

SUSTAINABLE ENERGY  
**SET@Work**  
 TECHNOLOGY AT WORK

# Sustainable Design

## Tools

Authorized by Lars Munklee

[www.setatwork.eu](http://www.setatwork.eu)

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# Course structure

1. Introduction
2. Workflow in Sustainable Design projects
- 3. Tools for Sustainable Design**
4. Integration with design practices
5. Organisation and stakeholders
6. Success with Sustainable Design

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2

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# Agenda

- Baseline data collection tools
- Onion diagrams
- Introduction to Process Integration
- Performance indicators

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3

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## Agenda

- **Baseline data collection tools**
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4  
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## Data collection – meta data

- Site specific utility prices
- Utility specific CO<sub>2</sub>-emission
- Operation key figures (days/year, hours/year)
- Utility key figures (steam quality, Chilled water temperature, compressed air pressure)
- Meteorological data (Temperature and RH on hourly basis throughout a year)
- Assumptions

5  
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## Baseline components

- Process
  - Process flow Diagrams
- Operational data
  - Production rate
  - Capacity analysis
  - Project time schedule
- Utilities
  - HVAC
  - CIP
  - Inactivation
  - SIP
  - Vacuum
- Infrastructure
  - Lighting
  - Cold storages
  - Domestic heating
  - Hot tap water

6  
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## Utility prices, example

Unit prices		CO <sub>2</sub> emission	
Electricity	0,15 [€/kWh]	0,8 [kgCO <sub>2</sub> /kWh]	
Plant steam	0,06 [€/kWh]	0,4 [kgCO <sub>2</sub> /kWh]	
Clean steam	0,1 [€/kWh]	0,4 [kgCO <sub>2</sub> /kWh]	
Low temperature heating water, LTHW	0,8 [€/kWh]	0,4 [kgCO <sub>2</sub> /kWh]	
Cooling tower	0,005 [€/kWh]	0,03 [kgCO <sub>2</sub> /kWh]	
5°C chilled water	0,05 [€/kWh]	0,15 [kgCO <sub>2</sub> /kWh]	
D°C	0,06 [€/kWh]	0,25 [kgCO <sub>2</sub> /kWh]	
Compressed air	0,014 [€/m <sup>3</sup> ]	0,08 [kgCO <sub>2</sub> /m <sup>3</sup> ]	
Water For Injection (WFI)	15 [€/m <sup>3</sup> ]		
Purified water (PWTR)	0,8 [€/m <sup>3</sup> ]		
High Purified water (HPW)	0,8 [€/m <sup>3</sup> ]		
Water for operation (WFO)	0,5 [€/m <sup>3</sup> ]		
WWTP variable costs	4 [€/m <sup>3</sup> ]		
WWTP total	10 [€/m <sup>3</sup> ]		

7  
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## Case - Cleaning

### CIP sequence

```

    graph LR
      A[Pre-rinse (5 min)  
ambient PW  
to remove soil from eqp.] --> B[Caustic wash (15 min)  
65°C  
Removal of organic  
materials]
      B --> C[Rinse 1 (5 min)  
ambient PW  
remove caustic & organic  
materials]
      C --> D[Acid wash (10 min)  
60°C (weekly)  
to remove soil from eqp.]
      D --> E[Rinse 2 (5 min)  
ambient PW (weekly)  
remove acid CIP solution]
      E --> F[Final rinse (5 min)  
ambient PW  
Must meet TOC and  
conductivity specs.]
      F --> G[Air purge  
if eqp. will not be used  
immediately after cleaning]
  
```

8  
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## Case - Cleaning

### Baseline

Annual costs for CIP: 279000 €/year

- CIP sequence
- Number of equipment
- CIP frequency
- CIP equipment consumption

9  
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## Case – Cleaning

### Baseline breakdown

Resource		Consumption per cycle	Annual consumption	Costs [€/year]	Emission [kg <sub>CO2</sub> /year]
Electricity (pumps + air)	[kWh]	8	80,000	12,000	64,000
Heat	[kWh]	45	450,000	27,000	180,000
Water	[m <sup>3</sup> ]	5	50,000	40,000	80,000
WWTP	[m <sup>3</sup> ]	5	50,000	200,000	
<b>Total</b>				<b>279,000</b>	<b>324,000</b>

10  
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11  
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## The Onion diagram

'What you pay is not necessarily what you need'

Core energy needs → (points to Energy service layer)

The invoice → (points to the entire diagram)

12  
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## The Onion diagram

- Good Housekeeping
- Operation & Maintenance
- Control
- Equipment
- Process
- Energy service

E.g. Standby mode possible

Equipment efficiency

E.g. Thermal sterilisation process as alternative to chemical or x-ray

Production process needs e.g. sterilisation of product

13

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## Energy needs, examples

- Process
  - Could 80% Ethanol (default: 88%) satisfy process requirements?
  - Could cooling tower water substitute cooling with chilled water?
  - Could Process water substitute Purified water for the process?
  - Could inactivation temperature and holding time be reduced?
  - Could process heating demand be satisfied from heat recovery systems?
- Utilities
  - Clean rooms
    - What is the correct air change rate for a ISO Class 7 clean room?
    - Is humidity control required in production rooms?
    - May acceptable room temperature be expanded from 19°C-21°C?
  - Cleaning In Place
    - Could 60°C Acid rinse satisfy cleaning process?
    - Is drying with compressed air necessary?
  - Compressed air
    - Why is a supply pressure of 7 BarG required?

14

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15

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## Process Integration

Cost, impact

Technology changes  
(new processing techniques, new chemistry)

Equipment replacement

Material substitution

Segregation, recycling

Change in operating conditions

Target

16

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## Pinch analysis

- Technique developed by Bodo Linnhoff 1970's, Manchester University
- Illustrates potential for heat recovery by network of heat exchangers
- Determines theoretical minimum heating and cooling demand of an energy system
- Graphical representation via composite curves

17

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## Composite curves

T [°C]

Q [kW]

$Q_{cool, minimum}$

$Q_{heat, maximum}$

$Q_{heat, minimum}$

— Hot composite curve (processes to be cooled)

— Cold composite curve (processed to be heated)

18

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## Process Integration in industry

Saving initiative	Cold process stream	Hot process stream
Distillation column	Preheat feed	Cool distillate
HVAC	HVAC heating coils	Heat recovery, chillers
CIP	Preheating water	Heat recovery, air compressors
Autoclave	Preheating products	Water in autoclave
Energy efficiency of inactivation	Waste water with GMO	Inactivated waste water
Efficiency of pasteurizer	Cold product	Pasteurised product
Spray dryer	Feed water	Humid exhaust air

19  
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20  
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## Performance indicators

- Management systems are rarely involved in investment projects
- Sustainable Design holds the overview of the processes
- Sustainable Design has identified equipments with high cost and environmental impact

21  
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## Management KPI's

- Purpose
  - Document current environmental performance
  - Improve performance
  - Contribute to Full manufacturing costs analysis
  - Benchmarking
    - Products
    - Systems
- How
  - Consumption index for resources vs. Time [kWh/week]
  - Consumption vs. Production [kWh/kg]

22  
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## Operational KPI's

- Purpose
  - Maintain/improve environmental performance of equipment and systems
  - Benchmarking
- Operational KPI ownership
  - Environmental management system
  - Maintenance
  - Operation

23  
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## Case - KPI

System	Management KPI	Operation KPI	Resources included
Ventilation	Costs per year CO <sub>2</sub> /year kWh/year	kWh/m <sup>3</sup>	Electricity, Heating & Cooling
Cooling systems	Costs per year CO <sub>2</sub> /year kWh/year m <sup>3</sup> <sub>water</sub> /month	COP (kWh <sub>cool</sub> /kWh <sub>elect</sub> ) kW (chiller, system & towers) kWh <sub>cool</sub> /day (week, month) m <sub>water</sub> <sup>3</sup> /day T <sub>supply</sub> * T <sub>return</sub>	Cooling tower water  Electricity

24  
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## Case - KPI

System	Management KPI	Operation KPI	Resource
Air compressor	Costs per year CO <sub>2</sub> /year kWh/year	COP (m <sup>3</sup> /kWh <sub>elect</sub> ) kW kWh/day (week, month)	Electricity
Distillation column	Costs per year CO <sub>2</sub> /year kWh/year Kg <sub>distillate</sub> /year	kWh <sub>steam</sub> /kg <sub>distillate</sub> kWh <sub>cooling water</sub> /kg <sub>distillate</sub>	Steam Cooling tower

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25

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**The end**

Thank you for your attention

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