Table 8. Annual gross output of industry at current prices by industry activity in HCMC and population of HCMC over the years provided by the HCMC Statistical Yearbook.

Year	2009	2010	2011	2012	2013	2014	2015	2016
Annual gross output of industry at current prices by industry activity (millions of USD)	22.43	25.74	27.61	29.48	32.51	35.5	38.1	41.36
Population (1000 people)	5981	6189	6406	6629	6861	7100	7348	7605

Table 9. Electricity consumption of manufacturing industry and construction and residential sectors and grid emission factors in HCMC (2013, 2014, 2015), provided by Electricity of Vietnam (EVN).

Item	2013	2014	2015
Electricity consumption from manufacturing industry and construction sector ($kWh\,yr^{-1}$)	7 186 161.42	7 557 369.66	8 094 021.38
Electricity consumption from residential sector ($kWh\,yr^{-1}$)	7 073 622.59	7 452 131.41	8 132 452.78
Grid emission factors (ton of CO_2 MWh^{-1})	0.75	0.78	0.79

et al. (2019). Urban morphology maps include three land use types most commonly associated with urban emissions: residential, commercial and industrial land. In this study, the industrial emission sector is considered an area source instead of point source like in previous studies. Identification of the three land use type areas (residential, commercial and industrial) was based on the hypothesis that each land use typology generally follows a distinct morphology with regards to the height of structures and nighttime artificial lighting. Therefore, urban morphological maps were prepared at 30 m spatial resolution by classifying digital building heights and nighttime light over each pixel into the three land use types.

Digital building heights were extracted from publicly available ALOS World 3D (AW3D30) digital surface model (DSM) data at 30 m resolution. A DSM is a representation of visible geological Earth terrain and any other features (tree and crop vegetation, built structures, etc.) occurring over the ground terrain. The AW3D DSM was generated using images acquired from PRISM's (Panchromatic Remote-Sensing Instrument for Stereo Mapping) front, nadir and backward-looking panchromatic bands aboard ALOS (Advanced Land Observing Satellite) between 2008 and 2011. It is publicly available at 1 s (30 m) horizontal resolution from JAXA (http://www.eorc.jaxa.jp/ALOS/en/aw3d30/, last access: 18 September 2017). The AW3D DSM generally meets the 5 m root-mean-square target height accuracy as per its producers (Tadono et al., 2015). To extract the height of features that do not form part of the terrain (known as normalized digital surface model or nDSM), first a continuous ground terrain (known as digital terrain model or DTM) needs to be constructed, which can then be differenced from the DSM (Eq. 6). A multidirectional processing and slope-dependent (MSD) filtering approach was used for DTM extraction and is further described in Misra et al. (2018). Accordingly, the MSD filtering technique requires four parameters to generate a DEM: the Gaussian smoothing kernel size, the scan line filter extent, the height threshold and the slope threshold. Each DSM pixel was checked to determine whether it should be considered ground by comparing it with other pixels within the predefined neighborhood scan line filter extending in eight directions. If the pixel was identified as a ground pixel in more than five directions, it was labeled as a terrain pixel by the majority voting method. To draw the comparison, a local reference terrain slope was first generated by 2D Gaussian smoothing. Then, the pixel's height was compared with the lowest elevated pixel within the scan line filter extent. If this height difference was more than the height threshold parameter, the pixel was classified as a non-ground pixel. Then, if the slope difference between the current and the successive pixel in the scan line direction was greater than the slope threshold, it was labeled as a non-ground pixel. If the slope was positive and less than the slope threshold, then that pixel was given the same label as its previous pixel. Otherwise, that pixel was labeled as ground.

$$\mathrm{nDSM} = \mathrm{DSM} - \mathrm{DTM} \tag{6}$$

To ascertain that the height of the extracted features was indeed from the built-up structures and not features like trees, a built-up class binary mask was generated and multiplied with the corresponding pixels in the nDSM raster to generate nDSM for built-up area (subsequently referred to as digital building height). A time series of Landsat imagery (Landsat 7 for 4 years: 2009 to 2012 and Landsat 8 for 4 other years: 2013 to 2016) was classified to generate the urban built-up extent for 2009 to 2016. A Mahalanobis-distance-based supervised classification was performed to identify five classes (including built-up, vegetation, fallow land, lake and river).

Nighttime light was obtained using the VIIRS (Visible Infrared Imaging Radiometer Suite) DNB (Day–Night Band) monthly images for the year 2014. The VIIRS DNB was freely obtained from https://ngdc.noaa.gov/eog/viirs/ (last access: 28 October 2017); its spatial resolution of approx-

Table 8. Annual Gross output of industry at current prices by industry activity in HCMC and Population of HCMC over years provided by HCMC Statistical Yearbook

Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Annual Gross output of industry at current prices by industry activity (Mil. USD)	22.43	25.74	27.61	29.48	32.51	35.5	38.1	41.36
Population (Mil. people)	5.98	6.19	6.41	6.63	6.86	7.10	7.35	7.61

Table 14. Comparison of sharing ratios of emission from MC and personal car (PC) in this study and previous studies for 2010 and 2013 (Unit: %)

Unit (%)	**Ho, B. Q., 2010**	**N.T.K.Oanh et al, 2015**		***This study***		
	2010	**2013**		***2010***	***2013***	
	MC	**MC**	**PC**	***MC***	***MC***	***PC***
CO	94	85	12	*94.40*	*94.60*	*3.50*
NOx	29	80	14	*15.60*	*13.20*	*14.90*