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Towards A Cooler Singapore

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Abstract- Urban heat island, together with urban noise and urban air pollution, are the three major environmental challenges of future more livable cities. Urban heat island is defined as the phenomenon that the air temperature in urban area is consistently higher than its rural area (Oke, 1973). It has posed similar heat-related stress and health issues (Kovats and Hajat, 2008; Lo and Quattrochi, 2003; Oikonomou et al., 2012), higher energy costs (Kolokotroni et al. 2012) and downgraded urban living quality (Mavrogianni et al., 2011).

Earlier studies in Singapore has identified an urban heat island intensity of 4.5 °C (Wong and Chen, 2006). Another study of Chow and Roth (2006) has reported that the maximum urban heat island intensity occurs in central business districts, low-rise and high-rise residential area around six hours after sun sunsets. It is also found that stronger urban heat islands are observed in May to August during Southwest monsoon. The maximum urban heat island intensity could be as high as 7 °C observed at Orchard Road at 9pm.

While many causes of the urban heat island have been identified as in Gartland (2008), the contribution of each component strongly depends on the individual city and its geography. To understand the science behind urban heat island and propose possible countermeasures in Singapore, it is of critical importance to identity each type of heat sources and sinks and their respective contributions.

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I. Heat Sources

a) Solar radiation (93%)

Built-up urban area will absorb solar radiation during daytime and emit heat during nighttime, which is the major heat source of urban heat island. Table 1 shows the total amount solar energy reaches the ground surface of Singapore is around 4,325,871TJ. With an average absorptivity of 0.7, the total amount of absorbed solar energy is 3,028,109TJ. In 2013, the total amount energy demand is 460,452TJ, which is only 15% of the absorbed solar energy. If 50% of the energy used in Singapore finally dissipate into the environment in the form of heat, the absorbed solar energy should account for 93% of total heat of 3,258,335 TJ.

b) Anthropogenic activities (7%)

In 2013, industrial activities in Singapore have consumed 252,078 TJ, which accounts for 4% of the total heat. Traffic in Singapore has consumed 108,490 TJ in 2013, which contributes 2% of the total heat into the environment. Other anthropogenic activities such as household energy consumption will account for the last 1% of the total heat.

II. Heat Sinks

a) Greenery

Greenery in Singapore, which includes trees and grasses, is the major heat sink of the city. Trees have the effects of wind shielding, air cooling, air humidifying, dissipating urban noise and purify urban air. In terms of cooling effects of trees, evapotranspiration contributes most but the exact amount of heat it removes needs to be investigated with more details. Grasses also help to cool down the environment through evaporation.

b) Water bodies

Water bodies include rivers, coastal seas, swimming pools and other water features in the city help to balance the surrounding air temperature by avoiding it to be neither too cold nor too hot. In Singapore, water bodies mainly help to keep the city away from being too hot. More detailed work needs to be done to identify its contribution to mitigating urban heat island in Singapore.

Towards a cooler Singapore, an integrated system which includes solar radiation, buildings together with air conditioners, traffic, greenery and water bodies needs to be established. With this fully coupled system which ensures interactions between all components, we will be able to identify their respective contribution to urban heat island and evaluate proposed mitigation countermeasures.

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Table 1: Solar energy (TJ) reaches the ground surface of Singapore

Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6:01- 7:00	0	0	0	0	0	0	0	0	0	3	3	0
7:01- 8:00	34	31	39	75	83	65	49	44	96	140	132	70
8:01- 9:00	342	360	391	479	481	414	404	378	469	595	541	430
9:01-10:00	777	872	846	973	968	810	857	826	880	1028	958	833
10:01-11:00	1180	1222	1294	1330	1390	1167	1188	1222	1276	1372	1279	1144
11:01-12:00	1504	1644	1563	1726	1662	1462	1582	1514	1558	1576	1494	1380
12:01-13:00	1695	1840	1719	1908	1750	1654	1739	1664	1558	1659	1561	1486
13:01-14:00	1721	1742	1791	1623	1649	1623	1569	1654	1667	1576	1483	1447
14:01-15:00	1582	1809	1631	1781	1519	1574	1636	1530	1462	1411	1343	1390
15:01-16:00	1310	1538	1369	1465	1240	1305	1354	1286	1382	1110	1074	1165
16:01-17:00	934	1038	1002	849	841	906	921	921	898	733	712	818
17:01-18:00	541	632	611	536	435	489	551	515	489	355	334	419
18:01-19:00	140	194	158	122	78	104	142	114	83	39	36	70
19:01-20:00	3	5	3	0	0	0	3	0	0	0	0	0
Daily total	11762	12926	12417	12867	12096	11573	11995	11669	11819	11596	10949	10651
Monthly days	31	28	31	30	31	30	31	31	30	31	30	31
Monthly total	364612	361941	384913	386008	374963	347182	371834	361724	354559	359477	328468	330189
Annual total	4325871											

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