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Selected papers from Creative Construction Conference 2014

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Creative Construction Conference 2014, CC2014

Preface

Peer-review under responsibility of the Diamond Congress Kft.

Creation is an inspiring endeavor. This is especially true when one creates objects of a size that only a few people can. Cathedrals or skyscrapers, bridges or aqueducts, highways or dams are not only fascinating due to their size but also because they greatly affect the lives of all people in their proximity – for decades or even centuries. The act of Construction is an act of true creation.

Growing demand for a "better" built environment – even though the meaning of "better" is often hard to define in this context – requires increasing levels of diverse knowledge. As time progresses, it is getting harder to live up to the ever growing societal expectations: trains begin to compete with the speed of airplanes, buildings are often expected to produce rather than to consume energy, and in the not-so-distant future we will build settlements in outer space, most likely with advanced robotics.

The Creative Construction Conferences are organized to provide an annual forum for ambitious researchers and practitioners from around the world who have realized that the construction industry is rapidly changing and who accept that building materials, construction technologies, and project management will quickly and creatively evolve in the future.

Creative Construction Conference 2014 (CCC 214) was held on 21 – 24 June 2014 in Prague, taking advantage of this charming and vibrant Central European city, home to leading international construction firms and leading academic institutions.

Academics from 34 countries and all continents attended CCC 2014 organized across six tracks:

- Creative management
- Creative construction technologies and materials
- Advanced automation and robotics for construction
- Creative scheduling
- Sustainable construction, health and safety
- Recent advances in Building Information Modeling, visualization and virtual reality.

Original papers have been published in the CCC 2014 proceedings, and selected and extended versions of those papers are now being published in this issue of Procedia Engineering.

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We are grateful to all the authors, speakers, poster presenters, members of the International Advisory Board, of the organizing and scientific committees, reviewers, and to the session chairs for contributing to the success of CC2014. Their contribution helped us become the largest construction engineering and management conference in Europe.

Prof. Mirosław Skibniewski
University of Maryland, USA
Chair of International Advisory Board
Chair of Scientific Committee

Prof. Miklós Hajdu
Szent Istvan University, Hungary
Chair of International Organizing Committee
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Creative Construction Conference 2014, CC2014

Toward the reduction of environmental impacts of temporary event structures

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Abstract

In the context of temporary events, the use of structural systems suitable for short-term use is a key strategy in terms of organization. However, this type of ephemeral structure currently requires the implementation of significant resources, for which the characteristics of flexibility and economic efficiency most often prevail over considerations related to sustainability.
This lack of sustainability exists due to several attributes of a temporary building. Firstly, the distance between the place of storage and the one of use requires transportation, which can sometimes represent a significant share of consumption and environmental impacts. Furthermore, heat energy required to achieve an acceptable level of indoor comfort in a building with little or no thermal isolation is disproportionate to the short time of use. Finally, the materials used, in most cases, have a significant life cycle in terms of embodied energy required for their manufacture and respectively their disposal. However, many parameters are not as yet subject to specific studies. Contributing to remedy this lack, the present paper aims to evaluate the environmental impacts and lack of performances of current temporary event structures. In order to compare them with the expected performances of an alternative proposition –the On STAGE Project-, which refers to architectural quality and high level of comfort with an optimal use of resources and a minimization of environmental impacts.
Firstly, a detailed analysis of a typical ephemeral structure system is presented, through an assessment process, that takes into account not only environmental criteria calculated on the whole life cycle, Non Renewable Energy (NRE) and Global Warming Potential (GWP), but also the thermal and acoustic comfort. Then the set of results will be compared to the simulated values for On STAGE Project, and show that it is possible, through an integrated design process based on the principles of bioclimatic architecture and the use of renewable energy sources, to design a temporary structure capable of high level of comfort, preserving resources and reducing environmental impacts, in order to meet sustainability goals, even in the case of a short lifespan.

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Keywords: temporary structure; sustainable construction; integrated design; energy; environmental impact; life-cycle assessment.

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1. Introduction

Today, the use of temporary or ephemeral structures is booming and therefore it should be designed in a sustainable way. Not only in terms of flexibility and speed of erection but also in term of inner comfort, thermal and acoustic performances, from architectural aesthetics point of view, or regarding gray energy needed for manufacture, use and transport and their environmental impacts.

To do so this article observes firstly some data on the development of the cultural sector to illustrate the favorable context for such development of a sustainable temporary structure. Then through a multi criteria evaluation of sustainability parameters of a typical structure system, representative of current practice, it goanna specify advantages and disadvantages of such structure. An useful assessment in order to set out the specific objectives of a first conceptual vision, both from design point of view than in terms of use comfort, or in order to minimize environmental impacts. Finally, the presentation of the "OnSTAGE project", currently under development through a process of integrated design will provide reliable base for realization of an operational prototype by optimizing iteratively different dimensions of the project [1].

2. Increasing demand regarding temporary event structures

In consideration of the especially significant number of cultural manifestations (festivals, shows, exhibitions, commercial, trade fairs, fairs, exchanges), sportive or political festivals, where the assembly of temporary structures is necessary, a tangible need regarding the material is manifested. Nevertheless, the consultation of all regional, national or international agendas, which appear on the media, induces an impression of the real growth in the event branch.

The specific analysis, as measured by a country like Switzerland, shows this importance: the revenues generated by the event industry have increased regularly since 2003 by 6% per year [2]. The Federal Statistical Office (OFS) adds a completion in term of frequentation linked to cultural practices. For example, 67 % of the Swiss population attended at least one music event per year [3]. For European countries, the average of the population attending a “live” performance in 2006, was around 40 % of the population [4].

Furthermore, it is noted that the International Organization for Standardization (ISO) has published a new standard for organizers of events in order to increase integration of sustainability into their activities (ISO, 2012). This standard emphasizes in particular the need for certain temporary event constructions, thus avoiding oversized infrastructures in relation to actual needs once the event happened. The London Olympics 2012 are a prime example of the application of these recommendations. These figures highlight the interest in the planification of a sustainable alternative, which is characterized by a strong development potential.

3. Limits of the common practice

In order to comprehend more precisely the advantages and the disadvantages of the usual practice, a case study has been conducted on a representative model of this kind of temporary structure. A tent of classical fabrication had been specifically chosen, which harbored the main stage at the Cully Jazz Festival (Switzerland), destined for about 1000 viewers. This case study took place in April 2011. The results of these analyses are summarized below.

3.1. Thermal comfort

In order to evaluate the climate inside more precisely, four data loggers had been place inside and outside the tent during this one-week festival. The results presented in figure 1 clearly highlight typical characteristics of light construction. The fact that the tent hasn't any insulation or thermal sealing, made it very susceptible for the different temperatures outside, but especially for the influences of the direct solar radiation. Indeed the important variation of the monitored temperatures, at the beginning of the afternoon, on a sunny day (March 30) and on a very cloudy day

(March 31) expresses the strong dependence of the inner climate on the direct solar radiation. A second peak in inner temperature had been registered at the end of the evening of the concert. The presence of one thousand viewers represents an huge energy input inside and may not be neglected and it is recommended to consider the users (viewers, musicians and technicians) in the objective for the improvement of the thermal comfort. These two major factors influencing the climate inside, which are the direct solar radiation and the internal heat gains, are furthermore not controllable by the operators. In case of the analyzed construction it remains difficult to compensate the climatic variations inside and however reach satisfactory thermal comfort [5].

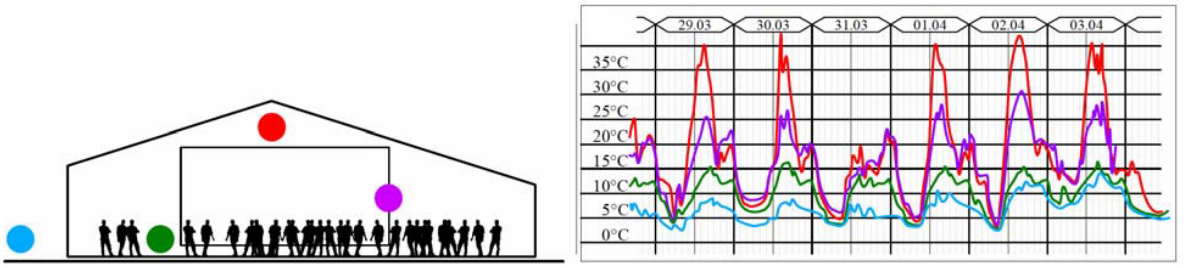


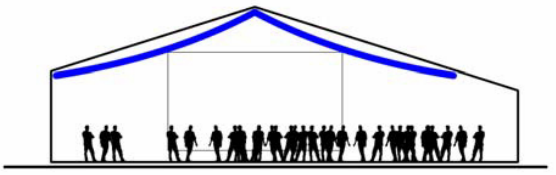
Fig. 1. Position of the data loggers and measurements of the temperatures during the Cully Jazz Festival (29th March to 3rd April 2011).

3.2. Acoustic comfort

The acoustic comfort and emissions sound to the neighborhood is also influenced by the light construction. To evaluate the acoustic quality inside, the times of reverberation had been measured during a concert. The results, illustrated in figure 2, indicate that it is possible to stay within the optimum area for jazz, but with one time measuring around the limits for the bass frequencies as a consequence of the light construction of the model. An optimization of the model with big awnings made of cloth tensed across the ceiling of the tent, contributes to improve the periods of reverberation in order to reach a satisfactory level for the jazz. [5].

During the analysis, a different type of noise pollution had been detected, that are especially annoying for viewers and musicians. These disturbing noises are due to constructive modalities of the infrastructure and more precisely due of vibrations of the base plates and structure of the seating rows for the placement of the viewers. These base plates are composed of wooden elements surrounded by a metal belt, which surely protects them from manipulation but which are a source for disturbing noise in case of repetitive vibration.

Furthermore, in case of strong wind you can also note additional noise resulting from the movement of the construction and the ceilings. This annoying noise is the result of the fact that cloth skin is not put under tension and



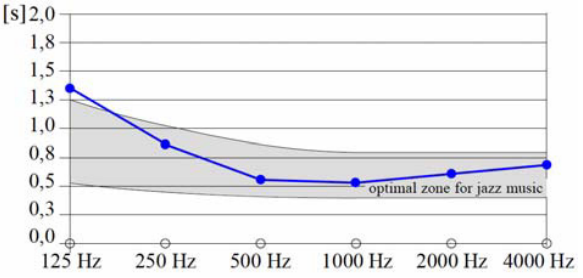


Fig. 2. Measurement of the time of reverberation during a concert on the occasion of the Cully Jazz Festival (2011) – by adding big awnings tensed across ceiling it is possible to stay within the optimum area for jazz but with one time measuring around the limits for the bass frequencies, as a consequence of the light construction of the model.

therefore can float in the wind. This kind of repetitive noises can be really disturbing for spectators and musicians, especially when the sound volume of the concert is low.

One last aspect is concerning the sound emissions outwards and inwards, that are very important and generate significant noise coming from inside for the neighborhood and coming from outside for spectators. However, on the occasion of the measurements and as illustrated in figure 3, measured values on different positions in the neighborhood are far above the legal limits. Even if this type of ephemeral use often benefits from a certain tolerance on the part of the neighborhood, a level that is so high reduces possibilities of implementation on certain sites [5] .

	External noise dB(A)				
Points	Leq.e	Lr max.e	Leq10.max	Lr.m	
1	64,5	68,9	75,5	75,5	Above legal limit
2	68,0	70,9	79,0	79,0	Above legal limit
3	67,2	70,1	78,2	78,2	Above legal limit
4	64,3	67,2	75,3	75,3	Above legal limit
5	62,0	64,9	73,0	73,0	Above legal limit
6	67,2	70,1	78,2	78,2	Above legal limit

Fig. 3. Measures of the medium noise level at several points in the neighborhood of the tent during a concert at the Cully Jazz Festival (2011). The measurements show values far above the legal limits for permanent constructions. A level that is so high constrains the area of hourly use and reduces as well the possibilities of implementation on certain sites.

3.3. Consumption of non-renewable energy (NRE) and environmental impacts (GWP)

Another aspect that is revealed by the assessment of current practice limits considering criteria of sustainability is the environmental impact of materials choices. Indeed the necessary grey-energy isn't subject to special verifications, especially regarding the influences on the environment. For example in this case study, aluminum is the main material used for the structure, as it offers interesting characteristics of lightness and hardiness, but it although requests a lot of energy during its production. As illustrate on figure 4, it represent until 63% of non-renewable energy (NRE) and 51% of global warming potential (GWP). In this way a better planning regarding the material use could optimize this aspect. Another environmental impact revealed by this assessment is the huge energy consumption required to heating system. To reach an acceptable inner climate during cooler periods, it is necessary to compensate the thermal losses of the casing of the tent by using temporary heating oil devices, which efficiency and influences on the environment are very bad. An energy that is very quickly dispersed due to the light construction [6].

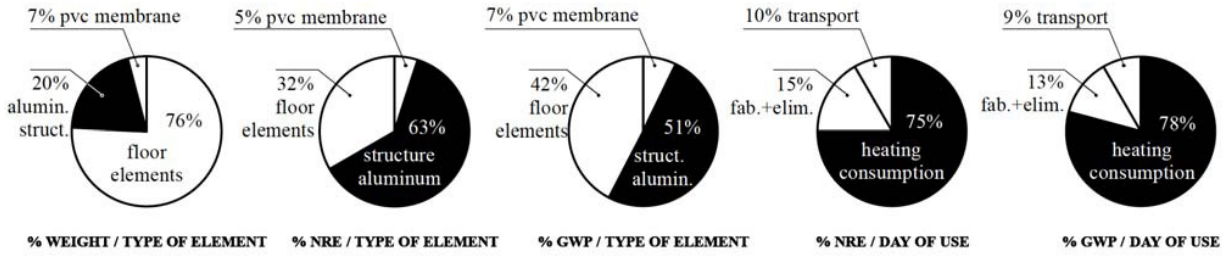


Fig. 4. The aluminum is the main material used for the structure, as it offers interesting characteristics of lightness and hardiness, but it although requests a lot of energy during its production. The environmental impact revealed by this assessment is the huge energy consumption required to heating system, it represent until 63% of non-renewable energy (NRE) and 51% of global warming potential (GWP).

4. Targeted objectives for the conceptual vision

Regarding the analysis and the significant points mentioned above, the following targeted objectives are formulated for the development of the “On STAGE project”, an alternative structure of the usual practice:

- Flexibility is the first objective. The project has to be able to offer adequate advantages for the current practice. Constructive modalities by elements, which have to offer an **important level of modularity**. The assembly of the whole or of parts of the systems must be possible, in order to adjust the size and comfort of the structure.
- Comfort optimization of the planned structure must permit the users the optimal management of the thermal and acoustic comfort. The objective is **to keep the inner climate in a comfortable zone**, which is the same condition as outside and the occupancy rate [7].
- For an **optimal use of resources** the project will include architectural bioclimatic principles, especially regarding the thermal insulation, protection from the sun, natural ventilation and passive refection, which allow the reduction of its energetic demand (warmth and cold) and the prior valorisation of resources that are locally disposable [8].
- The project aims at establishing a basis of a concept of **efficient economic exploitation** of the structure. By rationalizing the process, the project has to reach an economic feasibility for the operator. The project aims at establishing bases of a financially balanced concept, regarding its lifecycle including an optimization of production costs and exploitation [9].
- The concept and the realization of the new infrastructure, likewise temporary and permanent, will include a **special care for the architectural expression**. The system will be well conceived in a way that it will contribute to the expression of a spatial coherence and offer a harmonic integration of the object in the different contexts where it will finally take place.

5. From prime conceptual vision to operational prototype

Subsequent to the definition of the objectives of the project, a conceptual vision has been developed in order to set the basis of the constructive system and to specify the components that have to be developed in detail regarding the specific objectives mentioned. This conceptual vision is the basis of an iterative process of integrated design in the course of which the interdisciplinary competences of the different partners of the project (civil engineers, experts for thermal and acoustic, carpenters, specialists for photovoltaic and operators) have to optimize the conceptual vision in terms of the objectives stated. A development of solutions and complex systems based on several overlapping effects and integration with overall architectural design [1].

5.1. Bioclimatic strategies and inner climate control

The scheme of figure 5 shows the planned principle for the management of overheating situation at daytime. To avoid overheating due to the solar radiation during the day combine with internal heat gains by the users, the

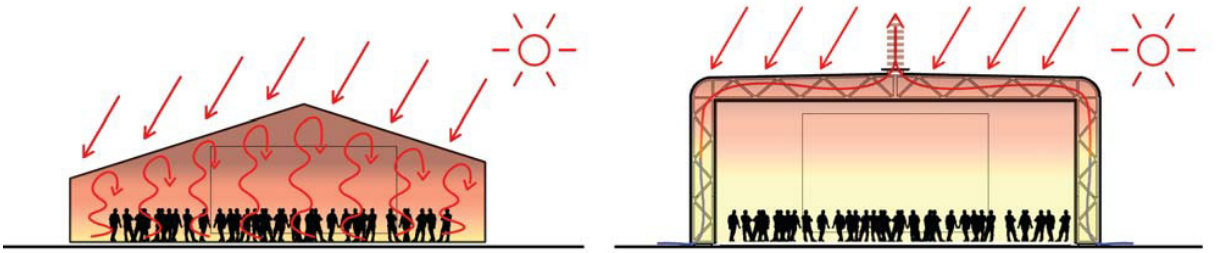


Fig. 5. Principles of bioclimatic architecture applied to the project "On STAGE" in response to the limits of comfort and durability that characterizes current practice during sunny days.

conceptual vision include architectural bioclimatic principles, especially regarding thermal insulation, protection from the sun, natural ventilation and passive cooling which allow comfortable climate inside. The passive strategy is based on the given space between the two layers of the casing, which is used as a sealed space that helps to deflect warm air by providing a tempered layer, which contributes to the thermal insulation for inside temperature's stability even in cooler periods.

For the energy demand proportion, the integration of models working with renewable resources has been researched, especially with reference to solar energy and the production of warmth and cold. As shown on figure 6 the efficiency of temporary heating oil devices is actually very bad, due of the light structure and a poor insulation the energy is very quickly dispersed. To control the inner climate the project proposes to use thermal heat pump as energy production and to mechanically ventilate warm and cold air inside the concert hall. To compensate the energy demand proportion, a solar roof skin including moveable photovoltaic cells produces renewable energy.

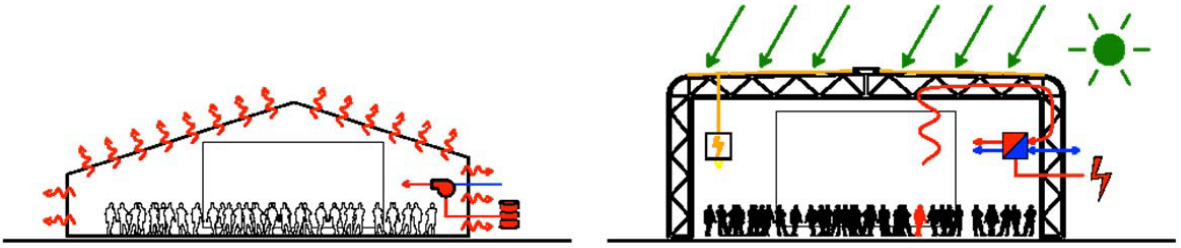


Fig. 6. The efficiency of temporary heating oil devices is actually very bad, the energy is very quickly dispersed. The project uses thermal heat pump as energy production and a mechanical ventilation to control inner climate. To compensate the energy demand proportion, a solar roof skin including moveable photovoltaic cells produces renewable energy.

5.2. Inner acoustic quality and noise transmission

Regarding the acoustic and as illustrates on figure 7, the additional mass that is filled inside the acoustic panels will help to control the acoustic of the room better, especially in term of low frequencies. The double side acoustic panels (smooth and absorbent) avoid flexible inside skin configuration for an optimal acoustic diffusion according to size and need of use (concert, theater, conference, cinema…)

For the reduction of the noise toward outside and inside and according to the law of mass action, the project proposes to add an acoustic skin of 10 kilograms per square meters to reduce sound emissions towards the envelop up to 25 dB. It may therefore benefit from a certain tolerance from the neighborhood, and increase opportunities for implementation on most sites [10].

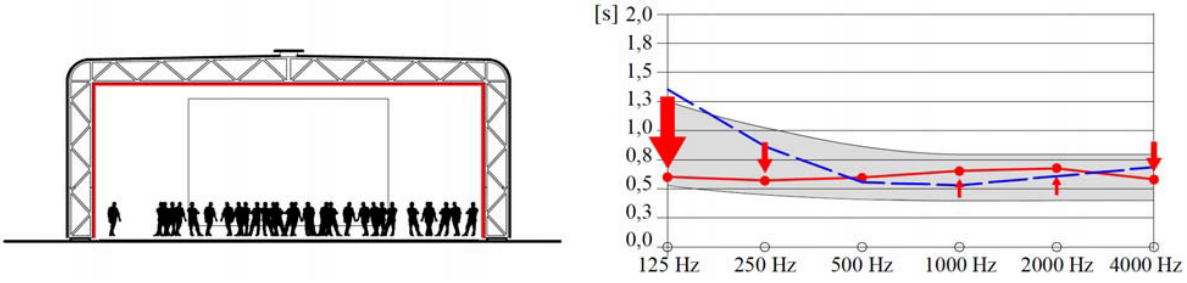


Fig. 7. The additional mass that is filled inside the acoustic panels will help to control the acoustic of the room better. The double side (smooth and absorbent) acoustic panels allow the flexibility to optimize the acoustic quality of the concert hall.

5.3. Reduction of non renewable energy consumption and environmental impacts

After reducing the needs of energy through bioclimatic strategies, as described above, it should fill the remaining energy needs with production of heat and cold that privileges renewable energy. To do so the project implements a concept of comfort ventilation with heat recovery, coupled to a battery (hot-cold) powered by an air heat pump. A device tested in the field of sustainable buildings, but which appears as a pioneer experience in the field of temporary constructions. Finally, the implementation of photovoltaic panels integrated into the roof structure (rigid / flexible technologies) also allows offsetting some of the electricity needs with renewable source of energy, which is directly available on the site. The graph in Figure 8 illustrate that a significant reduction of energy needs is possible. An optimization that is the result from the reduction of needs, the abandonment of oil as energy source and renewable energy output produced by the structure through the integration of photovoltaic cells in its outer envelope.

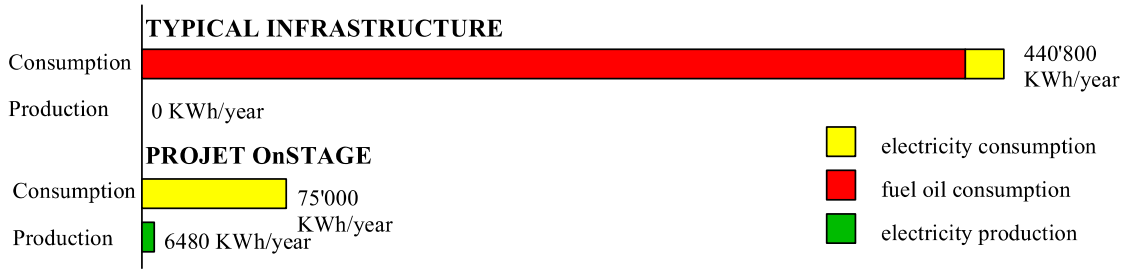


Fig. 8. The additional mass that is filled inside the acoustic panels will help to control the acoustic of the room better. The double side (smooth and absorbent) acoustic panels allow the flexibility to optimize the acoustic quality of the concert hall.

Along with these measures at the operating energy demonstration project "On STAGE" is also characterized by a significant reduction in embodied energy and emissions of carbon dioxide. A guidance and estimated the graph shown in Figure 9 shows a comparison of the overall balance in terms of non-renewable primary energy (NRE), and CO2 equivalent emissions (GWP). Reduction between the conventional system and the demonstration project "On STAGE" is of the order of 60% for primary non-renewable energy (NRE) and 40 % for CO2 equivalent emissions (GWP) [6].

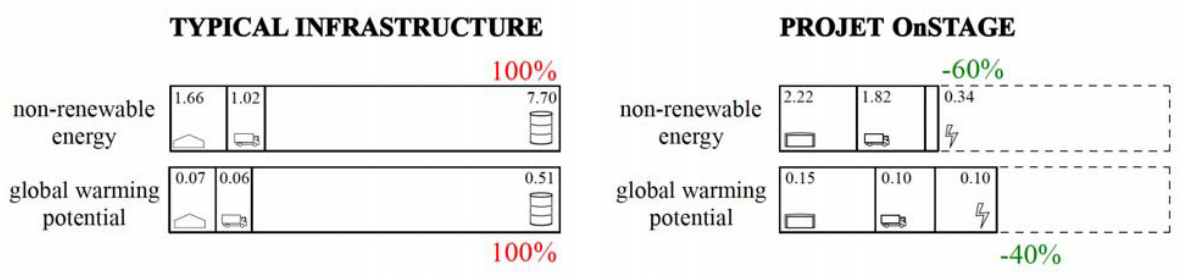


Fig. 9. Comparing the estimated overall record non-renewable primary energy terms (NRE) and CO2 equivalent emissions (GWP) for the conventional device and the project "On STAGE".

5.4. Constructive approach

As shown in figure 10 below, the structure is composed triangulated frames, compounds of wooden elements, prefabricated in the workshop and assembled on site [11]. On this structure, an inner casing is fixed consisting of wooden panels by means of which the mass is reduced in order to facilitate the operation, but sufficient to comply with the acoustic requirements and to offer a certain thermal insulation. Finally, an outer casing in form of a sheer cloth including a photovoltaic moveable system on the roof completes the model. As shown above, the assembly of this double casing allows the reduction of the amplitude of variations in temperature and the optimization of controlling the internal climate by allowing at the same time the reduction of further energy input. The modularity of the project is based on a small number of pieces which can be combined for different sizes with variables of quality level: SMLXL *,**,***. It means that, by its structural and constructive configuration, the project "On STAGE" offers a dual flexibility. Several dimensions are possible, based on the modular frame of 2.40 m (fixed width, variable length), and it is possible to adapt the standard for more simple uses by limiting the mounting structure (with or without liners, with or without floor).

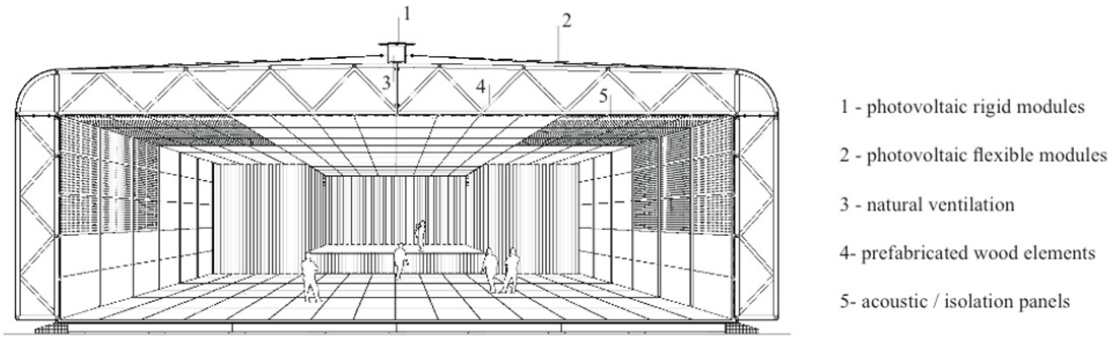


Fig. 10. Perspective cross-section. The project uses the space between the two layers of the casing as a sealed space assisting the bioclimatic control of comfort,

6. Prospects

Following this integrated design process it is possible to dispose of an operational prototype, for which feasibility is verified and demonstrated. The next phase of the project is to go deep each element imagined conceptual and technical level to achieve complete constructive study, establish plans prefabrication and finally build the structure, which takes value of first sustainable alternative in term of ephemeral event structures.

In the field of event-structures and linked professional constructors, the project appears as a breakthrough achievement that offers a real alternative to the current practice. By the way, such a realization has some interest and should thus contribute to the evolution of common practices. The project "On STAGE" will have also impact the general public and the awareness of energy issues. Indeed, the project will be the main area of concerts for the Cully Jazz Festival 2015. An annual event that hold on an history of over thirty years and an established reputation. Nine-day event bringing together many artists with greats name of jazz and about 50,000 visitors. The project "On STAGE" and the results obtained in terms of reduction of environmental impacts will be integrated into the communication strategy of the festival and thus benefit from its particularly important media coverage.

Fig. 11. Night view of the project "On STAGE" mounted on the site of the Place d'Armes in Cully (VD).

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