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TRAINING COURSE 16TH – 20TH SEPTEMBER 2024

## Energy Efficient Buildings

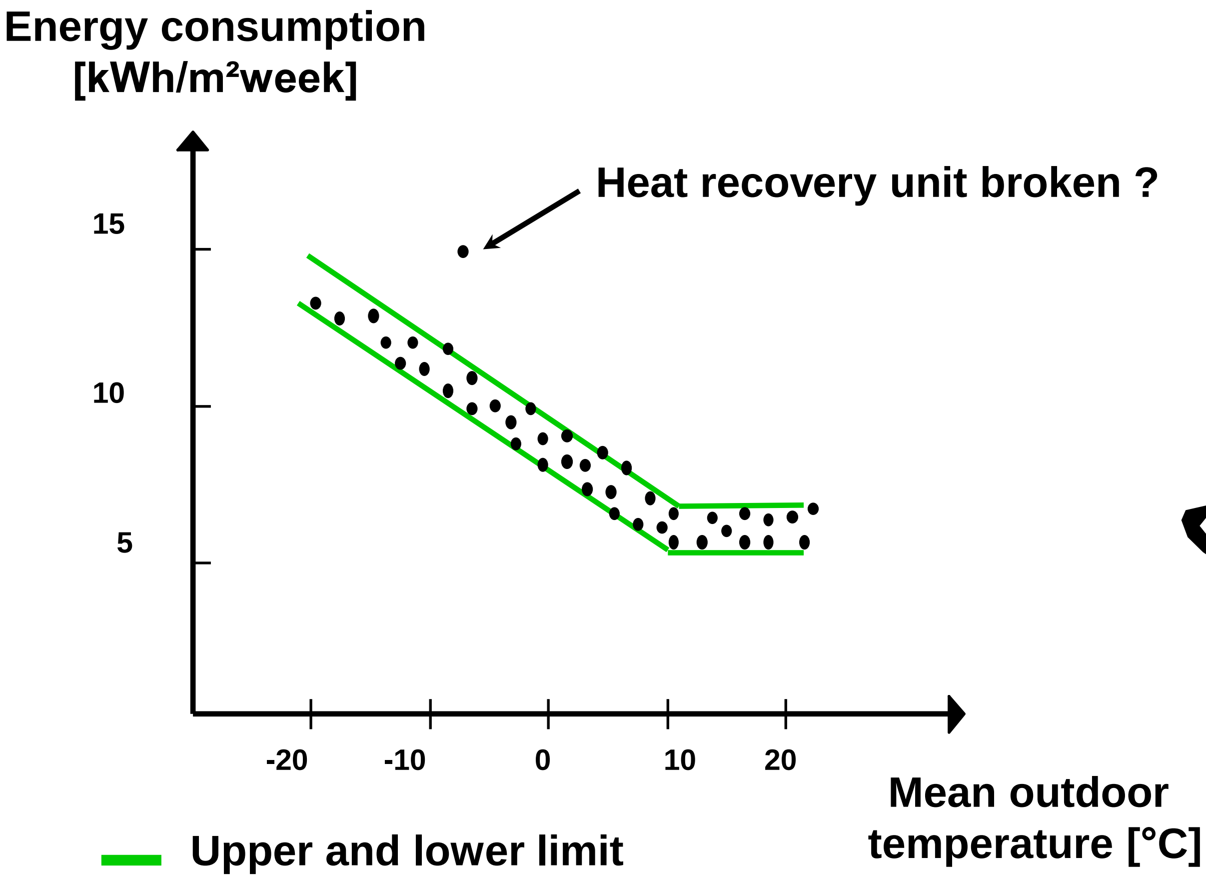
# Energy management and monitoring of buildings

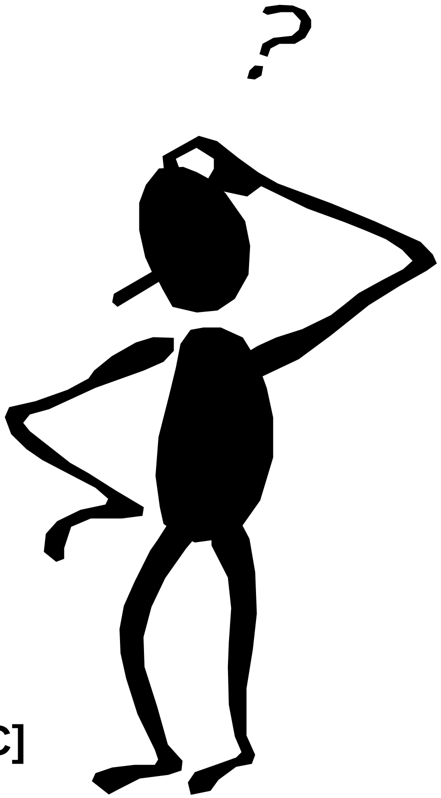
**Prof. Ing. Dušan Petráš, PhD.**

*Erasmus+ CBHE project n. 101082898-2022*
*Innovative Master Courses Supporting the Improvement of the Energy and Carbon Footprint of the Ukrainian Building Stock*

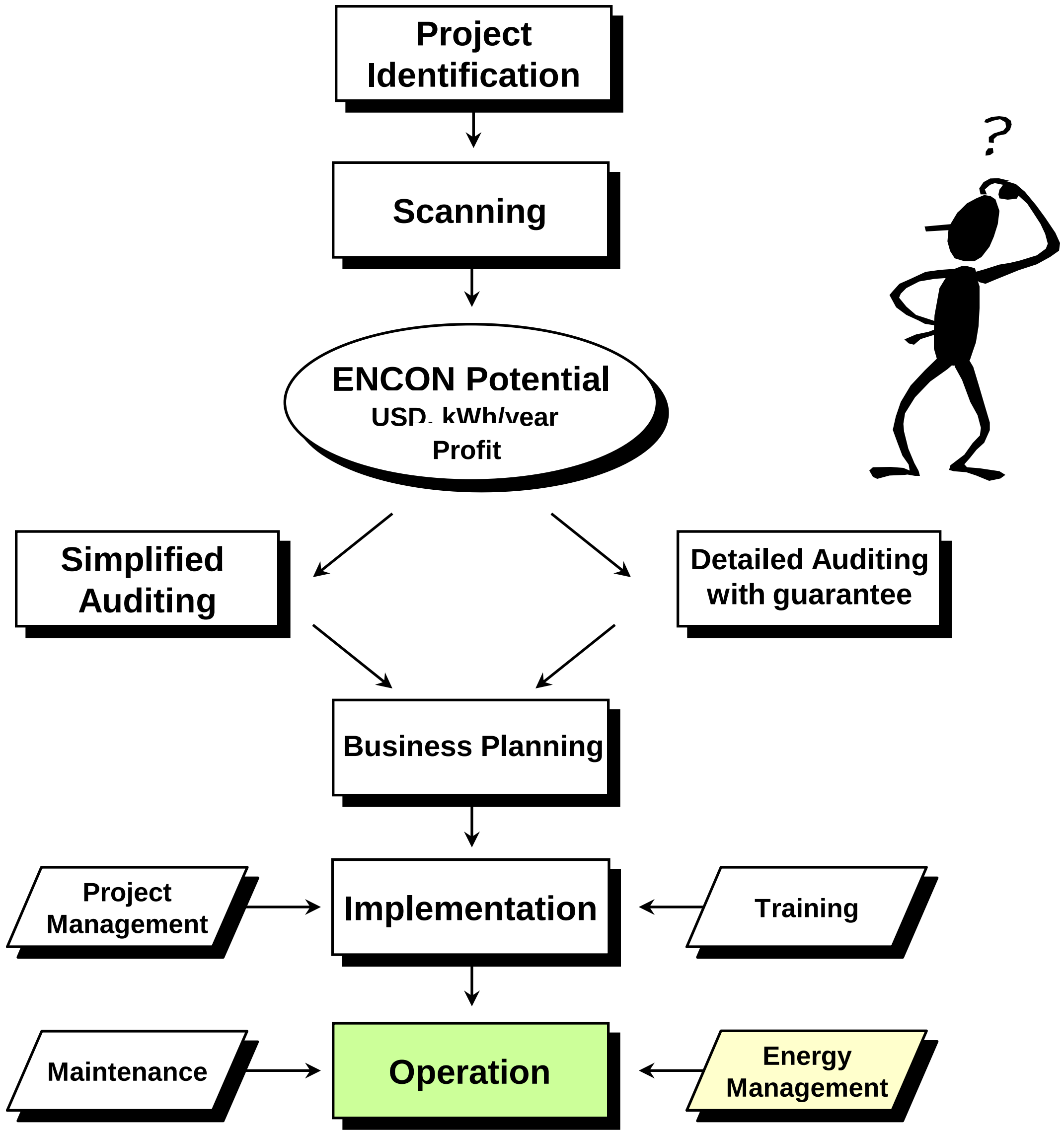
Co-funded by the European Union

# ENERGY MONITORING

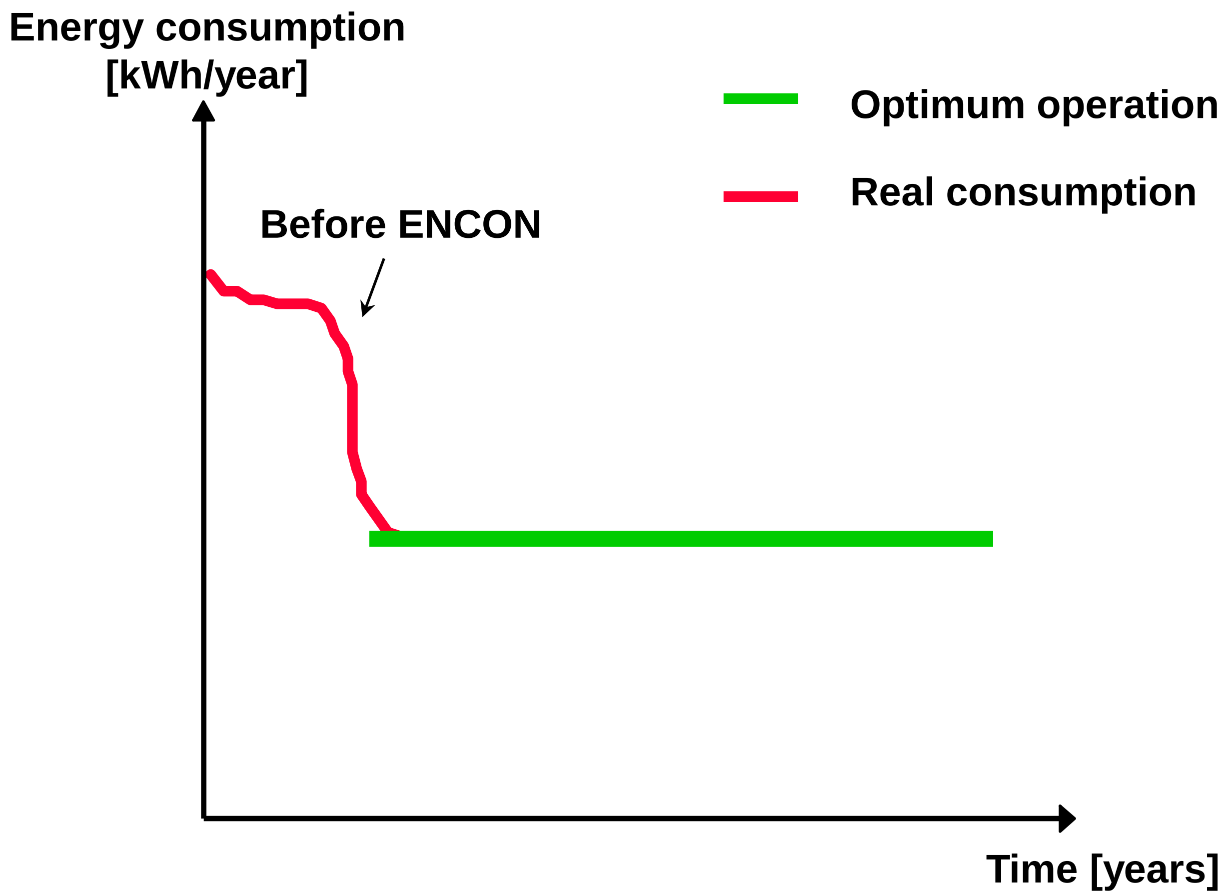


# The ENCON Process



# Norwegian Experience



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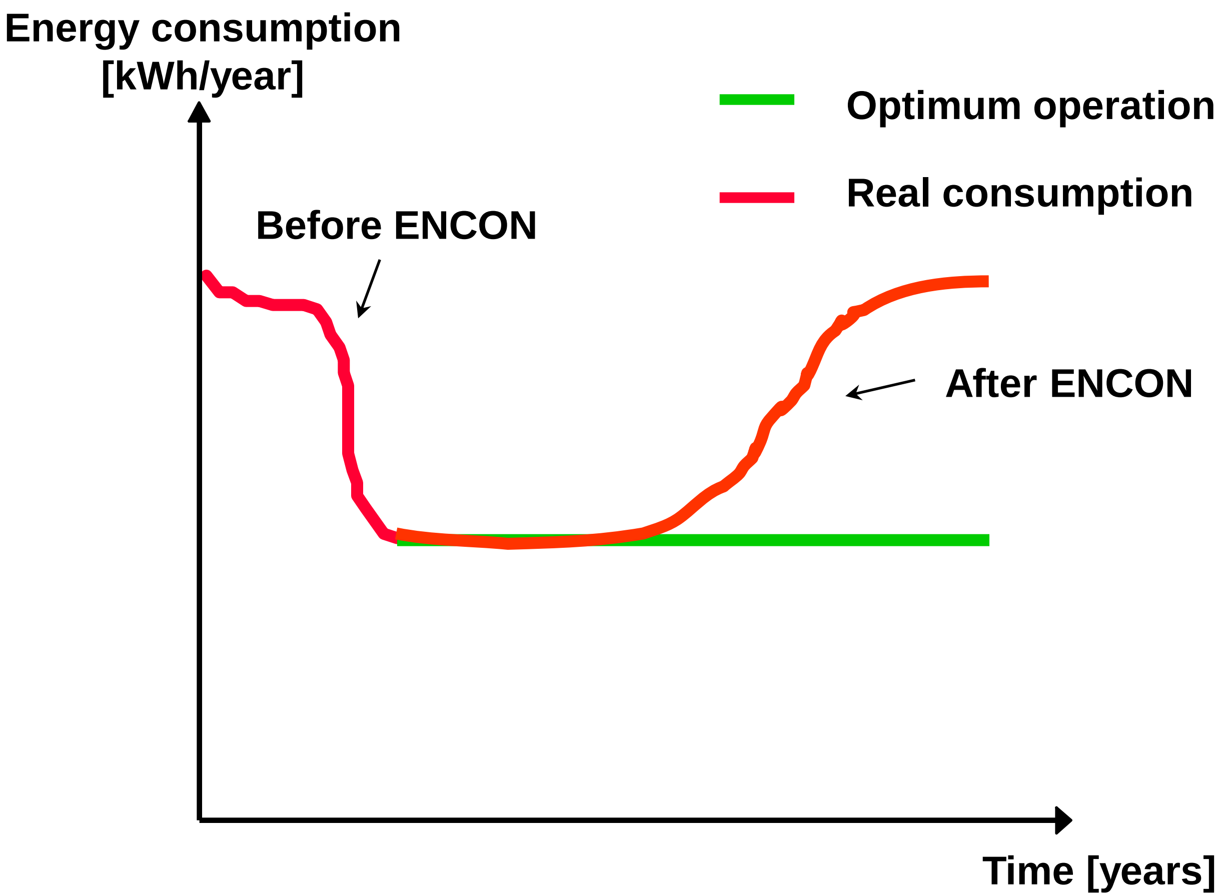

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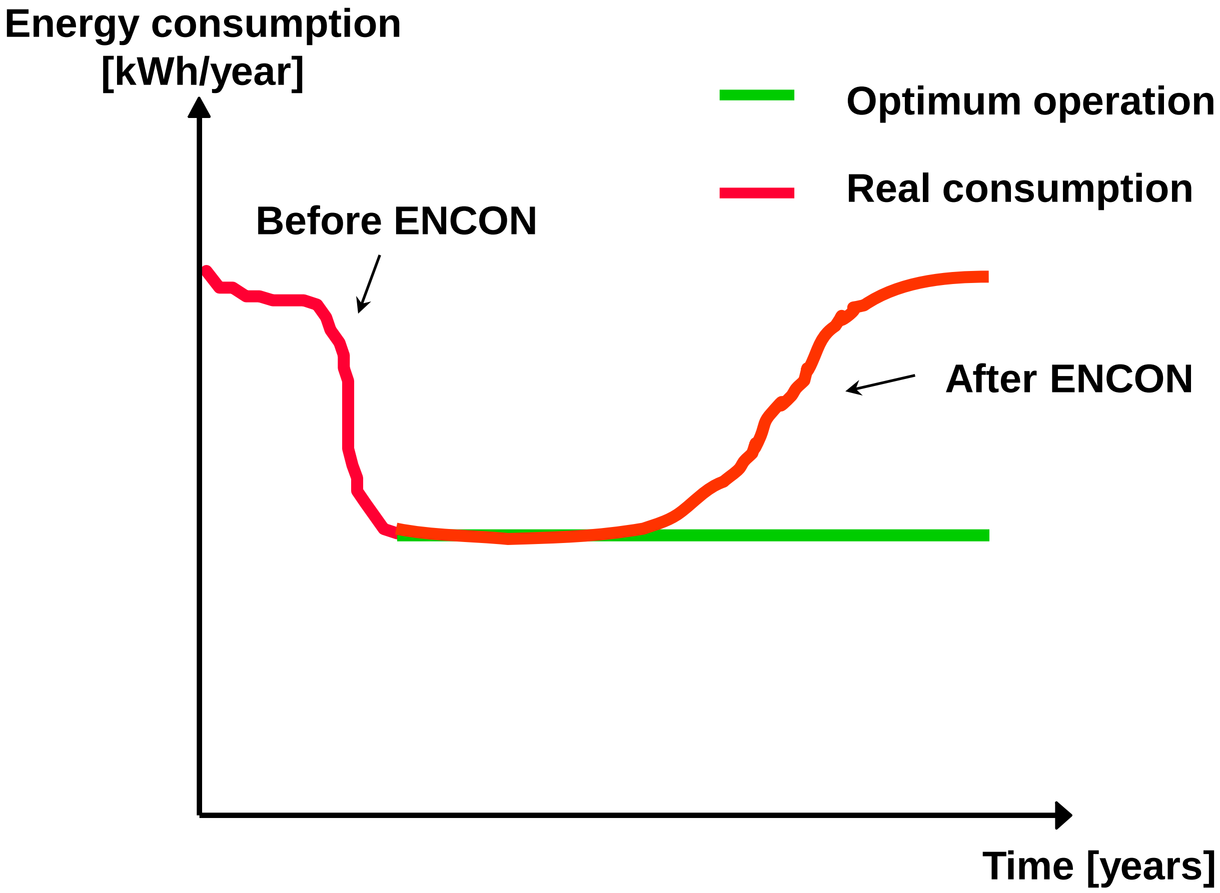
# Norwegian Experience



# Energy Monitoring

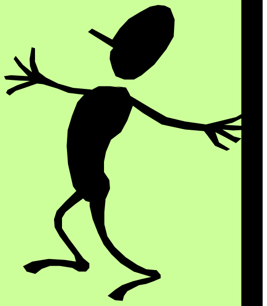
## Aims :

1. Correct operation of technical equipment

2. Quick detection of errors / breakdown of technical equipment

3. Reduced energy consumption

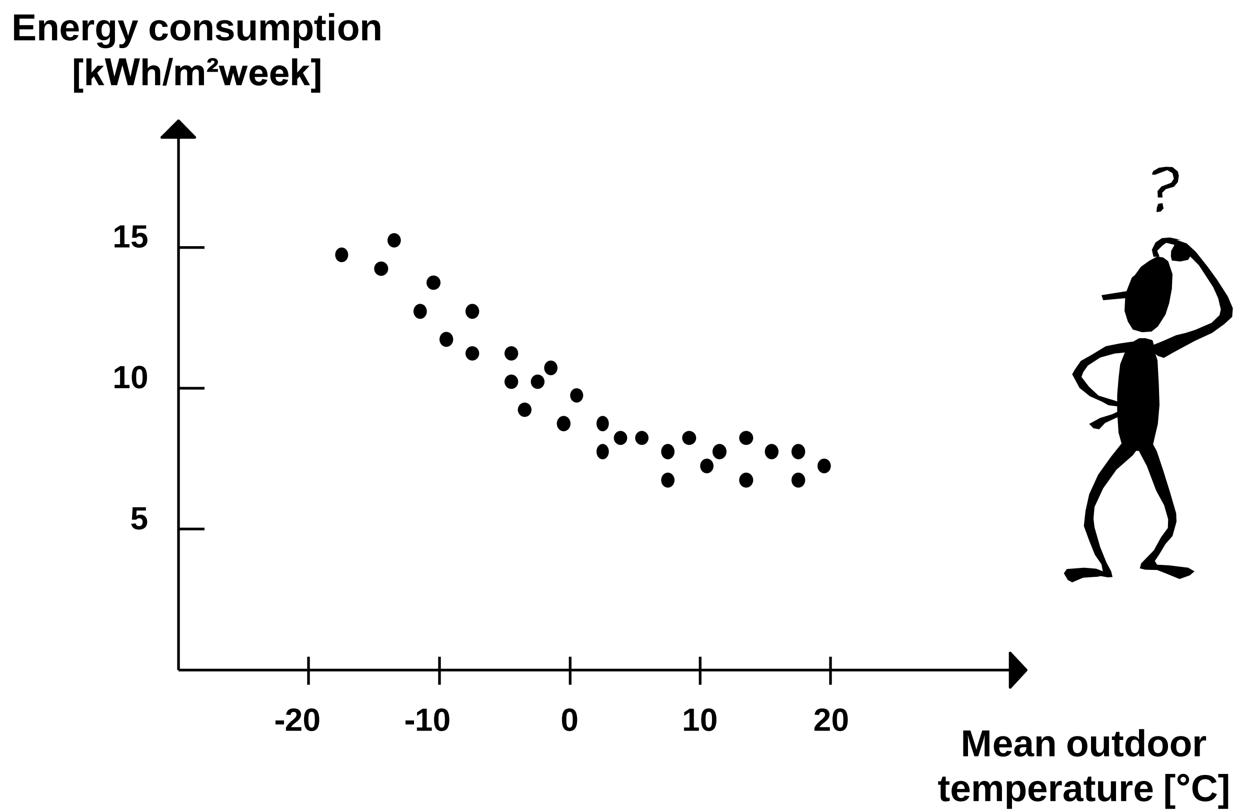
4. Documentation of results from energy conservation measures



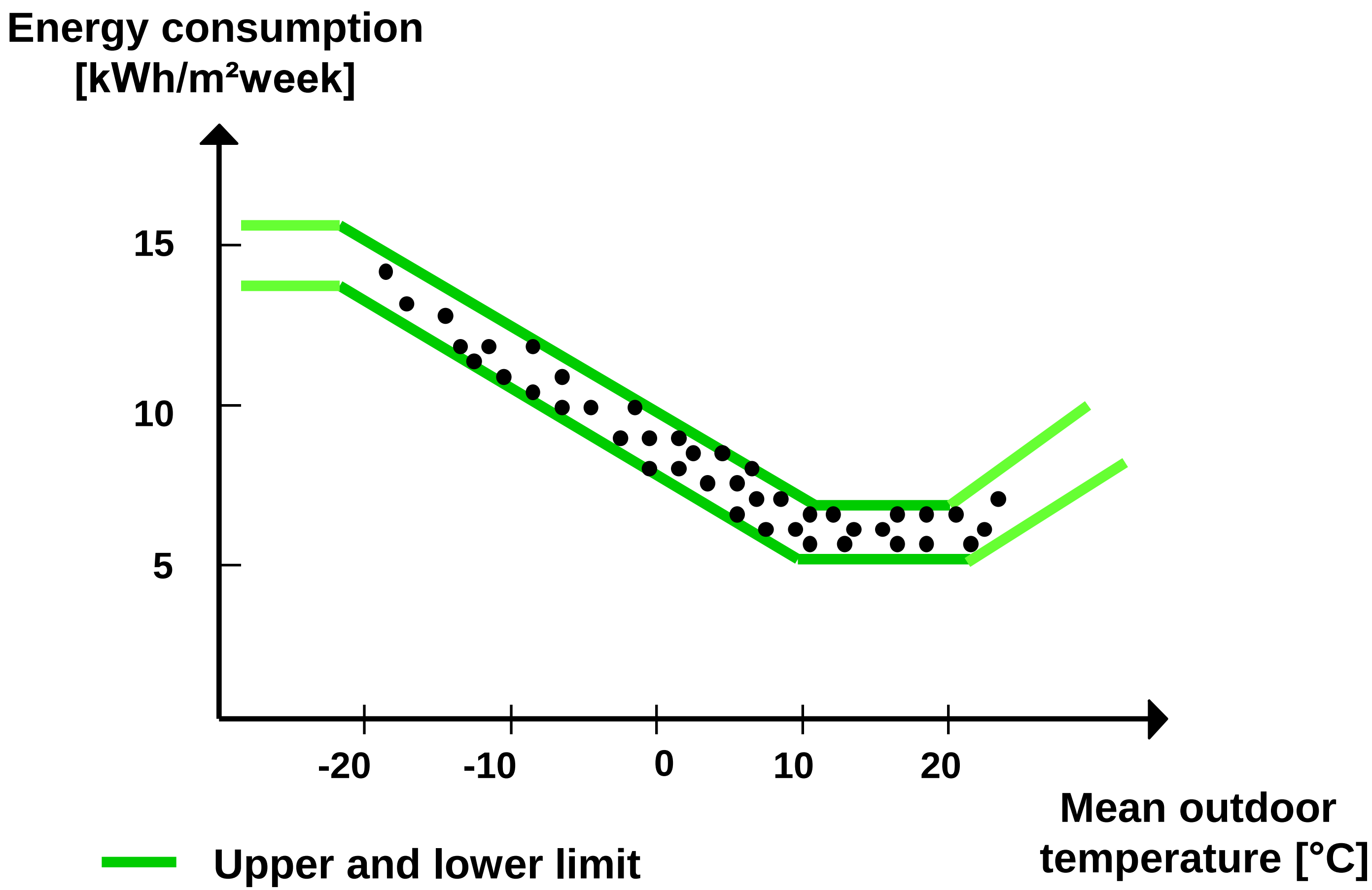
5. Up to date O&M personnel

# Energy Monitoring

**Periodic (weekly) registrations of the energy consumption and corresponding mean outdoor temperature**

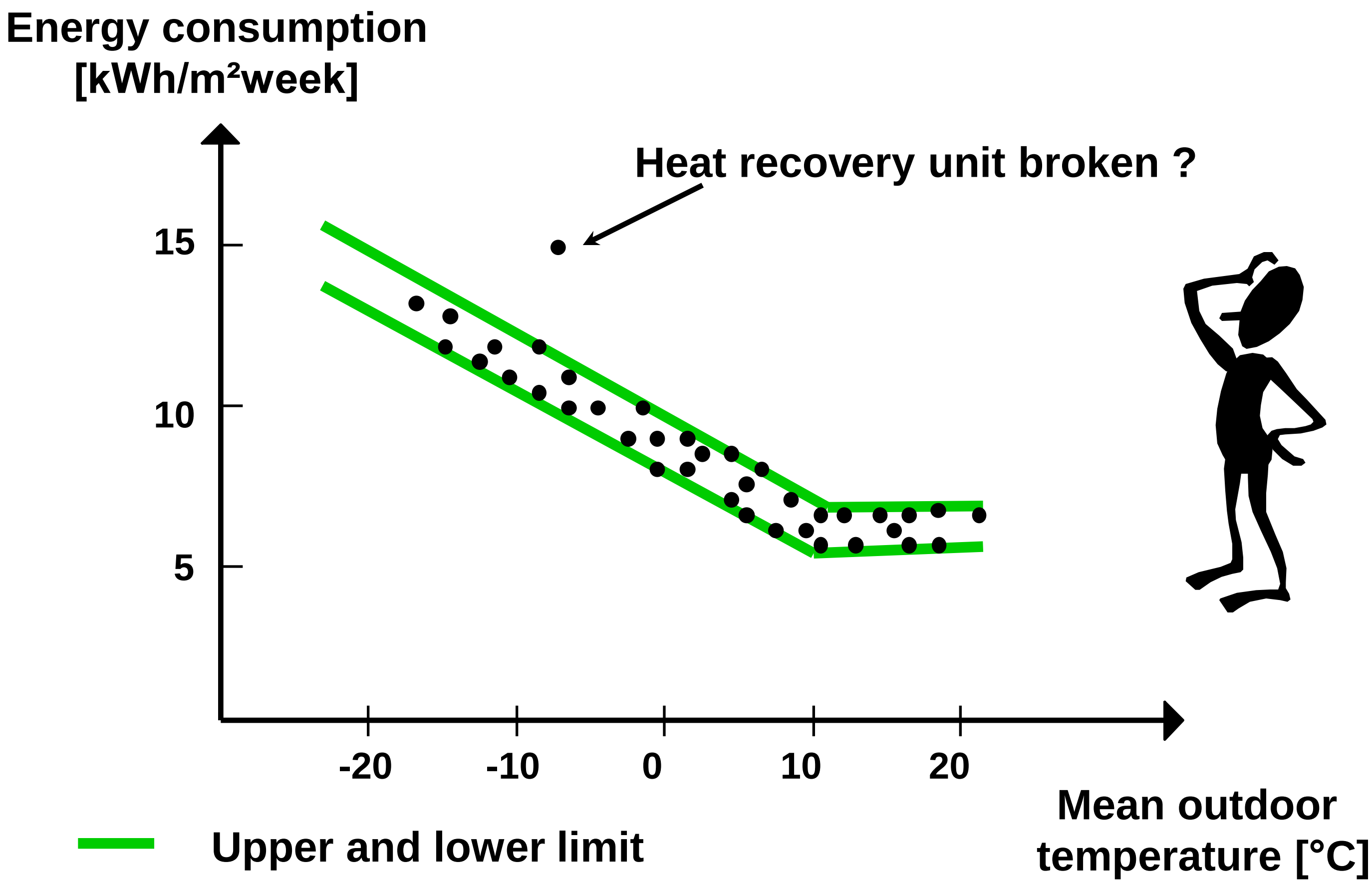


# ET-curve



Energy consumption
[kWh/m²week]
15
10
5
-20
-10
0
10
20
Mean outdoor
temperature [°C]
Upper and lower limit

# Deviations ?

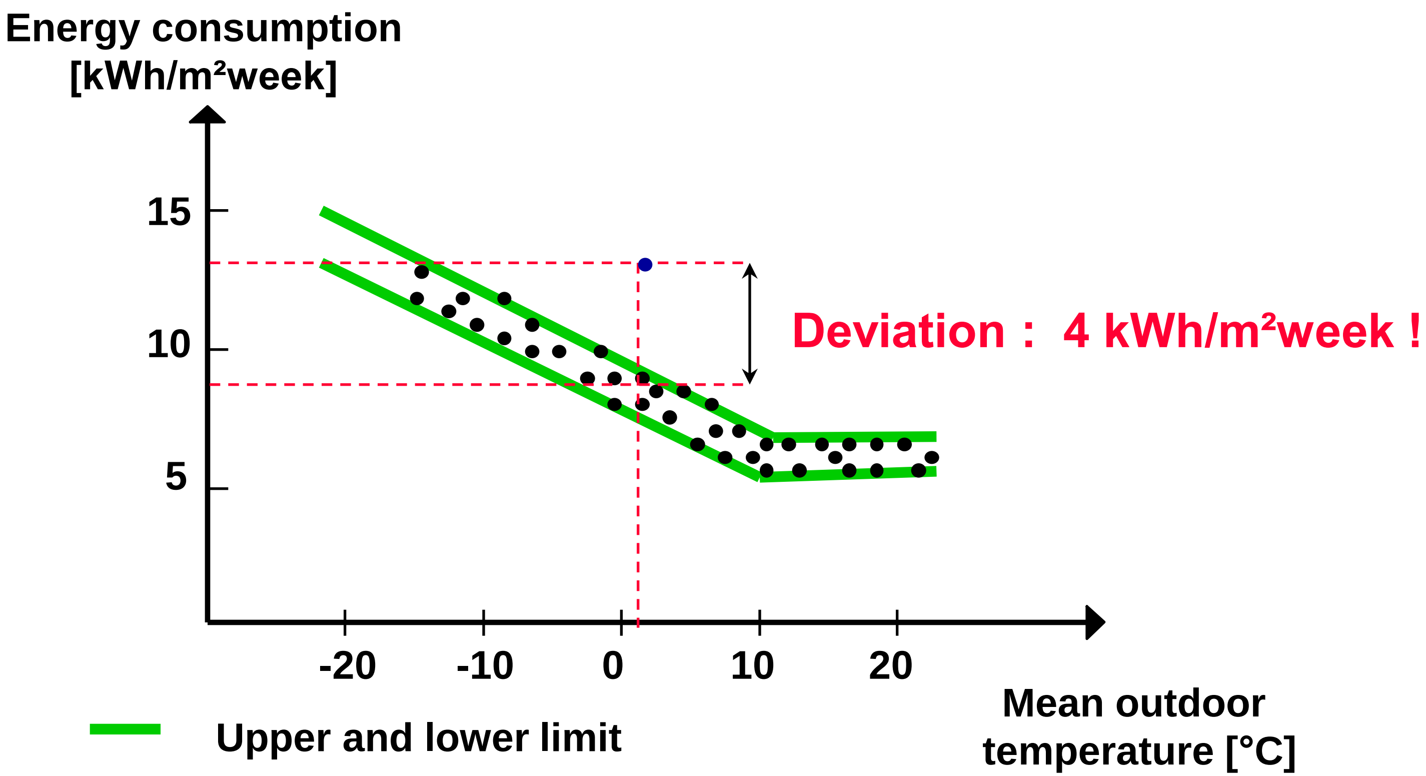


Energy consumption
[kWh/m²week]
Heat recovery unit broken ?
15
10
5
-20
-10
0
10
20
Mean outdoor
temperature [°C]
Upper and lower limit

# Broken automatic control system

## No temperature night set-back.

| | |
|---|---|
| Energy consumption | 13 kWh/m² |
| Outdoor temperature | + 2 ºC |



# Additional cost

**Building area** 2.300 $m^2$
**Energy price** 0,12 USD/kWh

**Additional costs:**

**4 kWh/$m^2$week · 2.300 $m^2$ · 0,12 USD/kWh = <u>1.100 USD/week</u>**

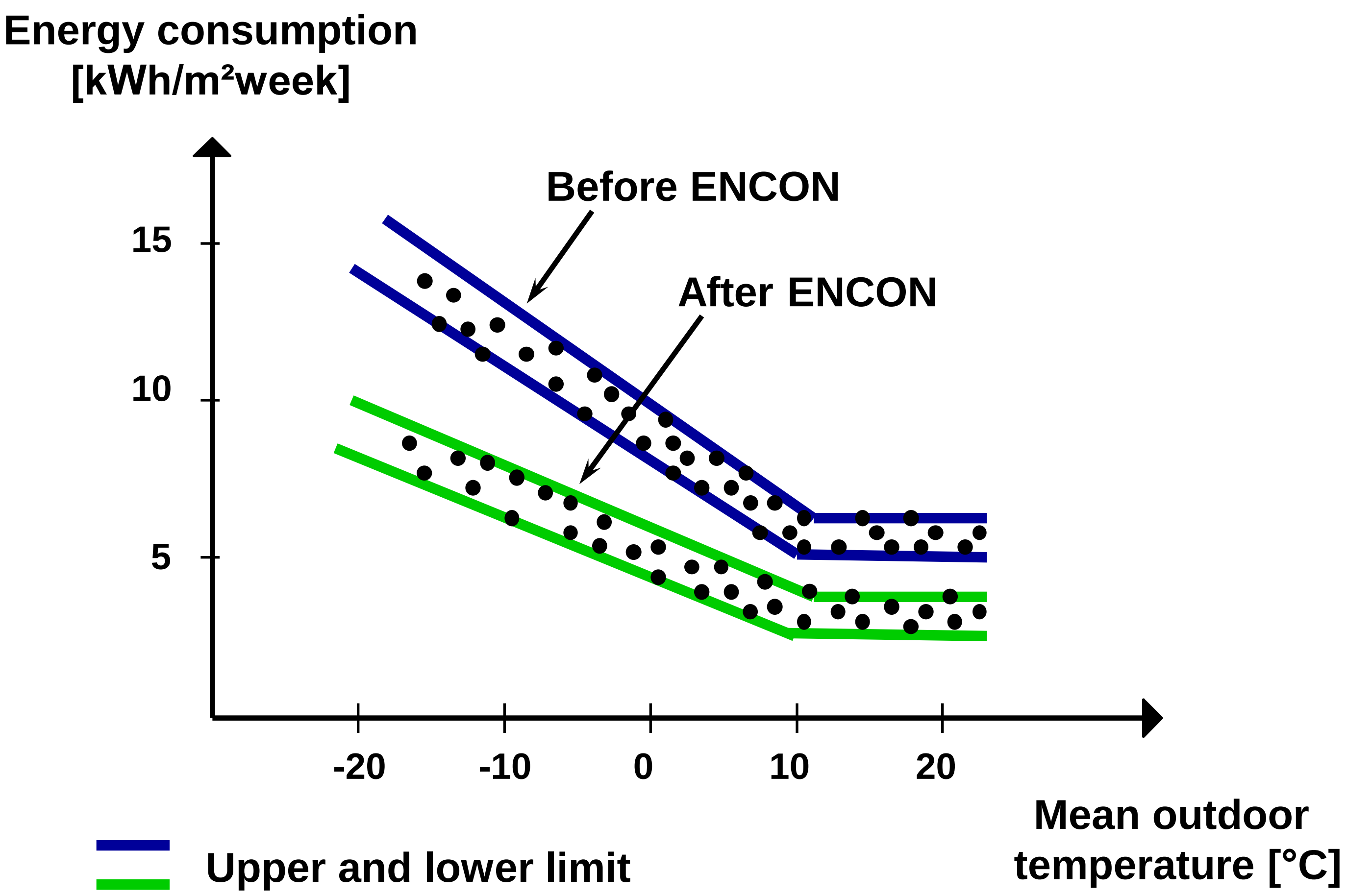
**Energy monitoring system**

↓

**The fault is repaired after only 1 week !**

**If the inspection is 8 weeks later, 8.800 USD is lost !**

# ET-curve before/after ENCON



# Procedure - every week

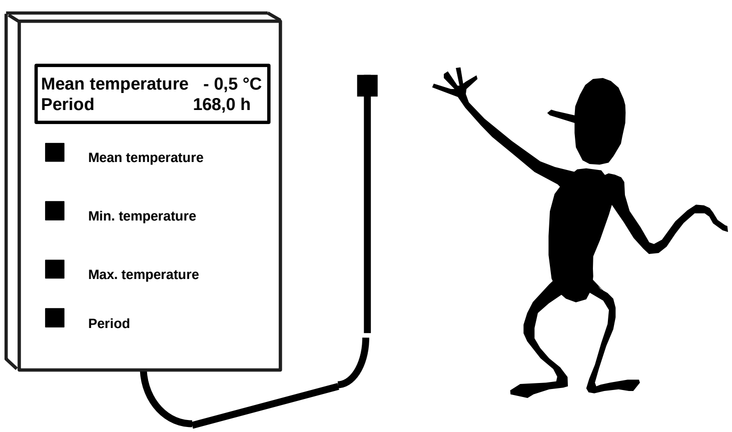
- Read the energy meter
- Calculate the specific energy consumption
- Register the outdoor mean temperature
- Plot these registrations in the ET-curve
- Deviations from the ET-curve ?
  Identify and carry out corrections !

# Equipment

- Mean outdoor temperature meter
- Energy meters
- Energy account schemes
- ET-curve
- Deviation checklist

# Mean temperature meter

- Measures the mean outdoor temperature and length of the period ( 1 week = 168 h )
- Placed indoor, easy to reach for the user
- The censor placed in a shady area

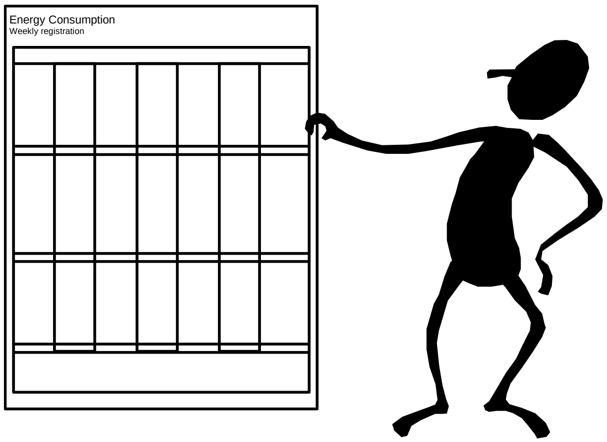


# Energy meter

- Meters for electricity, district heating, gas and oil
- Read the consumption ( kWh, GJ, etc. ) directly or calculate by conversion factors
- Additional meters to separate the building in energy sections / systems ?

# Energy account schemes

- Registrations from energy- and temperature meters
- Calculations to be plot into the ET-curve



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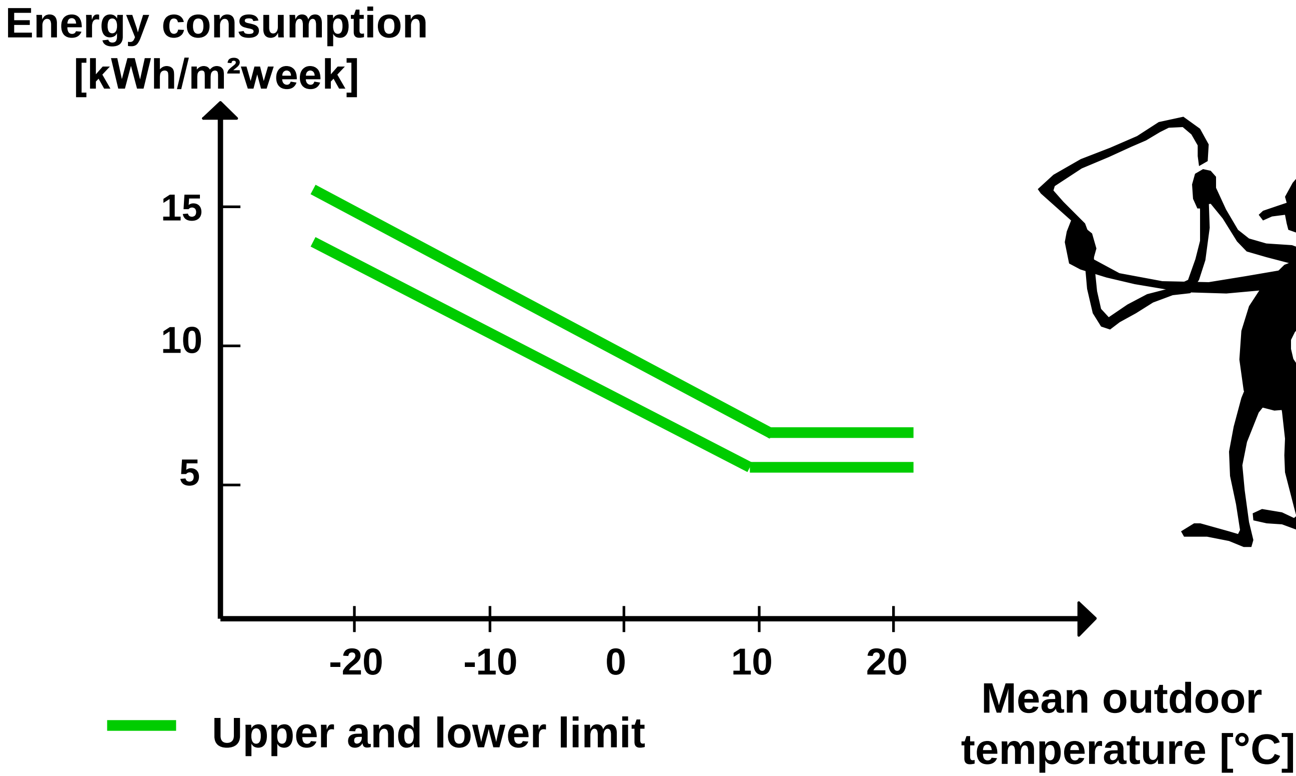
# ET-curve




**Unique ET-curve for each building**

# Deviation Checklist

| Systems to be checked | Possible reasons |
|---|---|
| Heating system | Wrong set point of thermostats |
| | Automatic control system in manual position<br>(i.e. no temperature control during the day) |
| | Broken timer for night set back |
| | Open dampers in boilers when no operation (draft loss) |
| | Open windows |
| | Broken control valves (no shunting of water) |
| | Leakage in the distribution system |
| | … to be continued |
| Ventilation system | Broken timer for start / stop |
| | Broken heat recovery unit |
| | … to be continued |

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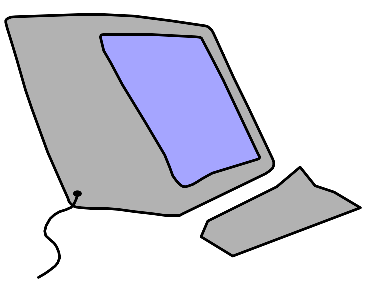
# Computerized Energy Monitoring

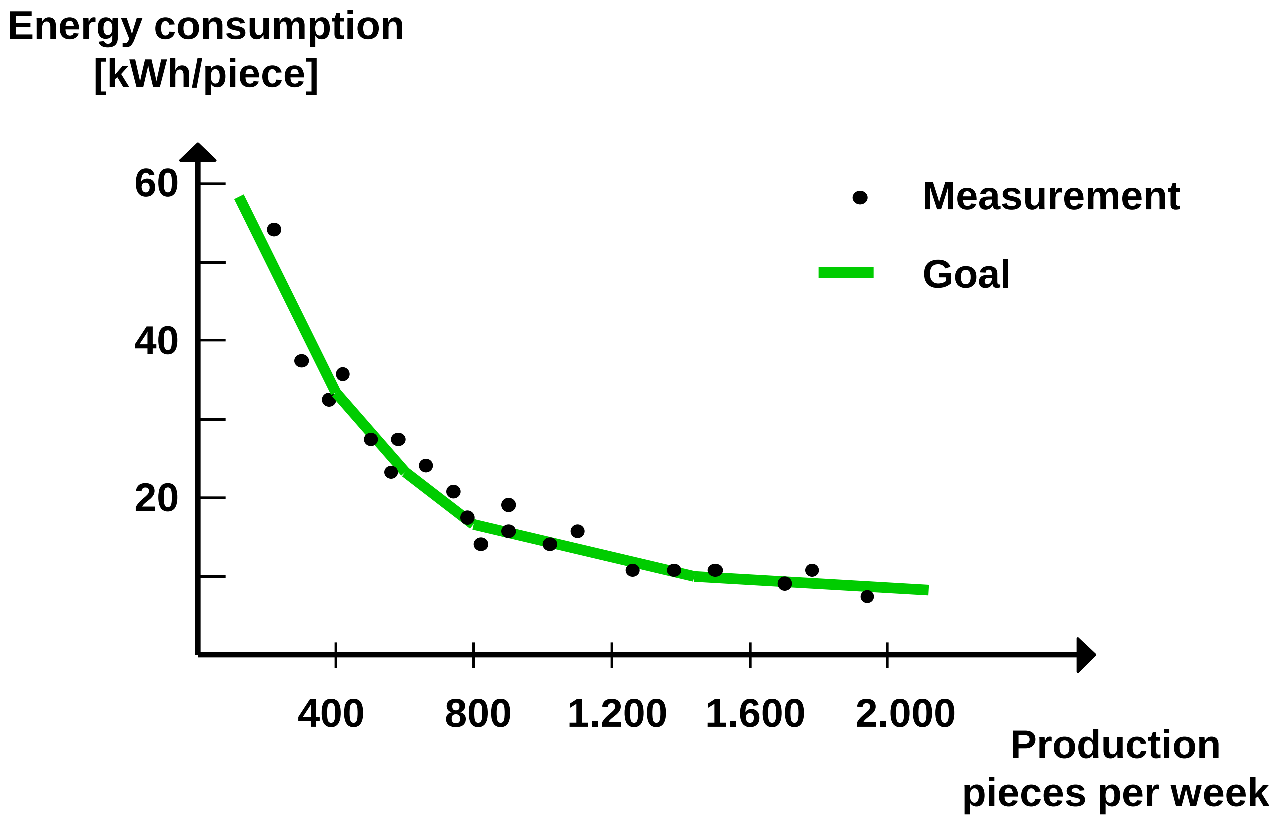
**Additional information:**

- **Energy costs**
- **Accumulated energy costs and consumption**
- **Continuous prognoses**
- **Measured energy consumption compared with the calculated consumption**
- **Weekly and accumulated deviations from the ET-curve**
- **Annual consumption and costs, measured and calculated**

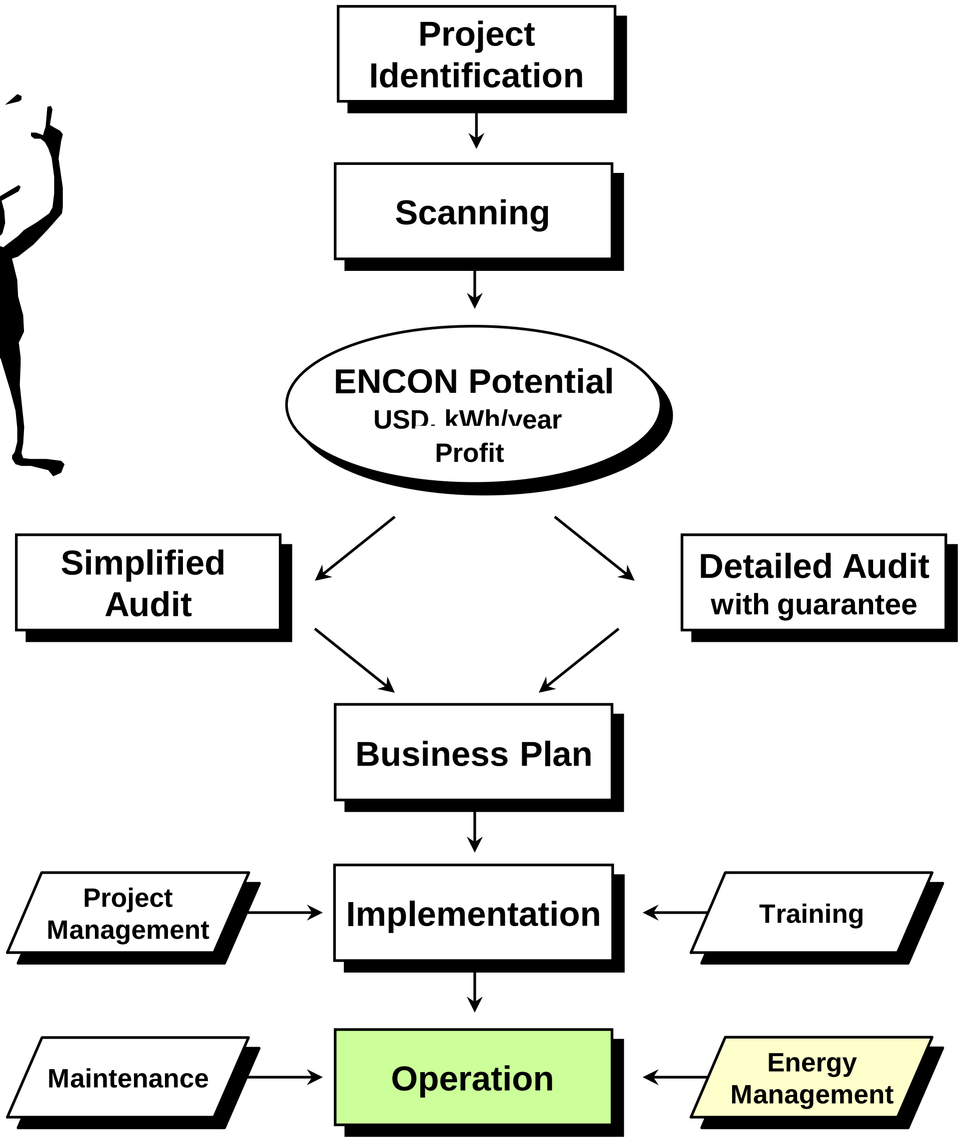


# Industry - EP-curve

## Energy - Production curve



# The ENCON Process



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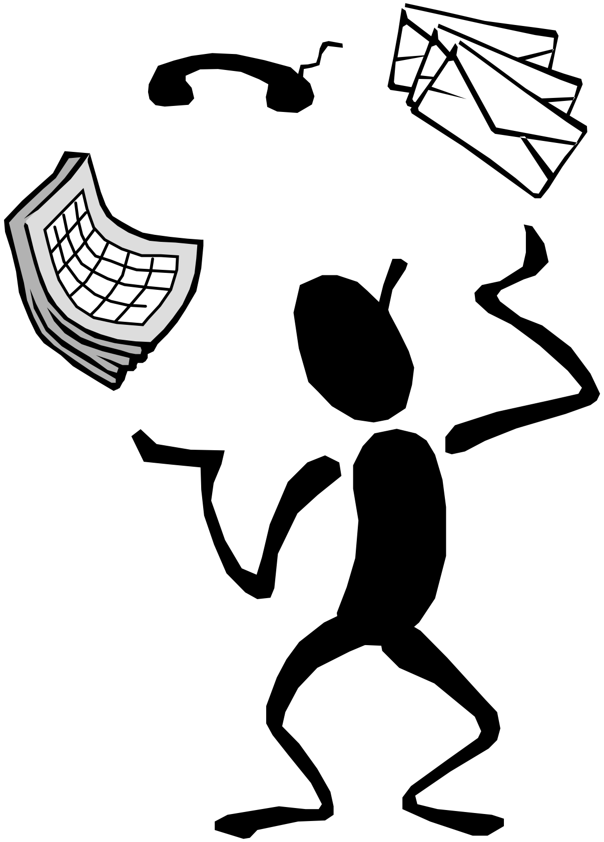
# OPERATION AND MAINTENANCE



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# The Project Development Process

**Identification**

↓

**Scanning**

↓

**Potential**
USD, kWh/year
Profit

↓

**Energy Auditing**

↓

**Business Planning**

↓

**Implementation**

↓

**Operation**

# Operation and maintenance

**Aims :**

**1.** Provide suitable conditions in the building/process

**2.** Keep the operation costs as low as possible, permanently

**3.** Prevent large and expensive repairs

# Operation and Maintenance

**Definitions:**

**Operation:**

**<u>Technical systems</u>:** Regular inspection of all technical systems

**<u>Building envelope:</u>** Regular inspection to ensure correct condition

**Maintenance, periodical:**

**Scheduled work required at certain intervals to maintain the condition of the building/process**

**<u>Technical systems:</u>** Planned work such as replacement of filters, greasing of motors, lighting bulbs, etc.

**<u>Building envelope:</u>** Planned work as painting of wooden facades, replacement of gaskets and outdoor grouting, etc.

**Maintenance, acute:**

**Replacement caused by worn out or broken systems and components**

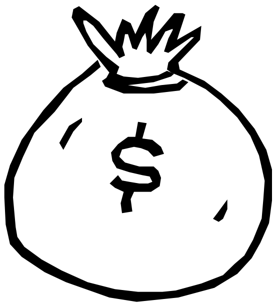
# Acute maintenance

**Replacement caused by worn out or broken systems and components**

- **Breakdown of pumps**
- **Breakdown of burner**
- **Leakage in the roof**
- **Broken windows**
- **etc.**

# Project economy

- Capital cost
- Administration cost
- Operation cost
- Maintenance cost

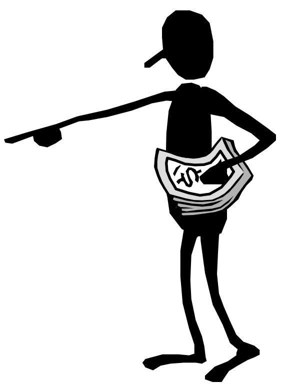


# Capital cost

**All investments to construct the building/project:**

- **Acquisition price of the site**
- **Consultancy fees**
- **Construction costs**
- **Insurance during construction, taxes, etc.**
- **Financing costs during construction**

**Major renovation = Capital cost**



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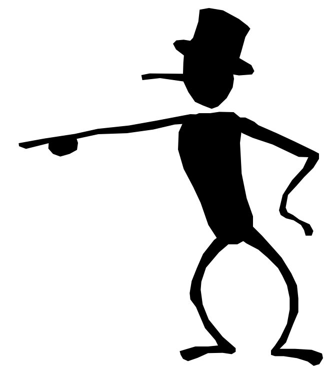
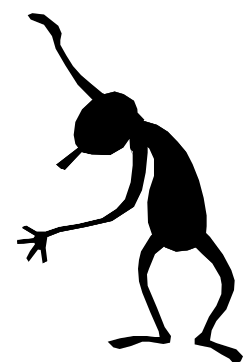
# Administration cost



- Taxes, duties and licenses
- Insurance
- Salaries for Management staff

# Operation cost

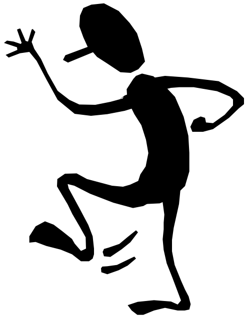
- Salaries for O&M personnel
- External service companies
- O&M components
- Cleaning
- Energy
- Water, etc.



# Maintenance cost

**Both periodical and acute maintenance:**

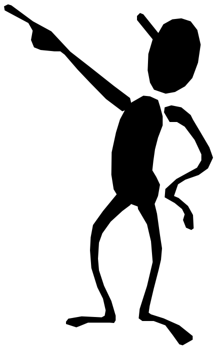
- **Regular, preventive maintenance (own and/or external personnel)**
- **Maintenance of components**
- **Improvements**
- **Repairs and replacements**



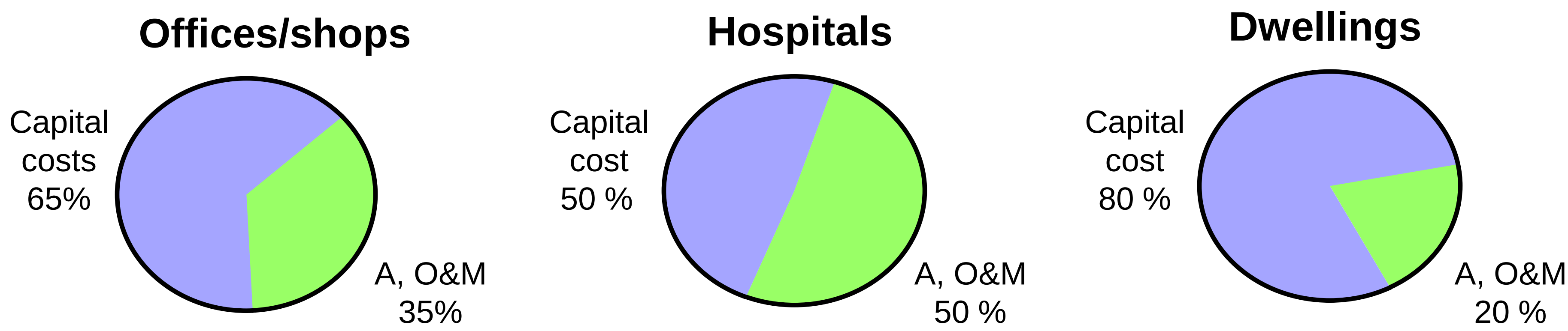
# Lifetime cost

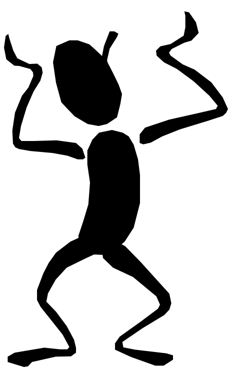
$$\text{Lifetime cost} = I_0 + (A + O + M) \cdot \frac{1 - (1 + r)^{-n}}{r}$$

| | |
|---|---|
| $I_0$ | Capital cost ( = Investment ) |
| A | Administration cost |
| O | Operation cost |
| M | Maintenance cost |
| r | Real interest rate |
| n | Lifetime ( normally technical lifetime ) |



# Lifetime cost



# Gas heating central

Investment $I_0$ = 10 000 USD

Real interest rate $r$ = 10 %

Regular maintenance $M$ = 700 USD/year $n$ = 20 years

No maintenance $M$ = 0 USD/year $n$ = 10 years

**The most profitable alternative after 20 years ?**

**Alternative 1**

$I_0$ = 10 000 USD

$M_{20\ years}$ = $20 \cdot 700$ USD = 14 000 USD

= 24 000 USD

**Alternative 2**

$I_0$ = 10 000 USD

$I_{10}$ = 10 000 USD

= 20 000 USD

**Regular maintenance not profitable ?**

# Lifetime cost

**Alternative 1** (Systematic maintenance for 20 years):

$$\text{Lifetime cost} = I_0 + M \cdot \frac{1 - (1 + r)^{-n}}{r}$$

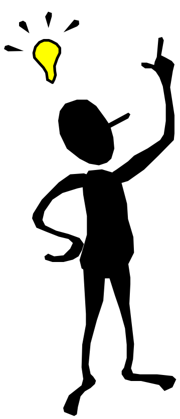
$$= 10.000 + 700 \cdot \frac{1 - (1 + 0{,}10)^{-20}}{0{,}10} \quad \underline{= 15\,960 \text{ USD}}$$

**Alternative 2**

$$I_0 = 10\,000 \text{ USD}$$

$$I_{10} \ \underline{= 10\,000 \text{ USD}}$$

$$\underline{= 20\,000 \text{ USD}}$$



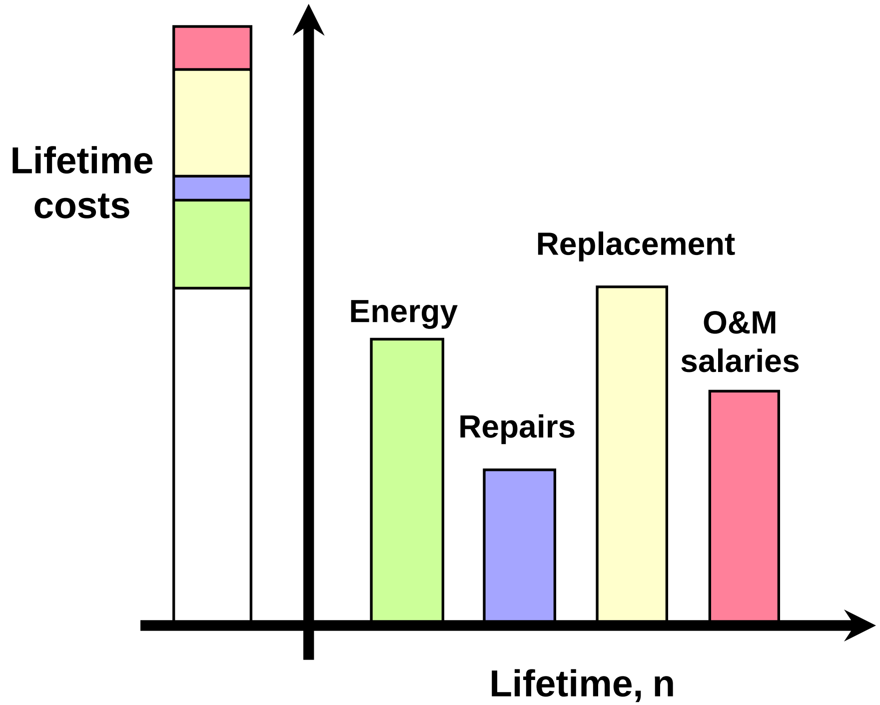
**Regularly maintenance = Profitable !**

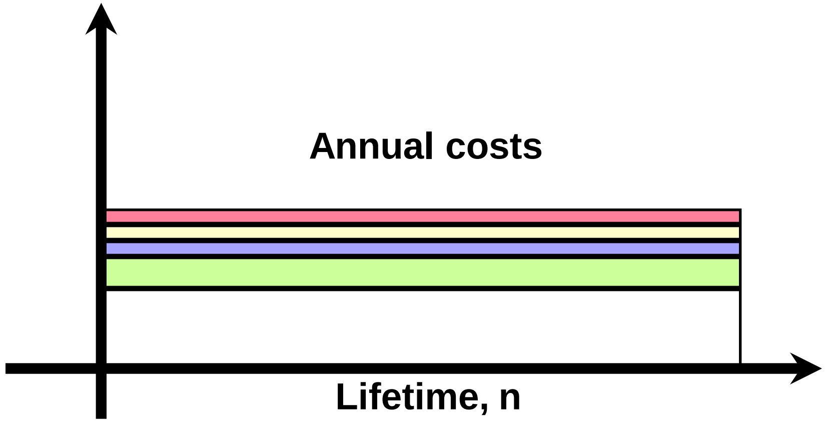
# Annual cost

**The lifetime cost as an annuity over the lifetime:**

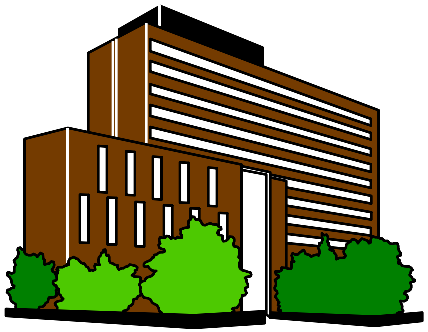
**Annual cost = f · Lifetime cost**

$$f = \frac{r}{1 - (1 + r)^{-n}} = \text{annuity factor}$$



# Office building



| | | |
|---|---|---|
| Lifetime cost | | 1 500 000 USD |
| Real interest rate | r | 5 % |
| Lifetime | n | 50 years |

**What is the annual costs ?**

**Annual costs = f · Lifetime cost**

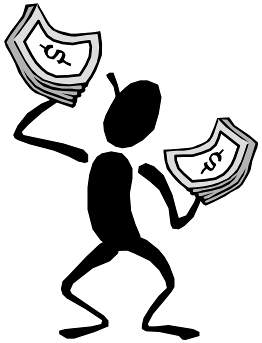
**= 0,05478 · 1.500.000 USD** <u>**= 82 170 USD/year**</u>

# Annual cost analyses

- During design/planning, implementation as well as operation
- Evaluation of alternative solutions
- Evaluation of changed operation procedures

**Profitable solution ?**

**Evaluate lifetime cost, not only investment**



# O&M costs

## Norwegian standard figures

| Buildings | Offices / shops | Schools | Nursing homes | Hospitals |
|---|---|---|---|---|
| Operation and inspection<br>Cleaning<br>Energy | 10 – 20<br>12 – 31<br>20 – 26 | 9 – 19<br>15 – 38<br>14 – 18 | 8 – 16<br>11 – 28<br>18 – 24 | 13 – 25<br>11 – 28<br>18 – 24 |
| **Sum, Operation (*)** | 42 – 77 | 38 – 75 | 37 – 68 | 42 – 77 |
| Maintenance | 6 – 19 | 6 – 20 | 7 – 27 | 5 – 14 |
| **Sum, O & M (**)** | 67 | 65 | 63 | 65 |

**All figures in USD/m$^2$year**

# Documentation

- **How** **are the installations supposed to operate**
- **Which** **installations to maintain**
- **How** **to maintain the installations**
- **When** **to maintain the installations**
- **Who** **is responsible for doing the work**

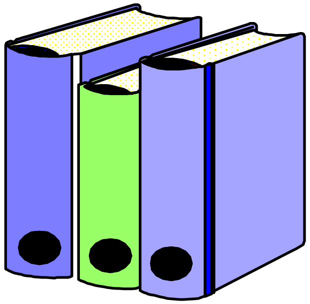
**The documentation must exist,**
**and be easily accessible and useable**

↓

## Operation and Maintenance Manuals

# Operation and Maintenance Manual

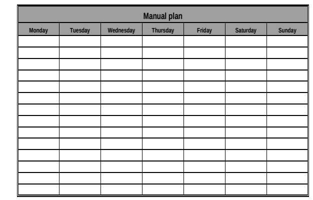
1. Address, phone list, etc.
2. System overview
3. Principal drawings
4. Operation tables
5. Operation check lists
6. Annual and monthly plans
7. Weekly plans (*)
8. Energy consumption
9. Component cards
10. Spare part list
11. Brochures
12. Drawings
13. Balancing protocols



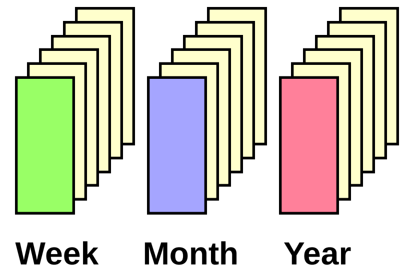
(*) Use of weekly plans must be decided for each project.

# Time-control tools

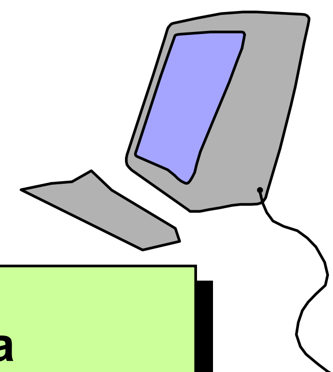
1. Manual forms or charts




2. Job card wall board

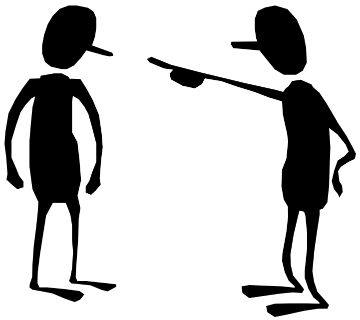



3. Computer based tools



**Manual systems:** < 10 - 15 000 m² floor area
**Computer based tool:** > 10 - 15 000 m² floor area

# Time-control tools



**The organisation depends on :**

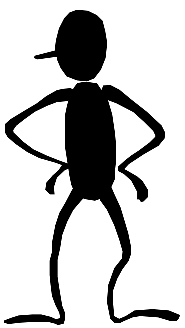
- **The size of the project/building(s)**
- **Installation complexity**

**towards:**

- **The qualification on the existing staff**
- **The size of the existing staff**
- **The need and availability of expertise**
- **The required equipment for O&M**

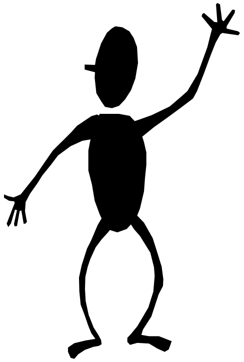
**O&M done by :**

1. **Internal personnel**
2. **Partly by internal personnel**
   **the rest by professional companies**
3. **All by professional companies**



# Efficient O&M ?

- Qualification and motivation of the O&M personnel
- Easy traceable responsibility
- Available O&M Manuals
- The O&M and automatic control system is compatible



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# THANK YOU FOR YOUR ATTENTION

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