

Supplementary Material.

Defining a quantitative framework for evaluation and optimisation of the environmental impacts of mega-event projects.

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Assumptions for the post-event site design scenarios.

Scenario 1 – ‘Business as Usual’

- Total number of new residential dwellings is 6,800 (4,000 apartments and 2,800 houses). One 10-storey apartment block with the total gross internal floor area of 7,000 m² consists of 100 units (SPONS’s, 2013). One typical UK three bedroom house has a gross internal floor area of 91 m² and a total footprint of 46 m² (Monahan and Powell, 2011). In this scenario assume 40 10-storey apartment blocks with 10 apartments on each floor. The total footprint area of all residential buildings is 408,000 m². The following constraints were introduced for the baseline scenarios:
 - Detached houses – minimum 5% of the total number of the residential dwellings;
 - Semi-detached houses – minimum 5% of the total number of the residential dwellings;
 - Terraced houses – minimum 30% of the total number of the residential dwellings;
 - Bungalows – minimum 2% of the total number of the residential dwellings;

- 2 bedroom flats – minimum 20% of the total number of the residential dwellings;
- 1 bedroom flats – minimum 20% of the total number of the residential dwellings.
- Two typical 13-storey London offices with the gross internal floor area of 21,300 m², net internal floor area of 14,600 m² and a total footprint of 1,638 m² and 4 small industrial units with the gross internal floor area and a total footprint of 900 m² (SPON's, 2013). Total footprint of all commercial buildings is 46,200 m². The following constraints were introduced for the baseline scenarios:
 - Office type 1 (no canteen, naturally ventilated cellular) – minimum 3% of the total area of all commercial offices;
 - Office type 2 (no canteen, naturally ventilated open plan) – minimum 0.3% of the total area of all commercial offices;
 - Office type 3 (with canteen, air conditioned standard) – minimum 95% of the total area of all commercial offices.
- Two community centres with the gross internal floor area and the total footprint of 860 m² (SPON's, 2013).
- 40 fast food restaurants (total floor area of 1 fast food restaurant is 100 m²) and 40 medium size restaurants (total floor area of 1 medium size restaurant is 743 m²), with the total floor area of 33,720 m².
- One 10-storey hotel with the total floor area of 16,800 m², net internal floor area of 6,720 m² and a total footprint of 1,680 m².
- Total retail area is assumed to be equal to the size of 3 average supermarkets each with the gross internal floor area of 7,530 m². Total floor area is 22,590 m².

Scenario 2 – ‘Commercial World’

- Ten 10-storey apartment block with 10 apartments on each floor with the total floor area of all apartment blocks being 70,000 m². The following constraints were introduced for the baseline scenarios:
 - 2 bedroom flats – minimum 40% of the total number of the residential dwellings;
 - 1 bedroom flats – minimum 10% of the total number of the residential dwellings.

- 15 typical 13-storey London offices each with the floor area of 21,300 m² and 30 industrial units each with the floor area of 900 m². Total internal floor area of all commercial buildings is 4,180,500 m². The following constraints were introduced for the baseline scenarios:
 - Office type 1 (no canteen, naturally ventilated cellular) – minimum 1% of the total area of all commercial offices;
 - Office type 2 (no canteen, naturally ventilated open plan) – minimum 40% of the total area of all commercial offices;
 - Office type 3 (with canteen, air conditioned standard) – minimum 25% of the total area of all commercial offices;
 - Office type 4 (with canteen, air conditioned prestige) – minimum 25% of the total area of all commercial offices.
- 50 fast food outlets and 20 medium size restaurants with a total floor area of 19,860 m². Assume 50% of the restaurant buildings are 1-storey and 50% are two-storey buildings.
- Total retail area is assumed to be equal to the size of 5 average supermarkets with the total internal floor area of 37,650 m². Assume that the total footprint area is 70% of the total internal floor area.
- 5 hotels with the total internal floor area of 84,000 m².
- 1 community centre with the total floor area of 860 m².

Scenario 3 – ‘High rise, high density’

- 40 high rise residential buildings (50% of the residential buildings are 20-storey buildings and 50% are 30-storey). Each floor has a total area of 898 m², thus the total floor area of all residential buildings is 898,000 m². Assume that there are 8 apartments on each floor of the residential building. Therefore, the total number of apartments is assumed to be 16,000. The following constraints were introduced for the baseline scenarios:
 - 3 bedroom flats – minimum 30% of the total number of the residential dwellings;
 - 2 bedroom flats – minimum 20% of the total number of the residential dwellings;

- 1 bedroom flats – minimum 20% of the total number of the residential dwellings.
- 30 high rise office buildings (50% of the office buildings are 25-storey, 50% are 30-storey buildings). Each floor has a total area of 2,563 m² (Yan et., 2010). Total internal floor area of all office buildings is 2,114,475 m². The following constraints were introduced for the baseline scenarios:
 - Office type 1 (no canteen, naturally ventilated cellular) – minimum 1% of the total area of all commercial offices;
 - Office type 3 (with canteen, air conditioned standard) – minimum 4 % of the total area of all commercial offices;
 - Office type 4 (with canteen, air conditioned prestige) – minimum 90% of the total area of all commercial offices.
- Total area of retail space is equal to the size of 15 supermarkets each with the floor area of 7,530 m². Total floor area is 112,950 m². Assume that 1/3 of the total area is comprised of 2-storey buildings, the rest are 1-storey buildings.
- 7 community centres with the total floor area of 6,020 m².
- 10 small industrial units with the total area of 9,000 m².
- 5 20-storey hotels with the total floor area of 168,000 m².
- 10 large restaurants (each with a floor area of 1,858 m²), 30 medium size restaurants (each with a floor area of 743 m²) and 100 fast food outlets (each with a floor area of 100 m²). Total floor area of all restaurants is 50,870 m².

Energy, water and transportation fuel consumption data and emissions conversion factors.

Table I. Energy consumption in residential and non-residential buildings.

	Electricity consumption	Gas consumption	Unit	Reference
Residential dwellings:				
Detached house	4,500	18,000	kWh/year	DECC, 2013
Semi-detached house	3,600	13,900	kWh/year	DECC, 2013
End terrace house	3,400	12,500	kWh/year	DECC, 2013
Mid terrace house	3,200	11,600	kWh/year	DECC, 2013
Bungalow	3,100	13,200	kWh/year	DECC, 2013
Flat (converted)	2,700	8,900	kWh/year	DECC, 2013
Flat (purpose built)	2,500	7,100	kWh/year	DECC, 2013
Offices:				
Type 1. Naturally ventilated cellular	54	151	kWh/m ² /year	ECG19, 2000
Type 2. Naturally ventilated open-plan	85	151	kWh/m ² /year	ECG19, 2000
Type 3. Air-conditioned, standard	226	178	kWh/m ² /year	ECG19, 2000
Type 4. Air-conditioned, prestige	358	210	kWh/m ² /year	ECG19, 2000
Retail:				
Average UK supermarket	1,500	250	kWh/m ² /year	Tassou et al., 2011.
Schools and nurseries:				
Primary schools and nurseries	43	139	kWh/m ² /year	Hong, S-M et al., 2013
Secondary schools	51	136	kWh/m ² /year	Hong, S-M et al., 2013
Restaurants and bars:				
Restaurant with bar	219	511	kWh/m ² /year	CIBSE, 2012
Restaurants in public house	450	1,050	kWh/m ² /year	CIBSE, 2012
Fast food outlet	267	623	kWh/m ² /year	CIBSE, 2012

Hospitals and medical centres:				
Hospital	471	314	kWh/m ² /year	Pérez-Lombard et al., 2007
Medical centre	44	104	kWh/m ² /year	EMSL, 2009.
Hotels:				
Budget hotel	150	160	kWh/m ² /year	HES, 2011, Bohdanowicz and Martinac, 2007
Luxury 4/5 star hotel	160	180	kWh/m ² /year	HES, 2011, Bohdanowicz and Martinac, 2007
Regular sports venues:				
Leisure pool centre	258	1321	kWh/m ² /year	ECG78, 2001
Fitness centre	194	449	kWh/m ² /year	ECG78, 2001
Olympic sports venues:				
Olympic Stadium	31169	24,349	kWh/day	London2012, 2010
Aquatic Centre	19,481	16,970	kWh/day	London2012, 2010
Hockey Centre	12,987	7,378	kWh/day	London2012, 2010
Velodrome	11,039	5,903	kWh/day	London2012, 2010
Basketball Arena	14,286	8,854	kWh/day	London2012, 2010
Handball Arena	11,688	6,641	kWh/day	London2012, 2010
Fencing Arena	11,039	5,903	kWh/day	London2012, 2010
IBC	64,935	29,513	kWh/day	London2012, 2010
MPC	16,234	11,068	kWh/day	London2012, 2010
Cauldron	0	9,464	kWh/day	London2012, 2010

Table II. Water consumption in residential and non-residential buildings.

Building type	Daily demand	Unit	Occupancy	Reference
Residential dwellings:				
Detached house (4 bedrooms)	145	litres per person	3.2 person	ODA, 2011
Semi-detached house (3 bedrooms)	158	litres per person	2.6 person	ODA, 2011
End terrace house (2 bedrooms)	176	litres per person	1.9 person	ODA, 2011
Mid terrace house (2 bedrooms)	176	litres per person	1.9 person	ODA, 2011
Bungalow (3 bedrooms)	158	litres per person	2.6 person	ODA, 2011
Flat (converted) (2 bedrooms)	179	litres per person	1.8 person	ODA, 2011
Flat (purpose built)	197	litres per person	1.3 person	ODA, 2011
Offices:				
Offices with canteen	2.25	litre/m ²	-	ODA, 2011
Offices without canteen	2.1	litre/m ²	-	ODA, 2011
Retail:				
Average UK supermarket	5	litres/m ²	-	Envirowise, 2002
Small store	3	litres/m ²	-	Envirowise, 2002
Schools and nurseries:				
Primary schools and nurseries	20	litres per pupil	-	DfES, 2002
Secondary schools	30	litres per pupil	-	DfES, 2002
Restaurants and bars:				
Typical medium-sized restaurant	54	litres/m ²	-	Dziegielewski et al., 2000.
Typical large bar and restaurant	147	litres/m ²	-	Dziegielewski et al., 2000.
Fast food outlet	90	litres/m ²	-	Dziegielewski et al., 2000.
Hospitals and medical centres:				
Hospitals	4.6	litres/m ²	-	DoH, 2013
Medical/health centre	2.5	litres/m ²	-	DoH, 2013
Hotels:				
Budget hotel	150	litres per bed-space	-	ODA, 2011
Luxury 4/5 star hotel	200	litres per bed-space	-	ODA, 2011
Olympic Sports Venues:				
Spectator	2	litres per spectator per hour	-	ODA, 2011

Staff	35	litres per staff per day		ODA, 2011
Competitors – all except for aquatic	35	litres per competitor per event		ODA, 2011
Competitors – aquatic	60	litres per competitor per event		ODA, 2011
Irrigation:				
Total amount of water required for irrigation during construction and Games phases (MI)	74.55	ML		ODA, 2011
Total amount of water required for irrigation of green space during 1 year of legacy phase (MI)	3.43	ML		ODA, 2011

Table III. Emissions conversion factors for water, electricity, natural gas and transportation fuels.

Fuel	Unit	Emissions conversion factor	Reference
UK electricity	kg CO ₂ -eq/kWh	0.45	DEFRA, 2014
UK water supply	kg CO ₂ -eq/l	0.34	DEFRA/DECC, 2011
UK water treatment	kg CO ₂ -eq/l	0.709	DEFRA/DECC, 2011
Natural gas	kg CO ₂ -eq/kWh	0.18	DEFRA, 2014
Petrol (average biofuel blend)	kg CO ₂ -eq/l	2.21	DEFRA, 2014
Diesel (average biofuel blend)	kg CO ₂ -eq/l	2.601	DEFRA, 2014
Passenger car - petrol (average)	kg CO ₂ -eq/km	0.198	DEFRA, 2014
Passenger car - diesel (average)	kg CO ₂ -eq/km	0.183	DEFRA, 2014
London bus	kg CO ₂ -eq/passenger.km	0.103	DEFRA, 2012
Rail	kg CO ₂ -eq/passenger.km	0.076	DEFRA, 2012
Coach	kg CO ₂ -eq/passenger.km	0.036	DEFRA, 2012
Eurostar	kg CO ₂ -eq/passenger.km	0.017	DEFRA, 2012
Ferry	kg CO ₂ -eq/passenger.km	0.16	DEFRA, 2012
Longhaul flight-economy	kg CO ₂ -eq/passenger.km	0.17	DEFRA, 2014
Longhaul flight-first	kg CO ₂ -eq/passenger.km	0.67	DEFRA, 2014
Shorthaul flight-economy	kg CO ₂ -eq/passenger.km	0.18	DEFRA, 2014
Shorthaul flight-business	kg CO ₂ -eq/passenger.km	0.28	DEFRA, 2014
Domestic flight	kg CO ₂ -eq/passenger.km	0.33	DEFRA, 2014
Freight transport - rail	kg CO ₂ -eq/tonne.km	0.063	DEFRA, 2014
Freight transport - barge	kg CO ₂ -eq/tonne.km	0.1	DEFRA, 2014
Freight transport - road	kg CO ₂ -eq/tonne.km	0.112	DEFRA, 2014

Table IV. Estimated annual number of spectators, visitors and employees in the sports venues operating on site in the legacy phase (assuming only 5 permanent venues are in operation) (ODA, 2011).

Venue	Number of spectators	Number of competitors	Number of staff
Olympic Stadium	310,000	8,000	6,300
Aquatic Centre	50,000	700,000	14,725
Hockey Centre	98,550	152,231	17,350
Handball Arena	130,000	202,875	15,025
Velodrome	547,570	179,180	50,735

Table V. Estimated daily number of competitors, staff and spectators in the Olympic Park sports venues during the Games period (ODA, 2011).

Venue	Number of spectators	Number of competitors	Number of staff
Broadcast Centre			54,120
Aquatic Centre	17,500	6,388	1,460
Olympic Stadium	80,000	426	9,316
Etonmanor	3,520	4,310	498
Handball Arena	5,520	228	546
Velodrome	3,120	224	256
Hockey Centre	10,610	140	1,241
Basketball Arena	10,620	173	1,815
Fencing Arena	4,320	86	637
Waterpolo	2,100	42	345
Sponsors' Village			14,182
Security			5,400
Catering	200,000		

Table VI. Embodied emissions coefficients for construction materials (Hammond and Jones, 2008b).

Building material	Embodied carbon (kg CO ₂ -eq/kg)
Aggregate	0.01
Aluminium	11.46 (recycled 1.59)
Asphalt	0.14
Bitumen polymer	0.48
Blockwork, medium weight	0.22
Brass	2.42
Bricks	0.22 (reclaimed 0.04)

Bronze	4.1
Carpet	3.9
Ceramics (tiles)	0.65 (reclaimed 0.22)
Copper	3.01
Concrete C40	0.17
Glass	0.85
Glass cladding	1.27
High density Polyethylene (HDPE)	1.6
Insulation	1.86
Iron	1.91
Lead	1.33
Linoleum	1.21
Low density Polyethylene (LDPE)	1.7
Paint (wet)	3.56
Paper	1.32
Plasterboard	0.38
Plastics	2.53
Plywood	0.81
Polymeric roof insulation (PVC)	2.41
Polystyrene, insulation	2.7
Precast concrete	0.22
Reinforced cement (precast concrete)	0.22
Reinforced concrete (RC30)	0.24
0.75% reinforced concrete	0.18
1% reinforced concrete	0.18
1.5% reinforced concrete	0.19
2% reinforced concrete	0.2
2.5% reinforced concrete	0.21
3% reinforced concrete	0.22
Reinforced concrete	0.18
Roof cladding - polycarbonate fabric	6
Rubber	3.18
Sand	0.01
Sealants and adhesives	3.85
Steel (structural)	2.77
Steel	2.75 (recycled 0.43)
Stone	0.06 (reclaimed 0.04)
Temporary roof membrane	2.7
Temporary steel structure	2.75
Timber	0.46 (reclaimed 0.06)
Tin	13.7
Toughened glass	1.27
Vinyl flooring	2.29
Windows	0.85
Zinc	3.31