

# Achieving Building Sustainability: A Whole Life-cycle Assessment of Exhibition Buildings



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## Summary

Much attention has been paid to research into and development of sustainable technologies for building construction. Some experimental sustainable buildings, such as the Dutch Pavilion for Hanover Expo 2000, have been seen as feasible solutions that address current environmental issues. However, there is the question of whether this kind of architecture with its “sustainable design” does or does not achieve ecological sustainability in terms of its whole life cycle.

This paper makes a first attempt at quantifying and estimating the energy consumption of a case study sustainable exhibition building (the Dutch Pavilion for the EXPO 2000) over its whole life cycle. The initial, recurring embodied energy and operating energy is analysed. The results are compared with the average energy use of a more conventional exhibition building through the construction, maintenance and operating phases. Owing to the high maintenance cost and impractical design for function of the Dutch Pavilion, the results of the research show that the energy intensity of the recurring embodied energy of the building is higher than that of the conventional building which was not designed to be sustainable.

**Keywords:** Sustainability, Dutch Pavilion, Embodied energy, Operating energy, Whole life cycle energy analysis

# 1. Introduction

In recent decades much attention has been paid to research into and development of sustainable technologies for building construction. These technologies mostly focus on the embodied energy and toxicity of materials, operational energy efficiency, passive design and the utilisation of building-integrated renewable energy systems. As a result, some experimental sustainable buildings, such as the Dutch Pavilion for Hanover Expo 2000, have been seen as feasible solutions that address current environmental issues. Such buildings are designed and constructed using relevant sustainable technologies to meet goals such as low energy and water consumption. Meanwhile, the construction of some buildings has indirectly enhanced local development and generated significant economic benefits for the local communities and this also has environmental impacts. From these buildings, it seems, therefore, that researchers and designers have explored appropriate technologies in terms of keeping a balanced relationship between the environment and development. However, there is the question of whether this kind of architecture with its “sustainable design” does or does not achieve ecological sustainability in terms of its whole life cycle.

To be complete whole life-cycle research on the environmental impact of exhibition buildings should be focused not only on the impact of the buildings themselves, but also on the exhibition-related economic effect and the visitor travel effect. Both the latter will also have an effect on the natural environment in terms of resource consumption. For example, earlier research into a typical exhibition building (the Shanghai Exhibition Centre) shows that energy usage for travel by each visitor is higher than the operating energy and the unit embodied energy, apportioned to each user, (based on a life of 50 years). However, the environmental impact from the exhibition-related stimulus to the economy is larger than that from visitor travel [1, 2]. Normally these associated exhibition-environmental impacts are ignored and the focus is on the building. As most international exhibitions generate a considerable boost to local industry, the construction of exhibition-related architecture needs to be assessed for the impact of these economic related aspects on the natural environment. This is the wide study of which this paper, with its focus on the impact of exhibition building life, is just a part.

This paper as a part of this whole life-cycle exhibition-related environmental study discusses the energy intensities of a claimed sustainable exhibition building, the Dutch Pavilion, using the Life Cycle Assessment method. The exhibition-related economic effect for The Netherlands from the Dutch Pavilion at Expo 2000 in Germany was extremely positive. A survey showed the Dutch Pavilion was one of the favourite pavilions attracting 2.7 million visitors [3], or 9% of all visitors to the Expo [4]. The study estimated € 350 million in revenue was generated for the Dutch economy from the Dutch Pavilion at Expo 2000 [4]. Since the total revenue of The Netherlands in 2000 was € 173 billion, the Expo revenue accounted for approximately 0.2% of total national revenue. This can be compared with the fact that, generally, revenue from the whole exhibition industry in the developed countries is about 0.2% of total every year. This shows that The Netherlands gained significant economic profit from this exhibition.

However, this paper is concerned with another aspect of the Dutch Pavilion its relatively short life of less than a year. The life of a building has a significant impact on its overall life cycle environmental impact. The Dutch pavilion was designed to be sold and reused but this did not happen. This paper therefore explores the actual environmental impact of the Dutch Pavilion with its short useful life and also what might have happened had the building been sold and its life extended to a more normal 50 years. The results are then further compared with another exhibition building, the Shanghai Exhibition Building, which has had a comparable life of just over 50 years but that was not designed to be sustainable.

## 2. Life Cycle Assessment

The Dutch Pavilion was designed as the exhibition hall of The Netherlands for World Expo 2000 in Germany by MVRDV. It mixed natural elements (agriculture (flowers), container gardens, forest, rain and sand dunes) and exhibition activities in a six storey building. The design concept followed

the EXPO 2000 theme of Humanity – Nature – Technique. The building was designed to be low energy, had low water use and had wind turbines on the roof to generate electricity. The total construction area of this building was approximately 6,144 m<sup>2</sup> (each floor has an area of 1,024 m<sup>2</sup>). The building has a hybrid steel – concrete structure, although concrete was the main structural material.

A Life Cycle Assessment (LCA) has been undertaken based on the relative energy data of the case study building, the Dutch Pavilion. The quantification of construction materials and energy use generally includes the estimation of embodied energy (initial and recurring), operating energy and demolition-related energy use. In this paper, embodied energy, operating energy and building life are considered and discussed, because these factors are the main influences on the whole life-cycle energy consumption of the building [5, 6, 7].

## 2.1 Embodied energy

Embodied energy is defined as “the total energy used to create a product including all the processes involved in harvesting, production, transportation and construction” [8]. The quantification of the embodied energy of buildings is to demonstrate the total energy used for the whole manufacturing process. As discussed above, the assessment of embodied energy in this case study building mainly includes the initial and recurring energy consumed by the building construction and maintenance. The recurring energy appears when a 50 year life is assumed for the Dutch Pavilion in order to look at the effect of short building life in a whole life-cycle assessment.

### 2.1.1 Initial embodied energy

The calculation of the initial embodied energy of the case study building uses the quantities of materials (volume, weight) and the relevant energy intensities as found in German data. Relevant parameters, such as the size or weight of components and structural elements, are sourced from the literature about the building [9, 10, 11]. A list of the quantities of construction materials and drawings of building floor plans were prepared and used for quantitative calculations in this research.

The energy intensities of materials used for the calculation of the embodied energy mainly come from German data [12, 13, 14], because the construction of the Dutch Pavilion was based on local German building technology. In addition, owing to the lack of referenced energy intensities for some materials, UK data [15] were also used in the quantification of energy used in making the case study building.

*Table 1 Embodied energy coefficient of the selected materials between different countries*

	Australia (MJ/kg) [16]	New Zealand (MJ/kg) [17]	UK (MJ/kg) [15]	Germany (MJ/kg) [12]
Kiln dried sawn softwood	3.4	2.5	1.6	1.49
Particleboard	8	8	9.5	5.71
MDF	11.3	11.9	11	10.52
Gypsum plaster	2.9	4.5	1.8	2.47
Plasterboard	4.4	6.1	6.78	3.39~8.5
Fibre cement	4.8	9.5	10.9	5.3
Cement	5.6	7.8	4.6	4.4
Precast steam-cured concrete	2.0	2.0	2.0	2.54
Clay bricks	2.5	0.07	3	2.22
Concrete blocks	1.5	0.94	0.6 (8MPa)	0.6~0.76
Glass	12.7	15.9	15	15

The reason for using UK data is because the UK energy intensity factor is similar to that of Germany [12, 15]. Table 1 shows the embodied energy coefficient of the selected materials using UK and German data. Further comparisons are given with Australian and New Zealand data. These show the match between UK and German data is reasonable.

Moreover, as a result of the special sustainable design approach of the Dutch Pavilion, the impact of the energy embodied in the building services needs to be considered separately from the quantification of other building elements in the calculation. The detailed data for

*Table 2 Initial embodied energy of six wind turbines*

Materials	Weight (kg) [18]	Factors (MJ/kg) [12-15]	Embodied energy (MJ)
Steel	6,643	15	99,645
Cast iron	600	25	15,000
Glass reinforced plastic (76% of glass fibres, 24% of epoxy resin)	495	100	49,500
Copper	92	50	4,600
Paint	39	68	2,652
Aluminium	9	155	1,395
PVC	7	77.2	540.4
Bronze	0.5	77	39
Total initial embodied energy: 173,371 MJ			

*Table 3 Initial embodied energy of green roof and roof pond*

	Materials	Weight (kg)	Factors (MJ/kg) [12-15]	Embodied energy (MJ)
Green roof	Waterproofing PVC	138	77.2	10654
	Asphalt (Waterproofing layer)	25000	2.6	65000
	Mineral wool (Insulation)	50	5	250
	PVC (Drainage layer)	138	77.2	10653
	PVC (Substrate)	138	77.2	10653
Roof pond	Reinforcement concrete (Structure)	512500	2.54	1301750
	Mineral wool (Thermal insulation layer)	620	5	3100
	Asphalt (Waterproof layer)	30000	2.6	78000

building services used in each floor is unknown. An average proportion (20%) of the embodied energy is applied to the six levels in the calculation due to the variety of service systems in the case study building. The reason for using the average energy intensity to calculate the embodied energy of building services is because on the water and windmill floors, the application of technologies such as the water pond and water reclamation systems, involves a greater level of energy for producing the equipment. On the other hand, the other floors (the forest floor, dunes floor, pot floor and glass floor) have less energy embodied in the manufacture of the services systems, because of using natural ventilation. The average energy intensity is used for the calculation to balance the two levels of energy use.

Cole concludes that the total initial embodied energy used in the building services for a general concrete office building (no underground parking) accounts for 24.5% of the total energy embodied in all the materials [19]. Treloar states the building services represent 19% of the embodied energy of a commercial building in Melbourne [20]. Pullen used 20% when calculating the embodied energy of building services for a campus building in Australia in 2000 [21]. Thus, a

proportion of 20% of the total embodied energy of the building is used in this research.

Special sustainable design features of the Dutch Pavilion were the installation of wind turbines on its top floor and its green roof. The total materials utilised during the wind generator manufacturing are steel, cast iron, glass reinforced plastic, copper, paints, lubricant oils, aluminium, PVC, bronze [18]. The initial embodied energy of wind turbines (six on the building) is quantified by using the weight and energy coefficients of the different materials (Table 2). In addition, detailed information on the green roof and roof pond are taken from the literature [22, 23, 24], and used to quantify their initial embodied energy (Table 3).

### 2.1.2 Recurring embodied energy

Recurring embodied energy is defined as the energy required for repairs, maintenance, and refurbishment of buildings in their useful life. The Dutch pavilion had a useful life of only 6 months although it was designed for a longer life. To reveal the impact of creating exhibition buildings that are not recycled a comparison is made here between the actual life of the building and an assumed life of 50 years (2000-2050) in the calculation of energy use for maintenance and replacement. The 50 year was taken because the pavilion was comparable in structure and construction to a normal commercial building. Energy consumption for maintenance and replacement of construction materials is quantified according to the useful life of different construction materials in Germany. The method of calculation for recurring embodied energy is the same as that for initial embodied energy.

*Table 4 Recurring embodied energy of six wind turbines*

	Embodied energy (MJ)	Useful life (years)	Recurring embodied energy (MJ)
Wind turbines	4,038,048	20	8,076,096
Transportation of personnel undertaking inspection	317,100 (45.3 MJ/kg)	20	792,750
Maintenance spare parts	605,707 (15% of embodied energy of wind turbines)	20	1,514,268
Total recurring embodied energy: 10,383,114 MJ			

The analysis shows the energy consumed by maintenance of the six wind turbines (Table 4) on the top floor is much more than for the other construction elements or materials. Ardente *et al* demonstrate that usually the useful life of a wind farm is 20 years, which means most of the wind turbines will be replaced in this period. In their investigation the electrical company concerned had specific scheduled maintenance and control cycles. These involved a daily inspection during the first operation period and, successively, one inspection every 2 ~ 3 weeks. If the inspection personnel choose to use

diesel cars the overall energy consumption for related transportation would be about 7,000 kg of diesel during the 20 years of useful life. Cycles of ordinary maintenance occur 2 ~ 3 times per year, and these involve lubrication, painting and substitution of necessary spare parts [18].

## 2.2 Operating energy

The operating energy is defined as the energy used for a building in its operation phase, such as the electricity consumption for lighting, cooling and ventilation. As the case study building has a special construction and different functions for each floor, the operating energy (mainly electricity) is not as much as found in conventional commercial buildings. In addition the electricity consumption of the whole building is less because some electricity comes from the wind turbines on the roof.

The steel tower of a wind turbine with nominal power rating of 660 kW as found in Ardente's study was 55m high and the rotor diameter was about 50m [18]. However, the output from the six windmills around 15m high and with a 5m rotor diameter as installed on the Dutch Pavilion will be small compared to the demands of the whole building. It can be assumed that the generation of a small windmill of this type (10 kW) is around 10,000kWh/year [25], making the total amount of energy generated 60,000kWh/year. The distance between two small turbines for maximum effectiveness is usually 20 ~ 30m [26, 27]. However, the distance between the small wind turbines installed on the Dutch Pavilion is less than 15m. This will reduce the generating capacity of the turbines [22]. Overall, the total maximum possible electricity production of the windmills of the Dutch Pavilion is 20,000 ~30,000 kWh per year, but this is assumed to be halved because of their less than optimal installation. In a UK study [31] building mounted wind turbines were found to be far less effective than predicted.

The operating energy for each level is significantly different due to the different functions. The office level is assumed to be the level with the highest energy consumption. There are no heating, cooling and ventilation systems in some levels, such as the forest floor and dunes floor, which are built as covered external open space. Because of the complex operational performance and use of strategies such as natural ventilation, the case study building has been assumed to act overall as an efficient office building in terms of its energy use. Generally a conventional air-conditioned office uses 200 ~ 400kWh/m<sup>2</sup>/year [28]. In this paper, the energy intensity of the office floor and windmill floor (VIP room), which have installed heating, cooling, ventilation and lighting systems, is assumed to be 300kWh/m<sup>2</sup>/year. Moreover, about 30kWh/m<sup>2</sup>/year is used for lighting for a typical German house [29]. In the absence of better data, this value has been used for the lighting intensity of the floors without HVAC installed. The operating energy of each floor is found by multiplying the floor area and the appropriate value for electricity usage per square metre.

## 3. Energy analysis

### 3.1 Embodied energy

The quantitative results of energy usage for the case study building, the Dutch Pavilion, in its construction and maintenance phases (assuming a 50 year life) are shown in Table 5.

*Table 5 Quantification of initial and recurring embodied energy of the Dutch Pavilion (assumed 50 year life)*

Floor	Initial embodied energy (GJ)	Percentage (%)	Recurring embodied energy (GJ)	Percentage (%)
Offices floor (Ground floor)	14,508	22.3	5,746	24.0
Dunes floor (First floor)	15,451	23.7	0.023	0
Glass floor (Second floor)	1,908	2.9	1	0
Pots floor (Third floor)	3,719	5.7	11	0.5
Forest floor (Fourth floor)	1,996	3.1	318	1.3
Rain floor (Fifth floor)	5,422	8.3	10	0.4
Windmill floor (Sixth floor)	2,869	4.4	420	1.8
Vertical circulation	1,523	2.3	220	0.9
Building services	13,763	21.1	6,881	28.7
Wind turbines and relevant equipment	4,038	6.2	10,383	43.3
Total	65,196 GJ (10.6 GJ/m <sup>2</sup> )	100	23,990GJ (3.9 GJ/m <sup>2</sup> )	100
Total embodied energy	89,186 GJ (14.5 GJ/m <sup>2</sup> ) (0.3 GJ/m <sup>2</sup> /year)			

*Table 6 Quantification of operating energy for each floor of the Dutch Pavilion (assumed 50 year life)*

Floor	Building services	Energy intensity (kWh/m <sup>2</sup> /year)	Operating energy (50 year) (kWh)
Offices floor (Ground floor)	Heating, Cooling, Ventilation, Lighting	300	15,360,000
Dunes floor ( First floor)	Lighting	30	1,536,000
Glass floor (Second floor)	Lighting	30	1,536,000
Pots floor (Third floor)	Lighting	30	1,536,000
Forest floor (Fourth floor)	Lighting	30	1,536,000
Rain floor (Fifth floor)	Lighting	30	1,536,000
Windmill floor ( Sixth floor )	Heating, Cooling, Ventilation, Lighting	300	135,000
Total	23,175,000 kWh (=83,430 GJ)		

The initial embodied energy is estimated to be 65,196 GJ or 10.6 GJ/m<sup>2</sup>. In detail, the office floor (22.3%), dunes floor (23.7%) and building services (21.1%) of the case study building account for the main proportion of the total energy usage (more than 60%) because most of energy is consumed in the production of the concrete (the main structural elements of the dunes floor are concrete).

Because the building was only used for six months in fact its total recurring embodied energy was zero. If the building were to be used over a life of 50 years, the total operating energy is estimated at 23,990 GJ or 3.9 GJ/m<sup>2</sup>. The percentage of the energy used to maintain the wind turbines (43.4%), building services (28.7%) and office level (24%) makes 95% of the total. It seems that the main energy for maintenance is consumed by the turbines.

The total embodied energy of the Dutch Pavilion, thus, is 65,196 GJ for its actual six month life or 89,186 GJ over the assumed 50 years.

### 3.2 Operating energy

Over the actual life of six months the total operating energy of the Dutch Pavilion was 620 GJ, made up of an energy consumption of 695 GJ and 75 GJ generated by wind turbines.

If the operating energy is determined by the electricity usage of the building over the assumed 50 year life, the total operating energy of the Dutch Pavilion is 74,430 GJ, which is equal to 1.0 GJ/m<sup>2</sup>/year. The result includes the energy consumption of the building operation (83,430 GJ) and energy generation (9,000 GJ) by the wind turbines over 50 years. Table 6 shows the energy consumed by the building in its operation phase for the assumed 50 year life.

## 4. Whole life cycle energy analysis

The total energy consumption of the Dutch Pavilion over its actual six month life, including embodied and operating energy, is calculated to be 65,817 GJ. Effectively, this makes the building unsustainable because this investment in energy is thrown away at the end of the exhibition. In order to make a more reasonable comparison of the impact of the sustainable strategies, it is assumed that this building is used for 50 years, which is similar to general commercial buildings.

The whole life-cycle energy consumption of the case study building used over 50 year is 163,616 GJ or 1.3 GJ/m<sup>2</sup>/year. Operating energy is 1.0 GJ/m<sup>2</sup>/year and the average embodied energy is 0.3 GJ/m<sup>2</sup>/year (Table 7).

*Table 7 Total energy consumption of the Dutch Pavilion (50 years)*

	Dutch Pavilion (2000-2050)	Percent age (%)
Initial embodied energy	10.6 GJ/ m <sup>2</sup> (65,196 GJ)	39.8
Recurring embodied energy	3.9 GJ/ m <sup>2</sup> (23,990 GJ)	14.7
Total embodied energy	89,186 GJ	
Average embodied energy	14.5 GJ/m <sup>2</sup> (0.3 GJ/m <sup>2</sup> /year)	
Operating energy	74,430 GJ	45.5
Average operating energy	1.0 GJ/m <sup>2</sup> /year	
Demolition	Negligible	0
Total energy consumption	1.3 GJ/m <sup>2</sup> /year (163,616 GJ)	

These results show that it is uncertain that mixing natural elements, such as plants, in a building and using renewable energy can protect the natural environment. For example, Arden et al state that the exploitation and utilisation of wind energy (a renewable energy) for electricity generation has become one of the most diffused technologies in Europe. These renewable energy sources are mainly presented as “clean” energy [18]. However, “clean” is here defined relative to fossil fuel conversion to energy. When the energy consumption

and the environmental impacts of fuels are assessed over their whole life, the “cleaner” energy sources, together with their relative technologies, need to be reconsidered for true sustainability, especially in their manufacture and maintenance phases [30], as demonstrated by the analysis of the wind turbines on the Dutch pavilion in this research.

The main problem in the overall energy consumption of the Dutch Pavilion is the energy consumed in maintaining the products related to sustainable technologies, such as the wind turbines, as this is much higher than for other construction elements. In this case study, if the building uses its wind turbines for 50 years, the recurring embodied energy would be 10,383 GJ (208 GJ/year). However, the energy generated by the windmills would be just 9,000 GJ, which is lower than the energy embodied in the turbines. Moreover, the percentage of energy used for maintaining the wind turbines accounts for 11.4% of the total embodied energy of the Dutch Pavilion. It means that producing and maintaining the wind turbines over 50 years is the equivalent of constructing several floors of a commercial building in Germany. Owing to this high maintenance cost and perhaps the impractical design for function of the Dutch Pavilion, the building was not reused after the exposition.

*Table 8 Comparison of energy intensity between two modern exhibition buildings*

	Shanghai Exhibition Centre (1955-2005) [1, 2]	Dutch Pavilion (2000-2050)
Initial embodied energy	11.1 GJ/m <sup>2</sup>	10.6 GJ/ m <sup>2</sup>
Recurring embodied energy	1.9 GJ/m <sup>2</sup>	3.9 GJ/ m <sup>2</sup>
Average embodied energy	13 GJ/m <sup>2</sup> (0.26 GJ/m <sup>2</sup> /year)	14.5 GJ/m <sup>2</sup> (0.3 GJ/m <sup>2</sup> /year)
Average operating energy	0.89 GJ/m <sup>2</sup> /year	1.0 GJ/m <sup>2</sup> /year
Total energy consumption	1.15 GJ/m <sup>2</sup> /year	1.3 GJ/m <sup>2</sup> /year

In addition, comparing the average energy intensity of the sustainable building (the Dutch Pavilion) and an ordinary exhibition building (the Shanghai Exhibition Centre), the average embodied energy per square metre of the former (14.5 GJ/m<sup>2</sup>) is similar to that of the latter over a 50 year useful life. The Shanghai Exhibition Centre is chosen for this comparison because it is a conventional exhibition building with a concrete structure like the Dutch Pavilion, and it has had a 50 year+

useful life. Although the Shanghai Exhibition Centre has a heavy structure, which causes the higher average initial embodied energy, the overall unit energy intensity embodied in the materials is still lower than that of the 'sustainable' Dutch Pavilion (Table 8). Most of the recurring embodied energy in the Dutch Pavilion is used for maintaining the wind turbines and relevant equipment, these being one of its sustainability features. Moreover, the overall operating energy of the case study building (1.0 GJ/m<sup>2</sup>/year) has not been reduced when compared with that of the Shanghai Exhibition Centre with its conventional HVAC and lighting systems (0.89 GJ/m<sup>2</sup>/year [2]).

Furthermore, nearly half of the exhibition space of the Dutch Pavilion is external exhibition area (42.7%), which cannot be represented as the equivalent in operating energy terms of an enclosed building, like the Shanghai Exhibition Centre. If only the indoor exhibition space of the Dutch Pavilion is apportioned to the building life-cycle energy over an assumed 50 years, the equivalent operating energy of the Dutch Pavilion would be increased to 2.0 GJ/ m<sup>2</sup>/year.

*Table 9 Energy consumption of the Dutch Pavilion and Shanghai Exhibition Centre (6 months)*

	Shanghai Exhibition Centre (MJ/m <sup>2</sup> /month)	Percentage	Dutch Pavilion (MJ/m <sup>2</sup> /month)	Percentage
Initial embodied energy	111	60%	106	56%
Recurring embodied energy	0	0%	0	0%
Operating energy	74	40%	83	44%
Total energy consumption	185	-	189	-

Table 9 shows the energy consumption per month for the two compared buildings under the assumption that they were both used for six months, which was the case of the Dutch Pavilion.

Table 9 demonstrates that the total energy consumption of the Shanghai Exhibition Centre is 185 MJ/m<sup>2</sup> per month and that of the Dutch Pavilion is higher at 189 MJ/m<sup>2</sup>/month. The figure shows that the design of the Dutch Pavilion in reality does not reach the goal of sustainability even over its actual useful life.

## 5. Conclusions

This paper makes a first attempt at quantifying and estimating the energy consumption of a case study sustainable exhibition building (the Dutch Pavilion) over its whole life cycle. The results are compared with the average energy use of a more conventional exhibition building through the construction, maintenance and operating phases. Owing to the high maintenance cost and impractical design for function of the Dutch Pavilion, the results of the research show that the energy intensity of the recurring embodied energy of the building is higher than that of the conventional building which was not designed to be sustainable.

This research raises questions about the range of environmental assessments for sustainable buildings. Generally, the operating energy of buildings is given more attention in the design phase by architects and researchers, owing to the fact that the energy consumption of conventional buildings in the operating phase is obviously higher than embodied energy. This study shows that sometimes making a sustainable building can have unexpected results. In this case the energy associated with the upkeep of the wind generators proved to be very high because they were not positioned optimally on the building. More importantly, the real useful life and practicality of reuse of an exhibition building need to be part of the sustainable design. Making a building that is easy to disassemble and move to make sure the resources that go into making an exhibition pavilion have a long and useful life maybe more important than having a building which incorporates sustainable technologies and gadgets. The fact that the Dutch Pavilion in Germany was only in use for around six months means it cannot be claimed as a sustainable building.

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