ambience

Active managed Buildings with
Energy performaNce Contracting

Deliverable 4.3 (D4.3)

Report of the Scenario results and their validation in the stakeholder co-creation workshop

The AmBIENCe Consortium

May | 2022

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EXECUTIVE SUMMARY

The purpose of the AmBIENCe project is to reduce the CO_2 emissions of buildings by introducing the flexible use of Renewable Energy Sources in combination with electrification and Demand Response (DR). By uniting the best of two worlds and combining Energy Performance Contracting (EPC) with DR, the Active building Energy Performance Contracting (AEPC) is developed as a new concept that allows specific new services, new business models and new actors. In recent years, buildings became more digital and smarter. The active EPC extends the classic EPC concept to include DR value streams, valorising the flexibility that is available in active buildings. The AEPC concept and tool were validated in two pilot buildings.

This report summarises the discussion had during a stakeholder workshop hosted on April 28th, 2022, to validate the methodology, scenarios, and assumptions to achieve nearly zero emission buildings by 2050 to specialists in the building and energy sector.

The main purpose of this report is to:

- **Validate the results from the scenarios defined in the** *"Scenario development and Energy System Impact calculation active control adoption"* (Task 4.2)
- **Document the content and the main outcomes of the stakeholder workshop conducted on 28th April 2022**, *"Energy system impact scenarios and methodology discussion"* (see annex I).

In conclusion, there was no major feedback from the stakeholder group and the methodology and scenarios were validated by the experts consulted.

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1. INTRODUCTION AND BACKGROUND

The purpose of the AmBIENCe project is to reduce the CO_2 emissions of buildings by utilising the flexible use of Renewable Energy Sources (RES) in combination with electrification and Demand Response (DR). By uniting these and combining Energy Performance Contracting (EPC) with DR, the Active building Energy Performance Contracting (AEPC) was developed as a new concept that allows specific new services, new business models and new actors. In recent years, buildings became more digital and smarter. The active EPC extends the classic EPC concept to include DR value streams, valorising the flexibility that is available in active buildings. The AEPC concept and tool were validated in two pilot buildings.

1.1. CONTEXT

In addition to the creation of a business model and the pilot projects, part of the Ambience project included the creation of an Energy System Impact Analysis methodology and tool, used to calculate Energy System Impact Key Performance Indicators (KPIs) in a transparent manner. Relevant scenarios were developed and tested related to evolutions in the energy system, tariff structures and regulation, the adoption rate of building level Demand Response services etc. Combining this information, an Energy System KPI calculation tool was developed, and for a few reference scenarios, KPIs were calculated.

Related material for the creation of the Energy System Impact Analysis was the creation of building stock information database [1], based on the Building Stock Observatory and the data from different EU projects such as TABULA and Hotmaps. Additionally, the Energy System Impact Analysis methodology and tool was developed to assess the impact on the upstream energy system of active control in buildings.

1.2. PURPOSE AND SCOPE OF THE REPORT

This report summarises the discussion had during a stakeholder workshop hosted on April 28th, 2022, to validate the methodology, scenarios, and assumptions to achieve nearly zero emission buildings by 2050 by specialists in the building and energy sector.

The main purpose of this report is to:

- **Show and analyse the results from the scenarios defined in the** *"Scenario development and Energy System Impact calculation active control adoption"*
- **Document the content and the main outcomes of the stakeholder workshop conducted on 28th April 2022**, *"Energy system impact scenarios and methodology discussion"* (see annex I).

2. SUMMARY OF SIMULATION SCENARIOS

The following table shows a summary of the considerations made for defining the scenarios, which are thoroughly explained in the *Report on the methodology of creating the scenarios, integrating the models and adopt* assumptions (AmBIENCe D4.2) [2]:

TABLE 1. CONSIDERATIONS MADE TO DEFINE THE SIMULATED AMBIENCE SCENARIOS [2].

AmBIENCe Scenario (AS)	Renovation rates	Carbon intensity	Electrification uptake	Flexibility uptake
SCENARIO 1 (AS1)	Start year renovation rate (2020) of **1%**, of which: - 80% shallow renovations, - 15% medium renovations, - 5% deep renovations. End year renovation rate (2050) of 1.5%, of which: - 20% are shallow renovations - 60% medium renovations - 20% deep/full renovations	As a function of greenhouse gas (GHG) targets (see Annex II)	80%	Start year (2020): 0.02 End year (2050): 0.2
SCENARIO 2 (AS2)	Start year renovation rate (2020) of **1%** (like **AS1**): End year renovation rate (2050) of **2.0%**, of which: - 10% shallow renovations - 70% medium renovations - 20% deep renovations	As a function of GHG targets (see Annex II)	80%	Those of AS1
SCENARIO 3 (AS3)	Start year renovation rate (2020) of **1%**, (like **AS1**): End year renovation rate (2050) of **3.0%**, of which: - 70% medium renovations - 30% deep/full renovations	As a function of GHG targets (see Annex II)	80%	Those of AS1
SCENARIO 4 (AS4)	Those of AS3	As a function of GHG targets (see Annex II)	40%	Those of AS1
SCENARIO 5 (AS5)	Those of AS3	As a function of GHG targets (see Annex II)	80%	Start year (2020): 0.05 End year (2050): 0.30

3. MAIN RESULTS FROM THE SIMULATION OF THE SCENARIOS

The simulations made with the KPI calculation tool developed in the *Report on the methodology of creating the scenarios, integrating the models and adopt assumptions* [2] which provided results for all the 27 EU MS in the form of graphs, covering the 2020-2050 period for the following parameters:

- Total CO_2 intensity[1] per capita (in 2020 vs in 2050) (in tons);
- Aggregated CO_2 intensity of each building typology, per year;
- Evolution of the CO_2 intensity per capita (in tons);
- Share of renovated buildings;
- Accumulated renovation investment costs (in millions of EUR).

In the following sections, 3.1 through 3.5, the main outputs are presented for each scenario in the form of graphs. In section 3.6 a summary of the main findings can be read – for a more detailed analysis of the energy system's impact of the adoption of active control see [2].

[1] Carbon intensity (CI) defined as the amount of CO_2 emitted to power the energy systems of buildings.

3.1. AMBIENCE SCENARIO 1 (AS1)

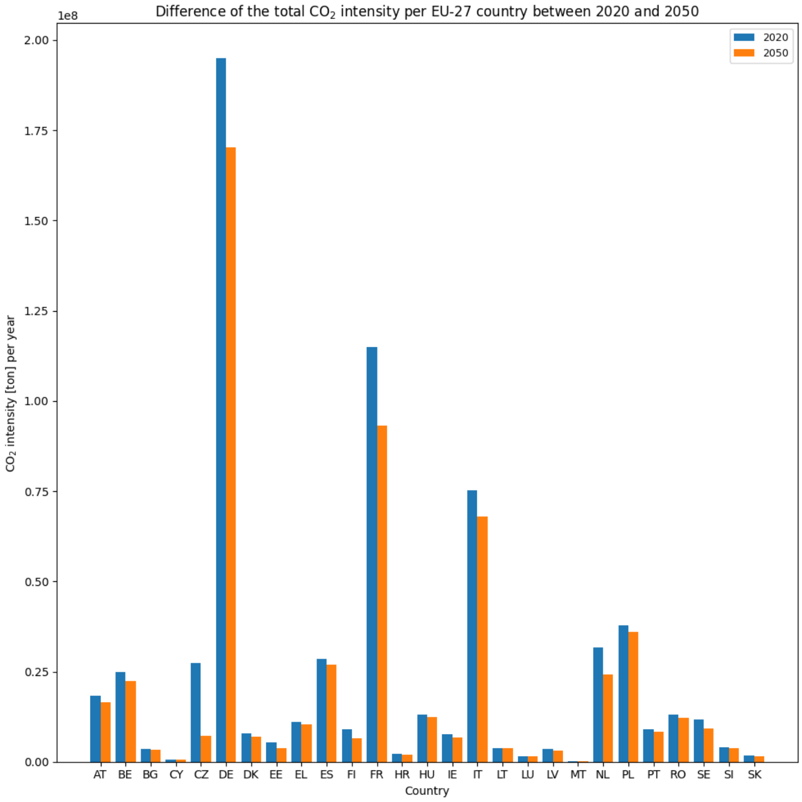


FIGURE 1: AMBIENCE SCENARIO 1 (AS1) TOTAL CO_2 INTENSITY OF EACH EU-27 COUNTRY – CURRENT STATUS *VS* 2050 RESULTS.

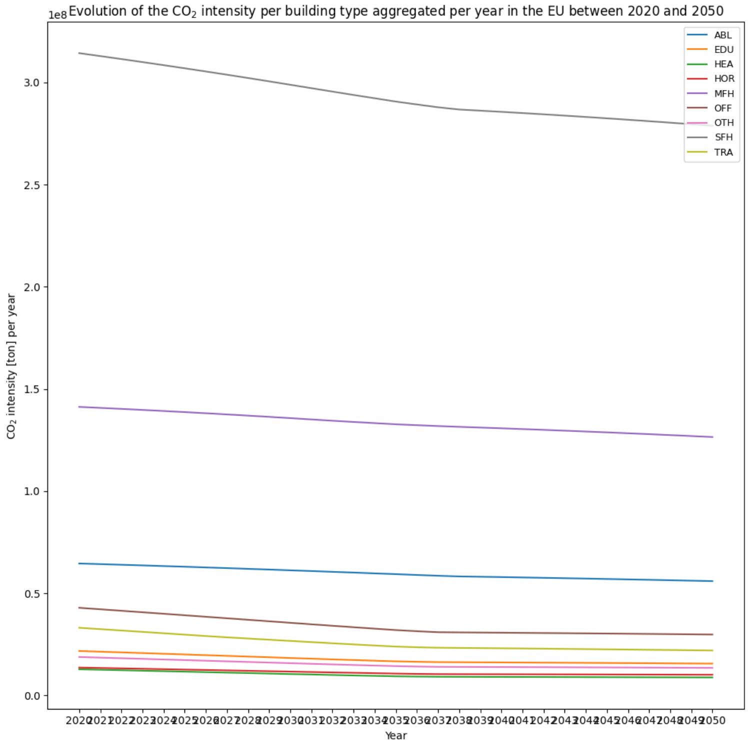


FIGURE 2: AMBIENCE SCENARIO 1 (AS1) EU AGGREGATED CO_2 INTENSITY OF EACH BUILDING TYPOLOGY, PER YEAR.

SFH – SINGLE FAMILY HOUSE; MFH – MULTI FAMILY HOUSE; ABL – APARTMENT BLOCK; HEA – HEALTH; HOR – HOTELS AND RESTAURANTS; OFF – OFFICES; TRA – TRADE; EDU – EDUCATION

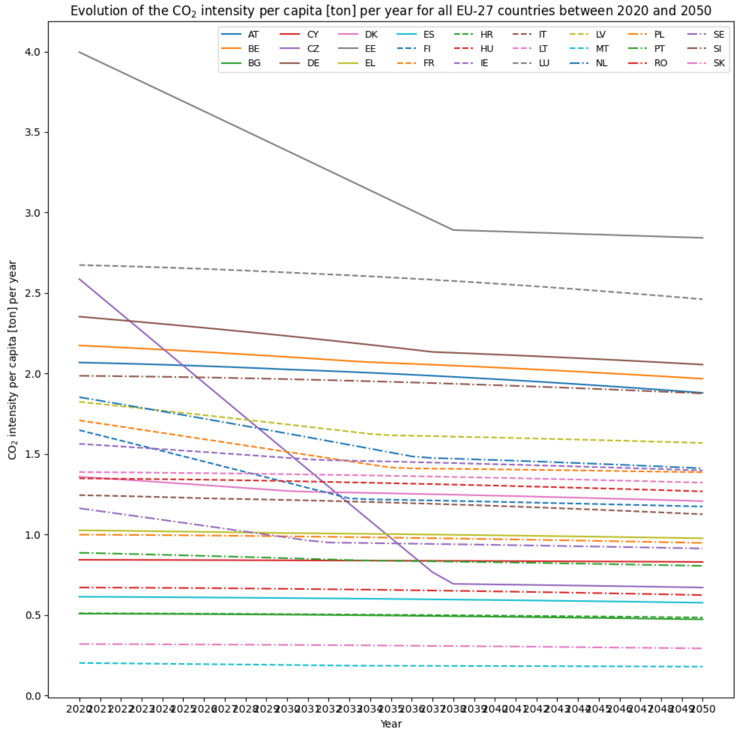


FIGURE 3: AMBIENCE SCENARIO 1 (AS1) EVOLUTION OF CO_2 INTENSITY PER CAPITA, FOR EACH EU-27 COUNTRY

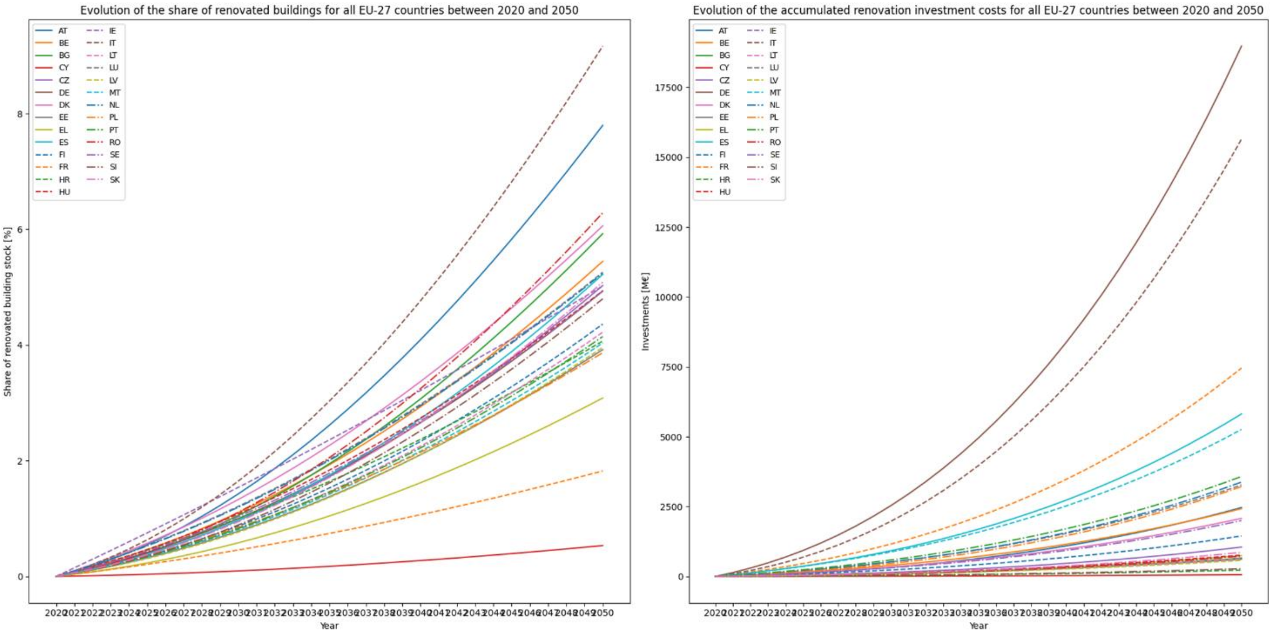


FIGURE 4: AMBIENCE SCENARIO 1 (AS1) SHARE OF RENOVATED BUILDINGS AND CORRESPONDING NECESSARY INVESTMENTS, FOR EACH EU-27 COUNTRY

3.2. AMBIENCE SCENARIO 2 (AS2)

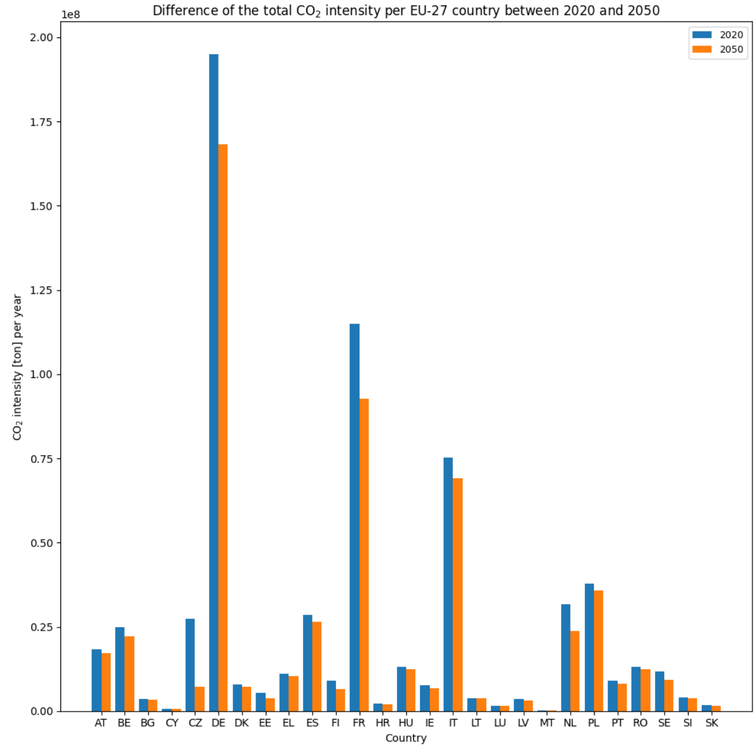


FIGURE 5: AMBIENCE SCENARIO 2 (AS2) TOTAL CO_2 INTENSITY OF EACH EU-27 COUNTRY – CURRENT STATUS *VS* 2050 RESULTS.

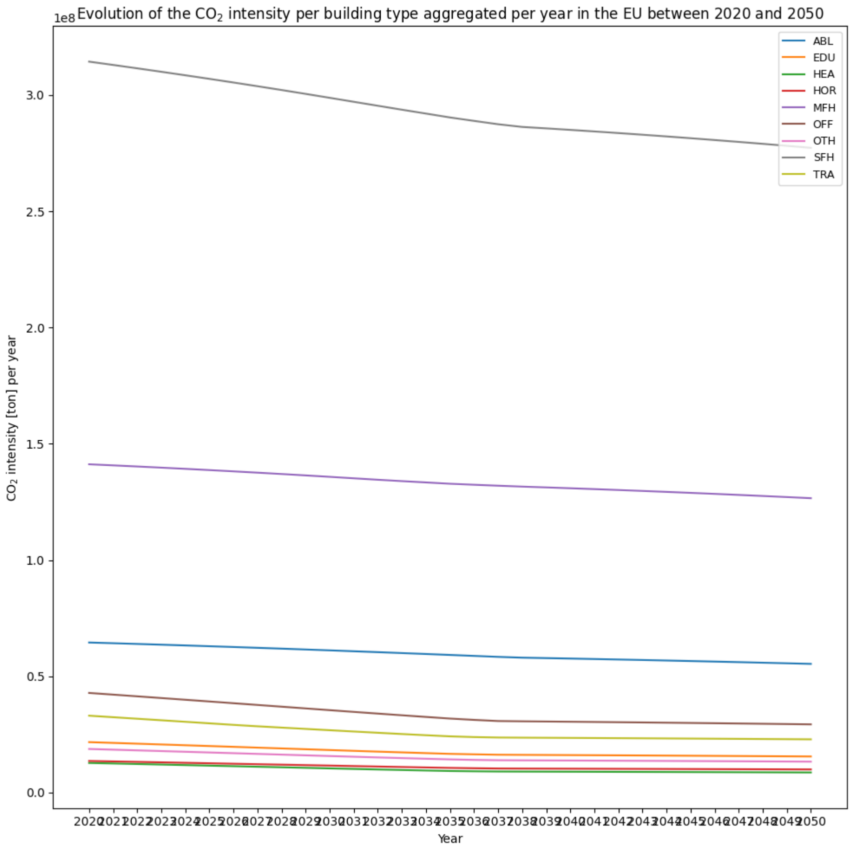


FIGURE 6: AMBIENCE SCENARIO 2 (AS2) EU AGGREGATED CO_2 INTENSITY OF EACH BUILDING TYPOLOGY, PER YEAR.

SFH – SINGLE FAMILY HOUSE; MFH – MULTI FAMILY HOUSE; ABL – APARTMENT BLOCK; HEA – HEALTH; HOR – HOTELS AND RESTAURANTS; OFF – OFFICES; TRA – TRADE; EDU – EDUCATION

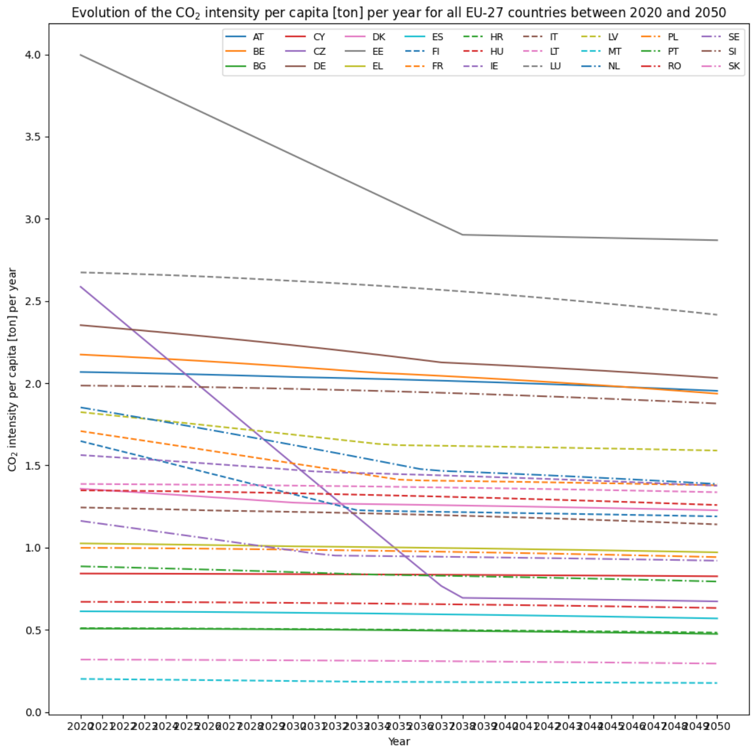


FIGURE 7: AMBIENCE SCENARIO 2 (AS2) EVOLUTION OF CO_2 INTENSITY PER CAPITA, FOR EACH EU-27 COUNTRY

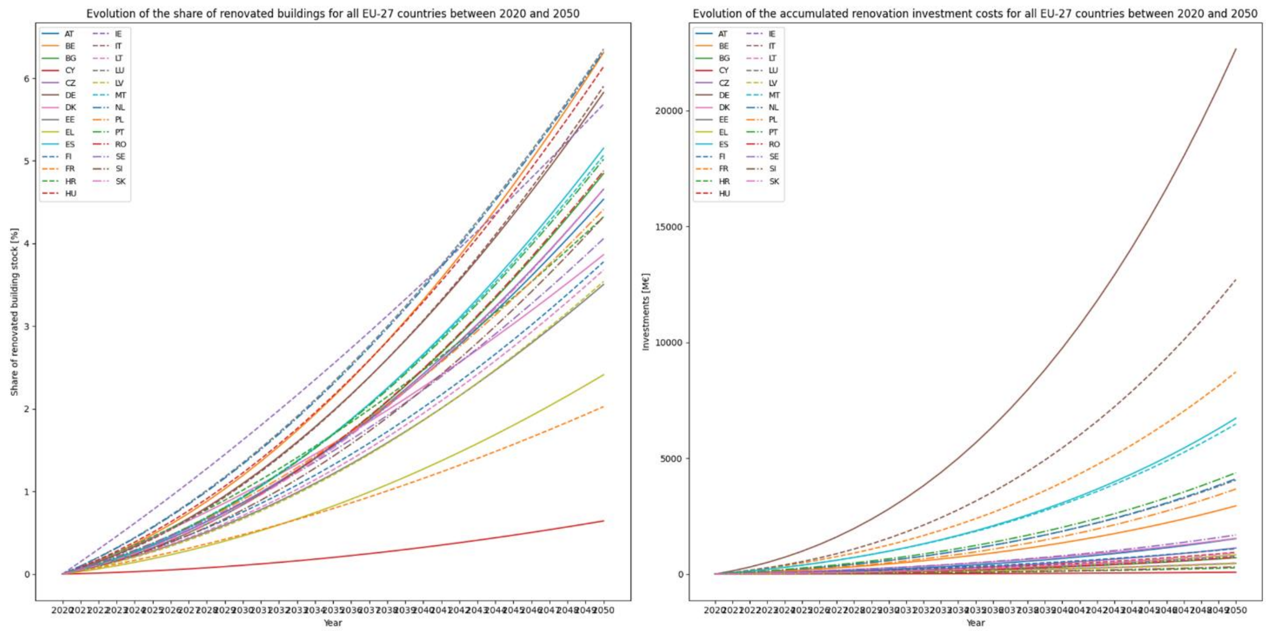


FIGURE 8: AMBIENCE SCENARIO 2 (AS2) SHARE OF RENOVATED BUILDINGS AND CORRESPONDING NECESSARY INVESTMENTS, FOR EACH EU-27 COUNTRY

3.3. AMBIENCE SCENARIO 3 (AS3)

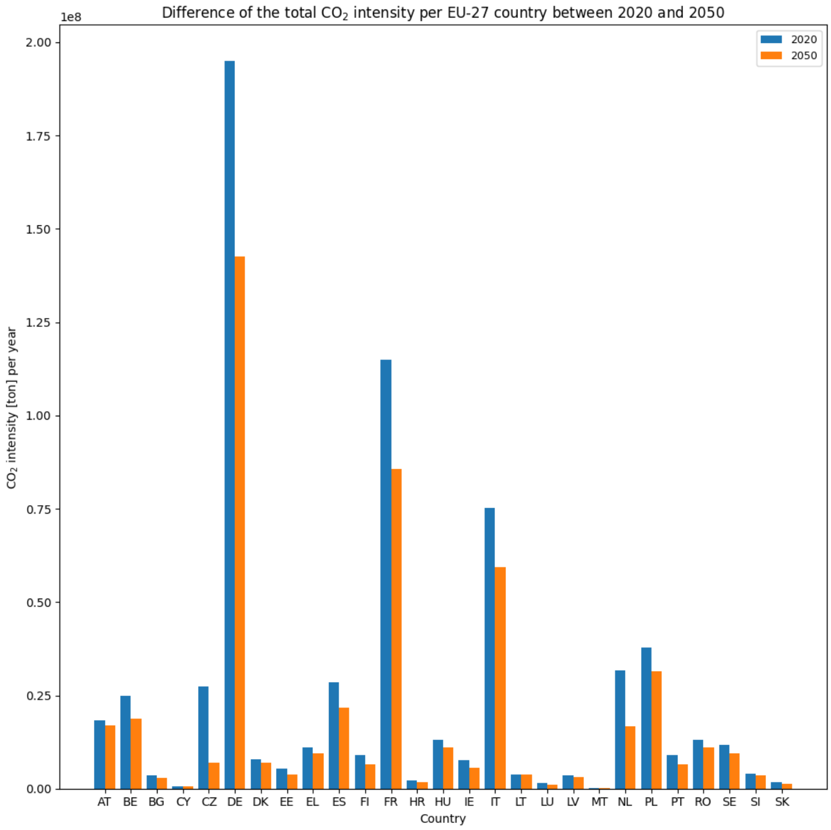


FIGURE 9: AMBIENCE SCENARIO 3 (AS3) TOTAL CO_2 INTENSITY OF EACH EU-27 COUNTRY – CURRENT STATUS *VS* 2050 RESULTS.

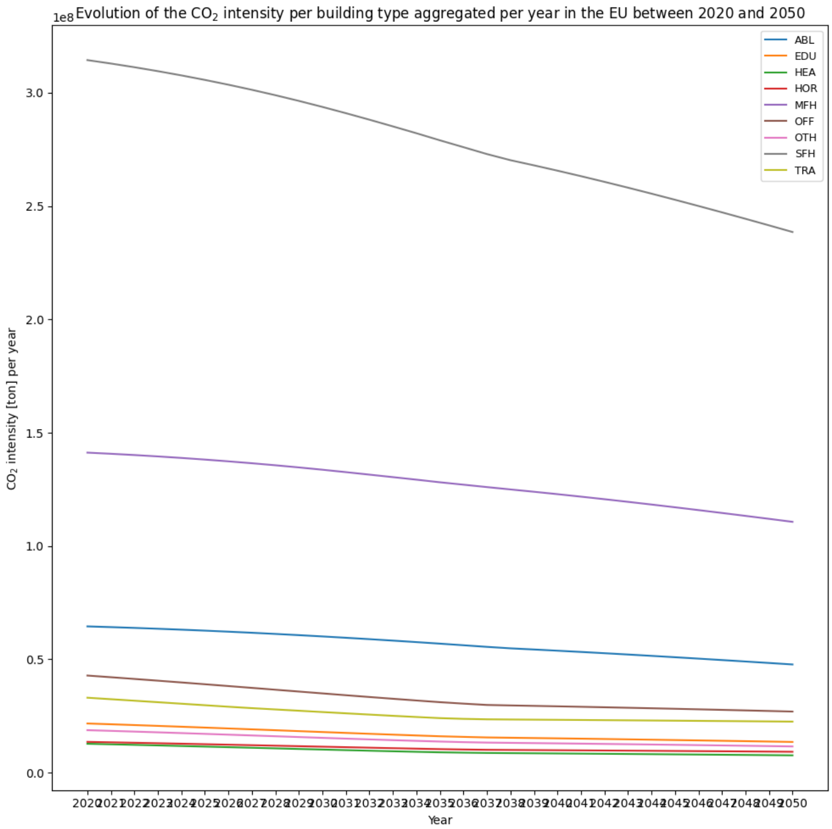


FIGURE 10: AMBIENCE SCENARIO 3 (AS3) EU AGGREGATED CO_2 INTENSITY OF EACH BUILDING TYPOLOGY, PER YEAR.

SFH – SINGLE FAMILY HOUSE; MFH – MULTI FAMILY HOUSE; ABL – APARTMENT BLOCK; HEA – HEALTH; HOR – HOTELS AND RESTAURANTS; OFF – OFFICES; TRA – TRADE; EDU – EDUCATION

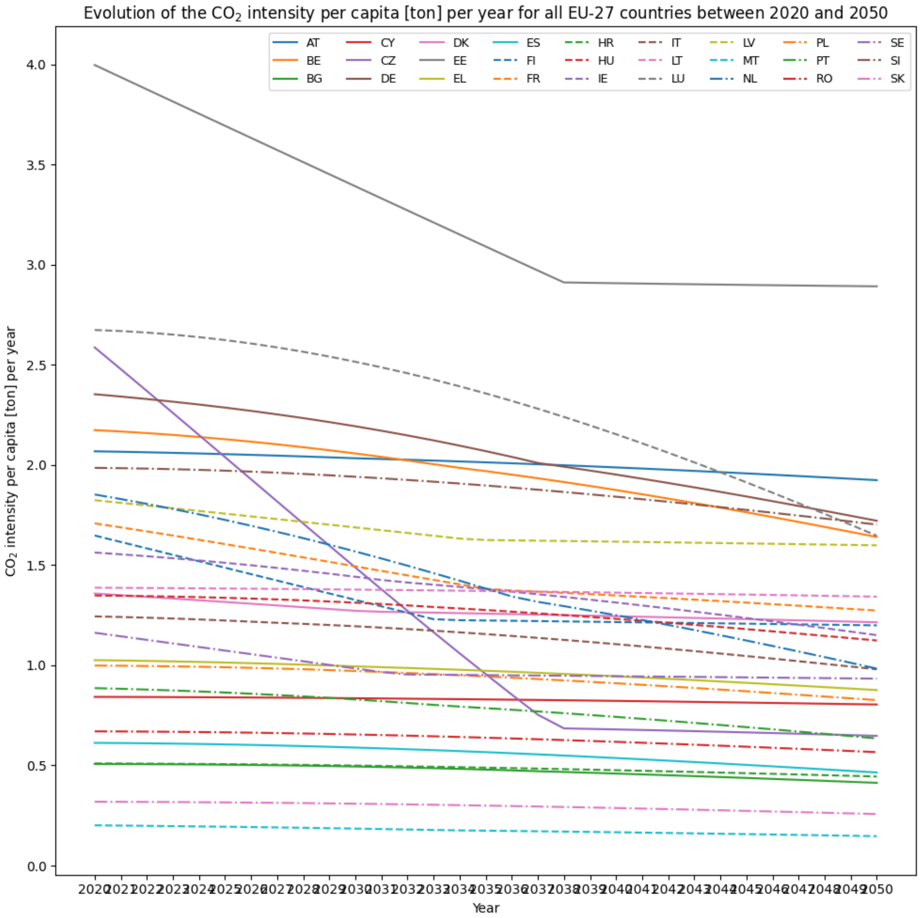


FIGURE 11: AMBIENCE SCENARIO 3 (AS3) EVOLUTION OF CO_2 INTENSITY PER CAPITA, FOR EACH EU-27 COUNTRY

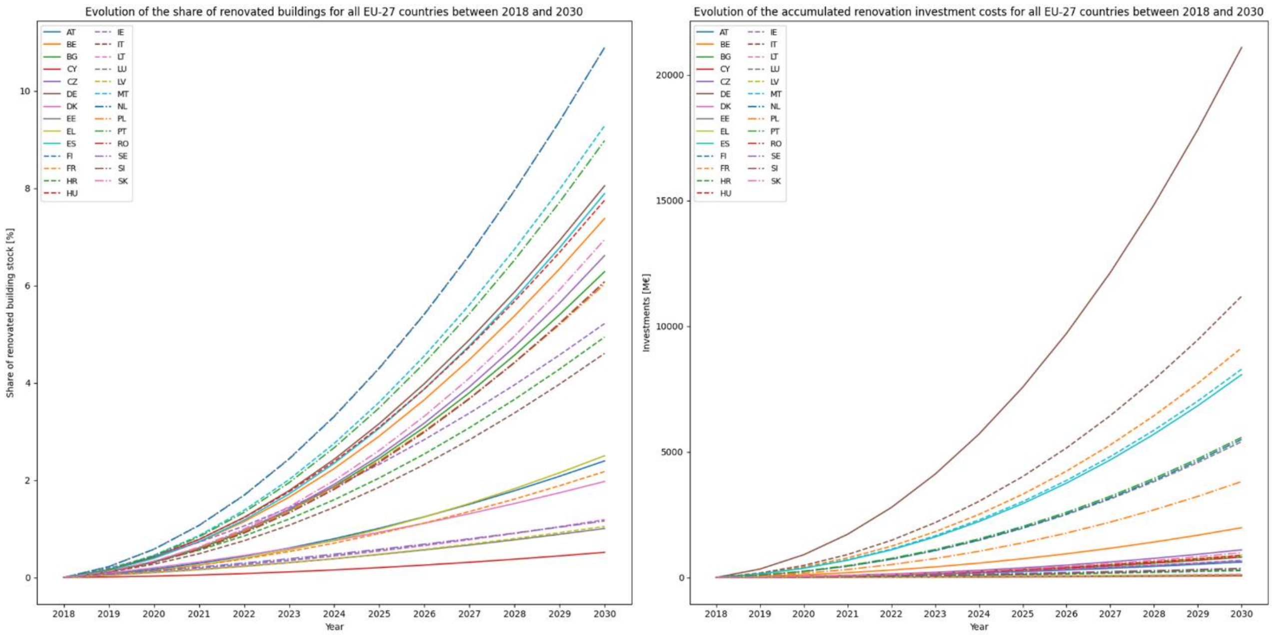


FIGURE 12: AMBIENCE SCENARIO 3 (AS3) SHARE OF RENOVATED BUILDINGS AND CORRESPONDING NECESSARY INVESTMENTS, FOR EACH EU-27 COUNTRY

3.4. AMBIENCE SCENARIO 4 (AS4)

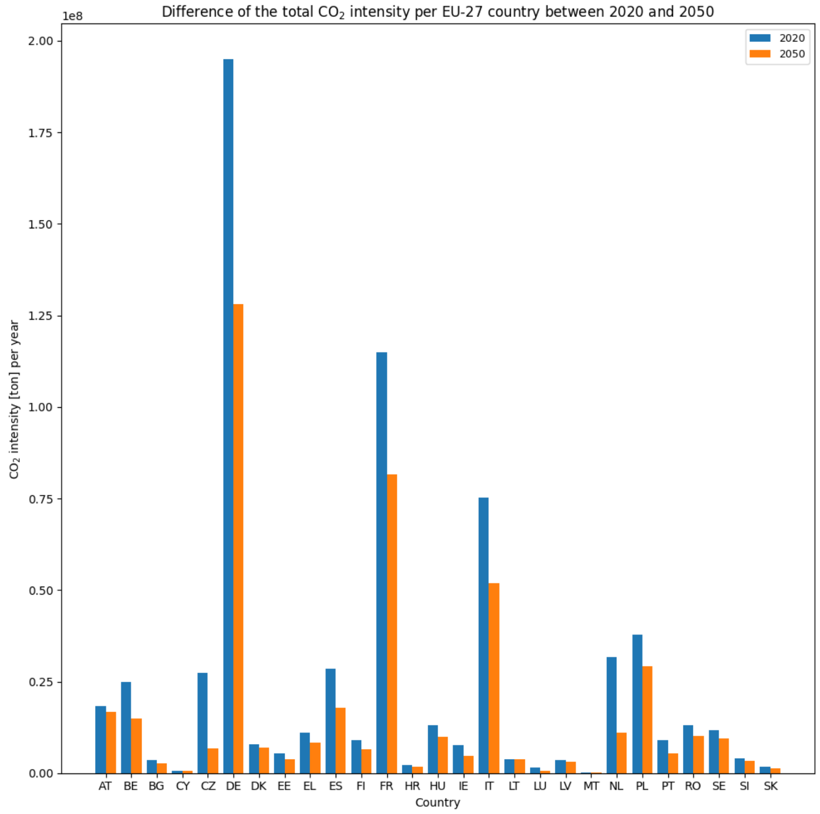


FIGURE 13: AMBIENCE SCENARIO 4 (AS4) TOTAL CO_2 INTENSITY OF EACH EU-27 COUNTRY – CURRENT STATUS *VS* 2050 RESULTS.

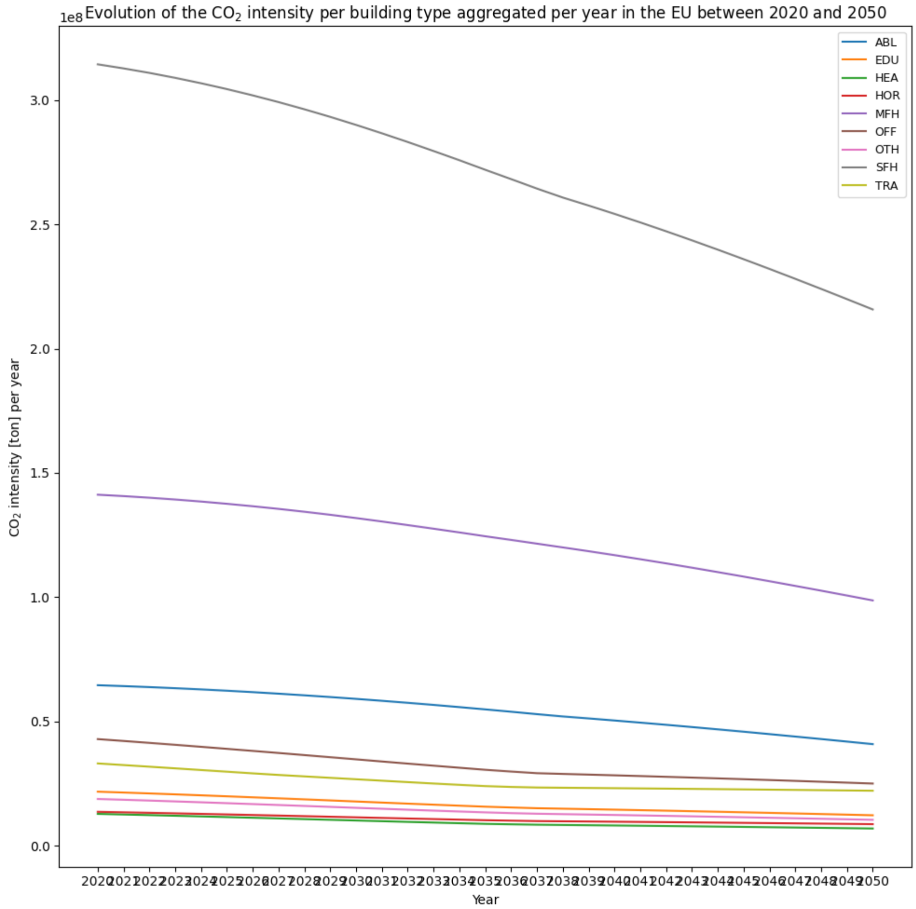


FIGURE 14: AMBIENCE SCENARIO 4 (AS4) EU AGGREGATED CO_2 INTENSITY OF EACH BUILDING TYPOLOGY, PER YEAR.

SFH – SINGLE FAMILY HOUSE; MFH – MULTI FAMILY HOUSE; ABL – APARTMENT BLOCK; HEA – HEALTH; HOR – HOTELS AND RESTAURANTS; OFF – OFFICES; TRA – TRADE; EDU – EDUCATION

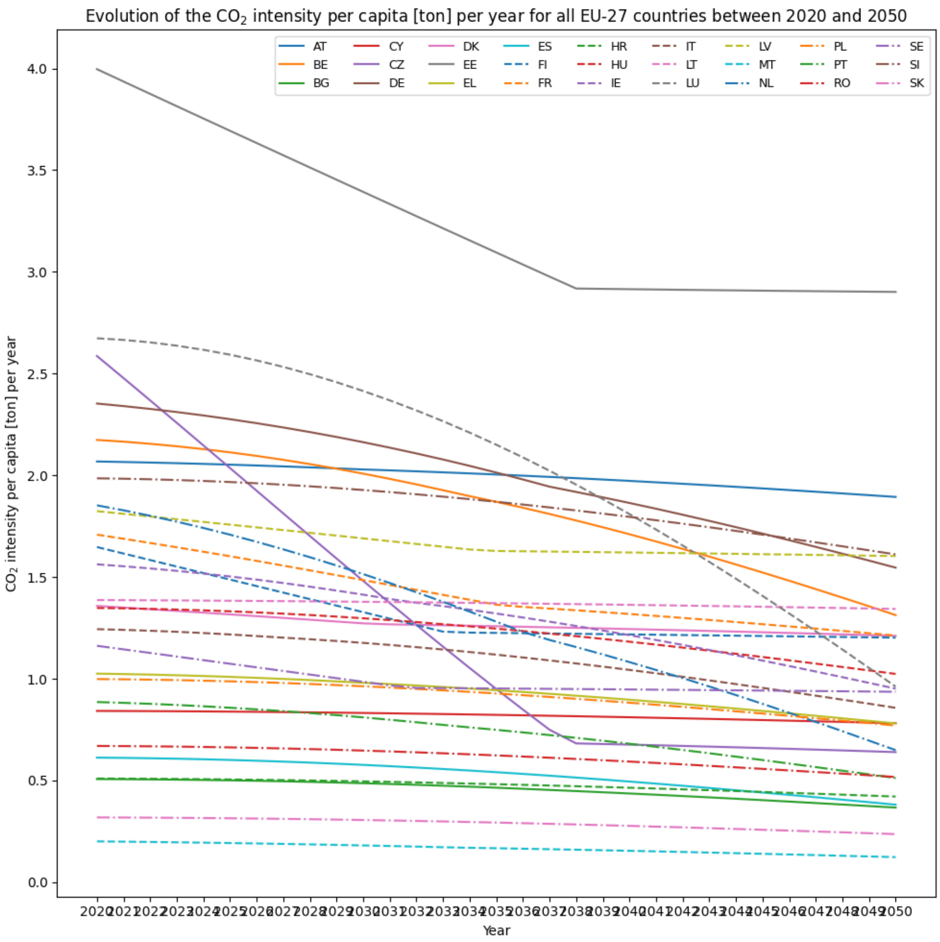


FIGURE 15: AMBIENCE SCENARIO 4 (AS4) EVOLUTION OF CO_2 INTENSITY PER CAPITA, FOR EACH EU-27 COUNTRY

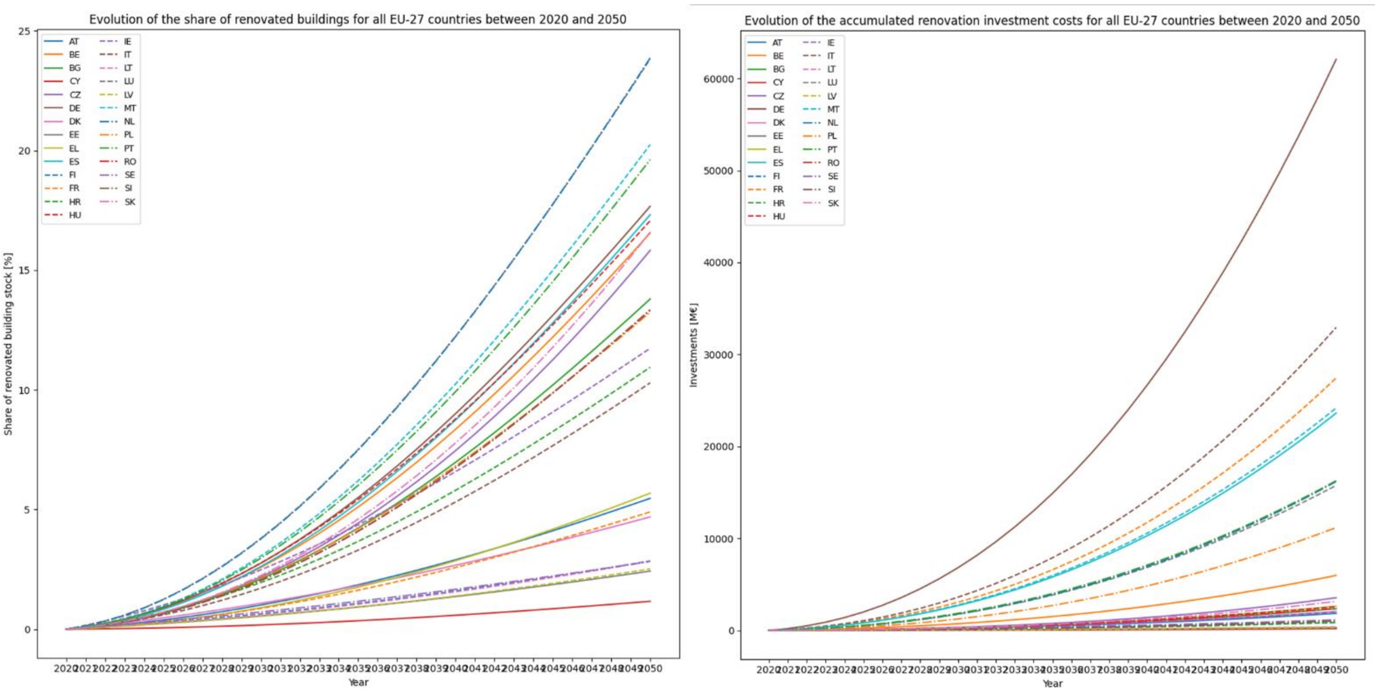


FIGURE 16:AMBIENCE SCENARIO 4 (AS4) SHARE OF RENOVATED BUILDINGS AND CORRESPONDING NECESSARY INVESTMENTS, FOR EACH EU-27 COUNTRY

3.5. AMBIENCE SCENARIO 5 (AS5)

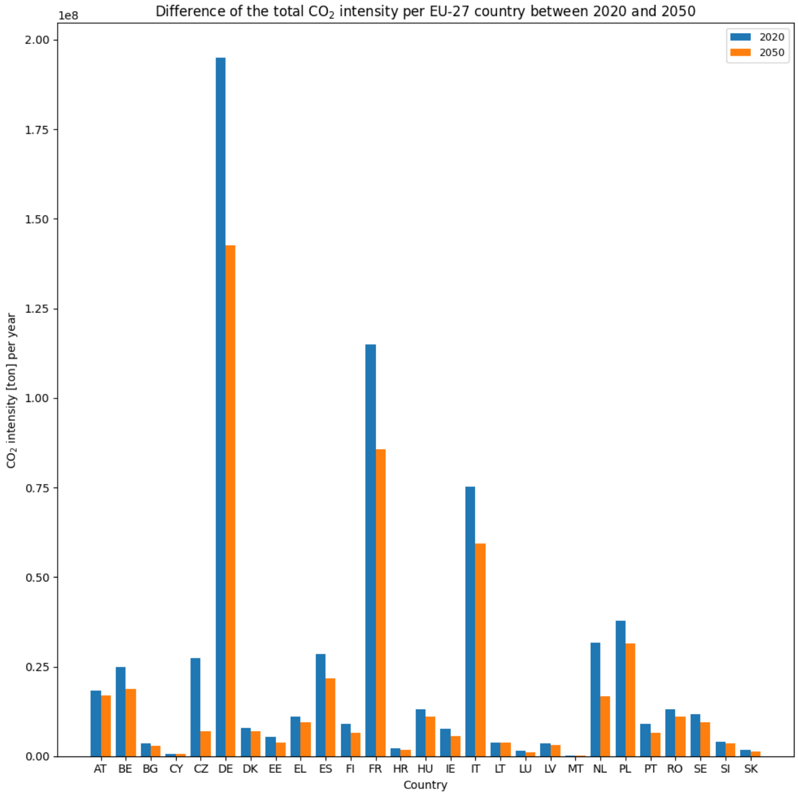


FIGURE 17: AMBIENCE SCENARIO 5 (AS5) TOTAL CO_2 INTENSITY OF EACH EU-27 COUNTRY – CURRENT STATUS *VS* 2050 RESULTS.

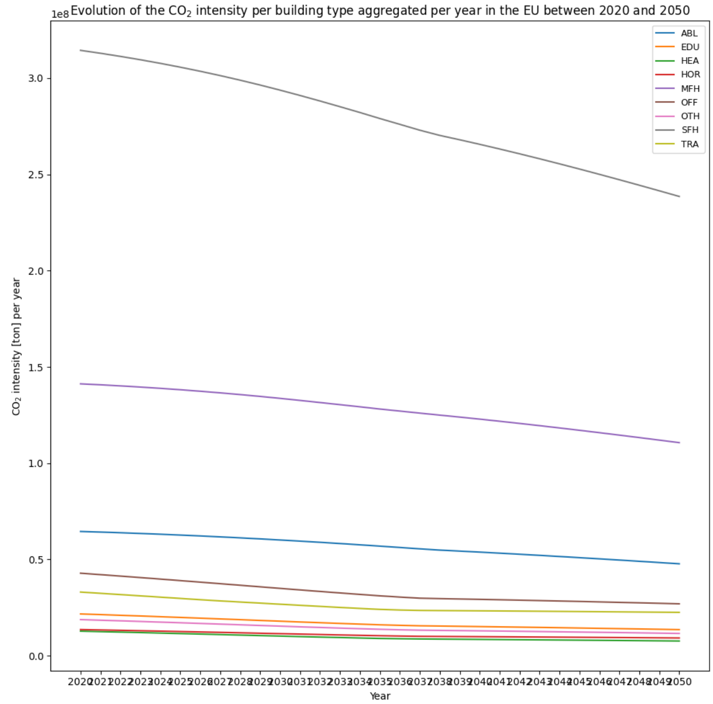


FIGURE 18: AMBIENCE SCENARIO 5 (AS5) EU AGGREGATED CO_2 INTENSITY OF EACH BUILDING TYPOLOGY, PER YEAR.

SFH – SINGLE FAMILY HOUSE; MFH – MULTI FAMILY HOUSE; ABL – APARTMENT BLOCK; HEA – HEALTH; HOR – HOTELS AND RESTAURANTS; OFF – OFFICES; TRA – TRADE; EDU – EDUCATION

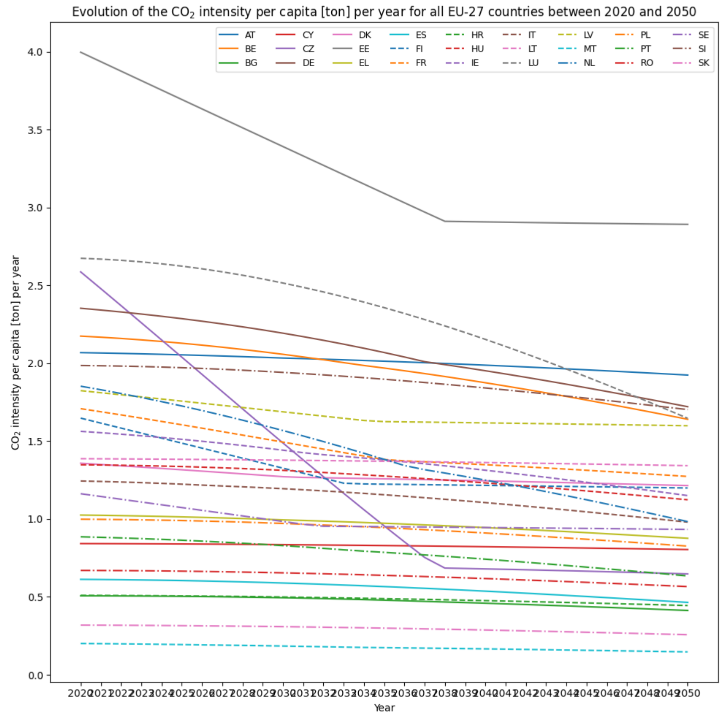


FIGURE 19: AMBIENCE SCENARIO 5 (AS5) EVOLUTION OF CO_2 INTENSITY PER CAPITA, FOR EACH EU-27 COUNTRY

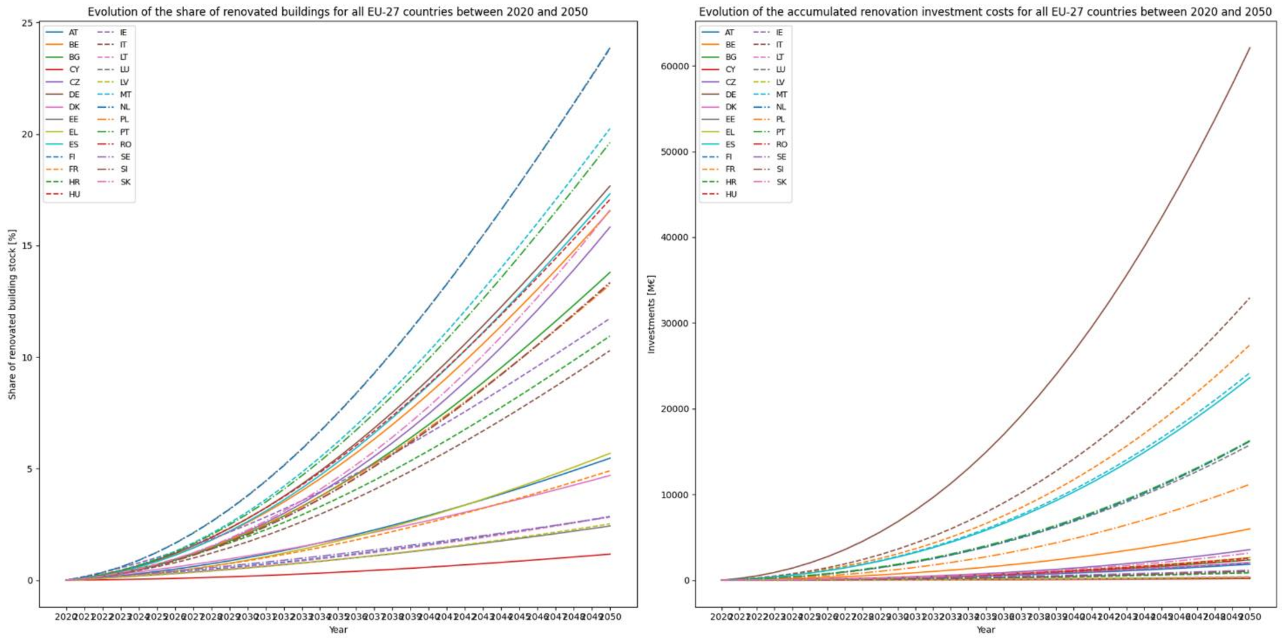


FIGURE 20: AMBIENCE SCENARIO 5 (AS5) SHARE OF RENOVATED BUILDINGS AND CORRESPONDING NECESSARY INVESTMENTS, FOR EACH EU-27 COUNTRY

3.6. ENERGY SYSTEM'S IMPACT ANALYSIS

Strongly based on guidelines, the analysis focused on the energy system decarbonization enablers – renovation, electrification and the active control adoption. The analysis concluded that as the renovation rates increase, logically, the bigger the share of renovated buildings.

The comparison between the sub-optimal AS1 annual renovation rates of 1.5% and the ideal annual renovation rates of 3%, by 2050, could amount to an accumulated avoided 823 kiloton of CO_2 emissions. The associated renovation costs – necessary for promoting the electrification of the building stock – can amount to an accumulated value of 2.74 trillion euros – around 19% of the current (i.e., 2021) EU's GDP [3].

An uptake of electrification at a large scale (represented by the difference between AS4 and AS3 levels) can represent a cumulative avoided CO_2 emissions by 2050 of 559 kilotons of CO_2 – representing 68% of the emissions avoided solely from the renovation of the building stock. The uptake of flexibility services, such as demand response, and active control adoption can further contribute to the successful decarbonization of the energy system – in the same order of magnitude of the impacts of renovating the building stock, highlighting the key-role which flexibility and the adoption of active control within the building stock will play in the energy transition.

Finally, and reflected by AS5, achieving the climatic targets for 2050 can contribute to the reduction of the European carbon intensity of around 26%, paving the way to the energy system's decarbonization.

4. WORKSHOP CONDUCTED ON VALIDATION OF THE SCENARIOS, METHODOLOGIES AND HYPOTHESIS APPLIED

4.1. CONTENT OF THE AGENDA

The stakeholder workshop was held on April 28, 2022. The agenda included:

15:30-15:40	**Welcome and introduction to the Ambience project** *Jesse Glicker, Project Manager, BPIE*
15:40-15:50	**Methodology and key assumptions** *João Cravinho, EDP*
15:50-16:00	**Key performance indicators and calculation tool** *Jan Diriken, Researcher, VITO*
16:00-16:10	**Optimization on costs and carbon intensity** *Sarnavi Mahesh, Senior Researcher, VITO*
16:10-16:40	**Discussion of results** *Jesse Glicker, Project Manager, BPIE and Xerome Fernández Álvarez, Researcher, BPIE*
16:40-16:50	**Wrap up and conclusions** *Jesse Glicker, Project Manager, BPIE*

4.2. STAKEHOLDERS PRESENT

Stakeholder organisations present at the workshop were:

1. VITO	8. Energinvest
2. CENSE FCT-NOVA	9. Ville de la Louvière
3. INESC TEC	10. BAM Energy Systems
4. EDP New	11. VINCI Facilities
5. ENEA	12. Sia Partners
6. Malvar Controls, Lda.	13. Agency for Energy Efficiency and Environment – Romania
7. Ep group	14. BPIE

5. CONCLUSIONS

There were no particular comments from the stakeholders during the call objecting the scenarios' assumptions, as they were deemed reasonable and based on sound data. Additionally, the audience didn't raise any objection when primary questions were asked regarding points of clarification on the analysis conducted, as these were considered well explained during the presentations given.

It was therefore concluded that the scenarios and the methodology applied were validated and thus suitable for the purposes of the project.

6. REFERENCES

[1] A. database, https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fambience-project.eu%2Fwp-content%2Fuploads%2F2022%2F03%2FAmBIENCe_Deliverable-4.1_Database-of-greybox-model-parameter-values.xlsx&wdOrigin=BROWSELINK, 2021.

[2] J. Cravinho, I. Jankovic, J. Diriken, X. Fernandez and S. Mahesh, "D4.2- Report on the methodology of creating the scenarios, integrating the models and active control adopt assumption (AmBIENCe project deliverable)," 2022.

[3] The World Bank, "GDP (current US$) - European Union," 2022. [Online]. Available: https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.MKTP.CD&country=EUU. [Accessed May 2022].

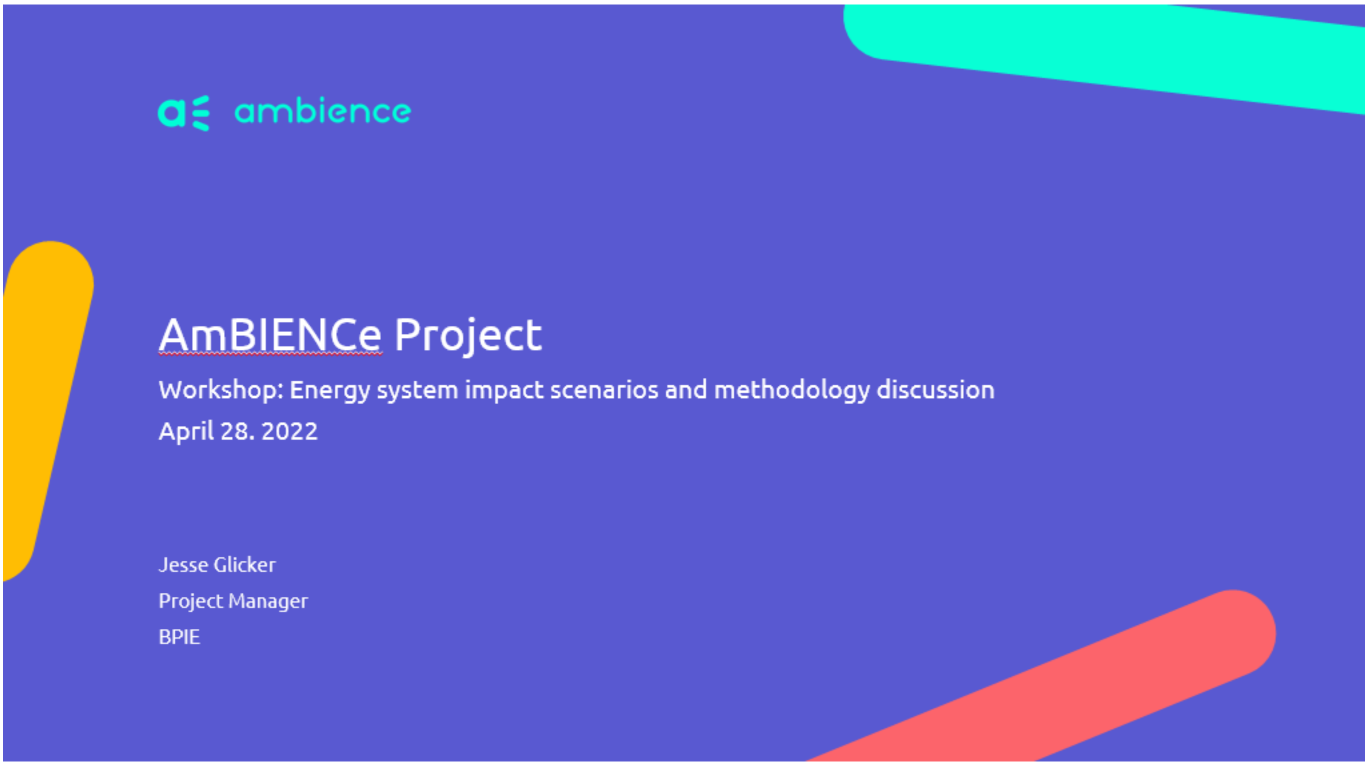
[4] Eurostat, "Simplified energy balances," 14 04 2022. [Online]. Available: https://ec.europa.eu/eurostat/databrowser/view/NRG_BAL_S__custom_2608841/default/table?lang=en.

7. ABBREVIATIONS

ABL	Apartment Block
AEPC	Active building Energy Performance Contract
AS	AmBIENCe scenario
DR	Demand Response
EDU	Education
EPC	Energy Performance Contract
GHG	Greenhouse gas
HEA	Health
HOR	Hotels and Restaurants
KPI	Key Performance Indicators
MFH	Multi Family House
OFF	Offices
SFH	Single Family House
TRA	Trade

8. ANNEX I

Below are the slides presented during the workshop: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AmBIENCe Project
Workshop: Energy system impact scenarios and methodology discussion
April 28. 2022
Jesse Glicker
Project Manager
BPIE


On the call today
ambience
Jesse Glicker
Moderator
BPIE
Xerome Fernández Álvarez
BPIE
edp
João Cravinho
EPD CNET
Jan Diriken
VITO
Sarnavi Mahesh
VITO

Agenda

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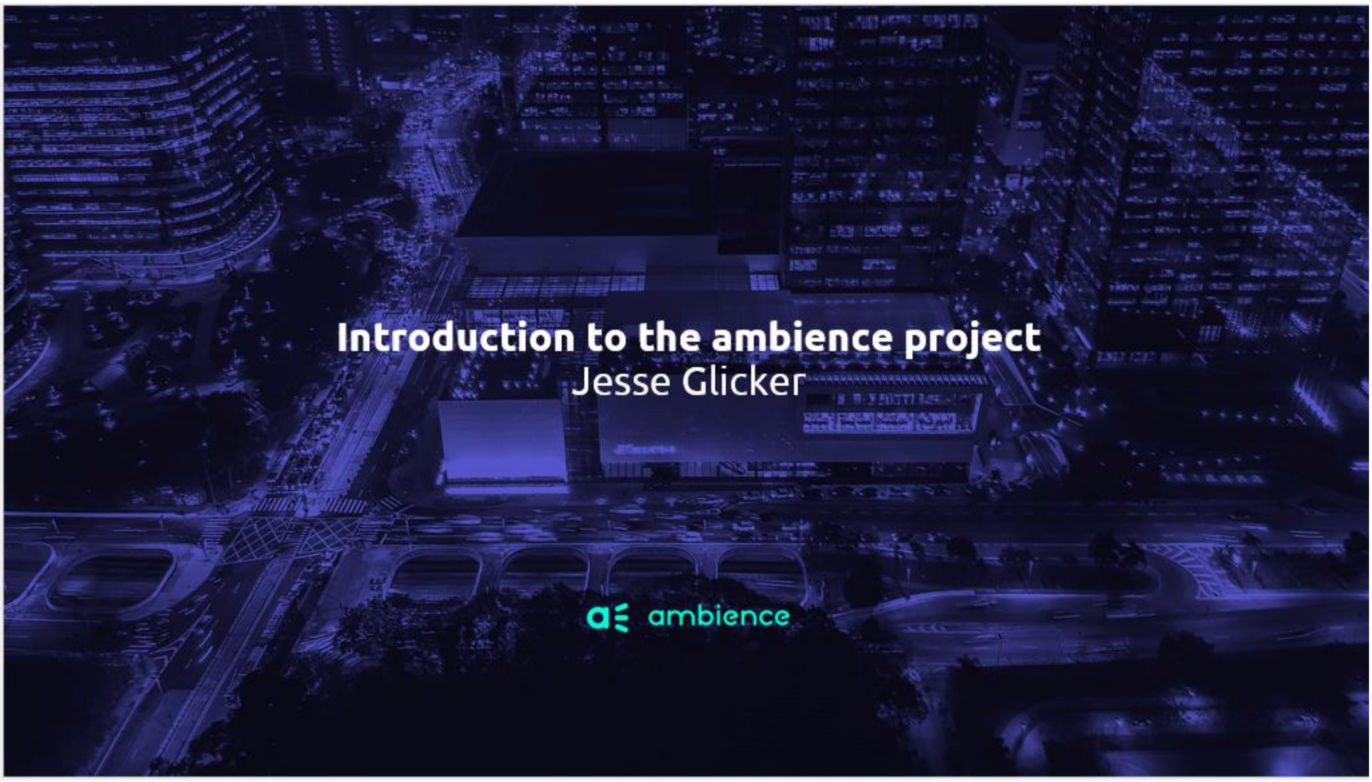
In this workshop the methodology, scenarios, and assumptions to achieve nearly zero emission buildings by 2050 will be proposed to specialists in the building and energy sector. After an in-depth discussion, the methodology, scenarios, and assumptions will be validated with specialists in the building and energy sector.

15:30-16:50	
15:30-15:40	**Welcome and introduction to the Ambience project** Jesse Glicker, Project Manager, BPIE
15:40-15:50	**Methodology and key assumptions** Joao Cravinho, EDP
15:50-16:00	**Key performance indicators and calculation tool** Jan Diriken, Researcher, VITO
16:00-16:10	**Optimization on energy costs and carbon emissions** Sarnavi Mahesh, Senior Researcher, VITO
16:10-16:40	**Discussion of results** Jesse Glicker, Project Manager, BPIE and Xerome Fernandez Alvarez, Researcher, BPIE
16:40-16:50	**Wrap up and conclusions** Jesse Glicker, Project Manager, BPIE



New Concept

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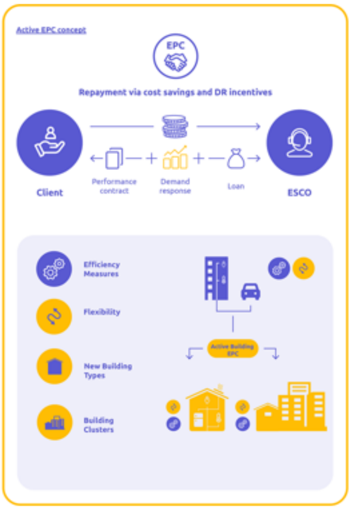
The AmBIENCe concept extends the traditional EPC concept in **3 dimensions:**

Traditional EPC



Active Building EPC

- Extending energy performance guarantees related to energy efficiency to include the valorisation of flexibility through Demand Response (DR) services
- Tailor EPCs to a broad scope of building types: residential, hospitals, education, offices, commerce, etc
- Extending the scope of EPCs to groups/clusters of buildings under the concept of (local) energy communities.

18/05/2022

Vision and Mission

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VISION: Reduced building emissions in the EU, as well as lower energy consumption, thanks to the application of **electrification combined with active control.**

- **Electrification** (of heating and hot water production) reduces emissions because compared to gas, electricity produces heat more efficiently and has a lower carbon intensity.
- **The carbon intensity of electricity** will continue to drop by more investments in wind and PV.
- **The carbon intensity** varies over the day, and the intra-day variability increases: emissions can be reduced by being smart and conscious about **WHEN** energy is consumed.

MISSION: Improve the economic attractiveness of building emission reduction measures by combining energy efficiency improvements with electrification and active control.

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New Opportunity: Buildings will become more digital and smarter

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Smarter: Active control based on data and measurements. Active management enables significant emission savings in a cost-effective way.

Smarter: Active control leveraging machine learning (e.g. smart thermostats)

More digital: adding sensors, meters, ICT, …
- to improve comfort, security, …. (non-energy)
- to support M&V (e.g. but not exclusively in the context of EPC)

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Active managed Buildings **with Energy Performance Contracting**

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GOALS and objectives : WHAT will we do?

- Extend the Energy Performance Contracting concept to include Demand Response value streams, valorizing the flexibility that is available in Active Buildings*.
- Make this Active Building EPC concept applicable to a broader range of buildings (incl. residential) and clusters of buildings.
- Develop a tool that supports the forecast of the DR value stream in the EPC contracting phase, along with a matching M&V methodology for the operational phase.
- Validate the concept, tool and M&V methodology through two pilots (real buildings, real ESCOs).
- Engage with all relevant actors and stakeholder groups (from building managers to ESCOs, policy makers and financial institutions) to remove barriers and ensure applicability.

***Active Buildings:** equipped with sensors, meters, ICT that enables them to optimally control the consumption of flexible assets and storage.

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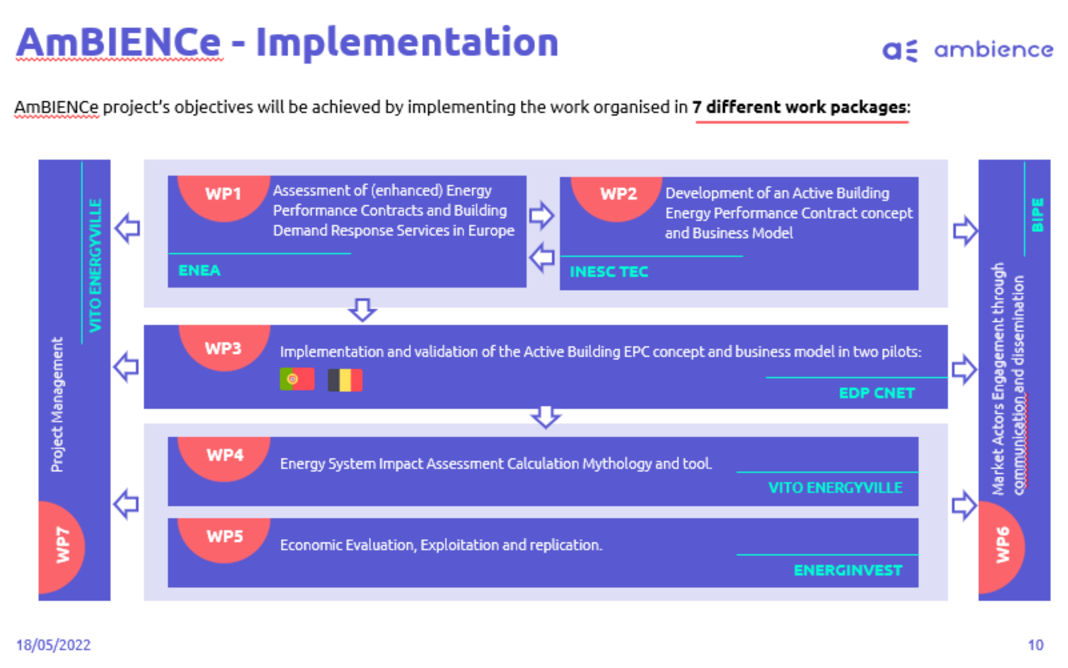
AmBIENCe - Implementation
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AmBIENCe project's objectives will be achieved by implementing the work organised in **7 different work packages**:
WP1
Assessment of (enhanced) Energy Performance Contracts and Building Demand Response Services in Europe
ENEA
WP2
Development of an Active Building Energy Performance Contract concept and Business Model
INESC TEC
WP3
Implementation and validation of the Active Building EPC concept and business model in two pilots:
EDP CNET
WP4
Energy System Impact Assessment Calculation Mythology and tool.
VITO ENERGYVILLE
WP5
Economic Evaluation, Exploitation and replication.
ENERGINVEST
WP7
Project Management
VITO ENERGYVILLE
WP6
Market Actors Engagement through communication and dissemination
BIPE
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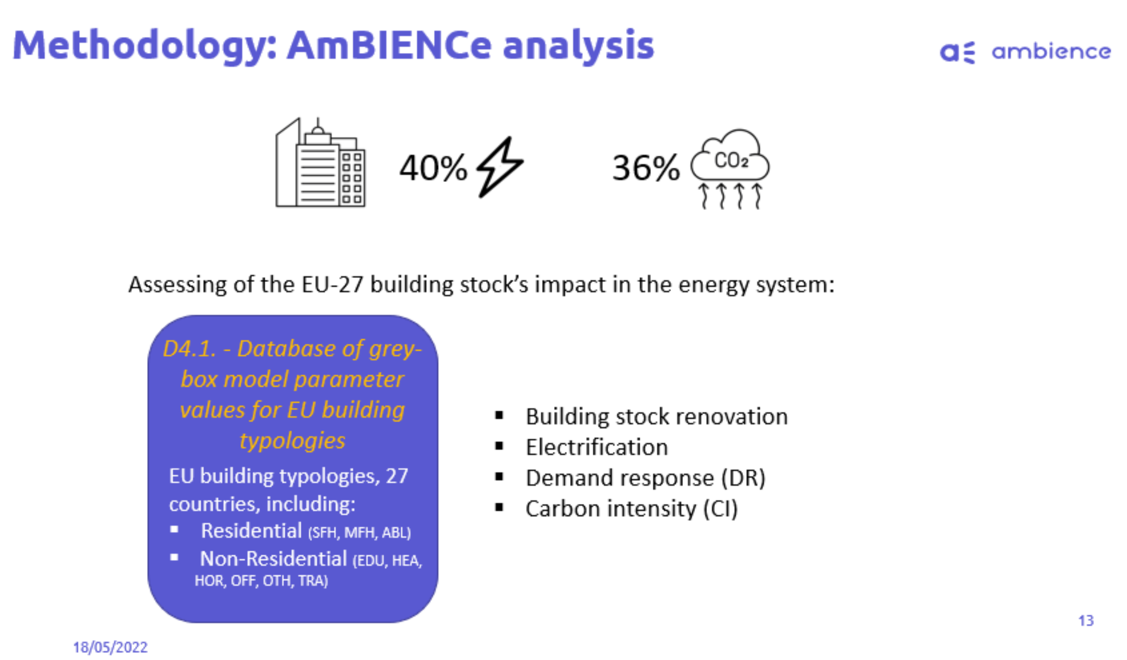
Methodology and key assumptions
João Cravinho
ambience



Sources: 4- "Commission Recommendation (EU) 2019/1019 of 7 June 2019 on building modernization," 2019. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019H1019;

AmBIENCe scenario: decarbonization targets

ambience

Climate policies

- Intermediate target of 55% CO_2 emissions reduction compared to historical baseline (1990), by 2030
- Achieve climate neutrality by 2050 (LTS – Long Term Strategy)

2020 2030 2050 LTS

Energy efficiency

- Intermidiate target of achieving 32.5% increase in energy efficiency in EU's final and primary energy consumption
- Renovation and electrification of building stock

RES (Renewable Energy Sources)

- 32% share of renewable energy in the final energy consumption by 2030
- Achieve high overall share of RES in power generation

Demand

- Demand response (DR) services will ensure active control within the building stock while providing more flexibility to the energy system and end-consumers – gradually available throughout each of the EU-27 Member States (MS).

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Sources: 1- European Council, "Long-term low greenhouse gas emission development strategy of the European Union," 6 March 2020. [Online]. Available: https://unfccc.int/sites/default/files/resource/HR-03-06-2020%20EU%20Submission%20on%20Long%20term%20strategy.pdf; 2- European Commission, Directorate-General for Energy , "Energy: Roadmap 2050 Impact Assessment and scenario analysis," [Online]. Available: Available at https://ec.europa.eu/energy/sites/ener/files/documents/roadmap2050_ia_20120430_en_0.pdf; 3- A. Esser, A. Dunne, T. Meeusen, S. Quaschning, D. Wegge, A. Hermelink, S. Schimschar, M. Offermann, A. John, M. Reiser, A. Pohl e J. Grözinger, "European Commission: Comprehensive study of building energy renovation activities and the uptake (Annex to final report)," November 2019. [Online]. Available: https://ec.europa.eu/energy/sites/ener/files/documents/2.annex_to_final_report.pdf. [Acedido em March 2022].

AmBIENCe within AmBIENCe: renovating the building stock

ambience

"Today, roughly 75% of the EU building stock is energy inefficient"

Light/Shallow		Medium		Deep	
Renovations which decrease primary energy demand of a building between 3% and 30%	Roof	Renovations which decrease primary energy demand of a building between 30% and 60%	Roof and walls	Renovations which decrease primary energy demand of a building >60%.	Full renovation
	Walls		Roof and windows		
	Windows		Walls and windows		

2020 2030 2050

1% 3%

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Sources: 5- European Council, "Long-term low greenhouse gas emission development strategy of the European Union," 6 March 2020. [Online]. Available: https://unfccc.int/sites/default/files/resource/HR-03-06-2020%20EU%20Submission%20on%20Long%20term%20strategy.pdf; 3- A. Esser, A. Dunne, T. Meeusen, S. Quaschning, D. Wegge, A. Hermelink, S. Scimschar, M. Offermann, A. John, M. Reiser, A. Pohl e J. Grözinger, "Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings (Final report)," European Comission, 2019; 6- A. Roscini e J. Kockat, "D2.8 - Results from EUCalc: Pathways Explorer for the building sector: European and Member States insights." (project

AmBIENCe within AmBIENCe: scenarios for the building stock renovation

ambience

2020 2030 2050

Renovation rate: 1%
- Light renovations (80%)
- Medium renovations (15%)
- Deep renovations (5%)

AmBIENCe scenario 1 (AS1): 1.5%
- Light renovations (20%)
- Medium renovations (60%)
- Deep renovations (20%)

AmBIENCe scenario 2 (AS2): 2%
- Light renovations (10%)
- Medium renovations (70%)
- Deep renovations (20%)

AmBIENCe scenario 3 (AS3): 3%
- Medium renovations (30%)
- Deep renovations (70%)

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Sources: 3- A. Esser, A. Dunne, T. Meeusen, S. Quaschning, D. Wegge, A. Hermelink, S. Scimschar, M. Offermann, A. John, M. Reiser, A. Pohl e J. Grözinger, "Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings (Final report)," European Comission, 2019; 6- A. Roscini e J. Kockat, "D2.8 - Results from EUCalc: Pathways Explorer for the building sector: European and Member States insights." (project deliverable), 2019.

AmBIENCe within AmBIENCe: Electrification impact and cost assessment

ambience

- What is the impact of electrification of the EU-27 building stock?

Electrification uptake	
80%	40%
AS1-3	AS4

- What are the associated costs of renovating the building stock?

Building Element	Renovation	Price
Walls	Air chambers filling	12-18 EUR/m2 (40mm)
Roofs	Internal insulation of roofs	17-42 EUR/m2
Windows	Glazing replacement with 8-20-6mm glazing low emissive (1,4 W/m2/K)	160 EUR/m2

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Source: 7- https://constructioncosts.eu/cost-index/

AmBIENCe within AmBIENCe: Unlocking flexibility through Demand Response (DR)

ambience

"DR and consumer empowerment are integral parts of the Energy Union and the Clean Energy Package for all Europeans"

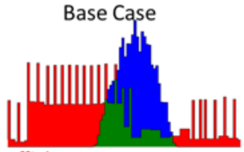
- Minimize energy consumption (offtake from grid)

D4.1. - Database of grey-box model parameter values for EU building typologies

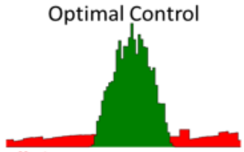
EU 27 building typologies, 27 countries, including:

- Residential (SFH, MFH, ABL)
- Non-Residential (EDU, HEA, HOR, OFF, OTH, TRA)

Base Case



Optimal Control



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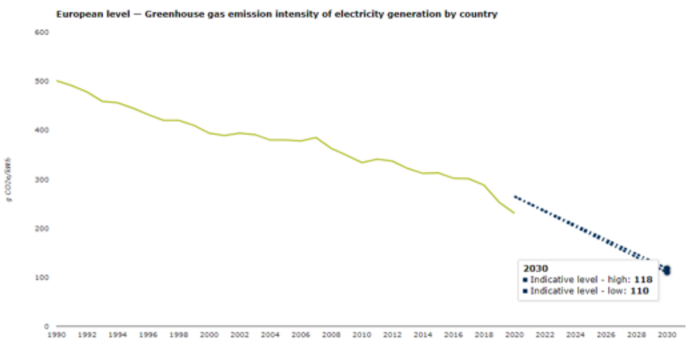
Source: 8- M. Di Somma, M. Caliano, C. Cancro, G. Rossi, J. Vanschoenwinkel, A. V. L. Delnooz, J. Costa, R. Santos, P. Kessler, J. Glicer, I. Alonso e F. . Díez, "D1.1 - Analysis of directives, policies, measures and regulation relevant for the Active Building EPC concept and business models. (project deliverable)," 2020. .

AmBIENCe within AmBIENCe: Carbon intensity (CI)

ambience

"The EU electricity sector is expected to provide one of the most significant contributions to climate mitigation targets by 2030 and be a cornerstone for the Union to reach net climate neutrality by 2050"

- CI as a quantifiable measure to the building stock's impact on the energy system
- CI targets, by 2050, as a function of the EU-27 decarbonization targets



Removed from: European Environmental Agency, "Greenhouse gas emission intensity of electricity generation in Europe,"

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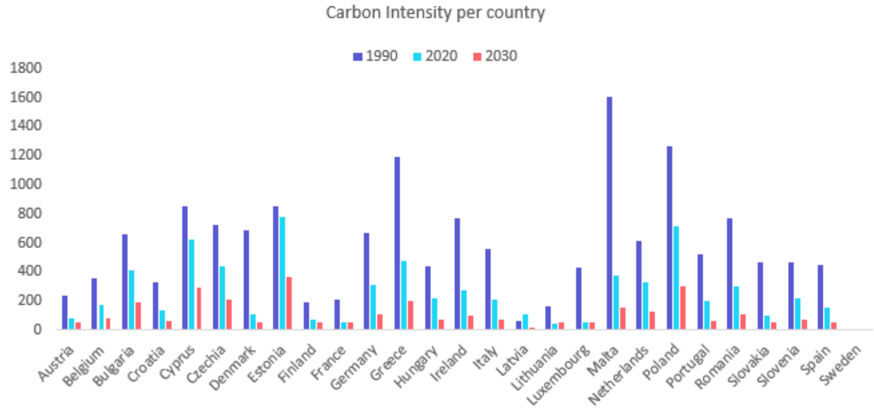
Source: 9- European Environmental Agency, "Greenhouse gas emission intensity of electricity generation in Europe," 18 November 2021. [Online]. Available: https://www.eea.europa.eu/ims/greenhouse-gas-emission-intensity-of-1.

Carbon intensity (CI): Quantifying the building stock's impact



2030

Account for decarbonization targets:

- Reduction of GHG emissions by 55% (2030 target)
- Increase of RES share in energy mix

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Source: 9- European Environmental Agency, "Greenhouse gas emission intensity of electricity generation in Europe," 18 November 2021. [Online]. Available: https://www.eea.europa.eu/ims/greenhouse-gas-emission-intensity-of-1.
10- Eurostat, "Energy statistics – an overview". Available: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_statistics_-_an_overview.

AmBIENCe inception: scenarios within scenarios

AmBIENCe Scenario (AS)	Description		
SCENARIO 1 (AS1)	**Renovation Rates:** - Start year renovation rate (2020) of **1%**, of which: - 80% shallow renovations - 15% medium renovations - 5% deep renovations - End year renovation rate (2050) of **1.5%**, of which: - 20% are shallow renovations - 60% medium renovations - 20% deep/full renovations	Carbon Intensity as a funciton of GHG targets	Electrification uptake: 80%
SCENARIO 2 (AS2)	**Renovation Rates:** - Start year renovation rate (2020) of **1%** (**AS1**): - End year renovation rate (2050) of **2.0%**, of which: - 10% shallow renovations - 70% medium renovations - 20% deep renovations	Carbon Intensity as a funciton of GHG targets	Electrification uptake: 80%
SCENARIO 3 (AS3)	**Renovation Rates:** - Start year renovation rate (2020) of **1%**, (**AS1**): - End year renovation rate (2050) of **3.0%**, of which: - 70% medium renovations - 30% deep/full renovations	Carbon Intensity as a funciton of GHG targets	Electrification uptake: 80%
SCENARIO 4 (AS4)	**Renovation Rates: AS3**	Carbon Intensity as a funciton of GHG targets	Electrification uptake: 40%

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AmBIENCe Scenario 3: Results

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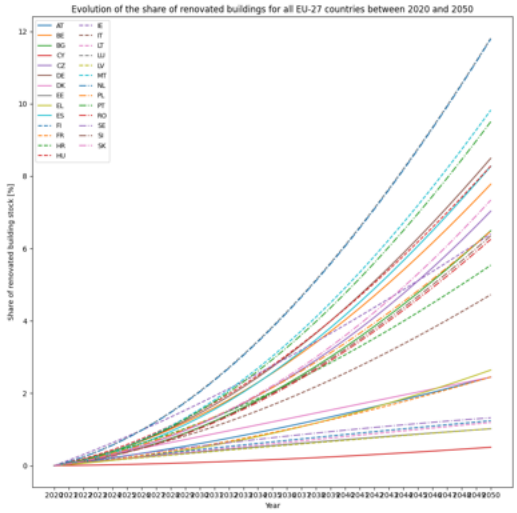

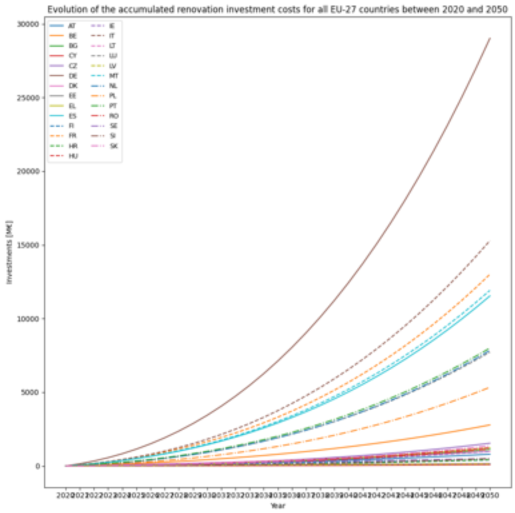

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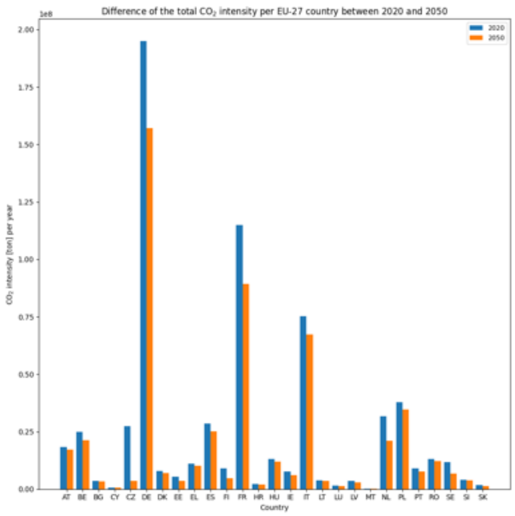
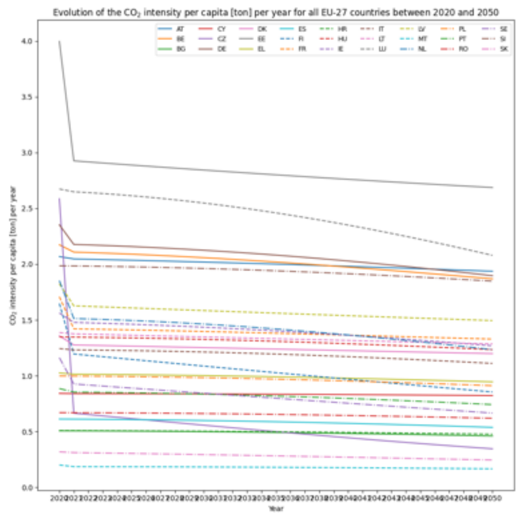
AmBIENCe Scenario 3: Results

ambience





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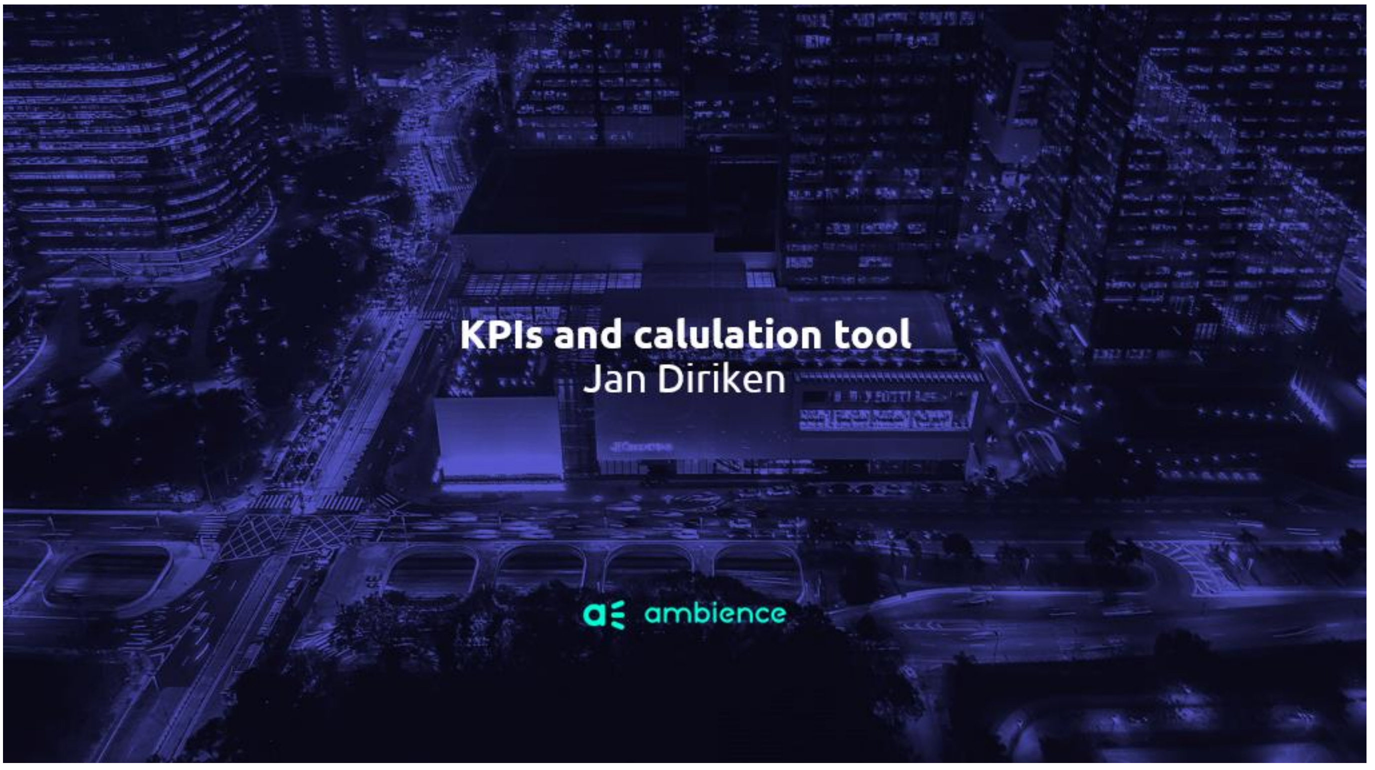
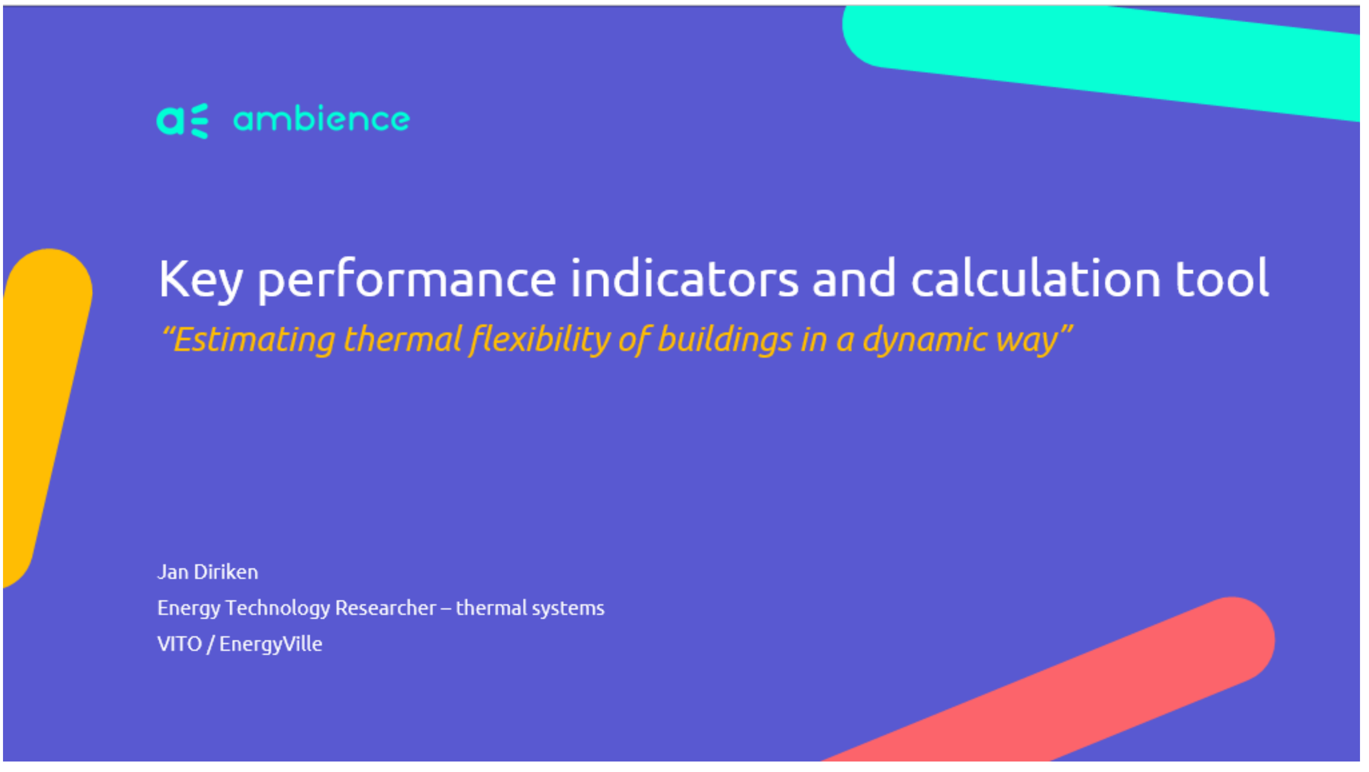

KPIs and calulation tool
Jan Diriken
ambience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Key performance indicators and calculation tool
"Estimating thermal flexibility of buildings in a dynamic way"
Jan Diriken
Energy Technology Researcher – thermal systems
VITO / EnergyVille

Contents

Methodology

Inputs

Results

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Methodology: What to include?

- Entire EU-27 building stock
- Different energy systems
- Effects of possible renovation measures and rates
- Effects of electrification of the energy system including uptake of Demand Response
- Evolution of the electricity carbon intensity of the coming years

Combined methodology as a Python simulation tool which can be used easily to estimate the effect of different input parameters on the CO_2 emissions (KPI)

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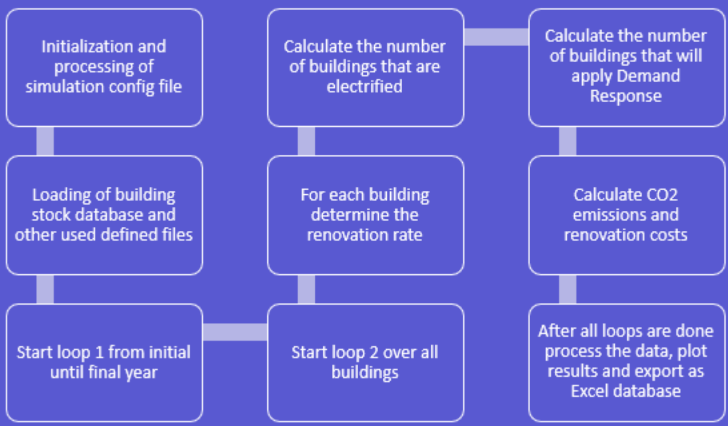
Methodology: flow



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User input (as cfg-file)

[GENERAL]
input = data/full_db_2.xlsx
output = scenario_analysis.xlsx
s_year = 2018
e_year = 2030

[CO2INT]
biomass = 230
natgas = 227
liquid = 314
solid = 414
electricity = data/co2_el_2018.csv
el_co2_decl_rate = 0.07
el_co2_decl_mode = 0
el_co2_min = 50

[RENOVATION]
renovation_rate.roof.s = 0.05
renovation_rate.roof.e = 0.15
renovation_rate.none.s = 0
renovation_rate.none.e = 0
renovation_rate.walls.s = 0.01
renovation_rate.walls.e = 0.05
renovation_rate.windows.s = 0.01
renovation_rate.windows.e = 0.015
renovation_rate.roofwalls.s = 0.001
renovation_rate.roofwalls.e = 0.01
renovation_rate.roofwindows.s = 0.001
renovation_rate.roofwindows.e = 0.01
renovation_rate.wallwindows.s = 0.001
renovation_rate.wallwindows.e = 0.005
renovation_rate.full.s = 0.0001
renovation_rate.full.e = 0.001
renovation_mode = 0
renovation_el_switch_rate = 0.8
cost_index_file = data/cost_index.csv
cost_file = data/cost_renovation.csv
cost_inflation = 0.025

[FLEXIBILITY]
flex_uptake.s = 0.02
flex_uptake.e = 0.20
flex_result = 0.8

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Input: Building Stock Database

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Not sure if needed? I can also mention it on the previous slide that this is based on the info contained in the BPIE database

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Input: electricity Carbon Intensity

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The user can specify the Carbon Intensity [gCO2 per kWh] in the initial year of the simulation

A CO2 declination rate can be specified for each country

In the config file also a minimum CI can be specified (note: if the initial CI is below the minimum, it will remain constant)

Two declination modes can be chosen:

Mode 0: constant decline: $CI_{n+1} = CI_n - decl * CI_{initial}$
Mode 1: dynamic decline $CI_{n+1} = CI_n(1 - decl)$

Country	gCO2_KWH	decl
AT	102	9,5
BE	207	6,4
BG	425	3,3
CY	664	7,6
CZ	445	8,5
DE	406	3,2
DK	189	6,6
EE	900	0,2
EL	662	2,4
ES	276	0,1
FI	111	8,5

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User input: renovation rates and costs

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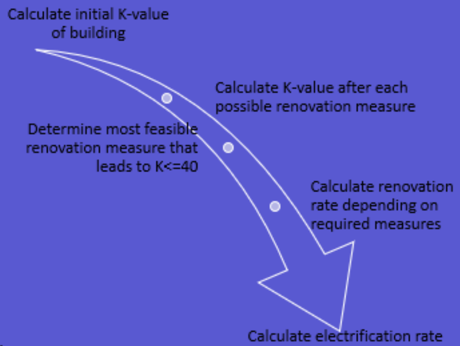

Component	Measure	Cost
Windows	Glazing replacement with 8-20-6mm glazing low emmisive (1,4 W/m2/K)	160 EUR/m2
Roof	Internal insulation of roofs (up to 200 mm)	17-42 EUR/m2
Walls	Filling of 6 cm cavity	13-19 EUR/m2
Floor	Not considered	

Notes:
For buildings not requiring renovation, electrification is still considered!
CO2 emissions due to DR are inputs calculated by ABePEM
A cost index can be specified for each country
A fixed inflation rate can be specified

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Example of results (I)

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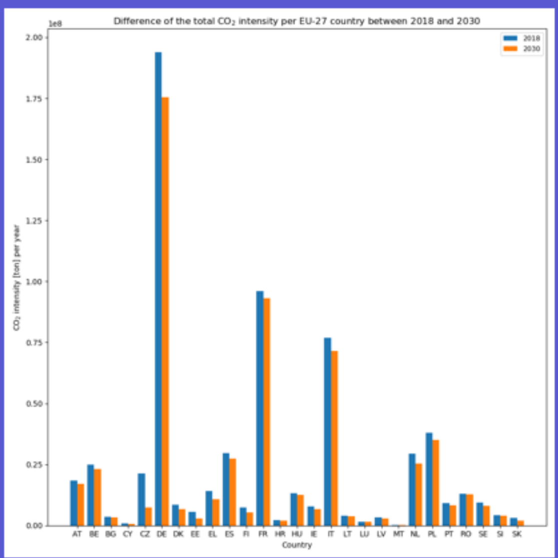

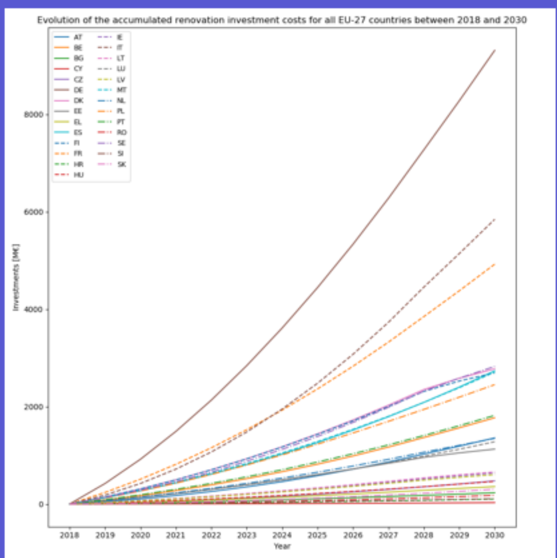

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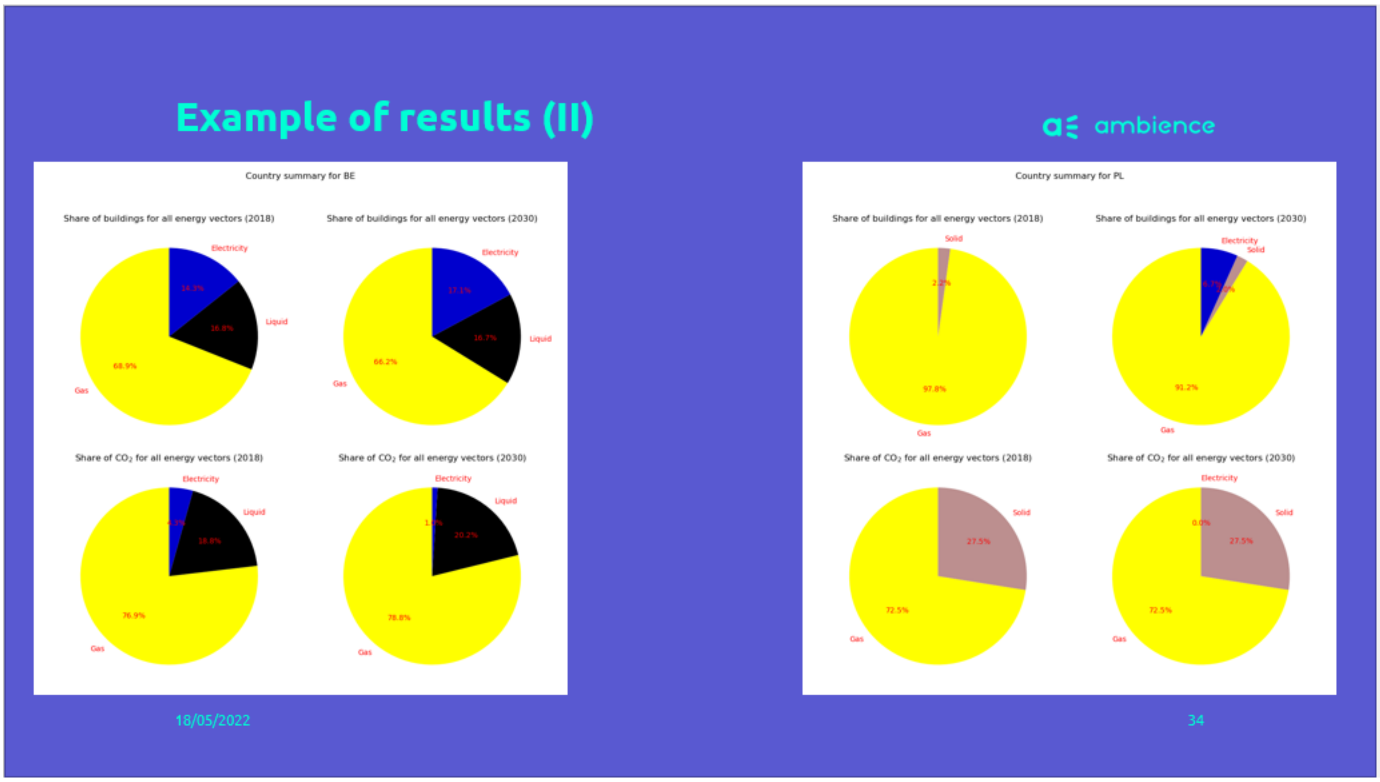
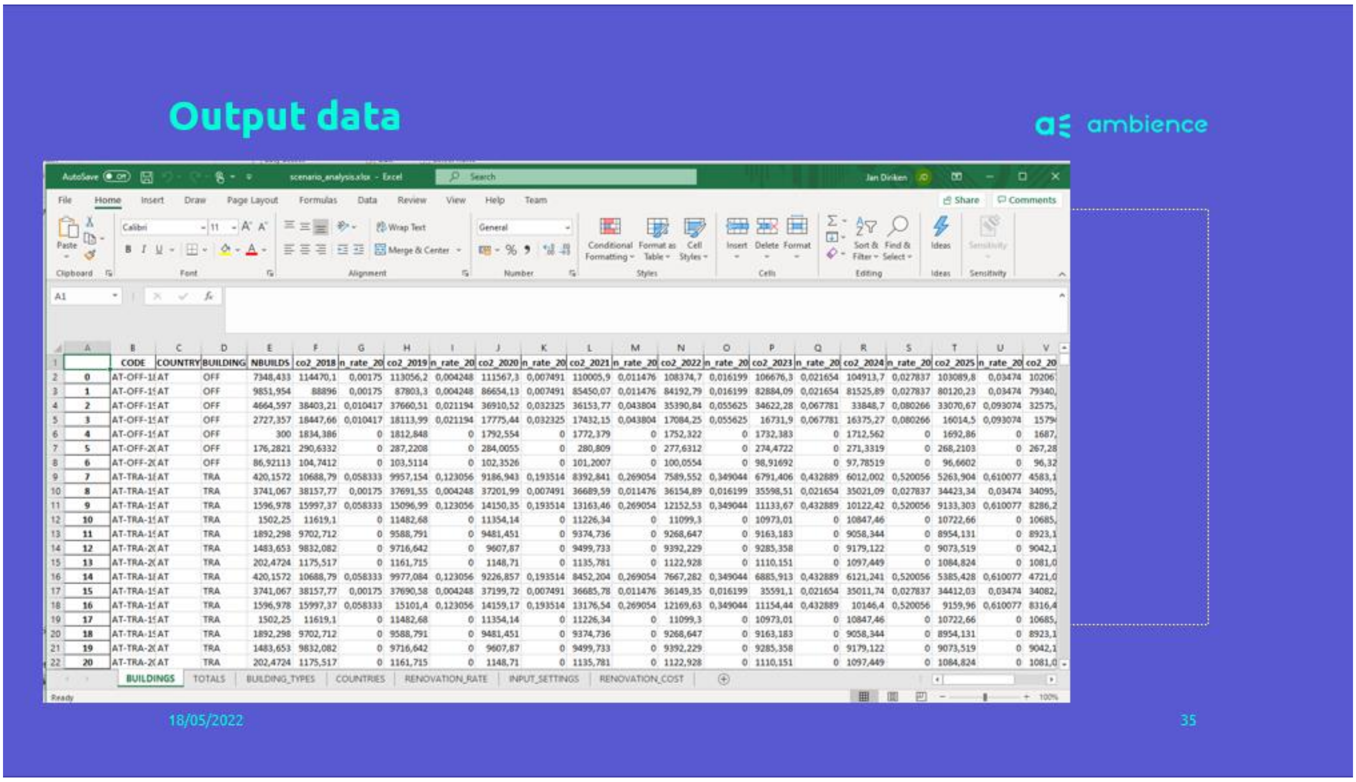
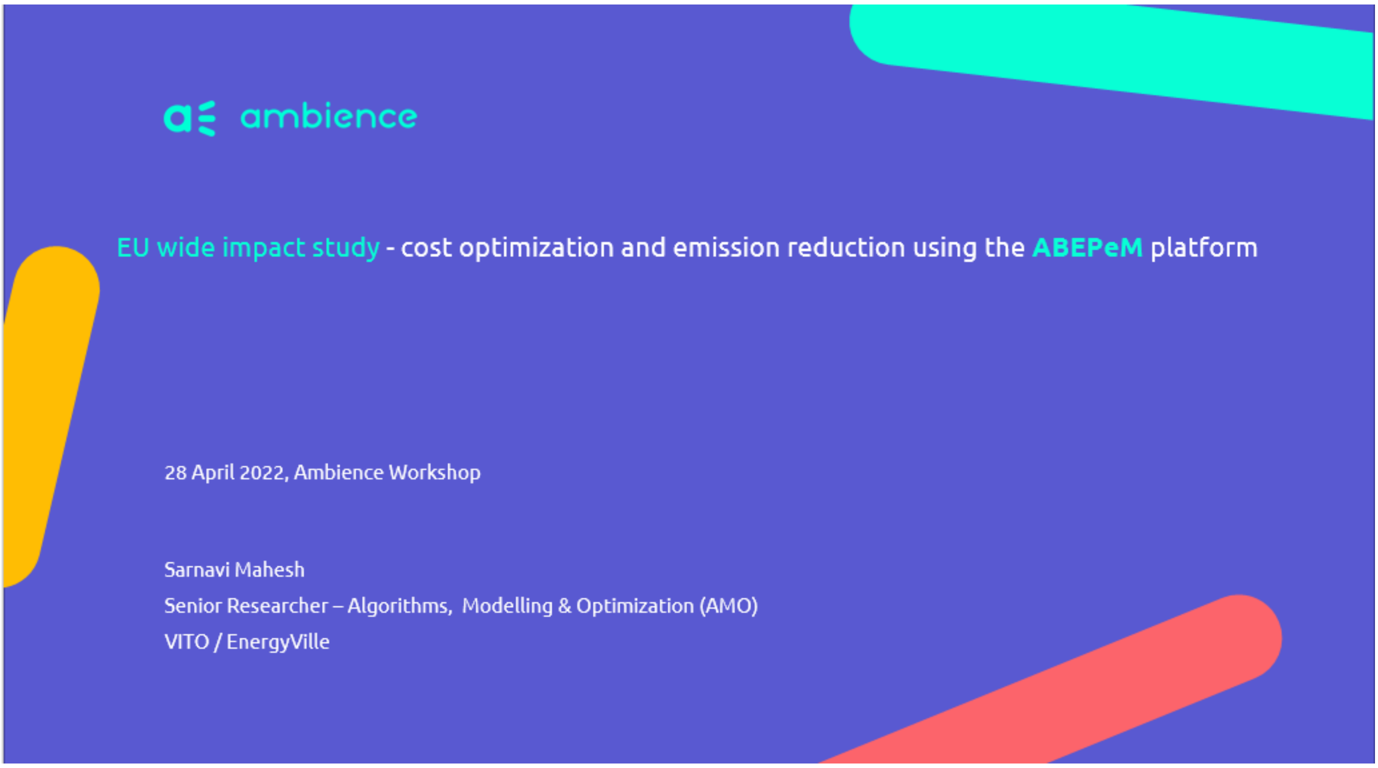




	CODE	COUNTRY	BUILDING	NBUILDS	co2_2018	n_rate_20	co2_2019	n_rate_20	co2_2020
0	AT-OFF-1£	AT	OFF	7348,433	114470,1	0,00175	113056,2	0,004248	111567,3
1	AT-OFF-1!	AT	OFF	9851,954	88896	0,00175	87803,3	0,004248	86654,13
2	AT-OFF-1!	AT	OFF	4664,597	38403,21	0,010417	37660,51	0,021194	36910,52
3	AT-OFF-1!	AT	OFF	2727,357	18447,66	0,010417	18113,99	0,021194	17775,44
4	AT-OFF-1!	AT	OFF	300	1834,386	0	1812,848	0	1792,554
5	AT-OFF-2(	AT	OFF	176,2821	290,6332	0	287,2208	0	284,0055
6	AT-OFF-2(	AT	OFF	86,92113	104,7412	0	103,5114	0	102,3526
7	AT-TRA-1£	AT	TRA	420,1572	10688,79	0,058333	9957,154	0,123056	9186,943
8	AT-TRA-1!	AT	TRA	3741,067	38157,77	0,00175	37691,55	0,004248	37201,99
9	AT-TRA-1!	AT	TRA	1596,978	15997,37	0,058333	15096,99	0,123056	14150,35
10	AT-TRA-1!	AT	TRA	1502,25	11619,1	0	11482,68	0	11354,14
11	AT-TRA-1!	AT	TRA	1892,298	9702,712	0	9588,791	0	9481,451
12	AT-TRA-2(	AT	TRA	1483,653	9832,082	0	9716,642	0	9607,87
13	AT-TRA-2(	AT	TRA	202,4724	1175,517	0	1161,715	0	1148,71
14	AT-TRA-1£	AT	TRA	420,1572	10688,79	0,058333	9977,084	0,123056	9226,857
15	AT-TRA-1!	AT	TRA	3741,067	38157,77	0,00175	37690,58	0,004248	37199,72
16	AT-TRA-1!	AT	TRA	1596,978	15997,37	0,058333	15101,4	0,123056	14159,17
17	AT-TRA-1!	AT	TRA	1502,25	11619,1	0	11482,68	0	11354,14
18	AT-TRA-1!	AT	TRA	1892,298	9702,712	0	9588,791	0	9481,451
19	AT-TRA-2(	AT	TRA	1483,653	9832,082	0	9716,642	0	9607,87
20	AT-TRA-2(	AT	TRA	202,4724	1175,517	0	1161,715	0	1148,71

	n_rate_20	co2_2021	n_rate_20	co2_2022	n_rate_20	co2_2023	n_rate_20	co2_2024	n_rate_20	co2_2025	n_rate_20	co2_20
0	0,007491	110005,9	0,011476	108374,7	0,016199	106676,3	0,021654	104913,7	0,027837	103089,8	0,03474	10206
1	0,007491	85450,07	0,011476	84192,79	0,016199	82884,09	0,021654	81525,89	0,027837	80120,23	0,03474	79340,
2	0,032325	36153,77	0,043804	35390,84	0,055625	34622,28	0,067781	33848,7	0,080266	33070,67	0,093074	32575,
3	0,032325	17432,15	0,043804	17084,25	0,055625	16731,9	0,067781	16375,27	0,080266	16014,5	0,093074	1579
4	0	1772,379	0	1752,322	0	1732,383	0	1712,562	0	1692,86	0	1687,
5	0	280,809	0	277,6312	0	274,4722	0	271,3319	0	268,2103	0	267,28
6	0	101,2007	0	100,0554	0	98,91692	0	97,78519	0	96,6602	0	96,32
7	0,193514	8392,841	0,269054	7589,552	0,349044	6791,406	0,432889	6012,002	0,520056	5263,904	0,610077	4583,1
8	0,007491	36689,59	0,011476	36154,89	0,016199	35598,51	0,021654	35021,09	0,027837	34423,34	0,03474	34095,
9	0,193514	13163,46	0,269054	12152,53	0,349044	11133,67	0,432889	10122,42	0,520056	9133,303	0,610077	8286,2
10	0	11226,34	0	11099,3	0	10973,01	0	10847,46	0	10722,66	0	10685,
11	0	9374,736	0	9268,647	0	9163,183	0	9058,344	0	8954,131	0	8923,1
12	0	9499,733	0	9392,229	0	9285,358	0	9179,122	0	9073,519	0	9042,1
13	0	1135,781	0	1122,928	0	1110,151	0	1097,449	0	1084,824	0	1081,0
14	0,193514	8452,204	0,269054	7667,282	0,349044	6885,913	0,432889	6121,241	0,520056	5385,428	0,610077	4721,0
15	0,007491	36685,78	0,011476	36149,35	0,016199	35591,1	0,021654	35011,74	0,027837	34412,03	0,03474	34082,
16	0,193514	13176,54	0,269054	12169,63	0,349044	11154,44	0,432889	10146,4	0,520056	9159,96	0,610077	8316,4
17	0	11226,34	0	11099,3	0	10973,01	0	10847,46	0	10722,66	0	10685,
18	0	9374,736	0	9268,647	0	9163,183	0	9058,344	0	8954,131	0	8923,1
19	0	9499,733	0	9392,229	0	9285,358	0	9179,122	0	9073,519	0	9042,1
20	0	1135,781	0	1122,928	0	1110,151	0	1097,449	0	1084,824	0	1081,0


Optimization on energy costs and carbon emissions
Sarnavi Mahesh
ambience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EU wide impact study - cost optimization and emission reduction using the ABEPeM platform
28 April 2022, Ambience Workshop
Sarnavi Mahesh
Senior Researcher – Algorithms, Modelling & Optimization (AMO)
VITO / EnergyVille

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- ABEPeM Introduction
- Energy cost cash flow estimation sub-tool

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What is ABEPeM ?

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Active Building Energy Performance Modelling

ABEPeM

1. *Calculate and guarantee* ***operational cost savings*** *and performance* ***KPIs***
2. *Calculate the* ***financial viability*** *of the renovation*
3. *Update* ***performance guarantees*** *during operational phase*

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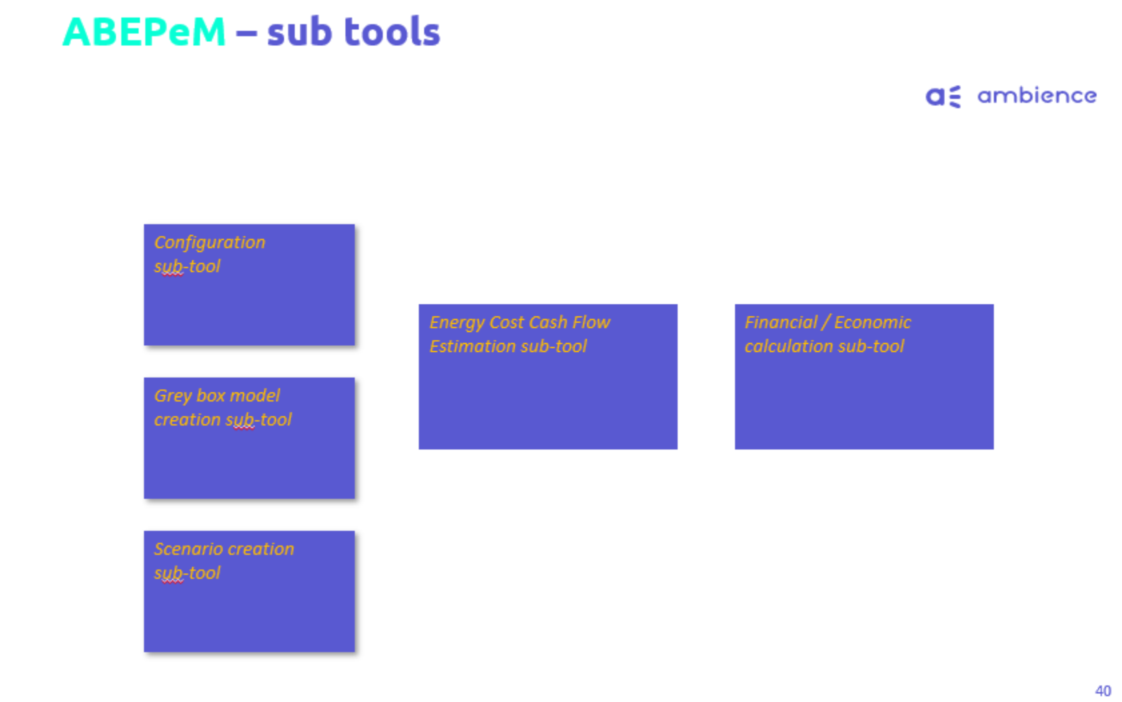
ABEPeM – sub tools
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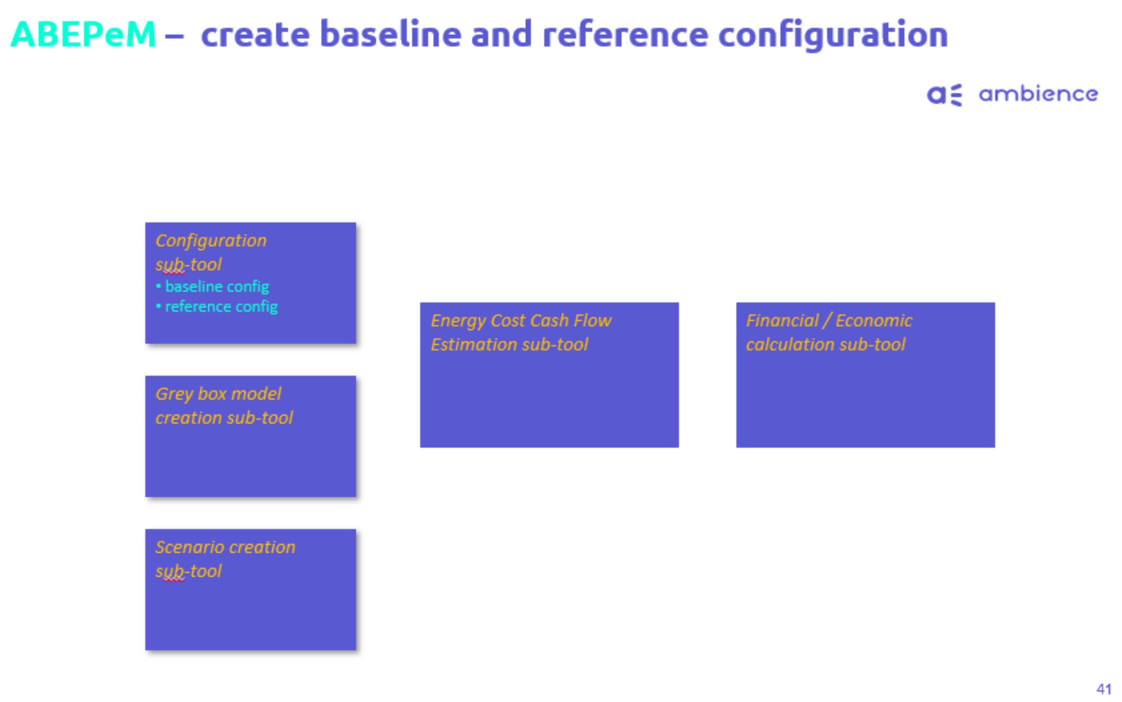
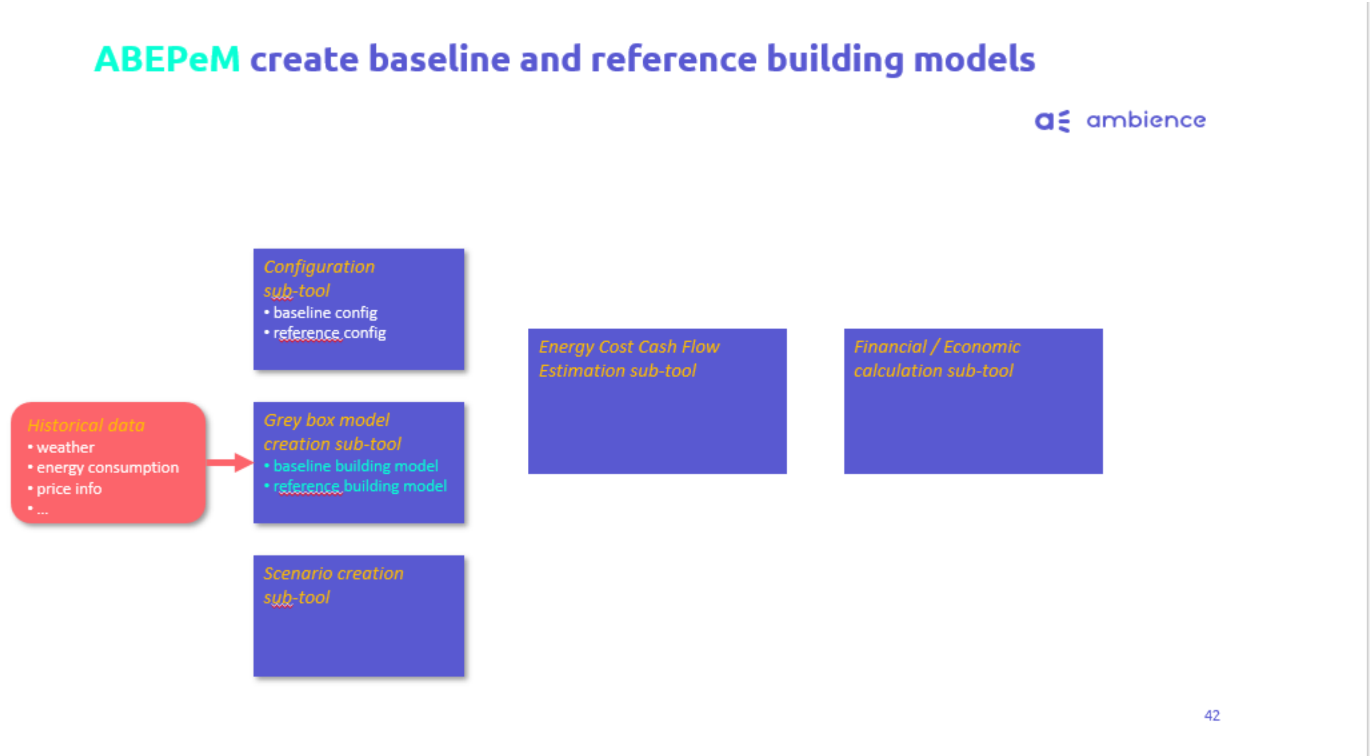
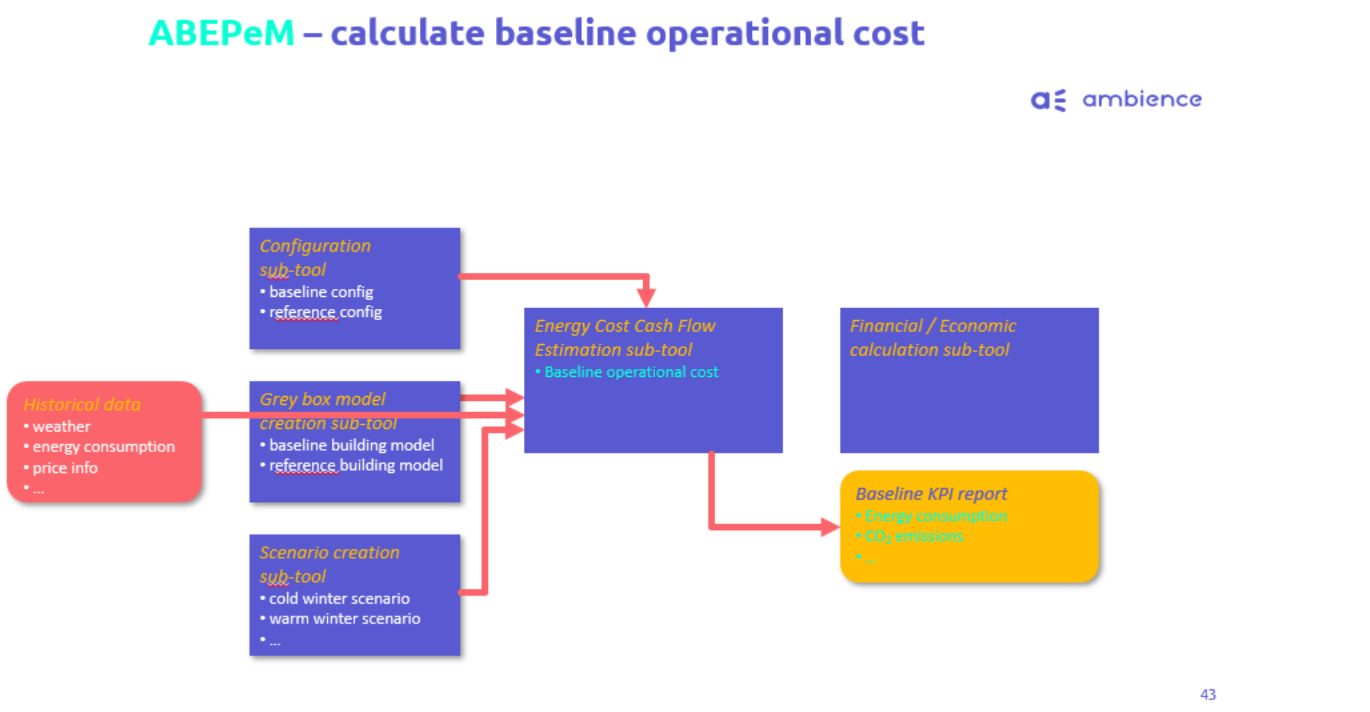
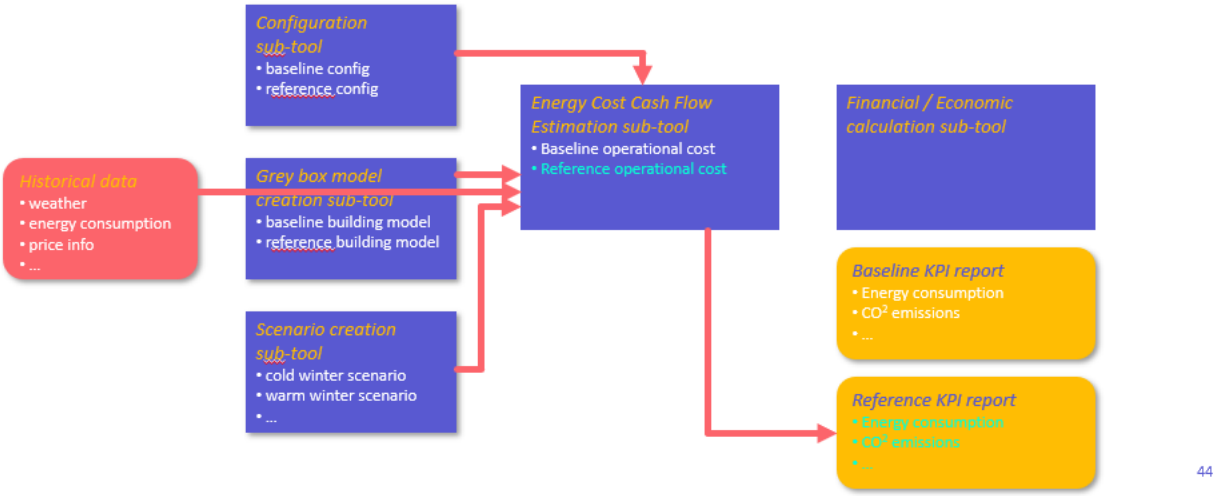
Configuration sub-tool
Grey box model creation sub-tool
Scenario creation sub-tool
Energy Cost Cash Flow Estimation sub-tool
Financial / Economic calculation sub-tool
40


ABEPeM – create baseline and reference configuration
ambience
Configuration sub-tool
• baseline config
• reference config
Grey box model creation sub-tool
Scenario creation sub-tool
Energy Cost Cash Flow Estimation sub-tool
Financial / Economic calculation sub-tool
41


ABEPeM create baseline and reference building models
ambience
Configuration sub-tool
• baseline config
• reference config
Historical data
• weather
• energy consumption
• price info
• ...
Grey box model creation sub-tool
• baseline building model
• reference building model
Scenario creation sub-tool
Energy Cost Cash Flow Estimation sub-tool
Financial / Economic calculation sub-tool
42


ABEPeM – calculate baseline operational cost
ambience
Configuration sub-tool
• baseline config
• reference config
Historical data
• weather
• energy consumption
• price info
• ...
Grey box model creation sub-tool
• baseline building model
• reference building model
Scenario creation sub-tool
• cold winter scenario
• warm winter scenario
• ...
Energy Cost Cash Flow Estimation sub-tool
• Baseline operational cost
Financial / Economic calculation sub-tool
Baseline KPI report
• Energy consumption
• CO2 emissions
• ...
43

ABEPeM – calculate reference operational cost



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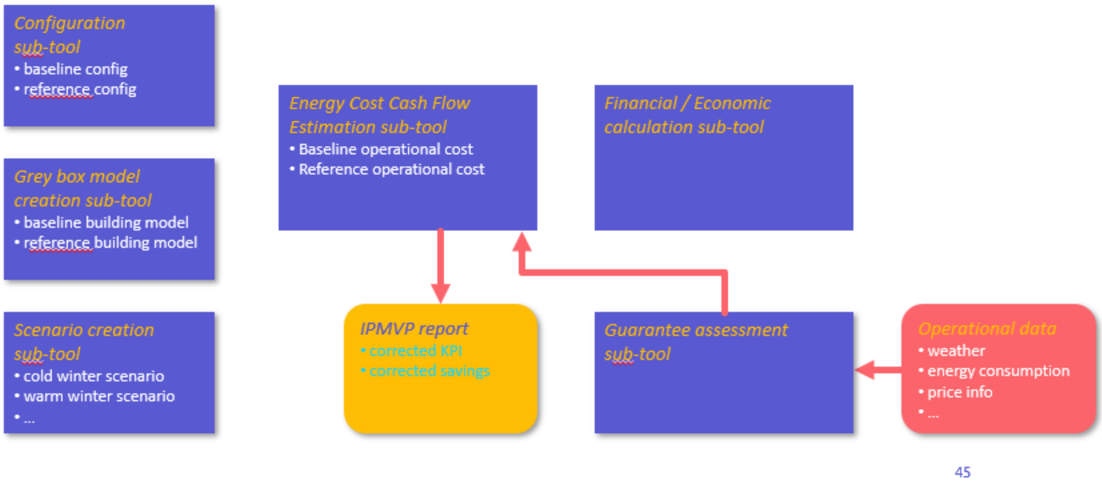
ABEPeM - update performance guarantees



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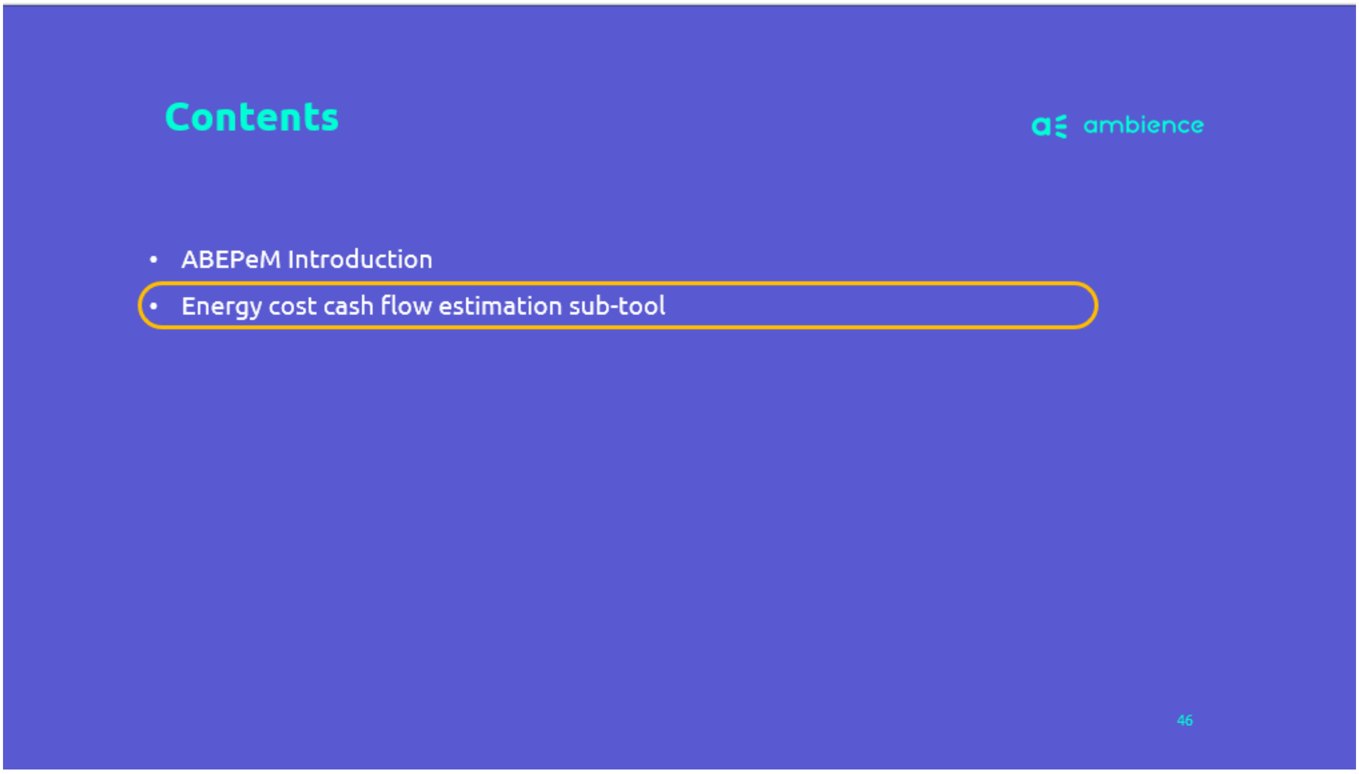
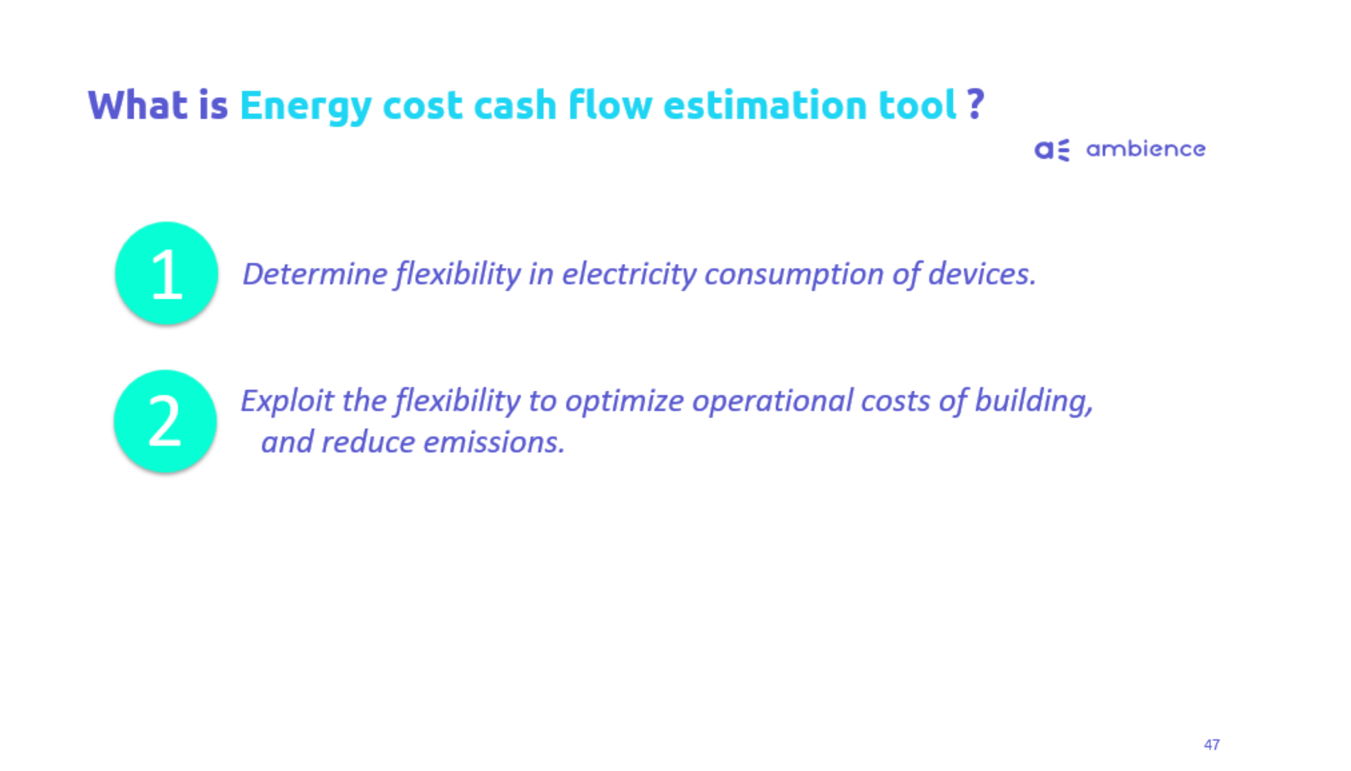
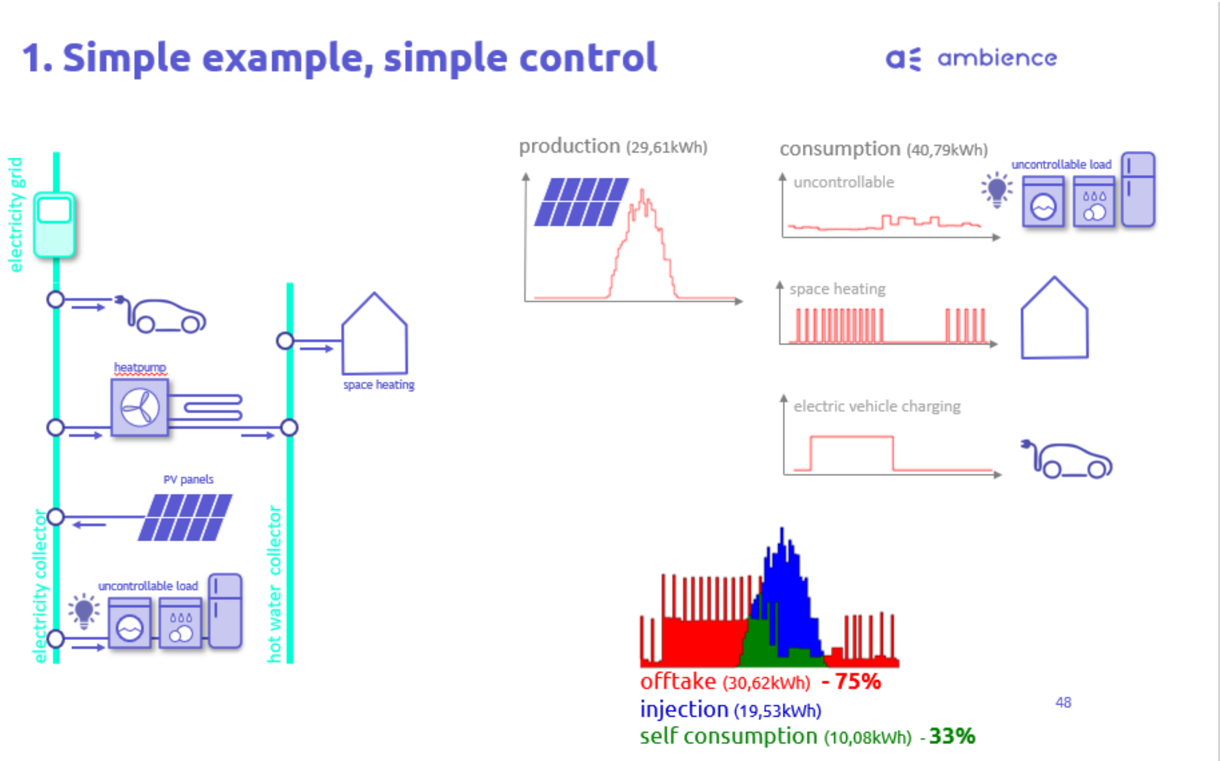
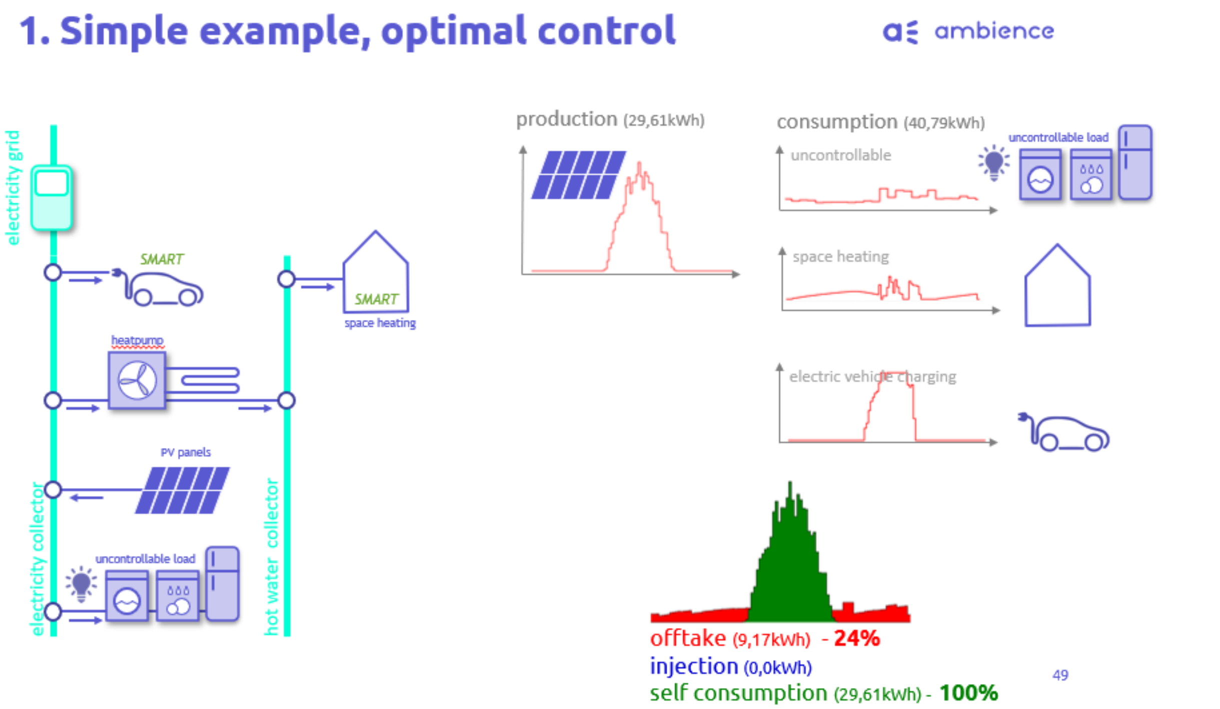
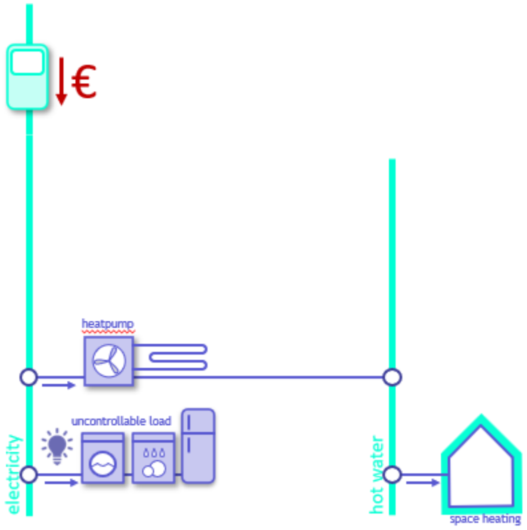

Contents
ambience
ABEPeM Introduction
Energy cost cash flow estimation sub-tool
46


What is Energy cost cash flow estimation tool ?
ambience
1
Determine flexibility in electricity consumption of devices.
2
Exploit the flexibility to optimize operational costs of building, and reduce emissions.
47


1. Simple example, simple control
ambience
electricity grid
heatpump
space heating
PV panels
uncontrollable load
electricity collector
hot water collector
production (29,61kWh)
consumption (40,79kWh)
uncontrollable
uncontrollable load
space heating
electric vehicle charging
offtake (30,62kWh) - 75%
injection (19,53kWh)
self consumption (10,08kWh) - 33%
48


1. Simple example, optimal control
ambience
electricity grid
SMART
heatpump
SMART
space heating
PV panels
uncontrollable load
electricity collector
hot water collector
production (29,61kWh)
consumption (40,79kWh)
uncontrollable
uncontrollable load
space heating
electric vehicle charging
offtake (9,17kWh) - 24%
injection (0,0kWh)
self consumption (29,61kWh) - 100%
49

2. Preliminary Impact study

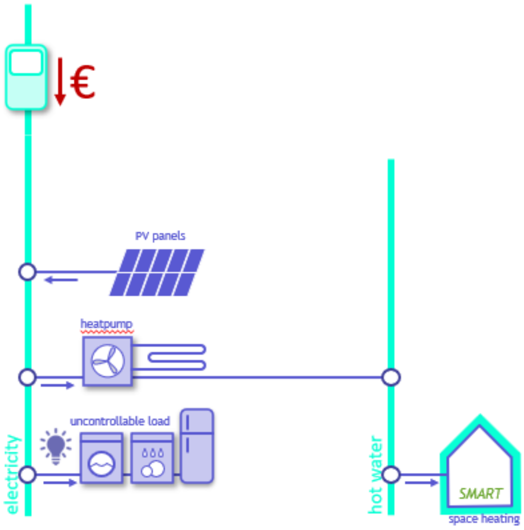


Simulation Conditions, Consumption and costs:

- Comfort constraints (Thermostat settings):
  - 7:00-23:00h: T >= 21 deg C
  - 23:00h-7:00h: T>= 18 deg C
- Electricity consumption :
  - Uncontrolled load: 8183.54 kWh/year
  - Heat pump : 3259.88 kWh/ year
- Electricity prices:
  - 0.25€/kWh in peak time
  - 0.19€/kWh in OFF peak time
  - 0.05€/kWh injection (from PV to grid)
- GHG emission: 51,1 g/kWh
- Electricity Meter:
  - Offtake Volume: 11443.42 kWh
  - Offtake cost: 2443.49 €
- Total Cost: 2443.49 €
- Total emissions: 0.58 t of CO_2

2. Preliminary Impact study

PV panels + Smart Heating



Simulation conditions, consumption, and costs:

- Smart control on heating system:
  - 7:00-23:00h: **23 >=** T >= 21 deg C
  - 23:00h-7:00h: **23 >=** T>= 18 deg C
  - heating using solar energy to reduce injection or at low offtake price
- Electricity generation (PV): 6054.20 kWh/year
- Heat pump, and uncontrollable load electricity consumption are identical.
- Electricity Meter:
  - Offtake Volume: 8413.63 kWh
  - Injection Volume: 2949.65 kWh
  - Self-consumption Volume: 3104.55 kWh
  - Offtake cost: 1756.38 €
  - Injection cost: 147.48 €
- Total Cost: 1608.90 €
- Cost savings of 34 %
- Total emissions: 0.43 t of CO_2
- Emission reduction of 26 %

EU wide impact study: in figures

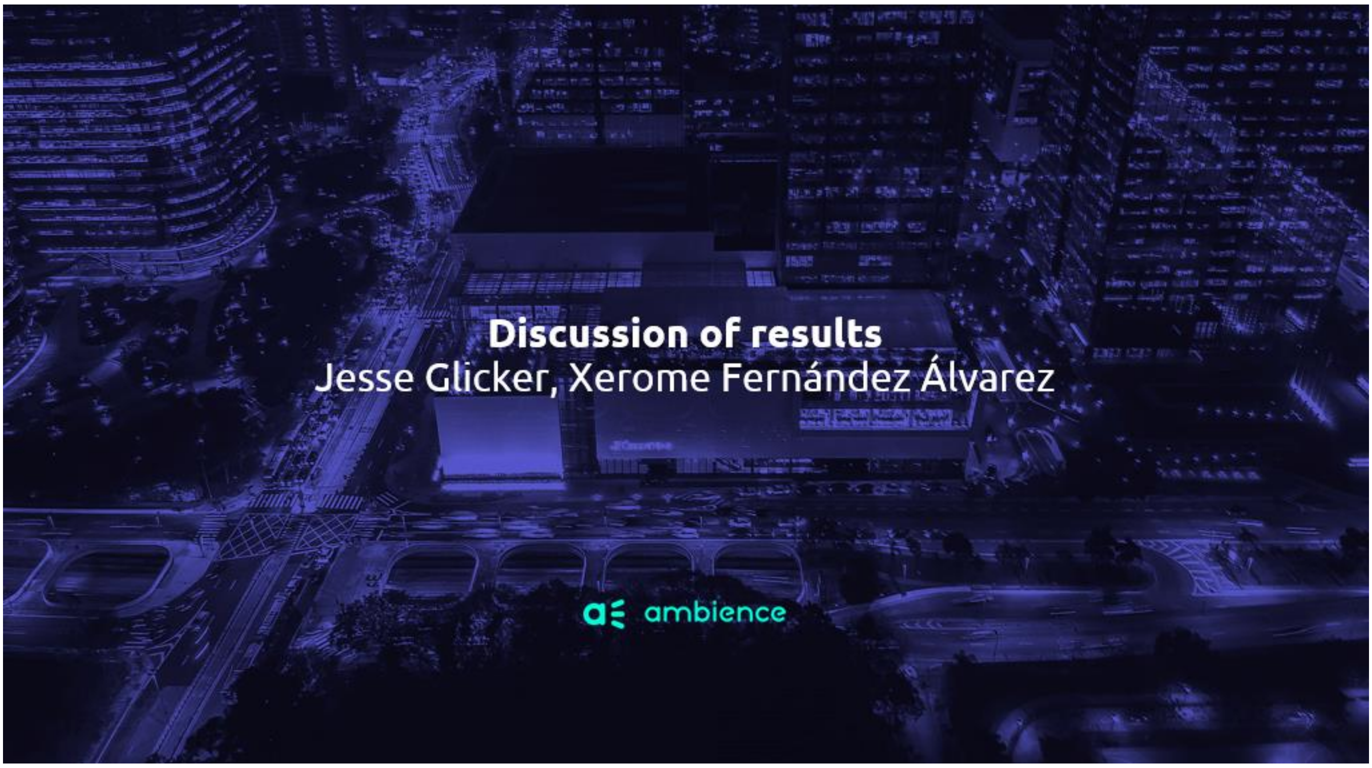
Simulation Conditions

- Automated optimization for 2245 buildings.
- Smart control on heating system:
  - 7:00-23:00h: **23** >= T >= 21 deg C
  - 23:00h-7:00h: **23** >= T>= 18 deg C
- Heat pump: COP ~ 3
- PV panels sizing: 65% of roof area
- PV panels efficiency: 26 %

Results

- 60 % cases – solved
- Costs reduction ranging from 10% - 44%
- Emission reduction ranging from 5 % - 35%

52



Discussion questions – Renovation

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- Renovation needed for combining electrification and demand response/flexibility was calculated by using the K value. Do you consider this a correct approach?
- Are the groups of countries and target renovation methods accurate?

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Discussion questions – Carbon intensity of the energy mix

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- What will be the prevalence of different energy sources for the following 30 years?
- Are the assumptions made for carbon intensity correct? Why not? What should be the carbon intensity for a certain country in a certain year?

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Discussion questions – Renovation costs

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- Are the assumptions made correct in terms of renovation costs?
- What is the future of the building renovation market in the short, mid, and long term? How will the European Green Deal funds alter the market?

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Thank you!

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9. ANNEX II

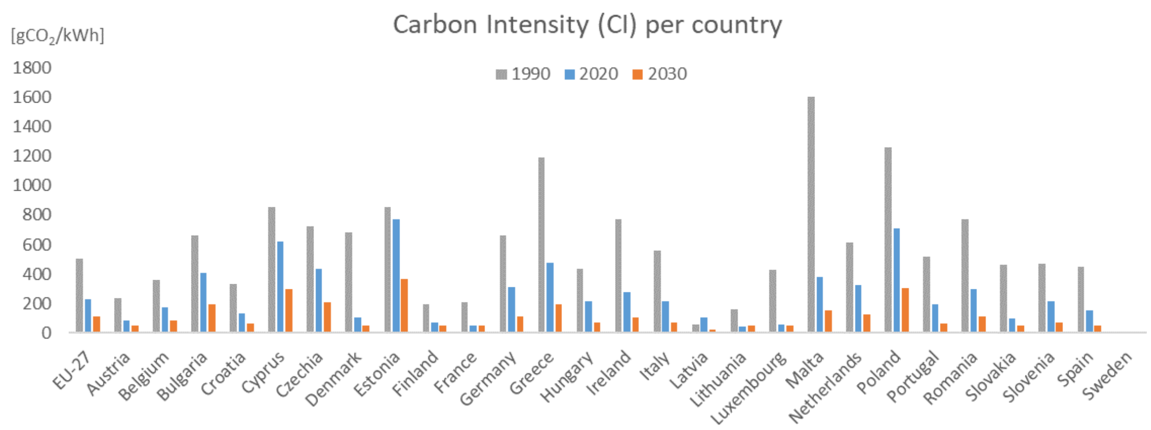

FIGURE 21: HISTORICAL BASELINE, CURRENT STATUS AND 2030'S TARGET FOR CI AT THE EU-27 LEVEL (AVERAGE) AND FOR EACH MS. HISTORICAL CI AND CURRENT CI FROM [3].