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Energy resilience to climate change of historic urban districts in Mediterranean area

by

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EXTENDED ABSTRACT (eng)

The scientific sources of utmost importance in impact evaluation and vulnerability caused by climate changes agree to future exposure of Mediterranean area towards an arid climate and of extreme events as heatwaves. Concerning energy issues, residential building stock represent the main object of strategies because of their responsibility in GHGs emissions as well as in ensuring safety and health for their inhabitant. For that reason, European and national strategies moved towards the improvement of building envelope and changing primary sources in order to reduce climate-altering emissions and mitigate effects in a long-term perspective. In addition, climatologist activities in monitoring and testing external changes define a positive contribute in studying future exposure and necessities, supporting the inter-relations between climate, socio-economic and technologies developments. However, the necessity to reduce impacts of uncontrollable events encouraged studies of local urban features and reactions at the same scale in order to reduce the amplification consequences defined by the Urban Heat Island (UHI) effect. Despite they derive from external un-controllable factors, at local scale amplification potentialities of UHI are strictly dependent on built environment and human activities, too. In that sense, several strategies moved towards the identification of best practices in new urban asset and improvement of optical properties in horizontal surfaces (pavements, roofs), supporting and enhancing the adaptability of built urban context and enhancing built market towards cool, reflective and green solutions.

In the whole residential built stock in Mediterranean area, buildings in historic urban districts represent an exception in traditional ***transformation*** management because of

their socio-economic, socio-cultural and environmental relevance that should be preserved, also concerning energy requirements. In the whole weight in energy responsibility of residential sector, these buildings participate to the climate unbalance even if the real complexity to couple their transformation and preservation leaves them in a frame of exception. However, continuous updating of energy thresholds towards Zero energy buildings can be in opposition with the safeguarding necessity in a long perspective.
On the other hand, Mediterranean historic districts and traditional buildings embody the positive experiences of genius loci collected during the time aimed at the creation of robust and ***adaptive*** system in reacting to boundary conditions, above all for climate; these elements enlarge the frame of preservation of their values from the single buildings to the whole district as a source to ***preserve***, while the recognition of deficiency constitutes the opportunity to enhance their efficiency.
As the result of collection of European experiences on single-case studies, energy retrofit of historic buildings can be reached open building market towards innovative solutions and materials (PCMs, VIPs, Aerogel) that can support transformation of heritage without compromise their formal features. However, considering the historic process of creation of these districts as well as the number of single buildings and necessities, the case-by-case strategies is unsuitable in the management of the whole: firstly, the absence of a disciplining instrument for energy retrofit actions at local scale drawing-out the process of transformation and management of them by public administrations; in the second instance, lack of management can contribute in a system of transformation system that, although technically correct, overcoming isolated and fragmented actions that can alienate singular buildings from the *unicum* of the context.
For those reasons, the historical districts required, in term of energy strategies, a systemic vision in order to compensate some operative constrains for single buildings with the opportunities at the large-scale that are mainly related with the genius loci activities and inherent bioclimatic characteristics. So, to undergo the heterogeneity and variety of buildings in historic districts, categories of local “types” as recurrent architectural,

constructional and functional characteristics for specific building typologies and ages can be analysed.

Adaptation, transformation and ***persistence*** necessities involved in *Resilience* as the key feature to ensure all them. Borrowing the widest meaning in an energy point of view, Energy resilience is introduced as key feature in management and planning adaptability and energy improvement of traditional building stock in historic district as the "capacity to undergo to the external changes, adapting and transforming itself in order to ensure his persistence". In detail of them, adaptability as the capacity to react to external conditions – above all for summer temperatures - and transformability, which concerns inherent opportunity for the envelope to be enhanced, should be highlighted in order to promote an energy resilient system of their retrofit.

To support all goals, a robust methodology is proposed, embodying the well-established structure of the refurbishment process for the built heritage –analysis, diagnosis and intervention – and the required features of resilience thinking to highlight the reference points of complexity of the strategies. Moreover, undergoing the specificity of all building cases and the management of the whole as a unicum system, the proposed methodology follows a scalar approach: from the district to the buildings in order to provide the types and his behaviours, while opposite process is useful to promote integrated and structured actions. In detail, the methodology concerns six phases:

1. Analytic phase as the systematic investigation of environmental, architectural and constructional features and regulation frame in energy improvement and preservation thresholds;
2. Taxonomy phase represents the codification of all collected data in previous scale aiming at the identification of "types" to support the concept of *geocluster* and to analyse and to perform their representativeness; in depth, types derive from the characterization at district, canyon and finally building scales;
3. Monitoring and testing phase of local behaviour constitutes the main instrument useful to monitor external dynamic processes and test them at different scale; key tool is the direct measure of micro-climate following

the direct procedure of evaluation of UHI effect with not-standard instruments; consequentially, horizontal analysis at district scale can be evaluated with the support of Envimet©.

4. Diagnosis phase concerns the assessment of energy behaviours (bioclimatic attitudes and deficiencies) of the type referring to the environmental conditions. In detail, diagnosis is the result of the iterative process of evaluation of energy consumption variations following widespread strategies useful for mitigation and adaptation purposes.
5. Taxonomy of suitable interventions concerns the phase of the methodology in which deficiencies are evaluated with the transformability capacity of the system and the formal significance of the envelope, in order to provide a system of solutions.
6. Finally, assessment of priorities of intervention at district scale which delineate a system of recurrent Minimum Units of Energy "Resilient" Interventions (MUERI), as the result of adaptabilities and transformabilities inherent features; supporting common priorities and controlled actions.

To support the methodology, an application on a pilot case, representative of the rigorous frame of landscape maintenance in Apulia Region, in the South of Italy, is presented and discussed. In detail, historic district of Molfetta is representative of several historic coastal towns in the same area, characterized by compact and dense urban arrangement and use of local calcarenitic limestone as construction material. Bioclimatic and critical features are evaluated, supporting results with experimental measures of local micro-climate and the characterization of the whole in a deep canyon compounded by tower houses assessed in series in long block. The high shading effect and good optical properties of materials ensure that exposure during middays of summer period could be reduced. However, previous process of decay transformed locally the district, introducing some exceptions. in addition, roofs represent the weak element in energy requirements but they offer good opportunity of enhancement because of his inherent capacity to be transformed.
Considering that frame, thesis is divided in three parts.

Starting from the critical review of literature at different level of analysis, chapters 1 focuses on climate changes analysing processes, measures and impacts at global– in actual and future projection – and local micro-scale; strategies and solutions already verified, with a specific focus on the energy effect on buildings and resilient experiences, in chapter 2.
As second part, third chapter introduces and frames historic urban districts and their values, correlating them with resilience meaning and previous experiences in energy retrofit; then, fourth chapter delineates the methodology of application.

key words

climate changes, historic urban districts, heritage, energy resilience, adaptability and transformability

EXTENDED ABSTRACT (ita)

Le principali fonti scientifiche di riferimento per la valutazione degli impatti e delle vulnerabilità ai cambiamenti climatici concordano nel sostenere l'elevata esposizione futura dell'area Mediterranea ad un clima arido e l'aumento di eventi estremi quali le ondate di calore. Nel dettaglio delle problematiche energetiche, il patrimonio residenziale esistente rappresenta il principale protagonista delle strategie in atto sia per l'elevata responsabilità nelle emissioni complessive che rappresenta, sia per la salvaguardia della popolazione in termini di sicurezza e salute. Le strategie europee e nazionali supportano azioni di retrofit energetico sull'involucro edilizio e l'utilizzo di energie primarie alternative di mitigazione degli effetti sul clima a lungo termine. Inoltre, le attività di monitoraggio e sperimentazione sui cambiamenti climatici contribuiscono allo studio delle future esposizioni e necessità, riconoscendo e analizzando le interazioni tra clima e sviluppo tecnologico e socio-culturale nelle società. Tuttavia, la necessità di limitare gli impatti delle incontrollabili ondate di calore ha incoraggiato lo studio dei caratteri urbani e delle relazioni tra queste e il clima a scala locale al fine di limitare l'amplificazione dovuta al ben noto effetto Isola di Calore Urbano (UHI). Infatti, seppure nella consapevolezza della impossibilità di controllare i fattori naturali alla base delle ondate di calore, l'amplificazione a scala urbana dell'UHI è strettamente connessa ai caratteri del costruito e alle attività umane. In tal senso, molteplici strategie sono state introdotte per individuare *best practice* sia nella pianificazione di nuove aree urbane sia nel migliora-

mento delle caratteristiche fisiche delle superfici orizzontali degli ambienti urbani (pavimentazioni e coperture), supportando l'adattabilità dei contesti critici urbani e potenziando il mercato edilizio verso soluzioni verdi, cool e riflettenti.
All'interno dell'intero patrimonio residenziale in area mediterranea, gli edifici inclusi nei centri storici rappresentano ancora oggi un'eccezione della gestione tradizionale della loro ***trasformazione*** in ragione della loro rilevanza socio-culturale, socio-economica e ambientale da preservare, anche in merito agli adempimenti energetici. Certamente tale patrimonio partecipa attivamente al disequilibrio climatico per inefficienza e criticità intrinseche energetiche ma la reale dicotomia tra necessità di trasformazione e responsabilità morale e culturale di salvaguardia ha prodotto il confinamento di tale patrimonio in una condizione di eccezionalità rispetto alle tradizionali strategie. Inoltre, l'aggiornamento continuo dei requisiti prestazionali energetici di involucro e dei sistemi di condizionamento finalizzato all'edificio a energia zero si oppone formalmente alle necessità di salvaguardia a lungo termine.
Di contro, il patrimonio tradizionale e soprattutto i distretti tradizionali in area mediterranea sono rappresentativi delle esperienze del genius loci nel corso del tempo il cui obiettivo finale era certamente di creare un sistema robusto e ***adattivo*** rispetto alle condizioni del luogo in cui esso si poneva, tra cui il clima; questi elementi di fatti, ampliano il concetto di salvaguardia dei valori dal singolo edificio all'intero sistema di distretto diventando essi stessi una risorsa da ***preservare***; di contro, il riconoscimento delle carenze presenti diviene l'opportunità di rafforzare complessivamente la loro efficienza.
Diverse esperienze europee di energy retrofit sul patrimonio hanno dimostrato la fattibilità dell'obiettivo supportando tali traguardi attraverso l'uso di materiali e tecnologie d'avanguardia che arricchiscono il mercato edilizio (PCM, VIP, aerogel) e garantiscono la piena integrabilità e sostenibilità tecnico-formale. Tuttavia, considerato il processo di creazione di questi distretti e le molteplici combinazioni di edifici e necessità derivate nel tempo, l'applicazione di metodologie basate su singoli casi risulta essere insostenibile nella gestione di interi distretti: innanzitutto la mancanza di strumenti di disciplina per le azioni di efficientamento energetico a scala di distretto dilata il tempo utile alla

sua trasformazione nonché di gestione delle azioni dalle pubbliche amministrazioni; inoltre, l'assenza di un sistema sovraordinato di controllo a larga scala genera un sistema di trasformazione che, seppure tecnicamente corretti, restano strettamente connessi alle peculiarità del singolo edificio compromettendo l'aspetto formale dell'*unicum* di contesto.
Per tali ragioni, i distretti urbani storici richiedono una visione sistemica nelle strategie energetiche al fine di compensare i limiti operativi dell'edificio singolo con le opportunità presenti a larga scala strettamente connessi alle attività del genius loci e dei caratteri intrinseci bioclimatici. Pertanto, l'utilizzo di "tipi" rappresentativi dei caratteri funzionali, costruttivi e architettonici ricorrenti per tipologie e periodi di costruzione può supportare tale obiettivo.
Inoltre, le necessità di ***adattamento***, ***trasformazione*** e ***persistenza*** introducono il concetto e costituiscono gli elementi cardine della *Resilienza*. Mutuando il significato in accezione energetica, la resilienza energetica è introdotta come carattere chiave nella gestione e pianificazione dell'adattabilità e nel miglioramento del comportamento energico del patrimonio storico; difatti è intesa come la "capacity to undergo to the external changes, adapting and transforming itself in order to ensure his persistence" dove l'adattabilità diviene la capacità del sistema e dei suoi elementi di reagire alle condizioni climatiche in cambiamento – soprattutto nel regime estivo – mentre la trasformabilità si riferisce all'opportunità intrinseca di migliorare l'edificato, offerta dall'attuale stato del patrimonio.
Al fine di raggiungere tali obiettivi, un solido sistema metodologico è proposto a partire dalla struttura consolidata dei processi di recupero del patrimonio costruito – analisi, diagnosi e interventi - ampliandola in accordo con i caratteri del "pensare resiliente" e i sistemi di controllo e monitoraggio del clima. Inoltre, con la necessità di andare oltre le specificità del singolo edificio a vantaggio di un'analisi a più ampio respiro a scala di distretto, la metodologia proposta segue un approccio scalare: dal generale alla scala di edificio per il riconoscimento dei tipi e dei caratteri ricorrenti e rappresentativi, mentre il processo opposto diviene necessario per promuovere azioni integrate e strutturate a

scala di distretto. Nel dettaglio della metodologia, sei fasi sono state identificate secondo cui:

1. La fase analitica consta nell'indagine sistematica dei caratteri ambientali, architettonici e costruttivi dell'edificato, nonché del quadro normativo riferito ai requisiti prestazionali energetici e di salvaguardia del patrimonio;
2. La fase di classificazione costituisce la riorganizzazione dei dati raccolti nella fase precedente utili all'individuazione dei "tipi" al fine di valutarne la rappresentatività; nel dettaglio, i tipi derivano dalla caratterizzazione a scala di distretto - secondo i caratteri delle zone climatiche locali -, di canyon come elemento unico rappresentativo tra micro-clima e sistema di edifici, ed infine di edificio;
3. Successivamente, il sub-processo di monitoraggio e validazione costituisce lo strumento utile alla misurazione dei processi dinamici esterni al costruito, nel rispetto della procedura di valutazione sperimentale dell'UHI con strumenti non standard; di seguito, la validazione del processo di misurazione e l'ampliamento dei caratteri a scala orizzontale nell'intero distretto, valutati con il supporto di EnviMet©;
4. La fase di diagnosi, cuore della metodologia, consente di valutare i caratteri energetici (come attitudini bioclimatiche adattive o deficit) del tipo nell'analisi delle interrelazioni con le condizioni ambientali; più nel dettaglio, si propone come risultato di un processo iterativo di valutazione delle variazioni dei consumi energetici rispetto ai sistemi di mitigazione e adattabilità diffusi a scala di edificio;
5. La tassonomia degli interventi possibili delinea il sistema di soluzioni utili alla correzione dei deficit energetici mettendo a sistema le opportunità di trasformazione offerte dal sistema edilizio e i valori formali del costruito;
6. Infine, la gestione delle priorità d'intervento a scala di distretto entro cui delineare un sistema di unità minime di intervento energeticamente resilienti

(MUERI), risultato del sistema dei caratteri intrinseci di adattabilità e opportunità di trasformazione, a supporto di un approccio prioritario di azioni controllate.

A supporto della metodologia, il caso applicativo di un esempio pilota è presentato e discusso nel dettaglio, all'interno del rigido quadro di recupero della Regione Puglia. Il caso scelto, il centro storico di Molfetta, è inoltre rappresentativo del sistema dei nuclei antichi costieri della stessa regione, caratterizzato da un sistema urbano denso, il cui costruito è prevalentemente realizzato in calcareniti locali.

Le criticità energetiche e i caratteri di adattabilità sono stati valutati a partire dalla misurazione sperimentale dei caratteri micro-climatici locali e dalla caratterizzazione dell'intero costruito secondo un sistema di canyon a larghezza ridotta definito dalla disposizione in serie di case torri secondo lunghi isolati. Il conseguente e dominante effetto di ombreggiamento del canyon assicura la riduzione dell'esposizione alle ore di picco durante il periodo estivo. Tuttavia, a partire dalle trasformazioni subite durante la precedente fase di abbandono e degrado del centro storico è stato possibile individuare alcune eccezioni. A valle dell'analisi, seppure nel riconoscimento delle criticità termiche e fisiche, le coperture definiscono un'opportunità di miglioramento maggiore rispetto alle murature grazie ai caratteri costruttivi.

L'applicazione ad un caso di studio offre la possibilità di evidenziare le potenzialità della metodologia nella creazione di sistemi rappresentativi semplificati di contesti complessi da cui derivano le osservazioni sulle criticità e qualità sotto il profilo energetico; inoltre, nell'ottica del geocluster, consente di derivare i risultati a contesti analoghi per caratteri morfologici, materico-costruttivi e climatici.

A valle della definizione di tale quadro, obiettivi e risultati, la tesi è suddivisa in tre parti. A partire dalla revisione critica della letteratura di riferimento nei diversi livelli di analisi, il primo capitolo introduce i processi, le misure e gli impatti – attuali e futuri – del cambiamento climatico globale e locale sull'edificato; le strategie e le soluzioni validate, con particolare attenzione sulle esperienze resilienti, sono discusse nel capitolo 2.

La seconda parte del contributo introduce e inquadra la questione dei centri storici nel capitolo 3 nella ricognizione dei loro valori, dell'accezione resiliente per essi e delle

esperienze di trasformazione nei processi di energy retrofit. Il quarto capitolo, quindi, raccoglie gli obiettivi, gli strumenti e le problematiche emerse nella definizione della metodologia.
Infine, la terza parte della tesi racchiude tutta l'esperienza applicativa del caso pilota del centro storico di Molfetta nel capitolo 5.

key words

cambiamento climatico, distretti urbani storici, patrimonio, resilienza energetica, adattabilità e trasformabilità

INTRODUCTION

Dynamicity and complexity surely represent major features of analysis, management and enhancing processes in mitigation and adaptation strategies in urban planning; in fact, active interrelations between urban elements (built system, stakeholders, public administrators) should be coupled with the actual and global future variability of climate interacting at lower scale and, potentially, amplifying effects because of local specificities. Although the multifaceted and multilevel correlations, built environment represents surely the key focus of scientific debate and global management of changes because of the high responsibility of residential sector in global emissions and the potential local effects on health and safety for inhabitants. Several experiences based on the “Resilience thinking” were introduced in that frame as the main instrument in evaluation and management of urban risk exposures to “extreme” events.

The high exposures of future changes in temperature trends and occurrences of extreme heatwaves in the southern part of Mediterranean areas recognize the necessity to couple mitigation and adaptation strategies aiming at the reduction of cooling needs as a short and long-term goals. However, local environmental processes of alteration of micro-climate, as the Urban Heat Island (UHI) effect, could increase these effects locally. European community moved towards the resolution of building deficiencies – inefficiency of the envelope and energy systems, promotion of renewable energy sources - as the main instrument in mitigation purpose in order to reduce climate altering emissions in a long perspective; moreover, adaptability strategies aim at limiting and preventing damaging of extreme natural events, above all in improving urban environment – green and blue areas, control of vehicular traffic – and the own buildings

– introduction of cool solutions and re-think the urban asset according with optimal adaptability features. Despite different actions, transformation of the built environment became the key to reach both purposes.

As a particular element of Mediterranean cities, residential buildings assessed in historic districts represent an exception in management, planning and transforming necessity because of the recognition of their socio-economic relevance in re-use of residential buildings stock, socio-cultural significance of historic and formal values and environmental as the explication of interaction between the necessity to accommodate "home" needs – health, safety, self-sufficiency - and external territory conditions. In detail of energy issue, the necessity to improve them following mitigation goals should be related to the uncertainties of future climates, inherent adaptive features that support the formal representativeness of these contexts both at single buildings scale and system as "a whole". In a resilient perspective, they constitute part of the sources to preserve guaranteeing their use in a long perspective, where their energy improvement should solve the emblematic necessity to transform them safeguarding all their values. In that sense, for inherent adaptive features and consequent deficiencies to be identified, whole traditional built environment and buildings should be analysed, focusing on external climate variabilities and actual energy lacks in envelope performances.

Finally, the representativeness of these buildings and districts in result of the complex overlapping necessities, knowledge and transformation processes stratified during an extended period should be solved in the recognition of "types" as a virtual model of recurring and representative characters of the built heritage.

Following these issues, a robust methodology for the resilient energy retrofit of buildings in historic district is required overlapping mitigation and adaptations necessities from the district to the building scale and promoting integrated and structured actions, which might ensure the homogeneity in results of solutions and optimization within the overall requalification and regeneration strategies at the district level, as well as in logistics management of resilient priority of at the same scale.

1. FROM GLOBAL TO LOCAL CLIMATE CHANGES: PROCESSES, MEASURES AND EFFECTS

1.1 GLOBAL CLIMATE CHANGES

1.1.1.DEFINITIONS AND PROCESSES OF GLOBAL CLIMATE CHANGES

Analysis of climate unbalances at global scale collected and promoted in Fourth assessment report of Intergovernmental Panel on Climate Change (IPCC) highlighted future scenarios referring to odds where, combining with different levels of emissions, the worst supports an increased temperature until 4°C, while the best 1.7°C (Parry 2007). In fact, the United Nation Framework Convention on Climate Change (UNFCCC 2007) defines climate changes in art. 1 as

"a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer".

That definition reports the interdependency between inner natural processes and external strains in which, surely, anthropogenic loads and changing in land uses have relevant responsibilities (UNFCCC 2007).
At the center of the discussion, climate-altering gases can be recognized as the main components of human activity. Fifth Assessment of IPCC recognized in GHGs the responsibility of climate alteration assigning to that odds a 95% of probability (Stocker

2014). Moreover, more than 40% of these emissions are caused by energy production using non-renewable sources.
So, unpredictability of global climate projections related to climate and meteorological events, as well as economic and technological development, is associated to ranges of possible odds where contribution of human activities represents the only way to concretely cope these variabilities (Field et al. 2014). To support their control, word governance moved towards wide actions aiming at GHGs while it transfer to local administration activities at lower scale, according to the specificity of the milieu. In fact, as an example, increasing temperatures surely support the wintry reduction in heating consumptions in Continental climate, while increasing of sea level odds certainly represents the most relevant issue in planning land and management of risks in Venice.
In Europe, the outmost research and observation scientific groups agree with global projections and recognize in Mediterranean area the most exposed land. Actually, according to the Euro-Mediterranean Center on Climate Change (CMCC) analysis of macro-scale climate projections, based on the same global development and emissions scenarios, and ENEA (Italian National Agency For New Technologies, Energy And Sustainable Economic Development) analysis, Europe will be exposed to increasing temperatures and reduction of precipitation with high differences between northern and Southern parts; these variations will generate a change of climate from Mediterranean to typically arid (Alessandri et al. 2014) above all in southern regions. In detail of results, temperatures changes vary between 3 and 5 °C while precipitation in 18 and 35%; moreover, focusing on seasonal anomalies in temperatures, studies indicate a substantial shift of the mean and a general widening and flattening of the distributions, most noticeably in summer. This is consistent with the increase in inter-annual variability. Moreover, it indicates a greater increase of extreme temperature seasons compared to the mean. Another feature to notice is that, especially in spring, the distributions become slightly asymmetric, with a longer hot season tail (Figure 1.1-1). This is a further indication of an amplification of the increase in hot seasons compared with the mean (Coppola & Giorgi 2010).

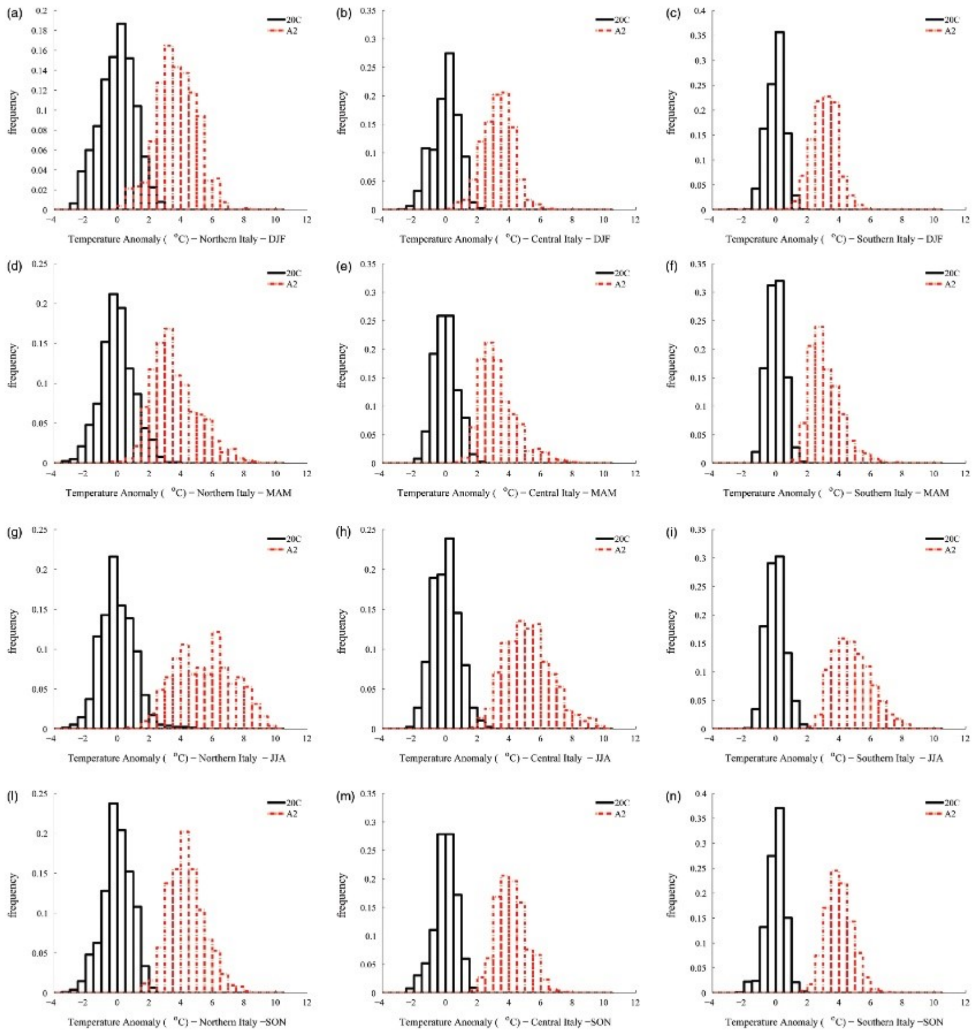


Figure 1.1-1 Normalized distribution of seasonal temperature anomalies: analysis for 1961–1990 (black line) and 2071–2100 (A2 scenario) scenario period (red line). Source (Coppola & Giorgi 2010)

1.1.2.PROJECTIONS AND FUTURE CLIMATE: THE IPCC SCENARIOS AND MEASURES OF CLIMATE CHANGE

Starting from '90s, IPCC started in develop long-term emissions scenarios, referred to future climate. As described in previous phase, GHG emissions constitute the main element of word strategies and mitigation actions; nevertheless, emission productions

representative of the complex dynamic system in term of demographic and socio-economic development as well technological progress. For that reason, at the base of future projection exists a high level of uncertainty. At the same time, driving the same variables could be useful to advance future scenarios; in that sense IPCC introduced scenarios referred to the period 2000-2100 to assist Climate Change analysis and the assessment of mitigation and adaptation strategies, publishing them in the Special Report on Emissions Scenario (SRES). IPCC future scenarios represent the way in which variable could be combined according to specific states accepted by scientific field in each singular field. These combinations are divided by the IPCC commission "storylines" in four "types" defined for their inherent will to express the development along the time of the elements, avoiding the positive climate initiatives, and partially divided in groups to allow the specification in some specific features.
In detail, IPCC scenarios could be described as it follows (Nakicenovic et al. 2000):

- A1 storyline is representative of a future rapid economic growth and global population – with a peak during the 2050; new and efficient technologies will be presented whereas major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita incomes. This storyline is divided in three groups, emphasising several types of sources as Fossil in an intensive way (A1FI), non-fossil energy (A1T) or balanced between all sources (A1B);
- A2 storyline is representative of a very fragmented world; in fact, the main themes are the self-reliance and the preservation of local identities. That frame is associated to a slow fertility patterns across the regions which is globally increasing. For his nature, economic development is connected to the regional scale while technological changes are fragmented and grows slowly than the others;
- B1 storyline is featured by the same population growth of A1, but with rapid changes in economic structures towards a service economy and the introduction of clean and resource-efficient technologies. Global solutions to economic,

social, and environmental sustainability, including improved equity, are emphasized while any climate initiatives are introduced;

- Finally, B2 storyline is based on local solutions to economic, social, and environmental sustainability; global population growth is lower than A2, while economic development has an intermediate level; technological changes are less rapid and more diverse than in the B1 and A1 storylines. In term of environmental protection and social equity, it focuses on local and regional levels.

The higher necessity to understand how these scenarios could affect the anthropic sphere for the energy needs of buildings to the energy capacity to support the same needs in electric systems, has provided the creation of specific tools of calculation. In that sense Meteonorm in V.7 (Remund et al. 2017) has been implemented to support future weather conditions according to the algorithm defined by IPCC for future scenario, starting from a local 10years reference measures.

Near to the growing interest of future climates, the necessity to measure the “future” the actual one referred to an “historical” one became a new object to evaluate climate changes. The main group that moved in that purpose is the Expert Team on Sector-specific Climate Indices (ET – SCI) which jointed with the World Meteorological Organization (WMO). The introduction of the ET-SCI indices of climate extremes has the aim to:

- Enable better management of the risks of climate variability and change, and adaptation to climate change, through the development and incorporation of science-based climate information and prediction into planning, policy and practice on the global, regional and national scale
- move the world in a new era of science based climate information and services to transform knowledge into action.

Indices are flexible to use it in different sector; some of them, in fact, require a reference value that could change applying them in different sector (health, transportation, agricultural, and so on). In detail, the temperature indices are summarized in Table 1.1-1. These indices are based on a percentile statistical analysis and can support the comparison between a reference period with actual and similar series of monitored data.

That kind of analysis requires long-term perspective of historical climate data that, usually, cannot be ensured.

Index	Calculation	Statistical / reference evaluator
FD0 – frost days 0	n. of days where TN*ij* <0°C	TNij: daily min temperature on day i in period j
FD2 – frost days 2	n. of days where TNij <2°C	
FDm2, frost days -2	n. of days where TNij <-2°C	
FDm20, frost days -20	n. of days where TNij <-20°C	
SU25, summer days	n. of days where TXij >25°C	TXij: daily max temperature on day i in period j
ID0, ice days	n. of days where TXij <0°C.	
TX30, hot days	n. of days where TXij >30°C.	
TX35, very hot days	n. of days where TXij >35°C	
TR20, tropical nights	n. of days where TNij >20°C	TNij: daily min temperature on day i in period j
GSL, growing season length	n. of days between the first occurrence of at least 6 consecutive days where TMij > 5°C and the first occurrence after 1 July of at least 6 consecutive days where TMij < 5°C	TM*ij* daily mean temperature on day *i* in period *j*
TXx	TXx = max (TXik)	TXik daily max temperature on day i in month k; Txx Daily max temperature
TNn	TNn = min (TNik).	TNik daily min temperature on day i in month k; TNn Daily min temperature
WSDI*, warm spell duration index	n. of days in intervals of at least six consecutive days TXij > TXib90.	TXib90 calendar day 90th percentile of daily max temperature calculated for a five-day window centred on each calendar day in the base period b; TXij daily max temperature on day i in period j
WSDIn*, user-defined warm spell duration index	n. of days in intervals of at least six consecutive days TXij > TXib90 where n<= 10	
CSDI*, cold spell duration index	n. of days in intervals of at least six consecutive days TNij < TNib10	TNib90 calendar day 90th percentile of daily min temperature calculated for a five-day window centred on each calendar day in the base period b; TNij daily min temperature on day i in period j
CSDIn*, user-defined cold spell duration index	n. of days in intervals of at least six consecutive days TNij < TNib10 where n<= 10	
TX50p, above average days	n. of days where TXij > TXib50	TXib50 calendar day 50th percentile of daily max temperature calculated for a 5-day window centred on each calendar day in the base period b;

		TXij daily max temperature on day i in period j
TX95t, very warm day threshold	n. of days where TXij > TXib95	TXib95 calendar day 95th percentile of daily max temperature calculated for a five-day window centred on each calendar day in the base period b; TXij daily max temperature on day i in period j
TM5a, growing days 5	n. of days where TMij >=5°C	TMij daily average temperature on day i in period j
TM5b, non-growing days 5	n. of days where TMij <5°C.	
TM10a, growing days 10	n. of days where TMij >10°C	
TM10b, non-growing days 10	n. of days where <10°C	
nTXnTN, user-defined consecutive hot days and hot nights	n. of times where, at least n consecutive nights TNij > TNib95 follow at least n consecutive days TXij > TXib95	TNib95/TXib95 calendar day 95th percentile of daily max/min temperature calculated for a 5-day window centred on each calendar day in the base period b; TXij daily maximum temperature on day i in period j; TNij daily minimum temperature on day i in period j
HDDheat, user-defined heating degree days	HDDheat where TMij< Tb	Tb user-defined location-specific base temperature B TMij daily average temperature on day i in period j
CDDcold, user-defined cooling degree days	CDDcold where TMij> Tb	
GDDgrow, user-defined growing degree days	GDDgrow =-Tb where TMij> Tb	

Table 1.1-1 ET-SCI indices of climate extremes

1.1.3.CLIMATE CHANGES IMPACTS: FROM THE GLOBAL ASSESSMENT TO THE CITY LEVEL

As the result of the outmost studies in future scenarios, impacts of climate changes in human activities and cities are strictly related to the local characters in geography of land and morpho-typology of context; consequent impacts in cities should be evaluated to limit their hazard, promoting interdisciplinary studies and actions, safeguarding human health, safety and quality of life in cities. Focus on the latter, Cities are concentrated in 2% of word surface but it is a growing process; currently, European cities host 73% of actual population and, with high relevance, in 2020 percentage will reach the 82 value, transforming more land to accommodate them (EEA 2010).

Efficient solutions in guaranteeing human comfort, health functioning and liveability in urban area should consider hazards in their dynamic structures. The Draft City Climate Hazard Taxonomy defined by C40 group with ARUP, classified possible hazards in urban areas relating them to field of impact (city climate hazard or natural hazard) and to their nature according to a classification in five types (meteorological, climatological, hydrological, geophysical e biological) (C40 2015).That helps in recognition of issues and their field of application and space of analysis. However, that frame highlighted the fundamental role of planning in management of impacts of climate changes in city where main responsibility to global emissions combine with them.

Heatwaves in urban areas represent the main extreme heat event (EHE) that affect the human life in term of temperatures. Currently, WMO does not provide in identification of a universal meaning because of the specificity of the field of application and impact that it generates (health, comfort, drought). However, some recurrent elements can be recognized by:

- US EPA (United States Environmental Protection Agency 2006) that defined it as a period featured “by summertime weather that is substantially hotter and/or more humid than average for a location at that time of year”;
- heath ministers, as Italian, that indicates “a period of 3 consecutive days at least with maximum air temperatures higher than 30 °C” (Ministero della Salute et al. 2014); however, it refers to an a-temporal hazard of meteorological and prolonged combination of features that generate extreme temperatures.

Nevertheless, outside any specificity, in several states heatwaves are referred to extreme events when “temperature exceeds a threshold value referred to the 90^{th} or 95^{th} percentile of the higher one, observed in a historical series for a specific area” (della Salute et al. 2014). So, that extreme events could be evaluate using previous WSDI index that follows the statistical meaning.

Moreover, defining risk exposure of hazard, disaster concept cannot be always related to risks: in fact, the hazard is the result of combination of physic, economic, social and cultural features of damaged system (Field 2012) that, surely, are amplified at local scale with anthropic loads and local built environment.

1.2 LOCAL CLIMATE CHANGES

1.2.1 CLIMATE CHANGE EFFECTS, URBAN CLIMATE AND URBAN HEAT ISLAND PHENOMENON

As previously described, climatic elements influence local features combining with natural and anthropic characters. The interference of them was fully discussed in literature, above all in the urban context (Oke 1982; Munn 2013; Stull 2012); to better understand the interconnection between climate and urban – soil layer, a brief analysis of the thermal exchanges is required. The air sphere over the cities is divided in (Figure 1.2-1):

a) The layer which divided the terrestrial surface and the highest in altitude (2000 mt) is the Planetary Boundary Layer (PBL): it is the air layer which has the high interference with the energy emissions and it can modify his feature (in term of temperature) in one hour;
b) Rural (RBL) or Urban Boundary Layer (UBL) are the sub-layers of PBL as the part of the air where crops or buildings define a perturbation of PBL equilibrium;
c) The roughness sublayer (RSL) defines the air level which is directly influenced by the obstacles (constructions or vegetation) and it could be characterized by the z_r that usually is the double height of the obstacles;
d) Finally, the Urban Canopy Layer (UCL) that correspond to the building height, defined by z_h, and it is the air layer where human activities and constructions, at the urban level, interact with climate features at the micro-scale.

In that classification, the exchange of energy between urban surfaces and the air becomes relevant in term of analysis of energy equilibrium of this system. The absolute differences that exist in energy balance between rural and urban areas result in a variation of their ambient temperatures ($\Delta T_{u\text{-}r}$), phenomenon called "Urban Heat Island". It the result of a different combination of the energy loads between air and urban or rural surface, according with the presence of obstacles, different materials, land uses and human activities.

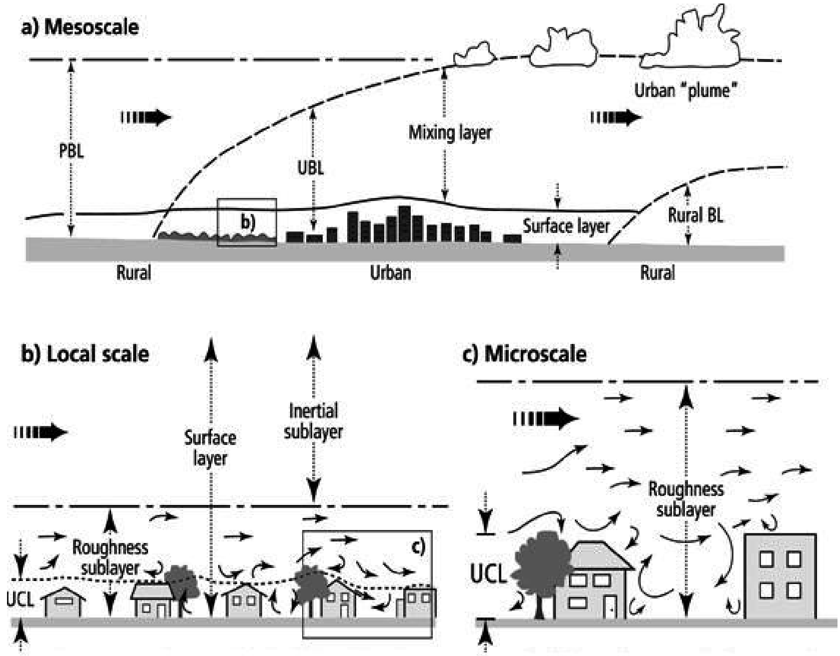


Figure 1.2-1 Climate interactions from the PBL to the micro-scale (ref. Oke 2006)

During the years and several applications in case studies, the intensity of that phenomenon has been introduced to identify, in the same city, different local anomalies for ambient temperatures, preserving the different intensity between cities. That evaluation derives from the necessity to understand how combined local features react in determining different intensities.

According with the best practice, the variation into the city of ambient temperatures is evaluated measuring them at 1-2mt above the street, so considering the effect at the Urban Canopy Layer (UCL); in fact, that level represents the air layer where human activities and constructions interact with climate at the micro-scale level of the city. In detail, at UCL scale main impacts on thermal comfort, building energy use, water use (irrigation), thermal circulation (with low intensity of winds), air quality, urban ecology, should be analyzed.

The UCL analysis allows to understand two processes of UHI effect: during the day, the sensible heat flux at surface is positive and it converges in canyon; during the night that sensible heat is supported by release of heat from ground and buildings daily storage, longwave radiative flux convergence and anthropogenic heat. For these processes, the magnitude of UHI is higher during the night and it is maximum between few hours after sunset to predawn hours, while it is maximum with "ideal conditions" of no wind and no clouds.

In detail, UHI effect is related by 5 elements classified in (Voogt 2007):

a) geographic location including climate, topography, and surrounding rural features;
b) seasonal and day time characteristics
c) synoptic weather, so wind and clouds;
d) city function in term of energy and water use, emissions and pollutions levels;
e) city form that is representative of the characters of built spaces, as materials, geometry and the presence of greenspaces.

These elements derive from the energy balance was defined by Oke in 1987 considering the UCL as volume of control of the urban energy balance of following loads:

$$Q^* + Q_F = Q_H + Q_E + \Delta Q_S + \Delta Q_A \qquad (1)$$

where:

Q^* is the net all-wave radiation flux;

Q_H is the sensible heat flux;

Q_E is the latent heat flux;

ΔQ_S is the net uptake or release of energy by sensible heat changes in the urban ground-canopy-air volume;

ΔQ_A the advective flux, as the air mass with different condition of humidity and temperatures that move in horizontal way;

Q_F the anthropogenic heat flux, result of energy processes of human activities.

These elements are representative of all types of energy transfers in nature and each of them includes the properties of changing surfaces considering rural and urban areas. Focus on the reactions that link city form and materials, Q^*represents the main energy balance for the evaluation of reflective properties and built geometry, in fact:

$$Q^* = K^* + L^* = K\downarrow - K\uparrow + L\downarrow - L\uparrow \ (Wm^{-2}) \qquad (2)$$

where K and L are the shortwave (from the sun) and longwave (or terrestrial) radiation flux, respectively, while arrows indicate whether the flow of energy is toward (↓) or away (↑) from the surface. The impact of materials and their photometric properties are strictly related to the first element of the balance that could be decomposed, using Kirkoff and Stefan-Boltzmann laws, as it follows:

$$Q^* = -\alpha K\downarrow + K\downarrow - \varepsilon_{IR}\, \sigma\, T^4 - (1-\varepsilon_{IR})\, L\downarrow + L\downarrow \qquad (3)$$

Where

α is the albedo of surfaces;

ε_{IR} is the emissivity coefficient in infrared;

σ is Stefan-Boltzmann constant;

T is the temperature of surfaces.

So, variation of radiative heat flux in cities depends by the variation of thermal and optical features of materials that substituted natural surfaces.

The influence of Evaporative Fraction (EF) and, consequentially, the difference on the energy equilibrium between rural and urban areas for the presence of impervious surfaces is represented by the Bowen ratio $\beta = QH/QE$ that is representative of the main channel of heat losses. In fact, if $\beta > 1$ the losses of heat occur for sensible flux (Qh), on the contrary, if $\beta < 1$ for latent flux (Q_E). Into the cities, the high incidence of impervious surface defines a lower value of Q_E that maximizes β. For that reason, the convective energy transfer in the cities is moved on the sensible heat flux that depends on the thermal capacity of materials to change their temperature gaining or losing heat.

Finally, the ΔQ_S considers the dynamical variation of heat flux during the day and the capacity of the system to storage the heat flux along the day. This element includes the thermal capacity of materials to storage the heat during the direct "heating" phase and to release it in a second-time step. In the case where the system decreases the sensible heat flux and the latent is predominant, could provoke a large cumulative heat effect, caused by the Heat Capacity of materials. The physical characteristic that includes that process is the Thermal Inertia that includes the capacity to storage heat C and the thermal conductivity k as:

$\mu = \sqrt{kC}$ (4)

In addition to the heat flux for natural exchanges processes, the Anthropogenic flux could be described as a supplement. Without technologies or transformation of energy for the human wellness, this term of the energy balance this term will be null. Currently, the presence of industrial productions, the use of vehicles for transportation of things and peoples and the necessity to improve the comfort indoor of buildings, introduce new heat gains to the system. In fact, the Anthropogenic Heat flux is representative of the Mean annual heat flux density (W m^{-2}) of fuel combustion and human activity (transportation, space cooling/heating, industrial processing, human metabolism), and it varies significantly with latitude, season, population density and development of society.

1.2.2 URBAN FEATURES AND URBAN HEAT ISLAND INTENSITY

However, urban surfaces are not plane and the general energy balance becomes complex in urban areas with relevantly 3D surfaces. The high ratio of constructions in a certain urban area, their height and their homogeneity represent the “roughness” of urban surface at macro-scale and it is strictly related to the main height of buildings and their density in a limited area.

The interaction between multiple surfaces in different orientation is usually analyzed at “canyon” level, considering the “urban Canyon” as the basic element of the urban assessment. Canyon-air volume is usually delimited by 3 surfaces: 2 walls which identify the vertically boundary of the space (H), and a floor, usually associated with the road that divides buildings with a specific width (W).

The Canyon unit defines the “typical” element that is representative of the urban distribution of a certain part of the urban area. For that reason, it could be classified in term of some features:

- Aspect ratio that identify the relation between height and width dimensions (H/W) of the canyon-air volume;
- Sky View Factor (SVF) that represents the Ratio of the amount of sky hemisphere visible from ground level to that of an unobstructed hemisphere (Oke

1981); considering another point of view, the SVF or ψsky could be described the magnitude of radiative exchange of a point into the Canyon with the sky (Unger 2008) as the ratio between received radiation from a plane surface and the release one from the whole hemispheric ambient (Watson & Johnson 1987);

- Orientation of canyon referring to the cardinal points that alters the quantity of direct radiation into the air volume.

All these elements are useful to understand how the energy balance and so local micro-climate, could be modified into UCL. The main interactions causes-effects for 3D scale could be classified in four macro aspects:

1. Alteration of plan geometry for solar gains: the presence of holes along the urban grid assessment defines the multiple reflection of solar radiation into it, cumulating more heat during the day than in horizontal surfaces. Moreover, infrared energy from buildings and street surfaces is captured and reflected more times along the surfaces that delimit the canyon; Oke in 1982 introduced the relation between SVF (ψsky), Aspect Ratio (H/W) and UHII as the formula:

   $$T_{(U-R)\,MAX}=7{,}45+3{,}97\ ln\ (H/W)\ =15{,}27-13{,}88\ \psi_{sky} \qquad (5)$$

   In that sense, density of buildings could modify the positive effect of wind that has the aim to decrease local heat storage defined as "hot spot" (Taleb & Abu-Hijleh 2013); the parallel construction, referring to the prevalent wind of a site, allows to it to increase wind velocity and to dissipate faster cumulated heat during the day (Radhi et al. 2013);
2. Alteration of latent heat flux caused by the limited green areas in the cities in favour of the Sensible heat flux that increases easily surfaces temperature and increase the phenomenon of cumulative heat during the day;
3. Finally, the introduction of external heat flux, as the anthropogenic ones, cause an over-heating system, moving the energy balance (1) towards the left.

Focusing on them, Oke (Oke 1982) schematized the effect of UHI comparing the altered energy balance terms that lead to positive thermal anomaly as following:

- Increased absorption of shortwave radiation caused by the high percentage of surface area and multiple reflections, that is strictly related to the canopy geometry;
- Increased longwave radiation from the sky that depends on the greater absorption and reemission during the night;
- Decreased longwave radiation loss due to the reduction of sky view factor; so, it depends on the Canyon geometry;
- Anthropogenic heat sources that derives from the traffic and building heat losses;
- Decreased evapotranspiration for the high incidence of “waterproofing” materials and the absence of green spaces;
- Decreased total turbulent heat transport that depends on the canyon geometry and its property to reduce the wind speed.

So, the variables that characterize and could vary the equilibrium of the system could be summarized in three kinds of features:

- Meteorological – climatic, including geographical position, winds, clouds, seasonal conditions and solar radiation;
- Urban, considering his structure, design and materials;
- Human, in term of responsibility of emissions and consumptions.

To study that, a fully literature focused on the differences between the energy equilibrium in urban and rural areas, starting from the observation of a singular phenomenon called Urban Heat Island (UHI). Because of combination of these factors, the magnitude of the UHI effect, define as Urban Heat Island Intensity (UHII), could change considering different cities, in term of dimension, different locations or different assessment of built environment into the city.

So, starting from the Mediterranean features and the causes of climate changes discussed before, the heatwave effects could be defined as the result of high emissions in the air, above all for the responsibilities of urban built environment; however, at the city scale, the presence of a different assessment of soil and surface generates an inherent variation of temperature at the microscale.

However, the processes generate an interference at city and micro scale; the IPCC highlighted that "It is unlikely that any uncorrected urban heat island effects and land use change effects have raised the estimated centennial globally averaged land surface air temperature trends by more than 10% of the reported trend. This is an average value; in some regions that have rapidly developed urban heat island and land use change impacts on regional trends may be substantially larger". In fact, even if a direct impact of UHI effect on the global climate changes cannot be recognized, it is true that at the city scale, the UHI effect could generate indirect effects:

- energy consumptions increase for cooling the buildings due to reduce the generated discomfort;
- subsequently, the emissions increase at the local scale, generating new production of GHGs, stoking the increasing temperatures and amplifying the effect of hot temperatures.

1.2.3 MONITOR AND EVALUATE UHI MAGNITUDE: INSTRUMENT AND LOCATION

As discussed before, interactions between urban environment and air sphere are multiple and differ in term of scale evaluation. According to the main goal of this thesis, evaluation of Urban Heat Island magnitude and his measure are related on the Urban Canopy Layer Scale, so at the same amount of urban roughness defined by building height, also known as CLUHI (Canopy Layer Urban Heat Island).

As widely accepted, UHI is the difference between the relative warmth of air temperature near to ground, usually associated to the UCL, referring to the rural temperatures; in this general definition, a complex system of variables is included, according with the multiple elements that interact at that level. In fact, as the description of controllable and un-controllable elements, urban assessment surely influences the interaction in term of morphology, land use, heat gains, materials. Because of that, different measures could be done to evaluate the magnitude of CLUHI. At the same time, the measure of that phenomenon should be measured according to similar features to evaluate the results in a comparable way.

For these reasons, some guidelines regulate of the experimental phase in choosing site of monitoring and physical and meteorological measures.
The main document in that field is the "Initial guidance to obtain representative meteorological observations at urban sites" wrote by Oke in collaboration with the WMO. In that document, the difficulty to make meteorological measures conforming to the previous "standard" guidelines defined in 1996 by the WMO (Jarraud 2008) are highlighted in term of exception of each investigated urban area. After the definition of the scale of measures – horizontal in term on microscale, local scale and mesoscale, as well the vertical one as in UCL or UBL – some information in term of field of efficacy of measures are described. In detail, the source area, or "footprint", defines the surrounding influencing area of a sensor/instrument (Oke 2004). That area, without wind, has a circular footprint defined by the formula (6) (Schmid et al. 1991):

$$r = z_1\,(\frac{1}{F} - 1)^{0.5} \qquad (6)$$

where F is the view factor, i.e. the proportion of the measured flux at the sensor for which that area is responsible and z_1 is the height of the sensor. Depending on the position of sensor and the surrounding object, the footprint area could be limited.
In monitoring the physical measures of humidity and temperature in UCL the site should be chosen according two conditions: location should be surrounded by average or "typical" conditions for the terrain, while sensor should be located at similar height of non-urban sites. these suggestions aim at avoiding a transition area in the city, e.g. change of land use, change of traffic exposure, and so, not representative part of the district/area.
The physical measures change according to the goal of monitoring actions. In that sense, different suggestions are proposed for measures and relative instruments. In detail:

- To evaluate air temperature, sensor should be shaded by the direct solar radiation and well ventilated;
- For relative humidity measure, some suggestions are made due to the high exposure of pollutants that could create some errors in monitoring phase.

Simultaneously, the guide provides some suggestions in term of choice of urban district for the evaluation. The main aim of the document is to suggest how evaluate the maximum UHI magnitude and so evaluate the maximum exposure. At the basis of that classification, several studies correlated different elements of urban structure and the UHI effect. As a first results of these analysis, quite similar values of UHI magnitude - measured at 2 mt height - could be related to recurrent combination of these elements as predominant in some urban districts but it represents the most frequent combination in actual cities. In fact, to various combination of urban assessment, heat gains, pollution and climatological features an UHII could correspond. That study and consequent work are the result of Stewart work (Stewart 2011) that introduced the Local Climate Zones (LCZs) defined as "regions of uniform surface cover, structure, material, and human activities that span hundreds of meters to several kilometres in horizontal scale" collected as the recurrent combination of some features in the city and they are the result of observation and numerical modelling data (Stewart & Oke 2010; Stewart 2011). This classification is useful to a first physical discretisation of the landscape; in fact, author highlighted that it is a general instrument that does not represent the peculiarities of the real urban and rural areas. Each LCZ has a characteristic screen-height temperature regime that could persist year-round and it is associated with the homogeneous environments of cities, natural biomes, and agricultural productions.
17 LCZs could be recognized by Steward where, 10 are referred to urban "built types", whereas 7 to "land cover types". In that division exists the necessity to define recurrent climatic zone starting from the combination of different elements: for example, in "built types" classification derives from different constructed features on predominant land cover (paved for compact zones and low plants / scattered trees for open zones) while, "land cover types" in term of seasonal properties (snow-covered ground, dry-wet ground).
Referring to the high numerical combination of measures, the LCZs represent the areas featured by range of value of the same elements.
In detail, the geometric and surface cover features that determine the "LCZs" combination could be described as it follows:

1. Sky View factor as the ratio of the amount of sky hemisphere visible from ground level to that of an unobstructed hemisphere;
2. Aspect Ratio which represents the mean height-to-width ratio of street canyons, building spacing or tree spacing referring to residential areas with high or low density, or soil “land cover types”;
3. The building surface fraction, ratio of building plan area to total plan area, expresses in %;
4. Impervious surface fraction that, similarly to the previous, is the Ratio of impervious plan area (paved, rock) to total plan area (%)
5. The complementary pervious surface fraction refers to the total plan area (bare soil, vegetation, water);
6. Height of roughness elements expressed in meters; in that case, it represents the geometric average of building heights for the built types, and tree/plant heights for the land cover ones;
7. Terrain roughness class expressed according to the Davenport classification (Davenport et al. 2000) of effective terrain roughness (z_0) for city and country landscapes; that value measure the aerodynamic roughness of the surface (referred to neutral one without roughness) which influences the wind turbulence at the same analysis quote.

Near to that, the same LCZs are featured by range of value of thermal, radiative and metabolic properties which are summarized as:

- Surface admittance as the ability of surface to accept or release heat (J /(m^2 $s^{1/2}$ K)); that Varies considering soil wetness and material density;
- Surface albedo, Ratio of the amount of solar radiation reflected by a surface to the amount received by it;
- Anthropogenic heat output that is representative of the mean annual heat flux density (W m^{-2}) from fuel combustion and human activity and it varies with latitude, season and population density.

1.3 IMPACTS OF GLOBAL AND LOCAL CHANGES IN BUILDING NEEDS AND REQUIREMENTS

The variation of local temperatures caused by the UHI effects create several effects and damages in indoor and outdoor comfort, health into the Canyon volume. Moreover, increasing external ambient temperatures obviously increase energy needs with a specific affection during summer period that, potentially, are also exposed to increase external differences according with IPCC previous observations. Santamouris assessed penalties of UHI intensities for representative buildings in different European cities, highlighting the affection in cooling consumption as average value of +13% with maximum problems in areas featured by average summer temperatures higher than 27°C (Santamouris 2014b; Santamouris 2014a).

As second effect, positive variation in external temperatures cause the peak electricity demand obliging utilities to build additional power plants to satisfy the demand. Analysis of the additional power induced by the combined impact of the UHI phenomenon and the global climate change were performed by Santamouris et al. (Santamouris et al. 2015) where the additional peak electricity demand per degree of increased temperature, varies between 0.45% and 4.6%, while the corresponding penalty per person is close to 21 W per degree of temperature raised. In that sense, electricity demand creates negative effect also in distribution and transmission network increasing cost of supply energy; in fact, according to Rübbelke and Vögele (Rübbelke & Vögele 2011) results, electricity prices in Switzerland and France may increase up to 80% and 30% correspondingly. Consequently, the increasing energy needs during the peaks increases the maximum instantaneous cooling load of buildings and requires the installation of additional cooling capacity in the buildings. Some results on that affection were performed in Athens by Hassid (Hassid et al. 2000) which evaluated in areas suffering from an intense urban heat island the instantaneous peak electricity demand for cooling was by 60–120% higher than in the reference suburban areas. That effect obliges users to implement cooling systems with additional equipment increasing capital investment costs to compensate the loss of efficiency.

Finally, focusing on the social dimension, Heatwaves, warm spells and increased summer heat stress will result to higher energy needs for air conditioning and will affect the economic situation of vulnerable populations.
These effects surely affect all buildings and all families not well-prepared to the external negative effects, but highlights the necessity to generate a system of decision making support in defining a scale of priority in term of vulnerability as well as in low performant buildings.
The necessity to improve energy efficiency in building sector, as described before, is the result of the almost relevant goals of energy policies in developed and under-developed countries. The relation between climate changes and buildings could be described as the long-term effect of the high emissions in the atmosphere and mitigation actions on the building sector surely are related to that purpose; whereas, the extreme local interaction with ambient events, in addition to the anthropic elements, is representative of the short-term effect of interaction of changes with natural processes. Therefore that, less obvious consequences exist scaling the problem into the urban scale. In fact, Cities are representative of multiple interactions between society, economy, culture and environment and surely the positive effect of energy improvement create similar in each of them. These synergies and interactions moved the promotion of Zero Energy buildings (Santamouris 2016). In detail, three issues, as consequence of cities interactions, interact each other: improvement of energy efficiency in building sector, global and local climate changes and energy poverty which are representatives of the combined urban dimensions as economy, environment and social ones.
The inter-relation between the goal of decreasing energy consumption and global&local climate change are previously discussed. Near to that, the socio-economic dimension of energy poverty should be added.
Different meanings exist of “energy poverty” (EP) according to the application; the International Energy Agency refers to the PE as the inability to access to energy systems referring to India and Africa region; in that case the focus is on the energy infrastructures. In European countries, where the infrastructural issue is solved (referring to the presence of it), the Energy Poverty is referred to the inability of household to afford to

heat their home. In that case the main sphere is referred to the economic capability to use energy as the result of income (Moore 2012). During last years, the EP issue moved towards the Fuel Poverty definition to consider more elements. In fact, in UK the FP was introduced to describe a situation in which a household needs to spend more than 10% of its total income (before housing costs) on all fuel used to heat its homes to an acceptable level; in that definition two problems are included (Bouzarovski 2014): 'needing to spend' refers not to actual expenditure, but to a hypothetical level that is closely related, inter alia, with the thermal energy efficiency of the dwelling; second, 'acceptable level' is taken to mean that the home is heated in line with the standards recommended by the World Health Organization (WHO 1987) —18◦C for bedrooms and 20–21◦C for living rooms. On the other hand, this issue includes the energy efficiency of buildings, household incomes and energy prices. Moreover, Energy poverty could be explicated in two levels:

- socio-economic level, focusing on the economic inability to pay
- and the technical one which, even if strictly connected to the economic ability of households, could be also defined as a deficiency of technical aspects.

Focusing on the relation with the energy efficiency of building stock, the eradication of EP (or FP) surely moves the research and industrial needs to develop high efficiency but also low-cost energy techniques and the policies towards enhancement of total costs of buildings renovation in a country. On the other hand, recognize the necessity to intervene on the low-income buildings, as a policy strategies, means:

- focus on the buildings that surely are energy inefficient (Santamouris & Kolokotsa 2015);
- deliver economic, social and labour benefits in term of:
    - reduction of GHGs emissions
    - generation of new economic opportunities and stimuli of the markets and consequent additional labour opportunities for low income communities;
    - increase the home value of rehabilitated ones and offer the opportunity to create an economic and social redemption of deprived;

- offer a higher independence on energy assistance programs, decreasing the public funding while improving the social status and dignity of that category of household;

- improvement of health conditions of vulnerable population, ensuring the standard condition defined by WHO;
- increase the adaptation potential and decrease their marginalization during the crisis phase; in fact, according with the necessity to maximize the standard house requirements, improvement in actual state means ensuring in the future the reduction of the gap between high and low efficient building stock and so the reduction in term of economic and social classes.

In line with the aim of thesis, preeminent focus will be on the effects on buildings that surely supports the socio-economic level.

Because of interactions between local&global climate change and building energy efficiency as well between the latter and energy poverty, the relation between energy poverty and climate changes could be explicated, assessing positive and negative effects. In that case, vulnerability and risk exposure become the file rouge of the analysis. In detail, the effects of local&global climate change on energy poverty could be summarized as:

- the amplification of the gap in capability to ensure indoor health and comfort, as well the energy efficiency of buildings, above all in temperate and hot climates (Santamouris 2014b) in summer in peaks and regular electricity demands;
- at the same way, decreasing outdoor conditions where usually are already social deprived because of their higher building density, lower percentage of green space and high level of anthropogenic heat (Gaitani et al. 2014; Santamouris 2016)
- use additional HVAC systems to fight the hot temperatures, increasing consumption and peak in the grid.

On the other hand, the energy poverty of low income participates and fosters the climate changes in term of:

- surely the inability to support mitigation and adaptation measures, increasing the local impacts;
- using traditional and/or polluting fuels;
- needing more energy per m^2 to heat houses.

That aim surely requires policies and strategies that create a breakthrough needing more investments that should became the opportunity to create economic, environmental and social benefits. In fact, in addition to the previous relations and benefits, minimizing energy consumptions (and consequently emissions) in buildings sector could be the way to improve labour jobs that the European Trade Association (European Trade Union Confederation 2007) estimates more than 1000 million jobs. Moreover, the improvement of innovative solutions, as materials, technologies and sources, will be the key to solve seriously the issue and create more jobs. Some examples are detailed as it follows:

- the rapid development of LED technology in lighting produced an annual growth rate of 6% (bmub, 2014) and will increase during the 2010-2020 reaching the 8%;
- regarding technologies useful to improve energy efficiency of building envelope:
    - smart glasses as the electrochromic and selective ones increase the market: e.g. smart glass products may reach an annual market of 635 million Euros by 2020 (Devlin 2015), while electrochromic glasses 2.7 billion Euros by 2019 (Markets Smart Windows 2012);
    - in term of insulation solutions, innovative and high-performant materials, e.g. Aerogel, may represent the future significant market in Europe; in fact, World Resources Institute refers to a market that will measure from 13.6 to 20 million of Euros by 2020 (Mulki & Hinge 2010);
    - in addition, smart materials like cool coating and phase change materials (PCMs) will be the sector to bet to increase the success of comfort indoor solutions, so much so that the PCM market reached 1.6 billion Europe in 2010, thanks to the diffusion in high performance HVAC systems;

- in term of use of renewable sources, advanced PV systems, like thin film technologies and integrated PV modules into building materials like roofing shingles, windows and curtain walls may contribute to supply the remaining load of buildings, are enhancing the solutions of solar panel market; in fact, building-integrated PV reached 1.8 billion Euros by 2012.

Focusing on the mitigation of local climate change, above all in term of mitigation of UHI effect, the main goal of technologies and technical strategies is to increase urban surface albedo. In a glance, the major solutions are referred to cool roofs and pavements; in fact, these horizontal elements currently represent the 60% of urban cover (Akbari et al. 2009) and they required 8E/mq of investment (Synnefa & Santamouris 2012), as an average value. Positive impacts can be produced in job creation: considering 6 jobs/million of investments as the average value proposed by European Commission (European Commission 2013), 13000 and 22000 jobs can be created for cool pavements investments and 3800 for cool roofs.

In term of environmental and social positive impacts, according to the analysis of UHI effect in cities by Santamouris (Santamouris 2014b), the average energy penalty per person induced is 237 ($\pm$130) kW h/person which corresponds to a value that varies between 0.022 and 0.035 PW h in potential energy gains from the mitigation of the urban heat island. Moreover, in term of reduction on carbon dioxide emissions, cool roofs and pavements may offset 64 and 38 kg CO_2/m^2, respectively (Akbari et al., 2009) which corresponds close to 0.178 and 0.185 $GtCO_2$ equivalent respectively that correspond to about 9.6% of the total emissions in the European Union in 2013.

These numbers, as in a first evaluation of the impacts, highlighted that interventions on a single case on one of these three elements surely create a benefit on the others and it point out the necessity contribute to evaluate them in a multifaceted vision to understand the real benefits and so the opportunities that derives from each of them.

2. STRATEGIES AND SOLUTIONS TO CLIMATE CHANGES

2.1 RESILIENCE IN CLIMATE CHANGES SOLVING

4.1.1 STATE OF THE ART OF MEANING

The concept of Resilience is well associate in literature as the key feature of a system fighting with extreme events and so, with the concept of climate change exposure. To understand the core, a review of the meaning and his use is analysed as it follows.

The term of resilience born with Holling in 1970s in ecological systems and it is referred to their persistence. Analysing their behaviours, Holling (Holling 1973) introduced the resilience meaning coupling it with "stability" as their properties. In fact,

"Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist. […] Stability, on the other hand, is the ability of a system to return to an equilibrium state after a temporary disturbance. The more rapidly it returns, and with the least fluctuation, the more stable it is. In this definition stability is the property of the system and the degree of fluctuation around specific states the result".

In a glance, the first meaning of resilience was related to the capacity of the system to undergo disturbances and maintain its functions and controls (Gunderson & Holling 2001) returning in the starting point of equilibrium without the possibility to introduce a new state.

Presenting this concept in complex systems, such as the social ones, the resilience has been strongly connected with the notion of "change", which is both what causes the perturbation and what characterizes the resilient behavior. In fact, Holling and Walker in 2004 (Walker et al. 2004) introduced the dynamical dimension of these systems recognizing the possibility to reorganize the element that compound them. These new aims were reached introducing "adaptation and transformation (that) are essential to maintain resilience, as a prerequisite to persist" changing the system reference. Thus, the "persistent system", featured by a combination of adaptability and transformation, can reach a new state of equilibrium that could be different than the starting one or, better, it might be in higher thresholds. In detail, Holling and Walker defined:

- "Adaptability is the ability of actors in a system to influence resilience" so as the attitude to conserve the internal features of the system despite the external stresses;
- "Transformability is the capacity to create a fundamentally new system when ecological, economic or social structures make the existing system untenable", considering that as the opportunity to recreate a new sustainable system featured by a new equilibrium.

So, these two features introduced the dynamical dimension of resilience considering time, the interaction of elements and the system threshold. At the same time, these "variations" should ensure the persistence of the system as the driving force of the process. In fact, in the same work, the concept of "resilience" has been defined by Walker et al. (Walker et al. 2004) as

"the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks".

The dynamical dimension of this resilience meaning allowed to define it as a “flexible” feature of system and, at the same time, it include the multilevel interactions of systems. Because of his wide scope, this resilience meaning was also used in literature in many fields of application, from the human social systems and ecological urban dimension to the economic recovery (Andersson 2006; Ernstson et al. 2010; Folke 2006; Rose 2004; Pendall et al. 2010; Vale & Campanella 2005; UNISDR 2009).
Nevertheless, the dynamical dimension of “resilience” could be related to two different ways of interpretation that change the nature of the property:

- In engineering field, resilience is referred to the capability of all the physical components of the system, including buildings and transportation infrastructures, to absorb the damages due to an external shock and to quickly restore their state before the shock (O’Rourke 2007; Reed et al. 2009; Bruneau et al. 2003) and focusing on the time of return to a global equilibrium following a disturbance (Gunderson et al. 2002);
- On the contrary, the ecosystem approach, in which the focus is the capability of the whole system – defined as a complex one - to recover the full set of functionalities and services that existed before the shock, trying to measure the amount of disturbance that a system can absorb before it changes state. This is usually much more articulate than the algebraic sum of the performances of its single components (Holling 1996).

However, the resilience in urban field represents the main field of application during last years and it is representative of that double approach; in fact, the “urban resilience”, in a general way, could be understood in two different ways (Ernstson et al. 2010):

- the first concerns “resilience in cities”, which operates at the city scale and deals with sustaining local-to-regional ecosystem services and it has been the main preoccupation of most urban ecologists; it is tightly linked to urban form and land-use patterns on the one hand, and local and spatial ecological processes on the other. This involves stakeholders like urban planners and housing companies, but also housing, squatter and urban social movements, along with those influencing and/or have knowledge about urban ecological processes;

- The second is "resilience of cities", which instead operates at the scale of a "system of cities," which is a concept from geography meaning a set of cities tied to each other through relations of exchange, trade, migration, or others that sustain the flow of energy, matter and information among the cities. It involves a broader category of stakeholders, but particularly those associated not only with technical networks like water, electricity, sewage, waste disposal, and telecommunications, but also with agriculture, mining and other broader interests in society.

4.1.2 RESILIENT STRATEGIES IN URBAN EXPERIENCES FOR DISASTER RISK REDUCTION

During last years, scientific researchers are pointing out the urban resilience evaluation. Cities, in fact, represent the milieu where the higher part of people currently live and the percentage will grow during next years, because of the re-organization of inhabitant areas in growing countries. In fact, main concept of resilience starting from the definition of the UNISDR (United Nation Office for Disaster Risk Reduction), as:

"the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of the hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UNISDR 2009),

The mention of "exposure of risk" is a clear reference of the "risk" that became the main way to measure the resilience that, concerning engineering and eco-systemic points of view, could be obtained summing the values of risk assessment of each element that compounds system or as the sum of critical levels considering the whole system. For sure, according with the widespread meaning, resilience is measured by the magnitude of disturbance that could be experienced without the system flipping into

another state and within which the system can absorb and still persist (Gunderson & Holling 2001).
Actually, the measure of urban resilience is strictly connected to the engineering meaning, as an overlap of risk as a consequence of vulnerabilities in different levels; at the same time, the way to measure is overlooked because of the real difficulty to realize a concrete evaluation of interconnection between multiple level of interests and in most cases, it still focused on particular problems of the whole city such as urban infrastructures and transportation networks (Currà & D'Amico 2014).
the urban resilience and his promotion is really connected to some specific activities promoted by two main entities involved in the management of that multi-level problematic at world scale: the UNISDR (United Nation Office for Disaster Risk Reduction), that is the secretariat for the implementation of the International Strategy for Disaster Reduction (ISDR), mandated by the United Nations General Assembly resolution to serve as the focal point in the United Nations system for the coordination of disaster reduction and to ensure synergies among the disaster reduction activities of the United Nations system and regional organizations and activities in socio-economic and humanitarian fields; the second one is the GFDRR (Global Facility for Disaster Risk Reduction) that is a global partnership which helps developing countries better understand and reduce their vulnerability to natural hazards and climate change. Both are representative of a general support of risk reduction, above all for developing countries that, according with the risk notion, represent the most vulnerable.
In detail, these two groups moved two campaigns which represent the actual way to improve urban resilience in a wide way; in fact, according to the multidisciplinary aspects and the multi-dimensional identity of the cities, both highlighted recurrent levels of resilience that could be summarize in 4 fields that also represent the interacting elements in the city: society, environment, culture (including also political field) and economy (Figure 2.1-1). This classification surely creates a conceptual map that describes the complexity of interactions and the difficulty to evaluate a way to measure the resilience.

Figure 2.1-1 UNISDR levels of urban resilience

For these reasons, the UNISDR supports the local government with a system of good practices in their handbook created during his campaign “make city resilient”, also known as the “10 essentials” and that sums up the levels of resilience and their interaction. In a glance, UNISDR promotes:

1. Coordination and preparedness in risk management
2. Management of funding and incentives during coordination phase for vulnerable elements of the city (families, communities, public sectors);
3. Planning the risk assessment and monitoring them in a continuous way;
4. Investments in critical field as the main way to reduce risk;
5. Guarantee and upgrade safety and health facilities;
6. Creation of urban planning regulations that consider risks and vulnerabilities;
7. Education programs on disaster risk management in every level of community knowledges;
8. Building on good risk reduction practices, protecting cities and natural spheres;
9. Warning systems to monitor and to manage emergency and changes during the time;
10. After any disaster, place at the center of reconstruction phase needs of affected population.

These essentials refer to the urban actions retain some specific features that characterized the resilience. The RockFeller foundation and his program "100 resilient cities" define the characters of a resilient city, summarized as:

- Reflectiveness and resourcefulness as the ability to learn from the past and act in times of crisis where resourcefulness is referred to the capability to recognize alternative ways to use resources at times of crisis to meet their needs or achieve their goals while reflectiveness to use past experiences to inform future decisions, and will modify standards and behaviours accordingly;
- Inclusive and integrated refer to necessity to relate to the processes of good governance and effective leadership that ensure investments and actions are appropriate, address the needs of the most vulnerable and collectively create a resilient city – for everyone; in detail, inclusive processes emphasize the need for broad consultation and 'many seats at the table' to create a sense of shared ownership or a joint vision to build city resilience and integrated processes bring together systems and institutions and can also catalyse additional benefits as resources are shared and actors are enabled to work together to achieve greater ends;
- Robustness, redundancy and flexibility as the qualities that help to conceive systems and assets that can withstand shocks and stresses as well as the willingness to use alternative strategies to facilitate rapid recovery, where:
    - robustness is referred to design that should be well-conceived, constructed and managed and includes making provision to ensure failure is predictable, safe, and not disproportionate to the cause,
    - redundancy refers to spare capacity purposively created to accommodate disruption due to extreme pressures, surges in demand or an external event and it includes diversity where there are multiple ways to achieve a given need;

- finally, flexibility refers to the willingness and ability to adopt alternative strategies in response to changing circumstances or sudden crises. Systems can be made more flexible through introducing new technologies or knowledge, including recognizing traditional practices.

However, in agreement with the multilevel aspect of "urban resilience" meaning, these properties represent the feature of resilience supported in a general overview by Rockfeller Foundations in management, planning and control of the whole urban system, including social, economic, political and environmental aspect.

More specific in their application is the Asian Cities Climate Change Resilience Network (ACCCRN), supported by the same foundation. In that experience, features were applied in two parts of the same system:

A. Agents or actors in urban systems - including individuals, households and private and public-sector organizations – whose should be featured by:
   - Responsiveness capacity to organize and re-organize in an opportune way; ability to establish function, structure, and basic order in advance of and immediately following a disruptive event or organizational failure;
   - Resourcefulness capacity to identify and anticipate problems, establishing priorities, and mobilize resources for action;
   - Capacity to learn as the ability to internalize past experiences, avoid repeated failures, and innovate to improve performance.
B. System that is potentially exposed; in that case, it should be featured by:
   - Redundancy as the capacity for contingency situations to accommodate extreme or surge pressures or demand;
   - Safe failure referring to the ability to absorb sudden shocks (including those that exceed design thresholds) or the cumulative effects;
   - Finally, Flexibility referring to the ability to perform essential tasks under a wide range of conditions, and to convert assets or modify structures to introduce innovative ways of achieving essential goals.

At the end of that discussion, the resilience meaning emerges as the feature of a kind of system (physical, anthropic, social, natural) exposed to a natural and/or anthropic perturbation in a general sense. Surely the characters that define resilience are strictly referred to different concepts:

- perturbation which create a disturbance in the system;
- risk management where perturbation combines with vulnerable system;
- vulnerability as the feature of the whole system or his element that identify the impossibility to react, in no way with the perturbation during the event, to easily and quickly react after the shock, and it is enable or unprepared to prevent or anticipate after the event;
- time in term of dynamical process that characterize every step of management and vulnerability but, at the same time it constitutes the main uncertainty in the management of inner or external changes);
- the persistence and the identity of the system after the new balance as the result of adaptive capacity and endured transformations.

The complexity of that concept, surely define the main differences between sustainability and resilience, above all focusing on the interaction of use of resources and city management.

Human, cities or development could be sustainable if they have “the ability to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland 1987) and so, it beats with scarcity of resources. In a certain sense, the oil crisis could be considered as the perturbation of the global human system, as well as the element which opened the analysis of interaction between nature and anthropic development. Moreover, sustainability and resilience are different concept and, at the same time, complementary.

The interactions between resilience and sustainability features, as complementary elements, were discussed in the Resilient Communities and Cities Partnership Program (ICLEI) in 2004:

“*How can a city be truly ‘sustainable’ if it lacks the capacity to reduce vulnerability to crisis and to respond creatively to change? This essential capacity can be described as ‘local resilience’. Therefore, a new agenda must be introduced in the sustainable* *cities movement. A Sustainable City must be a Resilient City. A Sustainable Community must be a Resilient Community".*

So, if the "sustainability" is mostly concerned with sustaining the 'stability' without requiring re-adaptation, "resilience" also accepts disequilibrium in the starting point to reach a new one that could be more "sustainable". At the same time, resilience distinguishes from sustainability because is not related exclusively to the maintenance of natural resources but also in transmission of these resources, acquiring the ability to compensate them in a different way (Ozel et al. 2013). Therefore, the two concepts, are inseparable and vital for the system but, also, resilience include the sustainability and became the key to enhance it (Common 1995).

2.2 STRATEGIES FOR CLIMATE CHANGES IN BUILDING SECTOR

Resilient experiences represent surely the new concept in management of actions to cope with climatic changes. In the United Nations Framework Convention On Climate Change system of actions to support that goals were identified where "The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects" (art.3, par. 3) (UNFCCC 1992).
In 2001 IPCC, creating glossary of climate change worlds, defined these actions as:

- Adaptation "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation";
- Mitigation "a human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs)".

That distinction derives from the impossibility to intervene simultaneously both in anthropic causes and mitigation of climatological effects.
At European scale, these goals were pursued following two different approaches.
Concerning Mitigation and restraint of emissions goals, the 2002/91/CE Directive, also called EPBD (Energy Performance of Buildings Directive), represented the most relevant European directive in energy retrofit. It introduced the "energy certification" of buildings, inciting European states towards the energy retrofit of building sector, because of his high relevance in total consumptions and emissions. Main goals of directive were: 22% of energy consumption within 2010 at European scale, reduction of 55 million tep of primary energy use and 100 tons reduction in CO_2 emissions. To support the control of these actions, EPBD identified two instruments for the evaluation of that energivor sector, focus on energy efficiency of:

- sub-systems of building envelope, introducing the necessity to evaluate each of them with quantitative values that vary in changing climate zones (referring to the Day Degrees);
- HVAC systems, introducing different indices of efficiency for Heating (and hot water if coupled) and cooling systems.

The 2010/31/CE directive replaced it, introducing the concept of nZeb buildings and disclosing the necessity to update quantitative standards for systems and envelope every 5 years, supporting the zero-energy consumption both for new constructions and existing buildings.

The high responsibility of the existing building could be read by the subsidy that European Community allocate to promote energy retrofit for them towards the high efficiency explicates by the quantitative values of envelope and HVAC systems performances. To support that priority action, the Covenant of Mayors (COM) (Covenant of Mayors 2012) initiative, as a citizen-based procedure, was launched in 2008, aiming at the exchange and apply best practices between European cities and towns (called "signatories"), concerning actions, planning strategies and final goals. Main and official instrument in that purpose is the Sustainable Energy Action Plan (SEAP) in which signatories state their targets in terms of CO_2 emissions reduction, including the key actions foreseen, both in the short and long term, along with the priority areas.

Concerning adaptation strategies, during April 2013 the European commission introduced three key objectives due to improve the climate-adaptation of cities; in this case, EC does not commit a quantitative result as in the mitigation case, because the specific requirements in term of adaptability is quite linked to the local needs and exposures to the climate changes. In summary, the EC proposed a widespread strategy which should promote:

- actions of adaptation at the national scale for each member state of the EU, supporting them by funding, for example the subscription to the COM;
- actions for the "climate-proofing" at European level focusing on agriculture, fisheries and cohesion policy, towards a more resilient infrastructure;

- platform to create an exchange of results and knowledges in Europe (called Climate-ADAPT), towards a continuous updating and monitoring of experiences due to create a solid and robust network to support decision-making.

Even if the European Commission recognized the differences between the large and local scale of exposures and interventions, it remarked the necessity to solve the problem involving different classes of expertise to operate in a holistic way, guaranteeing the active participation of inhabitants, while the coordination of them must be reserved to the legislative or executive authority of each State.

In Italy, the first strategy came in 2014 thank to the Ministry of the Environment and Protection of Land and Sea (MATTM) approving the National Strategy of Climate Change Adaptation (SNACC); pursuant to the general guidelines of European commission, it defines a series of interventions due to reduce the impact of climate changes on the environment, referring to the regions for the local context and exposures. The SNACC highlighted the complexity and the high exposure of cities in term of climate adaptation, above all for the built environment for which the local authority should intervene in a decisive way. However, it introduced three kinds of action of adaptation:

1. soft actions (monitoring, studies, land planning) due to promote analysis of climate changes in a downscaling approach, strategies and planning of urban areas according with the "mayor adapt" experience, integration of urban transformation and management plan for the existent built environment the creation of guidelines at the local scale and the collaboration and the education towards the adaptation to each kind of stakeholders (inhabitants, enterprises);
2. Green actions (preventive green infrastructures) to encourage green urban solutions to mitigate the extreme summer heatwaves, sensitize all the citizens;
3. Grey actions (protection constructions) to prevent risks linked to the disaster and for the absence of budget of intervention in case of calamities, and promote new model of dwelling to cope the climate changes.

So, the complexity of interventions, in a horizontal way between experts, as well as vertically from the authorities to the inhabitants, could be solved introduced a new way to manage the problem and above all through the knowledge it and its solutions.

2.3 MATERIALS AND TECHNOLOGIES FOR BUILDINGS IN CLIMATE CHANGES MITIGATION AND ADAPTATION STRATEGIES

As it is well known, building materials have a predominant role in the urban thermal balance as well as in their energy performance in term of absorption of incident solar and infrared radiation and dissipation of the accumulated heat through convective and radiative processes. For that reason, scientific and industrial fields moved towards traditional and innovative materials and technologies to support mitigation at built scale as well as to recover their fails. Cool, reflective and green are the most common adjectives associated to the roofs and discussed following.

2.3.1 DEVELOPMENT OF REFLECTIVE MATERIALS AND COOL ROOFS SOLUTIONS

During last years, "cool materials" are penetrating on building envelopes and open spaces for their specific peculiarities, contributing in a positive way in increasing reflection of solar radiation and dissipation the heat they have absorbed through radiation; for that reason, cool materials represent the main instruments both and consequentially in mitigation of urban heat islands and indirect energy improvement of buildings increasing the urban and surface albedo and maintaining lower surface temperatures. that generates a positive circle in research of innovative materials and techniques (Santamouris et al., 2011). At the base of their behaviour, there is the physic process in energy transmission at wide spectrum: Visible light (0.4–0.7 mm) contains 43% of the power in the air-mass at global solar irradiance spectrum (0.3–2.5 mm); the rest arrives as near-infrared (NIR) radiation (0.7–2.5 mm, 52%) or ultraviolet (UV) radiation (0.3–0.4 mm, 5%). A clean, smooth, and solar-opaque white surface reflects both visible and NIR radiation, achieving a solar reflectance of about 0.85. That purpose was reached using white materials as titanium dioxide (TiO_2), that reflects the energy in nearly all the sun's wavelengths (Gartland 2012), or lime (calcium hydroxide), well known for its whiteness, as the main element combined with acryl binder, to develop a cool white coating and concrete pavements (Santamouris et al. 2008) or adding it in light colour plaster for vertical surfaces.

In addition, materials can become cooler using different technologies; appropriate type of cool white/light coloured coatings are added as surface layers of traditional roofing materials - modified bitumen, various single ply materials, tiles and metals -. at the base of that process, two types of technical solutions could be recognised in cooling surfaces.

Cool roofs represent the main technological solutions in applying reflective materials, so their solar reflectance, or albedo, property applied in external materials, preventing overheating of both individual buildings and entire urban areas. Benefits of cool roofs could be summarized in:

- Reduction of building heat-gain maintaining surface temperatures of a cool reflective roof few degrees Celsius above ambient temperature during the day;
- Savings on summertime cooling consumption, in conditioned buildings; consequentially, reduction of air pollution and CO_2 emissions;
- Improvement of thermal comfort conditions in buildings not supported with air conditioning systems;
- Reduction of peaks demand guaranteeing the reduction of likelihood of power failures during extreme days, financial savings for electricity customers;
- Enhancing the life expectancy of the roof system reducing their exposure to UV degradation and thermal stresses;
- Mitigation of the heat island effect by 1–2 °C, decreasing heat transfer to the surrounding air.

Many studies have followed in order to evidence the usefulness of replacement of dark colour materials during routine maintenance of roofs; following, sponsored incentive programs, product labelling and standards were introduced to promote the use of high-albedo materials for buildings (Rosenfeld et al. 1995).

Cool roofing solutions can be classified in two types:

1. the widest cool white technologies for flat roof coverings in which field applied coatings (paints, fluid applied membranes, etc.), reinforced bitumen sheets made of modified bitumen (elastomeric or plastomeric), single-ply sheets and membranes (thermoset or thermoplastic), tiles (ceramic, concrete, etc.), asphalt or bituminous shingles, pre-painted metal roofs, built-up roofing are included;
2. cool colour technologies for sloped roofs useful to create surface that absorbs in the visible a specific part of the spectrum in order to appear having a specific colour but it is highly reflective in the near infrared (NIR) part of the spectrum. This results in an overall higher solar reflectance compared to a coloured surface of the same colour (same visible reflectance) that absorbs also in the near infrared part, taking into around that about 50% of the solar radiation falls in the NIR part of the spectrum.

In the first family, cool roofs achieve a high reflection over the whole solar spectrum, using white pigments such as titanium dioxide ($Ti0_2$) that could be dispersed in organic matrices such as acrylic or bituminous binders, but also in inorganic binders such as ceramic tiles and coatings; however, these technologies suffer performance decay during the time: in fact, despite their initial solar reflectance value (80–85%) and thermal emittance (80% to 95%), solar reflectance changes because of chemical and physical degradation of materials, biological growth and pollutant deposition. Recently, a method to evaluate aging in an accelerating way has been developed by (Sleiman et al. 2014). Different high technological solutions are studying in order to guaranteeing matrices and white pigments chemically and physically stable, to control surface porosity and roughness applying super-hydrophilic or super-hydrophobic surface treatments, or self-cleaning coatings based on photo-catalysis (Diamanti et al. 2013). Moreover, the most important requirement to limit degradation of cool white roofs is to introduce a slope ensuring storm water runoff avoiding stagnation areas.

Cool colour technologies are being developed for roof surfaces to undergo the formal landscaping constraints as in the centers of historical cities, using specific pigments with selective reflection (Levinson et al. 2004; Synnefa et al. 2007), or a production approach based on a multi-layered coating (Levinson et al. 2007). Cool colour technologies can be applied to either roofs or facades and other building surfaces not oriented skywards, but the presence of buildings that face each other and form the so-called urban canyon can cause the radiation that enters the canyon to bounce back and forth several times and not re-emerge (Takebayashi & Moriyama 2012).

In Europe, cool roofs potentialities have been supported by (Synnefa et al. 2007; Synnefa et al. 2006) and European Union started in promoting high-albedo surface co-funding the Cool Roofs Project by the (Synnefa & Santamouris 2012). The consequent European Cool Roof Council (ECRC) has been founded aiming to bring together all the relevant actors in the field of cool roofs, from the research and production phase to the end use, but also in dissemination of potential energy savings and economic enhancing of their market penetration. Moreover, ECRC support technical activities introducing the "cool roof database": it is an electronic tool created to present available products in European Market; every product is supported by his technical report on physical properties referring to optical and thermal features, maximum surface temperatures but also to the time of decay and consequent new values (Synnefa & Santamouris 2012).

2.3.2 REFLECTIVE PRODUCTS AND PHASE CHANGE MATERIALS COMBINATION

In addition to positive effect of cool materials, researchers combined latent heat storage materials with solar reflective materials in order to exalt their positive effect in surface temperatures.

In detail of physical behaviour, PCMs offer to storage energy taking advantages of natural process of change of phase -from liquid to solid and vice versa - reducing temperature swings. Usually, PCMs are organic or inorganic elements enclosed in polymer exterior shell: that microencapsulation technique provides increasing heat transfer area, the reduction of PCMs reactivity towards the outside environment and control of the changes in the controlled volume. According to the basic functioning process, PCMs have specific melting temperatures in phase change that represents the main refers features in application choice. Moreover, that feature change considering the nature of the ingredient. In building applications, organic PCMs are preferred for their chemical stability and high heat of fusion (Karlessi et al. 2011).

To develop the specific heat latent – high reflective product, PCMs were incorporating or combining with cool materials to create a composite featured by high solar reflection and high latent capacity. this technology mainly involves doping microencapsulated phase change materials (PCMs) into solar reflective (white or NIR reflective) coatings (Karlessi et al. 2011). Combining them, surface temperature control is amplified: in fact, during pecks of temperatures, the PCMs absorb part of the heat through the phase change process (from solid to liquid); on the opposite, during the cooler night time, the PCM solidifies again and releases the stored heat. In that double process, the net effect is the reduction of the daytime surface temperature of the material and so both in heat flow from the surface to indoor space and from surface to the ambient environment. For these reasons, PCMs used in building structures have the potential to reduce and delay the peak heat load leading to important energy savings and improvement of thermal comfort conditions (Karlessi et al. 2011).

2.3.3 GREEN ROOFS AND BUILDING PERFORMANCES

Green roofs represent the external part of roofs covered by a vegetation layer. Differently from cool roof that constitute simple solutions in installation for new and existing buildings, the green roof is a more complex technology; usually, it is compound by several layers including from down to top:

- the structural substrate of the roof,
- the waterproofing membrane,
- the root barrier,
- the thermal insulation layers (as predominant thermal layer of structural horizontal part of roof),
- the drainage, aeration and retention layers,
- the filter fabric, avoiding small particle to clog the drainage,
- the growing medium (soil), including the irrigation system if needed,
- and finally, the vegetation layer.

First classification of Green roofs is related to the type of vegetation layer representative of extensive and intensive greenery; near to the simply variation of types, different level of complexity in technology and maintenance are included. In fact, extensive solution requires no maintenance in general and limited water needs because of his superficial and light technology. On the contrary, Intensive green roofs are real gardens where usually vegetation layer is featured by shrubs and trees; for these reasons, it represents a more expansive solution in maintenance and technology of structural part of sublayers. A further class, the semi-intensive green roof, is also used in some cases (Theodosiou 2009).

In addition to their formal aspects, green roofs contribute in increasing thermal insulation for his vegetal soil layer (Theodosiou 2003; Wong et al. 2003), improving the level of sustainability in buildings and urban air quality (Takebayashi & Moriyama 2007), extension of roof life in reducing solar gain absorbed by roof structure (Ayata et al. 2011), enhanced architectural quality and biodiversity. During recent years, green roof technologies were included as key technology to interplay with outdoor air condition in order to mitigate the urban heat island phenomenon (Gaitani et al. 2007; Santamouris 2014a); in fact, planted roofs have usually much higher albedo values than traditional dark urban roof surfaces (Getter & Rowe 2006).

Actually, mitigation performances and potentialities of green roofs depend on several (micro) climatic parameters - air temperature, solar radiation, ambient humidity, precipitation and wind speed – that constitute the boundary conditions for the green roof system thermal response. However most important parameters that define green roof potentialities are:

- Thermo-physical properties of each layer of the roofing system (density, thermal capacity, thermal conductivity, thickness);
- Water content of the growing medium, referring both to irrigation systems and precipitations;
- Vegetation layer properties, in detail for leaves emissivity and solar reflectance, stoma resistance, leaf area index (LAI).

Focusing on vegetation layer, Detailed analysis performed in (Hodo-Abalo et al. 2012) on the rate of evapotranspiration from a green roof has concluded that the Leaf Area Index is the key parameter defining evaporation losses.

Several studies demonstrated the potentialities of green roof in improving the thermal and energy performances of the built environment, either during the heating and cooling season (Zinzi & Agnoli 2012). In fact, analyses of the latent heat flux magnitude were carried out at numerical, theoretical and experimental level (Santamouris 2014a) founding that fluxes vary in the 100–600 W/m^2 in changing site of analysis, building and green roof characteristics. As an example, climatic parameters were analysed in (Kolokotsa et al. 2013): in the island of Crete, Greece, it was found that the maximum sensible heat flux is 157 W/m^2 referring to a conventional roof, whereas the value decrease to 104, 70, 33 and 21 W/m2 for respectively 0.5, 1, 2 and 3 leaf area index. Moreover, analysis was also carried for London, focusing on differences of climate to the Mediterranean: the maximum sensible heat flux associated to a conventional roof is 87 W/m2, the value decreases to 56, 37, 17 and 10 W/m^2 for respectively 0.5, 1, 2 and 3 leaf area indexes.

Referring to the wide review of mitigation technologies, reflective and green roof performances were discussed; Santamouris (Santamouris 2014a) concluded that green roofs may present a similar or higher performance in high values of latent heat and in very intensive and well irrigated green roof system.

Studies show the potentiality of the green roof technology also in reducing the sensible and latent heat released to the urban environment and, consequently, mitigating the urban heat island phenomenon. However, main findings are that green roofs are more effective when the roof height is below 10 m with respect to the street level and that benefits decrease with the distance from the roofs (Wong et al. 2003). However, the topic still needs to be investigated in order to exploit the potential technology and support their market penetration, making the technology more cost effective, because of his main disadvantage in initial cost of installing that can be between two and ten times more than a conventional roof (Ferreira da Rocha 2014).

Focusing on efficacy at building scale, green roof functioning represents a complex matter. Impacts on rooftop surface temperatures and heat fluxes is usually performed by experimental measures; however, that process cannot be translated into direct knowledge of the impact on the energy use in a building, above all in evaluation of efficacy in Building Energy Model simulations. For that reason, different modules of simplified calculation processes are implemented. The widest used is represented by fast all season soil strength (FASST) model developed by Frankenstein and Koenig (Frankenstein & Koenig 2004) for the US Army Corps of Engineers, because of his implementation in EnergyPlus engine calculation. The green roof is modelled as a single vegetation layer on a soil surface. The vegetation layer model is a steady-state semi-infinite plane panel characterized by an emissivity, albedo, height and foliage fractional coverage that influence the heat exchange between the soil layer and the adjacent air. Soil is modelled as a homogeneous layer through which sensible and latent heat flux pass. The green roof model considers the following phenomena:

- long wave and short wave radiative exchange within the vegetation layer including the effect of multiple reflections between vegetation and soil layers;
- vegetation layer effects on convective heat transfer;
- evapotranspiration from the soil and plants;
- heat conduction (and storage) in the soil layer.

3. HISTORIC URBAN DISTRICTS IN MEDITERRANEAN AREA AND ENERGY RESILIENCE

3.1 MANAGEMENT OF HISTORIC URBAN DISTRICT AND HIS BUILDINGS AS "A WHOLE"

The high relevance of cities in management and planning, at built scale, the interrelations of social, economic, cultural and environmental issues surely should be combined with complexity and nature of the built setting.

As a specific focus of period of constructions, in Europe 35% of buildings are 50 years old and 14% were built before 1919 and 12% during the period 1919-1945 (Economidou et al., 2011). However, much less of them are currently listed but they make part of the cultural heritage of European countries and gives identity to cities, villages and public spaces.

In that stock, historic buildings in city land can be assessed as single cases or in specific areas as aggregation of them which, usually, refers to the historic part of the city, called "old core" or "historic center". Differently from the first, historic centers represent a value in the historic urban landscape (UNESCO 1976).

Historic centers could be associated to the vernacular practise, referring to the experience related to a place and which identify it. As defined by Cervellati and Scannavini (Cervellati & Scannavini 1973), they represent "an urban settlement where buildings, entities, men and environments exist and should be – physically and socially – preserved". In this sense, in fact, the whole system of an historic center could be considered as the result of three levels of interaction, as socio-cultural, socio- economic and environmental, both during its creation and in actual state. In detail:

A. Environmental level refers to the interactions between that built with the local and current climatic condition as well as the evolving environment during the time (Achenza and Glovagnorio, 2014).

   Considering the association of vernacular dimension with the historical urban district, some inherent elements could be recognised in term of bioclimatic and sustainable behaviours. Vernacular architectures are associated to the best way to exist within an environmental context (Oliver 1997) in:

   - Respecting nature using natural, renewable, recyclable and organic materials within the immediate proximity of the selected location; as the same, it is ensured integrating them in land morphology and providing protection and shelter to people;
   - Appropriately situating according to terrain qualities and climate, defining different solutions (shading elements, orientation, ventilation systems) (Vegas et al. 2014) and types (courtyard and porches) (Dipasquale et al. 2014);
   - Reducing pollution and waste materials using materials obtained from) the geographical area where the buildings were erected and handmade transformed, usually organic, renewable and biodegradable (Fernandes, Mateus, et al. 2014);
   - Mitigating the effect of natural hazards according to the sites and the necessities, introducing permanent solutions well integrated in buildings or temporary (nets, ropes, ground anchoring systems, moving shelters, etc.) (Caimi & Hofmann 2014).

   According to them, Mediterranean city is often associate with the best way to create "architectures" referring to the "types" but also as the best way to manage the urban distribution of them; in detail, some specific inherent qualities could be summarized as it follows (Fernandes, Dabaieh, et al. 2014):

1. compact urban layout reduces the number of surfaces exposed to the sun, above all during the summer; this technique is the most used in hot climate as a responsive feature to the critical hot months; the urban assessment could vary in order to the historical requirements; near to that reason, the final solution of compact layout is the result of the combination with others: as an example, as reported by Bouchar et al. (Bouchair et al. 2013), settlements in the hot climate of Algeria are generally encircled (Figure 3.1-1) with a wall for defence purposes and to prevent high velocity winds and sand storms from penetrating into the settlement during the day;

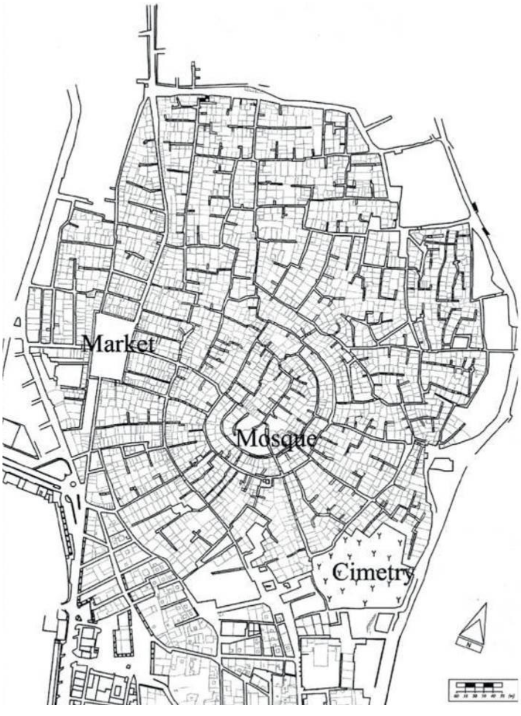


Figure 3.1-1 Plan of Ghardaia Ksar. Source of (Bouchair et al. 2013).

2. narrow streets and covered galleries protect pedestrians from harsh summer periods; the main difference is the place where "protection" is reached, as well

outside or inside the volume of buildings. That difference solves in two solutions: in the first one the distance between the façade, so width of streets, constitutes the defence solution, whereas in the second one, that paraments could be increased leaving to the arcades the predominant role (Figure 3.1-2).

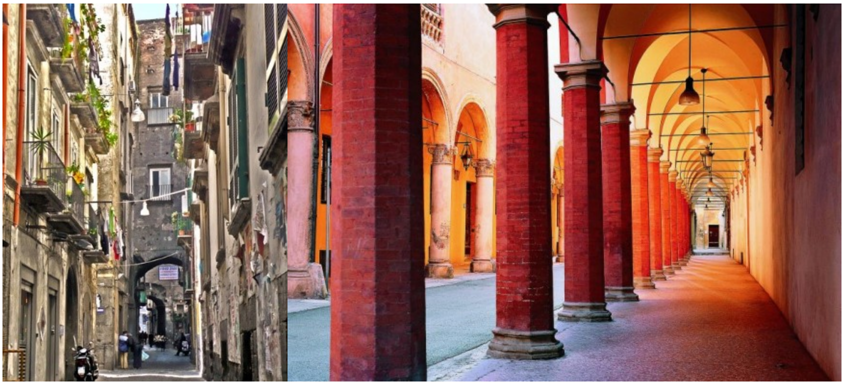


Figure 3.1-2 A) Narrow street of Neaples. B) Archades of Bologna.

Near to the urban layout asset, several studies linked the “types” and their technologies to the climate. At the building scale, the most recurrent solution could be summarized in (Fernandes, Dabaieh, et al. 2014):

1. building’s form is typically compact and usually arranged creating patios in urban areas;
2. orientation when buildings seek the south quadrant to maximize solar gains in winter and to reduce them during summer;
3. proper shading for windows using fix or mobile screens when heat gains are not desired;
4. minimizing the size and number of openings reducing heat gains;
5. using fountains and pools, usually placed in patios and cloisters, aiming at cooling air by water evaporation;
6. using vegetation to provide shade and to increase air moisture via evapotranspiration process, helping to cool the air streams before reaching the building;
7. the use of local materials, mainly earth and stone, that perfectly suited to local climate; their good heat storage capacity stabilizes indoor temperature that remain cooler during the day and warm at nigh);

8. the use of light-colors for the building envelope, and especially the roof which is the most exposed to the sun, aims at the reduction of heat gains by reflecting solar radiation.

Referring to these features, diverse types of buildings are described in literature as representative of the interaction with environment. The courtyard house is the widely representative type in hot climate: in fact, his presence is common in Arab countries - coupling two of them – or in Moroccan mountains and it represents the solution to ensure both vertical and horizontal ventilation or only the vertical one, respectively (Coch 1998).
Despite that, the environmental variations combined with and provoked by the human activities could generate an un-sustainable state, above all considering the actual emerging crisis of climate changes hazards, discussed in previous phase.

B. Socio-cultural level of interest focus on the social belonging to the places and the material and immaterial culture they represent (Guillaud 2014).
Main socio-cultural value of that heritage is kept in UNESCO definition (UNESCO 1976):

"ensembles of any group of buildings, structures and open spaces, in their natural and ecological context, including archaeological and palaeontological sites, constituting human settlements in an urban environment over a relevant period of time, the cohesion and value of which are recognized from the archaeological, architectural, prehistoric, historic, scientific, aesthetic, socio-cultural or ecological point of view".

Consequently, historic urban districts are representative of hundreds of years in optimisation of interaction between human mind and experience gathered by observing phenomena (Engin et al., 2007) aiming at providing comfortable shelter in a local climate using available materials and known construction technologies (Bodach et al., 2014). That can be summarized in the "genius loci" experiences, testimony to mankind's capability of adaptation in its living contexts, and of its deep respect of nature. In fact, according to the Quebec Declaration (ICOMOS 2008), the "spirit of place" is defined as

"*the tangible and intangible, the physical and the spiritual elements that give the area its specific identity, meaning, emotion and mystery. The spirit creates the space and at the same time the space constructs and structures this spirit*".

Transposing the concept of vernacular architectures in that kind of traditional buildings groups, they offer the possibility to recognize

- how cultural landscapes were modified by craftsmen before the industrial era using their capacities coupling human needs and adaptation necessity deriving from boundary natural conditions;
- how societies were collective as a more complex view to live, not nearby but together; that reflected the necessity both to live in proximity to work and spiritual places and to create collective places (markets, squares).

The recognition of their local identity involved in management of that heritage at local scale. In fact, control and refurbishment are transferred to national authorities and then to urban planners following common and accepted recommendations (ICOMOS 2011) that concern also safeguard and maintenance of building heritage, discussed three main elements as following:

- analysis of archaeological, historical, architectural, technical, sociological and economical values, aiming at the complete knowledge of them, as main tool in safeguarding values;
- diagnosis investigation as tool in recognizing affections are necessary to the preventative measure of repairs and improvement of actual human needs;
- transformation process should pursue the sustainability of the project, the inclusiveness and suitability of solutions in a long-term perspective, according with principles of persistence of them;

C. socio-economic level of interest concerns the resolution between needs and conditions of inhabitants (M. Correia et al. 2014).
Self-sufficiency represent one of the principles in genius loci activities in resolution of its needs that moved in efficiency of use of resources, land, materials and their persistence and maintenance along the time. During the time, improvement of industrial production and contraction of handcraft activities determined a crisis in self-management of that heritage, often a result of rapid and inappropriate solutions. However, their maintenance can support, in a sustainable way, the reduction land use in accommodating home needs. In fact, during the urban assessment strategies, the importance of the re-use of existing buildings was underlined during the '70 with the concept of "urban sprawl"; it is the result of the un-controlled growth in a horizontally way that characterized most of European cities along that period, coupling the necessity to create new dwellings for rural inhabitant which moved into the cities. In that historical phase, urbanists introduced the necessity to regulate the historical centres as a part of the city with specific planning activities, safeguarding it recovering them after their phase of abandon: the absence of their transformation instrument at urban scale, the development of new urban suburbs built with reinforced concrete, the high costs of maintenance of masonry construction compared with the cheapest of new technologies of construction (reinforced concrete) and the crisis of handicraft, produced the abandonment of the dwellings in the historical centres and their state of neglect. However, urban planning instruments was strictly related to the stability and healthy features of the dwellings, in order to guarantee the minimum condition to live herein. The main actions that planning strategy and law allows are strictly the ordinary/extraordinary maintenance, and restoration, until now; as of today, the obligation to preservation and the necessity to guarantee the safety to the inhabitants create slow actions of renovation and in some small cities this process is yet underway. To highlight some numbers, the 35% of European buildings built more than 50 years ago, counts more than 30 million dwellings (Troi, 2011) that, translating in people,

guest about 120 million Europeans. In detail, UK, Spain, Italy, France and Germany represent the most "affected" States, in that sense, in absolute value.

In detail of Italian case as example, the 28% of the national historic stock (built until 1919) is featured by mediocre and bad state of conservation even now (Istat 2011; Table 3.1-3).

State of conservation	excel-lent	good	medio-cre	bad	Total built stock (2011)
Buildings built before 1919 in Italy	420 010	896 196	441 737	74 561	12.187.698
	23%	49%	24%	4%	15%

Table 3.1-3 Relevance of Italian built (ante 1919) for state of maintenance. Source: ISTAT, 2011

State of conservation	excellent	good	mediocre	bad
North – Est	104423.00	155186.00	67292.00	12193.00
	31%	46%	20%	4%
North - west	143992	289503	133537	20648
	25%	49%	23%	4%
Center	98908	195793	74391	9721
	26%	52%	20%	3%
South	53516.00	198556.00	122889.00	20249.00
	14%	50%	31%	5%
Islands	19171	57158	43628	11750
	15%	43%	33%	9%

Table 3.1-4 Relevance of Italian built (ante 1919) for state of maintenance and geographical position. Source: ISTAT, 2011

Despite that, the system of management of historical building retrofit and preservation at Regional and local-urban scale creates a discrepancy in term of efficacy and application of several urban planning. In fact, according to the statistical data for Italian macro-areas (Table 3.1-4), south of Italy and Islands (Sardinia and Sicily) are less virtuous in Italy, where bad properties can be recognized in 36% and 42%, respectively, where, their improvement create a relevant opportunity in re-using them.

Finally, maintenance of historic district represented and is representative of another internal socio-economic support and development: tourism. in fact, above all in Europe, the cultural heritage is one of the oldest and most important generators of tourism (Thorburn 1986) that support local economic growth – services and infrastructures, and enhance the awareness of local potential and, so, identity.

That multilevel and multi-effect relevance represents the main core of Versus project (Mariana Correia et al. 2014) that defined and summarized the sustainability of traditional built environment at three levels from which fifteen principles derived for their management (Figure 3.1-5).

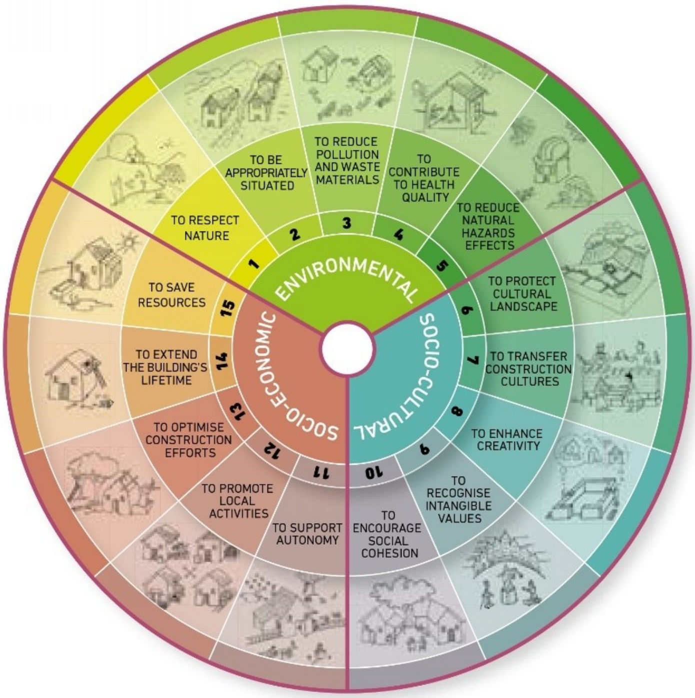


Figure 3.1-5 Wheel of environmental, socio-cultural and socio-economic sustainable principles of VerSus project. Source: (Mariana Correia et al. 2014)

3.2 *ENERGY RETROFIT FRAME FOR HISTORIC BUILDINGS IN ANCIENT CORE*

The European energy strategy aimed at reduction of consumption and CO_2 emission in Europe paying attention on the high responsibility of existing building stock – that represent more than 60% in Europe - featured by a low efficiency. In fact, looking to the built sector, the annual rate of new constructions is about 1% in the European Community (Economidou et al. 2011), while the wide interventions are referred to the energy retrofit of the wide existing building stock (International Energy Agency 2015). In fact, according with the European commission, 40% of energy consumption (EPBD, 2010) – and similar percentage for emissions (European Environment Agency 2004) – is related to the buildings sector that, as described before, because of low levels for energy efficiency and the use of not-renewable sources in residential buildings. According with the highlighted percentages, European historic buildings are part of them with a relevant share; however, during last decades, management and planning activities at various levels focused on their maintenance and refurbishment according with the fundamentals of persistence of their cultural and formal values. That was in line with the necessity to guarantee an acceptable level of health and security to their inhabitant. On the contrary, until now, this part of building stock is excluded by national or regional strategies of energy retrofit despite active participation to the global disequilibrium in consumption and GHGs emissions. In fact, the EPDB directives, introduced an exception on the historic buildings measures of energy efficiency: “Member States may decide not to set or apply the requirements referred to in paragraph 1 for the [...] buildings officially protected as part of a designated environment or because of their special architectural or historical merit, in so far as compliance with certain minimum energy performance requirements would unacceptably alter their character or appearance, etc.” (Point 2, art. 5, EPBD 2010/31/EU).

These historic buildings should comply with the EPBD requirements limited to energy certification and operation aimed at maintenance and inspection of technical installations. however, according to a recent study made by Building Performance Institute of Europe, “minor and moderate interventions might be performed also in case of heritage buildings” in order to achieve Energy and CO_2 reduction by 2050. In fact, they say that “these buildings are not excluded (from the energy renovations) because there will always be some energy efficiency measures that can be applied, even if it is not a total renovation. Minor and moderate measures may often be feasible in the case of heritage buildings”. So, if the energy retrofit activities in existing buildings are considered challenging because of the significant opportunities for reducing primary energy consumptions, on the other hand the problem in linking energy improvement to building protection arises when the intervention can be evaluated “invasive” in historical buildings. The main point is how to identify the “unacceptable alteration” the EPBD directives is referring to or “the minor and moderate interventions” that might be done.

According with EPBD, in the Italian law a derogation regime has been implemented for historic (i.e. protected) buildings as foreseen in the EPBD directive, which is based on the judgement of the competent authority. However, the Law does not specify how to comply with the EPBD requirements if the historic (i.e. protected) building may partially undergo to renovation or only rehabilitation or restoration. No mention at all to those building which are comprise in the category of historical buildings potentially declarable protected, as those in historical centres, which are equated to the contemporary existing buildings. However, the possibility of “minor or moderate intervention” has only partially been solved involving the competent Authority to declare if or if not, a historic building may undergo to a full or partial renovation, but there are no general rules to define all the intermediate cases (rehabilitation, restoration, etc.) and what are the most compatible available energy retrofit technologies.

In that frame two levels of complexity could be highlighted:

- In one hand, the difficult to divide the way to consider buildings not protected and protected ones in the energy efficiency procedures, considering the higher

level of preservation of “landscape heritage” and his elements, as well the buildings that compound them;
- On the other one, the real effort to merge preservation and transformation towards the energy efficiency, also considering the complexity of multilevel needs that provoked their transformation during the time and without an institutional instrument of supervision.

Clearly, these buildings in historic centers can be currently included in the inefficient residential sector because of their inefficiency – above all in envelope system – and for the use of non-renewable sources. In fact, the introduction of traditional renewable energy systems is avoided because of the high relevance of their invasiveness. These elements support the “energy poverty” of that kind of buildings, according with the elements discussed in chapter 2, sect.2.

For these reasons, energy retrofit of historic district is at the centre of attention by the scientific community, even now. The main purpose is the conciliation between the embodied values that require to be protected and safeguarded (Fusco Girard et al., 2002) and conventional energy retrofit transformations, preserving principles conformed to cultural restraints (Della Torre et al. 2010).

The European experiences, supported by European funds, took on this challenge studying methodologies and strategies on public and private buildings, e.g. SECHURBA (Sustainable Energy Communities in Historic Urban Areas) and New4Old (New Energy For Old Buildings); nevertheless, they have mainly focused on the analysis of singular cases that cannot be reproduced systematically for other ones, but they constitute the way to recognize how energy retrofit can be supported, proving advices and guidelines based on these case studies.

Consequentially, several studies follow these experiences highlighting that energy retrofit of single building should be supported by the assessment of the actual behaviour of the fabric, based on direct investigation, in order to carefully define residual performances and their technical features – materials, construction techniques, geometry - and, thus, efficient interventions in full compliance with their low invasiveness, high chemical, physical and mechanical stability and consequent low reactivity with existent

building elements (Litti et al. 2015; Giuliani et al. 2016; Roberti et al. 2015; Cornaro et al. 2016; Cantin et al. 2010)
Moreover, focusing on the environmental qualities of traditional buildings discussed in previous paragraph, other results follow the aim to enhance inherent bioclimatic qualities for air and heat passive control (Cardinale et al. 2013; Anna-Maria 2009; Canas & Martín 2004), focusing on case studies that usually can be referred to the inherent behaviour of specific built, e.g. courtyards.
Finally, as determined element in overcoming the dichotomy between necessity of transformation for the energy improvement and preservation of their formal values, jointing application of traditional and highly innovative retrofitting techniques in order to guarantee compatibility, reversibility and efficacy of intervention [FP7 – 3ENCULT] [FP7 - EFFESSUS]; in that field of research, several materials and technological solutions were analysed and supported also borrowing them from other markets; some examples:

- Phase Changing Materials (PCMs) (Shilei et al. 2007; Zhang et al. 2007) to improve thermal inertia of envelope sub-system using their store large amounts of heat in order to melt above a certain temperature and, thus, to mitigate the summer temperature peaks and to reduce the cooling loads, as discussed (Cpt. 3);
- Aerogel as high performing insulation material (λ=0.015/0.018 W/mK) (Jelle 2011; Soares et al. 2013; Stahl et al. 2012) that ensure the use of low thickness to achieve the required thermal transmittance; during the EFFESUS project [FP7 - EFFESSUS], two technological products have been created with aerogel:
    - A composed aerogel with polyester useful to fill up the masonry cavity preserving chemical stability, high mechanical resistance, vapour permeability and good values in thermal conductivity (λ=0.0255 W/mK) and density (70 kg/m3);
    - A thermos-plaster based on lime composition, perfectly compatible with traditional plasters and it maintains suitable properties of native siliceous material (λ_{10} = 0,0261 W/mK).

However, considering the complex level of bureaucracy that features the transformation processes of buildings in historic districts, the use of case-by-case strategy cannot be appropriate. In fact, due to the absence of a disciplining instrument for energy retrofit actions at local scale – according with the preservation of the local identity purpose-, public administrations cannot control the transformations during the time. Moreover, the time for retrofitting the whole historic district drew-out and the transformation actions, although technically correct, overcoming isolated and fragmented actions that alienate the singular building from the *unicum* of the context. For those reasons, the historical districts required, in term of energy strategies, a systemic vision in order to compensate some operative constrains for single buildings with the opportunities at the large-scale that are mainly related with the genius loci activities and inherent bioclimatic characteristics (Fatiguso & Caivano 2010). In that field, benchmarking categories for ex-ante assessment and ex-post control were introduced, given that the historic built heritage, despite its heterogeneity and variety, shows some recurring architectural, constructional and functional characteristics for specific building typologies and ages [IEE - TABULA] [IEE - EPISCOPE]; finally, to support the concept of the local dimension of historic buildings, the centrality of the context is introduced, which is not only the geographic-environmental background, but, according to the concept of "geo-cluster", a "transregional area with strong similarities in terms of climate, culture, behaviour, construction typologies, technological solutions and available products", in order to address the processes to the specific features of the local territory and community.

3.3 ADAPTATION EXPERIENCES IN HERITAGE

The IPCC introduced a focus on Cultural Heritage and Landscape in 2014 (Field et al. 2014)focusing on the Regional centrality of Europe that “has unique rural landscapes, which reflect the cultural heritage that has evolved from centuries of human intervention”. This report re-organizes all the scientific literatures that, however, focus on the extreme event that could affect material preservation from thermal stresses, e.g. thermal stresses of marble, changing traditional flux of tourism during the summer period and maintenance of collections in museums. While, a specific focus on the responsibility of residential sector on GHGs and consequent relevant contribution in mitigation could be found in the same report, while specific guidelines have not been added for historic residential buildings; that is the consequence of the lack in European and national regulations in term of their energy improvement.

Nevertheless, some scientific European studies and projects (AMECP, LASERACT, Noah's Ark, Friendly Heating, EUROCARE EU-1383 PREVENT, OnSiteforMasonry, SMooHS, Climate for Culture) focused on the exposure to climate change of listed cultural heritage highlighted some evidences in strategies:

- The necessity to evaluate their exposures in different period and location in Europe, analysis where made focusing on type of buildings, in term of their use and function (e.g. museum and churches) and material characters;
- Comparable instrument of weather conditions for analysis are needed to provide the classification of behaviour at required scale.

In that sense, as an example, in Climate for Culture project the complexity of analysis at European scale was highlighted; in fact, Regional Climate Models often couldn’t be representative of high scale of reference and it was supported by the local climate data of some Specific weather tools as Meteonorm (Remund et al. 2017); the project supports the analysis of single case studies in order to provide a categorization of them, in a general overview, in different boundary conditions, with particular focus on climate and energy requirements, material preservation of building envelope and contents of buildings (e.g. portrait and sculptures in museums).

3.4 PERSISTENCE OF HISTORIC DISTRICTS AND BUILDINGS AND ENERGY RESILIENCE

Cultural responsibility of technician and public administrators in ensuring preservation of heritage in a long perspective embraces two necessities for residential buildings in historic districts; firstly, the obligation to respect and preserve their formal, historical and cultural values, guaranteeing the transmission to future generations because of the relevance of their local identity; on the other hand, to ensure their liveability according to:

- Their actual socio-economic relevance in existent built stock;
- Necessity to ensure economic sustainable level of wellbeing for inhabitants in term of health, security and comfort indoor;
- original cultural relevance of their functions.

These elements are surely dependent to the well accepted relation that links heritage and his maintenance in Ruskin's lemma "the use of it ensure that it persists" (Ruskin 1872). At the same time, the concept of persistence overgoes the feature of sustainability including it in the resilient one, as discussed in chapter 2.
Moreover, resilience feature is recognized as an inherent behaviour in heritage because of the basic necessity of genius loci activities (Ripp 2013) in creating a persistent system recognized

1. by way of design and construction referring to the spatial configuration and construction design that often represented the inherent way of energy efficiency; compactness of enclosed historic districts can be representative of inherent robustness features of resilience; moreover, the massive way of construction represents the way to ensure along the time robustness;
2. by way of appropriate materials: in fact, the use of suitable solution and techniques, surely ensured that the formal aspect could be preserved and they could be easily repaired. In addition, the use of locally materials, surely increased this resilient aspect that, on the other hand, helped craftsman work that it was widespread on the local areas.

At the same time, recognizing the necessity to intervene is the first step to prevent the emergency. Looking to the past, the recovery planning of historical districts and their buildings started during the emergency and crisis phase with the recognition of low levels of stability and healthy features but no preventive actions has been founded before (Fatiguso et al. 2017). In that sense, the crisis for the heritage should be considered an opportunity. In fact, in line with the necessity to cope with changes and learning from the past mistakes – e.g. the lack in planning and management of maintenance of several buildings that lost their purposes (castles, monasteries) –, planning and anticipation of the crisis represent the opportunity to understand their vulnerabilities and to decrease them, so, increase the resilience towards future uncertainties. In that frame, Resilience should be introduced also as a feature of Planning activity aiming to couple the necessity to serve short-term (e.g. stability, comfort indoor and energy efficiency) and long-term necessities (maintenance, extreme events), guaranteeing preservation of formal and cultural values. Similarly, exposure to external variations should be evaluated in the actual state, but it requires to be re-evaluate considering the variability of the future that now can be determined by probabilistic approach and algorithms.

Focusing on energy management and the necessity to couple mitigation and adaptation actions, historic districts and their buildings require this point of view in planning a strategy of their energy retrofit. In fact, concerning the energy crisis, the high level of deficiency in that building stock, the energy poverty recognized in implementation with RES, the exposure of Mediterranean area to the future increasing temperature and the absence of a robust strategy to solve them reframe the actual system of vulnerabilities of that stock.

In fact, in a static point of view, energy retrofit is usually associated to the recognition of actual residual performances and technical-normative deficiencies – referred to the qualitative standards defined by national normative – and transforming them, preserving the cultural and formal values; on the contrary in a dynamically and in as “a whole” perspective, it represents the opportunity to recognize

- inherent behaviours as their adaptive capacity in local micro-climate variation and reaction in energy requirements (e.g. bioclimatic features),

- vulnerabilities as weak elements both in energy threshold requirements at actual state and in level of reaction to external changes
- and the level of transformability that ensure their variation preserving the persistence of the system in long term perspective.

Therefore, correlation between energy improvement of historic buildings as elements of a whole and effects of global uncertainties and local micro-climate changes introduces the possibility to borrow the wider concept of "resilience" and focusing on the energy declination and manage the interactions with environmental sphere.

Summarizing, environmental external conditions and the complex system interact dynamically at different levels as reported in previous analysis of processes where, in depth:

- each historic district is in a city in Mediterranean area featured by a local and actual typical weather – as the result of an extended period of observation -, uncertain future conditions based on a stochastic approach and by a specific relation with the boundary environment;
- the system, as the combination of "canyons", participates locally in altering external local climate conditions because of the specific position in the city, morpho-asset and vertical distribution of blocks and material features, creating a new one at micro-scale;
- finally, buildings constitute elements of main energy interaction with modified micro-climate for the external heat gains and emissions, as well as reacting to generate a consequent indoor condition.

In that scheme, adaptation level of the complex system is representative both of reaction of the system of canyons and buildings, while buildings embody the opportunity to enhance the level of adaptation of the complex system and improve their energy efficiency pursuing the mitigation aim.

In that frame, "energy resilience" could be introduced in their energy Improvement as the feature of the specific system aiming at a large time lapse strategy; in fact, it is based on his "capacity to undergo to the external changes, adapting and transforming itself in order to ensure his persistence" borrowing the widespread resilience meaning of UNISDR and ecological system feature (Folke 2006) and including the necessity of preservation and transmission of that resource, where:

a) Adaptation sub-feature represents the inherent capacity of the system and his elements to adapt to external variations, reacting in a positive manner; the capacity of the district to reduce local external features that generates distresses at building scale, as well as the capacity of building characters to support indoor quality can be included. similarly, their negative responses in behaviour are representative of deficiencies of elements and so, the system of vulnerabilities of the district;
b) on the other hand, transformation ability is the inherent character of the elements that offers to go beyond the deficiencies, repairing and enhance the complex level of adaptation.

The focus on buildings opportunities derives from the general aim to preserve the formal landscape of historic district as “a whole” and to observe opportunities in transformability at elements scale.

Focusing on the parameters of resilience discussed in chapter 2, adaptation capabilities of system and his elements are evaluated analysing two specific of them:

- Robustness as the capability to remain in thermal stability or in an acceptable state during the time;
- Redundancy as the feature of combined elements that ensure the acceptable state, during both typical and extreme periods.

In addition, transformation capability of elements is evaluated according to:

- Safe failure as the predominant character that links energy deficiencies emerged during the evaluation of adaptation capacity and the opportunity of transformation, aiming to enhance them;
- Flexibility as the inherent capacity to be easily transformed;
- Resourcefulness referring to the ability to accept new materials aiming at the improvement of final properties.

As analysed before, in addition to the necessity to monitor external features of environmental boundary – climate and land uses - and consequentially the reaction at district scale – micro-climate variation and uses of buildings -, real energy needs and thermal features of buildings represent another main problem in management of the complex built system due to their prolonged and unplanned previous transformation and creation. Unfortunately, historic districts are representative of an historic overlapping process that create the actual specific urban asset, several combinations of construction details and different state of maintenance. Despite that, some recurrent elements in urban asset and technological solutions became representative of the wider optimal way to build it and should became the main way to analyse them as macro-representative behaviour. In that sense, the concept of "geocluster" - as "transregional area with strong similarities in terms of climate, culture, behaviour, construction typologies, technological solutions and available products" - can support the large-scale analysis, coupling building, canyon and climate type to recognize and solve local behaviours [FP7 – GE2O; (Lombardo & Cicero 2015; Pizzi et al. 2013).

Referring to the management of energy resilience improvement, in line with the ACCCRN experience, supervision of the analysis and enhancing adaptability and transformability capabilities, strictly related to the required methodology, should be featured by:

- Capacity to learn that characterizes the robust strategies in analysing the correlation between boundary conditions and needs;
- dependency of local resources referring to the necessity to understand the specificities of the context and exalting them or solving fails locally;
- Resourcefulness as the main feature of the management of priority of interventions because of the complexity of the real case and processes;
- Responsiveness as the capacity of the management system to be reactive to changes to external conditions and new necessities that can be presented during the time; in that sense, the possibility to transform and control transformations, introducing new materials in technological solutions, allows to open the built market towards others and to cover the gap.

That frame delineates the possibility to solve the energy improvement of historic urban districts, considering them as system of buildings that interact with their boundaries at local and micro scale and should be preserved in a long perspective. Preservations as synonymous of persistence is solved guaranteeing their use in economical sustainability of life and comfort, without compromise cultural and historical formal values.

4. METHODOLOGY FOR A RESILIENT ENERGY RETROFIT PROCESS OF HISTORIC DISTRICT

The complexity of processes that characterizes actual and future energy external condition at local and micro-local scale in urban areas is amplified in historical district where the preservation of peculiarities is required, above all in some Mediterranean areas featured with a high incidence of that building stock and high confidence of exposure in Summer period. Moreover, the recognition of exposure of this area to the future climate uncertainties and awareness of their responsibility in foster the consequent and negative processes, highlighted the necessity to start thinking a system of activities to cope them at the actual state, as a pre-crisis phase. At the light of the previous experiences in energy retrofit of historic buildings and the widespread activities in reduction of energy demand aiming at adaptation and mitigation purposes, a robust methodology is proposed in Figure 4-1. In detail, the methodology embodies the well-established structure of the refurbishment process for the built heritage – including analysis, diagnosis and intervention – and the required features of resilience thinking to highlight the reference points of complexity of the strategies.
As a general necessity, different scales of detail should be followed aiming at link the local features to the building scale energy behaviours and from the buildings necessities to the whole district management of priorities. However, file rouge of the methodology is the necessity to highlight a dynamic process in knowledge, diagnosis and transformation phases as a circular method in recognizing adaptability and transformability features.

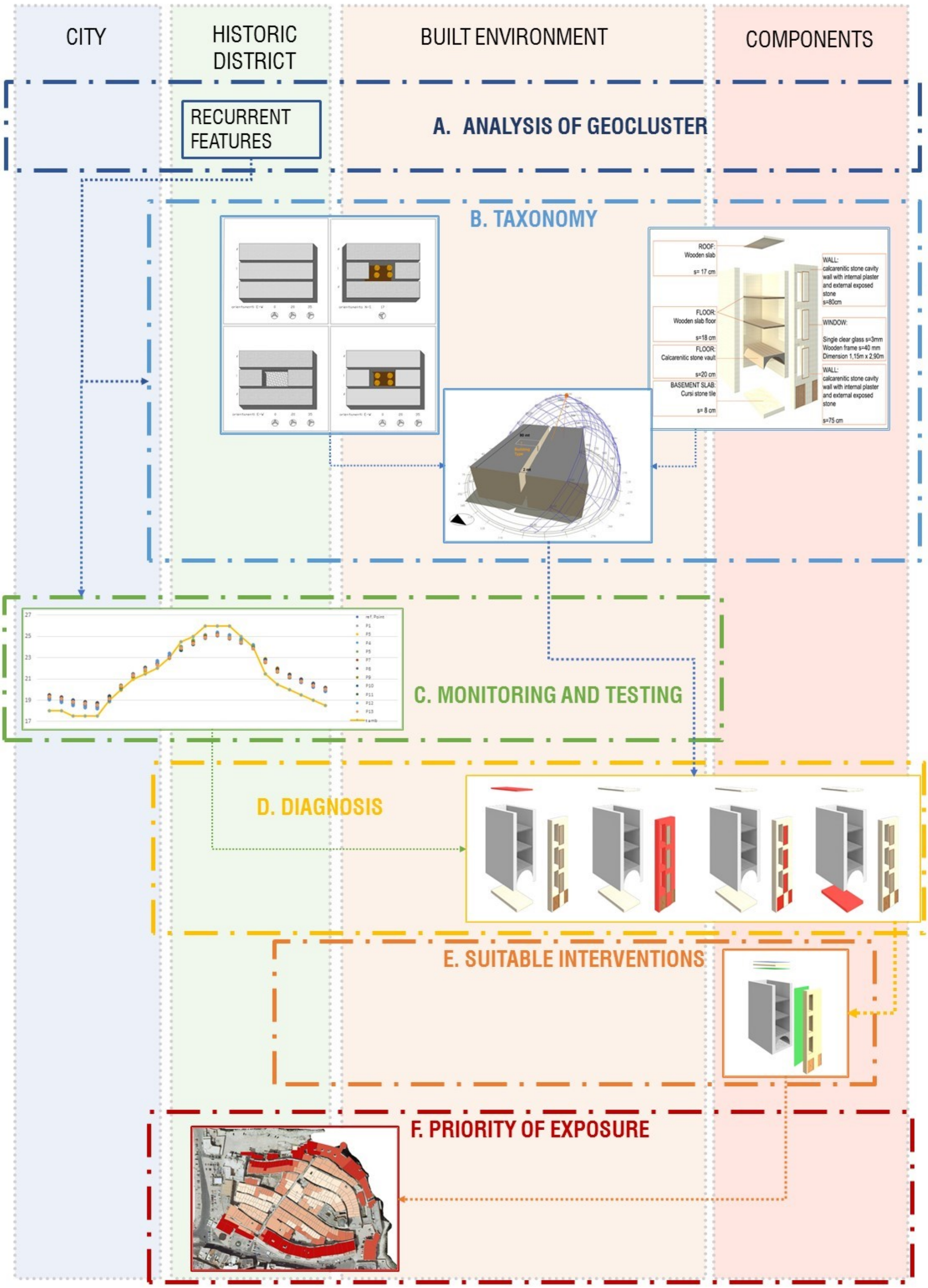


Figure 4-1 Outline of methodology

In detail of macro phases, persistence analysis is the result of a closed ring that connects the capacity to learn and the local dependency of historic district with the environment, with the new and final system that strictly depends to the starting one aiming at the preservation of formal and cultural values. In addition, dynamic evolution of external conditions, as control parameter for climate and local micro-climate, is solved introducing the monitoring process; however, that represents the instrumental support for the methodology in recognizing inherent qualities – e.g. bioclimatic characters – and local vulnerabilities.
The potentiality of transformable system should be supported by sheets following the necessity to pilot in an overarching way transformation, supplying technical sustenance in choosing of materials and solutions aiming at guidelines to "how to do it" (Zordan, Bellicoso, et al. 2006; Zordan, Morganti, et al. 2006)

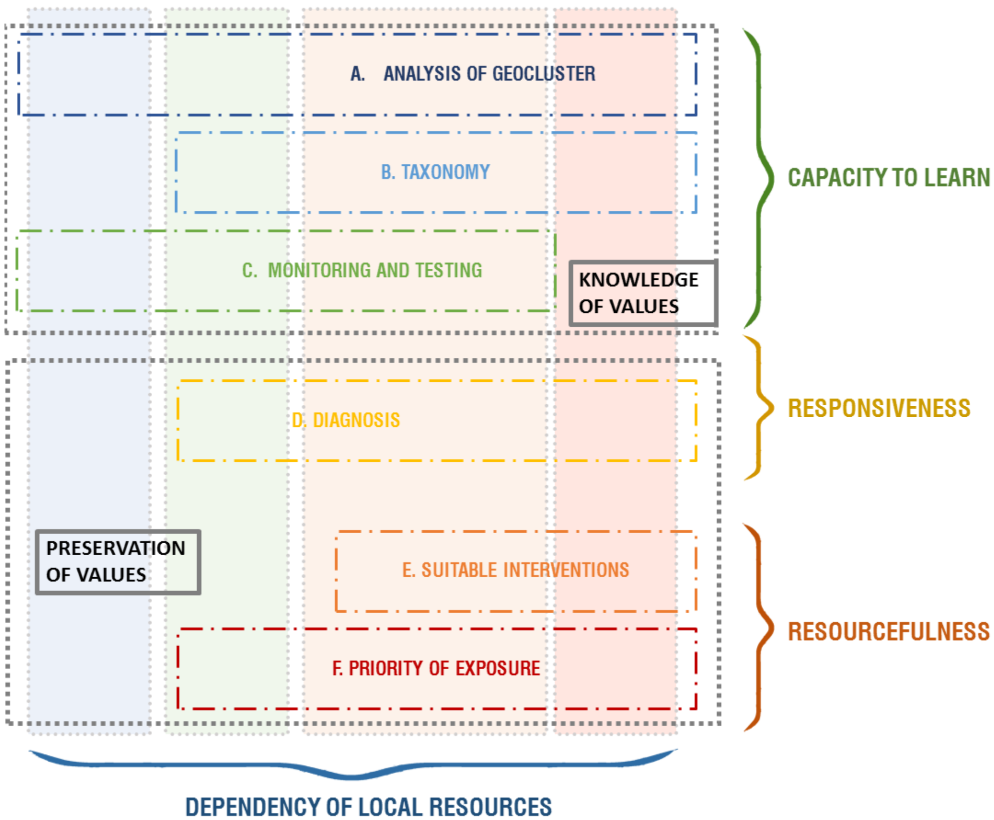


Figure 4-2 Level of Resilience necessities in the methodology

In all, the proposed methodology follows a scalar approach. From the analysis to the diagnosis phases, methodology proceed from the general to the specific aiming at meaningful and representative results and contain assessment methods and tools on a limited set of cases. On the opposite, the intervention phase goes from the specific to the general, to promote integrated and structured actions, which might ensure the most favourable technical congruence, logistics management and optimization of time and resources within the overall requalification and regeneration strategies, so, in determining the planning of priorities at district scale. Figure 4-2 outlines how levels and features of resilience are reflected in the proposed methodology.
Particularly, detailed phases concern in:

A) ANALYTIC PHASE (Figure 4-3) as the systematic investigation of environmental (Ae), architectural and constructional (Ac) features and regulation normative in energy improvement (AnE) and preservation (AnP) thresholds at different scales. In detail, data collection is classified in specific fields as it follows:

Ae. Environmental field as the investigation of:

Ae1.a TYPICAL CLIMATE FEATURES including statistical and historical monitored data used for the classification of typical climate at national, regional and local scales; moreover, focusing on the latter, the support of research activities in other fields on the same area, where available, can strongly support management and collection of more detailed data;

Ae1.b PROJECTION OF LOCAL CLIMATE referring to the stochastic global changing introduced in IPCC scenarios;

Ae2. HISTORIC DEVELOPMENT OF HISTORIC DISTRICT, focusing on the main characters of the use of land for his development during the time, also referring to the relation of the city;

Ae3. ACTUAL URBAN ASSESSMENT AND STATE OF USE focusing on use of buildings, services and energy distribution grids, traffic regulations;

Ac. Architectural and construction features as the work assessment of:

Ac1. morphology and typology of buildings at district scale referring to their classification in height, typologies and relations with the arrangement of districts; these data could be collected using archivist and bibliographic records and on-site investigation;

Ac2. CODIFICATION OF BUILDING FEATURES in a table of codes of construction assessing dominant technologies and materials actual used for the residential built envelope and energy system, highlighting possible endured transformations; in that case, the level of information requires direct on-site testing, both in identifying stratigraphy of the envelope and physical properties of materials;

Ac3. STATE OF MAINTENANCE and actual state of use of residential stock at district and buildings scale;

Ac4. ENERGY SYSTEM available at buildings scale focusing on Cooling and heating, where data are available.

An. ENERGY improvement (AnE) and PRESERVATION (AnP) REGULATIONS from national to local scale (1-3), toward the compliance with the bureaucratic national system of normative frame; overlapping built features and preservations thresholds, a TABLE OF VALUES is useful to summarize formal evidences.

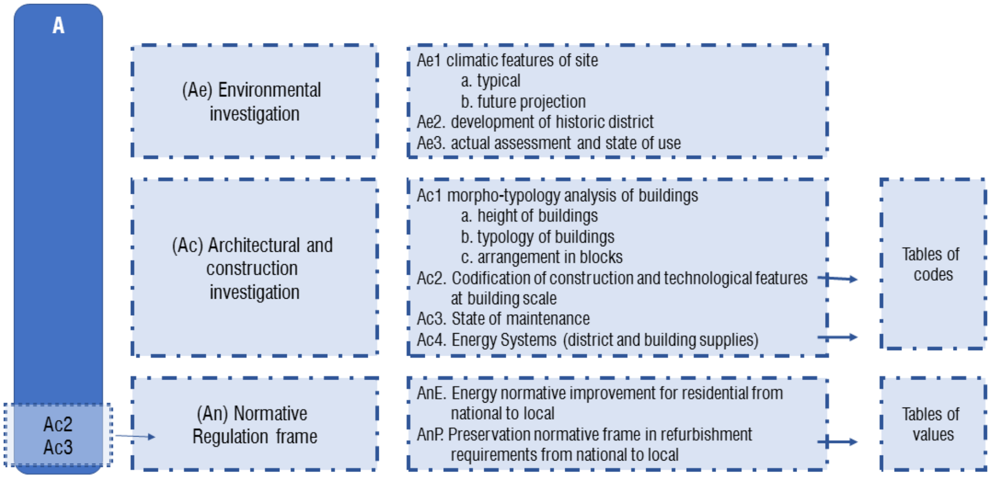


Figure 4-3 Methodological phase A

B) TAXONOMY PHASE (Figure 4-4) represents the codification of all collected data in previous scale aiming at the identification of a limited number of illustrative cases to support the concept of geocluster and to analyse and to perform their representativeness. In fact, geocluster should be representative of different levels of information and interaction of the system and his elements with the environment, aiming at:

B1. CHARACTERIZATION OF LOCAL CLIMATE ZONE, as the first macro-parametrization of the whole district using LCZ characterization process described in cfr 1.2.3; in detail, it represents the district parametrization of the geometric and surface cover features, and thermal, radiative and metabolic properties collected in Ae2, Ae4, Ac1, in order to provide:

- Building surface ratio (%)
- Impervious and pervious surface ratio (%)
- Average Sky View Factor
- Average height buildings [m]
- Aspect ratio
- Roughness length
- Surface admittance
- Surface albedo
- Anthropogenic heat gains

B2. CHARACTERIZATION AT CANYON SCALE, towards the identification of a recurrent type (canyon type) as the parametrization of recurrent elements of interaction between street system development and buildings along the predominant arrangement; that element is the result of a more detailed analysis that conciliates collected data in Ae3, Ae2 and Ac3 delineating a system of representative Canyons in term of main orientation referring to the cardinal points, geometrical features - Aspect Ratio (H/W) and Sky View Factor in representative range, local alteration of distribution of canyon referring to the urban development of the district and finally, predominant material information of canyon surfaces, so pavement of streets, walls and roofs of building organized along the blocks.

B3. CHARACTERIZATION AT BUILDING SCALE to determine the so-called “Building Types”, as the result of predominant use, height, geometrical, material features and construction techniques identified in detailed sub-phases of Ac. That Type presents the minimum presentative element of the whole interactions, useful in identifying strategies of “transformation”.

C) MONITORING AND TESTING PHASE OF LOCAL BEHAVIOUR (Figure 4-4) constitutes the main instrument useful to monitor external dynamic processes in a long-term period and, relating to the actual period, linkage step between taxonomy and diagnosis at different scale. For that reason, it represents the main phase in methodology aimed at the recognition of inherent qualities in adaptation features and vulnerabilities. For that phase two steps could be summarized in:

C1. MONITORING OF LOCAL CLIMATE step that constitutes the main instrument for evaluation of relations between buildings arrangement in the historical district and the local climate. In fact, according with the real difficulty in identifying real and local behaviours, a campaign of measures should be planned to provide a system of comparable measures between standard and similar instrument of evaluation between different points. Moreover, it could be useful to compare the representativeness of measures with the LCZ classification at district scale. For these purposes, WMO guidelines should be followed to realize a robust campaign following practical reference advices in point of measures and choice of their location; in detail, measure points should be located at comparable height and providing specific system of measure to avoid errors in measures as the overheating of sensors; focusing on choice of site, three measure point could be founded, taking care of some aspects:

- The internal and representative point of measure (E1) in the historic centre; starting from the identification of the “canyon Type” in B2 phase, monitoring point should be representative of the widespread characters, avoiding exception that could be representative of other micro-climate features as following:
  - Different SVF values;
  - irregular street arrangement;

- Presence of local temporary conditions that cannot be representative in a long-term evaluation (traffic variations, construction sites, etc.);
- Local different and temporary uses of buildings (e.g. unoccupied buildings or specific activities that differs for the main use of buildings);

- An external point of measure (E2) that represents the undisturbed area where typical climate could be evaluate at a fixed height; moreover, that location, as Zero-Reference point should be representative of the exposure of local weather condition with urban and historic district area;
- a comparative point (E3) externally to the historic district that could be representative of the rest of the city and referring to an intermediate point between internal historic district and external undisturbed conditions.

C2. TESTING DATA step concerns the possibility to assess, at district scale, exception in local climate conditions and system behaviours because of local differences. For these purposes, monitored data could be analysed:

C2.1 At temporal scale aiming at the recognition of LOCAL CLIMATE ANOMALIES referred to historical data;

C2.2 At spatial variation scale where monitored data are used to check

- the reference point of measure (E1) and his behaviour
- horizontally variation using specific software as Envimet©, to model the whole historic district aiming at:

C2.2a Firstly, test the reference point of measure aimed at the VALIDATION of horizontally measures, using and calibrating physical features of materials determined in phase Ac2 and then extend horizontally the model, using material and geometric features defined to characterize the canyon type;

C2.2b TESTING BEHAVIOUR IN EXTREME CONDITIONS on the same model if measured in C2.1; in that case, the recognition of extreme events follows the definition of Warm-Spell index and it represent the opportunity to evaluate the behaviour in reference point and the differences at district scale changing from typical to extreme conditions.

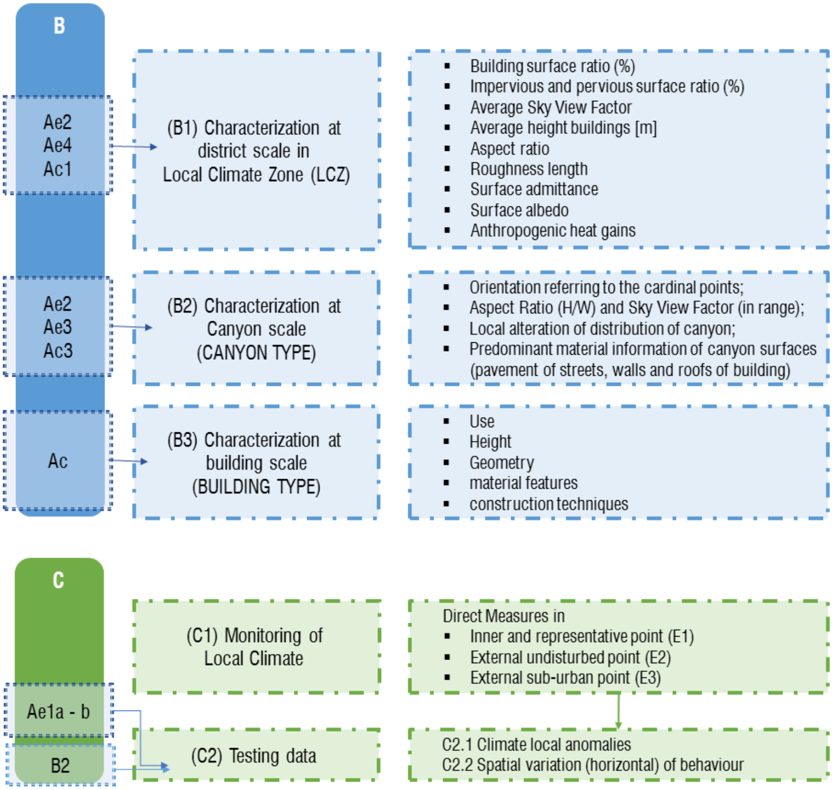


Figure 4-4 Methodological phases B - C

D) DIAGNOSIS PHASE (Figure 4-5) concerns the assessment of energy behaviour of the building types, focusing on different levels of investigation. In fact, the recognition of typical micro-climate and local exceptions and the physical and thermal features of building envelope allows the assessment of energy deficits and building pathologies, on one hand, and the critical recognition of distinctive features of the original fabric as interaction with micro-climate and inherent qualities of building. In detail, diagnosis is the result of the iterative process of evaluation of energy consumption variations aiming to the recognition of vulnerabilities and adaptabilities capacities, focusing on three levels of analysis at TYPE SCALE aiming at characterization of:

D1. REACTIONS TO CLIMATE CHANGES PROJECTION referring to different statistical weather conditions analysed in phase Ae1.b;

D2. REACTION TO LOCAL MICRO-CLIMATE focusing on measured data in reference point and different behaviour in unusual canyons, if observed in C2b.

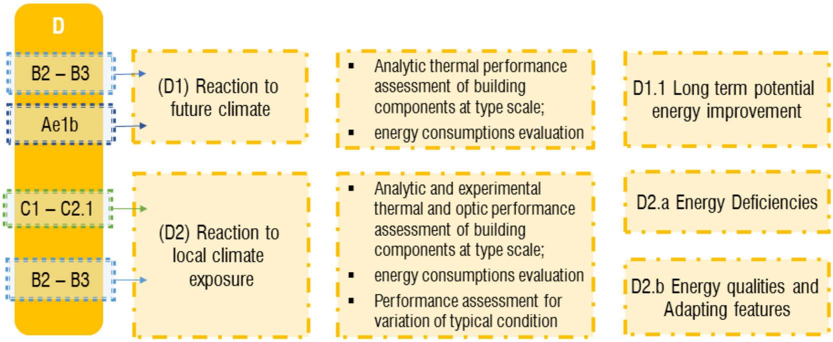


Figure 4-5 Methodological phase D

E) TAXONOMY OF SUITABLE INTERVENTIONS (Figure 4-6) concerns the phase of the methodology in which deficiencies, delineated in previous phase, are evaluated with the transformability capacity of the system and the preservation regulations (AnP). In detail:

E1. according to the general "resilience thinking" at the base of the strategy, identification of possibility of transformation delineates the inherent capacity to correct actual vulnerabilities. In fact, DEFINITION OF TRANSFORMATION DEGREE, namely their attitude to be modified without altering their historical and architectural features, is introduced as the result at building scale of the state of maintenance (Ac3), table of values (AnP) in identifying formal values;

E2. As a second step, transformation solutions are assessed with the preservation codes, in order to provide a SYSTEM OF SUITABLE SOLUTIONS referring to the mitigation and adaptation technical solutions delineated in the state of the art; in detail, developed solutions for each critical building component, are conceived as design guidelines and best practices to be translated in the selection of technological solutions, based on both traditional and innovative products and systems for energy efficiency.

F) ASSESSMENT OF PRIORITIES OF INTERVENTION (Figure 4-6) at district scale delineating an integrated system of recurrent "resilient" units. In that sense, different levels of adaptability at Canyon scale, delineated in C2b, and transformability of vulnerable elements at building scale identify different combination of "Minimum Unit of Energy Resilience Intervention" (MUERI); those units should help in development of scenarios toward the overall regeneration of homogenous urban/building areas, thus, involving common priorities and controlled actions, supported by their own MUERI technical data sheet. In detail, data sheet includes all information about type in term of location, exposure level, transformability degree of envelope sub-systems and can be useful in scheduling needed transformations and guiding with quality.

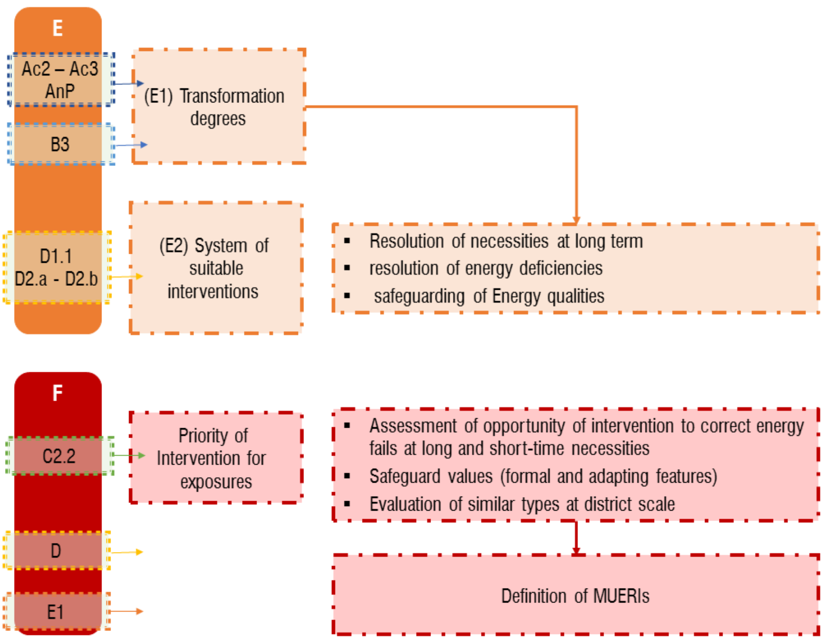


Figure 4-6 Methodological phases E - F

In that frame, a methodology that promote resilience thinking should support local public administration defining a flexible strategy during the time and in data management. The use of limited case studies that describe several buildings at similar conditions allows to focus on few real case studies in order to verify and correct assumptions and monitor external climate uncertainties and relative adaptability features along several years. Moreover, the dynamic process of transformation actions, because of an urban planning regulations applied in steps, can be processed during the time modifying the MUERI technical data sheet.
In the following section, as second part of dissertation, to detail operation aspects and achievable results, the methodology is applied to a pilot case, representative of the rigorous frame of landscape maintenance in Apulia Region, in the South of Italy.

5. CASE STUDY

Management of complex urban sub-systems as the old core of cities surely should be coupled with the complexity of climate alteration during the time. In that sense, the methodology, proposed and described in previous chapter, connects both levels of complexity. However, application on a case study helps in validation and management of results. The selected case study is representative for the climate of Apulia region, in the coastal south of Italy. In detail, the thesis focuses on the old core of Molfetta, located 25 Km north from Bari (Figure 5-1).

Historic center of Molfetta is one of coastal and sub-coastal historic districts analysed in the Regional funding program “Methodological framework for assessment of energy behaviour of historic towns in Mediterranean climate”[1] from which some data refer. All phases of the methodology are described following, as explicative way in processes and management of data and results.

The old core of Molfetta belongs to emblematic of the Mediterranean historic coastal towns (Figure 5-2) characterized by compact and dense urban arrangement and use of local calcarenitic limestone as construction material.

[1] Fondazione Cassa di Risparmio di Puglia – Research Project: “Methodological framework for assessment of energy behavior of historic towns in Mediterranean climate” (Scientific Coordinator: Prof. Fabio Fatiguso, Politecnico di Bari), indicate as MFE_project

Figure 5-1 Case study location in Italian land

Figure 5-2 Aerial photos and street views of coastal historic towns in Apulia Region

5.1 ANALYTIC PHASE (A)

Starting from the higher scale of knowledge, the analysis of environmental (Ae), architectural and constructional (Ac) features and regulation normative in energy improvement (AnE) and preservation (AnP) from the regional to the building scale are discussed as it follows.

5.1.1 TYPICAL CLIMATE FEATURES (Ae1.a)

Because of different orography in his land development, Apulia region has many different climates referring to the Koppen-Geiger classification. In fact, the along the promontories of Gargano – the north-east– and along the sub-appeninic – located at north-west - parts of the region, featured by high altitude, the oceanic climate is associated, whereas along the cost and hills, humid sub-tropical (Cfa) and hot-summer Mediterranean (Csa) climates are predominant.

Italian land is also divided in different climates according to the parameter of Day Degree (DD), according to Presidential Decree n. 142 on 26th August 1993. The Day Degree are counted according the (1)

$$DD = \sum_{e=1}^{n}(20 - Te) \qquad (1)$$

and it represents the thermic need in household in a specific part of geographic area, considering the External daily typical temperatures (Te). That classification is related to the necessity to improve a standard way in counting heating and cooling needs according to the European EN ISO 15927-6, recognised in Italy with the national UNI 9019:1987.

For the same reasons of Kopper classification, Apulian cities could be classified in three climatic zones (Table 5.1-1) even if the C zone is the most representative.

Climatic zone	DD	% of cities in Apulia region
C	901- 1400	65.9%
D	1401 – 2100	27.1%
E	2101 - 3000	7.0 %

Table 5.1-1 Classification and distribution of different climatic zone in Apulia region

Referring to the Koppen-Geiger classification, Molfetta climate is classified in the hot-summer Mediterranean climate (Csa), whereas for the national classification, 1202 DD are representative of a typical year; so, Molfetta is representative of the widely climate characters of Apulia region, according to the traditional way to measure them.
In term of local temperatures, municipal administration in planning activities refers to data measured in the airport of Bari, located 20 km far from the centre of Molfetta. Referring to them during the period 1960-1994, average, maximum and minimum temperatures are reported in Table 5.1-2.

	Jan	Feb.	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Taver	9.6	9.9	11.9	14.6	18.6	22.4	25	25	22.1	18.1	14	10.8
Tmin	6.6	6.9	8.5	11.1	15.2	19	21.5	21.5	18.7	14.8	10.8	7.8
Tmax	12.6	13	15.1	18	22.1	25.8	28.3	28.3	25.5	21.6	17.3	13.7

Table 5.1-2 Average, maximum and minimum temperatures of Bari Airport measured during 1960-1994.

For the same evaluation, anemometer analysis is referred to the same station, whereas the period of reference is 1951-1991. These data as general information at local scale are more representative, according to the high spectrum of analysis. Seasonal analysis of wind intensity and direction are reported in Figure 5.1-1.

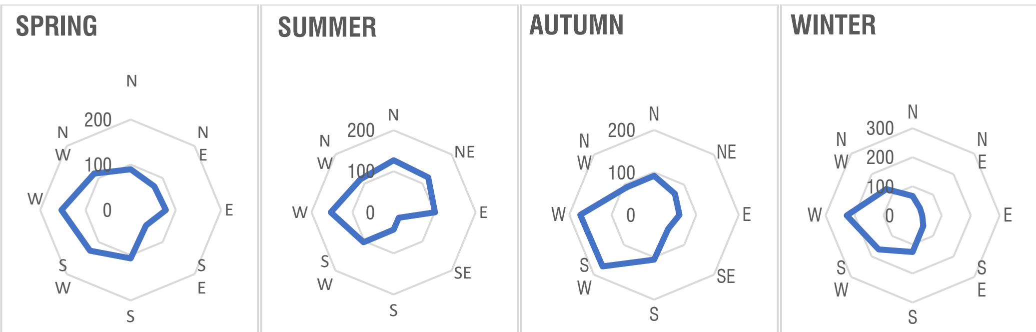


Figure 5.1-1 Seasonal anemometric analysis at local scale in Bari airport station

In detail:

- In spring (from march to May), West as the predominant wind direction, whereas the predominant class of intensity is 5-7 knots, assuming 3 m/s as the average value;

- Similarly, in summer (from June to August), west direction and 5-7 knots are representative of anemometric features; moreover, the higher frequency of calm could be highlighted;
- During the autumn (from September to November), West and South-West predominant axis and the most representative class of intensity is 5-7 knots, too;
- Finally, during the winter (from December to February), the same parameters of autumn could be considered.

That analysis highlights that the predominant direction of wind in the whole hinterland of Bari is the west.

Moreover, urban meteorological information was collected during last 10 years, thanks to the Arpa standard station located into a sub-urban area in Molfetta. In detail, local temperatures and wind are reported in following Figure 5.1-2 and Table 5.1-3

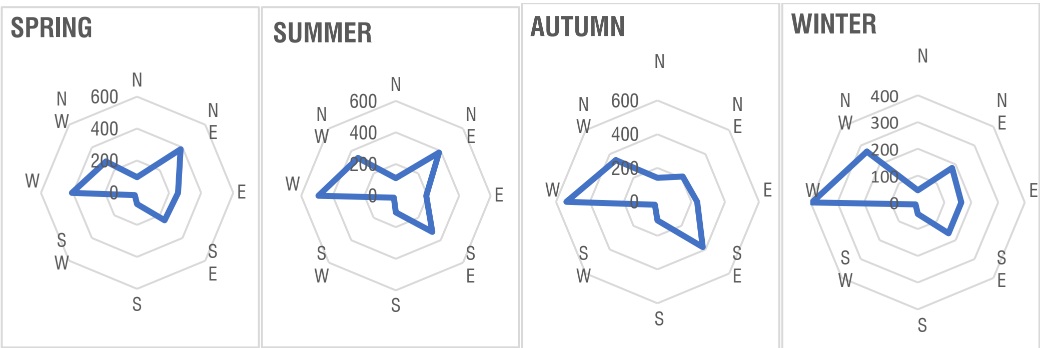


Figure 5.1-2 Seasonal prevalent Wind directions in Molfetta. Source: Arpa

	Jan	Febr	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Taver	8.8	8.8	12.5	16.0	20.3	24.2	27.7	26.9	21.9	17.6	13.9	10.7
Tmin	2.7	1.0	8.7	11.5	15.8	19.3	22.4	22.7	17.8	14.5	11.0	8.0
Tmax	16.6	18.9	17.0	21.0	25.1	28.6	32.2	31.6	27.0	21.6	17.2	13.6

Table 5.1-3 Average, minimum and maximum temperatures measured in Molfetta during 2008-2016. Source: Arpa

5.1.2 PROJECTION OF LOCAL CLIMATE (Ae1.b)

According to the algorithm for the evaluation of climate projection defined by IPCC, a specific weather data could be transformed evaluating different temporary steps in different scenarios. In detail, Meteonorm weather data, as a statistical result of measures referred to the period 2000-2009 - evaluated crossing Bari and near other stations to determine local climate of Molfetta - are considered as base data for the analysis. However, it requires to be compared with measured data in order to evaluate their validity. Meteonorm data, referred to the actual period (Met_Act), are compared in Table 5.1-4 with Arpa and Airport measures of monthly average temperatures. As a result, statistical data of 2000-2009 period are comparable with urban measures of standard Arpa station.

	Jan	Febr	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Meteonorm	9.1	9.1	12.5	16.9	20.6	24.6	28.2	27.3	22.1	18.8	14.6	10.6
Airport (1961-1990)	9.6	9.9	11.9	14.6	18.6	22.4	25.0	25.0	22.1	18.1	14.0	10.8
Urban Station Arpa	8.8	8.8	12.1	16.3	20.2	24.2	27.7	26.9	21.9	17.6	13.9	10.7

Table 5.1-4 Comparison of average monthly temperatures in different period and different sources.

As a second step, statistical weather data are transformed according to the IPCC algorithms referring to 2030 and 2050 future periods and A2, A1B and B1 scenarios. Figure 5.1-3,4 delineate differences between monthly average temperatures between the periods and hypothetical scenarios; in depth:

- Average annual temperatures are increased for 1 or 2 °C referring to the 2030 and 2050 scenarios; however, A2 and A1B are the worst cases in both scenarios;
- Average monthly temperatures highlight relevance in autumn and winter seasons when differences in projection are higher than the rest of period; however, in summer and September, temperatures increase for 2-3 °C until ‘50 in worst scenarios.

Despite the differences, relevant increasing temperatures during the cold period supports the energy efficiency in heating sub-system whereas, during spring and summer conditions, cooling energy needs could be evaluated in their incidence. These results surely are in line with IPCC evaluation of average future climate evaluations.

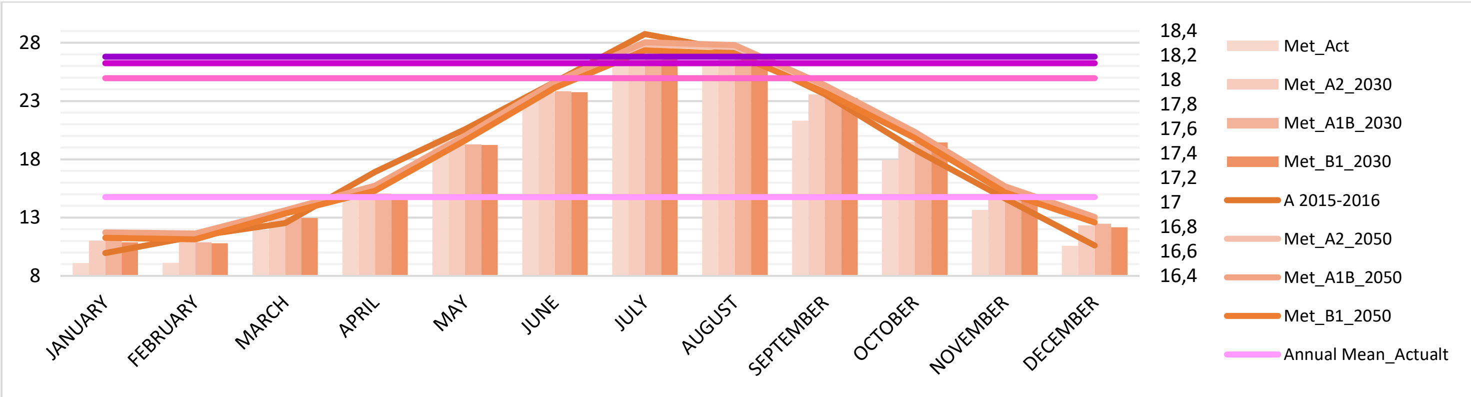


Figure 5.1-3 Average monthly and annual temperatures of A2, A1b and B1 scenarios on 2030. Source: Meteonorm

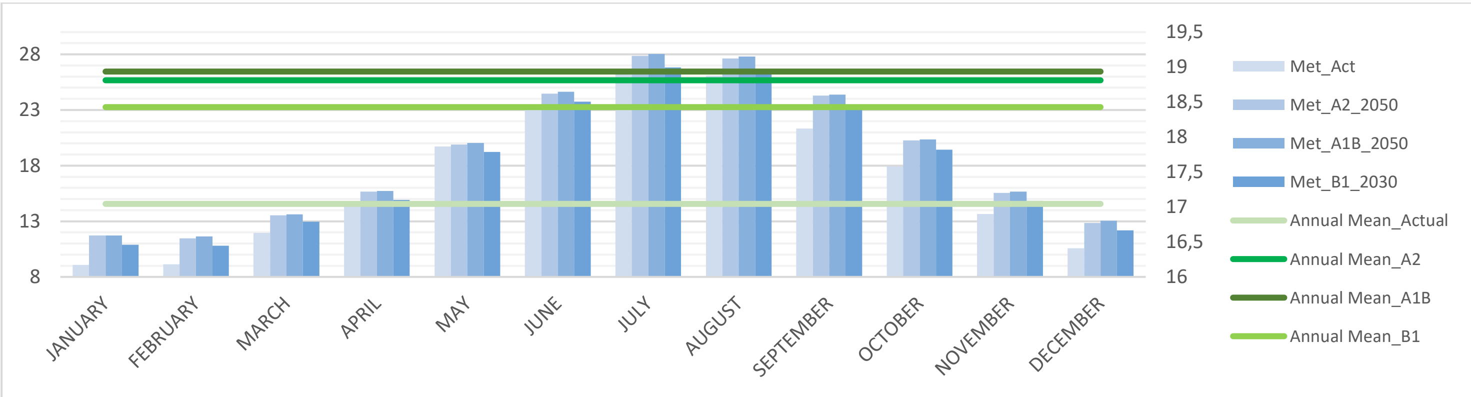


Figure 5.1-4 Average monthly and annual temperatures of A2, A1b and B1 scenarios on 2050. Source: Meteonorm

5.1.3 HISTORIC DEVELOPMENT OF OLD CORE (Ae2)

Molfetta counting 60.000 habitants approximately (2015) and it is located at north of Bari. Its urban land is developed in plan area considering with a height ranging from 15 to 140 meters.

Referring to the lithological aspect, Molfetta is located on a calcarenic limestone sub-surface defined as “Calcari di Bari”, featured by high density and high mechanical resistance. That composition created during the time the karst phenomena, above all in rural area for the higher permeability of the terrain. The most appreciate karst phenomena, called “Pulo”, is visible at 1,5 km to the South-West part of the urban area, as the widest doline in Molfetta area. Therefore, urban development follows the hinterland for 2.5 km and the coast for 3 km (Figure 5.1-5) where first urbanized asset can be founded.

Figure 5.1-5 Orthophoto of Molfetta urban area. Source: author

According to the census data in 2011 (Istat, 2011), building stock of Molfetta counts 3341 buildings and 92% of them are occupied; the residential part of them constitute

2900 approximately. The analysis of the residential building in term of period of construction highlights that 40% of them were built before the 1945, (Table 5.1-5) whereas new construction activities during the last decade constitute the 7% of the whole.

	Before 1919	1919 -1945	1946 -1960	1961 -1970	1971 -1980	1981 -1990	1991 -2000	2001 -2005	After 2005	Total
n. buildings	502	720	215	619	413	157	30	18	195	2869
% building	17.5	25.1	7.5	21.6	14.4	5.5	1.0	0.6	6.8	100

Table 5.1-5 Relevance of residential built for period of construction. Source: report of Molfetta PAES

Consequently, almost the 60% of residential buildings were built using masonry technique (Table 5.1-6).

	Masonry	concrete	others	Total
n. buildings	1681	1146	42	2869
% building	58.6	39.9	1.5	100.0

Table 5.1-6 Relevance of residential built for construction technique. Source: report of Molfetta PAES

A quarter of the residential buildings built in masonry technique and a third of the buildings built before the 1945 represent the 400 residential buildings present in the old core of Molfetta[2]. In detail, the old core of Molfetta is located on the so-called “Sant’Andrea” peninsula and represents the first urban assessment of the actual municipality. The whole core occupies 51.000 mq approximately and it is enclosed into a specific boundary, as the result of an historical process of preserved growth.

Referring to his historic development, first notices are referred to the Medieval period, during the XI and XIII centuries, when “Sant’Andrea” church (1126), Ancient Duomo consecrated to San Corrado (1236) and the Angioin Castle where erected; during the same period fortified city walls were built (Codice diplomatico Barese, 1185) featured by an elliptical shape and two gateways that allow the entrance near the Castle and the access from the main street that connects Ruvo (ancient core of the Magna Graecia period located in the Apulia hinterland) to Molfetta called “Porta di Terra” (Gateway from the Land). Outside and along that gateway, some magazines and productive buildings were built during the same period, while into the city walls, a big square existed for the urban market. Into the city walls 18 other buildings could be identified (Figure 5.1-6a),

[2] SEAP Molfetta, 2016, Consorzio Uning S.c.a.r.l. di Bari and Molfetta Municipality

assessed following the political, administrative and religious buildings existent, drawing the first street assess of the core (De Gennaro, 1977).
During the XIV-XV centuries, the Predominant Angioin period, the old core of Molfetta growth as a political and economic motivation to enrich the profits. During that period, some noble buildings were erected. As detailed in Figure 5.1-6b, urban arrangement continues following the previous phase (axis E-W), also building in the ancient market area; however, an early delimitation of N-S axis could be recognised and, the roman assessment following "*Cardo*" and "*Decumano*" axis could be neglected (De Gennaro, 1977).

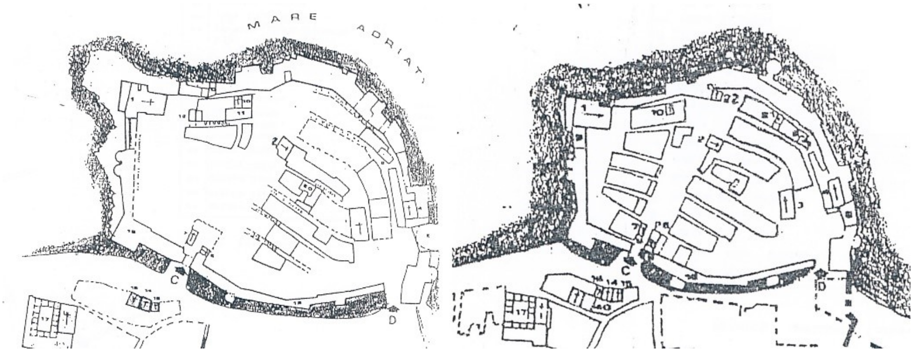


Figure 5.1-6 Development of historic district of Molfetta until medieval period. Source: Retrofit plan of historic district of Molfetta

In 1529 Molfetta was raid and re-built actions featured XVI and XVII centuries; moreover, buildings neighbouring the southern part of the city walls were built, above all noble ones. Along the northern part of city walls, residential buildings occupied the boundary (Figure 5.1-7a).
The XVIII century most of squares and public spaces were occupied by buildings, while along the "Porta di Terra" gateway clearly defined the N-S axis. At the end of that century, old core of Molfetta reaches the maximum development (Figure 5.1-7b).
The old core of Molfetta was the object of three recovery plans during the period 1900 – 1935. However, these plans included influences of previous experiences in Europe and Italy which characterized the previous century. In fact, the plans proposed the creation of new streets emphasizing two lines: the inner street S-N that divide in two parts the core and the enlargement of another one in order to link the extreme along the E-W

axis (Figure 5.1-8). Fortunately, no transformations were done and the original urban assessment was preserved, whereas recognition of urban district structure was identified.

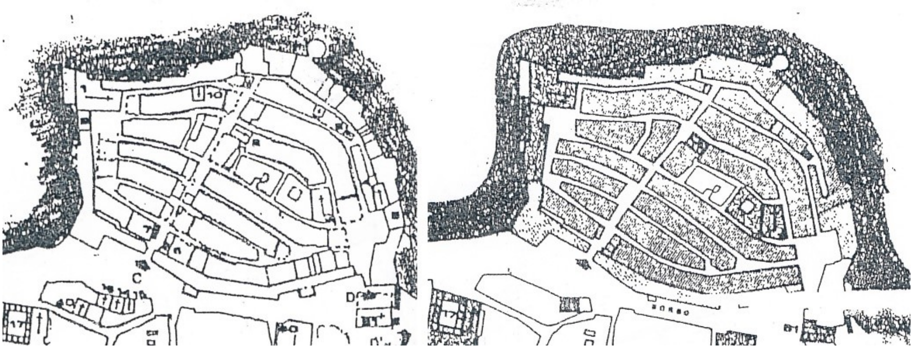


Figure 5.1-7 Development of historic district of Molfetta until 1930's. Source: Retrofit plan of historic district of Molfetta

However, during the 1930s the old core was featured by a prominent level of bad state of conservation. This state was the result of an absent recovery plan and, consequently, several and uncontrolled transformations, where the creation of a new higher floor was the most diffused[3]. These actions caused the serious state of statically instability for a wide percentage of buildings in the urban core until the 1964 when the collapse of a building caused three victims. That extreme event, was the first of several ones that caused the loss of some parts of the historic core of Molfetta that highlighted also the socio-economic impossibility of inhabitant to recover buildings.

The necessity to recover the hygienic safety and static preservation of the district, in 1977 the plan recovery was ratified aiming at:

- preservation of listed heritage;
- identification of buildings to recover, restore and demolish without reconstruction;
- definition of allowed actions of recovery in buildings, specifying technologies and materials;
- finally, identification of deficiencies in term of urban grid services to ensure at least the basic services, e.g. electricity and gas supplies.

[3] In Report of Recovery plan of Eng. Giancaspro, 1934

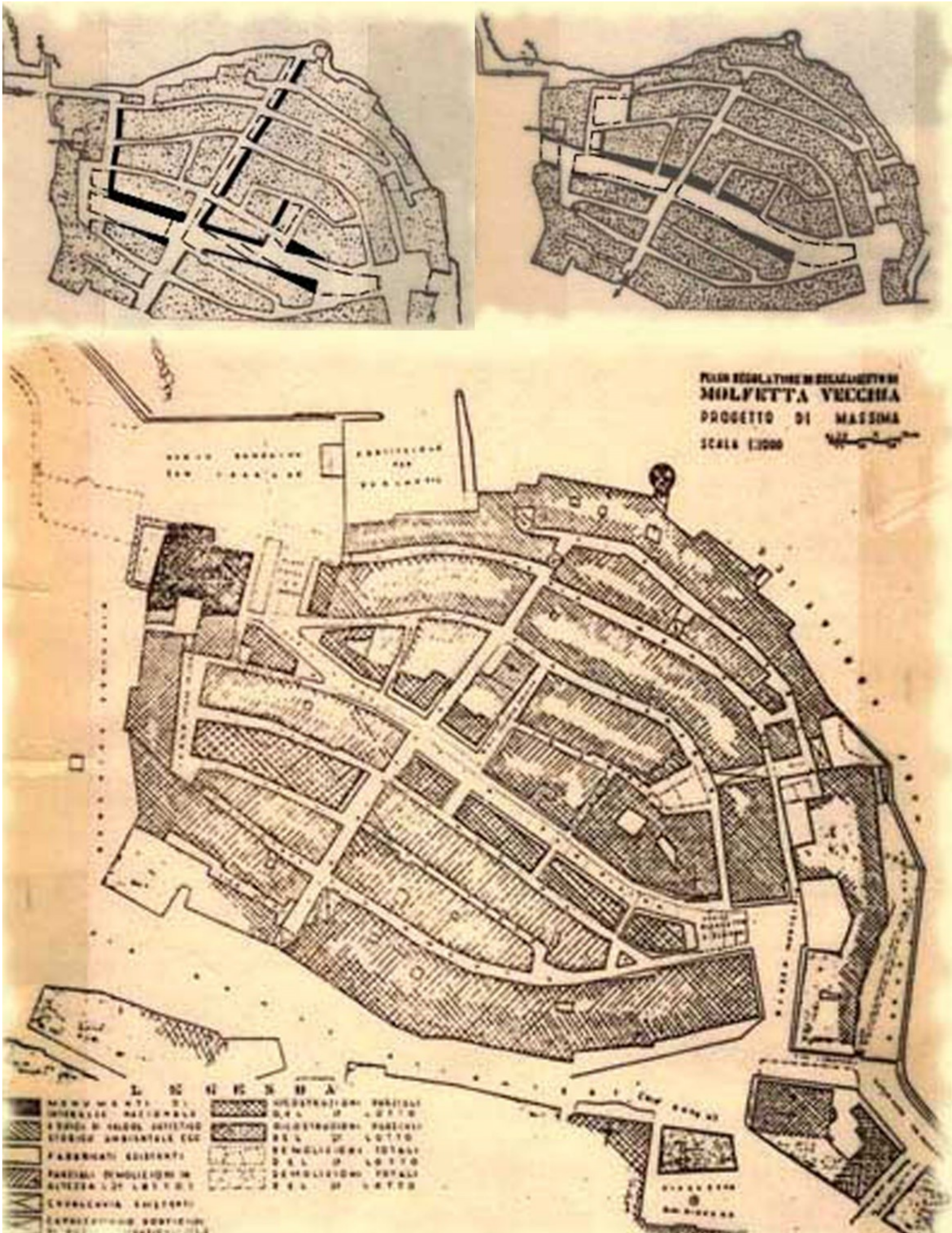


Figure 5.1-8 Drawn of a proposed variation of street asset during 1900-1930. Source: Retrofit plan of historic district of Molfetta

5.1.4 ACTUAL DISTRICT STRUCTURE AND STATE OF USE (Ae3)

As the result of previous planning activities, municipality of Molfetta moved towards the preservation of the milieu where it could be possible, except for extreme and disruptive events during the 1960-1970 that modified locally his district layout.
However, some actions to correct these fails can be classified in two types:

- creation of "close garden", that identifies a public space enclosed in the boundary walls at ground floor of collapsed buildings; their dimensions varies with the extension of the damaged zone (Figure 5.1-9); in detail, Mammoni Garden (a) identifies the disruption of several and adjacent buildings, while San Girolamo Garden (b) and Garden of aloe (c) represent the same solution for one or two collapsed buildings; that solution contributes to the preservation of plan original asset; however, these represent paved surfaces with low percentage of pervious surfaces;
- creation of paved square, delating part the block and enlarging the front of nearest blocks; in that option, Amente Square is the only case created (d).

Urban original asset could be identified surely starting from the historic development whereas his technical description depends on dimensions, orientation and distances between blocks. Apart from few cases, blocks have a length that varies between 80 and 100 mt and has a width between 16 and 18 mt.
Discussing orientation, the original asset defined three prevalent directions (Figure 5.1-9):

- the NW-SE direction with 20° and 35° orientation, referring to the SW and SE part of the old core;
- a curvilinear asset along the northern boundary;
- lastly, the main S-N street.

Finally, all the blocks delimited streets with width ranging between 2 and 4 mt (Figure 5.1-9) with some exceptions along the main street where 8 mt could be reached.

Figure 5.1-9 Street asset and local openness (gardens and square). Source: author

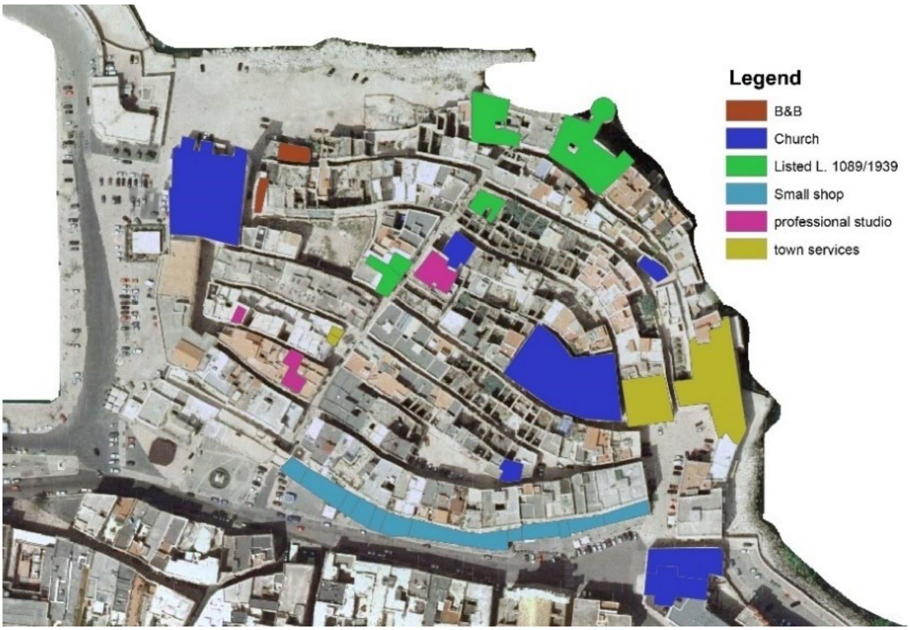


Figure 5.1-10 Localization of different uses and properties. Source: author

Focus on the state of use, actually most of private buildings are residential with some exception (B&B, professional studios), while other vacancies could be identified in un-occupied zones because of the expropriation process aimed at the recovery of some abandoned buildings for bed state of conservation actually at the center of construction sites activities until now; public buildings represent a reduced part of stock identifying churches, listed buildings and public services (Figure 5.1 10).
In all the street system, featured by a zero traffic, old core of Molfetta is featured by traditional pavement made with calcareous stone, using irregular squared tiles and a thickness of 15-20 cm (Figure 5.1-11) that constitutes the higher part of his impervious surface.

Figure 5.1-11 “Basole”: stone pavement of ancient core of Molfetta to preserve. Source: author.

5.1.5 ARCHITECTURAL AND CONSTRUCTION FEATURES (Ac)

5.1.5.1 MORPHOLOGY AND TYPOLOGY OF BUILDINGS (Ac1)

In term of vertical boundaries, the whole historic centre is featured by a dense system of E-W arranged blocks as the results of a series of buildings assessed in series (Figure 5.1-12); according to the recovery plan definition, residential buildings are classified in two typologies:

- tower-houses, featured by a vertical development of the house showing a simple plan, with only one room per floor, vertically connected with an inner staircase; it is often aggregated in blocks where units are arranged in two symmetrical rows so that each unit has only one narrow external façade;
- palace-houses, in which house is on a single floor, with large façade on the street and openings in all the rooms; it has two floors with an inner stone stair that link the access of them.

Figure 5.1-12 Development of a Tower Houses in series in a typical block front in Molfetta ancient core. Source: MFE_project.

Moreover, assessment in series along the block and different distribution of dwellings create four house-types (Figure 5.1-13), identified as:

A. Tower house
B. Palace house

Both typologies have different heights (Figure 5.1-14) and they can be arranged as

I. middle unit: the building is intermediate within the block and, thus, shows only one front toward the outside;
II. end unit: the building is at the extremities of the block and, thus, shows two fronts toward the outside.

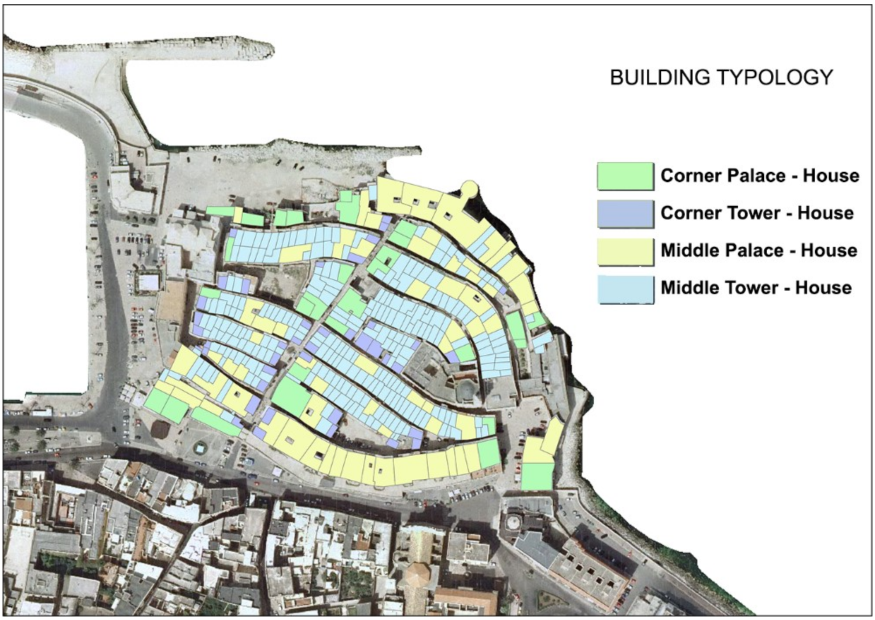


Figure 5.1-13 Arrangement of building typologies in the district. Source: author

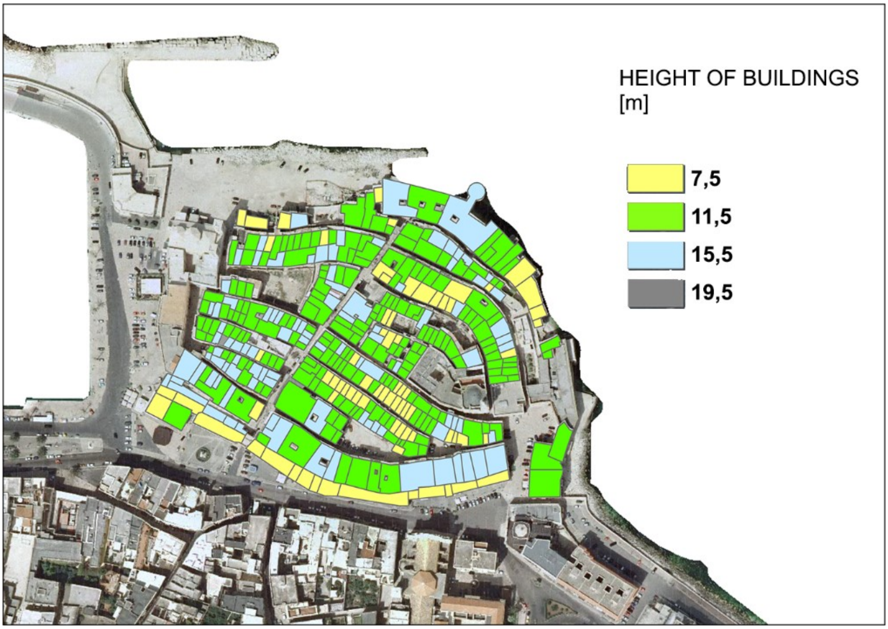


Figure 5.1-14 Height of buildings in the district. Source: author

As the result of the data, the tower house is the most representative typology in Molfetta old core, with prevalent wall exposure on South and North direction.

5.1.5.2 CODIFICATION OF BUILDING FEATURES (Ac2)

According to the general overview in significance of the local identity, structural materials and techniques are strictly depended on the availability of sources near the area and the genius loci experiences; in fact, in addition to the natural dimension of them, they are representative for most of buildings, so, as common traditional features. In detail, Table 5.1-7 reports all representative features of the building in historic district, where:

- masonry are usually compound walls, typically thick and made out local stone blocks; external and internal façades are plastered (Wa1) – using by 3cm thick plaster layer - or unplastered (Wa2); they are from 50cm to 90cm thick; that element represents the most preserved in original character;
- ceilings vary in material and construction technique depending on the position; usually, a barrel vault divides ground floor and first floor and it could be plastered (Cg1)

or not (Cg2); in most of cases, the inner ceilings are thin and plane using wooden beams and rarely it was substituted with a concrete slab; finally, the roofs are widely like the inner ceiling (compound with wooden beam) (Cin) and different external finishing;

- at the ground floor basement slab is made of concrete and it is placed above a layer of stone blocks and gravel (Bf);
- windows have a low percentage compared with the opaque envelope, according with the necessity of low exposition to solar radiation in hot climate; generally, windows are featured by a wooden frame and double-glazing (Wi1).

Despite these traditional features, some parts were modified during the time and could be classified for each sub-system:

- first of all, roofs featured by an external pavement using calcarenitic stone tiles (Cex.b) – called "chiancarelle" – or cotto (Cex.a) tiles and waterproof membrane (Cex.c); the latter two are the result of substitution of the original calcarenitic tiles; certainly, the loss of the original aspect cannot be associated to the administrative negligence but to the prominent level of bad state of conservation that most of buildings have during the static crisis phase;
- windows present a common level of transformation; preserving the formal wooden frame, original single glazes were substituted with the double, as the widest technology actual presented.

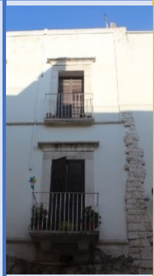
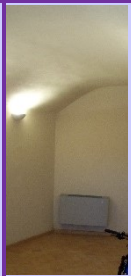
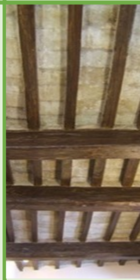
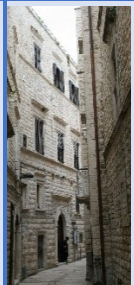
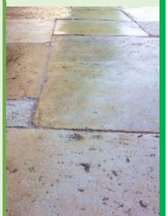
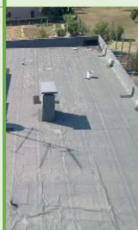
Wa	WALL	Wi	WINDOW	Cg	CEILING AT GROUND FLOOR	C	CEILING	Bf	BASEMENT
Wa1	 PLASTERED	Wi1	 WOODEN	Cg1	 PLASTERED	Cin	 WOODEN BEAMS AND BOARDS	Bf1	 BASEMENT SLAB ON GRAVEL
Wa2	 UNPLASTERED			Cg2	 UNPLASTERED	Cex .a	 COTTO TILES		
						Cex .b	 STONE TILES		
						Cex .c	 WATERPROOF MEMBRANE		

Table 5.1-7 Table of codes of buildings in the historic district. Source: author

5.1.5.3 Ac3. STATE OF MAINTENANCE

Currently, the whole historic centre of Molfetta is featured by a good state of conservation because of the previous interventions. Despite that, some exceptions could be found in the Est part where construction sites are situated, whereas along the Northern part, some building are unoccupied for their state of decay, as delineated in Ae3.

5.1.5.4 Ac4. ENERGY SYSTEMS

Focusing on summer events and cooling requirements, an aerial recognition (google maps satellite image) of cooling system penetration has been done. in fact, according to the preservation of formal features as the main aim of the Recovery plan, cooling engines are usually located over the roofs in order to conceal their presence.
The results of the analysis show that most of the buildings have been already affected by the penetration of cooling systems that is firstly representative of the clear necessity at that latitude but, now, only linked to the electric availability. In fact, other system solutions like the earth pipe cooling or cooling/heating district systems appear incompatible and more intrusive, as well as unusual for the socio-culture and socio-economic systems of the analysing geocluster.
Referring to heating systems, all historic district is connected to methane supply and heating system are supposed technologically near to use of that source (traditional or condensing boiler).
However, both for heating and cooling systems, main differences could be presented focusing on the technology used of air-conditioning (inverter or on-off control) but, in absence of any other detail, it could be representative of the period of installation.

S_H	Heating System	S_C	Cooling System
S_H.1	condensing boiler	S_C.1	air conditioning with inverter technology
S_H.2	new gas-fired boiler	S_C.2	air conditioning with on-off control

Table 5.1-8 Table of codes for heating and cooling systems

5.1.6 ENERGY REGULATIONS (AnE)

Energy requirements of residential buildings are reported in the D.I. 26th June 2015, specifying the thermal standards for each Climate zone – and relative DD values -, defined by the Presidential Decree n. 142 on 26th August 1993 as described before. That standards are referred to thermal transmittance of each sub-system of building envelope; in Table 5.1-9, standards for buildings sited in Molfetta – climatic zone C - are reported.

Envelope sub-system	thermal transmittance U [W/m^2 K]
Walls	0.38
Roofs	0.36
Windows	2.4
Ground floor	0.4
Internal floor	0.8

Table 5.1-9 Italian thermal transmittance thresholds for Climatic Zone C

In 2015, the city of Molfetta started joining the Covenant of Major, following the main purpose to decrease GHGs to 20%. That goal could be reached approving his Sustainable Energy Action Plan (SAEP) where Molfetta municipality described the environmental and landscape features, highlighting the main characters of land uses, urban development, population distribution and the socio-economic structure of the whole municipality.

In detail of energy issues, Molfetta SEAP describe accurately all energivor sectors, dividing them in public, commercial and private, providing energy consumption for each of them and the prevalent energy sources. In detail,

- comparing transport and civil building (considering public and private) sectors, the relative percentages of consumption are 35% and 65% which correspond to the 40% and 60% of emissions;
- dividing in public buildings and services, street lighting and residential buildings, 52% of consumption describes the high responsibility of the latter while 45% is ascribed to the tertiary private sector;

- moreover, emission for each of them and for kind of source (electricity, natural gas and diesel) are presented; mainly, electricity constitutes the predominant percentage of use (60%) with a range that varies from the 54% for the residential and 69% for tertiary private sector;
- finally, the emissions referred to the public transportation is analysed focus on the 64% of diesel fuel responsibility, and 31% for oil.

The recognition of responsibilities supports the description of goals and strategies. In that sense, Molfetta proposed a system of actions for macro-activities:

- buildings and cooling/heating systems, aiming to increase the energy efficiency of buildings and public services;
- Energy and Environment, encouraging the production electricity from FER both in private and public sector and stabilizing the cycle of waste;
- Transport, fostering the local public transportation, encouraging the diffusion of electric cars, reinforcing the system of bikeways and reorganizing the viability;
- urban rehabilitation, reorganizing public spaces and including modern technologies and new green areas;
- finally, education to strengthen the awareness of all urban stakeholders in sustainable challenge.

Despite the high percentage on residential sector responsibility, the plan in detail proposes a new system of regulation at the building scale, proposing new standards. However, it becomes the example of the correct way to pursue the goals proposing a wide set of energy retrofit interventions in schools and public buildings.
However, ancient core and his residential stock are not present in a specific energy strategy for future purposes.

5.1.7 MAINTENANCE AND PROTECTION OF CULTURAL AND LANDSCAPE HERITAGE REGULATION (AnP)

According to the national law (DD 42/2004, cfr. Cpt. 4), Apulia region provided his Regional Landscape Plan called “Piano Paesaggistico Territoriale e Regionale” (PPTR)

in 2016, in order to define the territorial development focusing on landscape and environmental values; according to the administrative procedures, PPTR is the link between the national laws and the local planning action in each city of the region.
Focusing on the buildings in historic centres, any specific requirements are presented if the buildings are not listed according to the 42/2004. However, the plan introduces - in the recognition phase - all the listed buildings according to the 42/2004.
Introducing the PPTR, Apulia region is moving towards the valorisation of "landscape", countertrending the previous management; in fact, the plan recognises the landscape as heritage and bets on it as "heritage of Apulian identity" to create a positive circle of regional development. That landscape-heritage approach, including all the anthropic and natural areas, is useful to identify specific areas in the Apulia region that could be associated to identity of each milieu – also defined as "territorial invariant" - aiming to their preservation, exaltation and persistence. In fact, the landscape-heritage is recognized as potential source independently to their actual use and, for that reason, requires long-time strategies aiming to their existence and persistence.
In this frame, landscape planning activity in Apulia does not introduce directly restriction in historical centres in term of single buildings but it elevates the meaning as the whole, point out to the identity of the milieu, recognising the representative feature for each the city and, in these specificities, recognize the whole identity of Apulian territory.
At city scale, municipality of Molfetta reports in his Recovery plan (1994) all suitable interventions aiming at the preservation of safety and health of inhabitant. Referring to the preservations of formal values, all surfaces featured by significant formal appearance should not be covered or modified. Similar application is referred to calcareous stones used in street system.
At building scale, starting from the sub-system features identified in Table of code (Table 5.1-7) and local Protection normative frame, recurrent values for formal significance concern:

- unplastered walls which represent the will to demonstrate the ability of stonemasons to create jambs and stone decorations, as well as the magnificence of the slow manual work in opposition with the modern construction technologies. hus, walls also participate to the overall visual perception of the historical center, highlighting the genius loci capacities, along with their evolution during the time; similar remarks are included for unplastered barrel vaults at the ground floors;

- in the same way, wooden beams and slabs that represent the ability of artisans that could not be reproduced in a serial industrial production today.

Table of values (Table 5.1-10) identifies and summaries historical and cultural qualities to preserve at district and building scales.

Built element	code	Preservation Action	Preservation Code
Building scale			
Wall	Wa.1	Substitution of plaster not avoided Covering of stone details avoided Use of clear coloured plaster	V.Wa.1
	Wa.2	Maintenance of exposed stone Covering avoided	V.Wa.2
Window	Wi1	Maintenance of wooden frame Observance of dimensions Substitution of glasses not avoided	V.Wi1
Ground floor ceiling	Cg1	Substitution of plaster not avoided if lacking decorations	V.Cg1
	Cg2	Maintenance of exposed stone Covering avoided	V.Cg2
Roof (inner)	Cin	Maintenance of wooden beams Covering avoided Overloading avoided	V.Cin
Roof (external)	Cex.a	No action	
	Cex.b	Maintenance of stone tiles Replacement avoided	V.Cex.b
	Cex.c	No action	
Basement slab	Bf1	Maintenance of stone tiles Replacement avoided	V.Bf1
District scale			
Basole	B1	Maintenance of stone tiles Replacement avoided	V.B1

Table 5.1-10 Table of code of values at building and district scale

5.2 TAXONOMY PHASE (B)

5.2.1 CHARACTERIZATION OF LOCAL CLIMATE ZONE (B1)

To evaluate micro-climate feature, a first analysis of the whole district is required referring to the geometrical, thermal and optical features, according to the LCZ classification; in detail, average data are reported in Table 5.2-1 and Table 5.2-2.

	Building surface ratio (%)	Impervious surface ratio (%)	Pervious surface ratio (%)	Average Sky View Factor	Average height buildings [m]	Aspect ratio	Roughness length
Molfetta	62,1%	35,4%	2.5%	0.05 - 0.3	11,5	>3.5	skimming

Table 5.2-1 Characterization of historic district according to geometrical and distribution district features.

	Albedo	Thermal conductivity
walls	0.6[4]	2[5]
roofs	0.07[6]	1,8[7]
Street pavement	0.65 [3]	-

Table 5.2-2 Characterization of historic district according to physic and thermal properties of surfaces.

So, referring to the energy external loads, anthropogenic heat value is evaluated as zero because of the absence of vehicular traffic and production activities.
referring to standard LCZs, historic district cannot be compared with other cases because of the low value of SVF. That lack could be overtaken focusing on results at district scale in following sub-phase, and experimental phase of measure of micro-climate characters.

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[4] Experimentally measured, see annex A.1
[5] measured during the project "Methodological framework for assessment of energy behaviour of historic towns in Mediterranean climate", of a wall with 75 cm of thickness
[6] (Bogoslovsky 1982)
[7] The thermal transmittance was calculated based on the national code UNI 10351

5.2.2 CHARACTERIZATION AT CANYON SCALE (B2)

Because of the real complexity in district asset, canyons are classified referring to geometric and material features, using range of values or features. In detail:

- Main orientation of blocks as
  - 20° or 35° of variation to E-W orientation (O1; O2);
  - Curvilinear asset (O3);
  - Prevalent N-S orientation (O4);
- Referring to the geometrical features
  - Height-to-width ratio referring to average height of building and width of streets;
  - SVFs are evaluated at the center of the canyons, using Oke formula (Oke, 1981) and referring to the previous geometric characters, classifying them in three representative ranges
    - $SVF < 0.1$;
    - $0.1 < SVF < 0.2$;
    - $SVF > 0.2$;
- Alteration of local geometric and use features as:
  - Un-inhabited blocks (AD) for bad state of maintenance;
  - Garden areas enclosed in ground floor walls of disrupted buildings (AG);
  - Open square and paved area (AP);
- Finally, focusing on material properties of surfaces referring to the table of codes whereas physic properties are reported in Table 5.2-3.

	Albedo	emissivity
Wa1	0.60 [3]	0.95 [3]
Wa2	0.5 [5] (Fatiguso, M. De Fino, et al. 2015; Fatiguso, M De Fino, et al. 2015)	0.9 [5,7]
Cex.a	0.4 (Sailor 2008) [3]	0.9 [8,3]
Cex.b	0.6 [3]	
Cex.c	0.07 [8,3]	

Table 5.2-3 Physic properties of surfaces in canyons

Material and morpho-typological features of district blocks are reorganized referring to a reference number of canyon (Figure 5.2-1) and summarized in Table 5.2-4.

Figure 5.2-1 Reference of numeration of canyon. Source: author

canyon	Building features		Geometric features		orientation	alteration
	walls	roofs	H/W	SWF		
1	Wa1	CG	3.28	0.1 ÷ 0.2	O3	AG - AD
2	Wa1	CG	3.83	< 0.1	O3	AG
3	Wa1	CG – CM	4.85	< 0.1	O1	AG
4	Wa1 – Wa2	CM	6.31	< 0.1	O1	-
5	Wa2	CM – CC	5.83	< 0.1	O1	-
6	Wa2 - Wa1	CC – CG	5.43	< 0.1	O1	-
7	Wa1	CG	5.5	< 0.1	O1	-
8	Wa1	CM – CG	3.5	0.1 ÷ 0.2	O3	AG
9	Wa1	CG – CC	3.65	0.1 ÷ 0.2	O3	AG - AD
10	Wa1	CC – CG	4.31	0.1 ÷ 0.2	O3	AD
11	Wa1	CG	6.39	< 0.1	O2	AD
12	Wa2 - Wa1	CG	3.48	0.1 ÷ 0.2	O2	-
13	Wa1	CG	4.87	< 0.1	O2	AD
14	Wa1	CG	4.87	< 0.1	O2	AP - AD
15	Wa1	CG	4.55	0.1 ÷ 0.2	O2	AP
16	Wa1	CG	2.3	> 0.2	O4	-

Table 5.2-4 Characterization of canyons

As result of the geometrical and material features assessment, the recurrent values are:

- a SVF value that is < 0.1 and $H/W > 4$, combined with an orientation of 20 or 35° along the E-W axis;
- unplastered walls, bituminous roofs and calcarenitic stone tiles for the external pavements;
- zero anthropogenic heat value.

In that sense, South part of the district is representative of the recurrent elements.

5.2.3 CHARACTERIZATION OF BUILDING TYPE (B3)

In the case of the historic town of Molfetta, as the result of height, geometrical, material and construction technique features, the most representative building-type is a tower-house, in the middle of a block, where units are arranged in two symmetrical rows. The plan is rectangular - 8m deep and 4m large -, with only one external façade and one opening per floor. The model has commercial use at the ground floor – 3m high – and three upper floors – 3.5m high - as one-family dwelling. The main construction materials and techniques are summarized as follows:

- Masonry cavity walls (75cm thick) with inner nucleus of limestone calcarenitic stone, outer leaves exposed from the ground floor to the upper one, internal leaves always covered by plaster (3cm thick);
- Windows with traditional wooden frame (110cm x 280cm x 40mm) and single glazing (0,3cm thick);
- Roofs made of wooden beams and slabs, covered by sloping lightweight concrete slab, mortars and bituminous waterproof finishing layer (overall thickness = 17cm);
- Stone barrel vault (20cm thick) between ground and first floor and wooden joists and board (18cm total thickness) at the upper floors;
- Basement slab with “Cursi” stone tiles (8cm thick) on soil, here assumed as wet due to sea proximity.

In Table 5.2-5 thermal properties are reported, highlighting the reference in Normative threshold, while in Figure 5.2-2 the geometric model is presented.

Building-type	Component	Thickness [m]	Current thermal conductance [W/m² K]	phase shift τ / attenuation of thermal wave σ	Normative threshold [W/m² K]
Middle Tower-house	Wall	0,75	2 [5]	12h / 0.7 [5]	0,38
	Roof	0,17	2,83 [5]		0,36
	Basement slab	0,08	1,83 [8]		0,40
	Window	-	5,4 [8]		2,40

Table 5.2-5 Thermal properties of Building type

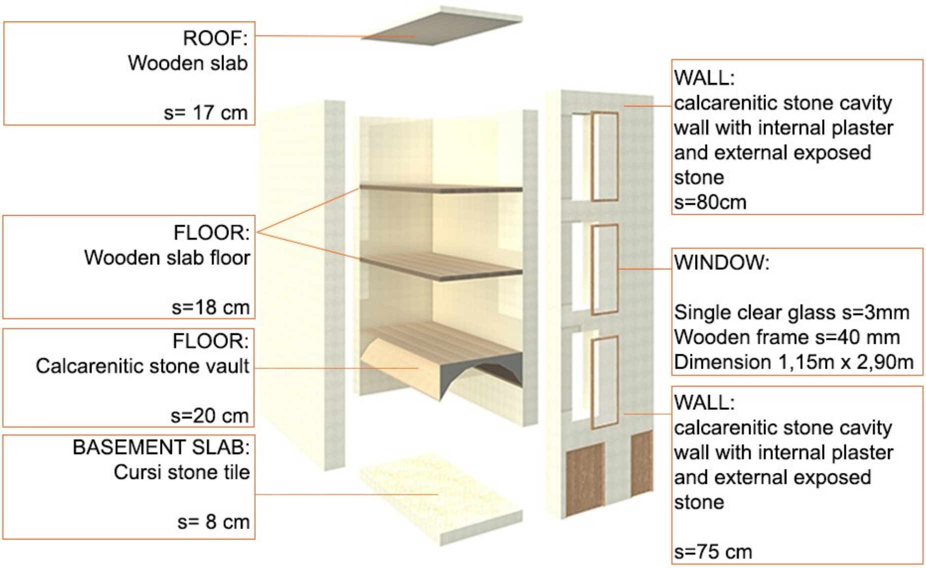


Figure 5.2-2 Characterization of Building type in Molfetta. Source: author

[8] The thermal conductivity of the "Cursi" stone are reported in literature (Santamouris 2013)

5.3 MONITORING AND TESTING PHASE OF LOCAL BEHAVIOURS (C)

5.3.1 MONITORING OF LOCAL CLIMATE (C1)

As discussed in methodology, on-site measures should be representative of the district in analysis in selecting location, avoiding local and not representative elements, and in mutual positions between point of reference. Referring to the case study (Figure 5.3-1):

- the south part of the historic center is the most representative of the whole district. However, the South-west part of it is featured by local anomalies; so, inner point of measure is in canyon 4 (E1) for the representativeness of the South-west part of the analysis, as highlighted in B2 sub-phase;
- considering external conditions that influence the local climate (predominant wind direction and urban asset) surely proximity of the sea all around the historic district influence the boundary conditions of microclimate, more than the urban one; the Harbour Master's office is chosen as the outer point because of his proximity to the sea and the historic district (E2);
- another external point is chosen in the economic popular sub-district; the site is representative for the presence of Arpa Station of measurement that is useful as the check-reference for measures (E3).

Moreover, the absence of local standard instrument of measure for other purposes, induced the creation of not-standard systems, located in each point, featured by:

- a wooden envelope (20 x 20 x 20 cm) as shading element for measure device; to limit inner overheating, surfaces were painted using a white and shiny paint and openings (2 split for each face with 1 cm of width) were created all around the envelope in order to guarantee the internal ventilation and avoid local overheating;
- RH/temperature datalogger, model EL-USB-2 of Lascar electronics (resolution 0.5°C, Accuracy 0.55°C), was suspended into the envelope to reduce measurement errors for superficial changes; 1 hour-detail measures have been collected.

Figure 5.3-1 Points of measure inside (E1), outside (E2) the district and in sub-urban area (E3)

About the specific locations (Figure 5.3-2):

-Envelope 1 (E1) is located at 4,5 mt height

-Envelope 2 (E2) at 5 mt height

-Envelope 3 (E3) at 2 mt.

Finally, the period between march and August 2017 as been analysed.

Figure 5.3-2 Positioning of white envelopes inside the canyon (E1, blue line), outside the district (E2, green line) and in sub-urban area (E3, orange line).

5.3.2 TESTING DATA (C2)

5.3.2.1 C2.1 ANALYSIS OF LOCAL CLIMATE ANOMALIES

First of all, the possibility to have an urban standard station (Arpa station) allows to evaluate changes and extremes in local climate, in a continuous way. As a first step, monthly average monitored data during monitored march-august period of 2017 are compared with previous of the same station in Table 5.3-1, Table 5.3-2, Table 5.3-3.

	March	April	May	June	July	August
2009-2016	12.5	16	20.2	24.2	27.7	27.3
2017	13.93	15.65	20.83	26.6	28.78	28.8
Δ	+1.83	-0.65	+0.63	+2.4	+1.08	+1.5

Table 5.3-1 Average mean monthly data

	March	April	May	June	July	August
2009-2016	17	21	25.1	28.6	32.2	32
2017	19.1	20.76	25.18	30.84	32.86	33.5
Δ	+2	0	0	+2	+0.6	+1.5

Table 5.3-2 Average maximum monthly data

	March	April	May	June	July	August
2009-2016	8.7	11.5	15.8	19.3	23	23
2017	10.39	11.64	16.42	22.59	24.46	24,6
Δ	+1.5	0	+0.5	+3	+1.5	+1.6

Table 5.3-3 Average minimum monthly data

As general overview, monitored data are recurrently higher that previous years above all during summer period, referring to the monthly average values. However, monitored maximum temperatures highlight the necessity to examine and recognize extreme period, using indices of climate changes. Main aim is recognition of warm-spells and quantification of their duration along the summer period (June-August); in detail, each day the daily maximum temperature is compared with the 90th percentile of daily maximum temperatures during the latest 9 years calculated for a five-day window centred on each calendar day. As result of analysis, 3 warm spells are recognized during the period: a three-days period at the end of June with an intensity of 5°C, a two-days in July with intensity of 1°C and 1 in August with a three day of +3 °C (Table 5.3-4).

data	Daily Tmax	90th Percentile (2008-2016)	Δ
27/06/2017	38.15	32.13867	+6
28/06/2017	36.67	32.23526	+4.5
29/06/2017	39.52	33.09764	+6.5
11/07/2017	37.38	35.72932	+1.6
12/07/2017	37.00	36.45102	+0.55
02/08/2017	36.66	34.41088	+2.25
03/08/2017	37.92	34.49173	+3.43
04/08/2017	37.03	34.87202	+2.16

Table 5.3-4 Warm-spells during monitoring period.

5.3.2.2 C2.2 ANALYSIS OF MONITORED MICRO-CLIMATE

As discuss before, three points of measures are introduced focusing on:

- Undisturbed zone of measure near to the sea as the ambient value of evaluation;
- Case study analysis as non-standard zone but near to the Undisturbed one;
- Traditional Sub-urban area where a standard station is located.

First of all, the comparison between the undisturbed zone and sub-urban zone is proposed in Table 5.3-5 for the monitored period.

	March				April			
	max	min	average	Dev.St	max	min	average	Dev.St
E2	18.92	10.21	13.61	3.34	22.80	11.55	15.71	4.50
E3	19.0	10.1	13.9	3.19	22.03	11.43	15.91	4.50
Δ	-0.08	+0.11	-0.29	-0.15	+0.77	+0.12	-0.2	0
	May				June			
	max	min	average	Dev.St	max	min	average	Dev.St
E2	27.06	16.10	20.29	3.98	32.05	22.27	26.04	3.86
E3	26.82	16.26	21.08	4.15	31.80	22.28	26.52	3.69
Δ	+0.24	-0.16	-0.79	-0.17	+0.25	-0.01	-0.48	+0.17
	July				August			
	max	min	average	Dev.St	max	min	average	Dev.St
E2	34.32	23.82	27.75	3.74	35.80	24.42	28.51	4.46
E3	33.98	23.97	28.62	3.59	33.51	24.59	28.87	4.16
Δ	+0.34	-0.15	-0.87	+0.15	+2.29	-0.17	-0.36	+0.36

Table 5.3-5 Comparative evaluation of measures and statistics outside the historic district (E2) and far from it (E3)

The sub-urban area, featured by a low-density buildings and vehicular traffic heat, presents comparable values of mean extreme temperatures measured in the undisturbed zone, whereas average ones are higher: in that sense, the sub-urban area is featured by a low intensity of Urban Heat Island magnitude (as the difference of mean rural and urban temperatures) that varies from 0.5 to 1 during May-August period, while it is close to zero during the March and April.

As second step, in following tables, average maximum, minimum, average temperatures and Standard deviation of each monthly series of measures have been reported, aiming to compare E1 and E2 measures and to determine micro-climate behaviour historic district behaviour (Table 5.3-6).

	March				April			
	max	min	average	Dev.St	max	min	average	Dev.St
E1	16.790	11.032	13.837	2.586	21.250	12.950	16.106	3.663
E2	18.92	10.21	13.61	3.34	22.80	11.55	15.71	4.50
Δ	-2.13	0.82	0.23	-0.75	-1.55	1.4	0.39	-0.84
	May				June			
	max	min	average	Dev.St	max	min	average	Dev.St
E1	26.032	17.403	20.661	3.385	31.300	23.483	26.421	3.296
E2	27.76	16.06	20.36	4.06	32.57	22.27	26.12	3.99
Δ	-0.5	1.33	0.41	-0.54	-0.2	1.21	0.49	-0.54
	July				August			
	max	min	average	Dev.St	max	min	average	Dev.St
E1	33.28	25.35	28.28	2.96	34.90	25.58	28.78	3.50
E2	34.32	23.82	27.75	3.74	35.80	24.42	28.51	4.46
Δ	-1.04	1.53	0.53	-0.78	-0.90	1.17	0.26	-0.96

Table 5.3-6 Comparative evaluation of measures and statistics inside (E1) and outside the historic district (E2)

Differently to the previous case, average temperatures are quite similar (with peak of 0.5°C), highlighting low magnitude of UHI. Moreover, some other remarks could be highlighted for the other measures:

- Mean maximum measures at the inner point of historic centre are always lower that the outside; this observation should be associate to the higher shading effect that, during the day, avoids the direct solar irradiation of canyon;

- Mean minimum data are always higher that the outside; it represents the nocturnal effect on direct radiation and absorption of them by the canyon during the day, referring to the thermal and reflective features of materials as well as to the geometry of the canyon; in fact, the presence of narrow street, reflective surfaces and vertical envelope with high heat capacity, contribute in multiple reflections and in low dispersion of latent heat; despite that, the reduction of direct radiation along the day contribute in decrease that exposure;
- Finally, the Standard deviation of measures are representative of a recurrent element: in fact, for all the months, standard deviation of the inner point of evaluation is always lower that the outer; according to the statistical significance of it, inner temperatures vary during the day remaining near the mean values. That result is also true during the summer when, even If the solar gains increase, the real exposure to the direct radiations is referred to few hours.

Moreover, comparing mean and maximum temperatures between historic district and sub-urban district ancient core seems to be colder than the sub-urban areas representative of outer boundary condition at the south of old core.
As the result of the experimental phase, a specific behaviour could be highlighted: as the massive walls - with high inertia - decrease the inner temperature ranges, the historic district uses his “massiveness” to create a local microclimate featured by lower temperature ranges.

5.3.2.3 C2.2a VALIDATION AND EXTENSION OF BEHAVIOUR

Starting from the monthly data, some typical days are analysed towards highlighting some evidences. In fact, the analysis at monthly scale surely includes a systematic combination of meteorological features (cloudiness, wind) that cannot be completely representative of canyon behaviour. To overcome that, specific days, featured by average monthly temperature measure, has been analysed considering maximum solar radiation and minimum interaction with cloudiness and minimum interference of wind intensity, focusing on monthly dominant directions (historical data and year of measure), as boundary conditions to evaluate standard maximum UHI intensity.

In detail, Table 5.3-7 represents daily conditions.

		Max	min	average	Dev.St	Wind direction[9]	Wind speed[4]
24/03/2017	E1	16.50	13	14.6	1.4	-	-
	E2	18.5	12	14.34	2.4	W	0.5
	Δ	-2	+1	+0.26	-1		
06/04/2017	E1	20.000	13	16.13	2.54	-	-
	E2	21.50	12	16.17	3.48	W	0.6
	Δ	-1.5	+1	0	-0.96		
27/05/2017	E1	25	18	21.4	2.37	-	-
	E2	26	17.5	21.4	3	W	0.6
	Δ	-1	+0.5	0	-0.63		
07/06/2017	E1	31.00	23	26	2.64	-	-
	E2	32.50	21.50	25.58	3.65	W	0.5
	Δ	-1.5	+1.5	+0.5	-1		
14/07/2017	E1	31.5	27	28.44	1.66		
	E2	32.5	26	28.69	2.28	W	0.5
	Δ	-1	+1	+0.2	-0.6		
AGOSTO	E1	33.50	24.50	28.15	2.83		
	E2	34.50	23.50	28.10	3.93	W	0.45
	Δ	-1	+1	+0.05	-0.9		

Table 5.3-7 Daily conditions of reference typical days for the evaluation at model scale

These daily weather conditions are used to prepare the double sensitivity analysis in evaluation of measures and horizontally variation of results. In detail, an Envi-met model of the whole historic district has been created using a 2mt-grid resolution with a final extension of 150*170*25 grids.

Physical properties of Materials and geometric information of the model are referred to Table 6.2 3 and Table 5.2-4. Local alterations, as garden and squares, are represented according to their properties, whereas un-inhabited buildings are not introduced.

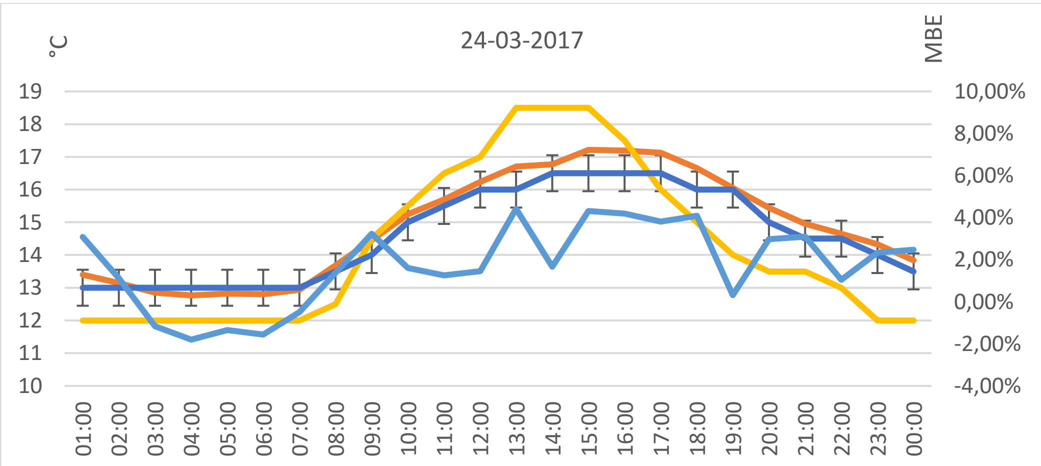
[9] Wind information, such as solar radiation data were registered by the Arpa Standard station

Material	thickness	albedo	Emissivity
Calcarenitic stone pavement (Clear calcareous, shiny)	0.2	0.6 [10]	0.95 [5]
Walls (clear calcarenitic)	0.75	0.60 [5]	0.95 [5]
Clear coloured plaster	0.025	0.55 (Fatiguso et al. 2016) (Santamouris 2013)	0.91 (Brewster 1992)

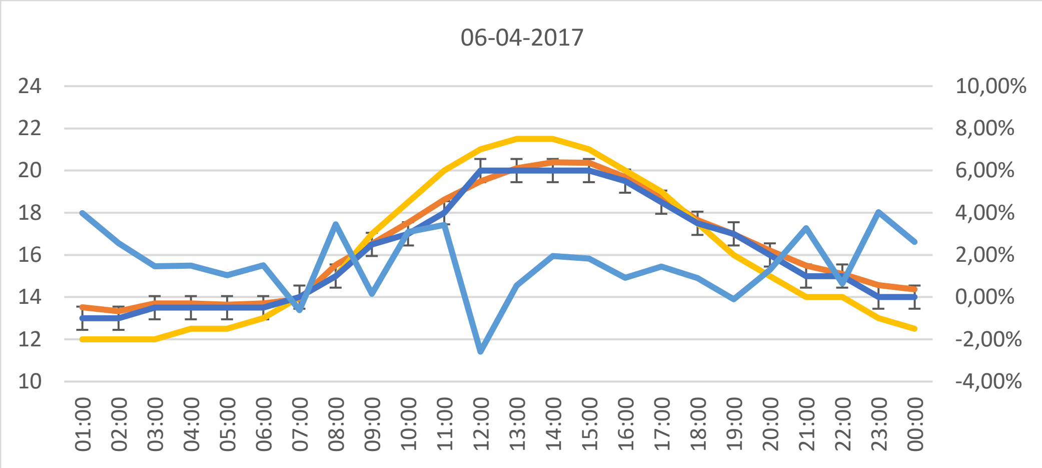
Table 5.3-8 Geometric, thermal and optical properties of surfaces inside the canyon of measure.

In detail, Envimet model has been performed forcing external hourly for 72 hours (Reference of days) but only the last is reported for an understandable lecture. In detail of results, following figures report and compare:

- Ambient temperature considering the measures at the Harbour Master office (outside the ancient core) – yellow line;
- Measured temperatures in narrow street featured by the Bar Error, representative of the instrument sensitivity used for measures (0,55 °C) – blue line;
- Simulated temperatures referring to the output of Envimet Simulation in the same position of the real point, extracted at 4 mt of height – orange line.



[10] Experimentally measured, see annex A.2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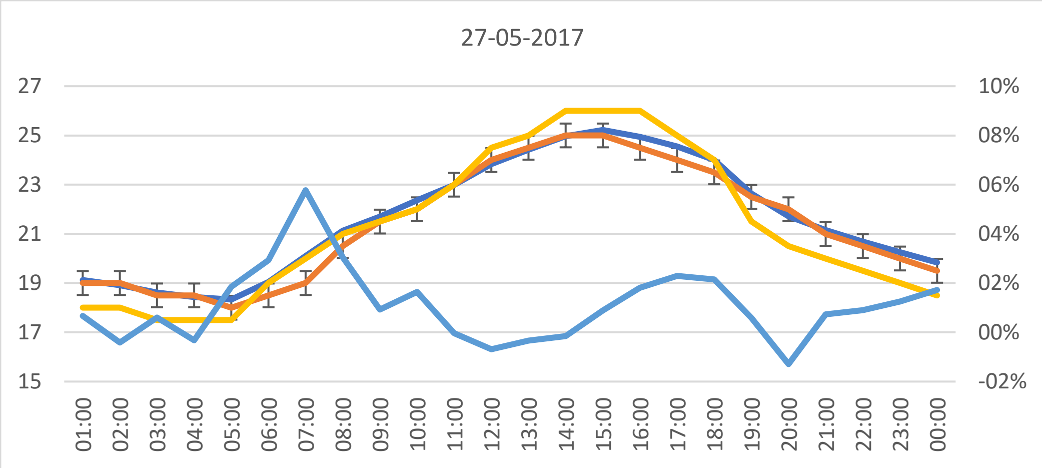
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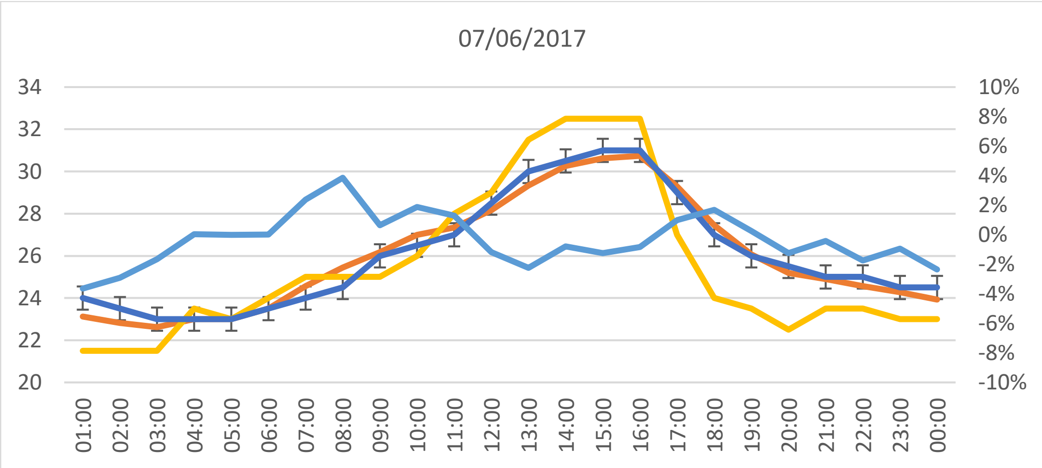
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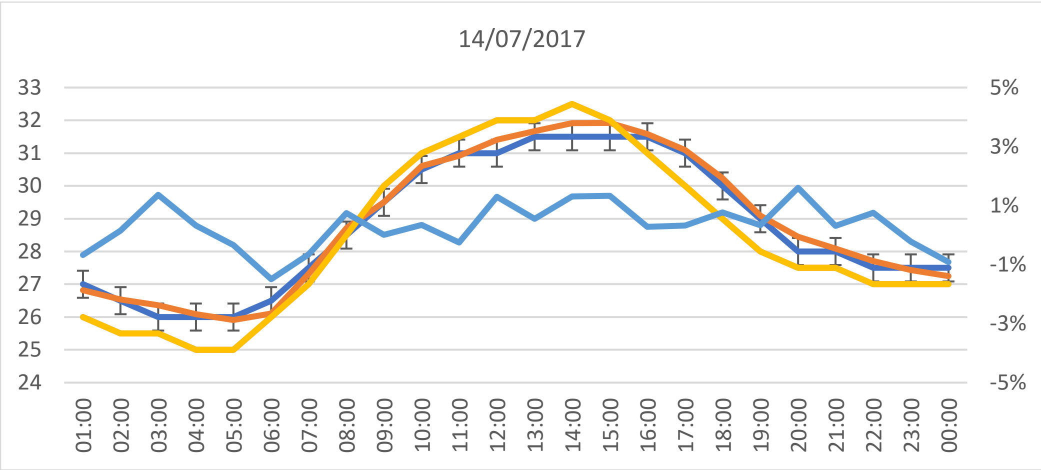
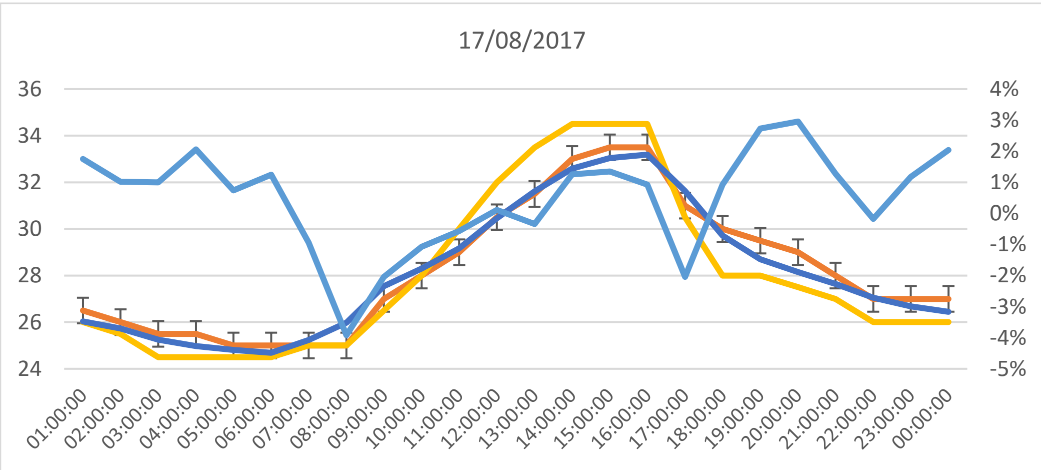




Model is well calibrated in point of analysis because of graphical and statistical comparability between results: in fact, differences between measured and simulated temperatures vary less that the Sensitivity of instrument (0.55°C) and MBE and CVRMSE[11] values are lower than 10% for each measure. For that reason, it is assumed that model well describe the canyon in analysis and all material features are well modelled. Moreover, focusing on the real location of measures (+5mt), point of measure is well chosen for the analysis at the level of canyon.

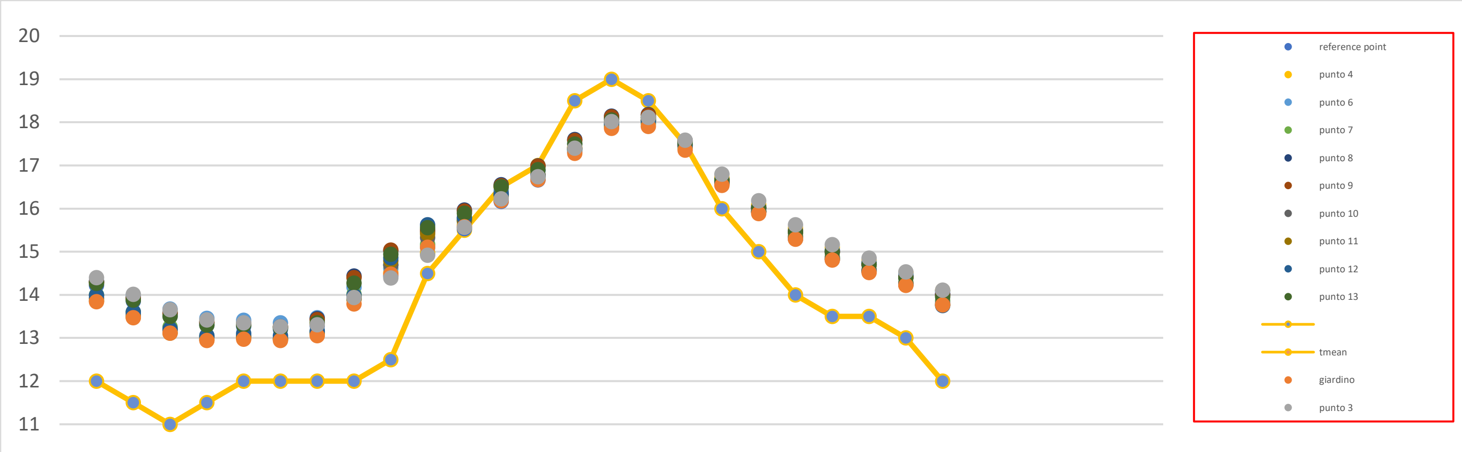
[11] Mean Bias Error (MBE) and Cumulative Variation of Root Mean Squared Error (CVRMSE) are comparative measures for error used in ASHRAE guidelines to compare measured and simulated temperatures of utilities; guidelines fix as acceptable values that has MBE < 10% and CVRMSE < 30%.

Starting from the same simulations, Envi-met model results were analysed in order to get dissimilarities at horizontal scale in sub-districts and canyons into the whole ancient core. Inner canyons are evaluated considering the daily variation of temperatures in the middle of canyons; moreover, results are compared with the measures to evaluate Substantial differences in behaviour. In fact, the aim is to determine differences in material properties and canyon orientation, and to verify the solidity of the choice of the site. Figure 5.3-3 explains the analysed points for the sensitivity process at district scale model realized in Envimet, reflecting all features described for canyon in Table 5.3-8.

Figure 5.3-3 Envimet model of historic district and points of comparison. Source: author

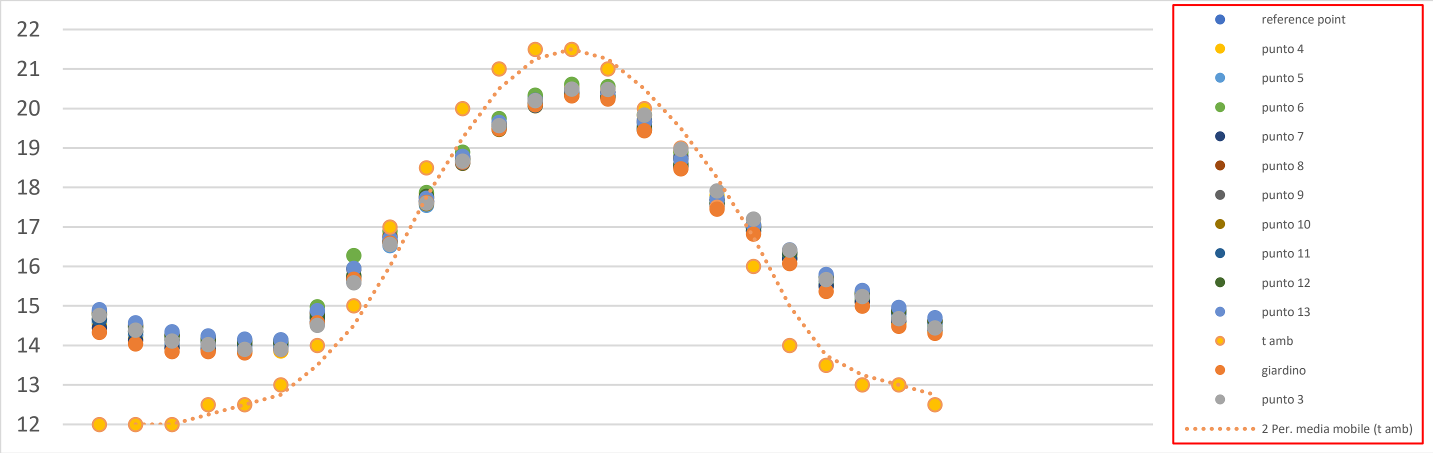
In detail, point 2 represents the Reference and calibrated point of simulation, whereas the other 13 are used for the sensitivity analysis. Following, specific data sheets are reported for every simulated day.

24/03/2017



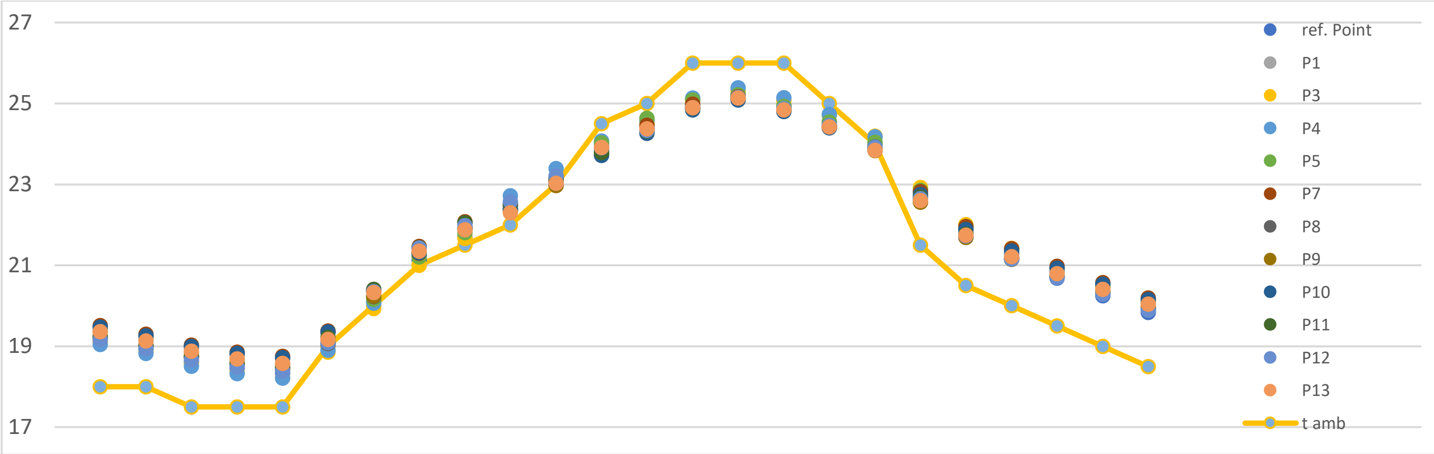
	Ref. Point	P1	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	Measured
mean	15.15	14.97	15.23	15.22	15.15	15.16	15.08	15.31	15.30	15.08	15.07	15.11	15.26	15
Δ(amb)	0.96	0.78	1.04	1.03	0.97	0.97	0.89	1.12	1.11	0.89	0.88	0.92	1.07	
Δ (ref.)		-0.18	0.08	0.07	0.00	0.00	-0.07	0.16	0.15	-0.07	-0.08	-0.04	0.11	
max	18.01	17.91	18.11	18.11	18.01	18.02	17.96	18.18	18.17	18.04	18.05	18.04	18.11	18
Δ(amb)	-0.99	-1.09	-0.89	-0.89	-0.99	-0.98	-1.04	-0.82	-0.83	-0.96	-0.95	-0.96	-0.89	
Δ (ref.)		-0.11	0.10	0.09	-0.01	0.01	-0.05	0.16	0.15	0.02	0.04	0.03	0.09	
min	13.21	12.90	13.26	13.26	13.19	13.25	12.98	13.26	13.26	13.00	12.96	13.06	13.23	13
Δ(amb)	2.21	1.90	2.26	2.26	2.19	2.25	1.98	2.26	2.26	2.00	1.96	2.06	2.23	
Δ (ref.)		-0.31	0.05	0.05	-0.02	0.05	-0.23	0.05	0.05	-0.21	-0.25	-0.15	0.02	
st.dev	1.56	1.68	1.57	1.57	1.59	1.55	1.64	1.60	1.60	1.67	1.69	1.66	1.60	1.5
	-0.98	-0.87	-0.97	-0.97	-0.96	-0.99	-0.91	-0.95	-0.94	-0.87	-0.85	-0.89	-0.95	

04/04/2017



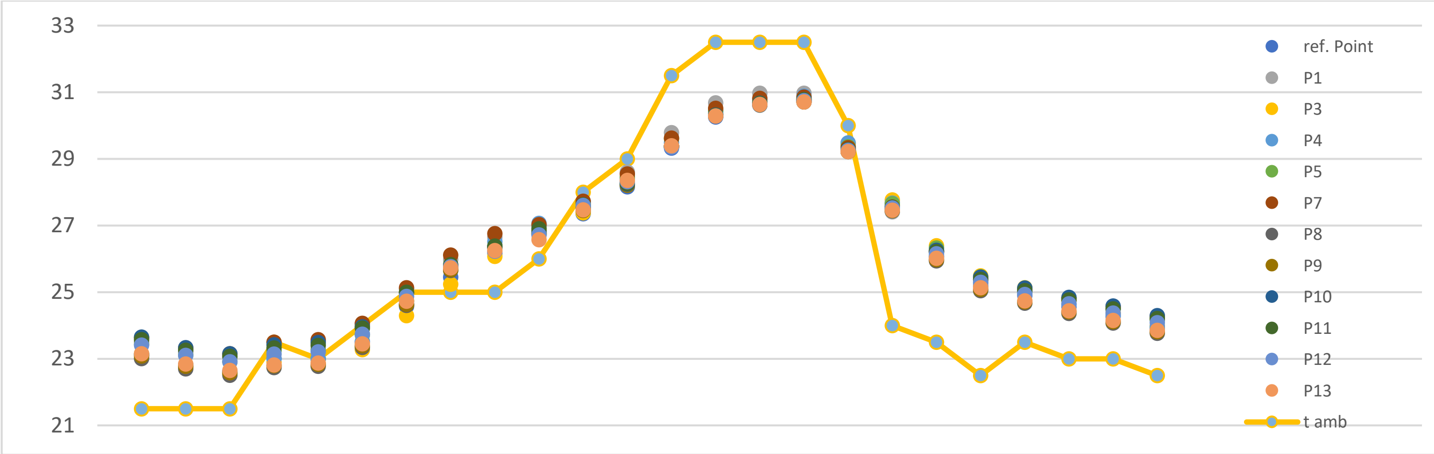
	ref. Point	P1	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	measured
mean	16.56	16.42	16.63	16.59	16.58	16.73	16.50	16.69	16.71	16.58	16.59	16.64	16.73	16.2
Δ(amb)	0.64	0.50	0.71	0.68	0.67	0.81	0.58	0.77	0.79	0.67	0.67	0.73	0.81	
Δ (ref.)		-0.12	-0.14	0.07	0.04	0.03	0.17	-0.06	0.13	0.15	0.03	0.03	0.09	
max	20.44	20.39	20.49	20.54	20.50	20.61	20.37	20.47	20.47	20.33	20.35	20.36	20.47	20
Δ(amb)	-1.06	-1.11	-1.01	-0.96	-1.00	-0.89	-1.13	-1.04	-1.03	-1.17	-1.16	-1.14	-1.04	
Δ (ref.)		-0.12	-0.05	0.05	0.09	0.06	0.17	-0.08	0.02	0.03	-0.11	-0.10	-0.08	
min	13.89	13.78	13.90	13.82	13.93	14.12	13.86	14.10	14.12	14.03	14.02	14.08	14.15	14
Δ(amb)	1.89	1.78	1.90	1.82	1.93	2.12	1.86	2.10	2.12	2.03	2.02	2.08	2.15	
Δ (ref.)		-0.08	-0.11	0.01	-0.07	0.04	0.22	-0.03	0.21	0.23	0.14	0.12	0.19	
st.dev	2.35	2.37	2.36	2.42	2.33	2.33	2.32	2.25	2.24	2.23	2.24	2.22	2.23	2.5
	-1.18	-1.17	-1.18	-1.12	-1.21	-1.21	-1.22	-1.28	-1.29	-1.31	-1.30	-1.31	-1.31	

27/05/2017



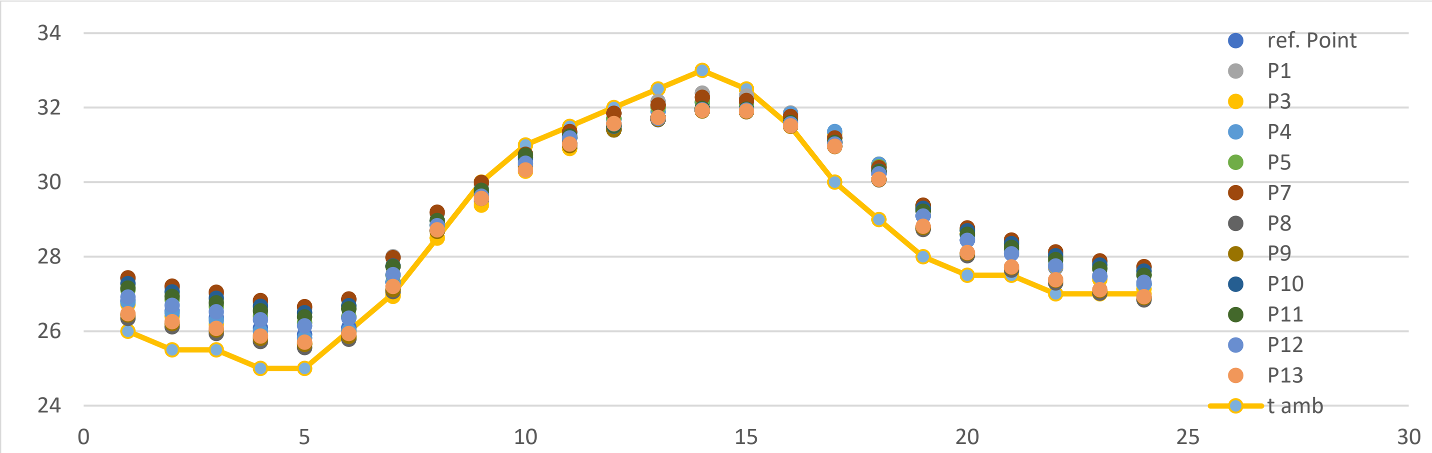
	ref. Point	P1	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	measured
mean	21.62	21.80	21.68	21.72	21.78	21.48	21.83	21.66	21.64	21.76	21.70	21.68	21.70	21.5
Δ(amb)	0.35	0.53	0.41	0.45	0.51	0.21	0.56	0.38	0.37	0.49	0.43	0.41	0.43	
Δ(ref)	-	0.18	0.06	0.10	0.15	-0.15	0.21	0.03	0.02	0.14	0.08	0.05	0.08	
max	25.22	25.30	25.32	25.39	25.21	25.33	25.17	25.13	25.12	25.09	25.14	25.15	25.13	25
Δ(amb)	-0.78	-0.70	-0.68	-0.61	-0.79	-0.67	-0.83	-0.87	-0.89	-0.91	-0.86	-0.85	-0.87	
Δ(ref)	-	0.08	0.10	0.17	-0.01	0.11	-0.05	-0.09	-0.11	-0.14	-0.09	-0.07	-0.09	
min	18.33	18.69	18.22	18.21	18.55	17.84	18.75	18.45	18.46	18.72	18.46	18.38	18.58	18
Δ(amb)	0.83	1.19	0.72	0.71	1.05	0.34	1.25	0.95	0.96	1.22	0.96	0.88	1.08	
Δ(ref)	-	0.36	-0.11	-0.12	0.22	-0.50	0.42	0.12	0.13	0.39	0.13	0.05	0.24	
st.dev	2.33	2.23	2.40	2.45	2.27	2.26	2.16	2.25	2.23	2.13	2.25	2.29	2.20	2.37
	-0.66	-0.76	-0.59	-0.54	-0.72	-0.72	-0.83	-0.74	-0.75	-0.86	-0.74	-0.70	-0.79	

07/06/2017



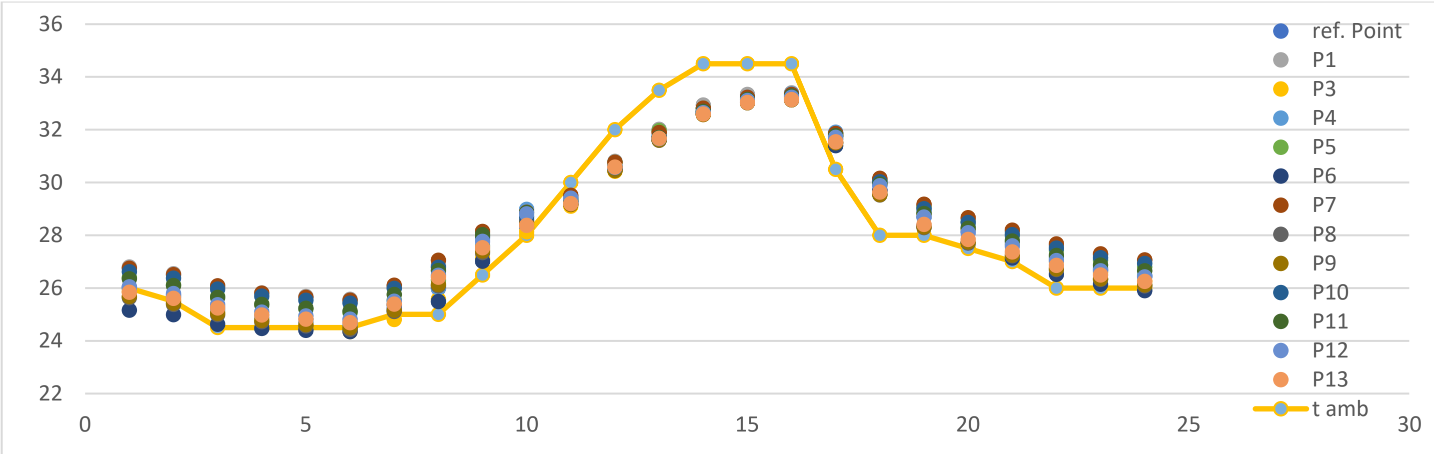
	ref. Point	P1	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	measured
mean	25.974	26.282	26.005	26.094	26.178	25.815	26.317	25.902	25.929	26.220	26.192	26.095	25.955	26
Δ(amb)	0.391	0.699	0.422	0.511	0.595	-0.068	0.734	0.318	0.345	0.636	0.609	0.512	0.371	
Δ(ref)	-	0.308	0.031	0.120	0.204	-0.179	0.343	-0.072	-0.045	0.246	0.218	0.121	-0.019	
max	30.742	30.973	30.813	30.887	30.794	30.767	30.854	30.711	30.713	30.777	30.775	30.745	30.713	31
Δ(amb)	-1.758	-1.527	-1.687	-1.613	-1.706	-1.733	-1.646	-1.789	-1.787	-1.723	-1.725	-1.755	-1.787	
Δ(ref)	-	0.231	0.071	0.145	0.052	0.025	0.112	-0.031	-0.029	0.035	0.033	0.003	-0.029	
min	22.621	23.052	22.566	22.61	22.914	22.638	23.154	22.507	22.579	23.154	23.077	22.914	22.646	23
Δ(amb)	1.121	1.552	1.066	1.11	1.414	0.138	1.654	1.007	1.079	1.654	1.577	1.414	1.146	
Δ(ref)	-	0.431	-0.055	-0.011	0.293	-0.017	0.533	-0.114	-0.042	0.533	0.456	0.293	0.025	
st.dev	2.646	2.609	2.703	2.715	2.597	2.704	2.535	2.716	2.690	2.478	2.511	2.569	2.674	2.84
	-1.106	-1.144	-1.049	-1.038	-1.155	-1.16	-1.218	-1.036	-1.062	-1.274	-1.241	-1.183	-1.079	

14/07/2017



	ref. Point	P1	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	measured
mean	28.86	29.32	28.97	29.09	29.12	29.31	29.34	28.67	29.14	29.09	28.95	28.70	28.82	28.78
Δ(amb)	0.30	0.64	0.41	0.53	0.56	0.74	0.67	0.11	0.57	0.53	0.51	0.14	0.26	
Δ(ref)	-	0.34	0.10	0.22	0.26	0.44	0.33	-0.19	0.27	0.23	0.21	-0.16	-0.04	
max	31.92	32.39	32.03	32.15	32.16	31.99	32.28	31.92	31.91	31.97	31.98	31.94	31.93	31.5
Δ(amb)	-1.08	-0.61	-0.97	-0.85	-0.84	-1.01	-0.73	-1.08	-1.09	-1.03	-1.02	-1.06	-1.07	
Δ(ref)	-	0.47	0.11	0.22	0.24	0.07	0.35	0.00	-0.01	0.05	0.06	0.02	0.01	
min	25.91	26.61	25.67	25.82	26.23	24.45	26.66	25.56	25.64	26.50	26.38	26.14	25.70	26
Δ(amb)	0.91	1.61	0.67	0.82	1.23	-0.56	1.66	0.56	0.64	1.50	1.38	1.14	0.70	
Δ(ref)	-	0.70	-0.24	-0.09	0.31	-1.47	0.75	-0.35	-0.27	0.59	0.47	0.23	-0.21	
st.dev	2.13	2.02	2.24	2.26	2.08	2.76	1.97	2.29	2.25	1.94	1.99	2.07	2.24	2.02
	-0.51	-0.62	-0.40	-0.38	-0.56	0.13	-0.66	-0.35	-0.39	-0.70	-0.64	-0.56	-0.40	

17/08/2017



	ref. Point	P1	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	measured
mean	28.11	28.66	28.00	28.22	28.42	27.44	28.67	27.92	27.94	28.40	28.38	28.22	28.06	28.15
Δ(amb)	-0.06	0.49	-0.17	0.05	0.25	-0.73	0.51	-0.24	-0.22	0.36	0.22	0.06	-0.10	
Δ(ref)	-	0.55	-0.11	0.11	0.31	-0.67	0.56	-0.19	-0.17	0.29	0.27	0.11	-0.05	
max	33.19	33.40	33.21	33.37	33.30	33.16	33.34	33.13	33.13	33.28	33.28	33.23	33.15	33.5
Δ(amb)	-3.31	-3.10	-3.29	-3.14	-3.20	-3.34	-3.16	-3.37	-3.37	-3.22	-3.23	-3.27	-3.36	
Δ(ref)	-	0.21	0.02	0.18	0.11	-0.03	0.15	-0.06	-0.06	0.09	0.09	0.04	-0.04	
min	24.69	25.58	24.34	24.57	25.07	23.49	25.53	24.44	24.49	25.10	25.12	24.82	24.69	24.15
Δ(amb)	-2.31	-1.42	-2.66	-2.43	-1.93	-3.51	-1.47	-2.56	-2.51	-1.57	-1.88	-2.18	-2.31	
Δ(ref)	-	0.89	-0.34	-0.12	0.38	-1.20	0.84	-0.25	-0.20	0.42	0.44	0.14	0.00	
st.dev	2.75	7.824	8.864	8.799	8.230	9.674	7.806	8.696	8.642	7.854	8.151	8.410	8.454	2.83
	-1.02	-1.676	-0.636	-0.701	-1.270	0.174	-1.694	-0.804	-0.858	-1.646	-1.349	-1.090	-1.046	

As general result of simulations, the whole district appears homogeneous in reacting to external micro-climate features and processes during spring period (March – May). Similarly, during summer (June – August) daytime temperatures are similar in each canyon of simulation underlining that orientation of block and finishing material, clear plaster or unplastered stone, determining a scarce variation at the district scale and so the high efficacy of system in reduction at district scale. This evidence is close related to the closeness and compactness of district that create irrelevant interactions between wall features and district temperatures. At the same time, the use of good reflective pavement ($\alpha=0.6$) contributes to the local micro-climate during the midday while different materials on roofs does not generate interactions with the air into the canyon for the same reasons, because of the relevant height of them.

However, some remarks could be highlighted focusing on some points above all during the night:

- increasing SVF in open spaces (as superior extreme in P1 and P7), different temperature values could be found horizontally, especially during summer night; in fact, differently from the Narrow and E-W oriented blocks, open spaces copes with a higher exposure during the day to the direct solar radiation, with +0.35 °C than reference point; during the night, differences reach +0.7 °C because of the higher solar heat storage during the day and low dissipation during the night because of low wind intensities; that generate an increasing mean daily temperatures;
- a halfway condition is presented in canyon where SVF and H/W values varies between narrow and open space cases; ensuring good shading properties along the midday, temperatures are quite similar than in narrow reference street; on the contrary, during the night, values are intermediate (+0.5).

Main cause of these features can be associated to the solar heat storage along the area. To support that idea, a comparison between five points has been developed during the 14th July. In detail, Reference Point, garden (P1), square (P7), large canyon E-W oriented (P10) and large canyon N-S oriented (P5) measures of solar contributes are reported in Figure 5.3-5 and Figure 5.3-6, while variation of hourly temperature measures and mean radiant temperatures in Figg. 5.3-4 and 7.

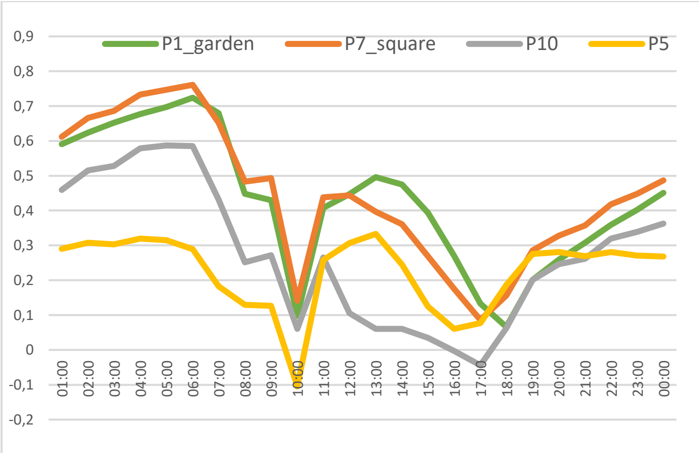


Figure 5.3-4 Variation of hourly temperatures with Reference point

Figure 5.3-6 Variation of direct solar radiation

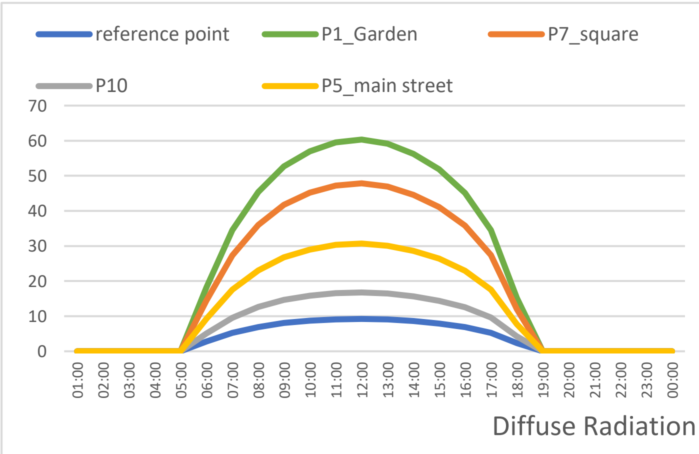


Figure 5.3-5 Variation of diffuse solar radiation

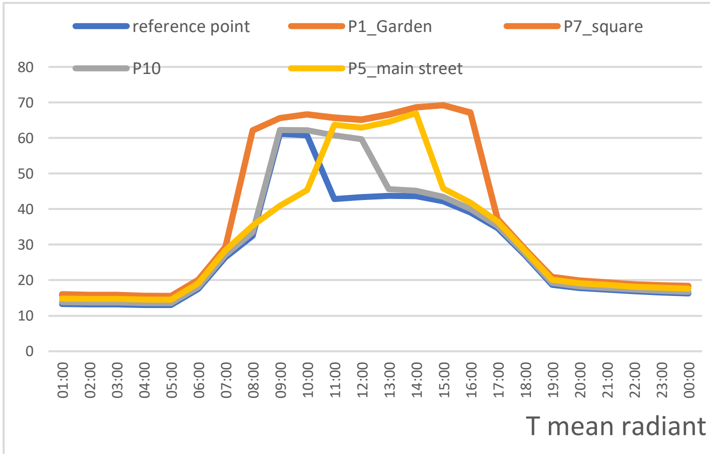


Figure 5.3-7 Variation of hourly radiant temperatures

It is comprehensible that midday peaks on temperature measures (both ambient and mean radiant) are strictly related to the direct solar radiation influence, while hourly variations while diffuse radiation differences influence mean values.
To summarize the behaviour of canyons in the whole historic district, two images are reported following.
It is well clear that, during midday to higher value of SVF is associate an increased temperature (fig. 5.3-8) with a maximum value of 0.5° C in open areas (squares and gardens).
On the contrary, higher classification can be associated for narrow canyon (SVF< 0.1), middle canyon (SVF = 0.1 ÷ 0.2) and open areas during the nightly temperatures where differences in range of 0.5 °C can be easily recognized in Fig. 5.3-9.

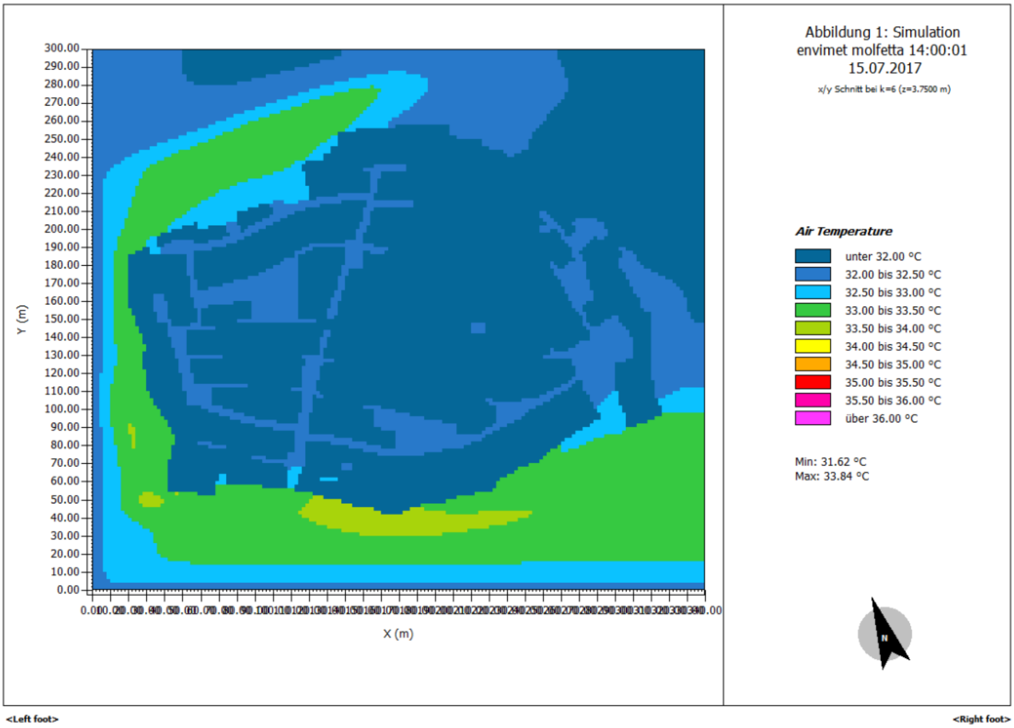


Figure 5.3-8 Horizontally variation of maximum temperatures simulated

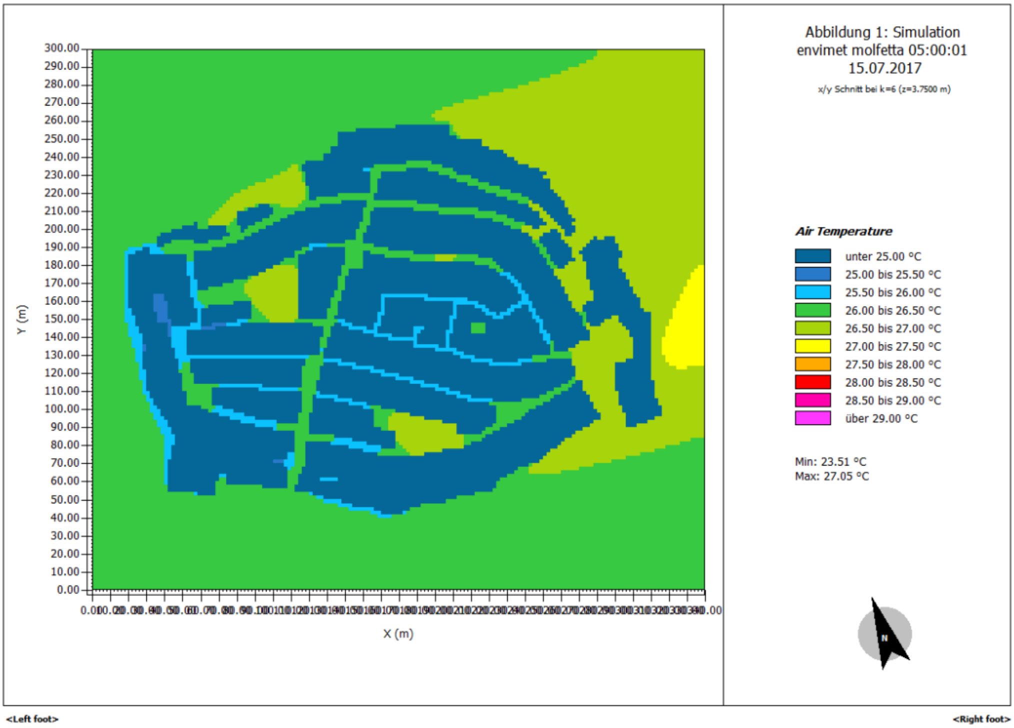


Figure 5.3-9 Horizontally variation of minimum temperatures simulated

In addition to simulations of inner points of district, boundary blocks are referred to have similar conditions of Harbour Master office measures.

At the end of discussion, summer behaviour of district can be summarized in 4 levels of reactions where:

R.1 refers to narrow canyons where both nocturnal and daytime temperatures are modified referred to external;

R.2 concerns middle canyons where only nocturnal conditions differ;

R.3 identifies open areas where temperature conditions are affected both in maximum and minimum conditions;

R.4 identifies external conditions for boundaries.

5.3.2.4 C2.2b TESTING BEHAVIOUR IN EXTREME CONDITIONS

Considering the measured “warm-spell” events as another opportunity of analysis, monitored data are evaluated again on these extreme events, focusing on June/August and his higher intensity. This analysis creates the opportunity to verify behaviours also during extreme conditions, as a test-step of future increasing temperatures. In detail, during the spells duration, dominant wind has North-East direction and it measure an intensity close to 0.5 m/s (Table 5.3-9) constituting an anomaly from the typical meteorological condition. For these reasons just measured temperatures of canyon type are reported (Figure 5.3-10,11,12), the low recurrence of that wind anomaly constitutes a not-representative element for the main aim of strategy.

In detail of results, also during the extreme events, historic center reports the high capacity to react to elevated temperatures during the midday along the measure point. In fact, despite the hot condition, during the midday measured and simulated ones into the narrow street (E1) are always lower than the Harbour Master office (E2) measures (-1 °C as mean value).

Period		Max	min	average	Dev.St	Wind direction	Wind speed
27-29/06/2017	E1	35	27.17	30.33	2.60	-	-
	E2	36.17	26.33	30.64	3.43	NE	0.58
	Δ	-1.17	0.84	-0.31	-0.83		
11-12/07/2017	E1	35.50	27.00	30.43	2.73	-	-
	E2	36.25	25.25	29.86	3.73	NE	0.53
	Δ	-0.75	1.75	0.45	-1.00		
2-4/08/2017	E1	38.33	28.83	31.68	2.79	-	-
	E2	39.5	27.67	32.08	3.76	NE	0.4
	Δ	-1.17	1.16	-0.51	-0.97		

Table 5.3-9 Extreme periods measures in E1 and E2.

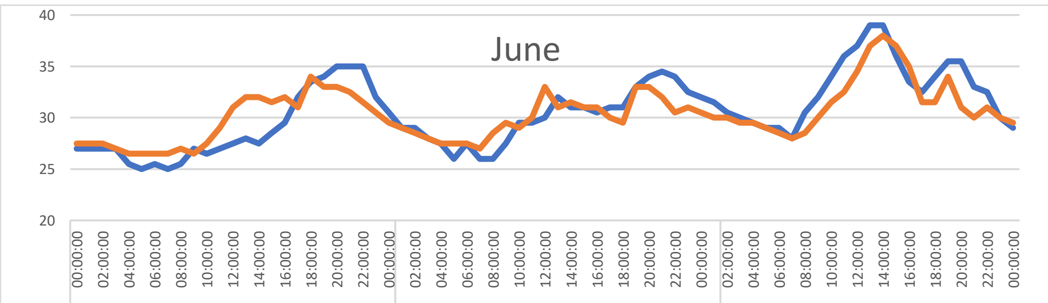


Figure 5.3-10 Temperature measures in E1 and E2 during 3-days warm spell of June

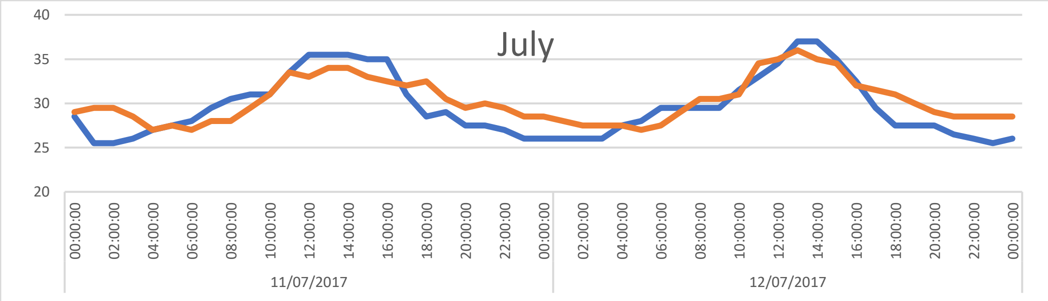


Figure 5.3-11 Temperature measures in E1 and E2 during 2-days warm spell of July

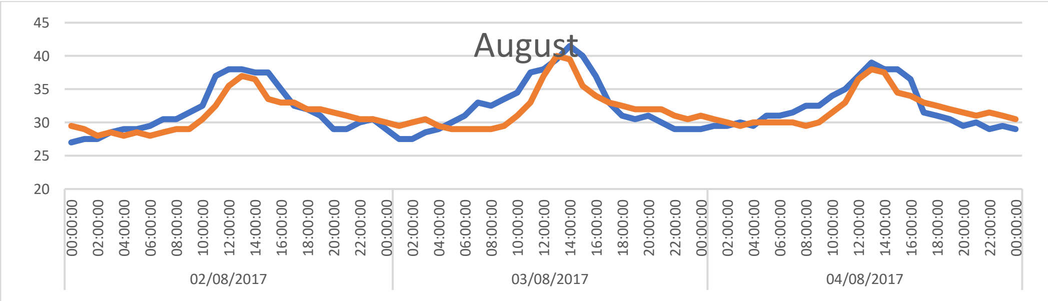


Figure 5.3-12 Temperature measures in E1 and E2 during 3-days warm spell of August

Comment to the monitoring and testing phase

Monitoring and testing phase is used in that methodology as an instrument useful to understand the interactions between urban district and local climate and inherent behaviours, as well as the local climate and his interactions with climate variations. However, it represents the opportunity to evaluate the potentialities of a “traditional” and “unplanned” urban area typical of the coastal land of Apulia region where some bioclimatic features can be recognized. The widespread concept of “Mediterranean city”, referring to the urban area featured by closed asset, can be recognized as the result of that case study focusing on the interactions between local “genius loci” activities in built arrangement and the use of materials and resulting micro-climate alteration. In fact, at the end of discussion, arrangement of blocks along dominant wind directions and his compactness, evaluated as reduced SVF and high H/W values, are representative of an adaptive model concerning his capacity to react to external change; in fact:

- the ancient core of Molfetta, despite some local variabilities in geometry, appears to be more reactive to external temperatures changes referring to the capability to reduce exposure to higher external temperatures during the midday and to react strongly in reducing mean daily temperatures and so, in controlling potential amplifications of the Urban Heat Island Intensity; these effects could be quantified referring to two elements:
  1. focusing on hourly measured, standard deviation represents the shrinkage of temperatures measured into the historic centre compared with boundary conditions; it could be evaluated as 1 point lower than the external as the combination of measured maximum and minimum temperatures;
  2. differences in Mean daily temperature are quite similar comparing external and inner points of monitoring phase and it never undergoes the 0.5 °C.

     That double effect is the result of different combination of elements:
  - firstly, deep canyons contribute to the closeness of external variation in term of mutual shading of walls and pavement that are featured by good optical properties ($\alpha=0.6$); these features surely contribute to the mitigation of daily maximum temperatures;
  - dominant urban asset is well oriented referring to the prevalent wind directions, useful to increase the effect of air mass transportation during the night;
  - finally, the absence of anthropogenic load helps in reducing potential increasing temperatures due to the high closeness of urban district;
- on the contrary, during the night, low wind intensity and enclosure to the sky avoid the rapid exchange of latent heat; nevertheless, the positive contribute of low exposure during the day, decrease magnitude that is evaluate as 1°C as mean value for spring and summer period.

5.4 DIAGNOSYS PHASE (D)

Diagnosis phase concern the discussion of consequent consumptions of the tower house identified as the recurrent element of residential type in the whole historic district. In detail, the model was created referring to thermal, physical and optical properties and geometry features described in sub-phase B3, whereas the most representative finishing layers are:

-Bitumen as the outer waterproof layer of roof (α=0.07; ε=0.95);

-Unplastered stone block as the outer layer of wall (α=0.60; ε=0.97).

Moreover, the tower house is representative of a middle unit in the block so, having walls in common with similar residential houses affected by similar internal temperatures and heat transfer value near to zero; for that reason, adjacent walls are modelled using the adiabatic property for three of them whereas the façade along the street is considered dispersant.

Additionally, interaction between context is represented by the construction of a 2mt width canyon using an on-face block made featured by the same optical features of the building type's envelope and a lateral block that delineate the linear canyon. Finally, system is rotated following the prevalent exposition of +20° on E-W axis (Figure 5.4-1). In term of HVAC technologies, traditional systems are introduced as representative of the mean system features, as a gas boiler for heating system (and heat water) and an electric fan coil system for cooling, with set-point temperatures of 20°C and 25°C, respectively.

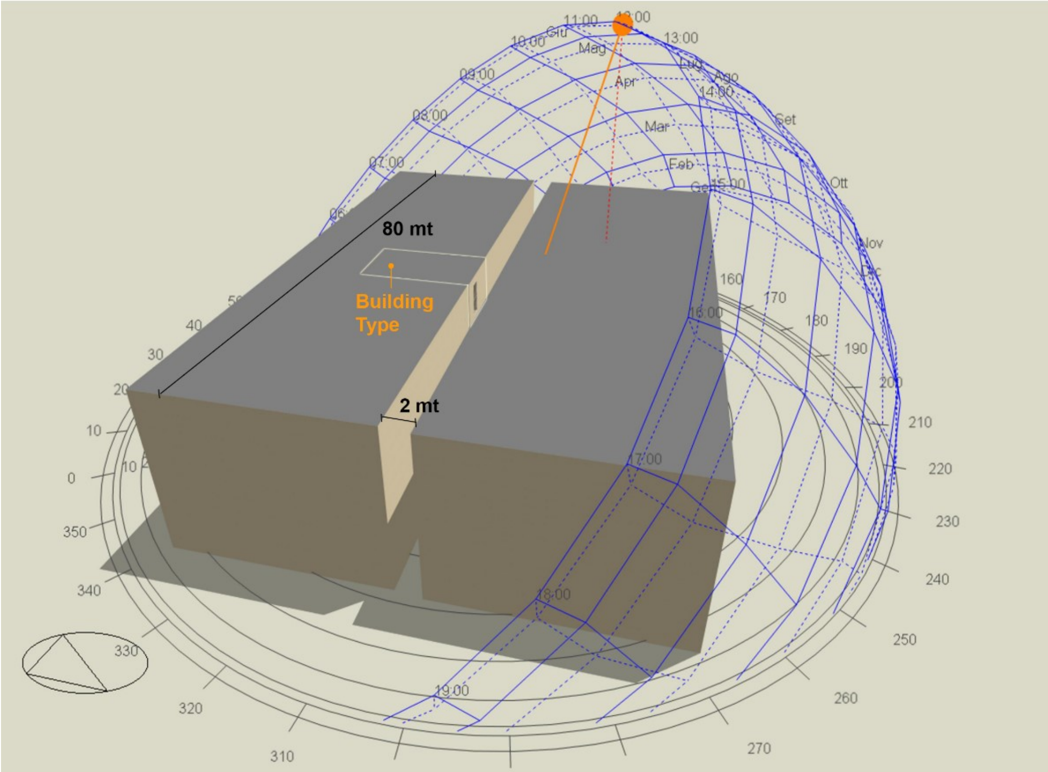


Figure 5.4-1 Building/canyon type model used for diagnosis

5.4.1 TYPE REACTIONS TO CLIMATE CHANGES (D1)

According to the future climate conditions discussed in the analytic phase, Tower house type is performed through dynamic simulations to provide his exposure to projections, focusing on heating and cooling yearly consumption variations between actual statistical weather condition (Met_actual) and future scenarios A2_2030, A2_2050, A1B_2030, A1B_2050, B1_2030, B1_2050. Results are reported in Figure 5.4-2 where unbalanced combination of future cooling and heating needs can be recognized; in fact, in all cases, increased summer cooling rate always exceed wintry heating one, pointing out the necessity to focus on cooling needs and deficiencies, in a general perspective.

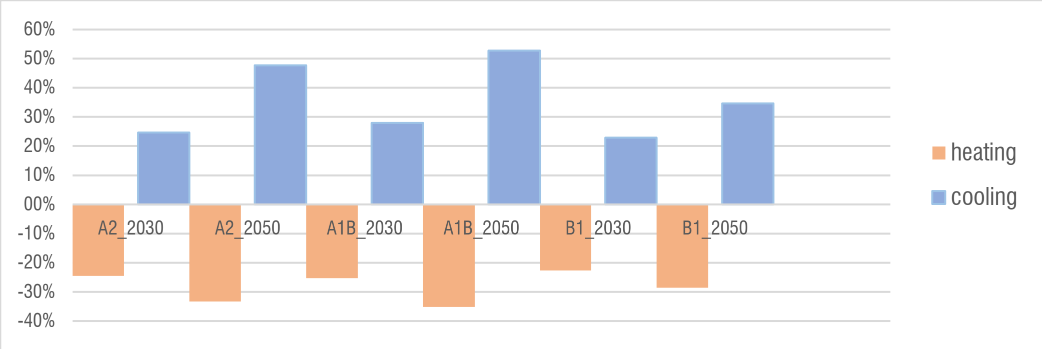


Figure 5.4-2 Evaluation of future consumption of the type in future statistic weathers.

As a first phase, a preliminary energy assessment of the representative model is evaluated. In fact, tower house has been improved focusing on transmittance values of wall and roof introducing a generic insulation on the outer faces aiming at reach actual normative thresholds. Windows and ground ceiling are excluded, according to previous discussed studies (Santamouris 2013). In detail, two phases are used to support these solutions: firstly, the evaluation of percentage of yearly energy reductions (heating and cooling) referring to own year of evaluation Figure 5.4-3; as a second step, the evaluation of percentages referring to actual energy consumption in the same energy retrofit frame Figure 5.4-4 so, combining the effect of energy consumption in future scenarios and the effects of actual energy improvement in wall and roof.

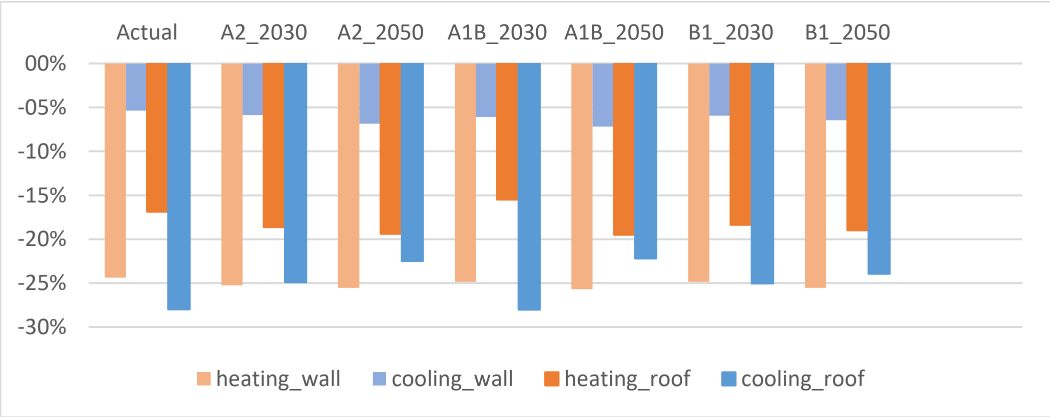


Figure 5.4-3 Yearly heating and cooling consumption of type referring to improved roof or wall

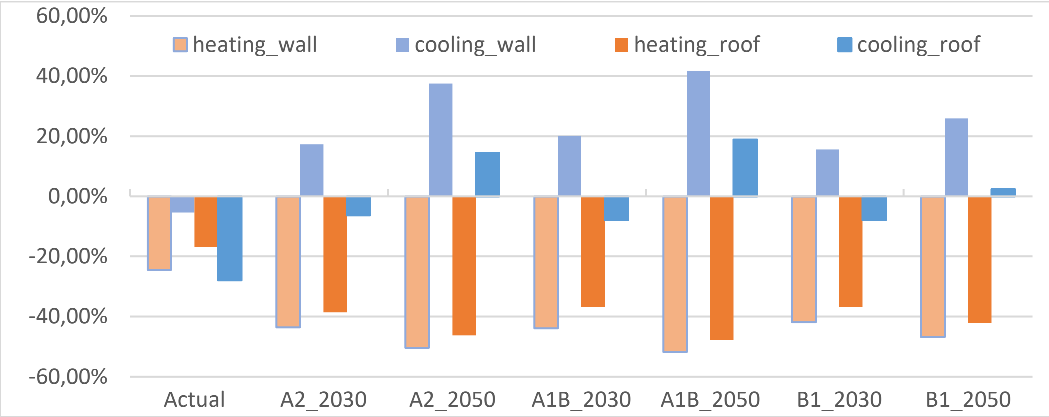


Figure 5.4-4 Yearly heating and cooling consumption variation of type referring to improved roof or wall and actual climate

In first analysis, similar energy reduction can be highlighted in each scenarios and actual state, whereas the efficacy of roof transmittance improvement is representative, comparing actual consumptions and future ones. In fact, if heating consumptions decrease clearly supporting the future increasing temperatures, cooling quote can be reduced with high efficacy focusing on roof interventions.

In detail of second step of analysis, Figure 5.4-4 evidences that:

- the percentage of cooling reductions have positive values as the combination of increasing cooling needs because of increasing temperatures;
- the effect of insulated wall cannot cover the differences for future climates in cooling demands; in each future scenario, positive support of improved wall determines a higher percentage in energy consumption than roofs.

This first assessment of energy consumption on statistical and representative weathers surely supports the necessity to focus on roof improvement especially in summer case, while wall became representative for wintry cases.

5.4.2 CANYON AND BUILDING TYPES – HORIZONTAL MICRO-CLIMATE EFFECTS ON MIDDLE TOWER HOUSE (D2.a)

The recognition and validation of micro-climate features of the whole historic district offer the possibility in determining priority of intervention at building level. In fact, homogeneity of district behaviour was recognized in previous phase (C2.2b) analysing variation of local microclimate in different canyons.

Contraction of temperature ranges (as the Standard Deviation reduction), compared with the external measures, is the main behaviour of the ancient core of Molfetta determined in results; however, the effect on consumptions on buildings should be analysed. In that sense, Tower house type has been performed during the typical coldest period of spring and during the hottest typical day of summer, so on 24th March and 14th July. Other weather conditions, as solar radiation intensity, direction and intensity of wind are modified introducing local data measured at 10 mt by Arpa station.

Following, results of simulation are discussed focusing on spring and summer cases.

day	ΔConsumption (inner – outer temperature measures)
24/03/2017 (heating)	+37%
14/07/2017 (cooling)	- 4%

Table 5.4-1 Differences in consumption in daily measures in E1 and E2

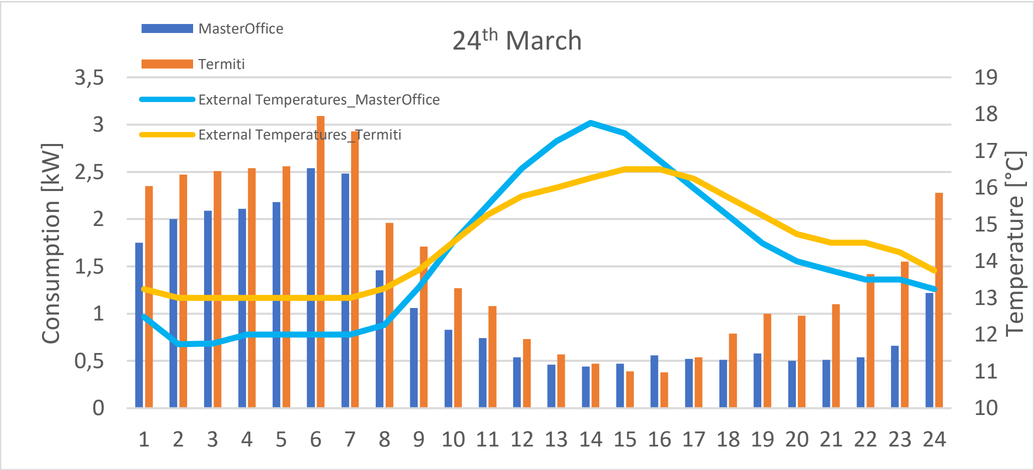


Figure 5.4-5 Hourly consumptions in measures E1 and E2 for Type for 24th march

As Result in Table 5.4-1 for spring results, Positive variations exist in evaluating heating consumption during March; moreover, hourly consumptions in Figure 5.4-5 mark a clear variation of consumption during the night; these evidences are linked to physic of walls: dispersant wall generates an inversion of temperatures of functioning on inner surfaces (as the effect of time shift of 12 hours) as the result of the double attenuation of temperature measured inside the historic district and by the inertial effect of wall. These results are representative of a negative effect in heating consumption that could be amplified during the winter period featured by average temperatures lower than 20°C (setpoint of heating system) even if it creates a lower temperature range of functioning of wall during the full day.

Referring to the summer case, the effect is completely inverted. As reported in results of Table 5.4-1, cooling consumptions have similar values in daily evaluation; nevertheless, positive impact on consumptions can be recognised during hotter hours of the day, while hourly peaks in cooling functioning are reduced (Figure 5.4-6). Despite that, during the night consumption increases because of higher temperatures, remaining below midday peak values.

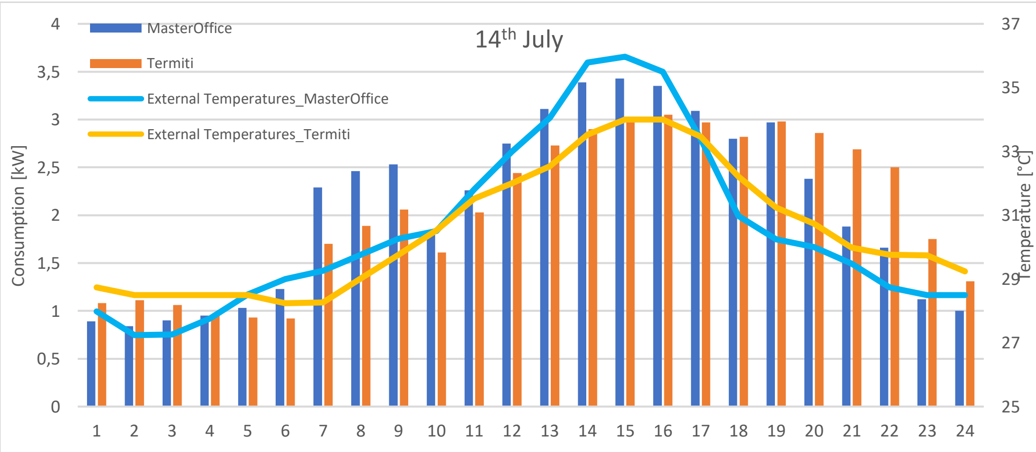


Figure 5.4-6 Hourly consumptions in measures E1 and E2 for Type for 14th July

In addition to typical local micro-climate, 14th July is analysed aiming at the comparison of behaviour in local changes in temperatures and geometry; in fact, referring to results of Micro-climate simulation model at large scale, along squares, temperature slope is vertical shifted of 0.5°C during the Summer extreme day (14th July), while during the spring period no differences exist. For that reason, Middle tower house is performed in three different cases for march and July described as following:

- Sp.A tower house type in canyon type considering measured temperature in canyon (E2) on 24th march;
- Sp.B tower house type in square (without on-face block) considering measured temperature in canyon (E2) on 24th march;
- Su.A tower house type in canyon type considering measured temperature in canyon (E2) on 14th July;
- $Su.B_1$ tower house type in square (without on-face block) considering measured temperature in canyon (E2) on 14th July; it represents an intermediate case useful to compare affection of openness and constant increase temperatures in separated way;
- $Su.B_2$ tower house type in square (without on-face block) considering measured temperature in canyon on 14th July, incremented of 0.5°C (E2 + 0,5).

Moreover, a specific focus has made on external wall temperatures, to evaluate the direct influence of solar radiation and the consequent reaction of vertical sub-system of the tower house envelope because of different relation with the context.

As in the previous case, interactions between two middle tower house cases are performed using the same physical model and discussed firstly for the spring case and then for summer; analysis of variation of consumption are checked in Table 5.4-2.

day	Case analysis	ΔConsumption
24/03/2017 (heating)	(Sp.A-Sp.B)	+ 12%
14/07/2017 (cooling)	(Su.A-Su.B1)	- 6,5%
14/07/2017 (cooling)	(Su.A-Su.B2)	- 12%

Table 5.4-2 Analysis of daily consumption variation in Sp.A, Sp.B, Su.A, Su.B1 and Su.B2

Spring cases are analysed representing in Table 5.4-3 and Figure 5.4-7 result of simulations in both cases. As result of hourly consumption analysis, spring case has clear results: tower houses in narrow street and in open space differ for direct solar exposure during the day, working at different surface temperatures, despite the same external ambient temperatures.

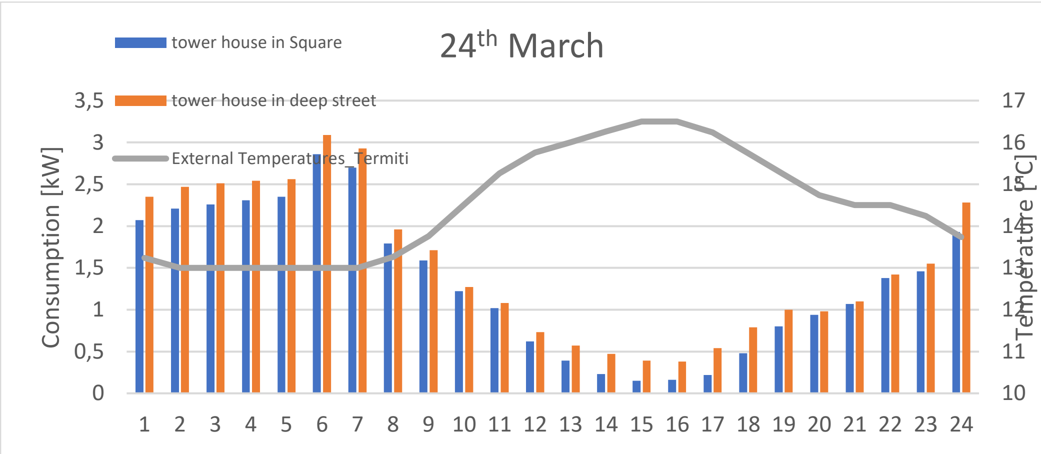


Figure 5.4-7 Hourly consumptions for type in Sp.A and Sp.B cases

	Tmax	Tmin	Tmean	daily range	St.Dev.
Sp.A					
external Temperature					
Termiti street	16.50	13.00	14.50	3.5	1.29
Surface temperature					
ground floor	16.60	14.30	15.38	2.30	0.81
first floor	16.49	14.11	15.25	2.39	0.87
second floor	18.10	13.95	15.33	4.16	1.29
third floor	19.65	13.29	14.96	6.35	2.08
ΔT(vertical)	3.04	-1.01	-0.42	4.05	1.27
Sp.B					
external Temperature					
Termiti street	16.50	13.00	14.50	3.5	1.29
Surface temperature					
ground floor	19.00	12.18	14.05	6.82	2.25
first floor	18.94	12.35	14.16	6.59	2.19
second floor	18.88	12.41	14.17	6.47	2.16
third floor	18.68	12.35	14.05	6.33	2.10
ΔT(vertical)	-0.33	0.17	0.00	-0.50	-0.15

Table 5.4-3 Analysis of daily variation of wall surface temperatures in Sp.A, Sp.B, cases

In fact, focusing on surface temperatures in vertical analysis, walls at ground, first and second floors are featured by external surfaces temperatures that vary considerable during the midday in Sp.A case, while nocturnal differences are extremely reduced.

However, temperatures range during the day varies between 2°C in lower floor in shaded tower house to 6°C in higher levels for both cases. This difference is lower than the ambient measures, considering the peak reached during the midday from the exposed walls. That effect contributes and justifies the positive difference in energy consumption.

On the contrary, focusing on summer cases, analysis of hourly consumptions in three cases are reported separately in Figure 5.4-8 and Figure 5.4-9, while external temperatures details are reported simultaneously in Table 5.4-4.

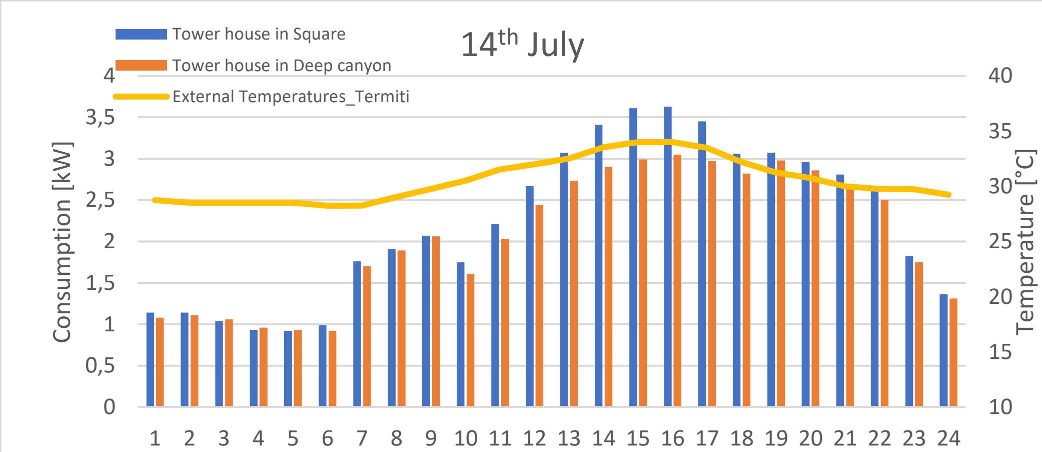


Figure 5.4-8 Hourly consumptions for type in Su.A and Su.B1 cases

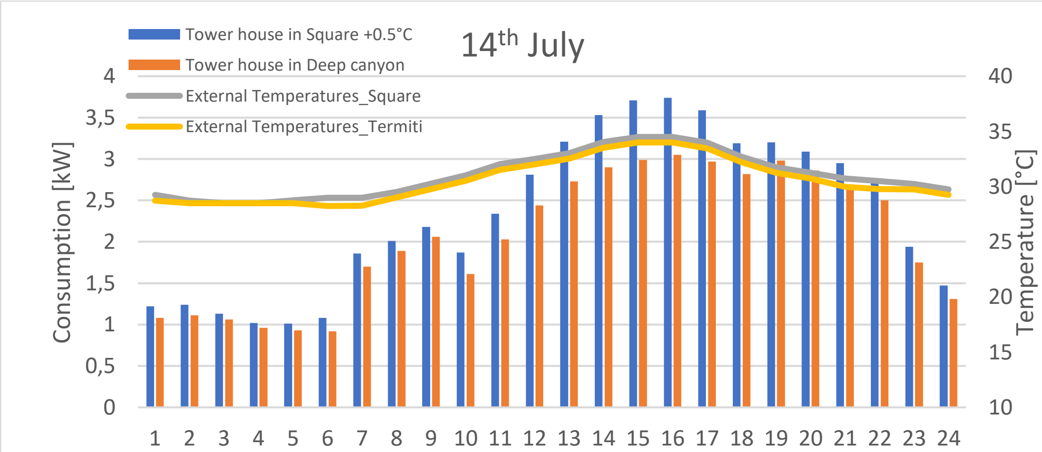


Figure 5.4-9 Hourly consumptions for type in Su.B1 and Su.B2 cases

	Tmax	Tmin	Tmean	daily range	St.Dev.
Su.A					
external Temperature					
Termiti street	34.00	28.00	30.50	6	2.00
Surface temperature					
ground floor	32.60	28.71	30.50	3.90	1.44
first floor	33.95	28.84	30.87	5.11	1.71
second floor	35.59	28.81	31.26	6.78	2.23
third floor	35.69	28.23	30.93	7.46	2.51
ΔT(vertical)	3.09	-0.48	0.43	3.57	1.07
Su.B1					
external Temperature					
Termiti street	34.00	28.00	30.50	6	2.00
Surface temperature					
ground floor	35.05	27.33	30.06	7.72	2.57
first floor	35.33	27.59	30.35	7.74	2.58
second floor	35.05	27.33	30.06	7.72	2.57
third floor	35.50	27.66	30.48	7.84	2.63
ΔT(vertical)	0.46	0.33	0.42	0.12	0.06
Su.B2					
external Temperature					
Termiti street +0.5	34.50	28.50	31.00	6	2.00
Surface temperature					
ground floor	35.42	27.71	30.44	7.71	2.57
first floor	35.71	27.98	30.73	7.73	2.58
second floor	35.69	28.01	30.76	7.68	2.57
third floor	35.90	28.06	30.87	7.84	2.63
ΔT(vertical)	0.47	0.35	0.44	0.12	0.06

Table 5.4-4 Analysis of daily variation of wall surface temperatures in Su.A, Su.B1 and Su.B2 cases

Analysing results, during the hottest part of the day, hourly consumptions are reduced in narrow street, more than nocturnal ones comparing with other two cases. However, shading effect on middle tower house in deep canyon represents the predominant effect in reduction of consumptions during both cases; whereas, focusing on midday hourly consumption, differences in consumption results for Su.B1 and Su.B2 are close related to the linear increasing temperatures externally.

Focusing on external surface, in elevated levels external temperatures have similar behaviour in three cases because of the same solar exposure. As an opposite case, temperature slopes at ground and first floor change considerable during midday hours, presenting a gap of 1,5-3°C, whereas it presents an inversion on behaviour during the nocturnal hours, when surface temperatures never varies more than 0.5°C.
Despite high external temperatures, operative range of external wall temperatures varies limited from 4 to 7 °C during the day, considering completely shaded (Su.A) and exposed surfaces (Su.B1-Su.B2), respectively. That is surely a positive effect considering that ambient temperatures are featured by the same range; in that sense, walls follow external climate variation during summer conditions, with low amplification effect in completely exposed conditions.
As a result of the process of thermal and optic properties of wall, a double system of analysis is supported. In detail, the first iterative process on the building type concerns in increasing thermal efficiency performing it during the same previous conditions of and focusing on vertical sub-systems using a 5-multistep analysis of thermal transmittance; that corresponds to the reduction of the wall thermal transmittance of 20%, 40%, 60%, 80% and 100% of the difference between actual and normative values. Moreover, reduction of the thermal transmittance of the opaque component corresponded to the application of an insulation layer with increasing thickness on the external sides. Referring to transparent sub-system, double glass, low-e double glass and low-e double glass with argon technologies were used to report windows to the normative thresholds. Microclimate conditions were kept equal for middle tower house in deep canyon and in open space, while, for boundary conditions, ambient temperatures are used. Even if, wall improvement significance was clearly supported in the analysis of future scenario, comparison between different exposure and boundary condition can support a state of priority between them.
Figure 5.4-10 and Figure 5.4-11 report the results of the iterative process.

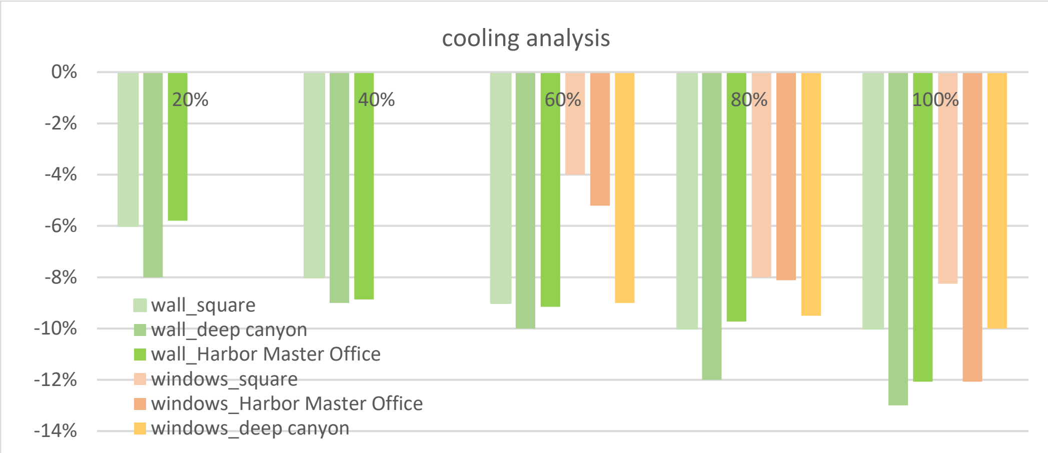


Figure 5.4-10 Reduction of cooling consumptions for thermal improvement of walls and windows in the iterative process in different exposure (deep canyon, square, external)

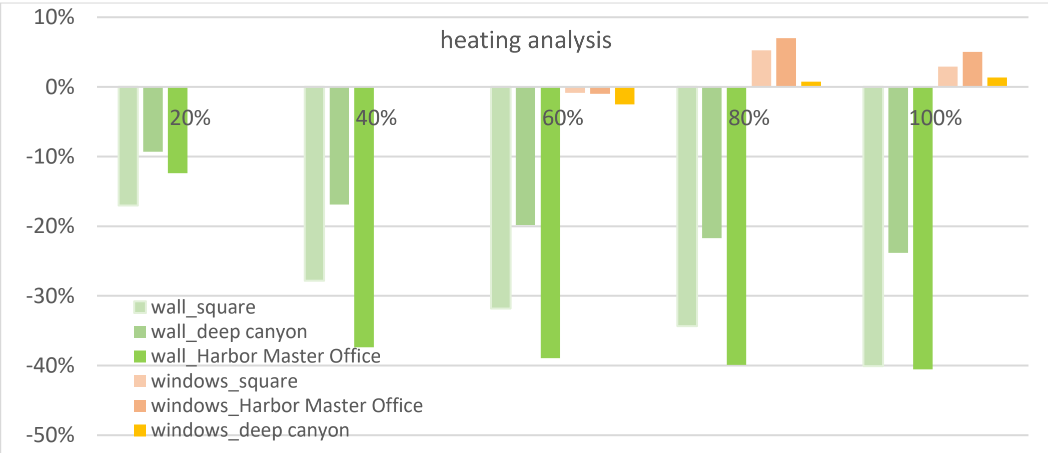


Figure 5.4-11 Reduction of heating consumptions for thermal improvement of walls and windows in the iterative process in different exposure (deep canyon, square, external)

For both, wall performances refer to comparable results:

- minor contribution in summer (savings up to 10% for cooling) reflects in all cases good behaviour because of high thermal inertia; on the contrary, during heating period, thermal enhancing of wall represents the major effect on reduction of consumptions, above all along canyon, confirming previous phase analysis.

- windows are not relevant both in square, in narrow street and boundary cases in summer (savings 8% for cooling in the case of low-emissivity double glazing systems that fulfil the normative standards), as walls. Moreover, an inversion can be highlighted in heating values where, enhancing thermal and optical properties, consumption increases. That result highlight that, despite different exposures to solar gain in shaded or open areas, the predominant effect is associated to limited percentage in extension of dispersant envelope.

Second part of analysis aimed at the discussion of incidence of optical property enhancement of wall during the same periods, to provide a scale of efficiency between different level of improvement. In detail, Figure 5.4-12 and Figure 5.4-13 demonstrate that improvement of optical property represents the worst case of energy improvement: despite similar result in reduction of consumption during the summer, on spring (and consequently amplified during winter) their increasing value unbalance negatively the results. As an example, referring to the maximum value of albedo ($\alpha=1$) energy reduction counts -4% and +10% in summer and springs cases. Similar behaviour can be associate for the middle tower house in other locations and conditions where the effect is amplified.

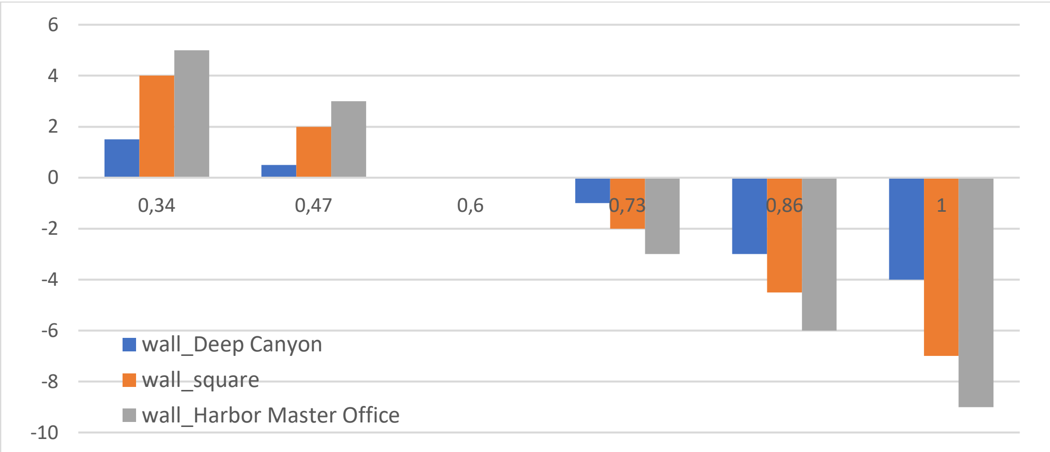


Figure 5.4-12 Reduction of cooling consumptions for optical improvement of walls in the iterative process in different exposure (deep canyon, square, external)

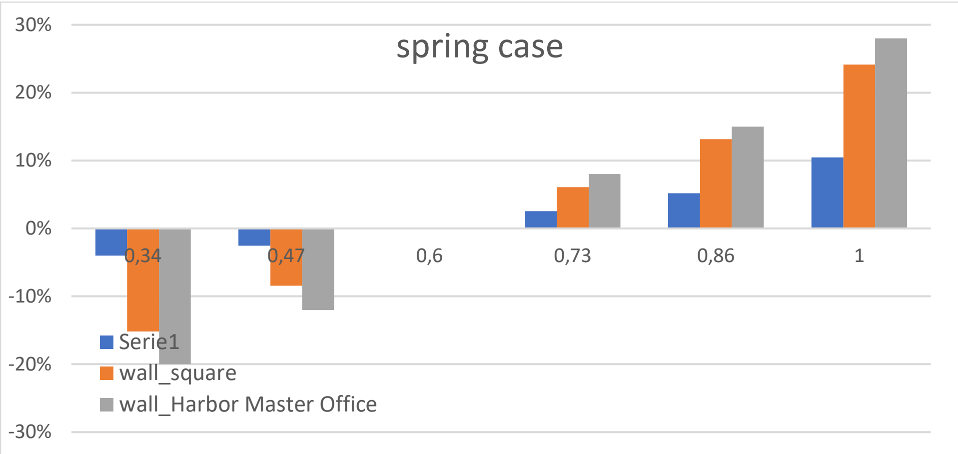


Figure 5.4-13 Reduction of heating consumptions for optical improvement of walls in the iterative process in different exposure (deep canyon, square, external)

Final comments on results:

During spring analysis, coordinated building-canyon type suffers the closeness increasing heating consumptions because of contraction of temperatures range at canyon scale, high level of shading effect that support a lower operative temperature (inside and outside the walls) and low solar heat benefits.

On the contrary, during summer cases, closeness represents the most relevant effect in building reaction; in fact, despite main differences can be recognized between close and open scenarios, consumption increase for the higher quote of solar gains. However, high optical property of calcareous stone limited surface overheating; similarly, surface temperatures can be founded in Su.B1 and Su.B2 cases.

Focusing on thermal properties of walls and discussed results, the presence of plastered surfaces generates, both in square than in narrow street, lower than 5% of changes in energy consumptions until a 0.34 value of albedo. However, albedo value of plaster rarely is lower than that value, also considering the restriction in using clear coloured plaster for the whole district. As in roof case, thermal properties of wall subsystem do not change in using that finishing layer, because of his low thickness (3cm) and his low thermal property.

In all cases, temperature ranges reach high values compared with external variations: during spring period, external temperatures have an oscillation of 25°C that create a positive contribution in heat transmission during midday hours.

5.4.3 ENERGY REACTION IMPROVING BUILDING TYPE ROOF (D2.b)

Roofs represent an independent element in local micro-climate alteration; in fact, differently from pavements, roofs work at different heights and, because of different shading effect, their influence could affect building consumptions. From the micro-climate analysis, pavement at street level surely contribute to the mitigation effect at district scale, considering the low differences in air temperatures in open spaces and along deep canyons. On the contrary, at higher quote, roofs do not contribute in advantages at street levels while, because of their direct exposure to external solar radiation and temperatures variation. Daily fluctuation and peaks of temperatures surely contribute to increase sensible heat flux of roof depending on external heat exchange; moreover, that cannot be divided by heat transfer along the same horizontal element that affect internal conditions and it strictly depends on their thermal features. For that reasons, tower house roof in his type, is analysed considering the same external temperatures of previous analysis in order to found a direct comparison between horizontal and vertical surface variations; moreover, aiming at the recognition of affections and interactions at building scale of thermal and optical properties, Tower house have been performed using an iterative process useful to focus on priority of interventions considering local typical condition collected in Meteonorm statistical weather.

5.4.3.1 DIAGNOSIS OF THERMAL PROPERTIES

Starting from the same process describes for walls, middle tower house roof is evaluated in spring and summer days to analyse surfaces temperatures. in detail of result reported in Table 5.4-5, midday effect is amplified reaching high values of temperatures affecting cooling peaks demands. In fact, temperature oscillation reaches 34°C during the day, while external ambient variation is 6°C.

These values confirm the widespread relevance of roof exposure in summer period especially highlighting the incidence of finishing external layer and his optical property above all for the widespread materials used during last years, as the dark waterproof bitumen.

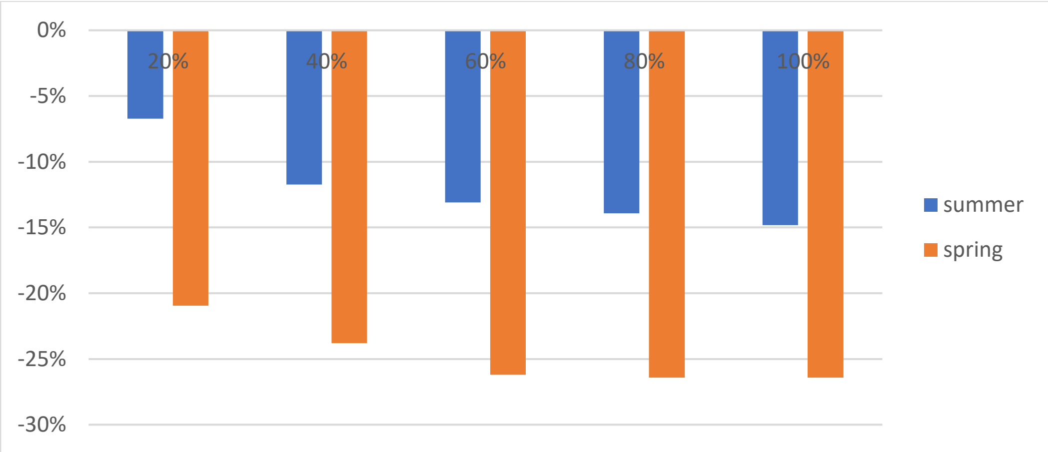


Figure 5.4-14 Consumption analysis increasing thermal transmittance of roof in summer and spring cases

In fact, thermal improvement represents good thermal enhancing strategy for roofs in spring case (-25%), to support walls; however, the latter determine higher results (-24% in deep canyon and -40% in both open area); finally, summer impacts have comparable results (Figure 5.4-14).

5.4.3.2 DIAGNOSIS OF OPTICAL PROPERTIES

Moreover, to support results in surface reaction based on physical properties and solar exposures represented in Table 5.4-5, both cases of tower houses have been performed changing albedo of external surfaces in 5-multistep analysis following the same iterative process of thermal transmittance improvement (+100% is representative of an $\alpha=1$). In detail, evaluation on roof aims at the maximum value of albedo, dividing in 5 improvement steps, whereas on wall, variation of albedo is considered for 5 superior steps (until $\alpha=1$). On the contrary, emissivity values are evaluated as constant (ε=0.9). In detail, Figure 5.4-15 reports the scale of ranges and results for spring and summer cases.

Similarly to the thermal analysis, during the summer roof is the most vulnerable to solar incidence (25-30%) and, so, to the responsibility in consequent transmission of heat at inner surfaces. Moreover, considering the same maximum value of albedo, improvement is higher than increasing his thermal property.

	Tmax	Tmin	Tmean	daily range	St.Dev.
Sp.B					
external Temperatures Termiti street	16.50	13.00	14.50	3.50	1.29
Surface temperature roof	28.69	3.02	12.54	25.67	7.71
Su.B1					
external Temperatures Termiti street	34.00	28.00	30.50	6	2.00
Surface temperature roof	58.47	24.13	35.83	34.34	12.92
Su.B2					
external Temperatures Termiti street +0.5	34.50	28.50	31.00	6	2.00
Surface temperature roof	58.79	24.46	36.14	34.33	12.92

Table 5.4-5 Analysis of daily variation of roof surface temperatures in Sp.B, Su.B1 and Su.B2 cases

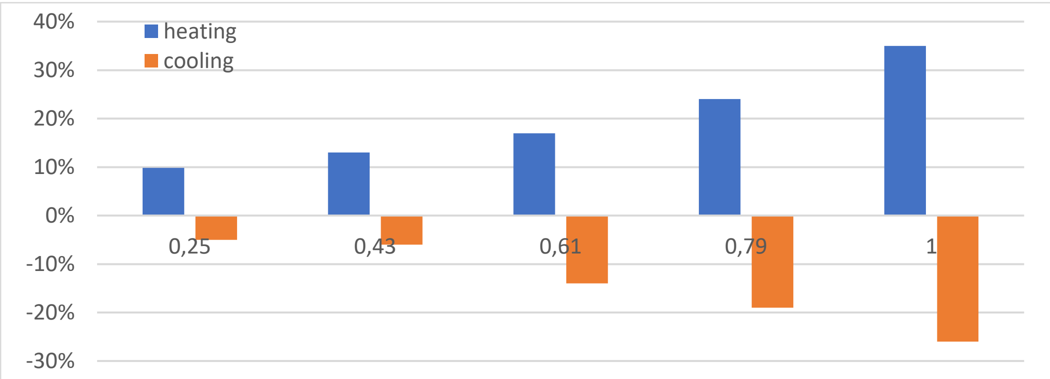


Figure 5.4-15 Reduction of heating and cooling consumptions for optical improvement of roof in the iterative process

On the contrary, despite different solar exposure in squares, walls maintain good performances recognizing in thermal behaviour the predominant deficiency of this sub-system.

Despite the high representativeness of middle tower house in the whole historic centre the type presents some differences in finishing materials as reported in table of codes of envelope sub-systems. Considering their high responsibility in energy consumption during the summer period, a remarkable focus should be done on roof features; in fact, calcareous stone tiles, bitumen waterproof layer and cotto tiles could represent exception in changing optical responsiveness of roof as combination of albedo and emissivity, while thermal properties of the whole system are considered constant. For that reason, to highlight a class of exposure in changing roof finishing, three cases are discussed in term of typical values (Table 5.4-6).

According to the previous analysis, paved roofs are more efficient than the waterproof ones, even if their positive contribute are higher (5-10%) than type case. However, albedo values could be enhanced to increase potentialities.

		α	ε
Cex.a	Roof with bituminous finishing layer	0.07	0.95
Cex.b	Roof with stone tiles	0.6	0.97
Cex.c	Roof with cotto tiles	0.4	0.9

Table 5.4-6 Albedo and emissivity features of roof finishing

Moreover, considering results, original features of roof value in using calcareous stone tiles (“chiancarelle”) represents an inherent value that is losing during the time in repairing infiltration failures of that sub-system, in favour of dark bituminous surfaces.

As result on roof behaviour, the improvement of cooling techniques and solution have surely positive results on summer condition. However, the same functioning system affect heating system at roof level, decreasing surface temperatures. So, cooling roofs cannot be useful as a stand-alone solution if thermal property remain insufficient.

5.4.3.3 DIAGNOSIS OF COMPLEX SOLUTIONS

According to the high responsibility of roof in summer condition both for optical and thermal conditions, combination of technical solutions is reported for the middle tower house in deep canyon. The necessity to re-balance optical effect on cold period and the widest necessity to improve thermally that sub-system envelope moved towards a combination of these solution to reach the highest energy improvement along all the years.

Tower house type was simulated during summer and spring period, two solutions are introduced aiming at the observance of normative thresholds and cool roofs requirements; in detail, 26% of consumption reduction is reached both for cooling and heating, solving roof energy retrofit with:

- 3 cm of aerogel panel ($\lambda=0.015$)
- on built reflective finishing layer ($\alpha=0.84$, $\varepsilon=0.89$).

Correction of roof deficiency can be considered also for his low level of thermal inertia. As discussed in first part of thesis, alternative solutions in energy improvement of roof concern the introduction of green solutions and high innovative materials as the PCMs. However, these technologies are useful to correct thermal inertia deficiency referring to the direct effect of soil layer and indirect with the introduction of PCMs.

Concerning green solutions, a 3-multisteps analysis is performed, evaluating three different solutions - following the classification in intensive (GR.in), semi-intensive (GR.sin) and extensive (GR.ex)- featured by different combination of LAI, Height of plants and Soil depth reported in Table 5.4-7. In term of irrigation, three green roof cases are defined without an irrigation system.

Code	LAI	Height of plant [m]	Soil depth [m]	U-value
GR.in	1	0.1	0.25	0.67
GR.sin	2.5	0.5	0.35	0.55
GR.ex	5	1	0.7	0.25

Table 5.4-7 Green roof techniques: features and codes

Sensitivity analysis in that field is supported by Sailor's model (Andriani & Walsh 2010) implemented in EnergyPlus dynamic simulation engine, evaluating the effect with the well-established ConductionTransferFunction (CTF).

Results of simulations are reported in Figure 5.4-16 where percentages specify the reduction of consumptions referred to the tower house type both for cooling and heating reductions.

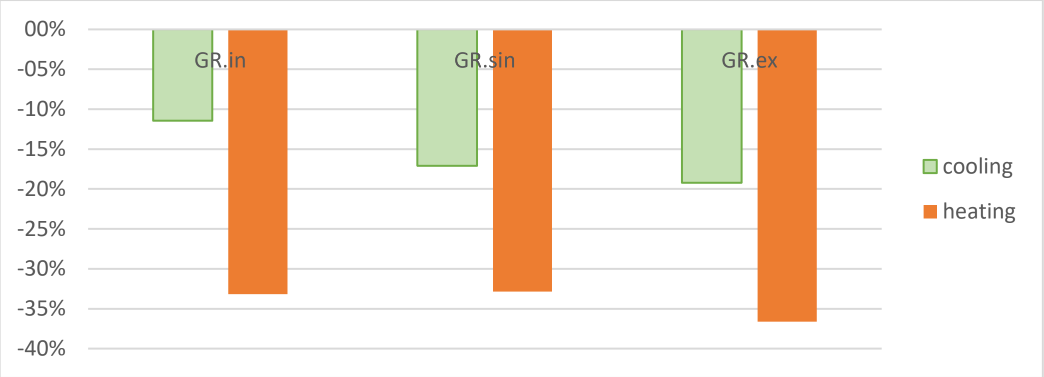


Figure 5.4-16 Consumption reduction for three cases of green roofs in spring and summer cases.

In detail, results highlight that green roof, referring to typical classification, can contribute in consumption reduction with comparable results of a solutions that increase albedo until 0.5 or an improvement of thermal insulation reaching +60% of starting U value, both in cooling and heating consumptions.

Similarly to cool roof, intensive and semi-intensive solutions were implemented with an insulation layer useful to reach actual normative transmittance value and evaluate for their enhancing. In detail, satisfactory results can be reached enhancing thermal property of roof on intensive case (Figure 5.4-17)

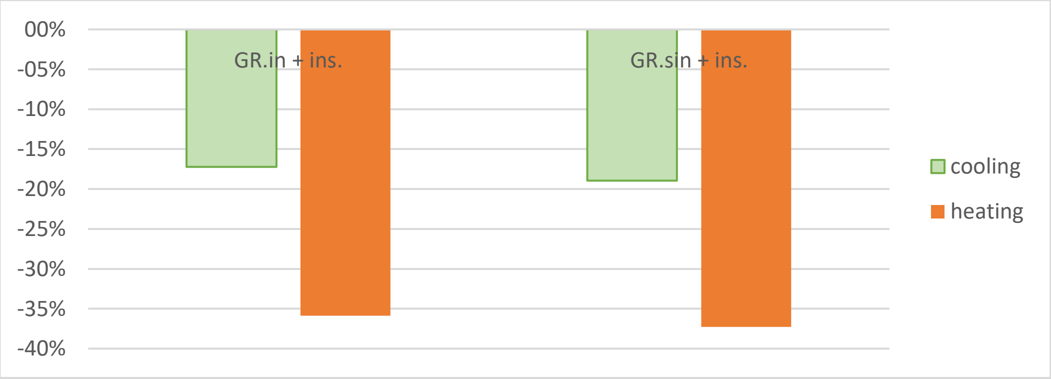


Figure 5.4-17 Consumption reduction for GR.in solution added to insulation layer.

Referring to the introduction of PCMs, smart materials are considered as a virtual thin layer located below and above the external finishing layer, to participate to the heat transfer flux along the roofs, working on superficial interstitial temperatures in all layers. In detail, PCMs are modelled in DesignBuilder as pure PCMs solution having different thickness.

In detail, external solution (R.PCM.1_cool/heat) should try to perform doped pavement with PCMs (concentration of 20%) where, combination of cooling effect and PCMs are guaranteed using a virtual liquid layer featured by:

- 5 mm of thickness as representative of 20% of total thickness of tiles;
- high albedo value (α=0.84, ε=0.89) according to high optical features,
- Latent temperatures of melting change as 29°.

Referring to the second solution (R.PCM.2_cool/heat), a virtual liquid layer has been introduced as on-market envelope solutions and introduced above the cooler external coating; in that case, layer is featured by:

- 70 mm of thickness;
- Latent temperature of melt as 25°C

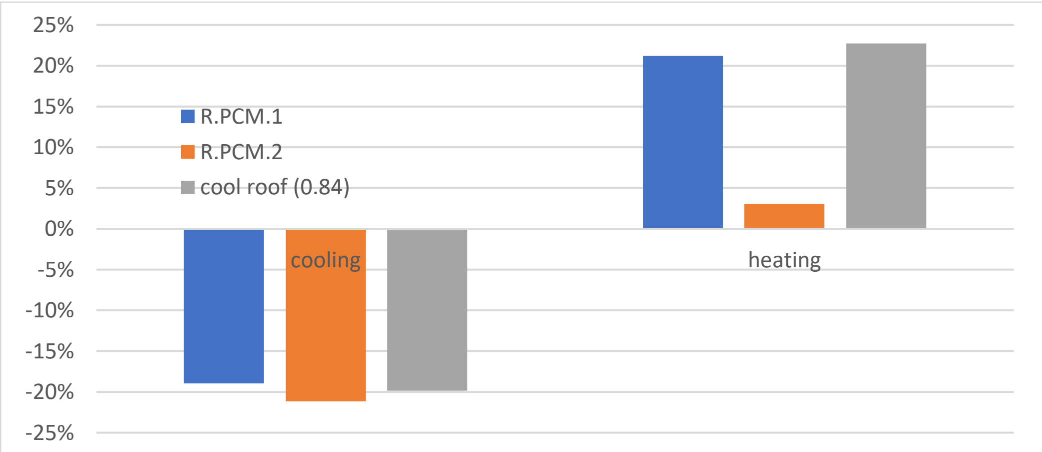


Figure 5.4-18 Cooling and heating consumption evaluation in R.PCM.1 R.PCM.2 and optic improved solution for roof

As result, both solutions demonstrate positive effect in reduction of cooling needs, while heating ones are not corrected (Figure 5.4-18).

Positive effect of PCMs latent changes can be recognized comparing result of R.PCM.1 and R.PCM.2 with simple reflective solution where, the first is representative of comparable results, while the efficacy second one is higher than the other two. Moreover, that highlight that:

- The use of PCMs in external surfaces support the reduction of surface temperatures, carrying negative impacts on heating consumptions;
- On the contrary, PCMs inside the stratigraphy of roof as the second layer towards outer surface, support thermal inertia of roofs also during heating functioning.

Finally, as discussed for cool roofs, both solution require to enhance thermal property to correct heating consumption amplification.

<u>Discussion of results in diagnosis phase</u>

Summarizing the result at building scale, some advices could be pointed out.

a. Firstly, combination of the future and probabilistic scenarios defined by IPCC studies and Tower house type in his typical boundary (deep street) will cause an increasing cooling need where:
    - the roof energy improvement appears to be more efficient in actual cooling reduction (-28%) and in a long perspective above all in summer condition (+19% in A1b_2050 and -8% in B1/A1B_2030 scenarios),
    - whereas wall is representative of a more efficient way to intervene in winter cases both in actual weather (-24%) and future (-40 in A1B/B1_2030 and -50% in A1B/A2_2050 scenarios);
b. as second aspect, the relevance of micro-climate effect of building type can be recognized in variation of energy consumption in:
    - increasing heating consumption during colder spring condition because of low solar heat exposure;
    - decreasing total daily consumption during summer, focusing on the reduction of peaks in energy need during midday (-0.5 kW);
c. moreover, focusing on wall reaction at different levels:

- the combination of a high shading effect on façade and high value of albedo along the canyon type surely represents a redundancy at that sub-system level reflected in a reduction of surface temperature at lower heights (-2°C);
- moreover, good optical feature of wall appears to be sufficient in adaptive behaviour even in exposed urban area and along vertical and exposed part of façade at high quote; in fact, surface temperatures never undergo +3°C and the effect of increasing albedo of that surface generates low benefit (-4/7%);
- finally, despite the recognition of low thermal property, his retrofit generates a scarce cooling reduction (5-10%);

d. focusing on the horizontal sub-system of envelope, it represents a singular element in reacting at different levels:
   - focusing on the micro-climate alteration, it contributes with low relevance at that system because of his vertical quote (+12m), referring to the street level;
   - however, referring to his thermal and massive features, energy improvement could be evaluated as a reduction of consumption that vary from 15-20% reaching the normative thresholds, from 10 to 20% for cooling and 35% in heating considering green roofs solutions and 20% for cooling increasing massive resistance using PCMs;
   - finally, direct exposure to solar radiation and weather conditions and his lower optical features can be solved increasing the albedo value offering a reduction of 24-29% in cooling needs.

These necessities create the opportunity to evaluate the efficacy of traditional (insulation, Green roofs, cool roofs) and innovative materials (PCMs) and solutions in a representative low efficient and traditional roof located in a specific Mediterranean area.

5.5 TAXONOMY OF SUITABLE INTERVENTIONS (E)

5.5.1 DEFINITION OF TRANSFORMATION DEGREES (E1)

According to the general aim of preservation defined at national, regional and municipality level discussed in AnP, the district formal asset cannot be modified, as well as canyons, introducing new balconies and new higher floors or demolishing part of them. Moreover, focusing on materials, substitution of stone tiles that occupied all the old core of Molfetta is avoided.

Moreover, at building scale, the "transformation degree" is introduced referring to envelope values (AnP) and their state of conservation (Ac.3) above all for roofs and walls; moreover, in term of system penetration, current cooling and heating system types are representative of the alteration in final technologies and level of urban energy grid.

For instance, three degrees can be identified and mapped for roofs (Figure 5.5-1):

[T.R.H] HIGH: for roofs that are severely damaged or collapsed, so that the intervention should concern their reconstruction;

[T.R.M] MEDIUM: for roofs covered by waterproofing layer (Cex.c) or not original pavement (Cex.a), where the design and construction of a compatible finishing might be required;

[T.R.L-M] LOW-MEDIUM: for roofs covered by original either/or valuable roof tiles, where the intervention should preserve the formal and material identity of the external finishing, eventually by removal, treatment and reuse (Cex.b).

Similarly, with reference to the walls (Figure 5.5-2):

[T.W.H] HIGH: for walls that are severely damaged or collapsed, so that the intervention should concern their reconstruction;

[T.W.M-H] MEDIUM-HIGH: for plastered walls, so that the design should concern the replacement of the original finishing with compatible layers of high performing materials;

[T.W.L] LOW: for unplastered walls, where the intervention is quite limited by the conservation requirements.

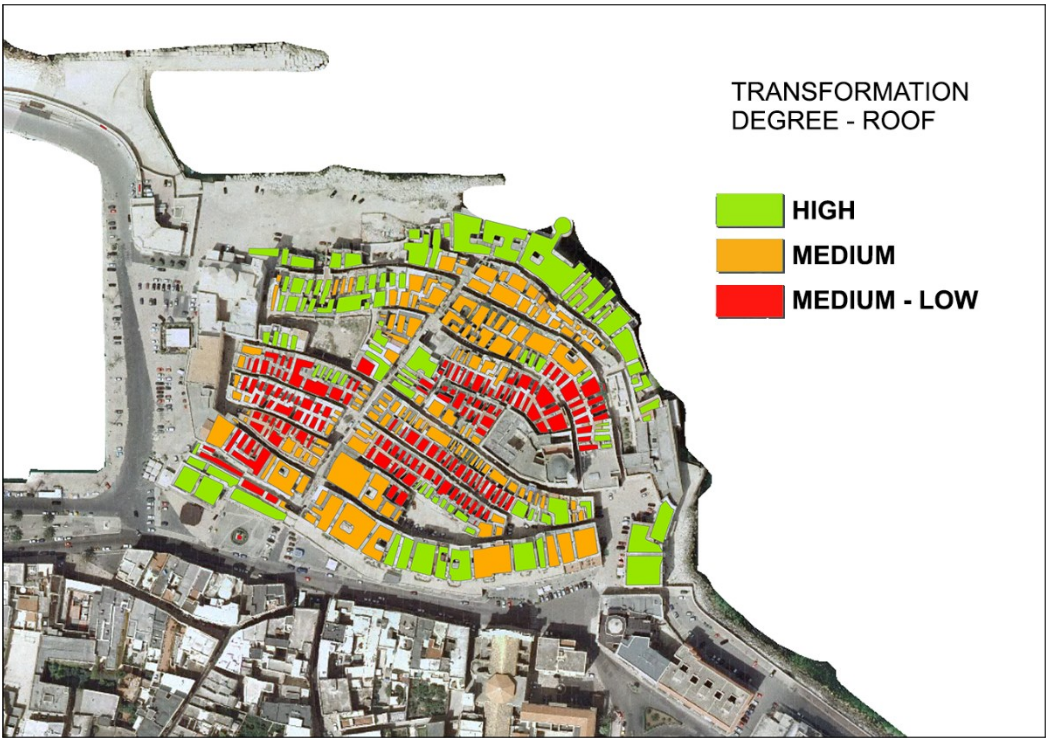


Figure 5.5-1 GIS map of transformation degree of roofs.

Overlooking the particular case on the northern part of the district, the ancient core id featured by Medium-High and Low level of transformability, according to the table of codes defined in Ac2, as reported in Table 5.1-7.

Finally, cooling and heating systems are divided in three levels:

[T.S.H] HIGH: for constructions already equipped with systems and connected to distribution grids;

[T.S.M] MEDIUM: for buildings like the first ones but not connected with the distribution grids;

[T.S.L] LOW: for buildings with obsolete and not connected systems.

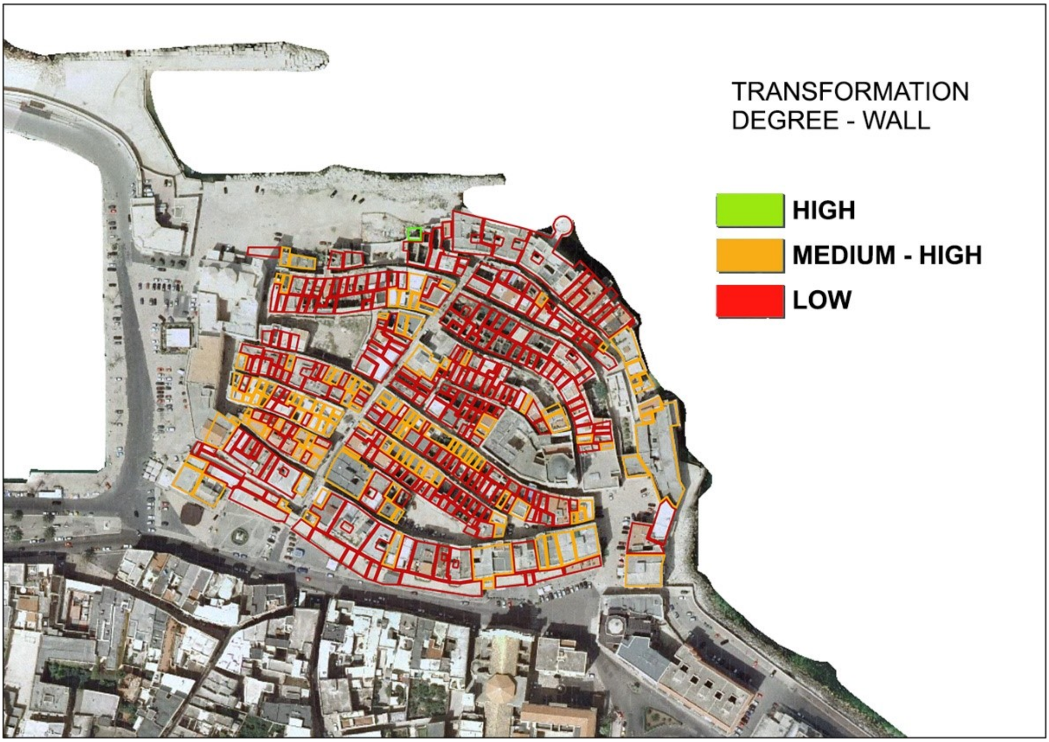


Figure 5.5-2 GIS map of transformation degree of walls.

In that case, methane and electric systems are completely distributed along the whole historic district and, as supposed before, all constructions are connected to them. Despite the specific case, that classification cannot be always expected because of the lengthy process of system modernisation and creations that can affect some other historic district, as discussed for the historic district of Bitonto, near to Bari (Italy) (Oke 2002).

That classification surely opens the recognition in opportunity of transformations, overlapping the necessities identified as vulnerabilities. In detail, walls and roofs should be improved focusing on wintry thermal deficiency and both in wintry and summer thermal and optical deficits, respectively.

5.5.2 SYSTEM OF SUITABLE SOLUTIONS (E2)

As supported in first part of thesis, historic centres are representative of a multilevel process of transformation and innovation in materials and technologies penetration and save failure experiences. From the analysis, the whole historic district appears more resilient in reacting to external changes while some failures are recognized at the building type scale.

Roofs are representative of the most inefficient (and so, less resilient) sub-system of the envelope to external variations, and increase albedo value, thermal transmittance and inertia are the final goals; however, different solutions could be found to solve that. The unquestionable evidence of the historic cases is the necessity to conciliate the preservation of formal and historic values in addition to his purpose.

The case of "fourth façade" in historic district is a troublesome aspect. Roofs are often considered as an especial façade of buildings where all the interventions cannot be visible at man height. So, traditional plane solutions (varying finishing layer) are well accepted by the Soprintendenza; on the contrary, vertical solutions (as shading systems or garden roofs) are considered invasive.

Moreover, the presence of light wooden roofs and their preservation cannot allow to transform them increasing static loads (V.Cin) and, consequentially, excessively their geometrical features that generate a change in floor amount.

Considering that, solutions should be classified for three levels of intervention for:

[I.C.Opt.] finishing solutions focusing on optical features improvement of roofs and, referring to their activities, in two types:

- [I.C.Opt.1] finishing addictions or substitution for roofs that are not used for daily uses (e.g. bituminous roofs that are accessible just during maintenance interventions); in that case, the use of Field-Applied Coatings or Fluid Applied membrane can support both ordinary maintenance, covering or substituting the bituminous surfaces;
- [I.C.Opt.2] substitution of not original pavements for accessible roofs with reflective technologies as clear reflective concrete or cotto tiles;

[I.C.Th.] improving thermal properties inserting insulation panels under finishing sub-layers replacing the inclined screed above the slab with high performing insulation lightweight concrete (e.g., with expanded clay, pumice, expanded glass) and adding an high performing insulation panel above the screed, in order to achieve the lowest thickness increase (e.g. aerogel, VIPs, multi-layer reflective boards); main differences concern the external finishing treatments, where:

[I.C.Th.1] in case of not original pavement and industrial external products (C.ex.a and C.ex.c) their substitution is allowed;

[I.C.Th.] for original or high relevant pavement (C.ex.b) removal and substitution are avoided in favour of their re-use after thermal improvement of roofs, according with the transformability degrees (cpt. 5.5.1);

[I.C.Ti] increase inertia of roof inserting new massive layers to the structural part of roofs, e.g. adding coatings or doped pavement with phase changing materials on the external surface to enhance attenuation and time shift of the summer temperature peaks through controlled latent heat storage and release.

Referring to wall deficiencies, the capacity to undergo his thermal vulnerability in winter conditions can be solved introducing, three kinds of solutions, according to values (APn):

[I.Wa.1] high performing insulation panels on the external façade to achieve the lowest thickness (e.g. aerogel, VIPs, multi-layer reflective boards), including a thermo-insulating plaster coating (e.g. hydraulic lime with EPS additives), in case of outer plastered surfaces; when it is compatible with thermal goals, natural and recyclable insulation panels are allowed, too.

[I.Wa.2] Filling up the inner cavity with high performing insulation mixtures (e.g. hydraulic lime with nanoparticles), for unplaster facades; thermal improvement along the inner surfaces of walls is avoided to preserve his thermal inertia and preventing interstitial condensations.

[I.Wa.3] Focusing on the built of new wall, where extremely damaged, reflecting the thermal thresholds value defined by the law, and using clear plaster as a reflection of positive behaviour of inherent qualities and formal homogeneity with the historic district.

Referring to Energy systems at building scale, solutions refer to the degree of penetration of them where:

[I.S.1] upgrade of cooling and heating systems technologies, when building is already connected to urban supplies;

[I.S.2] connection of the systems to the urban supplies and use efficient technologies;

[I.S.3] introduction of efficient systems that do not required grid supplies (e.g. biomass boiler).

That general overview of allowed solutions, Table 5.5-1 summarises interventions codes with building codes and values, and so with transformation degrees.

Component	Component code	Transformation degree	Intervention code
Wall	Wa.1	T.W.M-H	I.Wa.1
	Wa.2	T.W.L	I.Wa.2
Roof	Cex.a + C.in	T.R.M	I.C.Opt.2 + I.C.Th.1
	Cex.b+ C.in	T.R.M-L	I.C.Th.1
	Cex.c+ C.in	T.R.M	I.C.Opt.1 + I.C.Th.1
HVAC system	S_H – S_C	T.S.H	I.S.1

Table 5.5-1 Summing-up of building codes, transformation degrees and intervention codes for Molfetta built heritage

5.6 ASSESSMENT OF PRIORITY OF INTERVENTION

Suitable solutions discussed in previous phase represent different levels of interactions that could be associate to the state of maintenance and so to the state of conservation of roofs and wall. In fact, referring to the opportunity that single house in historical centre offers to the energy resilience improvement, technical solutions and real measures of them should be chosen as the overlap of degree of transformation, adaptation capacities and acceptable solutions defined by the preservation code, while measure of them should be defined on the real case and necessity.

However, the presence of different levels of deficiency and exposure from the district to building scale, introduce the necessity to define a flexible system that can support administration in the management of priority.

In detail of the minimum unit of energy resilience interventions (MUERI), the main need is to overlap energy deficiencies and adaptation capacity proposing a system of interventions that should be combined with the transformability degree.

Correction of energy deficiencies as recurrent and wide element of mitigation strategy, refers to the static lack of thermal properties of wall and roof sub-systems compared with the normative thresholds; adaptability capacity, as the predominant feature of system's resilience in monitoring and diagnosis phases in a dynamic point of view, should be supported focusing on adaptability levels at canyon and building scales – described in C2b and D3 phases – , highlighting robustness and redundancy characters; in detail:

a. at canyon scale, adaptability has been characterized following daily mean temperature and their standard deviation variation along the canyons and consequent effect on performant walls; specifically, three areas were recognized:
    - [A.C.H] high for inner canyons in any asset because of the minimum value of increased daily temperature in average and maximum value of reduction of Standard deviation; to that, lower value of surface temperatures can be evaluated during the midday;

[A.C.M] medium along open areas where average values of daily temperatures are increased (+0.5) and Standard deviation is comparable to the previous; in that case, surfaces reach similar surface temperatures of previous;

[A.C.L] low along the boundary where any adaptability capacity of the district has zero value and wall temperatures follows external variability.

b. at building scale, adaptability can be discussed as the potential capacity to reduce local superficial overheating outside the volume of canyons, and so the analysis of optical features of current materials on the roof; in depth:

[A.R.H] high for paved roofs made in stone ("chiancarelle") featured by high optical features; moreover, in unoccupied buildings, buildings without roof have potential high adaptability aiming at a good design of them;

[A.R.M] medium referring to paved roof with medium relevance in albedo and emissivity values;

[A.R.L.] low denoting roofs with low optical performances as bituminous finishing ones.

Following the purpose, the latter elements are collected in GIS platform to delineate the position and the boundary frame of single buildings as well as the instrument of flexible management; moreover, this overlapping delineates the priority of intervention based on extremely analysis, while energy deficiencies should be corrected focusing on their transformability degree.

Finally, the presence of buildings in state of maintenance is evaluated separately, so defining different level of priority and intervention for occupied and unoccupied buildings.

As a result of the overlapping phase of adaptability capacities, 8 level of exposure can be recognized for the occupied buildings (Figure 5.6-1), whereas 3 for unoccupied ones (Figure 5.6-2); moreover, boundary buildings are affected by a low adaptability.

However, for each of them, a different classification for wall code (and so transformability) should be introduced to define the MUERIs.

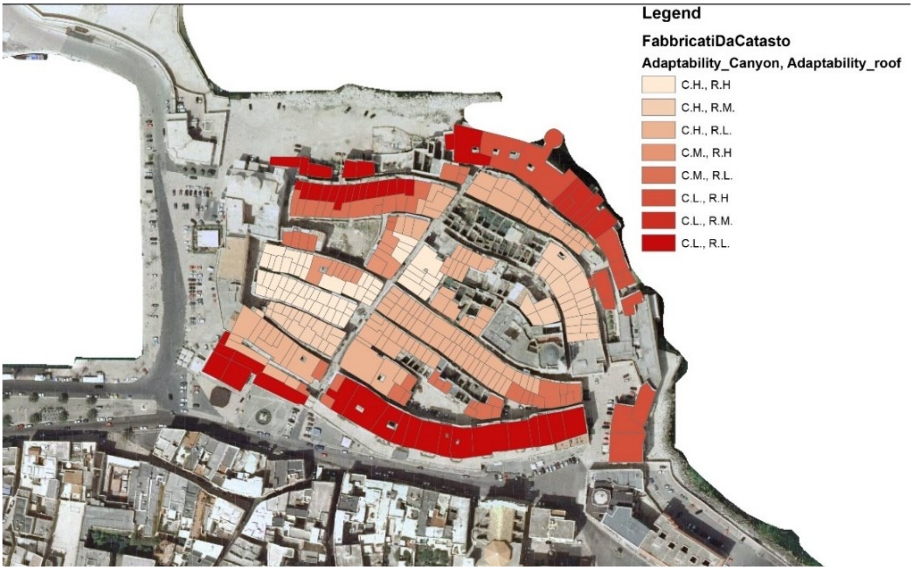


Figure 5.6-1 Occupied Building Adaptability

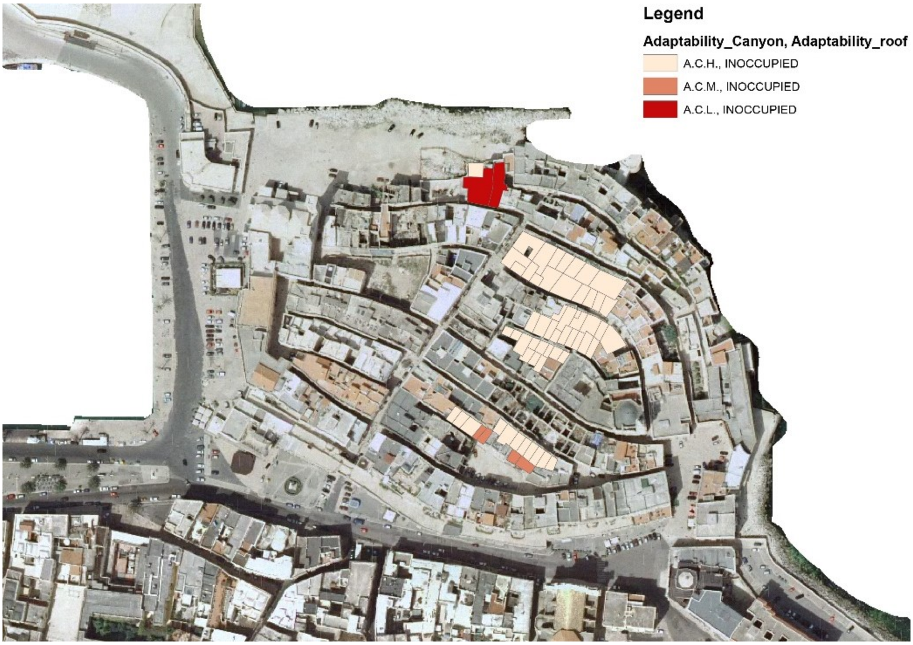


Figure 5.6-2 Unoccupied Building Adaptability

Identification of MUERIs occur adding information about transformation degree for walls. In detail, Table 5.6-1 and Table 5.6-2 report the MUEIs classification, and Figure

5.6-3 and Figure 5.6-4 distribution of them in the historic district, before to define sheets, distinguishing in occupied and un-occupied built bases.

MUERI code	Adapt_canyon	Adapt_Roof	Transf_Roof	Transf._wall	SCORE	Representativeness in district [%]
1a	A.C.H.	A.R.H.	T.R.M-L.	T.W.L.	8	8.70%
1b	A.C.H.	A.R.H.	T.R.M-L.	T.W.M-H.	9	8.40%
2a	A.C.H.	A.R.M.	T.R.M.	T.W.L.	8	7.20%
2b	A.C.H.	A.R.M.	T.R.M.	T.W.M-H.	9	5.70%
3a	A.C.H.	A.R.L.	T.R.M.	T.W.L.	7	29.90%
3b	A.C.H.	A.R.L.	T.R.M.	T.W.M-H.	8	14.32%
4a	A.C.M.	A.R.H.	T.R.M-L.	T.W.L.	7	2.10%
4b	A.C.M.	A.R.H.	T.R.M-L.	T.W.M-H.	8	0.60%
5a	A.C.M.	A.R.L.	T.R.M.	T.W.L.	6	9.00%
5b	A.C.M.	A.R.L.	T.R.M.	T.W.M-H.	7	4.50%
6a	A.C.L.	A.R.H.	T.R.M-L.	T.W.L.	6	1.20%
6b	A.C.L.	A.R.H.	T.R.M-L.	T.W.M-H.	7	3.00%
7a	A.C.L.	A.R.M.	T.R.M.	T.W.L.	6	1.50%
7b	A.C.L.	A.R.M.	T.R.M.	T.W.M-H.	7	0.30%
8a	A.C.L.	A.R.L.	T.R.M.	T.W.L.	5	8.40%
8b	A.C.L.	A.R.L.	T.R.M.	T.W.M-H.	6	3.90%

Table 5.6-1 MUERIs code for occupied buildings

MUERI code	Adapt_canyon	Adapt_Roof	Transf_Roof	Transf._wall	SCORE	Representativeness in district [%]
9a	A.C.H.	A.R.H.	T.R.H.	T.W.M-H.	9	1.76%
9b	A.C.H.	A.R.H.	T.R.H.	T.W.L.	8	12.06%
10	A.C.M.	A.R.H.	T.R.H.	T.W.L.	9	1.01%
11a	A.C.L.	A.R.H.	T.R.H.	T.W.H.	7	0.25%
11b	A.C.L.	A.R.H.	T.R.H.	T.W.L.	7	0.50%

Table 5.6-2 MUERIs code for unoccupied buildings

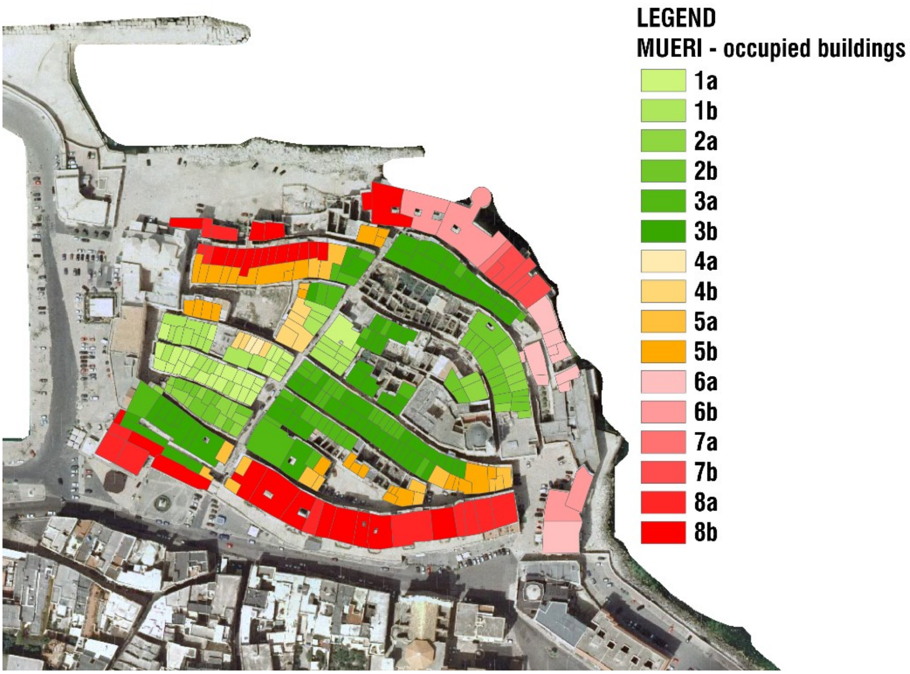


Figure 5.6-3 MUERI distribution for occupied buildings

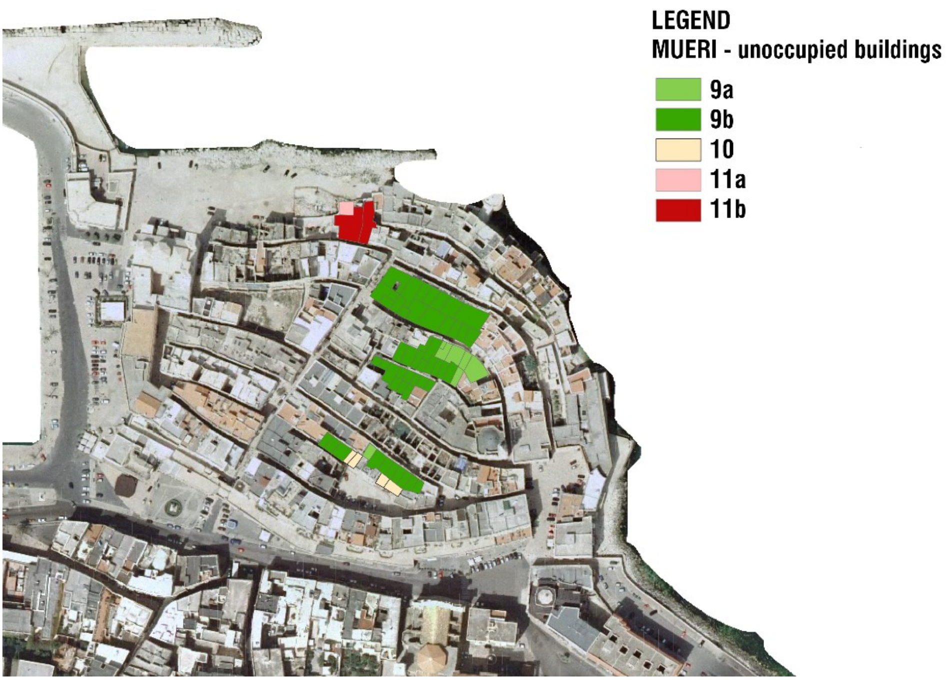


Figure 5.6-4 MUERI distribution for unoccupied buildings

As reported in Table 5.6 1and Table 5.6 2, a column of score is reported, to identify a degree of resilience, according to the main concept. In fact, for each code of transformability and adaptability, a score between 1 ÷ 3 is associated where in transformability features 1 point concerns the lowest capability to be transformed and 3 the higher; oppositely for adaptation capabilities.
So, collecting previous advices in transformations requirements, illustrative sheet for building interventions can be represented, as illustrative, for the widest type, that, surely, is representative of the previous analysed “building type”.
In detail, Figure 5.6-5 presents the illustrative sheet of the system of interventions on 3a MUERI, while Figure 5.6-6, Figure 5.6-7 and Figure 5.6-8 illustrate guidelines for choice and application of technical solution for thermal improvement of unplastered wall (code Wa2) and bituminous roof (code Cex.c) and optical improvement for roof, respectively.
Following, Figure 5.6-9 and Figure 5.6-10 proposed same information details for the MUERI 3b which differ for the external plastered wall (code Wa1).

GEOGRAPHIC LOCATION: Molfetta (BA), Italy, 0 - 143 mt a.s.l. 41° 12' 00" N, 16° 36' 00" E	CLIMATIC CLASSIFICATION: 1202 D.D. , ZONE C (DPR 142/1993)	CURRENT ENERGY REGULATION: D. 26 June 2015

M.U.E.R.I. CODE: 3a			
COMBINATION OF ACTIONS	SUB-SYSTEM OF ENVELOPE / SYSTEM	TRASF. DEGREE	ACTION
	WALL [Wa2]	T.W.L.	[I.Wa.2] decrease thermal transmittance with an inner insulation layer
	CEILING [C.in - C.ex.c]	T.R.M.	[I.C.Th.1] decrease thermal transmittance; [I.C.Opt.1] increase optical features; [I.C.Ti] increase thermal inertia
	HEATING AND COOLING SYSTEMS [S_H2 - S_C2]	T.S.M.	[I.S.1] upgrade cooling and heating systems

Figure 5.6-5 Illustrative sheet of combination of action for the MUERI 3a

GEOGRAPHIC LOCATION: Molfetta (BA), Italy, 0 - 143 mt a.s.l. 41° 12' 00" N, 16° 36' 00" E	CLIMATIC CLASSIFICATION: 1202 D.D. , ZONE C (DPR 142/1993)	CURRENT ENERGY REGULATION: D. 26 June 2015

M.U.E.R.I. CODE: 3a					
Sub-system code: Wa 2	State of desrepair: good Degree of transformation: T.W.L.	Energy resilient level: medium Dominant features: high thermal inertia and albedo	COMPATIBLE SYSTEMS OF INTERVENTION	MATERIALS and GUIDELINES	
			[I.Wa.2] Inner insulation	Filling up the inner cavity with high performing insulation mixtures	To fill up inner cavity, mixtures featured by certain chemical, physical and mechanical compatibility are preferred. All the holes for insufflations should be done preferring mortar slices, in order to preserve stone blocks.

Figure 5.6-6 Illustrative sheet of the choices of action for Wa2 code in MUEI 3a

GEOGRAPHIC LOCATION: Molfetta (BA), Italy, 0 - 143 mt a.s.l. 41° 12' 00" N, 16° 36' 00" E	CLIMATIC CLASSIFICATION: 1202 D.D. , ZONE C (DPR 142/1993)	CURRENT ENERGY REGULATION: D. 26 June 2015
M.U.E.R.I. CODE: 3a		

Sub-system code: Cex.c			COMPATIBLE SYSTEMS OF INTERVENTION	MATERIALS and GUIDELINES	
	State of desrepair: good	Energy resilient level: medium	[I.C.Opt.1] Outer coating application	Field-Applied Coating	Applied coating in case of substitution or protection of waterproof layer, covering and protecting the whole surface having care to overlap external strip. material featured by stable and high emissivity (ε) and albedo (α) values are preferred.
	Degree of transformation: T.R.M.	Dominant features: low transmittance, inertia, albedo		Fluid applied Membrane	Applied coating in case of substitution or protection of waterproof layer, covering and protecting the whole surface having care to overlap external strip. material featured by stable and high emissivity (ε) and albedo (α) values are preferred.

Figure 5.6-7 Illustrative sheet of the choices of optical actions for Cex.c code in MUEI 3a

GEOGRAPHIC LOCATION: Molfetta (BA), Italy, 0 - 143 mt a.s.l. 41° 12' 00" N, 16° 36' 00" E	CLIMATIC CLASSIFICATION: 1202 D.D. , ZONE C (DPR 142/1993)	CURRENT ENERGY REGULATION: D. 26 June 2015
M.U.E.R.I. CODE: 3a		

Sub-system code: C.in - Cex.c			COMPATIBLE SYSTEMS OF INTERVENTION	MATERIALS and GUIDELINES	
	State of desrepair: good	Energy resilient level: medium	[I.C.Th.1] Inner insulation	Natural and recyclable insulation panels (e.g. pressed wood, cork with λ= 0.04-0.05 W/mK) until 5 cm of increase of the component thickness.	Remove external bitouminus waterproof layer and inserting insulation pannel, be careful to insert it above the screed.
	Degree of transformation: T.R.M.	Dominant features: low transmittance, inertia, albedo		High performing insulation panels (e.g. Aerogel with λ= 0.015 W/mK) when the increase of the component thickness with natural insulating panels is greater than 5 cm.	Remove external bitouminus waterproof layer and inserting insulation pannel, be careful to insert it above the screed.

Figure 5.6-8 Illustrative sheet of the choices of thermal actions for Cex.c code in MUEI 3a

<table>
<tr><td colspan="2">GEOGRAPHIC LOCATION:
Molfetta (BA), Italy, 0 - 143 mt a.s.l.
41° 12' 00" N, 16° 36' 00" E</td><td colspan="2">CLIMATIC CLASSIFICATION:
1202 D.D. , ZONE C (DPR 142/1993)</td><td>CURRENT ENERGY REGULATION:
D. 26 June 2015</td></tr>
<tr><td colspan="5">M.U.E.R.I. CODE: 3b</td></tr>
<tr><td rowspan="4">COMBINATION OF ACTIONS</td><td>SUB-SYSTEM OF ENVELOPE / SYSTEM</td><td>TRASF. DEGREE</td><td colspan="2">ACTION</td></tr>
<tr><td>WALL [Wa1]</td><td>T.W.M-H.</td><td colspan="2">[I.Wa.1] decrease thermal transmittance with an exterior insulation layer</td></tr>
<tr><td>CEILING [C.in - C.ex.c]</td><td>T.R.M.</td><td colspan="2">[I.C.Th.1] decrease thermal transmittance;
[I.C.Opt.1] increase optical features;
[I.C.Ti] increase thermal inertia</td></tr>
<tr><td>HEATING AND COOLING SYSTEMS [S_H2 - S_C2]</td><td>T.S.M.</td><td colspan="2">[I.S.1] upgrade cooling and heating systems</td></tr>
</table>

Figure 5.6-9 Illustrative sheet of combination of action for the MUERI 3b

<table>
<tr><td colspan="4">GEOGRAPHIC LOCATION:
Molfetta (BA), Italy, 0 - 143 mt a.s.l.
41° 12' 00" N, 16° 36' 00" E</td><td>CLIMATIC CLASSIFICATION:
1202 D.D. , ZONE C (DPR 142/1993)</td><td>CURRENT ENERGY REGULATION:
D. 26 June 2015</td></tr>
<tr><td colspan="6">M.U.E.R.I. CODE: 3b</td></tr>
<tr><td rowspan="3">Sub-system code: Wa 1</td><td rowspan="2">State of desrepair: good</td><td rowspan="2">Energy resilient level: medium</td><td>COMPATIBLE SYSTEMS OF INTERVENTION</td><td colspan="2">MATERIALS and GUIDELINES</td></tr>
<tr><td rowspan="2">[I.Wa.1]
Exterior insulation and finishing system (EIFS)</td><td>Natural and recyclable insulation panels (e.g. pressed wood, cork with λ= 0.04-0.05 W/mK) until 5 cm of increase of the component thickness.</td><td>To fix panels, plastic or metallic anchors are forbidden to preserve stones. Adhesives are preferred if chemical, physical and mechanical compatibilities are certain. All the panels have to be covered with a plaster layer following the pre-existing characteristics (colours, materials, thickness).</td></tr>
<tr><td>Degree of transformation: T.W.M-H.</td><td>Dominant features: high thermal inertia and albedo</td><td>High performing insulation panels (e.g. Aerogel with λ= 0.015 W/mK) when the increase of the component thickness with natural insulating panels is greater than 5 cm.</td><td>To fix panels, plastic or metallic anchors are forbidden to preserve stones. Adhesives are preferred if chemical, physical and mechanical compatibilities are certain. All the panels have to be covered with a plaster layer following the pre-existing characteristics (colours, materials, thickness).</td></tr>
</table>

Figure 5.6-10 Illustrative sheet of the choices of action for Wa1 code in MUEI 3b

The use of sheets supports the guideline purpose both for technician and public administrators in transformation and management of them for that kind of complex heritage. As far as the specificity of case study, sheets could be enhanced with other kind of interventions, concerning static or hygienic necessities where could be required.
Moreover, the possibility to summarize all necessities and requirements for single case "type" offers the possibility to determine strategies of priority in the whole districts, also referring to percentage of each of them; for example, the representativeness of rare cases featured by low percentage of cases (MUERI 7a, 11a and 11b) help in standardizing the real character of district built environment and, above all, to support their transformation moving them toward other classes, where it is possible.

CONCLUSION

High responsibility of building stock in energy consumption and GHG emissions represents the main challenge for policies from global to national scales, until now. Simultaneously, the exposure to uncertainties of future changes in climate and extreme events moved in determine strategies that introduce the monitoring as the main instrument to evaluate pre-crisis states and to promote adaptive features in planning activities. Referring to the most exposed zone to future temperature increasing temperatures, Mediterranean area is at the centre of actual actions aiming at mitigation and adaptation goals. Finally, the study of UHI exposure of urban land represents the main element at the actual state for the evaluation of reaction at micro-local climate and so the amplification of future climate conditions.

Historic districts, as an anomalous element of cities for their unplanned design and complexity in historic origin and development, surely suffer and participate to the global changes and local interactions as innate elements of their environmental and anthropic existence. However, despite the widespread necessity to improve them, historic centres and their buildings require a particular **methodology** in planning their energy enhancing because of their socio-cultural, socio-economic and environmental significance; in fact, **preservation** and **transformation** of them should be planned in a dynamic way aiming at their **persistence** along the time as a cultural responsibility of technician and public administrations. For these reasons, traditional strategies require to be checked to determine a custom-planned strategy aimed at the recognition of inherent behaviours and values as well as their deficiencies and vulnerabilities. In fact, the common significance of Mediterranean city for his **adaptive potentiality** should be recognized as the result of the ***genius loci*** experiences in reacting with environment that cannot be neglected in strategy that support **resilience** at urban and building scales.

Proposed methodology encloses different key-concepts that could be summarized as:

- Necessity to work at local scale offers the opportunity to analyse, diagnose and, above all, provide interventions that are tailor-made on the case of analysis, according with the overarching necessity to preserve the local identity of the milieu, as the combinations of environmental, architectural and construction characters. However, the characterization of a FEATURES – TYPE – BEHAVIOURS system offers the possibility to recognize opportunity, deficiency and good efficiencies changing basic features as recognitions of similar on place types to evaluate differences and, so, priorities on the same districts; finally, that analysis tool supports the geocluster efficacy in translating them in similar conditions, as well as the result of an experience of good practices in these conditions;
- the possibility to work in reduced but representative models of the widest characters offers the possibility to sustain the unitary vision of the complex historic districts both in recognitions of behaviours, efficacy of interventions and management and control, in a long-term perspective, suitable solutions of transformations; moreover, it allows to abandon the case-by-case approach that supports the uniqueness of buildings;
- support the performance-based approach, where pre-design characteristics and behaviours are identified as guidelines and best practices, before the selection of specific solutions and products that are typically related to the technological and commercial evolution in a specific era or penetration in a certain area; in these cases appears both solutions actual present in other markets (e.g. high-performing insulation materials) or under development (e.g. compounded solution that couple PCMs with materials exposed outside the buildings);

- moreover, it allows to identify with comparable systems differences and, above all, system of priorities between them, sustaining the unitary vision of the whole landscape heritage and his administration towards the development of a robust decision-making support, compounding it in an enclosing circle of a continuous state of management;
- introduction of energy resilience features as the result of combination of adaptability and transformability capacity at type scale allows to overgoes the singular building analysis of compatible and suitable solutions in the pre-crisis phase and potentially, in crises; in fact, it constitutes the instrument for the recognition, placement and resolution of different levels of exposure to energy unbalances generated by canyon micro-climate reactions and buildings capacity in reduce peaks and so, priority at district scale of interventions; moreover, including in "transformation degree" codes the opportunity to transform and enhance the buildings types as well as in "Adaptability degree" codes the inherent quality at sub-district and building scale, allows both to determine resilience potential level in coping external variations and to overgo the dichotomy between preservation of inherent qualities and transformation of them – if necessary – supporting them with sheets of interventions;
- monitor local behaviour in micro-climate alterations offers the opportunity to provide environmental features in term of local climate characterization in actual state both in absolute and relative terms; efficacy of monitoring phase can be amplified if historical local data are available in order to observe and support climatological studies of local climate variations; finally, the creation of a well-observed data can enrich local databases that constitute the actual lack in real observations practices as well as it constitute the way to promote a local system of observing systems also for nearest cities;
- finally, the support and implementation of informative systems for data and results collections allows to upgrade them according to the dynamic process of transformation of built and weather conditions; moreover, the use

of database in management of built construction technologies and materials became the instrument to enrich local knowledge in term of storage of good or bad experiences, as well as in collection of other construction techniques and materials if ever presented.

Despite the specificity of the case study, the characterization of his features allowed to identify some remarkable features and vulnerability; in detail, the middle tower house with prevalent vertical development of dwelling – that surely is not a kind of type strictly presents in Molfetta historic center – located in a narrow street (2 mt of width) is representative of high adaptive performances at human scale because of redundancy of behaviours in term of:

- creation of a prominent level of shading between on-faced buildings;
- good optical performances of local calcareous stone used for wall construction and street pavement;
- finally, good thermal inertia of wall.

The possibility to enlarge analysis towards a district scale analysis based on a well-located monitoring phase allows to extend some features to the whole district; in fact, the relevance of the statistical analysis between all canyons reveals comparable properties in different materials and morpho-distribution of blocks; in fact:

- variation in orientation, width of long canyon and material differences in roofs and wall finishing do not generate relevant differences;
- on the contrary, openness in urban district as previous fails in district management, represents the actual fail in local wide behaviour of district scale in micro-climate alterations; the recognition of these fails, surely offers the opportunity to review of management of open areas.

Roofs represent the weak element of the system; despite his lower influence at district scale in alteration of local micro-climate at human height, the low level of adaptability can be recognized in:

- low efficiency both in thermal and optical features generating high level of dispersion and relevant surface temperatures peaks during midday;

- moreover, the lower level of thermal inertia generates a consequential inner fluctuation of temperatures.

Finally, the use of the type and the proposed opportunity to measure cold temperatures during March, highlighted that, despite relevant behaviour during summer periods, optical feature of wall and closeness of narrow street invert the energy consumption process increasing them; contrary of that, bad optical feature has a positive contribute even if thermal properties cannot be improved.

Application to the case study supports potentialities of the methodology in his capacity to create a representative outline of complex system of any case that, therefore, delineate the consequent and inherent behaviours.

However, at the end of results and discussion of methodology, further elements can be highlighted for future studies and strategy implementation.

Firstly, methodology can be supported with regional instrument of climate study, according with the requirement to implement the local relevance of results and behaviours, as well as the strong necessity to create a grid of a multilevel system of interests to support other fields of application as the earthquake and flood emergencies.

Moreover, focusing on monitoring processes, crisis emergency can be supported introducing a system of integrated “smart grid” systems to support the real-time evidences. That surely will contribute in enhancing the grid of information at regional scale but also in elaborating system of actions at middle period that can follow other urban planning strategies (e.g. enlarging and improving energy grid systems, variation of national energy thresholds).

Finally, the use of GIS databases to support the management of that building stock can be improved linked them with BIM and energy cadastral data lists as a new starting point of characterization of energy real consumption (which include also inhabitant behaviour and habits) and to improve it in a scheduled system of maintenance management that includes also energy systems and sub-system of the envelope.

Annex A

The specificity of local materials and their inherent belong to *loci* supported the use of traditional and not industrial products. It is the case of calcarenitic materials used for masonry and pavements (along streets and roofs). In detail, optical and thermal values are the results of the laboratory tests on a set of two samples directly got in historic center of Molfetta. It is important to point out that any buildings and kind of heritage were altered because of the use of part of stones present in construction sites. Following are described experimental phases of measures of emissivity and albedo values on two samples.

Finally, measures cannot be the explication of precise values of them because of the limited set of samples and measure points; it could be an experimental measure of the optical and thermal properties in their order of measure supporting the natural features and not industrial process of extraction, posing and superficial transformation.

Ann.A.1 Evaluation of Albedo

Because of the irregular shape of sample, stone was cut in slices in order to evaluate differences in albedo for surface roughness and cleaning, as well as for the presence of impurities in natural product. Measures have been done in Energy Management in the Built Environment Research Lab (EMBER Lab) (Technical University of Crete) using the UV-VIS-NIR spectrophotometer (DRA-2500).

In detail, following images and details of samples slices analysed are reported.

Despite different features of samples, SR values are quite homogeneous where, for flat surfaces counted mainly 0.6 while for rough ones 0.68.

Consider the low roughness of stone surfaces used for buildings and pavements, 0.6 value is considered as main value for all the applications, as well for the several combinations for nature and treatment in roughness and colour in building materials along the time.

However, dirty surfaces demonstrate good optical properties as much clear one.

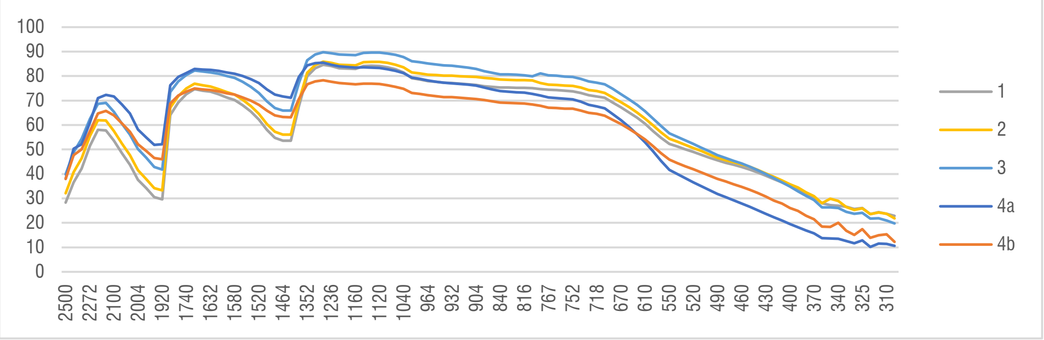


Figure Ann.A.1 Result of Spectrometer analysis

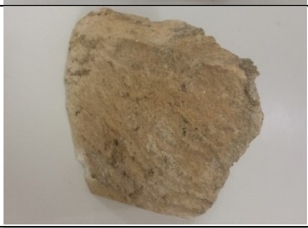
n. sample	Image of sample	Features	SR
1		Flat surface with low incidence of impurities	61.32
2		Flat surface with medium incidence of impurities	59.37
3		Flat surface with medium incidence of impurities	64.5
4a		Not flat surface, high surface roughness and dark colour	66.62
4b		Not flat surface, high surface roughness and clear colour	69.91

Table Ann.A.1 Table of samples and relative features and SR measures

Ann.A.2 Evaluation of emissivity

Considering a second sample of stone, emissivity was evaluated experimentally using a thermo-camera and the black paint test. Main principle is related to evaluate different apparently surface temperatures of the sample painted with black paint featured by a reference value of emissivity and heated in a hoover.

In detail, a second sample of stone was painted with a black paint having $\varepsilon = 0.97$ for a half of his surface and heated until 60 °C. As the second step, stone was located in an undisturbed zone in order to limit external reflections. Finally, using a thermo-camera (AVIO TVS-700) surface temperatures were evaluated considering 9 points of measures for each half surface of sample (Figure Ann.A.2). Results of main values report that stone has graphically the same temperatures in both surfaces and, so, the same value of emissivity (ε=0.97) (Table Ann.A.2); moreover, surface temperatures are tested also in other values for which $\Delta T_{surf\ (black\text{-}natural)}$ increases.

		Measured Temperatures (°C)	
ε		BLACK	NATURAL
	P1	56.63	55.02
	P2	56.48	56.41
	P3	56.56	56.92
	P4	57.14	56.41
	P5	56.41	56.05
	P6	56.56	56.19
	P7	57.57	56.99
	P8	57.14	56.77
0.97	P9	57.21	55.9
	MEAN	**56.86**	**56.30**

Table Ann.A.2 Table of surface temperatures for black and natural surfaces in reference points

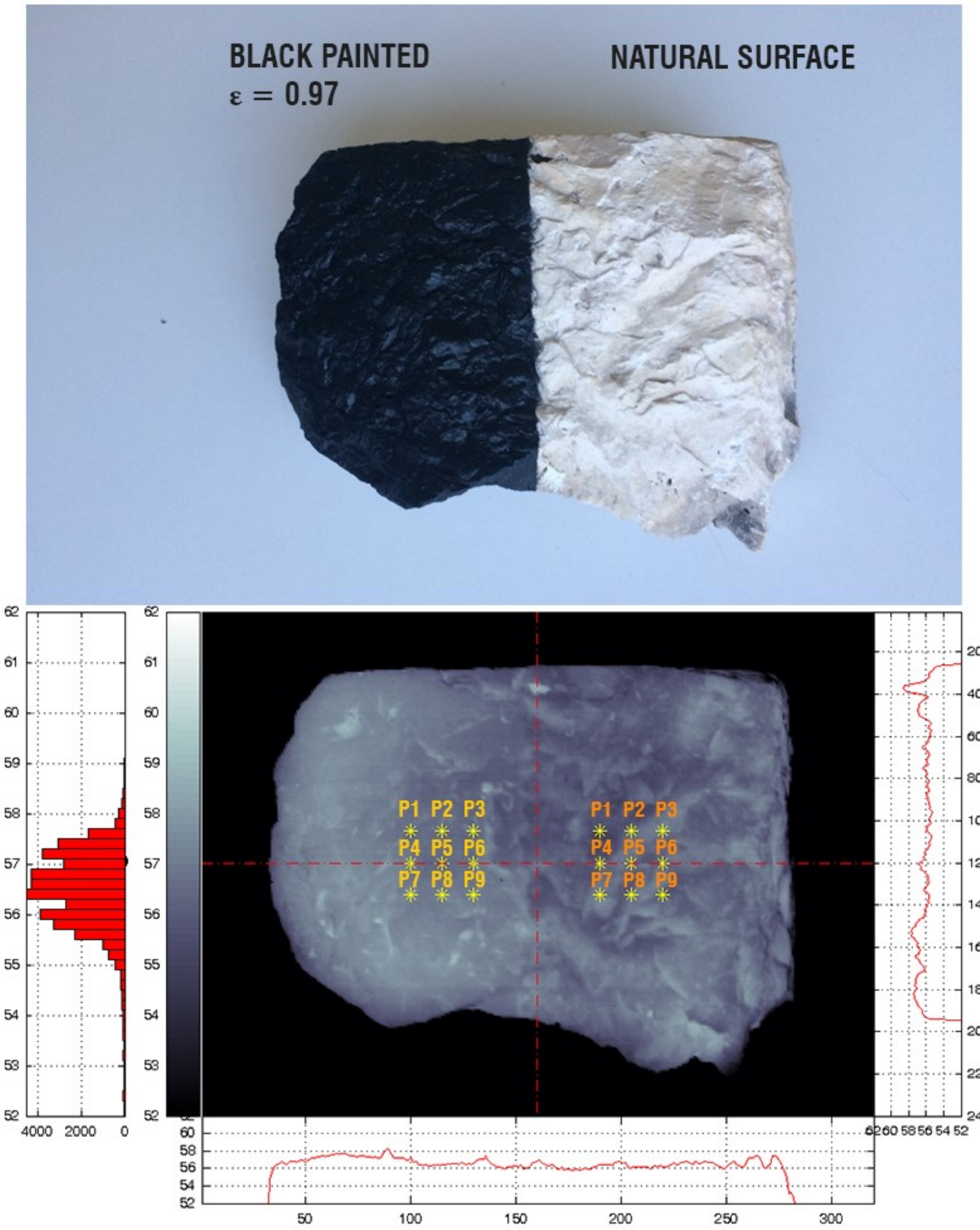


Figure Ann.A.2 Visible and thermal images of samples during the emissivity test and points of evaluation for black (yellow) and natural (orange) surfaces.

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PROJECTS

FP7 – 3ENCULT "Efficient Energy for EU Cultural Heritage", 2010-2014, http://www.3encult.eu/en/project/Info.html

FP7 – EFFESSUS "Energy efficiency for EU historic districts' sustainability", 2012-2016, http://www.effesus.eu/

FP7 – GE2O "Geo-clustering to deploy the potential of Energy efficient Buildings across EU", 2012-2016, http://www.geoclusters.eu/.

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Methodological framework for assessment of energy behavior of historic towns in Mediterranean climate – Research Project: - Fondazione Cassa di Risparmio di Puglia - Scientific Coordinator: Prof. Fabio Fatiguso, Politecnico di Bari.

NORMATIVE REFERENCE

EPBD 2010 - Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010

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Rec☼overy plan of Molfetta ancient core, 1994

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TABLE OF ACRONYMS

IPCC	Intergovernmental Panel on Climate Change
UNFCCC	United Nation Framework Convention on Climate Change
GHG	GreenHouse-Gas
CMCC	Euro-Mediterranean Center on Climate Change
ENEA	Italian National Agency For New Technologies, Energy And Sustainable Economic Development
ET-SCI	Expert Team on Sector-specific Climate Indices
WMO	World Meteorological Organization
UCL	Urban canopy layer
UBL	Urban Boundary Layer
UHI	Urban heat island
UHII	Urban heat island intensity
H/W	Aspect ratio
SVF (ψsky)	Sky view factor
CLUHI	Canopy Layer Urban Heat Island
LCZ	Local Climate Zone
EP	Energy Poverty
WHO	World Health Organization
PCM	Phase Change Material

UNISDR	United Nation Office for Disaster Risk Reduction
GFDRR	Global Facility for Disaster Risk Reduction
ACCCRN	Asian Cities Climate Change Resilience Network
EPBD	Energy Performance of Buildings Directive
COM	Covenant of Mayors
SEAP	Sustainable Energy Action Plan
MATTM	Italian Ministry of the Environment and Protection of Land and Sea
SNACC	National Strategy of Climate Change Adaptation
MUERI	Minimum Unit of Energy Resilience Intervention
MFE_project	Methodological framework for assessment of energy behaviour of historic towns in Mediterranean climate – research project

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OTHER COURSES

Courses with scholarship

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"Enhancing Energy Efficiency Solutions in the Mediterranean Region", first edition of the Advanced Training Course, organized by Politecnico di Torino, in partnership with RES4MED, IREN and ASJA

4-15 July 2016, Rome, Italy
"Summer school in efficienza energetica 2016" IV edition of Course, supporting the National Campaign on Energy Efficiency (Sec.13 of Legislative Decree 102/2014) aiming to train young engineers and architects to support Public Administrators in this area of interest. The course was organized by ENEA and promoted by the Italian Minister of Economic Development

INTERNATIONAL EXPERIENCES

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ACADEMIC ACTIVITIES

Publications

1. Fatiguso F., De Fino M., **Cantatore E.** (2015), *An energy retrofitting methodology of Mediterranean historicalbuildings*", Management of Environmental Quality: An International Journal, Vol. 26 Iss: 6, pp.984 – 997, ISSN: 1477-7835
2. Fatiguso F., **Cantatore E.,** De Fino M. (2016), *Strategies for energy retrofitting oh historical urban districts,* Progress in Industrial Ecology, an International Journal, 10(4), 334-352.
3. De Fino M., Fatiguso F., **Cantatore E. ,** Caponio V. (2017) *Resilience of historic built environments: inherent qualities and potential strategies*, Procedia Engineering, 180, 1024-1033
4. **Cantatore E.**, De Fino M., Fatiguso F. (2017) *Energy resilience of historical urban districts: a state of art review towards a new approach*, Energy Procedia, 111, 426-434
5. De Fino, M., Scioti, A., **Cantatore, E**., & Fatiguso, F. (2017). *Methodological framework for assessment of energy behavior of historic towns in Mediterranean climate*. Energy and Buildings, 144, 87-103.
6. F. Fatiguso, M. De Fino, **E. Cantatore,** A. Scioti, G. De Tommasi (2015), *Energy models toward the retrofitting of the historic built heritage*, in Proceedings of STREMAH 2015, International Conference on Studies, Repairs and Maintenance of Heritage Architecture, 13-15 July, 2015, A Coruña, Spain. Volume 153 of WIT Transactions on the Built Environment
7. **Cantatore E.** (2016) *Parametri della resilienza per l'efficientamento energetico di contesti storici urbani,* Atti del Convegno Colloqui.AT.e 2016: "MATER(i)A" (Materials, Architecture, Technology, Energy/Environment, Reuse, (Interdisciplinarity), Adaptability), pp. 1133-1142
8. **Cantatore E.** (2017), *Fattori intrinseci per l'analisi delle variazioni di temperatura a scala micro-urbana di un contesto urbano storico in area Mediterranea*, Atti del Convegno Colloqui.AT.e 2017: Demolition and Reconstruction? Ancona, 28-29 Settembre 2017. Pp. 1334-1345
9. **Cantatore E.** and Fatiguso F., Mitigation and local adaptability to climate changes of historic districts in Mediterranean Area. A case study. Proceeding

of REHABEND 2018 congress, Infrastructures (ISSN 2412-3811) (accepted article)

Co-relator of thesis

[1] "L'efficientamento energetico dell'edilizia monumentale ad uso pubblico"
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[2] "L'efficientamento energetico dell'edilizia monumentale ad uso residenziale"
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[3] "Riqualificazione energetica e tecnologica dell'edilizia residenziale pubblica",
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[2] Academic Year 2015/2016
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Common European Framework of Reference for Languages

Bari, 20th December 2017

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