INSULAtE - project 2010-2015

Focused on assessment of impacts of improved energy efficiency on IEQ and health

- **Possible improvements: adding thermal insulation, replacing old windows with energy efficient windows, updating heating, ventilation, and air conditioning (HVAC) systems**

NATIONAL INSTITUTE FOR HEALTH AND WELFARE

TAMPERE UNIVERSITY OF TECHNOLOGY

KAUNAS UNIVERSITY OF TECHNOLOGY

Ulla Haverinen-Shaughnessy, D. Sc. Tech. ulla.haverinen@thl.fi; haverinenshaughnessy@utulsa.edu; ulla@720.fi

INSULAtE

Indoor Environmental Quality (IEQ) attributes	Associated health effects
Thermal conditions (T, RH)	Comfort Performance/productivity
Air exchange, ventilation	Performance/productivity Spread of communicable diseases
Indoor air quality - Particles, fibres - Chemical and microbiological pollutants	Respiratory health Allergies, asthma
Radon	Cancer
Acoustics (noise)	Sleep quality Cardiovascular health

Energy improvements can affect all IEQ attributes

Effects can be positive and/or negative

Improved IEQ can benefit health

Objectives

- Develop and test a comprehensive assessment protocol
- Demonstrate the effects of improving EE on IEQ and health
  - –Assessments performed both before and after energy retrofits

An example of a Finnish multi-family building a) before and b) after retrofit
Pictures: Virpo Leivo, Tampere University of Technology, Finland

Case study buildings

- 46 multifamily buildings from Finland and 20 from Lithuania
  - In each building, a sample of three to eleven apartments was selected for IEQ assessment
  - Some of the buildings were control buildings, i.e. not retrofitted during the project
- Additional case studies
  - 13 singe-family homes
  - Multifamily buildings from UK, Latvia, and Estonia
  - School studies

Methodology

Thermal conditions

- Long-term monitoring of T/RH (2 - 12 mo), 1-hr sampling interval
- Wall-surface temperatures with thermo-imaging or surface thermometer

Indoor air quality

- 24h monitoring of CO, CO_2, and PM
- 7-day passive sampling VOC, CH_2O and NO_2
- 1- or 2-mo passive sampling for radon

Methodology

Microbial concentrations and fibers in settled dust

- Dust collection time 2 months
- Samples analyzed using microscopy and qPCR techniques

Information from the occupants

- Collected using health questionnaires and diaries
- Illnesses, health symptoms, comfort
- Time consumption, activities

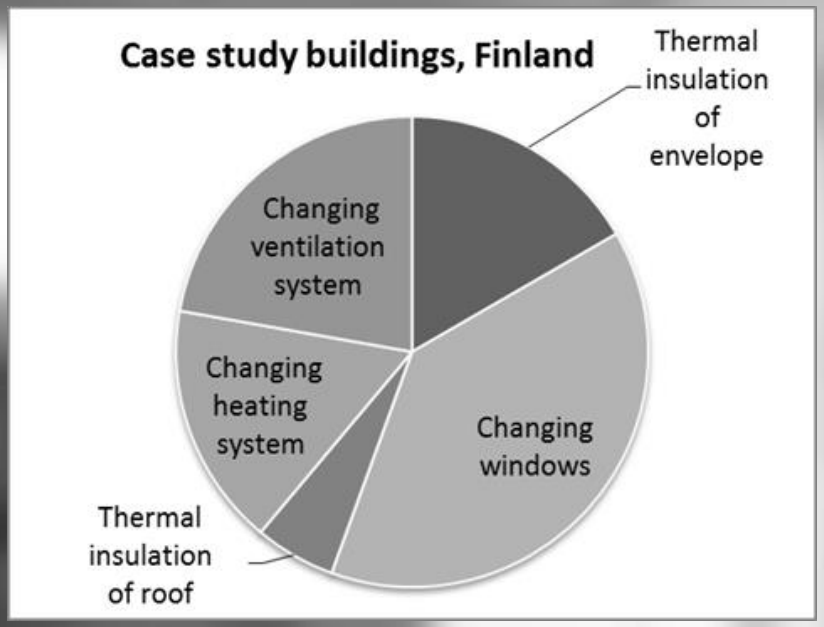
Read more

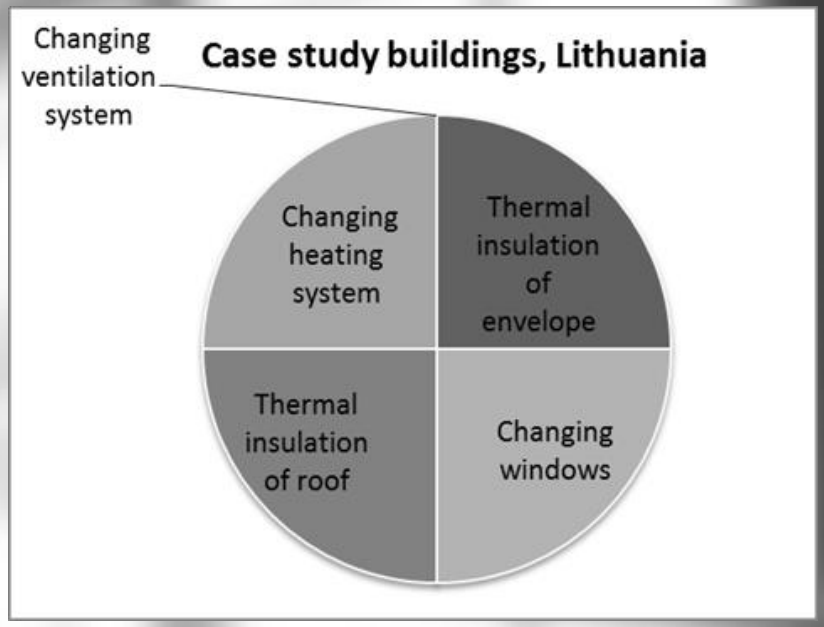
- Du L, Leivo V, Martuzevicius M, Prasauskas P, Turunen M, Haverinen-Shaughnessy U. INSULAtE-project results. National Institute for health and Welfare. Report 17/2016 (288p)
- Turunen M, Leivo V, Martuzevicius D, Prasauskas T, Kiviste M, Aaltonen A, Du L, Haverinen-Shaughnessy U. Improving energy efficiency of multi-family buildings, impacts on indoor environmen-tal quality and health. Data brief 2016. National Institute for Health and Welfare, Helsinki (8p)

Building characteristics

	Year of construction					Flats	Area	Ventilation type	
	-1960	1960-1970	1971-1980	1981-1990	1991-	N	m^2	Nat	Mech
Finland									
Control	0	1	4	0	1	30	78	0	10
FER	2	11	13	4	0	147	64	4	147
DER	3	1	3	0	0	23	56	11	12
Lithuania									
Control	0	0	1	1	3	24	58	11	12
FER	1	1	0	0	0	9	77	9	0
DER	1	4	3	5	0	57	58	31	30

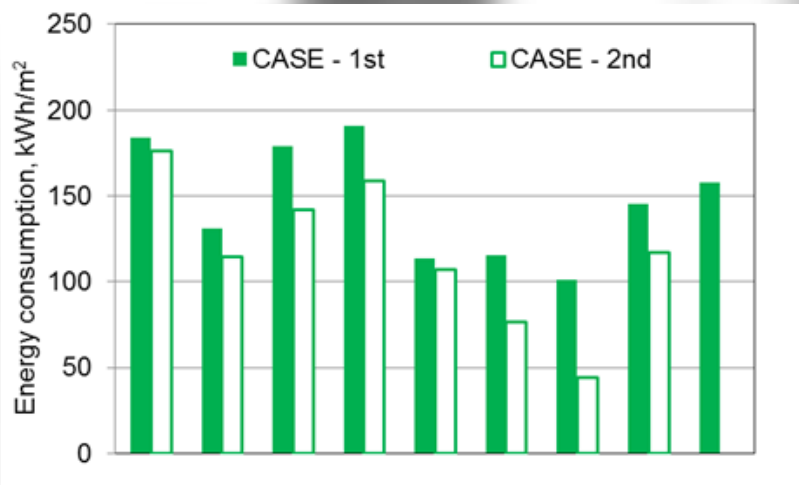
Retrofits


Case study buildings, Finland
Thermal insulation of envelope
Changing ventilation system
Changing heating system
Changing windows
Thermal insulation of roof


Changing ventilation system
Case study buildings, Lithuania
Changing heating system
Thermal insulation of envelope
Thermal insulation of roof
Changing windows

Energy consumption

In Finland, an average of 21 % reduction in the heating energy consumption after retrofits



In Lithuania, 30-60 % reduction in buildings with district heating.

- **Highest reductions in 2 buildings that added solar panels**

About 40% reduction in buildings with individual space heating system (gas boiler)

An average of 10% reduction in partially retrofitted buildings

Thermal conditions

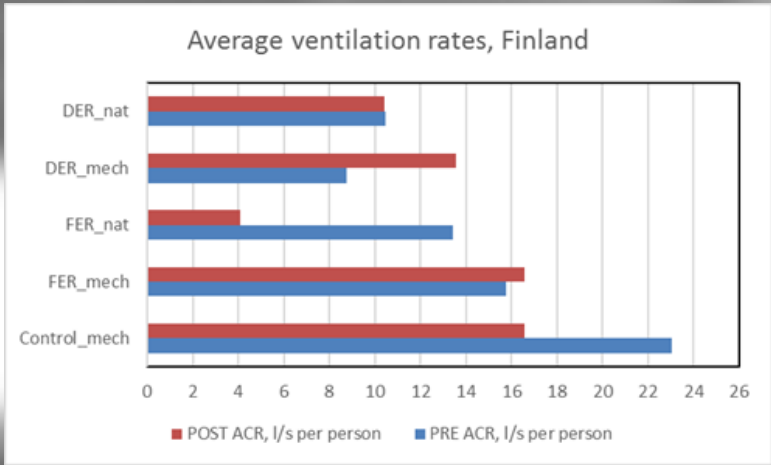
- **Over heating was common in Finnish buildings both before & after retrofits**
- **Indoor temperatures often below recommended (<20 oC) in Lithuania**

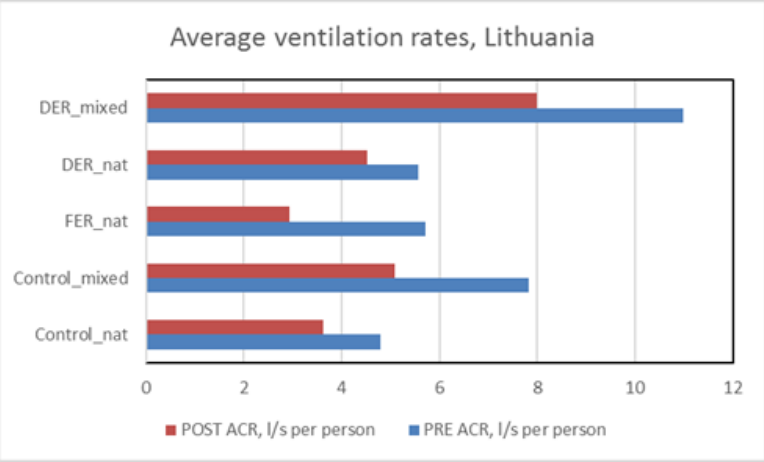
Linear mixed model for average indoor T in warm area during 2-month monitoring.

	All		Finland		Lithuania	
Parameter	Estimate	Sig.	Estimate	Sig.	Estimate	Sig.
Country						
Finland	**2.76**	***				
Lithuania	0[b]					
Retrofit status						
Control; 2nd measurement	.18		-.03		1.08	†
Case; 2nd measurement	.02		**-.19**	*	**.57**	**
Control; 1st measurement	.31		.35		.37	
Case; 1st measurement	0[b]		0[b]		0[b]	
Outdoor T	.08	***	.07	***	0.05	†

[b] Reference group.
*p<0.05 **p<0.01 ***p<0.001 †p<0.1

Ventilation





- In Finnish case buildings with mechanical exhaust, ventilation rates (l/s per person) were significantly higher after the retrofits
- In Lithuanian case buildings, ventilation rates were significantly lower after the retrofits

Indoor air quality

	Finland				Lithuania			
	Case		Control		Case		Control	
	1st (N)	2nd (N)[1]	1st (N)	2nd (N)	1st (N)	2nd (N)[1]	1st (N)	2nd (N)
PM_{10}, µg/m³	15 (157)	12* (107)	12(18)	10 (13)	19 (71)	25* (55)	18 (22)	18 (8)
Total fungi, cells/m³	**477 (81)**	**97* (56)**	148 (11)	138* (10)	2147 (69)	1960* (51)	3712 (22)	11706 (5)
Grampos, cells/m³	**6498 (81)**	**1363* (56)**	6727 (11)	1569* (10)	21288 (69)	31868* (51)	42436 (22)	156662 (5)
CH_2O, µg/m³	18 (140)	16* (103)	16 (16)	14 (13)	24 (71)	28*(57)	17 (24)	33* (8)
BTEX[2], µg/m³	**7(134)**	**9* (102)**	5(16)	7 (13)	16 (71)	19 (55)	7 (24)	8 (8)
Radon, Bq/m³	60(132)	50 (88)	40 (13)	40 (12)	**28 (33)**	**38* (31)**	14 (12)	18(4)

[1]After retrofits; N corresponds with the number of observations [2]Volatile organic compounds represented by benzene, toluene, ethylbenzene and xylenes

**indicates that there is a statistically significant difference between 1st and 2nd assessment ($p < 0.05$)*

Indicates that the statistically significant change held when adjusting for outdoor T and type of ventilation

Housing satisfaction and health[1]

	Suitable indoor T in winter	Satisfied with IAQ	No upper respiratory symptoms	Did not miss school / work
	OR (95%CI)	OR (95%CI)	OR (95% CI)	OR (95% CI)
Mechanical ventilation	1.0 (0.3-4.0)	0.6 (0.2-2.3)	1.3 (0.5-3.6)	1.4 (0.3-5.9)
Natural ventilation	1.0	1.0	1.0	1.0
Country				
Finland	1.1 (0.2-5.9)	**4.5 (1.1-18.5)**	**0.3 (0.1-0.9)**	0.7 (0.1-3.4)
Lithuania	1.0	1.0	1.0	1.0
Case status				
Control post	0.3 (0.1-1.3)	**6.0 (1.0-34.9)**	1.8 (0.3-9.3)	0.7 (0.1-9.8)
Control pre	0.6 (0.2-1.8)	**2.9 (1.2-7.1)**	0.9 (0.3-2.5)	0.7 (0.2-2.2)
Case post	**5.3 (2.6-11.0)**	**2.0 (1.2-3.4)**	**1.8 (1.1-2.9)**	**4.1 (1.2-13.8)**
Case pre	1.0	1.0	1.0	1.0
Tout [°C]	**0.9 (0.8-0.9)**	1.0 (0.9-1.0)	1.0 (0.9-1.1)	1.0 (0.9-1.1)
Tw [°C]	**1.4 (1.1-2.0)**	-	-	-
Thermal index	**1.1 (1.0-1.2)**	-	-	-
Air change rate [1/h]	**5.6 (1.0-31.2)**	-	-	-
Pressure difference, against staircase [Pa]	-	**1.1 (1.0-1.1)**	-	-

[1] Based on GEE models, adjusted for gender, age, smoking, pets, and tenure status

Conclusions

- After energy retrofits
  - Heating energy consumption decreased by 10-60 %
  - Indoor T increased in Lithuanian buildings
  - Ventilation rates increased in Finnish; decreased in Lithuanian buildings
  - Reductions in microbial concentrations could be attributed to retrofit status in Finnish buildings, whereas there was a significant increase in BTEX concentrations
  - In Lithuanian buildings, radon concentrations were significantly increased after retrofits
  - Thermal comfort and occupants' satisfaction with IAQ increased
  - Respiratory symptoms and missed work / school due to respiratory infections decreased
- Assessment of thermal conditions and ventilation, and adjusting heating and ventilation systems accordingly, should help to maximize positive effects of energy retrofits
- Potential to improve occupant health and productivity

Acknowledgements

- INSULAtE-project team
- Steering Board
  - Prof. Aino Nevalainen (THL), and Ralf Lindberg (TUT), Mr. Matthias Braubach (WHO), Prof. Derrick Grump (Cranfield University), Ms. Simona Iržikevičiūtė (HUDA), Ms. Kati Takala (Finnish Energy Industries), Mr. Pellervo Matilainen (Skanska), Mr. Hannu Kyckling (Saint Gobain)
- Building owners and occupants
- EU LIFE+ programme and Finnish Energy Industries

Other collaboration