Fraunhofer

MorgenStadt
City of the Future

INNOVATION NETWORK

»MORGENSTADT: CITY INSIGHTS«

City Report

SINGAPORE

May 2013

MORGENSTADT: CITY INSIGHTS (M:CI)

Climate change, energy and resource scarcity, a growing world population and aging societies are some of the large challenges of the future. In particular, these challenges must be solved within cities, which are today already home to more than 50% of the world's population. An ever-growing number of cities are actively developing new and sustainable infrastructures and services, in order to safeguard and improve their citizens' quality of life.

New technologies make sustainable development of municipal infrastructure and the availability of adapted services possible. Renewable energies, energy-efficient buildings, electric vehicles and new mobility concepts, as well as flexible logistics and modern security systems are developing dynamically. New information and communications technologies are saturating and connecting all sectors and allow for the use of these technologies. The transformation of our existent cities, and the development of new cities, with the expectation of sustainability require a clear set of objectives, a long-term plan and the continual implementation of a plethora of projects addressing parts of the solution. Intelligent steering of the processes and active citizen participation within the conceptualization of solutions – that is to say, mature governance – are conditions for successful implementation.

Within the motto »Morgenstadt – City of the Future«, the Fraunhofer Organization focuses on the development of technological solutions for future-compatible, sustainable cities. Of the 60 Fraunhofer institutes, which conduct applied research in different areas, 14 institutes are part of a network for the development of sustainable cities. The institutes contribute high quality competencies in their individual fields, and work together in an inter-disciplinary manner.

From May 2012 until October 2013, 12 Fraunhofer-Institutes conducted the project »Morgenstadt: City Insights« together with 30 industrial businesses and cities, with the goal of creating an inventory of good solutions for sustainable cities. Towards this end, a catalogue of inspiring cities world-wide was created and the following six cities were selected for in-depth study: Freiburg, Berlin, Copenhagen, New York, Singapore and Tokyo. A team of Fraunhofer researchers went to each of these cities, and through the use of interviews, discussions, and site visits they studied spear-heading projects and solution approaches. The goal was to determine how these projects were initiated, conceptualized and implemented, how successful they were/are, what success factors can be identified and what actors are involved. In addition, the goal was to determine under which conditions these approaches could be transferred to other cities.

Singapore is an international hot spot for economic activity and its living conditions are among the highest in Asia and the world. Singapore´s development towards becoming a big green "Garden City" is the result of strategic planning and efforts already initiated by the former Prime Minister Lee Kuan Yew. Sustainable urbanisation has always been a guiding principle in Singapore. Nowadays, Singapore ranks number 1 in Forbes World´s Smartest Cities 2009 and Asian Green City Index 2011, number 1 (followed by Frankfurt, Munich and Copenhagen) in Mercer´s Quality of Living Survey with a focus on infrastructure and number 3 in the Ericsson Networked Society City Index 2013. The city's ambitious environmental targets and its efficient solutions used to achieve these targets earned Singapore a worldwide reputation as a green cosmopolitan city. This report describes the results of the on-site research which took place in Singapore between May 6 and 17, 2013.

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City Report - Singapore

CONTENT

EXECUTIVE SUMMARY

Formerly a British colony, and departed from the Malaysian Federation in 1965, Singapore´s scarcity in terms of land space and resources led to the practice of achieving development while minimising its impact on resources right from its birth. Today, Singapore is an international hot spot for economic activity and its living conditions are among the highest in Asia and the world. Singapore´s development towards becoming a big green "Garden City" is the result of strategic planning and efforts already initiated by the former Prime Minister Lee Kuan Yew. Sustainable urbanisation has always been a guiding principle in Singapore. Nowadays Singapore ranks number 1 in Forbes World´s Smartest Cities 2009 and Asian Green City Index 2011, number 1 (followed by Frankfurt, Munich and Copenhagen) in Mercer´s Quality of Living Survey with focus on infrastructure and number 3 in the Ericsson Networked Society City Index 2013. The city's ambitious environmental targets and its efficient solutions used to achieve these targets earned Singapore a worldwide reputation as a green cosmopolitan city.

Governance
The Government in Singapore is goal-oriented and heads straight towards developing and realizing sustainable development in the city (e.g. frame-work for planning and developing a liveable city, multi-stage process for urban planning and development (Master plan, Concept plans etc.)). This top down approach also includes the participation of various stakeholders in a variety of different ways. If the government is convinced of a new idea or type of technology and its economic benefits, it takes quick steps to ensure the realization of this idea or concept. Regarding the understanding of sustainability in Singapore, the economic aspect has highest priority (economic sustainability). Economic success seems to be the dominating criteria for evaluating sustainability. As part of the social aspects, liveability is a desirable objective closely linked to sustainability. It seems that sustainability (in the sense of economic, ecological and social aspects) is not present in the daily lives of citizens. As pilot projects, many activities are initiated by government. Two present guidelines have been identified that focus on sustainability as a whole: the National Climate Change Strategy (NCCS) 2012 and the Strategy for Sustainable Blueprint. The NCCS functions as an umbrella for activities carried out in different sectors and by different actors (ministries, companies, R&D, citizens etc.). The strategy brings together actors within the entire value chain.

Energy
Singapore's energy supply is – and probably will continue to be – dependent on the importation of fuels. Renewable energy resources are very limited and do not offer a comprehensive supply strategy. Singapore runs many test-beds in the area of smart grid technologies and benefits from this extensive technical and operational know-how. Smart grids for the increased deployment of renewable energy generators are not pursued due to limited solar PV potential and no potential for energy from wind power and biomass. Only those energy technologies – as with other technologies in general – which show market viability after the test-bed phase will be rolled out; direct public subsidy programs are not supported by the Singaporean government. As a result of these requirements placed on technological innovations, priority is currently given to energy efficiency related activities, mainly dominated by the very successful Green Mark Scheme for buildings. Smart Metering is understood to contribute to the energy efficiency strategy but has, as of yet, not been decided on due to the lack of both a suitable business model and public acceptance.

Buildings
To improve energy efficiency in buildings and promote environmental sustainability in the building sector, the government of Singapore launched the Green Mark Scheme (GMS) in 2005. This green building rating system was developed and is managed by the Building and Construction Authority (BCA), and sets a benchmark with which the energy efficiency and environmental performance of buildings can be evaluated by various members of the private sector. These include building owners, developers and designers as well as building operators. Singapore has been making steady progress on its target to have 80% of the total building stock Green Mark rated. Now, at the end of March 2013, there are more than 1,500 Green Mark building projects in Singapore. Thereby, Singapore's robust investments into greening the building stock has benefited more than just the nation's energy consumption; developers, designers and architects, consultants, technicians and installers, manufacturers, research agencies, retailers and the real estate market have all been economically stimulated during the past decade as the government continuously rolls out green building incentives.

Security
The Singapore authorities are strongly committed to handling emergency response and resilience in the context of the city's uniqueness: finite space and a high population and building density, as well as numerous large-scale events, a large industry landscape and a very specific geographical location and climate zone. Resilience is a key component of the city's overall strategy to meet the challenges imposed by climate change on the one hand, and an ever-more interlinked environment on the other. Therefore, adaptation and preparedness, as well as self-sufficiency, are core elements which are supported by various measures at the urban level, such as the development of interlinked sensor networks, coastal protection strategies, stormwater management for heavy rainfalls and resilient and independent energy management. The challenges Singapore faces in terms of its security efforts include the assessment of the effects and impacts of climate change, demographic

factors such as a significant increase in the number of people living in a finite densely constructed urban space, the coordination of responsibilities of the agencies and authorities involved in security matters – all in the context of economic efficiency. The Singapore government thus builds on cooperation between research, industry and individual government authorities.

Mobility

Transportation has always played an important role in the economic and physical development of modern Singapore. As early as 1971, Singapore´s State and City Plan focused on the accommodation of 4 million people and recommended a Mass Transportation System in order for Singapore to meet increasing transportation demands. Today, there are about 12.5 million journeys made across the island every day and an increase of 50% by the year 2030 is expected. Therefore, the overall size of the rail network will be doubled and the peak hour rail capacity for travel into the city will be increased by 110%. Another transport aim is to reduce the reliance on private transport. To manage road use and vehicle population, Singapore is restricting private vehicle ownership by imposing high import duties, charging additional registration fees (ARF), using a vehicle quota system (VQS), controlling congestion in city centres through an Electronic Road Pricing System (ERP) and – in a moderate way due to land scarcity – expanding the road network. The vehicle population growth rate was reduced to 0.5% from 2013 onwards. Singapore plans to replace its current ERP system with a satellite-based system within the next years.

Information &C Communication Technologies (ICT)

ICT in Singapore represents one of the key drivers of its successful economy. Singapore ICT accounts for more than US$ 70 billion and grows at more than 12% per year. Singapore has strategically placed much of its effort on ICT development, both on infrastructure and on innovative services. The island has stable ICT infrastructure that covers more than 95% of the region with fibre-based broadband through the implementation of the Next Generation Nation Broadband Network. In parallel, Singapore mobile penetration has passed more than 150%, of which three quarters is based on 3G adoption. Nevertheless, mobile operators are already looking at the pre-4G long-term evolution (LTE) platform for providing faster mobile broadband internet access. Today, Singapore offers some of the most advanced ICT infrastructure of all the developed countries. To achieve such success, and also maintain outstanding economic performance since 1965, Singapore has embraced global trends and proactively seized opportunities brought about by emerging technologies. The ICT industry is regulated by the Singapore Infocomm Development Authority which is responsible for the planning and development of the sector as a whole and its infrastructure. ICT represents a top priority and strategic lever of Singapore's development strategy and policy. Nowadays, the ICT industry strongly attracts foreign investment and sustains long-term GDP growth through innovative ICT technology development, deployment and usage, which helps Singapore make progress on its path towards becoming a smart and sustainable city.

Water

After the Second World War, Singapore faced a lack of housing, schools and jobs. These problems were, however, soon resolved. The remaining con-straints are land and water. In the meantime, 17 reservoirs have been constructed and two thirds of the island's surface serves as a water catchment area. The Active, Beautiful and Clean (ABC) Waters Programme involves water-sensitive urban design and helps utilize these areas for recreational purposes for the public. Local open water bodies are transferred into vegetated bio retention swales and rain gardens. This also helps to slow down stormwater runoff in the pursuit of meeting the goal of treating "every drop on site". In order to meet the islands' growing demand for water, it has become obvious that other sources need to be "tapped". With Singapore being, to a large extent, dependent on imported water from Malaysia, the national Public Utility Board aims at closing the water loop and is putting a large amount of effort into R&D activities related to unconventional water sources. Two successful and important sources of water for Singapore are low energy seawater desalination as well as the recycling of used water using innovative treatment processes. NEWater is the name given to the high-grade reclaimed water that has gone through micro/ultrafiltration, reverse osmosis and ultraviolet disinfection. Although it is of a drinkable quality, this water is primarily used for commercial and manufacturing processes.

LIST OF ABBREVIATIONS

ABC	- Active, Beautiful and Clean
ALS	- Area Licensing System
AMI	- Advanced Metering Infrastructure
ARF	- additional registration fees
BCA	- Building and Construction Authority
BCM	- National Business Continuity Management Programme
BREEF	- Building Retrofit Energy Efficiency Financing
CBD	- Central Business District
CCAP	- Centre for Clean Air Policy
CCGT	- Combined-Cycle Gas Turbine
CLC	- Centre for Liveable Cities Singapore
COE	- Certificate of Entitlement
CREATE	- Campus for Research Excellence and Technological Enterprise
DC	- Data Centre
DGSL	- Deloitte Global Services Limited
DR	- Demand Response
E2 Singapore	- Energy Efficiency Singapore
E2PO	- Energy Efficiency Programme Office
EDB	- Economic Development Board
EEIA	- Economic Expansion Incentives Act
EMA	- Energy Market Authority
EMC	- Energy Market Company
ENV	- United Nations Environment Programme
ERI@N	- Energy Research Institute at the Nanyang Technological
ERP	- Electronic Road Pricing System
EV	- electric vehicle
GDP	- gross domestic product
GenCos	- power generation companies
GIC	- Government Investment Corp
GLS	- Government Land Sales
GMS	- Green Mark Scheme
GNSS	- global navigation satellite system
GREET	- Grant for Energy Efficient Technologies
GT	- Gas Turbine
HDB	- Housing and Development Board
HEMS	- Home Energy Management Systems
ICT	- Information &C Communication Technologies (ICT)
iDA	- Infocomm Development Authority
IEEE	- Institute of Electrical and Electronics Engineers
IES	- Intelligent Energy System
IMCCC	- Inter-Ministerial Committee on Climate Change
IMCSD	- Inter-Ministerial Committee on Sustainable Development
IPU	- indirect potable use
ITS	- Intelligent Transport Systems
ITSC	- IT Standards Committee
ITU	- International Telecommunication Union
IU	- in-vehicle units
JTC	- Jurong Town Council
LNG	- Liquefied Natural GAS
LTA	- Land Transportation Authority
LTE	- long-term evolution
MEWR	- Ministry of the Environment and Water Resources
MHA	- Ministry of Home Affairs
MIT	- Ministry of Trade and Industry Singapore
MMC	- Marsh & McLennan Companies
MND	- Ministry of National Development
MOT	- Ministry of Transport
MRT	- Mass Rail Transport
Mtpa	- million tonnes per annum
NCCS	- National Climate Change Strategy
NEA	- National Environment Agency
NEMS	- National Electricity Market of Singapore
NetCo	- Network Company
NEWater	- state of seawater desalination and wastewater purification
NextGen II	- Next Generation National Infrastructure
NextGenNBN	- Next Generation Nationwide Broadband Network
NGO	- non-governmental organization
NLB	- National Library Board
NParks	- National Parks Board
NRF	- National Research Foundation
NTU	- Nanyang Technological University
NUS	- National University of Singapore
OpCo	- Operating Company
PAP	- People's Action Party
PPP	- People, public and private
PSOD	- Power System Operation Division
PUB	- Public Utility Board
PV	- Photovoltaik
RAC	- Royal Automobile Club Foundation for Motoring Ltd
RSP	- Retails Service Provider
RZ	- Restricted Zone
SCP	- State and City Plan
SERIS	- Solar Energy Research Institute of Singapore
SGD	- Singapore Dollar
SMEs	- small and medium enterprises
SP	- services provider
SSB	- Sustainable Singapore Blueprint
SSIPO	- Safety and Security Industry Programme Office
ST	- Steam Turbine
T&D	- transmission & distribution
UNEP	- United Nations Environment Programme
UNESCAP	- United Nations Economic and Social Commission for Asia and the Pacific
URA	- Urban Redevelopment Authority
VQS	- Vehicle Quota System
WDA	- Workforce Development Agency
WWF	- World Wide Fund for Nature
WWS	- Waterways Watch Society
ZEB	- Zero Energy Building

LIST OF FIGURES

1 GENERAL

1.1 »M:CI« – CITY RESEARCH IN SINGAPORE

The six cities studied within »m:ci« were chosen after a rigorous selection process. Several international sustainable cities rankings were utilized and innovative projects and solution approaches were identified and analysed. This was the basis for selecting, together with the companies and cities involved in »m:ci«, the six cities which provided innovative and inspiring solutions in different technological sectors, located on different parts of the planet and demonstrating different climatic and other framework conditions.

Singapore´s development towards a big green "Garden City" is the result of strategic planning and efforts already initiated by the former Prime Minister Lee Kuan Yew shortly after Singapore´s independence in 1965. Because Singapore is an island with limited space and resources, sustainable urbanisation had been indispensable from the beginning. Nowadays, Singapore ranks number 1 in Forbes World´s Smartest Cities 2009 and the Asian Green City Index 2011, number 1 (followed by Frankfurt, Munich and Copenhagen) in Mercer´s Quality of Living Survey with a focus on infrastructure and number 3 in the Ericsson Networked Society City Index 2013. Singapore´s reputation as green model city rests partly on its efforts to control urban congestion and pollution, as well as
the retention of green landscapes within the built environment. The other cities analysed in m:ci are Freiburg, Berlin, New York, Copenhagen, and Tokyo.

All selected cities demonstrate interesting and trail-blazing projects and solution approaches for improving sustainability. Each of the cities, however, had a different strong-point in relation to the sectors studied in m:ci, those being: energy, buildings, mobility, water, productions and logistics, security, information and communication technologies (ICT) and governance.

The six cities selected belong to the world-wide most inspiring cities with innovative projects and solution approaches in the field of sustainability. However, this is not meant to suggest any judgment of the value of many other cities which also belong in this classification, but which were not studied.

1.2 OBJECTIVES

It is quite difficult to compare cities in terms of their sustainability and their projects designed to increase sustainability, since there is no uniform catalogue of sustainability criteria and because the framework conditions of each city are different. This brings up the question of whether it is even possible to learn from the experiences of individual cities.

m:ci works with the assumption that although a city with sustainability-oriented projects and approaches is reacting to specific problems, using resources locally available, and is implementing its project under local framework conditions, the main challenges addressed are, nevertheless, comparable in many cities worldwide and the projects are planned and implemented according to similar patterns. The objectives of m:ci are, therefore, to understand the activities within the individual cities, to identify the specific framework conditions present, and to recognize the patterns within the activities.

The m:ci research visits, thus, have the following objectives:

- Analyse the selected practice examples in relation to motivation, conception, planning, implementation success and the measurement of success
- Identify key drivers and framework conditions which have affected the projects and solution approaches either positively or negatively
- Analyse the network of actors involved and their roles within the projects and solution approaches studied
- Discuss the transferability of projects and solution approaches to different cities

1.3 SECTORS STUDIED

The criterion of sustainability permeates all dimensions and aspects of a city and can therefore never be wholly captured. A research project on sustainability must, therefore, always concentrate on a specific area. Seven sectors which are strongly characterized by technological solutions were identified within the m:ci project, and the governance sector was included additionally, as it is also considered important for the successful conception, planning, and implementation of projects designed to increase sustainability. The following eight sectors are therefore analysed and include the following aspects:

Energy
Import, creation, distribution and use of electricity, heating/cooling, gas und fuel.

Buildings
Energy-efficiency, comfort, holistic balance of all building styles within a city, buildings and public space, resource efficiency and recyclability of materials used.

Mobility
Range of available mobility options, modal-split, energy use, area requirements, emissions, use of public space.

Water
Water supply and disposal, water quality, reliability of supply, rainwater drainage, energy use.

Production & Logistics
Production in the city, distribution of goods to stores and to consumers, induced traffic volume and emissions.

Security
Security of public spaces and in buildings against vandalism, crime rate, terrorist attacks, security in relation to natural disasters.

ICT – Information and Communications Technology
City administration data, electronic availability of city services, information options in public spaces, ICT-infrastructure, ICT applied for intelligent steering and user-friendly options in the areas of energy, mobility etc.

BIG – Business Innovation and Governance
Policy and administration structures as well as methods and concepts applied to determine objectives, conception, decision-making, planning and implementation of solution approaches and projects aimed at increasing sustainability in relation to the initiation, organization, steering and evaluation of processes and projects, active participation of citizens and all relevant city actors, city development and planning as regards its linkage with politics and administration.

In Singapore, the energy, buildings, mobility, ICT, security, water and governance sectors were studied.

1.4 RESEARCH APPROACH

The two-week research visit from May 6th to 17th, 2013 was conceptualised as follows:

City support
In advance, Singapore based Fraunhofer IGD@NTU informed Her Excellency Ms Angelika VIETS Ambassador of the Federal Republic of Germany to Singapore about the m:ci research stay in Singapore in May 2013. Following this, H.E. Ms. Angelika Viets invited the Fraunhofer research team and high-level personalities in the field of sustainability from politics, research and industry to a high-tea reception on the first day of the m:ci research stay in Singapore.

Indicators
A set of indicators were identified for each sector, and the data associated with these indicators was studied in advance of the research stay.

Practice examples
Involved researchers identified interesting practice examples in their individual sectors, in advance, which were then studied during the visit. Data and information on the examples was collected and analysed.

Interviews
Relevant actors from government, industry and research as well as for each practice example were identified, and interview appointments were made for within the research stay period.

The interviews, typically 1.5h in duration, were conducted on the basis of a standardized guideline, which was adapted to each interview. The interviews were recorded, when permitted, and later analysed.

Networking Event
At the end of the research stay all interview partners were invited to attend an evening networking event. The event was hosted by Fraunhofer IGD@NTU and Fraunhofer research team presented first impressions of the research stay. The city's activities relating to sustainability were discussed during the subsequent event.

Morgenstadt Lab
During the'Lab' on the first Friday of the research stay, the researchers discussed – following a defined method – several hypotheses relating to the practice examples in Singapore. The hypotheses had been developed by the researchers and were based on the interviews conducted within the first week. The discussions served to recognize the patterns inherent in the implementation of projects and solution approaches in Singapore.

1.5 CITY TEAM SINGAPORE

The following Fraunhofer researchers conducted the study during the research stay:

Sector	Researcher
Mobility	Martha Loleit, coordinator of city team *Fraunhofer Institute for Industrial Engineering IAO, Stuttgart*
Governance	Inka Woyke (neé Mörschel) *Fraunhofer Institute for Industrial Engineering IAO, Stuttgart*
Buildings	Young Jae Yu *Fraunhofer Institute for Building Physics IBP, Stuttgart*
Energy	Sebastian Gölz *Fraunhofer Institute for Solar Energy Systems ISE, Freiburg*

Security	Hanna Leisz *Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institute EMI, Freiburg*
ICT	Antonio Feraco *Fraunhofer IDM@NTU*
Water	Stefan Klug *Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe*

Klaus Hoppe, (Head of Energy Department - City of Freiburg and Consultant – Energy solutions for Cities) supported the team during the research stay with his "municipal insights" in the fields of governance, energy and buildings.

Fraunhofer IGD@NTU, represented through Prof. Dr. Wolfgang Müller-Wittig, Centre Director, Mr. Gerald Lui, Director of Strategy & Planning, and Dr. Antonio Feraco, Assistant Director Technology Transfer and Innovation served as on-site contacts and thus significantly contributed to the success of the m:ci research visit.

2

2 GENERAL INSIGHTS SINGAPORE

The sovereign parliamentary Republic of Singapore is a Southeast Asian island city-state located between Malaysia and Indonesia (CIA 2013).

2.1 BASIC DATA

Singapore covers a land area of 715.8 km², making it not quite as large as the City of Hamburg. Due to its small area, Singapore has a high population density of 7,422 persons per square kilometre (Department of Statistics Singapore 2013b) with a total population of 5.4 million (Department of Statistics Singapore 2013c). Although the median age has increased slightly over the past years, it is still quite low at 38.4 years. Singapore's population is continuously growing due to many immigrants coming to the island state (Department of Statistics Singapore 2013c).

Singapore's land area is strongly influenced by roads, which take up 12% compared to 14% for housing areas. To keep traffic flowing and to avoid a gridlock, Singapore has limited the vehicle population growth and placed high taxes on cars. On the other hand, Singapore´s Land Transport Authority (LTA) is steadily expanding public transport by building more rail lines and employing more buses to offer an alternative to private transport (LTA 2013a). Singapore has one of the busiest harbours in the world and its airport has been voted the world's best airport several times. Singapore has a tropical climate with relatively stable temperatures throughout the year and high humidity. The average daily minimum and maximum temperatures range from 24°C to 31°C, and the average relative humidity is 63% on dry afternoons but frequently exceeds 90% in the early hours of the morning (DSS 2012).

Compared to other countries, Singapore has quite a low unemployment rate of only 2%. The majority of the work force is employed in the Community, Social & Personal Services sector, followed by Wholesale & Retail Trade and Manufacturing (Department of Statistics 2013d). The Gross Domestic Product as well as the Gross National Income has continuously risen over the past years – with the exception of 2009 (Department of Statistics Singapore 2013b).

Population and demographic development
Singapore's population has consistently grown, although the growth has changed over the decades. After World War II and up to the 1960s, the population grew mainly through births and migration. In the 1970s, births were the main reason for the growth.

Figure 1: Electoral divisions of Singapore (OneMap 2013)

Table 1: General data

Indicator	Singapore
Population	
Population (June 2013)	5,400,000
Population growth	1.6 %
Population density (p/km²)	7,422 people/ sqkm
Economy	
GDP 2012 (in Mio.)	205.515 billion €
GDP per capita GDP per labor person	38,686 € 62,467 €
Ø annual economic growth	1.3 %
Per capita debt	43,101 €
Unemployment rate	2.00 %
Environment	
Area	715.8 sq km
NOx	25 µg /m³
Respirable Dust (2010)	29 PM10
Amount of litter	7,269,500 t
Recycling quota	60%
CO_2- emissions per capita	12.39 t
Water consumption	152 l
Ecological footprint (2007)	5.34 gha/pers

Source: Department of Statistics Singapore 2013b; Department of Statistics Singapore 2013c; Department of Statistics Singapore 2013e; NEA 2013b; IEA 2012; MEWR 2013c; Global Footprint Network 2010

During this period the government maintained a minimum flow of migration and measures were implemented to reduce the population increase. This lead to a decrease in fertility forcing the government to rethink its policy towards a more pro-natalist approach in 1987. In the 1990s and 2000s there was a slight increase in fertility, but again migration became an important factor in population growth. Today, Singapore's population policy is still pro-natalist. Nevertheless, the main source of population growth is migration, as can be seen in Figure 2 (CSC 2013).

When it comes to demographic development, Singapore faces similar problems as do other industrial nations. Singapore´s population is growing older, while at the same time fertility is low. Currently, the median age is comparatively low at 38.9 years (Department of Statistics Singapore 2013f). However, the median age is expected to rise up to the age of 45 by 2025. Therefore dependency on foreign talent will grow in the long-term.

Characteristics and challenges

Singapore´s National Population and Talent Division forecasts a total population increase from today´s 5.4 million to between 6.5 and 6.9 million by 2030 (NPTD 2013). Challenges include managing the land requirements for present and future needs as well as the infrastructure and the social requirements. By ensuring good living and health-related conditions, Singapore has managed to establish a high quality of life in the city - despite its high population density.

Singapore has limited natural resources and therefore is heavily dependent on imports from other countries. One major challenge for Singapore is therefore to ensure appro-

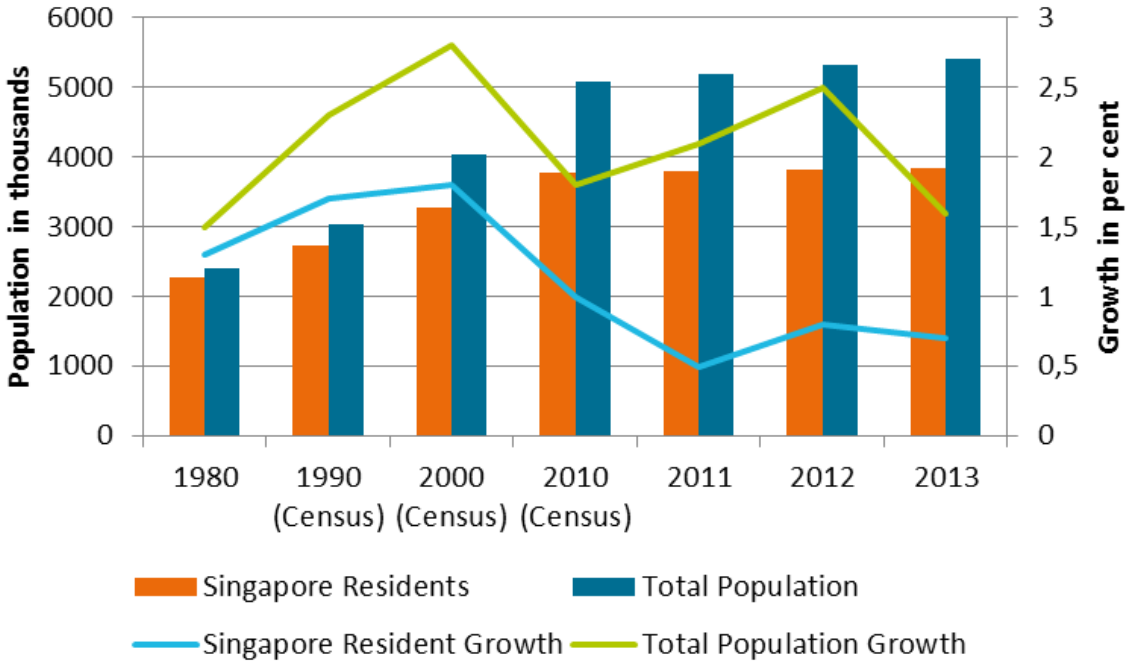

Figure 2: Population and population growth (Department of Statistics 2013d; Department of Statistics Singapore 2013c)

priate allocation of resources. In attempting to understand business and innovation in Singapore, the following became obvious as city objectives:

- Economic development / growth is the highest priority, sustainability meant to guarantee economic development
- Strengthen global (economic) position
- Reduce / eliminate dependence on other countries resources
- Efficiency
- Excellence
- Becoming a centre of creativity and innovation (Ray 2013)
- Liveability

2.2 HISTORICAL DEVELOPMENT

1819
The British East India Company founds modern Singapore. Singapore already existed earlier and was known under a variety of names, until – as legend tells it – Sang Nila Utama declared its new name "Singa Pura" (which is Malayan for "Lion City") after he had seen a lion in the 14th century. At this time Singapore had a population of around 1,000 indigenous people.

1867
Along with Malacca and Penang, which, together with Singapore, make up the Straits Settlements, Singapore becomes a Crown Colony.

1869
Singapore is a major port of call for the merchant fleets plying between Asia and Europe. The population has increased to over 80,000.

1942
During a fight against Japan in World War II Singapore falls and is renamed to Syonan meaning "Light of the South" in Japanese. It remains under Japanese occupation until the end of WWII.

1946
The Straits Settlements are dissolved and Singapore becomes a Crown Colony once again.

1948
The first election of six members to the Legislative Council is held. The Communist Party of Malaya tries to take over Singapore and Malaya by force. Therefor a state of emergency is declared. The state of emergency lasts for 12 years.

1958
The Constitutional Agreement is signed in London. The new Singapore Constitution allows Singapore to attain self-government.

1959
The first general election is held.

1963
After a referendum in 1962 on the terms of a merger between the Federation of Malaya, Sarawak, North Borneo, Brunei and Singapore, Malaysia is formed comprising of the Federation of Malaya, Sarawak, North Borneo (now Sabah) and Singapore.

1965
Singapore separates from Malaysia because of constant political strife and becomes a sovereign, independent and democratic nation - on the 22nd of December it then becomes a republic.

1971
The government devises a Concept Plan, which sets the direction for Singapore´s development over a forty- to fifty-year period, and is revised every ten years in light of changing circumstances and national goals.

1992
Singapore´s Green Plan identifies nineteen nature sites and pledges that 5% of land area will be reserved for nature conservation.

2008
First island-wide Leisure Plan, which seeks to increase parkland and enlarge the park connector network and other green areas.

2011
The 2011 version of the Concept Plan lists a good living environment, an inclusive society, homes to which people feel they belong and economic growth as core objectives. Singapore's government acknowledges that it can only be attractive to residents, visitors, businesses and investors if it has a "unique character and sense of history" (Henderson 2012).

2013
Singapore has developed into a top destination of the world in terms of liveability, the world's "easiest place" to do business and one of the most competitive cities in the world. It has a world-class education system and one of the best health care systems worldwide (MCI 2013).

2.3 POLITICAL AND ECONOMIC LANDSCAPE

Political system
Singapore is a sovereign republic, with a legal system based on the English common law (Government of Singapore 2013). The political system is illustrated in figure 3.

Since the change of the government in 1965 politics has been dominated by the People's Action Party (PAP). The island state has free elections but it could be categorised as a one-party-system.

Government and politics can actually be viewed from different angles. Singapore has, for several terms, been ranked as very good to really good by The World Justice Project. In this global ranking Singapore is number 1 in "Order and Security", number 3 in "Criminal Justice", number 4 in "Civil Justice" and number 7 in "Absence of Corruption" (The World Justice Project 2013). Transparency International ranks Singapore number 5 on the Corruption Perceptions Index 2012 (Transparency International 2012). Although the quality of democracy in Singapore is rated as high (Campbell et al. 2012) the non-governmental organization (NGO) Freedom House sees the status of Singapore as only partly free (Freedom House 2013). Freedom House claims, that "Singapore is not an electoral democracy" probably because there is no independent election authority. The NGO furthermore claims that "opposition campaigns have typically been hamstrung by a ban on political films and television programs, the threat of libel suits, strict regulations on political associations, and the PAP's influence on the media and the courts"(Freedom House 2013). The constitution of Singapore guarantees freedom of expression, association and peaceful assembly, yet "it also permits broadly interpreted restrictions not only for security, public order, and morality, but also for parliamentary privilege and racial and religious harmony"(HRW 2012). Additionally, all media companies – such as newspapers, television channels and radio stations – are linked to the government. This is probably one reason for the common self-censorship among journalists. Media (e.g. music), videos and books, referencing sex, violence or drugs are also censored. The internet is monitored by authorities, but widely accessible although some content is blocked (Freedom House 2013). These are just a selection of issues addressed by Human Rights Watch and Freedom House.

The current Prime Minister Lee Hsien Loong leads his country like a company striving for excellence in innovation and high-tech. Today, Singapore is one of the richest countries in the world. Nevertheless, competition with nearby countries like China, Malaysia, Indonesia and Vietnam is a priority. The long-term goal of the Singapore administration is to reinvent the island-state, pushing the economy into new spheres. Singapore's state funds support companies through large amounts of financial aid and there are low taxes. Funding and continuous trend analyses are designed to support the development of Singapore as a centre of creativity and innovation (Ray 2013).

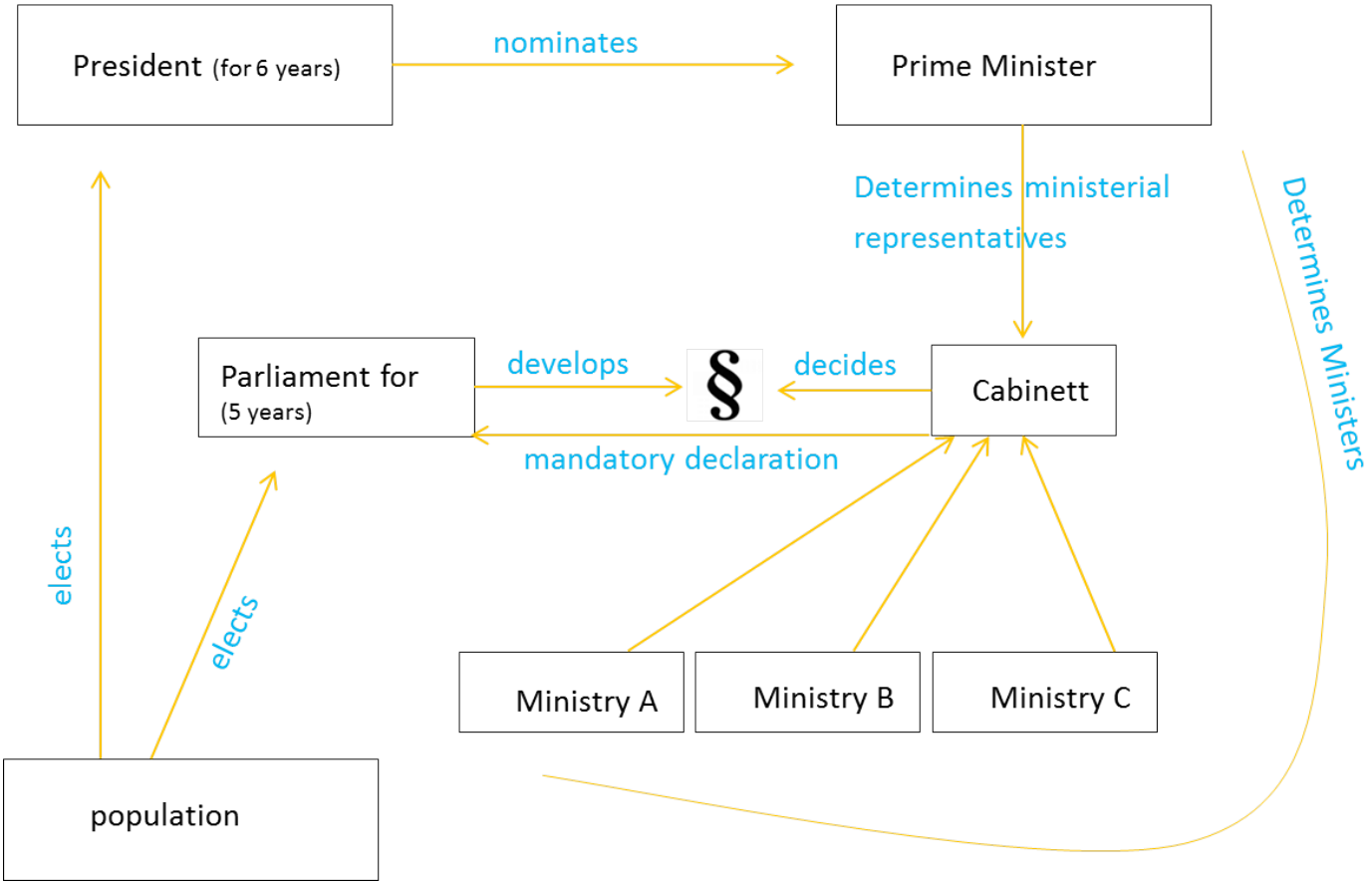

Figure 3: Political system of Singapore (illustration: m:ci)

Economic situation
Singapore has become one of the world's most developed countries with per capita gross domestic product (GDP) equal to that of the leading western nation and has strong international trade links. In 2012 the GDP per capita was 38,686€ (est.) (Department of Statistics Singapore 2013c) and in the associated world ranking it is on rank 7 (CIA 2013). Singapore is one of the most deregulated and privatized nations in the world. The solitary exception is the regulated housing market (The Economist 2000).

Singapore´s future markets
- Health care and aging society
- Life style
- Urban solutions

The city-state is characterized by an open, free-market and corruption-free economy with stable prices (CIA 2013). Due to the lack of space and limited natural resources, the economy depends heavily on imports. "Singapore has attracted major investments in pharmaceuticals and medical technology production and will continue efforts to establish Singapore as Southeast Asia's financial and high-tech hub" (CIA 2013). According to an interview partner, three markets of the future for Singapore are: Health Care and the aging society, life style and urban solutions.

Table 2 depicts Singapore's key business data.

2.4 ENERGY

Energy resources
Singapore does not have indigenous fossil and nuclear energy resources. Currently all of the natural gas and petroleum resources for electricity generation are imported from neighbouring countries. Localised energy resources such as municipal waste, biomass, solar and other renewable sources also form part of the Singapore electricity generation mix. However, these energy sources account for a mere 2.0% to 3.5% of the total electricity generated over the past 10 years. While petroleum products have traditionally been the pillar of electricity generation in Singapore, in recent years, the trend has been towards increasing usage of natural gas. This is due to several significant advantages of natural gas over petroleum, such as lower cost and less carbon emissions. In consideration of the importance of the gas supply for the city-state, Singapore seeks to enhance its supply security. Therefore, besides natural gas imports from Malaysia and Indonesia via conventional pipelines, Singapore has further diversified its gas supply base by building the nation's first Liquefied Natural Gas (LNG) receiving terminal. The terminal on Jurong Island will have an initial capacity of 3.5 million tonnes per annum (Mtpa); this will be increased to 6 Mtpa by the end of 2013 when a third tank and additional regasification facilities are completed

Table 2: Business Data Singapore

GDP	Agriculture: 0% Industry: 26.8% (Industries: electronics, chemicals, financial services, oil drilling equipment, petroleum refining, rubber processing and rubber products, processed food and beverages, ship repair, offshore platform construction, life sciences, entrepot trade) Services: 73.2% (2012 est.)
Imports	Amount: US$ 379.7 billion (2012 est.) compared to the world ranking: 14, Germany: 4, United States: 2
	Products: machinery and equipment, mineral fuels, chemicals, foodstuffs, consumer goods
	Partners: US 10.8%, Malaysia 10.7%, China 10.4%, Japan 7.2%, South Korea 5.9%, Indonesia 5.3%, Saudi Arabia 4.8% (2011)
Exports	Partners: Malaysia 12.2%, Hong Kong 11%, Indonesia 10.4%, China 10.4%, US 5.5%, Japan 4.5% (2011)
	Products: machinery and equipment (including electronics and telecommunications), pharmaceuticals and other chemicals, refined petroleum products
Unemployment rate	Low: 2% World ranking: the 12th lowest unemployment rate
Gross Investment (fixed)	24.7% of GDP (2012 est.)
Budget surplus (+)	0.9% of GDP (2012 est.) World ranking: the 29th budget surplus
Public debt	111.4% of GDP (2012 est.) World ranking: the 13th highest pubic debt
Labour productivity	Declining: (Percentage Change 2012:2013) -3,7 in comparison: -0,4% in Germany

Source: CIA 2013; Department of Statistics Singapore 2013; Statistisches Bundesamt 2013; Labor Productivity in Singapore in 2008

(EMA 2013a). The terminal's throughput capacity will rise to 9 Mtpa when a fourth tank and its related regasification facilities are ready (planned for 2015).

Energy market
Singapore is a small and highly urbanised island state, where the electrical grid reaches to almost all corners of the island. Singapore started a reform of its power sector in

1995, alongside the international movement towards innovation and liberalisation with the aims of improving efficiency, attracting investments, improving service quality and transferring an eventual cost benefit to consumers. On January 1st 2003, the new National Electricity Market of Singapore (NEMS) commenced operation as the result of market restructuring.

In the new NEMS structure, the Energy Market Authority (EMA) plays the role of an industry regulator, having ultimate responsibility for the market framework and mechanism, so as to protect consumer interests in obtaining high quality electricity at a fair price. Set up by EMA, the Energy Market Company (EMC) is licensed as the Market Operator to run and administer the wholesale generation market by calculating prices, scheduling generation, clearing and settling market transactions and procuring ancillary services. EMC also overlooks the market structure which encompasses changes in market rules, provision of resources to support market surveillance, compliance with the law and regulations and dispute resolution processes. The Power System Operation Division (PSOD) at the EMA is responsible for ensuring the security of the electricity supply. To do so, it controls the dispatch of energy flow, holds energy reserves and controls their regulation, co-ordinates scheduled outages and power system emergency planning, as well as directs the operation of the high-voltage transmission system.

The power generation companies (GenCos) participate in the electricity supply wholesale market in the NEMS and have not been involved in the transmission & distribution (T&D) network since its privatisation in 2009. All generation companies have the right to interconnect to the Singapore PowerGrid T&D grid network on the condition that the generation facility complies with the technical, safety, operational and commercial & legal requirements. In the wholesale free market, sellers (GenCos) and buyers (contestable consumers, electricity retailers and market licensee services provider (SP

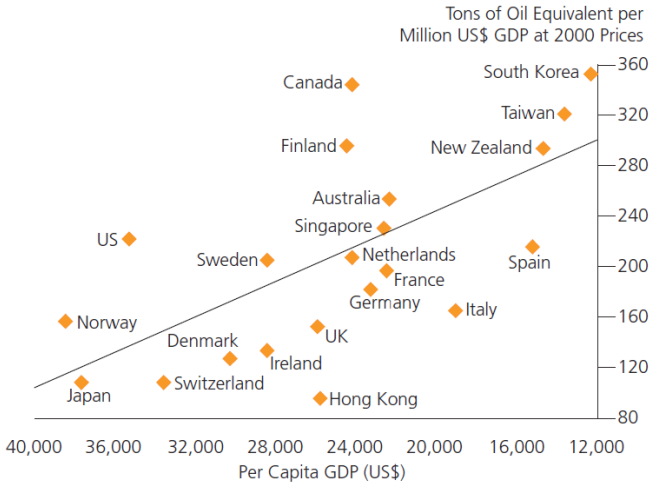

Figure 4: A plot of energy intensity against per capital GDP (2003) for selected countries (MTI 2006)

Services)) trade freely every half-hour (also called "trading period") to determine the next half-hour's actual dispatch quantity and nodal price (also known as "spot market price" or "auction price") for electricity sellers, whereas a uniform price for buyers is a weighted average of the nodal price with the charges incurred by EMC.

In order to control potential abuse of market power and to optimise the match between supply and demand, a vesting contract regime was introduced in 2004. With the vesting contracts, a certain amount of the total energy demand will be secured before the trading period at a fixed vesting price (lower than the auction price). The share of vesting contracts is reviewed by EMA on a regular base, it was 60% and 55% of the total demand in Singapore for 2011 and 2012 respectively, and will be 55% for the first half year of 2013, 50% for the second half year of 2013 and a flat 40% for 2014 (EMA 2013b). The balance of the energy demand will be secured through the auction at the spot market price.

The total licensed generation capacity in the market is approximately 9,900 MW, of which 62% are Combined-Cycle Gas Turbine units (CCGT), 31.6% Steam Turbine units (ST) and 2.9% Gas Turbine units (GT) (EMA 2013c). These GenCos' units can also offer 8 and 30 second reserves with already spinning and synchronized generation respectively, or 10 minutes of contingency reserve, depending on their generation capability and PSOD testing results. The interruptible loads in Singapore can also be applied as a type of reserve. The capacity for voltage control, reactive support and other ancillary services are mainly sourced through contractual agreements between the EMC and GenCos.

The electricity consumers are integrated into the third tier of the NEMS structure as the so-called „contestable" and „non-contestable" consumers. A contestable consumer is free to procure electricity from the retailer, SP Services or from the wholesale generation market directly. A non-contestable consumer will have his/her electricity demand supplied by either SP Services or the generation companies that win the bidding of vesting tender for its electrical demand. Full retail market liberalisation is still under study as of today.

Energy efficiency

The enhancement of energy efficiency is part of the Singapore government's core strategy to reduce emissions. Singapore's energy intensity has improved by 22% between 1990 and 2005 due to the adoption of better technology in power generation and the more productive use of energy in other sectors. Nevertheless, Singapore is able to further enhance energy efficiency across all sectors of the economy (see also Figure 4; EMA 2013a). The Singapore government's clear objective is to achieve a 35% reduction in the 2005 levels of economy-wide energy intensity by 2030 (NEA 2010).

Therefore, the government has established an Energy Efficiency Programme Office (E2PO) (Singapore Government 2013), to drive energy efficiency improvements in the various sectors of the economy. The E2PO also developed a national energy efficiency plan, called Energy Efficiency Singapore (E2 Singapore). The E2PO is a multi-agency committee co-led by the National Environment Agency (NEA) and the EMA, which assists in raising awareness and building capabilities to improve energy efficiency. A major part of these efforts involves addressing sector-specific barriers using incentives or regulatory measures where appropriate.

The main activity in the area of buildings is the Green Building Masterplan and the associated Green Mark Scheme (GMS) (launched in 2005), with the aim of having at least 80% of all existing buildings Green Mark certified by 2030. New buildings are supposed to reach „GoldPLUS" or „Platinum" status, which has now, in many cases, even becomes a prerequisite for the sale of land. Targeted programmes to reduce energy consumption in both, buildings and private households are underway, led by the E2PO.

Addressing the two largest sectors of Singapore's electricity consumption, two roadmapping exercises are currently underway:

i. Industry energy efficiency
ii. Energy efficiency in buildings

Furthermore, the NEA has contracted Siemens Pte. Ltd. To conduct a „comprehensive energy efficiency system study" with the key objective being to propose systems-wide solutions that go beyond energy-efficiency measures which operate only at the individual equipment level (NEA 2013a).

2.5 BUILDINGS

Existing buildings and construction

For sustainable urban development, Singapore faces some unique challenges due to limited resources, minimal land area and high population density. Singapore began addressing the issues related to rapid concentration of population and commercial services with compact and high-density urban development, employing efficient land use planning with its first Concept Plan in 1971 (MND 2009). In this context, many high-rise buildings have been built over the past few decades, in response to a growing demand for space in Singapore that not only challenges social and environmental development, but also creates an opportunity to generate sustainable economic development. Thereby, one of the key objectives is to provide affordable housing to meet the different needs of different population segments. Within this, the Housing and Development Board (HDB) is solely responsible for public housing development – from bidding for the land to designing the project, from overseeing construction to selling the flats directly to private buyers. This creates a monopoly by the HDB over the public housing market (MND 2008). To correspond to the rapid increase in Singapore's population in the past years, a comprehensive and holistic urban planning approach was promoted by the HDB as part of an urban housing solution, which includes the planning of high density public housing as well as integrated planning of commercial and transport facilities. Currently, there are approximately 1.2 million housing units in Singapore, of which 0.9 million are public housing (MND 2013). Today, 90% of resident households own their homes. Thus, Singapore has one of the highest home ownership rates in the world. According to the Building and Construction Authority (BCA), existing residential buildings account for more than one-half of the existing floor area in Singapore, and public housing makes up more than 80% of the existing housing stock (Tsai 2013). Therefore, the amount of new building construction – as a percentage of all buildings in Singapore – is very small. New construction makes up less than 5% of the total building stock in the country (BCA 2013c). Such high proportions of existing buildings places much pressure on energy efficient retrofits and upgrading work in the building sector.

Real estate market

The organisation of Singapore's real estate market puts the government in a very strong position to ensure that the nation will be able to reach its goal for 80% of the building stock to be Green Mark certified by 2030. There are two main reasons for this. First, the HDB is responsible for the construction of 86% of all residential buildings in Singapore (GPA 2012b). While 90% of Singaporeans own their homes, the HDB owns the buildings and can regulate the rate of retrofits to obtain Green Mark ratings. The second factor that gives the government great authority over the implementation of the GMS is that all land sales and development is strictly controlled by the government, which owns 90% of the land in Singapore (Lee 2002). The country is divided into 55 regions; each region is governed by a legally binding Development Guide Plan that outlines land use, allowable plot ratio (ratio of gross floor area to land area), building height, road systems and open space to guide both private and public sector development (Lee 2002). The Urban Redevelopment Authority (URA) has been able to use this structure to promote the GMS by requiring new developments to obtain a Green Mark rating as a condition of land sale. Furthering this tactic, the URA requires the highest Green Mark rating, Platinum, for large commercial buildings developed in strategic areas, such as the Central Business District (CBD). These buildings are the largest energy consumers in the building sector, and energy and water reductions of 30% or more have a substantial impact on the nation's overall usage (GPA 2012b). Reduced operational costs and favourable public opinion towards efficiency is reflected in real estate premiums which range from 5% to 21% for buildings and homes with a Green Mark rating, with higher rankings receiving higher premiums (UNESCAP 2012). Ultimate authority over all land use and development, and ownership of the vast

majority of residential buildings in the country, provides the Singaporean government with a uniquely strong position to push the entire building sector towards improved efficiency within a short timeframe. This authority, accompanied by a strong government which has retrofitted existing buildings and spends nearly S$200 million (€120 million) in incentive schemes, seems to be a powerful combination that will set a global example for innovative policy to promote sustainable development (CCAP 2012).

Population growth as a challenge

Singapore's population has grown by more than 60% since 1990 and the government expects the total population could increase to between 6.5 and 6.9 million by 2030 (MND 2013). Rapid population growth to such an extent will put more pressure on urban development with regard to limited land, water and energy resources, and especially housing capacity in the building sector. Given the limitations on the availability of land area for new development, new developments will have to incorporate more high-density and very high-rise housing stocks that are close to public transportation nodes. Thereby, the government faces a great challenge to meet the increasing demands for affordably priced new housing and for sustainable environments in these new town and housing developments within the limiting conditions. For the government, it is not just about providing affordable and available housing units. It is also about creating a sustainable environment and a high quality of life to meet the new expectations and consumption patterns of Singaporeans. Therefore, a comprehensive and holistic urban planning approach, which includes the planning of social and environmental aspects, will become increasingly important.

Limited land area as a challenge

Given Singapore's finite land area, planning high-density districts, with mixed-use environments to live and work in, is critical. Currently, Singapore's major business centres are located in the west region (CBD and Marina Bay) and residential areas are located in the north, northeast and east regions. Such single-use development leads to a high level of demand for transportation towards the city centre and high occupancy cost in the city centre. To tackle this problem, it is necessary to decentralise commercial activities to commercial centres outside of the city, and to integrate these new commercial centres with high-density housing blocks so that people can work where they live (Serene; Serene 2012). The decentralization of business activities from the city centre towards outer areas opens up opportunities to serve new business needs and brings jobs closer to homes. Furthermore, it would also help to reduce traffic and infrastructure congestion in the city centre. For this reason, decentralized commercial nodes are quickly developing island-wide to achieve a critical mass of offices and commercial facilities to serve business needs.

Energy consumption for cooling

Due to Singapore´s high temperatures and high humidity, air conditioning is widely used in non-residential buildings, contributing to about 40% of the average building's electricity consumption (BCA 2010b). Thus, non-residential buildings are responsible for 31% of total electricity consumption on the island-state, and contribute about 11% to 16% of Singapore's greenhouse gas emissions (Tsai 2013). As part of the vision within Singapore's Blueprint for Sustainable Development, demand-side greenhouse gas emissions reductions are focused on the building sector due to the increasing demand for commercial space and related cooling energy demand. Given limited renewable energy sources, an optimal solution to decrease greenhouse gas emission is energy efficiency improvements in various sectors. Particularly in the building sector, it has become critical to improve the energy efficiency of cooling systems, most importantly in existing buildings. In this context, the Singapore government developed the GMS in 2005, which defines the minimum efficiency standards for cooling systems in both new and existing buildings, and aims for at least 80% of existing buildings to achieve a minimum Green Mark Certification rating, by 2030 (BCA 2010a).

2.6 MOBILITY

Due to scarcity of land and space, Singapore has developed both a highly efficient transport strategy and system. The development and regulation of Singapore´s land transport is overseen by the Ministry of Transport (MOT) (established in 1968 as Ministry of Communications and renamed in 2001) which is responsible for setting Singapore's transport polices. The implementation of the policies and the day-to-day operations are handled by the LTA (founded in 1995).

Figure 5: Mobility at a Glance (illustration: m:ci)

History
To enable economic growth in land-scarce Singapore, the government developed a 20-year conceptual State and City Plan (SCP) in 1971 which was supported by the United Nations Development Programme. The plan focused on the accommodation of 4 million people and suggested a mass transportation system for Singapore to meet increasing travel requirements. To manage road use and the vehicle population in Singapore, the SCP recommended restricting private vehicle ownership by imposing high import duties, charging additional registration fees (ARF), using a vehicle quota system (VQS), restricting private vehicle use in city centres through an Area Licensing System (ALS) (heralding the Electronic Road Pricing System (ERP)), expanding expressway systems and constructing a mass rail transport (MRT) system. The government of Singapore implemented all instruments and optimized them during the following years.

To visualise its strategies the MOT developed a Land Transportation Masterplan in 2008 and revised it in 2013. It emphasizes user-friendliness and builds heavily on managing road use and making public transportation the key mode of travel.

Travel demand management
Singapore´s travel demand management is based on integrated instruments to limit the number and use of private cars:

Vehicle Quota System (VQS):
The MOT controls the number of vehicles allowed for registration in Singapore using the VQS which regulates the rate of increase in the number of vehicles on Singapore's roads. New-car quotas are based on an "allowable" growth rate. Prior to 2009 the growth rate was 3% per annum, from 2009 1.5% p.a., from August 2012 1% p.a. From February 2013 to January 2015 it will be 0.5% p.a.

Certificate of Entitlement (COE):
COE represents the right to own a vehicle and is limited to 10 years. At the end of the 10-year COE period, vehicle owners may choose to deregister their vehicle or to revalidate their COEs for another 5 or 10-year period by paying the Prevailing Quota Premium. COEs are released through competitive bidding (2 bidding exercises every month). Currently the price of the successful COE bid lies between 68.000 and 78.000 SGD. 11% of Singapore´s population own a private car (Germany: 54%). (Department of Statistics 2013c, KBA)

Vehicle ownership measures:
The imposition of high upfront ownership costs is part of Singapore's demand management strategy. In addition to the COE, the government implemented a variety of taxes and fees to make car ownership an expensive undertaking. Figure 8 shows examples for car buying costs breakdown.

Table 3: Singapore's Transportation Budgets

Budget MOT, FY2013	6.9 billion SGD
Bus Service Enhancement Programme (BSEP) launched in 2012	1.1 billion SGD to enhance the capacity of Singapore´s bus network
Rail network	4.6 billion SGD will be spent on rail projects in FY 2013
Managing Road Use	1,267.86 million SGD to expand road network and improve bus movements in FY 2013
National Cycling Plan announced in 2010	43.2 million SGD to build cycling infrastructure

Source: MOF 2013

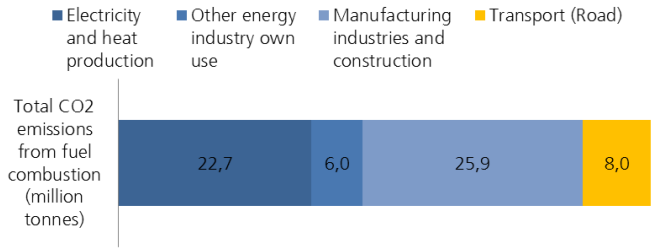

Figure 6: CO_2 emissions by sector in Singapore in 2010 (IEA 2012), Other energy industry own use: fuel combusted in oil refineries, for the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries.

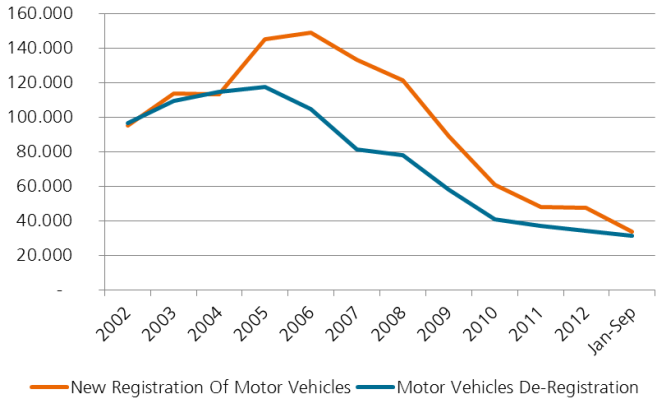

Figure 7: Total annual new registration and de-registration of motor vehicles in Singapore (excluding taxis and tax exempted cars) (illustration: m:ci, based on LTA 2013c)

Electronic Road Pricing System (ERP)
Singapore has an ERP which charges each car for its contribution to road congestion. 80 installed gantries ensure a point-based pricing where motorists are charged when they use priced roads during operating hours. The government plans to implement a new generation of ERP using a satellite-based system within the next years.

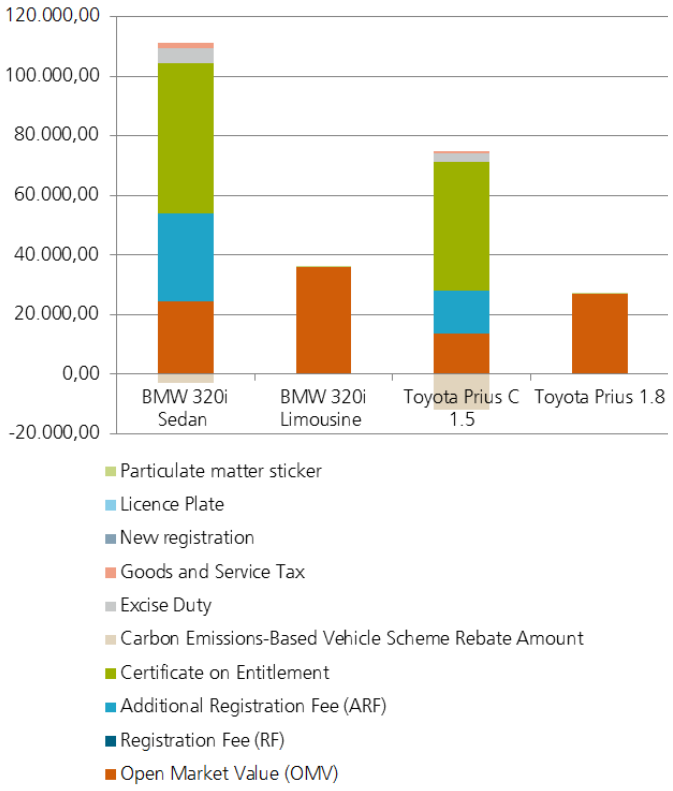

Figure 8: Vehicle purchasing costs in Singapore compared to Germany, COE based on first open bidding for November 2013 for CAT A (Toyota) and B (BMW) (illustration: m:ci, based on LTA 2013b)

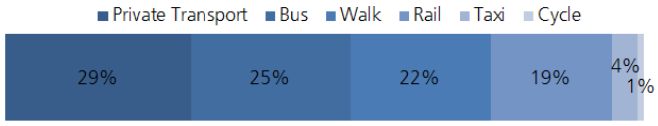

Figure 9: Modal split in Singapore (LTA Academy 2011)

Public transportation

Singapore has defined its public transport system as the key mode of transportation and aims to increase the share of public transportation during peak hours from around 63% today to 75% by the year 2030. In January 2013, the government announced its plans to expand the rail network by 2030, doubling it from the current 178 km to about 360 km and thus improving the connectivity, accessibility and coverage of Singapore's rail network. Due to Singapore's humid climate, the MOT invests in sheltered walkway networks to make access to bus and railway stations more convenient. The overall aim for 2030 is to bring 8 of 10 households to within a 10-minute walk of a rail station.

Cycling & walking

Singapore´s city infrastructure is not designed for bicycles. Cycling makes up just 1% of Singapore's modal split. One main reason for the low cycling rate is Singapore´s climate, which makes cycling an uncomfortable sport. More importantly, however, Singapore lacks bicycle lanes and infrastructure which would make the daily use of bicycles possible. However, cycling is understood as a possibility for recreation and a growing number of people are spending their free time cycling in the various parks Singapore has to offer. The government is interested in linking these parks through bike lines to offer a cycle network with a maximum possible length. To cater to older, less mobile, individuals Singapore introduced the Green Man Plus scheme in 2009 which gives around 5 seconds more time to cross a green light after tapping a dedicated user card to a reader.

2.7 ICT

In 2001, the International Telecommunication Union (ITU) defined the Republic of Singapore as one of the most wired places on the planet (ITU 2013). At that time, Singapore's household Internet penetration rate was the highest in the world at 42% (1999). One of the factors behind Singapore's economic success is the government's strong support for ICT. In 2008, the National University of Singapore (NUS) stated that the Singapore ICT sector is a key contributor to its economy. The aim of the industry was, and is, to use technology to enable the government to serve citizen and business more efficiently and effectively. National plans are to transform the economy and society through the utilizing of technology (NSU 2008). Many other studies have underlined the successful policy used by the Singaporean government in pushing the adoption of ICT technologies as an early adopter. The effort of the government to foster ICT adoption can be characterised by two prominent features (Vu 2013):

- A proactive ICT strategy with a clear master plan for each stage of development, and
- The government's pioneering role in developing e-government that leverages ICT to enhance its efficiency and effectiveness.

The government strategized the overall development in six different master plans in 1980 (updated regularly) which still represent the core of the Singaporean policies on ICT.

Each master plan focuses on a different stage of priorities and programs:

1. The National Computerization Plan, 1980-1985, was mainly focused on Computerization, ICT manpower and investment in the ICT industry,
2. The National IT Plan, 1986 – 1991, aimed to enhance the communication between government agencies, extending the government's ICT system into the private sector,
3. IT 2000, the third one plan from 1992 – 1999, embraced the emergence of the internet with a focus

on connectivity and internet enabled services,

4. The Infocomm 21, 2000 – 2003, emphasize convergence, fostering the penetration of ICT across economic sectors and in society at large,
5. The Connected Singapore Master plan, 2003 – 2006, sought to unleash the potential of ICT to create value and increase capabilities,
6. The sixth and current master plan, the iN2015, 2006 – 2015, aspires to embrace ICT for innovation, social and economic integration, and international collaboration.

Through the realization of these initiatives Singapore has become a leading country in ICT-readiness and e-government performance. The main agency for charge of the overall ICT development is the Infocomm Development Authority (iDA).

Economic performance

The ICT sector has demonstrated a continuous growth trend since 1998, quadrupling its revenues in 2012 and maintaining an average annual growth trend of 12.3%.

iDA' s aim is to ensure the Singaporean leadership in ICT. They continuously identify strategic information and communication technologies, joint actions with the relevant global players in the industry and government in areas such as policy, regulation, manpower development, technology pilots, and trend mapping. iDA continuously engages industry, academia, end-users and other stakeholders in the ICT ecosystem in order to identify significant trends which are used as a basis for the information and communication technology roadmap. This roadmap charts the national ICT blueprint for the future.

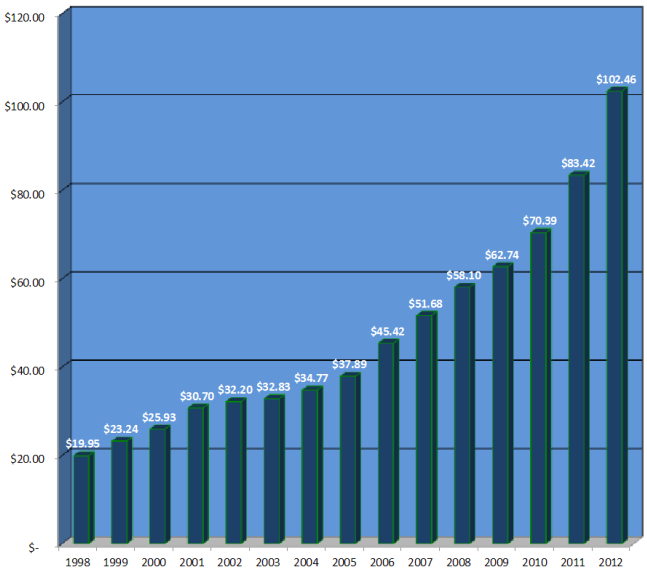

Figure 10: Total ICT industry revenue 2001 – 2012, annually (IDA 2012b)

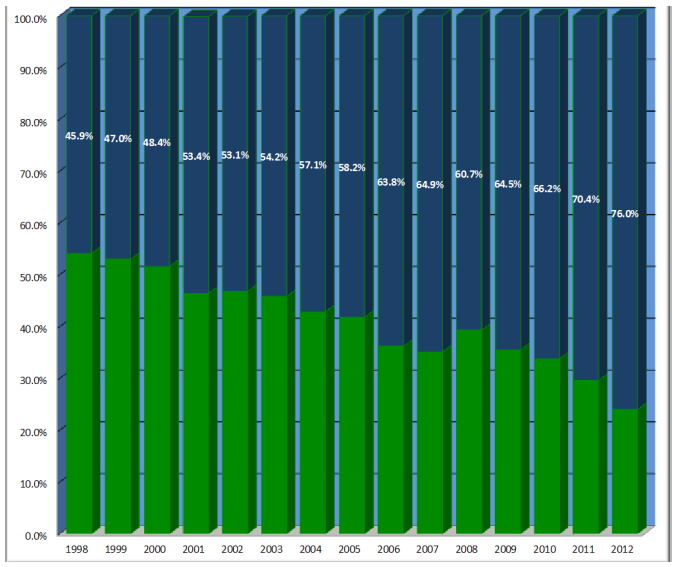

Figure 11: Revenue by domestic and export market, 1998 – 2012 (IDA 2012b); green: % of total revenue (Domestic Market), blue: % of total revenue (Export Market)

Today and Tomorrow

The developed ICT infrastructure represents the key enabler in boosting Singapore´s overall competitiveness within the ICT sector and as a support of new industries such as Interactive Digital Media and biomedical sciences as the next engines powering the growth of Singapore´s economy. In such a scenario, Singapore invests to deploy a seamless, trusted and intelligent Next Generation National ICT Infrastructure (NextGen II) which will complement the country's role as a major global telecommunications and trans-cable hub where regional submarine cable and international

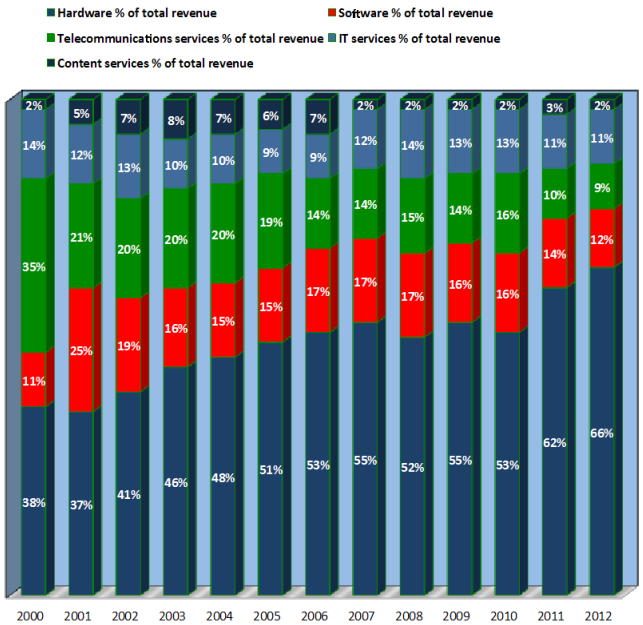

Figure 12: Total ICT industry revenue 2000 – 2012 (IDA 2012b)

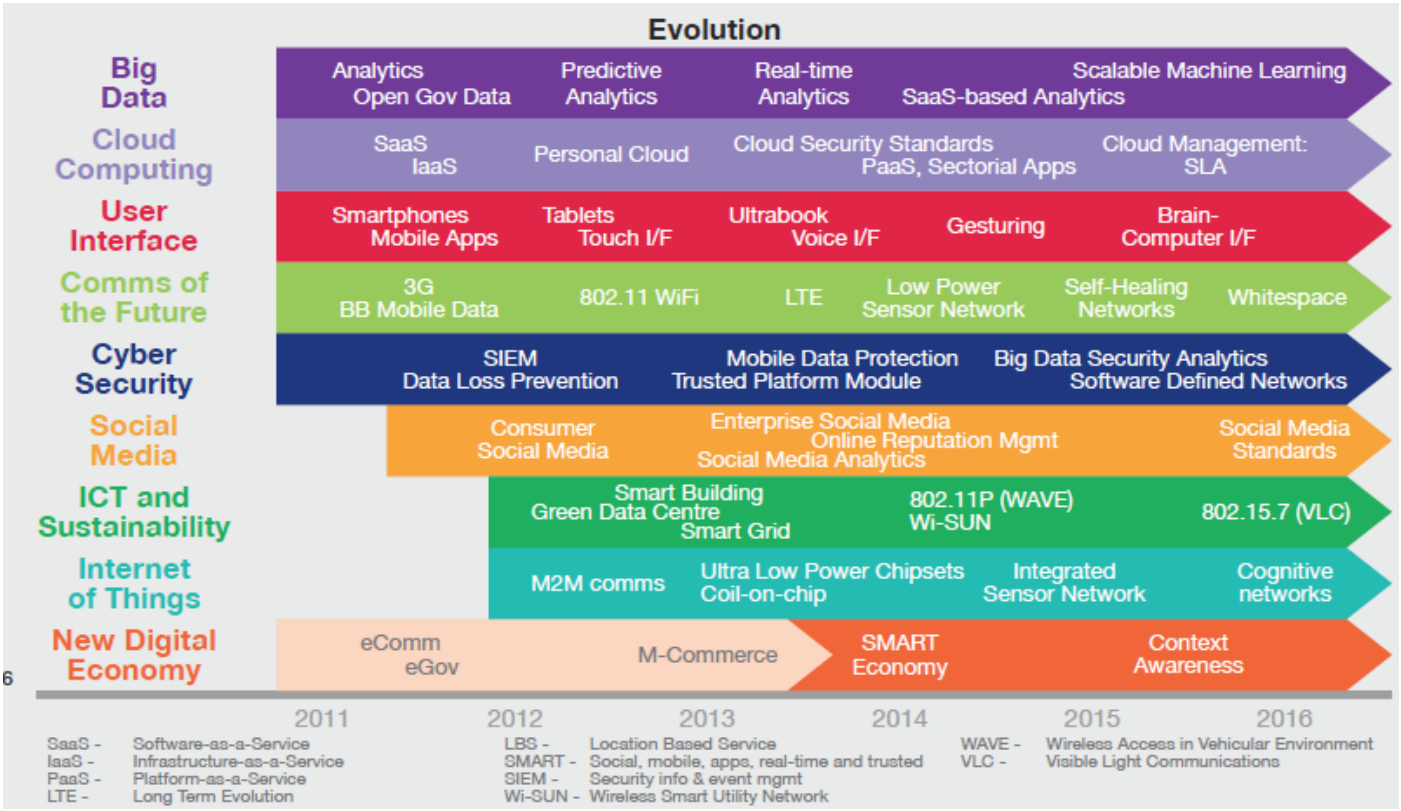

Figure 13: iDA ICT technology roadmap (IDA 2012a)

cable systems interconnect. On the other side, transparency and the continuous involvement of the citizenships citizens reflects the importance Singapore attributes to Open Data and the productivity of the government portals enabling citizens to improve their overall dialogue with the agencies.

Singapore is also focusing on the development of a Data Centre Park. The iDA, the Singapore Economic Development Board (EDB) and the Jurong Town Council (JTC) are working together on a joint project to strengthen Singapore's position as an economic and ICT hub. The project aims to attract more premium Data Centres (DC) such as banks and telco carriers, as well as attracting multinational companies to set up their headquarters and DC operations in the region.

In parallel, the iDA is implementing the iN2015 which aims:

- To establish an ultra-high speed, pervasive, intelligent and trusted ICT infrastructure
- To develop a globally competitive ICT industry
- To develop an ICT-savvy workforce and globally competitive ICT manpower
- To spearhead the transformation of key economic sectors, government and society through more sophisticated and innovative use of ICT

Such strategies are put in place to:

- Be the number 1 in the world when it comes to harnessing ICT to add value to the economy and society
- Realize a two-fold increase, to $26 billion, in the value-add by the ICT industry
- Realize a three-fold increase, to $60 billion, in ICT export revenue
- Create 80,000 additional jobs
- Achieve 90% home broadband usage
- Achieve 100% computer ownership in homes with school-going children

Based on these goals, the iDA developed a ICT roadmap that identified 9 different themes. The roadmap is depicted in figure 13.

The efforts the government is placing into ICT development is worth the results obtained. ICT forms the basis for innovative products and services and favours economic growth in Singapore. Singapore´s strong ICT development positively impacts the sector's overall performance.

2.8 WATER

Singapore's drinking water supply has been a highly important topic since the end of the 19th century, when Singapore´s port began rapidly developing. Overcrowding and pollution contaminated most of the wells in the city. Singapore's transition from a third world city to a highly urbanised economic centre was accompanied by major efforts in water resources management.

Many fundamental early water-related decisions were the result of Singapore's independence from Malaysia in 1965. Consequently, the island was cut-off from its hinterland, which became a special challenge in terms of water supply (Tortajada et al. 2013). Within a short time span, Singapore managed to transform its very poor urban water management system into one which is now one of the best in the world (Tortajada et al. 2013). Large scale measures for water reuse and water efficiency are carried out. The full water cycle (water supply, water catchment and used water) is managed by the Public Utility Board (PUB), Singapore's national water agency, in an integrated way (PUB 2013i).

Water resources

Due to ongoing political friction, the importance of an autonomous source of water supply has always been critical and diversification plays a crucial role in the overall development of the city state. Therefore, Singapore's government has declared that it aims to achieve water self-sufficiency in Singapore by the time the last water agreement with Malaysia expires in 2065.

The PUB's current focus is to meet the increasing demand for water, which is expected to double by 2060 compared to today´s 1.8 million m3/ day. In addition, a shift in consumption towards the non-domestic sector, from 55% currently to 70% in 2060, is expected (PUB 2013d).

Since natural catchments cannot be increased and the rainfall is quite stable over time, water resource management as well as the exploration of unconventional sources play an important role (PUB 2013e). To meet the current demand of about 400 million gallons (= 1.5 million m3) per day the water supply is based on four sources, the so called "Four National Taps", which are described below.

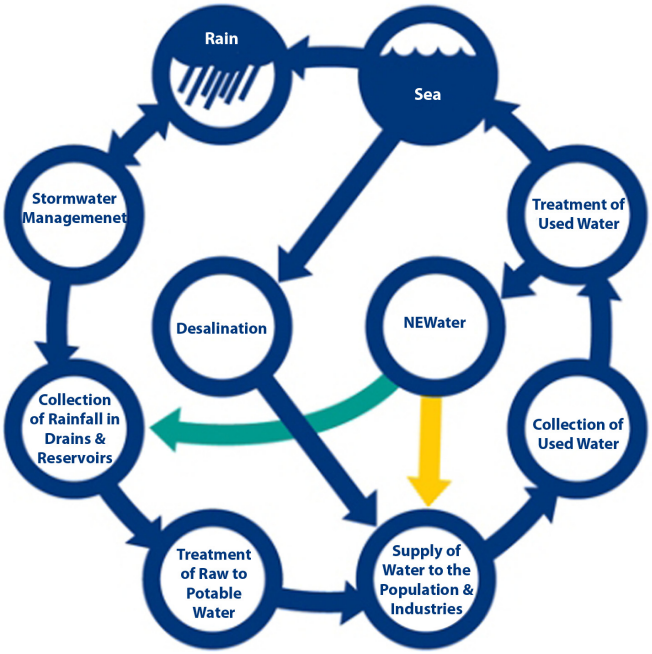

Figure 14: The Water Loop (PUB 2013e). Green arrow indicating indirect potable use. Yellow arrow indicating non-potable use.

Singapore´s four national taps
- Imported water
- Water from local catchment areas (Domestic water)
- Reclaimed water (NEWater)
- Desalinated water

Imported water

In 1961, a water agreement between the Singapore City Council and the state of Johor in Malaysia was signed. This agreement gave Singapore the 'full and exclusive right and liberty to take, impound and use all the water' within specific catchments and rivers until 2011. One year later another agreement was signed to supply up to 250 million gallons (= 945,000 m3) of water per day until the year 2061 (Tortajada et al. 2013). This corresponds to more than 50% of the fresh water requirement in Singapore.

Domestic water

In 1950, the first investigations on the availability of additional water resources in the island were undertaken. This resulted from the need to meet the increasing demand as well as to the desire to develop an emergency water supply should water from Malaysia be cut off. This study seems to have been commissioned as a result of lessons learnt during Singapore's fall in World War II, when water to the city was cut off and the island become very vulnerable (Tortajada et al. 2013). Three options were suggested: drawing water from rivers, tapping on available groundwater, and constructing wells and harvesting rainwater from roofs. Since it was assumed that it would be more economical to obtain groundwater from a single source rather than to produce drinking water from several scattered rivers, the subsequent research was focused on exploring groundwater in the Bedok area. However, the potential turned out to be very limited because of poor prospects for natural recharge from the ground surface (Tortajada et al. 2013). Therefore, the dominant sources of domestic water are local water catchments and reservoirs. In the early 1970s, main drainage systems were planned for each major catchment, facilitating the conversion of the runoff for water supply purposes. Thanks to these catchments and reservoirs 90% of the rainwater is harvested.

The latest reservoir is Marina Barrage, finalised in 2008, which is Singapore's first reservoir in the city. It has the largest and most urbanised catchment at a size of one sixth of Singapore and is separated from the sea by a dam. Its aims are threefold: to provide fresh water (currently 10% of the water demand of Singapore can be met), to be part of a comprehensive flood control scheme and to allow recreational activities on the water. Due to its central location within

the CBD it is crucial to keep the catchment and waterways clean. Therefore everybody ("People, Public and Private") is encouraged to take joint ownership of Singapore's water resource management (PUB 2013a).

NEWater and desalinated water
With the development of the Jurong Industrial Estate, first trials with water recycling began. The exploration of unconventional water sources started seriously in the 2nd half of the 1980s. It included desalinated and large-scale recycled water. Nowadays, seawater desalination and purified treated used water (NEWater) are two important pillars of the water supply in Singapore. However, there are many R&D activities going on to explore other unconventional sources to relieve the stress on water supply. At the time of the field visit, the exploration of aquifer storage water had just started in order to find the "next new drop" (PUB 2013e). Even the idea of obtaining water out of the humid air via membrane condensation has been explored. However, covering costs – mainly in terms of energy consumption – is the main problem faced by the innovative processes.

Result: the closed water loop
The elements described above are meant to "close the water loop" in Singapore (see Figure 15). Although not 100% of the water used is recycled, this closure is technically possible according to local experts (PUB 2013e).

By bringing the management of all the water aspects into a single entity it is possible to tackle the whole cycle: "The first drop of water which touches the ground belongs to us. It is collected, stored, treated for drinking, discharged to waste; the waste is collected back and cleaned and partly goes to the sea, back to the hydrological cycle. We short cut the process of evaporating from the seawater, because we tab the water directly from the sea" (PUB 2013e). In order to achieve this goal and provide "water for all" PUB continues its effort to utilize technological innovation to overcome water challenges. Therefore, the objectives of its R&D efforts are to increase water resources, protect water quality and security and reduce production costs.

2.9 SECURITY

The impacts of climate change and the adaptation to its consequences is one of Singapore's major challenges in moving towards becoming a resilient urban system. With much of its land below 15 m above sea level (Government of Singapore 2012), Singapore has to cope with coastal erosion as well as significant inundation events not only due to rising sea levels but also due to its specific climate and strong weather variability. This means increasing temperatures, changes in rainfall and the intensity of storms as well as significant changes in wind patterns which will consequently also affect haze events throughout Southeast Asia. Singapore's 5.3 million inhabitants (Department of Statistics and Singapore 2012) must be protected against threats caused by these highly distinct conditions. In addition to the finite land space and the resulting high population and building densities, Singapore also accommodates large harbour and petro-chemical industries which must be protected against natural as well as man-made threats.

Adaptation to climate change: for a more resilient, self-sufficient Singapore
Overall, the Singaporean government has identified three major areas in terms of adapting to climate change and the abovementioned consequences: protection of the coastlines through land elevation and improved drainage systems, increase of flood resiliency through drainage and flood management systems as well as elaborated forecasting technologies and modelling tools, and managing water resources in order to provide for an independent and reliable water supply.

The BCA has commissioned a risk-map study to be completed by the end of 2013 to identify those areas likely to be at risk of inundation and to better protect the coastline. The study includes several topographical surveys and analyzes 'soft' coastal protection strategies – for example the use of plants – as well as the use of hard walls and stone embankments to prevent coastal erosion. Currently, 70% to 80% of Singapore's coastline is protected by such constructions (Government of Singapore 2012).

Water conservation is one of the most important complementary resilience measures undertaken so far. Singapore, on a regular basis, is confronted with significant amounts of rain water which require innovative water conservation and drainage systems. Thus, the flood prone areas are to be decreased over time through improving existing drainage systems and installing new drainage systems. The PUB is currently commissioning the construction of new drains and canals, stormwater run-off systems for buildings as well as raised platforms, crest levels and flood barriers. This includes 20 drainage system projects over the next five years (Government of Singapore 2012).

The Singaporean government has developed a resilience framework with which to meet the requirements for safeguarding the city against future hazards. Core elements of this framework include the potential impact of climate change on public health, energy demand and biodiversity as well as the thorough mapping of the island in order to identify those areas at high risk of inundation and define the corresponding preparedness and response strategies.

Research in climate science, adaptation possibilities and resilience studies is also promoted by the Singaporean government. Therefore, particular emphasis is placed on vulnerability studies within the region and the consequences of extreme weather events. The Meteorological Service Singapore collaborates closely with local science and research

institutions to develop climate change modelling. Recent figures show that with a rise in temperatures from an average of 26.8 °C in 1948 to an average of 27.6 °C in 2011 as well as an increase in the annual frequency of days with heavier rainfall (Government of Singapore 2012), there is the need to form interdisciplinary research alliances in order to meet the new requirements for catastrophe risk management, infrastructure protection and water conservation.

Another crucial step towards Singapore's development as a resilient and self-sufficient city is promoting and increasing its independence from obtaining resources from abroad. This includes utilizing water supply from storm and rainwater management as well as managing the energy market. Diversification of energy resources is one strategic goal, however, 80 % of the city-state's energy consumption is currently generated through natural gas imported from Indonesia (Prime Minister's Office Singapore 2010).

Figure 15: National Climate Change Strategy 2012 – Resilience Framework (Government of Singapore 2012)

Emergency response

Emergency response efforts require the proactive implementation of technology systems as well as the provisioning of specific training to be engaged in by the corresponding decision makers and disaster response forces.

At the urban level, the Ministry of Home Affairs (MHA), in collaboration with the EDB , and various stakeholders from the industry are currently developing a roadmap for enabling government agencies to integrate sensor and database information in order to optimise emergency response operations. In addition to natural threats, such as those mentioned previously, Singapore – as the host for many large-scale events such as the Formula One racing competitions or major cultural festivities such as concerts or the annual New Year's Eve celebrations – is confronted with further security challenges. These include the handling of large crowds, vast amounts of traffic at peak times, arrival and departure of high person volumes at critical areas. All security efforts in this context require thorough integration of technological systems specifically designed for Singapore's unique urban landscape as well as effective operation methods and concepts to meet the city's security demands. Therefore, MHA's and EDB's Safety and Security Industry Programme Office (SSIPO) launched the SSIPO Safe City Test Bed which serves as a practice example and will be analyzed in greater detail in chapter 4.7. The SSIPO Safe City Test Bed is a typical example of Singapore's general implementation strategy: in order to implement new technological systems, the validation and development of such systems are performed as test beds involving the corresponding stakeholders. The execution of the SSIPO Safety Test Bed involves several government agencies ('whole-of-government approach') as well as the participation of the technology industry within the framework of a call for collaboration.

3

3 SUSTAINABILITY IN SINGAPORE

3.1 NGO SINGAPORE'S UNDERSTANDING OF SUSTAINABILITY

Sustainable development for Singapore is about achieving development while minimising the impacts on resources and environmental quality, such that the development today does not come at the expense of the quality of the living environment for current and future generations. Therefore, Singapore has identified the following four strategies to ensure Singapore's continued sustainable development (URA 2013):

- Improve resource efficiency in energy, water and waste management so that Singapore will be more cost competitive and efficient in the long run.
- Enhance the physical environment through controlling pollution, increasing our greenery as well as cleaning and beautifying our water bodies.
- Engage the communities and encourage them to play their part by adopting more responsible practices, habits and lifestyles.
- Build up technologies and capabilities in order to realize the sustainable development targets, spur economic growth and export Singapore´s expertise.

Four types of sustainability are identified , while the first three ones are widely used as a definition of sustainability all over the world:

- Economic Sustainability
- Social Sustainability
- Environmental Sustainability
- Land and sea sustainability

After investigating and conducting several interviews, the m:ci Singapore project team's impression was that the first dimension of sustainability (economic sustainability) is, compared to the other dimensions, the dominant focus in Singapore. This makes sense in relation to the objectives mentioned in Chapter 2.1 on basic data.

In Singapore, liveability is a desirable objective closely linked to sustainability. In order to achieve green growth and global leadership, figure 16 shows the way in a scheme.

The Centre for Liveable Cities (CLC) in Singapore has defined a framework for planning and developing a liveable city (CLC 2012). The "purpose of the CLC Framework is to provide a lens through which city leaders can view their cities and analyse the actions or approaches open to them to achieve high liveability and sustainability" (CLC 2012). The framework combines a competitive economy with a sustainable environment and a high quality of life.

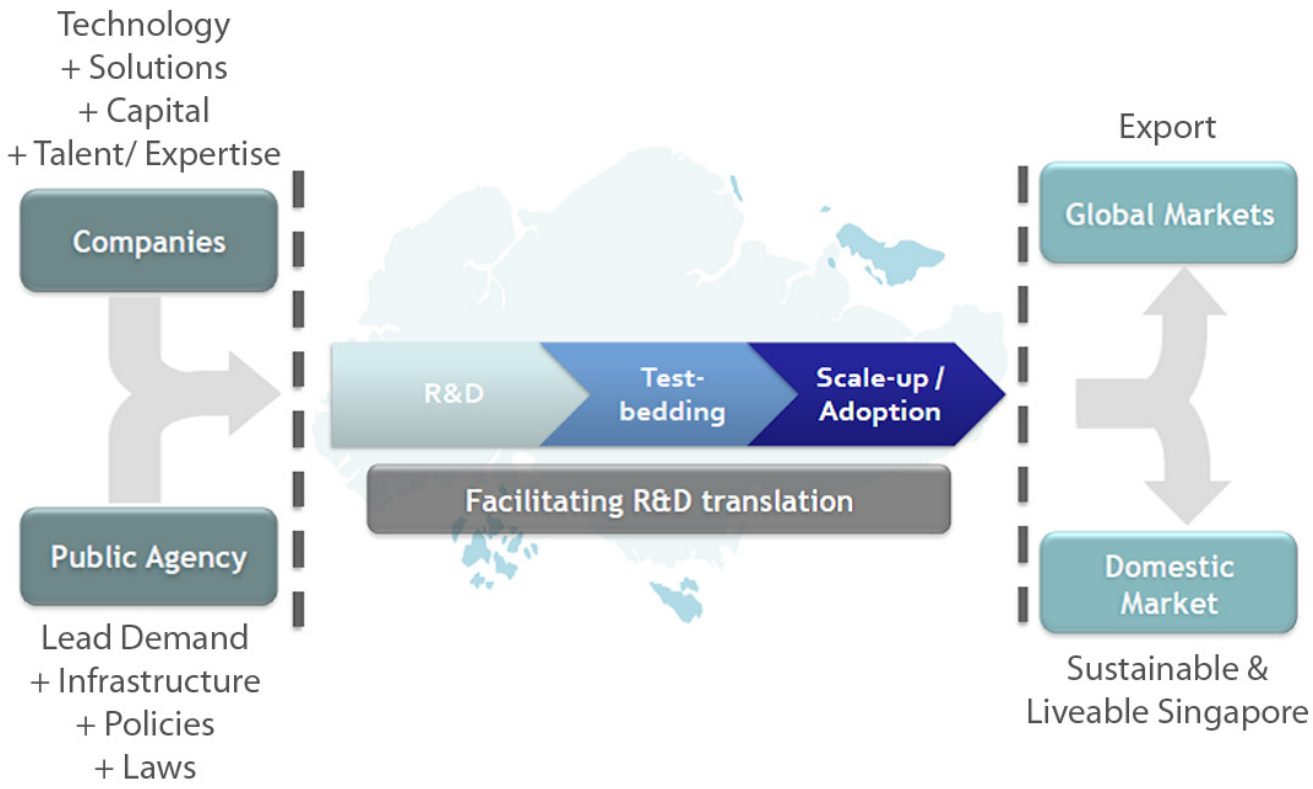

Figure 16: Creating opportunities for green growth and global leadership (NCCS 2012a)

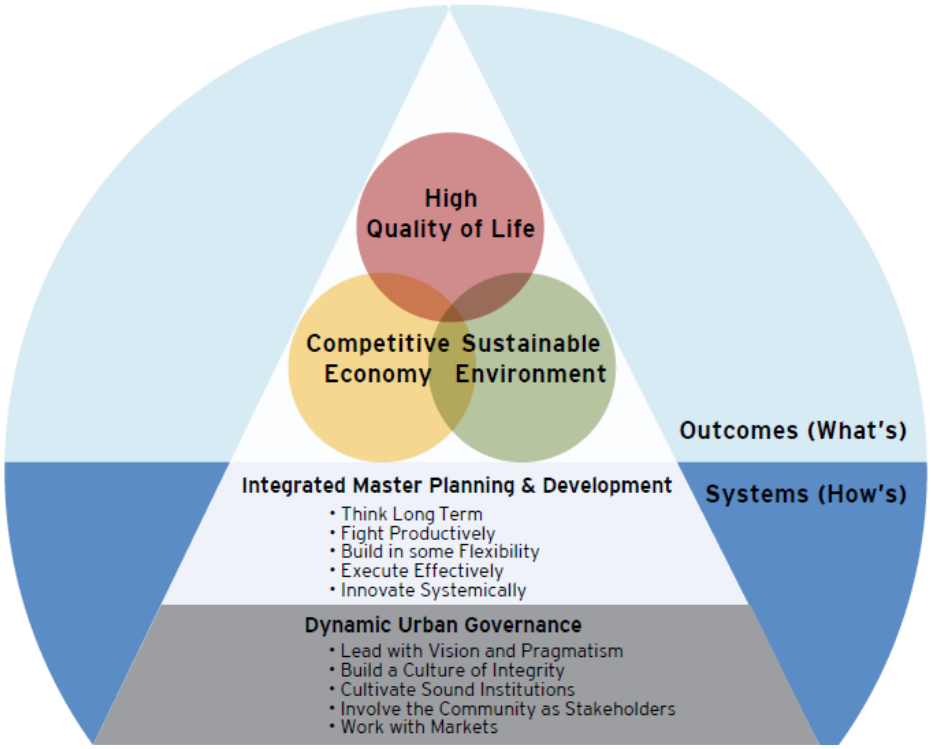

Figure 17: CLC Livability Framework (CLC 2012)

A competitive economy means a resilient economy, competitive workforce and inclusive growth. The following data gives an impression (Chye 2012):

- Singapore's average real GDP growth for the last 5 years > 5% (CIA 2013)
- Singapore's average unemployment rate for the last 5 years < 3% (CIA 2013)
- Land planning's moving in tandem with economic strategy

The strategy for creating a sustainable environment is focused on developing Singapore as a "City in a Garden" instead of "Garden in a City". Despite population growth of more than 3 million in the last 30 years, the green cover in Singapore grew from 35.7% to almost 50% (MEWR 2009). Environmental objectives include:

- Adequate land, water and energy to meet long term needs,
- Clean and good quality environment (air, water, waste management, noise level)
- Green and healthy eco-systems,
- Resilience to environmental risks (climate change, natural disasters, food security)

High quality of life is understood to mean (CLC 2012):

- A safe and secure living environment,
- A cohesive and diverse society (immigration and integration),
- An equitable and inclusive society,
- High public health standards,
- Accessible, adequate, affordable and diverse essential, social, recreational as well as cultural needs and services

3.2 URBAN PLANNING

The major challenges of preserving and developing Singapore as a prosperous and sustainable city state are listed as follows (MEWR 2009; NCCS 2012a):

- catering to a diverse range of land demands such as housing, commerce, industry, reservoirs, natural environment, recreation, security, etc. within the small land area of ~700km^2
- sustaining economic growth, creating jobs and improving standards of living
- enhancing quality of life, supporting resource conservation and environmental health
- alternative energy is disadvantaged, which limits the extent of use of low-carbon energy sources such as wind, hydro, and geothermal. Small land area also limits extent of deploying solar panels.

In Singapore urban planning is done in an integrated manner with various perspectives. Different institutions are involve:

Key Institutions

MND Ministry of National Development
http://app.mnd.gov.sg/ (MND 2013)

URA Urban Redevelopment Authority
http://www.ura.gov.sg/ (URA 2013b)

With contributions from

CLC Centre for Livable Cities Singapore
http://www.clc.gov.sg/ (CLC 2012)

NEA National Environmental Agency
http://www.nea.gov.sg/ (NEA 2010)

NCCS National Climate Change Secretariat
http://app.nccs.gov.sg/ (NCCS 2012b)

LTA Land Transportation Authority
http://www.lta.gov.sg/

MEWR Ministry of the Environment and Water Resources
http://www.mewr.gov.sg/

BCA Building and Construction Authority
http://www.bca.gov.sg/

For handling the challenges and realizing the strategies the Urban Redevelopment Authority's (URA) set up planning principles (MEWR 2009; NCCS 2012a):

- long term holistic planning
- providing clarity and transparency
- integrated planning as a partnership between the different aspects of urban living (physical, economic, social and environmental)
- planning for implementation
- involving both the private and public sectors

In Singapore, an integrated multi-stage and multi-agency process for planning and development is implemented. Main pillars are the Concept Plan from 1971, a Master Plan and the implementation. The plans are reviewed regularly (the Concept Plan is reviewed every 10 years and the Master Plan every 5 years) to adapt to emerging needs and trends. A large-scale public consultation process is realised to integrate stakeholders (from the public and private sector) into the planning. In the following figure the planning process is briefly outlined.

Innovation and urban solutions in city and land use planning are elementary for Singapore. Innovation (innovative urban solutions) helps overcome (resource) constraints and dependencies (a"strong impetus to innovate existed because the more conventional solutions simply would not work in Singapore's context" (CLC 2013)). Singapore's R&D

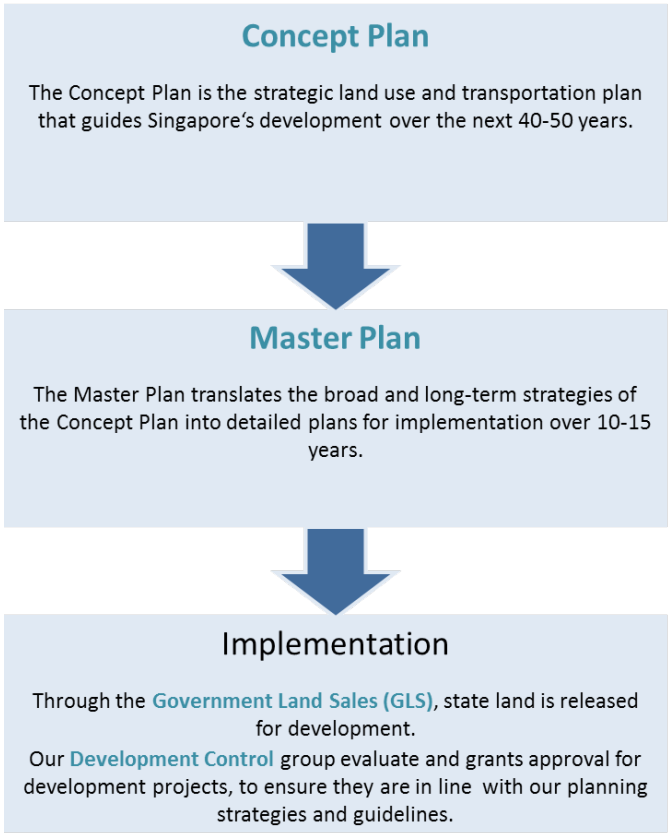

Figure 18: Summary of the planning process (URA 2013a)

investment in 2015 is proposed to amount to up to 3.5% of the city state's total GDP (Prime Minister's Office Singapore 2011). Singapore seeks to be a leader in innovative urban solutions; as a living laboratory for testing resource-efficient and clean technologies (CLC 2013). Examples of innovative solutions are introduced in this report (e.g. Chapter 4) and conditions are mentioned in Chapter 5 as fields of application.

The National Climate Change Strategy 2012 (NCCS-2012) and the 2009 Sustainable Singapore Blueprint (SSB) outline key plans for the sustainable development of the city to 2030 and beyond. Nevertheless, the government has also compiled several master plans for different sectors which focus on the processes and aims in a more detailed manner. The following table gives an overview of current master plans and other important plans and platforms relating to Singapore's sustainable development strategies.

Table 4: Assorted Plans and Strategies in Singapore

Sectors	Master Plans	Time Horzon	Ministry
Buildings	2nd Green Building Master Plan	2009-2030 First launched in 2006	BCA (BCA 2011a)
	3rd Green Building Master Plan	Launched in 2013 for plans for next 5-10 years	BCA (BCA 2011a)
Urban Planning	URA Draft Master Plan 2013	Launched 2013 for next 10-15 years	Urban Redevelopment Authority (URA)
	Land and Liveability National Innovation Challenge (L2NIC)	2013-2018	Multi-agency Committee led by National Research Foundation and Ministry of National Development
Energy	Energy Efficient Programme Office, Singapore (E2PO)	2007-present	Multi-agency committee (National Environment Agency: E2 Singapore, Singapore 2009) led by NEA and EMA
	Energy Innovation Programme Office (EIPO)	2011-2015	Multi-agency committee led by Ministry of Trade and Industry and EDB
	Energy National Innovation Challenge (ENIC)	2011-2015	Multi-agency committee led by National Research Foundation (NRF) and Ministry of Trade and Industry (MTI)
Mobility	Land Transport Master plan (LTMP) 2013	2013-2030	LTA (LTA 2009)
ICT	Continuing Education and Training (CET)	2008-2018	Workforce Development Agency (WDA), Ministry of Manpower (WDA 2012)
	eGov2015	2011-2015	Infocomm Development Authority of Singapore (iDA) (IDA 2011)
	3rd ICT in Education Master plan	2009-2014	Ministry of Education (Ministry of Education 2013)
	Intelligent Nation 2015 (iN2015)	2005-2015	iDA (IDA 2006)
	Library 2010	2010-2015	National Library Board (NLB) (National Library Board 2010)
	Media Fusion Plan	2009-Unknown	Media Development Authority (MDA) (MDA 2007)
	Social Service Sector ICT Master plan	2012-2016	iDA (IDA 2013a)
Security	Infocomm Security Master plan 2	2008-2013	Multi-agency effort under National Infocomm Security Committee (NISC), led by iDA (IDA 2013b)
	National Cyber Security Master plan 2018	2013-2018	Multi-agency effort under National Infocomm Security Committee (NISC), led by iDA (IDA 2013b)

Water	ABC Waters Master plan	2006-unknown	National Water Agency (PUB) (PUB 2013h)
	Integrated Water Plan	2013-2063	PUB (Liang 2013)
Other	Recycling Master plan	NUS Recycling Master plan	NUS (MEWR 2013b)

3.3 SUSTAINABLE SINGAPORE BLUEPRINT SSB

The Inter-Ministerial Committee on Sustainable Development (IMCSD) was set up in January of 2008 to formulate a national strategy for Singapore's sustainable development in the following 10 to 20 years. One year later, in 2009, the „Sustainable Singapore Blueprint" (SSB) was released. The strategy status: The SSB was launched in 2009 and reaches up to 2030. The major targets are reviewed and readjusted every five years if improvements in technology, cost-effectiveness, public response and/or international developments occur. According to interviewees, the next release is announced for 2014 with prospected topics about smart-sustainable cities, growth of green industries and energy management (MND 2009).

The current SSB focuses on four areas (MND 2009):

- Resource efficiency
- Urban environmental friendliness,
- Building Singapore's competencies in sustainable city development to strengthen its economy
- Encourage community action

The aim of this long-term strategy for sustainable growth is to provide strategies that increase liveability, decrease resource dependence and thus increase economic strength and independence. The goals of the SSB are to achieve a balance between economic growth and a good environment. To reach this goal they invented the "Singaporean way" which tries to follow the three key principles: long-term integrated planning, a pragmatic, cost-effective approach and flexibility (MND 2009).

The major objectives of the SSB are to decrease resource dependence by increasing resource efficiency, increase liveability and urban environmental friendliness by enhancing the urban environment, build up competencies and capabilities in sustainable city development and to encourage community action and increase economic strength (MND 2009).

„With the release of the SSB, the IMCSD completed its work and a Sustainable Development Policy Group was set up to monitor the implementation of blueprint initiatives and the progress towards reaching the Blueprint targets. The group is co-chaired by MEWR and MND" (MEWR 2013a). The key goals listed below can be placed into six different categories: live, commute, play, work, capability development and community.

The key goals in the 2009 Sustainable Singapore Blueprint have been listed as below (MND 2009):

Live

- Introduce minimum energy performance standards for household air-conditioners and refrigerators by 2011
- Set minimum water efficiency standards for water appliances in new buildings and in renovated houses
- Improve recycling rate from 56% in 2008 to 65% in 2020 and 70% in 2030 (-> reduce waste, towards zero landfill)
- Reduce energy intensity (per dollar GDP) by 20% from 2005 levels by 2020, and by 35% from 2005 levels by 2030 (-> greater energy efficiency)
- Reduce total domestic water consumption from 156 litres per capita per day in 2008 to 147 litres per capita per day by 2020, and 140 litres per capita per day by 2030. (-> Increase efficiency of water use)
- Establish a Green Mark GFA Incentive Scheme to encourage new buildings to attain green Mark GoldPlus and Platinum ratings
- 80% of the existing building stock should achieve at least a Green Mark Certified rating by 2030
- New public sector buildings with 5,000sqm of air-conditioned floor area to achieve Green Mark Platinum rating. Require existing government buildings with more than 10,000sqm air-conditioned floor area to attain Green Mark GoldPlus rating by 2020
- Implementation of large-scale solar test-bed for public housing spanning 30 precincts island wide
- Develop a new generation of environmentally friendly housing districts along the Punggol Waterway.
- Set up public education, cleaning and enforcement

Commute

- Double the rail network & develope a more integrated and seamless connection between bus and rail services to achieve that 70% of journeys made during morning peak hours are made using public transport
- Halve the annual vehicle population growth rate to 1.5%, refine the electric road pricing system and reduce car usage

- Improve energy and fuel efficiency for public and private transport, test-bedding diesel-hybrid busses and developing a green framework for the rail system
- Reduce the annual mean for ambient fine Particulate Matter (PM2.5) from 16µg/m^3 in 2008 to 12µg/m^3 by 2020 and maintain it at this level until 2030. (-> cleaner air)
- Establish a vehicle emission test laboratory
- Improve cycling and walking infrastructure

Play

- Increase green park space by 900ha to 4,200ha by 2020, park provision of 0.8ha per 1,000 people by 2030. Increase the length of park connectors from 100km in 2007 to 360km by 2020. Introduce 30ha of high-rise greenery by 2020 and 50ha of high-rise greenery by 2030. (-> City in a garden)
- Make parks more accessible
- Open 820ha of reservoirs and 90km of waterways for recreational activities by 2020 and open 900ha of reservoirs and 100km of waterways for recreational activities by 2030.
- Implement a National Biodiversity Strategy and Action Plan
- Develop a City Biodiversity Index

Work

- Facilitate energy-related benchmarking for key industrial sectors
- Establish a national Energy Efficiency Circle Programme to promote a culture of sustained energy efficiency improvements in companies
- Promote energy-efficient technologies and systems
- Expand NEWater infrastructure and promote water efficiency to support future industry needs
- Set standards to rise the uptake of recycled products
- Introduce an accreditation system for companies that recycle construction and demolition waste
- Cap ambient Sulphur Dioxide (SO_2) levels at 15µg/m^3 by 2020 and maintain it at this level until 2030. (-> cleaner air)
- Promote Clean Technology and Sustainable Urban Solutions as new economic growth sectors
- Develop a 55ha CleanTech Park at Jalan Bahar as a platform for test-bedding clean technologies

Capability Development

- Conduct research to maximise water resources and the energy efficiency of water treatment
- Establish a new S$5 million incentive scheme to develop prototype building designs with at least 50% improvement in energy efficiency
- Develop Marina Bay and Jurong Lake District as sustainable high-density districts
- Establish a five-year research program to adapt water sensitive urban design concepts and technologies to local use
- Invest R&D and manpower in clean energy, water technologies and waste management
- Promote the international exchange of ideas on sustainable development
- Help to build environmentally sustainable cities across the world

Community

- Government will make funding available to support NGOs and facilitate more networking among NGOs
- Community Development Councils will promote environmental awareness and action to more than 2 million people through programmes under their local district plans
- Government will use a $1.5 million 3P Partnership Fund to assist organisations from across the people, public and private sectors to implement worthy ideas related to environmental sustainability
- Schools will step up their efforts to promote environmental education
- The public sector will adopt more environmentally sustainability practices both as a consumer of goods and services and as a responsible employer.

Public participation in the development of the SSB is an important factor. Examples of public participation in this case are shown by more than 1300 suggestions via the Sustainable Singapore website and more than 700 people participating in focus group discussions, public forums and dialogue sessions. The combination of bottom-up (feed-back) and bottom-down (initiation, coordination, and implementation) should be high-lighted here (MND 2009).

Since there had been high public participation throughout the development process of the SSB, it might be assumed that it is (well) known to some well-informed actors. Furthermore, there have been many events to promote a more sustainable lifestyle (e.g. the „plant-a-tree program) which might help to improve the popularity of the SSB and behaviour in the direction of sustainability.

In sum, the SSB's contribution to the sustainability of Singapore can be viewed on three levels:

- Economic: One of Singapore's main goals is economic strength and independence. Singapore is business-focused and investor-friendly in an economically sustainable way; e.g. the government invests in environmental infrastructure and clean the waterways as well as green the city permanently, thereby attempting to select the most cost-effective method.
- Ecological: environmental infrastructure, species

conservation, protecting and enhancing biodiversity, more environmentally-friendly buildings, etc.
- Social: to ensure jobs, safeguard a high standard of public health, guarantee a good infrastructure for the inhabitants, increase greenery, guarantee safety and serve residents' needs.

The SSB, as a strategy, is transferable to cities that face problems such as limited natural resources, high density, population growth, prosperity, etc. In general, however, being a city-state means other types of decision making and implementation than would be the case for a city within a state.

3.4 NATIONAL CLIMATE CHANGE STRATEGY

The National Climate Change Strategy 2012 (NCCS-2012) document gives attention to Singapore's plans to address climate change through a whole-of-nation, integrated approach. It was released in 2012 by the National Climate Change Secretariat, and outlines both new and on-going activities carried out by different sectors and actors (ministries, agencies, public and private sector etc.). For Singapore, the vision is to be a climate-resilient global city that is well positioned for green growth (NCCS 2012a; Singapore 9th Mai 2013).

The Government of Singapore has formed the Inter-Ministerial Committee on Climate Change (IMCCC), the IMCCC Executive Committee as well as three working groups (Long Term Emissions and Mitigation Working Group, International Negotiations Working Group, Resilience Working Group) to address climate change-related issues (see Figure 20). Within the Prime Minister's Office, the National Climate Change Secretariat was set up to support addressing climate change. Its tasks are to facilitate coordination at the highest level and to develop long-term plans for mitigation and adaptation across all sectors and agencies. The National Climate Change Secretariat also identifies economic and green growth opportunities arising from climate change and creates public awareness and action on climate change (NCCS 2012a; Singapore 9th Mai 2013).

The figure 20 shows the guiding principles for responding to the challenges of climate change, as highlighted in the NCCS-2012:

Key areas of Singapore's climate change actions
• Mitigating climate change by reducing emissions • Adapting to climate change: building a more resilient Singapore • Creating opportunities for green growth • Fostering local and international partnerships on climate change

Singapore has pledged to reduce their emissions by 16% from the 2020 business-as-usual levels, contingent on a legally-binding global agreement. Singapore has also unconditionally pledged to reduce overall emissions by 7% to 11% below the 2020 BAU level. Other nation-wide goals include fostering sustainable growth (e.g. 35% reduction in economy-wide energy intensity by 2030 from 2005 levels as outlined in 2009 SSB) and forging partnerships on climate change action. Another motivation is to pursue green growth through the development and export of climate-friendly, clean technologies, services and solutions. Further-

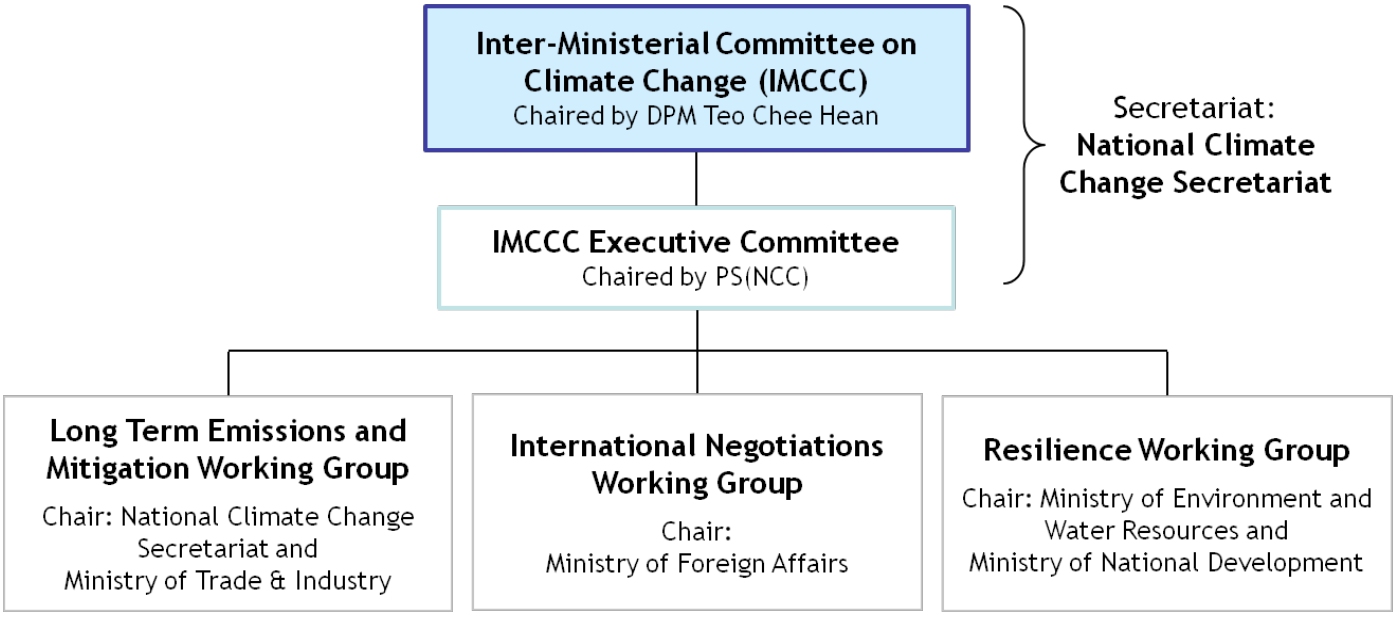

Figure 19: Organizational Chart for the Inter-Ministerial Committee on Climate Change (NCCS 2013)

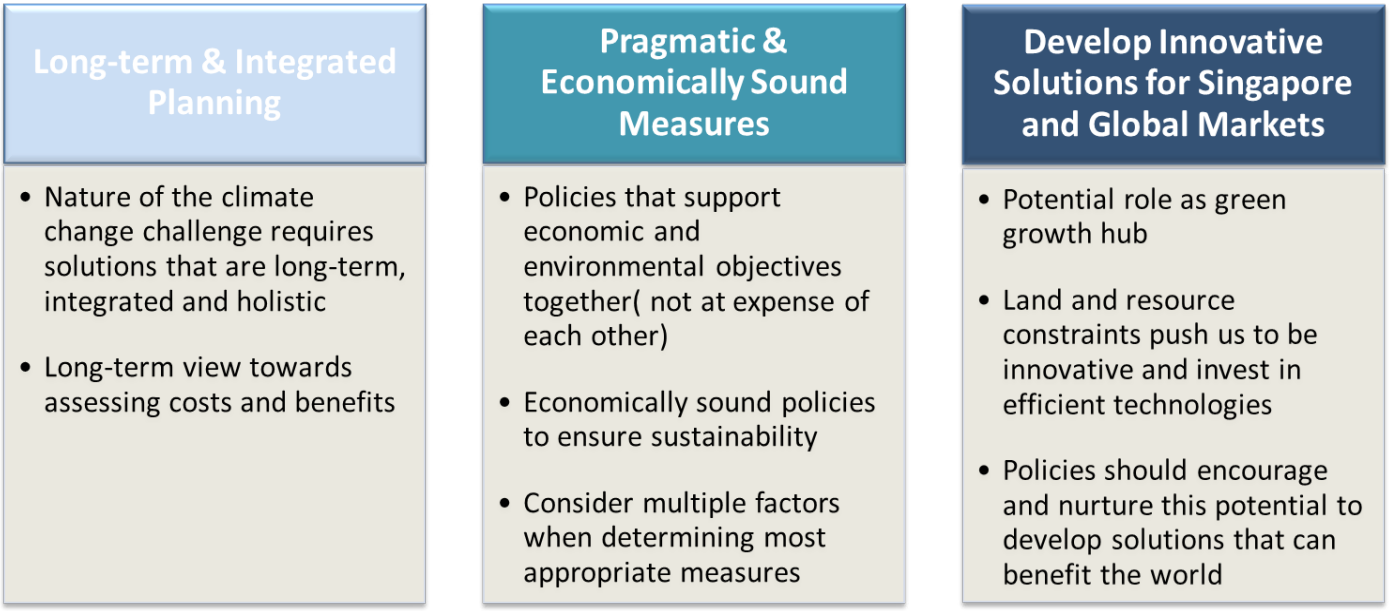

Figure 20: Guiding Principles for responding to the challenges of climate change (Presentation by NCCS for the project team (Singapore 9th Mai 2013))

more, a change in user behaviour is necessary and this is planned to be reached by effective policies, incentives and price signals. Minimizing the impact of climate change is part of a large, holistic approach to ensure that Singapore continues to develop in a sustainable manner, and stays an environmentally-friendly city in which current and future generations can work and live (NCCS 2012a; Singapore 9th Mai 2013).

Furthermore, the strategy adheres to the government's goal of building up the CleanTech sector in Singapore, and harnesses green growth opportunities in clean and green energy (e.g. solar), waste and water technologies, urban management, green ICT, etc. Singapore's approach to harnessing green growth opportunities include: 1) developing capabilities in R&D and human capital; 2) providing test-bedding opportunities; and 3) creating a favourable business environment. Since 2007 Singapore has rolled out a series of investments and installed tax benefits as well as other incentives for the green economy sector (Fogarty 2010), such as the Clean Energy Research Programme in order to promote the development of the clean energy industry. These initiatives help spur innovation and urban solution development by the private and academic sectors.

Various research institutes are working on a variety of cleantech domains such as the Solar Energy Research Institute of Singapore (SERIS), Energy Research Institute at the Nanyang Technological University (ERI@N) as well as the many research centres set up in partnership with global top universities and institutes within the Campus for Research Excellence and Technological Enterprise (CREATE; NCCS 2012a). Singapore has also provided test-bedding and demonstration platforms to support companies and research institutes in the effort to validate new technologies in a real-world setting (e.g. Cleantech Park for green companies, Punggol Eco-Town to test residential solutions, Electric vehicle test-bed, etc).

Singapore's climate change measures aimed at reducing emissions by 2020 can be categorized into six categories; examples for measures in each category are shown in the following figure. Mitigation measures as well as capability development measures exist in order to reduce emissions (NCCS 2012a; Singapore 9th Mai 2013).

The National Climate Change Secretariat will foster the economic sustainability of the city by creating high-value jobs for Singaporeans, and by pushing the economy along a green growth trajectory. On a social level, it will work towards reducing public health risks (dengue fever, heat disorders, and respiratory diseases) by reducing the impact of climate change.

Examples for activities which contribute to overall sustainability and climate change mitigation or adaptation (Singapore 9th Mai 2013):

- Long-term integrated urban planning: Land Use-Plan 2030
- Green Urban Environment: BCA, GMS, City in a Garden
- Eco-flagships: examples of integrated urban planning include: Marina Bay, Punggol Eco Town, Cleantech Park, Jurong Lake District
- Turning vulnerabilities into strengths: resilient and self-sufficient (Singapore as a global hydro hub)

- Creating opportunities for green growth and global leadership (see chapter 3.1)
- Living Laboratories to enable scale-up and to commercialize innovation (Intelligent Energy Systems, Zero Energy Building, Floating Photovoltaic Pilot, EV Test Bed etc.)
- Fostering strong partnerships, e.g. engaging the community, encouraging action

Adaptation: The multi-agency Resilience Working Group is responsible for reviewing existing measures and infrastructure that contribute to climate resilience and developing long-term adaptation plans for Singapore. In view of the inherent complexity of climate science and the need for early planning of adaptation measures, the Resilience Working Group has developed a Resilience Framework that provides flexibility to incorporate future developments. The Resilience Framework is divided into seven phases which can be seen in Figure 21.

Integration of stakeholders and the public: For example, a public consultation initiative launched by the National Climate Change Secretariat in September 2011 helped raise public awareness of Singapore's plans to tackle climate change. The consultation spanned five months, and generated more than 1,000 comments and suggestions from members of the public, companies and NGOs. A roadshow was also held from September 2012 to January 2013 at 15 venues to bring the NCCS-2012 messages to the community. The roadshow was viewed by some 60,000 visitors. Furthermore, Singapore has educational programs including environmental education, school excursions to power stations and an annual National Climate Change Competition for schools and tertiary institutions has existed since 2011 (the inaugural competition's theme was "Climate Change – how can I help?").

In August 2013, the National Climate Change Secretariat introduced an educational drama on climate change for primary schools as part of its outreach efforts. Entitled „Stop Melting My Home", the interactive drama aims to inspire climate change action amongst the young through the story of a polar bear whose home is melting. A resource kit, produced for students and teachers participating in the programme, reiterates the key messages of the drama and serves as a takeaway resource for students. Additionally, Singapore engages in both community and national campaigns (e.g. annual flagship Clean & Green Singapore campaign, NEA 10% Energy Challenge programme). The government has also supported stakeholder-initiated efforts to raise awareness and action on climate change, such as the annual Earth Hour event organized by the World Wide Fund for Nature (WWF) and the inaugural World Engineers Summit organised by the Institution of Engineers in Singapore, which had climate change as its theme. As a success factor for implementation, the participation of the public and the private sector is important. Government and all stakeholders need to work together.

Figure 21: Singapore's adaption approach (NCCS 2012a)

The strategy is transferable to cities that face a similar situation as the island nation. Since Singapore must deal with limitations in its ability to reduce carbon emissions and use green energy due to its small land area, constrained resources and dependence on other countries, Singapore is a good test-bed for the possibilities of green energy and renewable resources in high-density cities with limited energy resources and rapid economic growth.

Table 6: Measures for the reduction of emissions (by 2020)

Power generation
• Switch fuel mix away from fuel oil to natural gas for power generation • Build a Liquefied natural Gas (LNG) terminal (started commercial operations in May 2013) • Encourage more solar test-bedding and research
Waste water
• Incinerate sludge rather than dispose in landfills • Reduce plastics incineration
Households
• Tighten Minimum Energy Performance Standards (MEPS) for household air-conditioners and refrigerators (2013) • Extend MEPS to lighting (2014) and additional appliances
Buildings
• Require Green Mark Certification for all new buildings • Require Green Mark Certification for existing buildings when retrofitted (2013) • Audit of building cooling systems every three years in new and existing buildings that have undergone retrofitting (2013) • Submit energy consumption and energy-related building data (2013)
Transport
• Achieve 70:30 modal split between public and private transport • Implement Carbon Emissions based Vehicle Scheme(CEVS) to encourage purchase of low carbon emissions cars (2013) • Implemented the Fuel Economy Labelling Scheme (FELS) to enable customers to make more informed decisions on their vehicle purchase • Grow the existing public bus fleet significantly by about 800 buses (or 20%) over the next 5 years
Industry
• Extend the Grant for Energy Efficient Technologies (GREET) scheme (2012) • Develop and support energy efficiency by financing pilot schemes (2012) • Encourage new co-generation plants in energy intensive sectors

4

4 SELECTED PRACTICE EXAMPLES

4.1 INTELLIGENT ENERGY SYSTEM

One way forward for sustainable energy consumption is to explore smarter ways of managing energy demand and usage. The EMA's current IES pilot test-bed seeks to do this. Launched in 2009, the IES is a platform being built to prepare Singapore for the future by allowing for a greater adoption of renewable energy sources, offering consumers more choices in energy consumption and catering to other new technologies such as electric vehicle charging.

4.1.1 Development and Objectives

Increasing energy prices, coupled with the introduction of distributed generation, heightened expectations and increased consumer choices, have resulted in increased expectations for higher system performance as well as consumer involvement. This has led to the development of ‚smart' applications such as advanced building management, home automation and demand response programs.

In order to meet these ‚new' expectations, there is a need to ‚smarten' the ‚last mile', which can be achieved by implementing Advanced Metering Infrastructure (AMI). As such, besides offering direct benefits to customers, the IES pilot is designed to help strengthen the power systems capabilities and Singapore's network efficiency. For example, with information from the smart meters, the national power grid operator SP PowerGrid will be able to almost instantly detect the location and extent of any localized outages, and respond promptly to restore supply.

EMA project director describes expected potentials in an IEEE paper from 2012 (Chan et al. 2012). The Smart Grid Primer – published by NCCS and NEA - assess that the existing grid may need to be upgraded and sees the following as key drivers for Smart Grid development in Singapore (for details, see NCCS 2012b):

- Integration of distributed generation, such as renewable sources
- Integration of electric vehicle (EV) charging infrastructure
- Better energy management, outage management and improved grid reliability, which could successfully delay the need to build more power plants and upgrade the grid.

For the entire project, EMA anticipates the benefits depicted in table 7 for stakeholders.

Table 7: Anticipated benefits as a result of IES

Household	Business	Grid Operator	Research & Development
choice of electricity retailer and pricing plan	choice of electricity retailer and pricing plan	effective communication with households and businesses to enhance delivery of electricity	develop and test promising smart grid applications and technologies for commercialization
more information to monitor and manage energy usage	more information for building owners and occupants to manage energy usage	enhanced capability to detect and respond promptly to localized power outages	opportunities for the research community to test-bed energy solutions in real-world environments
better control of major home appliances to reduce energy usage	better control and automation of systems at the building level to reduce energy usage	easier integration of new energy sources into the grid	

Source: Fraunhofer ISE, Freiburg

4.1.2 Approach and Instruments

EMA expects that the IES will push the capabilities of Singapore's power grid to the next level and ensure that Singapore's electricity infrastructure is ready for the future. Phase 1 (2010-2012) focused on the implementation of enabling infrastructure for the IES. The key infrastructural components are the advanced metering infrastructure (commonly referred to as "smart meters") and the communications system. Hence, a key focus in this first phase of the pilot was based on establishing the smart metering communication protocols and standards. In phase 1, the IES pilot involved around 4,500 customers in various residential, commercial and industrial locations, including the Nanyang Technological University (NTU) campus, the CleanTech Park at Jalan Bahar and the Punggol Eco-Precinct.

Phase 2 (2012-2013) of the pilot is dedicated to smart grid applications. Customers with smart meters installed on their premises are able to experience the benefits of the IES through various services offered by the electricity retailers. Residential customers are able to monitor their energy consumption on a real-time basis with convenient in-home display devices. They can also choose from a range of electricity pricing plans, thus allowing them to better manage both their consumption and budget, for example, by shif-

ting their usage from peak to off-peak periods when electricity prices are lowest. Service providers are brought in to provide smart grid applications and services.

Architectural design of the IES

To develop the IES, certain guiding principles were followed, which are comparable to most current smart metering projects around the globe. For detailed descriptions, therefore, refer to the IEEE paper by EMA from 2012 (Chan et al. 2012).

4.1.3 Project Implementation and Lessons Learned Thus Far

Phase 1 (developing the enabling infrastructure 2010-2012) has been executed and finalized. The major outcomes were extensive experience gained in the installation and reliable operation of the infrastructure. The main challenge – as in most pilots around the world – was the reliable establishment of communication components. Another major challenge was the design and set up of the back-end systems enabling the intended functionalities. The back-end system currently being used was handed over from EMA to SP.

Phase 2 (rolling out smart meters to assess applications and consumer response 2012-2013) is currently under finalization. A major test trial with some 2,000 households in a residential estate was run, including 3 types of last mile communication concepts, some 1,000 Inhouse Displays, an SP Services web-portal, and email notification for all customers in the event of a significant consumption increase. Separately, 10 Home Energy Management Systems (HEMS) were integrated in the Demand Response (DR) trial from Panasonic (not an official part of the IES).

4.1.4 Financing the Project and Stakeholders

The total budget for the IES pilot project is $30 million, funded by the Government and Singapore Power. The consulting company Accenture was appointed to Phase 1 of the IES pilot project and it worked together with its selected partners including ST Electronics (Info-Comm systems), Oracle (software), Hewlett Packard (hardware), Power Automation (IT integration), Control4 (product vendor) and Greenwave (communication technology), in designing and implementing this phase of the project.

In Phase 2 of the pilot, other companies were brought in to provide smart grid applications and services. Here, Panasonic - with a small trial of 10 households in Punggol Eco town - participated in a DR trial including the IES's smart metering infrastructure and integrating the Panasonic HEMS to run the households air conditioning units according to the need for cutting high demand peaks.

Figure 22 displays the relevant stakeholders involved. Accenture played a key role in IES to design and implement the pilot in phase 1. This involved the implementation of a

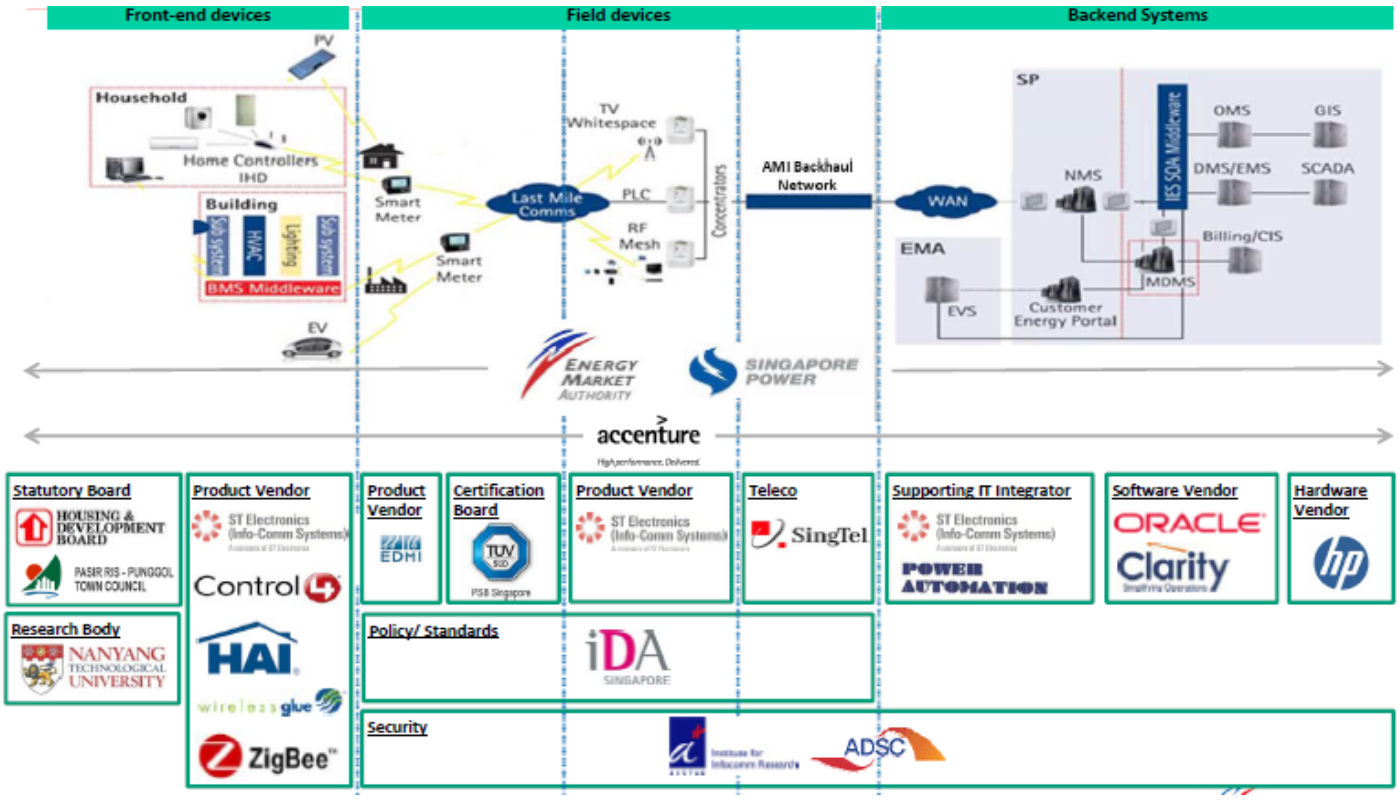

Figure 22: Structure and actors for the implementation of IES (Chan et al. 2012)

range of technologies, on the grid side, on the communication parts as well as on the consumer side, in home devices and smart meters. Accenture was managing a diverse team of business partners as well as stakeholders from government agencies and consumers. Ultimately, their role was to help Singapore determine what makes sense, to utilize smart grid and smart meter technologies to drive energy efficiency in the Singaporean context. A personal meeting and exchange during the Fraunhofer's research stay in Singapore was refused by Accenture.

4.1.5 Impact and Context Factors

The IES is one component of Singapore's strategy to secure the city state's energy supply. The IES was introduced by the EMA as a test-bed and its subsequent up-take is assessed as pending – by representatives from EMA and NEA.

The main impact factors for the project's initialization are described in 4.1. The following impact factors lead to the fact that roll-out of the AMI is not launched:

- Economic rationality: no market viability. Decisions are mainly made according to (macro) economic rationality with a short to medium term perspective (3-5 years). Introduction of new legislation must meet the national market viability at the time of enactment – which is not in place for IES under current conditions.
- A lack of public acceptance endangers political power: Singapore's government fears to lose its majority in votes by increased public discontent as a result of governmental actions. With IES, the cost of AMI for the residential sector will be charged to the residential customers; in such a case public denial is expected.

For the commercial sector, the roll-out of AMI and IES infrastructure is estimated as much more positive:

- Market viability: it is expected that introduction of new legislation will meet national market viability at the time of enactment.

From m:ci perspective, a promising linkage of IES with the GMS and DR plans for the commercial sector seems possible, as its economic viability is widely acknowledged. Nevertheless, appropriate legislation and regulation must be put in place.

4.1.6 Successes and Success Factors

For the EMA, the main challenge in the IES – as for other stakeholder such as NEA, Panasonic and the universities – is the creation of a business case for the IES infrastructure. Current legislation permits DR in the commercial sector of the energy market. Nevertheless, this DR scheme is only possible for the reserve market. EMA and EDB are currently leading a consultation process to adapt the Singapore Energy Market to the DR business. Today, generation costs vary between some SGD cents up to 45 SGD on the spot market. Within the relevant boards (EMA, NEA, EBD), there is economic potential amongst large consuming commercial customers to deploy the DR. The finalization of the legislation on the deployment of DR in the industrial/ commercial sector is expected for 2014. In combination with the current review of the 2nd roadmap for building energy efficiency under the BCA's GMS, the increase in energy efficiency of chillers (as part of the air conditioning systems) and – given suitable chiller technology – the participation in DR could be achieved. Currently, no final decisions have been made, but it is important to note that BCA's GMS is widely seen as Singapore's "gem for energy efficiency". The economic benefit resulting from either the GMS or the IES including DR – as well as their combination – is acknowledged by all stakeholders due to the high attractiveness for investors to construct new commercial buildings as a result of economic welfare and growth in Singapore.

4.1.7 Barriers and Challenges of IES in the Residential Sector

The expected benefits of IES within residential applications are primarily hindered through additional costs resulting from the implementation and operation of the AMI structure. Though EMA considers charging all customers for these additional costs, they are still hesitant to proceed with a roll-out of AMI as no added value could be marketed with this technology amongst residential customers. EMA is concerned with serious objection from the residential sector which would imply political consequences.

Panasonics approach towards the HEMS and opt-in for a DR program with air conditioning systems of residential customers is struggling with the same problem, as the business case for Singapore has not yet been established. Panasonic is asking for inquire additional legislation to solve the problem of aggregation and the lack of a market scheme / business model, while EMA and NEA do not see any good arguments for prioritizing DR in the residential sector. They do, however, see a major potential for an increase in energy efficiency and DR in commercial buildings and within industry.

As energy market liberalization has not yet touched the monopoly of Singapore Power as the electricity retailer for residential customers, the only positive aspect of the roll-out of IES for residential users would be better informed decision making (more information to monitor and manage energy usage, better control of major home appliances to reduce energy usage). EMA is currently analyzing the outcome of IES phase 2 in relation to these aspects.

4.1.8 Barriers and Challenges of IES in Renewable Energy Integration

A significant increase of PV deployment is highly doubted by almost all agencies and stakeholders in Singapore. Typical negative impact factors are seen within the limitations on space and the challenges presented by the local climate (quick change of insulation rate). These lead to high frequency solar generation intermittence and therefore pose challenges to competing with costs of "balance energy" (needed to balance the solar generation intermittences with other generation technologies).

Optimistic estimates of the percentage of overall PV deployment in energy supply range from about 10% (EMA) to 15 – 20% (until 2025, SERIS) and thus PV still does not liberate Singapore from their dependency on energy resources from abroad. Currently, the discussion on PV deployment is not directly linked with the IES; positive impact of the IES infrastructure does – due to the limited installation rate of PV – not play any role in current decision making. Energy generation from biomass and combined heat and power (CHP) is currently out of scope for the energy supply system in Singapore due to missing biomass resources.

4.1.9 IES and Sustainability

The contribution of IES to Singapore's sustainability is seen, according to statements made by Singapore stakeholders, as questionable. The m:ci impression is that economic, social and ecological/environmental sustainability would actually be decreased if the AMI would be rolled out at this stage. The following list provides the reasoning behind this opinion for all three pillars of sustainability:

- Social: no added value for marketing among residential customers, concerns with serious objections implying political consequences from the residential sector.
- Economic: the upfront investment costs and operation costs lack a clear source of refinancing in the residential sector. Economic sustainability is expected to be achievable in the commercial sector with DR and in combination with the monitoring mandated by the Energy Conservation Act.
- Ecological/environmental: the AMI infrastructure and the back-end systems increase the energy consumption for the infrastructure without a precise figure on the increase of energy efficiency or energy conservation.

4.1.10 Transferability of the Practise Example

The IES could be considered transferable in its potential to increase the energy efficiency within commercial buildings. The case of Singapore provides a perspective on the linkage of "smartening" the last mile of the electricity grid with the "GMS" as it is under discussion at the moment. As of yet, the combination of both is an official strategy of Singapore only. However, the synergies and positive impact factors – mainly the economic advantages for commercial building owners and facility managers – give the impression that it might be highly promising for other cities with similar building and climate conditions.

4.2 GREEN MARK SCHEME

To improve energy efficiency in buildings and promote environmental sustainability in the building sector, the government of Singapore launched the Green Mark Scheme (GMS) in 2005. This green building rating system was developed and is managed by the BCA, and sets a benchmark with which the energy efficiency and environmental performance of buildings can be evaluated by various members of the private sector such as building owners, developers, building designers and operators.

4.2.1 Development and Objectives

To encourage the private sector to develop sustainably and to expand the adoption of green building technologies, the BCA launched the GMS in 2005, which provides a comprehensive framework for assessing building performance and environmental aspects. In the development phase of the GMS, it was benchmarked from similar green building rating systems used in Germany, Denmark, the USA and the UK and well adapted to suit Singapore's tropical climate. Since most buildings must be air-conditioned throughout the year to ensure comfortable indoor environments in Singapore, energy efficiency of air conditioning system is one of the most important criteria within the GMS.

The GMS was fundamental to Singapore's 1st Green Building Masterplan (launched in 2006), which was comprised of policy instruments and initiatives to achieve sustainably built environments. To establish green buildings, the 1st Green Building Masterplan included several initiatives, examples of which include a S$20 million (€12 million) cash incentive for the private sector (GMS Gold and above), a S$50 million (€30 million) R&D Research Fund for cost-effective green building technologies and energy efficiency solutions, and a training and certification scheme for green building specialists (BCA 2011a).

In the initial phase of establishing the GMS, public sector buildings, new developments and existing buildings undergoing major retrofits had to meet minimum standards of the Green Mark Certified level. However, participation was voluntary for existing buildings in the private sector. Since 2008, all new buildings and all existing buildings undergoing major retrofits with gross floor area above 2,000 m², public and private sector alike, must meet at least the minimum Green Mark standard.

In 2009, the IMCSD set a target to have at least 80% of the buildings in Singapore achieve the minimum Green Mark standard by 2030 (BCA 2010a). To achieve this target, the BCA launched a new roadmap, the 2nd Green Building Masterplan, which set out initiatives for comprehensive sustainable development in the building sector. On the one hand, the 2nd Green Building Masterplan demonstrates strong public sector leadership through upgrading energy performance of public sector buildings with a higher standard of GMS. Independent of the Green Building Masterplan, the HDB has also required all new public housing buildings to be Green Mark certified since 2007. In particular, the HDB plans to develop Punngol, which is one of the largest HDB towns, as an Eco-Town and aims to implement higher Green Mark ratings as well as new green technologies in these new public housing developments (GPA 2012a). On the other hand, the 2nd Green Building Masterplan provides opportunities for the private sector with various economic and non-economic bonuses to encourage developers to achieve Green Mark ratings. The key incentive for the private sector is the S$100 million (€60 million) Green Mark Incentive Scheme for Existing Buildings (GMIS-EB), which encourages building owners and developers to upgrade their existing buildings (BCA 2011a). The government allocated such a substantial sum to the existing building sector because around 55% of Singapore's total electricity is consumed by the building sector (GPA 2012a). According to the BCA, since 2011 the government has launched an additional financing program, Building Retrofit Energy Efficiency Financing (BREEF), which partners with financial institutions to provide capital for the purchase and installation of energy efficient equipment needed to carry out retrofits and upgrading work on commercial buildings.

In addition to the GMIS-EB, developers are encouraged to achieve higher Green Mark ratings with the availability of Green Mark Gross Floor Area Incentive Scheme (GM-GFA; BCA 2011a). The GM-GFA, which was jointly launched by the BCA and URA, awards additional gross floor area to developments which obtain higher-tier Green Mark ratings (Green Mark GoldPlus or Platinum). In a country with such limited land, this kind of incentive gives private building owners and developers a significant advantage in the form of additional gross floor Area in building development. Within the framework of the 2nd Green Building Masterplan, the BCA developed a Zero Energy Building (ZEB) as a platform to test-bed and showcase new technologies and sustainable building designs. The ZEB is an example of how the smart integration of green building technologies and solar PV technologies can meet energy demands in existing buildings. Figure 23 shows the key stages in the development of the GMS.

4.2.2 GMS Applications

The GMS's assessment criteria cover various building categories including new and existing residential and non-residential buildings, office interiors, retail spaces, supermarkets, DC, restaurants, landed houses and existing schools. Furthermore, the BCA launched the GMS to measure the environmental performance of areas beyond buildings, such as districts, public parks and infrastructure, in cooperation with various government agencies such as the National Parks Board (NParks), the LTA and the URA (BCA 2011b). To enhance the environmental sustainability of new development areas, the GMS has also been applied to new development in highly-dense and commercial areas. The government has set the mandated minimum Green Mark Standards for selected strategic areas. Project developments on land sold under Government Land Sales (GLS) sites, such as Marina Bay, Downtown Core, Jurong Lake District, Kallang Riverside and Paya Lebar Central (see Figure 24), will be subject to higher Green Mark Standards, such as Green Mark GoldPlus (Downtown Core, Jurong Lake District, Kallang Riverside, Paya Lebar Central) or Green Mark Platinum rating (Marina Bay) to ensure that these land sales projects are truly green, high quality and distinctive (Sustainable Building Policies on Energy Efficiency) (BCA 2011b).

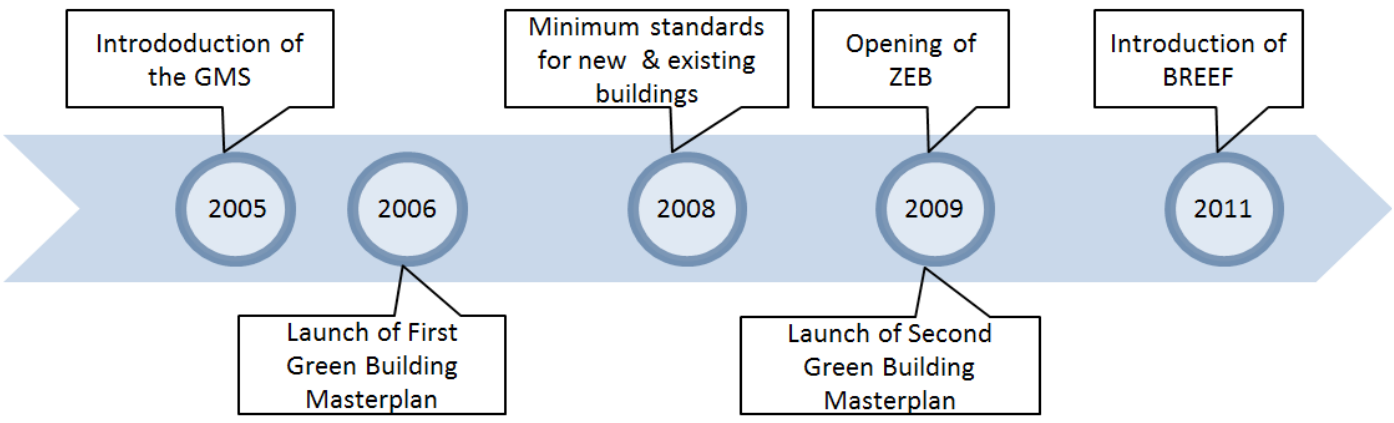

Figure 23: Key stages in the development of the GMS (BCA 2013)

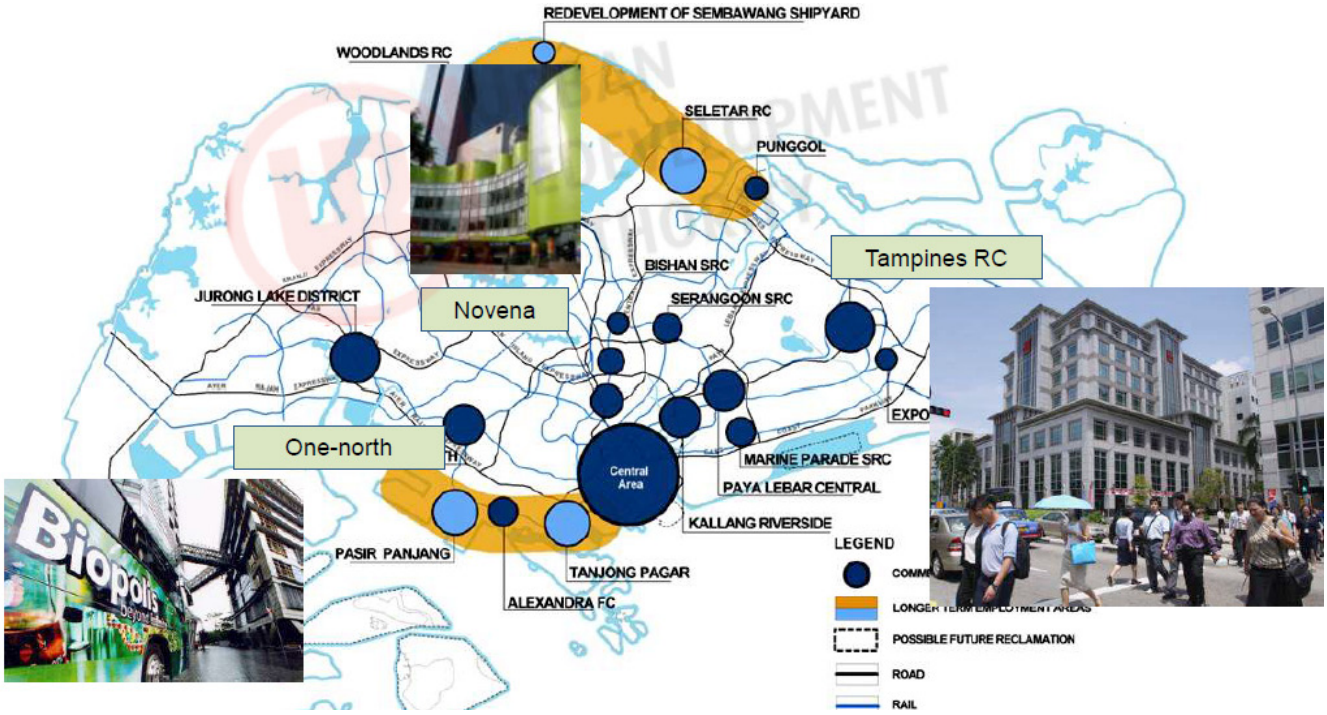

Figure 24: Major commercial nodes in Singapore (URA 2013c)

Type of Use	New / Existing	Criteria																		
		Energy Efficiency	**Water Efficiency**	Environmental Protection	Indoor Environmental Quality	Other Green Features	Sustainable Operation & Management	Community and Well-Being	Sustainable Awareness & Management	Material & Waste Management	Environmental Planning	Green Building & Green Transport	Community & Innovation	Greenery & Urban Ecology	Park Development & Construction Mgt	Ease of Maintenance & Accessibility	Conservation & Heritage	Renewable Energy	Landscape, ecology & land efficiency	Project Management	Innovation
Non-residential buildings	New	•	•	•	•	•															
	Existing	•	•		•	•	•														
Residential Buildings	New	•	•	•	•	•															
	Existing	•	•				•	•													
Data Centres	New	•	•	•	•	•															
	Existing	•	•		•	•	•														
Existing Schools	Existing	•	•		•				•												
Office Interior		•	•			•	•														
Retails		•	•		•	•			•												
Supermarkets		•	•	•	•	•															
Restaurants		•	•		•	•	•														
Landed Houses		•	•	•	•	•															
Districts		•	•							•	•	•	•								
Public Parks	New	•	•			•				•				•	•	•					
	Existing	•	•			•				•							•				
Infrastructure		•	•							•								•	•	•	•

Figure 25: Criteria for GMS Certification with different types of use (BCA 2013c)

Within the GMS, buildings are assessed for energy related requirements (energy efficiency) and other green requirements (water efficiency, indoor environmental quality, environmental protection and the adoption of other green features). Thereby, energy efficiency and water efficiency are the central pillars for the GMS assessment. This is mainly due to the lack of energy and water resources in Singapore. As such, every type of GMS assessment includes both criteria, even within the assessment of districts, infrastructures and public parks. Figure 25 shows the different criteria of the GMS.

However, the application process for each type of land use is unique to the peculiarities of developmental needs (see figure 26). The buildings are awarded GMS ratings based on an overall assessment of multiple criteria categories evaluated with a point system. Each GMS rating correspondents to the different levels of energy efficiency improvement, as based on the building performance of Singapore's standard building code. The additional construction cost for green buildings can be recovered through energy saving with a payback period of between 3 to 6.5 years. Figure 26 shows GMS award types, a range of green cost premiums, expected energy savings and the payback periods for commercial buildings.

GMS rating	Green Cost Premium	Expected energy saving	Payback period
Platinum	3 – 5 %	More than 30 %	2.5 – 6.5 years
Goldplus	2 – 4.5 %	26 – 30 %	2 – 4 years
Gold	1 – 3 %	16 – 25 %	1 – 4 years
Certified	0 – 2 %	10 – 15 %	0 – 3 years

Figure 26: GMS award types, the range of green cost premiums, expected energy savings and payback periods for commercial buildings (Tsai 2013)

In addition, to ensure the performance of Green Mark certified buildings, the BCA will require that by the end of 2013 building owners and developers conduct energy audits every three years to maintain their Green Mark status, especially on the cooling systems of new and existing buildings. Furthermore, building owners will now also be required to submit building information and energy consumption data, which will be used to monitor the energy efficiency of buildings and formulate the national energy benchmark. The benchmarking data will be made available publicly so that building owners can pro-actively improve their building's energy performance (Tsai 2013).

4.2.3 Financing Green Buildings and Stakeholders

Singapore's robust investments into greening the building stock has created benefits beyond decreasing the nation's energy consumption; developers, designers and architects, consultants, technicians and installers, manufacturers, research agencies, retailers, and the real estate market have all been stimulated during the past decade as the government continuously rolls out green building incentives. The modest 2% to 5% increase in construction premium for a Green Mark rated building is a desirable investment for building operators as the payback periods have proven to be rapid, 3-6.5 years, from energy and water savings (Tsai 2013). To further encourage the adoption of the GMS, the BCA has made robust cash incentives available, such as the Green Mark Incentive Scheme for New Buildings (GMIS-NB) and the Green Mark Incentive Scheme for Existing Buildings (GMIS-EB) to help developers and building owners afford the initial costs of purchasing, installing and monitoring more efficient technologies. The GMIS-EB and GMIS-NB contributed to a rapid increase of GMS implementation. Since 2011, the government provides credit services through the Building Retrofit Energy Efficiency Financing (BREEF) which assists building owners with upfront costs for energy efficiency retrofits of commercial buildings.

4.2.4 Impact and Context Factors

Besides Singapore's environmental conditions, government regulation as well as financial and non-financial incentives play pivotal roles in establishing the GMS in the building sector. The GMS helps shape market parameters for sustainable features in the building sector, while financial and non-financial incentives can encourage the private sector and reduce the costs of greening commercial properties. In addition, the following impact factors make green real estate investment in the building sector more viable:

- Tropical climate: due to Singapore's tropical climate, air-conditioning is one of the biggest contributors to energy usage in buildings. Air conditioning alone makes up about 40% of a building's electricity consumption (BCA 2010c).
- Very limited renewable energy resources: Singapore imports all of its fuel resources, resulting in very high electricity costs, making savings from energy efficiency highly valuable.
- Strong regulation of building sector by government: green buildings in both the public and private sectors owe much to the governments implementation of a strong regulatory framework for the GMS.
- Economic incentive schemes: decades ago the government of Singapore already placed heavy emphasis on environmental protection and climate mitigation, enabling the government to delegate substantial funds to support the implementation of efficiency retrofits thoughout the city.
- Non-economic incentive schemes: Singapore uses non-economic incentives, such as GM-GFA, by allotting additional development area to provide further incentives for developers to build green buildings. This type of scheme can easily be replicated in almost any city.

4.2.5 Successes and Success Factors

Since the introduction of the GMS, Singapore is making steady progress on its target to ensure 80% of the total building stock is Green Mark rated. Now, at the end of March 2013, there are more than 1,500 Green Mark building projects in Singapore (BCA 2013a). This amounts to more than 17% of Singapore's total building stock. The increase of green buildings has already made a contribution to reducing domestic electricity and water consumption in Singapore. For example, Singapore's daily per capita water consumption decreased almost 9% between 1995 and 2007 (UNESCAP 2012).

Another way to measure the success of the GMS is to look at the rate of implementation of financial incentive schemes. Under the GMIS-EB and GMIS-NB, the building owners and developers are encouraged to achieve improvements in energy efficiency in the building sector. According to the BCA, there was an overwhelming response from builders and the S$100 million (€60 million) GMIS-EB and S$20 million (€12 million) GMIS-NB funds were fully committed more rapidly than expected (BCA 2013b).

Furthermore, the GMS has been internationally recognized as a successful green building rating system, especially in countries with tropical climates. After the launch of the GMS, more than 120 international projects have applied for the GMS overseas in countries like China, Malaysia, Vietnam, Brunei, India, Thailand, Middle East and Indonesia (BCA 2011b).

4.2.6 Barriers and Challenges

Achieving the goal of having 80% of buildings be certified green by 2030 will mostly depend on whether the Singapore government succeeds in convincing owners of existing buildings to retrofit. Interviews with experts indicate that refurbishment of existing small and medium-sized commercial and private residential buildings (GFA smaller than 2,000 m²) will be one of the key challenges, due to the need for coordination with many different renters and owners of existing buildings, and a lack of financial incentives. For example, renters pay the electricity bill and as such will receive all of the financial benefits of efficiency retrofits. In this case, building owners do not have any incentive to upgrade building equipment to be more energy efficient.

Financial barriers put another hurdle in the realization of energy efficiency in the building sector. Many developers and building owners face huge financial barriers in the initial investment required when improving the energy efficiency of buildings and thus many developers and building owners often choose the short term benefit of not spending that money over the long-term benefit of lowering their operation costs. The key barrier is lack of sufficient knowledge about green buildings. To overcome this barrier, the building owners should be informed about the following benefits: lower maintenance and operating costs, higher occupancy and an increased asset value on the real estate market.

In addition, encouraging the use of energy efficient air conditioners and reducing reliance on air-conditioning are the key challenges in the residential building sector. Due to Singapore's hot and humid climate, air conditioning is widely used in residential buildings. In spite of the HDB's efforts to implement natural ventilation in new public housing developments, interviews with experts indicate that the use of split air-conditioners in existing privately owned residential buildings is continuously increasing. According to the EMA, households residing in private housing developments consumed more than twice the average monthly energy consumption compared to households in public housing developments, since all private housing projects in Singapore have air conditioning (Deng et al. 2010).

4.2.7 Transferability of the GMS

The GMS was developed especially for buildings in the tropics and the Singapore Government successfully established a rating scheme for sustainable buildings within the short span of just 8 years. This contributes to the popularity of the GMS in regions with similar climatic conditions, where green building rating systems are not yet as well-established. The transferability of Singapore's green building rating system has been demonstrated within numerous projects in several countries within the region. Furthermore, the BCA and the United Nations Environment Programme (UNEP) have joined forces in a coordinated effort to elevate sustainable solutions in the building sector since 2011. However, the success of the rapid implementation of the GMS in Singapore is mainly based on the specific framework conditions present in Singapore: the government's robust incentive schemes for the private sector, the policy framework and the technological know-how. Other countries desiring to implement similar building rating systems will need to be able to offer financial, legislative and technological assistance to building owners and developers in both the public and private sectors.

4.3 WATER AND LOW ENERGY SEAWATER DESALINATION

When the Jurong Industrial Estate was developed in the early 1960s, as a satellite town on the south-west coast, questions arose about how to satisfy the water requirements of industry. Consultants determined that treated effluent from one of the wastewater treatment plants could be further treated to meet the industry's non-potable water demands. The first trials with water recycling resulted in the

construction of the Jurong Industrial Waterworks in 1966 as a source of inexpensive lower-quality water for certain industrial sectors. The treatment process consists of coagulation, flocculation, clarification, sand filtration and aeration (Tortajada et al. 2013)

However, since the aim was to produce water which is good enough to drink, an advanced pilot water reclamation plant was set up in 1974 by the Sewerage United Nations Environment Programme (ENV). In order to produce water of a quality which complies with drinking standards, reverse osmosis and other advanced treatment processes including ion exchange, electro-dialysis and ammonia stripping were used. In the end, even the WHO guidelines for drinking water were met, however, the membranes were too expensive and required frequent cleaning, and thus the process was economically not viable (Tortajada et al. 2013)

After discontinuing the water recycling plant in 1976, another exploration into unconventional water sources began in the mid-1990s. Engineering and feasibility studies on desalination were carried out, which were completed in 1998. However, at the same time, rainwater catchment and waste water treatment were being promoted as well. A joint feasibility study by PUB and ENV included the construction of a demonstration plant using advanced membrane technology with reverse osmosis (PUB 1998). In the following section the most recent developments and the current state of seawater desalination and wastewater purification (NEWater) are described in more detail.

4.3.1 Seawater Desalination

The idea was for the private sector to build the desalination plant, from which the PUB would purchase the water. Among the range of available desalination processes to choose from, reverse osmosis also became an option after advancements in membrane technology. Currently, it is the cheapest way of extracting water from the sea. Previously, the main technology used was distillation, which requires high energy inputs to produce heat or pressure with which to evaporate water which then condenses on a cooler surface (Tortajada et al. 2013). In contrast, the SingSpring Desalination Plant in Tuas, opened in 2005, relies on reverse osmosis. It is the PUB's first public-private partnership (PPP) project. Seawater goes through a pre-treatment process where suspended particles are removed. In the second stage, the water undergoes reverse osmosis (RO), which is also used to produce NEWater (see figure 29). The very pure water is then re-mineralised in a third stage and finally blended with treated water before it is supplied to homes and industries in the western part of Singapore. This plant is able to produce 30 million gallons of water a day (136, 000 cubic meters) and is one of the region's largest seawater desalination plants using reverse-osmosis (PUB 2013b).

The Tuaspring Desalination Plant, which has just been opened, adds another 318,500 cubic metres of desalinated water per day to Singapore's water supply, so that desalinated water is now able to meet up to 25% of the current water demand (PUB 2013b). The first-year price for the desalinated water is $0.45 per cubic metre (PUB 2011b). However, even using the best available seawater desalination technology, the process requires between 3.4 and 4.8 kWh/ m3 (PUB 2011a) (for comparison: the processing of potable water from conventional sources uses approximately 1 kwh/m3 (Rosenwinkel; Hinken 2006)). However, with steadily growing energy prices, this will be quite expensive for PUB, and thus massive R&D efforts are in place to reduce the input of energy and chemicals and the output of waste. By means of a low-energy desalination system the energy required should be reducible by 50% within a short period of around five years (see figure 27). The technology behind this has already been demonstrated as viable since 2008, when Siemens was granted a contract to build a demonstration unit in the west of the island that aims to desalinate seawater using just 1.5 kWh/ m3. As stated in an interview with PUB on May 9, 2013, the numbers produced by the pilot plant are considered validated and verified at the moment (PUB 2013e).

In the long term, a period of around 20 years, it is even hoped to reduce the energy requirements by another 50%, by achieving a breakthrough in bio mimicry technology (e.g. mimicking the biochemical processes within a mangrove plant (see figure 27). Currently, PUB is attempting to understand the mechanism used by the plant to take up saltwater from the sea and change it into fresh water. For this process, the plant seems to need very little energy and thus of where the energy comes from needs to be solved. Another approach is to imitate the natural osmotic pressure used by the human kidney to clean the blood. By identifying and mimicking the aquaporin protein in the kidney,

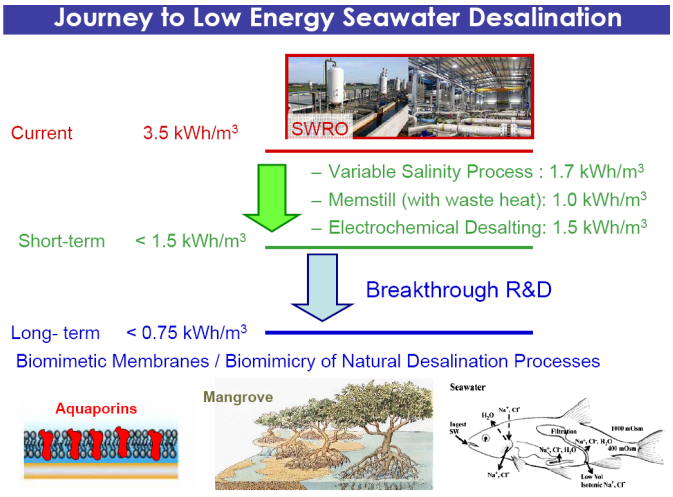

Figure 27: From conventional to low energy seawater desalination (Puah 2011)

the process of channelling water while holding back salt may be possible. Therefore, researchers are attempting to manufacture a synthetic protein, which can be placed as a coating on the membrane. This process requires a pressure of only 6 bar, which is 10 times less than the pressure which is currently required for the seawater to pass through the membrane (PUB 2013e).

4.3.2 NEWater

Similar to seawater desalination, the recycling of water has also been developed further in an effort to achieve water self-sufficiency for the island. In contrast to 1974, high-grade reclaimed water can now be produced from used water effluent "through a multi-barrier treatment process that comprises conventional used water treatment, micro/ ultrafiltration, reverse osmosis and, finally, ultraviolet disinfection" (Tortajada et al. 2013). This three-stage process has become possible thanks to advanced membrane technologies and ensures that all organisms are deactivated (PUB 2013c). The energy required to produce NEWater is 0.7 kWh, which is around 5 times lower than the current conventional process of seawater desalination (PUB 2013e).

Based on this, a demonstration plant was constructed at Bedok in 2000, and after two years the recycled water was found to be safe for drinking. In order to "tap" recycled water, the approach was to build new plants and, importantly, a communication plan was initiated. To confront the usually negative feeling towards recycled water, the water was named 'NEWater'. To replace the image of 'waste', waste water was renamed 'used water', which is treated in 'water reclamation plants'. The overall aim was to look at water as a renewable resource with unlimited usage.

As is the case in the desalination of water, the private sector is also actively involved in NEWater. Whereas the first three plants (Bedok, Kranji and Seletar) are owned and operated by the PUB, the Ulu Pandan plant and the Changji plant were designed, built, owned and operated by a private partner (DBOO-model). The goal was to achieve a higher level of efficiency and innovation in the water sector, while simultaneously providing a certain level of quality and cost-effective prices (Tan et al. 2009). The four plants are able to meet 30% of Singapore´s water needs.

The PUB was looking for ways to make the best use of this very thoroughly cleaned (almost distilled) water. Since it is clearer and cleaner than standard PUB water, it is used in wafer fabrication, electronics and power generation. By doing so, processes normally necessary to reduce organic substances can be omitted.

However, in order to prove the security and quality of the water for the general public it is an important part of PUB's strategy to use a minor portion (around 10%) of NEWater as potable water. In order to use the water directly for drinking purposes it would be necessary to remineralise it. Therefore, it is piped into the reservoirs for subsequent re-treatment at various waterworks for drinking purposes in indirect potable use (IPU) (Tortajada et al. 2013).

Figure 28: Bottled NEWater – with mascot Water Wally (Cookies with cream 2010)

4.3.1 Successes and Challenges

Both best practices finally turned out to be successful, but could not have been realised without overcoming some initial challenges. Beyond tackling the technological challenges and the R&D activities over several decades, it has taken some time and a huge effort to persuade the semiconductor and electronics industry, which is very conservative in terms of its water. The PUB argued that only one more ion exchange step is necessary for the NEWater to become outer pure, instead of additionally engaging in microfiltration and reverse osmosis, as is required for drinking water. Moreover, PUB installed Total Organic Carbon online meters in the industry's premises to allow the companies to monitor the quality of the water themselves. Finally, the companies were convinced to buy NEWater and now it has become a positive criterion for companies in these sectors when choosing where to settle (PUB 2013e).

Along with industry, the general public also needs to be well-informed and convinced that this water is safe to drink. "We need to maintain public awareness, although we do not use the water directly for drinking purposes at the moment" (PUB 2013e). This is the reason PUB continues to us it as IPU and for filling into bottles for social events and other promotional activities. This is accompanied by advertisement, posters and leaflets as well as briefings and exhibitions in order to spread the NEWater message.

A very important part of the public awareness strategy is the involvement of schools. Every primary school aged child is thoroughly informed about this water by way of a field trip to the NEWater Visitor Centre, which is designed as a game house and shows the animated processes. As a result, every taxi driver in Singapore is able to inform you about the background of NEWater (PUB 2013e).

This also raises awareness about the need to save water. The ongoing public relations efforts contribute to avoiding massive investments in network infrastructure resulting from the increase in demand due to the growth of the population (PUB 2013e).

These efforts are supported by technological measures: The Smart Water Grid has been tested within the "WaterWise@SG" project, involving PUB and MIT (WaterWise 2011). The aim is to gather information on the entire network in order to adjust the energy to what is really needed for each part of the network to provide the necessary pressure. Now, the system is being tested with 25 sensors located within the CBD. A tender for implementing 100 sensors across the whole island, as the next phase of the projects, has just been called (PUB 2013e).

An ongoing challenge and a driver for extensive R&D activities, is the energy demand, especially for the desalination process. In terms of the treatment of used water, the cleaning and recycling of industrial waste has not yet been successfully solved – the current technology is more focused on domestic waste water (PUB 2013e). Another challenge is the increasing demand for water, especially for industrial processes, which requires huge investments in infrastructure, including the construction of new plants.

The success factors are mainly twofold. On the one hand, Singapore has well-established and institutionalized cooperation amongst government ministries and agencies, including PUB, HDB and NEA. As a public agency and Statutory Board, the PUB's mission is to look after the water supply for Singapore (PUB 2013e).

On the other hand, the involvement of the private sector has been successful. This also helps to integrate water and wastewater management, envisaging the entire water loop. Therefore, a high degree of sustainability can be stated for this practice. The approach is regarded as transferable to regions with similar geographical conditions as Singapore, such as coastal regions with scarce water resources.

4.4 ABC WATERS PROGRAMME

Due to its climatic conditions, Singapore Island actually does receive enough water (2.40 m of precipitation per year), however, the problem is the scarcity of land to store it on (PUB 2013e). Consequently, when desalination was investigated in the mid-1990s, the increase of local sources, by developing suitable marginal catchments, was also investigated. This included tapping storm runoff from new housing estates and the collection and treatment of rainwater (Tortajada et al. 2013). Beyond achieving an adequate and affordable water supply, Singapore's authorities regard public buy-in and highlighting the value of water resources as equally important. People, public and private (3P) are encouraged to take joint ownership of Singapore's water resource management.

4.4.1 Active, Beautiful and Clean

The aim of the "Active, Beautiful and Clean (ABC) Water" Programme is to create beautiful and clean streams, rivers and lakes, creating a vibrant 'City of Gardens and Water'. The concept is to transform local open water bodies into vegetated bioretention swales and rain gardens, and to implement local catchment areas. Two-thirds of Singapore's land space functions as various local catchment areas, collecting and storing rainwater in 17 reservoirs, 32 major rivers and more than 7,000 km of canals and drains for water supply (PUB 2013g).

ABC is based on water sensitive urban design and was launched in 2006, when development agencies such as HDB, NPB and JTC started to incorporate the water bodies within the housing estate. They aimed to keep these bodies of water natural instead of constructing a new concrete shaped canal. The underlying driver behind this was the aim of opening up the catchment areas for public use (PUB 2013e). The program started with three demonstration projects at Kolam Ayer, Bedok Reservoir and MacRitchie Reservoir. Later on, consultants developed master plans for water bodies, divided into the three sub-catchments. Thus far, around 100 potential projects have been identified with which to enhance the aesthetic look of the water bodies and waterways while also cleaning and improving the quality of the water (PUB 2013e).

Singapore has relied on tropical rainfall to fill impounded reservoirs for water supply. However, this supply only met about 50% of the Singapore's water demand (Funamizu et al. n. y.). There are separate collection system for stormwater and used water. Stormwater is collected through a comprehensive network of drains, canals, rivers, stormwater collection ponds and reservoirs before it is treated to drinking water quality. This makes Singapore one of the few countries in the world to harvest urban stormwater on a large-scale for its water supply. Local catchment water is a pillar of Singapore's sustainable water supply. In order to increase the storage capacity, the water catchment was increased from half to two-thirds of Singapore's land surface with the completion of the Marina, Punggol and Serangoon Reservoir in 2011 (PUB 2013f).

With all the major estuaries already dammed to create reservoirs, the PUB aims to harness water from the remaining streams and rivulets near the shoreline using technology that can treat water of varying salinity. This will boost Singapore's water catchment area to 90% of the total land area by 2060 (PUB 2012b).

An important element of the ABC Water programme is the

protection of water catchments. This has clearly been promoted, as can be seen by increase in awareness of the importance of clean and reliable water supplies and the need for diversification of sources by politicians and the public. The slogan for this awareness campaign is "every drop treated on site". The PUB strongly seeks cooperation with other agencies, such as the HDB, to find ways to slow down and clean the water flows before they reach their drainage areas. This is done by way of vertical gardens, roof gardens, bio detention fields, and detention tanks. An example is a primary school site, which is being currently retrofitted. Often the top of the roof is turned into a roof-top garden in order to reduce the peak and cleansing of stormwater runoff (PUB 2013e).

4.4.2 Successes and Challenges

One of the pre-conditions for the program was the prior clean-up of the major rivers and canals, which took place in the 1980s. As part of catchment management, this removed the major sources of pollution such as farm waste, sewage, illegal disposal of waste water from street hawkers, vegetable wholesalers and industries. Pollution control measures, and a policy of phasing out undesirable activities such as animal farming, are still important elements of catchment management.

In the beginning, however, a new understanding of the catchment areas as recreation areas was a challenge for the PUB, which used to prohibit all access to the reservoirs. According to Pub, "only the cooperation with the other agencies made it happen, PUB alone would have not been able to do it"(PUB 2013e).

One prime example for successfully re-naturalising a canal and opening- up the waterway to inhabitants is Bishan Park.

Before re-design, the Kallang river divided the people living in a housing estate from the park. All concrete portions of the drain were removed and replaced with green slopes. Now, the water is very low and you can cross it by help of stepping stones (see figure 30). Therefore, the park area doubles during dry days, because the new area merges with the landscape of the park. However, in case of heavy rain the designed flood plain gets filled with water and the whole area becomes a catchment for stormwater. People are warned by visual and audible alarm as well as by park rangers. This project was only successful because of a fit of the PUB and NPB's timelines, as both wanted to do something with the waterway as well as with the park. However, no other areas in Singapore would be suited to repeating this approach, because the location must have enough space available to widen the canal and thus design it as a flood plain (PUB 2013e).

Figure 29: Bishan Park (Tan 2012)

However, other than in Bishan, getting inhabitants involved in terms of "owning" their waterways in order to keep them clean and thus attractive for other people has been a major challenge. In fact, a willingness-to-pay survey has shown that most people regard these activities as the responsibility of the government (PUB 2013e).

One of PUB's long term objectives is to show people how enjoyable water can be (water activities, common space, playground). That a lack of awareness of the value of waterways is often a problem can be seen by the existence of the Waterways Watch Society (WWS). The society was founded as a volunteer group because of the growing problem of littering in the waterways. The WWS's main activities include both education about the waterways and actually cleaning inside and along the waterways and water bodies. According to the chairman, who founded the Society in the 1980s, the problem of littering and illegal disposal of waste is still an issue, in spite of WWS's and PUB's activities (WWS 2013).

The PUB's approach to tackling this problem is to:

- Conceptualise masterplans for all water bodies,
- Cooperate with professional institutions (e.g. landscape architects, engineers) by providing ABC Design features, and
- Partner with the general public

An important success factor for ABC Waters is the high level of interagency collaboration in Singapore, which is easier in a country with only one tier of government. However, more external stakeholders (such as the town councils) need to take responsibility for the green areas. The PUB acknowledges that implementation is just one piece of the puzzle: in order for waterway efforts to be sustainable, the maintenance of these must also be financed and shared with the public.

4.5 ELECTRONIC ROAD PRICING (ERP)

In the field of transportation, road pricing – or congestion pricing – has long been associated with Singapore. Singapore was the first city in the world to implement an electronic road toll collection system for purposes of congestion pricing. It is an important component of Singapore's overall transportation strategy, intending to optimise road usage in terms of maximisation of traffic flows and internalising the external costs of driving. The system currently installed, called ERP I, is a point-based pricing system based on Dedicated Short Range Communication. Singapore plans to implement distance based congestion charging using global navigation satellite system GNSS technology within the next years (ERP II).

4.5.1 Development and Objectives

The forerunner of today's ERP system was an Area Licensing Scheme (ALS), a manual scheme based on paper permits. Due to the growth in the number of cars, and therefore an increase in congestion especially in the CBD of Singapore, the government began thinking about feasible traffic control instruments. In 1973, a high level inter-ministerial committee, set up to recommend measures to improve the transport situation, formulated and designed ALS. After a one-year period of public dialog, the system was finally implemented in 1975 and stayed in place until being replaced by its electronic equivalent – ERP I – in 1998. The government established a restricted zone RZ around the CBD with check points on congested roads. Car drivers could buy daily (for the price of 3 SGD, increased to 5 SGD in 1980, then reduced again to 3 SGD) or monthly paper licenses and had to display them in their front windows when passing a check point.

Looking back with today's technology point of view, the characteristics of ALS now seem almost adventurous. Around 60 enforcement personnel were required at the check points and another 60 officers at the dedicated licence sales points. ALS operated for 2¾ hours each weekday during the morning peak (supplemented by a 2.5 hours operation time in the evening due to an increase in the number of cars in 1989). The personnel next to the gantries, mostly women, were responsible for checking the paper licenses (16 types, different coloured) of passing cars with their naked eyes and marking the licence plate of the vehicle if the license displayed was missing or insufficient. The initial exclusion of taxis, goods vehicles, public busses and cars with more than 3 people from the ALS led to positive (increased car-pooling, dedicated car-pooling points in front of the RZ were installed) as well as contra productive results (more and more goods vehicles were used for private drives and people started to using their private cars to pick up passengers from bus stations before entering the RZ).

Nevertheless, ALS turned out to be an effective measure. It produced a drop in traffic entering the RZ of 44% mainly because (1) drivers who had been using the RZ as a tho-

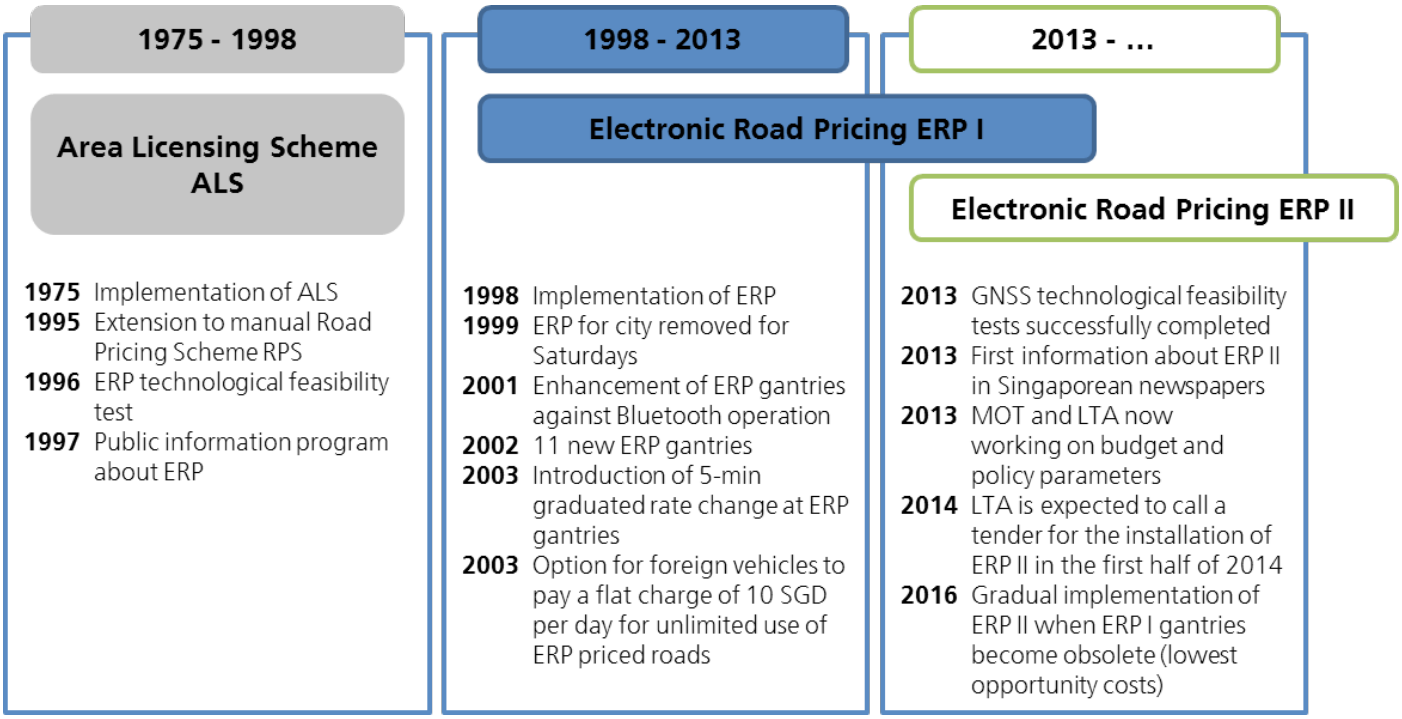

Figure 30: Development steps of Singapore's ERP System (depiciton: m:ci)

roughfare to another destination changed their routes and (2) people started to shift their drives before and after the ALS operating times. It is worth mentioning that no remarkable switches to public transportation were observed.

After the ALS's effectiveness had been proven and a strong learning curve and the development of new technologies in the early 1900s had taken place, the government decided to test Dedicated Short-Range Communication systems on their feasibility for an electronic pricing system (ERP). Together with an industry consortium (the winners of an open tender) consisting of Philips Singapore Pte Ltd, Mitsubishi Heavy Industries Ltd, Miyoshi Electronic Corporation as well as CEI Systems and Engineering, a test-bed on an unopened stretch of expressway was established. During December 1996 and August 1997, 12 ERP gantries were established and a fleet of 240 vehicles passed these and made around 4.8 million transactions. In 1997, a public information program about the oncoming technology migration was set up and 680,000 vehicles were equipped with in-vehicle units (IU) and cash cards. The installation of IU was non-mandatory. Rather, it was free (instead of 150 SGD) for an initial period of 10 months. Also, part of the information program was the possibility of already using the installed, so not yet charging, ERP system in Singapore for a couple of months. Finally, in 1998, the ERP system was implemented by the LTA, replacing the former ALS.

Figure 31: ERP gantries in Singapore in 2013 (LTA 2013b)

Today, Singapore plans to gradually replace the current ERP with a GNSS-based congestion pricing system within the next years. Since technological feasibility tests on GNSS were completed with positive results, concrete political and financial frameworks for the implementation of the system are currently being set up. LTA is expected to call a tender for the installation of ERP II in the first half of 2014 (Tan 2013).

4.5.2 Approach and Measures Within ERP I

Based on Dedicated Short Range Communication, the ERP I system – which is currently in place – consists of three major components which are displayed in figure 32.

With 80 gantries installed, charges are levied on a per-pass basis. The charge depends on both the location and time, with peak hours planned to be the most expensive. Offenders are not stopped directly, but rather fined via the mail within the following two weeks. Failures to pay the penalty can result in the offender being called up to appear in court.

In 2003, a research team from the local Nanyang Techno-

Gantries	In-Vehicle Unit IU + Cash Card	Control Centre
• 80 gantries located at all roads linking into Singapore's CBD • Located along the expressways and arterial roads with heavy traffic • Integrated sensors and cameras • Sensors communicate with IU via DSRC system • Data collected is transmitted to a Control Centre via telephone lines	• IU produced specifically for the ERP system • Cash cards were marketed by a consortium of local banks for multiple uses • After an audio signal deducted amount is displayed to the driver on an LCD screen of the IU • Cash card has to be reloaded (user will be alerted should balance fall below a predefined amount)	• Contains servers, does monitoring • Contains master-clock to start/stop operation hours at all gantries • Processes financial transactions send to the banks • Processes violation images and sends letters to offenders

Figure 32: Components of the ERP I (depiction: m:ci)

logical University developed speed-flow curves as a calculation basis for price determination in ERP. On CBD roads, optimal threshold speeds between 20 km/h and 30 km/h and on expressways between 45 km/h and 65 km/h were determined. When traffic speeds get close to one of the defined thresholds, road pricing charges are set up or downwards as needed every 3 months. In December 2007, a 5 months pilot program between LTA and a global IBM team with resources from Singapore, the UK and the USA took place, testing an IBM developed traffic prediction tool with the intention of more appropriate price adjustments. Based on the test bed in 1998, Singapore gradually implemented an 85th percentile speed management method aiming to ensure that 85% of drivers are able to move at speeds within the thresholds.

4.5.3 Financing the Project

Table 8 shows the financial background back in 1998 when the ERP I system was first established.

Table 8: Financial facts of the ERP I setup in 1998

Capital costs (up to 60 gantries and 1 Mio. IUs)	197.000.000 SGD
Annual operating costs	8.000.000 SGD
Annual maintenance costs	8.000.000 SGD
Annual revenues	100.000.000 SGD

Source: Numbers provided by interview partner

Costs of each ERP gantry, as well as costs of managing and maintaining the ERP system, have increased over the years (gantries now cost 50% more than in 1998). The system costs are consistent with the increase in the number of gantries and IU numbers, but remain at 20–30% of the total revenue collected. Singapore´s MOT emphasises that ERP is not meant to be a revenue-generating measure, but rather an effective tool for traffic management. The revenues of the current ERP system are not invested directly into the improvement of public transport. In Singapore, revenues flow back to the Ministry of Finance to be allocated in turn to other departments and to cross-finance other sectors with financial deficits or need for investment.

4.5.4 Actors

In 1973, Prime Minister Lee Kuan Yew himself instructed a team of transport experts in Singapore to develop a proposal for traffic management within 3 months. On the basis of the "Smeed Report" (a study about alternative methods of charging for road use, commissioned by the UK government between 1962 and 1964, led by R. J. Smeed), the team developed a proposal for congestion pricing in Singapore – which later became the ALS. The proposal convinced Lee Kuan Yew and under his strong endorsement ALS was implemented in 1975. Today, strategic decisions on the ERP system are made by the MOT. It is operated by the LTA and scientifically supported mainly by the LTA Academy. Four consortia (Kapsch TrafficCom; MHI Engine System Asia & NCS; ST Electronics (Info-Comm Systems) & IBM Singapore; Watchdata Technologies & Beijing Watchdata System) received 1 million SGD each to develop GNSS-based solutions and submitted proposals after testing various technological solutions between June 2011 and December 2012.

4.5.5 Barriers and Challenges

An increase in the demand for road use, but also the variety of lessons learned from 38 years of congestion pricing, began showing the limits of the current ERP I system. These limits provided the basis for beginning reflection on the implementation of a new GNSS-based road pricing scheme (ERP II). Since Singapore´s political system enables fast decision making and realisation, barriers exist mainly in terms of technological feasibility and public education, as follows:

- Static system: charges are levied on a per-pass basis, distance-based congestion charging is not possible with ERP I.
- Visual intrusion: gantries as part of Singapore´s roadside infrastructure have an impact in terms of space and visual intrusion.
- Not flexible: in terms of having physical gantries, the re-location of these points is difficult.
- Shift: effect of gantries to simply move the traffic somewhere else and potentially cause traffic bottlenecks along smaller roads, leading to localised congestion.
- "Chasing after jam effect": consequence of the "Shift"aspect which requires the setup of more and more gantries.
- Rising prices: due to an increase in the number of vehicles in Singapore, prices for ERP I charges tend to increase over time.
- Finding the right price: appropriate price setting and adjustment at gantries according to real congestion conditions on roads is technically challenging.
- Loss of "rights": the subjective rights of the citizens to use the road system without charge.
- Health: in the early days of ERP I, radiation from the system was a public concern. This was soon allayed, however.
- Exceptions: exceptions of specific vehicles led to circumvention of regulations, today only ambulance and police cars are excluded from ERP I.
- Privacy: now, authorities assure users that vehicles aren´t tracked and records of transactions are erased within 24 hours; with the implementation of satellite-based ERP II vehicle data will be systematically collected and processed.
- Behavioural testing: transition from a point based (ERP

I) to a satellite based system (ERP II) will produce changes in driving behaviour as motorists can be charged based on the distances they drive (pay-as-you-use); research on changing driving patterns as well as the behavioural influence of, for example, different payment models must yet be done.
- Transition management to ERP II: on the basis of behavioural research adequate policies, information, billing and incentive schemes will be developed

4.5.6 Successes and Success Criteria

The current ERP I system has served Singapore well. Compared to the ALS in 2002, traffic volumes into the CBD had been reduced by about 10-15% during the ERP I hours of operation. Furthermore, hours of peak vehicular traffic gradually eased and spread into off-peak hours. Today ERP I allows a relatively fine graduation in rates that are reasonably commensurate with the prevailing traffic conditions. Despite a growth in the number of cars, ERP I has successfully managed to keep congestion in Singapore low. The average road speeds for expressways and major roads remained the same, despite increasing traffic volumes over the years. The introduction of ERP I particularly influenced the behaviour of those who used to make multiple trips into the CBD. In contrast to ALS, ERP I provoked a switch to public transport. The implementation of ERP II will provide the basis for advanced solutions in fields such as real-time information services, road management, maintenance and traffic planning.

4.5.7 Transferability

Charging for the use of roads in congested cities is based on a solid theoretical foundation and well-developed techniques. Its implementation, however, is not yet widespread due to political resistance (e.g. from automotive interests) on a local as well as global level. New York City's Mayor Michael Bloomberg intended to follow Singapore´s example, but failed in 2008 in the New York State Assembly. The strong opposition viewed especially the congestion fees as (1) a regressive measure that only benefited inhabitants of Manhattan (2) a tax on their ability to move around their own city. As a consequence, $354 million reserved by the federal government for financing the system was distributed to other cities. Similar plans in Hong Kong failed in 1985 due to public opposition and in 2001 after a HK$90 million feasibility study couldn't find enough potential for adapting electronic road pricing in Hong Kong.

In recent years Oslo, London and Stockholm have successfully introduced congestion pricing for motorists. Lessons learned show that congestion pricing requires the following: (1) Strong alternatives. To enable a shift in modal split, an efficient and well-established public transport system must be in place. ERP revenues can then be used to finance public transport expansion and other transport improvements. Furthermore it is helpful if a city can provide a choice of roads to motorists or ring roads where people can pass instead of entering the pricing zone. (2) Congestion pricing must be integrated in an overall transport strategy, together with land use, transportation and road planning. (3) Congestion pricing needs strong champions in politics to promote the system. (4) Information and education of

Table 9: A comparison of pricing systems

City	Objective	Type of pricing	Milestones
Singapore Electronic Road Pricing (ERP)	1. Manage congestion 2. Promote transit	Cordon and expressway pricing according to time, day and vehicle class	1975: manually enforced paper permit system ALS 1998: Transition to ERP After 2016: Transition to GNSS-system
London, UK Congestion Charge	1. Manage congestion 2. Promote transit and protect environment	Area pricing in central London and its western extension (daily flat rate)	2003 Feb: Start in Central London 2005 Jul: 60% price increase 2007 Feb: Western extension 2010: Repeal of western extension
Stockholm, Sweden Congestion tax	1. Manage congestion 2. Promote transit and protect environment	Cordon pricing in city centre by time and day per crossing of cordon line and out of city centre	2006 Jan – Jul: Trial 2006 Sep: Referendum 2007 Aug: Permanently reinstated

Source: based on U.S. Department of Transportation; TRB; AASHTO 2010

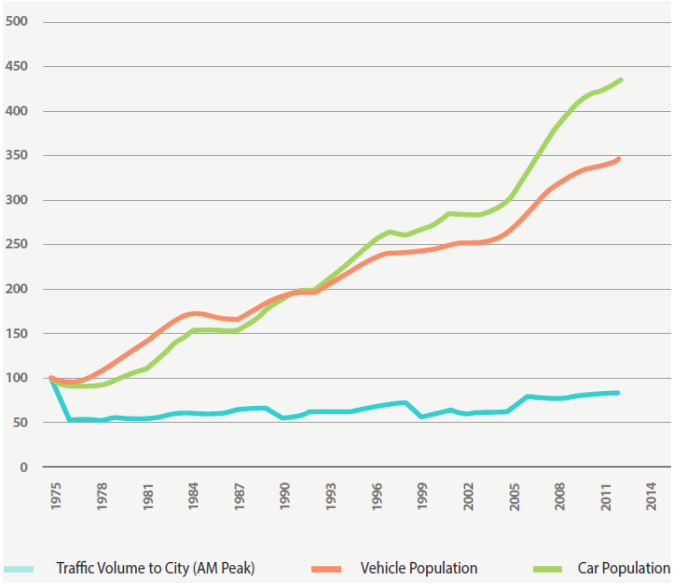

Figure 33: Effects of ALS and ERP (LTMP 2013)

the public is a major pillar for success. Even in Singapore, as mentioned above, once ERP revenues are used for transport improvements (e.g. public transport or road improvements) experience shows that support levels increase considerably.

4.5.8 Sustainability

The ERP system in Singapore provides a targeted solution for congestion pricing by allowing the authorities to pinpoint specifically congested spots and vary the congestion charge according to prevailing traffic conditions. It serves as a blueprint for a variety of cites around the globe handling similar congestion problems. The business case behind Singapore's ERP system is economically sound. However, since revenues are not directly re-invested in sustainable transport options such as public transport, its ecological effects are merely reflected in reduced congestion and realised traffic speeds. The ecological footprint generated in sectors cross-financed by ERP revenues is unknown.

The installation of a satellite-based system will enable unprecedented services and business models for a variety of stakeholders. Furthermore a distance-based congestion charge model realises the internalisation of – particularly environmental – external costs in an equitable, transparent, cost-effective and simple manner. Looking into the future, the pay-as-you-go approach of ERP II could serve as a catalyst for far-reaching car sharing schemes and shift the car´s status from being a rare luxury good towards a good commonly shared by broader levels of population. However, the considerable increases in effectiveness, service and business opportunities to be expected are consequences of the government´s ability to capture profound volumes of data on moving vehicles, causing significant repercussions on data privacy.

4.6 Safe City Test Bed

The Singapore government spends US $ 200 billion per year on homeland security (EDB 2013a). This includes all efforts, ranging from physical security to cyber security and civil defence. Singapore is considered one of the safest cities in the world and is "trusted for its integrity, quality, reliability, rule of law, and enforcement of intellectual property rights" (EDB 2013a). In order to maintain and expand Singapore's leading position in security, the MHA, in strong collaboration with the EDB, has launched the SSIPO which aims at incorporating and increasing cooperation with industry stakeholders working in security-related fields in Singapore

> "Beyond improved urban management, the creation of new solutions and innovation capacity will generate new economic activities and create good jobs for Singaporeans in the technology-intensive Safety and Security industry."
>
> Mr. Gian Yi-Hsen, Co-Director of the SSIPO.

While the MHA takes the lead position in identifying the risks and challenges of homeland security and urbanization processes in Singapore as well as developing new solutions with industry partners, the EDB is creating platforms for public-private-partnerships and test beds to provide room for collaboration with the industry. The focus of these test beds will be on the security demands of Asian countries. One project that has been developed within the SSIPO framework is the Safe City Test Bed, which will serve as the practice example to be analysed here.

4.6.1 The Safe City Test Bed

The SSIPO Safe City Test Bed is a collaborative project of the MHA and EDB, bringing together four project consortia including industry as well as six different agencies: from MHA, the Homefront Crisis Coordination Centre, the Singapore Police Force and the Civil Defence Force; from the MOT, the LTA; and from the Ministry of Environment, the NEA and the PUB. Conjointly, the four consortia form the test bed and will be evaluated against one another other. The overall aim is to develop a roadmap for governments on how to derive intelligence to better make use of sensor data and databases which are owned by different stakeholders in government as well as industry. The creation of a comprehensive situational picture on the ground, to be used in case of a possibly disastrous event, requires fusing together information from different sources. Central question addressed in the project include:

- How can the operations of the Civil Defence Force be optimised based on thorough traffic information?
- How can rescue operations be impeded based on weather information from different agencies?

- How can we conceptualise 'information sharing integration'?

4.6.2 Development and Implementation

The SSIPO Safe City Test Bed is based on a whole-of-government approach (WoG). Its main aim is to create an "iconic safe city concept based on a decentralized information sharing model" (MHA 2013). The overall project will be conducted over a period of 15 months; it was launched in April, 2013 and is currently running.

> "Technology is a force multiplier that can help government agencies to cope with the increasing demands and complex security challenges which arise from rapid urbanization."
>
> Mr. Anselm Lopez, Co-Director of the SSIPO and Director Capability Development and International Partnerships at MHA.

The SSIPO aims at providing an intelligent model for meeting these requirements and facilitates the daily operational activities of the corresponding authorities and agencies. Situational assessment and emergency response need to be both fast and effective. Therefore, the Safe City Test Bed enhances innovation capacities as to develop solutions specifically designed for metropolitan, highly urbanized and specialized spaces. Sensor information will be integrated and automated to create a real-time information model from which systematic insights can be derived without a temporal delay.

The central goal of the project is to develop an integrated system which is able to provide information in the event of a crisis only. On a need-to-know basis, information is shared while it is still anonymous: the system will rely on algorithms detecting disastrous events, i.e. information to create a situational picture, which then will be opened up to all responsible agencies.

The Safe City Test Bed is built on existing sensor networks and databases but aims at providing the possibility of integrating new systems on top of the existing infrastructure. Thus, "situational awareness, inter-agency coordination and anticipation of security threats" (MHA 2013) will be improved while using optimal resources and man-power.

In Singapore, there are four different locations for running the test bed. While architecturally similar, the four areas differ in social composition and technological equipment. The idea is to mix and match different existing systems to conclude which is the optimal implementation of the different sensor systems integrated in each of the four locations for a future safe city system. The sensors to be integrated are video cameras and water sensors which, in addition to databases for persons of interest, vehicles of interest and fire incidents, will provide the information and data. New sensor systems from the industry such as audio sensors, which can be used for picking up dialects, 360° cameras, aerial sensors, pollution measurement systems and systems for incorporating private information and data made available on the internet by the citizens (e.g. cell phone videos), will be analysed to assess the possible integration of these sensor systems in the future.

4.6.3 Financing the project, stakeholders and the call for proposals

The MHA and EDB's SSIPO Safe City Test Bed consists of four industry/government agency consortia which were chosen after a call for collaboration inviting the submission of proposals (EDB 2013b). The proposals were required to include solutions for the following:

- Maximizing agencies' situational awareness and response capacity,
- Streamlining manpower requirements,
- Providing technological solutions to meet the agencies' operational challenges,
- Overcoming infrastructural and technical constraints (EDB 2013b).

Additionally, the proposed solutions were required to improve certain key performance indicators, as well as offer solutions with a minimum of disruption to the overall system in order to develop an "operational test bed rather than a technical one" (David Lim Yin 1 Senior Assistant Director (Capability Development), Capability Development & International Partnerships Directorate, MHA – Interview May 16, 2013).

Figure 34: ERP – in the future this will possibly include traffic management systems, which may become part of the Safe City Concept (Walker 2011)

The four consortia are led by Accenture, AGT International, Cassidian and NEC Asia Pacific, respectively. The financing concept aims to share the risks of the test bed and development efforts. Thus, the Singaporean government will fund 50% of the total cost incurred by the participants selected (25 % MHA, 25 % EDB).

The main goal of this joint initiative is to leverage expertise as well as resources within the private sector and to develop capabilities which are both innovative and competitive. The Safe City Test Bed is tailored for the Asian Pacific Region but has the capability of being implemented elsewhere, too. For this initial phase, however, the idea is to vitally strengthen the Singaporean safety and security industry in order for it to function at its full potential.

4.6.4 Barriers, Challenges and Transferability

The SSIPO Safe City Test Bed project faced its most crucial challenges in terms of coordinating the different participants and consortia. In particular, coordination of the responsibilities held by different owners of the linked sensor systems and agencies in relation to processing the data provided by them turned out to be demanding. In conclusion, a system which is able to feed back on the information provided by the six different agencies, whose sensor systems are integrated in four different locations spread throughout Singapore, must be developed.

The Safe City Test Bed was developed to serve as a model for urban spaces in the Asian Pacific region. However, it is not exclusively focused on this area and may be adapted to other parts of the world as well, provided that the corresponding specifications are conducted.

4.7 SMART CITY PROGRAMME OFFICE - NEXT GEN NBN

The Next Generation Nationwide Broadband Network (Next Gen NBN) is the wired network of the Next Gen NII, a project under the Intelligent Nation 2015 Master plan. The project was initiated through a Request-For-Proposal for both Network Companies and Operating Companies in December 2007 and April 2008 respectively.

Its scope is to offer a pervasive, competitively priced broadband speeds of up to 1 Gigabit per second and more. It enables users to exploit a richer broadband experience at comparable prices to ADSL and cable connections. As per June 2012, Singapore had over 133.000 fibre optic subscribers served by 12 different service providers.

The Next Gen NBN is comprised of three distinct layers of industry:

- The Network Company (NetCo) is responsible for the design, construction and operation of the passive infrastructure (such as dark fibre and ducts);
- The Operating Company (OpCo) commits to offering

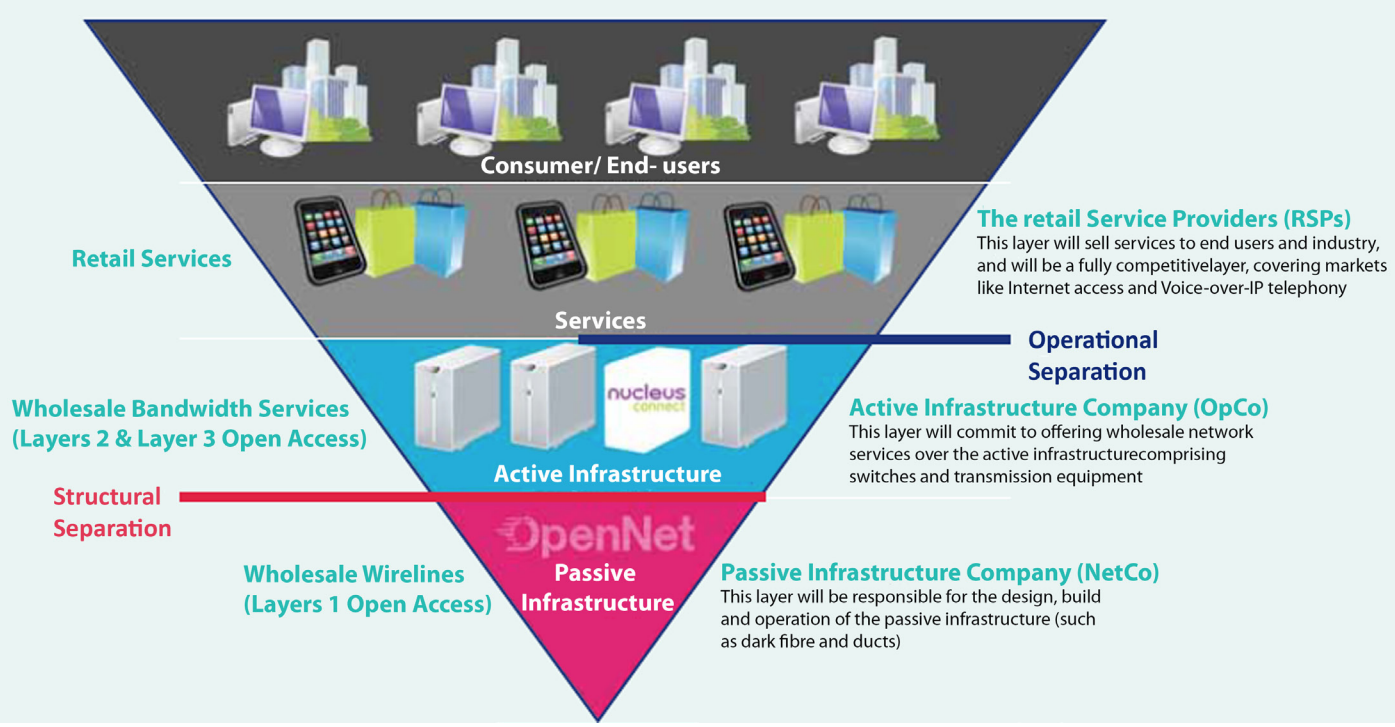

Figure 35: Next Gen NBN layer structure (IDA 2010)

wholesale network services via the active infrastructure comprised of transmission equipment, and
- The Retails Service Provider (RSP) sells services to end users and industry, and will be a fully competitive layer, covering markets like Internet access and Voice-over-IP telephony.

As stated by iDA, for Singapore to fully benefit from the economic opportunities of Next Gen NBN, it is critical that Next Gen NBN provides effective open access to downstream operators in order to ensure attractive wholesale prices to Retail Service Providers and offer a non-discriminatory platform for delivering innovative next generation services. To achieve this, structural and operational separation was implemented in the NetCo and OpCo layers respectively.

The structure of the Next Gen NBN industry will comprise a neutral open access NetCo and a competitive open access OpCo layer which will lower market barriers for Retail Service Providers.

The Singaporean Government provided a grant of up to SGD $1 Billion to support the rollout of the passive and active infrastructure, and in exchange, the NetCos and OpCos are required to provide wholesale services on a non-discriminatory basis, and to comply with Universal Service Obligation requirements.

The NetCos and OpCos pay for the cost of deploying, operating and maintaining their networks and equipment. While the Government provided a grant to support their business case and to facilitate timely achievement of the project objectives, the NetCos and OpCos were required to demonstrate that they would have a strong business plan to ensure the continued sustainability of their businesses, particularly after the Financial Support extended by iDA ceases.

Next Generation Services with Next Gen NBN

The Next Gen NBN project will catalyse the creation of innovative services for end-users in homes, schools and other outdoor locations.

Some of the services that will be able to make us of the Next Gen NBN include: interactive internet protocol TV, telemedicine, immersive learning, multi-user real-time simulation games and real-time grid computing. Furthermore, Next Gen NBN will allow Singapore to exploit new economic opportunities in the digital age and enhance the vibrancy of its ICT sector. Some of the services foreseen to be exploitable via this infrastructure in the near future are described as follows:

- Fast upload and download speeds: scalable speeds of up to 1 Gbps and beyond, for uploading and downloading files. This will enable an easier usage of Cloud technologies such as SaaS (Software as a Service), remote data backup and file restoration, and richer online learning and gaming experiences.
- High definition video conferencing: with HD video and voice and data communication running on the same broadband bandwidth, users will be able to conduct video conferenced that will be as real as possible without the need for heavy investments and bulky set ups.
- Interactive internet protocol television (Interactive IPTV): increase of the interactivity between users and television.
- Telemedicine: enabling the seamless and secure exchange of information among major hospitals, clinics and patients at home, improving home medical care through services providing remote medical consultation. This will ensure healthcare continuity by eliminating physical and geographical constraints and reducing the frequency of visits to clinics and hospitals.
- Grid services: grid computing services, delivered seamlessly via Next Gen NBN, offers enterprises and consumers access to huge computing power as well as software and data storage on a pay-as-you-use, on-demand basis. Such services will allow small and medium enterprises (SMEs) to save costs without having to incur heavy upfront capital in equipment and software licenses.
- Interactive digital signage: the combination of high resolution, high quality content over a network with no worries about bandwidth limitation, with digital authoring software and touch screen technology will result in a potential platform for rolling out highly engaging, interactive, high quality digital signage that can be updated in real-time via Next Gen NBN and with customised content to suit different purposes or target audiences.

4.7.1 Current Status of Next Gen NBN

Since its commercial launch three years ago, the Next Gen NBN project has achieved the following results:

- More than the 95% of residential and non-residential buildings have been provided with the Next Gen NBN since mid-2012.
  - For the residential segment, rollout is to the distribution point outside residential premises.
  - For offices, rollout is to the telecommunications room at the base of the commercial building.

- Affordable fibre bandwidth plans ranging from 25 Mbps to 1 Gbps with promotional retail prices for 200 Mbps residential plans starting as low as $40 per month.

- The Next Gen NBN Ecosystem has grown significantly, to a total of 25 RSPs and 8 OpCos.
  - Of the 25 RSPs, more than 20 offer services via

the Next Gen NBN covered by OpenNet* 's rollout. This represents a 10-fold increase in less than three years.

- More than 330,000 have signed for Next Gen NBN services as of the end of April 2013. This represents a close to 200% increase in the number of subscribers compared to January 2012, and signals continuing strong growth and interest from consumers.

To check the on-going status and results of the Next Gen NBN, iDA has put a governance structure in place that includes contractual oversight and regulatory controls. Key rollout activities are monitored through iDA' s contracts with the NetCos and OpCos, while the regulatory regime governs the NetCo's and OpCo's obligations under their respective licenses, including service provisioning obligations. In addition to the Next Gen NBN, there is also the need for common protocols and standards to optimize the overall benefits of such infrastructure.

Standards play an important and integral part in facilitating the development and adoption of new technologies. iDA works with various industry partners and standards organisations in Singapore and overseas to make standards a part of Singapore's ICT eco-system. ICT standards in Singapore are developed on a consensus basis and are the result of collaborative efforts amongst the government agencies, tertiary institutions, professional bodies and the ICT industry. The iDA Standards Team plays a key role in fostering and facilitating the industry's participation in local and international ICT standards forums. The team is the Secretariat of the IT Standards Committee (ITSC), which is one of the 11 Standards Committees under the National Standards Council appointed by the governmental agency SPRING Singapore.

ITSC provides a neutral and open platform for interested industrial and government parties to come together to agree on technical standards. The ITSC Council comprises representatives from associations, academia, research institutes, iDA and a variety of governmental agencies in Singapore, which charts the directions and policies. In addition, the appointed Technical Committees and Working Groups comprising technical experts from industry, academia and research institutes, develop and promote national ICT standards, and participate in international ICT standardisation activities. These standardisation activities are carried out by volunteers.

* OpenNet is a joint venture between four partners – Axia NetMedia (Axia), Singapore Telecommunications (SingTel), Singapore Press Holdings (SPH) and Singapore Power Telecommunications (SPT) and was established in 2008. OpenNet is responsible for building, managing and operating the high quality fibre platform for Singapore's Next Generation Nationwide Broadband Network.

5

5 RESULTS OF THE CITY RESEARCH

5.1 SINGAPORE'S DEFINED PROCESS PATH TO SUSTAINABILITY & INNOVATION

Regarding the initialisation and realisation of solutions in Singapore, the m:ci project team was able to identify a basic five-step process, shown in figure 36. The process has been derived from the interviews conducted in Singapore as well as being based on research about the practice examples. The main players for each process step are mentioned in the figure – which means that, depending on the topic, a large number of groups may be listed. An end-to-end role is dedicated to "politics" in Singapore as a central player. In summary, all stakeholders such as politics, research, economy and the general public, are considered over the span of the entire process in order to come to the best solution for Singapore – but intensity of integration varies.

Each step has several obligatory steps, as well as additional sub-steps or modules depending on the topic. Therefore, not every sustainable solution must pass through every sub-step. For example, test beds are not implemented for every solution – despite the fact that they are an important instrument in Singapore for determining a solution's feasibility and adaptation requirements.

In the "Beginning" phase, new topics are defined in a top-down manner. Singapore's international reputation is an important issue. For opinion making, companies located in Singapore are integrated as well as other stakeholders. After the political opinion has been formed the different sub-steps in the conception & feasibility phase follow, to determine what is feasible for Singapore and what would be the best solution under which framework. For evaluation, economic aspects are the most important consideration; however, technological, environmental and social aspects also play a role. In many cases, test beds are implemented and research programmes are launched. Most new solutions need a proper framework (e.g. legislation, standards etc.) to be successful. This must be designed and planned at an early stage in the process. After developing concepts and pre-testing solutions, a decision must be made before implementation can start. Within the implementation step,

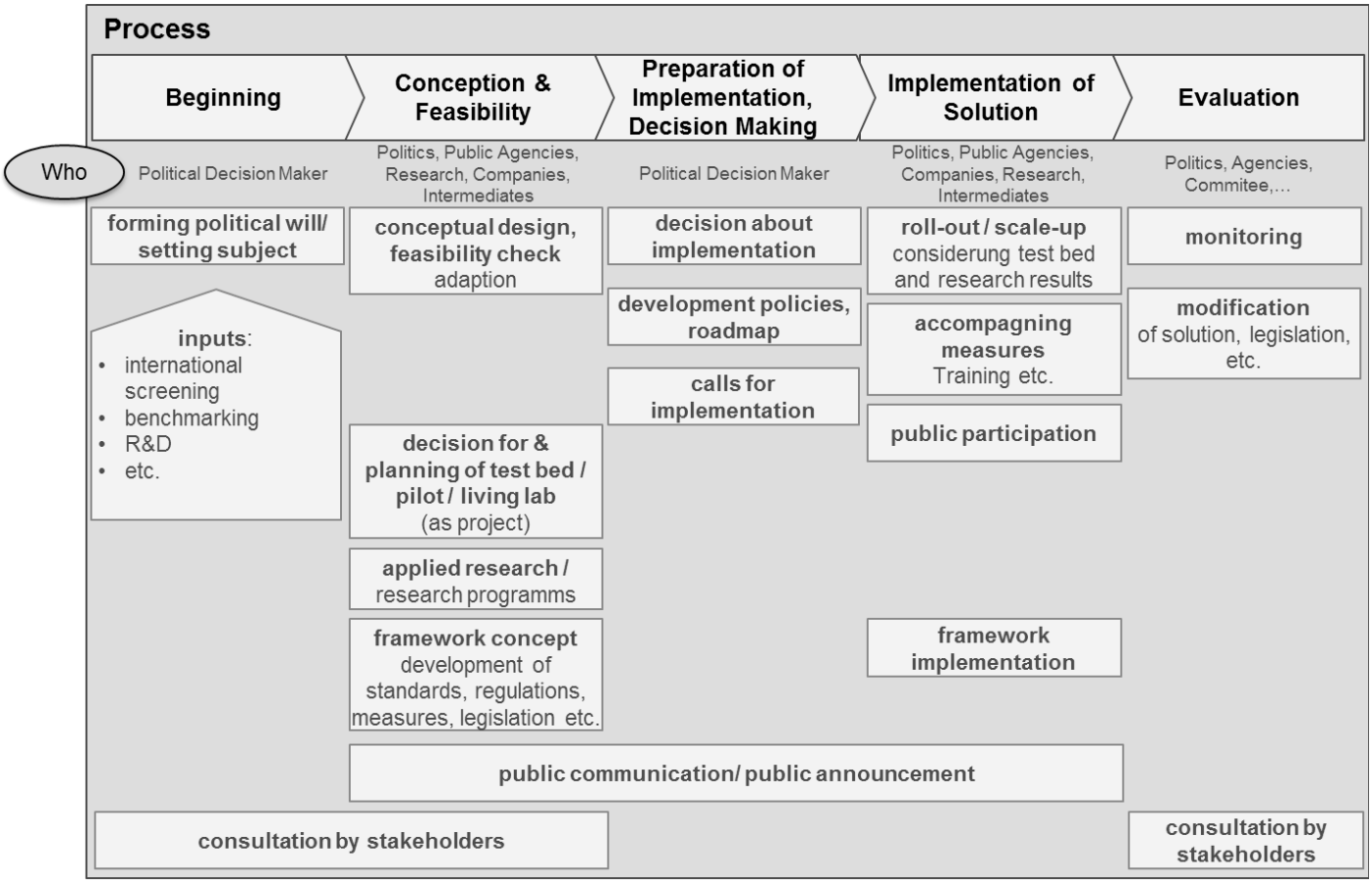

Figure 36: Initialisation and realisation of (sustainable) solutions in Singapore (depiction: m:ci)

or roll-out, in some cases the public is integrated; in that case they plan an active part in the realisation of the project. The process "finishes" with monitoring the solution and framework and, if necessary, modifying one or both. In this step, stakeholders are integrated for consultation. In parallel to several steps, communication with the public takes places. This happens mostly in form of one-way information about the undertaking and its status.

5.2 OVERVIEW OF STAKEHOLDERS

The Singapore m:ci project team has analysed various stakeholders in terms of their influence on sustainable city development in Singapore. The results are shown in Figure 38. The section on the left (orange colour) includes mainly political decision makers and administrative stakeholders, while the section on the right (green colour) includes stakeholders involved in the implementation of solutions/ projects and public services. Finally, the bottom section (blue colour) encompasses stakeholders involved in usage of urban structures, services and project results. The rating scale is from 1 (unimportant) near the periphery to 6 (very important) in the middle. In cases where one organisation seems to have different influences depending on the sector or practice example the project group analysed, it is mentioned a second time in a sector-specific manner.

One of Singapore's characteristic lies in having a highly dynamic environment, providing all stakeholders with the ability to cooperate in the overall portfolio of programmes and projects under the strategic policies defined by the stat. Thus, this allows stakeholders to be involved in the overall policy-making processes. One of the main strengths is represented by the way the Singaporean state acts involve public and private sectors as well as citizens in a horizontal

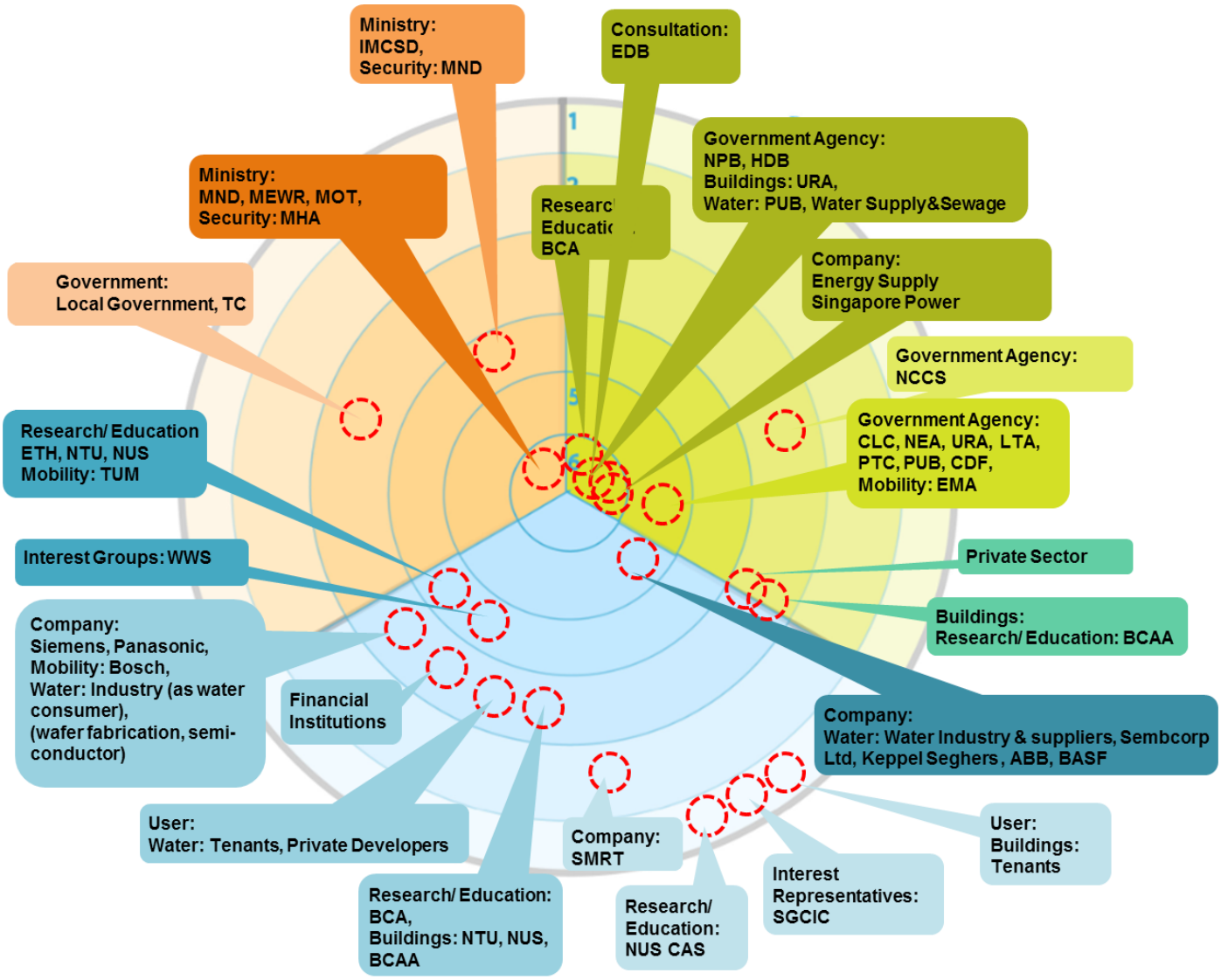

Figure 37: Selection of actors and stakeholders in Singapore (depiction: m:ci)

hierarchy. According to Conteh (Conteh, 2009) , the state is actively involved in the management of the economy and, more specifically, in the active implementation of private sector development policies in partnership with organized business and labour. Confirming Conteh's 2009 results, the Singapore m:ci project team's research was able to affirm the state's high level of involvement in driving the city nation's overall activities towards becoming a completely self-sustaining city nation.

All policy decisions are made at the top, after consultation with most prominent representatives of the industries in the various sectors and after involving citizens when opportune. Singapore has developed a highly efficient network of stakeholders, as shown in the previous figure, which collaborates right from the initiating to the closure phase of each individual programme established for sustainability.

The state's on-going efforts to build networks have consolidated Singapore within a solid policy partnership framework which enables the following:

i. Client and stakeholder participation in the design and implementation of sustainable policies
ii. Strong leadership to act as a voice for various interests
iii. Clear statement of strategic goals
iv. Appropriate choice of implementing agency
v. Improved organizational capacity, particularly the mobilization of stakeholders

In addition to the state's effort in network building, favourable economic and geographic conditions have allowed Singapore to attract the headquarters of major multinational corporations, which actively participate in the overall sustainability process of the city nation, continuously strengthening the abovementioned networks.

5.3 IMPACT FACTORS

Through analysis of best practices in Singapore, it was possible to identify a set of 35 impact factors, which have direct or indirect impacts on the practice examples analysed. A cross-impact analysis of these 35 factors on all best practices led to a ranking of factor strengths. Figure 38 shows the evaluation and ranking of the 14 most important direct and indirect impact factors.

Allocated to categories the 14 impact factors are city-specific, belong to strategic economic planning and to regulations set-up by the Singaporean government or the governmental system. Limited space and resources as well as the geographical location are triggers and have the most direct impact on the practices analysed.

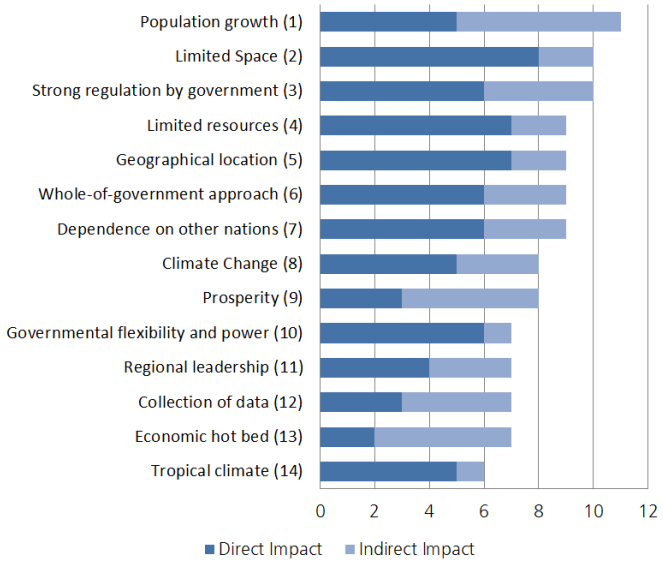

Figure 38: Direct and indirect impact factors identified in Singapore's practice examples (depiction: m:ci)

Some of the most important impact factors are linked, influencing and amplifying one another. The two most important impact factors, population growth (1) and limited space (2) are directly linked. The population of Singapore almost doubled within the past 20 years from 3 million to almost 5.5 million in 2013 and is still growing by 2.1 % annually. The growth in population is supported by the government, in order to maintain the status of Singapore's economy. The growing population means an increase in the need for housing, electricity, water and advanced transportation systems. Singapore has limited space and limited land and water resources which makes the provisioning of housing challenging. The amount of inhabitable land as well as land used for green areas is linked with the amount of water resources due to the land's function as a catchment area (4). Therefore, Singapore places great importance in sustainable as well as dense development. There are also huge R&D efforts to "tap" new sources of water (1, 10). The efficiency standards of the GMS (1, 3) for buildings help reduce Singapore's energy consumption. 40% of all end-use electricity in Singapore is consumed by buildings. Due to Singapore's' tropical climate, air-conditioning

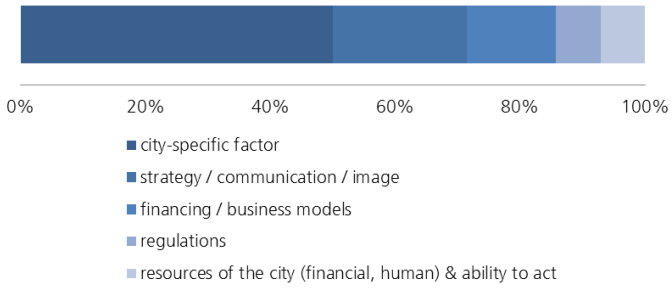

Figure 39: Categories of impact factors (depiction: m:ci)

is one of the biggest contributors to energy usage in buildings. It alone contributes around 40-50% of a building's average electricity consumption (14).

The mobility sector is also critically linked to the above-mentioned impact factors. Population growth goes hand in hand with the need for sufficient transportation (1). However, Singapore is restricted in the expansion of its road network and therefore regulates the car market and places large taxes on cars, roads and petrol (1-3). The island state's tropical climate amplifies the use of individual motorised mobility, as it is the favourite transportation option, not least due to its air conditioning possibilities (14).

Due to being a small, heavily urbanised, island city-state in Southeast Asia (5), Singapore is reliant on other nations for the supply of many goods. Thus, Singapore's strategy is to become as independent as possible in certain areas of supply (7). This strategy is faced with severe challenges, for example in the water supply sector. The impact of climate change (8) in Singapore is mainly felt in the form of growing periods of drought, rather than floods. The increase in droughts leads to a growing demand for water in the future (this effect is amplified when combined with forecasts of population growth).

Singapore has a strong regulatory environment. Its economic success has been achieved with a significant degree of state involvement in the economy and an authoritarian political system (3). For example, obligatory interactive collaboration between various government agencies (6) is meant to ensure the achievement of defined resilience and preparedness targets. The political system in Singapore allows governmental flexibility and the ability to act (10). Singapore's strong government allows it to move quickly when adapting and implementing good ideas, such as the R&D efforts around the water supply topic and investments in public transportation (10). To provide a basis for advanced regulations, Singapore is collecting consumer behavioural data (12). Therefore, behavioural testing within different incentive programs on preferences, decision making and target groups is done. This testing leads to, for example, fair distance-based road pricing (ERP II) (12).

Singapore, as a city-state, is pursuing a strategy aimed at becoming – or rather, remaining – an economic, political, social and environmental leader in Southeast Asia. Due to its small size and industrial structure, it is not a leading market; however, because of its strategic position, image and know-how it thrives as a leader (11). A variety of projects are possible and successful in Singapore due to the fact that Singapore is an economic hot bed. From an investor's point of view, the city is highly attractive as a result of its economic conditions (language, taxes, geographical position, infra-structure, market access, security, corruption etc.) (13).

5.4 FIELDS OF APPLICATION

The Singapore m:ci project team has identified 25 relevant sector-specific and sector-overlapping fields of application in Singapore, clustered into the following groups: (1) Resilience, Engineering & ICT, (2) Energy & ICT, (3) Buildings, (4) Transportation, (5) Water, (6) Business Tactics, (7) R&D Tactics, (8) Information and Education and (9) Strategy and Planning. Each group is discussed in more detail below.

5.4.1 Energy & ICT

Highly efficient and centralised energy supply (district heating / district cooling)
Singapore has implemented two applications with district cooling in its financial district. Up to now, operation management has been rather limited due to EMA regulations. Efficiency in cooling for commercial buildings could be increased if operators could identify additional possibilities for value creation. This would demand a more liberalized energy market model, so that demand-response programs could be used by operators to exploit the full potential of their generation and storage capacities.

Deployment of smart grid technologies
Another possibility within the energy and ICT field is the deployment of more "intelligence" into the energy supply system. Singapore runs many test-beds in the area of smart grid technologies and benefits from this extensive technical and operational know-how. Smart grids for the increased deployment of renewable energy generators are not being pursued in Singapore due to limited solar PV potential and no potential for wind power or biomass generation. Only energy technologies – as is the case with other technologies as well – which show market viability after the test-bed phase will be rolled out; direct public subsidy programs are not supported by the Singaporean government. Due to these requirements placed upon technological innovations, smart grid technologies are not currently being pursued.

Building cooling systems with high efficiency
Current legislation permits Demand Response in the commercial sector of the energy market. Nevertheless, this DR scheme is only possible for the reserve market. EMA and EDB are currently leading a consultation process to adapt the Singapore Energy Market to extent the DR business. Today, generation costs vary between some SGD cents up to 45 SGD on the spot market. Within the relevant boards , there is economic potential amongst large consuming commercial customers to deploy the DR. The finalization of the legislation on the deployment of DR in the industrial/ commercial sector is expected for 2014. In combination with the current review of the 2nd roadmap for building energy efficiency under the BCA's GMS, the increase in energy efficiency of chillers and – given suitable chiller technology – the participation in DR could be achieved. Currently,

no final decisions have been made, but it is important to note that BCA's GMS is widely seen as Singapore's "gem for energy efficiency". The economic benefit resulting from either the GMS or the IES including DR – as well as their combination – is acknowledged by all stakeholders due to the high attractiveness for investors to construct new commercial buildings as a result of economic welfare and growth in Singapore.

Energy related renovation and modernisation
In terms of sustainable urban development, Singapore faces some unique challenges due to limited resources and land area coupled with high population density. Today, new construction in Singapore makes up less than 5% of the total building stock, putting great pressure on energy efficiency retrofits and upgrading efforts within the building sector. Additionally, public housing accounts for 80% of the existing building stock and 90% of resident households own their own homes. Such high proportions of private building ownership require innovative policies and financial influence to enable rapid transitions in energy efficiency in the existing building stock.

5.4.2 Buildings

Reduction of building costs through a high level of prefabrication
Motivation for using modular construction generally arises because of increased client requirements concerning reduction of construction time and improved quality. The HDB has pioneered and is still leading prefabrication technology in Singapore, with an average precast implementation rate of 70% for each project. Precast construction reduces negative environmental impacts related to construction by reducing construction wastes and related pollution. Factory formwork for precast units is reused and concrete and interior re-enforcing steel members are recycled. Modular and standardized units facilitate rapid installation, minimizing construction time, energy usage and emissions from on-site equipment.

Setting of obligatory standards for new buildings / building certification
To encourage the private sector to develop sustainably, and to expand the adoption of green building technologies, the BCA launched the so-called GMS in 2005, which provides a comprehensive framework for assessing building performance and environmental aspects. Since the introduction of the GMS, Singapore is making steady progress on its target have 80% of the total building stock Green Mark rated. Now, at the end of March 2013, there are more than 1,500 Green Mark building projects in Singapore. This amounts to more than 17% of Singapore's total building stock. Since 2008, all new buildings and all existing buildings undergoing major retrofits with gross floor areas of more than 2,000 m² must meet at least the minimum Green Mark standard – this applies to the public and private sector alike.

State requirements enabling market creation for sustainable products
The organization of Singapore's real estate market puts the government in a very strong position, allowing it to ensure that the nation will be able to reach its goal of having 80% of the building stock Green Mark certified by 2030. In Singapore, all land sales and development is strictly controlled by the government, which owns 90% of the land, and the HDB owns and operates 86% of all residential buildings. Thereby, the Urban Redevelopment Authority (URA) has been able to use this structure to promote the GMS by requiring new developments to obtain a Green Mark rating as a condition associated with the sale of land. Reduced operational costs and favourable public opinion towards efficiency are reflected in real estate premiums ranging from 5% to 21% for building and homes with a Green Mark rating, with higher rankings receiving higher premiums.

5.4.3 Transportation

Intelligent traffic management with real-time operating systems
Today, a variety of Intelligent Transport Systems (ITS) already form the basis for Singapore´s transport planning. The ITS infrastructure spans over 161 km of expressways and road tunnel systems. Traffic data is aggregated, integrated and disseminated at the ITS Centre for traffic monitoring and management. The data is also collected for traffic analysis and planning. Real time and localised traffic information is disseminated through websites, radio broadcasts and smartphones. To reach out to the wider public and make use of the private sector's innovations, as well as their broad distribution channels, traffic information is also disseminated through private sector products and services. The market for ITS solutions and their possibilities will peak with the implementation of a GPS-system based road-pricing system.

Modal shift to public transport
In terms of public transport, Singapore plans to substantially expand its infrastructure and services. The government plans to double the length of Singapore´s rail network to about 360km by building more lines between 2020 and 2030 and to add more trains to every rail line for the next few years, starting in 2014. Singapore also plans to upgrade the train signalling system and to move towards higher train frequencies, minimise service delays, and enforce more stringent maintenance. As part of the Bus Service Enhancement Programme, 40 new bus services will be added to enhance the bus network's connectivity. Additionally, more real-time bus arrival information panels are planned for installation. The infrastructural build-up goes hand in hand with the development of price incentives aimed at encouraging more Singaporeans to use the public transport

system. Due to massive data collection through the use of smart cards, both the behavioural patterns and cost sensitivity of Singaporeans are well-known to the government.

Promoting non-motorised transport

Although it is not currently a bicycling city, Singapore has identified walking and bicycling as a pillar within its sustainable transport strategy. The main challenges lie in the belated integration of bicycle and walking infrastructure into the existing car-focused environment. The government plans to extend Singapore's sheltered walkway network by more than 200km by 2018, as part of the Walk2Ride programme. 90km of off-road cycling paths will be built to bring the total network to around 190km by 2020. Furthermore, Singapore plans to integrate intra-town cycling networks with park bikeways to create an island-wide cycling path network of more than 700km over the next 15 years. Combined with more racks to secure bicycles at the MRT stations by the end of 2014, Singapore plans to conduct a pilot bicycle-sharing scheme by the end of 2015.

5.4.4 Water

Active stormwater management

Facing growing problems caused by climate change, an awareness of the relevance of stormwater management in cities is beginning to increase. The benefits of active stormwater management are twofold: on the one hand, extreme rainfall can be partly absorbed by detention fields or tanks and green roofs; on the other hand it, provides increased drinking water in areas of water scarcity. Both points play an important role in Singapore, where around two thirds of the entire island is dedicated as water catchment area.

Active management of the water-energy-nexus

The nexus between water and energy is one of the key areas with a potential to increase sustainability within the water sector. Many processes in water management require a high input of energy: water supply, waste water treatment, seawater desalination. Moreover, the waste water contains thermal energy, since it has been used in washing machines, showers or other processes where it has been heated. Singapore is not only lacking in water, but also in energy and has barriers to producing regenerative energy. Therefore, the PUB is investing heavily into R&D to reduce the need for energy while recycling or desalinating water using cutting edge membrane technology.

5.4.5 Business Tactics

Targeted granting of tax benefits for certain commercial and industrial sectors used as an incentive to promote local settlement

Singapore is often called the "Switzerland of Asia" meaning that companies, investors and citizens stand to benefit from tax benefits in Singapore(SLC Europe 2013). There are no differences in taxation between businesses carried out in the island state by residents or non-residents of Singapore, which can be an incentive for foreign companies. A wide range of investment incentives are also offered in Singapore, including tax holidays and concessions, accelerated depreciation schemes, favourable loan conditions, equity participation and high-quality industrial estates. The tax incentives are described in the Income Tax Act and the Economic Expansion Incentives Act (EEIA)*.

Financial support for innovative technologies and projects to increase sustainability

In addition to the taxation system, the m:ci project team identified that financial support in Singapore is given in both an early stage of a project, for R&D of new technologies, and then again later, for the roll-out / implementation of a suitable solution. For R&D, the budget is allocated in the form of research programmes. Research programmes focus on a specific topic and not on sustainability in general, such as, for example, finding new ways of waste water treatment and water purification using desalination with a focus on saving energy. The money is provided by various ministries and agencies with responsibilities related to sustainability.

5.4.6 R&D Tactics

Creation of experimental areas and ways to promote innovative technologies

Many opportunities for testing and validating solutions are provided. All solutions or technologies are tested before implementation or dissemination. By doing so, the stakeholders can identify whether there is a need for adaption to address ecological, technological and social considerations. An evaluation of economic aspects is also an important criterion for Singapore. One of the organisations responsible for supporting experimental areas is the National Research Foundation (NRF). The NRF "seeks to strengthen Singapore's R&D capabilities, encourage greater innovation and nurture the growth of technology-based enterprises in Singapore. This will help Singapore to remain competitive and create high value jobs and prosperity for Singaporeans. The NRF was set up on 1 January 2006 as a department under the Prime Minister's Office" (National Research Foundation 2013). Another opportunity for innovation lies within cluster development. The Environment & Water Industry Programme Office provides overall direction regarding the

* "The EEIA relates to incentives for the establishment of pioneer industries and for economic expansion generally. The incentives provide for concessionary tax rates, ranging from 0 % to 15 %, with the concessionary tax rate generally dependent on the economic footprint or commitment in Singapore, e.g. the number if additional jobs that would be created, the local business spending, headcount, new activities introduces in Singapore, etc." (Deloitte 2012 p.4)

development and growth of the water and environment industry.

Joint industrial & scientific research institutions for sustainability issues
One prominent example for a research institutions which represents a collaboration between science and industry is the CREATE . „This complex of research centres from world-class research universities and corporate labs, together with the talent they train and their technology transfer activities, form CREATE" (National Research Foundation 2013). Projects are conducted with industry partners.

5.4.7 Information & Education

Creating an innovation and transformation-friendly „mood" in the city in terms of technologies and projects in the field of sustainability
The Government (ministries or agencies) as well as other involved parties inform the population about undertakings and ongoing projects. The m:ci project team identified some of the instruments used for such communication. These include printed articles in newspaper, online news, magazines, posters in public transportation areas, etc. Also, exhibitions and events (information and arts events and discussions) are organized to demonstrate and explain transformation processes. The activities address adults as well as children. Examples of topics for which such information has been conveyed include: water awareness initiatives, newly designed areas, urban planning in Singapore etc.

Awareness-raising campaigns for the careful and economical use of water
One of Singapore´s main challenges is the scarcity of water. In addition to investing in huge technical efforts aimed at tapping into new sources, such as desalinated water and recycled waste water, reducing private and industrial water consumption is an important target for the Public Utility Board. The PUB aims to reduce investments in the construction of new network infrastructure, which are necessary because of the growing population. An important element of the compaigns the involvement of schools, which ensures that every pupil is well informed about both the water supply and water problems within Singapore.

5.4.8 Strategy & Planning

Creation of advisory committees on sustainability issues within research, civil society, business, politics and urban administration
In Singapore, several advisory boards exist. They have either a direct or indirect link to sustainability. One example is the EDB, a central board of the Government of Singapore, involved in planning and executing strategies to sustain Singapore as a leading global hub for business and investment. The Research Innovation and Enterprise Council is an example of a board in which politics, research and private companies are represented. Another example is the IMCCC, which enhances Whole-of-Government coordination on climate change policies to ensure that Singapore is prepared for the impacts of climate change.

City participation in local businesses for the operation of infrastructure and for providing urban services
Singapore has a free enterprise economy. However, there are some companies which are owned by the government. According to the Institutional Investor Magazine there are two important sovereign wealth funds in Singapore: the Government Investment Corp (GIC) and Temasek Holdings. These companies placed fourth and sixth, respectively, in the sovereign wealth fund ranking in 2012 (Singapore Business Review 2013). GIC invests in private and public equity, real estate, alternative markets including foreign exchange, fixed income, foreign exchange, commodities and financial markets across the world. The Fund was founded 1981 and invests through different subsidiaries (Bloomberg Business Week 2013). The sovereign wealth fund and investment company Temasek Holdings is 100% government owned and the finance minister is the shareholder (Standards & Poor's 2012). Temasek Holdings owns a portfolio of S$ 215 billion and invests about 30% into the Singaporean market (Temasek 2013).

Creation of space for semi-formal and informal networks
Both formal and informal exchange processes occur between political decision-makers in Singapore. Advisory committees are formal exchanges on a specific topic. Due to the fact that the topic of sustainability is spread out over several ministries and agencies, general meetings, on the management level and otherwise, are used.

Creation of socially acceptable rent levels
To respond to the rapid population increase in the past years, a comprehensive and holistic town planning approach was promoted by the HDB as part of an urban housing solution which includes the planning of high density public housing as well as the planning of commercial and transport facilities. Currently, there are about 1.2 million housing units in Singapore, of which 0.9 million are public housing. Today, 90% of resident households own the homes in which they live; thus, Singapore has one of the highest home ownership rates in the world. Thus, the government faces a great challenge in meeting the increasing demands for affordably-priced new housing and for sustainable environments in these new town and housing developments. For the Singaporean government, the challenge is not just about providing affordable and available housing units; it is also about creating a sustainable environment and a high quality of life, in order to meet the new expectations and consumption patterns of Singaporeans.

6

6 KEY FINDINGS

The research results, based on the research visit in Singapore and remote research within the m:ci project, are summarized in the following points:

Influence of Government
- Being a strong government for the Singaporean people, the government occupies the role of caretaker for the welfare of all people in Singapore. The population generally does not engage directly in political discourses.
- Government has the role of initiator, decision maker, planner and sometimes operator.
- Agencies do not operate only as administration; they have great competences and often function as operators.

Civic Participation
- The government is widely accepted by the citizens.
- Citizens place high demands on their government to maintain momentum.
- Low degree of civic participation in Singapore; There is not much of a "participatory-mood," as citizens are used to a strong government which has made wise decisions over the past decades.
- More need for citizen-driven activities.
- Government starts to support bottom-up processes (involves certain groups of the population in the design, but not in the decision- making process.

Markets
- Singapore is an excellent provider of new technologies for other countries. But Singapore is not a leading market or big sales market for new technologies.
- Singapore is not a leading market or big sales market for new technologies.
- Good as a test bed & test market, because of well-functioning infrastructure and conducive framework conditions.
- Excellent location for companies as a hub and starting point for opening up the Asian market.
- Highly competitive market place due to density of companies and international tenders by the government
- Business opportunities for companies: solar industry, energy efficiency, machine industry (planers, technologies, machines).
- There are three markets of the future in Singapore: health care and the aging society, life style, and urban solutions.

Sustainability
- Definition by government: economical, ecological and social sustainability.
- Sustainability is not an aspect of daily life (for citizens) and no incentive scheme (to promote behaving sustainably) is visible.
- Singapore wishes to provide a "green and clean" space for living and thereby promote economic sustainable development.
- The Singapore m:ci project team experienced that sustainability is often equated with efficiency.

Innovation
- Singapore is a follower in regard to technological solutions.
- Decisions are generally made to avoid risk.
- Adaption of solutions that are successful in other parts of the world to environmental, social and technological requirements of Singapore.
- Social innovation comes too short.

Efficiency & Industrial Orientation
- Commercialization and local value-creation under the aspect of efficiency are prominent considerations in Singapore.
- New solutions are always evaluated in regards to their economic benefits.
- Companies are involved as consultants right from the beginning: during the idea, benchmarking, adaption and implementation processes.

7

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8

8 ANNEX

A1: Interviews conducted during the research stay

Sector	Interviewee	Company/ Institution	Function
BIG	Dr. Andreas Hauser	TUV Sud	Head of Water Services
	Panel	Singapore-ETH Centre - Future Cities Laboratory	
	Mr. Lai Choo Malone-Lee	NUS Centre for Asian Sustainable Cities	Director, CSAC, NUS
	Prof. Gerhard Schmitt	Singapore-ETH Centre - Future Cities Laboratory	Director
	Panel on Governance	Ministry of National Development	
	Mr James Hosking	Eco-Business.com	Editor
	Ms. Jessica Cheam	Eco-Business.com	Founder
	Ms. Joanne Wong	Sustainable Development Business Group	
	Mr. Chua Yew Peng	National Environment Agency	Head of Policy and Planning
	Dr. Ashish Lall	National University of Singapore	Professor at NUS, Verwaltungswissenschaften
	Mr. LIEW Choon Boon	National Development	Senior Director/ Eco City Project Office
	Mr. LEONG Eugene	National Development, Strategic Planning Division	Senior Director, Strategic Planning Division
	Mr. Jose Raymond	Singapore Environment Council	Executive Director
	Mr. Steffen Endler	Siemens	Account Manager Singapore
Energy	Mr. Bernard Nee	Energy Market Authority	Assistant Chief Executive Energy Planning & Development Division
	Panel on Buildings, Energy and Security	Ministry of National Development	
	Paul Gosling	Accenture	Project Coordinator IES
	Tbd	Infocomm Development Agency (IDA)	
	Mr Chan Eng Kiat	Energy Market Authority, Singapore	Project Director IES
	Mr King Jet TSENG	Nanyang Technological University (NTU)	Associate Professor
	Mr. Ashwin M. KHAMBADKONE	Agency for Science, Technology and Research (A*STAR)	Associate Professor
	Tbd	Singapore Power	
	Tbd	ST Electronics	
Buildings	Mr. Kian Seng Ang	Building and Construction Authority	Group Director
	Prof. Lee Siew Eang	National University of Singapore	Director, CTBP at NUS Department of Building, ZEB-Energy efficiency
	Mr. Yang Kwang Foo	District Cooling System	District Cooling System

Sector	Interviewee	Company/ Institution	Function
Buildings	Prof. Wong Nyuk Hien	National University of Singapore	Associate Professor at NUS Department of Building, ZEB-Greenery and natural ventilation
	Ms. Penny Low	Punggol Eco Town Council	MP for Pasir Ris - Punggol GRC (Punggol North)
	Mr. Kian Chuan Koh	Urban Redevelopment Authority	Head(M&E), Development Coordination Department
	Ms. Chen Yang-Ling	Panasonic R&D Center	Planning Group
	Dr. Fong Yok King	National Park Board	Senior Manager (Urban Greenery)
Security	Mr. Anselm Lopez	Ministry of Home Affairs	Director Capability Development, International Cooperation & Partnerships Division
	Ms. Grace Leong, Mr. Justin Chua	National Security Coordinating Secretariat	Resilience and Research Unit
	Panel on Buildings, Energy and Security	Ministry of National Development	
Mobility	Prof. Tien Fang Fwa	National University of Singapore	Director of Centre for Transportation Research
	Mr. Gordon Falconer	Cisco	Director Urban Innovation
	Prof. A P Gopinath Menon	National University of Singapore	Adjunct Associate Professor Division of Infrastructure Systems
	Mr. Thomas Jakob	Robert Bosch Singapore	Managing Director Asia Pacific
	Mr. Bernard Nee	Energy Market Authority	Assistant Chief Executive Energy Planning & Development Division
	Mr. Jeffrey Siow	Ministery of Transport	Director, Land Transport Division
	Assoc Prof Wong Yiik Diew	Nanyang Technological University	Director of Centre for Infrastructure Systems
	Mr. George Sun	Land Transport Authority	
	Mr. Harry Hoster	TUM Create Singapore	Scientific Director
Water	Dr. Cecilia Tortajada	Third World Centre for Water Management	President
	Dr. Andreas Hauser	TUV Sud	Head of Water Services
	Mr. Eugene Heng	Waterways watch society	Representative
	Mr. Aik Num Puah	Public Utility Board	Deputy Director of Technology&Water Quality Office
	Mr. Eric Soh	Public Utility Board	External Affairs/ Industry contact person

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