Spatial distribution of residential building energy demand in France for the 21st Century: impact of temperature and population projection

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Background and objectives

In a climate change context, it is crucial to understand in which extent energy demand will be affected within the next decades. With 487 TWh in 2019, residential sector is the first energy consumer in France just in front of transports sector [1]

•The energy demand for heating and cooling buildings is driven by: climatic conditions, socio-economic context and energy systems efficiency [2]. Projected temperature changes by climate models has a significant impact on heating degree-day (HDD) and cooling degree-day (CDD) evolution.

•In this work, we studied the spatio-temporal evolution of HDD and CDD within the Metropolitan France territory, taking to into account population evolution and climate change.

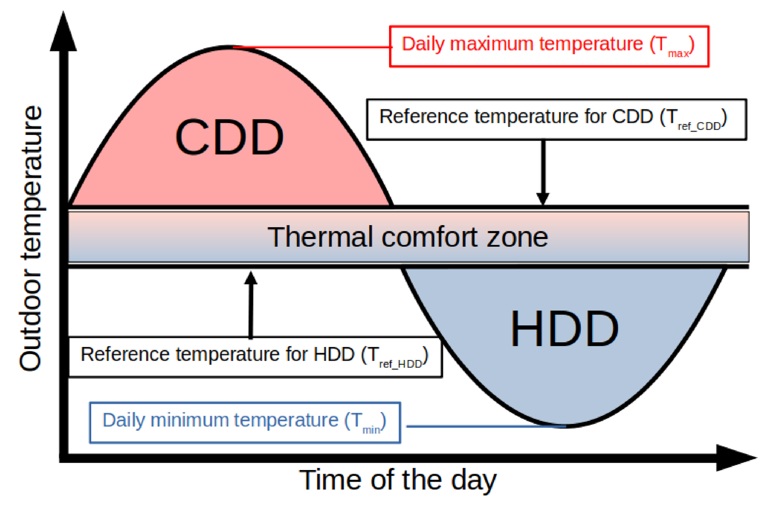
Air surface temperature projections

- We selected air surface temperature projections from nine different combinations of global circulation model (GCM) and regional climate model (RCM) available within the EURO-CORDEX simulations [3]:
  - Spatial resolution: 12.5 km
  - Time sampling: 3h
  - Period: 1981-2100
  - Greenhouse gas emission scenarios:
    - RCP4.5 (stabilization around 2050)
    - RCP8.5 (continuous increase until 2100)

Degree-days computation

HDD and CDD reflect the energy amount needed to heat or to cool the indoor environment compared to a reference temperature. The French Scientific and Technical Commitee for Climate Industries (COSTIC) [4] recommands the HDD and CDD computation method described in the table below with:

- Tref_HDD = 18°C
- Tref_CDD = 26°C
- CDD values are capped at +7°C to prevent thermal shocks



Condition	HDD	CDD
$T_{ref} > T_{max}$	$T_{ref} - (T_{min} + T_{max})/2$	0
$T_{min} < T_{ref} < T_{max}$	$(T_{ref} - T_{min}) * [0,08 + 0,42 * (T_{ref} - T_{min}) / (T_{max} - T_{min})]$	$(T_{max} - T_{ref}) * [0,08 + 0,42 * (T_{max} - T_{ref}) / (T_{max} - T_{min})]$
$T_{ref} < T_{min}$	0	$(T_{min} + T_{max})/2 - T_{ref}$

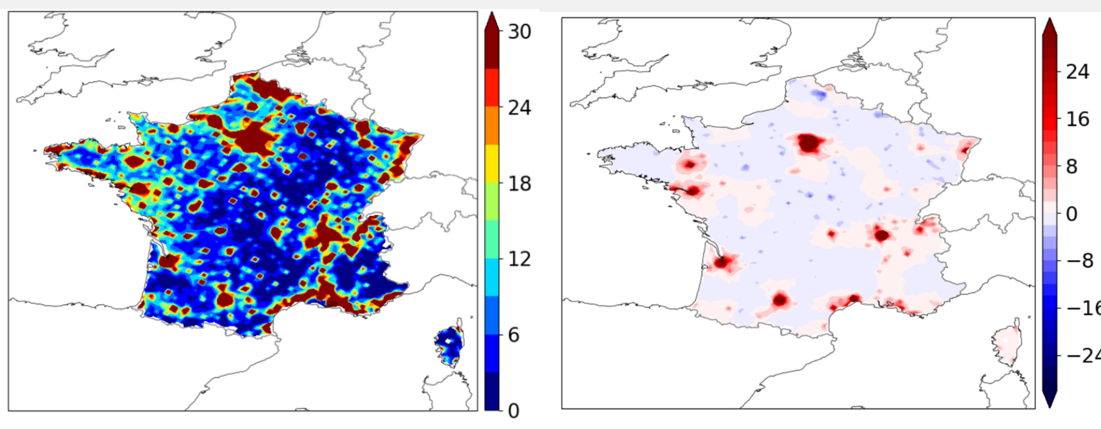
Population weighting

We weighted degree-day values with projection population data at each climate model grid point. For a RCM grid cell *i* within a country *k*:

- $w_{i,k} = P_i / P_k$
- $HDD_{pw} = HDD * w_{i,k}$
- $CDD_{pw} = CDD * w_{i,k}$

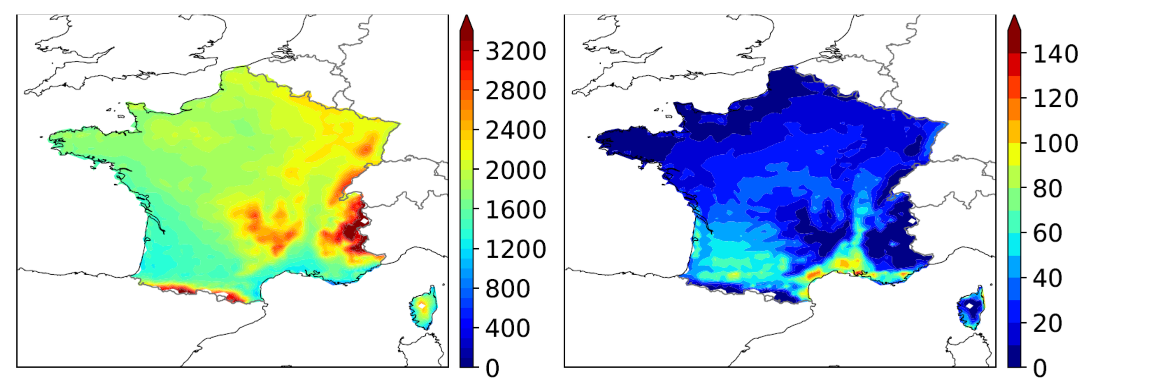
French population evolution

- Spatial distribution of population shows a strong contrast between highly concentrated urban areas and rural zones.
- Population evolution scenario provided by EUROSTAT [5] assumes a strong growth until 2050 located in large cities, before a stabilization until 2100

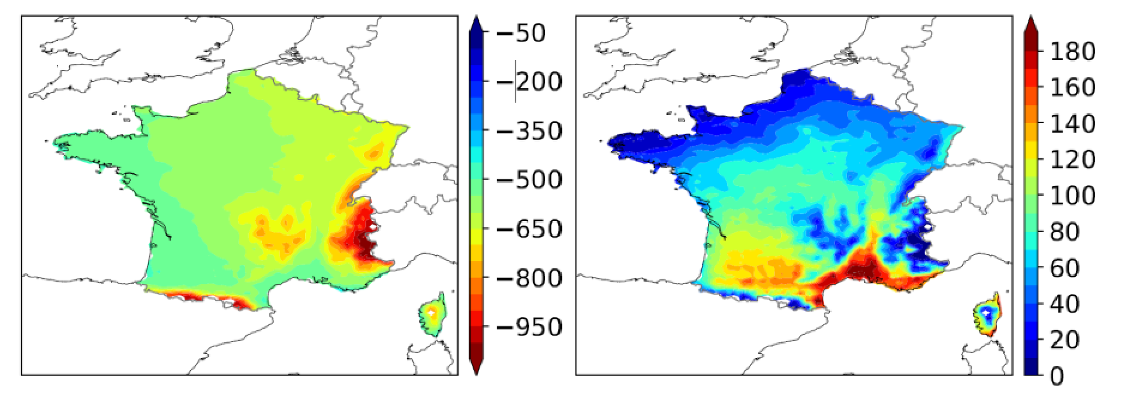


Spatial distribution of population (x1000 inhabitants) in 2019 (left) and its evolution between 2019 and 2050 (right)

Spatiotemporal analysis of degree-days without population influence



Spatial distribution of HDD (left) and CDD (right) annual mean for the period (1981-2010) in °C



Difference of HDD (left) and CDD (right) annual mean between the period (2070-2100) and (1981-2010) for scenario RCP8.5 in °C

Assuming no significant affection due to climate change between 1981 and 2010:

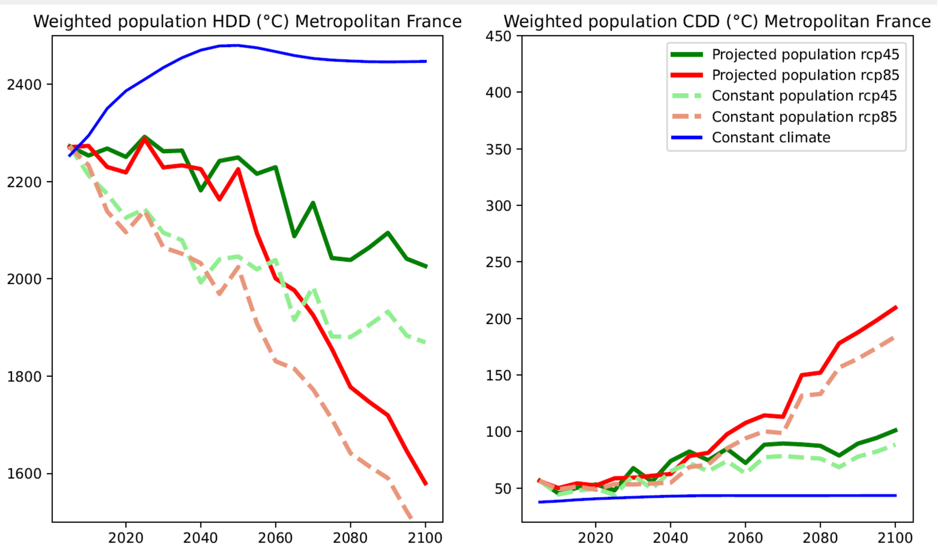
- HDD map shows the coldest parts in winter, mainly located in mountainous areas.
- CDD map highlights the warmest parts located in Mediterranean coast and Occitania. Channel coast and Brittany present the lowest needs in cooling energy.

For RCP8.5 scenario between 2100-2070 and 1981-2010:

- HDD map shows a relative uniform decreasing pattern, except in mountainous areas where larger temperature increase are expected
- CDD map shows an stronger temperature increase in the hottest areas identified in 1981-2010.

Population impact on temporal evolution of HDD & CDD

- Population weighted degrees-days follow the HDD and CDD with superior values until the end of the century. For scenario RCP4.5 the discrepancy between the two curves is larger than for RCP8.5. Temperature evolution in RCP8.5 has a larger influence than population evolution.
- Spatial distribution of HDD and CDD without population weighting has no significant influence on energy demand at country level.
- Populated areas are concentrated into limited surfaces which represent averaged trends of HDD and CDD.
- Mountainous areas, despite of their, contrasted climatic evolution, have no dense populated areas impacting significantly the energy demand.



Population weighted and spatially averaged HDD (left) and CDD (right) in yearly sums

Conclusion and perspectives

- We investigate the evolution of heating and cooling energy demand under the influence of spatially-differentiated climate change effects and population growth for mainland France.
- From 2005 to 2100, for both considered RCP scenarios HDD values slightly decrease and CDD values increase sharply. The expected increase of population has a significant impact on the energy demand
- HDD values decrease up to 33% with constant population and 28% with growing population. In 2100 under RCP85 scenario, CDD values are multiplicated by 3 and 4.5 with constant and growing population
- Energy demand evolution should be refined by coupling an energy-economy model of energy use in dwellings (Res-IRF) [6].
- Population projection scenarios have a large importance. They must take into account more factors than current trend extrapolation (also economical context, international migrations, heat stress...)

Bibliography and acknowledgement

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