



UNITED NATION ENVIRONMENT PROGRAMME

Final Environmental  
Review of the 2010  
World Exposition  
Shanghai, China



**Published:** June 2012

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**Director of Publishing:** Nick Nuttall

**Editor:** Theodore Oben

**Distribution Manager:** Mohamed Atani

**Design & Layout:** William Orlale

**Cover Photo:** ©Shutterstock

**Produced by:** United Nations Environment Programme (UNEP)

**Printed by:** UNON Publishing Services Section, Nairobi, ISO 14001:2004 - Certified

**Distributed by:** UNEP Division of Communication and Public Information

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# Acknowledgements

Chapter

# A

Acknowledgements



## **UNEP Expert Team (Authors)**

Vivek Gilani, Co-Founder, The no2co2 Project/Founder/Managing Director, Elimate Carbon Emissions (P) Ltd.

Husayn Anwar, Senior Partner, VERDAEON (China)

## **Publication reviewed by:**

David Owen and Mia Turner

**Produced by the UNEP Division of Communications and Public Information (DCPI)**

## **With Special thanks to the following:**

**Zhijia Wang**, UNEP Special Coordinator

**Bai Guoqiang**, Vice Chief Engineer, Shanghai Environmental Protection Bureau

**Dai Jianmin**, Special Assistant to director general, Bureau of the Shanghai World Expo Coordination

**Dai Jie**, Engineer, Low-Carbon Economy Research Center, Shanghai Academy of Environmental Sciences

**Guo Jianli**, Department of Resource Conservation and Environmental Protection, Shanghai Municipal Development & Reform Commission

**Hu Dongwen**, Engineer, Low-Carbon Economy Research Center, Shanghai Academy of Environmental Sciences

**Hu Jing**, Deputy Director, Low-Carbon Economy Research Center, Shanghai Academy of Environmental Sciences

**Huang Lihua**, International Cooperation Division, Shanghai Environmental Protection Bureau

**Li Lifeng**, Engineer, Low-Carbon Economy Research Center, Shanghai Academy of Environmental Sciences

**Lin Weiqing**, Ph.D., Chief Engineer, Deputy Director, Shanghai Academy of Environmental Sciences

**Lu Weiya**, Shanghai Landscape and City Appearance Administration Bureau, Waste Management Bureau

**Lv Liyong**, Shanghai Landscape and City Appearance Administration Bureau, Forestry Bureau, Developing Planning Department

**Ma Xingfa**, Chief, Comprehensive Planning Department, Science and Technology Commission of Shanghai Municipality



**Miao Peizhen**, Vice Director, Shanghai Municipal Tourism Administration

**Ni Qianlong**, Chief, Department of Resource Conservation and Environmental Protection, Shanghai Municipal Development & Reform Commission

**Qingyan (Jacqueline) Fu**, Vice Chief Engineer, Senior Engineer, Shanghai Environment Monitoring Center

**Shi Min**, Deputy Director, International Cooperation Division, Shanghai Environmental Protection Bureau

**Sun Jian**, Deputy Director, Shanghai Environmental Protection Bureau

**Tang Jiafu**, Chief, Development Planning Department, Shanghai Landscaping and City Appearance Administration Bureau

**Tang Qinghe**, Director, Low-Carbon Economy Research Center, Shanghai Academy of Environmental Sciences

**Wei Haiping**, Professor, Deputy Chief Engineer, Shanghai Environment Monitoring Center

**Wu Chengjian**, Senior Supervisor, Technical Office, Bureau of the Shanghai World Expo Coordination

**Xia Dexiang**, Director, Shanghai Academy of Environmental Sciences

**Xu Ding**, Assistant Director, Project Management Dept., Bureau of the Shanghai World Expo Coordination

**Xu Lu**, Supervisor, Project Management Dept., Bureau of the Shanghai World Expo Coordination

**Xu Zhanguo**, Deputy Director, Comprehensive Planning Division, Shanghai Environmental Protection Bureau

**Yang Chunlin**, Chief, International Cooperation Division, Shanghai Environmental Protection Bureau

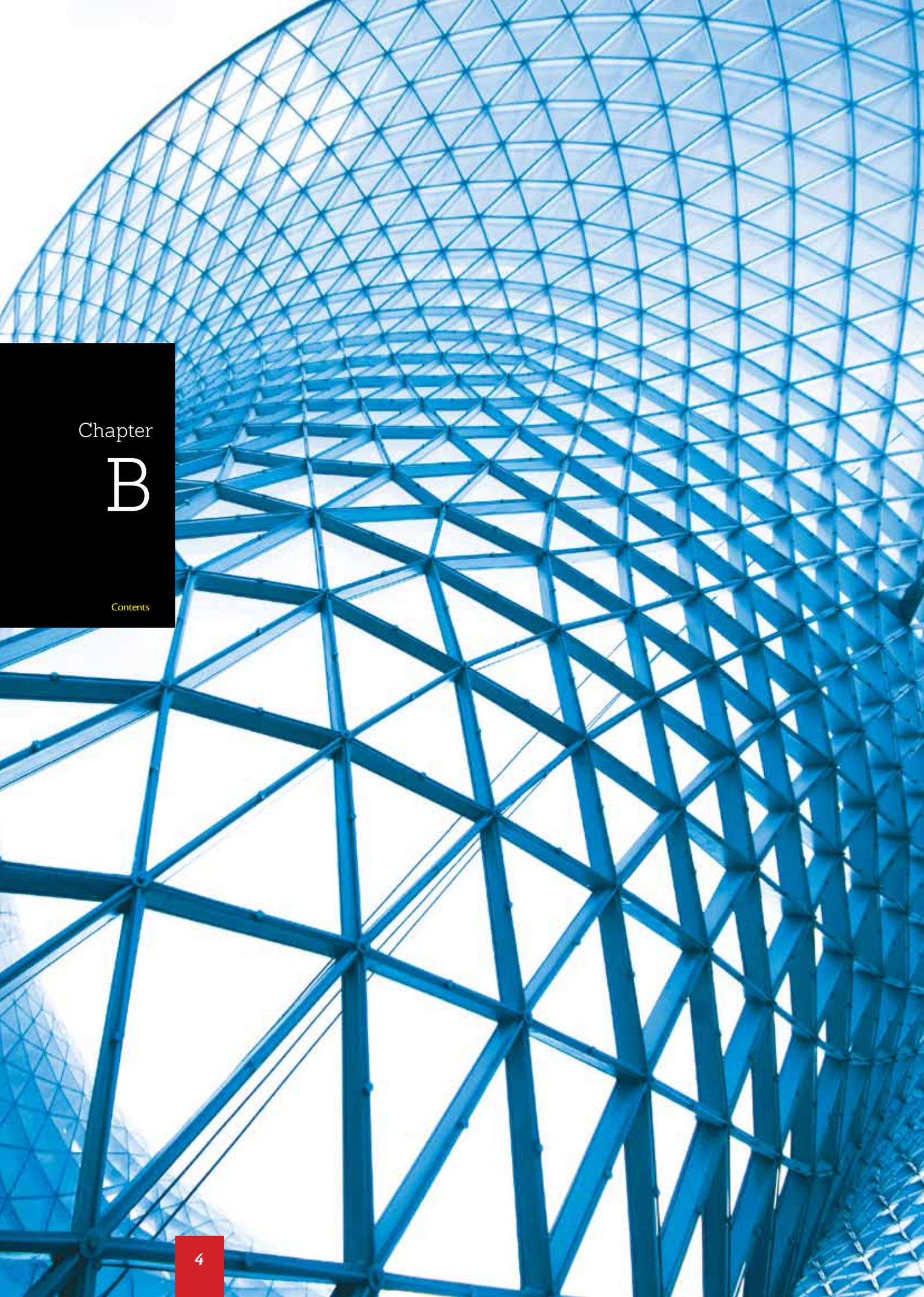
**Yu Qing**, Deputy Director, Department of Social Development, Science and Technology Commission of Shanghai Municipality

**Zhang Quan**, Director, Shanghai Environmental Protection Bureau

**Dr. Amit Garg** - Professor of Carbon Finance, Indian Institute of Management, Ahmedabad

**Jaya Chakravarty** - Director (Operations), Eliminate Carbon Emissions (P) Ltd. Co-Founder, Board Member - no2co2.in

**Savita Vijayakumar** - Director - EcoSlate.in, Board Member, no2co2.in



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# Foreword



**Achim Steiner,**

*UN Under-Secretary General  
and Executive Director, UN  
Environment Programme (UNEP)*

The 2010 World Exposition in Shanghai was staged two years after the Summer Olympic Games held in Beijing—two events that have demonstrated the increasing enthusiasm and determination of one of the world's rapidly developing economies to embrace a transition towards a low carbon, more resource efficient Green Economy.

The challenges facing Shanghai during the planning, construction and staging of the Expo were formidable including managing down air pollution and managing up improved air quality.

The experience of Beijing with the Olympics and air quality certainly assisted Shanghai in addressing this concern underlining how managers and stagers of mass events can learn from each other so that future event planners can constantly evolve sustainability aims and goals.

This assessment also underlines how Shanghai's organizers framed their activities in the context of improved urban life and quality of life for the city's citizens and visitors alike.

This is an important consideration in respect to the current and future attractiveness of a city to businesses and international corporations looking at where best to locate their operations in an increasingly competitive world.

With the theme "*Better City Better Life*" the Shanghai organizers experimented with various measures to reduce negative environmental impacts in densely populated urban areas. From the site selection, to measures to introduce green energy, public transportation and waste reduction, Expo 2010 aimed at reducing its carbon footprint--this was achieved in large part with the remaining emissions to be offset by Shanghai.

The development of the pavilions and the concept in and around Expo were also geared towards increasing environmental awareness. Indeed this assessment shows that the communications campaigns leading up to and during Expo were pivotal in increasing environmental awareness among citizens of Shanghai and the over 70 million visitors, thus leaving a positive legacy in respect to people in China and beyond.

UNEP's involvement in the Shanghai Expo and the Beijing Olympics is part of a continuum of engagement in the greening of mass spectator events and gatherings—in 2010 UNEP also participated in the FIFA 2010 World Cup in South Africa with similar aims building on experiences and lessons learnt at the FIFA 2006 World Cup in Germany and several years of involvement with the International Olympic Committee.

Such events offer an opportunity for creativity, vision and the demonstration of forward-looking environmentally-friendly technologies, policies and public participation. As the world looks forward to the Yeosu Expo and the London Olympics in 2012, this assessment of the Shanghai Expo can serve as an inspiration for organizers in the Republic of Korea and the United Kingdom alongside Russia and Brazil who will have the privilege to host the Winter Olympics and the FIFA World Cup respectively in 2014.

Chapter

C

Foreword



# Executive Summary

## Chapter

# D

### Executive Summary

This report is a review of the environmental impacts and the potential sustainability legacy of the 2010 World Exposition (Expo 2010) that took place in Shanghai, China from 1 May to 31 October 2010. It provides an objective appraisal of the environmental and social impacts of the six-month long event by examining its operations, its influences on the Shanghai Municipality and surrounding regions during this period and beyond, and its implications for similar events and in cities around the world.

The review examines the qualitative and quantitative environmental impacts of the Expo on the local and global environment, the successes achieved as well as challenges witnessed in the deployment of environmental technologies/management systems during the Expo and beyond.

Environmental Management and Communication Systems were studied for their direct and catalytic impact on a wide range of stakeholder groups. Sustainability principles incorporated in site selection, site planning and post-event use and their qualitative and quantitative impact were evaluated. Energy efficiency and renewable energy technologies along with alternative transport systems at the Expo were examined from an energy and air quality perspective.

Alternative construction materials and methods, waste management, water conservation and water recycling practices, as well as afforestation and greening projects deployed at the Expo and city-wide, through the influence of the Expo, were evaluated to gauge the direct influence on mitigating environmental impact and in the context of their potentials for mainstreaming and widespread deployment through local and national policy support. Air Quality impacts, successes and potential for improvement were studied exhaustively. Finally, the carbon impacts as well as offset measures that have been adopted to fulfil the legacy of a low carbon Expo are analyzed to the extent possible from the perspective of the carbon footprint savings and Life Cycle Analysis (LCA) impacts.

The review revealed that strategies adopted by Shanghai in the decade-long preparations for the Expo significantly improved municipal planning and management systems, including the creation of a proactive environmental monitoring system to ensure and verify improving municipal environmental quality trends.

The Expo demonstrated a model for decoupling the greenhouse gas (GHG) emission intensity of Shanghai from the city's gross domestic product (GDP). The global event served as a crucible for the application of innovative domestic and international green buildings, lighting, air conditioning and energy generation and efficient technologies to achieve significant carbon-emissions reduction.

Most of these technologies bear promise for rapid mainstreaming throughout the city and country. Practices related to waste management require rethinking in terms of communication strategies, system design and optimal capacity utilization. Widespread capacity expansion of electric and hydrogen fuel cell vehicles needs addressing in consonance with clean fuel supply chains to create a low-carbon and sustainable transport systems.

The Expo led to the creation of sizeable sustainable, energy-efficient and low-carbon infrastructure for permanent pavilions and city transport which will continue to yield environmental benefits throughout the entire products lifecycle. Exhibits and technologies deployed at the Expo have led to a clearinghouse of best-practice technology case studies, and have galvanized innovative urban planning through its catalytic impact on government planning agencies in Shanghai.

The Expo Park site selection contributed significantly to Shanghai's economic transformation, energy conservation and pollution reduction. It spawned the launch of Green Commuting and Voluntary Reduction and Offset Programme, fostered the effective communication of a carbon footprint concept to a vast majority of the Shanghai population and people of major urban centres in China.

Research centres such as Shanghai Academy of Environmental Sciences (SAES) and other local universities undertook LCA of construction and energy materials used in the Expo to ensure maximum reuse, recycling or bio-degradable disposal. The Expo became a showcase for the application of decentralized rainwater harvesting, groundwater recharge, and grey water recycling while meeting the demands of conventional urban infrastructure development.

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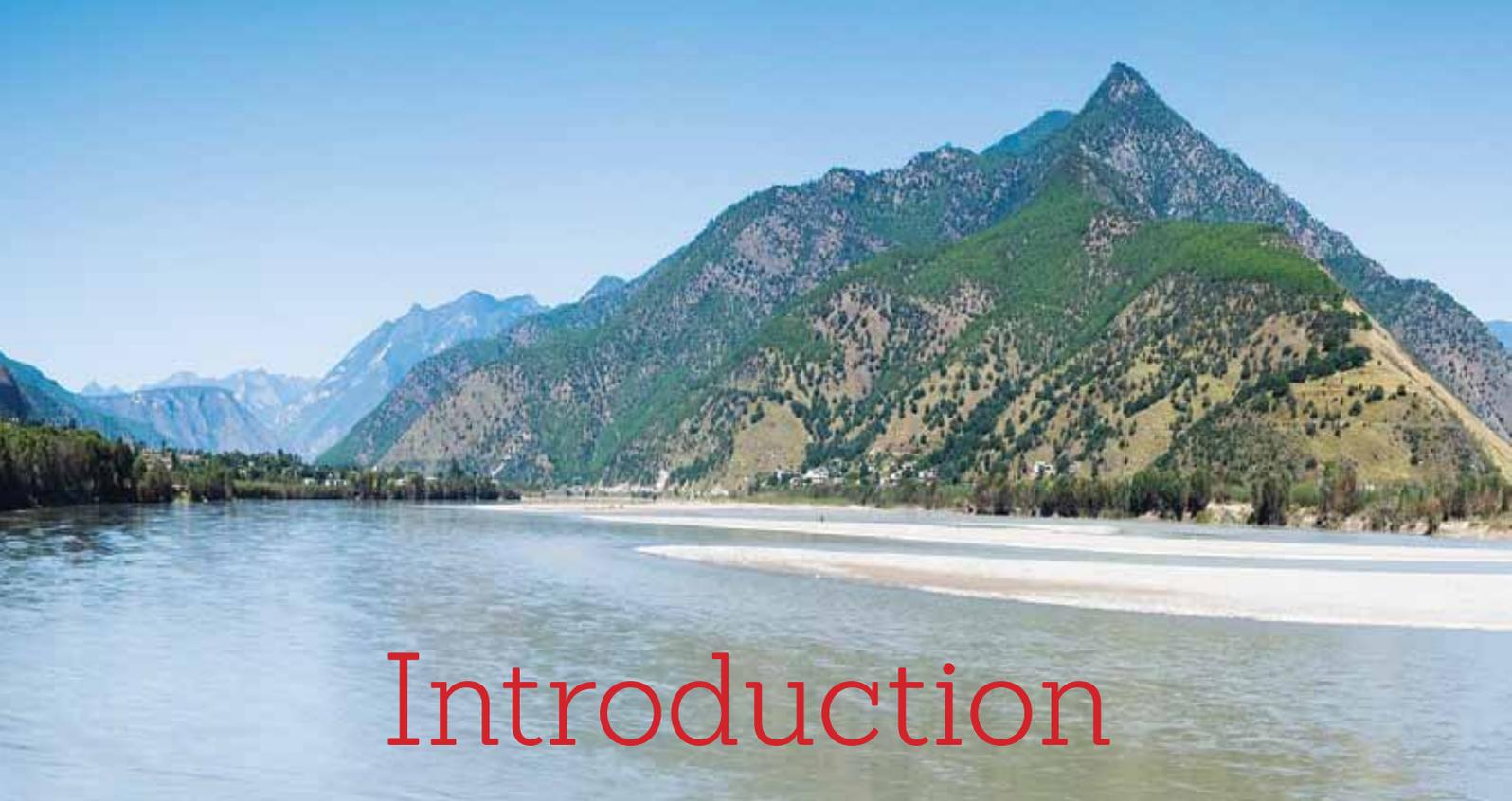
The review examines the qualitative and quantitative environmental impacts of the Expo on the local and global environment

On the Climate Change impact, the total Carbon Footprint of the Expo was estimated to be 4,922 kilotons of CO<sub>2</sub>e. A diverse range of GHG mitigation projects were planned and executed directly or indirectly related to the Expo. These projects, located outside the organizational and operational boundary of the Expo, are estimated to have mitigated 4,341 kilotons of CO<sub>2</sub>e before the close of the Expo. The balance GHG emissions that are planned to be offset after the Expo are therefore 581 kilotons of CO<sub>2</sub>e.

Through this report, the Expo has also disclosed its Climate Change impacts through a verifiable carbon footprint calculation adherent with IPCC and GHG Protocol Guidelines. The Carbon Footprint Assessment of the Expo has demonstrated the efficacy of using GHG emissions as a powerful 'key performance indicator' in planning and refining development programmes, planning large-scale public events and charting master plans for the city and the surrounding region. The Carbon Footprint allows for the communication of complex environmental trends in a concise manner to a wide spectrum of stakeholders.

This review recognizes the significant efforts of Shanghai Municipality in creating a sustainable municipal development programme that was implemented in major part of the city during the preparatory phase of the Expo and is continuing as part of China's current 12th Five Year Plan and beyond. The Shanghai Declaration issued at the conclusion of the Expo by all participants comments on the challenges and opportunities facing all urban regions and humanity at large and the role of unified human action in meeting critical challenges.

In conclusion, the review summarizes the future plans of the Shanghai Municipality in continuing its trend toward sustainable development and offers recommendations for further consideration during post-Expo policy planning and implementation in Shanghai as well as in other similar developing cities.



# Introduction

## Chapter

# 1

### Introduction

Situated on the Yangtze River delta on the central east coast of China, Shanghai is one of the largest cities in the world. With the population of approximately 23 million people, Shanghai has emerged as the leading shipping, commercial and manufacturing centre in China. Its rapid growth and development over the past decade positions it with New York, Tokyo and London as a centre of global finance, culture and arts. It also is home to leading Chinese universities and world class research and development centres operated by both Chinese institutions and major multi-national companies.

The Shanghai 2010 World Expo (Expo) opened on 1 May 2010 and ran for six months with a theme celebrating the role of cities in human development. Historically it was the largest Expo ever, with a record 190 nations and 56 international organizations participating in the 184 day event. The number of visitors exceeded 70 million also setting a record for the Expo. The decade long preparation for the Expo also witnessed a city-wide transformation that resulted in a significantly better environment for Shanghai as will be discussed in this report.

This report is a review of the environmental impacts and the potential sustainability legacy of the Expo. It provides an objective appraisal of the environmental and social impacts of the six-month long event, by examining its operations, its influence on Shanghai Municipality during this period and beyond, and its implications for similar events and developing cities around the world.

The preparatory activities leading up to the Expo, including site selection, have been well documented in the UNEP Pre-Expo report: "Environmental Assessment: Expo 2010 Shanghai China". Those

finding will not be re-stated but will be referred to as necessary in this report.

This report picks up where the previous report concluded and evaluates the:

- Qualitative and quantitative environmental impacts of the Expo period within the Expo Park as well as in the Municipality;
- Its long-term influence on the development of Shanghai and the surrounding region;
- How environmental achievements were sustained during, and will be continued after the event;
- The environmental legacy of the Expo will be reviewed by examining learning for future similar events, Shanghai Municipality and developing cities globally.

Additionally successes and challenges will be examined to identify:

- lessons learned;
- Anticipated or unanticipated synergies;
- Opportunities that may have been missed;
- The carbon impacts as well as offset measures that have been adopted to fulfil the legacy of a low carbon Expo are to the extent possible analyzed from the perspective of carbon footprint savings and Life Cycle Analysis impacts.

The decade-long activities culminating in the accession and preparation for the 2010 World Expo provided an impetus for Shanghai Municipality to accelerate its development strategy and address the challenges of a rapidly burgeoning developing community.



The thematic focus of the Expo was *Better City, Better Life*. With this theme Shanghai aimed to address the challenges of rapid urbanization, increasing affluence and its inherent implications as well as create a more sustainable model for its development.

In selecting the theme "*Better City, Better Life*" Shanghai acknowledged the role of emerging cities in human development.

It committed to delivering an Expo that minimized negative environmental impacts and encouraged sustainable city development by adhering to the following core principles:

- Site selection and planning conducive to sustainable urban regeneration;
- Environmental management throughout the Expo;
- Development and demonstration of green technologies and eco-designs;
- Post-event utilization of venues and facilities according to core principles;
- Delivering a low carbon Expo and offsetting climate change impacts;
- Broad stakeholder participation.

Early in the Expo planning process, it became clear that Shanghai could not plan for a mere event, therefore it set into motion a process that had as a major milestone a six-month long global activity whose implications and legacy may last for decades.

Central to its Expo preparations Shanghai instituted processes that assured a sustainable pattern of development by changing its:

- Industrial structure;

- Energy mix, generation and utilization schemes;
- Transport networks;
- Integrated air and water quality management as part of a broader intensive environmental management strategy;
- Construction and infrastructure development codes;
- Water and wastewater management structures;
- Urban greening;
- Agrarian patterns;
- Government department structures; and
- Public awareness and participation as stakeholders of sustainable development.

The Expo site selection, its environmental restoration, and designation as the nexus of all municipal sustainability plans and processes, assured the creation of a platform for advanced planning systems, urban design and urban regeneration planning. The site became an incubator for implementing new technologies that were showcased and evaluated during the Expo for potential adoption in future development plans in Shanghai and other developing cities in China and across the globe.

In the sections below, the major Expo aspirations and achievements are summarized followed by major learnings and the resulting influence on planning by various Shanghai government agencies.

Based on a review of findings and analyses this report suggests action that may be applied for future development planning for similar events in Shanghai and elsewhere.

This final review evaluates the environmental impacts relating to the various Priority Functional Activities of the Shanghai Expo including:

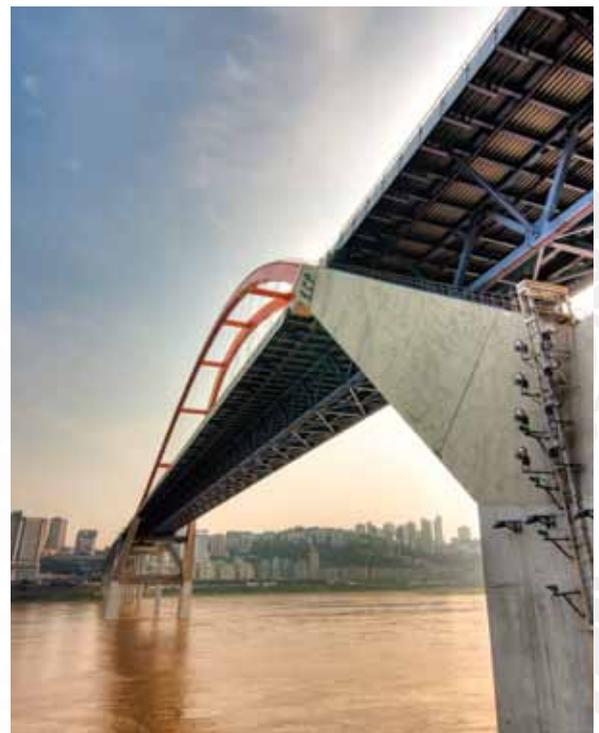
- Site and Venues: Sustainable Urban Development;
- Air Quality;
- Water Management;
- Waste Management;
- Energy;
- Transport;
- Forestry and Greening;
- Low Carbon Expo.

The common thread connecting the evaluation of the functional activities is a quantitative analysis of the Carbon Footprint Savings and where feasible Life Cycle Analysis impacts of individual activities and the entire Expo. Starting with concepts that were comprehensively summarized in the “*UNEP Environmental Assessment: Expo 2010 Shanghai, China*” published in August 2009, this final report will proceed to examine technological Interventions, and gain an understanding of three major impacts:

- Atmospheric: Local and Regional Air Quality;
- Climate Change impacts: related to energy utilization and efficiency; and
- Integration of learnings into future development planning for the City of Shanghai.

## **1.1** Report Layout

**Chapter 2** of this report examines the sustainability and management principles that underpinned the Shanghai Expo preparations. This includes an overview of environmental planning in support of the final preparations in 600 days prior to the Expo, Expo site selection, management structures established to ensure the effective delivery of the Expo over a six month period, low-carbon principles adopted that influence all aspects of preparation and execution, post-event site dismantling and utilization, communications: including education and public awareness campaigns; and coordination among government agencies.



**Chapter 3** covers practical measures implemented that supported the sustainability and low carbon commitments of the Expo. Issues covered include long-term industrial restructuring, changes in municipal energy mix and consumption patterns, Expo site preparation, public transport, Expo Park energy management, green energy usage, water consumption and reutilization, waste management, greening and afforestation.

**Chapter 4** examines air quality during the Expo period and measures that were taken to ensure the best air quality in the approach and during the Expo and what measures are being implemented to ensure good air quality is maintained in the city in the future.

**Chapter 5** examines and verifies the carbon footprint of the Expo and off-set measures adopted.

**Chapter 6** provides a summary of the Expo achievements, their implications on the Expo legacy and influence on the future development of Shanghai and beyond. Chapter 6 also provides high level UNEP recommendations for future policy development and actions.

# Environmental Planning, Management and Communication

## 2.1 Environmental Planning

Shanghai has developed increasingly sophisticated planning tools in the past decade to proactively address growth challenges. As a result, a substantial expertise exists in various local and regional government agencies, academies and universities that support the planning process. In undertaking research for this report, the UNEP team was made aware of numerous reports summarizing detailed modeling outputs that were utilized for every aspect of Expo planning.

Currently, a broad range of government agencies and academic institutions are undertaking detailed analyses of data gathered during the Expo both within the Expo Park and the Municipality.

The life cycle analyses (LCA) and performance of new energy vehicles, the performance of various energy saving technologies utilized, materials analysis, green coverage effectiveness and impacts represent a few of the broad range of analyses being undertaken which will likely be completed and reported on in the next one to two years.

The outputs of these detailed reports are destined to influence government policy and planning over the next decades.

### 2.1.1 Sustainable Site Selection, Planning and Urban Development

As was discussed in the first “UNEP Environmental Assessment: Expo 2010 Shanghai, China”, the Shanghai Government undertook a considerable number of technical feasibility studies to assess potential Expo sites.

There was much debate about locating the Expo either at a remote location or at the city centre. Finally the Expo site selection was incorporated with the overall rehabilitation of the urban centre.



Despite substantial difficulties encountered with community and industry relocations, site remediation and expansion of transport links, the final site selection contributed significantly to Shanghai's industrial restructuring and functional layout as well as the carbon footprint reduction of the Expo.

In the carbon footprint analysis below, the impact of selecting this site and closing obsolete industries, and relocation and upgrading other industries and plants is analyzed. The comparative carbon savings in selecting this site versus a more remote site are reviewed.

The selection of the river front urban centre area for the Expo re-vitalized the core of the city by removing some of the most polluting eyesores in Shanghai.

## Chapter 2

Environmental  
Planning,  
Management and  
Communication

The extensive remediation of the site which was a polluted brownfield has in itself spawned a very effective soil remediation industry thus motivating the government to begin a detailed risk based inventory of brownfields in Shanghai. These will be prioritized for remediation as part of Shanghai's continuing environmental improvement plans.

The Expo site, which previously was poorly integrated with the Shanghai public transport network, is now a main hub of an above ground, subway and river transportation system.

This development allowed the majority of the 400,000 daily Expo visitors to arrive at the park by public transport without impacting the life and traffic of the city.

## 2.1.2 Sustainability Principles and Low Carbon Strategy

The data on carbon efficient urban planning principles, site development techniques and material utilization in the Expo site is being compiled and will be comprehensively analyzed for the next 12-24 months.

The principles taken into consideration by organizers to reduce the Expo carbon impact include the following:

- Maximizing preservation and utilization of existing industrial buildings to avoid additional building materials and construction;
- Reusing of construction waste generated during Expo site rehabilitation by incorporating into pavilion and Expo pavement construction;
- Ensuring carbon emission reduction benefits from obsolete factory removal and efficiency improvement;
- Creating an urban design concept that encourages public transport usage;
- Exploiting passive energy sources including river and terrestrial heat exchangers, solar and wind. Requiring effective insulation, shading, green roofs and stereo walls and utilization of renewable, recycled and efficient building materials;
- Benefitting from shortened traveling distance from urban centre to Expo Park (compared with building Expo Park in remote suburban area) and reducing carbon emissions as a result.

## 2.1.2.1 Impact of Industrial Rehabilitation

The relocating and upgrading of industries and the communities servicing them has resulted in a significant emissions reduction in the urban centre area. The net emissions reduction has been substantial as relocated industries have become more efficient through upgrading of processes and management systems.

Additionally communities in the Expo site area that were relocated have been placed in better and more efficient housing at locations that are more conveniently located to amenities, closer to schools, places of employment and shopping centres.

- Industrial restructuring and pollution control:
  - I. In the Expo Park area alone more than 272 obsolete factories and plants were shut down, relocated and/or upgraded using advanced process technologies;
  - II. Within an additional 3 kilometer radius outside of the Expo Park area, a total of 540 factories and plants, including approximately 50 energy and pollution intensive facilities were shut down, relocated and/or upgraded using advanced process technologies, cleaner fuels substitution and strict emission management;
  - III. The Wujing Industrial zone was subject to a comprehensive rehabilitation programme which significantly reduced emissions and discharges throughout the zone.



Construction material 'reuse' through reutilization of existing industrial buildings as Expo facilities and pavilions avoided significant embodied carbon emissions and reduced emissions incurred during the construction process. Approximately 1/6th of the old warehouses, workshops, and other factory buildings, with a total area of 370,000 m<sup>2</sup> were preserved and used during the Expo. The assessment indicates that the approximate GHG emissions mitigated from building stock reuse due to embodied carbon in construction materials is 10,683 tons CO<sub>2</sub>e. The savings from construction-phase energy consumption is estimated to be 4,237 tons CO<sub>2</sub>e. The total GHG emissions benefit from reuse of 370,000 m<sup>2</sup> of built space is 14,919 tons CO<sub>2</sub>e.

**Table 1:** Summary of Major Industrial Rehabilitation Initiated at Expo Site

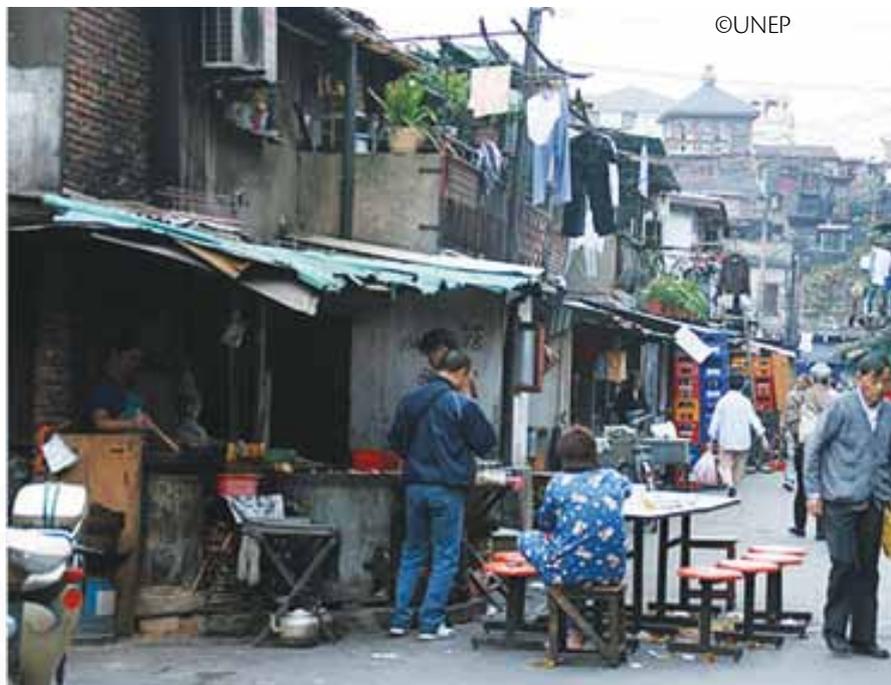
Sr. No.	Major Industrial Sectors	No. of Units
1	Machinery Manufacturing	31
2	Textile Printing and Dyeing	11
3	Food Processing	8
4	Shipyard	6
5	Chemicals Manufacturing	6
6	Plastic Manufacturing	4
7	Steel Production	1
8	Power Plant	1

The environmental benefits of this expansive rehabilitation project for Shanghai and China, are not from the artifact of merely relocating the industries to another location (i.e. problem shifting – a practice that was avoided).

The true impacts estimated below are those realized from the technological upgrades that were facilitated as part of the Expo planning process. The GHG emissions impact of rehabilitation of the major industrial units is presented in Chapter 5.

### 2.1.2.2 Impact of Other Rehabilitation Programmes

- Residential environmental improvements:
  - I. In excess of 18,000 residents living in poor circumstances were moved into new developed communities (“the Expo Home”) with modern and efficient facilities (Fig 1 and 2);
  - II. Through extensive studies and application of “humans-first principle” in the Expo master plan, another 15,000 households were maintained within the Expo zone (coordinating area). These households have benefited the most from the Expo Park site selection by remaining in their original communities and experiencing significant improvements in housing, infrastructure and services. The government also benefited by avoiding additional household relocation.



**Figure 1:** Typical Residential Area in Expo Site Prior to Rehabilitation



**Figure 2:** Typical Residential Area Housing Relocated and Upgraded Communities

#### ■ Ecological Benefits

Previously the banks of the Huangpu River within the Expo site were derelict wharfs with jetties that had been used for over a century to haul coal, raw materials and finished industrial products from the obsolete factories in the area. The current ecological landscape corridors along both sides of the river will be maintained after the Expo, and water front public spaces will continue to be created and expanded.

### 2.1.2.3 Emissions Reductions Resulting from Proximity to City Centre

World events of the scale of the Expo are often planned around a site located outside city limits. For instance, the 2005 Aichi Expo was located approximately 20 kilometres away from the city centre of Nagoya. The selected 2010 Expo site was a better alternative in terms of reducing GHG emissions from local transportation for visitors compared to alternate site.

The impact of locating the Expo within the city centre was two-fold in terms of the endeavour to hold a low-carbon Expo. The location encouraged public-transportation usage and the average distance to city centre was reduced significantly compared with building Expo Park in the alternative remote suburban area. In addition, the reduced distance also beneficially impacted the emissions from traveling of other groups – Participants, Organizers, Service Personnel, VIPs, Security Staff, Volunteers and Freight Transportation. These benefits will be discussed in Chapter 5.

There is some degree of uncertainty about the actual avoided emissions since these emissions are pegged against a Business-As-Usual Scenario which was never actually constructed. However, international methodologies (such as the IPCC's 2006 Guidelines related to Land Use Change Effects – LULUCF) often apply such methods to extrapolate what the possible emissions from scenarios would have been had an intervention not been implemented.

The protracted benefits of this urban planning decision will be amplified during the lifetime of the public assets though currently unquantifiable, for example, the public transportation assets (equipment and infrastructure) created to service this Expo site augmented the beneficial impact of the site selection greatly. These aspects are explored in later sections of the report.

### 2.1.2.4 Impact of Expo Site Dismantling, and Material/ Equipment Recycling and Reutilization

As part of the Expo preparations each temporary pavilion was required to submit a comprehensive dismantling plan to the Expo Bureau for review and approval together with the pavilion design and construction plans. Following the Expo, most pavilions were dismantled and the materials were recycled/ reused. Owners repatriated some pavilions while others have been transferred to new locations to be re-constructed by new owners.

**The dismantling process was divided into two parts:** above ground and below ground.

Above ground dismantling was undertaken according to strict health and safety standards to minimize dust, noise and light pollution particularly outside daylight hours.

Below ground dismantling is more hazardous and required excavation and thus could only be undertaken during daylight hours and in strict conformance with excavation codes that require shoring (to prevent excavation cave-ins and protect adjacent structures) and care to be taken during any activities in the proximity of underground utilities and within 80 meters of tunnels and bridges.

#### **Examples of Dismantling of Some Pavilions:**

**German Pavilion:** The special membrane outer walls were dismantled and the material was used to produce high quality shopping bags. All salvageable equipment, steel beams and pillars were stripped, dismantled and re-cycled. Any concrete was pulverized and used as aggregate or sub-base in construction.

**Swiss, Swedish and Norwegian Pavilions:** All these have been sold to private businesses or other provinces and are relocated and reconstructed elsewhere. Any foundation or structural materials left on the Expo site was removed and recycled.

**UK Pavilion:** All acrylic rods and seed pods were auctioned and delivered to new owners. The concrete structure was pulverized and earmarked for used as sub-base or aggregate in future construction.

**Japanese Pavilion:** Japanese technicians removed all proprietary technology. All salvageable equipment and material has been stripped to be re-used elsewhere

and the proprietary synthetic shell material has been stripped and recycled in a chemical factory. The steel frame was totally dismantled and the steel recycled. Any concrete was pulverized and used as construction material.

**Five temporary pavilions:** Saudi Arabia, Spain, Italy, Russia and France have been donated to the Shanghai government. The Saudi Arabian pavilion, which was the most popular of the national pavilions during the Expo, will be reopened without modification.

The remaining four pavilions shall be modified to include additional artistic, cultural and technology elements in line with the Expo theme and shall be reopened to the public.

#### Dismantling and recycling of material and equipment:

Structural steel was dealt with in one of two ways:

- (a) Modular steel was dismantled and used elsewhere;
- (b) All other steel piping or structural beams and columns were sent to steel mills for recycling. It is assumed that the waste steel generated

from the Expo was recycled through a physical/chemical processes which has a finite energy consumption of its own albeit significantly lower than that of virgin steel production.

Concrete and structural concrete used in pavilions was demolished and pulverized for use as sub-base or aggregate in future construction. Bricks have been reclaimed and reused as is normal practice in China.

Waste glass and aluminium were also being recycled through physical/chemical processes. Roadside water drainage and recycling systems are considered permanent structures associated with site infrastructure and are to remain in place.

Temporary water handling infrastructure associated with temporary pavilions was dismantled and to the extent possible salvageable parts were re-used.

The remainder was recycled. All non-salvageable waste such as dry walls, PVC piping, damaged hardware etc., were broken down and either re-cycled or where possible used for other purposes. .

**Table 2 - Structural and Surfacing Materials Recycling Carbon Footprint Mitigation Analysis**

Sr No	Description	Building Category	Allocation Ratio	Quantity	GHG EF (Virgin Material)	GHG EF (Recycled Material)	Activity CF	CF Mitigation
				(tons)	kgCO <sub>2</sub> e/kg	kgCO <sub>2</sub> e/kg	tons CO <sub>2</sub> e	tons CO <sub>2</sub> e
1	Steel	Permanent	0.033	243,758	1.5	0.43	12,188	343,292
2	Steel	Temporary	NA	167,241	1.5	0.43	71,914	178,948
3	Cement	Permanent	0.033	790,337	0.85	0.005	22,393	649,920
4	Cement	Temporary	NA	83,530	0.85	0.005	70,583	418
5	Glass	Permanent	0.033	9,124	0.99	0.313	301	8,774
6	Glass	Temporary	NA	3,619	0.99	0.313	1,134	2,448
7	Aluminum	Permanent	0.033	6,664	14.7	1.69	3,266	95,366
8	Aluminum	Temporary	NA	1,830	14.7	1.69	3,092	23,804
	<b>Totals</b>						<b>184,871</b>	<b>1,302,971</b>



**Figure 3:** Hydrogen Fuel-Cell Bus (above) and Car (Below)

The total Carbon Footprint mitigation arising from Structural and Surfacing Materials Recycling and Reuse was estimated to be 1,302,971 tons CO<sub>2</sub>e. A large share of this benefit was from the avoided embodied carbon from reuse of the buildings following the Expo while the direct savings from recycling material and making it available to the market is 205,618 tons of CO<sub>2</sub>e (16 per cent of the total carbon footprint mitigation from structural and surfacing material recycling).

#### Electrical Devices and Lighting

All lighting, sockets, control interfaces, power supplies, air purification systems, Heating Ventilation and Air Conditioning HVAC systems, detection devices and all re-usable electrical equipment from temporary buildings were removed and re-used elsewhere.

Wiring and conduits that could not be salvaged have been collected and fully recycled.

Most Audio Visual equipment used in the Expo was leased and thus returned to vendors. Recycling of LEDs following the Post-Expo period results in a salvaged value attributable to the avoided manufacturing LCA related impacts.

#### Solar PV Recycling

Recycling of solar PVs following the Post-Expo period results in a salvaged value attributable to the avoided manufacturing LCA related impacts. Since this manufacturing related embodied energy of Solar PV panels is known to be significant relative to other renewable energy technologies, recycling these systems is imperative to minimize their life cycle impacts. The conservation is estimated to be 9,216 tons of CO<sub>2</sub>e based on a residual lifespan of 98 per cent following the Expo.

#### Vehicles

Following the Expo, 60 Hydrogen Fuel-Cell vehicles were transferred to Guangzhou city (southern Guangdong Province in China) to serve in the Asian Games from 12 to 27 November 2010. These were returned to Shanghai following the Games for use at various public venues.

Additionally, 120 Battery-Supercapacitor buses, 61 Supercapacitor Trolleybuses, and 75 Hybrid Bus remain in service in the city centre; and 6 Hydrogen Fuel-Cell Buses were transferred to Jiading District in Shanghai to continue their operation, together with some of the remaining Hydrogen Fuel-Cell cars.

#### Future Site Use

A master plan has been formulated and publicly announced for dividing the Expo Park into five post-utilization areas. The plan is currently subject to public comment and shall be modified accordingly.

According to the preliminary plan, on the Puxi side, west of the Huangpu River, the Urban Best Practice Area (UBPA) will be maintained as it is and will continue promoting the "Better City, Better Life" theme as a cultural enclave for creative industries.

Adjacent to UBPA in what was the Expo's Cultural Exhibition Area, museums are being planned that

will incorporate the Nanshi Power Plant and the Jiangnan Shipyard buildings. On the Pudong side, east of the Huangpu River, an Exhibition and Business area is planned along the Expo Axis. This area will be developed as the central business district of the park post utilization.

The infrastructure of the Expo village, the residences developed for the Expo participants will be kept intact and the area will be converted into an International Community to accommodate housing and supporting facilities for the exhibition and business areas. Finally the Houtan area is still subject to further planning. All roads and basic infrastructure will remain for future utilization.

### 2.1.2.5 Urban Planning, Site Development and Material Utilization: Expo Lessons Learned and Impact on Planning Process

The Shanghai government is planning for its future development in part based on the Expo experience and outcomes. It is therefore suggested that the following considerations be integrated into its planning processes:

- Establish integrated eco-corridors linking urban centres with suburbs;
- Increase land allocations and incentives for development of tertiary industries specially focused on sustainable technologies;
- Based on energy savings and efficiencies implemented in the Expo develop strategies, create urban planning and construction codes requiring use of sustainable materials and minimum energy saving requirements.



*UNEP suggests that whatever the post-utilization plans are of the Expo Park, the Municipality and its planners should retain the original intent and vision of the park and ensure that it remains a showcase for sustainable development through energy conservation, low carbon practices, resource conservation and green material development as outlined in the Expo Green Guidelines.*

## 2.2 Environmental Management

### 2.2.1 Coordination Among Municipal Agencies

In 2003 the Shanghai Government created the Shanghai Environmental Protection Committee (SEPC) to integrate sustainability issues in the city's development priorities.

This high level body comprising of senior representatives from all Shanghai districts, all key municipal bureaus and major industrial parks, is presided over by both the Shanghai Mayor and Vice Mayor as described in the pre-Expo UNEP Environmental Assessment Report.

The SEPC is a high-level authority that cuts across much of the silo structures characterizing government organizations in China and elsewhere. As a result all plans and activities undergo an interdisciplinary review through SEPC to ensure that they are effective, efficient, sustainable and have adequate support by all key stakeholders.

The Shanghai Environmental Protection Bureau (SEPB) acts as the SEPC secretariat and is the authority that deals with the day to day functions of the SEPC, coordinates among its members, facilitates negotiations among various stakeholders of projects to ensure all are committed to its success and when necessary escalates issues to the SEPC and the Mayor for resolution.

While this integrated structure has its challenges, it assures high quality communication, exchanges and collaboration that supports an unprecedented level of coordination among the various districts, industrial parks and municipal organizations. It also raises the profile of the SEPB so that environmental and sustainability considerations are fully integrated into all plans and their implementation.

The SEPC implements policies and plans through Three Year Environmental Action Plans which have clear *objectives, standards and priorities* as described in the pre-Expo report and have been so successful in the revitalization of Shanghai that Three Year Plans will continue to be the leading tool in the sustainable development of the city. Other municipalities and provinces are now also working with Shanghai to emulate its experience.

The heightened profile and responsibility of the SEPB and other key agencies<sup>1</sup> throughout this process over the past decade has allowed it to become an indispensable part of Shanghai's development. Government agencies no longer see environment and development as conflicting but rather an integrated whole.

The responsibilities and inputs of SEPB have also touched every aspect of Expo preparation and execution ranging from municipal improvement, major infrastructure projects, and re-development schemes, through industrial and energy re-structuring, waterway remediation and air quality management and overall monitoring to list but a few. Consequently the influence and inputs of SEPB were apparent in all aspects of Expo operation and will continue in post Expo municipal development. The SEPB's lessons learned from preparation and operation of the Expo have influenced its forward planning.

**Section 6** includes UNEP's recommendations proposed for future short and long term planning.

### The Expo's Low-Carbon Programme:

The Shanghai Government was committed to making the 2010 Shanghai World Expo a low-carbon event to emphasize the sustainable urban development globally. On 5 June 2010, the Expo organizers launched a 'Low Carbon Expo Programme' as a major component of the Expo theme: *"Better City, Better Life"*

<sup>1</sup> Key agencies include Shanghai Development and Reform Commission, Science and Technology Commission of Shanghai Municipality, Shanghai Water Bureau, Shanghai Landscape and City Appearance Administration Bureau and Shanghai Environment Monitoring Centres among others

through application, demonstration and promotion of low carbon strategies, technologies, and practices, and by encouraging organizers, exhibitors, and visitors to participate in the realization of this goal.

The Programme also emphasized active implementation of carbon offset measures to realize the goal of a "Low Carbon Event", while simultaneously promoting an expedited transition to low carbon production patterns and lifestyles.

### Three primary objectives characterized the Low Carbon Expo Programme:

#### a) Achieving Overall Low-Carbon Development

The concept of sustainable development was incorporated throughout the process of planning, construction, operation and post usage of the sites to avoid and minimize additional carbon emission. Various measures would be taken to actively promote "carbon offset" projects, which would strive to offset 60-70 per cent of the additional carbon emission generated from the Expo before it closes. Additionally, the city aspired to neutralize all the additional carbon emission associated with the Expo within four to five years.

#### b) Demonstrate the Widest Array of Low-Carbon Strategies and Technologies

The Expo provided a platform for bringing together, exchanging, and displaying low carbon development accomplishments. The Expo managed, coordinated, encouraged, and guided the participants and exhibitors by promoting and providing low carbon concepts, technologies, and best practices through

**Figure 4:** Shanghai Expo Environment Management Institution Structure.



the designs of each pavilion and exhibition, as well as activities aimed to position the Expo as a model for sustainable urban development.

**c) Promote Low-Carbon Concept and Best Practices**

The Expo was used to raise awareness of low carbon lifestyles through a variety of publicity, educational and participatory programmes. Concepts and technologies displayed and promoted in the Expo were extended to low-carbon city/social initiatives.

A Steering Group including representatives from the Expo Bureau, the Shanghai Development and Reform Commission (SDRC), Science and Technology Commission of Shanghai Municipality (STCSM), the Shanghai Environmental Protection Bureau (SEPB), as well as other departments, was organized to undertake programme planning, organization, coordination, technology evaluation, public participation and communication to facilitate implementation of the low carbon programme throughout the Expo.

In addition to measures taken by the Expo organizers, participating countries, enterprises, NGOs, and visitors were encouraged to actively participate in the “low-carbon” activities. By encouraging active public participation, an interaction between stakeholders and participants was nurtured, thus actively encouraging “low-carbon” promotion and sharing the achievements of a low carbon Expo.

In order to understand the Expo sustainability legacy, follow-up assessments and a post review, for the “Low-Carbon Expo Programme” was planned and conducted during and after the

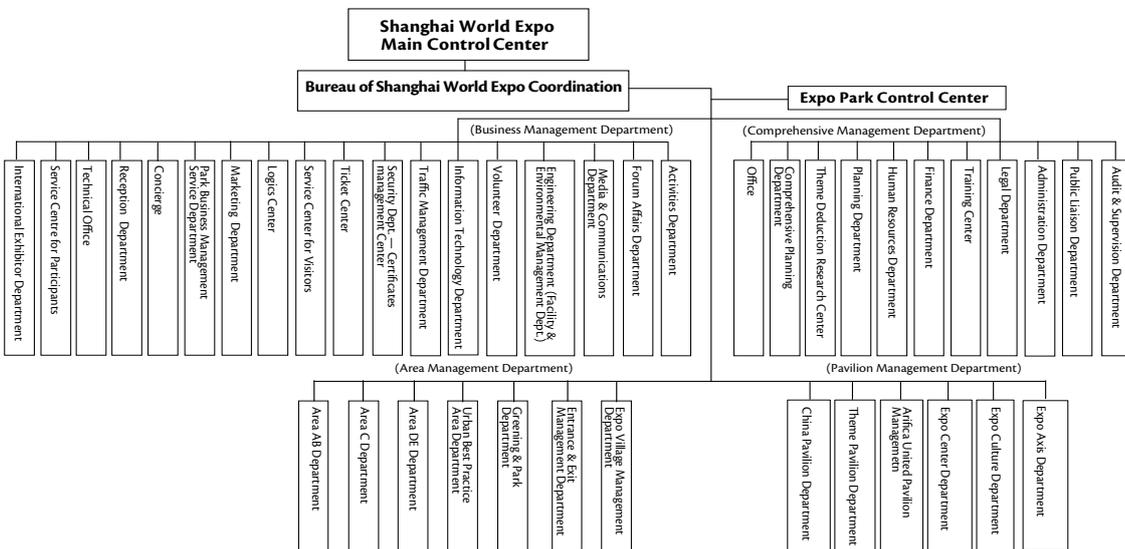
Expo. The focus of this activity was to develop a comprehensive and objective evaluation of the programme implementation impacts together with a carbon emissions calculation, offset conditions and related social impacts of the Expo, which will be discussed in **Chapter 5**.

**2.2.2 Departments, Operational Practices and Management Effectiveness**

The Expo was administered and managed by the Expo Bureau which was designed as a high level umbrella organization with a central Expo Park Control Centre, 11 Comprehensive Management Departments, 18 Business Management Departments, seven Area Management Departments, as well as six Pavilion Management Departments, having a total of approximately 2,500 employees functioning within it (Fig 5 below).

Each of these departments was in effect seconded from counterpart bureaus in the Municipality with the specific mandate to ensure that the Expo functioned efficiently. These departments functioned within the mandate of the Green Guidelines to deliver their accountability for achieving the low carbon Expo. The impacts of the Expo learnings on each of these departments and its influence on the functioning of their organizations within the Municipality are subject to ongoing internal analysis.

**Figure 5: Structure of the Expo Bureau Departments**



Associated with the coordination among municipal agencies, and environmental management and departmental operational practices and their effectiveness is the green hotel and travel partner programmes that were an integral part of the Expo theme. In the two case studies below, two different approaches to increasing efficiency and sustainable practices are observed.

The first which is more policy based and has significant opportunities for expansion is the Shanghai Green Hotel Programme. The second presenting the initiatives of transportation partners particularly China Eastern Airlines (CEA), shows how technology and non-technology policy issues may result in effective efficiency gains.

### 2.2.3 CASE STUDY I: Shanghai “Green Hotel” Programme

The “Green Hotel” Programme in Shanghai was initiated in 1999 by the Shanghai Tourism Bureau (STB) and SEP. Initially the Programme encouraged hotels to achieve ISO14,001 certification.

It later evolved with inputs from the Hong Kong Quality Bureau to include training for hotels that wished to institute green programmes. In 2006, the Government of China issued a Green Hotels Standard (LB/T007-2006) that STB adopted for certifying green hotels in Shanghai.



The Shanghai Green Hotel Programme stresses the “Four Rs” - Replace, Reuse, Reduce and Recycle - and has two major aspects:

#### 1. Criteria for Green Hotels.

- Energy Intensity Reduction;
- Waste Reduction;
- Water Conservation;

#### 2. Scoring System.

- Hotel (sustainable) Design;
- Energy Management;
- Environmental Management;
- Green Service;
- Socio-economic Benefit.

To date Shanghai has concentrated on greening star hotels as the total number of hotels in the city runs into the thousands. Hotel may be granted a Silver Leaf with a score of over 180 points or Gold Leaf with a score of over 240 points. Each hotel needs to submit a performance report annually which may be subject to audit. Should a “Leaf” hotel fail to continue meeting the required score, it will be given a grace period to correct shortfalls after which it would be downgraded.

Since 2006 all star rated hotels and some smaller hotels in Shanghai have been undergoing evaluation. By the end of 2010, 161 hotels were certified as “Green Hotels” of which 41 achieved Gold and 120 achieved Silver Leaf. Among these 161 hotels, 124 are star-rated hotels and 37 are not.

Considering the total number of star-rated hotels in Shanghai is 298, overall 41per cent of all star hotels have achieved either Gold or Silver leaf standards and a large number of the remaining hotels have instituted greening programmes.

Key criteria considered for candidacy as a “Green Hotel” in Shanghai includes:

- Reduce disposable waste;
- Reduce containers and paper usage;
- Increase proportion of green space on hotel property;
- Place environmental statements in all rooms to inform guests how they may participate in the hotel green actions;
- Reduce laundry load;
- Reduce volumes of soaps, shampoos, toothpaste and other consumables and agree with suppliers

to re-use/recycle spent containers or use fixed dispensers. The STB has distributed materials to tour operators to educate clients on reduction of disposables;

- Recycle used soaps and detergents for staff uniform laundry or for staff bathrooms;
- Reuse torn linens for making laundry bags;
- Compost grass cuttings, leaves and other vegetation for use on landscaping;
- Provide recycling bin in guest rooms;
- Encourage bio-degradable packaging (currently 50 per cent by 2015 100 per cent is required);
- By 2015 all Five Star hotels shall have bio-degradable food containers;
- Reduction of back office paper usage by double sided printing ;
- Energy savings criteria based on reduction of energy intensity (Equivalent Tons Coal /10,000 RMB income) compared to previous year but no specific requirements;
- All cooling tower water for HVAC systems recycled.

UNEP suggests there are significant opportunities to further develop the "Green Hotel" Programme in Shanghai by:

- Substituting decoration and cleaning products with environmentally-friendly alternatives;
- Creating specific standard for hotel energy consumption, an opportunity that was perhaps lost during the Expo preparation. However, STB is currently formulating a standard for discussion by the legislature;
- Developing uniform criteria for installation of water saving devices and effectively implementing in all hotels;
- Requiring all new hotels to have minimum energy efficiency performance and have a substantive rainwater and grey water recycling systems.

#### **The "Green Hotel" Programme and the Expo**

According to the Shanghai Municipal Tourism Board, these efforts were particularly visible in energy consumption in hotels.

For the first three quarters in 2010, compared with same period in 2009, although the occupation rate of hotels in Shanghai increased by 20 per cent, energy consumption only increased by 3.7 per cent - 7.7 per cent.

## **2.2.4 CASE STUDY II: Travel Partners**

While not administered by the Shanghai Tourism Bureau (STB), airlines and tour transport operators have a significant synergy with the tourism industry. These sectors, which are regulated by the Transport Bureau, had significant inputs into the Expo effort.

China Eastern Airlines (CEA) was the official Expo air carrier and a variety of tour bus operators were official passenger bus providers of the Expo. As far as it has been determined with the exception of the municipal public transport system and taxis that accepted the Green Commuting Card, no special green or offset programmes were initiated by any of the official long distance transport companies of the Expo or any of the other air carriers that brought passengers to Shanghai during the Expo.

It is believed that offset contributions could be greatly expanded if the long distance transport companies or any air carriers would also join the Green Commuting Programme or launch special green or carbon offset schemes.

However, CEA has instituted the Extended Twin Operational Performance Standard (ETOPS) which has adjusted air corridors and other technical flight standards resulting in a 6 per cent reduction in fuel consumption. Additionally a management reform adopted by CEA is 'second dispatch'. According to international airline regulations, 10 per cent extra fuel should be kept for backup though seldom used.

Thus second dispatch is a good practice adopted on international airlines that allows aircraft to have a second dispatch without stop for refill at the transfer airport as long as the remaining fuel could meet the '10 per cent more for backup' regulation for the rest of the flight. Based on the above good practices and other small programmes and activities, China Eastern Airline has been honoured in China as one of the low-carbon pioneers among enterprises in 2010.

Given that the transportation sector has one of the largest carbon footprints for any global event, in the future a minimum offset programmes need to be suggested to all carriers to account for efficiency programmes such as the one instituted by CEA.

Road transport providers need to be included in carbon accounting and offset calculations, and programmes such as the Green Commuting Card should be expanded to provide offset opportunities to carriers and passengers.

Additionally there are significant opportunities for recycling and re-use of disposables particularly in the airline industry which would have a positive net effect on the environment if implemented permanently.

**Table 3: Energy Efficiency Improvement of China Eastern**

Indicator	2006	2007	2008	2009	2010
Jet fuel consumption (t/hour)	3.459	3.376	3.193	3.104	3.130
Jet fuel consumption (t/10 000ton-km)	3.384	3.307	3.339	3.288	2.950

**Section Summary:**

The various departments have expressed that the concepts of low carbon operations, energy conservation, waste minimization, recycling and communications that made the Expo such a success be incorporated in the functioning, operations and planning of each Municipal organization so that the lessons learned are internalized and emulated at every level.

A clear learning and opportunity that emerged from the Expo for the Municipality was not only a display of ecological technologies and advanced city planning concepts but also exposure to sustainable operations from many domestic and international exhibitors. The operation of the Expo itself generated many



lessons learned that are currently being analyzed for incorporation into Municipal operations.

A learning opportunity that emerged from the Expo is the role that private enterprise can play given the right incentives to develop green materials and systems for all aspects of development in Shanghai, China and globally.

Many of the most innovative and cost effective technology displays presented in the Expo were assembled using Chinese developed or fabricated technologies. While the role of major State Enterprises should not be understated, these smaller private enterprises displayed a vitality that could potentially translate into exponential and verifiable green products growth.

Such industries would support robust expansion of the tertiary and technology sectors not just in Shanghai but throughout the Yangtze Delta and globally. Locally this may support the better environmental management of the Yangtze region and potentially create a new pillar industry.



UNEP strongly suggests that the Municipality ensure that the lessons learned from the Expo be incorporated into the internal operations of each Municipal bureau so each becomes an example of the sustainability and efficiency principles that they are promoting.

## 2.3 Environmental Communications

### 2.3.1 Effectiveness and Prevalence of 'Green Guide' in Practice

To guide the Expo visitor, exhibitor and operator environmental behaviors and practices, the Expo organizers together with UNEP and United Nations Development Programme (UNDP) developed and issued the Green Guidelines. The Green Guidelines were designed as a tool to encourage green initiatives in all aspects of the Expo operations. Although most of the initiatives were not mandatory, it was well received and achieved satisfactory implementation by most of the exhibitors, operators and visitors.

The Green Guidelines are divided into three parts according to groups targeted. The first part was for participants, the second was for operators and the third was for visitors:

- Participant guideline: including ecological exhibit design, pollution control, green construction, green management and green transport;
- Operator guideline: including green hotel, green restaurant, green marketing, event services, logistics services and green office;
- Visitor guideline: including green transport, exhibition visiting, consumption and lifestyle.

#### 2.3.1.1 Implementation and Effectiveness of Green Guidelines

##### Exhibitors: Design and Construction of Expo Park and Pavilions

As described below, all permanent buildings in the Expo Park were designed and constructed incorporating to the extent possible ecological design criteria and technologies. The "Design Guidelines for Expo Outdoor Space" and "Design Guidelines for Pavilion Construction" set out clear targets, requirements and references for good practices to guide contractors to build an environmentally friendly Expo Park according to Green Guideline criteria.

Special design and quality control standards were also issued for temporary buildings, which implemented some of the targets of the Green Guidelines so as to encourage maximum utilization of natural lighting and ventilation, renewable energy, recycled material, and to facilitate easy dismantling and material recovery.

As a result, many temporary pavilions used environmental friendly materials for construction, including wood, bamboo, recyclable paper, plastic and special membranes.

Additionally the UN, Vanke, and the Shanghai Case Pavilions among others built their walls and other structures with recycled straw, power plant fly ash and paper. All such practices were aimed at using less steel, cement or glass, and therefore reducing construction environmental impacts as outlined in the Green Guidelines.

Significant amount of construction waste would have been generated from the Expo site rehabilitation.



Figure 6: Construction and completed Broad Pavilion (Source: SAES)

To avoid this, a special management regulation was issued for construction wastes classification and reuse, among which, approximately 10 per cent with relatively high value such metals, glass and wood were recycled and sold for reuse.

The remaining 90 per cent which constituted millions of tons of construction rubble including unsalvageable concrete, plastic and wooden materials were used for paving material, construction fill, and

casting cores for manhole covers in the Expo Park. More than 60 per cent of the roads, green spaces and most of the manhole covers were fabricated using construction wastes from the Expo site rehabilitation.

During the Expo Park construction phase, new concepts and technologies inspired by the Green Guidelines were implemented to the extent possible. Notably the Broad Pavilion, one of 17 corporate pavilions at the Expo, was completed in less than 24 hours thus reducing construction energy usage. This six-story energy-efficient structure was designed to use just 20 percent of the materials used by other pavilions of a comparable size. It also consumed just one-sixth of the energy of similar-sized pavilions due to a series of passive solar design techniques: 15cm thick insulation, triple-layered non-metallic framed windows, exterior shading and fresh air heat recovery. It took the working team about two months to complete the design; producing all the prefabricated parts in a factory took less than a week.

Prefabrication of buildings or building elements for sustainable construction was successfully applied in many Expo temporary buildings. Based on this experience, the Shanghai Urban Construction and Communications Department will promote these technologies for future construction.

### 2.3.1.2 Green Management: Procurement and Operations

The Expo encouraged life cycle analysis (LCA) benefits to be taken into considerations when selecting, procuring and utilizing green technologies and materials. Exhibitors were encouraged to procure their materials and facilities locally. For example, during the Nanshi Power Plant renovation, most of the new materials were procured from within 500 kilometres to reduce energy consumption and carbon emission arising from transportation.

Another example of green procurement is the food supply to the Expo Park: more than 150 vegetable farms in 10 districts in Shanghai were selected as dedicated Expo food suppliers, all of which were provided with financial and technical incentives to use organic fertilizer as well as integrated pest management techniques. The selected farms were already recognized as among the most progressive within the municipality. Special environmental trainings courses were provided

to farmers and management teams of vegetable farms to assist with internalizing the ecological concepts required for organic farming.

Tracking systems were created to ensure the organic produce supply chains remain robust and green labeling and certification was specifically developed for this produce. The management and certification system has been maintained beyond the Expo period and premium niche organic farming and supply businesses have emerged to address consumer demand which is likely to expand significantly in the years ahead.

Encouraged by the Expo Green Guidelines, many exhibitors joined Voluntary Carbon Emission Reduction Programmes, among which the United Nations, United Kingdom, Vanke, Heilongjiang and Guangdong Pavilions, as well as the Private Enterprises Joint Pavilion participated in the Carbon Trading System supported by the Shanghai Environment Energy Exchange. The USA, Belgium and Portuguese Pavilions targeted 100 per cent carbon offsetting with Gold Standard projects or carbon sinking projects both in China and in other countries according to international and local standards.

#### Operators: Operations Management

For the routine management of all pavilions, green concepts and technologies were widely adopted and communicated. For example, the entire UBPA with a construction area of 150,000 m<sup>2</sup> was equipped with a river-water heat exchange system that was operated through a renovated process in the Nanshi Power Plant. This system is designed to continue serving a 600,000 m<sup>2</sup> building area in the neighborhood following the Expo, service that has been communicated to potential tenants in the neighborhood promoting green business and lifestyles.

During the Expo the majority of pavilions issued special operations manuals for implementation by operations staff to optimize air conditioning and lighting system. For example, in the China Pavilion, the central air conditioning system used an ice-storage facility for better utilization of non-peak electricity. During normal operation hours, all non-essential lighting was automatically switched off for energy saving as well as for better exhibition effect. The same concepts were adopted in water supply management to minimize energy wastage while optimizing utility.

Intelligent control systems also played an important role in energy saving and emission reduction. Energy monitoring and display system, motion-sensing (PIR) technology, intelligent control system for indoor



**Figure 7:** Notice Used to Discourage Elevator Usage in the Expo Bureau

temperature and air quality were installed in many pavilions to achieve energy and resource conservation.

In the Expo Bureau offices, green office initiatives as recommended in the Green Guidelines were the subject of a series of training campaigns for all employees and were widely adopted and reinforced through continued awareness building. In the Expo Bureau offices, employees were requested to reduce elevator use, consume less paper by promoting an e-office environment, utilize more tele-conferences to replace traditional conferences and reduce unnecessary travel. Recycled paper and double-sides printing was widely promoted. All employees were trained and guided to sorting and recycling office waste and used consumables.

Green commuting for Expo Operators was broadly implemented and promoted with the support of new energy vehicles both inside of the Expo Park and in the surrounding areas. Green commuting and transport was also encouraged for local transportation of all Expo service groups, logistics, the float parade shows, and waste collection and transportation.

Aside from hardware development and installation, almost all pavilions prepared presentations to promote concepts and best practices on sustainable development from different perspectives as described in 2.4.4. Furthermore, campaigns to promote energy conservation and emission reduction awareness and practices were organized by Expo operators both within Expo Park and the city.



### Use of Recycled Materials

*Using recycled paper milk cartons, Tetra Pak made 2,000 environmentally friendly benches, which it donated to the Expo. Since its launch in June 2009, the recycling campaign received extensive public support. Nearly 600 organizations responded to the call, including community organizations, universities, retailers, and celebrities.*

*According to official statistics from the Shanghai Municipal Waste Management Authority "Green Account" by the end of January 2010, the campaign had covered 12 districts in Shanghai, attracted 728,400 participants and recycled a total of 113 tons of cartons, equivalent to over 10 million 250 ml milk packs.*

### Visitors: Awareness Building

Millions of Shanghai citizens participated in a variety of training courses and awareness building campaigns inside and outside of Expo Park. These included campaigns on energy saving, environmental protection, as well as low carbon development. Hundreds and thousands of schools, communities and enterprises organized special activities to support awareness of the Low Carbon Expo.

Over 10 million people in Shanghai and nearby cities participated in the two-year long "Green Commuting Initiative" which was co-organized by the United States-based Environmental Defence Fund, Shanghai Environmental Protection Bureau, and Shanghai Expo Bureau. Special training programmes and campaign activities were widely organized in schools, enterprises, and residential communities to build awareness of sustainable commuting alternatives to reduce congestion and improve the environmental footprint of commuting.





**Figure 8:** “Green Commuting” promotion events (source: EDF)

### 2.3.1.3 Assessment of Guideline Content

Several in-depth surveys of the efficacy and the catalytic impacts of the Green Guidelines and awareness of the green technologies utilized in the Expo were undertaken by a variety of organizations such as Forbes China, the Economic Daily News, the National Statistics Bureau, Shanghai Municipality and a variety of academies and institutes. These studies focused on visitors, operators and participants and were either undertaken directly by interviewing people in the Expo site and in the city, or online. Some survey results have been published in Chinese, other results are still being analyzed.

Preliminary results indicate that there is a very wide awareness (over 70 per cent of those surveyed) of the Expo theme, carbon footprint, the ecological themes of the Expo and also the sustainable technologies that were promoted during the Expo. Predictably the benefits of clean energy vehicles, potable water, recycling and reuse of resources and solar energy were the most widely recognized.

Additionally, it will likely take some time to evaluate how awareness will be translated into personal or institutional action. How this will be achieved and how individual stakeholders will participate and contribute remains unknown at this time.



**Figure 9:** Students signing to support “Green Commuting and Low Carbon Expo” (through children influencing parents)

Another example of the awareness building which had a major impact: a large portion of Expo visitors brought empty water flasks into the Expo Park to drink the potable water provided instead of buying water bottles which saved consumption and disposal of tens of millions of plastic water bottles.

In July 2010, the National Statistic Bureau launched a survey impact of Expo awareness on various social groups, the main findings were:

- Non-Shanghai residents attending the Expo outnumbered Shanghai residents by 2:1;
- People between 18 and 44 made up more than 80 per cent of visitors;
- More than 90 per cent of visitors had an education level above high school;
- More than 50 per cent of attendees were employees of state-owned enterprises and research institutes affiliated with government, next largest groups were students, private entrepreneurs, and government employees, respectively.

#### Recommendations for Future Guidelines

- Online media including the official websites and social networks should be further encouraged by the government to build community participation around selected initiatives as was done in the recycled milk carton campaign as indicated above
- A communication strategy needs to be built around future similar Guidelines detailing responsibilities for promotion of initiatives and steps needed for successful implementation. The communication strategy has to be tailored to the different target segments – the Participants, the Operators and the Visitors.

### 2.3.2 Impact of ‘Expo Shanghai Online’ and other Media Channels

Expo Shanghai Online was designed as an innovation for presenting a World Exposition. Through touring and experiencing Expo Shanghai Online, visitors were able to interact with the Organizer and the participants on the Internet to suit their different interests and demands, even if they could not visit the Expo personally.

It further promoted awareness of sustainable lifestyle, resource efficiency and low carbon development displays in the Expo, while avoiding to some extent, the transportation pressure during the Expo period, as well as saving extra energy and resource consumption incurred by onsite visits. Approximately 82 million visits to the Expo Shanghai

Online were recorded. This innovation was listed as one of the ten Expo breakthrough technologies by Forbes China and as such will remain live as a public service after the Expo. Although the Expo website was well designed, it lacks some of the criteria for evaluating website effectiveness - communicating the Unique Value Proposition of the site effectively, ability to encourage participation, designing the navigation keeping in mind the Unique Value Proposition and a judicious use of graphics and animation.

In addition to ‘Expo Shanghai Online’, a large number of Expo-related reports, news releases and news features were issued during the Expo to the public through various media channels. According to partially compiled data, more than 150,000 news reports were published by nine local newspapers; over 34,000 reports were broadcasted by radio and TV stations; 17 Expo documentary programmes consisting of 700 episodes were developed and broadcast; and more than 50 major live broadcasts were made during the Expo period.

Between April and October 2010, more than 365 Expo related news release and interviews were organized citywide; according to the search results from Baidu and Google, Expo related Chinese news reports amounted to almost 4 million articles, English reports amounted to almost 400,000 articles. Three million copies of some 50 Expo related publications were also issued to the public which documented and promoted Expo best practice technologies and “software” lessons learned.



Figure 10: Home Page of “Expo Shanghai Online”

In addition some 49,000 video terminals were placed in public buses, metro lines, taxis, large screen panels on buildings, and ferries. These continually provided live Expo news and public service messages. In addition, screens were installed in more than 100,000 vehicles to air environmental public awareness messages, information and promotional pieces on Expo.



Figure 11: Interactive Media Screens in a Taxi and a Bus

### 2.3.3 Impact of Shanghai Expo's Environmental Communications

#### Exhibits in Expo Pavilions:

In alignment with the Expo theme 'Better City, Better Life', the exhibits installed at the various Expo pavilions endeavored to display the various approaches for striking a balance between urban development and a sustainable future showcased in designs and technologies displayed. Therefore, the exhibits and their presentation had some impact on the visitors

attending, who can be categorized as laymen-visitors and specialist (world leaders, architects, urban planners).

The effectiveness of these exhibits in capturing the Expo theme merits detailed study in order to fully determine impacts.

The exhibits and the various pavilions can be classified as Displays of Abstract Concepts, the Exhibit as an Experience, Solutions in Action, and Success Stories according to certain patterns of expression to convey the message of balance between urban development and sustainable future.

Since the message being conveyed is often indicative of future hopes and plans, the exhibit is often a model of bringing alive a vision or showcasing solutions. Therefore the impact of Exhibit as an Experience and Solution in Action are fairly lasting as they give the visitor insights and bring to life unimaginable possibilities and inspire new ones.

While introduction of success stories in different countries and cities may also bring fresh perspective and has the ability of inspiring the visitor in an even more powerful way. Appendix A presents the List of Pavilions and details of the exhibits contained within.

#### Expo Forums

An effectively organized and executed Expo theme communication tool utilized was the Expo Forums. These series of high profile themed interventions successfully presented by prominent leaders of thought in the sustainability arena enunciated the principles underpinning sustainable development.

#### The Forums are summarized below:

##### Theme Forum 1: ICT and Urban Development

Although the United Nations Millennium Declaration has been effective for almost ten years, the digital divide between the rich and poor countries is still expanding.

The Forum explored how existing information technology can be applied to society so as to improve the standard of urban life and how more people from different regions and countries can use information technology to improve their livelihoods.

##### Theme Forum 2: Cultural Heritage and Urban Regeneration

Cultural integration and extension are derived from urban regeneration. While the urban hardware

is drastically enhanced, issues such as how to preserve heritage and advance the innovation of traditional culture should be taken seriously specially by developing countries.

### **Theme Forum 3: Science & Technology Innovation and Urban Future**

Since the industrial revolution, the significant advancements made by human society have always been linked with the development of science and technology. Most developing countries are in the phase of rapid urbanization, during which they are facing pressures not only from deteriorated environments and scarce natural resources.

The vast numbers of developing countries, must rely on scientific and technological innovation and technological progress to promote economic growth and upgrade urban comprehensive competitiveness.

### **Theme Forum 4: Towards a Low-Carbon City: Environmental Protection and Urban Responsibilities**

This Forum, presided over by UNEP Executive Director Achim Steiner covered a wide range of issues involving urban environmental systems as well as the utilization, protection and governance of the environment. These issues, discussed by the government, enterprises and urbanites from three different levels of responsibility, focused on serious global and regional environmental problems involving climate change, desertification, water pollution, etc.

The forum delivered its own explanation to the three questions implied by World Expo that a more harmonious environment would make a better city; that a city actively coping with risks brought by various environmental changes would become better; that a resource-saving and environment-friendly urban development pattern would make our native earth better.

### **Theme Forum 5: Economic Transformations and Urban-Rural Relations**

Economic Transformations are a vital proposition in the world economic theory and practice today. While some traditional industrialized countries are confronted with the challenge of upgrading the industrial structure, more developing countries are confronted with double pressure from both the economic and the industrial structure conversion, in which the key question is how to realize the transformation from a traditional agricultural society to a modern industrial one.



### **Theme Forum 6: Harmonious City and Liveable Life**

As the first Expo in 150-plus years to set 'cities' as the theme, the planning of the Shanghai Expo site, based on the philosophical thinking of 'harmonious cities,' emphasized 3 themes, namely 'People and Nature,' 'People and Society,' and 'History and Future.' How to make the cities more livable is a question faced by city planners and managers.

This forum called on the globe to make communications of ideas, information and best practices so as to clarify urban orientations and future development trends. Additionally, various public forums were also organized targeted at different groups of participants to address a wide range of topics under the Expo theme. These included the Youth Forums, the Autonomous Regional, Provincial and Municipal Forums, Shanghai District Forums, and the Culture and Media Forums among others.

As the highest ranking among the three types of forums, the Expo Summit Forum was held at the close of the Expo, during which the "Shanghai Declaration" was issued as a significant document based on Expo participants' understanding on global urban development. The topic of the Summit Forum was "Urban Innovation and Sustainable Development."

### **Social Awareness of Expo Sustainability**

Based on information provided to the UNEP Review team by the organizers and media articles, the general public became very aware of carbon issues relating to the low carbon Expo, waste management, energy efficiency, water conservation, and sustainability as a whole due to the massive communication campaign leading up to the Expo. As such carbon footprint awareness per capita in Shanghai and its surrounding region is likely to be quite high.

To further reinforce the Expo's sustainability message, the government is continuing to provide subsidies and price incentives to enhance awareness and effect behavior changes in polluting industries (supply side) by financing upgrading or closure of the obsolete industrial processes and consumer (demand side) incentives to change purchasing behavior to greener and more efficient products.

The population has also been made more aware of Green Labels based on production LCAs which the government is attempting to make more reliable and credible.

Forbes China published a research report on the Expo's green technology in May 2010 listing the 10 most promising technologies applied or displayed at the Expo:

- TD-LTE web-based technology – 'information highway';
- Potable water technology – first time in Expo history that the organizer provided potable water on such a large scale. This technology has been further promoted in community development in Shenzhen, Beijing and Shanghai;
- Building Integrated Photo Voltaic;
- Intelligent transportation control system – including the overall system covering monitoring, control, decision-making supporting, charging, emergency response, and service provision, also including the P+R (Park and Ride) guidance system; 'internet of things' technology with transportation control systems which provided wireless video monitoring to all Expo buses, postal automobiles, and communication vehicles;
- 3D display technology – especially applied through Expo Online;
- Eco/Environmental friendly building materials;
- Smart Security Systems;
- Widely used Hydrogen fuel-cell vehicles.
- LED lighting
- "Internet of Things" technology –RFID was applied for the Expo ticketing system, it also applied to track and trace the food supply in Expo Park

### 2.3.4 Catalytic Impact of Expo Theme

A significant number of studies have been completed or are currently in process, undertaken by various Expo and city departments based on surveys completed in the Expo Park and elsewhere to evaluate the catalytic impact of the Expo theme. The catalytic impacts of the Expo theme will take many years to study and fully realize. However based on media articles and study information provided to the Review team already some trends are observed:

**Largest catalytic impacts:** cross department and cross city cooperation, joint efforts lead to successful outcomes not only for the Expo period, but also with long term benefits. The synergistic effects of government departments sharing information and responsibilities in preparation for, and operation of the Expo have resulted in close collaboration in further development activities. Different departments now are also collaborating as stakeholders on joint projects and collecting feedback to ensure consistent and sustainable results;

**Expo Park:** designed as a large incubator and testing site for technologies and ideas and a platform for the whole world to share and to learn. Successful experiences are being documented, shared and promoted;

**Expo Exhibitions:** capturing and displaying the Expo theme, the most efficient way to educate the 70 million visitors and through different media channels, promote low carbon and sustainability concepts and best practices from around the globe. The potential impact of this critical component is discussed below;

**Public Participation:** Significant participation and contribution from NGOs such as WWF, EDF among others, to show the effectiveness of NGO cooperation in promoting environmental protection and low carbon development. The Green Commuting Card is a good example of an NGO lead initiative with major impacts. The involvement of NGOs has broadened public participation and will leave an important Expo legacy not only for visitors, but also for Shanghai citizens and particularly the government.

Specific examples that have so far been noted include:

- Circumstantial evidence based on records of requests from various agencies across China indicates that a broad range of planning

departments from the Yangtze Delta and elsewhere in China have visited the Expo and consulted with their counterparts in Shanghai and are incorporating some of the lessons learned in their planning process;

- Some Shanghai districts such as Jiading have already started waste recycle industries inspired by Expo exhibits that collect food cartons and other composite wastes and process them into commercially viable paper products;
- Volkswagen has entered into cooperation with the Bremen Pavilion and is proposing launching a 'Car Sharing Programme' in Shanghai; and
- Many Shanghai district governments have initiated cooperation with UBPA case pavilions for building new affordable housing in Shanghai, applying more green building concepts and best practices.

A significant catalytic impact of the Expo theme is related to the effort and structural changes that Shanghai instituted in its preparation.

As a result and as mentioned in the pre-Expo report and elsewhere in this report, the Yangtze Regional

Environmental Agreement has resulted in region wide coordination on air quality monitoring and industrial pollution with Jiangsu and Zhejiang provinces and it is being expanded farther afield.

Jiangsu and Zhejiang are establishing organizations akin to the SEPC at the provincial level and have already established liaison counterparts with the SEPC secretariat in SEPB.

In addition, as the cooperation expands it is anticipated that water quality issues will be included in the cooperation framework as the biggest challenge for downstream provinces along the Yangtze River is discharges from upstream provinces all the way up the river course.

It is too early to evaluate the true impact of the Expo theme on the sustainability behavior in Shanghai or elsewhere, however based on the awareness observed in Shanghai and the Yangtze Delta and the innovation that has been inspired by the Expo in the government, State Owned Industry, private industry and society at large it is likely that some major outcomes will be observed within the next five years.

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The involvement of NGOs has broadened public participation and will leave an important Expo legacy not only for visitors, but also for Shanghai citizens and particularly the government





Chapter  
**3**

Environmental  
Technologies &  
Systems

# Environmental Technologies & Systems

The decade-long preparation for the Expo provided various government departments with the focus to both develop the Municipality and design an exceptional Expo.

The Expo thus became an early stage driver and major milestone for a multi decade process. Now that the Expo has passed, the lessons learned are being captured and analyzed for inclusion in short and long term plans over the next three to five years and beyond.

Thus according the SEPC secretariat the next Three Year Action Plan will particularly focus on:

- Capturing and institutionalizing Expo lessons at all levels;
- Internalizing lessons to cause behavior changes in the government and its agencies.

The latter point is recognized as the most challenging issue.

Technology can be developed and implemented, however ideas and software are needed to make technology successful. To encourage this process, civil society including local NGOs, local organizations and web-based fora has been given platforms for participation and comment as a major stakeholder in the process of behavior changes.

One of the key agencies that provided the research backbone for the Expo preparation was the Science and Technology Commission of Shanghai Municipality



(STCSM), which undertook extensive technology application research in preparation for the Expo, supported by the Ministry of Science and Technology of China (MOST), in the following fields:

- Urban Planning;
- Efficient Building Design and Construction;
- Environment;
- Energy;
- Operations Management;
- Security;
- Exhibitions.

Hundreds of research institutes, universities and academies were included in the research programmes which engaged tens of thousands of researchers.

Some 1,500 major outputs were realized including a large number of patents in ecological building practices and materials, wetland water treatment, water body recovery, solar energy and LED lighting and new energy vehicles among many others. All these activities contributed significantly to the low carbon Expo and created a region wide incubator for eco-development industries.

In addition, MOST and STCSM managed transport management and monitoring technology and web based Expo sites. The scope of showcased technologies in the Expo was so extensive that Shanghai Municipal Government is planning to promote the learnings and research broadly to maximize valuable applications for development in Shanghai and elsewhere.

The purpose of this section is two-fold: at a micro context, to assess the technologies in terms of their influence on the Expo's environmental impact; and, from a macro perspective, to assess their potential for transforming the environmental quality of the city and nation by comparing their relative efficacy through a common performance indicator (Greenhouse gas mitigation).

In this sense, the Expo can be viewed as a sustained pilot project for technological assessment of the most cutting-edge and promising environmental interventions on the horizon or in nascent stages of adoption.

In many instances, as will be demonstrated in the sections below, the 'cutting-edge' is essentially the latest principles espousing resource conservation, recycling, and replication of natural ecosystems to serve the developmental and environmental needs of urban areas.

## 3.1 Energy Technologies

The 11th Five-Year Plan (2006-2010) targeted 20 per cent average reduction in the energy consumption per unit of GDP in 2010 (compared with 2005). This was mirrored in the city's overarching development vision. Furthermore, at the UN Climate Change Conference 2009 Conference of Parties (COP15) in Copenhagen (Denmark), China announced as part of the Annex to the Copenhagen Accords that its carbon emissions per unit of GDP would be reduced by 40-45 per cent in 2020 compared to 2005 levels.

While the Shanghai Expo did not set an explicit goal to aid in meeting these targets, the role played by it as a landmark urban reform project for Shanghai made it an ideal case study for developing a blueprint for future city and national policies to facilitate the above mentioned goals.

The Expo showcased a very broad range of conventional and renewable energy technologies whose performance shall be discussed below. The technologies used represented a balanced mix of interventions targeted initially at minimizing the energy demand (i.e. demand-side management) on which the next layer of interventions based on clean energy alternatives rested. This two pronged approach is a robust approach for mitigating environmental impacts of developmental activities.

Impacts of various demand and supply side energy interventions applied in the Expo and city-wide as well as their roles as enablers towards a lower energy and GHG intensity was also evaluated. The outcomes yield meaningful lessons to help frame effective and competent development policies. This section aims to consolidate the impact of the energy technologies and seeks to assess their current and sustained impact on the overall energy and GHG intensity of Shanghai.

### 3.1.1 Evolution of the Energy Mix (Supply-Side Alternatives)

As more than 99 per cent of primary fuels (coal, oil, gas) are imported into Shanghai, the municipal government is committed to optimizing its energy structure, not only for energy security, but also to reduce its environmental impacts. By the end of 2009, coal consumption was reduced to 42.6 per cent compared

with 49 per cent in 2005 and natural gas consumption rose from 3.0 per cent in 2005 to 4.2 per cent in 2009.

Additionally, more than one third of Shanghai's electricity is imported. A newly completed hydropower supply from Sichuan is a direct benefit from the Expo preparations since the project was accelerated by two years to ensure it could contribute to the low carbon Expo. Since completion of this project more than half of Shanghai's external power supply has been generated from clean sources.

To continue the trend of generating cleaner energy, Shanghai Municipal Government aims to reduce coal consumption for all energy generation by increasing efficiency and substituting for cleaner energy sources.

Regarding renewable energy development, Shanghai recently launched an ambitious renewable energy programme and has already installed 200MW of wind power, 15MW solar, and 40MW biomass. Over the next Five years offshore wind installation is planned to reach a minimum of 200MW. Other wind power installations are also planned on-shore. Shanghai is also exploring water/ground based heat pumps and the potential for tidal energy.

### 3.1.2 Energy Efficiency Management (Demand-Side Management)

Demand side energy conservation has been linked to economic development as part of the recently launched 12th Five Year Plan.

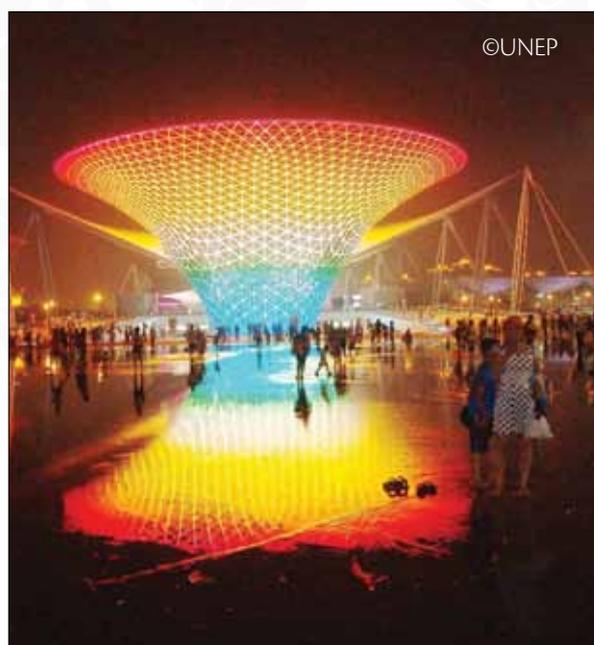
Detailed policies are being issued which require the municipal government and each district to have an energy efficiency monitoring office and sustainable efficiency targets that need to be achieved within the plan period. Performance evaluation of leaders at each level includes effectiveness of efficiency targets achieved.

- Energy Performance Certification, a verification system for energy conservation is being piloted and an incentive fund has been established to support upgrading of industries and industrial processes to achieve long term efficiencies.
- As stated in the previous assessment report, Shanghai has been addressing supply side efficiency improvements for almost a decade as such low hanging fruit has been harvested. Further efficiencies would require advanced management and control systems in support of cleaner

production and "circular economy" – i.e. systems integration, for smaller increments of improvement. As such demand side efficiency measures may result in greater benefits per unit of investment.

To date, with the city-wide efforts in almost all sectors and industries, the comprehensive energy intensity has been reduced from 0.89tce/ 10,000RMB in 2005 to 0.71tce/ 10,000RMB in 2010. The 20 per cent energy conservation target required by the 11th Five Year Plan was achieved indicating the city fulfilled its contribution to the national agenda of meeting its commitments to the UNFCCC.

### 3.1.3 Impact of Energy Efficiency Technologies Applied in the Expo



#### 3.1.3.1 Energy Efficient Lighting

##### LED Lighting

Light Emitting Diode (LED) lighting was used in 98 per cent of the Expo buildings and 80 per cent of the nightscape lighting at the Expo. It was also used in Expo Line-1 buses with ten 10-W lights in each vehicle.

LED Lighting is known to be 50 per cent more energy efficient (on a lum/W basis) relative to CFL Bulbs; CFL Bulbs are 75 per cent energy efficient relative

to Incandescent (GLS) Bulbs. Furthermore, the lifespan of LED bulbs is significantly longer (generally 25,000 hours) compared to GLS Lamps (generally 1,500 hours) and CFL Bulbs (generally 8,000 to 10,000 hours).

A detailed Carbon Footprint mitigation analysis for LED lighting was undertaken. With a rough estimate of a total of 30 MW installed capacity of LED lighting for the entire Expo site, the total electricity conservation and carbon footprint mitigation during the Expo was estimated to be 232 MU (million units or million kWh)<sup>3</sup>. The lifetime electricity savings is estimated to be 5,250 MU<sup>4</sup>. Manufacturing impacts deduct 0.2 per cent of the overall energy efficiency related beneficial impacts of LED lighting use<sup>5</sup>.

#### CFL and Energy Efficient Halogen Lighting

Compact Fluorescent Light (CFL) bulbs were used extensively at the Expo, especially at the Theme Pavilion while Efficiency Halogen Lighting was used at the Expo Centre.

Each CFL is estimated to conserve 75 per cent electricity relative to the BAU ( GLS Lamps ), and design specifications indicated the Lighting Power Density (LPD) of Halogen Lighting was 9W/m<sup>2</sup> at 300 Lux – this was approximately 18 per cent lower than national standard for LPD of 11w/m<sup>2</sup>.

### 3.1.3.2 Air Conditioning Energy Conservation

#### Gas-Fired Air Conditioners

Natural Gas based Air Conditioning (using absorption chillers functioning on the same cooling cycle as electric chillers) was used on a wide scale at the Shanghai Expo through technology and equipment installed by the Broad Corporation. The entire AC load, except the load addressed through river-water source and geothermal heat pumps for the Expo was met through this technology. The total cooling output of Gas Fired Air Conditioning was estimated at 22,083 tons<sup>7</sup>. A detailed analysis indicates that the avoided

3 ignoring manufacturing related LCA impacts.

4 lifespan of LED lighting (25,000 hours) extends well beyond the estimated 1,104 hours consumed during the Expo.

5 excluding manufacturing LCA impacts.

6 manufacturing LCA Carbon Footprint for this installed capacity was 9,928 tons CO<sub>2</sub>e.

7 AC tonnage was based on a cooling load of 114,054,774 kWh and estimates of daily consumption (accounting for natural ventilation periods etc.



GHG emissions during the Expo period was 6,730 tons CO<sub>2</sub>e.<sup>8</sup> Absorption Chiller based AC technology has great promise for Shanghai if it can be designed to use waste heat (as opposed to primary fuels) from industrial sources to meet cooling needs – turning a source of urban heat island effect into an energy conservation measure.

#### Thermal-Storage ACs

Thermal storage air conditioning technology was used at some of the largest pavilions at the Expo; China Pavilion, Expo Culture Centre and Expo Centre. This technology relies upon standard chillers operating at off-peak hours to produce ice around which water is circulated through heat-exchanger systems during peak hours to produce chilled water that is circulated through the buildings HVAC systems.

The primary impact of thermo-storage ACs was the reduced peak electrical load imposed on the grid relative to a conventional compressor based systems which draw maximum power during the afternoon peak cooling load periods. If applied on a large scale, the technology can also reduce environmental impacts by avoided construction impacts and reduced capacity

8 natural gas has a lower GHG EF per unit of equivalent energy relative to the coal-dominated Grid electric power in the East China Electric Grid, and hence this cooling strategy yielded significant Carbon Footprint benefits.

9 excludes manufacturing LCA-based impacts.



rotodynamic pumps (such as centrifugal pumps etc.)<sup>11</sup>.

Besides drastically reducing energy consumption, the intervention also has beneficial impact on the longevity of pump impellers and other equipment which materialize as the indirect environmentally beneficial impacts of the technology.



### 3.1.4 Impact of Renewable Energy Technologies Applied in the Expo

#### 3.1.4.1 Solar Photovoltaic Systems

Photovoltaic (PV) panels were used widely at the Expo as source of renewable energy to reduce dependence on grid electricity.

The approximate scale of Solar PV at the Expo was estimated to be 4.69 MW from permanent pavilions and a total of approximately 4.82 MW including

11 energy efficiency is achieved by eliminating flow control valves to throttle flow and instead using variable-frequency drives to provide continuous control to match motor speed to the specific instantaneous head requirement.

temporary pavilions. This excluded the stand-alone panels that were installed across the entire Expo Park for street-lighting and other area lighting purposes. The total installed capacity included multiple different solar technologies including Building-Integrated Solar and Thin-Film Solar Technologies.

Innovative Solar electricity generation applications in the form Ultra-Light membrane (ETFE) skin embedded solar cells at the Japan Pavilion<sup>12</sup>, Dye Sensitized Solar Cells at the Swiss Pavilion as well as Building-Integrated Solar PV at the Shanghai Eco House were showcased at the Expo. A detailed analysis of Solar PV at the Expo indicates a conservation of 2.29 MU electricity.

The lifetime electricity savings is estimated to be 113.5 MU<sup>13</sup>. Manufacturing impacts deduct approximately 10 per cent of the overall mitigation of solar PVs.<sup>15</sup> Thus, the energy payback or carbon payback period for Solar PVs is approximately 2.5 years of its lifespan.

#### 3.1.4.2 Solar Thermal Water Heating Systems

Solar Thermal Water Heating systems were applied at the Expo Centre, Shanghai Eco House and the London ZED Pavilion. The total solar thermal system processing capacity of the Expo was nearly 45.9m<sup>3</sup>/day of water<sup>16</sup>. A detailed analysis for the Expo Centre indicates that Solar Thermal Water Heating system saved approximately 202,463 kWh of electricity. The analysis emphasized the significantly superior specific power generation of Solar Thermal Flat Plate Collectors relative to Solar PV technology (discussed earlier) under Shanghai's temperate climatic conditions. On a per unit area basis, the analysis revealed that Solar Thermal Flat Plate Collectors with 55 per cent thermal efficiency can be expected to generate approximately 610 W/m<sup>2</sup><sup>17</sup>. This is six times higher than the specific power generation by Solar PVs under identical climatic conditions which is estimated to be approximately 102 W/m<sup>2</sup>.

12 installed capacity of 16.74 kW.

13 excluding manufacturing LCA impacts.

14 lifespan of solar PV modules extends well beyond the 184 days consumed during the Expo – to approximately 25 years.

15 manufacturing LCA related Carbon Footprint creation for this installed capacity was 10,601 tons CO<sub>2</sub>e.

16 hot water processing rate for the Expo Center was 35 m<sup>3</sup>/day, London ZED pavilion was 10m<sup>3</sup>/day, and Shanghai Eco House was 900 litres per day.

17 leading to and 459 kWh/m<sup>2</sup>/year energy generation.





### 3.1.4.3 Solar Air Conditioning Systems

An emerging technology, Solar Air Conditioning, was employed at the United Arab Emirates and Madrid Case Pavilions. Similar to Gas-Fired ACs discussed below, Solar Cooling systems rely upon heat as the energy input as opposed to electricity, and employ Thermal Compression technique instead of Mechanical Compressors.

A notable advantage of this technology relative to other Solar-based systems, is that it operates by harnessing Solar Heat energy through parabolic Solar Concentrators.

While LCA data for this highly-engineered aluminum-based technology is not available for conducting a comprehensive analysis, it is anticipated to yield relatively high specific energy generation per unit area (similar to Flat Plate Collectors with Solar Thermal Water Heating) relative to Solar PVs, for instance.

While this technology promises significant potential for mitigating GHG emissions from electricity generation, its complete Life Cycle Impacts relative to other Energy Efficient AC systems needs to be studied rigorously before application on a wider scale.

### 3.1.4.4 Wind Energy

Small scale wind power technology was used sporadically at the Shanghai Expo. The wind power installations along with their design capacities (contingent upon available data) as well as total energy generation during the Expo are presented in Table 4.

**Table 4:** – Wind Energy Installations at the Shanghai Expo

Pavilion	Design Capacity	Power Generation
Indian Pavilion	3 kW	Not Known
State Grid Pavilion	3.2 kW	Not Known
Madrid Case Pavilion	1.7 kW	Not Known
London ZED Pavilion	Not Known	Not Known
Shanghai Eco-House	3 kW	Not Known
Urban Future Pavilion	8 kW	90.9 kWh

While the pre-Expo assessment report delineated extensive plans at the city level to increase wind energy in the city's energy mix, the Expo was not a notable showcase of this technology. This is evident from the relatively slim dependence and contribution of this technology (in the vicinity of 100 kWh) to the overall energy consumption of the Expo.

In addition to the above, a few other installations were demonstration scale wind-solar hybrid-power projects such as the car "Leaf" in China Pavilion, the small power generator in front of Japan Pavilion, and two boats made by Jianglong Ship Company for Expo Park. It is noteworthy that the manufacturing emissions for wind farms were estimated to be 1.4 per cent of the lifetime GHG emissions savings during operation. This is significantly lower than the ratio for monocrystalline Solar PV wherein the share is estimated to be approximately 10.4 per cent.

In view of the fact that Shanghai's 2020 vision of wind energy development includes four more offshore wind farms in the coming decade, LCA analysis allows categorical endorsement of this emphasis on wind energy relative to solar (where both options are equally relevant) owing to the lower manufacturing emissions per unit power generated.

### 3.1.4.5 Geothermal (River Water) Cold-Storage/Heat Pump

Geothermal (River Water) Cold-Storage/Heat Pump technology was used on a wide scale at the Shanghai Expo as an alternative to conventional electric compressor based Air Conditioning systems<sup>18</sup>.

Design and performance parameters of the installations (contingent upon available data) as well as an analysis of the avoided GHG emissions were examined.

The total rated geothermal and river water source heat pump capacity of 91.4 MW (26,062 tons air conditioning) generated a total cooling energy of 54,883,541 kWh and the avoided electricity consumption during the Expo was 2.94 MU<sup>19,20</sup>.

Thermal pollution impacts of rejected warm water from the cooling cycle into the Huang Pu River were studied by Shanghai's Tongji University to ascertain the possible impacts on aquatic life.

The modeling showed that even during the low Flow Period when the warm effluent has the highest influence on Huangpu River, the general temperature rise (weighted average) was only 0.46° C, lower than the regulated maximal weekly-average temperature rise in summer 1° C according to "Surface Water Environment Quality Standard" of China.

### 3.1.5 Learning from the Expo

Based on Expo lessons learned, the Shanghai municipal government is considering issuing action plans for the following which have been included in the municipal 12th Five Year Plan:

- Promoting installation of renewable energy plants, In the 12th Five Year Plan: Shanghai is planning to increase the share of non-fossil fuel to 12 per cent in its energy mix;
- Migration to cleaner fuels in the energy mix will be accelerated with substitution of natural gas for coal

18 heat/cooling source was 70% water; 30% ground. For all other pavilions, the heat/cooling source was River Water.

19 after accounting for the internal system energy consumption.

20 analysis excludes manufacturing LCA-based impacts.

in selected power plants. No additional traditional coal power plants are planned;

- The ongoing conversion of the old coal power plant to a fully gas power plant on Chongming Island shall be completed by 2015. Any additional power needs on the island shall be supplied through the grid to minimize environmental impacts;
- Mandatory cleaner production audits for key industries shall be expanded. High energy consumption will trigger audits;
- The re-use of industrial wastes such as steel slag, power plant fly ash and lime from FGD will continue and increase (current re-use ratio for 18 million tons is 97.8 per cent);
- Recycling and reuse of waste heat, gases and industrial waste water shall be increased during the five year plan and proven approaches will be expanded.

### 3.1.6 UNEP recommendations (Energy)

Continue promoting enhancement of thermal power plant technology from conventional pulverized coal to supercritical coal technology as it compares very favorably with other renewable energy based interventions in terms of improving the energy mix of the city. Aggressively pursue LED and CFL lighting programmes keeping in mind the comparative marginal abatement costs of the two technologies.

Promote **Gas Fired Air Conditioning** such as those used at the expo for large scale applications as opposed to conventional electric AC systems.

Create economic disincentives to prohibit commercial entities from drawing peak-demand-period power for air conditioning purposes and incentivise **Thermo-storage AC systems** at all such facilities. City-wide savings from such technologies can help establishment of a 'green-fund' from which capital improvement programmes for less financially rewarding but imperative environmental technologies can be funded.

Establish benchmarking or ecolabelling of **Solar PV system** manufacturers to differentiate best-practice leaders and mandate transparent disclosure of energy, water consumption and waste generation data from manufacturers.

**Solar Thermal Water Heating** represents a far more efficient use of rooftop area for building energy



The Expo can be viewed as a sustained pilot project for technological assessment of the most cutting-edge and promising environmental interventions on the horizon or in nascent stages of adoption

conservation relative to Solar PVs and must be given immense policy support to enable widespread adoption of the technology in the residential and commercial sector.

**Energy payback periods for offshore-wind technology** are significantly lower than for monocrystalline Solar PV. The government should emphasise off-shore wind energy relative to solar PV technology (where both options are equally relevant) for Shanghai City.

**Geothermal and river water source heat pump technology** must be intently pursued especially in regions of the city adjacent to river water sources.

**Ducted Evaporative Air Cooler Systems** must be studied for their feasibility in Shanghai and adopted in large scale applications wherever possible to yield significant energy savings relative to conventional central AC systems.

## 3.2 Construction Technologies & Practices

Shanghai issued 21 construction energy standards during the preparations for the Expo impacting the major infrastructure construction programmes that characterize Shanghai today.

The Expo Centre was one of the Expo's flagship 3-Star certified Green Buildings under the National Green Building Certification Programme. It has also passed the pre-assessment criteria for U.S. LEED Gold Award.

The Expo provided a platform to showcase and evaluate many domestic and international green construction and energy efficiency/monitoring technologies. These have been examined in some detail by the Shanghai Municipal Government and many other cities in China.

Since energy consumption in commercial buildings operations are known to be a significant contributor to global GHG emissions, green building technologies are given serious consideration in this analysis on par with the previously discussed environmental technologies.

The Review seeks to underscore the imperativeness of integrating energy efficiency and renewable energy

technologies with low-carbon, energy efficient building designs to maximize environmental benefits. Implementing merely one aspect while ignoring the other would represent a lost opportunity by urban planners, architects and policy makers alike. A summary table of the Green Design and Construction practices used at the Expo are presented in Appendix B.

### 3.2.1 Energy Efficient Construction Practices

Modular / Reusable construction elements, Modular Built-Space Volume Reduction, Prefabricated Balcony, cells and construction panels were examples of some of the unique construction techniques used at the Norway Pavilion, Expo Culture Centre, Shanghai Eco-House, Finland Pavilion, Broad Pavilion, and Japan Pavilion to minimize construction, dismantling and operational energy consumption.

Prefabricated elements had a direct impact on the ease, pace and energy requirement during the construction and post-Expo dismantling phases. The prefabricated balcony at the Shanghai Eco House was estimate to reduce construction waste generation for its erection by 40 per cent.

Modular design elements incorporated in the Expo Culture Centre to enable the creation of optimal spatial volumes, catering to the needs to events and gatherings of various sizes, was an intervention that resulted in dramatic reductions in energy consumption from HVAC operations. Reducing air volume yielded commensurate reductions in the cooling and heating load imposed on the HVAC system.

Despite lack of quantitative data, these technologies are seen to have a palpable beneficial influence on reducing the environmental impact of the Expo's operations.

### 3.2.2 Low Embodied Carbon Construction Materials

A broad range of construction materials with low embodied carbon levels was used widely in the Expo. Given the high manufacturing GHG emissions impact of conventional construction materials (cement, steel,

glass and aluminium), their reduced use stemming from alternative construction materials had a significant mitigation impact on the Expo's Carbon Footprint. The primary alternative materials used at the Expo, for structural and non-structural purposes, were Bamboo, Hollow Silt Bricks, Inorganic Insulation Mortar, Low Carbon Concrete, Reinforced Hollow Bricks with fly ash, Synthetic Gypsum Plates (recovered material from power plant slag).

A review of embodied GHG emissions for construction elements using cement and brick substitutes i.e. Hollow Silt Bricks, Reinforced Hollow Bricks with fly ash indicates that carbon emissions of mud bricks is approximately 90 per cent lower than conventional brick<sup>21</sup>. Also, reuse of power plant slag in the form of gypsum plates can also greatly reduce the embodied Carbon emissions relative to conventional insulation materials.<sup>22</sup>

Bamboo was used as an alternative construction material at the Indonesia, Madrid Case, Rhône-Alps Region, India and Norway Pavilions. Analysis indicates that the use of bamboo in the dome of India Pavilion reduced structural steel use by approximately 80 per cent, cement use by 50 per cent, reinforcement steel by 50 per cent and eliminated the aluminium use. The overall weight of the dome was also reduced by 25 per cent thus having further beneficial implications related to reduced foundation weight and consequently reduced concrete utilization for its construction.



21 Conventional bricks have a GHG EF 0.23 kgCO<sub>2</sub>e/kg whereas that of soil is approximately 90% lower (0.023 kgCO<sub>2</sub>e).

22 According to research conducted by Sustainable Energy Research Team (SERT) in the Inventory of Carbon & Energy (ICE – Version 1.6a),

Construction impacts were also greatly dependent on building design, post-use plans for the construction materials, and dismantling practices adopted during post-use site clearance.

Impacts were greatly mitigated by designing structures that are modular and composed of easily reusable materials wherein no energy intensive processes were involved in re-deploying them at other construction sites.

The Expo endeavoured to implement this practice of modular design and reusable materials in many instances. Pavilions which utilized principles of material reuse, recycled and recyclable materials, and modular construction are listed in Appendix B

The Expo was a showcase for the use of recycled and recyclable materials in many instances. However, these must not be construed to be zero-environmental impact construction alternatives. Construction material recycling processes are often energy consuming processes - the impact of steel recycling is approximately 15 per cent of virgin steel, glass recycling is 33 per cent of virgin glass production and aluminium recycling is 14 per cent of virgin aluminium production.

It is therefore recommended that material reduction and reuse always be accorded higher priority over use of recycled or recyclable materials.

### 3.2.3 Heating & Cooling Efficiency Materials and Systems

#### 3.2.3.1 Building Materials and Systems

Building materials designed to reduce solar heat gain, heat loss, and enhance the insulation properties of pavilion spaces were widely used at the Expo. Energy efficiency related interventions, largely focused on demand side energy managements, used are briefly described and analyzed below.

Additionally, Double-Layer Water-Curtains (used at: The Alsace Case) and Thermal Insulated Window Frames and Thickened Walls Used at the Broad

Pavilion<sup>23</sup>. These interventions can be considered passive energy efficiency interventions as opposed to electro-mechanical equipment based interventions. GHG mitigation costs for passive energy technologies are more favourable relative to capital intensive equipment based interventions which involve extensive equipment overhaul<sup>24</sup>.

While specific data related to these technologies was not available for the Expo, it is likely that passive energy efficiency elements have a more lucrative cost payback and reduced manufacturing related LCA impacts relative to equipment based interventions per ton of GHG mitigated.

#### Double and Triple-Glazed Windows

**Used at: China Pavilion, Shanghai Eco-House, Theme Pavilion and Broad Pavilion (Triple Glazed)**

Double and Triple-Glazed Windows were applied for demonstration as well as functional purposes at the above pavilions to enhance insulation properties and thereby reduce the operational energy requirement of buildings<sup>25</sup>.

The advantage of these insulation methods compared to window systems that rely on solar reflection (such as tinted and coated window films) is they achieve heat gain reduction without greatly compromising visible light transmission.

Solar reflection based systems, while achieving comparable heat gain reduction, are compromised by the increased interior lighting load necessitated by their application.

A detailed review of the properties of Double and Triple Glazed Systems was undertaken. The analysis leads to the conclusion that heat gain/loss can be reduced by approximately 50 per cent to 75 per cent relative to Single Pane Glass Systems.

GHG emissions associated with manufacturing these systems utilizing high-embodied Carbon materials such as high thickness engineered glass, inert

<sup>23</sup> no technology analysis was possible for these technologies due to insufficient technical literature or site measurement data.

<sup>24</sup> Source: Pathways to a Low Carbon Economy (Version 2 of the Global Greenhouse Gas Abatement Cost Curve, McKinsey & Company, 2009).

<sup>25</sup> Double glazed windows consist of two panes of glass with a space between the panes wherein air or other inert gases such as Argon or Krypton are trapped between the panes of glass to form a layer of insulation. Double glazing windows when compared to single glazing windows reduce heat loss/gain significantly due to the insulating air space between the glass layers. Similarly, triple glazed windows are a standard double glazed window unit with an extra pane of thin glass inserted in the cavity between the other two glass planes.

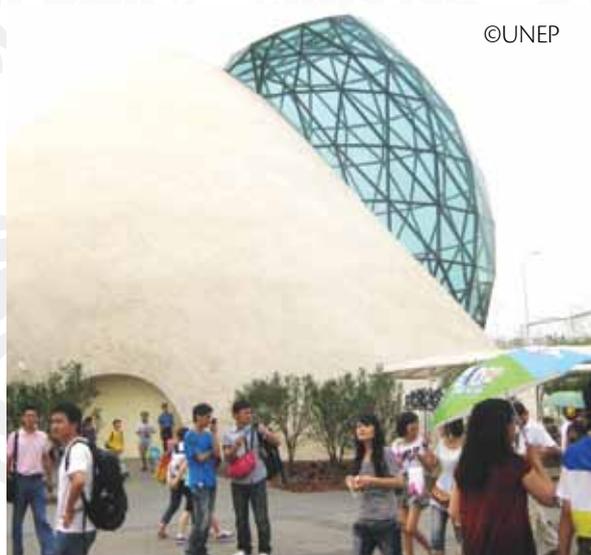
gases, PVC and aluminium frames relative to single pane timber-framed window systems must be assessed before widespread application<sup>26</sup>.

### Heat Gain Reducing Paint & Insulation Foam

#### Used at: China and the Rhône-Alps Region Case Pavilions

Paint technology that has the ability to reflect heat causing infrared rays from solar radiation was applied at the China and Rhône-Alps Region Case Pavilions to help reduce the internal temperature of the building i.e. reduce heat gain.

Compared to ordinary exterior wall paints, these paints are approximately twice as effective in curbing building wall temperature rise due to solar radiation.<sup>27</sup>



### Natural Lighting – including Dormer Windows, Skylights, and Transparent Cement.

#### Used at: Spain, British, Holland, Italy, Israel, Japan, Singapore, Vanke and Theme Pavilions, the Madrid, and Odense Case, Expo Culture Centre, Expo Axis and Shanghai Eco-House .

26 Center for Energy Studies and Research (CESR, India) studies indicate that Weather Shield Paints (i.e. solar reflective paints) can reduce the temperatures of walls by up to 5°C and that reflectivity rate for solar radiation through these paints is 0.40 relative to ordinary exterior wall paint which exhibit a reflectivity rate of 0.21

27 use of single-pane windows to promote natural lighting must be largely avoided since they reduce insulation effectiveness of the building envelope. Triple-glazed windows to promote natural lighting does not detrimentally impact insulation properties of the structure. Double-Glazed windows, though greatly insulated relative to single pane glass windows, still have poorer insulation properties relative to insulated walls

Natural lighting through dormer windows, skylights, and transparent cement as well as optimal positioning of windows can reduce the lighting load incorporated into building design.

This intervention has the twin beneficial impact of reducing manufacturing related LCA impacts of lighting fixtures as well as reducing energy consumption. Some green architecture guidelines specify design lighting loads in the vicinity of 7.5 W/ Sq.m. For building occupancy of 10 hours/day, the average annual electricity conservation and GHG emissions mitigation per sq. m of naturally lit space relative to conventionally lit space is estimated 27 kWh/sq.m and 24 kgCO<sub>2</sub>e/sq. m.

Reducing energy consumption of buildings requires an understanding of the balance between natural lighting benefits of a window system and their relatively poorer insulation effectiveness compared to masonry walls.<sup>28</sup>

In general, it is recommended that comprehensive energy modelling be conducted for alternative window-wall ratios as well as their inherent insulation properties for any proposed structure in order to achieve maximum operational energy efficiency.

This commendable approach to rational design choices was exemplified in the case of the Hamburg House at the Expo and must be replicated widely in building design for all future constructions planned in the city.

### Natural Ventilation

#### Used at: Baosteel Stage, China Aviation, China, Finland, Holland, Italy, Japan, Saudi Arabia, Singapore, Spain, Vanke, State Grid and Urban Future Pavilions; Shanghai Eco-House, The Hamburg House, and The Makkah and Mina Case.

Natural ventilation by creating air currents through open walls and from under floor spaces, channeling through hollow support pillars and stairwells were some of the ways in which natural ventilation was used in the Expo. Other pavilions used semi-porous exterior shells made of cane.

As in the case with natural lighting, natural ventilation has the twin beneficial impact of reducing manufacturing related LCA impacts of HVAC systems

28 According to Sustainable Energy Research Team (SERT) in the Inventory of Carbon & Energy (Version 1.6a), 1.2m x 1.2 m windows have embodied GHG emissions as follows: Single-Pane Timber Framed (i.e. baseline windows): 14.6 kgCO<sub>2</sub>e, 2) Double-Glazed Aluminum Framed (Air or Argon filled): 279 kgCO<sub>2</sub>e, Double-Glazed PVC Framed (Air or Argon filled): 110 to 126 kgCO<sub>2</sub>e.

(by either eliminating it in some spaces or reducing the design capacity) as well as reducing energy consumption.

While quantitative data on the electricity conservation and consequent GHG emissions mitigation impacts were not available for all natural ventilation installations at the Expo, a detailed analysis conducted by the Low Carbon Research Centre of SAES for the China Pavilion is illustrative of the beneficial impacts of natural ventilation systems relative to conventional forced ventilation systems<sup>29</sup>.

The primary savings from natural ventilation systems were the consequence of reduced power consumption for air handling unit fans. It was learned that natural ventilation based HVAC systems resulted in approximately 8.2 per cent energy savings relative to forced ventilation systems under spring weather conditions<sup>30</sup>.

### **Sunshading – including Dougong Brackets**

**Used at: China, Broad, Theme, Holland, and South Korea Pavilions; the Expo and Culture Centres; London Zed Pavilion, and Shanghai Eco-House.**

Sunshading, either through intrinsic design features such as Dougong Brackets (a design feature wherein the higher roof area to floor base ratio limits the heat gain caused by 45 degree solar radiation, i.e. the maximum diurnal solar influx) or through smart controlled window shades (to block sun rays during periods of high solar intensity) were used widely at the Expo.

The total quantity of Sun Shading devices used at the Expo Centre was 8114 m<sup>2</sup><sup>31</sup>. This technology is strongly recommended for future energy modelling studies.

<sup>29</sup> Modeling analysis conducted for a 90 day period revealed that natural ventilation resulted in approximately 486,000 kWh of electricity conservation and a GHG emissions mitigation of 429 tons CO<sub>2</sub>e. Energy modeling assumptions: Fan Power Consumption (baseline case) = 0.2 W/m<sup>3</sup>, 4.5 air volume changes/hour; Total Air Volume = 600,000 m<sup>3</sup>, system usage = 10 hours/day.

<sup>30</sup> natural ventilation was seen to yield negative energy benefits (i.e. increased energy consumption) during summer conditions where modeling results indicated a increase of energy consumption of 23.4% owing to the hotter outside air temperatures. It is therefore recommended that natural ventilation systems have sophisticated control systems wherein their operation can be discontinued under hot weather conditions wherein energy consumption could actually increase relative to forced ventilation operations.

<sup>31</sup> Energy modeling analysis has not been conducted to understand impact on mitigating Air Conditioning load of the interior environments as well as the possibility of increased lighting load requirements arising from reduced natural lighting.



## **3.2.3.2 Water-Based Cooling**

### **Direct Evaporative Water-Spraying Technology**

**Used at: China, Japan and Meteor World Pavilions**

This essentially comprises of spraying water on exterior building walls to reduce the temperature of the interior environment and thereby reducing Air Conditioning load and increasing operational energy efficiency of the built space. In the case of China Pavilion, the pumps used for the system were powered by solar PV systems, thereby increasing the energy efficiency of the system.

This system worked well during the dry, hot days of the Expo operation period due to the enhanced evaporation rate of the water sprayed. An analysis conducted by the Low Carbon Research Centre of SAES for the China Pavilion concluded that for per litre of water sprayed, the energy conservation due to cooling load reduction was approximately 0.71 kWh/L and the GHG mitigation was approximately 0.62 kgCO<sub>2</sub>e/L.

Even if grid electricity as opposed to solar power is used for spray pumps, this technology offers far greater energy conservation benefits relative to the increased power consumption from water pump operations. The benefits of this technology relative to other passive



technologies for reducing heat gain (such as double-glazed windows, sunshading, heat gain reducing paint etc.) need to be assessed in terms of their relative Marginal Abatement Costs and environmental impacts from manufacturing<sup>32</sup>.

### Indoor and Outdoor Water Pools

**Used at: Morocco, Switzerland, Vanke and France Pavilions**

Evaporative cooling in conjunction with natural ventilation was used in the above pavilions to lower indoor air temperature either directly (indoor pools) or through the cooling of surrounding air mass (outdoor pool).

The working principle and performance criteria of these systems is similar to that of direct evaporative water cooling utilizing spray technology – heat loss through evaporation reducing the Air Conditioning load and thereby leading to operational energy conservation and consequent GHG mitigation.

<sup>32</sup> rooftop spraying can result in a surface temperature drop of approximately 10<sup>o</sup>-15<sup>o</sup>C on the top of the roof and the corresponding interior temperature difference of 2<sup>o</sup> to 3<sup>o</sup>C. The study concluded there was a 60% reduction in heat transfer and a 20% reduction in the roof-top surface temperatures. Source: 'Evaluation Of A Direct Evaporative Roof-Spray Cooling System' by Carrasco, A., Pittard, R., Kondepudi, S. N., and Somasundaram, S., Mechanical Engineering Department, Texas A&M University, College Station.

Based on the low-tech and non-capital intensive nature of this intervention coupled with the marginal energy consumption for system operation, allows this intervention to yield a relatively high net energy conservation and GHG mitigation efficiency relative to other capital and technology intensive interventions.<sup>33</sup>

### 3.2.3.3 Impacts of Roof and Stereo (Wall) Greening

**Used at: Baosteel Stage, British Pavilion, China Pavilion, Expo Centre, Finland Pavilion, India Pavilion, London Zed Pavilion, New Zealand Pavilion, Saudi Arabia Pavilion, Shanghai Eco-House, Singapore Pavilion, Switzerland Pavilion, The Rhône-Alps Region Case, Canada Pavilion, Expo Park, France Pavilion, The Alsace Case, Theme Pavilion**

Green roofs and walls can serve several purposes for a building, such as absorbing rainwater, providing insulation, creating a habitat for wildlife, helping to lower indoor air temperature, combating heat island effects while at the same time sequestering atmospheric carbon dioxide.

In the case of the Expo Centre, nearly 52 per cent of the roof area qualified as a green roof and in the case of the London ZED pavilion, the green roof area was approximately 250m<sup>2</sup>. While Stereo Greening was applied in a number of locations at the Expo, quantitative data related to area of coverage is only available for the Theme Pavilion (6000 m<sup>2</sup>) and The Alsace Case (298 m<sup>2</sup>).

The total greening area at the Expo site was approximately 1,060,000 m<sup>2</sup> of which the majority was greening in plot areas and parks, while roof greening was relatively marginal in terms of area.

However, owing to the impacts on building energy conservation (due to insulation effects) the impacts of green roofs still warrant unique consideration aside from the sequestration impact (wherein the relative ratio of campus area green to roof greening is almost directly proportional to area covered).

Actual energy modeling analysis conducted by the Low Carbon Research Centre of SAES for the green walls at Theme Pavilion indicate a reduction in

<sup>33</sup> benefits relative to other evaporative cooling based passive technologies for reducing heat gain needs to be assessed to determine the marginal GHG abatement cost of this technology. This analysis could not be conducted due to lack of performance data from the Expo.

U value comparable to the impact of double-glazed window systems relative to single pane glass windows i.e. U value was reduced in the vicinity of 50 per cent to 75 per cent<sup>33 34</sup>.

### 3.2.4 Learning from the Expo

Based on lessons learned from the Expo the Shanghai Municipal Government has issued and is considering acts/action plans as following:

- “Shanghai Building Energy Conservation Act” was issued in 2010 and started implementation in 2011, requiring energy efficiency audit before official approval of new building construction;
- All new residential buildings less than 6 floors are required and those more than 6 floors are encouraged to install solar water heaters;
- Highly energy-consuming construction materials in a black list will be prohibited, and energy-efficient construction materials are encouraged to use, especially in governmental-funded projects;
- Retrofitting of 40 million m<sup>2</sup> existed residential buildings will be finished in the following five years.

### 3.2.5 UNEP Recommendations (Building and Construction)

UNEP suggestions for Shanghai and other cities:

- Existing building should be evaluated for retrofitting successful technologies showcased in the Expo to increase energy efficiency;
- New and existing buildings should be installed with integrated renewable energy technologies where possible;
- Construction energy intensity should be reduced utilizing some of the proven techniques utilized in the Expo.
- Owners and developers of older private high quality residential buildings and high rises should be required to retrofit energy saving windows or spectrally selective window films and wall insulation to achieve significant energy conservation;
- Developers of new high rise buildings should be incentivized to install building wide efficient gas central heating systems while owners of older high rises should be encouraged to retrofit heating systems within the next decade;
- Study the feasibility of and mainstream the application of alternative construction materials such as Bamboo, Hollow Silt Bricks, Inorganic Insulation Mortar, Low Carbon Concrete, Reinforced hollow bricks with fly ash and Synthetic Gypsum Plates (recovered material from power plant slag);
- Ensure dissemination of vital knowledge related to the energy consumption from recycling of construction materials as these processes are not zero-impact processes. It is recommended that material reduction and reuse always be accorded higher priority over use of recycled or recyclable materials;
- Adopt Direct Evaporative Water Spraying technology for further investigation and possible widespread application once results obtained at the Expo are corroborated;
- Promote indoor and outdoor pools at large public spaces as low-tech and non-capital intensive systems which can yield a high net energy conservation relative to other capital and technology intensive interventions;
- Green Roofs should be combined with food production and/or organic waste composting to effectively address food supply inefficiencies as well as municipal solid waste management;
- A comprehensive city-specific research study for comparison of all competing technologies for utilization of roof space must be conducted. Relative energy conservation and consequent GHG mitigation benefits for solar thermal, solar PV, skylights, green roofs etc. on a unit area basis must be comprehensively analyzed to determine the most cost and carbon efficient alternative for rooftop application on a wide scale;
- Common areas such as stairwells, elevators, lobbies etc. in residential buildings should become

34 Effective heat transfer coefficient (U value) of walls was reduced from 0.8 to 0.28 W/m<sup>2</sup>K. Energy modeling analysis though yielded a relatively modest annual energy conservation of 1% relative to the baseline case. However, this is understood to be primarily due to the highly insulated wall system already in place upon which green walls were installed. The operational energy conservation is anticipated to be significantly greater when green walls are applied on un-insulated walls

34 insulated walls can have a U value of 0.8, significantly lower than un-insulated brick or poured concrete walls (U values in the range of 1.8 to 3.1 for 12” brick and poured concrete walls, respectively).

synonymous with motion-sensing (PIR) technology which can yield significant cost and energy savings for all stakeholders;

- Exhaust heat recovery systems (as demonstrated successfully in many areas of the Expo), rooftop greening, solar thermal water heating, and geothermal/river water source heating systems need to be formally encouraged and incentivized in all new constructions where incorporation of these technologies is feasible;
- Traditional systems of sun shading of windows, natural lighting, and natural cross ventilation using architectural design features should be visibly encouraged and recognized as legitimate contenders for a 'green building' certificate;
- A comprehensive, prolonged residential Water Use, Water Heating, and Air Conditioning use related public communications campaign should be devised focusing on three simple aspects of household management which can dramatically curb per-capita energy use and carbon footprint;
- appropriate low-energy systems for disinfecting potable water (UV-based systems as opposed to boiling);
- regulation of water-heater thermostat setting to 45 to 50 degrees Celsius (as opposed to the conventional 60 degrees Celsius);
- regulation of AC thermostat setting to 24 to 26 degrees Celsius.

### 3.3 Transportation Technologies

#### 3.3.1 Overview of pre-Expo Transport System and Transformation During Expo Preparation

The Expo strategy in the transport sector allowed daily life and business in Shanghai to move forward during the Expo period without being impacted by the nearly 400,000 daily visitors 92 per cent of whom used public transportation.

This massive feat was achieved through management of private vehicle usage, as well as the

upgrading and extending of Shanghai's public transport network to efficiently carry a total of 13 million passengers daily. This system is being further expanded to allow passengers to reach any part of Shanghai from outlying municipal areas, already including the two city airports, by efficient and affordable public transport.

A green commuter card with one ton of Carbon Offset Credit was launched in Shanghai during the Expo that could be used on all public transportation including metro, buses and taxis. The opportunity for passengers to offset their Expo carbon footprint by purchasing the card indicated that within a reasonable cost range the public has the awareness and willingness to offset carbon footprint.

Additionally, a variety of new energy vehicles were showcased and tested during the Expo thus allowing transport professionals and officials to observe their effectiveness. Most of these vehicles are now on central Shanghai roads and some others have been lent to other cities for on-road trials and will be returned to Shanghai.

Based on the Expo experiences, Chongming Island, the eco development zone plans to run fifty percent of its bus lines with new energy vehicles by 2015. The effectiveness and life cycle performance of all these vehicles is the subject of a comprehensive LCA study by institutions, including Tongji University, to be issued within two years.



### 3.3.2 Transport improvement initiatives launched in preparation for the Expo and their impacts

A significant component of the Expo environmentally sustainable transport strategy was devoted to the acceleration of the expansion pace of Shanghai Metro.

The total visitor load of approximately 73 million visitors, with a range of 0.4 million average daily visitors to 1.03 million maximum daily visitors, would have challenged any urban transport system; likely causing a dramatic increase in road traffic congestion along with associated local air pollution and GHG emissions impacts.

To combat this adverse impact due to the additional visitors to Shanghai as well as provide a sustainable mode of low-carbon transportation to local citizens (traveling to the Expo or otherwise), the Expo catalyzed the pace of development and construction of the Shanghai Metro system beyond the usual (baseline) annual rate of subway network growth.

This was anticipated to have an emphatic impact on the overall GHG emissions of the Expo, by providing its visitors a low-carbon alternative relative to private vehicular transport, as well as the city in general.

The Shanghai Metro grew from approximately 63 kilometres of network length (370,000 passengers per day) in 2000 to 158 km in length and handling 1.8 million passengers per day in 2006. This represented an average annual growth rate of 15 kilometres of track/

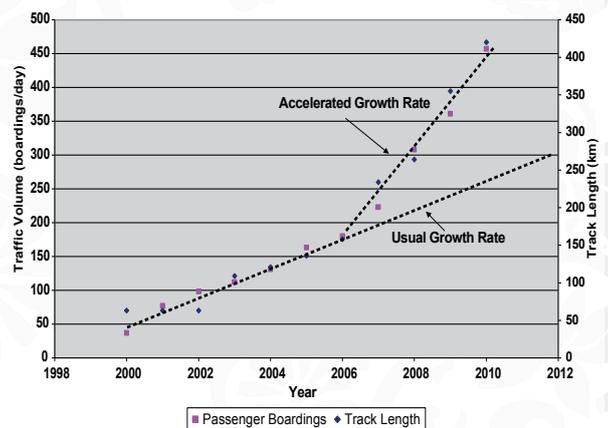
year and an increase of 0.28 million passenger/day capacity on a year on year basis from 2000 to 2006.

This is in sharp contrast to the significantly higher rate of growth observed during 2007 to 2010; the network grew to 420 km and 4.57 million passengers/day by October 2010. The corresponding annual growth rate for this period was 65.5 kilometres of track per year and an increase of 0.69 million passenger/day capacity on a year on year basis from 2000 to 2006.

A chart of rate of metro construction and the corresponding passenger traffic supported is presented in Figure 12.

The figure indicates a discernible incremental deviation from the usual rate of annual capacity addition from 2007 onwards, relative to the period of 2000 to 2006 prior to that.

Figure 12: Shanghai Metro Accelerated Growth Rate – 2007 to 2010



The results indicate that the 'additional capacity' added by the Metro since 2007, beyond usual annual capacity increase, resulted in approximately 3.95 million avoided trips through others modes of transport<sup>36,37</sup>.

The avoided GHG emissions due to accelerated Metro construction from 2007 to October 2010 were approximately 783,706 tons CO<sub>2</sub>e.

36 The analysis methodology was based on determining the impact of additional metro capacity (passenger/day) and network length (total route kms) on the daily travel modal split of Shanghai and the consequent reductions of trips that would have otherwise occurred through buses, taxis, ferries, private motor vehicles as well as non-motorized transport mechanisms including walking..

37 The travel modal split of the avoided trips assumed to be equal to the modal splits observed in the 'real' scenario of current traffic patterns in the city (specific to each year between 2007 and 2010). Distribution of avoided trips excluded metro transport since the capacity to absorb the avoided trips would not have existed in the usual scenario.



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The analysis presented is for the period of accelerated metro construction (from 2007 to 2010) through the end of the Expo (October 2010), the overarching impacts of this beneficial development for the years beyond the Expo have not been assessed.

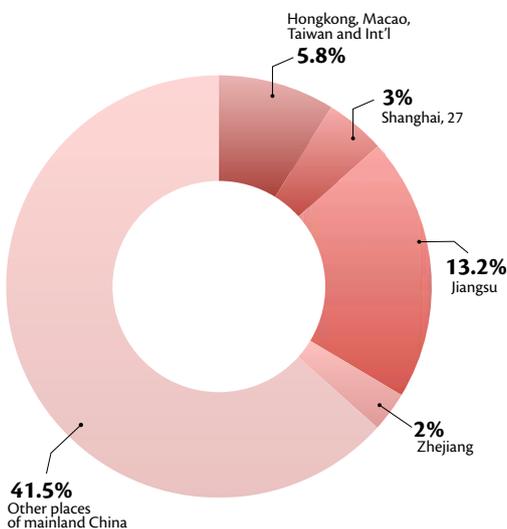
As the analysis alludes, a projection of the benefits of the accelerated Metro construction on reducing the per-capita and per-unit GDP GHG intensity over the coming years is almost certainly going to be witnessed; albeit not quantified in this report.

Also, it must be recognized that since all infrastructural development has an embodied GHG emissions impact owing to its manufacturing and construction phases, this impact must be considered in an exhaustive environmental impact analysis to gage the 'net' beneficial impact of the accelerated Metro development in the city's GHG emissions.

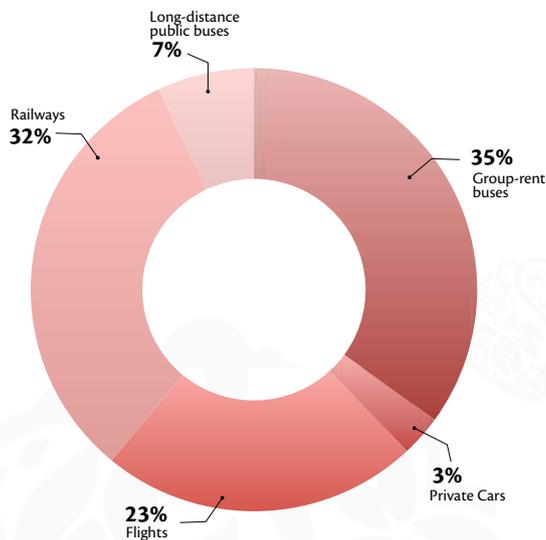
Furthermore, the increased traffic congestion related GHG emissions during the relatively long construction phases must be tallied against the benefits accrued during system operations. As a result, except for visitors taking long distant flights, most visitors from nearby locations were encouraged to take public transportation rather than driving private cars to reach Shanghai. Regarding commuting inside the city, travel to and from Expo site:

Utilization of public transportation (above 92 per cent) was significantly more than other transport modes, while private cars only carried 6 per cent of Expo visitors to reach the Site, much lower than the average private car trips at the city level (~18.8 per cent in 2010). Details are shown in Figures 13, 14, and 15 below:

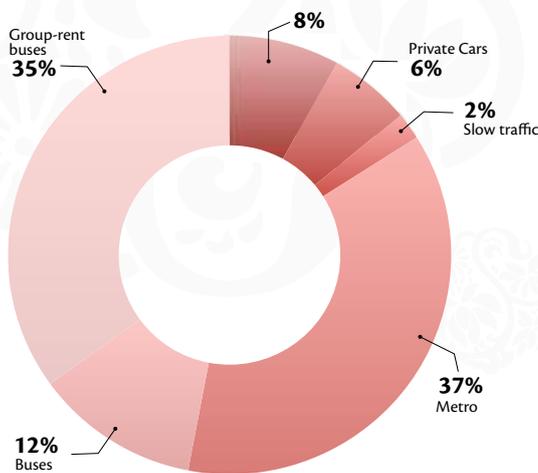
**Figure 13:** Breakdown by Expo visitors' origin.



**Figure 14:** Travelling Pattern to Reach Shanghai City.



**Figure 15:** Travelling Pattern to Reach Expo Site.



### 3.3.3 Impact of Clean Energy Vehicle Transport Systems at the Expo

A wide array of new energy technology vehicles were deployed at the Shanghai Expo, with a portion of them plying within the Expo site and others functioning across the city for Expo related transportation. Table 5 presents the inventory of new energy vehicles used at the Expo.

Following the Expo all new energy buses are either being used on Shanghai roads or have been temporarily leased to other locations for use. Small electric vehicles used in the Expo shall all be utilized elsewhere or for future activities in the Expo Park area.

**Table 5** – inventory of new energy vehicles used at the Expo.

Technology	Vehicle Type	Use Category	Qty
Battery-Supercapacitor	Bus	Visitors	120
Supercapacitor	Trolleybus	Visitors	61
Electric	Cart	Visitors & Pavilions	270
Hydrogen Fuel-Cell	Cart	Visitors	100
Hydrogen Fuel-Cell	Car	VIP	90
Hydrogen Fuel-Cell	Bus	VIP	6
Hybrid	Taxi	Visitors	350
Hybrid	Bus	Visitors	150

The detailed Carbon Footprint mitigation analysis for Hydrogen Fuel Cell Vehicles (HFCVs) and other alternate energy vehicles was undertaken and analyzed. While hydrogen use as a transport fuel does not have any direct GHG implications, it was understood that it would have non-trivial indirect GHG emissions from its production which would greatly influence its efficacy as a low-carbon alternative to conventional fossil fuel based transport.

The GHG emissions analysis was conducted for the best (i.e. lowest GHG EF) and worst case (highest GHG EF) scenarios to ascertain the entire range of anticipated impacts of this promising alternative fuel which is increasingly seen as an integral component of a sustainable development strategy for growing and fully developed economies across the world.

The results indicate that although the new energy vehicles create an innovative approach, they still require further development to perform on par with conventional internal combustion fuels in terms of GHG emissions impact and Carbon Footprint. This is due to the following factors:

- 1) **for electric vehicles** - significant dependence on fossil fuel technologies for electricity generation globally which decreases the potential Carbon

Footprint mitigation impacts of electric transport technologies;

- 2) **For HFCVs** – dependence on natural gas reforming or conventional electric sources for industrial production of hydrogen in most cases across the world.

On a positive note, the analysis yields the encouraging result since the hydrogen used at the Expo was sourced from industrial waste streams (petroleum refineries in particular).

The upstream energy consumption for waste hydrogen is then merely the energy required for liquefaction and transportation. In this scenario, the HFCVs would reduce overall Carbon Footprint from transportation.

Based on estimates provided by SAES, the total waste hydrogen produced by chemical companies in Shanghai is approximately 3,600 tons per annum. It is estimated that based on the hydrogen fuel efficiencies witnessed in the case of Expo buses, and an estimated average of 55,000 km/year of public bus travel, the total fleet that can be supported on the waste hydrogen supply in Shanghai is in the vicinity of 670 buses.

For fleets beyond this size or private vehicles using other sources of hydrogen, it must be assumed that a significant component of annual hydrogen needs for future fleets, in the long run, would be produced a primary industrial product to meet escalated demands.

Unless the primary source of energy for hydrogen creation is cleaner than is currently the case (i.e. substituting fossil fuel based energy generation with renewable clean energy sources such as wind, solar, geothermal etc.), this technology cannot be considered





competitive with other low carbon alternatives given the current state of the art.

Albeit, all alternative fuel technologies did have a undeniable beneficial impact on local air quality owing to elimination or greatly curbing fossil fuel combustion within the urban area.

Their impact on climate change is not realized and the emissions are merely shifted upstream into the fuel supply chain (through electricity generation at thermal power plants etc.).

It is noteworthy that a total of approximately 29.9 million kilometres of travel were achieved during the 6-month duration of the expo of which 7.7 million kilometres were conducted within the expo site (i.e. 26 per cent).

This was a strong indicator of the endeavour by the Expo's organizing authorities to positively influence not just the direct emission attributable to the Expo, but also facilitate the adoption of sustainable technologies in the entire city.

These changes spurred by the Expo are going to be long lasting since all the 1,147 new energy vehicles produced specifically with the expo in mind will eventually be deployed as alternative transport vehicles in the entire urban region within Shanghai and in other urban metropolises in China.

### 3.3.4 Learning from the Expo

- The positive impact of the metro system was very clear during the Expo, thus the city shall continue expansion of metro system to ultimately carry 50 per cent of commuters (vs taxis and buses);
- Expansion of bus lines into suburbs;
- Creation of more bus lanes and giving precedence to public buses at traffic signals and intersections;
- Replacement of conventional buses during normal replacement cycle with clean energy buses identified to be feasible for Shanghai conditions.

### 3.3.5 UNEP Recommendations (Transportation)

- Increase incentives for public to use public transport and disincentives for private vehicle usage to reduce congestion and GHG load within the municipality;
- As ridership of the public transport system increases a carbon offset charge may be included in ticket prices and utilized in offset programmes that are visible to the public such as integrated suburban forestation or energy efficiency programmes;
- Create a congestion zone within the inner ring road to discourage private traffic into the city;
- Encourage and enforce car-pooling in congested areas during peak periods through special car-pool lanes and privileged parking;
- Stringently enforce lane and open intersection laws to reduce road congestion;
- Coordinate traffic lights to optimize traffic flow particularly during peak periods and further train traffic officers who manually operate traffic signals to reduce congestion;
- Driver Education' programme should be devised and implemented, targeted at curbing Engine-Idling at traffic lights. Employ high-calibre communications experts/design firms to devise a robust and penetrative multi-pronged communication strategy to promote the campaign. Campaigns should continue until sustained results are obtained and not discontinued at a pre-determined time frame (as witnessed in many urban case studies).



## 3.4 Waste Management Systems

The Shanghai Municipal Government, like its counterparts in many major urban areas, has been acutely aware of its solid waste management challenges for over a decade.

With the growth of its population the municipality has experienced a steady increase in the volume of solid waste it needs to manage although according to waste statistics the per capita daily domestic waste generation remains at approximately 1kg/person/day despite the rising living standards, indicating that the total waste volume increase is most likely directly attributed to population increase.

Like many of its Asian counterparts Shanghai is also constrained by a lack of land, the NIMBY (not in my back yard) phenomenon, a difficulty to treat high moisture waste, the need for greater funding and large scale technologies, and above all a populace still needing awareness of the financial and environmental costs of waste management.

A comprehensive summary of waste management strategies and actions leading up to the Expo was provided in the UNEP pre-Expo Assessment. The summary below provides some additional historical

details but primarily focuses on waste management performance during the Expo and how the lessons learned from the decade-long preparation and the Expo itself has influenced waste management planning for the decade ahead.

### 3.4.1 Waste management performance during the Expo

Dual waste collection bins designed to manage recyclable and non-recyclable wastes were deployed throughout the Expo. However their design was inadequate and pointed to a basic absence of user-experience based design. The bins were not marked clearly enough and the ambiguity was exacerbated by the fact that both compartments of bins were painted the same colour. Thus even with training Expo visitors were not able to easily differentiate between the two. As such wastes were mixed in both bins and thus one of the main design advantages of the system was defeated by poor labelling.

The major challenge of the Expo relating to waste management was the behavior of visitors who unless a waste bin was immediately at hand would dispose of food waste and packaging on the ground. As such throughout of the Expo period public service announcements were made in the city and in the park reminding visitors to dispose waste properly. Also scores of additional wheeled bins and plastic containers were placed throughout the Expo Park to facilitate proper disposal and thus bypassing the originally designed waste management system.

#### 3.4.1.1 Waste Minimization at Source

The primary focus of this effort was installation of the potable water supply system at the Expo. This system supplied drinking water of a quality normally available in bottled water. The goal was to drastically minimize the quantities of plastic disposed of by Expo visitors through purchase of bottled drinking water. Estimates suggest that approximately 150,000 m<sup>3</sup> of drinking water was dispensed through the water supply system. Based on an average of 550 ml volume per bottle, this quantity of water consumed would have led to production, and waste generation, equivalent to 273

million plastic bottles. The estimated weight of avoided plastic is 5,460 tons.

Additionally, use of electronic information technology to reduce demand for paper materials was seen to have a palpable impact. China Mobile, as one of the major partners of Expo, provided a messenger platform for all visitors in the park to get easy access to introductory content related to Expo pavilions and to provide traffic information by sending short messages. This along with text-message based ticketing was seen to avoid consumption of paper or other material for printing posters, brochures and tickets to some degree.

### 3.4.1.2 Waste Segregation & Recycling

The total Solid Waste generated by the Expo was estimated to be 40,084 tons (including 29,608t of domestic waste and 10,476t of kitchen waste). The per-day and per capita waste generation quantities were 218 tons/day and 0.54 kg waste/visitor, respectively.

A Two-Bin Waste Segregation-at-source system was deployed at the Expo designed with signage indicating separate compartments for recyclable and non-recyclable wastes. The system was designed as part of the Expo's endeavour to improve the efficiency of downstream resource recovery processes, namely recycling of paper, plastic, aluminium, and glass (recyclable component). The non-recyclable wastes were landfilled at the Laogang Landfill site.



Kitchen wastes were collected, transported and treated separately from the domestic waste. Kitchen oil was treated by two local companies and recycled as biofuel while the solid components of kitchen waste were transported to another local company to be reused as animal feed additives by drying and sterilization at high temperature and high pressure conditions, followed by pulverization of the treated kitchen waste into powders—a new technology developed by the company itself.

The GHG emissions avoided by this process (assumed to be carbon neutral since carbon dioxide released is from biomass) relative to landfilling of waste from the Expo were 6,770 tons CO<sub>2</sub>e. Thus the overall reuse or recycling of Expo solid waste is estimated as 57.5 per cent.



### 3.4.1.3 Pneumatic Conveyance System (PCS)

An advanced aerodynamic waste conveyance system was constructed to serve the core area of the Expo Park (Figure 16) as an alternative to conventional vehicle-based waste management systems. The system consisted of a 5.5 kilometres of network of underground steel conveyor tubes approximately of 0.5 m diameter. The underground conveyors were designed to carry segregated waste from over-ground waste collection bins.

An automated actuation system was installed which triggered a vacuum 'pulse' through specific sections of the network to pull waste from bins which had reached their holding capacity. This system was intended to mitigate fuel consumption and consequent GHG emissions from a network of vehicles which would have been deployed for waste collection in a business-as-usual scenario.

Based on preliminary observations while the system is very advanced and would likely serve either a dense residential area or a specialized commercial area well, its effectiveness was limited in the Expo due to the fact that the daily volume of waste managed by the system was approximately half the design capacity as such despite energy controls within the system the process did not operate near optimal efficiency.

In comparison with conventional heavy-motor-vehicular (HMV) transport, the embodied Carbon Emissions of the waste handled through this system was significantly higher. It was estimated that the same GHG emissions would be emitted per kg of waste handled by HMV (approx. 10 tons payload capacity) travelling through an 884 km network. The PCS system can be considered to be viable in terms of its overall environmental impact when the daily loading rate can be increased significantly to approach its design capacity so as to ensure a far more favourable specific energy consumption ratio.

More feasibility study and financial analysis are needed to assess the performance of this system and the conditions it can be practically applied. If this cannot be achieved, a conventional vehicular waste collection systems with higher fuel efficiency vehicles might be a better option.

### 3.4.1.4 Alternative Wastewater Treatment Technologies

Wastewater treatment based on engineered ecological systems such as Biotreatment System (Bacillus Subtilis) and Constructed Wetlands were applied on a modest but visible scale at the Expo. The Japan Pavilion, The Chengdu Living Water

Park, Expo Park, and the Shanghai Eco-House used these treatment methods which were designed to accomplish treated wastewater quality goals while avoiding the detrimental impacts of construction and energy consumption related environmental impacts from operation of electro-mechanical equipment used in conventional wastewater treatment systems.

The intervention is designed to activate microbial processes that stimulate the natural breakdown of pollutants in specific wastewater environments. This is achieved due to the special characteristics of wetland plants, such as reeds, which transfer substantial amounts of atmospheric oxygen through to their root systems encouraging an extraordinary quantity and species diversity of micro-organisms to flourish.

Reed bed treatment systems essentially comprise self-contained, artificially engineered wetland ecosystems which utilise particular combinations of plants, soils, bacteria, substrates and hydraulic flow systems to optimise the physical, chemical and microbiological processes naturally present within the root zone of the plants. The effluent quality achieved meets most discharge standards across the world. Organic pollutants are broken down as a food source by the micro-organisms whilst other contaminants, such as metals or PCB's are fixed in humic acid and



Figure 16: – Pneumatic Conveyance System (PCS) in Expo Park.

cation exchange bonds in the soil or mineral substrates in which these plants are rooted.

An added advantage of these systems is their inherent robustness and buffering capability due to the diversity of the species that they harbour (and thereby the possible physic-chemical reactions that can flourish) and are able to perform under conditions which severely challenge many chemical or physical treatment systems. It is important emphasize this in the context of the Urban Reform-based theme of the Expo.

Contrary to conventional notions of these systems being fragile, they can provide a more robust treatment alternative in many domestic wastewater sewage applications in cities. Furthermore, they are ideally suited for decentralized and localized treatment of wastewater and/or grey water treatment which further curbs the environmental impacts related with heavy infrastructure construction related to wastewater treatment collection networks.

Additionally, the system minimizes land-use change effects caused by Greenfield constructions of large wastewater treatment plants by allowing for a reduced centralized treatment capacity for urban regions and provides the incomparable advantage (relative to conventional treatment) of promoting carbon sequestration through vegetative growth in the constructed wetlands while contributing to urban greening.

Prior to the Expo, Shanghai made a commitment that 100 percent of all waste generated in the Expo shall be collected and managed properly and approximately 50 percent shall be reused or recycled. Data indicates that Shanghai was successful with that aspiration. As also mentioned in the Expo dismantling section, all the waste generated from the dismantling of pavilions was either recycled or re-used according to the plans of individual structures.

### 3.4.2 Expo Lessons

The Shanghai Municipal Government used the opportunity afforded by the Expo to push forward innovative waste management plans that it has been developing over the past decade.

There is a realization that implementation of a comprehensive waste management process and its acceptance by the Shanghai population will not be realized within one Five Year Plan but may take 10 or even 15 years.

Many Chinese and internationally developed waste management systems were showcased during the Expo. These are being evaluated to understand their feasibility for application in Shanghai. Based on the case analysis thus far, particularly for those of Taiwan and Montreal pavilions in which effective separation and containment systems were displayed, Shanghai is further developing its systems to adapt and assimilate some of the showcased concepts.

Based on pre and post-Expo analyses, the Shanghai 12th Five Year Plan for waste management includes the following targets:

- Ninety five percent of all domestic solid waste shall be safely disposed including composting and other re-use;
- Measurable reduction of solid waste generated for disposal by end of 2015;
- Resource based reutilization of waste (such as composting or extracting fuels from kitchen waste) will be significantly increased by 2015;
- Strong emphasis shall be placed on recycling and reuse to reduce disposal volumes. Systems for separating waste in households shall be instituted and separate collection systems shall be put in place to create an effective separation, recycling and re-use system;
- Waste incineration shall be integrated into co-generation systems to generate electricity, which together with planned power generation from methane collected from landfill sites shall be fed into the state grid;
- All landfill sites are to be constructed with or upgraded to have leachate collection and treatment systems.

Greater emphases shall be placed on regulating product packaging to minimize resource wastage and waste generation at source. However, Shanghai is awaiting national legislation on this issue.

### 3.4.3 UNEP Recommendations (Waste Management)

- A strong policy to discourage disposable products and build confidence in re-usable products particularly in restaurants;
- Collaboration with the Tourism Bureau which is encouraging bio-degradable disposables in its Green Hotels to expand the programme to reputable restaurants and chain stores for take-away packaging;
- Since Shanghai has a robust system for composting kitchen wastes, smaller local systems in parks should be explored to allow compost to be produced for the park from local household waste in order to reduce transport cost to central waste management locations;
- Expand supply of clean potable water to discourage and minimize bottled water use;
- Biodegradable packaging for commercial purposes (including innovative solutions such as biodegradable 'PET' alternative bottles for bottled water businesses) need be incentivized by employing economic devices such as taxation on non-biodegradable packaging;
- Continue organizing community-based waste recycling campaigns for recycling of household waste packaging material such as plastic, paper and milk cartons;
- Consider incinerating non-recyclable wastes and stabilizing/fixing residues for use as sub-paving thus minimizing need for landfilling;
- The feasibility and practicality of high tech waste management processes such as the vacuum waste channelling showcased in the Expo should be thoroughly studied against other simpler systems for use in Shanghai;
- Overhaul the current design of two-bin waste collection systems across the city. Poor labelling and mono-coloured designs which do not clearly communicate the segregation system to be followed should be discontinued. Clearly designed and colour coded bins should gradually be phased in by recycling or reusing the materials of the current bins;
- Wastewater treatment based on engineered ecological systems must receive committed attention during any future urban master plans or long-term environmental policies for the city and nation.

## 3.5 Water Conservation and Rainwater Recycling Technologies

For a decade prior to the Expo Shanghai expended significant resources on improving surface water quality, rehabilitating some of the most polluted waterways such as Suzhou Creek and upgrading and securing the quality of catchment areas supplying water to the municipality. Pre-Expo activities are summarized in the previous UNEP assessment report.

### 3.5.1 Expo Water Management Performance

Various water conservation, rainwater recycling, as well as water treatment technologies were applied or displayed in the Expo Park. The environmental benefits from all these technologies when applied at a city wide scale are two-fold: a) significant reduction in the design capacity of the water, wastewater treatment, and storm water runoff and management systems; and b) reduced operational energy consumption for all the infrastructure facilities mentioned above stemming from their curtailed design capacity. These benefits are not explicitly mentioned in the assessment presented below for the sake of brevity but must be underscored in all policy recommendations emanating from this report.

#### 3.5.1.1 Water Conservation

##### Water Saving Toilets

**Used at: Expo Axis, China Pavilion, Expo Culture Centre, Expo Centre**

All toilet facilities along at the above mentioned sites were water saving. The total number of fixtures for the entire Expo is estimated to be 6,410 toilets. Water saving toilets can reduce water consumption by up to 65 per cent (assuming a 1.6 gal/0.8 gal configuration) relative to a convention (5 gal/flush) system. The primary benefits from this intervention are reduced water consumption and associated pumping energy conservation. This intervention has significant overall environmental benefits without any discernable disadvantages.

### Grey Water Recycling

**Used at: China Pavilion, Expo Axis, Expo Centre, Expo Culture Centre Shanghai Eco-House, Urban Future Pavilion, India Pavilion (Landscape Water Recycling)**

Grey Water Recycling (i.e. recycling of bath and wash water, excluding sewage from toilets) was applied across some pavilions. A total of 98,805 m<sup>3</sup> of grey water recycled during the Expo. The primary benefits from this intervention are reduced main water consumption stemming from reuse of treated grey water for non-potable uses (flushing, landscaping etc.) and associated pumping energy conservation.

### Irrigation Water Conservation

Programmed micro-irrigation (trickle irrigation) and sprinkler-irrigation were used at the Expo Culture Centre, Expo Centre and Israel Pavilion for green areas. Micro-irrigation can save approximately 60 per cent water, while sprinkler irrigation technology can save approximately 50 per cent relative to conventional surface irrigation technology.<sup>38</sup>

### Exterior Wall Nano-Coating and Self-Cleaning Curtain Walls

The Expo Axis (self-cleaning glass curtain walls) and the London ZED Pavilion (exterior wall nano-coating) used these interventions to reduce water consumption for cleaning exterior wall surfaces.<sup>39</sup> Both these interventions are able to utilize rainwater to self-clean exterior surfaces thus reducing maintenance cost and materials.

## 3.5.1.2 Rainwater Recycling & Stormwater Runoff Harnessing

### Roof Collection Systems

**Installed at: Canada Pavilion, China Pavilion, Expo Axis, Expo Centre, Expo Culture Centre, Finland Pavilion, India Pavilion, Japan Pavilion, London Zed, Pavilion, Shanghai Eco-House, the Alsace Case, Theme Pavilion, Urban Future Pavilion.**

<sup>38</sup> Absence of system performance data prevents a comprehensive assessment of the energy, water conservation and GHG mitigation benefits of this technology relative to other alternatives Used at the Expo.

<sup>39</sup> Insufficient system specification information and actual operational data on water conservation realized due to these interventions prevents a comprehensive analysis of their influence on the Expo's environmental impacts.

Rooftop rainwater capture, storage and recycling technology was applied extensively in several permanent and temporary pavilions. The primary benefits from this intervention are reduced mains water consumption stemming from reuse of captured rainwater for non-potable uses (flushing, landscaping etc.) and associated pumping energy conservation. The total quantity of rainwater recycled at the Expo was approximately 130,000 m<sup>3</sup> through the Expo Axis and 109,700 m<sup>3</sup> from permanent pavilions.



### Stormwater Run-off Prevention (Permeable Pavement)

**Used at: China Pavilion, Expo Centre, Expo Park, Shanghai Eco-House**

#### Theme Pavilion

Permeable paving technology was applied at specific locations across the Expo site as indicated in the list above. This technology comprises a range of materials and techniques for paving roads, cycle-paths, car-parks and pavements that allow the movement of water and air around the paving material.

This intervention, relative to conventional non-porous paving materials, has the primary benefit of reducing storm water runoff from paved areas. Furthermore, permeable paving can reduce thermal as well as sediment and chemical pollution of receiving water bodies into which stormwater runoff is discharged posing a threat to aquatic ecosystems.

The system is designed to reduce flow velocity of stormwater runoff by absorbing it through joints between paving blocks, which are filled with grit instead of the sand that is used in conventional paving,

and stored in a special sub base beneath the paving. The sub-base, comprising of aggregate, subsequently filters and reduces the pollutant concentration in the eventual discharge released into nearby streams, allowed to percolate into the underlying earth, or conveyed into the drainage system through pipes.

### 3.5.1.3 Water Treatment Technology

#### Soft Bank Development for Waterways

A shift to nurturing eco-recovery of water courses is observed from Houtan Park, the Expo Park and the Chengdu Water Park exhibit which were modeled on Beijing's successful upgrading of water courses before and after the Olympics. This includes removal of hard banks and wide planting of water plants along meandering river courses.

#### Ecological Purification

An ecological water treatment technology was employed at Houtan Park. This treatment system consisted of water plants, aquatic animals, indigenous microorganisms, without any chemical agents or special equipment.

A total of 2400 m<sup>3</sup> water from Huangpu River could be purified every day to supply both the landscape water for the Expo Park as well as green irrigation and road spraying for Houtan Park and the Expo Park. This intervention saved water resources for the Expo without application of equipment that would result in significant GHG emissions.

### 3.5.2 Expo Learnings

The Expo strengthened the awareness of visitors that water is a valuable resource and that resource protection through conservation at source is essential. It also provided an opportunity for Shanghai, which has struggled to secure new municipal potable water resources as discussed in the Pre-Expo Assessment Report, to incorporate Expo water conservation learning into the city's 12th Five Year Plan:

- The Construction Department and Sanitation Bureau jointly formulated a plan for aggressive demand side reductions in all sectors through conservation and reuse;

- The Plan encourages rainwater collection systems to be adopted in public buildings, newly built residence compounds, roads, industrial parks, as well as the agriculture parks;
- Utilization of grey water, rainwater, and river water will account for more than 2 per cent of the total water supply by end of 2015;
- Ecological treatment technologies will be widely applied in water course rehabilitation.

### 3.5.3 UNEP Recommendations (Water Management)

- Water audits may be considered as a standard environmental component for all future events, projects, sites and incentive campaigns which might currently only emphasize energy or carbon emissions audit;
- Include requirement for rainwater collection systems in all new residential developments feeding into sanitary water supply and landscaping;
- New construction should install grey water collection and reuse systems to augment sanitary, wash down and irrigation water on the property;
- Consider developing urban groundwater recharge areas to reduce capital requirements for capture and channeling or rainwater drainage;
- Incorporate permeable pavement zones in future city construction projects to enhance groundwater recharge and reduce need for drainage infrastructure;
- Programmed micro-irrigation (trickle irrigation) and sprinkler-irrigation used at the Expo must be rapidly propagated through the public parks system to achieve significant water savings relative to conventional surface irrigation technology.



## 3.6 Forestation and Afforestation Approaches

In preparation for the Expo, Shanghai undertook several major greening and park development projects. Additionally, approximately half a million square meters of roof and stereo (wall) greening was undertaken in the 11th Five Year Plan, in the 600 day action plan preceding the Expo.

As a result of the Expo preparation efforts, by 2008 Shanghai's green coverage had increased to 38 per cent almost double that of 2000; equating to 12.5m<sup>2</sup> green space per capita compared to 4.6m<sup>2</sup> in 2000. In 2010 green coverage constituted 38.15 per cent of city construction area equating to 13m<sup>2</sup> per capita.

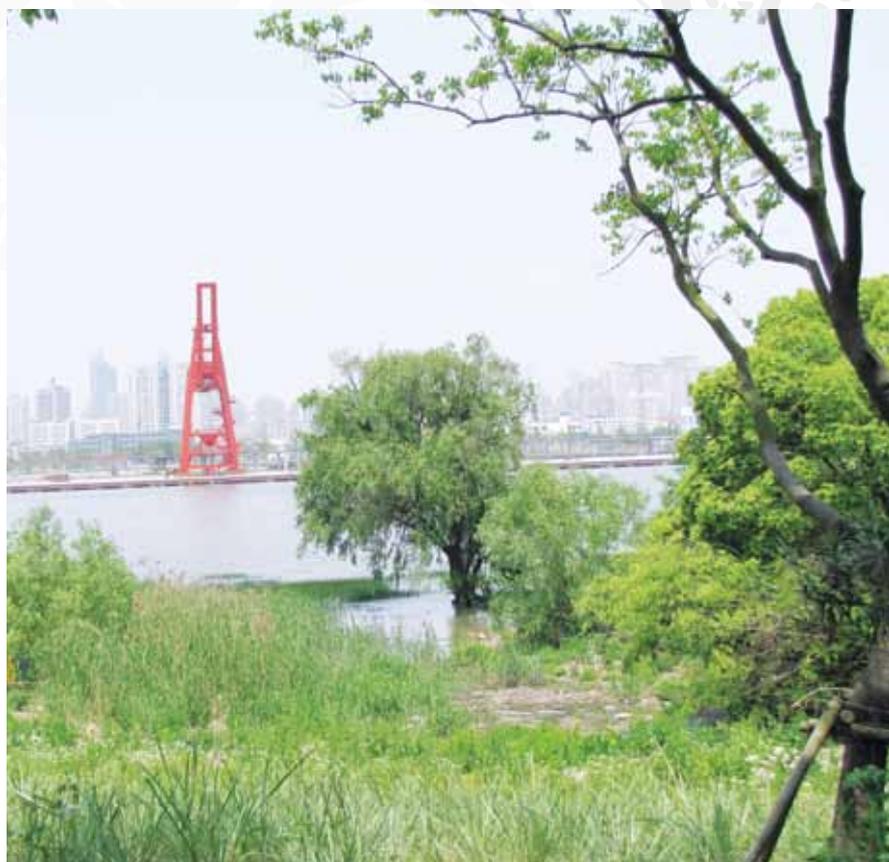
It is anticipated that these values will increase to 38.5 per cent and 13.5m<sup>2</sup> per capita by 2015. As Shanghai is land constrained, further greening is focused on improving quality of species and biodiversity as well as creating an integrated system to improve the city environment and provide corridors for indigenous biodiversity development.

### 3.6.1 Expo Park Greenbelt Design

The Expo occurred predominantly during Shanghai's hot season. The flora selected for Expo Park and city landscaping took temperature effects and shading needs into consideration. Zonal plant communities were selected to promote ecological function of greenery systems, relieving the urban heat island effect, and improving urban environmental quality. In order to protect biodiversity under artificial urban environments, measures were taken to preserve the existing wetlands and develop artificial wetland as habitats for animals and microorganisms.

The final result of the pre-Expo efforts includes:

- The greenery coverage achieved in the Expo Park was above 50 per cent;
- More than 80 per cent of pavilions in the park used roof greening, stereo greening or indoor greening;
- The greenery belt structure in the Expo Park included:
  - **One AXIS:** Along the entire Expo Axis (1km);
  - **Two Ribbons:** 2 belts along the Huangpu River (8km);



- **Three Gardens:** Expo Garden, Bailianjing Garden, Houtan Park.

### 3.6.2 Expo Learnings

- Optimized use of native species for city greening;
- Based on the Expo experience, Shanghai is promoting roof and stereo greening for parking structures and other similar buildings;
- Rainwater runoff collection systems are being encouraged in all green areas to promote utilization for irrigation;
- Development of efficient irrigation systems.

### 3.6.3 Integration of Urban and Sub-urban Green Cover to Enhance Sustainability and Development of Green Corridors

The extensive development and changes in municipal greening patterns as part of Expo preparation were discussed in the pre-Expo Assessment Report.

As a result of the Expo experience and learnings, Shanghai has devised a comprehensive integrated green corridor programme which is being implemented in the 12th Five Year Plan and beyond.

The implementation programme focuses on:

- Development of ecologically integrated green corridors utilizing native species;
- Ensuring that all major green spaces are interlinked to nurture development of indigenous flora and fauna;
- Minimize use of artificial fertilizers and chemicals to enhance natural environment;
- Create corridors that encourage city wide air movement to enhance air quality;
- Increase Municipal forest coverage to 15 per cent by 2015.

According to the plans formulated for the future development of green spaces in Shanghai, the ecologically integrated greening shall consist of the following as presented in the figure below:

- **Two Rings:** The alignment of the outer ring and suburban ring roads shall be greened along the margins;
- **Three Lines:** These will consist of three extensive near parallel stretches on coastlines along Chongming Island, Pudong and Hangzhou Bay;
- **Four Areas:** These will be within four major industrial zones including, Jingshan, Wusong, Fengxian and Baoshan;
- **Five Districts:** These shall be reserve areas in Chongming Island, Qingtaoshan reservoir, Nanhui (at the mouth of Hangzhou Bay), Chenhang reservoir, Dianshan Lake (Qingpu);
- **Six Arrows:** These are designed to focus air flow into the city centre and include: Taopu, Dachang, Donggou, Zhanggeiabang, Beicai, Sanling;
- **Ten Corridors:** To be developed along all major roads and rail alignments throughout Shanghai.

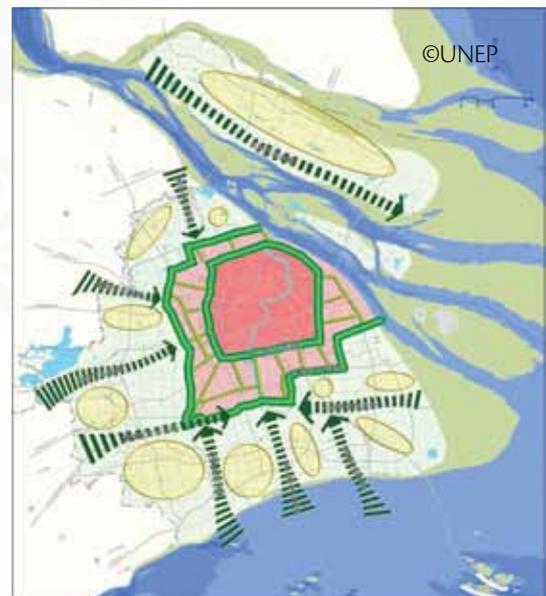


Figure 17: Planned Shanghai Eco-Corridor Concept to be implemented in 2011-2015

All these will be interconnected and shall be developed primarily using indigenous flora. Imported plants from southern China and other locations are already being tested in nurseries to ensure compatibility and endurance.

Additionally, soft bank areas are expected to build in some areas to support water quality through natural wetland systems. This is a concept that is based on the learnings from the Chengdu Water Park Case in the Expo.



Figure 18: View of Shanghai's skyline

# Atmospheric Impacts

Chapter

4

Atmospheric Impacts

## 4.1 Air Quality

The Shanghai municipal government identified air quality as a major component of the municipality's environmental improvement initiatives leading up to the Expo.

Air pollution became the most controversial issue before and during the Beijing 2008 Olympics, as such Shanghai was aware that world media and Expo visitors needed to be sensitized to how this issue would be managed.

As outlined in the UNEP pre-Expo report China adopted a National Ambient Air Quality Standards (GB 3095- 1996) in 1996. It sets limits for sulphur dioxide ( $\text{SO}_2$ ), carbon monoxide (CO), particulate matter with a diameter of around 10 microns (PM10) and nitrogen dioxide ( $\text{NO}_2$ ), amongst others.

The four pollutants listed above are the most commonly monitored in Chinese cities. Chinese air quality standards set separate limits for different locations as follows:

- Class I applies to special protected areas such as natural conservation areas, scenic spots, and historical sites;
- Class II applies to residential areas, mixed commercial/ residential areas, cultural, industrial, and rural areas;
- Class III applies to special industrial areas.
- Shanghai is designated a Class II area. The Chinese Class II air quality standards are summarized in Table 6. The WHO 2000 guidelines, as well as the 2005 Global Update WHO Air Quality Guidelines, are also presented.

**Table 6:** China's Class II Air Quality Standards

Pollutant mg/m <sup>3</sup>	Mean Level	Class II Upper Limit (China)	WHO EU 2000 Air Quality Guidelines	WHO 2005 Air Quality Guidelines
SO <sub>2</sub>	Annual Mean	60	50	None
	24-hour Mean	150	125	20
	Hour Mean	500	500 <sup>1</sup>	500 <sup>1</sup>
PM <sub>10</sub>	Annual Mean	100	-	20
	24-hour Mean	150	-	50
NO <sub>2</sub>	Annual Mean	80	40	40
	24-hour Mean	120	120 <sup>2</sup>	None
	Hour Mean	240	200	200
CO	24-hour Mean	4,000	10,000 <sup>2</sup>	10,000 <sup>2</sup>
	Hour Mean	10,000	30,000	30,000

<sup>1</sup>Ten minute mean; <sup>2</sup>Eight hour mean

Located on the Yangtze River delta, Shanghai enjoys comparatively better meteorological conditions than Beijing, enabling easier dispersion of air pollutants. However, Shanghai has a much longer history of industrial development and a wide range of factories. Its neighbouring provinces Zhejiang and Jiangsu are also rapidly industrializing and are highly urbanized, posing further challenges to the air quality of Shanghai.

As was noted in the UNEP pre-Expo report Shanghai expended significant efforts over the decade prior to the Expo to adjust its energy generation systems, retire or relocate and upgrade obsolete industries, consolidate heavy industries in integrated "circular economy" industrial zones, impose stringent vehicle emissions and management standards, adjust agrarian patterns and control agricultural waste burning, decrease energy intensity in industrial production, construction, commercial activities and residential areas, control dust pollution from construction and industrial sites and upgrade power station technology to create efficient generation and control emissions of dust, SO<sub>2</sub>, NO<sub>x</sub> and CO.

In effect Shanghai embarked on a process of cleaner development in every sector which allowed it to pro-actively control air pollution levels and decouple development and air pollution.

Key to this process is the Shanghai Environmental Monitoring Centre (SEMC) which combines highly skilled weather and air quality forecasting capabilities to provide short range and long range air quality forecasts. In the two years leading up to the Expo, this proactive monitoring capability that gathers information from an array of remote stations throughout Shanghai and more recently includes monitoring centres in the Yangtze Delta, has been instrumental in consistently

assuring a steady pattern of good or excellent air days according to the Air Pollution Index (API) as described in the pre-Expo Report.

The mechanism for assuring the over 336 good to excellent air quality days per year has been the ability to identify an air quality emergency within 48 hours and having in place a high level city wide authority through the SEPB to shut down or modify the most polluting activities to mitigate the effect. During the Expo period the 48 hour response to potentially poor air quality was considered an emergency and was somewhat more stringent than during pre-Expo periods.

While during the Expo there was a moratorium on all major construction within the core urban area in the Expo Park proximity and all agricultural burning, during 48 hour emergency periods major emitters in the city were either asked to stop operations or use more costly cleaner fuel to mitigate the emergency. The result was that there were few days in which API was over 100 and only two significantly poor quality air days during the Expo period resulting from high PM<sub>10</sub> concentrations due to a sand storm originating in the Gobi Desert.

On 1 November 2010, the day following the Expo closing ceremony the API increased three fold to approximately 150 due to seasonal factors and escalation of dust and SO<sub>2</sub> and NO<sub>x</sub>. This increase was due in part to the start-up of dormant construction sites as is discussed below. The API has however now stabilized to 2009 level in the range above good air quality.



## 4.1.1 Lessons from the Beijing Olympics incorporated into air quality planning and actions for the Expo

Since Shanghai faced a significantly greater challenge to manage air quality during the six months of the Expo compared to the two week Olympics period in Beijing, it instituted many long term programmes to improve air quality.

As such there was a systematic improvement in air quality resulting from the various industrial, agricultural and vehicular emissions control measures that were put in place as discussed above.

Additionally however there were lessons learned from the Olympics that were internalized and adapted to the more complex task facing Shanghai:

- The Expo Bureau, jointly with the Environmental Protection Bureau, invited core air quality experts that advised and supported the Beijing Olympics to join the Expo team and implement the successful forecasting and management programmes that were enhanced and adapted to Shanghai conditions;
- Shanghai reviewed all numerical air quality models and all monitoring systems and technologies utilized by for the Beijing Olympics and adapted applicable parts for use in the Expo by embedding them in SEMC, key universities and research institutes. SEMC also developed more useful forecasting tools including WRF-Chem, statistic models and concept models based on the cooperation demo project of Airnow-I between USEPA and SEPB;
- The Olympic mechanism for next day air quality forecasting and management was enhanced to 24 hour, 48 hour and 7 day forecasting and implemented for the Expo;
- The regional coordination and monitoring network that was developed during the Olympics was developed and adapted to the Yangtze Regional Air Quality Network;
- Diversified advanced stereoscopic monitoring including remote sensing systems developed by Beijing for the Olympics were adopted for the Expo;
- The high pollution warning and action system used during the Olympics was successfully used during

the Expo which required reduction of emissions from industrial sources through temporary cleaner fuel substitution during potentially high pollution periods;

- Banning all agricultural burning was a successful learning from the Olympics which will likely be permanently implemented in some form in the future;
- A moratorium on non-essential commercial construction was imposed. Essential construction relating to major infrastructure projects that continued during the expo were required to integrate strict dust control procedures.

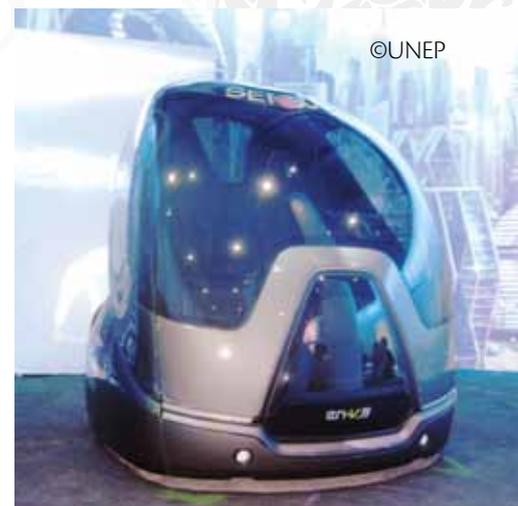
Additionally from 2004, an enhanced Shanghai wide emissions source inventory was created and upgraded periodically. This inventory allowed Shanghai to prioritize sources for management action. It is likely that this type of inventory will be expanded to the Yangtze Region cooperation programme.

## 4.1.2 Actions taken to ensure sustained air quality improvements during the Expo

The pre-Expo UNEP Environmental Assessment provides an in-depth summary of the actions taken by Shanghai during the past decade to improve air quality and effectively delink economic development from pollution.

These actions included desulphurization of power plants, industrial re-structuring, utilization of cleaner fuels, reduced energy intensities, improved efficiencies in power generation and industrial processes, better management of construction dust, and early implementation of Euro IV vehicle emissions standards among others.

The resulting impact on air quality has been significant as acknowledged by the Shanghai population during annual environmental surveys. The resulting air quality improvements are systemic and as such sustainable despite economic growth.

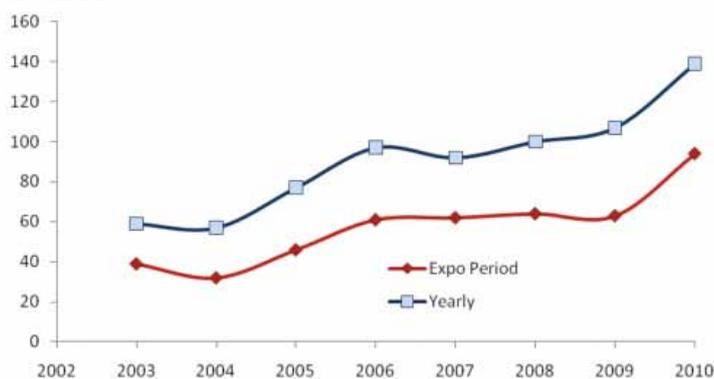


### 4.1.3 Analysis of air quality parameters during the Expo in Shanghai and at Expo site to evaluate effectiveness of measures implemented

During the Expo period, Shanghai maintained good to excellent air quality according to the National Ambient Air Quality Standards and achieved the best result in air quality improvement on historical record. As the API (Air Pollution Index) indicated based on monitoring data, the improvement was not only from May to October during the Expo period, but over the whole year. The air quality was "excellent" on 139 days in 2010, 32 days more than in 2009.

This was partially due to very stringent curbs on pollution sources such as agricultural burning, fugitive dust from construction and fuel substitution in some energy intensive sites within Shanghai. Stringent desulphurization enforcement of power plants and coal fired boilers also assured a consistently good air quality. It should be noted that by late 2009 all coal-fired power plants in Shanghai had been equipped with desulphurization facilities.

Figure 19: Days with excellent API during the Expo months and yearly



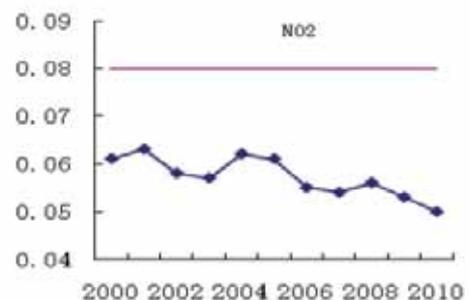
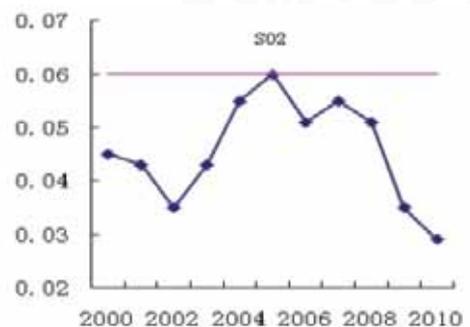
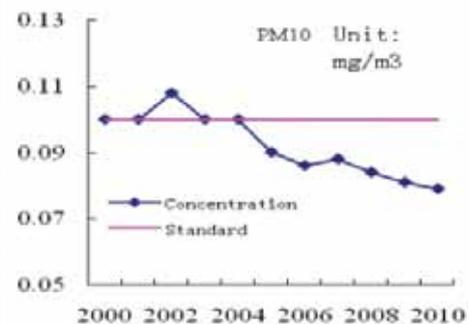
According to daily air quality data, only three days with pollution below the acceptable level were observed in the Expo period, one in May was due to the impact of a sand storm from Northern China, another two were mainly due to unfavorable meteorological conditions resulting from changes in wind direction that caused migration of inland air pollution into Shanghai.

Additionally, immediately after the Expo a spike in air pollutants increased the API primarily due to seasonal weather changes and the start-up of construction sites in Shanghai and surrounding provinces. Overall however the air quality for the remainder of 2010 was stable and the monitored data remained similar to the same period in 2009.

#### Air Pollutants

The overall evaluation of ambient air quality parameters used to calculate API indicated a positive trend through the end of 2010. The concentration of SO<sub>2</sub>, NO<sub>2</sub> and PM<sub>10</sub> in the air all achieved historical lows for the May to October period, and compared with 2009, were 25.0 per cent, 10.9 per cent and 18.1 per cent lower respectively.

Figures 20, 21 and 22: Concentration of PM<sub>10</sub> (Fig. 20) SO<sub>2</sub> (Fig. 21) and NO<sub>2</sub> (Fig. 22)



#### 4.1.4 Shanghai Plans for Ensuring Continuity of Positive Trends

- Continuing adjustment of energy mix structure to reduce air pollution;
- Policy to control coal consumption so there would be a net zero increase in coal consumption in the 12<sup>th</sup> Five Year Plan thus reducing coal to primary energy portion from 50 per cent to 40 per cent;
- Encourage cleaner fuel usage. Currently Gas consumption is 4.5 billion m<sup>3</sup>, target is 10 billion m<sup>3</sup> increasing gas usage as proportion of energy mix by 8 per cent;
- Continuing control of burning of agricultural waste which is a major contributor to air pollution in Shanghai. The measures used during Expo to prevent agricultural burning shall be continued where possible;
- Construction dust control measures shall be stringently enforced through further promulgation and enforcement of dust control area policies;
- Further collaborate with adjacent provinces in Yangtze Delta to establish an Air Quality Management District based on the experience of Beijing Olympics to encourage closure of polluting industries and prevent migration of polluting operations to non-regulated areas;
- Heavy industries relocated outside Shanghai will be required to upgrade to meet air quality standards;
- Old public vehicles such as 7000 old buses are to be retired and replaced with cleaner fuel vehicles such as CNG buses;
- Initiate a programme of cooperation with adjacent provinces in the Yangtze Delta to promote similar vehicle emission policies and standards;
- Control movement of vehicles not meeting Shanghai emission standards and prevent their entry within the outer ring road.

#### 4.2 Other Air Quality Issues

As mentioned in the pre-Expo report, until recently the Chinese air quality monitoring system only set standards for CO, NO<sub>2</sub>, PM<sub>10</sub> and SO<sub>2</sub>. PM<sub>2.5</sub> and Ozone have recently been included in the parameters

to be monitored starting in the 12th Five Year Plan. Monitoring the latter two parameters as well as VOCs has been recommended by the assessment reports on the environmental efforts of Beijing for the 2008 Olympics and was recently extensively reported in the China Daily and Chinese language publications in China through a study released by the Institute of Public and Environmental Affairs, a leading Beijing based NGO.

According to this recent study the impact of PM<sub>2.5</sub>, VOCs and airborne heavy metals poses a significant health threat to the Chinese urban population in particular, and therefore the current air quality indicators do not adequately represent the impact of pollutants on public health.

The Shanghai 12<sup>th</sup> Five Year Plan includes consideration to monitor and report PM<sub>2.5</sub>, VOCs and Ozone. Special researches and investigations on heavy metals and persistent organic pollutions (POPs) have already begun and will be further strengthened in the 12<sup>th</sup> Five Year Plan.



#### UNEP further recommends:

- Expedite implementation of PM<sub>2.5</sub> and Ozone monitoring and reporting, and develop regulations for controlling these pollutants;
- Begin monitoring of VOCs, heavy metals and POPs to assist the Shanghai Government with identifying sources and formulating regulations for future plans;
- Further encourage public transport usage by creating disincentives for private vehicle usage in core urban areas during rush hours to reduce pollution;
- Devise and implement a comprehensive 'Driver Education' campaign which shall run until sustained results are witnessed, targeted at curbing engine-idling at traffic lights and avoiding behaviours that cause traffic congestion;
- Significantly improve traffic flow through strict enforcement of open intersection regulations and better coordination of traffic signals.



# Climate Change Impacts

## 5.1 Carbon Footprint Calculation Model and Results

### 5.1.1 Activity-Boundary Definition: Direct and Indirect Emissions

The emission sources comprising the activity domain for Expo's Carbon Footprint calculation were as follows:

1. **Scope 1 Emissions:** Contributing Directly to Carbon Footprint – activities where direct control can be exercised over the magnitude of activity and the emission coefficient through technological choices;
2. **Scope 2 Emissions:** Contributing Indirectly to Carbon Footprint - activities where direct control can be exercised over the magnitude of activity but not the emission coefficient through technological choices;
3. **Scope 3 Emissions:** Contributing Indirectly to Carbon Footprint - activities where direct control can neither be exercised over the magnitude of activity nor the emission coefficient through technological choices.

The activity boundary identified by SAES in conjunction with UNEP, along with the Life Cycle Boundaries of the GHG Emission Factors used for the Expo's GHG inventory is presented in Table 7 along with their respective emissions<sup>40</sup>.

**Table 7: Activity Boundary Definition for Shanghai Expo GHG Inventory.**

No.	Activity Group	Activity Type	Scope Type	Source Category-Type	Emission Factor Type
1	Fuel	Fuel - Cooking Fuel	Scope 1		Direct Emissions
2	Fuel	Fuel - Power Generation	Scope 1	Key Source	Direct Emissions
3	Fuel	Fuel - Site Construction	Scope 1	Key Source	Direct Emissions
4	Fuel	Fuel - Site Demolition	Scope 1	Key Source	Direct Emissions
5	Fuel	Fuel - Other Fuel	Scope 1	Key Source	Direct Emissions
6	Electricity	Electricity	Scope 2	Key Source	Direct Emissions, Transmission
7	Water	Water	Scope 2		Electricity Use
8	Wastewater	Wastewater	Scope 2		Electricity Use
9	Mobility	Domestic Air Travel	Scope 3	Key Source	Direct Emissions
10	Mobility	International Air Travel	Scope 3	Key Source	Partial LCA
11	Mobility	Public Road & Rail Travel	Scope 3	Key Source	Partial LCA
12	Mobility	Private Vehicular Travel	Scope 3	Key Source	LCA
13	Mobility	Logistics	Scope 3		LCA
14	Food, Beverage, Waste	Bottled Water / Drinks	Scope 3		Partial LCA
15	Food, Beverage, Waste	Solid Waste	Scope 3		Partial LCA
16	Materials	Paper & Cardboard	Scope 3		LCA
17	Materials	Plastic	Scope 3		LCA
18	Materials	Construction Materials	Scope 3	Key Source	LCA
19	Accommodation	Hotel	Scope 3	Key Source	Electricity Use

40 In addition to the activities presented in the tables, manufacturing LCA impacts were incorporated into assessment of Solar PV, Wind Energy, and LED lighting equipment Used at the Expo as well as complete fuel-chain emissions from the quantity of reservoir-Hydropower Used at the Expo. These emission factors have been presented and discussed elaborately in the individual sections addressing these interventions.

## 5.1.2 Stakeholder-Boundary Definition

Stakeholders are defined as those groups of persons, service providers, beneficiaries, customers etc. that directly or indirectly participate in carbon footprint creation activities of an organization.

The stakeholder boundary determined by consultation between UNEP, SAES and the stakeholders contribution to the carbon footprint of the Expo is presented in Table 8.<sup>41</sup>

## 5.1.3 GHG Emission Factor Selection Methodology

The primary source of GHG Emission Factors used for the GHG inventory was from the Chinese National Development and Reform Commission (NDRC). In cases where nationally accepted GHG EF's were not available from the NDRC, factors from the GHG Protocol and IPCC 2006 guidelines were used followed by industry specific GHG Emission Factors.

The comprehensive list of GHG Emission Factors used for the GHG inventory is presented in Appendix C.

## 5.1.4 Research Methodology

A 'ground-up' activity data collection approach was adopted. This approach was designed to aid in benchmarking of emissions per unit of service delivered by various stakeholders as well as identifying best-practices in terms of GHG efficiency of operations.

Wherever a bottom-up approach was not feasible, activity data was obtained through centralized sources of the Expo bureau through the services of SAES.

<sup>41</sup> Stakeholder groups were sub-divided into operational zones and sub-zones for footprinting. This was done to facilitate intricate analysis of the contributing sub-operation and activities to the particular stakeholder's Carbon Footprint. This would also organically facilitate the development of a detailed Carbon Footprint mitigation roadmap which could prioritize interventions based on relative contributions from these zones and sub-zones.

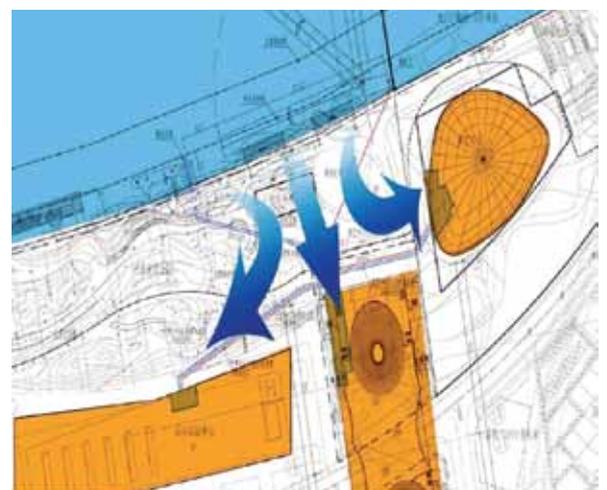
## 5.1.4.1 Pre-Event Period Activity Data

Satisfying the completeness criteria for the carbon footprint calculation process required inventorying of not just 'event duration' resource consumption of stakeholders, but also of pre-event duration for a subset of the stakeholders (comprising of construction activity, test visitor travel and travel activities of the Expo Bureau personnel during the entire expo planning phase prior to the actual event) who's operations related to Expo planning preceded the actual event.

## 5.1.4.2 Activity Data Gathering Methods

Activity data for the GHG inventory was obtained from a combination of the following methods:

1. direct data from the Expo Bureau through SAES consultation;
2. on-site observation and interviews of management personnel of various expo operation departments and pavilion facility managers;
3. email correspondence with relevant SAES and Expo authorities;
4. data extracted from official literature/websites and other communication published by the Expo and individual pavilions;
5. Survey of site drawings, construction drawings and interviews with pavilion architects and designers;
6. UNEP's Pre-Event Expo Assessment Report.





### 5.1.4.3 Visitor Travel Activity Data Research

A significant part of the emissions generated during the Expo was anticipated to be caused directly through the travel of the visitors, participants, and organizers (including volunteers, security and service people).

To ensure an exhaustive GHG emissions inventory of the Expo, it was imperative to analyze the footprint of the spectators that physically attended the Expo.

This extensive data gathering based on a statistically significant sample size was conducted for international, domestic and local visitors prior to the event and then refined based on during-event surveys.<sup>42</sup>

### 5.1.5 Analysis Methodology

The GHG Inventory Reporting for the Expo is not mandated by the United Nations Framework Convention for Climate Change (UNFCCC), and Expo's initiatives to address its climate change impacts are purely voluntary.

In this context, and in the absence of any widely accepted ISO Standard for GHG inventorying of events, the globally accepted methodologies for laid down by the IPCC (Inter-Governmental Panel on Climate Change) as part of the 2006 Guidelines, GHG Protocol,

<sup>42</sup> The total number of visitors in the international and domestic category were taken to be the net additional visitors relative to those predicted visitors to Shanghai in 2010 based on the record of previous years from these regions.

and the Department of Environment, Food and Rural Affairs (UK) were used for guidance wherever appropriate.

However, given the unique nature of this project and the unique operational activities of Expo, the overall methodology reflects a confluence of standard protocols and event-specific approaches which would provide an accurate estimate of the GHG inventory and its consequent climate change impacts.

## 5.2 Total Carbon Footprint: Activity Contributions

The Total Carbon Footprint of Shanghai Expo, for the activities presented in Table 8 and stakeholders (with their respective inventory durations) presented in Table 9, is estimated to be 4,921,827 tons of CO<sub>2</sub>e.

Table 9 presents the contributions to total carbon footprint differentiated across all activity groups. The percent contributions are depicted in Figure 22. The results make it clear that the primary activities contributing to the Expo's carbon footprint are international air travel (2,219 kilotons CO<sub>2</sub>e – 45.1 per cent), hotel accommodation (910 kilotons CO<sub>2</sub>e – 18.5 per cent), public travel (782 kilotons CO<sub>2</sub>e – 15.9 per cent) and domestic air travel (348 kilotons CO<sub>2</sub>e – 7.1 per cent), electricity consumption (277.5 kilotons CO<sub>2</sub>e – 5.6 per cent) and construction materials (185 kilotons CO<sub>2</sub>e – 3.8 per cent). These activities would be considered to be the 'Key Source Category' activities for Expo as defined earlier in the report.

**Table 8: Carbon Footprint Summary – Shanghai Expo 2010 - Activity Contributions**

Sr No	Activity Type	Activity Data	Measure Unit	Total Carbon Footprint (tons CO <sub>2</sub> e)	% of Total Carbon Footprint
	<b>Total Visitors Served</b>	73,080,000	Persons		
<b>1</b>	<b>Scope 1 (Direct Emissions)</b>				
1.1	Fuel - Power Generation & Cooking	26,654,362,000	liters	58,214	1.2%
1.2	Fuel - Site Construction <sup>1</sup>	489,555	m <sup>2</sup> (construction area)	12,839	0.3%
1.3	Fuel - Site Demolition	647,264	m <sup>2</sup> (construction area)	8,722	0.2%
1.4	Fuel - Other Fuel	12,000	kgs	6.6	0.0%
	<b>Sub-Total</b>			<b>79,781</b>	<b>2%</b>
<b>2</b>	<b>Scope 2 (Indirect Emissions - Electricity, Water, Wastewater)</b>				
2.1	Electricity	323,090,871	kWh	277,459	5.6%
2.2	Water	9,654,000,000	liters	8,520	0.2%
2.3	Wastewater	8,689,000,000	liters	2,066	0.0%
	<b>Sub-Total</b>			<b>288,045</b>	<b>6%</b>
<b>3</b>	<b>Scope 3 (Indirect Emissions - Other)</b>				
3.1	<b>Mobility</b>				
3.1.1	Domestic Air Travel	2,895,574,261	pass-kms	347,996	7.1%
3.1.2	International Air Travel	19,465,512,186	pass-kms	2,219,068	45.1%
3.1.3	Public Travel (Road, Rail, Ferry)	12,758,606,409	pass-kms	781,727	15.9%
3.1.4	Private Vehicular Travel	578,288,119	v-kms	78,497	1.6%
3.1.5	Logistics	400,630 liters + 224,941,880 ton-km	multiple units	12,513	0.3%
	<b>Sub-Total</b>			<b>3,439,801</b>	<b>70%</b>
3.2	<b>Food, Beverage, Waste</b>				
3.3.6	Solid Waste	17,347,490	kgs	10,929	0.2%
	<b>Sub-Total</b>			<b>10,929</b>	<b>0.2%</b>
3.4	<b>Materials</b>				
3.4.1	Paper & Cardboard	3,105,152	kgs	8,013	0.2%
3.4.2	Construction Materials	291,216,180	kgs	184,869	3.8%
	<b>Sub-Total</b>			<b>192,882</b>	<b>4%</b>
3.5	<b>Accommodation</b>				
3.5.1	Average Hotel	48,432,000	Overnight stays	910,388	18.5%
	<b>Sub-Total</b>			<b>910,388</b>	<b>19%</b>
<b>Total</b>				<b>4,921,827</b>	<b>100%</b>
				(tons CO <sub>2</sub> e)	
<b>Per Unit Served</b>				<b>67.3</b>	
				(kg CO <sub>2</sub> e)	

<sup>1</sup> area for construction activity are lower than actual areas due to use of allocation ratios for determining that share attributed to Expo vs. lifetime of building (1/30th allocation to Expo based on 30 year lifespan)

Figure 23: Carbon Footprint Summary – Shanghai Expo 2010 - Activity Contributions

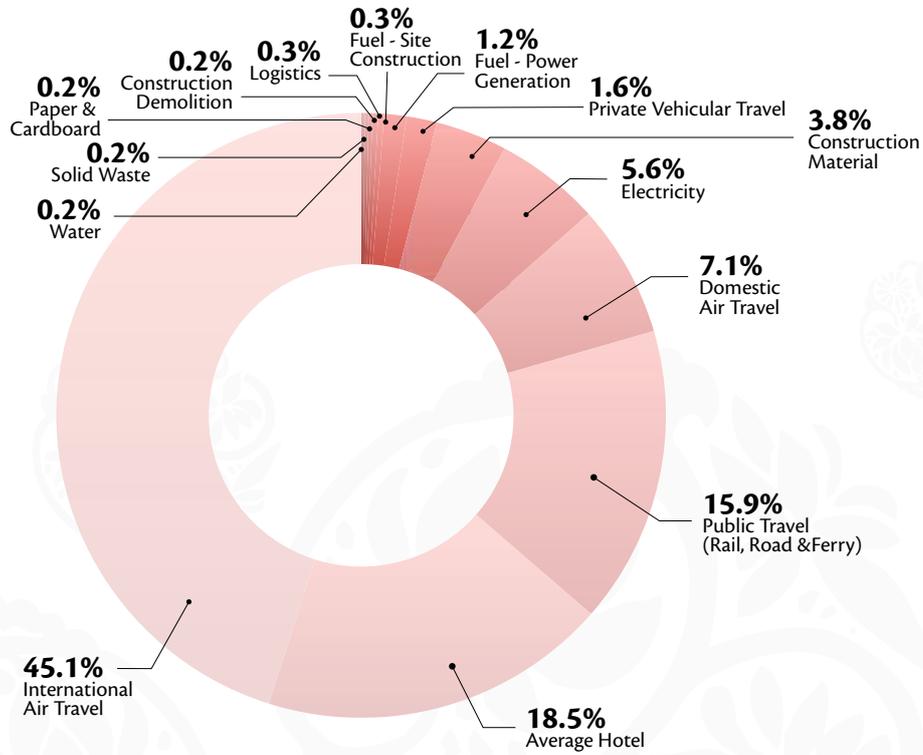


Table 9 presents the stakeholder contributions to the Carbon Footprints of all activities included within the footprint boundary of the Expo. Percentage contributions are depicted in Figure 24 and indicate the relative importance of the various stakeholder groups.

**Table 9:** – Carbon Footprint Summary – Shanghai Expo 2010 - Stakeholder Contributions

Stakeholder Name	Zone	Subzone	Total Carbon Footprint (tons CO <sub>2</sub> e)	per cent of Total Carbon Footprint
<b>Expo Bureau</b>				
Expo Bureau	Operations		20,976	0.4 per cent
Expo Bureau	Operations	Transportation	12,198	0.2 per cent
Expo Bureau	Operations	Waste Management	187	0.004 per cent
<b>Sub-Total</b>			<b>33,360</b>	<b>0.7 per cent</b>
<b>Expo Park</b>				
Expo Park	Construction		1,589	0.03 per cent
Expo Park	Operations	General	307,778	6.3 per cent
Expo Park	Operations	Transportation	16,676	0.3 per cent
Expo Park	Operations	Waste Management	13,796	0.3 per cent
Expo Park	Operations	Logistics	11,342	0.2 per cent
<b>Sub-Total</b>			<b>351,182</b>	<b>7.1 per cent</b>
<b>Permanent Pavilions</b>				
Permanent Pavilions	Construction		38,927	0.8 per cent
<b>Sub-Total</b>			<b>38,927</b>	<b>0.8 per cent</b>
<b>Temporary Pavilions</b>				
Temporary Pavilions	Construction		156,778	3.2 per cent
Temporary Pavilions	Post-Use		8,722	0.2 per cent
<b>Sub-Total</b>			<b>165,500</b>	<b>3.4 per cent</b>
<b>Expo Village</b>				
Expo Village	Operations		18,777	0.4 per cent
<b>Sub-Total</b>			<b>18,777</b>	<b>0.4 per cent</b>
<b>Visitors</b>			933,631	19 per cent
Visitors	Local		149,242	3 per cent

Visitors	Domestic	963,405	19.6 per cent
Visitors	International	2,058,897	41.8 per cent
<b>Sub-Total</b>		<b>4,105,175</b>	<b>83.4 per cent</b>
<b>Exhibitors, Media, Performers</b>			
Exhibitors, Media, Performers	Local	182	0.004 per cent
Exhibitors, Media, Performers	Domestic	856	0.017 per cent
Exhibitors, Media, Performers	International	66,857	1.4 per cent
<b>Sub-Total</b>		<b>67,895</b>	<b>1.4 per cent</b>
Organizers, Security, Volunteers		141,011	2.9 per cent
<b>Sub-Total</b>		<b>141,011</b>	<b>2.9 per cent</b>
<b>Total</b>		<b>4,921,827</b>	<b>100 per cent</b>

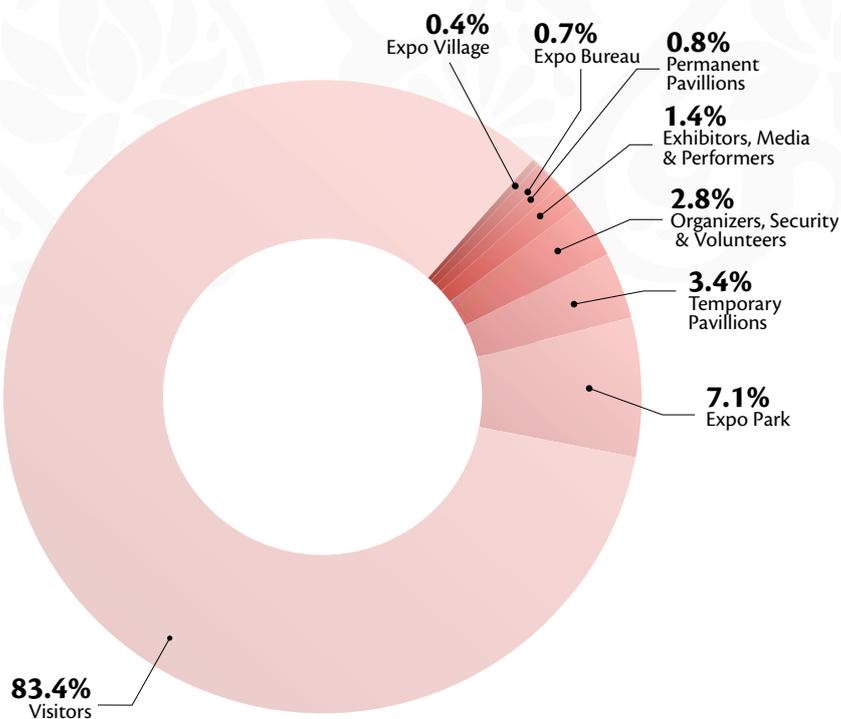


Figure 24: Carbon Footprint Summary – Shanghai Expo 2010 - Stakeholder Contributions

## 5.3 Avoided Carbon Footprint

### 5.3.1 Comparison with BAU Scenario

The Shanghai Expo used various technologies, interventions and resource management practices targeted at reducing the GHG emissions relative to a business-as-usual (BAU) scenario.

While each of these interventions has been extensively detailed in the specific sections presented earlier in the report, a consolidation of these relative GHG mitigation efforts is presented here. The comparisons of the baseline versus the actual Expo scenarios are presented through the following intervention groups along with the subsequent GHG mitigation summary in Table 12.

#### 5.3.1.1 Energy Efficiency and Renewable Energy related GHG Emissions Comparison

The impact of energy efficiency related interventions is presented in Table 11<sup>43,44</sup>

**Table 10:** Energy Efficiency and Renewable Energy related GHG Emissions Comparison

Sr. No	Item	Electricity Conservation (kWh)	CF Mitigation (tons CO <sub>2</sub> e)
1	Energy Efficient Lighting - LED	231,840,000	204,599
2	Gas Fired AC systems	28,513,694	6,730
3	River Water Source/ Geothermal Heating & Cooling	2,936,269	2,591

<sup>43</sup> area for construction activity are lower than actual areas due to use of allocation ratios for determining that share attributed to Expo vs. lifetime of building (1/30th allocation to Expo based on 30 year lifespan).

<sup>44</sup> includes manufacturing LCA adjustments to conservation estimates for solar PV and hydropower i.e. 'NET' savings.

4	Solar Thermal Heating	202,463	179
5	Xiangjiaba Hydro Power Station	6,728,190	5,864
6	Solar PV	2,287,680	1,805
	<b>Total</b>		<b>221,767</b>

#### 5.3.1.2 Reduced Local Travel related GHG Emissions Comparison

The comparison presented in Table 11 indicates the impact of reduced local travel for all visitor categories due to proximity of the Expo to the city centre relative to an alternate remote location that was planned earlier.

**Table 11:** Overall Comparison of all Mobility Related GHG Emissions

Sr. No.	Item	CF Mitigation (tons CO <sub>2</sub> e)
1	Visitor Travel	233,949
2	Pre-Event Test Visitor Travel	3,521
3	Participant Travel	286
4	Organizers, VIPs, Service, Security, Travel, Volunteers	88,402
5	Freight Logistics	154
	<b>Total</b>	<b>326,313</b>



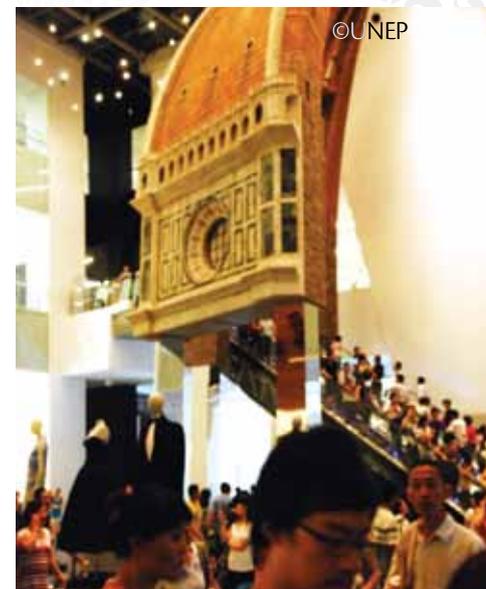
### 5.3.1.3 Other GHG Mitigation Measures

Detailed assessment of the GHG mitigation achieved by the efforts presented in Table 12.

**Table 12:** GHG Mitigation (tons CO<sub>2</sub>e) from Miscellaneous Efforts at Shanghai Expo <sup>45</sup>

Sr. No.	Item	Actual Case	Baseline Case
1	Hotel Energy Efficiency Programme	910,388	1,953,275
2	Solid Waste Management	10,929	14,485
3	Bottled Water Consumption	NA	13,800
4	Rain Water Harvesting	NA	269
5	Grey Water Recycling	NA	111
6	Avoided Construction Energy	NA	4,237
7	Reduced Construction Material	184,869	195,552

<sup>45</sup> only includes verifiable savings from major mitigation sources/ interventions wherein either primary or reliable secondary data was available.



**Table 13:** BAU vs. Actual GHG Inventory Scenarios for Shanghai Expo.

Sr No	Activity Type	Total Carbon Footprint (tons CO <sub>2</sub> e) - Actual	Total Carbon Footprint (tons CO <sub>2</sub> e) - BAU	tons CO <sub>2</sub> e
	<b>Total Visitors Served</b>	73,080,000	73,080,000	
<b>1</b>	<b>Scope 1 (Direct Emissions)</b>			
1.1	Fuel - Power Generation & Cooking	58,214	39,781	-18,433
1.2	Fuel - Site Construction	12,839	17,076	4,237
1.3	Fuel - Site Demolition	8,722	8,722	0
1.4	Fuel - Other Fuel	6.6	6.6	0.0
	<b>Sub-Total</b>	<b>79,781</b>	<b>65,585</b>	<b>-14,197</b>
<b>2</b>	<b>Scope 2 (Indirect Emissions - Electricity, Water, Wastewater)</b>			
2.1	Electricity	277,459	511,287	233,828
2.2	Water	8,520	8,818	299
2.3	Wastewater	2,066	2,147	80
	<b>Sub-Total</b>	<b>288,045</b>	<b>522,252</b>	<b>234,207</b>
<b>3</b>	<b>Scope 3 (Indirect Emissions - Other)</b>			
3.1	Mobility			
3.1.1	Domestic Air Travel	347,996	347,996	0
3.1.2	International Air Travel	2,219,068	2,219,068	0
3.1.3	Public Travel (Road, Rail, Ferry)	781,727	901,815	120,088
3.1.4	Private Vehicular Travel	78,497	272,692	194,195
3.1.5	Logistics	12,513	22,861	10,348
	<b>Sub-Total</b>	<b>3,439,801</b>	<b>3,764,433</b>	<b>324,631</b>
3.2	Food, Beverage, Waste			
3.2.1	Solid Waste	10,929	14,485	2,596
	<b>Sub-Total</b>	<b>10,929</b>	<b>14,485</b>	<b>2,596</b>
3.4	Materials			
3.4.1	Paper & Cardboard	8,013	8,013	0
3.4.2	Plastic	0	13,800	13,800

3.4.3	Construction Materials	184,869	195,552	10,683
	<b>Sub-Total</b>	<b>192,882</b>	<b>217,365</b>	<b>24,483</b>
3.5	Accommodation			
3.5.1	Average Hotel	910,388	1,953,275	1,042,886
	<b>Sub-Total</b>	<b>910,388</b>	<b>1,953,275</b>	<b>1,042,886</b>
<b>Total</b>		<b>4,921,827</b>	<b>6,537,393</b>	<b>1,615,567</b>
		<i>(tons CO<sub>2</sub>e)</i>	<i>(tons CO<sub>2</sub>e)</i>	<i>(tons CO<sub>2</sub>e)</i>
<b>Per Unit Served</b>		<b>67.3</b>	<b>89.5</b>	<b>22.1</b>
		<i>(kg CO<sub>2</sub>e)</i>	<i>(kg CO<sub>2</sub>e)</i>	<i>(kg CO<sub>2</sub>e)</i>

The results of the BAU versus the actual GHG inventory indicate a possible GHG mitigation of 1,615,567 tons CO<sub>2</sub>e (i.e. 1,616 kilotons CO<sub>2</sub>e). A predominant share of these savings resulted from:

1. Enhanced energy efficiency in hotels: 1,043 kilotons CO<sub>2</sub>e mitigation;
2. Reduced local travelling due to proximity of the Expo to the city centre (which encouraged use of public transport such as buses and the metro as opposed to private vehicular travel): 326 kilotons CO<sub>2</sub>e mitigation;
3. Enhanced energy efficiency of electrical equipment (lighting and HVAC systems) as well as renewable energy generation (solar PV, solar thermal heating and hydropower): 222 kilotons CO<sub>2</sub>e.

## 5.4 Assumption of the Marginal GHG Abatement Cost Study

It should be noted that the Marginal Abatement Cost (MAC) analysis is not specific to Expo 2010 and China as some of the capital costs for technologies used in this MAC analysis are not linked to prices prevalent in China.

Comprehensive data was not collected on this subject as it was not within the scope of this review, however international benchmarks are applied to make an implicit assumption to estimate the possible economic cost of Expo carbon emission mitigation interventions.

MAC analyzes the various technological interventions used to achieve GHG mitigation and indicates the extent to which some technologies achieved greater impacts relative to others.

In addition to assessing the magnitude of GHG emissions achieved through the various technologies, it is important to determine the economic cost

of achieving these mitigations. A potent tool for determining the relative efficacy of a technological measure's impact on GHG emissions per unit of economic resource expended is a Marginal Abatement Cost analysis leading to the a MAC Curve which depicts the lifetime cost expense (or saving) per ton of GHG emissions abated.

The results of such an analysis are perhaps the most vital policy-making tool in terms of developing a cost-effective roadmap for abatement of GHG emissions at a city-wide and national level.

The analysis conducted sought to compare the key GHG mitigation measures adopted relative to each other by comparing each alternative with a corresponding business-as-usual alternative. The results of the MAC analysis are presented in Table 14 and graphically depicted as an assumption of Expo's Marginal Abatement Cost Curve in Figure 24<sup>46 47</sup>.

46 Only GHG mitigations and not actual vs. baseline shown for bottled water, rainwater, grey water, and avoided construction energy related efforts.

47 The GHG mitigations used in the MAC analysis are annual GHG emissions and do not correspond with the GHG emissions mitigated for the Expo duration as presented in other sections of the report.

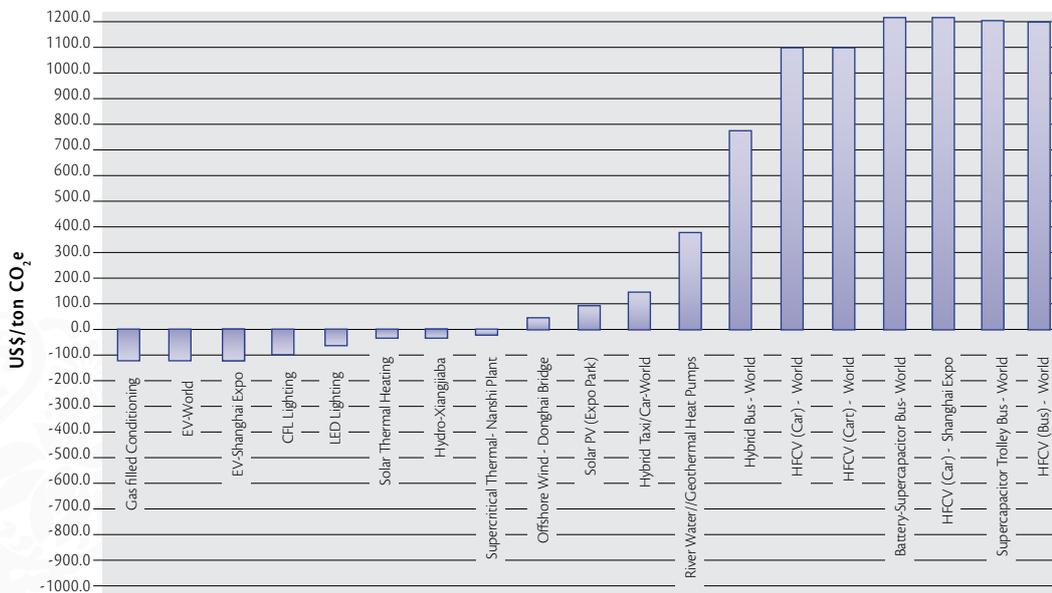
**Table 14:** The Assumption of Marginal GHG Abatement Analysis for Shanghai Expo 2010

Sr. No.	Project	Annual GHG Emissions Abatement (tons CO <sub>2</sub> e) <sup>3</sup>	MAC (USD/tCO <sub>2</sub> e)
1	Thermal Power Plant - Nanshi Power Plant	483,274	-27.1
2	Hydro - Xiangjiaba Hydro Power Station	37,455,799	-30.9
3	Wind Power - Donghai Bridge Offshore Wind Farm	341,675	37.8
4	Solar PV	5,991	86.2
5	LED Lighting	405,862	-61.3
6	CFL Lighting	110,084	-100.7
7	Battery-Supercapacitor Bus - Shanghai Expo	-559	-2,496.7
8	Battery-Supercapacitor Bus - World	1,838	1,251.1
9	Supercapacitor Trolley Bus - Shanghai Expo	-3,009	-32.7
10	Supercapacitor Trolley Bus - World	402	3,042.8
11	Electric Cart - Shanghai Expo	856	-109.1
12	Electric Cars - World	408	-120.2
13	Hydrogen Fuel Cell Cart - Shanghai Expo	-130	-1,764.5
14	Hydrogen Fuel Cell Cart - World	201	1,095.3
15	Hydrogen Fuel Cell Car - Shanghai Expo	71	2,729.6

16	Hydrogen Fuel Cell Car - World	181	1,095.3
17	Hydrogen Fuel Cell Bus - Shanghai Expo	-434	-539.1
18	Hydrogen Fuel Cell Bus - World	37	4,742.4
19	Hybrid Taxi/Car - Shanghai Expo	-290	-1,755.1
20	Hybrid Taxi/Car - World	965	141.3
21	Hybrid Bus - Shanghai Expo	-1,464	-4,117.6
22	Hybrid Bus - World	4,510	771.5
23	Gas Fired Air Conditioning	13,350	-121.1
24	River Water / Ground Source Heat Pumps	5,140	382.5
25	Solar Thermal Heating	277	-36



**Figure 25:** The Assumption of Marginal Abatement Cost Curve – Shanghai Expo 2010



\* Note: in the above figure, MAC values for technologies with abatement costs higher than 1200 US\$/tons CO<sub>2</sub>e not depicted entirely for reasons of scale. Actual values can be found in the corresponding table for the MAC analysis.

This above analysis is intended to serve as a template for a more accurate Shanghai and China specific analyses for drawing meaningful policy recommendations. The approximate conclusions presented below are to be taken as starting points for more refined analyses and not to be used without customization.

In the context of the constraints mentioned at the beginning of this section, the MAC study leads to the following useful approximations:

1. Gas-fired Air Conditioning, Electric Vehicles, and CFL lighting replacement represent the most cost effective GHG abatement technologies to be considered for wide spread application. The annualized savings are estimated to be greater than 100 US\$/ton CO<sub>2</sub>e abated;
2. LED Lighting, Solar Thermal Heating, Hydropower, and Thermal Power Plant Upgrade (through supercritical generator technology) represent the next set of very promising cost-effective technological choices for the future. The annualized savings are estimated to be from 27 to 61 US\$/ton CO<sub>2</sub>e abated through these methods;
3. From a marginal abatement cost (i.e. US\$ per tons CO<sub>2</sub>e mitigated) perspective, CFLs are still more

lucrative than LED lighting. However, this fact is price sensitive and a breakthrough point must be determined from which point onwards LED technology should be preferred unequivocally over CFL technology. LED technology is currently 8.5 more expensive per MW of installed capacity relative to CFL lighting based on average global costs. The installed costs of LED lighting would need to drop to 1.7 times the cost of CFLs (on a per MW basis) for them to achieve parity in terms of marginal abatement cost;

4. Offshore Wind Power is considerably more lucrative in terms of providing a cost effective pathway for mitigating GHG emissions – it is estimated to cost approximately 38 US\$/ton CO<sub>2</sub>e abated through Wind Energy relative to 86 US\$/ton CO<sub>2</sub>e abated through Solar PV technology;
5. Hybrid Vehicle and Geothermal/River Water Heating are considerably more expensive at 141 and 382 USD/ton CO<sub>2</sub>e abated, but are still more attractive economic options relative to the last set of mass transportation-related interventions employed at the Expo;
6. It must be emphasized that the local health and air quality impacts of alternative energy-based transport systems are considerable and must be certainly pursued wherein their application can improve the quality of life in urban areas. However, as options for mitigating GHG emissions (even when using

relatively favourable globally reported performance characteristics relative to the Shanghai Expo-based performance data for these technologies) Hybrid Buses, Battery Supercapacitor Buses, Supercapacitor Trolley Buses and Hydrogen Fuel Cars and Buses are decidedly more expensive. They should be pursued on a larger scale after the earlier options have been established and begun to yield the economic benefits which can then be diverted to funding these environmentally-advantageous but more expensive GHG abatement alternatives.

## 5.5 Carbon Emissions Offsetting

### 5.5.1 Expo GHG Mitigation Interventions Assessment

A wide array of domestic action based (i.e. internal) GHG mitigation measures were implemented at the Expo and have been described qualitatively in earlier sections. Two such key projects which can be counted as 'offsetting' the GHG emissions of the Expo are described in detail below followed by a summary of all such projects that led to 'offsetting' the GHG emissions of Expo. It must be borne in mind that these projects have not been registered as CDM projects and hence do not count as Certified Emission Reductions (or CERs) or registered Voluntary Emissions Reductions (VERs); these are essentially notional offsets wherein the potential GHG emissions mitigated are calculated and thought to have occurred to a high degree of certainty by the UNEP.

#### Power Plant Rehabilitation

The primary positive impact of power plant rehabilitation is derived from lower specific coal consumption per unit of electrical energy generated. The efficiency improvement is estimated to be in the range of 30 per cent to 50 per cent. The specific coal consumption improvements for the Nanshi Power Plant were explicitly obtained for this analysis while values used for other plants are extrapolated from the rehabilitation of the Wujing Power Plant due to absence of plant specific data.

The Nanshi Power Plant rehabilitation was directly related to the Expo while other projects were primarily related to city-wide reform efforts underway independently and part of prior urban and national master plans. The total annual GHG emissions mitigation resulting from Nanshi Power Plant closure is 483,274 tons CO<sub>2</sub>e. For the 2.8 years that the plant has been closed, the capacity replaced with higher efficiency processes, the total GHG mitigation is 1,367,666 tons CO<sub>2</sub>e.

#### Other Industrial Rehabilitation

Other industries closed and in some cases rehabilitated at the Expo site also had a positive impact on the continue GDP growth of the city and the region while decoupling development from pollution and GHG emissions. The assessment used fuel efficiency improvement as the Key Performance Indicator (KPI).<sup>48</sup>

The total annual GHG mitigations impact of rehabilitation of Jiangnan Shipping Group and other miscellaneous projects - are estimated to be 160,103 tons CO<sub>2</sub>e per year. Considering the period since closure of these units to the end of the Expo, the total GHG mitigated from the rehabilitations (excluding the Power Plants discussed earlier) is estimated to be 619,522 tons CO<sub>2</sub>e.<sup>49</sup>

#### Offsets Achieved

The overall assessment of the GHG mitigations is presented in Table 15. The assessment yields that a total of 4,224 kt CO<sub>2</sub>e are expected to be mitigated before the close of the Expo through thermal power plant upgrade, shipyard upgrade, other industrial upgrades, accelerated Metro construction, CFL lighting, and acceleration of the Xiangjiaba Hydro Power Station. It must also be recognized that significant contributors to this portion of GHG mitigations are greatly influenced by the chosen time-period of 'credit' attributed to the Expo.

There is a finite degree of uncertainty about the validity of these time frames as these are largely based on deductive reasoning and not based on actual documentation of these 'credit' periods being allocated exclusively to the Expo.

<sup>48</sup> Technologies which demonstrated negative abatement in the MAC analysis table were excluded from the chart to avoid confusion when comparing with other genuine GHG mitigation alternatives.

<sup>49</sup> The GHG mitigations presented here are annual GHG emissions and do not correspond with the GHG emissions mitigated for the Expo duration as presented in other sections of the report.

Hence it is recommended that in order to avoid double-counting of these credits by other agencies for these same efforts (say for instance the Metro Corporation claiming credits from these same efforts), there must be a concerted effort to 'lock-in' these benefits to prevent any further transferring of GHG mitigations to other projects in the future.

Explicit documentation asserting this and having these claims verified is an essential part of this process which must be undertaken by the Expo authorities.

**Note:** It is critical that the 1,308 kilotons CO<sub>2</sub>e credit claimed from the acceleration of the Xiangjiaba Hydropower Project be formalized through a Carbon Offset purchase agreement so as to ensure the validity of these GHG mitigations being attributable to the Shanghai Expo.

## 5.5.2 Carbon Compensation Project

In addition to the above mentioned GHG mitigations through technological interventions, the Expo endeavoured to improve its balance of offsets relative to its GHG emissions by facilitating purchase of Carbon Offsets (or Carbon Credits) through individual, pavilion, and corporate initiatives through the Expo Voluntary Emission Reduction Platform set on Shanghai Environment and Energy Exchange(SEE).

The assessment indicates that the purchased offsets contributed a total of 117 kt CO<sub>2</sub>e emissions mitigation through purchase of CERs and VERs.

### Overall Expo Footprint and 'Offsets' Summary

The final assessment of Expo Carbon Footprint versus the GHG emissions Mitigated (sum of GHG mitigations through project outside the Expo operational and organizational boundary of the Expo and purchased offsets) is as follows:

**Table 15:** Overall Expo Footprint and Offsets Summary

Sr. No.	Item	Value	Units
1	Total Expo GHG Emissions	4,922	kt CO <sub>2</sub> e
2	Industrial upgrading at Expo Site	1,988	kt CO <sub>2</sub> e
3	Accelerated Metro Construction	784	kt CO <sub>2</sub> e
4	Clean Electricity supply from Xiangjiaba Hydro Power Station	1,308	kt CO <sub>2</sub> e
5	Green Lighting (CFL lighting)	145	kt CO <sub>2</sub> e
6	Purchased Offsets	117	kt CO <sub>2</sub> e
	Total Carbon Emissions Offsetting (before the end of Expo )	4,341	kt CO <sub>2</sub> e

The balance GHG emissions that are planned to be offset after the end of the Expo are 581 kt CO<sub>2</sub>e.



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## Chapter 6

Conclusions and  
Recommendations

# Conclusions and Recommendations

## 6.1 Comments

The outstanding efforts of the Shanghai Government and its agencies in their preparations and execution of the 2010 Shanghai Expo should be acknowledged and applauded. Their recognition of the need for well-planned sustainable growth which impacted every aspect of city development for almost a decade prior to the Expo opening set a standard by which Shanghai will measure itself for decades to come and will likely influence major developing municipalities in China and perhaps other parts of the world.

Many challenges still lay ahead. Vigilance is needed to ensure there is no remission in the gains already achieved and to build on the many impressive achievements to realize the goal of a resource efficient and sustainable urban community.

The Expo offered a platform for a plethora of green concepts and initiatives to be displayed, explored and evaluated. The Expo provided the Shanghai Government and its various research and academic institution an opportunity to develop many indigenous technologies and examine sustainability concepts that

touched every aspect of urban development from around the world. These are now being rigorously evaluated and where feasible will be incorporated in architecture and urban development strategies within the municipality. They will be offered to other regions in support of sustainability agendas in China and internationally.

The paragraphs below provide the conclusions of this UNEP Review attempt to capture some of the highlights of the Expo lessons discussed in the report and provide some thoughts and recommendations in support of Shanghai's sustainable development aspirations and that of other developing cities.

## 6.2 The Shanghai Declaration

At the conclusion of the Expo the participants issued "The Shanghai Declaration" - a statement of the challenges faced by the global community:

"At present, with more than half of humankind living in cities, our planet has entered the urban

age. Rapid urbanization and industrialization have offered to humanity the abundant fruits of modern civilization, but at the same time they have brought unprecedented challenges.

Population explosion, traffic congestion, environmental pollution, resource shortages, urban poverty and cultural conflicts are becoming urban problems with a global scope. For historical and current reasons, these phenomena are especially prominent in many developing countries.”

The Statement offered a vision for meeting this challenge and aspirations for the future:

“... to build cities that establish harmony between diverse people, between development and environment, between cultural legacies and future innovations. A City of Harmony reveals itself when people are in harmony with nature, society, and themselves, and when there is also harmony between generations.”

The Statement goes on to describe actions needed to achieve these aspirations through building livable, ecologically balanced communities that integrate and balance urban and rural development. The mechanisms for realizing these aims the Statement describes as scientific and social innovations that provide technologies and tools that remove barriers. It encourages systems that overcome the information divide, integrate and respect communities at the local, district and broader levels and interlinks humanity through education, respect and protection for cultural heritage, safety and security, and effective social services.

The Statement likens cities to “the ocean that embraces all rivers,” and admonishes “cities should keep an open spirit and actively engage in intercultural exchanges and interactions. Cities should pursue cultural innovation based on respect for cultural traditions and the preservation of cultural diversity, so as to generate lasting momentum for urban and human development,” and “foster an open and sharing multicultural society”.

Above all the Statement carries a theme for the respect of the human spirit which unstated requires spiritual, moral and ethical underpinnings that must permeate the conscience and conduct of every individual regardless of their role or position. This sentiment was echoed by Premier Wen Jiabao in his speech at the closing ceremony of the Expo Summit: “Only when the fruits of human civilization are elevated onto the spiritual and philosophical level will they become the common assets of the entire humanity

and be passed down from generation to generation. It is therefore highly relevant that we review this Expo and see what experience and inspiration we can draw from it.”

## 6.3 Conclusions

The strategies and activities adopted by Shanghai in the decade long preparation for the Expo resulted in the following improvements throughout the Municipality:

- Significant and sustained improvements in air and water quality; industrial structure; energy mix, generation and usage efficiency; urban planning; mass transit; urban greening throughout the Municipality and awareness of environmental issues among the general public;
- Significantly improved municipal planning and management systems;
- Creation of a proactive environmental monitoring system to ensure and verify improving municipal environmental quality trends;
- A systemic prevention and control of pollutants that ensures consistently good environmental quality and carbon footprint reduction;
- Verifiable decoupling of GHG emission intensity as well as total pollutant emissions and development;
- Innovative domestic and international green building, lighting, air conditioning and energy generation and efficiency technologies to achieve significant carbon emission reduction;
- Sustainable, energy efficient and low carbon infrastructure for permanent pavilions and city transport which will continue to yield environmental benefits throughout the entire product lifecycle;
- Compilation and communication of best practice technology and “software” learnings from Expo to government planning agencies in Shanghai and other world cities, industry and the community for incorporation in future urban development planning;
- Expo Park site selection contributed significantly to the city’s economic transformation, energy conservation and pollution reduction. Annual survey data undertaken by Gallup consistently indicates that local citizens have greatly appreciated the improvement of their living environment;

- Launch of Green Commuting and Voluntary Reduction and Offset Programmes and by the end of the Expo, about 88 per cent of carbon emissions accrued by the Expo has been successfully offset;
- Effective communication of carbon footprint concept to a vast majority of the Shanghai population and people of major urban centres in China;
- Undertaking LCA of construction and energy materials used in Expo to ensure maximum reuse, recycling or bio-degradable disposal;
- Verifiable Expo carbon footprint calculation and expedited full offset programme;
- Leveraging market forces and industrial entrepreneurship to encourage development of a broad range of private and state owned green industries;
- Demonstration of applicability and benefits of decentralized rain water harvesting, groundwater recharge, and grey water recycling;
- Galvanized 'green' citizen volunteer community including 50,000 green volunteers trained in green concepts, developed not only through being communicated but empowered with tools and techniques to become change agents in their own community. This will reinforce the environmental legacy of the Expo by seeding ideas in the population that will germinate and yield fruit over extended periods of time;
- Introduction and nascent steps towards reorienting public attitudes towards waste and its traditional portrayal/perception as a nuisance – encouraging its perception as a mismanaged resource which can feed into the economy with useful products through recycling, reusing and harnessing of its inherent organic nutrients.

## 6.4 Recommendations

The following discussion provides a general policy and in some cases more focused framework of recommendations by UNEP that can be incorporated into broad development planning strategies.

These recommendations are to be read with specific recommendations in the various sections of this Review. In some cases, specific implementation

strategies are avoided to allow for a wide scope of potential solutions to be evaluated in addressing sustainable development opportunities.

The recommendations are aligned where relevant with the major subject headings in this document:

### Energy Mix and Conservation

- Further adjust energy mix to optimize renewable energy utilization and reduce air pollution;
- Place carbon cap on energy intensive activities to encourage conservation and alternative energy utilization;
- Develop and enforce realistic but stringent energy conservation, waste energy harnessing and utilization and integrated industrial energy processes to optimize industrial energy utilization;
- Develop and expedite enforcement of domestic, commercial and industrial energy conservation policies that require robust building and process insulation.

### Construction

- Encourage utilization of modular and energy conserving construction technologies successfully demonstrated in the Expo by incorporating into construction codes;
- Provide maximum policy support to encourage use of building materials and systems designed to reduce solar heat gain, heat loss, and enhance building insulation properties;
- Develop regulations requiring comprehensive energy modelling as an integral component of building design for all large scale commercial and residential constructions planned in the city;
- Promote re-use or substitution of concrete in construction projects with low-carbon construction alternatives.

### Transportation

- Incentivize public transport use and encourage fuel-electric hybrid engine technology based cabs by extension of the 'green commuting card' programme that can be transformed into a full-fledged privilege card programme wherein members are eligible for a spectrum of attractive incentives related to their distinguished status in the social structure as role models of social behaviour;

- Pursue alternate fuel vehicle technologies extensively only once a roadmap for reducing dependence on fossil fuels for electricity and hydrogen generation in the city is in place;
- Pursue alternative fuel transport technologies wherever severe local air quality impacts are an acute and immediate issue.

### **Solid Waste**

- Encourage/enforce domestic waste reduction targets through establishing domestic separation systems, reduction of packaging by producers, and minimization of domestic decoration materials;
- Consider localized organic kitchen and garden waste composting sites to supply district parks with fertilizer.

### **Water Resources Management**

Clean water should be considered a valuable commodity even in a water abundant area such as Shanghai and policies should be put in place to optimize its conservation and usage. This can be achieved through the following:

- Promote water-saving toilet fixtures in residential and commercial sectors;
- Grey Water Recycling should be mandated for commercial and large residential units to achieve water and energy conservation benefits on a large scale;
- The government should create policies, strategies and construction codes that maximize harvesting of rainwater by separating and diverting runoff to local groundwater recharge areas to avoid excessive sewage capacity and pumping energy requirements. Construction codes may incorporate buildings, residential developments and all infrastructure;
- The trend towards managing all point and non-point industrial and agricultural effluents should continue through encouraging greater water usage efficiencies and recycling/reuse.

### **Air Quality**

- Additional parameters such as VOCs, heavy metals and POPs should be incorporated into existing air monitoring efforts and PM2.5 and Ozone be incorporated into API calculations and sources of such pollutants should be managed to reduce negative health impacts on the population;
- Control strategies for construction dust and agricultural burning developed for the Expo should be further evolved and more strictly implemented to

minimize pollution from these sources;

- Develop traffic management strategies that minimize the impact of vehicle emission pollution;
- More closely collaborate and invest in schemes with adjacent provinces in Yangtze Delta to establish an Air Quality Management District based on the experience of the Shanghai Expo and Beijing Olympics to encourage closure of polluting industries, improve vehicle emissions and prevent migration of polluting operations to non-regulated areas without process upgrading;
- Encourage haulage of bulk goods by train or barge in the Yangtze region to reduce heavy vehicle traffic and pollution.

### **Green Consumption**

- Develop and enforce policies that discourage disposable products;
- Develop a potable water system in Shanghai similar to the one provided in the Expo to reduce significantly bottled water usage particularly at major events;
- Promote organic fertilizer and organic agriculture in the limited agricultural land in Shanghai and contract farmers in adjacent provinces to supply organic products to Shanghai;
- Reuse straw for mulching, organic fertilizer production or construction material to reduce need for burning.

### **Management and Professional Development**

- Continue the process of increasing sustainability awareness in all activities and professionalization of government staff in order to better support the various municipal functional bureaus and provide informed inputs to all sectors;
- Require department heads to have more integrated roles to ensure more effective internal/external coordination.

### **Role of Industry**

- In policy and project consultations the role of private industries including international industries should not be overlooked as this sector may have some of the most innovative and pragmatic approaches to sustainability challenges;
- Small and medium size private industries specialized in green technology development and manufacture should be encouraged and supported to develop a world class high-end manufacturing and tertiary industry in green construction, energy and agricultural technologies.

## Appendix

# A

List of Pavilions and  
Details of the Exhibits

### Appendix A - List of Pavilions and Details of the Exhibits

Pavilions	Exhibit Details
<b>China's Joint Provincial Pavilion</b>	
<b>Gansu Pavilion</b>	Demonstrating desert reforestation, urban water treatment, clean energy demonstration base, etc.
<b>Guangdong Pavilion</b>	Multimedia demonstration of a "tree of life"; showcasing the environmental advantages (natural lighting, ventilation and sunshading) of Arcade Building in Guangdong
<b>Guangxi Pavilion</b>	Demonstrating ecological views of Guilin Landscapes and mangrove forests
<b>Hunan Pavilion</b>	3D movie named "Green Forest," introducing and other Hunan's ecological scenery like Zhangjiajie; demonstrating a virtual "green bionic city"
<b>Ningxia Pavilion</b>	Interactive game on a flowing water screen, demonstrating induction of Yellow River to desert to turn it green
<b>Jiangxi Pavilion</b>	Demonstrating a blueprint of ecological economy zone around Poyang Lake
<b>Tianjin Pavilion</b>	Showcasing Sino-Singapore Eco-City, Circular Economy Demonstration Projects, etc.
<b>Pavilions for countries and international organizations</b>	
<b>United Arab Emirates Pavilion</b>	A plan to build the world's first "Zero Carbon City" near the capital Abu Dhabi.
<b>Belgium- EU Pavilion</b>	"Green Attitude" section: introducing EU's environmental policies and efforts to mitigate climate change
<b>British Pavilion</b>	Seeds of different plants collected in a bio-diversity project were displayed; urban landscapes in four capital cities of UK were showcased; precious plant seeds inside the rods were auctioned after Expo and the proceeds was donated to local common welfare projects.
<b>Canadian Pavilion</b>	Pictures and movie showing Canada's resources and landscapes, as well as environmental concepts
<b>China Pavilion</b>	A special exhibition section called "low-carbon future": Solar/wind powered car - "Leaf"; Demo of microalgae for biodiesel; Demo of wind power generation; Lanes standing for different vehicles/lighting for visitors to choose; Carbon sinking forest;
<b>Czech Pavilion</b>	Multimedia hall showed the country's strategies to solve traffic congestion and pollution in cities.
<b>Denmark Pavilion</b>	Visitors can choose to visit by walking or biking; introducing and appealing for biking.
<b>Devnet Pavilion</b>	Demonstrating environmental protection, energy saving knowledge; Holding an environmental and energy saving international forum
<b>Finland Pavilion</b>	Showing the solution to future urban architecture;
<b>Holland Pavilion</b>	Showing the innovation in space utilization, energy and water conservancy in Holland; Showing solar-powered car, wind power technology, and water treatment machine (which can change Huangpu River water to drinkable water for visitors).
<b>Indonesia Pavilion</b>	Showing protection of ecosystem and biodiversity in Indonesia
<b>Iran Pavilion</b>	Emphasizing harmony of human and nature; emphasizing harmonious development between Iranian urban and rural areas

<b>Israel Pavilion</b>	High efficiency trickle irrigation technology. Advanced Solar and efficient medical devices.
<b>Japan</b>	Demonstrating the harmony between human hearts and technology; Demonstration of the mini electric car, i-Real; Movie showing Japan and China's cooperation in protecting the rare bird, Crested Ibis
<b>Joint Pavilion of International Organizations</b>	Global Environmental Facility (GEF) Pavilion: introduction of the organization and its contributions to the global environment; promotion of environmentally-friendly technologies; International Association of Public Transport (UITP) Pavilion: promoting public transport; holding a creative writing contest named "choose public transit, choose beautiful future"; International Network of Bamboo and Rattan (INBAR) Pavilion: movie showing bamboo and rattan's contributions to comfortable living environment for humans; videos showing different bamboo eco-houses in the world; World Water Council (WWC) Pavilion: demonstrating successful and creative cases of urban water resource use; "children's corner" for interactive learning of water knowledge; World Wide Fund for Nature (WWF) Pavilion: displaying rare aquatic life in a spherical aquarium; promoting people's participation in environmental protection and ecological footprint reduction
<b>Luxembourg Pavilion</b>	Illustrating sustainable development through appearance and content design of the pavilion (forest and fortress)
<b>MeteoWorld Pavilion</b>	Climate-changing Corridor: introducing the threats of climate change and appealing for visitors' response in daily behaviors
<b>Norway Pavilion</b>	Construction formed of 15 model trees, showcasing sustainable development concept; promotion of protecting natural resources
<b>Portugal Pavilion</b>	A exhibition section called "a world of energy", showing new products and technologies in renewable energy and energy efficiency fields, and green building and traveling in Portugal; Handouts with contents of renewable energy and other
<b>Saudi Arabia Pavilion</b>	"Energy city" and "oasis city" - sustainability in harsh environment; importance of water and oil.
<b>South Korea Pavilion</b>	"Green city, green life" section: interactively demonstrating green technologies such as smart home system, new energy, etc.
<b>Devnet Pavilion</b>	Demonstrating environmental protection, energy saving knowledge; Holding an environmental and energy saving international forum
<b>Meteo Pavilion</b>	Climate-changing Corridor: introducing the threats of climate change and appealing for visitors' response in daily behaviors
<b>Theme Pavilion</b>	Urban People Pavilion: demonstrating the recycling channel networks in cities (asking for people's care for city system); Urban Planet Pavilion: urban expansion, ecological destruction, mind changing, visitors' introspection, etc.;
<b>Indonesia Pavilion</b>	Showing protection of ecosystem and biodiversity in Indonesia
<b>Belgium- EU Pavilion</b>	"Green Attitude" section: introducing EU's environmental policies and efforts to mitigate climate change
<b>British Pavilion</b>	Precious plant seeds inside the rods were auctioned after Expo and the proceeds was donated to local common welfare projects.
<b>Canadian Pavilion</b>	Pictures and movie showing environmental concepts
<b>Czech Pavilion</b>	Multimedia hall showed the country's strategies to solve traffic congestion and pollution in cities.
<b>Denmark Pavilion</b>	Visitors can choose to visit by walking or biking; introducing and appealing for biking.
<b>Finland Pavilion</b>	Showing the solution to future urban architecture;

<b>Holland Pavilion</b>	Showing the innovation in space utilization, energy and water conservancy in Holland; Showing solar-powered car, wind power technology, and water treatment machine (which can change Huangpu River water to drinkable water for visitors).
<b>Luxembourg Pavilion</b>	Illustrating sustainable development through appearance and content design of the pavilion (forest and fortress)
<b>Norway Pavilion</b>	Promotion of protecting natural resources.
<b>Portugal Pavilion</b>	A exhibition section called "a world of energy", showing new products and technologies in renewable energy and energy efficiency fields, and green building and traveling in Portugal; Handouts with contents of renewable energy and other
<b>Switzerland Pavilion</b>	The architecture incorporates the symbiosis between town and country, and emphasizes the perfect balance of man, nature and technology.
<b>United Arab Emirates Pavilion</b>	A plan to build the world's first "Zero Carbon City" near the capital Abu Dhabi.
<b>USA Pavilion</b>	Emphasizing "nature's wisdom" - electricity from skate by Franklin; multimedia display of an ordinary person's story about creativeness and sustainable development
<b>Pavilions for companies</b>	
<b>Broad Pavilion</b>	Interactive touching experience for different walls, window glass and frames; appealing for utilization of low-tech energy-saving building technologies; multimedia shows about population and environmental challenges.
<b>Information and Communication Pavilion</b>	Appealing for interconnection of environmental monitoring and research stations using ICT
<b>Oil Pavilion</b>	4D film demonstrating the development and preciousness of oil resource
<b>SAIC-GM Pavilion</b>	Demonstrating green transportation system in 2030; new energy vehicles: Leaf and EN-V
<b>State Grid Pavilion</b>	"Magic Box" multimedia room showed a movie about energy and environment; demonstrating smart grid systems and super high voltage transmission systems
<b>Urban Footprint Pavilion</b>	Demonstrating the interactive development of human, city and environment
<b>Vanke Pavilion</b>	Visions of future life in 2049; Five halls with five environmental stories: snow mountain elf, China's reforestation, Taipei's garbage sorting, adventure of ant's home, and stories of Chinese environmentalists.
<b>Pavilions of the organizer</b>	
<b>Theme Pavilion</b>	Urban People Pavilion: demonstrating the recycling channel networks in cities (asking for people's care for city system); Urban Planet Pavilion: urban expansion, ecological destruction, mind changing, visitors' introspection, etc.
<b>Urban Footprint Pavilion</b>	Demonstrating the footprint of urban development in three halls: City Origins, City Development, and City Wisdom
<b>Urban Future Pavilion</b>	New-Energy Exhibition Hall: Expo Park new energy and environment monitoring screen; Introduction pictures and videos for the new energy utilization in the Expo; Touch-screen questionnaire for low-carbon knowledge; Collected cards with visitor's "low-carbon" message
<b>Pavilions in Urban Best Practice Area</b>	
<b>London Zed Pavilion</b>	Taking the BedZed- the world's first zero carbon community of Beddington as the prototype, demonstrating green efforts in London and presenting the up-to-date technologies and best practices.

<b>Shanghai Eco-House</b>	Taking the first demonstrative eco-building in China as the prototype, demonstrating highly intelligent Eco-house including intelligent kitchen, CO <sub>2</sub> absorbing microalgae system, robot housekeeper, power generation by stationary bicycle, etc.
<b>Taipei Case Pavilion</b>	A movie showed Taipei's garbage sorting efforts and success in the past 10 years
<b>The Alsace Case</b>	A multi-facet journey of Alsace, including demonstration on hydro power generation and other innovative energy technology.
<b>The Chengdu Living Water Park</b>	Taking the Chengdu Living Water Park as the prototype, which is the first urban ecological landscape park in China. This concept is being applied to all waterways in Beijing
<b>The Hamburg House</b>	Promotion of old city area transformed into a big commercial residential area with lots of ecological buildings in the New Harbor City in Hamburg.
<b>The Madrid Case</b>	Introducing government low-cost housing estate from Madrid; demo of an "Air Tree" that improves the microclimate
<b>The Makkah and Mina Case</b>	As the largest 'tent city' in the world, demonstrating the advantage of tents made of new materials featured in windproof, rainproof, fire proof, anti-corrosion, flood resistance, expandable and with high accommodation capacity, providing sanitary and comfortable living spaces under harsh environmental conditions.
<b>The Odense Case</b>	Promotion of bicycles to reduce energy consumption and environmental pollution
<b>The Rhône-Alps Region Case</b>	Taking the INEED - a sustainable building in Rhone-Alpes Region as the prototype to promote ecological constructions.

*(Note: The list above only contains part of the Expo pavilions that displayed environmental concepts or technologies; it is in alphabetic order within each category.)*

## Appendix B - Summary of Green Construction/Architectural Interventions at Shanghai Expo 2010

Category	Technology	Pavilion	Design Parameters
Building Integrated Energy Systems	BIPV A-Si film system	Shanghai Eco-House	
	Ultra-light membrane (ETFE) skin w/ embedded solar cells	Japan Pavilion	16.74 kW
Construction Materials & Methods Interventions	Bamboo Construction	Indonesia Pavilion	
		The Madrid Case	
		India Pavilion	2,000 sq.m
		The Rhône-Alps Region Case	
	Biodegradable Construction Material	Switzerland Pavilion	
	Calcined Clay Construction	The Rhône-Alps Region Case	
	Green building materials	Finland Pavilion	
	Green building materials	Urban Future Pavilion	
	Hollow Silt Bricks	Shanghai Eco-House	
	Inorganic Insulation Mortar	Shanghai Eco-House	
	Low Carbon Concrete Structure	London Zed Pavilion	
		Shanghai Eco-House	5000 m <sup>3</sup>
	Modular / Reusable Construction	Norway Pavilion	
	Modular Space Volume Reduction	Expo Culture Center	
	Pre-fabricated construction elements	Broad Pavilion	
		Finland Pavilion	
		Shanghai Eco-House	
	Recyclable construction materials	Arab Emirates Pavilion	
		Brazil Pavilion	
		Canada Pavilion	
		India Pavilion	
		Information and Communication Pavilion	
		Japan Industrial Pavilion	
		Luxembourg Pavilion	
		Norway Pavilion	
		Oil Pavilion	
		SAIC-GM Pavilion	
		Singapore Pavilion	
		Spain Pavilion	
		The Makkah and Mina Case	
	Recycled construction materials	Coca-Cola Pavilion	
		Japan Industrial Pavilion	
Shanghai Corporate Pavilion			
Vanke Pavilion			
Reinforced hollow bricks with fly ash	Expo Center		
Reused construction materials	Baosteel Stage		
	Broad Pavilion		
	Japan Industrial Pavilion		
	The Madrid Case		
Urban Future Pavilion			
Strengthened insulation on glass curtain walls	Expo Center		
Synthetic Gypsum Plates (recovered material from power plant slag)	Shanghai Eco-House		
Zero-Chemical Design	India Pavilion		

## Appendix

# B

Summary of Green Construction/ Architectural Interventions at Shanghai Expo 2010

Energy Efficiency Interventions	Double-glazed windows	China Pavilion	
		Shanghai Eco-House	
		Theme Pavilion	
	Double-layer Water-Curtains	The Alsace Case	
	Energy Saving Building Materials	Poland Pavilion	
	Heat Gain Reducing Paint	The Rhône-Alps Region Case	
	Indoor Greening and Pool	Morocco Pavilion	
	Indoor Pool	Switzerland Pavilion	
		Vanke Pavilion	
	Natural Lighting	British Pavilion	
		Expo Axis	
		Holland Pavilion	
		Israel Pavilion	
		Japan Pavilion	
		Shanghai Eco-House	
		Singapore Pavilion	
		Spain Pavilion	
		The Madrid Case	
		The Odense Case	
		Vanke Pavilion	
	Natural Lighting (Dormer Windows)	Theme Pavilion	
	Natural Lighting (Skylights)	Expo Culture Center	
	Natural Lighting (Transparent Cement)	Italy Pavilion	
	Natural Ventilation	Baosteel Stage	
		China Aviation Pavilion	
		China Pavilion	
		Finland Pavilion	
		Holland Pavilion	
		Italy Pavilion	
		Japan Pavilion	
		Saudi Arabia Pavilion	
		Shanghai Eco-House	
		Singapore Pavilion	
		Spain Pavilion	
		State Grid Pavilion	
		The Hamburg House	
		The Makkah and Mina Case	
		Urban Future Pavilion	
	Vanke Pavilion		
	Outdoor Pool	France Pavilion	
Sunshading	Broad Pavilion		
	Expo Center	8114 m <sup>2</sup> Shaded Window Area	
	Expo Culture Center		
	Holland Pavilion		
	London Zed Pavilion		
	Shanghai Eco-House		
	South Korea Pavilion		
Theme Pavilion			
Sunshading (Dougong Brackets)	China Pavilion		
Thermal Insulated Window Frame	Broad Pavilion		
Thickened Wall	Broad Pavilion		
Triple Layer Window	Broad Pavilion		

<b>Greening Interventions</b>	Roof greening	Baosteel Stage	
		British Pavilion	
		China Pavilion	
		Expo Center	52 per cent Roof Area
		Finland Pavilion	
		India Pavilion	
		London Zed Pavilion	250 m <sup>2</sup>
		New Zealand Pavilion	
		Saudi Arabia Pavilion	
		Shanghai Eco-House	
		Singapore Pavilion	
		Switzerland Pavilion	
		The Rhône-Alps Region Case	
	Stereo Greening	Baosteel Stage	
Canada Pavilion			
Expo Park			
France Pavilion			
Shanghai Eco-House			
The Alsace Case		298 m <sup>2</sup>	
Theme Pavilion		6000 m <sup>2</sup>	
<b>Water Conservation Interventions</b>	Permeable Pavement	China Pavilion	
		Expo Center	>40 per cent Outdoor Pavement
		Expo Park	
		Shanghai Eco-House	
	Self-cleaning circular glass curtain walls	Expo Axis	
		Exterior Wall Nano-Coating	London Zed Pavilion

## Appendix C – GHG Emission Factors for the Shanghai Expo GHG Inventory

Category	Technology	Type 1: Weight Based		Type 2: Qty. Based		Type 3: Distance Based	
Activity Differentiator - Usage	Activity Differentiator - Technology	Value	Units	Value	Units	Value	Units
Electricity	Electricity - Grid			0.8825	kg CO <sub>2</sub> /kWh-generated		
Electricity	Electricity - Hydro			0.011	kg CO <sub>2</sub> /kWh-generated		
Electricity	Electricity - Wind			0.013	kg CO <sub>2</sub> /kWh-generated		
Electricity	Electricity - Solar			0.0934	kg CO <sub>2</sub> /kWh-generated		
Water	Municipal Water		kg CO <sub>2</sub> e/kg	0.0008825	kg CO <sub>2</sub> e/liter		
Wastewater	Municipal Wastewater Treatment			0.00024	kg CO <sub>2</sub> e/liter		
Flammables	Fireworks	0.55	kg CO <sub>2</sub> e/kg				
Power Generation	Diesel	3.16	kg CO <sub>2</sub> e/kg	2.63	kg CO <sub>2</sub> e/liter		
Power Generation	Natural Gas			0.002184	kg CO <sub>2</sub> e/liter		
Site Construction	Generic Energy Source			26.95	kg CO <sub>2</sub> e/m <sup>2</sup>		
Site Demolition	Generic Energy Source			13.475	kg CO <sub>2</sub> e/m <sup>2</sup>		
City Logistics - Road	Diesel HMV - City - Ambient	3.16	kg CO <sub>2</sub> e/kg	2.63	kg CO <sub>2</sub> e/liter	1.2271856	kg CO <sub>2</sub> e/v-km
Intercity Logistics - Road	Diesel Bus					1.034	kg CO <sub>2</sub> e/v-km
Intercity Freight - Road	Diesel - Ambient					0.0000386	kg CO <sub>2</sub> e/kg-km
Intercity Freight - Rail	Diesel - Ambient					0.0000300	kg CO <sub>2</sub> e/kg-km
Intercity Freight - Ship	Diesel - Ambient					0.00006	kg CO <sub>2</sub> e/kg-km
Private Vehicle	Diesel Car - City - AC	3.16	kg CO <sub>2</sub> e/kg	2.63	kg CO <sub>2</sub> e/liter	0.233	kg CO <sub>2</sub> e/v-km
Private Vehicle	Petrol Car - City - AC	3.17	kg CO <sub>2</sub> e/kg	2.3705872	kg CO <sub>2</sub> e/liter	0.2546	kg CO <sub>2</sub> e/v-km
City Travel - Individual	Taxi – AC					0.2546	kg CO <sub>2</sub> e/v-km
City Travel - Mass Transit	Local Bus - AC					0.0661	kg CO <sub>2</sub> e/pass/km
City Travel - Mass Transit	Local Rail					0.0796	kg CO <sub>2</sub> e/pass/km
City Travel - Mass Transit	Ferry Boat					0.4529	kg CO <sub>2</sub> e/pass/km
Intercity Travel - Mass Transit	Long Dist. Bus - AC					0.05	kg CO <sub>2</sub> e/pass/km
Intercity Travel - Mass Transit	Long Dist. Rail					0.06	kg CO <sub>2</sub> e/pass/km
Intercity Travel - Air	Domestic Long Haul - Economy					0.12	kg CO <sub>2</sub> e/pass/km
Intercity Travel - Air	Domestic Medium Haul – Economy					0.15	kg CO <sub>2</sub> e/pass/km

## Appendix

# C

GHG Emission Factors  
for the Shanghai Expo  
GHG Inventory

<b>Intercity Travel - Air</b>	Domestic Short Haul - Economy					0.15	kg CO <sub>2</sub> e/pass/km
<b>International Travel - Air</b>	International Medium Haul – Economy					0.114	kg CO <sub>2</sub> e/pass/km
<b>Hotel</b>	Average Hotel			18.8	kgCO <sub>2</sub> e/person/overnight stay		
<b>MSW</b>	Landfilled	0.63	kg CO <sub>2</sub> e/kg				
<b>Paper</b>	Copy Paper	2.5806	kg CO <sub>2</sub> e/kg	0.0124535	kg CO <sub>2</sub> e/sheet		
<b>Cement</b>	Virgin	0.85	kg CO <sub>2</sub> e/kg				
<b>Brick</b>	Virgin	0.22	kg CO <sub>2</sub> e/kg				
<b>Concrete</b>	Virgin	0.2	kg CO <sub>2</sub> e/kg				
<b>Limestone</b>	Virgin						
<b>Steel</b>	Virgin	1.5	kg CO <sub>2</sub> e/kg				
<b>Aluminum</b>	Virgin	14.7	kg CO <sub>2</sub> e/kg				
<b>Glass</b>	Virgin	0.99	kg CO <sub>2</sub> e/kg				
<b>Cement</b>	Recycled	0.845	kg CO <sub>2</sub> e/kg				
<b>Steel</b>	Recycled	0.43	kg CO <sub>2</sub> e/kg				
<b>Aluminum</b>	Recycled	1.69	kg CO <sub>2</sub> e/kg				
<b>Glass</b>	Recycled	0.313	kg CO <sub>2</sub> e/kg				

- 1 **Source:** Shanghai Municipal Tourism Administration
- 2 Area for construction activity are lower than actual areas due to use of allocation ratios for determining that share attributed to Expo vs. lifetime of building (1/30th allocation to Expo based on 30 year lifespan)
- 3 The GHG mitigations presented here are annual GHG emissions and do not correspond with the GHG emissions mitigated for the Expo duration as presented in other sections of the report.

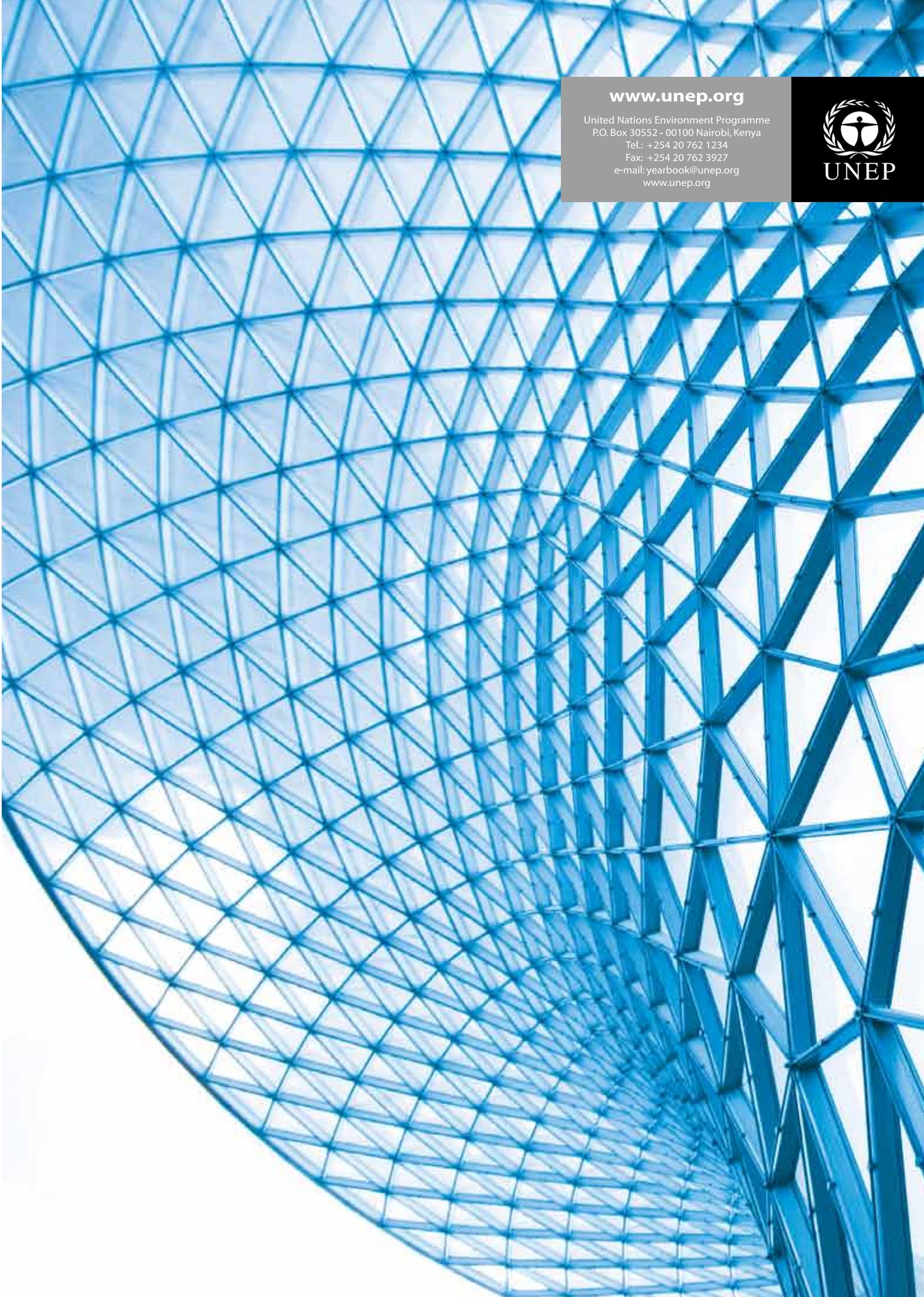












[www.unep.org](http://www.unep.org)

United Nations Environment Programme  
P.O. Box 30552 - 00100 Nairobi, Kenya  
Tel.: +254 20 762 1234  
Fax: +254 20 762 3927  
e-mail: [yearbook@unep.org](mailto:yearbook@unep.org)  
[www.unep.org](http://www.unep.org)

