SUSTAINABLE ENGINEERING

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ABSTRACT

In 2015 New Zealand committed to a reduction in carbon footprint in agreement with the Kyoto accord requiring a reduction in Net carbon of footprint of around 30MtCO2-e/yr from 2014, by 2030. (Ministry for the Environment, 2016).

To become sustainable, an organization must have leadership, a culture of sustainable thinking, metrics and governance to measure progress, innovation and standards, to continuously improve and apply consistently, with engagement of supply chain. (HM Treasury 2013)

Sustainable Engineering consists of applying a hierarchy to avoid, reduce, reuse/alternative materials, and recycle focused on carbon reduction. A culture of challenge and understanding risk will assist in decision making. However, informed decisions only come from estimating and recording carbon footprint at baseline and through a project.

Sustainable Best practice organisations have achieved 39% reduction in embedded carbon, 34% reduction in operational carbon and an associated 22% reduction in capital costs. (HM Treasury, 2014). To lead a change in thinking and leadership to think carbon, will not only benefit infrastructure, but also influence the culture of the community. Application of these principals in New Zealand will not only reduce the carbon footprint but also result in a reduction in materials and energy requirements so, lowering the cost of infrastructure

KEYWORDS

Infrastructure, Carbon footprint, sustainable engineering, cost saving, asset management

1 INTRODUCTION

In 2015 New Zealand signed up to a reduction in lowering its Carbon Footprint in agreement with the Kyoto accord. This set out that a reduction of footprint of 30% against 2005 levels will be achieved by 2030 and by 2050 a 50% reduction will be achieved against 1990 levels. Ministry for the Environment, (2016) gives a carbon footprint of New Zealand in 2014 of 81.1 Mt CO2-e, (Carbon Dioxide Equivalent) which was a 1% increase on the previous year. 44% of the carbon is associated with energy in terms of power generation and fuel for transport.(MBIE 2014) Even with a high level of forestry where carbon dioxide is removed by plant growth rather than generated, there is required a reduction in carbon footprint of over 30 MtCO2-e per year.

Infrastructure has a direct impact on the energy usage, whether direct energy for lighting, pumping water, removing waste from site, but also indirectly. The office chair needed energy to make and shape the steel and mould the plastic, and needed transport to deliver to the office, and will need transport for its disposal at the end of its life. The road that the truck drives on is made from aggregate, extracted by machine, moved by machine, mixed with cement that needed energy to be made from limestone. So everything in use has a carbon footprint. Therefore the infrastructure sector need to consider everything that is done to reduce the New Zealand carbon footprint.

The carbon footprint is measured as carbon dioxide or CO_2-e equivalents, as different substances having differing impact, and is derived from a number of sources in infrastructure. These are commonly referred to as Embodied Carbon, or Capital Carbon (capcarb) which is the carbon required to produce, and the Operational

Carbon, the carbon required long term to operate. The former is materials, including raw material extraction, transport, shaping, packaging, and delivery and construction activity. Operational carbon being largely power, vehicle fuel and chemicals.

This paper is focused on sustainable engineering, the delivery of infrastructure in a sustainable manner but this on its own it will not achieve the goals. To make a difference consideration is also needed for, energy efficiency, reduction in carbon from capital projects (sustainable engineering), renewable power, supplier engagement to reduce carbon from their products, reduction in transport, minimising process emissions, and encouraging customers to use resources considerately.

This paper describes how an awareness and willingness to change thinking by infrastructure leaders, about carbon footprint can be implemented to meet national and international targets, how this change can be achieved and how much it will actually cost.

2 DISCUSSION

2.1 WHERE AND WHAT IS AN ORGANISATIONS CARBON FOOTPRINT

Is the carbon footprint of an organisation known? An organization is made up of people and assets, using fuel electricity and requiring materials for new assets, and replacing old. Every activity such as laying a pipe in the street has a carbon impact in making the pipe, delivery of the pipe, excavation, disposal of waste and moving people. This makes a whole organisations footprint too complex and dynamic for a definitive number and is usually not thought about. By encouraging thinking about carbon footprint, an understanding the carbon footprint gives a base, and then targets may be set with steps of improvement.

There are a large number of publically available carbon calculators, and the data presented here is from the UK, Environment Agency calculator. (Environment Agency, 2016). These calculators work on an understanding of the materials and activities involved in creating infrastructure and a picture is built.

Table 1: Carbon footprint of common materials used in Water Infrastructure.

Activity	CO2-e	Example	CO2-e
Passenger vehicle /km	114.7g/km	Employee Drives 5000 km/yr	0.58 tCo2-e
Road Haulage/100 km/T	0.12T/100 km	10T moved 50 km	0.6 tCo2-e
Power /kwh (Euro average)	0.445 kg/kwh	A 10 kw motor 24/7/yr	38.9 tCO2-e/yr.
Renewable power/kwh	0.14 kg/kwh	A 10 kw motor 24/7/yr	12.2 tCO2-e/yr
Copper cable /t	0.79 tCO2-e/t (copper only)	200 m of 6mm cable (2 strand)	0.079 tCO2-e copper 0.04 tCO2-e plastic
Portland Cement /t	0.95 tCO2-e/t	100m of Kerb Stone 10% cement, 10% sand, 80% aggregate, plus bedding material	0.93tCo2-e
HDPE Pipe /t	2.5 tCO2-e/t	1000 m of 900 OD PE SDR 21	306 tCO2-e
		1000 m of 800 OD PE SDR 21	250 tCO2-e
Stainless Steel //t	6.52 tCO2-e/t	Tank, 6mx2mx3m, 3mm plate	94 tCO2-e
Aluminium /t	9.52 tCO2-e/t	100m2 chamber covers	9.8 tCO2-e
Steel Plate (some recycled) /t	1.66 tCO2-e/t	Tank, 6mx 2mx3m, 8 mm plate	53 tCO2-e
Recycled Steel /t	0.72 tCO2-e/t		

There are many figures for carbon footprint of many materials, and often quoted as a range of values. The main reason for variability is what is included in the calculation. To demonstrate the complexity, copper wire is considered for its carbon footprint to be calculated. Within this calculation, the raw ore is mined in South America, include the transport of the ore from the rock face, the smelting, the disposal of waste, the shipping, the empty ship going to collect the material, the re-melting of the metal to extrude into wire, the wood to make the cable drum and the plastic sleeve. A little less clear is consideration of the carbon footprint of the staff driving to work and the administration to support these activities. This approach is more accurate, but impractical to gather all of the information so boundaries must be set. For the purposes of considering the footprint of an activity, a calculator that uses a single value, so can be consistently applied is of greater meaning. Through the single value, base objective and progress against targets can be measured.

Every project must be developed, and is usually in steps, with need, optioneering, design and construction. Considering carbon at each stage could involve a lot of detail, but this is no different to how estimators work on costs of a project, developing the cost with increasing certainty as the project develops in detail. The same applies for carbon. At the early stages of a project reference to a similar project or component, that knowledge can be applied to build an estimate of carbon footprint with increasing certainty. This is one of the great reasons to get suppliers engaged in the discussion, as the supplier already has understanding of the carbon footprint of each product so avoiding first principal calculations on every component.

A common perception in New Zealand is that power generation is green and does not have a carbon footprint as it is renewable. This is a fallacy because only some energy is renewable, with coal and gas generation still in use and the generation has losses and infrastructure to support. With renewable, the energy source is renewable and replaceable at no cost nor direct carbon emission, but for all generation types there is infrastructure associated with the generation and transmission. Consider that to turn on water pump by flipping a switch, using power from a geothermal energy source, the steam must come from a bore, pass through water/steam separators, and be conveyed to the turbine, pass out of the turbine and water returned to the ground. The power generated must pass through controls and transformers, and then transmission lines and step down transformers. All of which have losses of energy and have physical infrastructure. This has a carbon footprint associated with delivering the energy to the point of use. The losses through the system are also part of the footprint.

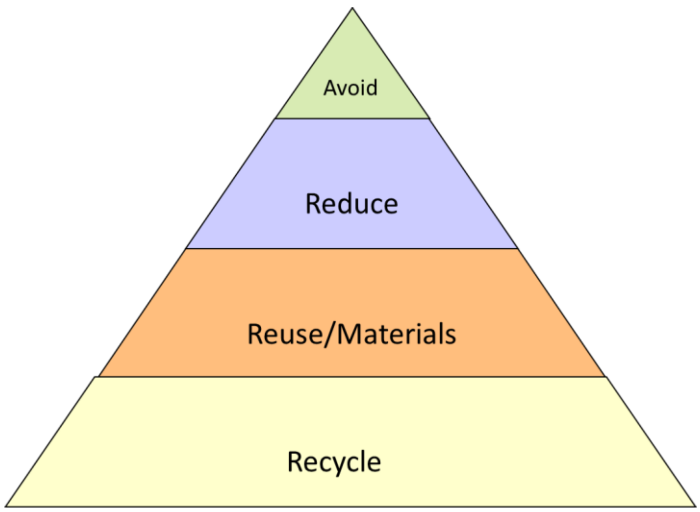
In Europe the typical carbon footprint of energy, is 0.445 kgCO2-e/kwh, whereas this could be as low as 0.12 kgCO2-e/kwh in New Zealand, (EnviroMark Solutions, 2016). This difference reflects that 90% of New Zealand power is now from renewable sources, where the Europe still relies heavily on fossil fuels. This means the challenge is to use less in New Zealand, rather than finding alternative sources.

2.2 HOW TO MANAGE CARBON FOOTPRINT

The key step to managing carbon footprint is to estimate and understand what makes that footprint. Undertaking a carbon footprint calculation on activities and capital investment will give that understanding.

Once a baseline is understood, or at least the main areas that can influenced in the business, then a start to addressing the challenge can be made. There is a hierarchy of approaches, shown in Figure 1.

Figure 1: Steps of Sustainable Thinking



This thinking is a statement of common reasoning. If something is not required, it is not built, and so will not have a carbon impact, and 100% saving is made. If a smaller amount of material is used, a reduction in material and carbon is also seen. Reuse of materials or assets serves to make extended life use of existing, and reduces the new. Alternative materials, such as lightweight concrete fillers can be used and so reduce the carbon footprint by using fewer raw materials. Consideration of the use of recycled materials lowers the carbon footprint, and by considering the recyclability of the material at the end of the asset life a reduction in the future generation's carbon footprint can be achieved. Table 1 data (Environment Agency, 2016) shows that if using recycled steel less than half the carbon footprint is required compared to using virgin material.

For example in a wastewater treatment plant, there is a need for a small tank with dimensions of 6m x 2m x 3m height. A painted mild steel tank with a wall thickness of 8mm will perform the duty. An alternative solution is to utilise a stainless steel tank of the same internal dimensions, which due to the difference in materials and method of construction has a wall thickness of 3mm. The carbon footprint of each tank, from the material required, is calculated as 53 tCO2-e and 94 tCO2-e respectively. The cost of each tank to produce is also considered, with the mild steel tank being only 80% of the cost of the stainless steel tank. The first impression is that the mild steel is a better selection. However, by thinking sustainably, the long term is considered over the whole life of the assets. For comparison in this example, the mild steel tank will have a functional life of 20 years, whereas the stainless steel tank will be structurally sound at 40 years. Factoring in the asset life, there are two mild steel tanks required for every 1 stainless steel tank, giving a carbon footprint of the materials over the 40 years period of 106 tCO2-e and 94 tCO2-e respectively. Similarly, the capital required of 160% or 100 % respectively. (Values used in this demonstration exclude the carbon required for the replacement delivery and installation, and neither associated costs, nor any cost escalation over time or NPV discount). This shows that although cheaper options are available now, the selection of material has a longer term sustainable benefit in carbon and cost.

Sustainable thinking provides long term benefits.

Sustainable Engineering is the practices of thinking about carbon footprint over the long term through the engineering lifecycle which leads to reduction in carbon footprint.

2.3 THE COST TO BE SUSTAINABLE

The steps that reduce carbon footprint are driving a reduction in materials and energy. By building less, there is less expenditure of resource and money. By selecting more efficient equipment, the longer term resource is reduced as is expenditure.

To quote HM Treasury, (2013) "Leading clients and their supply chains have already achieved reductions in capital carbon of up to 39 per cent, and 34 per cent in operational carbon. These reductions in carbon have been achieved in association with average reductions in capex of 22 per cent.

If emerging best practice is driven across the infrastructure sector over the coming years, analysis suggests that up to 4 MtCO2e/year of capital carbon and 20 MtCO2e/year of operational carbon could be saved by 2050. This represents a net benefit to the UK economy in that year of up to £1.46 billion/year."

Some organisations consider that by only looking at whole life cost that automatic consideration to carbon footprint is achieved. This thought process loses the indirect benefits seen in organisations that encourage a sustainable mindset.

Innovation. The challenge of 'why are we doing?' or 'how can we do better?' will drive more innovative thinking and behaviour in an organisation and the supply chain. This does not stop at just the project, but includes all aspects of the business, with improvement in efficiency, smarter working practices and improved morale.

Credibility. It is stated that many of the District Council's long term plans; that they are seeking a sustainable future for their district. By measuring the carbon footprint, there is a tangible reporting measure that shows this is really being done associated with great public relations. The cost savings associated with this efficiency will also be well received by the rate payers and the savings can easily be channelled into the lower priority and community nicer to have activities that are often not quite affordable or keeping customer bills low.

Increasing sustainable thinking will also see nationwide benefits. By reducing power usage across infrastructure and in the domestic sectors, there will be less need for upgrading transmission networks, and less need for investment in additional power generation. With less need for capital, the unit cost of power will increase less.

Sustainability culture in the community will influence customers and will see a reduction in area power usage, a reduction in water demand and a reduction in transport, which will also result in fewer upgrades to existing infrastructure,.

In the UK, (HM Treasury, 2014) Infrastructure contributes to 53% of the overall carbon footprint. The New Zealand basis is different, with greater emissions associated with agriculture (from animals not energy), largely related to dairy activity and a large reduction in carbon through forestry. Although data is not clearly defined, infrastructure is still a large user of energy, and is the largest user of concrete, steel and plastics and a change in behaviour in infrastructure will influence the rest of the nation.

Infrastructure is designed to last, with mechanical and electrical assets expected to be operational for 20 years, and civil structures up to 60 years. To replace the infrastructure in one step is not economic, but to replace these assets as they require replacement over a 20 years period means the mechanical and electrical infrastructure will become low carbon technology, using less power and needing less materials to construct with continuing cost to operate reductions.

Anglian Water (2014) in their annual report attributes the following efficiencies to their culture of sustainability over the period of 2014/15. 54% reduction in Embodied Carbon, 455,355 tCO2-e reduction, £235m (> 10% of capital budget) reinvested capital from efficiency savings over last 5 years, 7% drop in household bills,

The experiences elsewhere show that although so individual purchases may have a higher capital cost, by considering the overall carbon in every capital investment, decisions are based on sustainable solutions, saving carbon, capital and energy. The result is lower costs.

2.4 HOW TO BECOME SUSTAINABLE

For sustainability to exist in an organisation there needs to be a cultural of sustainable thinking throughout the organisation. This starts at board level, directing policy and supporting initiatives to the operator on the ground who thinks about recycling his waste and its segregation, the technician who replaces a bulb with low energy LED alternatives, the consultants who help shape strategies and designs, the construction partners who need to think of alternative methods of construction and waste reduction, to the suppliers of equipment. All must have a common direction.

HM Treasury (2014)

" Effective leadership: Provide highest level sponsorship of carbon reduction and set out a vision of how your organisation should address it; provide clear and consistent policy.

Communication and culture: Make carbon reduction part of your organisation's DNA. Articulate carbon reduction as a core organisational value; change behaviours, share best practice and develop carbon skills.

Metrics and governance: Make your carbon visible and set targets to reduce it against a clear baseline. Report transparently on progress; build carbon into decision making.

Innovation and standards: Unleash new thinking by challenging your supply chain to reduce carbon. Define outcomes and allow creative freedom in meeting them. Enable standards and specifications to be challenged.

Commercial solutions: Embed carbon reduction into your procurement process. Make carbon reduction a prerequisite for winning work. Integrate your supply chain and align it with your carbon objectives. Share carbon-related risk and reward equitably and incentivise outperformance of your targets. Create the environment in which innovation can thrive."

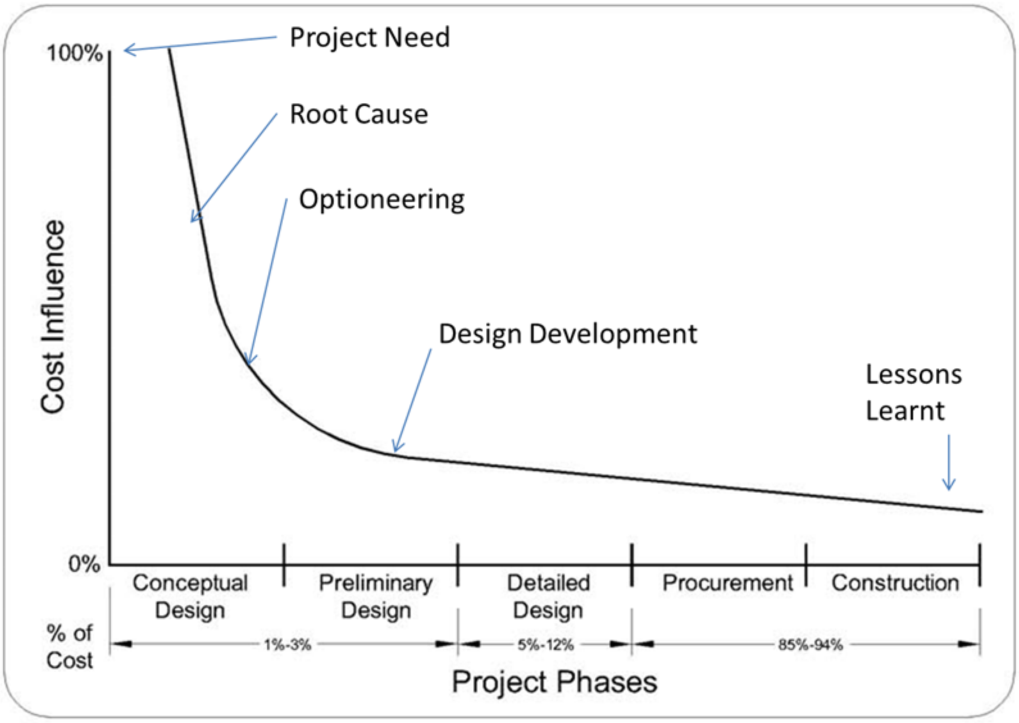
This guidance indicates that it starts by leadership changing culture, and starting a whole team journey. This journey, through change in workplace behaviours, will change domestic customer mindset, with far reaching benefits across sectors not directly influenced.

2.5 WHEN TO THINK ABOUT SUSTAINABLE ENGINEERING

Sustainable Engineering is the practices of thinking about Carbon footprint over the long term through the engineering lifecycle which leads to reduction in carbon footprint.

It is not good financial sense to invest in things that are not needed. However, there are many cases where perception of need has driven investment and decisions could have been better. It is recommended to challenge the need of every investment. This leads in many cases to a dilemma on whether investment is the correct choice. A simple tool that enables clear decisions is the use of a risk impact matrix, where by understanding the risk impact and the likelihood, the decision can be made in an informed manner at a level that is acceptable to the organization. This approach can be undertaken throughout the delivery steps that are put forward below.

Figure 2: Influence in the project life cycle



Project Need. Identify the need and drivers for a project. An understanding of risk at this stage informs on whether to promote a scheme. Saying No to a project at this stage saves 100 % of the carbon footprint and 100% of the costs. This starts a culture of 'We want…' becoming one of 'We need…'.

Root cause. A well-defined definition of the problem will ensure that the issue is understood and that the investment approach is focused on addressing the problem and not the symptom.

To demonstrate an example, is that a project was raised to install a tertiary sand filter on a sewage works because of elevated solids concentration in the effluent. This had a capital requirement of over \$2m and a large carbon footprint with tanks, pump station and continuous operation of the plant. Consider that to pump an average 10 l/s with 10m head, has a carbon footprint of 1.3 tCO_2-e per year. However, by root cause it was identified that the scraper on the clarifier had not been replaced for over 5 years, and was worn, so did not efficiently remove the solids from the tank floor, causing the problem. The carbon footprint for a 20 kg PVC scraper blade is 50 kgCO2-e, and costs < $2,000, being installed in house, rather than requiring a capital project.

Optioneering should consider all options and the whole of life carbon as well as capital and operational costs of options. Although this may require time to develop, the benefit is that options for the solution are more fully developed and the benefits understood. Comparison of options at this time using the risk matrix approach may make decisions of accepting slightly more risk and substantial savings.

An example where this detail in optioneering is of benefit is the selection of diffused air aeration. There are a number of diffusers on the market of differing materials and have varying asset lives. In many cases the selection of the solution is based on lowest capital cost, then the cheapest diffusers are selected which may not have the longest asset life, nor have the greatest efficiency. However, if whole life carbon and energy costs are considered, the life and replacement of the diffuser, which can range from 5 to 15 years, must be considered. The diffuser efficiency will also vary, with clean water new diffusers varying from 5 to 8%/m oxygen transfers, but also consider how this will change over time. This range may change to 3- 7% depending on type selected, and how the plant is operated. Consider that by spending 10% more on diffuser system, a whole life saving of 30% in aeration energy and carbon over the lifetime of the asset can be achieved with a payback for that additional capital in less than 5 years.

To demonstrate optioneering with risk, if in the tertiary treatment scenario in the root cause above, it was identified instead that at high flow to the plant the solids discharge was noncompliant, then there were two options possible for the sand filter. The first was to filter everything, which required 100 % of the carbon footprint capital and energy, or considered a blend of 50%. This reduced the embedded carbon as a reduced pump size and sand filter size, and reduced operational carbon with less power usage. However, there was an increase in risk, which must be considered in making the decision. Using historic information on performance and data an understanding of how often does this occur, and what is the impact if it does are considered. If that is acceptable, then a decision to move forward and make carbon and cost savings can be justified.

Design stages of a project will have less opportunity to influence carbon, as design will only make small changes to the nature of the project. However, many key areas are identified in this stage. Pump efficiencies, pipe sizes, material selection, and height of structures above ground, or into the ground, particularly considering the waste produced and its disposal, as well as construction materials and techniques.

Construction period of a project, although the period of major expenditure on any scheme, is also the period of least influence on the outcome, as design is completed and materials ordered. Engagement with the construction teams during design will result in better ways, materials or techniques being identified from their experience that will benefit carbon footprint and cost. Consideration to the build sequence and use of build off site techniques will reduce the carbon footprint by reduction in site activity, vehicle deliveries, waste production, staff journey numbers, and the time reduction reduces the capital cost.

Lessons learnt at the end of a project are usually focused on how the project on site could have worked better and not on the success. However, a good lessons learnt will consider the learning from project need, feasibility, design and construction, and asking the question "Of all the good things that have been done on the project, can we repeat these again, and repeat the saving of carbon and costs?"

2.6 HOW TO GET THE MOST OUT OF SUSTAINABLE ENGINEERING

Everyone working on a project has experience from what they have done before, and engineers get motivated by being asked to do the best that they can, so using the experience of owner, operator, consultant, designer, supplier and constructor will give more opportunity to reduce the carbon footprint. Successful teams are collaborative where all parties make a contribution.

Probably the biggest hurdles to changing this culture are met through encouragement and buy in. Consideration to how the economic contract model for professional services link to the team working on the project and motivate them and their organisation to do anything different. Where possible, look to ways to capture and repeat the learning and efficiency.

Where a culture of whole organisation and supply chain engagement has been developed on a programme of schemes, the result has been astounding. The UK Environment Agency and many other large organisations now make carbon footprinting part of their procurement process (Environment Agency, 2016). Anglian Water, (Anglian Water, 2015) a UK based water and sewerage services provider, have used this approach for more than 5 years, and as a result have seen a reduction in the overall carbon footprint in capital projects by 54%, and a capital expenditure saving of over 20%.

Caldwell & O'Brien (2014) give the project example of Bedford STW, in Anglian Water where an increase in capacity of 30,000 EP was required with an associated tightening of consent. The conventional solution was to build over 5000 m3 of activated sludge plant, two 30 m primary settlement tanks, and 4 of 25m clarifiers, with RAS pumping. Thinking about carbon and being innovative, with a willingness to take an increase in risk by trying new technology, resulted in the plant fully meeting its consent. The project was budgeted at £19m, with the standard solution at £24m, but was able to be delivered for £14m. This was achieved by a combination of reuse of existing percolating filters at lower loading rates, optimisation of flow splits, innovative use of Cleartech Biotextile (IFAS) to enhance the capacity of the existing activated sludge plants, improved aeration efficiency with Aquaconsult Aerostrip Diffusers, and use of Slashes Filters instead of large primary tanks. This resulted in a 66% reduction of embodied carbon, and a reduction of 170% of operational carbon compared to the conventional solution.

Similar success has been shown by Skanska, (2014) in their press release following a Highways Agency Sustainability Award that sustainability can be applied across all of infrastructure with their work on the London Orbital Motorway. "During the construction of the M25 Widening Projects between junctions 16-23 and 27-30 of the M25, Skanska Balfour Beatty used king sheet piles which were 100% recycled. It also reduced the quantity of piling required by a significant amount, reducing carbon emissions on the project overall by 44,000 tons.

Additionally, 92 per cent of aggregate used was either recycled or from a secondary source, which reduced combined energy and transport emissions by an estimated 35,000 tons compared with primary aggregate.

The project also managed to save around 400,000 tons of asphalt by matching existing construction rather than creating completely new surfaces. This method saved approximately 25,000 tons of carbon emissions."

Sharing learning across organisations and business sectors has benefits. By Anglian Water and Skanska sharing experiences a nonstandard outcome was achieved at Anglian Water's Uttons Drove STW(Anglian Water, 2014). After looking at different methods of construction, it was identified due to ground conditions the activated sludge tank walls, on 42m diameter tanks required to be sheet piled. Instead of installing the piles and then removing, with approximately 10% wastage, the project team decided to use the sheet piles as the walls of the structure. This resulted in time and cost savings for installation. The resultant embedded carbon reduction is shown in Table 2. The additional benefit was the reduction in construction time, with the structure being completed in 4 weeks per tank, instead of around 3 months by cast in situ.

This project also considered optimum pipework layouts to minimize, materials and pumping losses, lengths of cabling, with all mechanical electrical equipment being located as near the control building as possible. A decision was made on the carbon footprint of painting the tanks, with the decision not to paint saving a further 30 tCO_2-e as the pile thickness was held significant strength after 60 years, even if corroded.

Table 2: Carbon associated with wall options at Uttons Drove (Authors calculation)

Wall Type	Volume	Weight Material	Carbon/t	Carbon footprint
300mm concrete cast in situ, 10% steel (+Waste Piles) Total	2 of 237m3 (2.9 m3 steel)	2 of 570 t (22.3t steel)	0.5 tCO2-e/t (1.46 tCO2-e/t steel)	570 tCO2-e (32 tCO2-e steel) 602 tCO2-e
18 mm steel piles	2 x 14.3 m3	2 x 111.5 t	1.46 tCO2-e/t	324 tCO2-e

Figure 3: Aerial Photograph of Uttons Drove STW showing Steel wall tanks and optimized pipework layout

2.7 SOME SIMPLE IDEAS THAT WORK

- Reduction in water leakage reduces the carbon footprint of water extraction and treatment.
- Pumped wastewater requires a minimum velocity for pipe cleaning of 0.6 m/s. If the system allows, then size pipework to pump only at self-cleansing velocity to reduce the pump power requirement. Usually as a range of flows are to be pumped, aim to achieve 1 m/s or less.
- Power cables have energy loss and this result in heating. Going up a size reduces the resistance in the cable, so lowers losses. Fewer losses give more efficiency.
- Site access roads only need to be heavy duty where heavy vehicles turn. Consider reducing the grade of road if you do not need it.
- Think layout when designing. Can cable runs and pipelines by minimized so reducing losses and costs.
- Asset standards should be clear and not over prescriptive, except where a specific point is really required. Challenge the standard and encourage others to challenge too.
- Consider installation technique. For example directional drilling for a pipeline can reduce the waste produced by 80% compared to open trench methods, and removes the need for backfill material and reinstatement. It also can disrupt customers less than digging up the whole street.

- Use of swept bends reduces losses and energy on pumped systems and on gravity systems, removes the need for a manhole at every bend for cleaning as easily cleaned by jetting unit from another chamber.

- Undertake a lighting assessment and only install lights where they are needed for working. Use LED technology as the first choice.

- Design activated sludge plants to be turned down, whether by taking lanes out of service or by intermittent operation, both save energy.

- Running an activated sludge plant at the correct MLSS will save upto 5% of the energy for aeration

3 CONCLUSIONS

As a nation New Zealand has committed to a reduction in carbon footprint, and the best practice seen elsewhere shows that by thinking sustainably, the infrastructure sector can achieve a reduction in carbon. This reduction by not building, building less, reuse, or using alternative materials, all result in reduction in carbon and capital cost, and by consideration of best technology, results in lowering energy usage. The benefit outways any additional cost on the journey as savings of over 20% capital expenditure are being achieved.

To become sustainable an organization must have leadership, a culture of sustainable thinking, metrics and governance to measure progress, innovation and standards, to continuously improve and apply consistently, with engagement of supply chain. (HM Treasury 2013)

Sustainable Engineering consists of applying a hierarchy to avoid, reduce, reuse/alternative materials, and recycle focused on carbon reduction. A culture of challenge and understanding risk will assist in decision making. However, informed decisions only come from estimating and recording carbon footprint at baseline and through a project lifecycle.

Sustainable Best practice organisations have achieved 39% reduction in embedded carbon 34% reduction in operational carbon and an associated 22% reduction in capital costs. (HM Treasury, 2014). Application of these principals in New Zealand will not only reduce the carbon footprint but also result in reduction in materials and energy requirements so, lowering the cost of infrastructure and change by leadership, the culture of the community in an affordable way.

4 ACKNOWLEDGEMENTS

I would like to thank Anglian Water for their permission to use as references and examples of sustainable engineering practice.

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