Evaluating building-level parameters for lower temperature heating readiness

A sampling-based approach to address the heterogeneity of Dutch housing stock

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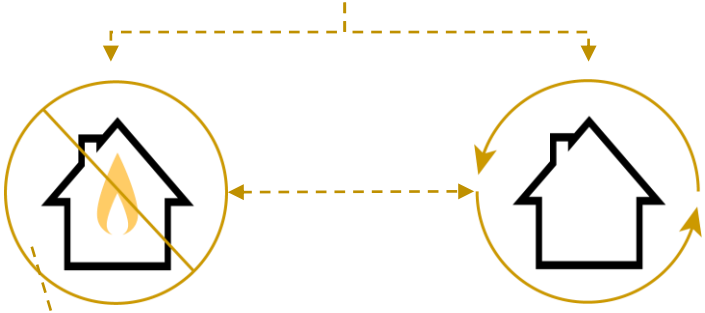
Cover: Image generated using Dall.E

Climate Agreement Goals : 2030

Decarbonising the built environment by transition towards sustainable source of heating



Making **1.5 million** homes gas free

Transformation rate of **200,000** homes / year

District heating with lower temperature supply

Energy Renovations for integrating lower temperature supply

IEBB

Integrated Approaches for the Energy Transition in the Existing Buildings.

Project 1.5 : Collective Warmte

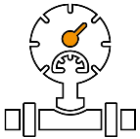
Develop methods to connect homes to medium-temperature heat networks cost-effectively.

Partners

TNO innovation for life · Eneco · VATTENFALL · ennatuurlijk · Stadsverwarming Purmerend · hvc energie en hergebruik · ARCADIS · Gemeente Almere

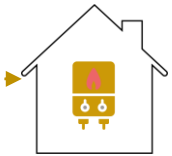
Source: CBS, 2022; Dutch Ministry of Economic Affairs and Climate, 2019; EUKN Secretariat, 2018,2019; IEA,2020

Energy renovations are often needed for a comfortably heated home



Lower temperature district heating Supply temperature ≤ 70℃

Space Heating Demands



Hot Water Preparation

How do you select appropriate strategies for preparing a home for LTH?

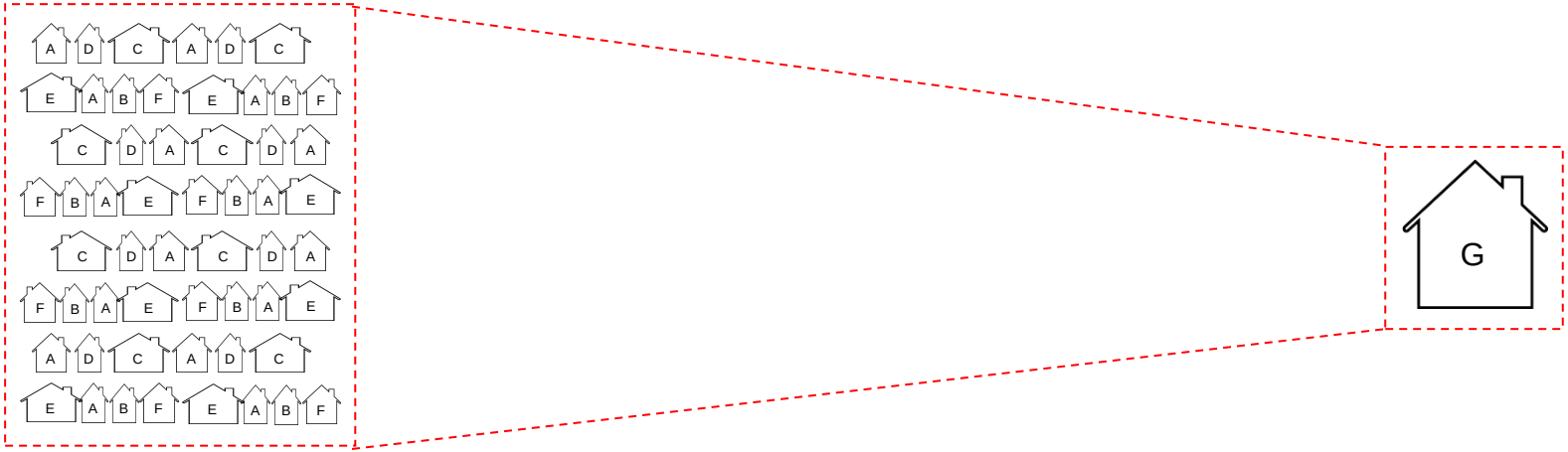
Challenge 1 :
Lack of lower temperature ready definition.

Challenge 2:
Various renovation options: Decision paralysis

Challenge 3:
Diverse dwelling require tailor-made solutions

Challenge 4:
Informational barrier due to lack of decision-support insights in the context of LTH

Wahi, P., Konstantinou, T., Tenpierik, M. J., & Visscher, H.. (2023). Lower temperature heating integration in the residential building stock: A review of decision-making parameters for lower-temperature-ready energy renovations. Journal of Building Engineering. https://doi.org/10.1016/j.jobe.2022.105811



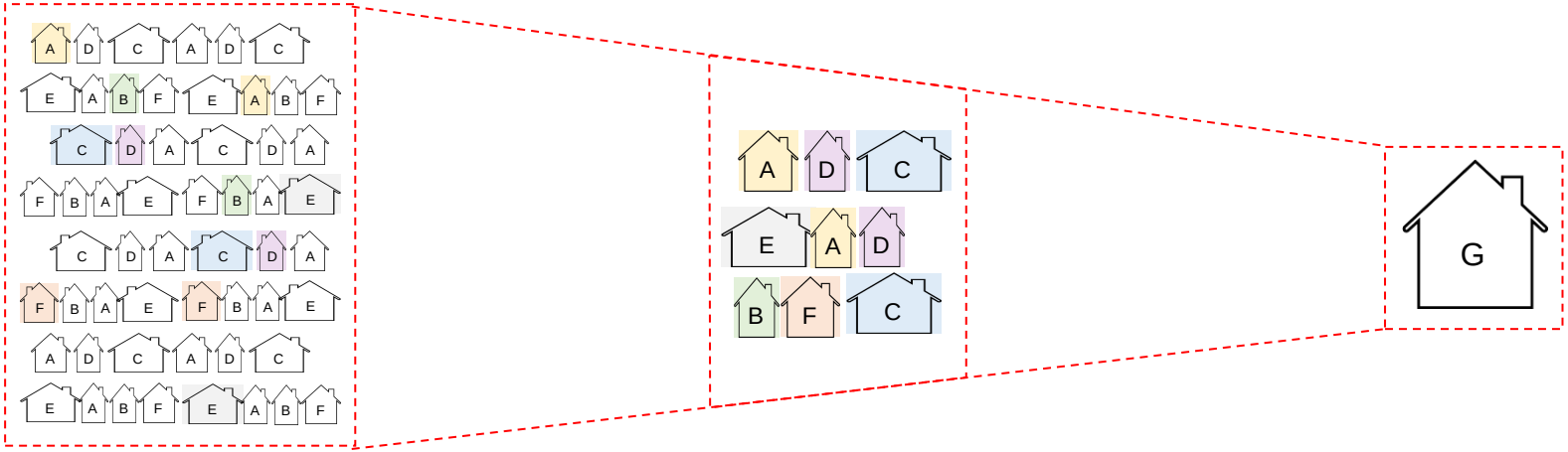
Dwelling stock is heterogeneous, thus varying the renovation requirements.

Building by building measurement and analysis ideal solution but cost and time intensive.

Archetype-Based analysis,

- good for policy level,
- but introduce uncertainties due to averaging of variations

Limited insights for stakeholders who manages diverse portfolios on which dwellings are ready, which needs renovations and what should be prioritised.



Dwelling stock is heterogeneous, thus varying the renovation requirements.

A possible solution is sampling based approach, but it has not been applied in the context of LTH readiness in the Netherlands.

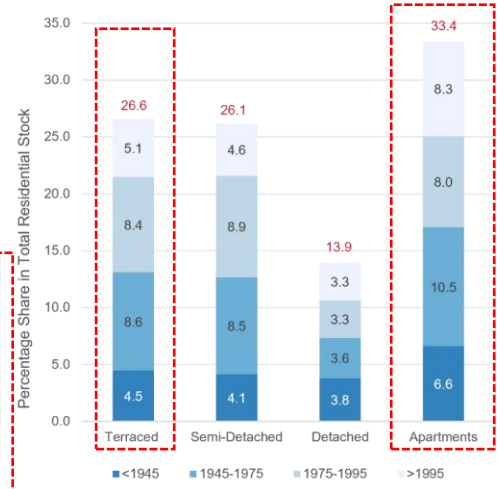
Traditionally there are archetype-based analysis,

- good for policy level,
- but introduce uncertainties due to averaging of variations

Objective:
To assess the LTH readiness of different dwelling types, while accounting for their inherent variations.

Methodological steps:
Determining the appropriate sample size that represent the variations within a dwelling type.

Identify the significance of building level parameters in assessing the readiness of a dwelling type for LTH



Covering 60% of the dwelling stock.

Category	Input Parameter	Units
Geometrical	Orientation	°
	Compactness-Ratio	-
	Window-to-Wall Ratio	-
	Position of Apartment*	-
Fabric	Ground Insulation	m^2 K/W
	External Wall Insulation	m^2 K/W
	Roof Insulation	m^2 K/W
	Glazing Insulation	W/m^2 K
	External Door Insulation	W/m^2 K
	Infiltration	$dm^3/s.m^2$
HVAC	Ventilation system	-
	Heating Capacity	W
Occupant and Control	Heating setpoint	°C

*Only for apartment typology

Define Interest Parameters

Parameters that :

- Characterises a dwelling
- Affects the LTH readiness

Wahi, P., Konstantinou, T., Tenpierik, M. J., & Visscher, H.. (2023). Lower temperature heating integration in the residential building stock: A review of decision-making parameters for lower-temperature-ready energy renovations. Journal of Building Engineering. https://doi.org/10.1016/j.jobe.2022.105811

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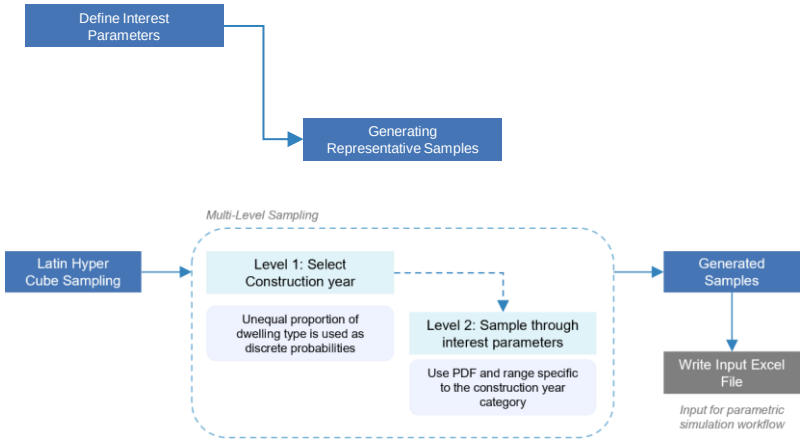

Category	Input Parameter	Units
Geometrical	Orientation	°
	Compactness-Ratio	-
	Window-to-Wall Ratio	-
	Position of Apartment*	-
Fabric	Ground Insulation	$m^2 \cdot K/W$
	External Wall Insulation	$m^2 \cdot K/W$
	Roof Insulation	$m^2 \cdot K/W$
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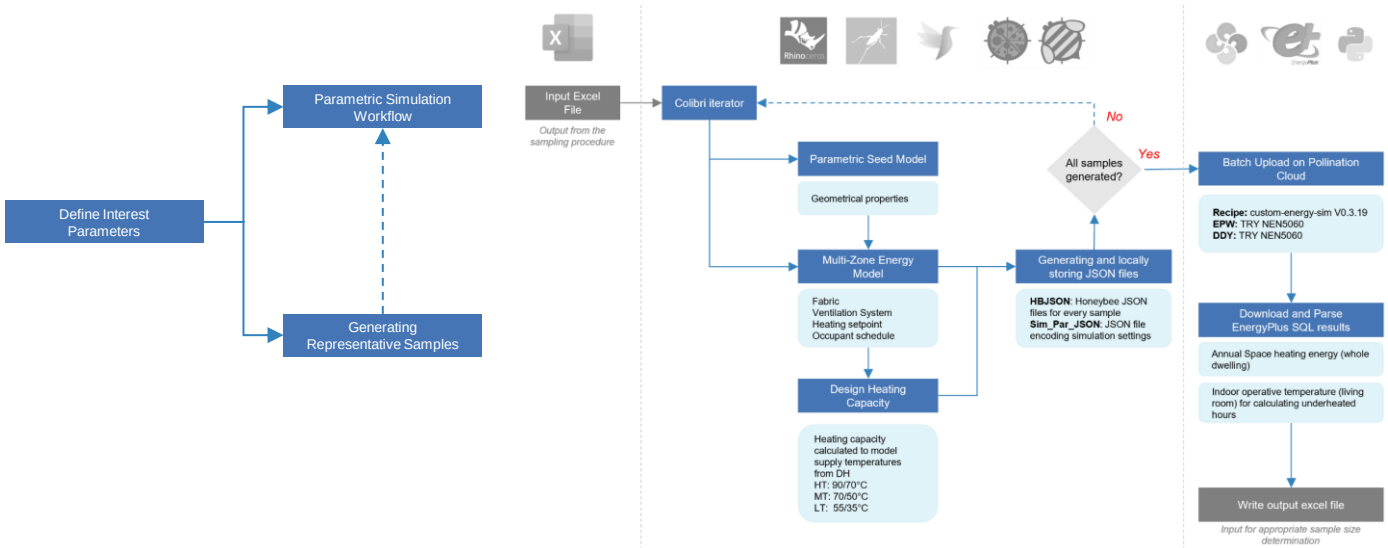
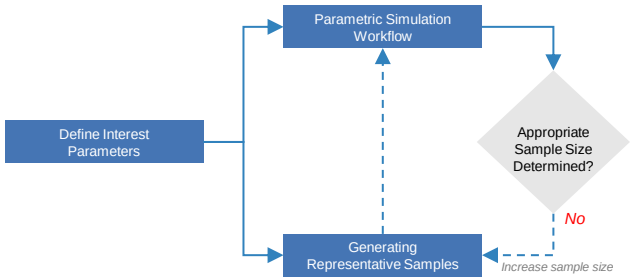
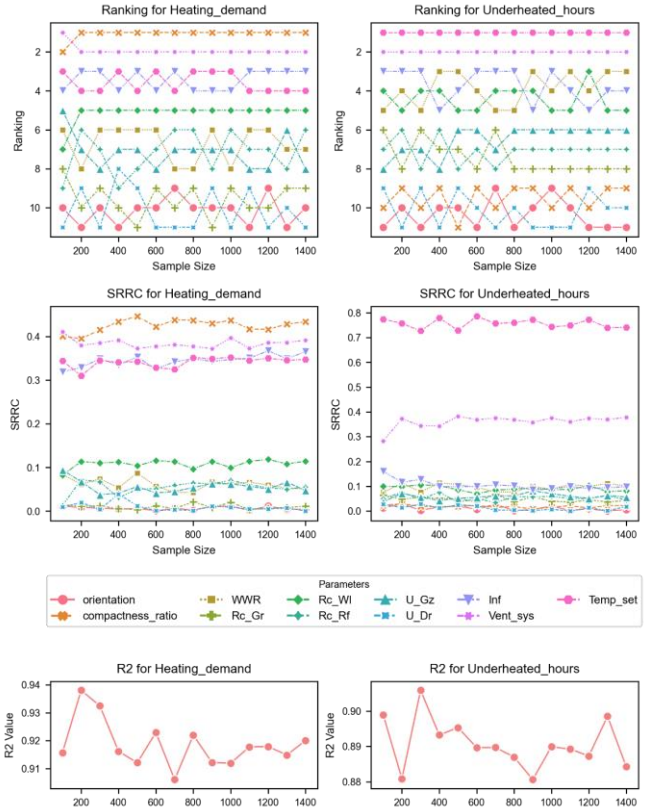
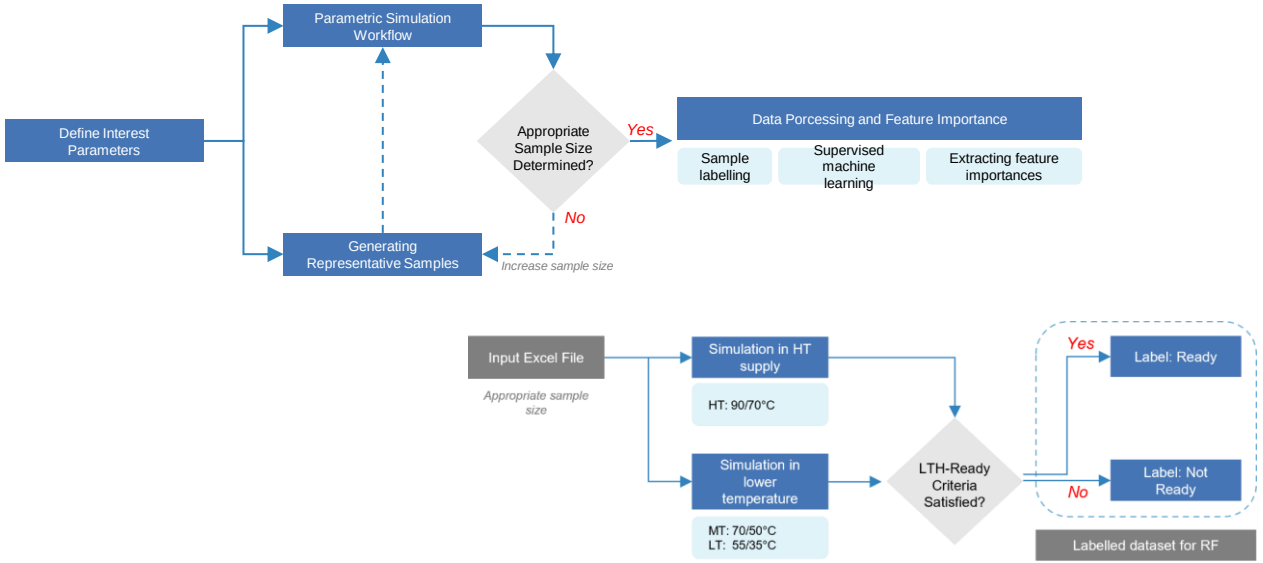


Output :
Annual space heating demand
occupied underheated hours


Define Interest Parameters
Parametric Simulation Workflow
Appropriate Sample Size Determined?
No
Generating Representative Samples
Increase sample size


Ranking for Heating_demand
Ranking for Underheated_hours
Ranking
Sample Size
SRRC for Heating_demand
SRRC for Underheated_hours
SRRC
Parameters
orientation
compactness_ratio
WWR
Rc_Gr
Rc_Wl
Rc_Rf
U_Gz
U_Dr
Inf
Vent_sys
Temp_set
R2 for Heating_demand
R2 for Underheated_hours
R2 Value


Parametric Simulation Workflow
Define Interest Parameters
Appropriate Sample Size Determined?
Yes
Data Porcessing and Feature Importance
Sample labelling
Supervised machine learning
Extracting feature importances
No
Generating Representative Samples
Increase sample size
Input Excel File
Appropriate sample size
Simulation in HT supply
HT: 90/70°C
Simulation in lower temperature
MT: 70/50°C
LT: 55/35°C
LTH-Ready Criteria Satisfied?
Yes
Label: Ready
No
Label: Not Ready
Labelled dataset for RF

Determining the appropriate sample size that represent the variations within a dwelling type.

- A sample size of 1300 was found to represent the variations that can exists in dwelling types.

Identify the significance of building level parameters in assessing the readiness of a dwelling type for LTH

- Heating setpoint has the highest influence (occupancy related parameter)

Rank	Terraced Intermediate		Apartments	
	MT	LT	MT	LT
1	Heating Setpoint	Heating Setpoint	Infiltration	Heating Setpoint
2	Ventilation System	Ventilation System	Compactness-Ratio	Infiltration
3	Roof Insulation	Roof Insulation	Heating Setpoint	Roof Insulation
4	Glazing Insulation	Infiltration	External Wall Insulation	Compactness-Ratio
5	Infiltration	Glazing Insulation	Glazing Insulation	Ventilation System
6	Orientation	Orientation	Roof Insulation	Glazing Insulation
7	External Wall Insulation	External Wall Insulation	Ground Insulation	External Wall Insulation
8	Compactness-Ratio	External Door Insulation	External Door Insulation	Ground Insulation
9	Ground Insulation	Ground Insulation	Ventilation System	External Door Insulation
10	External Door Insulation	Compactness-Ratio	Orientation	Orientation
11	Window-to-Wall Ratio	Window-to-Wall Ratio	Window-to-Wall Ratio	Window-to-Wall Ratio

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5	Infiltration	Glazing Insulation	Glazing Insulation	Ventilation System
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- Geometry : window to wall ratio has least significance

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- The individual feature importances must be consulted when investigating a particular dwelling type for a specifc supply temperatrue.

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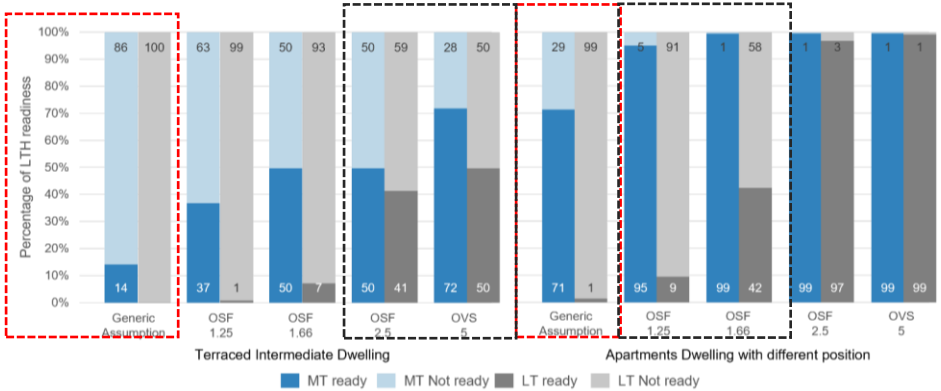

- For MT supply : 14% terraced and 70% apartments
- For LT : none are LT ready

- Radiator oversizing also has significant influence on LTH readiness.

- For Terraced-Intermediate : Radiator oversizing factor 2.5-5
- For apartments : Radiator oversizing factor 1.25-1.6

Terraced house archetype built between 1945-1975.

Supply Temperature	Annual space heating energy [kWh/m2]	Occupied underheated hours
HT supply (90/70)	163	1630
MT supply (70/50)	**130**	**2123 (+30%)**

Rank	Terraced Intermediate
	MT
0*	Radiator capacity
1	Heating Setpoint
2	Ventilation System
3	Roof Insulation
4	Glazing Insulation
5	Infiltration
6	Orientation
7	External Wall Insulation
8	Compactness-Ratio
9	Ground Insulation
10	External Door Insulation
11	Window-to-Wall Ratio

Scenario	Strategy	Measure
Basic	Increasing heating capacity	Existing HT Radiators[1], Radiators with extra convectors
	Reducing setpoint temperature	20[1], 19 [°C]
Moderate	Improving ventilation system	System A: Natural Ventilation[1], System C: Mechanical exhaust ventilation
	Cavity wall insulation *(U)* + infiltration rate	1.19[1], 0.63, 0.56, 0.48 [W/m²K]
	Improving window insulation *(U)* + infiltration rate	2.73[1], 1.6, 1.5, 1.2 [W/m²K]
	Infiltration rate due to improvement in envelope	3[1], 2 [dm³/s.m²]
	Basic + Moderate combinations	-
Deep	Replacing existing radiators	Radiators with extra convectors
	Reducing setpoint temperature	20[1], 19 [°C]
	Replacing ventilation system	System D: Balanced mechanical ventilation with heat recovery (MVHR)
	Airtight envelope	0.4 dm³/s.m²
	External Wall insulation *(U)*	0.26, 0.21, 0.17 [W/m²K]
	Replacing windows *(U)*	1 [W/m²K]
	Internal roof insulation *(U)*	0.27, 0.15, 0.14 [W/m²K]
	Underneath ground floor insulation *(U)*	0.48, 0.27, 0.24 [W/m²K]
	Replacing external door *(U)*	1.4 [W/m²K]

[1] *Existing condition of the dwelling.*

Basic	Moderate	Deep	Total
3	124	54	**182**

The dwelling needs renovations before being connected to MT supply

Helpful in developing targeted solutions for making dwelling LTH ready

LinkedIn

Research Paper

Prateek Wahi

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Cover: Image generated using Dall.E

DE CONTINGENTENAANPAK
CONTINGENTEN AS A BASIS FOR STANDADIZATION AND UPSCALING

UEI/IEBB SYMPOSIUM

NOVEMBER 2024

PUBLICATION

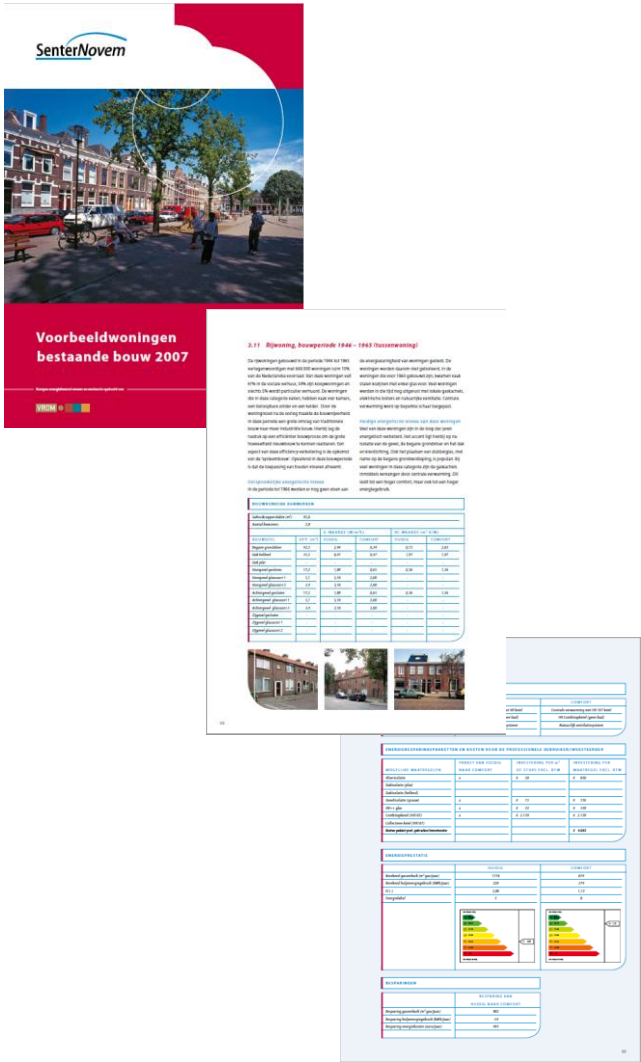
IN DE VOLGENDE VERSNELLING NAAR EEN KLIMAATNEUTRALE GEBOUWDE OMGEVING

- How can we help the renovation sector to organize continuity around standardized and industrial renovation products and processes:
  - Get more work done with less people
  - At lower costs,
  - With higher quality,
  - And make learning a core activity
- We started with suppliers of renovation solutions:
  - Wat do they need to start working like this?
  - Download the paper at www.tno.nl

BACKGROUND

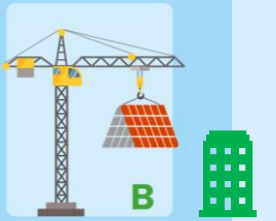
EXAMPLE HOMES EXISTING CONSTRUCTION

- The practice of developing scalable sustainability solutions: focus on specific target group of buildings
- 'Target groups' do not appear to be sufficiently homogeneous to guarantee large-scale application: energy renovations now simply often have a (too) great diversity of project-dependent / -specific solutions
- need for more refined subdivision of the housing stock in order to be able to respond to common differences



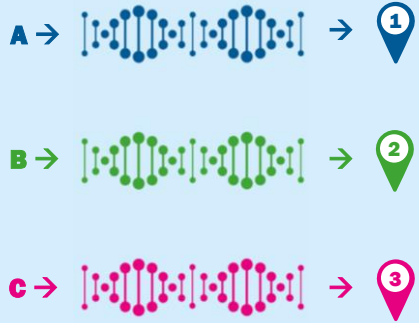
CONTINGENTENAANPAK: START FROM EXISTING SOLUTIONS

Verduurzamings-maatregelen



Kenmerken die het gebouw-DNA bepalen:

- Gebouwtype
- Vrijstaand / rij / complex
- Type spouw (mm)
- Dakvorm
- Gebouw oriëntatie
- Staat van onderhoud
- Mutatie of verkoopmoment
- Energielabel
- Gezinssamenstelling
- Beschikbaarheid (toekomstig) warmtenet
- Gebruikerswensen (nieuwe keuken, uitbouw, … etc.)
- Funderingsproblematiek
- … etc.

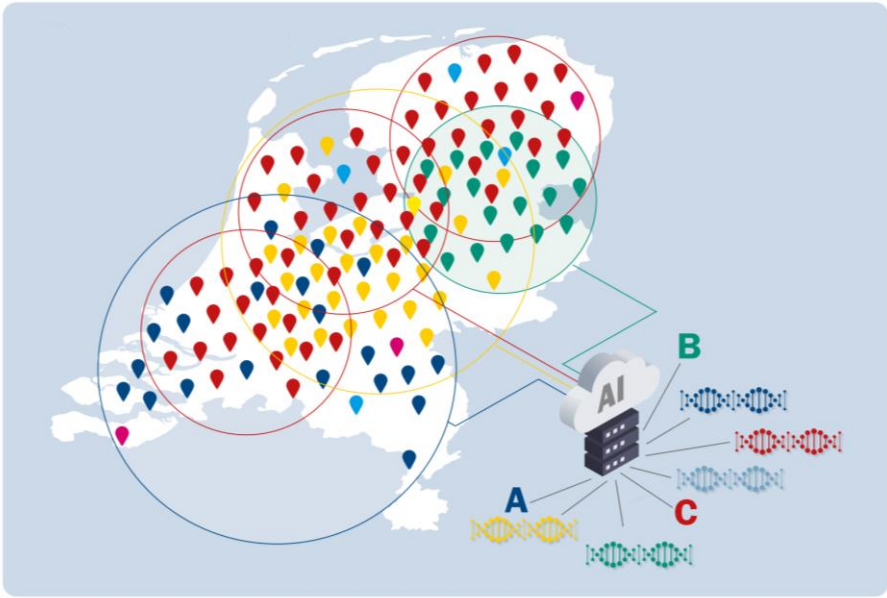


Koppeling
van verduurzamingsmaatregel met gebouwkenmerken: gebouw-DNA

Contingenten
worden zichtbaar in de woningenvoorraad

CONTINGENTEN

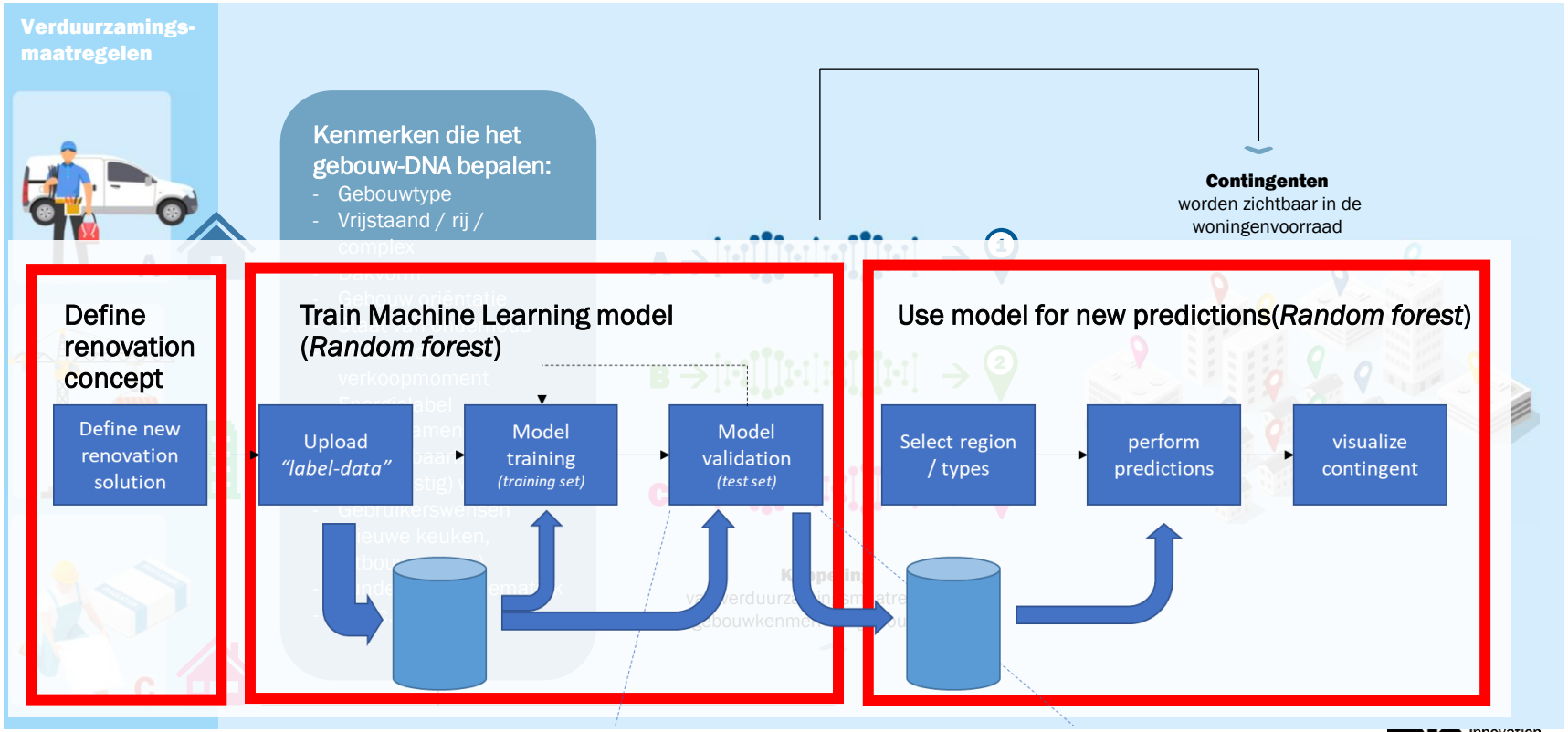
- **Contingent: cluster of homes/buildings in a certain area to which a (previously successfully implemented) renovation solution can be applied repetitively**



- State of play process benefits :

i. acquisition: 50% reduction in time use and lead time
ii. Work preparation: 10-20% reduction in time use
iii. production: 20% reduction cost price
iv. execution: 10% productivity gain

CLUETERTOOL: DATA AND AI BASED APPROACH

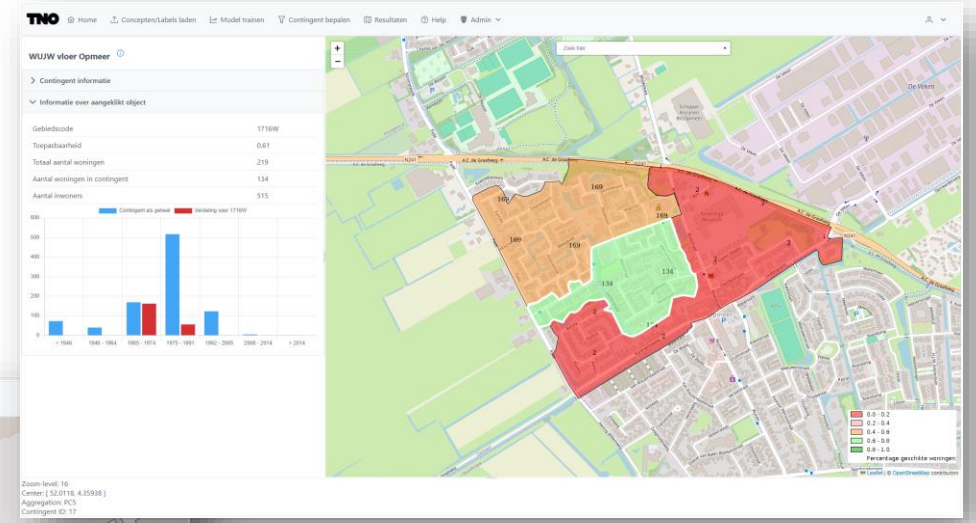


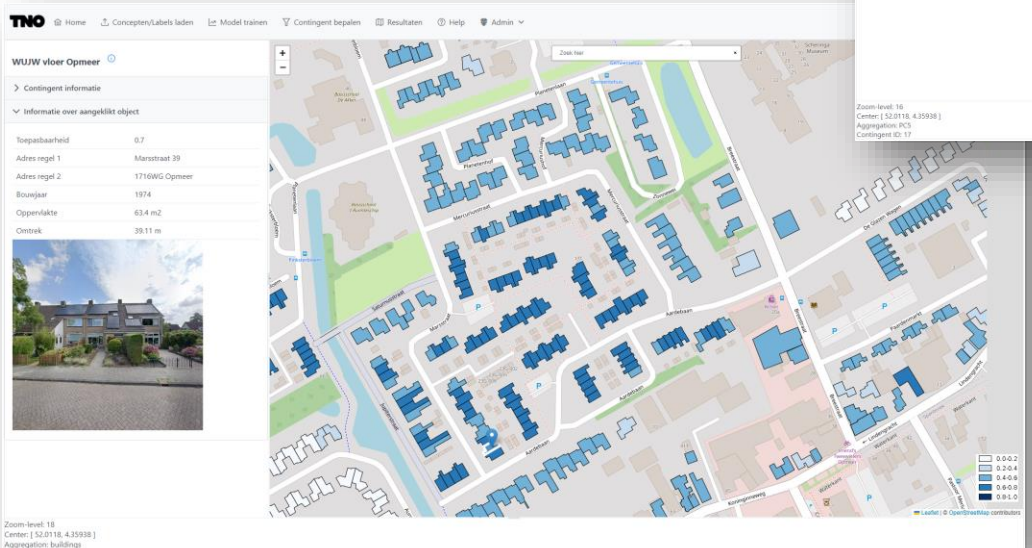
CLUSTERTOOL - 2024

Wijkniveau:
Groen = hoog percentage
Rood = laag percentage
woningen waar oplossing waarschijnlijk toepasbaar is

Input:
Track record = list 200+ renovated buildings: adresses + experiences (success, performance, price, …)

Output:
List/map with predicted experiences for <u>all</u> adresses in NL





Providers can use the clustertool without TNO involvement

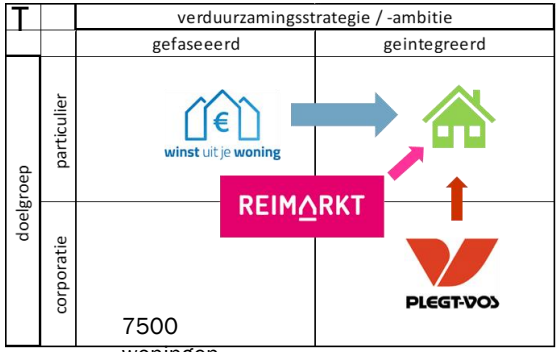
Individuele woningen:
Donkerblauw = hoge verwachte toepasbaarheid
Lichtblauw = lage verwachte toepasbaarheid

TNO innovation for life

ONGOING PROGRAM

FROM VALIDATION TO LARGE SCALE RENOVATION

CONTINGEN



Innovatieproject Noord-Holland

winst uit je woning

KLIMAAT MISSIE NEDERLAND

Provincie Noord-Holland

3500 woningen

Samen sterker, sneller, slimmer (MEER)

Penvoerder	KNOP OM — 1001 woningen
Consortium leden	winst uit je woning; insideout; parteon; gemeente Zaanstad; ZNSTD; Gemeente Wormerland; Heemstede

TDI500 – 500 extra duurzame installaties per dag

eneco · Feenstra · HeatTransformers · comfort partners | TBI · Mensen Maken de Transitie

mampaey INSTALLATIE BEDRIJVEN · BONARIUS · essent · Kemkens · Breman · TEAM

TNO innovation for life

INTERRESTED?

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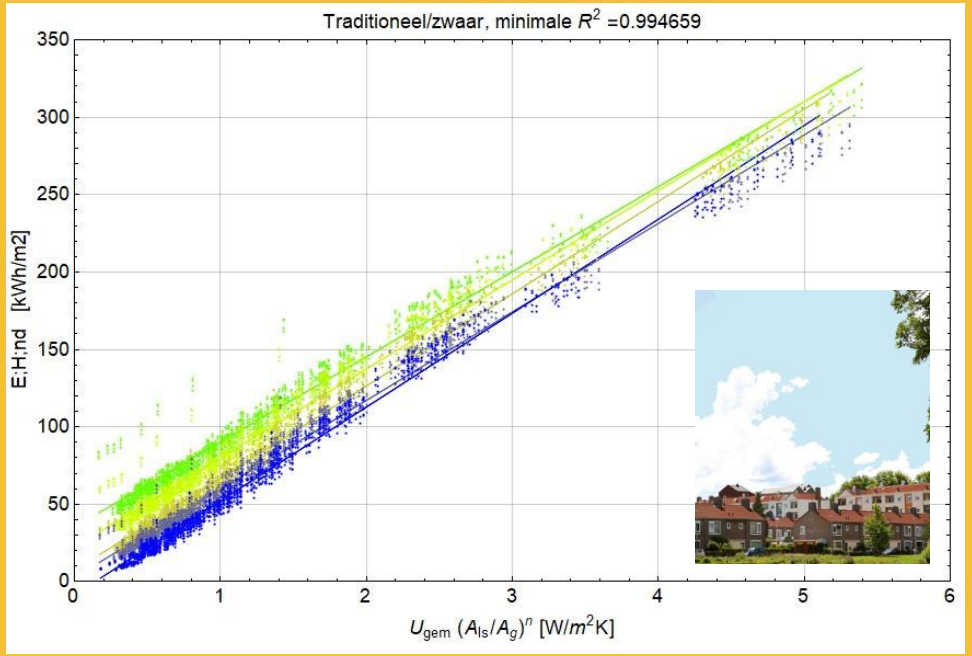
TNO innovation for life

Data-driven solution for scaling up renovations: impact assessment research and tools

Gerrit Renzenbrink

Delft - 19 November 2024



Introduction W/E Consultants

~45 years young, ~40 co-workers, based in Utrecht and Eindhoven
Consultancy social housing corporations, municipalities, RE investors, property developers, architects
Research-based consultancy national government (RVO, TKI, NMD, ...)
Software development (GPR Gebouw, Materiaal & Gebied): MCA tooling, MPG compliance, building certification, and other tools

mission-driven:
Accelerating the Sus

Built Environment

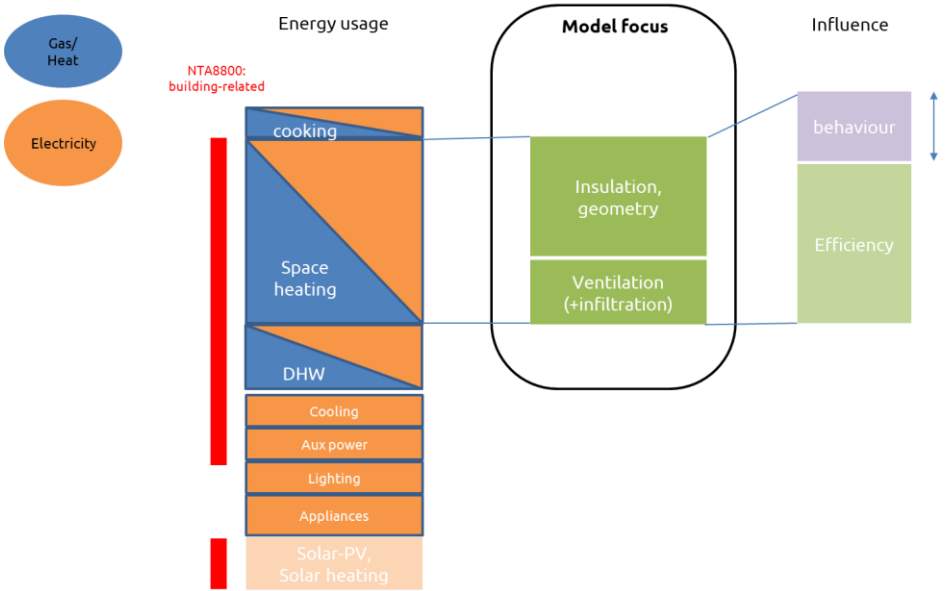
TU Delft stichting W/E adviseurs

TU Delft UEI

NTA 8800

- **NTA8800**: energy regulation Dutch building code as of 2021.
- Purpose: **Energy labeling** (based on primary fossil energy use kWh/m2)
- Comprehensive methodology: **bottom-up physics-based** algorithm for annual energy use
- Over **1.000** pages

→ How can we make this more accessible?



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Proposed pseudolinear model

(Black – **Grey** – White) empirical model
Physical envelope:
average **insulation** value U_{gem} [W/m²K]
compactness ratio $A_{\mathrm{ls}}/A_{\mathrm{g}}$
Distinctive **ventilation** concepts ($\ldots_{\mathrm{v}}$) →
Target: Energy need for heating in kWh/m²
Data: ~8,000 full NTA8800 calculations based on **reference buildings**

A:	natural ventilation
C:	simple mechanical ventilation
C4b:	CO_2 driven mechanical ventilation
D2:	simple balanced mechanical ventilation (heat recovery)
D5a/b:	high-end balanced mechanical ventilation (heat recovery)

Hypothesis: modified linear relationship (parameters a, b, n) per ventilation concept (v):

$$E_{\mathrm{v}} = a_{\mathrm{v}} + b_{\mathrm{v}} * U_{\mathrm{gem}} * \left(\frac{A_{\mathrm{ls}}}{A_{\mathrm{g}}}\right)^{n_{\mathrm{v}}}$$

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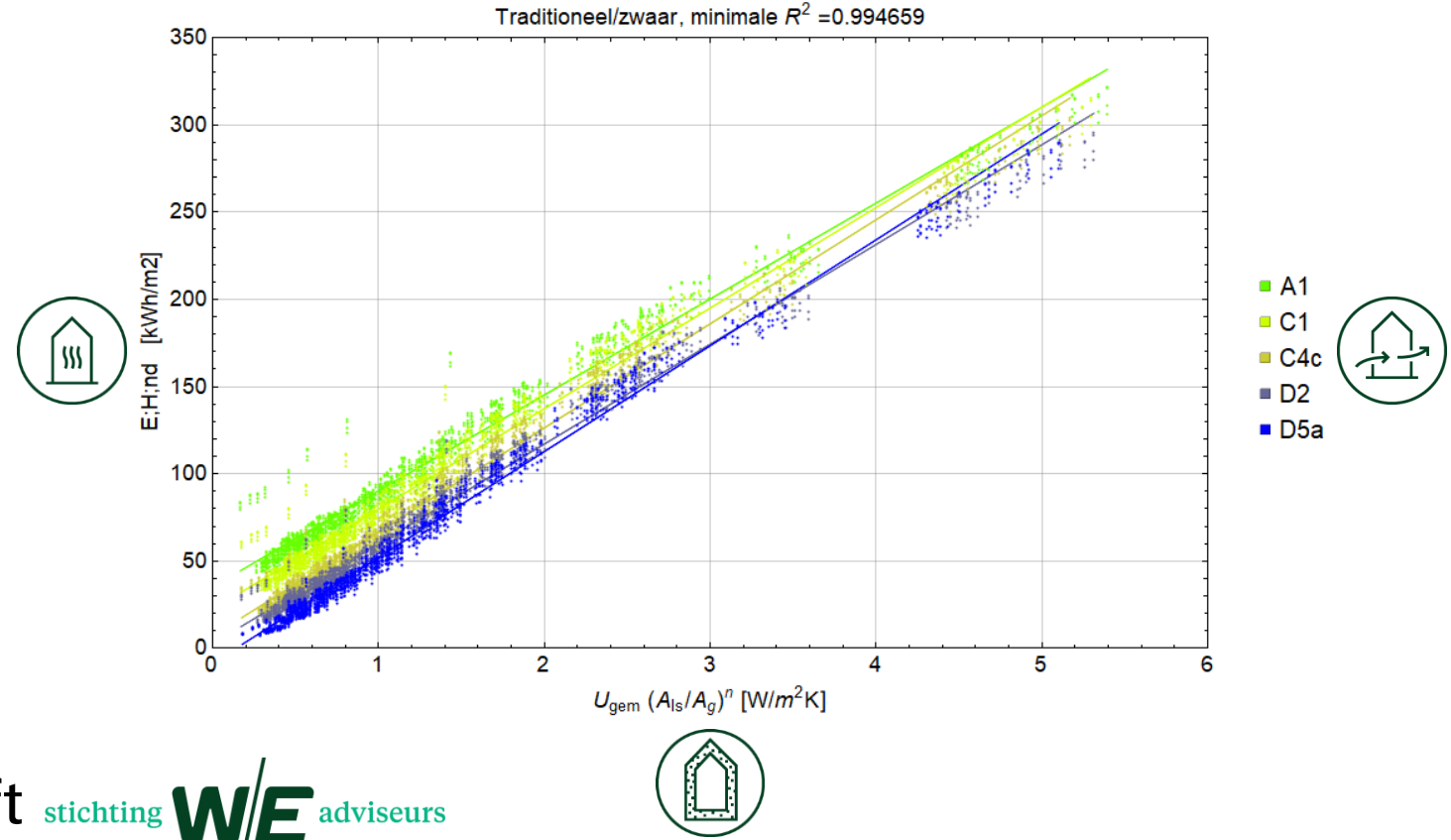
Results, discussion



Implementation in practice

- Implementation in consultancy: accessible indicative calculations
  - Useful for 'rapid prototyping' on building stock & asset level
- Pragmatic model = part of the bigger story
  - Operational energy use
  - Embodied carbon (MPG, GWP)

- Blind spot in the bigger story:
→Embodied impact of renovation!

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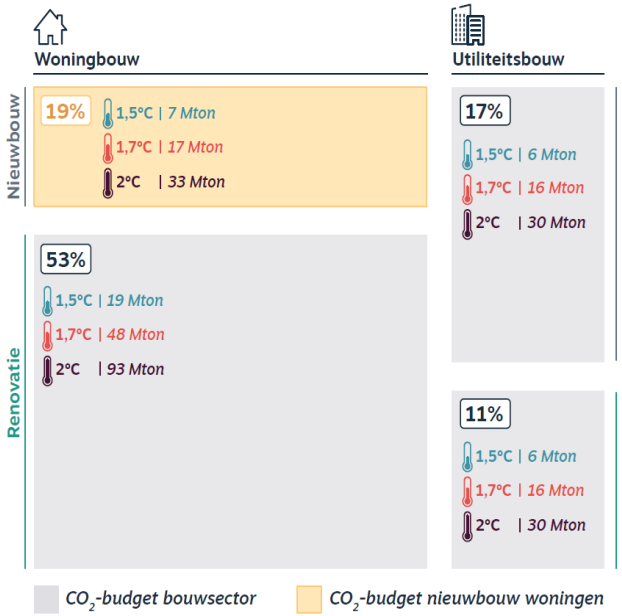
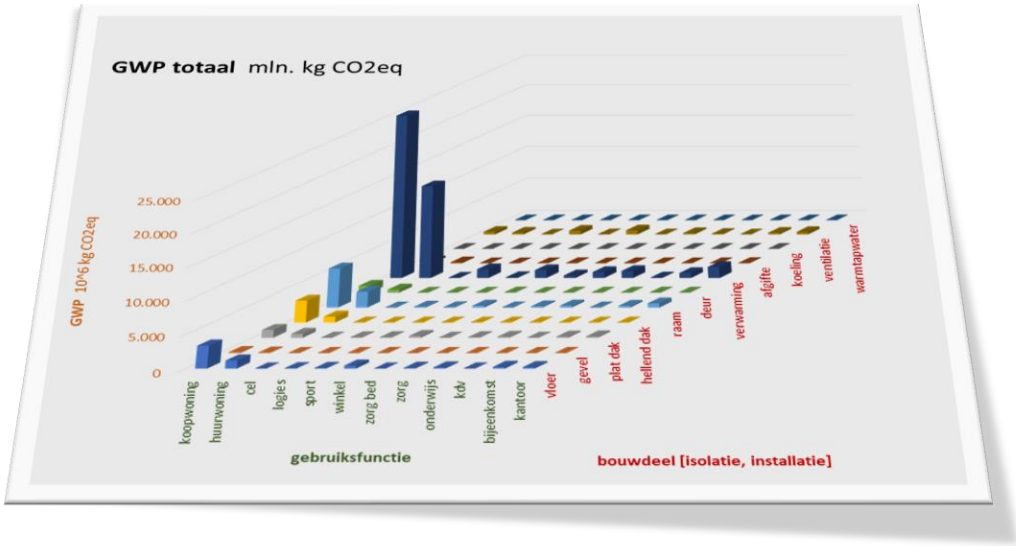
Embodied impact of housing renovation





Sources: Circulaire Energierenovaties (W/E Adviseurs),
Woningbouw binnen planetaire grenzen (Copper8)

Integral impact of housing renovations in sight

- Web-based tool for **renovation variant comparison** (VariantenVergelijker)
- Using the **pragmatic NTA8800 model** to get a grasp of operational energy use
- Using the National Environmental Database to get a grasp of **embodied impact**

- Result: **integral, data-driven approach** to sustainable housing renovation
- Comparing variants based on **environmental impact**, but also over **time**!
- Variant & scenario-studies for ~35 organizations

- Dedicated app built on Viktor platform

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VAN WIJNEN
Coen Hagedoorn

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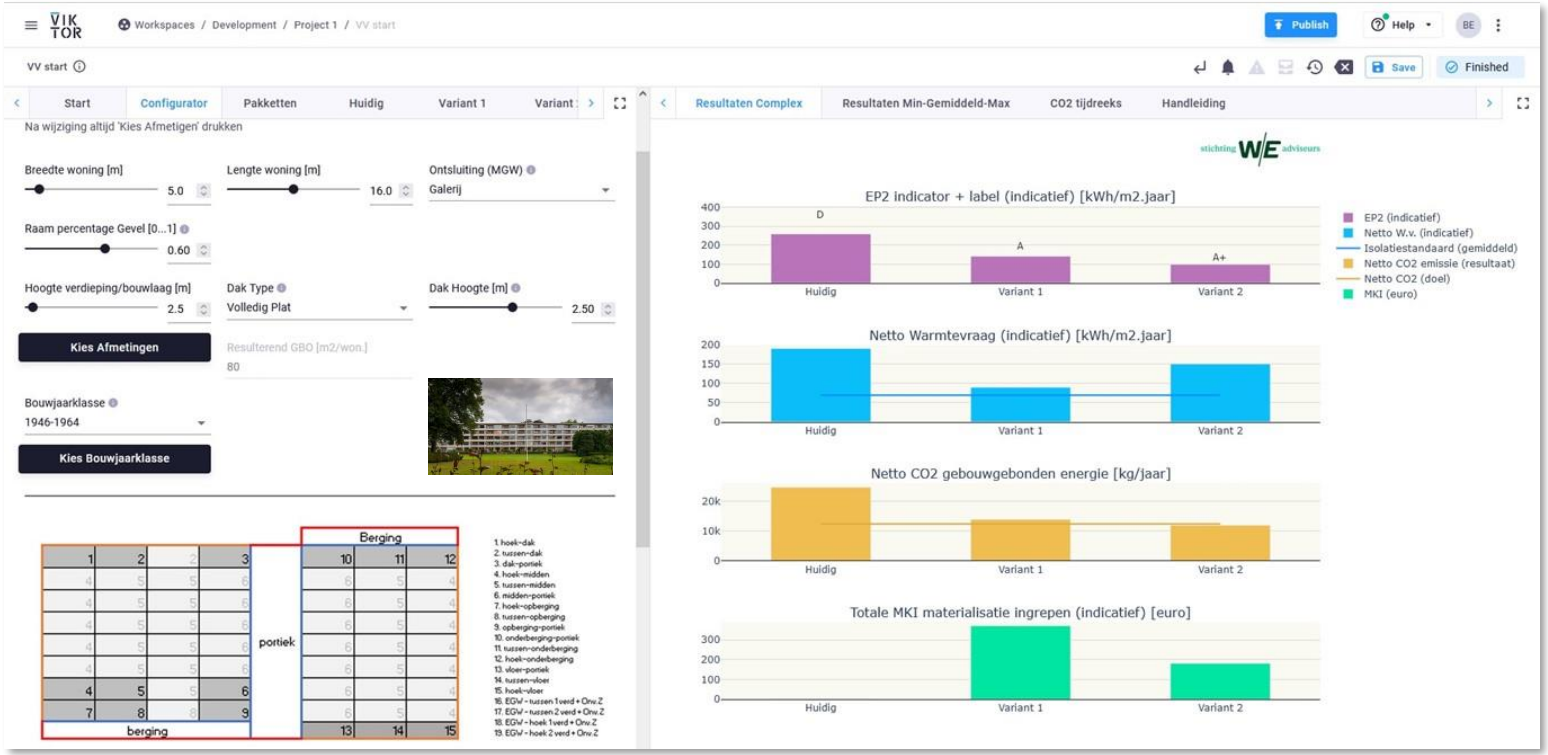
Operational & embodied impact of renovation in sight



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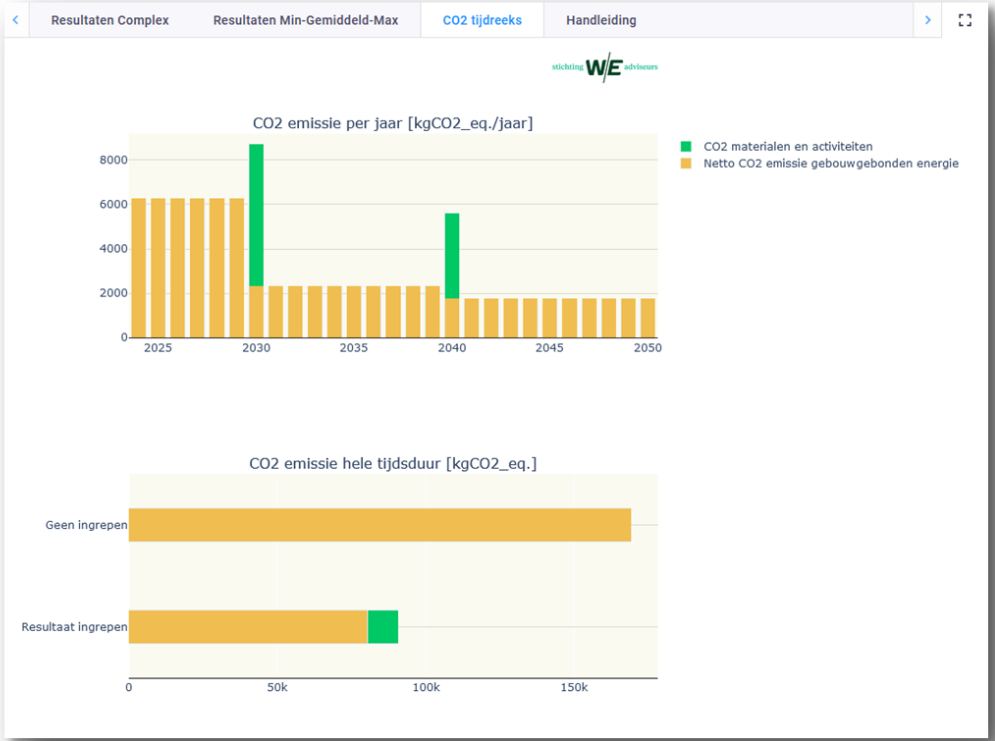
Operational & embodied impact of renovation in sight



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Thank you!

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