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APEC Low Carbon Model Town (LCMT) Project Dissemination Phase 2

Feasibility Study Report - Da Lat City, Viet Nam

APEC Energy Working Group

June 2020

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List of Abbreviations

2W	Two-Wheeler
4W	Four-Wheeler
APEC	Asia-Pacific Economic Cooperation
BEMS	Building Energy Management System
HEMS	Home Energy Management System
CEMS	Cluster/Community Energy Management System
BRT	Bus Rapid Transit
CAGR	Compounded Annual Growth Rate
CHP	Combined Heat and Power
CH_4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
Cogen	Cogeneration
COP	Coefficient of Performance
COP15	UNFCCC's 15^{th} Conference of Parties
°C	Degree Celsius
°F	Degree Fahrenheit
DCS	District Cooling System
EE	Energy Efficiency
EFLH	Equivalent Full Load Hours
EMM9	9^{th} APEC Energy Ministers Meeting
EMS	Energy Management System
EV	Electric Vehicles
ExSS	Extended Snap-Shot
GAMS	General Algebraic Modelling System
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GGAP	Da Lat Green Growth Action Plan
GSHP	Ground Source Heat Pump
GWh	Gigawatt hour
ha	Hectare
HVAC	Heating, Ventilation and Air Conditioning
IFC	International Finance Corporation
JICA	Japan International Cooperation Agency
kg	Kilogram
KII	Key Informant Interview
km	Kilometre
$ktCO_2e$	Kilo tonne of CO_2 equivalent
KTOE	Kilo-tonne of oil equivalent

kWh	Kilowatt Hour
LED	Light Emitting Diode
LCD	Low-Carbon Development
LCI	Low-Carbon Intervention
LCM	Low Carbon Measures
LCMT	Low-Carbon Model Town
LCT-I	APEC Low-Carbon Town Indicator
LULUCF	Land-Use Change and Forestry
MOIT	Ministry of Industry and Trade, Government of Viet Nam
mm	Milli-metre
MSW	Municipal Solid Waste
$MtCO_2e$	MIllion tonne of CO_2 equivalent
MW	Mega Watt
MWh	Mega Watt-hour
O&M	Operation and Maintenance
PPC	People's Committee of Lam Dong Province
PV	Photo Voltaic
RE	Renewable Energy
RON	Research Octane Number
sqkm	Square kilometre
tCO_2e	Tonne of CO_2 emissions equivalent
TOD	Transit Oriented Development
TODSF	Transit-Oriented Development Strategic Framework
TOE	Tons of Oil Equivalent
ToR	Tons of Refrigeration
URENCO	Ha Noi Urban Environment Company
USD	United States Dollar
VND	Vietnamese Dong
VNEEP	Viet Nam Domestic Energy Efficiency Programme
WtE	Waste to Energy

1 Executive Summary

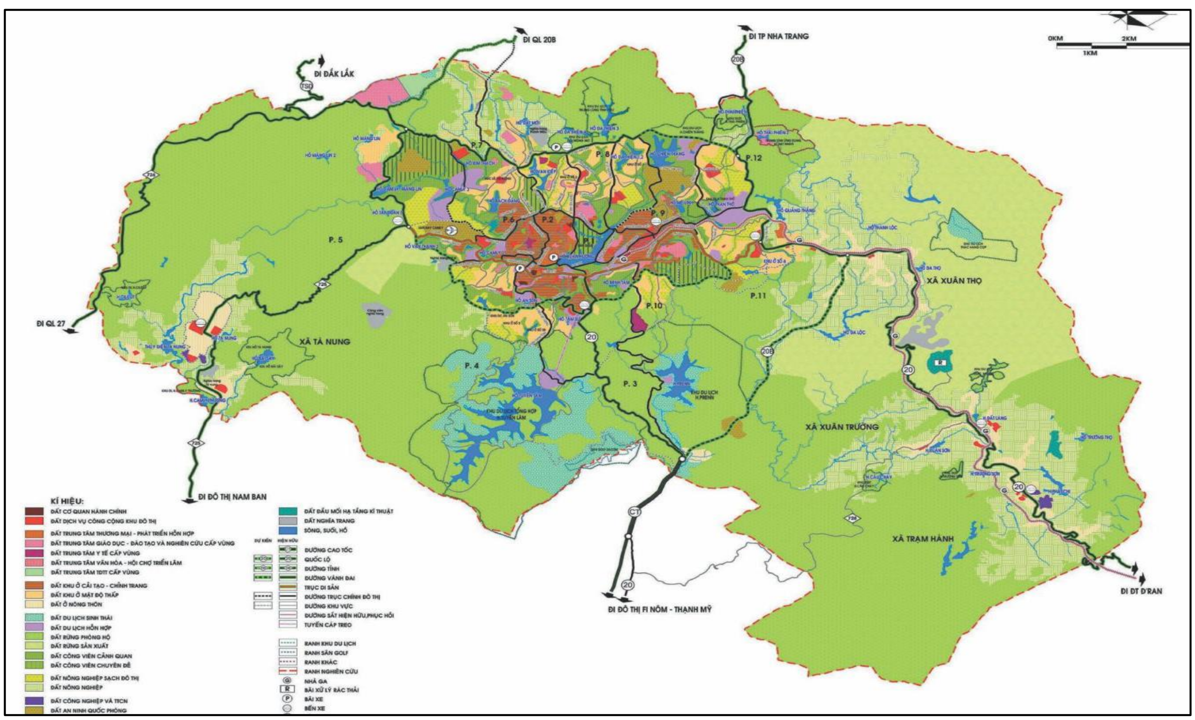
Level of urbanization has been witnessing unprecedented growth in APEC economies – it was 68.5% in 2010, which will increase to 80.9% by 2050. This has led to increased energy consumption – primary energy consumption in 2008 witnessed an 84.2% and 26.2% increase over 1990 and 2000 consumption levels respectively. This increased level of energy consumption will lead to increased emissions which can lead to detrimental effects on health and overall Quality of Life for the citizens.

In order to address the issue of CO_2 emission, Ministers attending the 9th APEC Energy Ministers Meeting (EMM9) in 2010 observed that "Introduction of low-carbon technologies in city planning to boost energy efficiency and reduce fossil energy use is vital to manage rapidly growing energy consumption in urban areas of APEC*"*. This led to the development of APEC Low-Carbon Model Town (LCMT) Project to encourage creation of low-carbon communities in urban development plans and share best practices for making such communities a reality. Subsequently, Low-Carbon Model Town concept for 7 cities have been prepared and refined and as a follow-up step, the project dissemination was initiated to accelerate the adoption of low-carbon interventions. The current project constitutes Phase 2 of Project Dissemination wherein two volunteer towns in Viet Nam (Da Lat) and Philippines (Davao) have been nominated.

In order to proceed with the development of Low Carbon Development (LCD) Strategy and subsequent feasibility study of the recommended low carbon interventions, the baseline assessment of the volunteer town, Da Lat was undertaken. This included analysis of geographic and demographic data; administrative structure; local economy; basic infrastructure, energy and resources; land-use structure and policies and targets related to low carbon strategies relevant to the volunteer town.

Overview of Volunteer Town: Da Lat (Viet Nam)

As shown in the figure below, this project will conduct Feasibility Study for the volunteer town Da Lat in Viet Nam:



Source: Vebando.com

Figure 1: Map of Da Lat

Nestled in Central Highlands region of Viet Nam, Da Lat is the capital of Lam Dong province and is the seat of the provincial administration as well as a separate city level administration. The city, comprising of rural and urban areas, has nearly 53% of its area as forest land and 35% of the area as agricultural land. The city has mostly temperate climate with temperatures hovering between 14°C - 23°C, with average annual sunshine hours exceeding 2000 hours. The city has been witnessing a population growth of 0.98% between 2010 and 2016, reaching approximately 227,000 by 2017. The local economy is dependent on agriculture and tourism and has connectivity with domestic and international locations through extensive road network and air travel infrastructure as well.

Energy consumption is in buildings sector (residential and commercial), agriculture, transportation and energy supply especially power supply[1]. Da Lat receives its power supply from the domestic grid and has no power generation plants within its boundaries, except for the Cau Dat Wind Power project which is expected to start production in 2020. The structure of the city is also set to change based on 2014 directive which will bring in surrounding areas under the boundaries of Da Lat, expanding the area from 394 sqkm to around 3359 sqkm.

The city implements a number of policies and initiatives, focused on emission reduction and sustainable development. The table below gives the brief of the areas where domestic level, provincial level and city level policies address areas with a potential to reduce emissions:

Table 1: Brief of policies with potential to reduce emissions

Policy Name	Sectors Covered	About Policy
Domestic Strategy on Climate Change	Power generation Energy efficiency Industries Transportation Agriculture Waste Management	The document acknowledges threat posed by climate change on Viet Nam and provides strategic viewpoints, targets and sector-wise missions along with implementation phasing and accountability for the missions. Specific target in the document is to develop a low-carbon economy and undertake green growth into main orientations for sustainable development; lower emission and higher absorption of greenhouse gases
Domestic Green Growth Strategy	Energy efficiency Industry Transportation Renewable energy Agriculture Waste Management Urban Planning	Document enumerates targets required to be undertaken to achieve the objective of green growth. Targets for three period 2011-20, 2020-30 and 2030-50 provided with reduction GHG emission intensity, reduction in overall GHG emission and reduction in energy consumption per unit GDP.
Law on Economical and Efficient Use of Energy	Industry Construction and public lighting Transport Agriculture Building	Law provides a view of providing economical and efficient use of energy and includes the measures to promote it along with the obligation and responsibilities of organizations, households and individuals in this regard. The law is supplemented with 2 decreed which support implementation – one which explains provisions of the law and the other provides applicable penalties and fines for violation

[1] Note: Energy consumption in supply side is considered on the basis of the losses in the conversion processes as well as the fuel consumed in generation of power

Policy Name	Sectors Covered	About Policy
Viet Nam Domestic Energy Efficiency Plan 2019-2030	Industry Transportation Construction	Part of a comprehensive plan to institute measures for improving energy efficiency and conservation in all sectors of the economy in Viet Nam. It expects to achieve contribute to reduced investment in energy supply system development, ensure energy security, environmental protection; rational exploitation of energy resources, and overall sustainability for socioeconomic development.
Lam Dong Provincial Green Growth Action Plan	Yet to be finalized	This document is being prepared with alignment Domestic Strategy on Green Growth and will contain provincial vision up to 2030, along with a set of key target indicators for green growth of different sectors.
Da Lat Green Growth Action Plan	Commercial & Residential Buildings Public Lighting Power distribution Transport Agriculture Town planning	Prepared in line with the Domestic Green Growth Action Plan, document outlines city specific objectives, targets and interventions to provide green orientation of future growth path of Da Lat. System of solutions set up for 5 groups viz. improving capacity and institutions, raising awareness, reducing intensity of GHG emissions, greening production, greening lifestyle and promoting sustainable consumption.

CO_2 Emission Estimation in the Base Year 2017 (Business as Usual Scenario):

In 2017, the economy's total final energy consumption reached 207 KTOE, up by 11% from its 2016 level of 187 KTOE. Transport and Energy Supply are the major energy consuming sectors in case of Da Lat, accounting for more than 98% of total energy consumed in 2017. The table below provides details of the energy consumption for Da Lat between 2010 and 2017:

Table 2: Sector level energy consumption for Da Lat

DA LAT	Energy Consumption (in KTOE)							
Sector	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Buildings (Residential & Commercial)	0.040	0.040	0.042	0.043	0.044	0.045	0.048	0.050
Transport	82.609	82.756	79.068	77.078	79.066	87.125	100.565	105.192
Agriculture (Fishery & crop production	0.448	0.431	0.689	0.739	0.881	1.161	1.412	1.957
Energy Supply	9.203	13.167	24.975	36.925	54.458	67.254	84.777	99.523
TOTAL	**92.300**	**96.394**	**104.773**	**114.785**	**134.449**	**155.585**	**186.803**	**206.722**

The GHG emission due to the energy consumed above in 2017 is **0.608 $MtCO_2e$**. Based on the information in GHG emissions released by MOIT (MOIT, 2017), GHG emission for Viet Nam in the year 2017 is projected to be 187.6 $MtCO_2e$ which means Da Lat city contributes to approximately 0.3% of the total GHG emissions of the entire economy.

Low Carbon Measures Suggested:

In order to minimize the GHG emissions in Da Lat, the following low carbon measures have been proposed for different sectors of the economy:

Table 3: Summary of low-carbon interventions for Da Lat

Sector	Emission in 2030 under BAU scenario ($ktCO_2e$)	Low Carbon Interventions (LCI) Proposed	Emission in 2030 after implementing LCI ($ktCO_2e$)
Transport	470	• Electrification of buses • Electrification of 2W • Increased use of biofuel in taxis	367
Buildings	0.347	• Implementing EE in buildings	0.344
Energy Supply	2910.00	• Promotion of solar rooftop system • Aggregated cooling system using trigeneration power systems • Waste-to-energy system	2909.97

Apart from the above, there are interventions proposed for Agriculture sector (i.e. installation of garden houses, regulation of greenhouses) as well as for town structure (i.e. installation of green corridors). These interventions are recommended for the proposed extension area of the city and hence, estimation of the benefits would be contingent on the proposed planning for the area.

Based on the intervention set given above, Da Lat can potentially cut cumulative emissions of 886.35 $ktCO_2e$ between 2020 and 2030 and will constitute 5.8% of the total emissions of the city in 2030. The figure below gives the visual representation of the emission reduction at city level by implementing the recommended low carbon initiatives:

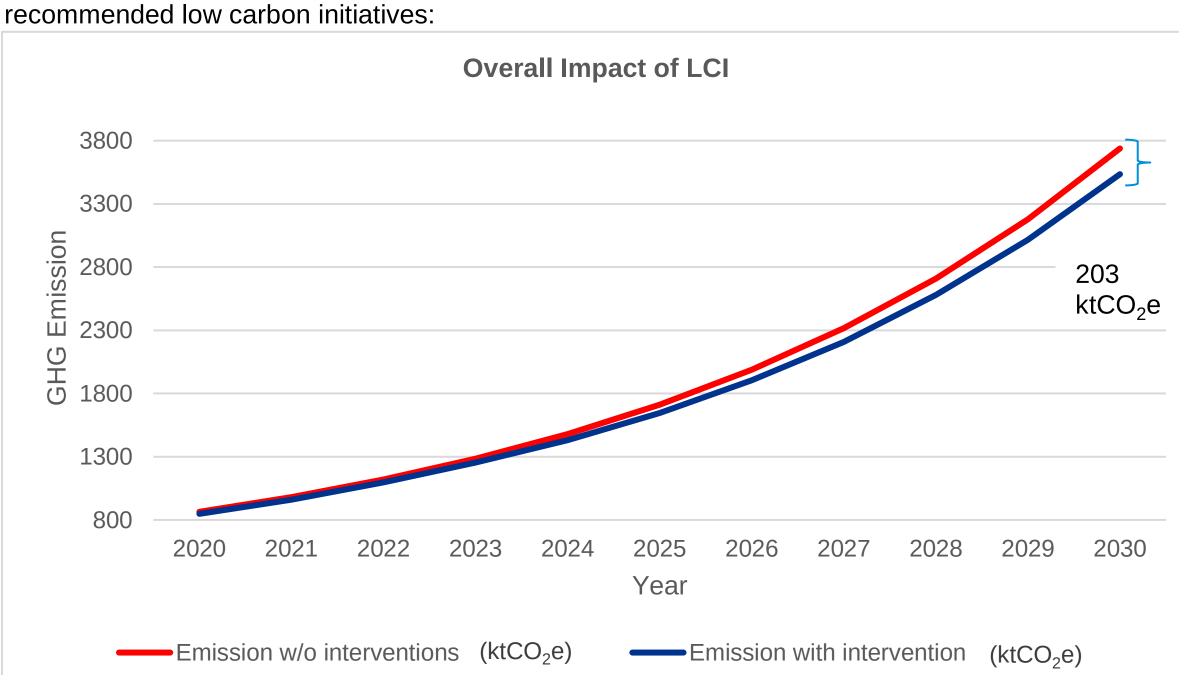


Figure 2: Impact on emissions due to low carbon interventions

2 Project Background

The APEC region[2] has been witnessing increasing urbanization in recent years and this trend is expected to continue in the near future as well – level of urbanization in all APEC economies was 68.5% in 2010, which will increase to 80.9% by 2050 (APEC, 2011). The growing rate of urbanization has had a cascading effect on the energy consumption – primary energy consumption in 2008 witnessed an 84.2% and 26.2% increase over 1990 and 2000 consumption levels respectively (APEC, 2011). With the expected growth in urbanization, the energy consumption levels is expected to carry on the upward trajectory in the future as well. Such increase in energy consumption will directly impact CO_2 emission in the atmosphere. Hence, if current trend of consumption continues unabated, level of CO_2 emission will reach harmful levels as well as lead to other detrimental effects like increase traffic congestion, overpopulation that will lead to decreased Quality Of Life for the citizens.

In the background of these facts, Ministers attending the 9th APEC Energy Ministers Meeting (EMM9) in 2010 observed that "*Introduction of low-carbon technologies in city planning to boost energy efficiency and reduce fossil energy use is vital to manage rapidly growing energy consumption in urban areas of APEC".* Responding to this observation, they called for the APEC Energy Working Group (EWG) to implement an APEC Low-Carbon Model Town (LCMT) Project *to encourage creation of low-carbon communities in urban development plans and share best practices for making such communities a reality*".

The concept of LCMT is to provide a basic principle and framework to assist central and local government officials to plan policies and implementing measures ensuring CO_2 emission reduction taking in to account prevalent socio-economic conditions and city-specific characteristics. The LCMT Project previous phases consists of two activities:

1. Development of "Concept of the Low-Carbon Town in the APEC Region"
2. "Feasibility Study" and "Policy Review" of planned development projects as examples of real-life applications of the concept.

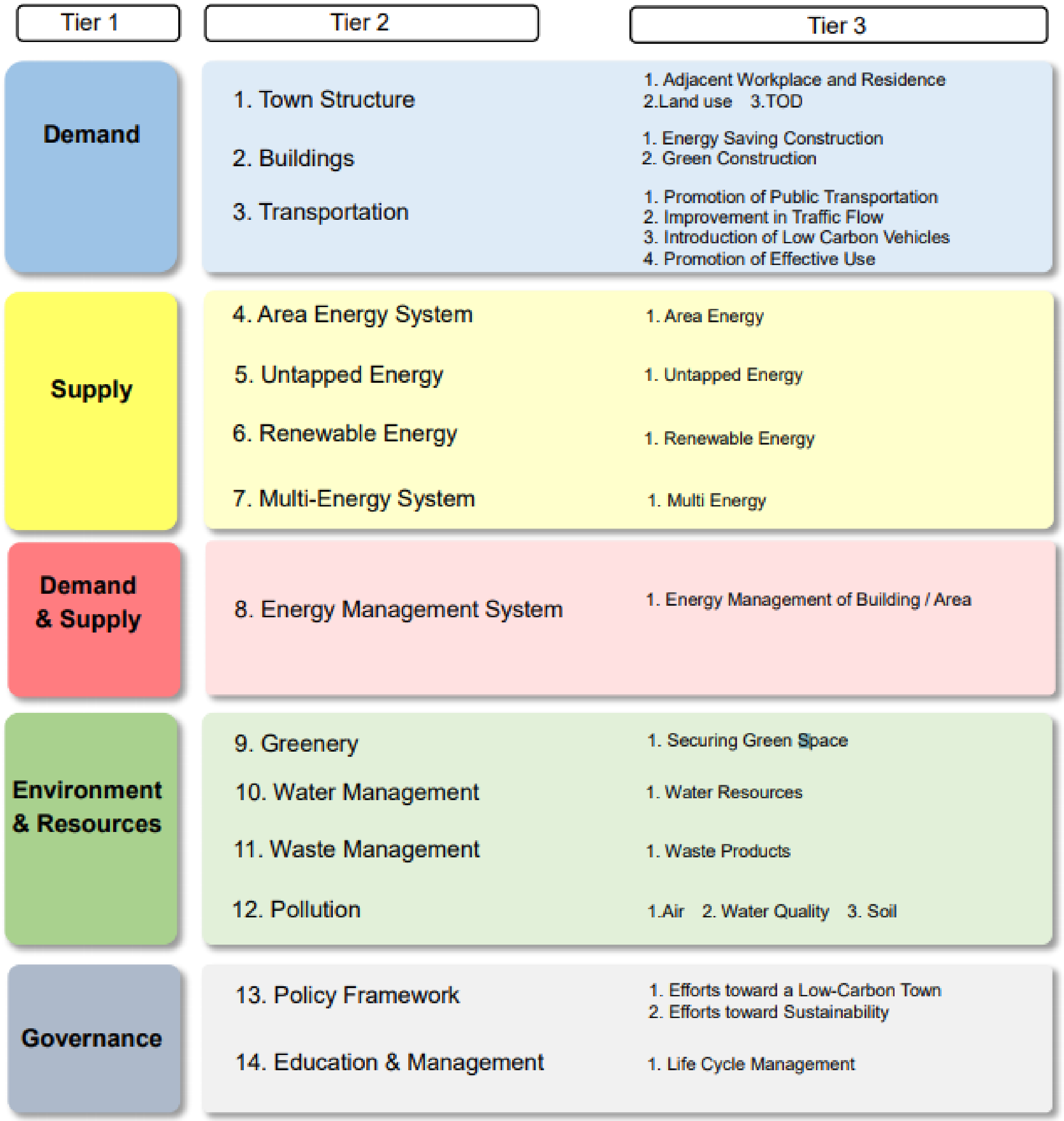
As an outcome of the project, Low-Carbon Model Town concept for 7 cities have been prepared and refined in 7 phases[3]. Through the process of developing the outputs of these studies, a self-assessment tool for providing assistance to local governments in evaluating and monitoring various low-carbon measures was conceived. After a basic survey in 2013, this tool - APEC Low-Carbon Town Indicator (LCT-I) System underwent trial evaluations in 2015 with the help of previous LCMT-case towns and endorsed in 50th APEC EWG Meeting in December 2015.

2.1 About the tool: LCT – 1 system

The tool, LCT-I System consists of 5 major items (Tier 1), 14 mid-level items (Tier 2) and 23 terminal level items (Tier 3) as given in the diagram below:

[2] Note: Asia-Pacific Economic Cooperation (APEC) region constitutes of 21 member economies located in the Asia-Pacific region

[3] Note: The 7 cities for which LCMT concept had been prepared are as follows: Krasnoyarsk City, Russia (October 2018); Mandaue, Cebu, The Philippines (May 2017); Bitung, North Sulawesi, Indonesia (June 2016); San Borja, Lima, Peru (January 2016); Da Nang, Viet Nam (May 2014); Koh Samui, Thailand (June 2013); Yujiapu CBD, Tianjin, China (September 2011)



Source: APEC LCMT Document

Figure 3: Structure of LCT-1 System

Tier-1 contains areas directly and indirectly related to energy usage – directly related areas are concerning technologies, design measures related to energy demand and supply, while indirectly related areas are the enablers that help ensure the directly related measures can be implemented successfully. Tier-2 further segregates the Tier-1 items into more definitive action areas. The Tier-2 items are further segregated to Tier-3 items which gives the development objective.

A 5-point marking scheme[4] is provided for each of the 23 Tier-3 items, along with the marking criteria to be followed. Marking criteria is based on the extent to which the proposed measure is expected to

[4] Note: Depending on the indicator and instruction for evaluation under the system, a 3-point or 4-point scale may be applied. In cases without plans, efforts, systems or criteria, or in cases where the numerical value cannot be measured, an evaluation is not given i.e. no point is given.

help achieve the specific objective for the Tier-3 item is concerned. To further aid evaluation an Excel worksheet[5] has also been prepared to capture the marking for each intervention/item.

2.2 Rationale

The LCMT Concept was developed and refined through the 7 phases of LCMT Project and it culminated in the development of LCT-1 system. This was succeeded by the APEC Low Carbon Model Town (LCMT) Project Dissemination Phase 1 (APEC, 2019) to accelerate the dissemination of low-carbon town for managing rapidly growing energy consumption in the APEC region and reduce corresponding CO_2 emission.

As part of Phase 1 of LCMT Project Dissemination, feasibility studies of low-carbon town developments in Banda Aceh City of Indonesia, Shah Alam City Center Section 14, Selangor of Malaysia and the City of Hang Tuah Jaya, Melaka of Malaysia were conducted to provide implementable advice towards low carbon urban development.

In the Phase 2, the Concept and LCT-1 will be utilized to provide advisory on low carbon urban development for two volunteer cities in the APEC region - Da Lat (Viet Nam) and Davao (Philippines). The key objectives of the LCMT Dissemination Phase 2 are as follows:

1. To provide feasibility studies of low carbon development projects on the two volunteer towns; checking CO_2 emissions reduction goals; verifying how to develop attractive and innovative development plans through the feasibility study.
2. To share best practices and real-world experiences of low-carbon town design with planners and policymakers throughout the APEC region.

2.3 Objective and Scope of Work

Under the current project, which forms a part of LCMT Dissemination Phase 2, feasibility studies will be conducted to examine CO_2 reduction goals in pre-decided sections for the two volunteer cities and verify how to develop an attractive and innovative low-carbon development plan.

Accordingly, the objective of the project is as follows:

1. Identify specific selection of mitigation measures in the pre-selected APEC LCT-I Assessment Areas based on the analysis on CO_2 reductions and investment costs for potential measures. This is expected to provide valuable advice on how to design an attractive and innovative low-carbon development plan for the respective cities.
2. Develop implementation methodology and action plans of proposed mitigation measures including potential implementing bodies and funding sources.

In order to achieve the objectives, the following activities need to be undertaken:

1. Prepare Low-Carbon Development (LCD) Strategy for the two volunteer towns' low-carbon town development projects which will contain the following elements:
    a. A high-level vision in low-carbon town design
    b. CO_2 emissions baseline in Business As Usual (BAU) scenario
    c. CO_2 emissions reduction and environmental targets
    d. Low-carbon guideline for the categories of low-carbon town design challenges
    e. Select CO_2 emissions reduction measures in each design category

2. Analyze CO_2 emissions reduction and costs for the selected design measures

[5] For reference: Evaluation sheet for LCT-I System (APEC website, 2016)

3. Study the implementation methodology and action plans of the proposed CO_2 reduction measures along with possible funding sources
4. Prepare Feasibility Study reports for each of the two volunteer towns in the pre-selected LCT-I Assessment areas will improve their low-carbon development projects. This will include the following areas:
    a. Current status of the assessment area for volunteer town i.e. Da Lat
    b. Government's vision defining future development pathway for assessment area
    c. Rationale and brief description of proposed low-carbon measures
    d. Implementation mechanism for proposed measures including possible business models[6].
    e. Financing sources for measures

The pre-selected LCT-I Assessment Areas for Da Lat is given below:

Table 4: Pre- Selected LCT-1 Assessment Areas

Tier-1	Tier-2
Demand	Town Structure
	Buildings
	Transportation
Supply	Area Energy System
	Untapped Energy
	Renewable Energy
	Multi-Energy System
Demand & Supply	Energy Management System

Source: APEC LCMT Document

[6] Note: 'Business model', as used in this document, means a feasible implementation model in case of implementing body is government entities and in case implementing body is a private entity, the term indicates an implementation model which exhibits a flow of revenue to the private entity.

3 Overview of Volunteer Town – Da Lat (Viet Nam)

3.1 Geographic Data

Da Lat is the capital of Lam Dong Province in Viet Nam, with area 394.46 sqkm (Lam Dong Statistics Office, 2017). The topography is majorly forest area comprising 53% of this area while agricultural land comprises 35% (Lam Dong Statistics Office, 2017). Figure 4 gives the geographical position of Da Lat with respect to Viet Nam and Lam Dong province. Da Lat is divided into 12 wards which are numbered 1 to 12, and 4 communes: Ta Nung, Xuan Truong, Xuan Tho and Tram Hanh.

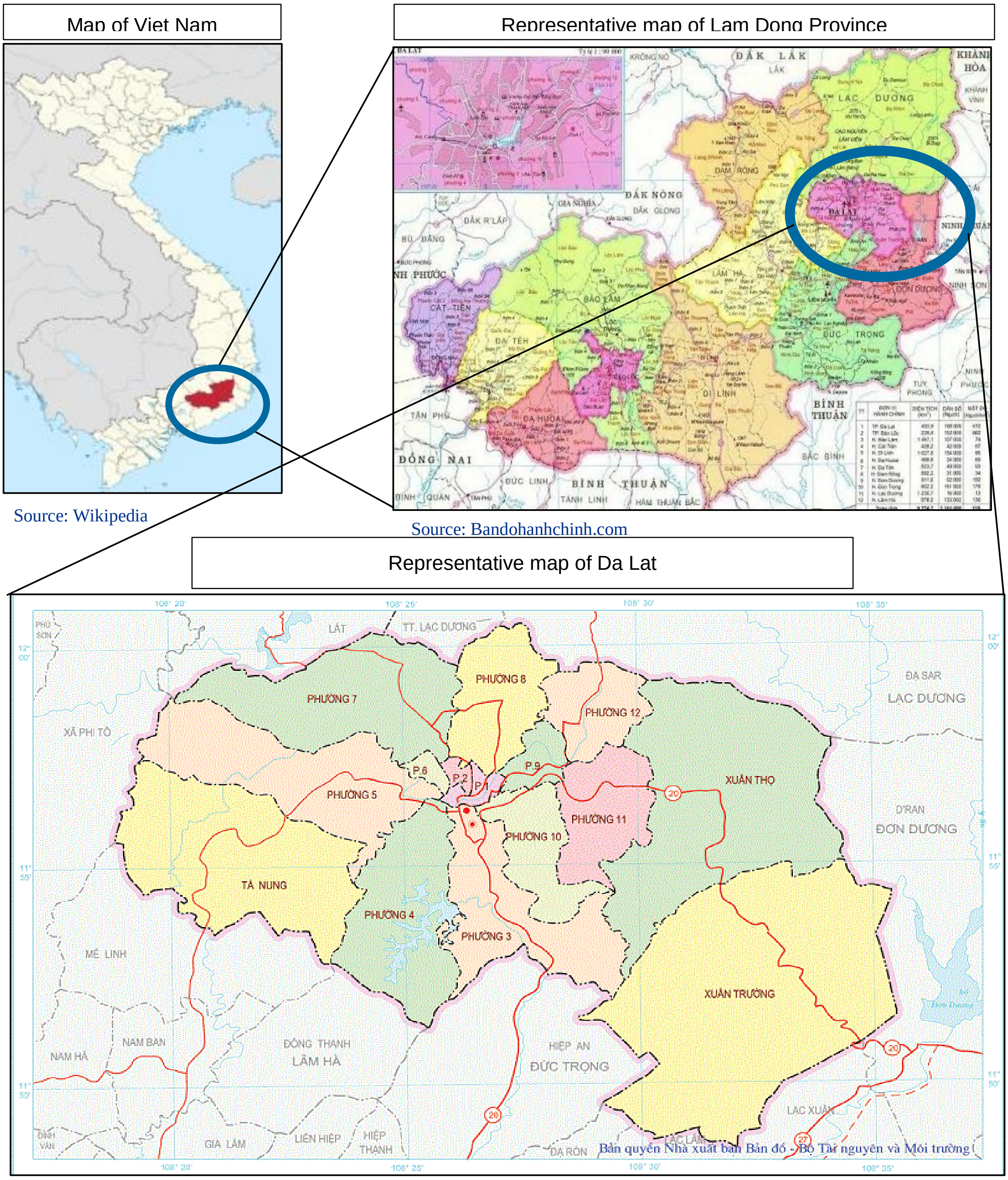
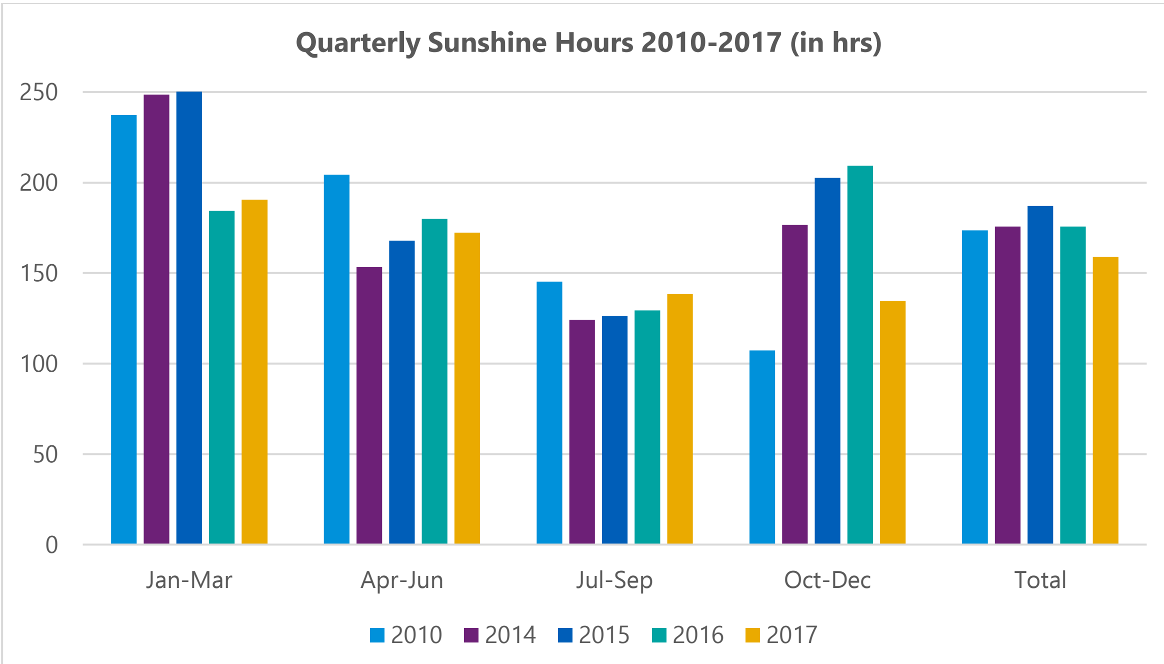


Figure 4: Geographical position of Da Lat within Viet Nam

The location of the city leads to a temperate weather unlike Viet Nam's otherwise tropical climate. Its subtropical highland climate is mostly mild throughout the year leading to its nick name of the "City of Eternal Spring". The average temperature is between 14 °C (57 °F) - 23 °C (73 °F) with highest recorded temperature being 31.5 °C (88.7 °F), and the lowest was −0.6 °C (30.9 °F) (Da Lat website, Archived). This temperate climate is ideal for agriculture and the serene valleys constituting its topography makes it one of the most popular tourist locations in Viet Nam.

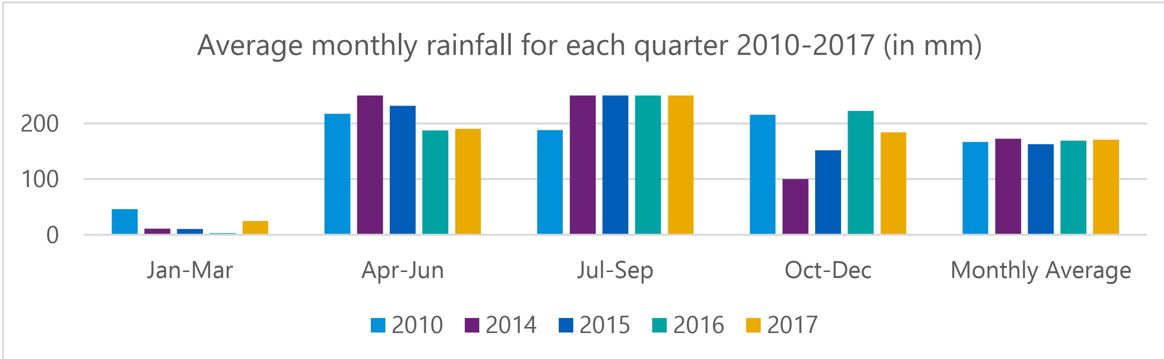


Quarters	2010	2014	2015	2016	2017
Jan-Mar	237.33	248.67	251.00	184.33	190.67
Apr-Jun	204.33	153.33	168.00	180.00	172.33
Jul-Sep	145.33	124.33	126.33	129.33	138.33
Oct-Dec	107.33	176.67	202.67	209.33	134.67
Average	173.58	175.75	187.00	175.75	159.00
Total annual	2083	2109	2244	2109	1908

Source: Lam Dong Statistical Handbook

Figure 5: Quarterly sunshine hours in Da Lat

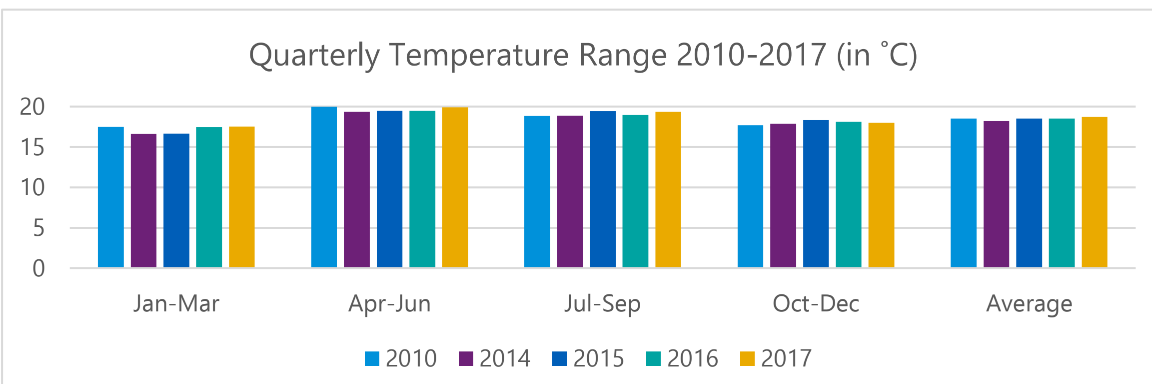
As given in Figure 5, the average sunshine hours incident in Da Lat is equivalent to major cities in the region like Manila (Philippines) (Danish Meteorological Institute, 2013), Da Nang and Ho Chi Minh City (Viet Nam) (Viet Nam Institute for Building Science & Technology, 2018).



Quarters	2010	2014	2015	2016	2017
Jan-Mar	46.00	11.00	10.67	3.00	25.00
Apr-Jun	217.67	282.00	232.00	187.33	190.67
Jul-Sep	188.33	297.67	257.33	263.67	283.33
Oct-Dec	215.67	100.00	151.67	222.33	184.00
Monthly Average	166.92	172.67	162.92	169.08	170.75

Source: Lam Dong Statistical Handbook

Figure 6: Precipitation in Da Lat



Quarters	2010	2014	2015	2016	2017
Jan-Mar	17.50	16.60	16.67	17.43	17.53
Apr-Jun	19.97	19.37	19.47	19.47	19.90
Jul-Sep	18.83	18.87	19.43	18.97	19.37
Oct-Dec	17.70	17.87	18.30	18.13	18.00
Average	18.5	18.2	18.50	18.50	18.70

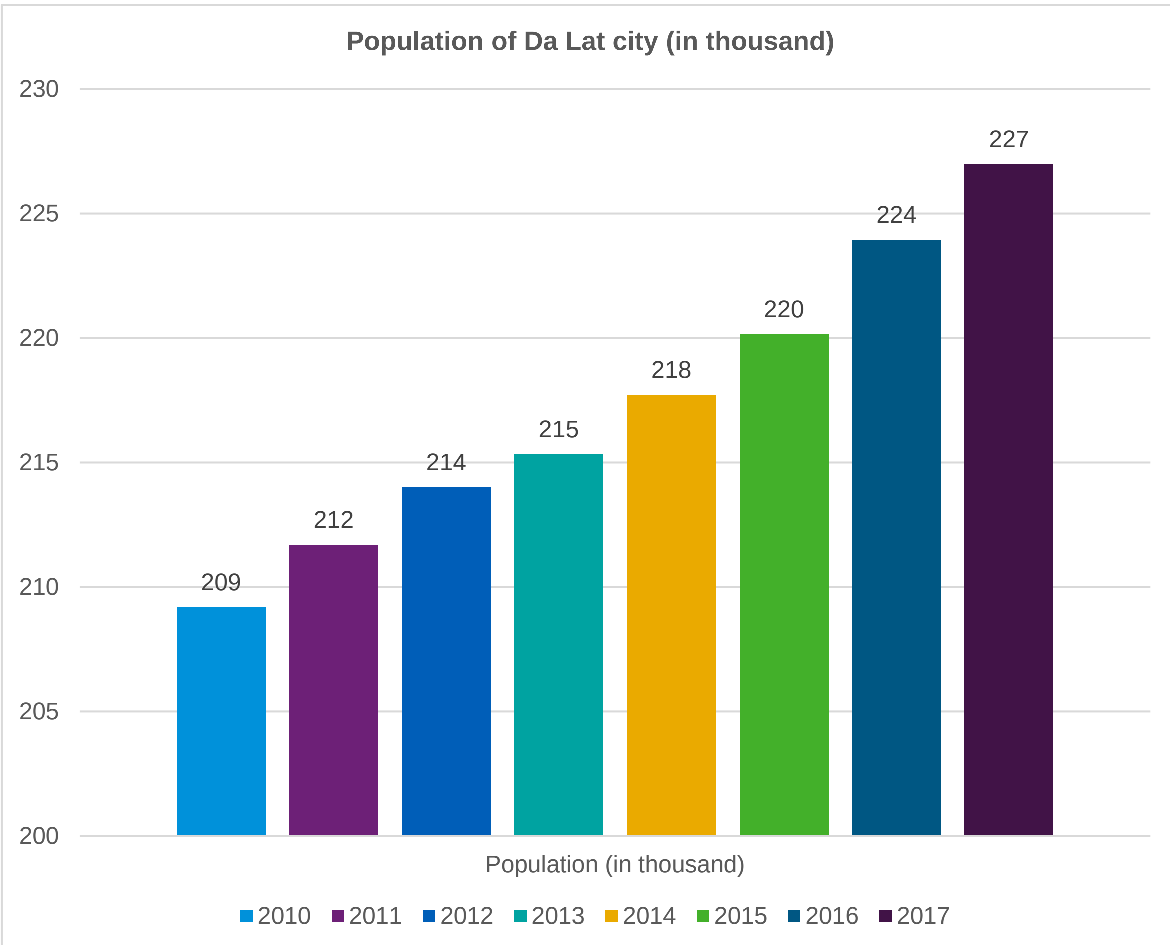
Source: Lam Dong Statistical Handbook

Figure 7: Quarterly Temperature Change in Da Lat

There are two seasons in Da Lat with the rainy season lasting from April to November and the dry season running from December to March. Accordingly, as given in Table 4, the average monthly rainfall is around 160-170mm, resulting in annual precipitation is around 2000mm^3 - equivalent to average annual precipitation of Viet Nam which is around 1800mm (Climate Research Unit, 2018). Figure 5 shows the average temperature of Da Lat which is around 18°C.

3.2 Demographic Data

Da Lat city houses nearly 17% of the total population of Lam Dong Province and has a population density which is over 4 times the average population density in the province (Lam Dong Statistics Office, 2017). The population growth is 0.98% CAGR between 2010 and 2016, which is slightly higher than the domestic population growth rate which stands at 0.9% in the same period. The numeric details of demography are elaborated in Figure 6 below (Viet Nam General Statistics Office, 2019):



Source: Viet Nam General Statistics Office

Figure 8: Population growth in Da Lat

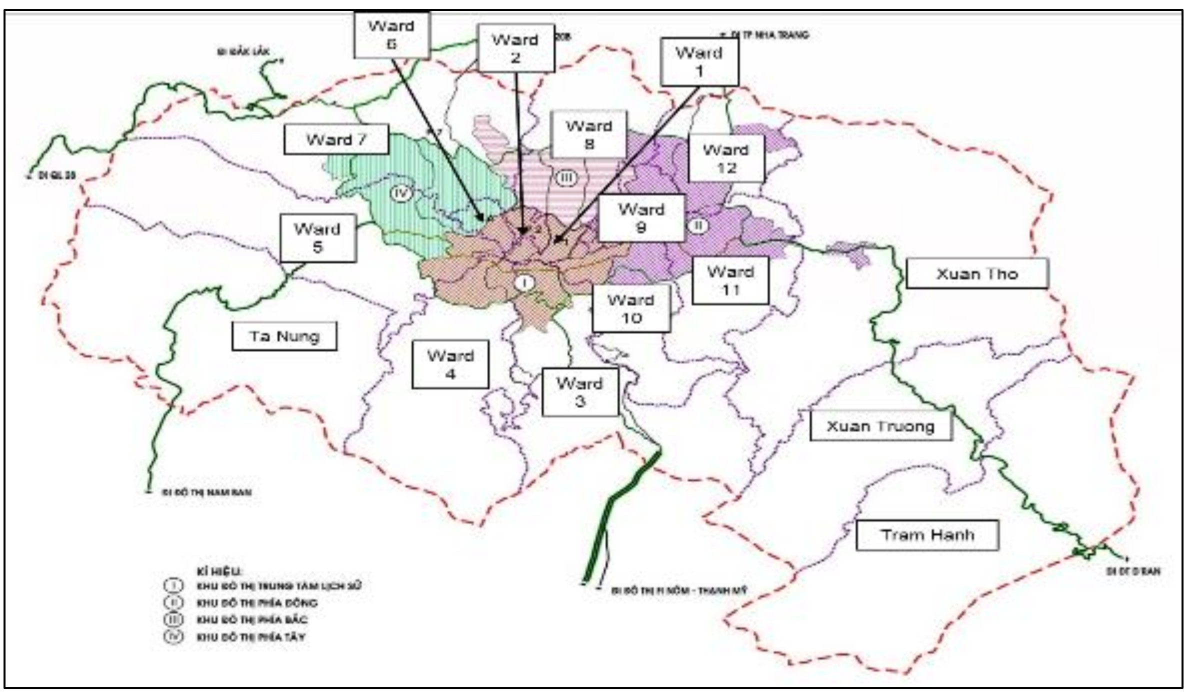
3.3 Administrative structure

The administrative structure of Da Lat lies at the 3rd level of administrative hierarchy of Viet Nam as given in Figure 9 below:

Source: Viet Nam central, provincial and city-level officials

Figure 9: Administrative structure of Viet Nam

Since Da Lat city is the capital of the Lam Dong Province, it is the seat of the Provincial administrative system. Da Lat comprises 4 communes (Xuan Tho, Ta Nung, Tram Hanh, Xuan Truong) and 12 Wards/Phường which have their own administrative bodies that support the city and provincial level bodies. The map showing wards and communes in Da Lat is given in Figure 10 below:



Source: Viet Nam central, provincial and city-level officials

Figure 10: Ward map of Da Lat

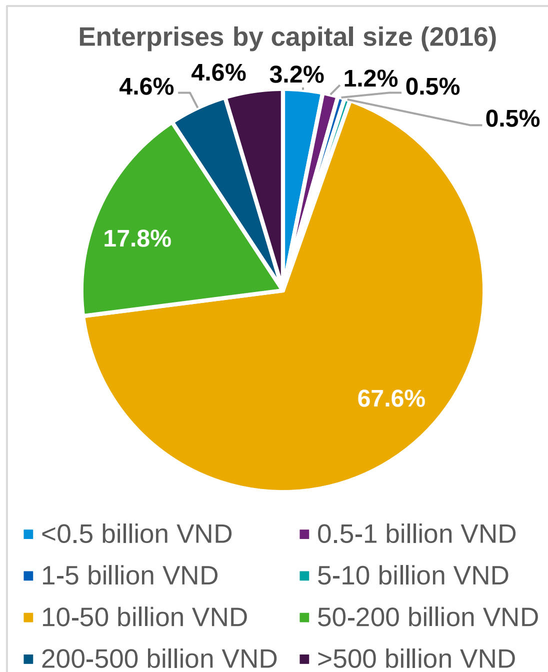
Da Lat is the seat of the People's Committee of Lam Dong Province (PPC) which is the executive agency of the Provincial People's Council and the State administrative agency at local level. It is responsible for executing and carrying out State management at local level in accordance with the Constitution, law and documents of State agencies at higher levels and resolutions of the Provincial People's Council (PPC). PPC has 18 specialized agencies to dispose its functions for the province. In its operation, PPC coordinates closely with the Provincial Committee of Viet Nam, Central Government, public unions and other social organisations in taking care of and protecting benefits of the local people, and in mobilising the local people to participate in State management and implement duties of citizenship (Lam Dong Province Portal, 2019).

Da Lat has a separate City People's Council and People's Committee which functions through 12 specialized departments. Each of the constituent communes and wards have a People's Committee which carry forth the administrative requirements of the citizens (Lam Dong Portal, 2018).

3.4 Local Economy

Da Lat is a trade centre among economic regions such as Southern, Central Highland and South Central Coast as well as is an important transport hub of domestic and international urban economic corridors such as Domestic Highway 20, Domestic Highway 27, Dong Truong Son Highway, Lien Khuong International Airport, Railway to Daknong, Ho Chi Minh City, Ninh Thuan and Binh Thuan province.

Agriculture and tourism are the two main economic activities being undertaken in Da Lat. The key crops and agricultural produce for the city are fruits, coffee, tea, industrial crops, sweet potatoes, paddy (especially winter paddy) and other annual crops. When compared to Lam Dong province, Da Lat has substantial production of flowers and accounts for nearly 65% and 69% of the total planted area and the total production of the provincial levels respectively (Lam Dong Statistics Office, 2017). The number of industrial establishments, which are mostly in to food processing, has remained steady across the last 7 years – indicating limited growth in the industrial sector of the city.



Source: Lam Dong Statistical Handbook

Figure 11: Enterprises by size of capital

3.5 Basic Infrastructure, Energy & Resources

1. Road Infrastructure

The external road systems of Da Lat city make it an important traffic hub of the province and Central Highlands region, connecting it with international routes and domestic routes as well. As of 2017, the urban road system comprises 178 urban roads with a length of about 231 km and alley roads for 12 ward with 1,016 routes with a length of 292.5 km. Rural roads comprise 135.7 km of rural roads mainly concentrated in 4 communes (Government of Viet Nam, 2017) .

2. Rail Infrastructure

Da Lat is served by a railway station which is the terminal station for Da Lat – Thap Cham railway line. Currently, Da Lat Railway Station is considered as a tourist destination and the railway from

Da Lat station to Trại Mát (Ward 1), 7 km in length, is still maintained for tourists. (Department of Culture, Sports and Tourism, 2019).

3. **Airport Infrastructure**

Currently, Lien Khuong is the primary passenger airport for reaching Da Lat (Lam Dong Province Portal, 2019).

4. **Buildings**

There are multiple buildings present from the France-occupied Viet Nam era in Da Lat. They have been marked as heritage buildings or have been converted in to hotels. Being a tourism centric economy, there are number of commercial buildings in the urban areas of the Da Lat city area especially hotels. Currently there are 1,251 accommodation establishments/hotels present with 17,807 rooms and 20 tourist attractions areas where these are located (Lam Dong Province Portal, 2019). Conventional building design is primarily used and although Viet Nam has an independent green building rating system – LOTUS, there are no rated buildings in Da Lat. A primary reason cited by stakeholders is the limited requirement for heating, ventilation and air conditioning (HVAC) in Da Lat. Typically, HVAC systems typically account for 40%-60% of the total energy consumption of a commercial building and forms a major part of energy efficient interventions. Hence, the lack of such systems reduces the scope for energy efficiency in buildings.

5. **Energy**

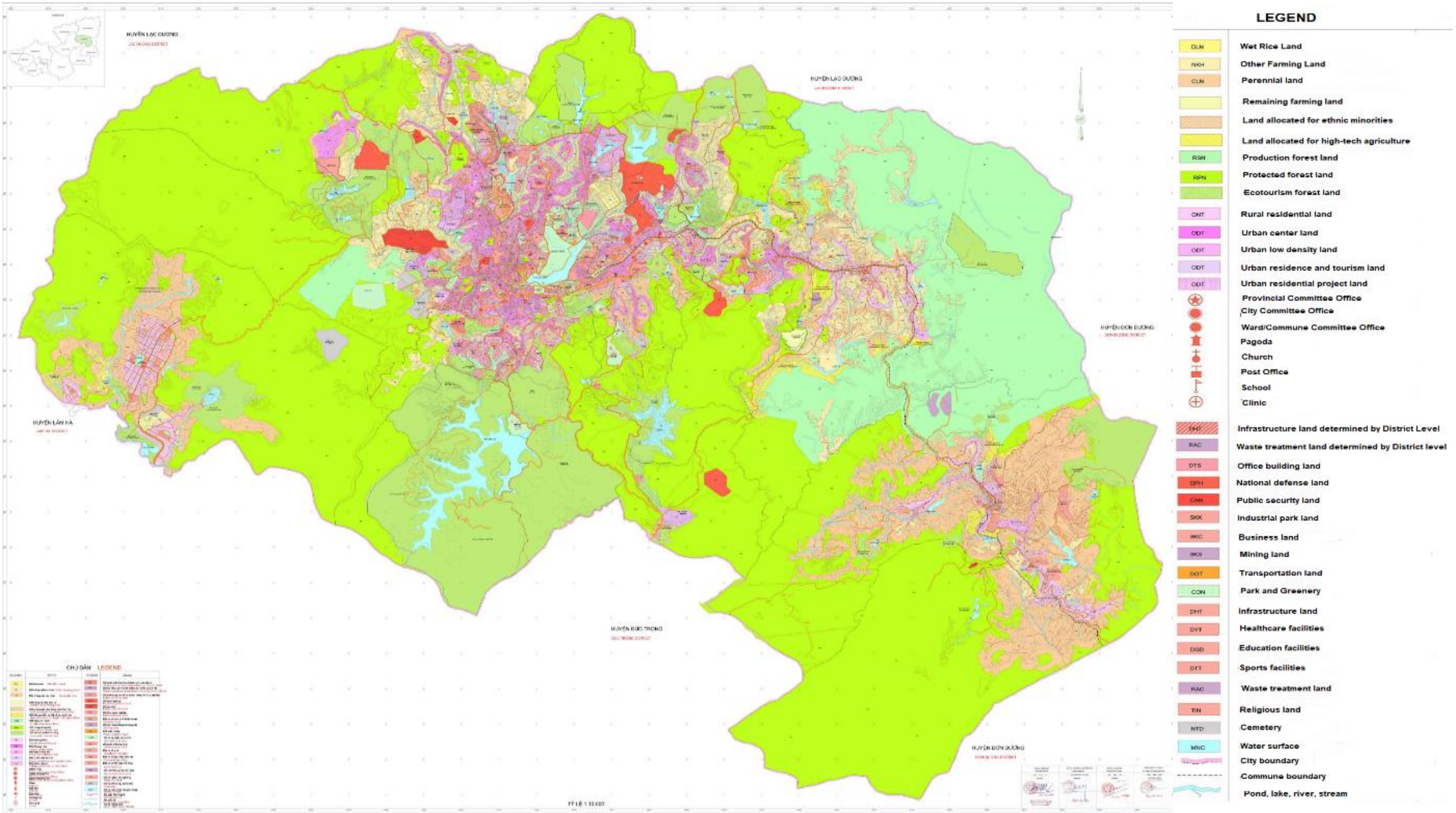
a. **Buildings (Commercial and Residential):** Electricity is the primary source of energy for buildings sector and the level of electrification in residential and commercial buildings in nearly 100%. For 2017, the combined electricity consumption in these two categories has been 165 thousand units (kWh) (KII , 2019). From empirical observation and stakeholder consultation, nearly 70%-80% of hotels and over 50% of residential houses have solar water heaters and stainless-steel overhead water tanks on roofs (KII , 2019). There is limited awareness of Building Energy Management Systems as well as limited scope for implementation, since HVAC systems are not prevalent in Da Lat.

b. **Agriculture:** The agriculture sector uses 100% electric pumps and there are no solar pumps that are in use. Since most farms are small scale in production levels, there is limited penetration of farm mechanization in Da Lat.

c. **Transportation:** This sector comprises majorly motorized passenger transport which run on petrol (RON 95-IV or RON 95-II) or diesel. Motorcycles and passenger vehicles i.e. taxis in Da Lat mostly run on petrol, while buses and personal vehicles run on diesel. While there is supply of bio-fuel (E5RON-92) in Da Lat, it is used sparingly by users. A recent directive from the Lam Dong administration has made the use of bio-fuel mandatory for all public vehicles in Da Lat. Also, Department of Transport has sent official communications to taxi associations for encouraging their association members to increase consumption of biofuel (KII , 2019) .

d. **Power Supply:** Power is supplied from the domestic grid where power is generated through thermal power plants and renewable sources. Hence, energy mix for power supply for Da Lat would be similar to the domestic level energy mix (IEA, 2017). Additionally, work on the first wind power project in Da Lat. The Cau Dat Wind power project, started in March 2019, with a total area of 350 ha with 50MW installation capacity from 15 wind turbines, with a total investment requirement of USD 74 million. The 1st unit will generate electricity from April 2020 and by September 2020, the entire project will be completed and inject electricity to the domestic grid (EVN, 2019). While there is an ongoing programme for promoting solar solar water heaters, there is scope to improve penetration of solar rooftop power, which is currently not present. There are plans to install 2MW solar rooftop in the Lam Dong administrative building in Da Lat (KII , 2019).

3.6 Land-use structure



Source: Da Lat City Officials

Figure 12: Land use plan of Da Lat

As given in Figure 12, which provides the land use plan of existing Da Lat boundaries, a major area of the city comprises forest cover. As per the 2017 figures (Lam Dong Statistics Office, 2017), nearly 52.8% of the total land of Da Lat is composed of forest land (off which 159 hectare is planted forest) and 34.6% is agricultural production land. The remaining area is used for residential purpose and special-use purpose i.e. construction land for offices, construction of non-business works; land used for defence and security purposes; non-agricultural production and business land and land use for other public purposes.

By Decision 704 - Approving the adjustment of the general planning of Da Lat city and the surrounding area till 2030 and vision till 2050) promulgated in May 2014, the adjustments in the existing land use plan of Da Lat is proposed. The Decision is discussed in detail in the following section

3.7 Policies and targets related to Low carbon strategies

Under the administrative structure of Viet Nam, all policy decisions are driven by the central government, while respective provinces develop strategies to ensure policies get implemented. The adopted policies then get implemented by respective municipalities within the jurisdiction of respective provinces. In this regard, much work has been undertaken in developing focused policies addressing climate change and sustainable development related issues both at central, provincial level. Specifically, the Provincial and City administration are actively working to decongest existing Da Lat city and retain the natural beauty of the city through multiple ‘green’ initiatives. This indicates the interest exhibited by the administration in improving living conditions and reduce emissions of the city and the economy at large. Such policies which contribute to the emission reduction are being discussed below:

Table 5: Policy structure for low carbon strategies

ADMINISTRATIVE LEVEL	NAME OF THE POLICIES/ PROGRAMME/ SCHEME	APPLICABILITY WITHIN SECTORS										
		ENERGY DEMAND SIDE SECTOR						ENERGY SUPPLY SIDE SECTOR				
		BULDING SECTOR		TRANSPORT	INDUSTRY	MUNICIPALITY	AGRICULTURE	CONVENTIONAL POWER SUPPLY/ PRODUCTION	RENEWABLE POWER SUPPLY/ PRODUCTION			
		RESIDENTIAL	COMMERCIAL						Solar	Wind	Geothermal	Waste to Energy
Domestic Level Policy	Domestic Strategy on Climate Change	NA	NA	Yes	Yes	Yes – In case of waste management	Yes	Yes	NA	NA	NA	NA
	Domestic Green Growth Strategy	Yes	NA	Yes	Yes	Yes, Waste management and Urban Planning	Yes	NA	Yes	NA	NA	NA
	Law on Economical and Efficient Use of Energy	Yes	Yes	Yes	Yes	Yes, public lighting	Yes	NA	NA	NA	NA	NA
	Viet Nam Domestic Energy Efficiency Plan 2019-2030	Yes	Yes	Yes	Yes	NA	NA	NA	NA	NA	NA	NA
Provincial level	Lam Dong Provincial Green Growth Action Plan	This document is under preparation										
City Level	Da Lat City Green Growth Action Plan (GGAP)	NA	Yes	Yes	NA	Yes	Yes -forestry	Yes	NA	NA	NA	NA
	Approving the Adjustment Plan of Da Lat city and its vicinity to 2030, with a vision to 2050	NA	NA	NA	NA	Yes - development natural carbon sinks	NA	NA	NA	NA	NA	NA
	Tax exemptions	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Yes

1. Domestic Level Policies and Strategies related Low Carbon Development

a. Domestic Strategy on Climate Change:

Issued by Prime Minister Nguyen Tan Dung in December 2011, the strategy document acknowledges the threat posed by the climate change on Viet Nam and provides the strategic viewpoints, targets and sector-wise missions along with implementation phasing and accountability for the missions.

The documents contain two sets of targets viz. General and Specific targets, which are envisaged to be realized through interventions in 10 key areas as given below (Viet Nam Government Portal, 2019).

Source: Viet Nam Government Portal

Figure 13: Key areas of Domestic Climate Change Strategy

A specific target in the document is to develop a low-carbon economy and undertake green growth into main orientations for sustainable development; lower emission and higher absorption of greenhouse gases to become compulsory indicators of socio-economic development.

The sector-specific interventions to achieve this target are provided for sectors like power generation, industry, transportation, agriculture and waste management, details of which are given in Annexure.

b. Domestic Green Growth Strategy (Govt. of Viet Nam)

This document provides the tasks required to be undertaken to achieve the objective of green growth. Green growth is defined as a means to achieve a low carbon economy and to enrich natural capital, will become the principal direction in sustainable economic development; reduction of greenhouse gas emissions and increased capability to absorb greenhouse gas are gradually becoming compulsory and important indicators in socio-economic development. Table 6

Table 6: GHG and energy consumption reduction targets

Particulars	Targets		
	2011-2020	2020-2030	2030-2050
Reduction intensity of GHG emission	8-10% (compared to 2010 level)	1.5%-2%	1.5%-2%
Reduction in overall GHG emission	10% -voluntary reduction 10% - through international support	10% -voluntary reduction 10% - through international support	-
Reduction in energy consumption per unit GDP	1%-1.5%	-	-

Source: GIZ website – Domestic Green Growth Strategy

The key sector-specific tasks contained in the document pertinent to the sectors examined in case of Da Lat are given in Annexure.

c. *Law on Economical and Efficient Use of Energy*

This law was promulgated in 2010 with a view of providing economical and efficient use of energy and includes the measures to promote it along with the obligation and responsibilities of organizations, households and individuals in this regard (Govt. of Viet Nam, 2018).

A brief of the measures required to be undertaken for each type of stakeholders pertinent to the case of Da Lat is given in Annexure:

This Law is supplemented by two specific decrees, to support implementation:

a. Decree No. 21/2011/ND-CP[7]: Issued in March 2011, provides detailed article-wise explanation of the provisions of the law in order to ensure support implementation.
b. Decree No. 134/2013/NĐ-CP[8]: Issued in October 2013, the decree provides the applicable penalties and fines for violation of the energy efficiency and energy conservation regulations

d. *Viet Nam Domestic Energy Efficiency Plan 2019-2030*

In 2005, the Ministry of Industry and Trade (MOIT) released the Domestic Strategic Programme on Energy Savings and Effective Use/Viet Nam Domestic Energy Efficiency Programme, (VNEEP) for 2006–2015 (APERC, 2017). The VNEEP was the first-ever long-term comprehensive plan to institute measures for improving energy efficiency and conservation in all sectors of the economy in Viet Nam (Govt of Viet Nam, 2019).

The programme expects to achieve the goal of total energy saving in the whole economy and in large energy consuming individual sectors, bring social and economic benefits; contribute to reduced investment in energy supply system development, ensure energy security,

[7] For further reference: Law on Economical and Efficient Use of Energy and measures for its implementation (FAO website, 2011)
[8] For further reference: Regulations on sanctioning administrative violations in the field of electricity, hydroelectric dam safety, economical and efficient use of energy (Govt. of Viet Nam Portal)

environmental protection; rational exploitation of energy resources, and sustainability for socioeconomic development.

2. Provincial Level Policies and Strategies related Low Carbon Development

a. Lam Dong Provincial Green Growth Action Plan

A Green Growth Plan for the Lam Dong province is currently under preparation. This document is being prepared with alignment Domestic Strategy on Green Growth and will contain provincial vision up to 2030, along with a set of key target indicators for green growth of different sectors.

3. City Level Policies and Strategies related Low Carbon Development

a. Da Lat City Green Growth Action Plan (GGAP)

The GGAP for Da Lat city was promulgated in 2017 in line with the Domestic Green Growth Action Plan outlining city specific objectives, targets and interventions to provide green orientation of future growth path of Da Lat.

The objectives for achieving this green growth under this plan is as follows:

i. Reduce the intensity of GHG emissions in the period 2016-2020 to 196,250 tCO_2e. It is expected that the total reduction of both energy and agro-forestry emissions in 2020 compared to 2010 will be 39.79%;
ii. Green the production through the transformation of economic activities towards becoming "cleaner" and mitigate the environmental impacts.
iii. Speed up economic development towards "green" industries, especially tourism and service sectors. At the same time, minimize the level of environmental damage due to the activities of industries that use a lot of energy and have a great impact on the environment;
iv. Green the lifestyles and promote sustainable consumption by combining traditional lifestyle with modern civilized means to create a comfortable and good quality life with the domestic identity of Da Lat city.

To implement these targets, a system of solutions has been set up in five groups, a brief of which is given below:

i. *Improve capacity and institutions* – It involves establishing current status and potential of green growth in the city as well as research and propose training/re-training programs to provide human resources to businesses towards green growth.
ii. *Raising awareness* – It involves action in the following areas:
    1. Propagate and raise public awareness about public transport
    2. Organize training and communication to improve the capacity of the community on energy efficiency benefits
    3. Organize the movement "High quality Vietnamese goods" in enterprises
    4. Organize the movement "Vietnamese people use Vietnamese goods" in the citizen

iii. *Reducing the intensity of greenhouse gas emissions* – In order to achieve the target on emission reduction, the Action Plan recommends 16 groups of solutions divided in to 2 sectors viz. Energy and Agriculture-Forestry. Based on the context of the current project, the solutions in the Energy sector can be further broken down in Power generation, Transportation, Buildings, and Municipality. Accordingly, the solutions for each of these sectors is given in Table 7 below:

Table 7: Measures to reduce GHG emission as per GGAP

Sector	Measures
Power Generation	1. Provide high performance transformers for power grid system 2. Support to deploy solar water heater
Transportation	1. Use biofuels in freight transport 2. Use biofuels in public passenger transport
Buildings	1. Replace existing lights with high performance lights in commercial hotels and service buildings 2. Install high performance refrigerators 3. Install high performance ACs in residential and commercial buildings 4. Provide solar hot water systems in hotels and high buildings
Municipality	1. High performance public lighting 2. Tourist information agencies and solar street lighting
Agro-Forestry	1. Use biogas in livestock 2. Save and control water in rice cultivation 3. Use biogas in living activities 4. Convert unused land to protective forest land 5. Convert unused land to production forest land

Source: Da Lat city officials

iv. *Greening the production* – It involves investment in construction of water supply system, building a biological product factory, development of high-tech agricultural production zone, development of waste recycling plant. It also identifies a program to apply new energy and clean for production. This element also aims to invest in building energy saving centre for Da Lat which will research and propose models on efficient means of energy use in industries.

v. *Greening lifestyle and promoting sustainable consumption* – It involves research to build a green urban model and education and training to citizens of the city on Green jobs and green lifestyles. In order to initiate the transformation process, pilot projects are proposed in green job training and green business incubator which can be later on scaled up.

In the context of the current study, a set of 15 interventions have been identified as part of the Action Plan which aim to reduce CO_2 emissions. All the initiatives will be financed based on allocation from local budget, except for one intervention, which will be funded by Viet Nam Electricity (EVN) – the state-owned company. A brief of these 15 interventions is given in the Annexure.

b. Approving the Adjustment Plan of Da Lat city and its vicinity to 2030, with a vision to 2050

As discussed in Section 2.6, Decision 704 was promulgated in May 2014 to make adjustments in the existing land use plan of Da Lat (Government of Viet Nam, 2014). The objective of this Decision was to build and develop Da Lat city and its vicinities till 2030 to become a modern and world-class urban area. This would include development of Da Lat into a special urban planning, architectural, cultural, historical and natural landscape as well as facilitate urban tourism, development of cultural and scientific centres and development as a high quality commercial and service centre.

The area of Da Lat city, under this plan, will include Da Lat city and Lac Duong, Don Duong, Duc Trong and a part of Lam Ha district (including: Nam Ban town and communes Me Linh, Dong Thanh, Gia Lam, Nam Ha) with a total natural land area of about 335,930 ha, a population of 529,631 people (in 2011).

Development zoning for the entire area will be as follows:

i. 232,000 ha of forest conservation area located in the northern forest area (in Lac Duong district), around and south of Da Lat city (in Don Duong and Duc Trong districts).
ii. About 70,400 ha of agricultural area and about 2,600 ha of concentrated rural residential area for a total area of about 73,000 is concentrated in Da Lat city and the districts of Lam Ha, Duc Trong and Don Duong.
iii. About 11,600 ha of total urban development area comprising 5,900 ha of central urban area of Da Lat city; about 2,600 ha of Lien Nghia - Lien Khuong (Duc Trong district); 1,700 ha of urban area of Finom - Thanh My (Don Duong district), 300 ha of Lac Duong urban area (Lac Duong district), 350 ha of D'ran urban centre, 500 ha of Nam Ban urban area and about 350 ha of Dai Ninh urban area.
iv. 6,500 ha for forest ecotourism development including four main tourist areas, namely tourist area of Dankia Lake - Da Lat, Tuyen Lam Lake tourist area, Prenn lake tourist area and Dai Ninh tourist area.

A specific model of urban development and planning for each of the areas in Da Lat and its surrounding areas is provided to achieve the development objective. These models aim to increase green urban landscape and restrict organized urban thereby leading to the development natural carbon sinks within city limits. The development of Low Carbon Strategies for Da Lat for future should take into consideration the specific requirements given under this decision.

c. *Specific mechanisms and policies for development of Da Lat city and its vicinity*

There are multiple incentives in Lam Dong Province provided to stimulate investment in the region. These incentives are present under the stipulations of different Decrees. Specific to Da Lat and the sectors present in the current scope of work, following incentives are provided (Government of Viet Nam, 2015):

i. Preferential tax rates of 10% for 15 years for production of renewable energy (RE), clean energy and Waste to Energy (WtE) projects
ii. 4-year tax exemption and 50% tax reduction in 9 consecutive years for corporate income from implementation of RE, clean energy, WtE projects

4 International Best Practices for Model Green Cities

This section discusses the best practices that several cities have adopted to become green cities/low carbon cities. In order to account for regional socio-economic considerations, several cities across South East Asia have been considered. The shortlisted list of cities for consideration of best practices were as follows:

1. Hue, Viet Nam
2. Jakarta, Indonesia
3. Samui Island, Thailand
4. Ngu Hanh Son, Viet Nam
5. Ho Chi Minh, Viet Nam
6. Ha Noi, Viet Nam
7. Cape Town, South Africa
8. Stockholm, Sweden

Further, four parameters were considered to assess the suitability of shortlisted cities with the context of volunteer city i.e. Da Lat. These four parameters along with their description are given as follows:

a. Climate and Topography
b. Economic Situation (GDP per capita)
c. Economic Activities
d. Previous LCMT study

The table below provides the comparative values of shortlisted cities with volunteer cities for points (a) to (c) as well as applicability of (d) for the shortlisted cities:

Table 8: Parameters of shortlisted cities for best practice consideration

No.	Parameters	Da Lat, Viet Nam	Hue, Viet Nam	Samui Island, Thailand	Ngu Hanh Son, Viet Nam	Ho Chi Minh, Viet Nam	Ha Noi, Viet Nam	Jakarta, Indonesia	Cape Town, South Africa	Stockholm, Sweden
1.	Climate	Temperate	Monsoon	Tropical monsoon	Tropical	Tropical	Warm humid	Tropical monsoon	Mediterranean	Humid Continental
2.	Topography	Combination of lowland and mountainous (Alotrip, 2015)	Mountainous (CDKN, 2016)	Coastal	Mountainous	Coastal	Combination of delta area, the midland area and mountainous zone (Alotrip, 2014)	Hilly and coastal plains (APN, 2014)	Mountainous, Coastal	Coastal
3.	Economic Scenario (GDP/capita)	USD 2900 in 2016 (Government of Viet Nam, 2017)	USD 2100 in 2016 (Emerhub, 2017)	USD 6500 in 2017 (World Bank, 2017)	USD 2400 in 2017 (World Bank, 2017)	USD 5428 in 2016 (Emerhub, 2017)	USD 3425 in 2016 (Emerhub, 2017)	USD 14570 in 2015 (Tempo.co, 2016)	USD 6500 in 2017 (ERU, 2018)	USD 61000 in 2015 (SCB, 2017)
4.	Major economic activities	Agriculture and tourism	Tourism hub	Tourism	Tourism	Industry, agriculture, tourism	Industry, trade, tourism, agriculture	Industry, banking and trading, tourism	Agriculture, Fishing, Shipping Companies, Industry, Tourism	Agriculture, Industry, Tourism
5.	APEC LCMT Phase I - cities	NA	NA	√	NA	NA	NA	NA	NA	NA

As is evident from the table above the shortlisted cities share limited similarities with respect to the climatic situation while topography for almost cities are similar to Da Lat. Similarity in major economic activities is observed across all cities, with tourism being a common economic activity. In terms of economic scenario, Da Lat exhibits considerable similarity with the other shortlisted cities. Of particular interest is Da Nang (Viet Nam) and Samui Island (Thailand) which have been part of APEC LCMT Phase I – a study of these cities can help provide measures which are aligned to the LCMT framework and hence, can be possibly be undertaken in the volunteer towns. However, based on stakeholder it has been observed that LCMT application in case of Da Nang has been unsuccessful due to limited consideration given to on-ground conditions while devising the solution.

A brief of the best practices considered in the shortlisted cities are given below:

Case Study 1 – Hue, Viet Nam

About the City:

Hue is a medium-sized city of 340,000 people, covering an area of some 71 km^2 in central Viet Nam (CDKN, 2014). A cultural and tourism hub, Hue is famous for its ancient capital area, pagodas, cuisine, gardens and overall cityscapes. Hue is also regarded as the Festival City of Viet Nam. It has successfully hosted seven domestically and internationally renowned festivals, attracting millions of tourists. The tourism sector alone contributed approximately 48% of GDP; revenues from the service sector were worth around USD 250 million in the same year. The city now welcomes around 2.5 million tourists annually, of whom 1.5 million are international tourists (CDKN, 2014).

Impacts of tourism:

The Hue Centre for International Cooperation, together with the municipality of Chiang Mai, Thailand, and Asian Institute of Technology undertook research on 'Sustainable Urban Tourism through Low Carbon Initiatives: Experiences from Hue and Chiang Mai'. The study was funded by the Sustainable Mekong Research Network (SUMERNET) and CDKN.

Table 9 summarizes the greenhouse gas emissions produced by Hue's tourism sector:

Table 9: GHG emissions by tourism sector

Sources	Emissions (tCO_2e)	Share (%)
Travel	377,617	76
-within city	6,683	1
- by visitors from other cities within the economy and abroad	370,934	75
Freight	58,571	12
Industrial	19,423	4
Residential & Commercial	17,805	4
Direct waste (food, waste and waste water)	12,889	3
Others	5,895	1
Total	**492,200**	**100**

Source: Kumar et al. (2014)

City initiatives and support mechanisms:

At the domestic level, Viet Nam has acknowledged the adverse impacts of tourism on the environment. Sustainable tourism is a key component of the United Nations Strategic Orientation for Sustainable Development in Viet Nam. The first Vietnamese domestic conference on sustainable tourism development was held in Hue in 1997 and at this the Vietnamese Government adopted the principle of sustainable tourism development. The concept recognized the importance of conserving tourism resources, the natural environment, biodiversity and cultural values, as well as the need for increased involvement of, and benefits to, local communities.

The promotion of Hue's garden houses was identified as the most viable mitigation option to address the twin goals of emissions reduction and job creation, noting that garden houses could increase the locals' income and offer unique recreational and cultural experiences to the tourists.

Solution: Garden houses – local people's choice for green growth
Garden houses form part of Hue's cultural heritage and number around 2,000 in total. They offer a kind of microcosm of nature within a house: house, garden, people, plants and water co-exist in a small urban space, helping reduce greenhouse gas emissions in situ, in various ways.

First, they offer a carbon sink function in contrast to denser, conventionally modern forms of urban housing. Second, garden houses can manage household waste through composting and/or using garden waste as animal feed, thereby reducing the amount of waste going to landfill. At the city level, since garden houses produce fruits and vegetables, they help reduce emissions from freight that would otherwise transport these products.

Thua Thien Hue Provincial Department of Culture, Sports and Tourism estimated that if the city authority promotes garden houses, it could attract 20 to 40% more visitors. At the same time, if the city authority and garden house association encourage these visitors to use bicycle to travel to garden houses, it could replace 127,950–255,900 km annually travelled by local petrol vehicles; this would translate to a reduction of 100–200 tCO_2e per year even with the estimated increase in visitors. This would constitute a reduction of 4–9% of greenhouse emissions from land-based transport within the city, while there will be higher tourism related economic activities.

Case Study 2 – Jakarta, Indonesia

About the city:

Jakarta, the capital city of Indonesia, is one of megacities in the world with 10 million population living in 662 km^2 of land area and 6,977 km^2 of sea area (Jakarta Regional Development Planning Board, 2018). The city is a coastal city (± 40% of land area is below sea level), located in a tropic region with dry and rainy seasons. Several rivers flows across the city, combined with low topography make Jakarta prone to flooding from swollen rivers in the wet season and high sea tides. In addition, lack of water level control infrastructure, deforestation in surrounding area of Jakarta, and complex socio-economic problems indirectly contribute to triggering a flood event. This situation makes the city vulnerable to the impact of climate change, especially the rise of sea level and rainfall intensity.

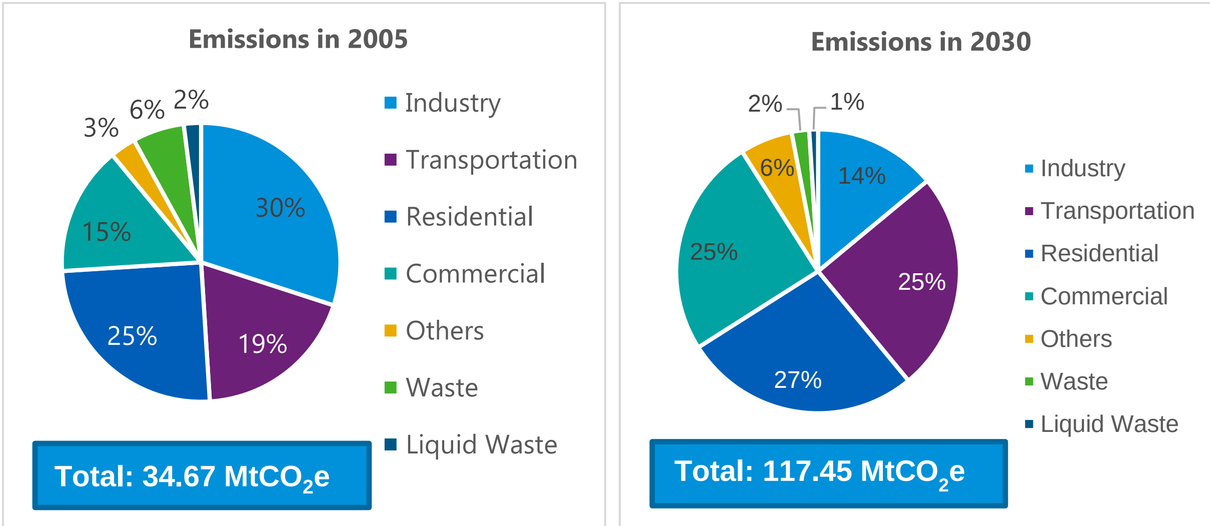
The population of this city grew 1%/year and the GDP grew 6.5%/year during 2005-2010. The main contributor of the city's GDP is tertiary industry/commercial (73%) and secondary industry or manufacturing (15%).

Current Scenario:

The city is characterized as having high motorized vehicle (cars and motorcycles) density, limited public transport infrastructure. Population growth, economic characteristics, and transportation condition lead to the high GHG emission level, i.e. 3.84 tCO_2e per capita (2005), of which energy sector accounted for 89% of total GHG emission. As comparison, at the same year, domestic GHG emission is 3.01 tCO_2e per capita.

This study presents results of a modelling study concerning Low Carbon City Scenario for Jakarta towards 2030. The study aims to identify development paths that will bring Jakarta becomes Low Carbon City in 2030, including emissions occurring due to Land Use, Land-Use Change and Forestry (LULUCF).

Methodology:
The tool used in this research is non-linear programming model ExSS (Extended Snap Shot) using GAMS (General Algebraic Modelling System) v 23.3 supported by various technical, economic and social parameters (Dewi et al., 2010 and Dewi, 2012). The method based on back casting approach is developed with sets of desirable goal first and then seek the way to achieve it.

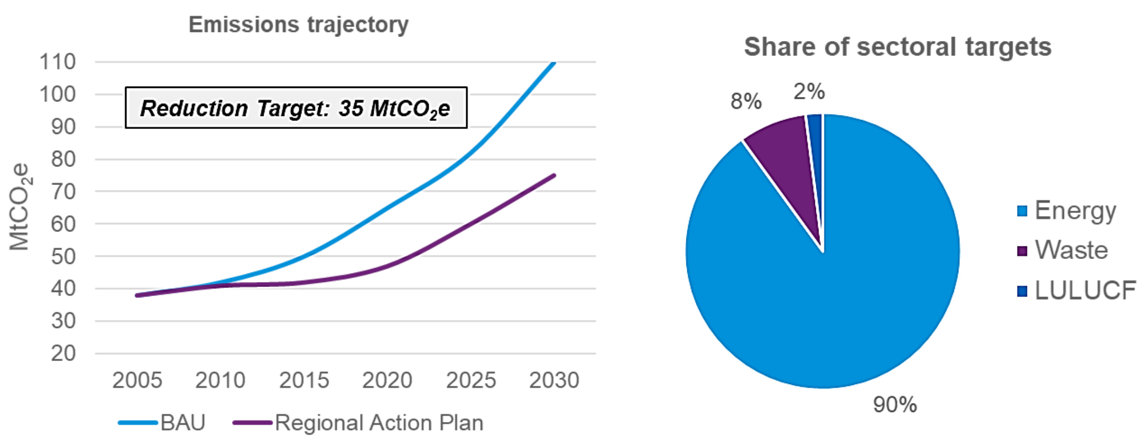


Source: Jakarta Planning Development Board

Figure 14: Sector Wise CO_2 emissions

Solution:

1. Under COP15 commitments, Jakarta committed to reduce GHG emissions by 30% by 2030
2. Released Governor Regulation 38/2012 on Green Building and Governor Regulation 131/2012: Regional Action Plan for reduction of GHG emissions
3. Released Grand Design of Jakarta a commitment to reduce the energy, consumption of water, and CO_2 emissions from buildings by 30% in 2030.



ENERGY SECTOR TARGET	
Industry	10.8 $MtCO_2e$
Transportation	9.8 $MtCO_2e$
Commercial	5.7 $MtCO_2e$
Residential	5.2 $MtCO_2e$
Others	0.07 $MtCO_2e$

WASTE SECTOR TARGET	
Solid	2.6 $MtCO_2e$
Liquid	0.3 $MtCO_2e$

LLUCF TARGET	
Forest	0.6 $MtCO_2e$

Source: Low Carbon Development in DKI Jakarta, Jakarta Planning Board

Figure 15: GHG reduction target for 2030

Till 2016, Jakarta has achieved 13.58% of its target and would require an emission reduction of 95 $MtCO_2e$ by 2030 to comply with the set targets, as given in Table 10 given below:

Table 10: GHG Reduction Achievement till 2016

Mitigation Action	Mitigation Monitoring Evaluation Report (tCO_2e)					Reduction Target (tCO_2e)	
	2012	2013	2014	2015	2016	2020	2030
Energy efficient Public street lighting	50	1293	11556	20314	28519	65147	67110
Public street lighting using solar cell	26	54	10	10	111	-	-
Solar cell in schools & government buildings	1	24	80	88	85	-	-
Solar cell in Sebira Island	4	69	62	60	59	-	-
Bus Rapid Transit	83993	207166	333835	162943	32214	182064	309917
Feeder busway	NA	NA	NA	10205	48502	100932	367306
Intelligent Transport System (ITS)	34405	34405	27424	5940	-	62437	65848
Electric Train	NA	NA	NA	241059	148107	169500	171300
Energy efficiency in government buildings	NA	NA	32446	35831	4601	49430	129458
Green Buildings	6809	8090	11913	13789	14388	1479086	55322972
Gas engine utilization in commercial buildings	NA	NA	NA	21504	19262	-	-
Reduce own use of power plant	NA	NA	NA	NA	40	-	-
Power plant efficiency	NA	NA	NA	NA	3711837	-	-
Landfill gas	276690	197557	117348	67785	48195	838937	838937
Green Open Area	8456	1494	653	741	671	445	445
Biodiesel	114975	179645	NA	NA	NA	1396600	4145200
LPG	1845185	1894197	NA	NA	NA	91633	101581
Composting	NA	NA	7698	18890	27377	138714	138714
3R Center	NA	NA	96096	22830	29155		
Sewage treatment plan (Duri Kosambi & Pulo Gebang)	NA	NA	NA	NA	606	214306	214306
Wastewater treatment	NA	NA	NA	NA	1849	100511	150766
TOTAL	2370594	2529996	1291518	1962608	4115578	4889742	62023860
Reduction Achieved for 2016 = 13.58%							

Source: Low Carbon Development in DKI Jakarta, Jakarta Planning Board

Green Zone (Climate Kampong) Development Acceleration Through New Building Standards

Current Scenario:

In 2004, in Indonesia, energy demand from the building sector accounted for around 27% of the total energy consumption, and this figure is expected to increase to up to 40% by 2030, with the majority of new buildings expected to rise in Jakarta (C40.org, 2018). The International Finance Corporation (IFC) noted that up to one-third of the energy and water consumed by buildings in Indonesia, including those in its capital city, can be reduced through better building design and management.

Solution:

Supported by the IFC and assisted by the Clinton Climate Initiative and since 2009 by C40, Jakarta's local government has identified low to middle-income high-rise housing in Daan Mogot as the pilot area for the Green Zone project. The built area will cover 17,6098 ha and will consist of 7 sixteen-storey high-rise buildings, the Jakarta Grand Mosque - in process of completion - schools and hospitals.

Innovation:

To accelerate the implementation and development of the Green Zone project, the Governor established a Green Building Forum composed of a group of various stakeholders, aiming to mainstream the concept of Green Building as it has been defined by the Governor Regulation of DKI Jakarta No.38/2012 on Green Building and the Governor Instruction No. 30/2017. This Green Zone Project is part of the pilot implementation of "30:30 Commitment", which is Jakarta's commitment to reduce water and energy consumption, as well as GHG emissions by 30% by 2030.

Energy Savings	•853,914 MWh/year
Cost Savings	•68,313,105 USD/year
CO_2 Reduction	•605,425 tCO_2e/year

Figure 16: Total amount of savings & CO_2 reduction

Case Study 3 – Samui Island (Thailand)

The Samui Green Island Project aims to reduce CO_2 emissions as well as reduce and reuse solid waste and treated waste water for non-sanitary purposes. The project has developed a comprehensive strategy to meet these goals that includes reducing CO_2 emissions in the transportation and building (both residential and commercial) sectors through public awareness campaigns, planning and engineering techniques, and advances in technology.

It was estimated during a previous feasibility study (2006) that energy supply/demand side management alone could avoid the release emissions of more than 80,000 tCO_2 per year. However, that target must be re-evaluated in light of current trends, such as increased private transportation, and the construction of additional tourist facilities (ESCI, 2017).

New estimates for potential CO_2 reduction have been estimated at 20 – 30 % in the year 2030 (over 2010) for a savings of between 120,000 – 180,000 tCO_2e per year. Potential projects for CO_2 reduction are (ESCI, 2017):

- reduction in energy use in homes and commercial buildings by installing energy efficient equipment and installing solar PV for generating clean energy;

- reduction from fuel switching either to bio-diesel or CNG in ferry transportation;
- reduction from the implementation of public transport, including EV buses;
- reduction from the implementation of district cooling;
- reduction from the implementation of renewable energy, along with recovery of waste heat;
- reduction from the introduction of LED street light;
- reduction from the reduced amount in landfill and methane (CH_4) fermentation

In addition to reducing CO_2 emissions, the plan for the Samui Green Island Project to be a "Clean and Green Development" calls for sorting solid waste to avoid sending it to the landfill, reusing treated waste water for non-sanitary purposes, and promoting the development of open, green spaces in an effort to attract tourist activity. Furthermore, the introduction of sidewalks and bicycle lanes along the beach will increase the island's attractiveness to tourists, while improving quality of life for the island's residents.

Case Study 4 – Ngu Hanh Son District, Viet Nam

Danang City has proposed a LCMT model for its Ngu Hanh Son District. The proposal incorporates new technologies and a "policy of an effective dissemination" to accomplish the ambitious goal of incorporating the use of biomass energy, effective transportation systems, and energy efficient buildings to achieve model LCMT status.

The Ngu Hanh Son District in Danang City intends to implement the following strategies (ESCI, 2018):

1. Methane recovery and effective utilization of biomass energy
   - Utilize methane generated from a sewage disposal and a kitchen waste for a fuel material of Bus Rapid Transit (BRT).
   - Utilize bio-diesel produced from seed oil of plant for a fuel material of BRT.
2. Low carbon-emission transportation system
   - Promote electric motorcycle: Establishing a restricted area for engine motorcycles in Ngu Hanh Son District and building free plug-in stations.
   - Establish a low-carbon transportation system using BRT along trunk road which runs from the airport and urban area to Ngu Hanh Son District.
3. Introduction of technologies of energy saving and CO_2 saving into buildings
   - Encourage employing the technologies into public facilities
     i. Air conditioning system with heat pump using river water or sea water,
     ii. BEMS, HEMS and CEMS,
     iii. Photovoltaic power plants,
     iv. Eco-friendly landscape design
   - Promotion policy introducing the technologies into the facilities of private sector
     i. Comprehensive assessment system for built environment efficiency,
     ii. Environment-consideration guideline for buildings.
4. Encouragement of dissemination of LCMT
   - Visualization of eco-friendly actions for urban residents,
   - Encouraging people's participation to eco-friendly action.

Table 11: Amount of CO_2 savings by implementing these strategies

Interventions	Description	Savings tCO_2e/yr
Utilization of Sewage/Sludge	Methane generated from sewage disposal & kitchen waste used as fuel for BRT	**18,571,070**
Use of EVs	80% motorbike is replaced by EV	**152,338**
	BRT in the city	**22,532**
	Energy Management System at Hotels (20% energy savings)	**49,292**

Source: LCMT scheme for Ngu Hanh Son District

Case Study 5 – Ho Chi Minh, Viet Nam

Current Scenario:

The city's current road system is congested and dangerous, experiencing an average of 4,700 accidents each year (C40.org, 2015). Many of these crashes involve motorbikes, of which there are eight for every 10 people. The Saigon BRT line, which will expand to six corridors upon completion, will help ease this congestion and prepare Ho Chi Minh City for a safer and more sustainable future.

Solution:

In cooperation with the World Bank, Ho Chi Minh City launched the Green Transport Development Project in 2013, with the aim of catalyzing a cultural shift around transportation in the region and getting more people onto mass transit and off of the congested roadways. The cornerstone of the project is Saigon BRT, a 23 km bus rapid transit system that will accommodate up to 28,300 passengers daily when fully operational.

In addition to the bus infrastructure, the BRT corridor will also provide space for cycling and walking, as well as bike parking facilities. With Saigon BRT, the city seeks to transform how citizens view public transport and lay the ground-work for a more sustainable future based on transit-oriented development.

Social Benefits:

By ensuring safer, faster, and more comfortable transportation, the Green Transport Development Project aims to change commuting habits and improve the public's attitude towards mass transit.

Economic Benefits:

The city anticipates a substantial decline in traffic accidents and their associated costs due to the introduction of the BRT system.

Health Benefits:

Ho Chi Minh City foresees improvements in air quality that will reduce cases of bronchial and asthmatic diseases among residents.

Key Impact:

23 ktCO_2e will be reduced by 2020

Case Study 6 – Ha Noi, Viet Nam

About the city:

Ha Noi is the capital and one of the five municipalities of Viet Nam. It covers an area of 3,328.9 sqkm. With an estimated population of 7.7 million as of 2018, it is the second largest city in Viet Nam. The metropolitan area, encompassing nine additional neighbouring provinces, has an estimated population of 16 million (C40.org, 2019). Located in the central area of the Red River Delta, Ha Noi is the commercial, cultural, and educational centre of Northern Viet Nam.
Current Scenario: With a population of 93 million people, Viet Nam generates daily nearly 35,000 tons of urban domestic waste and 34,000 tons of rural domestic waste. In the capital city of Ha Noi alone, 10,000 tons of solid waste are generated every day. Without a sustainable recovery process, waste resources are not being optimised.

Such resources could be for example utilised to generate electricity. Effective waste treatment for energy generation will help ensure energy security, reduce environmental pollution, and contribute to effective land use and green sustainable economic development.

Solution:

The Ha Noi Urban Environment Company (URENCO) and its partners (T&T Group and 3 leading Korean companies) agreed in September 2017 to jointly design, build, finance and operate a facility that will gather, process, and treat methane gas emitted from decomposing garbage to produce electricity, aiming to reduce methane emissions, environmental pollution and dependence on fossil fuels.

The landfill gas utilization plant will be developed at the Nam Son landfill in the Soc Son District, just outside Ha Noi. The waste treatment complex at Nam Son landfill is the largest of its kind in Ha Noi, treating around 4,000 metric tons of garbage per day and stretching across 83.5 hectares. Following the completion of a feasibility study, the facility is expected to have a total capacity of 5MW.

The equipment that will be installed includes a gas collection network, an extraction and flaring station including high temperature enclosed flares and monitoring and control systems.

Outcome:

It is estimated that the project will achieve emissions reductions of about **128.3 ktCO_2e/year.**

Bus Rapid Transit System

Current Scenario:

Ha Noi's transportation has been characterized by the dominance of motorcycles, a symbol of high personal mobility associated with rapidly rising incomes. Over 5 million motorcycles and 585,000 private cars are occupying 85.8% of the city's road networks (C40.org, 2019). Congestion was already becoming a critical problem in the city. Traffic was in general unorderly and sometimes chaotic at intersections, posing safety concerns and exacerbating air pollution

Solution:

The City of Ha Noi, backed by the World Bank, approved the construction of a critical road infrastructure (a Bus Rapid Transit system) to improve access to cities less developed areas and to facilitate an environmentally sustainable urbanization of Ha Noi.

This BRT project has been designed as a Specific Investment Loan, with the Global Environmental Facility (GEF) co-financing a set of initiatives that either would reduce barriers to project implementation or maximize its global environmental benefits. The project is consistent with the GEF Operational Program 11th objective of 'Promoting Environmentally Sustainable Transport' and the GEF climate change strategic priority related to sustainable transport. The Ha Noi Bus Rapid Transit (BRT) system proposed in this project has also been the first such system financed by the World Bank in Asia, with the potential to be a high-profile demonstration for bus-based mass rapid transit in the region.

Key Achievements:

14,000 people use the service each day, 80% of whom are students and office workers. According to the Ha Noi Department of Transport, 23% of riders have switched to using BRT from their private vehicles. The BRT system has helped to increase urban mobility in targeted areas of the city, promoting more environmentally sustainable transport modes. It increased the use of public transport in selected traffic corridors and reduced travel time between the center and the west and northwest sections of Ha Noi.

The principal GHG emissions reduction comes from reduced car and motorcycle trips. The total GHG emissions reduction estimated until 2025 is **122,177 tCO_2e**.

Traffic improvement	Emission Reduction
• Reduction of motor vehicle access pressure on the inner city • Improving urban mobility in targeted areas	• 20,000 tCO_2e/year

Source: Project team analysis

Figure 17: Key Impacts of BRT system

Case Study 7: Cape Town

About the city:

Cape Town is a legislative capital of South Africa, colloquially named the Mother City. It is the legislative capital of South Africa and primate city of the Western Cape province. It forms part of the City of Cape Town metropolitan municipality. The city is known for its harbour, for its natural setting in the Cape Floristic Region, and for landmarks such as Table Mountain and Cape Point. Cape Town is home to 64% of the Western Cape's population (C40.org, 2016).

Current Scenario:

The Transport sector of Cape Town consumes a great deal of diesel, and transport, as a whole, is responsible for 34% of the city's CO_2 emissions.

Solution:

With its Transit Oriented Development Strategic Framework (TODSF), Cape Town is using transport as the foundation of its long-term land use management and growth development, marking a paradigm shift for the city, which wants to become more compact and connected. The TODSF's priorities include a modal shift towards public transport, the reduction of travel distances and costs, and the alleviation of urban sprawl through the optimization of land use. Concrete measures include a 12% improvement in access to transit and a 23% reduction in passenger kilometers travelled by 2032. To embark on this new vision, Cape Town developed an optimized transport scenario that will direct the organization of different land uses, including transport zones, public utilities, and businesses, and identify the actors necessary to deliver the new developments. To facilitate the uptake of the new directives, this focus on transit-oriented development will be embedded within all strategic and built environment plans of the city and will be used as a sustainable growth management tool.

Benefits:

Environmental: The TODSF aims to have 20% fewer cars circulating in the city by 2032, which will improve the air quality of Cape Town. 1.6 $MtCO_2e$ of GHG emissions will be reduced from 2012 levels by 2032 under TODSF

Economic: By prioritizing transit-oriented development, the TODSF will decrease kilometers traveled and transportation costs, particularly for low-income groups who currently spend 43% of their income on transport.

Health Benefits: By reshaping the city to allow for greater use of non-motorized transport such as walking and cycling, the TODSF will help residents lead healthier lifestyles.

Case study 8: Stockholm

About the city:

Stockholm is the capital of Sweden and the most populous urban area in the Nordic countries. The city stretches across fourteen islands where Lake Malaren flows into the Baltic Sea. Stockholm is the cultural, media, political, and economic centre of Sweden. The Stockholm region alone accounts for over a third of the economy's GDP and is among the top 10 regions in Europe by capital. It is an important global city, and the main centre for corporate headquarters in the Nordic region (C40.org, 2015).

The Challenge:

Stockholm aims to be a true world leader as the largest city to become fossil-fuel free. In the past few years it has surpassed many of its climate change goals, proving it has the political will and technical experience necessary to achieve its ambitious target of a renewably-fuelled future.

Solution:

In 2012, the City of Stockholm set the goal of becoming fossil fuel-free by 2050. Driven by ambitious leadership and actionable goals, in 2015, the city pushed the target date up by a decade, and now plans to run exclusively on renewable energy by 2040. The comprehensive plan relies on overall energy reduction and an increase in renewable energy use. For instance, energy standards for new buildings built on city-owned land are 55 kWh/m^2 compared with domestic standards of 80 kWh/m^2. Similarly, the city aims to reduce energy use in the building sector by 50% between 1995 and 2050.

By 2040, natural gas will be entirely phased out of the city's energy grid and heating system, replaced primarily by biogas. The energy company that provides district heating is particularly ambitious and has decided to phase out fossil fuels by 2030; starting in 2016, renewable energy will be able to fuel 90% of the city's district heating system, up from 80% today. Increasing the use of renewable energy in transportation from 16% to 100% by 2040 will likely be the city's most significant challenge, as this will entail removing all conventional fuel-powered vehicles from the city's streets. To achieve this goal, the city plans to double the capacity of the public transport system, while improving walking and biking infrastructure.

Key Benefits:

57% reduction in CO_2 emissions by 2020 based on 1990 levels

Comparison of best practices across shortlisted cities:

Table 12: Comparative table showcasing different interventions implemented in cities

Sectors	Hue, Viet Nam	Jakarta, Indonesia	Samui Island, Thailand	Ngu Hanh Son, Viet Nam	Ho Chi Minh, Viet Nam	Ha Noi, Viet Nam	Wuhan's Baibuting Community	Cape Town, South Africa	Stockholm, Sweden
Transport	Green houses for emission reduction.	Intelligent Transport System, Electric Train	Fuel switching to bio diesel or CNG, use of EVs	Utilized bio diesel and methane generated from sewage disposal as fuel for BRT, use of EVs	Use of bus rapid transit system	Use of bus rapid transit (BRT) instead of motorbikes	Use of bio fuels, intelligent transportation system	Optimisation of land use and efficient vehicles	Use of EVs in public and private transportation
Residential buildings		Green Buildings	Energy efficient equipment				Use of LED lightings, use of solar energy		Use of Solar PV, Solar heaters and use of biogas
Commercial buildings			Energy efficient equipment	Air conditioning system with heat pump, photovoltaic power plants, green buildings					Use of Solar PV, Solar heaters
Waste		Landfill gas, sewage treatment plant, wastewater treatment	Reduced amount of landfill and methane fermentation				Wastewater treatment		
Energy supply		Solar PV in schools and government buildings	Use of renewable energy and waste heat recovery			Waste to electricity generation			
Municipal Street Lighting		Public street lighting using energy saving lamps, solar cells	Use of LED street light						
Total CO_2 Reduction (tCO_2e)	**100-200 (average savings)**	**5,385,425 (estimated till 2030)**	**120,000 -180,000**	**187,500 (estimated for 2016)**	**23,000 (estimated till 2020)**	**148,304 (estimated till 2020)**	**30,000 (achieved till 2017)**	**1,600,000 (estimated till 2032)**	**4 (estimated till 2020)**

5 Business as Usual Scenario

This section of the report discusses the Business as Usual (BAU) scenario of following specific sectors for Da Lat.

Table 13: Sectors considered to study BAU scenario for Da Lat city

Da Lat City - the Specific Area for LCT - I				
No.	**Location**	**Demand/Supply**	**Sector**	**Sub areas considered for BAU section**
1	Whole city of Da Lat	Demand	Buildings	1. Residential 2. Commercial
			Transportation	1. 2-wheelers 2. 4-wheeler passenger vehicle (commercial and private) 3. Goods vehicle
		Supply	Conventional Sources	1. Power 2. Fossil fuels
			Renewable sources	1. Solar

For Da Lat, each sector in this report is further divided into three sub sections viz. Sector wise total energy consumption, total primary energy supply, and environmental impact. In a number of cases only Lam Dong level data was available and hence, the information provided in these sub-sections are derived by taking domestic or province level proxies. Following steps were adopted to derive city level information:

Table 14: Steps to determine City Level information from an Economy Level Information

STEPS TO DETERMINE CITY LEVEL INFORMATION FROM AN ECONOMY LEVEL INFORMATION	
Step 1	Base year has been considered as FY 2017-18
Step 2	Energy Supply and Energy Demand (sector wise) of the entire economy in FY 2017-18 is considered
Step 3	Domestic Level Population for FY 2017-18 was obtained via secondary research
Step 4	City level Population for FY 2017-18 was obtained via secondary research
Step 5	Domestic Energy Supply and Demand (Sector wise) was divided by Domestic Level population and the result was multiplied by City level population to get city level data.

In the succeeding sections, information pertaining to individual sectors is provided

5.1 Transport Sector

Transportation for Da Lat traffic includes only road and airways – with roadways being the major means of transportation.

Types of Transport: Transport services in the Da Lat city consist mainly of 2-wheelers and 4-wheeler passenger transport which includes cars, taxis which are privately owned and operated. The other significant category of vehicles is commercial vehicles present for freight transport.

Based upon the Viet Nam level data of vehicle registration (WHO, 2010) number of vehicles present in the economy has been derived as given in Table 15

Table 15: No. of vehicles in Viet Nam

Viet Nam	No. of vehicles (in thousand)							
Type of Vehicle	2010	2011	2012	2013	2014	2015	2016	2017
2W	31452	33167	38000	40072	42256	44560	45000	47453
4W Passenger vehicle	654	812	827	1027	1275	1583	1484	1842
Goods vehicles	552	614	652	725	806	897	1109	1233

Source: WHO, VNExpress, BHQ 2014

It can be observed that traffic in Viet Nam is heavily skewed towards 2-wheelers – in fact it is considered the 4th largest motorcycle market in the world (Motorcyclesdata, 2019), even though it is has the 15th largest population base globally. Based on the above data of vehicle registration and per capita vehicle density at the domestic level, the estimates of the total number of vehicles present in Da Lat has been estimated and results presented in Table 16

Table 16: No. of vehicles in Da Lat

Da Lat	No. of vehicles							
Type of Vehicle	2010	2011	2012	2013	2014	2015	2016	2017
2W	268.54	289.26	311.57	335.60	361.49	389.37	420.41	453.92
4W Passenger vehicle	4.23	4.52	4.77	5.10	5.51	6.03	6.88	7.74
Goods vehicles	4.45	4.95	5.42	5.86	6.44	7.24	8.14	9.22

Source: Project Team Analysis, Transport Department of Lam Dong Province

Type of fuel used: Type of fuel that is being used for vehicular transport is either gasoline or diesel. Accordingly, share of fuels across 2W and goods vehicle segment in Viet Nam is given in Table 17

Table 17: Share of fuels across 2W and goods vehicles segment in Viet Nam

No.	Type of Vehicle	Share of Diesel	Share of Petrol
1.	2W	0%	100%
2.	Goods vehicles	100%	0%
3.	Taxis (4W passenger)	0%	100%
4.	Personal vehicles (4W passenger)	100%	0%

Source: BAQ 2014 presentation, Lam Dong province Transport Department

Vehicle traffic:

Vehicle traffic data for Viet Nam in terms of million passenger km (in case of 2W and 4W passenger vehicles) and million tonne km (in case of freight vehicles) have been derived from the data available in Viet Nam Statistical Handbook (GSO Viet Nam, 2018) as given in Table 18

Table 18: Vehicular traffic in Viet Nam

Viet Nam	Vehicle traffic (million passenger km/million tonne km)								
Vehicle Type	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**CAGR**
2W	67787	76148	83171	88063	94048	101767	110553	120704	8%
4W Passenger vehicle	1410	1865	1811	2257	2838	3615	3646	4686	17%
Goods vehicle	36179	40130	43469	45668	48190	51515	57377	63459	8%

Source: Project Team Analysis

In case of Da Lat, domestic level vehicular traffic data (Lam Dong Statistics Office, 2017) was indexed to population at city level to derive vehicular traffic data as given in Table 19

Table 19: Vehicular traffic in Da Lat

Da Lat	Vehicle traffic (million passenger km/million tonne km)								
Vehicle Type	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**CAGR**
2W	342.35	366.13	392.88	417.63	415.28	458.81	497.17	549.87	6%
4W Passenger	5.41	6.81	6.49	8.13	9.51	12.37	12.45	16.21	15%
Goods vehicle	107.01	122.94	141.03	161.05	179.94	152.80	226.02	281.97	13%

Source: Project Team Analysis

Energy consumption by fuel types:

At Viet Nam level, the total energy consumption in entire transport sector is available (IEA, 2017) which is used along with average utilization of each category of vehicles to calculate the energy consumed, given in Table 20.

Table 20: Energy consumption of vehicles in Viet Nam

Viet Nam	Vehicle category-wise energy consumption (KTOE)								
Vehicle Type	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**CAGR**
2W	6369	6323	6242	6074	6197	6739	7648	7820	3%
4W Passenger vehicle	133	155	136	156	187	239	252	304	11%
Goods vehicle	3399	3332	3262	3150	3176	3411	3969	4111	3%
Total	**9900**	**9810**	**9640**	**9380**	**9560**	**10390**	**11870**	**12235**	**3%**

Source: International Energy Agency (IEA) and Project Team Analysis

Accordingly, based on the utilization of vehicles in Da Lat, the energy consumed for each category of vehicle is calculated and results are shown in Table 21

Table 21: Energy consumption of vehicles in Da Lat

Da Lat	Vehicle category-wise energy consumption (KTOE)								
Vehicle Type	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**CAGR**
2W	54.38	55.09	51.18	50.83	52.90	58.66	70.27	73.20	4%
4W Passenger	0.86	0.86	0.78	0.77	0.81	0.91	1.15	1.25	5%
Goods vehicle	27.38	26.81	27.11	25.48	25.36	27.56	29.15	30.75	1%
Total	**82.61**	**82.76**	**79.07**	**77.08**	**79.07**	**87.12**	**100.56**	**105.19**	**3%**

Source: Project Team Analysis

As mentioned beforehand, based on fuel type for each category of vehicle the total energy consumed in the sector on the basis of fuels. Results are provided in

Table 22: Fuel wise energy consumption in Viet Nam

Viet Nam	Fuel-wise energy consumption (KTOE)								
Fuel Type	2010	2011	2012	2013	2014	2015	2016	2017	CAGR
Diesel	3425	3289	3181	3213	3459	4020	4172	4291	3%
Gasoline	6447	6351	6199	6347	6931	7850	8063	8324	3%
Total	9872	9640	9380	9560	10390	11870	12234	12615	3%

Source: Project Team Analysis

According to the fuel mix, the vehicle type based fuel consumption is segregated to the fuel type consumption as well and the results are given in Table 23

Table 23: Fuel wise energy consumption in Da Lat

Da Lat	Vehicle category-wise energy consumption (KTOE)								
Fuel Type	2010	2011	2012	2013	2014	2015	2016	2017	CAGR
Diesel	28.22	27.65	27.87	26.23	26.11	28.39	30.20	31.88	1%
Gasoline	54.39	55.11	51.20	50.85	52.95	58.74	70.37	73.31	4%
Total	82.61	82.76	79.07	77.08	79.07	87.12	100.56	105.19	3%

Source: Project Team Analysis

5.2 Buildings Sector

In case of building sector both residential and commercial buildings have been considered. However, due to limitation on data available type of fuels being used in the commercial building, the calculations focus only on the electrical data that was available.

For residential buildings sector, domestic level data on type of fuels being used was utilized to estimate the fuel-wise energy consumption as given in Table 24: Fuel wise energy consumption in residential building of Viet Nam:

Table 24: Fuel wise energy consumption in residential building of Viet Nam

Viet Nam	Fuel-wise energy consumption in residential buildings sector (KTOE)								
Fuel Type	2010	2011	2012	2013	2014	2015	2016	2017	CAGR
Oil products (LPG & Kerosene)	900	880	860	870	830	850	1120	1162	4%
Coal	1200	1140	1080	1190	1120	1110	1180	1177	-0.3%
Biofuels	11240	11360	11480	11600	11730	11850	11980	12108	1%
Electricity	2710	2940	3300	3610	3930	4330	4790	5267	10%
Total	16050	16320	16720	17270	17610	18140	19070	19713	3%

Source: International Energy Agency

The Viet Nam level data was indexed based on the population data projected for Da Lat. The data thus generated was compared with the primary level data available (i.e. electricity consumption for residential buildings in 2017) and a correction factor[9] was introduced. The correction factor was multiplied with the population indexed energy consumption data to generate actual energy consumption data for residential buildings. The results are given in Table 25 for reference:

Table 25: Fuel wise energy consumption in residential building of Da Lat

Da Lat	Fuel-wise energy consumption in residential buildings sector (KTOE)								
Fuel	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**CAGR**
Oil products (LPG & Kerosene)	0.002	0.002	0.002	0.002	0.002	0.002	0.003	**0.003**	3.8%
Coal	0.003	0.003	0.003	0.003	0.003	0.003	0.003	**0.003**	-0.2%
Biofuels	0.028	0.028	0.028	0.028	0.029	0.029	0.029	**0.030**	1.1%
Electricity	0.007	0.007	0.008	0.009	0.010	0.011	0.012	**0.013**	10.0%
Total	**0.039**	**0.040**	**0.041**	**0.042**	**0.043**	**0.044**	**0.047**	**0.049**	3.0%

Source: Project Team Analysis

In case of commercial buildings, the data on electricity consumption for 2017 was available. This value was indexed against the GDP growth of Da Lat to derive the electricity consumption data for commercial sector – since it is expected that change in economic activity of the region will have direct impact on the commercial activities and subsequently the energy expended in these activities. As given in Table 26, the consumption for the sector comes out to be extremely low as compared to other sectors and even residential buildings.

Table 26: Fuel wise energy consumption in commercial building of Viet Nam

Da Lat	Fuel-wise energy consumption in commercial buildings sector (KTOE)								
Fuel	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**CAGR**
Electricity	0.0004	0.0004	0.0006	0.0007	0.0008	0.0010	0.0011	0.0013	22%

Source: Project Team Analysis

5.3 Agriculture Sector

Agriculture is an important contributor to GDP of Viet Nam as well as Da Lat. The data related to this sector, which includes both crop production as well as aquaculture, has been derived from domestic level sectoral energy consumption data (IEA, 2017), output per unit area of land/water body (GSO Viet Nam, 2018) and total amount of land being used for crop production and aquaculture. It is assumed that electricity utilized in thus sector is only for running irrigation pumps. The result thus obtained in given in Table 27 below:

Table 27: Energy consumption in agriculture & aquaculture sector of Viet Nam

Viet Nam	Fuel-wise energy consumption in agricultural sector (KTOE)								
Fuel Type	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**CAGR**
Agriculture	67	76	109	108	134	168	185	**215**	18%
Aquaculture	13	14	21	22	26	32	35	**45**	19%
Total	**80**	**90**	**130**	**130**	**160**	**200**	**220**	**260**	18%

Source: Viet Nam Statistical Handbook and Project team analysis

[9] Correction factor = Actual electricity consumption data for 2017/Population indexed electricity consumption data for 2017.

The domestic level values have been indexed to the total value of produce generated in Da Lat as well as value of production at Viet Nam level. The indexation helped generate the energy consumption data for the 2 sub-sectors. The result of the data extrapolation is given in Table 28:

Table 28: Energy consumption in agriculture & aquaculture sector of Da Lat

Da Lat	Fuel-wise energy consumption in agricultural sector (KTOE)								
Fuel Type	2010	2011	2012	2013	2014	2015	2016	2017	CAGR
Agriculture	0.45	0.43	0.69	0.74	0.88	1.16	1.41	1.96	21%
Aquaculture	0.00005	0.00005	0.00009	0.00010	0.00012	0.00054	0.0007	0.0008	54%
Total	0.45	0.43	0.69	0.74	0.88	1.16	1.41	1.96	21%

Source: Viet Nam Statistical Handbook and team analysis

5.4 Energy Supply

In case of domestic scenario, the energy supply has been derived from domestic and international level database as given in Table 29 (IEA, 2017):

Table 29: Fuel wise energy supply in Viet Nam

Viet Nam	Fuel-wise energy supply (KTOE)								
Fuel Type	2010	2011	2012	2013	2014	2015	2016	2017	CAGR
Oil & oil products	14771	13958	13522	14026	14941	16375	18557	19321	4%
Coal	2628	2830	2878	3315	3556	4372	4669	4993	10.0%
Natural Gas	1653	1571	1670	1801	1792	1723	1846	2040	2%
Hydro	513	824	1113	1141	1234	1054	1289	1425	16.6%
Solar	0	2	2	3	2	2	5	5	15%
Biofuels	11244	11365	11495	11605	11735	11854	11985	12113	1.1%
Total	30810	30550	30680	31890	33260	35380	38350	43043	4%

Source: IEA Viet Nam Sankey diagram

The energy supply for Da Lat has been derived from the table given above by indexing against the economic output i.e. GDP of the city. The data thus obtained is given in Table 30:

Table 30: Fuel wise energy supply in Da Lat

Da Lat	Fuel-wise energy supply (KTOE)							
In KTOE	2010	2011	2012	2013	2014	2015	2016	2017
Oil & oil products	8.005	10.307	18.597	27.153	39.745	49.090	62.088	72.140
Coal	0.786	1.673	3.314	5.398	8.121	11.237	13.716	16.342
Natural Gas	0.314	0.776	1.819	2.672	3.894	4.287	5.268	6.481
Hydro	0.098	0.407	1.213	1.692	2.681	2.624	3.679	4.526
Solar	0.000	0.001	0.003	0.004	0.005	0.005	0.013	0.016
Biofuels	0.001	0.002	0.029	0.008	0.010	0.011	0.013	0.016
Total	9.203	13.167	24.975	36.925	54.458	67.254	84.777	99.523

Source: Project team analysis

The energy supply mix for Da Lat comprises oil and oil products (like gasoline, diesel, LPG, kerosene), coal (in its primary form), biofuels (primarily biomass) as well as fuels involved in generation of electricity viz. coal, oil products, biofuels and other renewable sources of energy like solar and hydro. Power is supplied to Da Lat through the domestic grid and accordingly figures for electricity generation has been projected from domestic level data by indexing on basis of domestic and city-level economic growth.

As it is seen, coal is one of the primary sources of energy for Da Lat, along with oil and oil products in the supply side. There is a loss of energy while conversion from the primary form to the final form. The emission caused due to this loss of energy is considered in the supply side.

A notable phenomenon is the higher contribution of hydro power in electricity generation – nearly 21% contribution in the power generated.

5.5 Environmental Impact

The key impact of the BAU is the emission caused due to fuel mix involved in generation and consumption of energy for Da Lat. It is estimated that 0.382 $MtCO_2e$ emission has occurred in the baseline year 2017. The break-up of the emissions from supply and consumption side is given in Table 31 for comparison:

Table 31: Energy and emissions data for supply side for base year i.e. 2017

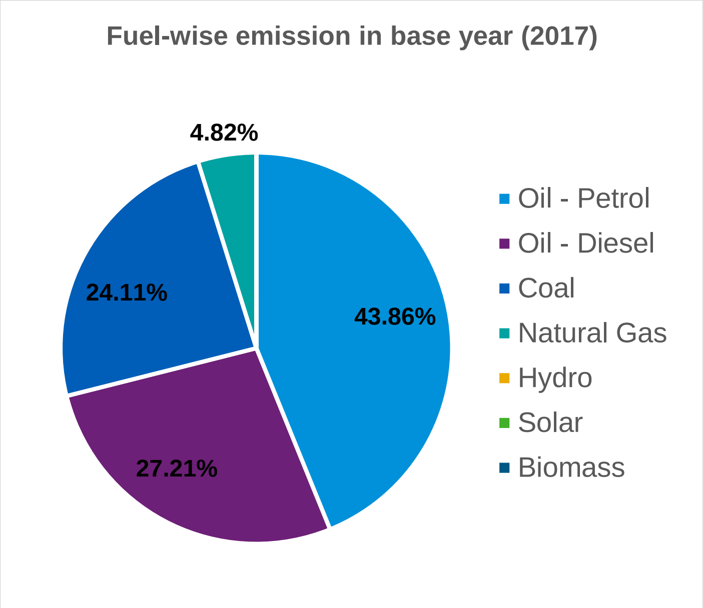
SUPPLY SIDE

Total Energy Supplied for Base year		
STATE	**FUEL**	**Energy Supplied (KTOE)**
Liquid	Oil	72
Solid	Coal	16
Gas	Natural Gas	6
RE	Hydro	5
RE	Solar	0
Solid	Biomass	0
TOTAL (kTOE)		**100**

Total Emissions for Base Year		
STATE	**FUEL**	**Total Emissions ($ktCO_2e$)**
Liquid	Oil – Petrol	141
Liquid	Oil – Diesel	64
Solid	Coal	70
Gas	Natural Gas	14
RE	Hydro	0
RE	Solar	0
Solid	Biomass	0
TOTAL ($ktCO_2e$)		**289**

Source: Project team analysis

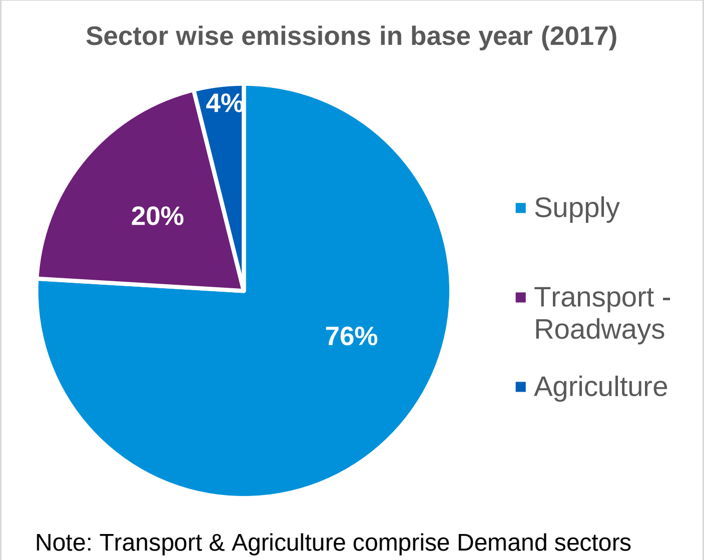
Oil products and coal are the major contributor to the emission of CO_2 for Da Lat contributing to a combined 71% of the total emission generated for the city. The generation of electricity contributes nearly 14% of the total emissions. A summary of the share of fuel-wise emission in base year is given in Figure 18 below.



Source: Project team analysis

Figure 18: Fuel-wise emission in base year for Da Lat

In case of supply side, there are two components to emissions – electricity generation and losses in conversion from primary form of fuel to final usable form. In case of electricity generation, the emissions are considered at the source of generation. Since, Da Lat draws electricity from domestic grid and there are no power generation stations within the city jurisdiction, the emissions thus generated will be at domestic level. However, pro-rata emissions are considered since city-level consumption will have direct effect on power generation requirement and subsequently on emission caused due to it. Oil products, supplying primarily to transport sector, contribute >70% of total emissions. Hydro, solar and biomass as energy source has limited emissions level i.e. <1%.



Source: Project team analysis

Figure 19: Emissions for demand sectors in base year for Da Lat

In the demand side, consumption of oil is primarily in the transport sector while coal is mostly used in power generation along with use in its primary form. The major oil products being used in LPG in residential buildings for cooking purposes. Bio-fuels include mostly bio mass – which is again a major energy source for cooking in the residential sector.

As given in **Figure** 19, demand sectors account for 24% of total emissions off which transport has the highest share. Transport sector accounts for nearly 84% of total emissions in demand sector, while agriculture accounts for nearly 16%. *Buildings sector which comprises both commercial and residential units comprises just 0.0014% of total demand sector emissions.*

Table 32: Energy and emissions data for Da Lat in base year i.e. 2017

Sector	Energy Consumption (KTOE)									
	Electricity	Coal	OIL		GAS		RENEWABLE			
			Gasoline	Diesel	Auto LPG	Natural Gas	Bioethanol	Fuelwood	Hydro	Solar
Buildings - Residential	0.0130	0.0029	-	-	0.0029	-	-	0.0298	-	-
Buildings - Commercial	0.0013	-	-	-	-	-	-	-	-	-
Transport - Roadways	-	-	73.3092	31.8826	-	-	-	-	-	-
Agriculture – Aquaculture	0.0008	-	-	-	-	-	-	-	-	-
Agriculture - Crop production	1.9564	-	-	-	-	-	-	-	-	-
Energy Supply	-	16.3419	21.8650	50.2753	-	6.4815	0.0164	-	4.5264	0.0164
TOTAL (KTOE)	**1.9715**	**16.3448**	**95.1742**	**82.1578**	**0.0029**	**6.4815**	**0.0164**	**0.0298**	**4.5264**	**0.0164**
29.03										

Sector	Emission (ktCO₂e)						
	Electricity	Coal	OIL		GAS		RENEWABLE
			Petrol	Diesel	Auto LPG	Natural Gas	Bioethanol
Buildings - Residential	0.1239	0.0124	-	-	0.0062	-	-
Buildings - Commercial	0.0123	-	-	-	-	-	-
Transport – Roadways	-	-	205.9416	93.7737	-	-	-
Agriculture - Fishery	0.0074	-	-	-	-	-	-
Agriculture - Crop production	18.6670	-	-	-	-	-	-
Energy Supply	-	69.8711	141.2342	64.3098	-	13.9575	-
TOTAL ($ktCO_2e$)	**18.8106**	**69.8836**	**347.1758**	**158.0835**	**0.0062**	**13.9575**	**0**
607.9171							

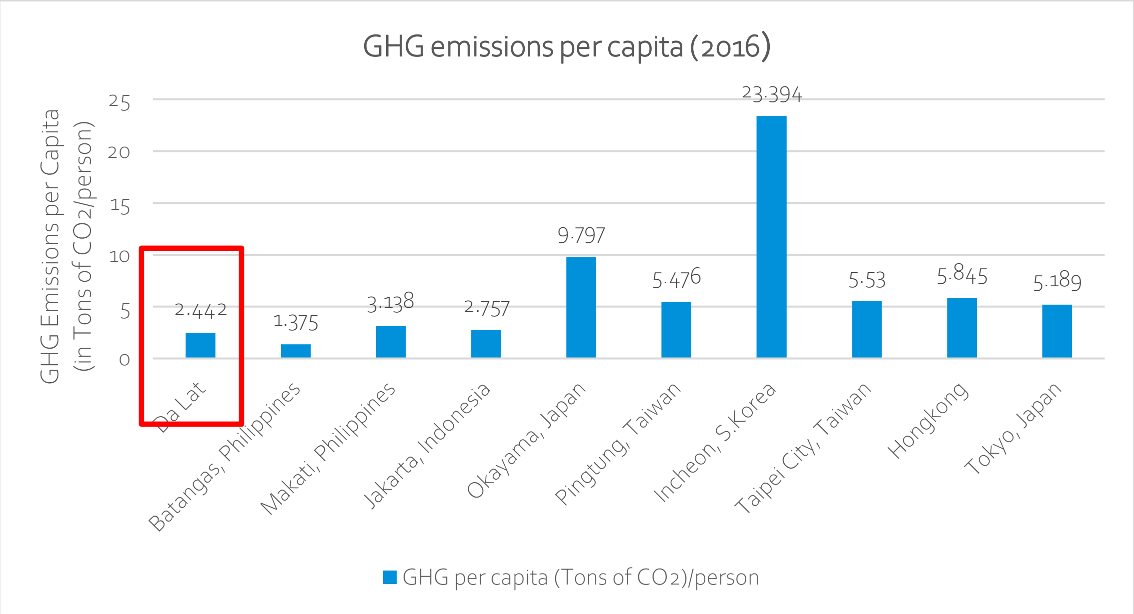
Source: Project team analysis

The total GHG emission for Da Lat city for the year 2017 is 0.608 $MtCO_2e$. Based on the information in GHG emissions released by MOIT (MOIT, 2017), GHG emission for Viet Nam in the year 2017 is projected to be 187.6 $MtCO_2e$ which means Da Lat city contributes to approximately 0.3% of the total GHG emissions of the entire economy. In comparison, the per capita emission of Da Lat for base year (2.678 tCO_2e per capita) is about 34% higher than the estimated values for Viet Nam (2.00 tCO_2e per capita). Also, the per capita emission has witnessed a year-on-year increase of nearly 10% in 2017 over 2016, when it stood at 2.442 tCO_2e per capita. The comparison is provided with the major cities of Asia in the table below:

Table 33: Comparison of emissions of major Asian cities

City	GHG Emission (tCO_2e)	Population in 2016	GHG per capita (tCO_2e)/person
Da Lat City	546,982	223,935	2.442
Batangas, Philippines	457,288	332,458	1.375
Makati, Philippines	1,660,370	529,039	3.138
Jakarta, Indonesia	27,780,000	10,075,300	2.757
Okayama, Japan	6,916,000	705,917	9.797
Pingtung, Taiwan	4,604,805	840,931	5.476
Incheon, S.Korea	69,794,140	2,983,484	23.394
Taipei City, Taiwan	14,957,404	2,704,810	5.530
Hongkong	42,700,000	7,305,700	5.845
Tokyo, Japan	70,125,000	13,513,734	5.189

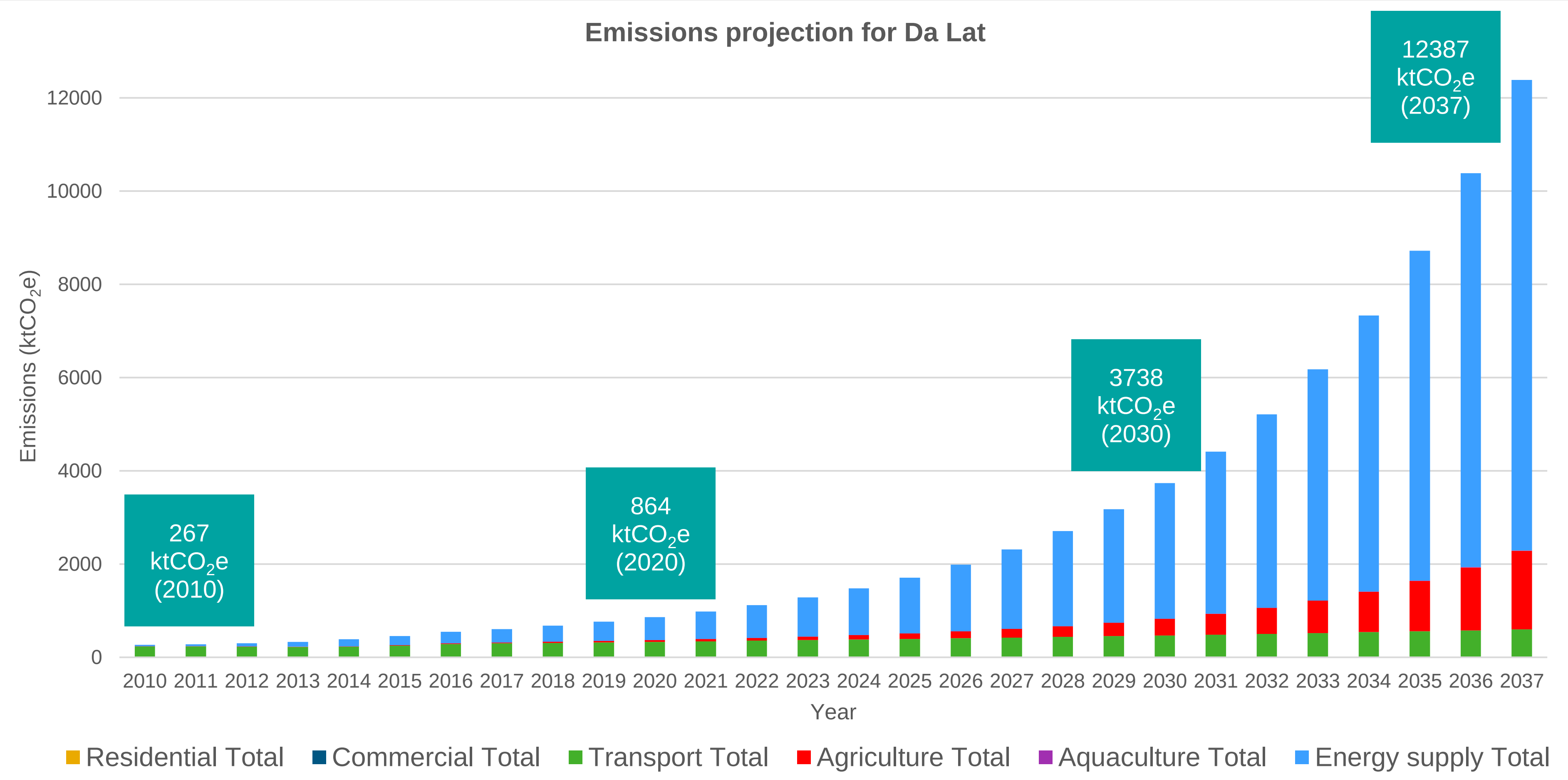
Source: Data.cdp website



Source: Data.cdp website

Figure 20: Comparison of per capita GHG Emissions of Da Lat with other cities (2016)

While the per capita emission is lower than major Asian cities, it is still more than the domestic average and it is substantially higher than cities with equivalent population i.e. Batangas (Philippines). If no corrective measures are undertaken, then emissions are expected to reach 12.39 $MtCO_2e$ by the next 20 years i.e. FY 2037. The result of the emission projections is given in Figure 21 below:



Note: In 2037, 3 sectors (Residential and Commercial Buildings, Aquaculture) will account for only 0.09% of total emissions. Historically, share of these sectors in total emissions has been low and hence, share of these sectors in Figure 21 is not visible

Source: Project team analysis

Figure 21: Emission projection for Da Lat (2010 to 2037)

6 Low carbon development strategy

As is observed from the baseline scenario, the sector wise emissions provide the areas where low carbon interventions should be focused on. Energy supply and transport are two sectors which accounted for 97% of total emission for the city in 2017. The best practice study provides the probable list of interventions which can be considered for reduction of emissions. Also, given the importance of agriculture for the city, incorporation of sustainable agricultural practice will have a positive impact on the living conditions of the city as well as contribute to abatement of emissions. Based on this premise, the following interventions have been considered as constituting the low carbon development strategy for Da Lat:

Table 34: Interventions constituting low carbon development strategy for Da Lat

Sector	Proposed Intervention	Description of intervention	Existing situation for the city
Transport	Use of alternate fuels for vehicles	Use of electric tourist buses in specified routes Replacement of existing gasoline based 2W with electric 2W Increased adoption of biofuel instead of gasoline for taxis	Transport sector is the 2nd highest contributor to emissions in the city with 48% share of total emissions City Green Growth Plan provides focus on use of biofuels in both passenger and freight transport
Buildings	Adoption of EE in public buildings	Identification of energy savings opportunities in public buildings Undertaking bulk purchase of EE equipment to reduce cost of acquisition and faster realization of costs through energy savings	Da Lat being provincial capital contains number of public buildings Funds allocated for VNEEP can be utilized to reduce energy consumption of public buildings as well as develop demonstration projects
Town Structure	Green city land use planning to increase green coverage	Development of interconnected roadways with increased green cover Possibility of extending concept into expansion areas of Da Lat. For which master plan is under preparation	Da Lat city is experiencing increased temperatures over the last decade Development of interconnected green corridors can help in reducing increased temperature as well as enhancing overall aesthetics of the city
Untapped Energy	Waste to energy systems	Generation of energy in the form of electricity through incineration of solid waste. Before incineration, hazardous material can be separated to allay health concerns	Da Lat has 2 waste incinerators (2 nos.) which are equipped to handle 30MT of solid waste Under current condition, incinerators are inadequate to handle existing waste Existing incinerators can be retrofitted for energy generation, which will lead to effective method of waste management and reduction in emission in power generation

Sector	Proposed Intervention	Description of intervention	Existing situation for the city
Renewable Energy	Solar rooftop	Installation of solar panels in buildings to be coming up in the extended area of Da Lat replace grid electricity. Encouraging development of flat-roofed buildings to support installation of solar panels and ensuring higher efficiency of panels with lower investment as compared to thatched roof.	Citizens are already using solar water heaters indicating incidence of adequate solar energy for consumption Installation of solar rooftop panels will help utilize incident solar energy, reducing dependence on grid electricity as well as reducing carbon footprint of household consumption Existing buildings have thatched roof which will lead to additional financial investment and may lead to weakening of building structure due to installation of solar rooftop. Hence, buildings in extended area to be targeted
Multi-energy system & Area Energy System	Aggregated cooling system using trigeneration power systems	Cooling requirement for a selected cluster of buildings can be provided by one chiller unit through a piping network supplying chilled water. The aggregated cooling system can derive its supply of chilled water from a trigeneration power system which can produce power, heat and cooling through incineration of waste or biomass	Temperature in Da Lat has been witnessing steep increase in last decade leading to need for cooling In the next decade, requirement for HVAC systems in envisaged HVAC systems contribute to nearly 40%-60% of building's energy consumption Having common infrastructure will cut down on capital cost of users as well as bring system efficiencies reducing overall energy consumption
Agriculture sector	Garden houses and increased regulation of greenhouses	Garden houses integrate nature with buildings architectural elements which can contribute to tourism as well as contribute to farming Growth of greenhouses should be regulated through policy changes as well as increased public awareness	Agriculture is one of the most important economic activity in Da Lat, apart from tourism Growth in agriculture contributed by unabated growth in greenhouses, which is leading to increased temperatures in surroundings as well as water logging Alternate means of combining tourism with agriculture can open up new avenues of income generation for residents of Da Lat as well as lead to carbon sequestration
	Innovative low carbon solutions	Wind power generation through small scale turbines Use of electric trucks for transportation of agricultural produce	Grid electricity to meet energy requirement of greenhouses Average wind speed in most parts of Da Lat city between 4.5-6m/sec

Sector	Proposed Intervention	Description of intervention	Existing situation for the city
			Diesel trucks are used for transportation of agricultural produce

The interventions given above have been suggested based on the existing scenario of Da Lat city and provide a strategic outlook on Low Carbon development for the city. These interventions will be further examined to establish the technical and commercial viability in the existing situation of Da Lat.

7 Feasibility assessment of low carbon interventions

Based on the information generated from baseline scenario, it is observed that there is scope for reducing emissions through interventions in specific sectors. In order to understand the impact of the interventions as well as commercial and technical viability of the project, the feasibility assessment is undertaken. Interventions in each of the project assessment area mentioned in Chapter 1 of this document. The sub-sections will elaborate the details of the feasibility study:

7.1 Transport

7.1.1 Current Status Analysis

Da Lat has been rapidly urbanizing and the increase in population for the city has correspondingly resulted in the increase in vehicles - population of the city has grown from 0.21 to 0.23 million between 2010 to 2018 (Project Team Analysis, 2019). Transport services in Da Lat city consist mainly of 2-wheelers and 4-wheeler passenger transport which includes cars, taxis (privately owned and operated) and buses (inter-city buses and tourist buses). The other significant category of vehicles is commercial vehicles used for freight transport.

7.1.1.1 Transport network

The external road systems of Da Lat city make it an important traffic hub of the province and Central Highlands region, connecting it with international routes and domestic routes as well. The urban road system comprises 178 urban roads with a length of about 231 km and alley roads for 12 wards with 1,016 routes with a length of 292.5 km. Rural roads comprise 135.7 km of rural roads mainly concentrated in 4 communes (Government of Viet Nam, 2017). Being a hill station, majority of the roads have a considerable slope as compared to cities present on plain land – slope being gentle within central part of city and becoming steeper in distance from the city centre.

7.1.1.2 Public transport

As of 2017, the city has approximately 454,000 two-wheeler vehicles, 7740 four-wheeler passenger vehicles and 9220 four-wheeler freight vehicles (Project Team Analysis, 2019). There are currently 30 electrically operated tourist vehicles, which is expected to increase to 70 in the following year. There are no buses operating within 5km perimeter of the city center (all the buses are inter-city in nature) and the only means of transport is taxis. Recently there has been introduction of ride sharing services in Da Lat and while usage of such transportation is present, the incidence is much lower than that of 2W or taxis.

The key fuel being used by private 4W is diesel due to substantial difference in price between diesel (VND 14720/L) and gasoline (VND 19180/L for RON95-III). Gasoline is used by 4W taxis, while trucks operate on diesel. Usage of bio-fuel (E5RON92) is used sparingly by population of vehicles. Under an existing order, all Government vehicles operating in the Lam Dong province have to operate on bio-fuel.

7.1.2 Government's Vision

Transport sector development is a key to sustaining Viet Nam's socioeconomic growth over the next decade as identified in Viet Nam's Socio-Economic Development Plan.

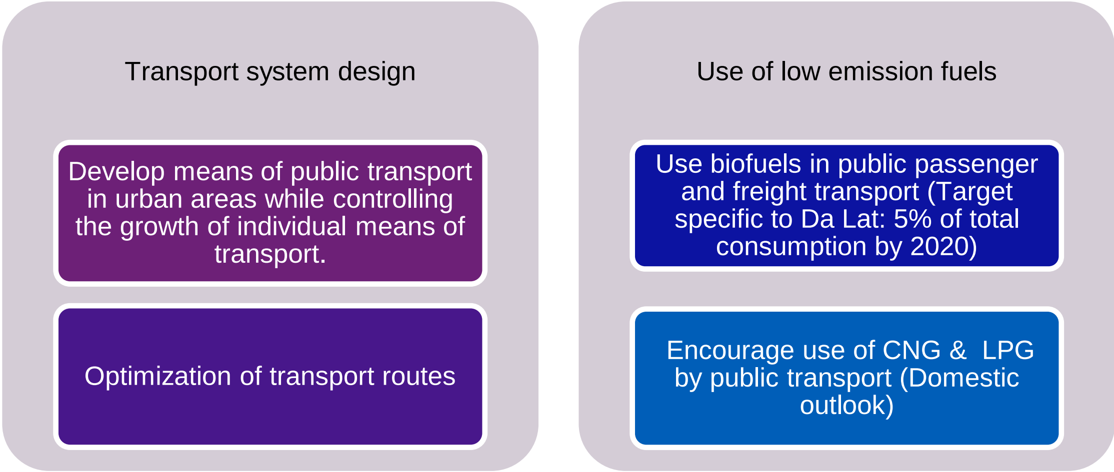


Figure 22: Government vision in Transport Sector

Apart from the policy documents, interaction with Provincial and City Committees as well as informal interaction with citizens led to the following observations:

1. 45-seater buses which convey tourists from outside Da Lat city limits are a major source of traffic congestion in the city. It is estimated that on an average 300 buses enter the city daily, some of which are used by tour operators to convey large groups of tourists. There is also talks of a decision to ban these 45-seater buses 15km from the city centre.

2. Use of electric buses with open rooftop is an option which is in early stage of consideration to promote tourism as well as to lower emission.

3. Public vehicles used by Government officials is currently running on bio-gasoline and there is availability of the fuel in all gas stations across the city.

4. Use of non-motorized transport like bicycles are not favoured by the general population for regular commuting owing to the increased slope of roads and would not be a feasible idea for a hill station like Da Lat.

5. EV use in Da Lat is seen to face issues due to ***sloping nature*** of roads.

7.1.3 Rationale for Interventions

In order to ensure the Low Carbon vision of Government of Viet Nam is achieved, the following low carbon interventions are proposed:

Table 35: Proposed list of LCM for Transportation sector of Da Lat

PROPOSED INTERVENTION	RATIONALE
Electrification in buses	• Tourist buses: These buses are reported to be leading to traffic congestion in the city. Also, these buses run on diesel adding to pollution levels of the city • Adoption of Electric buses and taxis will help in reducing dependence in fossil fuels and transfer to low carbon emission systems. • With corresponding low carbon interventions recommended in energy supply as well, Da Lat can reduce dependence on domestic grid from power generation and

PROPOSED INTERVENTION	RATIONALE
	hence, EVs can assume position as the prime mover of reducing emissions in transport sector.
Electrification of 2W	• 2W constitutes nearly 96% of vehicle population in Da Lat and contributes to nearly 1/3rd of the city's entire emission generation • Electrification will reduce the tail-pipe emission to zero
Increased use of biofuel in taxis	• Promotion of biofuel is a domestic priority area for reducing emissions • Increasing number of vehicles (especially taxis) • Adoption of biofuel requires no modification in the engine.

While the Government envisions natural gas options for vehicles, the recommendations above concentrate on electric and biofuel options only. The exclusion of gas related options in case of Da Lat is because of the following reasons:

1. ***Terrain of Da Lat:*** Da Lat has an average elevation of 1500-1700m and has mountainous terrain. Drawing pipelines through mountainous terrain will attract additional investment requirement over drawing pipeline through plains. Also increase in elevation would require investment in installing additional compressor stations to maintain appropriate gas pressure at user end for effective use.
2. ***Cost of setting up filling stations:*** While an EV charging station costs approximately USD 2,000 or USD 50,000 (in case of fast chargers) to set up, a CNG filing station costs around USD 750,000 to set up (Forbes, 2012).
3. ***Vehicle fuel efficiency:*** While 1000 cubic feet of natural gas vehicle provide a range of around 358.4km, EVs utilizing electricity with same energy content will provide 731km (MIT Report, 2010). Hence efficiency of EVs is more than double of CNG based vehicles.
4. ***Quantity of consumption:*** The total energy consumption in transport sector of Da Lat is about 0.2% of the domestic level consumption in 2018 (Project Team Analysis, 2019). Considering the volume of consumption, the investment in distribution network in gas can be better justified for cities having higher consumption levels and hence, lower payback period.
5. ***Increase in power generation capacity:*** Based on the Power Development Plan 8, Viet Nam intends to increase its power generation capacity to accommodate the increasing power consumption requirements. With power distribution infrastructure already available, additional investment will be limited to setting up charging stations.
6. ***Lower level emissions:*** In terms of tail-pipe emissions, EVs have lower emission level than gas vehicles. While CNG vehicles reduces tailpipe emissions by 90% over conventional gasoline vehicles, in case of EVs the emission reduces to zero (Gas South, 2019).

Taking in to considerations the above factors, the use of gas options as low carbon fuel for vehicles for Da Lat can be replaced by using electricity and biofuel as fuel options.

7.1.4 Description, environmental benefit, financing and implementation mechanism of interventions

1. Electrification of buses

Restricting entry of nearly 300 45-seater buses (45S) operating on diesel from entering city limits and replacing such buses with electrically operated buses can help reduce emissions and traffic congestion as well as create new job opportunities for citizens. With Da Lat experiencing a footfall of nearly 6.5 million tourists in 2018, which is set to increase to 7.5 million in 2019, there is a potential of utilizing open top buses for tourism purposes. Already there is 30 9-seater tourist e-buses have been piloted to serve tourists on several routes to tourist destinations.

There are two propositions in relation to electrification of buses:

a. Restricting entry of 45-seater buses within city limits (15km from city centre) and introducing electric transfer vehicles (15-seater) to ferry passengers from drop off point to city centre.

b. Introducing open top electric buses (with a capacity of 15-20 seats) to start tourist services

A description of the initiatives, along with the environmental benefits and implementation mechanism for the two propositions is given below:

A. Restricting entry of 45S buses within city limits

The following assumptions are taken to calculate financial feasibility of Intervention:

1. Electric bus considered is BYD eBuzz K6 with seating capacity of 18 people with a maximum gradeability of 23% (Commercialvehicle.in, 2018). The variant is under operation in Nepal and in the state of Himachal Pradesh in India (NDTV, 2017) – both having hilly terrain similar to Da Lat. The bus has regenerative braking system which recovers energy during deceleration of the bus and during the application of brakes (ICCT, 2018).

2. The bus is powered by an advanced Li-ion phosphate battery pack (300 kWh)[10], which takes 4 hours to charge, with a travel range of 200 km (Commercialvehicle.in, 2018). To take in to account reduction in efficiency due to hilly terrain the travel range is considered 150 km for a single charge.

3. Cost of electric bus is USD 200,000 (Commercialvehicle.in, 2018) and cost of setting up a fast charging station is USD 30,000 (Pluginindia, 2019). The charging station can be used for simultaneously charging 2 e-buses.

4. The bus will be charged in off-peak period and cost of electricity for commercial users is USD 0.062/kWh (KII , 2019)

5. 45-seater bus runs on diesel and fuel efficiency is 38L/100km (Transport Department, Lam Dong Province, 2019)

6. Cost of diesel is USD 0.63/L (KII , 2019)

7. Use of diesel bus will be avoided for 15km route and for each 45-seater bus there will be 2 e-bus which will be used. Each e-bus will undertake 10 trips each day with full capacity passengers.

8. Number of days of operation is 300 days and annual increase in number of 45S is considered at 10%.

9. Only tail-pipe emission for e-bus and diesel bus considered. Emission factor for e-bus will be zero and that of diesel bus would be 3.145kgCO_2/kg of diesel (IPCC, 2006).

Based on these assumptions, the annual environmental benefit by removing entry of 1 diesel bus up to 15km from city center is given in Table 36 below:

[10] Note: Assuming average efficiency of electric bus is 1.35kWh/km (Source: Elsevier, 2017)

Table 36: Details of environmental benefits

Parameter	Value for 1 diesel bus
Annual travel distance avoided	45000km
Diesel consumption avoided	17100L
CO_2 emission avoided	45.71 tCO_2e

Source: Project team analysis

If this program is extended to the entire fleet of 45S buses entering Da Lat, 36 $ktCO_2e$ of emissions can be avoided by 2030 as illustrated in the table below:

Table 37: Emissions avoided due to intervention

Parameter	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Annual influx of 45S	300	330	363	400	440	484	533	587	646	711	783
Total emission avoided ($ktCO_2e$)	14	15	17	18	20	22	24	27	30	33	36

Source: Project team analysis

Considering each bus is replaced the cumulative cost of replacement is USD 157million. However, the replacement of buses can be optimized based on the flow of traffic, since the entire population of 300 buses enter the city at different points in time.

However, in order to facilitate flow of passengers from designated drop-off point to city centre adequate facilities/infrastructure needs to be developed, which are as follows:

1. Bus terminus with a capacity of accommodating about 100 45S buses[11].
2. Acquisition of appropriate number of e-buses to ferry passengers to city centre[12] and setting up bus terminus with charging facilities to accommodate entire fleet of e-buses.
3. Acquisition of adequate human resources to operate e-buses as well as the terminals.
4. Selection of appropriate tariff to be charged to passengers for e-bus travel which will not be exorbitantly high for an average passenger as well as help operators recover their cost reasonably quick.

Also, over-the-board implementation of this intervention will disrupt the movement of tourists, which can be detrimental for tourism sector. Hence, a three-step implementation process is recommended as given below:

[11] As per qualitative data available from stakeholder discussion, majority of buses enter city in morning hours. However, to ascertain exact capacity of terminus which can handle future flow as well, separate study should be conducted at peak tourism period.

[12] Appropriate number of e-buses required is based on the daily frequency of influx of 45S and time taken for e-buses to travel designated route. Based on these figures, a fleet of e-buses can operate interchangeably across this route.

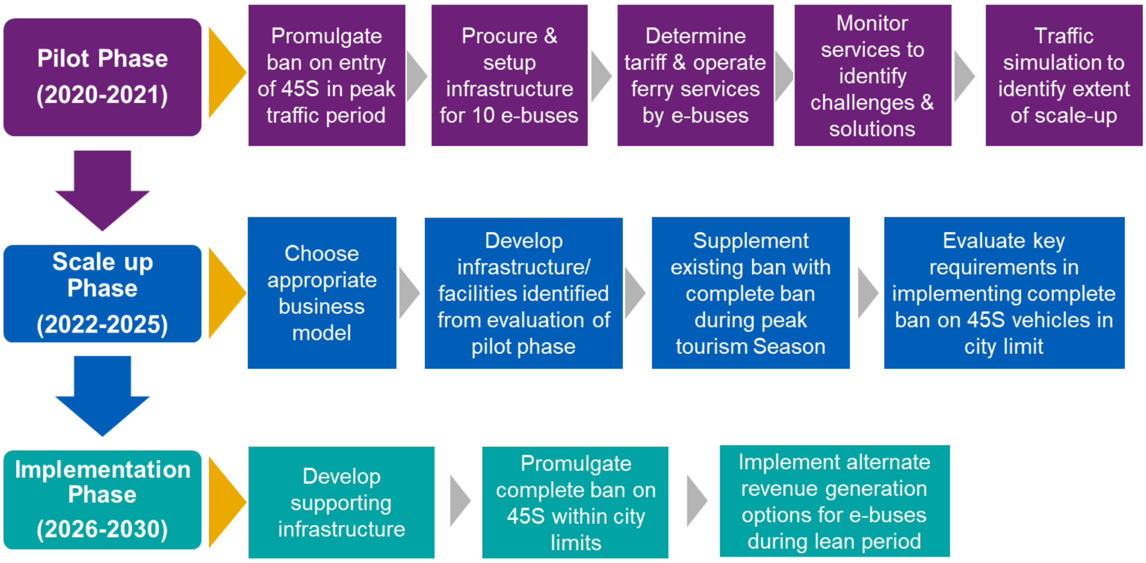
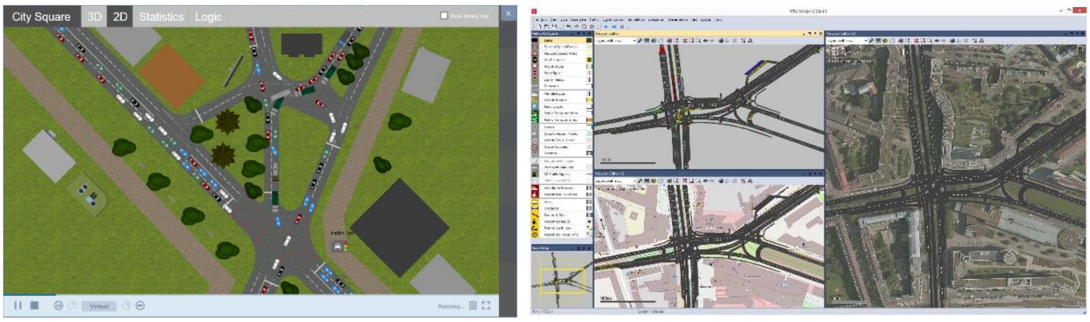


Figure 23: Activities required for electrification of tourist buses

A pilot implementation will help understand on-ground technical issues that are present in implementing intervention as well as assess effect of banning 45S on tourist influx. Accordingly, development of appropriate infrastructure/facilities/policies to support the initiative can be assessed and implemented before scaling up activities. As an example, use of electric buses has been implemented in hill stations like Shimla, Himachal Pradesh and Kathmandu, Nepal.

As discussed earlier, introduction of the e-bus service would require a separate study to determine the number of e-buses required, corresponding human resource and infrastructure requirement. Based on these parameters, financial requirement would be determined, which in turn would affect the tariff. A key element of the study would be traffic simulation, which will help in transport planning and forecasting. The simulation would be used to determine optimal number of e-buses which would help reduce congestion as well as ensure seamless transportation of tourists.



Source: Anylogic – Road traffic website

Source: PTV Vissim website

Figure 24: Screenshots of traffic simulation software

Development of e-bus facilities can be setup in Phuong Trang Interprovincial Bus Station can be gradually scaled up based on requirements. An area can be demarcated and suitably modified to allow housing of 10 e-buses within station

Source: On-site photo taken by Project team

Figure 25: Picture of existing bus terminal in Da Lat

In order to support implementation of this initiative, the following business model options can be explored for implementation:

Private party lease	Public Private Partnership	Private sector owned & operated
• Infrastructure & other assets developed and owned by Govt. • Pvt. Player provided access to facilities for a fixed period at a lump-sum lease value or monthly/quarterly/yearly sum • Application: Can be implemented in pilot phase	• SPV formed between Pvt. Party & Govt. provides capital to develop services & allied infrastructure/facilities for operations • SPV provides capital to develop services & allied infrastructure/facilities for operations • Application: Can be implemented to scale-up service	• Pvt sector companies owns & operates bus services under Govt. stipulations • Govt. provides bus terminus infrastructure only at an annual/monthly fee • Application: In case interested parties available, can be implemented from pilot phase or from scale-up phase

Figure 26: Operating model options for implementing electrification of buses

Considering the 3 options given above, proceeding with 3rd party vendor in the short term and thereafter proceeding with Public Private partnership model will help the Provincial government/City committee to steer the services in a way to enhance tourist experience. Considering that the Vietnamese conglomerate Vin Group will be starting e-bus service, VinBus in Viet Nam in 2020, the private lease model can also be explored based on the assessment of VinBus (VNExpress, 2019).

B. Use of electric buses for tourism purposes

In order to further enhance the image of Da Lat as a green and carbon-free city, the introduction of open top electric buses for tourism purposes can be introduced. These buses can operate on routes touching upon the places of interest. Such open-top tourist bus services are present in London (UK), Barcelona (Spain) and across Italy.

Source: sustainable-bus.com website

Figure 27: Picture of tourist e-buses operating in England and Italy

Such buses can add to the available options for tourists' attraction in the city but would not add to the carbon footprint of the city. In order to implement this intervention, the 15-seater e-buses can be suitably modified to make open top buses.

As in case of e-buses, implementation of tourist e-buses can be undertaken in two phases as given in Figure 28:

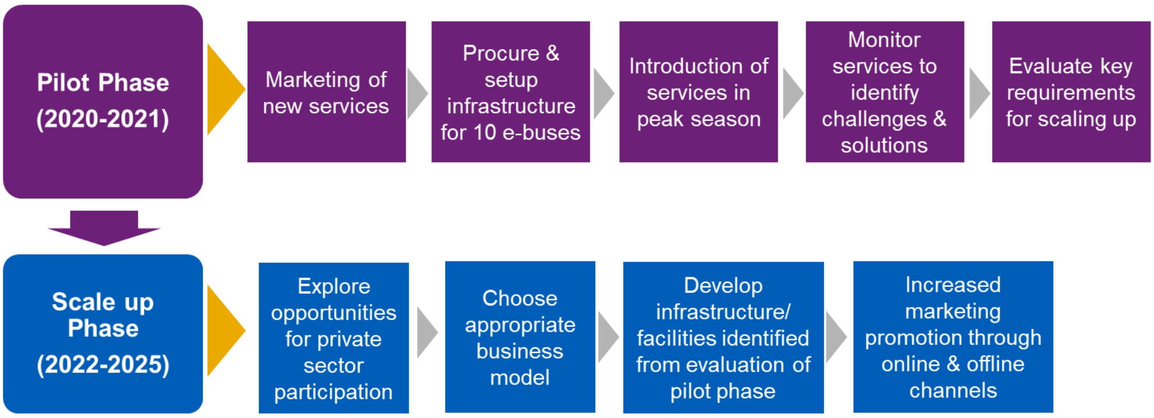


Figure 28: Activities for implementation of tourist e-buses

The pilot phase would involve introduction of 10 e-buses with which market assessment and on-ground technical issues will be assessed. Based on the route chosen for introduction of e-buses and existing market prices of alternate modes of transport, an appropriate fare can be determined. Use of online and offline channels to market the idea can be adopted substantially before the introduction of the services. The introduction should be made in the peak tourist season to ensure maximum utilization and promotion of the initiative.

Based on the assessment of the key challenges in implementing the initiative, additional infrastructure and facilities along with revision of fares can be undertaken to expand the initiative. The appropriate business model for the initiative can be taken from the three models available for e-buses as given in Figure 29 below:

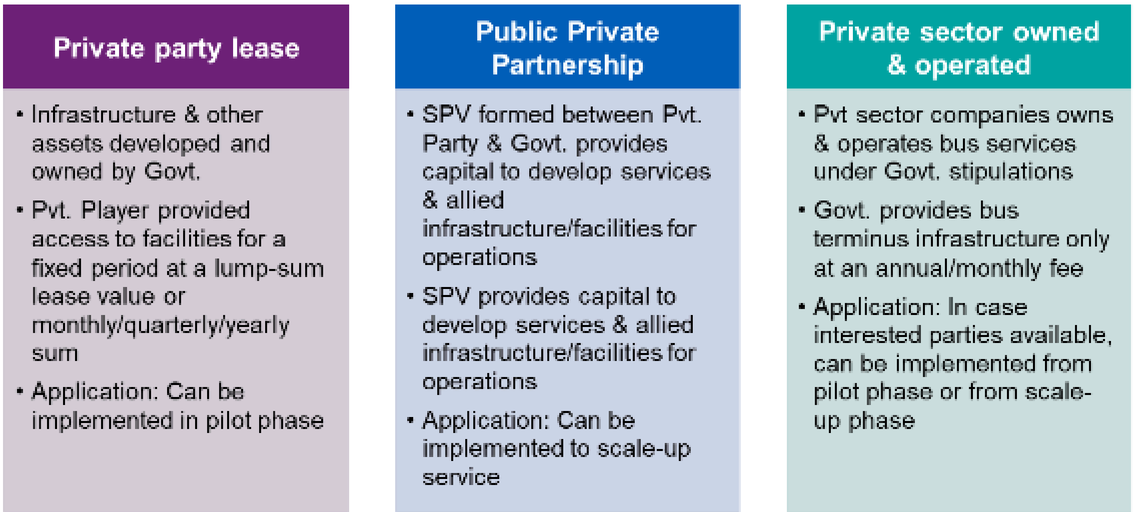
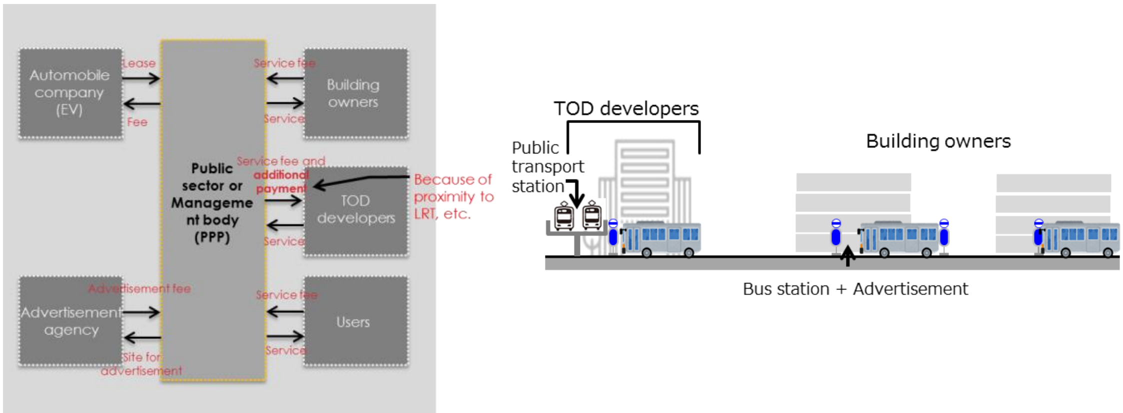


Figure 29: Operating model options for implementation of tourist e-buses

As given in the figure above, a private party lease model will be effective in the Pilot phase, while a public private partnership or private sector owned, and operated model can be adopted in scale-up phase. In case of scale-up phase, Government can collaborate with existing player in Da Lat who are operating electric tourist vehicles. Such businesses can bring private sector capital as well as knowledge of the needs of the tourism market in Da Lat.

A possible method of generating revenue for the proposed e-bus services can be through advertisement in the related infrastructure as given in Figure 29. Also, private sector participation can be stimulated through a PPP arrangement as given in Figure 30 . In case of tourist buses, the management organization can receive the basic service fee from the owner of the building that benefits from the service, as well as the advertising fee generated by the advertisement placed on the bus body and the bus station. The new financing mechanism will reduce the cost of maintaining a circular bus and lead to independent business operations.



Source: Project team generated image

Figure 30: Example of advertisement model in Da Lat

Public sector and regional management agencies lease electric buses from the company and manage circular bus services within designated areas. Electric bus services are considered to contribute to countermeasures in the event of natural disasters, regarding as excellent infrastructure for disaster prevention, such as being used as a backup power source in the event of a disaster. And also, it could reduce CO_2 emission by optimizing transportation routes.

In addition, it can be more effective to install a sensor monitoring human flow in each bus. The installation could optimize traffic volume and support the connection with other semi-public transportation such as taxi and vans.

2. *Electrification of 2W*

Transport in Da Lat, in line with nature of traffic in Viet Nam, is mostly based on 2W – 2W constitutes 96% of road transport in Da Lat (Project Team Analysis, 2019). Due to the nature of use i.e. 2W are used for short distances, energy consumption share is not commensurate to the proportion of vehicles. However, 2W still accounts for 70% of total energy consumption and approximately 66% of total emissions in the sector (Project Team Analysis, 2019). If the entire energy system of Da Lat is considered, use of 2W contributes to nearly 1/3rd of the total emissions in the city (Project Team Analysis, 2019). Hence, any intervention aimed at reducing emissions from 2W population of Da Lat can have a considerable impact in overall emission reduction for the city. In this regard, use of electric 2W can ensure zero tail-pipe emissions as compared to the gasoline driven units.

The situation for 2W in Da Lat is similar to the domestic context wherein Viet Nam has the second highest motorbike ownership per capita with nearly 500 motorbikes for 1,000 inhabitants. (Vietnamnet, 2019). In order to tackle the emission problem caused by such large number of fossil fuel based motorcycles, there has been a focus in introducing and expanding electric scooter usage in the economy. The use is set to be accelerated by the recent introduction of electric motorcycles by Vinfast, an automobile-manufacturing subsidiary of Vingroup conglomerate. While these e-motorcycles are marked around 30-40% higher than gasoline motorcycles, it is estimated that running costs can be up to 33% less, leading to a payback period of less than 2 years (NNA Business News, 2018).

Moreover, municipal government of Ha Noi has decided to completely ban motorcycles in the capital in 2030 to reduce traffic congestion and tackle air pollution, and Ho Chi Minh City reportedly will follow suit. This will set the tone for the growth of electric motorcycle market in Viet Nam. With increase in demand, market prices of electric motorcycles can be expected to come down, further increasing lucrativeness of buying an electric motorcycle over gasoline one. In the long term, it is envisaged that increased adoption of electric 2W will effectively reduce emissions for Da Lat as well.

To estimate the environmental benefits that can be derived by electrification of 2W, the following assumptions are considered:

1. Number of 2W between 2020 and 2030 is derived from estimates of 2W and the historical growth rate provided by Department of Transport.
2. Penetration rate of 2W in Da Lat was taken as given in Table 38

Table 38: Target penetration level for electric 2W

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1%	2%	3%	5%	10%	15%	20%	27%	32%	40%	50%

3. Based on baseline analysis, CAGR of number (7.7%) and energy consumption of 2W (4%) between 2010 and 2018 was used to project future figures
4. Based on baseline analysis, energy consumption of 2W in 2017 is 851290 MWh
5. Average market price of electric motorbike in Viet Nam is USD 1000 (Vietnamnet, 2018)
6. Emission factor of gasoline is 3kgCO_2e/kg of fuel and taking into consideration the GCV of gasoline and conversion from kcal to MWh, emission factor is 242.56 kgCO_2e/MWh of energy of fuel

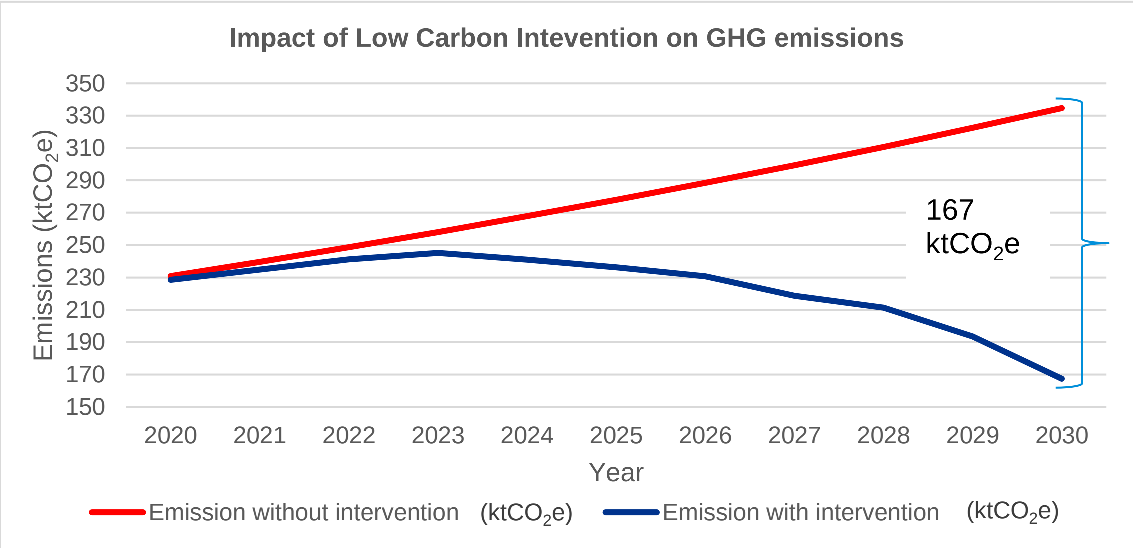
Accordingly, the following figures were derived for electric 2W to estimate the emission reduction potential:

Table 39: Summary of calculations for electric 2W

Parameter	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
No. of 2W	567266	611023	658155	708922	763605	822506	885951	954289	1027899	1107187	1192590
Energy consumption of 2W (MWh)	951671.9	987697.1	1025085.9	1063890.2	1104163.3	1145960.9	1189340.8	1234362.8	1281089.1	1329584.2	1379915.1
Share of electric 2W	1.0%	2.0%	3.0%	5.0%	10.0%	15.0%	20.0%	27.0%	32.0%	40.0%	50.0%
No. of electric 2W	5673	12221	19745	35447	76361	123376	177191	257659	328928	442875	596295
Energy consumption of replaced 2W (MWh)	9517	19754	30753	53195	110416	171894	237868	333278	409949	531834	689958
Total emission avoided ($ktCO_2e$)	2	5	7	13	27	42	58	81	99	129	167
Emission without intervention ($ktCO_2e$)	231	240	249	258	268	278	288	299	311	323	335
Emission with intervention ($ktCO_2e$)	229	235	241	245	241	236	231	219	211	194	167
Cost of transition (million USD)	6	7	8	16	41	47	54	80	71	114	153

Source: Project team analysis

Based on the assumptions and standard emission factor for gasoline, the emission savings achieved by reaching target penetration levels of electric 2W is depicted in Figure 31



Source: Project team analysis

Figure 31: Impact of electric 2W

In order to achieve such levels of penetration, procurement of adequate number of electric 2W would require an investment of approximately USD 2076 million. 2W being used mostly by retail consumers, there would be limited requirement for charging stations in public spaces. Motorcycles are used by individuals mostly for intra-city transport with most trips being expectedly less than 10km. Also, current e-scooter technology is comparable in performance to a gasoline two-wheeler in an urban environment, so e-scooters do not necessarily require exclusive infrastructure. However, addition of charging stations across the city would help reduce the range anxiety of consumers and encourage greater uptake.

Despite high investment requirement for electrification, Chinese 2W market has grown considerably to become the world's biggest electric 2W market. The key elements leading to the growth is policy level push, by banning/restricting use of gasoline based 2W through legislation and by making charging infrastructure available in public spaces.

Shanghai, confronted with poor air quality and high motorized vehicle use, outlawed the sale and use of gasoline scooters in city centers through license restriction. Due to the law, only 2W allowed to operate are LPG scooters, e-bikes, and bicycles. However, in order to increase proliferation of e-bikes, they were considered equivalent to bicycles – riding an e-bike required no license and the bike required no registration. This led to unabated surge in numbers, creating disruption in the city (as well as in other parts of China) due to lack of regulations – it was observed 44% and 56% e-bikers were driving the wrong-way and violating traffic signals respectively (Forbes, 2016). Accordingly, stricter regulations on e-bikes throughout the economy has been adopted since 2019, necessitating registration of vehicles and requirement of license for e-bikes.

In case of Da Lat, the following steps can be adopted to increase penetration of 2W:

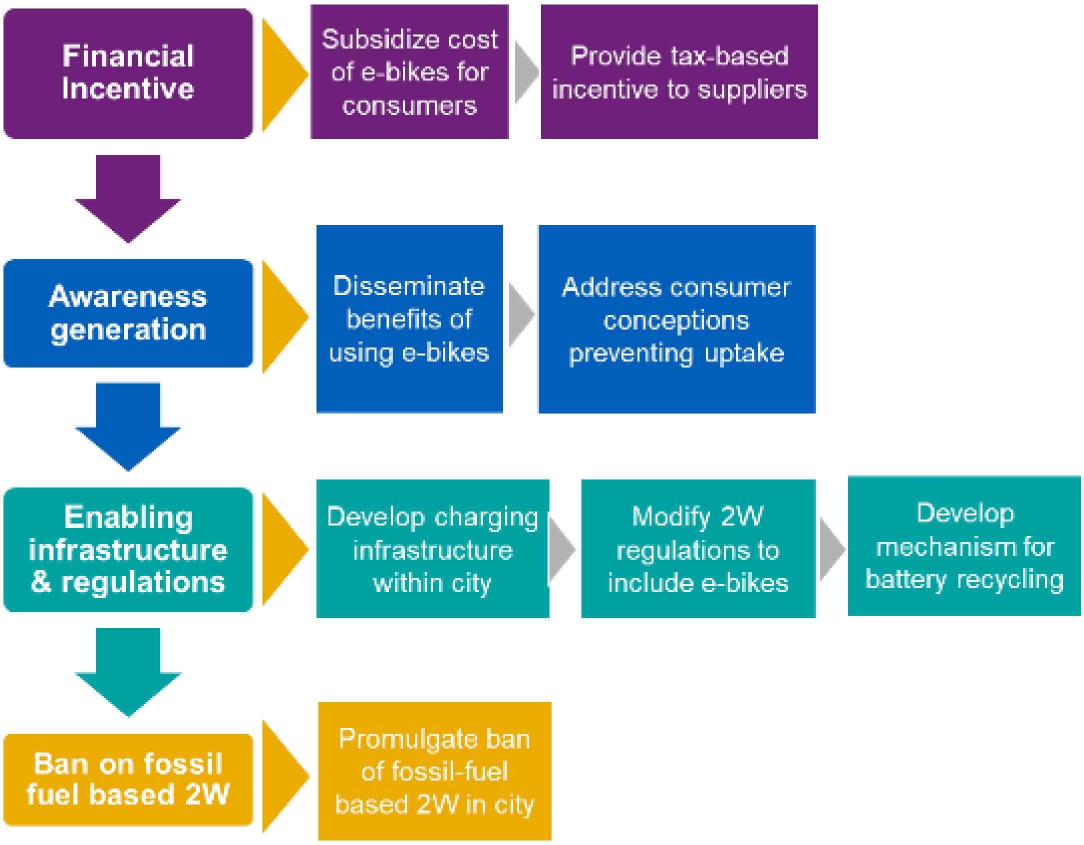


Figure 32: Roadmap for proliferation of e-bike in Da Lat

A key difference between the existing motorcycles and electric motorcycles is the cost component. In order to reduce the price gap and encourage users to take up e-bikes, Government can provide subsidies to end consumers as well as provide financial incentives to the bike manufacturing companies.

An average user also has the range anxiety and apprehensions related to costs of maintaining an e-bike. In order to understand such key issues which, prevent greater uptake of e-bikes, a survey of existing motorbike users can be undertaken. Accordingly, targeted awareness programmes can be designed and delivered to address these issues as well apprise users of benefits of e-bikes.

While the above measures can act as enablers for market transformation, development of adequate charging infrastructure should be present. Private-party lease model can be implemented to fast track installation of charging infrastructure. Also, to ensure that any unabated growth is prevented, adequate regulatory oversight should be introduced. Given that an average bike battery has harmful chemicals and costs nearly 50% of the bike price, a battery recycling mechanism can be introduced. The mechanism provides a business opportunity for private players to operate and hence, exhibits a potential to promote local entrepreneurship.

With the introduction of e-bikes already undertaken as well as awareness programme and development of enabling infrastructure being continued, the fuel transition for 2W is expected to be smoother. To ensure transition, a ban on fossil fuel based 2W can be promulgated. It is expected that

3. *Increased biofuel usage*

In line with the domestic policies and Da Lat green growth strategy, adoption of bio-ethanol mix in case of vehicles running on gasoline i.e. taxis.

E5RON92 is bio-ethanol mix which is currently promoted by Government of Viet Nam which has 5% ethanol mixed with 95% gasoline. This mix ensures that bio-fuel can be used in normal gasoline engines without the need for engine modifications.

Considering lifetime emissions, use of ethanol instead of gasoline can lead to decrease in GHG emission reduction between 23%-63% depending on the source crop (cassava, corn or sugarcane) and the method of production adopted (Ecofys, 2007). Tailpipe emissions from use of biofuel, although lower (since a blend of bio-ethanol and gasoline is commonly used), can still lead to emission reduction by about 5% as compared to gasoline (Project Team Analysis, 2019).

In order to understand the environmental benefits that can be derived by implementing the intervention, the following assumptions have been taken:

1. Emission factor and calorific value of ethanol are 0.97gCO_2e/MJ (FAO, 2018), 21.1MJ/L (Engineering Toolbox, 2015) respectively
2. Emission factor, calorific value of gasoline and density are 3.06kgCO_2e/kg of fuel, 32MJ/L and 0.75kg/L respectively (Engineering Toolbox, 2015).
3. Target for penetration of biofuel is as follows:

Table 40: Target penetration for biofuels

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
5%	10%	15%	20%	25%	30%	35%	45%	55%	65%	75%

7. Consumption of taxis will be in ratio of the number of taxis and number of 4W vehicle and historical growth rate has been considered for future projections

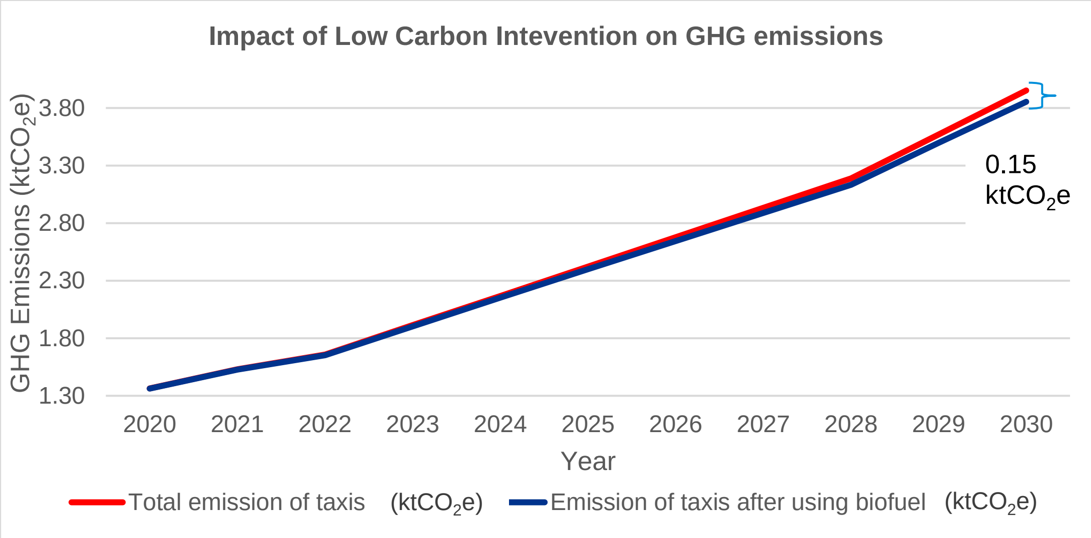
On the basis of the assumptions, the following results can be derived by implementing the intervention, as given in Table 41:

Table 41: Summary of biofuel promotion initiative

Parameter	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Proposed Target of conversion	5%	10%	15%	20%	25%	30%	35%	45%	55%	65%	75%
Total no. of 4W vehicle	10581	11746	13039	14474	16067	17836	19799	21978	24397	27082	30063
No. of taxis	1844	2100	2391	2722	3099	3529	4018	4575	5209	5931	6753
Total energy consumed by 4W vehicle segment (TJ)	61	65	69	73	78	83	88	93	99	105	111
Total energy consumed by taxis (TJ)	11	12	13	15	17	19	21	23	25	28	31
Total gasoline consumed (L)	334266	375000	406250	468750	531250	593750	656250	718750	781250	875000	968750
Total emission of taxis (ktCO$_2$e)	1.36	1.53	1.66	1.91	2.17	2.42	2.68	2.93	3.19	3.57	3.95
Total emission avoided by switching to biofuel (ktCO$_2$e)	0.003	0.008	0.012	0.019	0.027	0.036	0.047	0.066	0.087	0.115	0.147
Emission of taxis after using biofuel (ktCO$_2$e)	1.36	1.52	1.65	1.89	2.14	2.39	2.63	2.87	3.10	3.45	3.81

Source: Project team analysis

Figure 33 below shows the benefit derived from implementing the solution:



Source: Project team analysis

Figure 33: Impact of biofuel promotion intervention

Despite the environmental benefits and Government policies to promote bioethanol, voluntary uptake by citizens has been low. The key issues behind limited uptake are as follows:

1. ***Limited price difference***: There is a price difference of just USD 0.009 per litre between E5RON92 (biofuel variant) and RON95 (mineral gasoline variant). As per local enterprises, necessary cost reduction means should be undertaken to increase the price difference to USD 0.09 to 0.11 per litre to encourage average consumer to consume biofuels over mineral gasoline (VNExpress, 2019).

2. ***Storage issues***: Biofuel once produced cannot be stored for long durations since water separates from the fuel, causing it to spoil. Also, profit margins from selling biofuel is not high enough to compensate for any possible losses. Hence, in the face of lower demand, gas stations are prompted to reduce E5 storage or even completely switch to RON95 (VNExpress, 2019).

3. ***Consumer apprehension***: Average consumers are getting information through various platforms which are reinforcing their skepticism regarding the fuel. While, E5 gasoline may not be suitable for older vehicles running on carburetors and steel fuel tanks. Also, increased presence of ethanol in fuel mix can lead to premature failure of parts such as the fuel supply hose, fuel pump and fuel regulator. Such factors coupled with lower incentive to switch prevents consumer from choosing biofuel over mineral gasoline (Autopro, 2018).

In order to address the issues related to muted consumption of biofuels, the following steps can be undertaken:

1. **Policy intervention**: Interest for biofuels is dependent on the prices of its alternatives – rise in oil prices would result increase in biofuels. Hence, fuel prices are an important determinant to the uptake of biofuels. Case studies of economies and countries leading in biofuel usage i.e. Thailand, USA and Brazil indicate that multiple policy level initiatives have resulted in increased consumption. Few of the policy instruments that had been undertaken in these economies and countries are as follows (IRSD, 2018):

   a. ***Reduction in taxes*** – In May 2013, Brazilian government announced the package of incentives for the sector, including tax cuts and subsidized credit limit. The purpose of this package is to encourage manufacturers to choose, spends sugarcane to produce ethanol rather than sugar production - which is more attractive prices on international markets.

b. ***Subsidies for biofuel*** - In case of Thailand, difference in biofuel and traditional gasoline is USD 0.3-0.4/L. Such considerable difference in prices is important to motivate gasoline users to test biofuel.

c. ***Provide encouragement for production of raw materials substitution*** – In USA, an import tax up to level of USD 0.15/L of ethanol imported. Also, companies producing, trading and distribution of biofuel will be subsidized and supported the cost of mixing at USD 0.15/L.

Similar policy initiatives undertaken in Viet Nam can help in increasing the consumption of biofuel.

2. Market awareness: A focused market awareness program needs to be undertaken to disseminate information regarding bio-fuels and answer the queries of the general public. A few important pointers related to consumer awareness of biofuels is given below (University of Strathclyde, 2013):

a. The "knocking process" is caused by the incomplete combustion of the petrol fuel in the engine cylinder, which causes a sudden knock or blow to the piston, which over a period of time will seriously damage the vehicle engine. By adding an ethanol E10 blend to petrol, we can increase the octane number of the petrol fuel by two points. Therefore bio-ethanol is termed as an "octane enhancer".

b. Oxygen that is present in the ethanol can affect the air to fuel ratio at which the engine is operating at. The engine management systems that are fitted in most modern motor vehicles will electronically sense and change the air fuel mixing ratio in order to maintain the stoichiometric ratio when ethanol (oxygenated) fuels are added to the engine, unlike older vehicles which are usually fitted with normal fuel carburetor system.

c. It may be necessary to change the vehicles fuel filter more often as ethanol blends can loosen solid deposits that are present in vehicle fuel tanks and fuel lines.

d. Ethanol blends have a higher latent heat of evaporation than 100% petrol and thus ethanol blends have a poorer cold start ability in Winter. Therefore, some vehicles have a small petrol tank fitted containing 100% petrol for starting the vehicle in cold weather.

e. Vehicle owners running their cars on ethanol blends should adhere to the recommendations of the individual car manufacturers, since increased ethanol content of gasoline may have detrimental effect on equipment. However, maximum recommended level blending for most vehicles is below 5% by volume.

The above information can be supplemented with research work of effects of biofuel usage in Da Lat city to derive city specific results. The dissemination of city specific results of biofuel usage can help allay consumer fears and can increase uptake of biofuel.

Taxis also exhibit the possibility of implementation of electric cars. However, considering the domestic policy directives towards increased proliferation of biofuel and the existing initiatives already taken by the provincial and city administration, this initiative has been considered.

Also, complete electrification of the transport system by way of electrification of 2W and buses would require substantial investment in development of power generation infrastructure. Hence, it is proposed the use of biofuel be continued in case of taxis in short to medium term. In the long term, given the level of success achieved and the state of development of power generation and supply infrastructure, electrification of taxis can be undertaken. With the experience of successfully implementing electrification of buses and 2W – the more dominant modes of transport in case of Da Lat, a robust methodology based on the lessons learnt can be developed for the case of taxis.

7.2 Buildings

7.2.1 Current Status Analysis

Buildings sector is a major consumer of energy in case of Da Lat, being the second most energy consuming sector for the city after transport. Growth in energy consumption of commercial buildings has increased at a faster pace than that of residential buildings. The table below shows the energy consumption growth by fuel type of residential and commercial buildings in Da Lat:

Table 42: Energy consumption by residential buildings

DA LAT	in KTOE				
FY	Oil products	Coal	Biofuels	Electricity	Total
2010	0.0022	0.0029	0.0275	0.0066	0.0393
2011	0.0022	0.0028	0.0279	0.0072	0.0400
2012	0.0021	0.0026	0.0281	0.0081	0.0410
2013	0.0021	0.0029	0.0283	0.0088	0.0422
2014	0.0020	0.0027	0.0286	0.0096	0.0430
2015	0.0021	0.0027	0.0289	0.0106	0.0443
2016	0.0028	0.0029	0.0294	0.0118	0.0469
2017	0.003	0.003	0.030	0.013	0.049

Source: Project team analysis for baseline scenario

Table 43: Energy consumption by commercial buildings

DA LAT	in KTOE
FY	Electricity
2010	0.0004
2011	0.0004
2012	0.0006
2013	0.0007
2014	0.0008
2015	0.0010
2016	0.0011
2017	0.0013

Source: Project team analysis for baseline scenario

While the Government of Viet Nam is yet to finalize on the proposed Viet Nam Energy Efficiency Building Code (VBEEC), there is an independent organization Viet Nam Green Building Council (VGBC) which provides a set of voluntary green building rating systems collectively called LOTUS. However, there are no LOTUS-certified buildings in Da Lat and there is limited demand for green buildings in the city.

7.2.2 Government's Vision

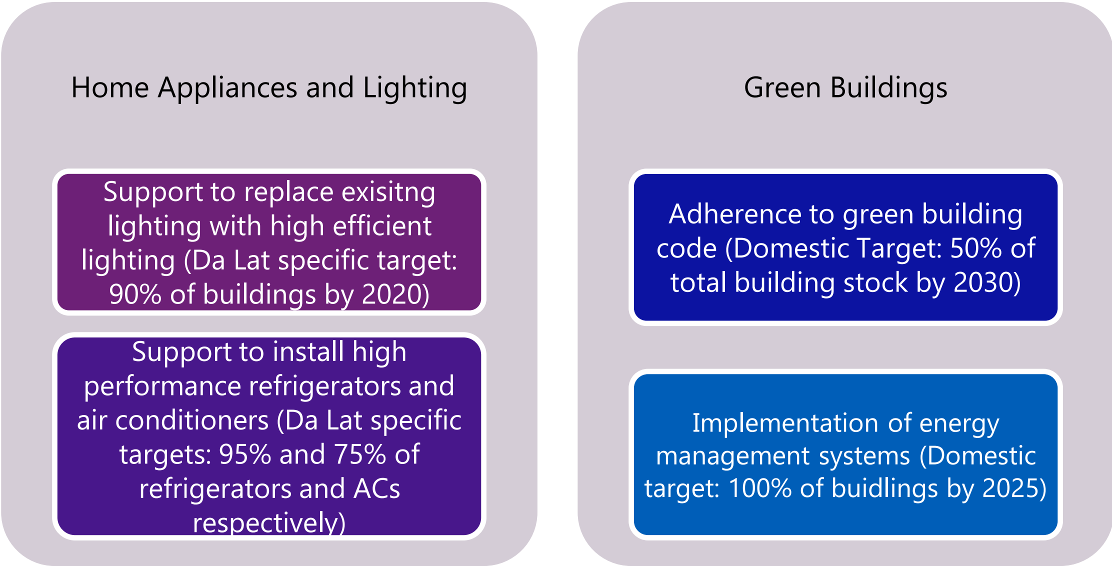


Figure 34: Government's vision in buildings sector

7.2.3 Rationale for Intervention

In order to reduce energy consumption and subsequently emissions from building sector, improving implementation of green building code (as well as VBEEC after it gets promulgated) is recommended. Future trends of key climate characteristics of Da Lat, indicate a need for employing HVAC systems, which can lead to increase in energy consumption (Worldweatheronline, 2018):

1. Temperature: Da Lat has witnessed an increase of 3°C in the last 10 years.

2. Average wind speed: It has decreased by over 100% from 10.8kmph in January 2009 to 5.1kmph in January 2020.

3. Rainfall: Rainfall has witnessed a 3-fold increase in the last 10 years – 563mm and 1429mm of rain was recorded in 2009 and 2019 respectively.

The change in the parameters given above indicates to considerable change in climatic condition of Da Lat. The increase in temperature and lowering of average wind speed indicates to a greater need for cooling measures for comfortable existence of citizens. While increase in rainfall indicates to relief from higher temperatures, it also indicates to increased frequency of floods – Da Lat was experienced an unprecedented flood in 2019. Analysis of the climatic parameters indicates to the fact that the city would require a green building code which will enhance living conditions for citizens.

Improved implementation would require policy level interventions, disbursal of financial incentives to end-users along with development of business opportunities around this aspect. In case of green buildings

7.2.4 Description of Intervention

Implementation of existing green building code or proposed energy efficiency building code, would lead to decrease in energy consumption by adopting resource/energy efficiency initiatives. Building rating systems, which measure the level of compliance with such codes, are a popular tool to add momentum in achieving energy efficiency. These help in assessing the level of performance of the building and provide opportunities in reducing the operation and maintenance (O&M) costs of the building besides creating a market pull towards environmentally sustainable buildings.

In order to enable rapid transformation towards energy efficiency in buildings, policies and measures that create a 'supply push', such as codes and standards need to be supplemented by policies and measures that simultaneously create a 'demand pull' as well.

The proposed Star Rating programme for buildings has been developed on the actual performance of a building in terms of its specific energy usage in kwh/sq m/year. This programme rates commercial & residential buildings on a 1-5 Star scale, with 5 Star labelled buildings being the most efficient. The scheme is propagated on a voluntary basis and the label provided under it is applicable for a period of 5 years from the date of issue. The Star Rating programme provides public recognition to energy efficient buildings and creates a 'demand side' pull for such buildings. Various categories of buildings have been identified under the scheme.

The rating normalises for operational characteristics that define the building use, hours of operation, climatic zone and conditioned space. Further to provide a useful benchmark the rating also provides a meaningful comparison to the building's peer group representing those buildings that have the same primary business function, and operating characteristics. It is important that the rating be based on an analysis of city level data that accurately reflects the distribution of energy use for each building type.

This energy performance rating is a type of external benchmark that helps energy managers to assess how efficiently their buildings use energy, relative to similar buildings economy-wide. Additionally, building owners and managers can use the performance ratings to help identify buildings that offer the best opportunity for improvement and recognition.

The test case has been developed by considering the following interventions, that impact energy efficiency level of building:

1. Window wall ratio (WWR): Globally, WWR has shown to be the most cost-effective solution in reducing the heat gain in the building. For commercial establishments, the maximum threshold for WWR is 60% whereas for more efficient buildings it has been reduced to 40%. In case of residential buildings, the ratio is further reduced to 25% going down to 15% for more efficiency.
2. Envelope (Opaque): It comprises exterior wall and roof and has a major impact on the heat transfer in a building. It is effectiveness of envelope is measured through R-value, which is a measure of thermal resistance, or the ability to prevent the transfer of heat. The larger the number, the harder that insulation is working at preventing heat conduction.
3. Shading: It causes twofold benefit - reducing heat gains in the building as well as improving the quality of daylight available in the building. For optimum shading in the building it is recommended to have customized shading as per the orientation, glazing size, glazing material. However, for the solution set shading requirement has been simplified to the ratio between depth of shading, D/ height of glazing, H and only horizontal shading is considered due to its effectiveness for the specified location.
4. Envelope (Glazed): Though glazing is essential for daylighting and view, it is recommended that the design, orientation and material selection and shading should be optimized to further reduce cooling requirement within building. There are three criteria that decide the glazing performance which are as follows:
   i. Solar Heat Gain Coefficient (SHGC) of glass: SHGC is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits.
   ii. Visible light transmittance (VLT): VLT is the amount of light in the visible portion of the spectrum that passes through a glazing material. A higher VT means there is more daylight in a space which, if designed properly, can offset electric lighting and its associated cooling loads.

iii. U- value: It is a measure of air to air heat transmission (loss or gain) due to the thermal conductance of the material and difference of indoor and outdoor temperature. Material with lower U-value is recommended.

The optimization of the building envelope ensures that the cooling and lighting demand of the building is reduced along with the operational cost of the building.

5. Cooling equipment efficiency: In case of cooling in buildings, system sizing is a critical aspect which determines how efficient the system will be based on the requirements - an oversized system design will prove to be inefficient despite having energy efficient equipment. Minimum EER 8 has been considered for the cooling equipment.
6. Air Conditioners: Air conditioners (rating system as per DOE 10CR Part430) star rating system specification is considered for the solution sets. Even though the rating system is voluntary, the same has been used to determine the incremental levels for the ease of market.
7. Lighting Power Density (LPD): LPD is one area that can be substituted with latest technology in the field of LEDs and other efficient lighting solutions. The lighting power density can be substantially reduced compared to the ASHRAE requirement with these technologies. Task desk lighting can be added to achieve the higher lux levels
8. Daylight Integration: Daylight integration (optimum lux level without glare) in the building design is definitely a wise design solution. Automated stepped daylight controls can help ensure that artificial lighting is operational depending on the availability of daylight.
9. Domestic hot water system (DHW): Rather than determining the efficiency of electric DHW it seems more sensible and practical solution to offset the requirement through heat pumps or solar DHW systems as per the building design possibility.

In order to assess the environmental benefit from implementing green building codes, energy simulation using eQUEST software had been used in case of Viet Nam. In order to use the software, the following assumptions have been taken:

- A rectangular box model of dimension 75m x 30m constructed for preliminary analysis with longer axis facing N-S
- Weather file of Ha Noi, Viet Nam (based on availability of weather files in software database)
- Green building code for Viet Nam studied for mandatory requirements to be followed.
- BAU case based on most commonly followed market practices
- Test case with recommended design parameter values as per Viet Nam green building codes
- Lighting power density: as per ASHRAE standard case
- All the schedules and load profiles were kept constant across all the cases.
- Multiple baseline analyses completed to derive appropriate building materials specification & passive strategies for Viet Nam specific climatic conditions

By taking into account the energy savings possible by the above design based points, the energy simulation provided the extent of energy savings possible for various categories of buildings under different star-rating was generated, which is given in Table 44:

Table 44: Emission reduction levels for energy star ratings

BUILDING TYPE		CO_2 Emission Reduction (%)					
		Overall	1 ★	2 ★	3 ★	4 ★	5 ★
Commercial	Office	23% - 50%	23%	31%	38%	46%	50%
	School	32% - 60%	32%	40%	45%	57%	60%
	Hospital	18% - 37%	18%	24%	29%	35%	37%
	Hotel	15% - 55%	15%	24%	37%	48%	55%
	Shopping Mall	25% - 54%	25%	35%	43%	50%	54%
Average savings		20%-55%	20%	30%	40%	48%	55%
Residential	House 30°C Set Point	26% - 59%	26%	32%	40%	50%	59%
	House 50% AC	14% - 52%	14%	27%	33%	44%	52%
	2 BHK	11% - 53%	11%	26%	36%	44%	53%

	1 BHK	15% - 52%	15%	26%	35%	43%	52%
	Studio Apartment	15% - 52%	15%	26%	33%	44%	52%
Average savings		16%-55%	15%	26%	35%	44%	52%

Source: Project team analysis

Taking into account the current penetration of green buildings in Da Lat and the domestic targets for implementation of green buildings, the following targets can be adopted in case of Da Lat:

Table 45: Target penetration of green building in Da Lat

Period	2020-2025	2025-2030
Residential	10%	30%
Commercial	15%	40%

Source: Project team analysis

The relative lower targets for residential sector are due to the capital costs involved in undertaking energy efficiency initiatives in buildings and retail consumers do not usually have high electricity consumption which would prompt such investments. Residential segment would have greater propensity to undertake efficient lighting investment rather than investments which involve changes in building structure.

Commercial sector buildings on the other hand have relatively higher consumption and have a higher propensity to reduce costs. Also, buildings like hotels periodically (usually between 5-10 years or less) undertake building refurbishment. Integration of energy efficient solutions can be implemented during such refurbishment periods. Hence, the targets for this sector is higher.

In order to assess the environmental benefits of the initiative, the following assumptions have been considered:

1. Average savings in residential and commercial buildings by implementing energy efficient building guidelines is 25% and 35% respectively[13].
2. Electricity consumption in residential and commercial building in baseline year i.e. 2017 is 151 MWh and 15 MWh respectively
3. CAGR increase in electricity consumption in residential and commercial building is 3% and 18% respectively (Project Team Analysis, 2019).
4. Progression of target levels between 2020 and 2030[14]:

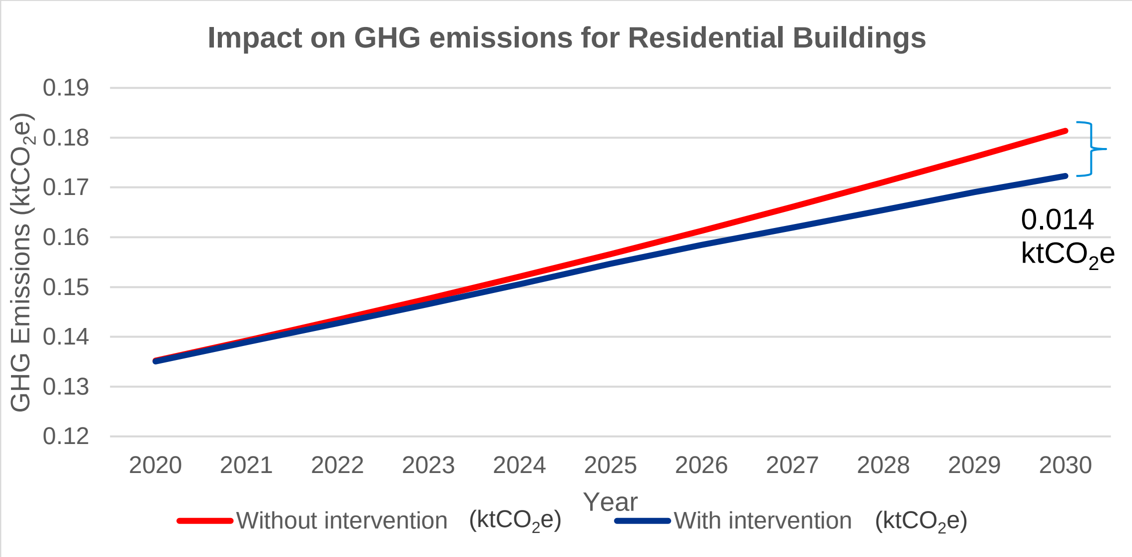
Table 46: Progression of targets for penetration of green buildings

Sector	Target levels of penetration (in %)										
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Residential	1	2	4	6	8	10	13	16	20	25	30
Commercial	1	3	5	9	12	15	19	25	30	35	40

5. Emission factor for electricity is 0.82kgCO_2e/kWh

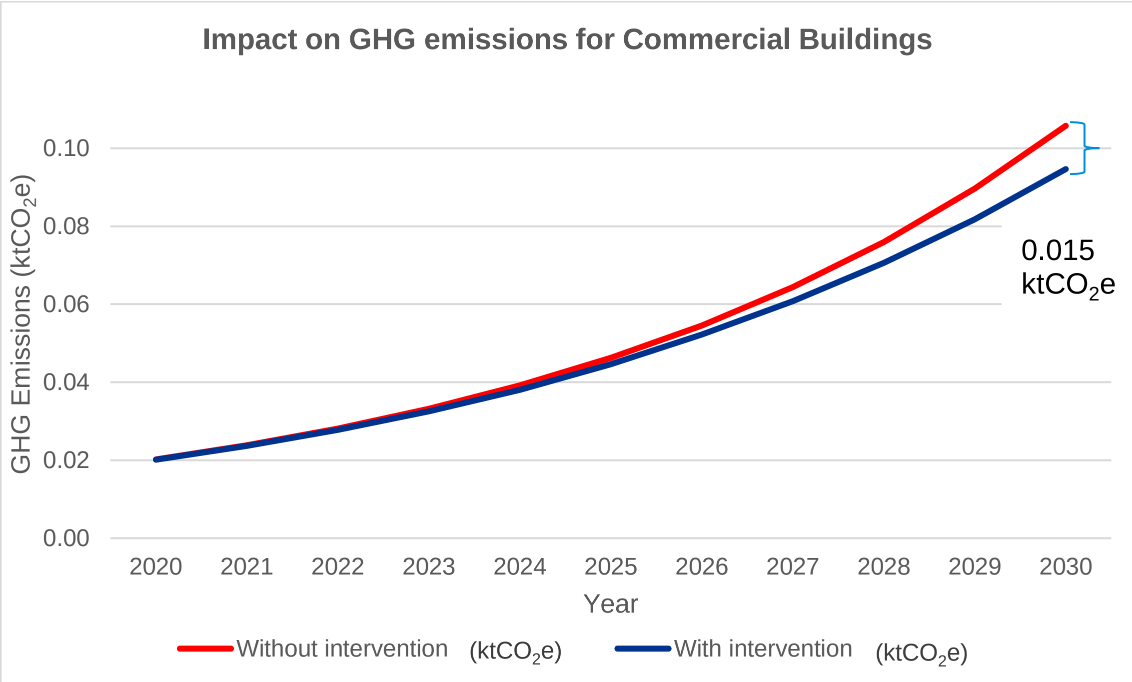
[13] Note: Most probable combination of savings achieved based on average savings for each building category, sub-category and star-rating.
[14] Note: The progression of transformation has been taken after considering the S-curve of progress of any project – muted progress in the short term, exponential growth in the mid-term and limited growth in long term

Accordingly, the following results on the environmental benefits have been obtained:



Source: Project team analysis

Figure 35: Impact of intervention on emission for residential buildings



Source: Project team analysis

Figure 36: Impact of intervention on emission for commercial buildings

The targets can be achieved by implementing the green building codes in existing or new buildings. In case of existing buildings, retrofitting of interventions given above can be undertaken, although changes in building envelope is limited to those interventions that do not interfere with structural integrity of the building. In case of new building, the entire set of interventions can be applied.

7.2.5 Financing of intervention

The incremental capital required to construct a 1 star- 5 star rated buildings is discussed below:

Commercial Buildings:

Increment based on its comparison with Business as Usual (BAU) case:

Table 47: Price increment of Commercial Buildings as compared to BAU scenario

Parameters	Rating Level	OFFICE	SCHOOL	HOSPITAL	HOTEL 3 STAR	SHOPPING MALL
Building Envelope	1	21%	21%	21%	21%	21%
	2	32%	32%	32%	32%	32%
	3	73%	73%	73%	73%	73%
	4	80%	80%	80%	80%	80%
	5	80%	80%	80%	80%	80%
Glazing and Shading	1	24.5%	24.5%	24.5%	24.5%	24.5%
	2	178%	178%	178%	178%	178%
	3	227%	227%	227%	227%	227%
	4	257%	257%	257%	257%	257%
	5	257%	257%	257%	257%	257%
HVAC/ Air Conditioning System	1	10%	10%	10%	10%	10%
	2	14%	14%	14%	14%	14%
	3	32%	32%	32%	32%	32%
	4	45%	45%	45%	45%	45%
	5	65%	65%	65%	65%	65%
Artificial Lighting & Controls	1	5%	5%	5%	5%	5%
	2	12%	12%	12%	12%	12%
	3	38%	38%	38%	38%	38%
	4	45%	45%	45%	45%	45%
	5	45%	45%	45%	45%	45%

Source: Project Team Analysis

Residential Buildings:

Increment based on its comparison with BAU case:

Table 48: Price increment of Residential Buildings as compared to BAU scenario

Parameter	Rating Level	Residential house (AC when set point is over 30°C)	Residential house (~50% AC)	Residential: 2 BHK	Residential: 1 BHK	Residential: Studio apartment
Building Envelope	1	21%	21%	21%	21%	21%
	2	32%	32%	32%	32%	32%
	3	73%	73%	73%	73%	73%
	4	80%	80%	80%	80%	80%
	5	80%	80%	80%	80%	80%
Glazing and Shading	1	24.5%	24.5%	24.5%	24.5%	24.5%
	2	178%	178%	178%	178%	178%

Parameter	Rating Level	Residential house (AC when set point is over 30°C)	Residential house (~50% AC)	Residential: 2 BHK	Residential: 1 BHK	Residential: Studio apartment
	3 ★	227%	227%	227%	227%	227%
	4 ★	257%	257%	257%	257%	257%
	5 ★	257%	257%	257%	257%	257%
HVAC/ Air Conditioning System	1 ★	5%	5%	5%	5%	5%
	2 ★	15%	15%	15%	15%	15%
	3 ★	27%	27%	27%	27%	27%
	4 ★	35%	35%	35%	35%	35%
	5 ★	55%	55%	55%	55%	55%
Artificial Lighting & Controls	1 ★	5%	5%	5%	5%	5%
	2 ★	12%	12%	12%	12%	12%
	3 ★	15%	15%	15%	15%	15%
	4 ★	20%	20%	20%	20%	20%
	5 ★	20%	20%	20%	20%	20%

Source: Project Team Analysis

Cost of implementation depends on the specific technical requirements of the intervention and method of implementation which makes any cost related calculations case specific. However, implementation of mandatory measures required to achieve any star-rating are generally cost intensive and globally, penetration of green buildings have been impeded by financial constraints. Provincial government can allocate financial resources from existing budgetary allocation to overcome such financial constraints. The nature of the financial support is discussed in the following sub-section.

7.2.6 Implementation mechanism

Based on the experience of driving green building codes in other parts of the globe, it is observed that policy push is key to driving changes, coupled with regulatory changes. While regulatory changes define the activities that need to be undertaken for transformation, policy measures help overcome the price barrier for implementation. Both these measures need to be supplemented by market promotion and awareness generation activities to stimulate citizen participation.

Guidance on how to implement regulatory changes can be taken from the case of Building Environmental Plan System promulgated by the Tokyo Metropolitan Government (Tokyo Metropolitan Government, 2005). Under this system, it is required for buildings that will be newly built or extended and whose total floor area exceeds 5,000 square meters to submit their building environment plans. Moreover, those buildings that will be newly built or extended and whose total floor area exceeds 2,000 square meters may submit their building environment plans on a voluntary basis. Details of plans and the results of evaluation of environment-friendly approaches are opened to the public on the official website of the Tokyo Metropolitan Government.

The submission system of building environment plan has four evaluation points, i.e., "streamlining of energy use," "appropriate utilization of resources," "protection of natural environment" and "mitigation of heat island phenomenon". Under this program, which began in 2002, more than 1,300 buildings have been covered, at the rate of roughly 200 buildings per year.

Table 49: Rating items under Building Environment Plan System

Fields	Items
Efficient energy use	Reducing building thermal load (insulation), use of natural energy, energy-conservation systems, efficient management systems
Appropriate use of resources	Usage of eco–friendly materials, protection of ozone layer, measures for longer building life.
Preservation of the natural environment	Hydrological recycling, greening
Mitigation of the heat-island effect	Measures to reduce effects of artificial heat emissions, measures to reduce heat accumulation in sites and buildings, consideration for the wind environment

Source: Tokyo Metropolitan Government website & C40 cities website

For the remaining two measures i.e. policy changes and awareness generation, the following activities can be implemented:

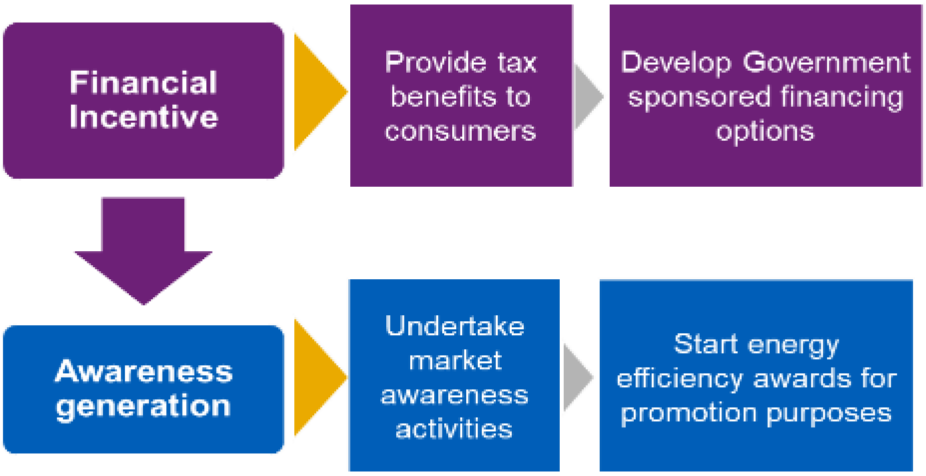


Figure 37: Operating model options for implementation

Explanation of the key activities given in the figure is as follows:

1. A suitable mechanism to provide tax benefits to consumers for undertaking construction of Green Buildings can be devised. In USA, there are guidelines developed to provide tax benefits (known as '179D Commercial Buildings Energy-Efficiency Tax Deduction') per unit area to the extent of USD 1.80 per sqft, depending on the savings exhibited (Office of EE & RE, US DOE, 2016).
2. Government can develop unique financing mechanism that will help increase uptake. For example, USA has a financing mechanism PACE (Property-Assessed Clean Energy) under which beneficiary can make installment-based payment for costs incurred on green building retrofits/construction along with their property tax (NREL, 2012).
3. Market awareness generation activities through printed media or through workshops can be conducted to generate awareness on the subject and motivate beneficiaries to start with energy efficient retrofits.
4. Starting energy efficiency awards can also help create awareness about green buildings and motivate more people to undertake such activities by organizing energy conservation awards. Such a practice has led to positive market transformation in a number of states in India[15]. The

[15] For reference: Scheme document for State Level Energy Conservation Awards (HAREDA)

recognition provided by such a platform is motivating many commercial users to undertake energy efficiency activities.

Based on the experience of driving green building codes in other parts of the globe, it is observed that policy push is key to driving changes. The Department of Construction (DOC) and Department of Industry and Trade (DOIT) should come up with some financing mechanisms which would support the implementation of Green building Codes in the Viet Nam, as the initial investment is the primary barrier in implementing energy efficient buildings. The mechanism should be designed with an objective to push the demand for EE technologies/materials by policy interventions of the Government.

The financing mechanisms developed by the Government, should empower the Central/ Domestic banks, Non- Banking Financial Institutions (NBFC) and International Funding Agencies to disburse loans for energy efficient buildings (both new and existing) on subsidized interest rates. The range for loan disbursement should be formulated in the financing scheme. Accordingly, a schematic flow of a proposed scheme for financing energy efficient buildings through loans issued by funding agency with subsidized interest rates is provided below:

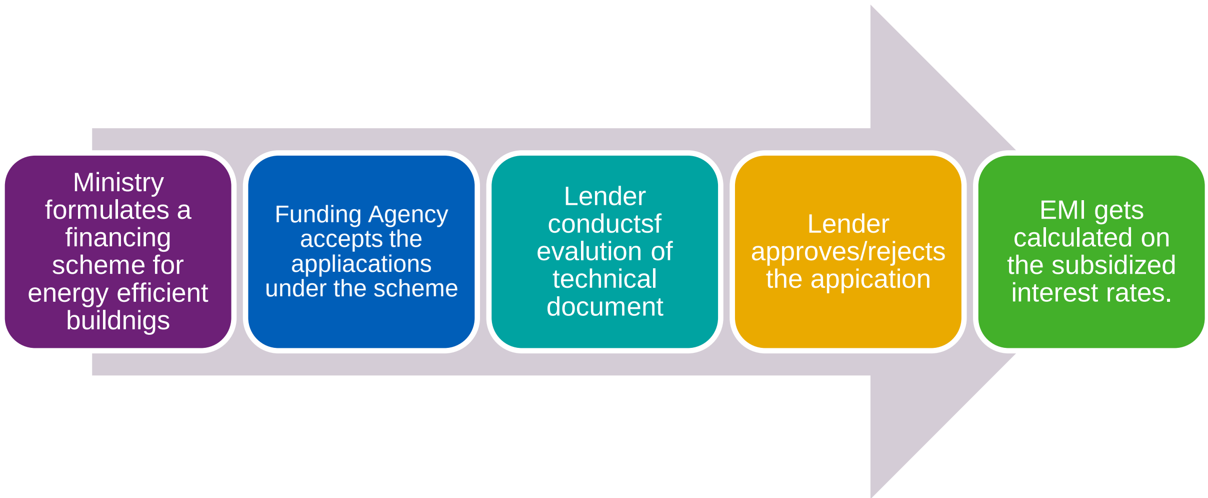


Figure 38: Funding for energy efficient buildings

Under the scheme given above, Government authorities will pay the interest accrued to the funding agency and the borrower would only be liable to pay the principal amount of the loan. Introducing such a scheme shall ensure lower investment requirement from the borrower, thereby accelerating the payback on investment. Exploring such an option can help provide the energy efficient building market the necessary stimulus to develop scale.

Apart from funding mechanisms for energy efficient buildings, options for reducing financing barriers for energy efficient equipment as well. A scheme has been devised, wherein electricity distribution companies collaborate with energy efficient equipment manufacturers, wherein the energy efficient equipment will be installed at the consumers' building and the cost of the equipment shall be paid by the consumer in Equated Monthly Installment (EMI) which will be added in the monthly electricity bill of the customer. The equipment manufacturer can provide discount on bulk purchase of the equipment.

Figure 39: Funding for energy efficient appliances

Apart from the above, the authorities can explore methods of increasing green cover by suitably modifying existing municipal bye-laws. A mandatory rule can be applied mandating all new buildings to mandatorily keep a part, along the boundary of the building area for developing green space. It can be mandated a building plan can be sanctioned only if indication of such green spaces in the plan. Adoption of such a measure shall ensure reduced building density as well as improve urban green spaces.

7.3 Town Structure

7.3.1 Current Status Analysis

As of 2017, nearly 52.8% of the total land of Da Lat is composed of forest land (off which 159 hectare is planted forest) and 34.6% is agricultural production land, the remaining (accounting for 12.6% of the total land area) is currently being used for residential purpose and special-use purpose i.e. construction land for offices, construction of non-business works; land used for defense and security purposes; non-agricultural production and business land and land use for other public purposes (Lam Dong Statistics Office, 2017). As per a new directive in 2014, adjustments have been proposed to the existing land use plan of Da Lat and accordingly, the land area as well as land use of the city is expected to change going ahead.

7.3.2 Government's Vision

The new directive in 2014, proposes to integrate surrounding Lac Duong, Don Duong, Duc Trong and a part of Lam Ha district (including: Nam Ban town and communes Me Linh, Dong Thanh, Gia Lam, Nam Ha) with existing boundaries of Da Lat (Government of Viet Nam, 2014). This integrated is planned to be divided in to 4 zones as given below:

Development zoning for Da Lat city under revised plan						
Urban Civil Land (11,700ha)	Forest eco-tourism land (6,500ha)	External transport & technical infrastructure (3,700ha)	Domestic defense land (2,500ha)	Agriculture & rural development (73,00ha)	Forest Land (232,000ha)	Landscape & water surface area (6,530ha)

Figure 40: Government's vision regarding town structure

Apart from the above, the Master Plan of adjusted area of Da Lat (Master Plan for original city limits given in Figure 12) also allocates specific areas to each activity (Government of Viet Nam, 2014):

1. Historic central urban area which will include administrative and political center at the city and provincial level, a trade center - a mixed tourist service, a domestic and international cultural and heritage tourism center, a city-level health center and regional level, the center preserves landscape space - open space - urban architectural space, city-level education and training center.
2. Eastern urban area which will include domestic and international tourism center, a nursing center, a cultural and artistic center - a regional and domestic landscape forest park, a regional and central education and training center, preserving architectural space - landscape.
3. Northern urban area which will include international domestic education-training, scientific-technological research center, an urban eco-agricultural tourist center, a tourist center for landscape and natural landscape space conservation and sport park.
4. Western urban area which will include commercial and entertainment service center, a tourist resort service center, mixed tourism, landscape tourism, urban eco-agricultural tourism.

Detailing of the Master Plan which provides specific measurement of area for each activity given above, is under preparation by the Department of Construction.

7.3.3 Rationale for intervention

Considering existing levels of urbanization in the current city limits of Da Lat, a number of measures which can help in reducing carbon emissions for the extended area of Da Lat are proposed as below:

Table 50: Proposed list of LCM for Town Structure of Da Lat city

PROPOSED INTERVENTION	RATIONALE
Green city land use planning to increase green coverage	1. Da Lat city is experiencing increased temperatures over the last decade 2. Development of interconnected green corridors can help in reducing increased temperature as well as enhancing overall aesthetics of the city 3. It can have a positive effect on improving prospects for attracting greater number of tourists

7.3.4 Description of Intervention

Increased emission within and around the city coupled with unabated growth of greenhouses in the vicinity of the city has contributed to increased temperature. The city has witnessed an increase of 3°C in the last 10 years (Worldweatheronline, 2018). While interventions addressing the root cause has been provided in other sections, increasing green cover in the city can help reduce the effect of detrimental effect in a relatively shorter duration.

International experience has shown the positive effect of increasing green cover can have on the overall living conditions of a city. A case in point is Medellin in Colombia which has been implementing 30 Green Corridors project across the city since 2016 (C40.org, 2019). As part of the initiative 8,800 trees and palms have been planted in 30 corridors that cover 65 ha. The USD 16.3 million initiative has resulted in carbon sequestration of nearly 18tCO_2e over a period of 3 years. The emission reduction has resulted in reduction in temperature by 2°C, which is expected to further decrease by 4-5°C in 28 years' time.

Source: acimedellin.org website

Figure 41: Example of 'Green Corridors' in Medellin, Colombia

A similar model can be implemented for Da Lat which focusses on roadways within the existing city and can help reduce temperature providing relief to residents. This model can be adopted both for the existing roads of Da Lat as well as provisions can be made in the designs of extended parts of the city integrating elements of Green Corridors.

7.3.5 Environmental Benefits of Intervention

Based on the conditions of existing city limits of Da Lat, the following assumptions have been taken to account for environmental benefits for the intervention:

1. Development of green corridor will be undertaken for arterial roads of city i.e. urban roads, axial and inter-village roads with a road width around 12m (Transport Department, Lam Dong Province, 2019).
2. The intervention will also be undertaken for 36 operating parking lots and 2 active bus stations with an area of 4.5ha and 1.8ha respectively (Government of Viet Nam, 2017).
3. Total length of urban roads is 231km and axial roads is 59.6km (Government of Viet Nam, 2017).
4. Cost of developing 1ha is USD 250,000 (C40.org, 2019).

Based on the assumptions the results, as provided in Table 51, have been generated:

Table 51: Summary of results for Green Corridor intervention

Parameter	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Penetration levels (%)	5%	10%	15%	20%	27%	35%	45%	55%	65%	75%	85%
Area covered (ha)	18	36	53	71	96	124	160	195	231	266	302
CO_2 sequestered (TCO_2e)	2	3	5	7	9	11	15	18	21	25	28
Cost (mn USD)	4.4	4.4	4.4	4.4	6.2	7.1	8.9	8.9	13.3	13.3	13.3

Source: Project team analysis

7.3.6 Financing and implementation mechanism

Implementation of the intervention will also lead to employment generation of nearly 100 citizens. Since no specialized skills is not required for planting trees, these citizens can be chosen from the lowest socio-economic strata of the city, thereby creating job opportunities and helping improve socio-economic condition of these people. Since, the corridors would require continued maintenance, the intervention would mean permanent job prospect for the selected citizens.

In order to implement the intervention, the following financing sources are available:

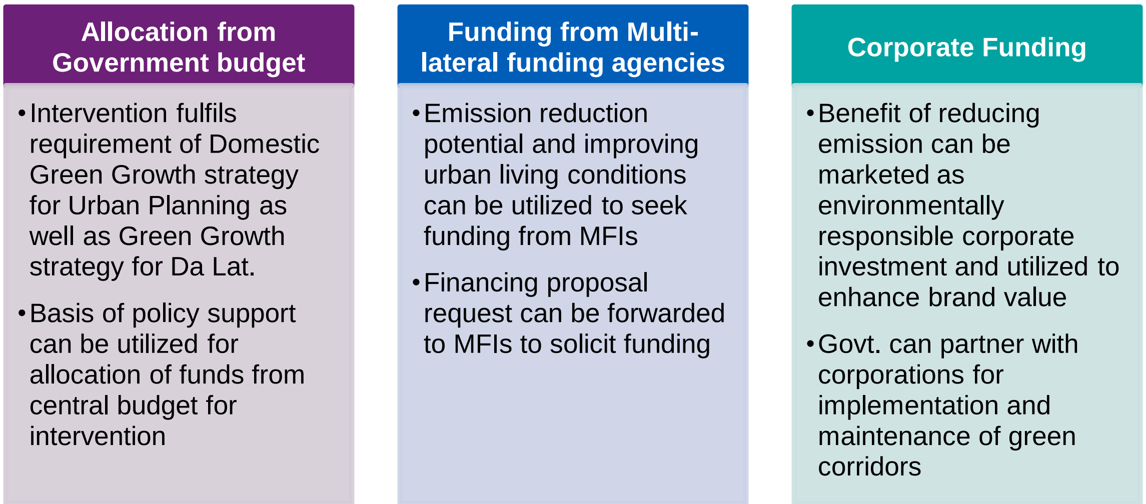


Figure 42: Operating model options for green corridor intervention

People's Committee of Da Lat can undertake implementation of the intervention in the 1st five years and the operations and maintenance can be outsourced to a private party in subsequent years of implementation to reduce operational burden for the city administration.

Since the master plan for the extended area is being developed and the availability of roads is yet to be determined, the concept can be piloted for the existing road ways of Da Lat. Based on the learnings and the implementation challenges in this pilot run, the intervention can be further extended to cover the roadways of the extended areas of Da Lat. The implementation of such measures for the new areas can be incorporated in the master plan to further support implementation in future.

7.4 Untapped Energy

7.4.1 Current Status Analysis

Da Lat has recently incorporated a new waste incinerator system to manage its garbage. The system they use is that of Thai company Siam Incinerator. Presently Da Lat only has one incinerator and can handle 15MT of waste a day. A second incinerator of the same specification is currently being installed (Siam Incinerator, 2015).

Approximately 180-200MT of waste is delivered to the waste management centre of the city, off which around 100MT of organic waste, 10MT of recyclable plastic and remaining 90MT is solid waste which is either incinerated or goes to landfill (Siam Incinerator, 2015). There is currently no infrastructure in place to generate electricity from the generated waste. Existing incinerators will be used to generate fertilizers.

7.4.2 Government's Vision

Domestic Strategy on Climate Change is directing mid to long term strategy vision to generate electricity through solid domestic waste and also to tap other energy generation sources:

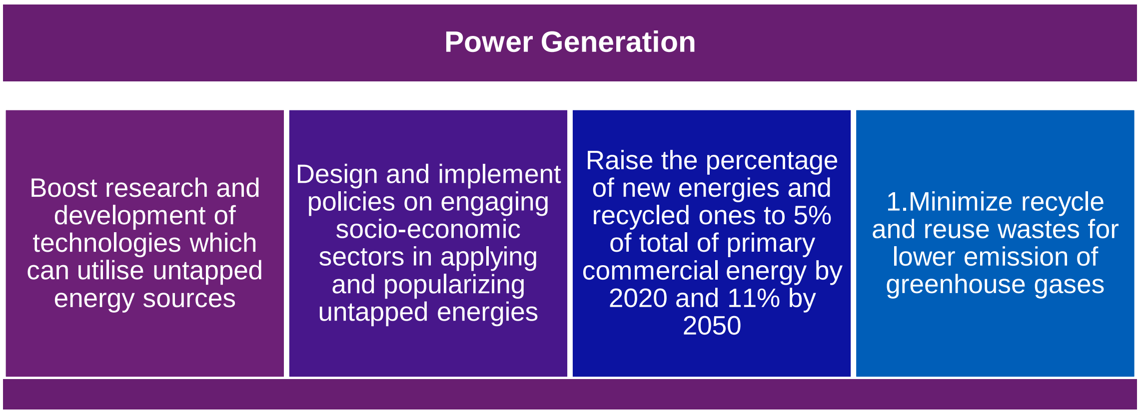


Figure 43: Government's vision regarding untapped energy system

7.4.3 Rationale for proposed Intervention

As city collects urban domestic solid wastes in a large volume, the project team proposes following low carbon interventions:

Table 52: Proposed list of LCM for Untapped Energy of Da Lat

PROPOSED INTERVENTION	RATIONALE
Waste to Energy	• Waste to Energy (WtE) is the process of generating energy in the form of electricity and/or heat from the primary treatment of waste, or the processing of waste into a fuel source. • Da Lat, being an urban centre, produces considerable amount of solid waste (160MT in 2017) (MDPI, 2017). • Existing incinerators can be retrofitted with requisite equipment to develop a WtE plant. • This will help tackle waste management issue as well as provide Da Lat with alternate means of power generation.

7.4.4 Description of Intervention

With the growing population, waste generation is expected to increase, and this waste can be used to generate electricity which can be sold to Viet Nam Electricity Company (EVN) at the predetermined rate of USD 0.1005/kWh (British Business Group Viet Nam, 2017). Moreover, negotiations with EVN can lead to increased rates of electricity sold, with a rate of 5% annual increase in predetermined rates.

7.4.5 Environmental benefits of intervention

In order to estimate environmental benefits and financial requirements required for establishing waste-to-energy plant, the following assumptions have been taken:

1. Average waste generation per day in existing city is 200MT/day (KII , 2019)
2. Population growth rate is 1.17% (Project Team Analysis, 2019)
3. 7500MT/day will be utilized by a power generation plant with a capacity of 110MW (ADB, 2017)
4. Cost of establishing a plant which has a maximum capacity of 500MT/day will cost USD 43 million (DTI News, 2018).
5. Annual electricity generated by a plant with a capacity to consume 600MT waste/day is 64.8GWh (GEC, 2014)
6. O&M cost of plant is 4% of capital cost (GEC, 2014).
7. Cost of outsourcing disposal handling work is USD 20/T of waste handled and annual cost appreciation is 3% (GEC, 2014).
8. Depreciation in straight line method for equipment for a period of 20 years (GEC, 2014).

Based on the assumptions the following calculations can be derived for establishing WtE plant in Da Lat, as given in Table 53:

Table 53: Details of WtE intervention

Parameter	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total waste generated per day (MT)	200	202	205	207	210	212	214	217	220	222	225	227	230
Plant capacity potential (MW)	2.93	2.97	3.00	3.04	3.07	3.11	3.15	3.18	3.22	3.26	3.30	3.33	3.37

Source: Project team analysis

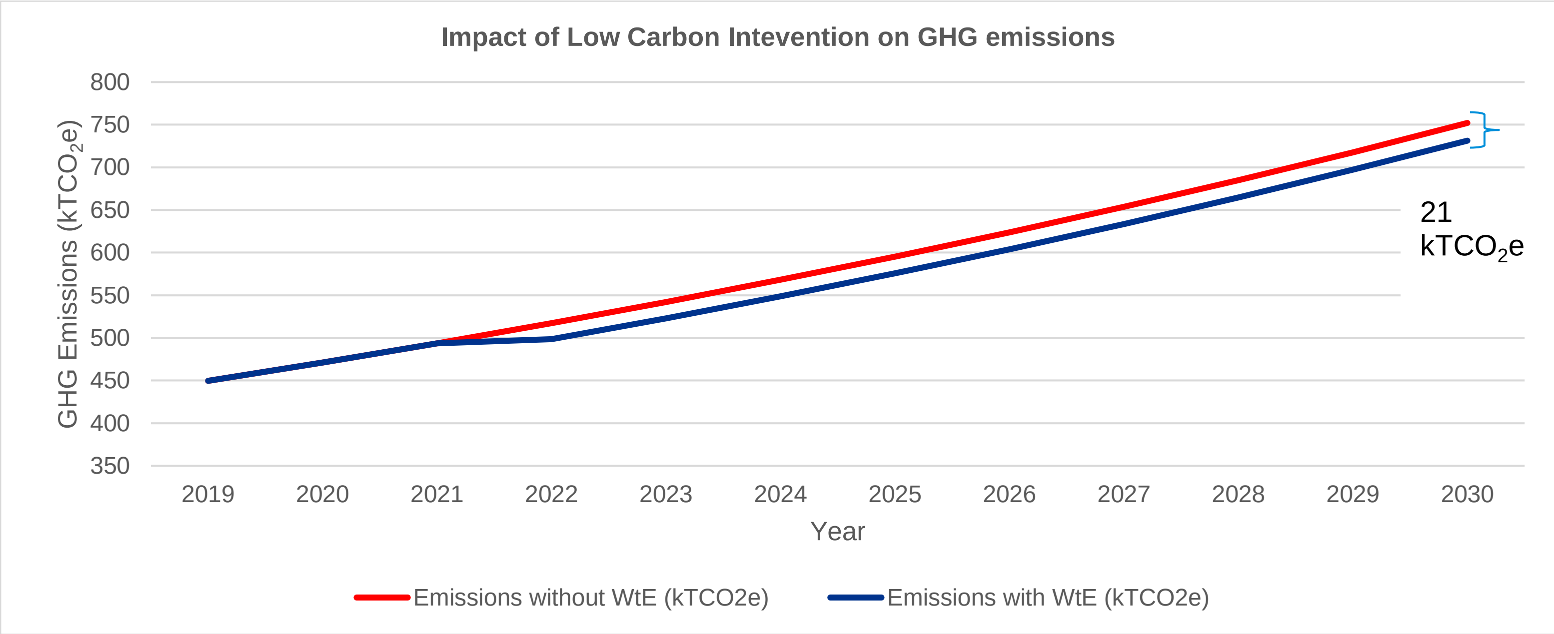
Based on values given in Table 53, by 2030, wastes from Da Lat can provide fuel for a 3MW WtE plant. Upon further extrapolation till 2042, the maximum power generation capacity based on availability of fuel is 3.9MW. Hence, a 4MW power plant can help the city prevent nearly 265MT of wastes from finishing up in landfills. Based on the assumptions given above the environmental benefit derived from implementing a 4MW WtE power plant is given in Table 54 below:

Table 54: Details of environmental benefit from WtE intervention

Scenario	Particulars	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Without WtE plant	Power Generated (GWh)	513.4	537.9	563.7	590.6	618.9	648.5	679.6	712.1	746.2	781.9	819.3	858.5	899.6
	CO_2 emission ($MTCO_2e$)	429	450	471	494	517	542	568	595	624	654	685	718	752
With WtE plant	Power Generated (GWh)	513.4	537.9	563.7	590.6	596.3	625.6	656.4	688.7	722.5	757.9	795.0	833.9	874.7
	CO_2 emission ($MTCO_2e$)	429	450	471	494	498	523	549	576	604	634	665	697	731
Net emission savings due to intervention		0	0	0	0	18.9	19.1	19.4	19.6	19.8	20.1	20.3	20.5	20.8

Source: Project team analysis

Figure 44 below shows the comparison of CO_2 emissions with and without the intervention:



Source: Project team analysis

Figure 44: Impact of WtE intervention

7.4.6 Financing and implementation mechanism

The cost of implementing the intervention is approximately USD 24 million and the cash flow for the project based on the assumptions give above is provided in Table 55 below:

Table 55: Financial analysis of WtE intervention

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
Capital Cost (USD million)	12	12																					
O&M Cost (USD Million)			0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Disposal cost (USD million)			0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Power generated (GWh/yr)			22.63	22.89	23.16	23.43	23.71	23.98	24.26	24.55	24.84	25.13	25.42	25.72	26.02	26.32	26.63	26.94	27.26	27.58	27.90	28.23	28.56
Power sale (USD million/yr)			2.27	2.30	2.33	2.35	2.38	2.41	2.44	2.47	2.50	2.53	2.55	2.58	2.61	2.65	2.68	2.71	2.74	2.77	2.80	2.84	2.87
Depreciation (USD million/yr)			1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Tax (USD million/yr)			0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.16	0.16	0.16	0.17
Net Profit			1.20	1.23	1.25	1.28	1.30	1.32	1.35	1.38	1.40	1.43	1.45	1.48	1.51	1.54	1.56	1.59	1.62	1.65	1.68	1.71	1.74

Source: Project team analysis

Based on the current scenario, the project has a 2% internal rate of return and payback period of approximately 16 years. In order to make the project attractive, the provincial Government undertake a PPP arrangement, wherein the Government will invest partly in the capital cost of the plant, while private player injects capital in the remainder of the investment. Another alternative would be providing private player access to concessional loans for implementing WtE plant, lower than the IRR rate of 2%. Alternatively, funding from multilateral funding institutions like ADB and bilateral funding agencies like JICA, GEC can be explored. There are existing case studies of ADB and Japanese government independently providing funding to two separate WtE projects in Viet Nam. Development of proposals indicating the environmental benefits and the financial support required to make the projects commercially attractive.

7.5 Renewable Energy

7.5.1 Current Status Analysis

Viet Nam is considered an economy with high solar potential, especially in the central and southern area of the economy. Direct normal irradiance in case of Da Lat is approximately 3.912 kWh/m^2 per day (Global Solar Atlas, 2019) and total number of hours of sunshine in a year is 2236 hours. (Government of Viet Nam, 2009) In Da Lat, only few hotels and commercial buildings are utilizing solar energy while there is a huge scope of implementation of solar energy.

7.5.2 Government's Vision

With electricity demand projected to increase by eight percent annually until 2025; the government is moving forward to develop renewable energy sources to ensure energy security and addressing the growing power demand.

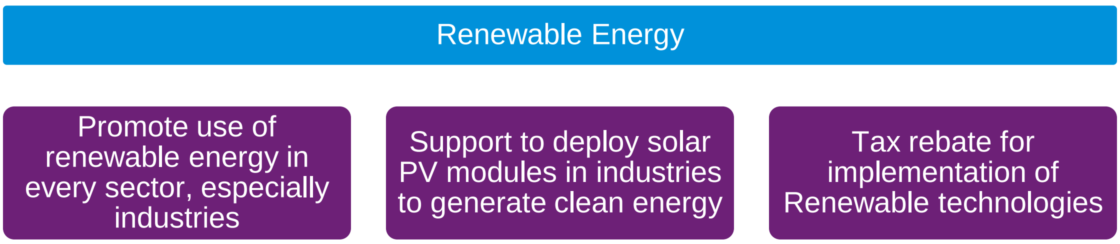


Figure 45: Government's vision regarding renewable energy

7.5.3 Rationale for proposed Intervention

As Da Lat has a lot of potential for solar energy, the project team proposes following low carbon interventions:

Table 56: Proposed list of interventions for RE sector of Da Lat

PROPOSED INTERVENTION	RATIONALE
Grid connected Net metering - Rooftop Solar Power Generation in the building sector.	The main advantage of photovoltaic systems is the fact that the electricity produced by the PV plant can be used by the company for its own consumption. This reduce the withdrawal by the electrical grid and consequently the cost of the electricity bill. It also helps in reducing the CO_2 emission.
Promotion of flat-roof structures for new construction	For the new construction outside existing area of Da Lat, construction of flat-roof/roof with lower slope can be promoted to ensure greater penetration of rooftop solar.

Apart from the policy documents, interaction with Provincial and City Committees as well as informal interaction with citizens led to the following observations:

1. Houses present in existing city limits of Da Lat have thatched roof and have varying orientation in terms of roof direction. This makes estimation of solar rooftop potential across the city would be challenging.

Source: On-site image taken by Project team

Figure 46: Examples of roof structure in Da Lat

2. Over 50% of buildings in existing city limits, especially commercial buildings like hotels already have solar water heaters installed on the roof. These arrangements occupy considerable area ranging from 20% for a 1-star hotel to about 60% for a 4-star property.

Source: On-site image taken by Project Team

Figure 47: Examples of solar water heater in Da Lat

3. Majority of existing buildings are considerably old and may not have required structural integrity to support additional weight of solar rooftop structures, which may be already burdened by a solar water heater. In such a case, additional investment would be required to develop additional support structures. This creates an additional challenge of mass-level adoption of solar rooftop.

4. Citizens are also concerned that the increased prevalence of solar rooftop panels will interfere with the aesthetics of the city – the presence of dark coloured panels across the picturesque city is not desired by the authorities or general citizens.

7.5.4 Description of Intervention

Considering the constraints of implementing solar within existing city limits, the extended city limits can be considered for implementing rooftop solar panel. In order to promote solar rooftop and get adequate levels of efficiency, panel orientation is a critical consideration – panels oriented in north-south direction have the highest efficiency. However, nearly all buildings of existing city has thatched roof with varying orientation. While these structures ensure better flow of rain water than a flat roof, installing solar panels on such structures may not provide desired results. In order to improve orientation, additional supporting structures can be provided, which will add to the cost of installation as well as increase load on roof.

Also, nearly 40%-50% of existing roofs in most cases are already occupied by solar water heaters. Additionally, there is limited use of air-conditioning system which consume substantial power – 40-60% in case of commercial buildings. Hence, lower consumption levels along with risk of weakening of roof structure, incentive to undertake additional investment for rooftop solar is low for existing building owners. For the case of feasibility assessment, the buildings in existing area of Da Lat has thus not been considered.

In order to increase penetration of solar panel, a key requirement would be promotion of flat roof structures across these extended parts of city which will ensure higher efficiency of solar panels. In order to promote flat roof structures, the benefits can be explained to the residents. In order to lower slope can be provided along with rainwater run-off drains along the edges of the roof.

Under present market conditions, installation of 1kW system in Viet Nam would cost USD 1200 (Vietnamnet, 2019) and occupy approximately 10sqm of shadow free area (MNRE, GoI, 2015). Under the new feed-in tariff (FiT) regime introduced in 2019, producers in Da Lat will fall under Region 3 as per new FiT and will receive USD 0.0838 per kWh of power produced through rooftop solar (WFW, 2019).

7.5.5 Environmental benefits

In order to estimate the solar potential and subsequently the environmental benefits, the future expansion areas of Da Lat have been considered. The following assumptions have been considered:

1. Difference of total urban residential land for future expansion area of Da Lat and existing city limits has been considered the area where intervention will take place for residential buildings.
2. Total land under mixed development land, trade and service area and land for industry and small industry as per the Master Plan for extended area of Da Lat is considered for development of rooftop solar under commercial buildings.
3. Since exact area allocated for commercial buildings not available as per the Master Plan, three levels of penetration till 2030 are considered based on the area in which solar rooftop would be installed. These levels are optimistic (20% of total area), realistic (10% of total area) and pessimistic (5% of total area). Based on the levels of penetration, solar rooftop potential for commercial buildings will be calculated
4. Maximum construction density for the area under consideration is 50% (Government of Viet Nam, 2017)
5. Nearly 70% of total building area will be rooftop area and available rooftop area for installation of solar panel would be 50% of total area (Effigis, 2018)
6. 1kW of power is generated from 10sqm of solar panel (MNRE, GoI, 2015) and cost of installing 1kW panel is USD1200 (Vietnamnet, 2019).
7. Panel efficiency is 15% (EAI, 2018), no. of days of sunshine in year for Da Lat is 2236 hours (Govt. of Viet Nam, 2009) and direct normal irradiance of 3.912kWh/m^2 per day (Global Solar Atlas, 2019)
8. Penetration of rooftop solar for residential building follows the trend given in Table 57

Table 57: Penetration level of rooftop solar in residential buildings

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1%	2%	3%	4%	6%	8%	10%	12%	14%	17%	20%

Based on the assumptions, the results obtained are provided in Table 58

Table 58: Environmental benefits of rooftop solar in residential buildings

Parameter	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Penetration of solar	1%	2%	3%	4%	6%	8%	10%	12%	14%	17%	20%
Power generation capacity (kW_{peak})	30714	61427	92141	122855	184282	245710	307137	368565	429992	522133	614275
Power generated from solar (MWh)	0.34	0.67	1.01	1.34	2.01	2.69	3.36	4.03	4.70	5.71	6.72
CO_2 emission avoided ($ktCO_2e$)	0.000	0.001	0.001	0.001	0.002	0.002	0.003	0.003	0.004	0.005	0.006
Total investment (USD Million)	37	37	37	37	74	74	74	74	74	111	111

Source: Project team analysis

Table 59: Environmental benefits of rooftop solar in commercial buildings

Parameter	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Scenario I - Optimistic penetration (20% by 2030)											
Penetration of solar	1%	2%	3%	4%	6%	8%	10%	12%	14%	17%	20%
Power generation capacity (kW_{peak})	46060	92120	138180	184240	276360	368480	460600	552720	644840	783020	921200
Power generated from solar (MWh)	0.25	0.50	0.76	1.01	1.51	2.01	2.52	3.02	3.53	4.28	5.04
CO_2 emission avoided ($ktCO_2e$)	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002	0.003	0.004	0.004
Total investment (USD Million)	55	55	55	55	111	111	111	111	111	166	166
Scenario II - Realistic penetration (10% by 2030)											
Penetration of solar	0.5%	1.0%	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%	9.0%	10.0%
Power generation capacity (kW_{peak})	23030	46060	92120	138180	184240	230300	276360	322420	368480	414540	460600
Power generated from solar (MWh)	0.13	0.25	0.50	0.76	1.01	1.26	1.51	1.76	2.01	2.27	2.52
CO_2 emission avoided ($ktCO_2e$)	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002
Total investment (USD Million)	28	28	55	55	55	55	55	55	55	55	55
Scenario III - Pessimistic penetration (5% by 2030)											
Penetration of solar	0.25%	0.50%	1.00%	1.50%	2.00%	2.50%	3.00%	3.50%	4.00%	4.50%	5.00%
Power generation capacity (kW_{peak})	11515	23030	46060	69090	92120	115150	138180	161210	184240	207270	230300

Power generated from solar (MWh)	0.06	0.13	0.25	0.38	0.50	0.63	0.76	0.88	1.01	1.13	1.26
CO_2 emission avoided ($ktCO_2e$)	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Total investment (USD Million)	14	14	28	28	28	28	28	28	28	28	28

Source: Project team analysis

The calculation for commercial buildings area has been provided to understand extent of impact of rooftop solar in commercial buildings. For final summary calculations, the realistic penetration level has been considered.

7.5.6 Financing and implementation mechanism

In order to implement the intervention, the following funding sources can be explored:

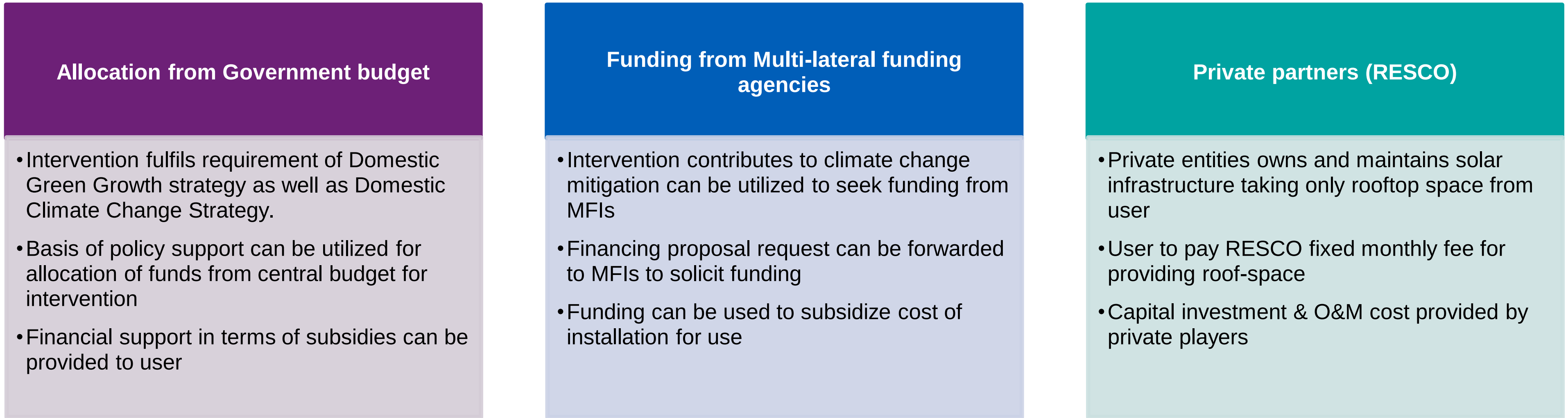
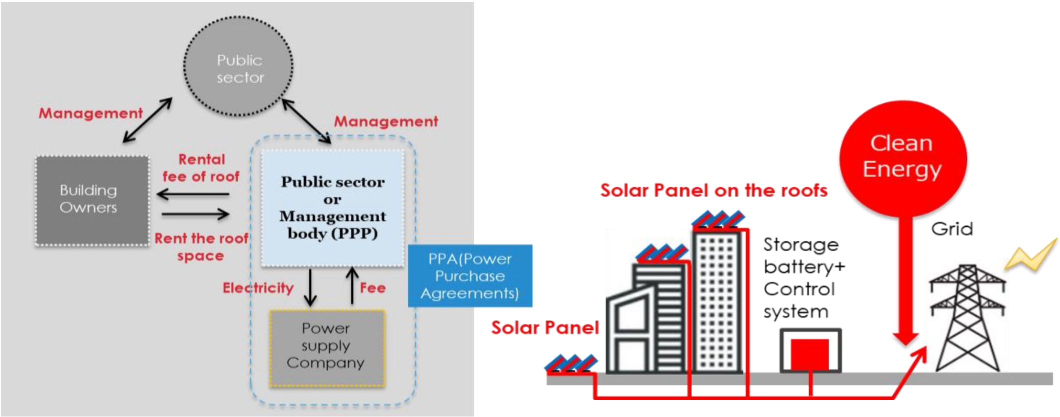


Figure 48: Operating model options for solar rooftop intervention

Apart from providing financial support to consumers, awareness regarding the benefits of undertaking renewable energy needs to be undertaken.

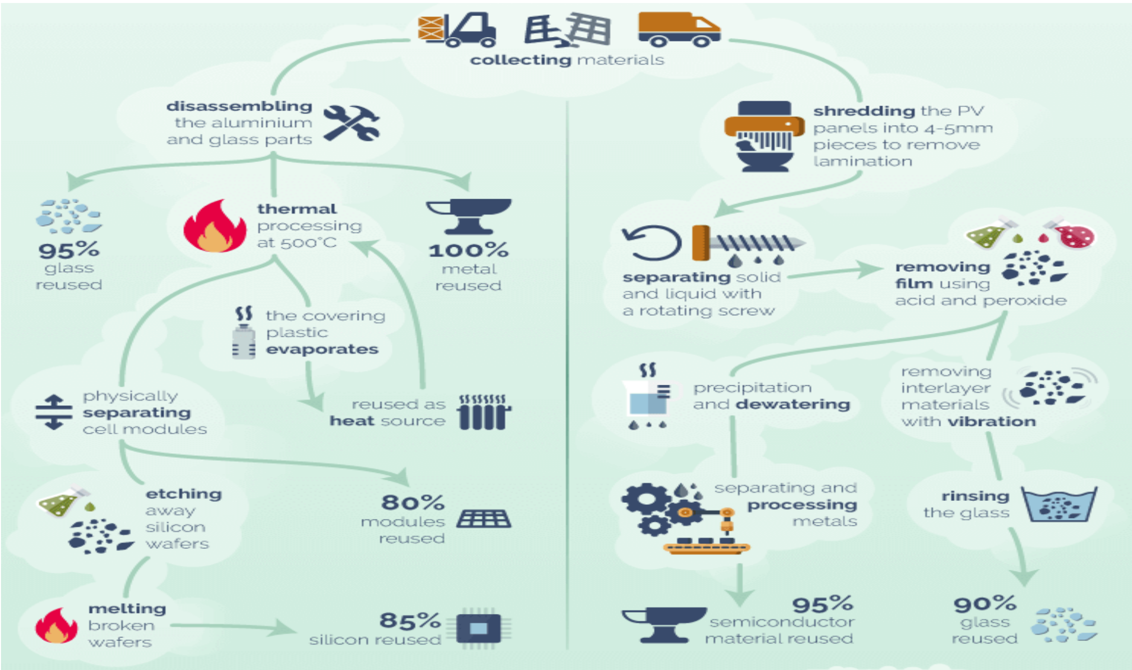
A sustainable business model for widespread adoption of this measure can be Neighborhood Solar Farm. Under this model, Local municipality or area management body installs solar panels by utilization of rooftop of building and unused land / open space within the designated area and gain an income by selling electricity through the 'Feed-In-Tariff' (FiT) system[16]. In case FIT system is terminated, Virtual Power Purchase Agreement (PPA)[17] should be considered as an alternative.



Source: Project team generated image

Figure 49: Neighborhood Solar Farm

Despite its benefit, unsafe disposal of solar panels after useful life poses a considerable threat to environment due to presence of certain toxic materials. Typical solar panels experience a degradation rate of 0.5%-0.7% per year, exhibiting failure (i.e. >20% decline in panel efficiency) in about 25-30 years (NREL, 2012). After failure, the panels are replaced and old panels disposed. Recycling of solar panels is an established process by which constituent glass, silicon and metals can be reused for producing new panels. Figure below gives the entire process:



Source: Greenmatch,uk website

Figure 50: Recycling process of solar PV panels

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[16] Note: Feed-in-tariff is a mechanism to promote renewable energy (RE) wherein long-term contracts are entered with RE producers, assuring them grid access and guaranteed, cost-based purchase prices i.e. payments are in proportion to the resources and capital expended in order to produce the energy.
[17] Note: Power-purchase agreement is a contract between the power generator and the consumer which defines the commercial terms for sale of electricity.

Given the limited penetration of solar panels in Da Lat for power generation and average lifetime of these panels is 20-25 years, increasing penetration of solar power now can provide Da Lat authorities with considerable time to setup such a recycling value chain. The value chain can also help recycle the discarded solar panels being currently used for generating hot water for commercial and residential purposes across the city. The time available can be utilized to track technological developments in the field of solar panel recycling, shore up financial resources required to setup the value chain, explore private sector participation opportunities and development of recycling guidelines by Da Lat city authorities.

7.6 Multi Energy System and Area Energy System

7.6.1 Current Status Analysis

DES converted to heating and cooling is not a new concept, but this technology is gaining traction in Viet Nam in the current era of urbanization, energy insecurity, and climate change mitigation. Presently, there is no concept of district heating or cooling in Da Lat. Utilization of cogeneration technology can also be used for especially for heating requirements in commercial (like hotels, shopping complexes) and residential buildings of Da Lat.

7.6.2 Government's Vision

The Ministry of Industry and Trade is the nodal body for the activities related to energy use statistics which will form the basis for strategies, master plan and programs related to energy efficiency.

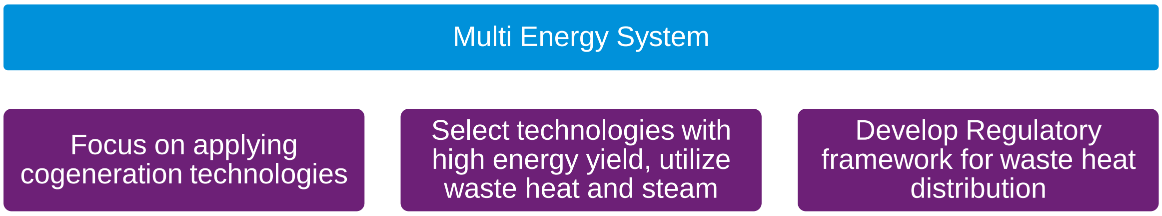


Figure 51: Government's vision regarding multi-energy system

Under the current policies/schemes developed by Government of Viet Nam, there is limited focus on the area energy systems like district heating/cooling system.

Apart from the policy documents, interaction with Provincial and City Committees as well as informal interaction with citizens and stakeholders led to the following observations:

1. Da Lat has typically moderate climate wherein maximum and minimum temperatures do not require artificial cooling or heating systems. Majority of commercial buildings and almost all residential buildings do not have any HVAC system.
2. In recent years, city has increased an increase in maximum temperature which is resulting discomfort for citizens in summer months. Most are coping with increasing temperature by using ceiling or standing fans.
3. Given the historical climate conditions, the architecture of existing buildings (especially hotels) do not have any provision for setting up a centralized HVAC system. Buildings constructed as recently as early 2000s, exhibit such features. Its only in case of new buildings, constructed after 2005 that centralized HVAC system is present.
4. It is estimated that nearly 80% of hotels are architecturally suited for setting up a centralized HVAC system. Also, installing standalone ACs would require substantial modification, based on the room structure.

7.6.3 Rationale for proposed Intervention

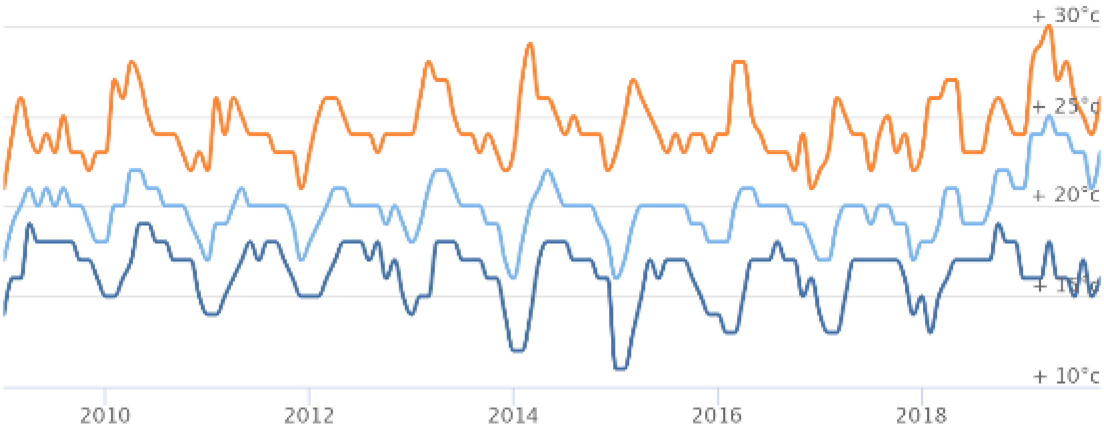
As district cooling/heating has not been implemented in the city, the project team proposes following low carbon interventions:

Table 60: Proposed list of LCM for Energy System of Da Lat

PROPOSED INTERVENTION	RATIONALE
Aggregated cooling system using trigeneration power systems	• Da Lat has been witnessing elevated temperatures which is becoming increasingly discomforting for citizens – 3°C average temperature increase has been witnessed in the last 10 years. • Sustained elevated temperatures will lead to requirement for artificial cooling • Instead of stand-alone systems, an integrated system which meets cooling requirement for a selected cluster of buildings through one chiller unit will help reduce energy consumption and corresponding emissions • Coupling such a system with trigeneration system operating on biomass will further help generate energy from renewable source with emission levels lower than grid generated power.

7.6.4 Description of Intervention

Given the existing climatic conditions of Da Lat, there is a need for hot water supply for daytime use and minimal need for cooling. However, given the inputs from the stakeholders as well as historical temperature data available, the temperature has witnessed an overall increase of 3°C in the last 10 years as given in the figure below:



Source: Worldweatheronline

Figure 52: Temperature variation in Da Lat between 2010 to 2018

Given the scenario and architectural structure of buildings, implementation of Aggregated Cooling System using trigeneration power system can be an option which can be explored. However, this intervention can only be applied for future expansion areas due to the following reasons:

1. Existing city has been designed for a population of approximately 100,000 (Department of Construction, 2019). However, current population has already increased to more than 2.2 times of the planned population. This has led to space constraints for undertaking additional infrastructure development within the existing city limits.

2. Plans for expansion of city limit has been undertaken to decongest core city area and develop surrounding areas. In fact, the Provincial government has the vision of diverting future population growth in these areas.

Given the fact that ideal temperature for thermal comfort is between 23.5°C and 25.5°C in summers (ASHRAE, 2017) and temperatures have been breaching 30°C mark for Da Lat, citizens have started to use fans for cooling purposes. It is expected that current trajectory of temperature increase would necessitate use of air-conditioning systems over the next 5-10 years. In order to provide citizens with an option of using aggregated cooling system over standalone AC systems, a market demand study needs to be undertaken after 5 years.

The key benefits of implementing Aggregated Cooling System using trigeneration power system over conventional/standalone air conditioning system are as follows (Comfortfutures, 2018):

1. Eco-efficient energy; reduction of power generation infrastructure, ability to use alternative, renewable and cheaper fuels, 50% reduction in power consumption, no need for refrigerants, reduced green-house gas emissions, flexibility of cooling load
2. Lower life cycle costs; less maintenance on machinery, longer life cycle of plant, ability to expand and distribute to more buildings so less construction of new operational machinery
3. Reliable; available 24 hours a day, unaffected by peak loading, back-up systems available, operated at external site to building thus can be responded to immediately
4. Decreased building costs and architectural flexibility; buildings connected to district cooling do not require energy equipment such as boilers and chillers or storage space for refrigerants, thus reducing cost and making space within the building; vibrations and noise problems are removed
5. Use of trigeneration system (based on waste/biomass) will help create a renewable source of energy.
6. Increased efficiency of fuel by using trigeneration system – Conventional thermal power generation systems have a thermal efficiency of 40-45% (IIR, 2017) (i.e. amount of input heat converted to output), while efficiency of a trigeneration system is around 80-85% (MWM, 2017).

In order to design a feasible district energy system, the following steps are required to be followed:

1. **Energy demand assessment**

   Estimate approximate cooling requirement per unit area based on local conditions and subsequently estimate total cooling requirement based on total available floor area. Da Lat specific estimates of cooling demand per unit area is not available. Taking the case of standard cooling requirement, 150-170kW or 43-48TR of cold output is required per 1000sqm of office space (Clarke Energy, 2018). Based on the total developed floor area, the total cooling demand can be determined.

2. **Energy supply assessment**

   Assessment of central plant options to determine preferred technology, fuel and energy centre location i.e. high requirement for cooling. Determine feasibility and cost of connection of energy centre to existing utilities. Electric driven chillers are the most common form of producing cooling. In this instance, a closed cycle refrigerant is taken through four stages:

   a. Compression of gas to high pressure increasing its temperature;
   b. Cooling of the gas in a condenser to return the fluid to liquid;
   c. Expansion of liquid to low pressure resulting in a reduction in temperature;
   d. Heating the liquid to return it to a gas

   It is the last stage that provides the cooling of the buildings, the heat rejected from the building into the chilled water is used to heat and boil the refrigerant liquid. Although a number of different compressor technologies are available (e.g. centrifugal, screw, scroll), it is the refrigerant used that is the main differentiator between chillers.

3. **Network route assessment:**

   Determine indicative routes for district cooling pipework and private wire power systems based on constraints faced in soft dig. Also, the connection to the buildings would be a determinant – buildings can have direct connection system (district cooling water can pass directly into building's cooling systems) or indirect system (transfer the cooling across a plate heat exchanger so that the district cooling water is kept separate from the building heating system. An indirect system is preferred since this prevents any issues arising from pressure differences and water quality.

4. **Financial assessment:**

   This would take in to account the capital cost and operation and maintenance cost along with the cost of energy source for the system i.e. trigeneration system.

   Based on the total cooling requirement, the total cost of setting up the plant can be determined by using the global standard cost of the following parameters (District Energy Initiative, 2017):

   a. Capital cost of District cooling plant: USD2000/TR.
   b. Land cost: USD500-1000/m^2
   c. Distribution network cost (including pipes, metering, insulation and installation): USD180-200/TR

   The system will be supplied energy from biomass trigeneration plant which will use a biomass incinerator to run gas turbine of the trigeneration plant. Based on case studies, the capital cost of setting up a biomass (straw-based) trigeneration plant is USD18,000/TR (University of Newcastle, 2012). Annual operation and maintenance cost for such a plant would be 4% of total capital cost.

   In accordance with the relevant regulations of Viet Nam, a tariff structure for supply of chilled water to end-users can be developed to estimate revenue generated from the project. On the basis of structure followed in advanced markets for such systems i.e. Malaysia, Singapore, China, tariff structure of chilled water from district cooling system would comprise 3 components (District Energy Initiative, 2017):

   a. Connection charge: One-time charge collected from end-users by the operator of district cooling system for connecting to the system. Total charge is equal to 20% of capital cost.
   b. Capacity charge: Charge collected monthly based on capacity of end-user. Annually, total of 7% of capital cost is collected under this head.
   c. Metering charge: Charge collected monthly based on actual consumption by the end-user and charged at per ton of refrigeration-hour (ToR.h). Annually, 13% of total capital cost can be collected under this head.

   Since a trigeneration plant has been proposed, the system can additionally supply heat to end-users for water heating requirements as well. This will provide an additional source of revenue for the operators.

   Based on the above information, the internal rate of return of the project can be determined. Accordingly, the project developer can determine the cost of financing which would make the project viable.

The data points required above would be contingent on the existing conditions of the buildings that will be coming up in the extended areas of Da Lat. It is expected that hotels and other commercial spaces that would be constructed would require cooling from the area energy system.

Also, based on future conditions of temperature change, Cooling requirement per unit area i.e. tonne of refrigerant per square meter (TR/sqm) and Total floor area for which cooling demand has to be met (sqm) be determined.

The product of these two parameters would help determine the cooling demand of the specified area. The cooling demand would be the key parameter which would help to assess the technical requirement and subsequently financial requirement for the system.

7.6.5 Environmental benefits

The combined environmental benefit derived by implementing the intervention is due to the savings coming from district energy plant and the trigeneration plant. Based on case studies referred previously, the annual GHG emission reduction capacity for the district energy plant and trigeneration plant is 1.4TCO_2e/TR and 7.3TCO_2e/TR respectively. This makes the entire setup capable of reducing GHG emissions by 8.7TCO_2e/TR annually.

7.6.6 Financing and implementation mechanism

In order to undertake and run the project the following models can be considered:

Domestic level support	• MoIT provide portion of funds or MoF provide import subsidies/tax benefits • Lowers risks and cost of financing for district cooling project. • Support provided in initial period and could be slowly phased out.
Utilities	• Power utility undertakes capital cost & O&M of system • Initiative provides alternate revenue stream for power utilities
Private developers	• Building developers undertakes capital cost & O&M of system • Proved successful in other economies and countries where initiative implemented
MFI Financing	• Concessional funding provided by MFIs • Provides opportunity to bring international expertise as TA to concessional fund
Public-private partnership	• Joint venture of Government undertaking and private company for capital & O&M expenditure • Leverage expertise of private player & low-risk profile of Govt.

Figure 53: Implementation options for district cooling system

7.7 Agriculture Sector

7.7.1 Current Status Analysis

Agriculture is a major contributor to the economy of Lam Dong province and Da Lat in particular. As per the Land Use plan, the city has 13,374ha of agricultural land which constitutes nearly 34% of total land area (Government of Viet Nam, 2014). Under extended limits of the city, the agricultural land is expected to increase to 70,400ha (Government of Viet Nam, 2019). The key agriculture produce is vegetables and flowers, along with coffee. After 2010 directive of Government of Viet Nam to develop hi-tech agriculture in the economy, there has been a steady increase in the number of greenhouses which has increased from 1328ha in 2012 to 2760ha in 2018 and accounts for 27.9% of total greenhouse area in Lam Dong province. Around 55% of the greenhouses are engaged in growing vegetables, while the remaining 45% are engaged in production of flower (Department of Agriculture, 2019).

The advent of greenhouses has increased farm productivity – while normal farming techniques yields approximately USD 4300/ha, application of greenhouses increases to an average of USD

7279/ha and even reaching USD 250,000/ha depending on the agricultural practices adopted. Greenhouses also protects crops/flowers from rain or hailstorms which are common in Da Lat and leads to resource efficiency. However, unchecked proliferation of greenhouses is causing increase in temperature of Da Lat as well as obstructing flow of rain-water in the region leading to floods (Vietnamnet, 2018). It also has a detrimental effect on the urban aesthetics of the city.

7.7.2 Government's Vision

The key themes present in government's vision for agriculture is increasing farm productivity while maintaining energy and resource efficiency.

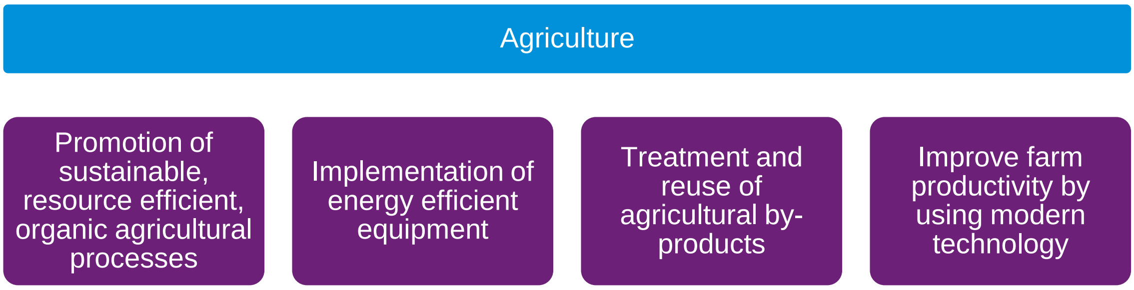


Figure 54: Government's vision regarding agriculture

While advent of greenhouses has helped achieve the objectives of productivity as well as resource efficiency, the growth has not been regulated, leading to detrimental effects on the core city.

7.7.3 Rationale of proposed Intervention

Table 61: Proposed list of LCM for Agriculture sector of Da Lat

PROPOSED INTERVENTION	RATIONALE
Eco-agricultural tourism by construction of garden houses	• Garden houses, in line with similar construction present in Hue, can provide for ecologically favourable agriculture practices. • At the same time, it can provide tourism opportunities as well as carbon sequestration • Aesthetic value of outskirts of the city can also be enhanced increasing prospects for tourism related activities
Improved legislation for greenhouses	• Unabated growth of greenhouses to tap enhanced productivity levels is having detrimental effect on living conditions in the surrounding urban areas • Growth of greenhouses should be regulated to ensure sustainable growth of the region
Low carbon solutions for agriculture and food processing industry	• Da Lat experiences average wind speed of 4.5-6m/sec • Use of power generated from small-scale wind power generation units will help reduce emissions • Trucks used for transportation of agricultural produce can be converted in to electric trucks, which can be charged through wind power generation units

7.7.4 Description, environmental benefit, financing and implementation mechanism of interventions

1. Eco-tourism through construction of Garden Houses

Garden houses are unique urban architecture which have harmonious design integration of architecture with nature and are examples of passive buildings designed considering local climatic conditions. In case of Da Lat, these garden houses can be utilized to promoted eco-tourism. There is success story of the concept in Viet Nam itself. Garden houses are a prime tourist attraction in the Vietnamese town of Hue and it houses nearly 2000 such buildings.

A garden house offers a kind of microcosm of nature within a house: house, garden, people, plants and water co-exist in a small urban space (CDKN, 2014). A typical garden house has a master architecture containing brick gate, front screen, Vietnamese miniature landscapes (imitating islands, mountains and surrounding environment), shallow pond, garden and lines of neatly cut tea leading to the house. Behind the brick front screen stand shallow pond with Vietnamese miniature landscapes, large garden and house. Trees, flowers and vegetables are also grown around the house (CDKN, 2012).

Source: Vietnam-travel.org

Figure 55: Examples of Garden Houses in Hue City, Viet Nam

Da Lat city can explore options to construct garden houses in the extended city limits which can provide the following benefits:

a. Garden houses can be effective means of promoting eco-tourism, creating alternate tourism centres for greater extent of Da Lat city leading to job generation and overall economic growth in the surrounding areas. Garden houses also provide for production of vegetables and fruits which can be sold for commercial purposes

b. Greenery will help sequester emissions in nearby locations and also lead to protection of environment

c. Socio-cultural development, the revitalization of local crafts, customs and cultural identities; increased opportunities for social contact and exchange.

Construction of garden houses would be contingent on the area and the specific structural and design elements included in the house. Cost of construction can be prepared by assessing actual elements to be present in a garden house and the space available.

Probable funding sources for undertaking garden houses can be the following:

Allocation from Government budget

- Intervention fulfils requirement of Domestic Green Growth strategy for Agriculture as well as Domestic Strategy on Climate Change.
- Basis of policy support can be utilized for allocation of funds from central budget for intervention

Funding from Multi-lateral funding agencies

- Emission reduction potential and improving livelihood of farmers can be utilized to seek funding from MFIs
- Financing proposal request can be forwarded to MFIs to solicit funding

Corporate Funding

- Benefit of reducing emission as well as sustainable farming can be marketed as environmentally responsible corporate investment by farming companies and utilized to enhance brand value
- Govt. can partner with corporations for implementation and maintenance of green corridors

Figure 56: Operation model options for garden house intervention

In order to proceed with investment estimation and further planning, identification of land parcels within the area earmarked for forest ecotourism. As per Master Plan for extended city limits of Da Lat, eco-tourism area covers about 6,500 hectares, including four main tourist areas i.e. tourist area of Dankia Lake - Da Lat, Tuyen Lam Lake tourist area, Prenn lake tourist area and Dai Ninh tourist area. These areas can be further explored to identify potential land parcels for development.

Construction and continued operations and maintenance of the garden houses can be undertaken by a public private partnership in case a blending of financing sources can be achieved and interest from privately operated farming and tourism ventures. Alternatively, in case of availability of fund solely from government-owned operating agency or privately-run corporate organization, the entire construction and operations can be undertaken by either of the two entities.

2. Policy intervention for greenhouses

As discussed, the unabated growth of greenhouse is having a detrimental environmental effect, despite enhanced economic contribution. Hence, continued growth of greenhouses should be encouraged with proper checks in place to reduce the harmful effects. The key instrument in bringing in control in growth is by developing regulations which provide guidelines for constructing and operating greenhouses.

The regulation on greenhouses should include the following key points to ensure sustainable growth of the agriculture sector as well as limited environmental impact:

a. A separate body within Department of Agriculture should be established to monitor greenhouse construction and operations.

b. Licensing system for constructing and operating greenhouses should be established to facilitate monitoring and verification.

c. Areas available for construction of greenhouses should be specified. Ideally areas earmarked for agriculture should only be allowed and residential, urban and forest landscape areas should not be permissible.

d. Design and construction of sewerage system in greenhouse production area should be specified to limit local flooding.

e. Adequate green coverage should be present around each greenhouse construction to ensure undue temperature rise is controlled. This would include implementation of planting shade trees and development of natural landscaping in immediate surroundings of greenhouses.

f. Specification of the maximum density of greenhouse construction in the earmarked area. Adequate space for development of green area, infield road and sewerage system along with should be considered while specifying the maximum density.

g. Standards on construction and operations of greenhouses should be developed depending on the specific requirement of agricultural practices. In view of the type of produce from greenhouses i.e. vegetables and flowers, two sets of standards for each type of produce can be developed to cater to specific needs.

h. Standards on operations should focus on limited use of pesticides and maximum use of biological products, without reducing productivity of greenhouse.

Apart from regulations, research needs to be undertaken to determine vegetables, flowers, decorative leaves can be grown outdoors with substantial productivity levels, methods of landscaping in interwoven with land for the greenhouse area and identification of dedicated land parcels which help reduce land pressure. Also, extent to which regulations applicable for new garden houses can be suitably implemented for existing ones without substantial impact on production should also be identified.

3. Innovative low carbon solutions

In order to further reduce the emission footprint of agriculture and allied sector i.e. food processing industry two additional initiatives can be implemented in case of Da Lat:

a. Wind Power Generation:

The average wind speed in Da Lat (at 50m above surface level) is between 4.5-6m/s – the variance caused due to topography (Global Wind Atlas, 2019). This value increases to an average of 5.5-7m/s at 100m above surface level – that is, an increase in height leads to higher wind speed. As discussed, the prevalent practice in Da Lat is setting up of greenhouses in hilly areas in the outskirts of the city, as given in the figures below:

Source: On-site image taken by Project Team

Figure 57: Example of greenhouses in outskirts of Da Lat

Source: On-site image taken by Project Team

Figure 58: Example of greenhouses in outskirts of Da Lat

This provides an opportunity of utilizing wind-power to supplement grid power, which is currently being utilized for green-houses in Da Lat.

Conventional large-scale wind power units which have rating of >1MW have horizontal-axis rotors (HAWT[18]), longer blade length (>50m) and higher mast height (>50m) are not feasible for Da Lat given the limited availability of land area in these regions and navigation issues in hilly areas. Another important factor is scale of investment since average capital investment is around USD 1000/kW) (Greenfish, 2019).

In such a scenario, use of small-scale wind turbines and smaller blade length can provide an option of utilizing wind power for the use of greenhouses. There are multiple options available of small-scale wind turbine with capacity varying between 0.4kW (blade length <1m, mast height <15m) to 30kW (blade length >5.5m, mast height >20m) as shown in the figure below (European Commission, 2009):

Source: Urban wind website

Figure 59: HAWT with rating 0.4kW

Source: Urban wind website

Figure 60: VAWT with rating 3kW

[18] Note: HAWT stands for Horizontal Axis Wind Turbine. Another type of wind turbine is VAWT i.e. Vertical Axis Wind Turbine

Source: Urban wind website

Figure 61: VAWT with 1.3kW - 30kW rating

Source: Urban wind website

Figure 62: VAWT with rating 1.3kW - 30kW rating

b. Electric trucks:

Use of such small-scale wind power sources can be utilized for greenhouse operations as well as for use of e-vehicles for transporting agricultural products. Currently, there is an example of e-truck developed specifically for medium capacity usage by Daimler under its sub-brand Freightliner i.e. eM2 106.

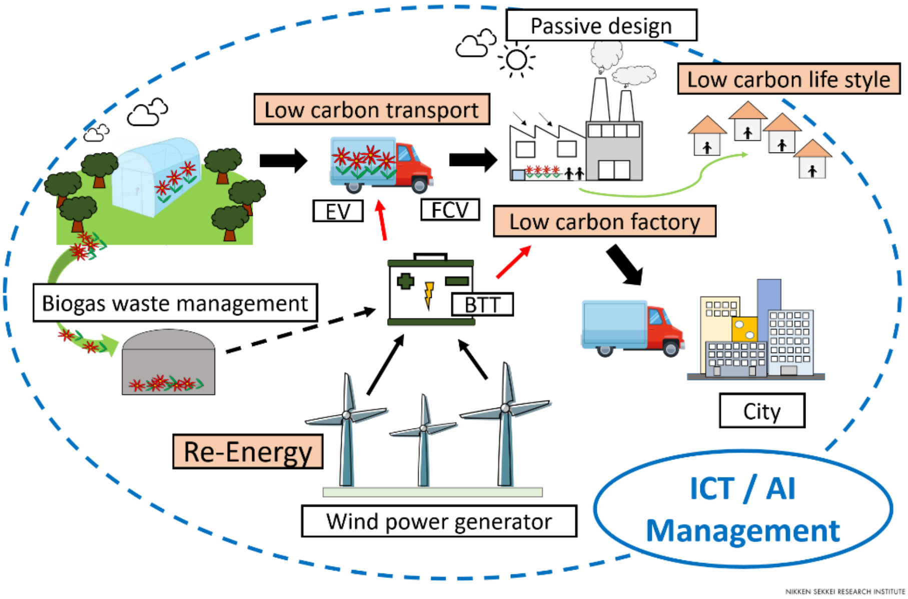
Source: Daimler Benz website

Figure 63: Examples of medium haulage electric truck

The Freightliner eM2 106 is ideally suited for local distribution of food and beverage goods, as well as for last-mile deliveries. The batteries of the first generation eM2 provide 325 kWh providing a range of 370km and the vehicle's batteries can be recharged to around 80% within just 60 minutes (Daimler, 2018). The vehicle is currently being tested in demonstration projects and is expected to be released in market 2020 onwards. Electric trucks have been developed by other truck manufacturers like eMoss, MAN, Volvo which are expected to commercially produced within similar time frames.

Such advancement provides an opportunity for the city to further reduce its carbon footprint in the near future. As the markets and technology mature, the city can take a view to implement such measures in the medium to long term.

A pathway for combination of such innovative measures for overall low-carbon development of Da Lat is given below:



Source: Project team generated image

Figure 64: Integrated low-carbon development of agriculture sector of Da Lat

It integrates the concept of renewable power generation and biogas waste management (comprising bio-degradable materials generated from agricultural activities) for power generation which can be utilized for low-carbon transport i.e. electric trucks as well as to provide electricity for low carbon plants. This entire system of low emission power generation and distribution can be optimized and managed by the application of integrated ICT systems.

8 Funding

As discussed in respective sections, there are multiple external funding sources. This section describes some of the potential institutions who can support the funding regarding the mentioned interventions in the current report.

Based on the assessment areas, a select list of projects being funded by 3 multi-lateral agencies viz. Asian Development Bank (ADB), World Bank and Japan International Cooperation Agency (JICA) is provided in Table 62.

Table 62: List of projects in Viet Nam funded by external funding sources

Assessment Areas	Funding Agencies	Project Name
Transport	ADB (ADB, 2019)	• Regional: Southeast Asia Transport Project Preparatory Facility Phase 2
	JICA (JICA, 2019)	• Project for enhancing management capacity of transport system focused on public transport in Binh Duong Province • Project for enhancing management capacity of transport system focused on public transport in Binh Duong Province • Ho Chi Minh City Urban Railway Construction Project: Ben Thanh - Suoi Tien Section
	World Bank (World Bank, 2019)	• Ha Noi Urban Transport Development Project GEF component
Town Structure	World Bank (World Bank, 2019)	• Mekong Delta Region Urban Upgrading Project
	JICA (JICA, 2019)	• Urban Planning Formulation and Management Capacity Development Project
Renewable Energy	ADB (ADB, 2019)	• Viet Nam: Gulf Solar Power Project
	World Bank (World Bank, 2019)	• Viet Nam Renewable Energy Development Project • System Efficiency Improvement, Equitization & Renewables Project
Agriculture	JICA (JICA, 2019)	• Sustainable Integration of Local Agriculture and Biomass Industries • Project of biomass liquid fertilizer from human waste for improving urban sanitation and supporting farmers in Da Nang City • Livelihood Diversification through Heritage Tourism in Remote Agricultural and Fishery Villages • Multi-beneficial measure for the mitigation of climate change in Viet Nam and Indochina area by development of biomass energy
Cross-sectoral	ADB (ADB, 2019)	• Regional: AC Energy Green Bond Project • Viet Nam: Ho Chi Minh City Climate Resilient Urban Services Project
	World Bank (World Bank, 2019)	• Viet Nam - Climate Change and Green Growth Development Policy Financing Project • Viet Nam Scaling up Urban Upgrading Project

Assessment Areas	Funding Agencies	Project Name
	JICA (JICA, 2019)	• Project for Green Growth Promotion in Halong Bay area, Quang Ninh province • Project to Support the Planning and Implementation of NAMAs (SPI-NAMA)

Beyond the three funding agencies, there are various other bilateral and multilateral funding agencies which are operating in Viet Nam and are undertaking multiple projects in the assessment areas enumerated for low-carbon development of Da Lat. Along with government funds and possible alliance with private partners, such multilateral and bilateral funding agencies can also be explored to finance low-carbon measures presented in this project.

9 Summary of Interventions

Table 63: Summary of low carbon interventions recommended for Da Lat

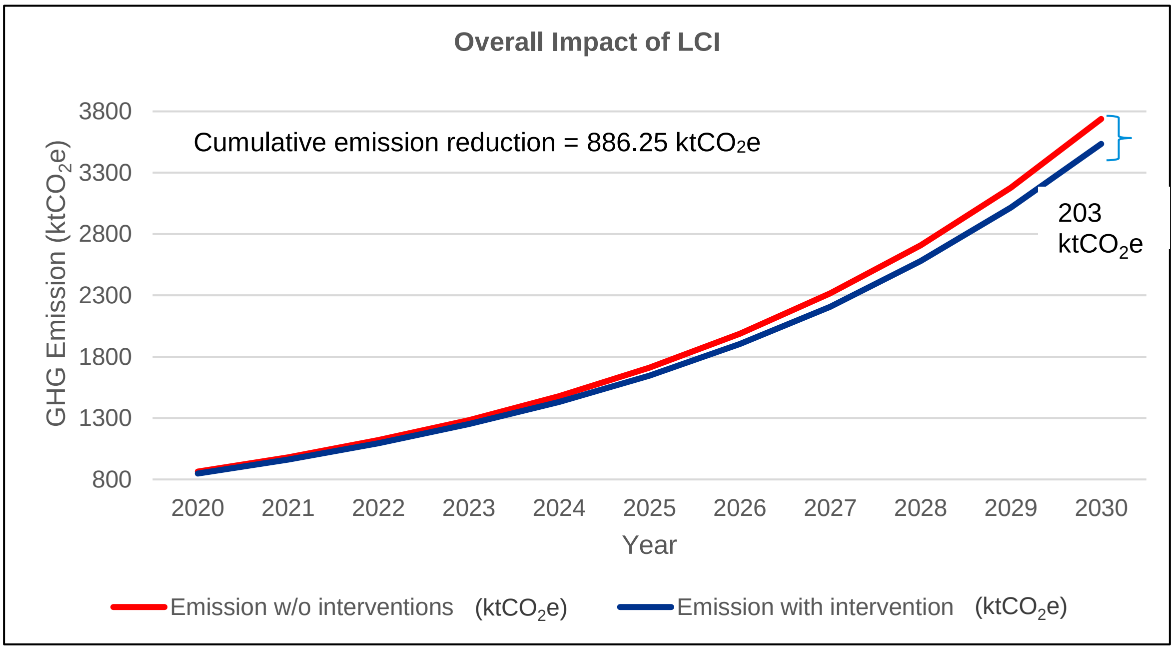
Intervention Name	Type of Intervention	Targets		Cumulative till 2030		Implementation Agency/ Department	Time period (Short/Medium Term)
		2020-25	2025-30	Financial Requirement (USD Million)	Reduction potential ($kTCO_2e$)		
Transport Sector							
Electrification of bus	Technical	50% replacement of 45S[19] within city limits	100% replacement of 45S within city limits	157	256	Department of Transport	Short to Medium Term
Electrification of 2W	Technical	5% replacement of existing fossil fuel based 2W	20% replacement of existing fossil fuel based 2W	596	630	Department of Transport	Short to Medium Term
Increased biofuel usage	Awareness generation	30% of taxis use biofuel	75% of taxis use biofuel	-	0.60	Department of Transport	Short to Medium Term
Buildings Sector							
Penetration of green/energy efficient building	Finance/ awareness generation	10% (Residential) 15% (Commercial)	30% (Residential) 40% (Commercial)	-	0.11	Department of Construction	Short to Medium Term
Town Structure							
Green Corridors[20]	Technical	35% of area along urban roads	100% of area along urban roads	89	0.15	Department of Environment	Short to Medium Term
Untapped Energy							
Waste to Energy plant	Technical	4MW power generation capacity		24	0.18	Department of Industry & Trade	Short Term
Renewable Energy							
	Technical/ Finance	8% of residential houses in extended city	20% of residential houses in extended city	737	0.03	Department of Industry & Trade	Short to Medium Term

[19] Note: 45S denotes 45-seater buses used to transport tourists to and from Da Lat
[20] Note: Only development of green infrastructure along existing roads considered. Similar intervention can be implemented for new town areas, quantification of which can be undertaken after Master Plan is prepared.

Intervention Name	Type of Intervention	Targets		Cumulative till 2030		Implementation Agency/ Department	Time period (Short/Medium Term)
		2020-25	2025-30	Financial Requirement (USD Million)	Reduction potential (kTCO_2e)		
Solar Rooftop[21]		5% of available commercial space in extended city	10% of available commercial space in extended city	553	0.01	Department of Industry & Trade	Short to Medium Term
Multi-Energy & Area Energy System							
District Energy System with Trigeneration[22]	Technical	NA	-	-	-	Department of Industry & Trade	Medium to Long Term
Agriculture Sector							
Garden Houses[23]	Technical	-	-	-	-	Department of Tourism/ Agriculture	Short to Medium Term
Regulation of greenhouses	Policy	NA	NA	-	-	Department of Agriculture	Short to Medium Term
Wind power for greenhouses[24]	Technical	-	-	-	-	Department of Industry & Trade	Medium to Long Term
Electric trucks for agricultural sector[21]	Technical	-	-	-	-	Department of Industry & Trade	Medium to Long Term

Source: Project team analysis

[21] Note: Calculations are based on estimation of residential and commercial building areas. Based on the area allocated provided in the under-preparation Master Plan of extended area, the exact potential of solar area can be estimated.
[22] Note: Extent of requirement of DES can be estimated after substantial temperature rise, which is expected to occur 2025 onwards. Depending on existing cooling demand, solution can be implemented.
[23] Note: Plans for extended city under finalization and exact location and extent of garden houses can be available only after determination of exact area present as well as features of garden houses.
[24] Note: Measures comprise technologies which are being implemented on pilot basis currently and are expected to reach full-scale commercial implementation in medium to long term.



Source: Project team analysis

Figure 65: Emission reduction at city level by implementation of intervention

Considering the estimations for the existing set of interventions, the cumulative emission savings between 2020 and 2030 is 886 ktCO_2e. The estimations are based on targets defined on the basis of stakeholder interaction, prevalent conditions.

Considering the planned expansion of the city, Da Lat exhibits higher potential of emission reduction. Development of the master plan of this extended area will help undertake a more accurate estimation of emission reduction.

Moreover, if the targets are met, it signals the acceptance of measures in the market and hence, penetration levels are expected to increase in future.

10 Appendix

A Stakeholders consulted in Da Lat during site study

Table 64: List of stakeholders consulted in Da Lat during site study

No.	Organization/Department	Name	Designation
1.	Department of Transport	Mr. Vu Quang Vu	Head (Division of Management of Transport, Vehicles and Drivers)
		Mr. Nguyen Pham Truong Giang	Division staff
2.	Department of Agriculture and Rural Development	Mr. Nguyen Van Danh	Head (Division of Crop Production, Crop Production Service)
3.	Department of Construction	Mr. Le Quang Trung	Director
4.	Department of Industry & Trade	Ms. Cao Thi Thanh	Deputy Director
5.	Da Lat People's Committee	Mr. Nguyen Van Son	Vice Chairman
6.	TTC Hotel	Ms. Nguyen Thuc Bich Tien	General Manager
7.	Da Lat City Tour	Mr. Ha Duy Trung Nguyen	Director

B Policies and targets related to Low Carbon Strategy

1. Domestic Strategy on Climate Change

Table 65: Sector-specific interventions under Domestic Strategy on Climate Change

Power Generation	Energy Efficiency	Industries	Transportation	Agriculture	Waste Management
1. Development of hydro projects to reach total output capacity of 20-22 GW by 2020 2. R&D of technologies utilizing recycled and untapped energy sources 3. Engagement with socio-economic sectors in promotion of recycled energies; 4. Development of different energy sources to ensure domestic energy security 5. Increase share of new and recycled energies in total primary commercial energy to 5% and 11% by 2020 and 2050 respectively.	1. Development of energy-efficient industries & narrowing energy-intensive industries through economic restructuring 2. Promote effective use of energies in economic fields by designing and implementing supporting policies 3. Identify inefficient technologies & develop phase-out plan by 2015 4. Promote R&D in energy efficient technologies, 5. Supplement efforts to assess effective use energy use by development of a sound energy valuing system 6. Monitor and supervise application of standards on energy saving products and systems in energy-intensive industries	1. R&D and application of low GHG emission technology in industries 2. Increase share of hi-tech industries to 42-45% and 80% of total industrial production by 2020 and 2050 respectively; 3. Ensure renewal of 20% of industry machinery and equipment by 2020. 4. Development and application of technical standards and norms of effective energy use in industrial production and construction projects	1. Promotion of public transport and controlling growth of personal transport in urban areas 2. Development of economy-wide transport network and externally-orientated transport corridor by 2050; 3. Introduction of fuels with low GHG emission in transport sector 4. Increase use of CNG & LPG in 20% and 80% of public vehicles by 2020 and 2050 respectively 5. Encourage use of energy-saving vehicles and phase out energy-intensive ones by development and application of supporting mechanisms and policies	1. Development of alternative agricultural cultivation methods to optimize use of water, fertilizers and cattle-feed 2. Manage and treat wastes from husbandry activities 3. Development and application of biogas as fuels 4. Development and application of phase-out of energy-intensive agricultural machinery. 5. Ensure sustainable development, domestic food security by promoting green agricultural production 6. Maintain 20% reduction in GHG emission and poverty every 10 years	1. Develop planning schemes for waste management in order to minimize recycle and reuse wastes for lower emission of greenhouse gases; 2. R&D and application of advanced waste treating technology 3. Apply modern waste treating technologies in urban and rural areas; 4. Strengthen the management, treatment and reuse of industrial and domestic sewage 5. Ensure collection and treatment of 90% of total urban domestic solid wastes and recycle and reuse of 85% of this volume by 2020

Source: Viet Nam Government Official Portal

2. Domestic Green Growth Strategy

Table 66: Sector Specific tasks to achieve the targets in Domestic Green Growth Strategy

Energy Efficiency	Industry	Transportation	Renewable Energy	Agriculture	Waste Management	Urban Planning
1. Development of fuel consumption norms, roadmap to phase-out energy intensive technologies in energy supply and demand systems 2. Development of law for application of technologies to capture, restore and trade emissions 3. Development domestic standard on energy saving equipment labelling and quality of equipment.	1. Promotion of clean and renewable energy sources and reduction of coal consumption 2. Promote energy efficiency through issuing domestic standards for equipment and developing market instruments.	1. Encourage shift to CNG & LPG for passenger transport. 2. Implement a quality management system which is based on fuel, gas emission standards 3. Development of energy efficient transportation systems 4. Development of public transportation infrastructure with modern technologies 5. Restricting personal vehicles in urban areas through economic instruments, route allocation for non-motorized vehicles and developing technical standards	1. Promotion of renewables, especially in rural households 2. Promotion of technologies utilizing renewable energy	1. Promotion and application of sustainable, resource efficient, organic agricultural practices 2. Application of technologies to treat and reuse agricultural by-products and waste to produce animal feed, mushrooms, materials for industries, biogas and organic fertilizer.	1. Establishment of law on waste recycling and treatment to and minimizes landfilling waste. 2. Develop a modern and environmentally friendly recycling industry, research the mainstreaming of this into the environment industry master plan. 3. Apply waste sorting and recycling technologies in new urban and industrial areas to turn waste into energy, construction materials and microbio-fertilizers.	1. Prioritize the allocation of public to expand area of green space and water 2. Develop green cities through compulsory application of green building measures and issuing systems of standards on urban planning, architecture, design 3. Introduce application of rating system for energy efficiency and green urban infrastructure

Source: GIZ website – Domestic Green Growth Strategy

3. Law on Economical and Efficient Use of Energy

Table 67: Sector wise energy efficiency measures Law on Economical and Efficient Use of Energy

Industry	Construction and public lighting	Transport	Agriculture	Buildings
a. For Industrial producers: i. Develop and implement annual plans on economical and efficient use of energy ii. Apply appropriate technological measures to conform to standards/regulation/ norms of energy use iii. Upgrade or replace outdated energy intensive equipment with energy efficient ones. iv. Improve processes to ensure energy efficiency & energy conservation v. Focus on applying cogeneration technologies. b. For Energy producers and suppliers: i. Selecting technologies with high energy yield, utilize waste heat and steam ii. Hydro power plants should adopt processes and technologies to ensure optimal use of water resources iii. Electricity transmission and distribution units shall develop and implement programs for reducing power loss	a. For Construction sector i. Using energy efficient building materials ii. Using energy management and control systems and installation of devices and equipment with high energy yield. iii. Applying standards, technical regulations and norms on economical and efficient use of energy to construction works b. For Public Lighting i. Conform to efficient public lighting design standards and equipment recognized ii. Operating public lighting systems appropriately by day time, season, region and area to ensure efficient use of energy	i. Development of mass transit networks, ii. Manufacture and use energy-saving vehicles iii. Exploit and expand the application of liquefied gas, natural gas, electricity, mixed fuels and biofuels in transport v. Optimizing transport routes .	i. Implementation of energy efficient equipment, machinery and processes involved from production to transportation of farm produce ii. Planning irrigation systems, optimizing reservoirs and canals and making use of natural flows as well as optimizing capacity of pumps. iii. Encourage production of biofuels from agricultural by-products and other renewable sources	i. Commercial building owners are responsible for economical and efficient use of energy ii. Households are encouraged to adopt measures to improve building envelope, lighting system and other household equipment which reduce energy intensity

Source: Grantham Institute website – Law on Economical and Efficient use of energy

4. Viet Nam Domestic Energy Efficiency Plan – 3rd Phase (2019-2030)

Table 68: Targets for each sector for 3rd phase of Viet Nam Domestic Energy Efficiency Plan (2019-2030)

Particulars	Targets	
	2019-2025	2025-2030
Reduction in domestic energy consumption	5%-7%	8% - 10%
Power loss	<6.5%	6%
Reduction in average energy consumption for various industries in comparison to energy levels in 2015-2018		
Steel industry (Depending on type of products)	3%-10%	5 – 16.5%
Chemical industry	>7%	>10%
Plastic industry	18%-22.46%	21.55 – 24.81%
Cement industry	>7.5%	>10.89%
Beverage industry (Depending on type of products)	3% - 6.88%	4.6% -8.44%
Textile and garment	>5%	>6.8%
Paper industry (Depending on type of products)	8%-15.8%	9.9% - 18.48%
Transportation Industry		
% of key transport enterprises receiving training on technical skills for energy savings	100%	-
Decrease in fuel and oil consumption in transportation against forecast of fuel consumption in 2030	-	5%
Construction Industry		
No. of works are certified to be green works with economical and efficient use of energy	80	150
% of all kinds of building implementing energy labeling programme for buildings	-	50%
% of key energy users implementing energy management systems	100%	-

Source: Viet Nam Domestic Government Portal

5. Da Lat city Green Growth Action Plan (GGAP)

Table 69: Interventions to reduce CO_2 emission according to GGAP

No.	Name of task/ project	Objectives	Content/ Expected results	Execution time	Total (thousand VND)	Emission reduction amount (tCO2)	Marginal costs (thousand VND/ tCO_2)	Implementing agencies	Note
1.	Support to replace lights with high performance lights in commercial hotels and service buildings	90% of facilities are replaced with high-performance lights	- Organize training and communication to improve the capacity of the community on energy efficiency benefits; - Develop support mechanisms and encourage households to replace conventional lamps to lamps with higher efficiency; - 90% of establishments implement the conversion	2016 - 20	4,908,450.00	7,785.78	630.44	- Industry and Commerce Department - Tourism Department - Urban lighting company - Buildings, offices and households	- In accordance with Law on economical and efficient use of energy - Coordinating with EVN's communication program on electricity saving - Tourism development planning
2.	Support to install high performance refrigerators	95% of refrigerators are installed and replaced	- Organize training and communication to improve the capacity of the community on energy efficiency benefits - Develop a mechanism to support and encourage households and businesses to replace common refrigerators with high-performance ones - More than 95% of existing refrigerators are converted	2016 - 20	2,208,802.50	2,335.74	945.66	- Industry and Commerce Department - Tourism Department - Urban lighting company - Buildings, offices and households	- In accordance with Law on economical and efficient use of energy - Tourism development planning - Green lotus, Eco-label program
3.	Support to install high performance Air conditioning systems	75% of existing air conditioners are converted to high performance air conditioners	Mechanism to support and encourage businesses and households to convert existing air conditioners to high-performance air conditioners 75% of existing air conditioners are converted	2016 - 20	49,477,176.00	29,196.69	1,694.62	- Industry and Commerce Department - Tourism Department - Urban lighting company - Buildings, offices and households	'- In accordance with Law on economical and efficient use of energy
4.	High performance public lighting	- Ensure traffic safety and urban beauty - Reduce electricity demand - 90% of the number of public lights are replaced	- High-tech application and high-performance lighting equipment for public lighting systems Building green tourism area, using environmentally friendly renewable energy 90% of the number of public lights are replaced	2016 - 20	1,597,500.00	1,409.31	1,133.53	- Industry and Commerce Department - Tourism Department - Transportation Department - Science and Technology Department - Urban lighting company	International support
5.	Provide high performance transformers for power grid system[25]	- Reduce power loss on power distribution and transmission systems - - Improve the quality, safety and stability of power supply - 95% of the transformers are converted	- Research and evaluate the effectiveness of the application of high-performance transformers in the grid - Performing step by step replacement of transformers that have expired - Make use of high-performance transformers in new projects, repair, increase capacity, raise voltage - 95% of the transformers are converted	2016 - 20	36,000,000.00	62,531.47	575.71	- Industry and Commerce Department - EVN - Science and Technology Department - Businesses	- Power development planning - International support
6.	Support to install solar water heater	- Reduce the need for additional load on the system at peak hours - Replace a part of the grid in heating water - Reduce greenhouse gas emissions	- Survey of total solar energy potential for hot water - Develop mechanisms and resources to encourage and promote households to use solar water heaters - 65% of families equip the system and reduce 8% of peak-time electricity demand for hot water in the household area	2016 - 20	18,445,856.00	11,237.98	1,641.39	- Industry and Commerce Department - Buildings and households	- Target program for energy saving and effective use - Under the EVN program
7.	Tourist information agencies and solar street lighting	- Ensure traffic safety and urban beauty - Reduce power demand	- Develop information points to guide and promote automatic tourism operated by solar energy - Build a solar lighting system to contribute to	2016 - 20	6,600,000.00	4,410.99	1,496.26	- Industry and Commerce Department - Tourism Department	Tourism Planning; Construction planning;

[25] Note: Only measure which will funded by State-owned power company, Electricity Viet Nam (EVN) and remaining measures will be funded from local budget

No.	Name of task/ project	Objectives	Content/ Expected results	Execution time	Total (thousand VND)	Emission reduction amount (tCO2)	Marginal costs (thousand VND/ tCO_2)	Implementing agencies	Note
		- Application of solar energy in public lighting - Develop environmentally friendly tourism - Build 10000 agencies to guide information	reducing electricity demand - Construct control lights and solar traffic guidance to reduce power consumption - Develop green tourism areas using environmentally friendly renewable energy - Build 10000 agencies to guide information					- Buildings, offices and households	Power development planning; Renewable energy planning
8.	Provide solar hot water systems in the areas of hotels and high buildings	- Reduce the need for additional load on the system at peak hours - Replace a part of the grid in heating water - Reduce greenhouse gas emissions	- Organize propaganda to raise awareness about solar energy application, develop image of businesses and environmentally friendly tourism - Survey of total solar energy potential for hot water - Develop mechanisms and resources to encourage and promote enterprises to use solar water heaters - About 65% of enterprises make investment	2016 - 20	25,523,940.00	15,031.90	1,697.99	- Industry and Commerce Department - Tourism Department - Buildings, offices and households	- Economical and efficient use of energy program - EVN program - Green lotus, Eco-label program
9.	Use biofuels in freight transport	- Use biofuel in transport widely, completely replace 5% of traditional energy - Reduce greenhouse gas emissions	Support the implementation of the supply and conversion of biofuel supply and application systems to completely replace 5% of traditional fuels, contribute to reducing greenhouse gas emissions	2016 - 20	80,000,000.00	373.26	214,325.92	- Transportation Department - Department of Science and Technology - Industry and Trade Department - Petrol and oil enterprises, transport enterprises - International organizations	Socio-economic development planning; International support
10.	Use biofuels in public passenger transport	- Use biofuel in transport widely, completely replace 5% of traditional energy - Reduce greenhouse gas emissions	Support the implementation of the supply and conversion of biofuel supply and application systems to completely replace 5% of traditional fuels, contribute to reducing greenhouse gas emissions	2016 - 20	50,000,000.00	32.82	1,523,390.24	- Transportation Department - Department of Science and Technology - Industry and Trade Department - Petrol and oil enterprises, transport enterprises - International organizations	Socio-economic development planning; International support
11.	Use biogas in livestock	- Using biogas in the livestock industry to generate electricity at livestock farms - Limit livestock emissions and reduce electricity demand	- Study the potential of reducing emissions in livestock centralized page size - Continue to maintain support mechanisms and encourage farm owners to invest in biogas systems in livestock farms to generate electricity for farms, reduce livestock emissions, reduce environmental pollution and replace part of electricity	2017 - 20	700,000.00	409.98	(18.76)	- Agriculture Department - Department of Natural Resources and Environment - Department of Science and Technology - Agriculture Extension Department - Farmer Association	- Scheme on reduction of rural agricultural greenhouse gas emissions - Livestock development planning - Biogas program
12.	Save and control water in rice cultivation	- Ensure food security - Implement industrialization and modernization in agriculture - Promote green agricultural production towards safe and environmentally friendly	Maintain, invest in equipment to improve the efficiency of irrigation pumping station system	2018 - 20	98,021.00	146.30	0.67	- Agriculture Department - Irrigation department - Extension Department - Farmer Association	Scheme on reduction of rural agricultural greenhouse gas emissions

<table>
<tr><th>No.</th><th>Name of task/ project</th><th>Objectives</th><th>Content/ Expected results</th><th>Execution time</th><th>Total (thousand VND)</th><th>Emission reduction amount (tCO2)</th><th>Marginal costs (thousand VND/ tCO_2)</th><th>Implementing agencies</th><th>Note</th></tr>
<tr><td>13.</td><td>Use biogas in living activities</td><td>- Using biogas in the livestock industry to replace people's traditional fuels
- Limit livestock emissions and reduce the need for fuel in cooking and daily life</td><td>Maintain a support mechanism and encouraging people to invest in biogas systems in livestock to serve people's cooking</td><td>2019 - 20</td><td>300,000.00</td><td>516.40</td><td>5.89</td><td>- Agriculture Department
- Department of Natural Resources and Environment
- Department of Science and Technology
- Farmer Association</td><td>- Scheme on reduction of rural agricultural greenhouse gas emissions
- Livestock development planning
- Biogas program</td></tr>
<tr><td>14.</td><td rowspan="2">Convert unused land to protective forest land</td><td rowspan="2">- Enhance carbon absorption and reduce greenhouse gas emissions in forestry
- Maintain 62% forest cover
- Stabilize people's livelihood</td><td rowspan="2">- Plant carbon absorption forests in combination with protection in the watershed area
- Encourage and motivate people to plant and protect forests, increase the allocation of unused land to people for afforestation, while improve the forest area and protect biodiversity and prevent erosion and degradation, prevent soil and flood
- Improve forest areas and create livelihoods for people, raise income and stabilize people's life, limit deforestation for shifting cultivation and food crops
- Maintain 62% forest cover</td><td>2020</td><td>456,776.72</td><td>23,686.67</td><td>19.28</td><td>- Agriculture Department
- Department of Natural Resources and Environment
- Forest Protection Department
- Farmer Association</td><td>- Land use planning
- Scheme on reduction of rural agricultural greenhouse gas emissions
- Climate change response</td></tr>
<tr><td>15.</td><td>2020 - 21</td><td>908,116.20</td><td>26,491.6</td><td>34.28</td><td>- Agriculture Department
- Department of Natural Resources and Environment
- Forest Protection Department
- Farmer Association</td><td>- Land use planning
- Scheme on reduction of rural agricultural greenhouse gas emissions
- New countryside program
- Climate change response</td></tr>
</table>

Source: Da Lat city officials

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C Building Analysis Report

1. Objective

The aim of this study is to derive a list of implementable solution sets for the building design that can be easily incorporated in the building design to make it energy efficient. Different building typologies have been studied for the set of defined parameters to achieve energy efficiency in the buildings in Viet Nam.

2. Methodology: Achieving Energy Efficiency in Building Design

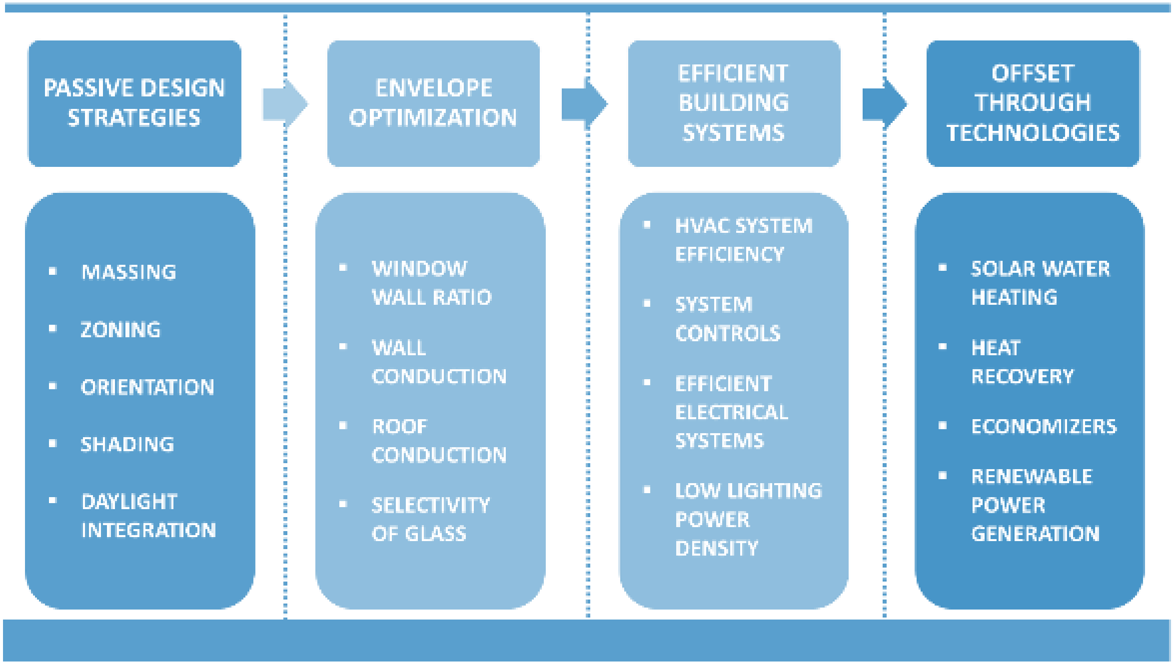

Figure 66: Flow process to achieve Energy Efficiency in buildings

When it comes to building design the key to energy efficiency in the building is by primarily reducing the operational load of the building. The first step to this approach is by reducing the heat load/ gain of the building by incorporating design strategies and thoughtful use of building materials and technologies keeping the energy saving and associated cost increment in mind. The conscience and intent to build better buildings for the future is a team effort and cannot be brought about by just one level of efficiency in a building. A quick run through of the methodology followed to derive at the solution set is as follows:

a. Passive Design Strategies

The first step in any building design is understanding the site, location climate type and associated requirements of building. Massing, site and space zoning, building orientation, shading play pivotal role in how efficient a building is. Daylight integration in the building further reduces the dependency on artificial lighting, promotes wellbeing, mental health and efficiency of building occupant. In simple words, a well-designed building reduces the magnitude of effort that is required to make a building energy efficient. The different parameters under this has been studied further and the impact assessment has been backed by a simulation study.

b. Envelope Optimization

Building envelope is the skin of the building that determines how the building behaves in a climate type and location. The materials used for the building construction further degerming how energy efficient a building can be. The heat ingress in a building can be significantly reduced by optimizing the building envelope, that reduces the cooling requirement of the building significantly. The same can be observed later in the preliminary analysis. A well optimized building envelope will reduce the system sizing of HVAC, lighting design and electrical backup which is often an overlooked benefit.

c. Efficient Building Systems

This is a direct saving that can be incorporated in the building design. The more efficient systems installed in the building, more the energy saving achieved. This comprises of HVAC, air conditioners, lighting system, hot water system and equipment.

d. Offset Through Renewables

After achieving an energy efficient building design, a part of the energy consumption can be offset through renewables energy generation bot on and off site.

3. Simulation Tools Description

For the analysis, Design builder energy analysis software has been used. Design builder uses the DOE 2.2 Building energy simulation engine and TARP algorithm for surface convection. Design Builder comprises of a core 3-D modeller and 9 modules of which work together to provide in-depth analysis of energy use, consumption and commitment for any building. It has the ability to explicitly model all of the following:

- 8,760 hours per year
- Considers local direct solar obstructions, enables the simulation for modulating airflow openings, accounts for the characteristics of heat emitters.
- Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat set points, and HVAC system operation, defined separately for each day of the week and holidays
- Thermal mass effects
- Part-load performance curves for mechanical equipment
- Capacity and efficiency correction curves for mechanical heating and cooling equipment.
- This simulation software utilises annual hourly climate data from ISHRAE’s Energy plus Weather data (EPW format) downloaded from the Energy Plus website.

4. PRELIMINARY ANALYSIS

To achieve energy efficiency in buildings in Philippines, the preliminary study analyzes the thermal performance of the building envelope. Sensitivity of different components like wall construction and window material, envelope design, WWR, building orientation, etc. was carried out to provide probable efficient building envelope options with minimal cost.

a. Assumptions

For the preliminary analysis, Box model for Office type building (9-6 occupancy) has been considered. Rectangular box model of dimension 75m x 30m has been constructed for preliminary analysis with longer axis facing N-S. Weather file of **Ha Noi, Viet Nam** has been used as it was the closest to **Da Lat**

- Ext wall U-value: 1.88 W/m²-K
- Roof U-value: 1.57 W/m²-K
- Glazing specification

  U- value- 5.7 W/m²-K
  VLT- 0.51
  SHGC- 0.56
  WWR: 60%

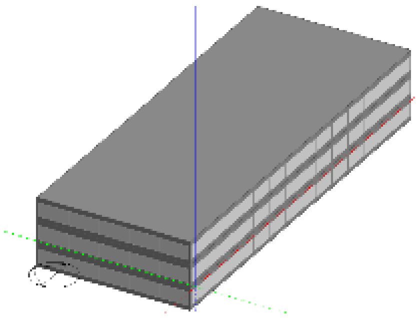

Figure 67: Snapshot of Box model

b. ORIENTATION

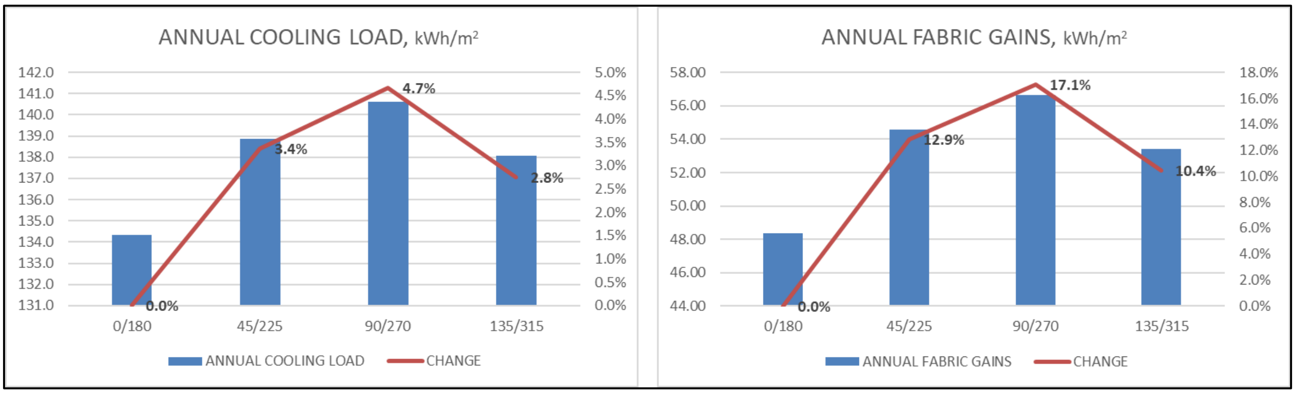

Figure 68: Annual Cooling and Fabric Gains corresponding to different Orientation

Orientation plays a major role in achieving energy efficiency in buildings. As the base case is Business as usual (BAU), Low single glazed unit has been used in this analysis, hence the impact of rotating the building axis is not very significant. Changing the longer axis of the building from N-S to E-W does show an increase in Fabric gains by ~9% annually. In addition, if daylight has to be harnessed, N-S facades have better access than E-W, which might bring in glare despite any practical dimension local shading.

c. WINDOW WALL RATIO

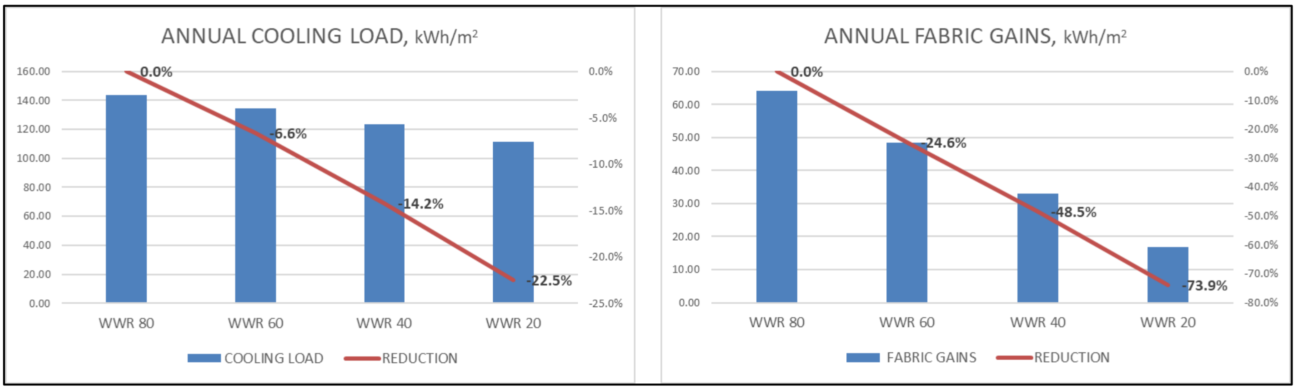

Figure 69: Annual Cooling and Fabric Gains corresponding to different WWR

Window area or window-to-wall ratio (WWR) is an important variable affecting energy performance in a building. Window area will have impacts on the building's heating, cooling, and lighting, as well as relating it to the natural environment in terms of access to daylight, ventilation and views. The window-to-wall ratio is the measure of the percentage area determined by dividing the building's total glazed area by its exterior envelope wall area.

Facades can have optimized WWR in design to reduce the unwanted solar gain through the large window area, while still allowing natural daylight to enter spaces which results in reduced artificial lighting use along with reduced cooling load. In our study, significant impact of WWR reduction can be observed which was mainly due to the reduced solar gains through windows.

d. ENVELOPE SENSITIVITY: OPAQUE

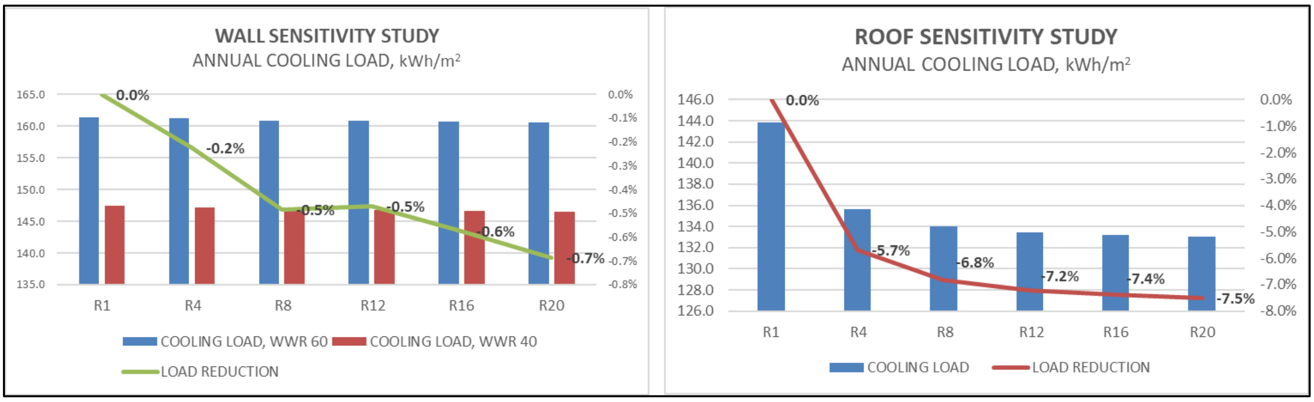

Figure 70: Wall and Roof Sensitivity Study

- Wall and Roof sensitivity study with variable R-value was carried out.
- An insulating material's resistance to conductive heat flow is measured or rated in terms of its thermal resistance or R-value -- the higher the R-value, the greater the insulating effectiveness.
- As the outside temperature is ambient more than 50% of the total annual hours of simulation, very less impact of increasing insulation can be observed.
- Hence, considering revised WWR works better than adding extra insulation to BAU case.
- U value closer to 1 W/m² K seems to take care of wall efficiency.

Table 70: U Value for corresponding R values

R VALUE	U VALUE, W/m² K
R1	1
R4	0.25
R8	0.125
R12	0.083
R16	0.0625
R20	0.05

e. ENVELOPE SENSITIVITY: GLAZED

i. GLASS SELECTION

1. LIGHT TRANSMISSION: Percentage of visible light directly transmitted through the glass
2. REFLECTION OUTSIDE: Percentage of visible light directly reflected from the exterior glass surface
3. SOLAR FACTOR: Percentage of solar energy transmitted through the glass. It therefore measures the ability of a glazing to reduce the heating of the room. The lower the solar factor is, the better it helps to improve the comfort inside of the building
4. U-VALUE: The U-value is a measure of the heat loss by penetrating the glass. The lower the U-value is, the better the insulating properties are. Expressed in W/m^2K
5. SELECTIVITY: The selectivity of glass is expressed as the ratio between its light transmission and solar factor. When the selectivity of glass is higher than 2, it gives you twice as much light versus heat.

f. GLAZING OPTIMIZATION

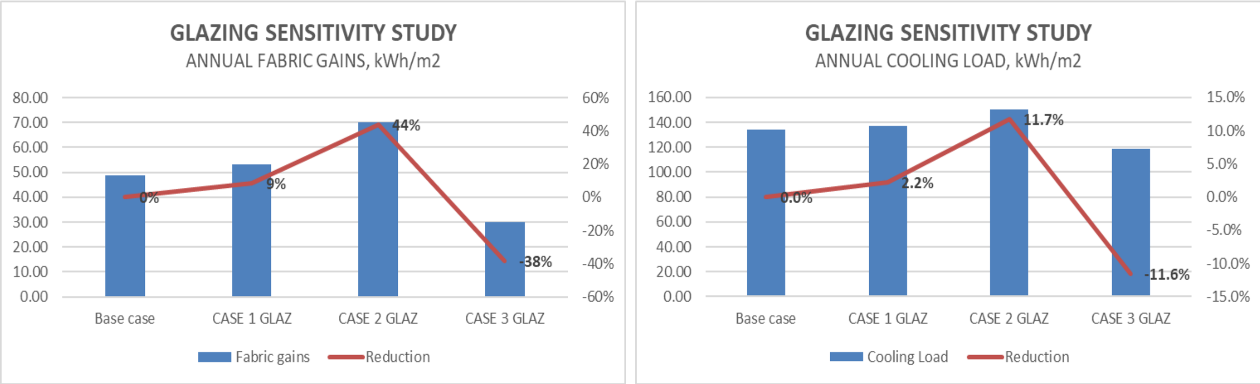

Figure 71: Annual Cooling Load And Annual Fabric Gains of Glazing Sensitivity

The study shows how selectivity of glass has larger impact than U value of glass for its selection in building design Glass selectivity index takes into account the light transmittance and solar factor for better envelope optimization. If sufficient shading is provided for glass, U value plays a more important role in glass selection.

Table 71: Selection of glass based on SHGC, VLT, U Value

	SHGC	VLT	U value, W/m^2 K	Selectivity VLT/SHGC	Description
Case 1	0.59	0.75	6.12	1.27	Low e single glazed
Case 2	0.65	0.8	1.44	1.23	Low e DGU (16mm argon)
Case 3	0.275	0.6	1.35	2.18	Low e DGU(12mm air)
Case 4	0.486	0.4	2.7	0.82	Low e DGU(12mm air)
BASE CASE	0.56	0.51	5.7	0.91	Low e single glazed

g. SHADING OF GLAZED FAÇADE

Shading the glazed façade can significantly reduce the direct solar gains of the building by cutting out the direct solar radiations entering the building. A well shaded glazing is any day better than having a high SHGC glazing installed in the building both in terms of energy and cost saving.

h. SHADING REQUIREMENT

Da Lat city has a north latitude of 7.4º. As seen in the sun path chart below, the city receives a good amount of south sun in most of the months of the year. Summer months have sun coming in from the North direction which requires shading. Shading will be different for different facades of the building. Here, a simple study considering the building to be oriented true north and 45º to true north has been done. While North and south facades of the building can easily be shaded for most time of the year with shading, the east, west and angular orientation (closer to 45º to true north) is difficult to shade even despite increasing the shading.

For orientation closer to true north:
18º vertical or 20º horizontal shading for north facing façade
50º horizontal shading for south facing façade
60º horizontal shading for west facing façade
50º horizontal shading for east facing façade

For orientation closer to 45º north:
30º horizontal shading for North-east/west facing façade
Min 50º horizontal shading for south-east/west facing façade

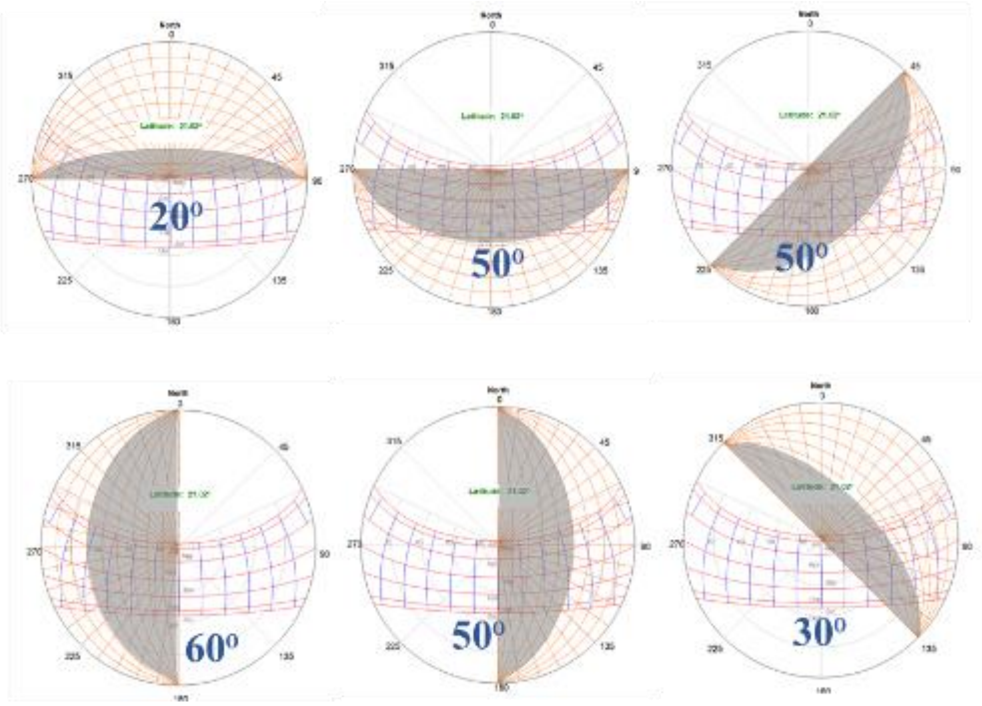

Figure 72: Building Orientation Types

i. SHADING IMPACT

Table 72: Shading impact options and corresponding sensitivity

CASE	SHADING DESCRIPTION
BASE CASE	No shading
SHADING OPTION 1	1000mm horizontal shading
SHADING OPTION 2	2000mm horizontal shading on N/S fenestration Horizontal fins on E/W fenestration

Shading of fenestrations shows a considerable impact on envelope gains and cooling load of the building. The impact is clearly outstanding and emphasis the need for integration of shading in building design as a must for energy efficient & cost-effective intervention.

5. INCREMENTAL LEVELS FOR ENERGY EFFICIENCY

After analysing how the different building components perform in the given climatic conditions there was a definite clarity on the minimum interventions that would help achieve the incremental levels of performance in the building by the optimum incorporation of interventions in the building design.

6. ENERGY EFFICIENCY INTERVENTIONS

To derive a practical and implementable solution set, it is imperative to list down the major interventions that impact energy efficiency in a building and is easily implementable in the building design of all kinds. The list of interventions is studied further in detail below and its possibility of being implemented.

a. ORIENTATION

preferred for the location is having the longer axis along the N-S. However, as there is site constraints, we may leave that from our final list of interventions to achieve Energy Efficiency. Preparing the solution sets this was taken into account that the solutions should have vast applicability and hence, location orientation and specific shading analysis was omitted here.

b. WINDOW WALL RATIO

WWR has shown to be the most cost-effective solution in reducing the heat gain in the building. Hence, we tried incorporating that in the building design to achieve energy efficiency. For commercial establishments, the maximum threshold for WWR is 60% whereas for more efficient buildings it has been reduced to 40%. In case of residential buildings, the ratio is further reduced to 25% going down to 15% for more efficiency.

c. ENVELOPE (Opaque)

It comprising of the exterior wall and roof have a major impact on the heat transfer in a building. Essentially R-value is a measure of thermal resistance, or the ability to prevent the transfer of heat. The larger the number, the harder that insulation is working at preventing heat conduction. The less heat loss, the lower your energy consumption. As per the sensitivity analysis for walls and roof R-values, we could analyze that after a certain point there was no significant improvement in the cases despite increasing the R-value of walls and roof. This could possibly be because of the hot and humid climate that the location has. Hence, it is recommended that R-8 to R-12 is ideal for the location for both walls and roof.

d. SHADING

Shading was another intervention that proved effective for both – reducing heat gains in the building as well as improving the quality of daylight available in the building. It even is a sensible alternate solution to providing High performing glass in the building. For optimum shading in the building it is recommended to have customized shading as per the orientation, glazing size, glazing material. However, for the solution set we have simplified the shading requirement to the ratio between **depth of shading, D/ height of glazing, H.** We have considered only horizontal shading in the solution set as it is more effective in terms of shading the building for the specified location.

e. ENVELOPE (GLAZED)

This is the major culprit when it comes to the heat gain in the building. Though glazing is essential for daylighting and view, it is recommended that the design, orientation and material selection and shading should be optimized to reap benefits rather than suffer owing to poor design and material choice. Apart from window wall ratio and shading that has been considered essential for optimized glazing, the glass selection is considered the most important aspect for achieving energy efficiency in the building envelope. There are three criteria that decide the glazing performance primarily:

f. GLASS SELECTIVITY

i. SHGC

The **SHGC** is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward. **SHGC** is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits.

ii. VLT (Visible light transmittance)

VLT is the amount of **light** in the **visible** portion of the spectrum that passes through a glazing material. A higher VT means there is more daylight in a space which, if designed properly, can offset electric lighting and its associated cooling loads.

iii. U- value

It is a measure of air to air heat transmission (loss or gain) due to the thermal conductance of the material and difference of indoor and outdoor temperature?

As SHGC and VLT play a more pivotal role in determining the selectivity of glass compared to U-value the same has been considered for the solution sets. However, it is recommended to use glass of lower U-value as well. The previous analysis shows that how glass with better SHGC performed better in terms of heat transfer than U-value. VLT of glass will ensure that optimum daylight is available inside the building.

The optimization of the building envelope ensures that the cooling and lighting demand of the building is reduced along with the operational cost of the building. Hence, once that is achieved, we have made through the first phase of Energy efficiency in the building. The second phase involve determining the reduced demand in the building and selection of efficient electromagnetic and lighting systems.

g. Cooling equipment efficiency

This is a direct benefit. The more efficient the system the lesser the operational cost of the building. System sizing is something that needs to be carefully calculated for the building specially post the list of detailed interventions in envelope design that ensures reduction in cooling demand. An oversized system design will prove to be inefficient despite the impressive specification it may boast of. Minimum EER 12 has been considered for the cooling equipment. EER 8 is the minimum efficiency requirement of green building code in the economy.

h. Air Conditioners

Air conditioners (rating system as per DOE 10CR Part430) star rating system specification is considered for the solution sets. Even though the rating system is voluntary, the same has been used to determine the incremental levels for the ease of market.

i. Lighting Power Density, LPD

LPD is one area that can be substituted with latest technology in the field of LEDs and other efficient lighting solutions. The lighting power density can be substantially reduced compared to the ASHRAE requirement with these technologies. Task desk lighting can be added to achieve the higher lux levels

j. Daylight Integration

Daylight integration (optimum lux level without glare) in the building design is definitely a wise design solution. Automated stepped daylight controls can help ensure that artificial lighting is operational depending on the availability of daylight.

k. Domestic hot water system, DHW

DHW is another energy guzzler in the buildings. Rather than determining the efficiency of electric DHW it seems more sensible and practical solution to offset the requirement through heat pumps or solar DHW systems as per the building design possibility.

7. SIMULATION DETAIL

Energy simulation for different building typologies were done for the 5 incremental levels of Energy Efficiency in the building design, namely:

- Office
- School
- Hotel
- Hospital
- Shopping Mall
- Residential House (~50 AC)
- Residential House (AC only when int. setpoint temp above 30° C)
- 2 BHK
- 1 BHK
- Studio Apartment

a. Assumptions:

1. All the schedules (occupancy, lighting, equipment, HVAC) have been kept constant for all the 5 incremental levels for each typology.
2. All incremental level incorporates all the mandatory requirements of the green building code of the economy and further improvements if specified in the table
3. The building energy performance is expressed in the form of EPI (Energy performance Index, kWh/sqm/annum)
4. For the study, Box model for each building typology has been considered
5. Weather file of **Ha Noi, Viet Nam** has been used as it was the closest to **Da Lat City**
6. Design builder has been used for the following Energy simulation.
7. Deliberately, worst case scenario has not been presented as the baseline case to give a more realistic analysis. The present market analysis formed the basis to formulate the baseline.

8. INTERVENTIONS FOR ENERGY EFFICIENCY: Solution Sets

Table 73: Summary of simulation results for office building

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
1.	Window Wall Ratio	60	Less than 60	Less than 60	Less than 60	Less than 40	Less than 40
2.	Walls R Value	R1	R2	R4	R6	R8	R8
3.	Roof R Value	R2	R8	R8	R10	R10	R10
4.	Glass SHGC	0.67	0.37	0.37	0.37	0.45	0.45
5.	Glass VLT (Min)	0.5	0.5	0.5	0.5	0.6	0.6
6.	Glass Shading-Horizontal (D/H)	-	-	Min (0.1)	Min (0.5)	0.5	1
7.	Cooling Equipment Efficiency	EER 8	EER 12	EER 12.4	EER 12.8	EER 13.2	EER 14
8.	Air Conditioners (rating as per DOE 10CR Part 430)	Not Rated	1★	2★	3★	4★	5★
9.	Lighting Power Density (Building)	14	10.8	8	6	4	4
10.	Lighting Controls	Manual Control	Manual Control	Manual Control	Manual and Motion Control	Daylight and Motion Control	Daylight and Motion Control
11.	Energy saving over BAU, kWh/m^2	161	124	111	101	86	81
12.	CO_2 emission mitigation		23%	31%	38%	46%	50%

Table 74: Summary of simulation results for school building

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
1.	Window Wall Ratio	60	Less than 60	Less than 60	Less than 60	Less than 40	Less than 40
2.	Walls R Value	R1	R2	R4	R6	R8	R8
3.	Roof R Value	R2	R8	R8	R10	R10	R10
4.	Glass SHGC	0.67	0.37	0.37	0.37	0.45	0.45
5.	Glass VLT (Min)	0.5	0.5	0.5	0.5	0.6	0.6
6.	Glass Shading-Horizontal (D/H)	-	-	Min (0.1)	Min (0.5)	0.5	1
7.	Cooling Equipment Efficiency	EER 8	EER 12	EER 12.4	EER 12.8	EER 13.2	EER 14
8.	Air Conditioners (rating as per DOE 10CR Part 430)	Not Rated	1★	2★	3★	4★	5★
9.	Lighting Power Density (Building)	14	12.9	10	8	6	4
10.	Lighting Controls	Manual Control	Manual Control	Manual Control	Manual and Motion Control	Daylight and Motion Control	Daylight and Motion Control
11.	Energy saving over BAU, kWh/m^2	200.3	129.6	117.4	108	86.8	81
12.	CO_2 emission mitigation		35.3%	41.4%	46%	56.6%	59.6%

Table 75: Summary of simulation results for hospital building

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
1.	Window Wall Ratio	60	Less than 60	Less than 60	Less than 60	Less than 40	Less than 40
2.	Walls R Value	R1	R2	R4	R6	R8	R8
3.	Roof R Value	R2	R8	R8	R10	R10	R10
4.	Glass SHGC	0.67	0.37	0.37	0.37	0.45	0.45
5.	Glass VLT (Min)	0.5	0.5	0.5	0.5	0.6	0.6
6.	Glass Shading-Horizontal (D/H)	-	-	Min (0.1)	Min (0.5)	0.5	1
7.	Cooling Equipment Efficiency	EER 8	EER 12	EER 12.4	EER 12.8	EER 13.2	EER 14
8.	Air Conditioners (rating as per DOE 10CR Part 430)	Not Rated	1★	2★	3★	4★	5★
9.	Lighting Power Density (Building)	14	12.9	10	8	6	4
10.	Lighting Controls	Manual Control	Manual Control	Manual Control	Manual and Motion Control	Daylight and Motion Control	Daylight and Motion Control
11.	DHW	100% Electric	100% Electric	50% demand by solar/heat pump	50% demand by solar/heat pump	100% demand by solar/heat pump	100% demand by solar/heat pump
12.	Energy saving over BAU, kWh/m^2	639.6	500.1	459	433.6	388	363
13.	CO_2 emission mitigation		21.8%	28.2%	32.2%	39.3%	43.24%

Table 76: Summary of simulation results for hotel building

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
1.	Window Wall Ratio	60	Less than 60	Less than 60	Less than 60	Less than 40	Less than 40
2.	Walls R Value	R1	R2	R4	R6	R8	R8
3.	Roof R Value	R2	R8	R8	R10	R10	R10
4.	Glass SHGC	0.67	0.37	0.37	0.37	0.45	0.45
5.	Glass VLT (Min)	0.5	0.5	0.5	0.5	0.6	0.6
6.	Glass Shading-Horizontal (D/H)	-	-	Min (0.1)	Min (0.5)	0.5	1
7.	Cooling Equipment Efficiency	EER 8	EER 12	EER 12.4	EER 12.8	EER 13.2	EER 14
8.	Air Conditioners (rating as per DOE 10CR Part 430)	Not Rated	1★	2★	3★	4★	5★
9.	Lighting Power Density (Building)	20	16	12	10	10	10
10.	Lighting Controls	Manual Control	Manual Control	Manual Control	Manual and Motion Control	Daylight and Motion Control	Daylight and Motion Control

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
11.	DHW	100% Electric	100% Electric	50% demand by solar/heat pump	50% demand by solar/heat pump	100% demand by solar/heat pump	100% demand by solar/heat pump
12.	Energy saving over BAU, kWh/m^2	486.5	405.32	366.5	309	261	232
13.	CO_2 emission mitigation	-	16.7%	24.6%	36.5%	47.8%	53.3%

Table 77: Summary of simulation results for shopping mall

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
1.	Window Wall Ratio	60	Less than 60	Less than 60	Less than 60	Less than 40	Less than 40
2.	Walls R Value	R1	R2	R4	R6	R8	R8
3.	Roof R Value	R2	R8	R8	R10	R10	R10
4.	Glass SHGC	0.67	0.37	0.37	0.37	0.45	0.45
5.	Glass VLT (Min)	0.5	0.5	0.5	0.5	0.6	0.6
6.	Glass Shading- Horizontal (D/H)	-	-	Min (0.1)	Min (0.5)	0.5	1
7.	Cooling Equipment Efficiency	EER 8	EER 12	EER 12.4	EER 12.8	EER 13.2	EER 14
8.	Air Conditioners (rating as per DOE 10CR Part 430)	Not Rated	1★	2★	3★	4★	5★
9.	Lighting Power Density (Building)	20	16	12	10	8	8
10.	Lighting Controls	Manual Control	Manual Control	Manual Control	Manual and Motion Control	Manual and Motion Control	Manual and Motion Control
11.	Energy saving over BAU, kWh/m^2	343	256.8	194.6	176.5	162.8	155.7
12.	CO_2 emission mitigation	-	25.1%	43.2%	48.5%	52.5%	54.6%

Table 78: Summary of simulation results for residential building (Case-1 – AC set point >30°C)

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
1.	Window Wall Ratio	30	Less than 25	Less than 20	Less than 20	Less than 15	Less than 15
2.	Walls R Value	R1	R2	R4	R6	R8	R8
3.	Roof R Value	R2	R8	R8	R10	R10	R10
4.	Glass SHGC	0.67	0.37	0.37	0.37	0.45	0.45
5.	Glass VLT (Min)	0.5	0.5	0.5	0.5	0.6	0.6
6.	Glass Shading- Horizontal (D/H)	-	-	Min (0.1)	Min (0.5)	0.5	1
7.	Domestic Equipment Efficiency	Not Rated	1★	2★	3★	4★	5★
8.	Air Conditioners (rating as per DOE 10CR Part 430)	Not Rated	1★	2★	3★	4★	5★

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
9.	Lighting Power Density (Building)	11	10.8	8	6	4	4
10.	DHW	100% Electric	100% Electric	50% demand by solar	50% demand by solar	100% demand by solar	100% demand by solar
11.	Energy saving over BAU, kWh/m^2	72	60.7	53.1	47.6	41.2	35
12.	CO_2 emission mitigation	-	16%	26.25%	33.8%	42.8%	51.4%

Table 79: Summary of simulation results for residential building (Case-2 – 50% cooling from AC)

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
1.	Window Wall Ratio	30	Less than 25	Less than 20	Less than 20	Less than 15	Less than 15
2.	Walls R Value	R1	R2	R4	R6	R8	R8
3.	Roof R Value	R2	R8	R8	R10	R10	R10
4.	Glass SHGC	0.67	0.37	0.37	0.37	0.45	0.45
5.	Glass VLT (Min)	0.5	0.5	0.5	0.5	0.6	0.6
6.	Glass Shading-Horizontal (D/H)	-	-	Min (0.1)	Min (0.5)	0.5	1
7.	Domestic Equipment Efficiency	Not Rated	1★	2★	3★	4★	5★
8.	Air Conditioners (rating as per DOE 10CR Part 430)	Not Rated	1★	2★	3★	4★	5★
9.	Lighting Power Density (Building)	11	10.8	8	6	4	4
10.	DHW	100% Electric	100% Electric	50% demand by solar	50% demand by solar	100% demand by solar	100% demand by solar
11.	Energy saving over BAU, kWh/m^2	105	74.5	69	61	55	42
12.	CO_2 emission mitigation	-	29%	34.3%	41.9%	47.6%	60%

Table 80: Summary of simulation results for residential building (2BHK)

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
1.	Window Wall Ratio	30	Less than 25	Less than 20	Less than 20	Less than 15	Less than 15
2.	Walls R Value	R1	R2	R4	R6	R8	R8
3.	Roof R Value	R2	R8	R8	R10	R10	R10
4.	Glass SHGC	0.67	0.37	0.37	0.37	0.45	0.45
5.	Glass VLT (Min)	0.5	0.5	0.5	0.5	0.6	0.6

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
6.	Glass Shading-Horizontal (D/H)	-	-	Min (0.1)	Min (0.5)	0.5	1
7.	Domestic Equipment Efficiency	Not Rated	1★	2★	3★	4★	5★
8.	Air Conditioners (rating as per DOE 10CR Part 430)	Not Rated	1★	2★	3★	4★	5★
9.	Lighting Power Density (Building)	11	10.8	8	6	4	4
10.	DHW	100% Electric	100% Electric	50% demand by solar	50% demand by solar	100% demand by solar	100% demand by solar
11.	Energy saving over BAU, kWh/m^2	105.2	88	71.6	62	54	42.3

Table 81: Summary of simulation results for residential building - 1BHK

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
1.	Window Wall Ratio	30	Less than 25	Less than 20	Less than 20	Less than 15	Less than 15
2.	Walls R Value	R1	R2	R4	R6	R8	R8
3.	Roof R Value	R2	R8	R8	R10	R10	R10
4.	Glass SHGC	0.67	0.37	0.37	0.37	0.45	0.45
5.	Glass VLT (Min)	0.5	0.5	0.5	0.5	0.6	0.6
6.	Glass Shading-Horizontal (D/H)	-	-	Min (0.1)	Min (0.5)	0.5	1
7.	Domestic Equipment Efficiency	Not Rated	1★	2★	3★	4★	5★
8.	Air Conditioners (rating as per DOE 10CR Part 430)	Not Rated	1★	2★	3★	4★	5★
9.	Lighting Power Density (Building)	11	10.8	8	6	4	4
10.	DHW	100% Electric	100% Electric	50% demand by solar	50% demand by solar	100% demand by solar	100% demand by solar
11.	Energy saving over BAU, kWh/m^2	109.1	90	73	65.4	58	48.3
12.	CO_2 emission mitigation	-	17.4%	33%	40%	46.8%	55.7%

Table 82: Summary of simulation results for residential building - Studio apartment

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
1.	Window Wall Ratio	30	Less than 25	Less than 20	Less than 20	Less than 15	Less than 15
2.	Walls R Value	R1	R2	R4	R6	R8	R8
3.	Roof R Value	R2	R8	R8	R10	R10	R10
4.	Glass SHGC	0.67	0.37	0.37	0.37	0.45	0.45
5.	Glass VLT (Min)	0.5	0.5	0.5	0.5	0.6	0.6

No.	Building Component	BAU Case	1★	2★	3★	4★	5★
6.	Glass Shading- Horizontal (D/H)	-	-	Min (0.1)	Min (0.5)	0.5	1
7.	Domestic Equipment Efficiency	Not Rated	1★	2★	3★	4★	5★
8.	Air Conditioners (rating as per DOE 10CR Part 430)	Not Rated	1★	2★	3★	4★	5★
9.	Lighting Power Density (Building)	11	10.8	8	6	4	4
10.	DHW	100% Electric	100% Electric	50% solar	50% solar	100% solar	100% solar
11.	Energy saving over BAU, kWh/m^2	114	91	76	68	59.3	51
12.	CO_2 emission mitigation	-	20.2%	33.3%	40.3%	48%	55.3%

9. INCREMENTAL COST OF ENERGY EFFICIENCY INTERVENTIONS

a. Commercial Buildings

Table 83: Cost increment for commercial buildings in comparison to BAU case

Parameters	Rating Level	OFFICE	SCHOOL	HOSPITAL	HOTEL 3 STAR	SHOPPING MALL
Building Envelope	1	21%	21%	21%	21%	21%
	2	32%	32%	32%	32%	32%
	3	73%	73%	73%	73%	73%
	4	80%	80%	80%	80%	80%
	5	80%	80%	80%	80%	80%
Glazing and Shading	1	24.5%	24.5%	24.5%	24.5%	24.5%
	2	178%	178%	178%	178%	178%
	3	227%	227%	227%	227%	227%
	4	257%	257%	257%	257%	257%
	5	257%	257%	257%	257%	257%
HVAC/ Air Conditioning System	1	10%	10%	10%	10%	10%
	2	14%	14%	14%	14%	14%
	3	32%	32%	32%	32%	32%
	4	45%	45%	45%	45%	45%
	5	65%	65%	65%	65%	65%
Artificial Lighting & Controls	1	5%	5%	5%	5%	5%
	2	12%	12%	12%	12%	12%
	3	38%	38%	38%	38%	38%
	4	45%	45%	45%	45%	45%
	5	45%	45%	45%	45%	45%

b. Residential Buildings

Table 84: Cost increment for residential buildings in comparison to BAU case

Parameter	Rating Level	Residential house (AC when set point is over 30°C)	Residential house (~50% AC)	Residential: 2 BHK	Residential: 1 BHK	Residential: Studio apartment
Building Envelope	1	21%	21%	21%	21%	21%
	2	32%	32%	32%	32%	32%
	3	73%	73%	73%	73%	73%
	4	80%	80%	80%	80%	80%
	5	80%	80%	80%	80%	80%
Glazing and Shading	1	24.5%	24.5%	24.5%	24.5%	24.5%
	2	178%	178%	178%	178%	178%

Parameter	Rating Level	Residential house (AC when set point is over 30°C)	Residential house (~50% AC)	Residential: 2 BHK	Residential: 1 BHK	Residential: Studio apartment
	3 ★	227%	227%	227%	227%	227%
	4 ★	257%	257%	257%	257%	257%
	5 ★	257%	257%	257%	257%	257%
HVAC/ Air Conditioning System	1 ★	5%	5%	5%	5%	5%
	2 ★	15%	15%	15%	15%	15%
	3 ★	27%	27%	27%	27%	27%
	4 ★	35%	35%	35%	35%	35%
	5 ★	55%	55%	55%	55%	55%
Artificial Lighting & Controls	1 ★	5%	5%	5%	5%	5%
	2 ★	12%	12%	12%	12%	12%
	3 ★	15%	15%	15%	15%	15%
	4 ★	20%	20%	20%	20%	20%
	5 ★	20%	20%	20%	20%	20%

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