An integrated planning framework for the development of sustainable and resilient cities - The case of the InSMART project

www.insmartenergy.com

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The InSMART project in one slide

- The Integrative Smart City Planning (InSMART) is an EU FP7 funded project bringing together cities, scientific and industrial organizations.
- Establish and implement a comprehensive methodology for developing sustainable planning (focusing on energy).
- Integrative and multidisciplinary planning approach - specialized tools and models.
  - ✓ Comprehensive GIS energy database.
  - ✓ Building simulator.
  - ✓ Transport simulator.
  - ✓ Technology explicit planning model (cost-optimal mix of measures) - TIMES
  - ✓ Multi-criteria decision making method

Outputs

- Integrated analysis of the mid-term measures.
- Applicable mid-term implementation plan (necessary steps, required resources and monitoring procedures) at city level.

Key words: *integrative / participatory / multi-model*

InSMART cities and partners

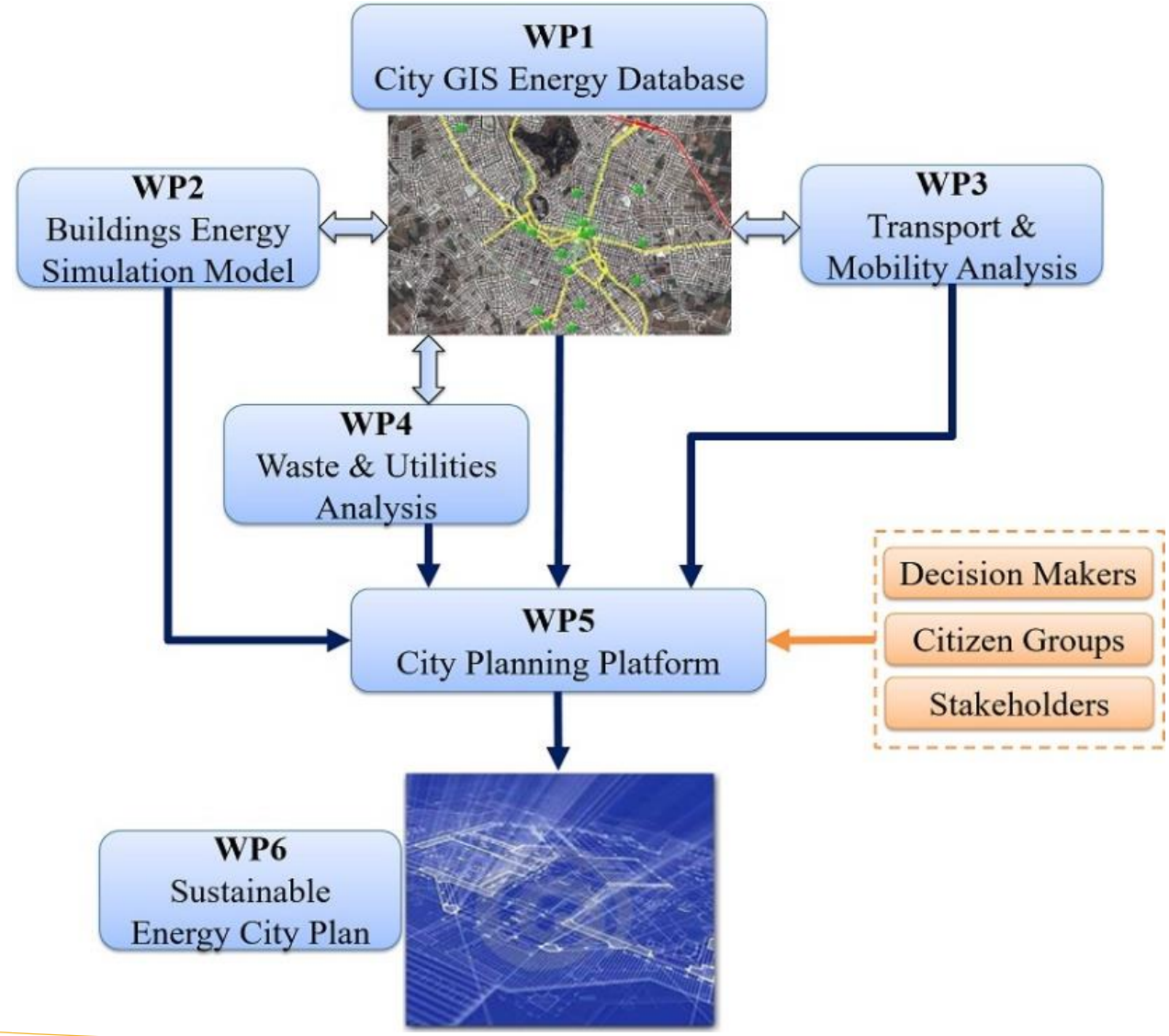
Methodology

The InSMART EU FP7 project developed an innovative city planning method based on a multi-model approach used to explore and rank alternative plans (combinations of actions and measures) towards the sustainable development of the municipality, with a particular focus on the residential and transport sectors.

- A technology-explicit model of the city designed in TIMES to test and exploring the evolution of energy-environmental variables in the urban area.
  - For each City a reference projection of the local system has been developed and then modified through different combinations of actions and measures aiming at representing different possible sustainable planning hypotheses.

- A multi-criteria method used to determine the ranking of the alternative options, evaluated against a set of elements (technological, social, environmental, economic) → dynamic responses of the urban system model (results per each alternative).

Project Workpackages

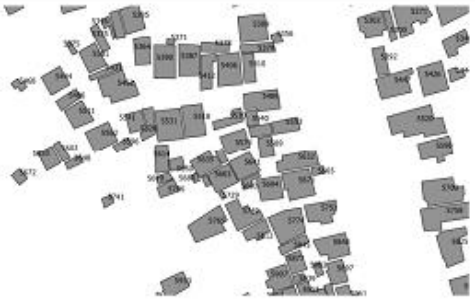


WP1 - The city's GIS platform on energy use

City sectors

Blocks

Road segments



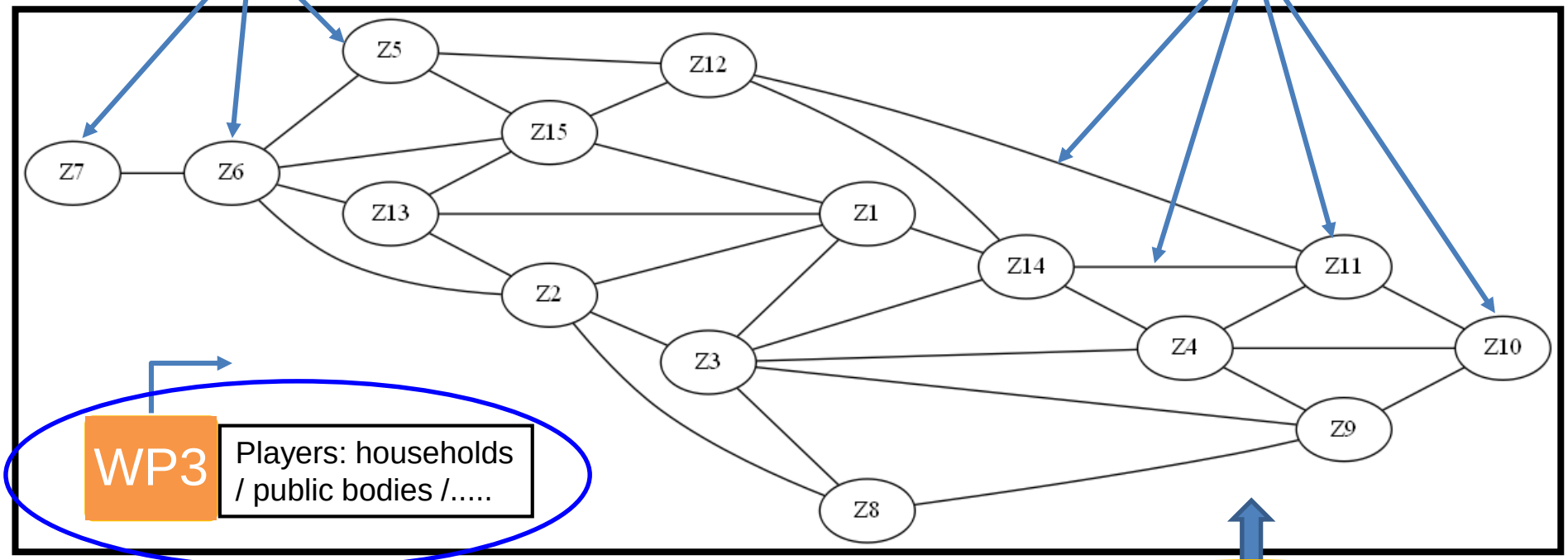
Individual buildings

- WP1 analyse the current status of the cities' energy strategy and data availability, design and conduct city specific surveys and develop a GIS energy database for each city.
- The GIS platform is used to supply all the thematic models that are developed for the participating cities and to visualize and analyse the results.

Methodology: City geographical representation

WP2 Players: households

Players: public bodies WP4



WP3 Players: households / public bodies /.....

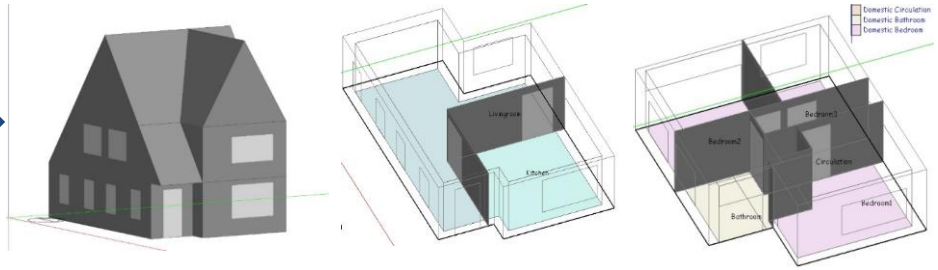
The identified zones are City specific and represent the geographical distribution of the information (according to the planning criteria).

Supply (centralised)

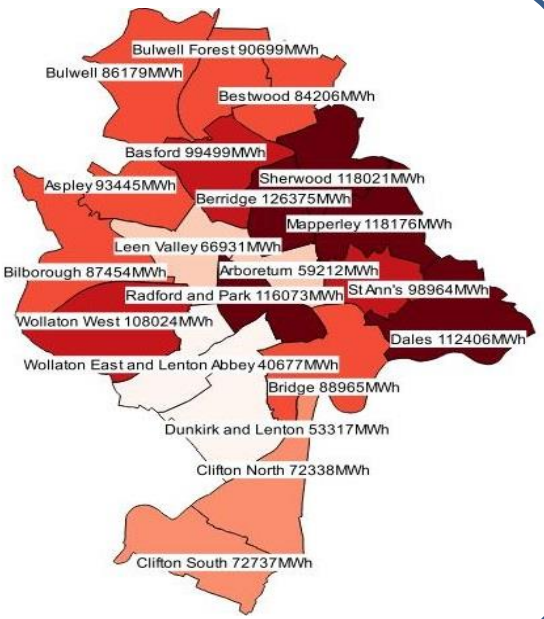
WP2 - Building analysis

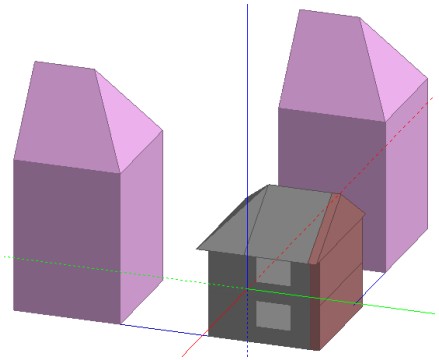
Survey/ Analysis

Simulation



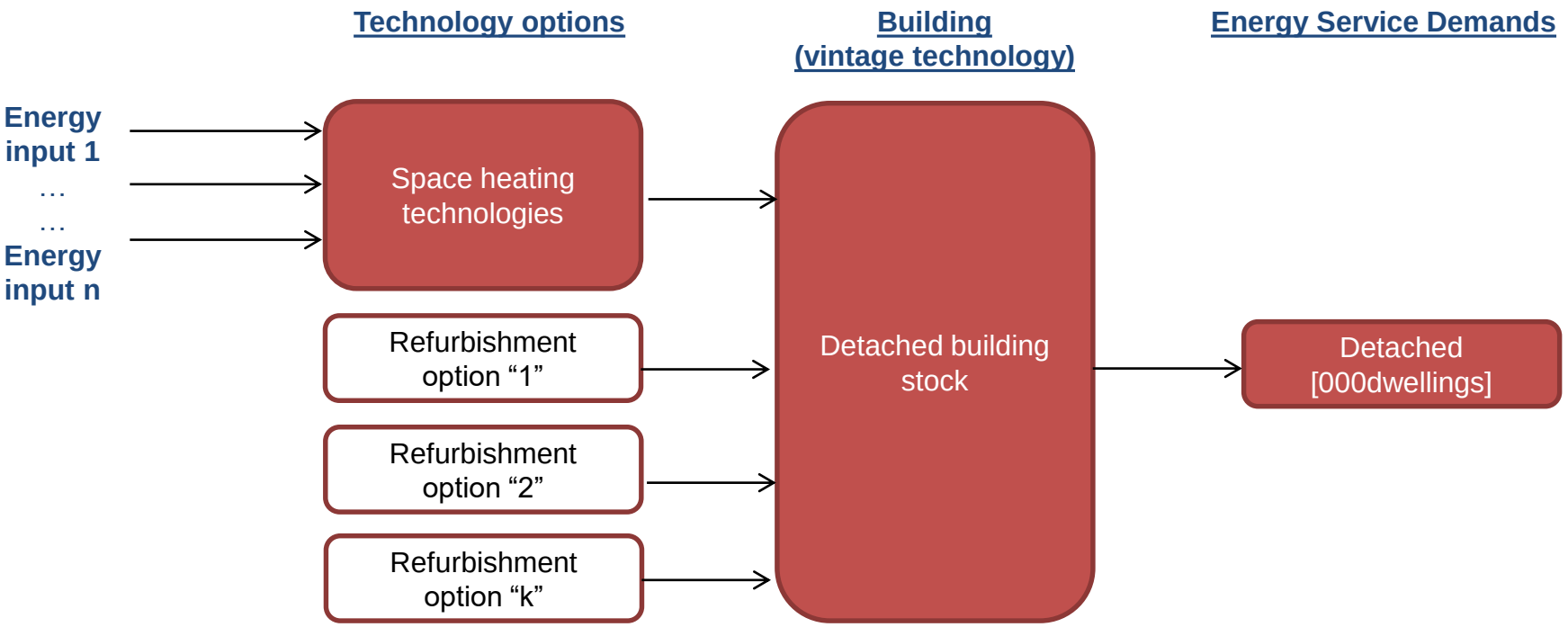
Synthetic stock





- Simulation of city residential building stock and possible energy retrofit measures.
- Providing the necessary techno-economic input for the energy modelling of the building sector in each city.

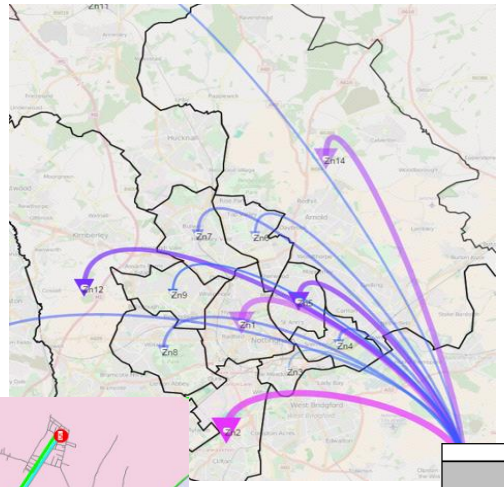
WP3 - Transport and mobility analysis

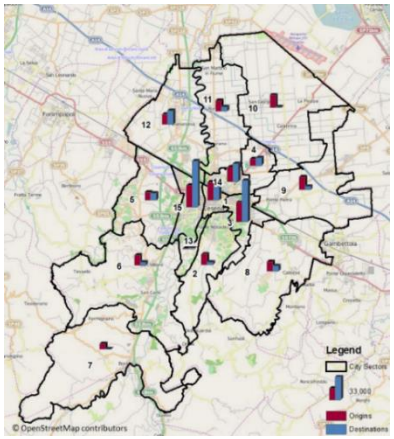


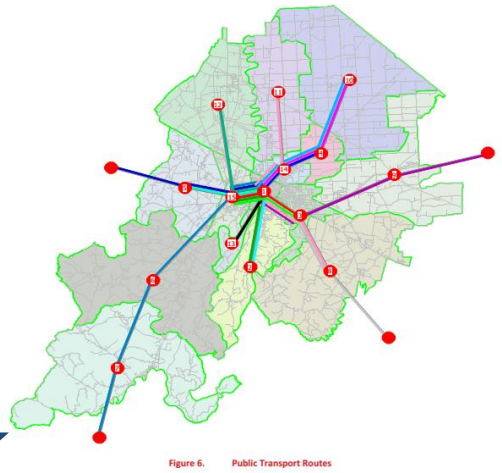
Retrofitting scenarios in order to calculate the potential energy saving were examined for each typology (roof, external walls, windows).

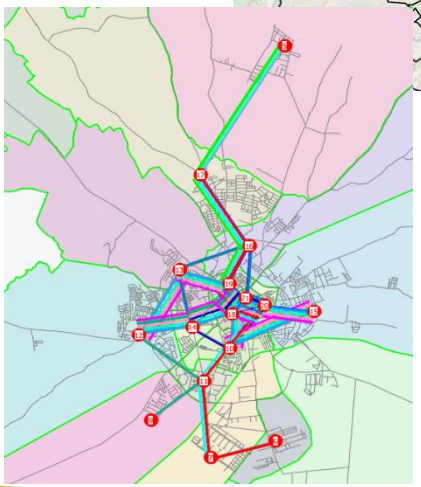
WP3 - Transport and mobility analysis

- Assessment of current traffic dynamics within the cities, and estimate the impacts underpinned by planning measures such new restrictions, new infrastructures, or new development areas.









Movements between model zones (From / To)

		1	3	14	15	2	4	5	11	12	13	6	7	8	9	10	16		
	All Purposes	Centro Urban 2	Fiorenzuola	Cervese Sud 2	Oltre Savio 2	Cesuola	Cervese Sud 1	Oltre Savio1	Ravennate	Dismano	Centro Urban 1	Valle Savio	Borello	Rubicone	Al Mare	Cervese Nord	External	Total	Origin Splits
1	Centro Urban 2	7979	4900	1403	5538	251	334	493	236	687	44	100	0	158	65	12	2604	24804	10%
3	Fiorenzuola	454	12877	2593	2192	167	1300	417	411	1392	22	131	0	1051	242	44	2732	26025	11%
14	Cervese Sud 2	373	4310	4564	2674	133	1309	327	378	1040	17	70	0	261	114	31	1830	17432	7%
15	Oltre Savio 2	872	1917	1420	16403	247	337	1196	303	1326	259	206	1	189	31	15	2899	27621	11%
2	Cesuola	372	2264	1245	2459	656	461	496	350	1196	126	287	1	510	97	30	1237	11787	5%
4	Cervese Sud 1	169	2245	1323	861	58	1370	57	158	437	7	19	0	124	96	31	816	7772	3%
5	Oltre Savio1	351	815	556	4586	115	85	1785	153	993	78	154	1	110	33	7	1152	10975	5%
11	Ravennate	609	2925	1033	3516	293	344	437	706	1112	40	69	1	149	115	76	1340	12767	5%
12	Dismano	442	1320	960	2880	126	308	773	470	3694	55	118	1	139	55	21	1332	12693	5%
13	Centro Urban 1	41	92	99	201	11	32	39	28	95	90	49	0	20	3	2	94	894	0%
6	Valle Savio	597	1103	560	4557	375	139	1051	212	1026	325	1608	26	176	65	13	1388	13222	5%
7	Borello	366	701	318	2104	204	93	494	133	604	161	763	250	121	47	10	747	7115	3%
8	Rubicone	631	4727	727	1287	266	289	249	226	440	24	67	1	2433	241	20	1364	12991	5%
9	Al Mare	537	6274	1325	1209	253	809	362	285	855	26	110	1	814	2472	96	1809	17236	7%
10	Cervese Nord	580	3697	1835	2295	259	1457	369	1107	1783	39	131	1	516	647	419	1775	16909	7%
16	External	1686	5883	2341	6188	400	1016	1002	605	1956	154	455	33	794	507	97	0	23119	9%
	Total	16060	56048	22301	58949	3814	9681	9547	5761	18638	1468	4337	317	7566	4830	923	23119	243360	
	Destination Splits	7%	23%	9%	24%	2%	4%	4%	2%	8%	1%	2%	0%	3%	2%	0%	9%		

WP4 - Analysis of the cities' energy systems and networks

- Analysing the current status of urban spaces, water/sewage system, waste chain and decentralised energy supply.
- Characterization of technologies and consumption patterns in non-residential sectors, and estimation of renewable potentials for the urban area. For example solar potential evaluation.

Zona	Superficie tetti disponibile (m2)	Potenziale fotovoltaico (kW)							Solare termico
		Tetti				Facciate			
		Monocrystalline silicon	Multicrystalline silicon	HIT (Heterojunction with Intrinsic Thin Layer)	Amorphous silicon (non-transparency type)	Superficie disponibile - facciate (m2)	HIT (Heterojunction with Intrinsic Thin Layer)	Amorphous silicon (non-transparency type)	Produzione di energia annuale (MWh)
AL MARE	35,986	6,362	4,991	5,495	2,264	6,543	999	412	1,892
BORELLO	11,226	1,985	1,557	1,714	706	1,973	301	124	546
CERV NORD	40,140	7,097	5,567	6,129	2,525	5,287	807	333	1,857
CERVSUD 1	15,146	2,678	2,101	2,313	953	2,901	443	182	1,095
CERVSUD 2	24,103	4,261	3,343	3,681	1,516	10,239	1,564	644	2,201
CESUOLA	24,582	4,346	3,409	3,754	1,546	4,353	665	274	1,317
DISMANO	17,563	3,105	2,436	2,682	1,105	4,603	703	290	1,131
FIORENZUOLA	32,859	5,810	4,558	5,018	2,067	14,685	2,242	924	2,926
OLTRE S1	22,153	3,917	3,073	3,383	1,393	4,396	671	277	1,391
OLTRE S2	39,895	7,053	5,533	6,092	2,509	17,623	2,691	1,108	3,648
RAVENNATE	21,302	3,766	2,955	3,253	1,340	3,512	536	221	1,080
RUBICONE	32,218	5,696	4,469	4,920	2,027	5,335	815	336	1,526
URBANO 1	2,131	377	296	325	134	45	7	3	72
URBANO 2	31,053	5,490	4,307	4,742	1,953	16,819	2,568	1,058	2,336
VALLE SAVIO	24,825	4,389	3,443	3,791	1,561	4,131	631	260	1,227
Total	**375,181**	**66,332**	**52,038**	**57,290**	**23,599**	**102,445**	**15,643**	**6,444**	**24,244**

WP5 - Integrated planning tool for the development of Strategic Sustainable Energy Plans

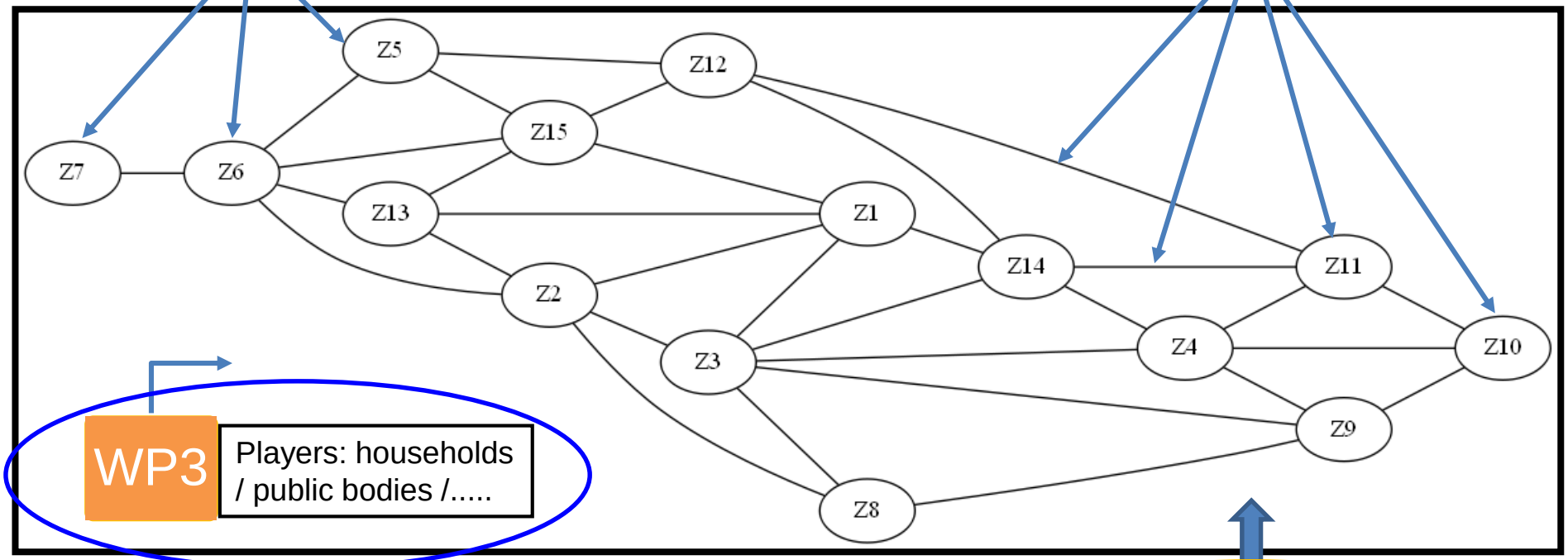
- Develop an Integrated City Energy System model to explore the dynamics of the urban systems in the medium term (to 2030).
- The integrated city models are fed by the model simulations developed in residential (WP2), transport (WP3), aiming:
  - at simulating the energy requirements of the existing residential building stock and the corresponding potential of savings, and
  - at determining the expected future transport modes (number of trips, directions) in the time horizon.

  Also data from WP4, for example on the renewable potential, has been used to develop the City models.
- In the City models, the urban area is represented in “zones” and each zone as a subsystem characterized by a certain number and type of energy service demands (space heating, water heating, cooling, lighting, etc.), building types (detached, semidetached, blocks, hospitals, schools, etc.), potentials for renewables (e.g. PV solar), and constraints.

City zones

WP2 Players: households

Players: public bodies WP4

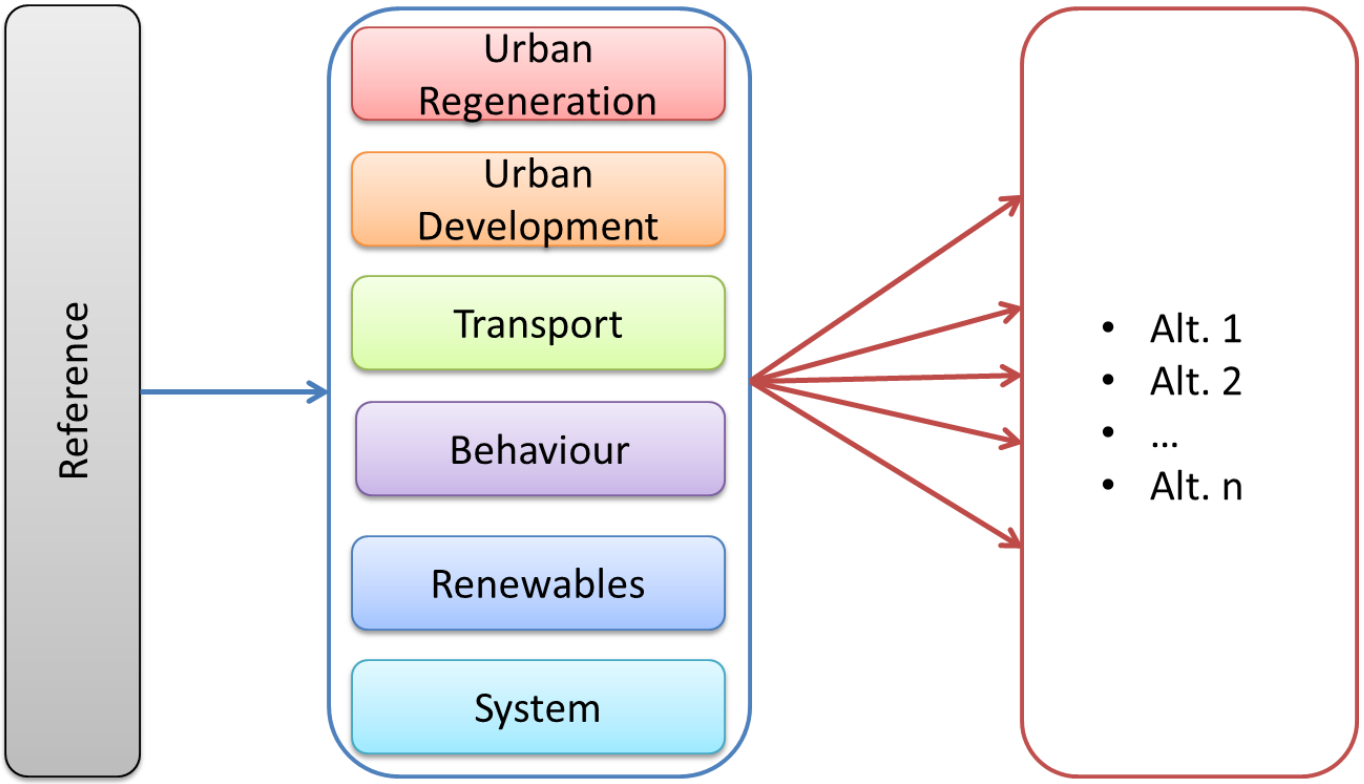


WP3 Players: households / public bodies /.....

The identified zones are City specific and represent the geographical distribution of the information (according to the planning criteria).

Supply (centralised)

- **The City Energy System Model (City-ESM) based on TIMES,** allows the exploration of a set of alternative planning hypotheses, with an explicit representation (till 2030) of energy flows, technology and measures, costs, and emissions.



WP5 - Integrated planning tool for the development of Strategic Sustainable Energy Plans

- The output from the City-ESM models (economical optimum mix of measures and technologies for enhancing sustainable planning) for both the current and future city needs is coupled and refined making use of a **Deliberative MultiCriteria Evaluation (DMCE) methodology**.
- The DMCE aims to take into account the key merits of the planning problem, and to engage participatory methods for the design of such strategies.
- The PROMETHEE Method has been used for the multi-criteria evaluation approach. It is based on the identification of alternatives (ai), attributes (gi) and weights (wi) → Estimated and agreed trough stakeholder meetings.

	g_1	g_2	.....
a_1	$g_1(a_1)$	$g_2(a_1)$	.....
a_2	$g_1(a2)$	$g_2(a2)$	.....
.....	.....	.....	.....
W	w_1	w_2	.....

WP6 - Development of mid-term Implementation Action Plans

- Analyse further the economics of the mid-term sustainability measures and develop realistic and feasible implementation action plans indicating specific capacity needs at city level.

Cesena municipality case study

Cesena City ESM – Drivers and assumptions

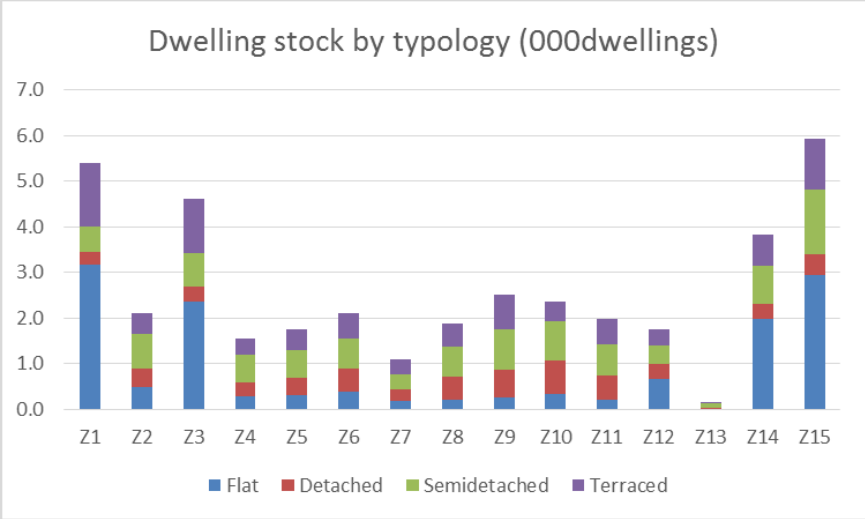
Space granularity: Zone/District level (15)
Time granularity: base year 2013; 24 intervals within the year, EOH: 2030-(35)

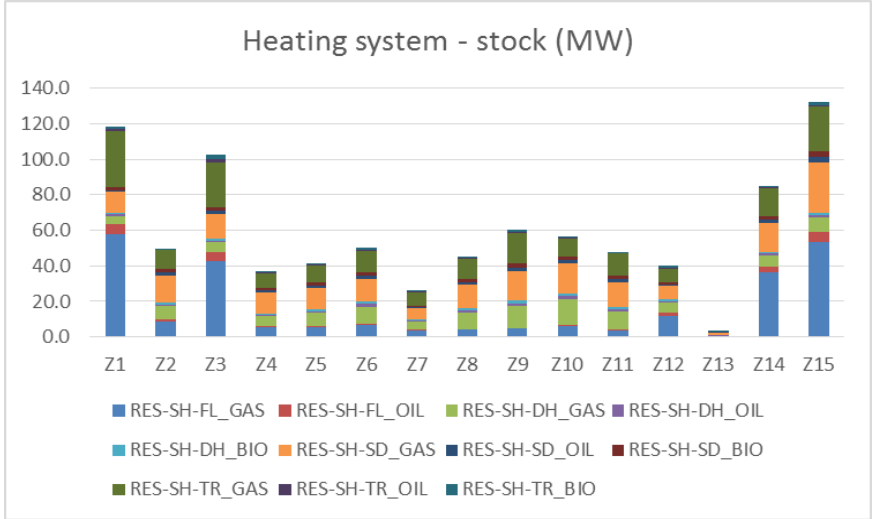
Time of day	N	M	A	E	Year	
Season	N. hours	N. hours	N. hours	N. hours	N. days	Start - End
S1		7	6	5	6	31 1 Jan - 31 Jan
S2		7	6	5	6	74 1 Feb - 15 Apr
S3		7	6	5	6	76 16 Apr–30Jun
S4		7	6	5	6	62 1 Jul - 31 Aug
S5		7	6	5	6	44 1 Sept - 14 Oct
S6		7	6	5	6	78 15 Oct - 31 Dec

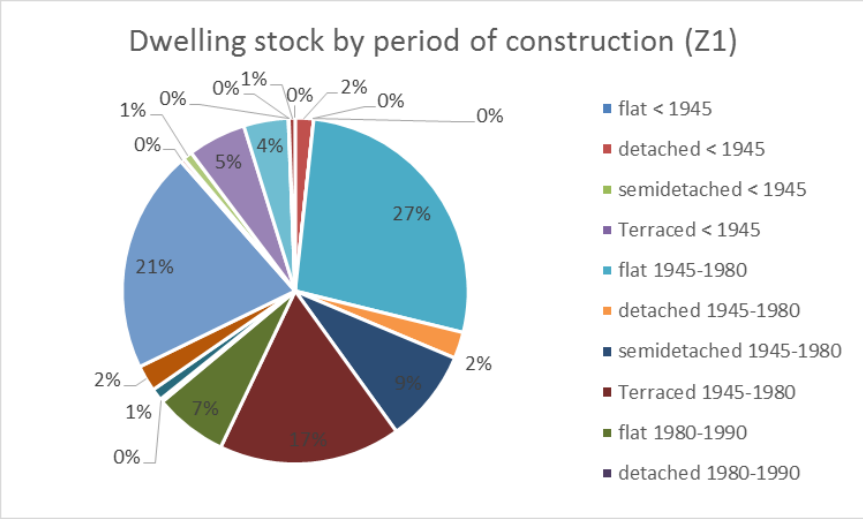
Key drivers and assumptions

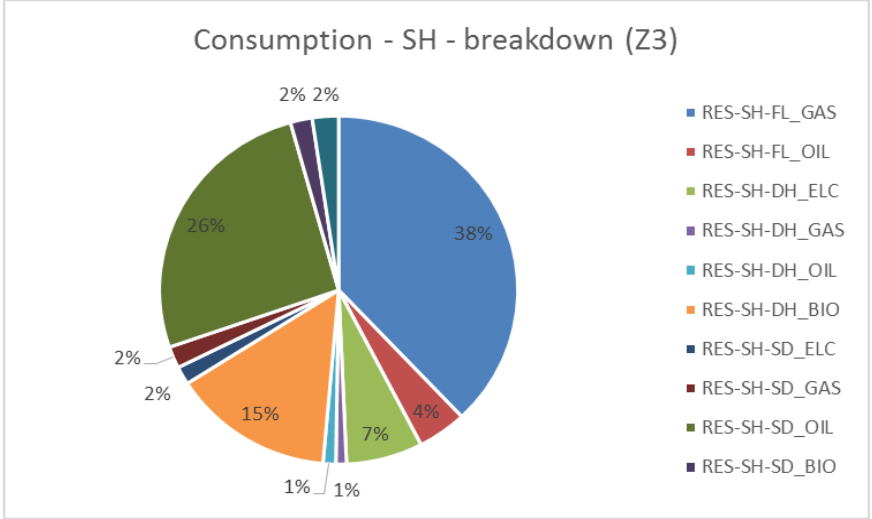
- 17 building typologies in the base year
- *Demands*:
  - constant number of total dwellings over the time horizon (driving energy service demands);
  - transport demands (by transport mode) inherited.
- *Centralised supply*: (exogenous) controlled by quantities/prices
- *Decentralised supply*: potentials (solar)
- Retrofit measures: driven by scenario hypotheses
- Non-Residential: simplified representation (partially endogenous)
- Transport: 60.9 (000cars) in the base year

Cesena City ESM – Example of inputs









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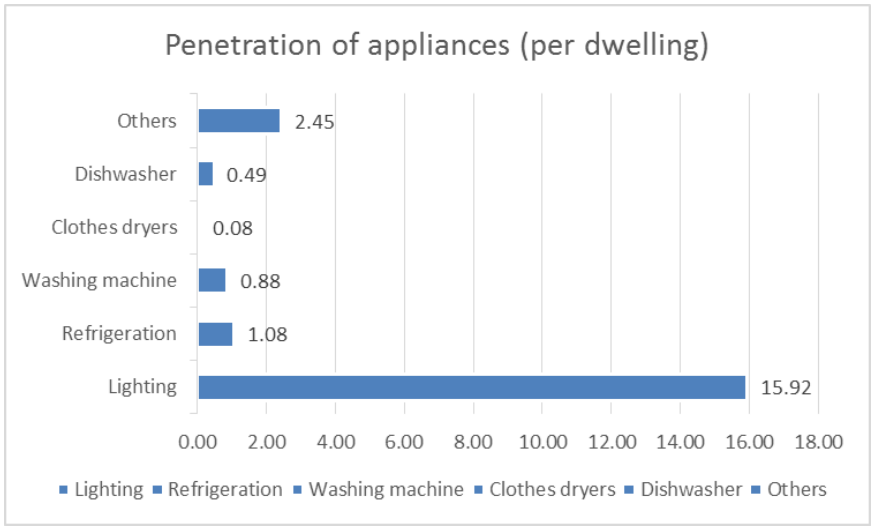

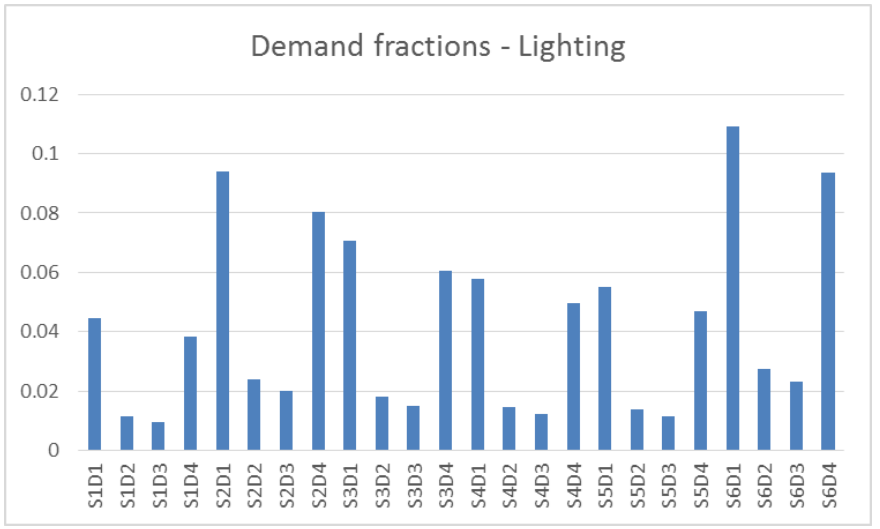

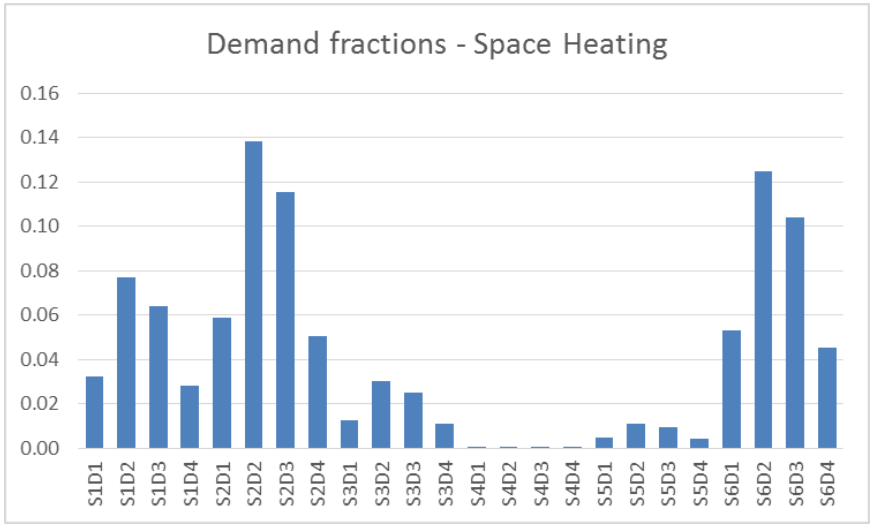

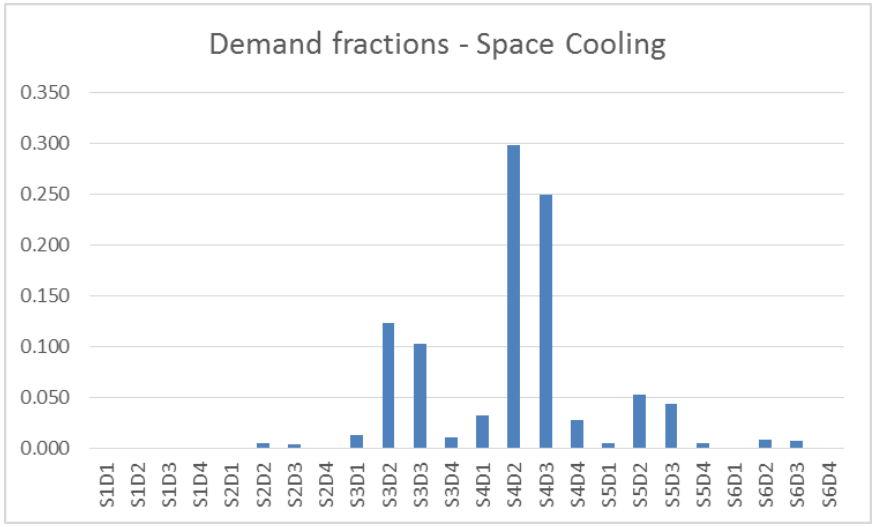

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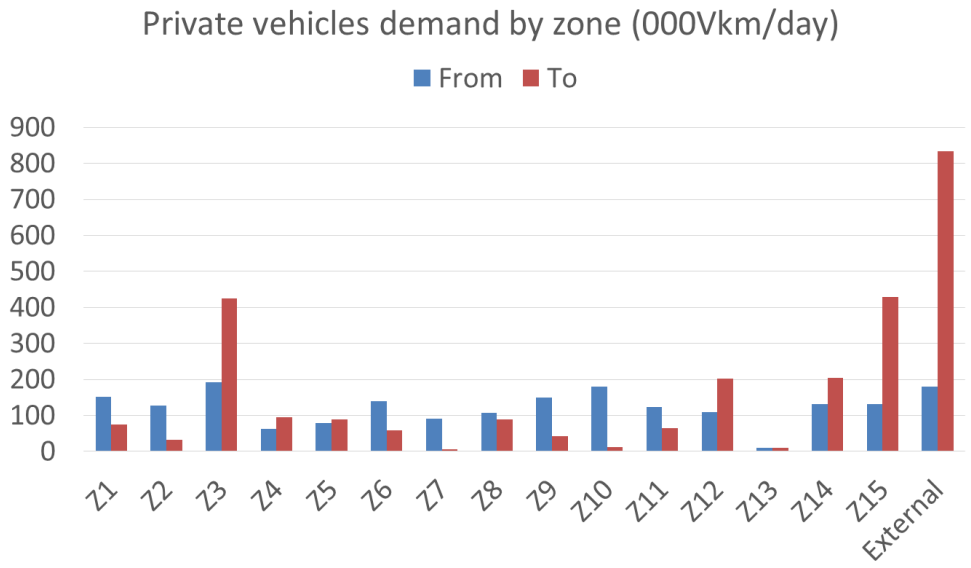

City is divided in 15 “internal” zones +1 external zone (outside municipality boundary).

Z3 and Z15 are frequent destinations (shops and entertainment areas).

	1	3	14	15	2	4	5	11	12	13	6	7	8	9	10	16		
All Purposes	Centro Urban 2	Fiorenzuola	Cervese Sud 2	Oltre Savio 2	Cesuola	Cervese Sud 1	Oltre Savio1	Ravennate	Dismano	Centro Urban 1	Valle Savio	Borello	Rubicone	Al Mare	Cervese Nord	External	Total	Origin Splits
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Total	16060	56048	22301	58949	3814	9681	9547	5761	18638	1468	4337	317	7566	4830	923	23119	243360	
Destination Splits	7%	23%	9%	24%	2%	4%	4%	2%	8%	1%	2%	0%	3%	2%	0%	9%		

Movements between model zones (From / To).

This information in used in the City-ESM to defined the transport service demand linked to the dwellings.

Stakeholders engagement

Modes of Governance in the energy sector

- Regulator and planner
- Consumer (behaviour of the municipal administration)
- Supplier of energy (and services)
- Support and information

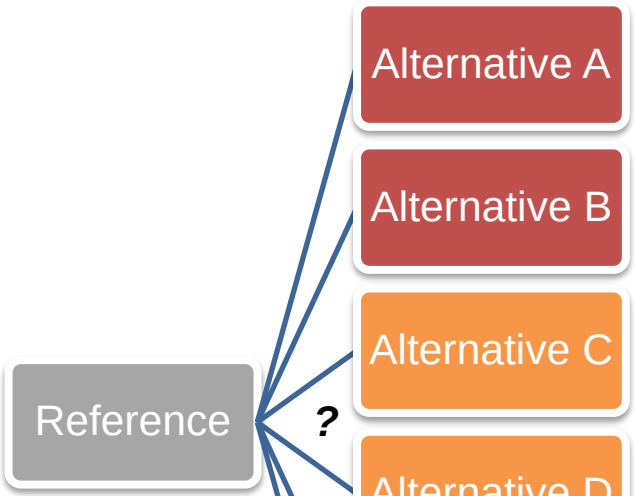
Example of actions

- New district in the city (all buildings in class B + district heating)
- Standards on refurbishment measures in the building sector
- Policies on renewable uses
- Development of new bike lanes
- Creation of new bus stops / and new bus between zones
- Reorganization of school schedule for saving on heating systems
- 10% of work from home for Municipality workers
- Communication campaigns on efficiency and renewable development
- ……..

→ different combinations of actions generate "**Alternative planning hypotheses**".

The City-ESMs provide least-cost pathway of possible future developments (scenario analysis) of the local system subject to different targets, policies, actions.

Stakeholders engagement (1st step)



More oriented on **urban regeneration**
Existing building stock: 10% from class E to class A and 30% from class E to class C; Simple measures on transport; Strong info campaigns

More oriented on **urban regeneration**
Buildings: 40% from E to B; Important measures on transport; Moderate info campaigns

More oriented on **"new" constructions**
Standard building efficiency for new construction; Simple measures on transport; Moderate info campaigns

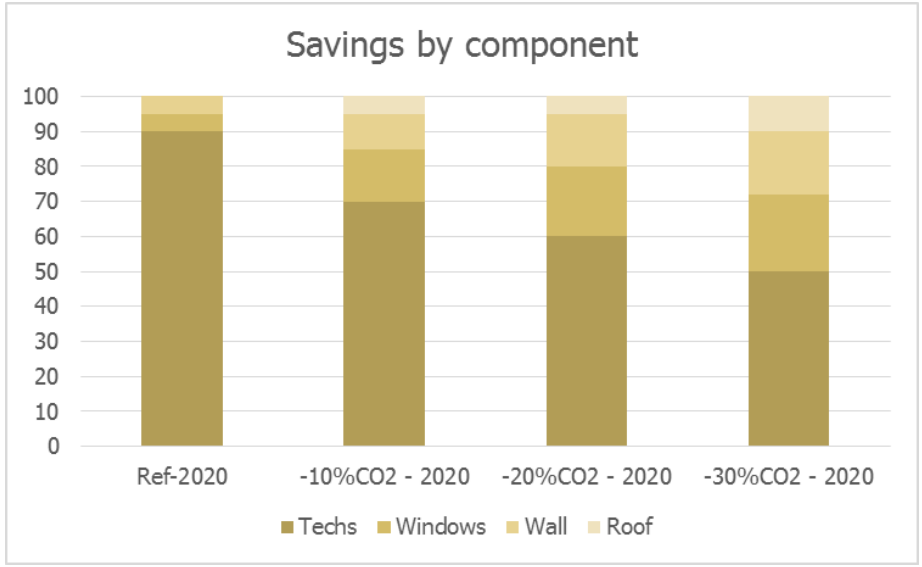
More oriented on **"new" constructions**
High building efficiency for new construction; Different organization of transport; Strong info campaigns

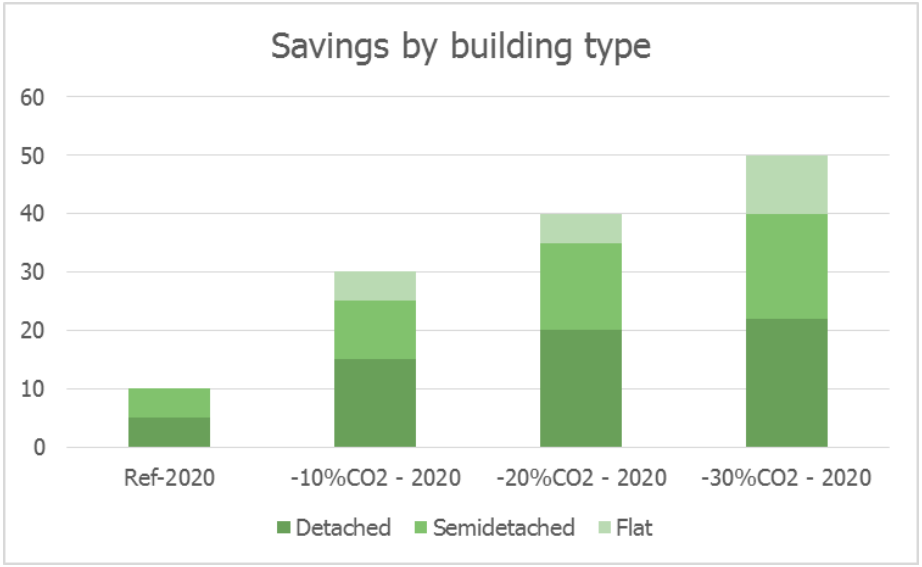
More oriented on **transport**
New transport infrastructures; Moderate regeneration of existing building stock; Moderate info campaigns

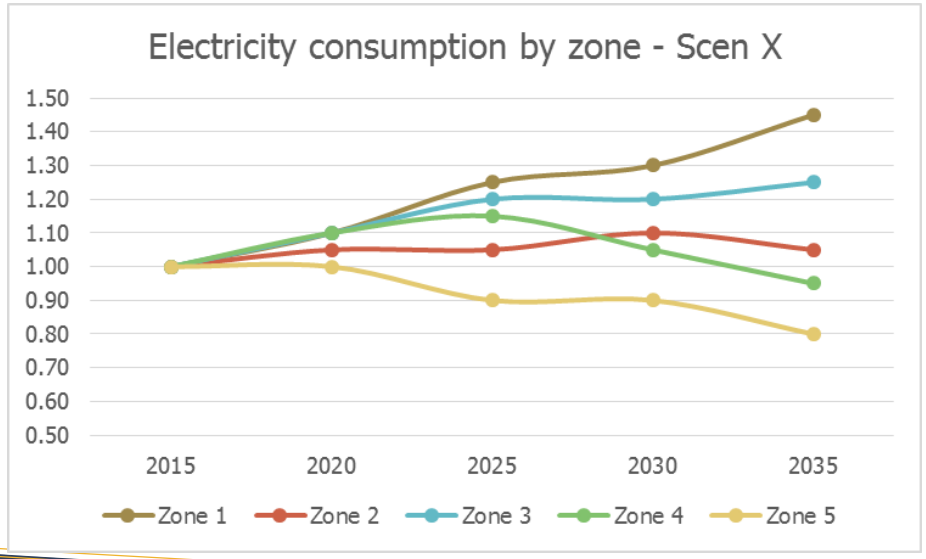
More oriented on **renewables**
New renewables; Moderate regeneration of existing building stock; Strong info campaigns

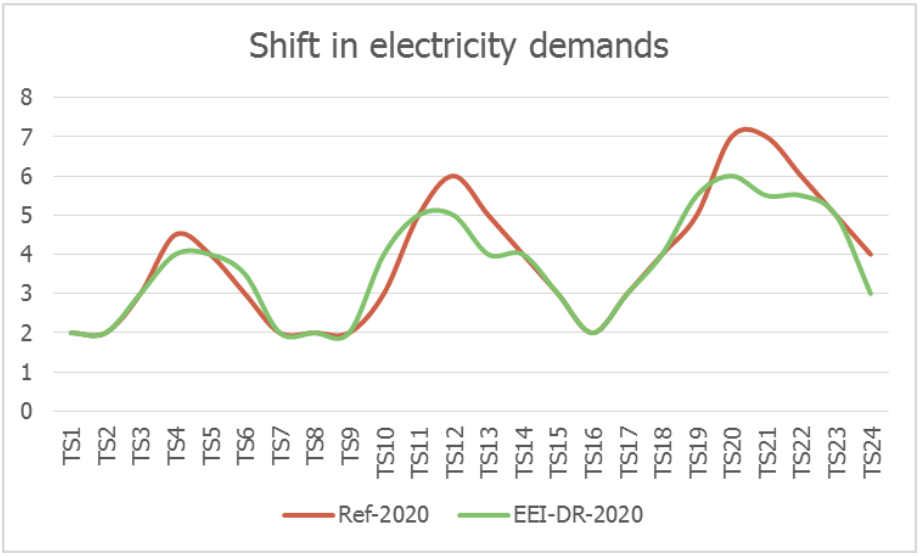
The key outcome of such an explorative analysis of **alternative planning hypotheses** (making use of a city energy system model) is the identification of an optimum mix of applicable measures and technologies that will pave the way towards the achievement of the sustainable targets of the municipality of Cesena.

City-ESM example of resutls

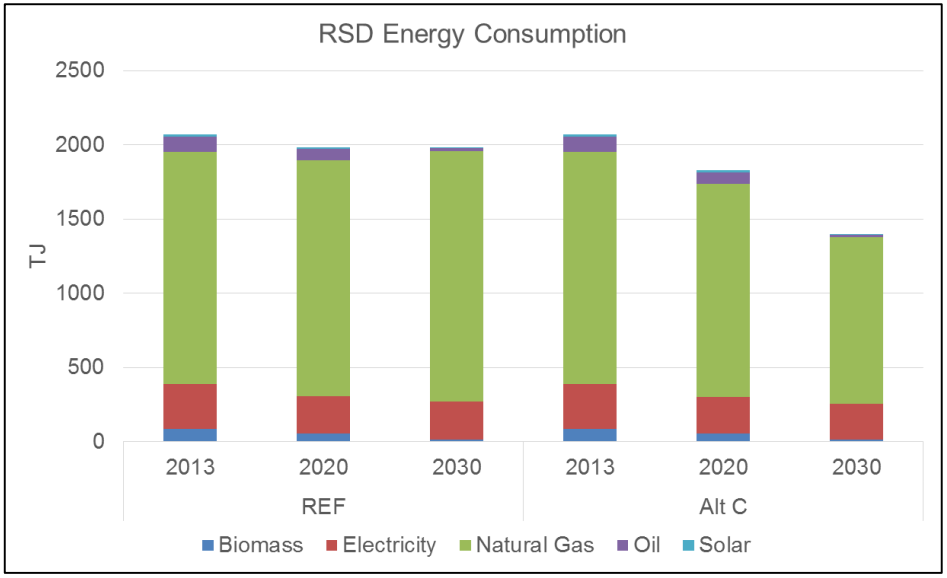


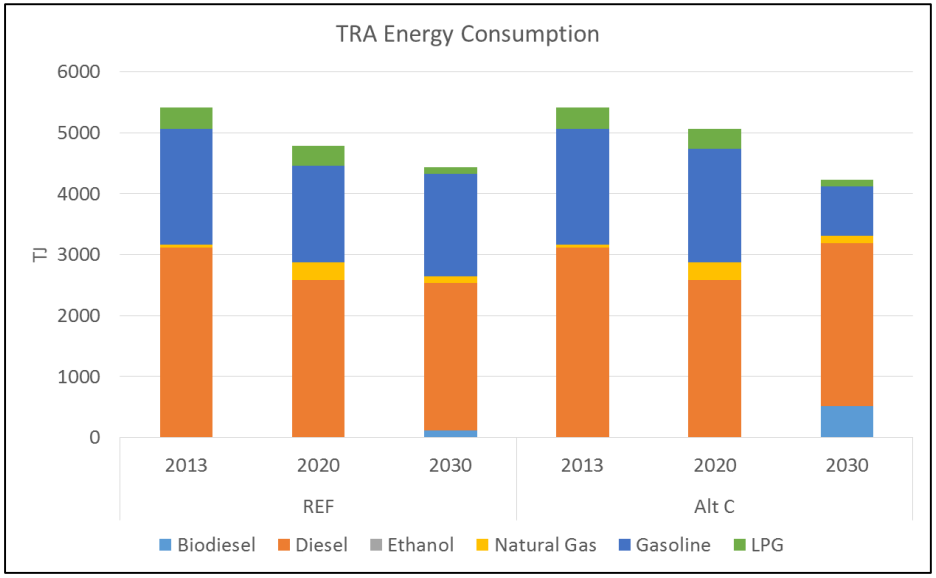


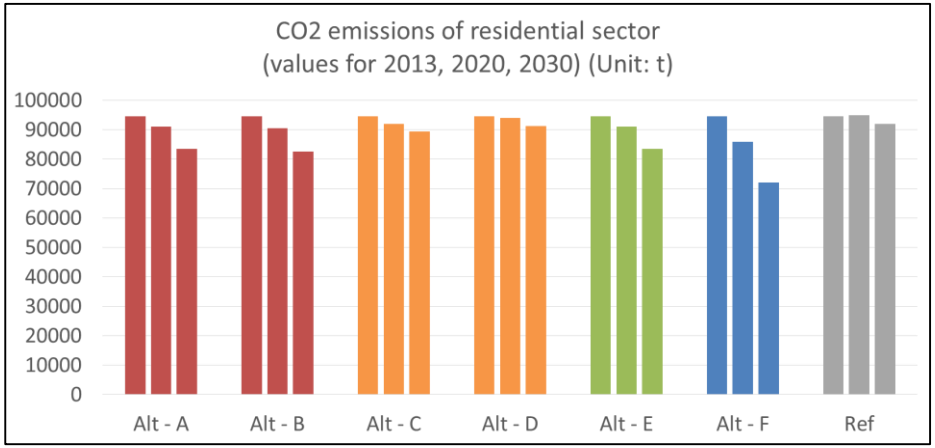




City-ESM example of resutls







Multi-Criteria analysis - Stakeholders engagement (2nd step)

The information requested by PROMETHEE method consists in *weights describing their relative importance* and in a *preference function* associated to each criterion. Six Alternatives and nine criteria (quantitative and qualitative) have been identified.

Quantitative

C1: Energy consumption in the building sector in 2030. (TJ). MIN. Energy.

C2: Total CO_2 emissions in 2030. (t). MIN. Environment.

C3: Total particulate emissions in 2030 (kg). MIN. Environment.

C4: Investments (and maintenance) costs (until 2030). (kEuro). MIN. Economy.

C5: Onsite renewable production of energy in 2030. (TJ). MAX. Energy.

C6: Indicator of private vehicles (cars, moto) dependency in 2030. (Mpass-km). MIN. Social.

Qualitative

C7: Aesthetics/architectonic integration of technologies and infrastructures. (5-points scale). MAX. Environment.

C8: Easiness of implementation of the strategy. (5-points scale). MAX. Social.

C9: Local development. (5-points scale). MAX. Social.

Multi-criteria analysis - Evaluation Table

	C1	C2	C3	C4	C5	C6
Scenario	Unit: TJ	Unit: t	Unit: kg	Unit: kEuro	Unit: TJ	Unit: Mpass-km
Ref	1,965	273,868	11,296	2,353,204	1,358	1.168
ScenA	1,809	255,730	10,924	2,471,972	1,358	1.123
ScenB	1,828	272,480	12,324	2,787,580	1,358	1.165
ScenC	1,877	254,160	9,542	2,228,977	1,361	1.151
ScenD	1,874	305,136	13,055	2,846,468	1,358	1.198
ScenE	1,886	227,719	6,901	2,118,472	1,358	1.076
ScenF	1,838	246,819	9,624	2,381,794	1,673	1.168

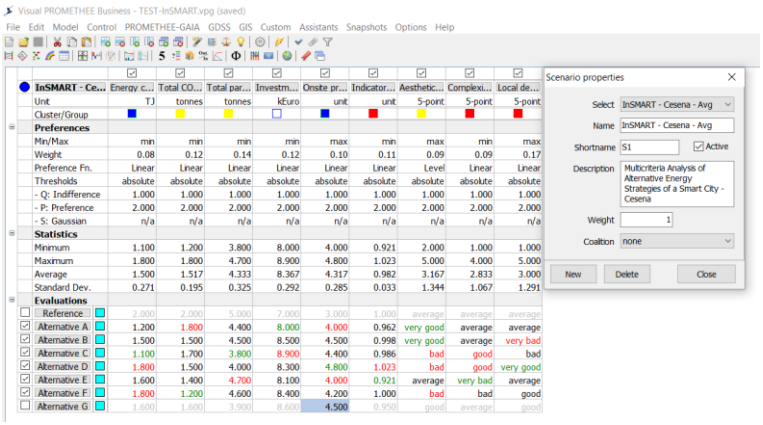
Quantitative → output of the City-ESM

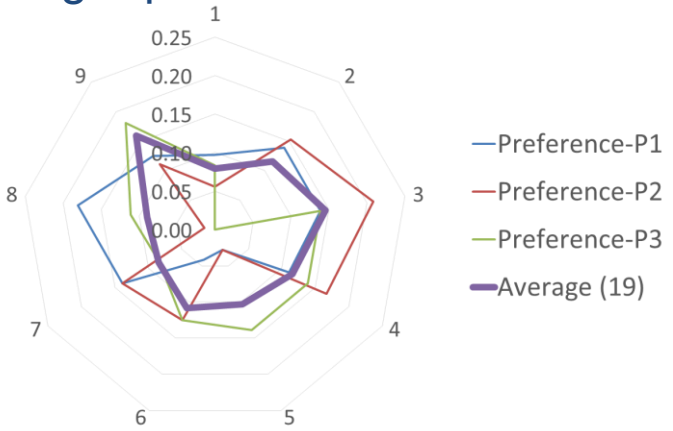
	C7	C8	C9
Scenario	Qualitative	Qualitative	Qualitative
Ref	Average	Very good	Very bad
ScenA	Good	Average	Good
ScenB	Good	Average	Good
ScenC	Bad	Good	Average
ScenD	Bad	Average	Very good
ScenE	Very bad	Very bad	Bad
ScenF	Average	Average	Good

Qualitative
Determined in collaboration with an independent group of technicians of the municipality and experts

Multi-Criteria analysis – Weights and reuslts

- The 3rd stakeholder meetings quantified the weights for the MCDE approach.
- Making use of the average weights, outranking flows (“positive”, “negative”, and “net”) are calculated to determine the partial ranking and the complete ranking of the alternatives taking into consideration the “average” preference.





- The higher Phi+, the better is the alternative. The lower Phi-, the better is the alternative

Ranking	Alternative planning hypotheses	Phi	Phi+	Phi-
1	**Alternative F**	**0.2871**	0.4777	0.1906
2	**Alternative A**	**0.1986**	0.381	0.1824
3	Alternative C	0.0455	0.3863	0.3408
4	Alternative B	-0.0338	0.2729	0.3066
5	Alternative E	-0.1552	0.3121	0.4674
6	Alternative D	-0.3421	0.1986	0.5407

Ranking	Alternative planning hypotheses	Results / Decisions
1	**Alternative F**	**Shortlisted**
2	**Alternative A**	**Shortlisted**
3	Alternative C	Below the threshold
4	Alternative B	Likely not of interest
5	Alternative E	Likely not of interest
6	Alternative D	Discarded

Conclusions

- The key innovation of this project is in its multi-model participatory approach which combines ad hoc city specific tools in an integrated manner.
- The specific strategies identified by the “planning tool (City-ESM + MCDE)” will form the technical basis of the city’s Sustainable Energy Action Plan. For the example developed for Cesena is (F, A).
- Urban planning and energy planning are carried out together in an integrative manner, making use of ad-hoc models.
- Participation of the Municipalities and of a broad stakeholder group is the “key”.

THANK YOU!

Gargiulo M., De Miglio R., Chiodi A.

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Comune di Cesena