

Long-term assessment for sustainable evolution of cities: combining land-use and building allocation with an energy system model

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IEW Paris - June 2019



Context

Population (Millions)	GHG Emissions (M tCO ₂ e)	GDP (billion \$ PPP)
1. China: 1,192	1. USA: 7,107	1. USA: 14,204
2. India: 916	2. China: 4,058	2. 50 Largest Cities: 9,564
3. 50 Largest Cities: 500	3. 50 Largest Cities: 2,606	3. C40 Cities: 8,781
4. C40 Cities: 393	4. C40 Cities: 2,364	4. China: 7,903
5. USA: 301	5. Russian Federation: 2,193	5. Japan: 4,354
6. Indonesia: 190	6. Japan: 1,374	6. Top 10 GHG Cities: 4,313
7. Brazil: 159	7. Top 10 GHG Cities: 1,367	7. India: 3,388
8. Russian Federation: 142	8. India: 1,214	8. Germany: 2,925
9. Top 10 GHG Cities: 136	9. Germany: 956	9. Russian Federation: 2,288
10. Japan: 128	10. Canada: 747	10. United Kingdom: 2,176

Source: See Annex D. Data for the urban agglomeration associated with each C40 city is used in calculations to maintain consistency with the 50 largest cities, 2005.

Figure: The 50 largest cities, C40 Cities and 10 GHG emitting cities position amongst population, GHG emissions and GDP top countries.

source: Worldbank, 2012

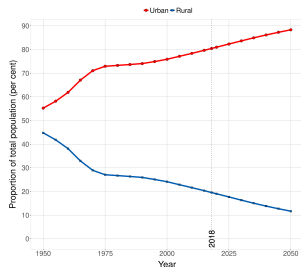
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Figure: Percentage of population in urban and rural areas in France.

source: United Nations, Department of Economic and Social Affairs, Population Division (2018).

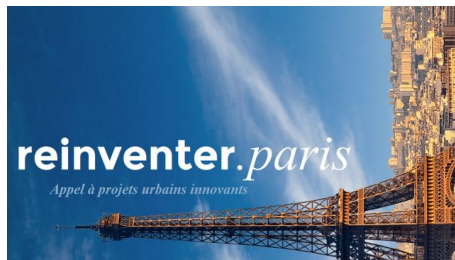
Urban planning revolution in France



Urban planning revolution in France



Urban planning revolution in France



What can prospective modeling bring to the issue?

Need for:

- **Long-term** study;
- **Scenario** comparison;
- Integrated assessment with **energy and environmental issues**.

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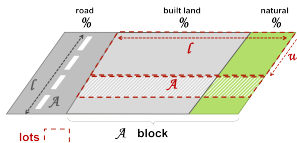
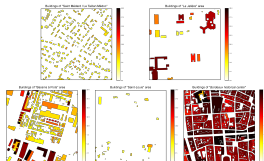
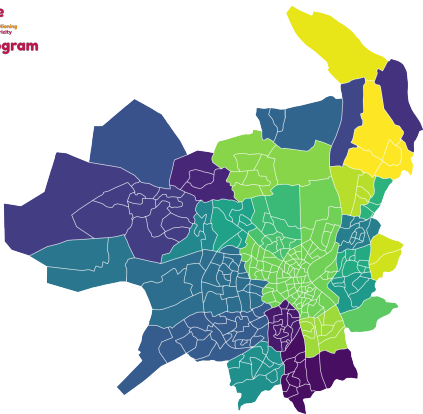
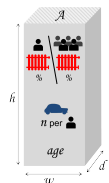
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Optimization bottom-up models (*TIMES* from IEA-ETSAP):

- **Scenario-based** approach;
- **Territory** centered (no general solution);
- **Optimization** flexible tool;
- **Integrating** diverse sources of information.

Data gathering

bathroom
families
age
inhabitants
density
number
household
length
heating
windows
air
conditioning
electricity
program



equipment
footprint
angle
ground
area
urban
lot
size
average
block
length
entropy
width
vegetated
spaces
plots
green
occupancy
road
coefficient

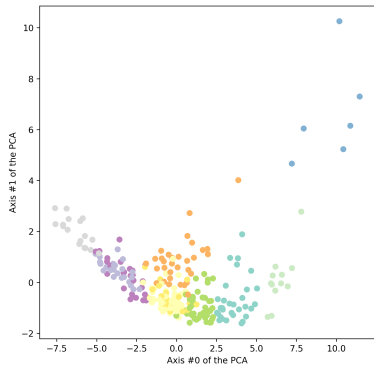
Figure: Bordeaux Metropolitan territory, colored by city (27 gathered) and separated by IRIS zones.

From Bonhomme, 2013, Adam et al., 2005, Cerezo et al., 2017, Gonçalves et al., 2017 and Delmastro et al., 2016 among others.

Data processing: PCA/ k-means

Parameter	Contribution to first axis
Floor area ratio	-0.258866226
Average size of lots (log m ²)	0.256179325
Average coverage ratio of lots	-0.247272853
Average blocks area (log m ²)	0.243078477
Average coverage ratio of non empty lots	-0.241760861
Average distance to public transportation (log m)	0.239797541
Lots' density	-0.239673269
Ratio of road surface	-0.237407088
Ratio of road length	-0.234629399
Building coverage ratio	-0.232312303
Ratio of non-empty lots	-0.22799179
Teaching equipment (per m ²)	-0.22406754
Health equipment (per m ²)	-0.221496668
Lots' width average	0.218652122
Lots' height average	0.213608755
Entropy coefficient from Corine Land Cover data	0.212987077
Ratio of vegetalized area	0.204970888
Average size of lots (m ²)	0.162629794

Table: List of parameters ordered by contribution to PCA's most important axis.



Outputs

Name	Description	Nb IRIS	Teaching equipment (per m ²)	Area green spaces	of	Block area (log m ²)	Ratio of vegetalized area	...
Dense close city 1	Bordeaux's highly dense center (small lots, few green spaces, few variety of land cover, high CES, much road surface)	34	0.02	1708.18		8.83	0.08	
Suburbs / smaller towns 1	Similar lots of suburbs/smaller towns (average CES, small lots, few road surface)	63	1.4E-4	3668.88		9.45	0.21	
Rural area 1	Rural areas (few schools, larger portion of green areas, diverse land-use, very little built or road surface, very large lots)	16	1.63E-06	20931.12		11.15	0.51	
Historical centre	Highly dense historical center (small lots, few green spaces, high CES, much road surface, many schools/health infrastructure)	13	0.0038	671.66		8.28	0.03	
Dense close city 2	Bordeaux's dense diverse further surroundings (variety of land-use, fewer public equipments, smaller CES, rather dense and small lots)	45	3.3E-4	1709.28		9.25	0.11	
Suburbs / smaller towns 2	Similar lots of peri-urban small towns/suburbs (average/small CES, few equipments, normal/large lots, few road surface)	43	2.91E-05	7824.59		9.97	0.33	
Activity zone 1	Activity zones around the metropolitan territory	4	2.91E-06	2.51E+04		1.11E+01	3.12E-01	

...

Outputs

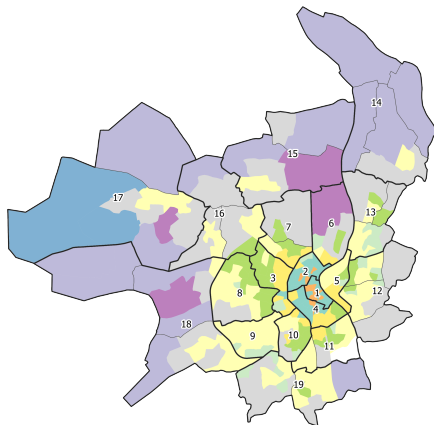


Figure: Map of clusters created on parameters concerning land-use.

Reference land system

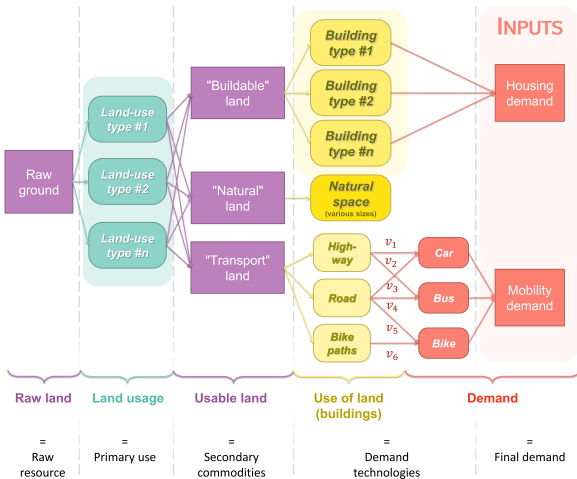


Figure: System used

Energy related and environmental outputs

Urban constraints:

- *Limited areas* by local plans;
- *Historical center* and other specific areas;
- *Lifespan* of buildings;

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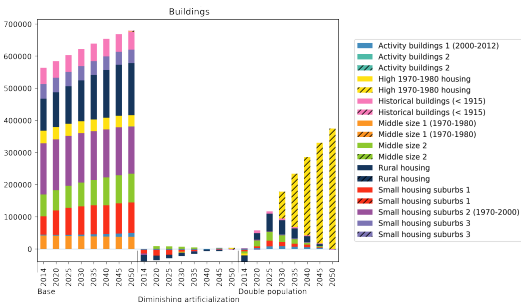
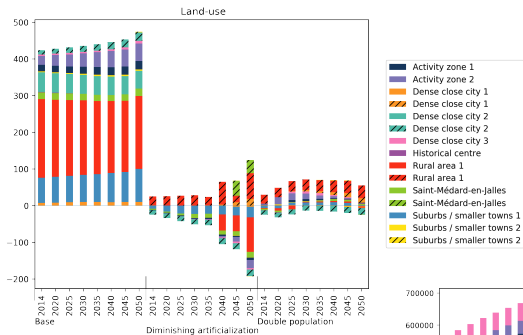
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Environmental constraints:

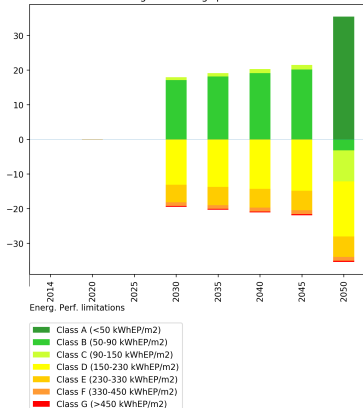
- WHO recommendations on *green areas access* [WHO Regional Office for Europe, 2016];
- *Limited artificialization* of the land;
- *Retrofitting program* to diminish buildings performing weakly;
- ...

Results: land-use and buildings



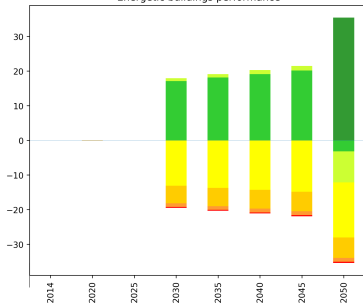
Results: DPE constraint

Energetic buildings performance

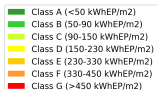


Results: DPE constraint

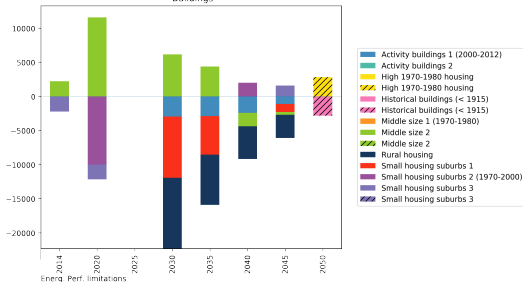
Energetic buildings performance



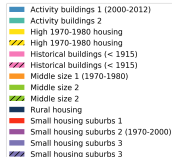
Energ. Perf. limitations



Buildings

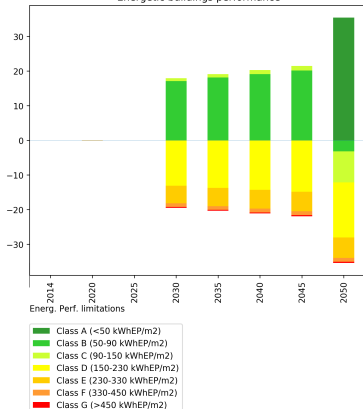


Energ. Perf. limitations

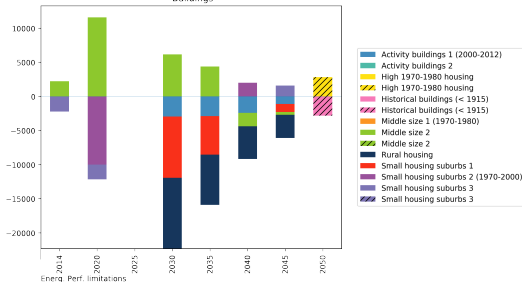


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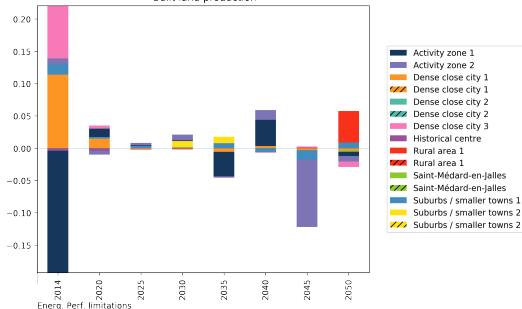
Energetic buildings performance



Buildings



Built land production



Energy model scheme

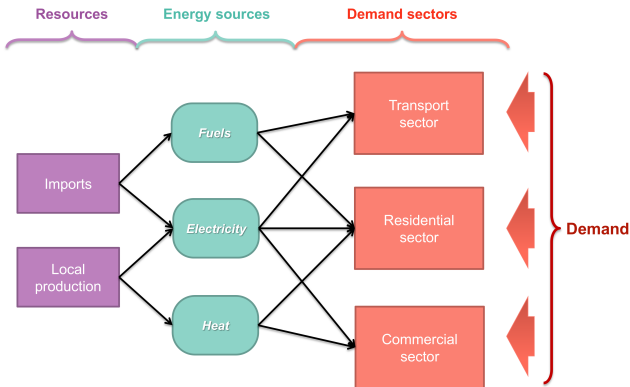


Figure: Reference Energy System

Perspectives

Three approaches for the **coupling**:

- Changing **final demand** using converting tools based on land-use model outputs [Le Gallic et al., 2016];
- Changing **technologies** themselves proposed to the model;
- **Constraining potential** of each technology (e.g. no collective heating if no collective buildings are built).

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Other perspectives on land-use:

- Add urban planners' **future projects**;
- Combine with **jobs and commercial sector** data;
- Link **transportation demand** with urban shapes;

Thank you!

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