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Catalonia Institute for Energy Research

The uncertainty of the energy demand in existing Mediterranean urban blocks

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The uncertainty of the energy demand in existing Mediterranean urban blocks

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3. Sample size analysis
4. Conclusion

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1. MOTIVATION & OBJECTIVES

- Test and optimize EE measures → use of energy simulation tools
- Heating/Cooling loads → external phenomena and user behaviour
- DWH, electric loads of appliances → depend on **user behaviour**
- Energy efficiency in buildings & NZEB→ **electric loads become more important**
- Most of the studies done in this area are focus on North Europe and UK

The need to develop a stochastic model to obtain high resolution profiles for household electricity

- Low rate of energy efficiency refurbishment in Mediterranean regions
- High uncertainty of the energy demand in residential sector

How to reduce the uncertainty in the energy demand during the design process of EE measures in a block of dwellings

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2. STOCHASTIC MODEL

Description

Implemented as a component of TRNSYS 17.1

Hourly simulation

1 or more dwellings in the same simulation

- **Basis: Statistical data**

  SECH-SPAHOUSEC[1] project:

  - Energy consumption characterization of residential sector in Spain
  - **Mediterranean**, Continental and Atlantic regions
  - Detached houses and **block of apartments**
  - Equipment: **refrigerator, freezer, washing machine, dishwasher, television, dryer, microwave, computer, lighting, others** (group of small appliances) and electric **stove** and **oven**

[1] *"PROYECTO SECH-SPAHOUSEC: Análisis del consumo energético en el sector residencial en España", Instituto para la Diversificacion y Ahorro de la Energía (IDEA), 2011*

2. STOCHASTIC MODEL

Description

- **Inputs and parameters for each equipment**:
  - Stock characterization
  - Technical data
  - Statistics of use

- **Source of stochasticity**:
  - Dwelling characterization: random selection of which and how many equipment there are in each dwelling
  - Use of the equipment: random selection of the ON/OFF of each equipment at each time step (hour)

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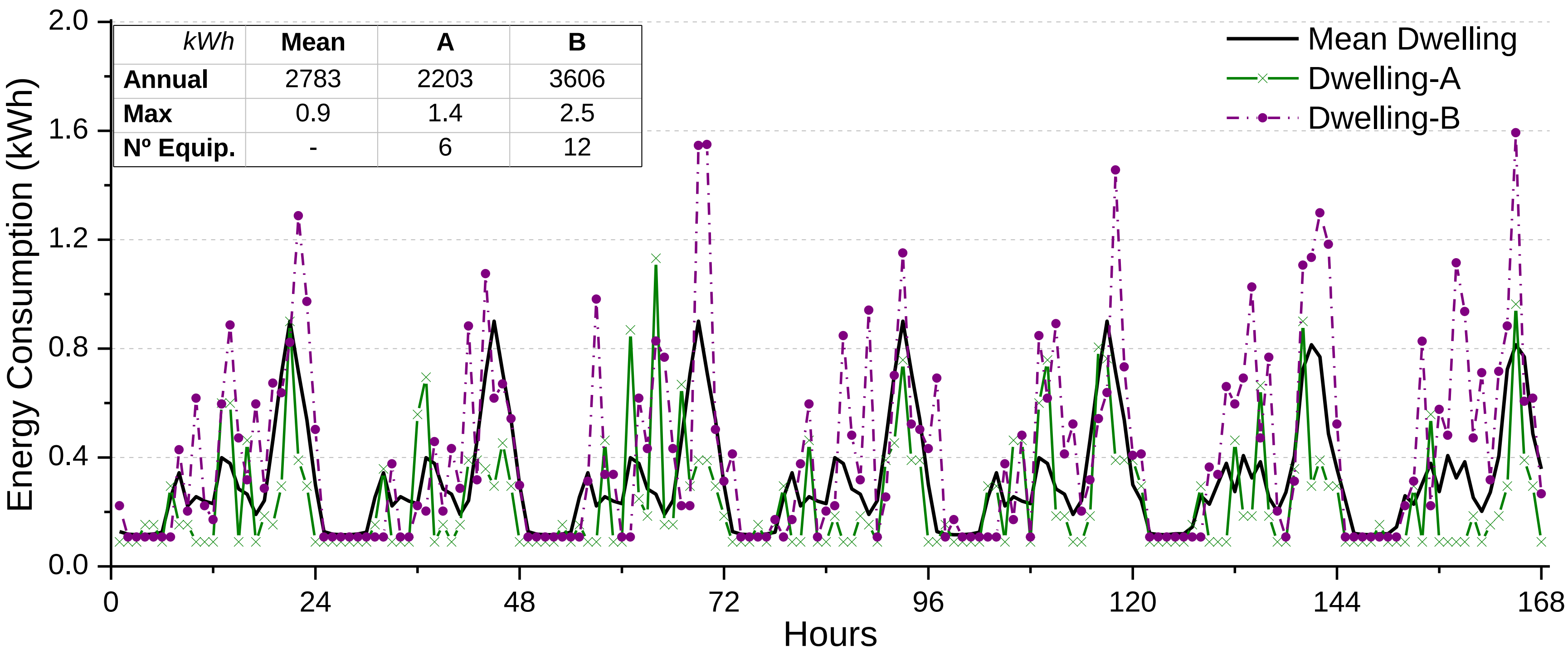
2. STOCHASTIC MODEL

- **Output of the model**:



kWh	Mean	A	B
Annual	2783	2203	3606
Max	0.9	1.4	2.5
Nº Equip.	-	6	12

Fig. 1 Hourly electric consumption for a winter week. Example output of the model, two random dwellings and the mean dwelling (reference data).

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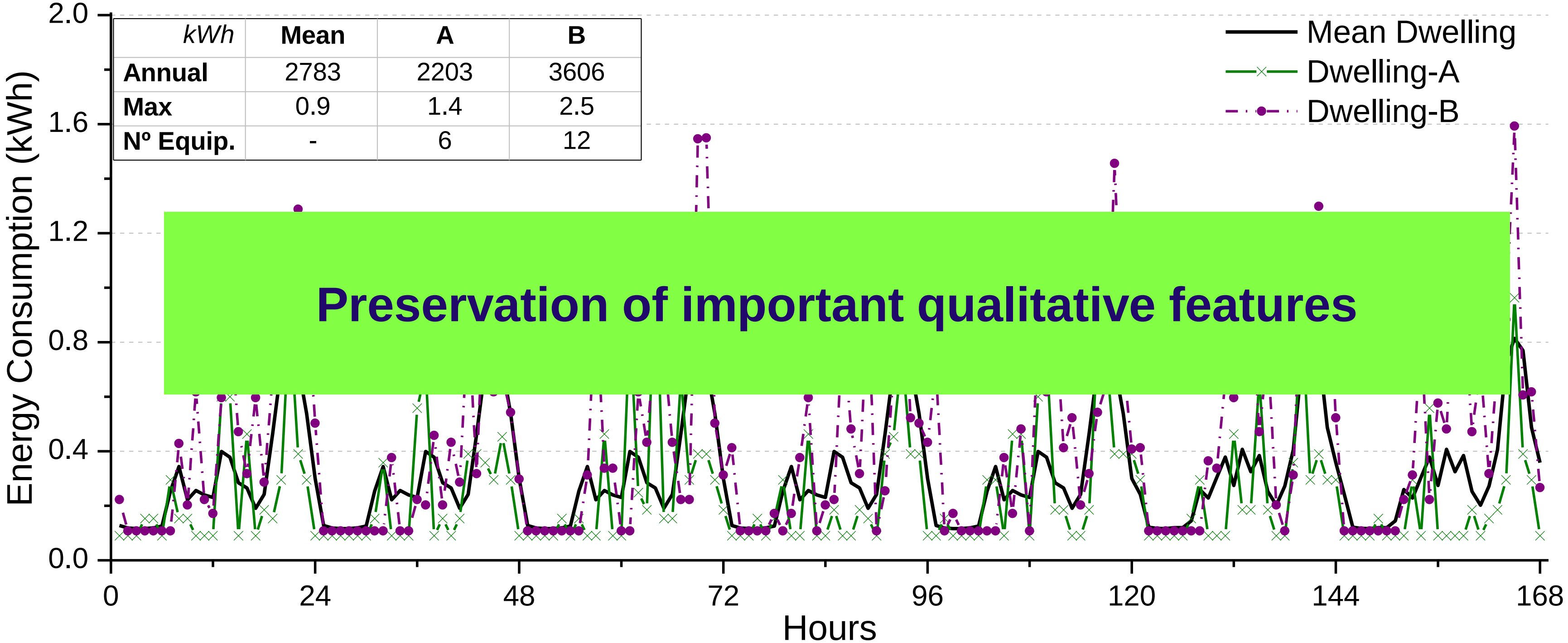

Fig. 1 Hourly electric consumption for a winter week. Example output of the model, two random dwellings and the mean dwelling (reference data).

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2. STOCHASTIC MODEL

Validation

Simulation 1000 dwellings vs. Mean dwelling (reference data)

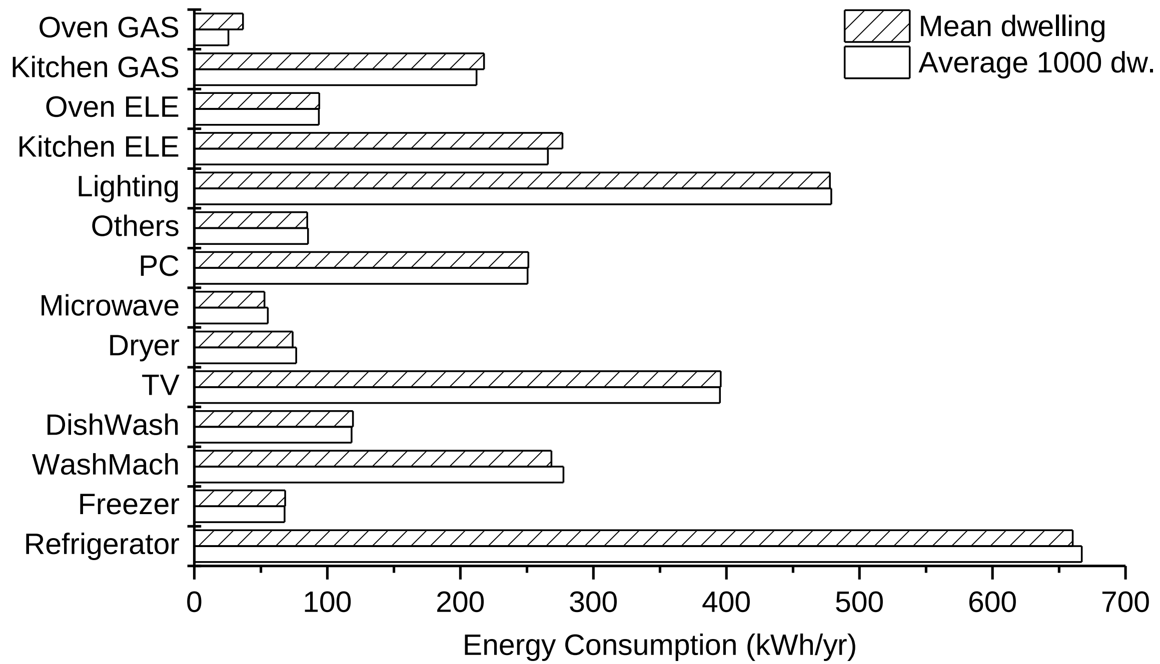

Fig. 2 Annual energy consumption for equipment type. Comparison of the average consumption of 1000 simulated dwellings with the mean dwelling (reference data).Right: Normalized root mean square error (NRMSE) of hourly energy consumption for each equipment for the year.

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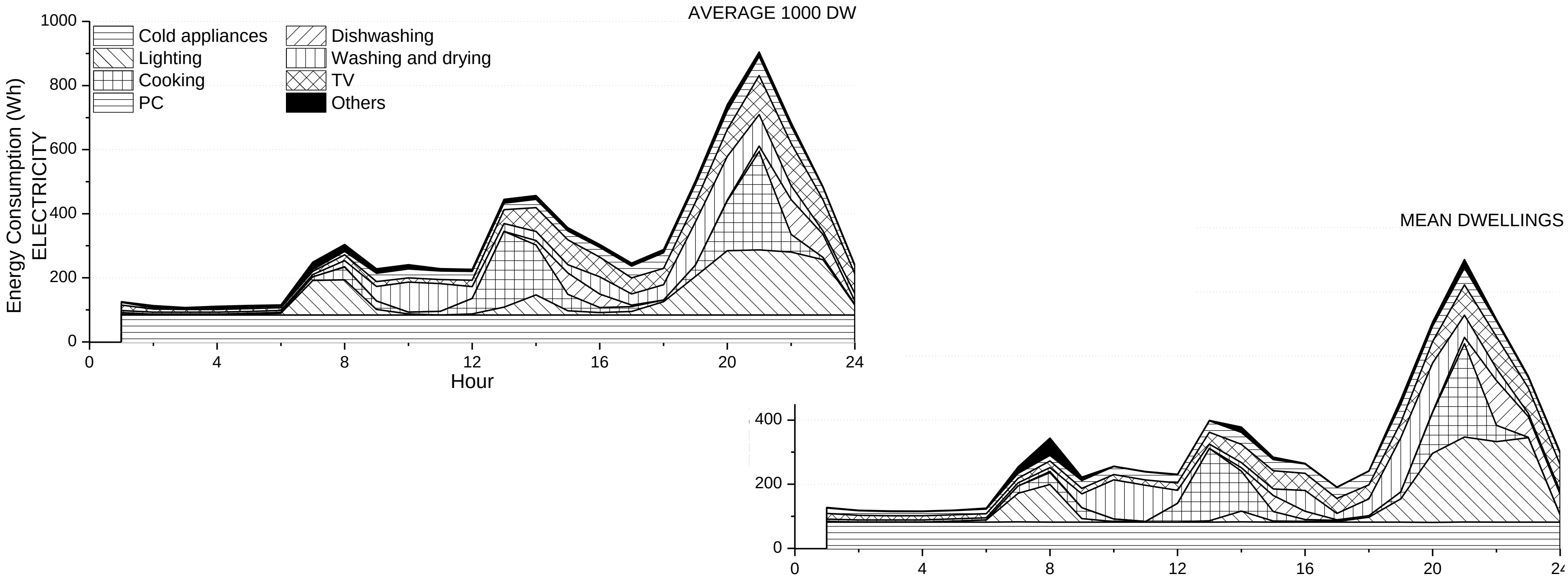

Fig. 3 Electric energy consumption for a winter weekday, breakdown by end uses. Upper: average of 1000 dwellings (simulation results). Lower: mean dwelling (reference data).

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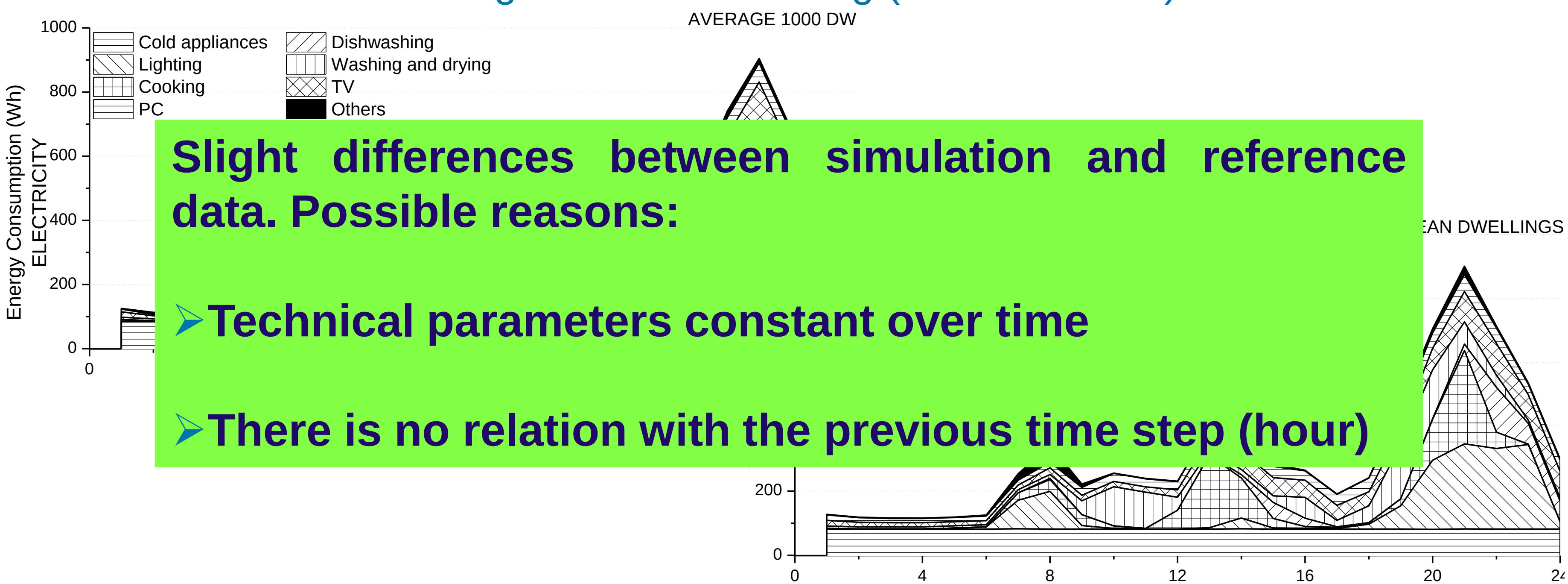

Slight differences between simulation and reference data. Possible reasons:

- **Technical parameters constant over time**
- **There is no relation with the previous time step (hour)**

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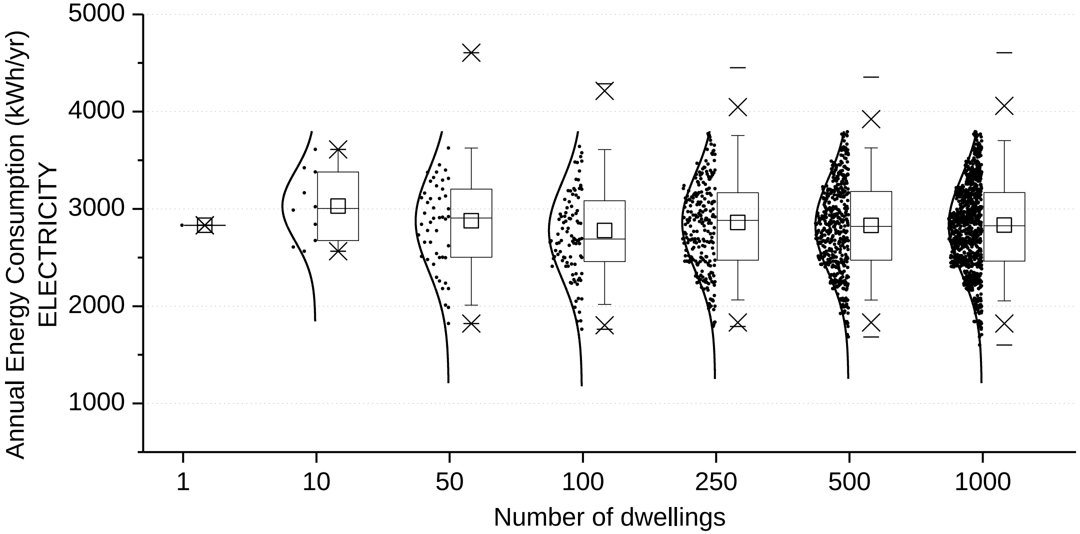
3. SAMPLE SIZE ANALYSIS

Objective

Analyse the sample size needed to characterize the buildings during the design process of energy efficiency measures

Empirical Distribution of the Annual Energy Consumption



nº DW	STATISTICS (kWh/yr)			
	Mean	SD	MIN	MAX
10	3028	364	2565	3611
50	2877	513	1822	4606
100	2777	492	1763	4287
250	2861	495	1791	4452
500	2829	484	1683	4354
1000	2834	499	1600	4606

Fig. 4 Distribution of the annual energy consumption for dwelling, increasing the number of dwellings. Description of the box plot parameters: mean by square; median by horizontal line; 25% and 75% percentile by box; 5% and 95% by whiskers; 1% and 99% percentile by cross; minimum and maximum by dash. In the right table, the statistical values of each sample (mean, standard deviation (SD), minimum and maximum).

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3. SAMPLE SIZE ANALYSIS

First test:

How many dwellings are required to represent the annual mean consumption of the target population?

Target population size	Accuracy		
	1%	5%	10%
20	20	14	8
100	92	33	11
500	354	44	12
1000	548	46	12
3000	862	48	12
10000	1079	48	12
Unknown	4839	194	48

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3. SAMPLE SIZE ANALYSIS

First test:

How many dwellings are required to represent the annual mean consumption of the target population?

As the target of dwelling increase, the sample size needed is proportionally smaller

[illegible]	[illegible]	[illegible]	[illegible]
100	92	33	11
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Second Test:

How many dwellings are required to reflect the energy saving designed?

Energy saving	Sample size
5%	265
10%	66
15%	29

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The EE measures with high impact could be apply in less dwellings to obtain the expected energy saving

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4. CONCLUSIONS

- Reproduce hourly and annual patterns of electric consumption
- May simulate single dwelling or a block of dwellings of Mediterranean region
- A general validation has been done
- Help to reduce the uncertainty of the energy consumption in residential sector → improve the making decision process in the early stage of design

To be done

- Sensitive analysis of the influence of the variation of the technical parameters
- Validate the model at hourly level → verify the hourly peaks
- Include the occupancy level and the user behaviour in the model (TUD)

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MARIE
MEDITERRANEAN BUILDING RETHINKING FOR ENERGY EFFICIENCY IMPROVEMENT

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Thanks for your attention

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STATISTICAL EQUATIONS

(1) and (2) → define the number of dwellings that are required to estimate the mean annual energy consumption of the total population, with different levels of accuracy. (1) for a known target population size and (2) for an unkonw one.

(3) → define the sample size for an energy efficiency measures in a set of dwellings for an expected energy saving

$$n = \frac{N \cdot \sigma^2 \cdot Z_{\alpha/2}^2}{(N-1) \cdot e^2 + \sigma^2 \cdot Z_{\alpha/2}^2} \quad (1)$$

$$n = \frac{\sigma^2 \cdot Z_{\alpha/2}^2}{e^2} \quad (2)$$

$$n = \frac{2 \cdot \sigma^2 \cdot \left(Z_{\alpha/2} + Z_{\beta}\right)^2}{\Delta^2} \quad (3)$$

n: sample size
N: target population
$Z_{\alpha/2}$: normal distribution value
e: error corresponding to the defined level of accuracy
α: confidence level
σ^2: variance
Δ: expected energy saving

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PARAMETER

Data type	Parameter	Units	Description
Stock characterization	Penetration rate (Pr)	%	Fraction of dwellings with at least one equipment. The input of the model is its complementary (1-Pr).
	Multi-equipment probabilities (Mp)	%	These values represent the probability to have 1, 2, 3 or 4 equipments in a dwelling. The multiequipment is defined with 4 probabilities (probability to have 1 equipment, to have 2...). At the same way of the penetration rate, the input of the model is its complementary (1-Mp).
	Fraction of electric devices (FE)	%	In the case of the kitchen devices, it is necessary to include the fraction of electric devices. The gas devices are calculated as the difference of the electrical ones.
Technical data	Power (P)	kW	This power has reference to the nominal power. This information is available in the technical sheet of the equipment. This power could be different to the used power when the equipment is working.
	Power Fraction (PF)	%	PF is the hourly mean power when the equipment is ON divided by the power (P) of the equipment. This parameter is constant over time.
	Cycle Length Fraction (CF)	%	CF is the relation between the cycle length and the integer hours. For example, the duration of the cycle of a washing machine is 1.5 hours, then the integer hours is 2, and CF is 1.5/2. This parameter represents the fraction of the hour when the equipment is spending energy. This parameter is constant over time.
	Power of Stand-by (Pstb)	kW	Pstb is the power of the stand-by mode. If the equipment does not have stand-by, the value should be 0.
Statistics of use	Hourly profile of probabilities of use (prob(t))	%	The probabilities of use represent the probability to use one equipment at each hour. There are hourly profiles for each season (summer, winter and mid season) and type of day (weekday and weekend). It means that there are six hourly profiles of probabilities of use.

SOURCE OF STOCHASTICITY

Dwelling characterization

$$\left.\begin{array}{ll}
RNE_e^d < (1-\Pr_e) & \rightarrow \text{There is no equipment } e \text{ in dwelling } d \\
RNE_e^d \geq (1-\Pr_e) \begin{cases} (1-Mp_{e1}) > RNE_e^d & \rightarrow \text{There is 1 equipment } e \text{ in dwelling } d \\ (1-Mp_{e1}) \leq RNE_e^d < (1-Mp_{e2}) & \rightarrow \text{There is 2 equipments } e \text{ in dwelling } d \\ (1-Mp_{e2}) \leq RNE_e^d < (1-Mp_{e3}) & \rightarrow \text{There is 3 equipments } e \text{ in dwelling } d \\ (1-Mp_{e3}) \leq RNE_e^d < (1-Mp_{e4}) & \rightarrow \text{There is 4 equipments } e \text{ in dwelling } d \end{cases}
\end{array}\right\} (1)$$

$$\left.\begin{array}{ll}
RNE_e^d < (1-\Pr_e) & \rightarrow \text{There is no equipment } e \text{ in dwelling } d \\
RNE_e^d \geq (1-\Pr_e) \begin{cases} FE_e < RNE_e^d & \rightarrow \text{There is an electrical equipment } e \text{ in dwelling } d \\ FE_e \geq RNE_e^d & \rightarrow \text{There is a gas equipment } e \text{ in dwelling } d \end{cases}
\end{array}\right\} (2)$$

Use of equipments

$$\left.\begin{array}{ll}
RNP(t)_e^d \geq prob(t)_e \rightarrow E(t)_e^d = Pstb_e \cdot \Delta t & \rightarrow \text{The equipment is OFF or in Stand-by} \\
RNP(t)_e^d < prob(t)_e \rightarrow E(t)_e^d = P_e \cdot PF_e \cdot CF_e \cdot \Delta t & \rightarrow \text{The equipment is ON}
\end{array}\right\} (3)$$

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