SCHOOL OF ENGINEERING AND BUILDING ENVIRONMENT

# 2017-8 TR1

# SUSTAINABLE BUILDING AND PROJECT DESIGN

BSV11114

# COURSEWORK 2

DEVELOPMENT OF A SUSTAINABLE
SPORTS COMPLEX IN SCOTLAND

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# Contents

## Table of Figures



## List of Tables

## Main Findings

The existing structure is a 150 year old derelict textile factory (40m*30m*12m in height) a large masonry and brick three storey building which was subsequently used as a furniture factory and over the past couple of decades as a truck repair workshop. So, it was created in late nineteenth-century within the Victorian era (1837–1901) during which period the styles known as Victorian were used in construction.

The pictures of Blackwood Brothers' River Mill has taken as a benchmark for characterization of the existing factory due to the similarity of its built time corresponds to second half of 19$^{th}$ century and its function as a textile (carpet) factory.

In this time multi-storey textile mills where workers and machines were crowded together are common iron-framed industrial building types. Stout timber sections were becoming scarce and expensive, and cast iron offered a versatile and cheaper alternative. Equally, the valuable contents made it important that these buildings were 'fireproof', particularly in mills where rags, lubricating oil-soaked timber floors and candles were a potentially inflammable combination. For a long time 'fireproof' was equated with 'incombustible', so a cast iron skeleton was provided in place of timber to support floors of brick arches covered with rubble and flagstones, or, less commonly, flagstones laid directly onto a more closely-spaced grid of iron beams (Bussell, 2011).


*Figure 1 Blackwood Brothers' River Mill, Kilmarnock (Left)The floors were supported on cast iron structure ; (Right) beams were supported by hollow circular columns (East Ayrshire Libraries, 1917)*

In the late 19$^{th}$ century, roof trusses were often 'composite': principal rafters of cast iron or timber were combined with a bottom boom and other tension members (Bussell, 2011). Slate, tile, pantile, corrugated iron and thatch was widely in use as a traditional roofing material in vernacular rural buildings, such as byres, mills and kilns (Scottish Government, 2014)

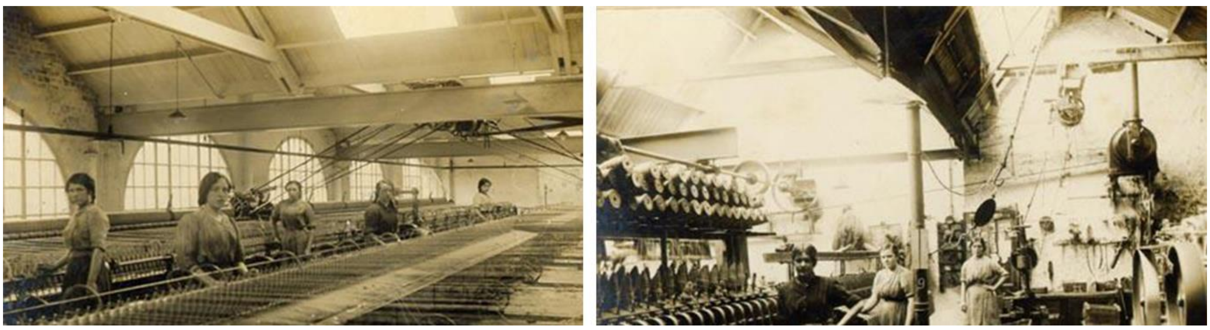

*Figure 2 Blackwood Brothers' River Mill, Kilmarnock (Left) Principal rafters are constructed of cast iron while purlins and ties are made of timber ; (Right) hollow circular columns support the roof structure*

In this circumstances with taking into consideration of the latter uses of building, it is assumed the beams and the columns were employed by cast iron supply the timber substructure with a rubble flooring on top(see fig1). Roof trusses were contributed by timber rafters, purlins and ties connected to cast iron beams at the bottom(see fig2). The pitched roof was topped by slate.

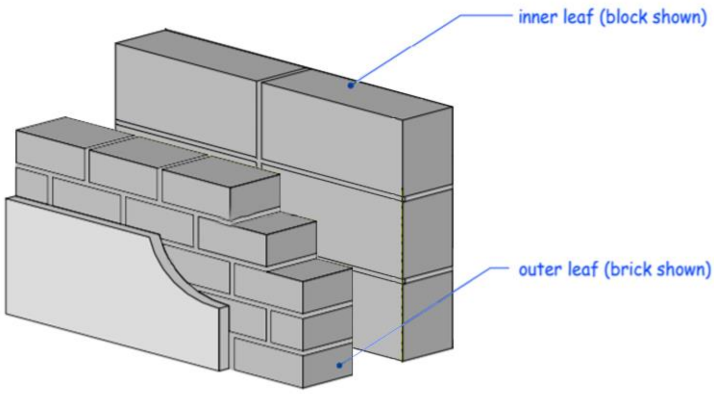


*Figure 3 Masonry and Brick Cavity Wall Illustration (SBSA Technical Guide, n.d.)*

A cavity wall is made up of two walls with a gap in between, the outer leaf is made of brick, and the inner layer of stone block (see fig3).

Figure 4 below show typical foundations at the end of the 1800s (University of the West of England, 2009). The foundation of existing building is considered that every wall had a simple continuous strip concrete foundation below it.

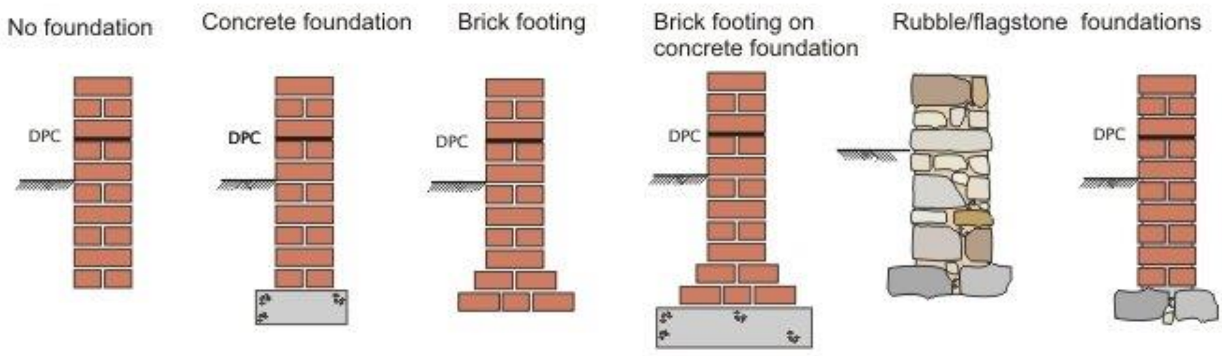


*Figure 4 Typical foundations at the end of the 1800s in UK (University of the West of England, 2009)*

# 1 Introduction

“A sustainable society is one which satisfies its needs without diminishing the prospects of future generations.“
Those words, attributed to Lester R. Brown, Founder and President of Worldwatch Institute, offer a fairly generic definition on the subject of sustainability. Such is the depth of this subject that only when specific boundaries or scope are defined can meaningful conclusions be drawn. Brown’s definition suggests that actions are sustainable if;

(a) there is a balance between resources used and resources regenerated
(b) each generation preserves the legacies of future generations
(c) the viability, integrity and diversity of natural systems are restored and maintained (Peden, 2003).

With the considerations of those words, the new sport complex projection in brownfield area is introduced in this paper. It starts with proposing methods for demolition and remediation of hazardous materials later explains the design considerations. The following part examines suitable construction systems with materials and renewable energy systems. The social impacts of the project discussed after the convenient sustainable drainage systems presented. All of action are taken with the tomorrow in mind as the sustainability means.

Previously investigated closely, the existing building is a year old derelict textile factory building with no outstanding features consisting of a large masonry and brick three storey in Dumfries. The town sits in an enviable position of being a rural and coastal destination, rich in a wide range of product and sectors, within relatively easy reach of the key markets of the Central Belt of Scotland and the North and Midlands of England. Such a configuration generates enormous opportunities, around the affinity between distanced sector and local interest groups.

# 2 Demolition

Demolition is an activity in which the construction process is reversed. It is an activity in which the structure or parts thereof are disassembled and removed. Sometimes the structure may be dismantled or deconstructed so that more materials can be reused and recycled (Anumba, et al., 2008). Due to diminishing natural resources, increasing community awareness on the environment and pressure from the government’s increasingly strict regulations and standards relative to demolition waste, the demolition industry has become more innovative in their methods and techniques. In particular, increasing landfill tipping fees and compulsory high recycling rates on demolition wastes impose strong legal incentives for the construction industry to a lot attention on

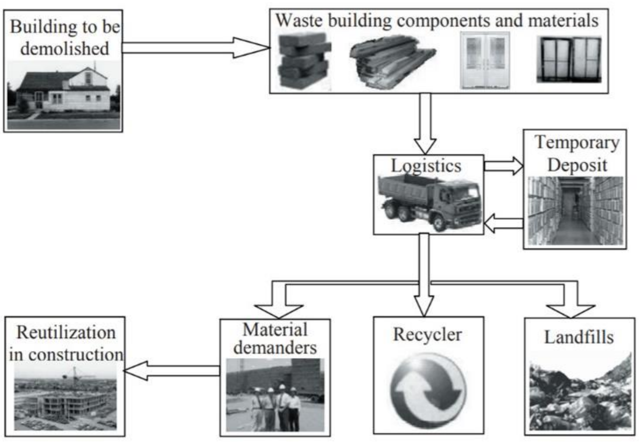

*Figure 5 Procurement of the demolition*

environmental issues (Ling & Lim, 2002). Scottish Landfill Tax (Standard Rate and Lower Rate) Order 2017 specifies that the standard rate of SLfT will be £86.10 and the lower rate of SLfT will be £2.70 per tonne. The rates vary regarding to the material disposed of consists of qualifying or non-qualifying material. That is to provide appropriate financial incentives to support delivery of its waste policies, namely reducing generally the amount of material being sent to landfill, but especially non-qualifying material which is particularly harmful from an environmental point of view (SLfT Legislation Guidiance, 2015).

Prior to handing the area the first task was to impose the execution of a waste management plan to promote the optimum use of resources. Plan contains information about;

• Characterization of the construction works;
• Main waste streams;
• Estimation of the quantities of each material;
• Proposal for minimization,
• Reuse and recycling;
• Transport of the C&D wastes.

## 2.1 Method

Conventional mechanical building demolition produces numerous solid wastes, most of which are sent to landfill directly and severely degrade the living environment (Pun & Liu, 2006). The minimization of the time spent in this operation, as a consequence the different waste streams would end all mixed up. However, the need to maximize the reuse and recycling of C&D wastes has forced the appearance of a new principle named "selective demolition" (Torgal & Jalali, 2011).

The selective demolition involves the removal of components of the building in the inverse direction of its construction;

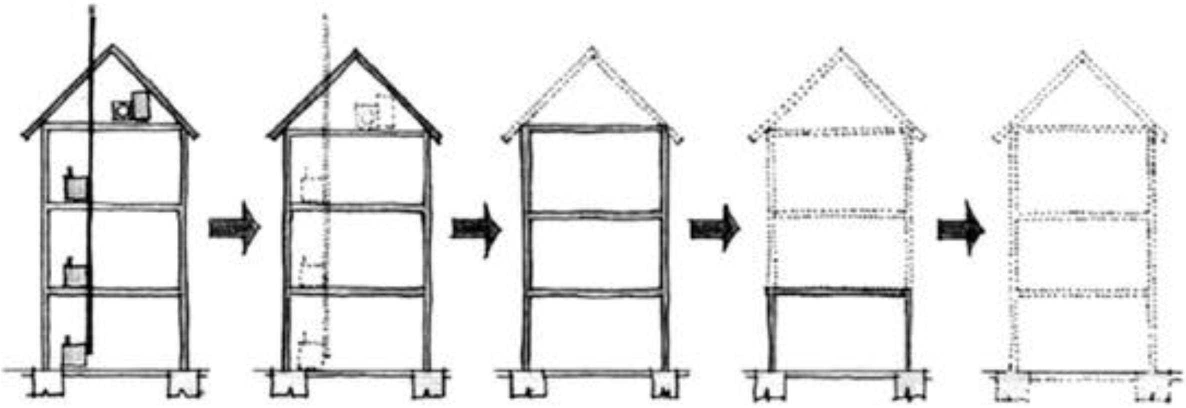

*Figure 6 Dismantling of a building in terms of selective demolition (Torgal & Jalali, 2011)*

One of the keys to maximising the yield of recyclable C&DW-derived aggregates is separation of materials at source, through selective demolition and good management of construction sites. The goal must be to minimise the waste quantities requiring special treatment and disposal, leading to optimum recycling and environmentally friendly, sustainable disposal of building waste materials. This is in principle carried out as the reverse of the construction process and the principal procedures are as follows;

(a) Removal of remains and non-fixtures.
(b) Stripping, comprising internal clearing, removal of doors, windows, roof components, installations, water, heating and electric installations and so forth. This leaves only the foundations and main structures of the building in place.
(c) Demolition of the foundations and main structures. All three of these phases can involve handling of hazardous materials (Strufe, 2005).

The factory once used as a furniture factory followed by various other incarnations including truck repair workshop before being abandoned. As the characterization of the building was examined previously, the materials carefully deconstructed from the derelict factory will be used in the proposed building in the different forms. Mainly recycling of demolished masonry rubble as coarse aggregate in concrete system which is the selected structure system for the new complex. The other recycling opportunities are discussed in construction part detailed.

# 3 Hazardous Materials

The use of pesticides and fertilizers, in addition to water, makes the global textile industry one of the most polluting and waste-generating sectors in the world.

According to the European waste catalogue-EWC ,encompassed 20 chapters related to different waste categories, the list of wastes regarding our case as follows;

- Wastes from wood processing and the production of panels and furniture,;
- Wastes from the leather, fur and textile industries;
-Oil wastes and wastes of liquid fuels (except edible oils, 05 and 12).

Identifying the presence of a particular hazardous substance, found in buildings and the processes of demolition and handling of the hazardous materials. In this step, a waste inventory was created.

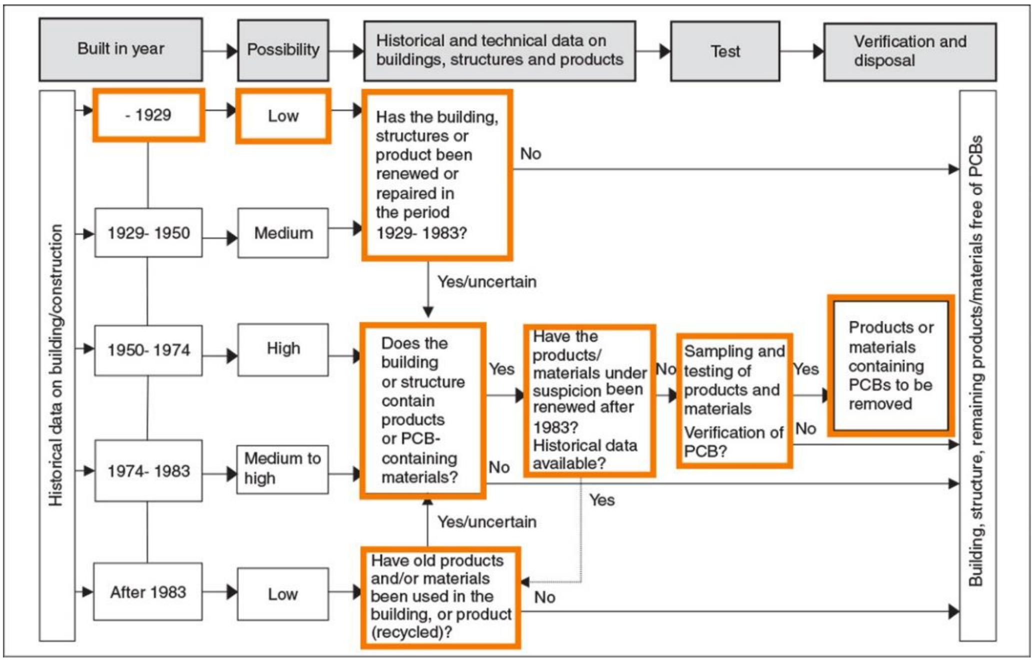


*Table 1The identification process of hazardous materials in building (stroked boxes are to indicate the route to identify hazardous materials in current building) (Strufe, 2005)*

According to Consolidated European Waste Catalogue (2002), the hazardous waste specification is maded. There are three types on entry in the EWC 2002;
• Absolute hazardous that are colour-coded red and marked with an A,
• Mirror hazardous that are colour-coded blue and marked with an M
• Non-hazardous that are colour-coded black as follows;

| | | |
|---|---|---|
| **03** | **Wastes from Wood Processing and the Production of Panels and Furniture, Pulp, Paper and Cardboard** | |
| **03 01** | **wastes from wood processing and the production of panels and furniture** | |
| 03 01 01 | waste bark and cork | |
| 03 01 04* | sawdust, shavings, cuttings, wood, particle board and veneer containing dangerous substances | M |
| 03 01 05 | sawdust, shavings, cuttings, wood, particle board and veneer other than those mentioned in 03 01 04 | |
| 03 01 99 | wastes not otherwise specified | |
| **03 02** | **wastes from wood preservation** | |
| 03 02 01* | non-halogenated organic wood preservatives | A |
| 03 02 02* | organochlorinated wood preservatives | A |
| 03 02 03* | organometallic wood preservatives | A |
| 03 02 04* | inorganic wood preservatives | A |
| 03 02 05* | other wood preservatives containing dangerous substances | M |
| 03 02 99 | wood preservatives not otherwise specified | |
| **04** | **Wastes from the Leather, Fur and Textile Industries** | |
| **04 02** | **wastes from the textile industry** | |
| 04 02 09 | wastes from composite materials (impregnated textile, elastomer, plastomer) | |
| 04 02 10 | organic matter from natural products (for example grease, wax) | |
| 04 02 14* | wastes from finishing containing organic solvents | M |
| 04 02 15 | wastes from finishing other than those mentioned in 04 02 14 | |
| 04 02 16* | dyestuffs and pigments containing dangerous substances | M |
| 04 02 17 | dyestuffs and pigments other than those mentioned in 04 02 16 | |
| 04 02 19* | sludges from on-site effluent treatment containing dangerous substances | M |
| 04 02 20 | sludges from on-site effluent treatment other than those mentioned in 04 02 19 | |
| 04 02 21 | wastes from unprocessed textile fibres | |
| 04 02 22 | wastes from processed textile fibres | |
| 04 02 99 | wastes not otherwise specified | |
| **13** | **Oil Wastes and Wastes of Liquid Fuels (except edible oils, and those in chapters 05, 12 and 19)** | |
| **13 01** | **waste hydraulic oils** | |
| 13 01 01* | hydraulic oils, containing PCBs[1] | A |
| 13 01 04* | chlorinated emulsions | A |
| 13 01 05* | non-chlorinated emulsions | A |
| 13 01 09* | mineral-based chlorinated hydraulic oils | A |
| 13 01 10* | mineral-based non-chlorinated hydraulic oils | A |
| 13 01 11* | synthetic hydraulic oils | A |
| 13 01 12* | readily biodegradable hydraulic oils | A |
| 13 01 13* | other hydraulic oils | A |
| **13 02** | **waste engine, gear and lubricating oils** | |
| 13 02 04* | mineral-based chlorinated engine, gear and lubricating oils | A |
| 13 02 05* | mineral-based non-chlorinated engine, gear and lubricating oils | A |
| 13 02 06* | synthetic engine, gear and lubricating oils | A |
| 13 02 07* | readily biodegradable engine, gear and lubricating oils | A |
| 13 02 08* | other engine, gear and lubricating oils | A |
| *"Absolute Entries"* | - Hazardous waste regardless of any threshold concentrations: | A |
| *"Mirror Entries"* | - Hazardous waste only if dangerous substances are present above threshold concentrations: | M |

*Table 2 Identification of the waste type regarding the older uses of the factory*

Hazardous waste should be collected, stored each type in a separate container, clearly marked with warning label to show what it is contained, and finally, delivered off site to a hazardous waste treatment, storage and disposal facility (TSDF) using a registered hazardous waste transporter.

# 4 Construction/Design

The chosen sport facility is skate park. Many public officials still see skateboarding as a fringe sport, despite the sport's persistent popularity. Rather than sketchy, graffiti-filled places, today's skate spots tend to be well maintained public parks that draw families skating with their kids, older skateboarders, and fans of the sport. It's even an Olympic sport now, and will make its debut at the Tokyo 2020 Olympic Games (Chilcote, 2016). To justify about which features to be accommodated in skatepark and the possibilities of different facility to be linked, the precedent projects within the UK were analysed. According to Mpora, Europe's leading adventure sports and outdoor lifestyle site, 10 of the best places to BMX & Skateboard in the country are listed as follows (Renhard, 2016) ;

| VENUE | LOCATION | TYPE | FACILITES | FEATURES | PRICING | TIMETABLE |
|---|---|---|---|---|---|---|
| **Projekts MCR** | Manchester/ENG | outdoor *undercovered | skateboard/BMX | Large, concrete skate area.Ramps to stairs, rails to banks, boxes, to ledges, and a mini-ramp | •£3 per hour •Membership: £22.50 monthly | Monday to Saturday: 12.00-21.00 Sunday: 12.00-18.00 |
| **The Front** | Weymouth/ENG | outdoor *partly undercovered | skateboard/BMX | Undercovered half pipe and vert ramp, split into two heights for both intermediate and advanced riders.Open street park, complete with stairs,hubbas,rails,ledges,wedges and mini ramps. | •£3 per hour •Membership: £2.50 weekly £10.00 annually | Monday to Tuesday : 16.00-19.00 Saturday and Sunday : 12.00-17.00 |
| **Hereford Skatepark** | Hereford/ENG | outdoor | skateboard/BMX | A large, curved bowl in the centre with a slightly wedgier bowl next to it. Additionally large street skating area with a tight bowl, and another large, expansive street section. | •£2.50 per hour •Membership:£5 one-off fee | Monday to Saturday: 8.00-18.00 Sunday: 8.00-13.00 |
| **Radlands Skatepark** | Northampton/ENG | outdoor | skateboard/BMX | Smooth diamond shape plaza with plenty of ramps, rails, and ledges. Astrip through the middle that's packed with stair sets, boxes, rails and manual pads. | •Free | Monday to Sunday: 12.00-21.30 |
| **The Level** | Brighton/ENG | outdoor | skateboard/BMX | Bowls with hubbas, rails, stair sets, ledges, boxes and wedges.Butter-smooth concrete park is triangular in shape,the Northern point is a shallow,mellow bowl to the South,deeper;the east bowl rectangular. | •Free | Monday to Sunday : 8.00-18.00 |
| **Unit 23 Skatepark** | Dumbarton/SCO | indoor | skateboard/BMX | 1st floor traditional skatepark with ramps, boxes, rails, bowls, mini ramps, quarter-pipes; 2nd floor street skating area; 3rd floor skatepark having a foam pit and a resi-ramp for beginners. | •£4 per hour •Membership:£40 annually + £3 per hour | Monday to Friday: 12.00-22.00 Saturday and Sunday: 12.00-20.00 |
| **House Of Vans** | London/ENG | indoor | skateboard/BMX /culture&art hub | Built in the disused tunnels underneath Waterloo station, occupies five of the tunnels. Tunnel four has a deep bowl with some smooth transitions, ideal for all levels. Tunnel five has a whole mini ramp area, and separate street skating section, made by butter-smooth concrete. | •Free *still ticketed. | Only nights/Opening times for ary depending on what events they have on |
| **Creations Sk8park** | Birmingham/ENG | indoor | skateboard/BMX | A combination of street section and ramps with smooth wooden on a concrete floor. Ramps are full sized vert accompanied by a nice flowing bowl, a flow section, jump boxes and a foam pit . | •£8.50 per day in weekdays •£10.00 per day in weekends | Monday to Friday: 10.00-22.00 Saturday and Sunday: 10.00-19.00 |
| **Rampworx** | Liverpool/ENG | indoor | skateboard/BMX | 4 big room included: 1st with jumps, boxes, ledges, rails ideal for grinding and sliding.2nd is a bowl.3rd is for street skating, competition-worth street course. The final is with foam pits. | •£6.50 per 2 hour & £7.50 all day •£7.50 per 2 hour & £12.00 all day •£20 per week | Tuesday to Friday: 16.00-22.00 Saturday and Sunday: 10.30-19.00 |
| **Dynamix** | Gateshead/ENG | indoor | skateboard/BMX /cultural hub | Built by using recycled and reclaimed materials. It is a wood and concrete construction, and consists of specially designed ramps, bowls, boxes, spines, and two foam pits. | •£5 per a day •Membership: £2.00 | Tuesday to Friday : 9.00-21.00 Saturday and Sunday : 10.00-21.00 |

*Table 3 Comparison of the skateparks based in UK*

This analyse can be useful for timetable arrangements and pricing later. The main points from the analysis which form our conceptual idea are;

-Each skating facility is combined with BMX ride,
-Indoor facilities rarely are companied with other programmes such as it is in House of Vans and Dynamix.
-The separation is defined between rooms in terms of skating skills of the visitors,
-Bowls, street style mannered pitches are the most outstanding,
-Modules are made of either concrete or timber,
-Ledges, stairs, rails are essential.

Dumfries is a small town without meeting the social needs of local youth yet in a good location. Accordingly it is proposed a indoor skatepark which will be main and only activity accompanied by some spaces in the context of youth centre and cafeteria. Moreover, creating a place, where provides collaborations of young people and also the seniors. It is also important that it should generate an income.

## 4.1 Plans

The complex, compromises two building in the same size, stands close the north-east corner of the site. Therefore the positioning of the building can be interpreted as welcoming the its guests while the landscaping defined by the lines track the main axes lie along the main roads (see fig 9). It is seen one of those axes emphasized by the way of material change on the building envelope to refer the flows of skating. Same approach was kept in plan organization.

In ground floor there are two entrances, one leads directly into the skate hall while the other welcomes the guests not necessarily coming for skating but for either the spaces such as cafeteria, meeting room in ground floor where the planned collaborations will be held or multipurposed hall in upstairs. The skate hall accommodates a launch area then continues ramps with stair sets, ledges, rails and ends with a bowl complex. The quarter pipe has been placed into the south facing building where fun boxes are aligned by the angular line. The total ground floor is 1810 $m^2$.

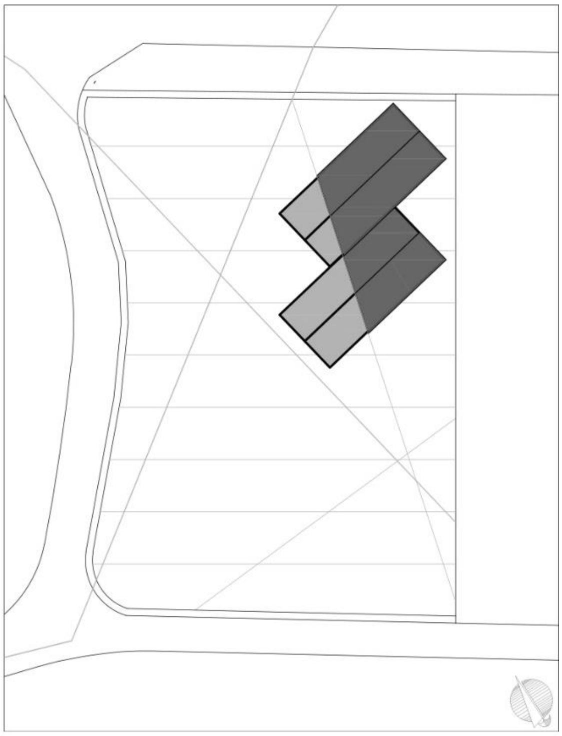

*Figure 7 Site Plan*

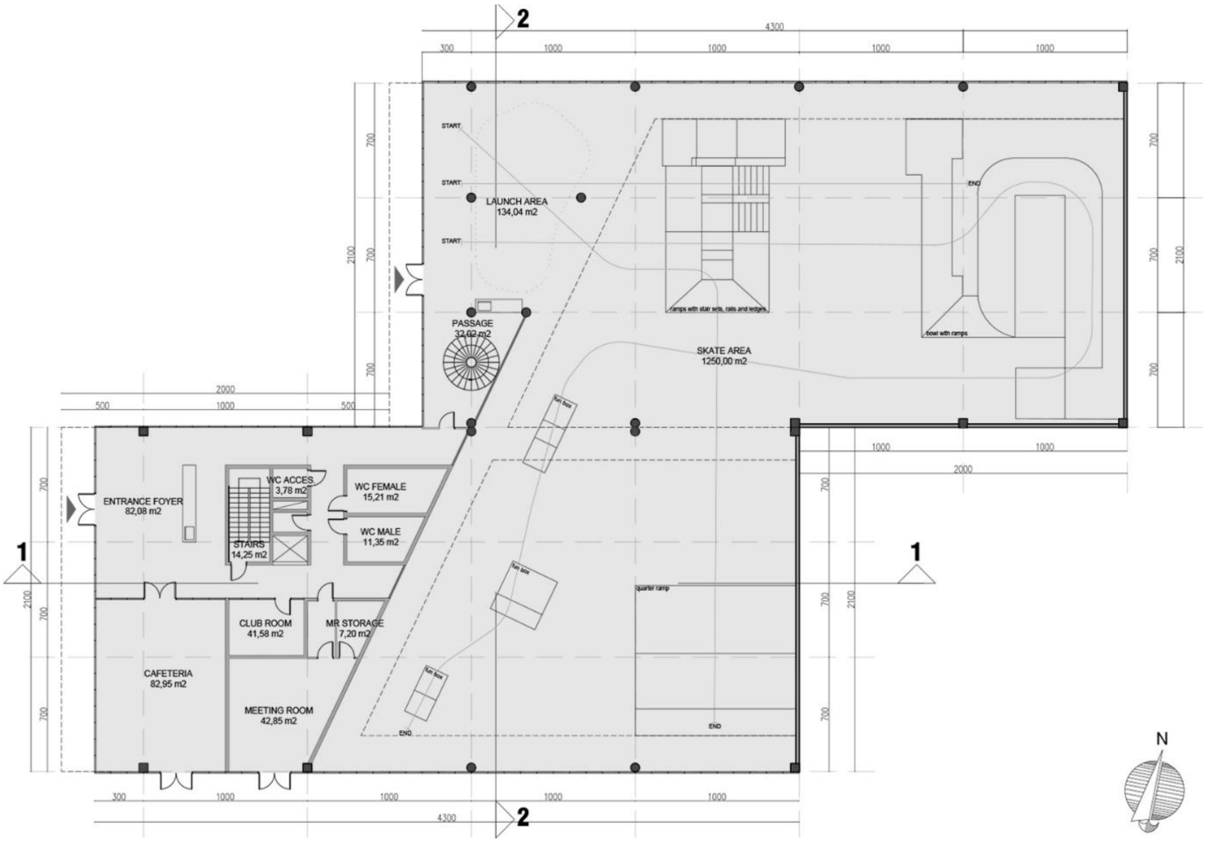


*Figure 8 Ground floor plan*

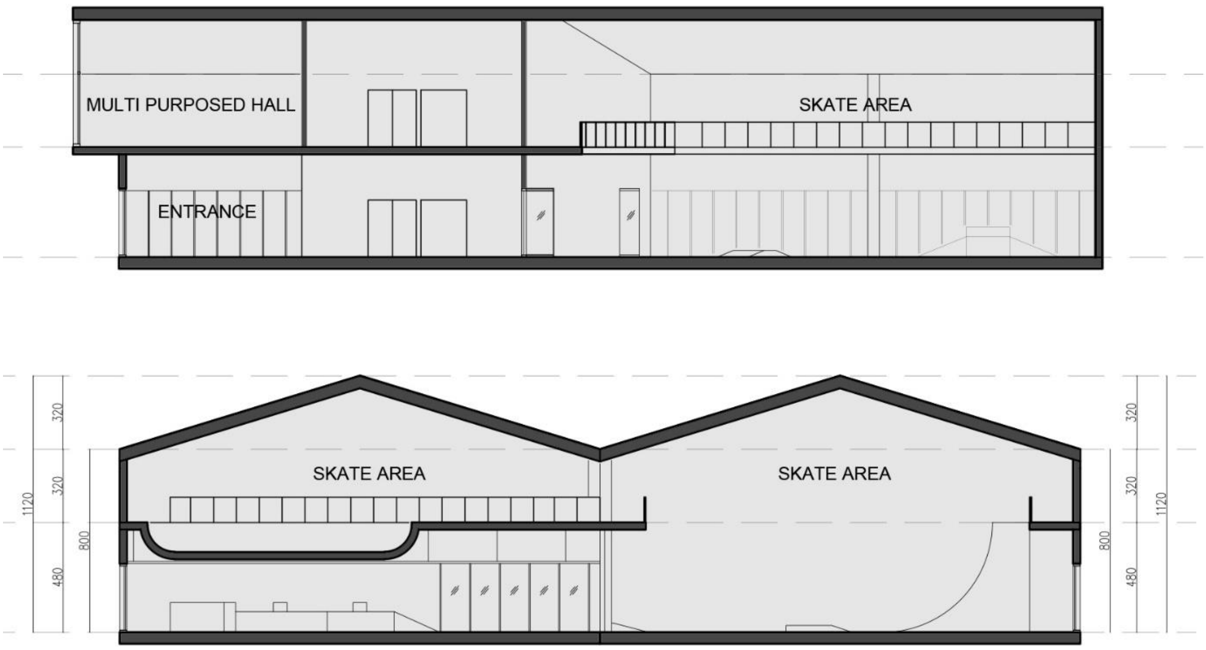


*Figure 9 (Upper) Section 1; (Bottom) Section 2*

Second floor accommodates a multipurposed hall (200m$^2$) where a badminton pitch or a ping pong table fits or either can be used dance studio with the scenery through the window in front. Those studios benefit from the attractive volumes under the roof. It has been taken into consideration the negative effect of noise distribution emerges from the skate hall in the placement. Especially when multipurposed hall is used as an assembly hall. Therefore, a buffer zone created in between by the spaces in common use (Changing rooms, WCs and the building core). A small bowl area placed here for the beginner's practise. Moreover, the walkaways supplied for the families and the fans of the sport. It enables spectators to watch the skaters safely. The floor area here is 810 m$^2$, so the total surface of the complex is 2620 m$^2$.

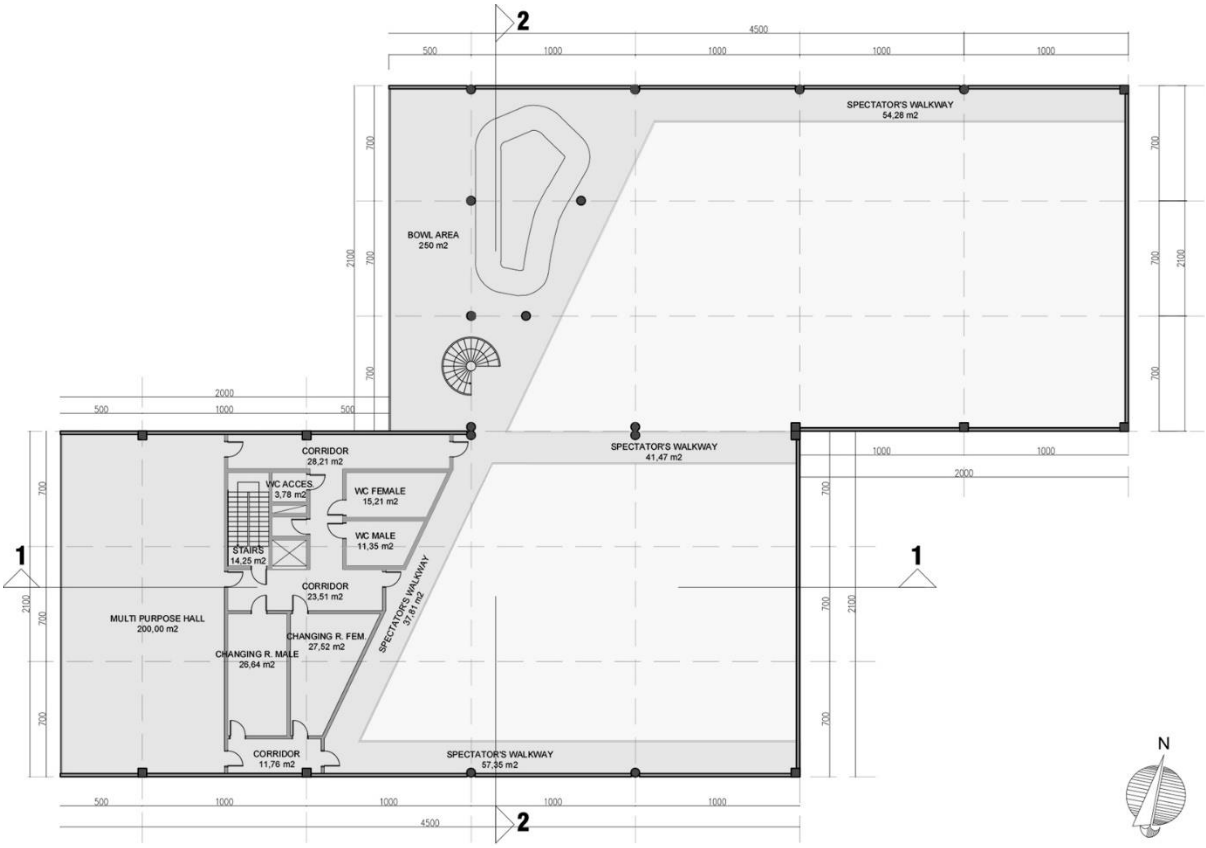


*Figure 10 First floor plan*

## 4.2 Construction and Materials

• The structure will be built by pre-cast concrete technology. The considerations has been taken in the design stage as the two building sized equally and modular approach was kept in plan arrangement by repeating grid system. The facts are stated that claim the sustainability strengths of precast units:

1 Speed of construction: Precast components can be manufactured in much larger sizes, reducing shipping and erection time, and costs in parking garages and other structures. Lighter, larger wall panels allow for a faster and more economical enclosure. Lightweight precast mixes and newer, alternative reinforcement technologies reduce the energy required to produce, transport and erect by as much as 50 percent.

2 Maximizes available space: Precast concrete wall sections can be produced with longer spans, and

in more narrow thicknesses, allowing more usable space within the same building footprint as other construction methods.

3 Smaller footprint: Because precast concrete is formed offsite, casting can begin while foundations are being placed. Fewer trucks and less time are needed than would be for transporting other building materials to the jobsite. The result is a smaller site construction footprint with less dust and waste.

4 Durability: Factory-controlled precast ensures a low water-cement ratio (0.40), ensuring the concrete will resist water penetration, which results in a higher quality concrete than what is typically poured onsite.

5 Energy conservation: The national energy code recognizes mass walls as requiring considerably less insulation than other construction types. Concrete, a thermal mass, absorbs and then slowly releases heat. The lagged effect of heat transfer can reduce the heating and cooling loads and the equipment needed to condition a building. Lighter-colored concrete helps reduce the heat-island effect and associated HVAC costs.

6 Recyclability: Precast concrete by nature is a highly durable material, outlasting many other construction types. Not only is it resistant to moisture, mold, severe weather and other environmental factors, it can be designed to allow for expansions and changes that reuse existing precast components in new designs (Anon., 2009).

• Skate modules will be employed by concrete by the favour of its longer lifespan in terms of durability and easily formed because of its plasticity. Moreover the recycling of the wastes generated by demolition which are used as aggregate in cement production was the key which guided the use of concrete.

| Material | Pros | Cons | Cost | Lifespan |
|---|---|---|---|---|
| Concrete | -Durability, long life 30+ years<br>-Organic Shapes, curves and bowls flow better in concrete.<br>-Surface / Structure repairs should be minimal | -More difficult to work with<br>-Longer build time<br>-Expensive<br>-Generally the most expensive surface | -Most expensive | 50+ years indoor/outdoor |
| Skatelite© | -Specially designed skate, BMX and inline surface<br>-Good for BMX parks<br>-Withstands weather better than plywood, masonite<br>-Cheaper than concrete<br>-Exceptionally long lifetime indoors | -Expensive<br>-Some or all surface needs replacement in 4-6 years | -More expensive than plywood less than concrete | 4+ years *outdoor heavy use<br>6+ years indoor heavy use |
| Metal | -Exceptional lifespan, no surface replacement needed<br>-Good for BMX parks<br>-Will withstand the elements; snow, rain, ice, fog, etc... | -Absorbs heat, Gets very hot<br>-Non porous, gets very slick with little moisture<br>-More difficult to work with than wood, requires more labor cost to install | -Less expensive than poly-carbonate skate surfaces<br>-More expensive than plywood | 20+ years indoor/outdoor |
| Birch Plywood | -Smooth skateboard/inline surface | -not recommended for BMX<br>-Does not last outdoors | -Less expensive than all of the above surfaces | 5+ years indoor heavy use<br>1+ year *outdoor |
| Masonite | -Smooth skateboard/inline surface | -not recommended for BMX<br>-Does not last outdoors | -Less expensive than all of the above surfaces | 3+ years indoor use<br>1+ years *outdoor heave use |
| Plywood | -Cheap | -Does not last long indoor/outdoor<br>-Will detiorate fast | -Cheap | 2+ years indoor use<br>1+ years *outdoor |

*Table 4 Material comparisons for skatepark surfaces*

• Ceiling: composite material based on gypsum and recycled wood (Wood waste from demolition such as wood shavings and sawdust). Pedreño-Rojas, et al. (2017) conducted the theoretical and experimental mechanical study of these plates has revealed that it is possible to use composites with up to 20% recycled material without additives, and which comply with the standard requirements for mechanical capacity. It claims that the addition of recycled wood material to a gypsum matrix yields new, more eco-efficient composites; and efficiency increases with the addition of more recycled material. In addition, as the percentage of added wood waste rises, the lightness of the new material increases while also improving its thermal and sound absorption properties relative to the reference material (Pedreño-Rojas, et al., 2017). Suspended composite materials will increase acoustic comfort for users.

• Roofing: pre-cast concrete surfaces are considered to be exposed in front of the angular line seen on site plan. The rest of the roof is covered by self-protected bitumen. Peden (2003) examined the sustainability of bitumen use. It claims that In general terms, once a the bitumen based material is constructed, it can be considered an environmentally friendly, sustainable. Because it can be recycled back into bitumen to be used for instance in roofing membranes or for use within asphalt for roads. So old roofs are no longer destined for landfill, it further improves the sustainability of the entire production chain.

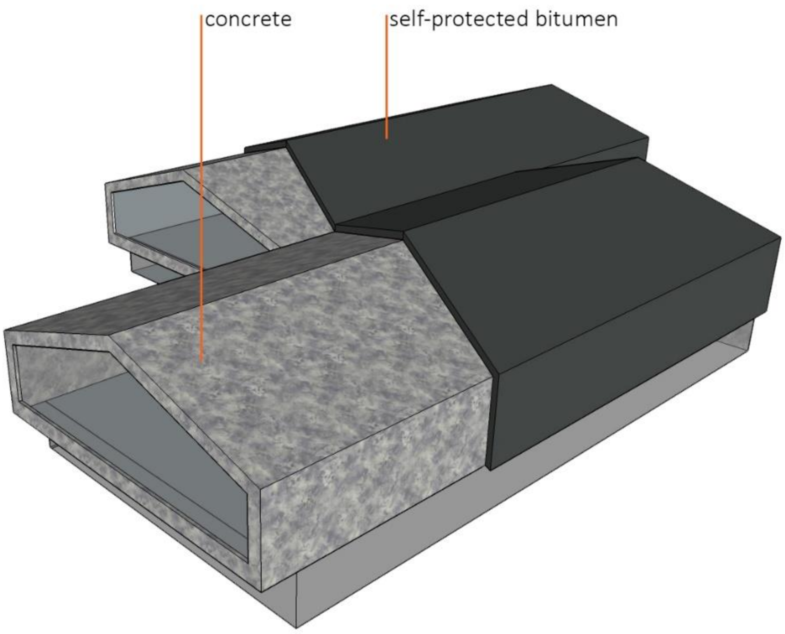

*Figure 11 The illustration of the building envelope*

## 4.3 Energy

The UK's sports sector buildings spend £700 million on energy every year, resulting in annual emissions of 10 million tonnes of carbon dioxide ($CO2$) – the principal contributor to climate change. Sports facilities can have high associated energy costs. The introduction and upgrading of energy-saving measures can therefore be very rewarding, both financially and in terms of user comfort (CIBSE, 2001). The main energy conservation goal of the sports building is to consume as less energy and resources as possible, in the meanwhile minimizing the impact on environment and ecology, and providing the users with a healthy and comfortable building environment.

Energy Consumption Guide in Sports and Recreational Buildings, introduced by CIBSE, was used to assess the annual energy consumption of the building. Guide incorporates a range of benchmarks against which the actual performance of sports centres can be compared. appendix 10.1 was based on to build up to energy use for each specific area. It is seen in Table 5 that there are two type of consumption value for electricity and gas defined as good practice and typical respectively which should be interpreted typical use can be improved by the selection of building fabric, heating and ventilation systems, lighting. The Skate Hall is considered building up with high insulation levels and detailing to avoid air leakage. Lighting will be provided with high-frequency fluorescent, stepped lighting levels. But experiences shows that, the discrepancies might occur between energy performances in design and in operation due to various reason such as workmanship, occupant behaviour, management and maintenance. Therefore, the average of both state was taken into consideration.

| | ANNUAL ENERGY USE AND COST | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ZONE | ELECTRICITY(kWh/m2) | | HEATING FUEL(kWh/m2) | | COST(£/m2) | | EXAMPLE | COST(£/m2) | |
| | Good Practice | Typical | Good Practice | Typical | Good Practice | Typical | Area(m2) | Good Practice | Typical |
| Skate Area | 56.6 | 99.13 | 146 | 321 | 3.2 | 6.0 | 1250 | 4000 | 7500 |
| Cafeteria (based on 200 days in use) | 109.5 | 182.5 | 29.21 | 61.7 | 6.0 | 10.0 | 40 | 1205 | 2008 |
| Bowl Area | 11.32 | 19.826 | 29.2 | 64.2 | 3.2 | 6.0 | 250 | 800 | 1500 |
| Multi Purpose Hall | 17.46 | 28.73 | 28.76 | 63.5 | 3.7 | 6.6 | 200 | 740 | 1320 |
| Changing Rooms/WCs (mech. vent) | 92.4 | 149.6 | 299.4 | 676 | 8.1 | 15.0 | 140 | 1134 | 2100 |
| Common Areas (mech. Vent.) | 74.1 | 117.7 | 168.4 | 354.8 | 5.8 | 10.0 | 740 | 4292 | 7400 |
| **TOTAL** | **361.38** | **597.486** | **700.97** | **1541.2** | **30** | **53.6** | **2620** | **12171** | **21828** |
| **AVERAGE** | **479.433** | | **1121.085** | | **41.8** | | **2620** | **17000** | |

*Table 5 Annual energy consumption of the Skate Hall*

The table below shows the amount of solar and wind power generated based on the coordinates of location (see appendix 10.2). It is seen that the min. wind speed is 4.49 m/s which is reliable as the most wind turbines start generating electricity at wind speeds of around 3-4 metres per second (m/s).

| Month | Air temperature | Relative humidity | Daily solar radiation - horizontal | Atmospheric pressure | Wind speed | Earth temperature | Heating degree-days | Cooling degree-days | Wind Power | Wind Power Daily | Wind power monthly | Solar power Daily | Solar power monthly |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | °C | % | kWh/m$^2$/d | kPa | m/s | °C | °C-d | °C-d | W | kWh | kWh | kWh | kWh |
| January | 2.74 | 85.30% | 0.57 | 99.2 | 6.74 | 2.74 | 472 | 0 | 438.63 | 10.53 | 315.81 | 2.28 | 68.40 |
| February | 3.06 | 82.40% | 1.27 | 99.5 | 6.29 | 3.06 | 417 | 0 | 356.51 | 8.56 | 256.68 | 5.08 | 152.40 |
| March | 4.63 | 80.50% | 2.17 | 99.4 | 6.41 | 4.63 | 412 | 0 | 377.30 | 9.06 | 271.66 | 8.68 | 260.40 |
| April | 6.48 | 76.70% | 3.3 | 99.4 | 5.37 | 6.48 | 345 | 0 | 221.84 | 5.32 | 159.72 | 13.20 | 396.00 |
| May | 9.77 | 71.00% | 4.6 | 99.7 | 4.99 | 9.77 | 253 | 0 | 178.00 | 4.27 | 128.16 | 18.40 | 552.00 |
| June | 12.8 | 67.80% | 4.61 | 99.7 | 4.62 | 12.8 | 159 | 1 | 141.27 | 3.39 | 101.71 | 18.44 | 553.20 |
| July | 15 | 67.80% | 4.32 | 99.7 | 4.49 | 15 | 97 | 5 | 129.67 | 3.11 | 93.37 | 17.28 | 518.40 |
| August | 15 | 69.10% | 3.64 | 99.6 | 4.58 | 15 | 100 | 8 | 137.63 | 3.30 | 99.09 | 14.56 | 436.80 |
| September | 12.2 | 73.30% | 2.49 | 99.6 | 5.36 | 12.2 | 172 | 0 | 220.60 | 5.29 | 158.83 | 9.96 | 298.80 |
| October | 8.85 | 80.70% | 1.42 | 99.2 | 5.89 | 8.85 | 281 | 0 | 292.73 | 7.03 | 210.76 | 5.68 | 170.40 |
| November | 5.43 | 86.00% | 0.73 | 99.2 | 6.23 | 5.43 | 378 | 0 | 346.40 | 8.31 | 249.41 | 2.92 | 87.60 |
| December | 3.54 | 86.40% | 0.44 | 99.3 | 6.59 | 3.54 | 449 | 0 | 409.99 | 9.84 | 295.19 | 1.76 | 52.80 |
| | | | | | | | | | | | Year Tot | | Year Tot |
| | | | | | | | | | | | 2340 | | 3547 |
| Monthly averages | 8 | 77 | 2 | 99 | 6 | 8 | 295 | 1 | 271 | 7 | 195 | 10 | 296 |

*Table 6 The estimation of solar power energy and wind power energy*

Accordingly, it is proposed to install wind turbine. Wind turbines produce electricity by using the natural power of the wind to drive a generator, clean and sustainable fuel source, it does not create emissions. Because the wind blows intermittently, and is not always blowing when the energy is needed, to ensure the energy demand will be rely on the resources in its minimum, it is projected to place photovoltaics by the side of the roofs face south with vertical angle (see Fig 14). The presence of the photovoltaics panels was one of the starting point of building's location in site plan. Co-locating wind and solar plants was considered solution to create a fairly constant yearly energy supply. With the provided inputs, further research should be undertaken to define the size of the wind turbine by the counsel of engineers.

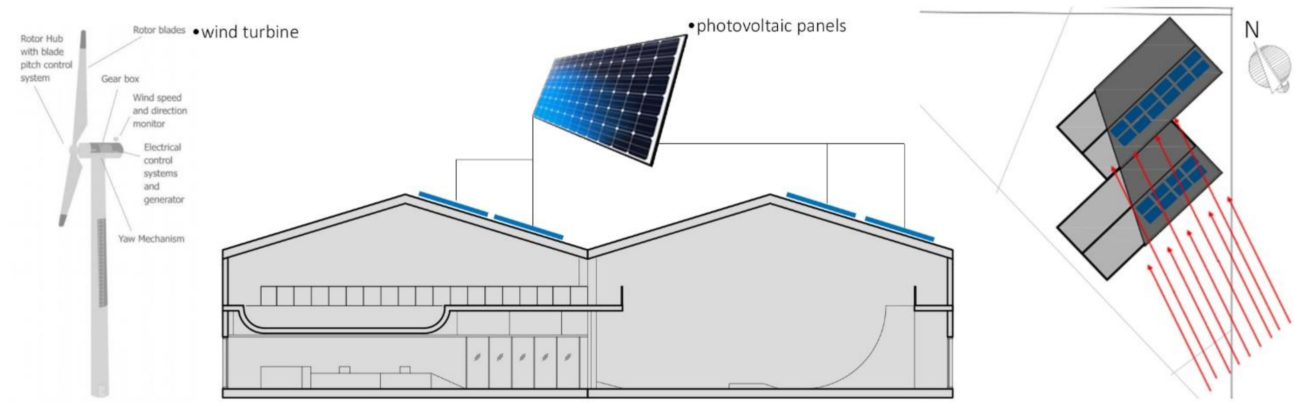


*Figure 12 The illustration of energy strategy*

## 4.4 Health and Safety

Health and safety law requires that a risk assessment be carried out of playground equipment to identify what precautions should be taken to protect against harm. Part of the assessment process will involve deciding whether the equipment complies with the relevant standards. Of these, the principal one is BS EN14974 "Facilities for users of roller sports equipment", BS EN 1176 "Playground Equipment" is relevant in parts, but it is is 200 pages long and covers mainly general safety requirements, test methods and specific requirements for swings, slides, runways, carousels and rocking equipment. PAS 30 is also marginally relevant. The hey action steps are summarized as follows;

• Carry out and record a risk assessment or review any existing assessment of the playground equipment.

• Give consideration to whether the equipment complies with the new standards or not and what action is needed to make it comply.

• Take into account the typical usage of the equipment and likely damage / wear and tear from previous inspection and maintenance records.

• Make reference to accident records and reports including incidents with the potential for a more serious outcome.

• Develop a prioritised action plan to address any deficiencies identified by assessments (Wheelscape, n.d.).

Developing safe and high-quality instructional programming for the community, skate park also can help and a safe skateboarding environment for all participants. Introductory lessons and educational programs will benefit all user groups at the skatepark. Using local resources such as skateboarding speciality shops and colleges can help the organization find qualified instructors. This will also help to build a sense of ownership and trust between the skatepark and the local skateboard community. Although experience working in instructional setting is preffered, most proficient and responsible skateboarders can learn to teach skateboarding safely when given the right tools and resources to work with (Wixon, 2009).

## 6 SuDS

The Scottish Environment Protection Agency (SEPA) defines SUDS, or sustainable urban drainage systems that are a sequence of water management practices and facilities designed to drain surface water in a manner that will provide a more sustainable approach than what has been the conventional practice of routing run-off through a pipe to a watercourse.

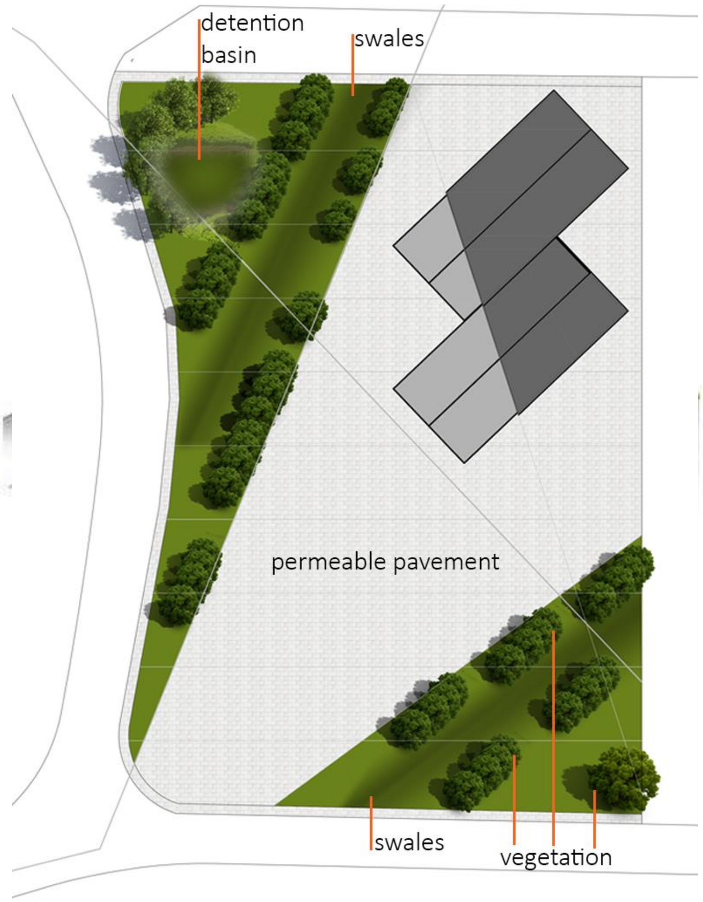

*Figure 14 SuDS strategy demonstrated in site plan*

In our case 3 different techniques were faciliated (see fig 16) :

1) A swale, lush with native grasses, runs through the courtyard, treating and filtering storm-water runoff. They are located close to the source of runoff and can form a network within a development linking storage ponds and wetlands. A swale is dry during dry weather but in wet weather, rainwater flows into it along its length and moves slowly through the grass area. The grass slows down and filters surface water flows. Sediment is deposited while oily residues and organic matter are retained to be broken down in the top layer soil and vegetation. They reduce risk to amphibians such as toads and newts, which are often trapped in gully pots. Some regular maintenance is required to keep a grass swale operating correctly; chiefly, mowing during the growing season. The optimum grass length is around 150mm (SuDS Wales, n.d.).

2) A detention basin stores storm water on the north-west edge. It is designed to retain flood events, reducing peak flows and limiting the risk of flooding.

3) Permeable paving reduces peak storm water flow by filtering the water through the paved structure rather than running it off. Both the surface and the sub-grade need to be designed with this function in mind. Water may infiltrate directly into the subsoil where conditions are suitable. Several researchers studied the benefits of permeable pavement in reducing pavement runoff and pollutants (Radlinska, et al., 2010).

As a matter of next step for landscaping design, instead of going for conventional type of permeable paving, the same approach which allows the water infiltration in paving can be implemented in more imaginative manner as seen in figure 17.

*Figure 15 Pavement alternative from public plaza design in Landhausplatz by LAAC Architekten and Stiefel Kramer Architecture*

Additionally, natural vegetation is proposed in the landscape. It helps attenuate flows, trap silts and pollutants, promotes infiltration and be robust enough to prevent erosion. It also enhances evapotranspiration and reduces the heat island effect (Graham, et al., n.d.)

# 7 Social Impacts

Anecdotal evidence suggests that the provision of public skateparks can dramatically improve the sometimes antagonistic relationship between police forces and young people; far from places of lawlessness, skateparks are places where people work within codes of behavior, and are spaces where sometimes aggressive energies are focused on positive sporting goals. It is important to realise that the public provision of sports facilities is part of the responsibility of the local and central government. These places offer the chance to relax, to exercise, and allow young people a place to enjoy activities together; they are important places for the well being of society. (Council, 2014)

As skateboarding goes mainstream, cities are investing in infrastructure. One of the world's best-known skateboarding parks is located beneath the Burnside Bridge in Portland, Oregon. One night in 1990, local skaters Bret Taylor, Chuck Willis, and Osage Buffalo made their own ramp by pouring concrete against a slanted wall. They convinced local contractors building the 1-80 freeway ramp to "donate" some excess concrete and the skate spot grew. Burnside Skate Park drew skaters from up and down the West Coast, but because it was unsanctioned by the city it was in constant danger of getting torn down."Títere was concern locally that it would draw crime, drug addicts, undesirable populations and activity, but the reverse became true," says Mark Ragget, senior planner with the city of Portland. "It was a place where a lot of people would come, and skateboarders helped clear up the park and keep things generally workable around the facility. The owners and businesses around them started to appreciate having them around." (Chilcote, 2016)

Community-oriented projects like Skateistan (Afghanistan, Cambodia and South Africa), Skatepal (Palestine), 7Hills (Jordan), Bedouins (Tunisia) and All Nations Skate Project (Native American reservations) all use skateboarding to build social capital and to help counter deep-rooted social issues of alcohol and drug abuse, unemployment, violence, gender prejudices and access to education (Borden, 2014).

## 8 Conclusions

With the creation of a design based on the “sustainable development objectives” it is projected to revitalize the brownfield site and to create a comfortable and functional space, with the environmental friendly process, with the less building construction cost and operation, and with the development of local economy and society. To assess the achievement of environmental sustainability of the building, it is essential to mention 4Es which are the objectives of environment, efficiency, effectiveness and economy. Environmentally-conscious approach provided by the complex targeted low carbon footprint mainly with the recycling and repurposing of the existing materials by so cost-effectiveness is also achieved where possible and the implementation of renewables with co-operation of airtight building envelope. Energy systems are suitable and efficient regarding the location. The youth centre and the skate park programme effective solution for the area as it fits the purpose which was creating a sport center should become a 'focal point for the local community' while giving attention to generate an income by the supply of extra facilities such as cafeteria and multi-purposed hall can make profit besides the skate hall facility.

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# 10 APPENDIXES

## 10.1 CIBSE table demonstrates energy use in sports and recreation buildings

| Zone | Electricity ($kWh/m^2$) | | Heating fuel ($kWh/m^2$) | | Cost (£/$m^2$) | | $kgC/m^2$ | | Example | Cost (£/year) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | GP | Typ | GP | Typ | GP | Typ | GP | Typ | Area ($m^2$) | GP | Typ |
| Leisure pool hall | 208.1 | 318.4 | 999.6 | 2325.6 | 21.4 | 40.8 | 77.9 | 160.4 | 580 | 12 435 | 23 647 |
| Conventional pool hall | 208.1 | 318.4 | 824.9 | 1936.7 | 19.7 | 36.9 | 68.8 | 140.3 | 580 | 11 422 | 21 391 |
| Sports hall | 39.4 | 69.0 | 102.6 | 224.3 | 3.2 | 6.0 | 10.3 | 20.3 | 870 | 2779 | 5254 |
| Bowls hall | 31.8 | 51.9 | 67.6 | 130.5 | 2.4 | 4.2 | 7.5 | 13.3 | 670 | 1626 | 2786 |
| Ice rink hall | 204.8 | 307.7 | 73.8 | 158.8 | 12.0 | 18.5 | 29.5 | 46.8 | 2500 | 30 005 | 46 286 |
| Fitness/health suites | 78.4 | 130.0 | 209.3 | 482.3 | 6.4 | 12.0 | 20.7 | 41.3 | 160 | 1025 | 1916 |
| Internal courts | 52.4 | 86.2 | 86.3 | 190.5 | 3.7 | 6.6 | 11.0 | 20.7 | 600 | 2247 | 3987 |
| Wet changing and showers | 93.4 | 167.1 | 529.7 | 1267.0 | 10.4 | 21.9 | 39.2 | 86.6 | 220 | 2296 | 4809 |
| Dry changing and showers | 92.4 | 149.6 | 299.4 | 676.0 | 8.1 | 15.0 | 27.1 | 53.8 | 140 | 1131 | 2098 |
| Spectator | 62.3 | 102.4 | 168.4 | 354.8 | 5.1 | 9.2 | 16.5 | 31.2 | 80 | 409 | 734 |
| Common areas (mech vent) | 74.1 | 117.7 | 168.4 | 354.8 | 5.8 | 10.0 | 18.0 | 33.2 | 230 | 1325 | 2305 |
| Common areas (nat vent) | 52.7 | 80.9 | 109.5 | 185.3 | 4.0 | 6.3 | 12.3 | 19.7 | 200 | 798 | 1261 |
| Plant rooms | 74.1 | 117.7 | 168.4 | 354.8 | 5.8 | 10.0 | 18.0 | 33.2 | 160 | 921 | 1604 |
| Stores | 52.7 | 80.9 | 109.5 | 185.3 | 4.0 | 6.3 | 12.3 | 19.7 | 90 | 359 | 567 |
| **Feature and unit of size** | **Electricity (kWh/unit)** | | **Heating fuel (kWh/unit)** | | **Cost (£/unit)** | | **kgC/unit** | | **Example** | **Cost (£/year)** | |
| | GP | Typ | GP | Typ | GP | Typ | GP | Typ | Size (units) | GP | Typ |
| Car park, area ($m^2$) | 4.6 | 6.6 | 0.0 | 0.0 | 0.3 | 0.4 | 0.6 | 0.8 | 1700 | 427 | 614 |
| Floodlit courts/pitch, are ($m^2$) | 3.3 | 5.8 | 0.0 | 0.0 | 0.2 | 0.3 | 0.4 | 0.7 | 5000 | 903 | 1606 |
| Snack bar, hot meals/day | 109.5 | 182.5 | 0.0 | 0.0 | 6.0 | 10.0 | 13.7 | 22.9 | 200 | 1205 | 2008 |
| Sauna/steam room, size (persons) | 1168.0 | 1752.0 | 0.0 | 0.0 | 64.2 | 96.4 | 146.5 | 219.8 | 8 | 514 | 771 |
| Solarium, no of sunbeds | 2628.0 | 3942.0 | 0.0 | 0.0 | 144.5 | 216.8 | 329.7 | 494.5 | 2 | 289 | 434 |
| Exercise machines | 788.4 | 1051.2 | 0.0 | 0.0 | 43.4 | 57.8 | 98.9 | 131.9 | 12 | 520 | 694 |
| Wave machine | 13 140.0 | 17 520.0 | 0.0 | 0.0 | 722.7 | 963.6 | 1648.5 | 2198.0 | 1 | 723 | 964 |
| Flumes | 3504.0 | 6570.0 | 0.0 | 0.0 | 192.7 | 361.4 | 439.6 | 824.2 | 2 | 385 | 723 |
| Spa pool/jacuzzi, no of persons | 876.0 | 1752.0 | 0.0 | 0.0 | 48.2 | 96.4 | 109.9 | 219.8 | 4 | 193 | 385 |

## 10.2 Climate Data extracted by NASA

**Latitude 55.093 / Longitude -3.58 was chosen.**

**Geometry Information**

Elevation: **146** meters
taken from the
NASA GEOS-4
model elevation

Northern boundary
**56**

Western boundary
**-4**

Center
Latitude **55.5**
Longitude **-3.5**

Eastern boundary
**-3**

Southern boundary
**55**

### *Parameters for Solar Cooking:*

**Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m²/day)**

| Lat 55.093 Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-year Average | 0.56 | 1.28 | 2.19 | 3.32 | 4.58 | 4.56 | 4.30 | 3.68 | 2.54 | 1.45 | 0.74 | 0.44 |

*Parameter Definition*

### *Parameters for Sizing and Pointing of Solar Panels and for Solar Thermal Applications:*

**Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m²/day)**

| Lat 55.093 Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-year Average | 0.56 | 1.28 | 2.19 | 3.32 | 4.58 | 4.56 | 4.30 | 3.68 | 2.54 | 1.45 | 0.74 | 0.44 | 2.47 |

**Minimum And Maximum Difference From Monthly Averaged Insolation (%)**

| Lat 55.093 Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Minimum | -19 | -23 | -16 | -16 | -18 | -15 | -19 | -13 | -18 | -21 | -20 | -9 |
| Maximum | 26 | 20 | 31 | 19 | 17 | 26 | 25 | 29 | 20 | 32 | 15 | 11 |

*Parameter Definition*

### *Solar Geometry:*

**Monthly Averaged Daylight Hours (hours)**

| Lat 55.093 Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average | 7.85 | 9.76 | 11.8 | 14.1 | 16.1 | 17.2 | 16.7 | 14.9 | 12.7 | 10.5 | 8.48 | 7.28 |

*Parameter Definition*

## *Parameters for Tilted Solar Panels:*

**Monthly Averaged Radiation Incident On An Equator-Pointed Tilted Surface (kWh/m²/day)**

| Lat 55.093 Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SSE HRZ | 0.56 | 1.28 | 2.19 | 3.32 | 4.58 | 4.56 | 4.30 | 3.68 | 2.54 | 1.45 | 0.74 | 0.44 | 2.47 |
| K | 0.33 | 0.40 | 0.39 | 0.40 | 0.43 | 0.39 | 0.39 | 0.40 | 0.39 | 0.36 | 0.35 | 0.34 | 0.38 |
| Diffuse | 0.40 | 0.78 | 1.36 | 2.03 | 2.58 | 2.71 | 2.66 | 2.21 | 1.48 | 0.87 | 0.49 | 0.31 | 1.49 |
| Direct | 0.94 | 1.82 | 2.17 | 2.66 | 3.69 | 3.33 | 3.00 | 2.86 | 2.48 | 1.86 | 1.19 | 0.82 | 2.24 |
| Tilt 0 | 0.57 | 1.27 | 2.17 | 3.30 | 4.60 | 4.61 | 4.32 | 3.64 | 2.49 | 1.42 | 0.73 | 0.44 | 2.47 |
| Tilt 40 | 1.01 | 1.97 | 2.71 | 3.58 | 4.54 | 4.33 | 4.16 | 3.81 | 2.99 | 2.06 | 1.25 | 0.87 | 2.78 |
| Tilt 55 | 1.10 | 2.07 | 2.69 | 3.40 | 4.16 | 3.94 | 3.78 | 3.57 | 2.94 | 2.12 | 1.34 | 0.95 | 2.67 |
| Tilt 70 | 1.12 | 2.06 | 2.55 | 3.08 | 3.69 | 3.45 | 3.33 | 3.19 | 2.75 | 2.08 | 1.36 | 0.99 | 2.47 |
| Tilt 90 | 1.06 | 1.88 | 2.20 | 2.50 | 2.85 | 2.63 | 2.56 | 2.53 | 2.31 | 1.87 | 1.28 | 0.95 | 2.05 |
| OPT | 1.12 | 2.08 | 2.72 | 3.61 | 4.75 | 4.66 | 4.41 | 3.88 | 3.00 | 2.12 | 1.36 | 0.99 | 2.90 |
| OPT ANG | 69.0 | 61.0 | 46.0 | 30.0 | 18.0 | 11.0 | 15.0 | 26.0 | 41.0 | 57.0 | 67.0 | 72.0 | 42.6 |

| | |
|---|---|
| NOTE: | *Diffuse radiation, direct normal radiation and tilted surface radiation are not calculated when the clearness index (K) is below 0.3 or above 0.8.* |

***Parameter Definition***

## *Parameters for Sizing Battery or other Energy-storage Systems:*

**Minimum Available Insolation Over A Consecutive-day Period (%)**

| Lat 55.093 Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min/1 day | 3.50 | 6.25 | 5.47 | 13.8 | 18.9 | 16.4 | 24.8 | 16.3 | 18.1 | 4.13 | 2.70 | 4.54 |
| Min/3 day | 36.8 | 19.2 | 34.7 | 26.2 | 31.8 | 38.2 | 40.3 | 36.9 | 33.7 | 27.5 | 25.6 | 33.3 |
| Min/7 day | 46.1 | 37.2 | 51.5 | 41.7 | 58.8 | 49.6 | 49.8 | 53.9 | 48.3 | 47.7 | 42.0 | 59.7 |
| Min/14 day | 62.7 | 57.5 | 59.1 | 63.3 | 69.9 | 69.4 | 67.0 | 66.9 | 67.5 | 64.1 | 58.3 | 72.2 |
| Min/21 day | 66.2 | 70.2 | 68.7 | 65.9 | 73.2 | 80.5 | 77.3 | 73.9 | 68.5 | 72.7 | 68.4 | 74.4 |
| Min/Month | 80.7 | 76.5 | 84.0 | 83.7 | 82.0 | 85.3 | 80.7 | 86.9 | 82.2 | 78.6 | 79.7 | 90.9 |

***Parameter Definition***

## *Parameters for Sizing Surplus-product Storage Systems:*

**Available Surplus Insolation Over A Consecutive-day Period (%)**

| Lat 55.093 Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max/1 day | 268 | 223 | 220 | 212 | 186 | 192 | 192 | 202 | 217 | 221 | 234 | 193 |
| Max/3 day | 202 | 211 | 198 | 194 | 174 | 187 | 182 | 191 | 205 | 194 | 219 | 163 |
| Max/7 day | 193 | 171 | 171 | 179 | 150 | 179 | 163 | 180 | 187 | 179 | 181 | 143 |
| Max/14 day | 153 | 154 | 169 | 147 | 137 | 147 | 151 | 156 | 154 | 147 | 141 | 121 |
| Max/21 day | 137 | 132 | 160 | 129 | 126 | 141 | 141 | 151 | 133 | 144 | 127 | 113 |
| Max/Month | 126 | 120 | 131 | 119 | 117 | 126 | 125 | 129 | 120 | 132 | 115 | 111 |

***Parameter Definition***

## *Meteorology (Temperature):*

**Monthly Averaged Air Temperature At 10 m Above The Surface Of The Earth (°C)**

| Lat 55.093<br>Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-year Average | 2.74 | 3.06 | 4.63 | 6.48 | 9.77 | 12.8 | 15.0 | 15.0 | 12.2 | 8.85 | 5.43 | 3.54 | 8.33 |
| Minimum | 0.61 | 0.76 | 1.77 | 2.80 | 5.57 | 8.61 | 11.1 | 11.5 | 9.16 | 6.33 | 3.23 | 1.47 | 5.28 |
| Maximum | 4.87 | 5.69 | 7.61 | 10.1 | 14.0 | 16.7 | 18.8 | 18.5 | 15.3 | 11.4 | 7.50 | 5.50 | 11.3 |

***Parameter Definition***

**Monthly Averaged Cooling Degree Days Above 18 °C**

| Lat 55.093<br>Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-year Average | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 8 | 0 | 0 | 0 | 0 | 14 |

***Parameter Definition***

**Monthly Averaged Heating Degree Days Below 18 °C**

| Lat 55.093<br>Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-year Average | 472 | 417 | 412 | 345 | 253 | 159 | 97 | 100 | 172 | 281 | 378 | 449 | 3535 |

***Parameter Definition***

**Monthly Averaged Earth Skin Temperature (°C)**

| Lat 55.093<br>Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-year Average | 1.54 | 2.14 | 4.26 | 6.81 | 10.6 | 13.9 | 16.4 | 16.2 | 12.8 | 8.43 | 4.53 | 2.38 | 8.39 |

***Parameter Definition***

## *Meteorology (Wind):*

**Monthly Averaged Wind Speed At 10 m Above The Surface Of The Earth For Terrain Similar To Airports (m/s)**

| Lat 55.093<br>Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10-year Average | 6.74 | 6.29 | 6.41 | 5.37 | 4.99 | 4.62 | 4.49 | 4.58 | 5.36 | 5.89 | 6.23 | 6.59 | 5.62 |

| | |
|---|---|
| ***It is recommended that users of these wind data review the SSE Methodology. The user may wish to correct for biases as well as local effects within the selected grid region.*** | ***All height measurements are from the soil, water, or ice/snow surface instead of "effective" surface, which is usually taken to be near the tops of vegetated canopies.*** |

***Parameter Definition*** ***Units Conversion Chart***

## *Meteorology (Other):*

**Monthly Averaged Atmospheric Pressure (kPa)**

| Lat 55.093<br>Lon -3.58 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-year Average | 99.2 | 99.5 | 99.4 | 99.4 | 99.7 | 99.7 | 99.7 | 99.6 | 99.6 | 99.2 | 99.2 | 99.3 | 99.5 |

***Parameter Definition***

Back to SSE *Responsible > Data: Paul W. Stackhouse, Jr., Ph.D.*