Deep energy renovation to nZEB of old concrete apartment building to nZEB by using wooden modular element

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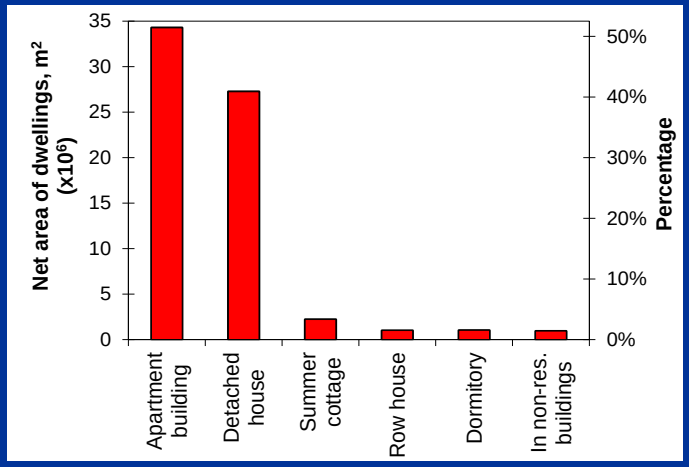
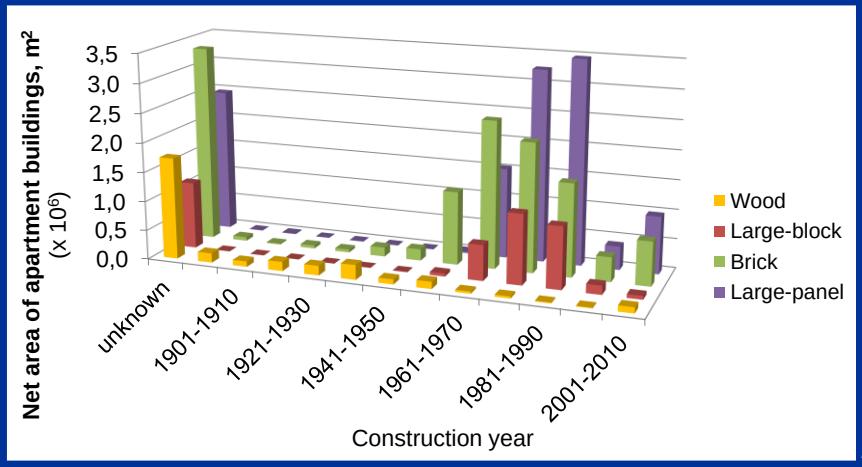
Apartment buildings in Estonia

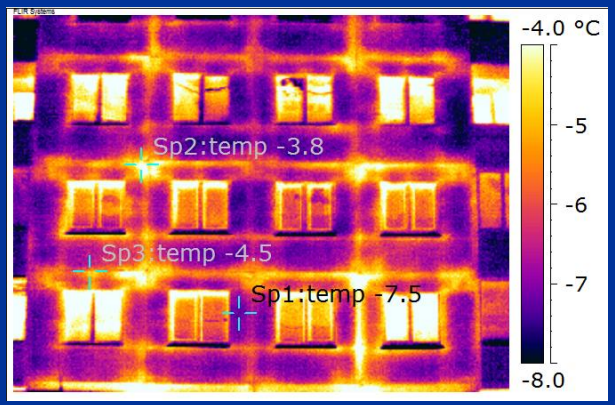
- ≈ 27 000 buildings, ≈ 34 miljon m^2
- 71% of population lives in apartments
- Built mainly during: 1950−90
- Loadbearing structures:
  - brick: 37%,
  - concrete: 36%,
  - lightweight concrete: 12%,
  - wood: 8%





The main problems with apartment buildings

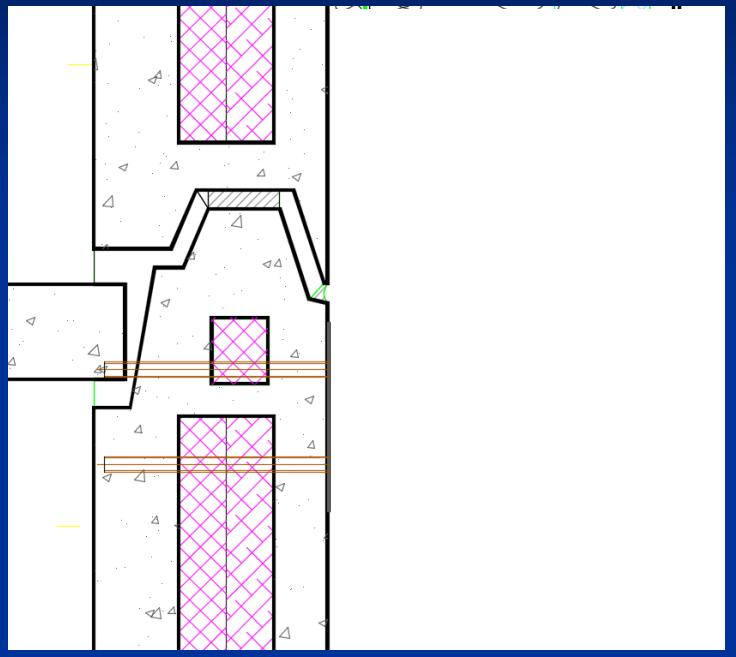
- Building envelope structures
  - High energy loss: $U \approx 0.7-1.0$ W/(m^{2}K)
  - A lot serious thermal bridges
  - Degradation of facades (corrosion, frost resistance)
- Service systems
  - Natural ventilation: inadequate airflow, draft
  - Heating systems: no thermostats, unbalance
  - District heating: high heat loss
- The designed service life is over.



Deep energy renovation with prefabricated wooden elements: a pilot

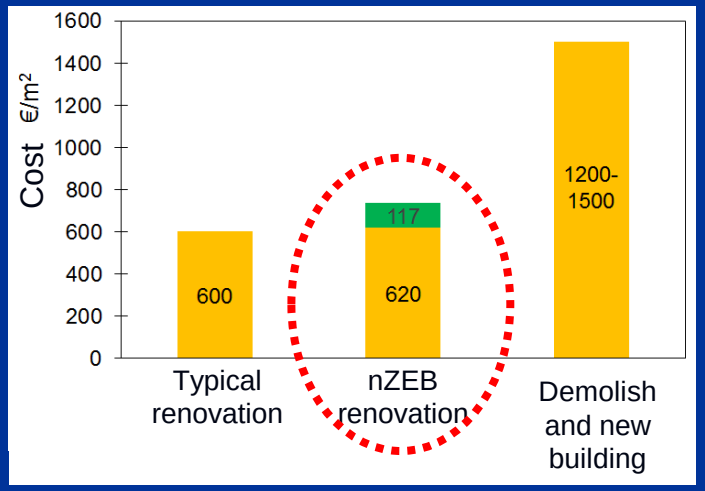
Situation before renovation

- Built 1986
- 5 storey, 80 apartments
- Concrete large panel building (series 121)
- Primary energy use
  before renovation ~300 kWh/(m²a)
- Mould on thermal bridges



Scenarios

- *Status qou*, no changes
- Concentrating only on indoor climate
- Typical renovation
- Deep energy renovation with prefab.wooden elements
- Demolish current and to build a new building



Deep energy renovation to nZEB

Pilot building: TUT dormitory

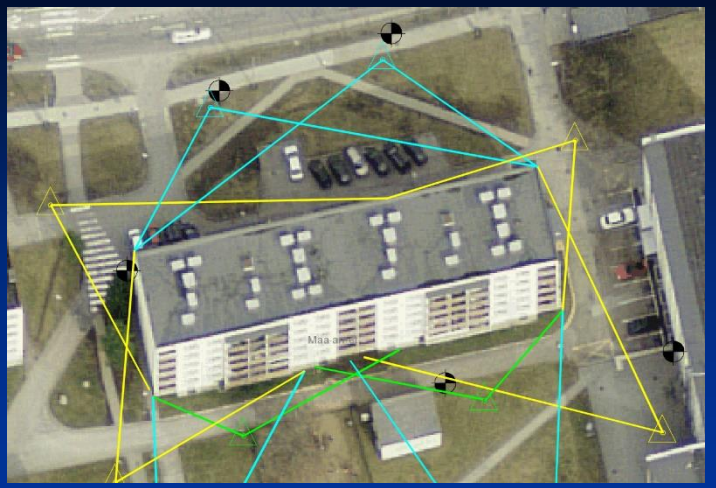
- Nearly Zero Energy Building
  - Energy need:
    - energy need for heating and ventilation: 18 kWh/(m^2 a)
    - domestic hot water: 30 kWh/(m^2 a)
    - appliances, lighting, ventilators, pumps: 30 kWh/(m^2 a)
  - Onsite energy production RES:
    - Solar collectors and sewerage heat recovery for DHW: 8 kWh/(m^2 a)
    - PV panels for electricity: 2 kWh/(m^2 a)
  - Designed primary energy use: 95 kWh/(m^2 a)

Deep energy renovation to nZEB

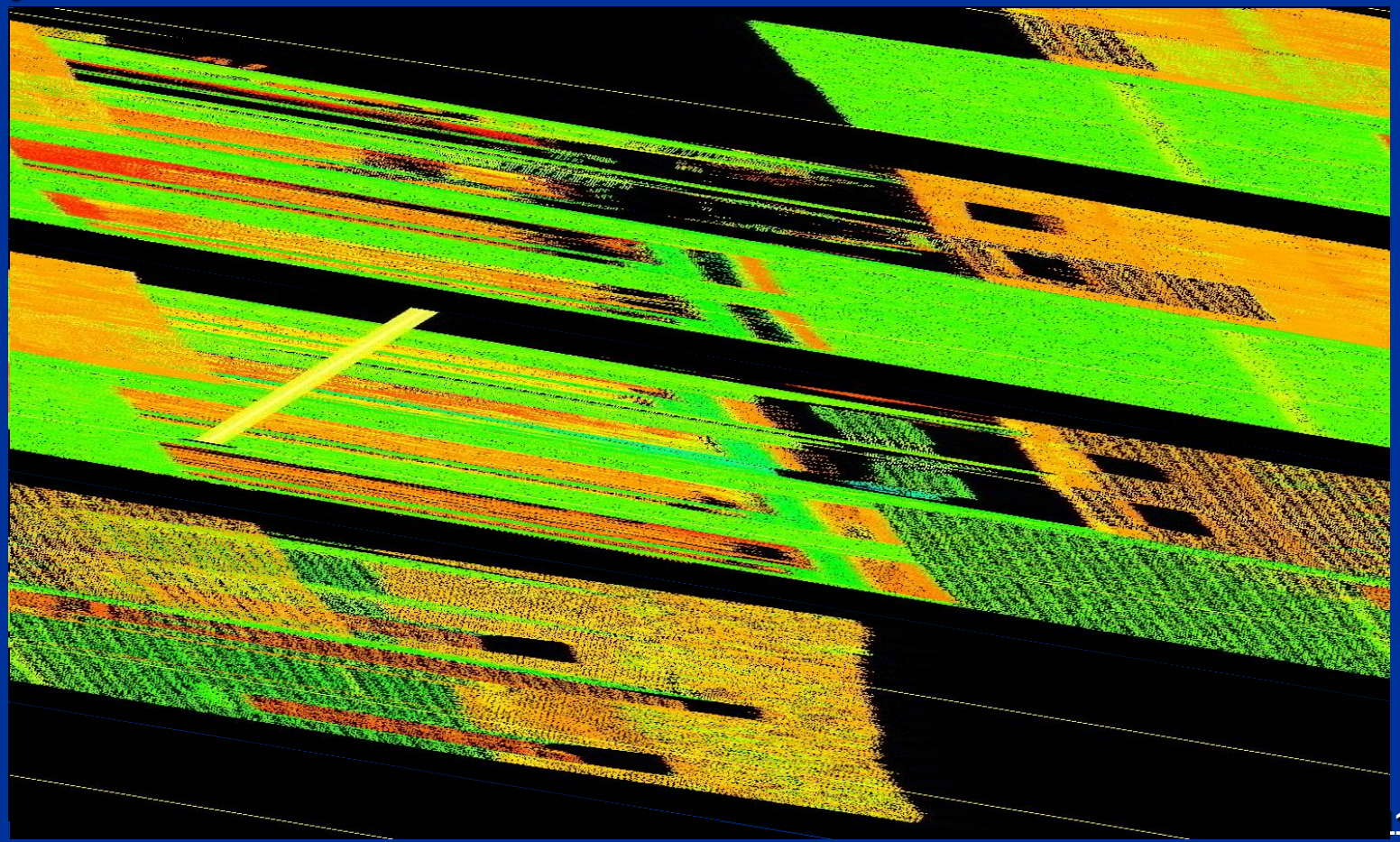
- Pilot building: TUT dormitory
  - Nearly Zero Energy Building
  - Wooden elements for additional insulation:
    - Facade U 0.11 W/(m^{2}K)
    - Windows U 0.85 W/(m^{2}K)
    - Roof U 0.10 W/(m^{2}K)
  - Effective service systems:
    - Mech. supply and exhaust ventilation with heat recovery
    - New two-pipe heating system with radiators and thermostats
    - PV panels, solar collectors
    - Sewerage heat recovery

Design and development prefabricated insulation elements

Laser scanning

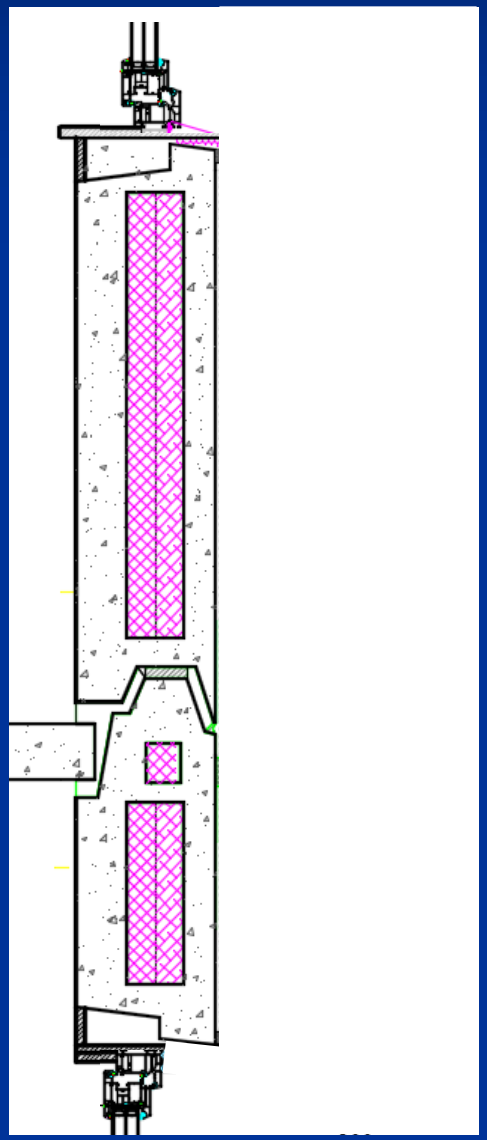


- 10 scan stations; 7 reference points
- Average resolution – 8300p/m^2
- Duration: 1-2 days

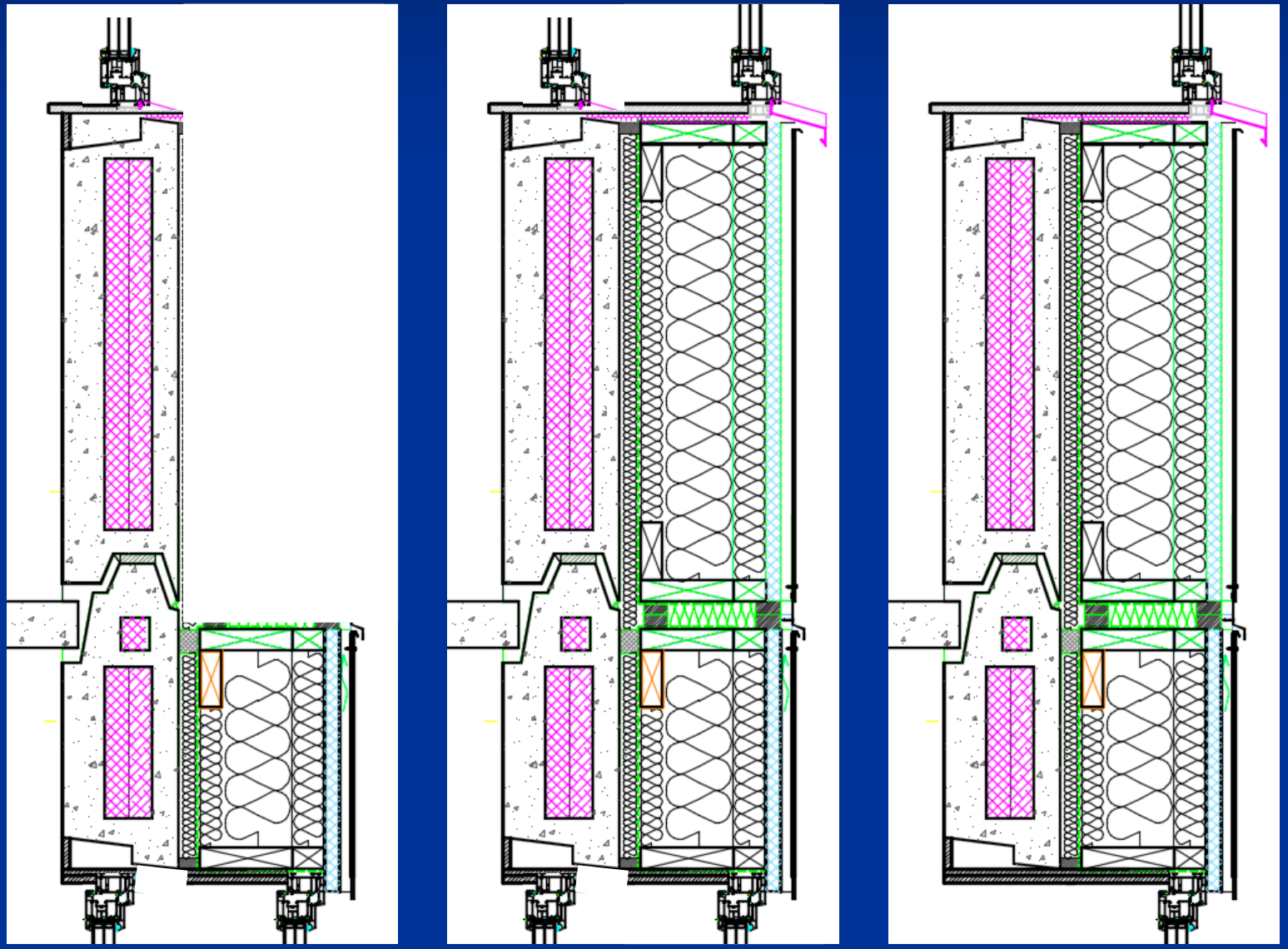


Facade

Original facade

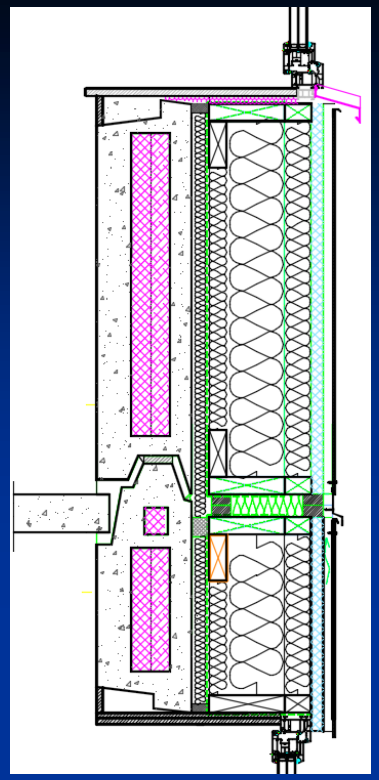


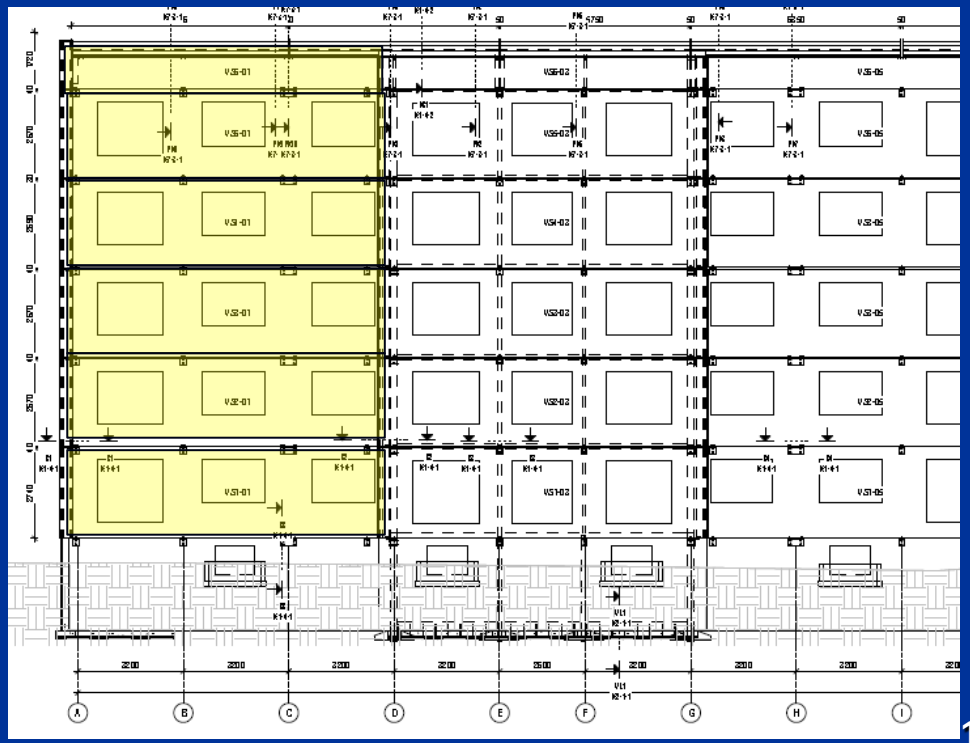
Renovated facade



Facade

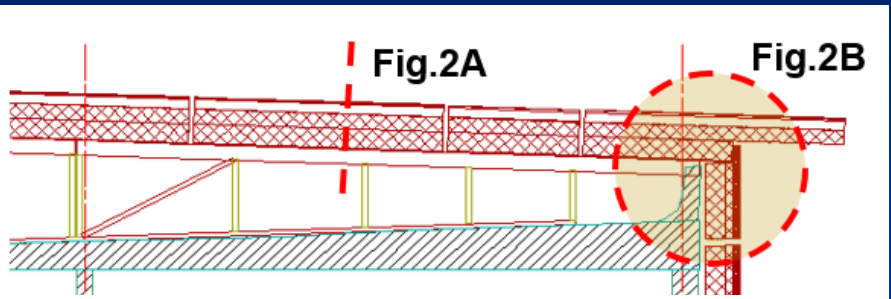
- Dimensions of elements ~9.3 x 2.7m
- 2-3 windows were preinstalled in factory
- Installation of elements: ideally 15...20 minutes

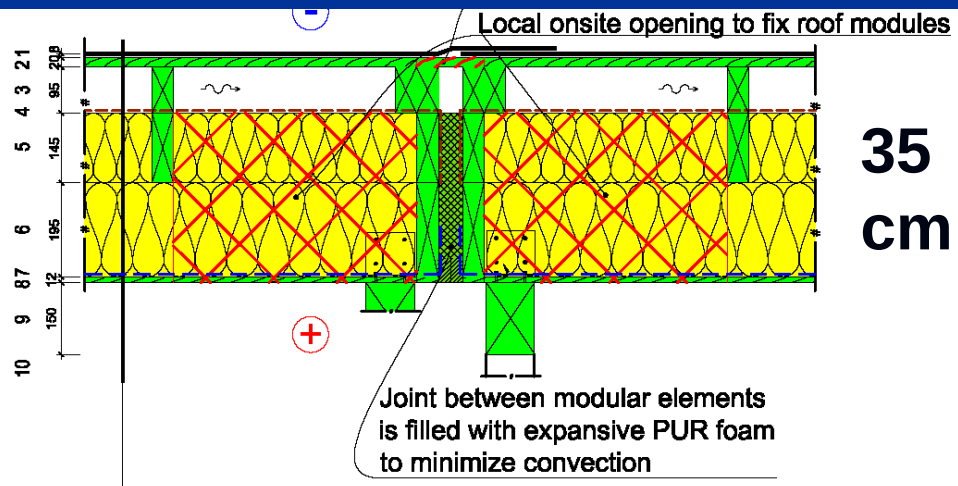




Live in Youtube

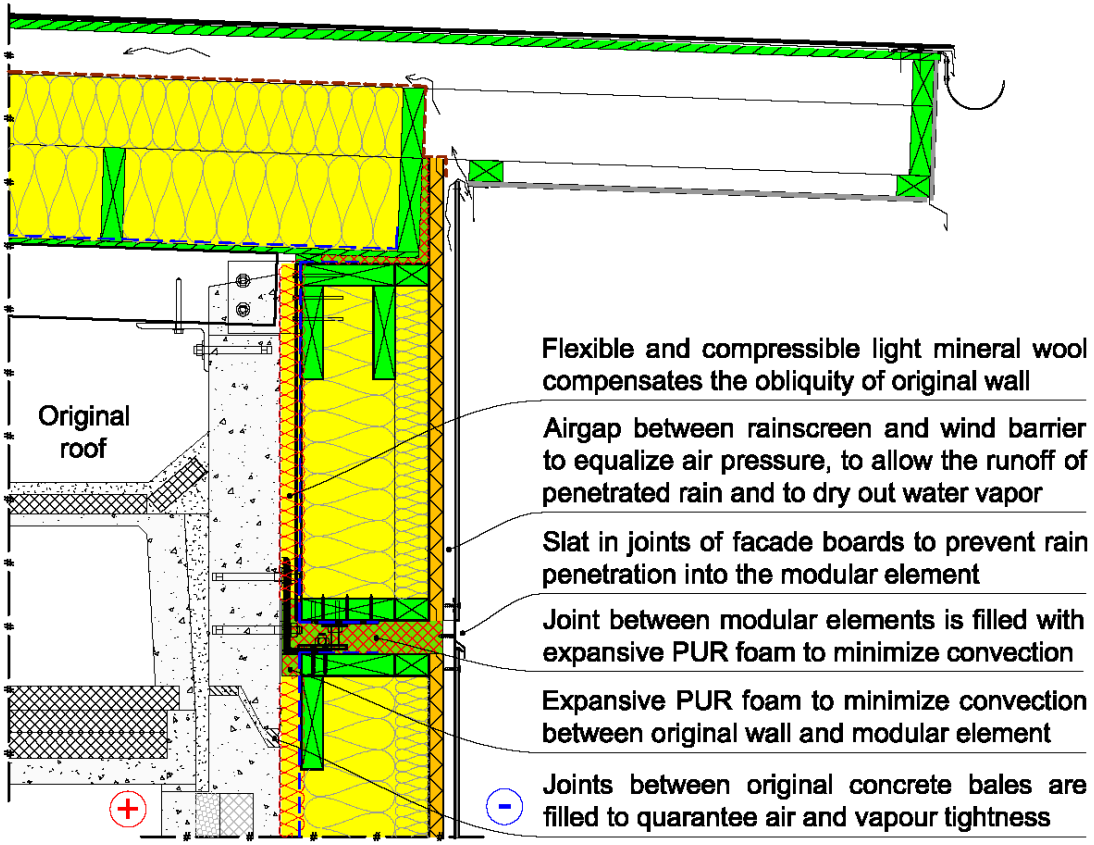
Design solution: roof





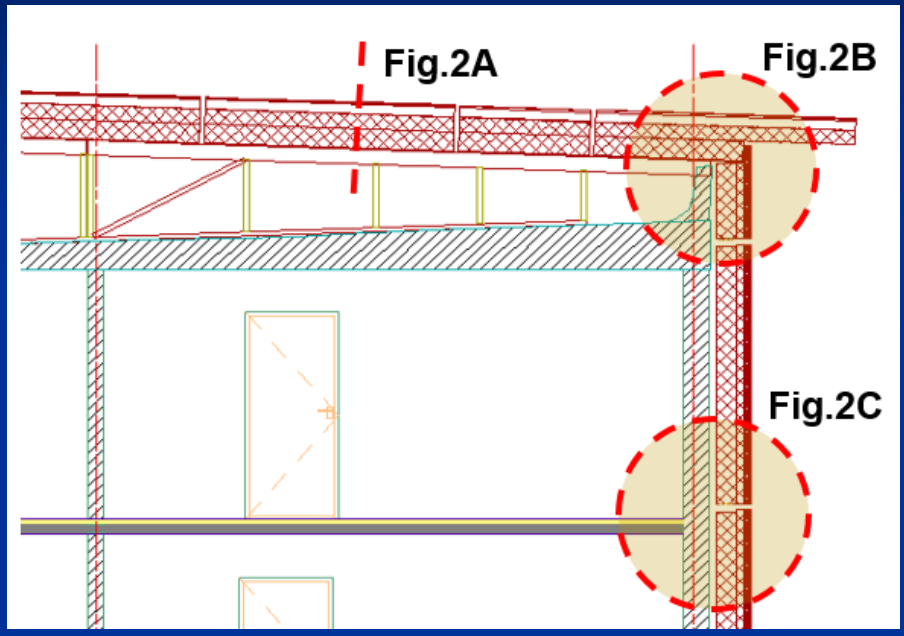
1. 2xSBS roof membrane	8mm
2. Waterproof plywood boards	20mm
3. Ventilated aircap	95mm
4. Water vapour permeable roof membrane $S_d \geq 0.02$m	
5. Timber frame 45×145mm cc.600mm / mineral wool (A1; λ_D=0.035 W/(mK))	145mm
6. Timber frame 45×195mm cc.600mm / mineral wool (A1; λ_D=0.035 W/(mK))	195mm
7. Vapour barrier: PE foil	0.2mm
8. OSB-board	12mm
9. Supporting timber frame (beams)	150mm
10. Supporting timber frame (columns)	>400mm

35 cm



A B

Design solution: walls



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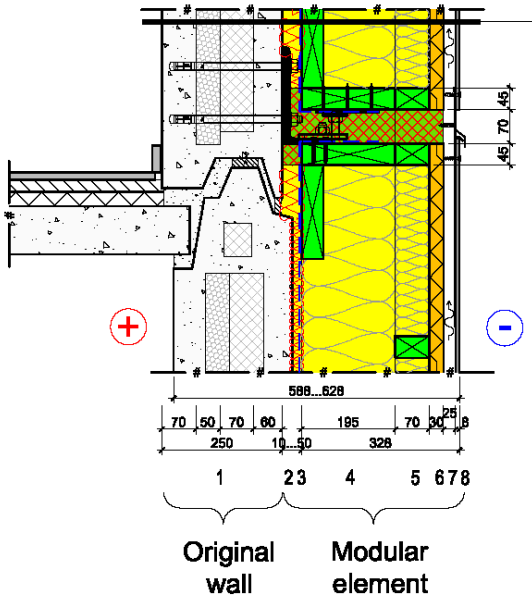
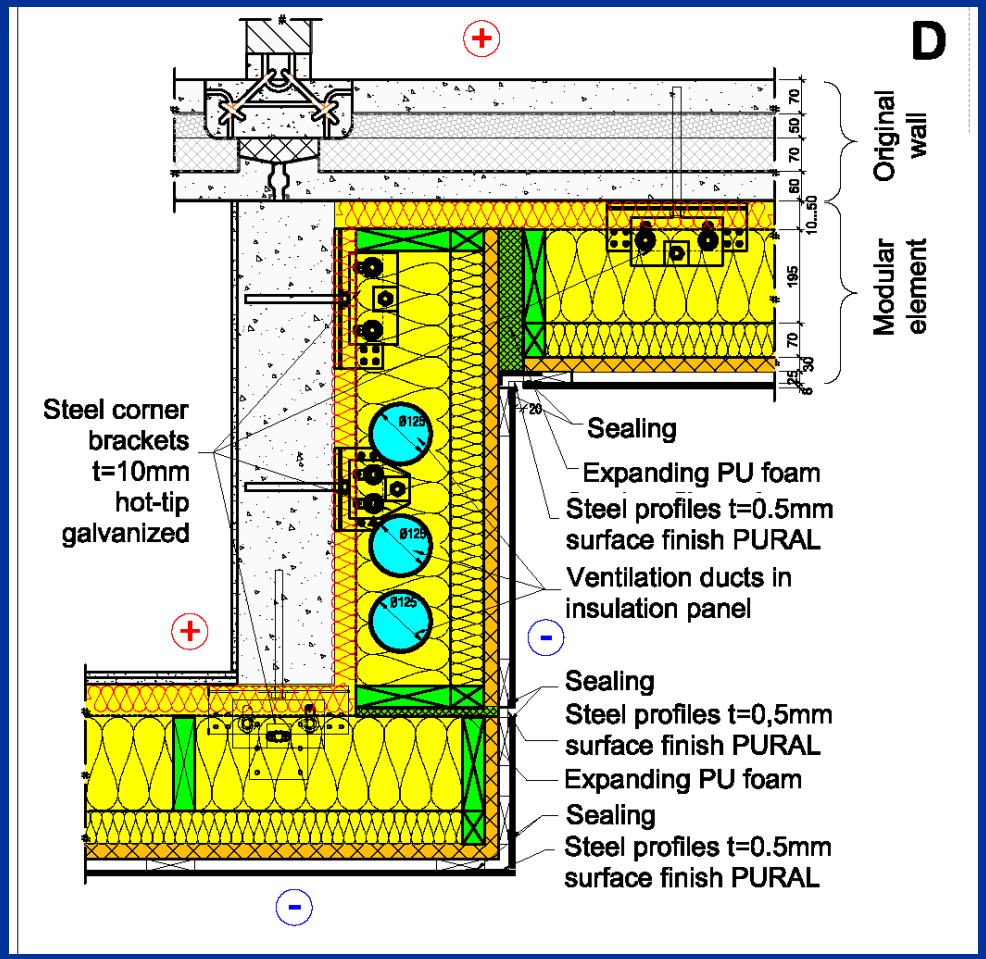
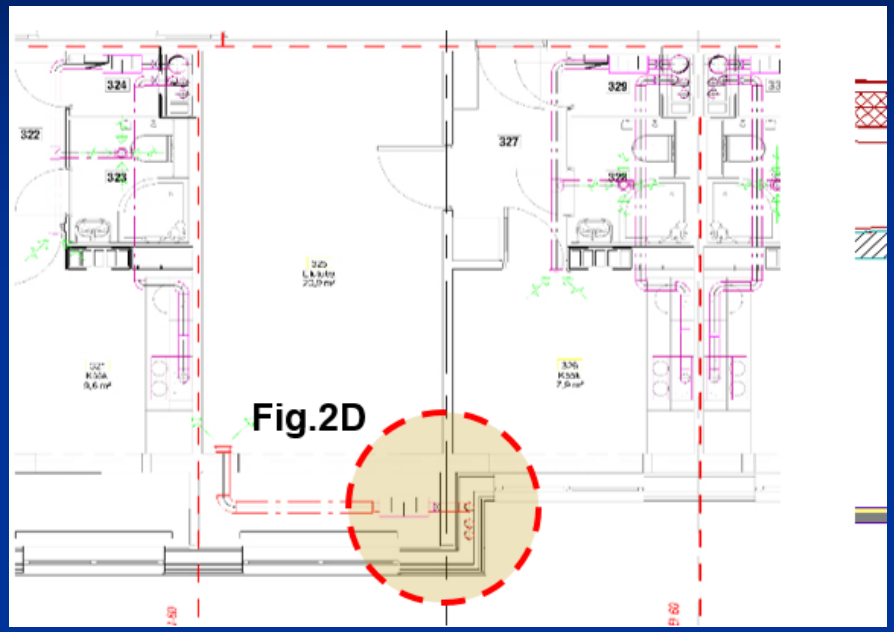


1. Existing concrete panel	250mm
2. Filling mineral wool (A1; λ_D=0.035 W/(mK))	10...50mm
3. Air&vapor retarder (vapor resistance Z_p=1.6...27×10^9 (m^{2}sPa)/kg)	
4. Timber frame 45×195mm cc.600mm / min.wool (A1; λ_D=0.035 W/(mK))	195mm
5. Timber frame 45×70mm cc.600mm / min.wool (A1; λ_D=0.035 W/(mK))	70mm
6. Semi-rigid mineral wool slab with special wind barrier facing (vapor permeability δ_p=150×10^{-12} kg/(msPa); taped joints, A2-s1,d0; λ_D=0.031 W/(mK))	30mm
7. Ventilated airgap	25mm
8. Facade board - rainscreen	8mm

30-35 cm

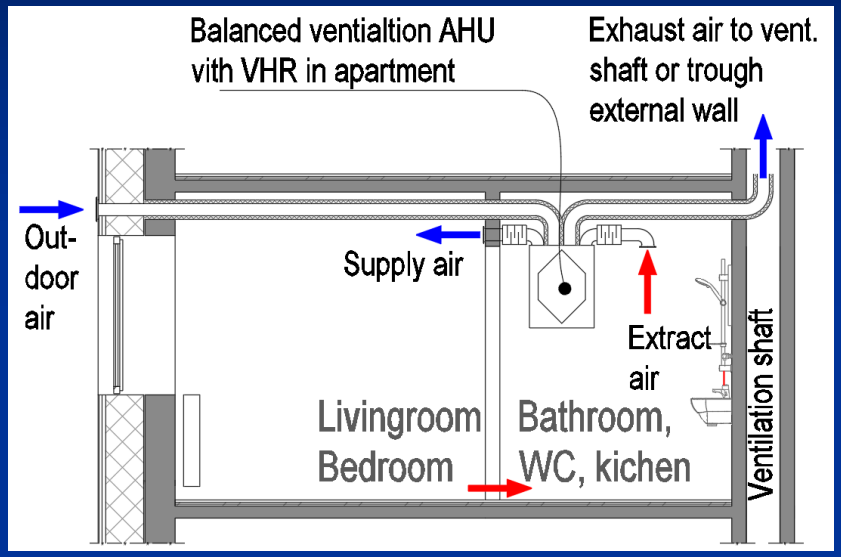
Design solution: ventilation ducts in wall

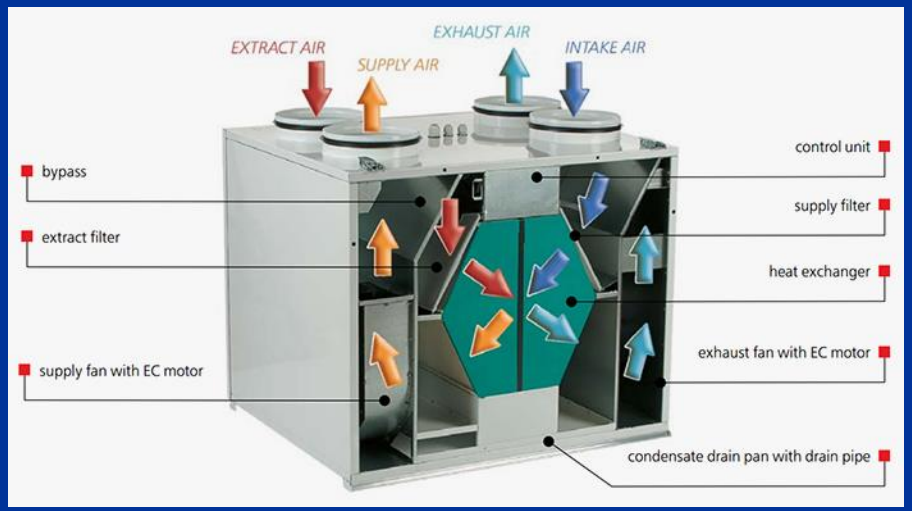




HVAC systems: in general

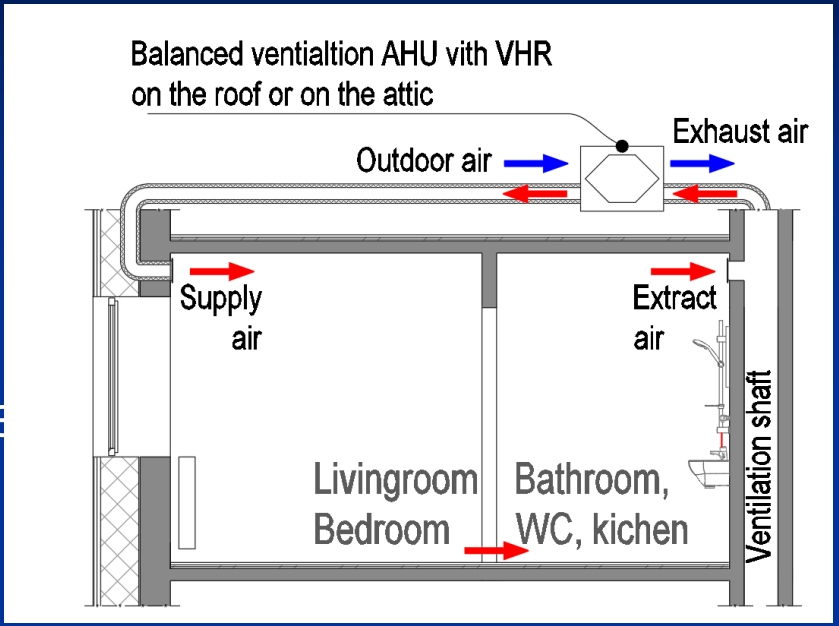
- Apartment based AHU with VHR
  - Pro:
    - High efficiency
    - Guaranteed performance
    - Occupant can adjust the speed
  - Contra:
    - Ductwork installation in apartments
    - Expensive and requires space

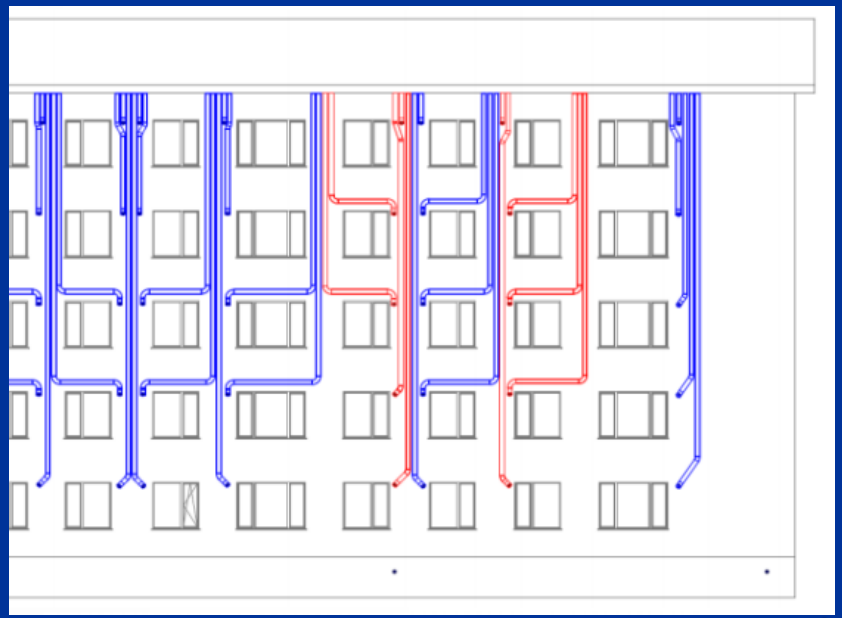




HVAC systems: in general

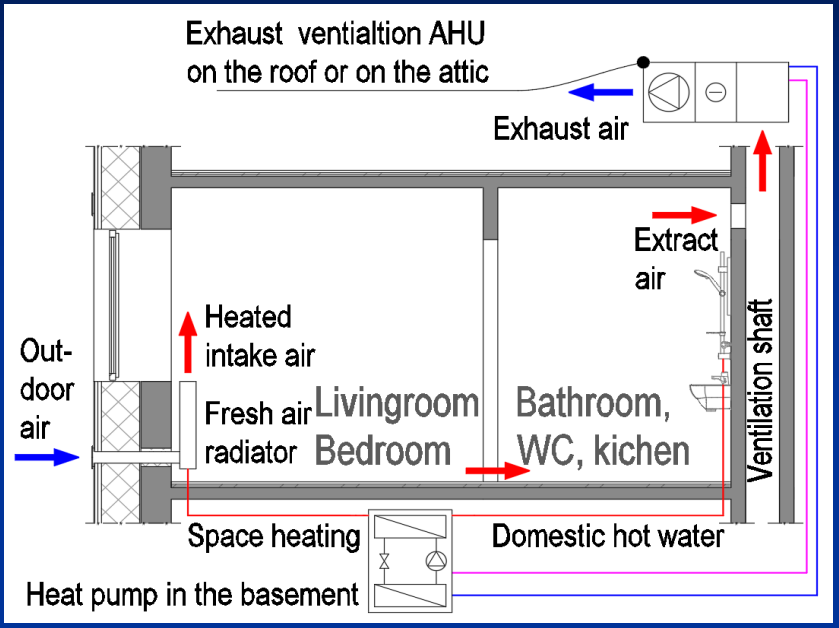
- Apartment based AHU with VHR
- Centralized AHU with VHR
  - Pro:
    - High efficiency and guaranteed performance
    - Minimal construction works in apartment
    - Most common solution in Estonia
  - Contra:
    - Difficult to use in buildings higher than 5 floors (too big ducts on the façade)





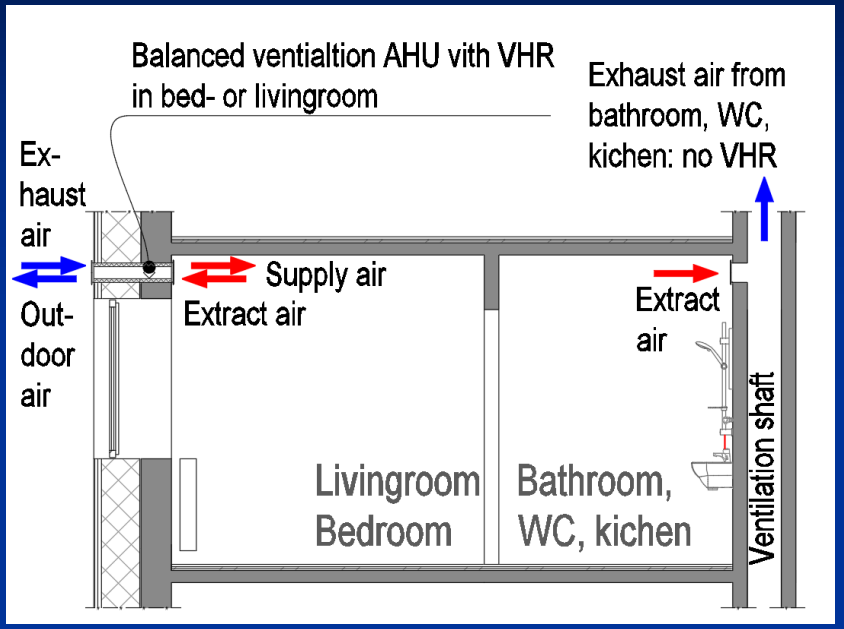
HVAC systems: in general

- Apartment based AHU with VHR
- Centralized AHU with VHR
- Exhaust AHU with heat pump HR
  - Pro:
    - Minimal construction works in apartment
    - Main solution in 9-storey buildings
  - Contra:
    - Electricity of HP
    - Parallel heating for district heating
    - Ventilation radiators to be used for intake air pre-heating



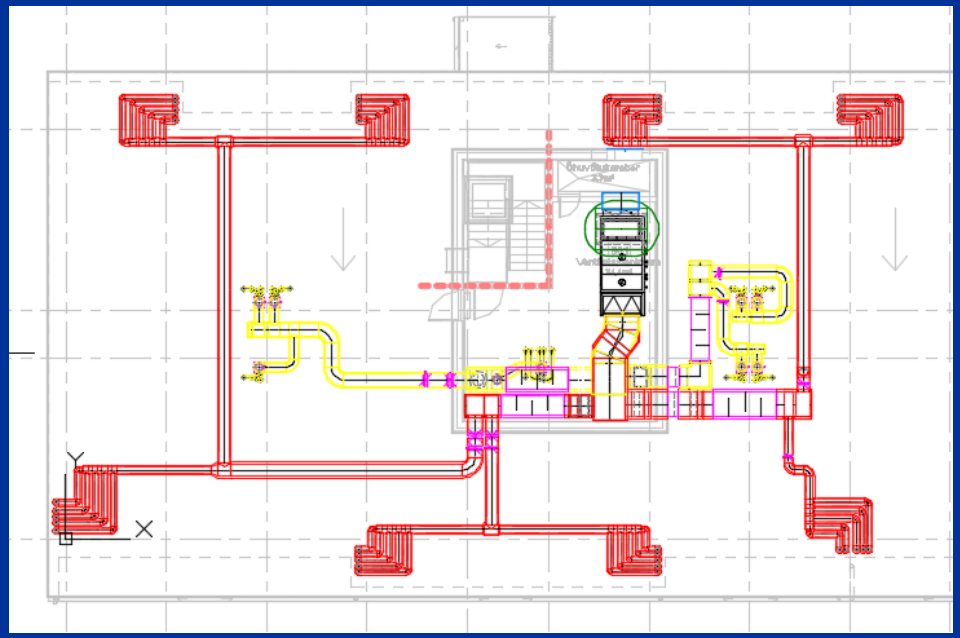
HVAC systems: in general

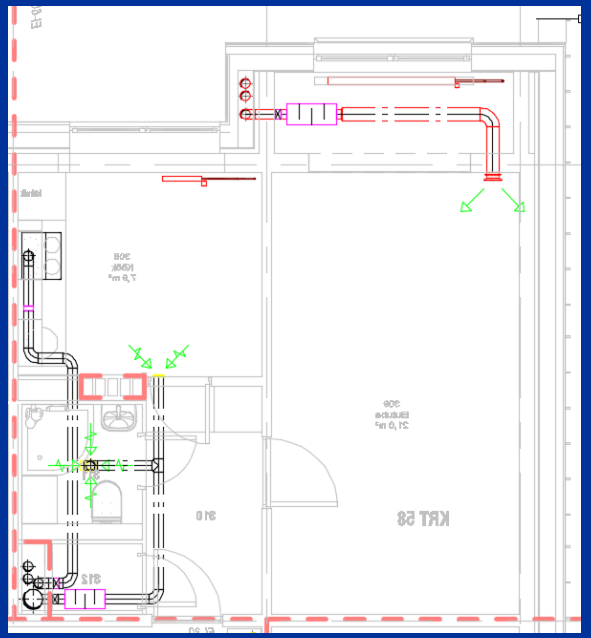
- Apartment based AHU with VHR
- Centralized AHU with VHR
- Exhaust AHU with heat pump HR
- Room based AHU with VHR
  - Pro: Easy to install
  - Contra:
    - Wet rooms not solved
    - Unbalanced, low heat recovery
    - too high noise, frosting issues
    - too small pressure drop (wind and
    - too small airflow (many units are need
    - Not accepted to be used for renovation grant



HVAC systems: ventilation

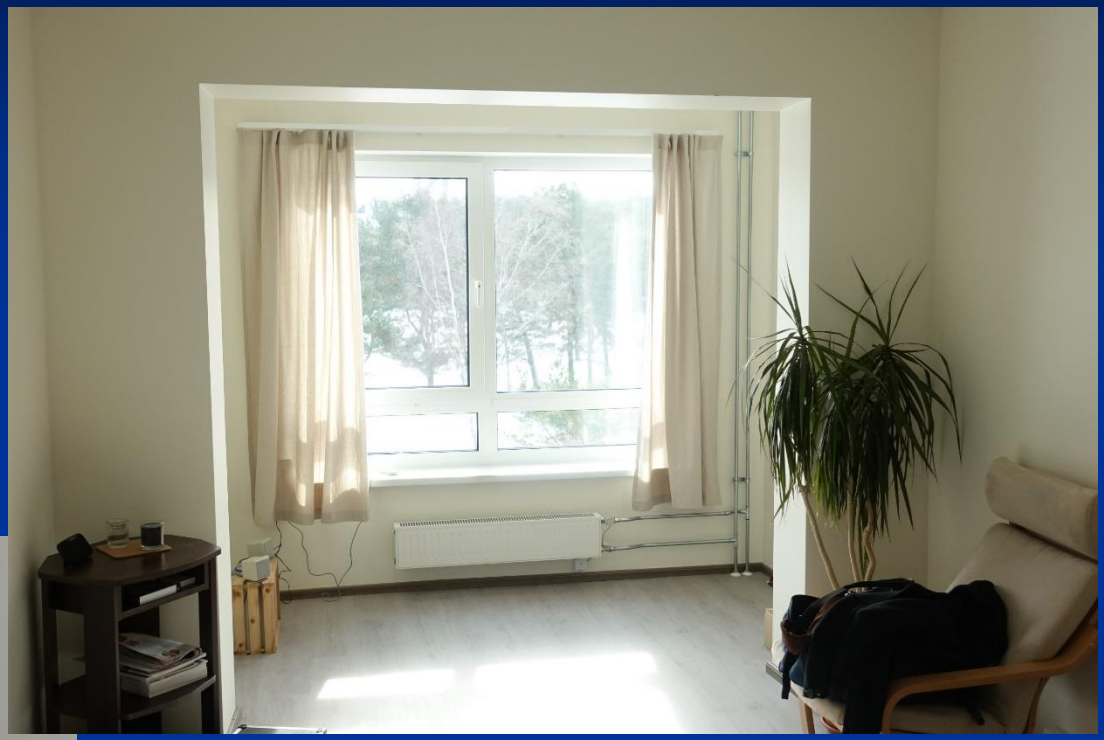
- ½: centralized balanced ventilation with VHR
  - Ventilation unit on roof,
  - Ducts in insulation elements
- ½ apartment based balanced ventilation with VHR
  - AHU in balcony or in coatroom





HVAC systems: space heating

- District heating
- Hydronic radiators
- Room thermostats
- 2-pipe system



HVAC systems: domestic hot water

- ½ solar collectors
  - 50 plate-type collectors, 100m^2
  - 4x1.5m^3 storage tanks in basement

HVAC systems: domestic hot water

- ½ solar collectors on roof
- ½ sewerage heat recovery
  - 2 passive units in basement

HVAC systems: renewable electricity

- PV panels on roof
  - 45 degree, south direction
  - 2 inverters

Construction during 2017

- Public procurement: 2 offers (including VAT 20%):
  - 3,456 milj. €
  - 3,560 milj. €
- Total cost
  - 822€/m^2 closed net area (all works)
    - 372€/m^2 (interior and general constructions)
    - 334€/m^2 (energy performance and indoor climate)
    - 116€/m^2 (nZEB, research)
- Duration
  - Preparing and reinforcement the facade: May
  - Installation of wall and roof elements: June - August

Future targets

- Simpler and cheaper element and facade material (rainscreen)
- Simpler fixation of elements to facade
- Quicker installation, better on site logistics
- Quicker insulation and tightening of joints of elements
- More space between elements (tolerance)
- More automatized design and production
- More development and testing during design and before installation
- Additional floors
- Moisture safety issues!!!