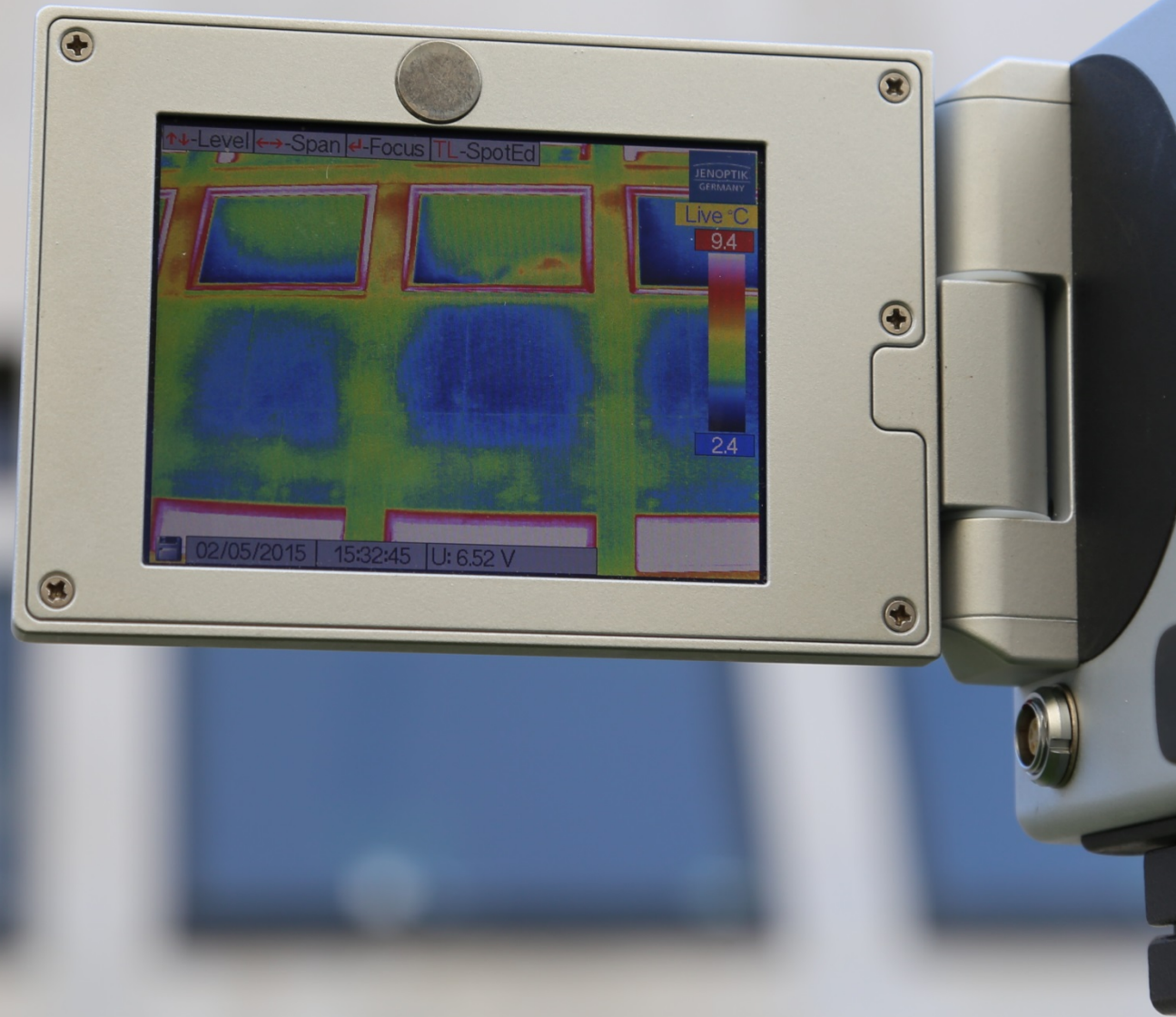


# ‘Technologies to allow behaviour change to save energy: The APERIO project’

B58 / 1067  
18<sup>th</sup> May 2016

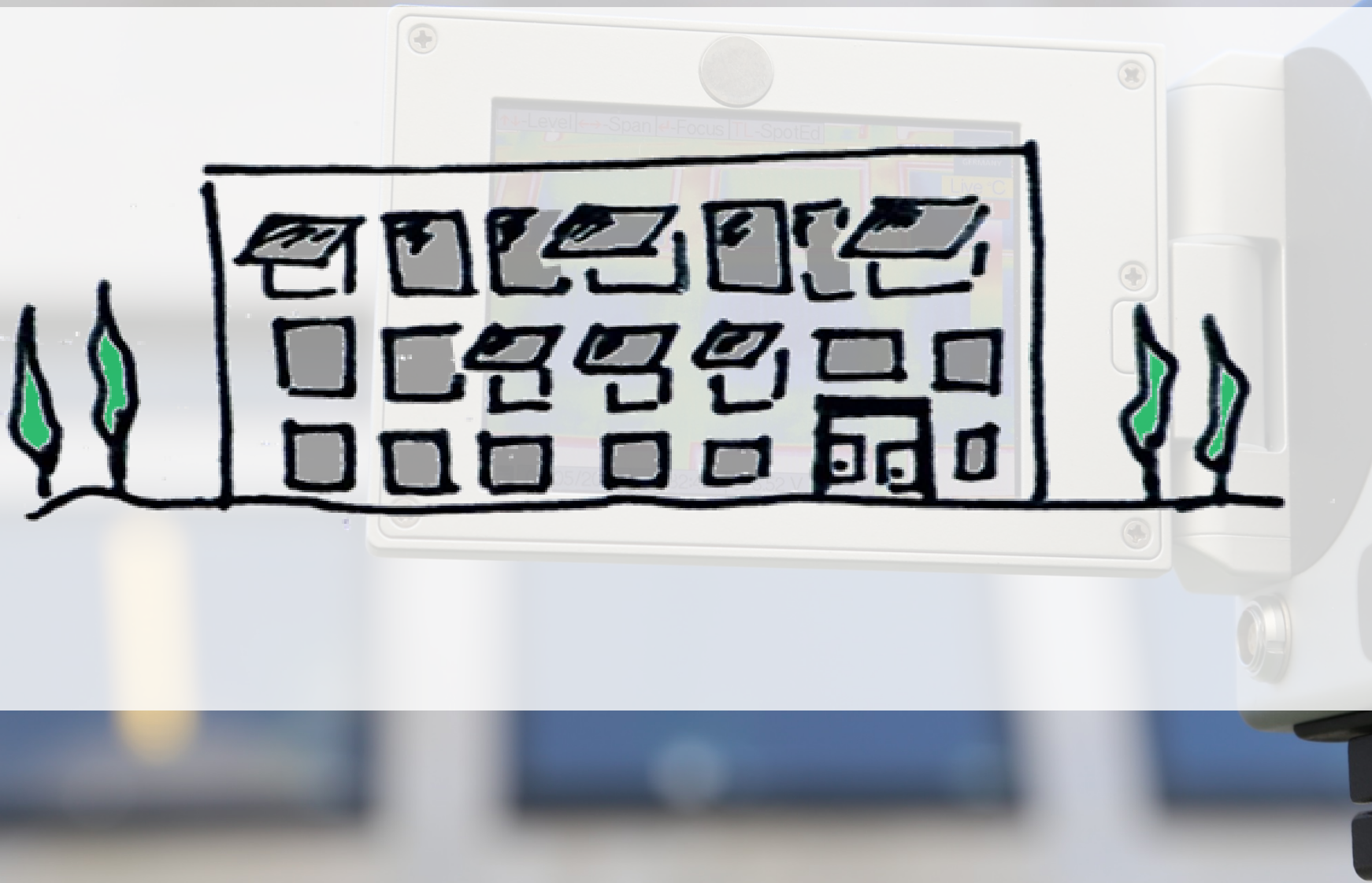
Patrick James (and ... Rogers A., Costanza E., Ornaghi C., Saadatian E.,  
Kittley-Davies J., Bourikas L. & Rushby T.)  
Faculty of Engineering & Environment / ECS / Social Sciences  
University of Southampton

Heating is the major issue in the UK





Heating is the major issue in the UK



# Heating is the major issue in the UK

OPTIONS?

REDUCE THE HEAT LOSS RATE (INSULATE)

SUPPLY THE HEAT MORE EFFICIENTLY (NEW BOILER)

BEHAVIOUR CHANGE





# Performance Gap

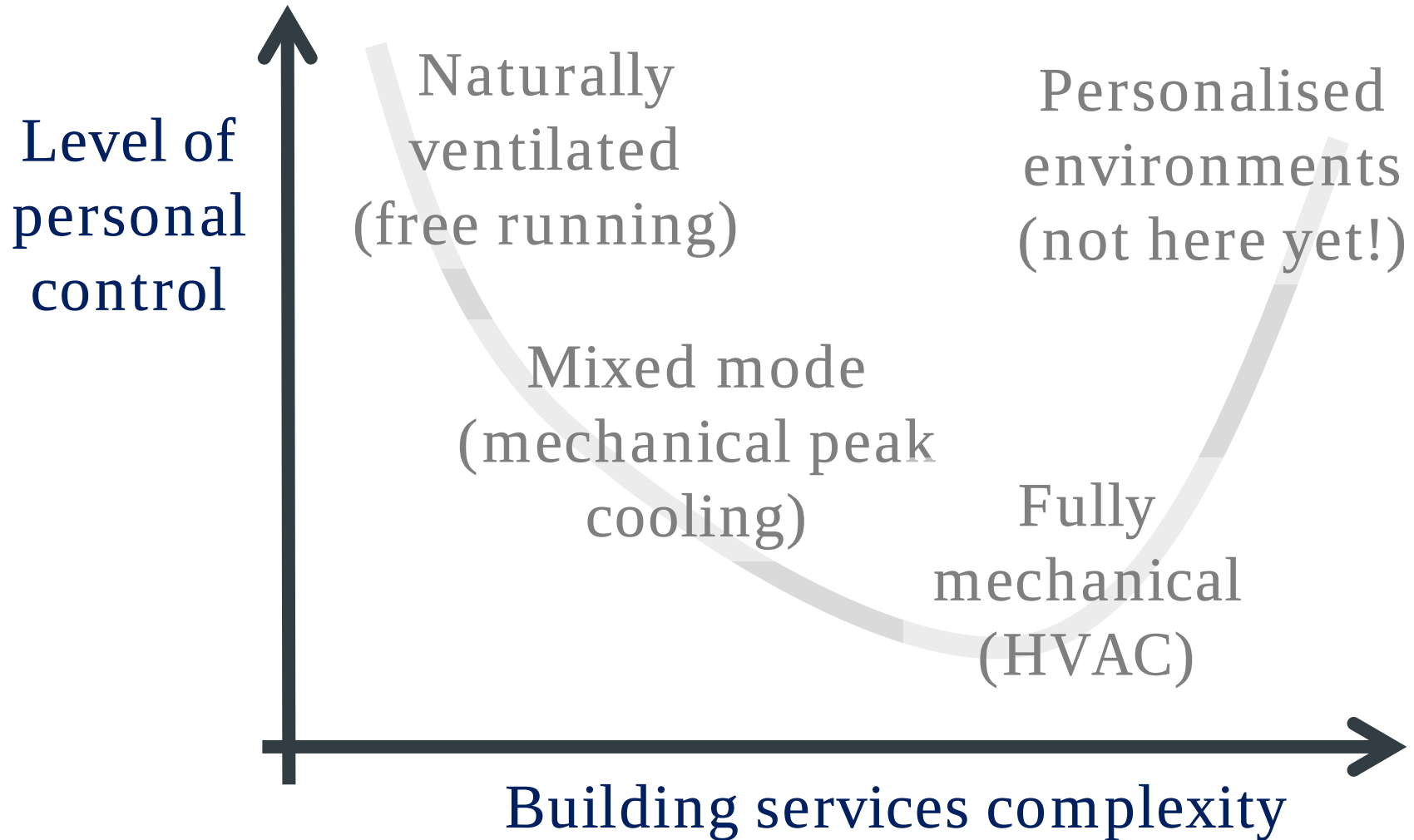
*'Actual performance is almost always WORSE than predicted performance'*

*Why?*





# Windows in offices and residential blocks





# Windows

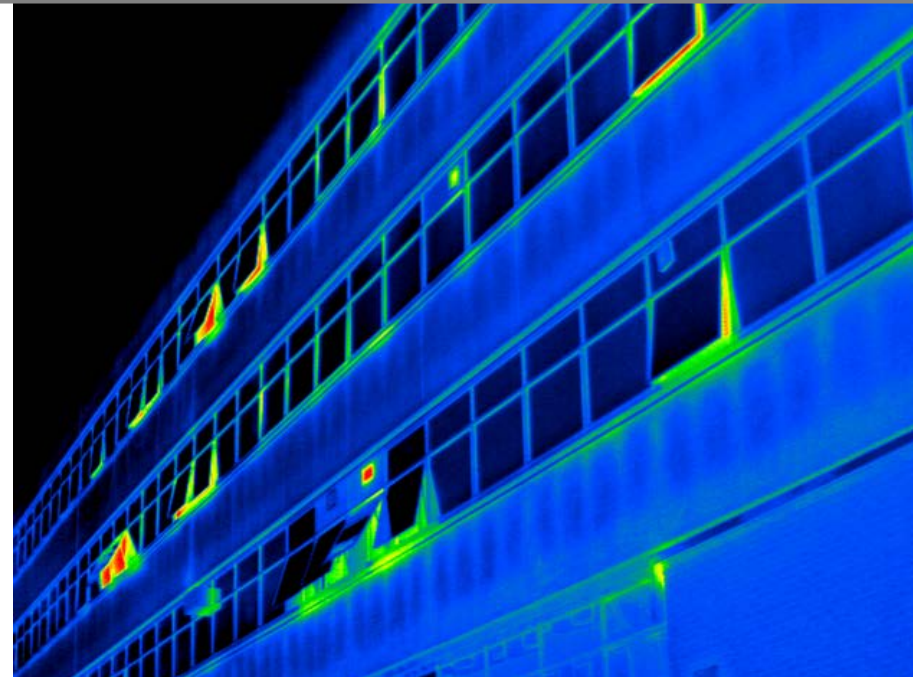
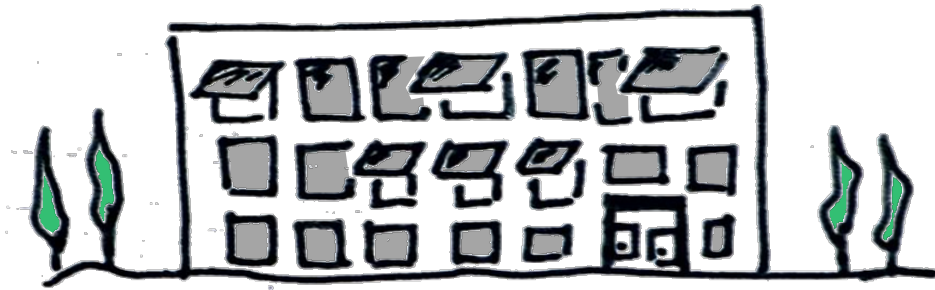


Naturally ventilated  
(free running)



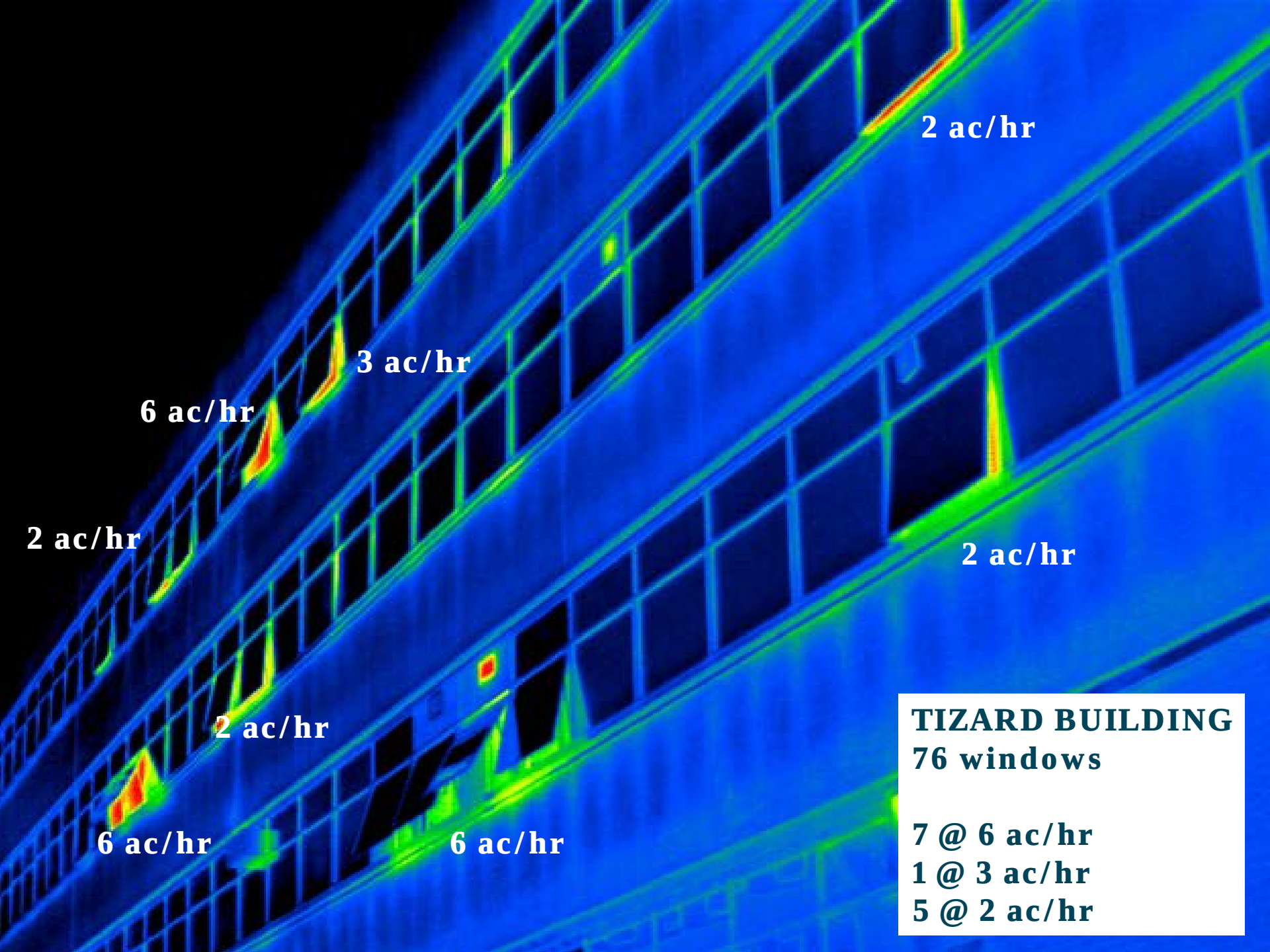
Mixed mode  
(mechanical peak cooling)

# Windows in an office?



University  
office building





**6 ac/hr**

**3 ac/hr**

**2 ac/hr**

**2 ac/hr**

**2 ac/hr**

**2 ac/hr**

**6 ac/hr**

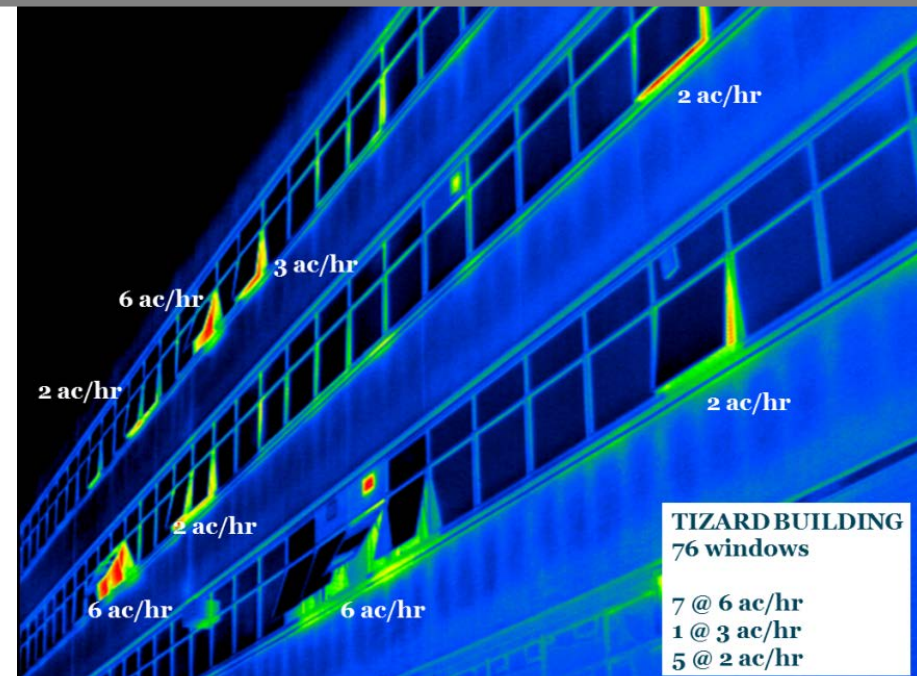
**6 ac/hr**

**TIZARD BUILDING**  
**76 windows**

**7 @ 6 ac/hr**  
**1 @ 3 ac/hr**  
**5 @ 2 ac/hr**

# Window opening overnight: Impact on building energy performance

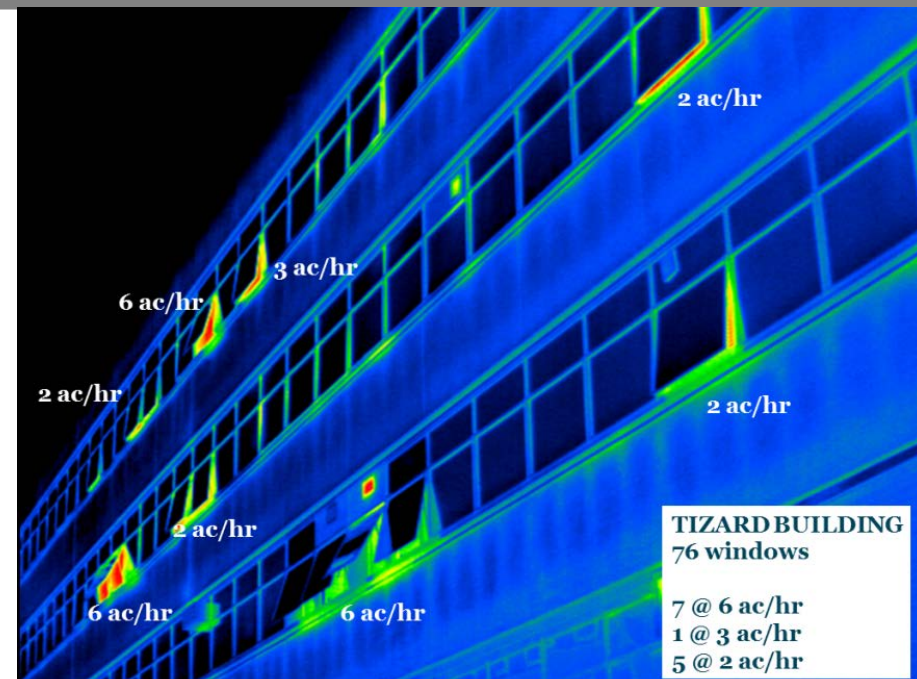
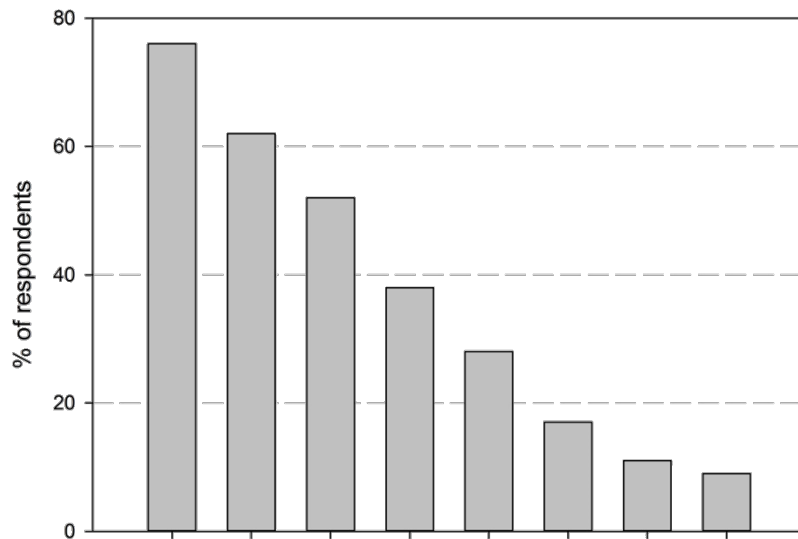
- University Campus space average heating demand = 200 kWh/m<sup>2</sup> annum.
- Impact of window opening = 23 kWh/m<sup>2</sup> annum.





This raises some questions...

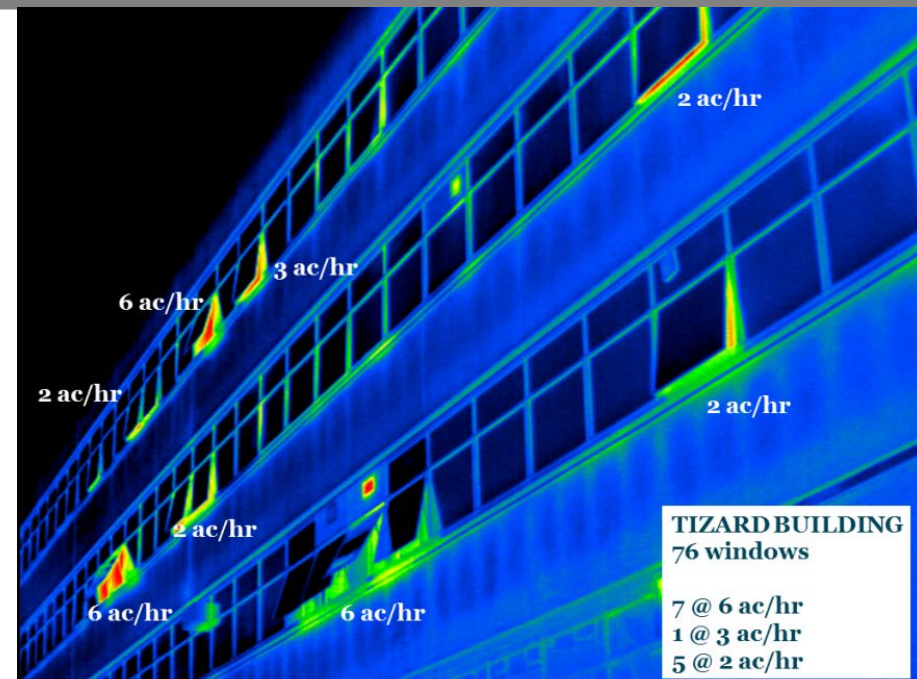
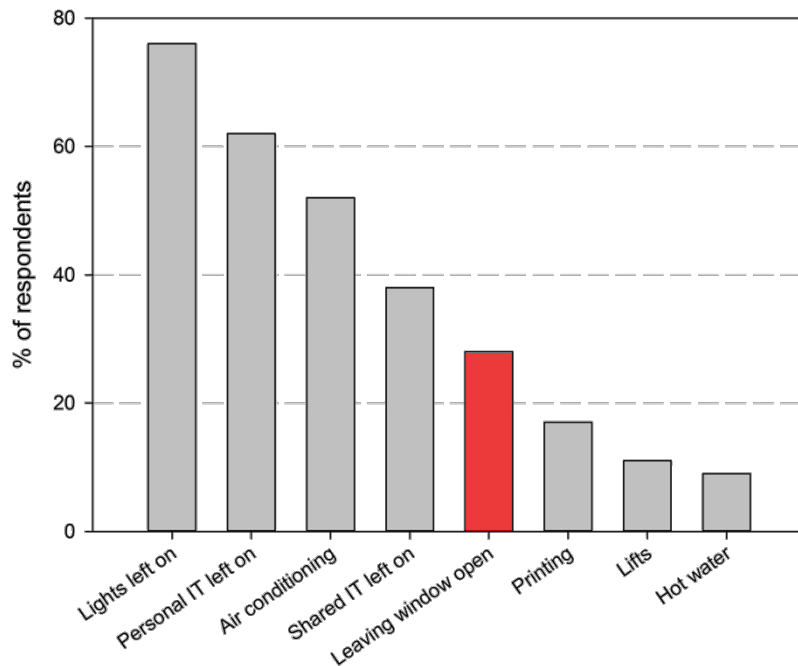
‘Awareness’ of office users of windows as an issue?



UoS office users ‘perceptions of wasteful behaviour’  
APERIO 2015

This raises some questions...

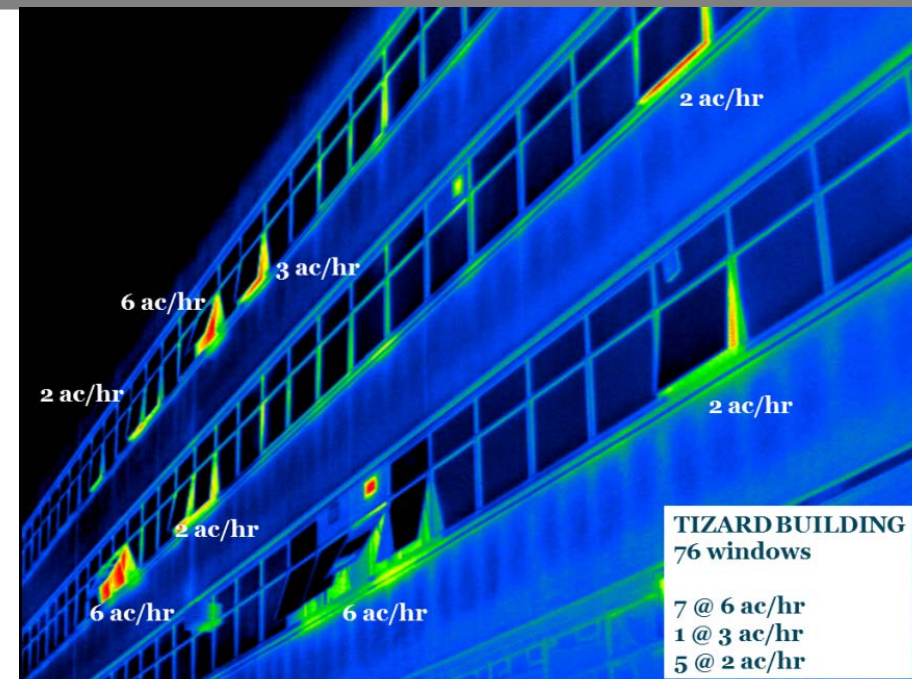
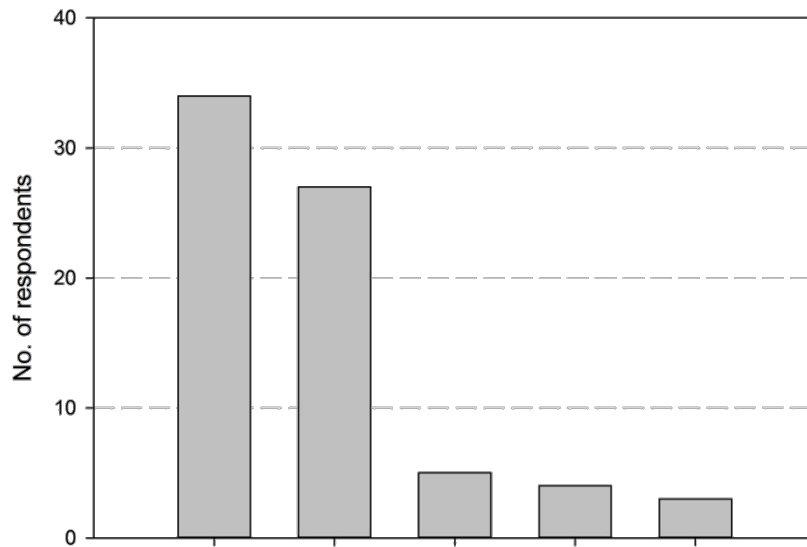
‘Awareness’ of office users of windows as an issue?



UoS office users ‘perceptions of wasteful behaviour’  
APERIO 2015

This raises some questions...

‘Awareness’ of office users of windows as an issue?

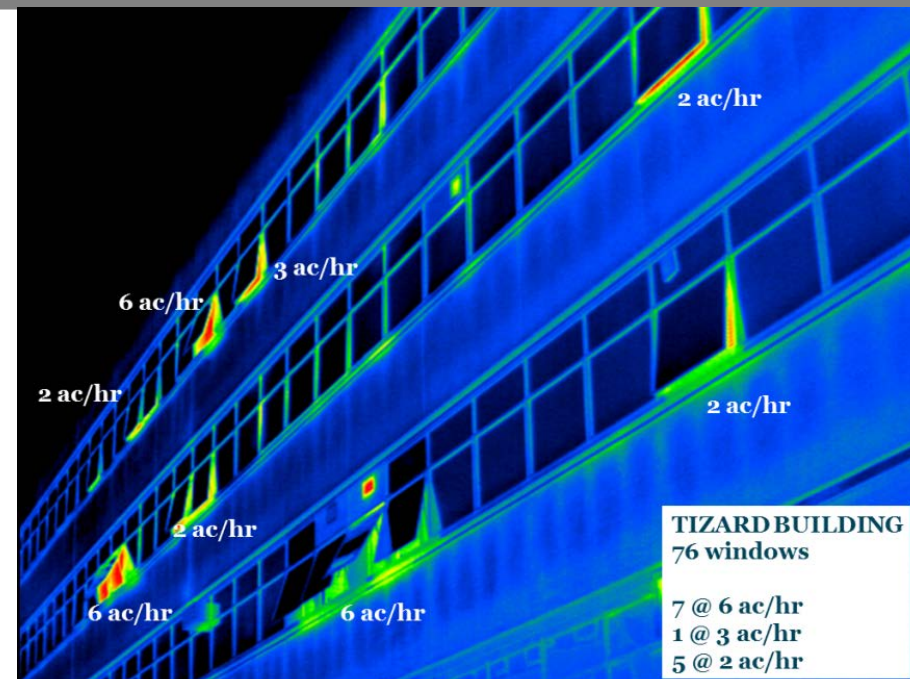
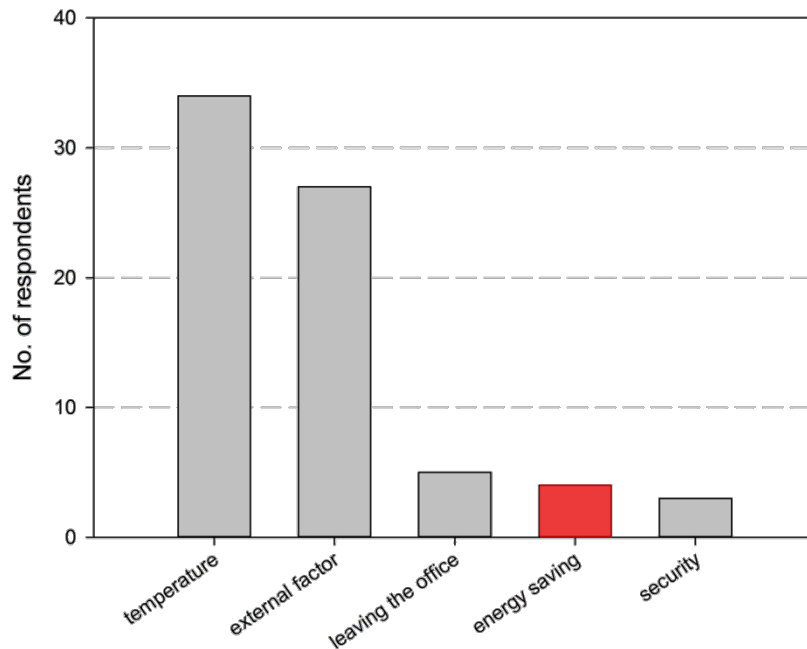


UoS office users ‘factors leading to closing of window’  
APERIO 2015



This raises some questions...

‘Awareness’ of office users of windows as an issue?

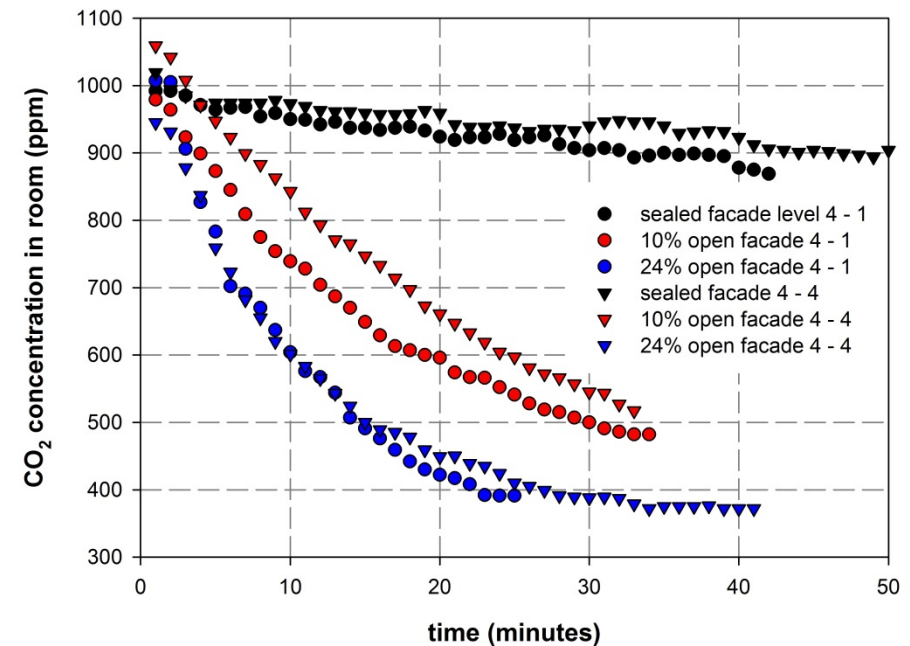


UoS office users ‘factors leading to closing of window’  
APERIO 2015

# APERIO (EPSRC grant, 2015..2017)

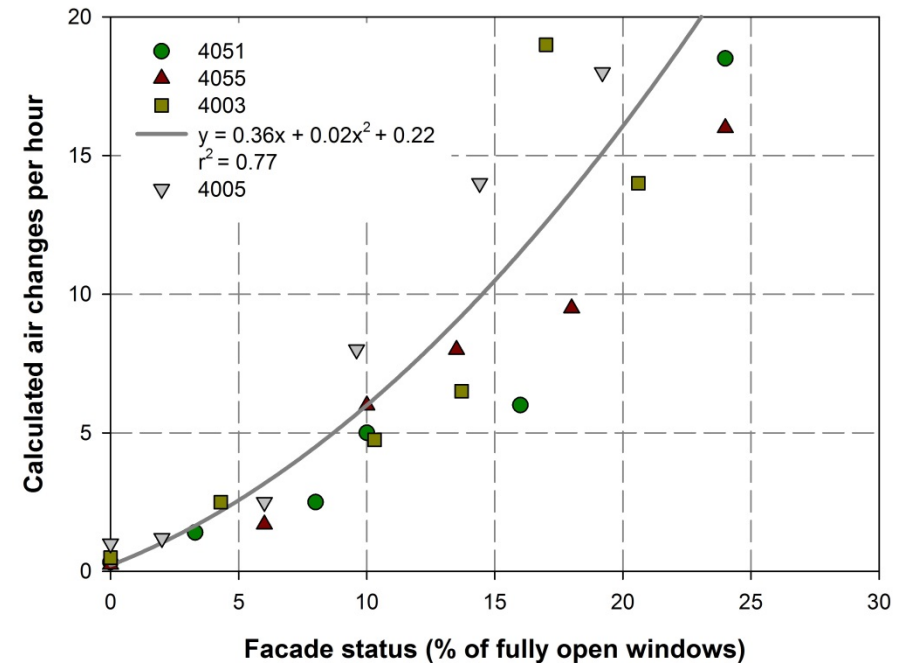


# Quantifying heat loss ...

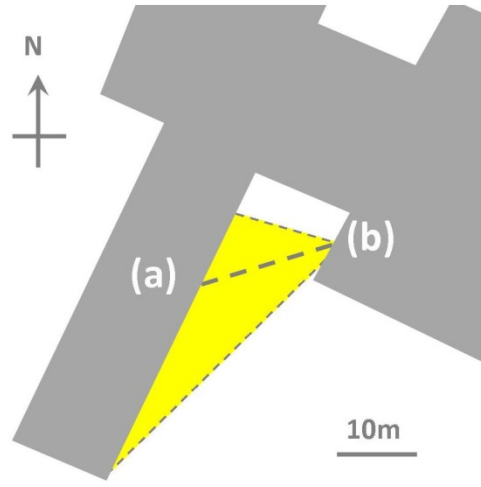
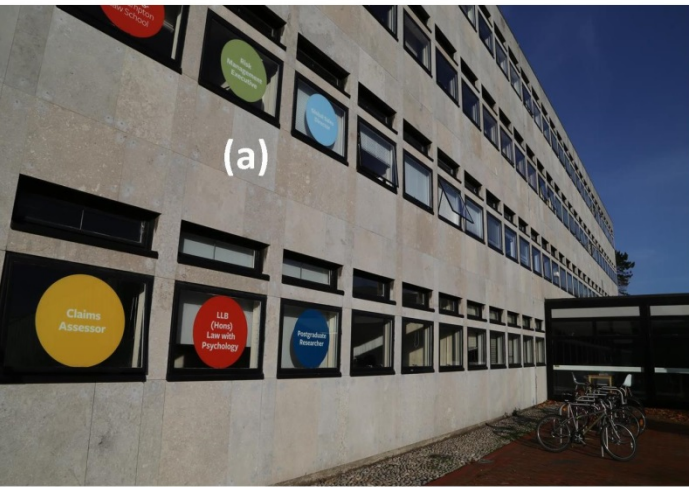




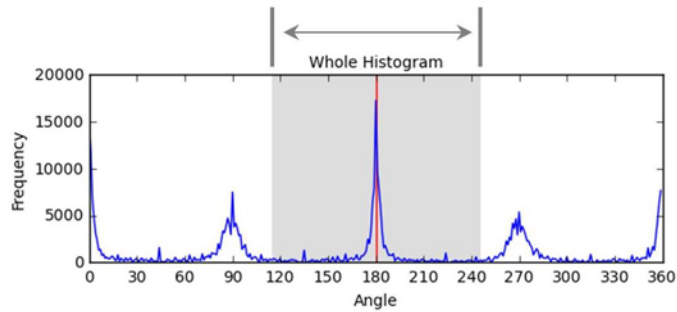
# Quantifying heat loss ...



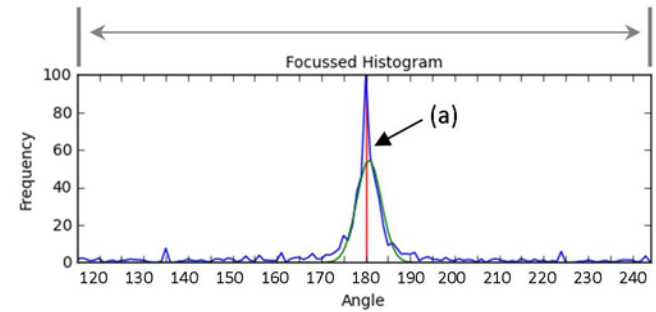
# APERIO (EPSRC grant, 2015..2017)



# Skewness of a frame

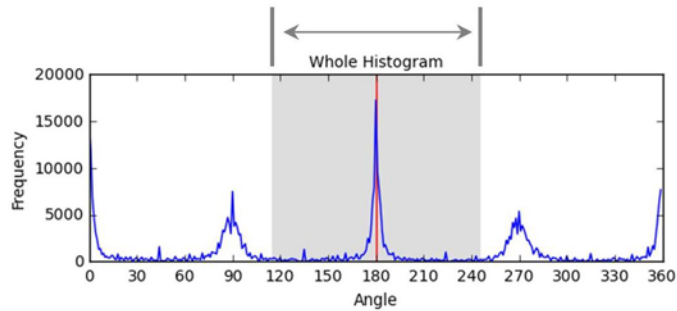


Closed Window

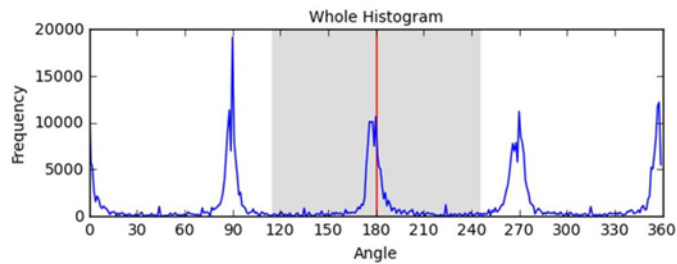
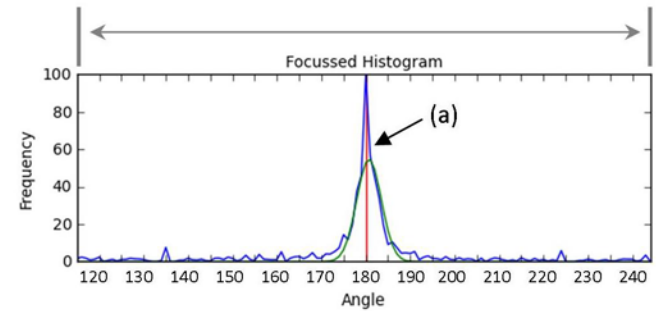




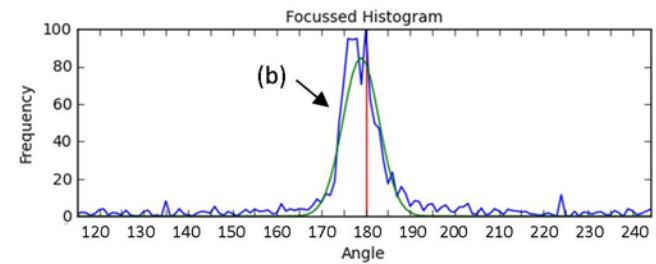
# Skewness of a frame



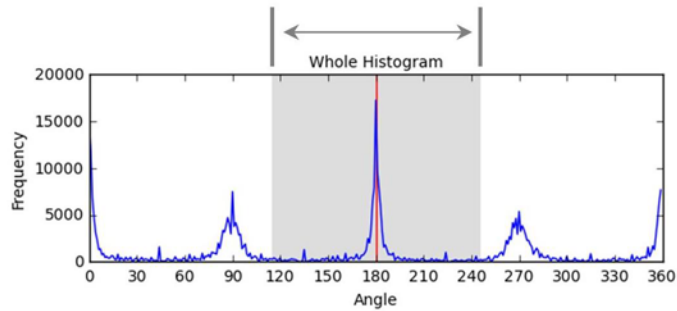
Closed Window



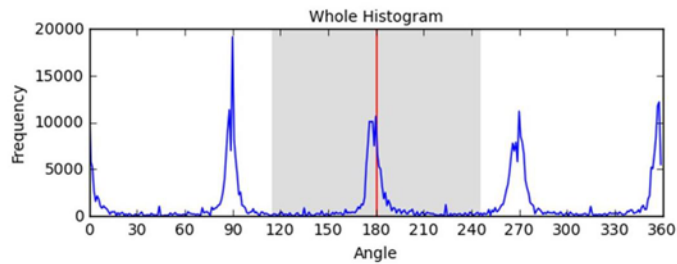
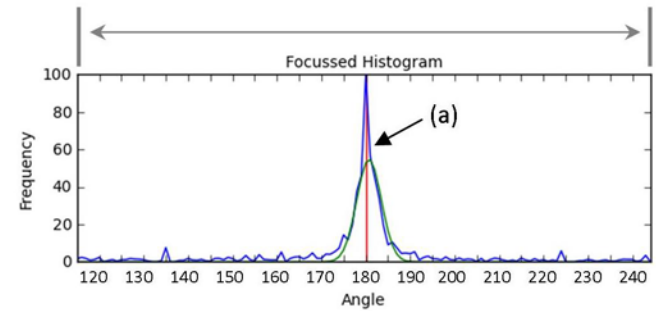
Partially Open



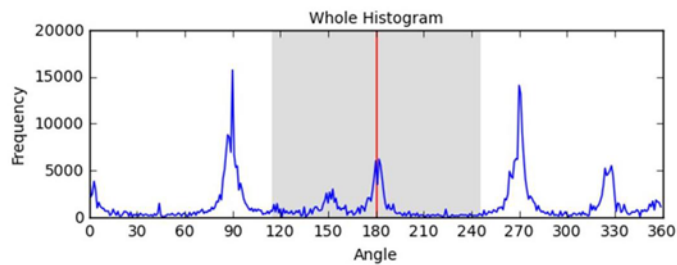
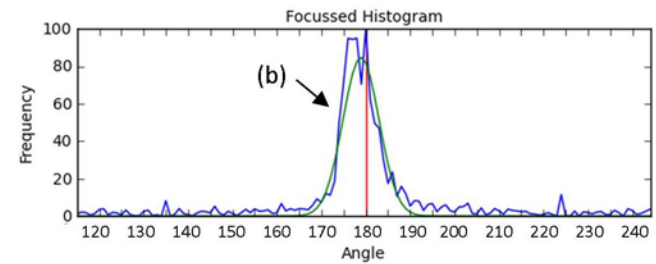
# Skewness of a frame



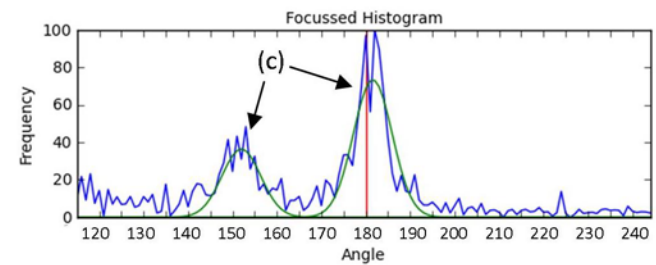
Closed Window



Partially Open



Open Window



# Validation of camera system



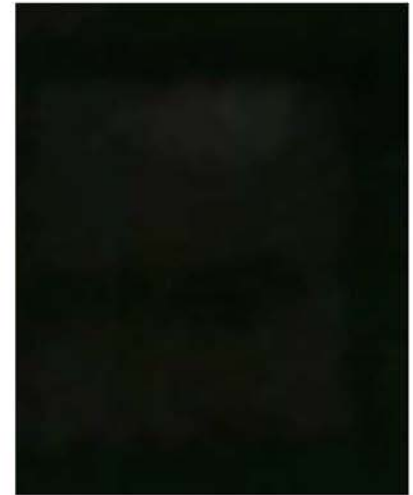
**'open'**



**'closed'**



**'unknown'**



**'too dark'**

Groundtruth 300,000 window states by human eye



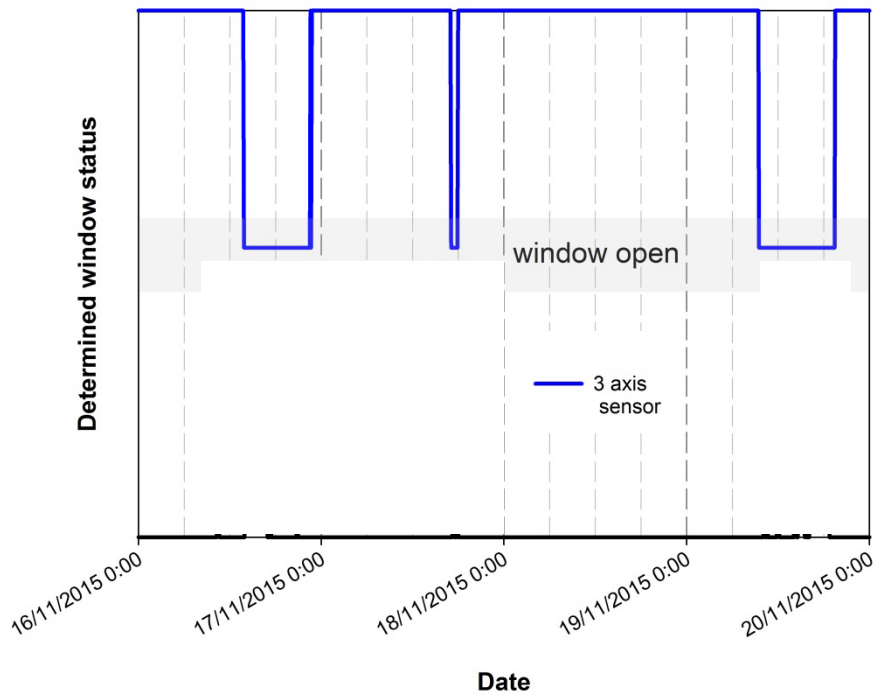
# Validation of camera system



3 axis accelerometer

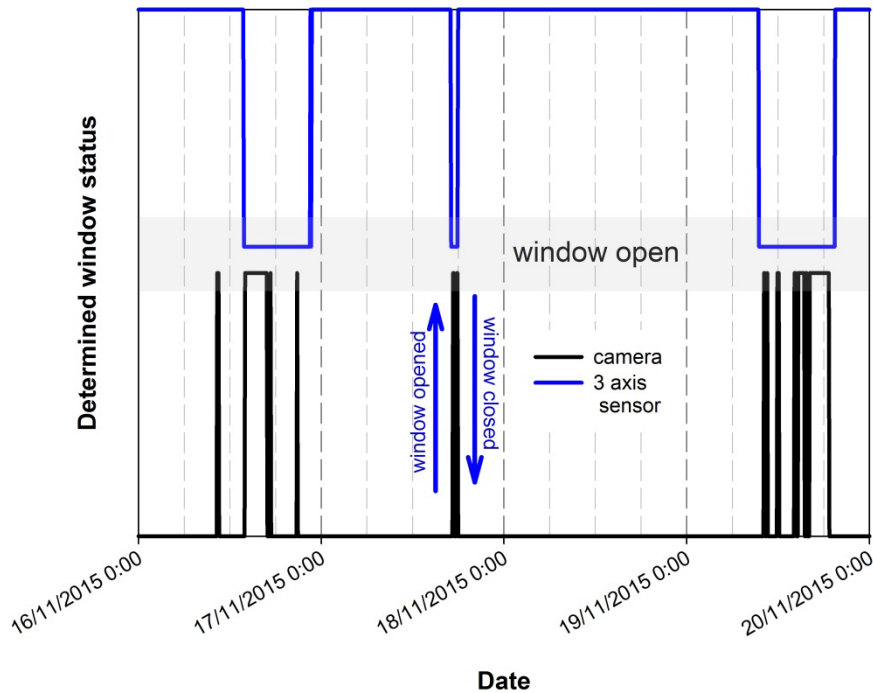
by human eye

# Validation of camera system



Accelerometer = true, angle of 10 degrees

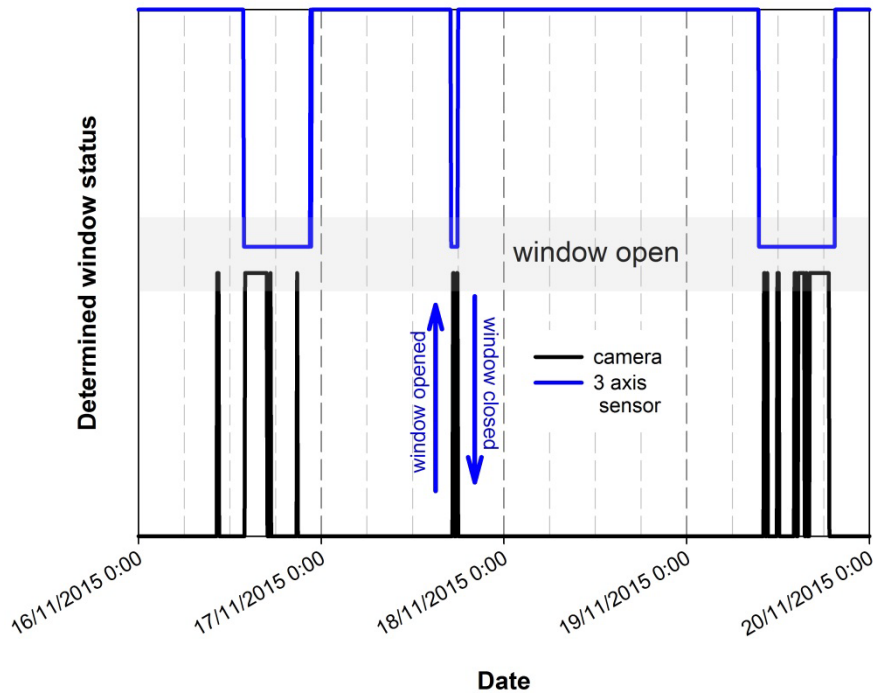
# Validation of camera system



Camera = true, 2 consecutive 5 min 'open' estimates

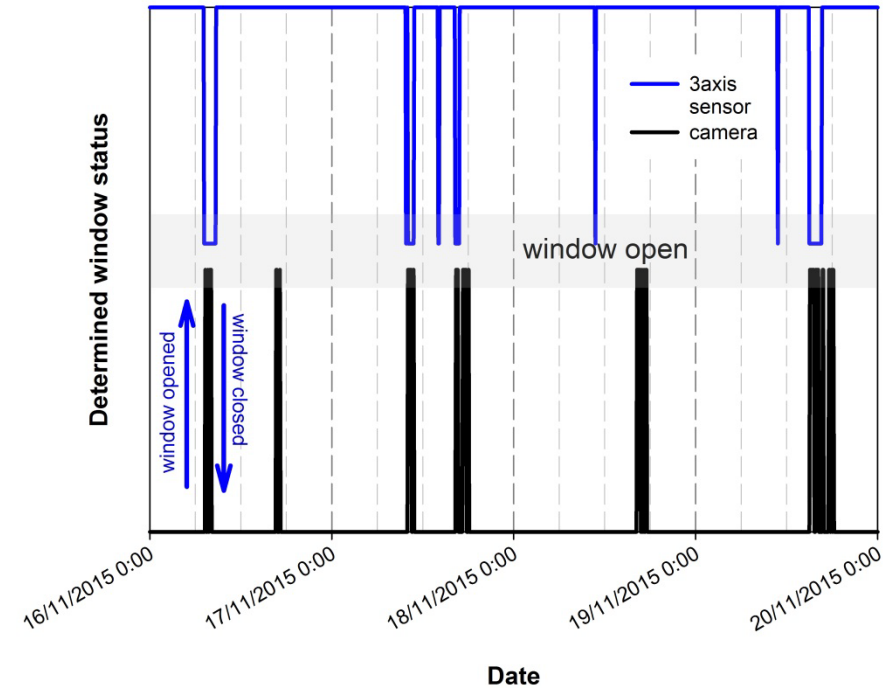
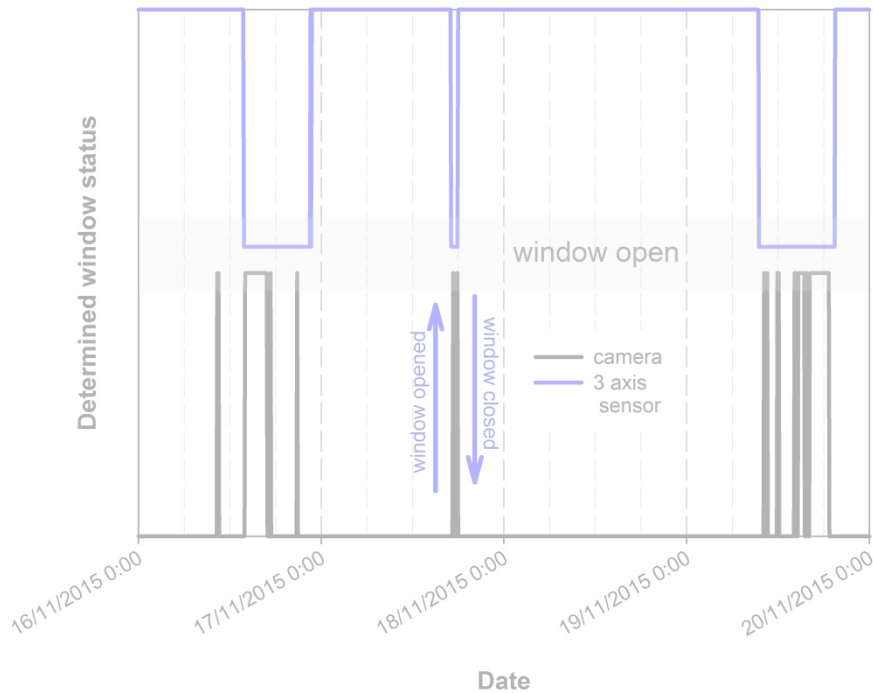


# Validation of camera system



Camera = true, 2 consecutive 5 min 'open' estimates

# Validation of camera system



Camera = true, 2 consecutive 5 min 'open' estimates

# Validation of camera system

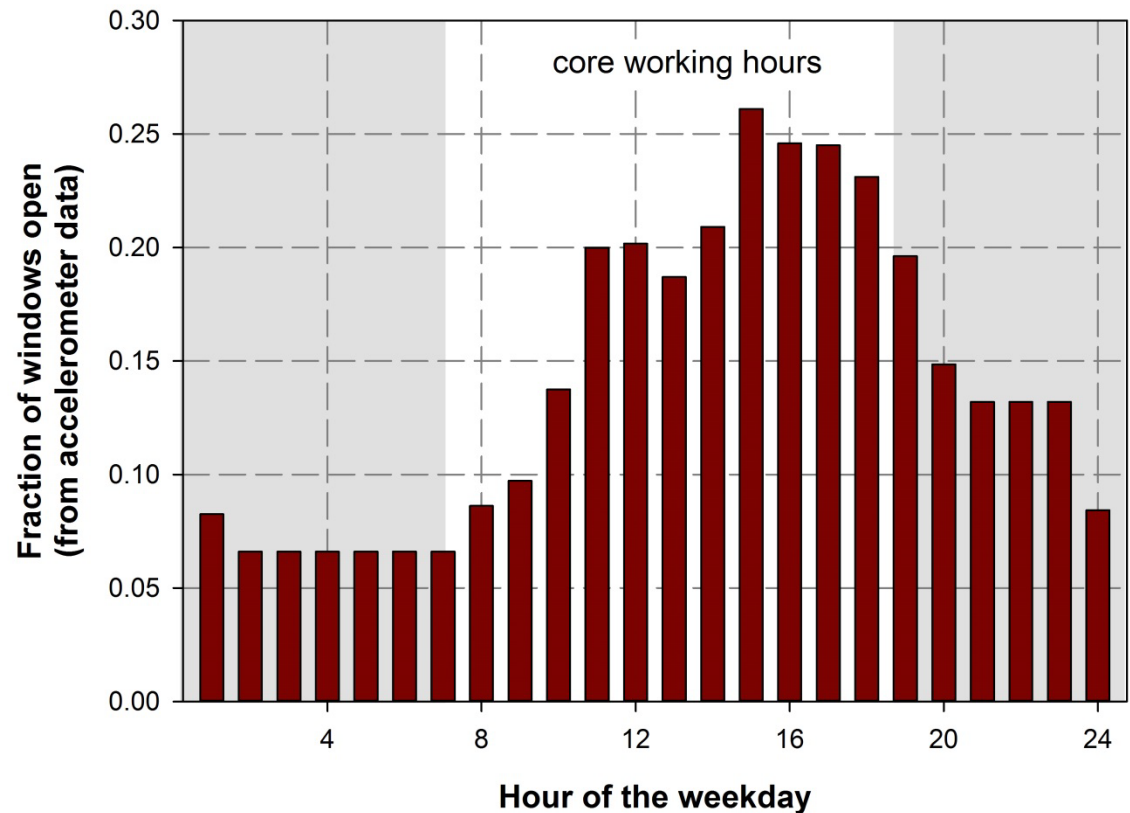


- ☑ > 94% accuracy in both summer and winter operation
- ☒ Sensitive to light levels, raindrops, WiFi stability

# Energy implication of window opening behaviour?

Out of hours:  
10% windows open,  
average angle 20 degrees

19% of annual heating  
load in an F rated  
building





Next steps ...  
Multiple buildings





Next steps ...  
Engaging building users



£££

CO<sub>2</sub>



Next steps ...  
Engaging building users



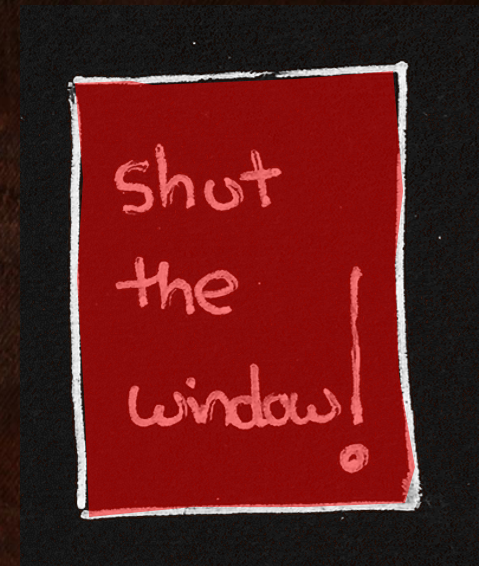
carrot



stick.



Next steps ...  
Engaging building users



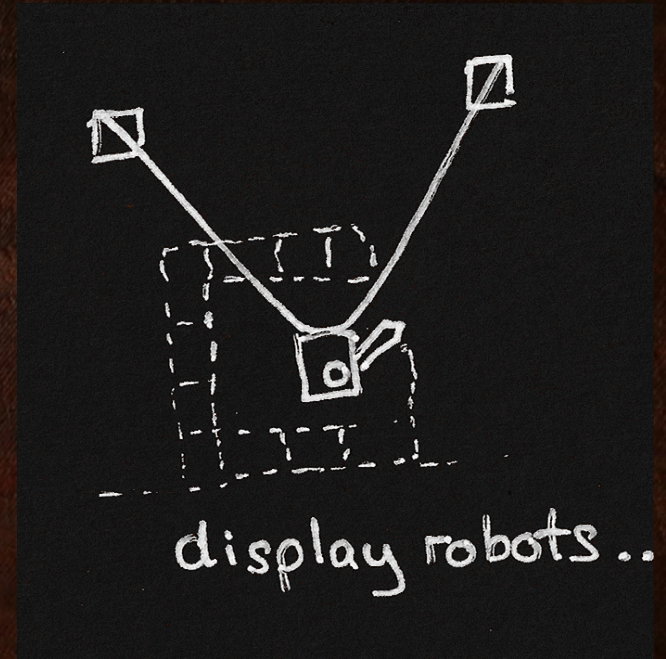


Next steps ...  
Engaging building users



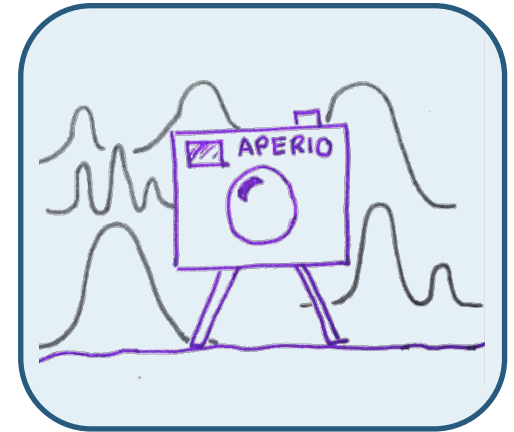


Next steps ...  
Engaging building users





Thank you ...



@AperioProject

