume extraction scrubbers, which remove the chemicals from the factory fume extraction system.	See above	See above	See above

WASTE STREAM	CAN THIS WASTE PROCESS BE ELIMINATED	CAN THIS WASTE PROCESS BE SUBSTITUTED	CAN THE RAW MATERIALS BE SUBSTITUTED	CAN THIS WASTE BE RECYCLED OR REUSED
Solvents and organic liquids	Primarily organic solvents (alcohols and glycol ethers) are used to vapour dry wafers at several stages of the manufacturing cleaning/etching processes and to dissolve or remove resin based coatings applied to wafers during lithography process cycles. There is no current alternative industry technology available to remove these process steps during semiconductor manufacturing.	There is no current alternative semiconductor industry technology available to substitute these process steps during semiconductor manufacturing.	The types of organic solvents used are chosen to produce the safest, most efficient and most cost effective processes for the manufacture of semiconductors. Currently no alternative substitutes are available from semiconductor chemical suppliers or being suggested by leading industry technology companies.	Organic solvents are required to have impurity levels < 1ppb and filtered to 0.2 micron. Once used within the manufacturing process there is no technology available to remove contamination and allow reuse. However recycling for other industry applications via a solvent recovery plant. Currently IR Newport sends 100% of organic solvents for recycling
Organic (VOC) emissions (air)	Organic solvent emissions are generated by the process steps discussed above therefore at present there is no scope for process step elimination. However, because of the harmful and hazardous nature of these chemicals all processing is conducted under solvent fume extract which removes VOC from any human interface – this is then discharged via dilution	See above	See above	VOC are removed from the process tolls and sent to a common solvent extract system. The combined VOC are extracted and discharged via a “solvent” extract dilution system.
Canteen waste	Waste is generated by the delivery of supplies to the Catering contractors. No acceptable alternatives for current food packaging regulations have been found by the current Catering company	No	Audit of the raw materials (food) found the packaging materials used are the same regardless of food type	Separate bins now ensure that cardboard, plastic and metal packaging is recycled. Food waste is collected separately and sent for recovery via anaerobic digestion

WASTE STREAM	CAN THIS WASTE PROCESS BE ELIMINATED	CAN THIS WASTE PROCESS BE SUBSTITUTED	CAN THE RAW MATERIALS BE SUBSTITUTED	CAN THIS WASTE BE RECYCLED OR REUSED
Wood	Wood waste is a by-product of current transportation methodologies, in the case of IRN, pallets and packing cases. No alternative is available currently by suppliers	Wood is currently being used for pallets because of the prohibitive costs of alternative materials such as plastic. Packing cases are constructed of wood to provide cost effective protection to machinery and tools delivered to site. No alternative available	See opposite. Wood is suppliers and transportation companies material of choice.	Pallets are returned to suppliers or sent for redistribution via Licensed waste subcontractor. Damaged pallets are sent for recycling. Wooden packing cases are one-trip as they are dismantled as part of the un-packing process and are sent for recycling.
Metal (Ferrous)	Metal waste is a by-product of construction & civil work carried out on the site and the disposal of obsolete equipment, materials and furniture. Audit of waste stream shows elimination of metallic waste is not attainable	Currently no opportunity to retain in service obsolete or malfunctioning metal equipment or materials with e.g. plastic	Because of the application attributes of metal, there is limited (if any) opportunities to replace metal with other materials	100% of metal waste is currently recycled via a scrap metal company
Plastic	Process cannot be eliminated as primary waste streams are plastic stream is wafer shipping boxes and solvent bottles	Shipping of wafers and solvent can only be substituted if they were manufactured on site which is not viable	Materials used in shipping wafers and solvents are required to be of ultra high purity PP and HPPE to eliminate contamination of raw material. Industry technology leaders have not identified alternatives	100% of major plastic waste streams are shipped to a plastics recycler.
Aluminium	Aluminium waste results from use of aluminium targets to sputter metal layers onto wafers. These layers are the circuitry of the device therefore the process cannot be eliminated	Waste aluminium is generated by the change out of the target before it is fully used. The change out process cannot be substituted since this is a process scrap protection step whereby the risk of fully depleting the target and sputtering the target support material on the wafer is eliminated.	Aluminium is chosen because of its metallurgical properties. No other metals have be found suitable for the processes currently in production	100% of aluminium waste is currently recycled by shipping to a smelter

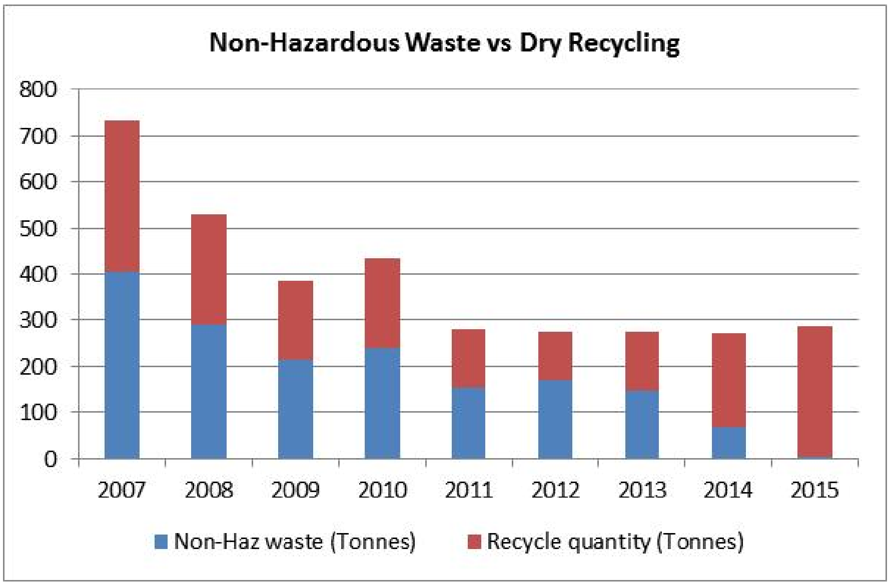
WASTE STREAM	CAN THIS WASTE PROCESS BE ELIMINATED	CAN THIS WASTE PROCESS BE SUBSTITUTED	CAN THE RAW MATERIALS BE SUBSTITUTED	CAN THIS WASTE BE RECYCLED OR REUSED
Cardboard	Cardboard waste is being produced via raw material packaging. Cardboard is the choice of outer packaging of the majority of suppliers because of its cost and recycling opportunity. At the time of audit suppliers had no roadmaps to replace cardboard packaging	The use of cardboard packaging that is disposed of after delivery cannot be substituted by shipping IR finished goods because of the type of shipping containers used	Substitutes such as corrugated plastic are currently minimal and only suitable when used in conjunction with foam inserts therefore producing a less environmentally friendly package	Cardboard is recycled via segregation and shipping to a re-processing factory
Glass	Glass waste is the result of breakage of furnace tubes and the replacement of worn or contaminated quartz glass. Currently wear and contamination are a factor in every semiconductor facility and cannot be eliminated	Furnace operations which utilise glass cannot be substituted because of the risk of product contamination	Glass (quartz) is the industry choice for materials of construction for furnace tubes and tube furniture. No other material has been found to be comparable in terms of ionic and particle contamination risk	Quartz glass parts can be repaired and reused whilst broken or contaminated items can be recycled
Paper	Waste paper is primarily originating from office bins. Paper (lint free) has been minimised in manufacturing areas by the introduction of electronic document control. WIP tracking and data entry are also via electronic interface, negating the need for paper. Several office operations (reports, records, databases, training material) still require a degree of hard copy media	Paper being substituted by “soft copy” electronic communication is widespread and the method of choice within the factory.	No alternative to paper has been found where “hard copy” is required although wherever possible data and information is exchanged via electronic means	Paper recycling bins are widespread within the office areas. Waste paper is collected and recycled via licensed waste subcontractor

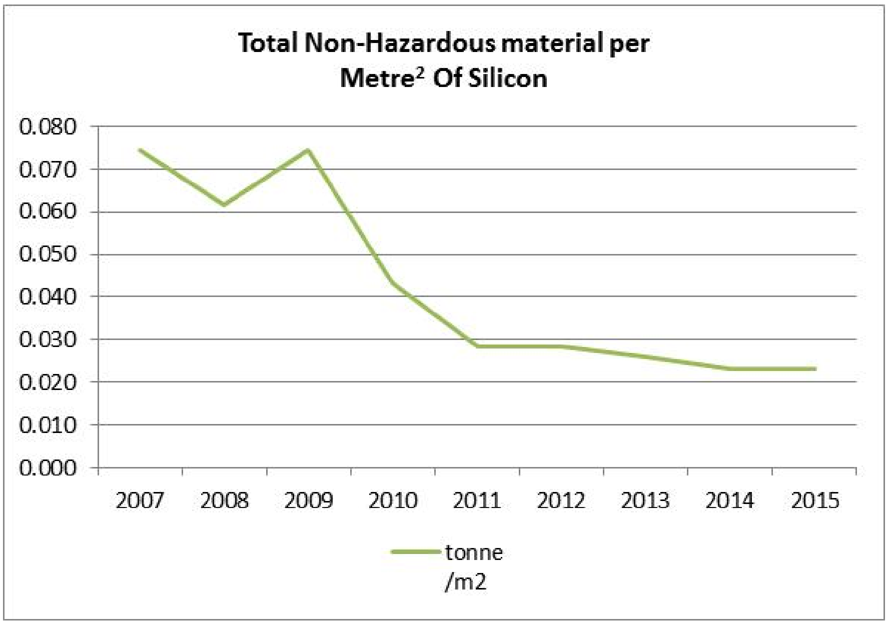
WASTE STREAM	CAN THIS WASTE PROCESS BE ELIMINATED	CAN THIS WASTE PROCESS BE SUBSTITUTED	CAN THE RAW MATERIALS BE SUBSTITUTED	CAN THIS WASTE BE RECYCLED OR REUSED
General Dry Waste (unsortable combinations of above)	Waste that is impossible or difficult to segregate into recycling streams is designated General Waste. This waste originates from Manufacturing bins and site civil or project work and cannot be eliminated further	Site maintenance and re-engineering will generate waste due to renewal and replacement of materials. Waste from Manufacturing bins cannot be substituted since clean up materials, wipes, cloths etc are essential in maintaining contamination free conditions	Cleanroom wipes are essential in removing contamination and maintaining a safe working environment and have been developed for semiconductor operations. No viable substitutes exist	All General waste that is not pre segregated is now sent for RDF (Refuse Derived Fuel) and the heat generated is classed as reuse rather than waste.
Hazardous waste	Hazardous waste is produced via the process chemicals and gases used to manufacture semiconductors therefore these material cannot be eliminated	The creation of hazardous waste is an inherent part of the production process.	Hazardous raw materials (chemicals and gases) are substituted wherever possible to introduce safer and less environmental impacting materials. Majority of the industry initiatives are driven by technology leaders and regulations such as the Montreal protocol	No opportunity exists to recycle or reuse hazardous waste.. Better analysis and sorting has resulted in overall reduction in hazardous waste.
Batteries (lead acid & alkaline)	This waste stream is a product of equipment necessity and cannot be substituted at this time	No further opportunity for substitution exists. Batteries are required for portable equipment and tools	Wherever possible re-chargeable batteries are used in laboratory situations. Most batteries are required to be changed out before depletion to meet safety and risk assessment criteria.	Waste batteries are segregated into dedicated waste bins for disposal via licensed waste subcontractor.
IT and electronic scrap	IT scrap cannot be eliminated since equipment (PC, printers, VDU etc) become unserviceable or incapable	There is no substitution available for this type of waste	There is no substitution available for this type of waste	Scrap IT equipment is potentially reusable at component level and most materials of construction (plastic, metal) can be recycled (this is disposed of via licensed waste subcontractor)

WASTE STREAM	CAN THIS WASTE PROCESS BE ELIMINATED	CAN THIS WASTE PROCESS BE SUBSTITUTED	CAN THE RAW MATERIALS BE SUBSTITUTED	CAN THIS WASTE BE RECYCLED OR REUSED
Ink and toner cartridges	Printer consumables cannot at present be eliminated with the current generation of printers onsite	(see paper waste stream). Wherever possible hard copy information is avoided	High volume ink cartridge machines have been replaced by laser printers to minimise waste. However opportunities limited in applications such as drawing office	Ink toner and cartridge waste is suitable for reuse. All empty toner/ink cartridges are consigned to recycling points and despatched for refilling and reuse.
Polishing slurry waste (slurry)	Polishing is an essential process and cannot be replaced.	No alternative is currently available for wafer planarisation	The raw materials are silicon oxide and buffering agents. Currently there is no alternative technology	The polishing slurry waste is non-hazardous. It is discharged in a controlled manner via the onsite effluent treatment plant.

APPENDIX 1: WASTE DATA

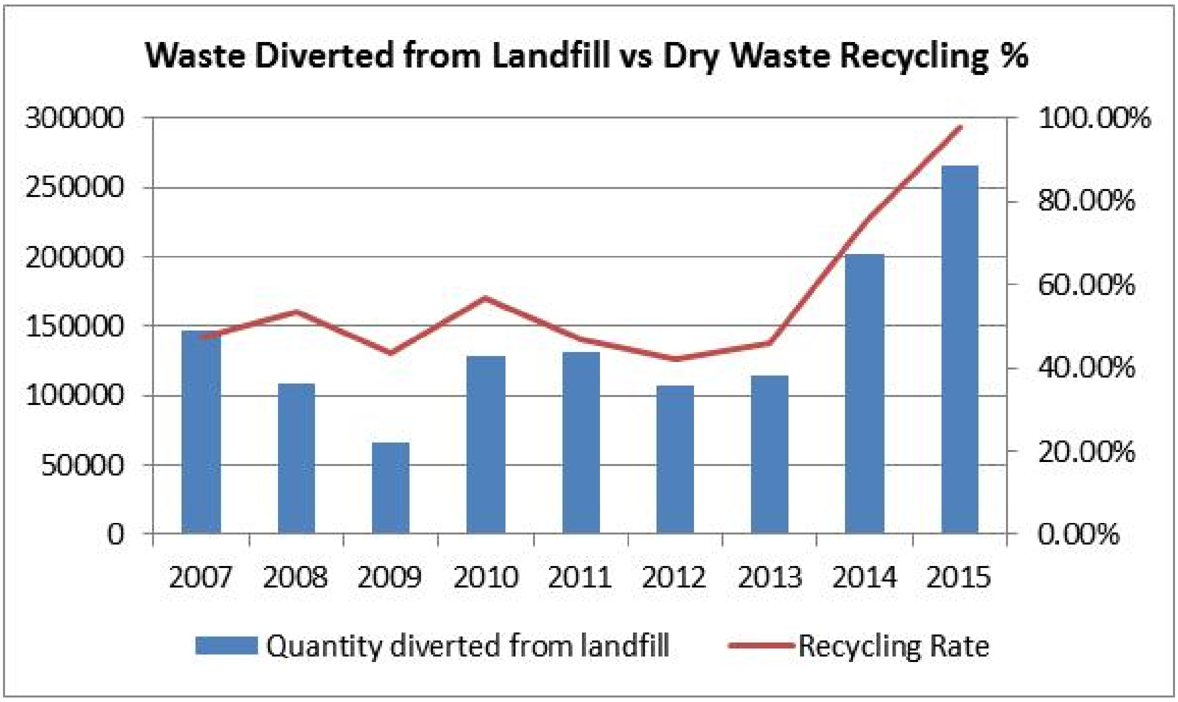
The onsite waste contractor provides comprehensive metrics which are reviewed on a regular basis and performance against targets is reviewed annually as part of IRN's EMS process.





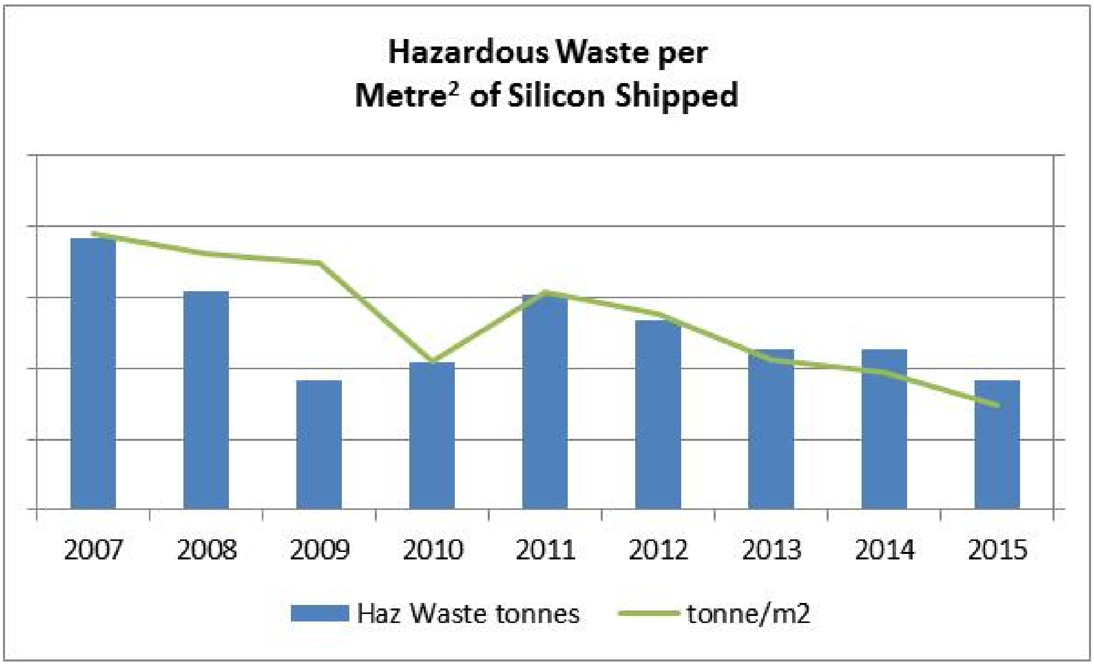
From the graphs it can be seen that the overall trend for the quantity of non-hazardous material produced on site has fallen significantly. The stabilisation in overall quantity in recent years is impressive when viewed against the continued rise of material output (e.g. we are making more product without an increase in waste).

The other half of the story is also the shift in what happens with this waste (disposal vs recycling). This has changed from a typical 50% recycle rate to 98%+



The biggest changes on site in recent years has been with the reduction of “disposed” waste with the push on site to be a “0 to landfill site”

The quantity of waste diverted from landfill has increased meteorically since 2013 with the site now running at 98% (or higher) recovery or recycle rate for non-hazardous material.



Hazardous waste is influenced by manufacturing activity on site; the graphs above reflect the transfer of production to the more modern and efficient 8" facility since 2011.

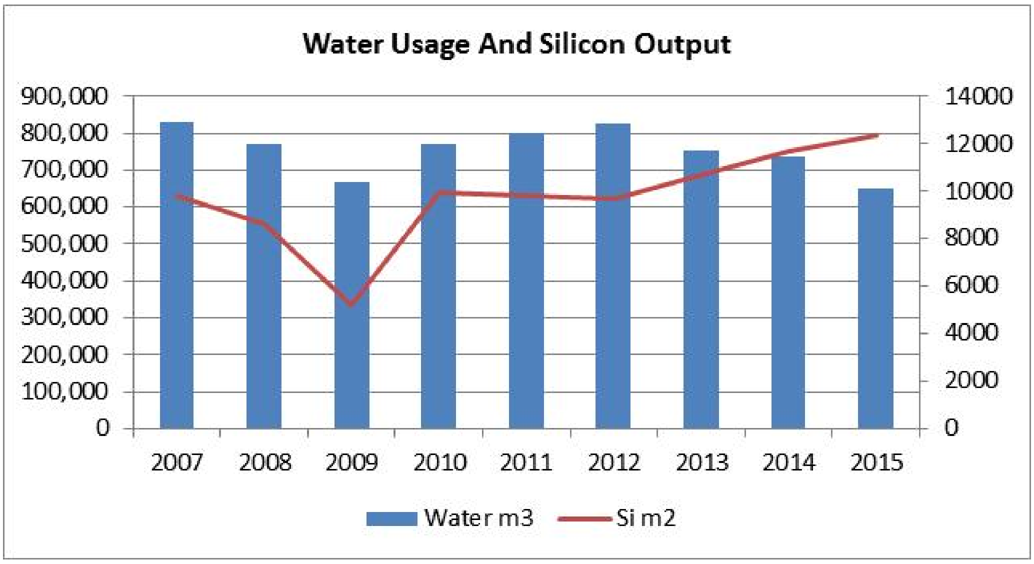
APPENDIX 2: WATER DATA

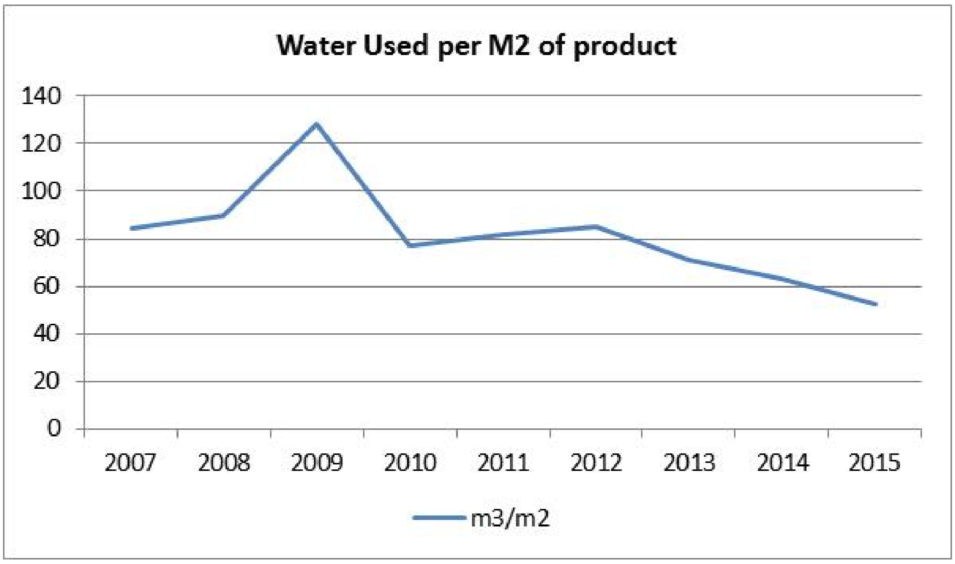
The silicon industry, in a similar way to the steel industry, can have a very high fixed water usage value. As discussed in these reports previously, many of our systems cannot simply be switched off, as it is necessary to control the performance of tools to allow future re-enabling. A formerly cited example was temperature and humidity control systems that are very water intensive, and are required to run 24/7 to maintain fab control regardless of manufacturing throughput.

On top of this, our processes use a large base quantity of resource, regardless of the quantity of silicon being produced.

We noted in our last review that IRN had seen a significant investment in new production equipment and processing capacity: in 2009 during a period of output contraction, and in 2012 during a period of output growth. This had the effect of skewing our water usage figures because of the large water footprint during the commissioning phase.

The tool suite is now fully installed and as can be seen from the graphs below, total water usage has fallen consistently and significantly since the completion of the commissioning. This has corresponded with a steady increase in output and has resulted in the lowest ever usage figures per m^2 of silicon output.





An increased focus on water use / minimisation and associated projects have also helped to maintain the falling trend for water usage with some of the significant water saving projects (RO reject reclaim and heat pipes / larger cooling coils) being listed in Appendix 3

WATER USAGE PLAN

IRN sets a target of reducing water usage against silicon output through the Environmental Management System (EMS) review each financial year.

Past performance can be summarised thus:

FY07 vs FY06	7% reduction
FY08 vs FY07	21% reduction
FY09 vs FY08	49% increase
FY10 vs FY09	25% reduction
FY11 vs FY10	18% reduction
FY12 vs FY11	14% increase
FY13 vs FY12	12% reduction
FY14 vs FY13	10% reduction
FY15 vs FY14	9% reduction

APPENDIX 3: PROJECTS

1. **Heat pipes + larger cooling coils**
   When: 2015 phase1, 2016 phase2 planned.
   Area of improvement: Energy and manufacturing stability
   Explanation: save energy and improve manufacturing stability by installing and using a passive heat transfer system and increasing the surface area of the cooling coils
   Detail: utilising heat transfer fluid technology air is pre cooled prior to dehumidification. Then, that (previously removed) energy is used to reheat the air following the dehumidification process (all of this is a passive process and so requires no additional energy input). This is a significant change to original "active" powered systems used as an industry norm. The second area is the install of larger cooling coils allowing more efficient transfer of heat to our existing free cooling system and tighter system control.
   Cost: ~£35,000
   Payback: 3 years in terms of cost, energy savings of 174MWh reheat energy and 48MWh cooling energy + unquantified increase in free cooling savings
   Project Scale: medium
   Challenges: higher install costs than expected, space restrictions leading to increased condensation carryover initially (now rectified)

2. **Process vacuum pump replacement**
   When: 2015/16
   Area of improvement: energy + reliability
   Explanation: save energy and improve reliability of process equipment by implementation of new technology
   Detail: installation of new technology vacuum pumps with increased efficiency allowing reduction in use of electricity, nitrogen and cooling water (project replaced 60+ high vacuum pumps).
   Cost: ~£650,000
   Payback: 2.5 years on cost
   Project Scale: Large
   Challenges: managing down time of production tools while install being undertaken – no impact of processing line allowed.

3. **LED lamp replacement**
   When: 2014
   Area of improvement: energy + reliability
   Explanation: Replacement program of site lighting to LED type lamps
   Detail: Rolling program for offices and support building to replace incandescent lamp options to high efficiency LED lamp versions.
   Cost: ~£80,000
   Payback: 14 months on cost, increase in quality of lighting, reduction in ongoing maintenance requirements, reduction in stores stock held.
   Project Scale: medium
   Challenges: unexpected modifications for some fittings to allow use of new lamps, decision of lighting colour temperature (how white), longevity of support electronics with some lamp options (premature failure of power supplies)

4. **High efficiency air handler filtration**
   When: 2013/14
   Area of improvement: Energy
   Explanation: Energy saving by change of filtration type
   Detail: Through the use of technology improvements, standard filters were replaced with low pressure drop / high flow units allowing main air handler fan speeds to be reduced while still maintaining required flow volume.
   Cost: ~£10,000
   Payback: < 1year on cost
   Project Scale: small

5. **High efficiency Reverse Osmosis (RO) – High Purity water generation**
   When: 2016
   Area of improvement: energy + quality of RO water
   Explanation: Energy saving and improvement of water quality achieved by change of filtration type (similar to project 4 above (water not air!!))
   Detail: Again through the use of new technology for water filter membranes – “old style” membranes were replaced with low pressure drop / high flow units, thus pumps could be run at a lower speed, while still maintaining required flow.
   Cost: £35,000
   Payback: 1 year – Project was timed to coincide with replacement of membrane (therefore incremental cost was circa £12,000)
   Project Scale: Medium
   Challenges: no inverters on system so these needed to be fitted to enable control of 7motors and realise savings.

6. **RO (high purity) reject water reclaimed**
When: 2015
Area of improvement: water + electricity
Explanation: Following further treatment, reuse of partially processed water back into high purity water stream
Detail: As part of the high purity water generation, salts and contamination were originally rejected – this reject fluid is now recovered and fed back into the process. Further cleaning is undertaken on this stream and the recovered water is then added into the high purity process water (all with less processing required than for mains water as originally used)
Cost: £80,000
Payback: saving of $10m^3$/hr of high purity water (equivalent to $13m^3$/hr raw (mains) water), equivalent to <1 year for cost + reduction in effluent stream quantity.
Project Scale: medium
Challenges: needed to install a Carbon dioxide removal system as premature fouling of membranes was occurring.

7. **Development of load modelling and load centre review system**
When: 2015
Area of improvement: monitoring and reporting
Explanation: Development of a detailed monitoring **and** prediction system to highlight unexpected changes in energy consumption
Detail: Creation of a prediction system that allows simple review of energy use to highlight changes in significant energy streams (now expanded to include gas and some water) and thus enable early investigation into saving opportunities **or** highlighting and early intervention for systems that are not behaving normally.
Cost: time of internal energy experts
Payback: achievement of ISO 50001 energy standard, early detection of problems and energy saving opportunities (within first year, numerous examples of system issues being identified – eg. Systems historically always running that way that (when changed) can be shown to save £1000's of pounds a week!
Project Scale: medium
Challenges: installation of further meters, training and expertise of internal energy team, quantity of time to create, manage and maintain system.

8. Zero percent to land-fill waste programme

When: 2015 to current
Area of improvement: Waste minimisation
Explanation: Challenge was to move from existing running regimen to a “0% to landfill” status
Detail: Over 2015 we modified and improved options for our waste stream to enable us to move from a good situation (typically 40% recycle/ recovery / 60% landfill) to a “Best in class” of 0% landfill.
This transformation entailed installation of further segregation routes to allow increased division of “waste” thus allowing increases in recycling, the installation of a process to allow RDF (refused derived fuel) option for the streams not suitable for recycling, including auditing of facilities, increased control of “general waste”, office segregation options, more detailed training of staff and embedded contractors, reinforcement of waste policy and improvement in communications and staff engagement.
Cost: ~£5,000
Payback: Achievement of Carbon Trust Waste Standard award, support of ISO 14001, accolade of 0% Waste to landfill and recognition of such by NRW (Natural Resources Wales), plus <1 year on cost
Project Scale: Medium
Challenges: Education of staff, increase in duty of care auditing, small increase in management time requirement.

9. Review of process air extract system – damper rationalisation

When: 2014/ 2015
Area of improvement: Energy
Explanation: Energy reduction through removal of false restrictions
Detail: Following thorough investigation of the air extract system, a number of unexpected pressure drops were identified. Through re-evaluation of this, a number of un-necessary dampers were removed reducing system pressure drops and thus allowing fans to run at a reduced speed with no impact to process extract pressure or quantity.
Cost: £2000
Payback: <6months on cost + improvement in process stability
Project Scale: Medium
Challenges: Access to full ductwork network. Access to dampers and removal without impacting manufacturing

10. High efficiency toxic extract scrubber packing

When: 2014
Area of improvement: Energy and air scrubbing efficiency
Explanation: Energy saving and improvement of scrubbing achieved by change of internal packing media
Detail: Use of design improvements for packing material allowing replacement of "old style" toxic scrubber internals with technologically advanced high flow units, thus enabling lower running rates of pumps while still maintaining scrubber efficiency and scrubber flow.
Cost: £150,000
Payback: <3 years on cost + reduction in likelihood of failure due to build-up of precipitates
Project Scale: medium
Challenges: Project had to be completed during full site shutdown (site normally runs 24/7/365), therefore time constrained and limited opportunity (actually completed over Christmas period)

11. Reconfiguration of bulk gas pad

When: 2016
Area of improvement: Energy
Explanation: Energy reduction by reconfiguring operation of system.
Detail: Following load reduction, compressor reconfiguration is possible allowing a reduction in energy use through selective use of "improved efficiency" compressors
Cost: time of internal gas experts and contractor (free value added service)
Payback: Instant
Project Scale: medium
Challenges: Balancing of system to ensure manufacturing was not impacted whilst changes were made

12. General review of systems and maintenance operations for environmental performance improvements.

These included but were not limited to:

- High reliability probe in boilers (savings on energy, labour, chemicals and water)
- Drive belt replacement project (from V belts to tooth belt options) ~10% efficiency savings
- Rationalisation of systems (removal of systems running but not required)