On the urban heat island in Beirut and transfer of urban climatic knowledge to urban planners

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Rationale

- Two reasons for why the study was conducted:
  - First, literature points to the lack of research on UHI in Beirut.
  - Second, the mechanisms through which the transfer of urban climate knowledge is taking place between and amongst relevant authorities is weak.

Research Objectives

Research Objective 1:

- To model the UHI across the entire city of Beirut using the Town Energy Balance model of Météo France (Masson, 2000).

Research Objective 2:

- To identify the urban factors that play the most significant role in exacerbating urban heat island phenomenon in Beirut.

Research Objectives

Research Objective 3:

- To propose technical measures to alleviate the effects of the UHI from an urban planning and design perspective and to recommend measures to improve transfer of urban climatic knowledge to relevant authorities and/or decision-makers.

BEIRUT CONTEXT

1. Urbanized and Artificial Beirut

Figure 1. Dense artificial city of Beirut. Source: Google Image, 2015

- Beirut -> capital city of Lebanon.
- Coastal city along Mediterranean Sea.
- Surface area -> ~20km²
- Population -> ~500,000 (MOE/ECODIT/LEDO, 2001)
- Very high population density -> 21,000 inhabitants/km2
- Beirut -> predominantly artificial city (NPMPLT, 2005),
- Comprised primarily of ->concrete roofs, asphalted roads & a small fraction of urban vegetation

=>contributions to the effects on UHI are expected to be high.

2. Climate in Beirut

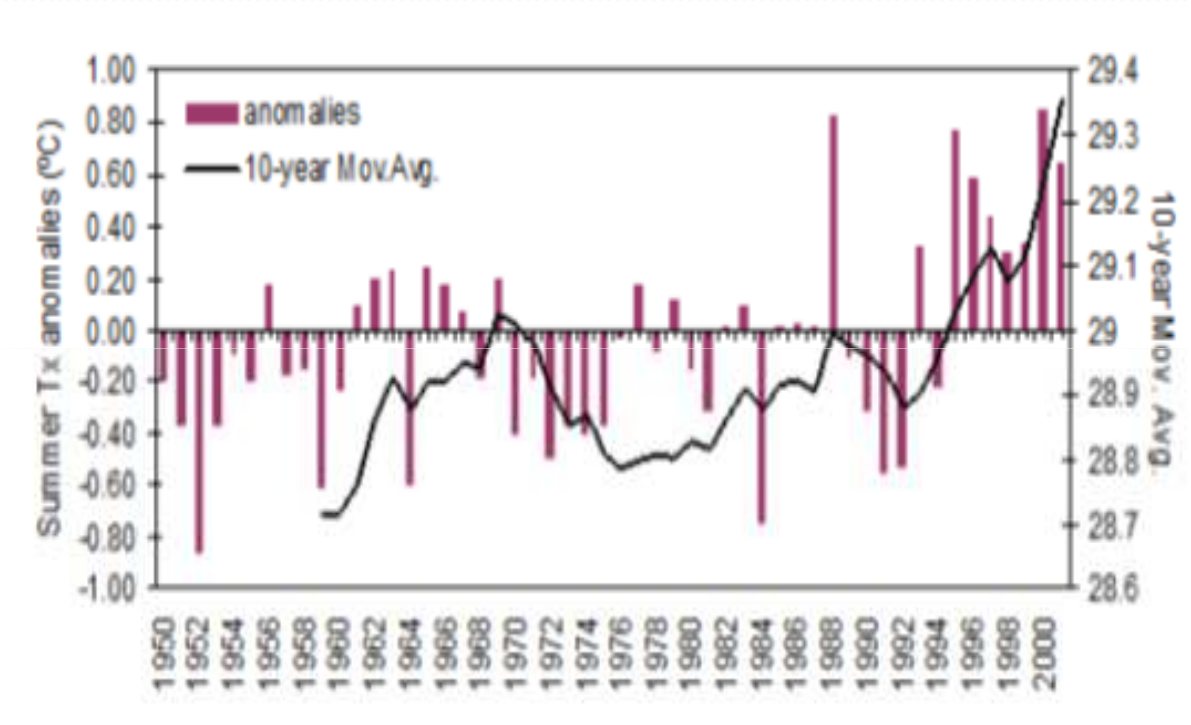


Figure 2. Number of 'hot days' (Tx > 31°C) anomalies from the 1971-2000 average (left axis, bars) for the Beirut International Airport (BIA) station. 10-year moving average of 'hot days' (right axis, solid line) for the BIA station. Source: Hatzaki, et al. 2010; CIRCE urban case studies: Beirut

- Mediterranean climate -> long, hot, dry summers and short, cool, rainy winters.
- Hottest days -> July and August
- Coldest days -> January and February
- Over the last 10 years, an intense warming of 0.12°C per decade is virtually certain to have occurred (>99% likelihood of occurrence)
- The no. of hot days has increased at a rate of about 2 days/decade.

3. Urban heating and population in Beirut

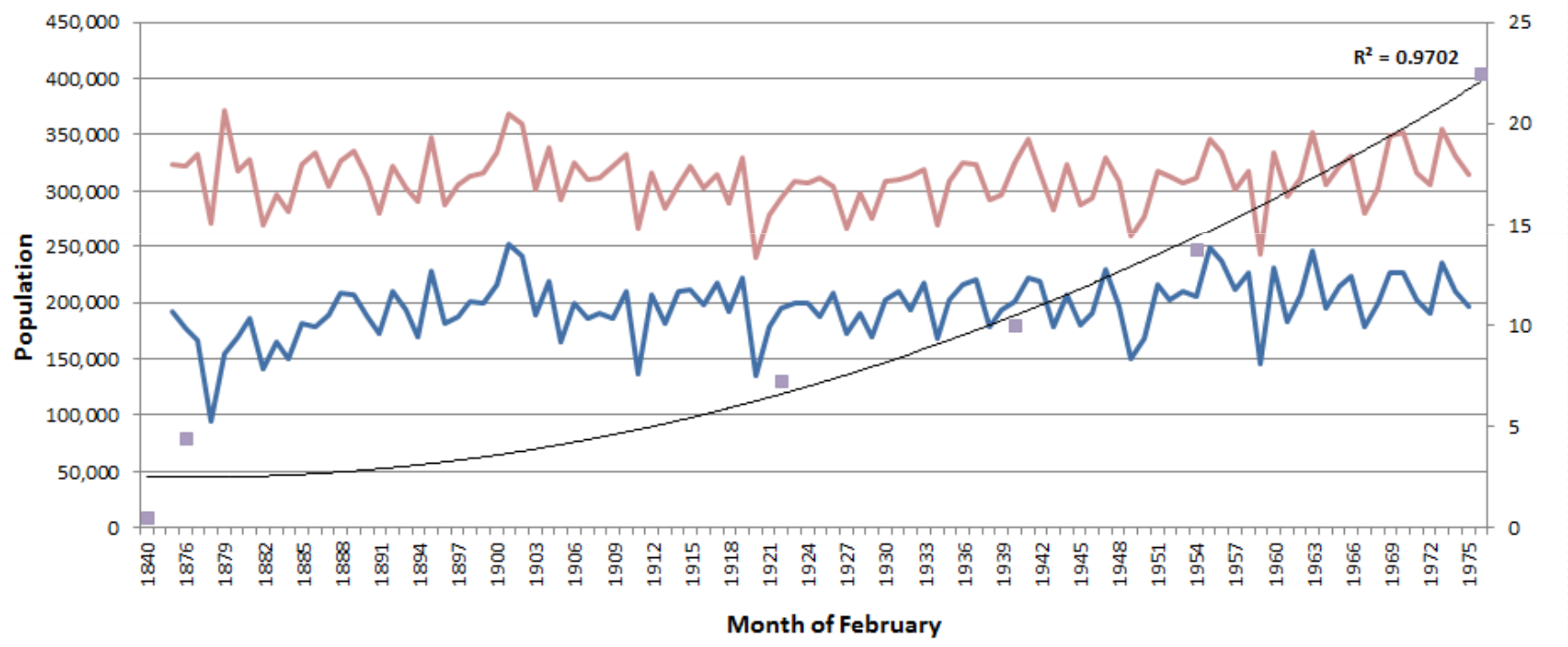


Figure 3. Correlation between historical temperature records and population growth. Source: AUB (2013) and Saliba (1998)

4. Urban planning policy and building code

- **Urban Planning Law #69 (1983)**

It is under this law that Lebanon functions today

although takes into consideration environmental discipline in 8/43 of its directives

none of these mention the need to protect the urban climate.

- **Building Code #646 (2004)**

This is the centerpiece of all construction activities in Lebanon.

this code has some important requirements for the protection of the environment and landscape

but again -> **there are no specific requirements that take into consideration the urban climate.**

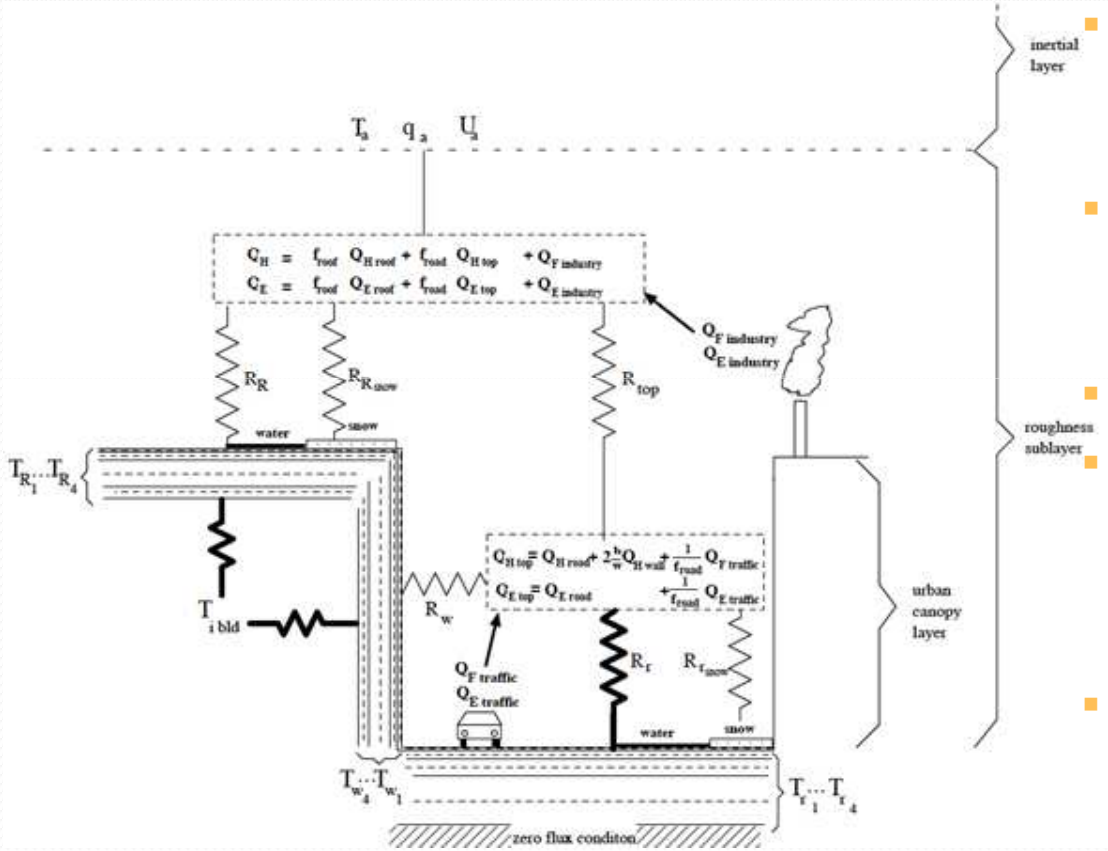
5. Weaknesses and challenges in legal and administrative framework in Lebanon

- Weak communication amongst relevant authorities
- => protection of urban climate is not considered to be a priority
- there is no scientific evidence to show the relevance of urban heating in Beirut
- => decision-making is not effective in this regard
- => there are serious implications on environmental quality and urban climate as documented in the most recent assessment of the state of the environment of Beirut (MOE/UNDP/ECODIT, 2010).

It is necessary to provide scientific evidence to decision-makers so that urban climatic factors are considered and implemented in future and present urban planning and design

METHODOLOGY

Applied Modeling Tool



- The Town Energy Balance (TEB) urban surface exchange modeling scheme (Masson, 2000) was used
- The mechanism by which TEB functions -> based on Oke's energy balance equation.
- It is a single-layer model
- Surface-atmosphere energy interactions are parameterized by forcing the boundary conditions with specific atmospheric data.
- It as an adequate model for large-scale studies like Beirut city

Figure 4. Schematic representation of surfaces (roof, wall, road indicated by subscript R, w, and r, respectively), prognostic temperatures (T) and aerodynamic resistances (R) used in TEB and the output fluxes. Resistances are shown with thick lines. Source: Masson et al., 2002

MAJOR FINDINGS

Results: Control Run

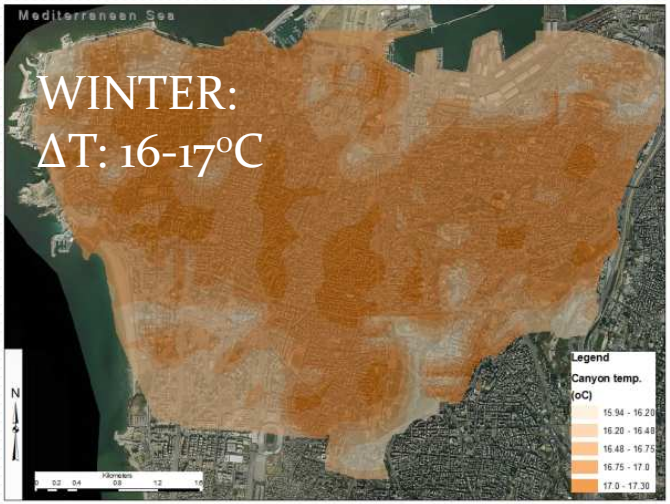


Figure 5. Canyon temperature simulations across Beirut on 01-February at1200 UTC

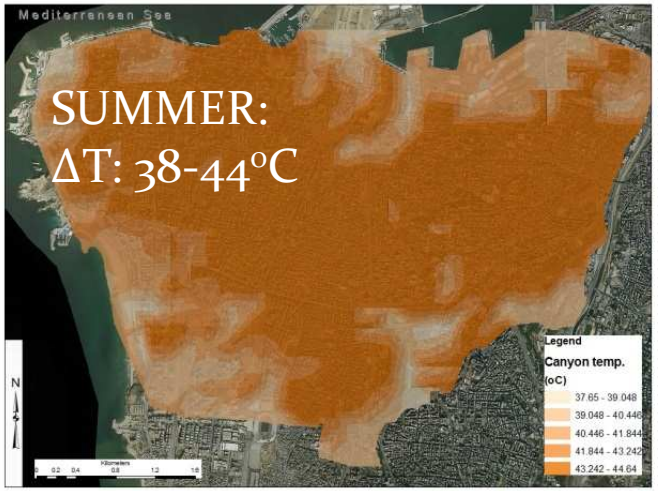


Figure 6. Canyon temperature simulations across Beirut on 01-July at 1200 UTC

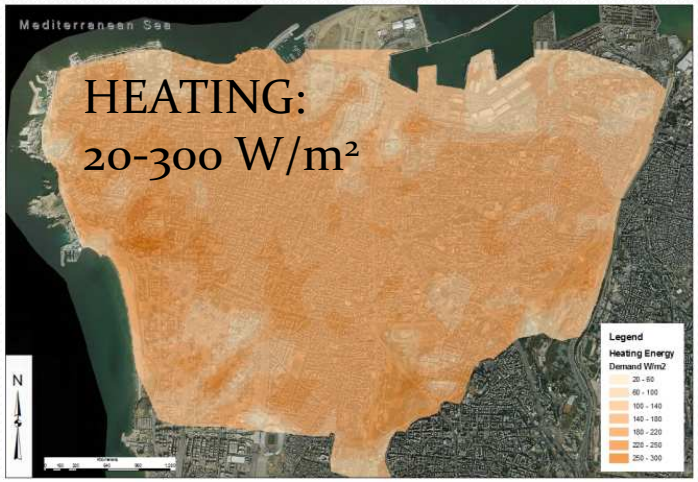


Figure 7. Heating energy usage simulation results across Beirut on 01-February at 1200 UTC

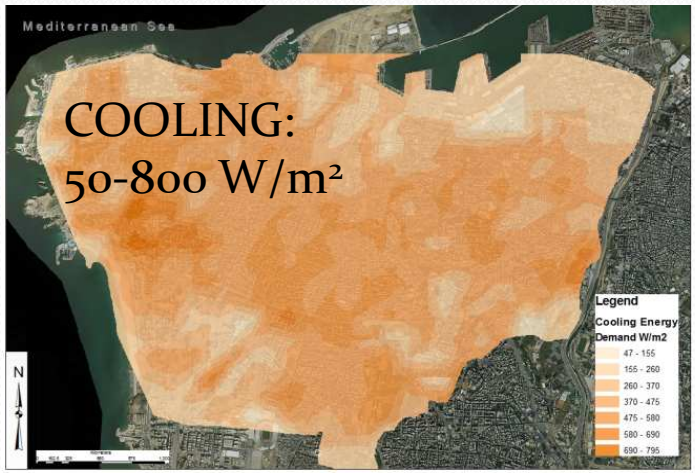


Figure 8. Cooling energy usage simulation results across Beirut on 01-July at 1200 UTC

Devised scenarios

Scenarios	Description
Scenario 1	Albedo of roofs increased to 0.7 (previously α=0.2) in all grid cells across Beirut
Scenario 2	Albedo of roads increased to 0,8 (previously α=0.225)
Scenario 3	Glass ratio increased from 40% to 80%
Scenario 4	Building height was increased from 15m to 35m and the roughness length was accordingly modified from 1.5 to 3.5m
Scenario 5	Increase in vegetation height from 10m to 25m height
Scenario 6	Increase in garden fraction by same amount by which road fraction was decreased (50%)

Results: Devised scenarios vs. control Run

Outputs for Scenario 1	Impact during winter	Impact during summer
TCANYON		
TROOF1		
TROAD1		
TWALL1		
TI_BLD		
HVAC_HT		
HVAC_CL		
Outputs for Scenario 2	**Winter results**	**Summer results**
TCANYON		
TROOF1		
TROAD1		
TWALL1		
TI_BLD		
HVAC_HT		
HVAC_CL		
Output for Scenario 3	**Winter results**	**Summer results**
TCANYON		
TROOF1		
TROAD1		
TWALL1		
TI_BLD		
HVAC_HT		
HVAC_CL		
Outputs for Scenario 4	**Winter results**	**Summer results**
TCANYON		
TROOF1		
TROAD1		
TWALL1		
TI_BLD		
HVAC_HT		
HVAC_CL		
Outputs for Scenario 5	**Winter results**	**Summer results**
TCANYON		
TROOF1		
TROAD1		
TWALL1		
TI_BLD		
HVAC_HT		
HVAC_CL		
Outputs for Scenario 6	**Winter results**	**Summer results**
TCANYON		
TROOF1		
TROAD1		

Significant cooling scenarios:

1) ↑ albedo of roofs and roads

2) ↑ garden fractions

Legend

Cooling impact <1°C	
Cooling impact >1°C	
Heating impact <1°C	
No significant changes in heating or cooling	
Energy savings <10W/m	
Energy savings >10W/m	
Energy savings >50W/m	
Energy demand <10W/m	
Energy demand >10W/m	
Energy demand >50W/m	
No heating and/or demand depending on time of year	

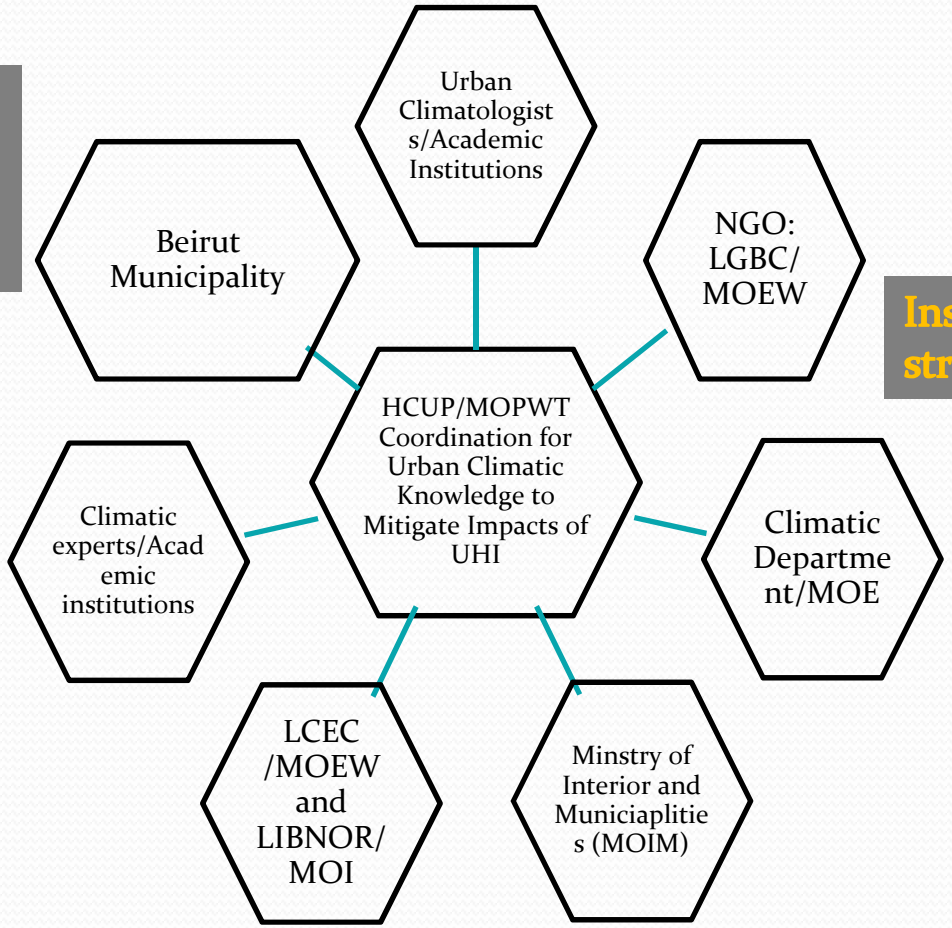
RECOMMENDATIONS

Recommendations for urban planning and design

Figure 9. Recommendations for alleviation of UHI in Beirut (inspired by Colombert, 2008)

Recommendations for improved institutional framework

Improve communication channel amongst all involved authorities



Institutional strengthening

Figure 10. Recommended organization chart for the transfer of urban climatic knowledge amongst all parties involved in urban planning process in Beirut

Implement evidence-based planning scheme

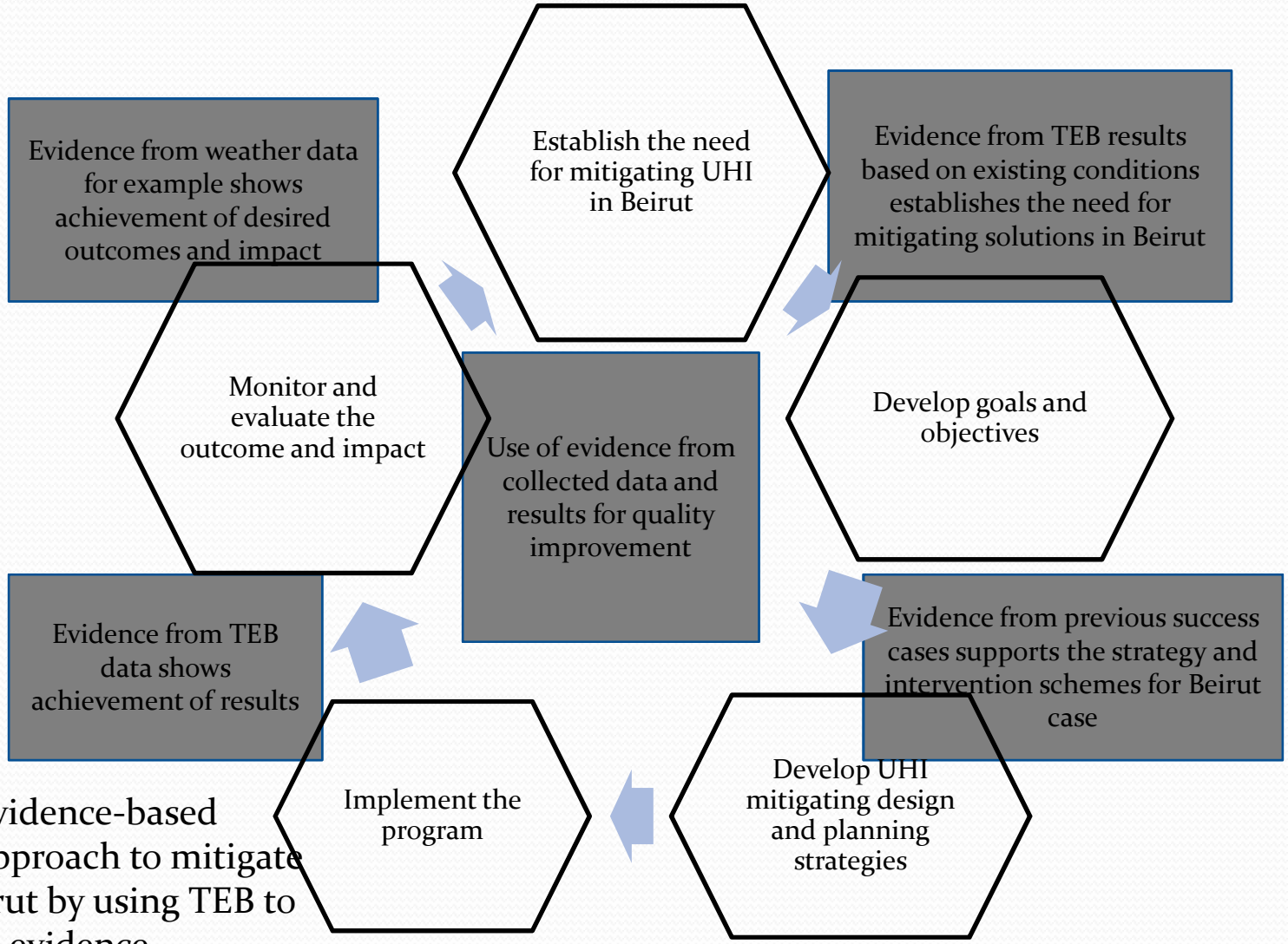


Figure 11. Evidence-based planning approach to mitigate UHI in Beirut by using TEB to provide the evidence

CONCLUSIONS

In our research we found that=>

- Based on TEB, areas of larger vegetated fractions -> greatest cooling impact on air temperatures in comparison to dense artificialized urban areas.
- Increasing albedo of urban surfaces -> rooftops and roads -> significant alleviation of UHI
- Urban Planning Law #69 & Building Code #646 -> do not consider protection of the urban microclimate
- Implement major findings of TEB into Building Code #646 as design criteria that determine whether building permits will be approved.
- Modify and ensure that protection of urban climate is one of the key environmental requirements in the Urban Planning Law #69
- Strengthen communication channels between all involved authorities
- To implement evidence-based planning scheme where TEB can be used to provide the evidence upon which decision-making for urban planning and design are made.

Thank You

Nature of Date Collected

Table 1. Albedo (α) of dominating artificial urban surfaces in Beirut, adapted from Oke (1987)

Description of dominating urban surfaces in Beirut	Material compositions in contact with ambient air	Albedo (α)
Facades of buildings	Beige/white paint and plaster	0.7
Rooftops	Grey concrete slab	0.225
Roads	Asphalted road surfaces	0.2