

Contents

Foreword	3
Acknowledgements	5
Contents	7
Executive summary	15
1. Rationale	19
Historic context and future projections	20
2. The vision	27
“A Tale of Two Cities”	27
“ <i>Bleak House</i> ”	27
“ <i>Great Expectations</i> ”	31
In summary	36
3. Current status	39
Spatial energy densities	43
In summary	44
4. The concept of sustainable energy supply	45
Distribution of energy through carriers	46
Storage	47
Electricity supply systems	49
<i>Smart metering</i>	52
<i>Distributed generation</i>	54
<i>Intelligent grids</i>	58
<i>Micro-grids, building integration and electric vehicles</i>	62
<i>Utility restructuring</i>	63
In summary	64
5. Renewable energy resources and technologies	65
Electricity generation	66
<i>Solar</i>	66
<i>Wind</i>	69
<i>Small hydro and water supply systems</i>	71
<i>Geothermal</i>	72
<i>Bioenergy</i>	73
Heat resources and technologies	73
<i>Bioenergy</i>	74

<i>Solar thermal</i>	78
<i>Geothermal</i>	79
Hydrogen.	82
District heating and combined heat and power (CHP)	85
Cooling technologies	85
In summary	90

6. Transport resources and technologies 91

Electric rail	91
Electric vehicles	92
Biofuel production	93
In summary	94

7. Policy options 95

Influence of national policies	104
Climate change policies and measuring emissions.	108
<i>Voluntary carbon markets</i>	109
<i>Distributed energy policies</i>	111
<i>Heating and cooling policies</i>	111
In summary	112

8. Case studies of cities 113

Case study 1	116
<i>Tokyo, Japan.</i>	116
Case study 2	120
<i>Cape Town, Western Cape, South Africa</i>	120
Case study 3	123
<i>Nagpur, Maharashtra, India.</i>	123
Case study 4	126
<i>Adelaide, South Australia</i>	126
Case study 5	132
<i>Merton, London, England</i>	132
Case study 6	136
<i>Freiburg im Breisgau, Baden-Württemberg, Germany</i>	136
Case study 7	143
<i>Palmerston North, Manawatu, New Zealand.</i>	143
Case study 8	148
<i>Växjö, Småland, Sweden</i>	148
Case study 9	152
<i>Masdar City, Abu Dhabi, United Arab Emirates.</i>	152
Case study 10.	157
<i>El Hierro, Canary Islands, Spain</i>	157

Case study 11.	161
<i>Samsø, Denmark</i>	161
Case study 12.	165
<i>Güssing, Burgenland, Austria</i>	165
Case study 13.	170
<i>Greensburg, Kansas, United States</i>	170

9. Policy recommendations. 175

Recommendations relating to the suite of available policies.	176
<i>Renewable energy resource assessment</i>	176
<i>Citizen support</i>	179
In summary	181

References 183

List of figures

Figure 1. Carbon dioxide emissions from energy use in cities grows by 1.8% per year (versus 1.6% globally) under business-as-usual scenarios between 2006 and 2030, with the share of global CO ₂ from cities rising from 71% to 76%.	21
Figure 2. The various sections of the report have been structured to provide information and inspiration to members of the target audience who may wish to encourage the greater deployment of renewable energy technologies for the provision of energy services within their local community.	24
Figure 3. Producing significant shares of heat, power and biofuels from locally available resources including solar, wind, ocean, geothermal, energy crops and biomass from wastes, could be a future option for a municipality	32
Figure 4. The conversion from primary energy to energy carriers and end-uses is an inefficient process exemplified here by electric lighting (a), even where more efficient power generation plants are employed(b) and energy efficient light bulbs have been installed (c)	40
Figure 5. World anthropogenic greenhouse gas emissions in 2005 by source, amounting to 44.2 Gt CO ₂ -equivalent with cities accounting for around half of total emissions	42
Figure 6. A concentrating solar thermal power plant with heat storage (e.g. brine) to enable power and heat generation to continue after sunset	48
Figure 7. A simplified representation of the conventional electricity system with electrons flowing in one direction (solid lines) and revenue in the other (dashed lines).	50
Figure 8. Capacity and age of the fleet of power generating plants in developed countries in 2006	51
Figure 9. Vision for the electricity system of the future	52
Figure 10. Cutaway diagram of the Whispergen micro-CHP generation technology showing yoke coupling between the Stirling engine and alternator and example of the domestic installation of the appliance	57

Figure 11. Representation of a distributed generation system with two-way flows of electrons (solid lines), revenue (dashed lines) and information (dotted lines) through smart meters and intelligent grids	60
Figure 12. Example of electricity load duration curve reshaped by peak load reductions (blue) using discharged energy storage and demand response techniques and by lower load increases (green) as a result of recharging energy storage including electric vehicles . . .	64
Figure 13. The measured electricity demand of a small New Zealand community was compared with the local wind resource to attempt to match supply with demand.	65
Figure 14. In Berlin, the old gas lamps still function next to the new solar-powered parking meters (left) and the advertisement lighting at the bus stop (right) is solar-powered with battery storage under the seat	67
Figure 15. Illustrative representation of wind flows around a building showing increasing speed with height and resulting turbulent air movements around the top and sheltered parts of the building.(Not to scale)	70
Figure 16. Examples of roof-mounted micro-turbines include the Swift 2m diameter, horizontal axis, rated at 1.5 kW at 14 m/s wind speed with a ring that reduces noise levels down to 35 decibels (left); the Turby 2.5 kW (at 14 m/s) vertical axis design (centre); and the Aerotecture 1 kW modular system based on a combination of Darrieus and Savonius designs that can be operated horizontally (right) or vertically	71
Figure 17. In the outlet pipe of the 80 year old city water supply dammed reservoir 5 km from the city centre of Palmerston North, New Zealand, four Pelton wheel turbines installed recently generate almost 1 MW of power for use at the nearby water treatment plant . . .	72
Figure 18. A binary geothermal facility commissioned in late 2007 at Landau, Germany, showing heat exchanger pipework (centre) and fan cooling platform (top left), and with the turbine in the white building generating 3 MWe and providing 28 MWth to the local district heating scheme	73
Figure 19. Pipes inserted vertically into a landfill before sealing collect the gas mixture which, if not to be used directly on-site, can be compressed and scrubbed clean of CO ₂ and other contaminants before being injected into a natural gas pipeline for distribution	75
Figure 20. The gas mix changes over time from the commencement of a landfill gas site, with methane reaching a peak before going into slow decline over two to three decades to be taken into consideration when planning for the use of the gas and calculating the overall economics.	75
Figure 21. Combining waste resources from sewage treatment and MSW in a city for conversion to energy can be linked to nearby energy crop production in order to gain nutrient cycling benefits as well as economies of scale.	76
Figure 22. Separating the organic fraction of MSW for anaerobic digestion of it to produce biogas with the dried solid residues combusted for heat and power (Sims, 2002)	77
Figure 23. The concept of a hydrogen-based city of the future.	83
Figure 24. Standard refrigeration cycle based on the phase change of the refrigerant from liquid to gas and driven by electrical energy	87

Figure 25.	Absorption chilling principle driven by heat input to separate the sorbent from the refrigerant and enable the refrigeration cycle to continue.	88
Figure 26.	Simplified illustration of the absorption chilling process for cooling air	89
Figure 27.	Simplified illustration of the adsorption process for chilling water	89
Figure 28.	Electric vehicle charging points have been installed in Paris for several years and more recently by Camden Council, City of London to provide free parking for registered owners whilst recharging the vehicle batteries for up to three hours at no charge	93
Figure 29.	Employment requirements for operation and maintenance jobs for various renewable electricity projects per 100 GWh of energy output, with bioenergy projects requiring additional labour inputs to produce and deliver the biomass to the plant from various sources (IEA, 2007b)	106
Figure 30.	A voluntary carbon market within a community works by those members investing in carbon emission reduction projects such as renewable energy with the ability to sell the “tradeable voluntary action credits” to those wishing to reduce their carbon footprint but unable to do so directly	110
Figure 31.	The hazy Tokyo city skyline shows a number of large PV installations, many now more than 10 years old	117
Figure 32.	1.5kW mini-wind turbine above Wakefield House	127
Figure 33.	Adelaide’s popular public digital art display, Rundle Lantern (left), is powered by a solar photovoltaic system as are the solar “Mallee trees” (right) on the Adelaide Festival Plaza	128
Figure 34.	The Tindo bus is the world’s first to be fully solar-powered using both roof mounted PV panels and a PV recharging system	130
Figure 35.	Examples of buildings in the Vauban suburb with solar PV on their roofs include a car park, a supermarket (just across the boundary in Merzhausen), private houses and an apartment block with the tram to the city centre running on grass covered areas	138
Figure 36.	Wind turbines on Freiburg council-owned land in the Black Forest overlooking the city	138
Figure 37.	Displays of solar, wind and hydro systems are evident in the front of the Freiburg Polytechnic college, where technicians and installers are trained in renewable energy technologies	141
Figure 38.	The 1.5 MW turbines of the 120 MW Te Apiti wind farm under construction (left) and in the foreground (right) are just outside of the Palmerston North city boundary (delineated by the Manawatu Gorge shown by the rising mist). Within the boundary are the original 660 kW turbines of the Tararua wind farm and the 31 recently added 3 MW turbines (seen on the plateau across the gorge). The urban city centre is located 12 km away to the right of the photo, down on the plains	144
Figure 39.	Woodchips from forest residues are used as the renewable energy fuel in the biomass district heating plant (left). A York adsorption cooling unit in the Växjö Energi AB plant converts heat into chilled water for cooling (right)	150
Figure 40.	The 10 MWpeak solar PV plant, located on the edge of the planned city (right), is already producing power for use during the first construction phase	153

Figure 41.	In these conceptual pictures of Masdar City, the PV panels are visible on the building roof (left) and the solar-powered LED street lights are illuminated (right)	155
Figure 42.	The Personal Rapid Transit car, to be powered by renewable energy, will operate non-stop throughout the city subways and eliminate potential traffic congestion if conventional vehicles were to be allowed on the roads	155
Figure 43.	Due to its location, El Hierro has very high renewable energy potential, particularly in wind and hydro due to the rugged terrain and good rainfall, as well as high solar radiation levels	158
Figure 44.	The wind/hydro system uses wind power when available to meet demand and, when in surplus, to pump water to the upper storage used for peak power demands and calm periods	159
Figure 45.	An array of solar thermal collectors heats water to 70°C, which is then piped to local houses for heating. A wind turbine is visible in the background.	162
Figure 46.	Biomass resources, collected from the local district (left), are stored at the fluidised-bed, steam gasification, CHP plant (centre). The methanation pilot plant (right) attached to the CHP plant, produces synthetic natural gas and has been operational since October 2008	166
Figure 47.	Güssing is implementing the concept of “polygeneration” from the wide range of renewable energy resources locally available	167
Figure 48.	Solar-school Güssing uses and demonstrates solar energy systems during training courses that provide information for the craftsmen who consult, design, service, and install renewable energy technologies	168
Figure 49.	The devastated town of Greensburg after the tornado struck.	170
Figure 50.	The 5.4.7 Arts Center, (named after the date of the tornado strike), is the first Leadership in Energy and Environment Design, platinum building in Kansas. It has solar PV panels situated on the ground, eight solar PV panels on the roof and solar lighting installed. The three wind turbines, visible to the rear of the Center, each produce 600 W and are connected to a battery bank	172

List of tables

Table 1.	Summary of energy storage technologies for electricity generation showing applications and response times	48
Table 2.	Types of policy instruments available for use by local governments to encourage deployment of renewable energy technologies within their boundaries. (Framework reproduced from Table 1 of Martinot <i>et al.</i> , 2009, courtesy of REN21, ISEP, and ICLEI, with modifications and additional examples based on IEA, 2007a)	99
Table 3.	Case study cities and towns listed by population showing summary of the relevant policies currently in place as outlined in detail below	115

List of boxes

Box A.	Whispergen domestic CHP technology	57
Box B.	The Barcelona Solar Ordinance.	80

Box C.	Ground Source Heat Pump, Three Rivers District Council, Rickmansworth, England	82
Box D.	Fukuoka hydrogen town, Maebaru, Japan	84
Box E.	Sorption chillers	87
Box F.	Electric light rail powered by wind.	92
Box G.	The Merton Borough initiative	97
Box H.	Employment opportunities	106
Box I.	Funafuti, Tuvalu, South Pacific	114
Box J.	Hydrogen production, Nakskov, Denmark	163