



Mobile Event Village

A research on how to make
mobile architecture more sustainable

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Keywords: Flexible, mobile, relocatable, moveable, temporary, sustainable, self-sustaining, off the grid, sustainability, renewable, energy, festival, event, production.

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Abstract

With an increasing demand for flexible, adaptable and temporary architecture and an increasing awareness for sustainable development, events, relying on mobile architecture, are expected to reduce their carbon footprint. This research paper aims to understand how mobile architecture (pavilions, stages, event venues, etc.) can become more self-sufficient in energy by exploring renewable power options for on site energy production that are applicable for mobile architecture.

The technical research is clearly divided into two subjects: Mobile architecture and temporary sustainable power generation. Findings from both chapters will be combined to understand the implications of mobility and sustainability in the architectural design of a sustainable Mobile Event Village: a collection of mobile functions needed for the organisation of an event or festival onsite.

The first chapter describes mobile architecture in general by elaborating on what mobile architecture actually is. What is its function and how comes it into being? In order to categorise these

the questions Why, Who and How were answered. This resulted in a summary diagram that places mobile architecture in relation with its purpose, function segment and client. The research is mostly on mobile architecture used in public space rather than mobile architecture used for shelter specifically (e.g. holiday homes). The chapter on Sustainable Mobile Architecture will set out different technologies for onsite power generation and sustainable developments suitable for mobile architecture.

It was concluded that for the Mobile Event Village a relocatable solution would be most appropriate due to its high adaptability to different contexts and users in relation to a medium deployment time and therefore medium costs. For supplying mobile architecture with energy, hybrid systems (e.g. solar power and bio diesel) would probably be the most likely option in the near future as the relation between transportability and renewable power generation should be taken into account: the reduction of the carbon footprint by the production of renewable energy generation, e.g. solar PV panels,

might be undone by the increase in carbon emissions by its transportation. It is however, of high importance to first clearly specify the energy demand needed as renewable production of energy is very limited for mobile architecture and reducing the energy demand needed is already very effective. Large reductions can already be achieved by the smart configuration and exchange of waste flows between functions which will be further explored in the architectural design of the Mobile Event Village.

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Introduction

With an interest in temporary architecture and user experience I have always been intrigued by pavilions exploring new architectural concepts or technologies, large events with their scattered functions and music festivals with their extensive stages. Temporary or mobile architecture goes back as long as men builds (Tipi's, Bedouin tents and yurts are ancient examples of mobile architecture) but has only recently been named as architecture due to its temporary nature. With an increasing demand for flexible, adaptable and temporary architecture today, mobile architecture exists in all forms and shapes and for almost any function and uses different technologies to relocate itself [Kronenburg, 2007].

With an increasing awareness for sustainable development, events, relying on mobile architecture, are expected to consciously re-think their events and reduce their carbon footprint*. Current events usually run on diesel generators and together with transport

* A carbon footprint measures the total greenhouse gas emissions caused directly and indirectly by a person, organisation, event or product [Time for Change, 2007].

they account for a high carbon footprint. Where sustainable solutions for static buildings are becoming more and more available (e.g. thermal heat storage, solar pv panels, etc.) these are often not suitable for mobile architecture. This research paper aims to understand how mobile architecture (pavilions, stages, event venues, etc.) can become more self-sufficient in energy and how these solutions can be integrated in the architectural design of a Mobile Event Village.

In order to do so the first chapter will elaborate on what mobile architecture actually is. What is its function and how comes it into being? The chapter on Sustainable Mobile Architecture will set out different technologies for onsite power generation and sustainable developments suitable for mobile architecture. This knowledge then will be combined in the last chapter, Architectural Conclusions, to understand the implications of mobility and sustainability and explore the possibilities for a sustainable Mobile Event Village.

Methodology

The technical research is clearly divided into two subjects: Mobile architecture and temporary sustainable power generation.

For both subjects literature study was done using books, scientific articles and webpages.

For the subject of mobile architecture most research was on case studies (Appendix A) which clearly demonstrated the wide variety of types within mobile architecture. In order to categorise these, the questions Why, Who and How were answered resulting in a summary diagram that places mobile architecture in relation with its purpose, function segment and client. During the research the focus was mostly on mobile architecture used in public space rather than mobile architecture used for shelter specifically (e.g. holiday homes).

As previous research** has provided a

** As a projectmanager of Delft Experience Tomorrow (D-Exto) and Innofest I have visited up to 8 different festivals where we did backstage research and interviews on sustainable innovation on festivals.

My graduation research

basis knowledge of the sustainability of festivals and most literature was used to support the existing knowledge with figures and facts. During the research an interview with Paul Schurink, frontrunner in making festivals more sustainable, has provided many useful insights.

Background

Problem Statement

In a society with fast changing culture- and consumer demands, economic awareness and a need for temporary, flexible and adaptable architecture, mobile architecture is becoming more important. Mobile or temporary architecture is present at many different occasions of which events are the most obvious. Temporary events like the Olympic Games, World Expos, the Venice Biennale, Sport Championships, Music, Film and Cultural Festivals all rely on tents, trailers, pavilions and even huge temporary stages or stadiums for their programme. These can all be categorised as mobile architecture but also simple construction trailers, small holiday homes or refugee shelters are part of mobile architecture.

With an increasing awareness of the results of Climate change, the growing world population and an increasing scarcity of resources events are forced to re-think their energy- and resource consumption. Where mobile architecture offers a fast and temporary solution with a minimal impact to the existing (urban) landscape temporary constructions seem

to be quite sustainable. They have however, a large carbon footprint as they are powered by diesel generators, need a lot of transportation and events create quite some waste (just think of the festival streets or fields covered with plastic cups at the end of a music festival). A research on the energy consumption of festivals in the UK shows that UK music festivals generate an estimated 48 000MWh of electricity, 31 600t of CO₂e emissions and consume about 12 million litres of diesel per year! This equals the powering of 10 000 homes for a year and with a still increasing number of festivals in the Netherlands each year [Graph 1], the carbon footprint of events should be reduced [Challis, 2011]. Luckily more and more innovative technologies become available but many of these are often not suitable for mobile architecture as the temporary nature makes it difficult or impossible to apply these to mobile architecture (e.g. heat pumps, green roofs, aquaponic systems, etc.).

Objective

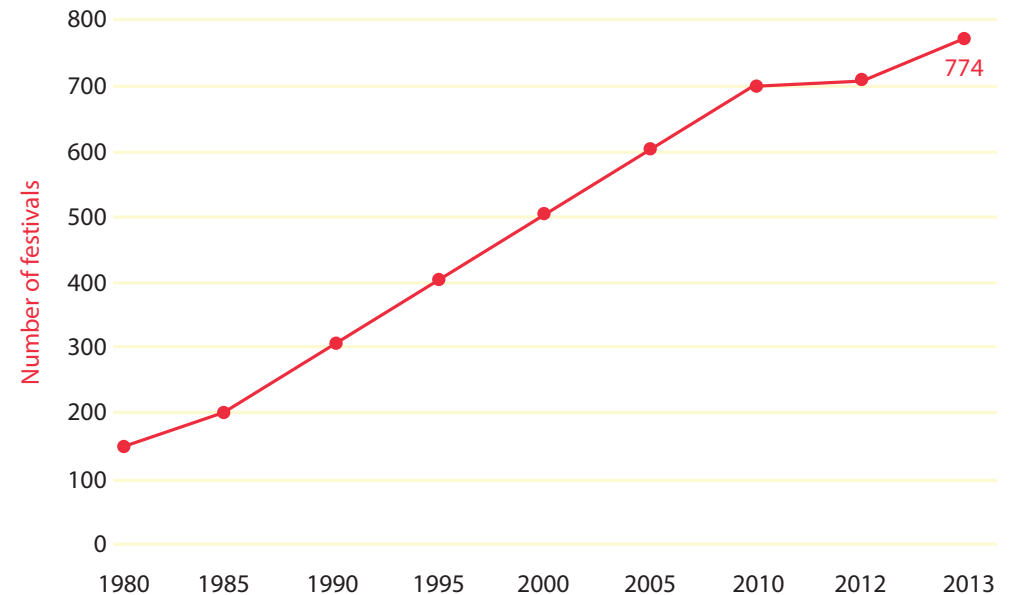
Many events are already working on becoming more sustainable but often

the effectiveness of their measures is lacking. The objective of this graduation research is to understand why it is so difficult for mobile architecture to become more sustainable and what renewable technologies could be used to make mobile architecture more sustainable.

Technical Fascination

Flexible architecture that can adapt to different situations, that can travel and function in any context seems like an impossible challenge as architecture relates to its surrounding [Dijkstra, 2014]. Some projects however, seem to be able to do this and with an increasing

1. Amount of festivals per year



Source: Respons

demand for flexible and temporary space I am fascinated by temporary and mobile architecture. How can this ephemeral architecture create a sense of place that is independent from its context and above all, how can this be achieved in such a way it does not harm the environment it is in or with a high carbon footprint?

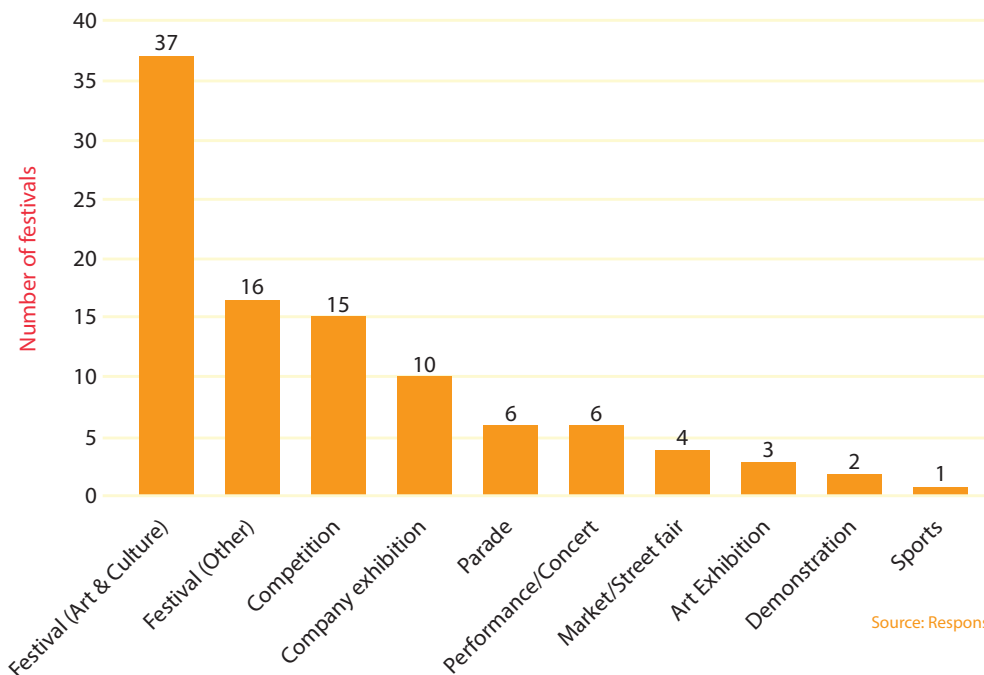
Technical Research Question

In what way can mobile architecture create a sense of place and generate energy in a sustainable way?

Concept

In order to explore the options for making mobile architecture more sustainable I will develop a Mobile Event Village (MEV) for my graduation project.

2. Top 100 largest events divided per type



Considering the majority of events organised are festivals [Graph 2] and their increasing popularity, festivals seem like a good place to start to integrate sustainable solutions with mobile architecture and reduce carbon emissions. As mentioned previously, events are already working on becoming more sustainable but often measures taken are simple and sometimes seem to be more an act of green washing* rather than being effective. Looking at a festival a distinction can be made between the front stage (the festival open to visitors) and the backstage (only open for crew, artists, suppliers and volunteers). Where most developments are happening at the front stage of a festival (e.g. reducing the energy needed for the main stage, introducing bio- or fair-trade food, separating waste, etc.) and are very effective in raising awareness about sustainability, not much grand or effective measures are yet taken at the backstage of a festival. When looking at the total energy demand of

* A company or organisation can be accused of green washing when it spends more time and money on claiming to be "green" through advertising and marketing than actually implementing business practices that minimize their environmental impact. [Greenwashingindex.com, 2014]

a music festival however, the electricity consumption can be roughly divided in three categories all representing about one third of the total consumption: Stages (33%), Traders (36%) and Infrastructure (31%). As stages are the most obvious consumer of electricity most developments are focussing on decreasing their demand. Graph 3 illustrates however, that the infrastructure (Crew catering, Campsites, Tour buses and Production offices) are responsible for a similar demand of electricity [Marchini a.o., 2011].

Research increasingly shows that significant energy savings can be made by re-thinking the energy management and with the use of renewable power technologies. Considering that currently the production area of a festival exists of many separate tents, trailers and trucks with each their own power generator, improvements can be made by integrating the different functions and redesigning the energy-, water-, waste-, and material flows present which might greatly reduce the infrastructure's carbon footprint. Focussing on the backstage area of a festival has two main advantages: 1) The production area of a festival has a longer time span than its stages and can

therefore generate energy over a longer time span therewith increasing the total amount of renewable produced energy.

2) Festival organisations will be more open to new technologies backstage as they will not directly influence their visitor's experience of the festival which is their biggest concern.

The Mobile Event Village will be a collection of integrated functions needed for the production of a festival. Considering this programme it would have

been more obvious to call the Mobile Event Village a Mobile Production Village but as the communal area of the village could be used to host small events too, Event Village is less specific. Due to its need for relocatability, the Mobile Event Village will need to be adaptable to different locations. In order to create an integrated uniformity, sustainable power generation will have to be integrated within the architectural design taking into account e.g. orientation, deployment and mobility.

Overall Design Question

How can renewable and onsite power generation for mobile architecture contribute to the architectural experience and character of a Mobile Event Village for the production of Dutch outdoor events/festivals?

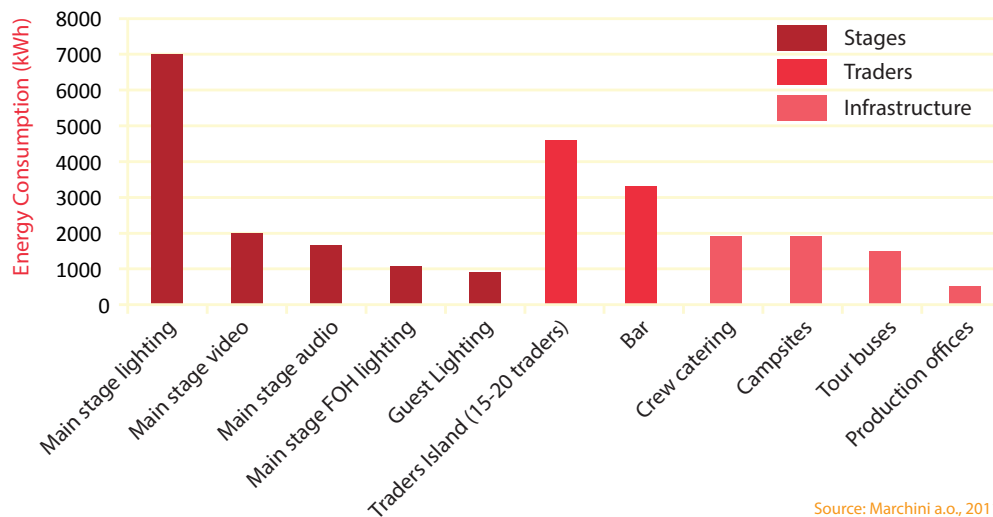
Relevance

Festivals are becoming more popular each year as they provide a short escape from fast pace, daily reality and with 774 Dutch festivals last summer the amount

of festivals is still growing. One fifth of a festival's expenses is power which can represent up to 70% of the festival's core carbon footprint and is mostly provided by diesel generators: A festival like Lowlands uses over 865 000 kWh per edition which equals 4000 litres of diesel and is more than a city like Assen in three days! [Duurzaamnieuws, 2010]. With the increasing oil prices energy is becoming more and more expensive which highly influences the festival's expenses and might make it financially unfeasible in the

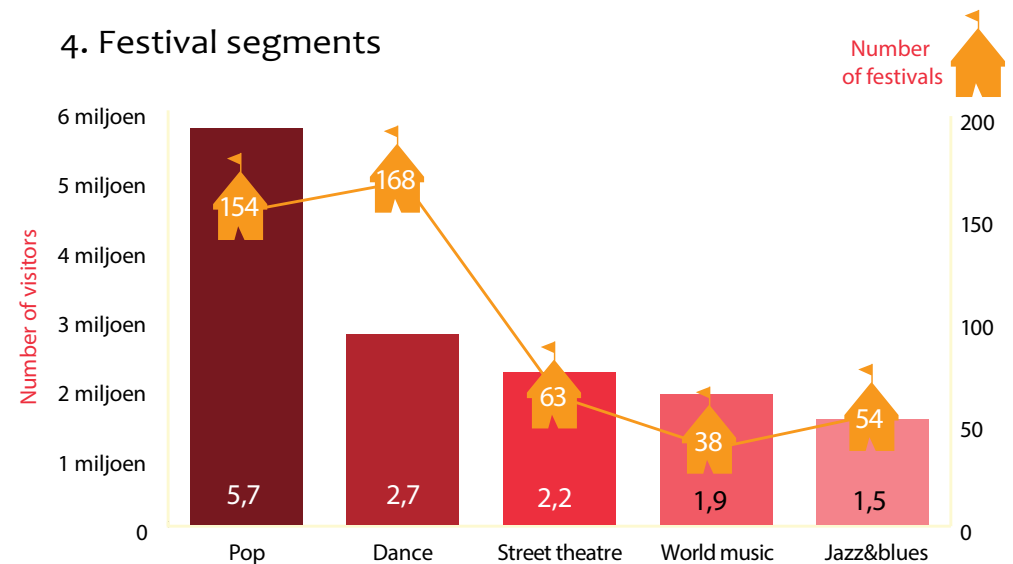
3. Typical electricity consumption per category

Data based on 73 different activities at 18 festival events at 7 different festivals between 2009 and 2012.



Source: Marchini a.o., 2011

4. Festival segments



Source: Respons

end for a festival to take place.

“Power has significant implications for the practical, economic and environmental success of any event. With rising fuel costs and an increasing awareness of sustainability, the industry is asking for more knowledge, understanding and expertise on sustainable power at festivals.” [The Power behind Festivals, 2011].

Also, as festivals are a daily life escape for many of its visitors their mindset is much more responsive to new concepts and ideas which make them a perfect condition for raising awareness and pilot new innovations about sustainability which makes them more open for sustainable solutions in daily life.

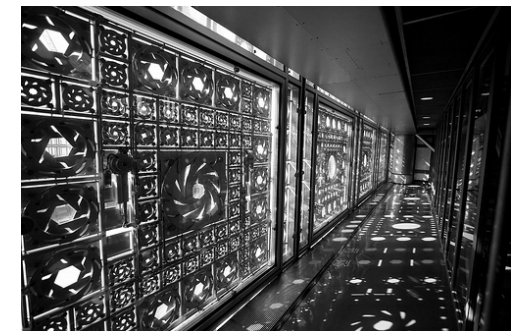
Mobile Architecture

What is mobile architecture?

Mobile architecture “are those that have a strictly ephemeral nature – that are moveable in some form, and are designed specifically for deployment in different situations and/or locations.” [Kronenburg, 2003]. At first this seems like a very simple definition but when exploring mobile architecture, it turns out that there are many different types of mobile architecture with different purposes, functions, target groups and clients: By mobile architecture you might think of intriguing pavilions, art installations and music stages but also temporary offices, refugee shelters, construction trailers and even some stadiums are all part of mobile architecture. In order to understand the extensive array of what mobile architecture

is, how it comes into being and what its actual function is, this chapter aims to categorise the different types of mobile architecture to set some boundaries for the design of a Mobile Event Village.

Mobile architecture can be categorised in different ways: by its purpose, users, functions, clients, the way it is transported, etc. To give a brief but accurate summary of mobile architecture the simple questions Why?, How? and (by) Who? will be answered in this chapter.



Why?

Purpose

The key characteristic and therewith the main advantage of mobile architecture is its temporary nature. Due to this, mobile architecture often has a low impact on its surrounding as it should appear and disappear like it was never there. Even though all mobile architecture shares this key characteristic their purpose can be very different. The purpose of mobile architecture can be divided in three main categories:

- A) Shelter
- B) Learn
- C) Entertain

Mobile architecture has been around as long as men builds and arose as mobile shelter for nomadic tribes. Some ancient examples are the Bedouin tents, North American tipis and Asian yurts [Kronenburg, 2003]. Nowadays, temporary shelter is especially used for shelter after natural disasters, for political refugees or, totally opposite, for holiday homes.

Within the category learn there are two

different ways “learn” can be interpreted. Firstly, the mobile object can be used to provide information for its users to learn about a subject: e.g. temporary information kiosks, exposition spaces or mobile schools. Secondly, the construction of the object itself can be used to learn about new technologies or used to explore new architectural concepts in which the design is usually focused on exploring one aspect. Art installations or pavilions are a great example of these. It is also herefor that mobile architecture “seems to be always new: modern, lightweight and futuristic. This relates to their requirement to be light and strong which are usually innovative technological systems [Kronenburg, 2003].

Lastly mobile architecture can be used for the purpose of entertainment. Large stages for music, dance or opera performances or video installations are well known examples of these.

All mobile architecture can be divided in these three categories but when designing mobile architecture, it is important to make a distinction between a portable

building and portable architecture: are they “Structures performing the functions of environmental modification (climate) and the purpose of activities carried out within their enclosure” or are they “the physical manifestation of their creators’ ambitions” [Kronenburg, 2006]?

Function

The previous paragraph clearly distinguished the three different purposes of mobile architecture Shelter, Learn and Entertain. A second distinction can be made for the different function segments mobile architecture is used in. This second distinction is made because within these segments the purpose of the mobile architecture can be different.

Entertainment

Entertainment and mobile architecture often go hand in hand as temporary festivals and parties are totally build up from scratch, sometimes at locations with no existing services present at all. Within the entertainment sector mobile architecture is mostly used for entertainment (stages) but also shelter

is being provided for the production of the event and at larger events (e.g. the Wereld Haven Dagen or the Olympics) special information kiosks are designed. Specific for the entertainment sector is the need for mobile architecture that is flexible in its character as these changes annually.

Arts & Education

Related to entertainment but with a higher focus on learning, the arts and education category exists more of installations and pavilions. By exhibiting art work or showing images or film mobile architecture within the Arts & Education category are learning the visitor (unconsciously) about the artwork or a subject. Examples of these are the Venice Biennale on Architecture or the Filmfestival showing films on different cultural opinions and ideas. Herewith climatized spaces for art etc. are of higher importance.

Exhibition & Commerce

Mobile architecture within this category is mostly about learning about company products and creating an environment in which the visitor is more likely to purchase

their products. Herefor impressive temporary stands are made traveling different trade shows a year. A quite recent development within this category are pop-up retail stores. Large brands like Puma, Illy or H&M have a temporary store “popping-up” at an unexpected location to sell (limited) products for a short amount of time. By attracting “the consumer long enough with something exclusive, surprising and exciting, [...] “the brand gets exposure to create an impact and communicate something specific to a large audience” [Brandspots, 2015].

Shelter & Residential

Like it name says this category’s functions is providing shelter. This means the architecture is climatized and usually has a kitchen and bathroom which leads to challenges concerning services like water and waste. Also refugee shelters belong to this category. Besides the challenge of applying a proper service network the architectural challenge herewith is the fast deployment, low cost and lack of identity due to its immense repetition.

Military & Expedition

Specific to this category is the often special programme needed for research

and the often difficult or extreme location or weather conditions these constructions have to withstand, Halley VI in Antarctica being a great example.

Programme

At the beginning of my research I mostly focused on mobile architecture with a public programme. Herein I distinguished three different types of public space (mobile) architecture can provide: Stage, Space and Place.

Stage

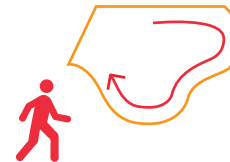
The characteristic of a “Stage activity” is that the visitor is passively receiving information; he or she is just looking or listening. Examples of these are theatres, music festivals, conferences, etc.



Space

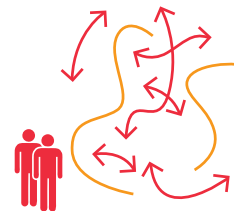
A Space hosts public activity where the visitor can walk around freely but is guided by a certain route. The visitor can decide for him- or herself to which extent

he or she is interested in the subject. Examples are exhibitions, trade shows, art installations and pavilions.



Place

However looking similar to a Space, a Place is a surrounding where people interact. Whether this is with each other or with the building, it is mostly about experience. The visitor is triggered but not guided by the architecture. Activities happening at a Place are receptions, encounters, discussions, etc. and can be hosted in pavilions, triggered by art installations, etc.



Conclusion

This paragraph started with categorising mobile architecture by purpose and function and briefly categorised public space in mobile architecture. The Mobile Event Village can be categorised as Shelter for the entertainment sector as it will have to provide several climatized spaces and be able to have a changing character relating it the identity of the festival. Its communal area will have to be a multifunctional Space where people crew and artists can meet.

How?

Transportation

Mobile architecture is characterised by its ability to travel from its production site to a different location. From there it might be broken down and recycled or used many other times at different locations. There are different ways to transport mobile architecture which is roughly chosen on its deployment time and flexibility in layout. The deployment time is the total time needed to get the building ready for opening to its visitors. This therefore includes transport, construction and connecting services. The type of mobile architecture will be based on the time span of the event in relation to the costs which is mostly dependant on the deployment time and transport costs: e.g. a deployment time of two weeks for an event of a couple hours is not realistic. For festivals an average deployment time of two weeks for the whole festival of three days is common.

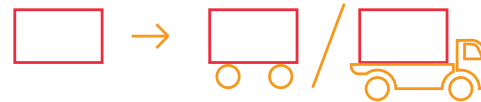
Portable

Portable architecture is transported as one piece and where all services are integrated. It can be towed or carried or have wheels integrated, a caravan being

the most obvious example.

Advantages are its very little deployment time, instant created space and the integrated services.

Disadvantages are the limited amount of flexibility in its space and layout and its size is restricted to the size of the transport vehicle.



Examples: Containers, vans, folding structures, etc.

Relocatable

Relocatable architecture is transported in multiple prefabricated modules or units that can be connected to each other in different ways making them adaptable to different locations. The main advantage of this type is that it can provide space almost as quickly as the portable building without restriction in size imposed by transportation [Kronenburg, 2013].

Advantages are a medium deployment time, almost instant space, plug and play

integrated services and a size not bound to transportability possibilities.

Disadvantages are a still limited amount of flexibility in space and layout and higher costs due to a longer deployment time.



Examples: interlinked container units, modular systems, etc.

Demountable

Demountable architecture is architecture that can be (almost) totally taken apart in a number of standardised parts, scaffolding being a great example.

Demountable architecture is really flexible in size and layout and can be transported

in a relatively compact space.

Advantages are a maximum flexibility in space, shape and form.

Disadvantages are a long deployment time depending on the size, complexity and ingenuity of the system and the limitations that site operations can bring (safety), high costs and no integrated services



Examples: Scaffolding, tents, etc.

Comparison

In the table below the three transportation types are compared to each other by ranking the flexibility in layout, transport

-- - + ++	Portable	Relocatable	Demountable
Flexibility in layout	--	-	++
Compactness during transport	--	-	++
Deployment time	++	+	--
Integrated services	++	-	--
Deployment costs	++	-	--
Portability (ease of use)	--	-	++

size, deployment time, the integration of services, the deployment costs based on extra construction material needed (like manitou) and the portability: the ease of use due to the weight of the materials for the construction team.

Flexible Architecture

Mobile and flexible architecture are closely related but where mobile architecture is specific about transport, flexibility can be about different subjects like location, production or use. Mobile architecture is therefore always relocatable, often adaptable but not always transformable or interactive.

Relocatable

Buildings that relocate from place to place: Mobile Architecture. They can be moved in one piece (portable), be transported in units or modules (relocatable) or be taken down into smaller parts (dismountable).

Adaptable

Adaptable buildings are designed to adjust to different functions, users or climate changes and feature repositionable partitions or elements that are changeable per user (e.g. solar shading for the

individual) or function (e.g. moving walls to create smaller or larger spaces).

Transformable

Buildings that change shape, space, form or appearance by the physical alteration of their structure, skin or internal surfaces. Transformable buildings are characterized by modular design (capability of adding or removing units or components).

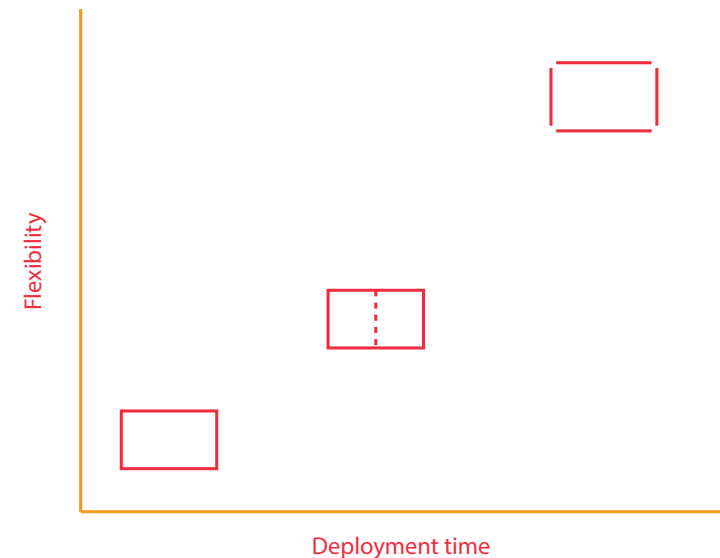
Responsive/interactive

Responsive or Interactive buildings are buildings that respond to “external stimuli” like energy consumption, indoor or outdoor climate, occupation or other user’s requirements in automatic or intuitive ways with the help of sensors, kinetic systems and intelligent materials. The facade automatically regulating the amount of light entering the Institut du Monde Arabe in Paris is one of today’s best known examples.

Conclusion

Categorising the Mobile Event Village I will focus on relocateable architecture. This is due to its high adaptability to different contexts and users in relation to a medium deployment time and therefore medium costs.

5. Flexibility vs. deployment time



Who?

Clients

The previous paragraphs have illustrated that there are many types of mobile architecture within different fields and all with their own function. In order to understand how mobile architecture is funded this paragraph divides mobile architecture in five client groups. It is interesting to see how specific functions relate to different clients. This is clearly illustrated in the diagram on the next page where purpose, function segment and client are set out to each other including with some of the case studies that were made during this research and can be found in Appendix A.

Cultural Institutions

Cultural institutions like museums, art galleries, etc. are clients that are often interested in pavilions to exhibit art or art installations that depict artistic or architectural ideas. Some functions:

- Exhibition pavilion for cultural programme: art, photography, sculpture, etc.
- Performance space for dance or music
- Spatial exploration (mostly architecture and design)

Event Organisations

The programme of Event organisations might be quite simple as it mostly concerns stages and tents, but it has the challenge of wanting to be decorated differently each year.

- Stage for performances
- VIP area
- Production offices
- Toilets

Companies & Research Institutions

Companies and research Institutions like universities are actually a large client group as it includes a demand for the marketing of company products and research facilities. Some functions:

- Stands (for on trade shows)
- Mobile displays
- Temporary residence
- Research facilities
- Mobile businesses
- Technical investigation (mostly architecture and building technology)

Private

A smaller sector of clients are the private clients who are mostly interested in

temporary shelter for either housing, holiday or office space. Some functions:

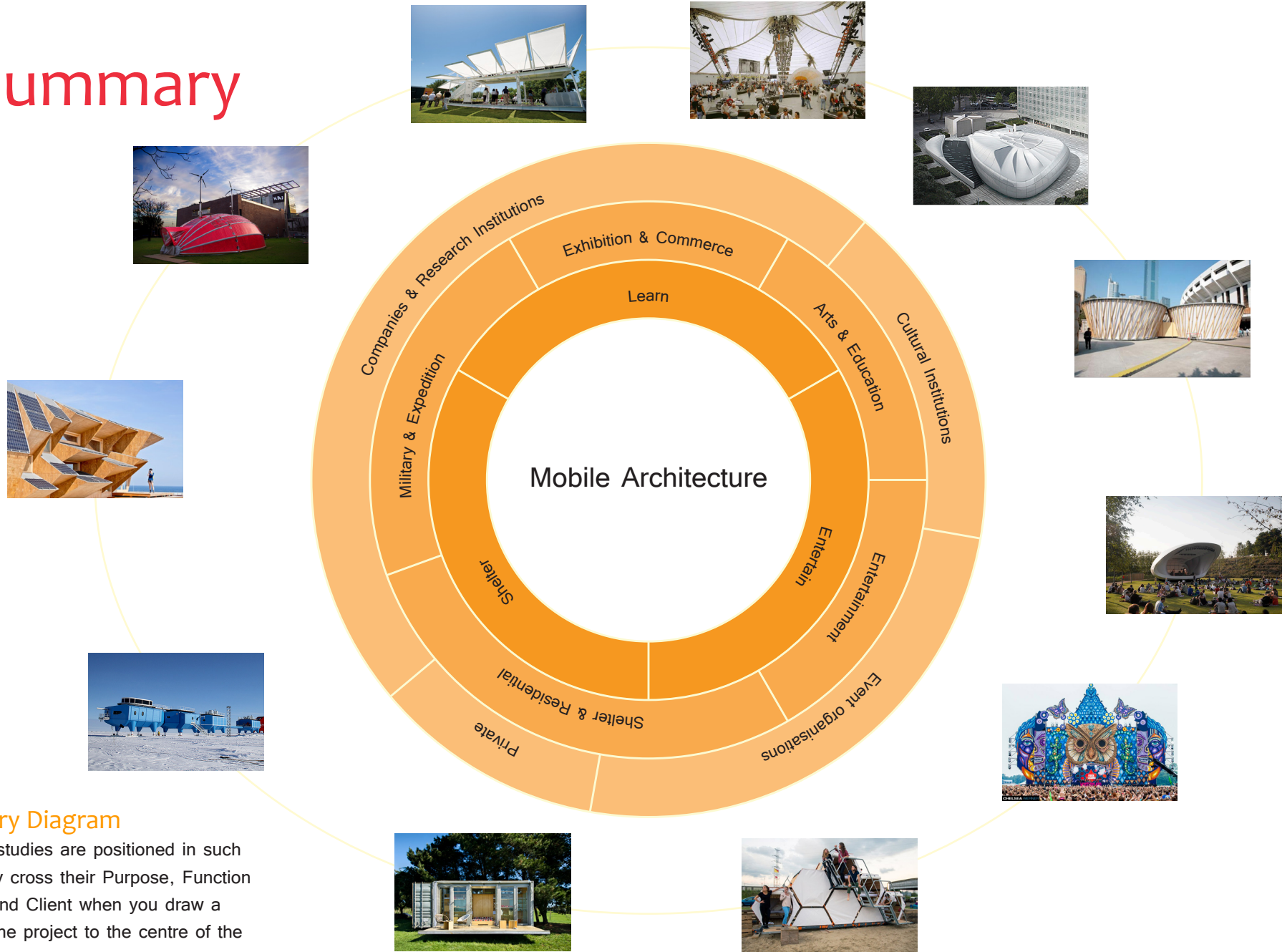
- Holiday homes (off-the-grid)
- Mobile office

Municipality

The municipality is one of the largest clients as it demands functions in all different fields (here for it is not included in the summary diagram on the next page) some of which are:

- Information kiosks for tourists
- Public transport information during road constructions
- Temporary catalyst functions for public space
- Seasonal bars, cafes or restaurants (e.g. beach pavilions)
- Internet hotspots
- A public stage
- Temporary shelter for neighbourhood development where the inhabitants are involved
- discussion programmes/workshop areas for urban events
- Emergency shelter: after disasters refugee camps are initiated.

Summary



Summary Diagram

The case studies are positioned in such a way they cross their Purpose, Function segment and Client when you draw a line from the project to the centre of the diagram.

Sustainable Mobile Architecture

• *What makes it so difficult to make mobile architecture more sustainable?*

Sustainability

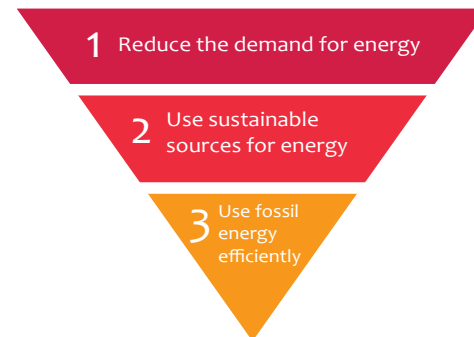
Brundtland defined sustainable development as: “development which meets the needs of current generations without compromising the ability of future generations to meet their own needs”. This does however, does not say anything about who, when or how we should do this. Within architecture there are different approaches to making architecture more sustainable. Terms like People, Planet, Profit, Zero Energy building, Self-sustaining, Cradle to Cradle and Earth ships pop up when exploring sustainable architecture. A brief definition of some of these terms will be given in order to clarify what kind of sustainability will be focussed on in this chapter.

Trias Energetica

The Trias Energetica is a simple strategy for buildings to become more energy efficient. It was introduced by Novem (Nederlandse Onderneming voor Energie en Milieu) in 1996 and further developed by the TU Delft. It consists of the three following steps which should be executed

in this order to be fully efficient:

- 1) Reduce the demand for energy
- 2) Use sustainable sources of energy
- 3) Use fossil fuel energy as efficiently as possible and only if sustainable sources of energy are unavailable [Schrooten, 2014].

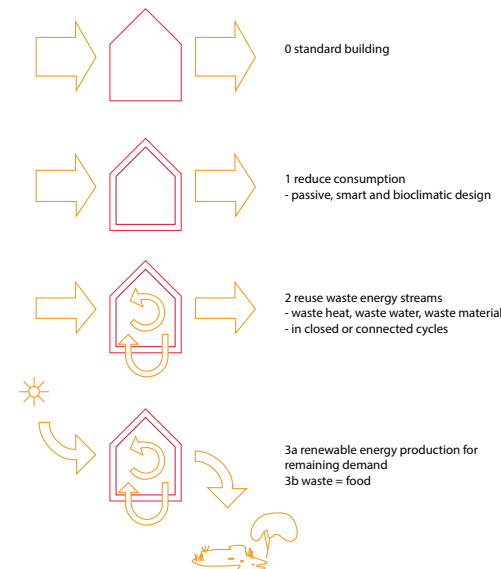


The New stepped Strategy

After almost 20 years in use the Trias Energetica was reformulated as the upcome of new renewable energy sources was minimal. The new stepped strategy adds an intermediate step between the reduction in consumption and the development of sustainable sources and incorporates a waste products strategy:

- 1) Reduce the demand
- 2) Utilise waste flows
- 3) Generate sustainably

Rather than only being about energy this strategy can also be applied to other cycles [Dobbelsteen, 2009].



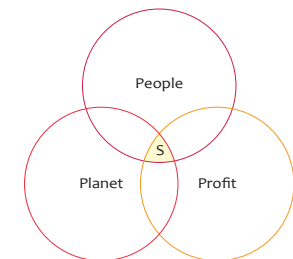
Reduce, Reuse, Recycle

A similar strategy and often confused with the Trias Energetica/New stepped strategy is the Reduce/Reuse/Recycle

strategy. The simple difference is that where the Trias Energetica is about energy, this strategy is about recycling waste.

People, Planet, Profit

Where the two previous strategies focussed on the technical side of sustainability the strategy People, Planet Profit aims to find a balance between the social, environmental and economic aspect of sustainable developments.



Zero-energy and Passive buildings

Zero-energy and Passive buildings are buildings that can generate all their energy demand with renewable technologies like wind or solar. In order to achieve this they have greatly reduced energy

needs through efficient use of energy-, waste- and air flows. Zero-energy or passive therefore says nothing about the sustainability in terms of its material, heating, cooling, waste, etc. Also, only the energy needed on site is taken into account which does not include carbon footprints, embodied energy or transport in the material's or technology's life cycle assessment [Torcellini, 2006].

Earthships

In contrary to passive or zero-energy houses, earthships are fully autarkic: in energy, food, water and waste treatment. Also the material used for building an earthship are either natural (e.g. clay, straw, wood, etc.) or recycled (e.g. old car tires, bottles, etc.) [Biotecture, 2014].

Cradle to Cradle

The Cradle to Cradle (C2C) strategy is about looking for production techniques for products with no waste. This means that waste is "food" for new products. A distinction between technical and biological nutrients can be made of which "Technical nutrients can be recycled or reused with no loss of quality and biological nutrients composted or consumed." [Sustainability Dictionary, 2014]

Sustainability themes

A last strategy for making architecture more sustainable and which is used for research within D-Exto and Innofest are the five sustainability themes Energy, Water, Waste, Material and Food. By applying the new stepped strategy to all these themes all sustainability aspects will be covered. One could note that transport should be a sixth topic but this is part of each theme individually.

Challenges for Mobile Architecture

Over the past decades architectural practice has been working on making buildings more sustainable. Earthships have popped up, buildings systems have been made more efficient and C2C materials have been introduced. Also for mobile architecture there have been renewable developments. Many events try to become more sustainable, sometimes very succesful (e.g. Shambala festival in the UK who was powered for 94% by renewable resources in 2013 [Powerful-thinking, 2014]) and sometimes more focussing on raising awareness about sustainability amongst

their audience. Focussing on sustainable for mobile architecture for events there are some specific challenges regarding the introduction of renewable power sources that will be explained below.

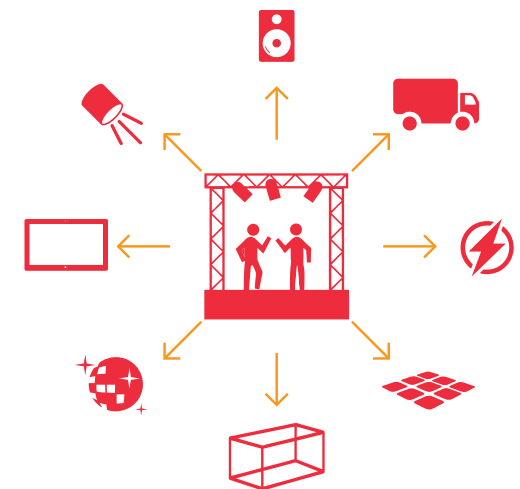
Temporary nature

The key characteristic of mobile architecture is its temporary nature. Where this is its main advantage it is the main disadvantage in introducing renewable power sources as sources like wind and solar energy are dependent on orientation and weather conditions. These conditions can highly vary per location and time span resulting in a fluctuating power supply. Also, sustainable solutions for other streams like waste treatment and water purification are often static and take a long time to have effect e.g. the production of biogas or water purification by algae.

Many stakeholders

A more practical challenge for events to become more sustainable is the large amount of stakeholders involved. A production team for even the largest festivals often consists of not more than 5-10 people managing an extensive network of different suppliers with all their

own interests. What makes it difficult for many parties to have an interest and invest in sustainability aspects, is that the investment to be more efficient not always directly influences their own profit: the investment is not always with the same supplier where the profit is made.



Visitor experience

The main objective for a festival is to create an amazing experience for the festival visitor. This results in high budgets for the stages, lighting, fireworks and decorations which sometimes comes at the expense of other services: the budget will be split differently, almost always in

favour of the experience. This means that sustainability is often no priority as it is more expensive and comes at the expense of the festival experience. Here for implementation costs for sustainable solutions are of high importance. Due to the limited budget (smaller) festivals usually do not 'invest' in future editions as it often is not sure whether it will survive till next summer as its income mostly depends on the tickets sold which are again dependant from the weather and the competition with other festivals

“Meten is Weten”

Once a festival is interested in becoming more sustainable it often does not know where to start. This is mostly due to the fact that there is no data available from where adaptations or innovations can be made. Here for the first important step is to quantify and collect the appropriate data. There are companies that help festivals with measuring their energy use and several certification systems have been developed. Julies Bicycle, Powerful Thinking, EE Music, A Greener Festival and the Industry Green Award are some of the leading initiatives.

Conclusion

The strategies described in this paragraph can be used together to come up with solutions for the different challenges hereby covering all sustainability aspects. For festivals, especially the social and economic aspects should be carefully taken into account as the social and economical balance will decide whether sustainable interventions will succeed.

Situation

An average festival lasts 3 days, has over 20.000 visitors, a production time of around two-three weeks and has its peak in electricity demand at the end of the festival during the final act. Most contemporary festivals still produce their energy with the use of diesel generators.

In the spring of 2013 Stimular executed a research providing a benchmark of the carbon footprint of 7 Dutch festivals

(Breda Barst, the Indian Summer Festival, Bruis Maastricht, Extrema Outdoor Live, the Solar Festival, the Amsterdam Light Festival and the Bevrijdingsfestival Roermond) that resulted in the average carbon footprint per category shown in the diagrams below [Stimular, 2013]. It is apparent that transport of visitors (24-44%), electricity (24-25%) and waste (11-28%) are the largest contributors to the carbon footprint of a festival. A (renewed)

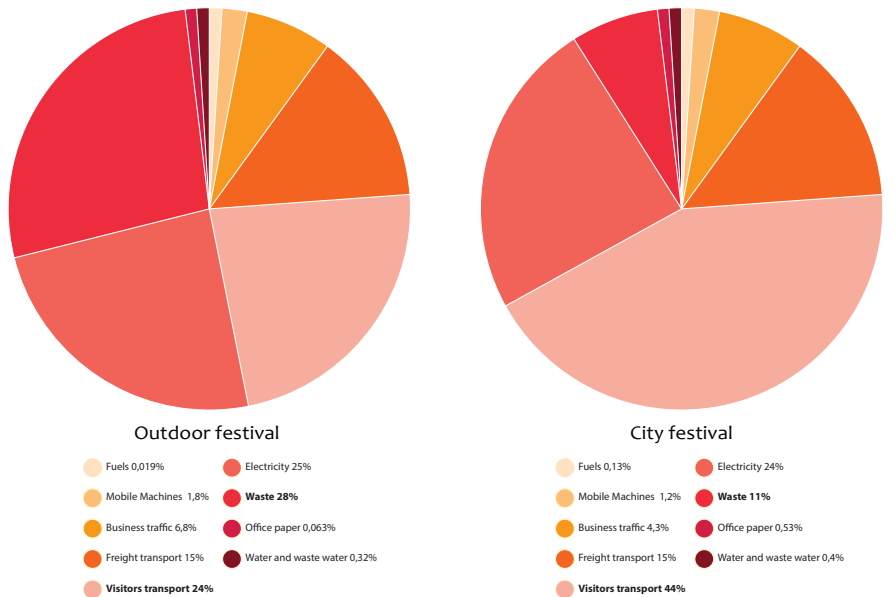
benchmark for the average diesel and water consumption and the amount of waste produced has been developed by Julies Bicycle. Numbers are in a per audience per day metric (1 audience day is equal to 1 person visiting the festival for 1 day):

- Diesel: 0,7 litres (15% biodiesel)
 - Waste: 2 kg (32% recycled)
 - Water consumption: 11 litres
- This results in an average of 1,9 kg CO₂e

total emissions per audience per day [EE Music, 2014].

In this research I will focus on exploring possibilities for reducing the electricity demand. This is due to the fact that energy is often responsible for one fifth of the total costs of the festival (and diesel prices are rising!) and sometimes even for 70% of the total carbon core footprint of a festival or event (excluding audience

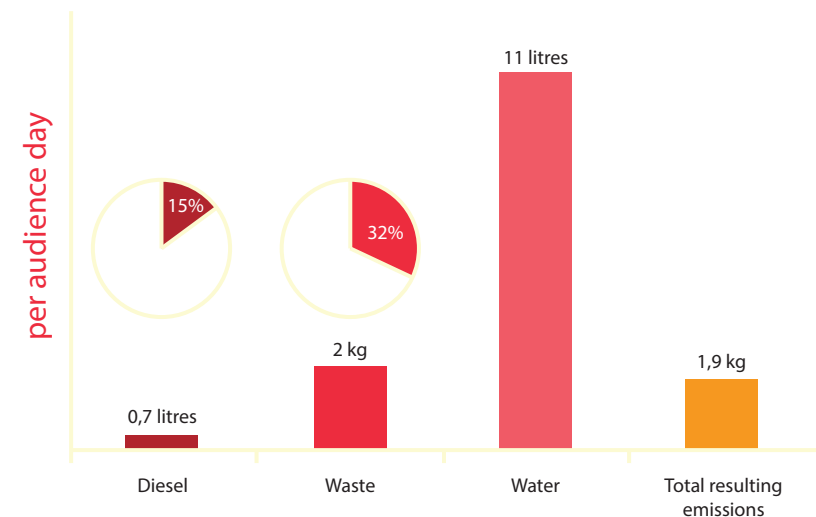
6. Environmental impact festivals



Source: Milieubarometer

Festival Benchmarks

Data based on 13 UK festivals spanning 2011, 2012 and 2013



travel and transport) [The Power behind Festivals, 2011]. Also, renewable energy can be well integrated in the sustainable development of mobile architecture; visitor's transport is mostly about creating awareness amongst visitors and that cannot be influenced directly by the festival organisation, freight transport is about creatively re-organising and sharing transport between suppliers and waste is a more logistically challenge as well.

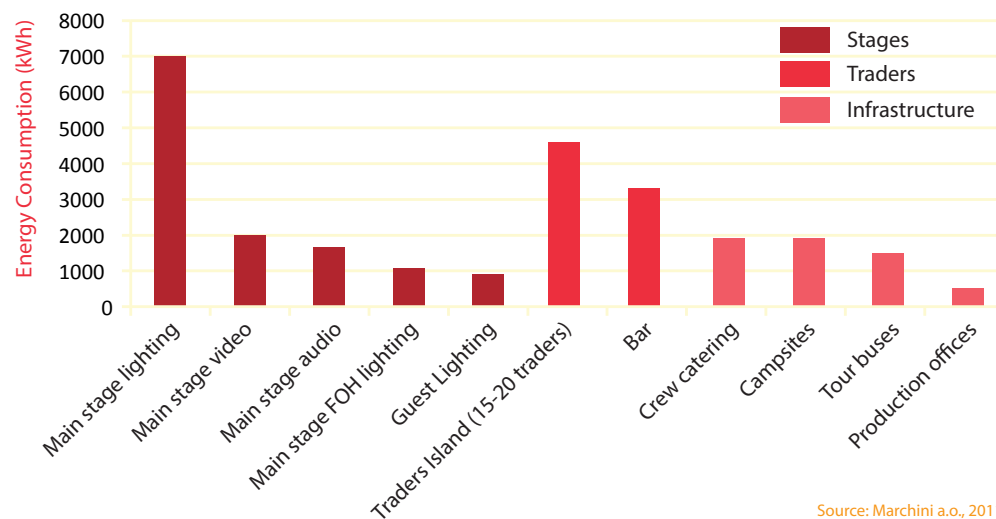
As already mentioned in the introduction

the electricity consumption of a festival can be roughly divided in three categories all representing about one third of the total electricity consumption: Stages (33%), Traders (36%) and Infrastructure (31%) [Marchini a.o., 2011]. To reduce the energy consumption in the Infrastructure category (Crew catering, Campsites, Tour buses and Production offices) the concept of a Mobile Event Village was developed. The Mobile Event Village is a relocatable "village" that contains all the functions needed for the production of an event or

festival. By approaching the backstage area as a village rather than a collection of separate functions, functions can be integrated and share services more efficiently and a reduction of the carbon footprint in this category is expected. Although the focus in this research paper is on energy, waste and water flows will be taken into account during the design process.

3. Typical electricity consumption per category

Data based on 73 different activities at 18 festival events at 7 different festivals between 2009 and 2012.



Source: Marchini a.o., 2011

The Production Area

The production area is the first to arrive at the event location and will be therefore an average time of two-three weeks from the very first beginning to the very end. It hosts crew, construction crew and suppliers during construction and crew, artists and volunteers during the festival. The production area holds different functions among which:

- Production office
- Financial office
- Press office
- Kitchen
- Communal area
- Artists area
- Lounge area
- Toilets

Where festival stages have high peak loads for a short amount of time (often only a couple of hours), the backstage area has a smaller range between base and peak loads but as it uses energy over a longer period of time the total energy demand is similar and the total amount of diesel by generators used can still add up to quite an amount [Marchini a.o., 2011]. A research by Paul Schurink on DefQon revealed that the crew catering only already used 2300 litres of diesel!

Functions

Production office

The production office is the central organisation unit of the festival and usually hosts up to two people. It is the place

you will have to report your presence and where all registration takes place. It is usually a rented mobile office space (see image next page). These units are very basic and often badly isolated which results in running fans and additional heating during warm or cold days.

Kitchen

The kitchen area is where breakfast, lunch and dinner are prepared for the crew. Construction crew accounts for most people during the construction and deconstruction of the festival and can easily add up to 100 people. During the festival meals for crew and volunteers are made. It is very different per festival whether all meals are served, to whom and whether you have to pay additionally.

Communal area

The communal area is often a large tent or covered area and is the central meeting space for crew and volunteers. It is the place where meals are served and it often includes a small lounge area. Furniture exists of simple camping tables, benches and a pile of old sofa's and carpets.

Artist area

At most festivals crew/volunteer and artist areas are separated to provide some privacy for the artists. It differs per festival whether artists arrive in a private tour bus or sleep in tents and therefore need basic services. Also, artists are often not therefore the total length of the festival as they often have multiple performances per weekend.



Financial office

At the financial office traders can hand in their earned festival coins for money. It is usually a mobile office placed more to the back. Not all festivals have a separate financial office.

Press office

The press office hosts press as its name suggests and becomes of more and more importance to keep visitors informed via Facebook, Twitter, special festival apps and other media. It is herefore the press

office is developing into an actual function on festivals.

Toilets

Dependant on the size of the festival there is usually one toilet unit present at the central backstage area. It is however no exception if only two or three porta potties (dixies) are present. It is only seldom running water is available.

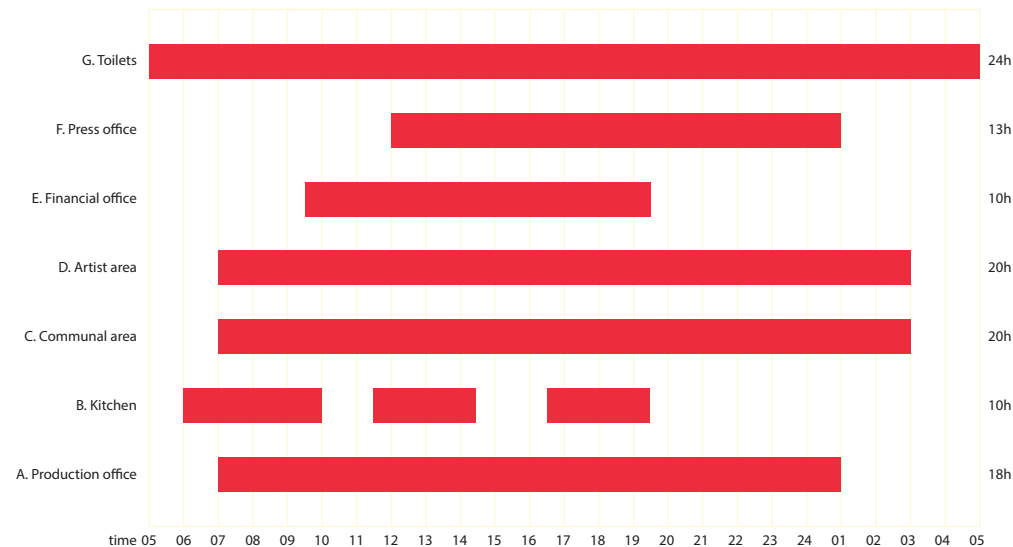
Other

As most events and festivals are outdoor,

a lot of additional lighting is needed to light the areas at night. This can vary from simple atmosphere lighting to large lighting posts. Besides the actual functions a lot of backstage space is reserved for parking and storage of objects, construction material, packaging, etc. Also, a lot of creative construction like painting and carpenting is done at location. This is usually scattered all over the festival grounds.

Energy demand

In order to say something about the energy demand of the production area, an inventarisation of the energy demand needed per function has been made (Appendix B). For each function (or "powerzone") the amount of appliances was listed with their electrical demand in watts and its total running hours per day. By multiplying and adding these, the total kWh per day needed by each powerzone was calculated. The total amount of kWh needed for all powerzones



Total Energy Consumption Production Area

Powerzone	# persons	m2	Subtotal kWh
A. Production office	2	12,5	12,28
B. Kitchen	4	25	56,87
C. Communal area	150	100	15,07
D. Artist area	25	20	22,37
E. Financial office	2	12,5	7,22
F. Press office	6	12,5	21,18
G. Toilets	6	12,5	2,19
H. Other	n.a.	n.a.	2,64
Totals	195	195	137,175 kWh per day

resulted in 137,18 kWh per day (see table on the next page). Considering that an average household in the Netherlands uses only 3340 kWh per year (which is equal to only 9,2 kWh per day) this is a huge amount! [Nibud, 2014]. Considering however, that Lowlands (a 3 day festival with 55 000 visitors) uses over 865.000 kWh per edition and is about 10% more than an average city like Assen or Hoorn uses in three days, this does not seem to be unreasonable [Duurzaamnieuws, 2010]. Also, the average household consumption is based on four persons and an average production area can house over a 100 people easily.

Looking at the different powerzones the highest energy consumers are the fridges. This too, seems to be reasonable as the main consumption within the Traders category is electricity needed for cooling of food and drinks and for electric cooking and also covers one third of the total energy demand of a festival. Striking is however, the energy that is needed for making coffee and tea (which is drunk by litres all day) which turns out to be quite energy intensive.

On site Power Types

There are different options for the temporary production of power on event sites of which the diesel generator is still the most commonly used. Options for on site power generation include generators, solar and wind power but also pedal power and hydrogen fuel cells are emerging. Due to the temporary nature of mobile architecture renewable energy from e.g. tidal wave, algae or biogas is not applicable.

Grid connection*

For annual festivals a connection to the national grid might be the cheapest option. It reduces transportation costs and by using a “green tariff” provided by the energy company it can decrease the

* Sources: Powerful Thinking, 2014: Power behind Festivals, Factsheet #8, Factsheet #10 and derived from the interview with Paul Schruing. Figures from the UK Department for the Environmental, Food and Rural Affairs (Defra) 2012.

festival's carbon footprint. This option is however, most suited for festivals in an urban environment as installing new substations or extensions to the underground cable network can be highly expensive for temporary events [Power behind Festivals, 2011]. One of the locations where a grid connection is considered is the NDSM werf in the old harbour of Amsterdam as it hosts many festivals a year [Schurink, 2014].

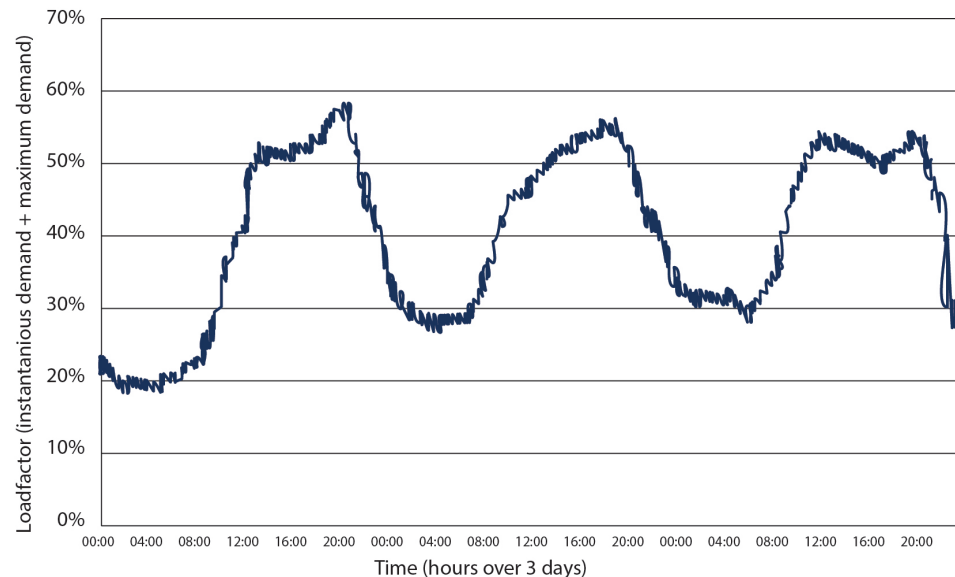
Advantages

» Reduction in carbon footprint (when green energy used) and transport costs

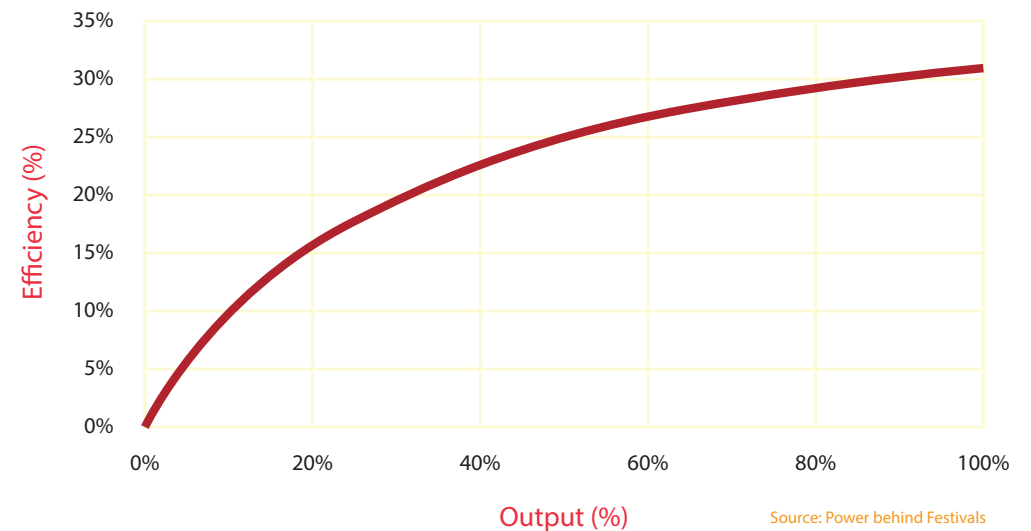
Disadvantages

» Expensive and therefore not applicable for smaller events or events at specific locations

Carbon emissions: 0,54 Kg per kWh



Generator Efficiency Curve



Diesel fuelled generators*

The most commonly used power source for temporary events and mobile architecture are generators run on diesel. To understand the case around generators it is important to firstly distinguish energy and capacity (or load). The generator capacity says something about the power level a generator can provide. Herein the base load is the minimum capacity and the peak load the maximum capacity needed. The energy is the total amount of kWh produced.

The graph below shows the efficiency curve of a generator. A diesel generator runs efficient if it runs at a capacity above the 60–75%. As event organisations do not want to risk energy fall out many generators at festivals are oversized due to the high peak loads they need to cover during the final act of the festival. This means that many generators often run on a low capacity during the festival resulting in a low efficiency which therefore results in a high amount of litres diesel needed. Besides the fact that running a generator on a low capacity damages the generator due to internal glazing and carbon build up and therewith decreases its life time, a generator is already running

An example of the mis-use of generators is that during construction generators are used to charge cellphones of the construction crew which is obviously a very small load for a generator [Power behind Festivals, 2011 & Schurink, 2011].

Advantages

- » generally reliable
- » Many lease companies and high compatibility of products between companies

Disadvantages

- » An easy solution– it's the way it's done.
- » Emissions are damaging to the environment
- » Energy market increasingly volatile causing fuel cost rises
- » Inefficient with varying loads

Carbon emissions: 2,63 Kg per litre

Biodiesel fuelled generators*

Diesel generators can be simple replaced by biodiesel generators however a certain level of expertise is needed. Biodiesel is created using plants such as corn, sugar cane and sugar beet and plant by-products such as from pulp and paper.

Also, oils from inedible plants such as soybean oil, palm oil and waste cooking oil can be used. It is considered zero carbon as the carbon emitted when burnt has been pre-absorbed by the growth of the plant. When using biodiesel WVO biodiesel (Waste Vegetable Oil biodiesel: which is derived from waste from industrial processes and food factories) is recommended as the production of others biofuels (Virgin oils) are competing with food production resulting in high food prices, a scarcity of cultivation land and “in many parts of the world biofuel cultivation is linked to rainforest clearance, loss of biodiversity, displacement of local communities and the diversion of food crops to fuel.” [Power behind Festivals, 2011].

Advantages

- » Zero carbon rated
- » Non toxic and non hazardous
- » No major implications for power reduction to enable use of this technology
- » Reliable
- » Cleaner emissions from the generator – minimal sulphur
- » No limit to the size of generator available (in theory)

Disadvantages

- » Biofuel can be more expensive than ordinary diesel
- » Potential supply-chain problems with WVO biodiesel at large-scale events.
- » Inexperience in using biodiesel can lead to generator problems
- » Using virgin biodiesel can have many damaging impacts, depending on how it is produced.

Carbon emissions: zero rated

Hybrid Generator*

Hybrid generators are generators using a combination of technologies, e.g. diesel generators with storage batteries and solar panels or wind turbines where batteries are fed by solar or wind energy and using the generator only when the battery is low on charge, or when a higher load is required than the battery can deliver. The advantage of hybrid generators over (bio) diesel generators is that they can provide energy at any time and their efficiency is not depending on load. Herefor “They are considered as potentially the most efficient approach to delivering large amounts of power at festivals.” A disadvantage

however is that switching from one technology to the other might take up to 10% of the energy produced [Schurink, 2014]. A more practical disadvantage is the business model around generators. Nowadays event organisations pay a set price for the capacity of the generator relating to size and weight and a set price per “working hour”. When renewable energy from solar or wind can replace some of the working hours of the generator the generator company misses out on profit. A simple solution for this however is to let the event organisation pay the amount of kWh produced by the hybrid system [Schurink, 2014]. Hybrid systems are currently emerging on the event hire market.

Advantages

- » Perhaps the most efficient approach



to producing larger amounts of power at festivals

- » Reduces fuel consumption by an estimated 40% based on field trials.
- » Lower emissions.

Disadvantages

- » Not currently widely available for the hire market
- » Standalone/combined units have only been developed up to 15kVA in 2012
- » May require higher upfront costs for equipment hire

Carbon emissions: variable

Solar power*

A solar generator exists of a set of solar PV panels, batteries and a convertor. Although working best with direct sunlight, energy is also produced while overcast



as it is the light that generates energy. Solar PV panels are easy in transport, to construct and to take down and only need a south orientation not covered by shade. Solar generators usually produce a smaller amount of energy than diesel generators but the demand for the event organisation to know the exact amount of energy needed however, already benefits the total energy usage as they are forced to know their energy demand rather than just letting a (-n oversized) generator run. Also, power can not be guaranteed due to unclear weather conditions. The main advantage of solar generators however, is their ability to store energy for later use. When using multiple or hybrid systems solar batteries can be used to capture excess power from stage generators when they are running which can then be used at night when peak loads are low allowing



the generator to be switched off.

A great development for festivals are flexible solar PV cells that can be used on (double) curved surfaces.

Advantages

- » Zero carbon – helps you lower your event’s emissions
- » Very efficient
- » Silent
- » No exhaust emissions
- » Visible demonstration of a festival’s commitment to low carbon energy
- » No fuel bill at the end of the event
- » Reliable systems (no moving parts to break down)
- » Potential to save costs and fuel if used in conjunction with existing technology



Disadvantages

- » Requires an area of south facing land (Northern Hemisphere) to locate the solar panel array
- » Lower power output
- » As a stand-alone solution on a small scale can cost more than diesel alternative if demand for power is high
- » Finite amount of power
- » Requires more detailed pre-production

Carbon emissions: zero rated

Wind power*

Similar to solar power is dependant from the right weather conditions. Kinetic energy is converted into electrical energy and then generally stored in batteries. Despite the widespread use of small wind turbines in many other fields, wind power is not widely available on the market for events. This is due to their vulnerability to the weather (i.e. no wind) which, in very short term applications that need consistent power, can be a problem. Hybrid systems combining wind and solar are more common.

Advantages

- » Zero carbon
- » Strong visual commitment to low carbon energy

Disadvantages

- » Vulnerable to weather conditions
- » Requires space to set up and rig supporting guy ropes
- » Not commonly available

Carbon emissions: zero rated

Hydrogen Fuel Cell*

The hydrogen fuel cell is an emerging technology where hydrogen is converted into energy with only water and heat as by-products which makes it a very clean technology. Normally the hydrogen 'fuel' is sourced as the by-product from chemical processes or from composting facilities. Contemporary research explores the possibility of sourcing the hydrogen fuel as a by-product generated by solar and wind technologies. Eventhough hydrogen is the most common fuel, also so called hydrocarbons (natural gasses and alcohols like methanol) are sometimes used. In contrary to a solar or hybrid generator, a fuel cell does not have a battery to store power which means it needs a

constant supply of fuel and oxygen but can generate electricity continually for as long as these inputs are supplied. Due to their small size hydrogen fuel cells would be perfect for mobile architecture it is however, at this point about 15-20 times more expensive than diesel. Also, transport of the compressed hydrogen has some safety complications.

Advantages

- » Very small
- » Silent

Disadvantages

- » Very expensive
- » Possibly explosive

Carbon emissions: zero rated

Methanol Fuel Cell*

Similar to hydrogen fuel cells methanol fuel cells are comparatively expensive and are inefficient compared to the hydrogen fuel cell. However, still a lot of research is done as the methanol fuel cell is very small, light weight and silent and the methanol fluid is much easier to store than the compressed hydrogen. The topping of fluid is very limited and it can achieve up to 52 days runtime from

one fuel cartridge. Methanol fuel cells are generally ranging from 25W to 850W with 12 or 24V outputs which make them well suited for small appliances.

Carbon emissions: 0,9 Kg per litre

Kinetic energy*

Similar to wind power, pedal and dancepower are generated by kinetic movement.

Pedal power

Pedal power is power generated by kinetic movement, usually from bikes, that is stored in batteries to provide a consistent supply. It is a great way to involve the audience in creating green performances and however not suited for large power supply, there are examples of full stages powered by 20-30 bikes. Each adult bicycle typically generates an average of 60watts of power and child bicycles generate an average of 30watts of power each. Common applications at festivals are phone charging, cinemas, sound and lighting, and interactive art installations.

Advantages

- » Zero carbon
- » Often inexpensive

» Very interactive

Disadvantages

- » Relatively low capacity
- » Requires some audience space in venue for equipment (the bikes).

Carbon emissions: zero rated

Dance power

Another great kinetic energy based concept is The Sustainable Dance Floor where dancing and moving people are the source of energy. The produced kinetic energy is converted into electricity and is used to make the dance floor react to the public in an interactive way. Similar to the pedal power, dance power a great technology to involve the audience but will not be able to generate a sufficient supply of energy. The floor which is compressed for 10 mm when stepped on, activates internal generators that can produce up to 35 Watts of sustained output per module.

Advantages

- » Zero carbon
- » Interactive

Disadvantages

- » Fragile
- » Expensive in relation to the amount of

power produced

Carbon emissions: zero rated

Power from Urine*

A technology “under construction” is the possibility to gain energy from Urine. However not much is yet known it is said to work like this [Power behind Festival]: “» Urine is put into an electrolytic cell which separates out the hydrogen.

- » The hydrogen goes into a water filter for purification, which then gets pushed into a gas cylinder.
- » The gas cylinder pushes hydrogen into a cylinder of liquid borax, which is used to remove the moisture from the hydrogen gas.
- » This purified hydrogen gas is pushed into the generators.”

Accu containers

As solar and wind energy are dependant on the weather, the new company GreenBattery provides containers filled with renewably charged batteries to events which hold up to 1500 kWh of sustainable energy.

Car powerplant

With the emerging of electric cars the idea of using the cars parked at the car park providing energy for the festival is developing. With a future range of 600km on average and an average need of 200km to reach the festival and return home, the power of 400km electricity would be available to provide events from energy. It is estimated that about 1500 cars would be needed to power the main stage of Lowlands. Considering Lowland has 55 000 visitors (lets say divided by four is about 13 000 cars) this would be more than enough energy [Schurink, 2014].

Conclusion

All described technologies have their own ad- and disadvantages and of which some are more focussing on involving the visitor than efficiently reducing the energy demand. In general, before being able to reduce the energy demand of an event or festival, it is important to actually know the demand. Herefor monitoring the energy consumption is the first step. With this knowledge reduction measures and there after proper decisions on generating renewable energy can be made.



Architectural Conclusions

A sustainable Mobile Event Village

The previous two chapters have explored the nature of mobile architecture and how renewable energy can be generated on site. As both mobility and sustainability have their own advantages, disadvantages and challenges that can influence and be dependant of each other in the architectural design, this chapter describes the architectural considerations on mobility and sustainability for a Mobile Event Village.

Mobility

The essence of the Mobile Event Village (MEV) is that it can be used on different locations. Therefore the MEV has to be able to be transported easily. As stated in the first chapter, focussing on a relocatable solution for the MEV is most appropriate due to a high adaptability to different contexts and users. As transport is one of the higher expenses of a festival the volume in need of transport should be as small as possible. Herefore a demountable solution would be best as its volume is smallest. The advantage of a relocatable solution as opposed

to a demountable solution however, is that installations and services can be integrated which saves greatly on deployment time and costs.

A different approach would be of creating multiple relocatable units containing all services needed and creating spaces in between these units with a flexible and easy transportable structure. These could be tensile or folding constructions or even inflatable ones that can be connected to the different units and therewith creating space.

Sustainability

In order to explore the different options for the MEV to become more sustainable the New Stepped Strategy is followed. It exists of the following three steps:

- 1) Reduce the demand
- 2) Utilise waste flows
- 3) Generate sustainably

These steps can be applied to all themes (Energy, Water, Waste, Materials and Food) but here the focus is on energy.

1. Reduce

As explained in the second chapter the first step for a festival to become more sustainable is to start with monitoring its demand. For the MEV the demand was approximated by calculating the energy demand for the different powerzones. These show that many functions (like the offices) share similar appliances and, as most have a similar desired climate as well, starting by smartly configuring (e.g. orientation) and sharing functions could already reduce the electricity demand. Last year Lowlands had a pilot where they did not had a separate artist's area which can save a lot of energy as it is more efficient to climatise one somewhat larger area than two medium ones. Other large energy consumers are the fridges. It would be best to reduce its use as they operate 24 hours. This could be achieved by reducing the amount of refrigerators needed by cooking fresh meals (no frozen foods) and by using local supplies that do not need to be refrigerated. These are however, solutions that are rather dependant of behaviour and are hard to

influence by design. Another reduction in the electricity demand can be made by using biogas for cooking and heating instead of electricity as the conversion from electricity to heat is way less efficient than from gas to heat. For cooling, natural ventilation principles can be used to reduce the use of fans or aircons.

Conclusions:

- smartly configure and combine functions
- reduce the need for refrigerators and freezers
- use biogas for cooking and heating
- use natural ventilation principles for cooling spaces

2. Reuse

After reducing the initial amount of energy needed, this can be further reduced by reusing waste flows between the different functions. Herefore waste flows should influence the configuration of functions: by reusing e.g. waste heat from the kitchen to heat the offices, energy is saved. Although there are some great technologies applicable for reusing

water and waste (e.g. producing biogas from waste or filtering water by bio filtration) these are, unfortunately, often not applicable for mobile architecture as their process takes too long, are too fragile or impossible to move or simply too large which would make transport too expensive.

Conclusions:

- reuse generated heat
- reuse water and waste where possible

3. Produce

When the energy demand is reduced where possible, the remaining energy demand should be generated sustainably. An obvious choice is to use solar PV panels but it is unlikely that this will cover the total demand: for the total calculated demand of the production area, which is 137,18 kWh per day, an area of about 385m² of solar PV panels would be needed (Appendix D). This is way too much to transport. It is therefore important to find a balance between the amount of renewable energy produced and the resulting carbon footprint (and costs) due to its transport. Although fuel cells and using electric cars as power sources would be very applicable, these

are still too embryonic to use in this stage. Therefore a hybrid solution where a combination of solar (and wind) energy and bio fuel generators will be used is more realistic. The development of flexible PV cells however, might be very interesting to increase the contribution of solar energy as these could be used on tensile constructions which are compact in transport.

Conclusions:

- use a hybrid system with solar (and/or wind) and biodiesel to generate energy

Conclusion

As renewable production of energy is very limited for mobile architecture and many developments are still too embryonic, reducing the energy demand needed is most effective at this stage. Large reductions can already be achieved by the smart configuration and exchange of waste flows between functions.

Conclusion

The research on mobile architecture and possible renewable energy generation technologies has shown that it is important to keep in mind the relation between the amount of carbon emissions saved by the generation of renewable power, and the increasing carbon emissions created by the additional transport needed for transporting these technologies. Herefore decreasing the initial amount of energy needed in the first place is most efficient. High energy reductions can be made by reconfiguring functions and by re-using waste flows but are often also a result of behaviour. This is more difficult to change but by providing proper and simple information. After energy savings have been made, a hybrid system where solar PV cells and bio fuel generators are used seems to be the most feasible option for the near future. Later, fuel cells and/or car plants could be very interesting options but these are still in a too embryonic stage of development.

For the design of a Mobile Event Village the research has concluded that a relocatable option would be the most appropriate considering the high

adaptability to different contexts and users in relation to a medium deployment time and therefore medium costs.

Both the research on mobile architecture and renewable onsite power generation has provided basis knowledge from where an architectural design for a Mobile Event Village can be made. From here several architectural challenges will have to be explored further. These include:

- How can the configuration of functions reduce the energy demand? Where can energy-, water-, heat flows, etc. be combined?
- How can the configuration of functions create context? A village feeling, as its relation to the context changes per location.
- Can flexible PV panels contribute to the overall energy generation of the Mobile Event Village?
- If so, how can these be integrated technically and architecturally, be safely transported and be integrated in the design of a Mobile Event Village adaptable to different locations.

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Appendix

A. Case studies

In order to understand the extensive array of mobile architecture many case studies were done. This appendix gives you a summary of some of them. Each project will be briefly described based on Why? (What is its purpose and function?) How (is it transported and assembled)? and Who (was the client)? which is based on the methodology of the master thesis from Leon Zondervan about Transformable Living Units [Zondervan, 2014].

Purpose | Transportation method | Client



Bamboo Pavilions

Markus Heinsdorff

Multiple locations in China, 2007 – 2010

Why: The different Bamboo pavilions based on Chinese lanterns by Markus Heinsdorff are multifunctional spaces for exhibitions, presentations, small conferences, concerts and other related events.

How: Bamboo constructions with a varying textile or steel mesh. The modules can be connected in various arrangements resulting in an adaptable design.

Who: Designed for the Germany Esplanade Exhibition.

Learn | Demountable | Municipality



Texas Prairie Hopper

Anderson Anderson

Texas, 2009

Why: To showcase an innovative green roof technology allowing native Texas plants to survive in Southwest climates without irrigation to visitors that are usually not exposed to green technology on different NASCAR events.

How: The pavilion is constructed of one single frame module with folding elements creating shade. Multiple modules can be combined to create a larger exhibition structure in a range of configurations.

Who: Collaboration of different companies and an university.

Learn | Portable | Company



Chanel Mobile Art Pavilion

Zaha Hadid

Multiple: Hong Kong, Tokyo, New York, Paris, 2008–2010

Why: Designed by Zaha Hadid as an exhibition and small event space for Chanel inspired by the Chanel hand bag.

How: The structure that was set up at different locations around the globe can be totally deconstructed as transported in 55 shipping containers.

Who: Chanel for their mobile art initiative.

Learn | Demountable | Company



Endesa Pavilion

IAAC

Barcelona, 2011

Why: The Endesa pavilion is based on the concept of form following energy and functions as a control room for monitoring and testing several projects related to intelligent power management.

How: It is constructed from a pine-wood frame with oriented strand board (OSB) making up floor and ceiling planes. All the components were digitally fabricated using CNC machines.

Who: The pavilion was built for the International BCN Smart City Congress in Barcelona.

Learn | Static | Research Institution



World in a shell

Hans Kalliwoda

Multiple: Amsterdam, Rotterdam, ...

Why: The World in a Shell is a 100% self-sufficient traveling exhibition and cultural data collection unit functioning as a mobile artist studio and multi-media laboratory that facilitates intercultural swap-shopping activities.

How: The folding structure fits into the central container frame which can then be transported as a regular shipping container.

Who: The project was privately initiated by Hans Kalliwoda with the help of sponsors.

Learn | Portable | Research Institution



Mysteryland Mainstage 2013

ID&T

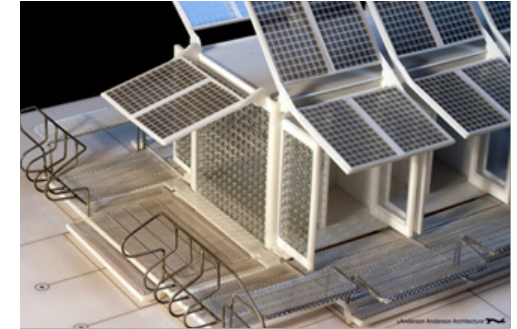
Haarlemmermeer Amsterdam, Netherlands

Why: The main stage of the music festival of Mysteryland.

How: The stage is based on a scaffolding structure decorated with recycled wooden planks, textiles and lighting. It can be totally dismantled and shipped in regular shipping containers.

Who: The stage was built by the event organisation ID&T.

Entertain | Demountable | Event Organisation



ZEBRA Power House

Anderson Anderson

Concept, 2011

Why: The concept aims to provide high-tech infrastructure in places with no services or utility connections for different functions: e.g. open air education, fully climate controlled office spaces, cell phone recharging station, internet hotspot, pop-up retail outlet, broadcast centre for journalists, internet café, etc.

How: The container sized structure consists of a steel frame with additional ramps and stairs to have it easily laid out on all different sorts of terrain.

Learn | Portable | Concept



Soundworks Portable Stage

BFLS Architects & Arup Acoustics

Why: The Soundworks portable stage was newly developed to produce a new and iconic staging concept that provides a high quality acoustic environment for the staging of outdoor music events.

How: The Shell is constructed of a steel frame then covered with textiles.

Who: Soundforms PLC company as a product.

Entertain | Portable | Company



Machine Tent

FTL Design Engineering Studio

Multiple: US, Tokyo, Sydney, Cologne, Mexico City, Vancouver & Barcelona.

Why: The Machine tent was designed as an exhibition space for the Harley-Davidson Travelling Tour to celebrate their 100th anniversary.

How: The circus tent like structure is erected with the use of one central and six secondary masts with the help of internally mounted winches which haul up the elevated components so no heavy machinery is needed.

Who: Harley-Davidson

Learn | Demountable | Company



Halley VI

Hugh Broughton Architects

Brunt Ice Shelf, Antarctica

Why: The Halley VI is a self-sustaining research centre on the North Pole that can relocate itself as it stands on enormous skies to prevent it being buried in the snow.

How: The station was produced in North America and then modular shipped to Antarctica where all parts were assembled.

Who: The design was winner of an international competition.

Learn | Relocatable | Research Institution



Port-a-Bach

Atelierworkshop

2001-2006

Why: To find a solution for used container Atelierworkshop transformed this 20ft shipping container into a holiday home.

How: The basis of the construction is a shipping container with foldable elements.

Who: The prototype is in possession of the Puke Ariki Museum in New Plymouth in New Zealand.

Shelter | Relocatable | Company



B-and-Bee

Compaan and Labeur
Antwerp, 2014

Why: To offer an alternative for tents on festival grounds as they are often left behind.

How: The construction consists of multiple stackable wooden elements covered with textile fronts.

Who: The design was a student's project.

Shelter | Relocatable | Event organisation



Theatre Podium

Atelier Kempe Thill
Rotterdam, 2009

Why: The theatre podium is a restrained space which has no specific function:

"The aim is for the people of Rotterdam to discover this space at their own terms and put it to creative use." and there with revitalize the urban area bombed in the WW2.

How: The stage consists of two concrete blocks holding a dressing room and storage space for the curtains covered by a roof.

Who: The Municipality of Rotterdam

Entertain | Static | Municipality



New Amsterdam Plein and Pavilion

UNStudio
New York, 2008 - 2011

Why: The Pavilion is used as an information centre to learn more about the historical location and functions as a light installation at night. It marks the location as a destination and a hub of various activities, aiming to create a social Place.

How: A concrete shell construction.

Who: The pavilion was designed for the Battery Conservancy and given as a gift to New York.

Learn | Static | Municipality



The Mirazozo luminarium

Architects of Air
Global

Why: The luminariums of Architects of Air are about the experience of light and creating a place of color.

How: With PVC material they create inflatable spaces. Due to the lack of construction they can be transported small.

Who: Architects of Air is an architecture firm that creates luminariums that events or companies can rent.

Entertain | Relocatable | Company

B. Power zones

On the side you will find the energyconsumption per powerzone used to calculate the energy demand of the production area.

For each powerzone the amount of appliances are listed with their watts and running hours resulting in the total kWh per day of each powerzone. The total kWh of all powerzones is 137,18 kWh per day.

A. Production office					
Number of persons: 2					
Appliance	No of units	Watts (W)	Subtotal W	Daily use (hrs)	Subtotal kWh
Laptop	2	200	400	18	7,2
Printer	1	35	35	2	0,1
Portable Fan	1	100	100	5	0,5
Electric heater (fan)	1	600	600	5	3,0
Mobile charger	3	3	9	14	0,1
Lighting (CFL)	4	11	44	8	0,4
Radio	1	20	20	18	0,4
Router	1	28	28	24	0,7
Totals			1236 W		<u>12,28 kWh per day</u>

B. Kitchen					
Number of persons: 4					
Appliance	No of units	Watts (W)	Subtotal W	Daily use (hrs)	Subtotal kWh
Coffee machine	1	900	900	0,8	0,7
Electric water heater	1	1725	1725	0,5	0,9
Keukenmachine	1	450	450	1	0,5
Toaster (automatic)	2	750	1500	3	4,5
Refrigerator (500 litres)	3	260	780	24	18,7
Freezer (450 litres)	2	230	460	24	11,0
Hotplate (large portabl	2	1310	2620	2	5,2
Oven (large)	2	700	1400	6	8,4
Portable Fan	1	100	100	5	0,5
Electric heater (fan)	2	600	1200	5	6,0
Lighting (CFL)	8	11	88	5	0,4
Totals			11223 W		<u>56,825 kWh per day</u>

C. Communal Area					
Number of persons: 150					
Appliance	No of units	Watts (W)	Subtotal W	Daily use (hrs)	Subtotal kWh
Coffee machine	1	900	900	1,5	1,4
Electric water heater	1	1725	1725	0,5	0,9
Television	1	120	120	15	1,8
Lighting (CFL)	8	11	88	6	0,5
Radio	1	20	20	15	0,3
Refrigerator (250 litres)	2	210	420	24	10,1
Mobile charger	5	3	15	10	0,2
Totals			3273 W		<u>15,0705 kWh per day</u>

D. Artist area					
Number of persons: 25					
Appliance	No of units	Watts (W)	Subtotal W	Daily use (hrs)	Subtotal kWh
Coffee machine	1	900	900	5	4,5
Electric water heater	1	1725	1725	5	8,6
Television	1	120	120	5	0,6
Lighting (CFL)	8	11	88	6	0,5
Radio	1	20	20	10	0,2
Refrigerator (250 litres)	1	210	210	24	5,0
Portable Fan	1	100	100	4	0,4
Electric heater (fan)	1	600	600	4	2,4
Mobile charger	3	3	9	8	0,1
Totals			3063 W		<u>22,37 kWh per day</u>

E. Financial Office						
Number of persons: 2						
Appliance	No of units	Watts (W)	Subtotal W	Daily use (hrs)	Subtotal kWh	
Laptop	2	200	400	10	4,0	
Printer	1	35	35	2	0,1	
Portable Fan	1	100	100	4	0,4	
Electric heater (fan)	1	600	600	4	2,4	
Mobile charger	3	3	9	3	0,0	
Lighting (CFL)	4	11	44	5	0,2	
Radio	1	20	20	5	0,1	
Totals			1208 W		7,22 kWh per day	

F. Press Office						
Number of persons: 6						
Appliance	No of units	Watts (W)	Subtotal W	Daily use (hrs)	Subtotal kWh	
Laptop	6	200	1200	13	15,6	
Printer	1	35	35	2	0,1	
Portable Fan	2	100	200	6	1,2	
Electric heater (fan)	1	600	600	6	3,6	
Mobile charger	6	3	18	10	0,2	
Lighting (CFL)	4	11	44	7	0,3	
Radio	1	20	20	11	0,2	
Totals			2117 W		21,18 kWh per day	

G. Toilets					
Number of persons: 6					
Appliance	No of units	Watts (W)	Subtotal W	Daily use (hrs)	Subtotal kWh
Hand blower	2	350	700	2	1,4
Lighting	6	11	66	12	0,8
Totals			766 W		<u>2,19 kWh per day</u>
H. Other					
Appliance	No of units	Watts (W)	Subtotal W	Daily use (hrs)	Subtotal kWh
Lighting	20	11	220	12	2,64
Totals			220 W		<u>2,64 kWh per day</u>

Total Energy Consumption Production Area

Powerzone	# persons	m2	Subtotal kWh
A. Production office	2	12,5	12,28
B. Kitchen	4	25	56,87
C. Communal area	150	100	15,07
D. Artist area	25	20	22,37
E. Financial office	2	12,5	7,22
F. Press office	6	12,5	21,18
G. Toilets	6	12,5	2,19
H. Other	n.a.	n.a.	2,64
Totals	195	195	<u>137,175 kWh per day</u>

C. Solar PV Panels

This calculation shows how much squared metres of solar PV panels would be needed to generate enough energy to supply the whole production area with solar energy: 383,75m².

Solar PV panels									
PV Panel									
Name:	Average								
Type:	Mono-Crystalline								
Dimensions bxh:	1,956 x	0,992 m	=	1,940 m2					
Wp:	285 -	300 wp	=	290 wp on Average					
Energy Production (per year)									
$P = \text{totaal vermogen paneel} * \text{instalingsfactor} * \text{verliesfactor}$									
Vermogen cell:	290 wp								
Solar Irradiance (zoninstralingsfactor):	90 %	}	253,2 kWh	per panel/year					
Conversion Efficiency (verliesfactor):	97 %	=	911,4 MJ	per panel/year					
Area of Panels needed									
Energy production per panel:		911,4 MJ/year	=	2,5 MJ/day					
Energy demand festival:		137,2 kWh/day	=	493,8 MJ/day					
Amount of Solar panels:		198 panels	=	383,75 m2					

