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Apmācību semināru būvspeciālistiem un projektētājiem organizēšana

ID Nr. EM 2022/53

Rīga, 2022

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Training seminar / Apmācību seminārs

Improving Energy Performance to be Ready for Zero-emission Buildings

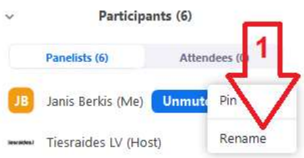
Energoefektivitātes paaugstināšana ēkās, lai tās atbilstu nulles emisijas ēkām

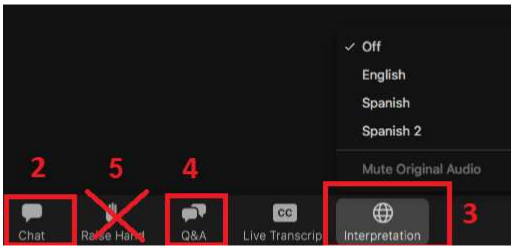
November 10, 2022, Riga

By Prof. Jarek Kurnitski, PhD and Raimo Simson, PhD (Estonia)

Instructions to participants

1. Write your full name (Vārds, Uzvārds) in participants list
2. Register your name using chat (Vārds, Uzvārds)
3. Interpretation available in Latvian
4. For questions use the Q&A functionality
5. Do not use the reactions or raise hand





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Agenda

09:00 – 10:00	**Registration**
10:00 – 11:30	Energy performance in buildings regulation and requirements in EU (by Prof. Jarek Kurnitski) • Energy performance minimum requirements for new buildings and major renovation • Energy calculation methodology framework – EPBD and EPB standards • Cost optimality principle for determination of mi requirements and for energy performance improvement monitoring • New items in ongoing EPBD revision • NZEB requirements comparison in selected countries
11:30 – 12:00	**Coffee break**
12:00 – 13:30	Energy calculation with dynamic simulation software (By Raimo Simson) • Energy calculation input data – standard use of a building • Energy need simulation • Options for systems energy use calculation • Self-use of on-site electricity generation • Delivered, exported energy and primary energy calculation • Summer thermal comfort simulations for overheating prevention in buildings without cooling systems • Example of NZEB new building energy calculation
13:30 – 14:30	**Lunch break**
14:30 – 15:30	Estonian experience on energy performance certificates (EPC), energy audits and deep renovation grant schemes (by Jarek Kurnitski, Raimo Simson) • EPC-s for new buildings, checking mechanisms by input data and results tables • EPC in the design and construction process • EPC-s for existing buildings and energy audits • Renovation grant scheme system for residential buildings: main steps in the application process • Renovation grants technical requirements for apartment buildings •Examples of typical renovation solutions
15:30 – 16:00	**Question and answer session**

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Agenda / 10:00 – 11:30

Energy performance in buildings regulation and requirements in EU (by Prof. Jarek Kurnitski):

- Energy performance minimum requirements for new buildings and major renovation
- Energy calculation methodology framework – EPBD and EPB standards
- Cost optimality principle for determination of minimum requirements and for energy performance improvement monitoring
- New items in ongoing EPBD revision:
  - Zero-emission buildings
  - Deep renovation (and major renovation)
  - Minimum energy performance standards MEPS
  - Harmonised energy performance certificate scale
  - Hourly energy calculation method
  - Monitoring and regulation of indoor air quality
  - Inspection of stand-alone ventilation systems
- NZEB requirements comparison in selected countries
- Q&A

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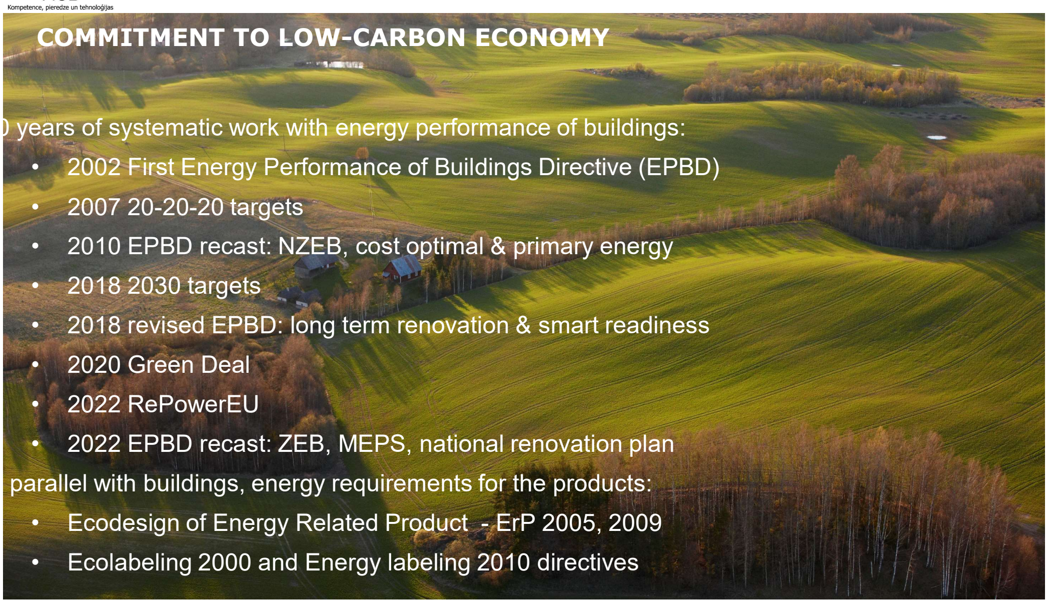

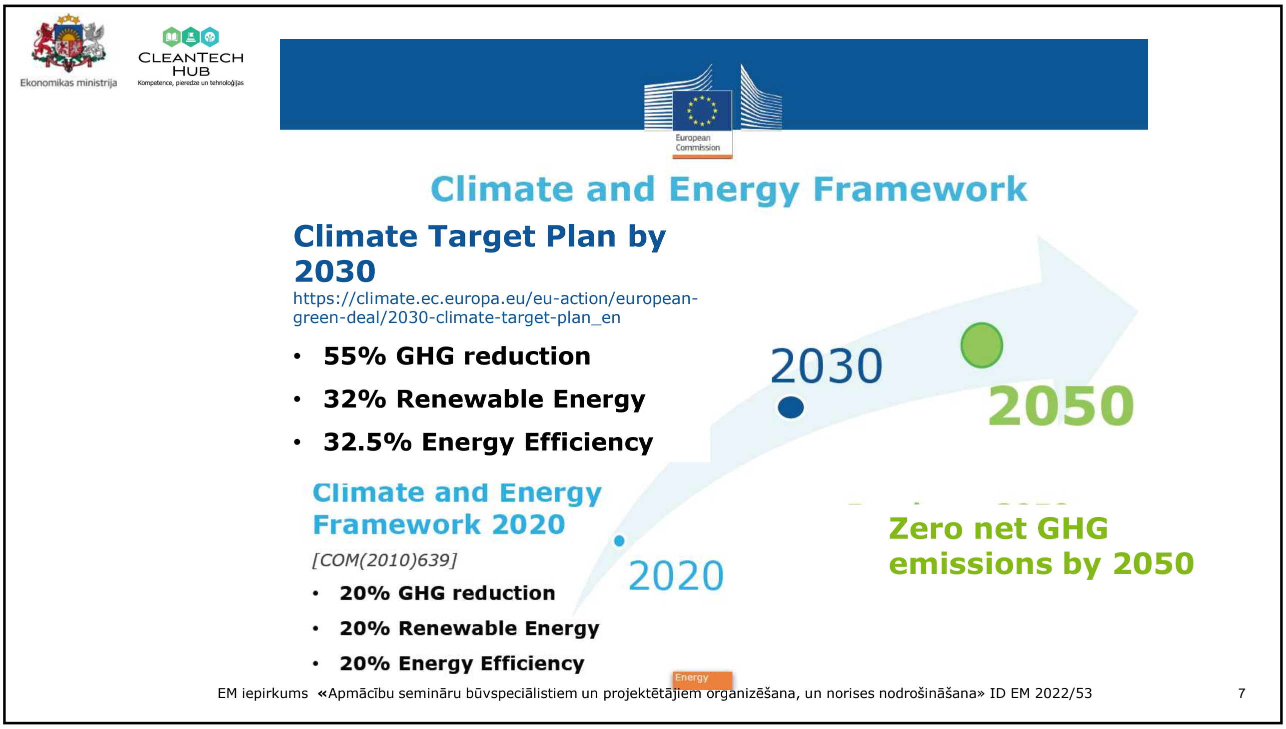
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European Commission
Climate and Energy Framework
Climate Target Plan by 2030
https://climate.ec.europa.eu/eu-action/european-green-deal/2030-climate-target-plan_en
• 55% GHG reduction
• 32% Renewable Energy
• 32.5% Energy Efficiency
Climate and Energy Framework 2020
[COM(2010)639]
• 20% GHG reduction
• 20% Renewable Energy
• 20% Energy Efficiency
2020
2030
2050
Zero net GHG emissions by 2050
Energy
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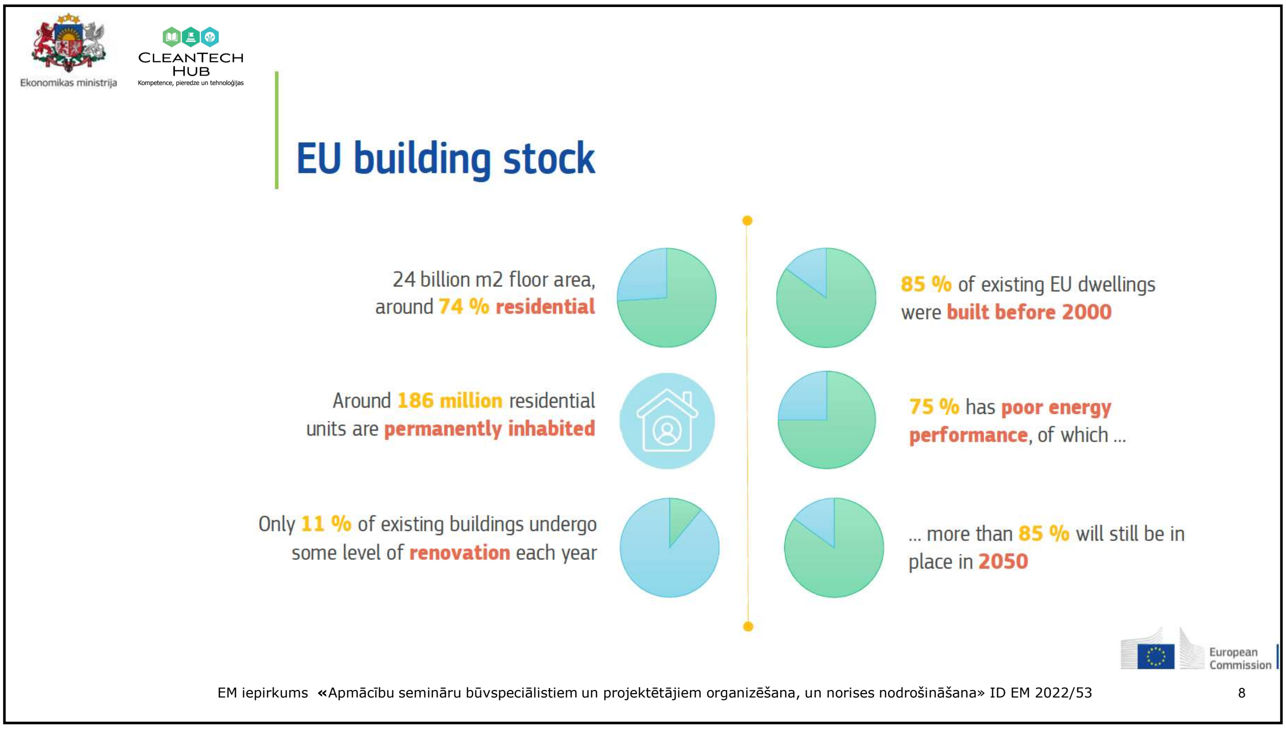
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EU building stock
24 billion m2 floor area, around 74 % residential
Around 186 million residential units are permanently inhabited
Only 11 % of existing buildings undergo some level of renovation each year
85 % of existing EU dwellings were built before 2000
75 % has poor energy performance, of which ...
... more than 85 % will still be in place in 2050
European Commission
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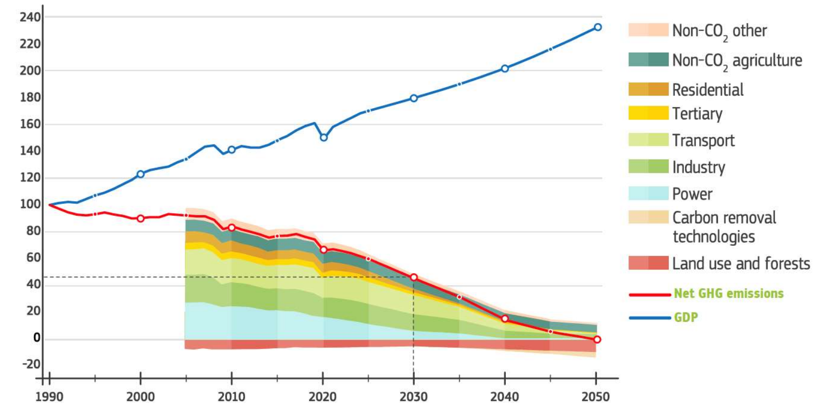
Climate Target Plan by 2030



Energy – 75% of emissions

- The burning fossil fuels is the largest source of greenhouse gas emissions in the EU
- The energy system plays a central role in the transition to a climate-neutral economy

Buildings – 36% of emissions

- The building sector is responsible for 40% of final energy use
- This sector has a large and cost-effective potential to become more energy-efficient and reduce emissions

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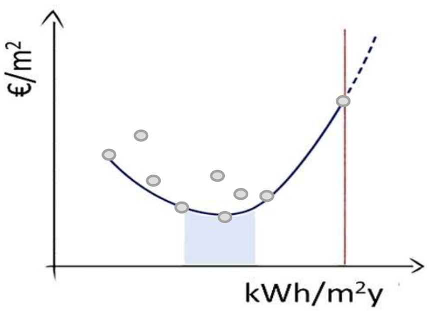
Main drivers for energy and IEQ improvement in buildings

- Nearly zero energy buildings NZEB set in 2010 EPBD recast and revised EPBD 2018/84/EU (2010/31/EU) – implemented in all MS from 2019/2020
- Cost optimality principle set in 2010 recast and revised EPBD 2018/844/EU (2010/31/EU)
- The **cost-optimality** principle has to be followed – **NZEB should be at least cost-optimal**, and cost-optimality calculation has to be conducted with 5 years interval
- Minimum requirements may change in every 5 years



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2010 EPBD recast (2010/31/EU) – Nearly zero energy buildings NZEB

- In the directive 'nearly zero-energy building' means a building that has a very high energy performance (EP). The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources (RES) produced on-site or nearby.

⇒ **NZEB = very high EP + on-site or nearby RES**

- Definition of "a very high EP " and "significant extent of RES" let for Member States (MS), however the cost-optimality principle has been set.

EPBD Article 9

http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm:

- By 31 Dec 2020, all new buildings are **nearly zero energy** buildings
- After 31 Dec 2018, public authorities that occupy and own a new building shall ensure that the building is a nearly zero energy building

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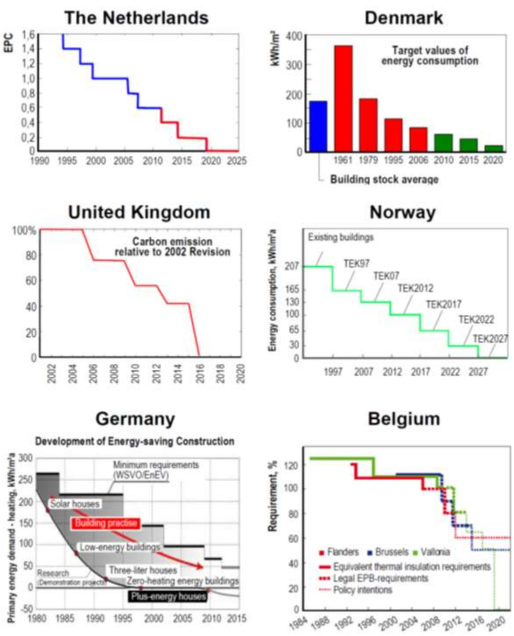
REHVA J May 2011

Towards nZEB:

- **Roadmap of some countries towards nearly zero energy buildings to improve energy performance of new buildings**
- **Many countries have prepared long term roadmaps with detailed targets**
- **Helps industry to prepare/commit to the targets**



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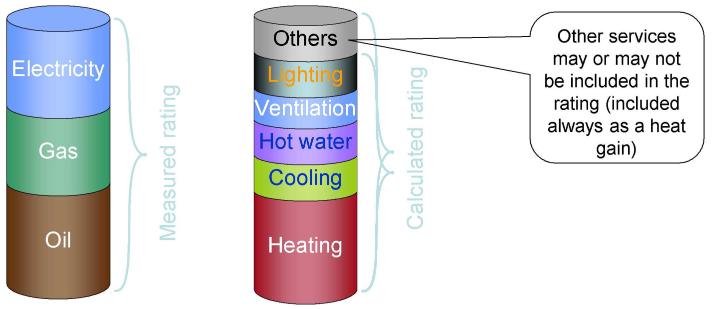
EPBD definition for energy performance

EPBD energy performance (Annex I):

- The energy performance of a building shall be determined on the basis of **calculated or metered energy use** and shall reflect typical energy use for **space heating, space cooling, domestic hot water, ventilation, built-in lighting** and other technical building systems



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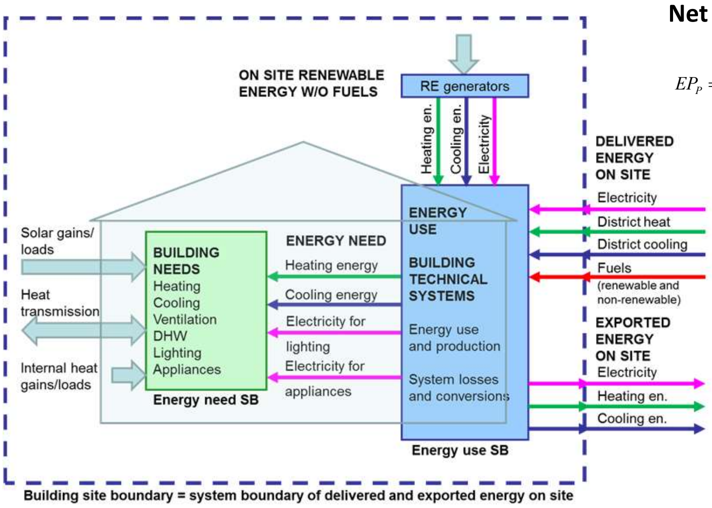
System boundaries



Net primary energy indicator

$$EP_P = \frac{E_P}{A_{net}} = \frac{\sum_i (E_{del,i} f_{del,i}) - \sum_i (E_{exp,i} f_{exp,i})}{A_{net}}$$

or

Primary energy indicator

$$EP_P = \frac{\sum_i (E_{del,i} f_{del,i})}{A_{net}}$$

(exported energy not accounted)

REHVA Report No 4: 2013

- System boundaries (SB) for energy need, energy use and delivered and exported energy calculation. The last one may be interpreted as the building site boundary.
- Demand reduction measures can be distinguished from RE solutions in the energy use SB, not in the delivered/exported energy SB

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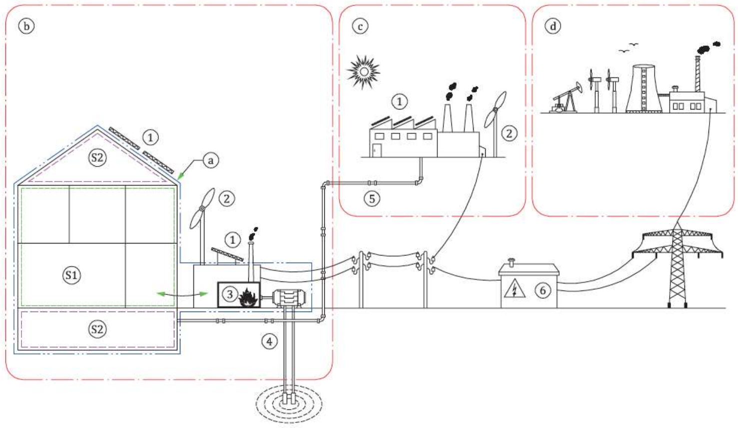
OAS ISO 52000-1:2017 SYSTEM BOUNDARY



Key

a	assessment boundary (use energy balance)	1	PV, solar
b	perimeter: on-site	2	wind
c	perimeter: nearby	3	boiler room
d	perimeter: distant	4	heat pump
S1	thermally conditioned space	5	district heating/cooling
S2	space outside thermal envelope	6	substation (low/medium voltage and possible storage)

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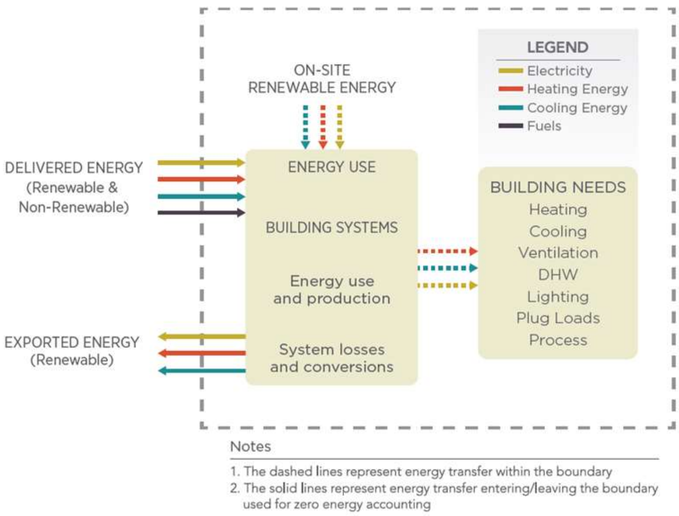
US DOE Site Boundary for ZEB Accounting



- Launched Sept 15, 2015
- http://energy.gov/eere/buildings/articles/doe-releases-common-definition-zero-energy-buildings-campuses-and

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US DOE Site Boundary for ZEB – terminology differences

- DOE site boundary = REHVA/CEN on-site delivered and exported energy boundary
- DOE **Source Energy** = REHVA/CEN **Primary energy**

- DOE includes lighting, plug loads and even processes into energy use (=REHVA proposal), but EPBD allows not to account plug loads and lighting is accounted only in non-residential
- Instead of nearby RE, DOE definition addresses the use of Renewable Energy Certificates (REC) and a separate category of **Renewable Energy Certificate - Zero Energy Building** (**REC-ZEB**) is defined

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COST optimality in EPBD

- EP requirements to be set with a view to achieving cost optimal levels using a comparative methodology framework established by the Commission
- **Cost optimal performance level means the energy performance in terms of primary energy leading to minimum life cycle cost**

- MS have to provide cost optimal calculations to evaluate the cost optimality of current minimum requirements due June 30th 2012 (Articles 4&5):
  - The draft methodology called "delegated Regulation supplementing Directive 2010/31/EU" published http://ec.europa.eu/energy/efficiency/buildings/doc/draft_regulation.pdf
  - Net present value calculation according to EN 15459
  - **Global cost (=life cycle cost) sums construction cost and discounted energy and maintenance etc. costs for 20 year period in non-residential and 30 year period in residential buildings**

Up to 15% deviation of EP minimum requirement relative to cost optimal is accepted

2nd round of cost optimal calculations conducted in 2018, 3rd round in 2023

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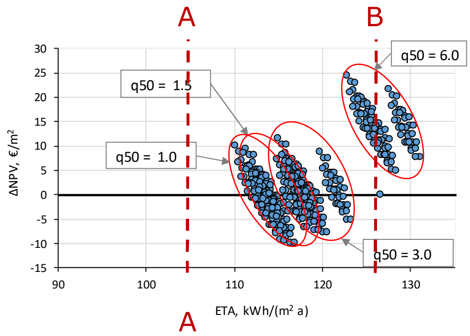
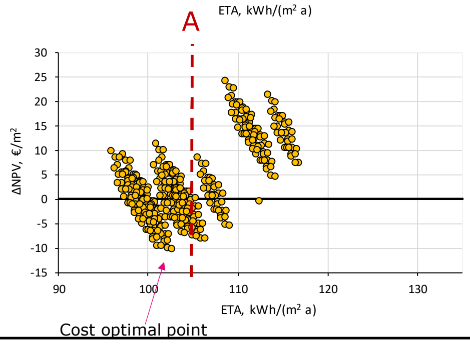
Example of EE cost optimal calculation (2017)

Apartment building:
- Building envelope variants
- EPC class B



- + PV panels
- EPC class A



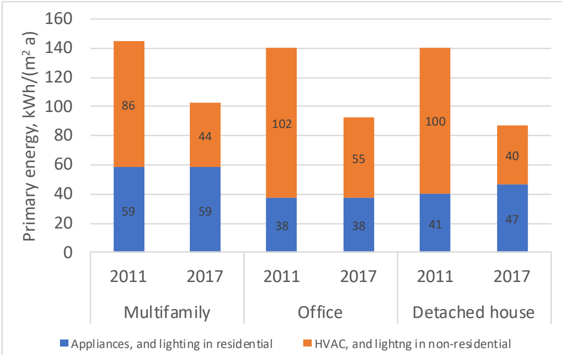
Cost optimal performance development 2013-2018

Member States' average	New single-family house	New multi-family house	New office	Existing single-family house	Existing multi-family house	Existing office
	-23%	-23%	-17%	-17%	-21%	-9%

Source: JRC's own calculations based on Member States reporting (COM(2020) 954 final)

In Estonia:

- 2017 cost optimal EP values have improved roughly by factor 2 (not accounting the fixed/standard use part of EP values – including appliances as well as lighting in residential buildings)
- Cost optimal EP-values reached Estonian NZEB values which are 105, 100 and 120 in multifamily, office and detached houses
- In new buildings have improved by two EPC class, and in major renovation by one EPC class (from EPC class D to C)



Redefining cost-optimal nZEB levels for new residential buildings

https://www.e3s-conferences.org/articles/e3sconf/abs/2019/37/e3sconf_clima2019_03035/e3sconf_clima2019_03035.html

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New items in ongoing EPBD revision

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EPBD 2002-2010-2018-2022

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EPBD is in the third revision, the recast proposal was published in 15.12.2021, the Council version 21.10.2022

Main outcomes of EPBD:

- 2006-2008 energy frame and requirements based on the primary energy & energy performance certificates
- 2012-2013 cost optimal calculations – second round 2018 – progress easy to measure
- NZEB 12/2018 and 12/2020, NZEB level finally at least the 2021 cost-optimal level
- 2018 revised EPBD: long term renovation strategy & smart readiness

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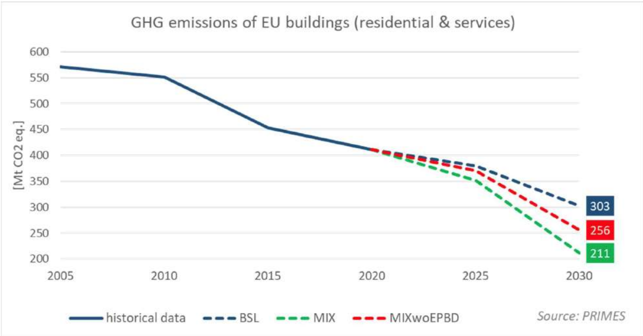
Objectives of the EPBD revision



- **Climate Target Plan** by 2030
  - reduce GHG emissions by 55%
  - integrate 32% RES
  - reduce final energy consumption by 14%
- **Renovation Wave** by 2030
  - renovate 35 million units
  - double and deepen renovation
  - establish minimum standards
  - harmonise EPC classes

Twofold objective:

Provide a **long-term vision** for buildings and ensure an adequate contribution to achieving climate neutrality in 2050

Set **an enabling framework** for an orderly transition by empowering all levels of action

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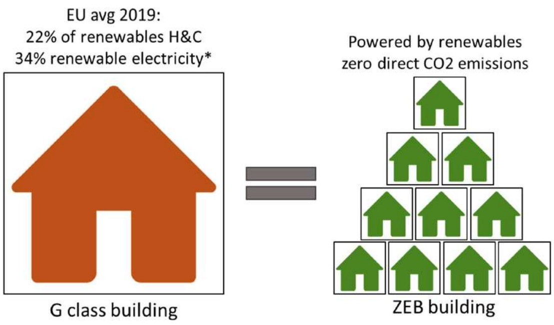
A zero emission building stock by 2050



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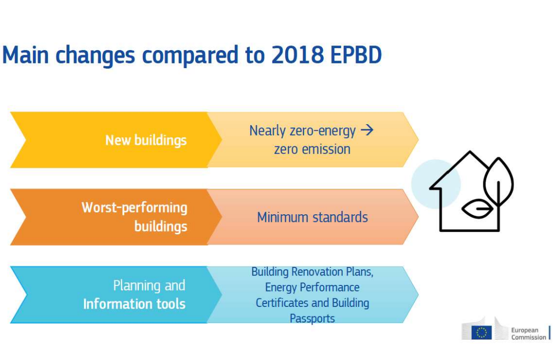
Many new items

- Zero-emission buildings
- Deep renovation (and major renovation)
- Minimum energy performance standards MEPS
- Harmonised EPC scale
- ~~Hourly energy calculation method~~
- Non-res. ZEBs to be equipped with measuring and control devices for the regulation of IAQ
- Inspection of stand-alone ventilation systems



- A new vision to transform EU building stock into zero-emission buildings by 2050
- The main new instrument to realize the ambition are National building renovation plans that are next step from long term renovation strategies

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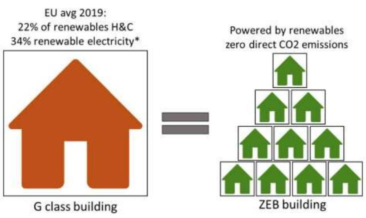
Transforming EU building stock into ZEB

- Existing major renovation is complemented with deep renovation, intending to ZEB level (NZEB before 2030)
- In national building renovation plans, MS must set targets for 2030, 2040 and 2050, including renovation rates, primary and final energy consumption, GHG emissions and to assure finance for renovation
- It is said that the necessary decarbonisation of EU building stock requires energy renovation at a large scale: almost 75% of today's building stock is inefficient according to current building standards, and 85-95% of the buildings that exist today will still be standing in 2050



- **Renovation Wave** by 2030
  - renovate 35 million units
  - double and deepen renovation
  - establish minimum standards
  - harmonise EPC classes

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Zero-emisson buildings ZEB

- New public buildings shall be ZEB from 2028 and all new buildings from 2030
- For existing buildings, major renovation and Minimum Energy Performance Standards (MEPS) requirements

ZEB definition (Art 2):

- 'zero-emission building' means a building with a very high energy performance, as determined in accordance with Annex I, requiring zero or a very low amount of energy, producing zero on-site carbon emissions from fossil fuels and producing zero or a very low amount of operational greenhouse gas emissions, in accordance with the requirements set out in Article 9b

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Article 9b

Zero-emisson buildings requirements

1. Requires to set a maximum **threshold of the energy use**, to be at least cost optimal (Annex I requires numeric indicator of primary energy use)
2. Requires to set a maximum **threshold of the operational greenhouse gas emissions** (Both thresholds may be adjusted for renovated buildings – deeply renovated building may have another EP-value than new ZEB)
3. The total annual primary energy use of a new or renovated ZEB is to be covered, where technically and economically feasible, by:
   - On-site, nearby, renewable energy community generated renewable energy
   - Effective district heating and cooling
   - Energy from carbon free sources (refers to grid electricity)
4. ZEB cannot cause any on-site carbon emissions from fossil fuels

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Energy calculation methodology (Art. 4, Annex I)

- Energy performance of a building shall be determined on the basis of calculated or metered energy – no change
- Energy performance of a building shall be expressed by a numeric indicator of primary energy use + additional indicators possible – no change
- ~~**Hourly energy calculation method required**~~
- Primary energy factors (distinguishing non-renewable, renewable and total) or weighting factors may be set nationally on annual, seasonal, monthly, daily or hourly basis
- MS may opt for an average EU primary energy factor for electricity instead of a primary energy factor reflecting the electricity mix in the country
- District heating and cooling: the benefits to be accounted through individually certified or recognised primary energy factors

Min reqs. & cost-optimal levels (Art. 5-6)

- Energy performance levels for ZEB and as well as for major renovation requirements will stay to be based on the **cost-optimality principle**
- Next cost-optimal levels calculation in 2023 will be conducted with existing methodology
- NZEB requirements that will stay in use until 2028 in public and 2030 in other new buildings cannot have the lower ambition than the **2023 cost-optimal level**
- By June 2025, EC plans to revise the cost-optimal methodology of minimum energy performance requirements in existing buildings undergoing major renovation, and 2028 cost-optimal calculations are to be done with this revised methodology
- A review of the methodology should take into account ETS extension, carbon prices and environmental and health externalities

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Energy performance certificates (Art. 16)

- Energy performance certificate scale is planned to be harmonised from 2027 so that:
  - Class A^0 is ZEB
  - Other classes are only letters from A to G
  - G shall correspond to worst performing buildings in the building stock
  - Voluntary A+ to buildings which in addition to being ZEB also make a positive net annual contribution to the energy grid from on-site renewables, calculated in terms of total primary energy (excluding ambient heat)
- There is no guidance how the classes should be divided, but the same scale must be used both for new and existing buildings (the major renovation requirements do not need to be class A)
- **Life cycle carbon footprint** (GWP with the Level(s) framework) is required to be calculated and reported in EPCs from 2027 for new buildings larger than 2000 m^2 and from 2030 for all new buildings (Art 7)

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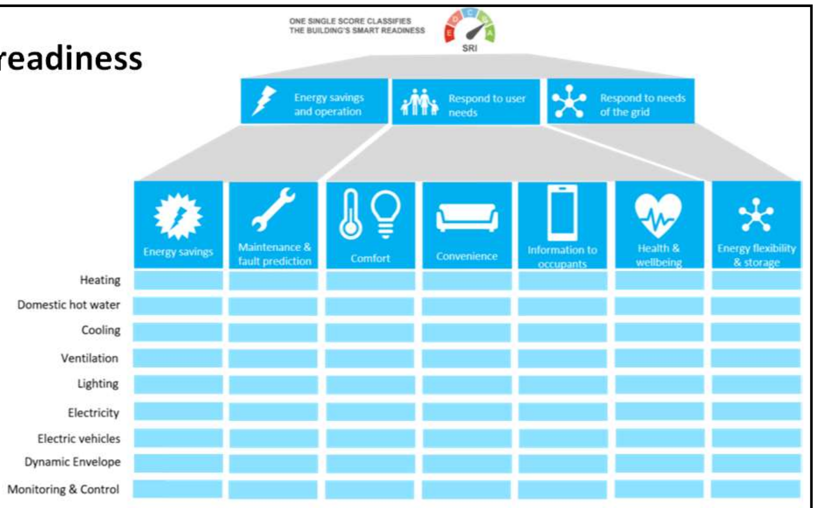
SRI smart readiness



- An optional common Union scheme for rating the smart readiness of buildings
- A mandate to the Commission to adopt a delegated act to require SRI rating for non-residential buildings > 290 kW heating by the end of 2026 (if SRI test phase is positive)
- Not performance based but checklist type of scoring

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Deep renovation & MEPS (Art. 9)

- It is expected that MS stimulate EPC class A renovation that is called deep renovation by financial incentives
- Deep renovation is defined as NZEB before 2030 and ZEB as of 1 January 2030 (requirements stay for major renovation)
- National renovation plan (Art 3) should include the sufficient allocation of budgetary and administrative resources
- Art. 15 about financial incentives sets that MS have to provide appropriate financing and support measures to stimulate both deep renovation as well as mandatory renovation of worst performing building stock that is targeted with MEPS

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MEPS - Minimum energy performance standards (Art. 9)

Non-residential buildings shall not exceed a maximum energy performance threshold:

- 15% threshold as of 2030 (refers to 2020 worst performing buildings, ≈ EPC G → F)
- 25% threshold as of 2034 (roughly EPC F, i.e. EPC class ≈ E to be achieved)

MEPS for residential buildings shall be based on a national trajectory for the progressive renovation of the building stock:

- The average primary energy use in kWh/(m2.y) of the whole residential building stock must be at least equivalent to:
  - (a) the D energy performance class level by 2033;
  - (b) by 2040, a nationally determined value derived from a gradual decrease of the average primary energy use from 2033 to 2050 in line with the transformation of the residential building stock into a zero-emission building stock.
  - Single-family may be excluded, but when sold or rented, D must be achieved in 5 years

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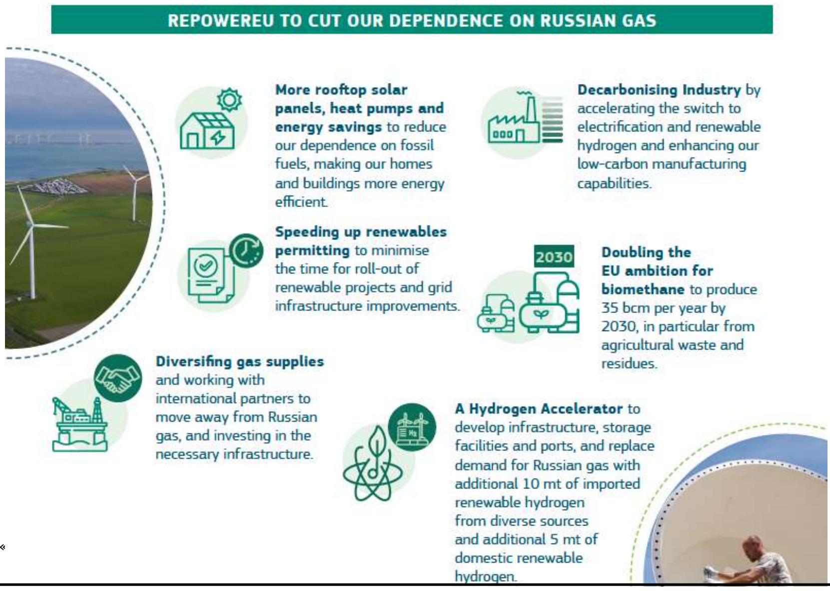
2022 Joint European action: REPowerEU

Focus to heat pumps, renewables and energy efficiency to reduce the dependency of fossil fuels

Solar energy implemented in EPBD



EM iepirkums «

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Solar energy in buildings (Art 9a)

All new buildings to be designed to optimise their solar energy generation potential on the basis of the solar irradiance of the site, enabling the cost-effective installation of solar technologies

Member States shall ensure the deployment of suitable solar energy installations:

- by 31 December 2026, on all new public and non-residential buildings with useful floor area > 250 m2
- by 31 December 2027, on all existing public and non-residential buildings undergoing a major or a deep renovation with useful floor area >400 m2
- by 31 December 2029, on all new residential buildings

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Indoor environmental quality and ventilation

- There is a new requirement to equip non-residential ZEB with **measuring and control devices for the regulation of indoor air quality** (Art. 11)
- In existing buildings, the installation of such devices shall be required, where technically and economically feasible, when a building undergoes a major renovation
- Regular inspection of heating and air conditioning systems is extended to stand alone ventilation systems. Ventilation systems are also specified as part of the EPBD measures aimed at addressing indoor air quality
- When setting minimum energy performance requirements, taking into account indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation, was already included in the existing EPBD (Art 5). Indoor environmental quality is stressed now for both new buildings and major renovations by mentioning that **the issues of healthy indoor climate conditions shall be addressed** (Art 7 and 8) – may interpreted so that national regulation on IEQ should be present

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EPBD application to set national requirements

- EPBD proposal 21 October 2022
- Non-renewable primary energy or total primary energy? In many places EPBD uses unspecific expression of "primary energy" – so, which primary energy factor (PEF) should be used?
- Minimum requirements for ZEB/NZEB and EPC classes

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Step 1 – assessment boundary

- Art 2 definition 47 'assessment boundary' means the boundary where the delivered and exported energy are measured or calculated;
  (May depend on national practices where energy meters are installed)
- Def 56 'delivered energy' means energy, expressed per energy carrier, supplied to the technical building systems through the assessment boundary, to satisfy the uses taken into account or to produce the exported energy;
- Def 57 'exported energy' means, expressed per energy carrier and per primary energy factor, the proportion of the renewable energy that is exported to the energy grid instead of being used on site for self-use or for other on-site uses.

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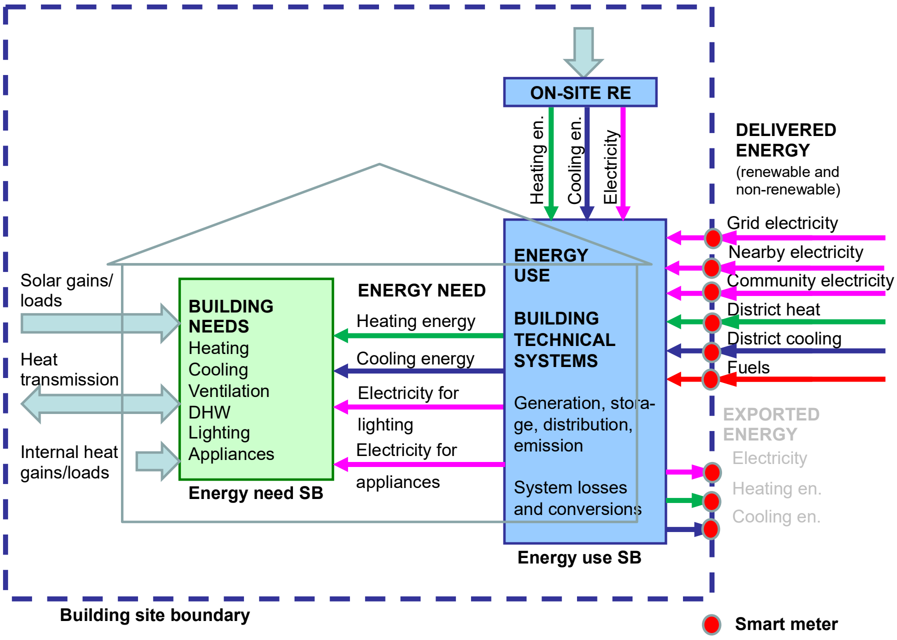
- Defining assessment boundary as the building site boundary
- Common location of energy meters
- Note separate meters for grid, nearby and community electricity



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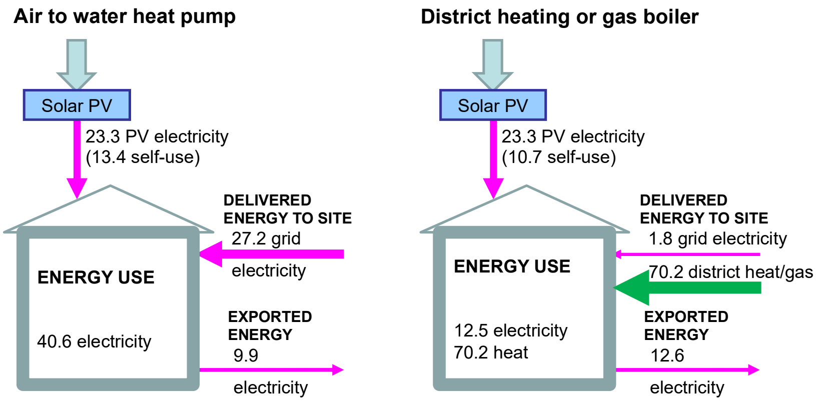
Step 2 – cost optimal calculation and ZEB/NZEB requirements

- Non-renewable primary energy is needed for meaningful cost optimal calculations to distinguish the use of fossil fuels and energy from renewable sources
- Non-renewable primary energy is in line with Art 9b stating that ZEB “***energy use***” requirement is “***maximum threshold established at the Member State level***”. Here each MS has a freedom to define ZEB by following cost optimality and ANNEX I principles (referred to in Art 2 ZEB definition)
- According to ANNEX I, ZEB should use “***a numeric indicator of primary energy use***” and “***The calculation of primary energy shall be based on primary energy factors, (distinguishing non-renewable, renewable and total) or weighting factors***”
- ANNEX I also requires recognising the **benefits of district heating and cooling**, and **positive influence of renewable energy** which support the use of non-renewable primary energy indicator

EP-value calculation example

- Input data from https://www.rehva.eu/rehva-journal/chapter/how-to-set-primary-energy-requirements-so-that-poor-building-envelope-cannot-be-compensated-with-extensive-pv
- Assume that this data represent cost-optimal solutions (in a cold climate) and use exactly the same generation efficiency for district heating and gas boiler for illustrative purposes
- self-used and used in other on-site uses PV is included
- Total primary energy is calculated from the delivered energy to the site (ambient heat and on-site PV are excluded) = total primary energy of the delivered energy to the site



EP_{nren} = 27.2 x 2.3 = 62.4

EP_{tot} = 27.2 x 2.5 = 68.0

EP_{nren} = 1.8 x 2.3 + 70.2 x 0.6 = 46.3 for district heat

EP_{nren} = 1.8 x 2.3 + 70.2 x 1.1 = 81.3 for gas

EP_{tot} = 1.8 x 2.5 + 70.2 x 1.2 = 88.7 for district heat

EP_{tot} = 1.8 x 2.5 + 70.2 x 1.1 = 81.7 for gas

Energy balance	Energy need kWh/m² a	Energy use kWh/m² a DH	Gas	AWHP
space heating	38.5	43.9	43.9	16.6
DHW	25.0	26.3	26.3	13.5
supply air heating (electric)	5.0	5.0	5.0	5.0
fans and pumps	5.5	7.5	7.5	5.5
PV self use		10.7	10.7	13.4
PV export		12.6	12.6	9.9
Non-ren. primary energy, self-use only		**46.2**	**81.3**	**62.4**
Non-ren. primary energy, export included		17.3	52.4	39.7
Total primary energy, self-use only		**88.7**	**81.7**	**67.9**
Total primary energy, exported included		57.2	50.2	43.1
Renewable energy		**65.8**	**23.7**	**62.2**
CO_2 emissions, $kgCO_2/m^2$ a		3.9	10.9	7.2

Primary energy factors & CO_2 emission coefficients	non-ren.	renewable	total	$kgCO_2$/kWh
grid electricity & PV export	2.3	0.2	2.5	0.42
natural gas	1.1	0	1.1	0.22
DH (district heat)	0.6	0.6	1.2	0.12
RE (solar, geo, ambient)	0	1	1	0

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Step 3 – primary energy requirement

- Total PE calculation withoud on-site PV and ambient heat (conflicts with EN ISO 52000-1) is justified by the assessment boundary definition as well as with EED directive energy and primary energy consumption definitions which refer to energy products and exclude ambient heat
- PV inclusion would affect the EP_{tot} values but will not significantly change the difference between studied cases
- To set cost-optimal requirement in terms of the total primary energy:
  - to enable the use the of effective district heat, the cost-optimal value cannot be smaller than EP_{tot} = 89.
  - in the case of gas boiler or AWHP the building envelope or technical systems performance may be reduced to comply with this value

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Step 3 – primary energy requirement

- By setting the EP_{tot} cost-optimal value we did not follow ANNEX I requirements to take into account the positive influence of renewable energy and benefits of district heating because we account renewable energy with the total primary energy factor which makes no difference to fossil fuels
- To follow ANNEX I, an additional numeric indicator must be set:
  - In this case, additional non-renewable primary energy indicator EP_{nren} = 63 can be set to enable the use of AWHP and district heat
- In conclusion, the threshold EP_{tot} = 89 enables to use all three systems studied, but EP_{nren} = 63 only AWHP and district heat. **Therefore, it can be concluded that EP_{tot} threshold is redundant, and it is enough to use Ep_{nren}**
- Conclusion: use non-renewable primary energy indicator for ZEB/NZEB requirement

Step 4 – PE covering requirement (Art 9b)

- The total annual primary energy use of a new or renovated ZEB is to be covered, where **technically and economically feasible**, by:
  - On-site, nearby, renewable energy community generated renewable energy
  - Effective district heating and cooling
  - Energy from carbon free sources (refers to grid electricity)
- Another factor needed to account carbon free electricity (does not equal to renewable PEF, because nuclear energy is carbon free). If no nuclear electricity, carbon free factor = renewable PEF = 0.2 in this example
- AWHP case: 23.3 + 27.2x0.2 = 28.7 < 27.2x2.5 = 68.0, where 23.3 is PV and 27.2 grid electricity – not satisfied
- Effective DH case: 23.3 + 70.2 + 1.8x0.2 = 93.4 > 88.7 – satisfied
- Extensive PV and/or smaller grid electricity PEF needed to satisfy for AWHP, currently not technically and economically feasible

Step 5 – EPC classes

- To calculate EPC classes Art 9 (MEPS) clarifies that by unspecific expression of "primary energy", the total primary energy is meant
- Art 16 EPC A+ class uses explicitly total primary energy and excludes ambient heat
- Therefore, while non-renewable PEF can be applied for the requirements, EPC classes should be calculated with total PEF

- In all, three type of factors are needed to follow EPBD:
  - Non-renewable PEF for the requirements
  - Total PEF for EPC classes
  - Carbon free electricity factor for the second requirement of ZEB
- Alternatively, Annex I allows to use weighting factors for numeric indicator of primary energy, which would allow to use the same factors for requirements and EPC

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How to compare NZEB requirements?

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Commission Recommendation (EU) 2016/1318

European Commission

NZEB level of energy performance	**Mediterranean** Zone 1: Catania (others: Athens, Larnaca, Luga, Seville, Palermo)	**Oceanic** Zone 4: Paris (Amsterdam, Berlin, Brussels, Copenhagen, London, Prague)	**Continental** Zone 3: Budapest (Bratislava, Ljubljana, Milan, Vienna)	**Nordic** Zone 5: Stockholm (Helsinki, Tallinn, Riga, Gdansk, Tovarene)
Offices, kWh/(m²/y)				
net primary energy	20-30	40-55	40-55	55-70
primary energy use	80-90	85-100	85-100	85-100
on-site RES sources	60	45	45	30
New single family houses, kWh/(m²/y)				
net primary energy	0-15	15-30	20-40	40-65
primary energy use	50-65	50-65	50-70	65-90
on-site RES sources	50	35	30	25

- Appliances not included in offices
- Appliances and lighting not included in single-family

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Example: NZEB requirements for apartment buildings in some selected countries

Country	kWh/(m²/y)	Energy uses included
EU-Nordic	40...65	HVAC
Denmark	30 +1000/A	HVAC
Estonia	105	HVAC, appliances, lighting
Finland	90	HVAC, appliances, lighting
Sweden	85	HVAC, facility lighting
Norway	95	HVAC, appliances, lighting

How to compare these requirements?

https://www.rehvam2018atic.eu/images/workshops/4/Kurnitski.pdf

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EC collected data from 2018

Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU *Annex to final report*
https://ec.europa.eu/energy/sites/ener/files/documents/2.annex_to_final_report.pdf

- The Primary Energy Requirements contain indicative information about the range of primary energy requirements for new buildings
- However, it should be noted that different calculation approaches might exist on national level, therefore values cannot easily be compared to each other

Member States	NZEB Defnintion Status*	Primary Energy Requirements (new buildings) (kWh/(m².a))
Austria	Yes	160-170
Belgium (Brussels)	Yes	45-85
Belgium (Flanders)	Yes	32-45
Belgium (Wallonia)	Under development	95
Bulgaria	Yes	30-50
Croatia	Yes	30-80
Cyprus	Yes	100
Czech Republic	Yes	43-51
Denmark	Yes	20
Estonia	Yes	50-100
Finland	Under development	78-150
France	Yes	40-105
Germany	Under development	36-45.75
Greece	Under development	-
Hungary	Under development	50-72
Ireland	Yes	45
Italy	Yes	15-20 & Class A1
Latvia	Yes	95
Lithuania	Yes	A++
Luxembourg	Yes	45 & Class A/Class AAA
Malta	Yes	55-115
Netherlands	Yes	0-25
Poland	Yes	65-75
Portugal	Under development	33
Romania	Yes	93-117
Slovakia	Yes	32-54
Slovenia	Yes	50-80
Spain	Under development	40-70 & Class A
Sweden	Yes	30-75
United Kingdom	Yes	39-46

* status April 2018

(green) Yes
(orange) Under development

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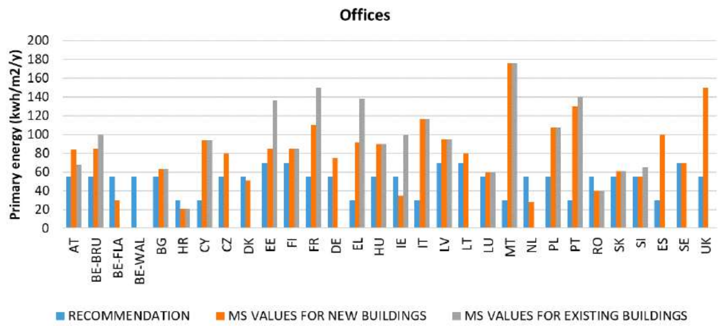
EC 2020 data

2020 assessment of the progress made by Member States towards the implementation of the Energy Efficiency Directive 2012/27/EU and towards the deployment of nearly zero-energy buildings and cost-optimal minimum energy performance requirements in the EU in accordance with the Energy Performance of Buildings Directive 2010/31/EU

Brussels, 14.10.2020 **COM(2020) 954 final**



Source: JRC's own calculations based on Member States reporting

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Example: NZEB requirements for apartment buildings – recalculation to EPBD uses

Country	NZEB primary energy, kWh/(m²·a)	NZEB primary energy, HVAC only, kWh/(m²·a)
EU-Nordic	40...65	40…65
Denmark	30	30
Estonia	**105**	**46**
Finland	90	56
Sweden	85	82
Norway	95	66

- HVAC only limit value represents primary energy without lighting and appliances
- EU-Nordic, Denmark and Sweden values do not include lighting and appliances; in Sweden facility lighting is included
- Estonian, Finnish and Norwegian values include lighting and appliances

→ The problem is that the same energy flows and PE factors are not used

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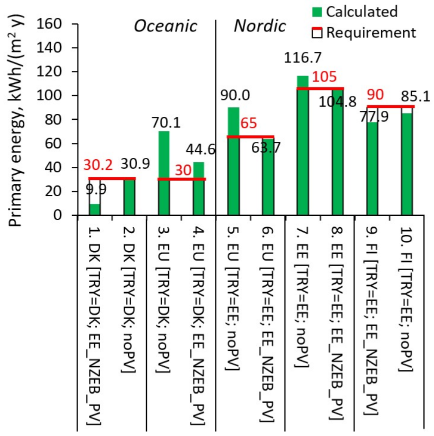
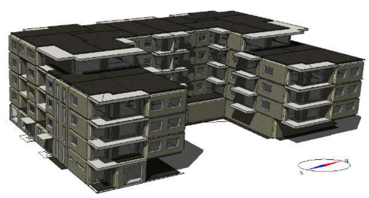
NZEB comparison with (EU) 2016/1318





- EE NZEB apartment building EP = 104.8 corresponds to EC recommendation, 63.7 < 65
- EE NZEB in DK (=over insulated) fulfils Danish NZEB, but not Oceanic zone EC recommendation, 44.6 > 30
- Finnish NZEB requirement fulfilled without PV system
- EE NZEB requirement the most stringent (however U-value normalisation to DK climate not done)

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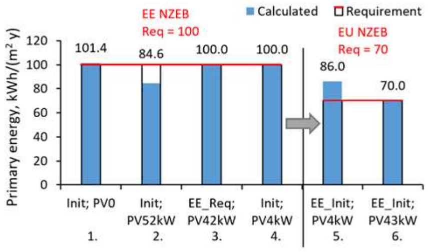
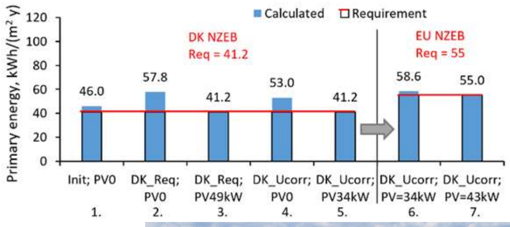
NZEB comparison with (EU) 2016/1318





- EP-value of an office building that exactly fulfils EE NZEB requirement needs to be reduced by 23% to reach EC recommendation
- EP-value of office building with normalized U-values that fulfils DK NZEB requirement needs to be reduced by 7% to reach EC recommendation
- DK has stringent requirement than EE

https://vbn.aau.dk/ws/portalfiles/portal/471932541/Nordic_Baltic_NZEBs.pdf

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Thank you for attention!

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Training seminar / Apmācību seminārs

Energy Calculation with Dynamic Simulation Software (Session 2)

Energoefektivitātes aprēķins ar dinamiskās simulācijas programmatūru (Sadaļa Nr.2)

Raimo Simson, PhD (Estonia)

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Agenda / 12:00 - 13:30

Energy calculation with dynamic simulation software (by Raimo Simson):

- Energy calculation input data – standard use of a building
- Energy need simulation
- Options for systems energy use calculation
- Self-use of on-site electricity generation
- Delivered, exported energy and primary energy calculation
- Summer thermal comfort simulations for overheating prevention in buildings without cooling systems
- Example of NZEB new building energy calculation
- Q&A

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Estonian regulation – EP compliance assessment

- For all buildings except detached houses, energy performance calculation shall be based on **dynamic building simulation**
- Dynamic simulation with a **commercial simulation tool** has been required since 2008
- The main idea was to make energy calculation an integrated part of the building design – the same tools are used for the design (cooling load, summertime overheating prevention, daylight, systems sizing) and for the compliance assessment with requirements and EPC generation
- Energy simulation is typically conducted by HVAC specialist who owns **energy modeller or energy specialist qualification** (master level university education available)
- Existing building EPCs are based on metered energy – simulation needed only for new buildings and major renovation

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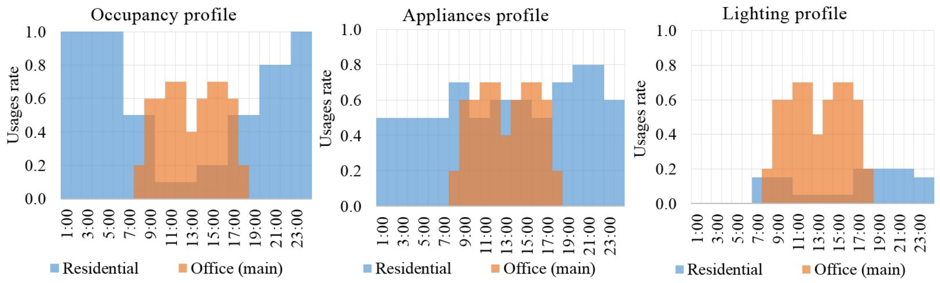
What is different with dynamic simulation?

- Hourly input data specification – hourly schedules for occupancy, lighting, appliances (and domestic hot water)
- Quite **short/compact methodology** because of the requirement to use a **validated simulation tool** ensures correct energy need calculation
- Hourly input data specification increased the number of building categories – residential and non-residential will not work because the building operation patterns are well visible



INTERNATIONAL STANDARD ISO/FDIS 17772-1

Energy performance of buildings -- Indoor environmental Quality -- Part 1: Indoor environmental input parameters for the design and assessment of energy performance of buildings.

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Schedules in EN 16798-1 and ISO 17772-1

Office, main

Parameters and setpoints

	Parameter	Value	Unit
Operation time	Hour at day, START	7	hour
	Hour at day, END	18	hour
	Breaks, inside range	0	hours
	days/week	5	days
	hours/day	11	hours
	hours/year	2868	hours
Internal gains	Occupants	17	m2/pers
	Occupants (Total)	8.3	W/m^2
	Occupants (Dry)	5	W/m^2
	Appliances	12	W/m^2
	Lighting		
	Moisture production	3.53	g/(m2, h)
	CO_2 production	1.10	l/(m2, h)
Setpoints	Min T,op in unoccupied hours	16	°C
	Max T,op in unoccupied hours	32	°C
	Min T,op	20	°C
	Max T,op	26	°C
	Ventilation rate (min.)	0.8	$l/(s\ m^2)$
	Ventilation rate for CO2 emission	0.53	$l/(s\ m^2)$
	Max CO_2 concentration (above outdoor)	500	ppm
	Min. relative humidity	25	%
	Max. relative humidity	60	%
	Lighting, illuminance in working areas	500	lux
Other	Domestic hot water use	100	l/(m2 year)

* u.r. : Usage rate, summed load factors/usage time

Usage schedule

	Energy calculation					
	Weekdays			Weekends		
h	Occupants	Appliances	Lighting	Occupants	Appliances	Lighting
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0.2	0.2	0.2	0	0	0
9	0.6	0.6	0.6	0	0	0
10	0.6	0.6	0.6	0	0	0
11	0.7	0.7	0.7	0	0	0
12	0.7	0.7	0.7	0	0	0
13	0.4	0.4	0.4	0	0	0
14	0.6	0.6	0.6	0	0	0
15	0.7	0.7	0.7	0	0	0
16	0.7	0.7	0.7	0	0	0
17	0.6	0.6	0.6	0	0	0
18	0.2	0.2	0.2	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
*u.r.	0.55	0.55	0.55	0.00	0.00	0.00

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Kompetence, pieredze un tehnoloģijas

EE Energy calculation schedules

(Different schedules for summer thermal comfort in offices, schools & day care)

Time	Residen-tial, lighting	Residen-tial, appliances	Residen-tial, occupancy	Office	Meeting room	Classroom	Day care centre	Day care centre, bedroom	Health care center	Barrack, occupants	Barrack, appliances and lighting	Hotel, occupants	Hotel, appliances and lighting	Shopping and terminal, occupacy	Shopping and terminal, appliances and lighig	Industrial building	Warehouse
00:00-01:00	0	0.5	1	0	0	0	0	0	0	0.7	0	0.7	0.3	0	0	0	0.05
01:00-02:00	0	0.5	1	0	0	0	0	0	0	0.7	0	0.7	0.1	0	0	0	0.05
02:00-03:00	0	0.5	1	0	0	0	0	0	0	0.7	0	0.7	0.1	0	0	0	0.05
03:00-04:00	0	0.5	1	0	0	0	0	0	0	0.7	0	0.7	0.1	0	0	0	0.05
04:00-05:00	0	0.5	1	0	0	0	0	0	0	0.7	0	0.6	0.1	0	0	0	0.05
05:00-06:00	0	0.5	1	0	0	0	0	0	0	0.7	0	0.5	0.3	0	0	0	0.3
06:00-07:00	0.15	0.5	0.5	0	0	0	0	0	0	0.2	0.8	0.5	0.5	0	0	0	0.3
07:00-08:00	0.15	0.7	0.5	0.2	0	0	0.4	0.1	0.4	0.2	0.4	0.4	0.5	0.1	0.55	0.5	0.3
08:00-09:00	0.15	0.7	0.5	0.6	0.5	0.6	0.8	0.1	0.6	0.1	0.4	0.4	0.5	0.3	0.55	0.6	0.4
09:00-10:00	0.15	0.5	0.1	0.6	0.7	0.6	0.8	0.1	0.6	0.3	0.7	0.2	0.4	0.4	0.55	0.6	0.2
10:00-11:00	0.05	0.5	0.1	0.7	0.7	0.6	0.3	0.1	0.8	0.3	0.7	0.1	0.4	0.9	0.55	0.6	0.2
11:00-12:00	0.05	0.6	0.1	0.7	0.7	0.4	0.3	0.1	0.8	0.3	0.7	0.1	0.1	1	0.55	0.6	0.2
12:00-13:00	0.05	0.6	0.1	0.4	0	0.3	0.8	0.1	0.6	0.1	0.3	0.1	0.1	0.8	0.55	0.2	0.2
13:00-14:00	0.05	0.6	0.2	0.6	0.7	0.6	0.1	0.8	0.6	0.1	0.3	0.1	0.1	0.6	0.55	0.6	0.2
14:00-15:00	0.05	0.6	0.2	0.7	0.7	0.6	0.1	0.8	0.8	0.3	0.7	0.1	0.1	0.5	0.55	0.6	0.2
15:00-16:00	0.05	0.5	0.2	0.7	0.7	0.3	0.4	0.4	0.8	0.3	0.7	0.1	0.3	0.3	0.55	0.6	0.2
16:00-17:00	0.2	0.5	0.5	0.6	0.7	0	0.3	0.1	0.6	0.4	0.7	0.1	0.5	0.4	0.55	0.6	0.4
17:00-18:00	0.2	0.7	0.5	0.2	0	0	0.3	0.1	0.4	0.4	0.7	0.1	0.5	0.7	0.55	0.6	0.4
18:00-19:00	0.2	0.7	0.5	0	0	0	0.3	0.1	0.4	0.1	0.7	0.4	0.7	0.8	0.55	0.5	0.3
19:00-20:00	0.2	0.8	0.8	0	0	0	0	0	0.4	0.1	0.7	0.5	0.8	0.7	0.55	0	0.3
20:00-21:00	0.2	0.8	0.8	0	0	0	0	0	0	0.1	0.3	0.5	0.8	0.2	0.55	0	0.2
21:00-22:00	0.2	0.8	0.8	0	0	0	0	0	0	0.7	0.8	0.6	0.9	0	0	0	0.2
22:00-23:00	0.15	0.6	1	0	0	0	0	0	0	0.7	0	0.7	0.7	0	0	0	0.05
23:00-00:00	0.15	0.6	1	0	0	0	0	0	0	0.7	0	0.7	0.7	0	0	0	0.05

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EE Internal heat gains (no difference to monthly method)

Building category	Time	Operation time h/24h	d/7d	Usage rate, -	Lighting[a] W/m²	Appliances[c] W/m²	Occupants[b] W/m²	Occupants m²/person
Detached house <120 m2	00:00-00:00	24	7	0.6	6	3	3	28.3
Detached house 120 - 220 m2 and row house	00:00-00:00	24	7	0.6	6	2.4	2	42.5
Detached house >220 m2	00:00-00:00	24	7	0.6	6	2	1.4	60.7
Apartment buildings	00:00-00:00	24	7	0.6	8	3	3	28.3
Military barracks	00:00-00:00	24	7	0.4	10	2	10	8.5
Office buildings	07:00-18:00	11	5	0.55	10	12	5	17.0
Accommodation building (Hotels)	00:00-00:00	24	7	0.4	10	1	4	21.3
Restaurants	12:00-22:00	10	7	0.4	19	4	14	6.1
Public buildings	08:00-22:00	14	7	0.5	14	0	5	17.0
Shopping and terminals	07:00-21:00	14	7	0.55	19	1	5	17.0
Educational buildings (schools)	08:00-16:00	8	5	0.5[d]	12	8	14	5.4
Daycare centers	07:00-19:00	12	5	0.4	12	4	8	4.4
Health care buildings	07:00-20:00	13	5	0.6	10	4	8	10.6
Warehouses	00:00-00:00	24	7	0.2	10	0	0	0.0
Industrial buildings	07:00-19:00	12	5	0.55	12	12	4	21.3
Building with high energy consumption								

[a] In residential buildings, usage rate of lighting is 0.1

[b] dry heat gain only, for total heat gain divide by 0.6

[d] in residential buildings, appliances electricity use equals the heat gain divided by 0.7

[d] during holiday June 15 to August 15, usage rate is 0.1 and ventilation in out of occupancy mode

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Building categories & NZEB requirements, kWh/(m² a)

Not dynamic simulation specific, but dynamic simulation makes different use patterns and energy intensity more visible

NZEB requirement = non-renewable primary energy

Building category	A (EST)	A(EPBD)
1) Detached house <120 m²	145	89.4
2) Detached house 120 - 220 m² and row houses	120	73.4
3) Detached house >220 m²	100	59.5
4) Apartment buildings	105	45.9
5) Office buildings	100	62.1
6) Shopping and terminals	160	154
7) Hotels	145	138
8) Restaurants	130	118
9) Public buildings	135	135
10) Educational buildings (schools)	100	82.6
11) Daycare centers	100	90.0
12) Health care buildings	100	83.7
13) Military barracks	170	85.9
14) Industrial buildings	110	68.7
15) Warehouses	65	65.0

Residential buildings: appliances and lighting are not included in EPB services
Non-residential buildings: appliances are not included in EPB services

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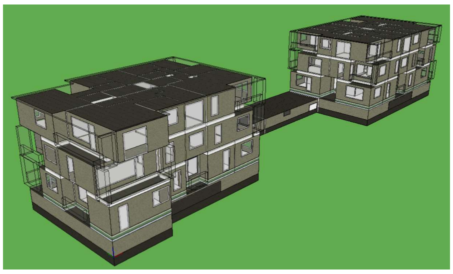
Commercial simulation tools

- Many tools >20 available but with Estonian input data localization only one
- Localization generates input data automatically (schedules, loads, setpoints) from selected building category
- Advanced tools support BIM: geometry input from IFC files or dwg drawings
- EE methodology allows flexible zoning; similar spaces can be merged – typical zones apartments and staircases, in offices façade and inner zones
- Automated geometry input is one of the main advantages – even small buildings may have complicated geometry



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Validated simulation tools

Minimum requirements are specified for **commercial simulation tools:**

- Is to be validated according to relevant European, ISO, ASHRAE or CIBSE standards, IEA BESTEST or other equivalent generally accepted method
- The climate processor should be capable to read Estonian TRY
- Heat recovery is to be included in the energy balance simulation (only system requirement because it affects the utilization of heat gains)
- Simulation is to be conducted with real room temperatures (not with constant setpoints)

As an exception, dynamic simulation is not required for detached houses, for which an alternative compliance assessment method based on simple energy calculator may be used

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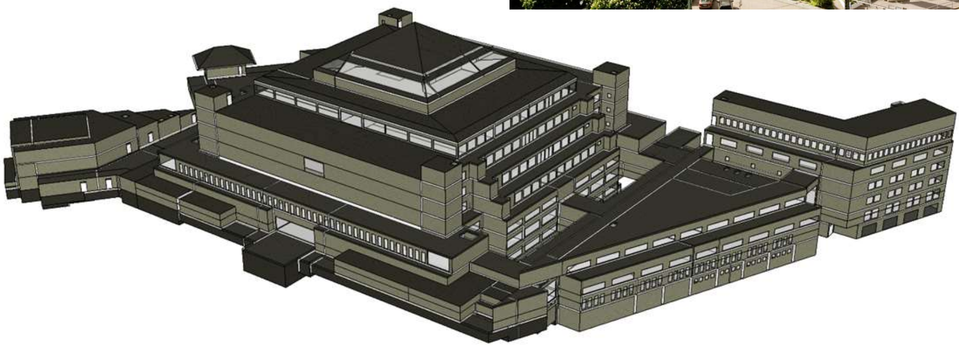
Capacity limits?

- Simulation tools "eat" almost everything, >100 zones possible
- Example: Estonian National Library building – major renovation, complicated storage rooms etc. – practically impossible to design w/o simulation



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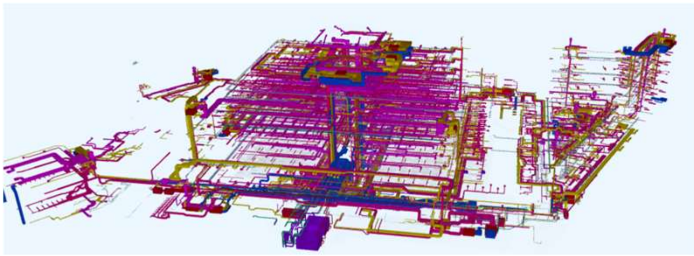
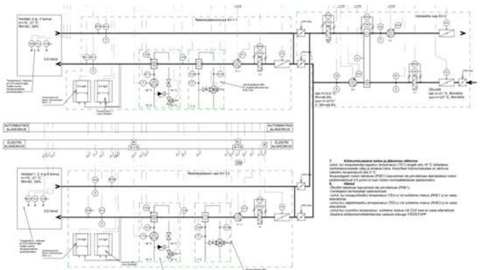
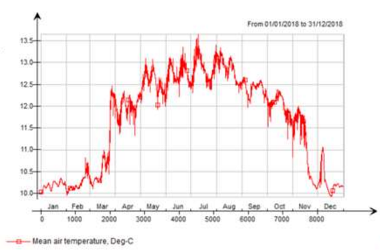
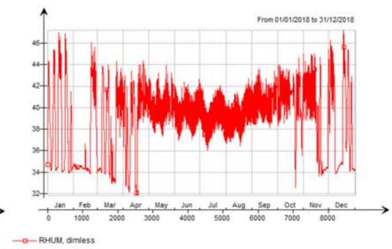
Capacity limits?

- 33 airhandling units
- many zones with different usage profile
- strict archival storage room climate requirement (e.g. -3C ... -7C / RH 30...40%)









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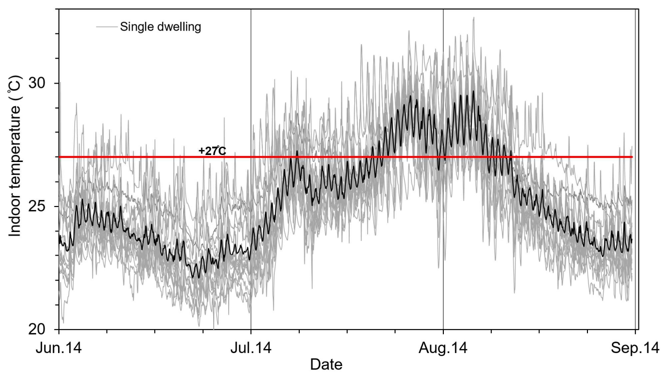
Summer thermal comfort – overheating prevention

- Trends in architecture - large windows and glazed surfaces
- Overheating – a relatively new problem
- Difficult to estimate cooling need without dynamic calculations



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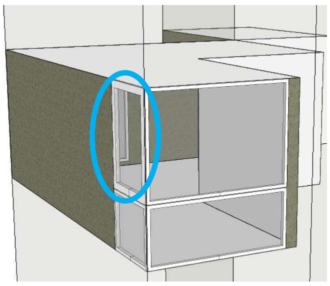
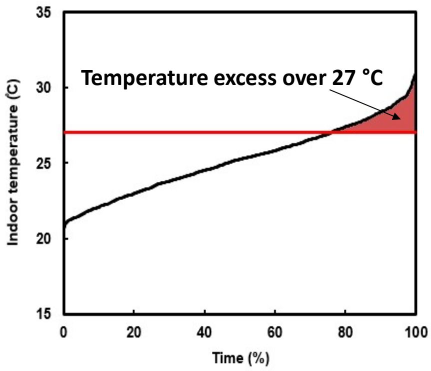
Summer thermal comfort – overheating prevention

- If no cooling is installed, a dynamic **temperature simulation** in critical rooms is required in order to comply with summer temperature requirements (25°C + 100 °Ch in non-residential and 27°C + 150 °Ch in residential buildings during three summer months simulated with TRY)
- An exception for detached houses, there the compliance may be alternatively shown with tabulated values for solar shading, window sizes and window airing





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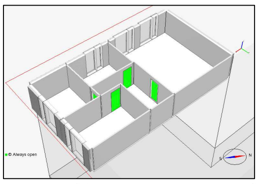
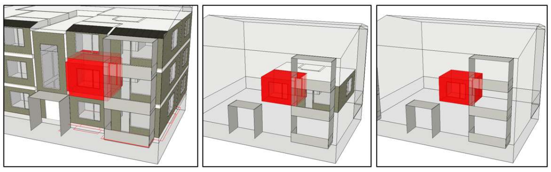
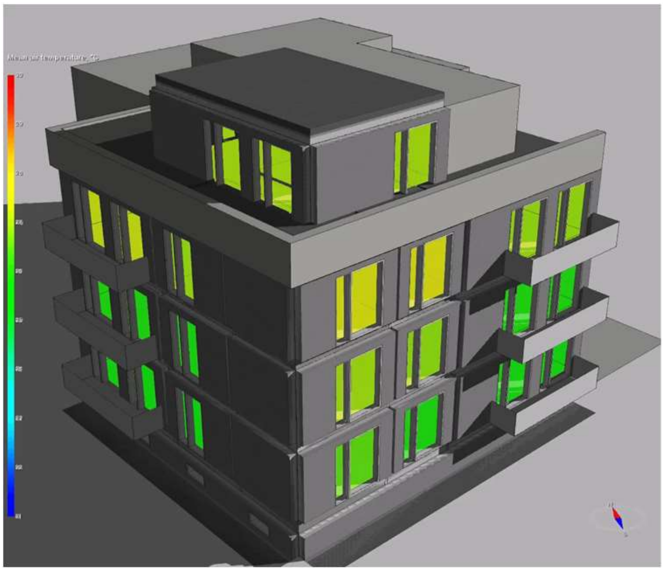
Summer thermal comfort – overheating prevention

- Thermal zoning and modelling – simulations can be room based or apartment based
- If temperature excess limit is exceeded, then building design must be altered or cooling system must be foreseen







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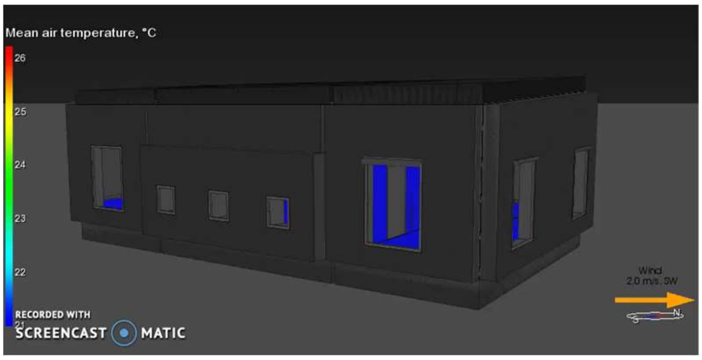
Summer thermal comfort – overheating prevention

Assessment of passive or semi-passive measures for overheating prevention or cooling load reduction can be accounted:

- architectural shading elements
- shading buildings
- trees/foliage
- shading buildings
- active shading elements
- dynamic control



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Systems calculation (HVAC and renewable energy)

- Energy calculation logic is built up so that energy needs are to be simulated, but the systems calculations can be conducted as post processing of the results
- Systems may also be modelled – choice by energy modeller
- There are no limitations for any advance solution to be modelled – energy modeller time and competence, and in a less extent simulation tool capabilities are limiting factors in practice
- Generally accepted calculation methods should be used (European standards, etc.)
- Tabulated values of common systems losses/efficiencies are given in the methodology to enable fast calculation of common cases (often preferred option)
- Instead of a tabulated value, detailed calculation can be always conducted
- On-site energy generation and its self-use may be simulated, or tabulated values can be used

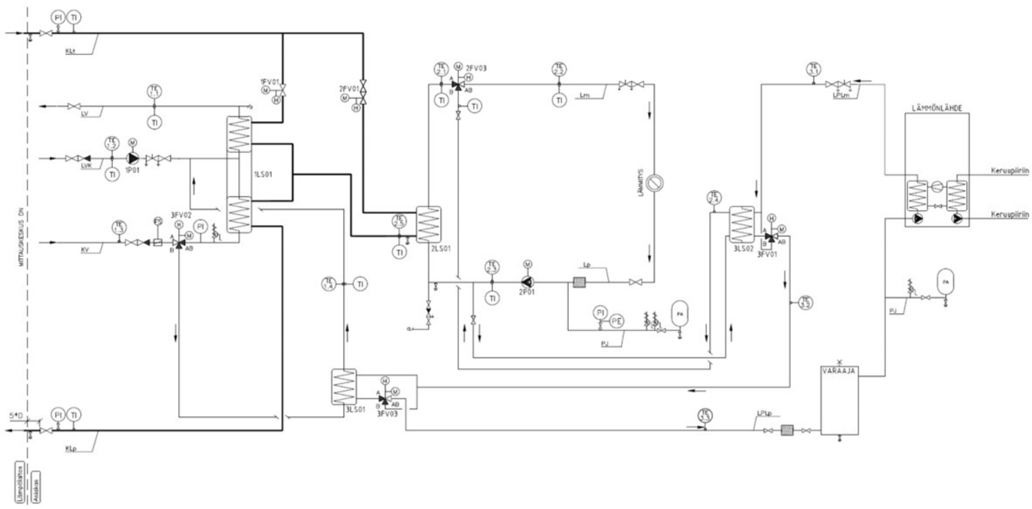
Example: Heat pumps

Three options to calculate heat pumps introduced in EE mehtodology:

1. With tabulated values of seasonal performance factor and energy ratio
2. From seasonal space heating and water heating energy efficiency energy label data for cold climate (package fiche)
3. Detailed calcuation with product data (EN standards, manufactures and simulation tools)

$\frac{\phi_{sp}}{\phi_{ruumid}}$	$\frac{Q_{küte}^{ruumid}}{Q_{küte}^{soe\ vesi}}$	Maasoojuspump T_p				Õhk-vesi SP T_p			
		30	40	50	60	30	40	50	60
0,30	0,50	0,39	0,39	0,39	0,39	0,33	0,33	0,33	0,33
	1,00	0,47	0,47	0,47	0,47	0,39	0,39	0,39	0,39
	2,00	0,62	0,60	0,58	0,56	0,49	0,48	0,47	0,46
	4,00	0,68	0,65	0,62	0,59	0,56	0,54	0,52	0,50
0,40	0,50	0,52	0,52	0,52	0,52	0,44	0,44	0,44	0,44
	1,00	0,67	0,66	0,65	0,64	0,52	0,52	0,52	0,52
	2,00	0,78	0,75	0,72	0,70	0,63	0,61	0,60	0,58
	4,00	0,84	0,79	0,76	0,73	0,68	0,65	0,63	0,61
0,50	0,50	0,65	0,65	0,65	0,65	0,54	0,54	0,54	0,54
	1,00	0,82	0,80	0,78	0,76	0,65	0,64	0,64	0,63
	2,00	0,90	0,87	0,84	0,81	0,73	0,71	0,69	0,68
	4,00	0,92	0,89	0,86	0,83	0,78	0,75	0,72	0,70
0,60	0,50	0,81	0,80	0,79	0,78	0,64	0,64	0,64	0,64
	1,00	0,92	0,90	0,88	0,86	0,75	0,74	0,72	0,72
	2,00	0,95	0,93	0,91	0,89	0,82	0,79	0,77	0,75
	4,00	0,96	0,94	0,92	0,90	0,84	0,82	0,80	0,77
0,70	0,50	0,92	0,90	0,88	0,87	0,73	0,73	0,73	0,73
	1,00	0,97	0,95	0,94	0,92	0,83	0,81	0,80	0,78
	2,00	0,98	0,96	0,95	0,93	0,87	0,85	0,83	0,82
	4,00	0,98	0,97	0,95	0,94	0,89	0,87	0,85	0,83
0,80	0,50	0,97	0,96	0,95	0,94	0,81	0,80	0,80	0,79
	1,00	0,99	0,98	0,97	0,96	0,88	0,87	0,85	0,84
	2,00	0,99	0,98	0,97	0,96	0,90	0,89	0,88	0,86
	4,00	0,99	0,98	0,97	0,96	0,91	0,90	0,88	0,87
0,90	0,50	0,99	0,98	0,98	0,97	0,89	0,88	0,88	0,87
	1,00	1,00	0,99	0,98	0,97	0,92	0,91	0,90	0,89
	2,00	1,00	0,99	0,98	0,98	0,92	0,91	0,90	0,89
	4,00	1,00	0,99	0,98	0,97	0,92	0,91	0,90	0,89
1,00	0,50	1,00	0,99	0,99	0,98	0,92	0,92	0,91	0,90
	1,00	1,00	1,00	0,99	0,99	0,93	0,92	0,92	0,91
	2,00	1,00	1,00	0,99	0,99	0,93	0,92	0,92	0,91
	4,00	1,00	1,00	0,99	0,99	0,93	0,92	0,91	0,90

Exhaust air heat pumps coupled with district heating



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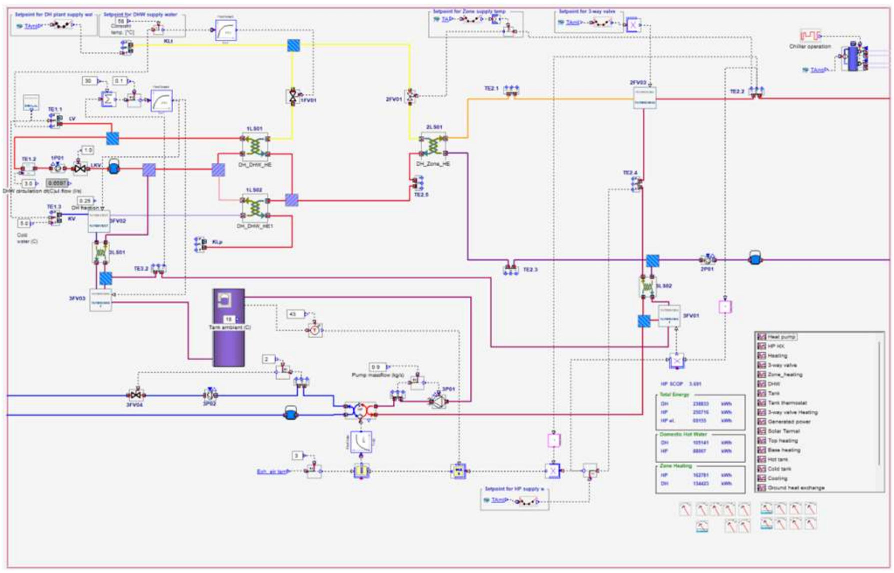
Exhaust air heat pumps coupled with district heating



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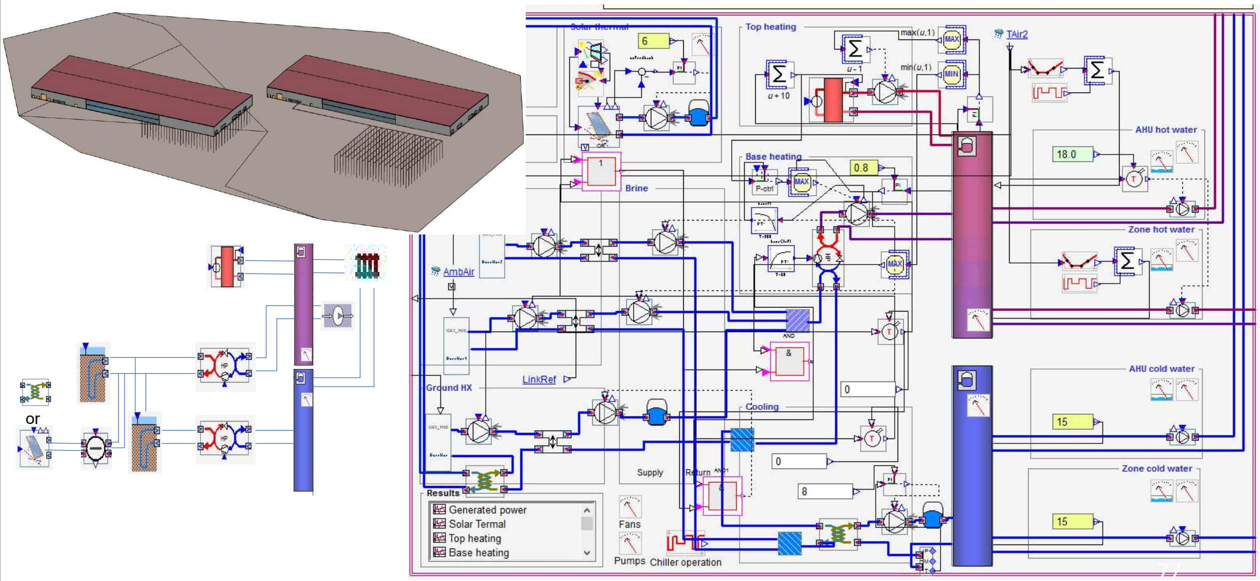
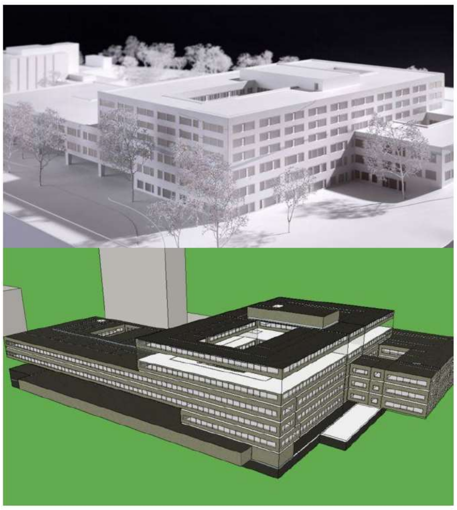
Complex systems: example of the geothermal plant with separated thermal storage and free cooling



Complex systems: large buildings with combined HVAC incl. boreholes



- 147 zones with floor heating/cooling
- Plant with
  - 4 air handling units
  - 4 tanks
  - 3 heatpumps and chillers
  - 2 burners
  - 1 brine to ambient heat exchanger
  - 15 pumps
  - 5 brine to brine heat exchangers
  - 55 controlers
- 100 boreholes

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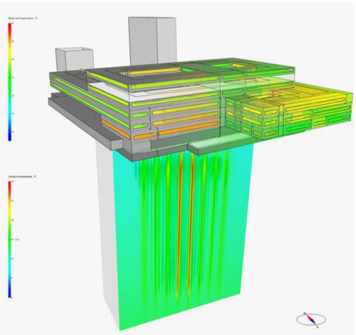

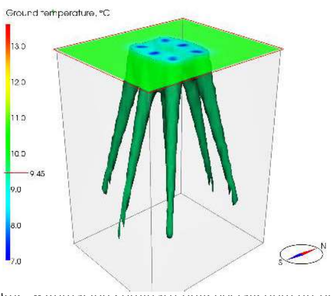

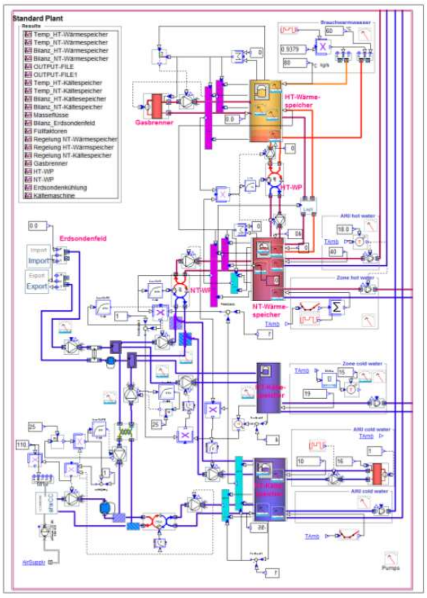

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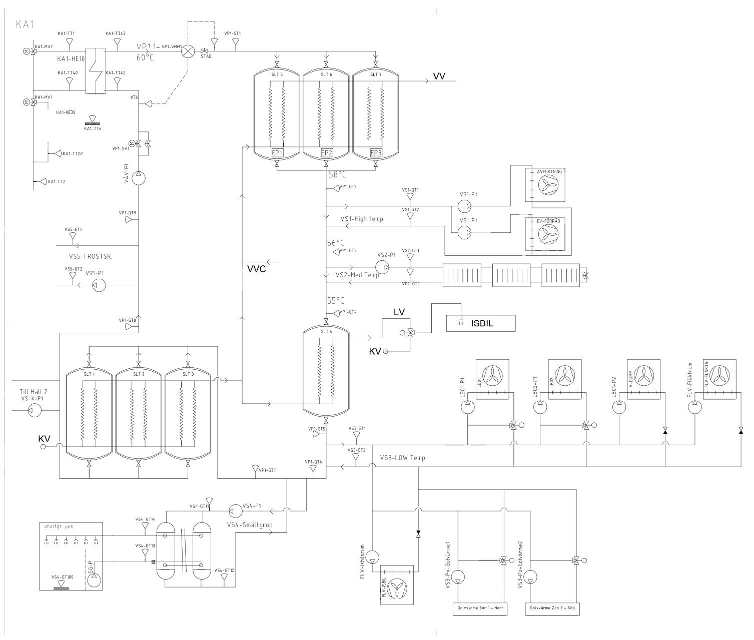

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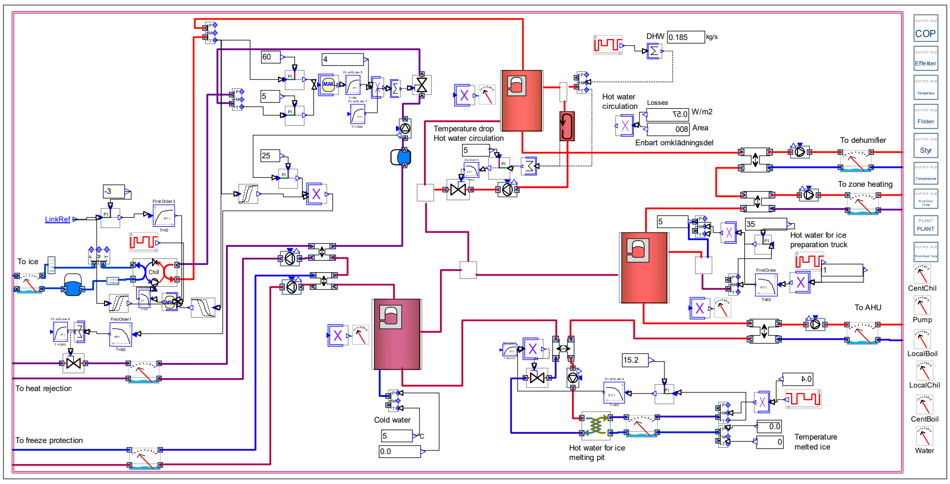

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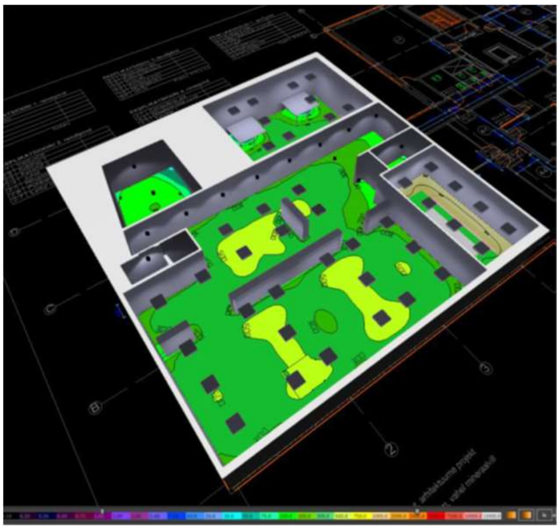
Lighting & appliances energy consumption: tabulated or design values, dynamic control

- For appliances only tabulated values must be used
- Lighting energy use may be calculated based on design – but illuminance calculations must be provided



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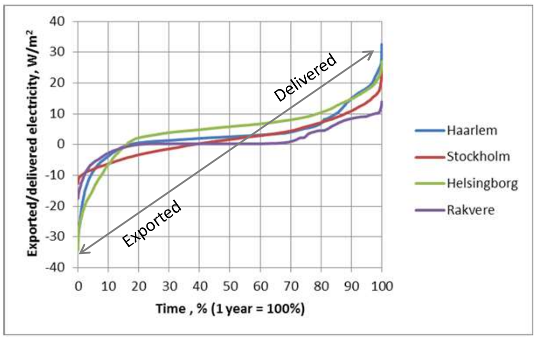
Self-use of on-site RENEWABLE ENERGY generation

EE methodology allows to account only the self-use of on-site renewable energy generation

Exported electricity is not accounted in the primary energy indicator

The self-use may be calculated:

- Hourly simulation
- Tabulated values (conservative)



	Haarlem	Stockholm	Helsingborg	Rakvere
Max delivered, W/m²	32,6	24,2	27,0	13,9
Max exported, W/m²	-31,6	-12,6	-34,2	-17,5
10th percentile, W/m²	-3,8	-6,2	-6,5	-2,7
90th percentile, W/m²	15,0	10,9	14,8	8,4

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On-site PHOTOVOLTAIC (PV) ELECTRICITY generation

- Tabulated values based on PV azimuth, tilt angle and installation method
- Self-use percentage depends on building type (35%...95%)

Building type	Share of self-consumption, %
1) small house with heated surface < 120 m²	45
2) a small house with a heated area of 120–220 m² and a terraced house	40
3) small house with heated surface > 220 m²	35
4) apartment building	55
5) barracks	80
6) office building	90
7) accommodation building	70
8) commercial building	60
9) public building	80
10) commercial building and terminal	90
11) educational building	60
12) preschool building	75
13) hospital	85
14) warehouse	40
15) industrial building	90
16) building with high energy consumption	95

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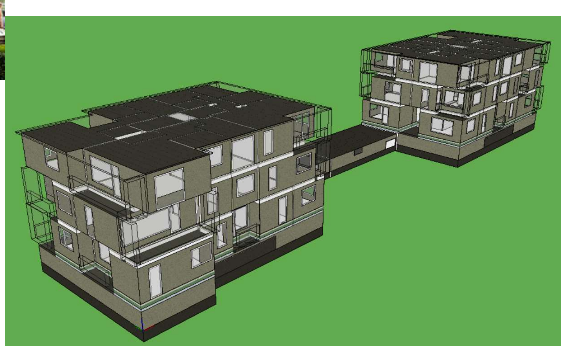
Apartment building example

- Small building and compactness not best possible – relatively high heat losses
- Reference building used in NZEB requirement testing
- Calculated with several heat sources and PV

Cost optimal solutions:
External wall U=0.14, roof U=0.12, external floor U=0.14, windows U=0.9 (overall), building leakage rate q_{50}=1.5, heat recovery ventilation with single dwelling units having electrical reheating coils and rotary heat exchangers of 80% temperature ratio



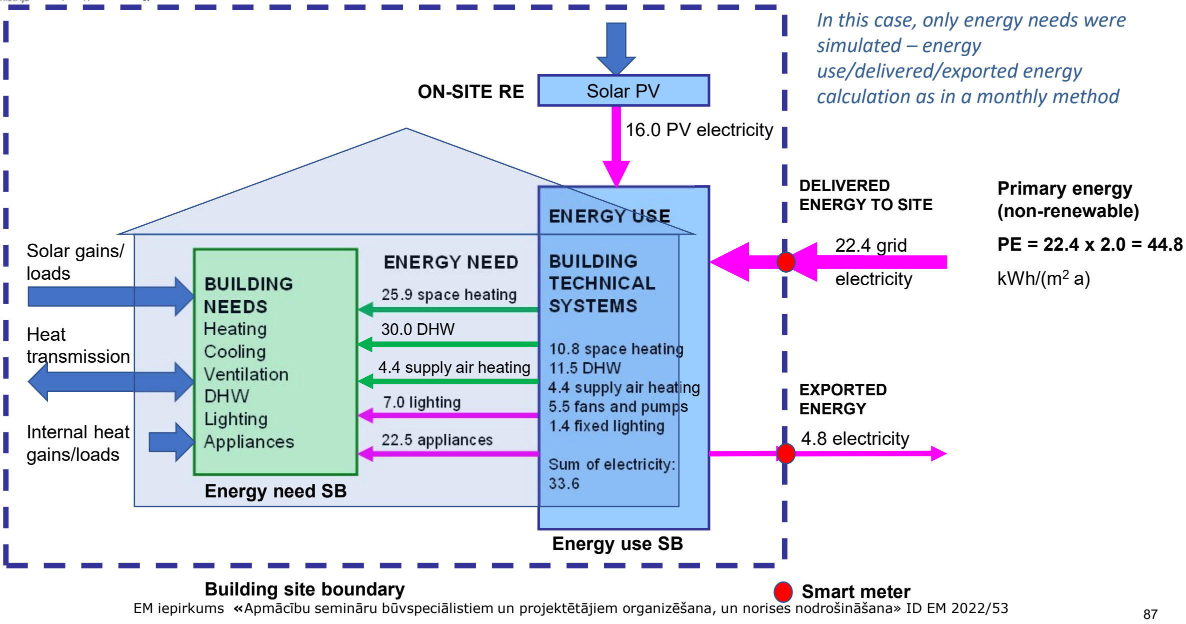
Apartment building example – energy use

Heat source			District heat. 0.9	District heat. 0.65	Ground source heat pump	Air to water heat pump	Gas boiler
Energy balance		Energy need kWh/(m^2 a)	Delivered en. kWh/(m^2 a)	Delivered en. kWh/(m^2 a)	Delivered en. kWh/(m^2 a)	Delivered en. kWh/(m^2 a)	Delivered en. kWh/(m^2 a)
Space heating		25.9	29.7	29.7	10.8	12.8	28.1
Ventilation supply air heatin		4.4	4.4	4.4	4.4	4.4	4.4
Domestic hot water heating		30.0	33.3	33.3	11.5	15.0	31.6
Cooling		0.0	0.0	0.0	0.0	0.0	0.0
Fans and pumps		5.5	6.0	6.0	5.5	5.5	6.0
Lighting		7.0	7.0	7.0	7.0	7.0	7.0
Appliances		22.5	22.5	22.5	22.5	22.5	22.5
Total		95	103	103	62	67	100
EPC class B	**125**	**EP_p**	**137**	**121**	**123**	**134**	**139**

- Calculated without PV to check the EPC class B requirement – achieved with district heating and ground source heat pump
- For heat pumps 80% power sizing is used
- DHW, lighting and appliances are regulated values
- To achieve NZEB/class A=105, **15 kWh/(m^2 a) PV** production is needed with DH (18 with GSHP) at default 55% usage rate in the building [16/2.0/0.55=15 kWh/(m^2 a)]

EPBD: fixed lighting and no appliances, GSHP case

In this case, only energy needs were simulated – energy use/delivered/exported energy calculation as in a monthly method



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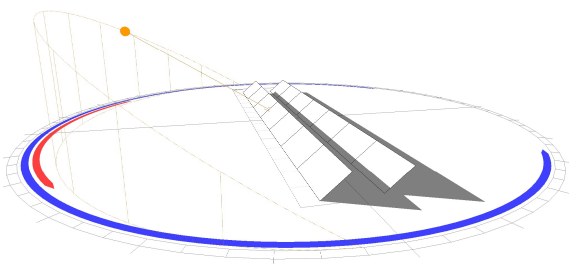
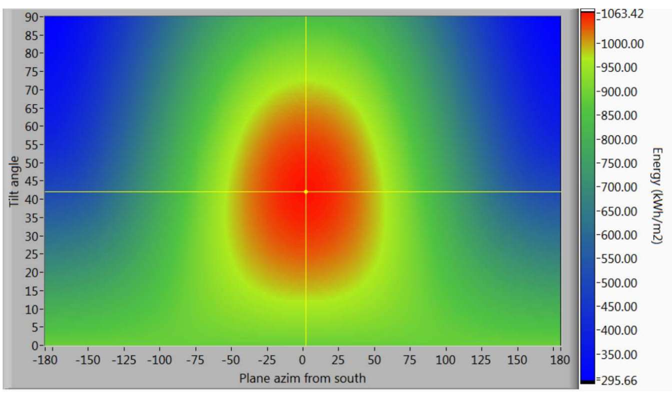
On-site PHOTOVOLTAIC (PV) ELECTRICITY generation

- Tabulated values based on PV azimuth, tilt angle and installation method
- Self-use percentage depends on building type (35%...95%)





Calculation of optimal single solar array orientation. Yearly optimum in Tallinn

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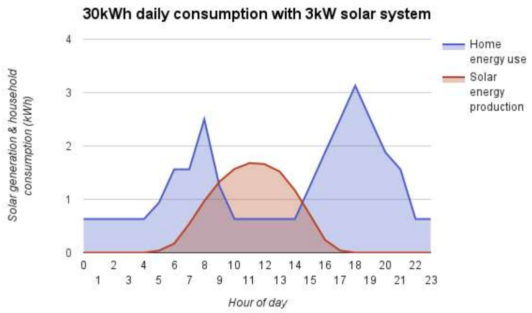
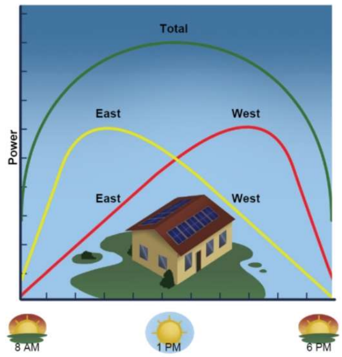
On-site PV ELECTRICITY generation

- South oriented PV panels with tilt angle 45°:
 produces more during mid-summer and mid-day
how high is self-consumption?

- East/west oriented PV panels with tilt angle 20°
more uniform production, higher self-consumption for office buildings etc

needs optimization for maximal self-consumption





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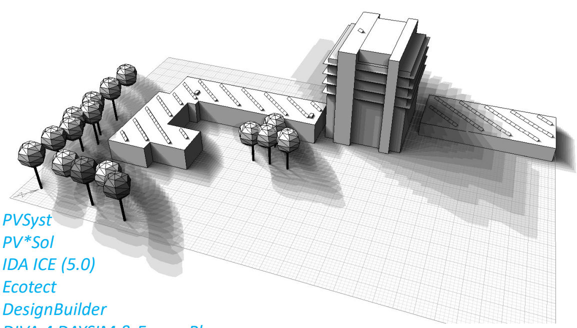
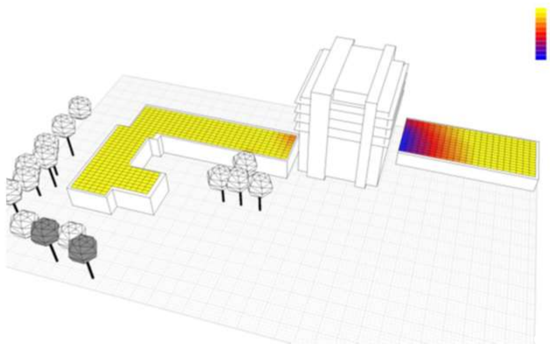
PV electricity generation modelling

- Tabulated values are conservative and imprecise for production estimation and self-consumption optimization for more complex systems or installations
- Due to the hourly cycle of energy market, short-term prediction becomes more important
- Accurate yield estimation is especially important for off-grid systems
- Detailed modelling and simulations also allow for accurate estimation of shading, inverter and cable losses, module degradation etc.
- Important for adequate investment decisions





PVSyst
*PV*Sol*
IDA ICE (5.0)
Ecotect
DesignBuilder
DIVA 4 DAYSIM & EnergyPlus
…

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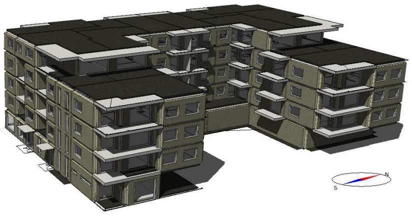
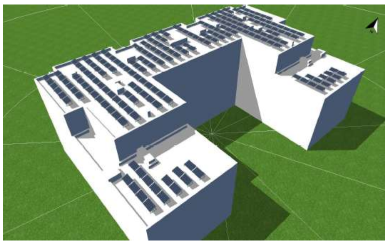
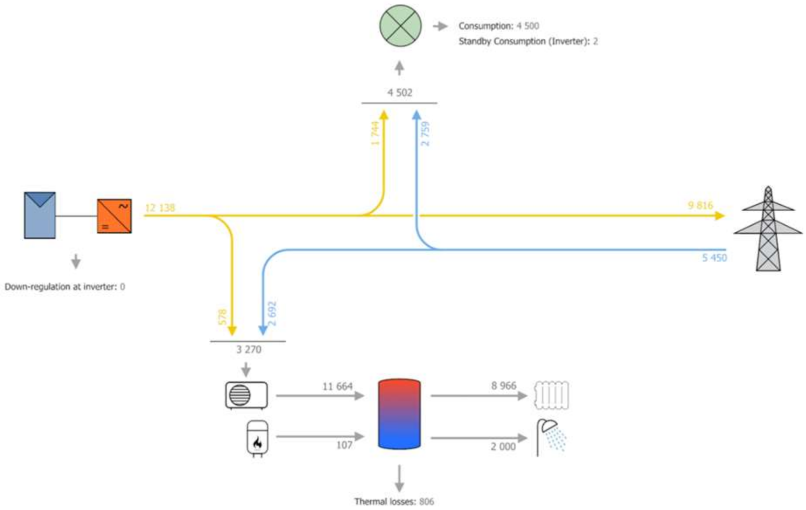
On-site PV electricity generation







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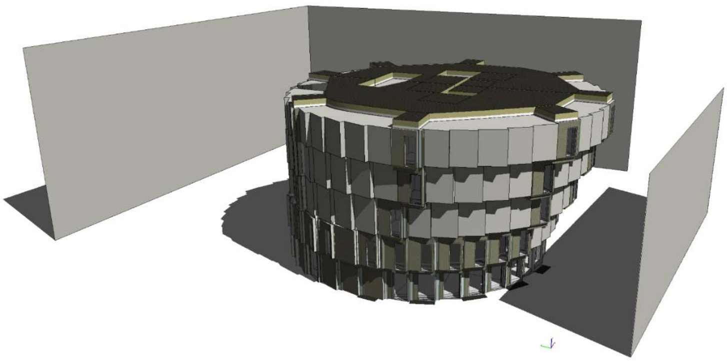
Complex architecture: sunlight and daylight exposure, shading elements and thermal zoning



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Early-stage building modelling and optimization

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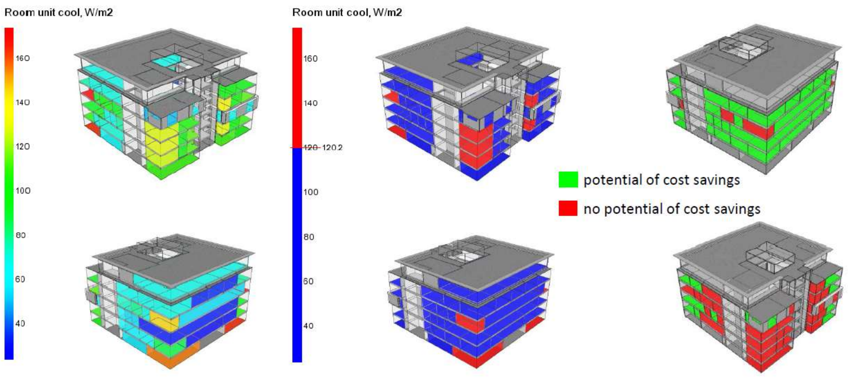
Energy performance, heating and cooling load calculations



- Precise dimensioning of all room supply units
- Avoiding any oversizing
- Savings in investment costs

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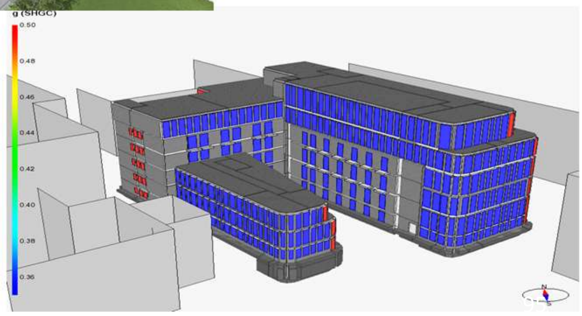
Energy performance, heating and cooling load calculations: examples



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CONCLUSIONS

- Dynamic simulation with commercial tools has been required since 2008 in EE
- Energy needs must be, but systems may be simulated – in many cases small difference to monthly calculation
- Relatively compact energy regulation as “validated simulation tool” specifies a lot (requirements 10 pp, methodology 27 pp and EPC 19 pp)
- Automated geometry input, input data generation and developed user interfaces save time (+availability of advanced models)
- Made energy calculation an integrated part of the building design and energy requirements started to steer the design process
- Latest developments – high performance, heat pumps, on-site generation, overheating prevention – support simulation

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EXAMPLE OF NZEB NEW BUILDING ENERGY CALCULATION

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Thank you for attention!

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Training seminar / Apmācību seminārs

Estonian Experience on Energy Performance Certificates (EPC), Energy Audits and Deep Renovation Grant Schemes (Session 3)

Igaunijas pieredze energoefektivitātes sertifikātu (EPC), energoauditu un padziļinātas renovācijas grantu shēmās (Sadaļa Nr.3)

Prof. Jarek Kurnistki, PhD and Raimo Simson, PhD (Estonia)

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Agenda / 14:30 - 16:00

Estonian experience on energy performance certificates (EPC), energy audits and deep renovation grant schemes (by Prof. Jarek Kurnitski, Raimo Simson)

- EPC-s for new buildings, checking mechanisms by input data and results tables
- EPC in the design and construction process
- EPC-s for existing buildings and energy audits
- Renovation grant scheme system for residential buildings: main steps in the application process
- Renovation grants technical requirements for apartment buildings
- Examples of typical renovation solutions
- Q&A

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EPC and NZEB requirements

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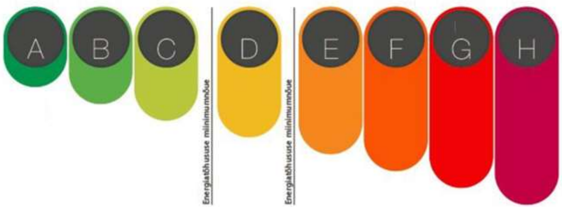
Estonian energy performance regulation

- The energy performance requirement of buildings is based on **primary energy use** that is the only requirement (since 2008) and therefore allows very flexible design and construction
- Energy performance requirements are linked with EPC classes (NZEB = A)
- The NZEB requirements have been in place since 9th of January 2013 but were detailed in Nov 2018



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NZEB in Estonia

EPC Class A = new building NZEB

EPC Class C = major renovation NZEB

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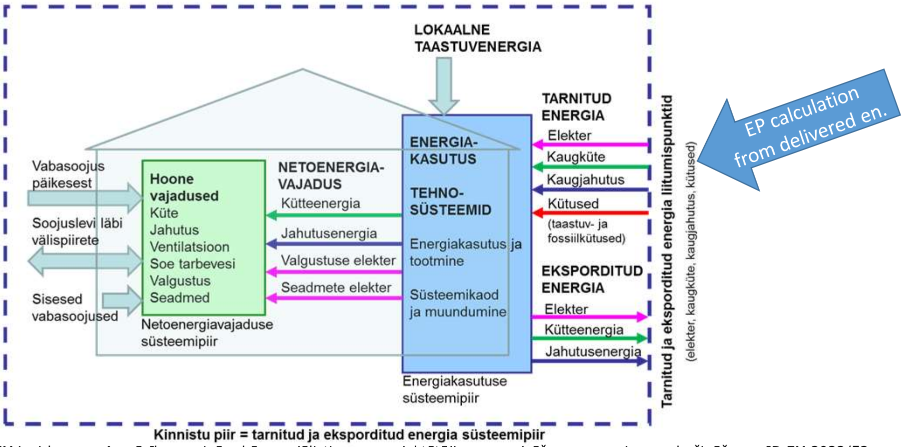
NZEB in Estonia

- Energy performance (EP) values based on non-renewable primary energy
- Exported energy is not accounted in EP calculation
- Assessment boundary = site boundary = connection points of main meters



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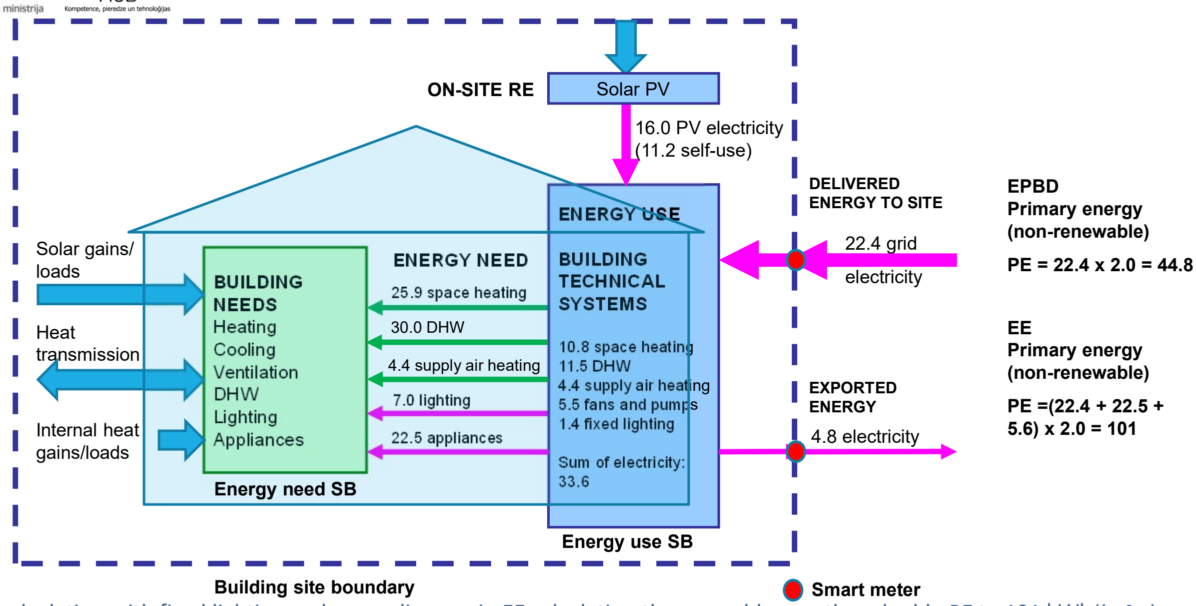
EXAMPLE: apartment building with GSHP



EPBD calculation with fixed lighting and no appliances, in EE calculation these would more than double PE to 101 kWh/(m² a)

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New building NZEB requirements

In Estonia new NZEB has two requirements:

1. **EPC Class A**
2. Additional NZEB requirement – **EPC class B** is to be achieved **without on-site electricity generation**:
    - Energy efficiency measures cannot be fully compensated with RE generation
    - On-site/nearby RES is not specifically required, but the easiest way for EPC Class A

NZEB **exceptions**, EPC Class may remain in between A and B if:

- not enough space on the roof;
- or shadings limit the PV generation below 70% of optimal.
- In such cases EPC Class A is not required to be sure that **strict NZEB requirements will not block construction** in specific cases

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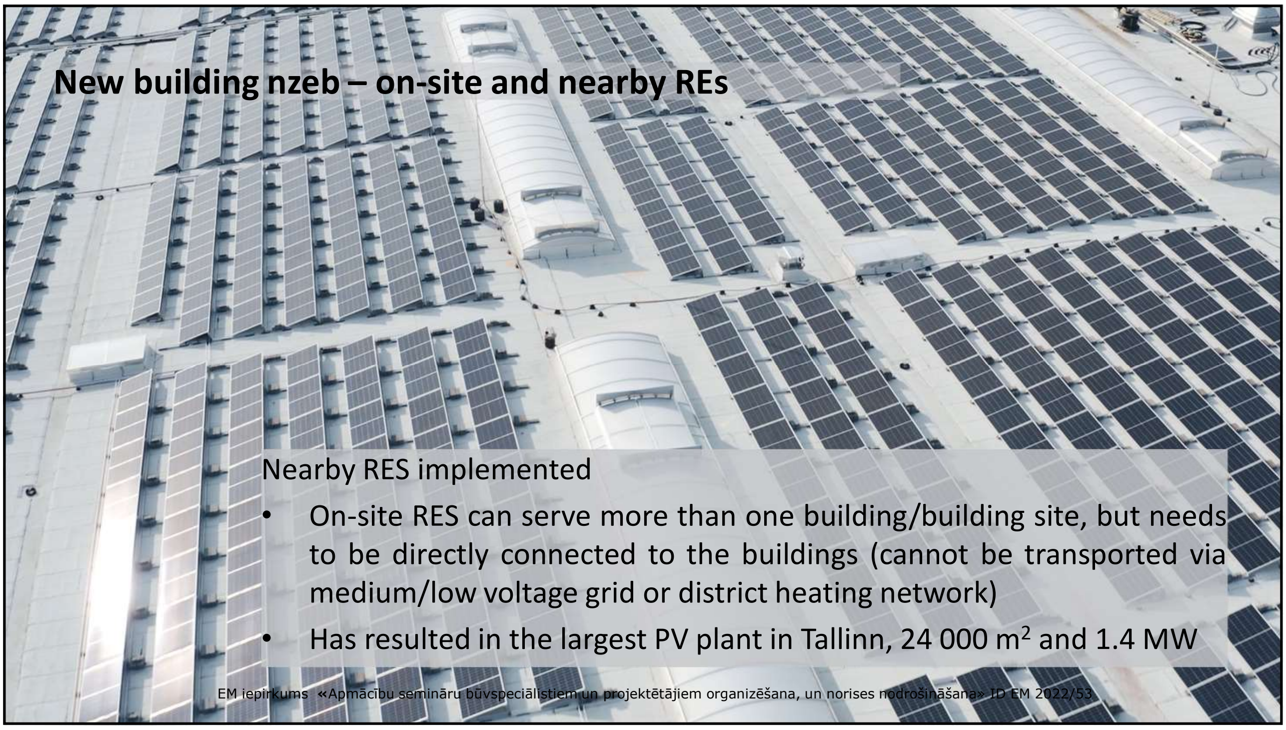

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Building categories & NZEB requirements, kWh/(m² a)

NZEB requirement = non-renewable primary energy

Primary energy factors:

- electricity 2.0;
- district heating 0.9;
- efficient district heating 0.65;
- renewable fuels 0.65;
- district cooling 0.4;
- efficient district cooling 0.2;
- fossil fuels 1.0.

Building category	A (EE)	A(EPBD)
1) Detached house <120 m²	145	89.4
2) Detached house 120 - 220 m² and row houses	120	73.4
3) Detached house >220 m²	100	59.5
4) Apartment buildings	105	45.9
5) Office buildings	100	62.1
6) Shopping and terminals	160	154
7) Hotels	145	138
8) Restaurants	130	118
9) Public buildings	135	135
10) Educational buildings (schools)	100	82.6
11) Daycare centers	100	90.0
12) Health care buildings	100	83.7
13) Military barracks	170	85.9
14) Industrial buildings	110	68.7
15) Warehouses	65	65.0

Residential buildings: appliances and lighting are not included in EPB services
Non-residential buildings: appliances are not included in EPB services

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Estonian energy performance regulation

1. MKM no 63 regulation 01.01.2019 **Minimum requirements for energy performance**
2. MKM no 58 regulation 21.01.2019 **Methodology for calculating the energy performance of buildings**
3. MKM no 36 regulation 21.01.2019 Format and procedure of issuance of **energy performance certificates**

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Estonian regulation – EP Compliance assessment

- For all buildings except detached houses, energy performance calculation shall be based on **dynamic building simulation**
- Dynamic simulation with a **commercial simulation tool** has been required since 2008
- The main idea was to make energy calculation an integrated part of the building design – the same tools are used for the design (cooling load, summertime overheating prevention, daylight, systems sizing) and for the compliance assessment with requirements and EPC generation
- Energy simulation is typically conducted by HVAC specialist who owns **energy modeller or energy specialist qualification** (master level university education available)
- Existing building EPCs are based on metered energy – simulation needed only for new buildings and major renovation

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Energy performance calculation methodology

- Building leakage rate measurement or declaration/verification method mandatory (blower door test) to use q_{50}=1.5 $m^3/(h\ m^2)$
- Guideline and catalogue values for thermal bridges have been made available
- Guideline for simulation of energy use for lighting – illuminance levels (lx), installed power density (W/m^2), controls and daylight contribution
- Temperature simulation guideline for overheating requirement
- Energy metering requirements to distinguish regulated and not regulated (processes) energy use

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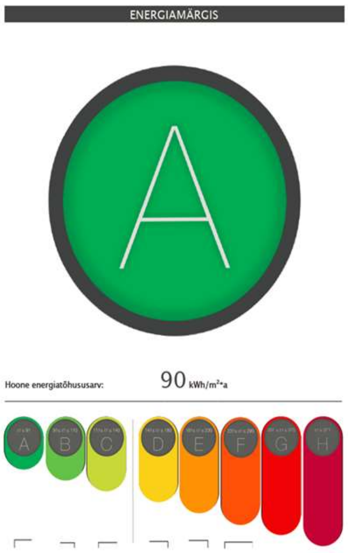
Energy performance certificates

- Calculated EPCs and EPCs based on real metered use expected to be as close as possible – possibility to reduce metered energy not accounted in energy calculation
- EPC must be issued before the building permit, but an updated calculated EPC must be issued for the use permit application
- After 2 years of operation EPC based on metered energy use will be issued



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EPC Quality control

Energy calculation input data report

Energy calculation input data	
Number of calculation zones	116
Heating system type	
-heat generation and fuel	Ground source heat pump
-heat distribution	TABS
Ventilation system type	CAV
Cooling system (yes/no)	Yes
Building leakage rate data reference	
Linear thermal bridge data reference	

Heat loss through building envelope elements

Building envelope element	g, -	U_i, W/(m²·K)	A_i, m²	$H_{conduction}$ W/K
External wall		0.12	1223.0	146.8
External roof		0.09	901.0	81.1
External floor above parking lot		0.13	956.0	124.3
External door		1.00	13.0	13.0
Window (north-east)	0.24	0.83	64.0	53.1
Window (south-east)	0.24	0.83	288.0	239.0
Window (south-west)	0.24	0.83	80.0	66.4
Window (north-west)	0.24	0.83	288.0	239.0
Sum:		$H_{conduction}$, W/K		962.7

Heat loss through linear and point thermal bridges

Linear or point thermal transmittance	Ψ_j, W/(m·K)	l_j, m	H_{linear} W/K
External wall-external wall (outer corner)	0.09	63.0	5.7
Roof-external wall	0.09	142.0	12.8
External floor above parking lot-external wall	0.11	147.0	16.2
Window perimeter	0.03	1456.0	43.7
External door perimeter	0.06	30.0	1.8
	H_{linear}, W/K		80.1

Infiltration heat loss

Property	Quantity
Building leakage rate q_{50}, m³/(hm²)	1.5
A_{vp} (building envelope), m²	3813
No of floors	5
$\dot{v}_{inf}$, m³/s	0.106
$H_{infiltration}$, W/K	127.7

Total heat loss coefficient	ΣH, W/K	1170.6
Average thermal transmittance	$\Sigma H/A_{vp}$, W/(m²K)	0.31
Heated area	A_{heated}, m²	3605.1
Low temperature setpoint area	A_{low}, m²	0.0
Specific heat loss calculated per heated area	$\Sigma H/A_{heated}$, W/(m²K)	**0.32**

Ventilation system	Air flow rate supply/extract m³/s	System SFP kW/(m³/s)	Heat recovery type	Heat recovery temperature -	Exhaust air min. temp.[1] °C	Supply air temperature[2] °C
CAV-1	6.40/6.40	1.84*	Wheel	0.85*	-5	variable
CAV-2	0.80/0.80	1.47	Plate	0.74	2	variable

[1] heat recovery frost protection
[2] to be reported for systems with constant supply air temperature
* weighted average values for the all thermal wheels

Heating system	Generation efficiency, -	Emission and distribution efficiency, -	Heating period[3] average COP, -	Heat pump[3] energy fraction, -	Auxiliary[4] electricity, kWh/(m²y)	Heating curve[5] °C / °C	Heating system power[4] Electricity kW	Heat kW
Space heating	-	1.00	4.2	0.94	-	40/35		
Air handling units	-	1.00	4.2	0.94	-	40/35		
Domestic hot water	-	1.00	2.7	0.94	-	5/55		

[3] to be reported for heat pump systems
[4] not available, if reported in the COP of the heat pump system

Cooling system	Cooling period average EER -	Fraction of total cooling energy[6], -	Auxiliary electricity kWh/(m² a)	Cooling curve[5] °C / °C	Cooling losses factor β_{je}, β_{jek}, β_{rs}, -
Central cooling	3.6	1.00	0.2	15/18	0.0, 0.0, 0.0

[5] at design outdoor temperature, to be reported for hydronic systems
[6] 1.0 if no free cooling

On-site renewable energy systems	Solar collector active area, m²	PV panels max power, kW	Wind generator nominal power, kW
1 (e.g. solar PV panels)		15	

Internal heat gains	Occupancy W/m²	Appliances W/m²	Lighting W/m²	Usage rate %	Usage time days in week d	Usage time hours in day h
	5	15	8.5*	55	5	11

* weighted average value. LED-lighting is used in common areas (5W/m²)

Date Name /digital signature/

Energy calculation results report

Building data		
Buidling category	Office building	x New building
Address	Järvevana tee 7b, Kesklinna district, Tallinn	Major renovation
Construction year	2018	Renovation
Heated area	3605.1 m²	Existing building
Low temperature setpoint area	0 m²	
Net area	3605.1 m²	
EP value	99.7 **kWh/(m²y)** (kWh per heated area)	
EP value B	105.8 **kWh/(m²y)** (kWh per heated area)	

[B] EP value without on-site electricity generation

Energy use summary	Delivered fuel mass or quantity/volume unit		Delivered energy kWh/y	Delivered energy kWh/(m²y)	Exported energy kWh/y	Exported energy kWh/(m²y)	Weighting factor -	Weighted energy use kWh/(m²y)
Electricity	-	-	179754	49.9	1223	0.3	2.0	99.0
Sum	-	-	**179754**	**49.9**	**-**	**-**	-	**99.0**

On-site generated and exported energy	On-site generated kWh/a	On-site generated kWh/(a m²)	Exported kWh/a	Exported kWh/(a m²)	Self-use fraction %
Photovoltaic electricity	12226	3.4	1223	0.3	90

Energy use of technical systems	Electricity kWh/a	Heat kWh/a	Electricity kWh/(a m²)	Heat kWh/(a m²)
Heating system	-	-	-	-
Space heating	14318	-	4.0	-
Supply air heating	4942	-	1.4	-
DHW heating	8011	-	2.2	-
Auxiliary electricity	-	-	-	-
Ventilation system[1]	41460	-	11.5	-
Cooling system	4623	-	1.3	-
Auxiliary electricity	832	-	0.2	-
Lighting	48334	-	13.4	-
Appliances	68237	-	18.9	-
Sum (total energy use of technical systems)	190757	-	52.9	-

[1] supply air heating is accounted as a part of heating system

Energy need	kWh/a	kWh/(a m²)
Space heating[2]	42774	11.9
Supply air heating[3]	20755	5.8
DHW heating	21631	6.0
Space cooling	4181	1.2
Supply air cooling	16724	4.6

[2] includes infiltration and supply air heating in the room
[3] calculated with heat recovery

Calculation tool name and version	IDA Indoor Climate and Energy 4.6

09.07.2015	Indrek Raide	/digital signature/
Date	Name	signature

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Conclusions on NZEB and EPC

- NZEB has two requirements: with and without renewable energy generation
- NZEB exceptions allowing less renewable energy generation in unfavourable building site are important – otherwise strict requirements could block construction
- Dynamic simulation with commercial tools has been required since 2008
- Energy needs must be, but systems may be simulated – in many cases small difference to monthly calculation
- Relatively compact energy regulation as "validated simulation tool" specifies a lot (requirements 10 pp, methodology 27 pp and EPC 19 pp)
- Automated geometry input, input data generation and developed user interfaces save time (+availability of advanced models)
- Energy calculation is an integrated part of the building design and strict energy requirements started to steer the design process
- Latest developments – high performance, heat pumps, on-site generation, overheating prevention – support simulation

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Deep energy renovation in Estonia

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Deep energy renovation experience from Estonia

- KredEx renovation grants have been available for apartment buildings since 2010 so that 3 000 apartment buildings are deeply renovated and 14 000 are still to be renovated by 2050 (LTRS)
- Cost optimal energy performance level calculated with 30 years period leads to extensive renovation – housing associations need financial support to undertake such deep renovation
- 32% tax return has been reported from deep renovation projects, thus renovation grants can be budget neutral:
  Pikas et al. 2015 https://doi.org/10.1016/j.enbuild.2014.10.004

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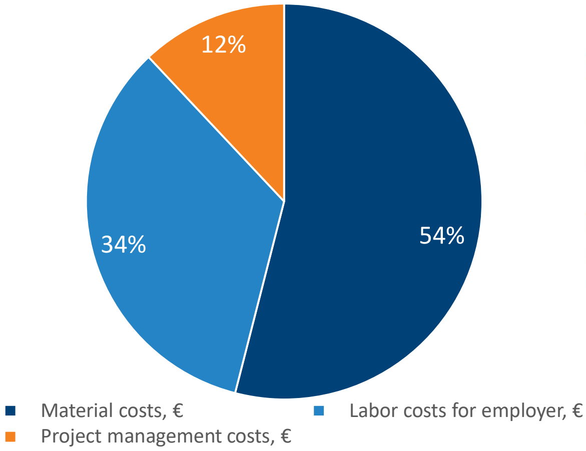
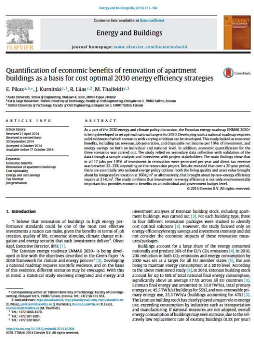
Cost structure of renovation projects





- Labor cost of 34% includes all labor cost in design, constructin and manufacturing
- Project management cost of 12% includes all costs in design and construction

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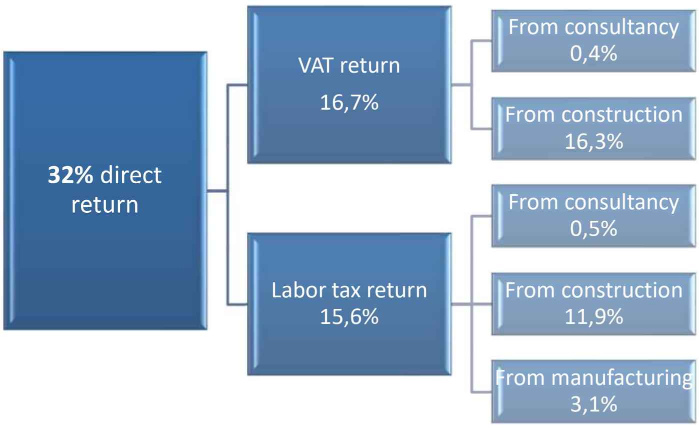
Tax return breakdown



32% tax return shows that renovation grants can be budget neutral

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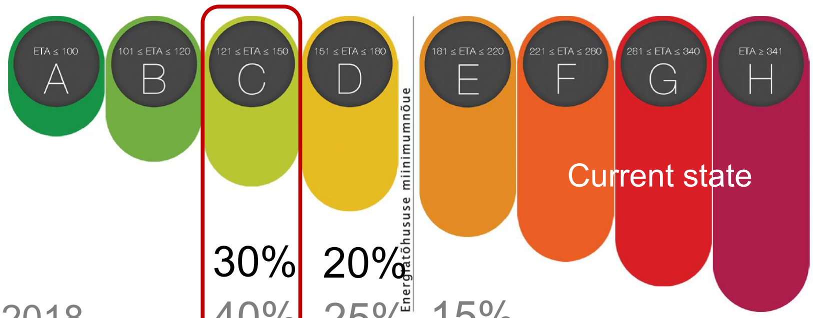
Kredex renovation grants – 30% financial support



	C	D	E
2019-	30%	20%	
2015-2018	40%	25%	15%
2010-2014	35%	25%	15%

- >80% of buildings/grant applications have targeted the maximum financial support
- 2019 onwards: C class grant split to 30% support in Tallinn and Tartu, and 40-50% in periphery
- **Since 2015 room-based ventilation rate and heat recovery requirements**
- **EPC Class C = major renovation NZEB requirement since 2020**
- **EPC Class A = new building NZEB**

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Field tested scheme, example from 2012: sõpruse pst 202, Tallinn

- 11 375 m² (162 ap. 2012-2013)
- Investment € 2 062 000, 181 €/m²
- Grant 35% € 721 600, 63 €/m²
- Credit € 1 340 000, 20 years
- Measured annual savings 63%, ~500 MWh

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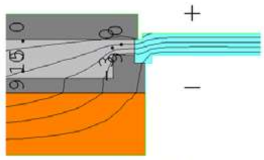
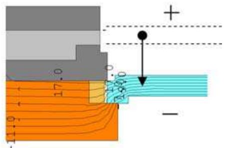
Kredex insulation requirements

U-value and thermal bridge requirements

	30% grant
External wall (opaque), W/(m²K)	**0.20**
Windows (tot value), W/(m²K)	**1.1**
Roof, W/(m²K)	**0.12**
Linear thermal bridge (window-wall) W/mK	**0.05**



f_{Rsi} =0.78; Ψ=0.35 W/(m·K)



f_{Rsi} =0.88; Ψ=0.03 W/(m·K)

In the case of 30% grant, **windows are to be replaced and moved to the insulation layer** in order to comply with thermal bridge requirement

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Kredex ventilation requirements

20% renovation grant:

- Continuous an average ventilation (for total apartment) 0.5 1/h;
- Supply or intake air flow rates to be at least **10 l/s in bedrooms and living rooms at sound power level no more than 25 dB(A)**;
- Extract air flow rates at least **10 l/s WC, 15 l/s bathroom and 8 l/s kitchen** (10 l/s in bathroom and 6 l/s in kitchen in one room flats);
- Heat recovery is NOT required (EPC class D is to be achieved)

Additional requirements for 30% renovation grant:

- **Mechanical supply and exhaust ventilation with heat recovery OR exhaust air heat pump with ventilation radiators required**
- AHU-s must have reheating coil (supply temp. 18°C) and cannot have electrical preheating coil (refers to sectoral defrosting)

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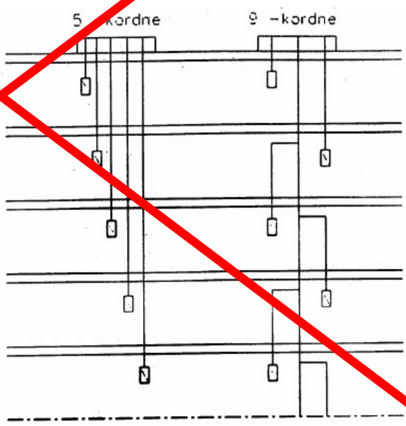
Lessons learnt: renovation grant period 2010-2014

Natural ventilation:

- Almost no air change – 0.13 h^{-1} measured in average
- Modest energy savings
- Draught problems from air intakes
- Moisture and mould problems

- Banned since 2015 in KredEx renovation grant requirements



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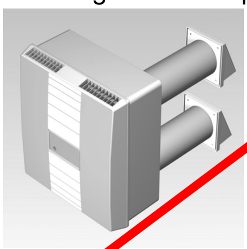
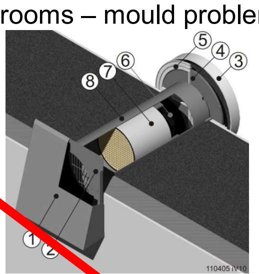
Lessons learnt: renovation grant period 2010-2014

- Almost no air change – 0.12 h^{-1} measured in average
- Noise: too low airflow rate at 30 dB(A), 2015- requirement 10 L/s & 25 dB(A)
- Frosting in in winter, dedicated frost protection too expensive for small units
- Small pressure rise – stack effect overruns in lower floors – start to work as intakes with no heat recovery – no thermal comfort if no heat recovery
- Wrong ventilation principle – do not exhaust from wet rooms – mould problems





SRVU with HR (used 2010 - 2014) are banned since 2015 in KredEx renovation grant requirements: Mikola et al. *Energies* **2019**, *12*(13), 2633; https://doi.org/10.3390/en12132633

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Sizing of ventilation in typical apartments

Ventilation air flow rates according to requirements:

	Floor	Exctract airflow rate, l/s				Supply airflow rate, l/s					Air change	
	area, m²	WC	Bathr.	Kitchen	Total	Living	Bed1	Bed2	Bed3	Total	l/s m²	1/h
Single room	35		10	6	16	10				10	0.46	0.63
1 bedroom	55		15	8	23	10	10			**20**	0.42	0.58
2 bedrooms	70	10	15	8	33	10	10	10		**30**	0.47	0.65
3 bedrooms	80	10	15	8	**33**	10	10	10	10	40	0.50	0.69

To balance the ventilation, supply airflow rates are increased in small apartments and extract airflow rates in large apartments:

	Floor	Exctract airflow rate, l/s				Supply airflow rate, l/s					Air change	
	area, m²	WC	Bathr.	Kitchen	Total	Living	Bed1	Bed2	Bed3	Total	l/s m²	1/h
Single room	35		10	6	16	**16**				16	0.46	0.63
1 bedroom	55		15	8	23	**11**	**12**			23	0.42	0.58
2 bedrooms	70	10	15	8	33	10	**12**	**11**		33	0.47	0.65
3 bedrooms	80	**12**	**16**	**12**	40	10	10	10	10	40	0.50	0.69

- Airflow rate measurement protocols are required
- If extract airflows are not met, 0.5 1/h air change rate it is accepted in up to 20% of apartments

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Estonian innovation 2015: enables cost effective heat recovery ventilation – ventilation problems solved

Estonia, KredEx –
A Deep Renovation model for Europe

Estonia has achieved great results in deep renovation, thanks to the KredEx renovation grant system. Backed by the EU since its 2010 kick-off, KredEX features strict technical requirements, focusing on high-level energy efficiency and indoor climate conditions.

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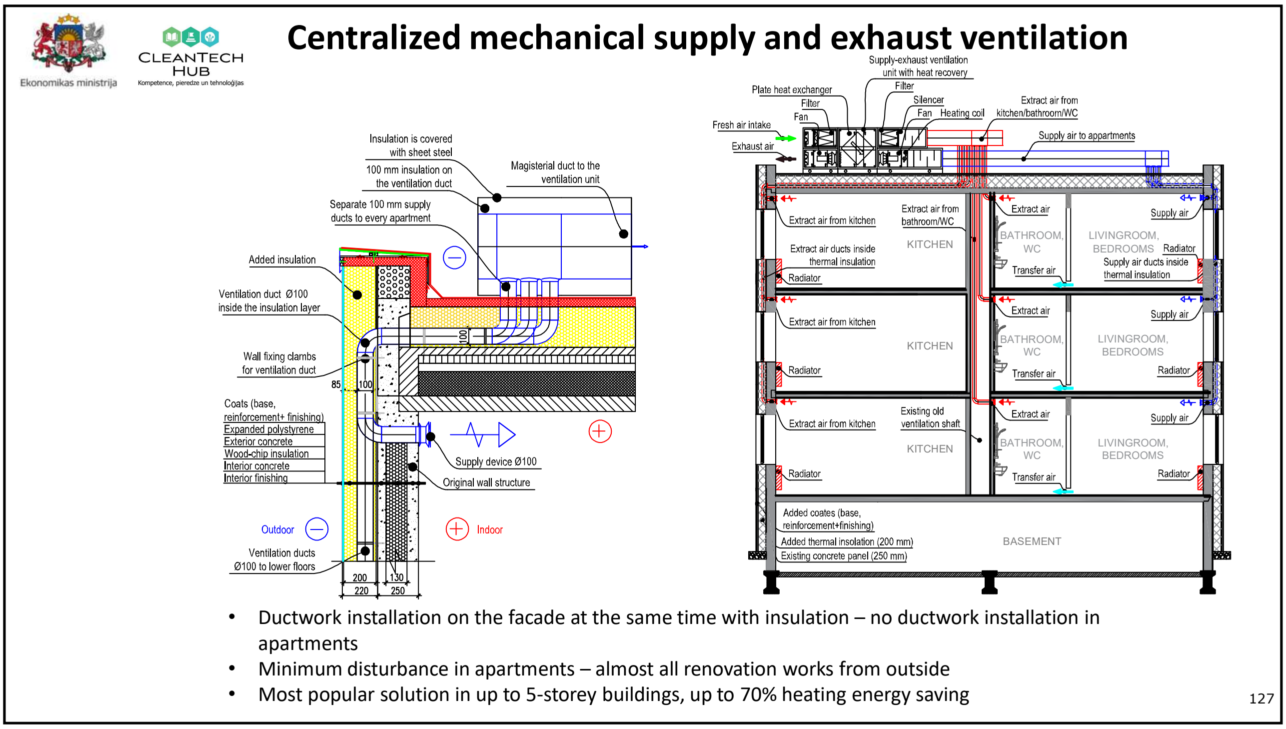
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Centralized mechanical supply and exhaust ventilation
Supply-exhaust ventilation unit with heat recovery
Plate heat exchanger
Fresh air intake
Exhaust air
Extract air from kitchen/bathroom/WC
Supply air to appartments
KITCHEN
BATHROOM, WC
LIVINGROOM, BEDROOMS
BASEMENT
Outdoor
Indoor
Added insulation
Supply device Ø100
Original wall structure
Ventilation ducts Ø100 to lower floors
• Ductwork installation on the facade at the same time with insulation – no ductwork installation in apartments
• Minimum disturbance in apartments – almost all renovation works from outside
• Most popular solution in up to 5-storey buildings, up to 70% heating energy saving
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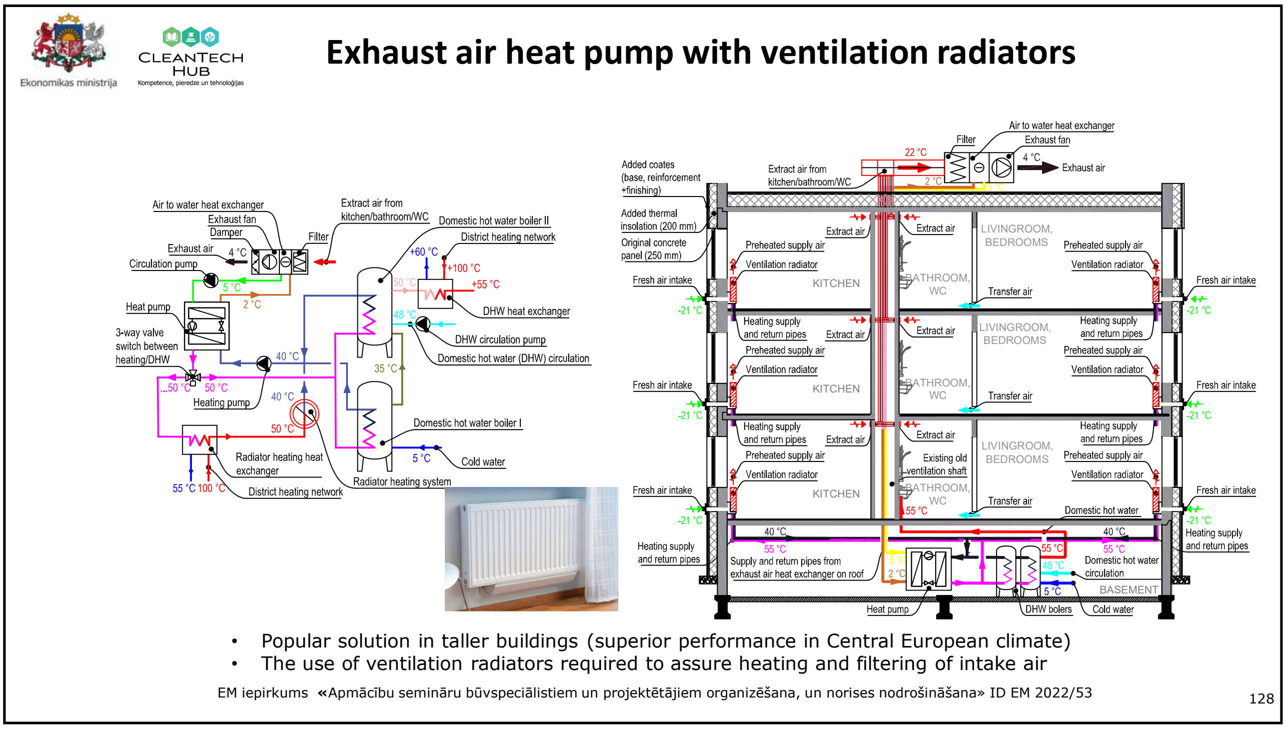
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Exhaust air heat pump with ventilation radiators
Air to water heat exchanger
Heat pump
District heating network
Domestic hot water boiler
Radiator heating system
KITCHEN
BATHROOM, WC
LIVINGROOM, BEDROOMS
BASEMENT
Fresh air intake
Ventilation radiator
Preheated supply air
• Popular solution in taller buildings (superior performance in Central European climate)
• The use of ventilation radiators required to assure heating and filtering of intake air
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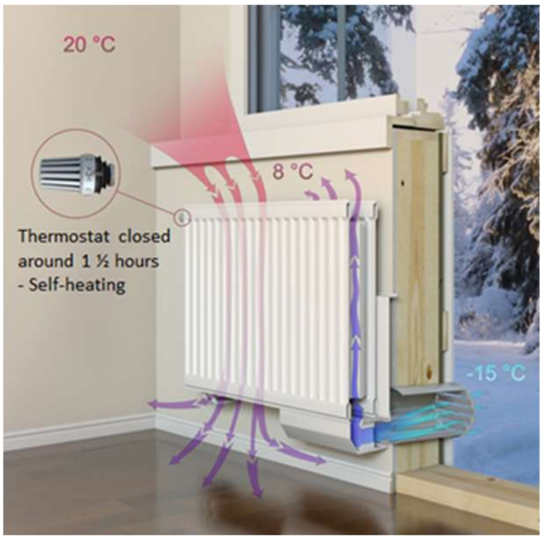
Ventilation radiators are not sensitive to freezing, but have a self-heating performance with closed thermostats



With closed thermostats ventilation radiator induces room air driven heating of intake air

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Typical energy savings

Before renovation	Electricity, kWh/(m²a)	Heating energy, kWh/(m²a)
Heating system		
Space heating		114
DHW heating		63
Auxiliary electricity	0.5	
Lighting	7	
Appliances	22.5	
Delivered energy	30	177
Primary energy, kWh/(m²a)	175	

After renovation	Electricity, kWh/(m²a)	Heating energy, kWh/(m²a)
Heating system		
Space heating		22
Supply air heating		12
DHW heating		33
Auxiliary electricity	0.5	
Ventilation system	7.9	
Lighting	7.0	
Appliances	22.5	
Delivered energy	38	67
Primary energy, kWh/(m²a)	119	

Renovation technical solutions:

- Insulation of external walls (200 mm, λ-0.036 W/(mK)), U-0.15 W/(m²K);
- Insulation of roof (300 mm, λ-0.036 W/(mK)), U-0.10 W/(m²K);
- Installing new triple-glazed windows, U-1.10 W/(m²K);
- Installing a new two-pipe heating system with thermostats;
- Installing a new supply-exhaust mechanical ventilation system with heat recovery;
- Heat recovery temperature ratio 80% and air handling unit SFP – 1.8 kW/(m³/s).

- Heating reduction by 62%
- PV installation would allow to reduce electricity use – popular (but not required) in renovation projects

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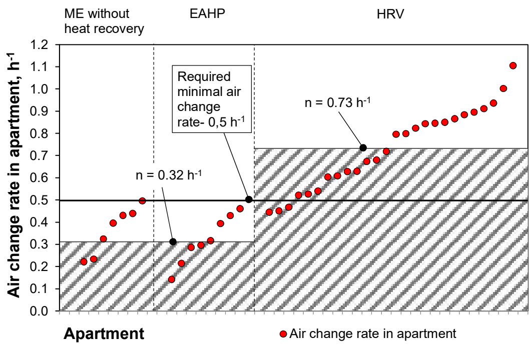
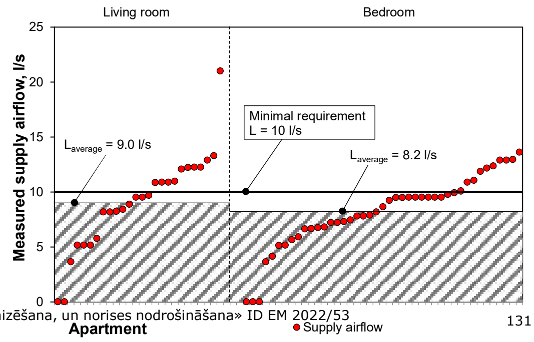
Ventilation in operation 2015-2017

- Measurement protocols: when handed over, the requirements were met
- **Measured in operation, average of all apartments 0,57 h⁻¹**
- According to ventilation system:
  - **Heat recovery mechanical supply and extract (HRV) 0,73 h⁻¹**
  - Exhaust air heat pump (EAHP) 0,32 h⁻¹
  - Mechanical exhaust (ME) 0,32 h⁻¹
- Supply and extract air flows in the rooms in adequate level:
  - Living rooms 9 L/s
  - Bedrooms 8 L/s
  - Bathrooms and toilets 11 L/s
  - Average per person 6 L/s, pers

→ **First time in the history** (in large scale in the world) renovated apartments have an adequate ventilation!





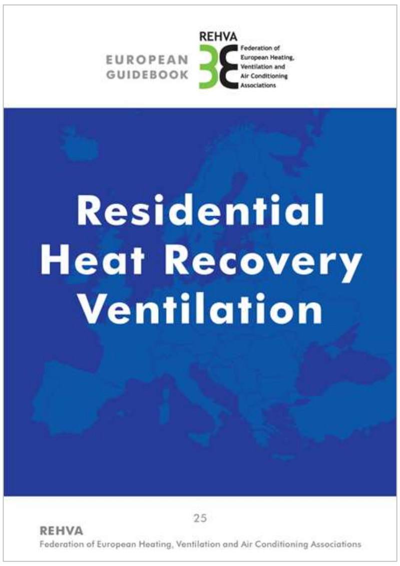
https://doi.org/10.1016/j.buildenv.2021.108698

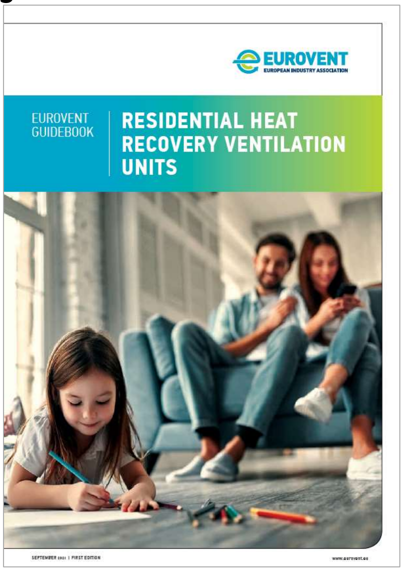
Main steps in the Kredex grant application process

- Housing association decision – simple majority 50% +1 in general assembly meeting
- Qualified technical consultant required – steering the preparation
- Energy audit/EPC of the building and investigations (stacks etc.)
- **Detailed technical design: full set of building design documents (including calculated EPC for compliance approval)**
- Building permit applied/issued
- Credit decision from bank issued
- **Grant application to KredEx:**
  - Investigation of design documents by third party experts (KredEx)
  - Revision of design documentation if needed (applicant)
  - Funding decision by KredEx if all requirements met
- Tendering with contractors
- Construction (KredEx has special supervision rights)
- Commissioning **protocols for ventilation rates** and heating system
- **Grant payment by KredEx after handing over**
- EPC based on measured use after one year operation

Solving ventilation has been a key of successful renovation of residential buildings

See NZEB renovation concepts comparison (Estonia-Germany-Italy): Kuusk et al. 2020 https://doi.org/10.1051/e3sconf/202017218009





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SUMMARY of Estonian renovation grants

- Lessons learnt 2010-2014 period – poor ventilation sometimes resulting in moldy apartments the most significant problem
- 2015-2018 grants required HRV ventilation, and moving windows to insulation level in the case of 40% grant as major changes
- Both changes were first seen as „fully impossible" by stakeholders, but after 6 months economic solutions were found
- Model renovation solutions – KredEx renovation manual is prepared – designers can copy and customize
- The same practice has followed from 2019 onwards by splitting 40% grant to 30-40-50% depending on the location

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Thank you for attention!

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