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DRIVE 0

Driving decarbonization of the EU building stock by enhancing a consumer centred and locally based circular renovation process



Autor Principal: Miriam Navarro Escudero (Instituto Valenciano de la Edificación)

Otros autores: Leticia Ortega Madrigal (Instituto Valenciano de la Edificación); Ana Sanchís Huertas (Instituto Valenciano de la Edificación); Vera Valero Escribano (Instituto Valenciano de la Edificación).

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1. INTRODUCTION

DRIVE 0 aims to come to a decarbonisation of the EU building stock and to accelerate deep renovation processes by enhancing a consumer centred circular renovation process in order to make deep renovation more attractive for consumers and investors, and more environmentally friendly.

In order to make renovation concepts both more attractive and more reliable to consumer/end-users (meant also as potential investors) an important objective in Drive 0, among others, is to provide attractive and understandable information of the total performances of their renovated homes through a user-centred information service (digital platform). This implies the engagement of end-users into the renovation process from pre-design stage to the post-renovation occupancy stage with the monitoring of energy, comfort and indoor environmental quality (IEQ), and user behaviour, and translating the data into understandable information including guidance and tips.

The DRIVE 0 concept is based on developing circular deep renovation solutions and supporting consumer centered business models for 7 specific study and demonstration cases as real environments. Each of these cases have a specific local driver for the need of a holistic and circular deep renovation, which is translated in 'case specific challenges and tasks' and case specific key performance indicators.

One of the key activities developed in this framework, focused on collecting real inputs in real scenarios, is a monitoring and data processing methodology to display and present this information to end-users by user-centred information services. The protocol below presents the procedures needed to collect data in the demonstration cases as well as the tools that could be used and the timeline for the different monitoring campaigns.

This protocol measures circularity concepts on a dwelling scale for the in-use phase to accomplish these objectives:

- Awareness, engagement, and self-comparison of owners/ occupants (understanding decision processes and motivations of users)
- Validation of principles and assumptions to improve circularity implemented in the renovation project
- Justification of impacts according to EU-H2020 program

In order to meet the established objectives this protocol offers information about the data, measurements, methods, calculations and tools that can be used during the in-use phase and how to use these.

Circularity measures will rely on data obtained from:

- monitoring building and service performances
- surveying demonstration sites occupants and all the related stakeholders that may have valuable information, about a series of measurable parameters related to circularity concepts.

Demonstration of project impacts will be evaluated using the above measures before and after the renovation project. Pre-refurbishment data gathering will be exploited for the design stage of the retrofit. Updated information can be found here: <https://www.drive0.eu/>

This protocol is a measuring framework for the development of further project calculations and developments, and for anyone who wants to assess circularity of a dwelling during its in-use phase.

2. PROTOCOL FOR THE MONITORING OF THE CIRCULARITY OF RESIDENTIAL RENOVATIONS

2.1. Selection and characterization of study areas

This section proposes a methodology for the selection of representative residential units of a building on which to perform the monitoring campaigns, calculate indicators, measure circularity and later on, test and evaluate project methodologies and tools.

This protocol is proposed for the dwelling scale, therefore, for assessing the whole-building circularity during its in-use phase it is recommended to use this section advice to select the most representative dwellings to monitor (in terms of sizes, operational schedules and orientation), and to extrapolate whole-building performances based on the weighted monitored results. Also, the consideration of common conditioned areas should be undertaken to improve the performance accuracy over the whole building.

Initial visit

The objective of this visit is to present the project to the building owner/manager and occupants, explain the activities foreseen and solve doubts and collect information needed for planning the measurements campaigns, in order to obtain the most reliable results for the project development.

Activities for initial building visit might include:

Table 1. Initial visit planning.

Step no. and Scope	Purpose	Activities	Stakeholders involved
1-Retrieve information on building case-study	Obtain building plans, information on services, number of occupants per unit of floor area, energy bills, etc.	Develop Ethics form to be approved by stakeholders to allow the share of information relevant to the project including access to MPRN and GPRN data, access to EPC data (see below), architectural plans, etc.	Building Owners, Managers and Representatives
		Obtain insight of occupant profiles (potential local heroes, antagonists, early adopters...)	
	Retrieve data from the National Energy Performance Certificate (EPC) and other databases: Certificate and report on tests & surveys done.	EPC DB/ Cadastre, etc...	

Step no. and Scope	Purpose	Activities	Stakeholders involved
2-Planning building visit	Assess the potential access level to dwellings and foresee potential issues.	Analyse features of interest according to building specifics (orientations, sizes, occupants...)	Demonstration case team
		Prepare selection forms/tools to distribute and gather this information	
		Prepare speech covering key points	
	Notify	Identify desired dwellings to monitor. Request meetings to present the project, document what will be done and requested and at what time, sign ethics and approval forms well in advance.	Occupants
3-Explain the scope of the study	Present circularity concepts and methods; what will be required from building stakeholders and provided to them; and how data are managed	Presentation and hand-over of documentations	Building Owners, Managers and Representatives and Occupants

Selecting residential units

For reliability and comparability matters it is highly recommended to select **at least 3 residential units** to study.

Considerations when selecting study residential units are:

- Occupants' willingness to be involved in the study.
- Enough space to install the monitoring equipment.
- Select different orientations (if possible).
- Preferably with different demographic structure (e.g. elderly retired couple, young family and working couple without kids).
- Number of occupants in residential units (as much as possible – to increase the sample).
- Higher energy consumption (higher potential for savings and for implementing renovation or behavioural change actions).
- More time spent at home.
- Floor area and number of floors (it is recommended that all the spaces in the residential unit are in the same floor).
- Needs in relation to renovation actions and in terms of communication and information exchange.

One of the key points in the initial visit is the identification and selection of the study units, which will participate during the measurement campaigns, so there are several key points that are pointed in order to increase occupants' engagement, right from the beginning. Tools selected (for accurate reporting, motivating, and encouraging participation) will depend on the users' profile in the selected residential units.

In this context, each section of the protocol includes which data and information could and should be collected and under which specific conditions, but its actual implementation will depend on each demonstration case and will be included on each Monitoring Action Plan. In general:

- for quantitative measurements, monitoring equipment will be used, and
- for qualitative and perceived information, survey tools will be used, for example, face-to-face, call or online interviews, questionnaires, or focus-groups

Units characterization

This part of the protocol aims to characterize the different selected units by using a common template, collecting data including building location, floor area, year of construction, energy consumption, tenure, number of residential units and number of occupants per unit.

Table 2. Units characterization data to be collected.

Building description	Highlights and pictures	literary description of demonstration case, background, motivation and highlights with building images (satellite, aerial & elevations) with source reference
	Address	Street name or neighbourhood or district, postal code, city, region and country.
	Climate zone / aspects / characteristics	select 1 to 5 according to nZEB climate zones for Level(s) ¹ compliance
	Ownership	Select from (i) condominiums, (ii) multifamily buildings owned by a social housing company, (iii) multifamily buildings owned by a municipality or (iv) privately-owned single-family dwelling
	Year of construction	YYYY
	Actual building use	Select from (i) Residential, (ii) Residential mixed-use or (iii) "Other: specify".
	Future building use	Select from (i) Residential, (ii) Residential mixed-use or (iii) "Other: specify".
	Number of buildings	list street numbers affected by the renovation.

¹ Dodd.N, Cordella.M,Traverso.M and Donatello.S, (2017). *Level(s) – A common EU framework of core sustainability indicators for office and residential buildings: Parts 1 and 2*, EUR 28899 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-76914-6, doi:10.2760/827838, JRC109285.&Dodd.N, Cordella. M,Traverso.M and Donatello.S, (2017). *Level(s) – A common EU framework of core sustainability indicators for office and residential buildings: Part 3*, EUR 28898 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-76907-8, doi:10.2760/95143, JRC109286.

Building form	Select from (i) Free standing, (ii) Detached house, (iii) Semi-detached house, (iv) Row or terraced house, or (v) Multi-family house or apartment block
Number of floors	Select from (i) up to 4, (ii) 5 to 9, or (iii) more than 9 (level(s) compliant)
Number of residential units	defined as a set of room(s) within a larger structure that provide a space for occupants making up a single household to live and eat.
Floor area	measurement of the built area, comprised within the external perimeter of the thermal envelope, in square-meters (m ²).
Conditioned floor area	the total floor area in m ² of enclosed conditioned space on all floors of a building, as measured at the floor level of the exterior surfaces of exterior walls enclosing the conditioned space (heated and/or cooled).
Was it inhabited before the renovation?	Select from Yes or No
User profile	Select (one or more) from (i) young people, (ii) family, (iii) ageing people, or (iv) "Other: specify", and add % for each one
Final users	Select from (i) tenant, (ii) owner, or (iii) "Other: specify"
Average number of occupants per residential unit	n , (= total inhabitants / number of residential units)
Total Non-Renewable Primary Energy consumption (from EPC)	Total Non-Renewable Primary Energy Consumption in kWh/m ² /yr.
Non-Renewable Primary Energy consumption for Heating (from EPC)	Heating Non-Renewable Primary Energy Consumption in kWh/m ² /yr.
Non-Renewable Primary Energy consumption for Cooling (from EPC)	Cooling Non-Renewable Primary Energy Consumption in kWh/m ² /yr.
Non-Renewable Primary Energy consumption for DHW (from EPC)	DHW Non-Renewable Primary energy Consumption in kWh/m ² /yr.
Non-Renewable Primary Energy consumption for Lighting (from EPC)	Lighting Non-Renewable Primary Energy Consumption in kWh/m ² /yr.
Final Energy consumption	total real building consumption obtained from energy bills per energy source, in kWh/yr.

	Who pays the energy bills?	Select from (i) occupant-owner, (ii) occupant-tenant, or (iii) owner that does not live in the building
	Can you access energy bills?	Select from Yes or No
Systems	In-built lighting system	Light fittings; Control systems and sensors.
	Energy system	Heating system; Cooling system; Electricity generation (renewables); DHW system; Control of heating system; Control of cooling system; Heating/cooling plant and distribution.
	Ventilation system	Air handling units; Ductwork and distribution.
	Sanitary systems	Cold water distribution; Hot water distribution; Water treatment systems; Waste management system.
	Other systems	Lifts/stairs; Firefighting installations; ICT & security installations; Telecoms & installations; Charging station for electric or hybrid vehicles.
Construction elements	Facades	Walls, cladding and shading devices; Windows; External paints, coatings & renders.
	Roof	Structure; Weatherproofing
	Fittings	Sanitary fittings; Ceilings; Wall and ceiling finishes; Floor coverings and finishes
	Other elements	Foundations; Load bearing structural frame; Non-load bearing frame elements

2.2. Monitoring campaigns definition

Timeline

Measurements to assess performances are carried out in the occupation stage (i.e. the in-use phase), according to Level(s) framework, before and after renovation, to compare results.

- Campaigns 1 & 2: Ex ante, pre-renovation, 1 in Winter, 1 in Summer.
- Campaign 3 & 4: Post-renovation, 1 in winter, 1 in Summer.

Duration

The minimum monitoring time recommended follows the standard EN ISO 15251 recommending performing measurements for **at least 10 days**. Based on Environmental Protection Agency (EPA) protocols², previous H2020 projects and Climate-KIC projects³, the planned activities could further recommend including:

² United States Environmental Protection Agency. (2003). *A Standardized EPA Protocol for Characterizing Indoor Air Quality in Large Office Buildings*.

³ Such as: Valencia Institute of Buildings - IVE, University Institute of Research in Human Resources Psychology, Organizational Development and quality of Working Life – IDOCAL, Chalmers University of

- Preferred start and end on working days (e.g. starting on Mondays allow following working days to answer possible occupants' questions and checking the correct operation of monitoring equipment)
- Tasks might be performed by one or more persons, according to the responsibilities assigned to each team member, being recommended to be performed by the same person/ team for every residential unit in the demonstrator case.

Table 3. Proposed activity planning.

Day	Activity
Pre-Monitoring	
	Initial visits and/or interviews
	Calibrate monitors
Monitoring campaign	
Monday a.m.	Travel Meeting with building manager Supply information and tools to occupants
Monday p.m.	Collect data about the residential unit (for characterization and EC forms) Verify monitoring location Assemble instruments Set-up fixed-site sampling locations Deploy samplers if needed (e.g. TVOC) Take spotty measurement 1 Start fixed-site continuous monitoring Check connectivity to storing system (if applicable)
Tuesday to 2 nd Thursday	Continue fixed-site continuous monitoring
2 nd Friday a.m.	Collect samples (and ship to laboratory) Take spotty measurement 2 Finish fixed-site continuous monitoring Download data Validate integrity of data Pack equipment Change to next residential unit (if applicable)
Post-Monitoring	
	Check documentation completeness and validate data Send to task leader

Administrative guidelines

The administrative activities could follow next recommendations based on previous experience in H2020 and Climate-KIC projects³:

- Use the checklists and templates for data collection

Technology. (2015). *Smart and sustainable Offices (SSO) protocols for monitoring*. BTA Flagship. Eit – Knowledge & Innovation Community. Climate-KIC.

- Assign a unique code to each residential unit FILE, including demo case number, country, building number and residential unit number (e.g. 02ES0101, meaning demonstration case number 2, Spain, building 1, residential unit 1)
- Assign a unique code to each measurement TAB, including the measurement number, season, phase, variable and number of same measurements done (e.g. 001SA-ATE01, meaning measurement number 1, Summer, ex-ante renovation, Temperature, measurement of temperature number 1)
- Store data fulfilling the legislation in force depending on the type of data stored
- Review collected data and assure consistency and completeness
- Send/integrate data only when measurement campaign is completed, and all data are validated.

2.3. Data collection

Circularity measures will rely on the data obtained from monitoring equipment and information gathered from occupants about a series of measurable parameters related to circularity concepts. Therefore, the protocol covers five areas of interest related to circularity:

- Energy
- Water
- Materials
- Well-being, and
- Occupants' Behaviour & Consciousness (organization and activities)

The following measurements and data collections are considered necessary for supporting the accurate characterization of the dwelling circularity level baseline and in-use performance. There are some parameters considered as mandatory with the purpose to assure a minimum comparability analysis between demonstration cases, other parameters considered voluntary, are highly recommended to include at the least to the extent that help to achieve the goals set by the project.

The protocol includes guidance on market available monitoring equipment as well as on the reference standards to perform calculations, which have not been included in this document.

The measurements are proposed to be collected at dwelling scale as this protocol measures circularity concepts on a dwelling scale for the in-use phase. In case measurements are performed at building level they should be disaggregated as much as possible with the objective to obtain equivalent measures at dwelling scale. In this case calculation methodologies must be provided with original data and calculated data that must be as realistic as possible.

Energy consumption

Table 4. Energy Consumption Measurements

Measurement	Mand.	Scale	Description	Units		
Primary demand	energy	Y	Dwelling	Time series	Renewable	kWh/m ² yr
					non-Renewable	kWh/m ² yr
Delivered demand	energy	Y	Dwelling	Time series	Electricity	kWh
					Gas	m ³
					Fuel	l
					Thermal grid	kWh
					RES	kWh
					Disaggregate as much as possible heating, DHW, cooling, ventilation, lighting & appliances	
Renewable delivered energy demand	Y	Dwelling	Produced on-site		%	
			delivered by utilities that ensure 100% purchase of renewable energy		%	
			renewable energy ensured by utilities in their mix		%	
Thermal transmittance	Y	Dwelling	Spotty (one-time)		W/m ² K	
			To be collected for every element part of the thermal envelope of the dwelling			

Energy production

Table 5. Energy Production Measurements

Measurement	Mand.	Scale	Description	Units
Total renewable energy production by renewable energy sources	Y	Dwelling	Time series	kWh
Exported renewable energy by renewable energy sources	N	Dwelling	Time series	kWh

Water

Table 6. Water Consumption Measurements characteristics

Measurement	Mand.	Scale	Description	Units
Water consumption	N	Dwelling	Time series Total water consumption in relation to the dwelling occupants	Potable
				Non-potable
m ³ /occ (report also as m ³ /occ.yr)				
Disaggregate data as much as possible by components and/or locations				
Re-circulation of water	N	Dwelling	Total re-circulated water	m ³ /occ (report also as m ³ /occ.yr)

Materials

Table 7. Materials Measurements

Indicator	Mand.	Scale	Description	Categories
Lifespan	N	Dwelling elements	Information about estimated service life	YES/NO
Repairability	N	Dwelling elements	Assessing the cost, easiness and accessibility to reparation to enlarge lifespan	YES/NO
Deconstruction	N	Dwelling elements	Assessing the potential to recover, reuse and recycle dwelling elements. (see checklist of design criteria)	YES/NO
Origin	N	Dwelling elements	Information about the origin of the elements	YES/NO
ECO-Labeling	N	Dwelling elements	Elements (eco)labelled	YES/NO
Recycled and reused content	N	Dwelling elements	Elements including recycled and reused content	YES/NO
Reused elements	N	Dwelling elements	Elements acquired from the second-hand market or from other dwelling, used for either the same purpose it had or another purpose without changing the object's structure in a significant way.	YES/NO %
Toxic presence in paints and varnishes	N	Dwelling elements	Percentage of elements with toxic presence in paints and varnishes	%

These indicators should be assessed by the Demonstration Case Team, who will get the information by making occupants answer the questions included in the protocol (not in this document) through the most suitable tool, according to the occupants' profile: reporting tools, questionnaires, interviews or observation exercises. All methods that involve ethnographic tools are also described in an annex to the protocol, as a quick guide on ethnography research means.

Well-being. Objective Qualitative data

Table 8. Qualitative Well-being Measurements

Indicator	Mand.	Scale	Description	Categories
Control of heating and cooling system	N	Dwelling	No system/ No control/ Central (building) temperature control/ Apartment temperature control/ Room temperature control	5 cats.
Fresh air flow (mechanical ventilation) per number of occupants	N	Dwelling	No mechanical ventilation/ EN 16798-1 category I or category II/ EN 16798-1 category III/ Less than EN 16798-1 category III	4 cats.
Air tightness of windows and doors	N	Dwelling	Poor airtightness (warped, poorly fitted or unsealed windows and doors)/ Medium airtightness (windows and doors with well fitted sealings)/ Good airtightness (factory-fitted shaped sealing profiles or certification document according to EN 12207 Class 4).	3 cats.
Exterior shading	N	Dwelling	% of windows from East to West which have exterior shading	10 cats.
Radiant heating and/or cooling system	N	Dwelling	% of the conditioned floor area (above or below 50%)	YES/ NO
Radiant temperature asymmetry	N	Dwelling	ISO 7730:2005 Category A or B/ ISO 7730:2005 Category C or worst	2 cats.
Thermal bridges	N	Dwelling		YES/ NO
Presence of humidity or moisture stains	N	Dwelling		YES/ NO

These are qualitative attributes that can be registered as existing or not, or into categories. This will be reported as a set of tables, one per dwelling, containing the above table. These indicators should be assessed by the Demonstration Case Team, who will get the information by making occupants answer the questions included in the protocol (not in this document) through the most suitable tool, according to the occupants' profile: reporting tools, questionnaires, interviews or observation exercises. All methods that involve ethnographic tools are also described in an annex to the protocol, as a quick guide on ethnography research means.

Well-being. Objective Quantitative data

Table 9. Quantitative Well-being Measurements

Measurement	Mand.	scale	Description	Units
Air temperature	Y	Indoor + outdoor	Time series	°C
Relative Humidity			Time series	%
CO ₂		indoor	Time series	ppm
Globe temperature*	N	indoor	Time series	°C
Air velocity**			Time series	m/s
TVOCs			Isolated measure	µg/m ³
NO ₂			Isolated measure	
Formaldehyde			Isolated measure	ppb
PM2,5			Isolated measure	µg/m ³
PM10			Isolated measure	µg/m ³
Noise Level			Time series	dB(A)
Illuminance level			Time series	lux
Global Solar Radiation			outdoor	Time series
Wind speed		Time series		m/s
Wind direction		Time series		8 cats.
Precipitation		Isolated measure		l/h
Hygrothermal Analysis		Envelope		Isolated measure

* Equivalent to the air temperature except that big radiant surfaces exist (heated floors, cool chilled beams...etc)

** It can be considered 0,2m/s in residential buildings where there isn't mechanical air circulation. If mechanical air circulation exists, it should be measured.

Well-being. Subjective perception data

The protocol comprises several aspects to consider for a correct measurement of subjective well-being and health and data collection process using a diary study. The target group are residential units' occupants who would provide data on their subjective well-being and health.

For one week, the participants will be provided with paper questionnaires, on-line surveys, tablets or mobiles apps. Tools selected will depend on the users' profile in the selected residential units. It is recommended that twice a day (morning-afternoon)–once a day mandatory - the participants will be prompted to respond to a brief questionnaire about their feelings and sensation during the past hour. The time needed to respond to the questions will not exceed 2 minutes. The diary studies will mainly address the eudemonic components, listed in the table below.

Table 10. Subjective Well-being Measurements

Measurement	Mandatory	scale	Description	Units	Periodicity
Health symptoms	Y	Occupant	Intensity scale	5 cats.	Twice a day
Physical stressors	Y	Occupant	Intensity scale	5 cats.	Twice a day
Thermal comfort	Y	Occupant	Intensity scale	7 cats.	Twice a day
Clothing	Y	Occupant	Intensity scale	4 cats.	Twice a day
Activity	Y	Occupant	Intensity scale	4 cats.	Twice a day

These indicators should be assessed by the Demonstration Case Team, who will get the information by making occupants answer the questions included in the protocol (not in this document) through the most suitable tool, according to the occupants' profile: reporting tools, questionnaires, interviews or observation exercises. All methods that involve ethnographic tools are also described in an annex to the protocol, as a quick guide on ethnography research means.

Behaviour and consciousness

The amount of energy consumed by building users depends not only on the criteria set for the indoor environment and applied technology but also on the behaviour of occupants and choices in the renovation phase.

Table 11. Users' Behaviour Measurements

Measurement	Mand.	Scale	Description
Profiling	Y	User/occupant	Gender/Age/ education/employment
Presence	Y	User	Schedules or presence sensors
Context	Y	Project developer and user	Broad context of the project, including social, economic, geographical, historic and demographic factors
Perception	Y	User	Building Renovation
key actors	Y	Project developer	Set of questions regards individuals and institutions involved in the circular renovation project.
Other key informants	Y	Case specific stakeholders	Set of questions addressed to other key informants, such as representatives of institutions and businesses, likely to have a completely different view of the renovation projects.
Stance and behaviour	Y	User and Project developer	Circularity Energy Water Materials Well being

These indicators should be assessed by the Demonstration Case Team, who will get the information by making occupants answer the questions included in the protocol (not in this document) through the most suitable tool, according to the occupants' profile: reporting tools, questionnaires, interviews or observation exercises. All methods that involve ethnographic tools are also described in an annex to the protocol, as a quick guide on ethnography research means.

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