

Evaluation of electricity related impacts using a dynamic LCA model



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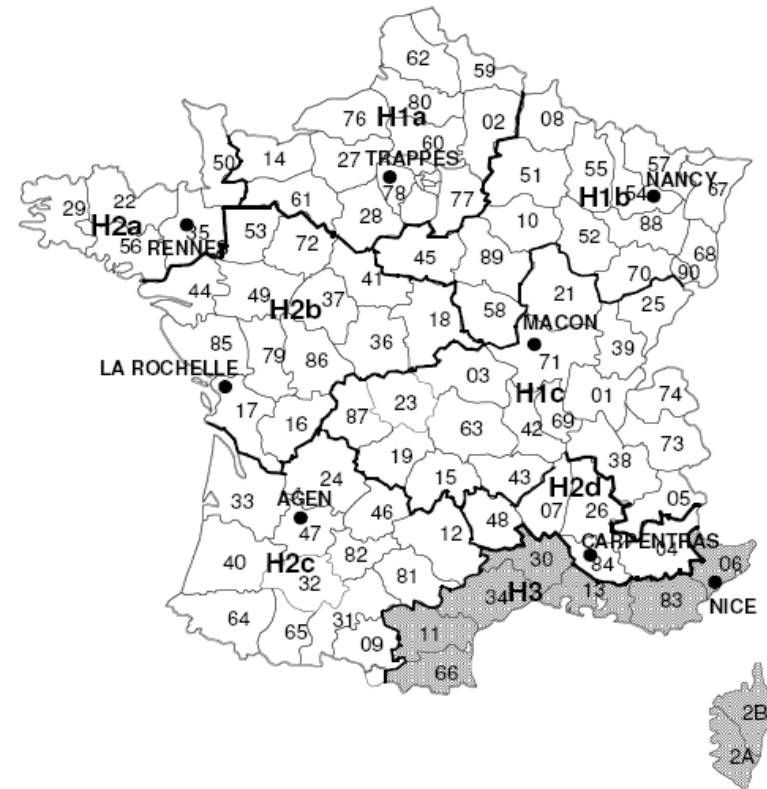
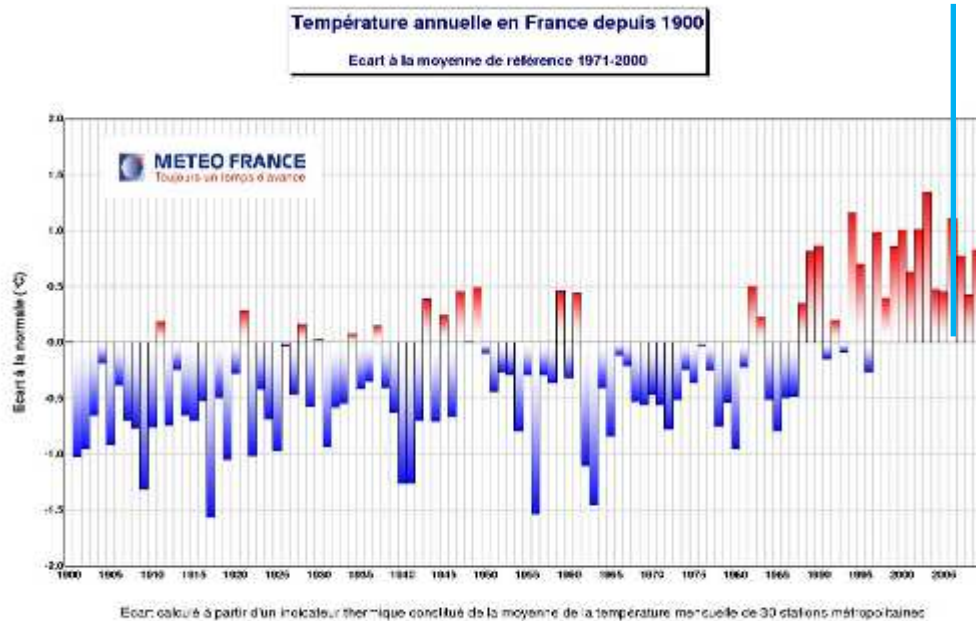
MODELLING OF TEMPORAL ASPECTS

Principles

- Modelling of french electricity production curves, regarding the type of energy used, and based on time and temperature-dependant functions
- Choice of a year supposed to be representative
- Analyse of production dynamics, identification of specific evolution morphologies, supposed to be linked with electricity uses categories in the building sector
- Differentiated determination, regarding uses and function of time, of production mix for every category

Climatic aspects: definition of a representative value

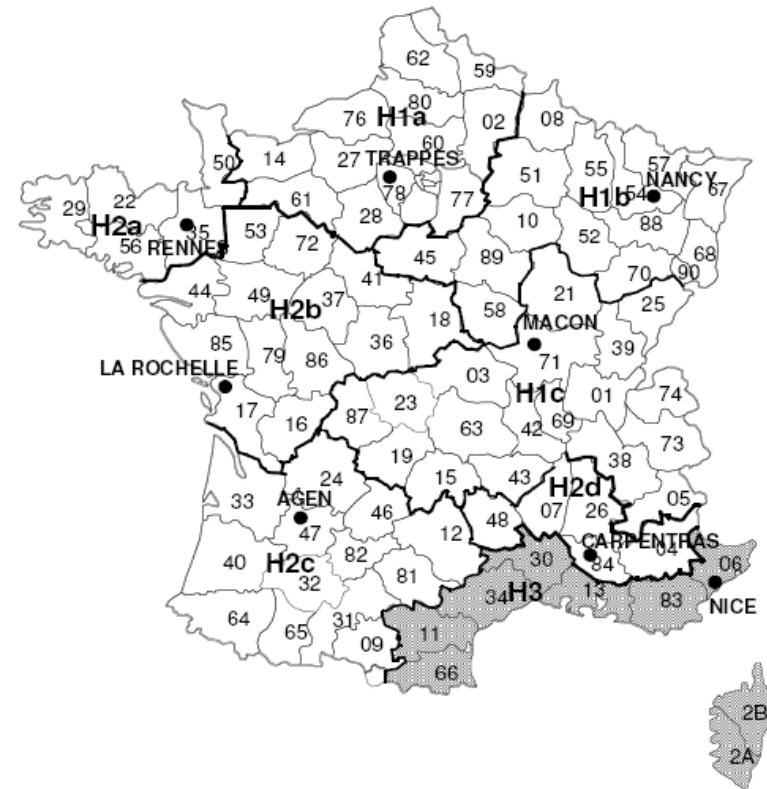
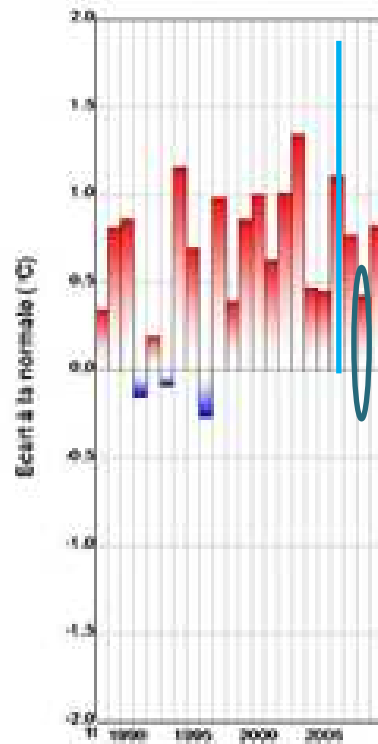
Available RTE data



$$T_{av} = \frac{T_1 * n_1 + T_2 * n_2 + T_3 * n_3}{n_1 + n_2 + n_3}$$

Climatic aspects: definition of a representative value

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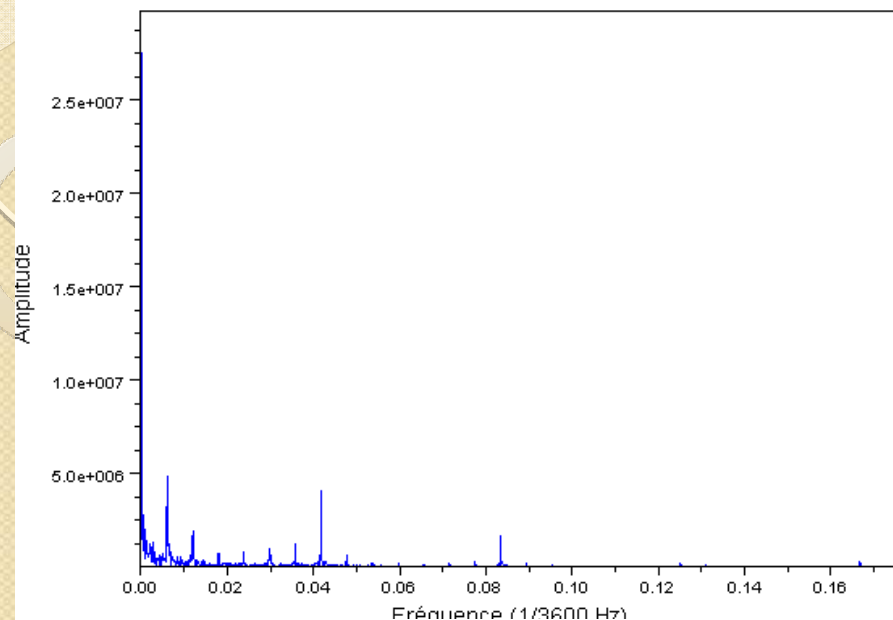


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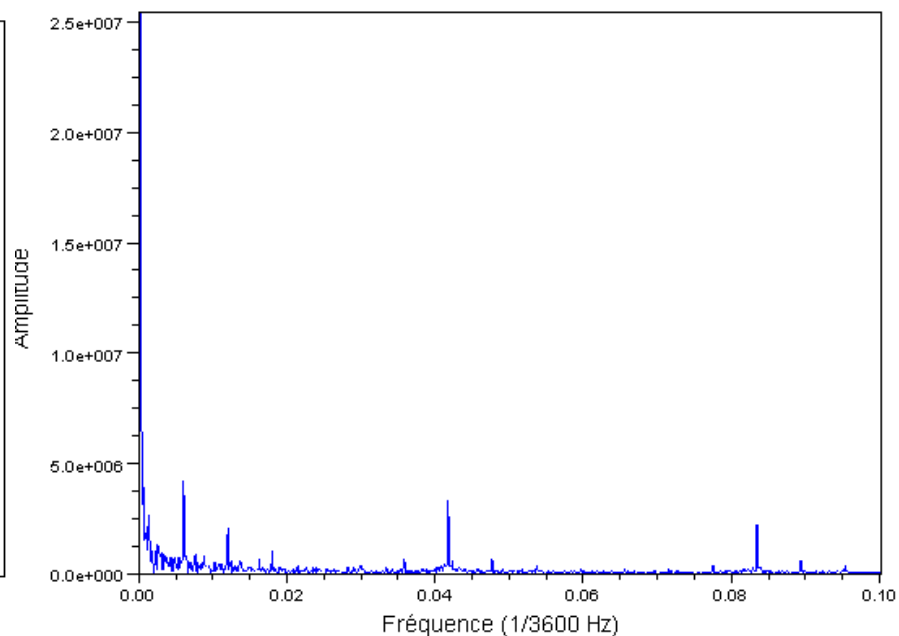
Electricity production: data

- Telemetric hourly production measurement, for installations of more than 20 MW, given by RTE since 2007
- Available for the main means of production (nuclear, hydro-electricity , fuel+peak production, coal+natural gas, others)
- Choice of data for 2008, supposed to be representative on a first step
- Modelling: analysis of frequencies aspects

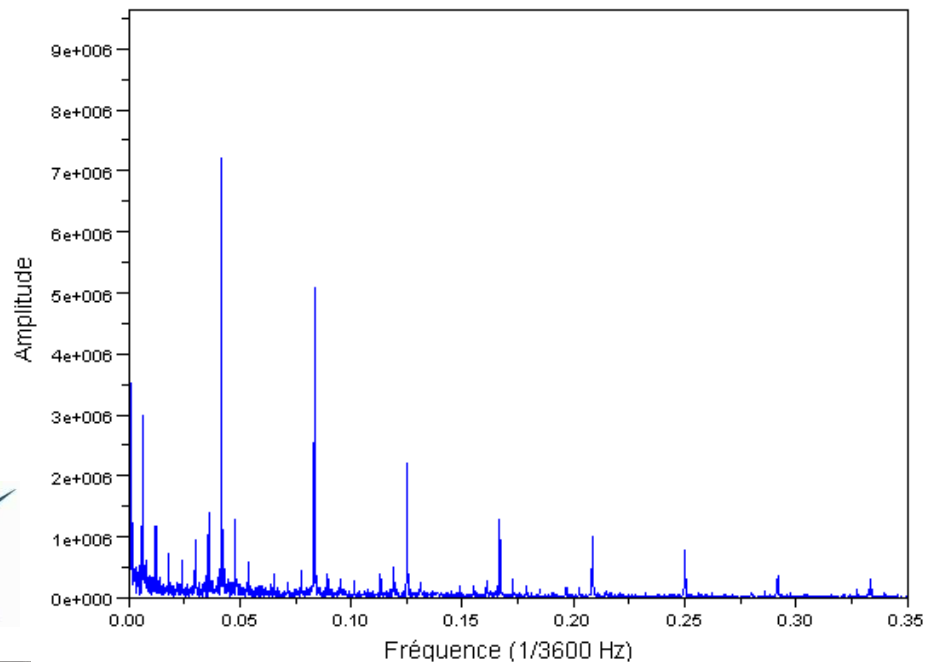
Spectre fréquentiel de la production électrique thermique en 2008



Spectre fréquentiel de la production électrique nucléaire en 2008



Spectre fréquentiel de la production électrique hydraulique en 2008



| i values | Corresponding period (hours) |
|-----------------|-------------------------------------|
| 1 | 12 |
| 2 | 24 |
| 3 | 48 |
| 4 | 168 |
| 5 | 8784 |
| 6 | 672 |
| 7 | 4392 |

Methodology

- Modelling of the production with functions of sinusoidal form:

$$P(t, T_{av}) = \sum_{i=1}^n (X_i(T_{av}) * \cos (w_i * t + Y_i)) + Z(T_{av})$$

In the case of nuclear and hydro power production:

$$X_i(T_{av}) = A_i * T_{av} + B_i$$

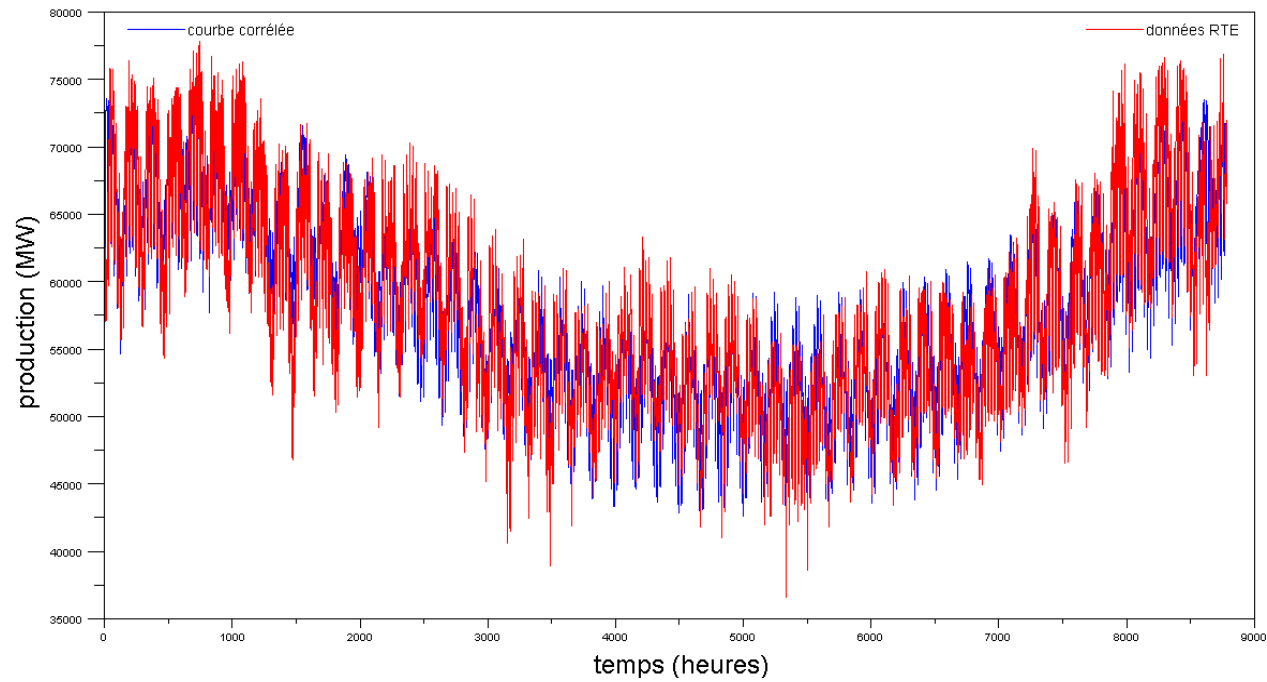
$$Z(T_{av}) = C * T_{av} + D$$

In the case of thermal production:

$$X_i(T_{av}) = A_i * T_{av}^2 + B_i * T_{av} + C_i * \bar{T}_{48} + D$$

$$Z(T_{av}) = E * T_{av}^2 + F * T_{av} + G * \bar{T}_{48} + H$$

Results:

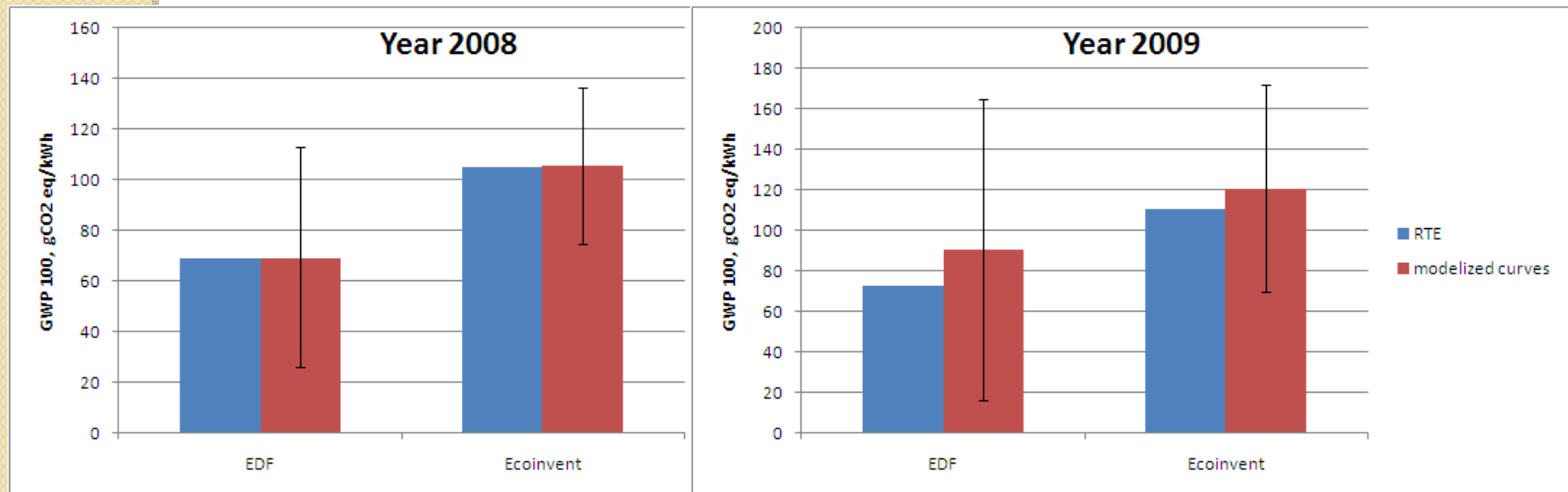


$$\sigma_{2008} = \frac{\sum_{h=1}^{8784} \frac{|(Prod(h)_{RTE\ 2008} - Prod(h)_{corrélés\ 2008})|}{Prod(h)_{RTE\ 2008}}}{8784}$$

| | |
|------------------------------------|------|
| $\sigma_{2008}(nuclear)$ | 0.03 |
| $\sigma_{2008}(hydro\ lectricity)$ | 0.24 |
| $\sigma_{2008}(thermal)$ | 1.03 |
| $\sigma_{2008}(total)$ | 0.04 |

Validation: comparison of GHG emissions

| Production mean | kg CO2 eq/kWh according to EDF [EDF, 2009] | kg CO2 eq/kWh according to Ecoinvent |
|--------------------|--|--------------------------------------|
| Nuclear | 4 | 7,9 |
| Hydro production | 7 | 3,5 |
| Natural gas | 1329 | 640.8 |
| Coal | 1030 | 1065.6 |
| Fuel oil | 1067 | 882 |
| Thermal production | 1200 | 854,5 |



Curves exploitation: annual balance for each use type

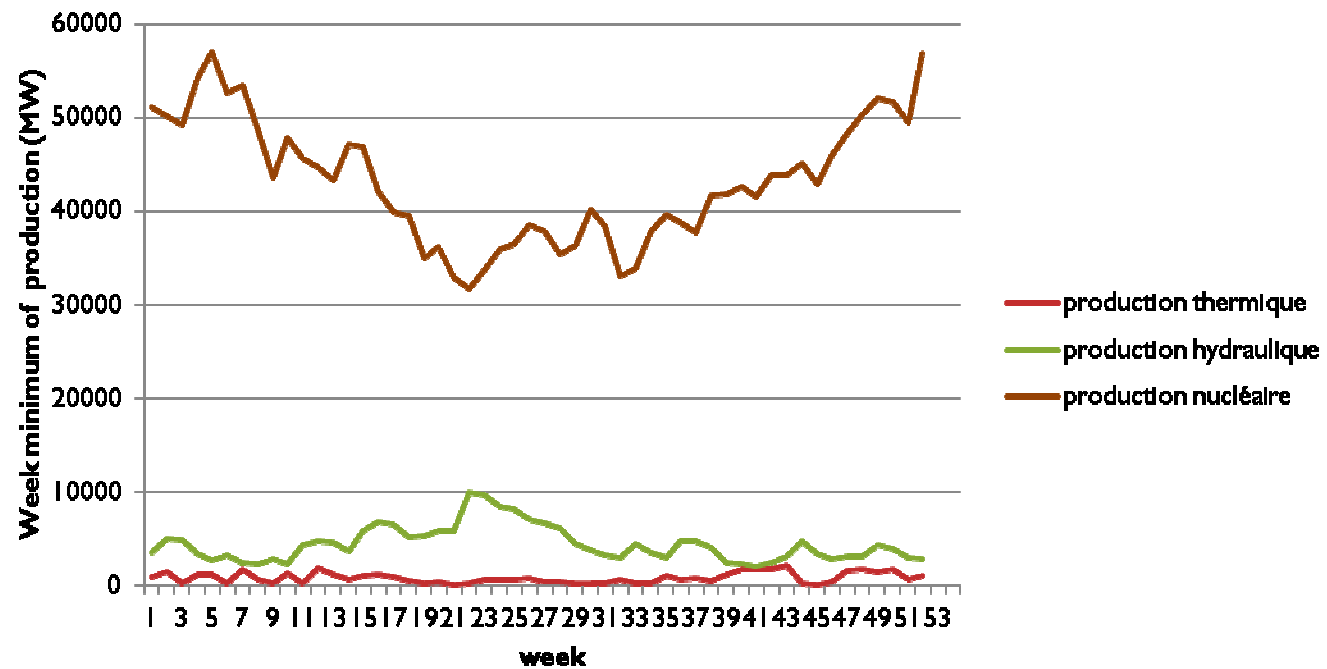
Definition of uses categories:

- Base uses, which absolute importance doesn't vary during the year
- Seasonal uses, varying on one year
- Specific uses during working days (professional uses)
- Daily uses (domestic uses)

$$\left\{ \begin{array}{l} Th_{TOT}(h) = Th_B(h) + Th_H(h) + Th_C(h) + Th_D(h) + Th_P(h) \\ H_{TOT}(h) = H_B(h) + H_H(h) + H_C(h) + H_D(h) + H_P(h) \\ N_{TOT}(h) = N_B(h) + N_H(h) + N_C(h) + N_D(h) + N_P(h) \end{array} \right.$$

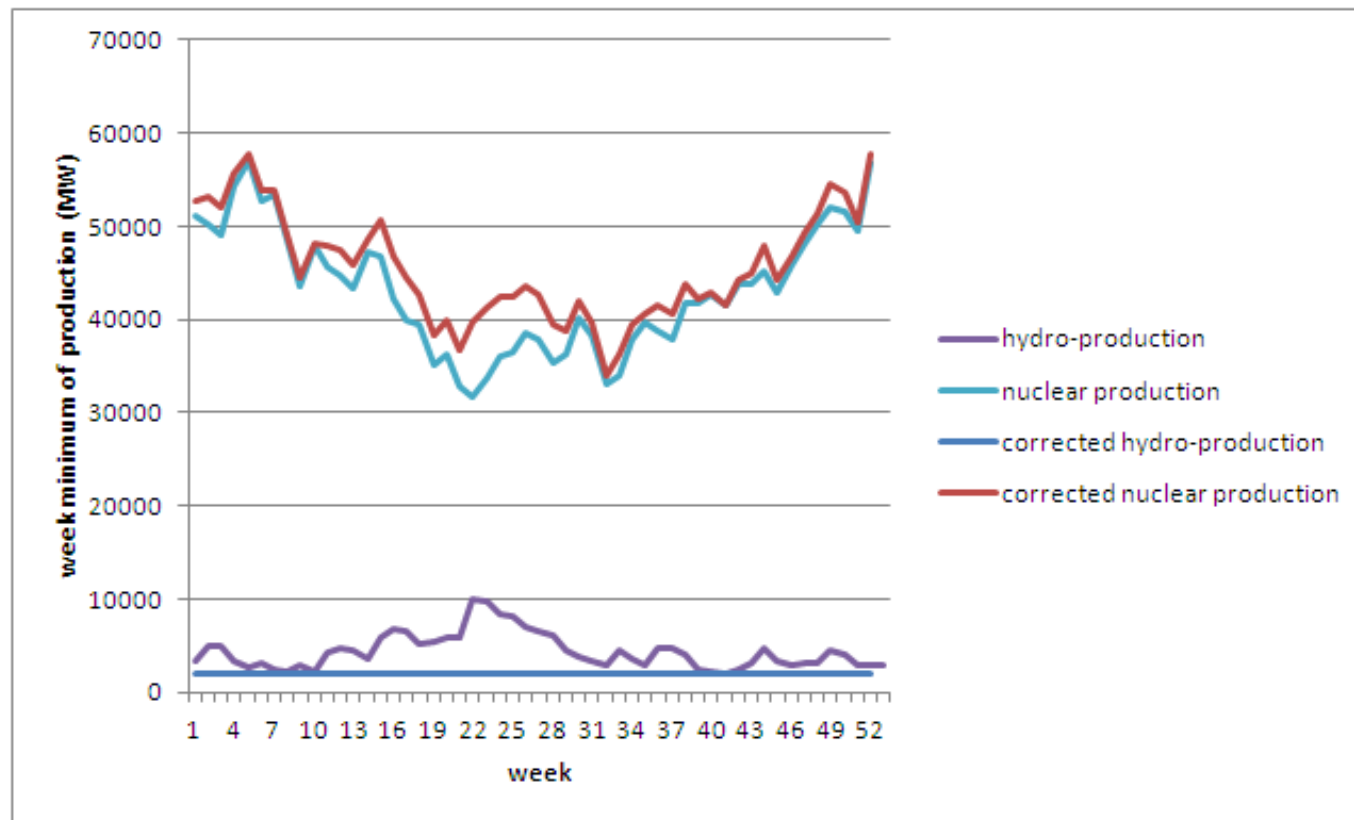
Curves exploitation: annual balance for each use type

Détermination of « base » mix



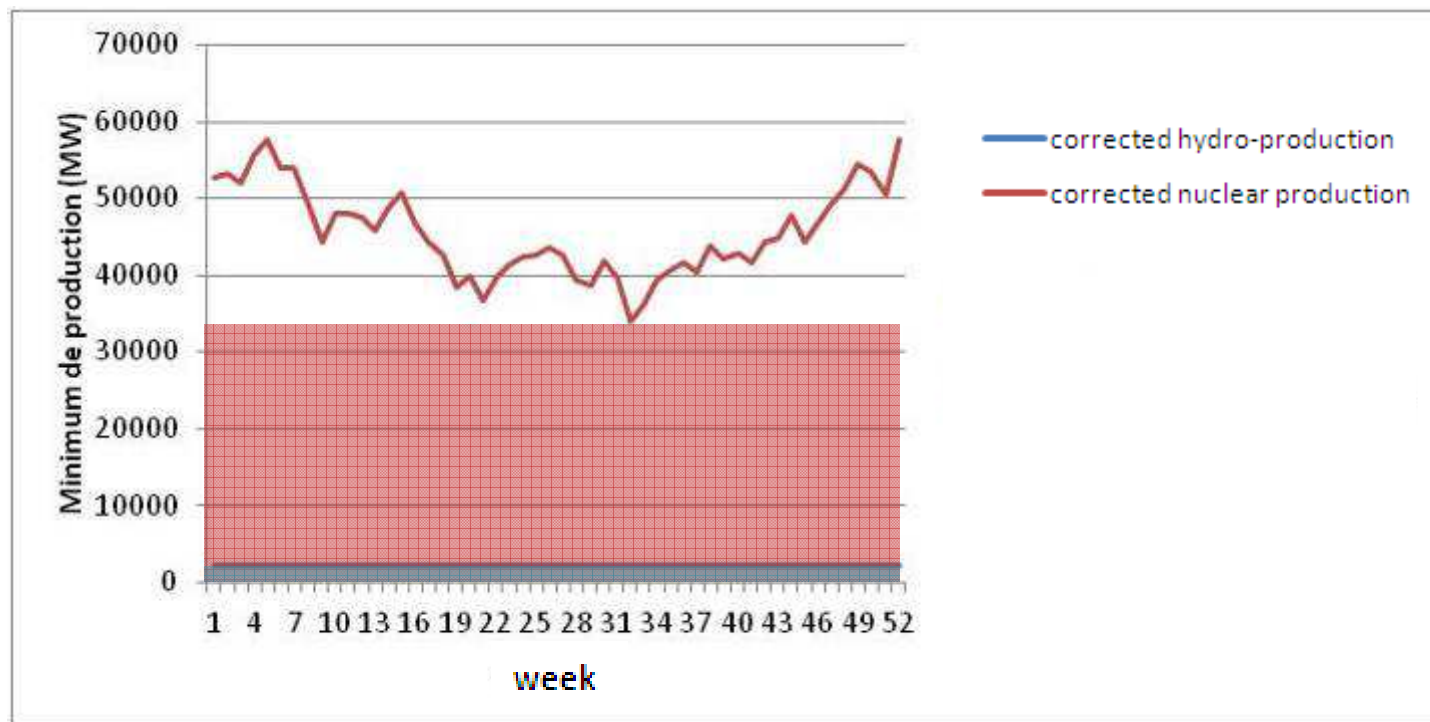
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Détermination of « base » mix



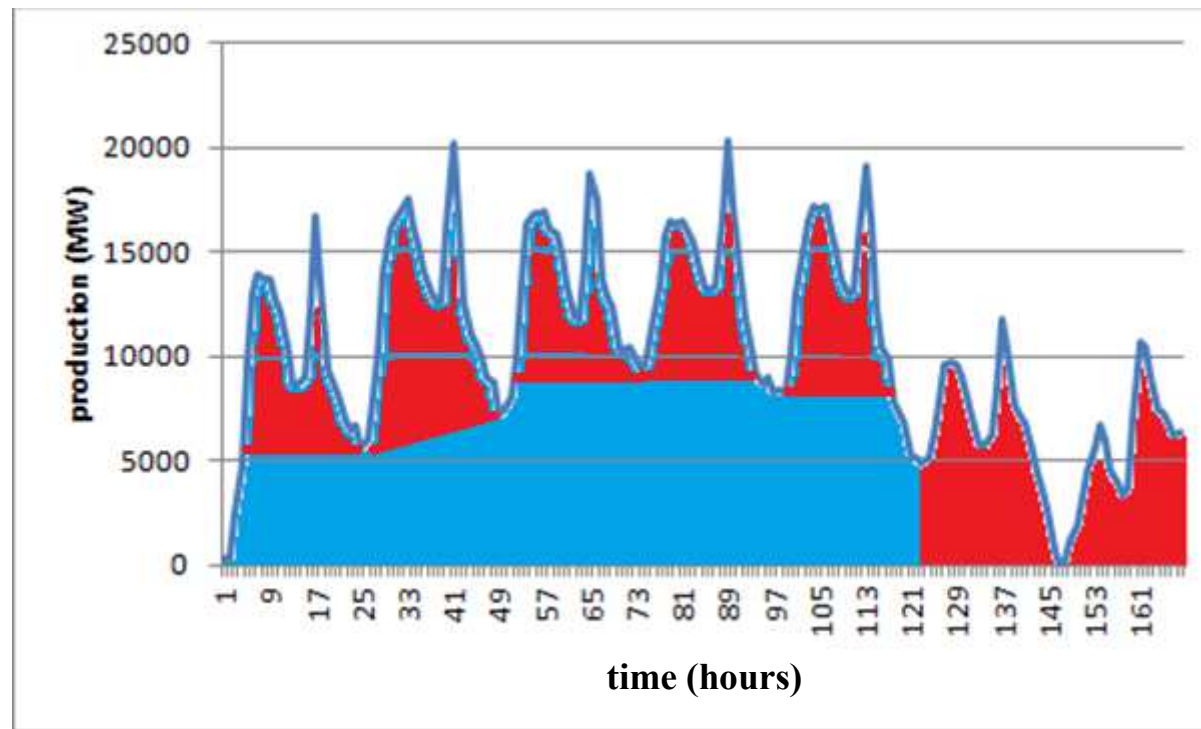
Curves exploitation: annual balance for each use type

Détermination of « base » mix: curves correction



Curves exploitation: annual balance for each use type

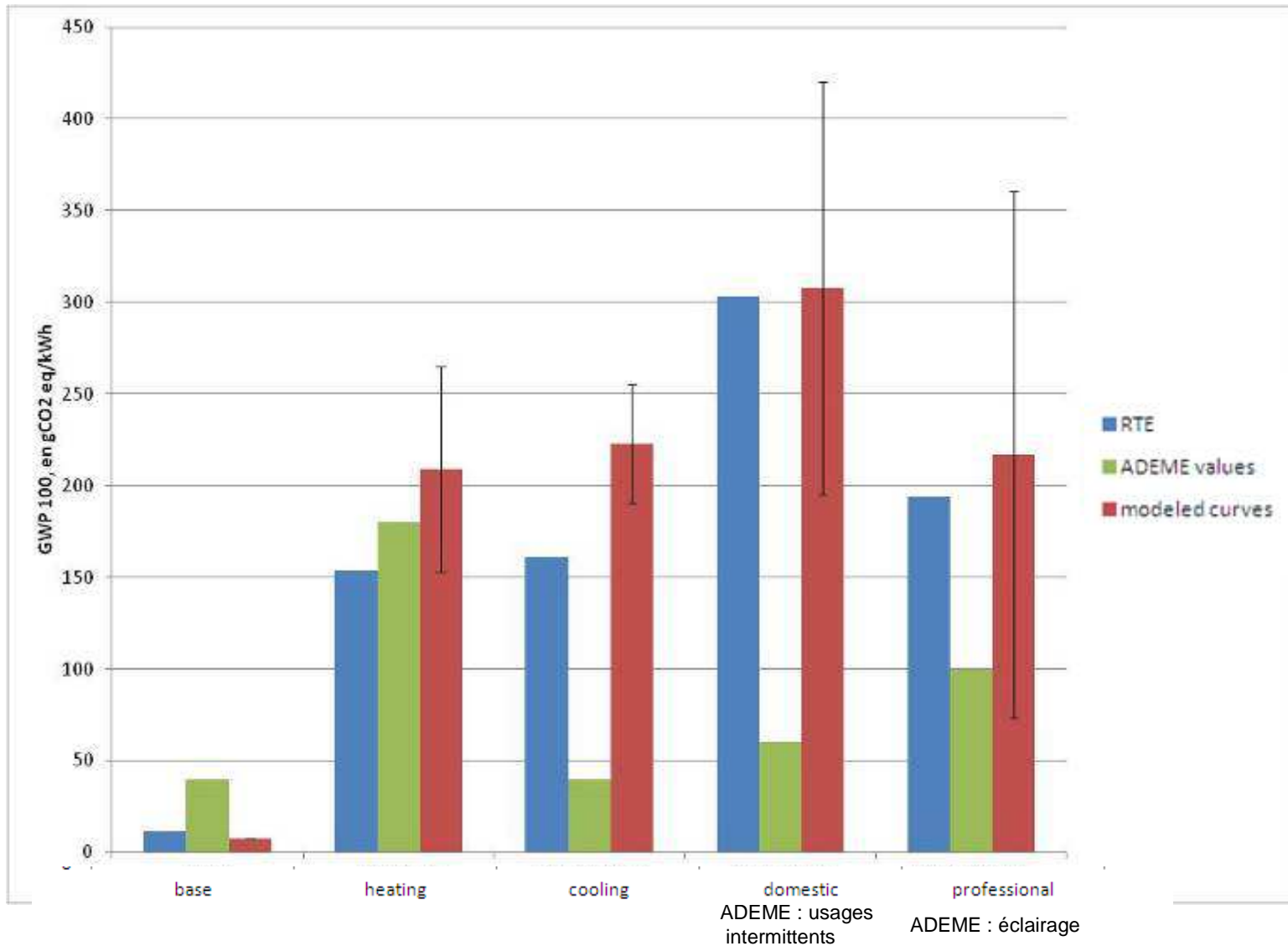
Determination of professional and domestic mix



Import-Export of electricity

- Taking into account trans-border exchanges of electricity, with neighbor countries
- Exploitation of RTE data giving exchanges by hour
- Taking into account the production means concerned by the exchanges, using different alternatives (average production mix for each country, european mix, hypothesis)

Curves exploitation: annual balance for each use type



Limits, conclusions, perspectives

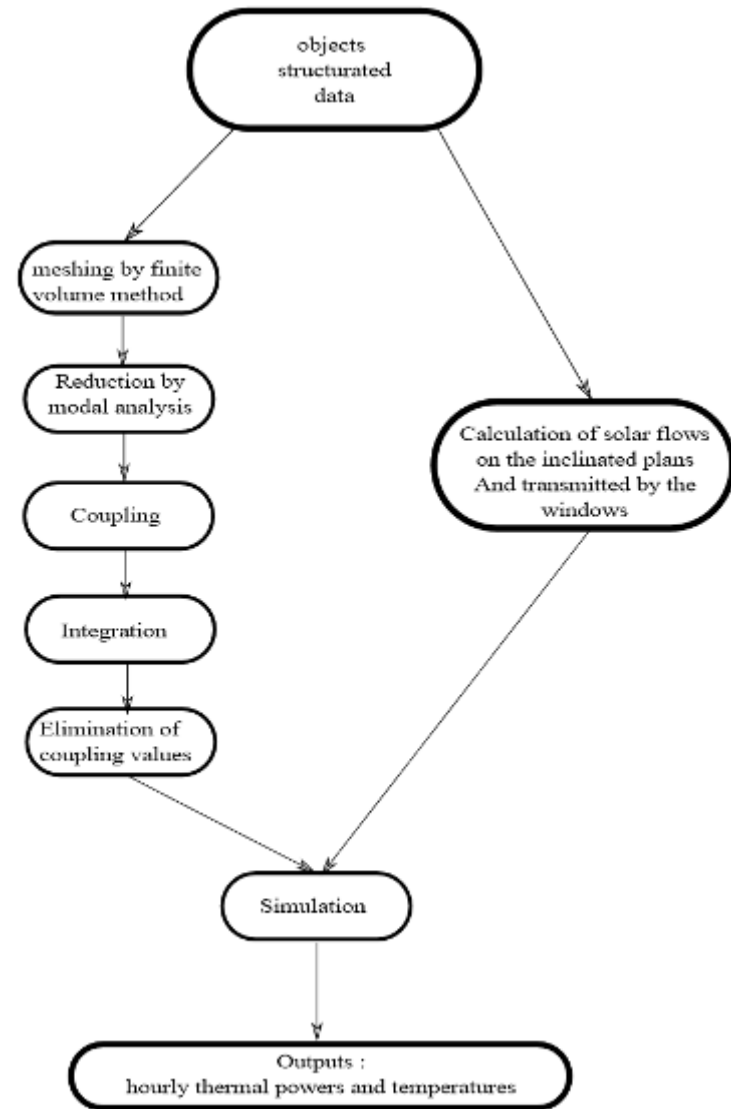
- Only one year used: need of a more wide sample of data
- Simplifying hypothesis: limited number of variable considered for production modelling: $\text{prod} = f(\text{time}, \text{temperature})$
- Sensitivity to temperature problematic: time and temperature partially correlated
- Modelled data built on restrictive bases (infrastructures > 20 MW)
- No consideration for holidays



DYNAMIC LCA IMPLEMENTATION

Modelling of thermal comportment of buildings

- Thermal Dynamic Simulation
- Data available on an hourly time base :
 - Heating needs
 - Cooling needs
 - Specific electricity consumption
 - Occupation scenarios
 - Needs of hot water



Hourly LCA: methodology

- Articulation with existing tools of the hourly differentiation of electricity production and consumption
- Use of models already developed
- Dynamic calculation, on an hourly time basis, of the inventories linked to electricity production and consumption

Hourly LCA: common mix method

- Heating and/or cooling needs
- Hot water needs
- Domestic or professional uses
- Localized electricity production

$$I_{use}(h) = \left(\frac{N(h)}{N(h) + H(h) + Th(h)} * I_N + \frac{H(h)}{N(h) + H(h) + Th(h)} * I_H + \frac{Th(h)}{N(h) + H(h) + Th(h)} * I_{Th} \right) * \frac{B_{use}(h)}{\eta_{network}}$$

Hourly LCA: specific mix method

- Allocation question for impacts, uses of electricity considered as co-products
- Differentiated approach regarding uses, as the one developed before, but on an hourly base:
 - definition of a « base » mix, related to hot water production, constant
 - definition of mix related to seasonal uses, depending of time and temperature
 - « domestic » and « professional » mix, depending of time

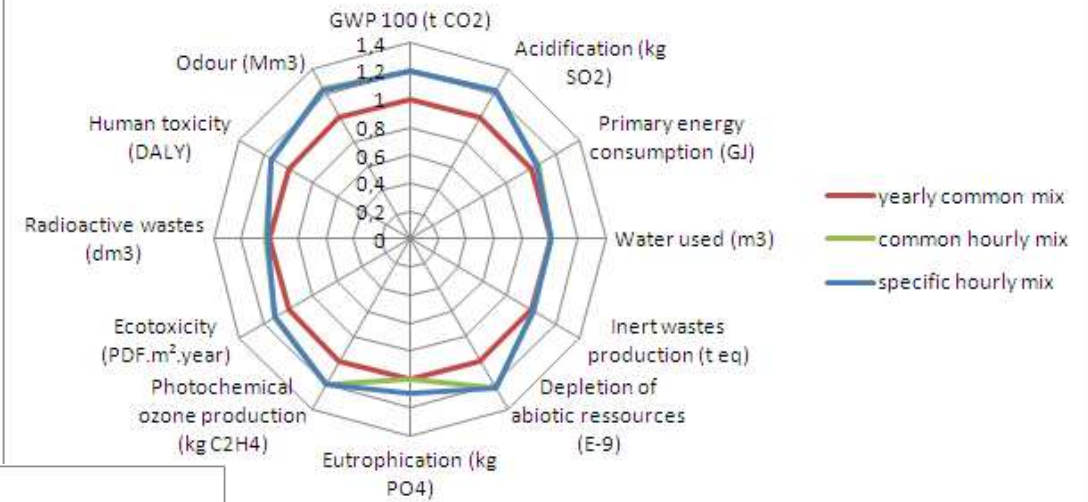
Application: INCAS plus energy house



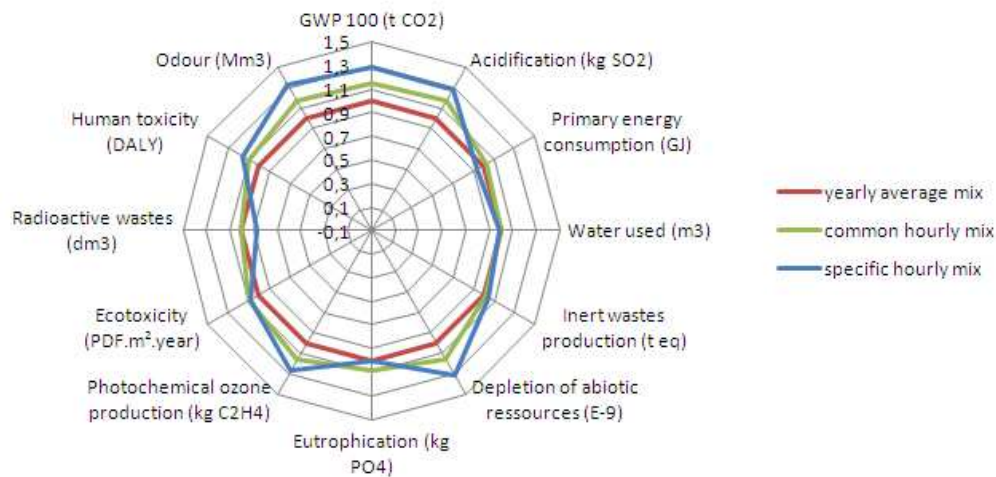
- DTS results: 18 kWh/m²/year
- Alternative I: « all electricity »
- Alternative II: « all electricity », PV and solar hot water production

Methodology comparison for the two alternatives

Solar passive house



Passive house



Conclusions

- The case study is not decisive for LCA results
- Needs for a sensitivity analysis regarding production and consumption volumes
- Dynamic aspects of production and consumption of electricity are taken into account, this can permit a better comparison of technological options (particularly for local electricity production)
- Interesting for peak consumption limitation strategies

Perspectives

- Needs for sensitivity analysis
- Production analysis: use of a wider set of data (more years), better modelling (other aspects, variables), integration of infrastructures of less than 20 MW (cogeneration)
- Other dynamic aspects to consider: evolution of components characteristics (insulation, technological systems), consequential LCA, probabilistic evolution of energetical context