ROUND TABLE

BUILDINGS' ENERGY MODELS AND APPLICATIONS AT URBAN SCALE

open door

9 June 2022, 11:45 am
Università di Parma
aula K8 - Polo Didattico Kennedy
Vicolo S. Maria 11, Parma

Introduction on data-driven and process-driven models at urban scale
Prof. Guglielmina Mutani, Politecnico di Torino

Toronto Platform 2030 and data-driven statistical models
Prof. Umberto Berardi , Ryerson University (CA)

Machine Learning models
Dr. Javanroodi Kavan and Dr. Valeria Todeschi, EPFL (CH)

The road map of ENEA on Renewable Energy Communities
Dr. Antonella Tundo, ENEA (IT)

Oil Free Zones and Renewable Energy Communities in Italy
Prof. Angelo Tartaglia and Dr. Silvia Santantonio, Comunità Energetica del Pinerolese

Live streaming: shorturl.at/txBDX

shorturl.at/txBDX

Reinventing Cities

Participating cities include: **Bologna, Milan, Naples** and **Rome**

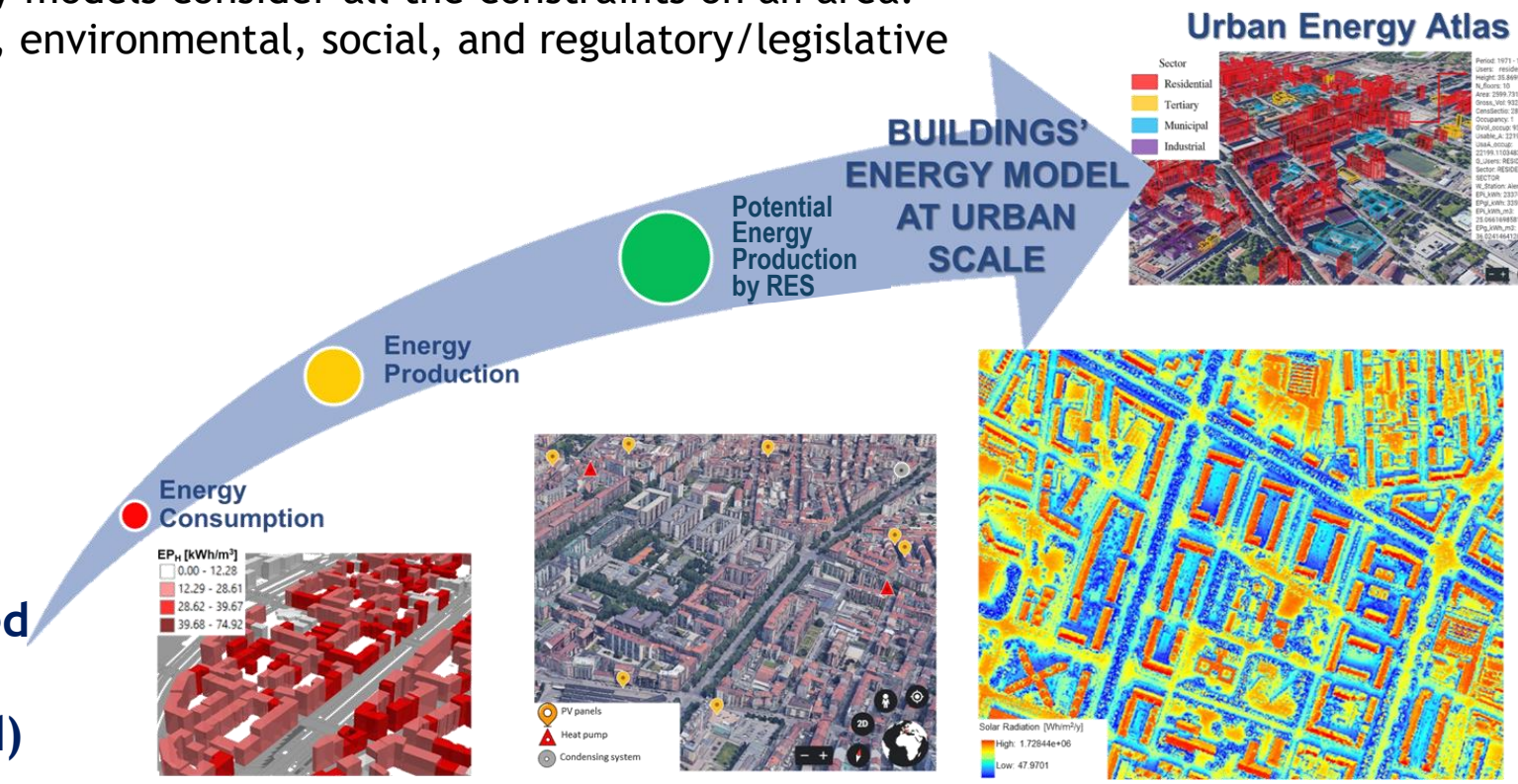
Expressions of interest will be accepted …

- ✓ **100 climate-neutral and smart cities by 2030**
- ✓ Ensure that cities act as **experimentation and innovation hubs** by 2050
- ✓ Italian cities: Bergamo, Bologna, Florence, Milan, Padova, Parma, Prato, Rome and Turin

Place-based Energy Models at Urban Scale

Urban scale and data/process-based energy models (bottom-up, top-down):

- Annual, monthly and hourly models of energy consumption, actual production and potential production considering the availability of RES
- Feasibility models consider all the constraints on an area: technical, environmental, social, and regulatory/legislative



"An Urban Energy Atlas and Engineering Model for Resilient Cities", International Journal of Heat and Technology, Vol. 37, No. 4, pp. 936-947 (2019) DOI: 10.18280/ijht.370402

GIS-based Energy Models at Urban Scale

Energy consumption

Energy production

Energy potential production

1 Input data

Buildings features, users, heating system, climatic data (HD, air temperature, relative humidity, solar irradiation) DTM, DSM, CTR, CTC, energy consumption data

Production plants features, Production plants from Renewable Energy Sources (RES - database:Atlaimpianti) energy production data

Features of available local renewable energy sources :
- Solar irradiation
- Biomass and waste
- Wind
- Wavy way
- …

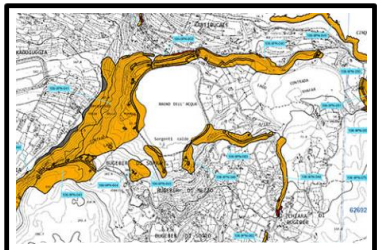
2 Models

Cluster of buildings (archetype) Utilities (household, industrial, commercial, public) → Energy consumption profile

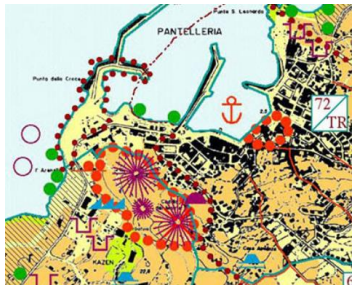
Cluster of energy production plants: Installed power + Hours of utilization→ Energy production profile

Conversion efficiency of technology→ Energy productivity profile

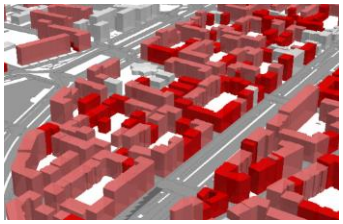
3 Constraints



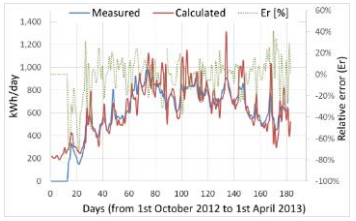
Constraints :
- Technical
- Environmental
- Economical
- Legislative
- ….



4 Scenarios



- BAU
- Future scenarios (medium and long term)
- Energy efficiency & low-carbon scenarios (energy policies)



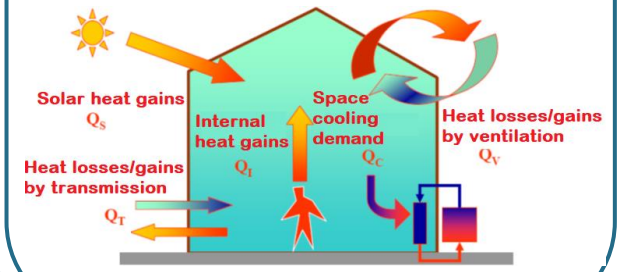
REF. "Energy at urban scale modelling: a tool for energy transition urban regeneration and the resue of existing and empty spaces" G. Mutani, V. Todeschi, in: A&RT - Atti e Rassegna Tecnica 3/2019, Società degli Ingegneri e degli Architetti in Torino, (2019) ISSN 0004-7287 (http://art.siat.torino.it/ultimo-fascicolo/)

Process-driven e data-driven models

Input data and boundary conditions

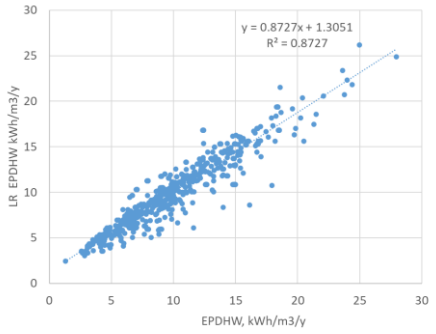
process-driven models (engineering)

Energy balance equations



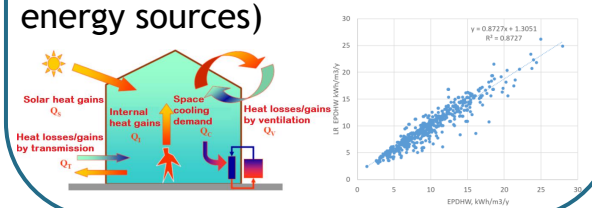
data-driven models (statistics and AI)

Identification of energy variables and correlations



hybrid models

Energy variables whose physical relationships are known in integration to complex real-world models (stochastic nature of occupant behavior and energy production with some renewable energy sources)



Comparison with measured energy consumption data validation

place-based energy models

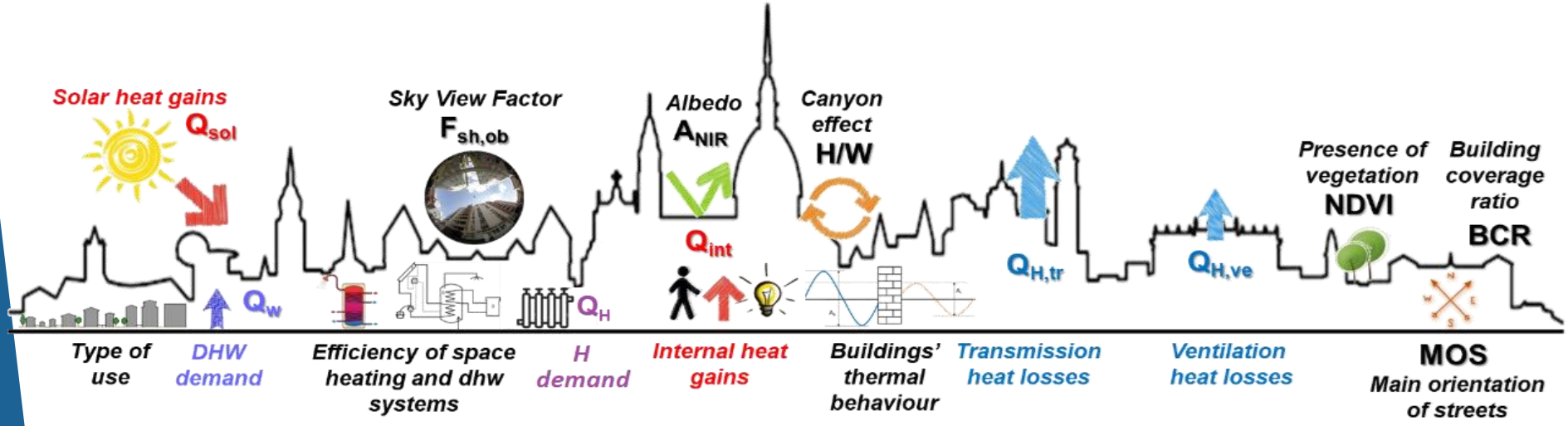
REF. “Impact of the COVID-19 pandemic on the energy performance of residential neighborhoods and their occupancy behavior”, Todeschi, V; Javanroodi, K; Castello, R; Mohajeri, N; Mutani, G; Scartezzini, JL. SUSTAINABLE CITIES AND SOCIETY 82:(2022), p. 103896, DOI: 10.1016/j.scs.2022.103896.

Urban energy models: engineering approach

Urban building thermal balance for space heating consumption:

$$Q_{H,nd} = \sum Q_{H,ht} - \eta_{H,gn} \cdot \sum Q_{gn} = \left(\sum Q_{H,tr} + \sum Q_{H,ve}\right) - \eta_{H,gn} \cdot \left(\sum Q_{int} + \sum Q_{sol}\right)$$

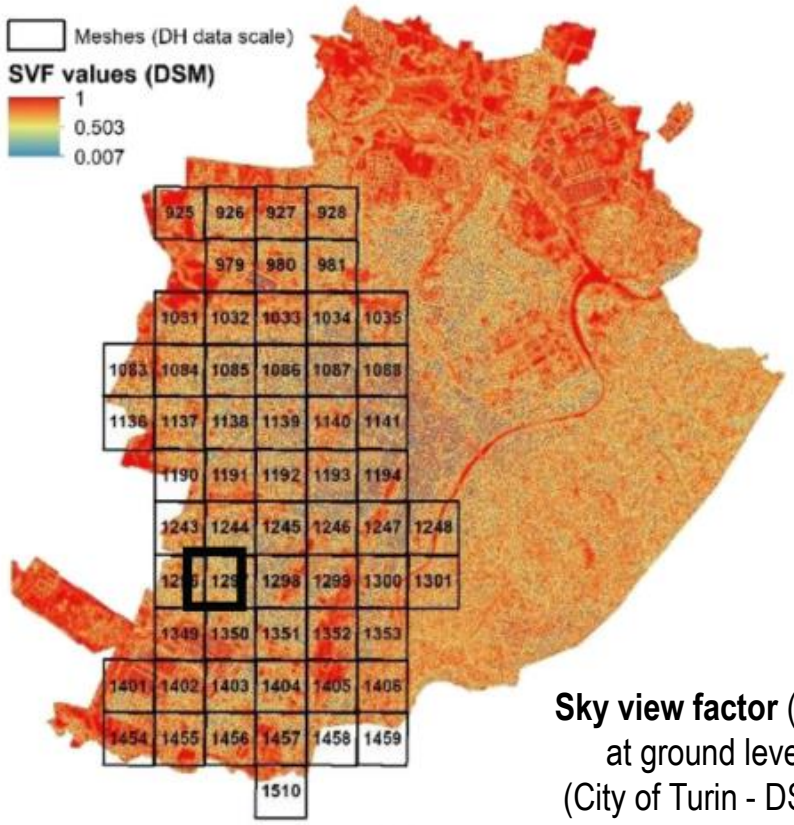
$$C_{TS} \frac{dT_{TS}}{dt} = \emptyset_{sol} + \emptyset_I + \emptyset_H - (\emptyset_T + \emptyset_V)$$

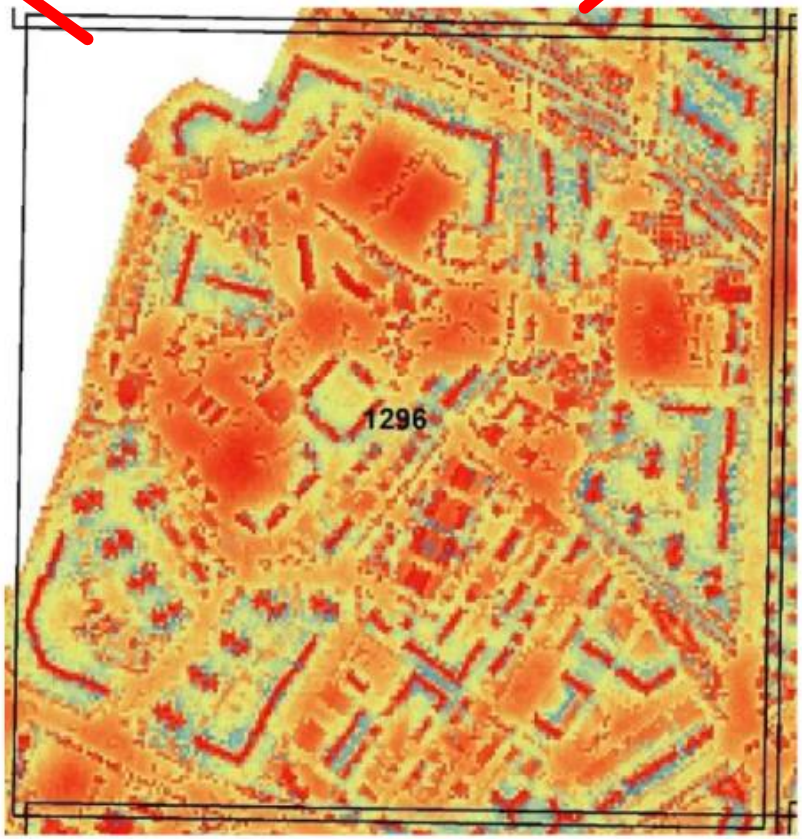


REF: R. Boghetti, F. Fantozzi, J. Kämpf, G. Mutani, G. Salvadori and V. Todeschi, Building energy models with Morphological urban-scale parameters: a case study in Turin, in: Proceedings of 4th Building Simulation Applications Conference - BSA 2019

Input data: collection and processing

$$Q_{H,nd} = \sum Q_{H,ht} - \eta_{H,gn} \cdot \sum Q_{gn} = \left(\sum Q_{H,tr} + \sum Q_{H,ve}\right) - \eta_{H,gn} \cdot \left(\sum Q_{int} + \sum Q_{sol}\right)$$



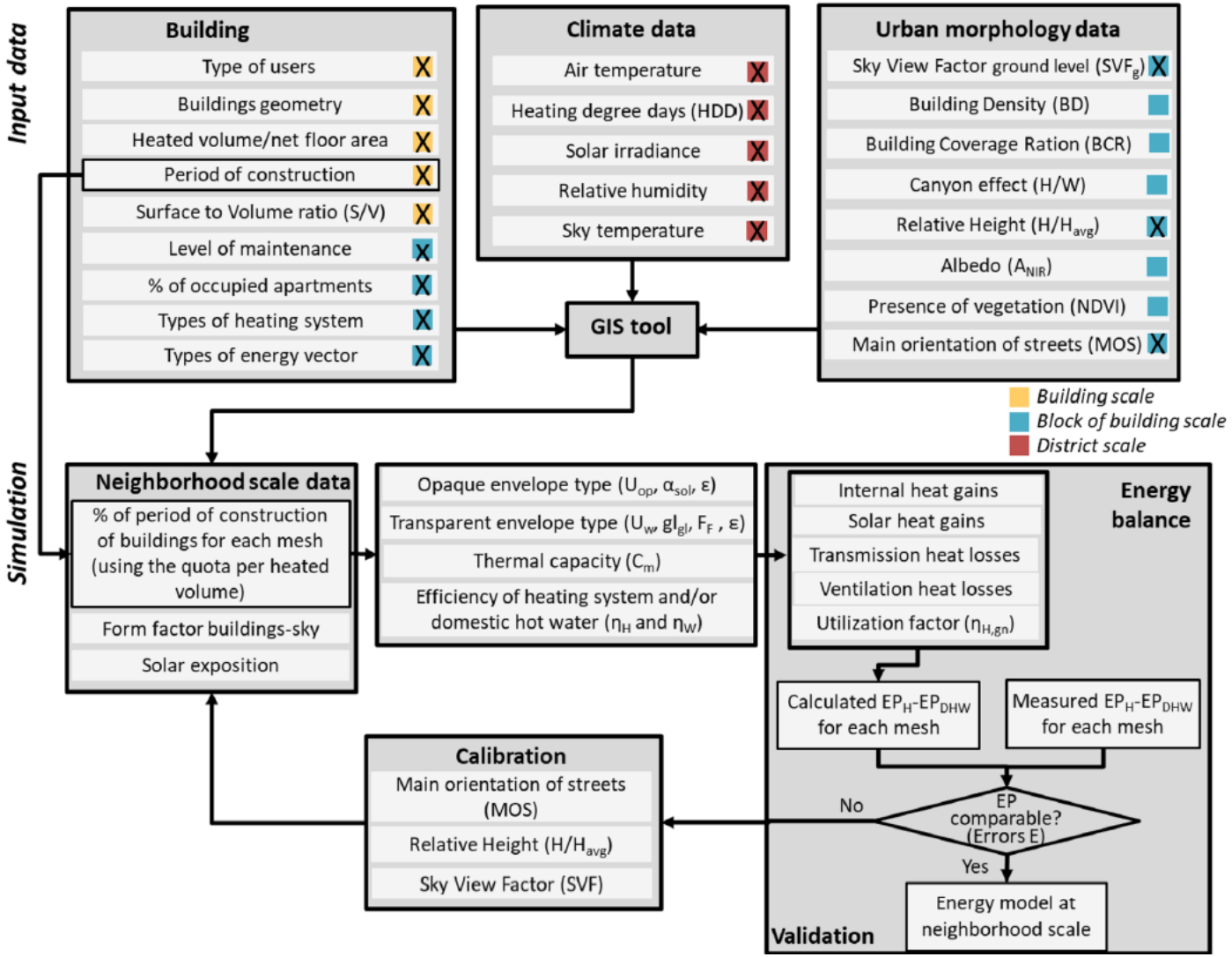


Sky view factor (SVF) at ground level, (City of Turin - DSM 5 m× 5 m)

REF. "Smart Solutions for Sustainable Cities—The Re-Coding Experience for Harnessing the Potential of Urban Rooftops", V. Todeschi, G. Mutani, L. Baima M. Nigra, M. Robiglio, in: Applied Sciences, Vol. 10(20), 7112 (2020) DOI: 10.3390/app10207112

GIS-based approach: monthly heat balance at district scale

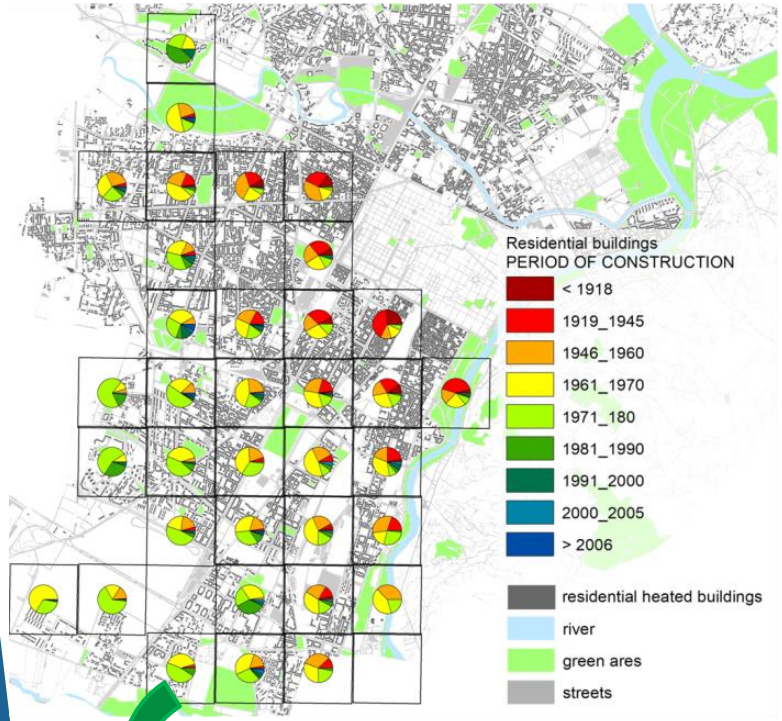
1. **Data input** refers to the buildings, climate, and urban morphology characteristics
2. **Pre-processing phase**: the input data were elaborated and associated to each mesh
3. **Validation**: the resulting energy consumptions were compared with the measured data and some urban variables were added to optimize the model and reduce the error

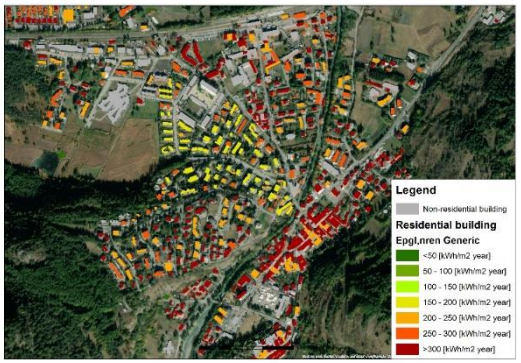


REF. "Building energy modeling at neighborhood scale", G. Mutani, V. Todeschi, in: Energy Efficiency, Vol. 13, 1353–1386 (2020) DOI: 10.1007/s12053-020-09882-4

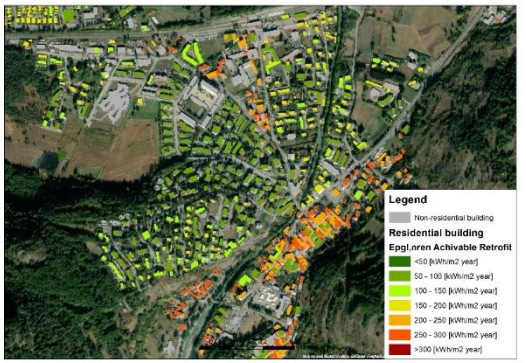
Urban statistical models: top-down approach

Torino

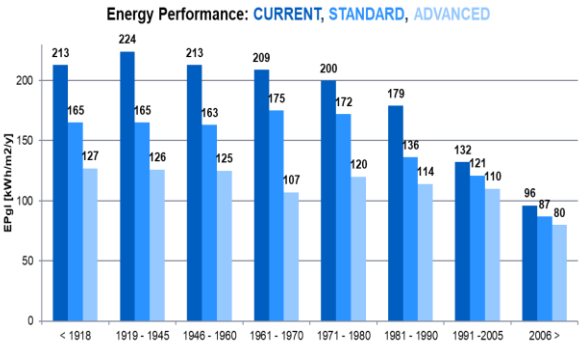


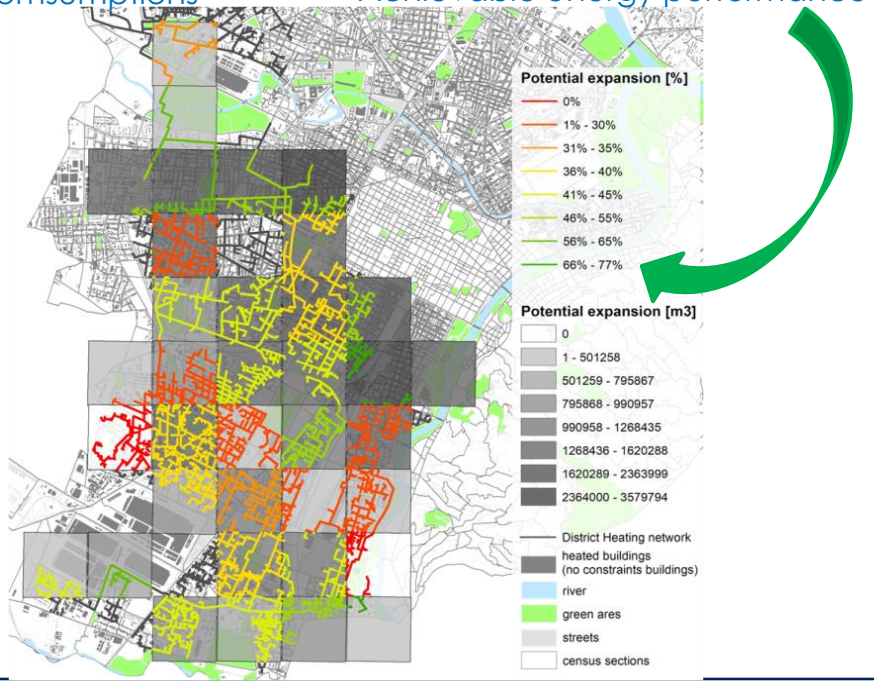


Energy comsumptions



Achievable energy performance



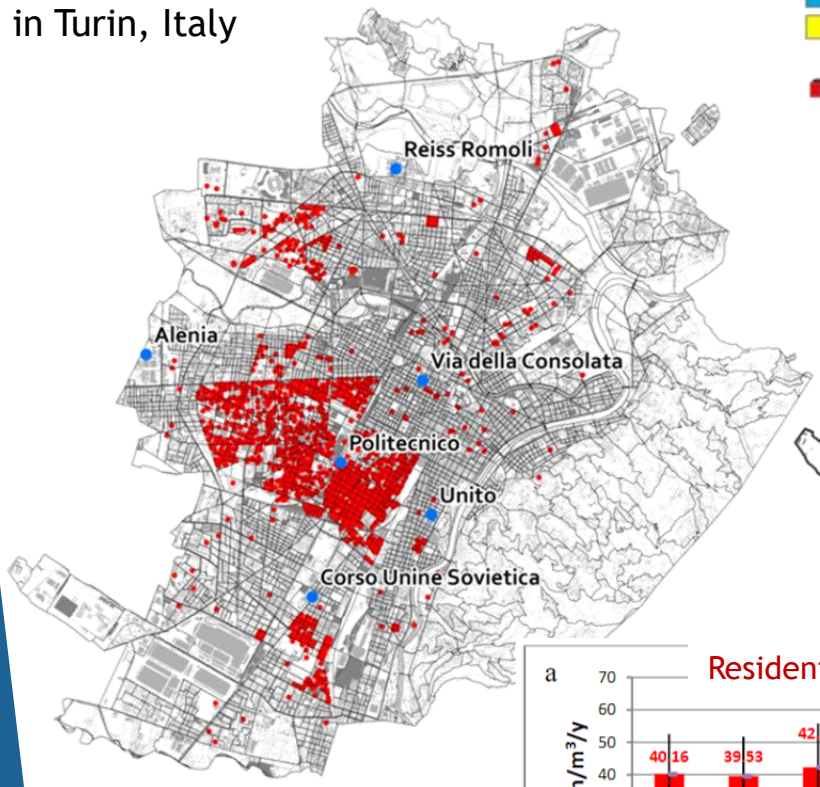


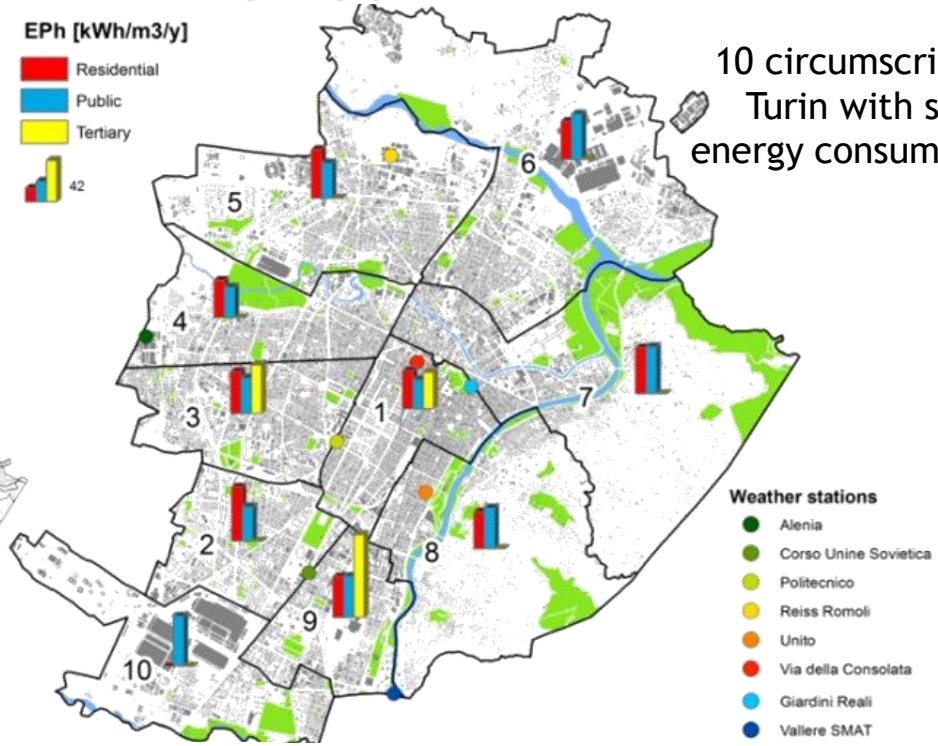
REF. “A feasibility study on the potential expansion of the district heating network of Turin”, E. Guelpa, G. Mutani, V. Todeschi, V. Verda, Energy Procedia, Volume 122 (2017), CISBAT 2017, 2017, Lausanne, ISSN 1876-6102, Pages 847-852, DOI 10.1016/j.egypro.2017.07.446.

Urban statistical models: bottom-up approach

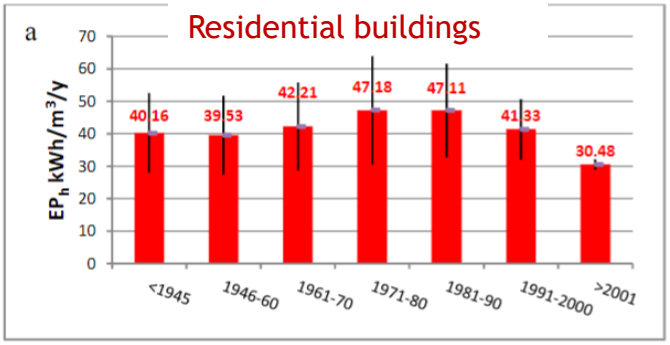
Torino

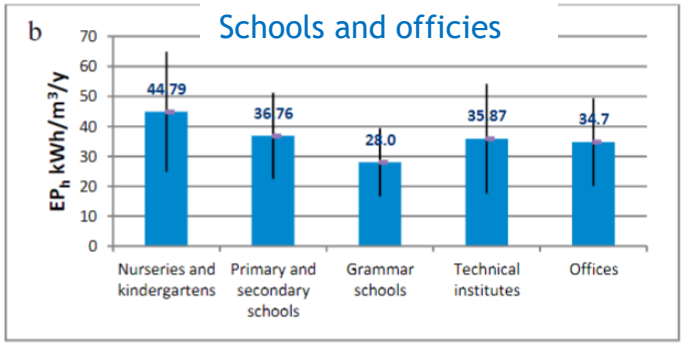
Consumption data from 2,092 buildings and 6 weather stations in Turin, Italy





10 circumscriptions of Turin with specific energy consumption EPgl





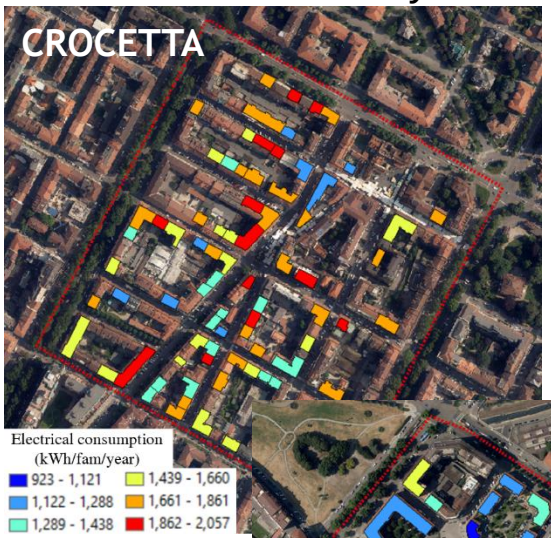
REF. : G. Mutani, V. Todeschi, Space heating models at urban scale for buildings in the city of Turin (Italy), Energy Procedia, 2017
https://doi.org/10.1016/j.egypro.2017.07.445

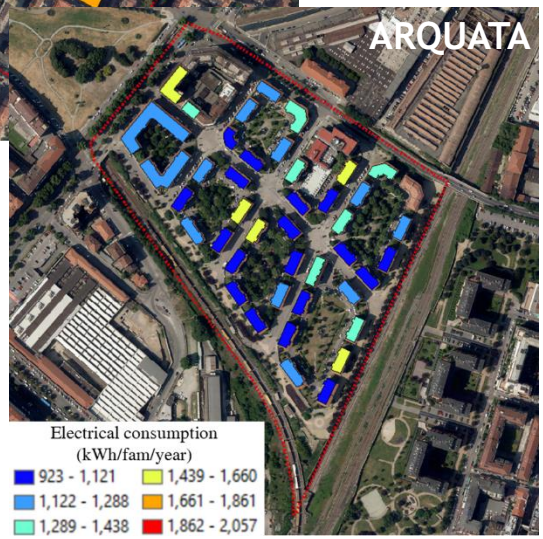
Analysis of solar radiation in urban environment

Torino

Winter solar irradiation

Annual electricity consumption per household





e.g. Solar Portal for the Metropolitan City of Turin (Cities On Power)

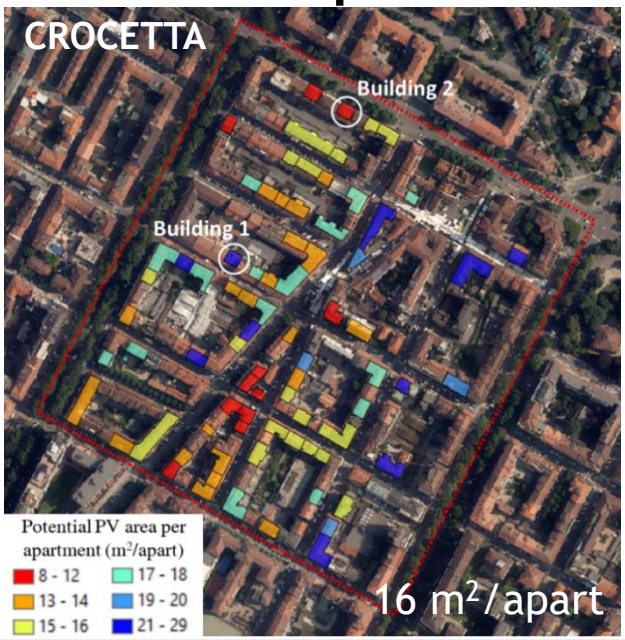
REF. “Towards energy self-consumption and self-sufficiency in urban energy communities”, Todeschi V., Marocco P., Mutani G., Lanzini A., Santarelli M., International Journal of Heat and Technology 39:1(2021), pp. 1-11, doi: https://doi.org/10.18280/ijht.390101

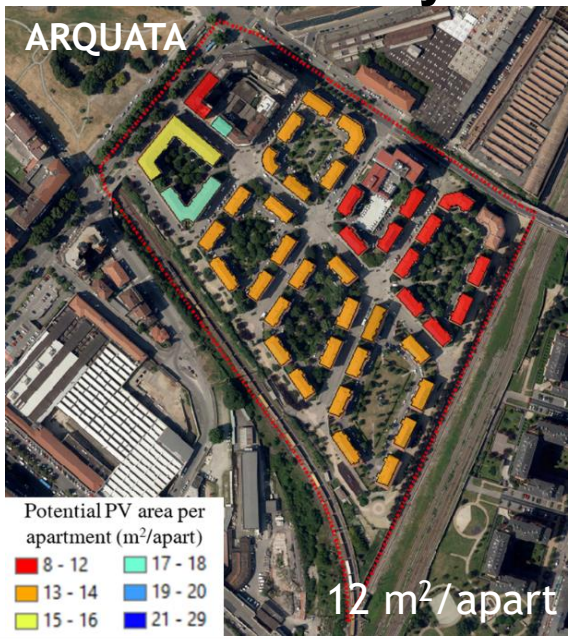
Self-consumption ‘SCI’ and self-sufficiency ‘SSI’

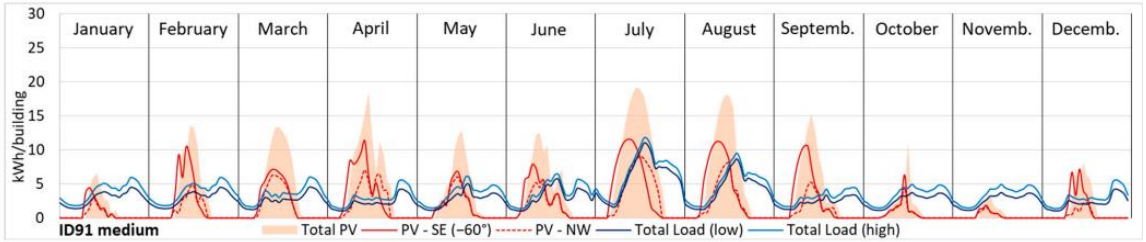
Turin

SCI = SC/P

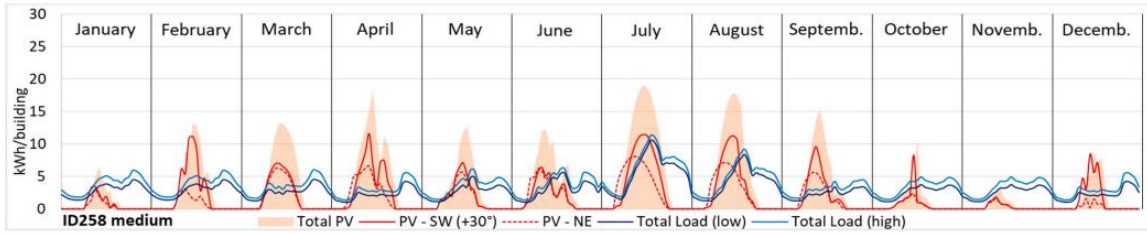
SSI = SC/C







Medium condominium with SE -60◦ orientation

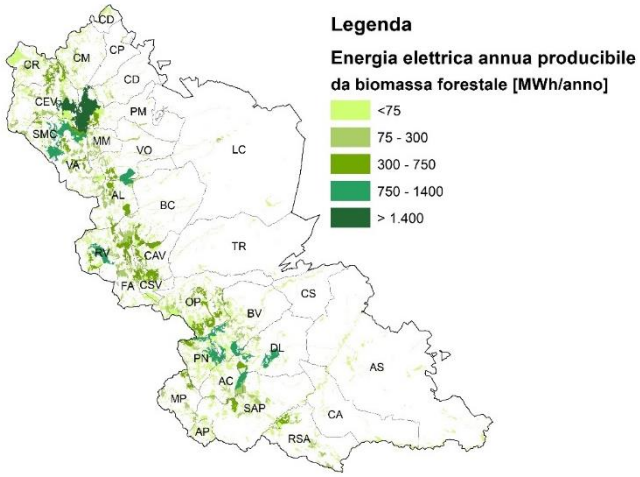


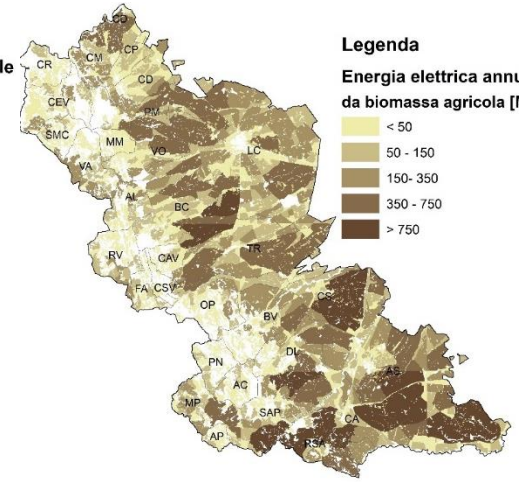
Medium condominium with SW +30◦ orientation

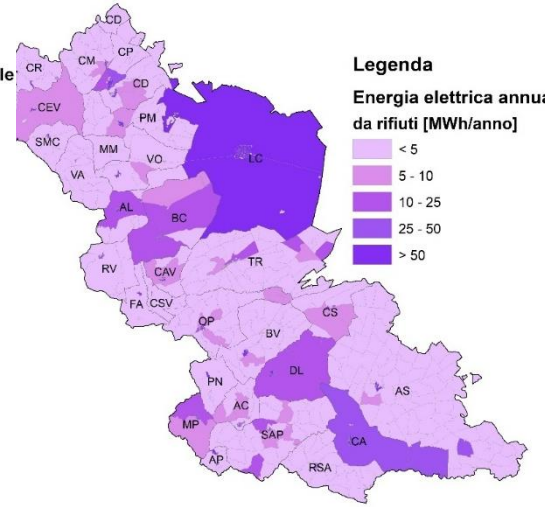
REF. “Optimization of Costs and Self-Sufficiency for Roof Integrated Photovoltaic Technologies on Residential Buildings”, G. Mutani, V. Tedeschi, Energies, Section Sustainable Energy, Special Issue “Electrical Engineering for Sustainable and Renewable Energy”, Volume 14 (13), 4018, pp. 1-25, 2021, DOI 10.3390/en14134018

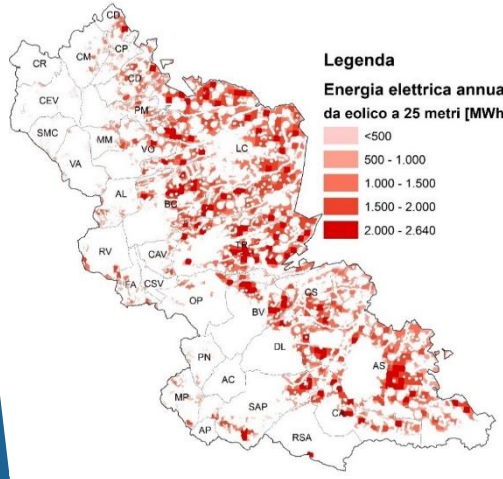
Energy Production from Renewable Energy Sources

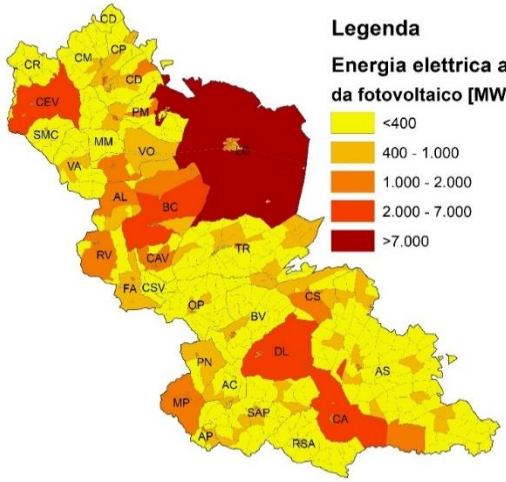
Monti Dauni in Puglia

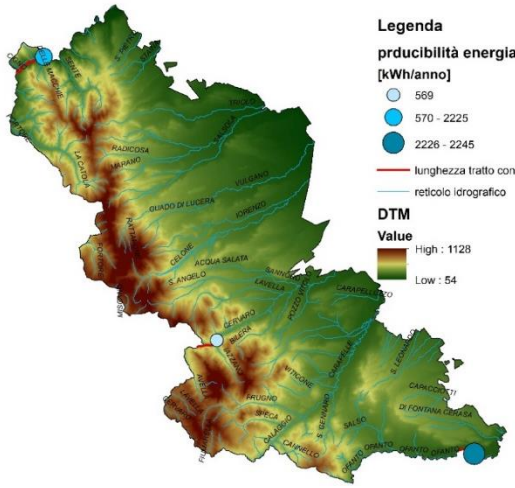










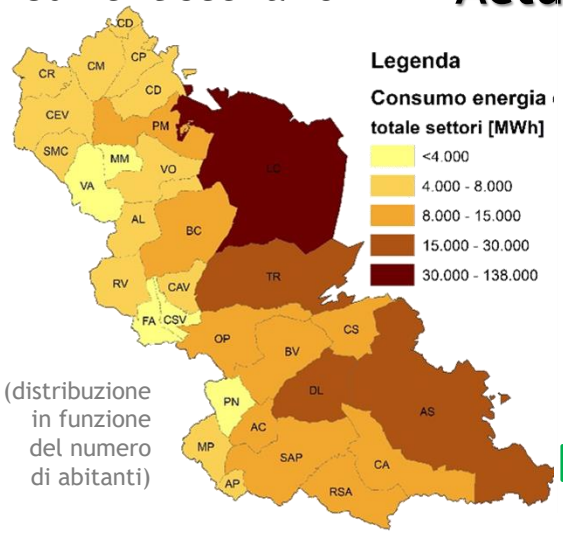


REF: "A Clean Energy Atlas for Energy Communities in Piedmont Region (Italy)", International Journal of Design & Nature and Ecodynamics, Vol. 15, No. 3, 2020, pp. 343-353, DOI 10.18280/ijdne.150308 http://www.iieta.org/journals/ijdne/paper/10.18280/ijdne.150308

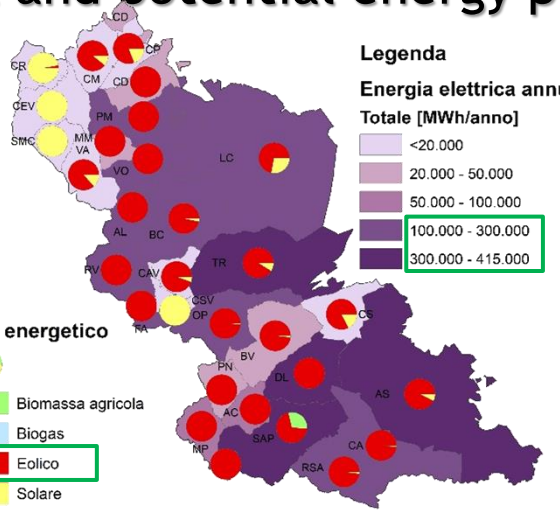
Actual and potential energy production

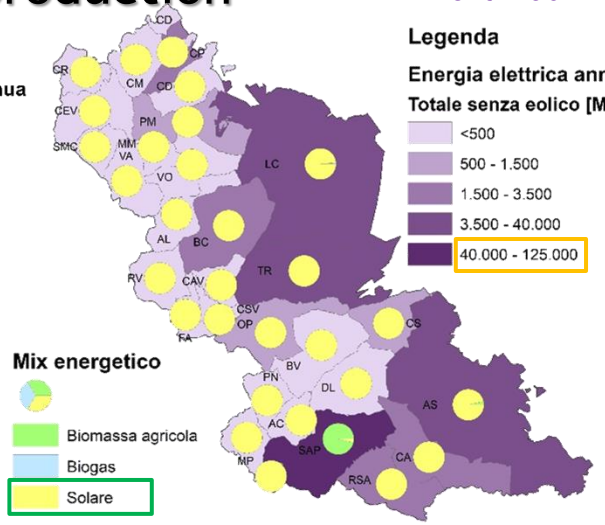
Current scenario

Monti Dauni in Puglia

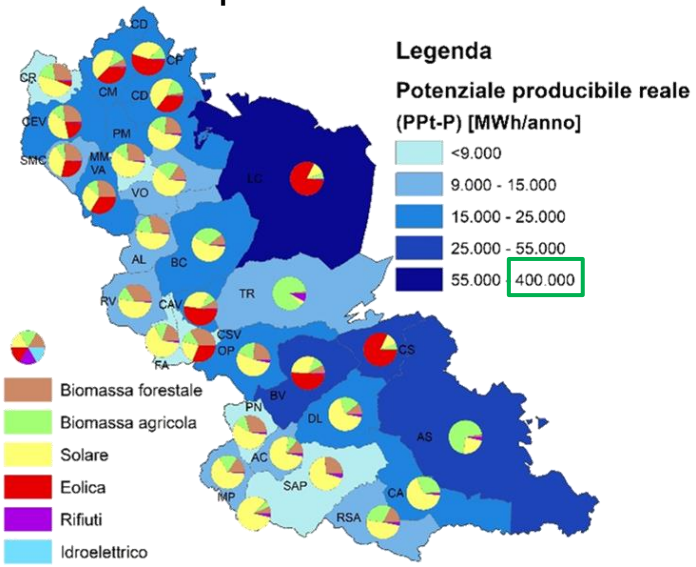


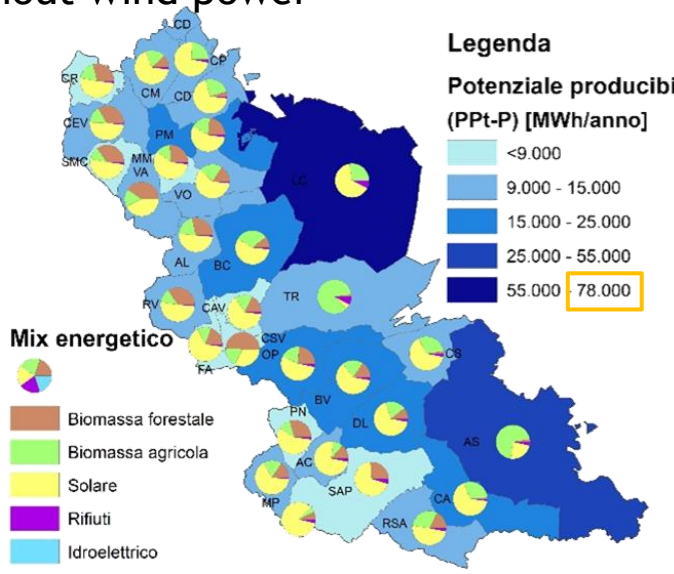
(distribuzione in funzione del numero di abitanti)





Maximum production: scenario with and without wind power





REF:"Pianificare per la resilienza dei territori. L'esperienza delle comunità energetiche", ARCHIVIO DI STUDI URBANI E REGIONALI - ASUR special issue Energia 2021 Fascicolo: suppl. 131, pp. 44-70, DOI: 10.3280/ASUR2021-131-S1003 (https://www.francoangeli.it/riviste/Sommario.aspx?IDRivista=3).

Tools to support spatial energy planning

ENERGY ASSESSMENT

Input data

Energy profile	Source	Data accuracy	Time scale
Consumption – By type of user	-Database -Bill -Measures	max → min	h, d, m, y
Production – By type of RES			
Productivity			

Energy model

h

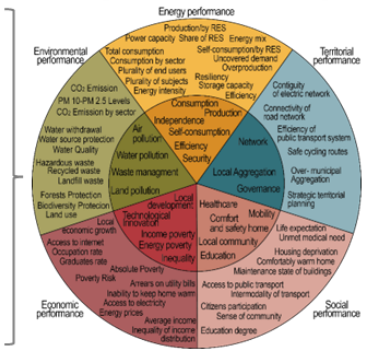
Output data

Time scale	Data aggregation	Spatial scale
y	max	Territorial
m		Municipal
d		Single REC
h	min	Single user

Comparing scenarios

PERFORMANCE INDEXES

SDG (UN)



Performance	Index	Formula	Unit measure	Time scale	Treshold	Reference
1. Energy	SSI	$\frac{\Sigma SC_{i=1}^{n}}{\Sigma C_{i=1}^{n}}$	[-]	Hourly	-	-
2. Territorial						
3.Environmental	SCI	$\frac{\Sigma SC_{i=1}^{n}}{\Sigma P_{i=1}^{n}}$	[-]	Hourly	70%	LR12/2018
4. Economic						
5.Social						

DIGITAL PLATFORM

GIS
Spatialization
& integration