

## How to perform process and outcome evaluation in “EPC-based Digital Building Twins for Smart Energy Systems”

Anna Maria Urbaniak-Brekke, PhD

Hans Jakob Walnum, PhD



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<p><b>RESEARCHERS</b> Anna Maria Urbaniak-Brekke, PhD Hans Jakob Walnum, PhD</p>	<p><b>PROJECT LEADER</b> Hans Jakob Walnum, PhD</p>
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**SUMMARY**

This report presents the background and methodology to be used by Western Norway Research Institute (Vestlandsforskning) in evaluating the project. The main focus is the two types of evaluation (process evaluation and outcome evaluation) that will be used in regard to the project’s life span and effects.

**OTHER PUBLICATIONS FROM THE PROJECT**

As the project began in late 2019, this is the first publication. Further publications are planned during and at the end of the project’s life span.

VESTLANDSFORSKING , Postboks 163, 6851 Sogndal

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# 1. Introduction

In the research project “EPC-based Digital Building Twins for Smart Energy Systems”, Western Norway Research Institute (WNRI) is responsible for evaluation of energy policy, built on a simulation using digital building models, based on EPC-data, developed in an international ERA-NET project<sup>1</sup>. The EPC4SES project seeks to develop a method for obtaining and utilizing data from energy certificates in the modelling and planning of energy savings in large buildings. The modelling will be done through developing a concept called a ‘digital twin’ in order to achieve a complete simulation of energy consumption and energy saving potential in buildings. The applications will be tested in three European case cities: Seville, Berlin, and Salzburg/Vienna. The consortium consists of eight partners from four European countries (Spain, Norway, Germany, and Austria).

Work package 4 of the EPC4SES project, ‘Evaluation and Exploitation’, which is led by WNRI, comprises evaluation of the implemented concepts in terms of stakeholder acceptance, environmental impacts, and wider economic impacts of sector coupling smart energy systems by the use of renewables. While WNRI handles the set-up of the evaluation and data analysis, exploitation work will be managed by SEnerCon (SEC), a German-based company specializing in engineering and consultancy in the field of supporting private households in energy efficiency measures. All partners will contribute, expanding the exploitation over the core approach with specific exploitation plans for their situation. This work package has following tasks:

- a) Specification of the evaluation scheme
- b) Data collection for the evaluation (survey data, simulation results, operational statistics, market data)
- c) Put together the evaluation report
- d) Set up the protection and exploitation scheme for the Intellectual property right (IPR)
- e) Quantifying the European impact

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<sup>1</sup> ERA-NET under Horizon 2020 is a funding instrument designed to support public-public partnerships in their preparation, establishment of networking structures, design and implementation, and coordination of joint activities. The instruments mainly ‘tops-up’ funding for single joint calls and transnational actions:  
<https://ec.europa.eu/programmes/horizon2020/en/h2020-section/era-net> [Accessed: 28.04.2020].

WP4 starts in month 9 of the project with defining the evaluation methodology and will recommence in month 29 with the task of quantifying the European impact based on the evaluation results. The evaluation team has interfaces towards WP3, so the research pilots might collect data for evaluation. The exploitation plan will recognise potential improvements of the approach, in accordance with recommendations from the research pilots in WP3.

As described in the project application, the evaluation team (independent from the owner of the project), will review the scientific merit of the research approach, to analyse its contribution within the field. Procedures will be consistent with the research design, methods appropriate to test the hypothesis and the data collection adjusted according to research questions, allowing valid analysis. This comprises size and clustering of the samples.

It is important to add that the experiments within the EPC4SES project will not affect people's health or put security or safety of persons or nature at risk. There are also no negative ethical impacts envisaged from the current view, but the evaluation team will analyse the details of the project implementation.

The overall evaluation concept of the EPC4SES project is based on the following questions:

1. Is the project targeting the right applications?
  - i. Are the experimental pilots useful to achieve the aims with regards to decarbonisation?
  - ii. Can the results be further used in other cases (generalization)?
2. Is the right input data used?
3. How accurately do the digital twins represent reality?
4. What are the potential effects?
  - a. Energy efficiency
    - i. Avoiding the use of boilers
    - ii. Reducing peak load
  - b. Use of renewable energy
    - i. Increasing solar thermal energy, photovoltaics (PV), and wind usage by shifting demand
  - c. Environmental impact
    - i. Life cycle approach

The evaluation overarching the pilot applications will mainly assess three issues:

1. What amount of CO<sub>2</sub> equivalents may be saved in the different scenarios, originating from the shift to regenerative energy and increasing energy efficiency?
2. How much additional effort is needed if input data from calculating the basis for issuing EPC is not sufficient for building and using the digital twin relating that to the economical savings?
3. Success in integrating with local and regional development in the frame of the Strategic Energy Technology (SET) plan directive 2018/844/EU

Benefits and risks of the innovative approaches will be evaluated by use of following criteria:

1. Global warming potential (GWP) of production, usage and recycle phase (cradle to grave)
2. Potential side and rebound effects
3. Social and gender issues along the use cycle

Based on the diversity of the elements of work package 4 presented above, we decided to implement a twofold evaluation of that project: both during its lifetime (process evaluation) and of its effects (outcome evaluation). The reason for this is that, as Bingham and Felbinger note, each evaluation is *appropriate to a different set of research questions* [2002, 4] and the different approaches are complementary. At the beginning of evaluation research there was only focus on measuring the effects of projects, and creating models based on those effects. Later the approach changed and the acceptance for process evaluation rose. It is not only interesting for the researchers but also useful for the stakeholders and projects owners to follow and understand the process that occurs when a project is conducted. Evaluation research had become more and more dialogue-oriented [Baklien 2000, 53-54].

## 1.1. Definitions

In order to unify the understanding of different concepts, we provide definitions of expressions that are used throughout the whole text. Process can be defined as *the content and implementation of an evaluand (that which is being evaluated) and often includes its outputs*, while process evaluation is *the part of evaluation that focuses (...) primarily or exclusively on process, usually (and not prudently) omitting outcome evaluation*. Outcome evaluation on the other hand is understood as *the part of an evaluation that focuses (...) primarily or exclusively on outcomes, usually (and not*

*prudently) omitting process evaluation* [Davidson 2005, 245]. When different types of evaluation are concerned, authors refer to them as levels [Trisko & League 1978], models [Tornes 2012, 110] or approaches [Bingham & Felbinger 2002, 4] to evaluation. In this paper we decided on the latter.

## 1.2. Evaluation theories – transferability from public policy to research

Much of the literature about both process and outcome evaluation is focused on whether public policies have the desired effect. However, in a research project such as the one described here, the goal is to develop something new in collaboration with an international and interdisciplinary team. The latter entails a heightened risks of unintended consequences and deviations from the project plan, which in turn highlights the need to reflect on the transferability between theories applied to public policy and a research project.

The first and classical effect evaluation paradigm focuses on the relation between causes and effects, thereby checking whether the actions or program undertaken yielded a positive result [Sverdrup 2014, 28]. This approach can also be used to evaluate a research project where something new is going to be developed, by looking more closely at the relationship between the goals set in the project description and the achievement of these goals at the end. In the process evaluation approach, the main question is how a program or action can be improved and changed. This can be applied both to projects within public policy and research.

Researchers from Brown University published the following list of characteristics for both process and effect (outcome) evaluation in research projects:

### ***Formative or Process Evaluation does the following:***

- *Assesses initial and ongoing project activities*
- *Begins during project development and continues through implementation*
- *Provides new and sometimes unanticipated insights into improving the outcomes of the project*
- *Involves review by the principal investigator, the steering or governance committee, and either an internal or external evaluator (depending on grant requirements)*

### ***Summative or Outcomes Evaluation does the following:***

- *Assesses the quality and success of a project in reaching stated goals*
- *Presents the information collected for project activities and outcomes*

- *Takes place after the completion of the project*
- *Involves review by the principal investigator, the steering or governance committee, either an internal or external evaluator, and the program director of the funding agency*
- *All evaluation plans should identify both participants (those directly involved in the project) and stakeholders (those otherwise invested by credibility, control or other capital), and should include the relevant items developed in the evaluation process.<sup>2</sup>*

The main objectives are in this case very similar to the ones applicable for evaluation of public policy.

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<sup>2</sup> Writing an Evaluation Plan, <https://www.brown.edu/research/conducting-research-brown/preparing-and-submitting-proposal/proposal-development-services/writing-evaluation-plan> [Accessed: 15.06.2020].



## 2. Methods

### 2.1. Process evaluation

Process evaluation focuses on following actions carried out in order to achieve a project's goals from the idea stage at the outset of the project, through its implementation, until the moment the results are received by the stakeholders [Tornes 2012, 117]. The main questions in this evaluation approach include: Is the level of activity in the project satisfying? Are there any problems with the implementation of the project? [Tornes 2012, 111].

Baklien writes about three different types of process analyses: 1. describing which processes are initiated (effects, interventions, or actions), 2. describing processes that created the effects, 3. A combination of both [Baklien 2000, 54].

Other authors, following Trisko and League [1978], divide process evaluation into two approaches: the first one monitors the daily tasks and focuses on questions regarding the project operation. This process evaluation approach is supposed to *uncover management problems or assure that none are occurring* [Bingham & Felbinger 2002, 4]. It pertains to the behaviours and practices of the project staff. At this point, the goals and objectives of the project are also being evaluated in order to *determine the predicted impact* of the project [Bingham & Felbinger 2002, 5]. The second approach focuses on stakeholders' satisfaction and its main concern is what is happening to them. The questions suggested here by Bingham and Felbinger are: *What is done to whom and what activities are actually taking place? How could it be done more efficiently?* [2002, 5]. Davidson explains briefly that process evaluation takes into consideration all the stages of a project *except outcomes and costs* [Davidson 2005, 56].

The same author also lists categories of elements in a project that need to be considered within the process evaluation:

- content - the content of the evaluand: its basic components and design
- implementation - quality and efficiency of implementation of the evaluand or its delivery to the customers
- other features - all the other elements which make the project good or bad and are neither covered by the other two points nor related to outcomes or costs [Davidson 2005, 56]

Those three categories should include all the elements of the project process after assessing project's needs, all other relevant sources of value, and any additional considerations.

Process evaluation, according to Baklien, is about identification of barriers and 'pushfactors' that have a bearing on goal achievement. The connection between the action and its effect is as important as the effect itself [Baklien 2000, 54]. That is why the description of which processes and effects that derive from an action, should be based on data collected from the beginning of the process to its end [Baklien 2000, 57].

As commented by many authors, process evaluation is often one of the first activities to be cut out from the project in order to lower the budget and its importance is often not realized [Bingham & Felbinger 2002; Davidson 2005].

## 2.2. Outcome evaluation

Sometimes also called impact, summative [Bingham & Felbringer 2002, 5], result or effect [Tornes 2012, 111] evaluation, this outcome evaluation approach focuses on the *things that happen or are prevented from happening as a result of a project* [Davidson 2005, 59]. This category is connected directly to the goals and objectives of the project and it answers questions related to whether the goals were achieved, how effectively it was done, and what the effects are.

Outcome evaluation, as well as process evaluation, is divided into two categories. Some authors suggest the following names: enumerating outcomes and measuring effectiveness [Bingham & Felbinger 2002, 5-7]; others prefer to call them the goal-achievement model and the effect model [Tornes 2012, 111]. The first approach, whichever name is used, focuses on the following questions: Are the goals achieved? If yes, to which extent? If not – why? The second approach, measuring effectiveness, asks: What are the effects of the project? Was the project effective? What would happen if it had not been implemented? [Tornes 2012, 111-112; Bingham & Felbinger 2002, 5-7]. Bingham and Felbinger, who tend to call this type of evaluation 'impact evaluation', also explain that outcome evaluations are often quite objective and easy to use in empirical investigations, as the data can be extracted from records or from observation and testing, sparing the evaluator of reliance on clients or staff in data-gathering [Bingham & Felbinger 2002, 7].

### 2.3. Why and how we combine the two types of evaluation

In the previous paragraphs we have explained the contents of the two different approaches to evaluation and, indirectly, why each of them are important and complementary to each other. As shown, they cover separate parts of a project and answer different questions. To deliver a satisfying evaluation of a project from the idea stage, through its life span to the end, those who are responsible should therefore in our opinion apply both evaluation approaches: first process evaluation, then outcome evaluation. The Key Evaluation Checklist published by E. Jane Davidson (modified from Scriven’s 2003 version) presents, among other elements, a short explanation of the characteristics of those two evaluations (Table 1).

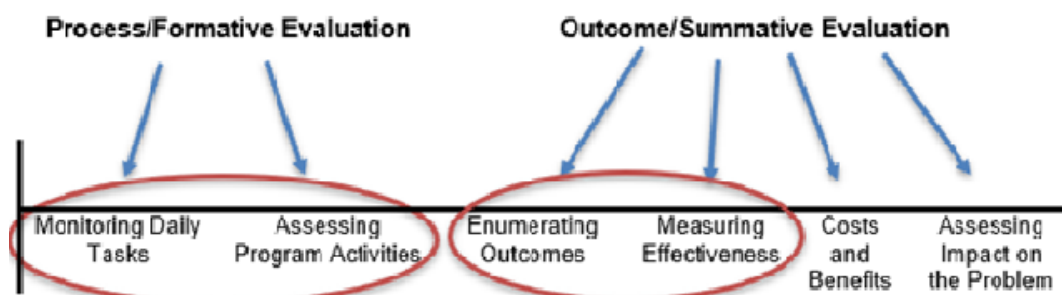
Table 1. The Key Evaluation Checklist – part of it.

Process Evaluation	Outcome Evaluation
How good, valuable, or efficient is the evaluand’s <b>content</b> (design) and <b>implementation</b> (delivery)?	How good or valuable are the <b>impacts</b> (intended or unintended) on immediate recipients and other impactees?

Source: Davidson 2005, 6.

We mentioned that none of the evaluations are ‘better’ than the other, but that they are all *appropriate to a different set of research questions* [Bingham & Felbinger 2002, 4]. T. Bartik and R. Bingham refer to that fact, dubbing it a *continuum of evaluations* [Bartik & Bingham 1997, 247]. The figure below shows the continuum and (in circle) those approaches we will use in the EPC4SES project evaluation.

Figure 1. Continuum of Evaluations.



Source: Bartik & Bingham 1997, 248.

As presented in Figure 1, we are planning firstly to focus on the two subcategories of the process evaluation, which should be done during the project’s life span. Secondly, as the project approaches its ending, we should focus on the evaluation of the outcomes, again in two subcategories. In the next paragraph we deliver a proposal of concrete actions to be applied within the EPC4SES project when evaluation tasks are considered.

### 3. Practical applications in the EPC4SES project

The EPC4SES project was launched in the autumn of 2019 but due to various circumstances, the first meeting of project partners was organised in late January 2020. The type of program (ERA-NET) our project is part of creates many opportunities and useful synergies because of its international character. There are however also some complications connected to legal and administrative issues (different approaches and applications’ evaluation systems in different countries). That is why in October 2020, the project is still in its initial phase. The advantage of this situation is that, as the partner in charge of the evaluation procedure, we have had enough time to prepare for both process and outcome evaluation. Below, based on a literature review briefly presented above, we describe our approach to the evaluation tasks in the EPC4SES project.

#### 3.1. Application of the process evaluation

As suggested by Davidson, we tend to create Criterion Lists for EPC4SES Process Evaluation and Outcome Evaluation. The first one is presented in the table below, based on the knowledge we have gathered about the project so far.

Table 2. The Criterion List for Process Evaluation of the EPC4SES project.

Category	Subcategories and Criteria	Sources of Evidence
Content evaluation (monitoring daily tasks)	<ul style="list-style-type: none"> <li>- Identification of the project’s goals and objectives</li> <li>- Actual project reflects what was written in the application</li> <li>- Project makes sense ‘as a package’ (not disjointed or inconsistent)</li> <li>- Content of the project corresponds to current knowledge</li> </ul>	<ul style="list-style-type: none"> <li>- Analysis of project documentation</li> <li>- Participants’ feedback</li> <li>- Evaluators’ observations</li> </ul>
Implementation evaluation (assessing program activities)	<ul style="list-style-type: none"> <li>- Basic legal and ethical considerations: participant and staff legal rights are protected, fairness, equity</li> <li>- Respect to diverse cultures and viewpoints, and understanding of the key issues in the context, Social and gender issues along the use cycle</li> <li>- Increase in knowledge about the outcomes of the WPs (especially WP3 - pilots)</li> </ul>	<ul style="list-style-type: none"> <li>- Evaluators’ observations</li> <li>- Participants’ feedback</li> <li>- Comparison with relevant standards</li> </ul>

Source: Own study based on Davidson 2005, 57.

*Based on the project’s organisation and proceeding, we propose following, detailed plan for the process evaluation: Table 3. Plan for Process Evaluation of the EPC4SES project.*

<b>Time (M-month of the project)</b>	<b>Work package</b>	<b>Criteria</b>	<b>Evaluation tool</b>
M13	1. Project Management	- Project makes sense ‘as a package’ (not disjointed or inconsistent)	- Analysis of the documentation - Short interview with the project partners
M17	2. Specification System Architecture and Verification	- Identification of the project’s goals and objectives (Are we targeting the right applications?) - Extend to which actual project reflects what was written in the application (Is the right input data used?)	- Analysis of the documentation - Questionnaire and interview with project partners
M25	3. Implementation of Research Prototypes	- Content of the project corresponds to current knowledge - Valid data available from research pilots (WP3) to evaluation	- Analysis of the documentation - Questionnaire and interview with project partners - Evaluators’ observations
M27	4. Evaluation and Exploitation 5. Knowledge Community	- Increase in knowledge about the outcomes of the WP’s (especially WP3): 1. How much CO2eq may be saved in the different scenarios, originating from the shift to regenerative energy and increasing energy efficiency? 2. How much additional effort is needed if input data from calculating the basis for issuing EPC is not sufficient for building and using the digital twin relating that to the economical savings? 3. Success in integrating with local and regional development in the frame of the SET plan directive 2018/844/EU. - Potential side and rebound effects, GWP of production, usage and recycle phase – cradle to grave	- Interview with project partners - Questionnaire with external groups of interest (need owners)

Source: Own study based on Davidson 2005 and Galas et al. 2018.

### 3.2. Application of the outcome evaluation

We suggest a similar Criterion List for the Outcome Evaluation to be further evolved towards the end of the project.

Table 4. The Criterion List for Outcome Evaluation of the EPC4SES project.

Category	Subcategories and Criteria	Sources of Evidence
Knowledge, skill, and attitude gain (enumerating outcomes)	- Knowledge about the objectives of the project	- Evaluators’ observations
	- New solutions and synergies developed	- Participants’ feedback - Project leader’s assessment
Application of knowledge, skill, and attitudes (measuring effectiveness)	- Achievement of the project’s goals	- Participants’ feedback - Project leader’s assessment
	- Quality of the deliverables	- Assessments by an expert

Source: Own study based on Davidson 2005, 59.

The outcome evaluation of the projects aims, as mentioned above, at analysing the relations between the goals set in the beginning of the project life span and their achievement at the end of it. In EPC4SES project the following goals were identified:

**Main goal:**

Reduction of energy use and greenhouse gas emissions by using Energy Performance Certificates (EPC) data to optimize the design and operation of smart electricity grids for larger buildings.

**Subgoal (in order to achieve the main goal):**

Development of simulation tools so that energy planning can be improved by using digital representations of buildings (digital twins).

**Characteristics of the subgoal-tools:**

1. Better control of indoor climate and heat pumps as well as electric mobility contribute to reduced CO2 emissions.
2. Contribution to decarbonisation of local energy supply to buildings and easier planning of deep renovation with renewable energy and utilization of waste heat from district heating systems and cooling systems.

Based on the abovementioned goals, we therefore suggest a two-stage plan for outcome evaluation of EPC4SES that takes into consideration different levels of expected effects. In the first stage, we will evaluate achievement of the subgoal using the 2-point characteristics described above. In the second stage, the evaluation tasks will focus on assessing whether and how the tools developed as the subgoal contribute to the achievement of the main goal. The detailed plan here is as follows:

Table 5. Plan for Outcome Evaluation of the EPC4SES project, from Month 25.

Category	Stage	Criteria	Evaluation tool	
Knowledge, skill, and attitude gain	<ul style="list-style-type: none"> <li>- Knowledge about the objectives of the project (How accurate the digital twins depict reality?)</li> <li>- New solutions and synergies developed</li> </ul>			<ul style="list-style-type: none"> <li>- Evaluators’ observations</li> <li>- Questionnaire and interview with project partners</li> <li>- Interview with project leader</li> </ul>
	<b>Stage 1</b>			
	Development of simulation tools so that energy planning can be improved by using digital representations of buildings (digital twins)	<ul style="list-style-type: none"> <li>- Better control of indoor climate and heat pumps as well as electric mobility contribute to reduced CO2 emissions.</li> <li>- Contribution to decarbonisation of local energy supply to buildings and easier planning of deep renovation with renewable energy and utilization of waste heat from district heating systems and cooling systems.</li> </ul>	<ul style="list-style-type: none"> <li>- Analysis of the specific parameters and measurements</li> </ul>	
	<b>Stage 2</b>			
Reduction of energy use and greenhouse gas emissions by using Energy Performance Certificates (EPC) data to optimize the design and operation of smart electricity grids for larger buildings.	<ul style="list-style-type: none"> <li>- Simulation tools work as planned.</li> <li>- Size of the reduction of energy use. What are the effects?</li> <li>1. Energy efficiency</li> <li>2. Avoiding use of boilers</li> <li>3. Reducing peak load</li> <li>4. Use of renewable energy</li> <li>5. Increasing solar thermal energy, PV, wind usage by shifting demand</li> <li>6. Environmental impact</li> <li>7. Cradle to grave analysis</li> <li>8. Power demand of IoT vs. savings</li> </ul>	<ul style="list-style-type: none"> <li>- Interview with project partners engaged in the relevant case studies</li> <li>- Questionnaire with the users</li> </ul>		
<b>Stage 3</b>				
Application of knowledge, skill, and attitudes		<ul style="list-style-type: none"> <li>- Achievement of the project’s goals (Stage 1 and 2)</li> <li>- Quality of the deliverables</li> </ul>	<ul style="list-style-type: none"> <li>- Questionnaire with project partners</li> <li>- Interview with project leader</li> <li>- Assessments by experts</li> </ul>	
Evaluation report comprising environmental, performance and economic assessment				

Source: Own study based on Davidson 2005 and Galas et al. 2018.



## 4. Conclusions

In this document, we present the description, adaptation and application of the process and outcome evaluation in the EPC-based project «Digital Building Twins for Smart Energy Systems» (EPC4SES). Here we would like to sum up the key facts important for carrying out these tasks:

1. Expression ‘evaluation’, as much as the more detailed ‘process evaluation’ and ‘outcome evaluation’ are widely described in international literature, the definitions differ and the expressions are used in several different contexts. We therefore described their transferability from public policy to research. It is essential to follow the same understanding of the definitions throughout the whole project.
2. Before presenting the application of evaluation in EPC4SES, we proved that the combination of process and outcome evaluations has been conducted before and is known in the scientific literature we will rely on in our work. Referring to the Continuum of Evaluations, we explained which parts of the action belong to each of the two types of evaluation. The elements included in those two expressions were adapted to the thematic area of our project and presented in tables.
3. We also presented detailed time plans for conducting the evaluation tasks that need to be followed in order to successfully carry out the whole project.
4. Some possible deviations must be mentioned:
  - a. Force Majeure – the Covid-19 situation that dominated the year 2020 has influenced communications, travel, and meeting possibilities in international projects, and could therefore also cause delays in the EPC4SES project.
  - b. Illness within the project team (other than Covid-19) may also cause a delay in deliveries connected to different work packages.
  - c. In the case of communication and cooperation difficulties within the project team, fulfilment of some tasks can be delayed or rendered impossible. Should such a situation occur, the project leader must take appropriate action to ensure that the project can still be completed.
  - d. The quality and time of delivery of the evaluation work package depends heavily on the deliveries from other partners working with elements (other work packages) that are to be evaluated. However, as we are in charge of the abovementioned work package, we will do our best to keep to the time schedule presented in this document.

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