improving
public transport
through technology

Environmental Impact of Displays

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1 Introduction

1.1 About this document

1.1.1 This document has been produced for the Real Time Information Group (RTIG). It provides RTIG members with information on the environmental impact of displays throughout their lifecycle and how to mitigate and reduce their impact.

1.2 Background and context

1.2.1 There are a bewildering range of displays on offer from suppliers - from LED to TFT, powered by mains, battery and solar. With the climate emergency and environmental concerns high in people's minds, the impact of our choices of technology needs to be considered more than ever.

1.2.2 Purchasing and environmental teams are increasingly expecting questions to be asked whenever equipment is purchased.

- What is the impact of the choices we make?
- Do we know which technologies are better for the environment?
- Do we know the carbon impact of different display types and technologies?

1.2.3 RTIG has instigated a project to assist in answering these questions and indeed, to determine if they are they are in fact the right questions to be asking. To deliver the project a working group was formed of authorities and suppliers to identify current good practice and turn this into a guidance document.

1.2.4 The headline conclusions are, to reduce your environmental impact, focus on:

- managing unnecessary consumption to reduce waste;
- taking a "whole of life" approach to assessing the extent of environmental impacts;
- building environmental considerations into the value for money assessment of a procurement activity; and
- where appropriate, engaging with suppliers who are committed to better environmental performance.

1.3 Calculating what is ‘green’.

1.3.1 It would be challenging to provide a matrix which could be used by non-specialists to generate a ‘best’ answer to the which display is ‘green’ question. Whilst this could be done, the limiting factor is having adequate information on which to base the mathematics – how do you compare sign A with sign B in realistic and sensible terms, when manufactures and their supply chain are unable to provide the necessary data sufficiently accurately at the moment. Whilst it is possible that this practice will be become more standard in future, just as other certifications have, it is certainly not available yet.

1.3.2 Hence, it is necessary to understand the different technologies and their relative impacts in more general terms.

1.3.3 This report seeks to provide some guidance on how public transport real time information suppliers and purchasers can plan for environmentally sustainable displays. It provides an analysis of different technologies to determine their potential environmental impacts and the significance of such impacts.

1.4 Scope

1.4.1 This report has no statutory or other legal basis and is purely to provide advice to suppliers, authorities and bus operators who produce, procure or use display technologies.

1.5 Limitations and The Future

1.5.1 This report reflects the available technology and those practices which have been found to be effective at the date of publication. However, technology and its applications are evolving and therefore it is probable that new technologies, new developments of existing technologies and new ways to adopt them on buses will evolve, perhaps more rapidly - given that there is now impetus for on-bus systems to be adopted.

1.5.2 RTIG understands that technologies and practices which are not on the market at the time of writing this document will evolve; and that such developments should not be excluded from consideration.

1.5.3 Operators and authorities are encouraged to consider new approaches - bearing in mind the general principles promoted in this document.

1.6 Acknowledgements

1.6.1 RTIG is grateful to the members of its Working Group for contributing to the construction and validation of this document - in particular: Aesys, Hampshire County Council, Journeo, M2M Tech, Nexus Alpha, React Accessibility, South Yorkshire Mayoral Combined Authority, VIX and West Yorkshire Combined Authority.

2 Environmental Context

2.1.1 There is an undeniable challenge to ensure that we look after and protect the environment and the earth's resources more effectively than we have in the past.

2.1.2 Many Authorities have declared climate emergencies and the public transport technology sector cannot ignore this, or the changes that will be expected in the products and technologies used.

2.1.3 There is, however, much more involved in looking at the environmental impact than just CO_2 emissions and global warming.

2.1.4 The Cambridge Dictionary defines environmental impact as

'the effect that the activities of people and businesses have on the environment'.

2.1.5 To understand our effect on the environment we need to be able to identify and measure the impact we have.

2.1.6 Environmental impact assessment (EIA) is one of the main legislative tools established to minimise an impact on the environment. EIA can be defined as "a process by which information about the environmental effects of a project is collected, both by the developer and from other sources, and taken into account by the relevant decision-making body before a decision is given on whether the development should go ahead."

2.1.7 All activity has some impact on the environment, either positive or negative, and whilst we need to reduce our impact in everything we do, some activity with a negative impact can improve the impact elsewhere. Public transport is one of these areas: whilst operating public transport generates emissions and has a negative impact on the environment, it has much less impact than the alternative of travellers using multiple private low occupancy vehicles.

2.1.8 Indeed, increased use of public transport has a measurable net *positive* impact because it reduces the number of people driving single occupancy vehicles. By increasing passengers on public transport, more fuel is conserved, air pollution decreases, and an area's overall carbon footprint is reduced. The cleaner air resulting from increased public transport use benefits the entire area.

2.1.9 When compared to single occupancy vehicles, public transportation produces up to 95% less carbon dioxide; 92% fewer volatile organic compounds; 45% less carbon dioxide; and 48% less nitrogen oxide.

2.1.10 The primary aim of installing displays is to encourage the use of public transport - a more environmentally friendly transport mode. If displays were not in place, what would the environmental impact be from higher overall transport emissions? This is extremely challenging to measure - particularly as displays are often installed as part of a wider package of measures.

2.1.11 Estimates of increases in patronage as a result of the implementation of advanced traveller information systems (of which RTI is a subset), are thought to be between 1 and 3% (Schweiger, 2003[1]). It was noted that it is difficult to determine how much of this increase results solely from real time bus arrival information, rather than as one of a combination of measures - as RTI is rarely introduced in isolation.

2.1.12 Displays at bus stops play an important role in passenger satisfaction with 'More bus stops with next bus displays' being number 8 in the priority list of improvements identified in the 2019 research on *Passengers Priorities for Improvements by Transport Focus*[2]*.*

2.1.13 It is within this context that this report needs to be viewed. Each of the different technologies discussed has a negative environmental impact but if they can be used to successfully encourage increased use of public transport, then they help towards the net overall benefit that arises from this.

2.1.14 A reasonable analysis of the "cradle to grave" impacts of display systems is extremely complex and to some extent actually defies reasonable analysis. However, there are some very evident principles:

- lower power demand has to be a positive factor;
- in general the bigger, heavier and more complex the hardware, the more impact it must have in terms of carbon emissions from manufacturing;
- something made of materials which cannot be recycled must have more impact than something that is 100% recyclable; and
- reducing the need for maintenance visits will have a significant reduction in the whole life impact.

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[1] Schweiger, C.L. (2003) Customer and media reactions to real-time bus arrival systems: In Transportation Research Board (2003) Real-time bus arrival information systems. TCRP Synthesis 48. Washington DC, TRB, Chapter 5 pp. 24-25.

[2] https://www.transportfocus.org.uk/publication/bus-passengers-priorities-for-improvement/

2.1.15 So whilst specific impacts such as power demand can be calculated, it actually makes little sense to calculate and compare the relative merits of individual components of a system. Instead, it makes much better sense to compare the whole lifecycles and look for what minimises the impact of the customer outcome you want. That is a much simpler task. However, whichever route you choose to take, it is essential to understand the technologies available, what impacts each has; and where the potential is to reduce/minimise impacts.

3 The Challenge for Electronics

3.1.1 There are seven key phases in an electronic product's lifecycle:

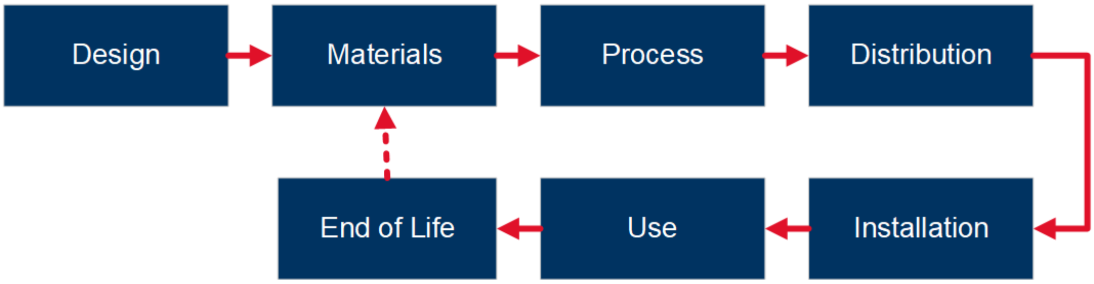

Figure 1 Seven phases of an electronic product lifecycle

- Design – the requirements and functions that lead to decisions on the choice of components.
- Materials – extraction of raw materials, such as ore mining, choice of materials and manufacture of components.
- Process – assembly of product components and packaging, such as plastic injection moulding or metal casting.
- Distribution – engineering and transport to the end location.
- Installation – civil engineering, installation of display, power supply (if required), commissioning.
- Use – electricity demand, including any consumables during its lifetime and maintenance.
- End of life – disposal - including re-use, recycling, and landfill.

3.2 Design

3.2.1 This is addressed in this report in the sections on Procurement decisions and Display Technologies.

3.3 Source Materials

3.3.1 There are significant concerns around the environmental impact of extracting and creating the source materials used in electronics - particularly the metals. The major environmental concerns for the main metals used as raw materials are:

- Copper (used in cables, electronic modules, and computer chips) – the main copper producer is Chile. Copper mines cause severe environmental impacts through resource consumption and emissions. Although most copper mines are certified according to ISO 14001, local communities are affected by the mining activities. A major issue, for example, is the high water requirement of copper mining and the location of most copper mines in the Atacama Desert (the driest desert worldwide), which leads to water shortages and associated environmental complications.
- Cobalt (used in rechargeable batteries, integrated circuits, semi-conductors) – the main producer of cobalt is the Democratic Republic of the Congo (DRC). Although several foreign companies established codes of conduct to protect human rights and improve labour conditions, effective monitoring systems are absent. There are hardly any efforts to minimise environmental impacts, or to reduce the risk of conflicts.
- Gold (9% of world production is used in connectors, solders, microprocessors, and memory chips onto motherboards) – gold mining activities require a very high resource consumption, which along with the use of hazardous substances such as mercury or cyanide to dissolve the gold, entail a massive environmental load. The efforts of the mining sector to reduce environmental impacts are currently estimated as low.
- Tin (used as solder on printed circuit boards) - in the past, tin solder was mainly alloyed with lead, but this is now generally forbidden under the Restriction of Hazardous Substances (ROHS – see 10.3 below) directive. As a result, the demand for tin has increased in recent years. Lead-free tin alloys contain copper, silver, zinc, or bismuth as a replacement for lead. China and Indonesia are the two largest tin producers and mining in China has similar environmental issues as gold mining (see above). In Indonesia informal (artisan) mining has been growing because many fishermen and farmers have become miners, as the environmental pollution caused by tin mining has destroyed their original livelihood. Tin mining is one of the major causes of widescale deforestation in SE Asia.

- Aluminium (used in frames, casings, heat exchangers) - roughly one third of the global aluminium supply stems from scrap. Bauxite is the most common ore of aluminium and is its primary source. Its mining contributes to environmental impact mainly via its vast land use (deforestation, water pollution, air pollution in urban areas, and forest fires). The extraction of aluminium from the bauxite ore requires significant electrical energy. Aluminium production consumes approximately 5 percent of electricity generated in the United States[3].
- Lithium (used in batteries) - is found in the brine of salt flats. The brine is pumped to the surface - leaving it to evaporate in ponds. This allows lithium carbonate to be extracted through a chemical process. The extraction of lithium has significant environmental and social impacts, especially due to water pollution and depletion: with approximately 2.2 million litres of water required per metric ton of lithium - often in areas that do not have sufficient water any way. In addition, toxic chemicals are needed to process lithium; and the release of such chemicals through leaching, spills or air emissions can harm communities, ecosystems and food production.

3.3.2 Other common hazardous substances include:

- Brominated Flame Retardants (BFRs): used in printed circuit boards, cables, wires and plastic for casings. Certain BFRs can affect learning and memory functions in humans.
- Mercury: used in flat panel displays, may be harmful to the nervous system and toxic in high doses. Approximately 0 to 50 mg mercury is present in an LCD monitor, due to the use of energy efficient CFL backlighting. However, LED and OLED backlighting do not require mercury content and there are predicted trends towards wider use of these in the market over the next 5 to 10 years.
- Lead: used in many processes and components but particularly batteries - can be harmful to the nervous system and poisonous in high doses.

3.3.3 The recently updated RoHS Directive (2002/95/EC – see section 10.4) has now severely restricted the use of a number of substances in electronic and electrical equipment: lead, mercury, cadmium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE).

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[3] https://www.aluminum.org/industries/production/primary-production

3.4 Supply Chain Management

3.4.1 Many of the issues with electronics could be resolved by more thorough supply chain management.

3.4.2 Without established and vetted relationships with suppliers, it is simply not possible, for example, to know what chemicals suppliers are using - especially those such as degreasers or solvents, which do not end up in the final product.

3.4.3 But the issues surrounding the supply chain go deeper than just these later stage impacts. Electronics manufacturing involves material and labour from almost every continent.

3.4.4 The supply chains for a single electronic device typically involve hundreds of companies in a chain that must be owned and managed if it is going to be understood. This is not always happening and it is difficult for end users of the product to make an impact. The more questions that are asked at all levels of the supply chain, starting with the end user - the more likely the supply chain will start to address the challenges.

3.4.5 The increasing complexity of electronics means greater amounts of energy are required to produce each device, with 70 to 80% of the energy footprint of personal electronic devices occurring during the manufacturing phase. The manufacturing of electronics in China and Southeast Asia - where the supply chains for many companies are located, is largely powered by coal rather than renewable energy sources.

3.4.6 While offices and the end product may be powered by renewable energy, this is a “drop in the ocean” compared to the fact that the manufacturing of many products by suppliers is where the most environmental impact is being generated.

3.5 Distribution

3.5.1 We do not dwell on this topic as there is an implicit assumption that transport operations are being managed to be efficient and as environmentally conscious as possible.

3.6 Product Use

3.6.1 This is addressed in this report in the sections on Power Supply and Maintenance.

3.7 Re-use and Disposal

3.7.1 This is addressed in this report in the sections on Re-use and Disposal.

4 Display Technologies

4.1 Available technologies

4.1.1 The array of available display technology is considerable, the most common being:

- TFT LCD (essentially TV panels): which are available in high bright versions for outdoor use.
- LED matrix: for example the traditional ‘3-line LED’, only capable of showing simple text.
- LED full matrix: which are suitable to add graphics and dynamicity to the traditional countdown contents. Full colour versions are available and because they tend to be physically larger than LCDs (because LEDS are inherently large), the pixel size is only suited to the very large displays that might be seen in rail stations and sports arenas.
- Various LCD technologies which are generally used for very low power equipment, have different merits and demerits. They are also usually monochrome. Some support scrolling and some can have graphical elements included but these cannot be changed.
- e-ink: e-ink is best known for being used in the Kindle book readers. A monochrome display - it is high resolution and low contrast; but unlike all the above displays it retains an image when powered down. It has therefore generated interest for use, for example, in timetable displays which are rarely changed. However, lighting is required for night-time viewing.
- Flip-dot: An old technology which uses an array of large mechanical dots: black on one side and coloured (usually yellow) on the other. The dots are reflective and once set, remain in position without requiring any power other than for lighting at night. Flip dots fell out of fashion, perhaps because they gained a poor reputation for reliability when used on buses. However, they are very reliable for static signage and are worthy of consideration for large format text displays which are to be viewed from distance.

4.1.2 It is always important to recognise that lists such as this may omit an obscure current technology and will not include any technology which emerges subsequent to publication. Whilst we cannot comment on any specific new (unknown) technology, in general, it will fall into one of the above categories in terms of its operational parameters. Hence, the analysis in this document can be used - provided you are able to define the category to which it is most similar.

4.1.3 There is a perpetual footprint for as long as an electronic display is in place and operational; the challenge is to manage the impact. However, even for displays using the lowest energy, there are emissions either from the creation or disposal of the product.

4.1.4 The choice of display technology should reflect the information that needs to be presented. If just the display of text or pictograms is required, then a high bright colour TFT may not be needed.

4.1.5 Clearly no single technology does everything, nor does it do it equally well. All of the above have strengths and weaknesses. Equally, all of the above have different impacts on the environment - both from manufacture and in use.

4.1.6 The technology you choose for your displays depends upon what you want to show, where you want to show it and on your priorities - one of which is increasingly now ‘how green is your display?’

4.1.7 However, the display technology itself is only part of the equation. The most power frugal display technology will not save energy if the drive electronics employed by the manufacturer consume too much power. The need to attend a near-zero carbon display every month will negate its intrinsic environmental advantages as a result of the carbon expended in making the visits. An assessment of carbon footprint must therefore consider lifetime carbon costs, including maintenance and disposal.

4.1.8 Energy-draining CRT monitors that were once used have been replaced by more efficient display technologies that not only outlast the older models, but require far less electricity to operate. Newer designs of electronics are increasingly mindful of the energy consumption, which is consequently on a general decreasing trend.

4.2 Brightness

4.2.1 Specifications often require a display to have a particular brightness; and the temptation is, of course, to make this as high as possible.

4.2.2 The screen brightness actually required depends on the content contrast, viewing distance and angle. Therefore, the simple pursuit of high brightness is not necessarily going to achieve the best application effect. Indeed, it can have a negative effect on the overall impact. For instance, the higher the screen brightness, the more heat will be generated and the consumed power will increase. In addition, maintenance costs will increase and the expected service life will be shortened.

4.2.3 The best management of environmental impact will be achieved by specifying displays that are fit for purpose and achieve the overall objective - rather than for a particular technical specification.

4.3 Location and Mounting

4.3.1 A common customer complaint is the readability of a display - either because it is not bright enough for the content to be visible, or because there is too much glare or reflection on the screen.

4.3.2 There are three approaches to addressing this problem:

- anti-reflective coatings or glazing;
- increasing brightness; and
- changing location and/or mounting position.

4.3.3 LED displays generally provide better visibility of their content in bright conditions than TFTs, for the same level of power input - without mitigating measures being in place.

4.3.4 The simplest solution to reflections and some contrast-related visibility issues is to provide an anti-reflective coating to the screen. This can be seen in the figure below which shows a TFT display with anti-reflective glass that is mounted behind a half end glass panel which is not anti-reflective glass. The part of the display behind the shelter glass has reflections and the contrast is not as good.

Figure 2 TFT display that is mounted behind a half end glass panel. © M2M Tech

4.3.5 Figure 5 clearly shows the effect of a semi-mirror window in front of an LED display; despite both sides of the windows being in the shadow, the brightness of the reflected landscape is affecting how the display appears. This issue can be mitigated but not eliminated; and the impact depends on the position from which the display is viewed.

Figure 3 The effect of a semi-mirror window with different reflections in Iseo, Italy in front of LED displays is clearly visible © Aesys

4.3.6 Increasing the brightness of the display improves the contrast between reflections or a bright sky to improve readability, but will increase power consumption and reduce the life of some or all of the display components.

4.3.7 A combination of an anti-reflective coating and increasing brightness is often required to improve the readability of content. This does not, however, resolve the problem, it merely masks it. The most effective and most environmentally friendly solution is to reduce the cause of the reflections and poor contrast in the first place.

4.3.8 Increasing font size facilitates improved readability if there are reflections and at distance.

4.3.9 The optimum solution is to mount the display so that reflections from bright sources such as the sky or streetlights (as in Figure 3) are reduced or eliminated – as this will require a lower brightness level to achieve the same level of contrast.

Figure 4 A TFT display installed on a low pole to reduce reflections © M2M Tech

4.3.10 Mounting a display so that when the passenger is looking at it, the background is a building or shelter (Figure 4) rather than the much brighter sky (Figure 3), will make a bigger difference to readability than anything that can be done through display design or by increasing its brightness.

Figure 5 A TFT displayed on a High pole increasing bright reflections © M2M Tech

4.3.11 Light sensors on the back of a display to control brightness make good sense, as TFTs in particular, are less visible against a bright sky.

4.3.12 Fitting a display at 2.1 to 2.4 meters off the ground rather than higher up, improves the ability to use reflecting ground objects - significantly improving contrast, as well as providing better viewing distances.

4.3.13 The viewing angle of a display also has a significant impact on readability. TFTs in particular can become unreadable if the angle is too great - suggesting lower placement, more aligned to normal sight lines. Providing a 5 to 15 degrees downward rake on the display can almost eliminate contrasting caused by reflected sky - reducing the need for brighter, more energy consuming, panels.

4.3.14 Downward angled can be provided by the design of the casing or brackets or a combination of both. A 15 degree downward angle makes a big difference - particularly for wheelchair users.

Figure 6 A Daktronics LED display with downward angle to improve readability

Figure 7 Brackets can be used to provide downward angles and shading © M2M Tech

4.4 TFT-LCD

4.4.1 TFTs are increasing in size and brightness, both of which are undeniably positives for the presentation of information in a dynamic, colourful and attractive way. However, with an increase in size and brightness comes an inevitable impact on both power demand and the environmental impact of manufacture.

4.4.2 The comparative power consumption of different sizes of TFT displays used in vehicles is shown in the following table:[4]

DISPLAY TYPE	TYPICAL POWER CONSUMPTION [W]
On Vehicle Displays	
Small (20" and below) on-board TFT with embedded computer	40
Medium (21" -> 30") on-board TFT with embedded computer	50
Large (32" and above) on-board TFT with embedded computer	65
Static Location Displays 2000 nits[5]	
Small (32”) TFT with embedded computer	130
Medium (46”) TFT with embedded computer	190
Large (55”) TFT with embedded computer	180

[4] Figures provided by aesys and Journeo

[5] The nit is the standard unit of luminance

4.4.3 Whilst it is technically possible to run a large, high, bright TFT on solar with battery backup, it is entirely unrealistic to do so without implementing significant energy saving techniques such as the display panel being turned on only when a passenger is within a shelter. Through a carefully controlled and managed design, it has been proven over a number of years that displays as large as a stretch 28” TFT can be battery powered with solar recharging.

4.4.4 The unmanaged TFT power demand is so substantial that the panel area and massive battery backup capacity would render such a project financially and practically impossible. It is easy to illustrate this with some basic calculations.

4.4.5 Let us presume that ‘going green’ is paramount but a large high bright LCD is deemed essential. This suggests the use of solar power, off-grid, with battery backup. What exactly will be required?

4.4.6 To sustain a high, bright display of 90W through three months of winter may require a battery capacity of over 180,000 Wh. The Tesla Powerwall 2.0 is rated at 13.500 Wh so you’d need approximately 14 to sustain the system through winter.

4.4.7 This is a crude calculation and the numbers would be reduced by any available solar input. However, solar input is a major challenge in winter – less sun, lower angle, shorter days. Adding sufficient panel area to deliver useful power naturally in the winter also requires very significant investment in an extensive array of panels. Whilst two standard rooftop panels may provide enough power in perfect sunlight in summer, catering for night, winter sun, rain and snow expands that number considerably.

4.4.8 Ignoring the practical aspects, the financial investment in hardware and the inevitable carbon footprint of its manufacture is very significant indeed and would make the project non-viable from an environmental perspective.

4.4.9 Whist large TFTs may not be viable in an off-grid environment, with a more practical size display with good electronics design and usage management in place, it is possible to operate off-grid TFT displays. For example, in Oxfordshire, 10” TFT solar pole mounted displays that are triggered by passengers have been successfully operating at busy stops with over 1200 uses per month at a high profile site over a multi-year period.

Figure 8 a pole mounted battery / solar 10" TFT display © M2M Tech

4.4.10 Any low power, full colour, high, bright TFT LCD can only be low power compared to other TFT LCD displays because of the need for backlighting of the display.

4.4.11 Where the requirement is to display colour, high resolution images or rapidly changing graphics, the TFT-LCD display is the most capable.

4.5 LED

4.5.1 The initial technology deployed for roadside real time information displays was dictated by the purchase cost of the LEDs. It used to be that amber was the lowest cost but it is now white that has the lower cost. Modern white surface mount LEDs consume significantly less electricity than the older amber 3-line displays. This will be due to a combination of the need to drive the white LED less because its contrast is greater – together with improvements in electronic circuit design.

4.5.2 The traditional LED display is not as capable as a TFT for displaying graphics. They will, however, meet most customer information requirements including scrolling text

4.5.3 Displays can be designed to operate successfully in harsh environmental conditions using simple techniques. For example, there is no need for fans if heat convection is designed properly.

4.5.4 Some examples of LED installations in what could be regarded as hostile environments when compared to the UK operating environment, are set out below.

4.5.5 Riyadh – Saudi Arabia

- Operating (external) Temperature -15° - 65°C
- Fanless, Natural convection
- Thermal brightness de-rating (to manage over-heating at direct sunlight)
- Typical power consumption: 170 W @ Daylight and ambient temperature T=25°C
- Typical reading range: 0 to 30 m
- (Three information lines with font height of 20px @ 7.000cd/m2)

Figure 9 SMD LED Display Riyadh – Saudi Arabia © aesys

Figure 10 SMD LED Display Riyadh – Saudi Arabia © aesys

Astana - Kazakhstan

- Operating Temperature - 45°/ + 55°C
- Embedded heating system
- Fanless, Natural convection
- Typical power consumption: 120 W
- @ Daylight and ambient temperature T=25°C
- Typical reading range: 0 to 20 m
- (7 information lines with font height of 8px @ 5.500cd/m2)

Figure 11 SMD LED Display Astana - Kazakhstan © aesys

4.5.6 The actual location of a display is a key factor in determining the detailed requirements; and early discussions with suppliers can help address some of the common pitfalls.

4.5.7 Rail dictates a lot of display development as it typically has bigger budgets. RGB LED displays are the new Rail requirement so this will trickle down to bus in time. The power consumption requirements of these needs to be considered against alternatives - as RGB colour LEDs can have higher power requirements than TFT but are visible at significantly greater distances.

4.5.8 Full colour matrix is generally likely only to be used for very large video displays with suitable connections to permanently connected power supplies. They can be highly effective in these locations.

4.5.9 A common challenge in locating a display is the need to manage its contrast to ensure readability. Overall, amber / black is better than white / black - particularly in bright light conditions. Fittings such as blinds above the LEDs, can help manage glare and reflection.

4.5.10 LEDS often run brighter in more northern regions because the sun is lower in the sky - thereby triggering the brightness sensor when a display is in direct sunlight. This is, however, just the time when brightness needs to be reduced. Mounting a display so that when the passenger is looking at it, the background is a building or shelter - rather than the much brighter sky, will make a bigger difference to readability than anything that can be achieved through display design.

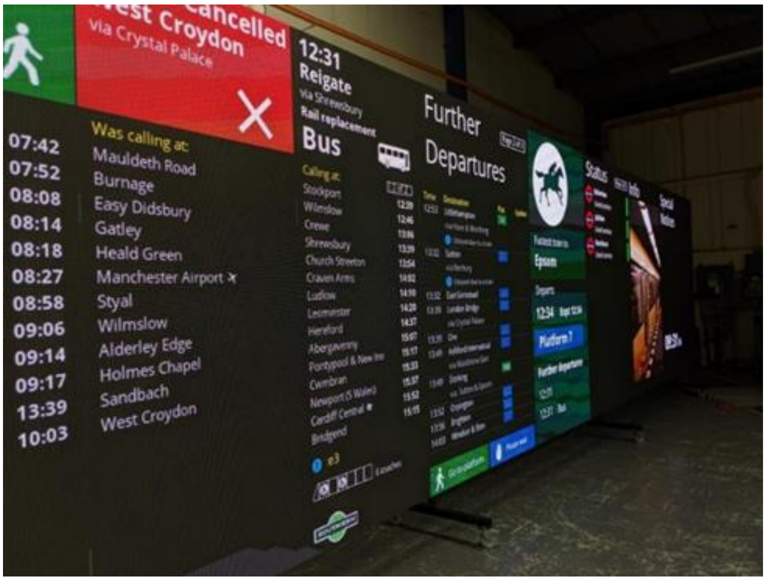

Figure 12 Large RGB LED display for Rail © Infotec

4.5.11 This requirement to increase the brightness of the LED to counteract increased light levels, results in higher energy requirements: when compared to the use of reflective LCD technologies.

4.5.12 Continuity of aesthetics is also important for the look and feel of a location. For example, a mix of yellow and white LED does not look good at a bus station. Cascading older displays, discussed later in the document, should be considered to reduce the whole life impact.

Figure 13 An aesys LED destination blind

4.5.13 The comparative power consumption of different types of LEDs used in on-bus external LED kits is shown in the following tables[6]:

DISPLAY TYPE	TYPICAL POWER CONSUMPTION AT FULL BRIGHTNESS [W]
On Vehicle Displays	
Typical LED display kit (front-side-rear) - white	150
Typical LED display kit (front-side-rear) - amber	180
Typical LED display kit (front-side-rear) - full colour	370
Typical LED display kit (front-side-rear) - mixed, full Colour + monochromatic	200

DISPLAY TYPE	TYPICAL POWER CONSUMPTION AT FULL BRIGHTNESS [W]
Static Location Displays Max Brightness 8500 nits (white), 5500 nits (amber)	
144 x 64 pixels – white	177
144 x 64 pixels – amber	174
192 x 64 pixels – white	219
192 x 64 pixels – amber	223

[6] Figures provided by aesys and Journeo

4.6 LCD (Other than TFT)

4.6.1 LCDs come in many variants. Whilst the basic concept of the LCD are all technically the same, the internal operation differs with type – each of which has its own attributes. TFT LCD (i.e. the TV type panels already covered) can be used for large, high bright colour panels showing moving images. Other LCD variants have been used for digital watches and calculators. But there are many more types.

4.6.2 Binary Cholesteric Displays (BCD) retain an image even when they are not powered up so they can be written to and the power removed, whilst the image is retained on the screen. This can save power, but colour is not supported and the image cannot be changed quickly, hence video is impossible. However, if the requirement is to show a timetable which changes once a month, BCD and similar technologies can be the solution.

4.6.3 Whilst the retention of the image on a shut down display is good for power consumption, if power is lost, the information cannot be updated - potentially resulting in incorrect information being displayed until power is restored. This means that it is important to ensure that the diagnostic and fault reporting back to a central management centre is advanced; and alerts are generated when there is a fault or loss of power.

4.6.4 At least one type of LCD is essentially equivalent to LED in terms of capability. With a dot size better than LED and no brightness problem, it can support scrolling and is transflective* so is extremely low power in use.

* Transflective means that the display can be front and/or back lit. Consequently, if properly deployed, during daylight hours it can be read without any artificial lighting. It does require lighting at night but such lighting is relatively very low power and can be managed using proximity sensors.

4.6.5 An additional benefit of transflective technology is that with appropriate design, a transflective panel can use daylight from the front and the back and is therefore easily read when there is bright sun behind it. This gives it advantages over a purely reflective type of LCD: where the sunlight makes it difficult to read the panel against a high brightness background - overcoming the need for the careful location selection commonly required by other display types.

4.6.6 Low power LCD is a good option for low power displays running from battery or solar; and when running from mains power, they use extremely small amounts of power.

4.7 E-Ink

4.7.1 E-ink is a proprietary technology of the e-ink corporation and has carved out its own niche. It is a type of LCD best known for its application in the original Amazon Kindle.

4.7.2 As with the cholesteric LCD, the image is 'sticky' – once written it stays put even when power is removed. Hence, whilst the act of writing an image is quite demanding in power terms, images that remain the same for long periods are very power efficient in use. Images that are constantly being rewritten significantly increase power demand and as a result, E-ink is not as efficient as other technologies where dynamic images need to be displayed.

Figure 14 A Journeo E-Ink solar Flag display © Journeo

4.7.3 As with cholesteric LCD, effective fault management is critical to ensure that inaccurate information is not displayed.

4.7.4 There were mixed results with early trial installations of E-Ink solutions. They have, however, been successfully used in Denmark since 2015.

Figure 15 An E-Ink display at a Movia bus stop in Denmark

4.7.5 E-ink panels are high resolution, are now available in sizes up to 43" (diagonal); and are even available in colour.

4.7.6 The downsides of e-ink are: that contrast is relatively poor, they cannot be backlit which makes lighting them sometimes problematic (though this has been improved); and image changes are both power hungry and slow - particularly in the cold when a full update using a standard write routine may take over 20 seconds. Images cannot be rewritten below -20°C.

4.7.7 Because e-ink cannot be backlit, a panel with sunlight behind, for example mounted high on a shelter wall where the reader must face towards the sun to see the panel, may not be readable.

4.7.8 As a result of the high energy efficiency it is possible to use E-ink type displays off-grid, with some suppliers offering products that will operate for multiple years from a battery without the need for solar or other power top up solutions.

4.8 Flip Dot

4.8.1 Whilst many may feel this is an old and abandoned technology, the renewed focus on limiting power demand means it may once again have a role to play.

4.8.2 Flip dots are literally dots that flip over. They are plastic discs which are black on one side and coloured on the other (usually using a highly reflective yellow film). They are magnetised and can be 'flipped' by changing the magnetic field in which they are held. Whilst the act of flipping does demand significant levels of power, the attraction of the flip dot for signage is that in most cases the image is only changed occasionally. Hence, a brief burst of energy lasting maybe 1/10th of a second may set a dot which stays put, unpowered, for many hours or even days or weeks – making the power demand miniscule.

4.8.3 The reflective nature of the film and the deep black of the reverse side make for a very high contrast display which is clearly visible in all daylight conditions. They can also be easily seen at night when illuminated by external lighting such as car headlamps, streetlights or even by using a small, dedicated LED.

4.8.4 The big limitation is size: the smallest available ‘dot’ being just under 10mm. They are, however, superb for large displays of text which must be seen from significant distances (10mm dots can easily be read at 50 m by someone with normal sight). Yet the power consumption of even the largest dots is tiny.

4.8.5 A further potential problem is that flip dots cannot scroll information. Whilst there are ways to use them to change the image more rapidly, constant changes clearly adversely affect power efficiency.

Figure 16 Flip-dot departure boards at a bus station in Děčín, Czech Republic © ŠJů, Wikimedia Commons.

4.8.6 Flip dots are therefore superb for large text which is not changed all the time. It is visible at distance, can easily be lit at night and contrary to reputation, is very reliable in static displays.

4.9 Paper

4.9.1 When considering the environmental impact of displays, it is easy to fall into the trap of only considering electronic forms, when the oldest format of a display is on paper.

4.9.2 In selecting a suitable technology to display information to a customer, consideration needs to be given to the purpose and lifespan of the information and the accessibility requirements. It may be that paper is the most suitable format to use. Indeed, for information that is long lasting and does not need to be changed quickly, then paper should remain an option.

Print's only direct carbon footprint is when it is produced. Many paper producers claim low environmental impact using suitably managed forests and increasingly low carbon transport. In addition, paper can be recycled up to seven times before it becomes unusable. Print production can take place very close to its point of use and once installed, printed signage has no ongoing carbon footprint. The biggest environmental impact for paper is in the installation process.

5 Display Drivers

5.1.1 Within any display there is a computer and some associated electronics. These vary dramatically for two primary reasons: manufacturers take different approaches to what is required; and the different technologies require different driver circuitry. This internal hardware has a significant impact on power demand of the system as a whole.

5.1.2 To illustrate this we can use some examples:

- In previous generations of displays it was not uncommon to find a standard desktop tower computer driving an on-street LCD display. Such hardware probably used around 60-100W of power continuously. That equipment did little more than receive and process the image – it did not provide any diagnostics.
- Today, most displays will use a much smaller embedded computer running typically, between 2 to 5 watts.
- A specialist lower power display driver will employ custom hardware running at power levels measured in milliwatts.

5.1.3 Quantitively this works out at:

• Custom driver system:	50mW (baseline)	
• ‘Normal’ embedded hardware:	5 W	x 100
• Tower PC:	100W	x 2000

5.1.4 When you consider that the electronics are running at this level all the time, this differential has a major impact on overall system power demand. It also dictates whether the hardware can be solar, or battery powered and if it can, what panel area is required? The lower the power consumption of the display driver - the more likely that a solar or battery solution is going to be successful over a multi-year period.

5.1.5 The more custom the electronics - the more likely a display will have detailed fault diagnostics to improve its overall life.

5.1.6 Historically, Microsoft Windows has always required comparatively high-powered processors as it was designed for desktop PCs. Windows Embedded improved on this but still requires considerable processor resource compared to more specialised operating systems such as Linux. With recent developments there is now little difference in power consumption between MS Windows and Linux running on an off-the shelf single board computer.

5.1.7 There does, however, remain a major difference at the lowest power levels. It is not possible to cut Windows Embedded back to the efficiency levels of a carefully customised Linux based code but this should not impact on overall performance. In fact, because the lower power systems are designed for the task, they are able to perform better.

5.1.8 It is important to be able to effectively control the operating environment of the display driver and software: to ensure good power management, stability and security. A display driver that crashes and requires maintenance visits is not environmentally friendly.

5.1.9 Software updates and patches need to be thoroughly tested before rollout to ensure they can be successfully carried out with minimal impact. Ideally, they should be carried out over air to avoid a maintenance visit.

6 Display Power Supply

6.1 Power Source

6.1.1 A critical question at the core of the assessment is likely to be the source of power to use for a display. Of itself this poses multiple considerations:

- Which is better, solar or wind, or a combination?
- Should you use mains or off-grid power?
- Which technologies can realistically be deployed off-grid: powered from integrated renewables?
- Is any other 'renewable energy' technology worth considering?

6.1.2 As is the case generally, there are no absolute answers. It is, however, worth considering the factors that will influence the conclusion to be reached in any given situation.

6.2 Mains powered vs off-grid

6.2.1 Displays have historically mostly been mains powered for the simple reason that they are not viable for running from solar or other power sources. Early solar installations were not always successful and resulted in solar getting a bad name because of false promises. However, there are some examples of equipment in use in the UK where solar has been proven to be reliable over many years across multiple installations.

6.2.2 Of the different display technologies, three can be considered as candidates for off-grid use: the LCD variants, e-ink and Flip Dots. LED consume too much power to be deployed off-grid.

6.2.3 Three factors are now generating interest in off-grid deployments:

- 'green' considerations make solar powered hardware attractive;
- it is possible to install off-grid displays at remote sites where it is uneconomic to install a mains power supply; and
- the increased focus on Unmetered Supplies User Group (UMSUG) and the change in UMSUG regulations, add significantly to the price of equipment. Off-grid hardware does not require an UMSUG code.

6.2.4 The primary off-grid power options are:

- Solar Panels;

- Wind Turbine;
- Batteries.

6.2.5 Displays powered by solar panels and wind turbines will also require rechargeable batteries - given that renewable power is not always available.

6.2.6 What is key to assessing the environmental impacts is to understand the options for how such systems can be designed so they operate reliably: the implications that has for carbon generation during manufacture; the carbon expenditure required to keep them going; and the implications for eventual disposal.

6.2.7 To gain an understanding of how these issues are inter-related, it is worth explaining the technical issues in more detail and looking at how different technologies impact the environment.

6.3 Mains Electricity

6.3.1 If 240v mains electricity is being used then the cleaner the generating source - the less impact, so wherever possible, contract for green, low carbon sources.

6.3.2 Electricity generation in the UK was the greenest on record in 2020, according to the National Grid Electricity Systems Operator (ESO). The average carbon intensity over the year fell to 181g of CO_2 per kilowatt hour (gCO_2/kWh) - a reduction of 66% over the previous seven years. This reduction is good news but still represents a significant volume of carbon being produced; and anything that can reduce the overall take from the power grid will assist further - as 43% of the UK power production is still fossil fuelled power (almost all from natural gas).

6.3.3 As more vehicles move to electric power, the overall power consumption from the grid will increase with at least some of the additional requirement being generated from fossil fuel - particularly at peak load times.

6.3.4 The process of getting electricity to the correct location on street has an impact. The pavement needs to be dug to the nearest power source and then filled - often with tarmac. The impact of tarmac is the topic of much debate because of its production process and the need to heat it before laying. However, in its favour it is very recyclable. Nonetheless, there are certainly significant emissions generated through the process of travel to and from a site and by the equipment used to dig and fill.

6.4 UMSUG

6.4.1 Mains power needs to consider the UMSUG requirements for codes: to signify power consumption where a metered supply is not being used. These are proving difficult to get for some suppliers with lower volumes of a given display type being purchased.

6.4.2 Large displays such as totems may have a power consumption of more than 500w, which is not eligible for UMSMG and therefore require a power consumption meter to be fitted.

6.5 Solar, Wind or a combination

6.5.1 Several companies have attempted to use wind power in display systems. Results have, however, been disappointing and as a result, none of the experiments have resulted (to our knowledge) in wind being offered as a standard option. Examples include:

- A trial in Scotland where a small vertical axis turbine was used close to the coast in a ‘good’ wind area, did not generate significant power levels. The attached display hardware was an early example of ultra-low power display (using BCD with LED front lights for night-time operation) so the hurdle for power generation was very low!
- A similar trial using a horizontal axis turbine was terminated when a gust broke the installation. Until then, the trial did not generate sufficient power for the attached essentially conventional ‘3 line’ LED display to be powered reliably.
- A city centre trial saw the turbine only generate energy when a large vehicle passed by.

6.5.2 At least two of the three examples above were wind/solar.

6.5.3 The conclusion is that wind power will only be worth considering when very specific conditions are met. These conditions are virtually never met in real life and never in cities. It might, nonetheless, be useful for purchasers to seek a supplier able to offer wind as an option.

6.5.4 Current experience is that wind alone is not viable, except on islands such as The Orkneys, The Shetlands or other largely coastal areas where wind is more reliable. Even there, for efficiency, a turbine should be on a mast of significant height.

6.5.5 New trials started in 2021 and it is possible that with new technologies and designs, wind will become viable; but not enough is understood at the moment.

6.5.6 Solar has been proven to be viable in the UK, with one supplier having deployed systems successfully for over a decade - the most northerly being within a few miles of John O'Groats. A variant of these systems, essentially a '3-line LED' equivalent, has been supplied to Illinois (Chicago) where they have been proven to work through the winter down to -25°C.

6.5.7 However, such systems only work if they are designed from the ground up to be suitable for solar operation.

6.5.8 The conclusion is that solar is possible – with care, correct technical design and experience.

6.6 Energy Consumption

6.6.1 It is often assumed that the lower the electrical power requirement of a display in operation - the more green or environmentally friendly the product is. Whilst electrical power consumption during operation is an important factor in the overall environmental impact of a display, it is not the only factor and for some technologies may only be a small proportion of the whole life energy requirement.

6.6.2 Nonetheless, management of the power consumption of a display when installed, no matter the type, can have a large impact so consideration should be given to using:

- sensors to adjust brightness levels so that it's brighter in the day and using less energy during the night when less brightness is needed.
- PIR sensors to detect the presence of a passenger to trigger the display to switch on, or increase brightness to manage power consumption.

6.7 Solar Panels

6.7.1 The material source and manufacturing processes of solar panels have a significant environmental impact. Almost all solar panels are made in China - an economy which relies heavily on coal fired power stations: the most heavily polluting method of electricity generation.

Figure 17 Shelter roof mounted solar panels in the West Midlands © Journeo

6.7.2 Solar panels can be recycled (and must be treated as waste electrical and electronic equipment: WEEE – see 10.2 below) but yield very little useful material.

6.8 Photovoltaic (PV) Modules and Inverters

6.8.1 The electronics that link solar panels and batteries and the power consuming devices are photovoltaic modules and power inverters. There is an emerging standard: *NSF/ANSI 457 - 2019 Sustainability Leadership Standard for Photovoltaic Modules and Photovoltaic Inverters* - to establish product sustainability performance criteria and corporate performance metrics that show sustainability leadership in the market.

6.8.2 The Standard provides a framework and standardised set of performance objectives for manufacturers and the supply chain - in the design and manufacture of PV module and PV inverters components. For purchasers, this Standard provides a consensus-based definition of key sustainability attributes and performance metrics, negating the need for individual purchasers to go through the arduous and complex task of defining.

6.9 Batteries

6.9.1 While they are named after individual metals, many batteries actually contain a mix of metals. For example, lithium-ion batteries contain nickel and some nickel batteries contain lithium. Cobalt also tends to be present in most rechargeable batteries.

6.9.2 The impacts of extracting these metals paint a bleak picture. However, none of this is a reason to completely avoid such batteries, which are essential for the transition from fossil fuels to renewable energy, which in turn, is reliant on the ability to store power.

6.9.3 There are actions that purchasers can take, such as ensuring that batteries are charged as efficiently as possible to ensure long life; and that they are properly recycled.

6.9.4 Asking questions of manufacturers and suppliers will encourage their adoption of good practice.

6.9.5 Lead Acid

6.9.5.1 This is the oldest technology and is heavy and difficult to manage successfully using solar power sources. Its weakness is that when badly managed (which is commonplace in renewable equipment), the cells degrade rapidly and have to be changed frequently – as often as every two years, though good systems can run well managed batteries for ten years.

6.9.5.2 The single biggest environmental issue with lead-acid batteries involves the lead component of the battery. Lead is a heavy metal with potentially dangerous health impacts. Its ingestion is especially dangerous for young children because their brains are still developing.

6.9.5.3 In the 20th century, leaded gasoline and lead-based paints were extensively disseminated into the environment. Today, those sources have largely been eliminated. According to the World Health Organization (WHO), around 85% of the world’s current lead consumption is for the production of lead-acid batteries.

6.9.5.4 Lead acid batteries can be very successfully recycled. The lead is mostly recoverable and is valuable so lead acid cells are well catered for.

6.9.5.5 Lead acid cells do not, therefore, present a major environmental cost if properly managed. Indeed, the ongoing costs are largely associated with visits to replace the battery (see support costs).

6.9.6 Lithium Ion

6.9.6.1 This is a newer technology but is rapidly gaining ground due to its deployment in electric vehicles.

6.9.6.2 LiFePO4 is currently the dominant type but cannot be charged below 0°C so must be deployed with care.

6.9.6.3 Lithium Titanate (LTO) is a better technology, is easy to charge and manage, and works down to -50°C. However, it is currently very expensive and manufacturing quality is variable.

6.9.6.4 Both types will last for many years if managed correctly. Bad management will, however, degrade performance.

6.9.6.5 Relatively few lithium-ion batteries (compared to lead-acid batteries) have reached the end-of-life stage because they haven't been in the market all that long and they last a long time.

6.9.6.6 Recycling is in its infancy and not very well developed - only 5% of lithium batteries are currently recycled in Europe. In addition, the lithium content has low value due to it being plentiful, so there is less incentive to recover it. However, lithium has a low toxicity so can be disposed of safely.

6.9.6.7 According to a research study[7] on the impact of lithium batteries, the benefits of the electric mobility from reduced tailpipe emissions will be counteracted by an increase in emissions linked to the battery manufacturing.

6.9.6.8 At this stage, it is probably most sensible to regard lithium cells as disposable items. However, given they are rechargeable, their life span may, dependent on type and if used properly, match the life span of the display hardware.

[7] https://www.orizzontipolitici.it/il-dilemma-del-litio-transizione-ecologica-e-danni-ambientali/

6.9.7 Nickel Metal Hydride (NiMH)

6.9.7.1 Nickel metal hydride batteries outperform alkaline and other primary batteries in high-drain and high current applications - making them a suitable replacement in many devices. Their voltage remains constant until the battery is almost completely discharged; and they have a wide operating temperature range.

6.9.7.2 For low power devices, they will often lose more of their stored energy through self-discharge than the device will actually draw. They are therefore not suitable for long life low power use. They need to be charged more slowly than lithium ion – making them less effective when charged through solar panels and there are variable light levels.

6.9.7.3 In addition, NiMH cells are heavier and larger than the equivalent capacity lithium-ion cells.

6.9.7.4 For these reasons, NiMH is not widely used for powering displays.

6.9.8 Non-Rechargeable Batteries

6.9.8.1 The challenge for any system using a battery pack which is not being recharged, is that it must have sufficient capacity to run the display for long enough without necessitating costly site visits. Clearly, visiting a site every week to change the battery pack simply isn't viable.

6.9.8.2 The logical choice for a high energy density pack with a long shelf life is Alkaline Manganese. These are common so are not hugely expensive. However, any such pack will still have to be replaced in due course.

6.9.8.3 These cells are recycled but the percentage of electrolyte recovered is very low – around 2% and it is not clear how much energy is wasted in recovering this 2%. Currently, it makes sense to assume that there is no recycle value worth consideration but there is a disposal cost.

6.9.8.4 By definition, single use cells will have to be replaced, probably several times during the lifespan of the hardware. Such replacements will also involve support trips which themselves generate emissions – hence, this environmental cost is a major negative factor. (See support costs).

6.10 Energy Harvesting

6.10.1 Energy harvesting can be defined as a process wherein the sources such as mechanical load, vibrations, temperature gradients and light, are scavenged and converted to obtain relatively small levels of power.

6.10.2 Solar panels are the most well-known form of energy harvesting, whilst self-winding and charging wrist watches that obtain their energy from the rotation of the wrist are an example that has been widely used.

6.10.3 Other forms of harvesting are emerging - with trials taking place in a number of places to collect the energy of pedestrians walking on pavements, for example. These are not, however, currently commercial enough to consider as power sources for public transport displays.

7 Assessment Matrix

7.1.1 The following matrix has been devised as a way to check whether a design features all the optimisation measures which contribute to reducing carbon emissions overall. What it cannot do is provide a means to compare relative impacts of the measures when applied. For example, brightness management of a transflective LCD has a similar effect to brightness management for LCD or LED - in proportion to overall power use of the system. However, because LCD and LED use more power, the power savings are much greater in absolute terms. This does not mean that the LCD or LED with brightness control is better than a transflective LCD, it merely means that the functionality is more important in absolute terms for the higher power systems.

7.1.2 The matrix has not been developed with Visual Impairments in mind. This subject is covered by the RTIG document: *RTIGPR003-D002 Inclusive passenger information - A guide to good practice for bus passenger technology providers*. However, it is worth noting that different technologies do pose specific problems for the visually impaired and that this aspect is worthy of consideration alongside evaluating 'green' credentials. This is particularly true for low contrast technologies such as e-ink and some low power LCD - where intrinsic low contrast, allied to poor design can make them harder to read. For such technologies, good design is more important, as are other mitigating measures such as audio support technologies.

Technology \ Factor	Size	Brilliance	Thermal management	Brightness Management	Ambient light management	Low power driver systems	Design for low maintenance
LCD					N/A		
LED - full colour matrix					N/A	N/A	
LED - 'normal'							
Low power LCD			N/A		Where viable		
e-ink			N/A		N/A		
flip dot			N/A		N/A		

Technology \ Factor	Remote diagnostics	Remote updates	Design for recycling	Design for reliability	Status monitoring	Solar Option	Battery (non-recharge)
LCD						N/A	N/A
LED - full colour matrix						N/A	N/A
LED - 'normal'						N/A	N/A
Low power LCD						Yes	
e-ink						Yes	
Flip-dot						Yes	

KEY	
	Significant negative impact: for example LCD is a high energy technology, therefore size is a major factor in power usage
	Negative impact: the low power nature of the technology means the negative effect of increased size is real but less dramatic
N/A	Not applicable to this technology
	Systems which have been designed with this aspect in mind will in general be better than those that do not. The vast range of options and technical competence in application make it impossible to generalise relative impacts.

Where viable	Not all technology variants in this category will necessarily support this potential, for example, not all low power LCD types are transflective.
Yes	Not all systems are suitable for solar, a 'Yes' means it is possible to run the technology from a viable solar power installation. However, it does not imply that solar is necessarily better: an ultra-low power unit using an existing mains supply may be better (and less expensive) overall than a poorly designed solar powered system.

8 Maintenance

8.1 Design for Maintenance

8.1.1 During the design stage of a product it is possible to make it easily maintainable and to have a long design life; but it is only possible to know if the design criteria have been achieved once the product has been in use for a period of time. Lessons can be learnt, however, from previous versions or similar products.

8.1.2 To assess the success of a design, as many displays as possible need to be reviewed and monitored over a period of time. Authorities or operators with large display networks will provide good sources of long-term cost and impact data, as they will be able to average out costs and impact over many displays: thereby overcoming the problem of location specific power problems skewing maintenance visit numbers, for example.

8.1.3 Servicing of displays requires travel - causing emissions. Low maintenance and remote monitoring requirements are therefore increasingly important to reduce the impact of maintenance. Indeed, the impact of visits to an unreliable display can easily outweigh any reduction in power consumption.

8.1.4 If we take the example of a short 50 km (31 mile) round trip maintenance visit to a faulty display, we can calculate the energy cost of the visit compared to the energy used by the display.

A 100 W display uses ~ 2400 Wh of energy in a 24-hour period. This is 8.64 million joules.

1 litre of petrol provides 31.5 million joules of energy

A 100 W display will run for 4 days on 1 litre of petrol.

A 5 W display will run for 73 days on 1 litre of petrol.

Using a vehicle that uses 55 mpg (88 km per gallon) which is 19.3km per litre. A 50km maintenance visit will use 2.6 litres of petrol. This is equivalent to:

9 days of operation of 100W display

189 Days of operation of 5W display or

Half a year of operation of 5W display

8.1.5 It is easy to see from this example that the impact of a visit is more significant than the energy efficiency of the display.

8.2 Remote Management

8.2.1 Remote management (configurations, content, software updates, fixes etc.) should be supported over the communications links and not require a visit.

8.2.2 Carbon costs can also be reduced through enhanced monitoring – increasing the chances that problems can be averted. It may also provide an understanding of the fault prior to the visit, enabling the operative to carry the required spares and fix it on first visit.

8.3 Frequency of Maintenance

8.3.1 Does a display really need to have a maintenance visit annually - as was specified previously; or could this be reduced to bi-annually or less frequently? Can a preventative maintenance visit be avoided entirely? The fewer the visits - the less the impact of travel.

8.3.2 To check for problems that are only visible and not detectable by remote monitoring, is there another planned visit to the bus stop by another organisation that could be shown how to test the visible aspects - thereby reducing the overall environmental impact?

9 Re-use and recycling

9.1.1 When it comes to recycling, electronics are not the first thing that springs to mind. However, as the fastest growing global waste stream, the environmental impact of electronics manufacturing is a critical issue that must be addressed.

9.1.2 According to the European Environment Agency (EEA), the amount of waste electrical and electronic equipment (WEEE or e-waste) in Europe alone is over 10 million tonnes per year. Of that, only approximately 40% is currently collected for recycling (Huisman et al., 2017[8])

9.2 Material Choice

9.2.1 The use of materials with good recycling performance (e.g. glass, metal instead of plastics) should be encouraged.

9.2.2 Front covering

9.2.2.1 Glass, as long as it is not laminated is widely recycled, but polycarbonate is not.

9.2.2.2 Polycarbonate will degrade over time when exposed to sunlight so it needs regular visual checking to ensure displays remain readable; and are replaced if the polycarbonate is too degraded.

9.2.2.3 Typically, the requirements specified in UK procurements have been for high impact protection ratings to protect against vandalism. The applicable standard: EN 62262, provides numeric classification for the degrees of protection provided by enclosures for electrical equipment against external mechanical impacts.

9.2.2.4 The UK requirement is normally for an impact protection of IK09[9]. This is higher than required elsewhere and requires thicker front material for displays, which will of course, affect the environmental impact.

9.2.2.5 IK09 is easier to achieve with polycarbonate, which was formerly used when concerns about broken glass were prevalent. Modern glass can, however,

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8 https://www.researchgate.net/publication/322603063_Prospecting_Secondary_Raw_Materials_in_the_Urban_Mine_and_mining_wastes_ProSUM_-_Final_Report

9 https://en.wikipedia.org/wiki/EN_62262

have a coating which stops shattering. Such glass can achieve the IK09 impact rating but needs to be thicker than that normally supplied - increasing cost.

9.2.2.6 The cost of replacing any broken glass may be lower than the overall cost and environmental impact of polycarbonate.

9.2.2.7 The specification of requirements such as impact protection has a material implication on the environmental impact of a display.

9.2.3 Housing

9.2.3.1 Metals such as aluminium and steel are more recyclable than other alloys and plastics. Although the additional weight of metal increases transport costs, the overall impact is probably lower.

9.3 Re-Use

9.3.1 Re-use is always better than re-cycling. It is common practice in the UK to refurbish LED displays with new single board computers retaining the original housing and display boards.

9.3.2 Recycling of displays between authorities should be encouraged. One example is Nottingham City passing older LED displays to Derbyshire for re-installation. This, as well as recycling on-bus equipment, has also been done in other areas of the UK.

9.4 Modular Components

9.4.1 Replaceable / modular components make it easy to replace parts to keep the overall display working - thereby reducing overall long-term cost.

9.4.2 Systems that are harder to vandalise will require fewer repair visits - all of which will incur carbon costs.

10 Environmental Standards

10.1 ISO 14001

10.1.1 For many contract electronics manufacturers, the increased focus on reducing the environmental impact of their operations means reviewing all stages of the production cycle – from procurement and storage, to product development and distribution.

10.1.2 When it comes to assessing an organisation's environmental impact, ISO14001: 2015 is probably the most widely regarded standard.

10.1.3 At the heart of ISO 14001 certification is the creation of an environmental management system (or EMS) which is a set of policies, practices and records that helps a company determine how it interacts with, and impacts upon, the environment.

10.1.4 ISO 14001 includes legal and other requirements and describes how to apply them to the business. The standard does not state specific environmental performance criteria, but focuses instead on establishing, implementing, maintaining, and improving an EMS.

10.1.5 An EMS is evidence-based, which means companies are able to benefit from actual, accurate data to aid their decision-making and track their progress. It can help companies to better manage cost control, whether through reducing energy usage, minimising waste, or conserving materials. And it provides reassurance for customers and stakeholders that their contract electronics manufacturer takes environmental sustainability seriously.

10.1.6 Requiring a supplier to have achieved ISO 14001 certification will be helpful in encouraging good practice and enabling a purchaser to ensure that the supplier understands their environmental impact.

10.2 WEEE

10.2.1 WEEE is the acronym for Waste from Electrical and Electronic Equipment. WEEE, also known as Directive 2002/96/EC, mandates the treatment, recovery, and recycling of electric and electronic equipment. All applicable products in the EU market after August 13, 2006, must pass WEEE compliance and carry the "Wheelie Bin" sticker. WEEE compliance aims to encourage the design of electronic products with environmentally safe recycling and recovery in mind. RoHS compliance dovetails into WEEE by reducing the amount of hazardous chemicals used in electronics manufacture.

Figure 18 Waste Electric and Electronic Equipment (WEEE) logo

10.2.2 Manufacturers have to subscribe to a registered disposer under the directive.

10.2.3 The WEEE Directive has been ported into UK law following the exit from the EU.

10.3 ROHS

10.3.1 RoHS stands for Restriction of Hazardous Substances. RoHS, also known as Directive 2002/95/EC, originated in the European Union and restricts the use of specific hazardous materials found in electrical and electronic products (known as EEE). All applicable products in the EU market after July 1, 2006, must pass RoHS compliance.

Figure 19 Restriction of Hazardous Substances Compliant logo

10.3.2 The substances banned under RoHS are lead (Pb), mercury (Hg), cadmium (Cd), hexavalent chromium (CrVI), polybrominated biphenyls (PBB), polybrominated diphenyl ethers (PBDE), and four different phthalates (DEHP, BBP, BBP and DIBP).

10.3.3 The restricted materials are hazardous to the environment and pollute landfills; and are dangerous in terms of occupational exposure during manufacturing and recycling.

10.3.4 RoHS 1 required that any product in scope should not contain any of the 6 restricted substances and that the company (manufacturer, importer, or distributor) placing the product on the EU market should maintain records to show compliance. RoHS 2 requires additional compliance recordkeeping from everyone in the supply chain. This additional compliance record keeping (which must be kept for 10 years) can include a conformity assessment, CE marking, maintenance of compliance throughout production, and self-reporting of non-compliance.

10.3.5 RoHS 2, or the Recast RoHS 2 Directive 2011/65/EU, was published in July 2011 by the European Commission. The scope of the original RoHS was expanded to cover all electrical/electronic equipment, cables, and spare parts: with compliance required by July 22, 2019, or sooner, depending on product category.

10.3.6 RoHS 2 is also a CE-marking directive, with RoHS compliance now being required for CE marking of products. As such, all manufacturers of electrical/electronic products must comply with RoHS 2 before the CE mark can be applied on their products. The original green RoHS label with the checkmark is no longer required or used, as the CE mark now includes RoHS compliance.

10.3.7 RoHS 3, or Directive 2015/863, adds four additional restricted substances (phthalates) to the original list of six, as cited under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation. It also adds Category 11 products. RoHS3 took effect from 22 Jul 2019.

10.4 International Material Data System

10.4.1 The International Material Data System (IMDS) is a global data repository that contains information on materials used by the automotive industry.

10.4.2 Several leading auto manufacturers use the IMDS to maintain data for reporting requirements. In IMDS, all materials used for automobile manufacturing are collected, maintained, analysed and archived.

10.4.3 Using the IMDS, it is possible to meet the obligations placed on automobile manufacturers, and thus on their suppliers, by national and international standards, laws and regulations.

10.4.4 It was designed to facilitate recycling efforts that target scrapped vehicles. To recycle a car, you first have to know what it's made of, which is where IMDS comes in. Every component will have an IMDS number which identifies the materials it comprises - aiding recycling.

10.4.5 Compliance with IMDS is required in the EU for vehicles with up to 8 seats. It may be extended to buses and then require all bus equipment suppliers to comply and provide the required information.

10.5 Enforcement and Auditing

10.5.1 It is not easy to achieve certification to a particular standard at a moment in time. Indeed, achieving the same behaviour and standard over time is another matter entirely and requires consistent effort and focus.

10.5.2 The retention of a standard over review periods - typically 3 or 5 years, attests to an organisation's commitment. A supplier that has newly achieved a standard should not be discriminated against because they cannot show a long-term record, but could be asked to demonstrate how they plan to retain the standard.

10.5.3 The environmental requirements for manufacturers differ significantly between countries; this is particularly noticeable in the auditing of the compliance. This makes comparisons challenging, for example the environmental rules that apply to a manufacturer with a factory in the UK are potentially very different to those of one in the Far East.

10.5.4 In making procurement decisions, care is needed to ensure environmental requirements are being compared on a like for like basis.

11 Whole Life Impact

11.1 Assessing Impact

11.1.1 To assess the environmental impact of a display, or any other process or piece of equipment, it is necessary to look at its whole life and not just at one particular stage.

11.1.2 It is possible to design something to have a very low impact in one area that has a high impact in another. It is only when the whole is assessed that it becomes possible to understand the real impact.

11.1.3 Assessing the whole life impact from raw materials through to recycling or disposal is challenging - as not all stages are likely to be within a single organisation's control. This should not, however, stop the assessment of those areas that can be assessed now. Nonetheless, the wider context needs to be understood as far as is possible when making decisions based on incomplete knowledge of all relevant aspects.

11.2 Power Use

11.2.1 Power use is highly dependent on the technology and age of equipment. The specific equipment being reviewed needs to be studied.

11.2.2 Techniques to reduce the time that the high energy components of a display are active, for example, timers to switch off overnight and presence detection, can be used to reduce the total power used.

11.3 Design

11.3.1 Design for low power, as such equipment generates less carbon. When low power kit is selected:

- Off-grid systems require less battery capacity and fewer panels.
- Mains powered hardware uses less energy.
- In general, lower power hardware is more reliable and may not require additional power-hungry devices such as fans. If no air exchange is required, fewer visits are required to change filters and clean the internals.

11.3.2 Design for low maintenance. Lower regular maintenance demands fewer visits and the associated carbon generation:

- Intrinsic reliability reduces visits.
- Equipment designed for its purpose is likely to include fewer failure points and be more reliable.

11.3.3 Design for low carbon – aspects such as material choices and battery selection can have a significant impact on carbon generation from manufacture - through use - to disposal. Longevity of a system is a major factor in overall carbon generation. Carbon costs involved in manufacture and installation should be amortised across the duration of a system's life. Clearly, a system that lasts ten years will give a better return on its initial carbon cost than one that lasts five.

11.3.4 The operational life of hardware is influenced by many factors:

- All technology has an operational life span: LCD panels are generally thought of as having a five-year life whereas some low power LCD technologies have a near infinite life. LEDS grow dim (and less efficient) over time – a 50% loss over five years of operation was commonly quoted.
- Many lower cost system parts are essentially 'consumer' items repurposed. These are not designed for longevity but for lower purchase price. They are cheaper but not generally the best basis for hardware that is expected to have a long service life.
- System design hugely affects longevity. A badly managed, high, bright LCD run in a location where it is subject to direct sunlight may be seriously damaged in one summer if not properly managed.

11.3.5 A proper analysis of what a display is required to do may reveal that a lower power type will not compromise actual function on street. For example, if all you want to show is a list of bus departures, a TFT-LCD may look prettier, but will not deliver any real benefit over a low power device.

11.3.6 System design is important. For example, if you have power to a site it may well be that using a very low power display technology on mains power, will save energy over using the same display with solar and battery. However, this is a very difficult equation to calculate effectively.

11.3.7 Integration of support for the visually impaired in a low power system is very likely to be vastly more power efficient overall than adding a separate, non-optimised unit.

11.4 Location of Manufacture

11.4.1 Place of manufacture is a challenging issue. Manufacturing activity in the UK obviously generates carbon in the UK. However, overseas manufacture, which does not contribute to UK figures, incurs increased carbon generation – as the power systems are coal powered to a far greater extent, and sea transport is extremely carbon heavy. Since the atmosphere is global, it is more logical to assess carbon generation holistically. Hence, UK manufacture may be a positive factor.

11.4.2 The supplier organisation's own policies for sourcing materials and travel are important, for example, encouraging the use of public transport is a positive factor.

11.4.3 At this stage, the use of electric vehicles is not a net positive. It is probable they will become so, but at the current state of power generation, technology and infrastructure, they do not save emissions (and arguably increase them). If calculating transport miles, mileage irrespective of drive technology, is vastly more important.

11.5 Installation

11.5.1 The selection of the exact location for a display has not historically been given as much consideration as it should have been. Advice earlier in this document to avoid having a display against a bright sky for example, can have a lasting impact on its operational life and energy cost.

11.5.2 If mounting on a pole outside a bus shelter, ensuring the display is visible from within the shelter reduces the need to re-locate later.

11.5.3 The use of high-quality galvanised poles will ensure that they can outlast a display - reducing the overall life impact.

11.5.4 The planning of installations in groups in a particular area can reduce travel distance; as can fully testing and commissioning a display at the initial installation visit.

11.6 Maintenance

11.6.1 This is covered in the separate chapter on Maintenance.

11.7 Design life vs operational life

11.7.1 How long is a display expected to be operating and maintainable?

11.7.2 It is not unusual for a design for a display to be manufactured for three years but have an operational life to last 10 years: to satisfy customer demand for a consistent display experience across their estate of displays.

11.7.3 Displays may be expected to have an operational life of 10+ years from installation. This means that production lines for spares need to be available for 20+ years and this very costly for manufacturers to keep operating. New, more efficient, or lower environmental impact processes can only have their full impact many years in the future once the old production processes can be switched off.

11.7.4 Longevity of support is a significant factor. For example, even if a display was repairable after five years, if the component spare parts are no longer available, it could result in the need for a more significant repair through having to ‘upgrade’ more parts of the system, or even the display being scrapped altogether.

11.7.5 The long-term availability of parts can be ensured either by selecting suppliers who actively manage the long-term availability of their parts, or by the up-front initial purchase of suitable spares to avoid problems caused by obsolescence.

11.7.6 The same delayed impact of old technology is felt by customers having to pay for more maintenance visits and higher electricity bills, than if newer displays were in use. There is a balance to be struck between maintaining old displays for as long as possible and the introduction of ‘better’ new technology.

11.7.7 Many LED displays installed in the UK are now well beyond the manufacturer’s design life (typically 10 years) - with a current life of 15 years being common; with authorities planning to extend life to 20 years through upgrades to display drivers and modems.

11.7.8 A factor in longevity is how smart the system is. One that has limited functionality may have to be replaced sooner than one that has more functions. For example, if audio is supported as standard, it can be activated at a later date even if not initially used. A system that can have functions added (through having smarter, more adaptable software), may not have to be replaced when additional functions are required.

11.7.9 The energy cost of manufacturing can be calculated and compared against the operating energy cost in a similar way to the maintenance visit calculations.

11.7.10 Using the manufacturing energy calculation from a United States Environmental Protection Agency document on the *"Life Cycle Assessment Data for TV-LED"*[10] we get a manufacturing cost of 226.83 kwh / kg for a domestic plastic housed 32" TV. If we assume the weight of the display as 5 kg, which is much lighter than a typical on street display (which have metal cases and for which the data is not available):

> The manufacturing energy requirement is 1.633 billion Joules.
>
> A 100 w display requires 8.64 million joules to run for 24 hours.
>
> The manufacturing energy cost is therefore equivalent to 1.3 years of operational energy requirement.

11.7.11 External specification displays will have a higher manufacturing energy cost because of their heavier weight and use of metal casings. This serves to increase the number of years before operating energy creates the higher environmental impact. This will be significantly increased for low power designs - where the manufacturing energy could easily be greater than 10 years of operating energy.

11.7.12 This highlights that the biggest environmental impact is in the manufacturing processes and this where the focus and effort should be to achieve a reduction in overall impact.

11.8 Re-use and recycling

11.8.1 Consider if the original supplier or another authority could use a display that is being replaced - either to expand their network, or as spares for existing displays to increase their life?

11.8.2 If re-use is not possible, then ensure that the display is recycled responsibly to the latest standards.

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[10] https://www.epa.gov/sites/default/files/2018-02/documents/lca_tv.pdf

11.9 Passenger Impact

11.9.1 In any discussion about impact, the whole raison d’être for displays needs to be considered.

11.9.2 Upgrades to existing systems or the introduction of new systems can be used to promote public transport. For example, changing from amber to white LED will be a noticeable change and can be an opportunity to promote the ‘improvement’.

Figure 20 Double sided LED outside of bus shelter in Nottingham.

11.9.3 In the above photo the decision to locate a display outside a shelter so its presence is visible to passing motorists helps promote public transport - offsetting the increased cost of double-sided panels.

12 Procurement Considerations

12.1 Procurement and the environment

12.1.1 All procurement has some level of impact on the environment that needs to be minimised to ensure sustainable procurement practices.

12.1.2 Many environmental impacts such as resource extraction, design development, manufacturing, transportation and storage, etc. occur before a product or service is procured.

12.1.3 The greatest opportunity to influence environmental outcomes is by selecting products and services with the least ongoing environmental impacts in aspects such as the use of water, electricity and fuel, waste/disposal management, and impact on human health - over the life of the product or service.

12.1.4 Lifecycle stages that impact on the environment:

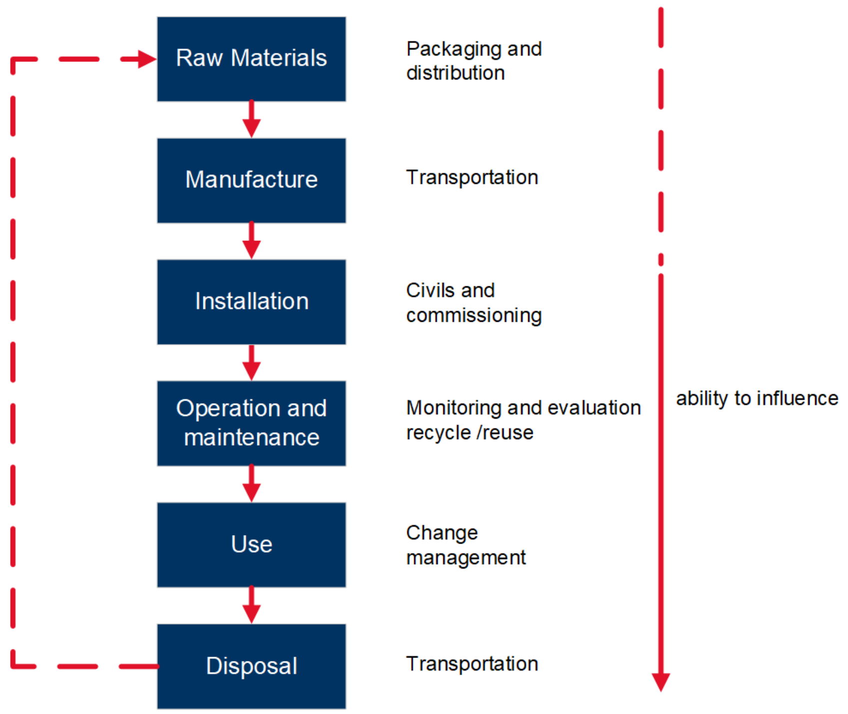

Figure 21 Lifecycle stages that impact on the environment

12.1.5 The figure shows lifecycle stages that impact on the environment. The figure shows the following stages:

- Raw materials - packaging and distribution
- Manufacture - transportation

- Installation – Civils and commissioning
- Operation and maintenance - monitoring and evaluation recycle / reuse
- Use - change management
- Disposal - transportation

12.1.6 These stages form a cycle and the potential to influence increases between the operation and maintenance, and disposal stages.

12.1.7 The whole supply chain impact is what will ultimately be important. With the expectation increasing that a product will be able to be traced back to the sourcing from mines etc., the process of achieving that level of traceability will take time to complete, so the sooner the questions are asked by purchasers - the more quickly full traceability will come about.

12.2 Integrating environmental impact into the procurement process

12.2.1 You need to consider environmental impacts at the front end of the procurement process if you are to position environmental impact across the latter stages.

12.2.2 Crown Commercial Services are increasing their focus on environmental requirements and will be asking for more information in future frameworks. This is expected to play a significant role in improving awareness and accountability.

12.3 Environmental impact and market analysis

12.3.1 The Victoria state government in Australia has a helpful three step approach to assessing the environmental impact that can be applied to many procurements.

12.3.2 The market analysis stage should aim to answer the following questions:

Step 1: Is there an environmental impact associated with the product or service?

12.3.3 Most goods and services will have an element of environmental impact in a number of areas. The five main impact areas are listed in the following table.

Impact area	Details
Greenhouse emissions	Does the product/activity consume electricity, natural gas, diesel, LPG, oil or any other fossil fuels? Is the delivery of the service likely to result in the use of electricity, natural gas, diesel, LPG, oil or any other fossil fuels?
Water	Will normal use of the product result in the use of potable water? Is the delivery of the services likely to result in the use of potable water?
Waste	Does the product include non-recyclable components (including packaging) that are expected to be committed to landfill at the end of its useful life? Will purchase/use of the product/service result in waste to landfill?
Air	Will normal use of the product result in the release of air pollutants? Is the delivery of the services likely to result in the release of air pollutants?
Biodiversity	Will purchase of the product/service result in an impact on native flora or fauna?

Step 2: What is the estimated level or extent of risk associated with the environmental impact?

12.3.4 Understanding the potential level of environmental impact risk will influence the scope and depth of your market research and analysis. Critically, it will help you target the most appropriate market sector for further investigation.

Step 3: What are the minimum performance requirements of the market?

12.3.5 Taking into account the level of environmental impact, what are the minimum standards of environmental performance required from the market? Is there:

- a government (policy/statement) or organisational policy requirement relating to a minimum standard for the procurement category/requirement; and/or
- an industry standard or level of best practice relevant to the procurement category/requirement?

12.3.6 Be careful when adopting and/or attributing importance to an industry standard where there is concern regarding the independence of the party providing the certification. For example:

- As a general rule, an ecolabel, 'green label' or star rating awarded by an impartial third-party body is considered to demonstrate a higher degree of environmental assurance than that of other claims developed by manufacturers and service providers.
- Alternatively, adopt a benchmark based on actual data held by the organisation to calculate the average usage over a period consistent with the intended usage of the good or service. Where possible, the benchmark or standard developed should be compared with any available industry/business information.

12.3.7 If there is no applicable standard, the market analysis may need to focus on market sectors that:

- operate in an area of business related to the area of environmental impact
- purport to have environmental credential/experience
- are associated with associations or organisations with an interest in environmental issues

12.4 Environmental impact - market approach

12.4.1 Environmental performance is continuously evolving throughout industry and business. Given these dynamics, consideration should be given to driving environmental improvement throughout the period of the contract. Suppliers who are moving towards minimum standards should not be excluded when carrying out market analysis.

12.4.2 The following table details some environmental performance requirements to consider when making a formal approach to the market:

AREA	DETAILS TO INCLUDE
Evaluation criteria	1. Supplier's commitment to environmental sustainability Relate to the internal processes and policies of the supplier. 2. Environmental impact of the product/service If the market analysis identifies that the product/service has an environmental impact, it may be appropriate to include a separate evaluation criterion to preference products/services with lower impact.
Specification	Include any minimum environmental standards that are required either known or determined, during the market analysis. When developing targeted specifications maximise the use of performance-based standards where applicable.
Contract	Any minimum environmental standards that are considered important may also be included in a contract.
Supplier's response	1. Supplier's commitment to environmental sustainability As per the evaluation criteria, seek details relating to the supplier's commitment to environmental sustainability. Does the supplier: • have an environmental management system (EMS);

	• carry out any actions to improve environmental credentials; • have an environment policy; and/or • has it undertaken any activities to manage its environmental impact. 2. Environmental impact of the product/service If an industry standard exists, assess suppliers against that. It can be hard to assess suppliers against one another given the many different approaches to environmental management. You will need to make a balanced judgement against multiple competing standards.

12.5 Quality Questions

12.5.1 The challenge is to develop a justifiable framework whereby suppliers can be evaluated in a consistent manner based on differences in their environmental performance. You will need to consider whether the relative environmental performance of goods/services of different suppliers can be compared. If so, can the benefits of an improved environmental performance be quantified?

12.5.2 Specifying a minimum standard allows you to monitor compliance and encourage improvement of performance.

12.5.3 Another approach is to develop a series of standard questions and instructions that require a response from the supplier.

12.5.4 Your procurement team may have a set of questions that have been used in other procurements that may be applicable or able to be adjusted to reflect the requirements of a procurement for electronic displays.

12.5.5 It is also possible to devise a range of generic environmental performance questions that can be integrated into evaluation criteria to indicate a supplier's general commitment to environmental performance and continuous improvement. Some generic questions can be framed around whether the supplier applies an environmental performance management framework in their workplace. You might also ask whether:

- the framework is aligned with the business plan of the organisation;

- there is a programme of framework review, promotion, training and discussion to drive continuous improvement; and
- the organisation records performance against yearly benchmarks.

12.6 Requirements Specification

12.6.1 Within a procurement, in addition to quality and company compliance questions, there will be a specification that details the requirements that are to be met.

12.6.2 Within the specifications, there are significant opportunities to include environmental requirements in a way that may provide a more robust challenge than the quality questions.

12.6.3 At a high level, the specification of a particular technology will have an impact on the overall environmental impact. It is easy to specify a requirement for ‘energy efficient displays’, quantifying what is meant by that is an entirely different thing.

12.6.4 Requirements can be targeted at specific areas of environmental impact, for example, ensuring the use or recycled packaging or the proportion of recycled material used in plastic components.

12.6.5 More technical requirements can be set, such as the type of battery used or a particular power consumption.

12.6.6 Behaviours can be addressed through requirements to take back and commit to recycling products or requiring a particular maintenance profile. These need more significant consideration as they have more impact on product design than simply providing a display of a particular type or size. The long-term implications are more significant and costly for suppliers to achieve quickly but are important and therefore, need careful consideration to ensure a fair and open competition.

12.6.7 It is standard practice for manufacturers to specify a Mean Time Between Failure for a product. They are, however, less likely to specify an expected lifespan – which is more significant in assessing overall environmental impact. Consider specifying the expected product life - to encourage long term reliability planning at the design stage.

Appendix 1 Glossary

BCD	Binary Cholesteric Displays
BFR	Brominated Flame Retardants
CFL	Compact Fluorescent Lamp
DRC	Democratic Republic of the Congo
EEA	European Environment Agency
EIA	Environmental impact assessment
ESO	Electricity Systems Operator
IMDS	International Material Data System
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LTO	Lithium Titanate
NiMH	Nickel Metal Hydride
OLED	Organic Light-Emitting Diode
PBB	PolyBrominated Biphenyls
PBDE	PolyBrominated Diphenyl Ethers
PIR	Passive Infra-Red
PV	Photovoltaic
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RGB	Red Green Blue
RoHS	Restriction of Hazardous Substances
RTI	Real Time Information

RTIG	Real Time Information Group
TFT	Thin Film Transistor
UMSUG	Unmetered Supplies User Group
W	Watt
WEEE	Waste Electric and Electronic Equipment
Wh	Watt Hour
WHO	World Health Organization