

# Optimisation and control of energy lighting consumption in offices

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Architecture et Climat

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# Introduction

- Work done during a master thesis at UCL in collaboration with BBRI and continued at the architecture and climate unit of the UCL
- Reducing the energetic consumption of office would surely pass through a reduction of lighting consumption
- This need a good knowledge of what is achievable
- Objectives of this work :
  - Identify the comportment of different lighting equipments and different lighting control systems
  - Use these results to predict and to optimise the consumption of lighting



# Contents

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- First part : measurement of the consumption of several lighting systems
- Second part : prediction and optimisation of lighting consumption in a single office
- Conclusions



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# First part : Equipment Analysed

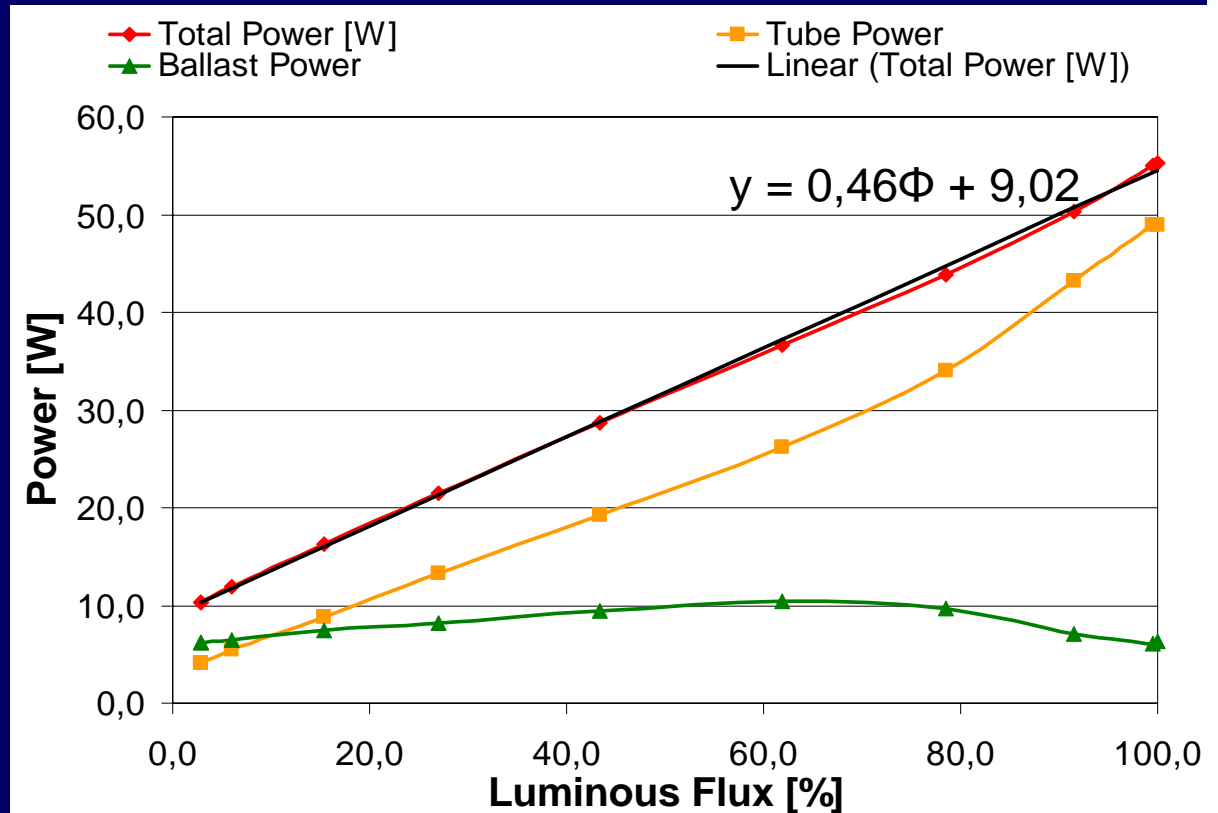
- Fluorescent lamps : T8 tubes
- 2 kinds of tubes : classical "133" or high efficient tri-phosphor "840"
- 2 kinds of control gear : ferromagnetics or electronics
- 2 ranges of power : 58 or 36 W
- 2 kinds of controls : single captors or centralised controllers controlling presence and/or daylight
- 2 kinds of command : digital (DALI) or analog (1-10V)



# First part : Results

Example : Analog System (58W Philips TLD super 80 with Philips HFR 1-10 DIM)

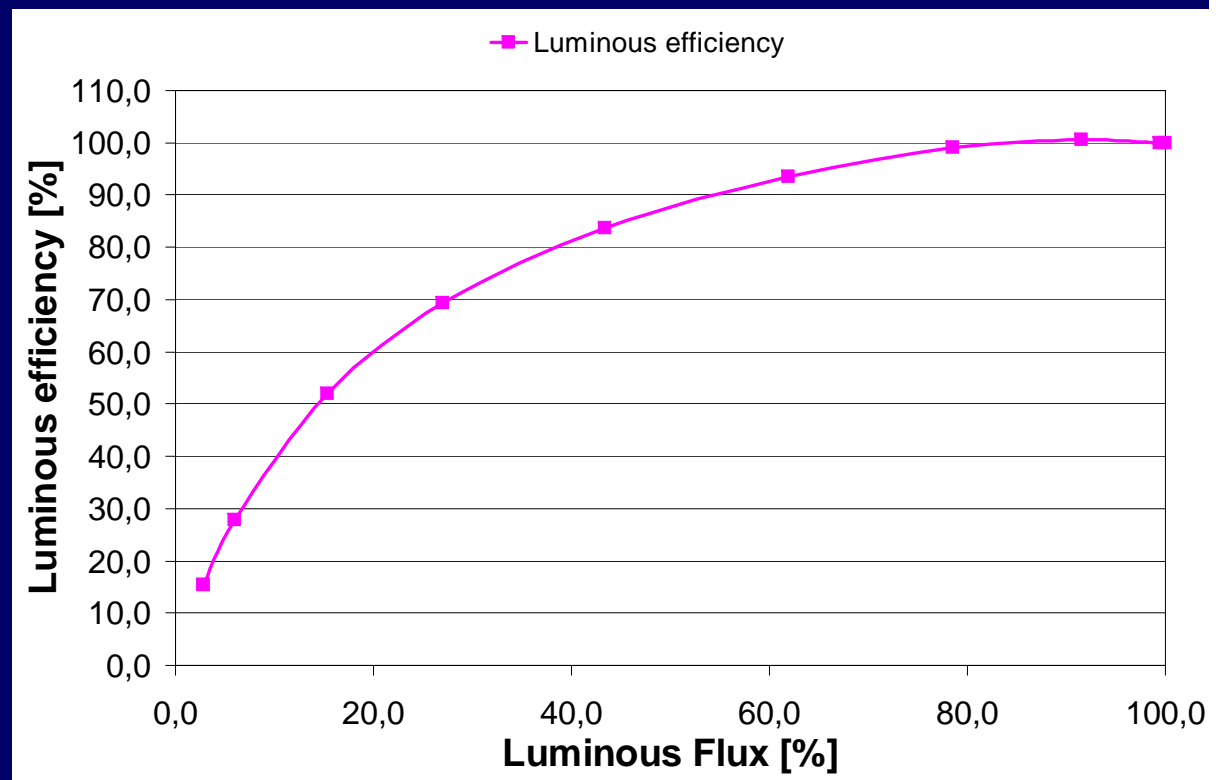
- Linear relation between  $P$  and  $\Phi$ :  
 $P = 0.46\Phi + 9.02$
- Ballast Power quite constant whatever the flux
- For  $\Phi = 0$ ,  $P > 0$



# First part : Results

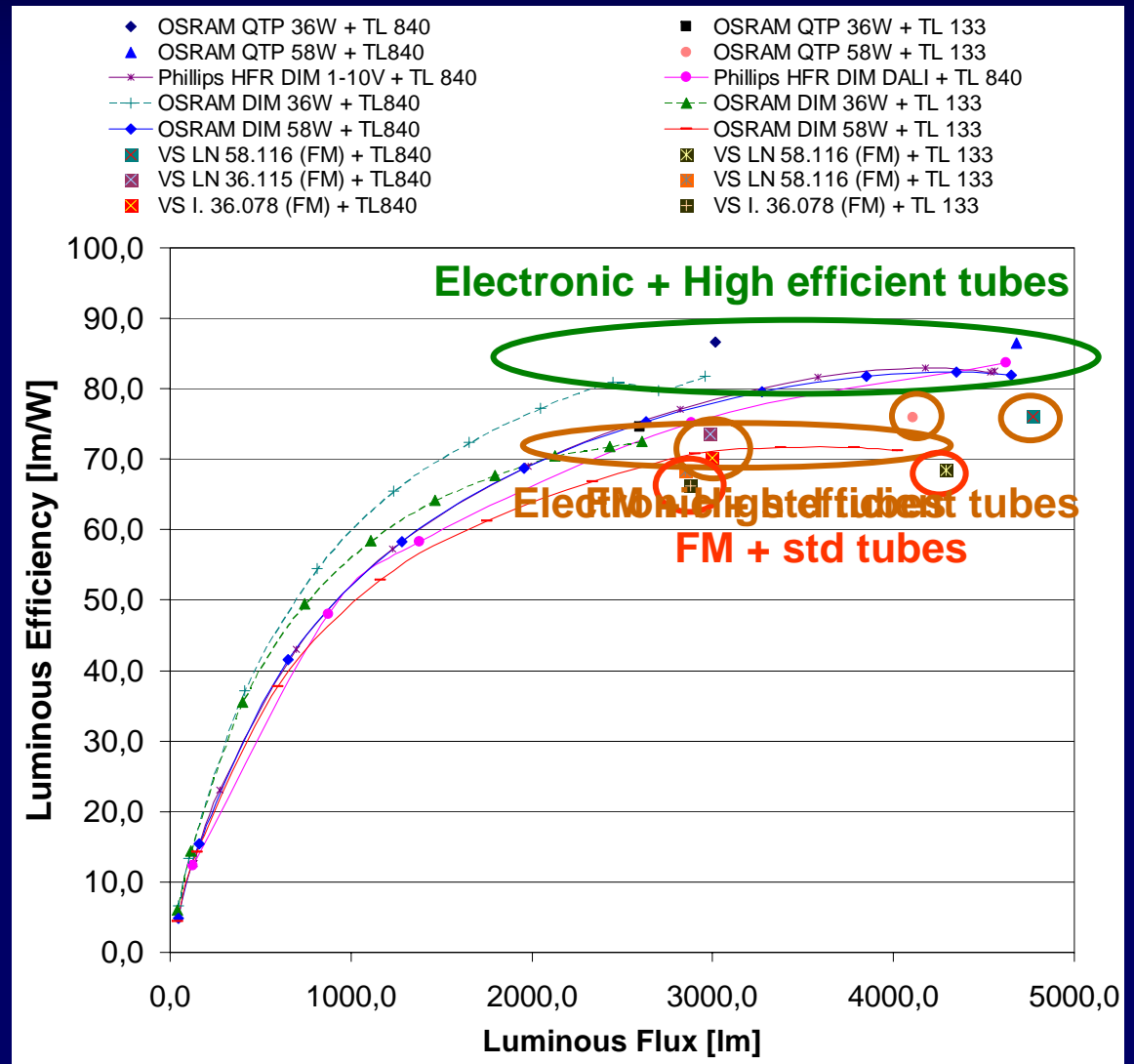
Example : Analog System (58W Philips TLD super 80 with Philips HFR 1-10 DIM)

- Maximum luminous efficiency for a maximum flux
- Very small luminous efficiency at small flux (due to ballast power)



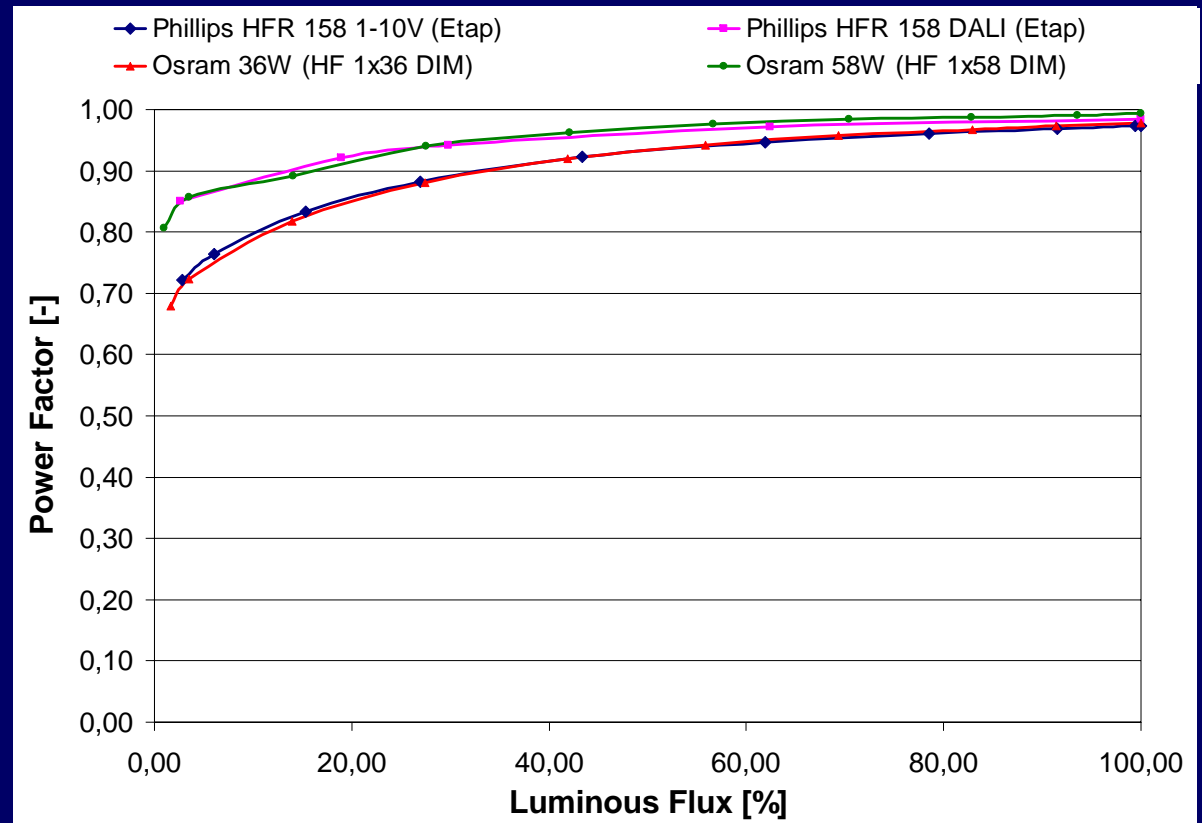
# Results : Comparison

- Better efficiency for electronic ballasts (~10%)
- Better efficiency for high-efficient tubes (~12%)
- Same efficiency (at maximal flux) for dimmable ballasts
- Same efficiency (at same relative flux) for 36W and 58W



# Results : Power factor

- Decrease of the power factor when dimming
- In large buildings, difficulty to forecast and to balance with capacitors



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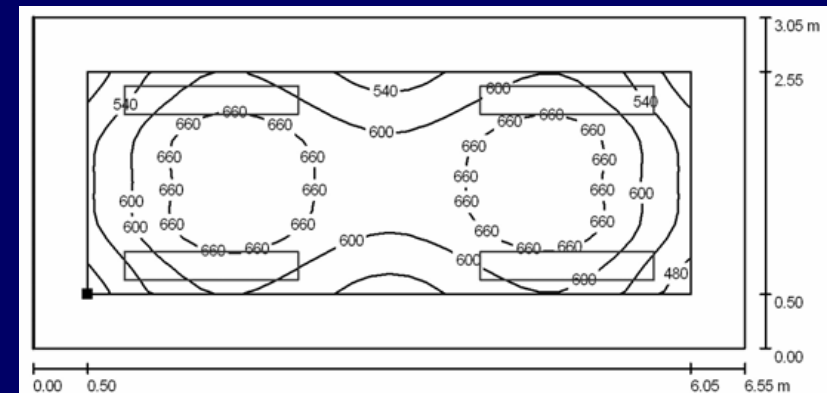
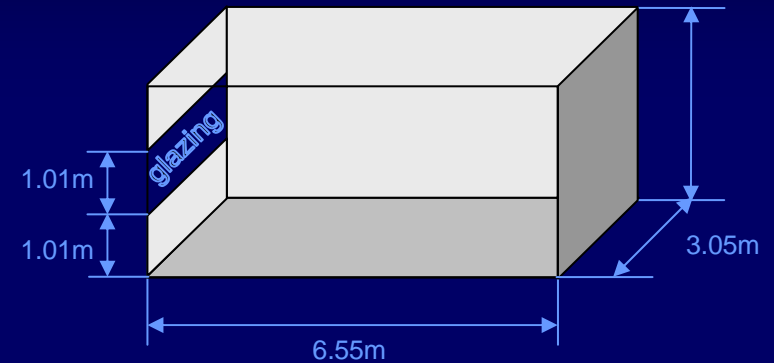
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# Second part : Simulations

- One room of arbitrary dimensions
- Three locations : Athens, Brussels, Stockholm
- Four orientations : N, S, W, E
- Four luminaires in two rows



# Second part : Control Systems

- **IDDS (ELS)** : Daylight Regulation (closed loop sensor)
- **MDD** : Presence Regulation (dimming at 3% of full flux)
- **MDS** : Presence Regulation (switching)
- **IDDS+MDD** or **IDDS+MDS** : Daylight Regulation while presence. Dimming or Switching while absence
- Night time switch



# Second part : Modelling (IDDS)

- Iterative process :

- Under each sensor : Daylight (DAYSIM) + Artificial light (DIALux) = set point

$$E_{dl,i}(t) + \sum_{j=1}^n \tau_j(t)E_{j,i} = SP$$

- For each luminaire, we can calculate the dimming rate in function of daylight and the state of the others luminaires

$$\tau_i(t) = \frac{SP - E_{dl,i}(t) - \sum_{j=1}^n \delta_{i,j} \tau_j(t) E_{j,i}}{E_{i,i}}$$

- We make an iteration for each luminaire

$$\tau_{i,k}(t) = \frac{SP - E_{dl,i}(t) - \sum_{j=1}^n \delta_{i,j} \tau_{j,k-1}(t) E_{j,i}}{E_{i,i}}$$

- The power can be found with results of first part :  $P = 0.46x + 9.02$

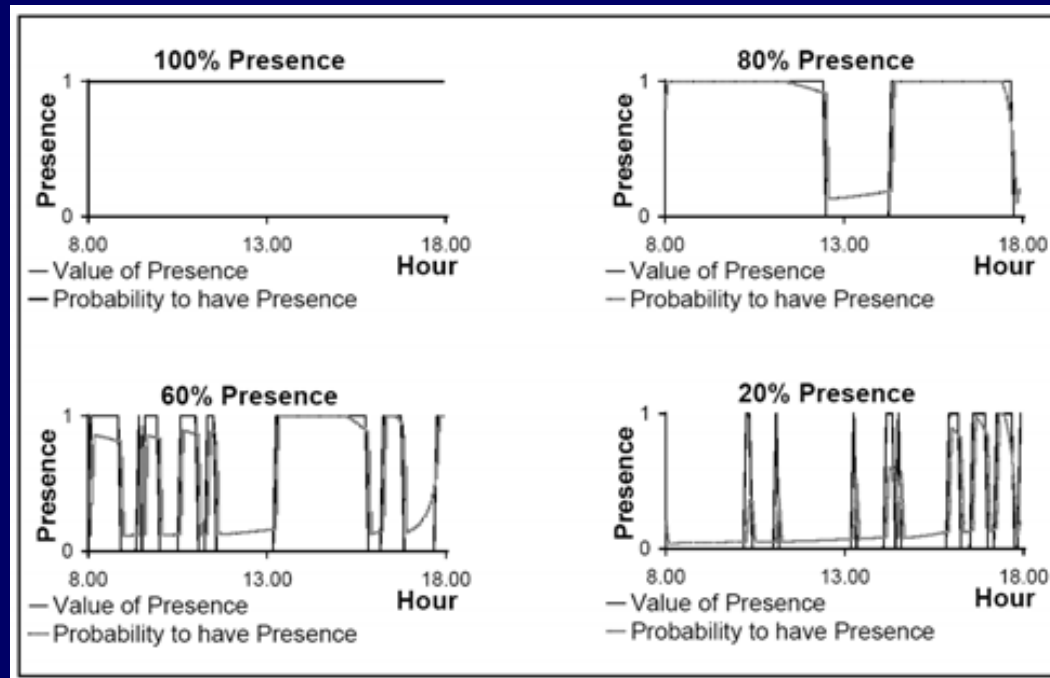


# Second part : Modelling (Presence)

- Dimming rate depends on the presence

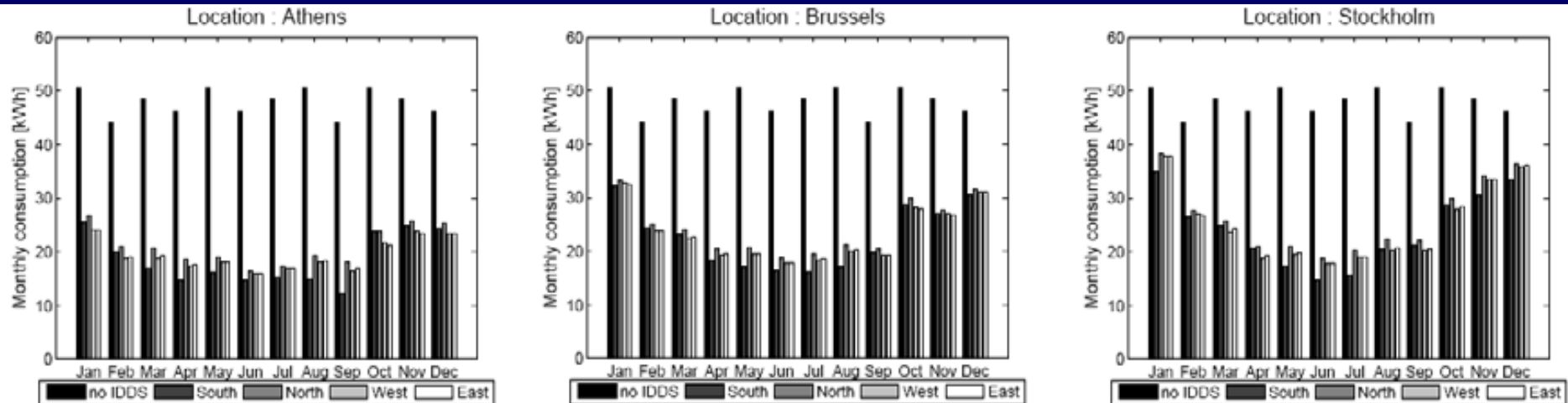
$$\tau_i(t) = P(t) \cdot \tau_{on,i}(t) + (1 - P(t)) \cdot \tau_{off,i}(t)$$

- Presence ( $P(t)$ ) following a probabilistic reasoning



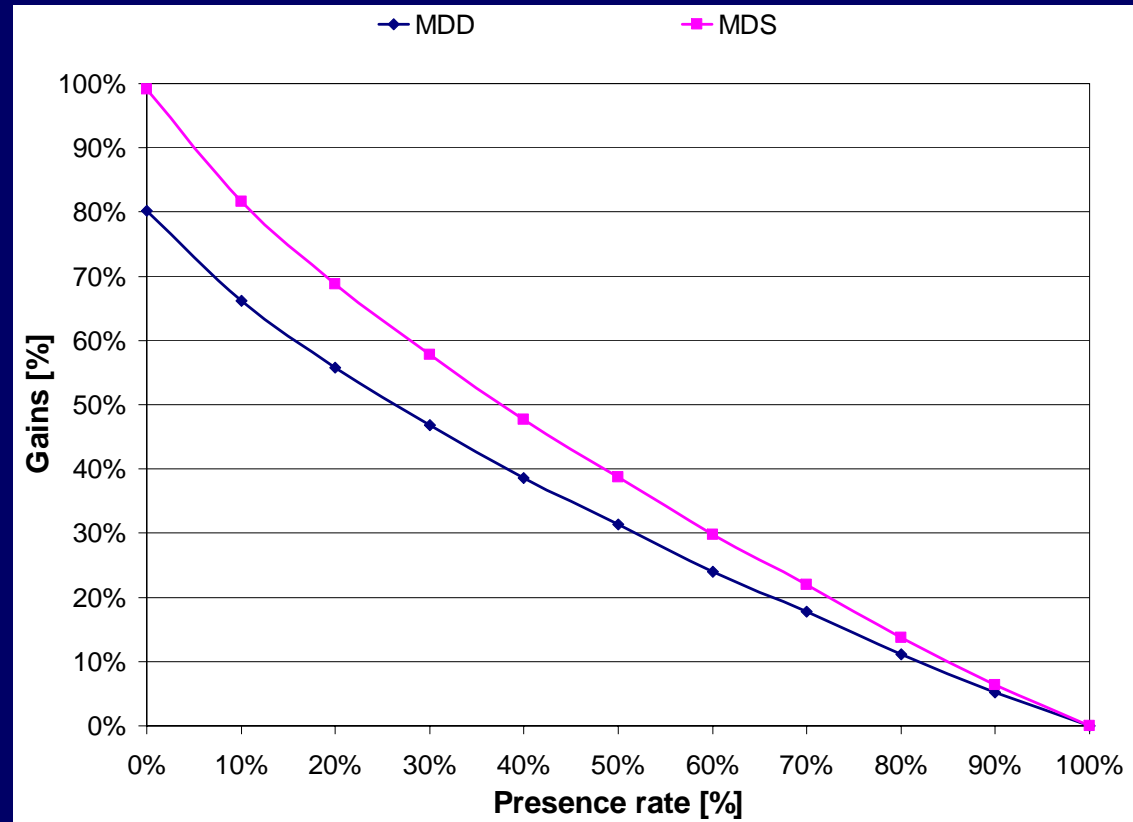
# Second part : Results (IDDS)

- Better gains in low latitudes countries due to daylight availability (~5-10%)
- Better gains for South orientations (~7-12%)
- Even in the worst cases, important gains (more than 45%)
- Annual consumption proportional to the desired workplace illuminance
- More sensors leads to better comfort and less consumption
- If one sensor : centre of the room



# Second part : Results (MDD/MDS)

- Linear relation between consumption and switch-off delay
- Not a linear curve between gains and presence (due to delay before switching/dimming)
- Gains  $\neq$  100% when presence = 0 (due to parasitic consumption)
- MDS better for consumption
- MDD interesting in landscape offices (visual reasons)



# Second part : Results

- MDD better than IDDS when presence is less than 15 to 30%
- MDS better than IDDS when presence is less than 25 to 40%
- Centralised control (Analog or Digital (DALI)) energetically profitable when only one controller can replace single presence detectors of at least four luminaires. So avoid embedded DALI controllers.
- Importance to install a scheduler to switch off the installation during the night



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# Conclusions

## ■ Summary of achievable gains :

- Install Electronic ballast in place of ferromagnetics 10 %
- Choose High efficient “tri-phosphor” tubes 12 %
- Choose for daylight regulation 45 to 60%
- Presence control Variable
- **TOTAL** **Min 60%-70%**



**Thank you**

For more Information :

B. Roisin, M. Bodart, A. Deneyer, P. D'Herdt, *Lighting energy savings in offices using different control systems and their real consumption*, accepted for publication in Energy and Building.

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