HORIZON EUROPE PROGRAMME - HORIZON-CL5-2023-D3-01-01

*Renewable Energy Valleys to increase energy security while accelerating the green transition in Europe - Innovation action (IA)*

REFORMERS

**R**egional **E**cosystems **FOR M**ultiple-**E**nergy **R**esilient **S**ystems

Grant Agreement No. 101136211

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# D3.1: KPI LIST

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| **Lead author(s)** | Ander Martinez Alonso, Alex Felice, Shary Heuninckx, Thierry Coosemans (VUB) |
| **Contributors** | Rebecca Hueting, Manuele Messineo (DBL), Joep Sanderink, Mark de la Vieter, Shubra Chaudhry (NEC), Vaso Stergiou, Petros Iliadis (CERTH), Johan O Sändstrom (RISE), Bart Kaas (TNO), Ben Tubben (Alliander) |

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# EXECUTIVE SUMMARY

D3.1. KPI List defines a list of key performance indicators (KPIs) to quantify/qualify the performance and achievement of the objectives of the flagship valley throughout the project, with respect to technical, environmental impact, economic, and social aspects. In this deliverable, the proposed KPI list will be defined at a holistic and general level so that they serve to adequately quantify the achievement of the objectives of the Flagship Valley (FV). Additionally, Project-level KPIs that apply to the wider impact of REFORMERs have been included.

The possibility of further refinement of these KPIs will be kept until the later stages of the project, depending on the final design, implemented technologies, available data, and FV measurement approach. Besides their relevance, the feasibility of correct measurement and assessment is the criterion for the integration of KPIs in the list. As the project progresses, these KPIs will be further fine-tuned in D3.2 and 4.2, incorporating new information to reflect the FV and the Project's evolving state.

As indicated, the KPIs are divided into four key areas: technical, environmental impact, economic, and social indicators. The technical category focuses on various energy vectors and related technologies, addressing factors such as energy positivity, efficiency, safety, and resilience. Social indicators include end-user comfort, acceptance, ease of use, and inclusivity. The economic category concentrates on revenue creation, operational cost reductions, return on investment, profitability score, and business cases. Environmental impact indicators encompass greenhouse gas emissions and their implications for global warming and air quality, considering a life-cycle perspective.

The comprehensive KPI list will facilitate in-depth analyses of the FV performance during the execution of Work Package 8 (WP8).

In addition, this deliverable also includes KPIs that assess the overall performance of the project since they are closely linked and often overlap with the objectives of the FV. The Project-level KPIs are divided into 3 groups: Dissemination and communication (covering WP2) and wider REFORMERS impact, covering the projected impact of the RV.

Further relevant KPIs for the project deployment related to the different digital tools will be addressed through the relevant deliverables within their own WP: WP5 for the Digital Twin, WP6 for the toolbox covering Energy modelling, Stakeholder engagement, Environmental impact assessment, Business model, governance and policy/legal assessment.

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| Acronyms | |
|---|---|
| **BAU** | Business as Usual |
| **CA** | Consortium Agreement |
| **CAPEX** | Capital Expenditure |
| **CEO** | Call Expected Outcomes |
| **CO2** | Carbon Dioxide |
| **DX.X** | Deliverable number X.X |
| **DER** | Distributed Energy Resources |
| **EU** | European Union |
| **EX** | Expenditures |
| **FE** | Final energy |
| **FI** | Fuel imports |
| **FV** | Flagship Valley |
| **GHG** | Greenhouse Gas |
| **GWh** | Gigawatt-hour |
| **I_GHG** | Infrastructure (embodied) GHG emissions |
| **kWh** | Kilowatt-hour |
| **KPI** | Key Performance Indicators |
| **LCOE** | Levelised Cost of Energy |
| **L_GHG** | Lifetime greenhouse gas emissions of the project |
| **MWh** | Megawatt-hour |
| **MN** | Component maintenance |
| **N** | Number of years considered for analysis |
| **O_GHG** | Total annual greenhouse gas emissions |
| **OPEX** | Operational Expenditure |

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| | |
|---|---|
| **O_PE** | Operational primary energy consumption |
| **PC** | Project Coordinator |
| **PEF** | Primary energy factor |
| **PV** | Photovoltaic |
| **REFORMERS** | Regional Ecosystems FOR Multiple-Energy Resilient Systems |
| **RE** | Renewable Energy |
| **RES** | Renewable Energy Sources |
| **REV** | Renewable Energy Valley |
| **RV** | Replication Valley |
| **SAIDI** | System Average Interruption Duration Index |
| **SAIFI** | System Average Interruption Frequency Index |
| **SC** | Self-consumption |
| **SME** | Small and Medium Enterprise |
| **SMEs** | Small and Medium-sized Enterprises |
| **SS** | Self-sufficiency |
| **T** | Time period considered in the assessment of the KPIs, normally 1 year. |
| **EUR** | Euro |
| **V** | Total amount of energy vectors considered |
| **VUB** | Vrije Universiteit Brussel |
| **WPX** | Work Package number X |

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# 1. INTRODUCTION TO THE FLAGSHIP AND PROJECT OBJECTIVES

In Task 3.1, led by VUB, the REFORMERS Flagship progresses from the initial planning phase to the strategic selection and definition of key performance indicators (KPIs) [M1–M3]. This pivotal task focuses on establishing the overarching objectives for the Flagship's deployment and operational phases. The comprehensive set of objectives encompasses technical, environmental impact, economic, and social categories, as specified in the GA. Furthermore, a detailed KPI list will be crafted, serving as a quantifiable measure for tracking these objectives, using the pre-REFORMERs scenario as a baseline for comparison when required. Also, an annual scope will be defined as the timeframe for calculation when required.

Additionally, Project-level KPIs that apply to the wider impact of REFORMERs have been included. Within the objective of these KPIs lays the projected/expected impact of the Replication Valleys (RV) which share target KPIs with the FV. The calculation of these KPIs in the RV will be calculated or simulated theoretically.

The role of the present D3.1 within REFORMERs is to set the guidelines for the KPIs that will measure and account for the progress, improvements and impacts of the FV of REFORMERs. However, given the still early stage of deployment of the Project, subsequent Tasks and Deliverables will refine the present document: D3.2, The Implementation Plan and D4.2. Implementation and Operation Plan of REVT. Moreover, this Deliverable plays a pivotal role in the project, which can be further understood by analysing its context within the related WP:

WP3:

- Task 3.2. Current flagship assessment and pathways forward [M1 –M6]: Based on the KPI's from T3.1, the proposed testing and validation methods in T3.2.
- Task 3.4. Data framework, collection, measurement tools and equipment [M3 –M8]: Based on the KPI's from T3.1, the proposed testing and validation methods in T3.2 and the conceptual design in T3.3, Task 3.4 will define the required equipment and tools, providing the backbone for measuring, logging, storing, and monitoring of the technical and socio-economic data links and energy vectors.

WP5:

- Task 5.1. Digital twin requirements and initial architecture [M1 –M6]: Building upon the results of T3.1 that considers energy valley requirements, T5.1 is focused on the digital realm, and hence, delivers a set of requirements, KPIs and architecture for the digital twin. The results serve as input to T3.4.

WP8:

- T8.1 Flagship demo assessment and KPI Monitoring, [M8 –M60]: The Flagship demo assessment will be done by getting the input from the KPIs calculation and monitoring done in WP4, to assess the performance from a technical, economic, environmental,

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regulatory and social point of view, also taking into consideration the end users (citizens, businesses and others) and critical stakeholders' perception and acceptance of the REFORMERS concept. The performance will be assessed against the impact parameters defined in T3.1, to quantify the real impact of the project concept in the flagship valley, from a replication perspective. A workshop with the most relevant stakeholders of each site at the beginning of the project in collaboration with task 3.1 and 7.1.

The Call Expected Outcomes (CEO) outline the extensive contributions and impacts that REFORMERS aims to achieve. Derived from the Grant Agreement, these CEO encompass quantifiable targets across three categories: scientific, societal (including environmental), and economic/technological aspects. They serve as the foundation for defining the KPIs for both the development of the FV and the broader Project.

#1: Contribute to the implementation of the REPowerEU Plan, specifically ~~by~~:

1. Maintain a citation rate of at least 5 citations per year per publication for new knowledge on diversifying supply and substituting fossil fuels in hard-to-abate industrial and transport sectors.
2. Achieve a reduction of at least -85% in GHG emissions by 2030 for REFORMERS's FV.
3. Produce 147 GWh/y of biomethane and 259 tons of renewable hydrogen until 2028.
4. Produce 230 GWh/y of biomethane and 3,259 tons of renewable hydrogen until 2030.
5. Eliminate fossil fuel consumption by 100% by 2028.
6. Increase the share of renewable energy by 50% by 2028 and by 119% until 2030.
7. Increase solar photovoltaic - wind capacity by 36% by 2028 and by 149% until 2030.
8. Increase yearly energy savings by 8.5% by 2028 and by 15.6% until 2030, corresponding to a 30 GWh reduction.
9. Energy positivity, elaborated in 3.1.1.1, will increase from 173 to 286% by 2028.

#2: Increase the roll-out of local or regional renewable energy system solutions for electricity, heat, and fuel needs and contribute to their market uptake in Europe.

10. Attain a Likert Scale rating of 4.0/5.0 (High) for the potential of REFORMERS solutions to be scaled and replicated.
11. Involve at least 600 citizens in renewable energy communities or equivalent by the end of REFORMERS.
12. Include a minimum of four end-users (e.g., building, mobility, industry, etc.) in the RE Valley (i.e., buildings, mobility, industry/industrial parks, stadiums).
13. Ensure economic benefits deriving from the project's implementation exceed €25 million per year.

#3: Create new sustainable jobs linked to local or regional renewable energy system value chains and enhance economic growth in local or regional European communities.

14. Generate 40,000 new jobs by 2030 linked to renewable energy system value chains.
15. Have at least 10,000 interested stakeholders acquire new skills in renewable energy production.

16. Invest over €1.1 billion until 2028 for the creation of the RE valley.
17. Invest an additional €3 billion in RE valley until 2030.

#4: Enhance security and autonomy of local or regional energy supply in EU Member States/Associated countries in current and future climate conditions.

18. Reduce energy imports (of any type) by 100%, corresponding to over €8.3 million per year.
19. Aim for 35% of the energy produced within the boundaries of the FV valley to be consumed locally.
20. Increase energy storage capacity by 181,738 kWh per year in the FV by the end of the project.

#5: Increase the readiness, reliability, performance, and affordability of local or regional renewable energy system solutions in Europe.

21. Maintain a citation rate of at least 5 citations per year per publication for new knowledge on increasing the reliability, performance, and affordability of renewable energy system solutions.
22. Target final electricity and heating prices (cost to the end-user) at €230/MWh and €100/MWh respectively.
23. Increase electricity and thermal flexibility by at least 15% and 28% respectively.
24. Ensure the majority of installed RE can be 100% utilised to reduce energy curtailment of RES and DER.
25. Maintain System Average Interruption Frequency Index (SAIFI) below 1.5 interruptions/year and System Average Interruption Duration Index (SAIDI) below 2.5 hours/year.
26. Increase the accuracy of RES forecasts by more than 10%.

# 2. OBJECTIVES AND KPIS DEFINITION

The Call Expected Outcomes (CEO) establish the need for quantifiable and/or qualifiable KPIs that measure the advancement of the Project, both FV and wider impact. Therefore, as a means to facilitate the designation and definition of these KPIs, the original categories included in the CEO are extended and reshaped:

- Technical: Energy system and -device level, covering the different vectors and technologies
- Economic: Revenue and cost change of the main actors
- Social: Community and behavioral change, involvement
- Environmental: Reduction of greenhouse gas emissions and impact on the environment

Furthermore, the Project level KPIs have been categorised according to the wider impacts:

- Dissemination and communication
- Wider REFORMERS impact

- Projected impact from Pilots

Each category has at least one objective. Each objective comprises at least one KPI that will quantify the progress in that area. KPIs will rely on one or more measurements for quantification/qualification purposes. In REFORMERS, all FV objectives and KPIs will be assessed using real measured data from the Flagship case and third-party sources if necessary. A clear definition of applicable KPIs is necessary to define the measurements that will be made and delivered.

The baseline reference for comparison of the KPIs will be the pre-REFORMER's situation.

## 2.1. Flagship Valley

Table 1 - KPIs related to the REFORMERS' Flagship Valley

| *Category* | *Objective* | *Relevant KPIs* | *CEOs cross ref.* |
|---|---|---|---|
| **Technical** | **Multi-energy system** | Energy positivity | 9 |
| | | Renewable energy curtailment | 24 |
| | | Diversification of gas supply | 5, 18 |
| | | Flexibility | 23 |
| | **Grid reliability and stability** | System average interruption frequency index | 25 |
| | | System average interruption duration index | 25 |
| | **Assets and gas production capacity** | PV power capacity | 6, 7 |
| | | Wind power capacity | 6, 7 |
| | | Storage capacity | 20 |
| | | Biomethane production capacity | 3, 4 |
| | | Hydrogen production capacity | 3, 4 |
| | **Forecasting** | Predictability of supply | 26* |
| | | Predictability of demand | 26* |
| **Social** | **Engagement representativeness** | Variation in types of stakeholders engaged | 10, 11, 12, 15 |
| | | Participation rate (of various stakeholder groups) | 10, 11, 12, 15 |
| | | Type of participation | 11, 12, 15 |
| | | Compliance with stakeholder objectives | 11, 12, 15 |

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|---|---|---|---|
| | **Increased stakeholder acceptance** | Countering of perceived hurdles for participation | 10, 11, 12, 15 |
| | **Increased stakeholder expertise** | Change in energy (valley) knowhow of users | 11, 12, 15 |
| | | Impact of education and community events | 1, 12, 15 |
| **Economic** | **Affordability** | Levelised Cost of Energy (LCOE) | 22 |
| | | Capital Expenditure (CAPEX) | 16, 17 |
| | | Operational Expenditure (OPEX) | 8, 13 |
| | **Viability** | Payback period | 13 |
| **Environmental** | **Environmental impact** | Total direct $CO_2$ emissions | 2 |
| | | Total GHG footprint (use-stage impacts) | 2 |
| | **Self-sustainability** | Primary energy consumption | 18, 19 |
| | | Self-sufficiency ratio | 18 |
| | | Self-consumption ratio | 19 |

**The forecasting tools have been left out of the scope of the present deliverable as these services will be provided by the Digital Twin in WP5.*

## 2.2. REFORMERS whole Project

Table 2 - KPIs related to the REFORMERS project

| *Category* | *Objective* | *Relevant KPIs* | *CEOs cross ref.* |
|---|---|---|---|
| **Dissemination and communication (WP2)** | **Products** | Press releases delivered to traditional media | 11, 15 |
| | | Videos | 11, 15 |
| | | Webinars | 11, 15 |
| | | Brochures | 11, 15 |
| | | Tech briefs/info packs | 11, 15 |
| | | General press/magazine articles published | 11, 15 |
| | | News from the project (website + social media) | 11, 15 |
| | | Unique website visitors | 11, 15 |
| | **Activities** | Large public events organised for external audiences | 11, 15 |

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| | | | |
|---|---|---|---|
| | | External events attended representing the project | 11, 15 |
| | | Liasing activities with other EU-funded projects | 15 |
| | | Workshops organised by the project | 11, 15 |
| | | Workshop participants | 11, 15 |
| | **Scientific outreach** | Number of publications in peer-reviewed journals | 1, 21 |
| | | Number of publications in peer-reviewed conferences | 1, 21 |
| | **Online presence** | Twitter followers | 11, 15 |
| | | LinkedIn followers | 11, 15 |
| | **Gender balance** | Female presenters/keynotes/panelists over total | 11, 15 |
| | | Female participants over total | 11, 15 |
| | | Female respondents over total | 11, 15 |
| **Wider REFORMERS impacts** | **Socio-economic** | Research and industry collaborations | 15 |
| | | Local employment creation | 14 |
| | | Number of SMEs involved | 12, 15 |
| | **Environmental** | Total direct CO2 emissions (FV + Pilots) | 2 |
| **Projected impact on Pilots** | **Technical** | Energy positivity | 9 |
| | **Economic** | Levelised Cost of Energy (LCOE) | 22 |
| | | Operational expenditures (OPEX) | 8, 13 |
| | **Social** | Participant acceptance | 10, 11, 12, 15 |
| | | Participation rate (of various user groups) | 10, 11, 12, 15 |
| | **Environmental** | Total direct CO2 emissions | 2 |
| | | Self-sufficiency ratio | 18 |
| | | Primary energy consumption | 18,19 |

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# 3. FLAGSHIP VALLEY KPIS

## 3.1. Technical KPIs

### 3.1.1. Multi-energy vector system integration

#### 3.1.1.1. Energy positivity

Energy positivity refers to the measurement of the FV's ability to generate more energy than it consumes over a specified period. Energy positivity will be used as a KPI to measure the balance between the energy generated and consumed in the FV.

$$\mathrm{EP} = 100.\left(\frac{\sum_{v=1}^{V}\sum_{\mathrm{t}=1}^{\mathrm{T}}\left(\mathrm{E(t)}_{\mathrm{production}}^{\mathrm{v}} - \mathrm{E(t)}_{\mathrm{consumption}}^{\mathrm{v}}\right)}{\sum_{v=1}^{V}\sum_{\mathrm{t}=1}^{\mathrm{T}}\mathrm{E(t)}_{\mathrm{consumption}}^{\mathrm{v}}}\right)$$

EP [%] = Energy Positivity of the FV over a year, expressed as a percentage.

$\mathrm{E(t)}_{\mathrm{consumption}}^{\mathrm{v}}$ [kWh] = Final energy consumption per time step, t, for a given energy vector, v.

$\mathrm{E(t)}_{\mathrm{production}}^{\mathrm{v}}$ [kWh] = Energy production per time step, t, for a given energy vector, v.

V = Total amount of energy vectors considered among electricity, heat, cooling, hydrogen, etc.

T = Time frame considered for the calculation of the Energy Positivity, 1 year.

Refinement on the inclusion of energy vectors and the energy conversion values to kWh for all energy vectors is expected in future deliverables.

#### 3.1.1.2. Renewable energy curtailment

Renewable energy curtailment assesses the amount of renewable energy production that goes unused or is deliberately reduced (controllable producer assets) due to grid constraints or operational limitations. Monitoring renewable energy curtailment helps identify system bottlenecks, optimise grid infrastructure, and improve overall renewable energy utilisation, contributing to energy sustainability goals.

$$\mathrm{RE}_{\mathrm{curtailment}} = 100.\sum_{a=1}^{A}\sum_{\mathrm{t}=1}^{\mathrm{T}}\frac{\mathrm{RE(t)}_{\mathrm{curtailed}}^{\mathrm{a}}}{\mathrm{RE(t)}_{\mathrm{produced}}^{\mathrm{a}}}$$

$\mathrm{RE}_{\mathrm{Curtailment}}$ [%] = Renewable energy curtailment of the FV over a year, expressed as a percentage.
$\mathrm{RE(t)}_{\mathrm{curtailed}}^{\mathrm{a}}$ [kWh] = Renewable energy curtailed in a controllable asset a, at a time step t.
$\mathrm{RE(t)}_{\mathrm{produced}}^{\mathrm{a}}$[kWh] = Renewable energy produced in a controllable asset a, at a time step t.

A = Total amount of controllable producer assets such as PV panels, wind turbines.

T = Time frame considered for the calculation of the RE curtailment, 1 year.

In the case of unavailability of measurements, the curtailment of RES, will be calculated by means of the absolute and relative curtailment:

$$\mathrm{RE_{curtailment}} = 100.\sum_{a=1}^{A}\sum_{\mathrm{t}=1}^{\mathrm{T}}\frac{\mathrm{RE(t)^{a}_{expected}} - \mathrm{RE(t)^{a}_{produced}}}{\mathrm{RE(t)^{a}_{expected}}}$$

$\mathrm{RE_{Curtailment}}$ [%] = Renewable energy curtailment of the FV over a year, expressed as a percentage.

$\mathrm{RE(t)_{expected}}$ [kWh] = Calculated energy generated by the asset, a, at a time step, t. The calculation is expected by means of the energy modelling tools by feeding meteorological data,

$\mathrm{RE(t)_{produced}}$[kWh] = Renewable energy produced in a controllable asset a, at a time step t.

A = Total amount of controllable producer assets: PV panels, wind turbines.

T = Time frame considered for the calculation of the RE curtailment, 1 year.

#### 3.1.1.3. Diversification of gas supply

As part of the strategy to increase the resiliency of the energy system and reduce external dependency, aligned with REPowerEU, the diversification of gas supply and inherent reduction of natural gas consumption is one of the main goals of the FV. The increase in biomethane and renewable hydrogen production will be a key element in addressing this point.

$$\mathrm{DGS} = 1 - \sum_{\mathrm{t}=1}^{\mathrm{T}}\left(\mathrm{C(t)_{natural\ gas}} \Big/ \textstyle\sum_{\mathrm{g}=1}^{\mathrm{G}} \mathrm{C(t)_{g}}\right)$$

DGS [%] = Diversification of Gas Supply, as a function of the reduction of the Natural Gas usage share.

$\mathrm{C(t)_{natural\ gas}}$ [kWh] = Natural gas consumption per time step, t.

$\mathrm{C(t)_{g}}$ [kWh] = Consumption of a gas, g, over a time step, t.

T = Time frame considered for the calculation of the Diversification of gas supply, 1 year.

#### 3.1.1.4. Flexibility

The project aims to measure how much better renewable energy systems can adjust electricity and heat generation to match demand fluctuations, grid conditions, and market dynamics. We propose using the following formulation to assess this aspect.

$$\mathrm{FLEX}_v = 100.\int_{t=1}^{T}\left(\frac{\left|P(t)_v^{generation} - P'(t)_v^{generation}\right|}{P(t)_v^{generation}} + \frac{\left|P(t)_v^{demand} - P'(t)_v^{demand}\right|}{P(t)_v^{demand}}\right)dt$$

$\mathrm{FLEX}_v$ [%] = Flexibility evaluated as a percentage of the original power generation and power demand curves over time, for an energy vector, v.

$P(t)_v^{generation}$ [kWh] = Original power generation curve over time, for an energy vector, v.

$P'(t)_v^{generation}$ [kWh] = Flexible power generation curve over time, for an energy vector, v.

$P(t)_v^{demand}$ [kWh] = Original power demand curve over time, for an energy vector, v.

$P'(t)_v^{demand}$ [kWh] = Flexible power demand curve over time, for an energy vector, v.

T = Time frame considered for the calculation of the Flexibility, 1 year.

### 3.1.2. Grid reliability and stability

#### 3.1.2.1. System average interruption frequency index

The System Average Interruption Frequency Index (SAIFI) measures the average number of interruptions that a customer experiences within a specified time frame, typically per year. To elaborate on this KPI:

SAIFI = (Total number of customer interruptions) / (Total number of customers)

#### 3.1.2.2. System average interruption duration index

The System Average Interruption Duration Index (SAIDI) measures the average duration of interruptions experienced by customers within a specified time frame, usually per year. To elaborate on this KPI:

SAIDI = (Total duration of interruptions) / (Total number of customers)

### 3.1.3. Assets and gas production capacity

In order to measure the achievement of the deployment goals and production targets. The following KPIs are to be measured:

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- PV power capacity [kWp]
- Wind power capacity [kW]
- Storage capacity per vector [kWh/y]
- Biomethane production capacity [GWh/y]
- Hydrogen production capacity [GWh/y]

## 3.2. Social KPIs

### 3.2.1. Engagement representativeness

#### 3.2.1.1. Variation in types of stakeholders engaged

An energy valley is an ecosystem that requires the active participation of various types of stakeholders in its design as well as its deployment phase. Following the quadruple helix model, 4 main types of stakeholders can be identified: governments, industry, social organizations and citizens, and academia. The variation in stakeholders that cooperate in engagement efforts will be identified through an analysis of the helix-types that are represented, as well as of the percentage of participants that represent each of these stakeholder types.

#### 3.2.1.2. Participation rate (of various stakeholder groups)

The participation rate represents the success rate of invitations to stakeholder engagement activities for different stakeholder types. It will be calculated as follows:
Participation_rate (per stakeholder type) =
Number_of_Engaged_Stakeholders / Invited_Number_of_Stakeholders

#### 3.2.1.3. Type of participation

To create an insight into the intensity of the engagement initiatives and their potential impact, an overview will be kept of the number and % of stakeholders that are actively engaged in the project versus the ones that are passively engaged. 'Active engagement' is defined as the opportunity for direct participation various project aspects, and regular interaction and communication between the stakeholders and the project leaders; 'passive engagement' is defined as being informed or consulted about the project without necessarily having a direct role in shaping its outcomes or processes.
The goal will be to ensure a balance between actively and passively engaged stakeholders.

### 3.2.2. Increased stakeholder acceptance

#### 3.2.2.1. Compliance with stakeholder objectives

At the start of the project, a survey will be sent out to all relevant stakeholders, with the goal of identifying their main objectives when joining an energy valley initiative. The evaluation of the alignment between the project's final outcomes and the stakeholder objectives will hinge on the findings from a subsequent survey. This second survey, directed at the same stakeholders as the initial survey, will explicitly inquire about the achievement of the objectives they identified earlier, and incentives will be used to recruit the same stakeholders as during the first survey. Additionally, a theoretical desktop analysis of how the identified main objectives are specifically integrated in the project outcome will be conducted. In case the participation rate in the post-survey is low, this desktop analysis will be the main qualitative assessment method for this KPI.

#### 3.2.2.2. Countering of perceived hurdles for participation

At the start of the project a survey will be sent out to all relevant stakeholders, to identify what they perceive as the main hurdles to joining an energy valley initiative. The assessment of how solutions to address these barriers are incorporated into the project's final outcomes will rely on the findings of a follow-up survey. This second survey, distributed to the same stakeholders as the initial survey, will specifically inquire about the extent to which the project results offer tools to overcome the hurdles previously identified by the stakeholders. Additionally, a theoretical analysis of how the identified main hurdles are specifically integrated in the project outcome will be conducted. In case the participation rate to the post-survey is low, this desktop analysis will be the main assessment method for this KPI.

### 3.2.3. Increased stakeholder expertise

#### 3.2.3.1. Change in energy (valley) knowhow of users

At the end of the project, a self-assessment survey will be developed per stakeholder type. This survey will include inquiries regarding the stakeholders' perceived enhancements in knowledge acquired during their engagement in the project. The topic or the concrete questions will depend on what will be identified as essential user skills and knowledge throughout the course of the project for each stakeholder group (e.g. business model knowledge or understanding of necessary governance structures).

#### 3.2.3.2. Impact of education and community events

In stakeholder events aimed specifically at providing information or education on a specific energy (valley) topic, an assessment/self-test will be incorporated. This assessment will include questions related to the focal topic, enabling the evaluation and analysis of any shifts in the participants' knowledge and/or skills resulting from the event. The format of the assessment will be tailored to the subject and setup of the event (e.g. employing a pre- and post-(group) quiz or a concise evaluation survey).

## 3.3. Economic KPIs

### 3.3.1. Affordability

#### 3.3.1.1. Levelised Cost Of Energy (LCOE)

The Levelised Cost Of Energy (LCOE) is a life-cycle indicator of the cost of producing or consuming a certain energy vector. It measures the lifetime costs of a certain amount of energy. The LCOE calculation can be performed at different points of an energy system, f.e. production point vs. consumption point. Each point provides insights into different aspects of the system's economics and efficiency. Furthermore, in Multi-Energy Systems, the calculation of the LCOE must account for not only the costs associated with each energy vector and their respective production technologies but also the different balances and respective distribution pathways of each vector.

$$\mathrm{LCOE}^{\,v} = \sum_{y=1}^{L}\sum_{s=1}^{S}\sum_{t=1}^{T}\frac{\frac{\mathrm{EX}^{v,s}}{(1+\,i)^{y}}}{\frac{E(t)^{v,s}_{consumption}}{(1+\,i)^{y}}}$$

$\mathrm{LCOE}^{\,v}$[EUR/kWh] = Levelised Cost Of Energy of vector, v, at the consumption point.

$\mathrm{EX}^{v,s}$[EUR] = Expenditures from consumption of the vector, v, from the source, s.

$E(t)^{v,s}_{consumption}$[kWh] = Energy consumption of the vector, v, form the source s.

$i$ [%] = Discount rate

y [year] = Year within the lifetime, L, of the system/project

T = Total number of time steps within a year, for a given time step granularity, t.

S = Total amount of sources supplying the vector, v, at the point of consumption measuring the LCOE.

#### 3.3.1.2. Capital Expenditures (CAPEX)

Capital Expenditure (Capex) is indicating the value an entity has spent on purchases of property and equipment. These purchases are considered as investment flows to expand or improve existing assets. All capital expenditures must be listed and totalized. Capex is measured in €.

#### 3.3.1.3. Operational Expenditures (OPEX)

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Operating Expenditures (Opex) are the expenses required to maintain and operate existing assets. All Opex must be listed and totalized. One of the goals the efficiency of minimising expenses associated with the operation and maintenance of renewable energy infrastructure. It focuses on optimising processes, technology utilisation, and resource management to drive down operational expenditures while advancing sustainable energy goals. Opex is measured in €.

### 3.3.2. Viability

#### 3.3.2.1. Payback period

The payback time is the period required for the cumulative financial returns from an investment to equal the initial capital outlay, indicating the efficiency of the investment. It is measured in [years], it can be calculated using the following formula:

$$\text{Payback time [years]} = \frac{\text{CAPEX}}{\text{TYC}_{\text{reduction}}}$$

CAPEX = Capital Expenditures [€]

$\text{TYC}_{\text{reduction}}$ = Total Yearly Cost reduction compared to the reference scenario BAU [€/year]

## 3.4. Environmental KPIs

### 3.4.1. Environmental impact

#### 3.4.1.1. Total direct CO2 emissions

This KPI refers to the annual $CO_2$ emissions incurred as a result of the FV's operation. Operational $CO_2$ emissions are incurred during the use-phase of the components and are calculated as the sum of the emissions incurred due to component maintenance and the emissions incurred due to component fuel consumption. In this KPI, "fuel" refers to both fossil fuels and electricity consumed by the building's components, as applicable. Moreover, the KPI includes embodied emissions due to component replacements. The calculation does not take into account emissions offset due to RES production and the KPI is calculated on a per-building basis. For district-level analysis, the corresponding calculation is the sum of the values calculated for each individual building. Although the KPI is calculated as an aggregate, the values per energy vector can be reported as well.

The total operational CO2 emissions of the FV are calculated as the sum of the alley's GHG emissions over an analysis period. The granularity and dimensions of the output depend on the scope of the analysis (e.g. project-level, annual, monthly, etc). For the indicative example of calculations of a total sum calculated on an annual basis and an analysis period of N years, the corresponding calculations are as follows:

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$$O_{GHG} = \sum_{i=1}^{N} \left( O_{GHG,MN}^{(i)} + O_{GHG,FI}^{(i)} \right)$$

$O_{GHG,MN}^{(i)}$ are the annual emissions incurred due to component maintenance in year $i$;

$O_{GHG,FI}^{(i)}$ are the emissions due to energy consumed by the (electrical or fuel) in year $i$.

The annual emissions due to component maintenance are calculated as the sum of emissions for all components, as provided by manufacturers and/or contractors:

$$O_{GHG,MN}^{(i)} = \sum_{\forall j \in Components} O_{GHG,MN,j}^{(i)}$$

$O_{GHG,MN}^{(i)}$ are the annual GHG emmissions required for the maintenance of component $j$ in year $i$.

#### 3.4.1.2. Total CO2 footprint (use-stage impacts)

This KPI indicates the total GHG emitted during the analysis' lifetime. This total consists of the infrastructure (Embodied) GHG emissions and of Operational & Maintenance (Use stage). Specifically, the Use Stage includes maintenance-related GHG emissions (Use / Maintenance / Repair / Replacement (inc. end of life of components) / Refurbishment) and Operational emissions (due to energy consumed as electricity or fuel). Finally, Building-level End-of-Life emissions are not considered in this KPI. The GHG emissions over the lifetime of the entire project (assumed to be N years) is calculated as the sum of the infrastructure (product / construction) emissions and use-stage emissions over the period of estimation.

$$L_{GHG} = I_{GHG} + \sum_{i=1}^{N} \left( O_{GHG}^{(i)} \right)$$

$L_{GHG}$ is the Lifetime GHG Emissions of the Project;

$I_{GHG}$ is the Infrastructure (embodied) GHG Emissions;

$O_{GHG}^{(i)}$ is the Operational GHG emissions of the building's components in year $i$.

The Infrastructure (embodied) GHG emissions, which are incurred only when components are installed at the beginning of a project and are not included in the calculation of this KPI for pre-existing components, are defined as:

$$I_{GHG} = \sum_{\forall j \in Components} I_{GHG,j}$$

$I_{GHG,j}$ are the GHG Emissions embodied in component $j$.

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The Total Operational annual GHG emissions are defined as:

$$O_{GHG}^{(i)} = O_{GHG,MN}^{(i)} + O_{GHG,FI}^{(i)} - O_{GHG,PR}^{(i)}$$

These three terms are further elaborated in the subsequent bullet points:

Annual emissions due to component maintenance, $O_{GHG,MN}^{(i)}$:

$$O_{GHG,MN}^{(i)} = \sum_{\forall j \in Components} O_{GHG,MN,j}^{(i)}$$

$O_{GHG,MN,j}^{(i)}$ are the annuall GHG emissions required for the maintenance of component $j$ in year $i$.

Emissions generated due to fuel imports, $O_{GHG,FI}^{(i)}$:

$$O_{GHG,FI}^{(i)} = \sum_{\forall k \in Fuel\ Types} FI_k^{(i)} \cdot EF_k^{(i)}$$

$FI_k^{(i)}$ is the total Fuel Imports for fuel type $k$ in year $i$, obtained from energy demand timeseries (in kWh);

$EF_k^{(i)}$ is the GHG emission factor associated with fuel type $k$ (this can differ depending on the project country and the energy mix) in year $i$.

Emissions avoided due to RES production, $O_{GHG,PR}^{(i)}$:

$$O_{GHG,PR}^{(i)} = \left(SC^{(i)} + EX^{(i)}\right) \cdot EF_{el}^{(i)}$$

$SC^{(i)}$ and $EX^{(i)}$ are respectively the total RES energy that was self-consumed and exported by the building in year $i$.

$EF_k^{(i)}$ is the GHG emission factor associated with fuel type $k$ (this can differ depending on the project country and the energy mix) in year $i$.

### 3.4.2. Self-sustainability

#### 3.4.2.1. Primary energy consumption

This KPI indicates the total primary energy (PE) consumption during the analysis' lifetime. This total consists of the Infrastructure (Product / Construction stages) that incurred the first time a component is installed) and of Operational & Maintenance (Use stage) that incurred during the use-phase and includes maintenance PE demand (Use / Maintenance / Repair / Replacement (inc. EoL of components) / Refurbishment) and operational PE consumption

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(energy consumed as electricity or fuel). Moreover, End-of-Life of Building lifecycle is not considered in this KPI.

$$L_{PE} = I_{PE} + \sum_{i=1}^{N} \left( O_{PE}^{(i)} \right)$$

$L_{PE}$ is the Lifetime PE consumption of the Project;

$I_{PE}$ is the Infrastructure (embodied) PE consumption;

$O_{PE}^{(i)}$ is the Operational PE demand of the building's components in year $i$.

The Infrastructure (embodied) PE consumption is defined as:

$$I_{PE} = \sum_{\forall j \in Components} I_{PE,j}$$

$I_{PE,j}$ is the PE embodied in component $j$.

When calculated on the basis of component consumption, the Operational PE consumption is defined as:

$$O_{PE}^{(i)} = \sum_{\forall j \in Components} FE_j^{(i)} \cdot PEF_{fuel,j} + O_{PE,MN,j}^{(i)}$$

$FE_j^{(i)}$ is the Final Energy consumed by component $j$ in year $i$, obtained from energy conumption timeseries;

$PEF_{fuel,j}^{(i)}$ is the PE factor associated with the fuel consumed by component $j$ (this can differ depending on the project country and the energy mix), for year $i$;

$O_{PE,MN,j}^{(i)}$ is the maintenance PE demand (inc. replacement \& EoL) of component $j$ for year $i$.

Unless explicit values are provided, maintenance PE demand is calculated as a percentage of a component's em-bodied PE, while EoL PE demand depends on the scheduled fate of the component at the end of its useful lifetime. If a component's life ends during the analysis' lifetime and has been scheduled to be replaced, the corresponding embodied PE demand is added to that component's Operational PE Demand for that year.

#### 3.4.2.2. Self-sufficiency ratio

The ability of a system to meet its energy requirements independently, without relying extensively on external energy sources, is defined as the ratio between the total energy produced locally that is directly consumed (energy injected into the grid is not counted) and the total consumption over a year:

$$\mathrm{SS} = 100.\sum_{v=1}^{V}\sum_{t=1}^{T}\frac{\mathrm{E(t)}_{consumption}^{v} - \mathrm{E(t)}_{net\ imports}^{v}}{\mathrm{E(t)}_{consumption}^{v}}$$

$\mathrm{SS}$ $[\%]$ = Self-sufficiency of the FV over a year, expressed as a percentage.

$\mathrm{E(t)}_{consumption}^{v}$ [kWh] = Energy consumption of an energy vector, v, over a time step, t.

$\mathrm{E(t)}_{net\ imports}^{v}$[kWh]= Net imported energy of an energy vector, v, at a time step t.

= Total amount of energy vectors considered, electricity, heat, cooling, hydrogen, etc.

T = Time frame considered for the calculation of the Self-sufficiency, 1 year.

Refinement on the inclusion of energy vectors and the energy conversion values to kWh for all energy vectors is expected in future deliverables.

#### 3.4.2.3. Self-consumption

Self-consumption refers to the percentage of energy produced on-site that is actually consumed or used on-site; it is evaluated over a year.

$$\mathrm{SC} = 100.\sum_{v=1}^{V}\sum_{t=1}^{T}\frac{\mathrm{E(t)}_{produced\ on-site}^{v} - \mathrm{E(t)}_{exports}^{v}}{\mathrm{E(t)}_{produced\ on-site}^{v}}$$

$\mathrm{SC}[\%]$= Self-consumption of the FV over a year, expressed as a percentage.

$\mathrm{E(t)}_{produced\ on-site}^{v}$ [kWh] = Locally produced energy of an energy vector, v, at a time step, t.

$\mathrm{E(t)}_{exports}^{v}$[kWh]= Exported energy of an energy vector, v, at a time step t.

V = Total amount of energy vectors considered, electricity, heat, cooling, hydrogen, etc.

T = Time frame considered for the calculation of the Self-consumption, 1 year.

Refinement on the inclusion of energy vectors and the energy conversion values to kWh for all energy vectors is expected in future deliverables.

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# 4. REFORMERS PROJECT KPIS

## 4.1. Dissemination and communication

### 4.1.1. Products

Various dissemination products will be developed to provide visibility to the project. A count of the final amount of produced products per type will be compared to the set target amount (indicated between brackets).

- Press releases delivered to traditional media [24]
- Published videos (e.g. on YouTube, Vimeo) [1]
- Webinars [3]
- Layouted media (e.g. brochures) [1]
- Tech briefs/info packs [2]
- News items published on the project (e.g. project website and social media) [60]

The effectiveness of the dissemination will be assessed through a count of the number of unique website visitors, with 3000 as a target number.

### 4.1.2. Activities

Various activities will be organised to make the project known to the general public, as well as to provide participation opportunities to the project stakeholders. A count of the final amount of produced activities per type will be compared to the set target amount (indicated between brackets).

- Large public events organised for external audiences [5]
- External events attended representing the project [10 participating partners]
- Liasing activities with other EU-funded projects [2]
- Workshops organised by the project [24]

The dissemination success of the workshops will be assessed through a count of the amount of participants, with 400 as a target number.

### 4.1.3. Scientific outreach

The scientific outreach will be measured through a count of scientific publications per type (with the target amount indicated between brackets).

- Publications in peer-reviewed journals [7]
- Publications in peer-reviewed conferences [10]

### 4.1.4. Online presence

The impact of the online presence will be assessed through a count of the amount of Instagram followers, with 200 as a target number, and the amount of LinkedIn followers, with 500 as a target number.

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#### 4.1.5. Gender balance

To determine whether the envisioned gender balance is reached, the representation of women in various activities will be monitored. The target is to have a 50% representation rate in the following cases:

- Female presenters/keynotes/panelists over total
- Female participants over total
- Female respondents to surveys over total

### 4.2. Wider REFORMERS impact

#### 4.2.1. Socio-economic impacts

##### 4.2.1.1. Research and industry collaborations

The collaborative efforts between academic and industrial partners regarding R&D activities within the scope of the REFORMERS project will be counted. It encompasses the number of joint ventures, research stays, partnerships, and initiatives established to advance research and development (R&D) activities aligned with the project's objectives.

##### 4.2.1.2. Local employment creation

Number of jobs that have been created as a result of the activities connected to the flagship valley development in Alkmaar. This will be evaluated by checking with the involved partners.

##### 4.2.1.3. Number of SME involved

The number of small and medium-sized companies involved in the project will be counted and followed throughout the project, that means companies that have business related to the project activities and the development of the flagship. A survey including questions regarding what type of sector the companies are connected to will be circulated amongst the partners.

#### 4.2.2. Environmental impact

##### 4.2.2.1. Total direct CO2 emissions

Comprising Flagship Valley and Pilots direct CO2 emissions reduction.

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## 4.3. Projected impact on pilots

The calculation of the projected impact on RV will be achieved by means of the energy modelling tools developed within the scope of WP6. The definition and formulation of these KPIs is aligned with those included in the FV's KPIs. Hence, have already been described.

- Energy positivity
- Self-sufficiency ratio
- Primary energy consumption
- Levelised Cost of Energy (LCOE)
- Operational expenditures (OPEX)
- Participant acceptance
- Participation rate (of various user groups)
- Total direct CO2 emissions
- Renewable energy penetration

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