MORE—CONNECT
MORE—CONENCT 4th training module

Ventilation and modular HVAC systems

Duration: 4 hours
Type: class room lectures

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Introduction

• As the buildings are built for people not to consume/save energy it is vitally important also for nZEB to provide comfortable and non-harmful indoor air parameters for occupants. This usually involves designing and installing various HVAC systems. Just in case of nZEB the added challenge of keeping the energy consumption as low as possible comes into play.

• The primary objective of this learning module is to give information and present study results on how to evaluate possible heating, ventilation and air-conditioning solutions for nZEB multi apartment buildings.

• In scope of this module technology inventory and review of all necessary components that are necessary to climatize the buildings will be evaluated. A specific focus will be paid to modular solutions. The design specifics of embedded ventilation ducts and modular energy unit will also analyzed.

• The ventilation norms and guidelines for MORE-CONENCT project countries will be compared and discussed. The module will summarize a brief overview of different ventilation systems advantages and disadvantages. It will provide comparison of installation and running costs for various ventilation solution for Latvian case study.

• After completing this module individuals will be able to choose ventilation strategy considering building type, technical conditions and user behavior. Also knowledge on duct sizing and selection of ventilation units will be obtained.
Ventilation is one of the most complex systems as it has many possible solutions and variations. However it is one of the most important systems as it provides fresh air and in many cases is the main reason for bad IAQ and cause of Sick Building Syndrome.

The ventilation systems can be dived in three large groups according to types:

- natural ventilation,
- hybrid ventilation (mechanical exhaust ventilation),
- mechanical supply-exhaust ventilation
  - Apartment based ventilation system
  - Building based ventilation system
Learning tasks and methodology

• To evaluate possible ventilation solutions for nZEB multi apartment buildings in three European geoclusters
• To perform economic and technical comparison of different ventilation systems
• To develop introduction of modular solutions and integration of ventilation ducts into external insulation

• Determining the necessary ventilation air volumes in case of each country;
• Designing most common ventilation system types for an apartment;
• Estimating construction costs of ventilation system installing;
• Calculating and comparing the life cycle costs of each ventilation system including maintenance, necessary electrical energy and necessary energy for heating;
• Estimating practical solutions for integration of ventilation systems elements into limited technical space available in exiting post-war multi apartment buildings;
Geo-cluster concept illustrates trans-national areas where strong similarities are found in terms of climate, culture, construction typologies and other factors. During this paper the focus will be on GC 1 represented by Denmark, GC2 represented by Estonia and Latvia and GC4 represented by Portugal.

Fig. 1. EU H2020 MORE-CONNECT project geo-cluster
# Ventilation air calculation

## Table 1. Necessary residential ventilation airflow rates according to local regulations

<table>
<thead>
<tr>
<th>Room type</th>
<th>Unit</th>
<th>Geo-clusters and countries*</th>
<th>GC1</th>
<th>GC2</th>
<th>GC2</th>
<th>GC4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Denmark</td>
<td>Estonia</td>
<td>Latvia</td>
<td>Portugal</td>
<td></td>
</tr>
<tr>
<td>Toilet</td>
<td>m³/h</td>
<td>36</td>
<td>36</td>
<td>25</td>
<td>30 to 60</td>
<td></td>
</tr>
<tr>
<td>Bathroom with toilet</td>
<td>m³/h</td>
<td>54</td>
<td>54</td>
<td>50</td>
<td>45 to 90</td>
<td></td>
</tr>
<tr>
<td>Staircases</td>
<td>m³/(h·m²)</td>
<td>1.08</td>
<td>1.25</td>
<td>1</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Bedroom</td>
<td>m³/(h·m²)</td>
<td>1.08</td>
<td>12 l/s (8 l/s in &lt;11m² bedroom)</td>
<td>3</td>
<td>Dependent on room size. Approximate value is 1h⁻¹</td>
<td></td>
</tr>
<tr>
<td>Kitchen</td>
<td>m³/h</td>
<td>72</td>
<td>30 (22 for 1 room apartment)**</td>
<td>60-90</td>
<td>60 to 120</td>
<td></td>
</tr>
<tr>
<td>Hallway</td>
<td>h⁻¹</td>
<td>0.5</td>
<td>-</td>
<td>0.5 - 1</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Technical room</td>
<td>h⁻¹</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5 - 1</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Total supply air</td>
<td>m³/(h·m²)</td>
<td>1.08</td>
<td>1.5</td>
<td>-</td>
<td>The sum of the supply air of all bedrooms and living rooms</td>
<td></td>
</tr>
</tbody>
</table>

Latvia – 4200 m³/h; Denmark – 1250 m³/h; Estonia – 2745 m³/h; Portugal – 4050 m³/h
Calculated ventilation air volumes for Latvian case study building

<table>
<thead>
<tr>
<th>Room nr.</th>
<th>Room type</th>
<th>Supply air $m^3/h$</th>
<th>Exhaust air $m^3/h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bedroom</td>
<td>55 (90 for 2-room apartment)</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Kitchen</td>
<td>-</td>
<td>90</td>
</tr>
<tr>
<td>3</td>
<td>Bathroom</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Storage</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total for an apartment ($m^3/h$)</strong></td>
<td>55 (90)</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td><strong>Total for whole building ($m^3/h$)</strong></td>
<td>$6 \cdot 5 \cdot 140 = 4200$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculated ventilation air volumes for Estonian case study building

<table>
<thead>
<tr>
<th>Room nr.</th>
<th>Room type</th>
<th>Supply air $m^3/h$</th>
<th>Exhaust air $m^3/h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bedroom</td>
<td>86*</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Kitchen</td>
<td>-</td>
<td>22 (30 for 2-room apartment)</td>
</tr>
<tr>
<td>3</td>
<td>Bathroom+WC</td>
<td>-</td>
<td>54</td>
</tr>
<tr>
<td>4</td>
<td>Storage</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total for an apartment ($m^3/h$)</strong></td>
<td>86*</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td><strong>Total for whole building ($m^3/h$)</strong></td>
<td>$(5 \cdot 86 + 119) \cdot 5 = 2745$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculated ventilation air volumes for Denmark case study building

<table>
<thead>
<tr>
<th>Room nr.</th>
<th>Room type</th>
<th>Supply air $m^3/h$</th>
<th>Exhaust air $m^3/h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bedroom</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Kitchen</td>
<td>-</td>
<td>72 - VAV</td>
</tr>
<tr>
<td>3</td>
<td>Bathroom</td>
<td>-</td>
<td>54 - VAV</td>
</tr>
<tr>
<td>4</td>
<td>Storage</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total for an apartment ($m^3/h$)</strong></td>
<td>40 (50)*</td>
<td>40 (50)*</td>
<td></td>
</tr>
<tr>
<td><strong>Total for whole building ($m^3/h$)</strong></td>
<td>$(5 \cdot 40 + 50) \cdot 5 = 1250$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ventilation type selection (1)

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### Ventilation system through openable windows and natural exhaust

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Units</th>
<th>Quantity</th>
<th>Average price in EU for one unit (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extract grille</td>
<td>200x100 mm</td>
<td>Pcs.</td>
<td>1</td>
<td>17.00</td>
</tr>
<tr>
<td>Extract grille</td>
<td>200x200 mm</td>
<td>Pcs.</td>
<td>2</td>
<td>20.00</td>
</tr>
<tr>
<td>Duct</td>
<td>Ø200 mm</td>
<td>m</td>
<td>3</td>
<td>1.50</td>
</tr>
<tr>
<td>Total cost with 30% added</td>
<td></td>
<td></td>
<td></td>
<td>60.00</td>
</tr>
</tbody>
</table>

### Ventilation system through air inlets and natural exhaust

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Units</th>
<th>Quantity</th>
<th>Average price in EU for one unit (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply vents</td>
<td>Ø160 mm</td>
<td>Pcs.</td>
<td>2</td>
<td>120.00</td>
</tr>
<tr>
<td>Extract grille</td>
<td>200x100 mm</td>
<td>Pcs.</td>
<td>1</td>
<td>17.00</td>
</tr>
<tr>
<td>Extract grille</td>
<td>200x200 mm</td>
<td>Pcs.</td>
<td>1</td>
<td>20.00</td>
</tr>
<tr>
<td>Duct</td>
<td>Ø200 mm</td>
<td>m</td>
<td>2</td>
<td>1.90</td>
</tr>
<tr>
<td>Duct</td>
<td>Ø160 mm</td>
<td>m</td>
<td>3</td>
<td>1.50</td>
</tr>
<tr>
<td>Total cost with 30% added</td>
<td></td>
<td></td>
<td></td>
<td>370.00</td>
</tr>
</tbody>
</table>
Ventilation type selection (2)

Hybrid type ventilation system with supply through air inlets and mechanical exhaust

Decentralized ventilation system with room based mechanical supply and exhaust with room based heat recovery

### Supply vents
- **Ø160 mm**
  - Size: Ø160 mm
  - Units: Pcs.
  - Quantity: 2
  - Average price in EU for one unit (EUR): 120.00

- **Ø100 mm**
  - Size: Ø100 mm
  - Units: Pcs.
  - Quantity: 1
  - Average price in EU for one unit (EUR): 70.00

- **Ø200 mm**
  - Size: Ø200 mm
  - Units: Pcs.
  - Quantity: 1
  - Average price in EU for one unit (EUR): 90.00

### Domestic type extract fan

- **Ø100 mm**
  - Size: Ø100 mm
  - Units: Pcs.
  - Quantity: 1
  - Average price in EU for one unit (EUR): 70.00

### Paired decentralized ventilation devices
- **50 m³/h**
  - Size: 50 m³/h
  - Units: Pcs.
  - Quantity: 4
  - Average price in EU for one unit (EUR): 485.00

### Control unit
- **-**
  - Size: -
  - Units: Pcs.
  - Quantity: 1
  - Average price in EU for one unit (EUR): 320

### Domestic type extract fan
- **Ø100 mm**
  - Size: Ø100 mm
  - Units: Pcs.
  - Quantity: 1
  - Average price in EU for one unit (EUR): 70.00
• High-tech ceramic energy accumulator with regenerating efficiency up to 90%
• Reversible EC ventilator with low energy demand from 3.5 up to 6.1 W and safe voltage 12 V
• Cena ap 350 EUR gabalā
Ventilation type selection (4)

Decentralized ventilation system with apartment based mechanical supply and exhaust with apartment based heat recovery

### Centralized ventilation system with building based mechanical supply and exhaust with heat recovery

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Units</th>
<th>Quantity</th>
<th>Average price in EU for one unit (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AHU (4200 m³/h)</strong></td>
<td>-</td>
<td>Pcs.</td>
<td>1</td>
<td>9500.00</td>
</tr>
<tr>
<td><strong>Air intake grill</strong></td>
<td>Ø560 mm</td>
<td>Pcs.</td>
<td>1</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Extract air roof hood</strong></td>
<td>Ø560 mm</td>
<td>Pcs.</td>
<td>1</td>
<td>700.00</td>
</tr>
<tr>
<td><strong>Silencers</strong></td>
<td>Ø560 mm/ L=1000mm</td>
<td>Pcs.</td>
<td>4</td>
<td>250.00</td>
</tr>
<tr>
<td><strong>Duct</strong></td>
<td>Ø560 mm</td>
<td>m</td>
<td>20</td>
<td>17.30</td>
</tr>
</tbody>
</table>

*The total cost includes the cost of all units located in the apartment and 1/30 of whole price for whole building units, as there are thirty apartments that would be served by the AHU.*
## Life cycle cost analysis

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Comparison of installation and running costs for Latvian / Estonian case study (upper numbers are for Latvia, lower for Estonia)

<table>
<thead>
<tr>
<th>Type of ventilation system</th>
<th>Installation costs(^1) (EUR)</th>
<th>Maintenance costs(^2) (EUR)</th>
<th>Heating costs(^3) (EUR)</th>
<th>Powering costs(^4) (EUR)</th>
<th>Total Annual costs (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural by opening windows and natural exhaust</td>
<td>1800</td>
<td>-</td>
<td>8005</td>
<td>-</td>
<td>8005</td>
</tr>
<tr>
<td>Natural by having inlet valves and natural exhaust</td>
<td>11 100</td>
<td>300</td>
<td>8005</td>
<td>-</td>
<td>8305</td>
</tr>
<tr>
<td>Hybrid by having inlet devices in walls and mechanical exhaust</td>
<td>15 750</td>
<td>450</td>
<td>8005</td>
<td>1155</td>
<td>9610</td>
</tr>
<tr>
<td>Decentralized mechanical supply and exhaust with heat recovery (room based system)</td>
<td>76 800</td>
<td>750</td>
<td>1600 (eff. 0.80)</td>
<td>535</td>
<td>2885</td>
</tr>
<tr>
<td>Decentralized mechanical supply and exhaust with heat recovery (apartment based system)</td>
<td>87 000</td>
<td>1050</td>
<td>1200 (eff. 0.85)</td>
<td>3455 (SFP 1.0)</td>
<td>5705</td>
</tr>
<tr>
<td>Centralized mechanical supply and exhaust with heat recovery</td>
<td>16 760</td>
<td>1000</td>
<td>1600 (eff. 0.80)</td>
<td>2070 (SFP 1.2)</td>
<td>4670</td>
</tr>
</tbody>
</table>

The cost comparison is done for one staircase of previously described case study building and with following assumptions:

1. Cost of installing all necessary equipment;
2. Annual maintenance cost for all necessary equipment for whole staircase section;
3. Cost of heating supply air for one heating season assuming the Heating degree days for base indoor temperature of +21,0°C for Latvia 4263, for Estonia 5656 (8) and assuming that the heating occurs by district heating system with following costs - for Latvia 55.55 EUR/MWh; for Estonia 65 EUR/MWh;
4. Annual cost of all energy necessary to power the ventilation devices for whole staircase apartment assuming that they are powered by electricity with the cost of 0.169 EUR/kWh for Latvia; 0.15 EUR/kWh for Estonia.
Life cycle cost analysis

- Natural by opening windows and natural exhaust
- Natural by having inlet valves and natural exhaust
- Hybrid by having inlet devices in walls and mechanical exhaust
- Decentralized mechanical supply and exhaust with heat recovery (room based system)
- Decentralized mechanical supply and exhaust with heat recovery (apartment based)
- Centralized mechanical supply and exhaust with heat recovery
## Comparison of ventilation systems

<table>
<thead>
<tr>
<th>Type of ventilation system</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| **Windows opening and natural exhaust** | +Low investments and maintenance  
+Does not involve any technologies (solid)  
+Easily controllable  
+Does not affect architecture | -Incoming air does not heat up therefore causing draft  
-Incoming air does not go through filters therefore letting insects and dust inside  
-Low control options  
-Requires human interaction  
-Very low working efficiency during warm period of year  
-Let's through extra noise from outside  
-No possibilities for heat recovery  
-Affected by outside weather (wind, temperature) |
| **Natural ventilation with inlet valves** | +Relatively low investments and maintenance  
+Requires only some equipment  
+Easily controllable  
+Incoming air goes through filters therefore not letting insects and dust inside  
+Moderate control options  
+Incoming air goes through filters therefore not letting insects and dust inside  
+The exhaust fans can be equipped with light switch or moisture sensor  
+Stable working throughout the year | -Incoming air does not heat up therefore causing draft (can be solved by placing inlet valves behind radiators)  
-Requires some human interaction  
-Very low working efficiency during warm period of year  
-Let's through extra noise from outside  
-No possibilities for heat recovery  
-Affects building façade by requiring openings |
| **Mechanical exhaust ventilation with natural supply through inlet valves** | +Relatively low investments and maintenance  
+Requires only some equipment  
+Easily controllable  
+Incoming air goes through filters therefore not letting insects and dust inside  
+The exhaust fans can be equipped with light switch or moisture sensor  
+Stable working throughout the year | -Incoming air does not heat up therefore causing draft (can be solved by placing inlet valves behind radiators)  
-Requires some human interaction  
-Very low working efficiency during warm period of year  
-Let's through extra noise from outside  
-No possibilities for heat recovery  
-Affects building façade by requiring openings |
| **Mechanical supply-exhaust ventilation** | | |
| Room based | +Incoming air goes through filters therefore not letting insects and dust inside  
+The devices can be equipped with moisture sensor  
+Stable working throughout the year  
+With heat recovery therefore reducing heating costs and supplying warm air  
+Complete control options  
+All-in-one equipment includes all necessary parts  
+High control options | -Very high investment costs  
-Let's through extra noise from outside and is a source of noise (relatively quiet)  
-Affects building façade by requiring openings  
-Low air volumes  
-Requires place for ducts in shafts and rooms  
-Requires multiple devices for each apartment |
| Apartment based | +Incoming air goes through filters therefore not letting insects and dust inside  
+The devices can be equipped with moisture, CO₂, VOC or occupancy sensors  
+Stable working throughout the year  
+With heat recovery therefore reducing heating costs and supplying warm air  
+All-in-one equipment includes all necessary parts  
+Average investment costs  
+High control options | -Very high investment costs  
-Can be a source of noise if designed incorrectly  
-Requires place for ducts in shafts and rooms |
| Building based | +Incoming air goes through filters therefore not letting insects and dust inside  
+The device can be equipped with moisture, CO₂, occupancy sensors  
+Stable working throughout the year  
+With heat recovery therefore reducing heating costs and supplying warm air  
+All-in-one equipment includes all necessary parts  
+High control options | -Occupants are not in control of the centralized device  
-Can be a source of noise if designed incorrectly  
-Requires place for ducts in shafts, building envelope and rooms |
### Integrated duct design

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<table>
<thead>
<tr>
<th>Velocity in ducts</th>
<th>Latvia (140 m³/h)</th>
<th>Estonia (119 m³/h)</th>
<th>Denmark (50 m³/h)</th>
<th>Portugal (135 m³/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3 m/s</td>
<td>160</td>
<td>125</td>
<td>100</td>
<td>160</td>
</tr>
<tr>
<td>&lt;4 m/s</td>
<td>125</td>
<td>125</td>
<td>100</td>
<td>125</td>
</tr>
<tr>
<td>&lt;6 m/s</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Fig. 4. Integration of ducts into prefabricated panel (approx. thermal transmittance is 0.18 W/(m²·K))
HVAC systems “house engine”

Typical components of modular HVAC unit are:

✓ Heat exchanger for heating loop;
✓ Hot water heat exchanger;
✓ Local energy source (gas boiler, heat pump, connection to external energy sources);
✓ Expansion tank;
✓ Air handling unit including ventilation heat recovery;
✓ In rarer case also cooling source.
HVAC systems “house engine”

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• Example of “engines” in Estonian pilot:
  • Ventilation
    • ½ building based balanced ventilation units with VHR
      • “engine“ on roof,
      • ducts in modular panel
  • ½ apartment based balanced ventilation units with VHR
    • “engine“ in balcony or in coatroom
    • ducts trough modular panel

<table>
<thead>
<tr>
<th>pos.</th>
<th>neg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilation is always on</td>
<td>Difficult to control</td>
</tr>
<tr>
<td>Quiet</td>
<td>Kitchen without VHR</td>
</tr>
<tr>
<td>Less disturbance of the</td>
<td></td>
</tr>
<tr>
<td>residents.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>pos.</th>
<th>neg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced control</td>
<td>Risk for higher noise</td>
</tr>
<tr>
<td>Kitchen with VHR</td>
<td>More ducts in apartment</td>
</tr>
<tr>
<td>Higher efficency of VHR</td>
<td></td>
</tr>
</tbody>
</table>
To choose, calculate and design ventilation systems for given building:

- Determine the necessary ventilation rate for each premise;
- Design the ventilation system;
- Make a rough cost estimate of designed system;
- Perform Life cycle cost analysis for chosen ventilation system.

**Initial data:**
- Building plans;
- Location of building.