

# 2011 AEIC Annual Load Research Conference

## A model of UK domestic appliance-use using Artificial Neural Networks

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- 2. Aims and objectives**
- 3. Energy modeling**
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- 6. Conclusion**

# 1. Background

*“what’s the UK situation?..”*

3. Energy modeling

4. Data

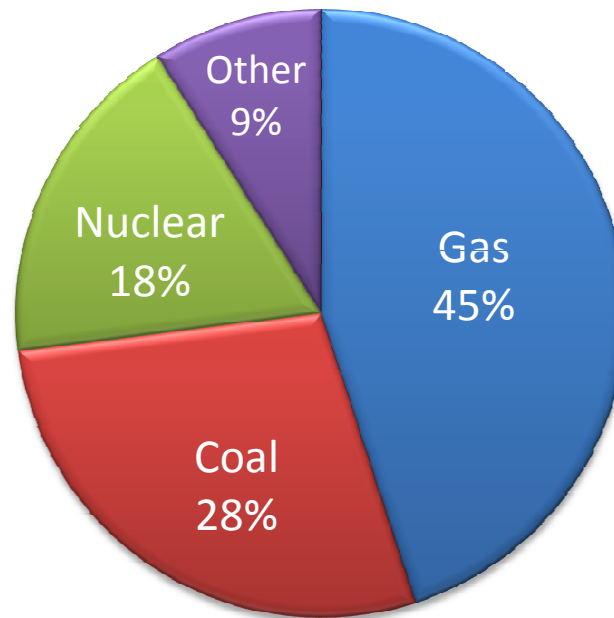
5. Model and applications

6. Conclusions

## 1 Background

### Supply side

### UK Electricity generation 2010

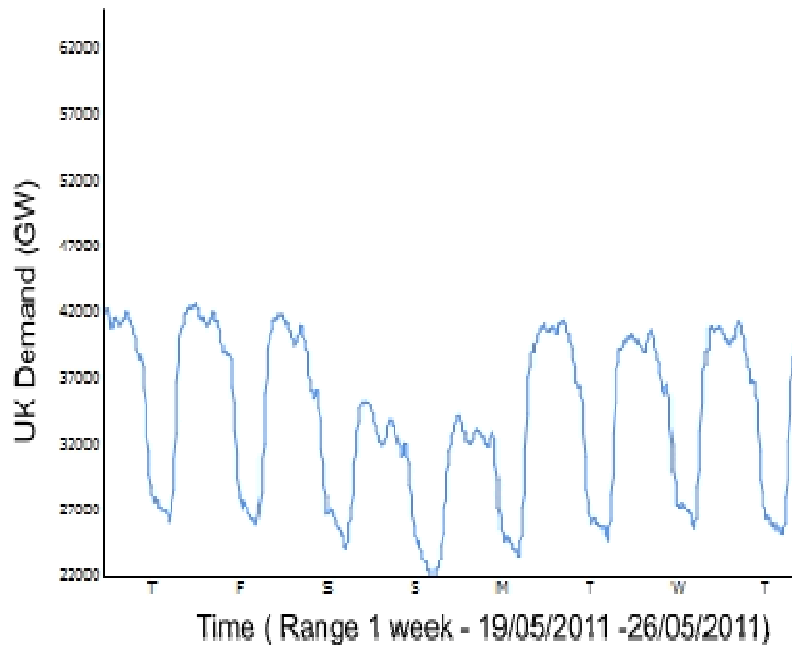


**Consumption**  
 **$345 \times 10^{18}$  kWh**  
**(US:  $3,873 \times 10^{18}$  kWh)**

Generation capacity: 78GW

# 1 Background

## Demand side



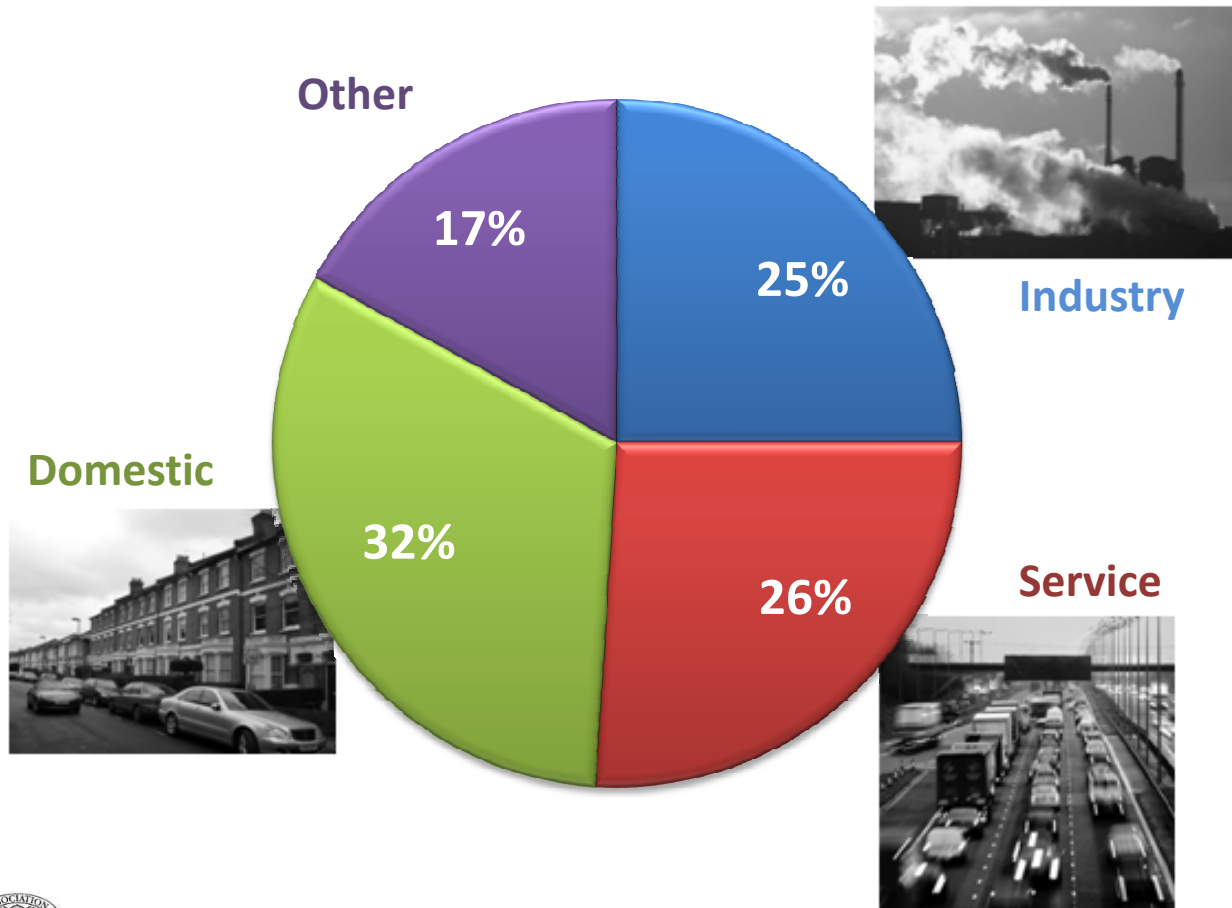
Typical UK electrical Power Demand on national Grid

- **Ave. variation: 22 - 42 GW**
- **UK Net importer since 2004**
- **HVDC connectors with Ireland and France for peak demand**

# 1 Background

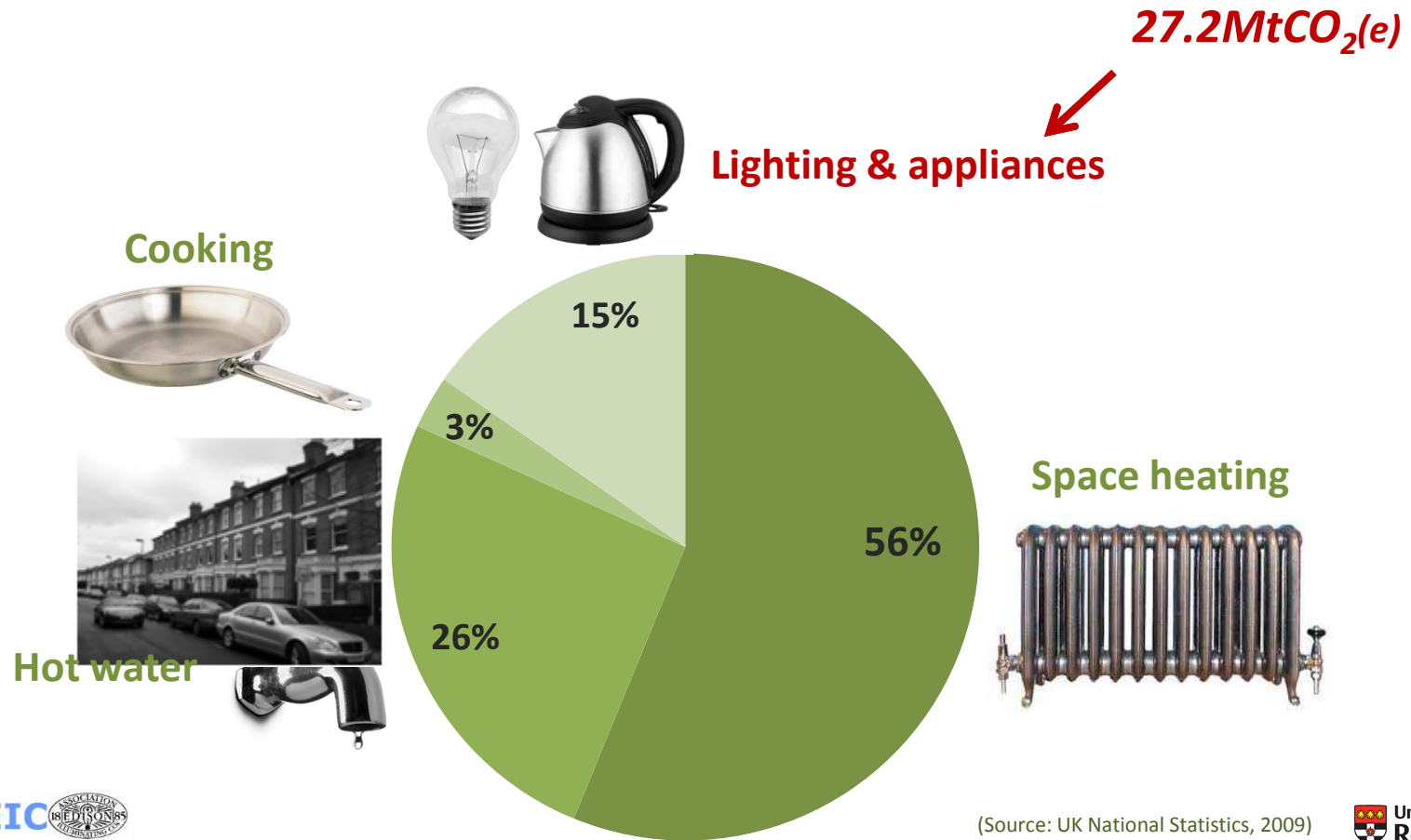
## Demand side

## Sector end use



# 1 Background

sector energy by end use - 2008



## 2 Background

Appliances, appliances, appliances...



# 1 Background

## Appliances, appliances, appliances...

air conditioning unit	electric blanket	hard drive (external)	pasta cooker	speakers (surround)
air purifier	electric fireplace	heated towel rail	PC	steamer
alarm clock/radio	electric gardening tool	heater (portable)	PC monitor	sterilizer (baby)
alarm system	electric hob	hi-fi	phone	Straighteners
all-in-one printer	electric shaver	hob (electric)	Playstation	tea maker
amplifier	electric toothbrush	hoover	power tools	telephone
baby monitor	extractor fan	humidifier	printer	toaster
battery charger	fan	iron	projector	toothbrush
blender	fax machine	i.pad	radio	towel rail
bread maker	file electric	iphone/touch	single rocker	TV (flat screen, big)
built-in oven	food processor	Kettle	rice cooker	tumble dryer
camera	foot spa	lamp	router	TV (flat screen, small)
cell phone	freezer (upright)	landline	sandwich	TV (flat screen, big)
clippers (hair)	freezer (chest)	laptop computer	toaster	TV (old style)
coffee maker	fridge (small)	light (LED ceiling)	toaster	vacuum cleaner
computer	fridge (medium)	microwave oven	screen	video camera
cooker (upright)	fridge (large)	mini-fridge	security system	washer-dryer
cooker (range)	fridge-freezer	mini-cooker	sewing machine	washing machine
dehumidifier	griller	mixer	shaver	wine cooler
digi-box	gym equipment	mobile phone	shredder	X-Box
dishwasher	fryer	monitor	Sky-box	
dock (mp3)	games console	musical instrument	slow cooker	
DVD player	hairdryer	oven (built-in)	sound system	
Dyson vacuum cleaner	hair straighteners	oven (upright)	speakers (PC)	

• Energy consumption has doubled in past 40 years

• Projected demand > 45% total consumption by 2020

• Consumer electronics most significant growth sector

1. Background

**2. Aims and objectives**

*“what do we want to achieve?..”*

4. Data

5. Model and applications

6. Conclusions

## 2 Aims and objectives

### Research aim

- Develop a statistical model of UK appliance energy use using Artificial Neural Networks

### Objectives

- Process highly disaggregated input data
- Accurately reproduce characteristics embedded in UK appliance load profiles
- Sensitivity towards socioeconomic, physical and weather variables
- Capable of assessing different scenarios (eg. efficiency improvement)
- Adaptable to other geographical regions and appliance types

1. Background
2. Aims and objectives
- 3. Energy modeling**

*“How do we model energy use?..”*

4. Data
5. Model and applications
6. Conclusions

## 2 Energy modeling

Statistical,  
Empirical  
models of  
energy

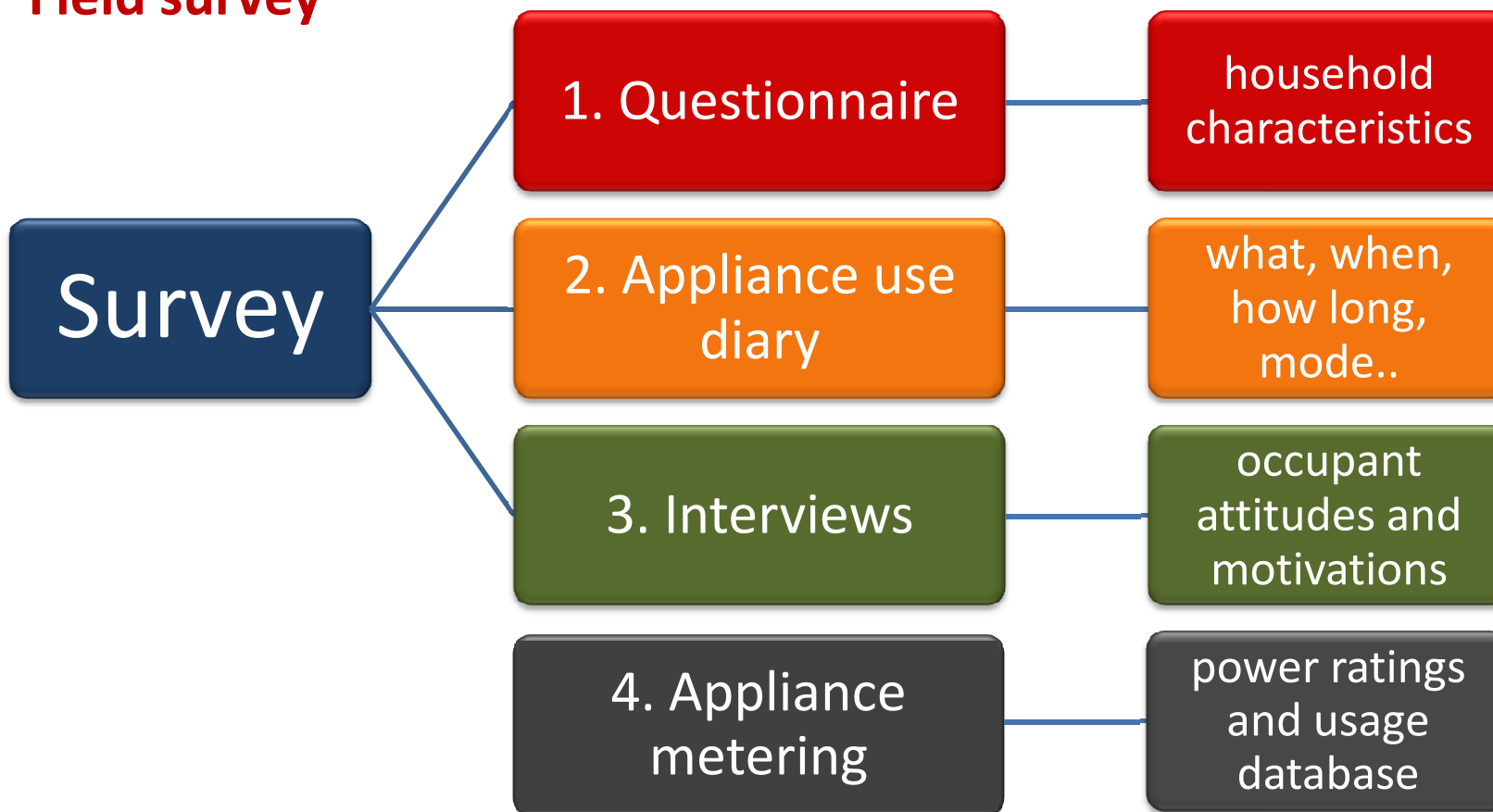


Physics,  
Engineering  
models of  
energy



1. Background
2. Aims and objectives
- “What are we going to measure?..”*
3. Energy modeling
- 4. Data**
5. Model and applications
6. Conclusions

## Field survey





1. Background

2. Aims and objectives

***“How to connect all the components?..”***

3. Energy modeling

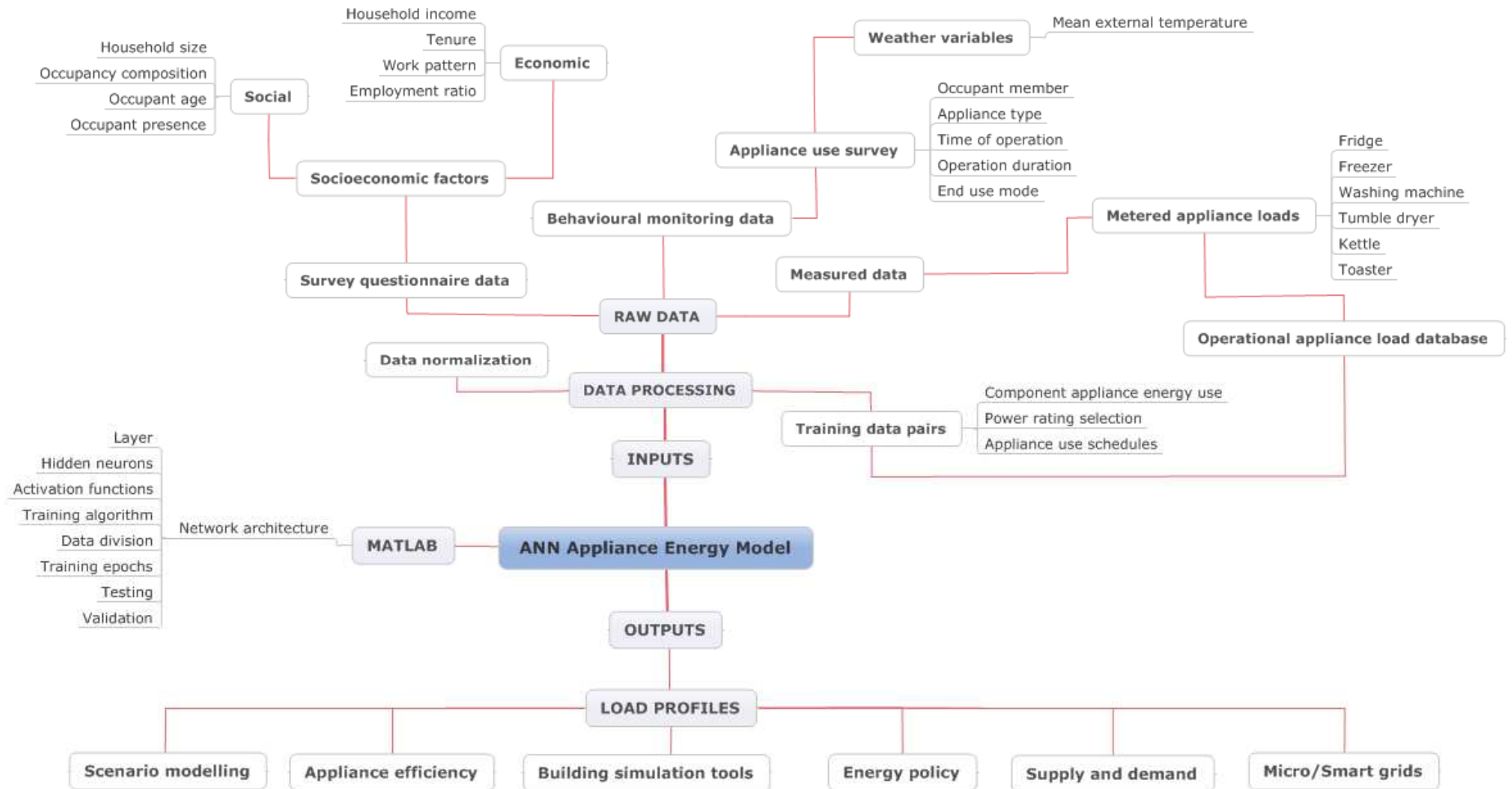
4. Data

**5. Model and applications**

6. Conclusions

# 5 Model and applications

## Model schematic



## 5 Model and applications

### Artificial Neural Networks (ANNs)

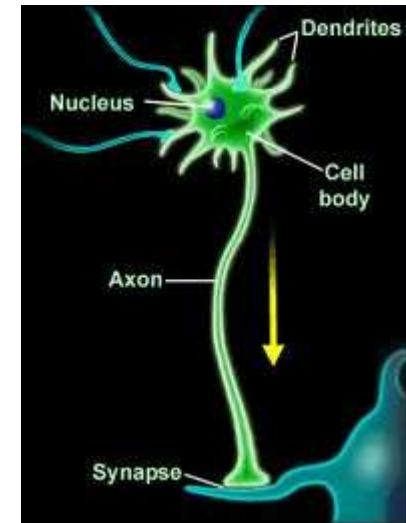
- Biologically inspired method proposed by McCulloch and Pitts (1943)
- Mimics the operation of the human brain



(source: drshivav.blogspot.com)



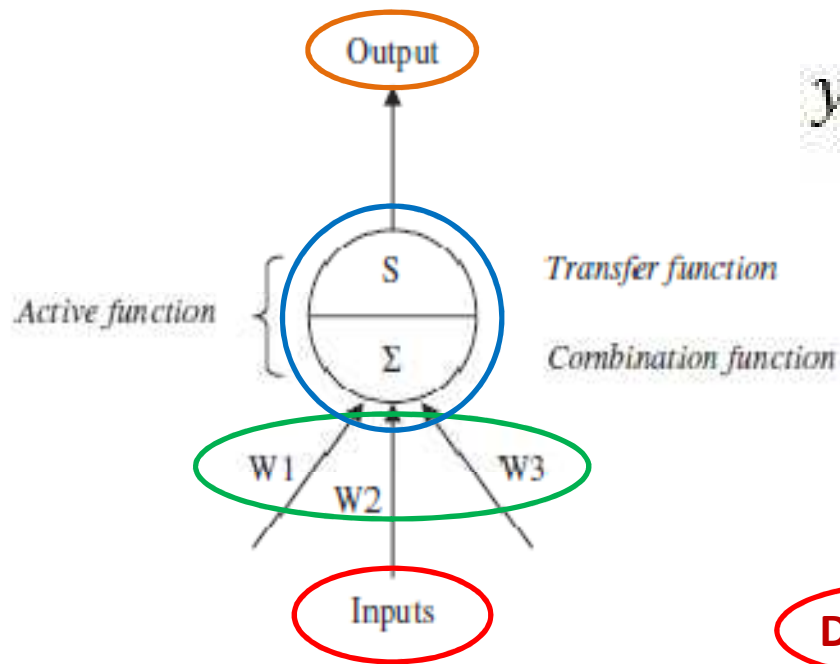
(Source: scientopia.org)



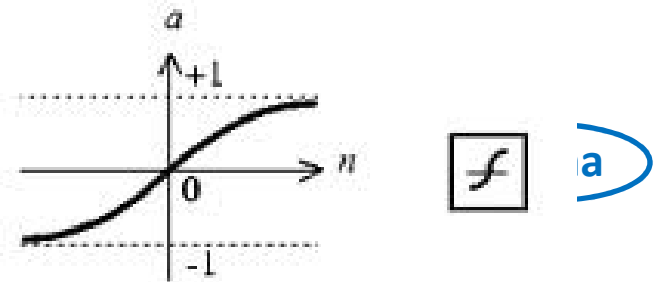
(source: morphonix.com)

## 5 Model and applications

### Artificial Neural Networks (ANNs)



$$y_j = f \left( \sum_{i=1}^n w_{ji} x_i - b \right)$$



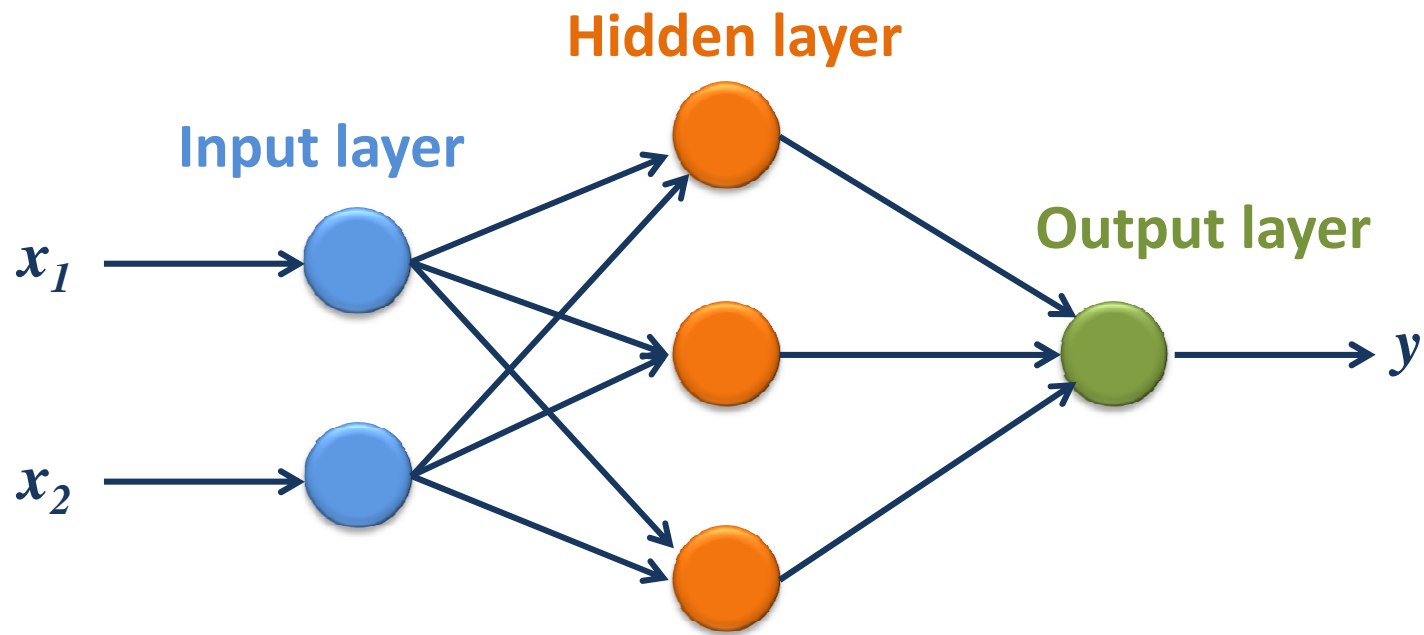
Dendri

$$a = \text{tansig}(n)$$

Tan-Sigmoid Transfer Function

## 5 Model and applications

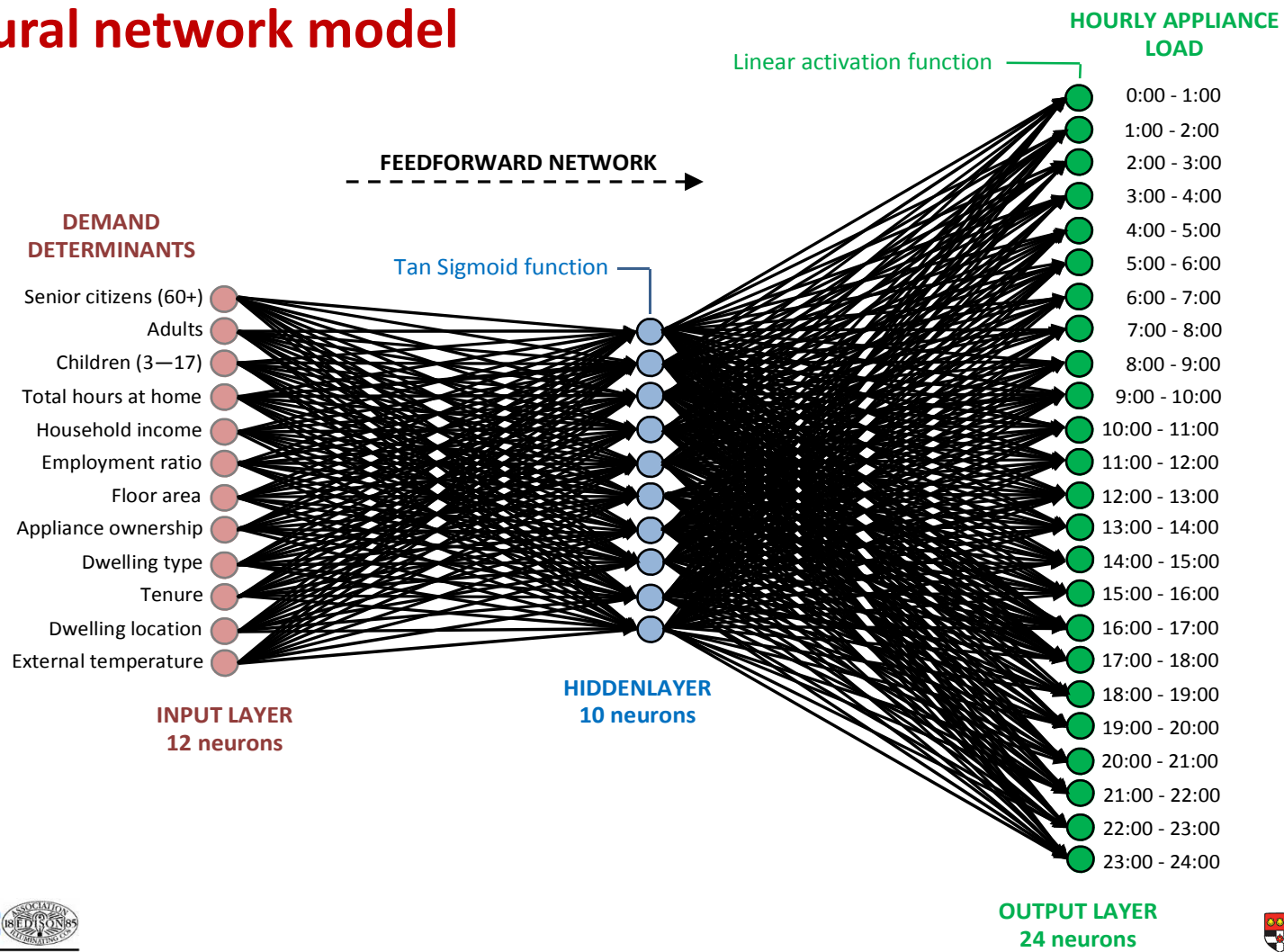
### Artificial Neural Networks (ANNs)



2:3:1 architecture

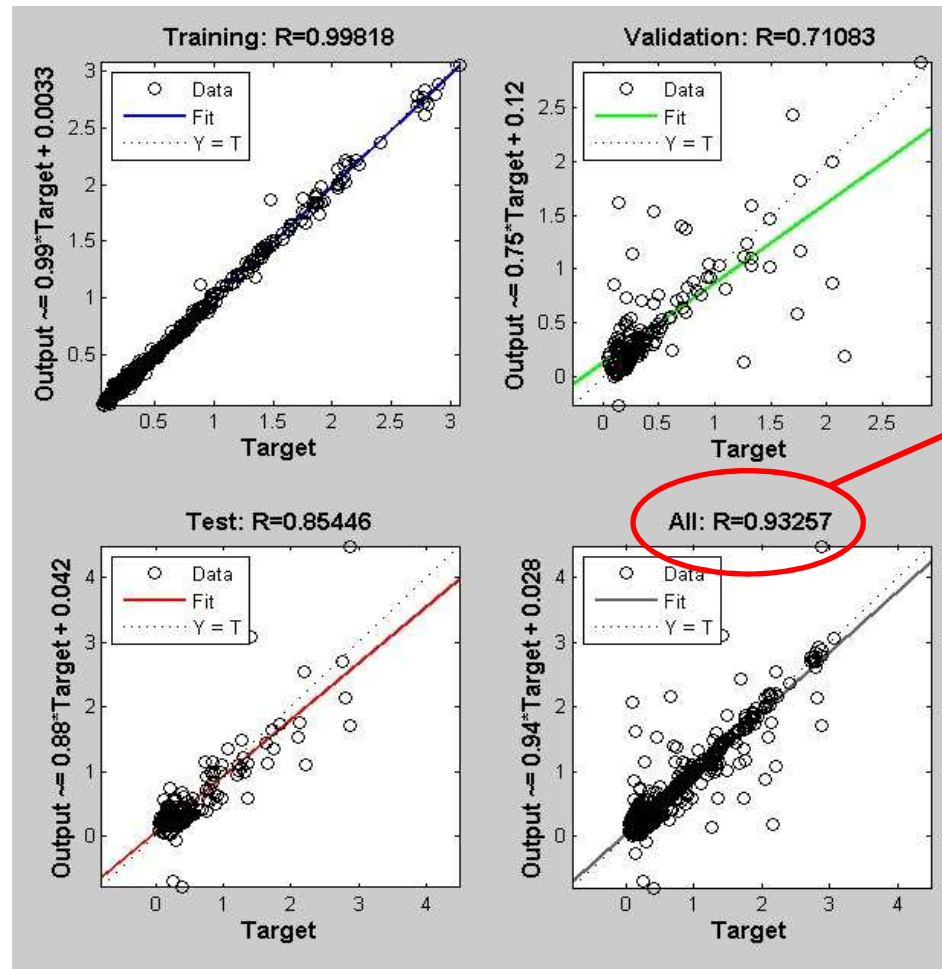
## 5 Model and applications

# Neural network model



## 5 Model and applications

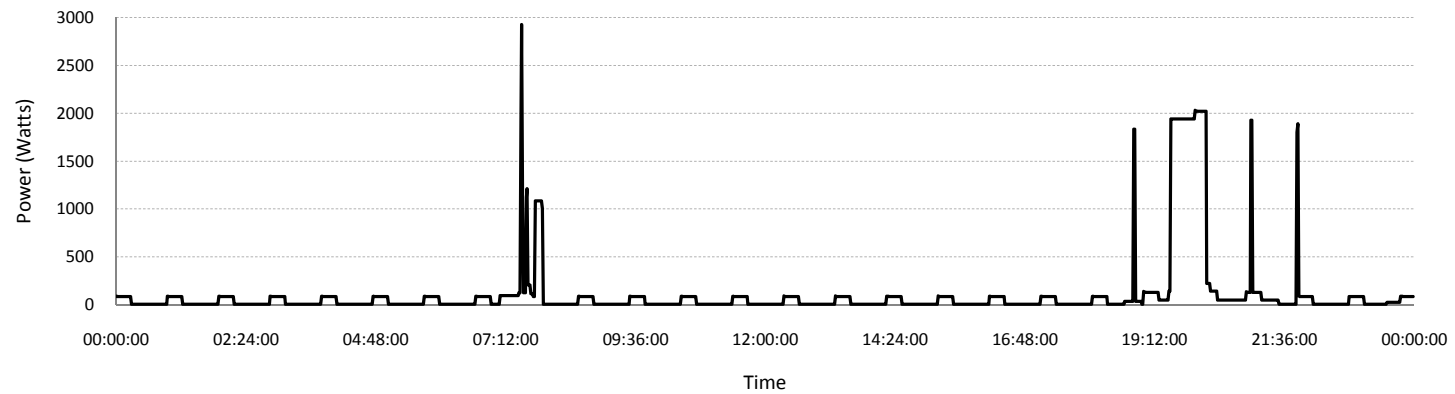
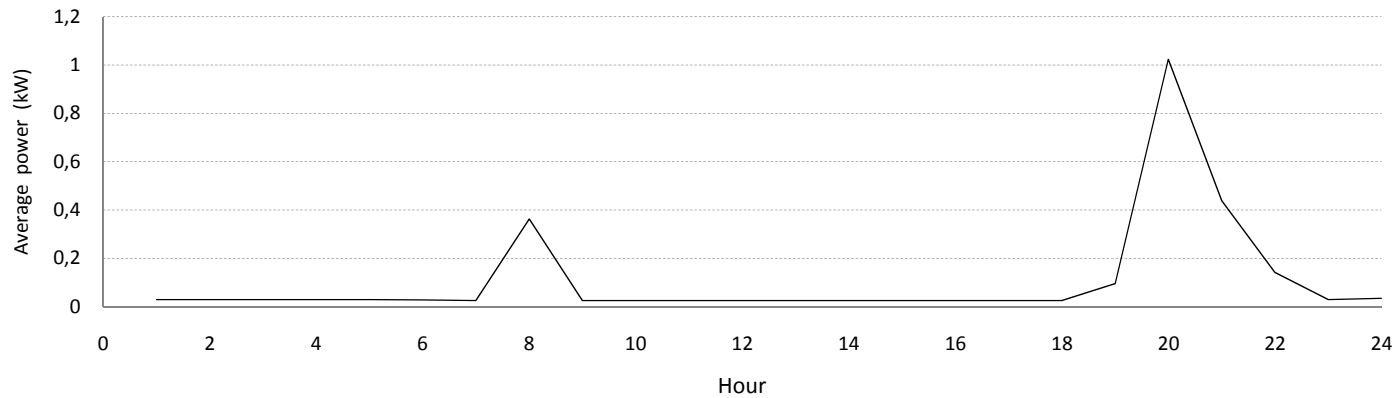
### Model training and error



## 5 Model and applications

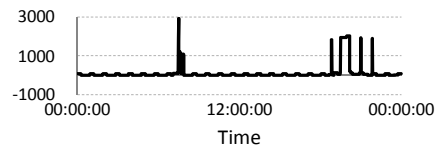
### Model outputs

### Appliance load profile – respondent no.22



## 5 Model and applications

*“So what!...”*



## 5 Model and applications

### Applications

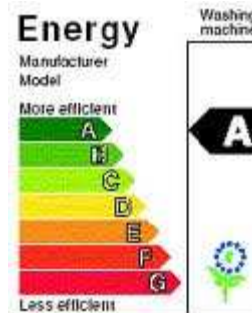
#### 1. Scenario modelling



# 5 Model and applications

## Applications

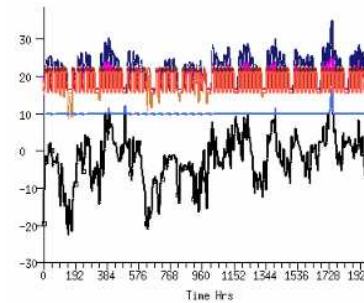
### 2. Appliance efficiency



## 5 Model and applications

### Applications

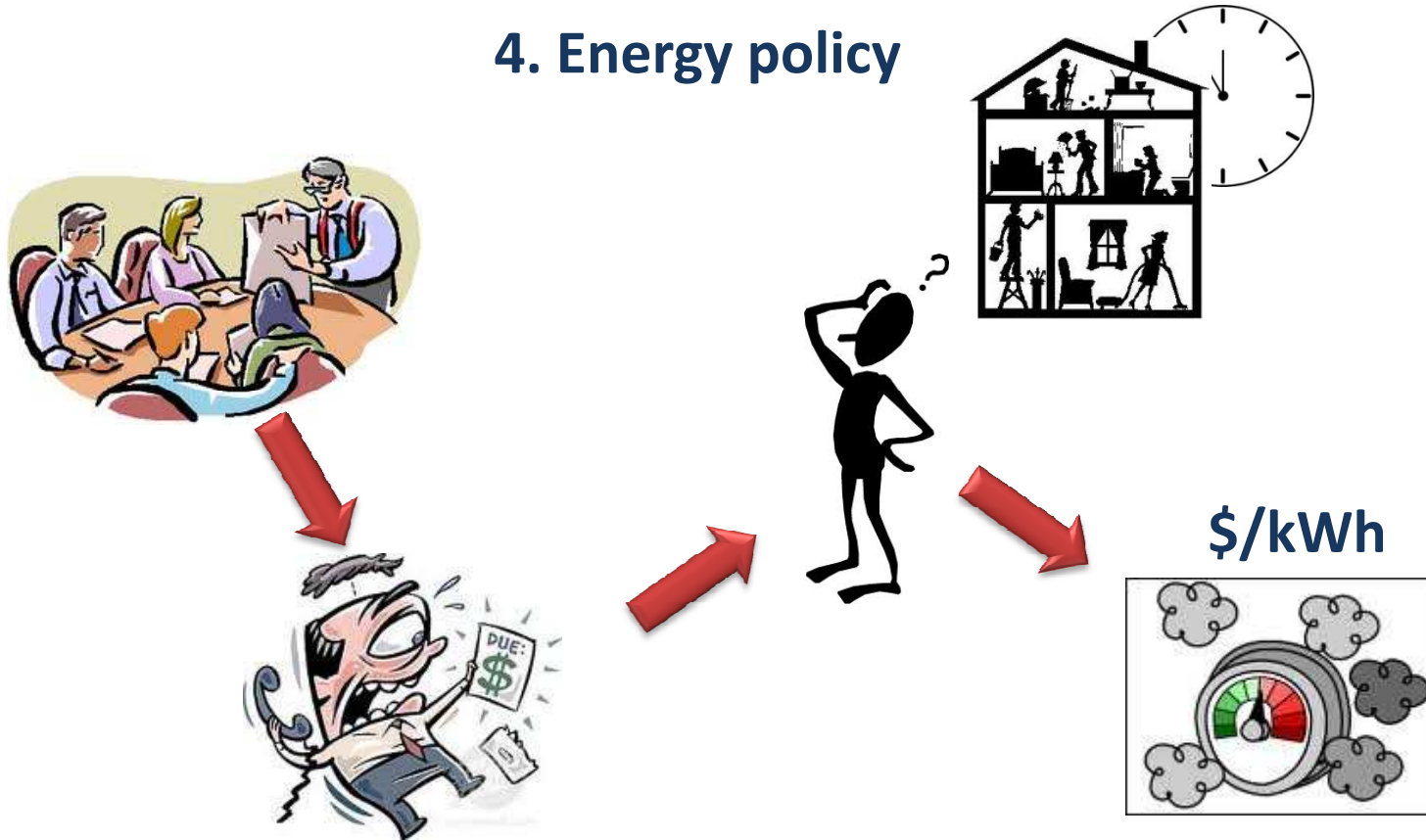
### 3. Building simulation tools



## 5 Model and applications

### Applications

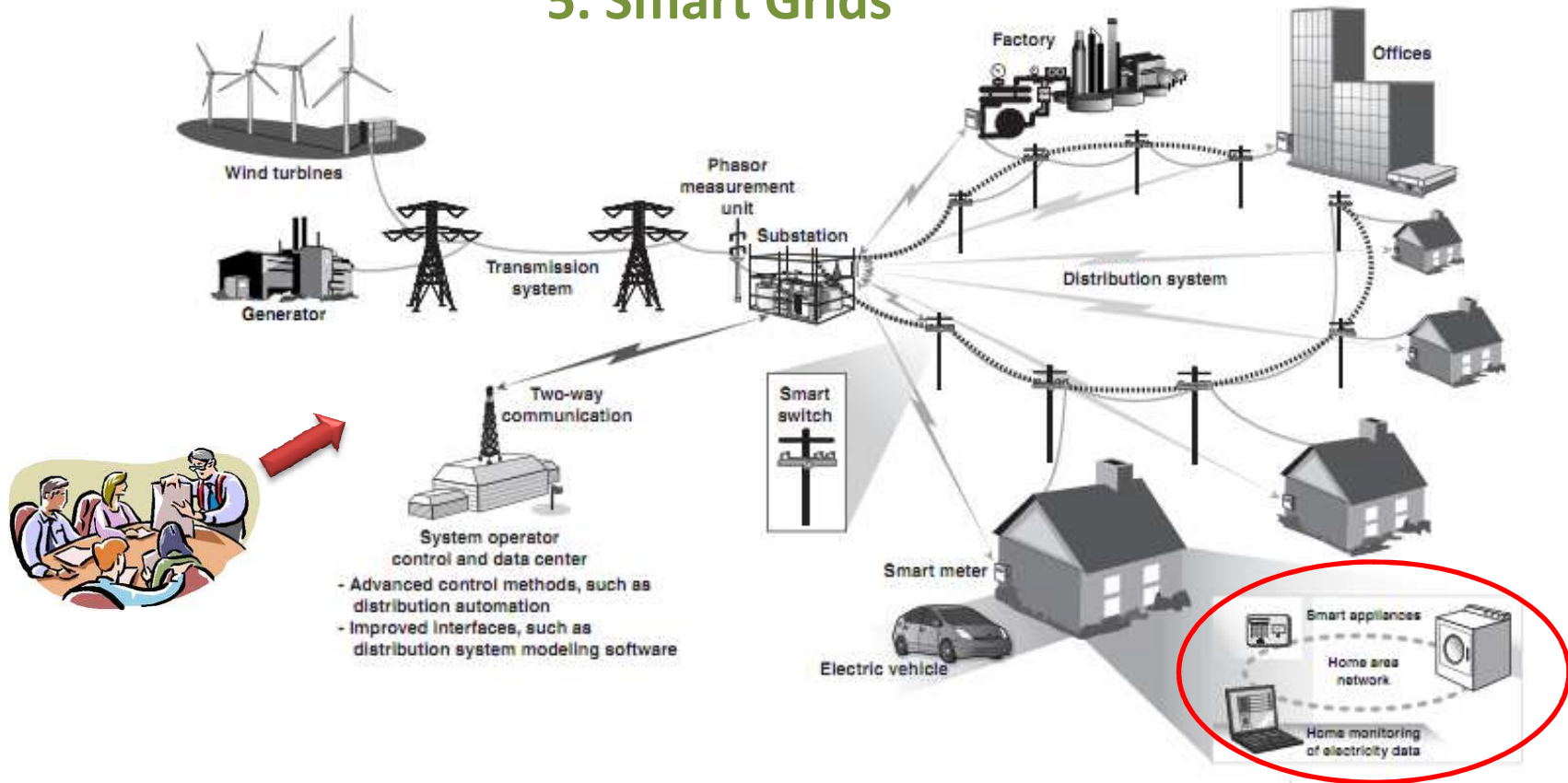
#### 4. Energy policy



## 5 Model and applications

### Applications

### 5. Smart Grids



1. Background
2. Aims and objectives
3. Energy modeling  
*“I’ll be quick!”*
4. Data
5. Model and applications
- 6. Conclusions**

## 6 Conclusions

### Final thoughts

- The study demonstrates the suitability of Artificial Neural Networks for domestic energy modeling
- The appliance sector is anticipated to be of increasing importance
- There will be an increased focus on behavioural adaptation on energy use in the home
- Development of energy models must have a clear focus on the user's needs

## 6 Conclusions

**Thanks for your attention...**



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