triangulum

DEMONSTRATE·DISSEMINATE·REPLICATE

D2.6 Final Impact Report M60

January 2020

Project coordination:
Fraunhofer Institute IAO

H2020-SCC-2014-2015/H2020-SCC-2014: “Smart Cities and Communities solutions integrating energy, transport, ICT sectors through lighthouse (large scale demonstration - first of the kind) projects”

Collaborative Project – **GRANT AGREEMENT No. 646578**

Project Acronym	TRIANGULUM			
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DoA	Report capturing the impact of ongoing demonstration activities across cities and sectors to enable impacts to be clearly detected and measured. The report makes reference to indicators on energy, mobility, citizen engagement, socioeconomic aspects and finances.			
Date	Version	Author	Contributors	Comments
05/11/2019	1	Kelly Watson, UNIMAN	James Evans, Joe Rees	Updated structure from M48 Refreshed Impact Report
19/12/2019	2	Joe Rees, UNIMAN	James Evans, Kelly Watson, Dujuan Yang, Faraz Barzideh	Updated city reports from TU/e and UiS
17/1/2020	3	Kelly Watson, UNIMAN	James Evans, Joe Rees, Dujuan Yang, Faraz Barzideh	Updated city sections from WPs 3-5 and updated throughout
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31/1/2020	5	James Evans, UNIMAN	Kelly Watson, Joe Rees, Faraz Barzideh, Trinidad Fernandez, Phillipp Lammel	Updated data for Stavanger, incorporated comments from WPs 1 and 6, added new figures and updates for district level monitoring
03/02/2020	6	James Evans, UNIMAN		Final edits
13/03/2020	7	Faraz Barzideh UiS		Update information (impacts numbers) Module 522 Central Energy Plant (p.168-173)

09/06/2020	8	Joe Rees, UNIMAN		Update information Module 323 Additional Energy Resources (p.60-61)

Table of Contents

List of Figures

List of Tables

Executive Summary

Triangulum has conducted a novel form of smart district development that integrates energy, mobility and ICT to improve the efficiency of commerce and governance as well as reduce greenhouse gas emissions. The goals of Work Package 2 (WP2) were to monitor and assess the impacts of the demonstration projects in the lead cities of Manchester, Eindhoven, and Stavanger in order to support learning within and between them, and to underpin the WP6 replication framework.

Deliverable 2.6 Final Impact Report: M60 presents the final deliverable outlined in the Description of Work (DoW), which gives a final account of the impacts and impact indicators in the three Lighthouse Cities. Previous deliverables (referred to henceforth as D2.*) are outlined below:

D2.3 Baseline Report, submitted in M12 and in updated version in M24, set out the impact indicators for each module and provided the first overview of the complete set of modules being implemented by the project. D2.5 Impact Report submitted in M36 provided updates to the baselines and where available an early indication of the impacts of the Triangulum project. D2.7 Impact Report was submitted in M48 as an extra deliverable to provide an update to the original D2.5, due to new module implementations and data becoming available by M48.

This report is based upon D2.7 submitted in M48, with the following additions and updates:

1. A section has been added to the Introduction Chapter called “Relationship to SCIS” to explain how Triangulum aligned monitoring and assessment of impact indicators with SCIS.
2. The summary of our “Approach to GDPR requirements” from the M48 report has been moved to the Introduction Chapter of this final deliverable.
3. As agreed with INEA at the M48 review and the project partners at the 2019 General Assembly, modules and/or impact indicators with no data available have been removed as at least 12 months of data is required for D2.6: Final multi-level impact assessment and monitoring.
4. The sub-heading “Changes from M36” in each module section has been updated to “Changes from M48”, to provide details of changes to impact indicators since the M48 report.
5. Two additional chapters have been added to this M60 deliverable in accordance with the description of D2.6 given in the DoW:
    - District Level Monitoring
    - City Level Monitoring
6. Two additional sections have been added to the “Overall synthesis of impact” Chapter: “Assessment of district level impacts” and “Assessment of city level impacts”, and the chapter has been updated.
7. A new chapter has been added to the report in Section 9 to outline the post M60 activities that are expected to be delivered after formal project close.

The D2.6 Final Impact Report presents the following achievements:

246 impact indicators have been finalised across the 27 modules implemented in the Lighthouse Cities. A total of 27 modules have been fully implemented out of 27 (100%; up from 86% at M48). 239 baselines have been set out of the 246 impact indicators required in total (97%; up from 87% in M48).

235 impact indicators have had impact values calculated (96%; up from 85.5% in M48). In terms of modules, 25 (93%; up from 86% in M48) have generated impacts. 85% of the modules have produced >24 months of monitoring data (compared to 59% at M48), and 96% of the modules have produced >12 months of monitoring data (compared to 89% at M48). One module in Stavanger was fully implemented but reported no data due to GDPR concerns that were unable to be resolved within the timeframe of the project. This shows considerable progress between M48 and M60 in terms of implementation, data collection and impacts. The report is organised into 10 sections.

Section 1 provides an introduction to the report, setting it within the context of the broader Triangulum project and the goals of WP2. It summarises the multi-level impact assessment methodology that was set out and elaborated in deliverables 2.1 and 2.3, final versions submitted in M26. It also covers the approach developed and implemented to ensure GDPR compliance by M48, including a summary of the results of implementing this process, and a description of the work undertaken to ensure our monitoring and assessment activities satisfy SCIS reporting requirements.

Section 2 summarises the Module Level impact assessment approach, and explains the structure used to report impacts in each city in the following three sections.

Sections 3, 4 and 5 present the updated and final Lighthouse city impact reports for Manchester, Eindhoven and Stavanger respectively. The structure of this report mirrors the structure of the overall Triangulum project, with city sections following work package numbering and addressing sectors in the order of energy, mobility and ICT. The sections give detailed breakdowns of module level impacts by sector, starting with energy, then mobility and finally ICT. For each module a detailed explanation is provided explaining why data or information is missing, what actions have been taken to address this, and any changes made to the module section since D2.7.

Section 6 is a new addition presenting the District Level impact assessment approach and results at M60. There is a separate section for each city, and each begins by providing an overview of the districts and modules in that particular Lighthouse City, followed by the aggregated results within each district.

Section 7 is also a new addition and presents the City Level impact assessment approach and results at M60. It presents an overview of softer impacts across all cities and organisations involved in the project, and it covers leveraged spin-off benefits, process learning impacts and replication, and the need for scaling and contextualising impacts to target different city audiences. The results of this work have informed the European Commission through the EIP-SCC Smart Cities Guidance Package https://eu-smartcities.eu/news/smart-city-guidance-package and other relevant project through engagement with the SCC1 Monitoring and Evaluation Task Group.

Section 8 provides a final synthesis of progress and impacts at module, district and city level. Module-level highlights include:

- For Manchester, six months' worth of energy trials in the final year (January to June 2019) carried out showing significant potential for reducing energy demand and lowering GHGs, 10,300 m^2 optimised building space in MCC for smart energy interventions with over 400 tCO_2e avoided GHGs, and a further 35 tCO_2e avoided GHGs as a result of PV energy generation. The purchase of 10 Triangulum procured EVs has reduced GHG emissions by 35 tCO_2e since 2016, and the overall impact of Triangulum has been to increase university share of EVs in vehicle fleets from 5% to 25%, with reduced GHG emissions of over 125 tCO_2e, 11kg NOx, and 70kg CO. 4 cargo bikes have made 4,493 journeys and travelled 6,697 km over a three-year period and saved 820 $kgCO_2e$. The Manchester-I data platform hosts 9 real time data feeds and has 4 organisational users and 307 users that have downloaded data 427 times. Over 50 people have attended the Innovation Challenges hosted in 2018 and 2019.

- For Eindhoven, in Strijp-S, biomass and Sanergy have replaced the old heating system and provided 100% renewable energy for heating. In 2019, 14% of all energy was generated by Sanergy. 14 EV charging stations have been implemented. The fiber-optic network has been expanded extensively with 350 home connections and 7,050 office connections. 40 sensors have been installed in Strijp-S. 28 SMEs from the iCity tender have been created, and €50m p.a. additional investment has been secured from partners since 2016. In Eckart-Vaartbroek, for social housing, 11,200 m^2 buildings have been renovated, reducing GHG emissions by 20%. The estimated energy bill reduction in 2019 was 55%. For the digital renovation platform of Woonconnect, 284 households (29%) used it, and 174 made a plan (scenario) for the renovation of their home. The Eindhoven open data platform has been viewed 96,000 times per month in 2019 and actively downloaded nearly 4,000 times per month.

- For Stavanger, 56 smart gateways have been installed in residential buildings, and the Central Energy Plant (CEP) in Stavanger Commune has avoided a total of 500 tCO_2 p.a. which represents an 87.5% reduction in CO_2 emissions and annual savings of 1.37m NOK. 5 battery buses have been deployed by the bus operator in the city, travelling >18,000km per year and avoiding 135 tCO_2, 250 kg CO and 66 kg NOx. The Cloud Data Platform has 6 internal users, hosts 4 datasets, and currently has 35 completed impact indicators.

Across the three Lighthouse Cities:

- The main Energy sector impacts are reduced local energy use with more demand being met by renewable sources, reduced energy costs, and decreased greenhouse gas emissions. Energy technologies have shown an ability to generate savings of up to 85% in municipal buildings (STAV), 20% in business premises (MAN) and 20% in residential (EIN). The Triangulum project has saved 10936 GWh in total.

- The main Mobility sector impacts are improvements in efficiency, and reduced greenhouse gas emissions (CO_2, NOx, CO). >5000 business journeys have been electrified or shifted to cargo bike, while four fleets comprising >300 vehicles (UNIMAN, MMU, Kolumbus and MCC) are now considering electrification.

- The main ICT sector impacts are increases in the availability of open data, data downloads, and improvements to fibre optic networks. >1000 citizens have been directly engaged in ICT modules across the Triangulum project, with >1.5m engagements with data platforms.

At a district-level the modules that have been implemented generated impacts contributing to 26/26 city level objectives, as follows:

- For Oxford Road Corridor: modules have generated impacts that contribute to seven out of seven of the district objectives, with the energy and mobility modules performing particularly well.

- For Strijp-S: modules have generated impacts that contribute to eight out of eight of the district objectives, with the energy and ICT modules performing particularly well.

- For Eckart-Vaartbroek: modules have generated impacts that contribute to six out of six of the district objectives, with the energy and ICT modules performing particularly well.

- For Paradis/Hillevag: modules have generated impacts that contribute to five out of five of the district objectives, with the energy and mobility modules performing particularly well.

At a city-level key impacts relate to leveraged investments, process learning and scaling up:

- The key impacts around leveraged value are related to secured funding, supported jobs (FTEs) and associated Gross Value Added (GVA). Triangulum leveraged benefits including >€70m of research and innovation funding and three spin-out companies, including the largest Smart City expo in Northern Europe.

- The key impacts associated with process learning impacts involve the organisational and professional changes that have been stimulated by Triangulum. These were identified in a survey of participants as the most important impacts of the project, and are critical in equipping cities with the skills and deep partnerships required to accelerate their low carbon transitions.

- The main impacts associated within scaling up and contextualising impacts are the potential for Triangulum interventions to be rolled out across the wider city contributing to a range of local policy drivers, as well as making a significant saving towards city Carbon Budgets.

Section 9 provides a discussion of the anticipated activities that will be delivered post-M60 and after official project close out. WP2 has achieved 42 exploitation activities including 7 MSc projects, 3 PhDs, 9 peer reviewed papers, 10 papers in conference proceedings and >€10m of research funding. Many of these are ongoing and this section outlines how each of the four universities is continuing to research Triangulum initiatives.

Section 10 offers a summative conclusion.

1 Introduction

This introduction provides a concise summary of Triangulum and the role of WP2: Monitoring and Assessment. It outlines the tasks that this deliverable contributes to, and the methodology that has been used to develop the impact assessment that has been used in the overall project.

1.1 Triangulum and the role of WP2: monitoring and assessment

The main goal of Triangulum is to demonstrate how technologies from the energy, buildings, mobility and ICT sectors within one district leads to a significant reduction of energy demand and local GHG emissions whilst at by at the same time enhancing quality of life, delivering efficient and clean mobility to residents and local workers and providing the basis for economic growth and development. Cross-sectoral smart city modules are being demonstrated in Manchester, Eindhoven, and Stavanger to provide a test bed for new business models, technologies, and strategies of citizen engagement. The five-year project is structured to have 3 years for implementation and then 2 years for monitoring and assessment. The goal of WP2 is to rigorously monitor and assess the impacts of the implementations to support the work of the lead city partners and learning between them.

The framework for monitoring and evaluation presented in Deliverable 2.1 submitted in M26 provided the basis to assess the successes and challenges of the smart city modules developed within Triangulum. It reviewed leading smart city frameworks and with WP6, developed an innovative model of co-production to ensure that monitoring and assessment reflects best practice in terms of existing frameworks such as CITYkeys and SCIS, while also capturing impacts that city partners are most interested in and able to monitor. Deliverable 2.2 submitted in M36 produced a Cloud Data Hub (CDH), hosted at the University of Stavanger, to collect and store relevant datasets from all modules. To date, the CDH has been used to collect data from some modules in Stavanger, but is not being used to collate data across all three cities for the purpose of impact assessment reporting as many of the relevant datasets are either static or not available to be shared. Deliverable 2.3 submitted in M26 presented the baseline report based on the expected impacts and impacts indicators that modules foresee, including a detailed account of the methodology that was used to co-produce the monitoring framework with WP2 staff and partners in the Lighthouse cities. Deliverable 2.3 provided a first attempt to set the baseline for the module impact assessments, although this was not possible for modules that were not yet fully specified. Deliverable 2.4 submitted in M26, presented the interim report which focused on the sustainability of data generation, collection and use in Triangulum. Deliverable 2.5, presented in M36 (and the M48 refresh presented in D2.7), presented the module-level impacts in each Lighthouse City that were available at that time, as well as providing an overview on progress and outlining next steps for the coming year. These reports were vital in encouraging partners to supply data for monitoring and assessment. The deliverables are publicly available on the Triangulum website (https://www.triangulum-project.eu/?page_id=119) and also on the Research Gate website as outlined in the DoW as follows:

- Deliverable 2.1: Common monitoring and impact assessment framework (http://bit.ly/2GpeOm6)
- Deliverable 2.3: Baseline report (http://bit.ly/2novDov)

- Deliverable 2.4: Interim report (http://bit.ly/2rJN9cA)
- Deliverable 2.5: Impact Report (https://bit.ly/2Rt1eWt)
- Deliverable 2.7: Impact Report - M48 Refresh (https://bit.ly/2RSYyAv)

This report, Deliverable 2.6: Final Impact Report, is the final deliverable for the project. It provides a full set of baseline data, and gives a final picture into the impacts that are being generated by the Triangulum modules. As outlined in D2.1, it provides a full account of the impact of the modules, including an assessment of the district and city-level impacts.

1.2 Multi-level impact monitoring and assessment approach

The framework for monitoring and evaluation developed for Triangulum is a multi-level approach, across module, or project, level impacts, district level impacts and city level impacts. The following outlines how each impact level has been dealt with in this report:

- Module level impacts – Sections 3, 4 and 5 provide a full set of impact indicators for each Lighthouse City across the baseline, M36, M48 and M60 values (where data availability allows).
- District level impacts – Section 6 provides an overview of the aggregated impact indicators for each of the districts in the Lighthouse Cities.
- City level impacts – Section 7 provides an overview of the impact of Triangulum at a city level, comprising sections on leveraged value, process learning and scaling-up and contextualising impacts.

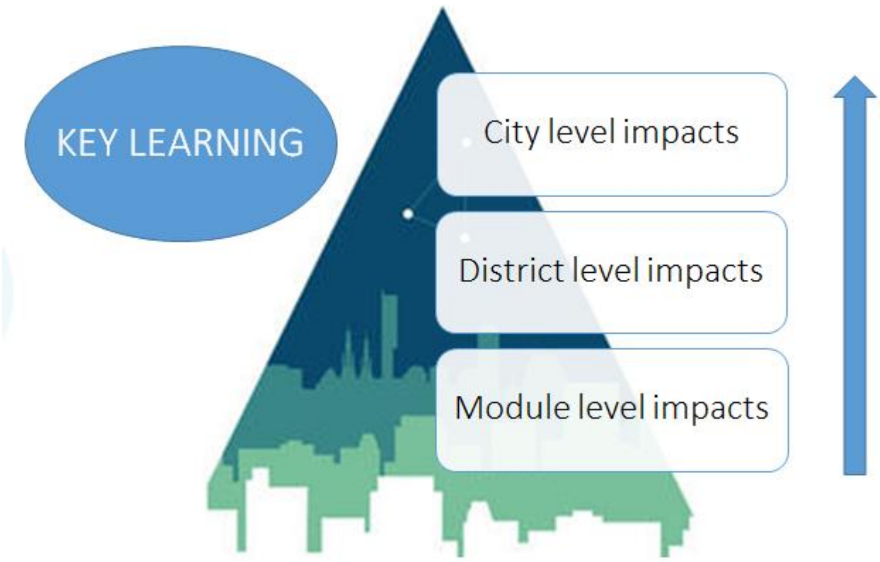


Figure 1.2.1: Multi-level impact framework

1.3 Modules and use cases: the relationship between monitoring and replication

WP2 monitors and assesses the impacts of the implementation projects in the Lighthouse Cities. Implementation projects are conceptualised as 'modules'. This is an innovative approach to smart city development that considers interventions as combinations of technology, interfaces, business cases, stakeholder structure, and policy. Section 3.1.2 of D6.2 Smart City Framework details the development of the 'module' concept as a way to capture the value of smart city projects in a more holistic way than has previously been managed. Modules provide the units of analysis for monitoring and assessment, and this informs D6.2 Smart City Framework technology approach. The modules also underpin the development of use cases as the units for replication in D6.2 Smart City Framework. Use cases build on the Triangulum implementations, but also go beyond them to focus on business models and the specific contexts in which they operate successfully. Some modules map onto single use cases, while others split into multiple use cases. For example, Module 444: Public space sensor network in Eindhoven supports numerous potential use cases related to smart lighting and safety. Use case nomenclature follows the WP2 module numbering system and simply adds a letter to the end to denote each separate use case. So Module 444 supports UC-444a, UC-444b, and so forth. For modules with multiple use cases, impact indicators that vary by use case (e.g. amount of energy used in the different types of building) have also been split. This is denoted by the addition of a letter to the impact indicator number. This means that data collected as part of WP2 can be linked to WP6 use cases in order to provide evidence for them where possible. In other instances, use cases emerged from WP6 onsite assessments and are not directly linked to actual implementations, meaning that there is nothing to monitor and assess. For this reason, WP2 focuses on modules as the unit of analysis for monitoring and assessment, while WP6 adopts use cases as the unit of analysis for replication. Table 2.5.1 on page 27 of this report gives an overview of the modules included in this report and how they relate to WP6 use cases.

1.4 Contribution of this deliverable towards tasks outlined in the DoW

Deliverable 2.6 Final Impact Report contributes to the following tasks:

2.2 Monitoring. UNIMAN (Lead), MMU, UiS, TU/e.

Gather baseline data to capture conditions before the demonstrator projects begin to allow subsequent measurement of the success and impacts of demonstrator projects.

100% complete. WP2 have collected all available baseline data to capture conditions before the demonstrator projects began. 239 baselines have been set out of the 246 impact indicators required in total (97%; up from 87% in M48). Outstanding baseline data exists for two modules due to GDPR concerns. All missing data is noted in the dataset tables provided in Sections 3-5.

Liaise with key city stakeholders and, where necessary, third party data providers who are not part of the project team to secure appropriate data in a timely and orderly fashion.

100% complete. 246 impact indicators have been finalised across the 27 modules implemented in the Lighthouse Cities. A total of 27 modules have been fully implemented out of 27 (100%; up from 86% at M48). All data holders were identified and contacted. Specific processes were used to negotiate with third party data holders and data holders with privacy concerns, as outlined in the 'steps taken' columns of the dataset tables for each module in Sections 3-5 and Section 1.5 describing the process for ensuring compliance with GDPR regulations that came into force 20 months before the end of the project.

Maintain and populate Cloud Data Hub.

100% complete. Relevant and appropriate data was captured by the Cloud Data Hub as part of the process of collecting data. See Deliverable 2.2 Cloud Data Hub for further details.

Process and analyse data in accordance with the common monitoring and assessment frameworks identified in task 2.1.

100% complete. 235 impact indicators have had impact values calculated (96%; up from 85.5% in M48). In terms of modules, 25 (93%; up from 86% in M48) have generated impacts. 85% of the modules have produced >24 months of monitoring data (compared to 59% at M48), and 96% of the modules have produced >12 months of monitoring data (compared to 89% at M48). The common monitoring and assessment frameworks have been applied as part of this report, and have been completed as far as allows.

Assist with the implementation of long-term monitoring protocols in smart city districts in the Lighthouse cities to cover years four and five of the project.

100% complete. The framework described in this report was implemented in year 5 and the results presented here in the final M60 deliverable, D2.6 Final multi-level impact assessment and monitoring summary report. Section 1.5 outlines the work of WP2 to enable partners to report impacts to SCIS after the project ends in M60.

2.3 Reporting. UNIMAN (Lead), MMU, UiS, TU/e.

Produce assessment reports capturing the baseline conditions for each city and the subsequent impacts and success of demonstrator activities and improvements in data collection and monitoring capacity.

100% complete. This final deliverable captures the baseline conditions for each city and the subsequent impacts and success of the implemented demonstrator activities and improvements in data collection and monitoring capacity.

Produce synthesis reports comparing baseline conditions and subsequent impacts between the cities and between sectors (energy, mobility, ICT, citizen engagement and socio-economic) to assess success of activities and enable identification of common challenges and opportunities and promote learning and replication.

100% complete. This M60 deliverable provides a comparison of baselines across the three cities and summative data concerning key impacts. It also contains district-level and city-level syntheses in order to meet the objectives outlined above.

2.4 Learning. UNIMAN (Lead), UiS, TU/e and FhG.

Disseminate baseline and impact reports to key city and project partners to enable formative learning.

100% complete. The process of co-producing monitoring and impact reporting with partners has embedded data collection in their operations and a clear definition of the desired outcomes of the modules. Formative learning has thus been occurring throughout the project. WP2 has achieved 42 exploitation activities including 7 MSc projects, 3 PhDs, 9 peer reviewed papers, 10 papers in conference proceedings and >€10m of research funding. Many of these are ongoing and each of the four universities is continuing to research Triangulum initiatives. The final version of this report has been circulated to partners and has been proposed as an agenda item at final city board meetings in Spring 2020, coordinated by WP2 representatives across the three Lighthouse Cities.

Provide an evidence base of data and assessment for the on-site visits that form part of WP6.

100% complete. The WP2 evidence base of impacts informed new WP6 activities post-M48 that were part of the amendment AMD-646578-58 approved in M48.

1.5 Working with SCIS

The Smart Cities Information System (SCIS) is a knowledge platform created by the EU to exchange data, experience and know-how and to collaborate on the creation of smart cities, providing a high quality of life for its citizens in a clean, energy efficient and climate friendly urban environment. SCIS provides reference for how cities might move towards smarter infrastructure: reducing building and transport pollutant emissions, lowering energy consumption and costs, improving citizen engagement, and increasing provision for citywide data. This list is only a handful of broad effects due to the implementation of smart city solutions, there are many more niche use cases and key performance indicators (KPIs) explored throughout the SCIS platform.

Through the final months of the Triangulum project SCIS developed and launched a new reporting methodology to capture evidence generated by the Smart Cities and Communities Lighthouse Projects. WP2 led the contribution of Triangulum to SCIS, as outlined in the DoW. WP2 have been aligning our impact indicators with SCIS since 2016 (see D2.1 and 2.3) to ensure compliance with EU reporting requirements where possible. SCIS is not intended to capture all impacts however, due to the varied nature of the demonstration projects that comprises the SCC projects, so it was not considered appropriate to base module level impact monitoring and assessment solely on the SCIS framework. As one of the first batch of SCC projects to report, UNIMAN led an intensive programme of consultation with SCIS on behalf of our partners to understand how to present and derive data required for the SCIS platform. The following table presents a summary of WP2's interaction with SCIS and other SCC partners. Please note, where WP2 is used to indicate attendance it includes Joe Lake Rees who led the work with SCIS from UNIMAN, and representatives from TU/e and UiS.

Comms mode	Date / place	Attendance	Content covered	Outcomes
Skype	30/09/2019	WP2, Rudy Rooth (SCIS)	SCIS issues identified by partners, what elements were essential to report for the energy modules	Discovered KPI's are the key reporting essentials for SCIS. Concentrate on KPI section
Open questions	15/10/19 Prague	Triangulum GA	SCIS reporting time-frames and actions in order to complete reporting. Appropriate representation of social KPI's within the SCIS platform queried	Agreement on the time-frames for reporting
Workshop	16/10/19 Triangulum Replication workshop, Prague	WP2	SCIS finer issues: questions including: - Design sheets intervention planned, first year, comparable technologies as baseline? - Reference systems	List of final barriers to design sheets, answering these should unlock. Answers to be found over Skype with Rudy Rooth. Completion of these as far as possible.

			- Reflecting the project appropriately e.g. before no electricity consumption now due to presence of intervention electricity is consumed. How to reflect the projects appropriately	
Workshop	18/10/19 SCC conference, Lyon	Aapo Houvila (chair of SCC monitoring and evaluation task group), Barbara Branchini, Sergio Diaz de Garayo, Gabriele Zacco, Terttu Vainio, Tomas Vacha, Carl-Magnus Capener, Joe Lake Rees (UNIMAN)	SCIS reporting coverage some key issues highlighted: - Baseline what do we use - Reference – EV's compared to: bikes, diesel vans, ICE car - Methods of reporting through SCIS - Projects have different objectives	Report the answers found in the Skype call with Rudy Rooth, use as a launch piece to complete understanding of the platform within the monitoring and assessment task group.
Skype	24/10/19	Rudy Rooth (SCIS), WP2	Questions raised at Triangulum GA, most (~95%) questions answered. Partners had opportunity to clarify with Rudy Rooth. Answers compiled and sent to Rudy for review.	Answers compiled and sent for review by Rudy Rooth, skype call recorded for partners. Once answers confirmed by Rudy the will be circulated and used to inform 'recipe books' for data entry into SCIS and assist.
Skype	31/10/19	WP2	Deadlines for reporting, MMU have begun to report energy, UiS are hiring a full time member of staff to complete SCIS. Recipe books for how to fill in SCIS for ICT and Mobility complete.	Recipe books for: new buildings, refurbished buildings, and energy systems to be sent out to WP2 partners on 01/11/19.
Skype	13/11/19	Rudy Rooth (SCIS), Joe Lake Rees (UNIMAN)	Skype answering questions for the recipe book.	SCIS recipe book almost all questions answered, one question sent to Rudy by email. Once document

				complete, checking by WP2 UNIMAN, then circulated across consortium and to Rudy Rooth.
Skype	14/11/19	WP2	Follow up to ensure that design form completion is progressing. Eindhoven cannot report on one module until 2021 due to the delay in the building being built. Many SCIS template for Eindhoven and Stavanger have not been reflective of the project.	Completion of remaining design templates by 22/11/19
Face to face discussion	19/11/19	Rudy Rooth, Jelle Jaubin	Explanation of the up coming changes to scis, some 'how to' reporting questions.	
Skype	29/01/20	Rudy Rooth, Dujuan Yang (TU/e), Joe Lake Rees (UNIMAN)	Exploration of how to report some energy modules for Eindhoven regarding powerlines	

Table 1.5.1 WP2 interactions with Triangulum partners, SCIS and wider SCC community

The interactions described above focused on identifying the problems, and trying to come to a collective methodology on how best to translate the previous four years of project impacts into the new SCIS platform. WP2 liaised with the proprietary stakeholders of the SCIS online database. It was determined that a large proportion of the questions being requested could be covered in a guide format, reducing the time taken discussing within the project and corresponding with SCIS staff, and providing a reference material for a collective reporting methodology across Triangulum and the SCC community more widely.

UNMIAN developed a comprehensive 65 page SCIS guidebook for Triangulum partners (available at: https://www.dropbox.com/s/qb49gpwe88o3x73/SCIS%20guidebook%20for%20Triangulum%20partners.docx?dl=0) that covers nine distinct modules: new buildings, refurbished buildings, mobility infrastructure, mobility vehicles, ICT, and energy systems integration: infrastructure and system integration for a waste heat cluster, sustainable generation for absorption chiller and sustainable generation for a boiler cluster, and electrical storage. The Triangulum modules map to the SCIS modules as shown in Figure 1.5.1.

For SCIS to operate it requires two key periods of information, before and after intervention; these are covered within design and monitoring forms. As these forms are distinct and require completion in slightly different ways, the produced guide covers both design and monitoring. Only module types represented in the Triangulum project were developed, however the use of the guide is not restricted to Triangulum as the guidance does not reference specific translation for modules in the project, the guide may be of use to ongoing and future smart city projects.

Figure 1.5.1 Complete list of all SCIS modules and their related M60 report sections

1.6 Approach to GDPR requirements

This section outlines the approach developed and implemented to ensure GDPR compliance of the project.

1.6.1 Triangulum GDPR compliance procedure

The second Triangulum review meeting in April 2018 highlighted that Triangulum *as a consortium* must develop and deploy an approach to GDPR by month 48. This section presents an approach to ensuring GDPR compliance within the Triangulum project for comment from the project Steering Committee.

The first part outlines the basis for the approach that has been presented here. The second presents the approach taken to ensuring GDPR compliance including the timeline to ensure completion before M48 in accordance with the project review. Appendix 11.3 outlines the GDPR roles relating to data within the Triangulum consortium. Appendix 11.4 contains the GDPR checklist that was sent to partners as part of the Policy and procedure audit. Appendix 11.5 contains the Triangulum adapted Privacy Impact Assessment (PIA) screening form.

1.6.2 Basis for Approach

The approach seeks to i) audit existing policies, procedures and actions that have been taken locally by partners in a structured way, and ii) use Privacy Impact Assessments (PIAs) to identify and address potential data concerns in modules and provide a robust basis for the development of suitable policies.

Structured WP2 discussions with local partners at Lighthouse City board meetings in June and July 2018 identified numerous existing actions that have been taken locally by partners. It is necessary to first capture these actions across the consortium to understand where gaps and issues remain. Once this has been done PIAs can be used to identify and address remaining issues.

The PIA approach has been used by the Innovate UK £10m funded CityVerve IoT project, the EU H2020 SCC1 REPLICATE project, and the £140m UK government funded UK Collaboratorium for Research in Infrastructure and Cities (UKCRIC) programme. Each of these shares key characteristics with Triangulum in that they are data-driven, involve partnerships of cities, companies and universities, and are research and innovation projects. The approach here has been developed following discussions with Triangulum partners at city board meetings and WP2 partners (06-07/18), the GDPR advisor to CityVerve (10/2017), the UK Information Commissioner's Office (11/2017), and the GDPR leads for the UKCRIC Urban Observatories programme (06/2018).

1.6.3 Approach to ensuring GDPR Compliance

The developed process involves four stages, outlined in Table 1.6.1 below:

Stage	*Purpose*	*Actions*	*Month*
Policy and procedure audit	Capture actions that have already been taken by partners, including updated privacy statements, GDPR procedures, staff communications, and training. This also includes module specific actions such as	WP2 to draft survey. WP1 to email survey to all partners asking for details of actions and documentation.	M42

	GDPR audits or privacy impact statements.	Individual responses required from every partner.	
PIA screening	Screen modules for GDPR privacy issues. The answers will allow WP2 to determine whether the city will need to complete a PIA for an individual module.	WP2 prepare PIA screening documents for each module and distribute to city leads. City leads coordinate completion of PIA screening documents.	M43 M44
Conduct PIAs	PIAs conducted for modules that have been highlighted through screening to help organisations identify the most effective way to comply with their data protection obligations and meet individuals' expectations of privacy.	WP2 prepare PIA documents for modules highlighted by screening. City leads coordinate completion of PIAs for highlighted modules.	M45
Review and update policies and procedures	Review and Update Policies and Procedures as required including WP2 data processing agreements, D8.1 DMP, and Internal Data Breach Procedures & Detection Methods	WP2 identify updates that are required and WP1 inform relevant partners. Partners complete updates.	M46 M47

Table 1.6.1: Four stage compliance process

WP2 supported this process, but as a consortium-wide process it was proposed that WP1 / the project coordinator to lead communication with partners to ensure compliance and leverage the existing management structure and communication channels. Self-assessment was preferred as partners may be collecting forms of data above and beyond that which is being used by WP2.

1.6.4 Results of the GDPR Approach

The project partners returned completed PIA screening forms in November 2018, via the project coordinator in each city. These forms are being held on a secure University of Manchester server by WP2. The results are summarised for each city below:

- Manchester PIA screening forms showed no GDPR non-compliance issues for any module.
- Eindhoven PIA screening forms showed no GDPR non-compliance issues for most modules. The only issues identified was with Module 432: Mobility management and Module 444: Public space sensor network, where the project leads answered "Yes" to collection of email / password data combinations for the software technologies being developed. The module leads are conducting full Privacy Impact Assessments (PIAs) for these modules to identify full mitigation procedures.
- Stavanger PIA screening forms showed GDPR non-compliance issues for two modules. The privacy issues were resolved for one and data is flowing, but ongoing complexities with a second were unresolved at the end of the project.

1.7 Overview of progress: using this report

This report provides a final picture of the Triangulum project's success in implementing modules and achieving expected impacts in the city districts. It will be of use to key audiences in the following ways:

- Researchers: the report clearly highlights final achievements and can be used as a basis for identifying further avenues of research.
- Project partners: the report indicates final progress in terms of implementation and impacts for the city modules that can be used in promotional materials and to support future investment.
- Project coordinator: the report indicates overall progress and comparative progress in terms of achieving expected impacts across the three Lighthouse Cities.
- Potential customers: the report gives an insight into the different dimensions of impacts that are being achieved by each module, and the magnitude of each.
- Project participants: the report outlines key information about the approach to monitoring and assessment that will be of use to participants in other SCC1 projects or those partners part of the SCC1 TF Data.
- Funding bodies, policy makers and municipalities: the report gives critical insights into the impacts at different levels of implementing smart solutions in terms of meetings sustainability goals and softer impacts around process learning and organisational change.

2 Module Level Monitoring

This section outlines the methodology used for the monitoring and assessment of module-level impacts across the three Lighthouse Cities since the monitoring period began in M36.

This section draws on the baseline and impact assessment methodology outlined in Deliverable 2.1, adding details about impact assessment that has been undertaken since the submission of Deliverable 2.3 in M24, Deliverable 2.5 in M36, and Deliverable 2.7 in M48.

2.1 Baseline and Impact Assessment Methodology

The seven stage methodology adopted by WP2 for developing impact indictors and calculating impacts was presented in Deliverable 2.1 (the Common Monitoring and Impact Assessment Framework), submitted in M26. The stages of the methodology are reiterated in Figure 2.1.1 to aid interpretation of the impact report.

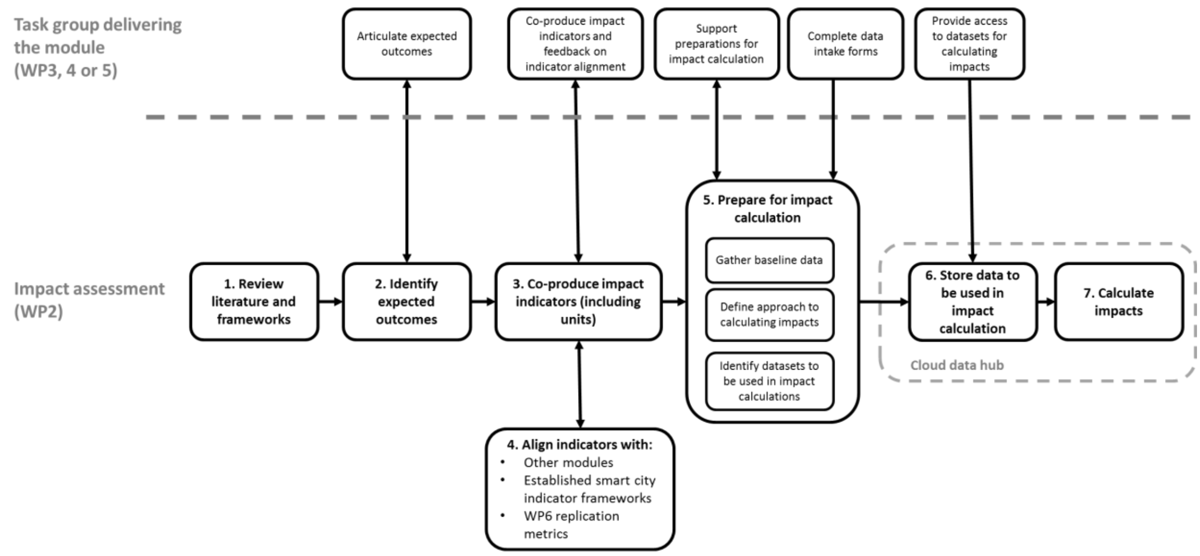


Figure 2.1.1: A Seven-Stage Methodology for Developing Indicators and Calculating Impacts

Explanation of Seven-Stage Methodology for Developing Indicators and Calculating Impacts:

1. **Review of existing literature and frameworks**. WP2 conducted a desk based review of the key literatures on sustainability and smart city indicator development and assessment. WP2 conducted a review of ongoing sister projects developing smart city indicator and assessment frameworks. The desk study was used to determine the general framework and parameters for the work.

2. **Identify and document expected outcomes**. WP2 engaged with the city task groups delivering the modules to identify the scope and expected outcomes of each module. In each Lighthouse City, a local university researcher (Manchester: MMU and UNIMAN; Eindhoven: TU/e; Stavanger: UiS) was tasked with developing impact indicators and associated reports for the modules of the local

partners. Engagement was aligned with the operation of the task group. Methods used included contributing to task group meetings, conducting workshops and semi-structured interviews, electronic consultation and opportunities to feedback on draft WP2 documents.

3. **Co-produce and document impacts, indicators and datasets.** Based on the expected module outcomes and review of existing literature and frameworks WP2 proposed impact indicators including quantitative units. The city task groups were invited to propose impact indicators. The set of indicators for the module was then collaboratively refined by WP2 and the task group through workshops and inviting comments electronically on draft WP2 documents. Follower Cities also provided input to this process at the GA in Berlin 2015.

4. **Align and verify impacts, indicators and metrics.** The impact indicators for each module were included in analyses which identify opportunities to align: with other indicators across energy, ICT and mobility activities across the three cities; established smart city indicator frameworks (CityKeys and SCIS); and, WP6 replication metrics. The aligned impacts, indicators and metrics were verified with the task groups through electronic consultation.

5. **Prepare for impact calculation.** With support from task groups WP2 preparation for impact calculation included: gathering baseline data; defining the approach to calculating impacts; and, identifying datasets that could be used in the calculation of the impacts. Two modes of engagement were used: (1) ongoing collaboration through workshops and interviews; and, (2) task groups completing a data intake form (DIF) document which formally specifies the indicators and approach to be taken to calculate them. The data intake form was used for more complex data sets that go beyond individual data points or simple spread sheets. Additional work facilitated documentation and transfer of data, but partners were not asked to perform additional work to generate the data.

6. **Store data to be used in impact calculation**. Based on the details provided by stakeholders and in the data intake form WP2 (UiS) has imported datasets for impact calculation into the cloud data hub. Where data is not in the appropriate format or does not warrant automation, datasets have either been manually collected by WP2 researchers in each city or specific data items have been requested from dataset holders.

7. **Calculate impacts**. Impacts have been calculated in three ways. The preferred option is to calculate impacts automatically in the Cloud Data Hub. This has only been possible for a limited number of impacts based in the Stavanger modules, reflecting the fact that not many datasets were available and / or appropriate for storage in the cloud data hub. Where this is not possible, WP2 researchers have requested the relevant data to make impact calculations. Where data has been unavailable for sharing, WP2 researchers have requested pre-calculated impacts from data holders.

Table 2.1.1 shows the timescales, key input required for each activity from partners, and the key instruments used at each stage.

Stage	Impact assessment activity (WP2)	Timescale	Input required from other WPs and partner organisations	Key methods used by WP2 staff
1.	Review of existing literature and frameworks	M1-M6	N/A	Desk study.
2.	Identify and document expected outcomes	M3-M9	Articulation of module scope and expected outcomes (WPs 3, 4 and 5)	Participation in task group meetings, email consultation on module outcomes.
3.	Co-produce and document impacts, indicators and datasets	M6-M12	Input to identify, review and validate indicators (WPs 3, 4, 5 and 6, and follower cities)	Semi-structured interviews, electronic consultation on module impact tables.
4.	Align and verify impacts, indicators and metrics	M9-M24	Feedback on alignment and verification of impacts indicators and metrics (WPs 3, 4, 5 and 6)	Alignment with SCIS and CityKeys. Electronic consultation with the city task group.
5.	Preparation for impact calculation	M9-36	Engagement with Data Intake Form to review and validate impacts and indicators (WPs 3, 4 and 5) Collect and provide access to baseline data (data owners within and outside the Triangulum consortium)	Webinars and email support to partners to complete Data intake form. Electronic requests for data and meetings.
6.	Store data to be used in impact calculation	M12-36	Provide access to datasets required to calculate impacts (as detailed in the Data Intake Form) (WPs 3, 4 & 5)	Email reminders and communications through Triangulum steering committee.
7.	Calculate impacts	M33-60	Relevant formulae and additional data required from partners for some indicators	Electronic requests for data and meetings.

Table 2.1.1: Impact assessment methodology overview

2.2 Calculation of Impacts

A number of complexities exist in relation to the specific calculation of impacts from data. This section considers three key challenges: units and formulae, extrapolated values, cumulative values, and calculation approaches.

Units and formulae

Where possible impact indicators have been aligned with the SCIS smart city indicator framework, as outlined in stage 4 of the impact methodology described above and available here: http://www.smartcities-infosystem.eu/sites/default/files/document/scis_kpi_guide.pdf. As SCIS was only initiated in November 2017, impact indicators have been identified as either in alignment or not with the SCIS framework, but no indicators have been removed as a result of this exercise. As a result D2.7 uses standard metric measures and units that are outlined in the SCIS framework. For indicators not aligned with SCIS consistent units are used across the three modules and cities.

Extrapolated values

Many modules have only recently been implemented, making it hard to assess impacts. To produce comparable impacts we have provided extrapolated values for impact indicators showing how the trend would look over a calendar year using simple linear extrapolation. It should be noted that extrapolated impacts that are based on relatively short implementation periods should be taken as indicative of general trends rather than as absolute figures. The validity of extrapolated values also varies by type of indicator. For example, absolute numbers of cargo-bikes deployed will not change over the duration of the rest of the project so are relatively time-independent. Changes in energy use meanwhile need to reflect seasonal variations, so require data covering at least a year. For any indicator which is subject to complex causal factors that vary over time, simple linear extrapolation is a major simplification[1].

The relative change and extrapolated rate per annum of relative change are both included to give some measure of scale for comparison between the impact indicator values. They are not intended to imply that changes will continue indefinitely with the values shown. For example, a value that increased 400% in 6 months, and therefore extrapolated to 800 % per year, is not expected to grow by 800 % every year.

Cumulative values

For specific impact indicators impacts are clearly cumulative. For example, km travelled by cargo bikes and the associated emissions avoidance accumulate over each reporting period. The presentation of impacts in the impact indicator tables in this report does not give cumulative impacts, but rather the M36, M48 and M60 values relative to the baseline period. This is for three reasons:

1. To allow the performance over each reporting period to be seen.
2. Because not all impact indicators are cumulative (for example, more static data like the number of buses purchased does not accumulate).
3. Because the reporting periods are not perfectly continuous for certain indicators due to the availability of data.

[1] Franklin, J. (2013) Arguments whose strength depends on continuous variation, *Journal of Informal Logic* 33, 33-56.

Calculation approaches

Where possible, impacts have been calculated automatically in the cloud data hub. Where this is not possible, WP2 researchers have requested necessary data directly from data holders to make impact calculations. Where data has been unavailable for sharing, WP2 researchers have requested pre-calculated impacts from data holders in modules. Impact calculation options in order of preference are presented in the figure below.

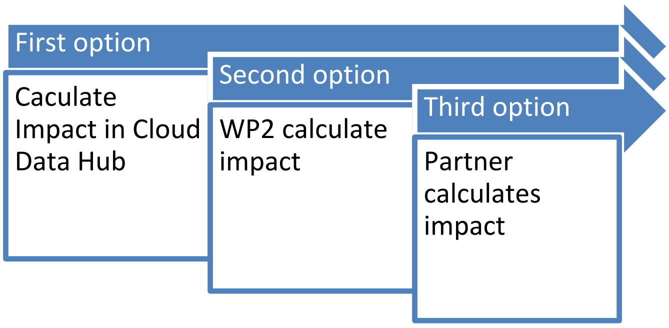


Figure 2.2.1: Impact calculation options in order of preference

For each module the section titled '*Factors limiting progress towards defining the approach to calculating impacts, identifying associated datasets, and establishing impact'* describes formulae where relevant to enable third parties to understand exactly how impacts have been calculated. For some indicators these formulae are country specific. For example, CO_2e calculations that reflect different national fuel mixes. Financial values for Manchester and Stavanger have been reported in Pounds and Norwegian Krona respectively *and* Euros, using the currency exchange rate at 13th January of the end of the reporting period year.

2.3 Structure of report for each city

For each city the module-level impact report (see sections 3-5) provides an overview and update of the Triangulum activity that has taken place and a summary of the results, followed by a detailed account of the Energy, Mobility and ICT modules with impact assessment indicator, data set and impact assessment tables for each module. The structure for each city report is as follows:

- *An executive summary:* A brief summary outlining the modules that have been implemented within the city and the key findings from the baseline and impact data.
- *Overview and initial assessment:* a synthesis of the context of each module, an update on its progress since the submission of Deliverable 2.7 impact report (M48 refresh), and an assessment of the baseline and impact assessment data.
- *The modules:* a description of the modules that have been implemented including objectives, partner organisations involved, technologies used, implementation dates, and the indicators that have been used for assessing the impacts and benefits. For each module baseline data is presented and, where available, impact data is also presented. This includes quantitative data gathered and text summarising the important features of the baseline and impact data.

Deliverable 2.3 gives details for each module concerning: Objective, Approach, Expected Impacts, Links with other modules, the Socio-technical configuration of the module, and the stakeholder structure of the module. These have not been repeated here. This report follows the same structure as D2.5 and D2.7, and considers four elements for each module under the following headings.

- The implementation dates of the module, which outlines the dates of implementation.
- Factors limiting progress towards defining the approach to calculating impacts, identifying associated datasets, and establishing impact, which records changes that were made between D2.3 to D2.6. Notable issues with the indicators used for assessing the impacts and benefits and baseline conditions.
- Changes since D2.7 (M48), which records changes that have been made since the D2.7.

2.4 The structure of module impact indicator, dataset and impact calculation tables

For each module described in sections 3-5 below, impact indicators, datasets and impact assessment calculations are presented in detail in the form of tables. To aid interpretation of these tables their structures are outlined below (in Table 2.4.1, Table 2.4.2 and Table 2.4.3) including a description of the column headings, column content and approach to populating the column. This approach has been adopted with partners through regular meetings with WP2 researchers to link the co-produced monitoring framework to the available datasets in a clear and actionable way. They reflect the structure of module impact reporting outlined in D2.3 Baseline Report, but have added a table for the impacts which includes baseline data.

Column headings (impact indicator tables)	**Description of column contents**	**Approach to populating the column**
Impact indicator identifier	Unique identifier for impact indicator	List impact indicator identifiers for all relevant rows in the indicator table. Impact indicator identifier format to be confirmed. Most likely a 6 digit number. For example, 311003 would be the third impact indicator for module 311.
Impact	A qualitative description of an impact that the module is expected to make.	Text. Noun phrase, preferably.
Impact indicator	Specific indicator that could be used to make quantitative measurements of a specific impact.	Text. Noun phrase, preferably.

Column headings (impact indicator tables)	**Description of column contents**	**Approach to populating the column**
Quant. Unit	Quantitative unit: Unit to be used in baseline measurements and the quantitative value calculated for the impact indicator.	SI Units Alternatively, use units with explicit reference to the standard to which they belong. If the quantity has no dimension, and hence no units, state "dimensionless integer", or "dimensionless decimal", or "percentage", as appropriate.
Datasets to be used in impact calculation	Designates the names of the datasets that are expected to be used in the calculation of a quantitative value for the impact indicator. Further details of the datasets to be provided in the Dataset table for each module.	List dataset names corresponding to those in the Dataset table.
Aligned with SCIS?	Is this indicator aligned with an indicator in the SCIS (Smart Cities Information System) Key Performance Indicator Guide. *(Feedback from module delivery teams not required)*	Y : Yes N : No

Table 2.4.1: Indicator Tables - description of the structure of the tables which identify impact indicators for each module.

Column headings (dataset tables)	**Description of column contents**	**Approach to populating the column**
Dataset identifier	Unique identifier for dataset.	List dataset identifier for all relevant rows in the dataset table. Dataset identifier format confirmed from WP8 Data Management Plan.
Dataset name	Unique name for the dataset	Text.

Column headings (dataset tables)	Description of column contents	Approach to populating the column
Dataset description	Brief description of the dataset, with some reference to how the data is generated.	Text.
Required for impact calc. for indicators	Identify the impact indicators which this dataset will be used to calculate.	List impact indicator identifiers for all relevant rows in the indicator table. Impact indicator identifier format to be confirmed. Most likely a 6 digit number. For example, 311003 would be the third impact indicator for module 311.
Dataset owner	Identify which organisation owns the dataset.	Text.
Dataset contact	Identify who WP2 can contact to access the dataset and gather the contextual information needed to understand and use the dataset.	Text. Name and email address.
Comments	Any additional information relating to the dataset and its availability. Where possible and appropriate, justify why dataset is currently unavailable.	Text.
WP2 steps taken	Identify next action for WP2 relating to the dataset.	Text.

Table 2.4.2: Dataset Tables - description of the structure of the tables which identify datasets to potential be used in calculating impact indicators for each module.

Column headings (impact calculation tables)	**Description of column contents**	**Approach to populating the column**
Impact indicator identifier	Unique identifier for impact indicator	List impact indicator identifiers for all relevant rows in the indicator table. Impact indicator identifier format to be confirmed. Most likely a 6 digit number. For example, 311003 would be the third impact indicator for module 311.
Impact indicator	Specific indicator that could be used to make quantitative measurements of a specific impact.	Text. Noun phrase, preferably.
Quant. Unit.	Quantitative unit: Unit to be used in baseline measurements and the quantitative value calculated for the impact indicator.	SI Units Alternatively, use units with explicit reference to the standard to which they belong. If the quantity has no dimension, and hence no units, state “dimensionless integer”, or “dimensionless decimal”, or “percentage”, as appropriate.
Baseline value	The baseline value	The units specified in the Impact indicator table
Baseline value period	The time period that baseline data was collected, preferably for 12months until the month preceding implementation	Dates in the format MMM YYYY – MMM YYYY
M36 value	The interim calculated impact value, as reported in M36 Impact Report.	The units specified in the Impact indicator table.
M36 value period	The time period that interim impact Data was collected, preferably from month of implementation for 12 months.	Dates in the format MMM YYYY – MMM YYYY.

M48 value	The calculated impact value, as reported in this M48 Impact Report Refresh.	The units specified in the Impact indicator table
M48 value period	The time period that impact data was collected, preferably from M36 for at least 12 months	Dates in the format MMM YYYY – MMM YYYY
M60 value	The calculated impact value, as reported in this M60 Final Impact Report.	The units specified in the Impact indicator table
M60 value period	The time period that impact data was collected, preferably from M48 for at least 12 months	Dates in the format MMM YYYY – MMM YYYY
Absolute change (from Baseline to M48)	The difference between the baseline and the impact at M60 Value.	Baseline value minus M60 value
Derived rate of absolute change (p.a.)	The difference value over the course of one year, if not already reported in this format	Absolute change as a per annum figure
Relative change	The absolute change as a percentage of the start value	Absolute change divided by baseline value
Derived rate of relative change (p.a.)	The relative change value over the course of one year, if not already reported in this format	Relative change as a per annum figure

Table 2.4.3: Impact Tables - description of the structure of the tables which show the impact assessment calculation for each module.

2.5 At-a-glance summary of modules

A summary of the modules and related sub-tasks from the DoW is presented in the Table below to give an overview of the entire set of modules under consideration in this deliverable. The modules are listed by city, sector and related to the subtasks and deliverables in the DoW. The Table also shows how the Use Cases developed by WP6 relate to the impact assessment modules.

The modules are colour-coded to indicate implementation progress at January 2020:

- Green indicates that a module has been fully implemented.
- Strike-through indicates that the module has been removed as the module was not implemented.

The stage of implementation has a major bearing on the availability of data to use to calculate baseline and impact values for impact indicators, but is not the only factor causing delays in the gathering of data as outlined in the later city report sections.

City	Sector	Module	Use Cases	Subtasks and Deliverables
Man	Energy	Module 321: Central energy controller (Subtasks 3.2.2-5)	Demand Side Response Control for Student Accommodation (UC-321a) Demand Side Response Control for Office Block (Academic Building) (UC-321b) Demand Side Response Control for Public building (UC-321c) Micro-grid management system (UC-321d) City Energy Controller (UC-321e)	Subtask 3.2.2 Construction and Installation Subtask 3.2.3 Hardware/IT integration Subtask 3.2.4 Testing and Resilience Subtask 3.2.5 Operation and Evaluation
		Module 322: Energy optimization in buildings (Subtasks 3.2.2-5)	Building Benchmark Assessment (UC-322a)	Subtask 3.2.2 Construction and Installation Subtask 3.2.3 Hardware/IT integration Subtask 3.2.4 Testing and Resilience Subtask 3.2.5 Operation and Evaluation
		Module 323: Low-carbon energy generating assets (Subtasks 3.2.2-5)	Energy Storage Assets (UC-323a) Photovoltaic Installation on post 2000 building (UC-323b)	Subtask 3.2.2 Construction and Installation Subtask 3.2.3 Hardware/IT integration Subtask 3.2.4 Testing and Resilience Subtask 3.2.5 Operation and Evaluation
	Mobility	Module 331: Electric vehicle procurement	Corporate Electric car sharing for University (UC-331a)	Subtask 3.3.2 Procurement and Implementation

City	Sector	Module	Use Cases	Subtasks and Deliverables
		(Subtasks 3.3.2-4)	Leasing electric vans for estate management (UC-331b)	Subtask 3.3.3 Monitoring Subtask 3.3.4 Evaluation
		Module 332: Electric assist cargo bikes (Subtasks 3.3.2-4)	Electric Assist Cargo bikes (Pedelecs) for goods delivery (UC-332)	Subtask 3.3.2 Procurement and Implementation Subtask 3.3.3 Monitoring Subtask 3.3.4 Evaluation
	ICT	Module 341: Data curation service (D3.4.1)	Data Curation & 342a Data Visualization Platform (UC-341)	Subtask 3.4.1 Establish Open Data and Service Engine Subtask 3.4.2: Ongoing Running and Monitoring of Open Data and Service Engine D3.4.1 Open Data and Service Engine (ODSE)
		Module 342: Data visualization platform (D3.4.2)	Data Visualization Platform (UC-342)	Subtask 3.4.3: Establish Visualisation Platform and Incubation Structures Subtask 3.4.4: Support Manchester-i and Open Application Marketplace D3.4.2 Full Manchester-i platform
		Module 343: Data-enabled innovation challenges (D3.4.3)	Data-Enabled Innovation Challenges (UC-343a) App to train electric vehicle drivers (UC-343b) Behavioural change application for students (UC-343c) Vehicle charging Application (UC-343d)	Subtask 3.4.3: Establish Visualisation Platform and Incubation Structures D3.4.3 Suite of Open Market Apps

City	Sector	Module	Use Cases	Subtasks and Deliverables
Eind	Energy	Module 421: Sustainable energy supply and soil sanitation (Subtask 4.2.1)	Sustainable Energy Supply by Soil Sanitation (UC-421)	Subtask 4.2.1 Sustainable energy supply and soil sanitation
		Module 422: Optimization of heat provision in existing buildings (Subtask 4.2.2)	Switching from steam based to water based heating systems powered by biomass (UC-422)	Subtask 4.2.2 Optimization of heat provision in existing buildings of Strijp-S
		Module 423: Smart energy for offices (Subtask 4.2.3)	Smart Control of individual rooms in existing buildings (UC-423a) Smart control of individual floors in existing buildings (UC-423b)	Subtask 4.2.3 Smart energy savings offices on Strijp-S
		Module 424: Renovation of family homes and creation of participative society (Subtask 4.2.4)	Renovation of Semi-attached homes of housing association using woonconnect tool (UC-424a) Renovation of Semi-attached homes of privately owned apartments using woonconnect tool (UC-424b) Renovation of Semi-attached homes of privately owned houses using woonconnect tool (UC-424c)	Subtask 4.2.4 Renovation of family homes Eckart-Vaartbroek & creation of participative society
	Mobility	Module 431: Smart charging of electric vehicles (Subtask 4.3.1)	Public Charging Infrastructure (UC-431a)	Subtask 4.3.1 Smart charging of electric vehicles on Strijp-S

City	Sector	Module	Use Cases	Subtasks and Deliverables
		Module 432: Mobility management (Subtask 4.3.2)	Parking Management System (UC-432a) Station bound district car sharing (UC-432b) Single base bike sharing (UC-432c) Point-to-point station bound bike sharing (UC-432d)	Subtask 4.3.2. Mobility management
	ICT	Module 441: Eindhoven smart city open data platform (Subtask 4.4.2)	Eindhoven Open Data Portal (UC-441a)	Subtask 4.4.1 Eindhoven facilitation smart city ICT open data platform
		Module 442: Interactive energy retrofit for dwellings (Subtasks 4.4.2-3)	Public Sound Sensor Safety Project in Stratumseind (UC-442a) Sensor based citizen initiative for environmental monitoring (UC-442b) Camera based crowd management in the Eindhoven city center (UC-442c)	Subtask 4.4.2 Interactive process for dwellings in Eckart-Vaartbroek Subtask 4.4.3 Eckart-Vaartbroek area: Stimulating private owners and other housing corporations in the area to follow
		Module 443: Smart environment fibre-optic infrastructure (Subtask 4.4.4)	Fibre Optic Infrastructure in Stijp S (UC-443a) Public Wi-Fi (UC-443b)	Subtask 4.4.4 Second phase of implementation and integration of the fibre-optic data infrastructure
		Module 444: Public space sensor network (Subtask 4.4.5)	Smart Lighting in Strijp-S (UC-444a) Public Sound Sensor Safety Project (UC-444b)	Subtask 4.4.5 Sensor network in the public space
		Module 445: Smart city		Subtask 4.4.6 Stimulating the development of

City	Sector	Module	Use Cases	Subtasks and Deliverables
		innovation fund (Subtask 4.4.6)		innovative services / applications
		Module 446: Smart streetlights for social interaction and health route (Subtask 4.4.7)	IOT Security Systems (UC-446a) High-End solar E-bike sharing system (UC-446b) Navigation device for visually impaired people in Smart Cities (UC-446c) Preference based work space finder for Flex buildings (UC-446d) Interactive neighborhood screen for development projects (UC-446e) Self-sufficient modular plant-panels (UC-446f) Smart City Data Platform of Platforms (UC-446g) Non-intrusive camera based vehicle recognition system (UC-446h) Sound Sensor for Vehicle operation safety (UC-446i) Smart Interactive floorlight for walking and running in Eckart (UC-446j) Unidirectional functional lighting in Eckart (UC-446k)	Subtask 4.4.7 Smart streetlights for a 1-KM social interaction and health route
Stav	Energy	Module 521: Smart gateways (Subtask 5.2.1)	Smart Gateway for Homes (UC-521a) Smart Gateway for nursing homes (UC-521b)	Subtask 5.2.1 Smart gateway introduction and energy management

City	Sector	Module	Use Cases	Subtasks and Deliverables
			Smart Gateway for Schools (UC-521c)	
		Module 522: Central energy plant (Subtask 5.2.2)	Sewage heat pump system (UC-522a)	Subtask 5.2.2 City goes zero – switching to renewables
	Mobility	Module 531: Electric battery bus demonstration (Subtask 5.3.1)	Public Transport with battery electric busses (UC-531a)	Subtask 5.3.1 Demo project of eBuses
		Module 532: Electric vehicle charging infrastructure upgrade (Subtask 5.3.2)	Electric vehicle private home charging infrastructure (UC-532b) Electric vehicle apartment building charging infrastructure (UC-532c)	Subtask 5.3.2 EV charging infrastructure, expanding the super charging hubs
	ICT	~~Module 541: Innovative video (Subtask 5.4.1)~~	~~Blink: Innovative video for distance health care (UC-541a)~~ ~~Blink: Innovative video for communication services (UC-541b)~~	Module moved to WP6. Removed from this report.
		Module 542: Data analytics toolkit (Subtask 5.4.2)	Data Analytics Toolkit (UC-542a)	D5.4.2: Design of tools for data analytics
		Module 543: Sustainable citizen service development (Subtask 5.4.3)	Multimodal decision support service (UC-543a)	Subtask 5.4.3 Sustainable citizens' service development
		Module 544: Cloud data platform (D2.2)	Cloud Data Platform for Stavanger (UC-544a) Computing Platform (UC-544b)	D2.2 : Cloud Data Hub

Table 2.5.1: Module, subtask and implementation progress overview

3 Manchester Impact at Module Level

Executive Summary

The Manchester report presents a strategic overview of the ongoing process of understanding the impact of the Triangulum modules being implemented in Manchester, through the development of a set of indicators and data to assess the impacts of these modules. This is organised into four sections.

Section 1 offers an initial evaluation of the module impacts followed by a high-level overview of the impact and assessment and monitoring activities to continue in Manchester during 2019. Section 2 describes the Energy modules in detail including objectives, implementation details, factors limiting success and changes since the M36 report. The indicators used for assessing the impacts and benefits of the module and the current understanding of impacts are then presented. Sections 3 and 4 provide module descriptions and impact indicators for the Mobility and ICT modules respectively.

3.1 Overview and initial assessment

This section briefly assesses the local modules and their impacts. The progress of the Manchester partnership in terms of module implementation and impact reporting is summarized in Table 3.1.1.

	#modules implemented	**#baseline indicator values available**	**#impact indicator values available**
Overall value	8/8	103/103	101/103
Energy	3/3	43/43	43/43
Mobility	2/2	42/42	40/42
ICT	3/3	18/18	18/18

Table 3.1.1: Implementation and impact reporting of Manchester modules

Key impacts achieved in Manchester include impressive potential to lower greenhouse gas emissions from the trials data (Module 321) due to the Energy modules, lowered greenhouse gas emissions (Module 331 and 332) due to the Mobility modules, and enhanced digital infrastructure and increased user engagement (Module 341 and 342) due to the ICT modules.

3.2 Energy Modules

The Energy task group in Manchester defined the scope of three modules to demonstrate the potential of smart and low carbon energy technologies within the Corridor. Hence, the module descriptions and proposed impact indicators presented below have been revised over the course of the project as module scope was refined.

1. Trialling *a central energy controller:* delivering a Central Controller that connects to existing and new energy infrastructure across multiple buildings providing an extra mechanism for optimising energy generation, storage and consumption.
2. Implementing *building energy optimisations:* optimising the energy infrastructure within individual buildings by making recommendations to: (a) change current processes; (b)

implement energy control devices; and, (c) encourage building occupants to make more efficient use of energy through the implementation of behaviour change campaigns.

3. Installing *additional energy resources:* including the design, approval, procurement, installation, commissioning and operation of additional assets throughout the corridor which demonstrates additional benefit of existing low carbon generation assets. *An amendment, related to this module, has been submitted by the Manchester energy task group. AMD-646578-58 was approved and the scope of this module has changed significantly. WP2 have updated the module description, impact indicator table and dataset table, and the impact calculation table has been presented accordingly.*

Table 3.2.1 presents a summary of the expected impacts of each module.

Module	**Mechanism for creating impacts**	**Expected Impacts**				
		Reduced energy consumption	Reduced energy costs	Optimised building energy management systems	Increased use of low carbon energy sources	Reduced greenhouse gas emissions
321: Central energy controller	Optimising energy generation, storage and demand across multiple buildings	*	*			*
322: Building energy optimisations	Optimising the energy demand within individual buildings	*	*	*		*
323: Additional energy resources	Delivering low carbon energy generation flexibility with addition of energy resource				*	*

Table 3.2.1: Expected impacts of Manchester Energy modules

3.2.1 Module 321: Central energy controller (Subtasks 3.2.2-5)

The implementation dates of the module

The module was implemented in MCC (the Town Hall Extension and the Central Library) in November 2017, and was implemented in UNIMAN (Alan Gilbert and Alan Turing Buildings) in April 2018 as a series of trials. It is due to be implemented at MMU (Birley Fields campus) in December 2018.

Factors limiting progress towards defining the approach to calculating impacts, identifying associated datasets, and establishing impact

- All impact indicators have updated baselines, and only some of the impact calculations, due to delay to module implementation.
- **M48 (2019):** The energy controller technology has been implemented at two sites of three. Therefore, the baselines have been updated to coincide with the 12 months preceding implementation.
- The trials period was halted at MCC in September 2018 for a number of months due to technical challenges and restarted in late November 2018.
- UK government Co2e factors have been used to calculate emissions, available from the Department of Energy and Climate Change [https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting]

Changes from M36 to M48

- The module has been impended at UNIMAN since the last report. However, it was not implemented at MMU until December 2018.
- As the module has been implemented as a series of trials, an additional performance indicator set has been added for this module only, to capture the Siemens trials data. Five new impact indicators have been added: 321017-321021.
- A total of 86 trials have been carried out for 30 or 60 minutes each in two buildings, Alan Gilbert and Alan Turing at UNIMAN, over a 5-month timeframe from June – October 2018. The impact indicators 3221017-321021 have been calculated by taking a Mean average across the results for each month.

Changes since last report (M48 Impact Report)

- UNIMAN building energy consumption (321005, 321006, 321011, 321015) were updated to include natural gas use. This resulted in recalculation of the figures from baseline to present. The changes to UNIMAN data also affect aggregated data (321007, 321008, 321012, 321016).

- Energy reduction trials (321017-321021) figures have been updated to improve accuracy of data and reflection of trial outcomes.
- Due to a high prevalence of laboratories in the Alan Gilbert building, the trials faced many retractions by building stakeholders, Alan Gilbert was de-scoped.
- MCC energy data has been reviewed for the baseline and M48 as the kWh and tCO_2e did not match. Data was reprocessed and the figures have been updated.

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
321001	Reduced energy consumption	Change in annual primary energy use (MCC buildings)	kWh	Primary energy use data (MCC), CC operational data	Y
321002	Reduced energy consumption	Percentage change in annual primary energy use (MCC buildings)	Dimensionless decimal	Primary energy use data (MCC), CC operational data	Y
321003	Reduced energy consumption	Change in annual primary energy use (MMU buildings)	kWh	Primary energy use data (MMU), CC operational data	Y
321004	Reduced energy consumption	Percentage change in annual primary energy use (MMU buildings)	Dimensionless decimal	Primary energy use data (MMU), CC operational data	Y
321005	Reduced energy consumption	Change in annual primary energy use (UNIMAN buildings)	kWh	Primary energy use data (UNIMAN), CC operational data	Y
321006	Reduced energy consumption	Percentage change in annual primary energy use (UNIMAN buildings)	Dim. Int.	Primary energy use data (UNIMAN), CC operational data	Y

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
321007	Reduced energy consumption	Change in annual primary energy use (all buildings)	kWh	Primary energy use data (MCC, MMU & UNIMAN), CC operational data	Y
321008	Reduced energy consumption	Percentage change in annual primary energy use (all buildings)	Dim. Int.	Primary energy use data (MCC, MMU & UNIMAN), CC operational data	Y
321009	Reduced energy costs	Change in annual energy costs (MCC buildings)	€	Energy cost data (MCC), CC operational data	Y
321010	Reduced energy costs	Change in annual energy costs (MMU buildings)	€	Energy cost data (MMU), CC operational data	Y
321011	Reduced energy costs	Change in annual energy costs (UNIMAN buildings)	€	Energy cost data (UNIMAN), CC operational data	Y
321012	Reduced energy costs	Change in annual energy costs (all buildings)	€	Energy cost data (MCC, MMU & UNIMAN), CC operational data	Y
321013	Reduced greenhouse gas emissions	Change in annual greenhouse gas emissions (MMC buildings)	tCO_2e	GHG emission data (MCC), CC operational data	Y
321014	Reduced greenhouse gas emissions	Change in annual greenhouse gas emissions (MMU buildings)	tCO_2e	GHG emission data (MMU), CC operational data	Y

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
321015	Reduced greenhouse gas emissions	Change in annual greenhouse gas emissions (UNIMAN buildings)	tCO_2e	GHG emission data (UNIMAN), CC operational data	Y
321016	Reduced greenhouse gas emissions	Change in annual greenhouse gas emissions (all buildings)	tCO_2e	GHG emission data (MCC, MMU & UNIMAN), CC operational data	Y
321017	Reduced energy consumption	Average reduction in energy use during the trials (UNIMAN buildings)	kWh	CC trials data	Y
321018	Reduced greenhouse gas emissions	Average reduction in carbon (UNIMAN buildings)	tCO_2e	CC trials data	Y
321019	Reduced energy costs	Average cost savings (UNIMAN buildings)	€	CC trials data	Y
321020		Average number of user complaints (UNIMAN buildings)	Dim. Int.	CC trials data	N
321021		Average number of technical errors (UNIMAN buildings)	Dim. Int.	CC trials data	N

Table 3.2.2: Impact assessment indicators description for Module 321

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
32100A	Primary energy use data (MCC)	Longitudinal dataset detailing primary energy use (heat and electricity) in specified MCC buildings	321001 321002 321007 321008	MCC	Andrew Jackson (a.jackson2@manchester.gov.uk)		
32100B	Energy cost data (MCC)	Longitudinal dataset detailing the costs arising from primary energy use in specified MCC buildings	321009 321012	MCC	Andrew Jackson (a.jackson2@manchester.gov.uk)		
32100C	GHG emission data (MCC)	Longitudinal dataset detailing the GHG emissions arising from primary energy use in specified MCC buildings	321013 321016	MCC	Andrew Jackson (a.jackson2@manchester.gov.uk)		

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
32100D	Primary energy use data (MMU)	Longitudinal dataset detailing primary energy use (heat and electricity) in specified MMU buildings	321003 321004 321007 321008	MMU	Callum Donnelly (C.Donnelly@mmu.ac.uk)		
32100E	Energy cost data (MMU)	Longitudinal dataset detailing the costs arising from primary energy use in specified MMU buildings	321010 321012	MMU	n/a		
32100F	GHG emission data (MMU)	Longitudinal dataset detailing the GHG emissions arising from primary energy use in specified MMU buildings	321014 321016	MMU	Callum Donnelly (C.Donnelly@mmu.ac.uk)		

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
32100G	Primary energy use data (UNIMAN)	Longitudinal dataset detailing primary energy use (heat and electricity) in specified UNIMAN buildings	321005 321006 321007 321008	UNIMAN	Ettore Murabito (ettore.murabito@manchester.ac.uk)		
32100H	Energy cost data (UNIMAN)	Longitudinal dataset detailing the costs arising from primary energy use in specified UNIMAN buildings	321011 321012	UNIMAN	n/a		
32100I	GHG emission data (UNIMAN)	Longitudinal dataset detailing the GHG emissions arising from primary energy use in specified UNIMAN buildings	321015 321016	UNIMAN	n/a		

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
32100J	CC operational data	Data detailing the operations and impacts of the central controller.	All indicators from 321001 to 321016	Siemens	Andrew Smyth (Andrew.Smyth@siemens.com)	Format and frequency of data remains to be specified by WP3.	
32100K	CC trials data		All indicators from 321017 to 321021	Siemens	Andrew Smyth (Andrew.Smyth@siemens.com)		

Table 3.2.3: Datasets description for Module 321

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relate change
321001	Change in annual primary energy use (MCC buildings)	kWh	10,414,692	Nov 2016 – Oct 2017	N/A	N/A	10,458,505	Nov 17 - Oct 18	11,560,780	Nov 18 - Oct 19	1,146,088	565,194	-0.11

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative chan
321002	Percentage change in annual primary energy use (MCC buildings)	Dim. Int.	0	Nov 2016 – Oct 2017	N/A	N/A	0.00	Nov 17 - Oct 18	0.11	Nov 18 - Oct 19	0	0	NA
321003	Change in annual primary energy use (MMU buildings)	kWh	10,338,644	Jan 2017 – Dec 2017	N/A	N/A	10,283,163	Nov 17 - Oct 18	9,513,920	Nov 18 - Oct 19	-824,724	-443,798	0.08
321004	Percentage change in annual primary energy use (MMU buildings)	Dim. Int.	0	Jan 2017 – Dec 2017	N/A	N/A	-0.01	Nov 17 - Oct 18	0.08	Nov 18 - Oct 19	0	0	NA
321005	Change in annual primary energy use (UNIMAN buildings)	kWh	2,372,043	Jan 2017 – Dec 2017	N/A	N/A	3,936,630	Nov 17 - Oct 18	2,368,830	Nov 18 - Oct 19	-3,213	-1,729	0.00
321006	Percentage change in annual primary energy use (UNIMAN buildings)	Dim. Int.	0	Jan 2017 – Dec 2017	N/A	N/A	0.02	Nov 17 - Oct 18	0.00	Nov 18 - Oct 19	0	0	NA
321007	Change in annual primary energy use (all buildings)	kWh	23,125,379	n/a (impacts not aligned)	N/A	N/A	24,678,298	Nov 17 - Oct 18	23,443,530	Nov 18 - Oct 19	318,151	NA	-0.01

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relate chan
321008	Percentage change in annual primary energy use (all buildings)	Dim. Int.	0	n/a (impacts not aligned)	N/A	N/A	0.05	Nov 17 - Oct 18	-0.02	Nov 18 - Oct 19	0	NA	NA
321009	Change in annual energy costs (MCC buildings)	€	532,964 (£467,827)	Nov 2016 – Oct 2017	N/A	N/A	548,355 (£486,131)	Nov 17 - Oct 18	672,250 (£580,026)	Nov 18 - Oct 19	130,038 (£112,199)	64,128 (£55,331)	-0.24
321010	Change in annual energy costs (MMU buildings)	€	570,369 (£500,661)	Jan 2017 – Dec 2017	N/A	N/A	731,150 (£648,183)	Nov 17 - Oct 18	676,495 (£583,689)	Nov 18 - Oct 19	96,229 (£83,028)	51,782 (£44,679)	-0.17
321011	Change in annual energy costs (UNIMAN buildings)	€	141,671 (£262,394)	Jan 2017 – Dec 2017	N/A	N/A	288,510 (£255,772)	Nov 17 - Oct 18	301,023 (£259,727)	Nov 18 - Oct 19	-3,091 (-£2,667)	-1,663 (-£1,435)	0.01
321012	Change in annual energy costs (all buildings)	€	1,245,797 (£1,230,882)	n/a (baseline periods not aligned)	N/A	N/A	1,568,017 (£1,390,086)	Nov 17 - Oct 18	1,649,769 (£1,423,442)	Nov 18 - Oct 19	223,273 (£192,560)	NA	-0.16
321013	Change in annual greenhouse gas emissions (MMC buildings)	tCO_2e	2523	Nov 2016 – Oct 2017	N/A	N/A	2394	Nov 17 - Oct 18	2498	Nov 18 - Oct 19	-25	-12	0.01

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relate chan
321014	Change in annual greenhouse gas emissions (MMU buildings)	tCO_2e	3,635	Jan 2017 – Dec 2017	N/A	N/A	2,389	Nov 17 - Oct 18	2153	Nov 18 - Oct 19	-1,482	-798	0.41
321015	Change in annual greenhouse gas emissions (UNIMAN buildings)	tCO_2e	1287	Jan 2017 – Dec 2017	N/A	N/A	1117	Nov 17 - Oct 18	959	Nov 18 - Oct 19	-328	-176	0.25
321016	Change in annual greenhouse gas emissions (all buildings)	tCO_2e	7,445	n/a (baseline periods not aligned)	N/A	N/A	5,901	Nov 17 - Oct 18	5611	Nov 18 - Oct 19	-1,835	-968	0.25
321017	Average reduction in energy use during the trials	kWh	0	N/A	N/A	N/A	26.4	Jun 18 - Oct 18	2906.11	Jun 18 - May 19	2906.11	2906.11	NA
321018	Average reduction in carbon	tCO_2e	0	N/A	N/A	N/A	0.0093	Jun 18 - Oct 18	0.893	Jun 18 - May 19	0.893	0.893	NA
321019	Average cost savings	€	0	N/A	N/A	N/A	0.68 (£0.61)	Jun 18 - Oct 18	326.14 (£276.08)	Jun 18 - May 19	326.14 (£276.08)	326.14 (£276.08)	NA

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relate chan
321020	Average number of user complaints	Dim. Int.	0	N/A	N/A	N/A	0	Jun 18 - Oct 18	1	Jun 18 - May 19	1	1	NA
321021	Average number of technical errors	Dim. Int.	0	N/A	N/A	N/A	1.6	Jun 18 - Oct 18	8	Jun 18 - May 19	8	8	NA

Table 3.2.4: Impact assessment for Module 321

3.2.2 Module 322: Energy optimization in buildings (Subtasks 3.2.2-5)

The implementation dates of the module

The module was implemented in the MCC (Manchester Art Gallery) in December 2017. However, its implementation has been de-scoped in UNIMAN estates (Ellen Wilkinson Building) due to stakeholder resistance to intervention in the building.

Factors limiting progress towards defining the approach to calculating impacts, identifying associated datasets, and establishing impact

- All impact indicators have updated baselines, due to delayed implementation.
- Baselines have been updated to the 12-month period preceding planned implementation.
- Data was not yet available for the full 12 months prior to implementation for MCC buildings. Therefore, this baseline period is set back by 3 months.
- Impact calculations are presented for MCC.

Changes from M36 to M48

- Impact calculations available for MCC.
- Some progress with securing implementation at UNIMAN, yet to be agreed.

Changes since last report (M48 Impact Report)

- UNIMAN building optimisation was not carried out by Siemens during the course of the project, there for the related modules have been removed (322009, 322010, 322014, 322017). The removal of UNIMAN data means that the aggregated data is now a copy of the MCC data, these modules were also removed (322005, 322006, 322011, 322012, 322015, 322018).
- M36 or M48 MCC kWh and tCO2e did not match, data from the Manchester Art Gallery was reassessed, the figures have been updated for accuracy.

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
322001	Optimised building energy management systems	Number of MCC buildings optimised	Dimensionless integer	WP3 self-reports on module implementation progress	N
322002	Optimised building energy management systems	Area of MCC building floor space optimised	m^2	WP3 self-reports on module implementation progress	N
322007	Reduced energy consumption	Change in annual primary energy use (MCC buildings)	kWh	Primary energy use data (MCC), Optimisation operational data	Y
322008	Reduced energy consumption	Percentage change in annual primary energy use (MCC buildings)	Dimensionless decimal	Primary energy use data (MCC), Optimisation operational data	Y
322013	Reduced energy costs	Change in annual energy costs (MCC buildings)	€	Energy cost data (MCC), Optimisation operational data	Y
322016	Reduced greenhouse gas emissions	Change in annual greenhouse gas emissions (MMC buildings)	tCO_2e	GHG emission data (MCC), Optimisation operational data	Y

Table 3.2.5: Impact assessment indicators description for Module 322

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
32200A	Primary energy use data (MCC)	Longitudinal dataset detailing primary energy use (electricity and heat) in specified MCC buildings	322007 322008	MCC	Andrew Jackson (a.jackson2@manchester.gov.uk)		
32200B	Energy cost data (MCC)	Longitudinal dataset detailing the costs arising from primary energy use in specified MCC buildings	322013	MCC	Andrew Jackson (a.jackson2@manchester.gov.uk)		
32200C	GHG emission data (MCC)	Longitudinal dataset detailing the GHG emissions arising from primary energy use in specified MCC buildings	322016	MCC	Andrew Jackson (a.jackson2@manchester.gov.uk)		
32200G	Optimisation operational data	Data detailing the operations and impacts of the optimisations.	All indicators from 322007 to 322018	Siemens	Andrew Smyth (Andrew.Smyth@siemens.com)	Format and frequency of data remains to be specified by WP3.	WP2 continued to liaise with WP3 throughout 2019, in order to include data in M60 report.

Table 3.2.6: Datasets description for Module 322

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 reporting period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)
322001	Number of MCC buildings optimised	Dim. Int.	0	Nov 2017	N/A	N/A	1	Nov-18	1	Nov 18 – Oct 19	1	1
322002	Area of MCC building floor space optimised	m^2	0	Nov 2017	N/A	N/A	10,300	Nov-18	10300	Nov 18 – Oct 19	10,300	5,305
322007	Change in annual primary energy use (MCC buildings)	kWh	3,317,570	Oct 2016 – Sept 2017	N/A	N/A	3,793,186	Nov 17 - Oct 18	2370693	Nov 18 – Oct 19	-946,877	-448,521
322008	Percentage change in annual primary energy use (MCC buildings)	Dim. Int.	0	Oct 2016 – Sept 2017	N/A	N/A	0.14	Nov 17 - Oct 18	-0.29	Nov 18 – Oct 19	0	0
322013	Change in annual energy costs (MCC buildings)	€	243,439 (£208,068)	Oct 2016 – Sept 2017	N/A	N/A	€291,099 (£248,803)	Nov 17 - Oct 18	€281,200 (£240,312)	Nov 18 – Oct 19	€37,725 (£32,244)	NA
322016	Change in annual greenhouse gas emissions (MMC buildings)	tCO_2e	1017	Oct 2016 – Sept 2017	N/A	N/A	1007	Nov 17 - Oct 18	604	Nov 18 – Oct 19	-412	-195

Table 3.2.7: Impact assessment for Module 322

3.2.3 Module 323: Additional energy resources (Subtasks 3.2.2-5)

An amendment, related to this module, was submitted by the Manchester energy task group. The amendment was approved and the scope of this module has changed significantly. WP2 has updated the module description, impact indicator table and dataset table, and the impact calculation table has been presented accordingly.

The implementation dates of the module

The module was implemented in MMU (Birley Fields Building) estate in December 2019.

Factors limiting progress towards defining the approach to calculating impacts, identifying associated datasets, and establishing impact

- **M35 (2017):** Amendment to the module, causing scope to be changed and module implementation to be delayed to February 2018.
- Module implemented in MMU Birley Fields campus only, causing removal of impact indicators relating to UNIMAN: 323003-323006, 323008-323009, 323011-323012.

Changes from M36 to M48

- Module implemented in February 2018. Baselines updated and impact calculations presented.
- Note: impact data available Feb to Dec 2018 based on implementation date. Data extrapolated up to 12 months.

323010: calculated as avoided GHG emissions as a result of renewable electricity generation, using BEIS Conversion factors for 2018, https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting.

Changes since last report (M48 Impact Report)

The first battery trial began on 17th December 2019 (Figure)

The installed battery has a maximum charging and discharging capacity of 420kW with a maximum storage space of 484kWh.

As shown in Figure average discharging power of 125kWh over 3 hours: a total of 375kW, and an average charging power of 140kWh over 3 hours: a total of 420kW.

The battery is been charged at midnight when the prices from the grid is low (11p) and discharged at the peak period when the prices of energy from the grid is high (16p). The Red Band Saving and Total Savings are shown below:

Unit Rating Saving

kW	kWh	Unit Rates	Cost
420	153,300	0.11	£ 16,863
375	136,875	0.16	£ 21,900
		Red Band Saving	£ 5,037

Triad Saving

KW	Rates	Saving
420	£47	£ 19,740 (€ 22,160)

Yearly estimated savings	£ 24,777 (€ 27,814)

When the battery operates at its full capacity of 484KW, the Red Band Saving will be £8, 833 and total savings £28,578.

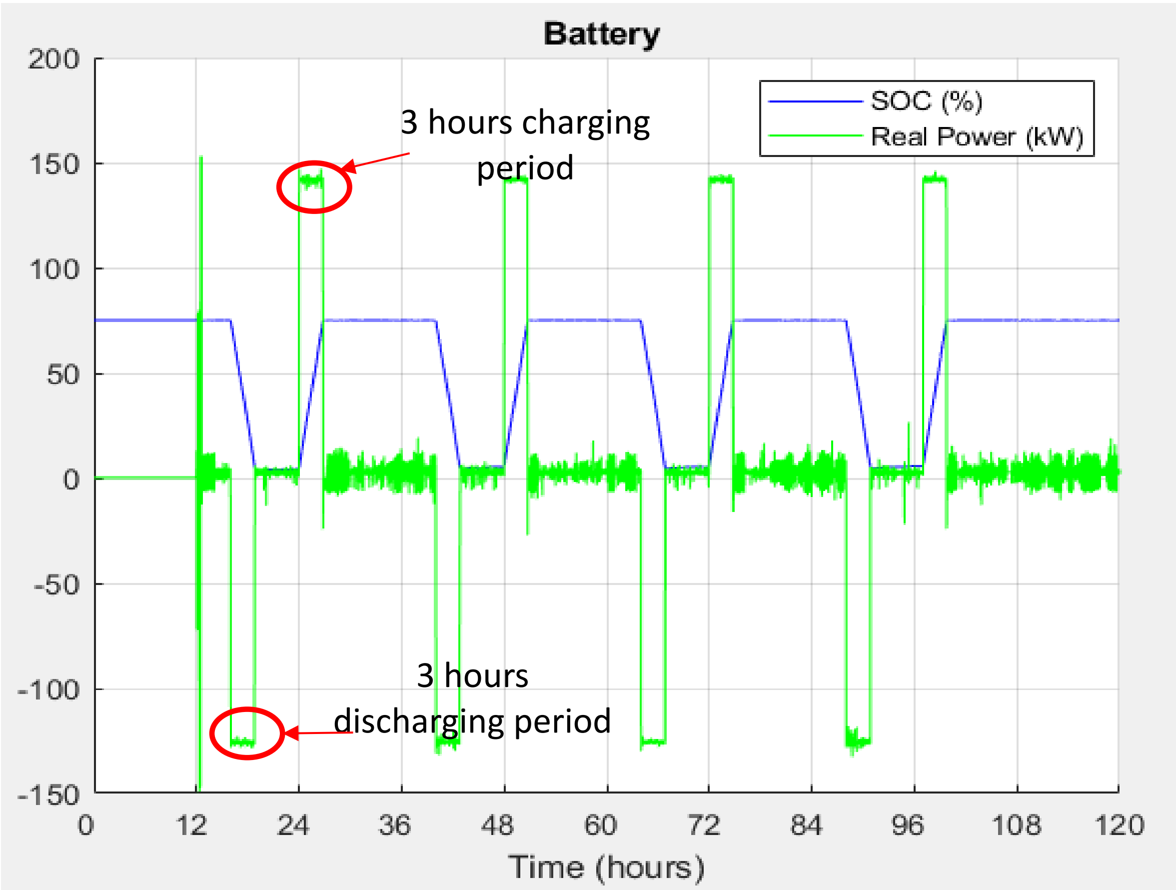


Figure 3.2.3.1 : Battery charge and discharge over 5 days period.

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
323001	Increased use of low carbon energy sources	Energy delivered by the low carbon energy generation assets (MMU buildings)	kWh	Energy generation asset operational data	Y
323002	Increased use of low carbon energy sources	Change in share of primary energy demand met by onsite renewables (MMU buildings)	Dimensionless decimal	Energy generation asset operational data	Y
323007	Reduced energy costs	Change in annual energy costs (MMU buildings)	€	Energy cost data (MMU), Energy generation asset operational data	Y
323010	Reduced greenhouse gas emissions	Change in annual greenhouse gas emissions (MMU buildings)	tCO_2e	GHG emission data (MMU), Energy generation asset operational data	Y

Table 3.2.8: Impact assessment indicators description for Module 323

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
32300A	Energy cost data (MMU)	Longitudinal dataset detailing the costs arising from primary energy use in specified MMU buildings	323007 323009	MMU	n/a		
32300B	GHG emission data (MMU)	Longitudinal dataset detailing the GHG emissions arising from primary energy use in specified MMU buildings	323010 323012	MMU	Callum Donnelly (C.Donnelly@mmu.ac.uk)		
32300C	Energy generation asset operational data	Data detailing the operations and impacts of the low carbon energy generation assets.	All indicators 323001 to 323012	Siemens	Andrew Smyth (Andrew.Smyth@siemens.com)	Format and frequency of data remains to be specified by WP3.	WP2 continued to liaise with WP3 throughout 2019, in order to include data in M60 report.

Table 3.2.9: Datasets description for Module 323

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)
323001	Energy delivered by the low carbon energy generation assets (MMU buildings)	kWh	0	Apr 2017 – Mar 2018	N/A	N/A	142,784	Feb 18 - Jan 19	119,735	Nov 18 – Oct 19	119,735	74,447
323002	Change in share of primary energy demand met by onsite renewables (MMU buildings)	Dim. Int.	0	Apr 2017 – Mar 2018	N/A	N/A	3%	Feb 18 - Jan 19	1.26%	Nov 18 – Oct 19	0	0
323007	Change in annual energy costs (MMU buildings)	€	561,667 (£500,661)	Aug 2016 - Jul 2017	N/A	N/A	742,190 (£661,577)	Feb 18 - Jan 19	834,656 (£706,812)	Nov 18 – Oct 19	243,438 (£206,151)	106,615 (£90,285)
323010	Change in annual greenhouse gas emissions (MMU buildings)	tCO_2e	0	Aug 2016 - Jul 2017	N/A	N/A	-43.86	Feb 18 - Jan 19	-35.58	Nov 18 – Oct 19	-34	-15

Table 3.2.10: Impact assessment for Module 323

3.3 Mobility Modules

The Mobility task group has defined the scope of two modules (see below). Hence, the module descriptions and proposed impact indicators presented below have been revisited and revised over the course of the project as module scope was refined.

1. Support for *electric vehicle procurement:* enabling the additional costs of purchasing or leasing electric vehicles (relative to conventional vehicle costs) to be met, with the objective of reducing the CO_2 and air quality pollutant emissions of the vehicle fleets owned by partner organisations.
2. A trial of an e*lectric assist cargo bike* sharing scheme: making cargo bikes more accessible to organisations and citizens, with the objective of increasing the number deliveries made by low emission vehicles and hence reducing the CO_2 and air quality pollutant emissions within the Corridor.

Table 3.3.1 presents a summary of the expected impacts of the two modules.

Modules	**Mechanism for creating impacts**	**Expected impacts**			
		Reduced Greenhouse Gas Emissions	Reduced emissions of air quality pollutants	Reduced traffic congestion	Evaluation of new technologies
331: Electric vehicle procurement	Replacing conventional vehicle journeys with low emission vehicle journeys (i.e. EVs)	*	*		*
332: Electric assist cargo bikes	Replacing conventional vehicle journeys with low emission vehicle journeys (i.e. Cargo Bikes)	*	*	*	*

Table 3.3.1: Expected impacts of the Manchester Mobility Modules

3.3.1 Module 331: Electric vehicle procurement (Subtasks 3.3.2-4)

The implementation dates of the module

The module was implemented in the MMU fleet in August 2016, and the UNIMAN fleet in November 2016.

Factors limiting progress towards defining the approach to calculating impacts, identifying associated datasets, and establishing impact

- The Triangulum procured EVs are part of larger EV fleets at MMU and UNIMAN. Therefore, it was necessary to gather a wider set of data in relation to the fleets, EVs, and Triangulum EVs, in order to understand and calculate all required impacts.
- The following modules have been amended: 331001 into 331001a and 331001b; 331002 into 331002a, 331002b and 331002c; 331003 into 331003a and 331003b; 331004 into 331004a and 331004b; 331005 into 331005a, 331005b and 331005c; 331006 into 331006a and 331006b; 331007 into 331007a and 331007b; 331008 into 331008a, 331008b and 331008c; and 331009 into 331009a and 331009b.
- NOx and CO data was not collected. These impacts were calculated using Euro 6 emission standards for diesel vehicles, with 0.5g/km CO and 0.08g/km NOx criteria multiplied by the distance travelled by the electric vehicles. This represents the avoided emissions.
- No charging station was installed at UNIMAN. Two charging stations were installed at MMU.

Changes from M36 to M48

- No changes

Changes since last report (M48 Impact Report)

- Calculation of MMU greenhouse gas emissions (331003a) multiplied litres of fuel by the diesel carbon factor (UK 2019). The fuel used is an unknown ratio of petrol to diesel. The carbon factors for these fuels (UK 2019) differ by 5%. For the reporting it is assumed that all fuel used is diesel. Calculation of UNIMAN greenhouse gas emissions (331006a) is calculated using associated factors for diesel and petrol. The figures for petrol and diesel were provided by UNIMAN so the relevant calculations for each set were carried out, and the data compiled for the final figure.
- 331017 value is reporting for 2 out of 3 charging stations, the missing data has not been reported by the technology since July 2018.

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
331001a	Reduced Greenhouse Gas Emissions	Number of electric vehicles within MMU vehicle fleets	Dimensionless integer	EV module impact data	Y
331001b	Reduced Greenhouse Gas Emissions	Number of Triangulum electric vehicles within MMU vehicle fleets	Dimensionless integer	EV module impact data	Y
331002a	Reduced Greenhouse Gas Emissions	Percentage of electric vehicles within MMU vehicle fleets	Dimensionless decimal	EV module impact data	Y
331002b	Reduced Greenhouse Gas Emissions	Percentage of Triangulum electric vehicles within MMU vehicle fleets	Dimensionless decimal	EV module impact data	Y
331002c	Reduced Greenhouse Gas Emissions	Percentage of Triangulum electric vehicles within MMU electric vehicle fleet	Dimensionless decimal	EV module impact data	Y
331003a	Reduced Greenhouse Gas Emissions	Reduction in greenhouse gas emissions from MMU vehicle fleets	tCO_2e	MMU vehicle emission telematics data	Y
331003b	Reduced Greenhouse Gas Emissions	Reduction in greenhouse gas emissions attributable to Triangulum electric vehicles in MMU vehicle fleets	tCO_2e	MMU vehicle emission telematics data	Y

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
331004a	Reduced Greenhouse Gas Emissions	Number of electric vehicles within UNIMAN vehicle fleet	Dimensionless integer	EV module impact data	Y
331004b	Reduced Greenhouse Gas Emissions	Number of Triangulum electric vehicles within UNIMAN vehicle fleet	Dimensionless integer	EV module impact data	Y
331005a	Reduced Greenhouse Gas Emissions	Percentage of electric vehicles within UNIMAN vehicle fleet	Dimensionless decimal	EV module impact data	Y
331005b	Reduced Greenhouse Gas Emissions	Percentage of Triangulum electric vehicles within UNIMAN vehicle fleet	Dimensionless decimal	EV module impact data	Y
331005c	Reduced Greenhouse Gas Emissions	Percentage of Triangulum electric vehicles within UNIMAN electric vehicle fleet	Dimensionless decimal	EV module impact data	Y
331006a	Reduced Greenhouse Gas Emissions	Reduction in greenhouse gas emissions from UNIMAN vehicle fleet	tCO_2e	UNIMAN vehicle telematic data	Y

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
331006b	Reduced Greenhouse Gas Emissions	Reduction in greenhouse gas emissions attributable to Triangulum electric vehicles in UNIMAN vehicle fleet	tCO_2e	UNIMAN vehicle telematic data	Y
331007a	Reduced Greenhouse Gas Emissions	Total number of electric vehicles within specified vehicle fleet	Dimensionless integer	EV module impact data	Y
331007b	Reduced Greenhouse Gas Emissions	Total number of Triangulum electric vehicles within specified vehicle fleet	Dimensionless integer	EV module impact data	Y
331008a	Reduced Greenhouse Gas Emissions	Percentage of electric vehicles within specified vehicle fleets	Dimensionless decimal	EV module impact data	Y
331008b	Reduced Greenhouse Gas Emissions	Percentage of Triangulum electric vehicles within specified vehicle fleets	Dimensionless decimal	EV module impact data	Y
331008c	Reduced Greenhouse Gas Emissions	Percentage of Triangulum electric vehicles within specified electric vehicle fleets	Dimensionless decimal	EV module impact data	Y

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
331009a	Reduced Greenhouse Gas Emissions	Reduction in greenhouse gas emissions from specified vehicle fleets	tCO_2e	MMU vehicle telematic data UNIMAN vehicle telematics data	Y
331009b	Reduced Greenhouse Gas Emissions	Reduction in greenhouse gas emissions attributable to Triangulum electric vehicles in specified vehicle fleets	tCO_2e	MMU vehicle telematic data UNIMAN vehicle telematics data	Y
331010	Reduced emissions of air quality pollutants	Reduction in NOx emissions from MMU vehicle fleet	g/vkm	MMU vehicle telematics data	Y
331011	Reduced emissions of air quality pollutants	Reduction in NOx emissions from UNIMAN vehicle fleet	g/vkm	UNIMAN vehicle emission and tracking data	Y
331012	Reduced emissions of air quality pollutants	Reduction in NOx emissions from specified vehicle fleets	g/vkm	MMU vehicle emission and tracking data UNIMAN vehicle emission and tracking data	Y
331013	Reduced emissions of air quality pollutants	Reduction in CO emissions from MMU vehicle fleet	g/vkm	MMU vehicle emission and tracking data	Y

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
331014	Reduced emissions of air quality pollutants	Reduction in CO emissions from UNIMAN vehicle fleet	g/vkm	UNIMAN vehicle emission and tracking data	Y
331015	Reduced emissions of air quality pollutants	Reduction in CO emissions from specified vehicle fleets	g/vkm	MMU vehicle emission and tracking data UNIMAN vehicle emission and tracking data	Y
331016	Evaluating new technologies	Number of electric vehicle charging stations installed	Dimensionless integer	EV charging station use data	Y
331017	Evaluating new technologies	Quantity of energy supplied by EV charging stations installed	kWh/yr	EV charging station use data	N
331018	Evaluating new technologies	Percentage of users satisfied with telematics	Dimensionless decimal	EV user satisfaction data	N
331019	Evaluating new technologies	Percentage of electric vehicles with telematics	Dimensionless decimal	MMU vehicle telematics data UNIMAN vehicle telematics data	N

Table 3.3.2: Impact assessment indicators description for Module 331

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
33100A	MMU vehicle telematics data	Telematics for Triangulum EVs within the MMU fleet	331003 331009 331010 331012 331013 331015 331019	MMU	Andrew Taylor – Travel Manager	Telematics data is available via Nissan's CarWings system pre-installed within EVs. However, an API is not provided. Ethical issues have been raised, and are being explored, regarding further use of telematics.	WP2 continued to liaise with partner to understand how this data could be harnessed ethically, and included in the M60 report.
33100B	UNIMAN vehicle telematics data	Telematics Triangulum EVs within the UNIMAN fleet	331006 331009 331011 331012 331014 331015 331019	UNIMAN	Fleet Manager – Phil Lord and Sustainability Manager Julia Durkan.		

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
33100C	EV user satisfaction data	Data detailing user satisfaction with EV	331018	MCC	Martine Tommis (m.tommis1@manchester.gov.uk)	WP3 has yet to define approach to capturing user satisfaction data post M36.	WP2 worked with WP3 to help support an evaluation programme. This data has been included in M60 report.
33100D	EV charging station use data	Data detailing the use of EV charging stations installed as part of module implementation	331016 331017	Greater Manchester Electric Vehicle Scheme	Transport for Greater Manchester	Data is owned by the commercial organisation that installed the EV charging stations. WP3 have gained access to charging data, but not number of users.	
33100E	EV module impact data	Data reporting module impacts including number of EVs procured by MMU and UNIMAN.	331001 331002 331004 331005 331007 331008	MCC	Martine Tommis (m.tommis1@manchester.gov.uk)		

Table 3.3.3: Datasets description for Module 331

Impact indicator identifier	Impact indicator	Quant Unit	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
331001a	Number of electric vehicles within MMU vehicle fleets	Dim. Int.	2	Aug 2015 –Jul 2016	12	Aug 2016 – Jul 2017	13	Nov 17 - Oct 18	11	Nov 18 – Oct 19	9	3	4.50	1.36
331001b	Number of Triangulum electric vehicles within MMU vehicle fleets	Dim. Int.	0	Aug 2015 –Jul 2016	2	Aug 2016 – Jul 2017	2	Nov 17 - Oct 18	2	Nov 18 – Oct 19	2	1	NA	NA
331002a	Percentage of electric vehicles within MMU vehicle fleets	Dim. Int.	0.1	Aug 2015 –Jul 2016	0.48	Aug 2016 – Jul 2017	0.52	Nov 17 - Oct 18	58%	Nov 18 – Oct 19	0	0	4.79	1.45
331002b	Percentage of Triangulum electric vehicles within MMU vehicle fleets	Dim. Int.	0	Aug 2015 –Jul 2016	0.08	Aug 2016 – Jul 2017	0.08	Nov 17 - Oct 18	11%	Nov 18 – Oct 19	0	0	NA	NA
331002c	Percentage of Triangulum electric vehicles within MMU	Dim. Int.	0	Aug 2015 –Jul 2016	0.17	Aug 2016 – Jul 2017	0.15	Nov 17 - Oct 18	18%	Nov 18 – Oct 19	0	0	NA	NA

Impact indicator identifier	Impact indicator	Quant Unit	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
	electric vehicle fleet													
331003a	Reduction in greenhouse gas emissions from MMU vehicle fleets	tCO_2e	44.3	Aug 2015 –Jul 2016	30.1	Aug 2016 – Jul 2017	25.2	Nov 17 - Oct 18	22.4 5	Nov 18 – Oct 19	-22	-7	-0.49	-0.15
331003b	Reduction in greenhouse gas emissions attributable to Triangulum electric vehicles in MMU vehicle fleets	tCO_2e	0	Aug 2015 –Jul 2016	2.4	Aug 2016 – Jul 2017	2.02	Nov 17 - Oct 18	1.78	Nov 18 – Oct 19	2	1	NA	NA
331004a	Number of electric vehicles within UNIMAN vehicle fleet	Dim. Int.	3	Nov 2015 – Oct 2016	13	Nov 2016 – Oct 2017	13	Nov 17 - Oct 18	14	Nov 18 – Oct 19	11	4	3.67	1.21
331004b	Number of Triangulum electric vehicles	Dim. Int.	0	Nov 2015 – Oct 2016	7	Nov 2016 – Oct 2017	7	Nov 17 - Oct 18	8	Nov 18 – Oct 19	8	3	NA	NA

Impact indicator identifier	Impact indicator	Quant Unit	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
	within UNIMAN vehicle fleet													
331005a	Percentage of electric vehicles within UNIMAN vehicle fleet	Dim. Int.	0.04	Nov 2015 – Oct 2016	0.15	Nov 2016 – Oct 2017	0.17	Nov 17 - Oct 18	17%	Nov 18 – Oct 19	0	0	3.32	1.09
331005b	Percentage of Triangulum electric vehicles within UNIMAN vehicle fleet	Dim. Int.	0	Nov 2015 – Oct 2016	0.08	Nov 2016 – Oct 2017	0.09	Nov 17 - Oct 18	10%	Nov 18 – Oct 19	0	0	NA	NA
331005c	Percentage of Triangulum electric vehicles within UNIMAN electric vehicle fleet	Dim. Int.	0	Nov 2015 – Oct 2016	0.54	Nov 2016 – Oct 2017	0.54	Nov 17 - Oct 18	57%	Nov 18 – Oct 19	1	0	NA	NA
331006a	Reduction in greenhouse gas emissions from UNIMAN vehicle fleet	tCO_2e	164.1	Nov 2015 – Oct 2016	143.4	Nov 2016 – Oct 2017	142	Nov 17 - Oct 18	135.91	Nov 18 – Oct 19	-28	-9	-0.17	-0.06

Impact indicator identifier	Impact indicator	Quant Unit	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
331006b	Reduction in greenhouse gas emissions attributable to Triangulum electric vehicles in UNIMAN vehicle fleet	tCO_2e	0	Nov 2015 – Oct 2016	11.2	Nov 2016 – Oct 2017	13.3	Nov 17 - Oct 18	5.45	Nov 18 – Oct 19	5	2	NA	NA
331007a	Total number of electric vehicles within specified vehicle fleet	Dim. Int.	5	2015-2016 (baselines not aligned)	25	2016-2017 (baselines not aligned)	26	Nov 17 - Oct 18	25	Nov 18 – Oct 19	20	NA	4.00	NA
331007b	Total number of Triangulum electric vehicles within specified vehicle fleet	Dim. Int.	0	2015-2016 (baselines not aligned)	9	2016-2017 (baselines not aligned)	9	Nov 17 - Oct 18	10	Nov 18 – Oct 19	10	NA	NA	NA
331008a	Percentage of electric vehicles within specified vehicle fleets	Dim. Int.	0.05	2015-2016 (baselines not aligned)	0.23	2016-2017 (baselines not aligned)	0.26	Nov 17 - Oct 18	25%	Nov 18 – Oct 19	0	NA	4.00	NA

Impact indicator identifier	Impact indicator	Quant Unit	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
331008b	Percentage of Triangulum electric vehicles within specified vehicle fleets	Dim. Int.	0	2015-2016 (baselines not aligned)	0.08	2016-2017 (baselines not aligned)	0.09	Nov 17 - Oct 18	10%	Nov 18 – Oct 19	0	NA	NA	NA
331008c	Percentage of Triangulum electric vehicles within specified electric vehicle fleets	Dim. Int.	0	2015-2016 (baselines not aligned)	0.36	2016-2017 (baselines not aligned)	0.35	Nov 17 - Oct 18	40%	Nov 18 – Oct 19	0	NA	NA	NA
331009a	Reduction in greenhouse gas emissions from specified vehicle fleets	tCO_2e	208.4	2015-2016 (baselines not aligned)	173.5	2016-2017 (baselines not aligned)	167.23	Nov 17 - Oct 18	158.37	Nov 18 – Oct 19	-50	NA	-0.24	NA
331009b	Reduction in greenhouse gas emissions attributable to Triangulum electric vehicles	tCO_2e	0	2015-2016 (baselines not aligned)	12.6	2016-2017 (baselines not aligned)	15.27	Nov 17 - Oct 18	7.24	Nov 18 – Oct 19	7	NA	NA	NA

Impact indicator identifier	Impact indicator	Quant Unit	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
	in specified vehicle fleets													
331010	Reduction in NOx emissions from MMU vehicle fleet	g/vkm	0	Aug 2015 –Jul 2016	- 792.8	Aug 2016 – Jul 2017	- 878.9	Nov 17 - Oct 18	1228 .32	Nov 18 – Oct 19	1,228	373	NA	NA
331011	Reduction in NOx emissions from UNIMAN vehicle fleet	g/vkm	0	Nov 2015 – Oct 2016	- 2,973 .2	Nov 2016 – Oct 2017	- 2898. 1	Nov 17 - Oct 18	2554 .16	Nov 18 – Oct 19	2,554	840	NA	NA
331012	Reduction in NOx emissions from specified vehicle fleets	g/vkm	0	2015-2016 (baseline s not aligned)	- 3,766	2016-2017 (baseline s not aligned)	- 3,777	Nov 17 - Oct 18	3,782	Nov 18 – Oct 19	3,782	1,212	NA	NA
331013	Reduction in CO emissions from MMU vehicle fleet	g/vkm	0	Aug 2015 –Jul 2016	- 4,955	Aug 2016 – Jul 2017	- 5493. 13	Nov 17 - Oct 18	7677	Nov 18 – Oct 19	7,677	2,328	NA	NA

Impact indicator identifier	Impact indicator	Quant Unit	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
331014	Reduction in CO emissions from UNIMAN vehicle fleet	g/vkm	0	Nov 2015 – Oct 2016	-18,582.5	Nov 2016 – Oct 2017	-18113.17	Nov 17 - Oct 18	15963.50	Nov 18 – Oct 19	15,963	5,248	NA	NA
331015	Reduction in CO emissions from specified vehicle fleets	g/vkm	0	2015-2016 (baselines not aligned)	-23,537	2016-2017 (baselines not aligned)	-23,606	Nov 17 - Oct 18	23,640	Nov 18 – Oct 19	23,640	7,577	NA	NA
331016	Number of electric vehicle charging stations installed	Dim. Int.	0	N/A	2	Nov 2017	3	Nov 17 - Oct 18	3	Nov 18 – Oct 19	3	NA	NA	NA
331017	Quantity of energy supplied by EV charging stations installed	kWh/yr	0	N/A	Not known	Nov 2017	7,019	Nov 17 - Oct 18	1,796	Nov 18 – Oct 19	0	NA	NA	NA
331018	Percentage of users satisfied with telematics	Dim. Int.	0	N/A	WP3 monitoring post M36	N/A	N/A	N/A	NA	Nov 18 – Oct 19	NA	NA	NA	NA

Impact indicator identifier	Impact indicator	Quant Unit	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
331019	Percentage of electric vehicles with telematics	Dim. Int.	0	N/A	1.0	Nov 2017	1	Nov 17 - Oct 18	0.75	Nov 18 – Oct 19	0.75	NA	NA	NA

Table 3.3.4: Impact assessment for Module 331

3.3.2 Module 332: Electric assist cargo bikes (Subtasks 3.3.2-4)

The implementation dates of the module

The module was implemented in June 2016.

Factors limiting progress towards defining the approach to calculating impacts, identifying associated datasets, and establishing impact

- A total of four cargo bikes were procured through Triangulum, however the fleet is made up of 12 cargo bikes in total. It is not possible to separate the tracking data for the four Triangulum procured bikes, and so the data has been presented as totals and as a proportion of 4/12.
- M35: Due to teething issues with the telematics, the data is not available from deployment date of June 2016. There are also some gaps in the data available. Therefore, data is provided from March 2017 when full set of data was available, with Jan-Feb 2018 extrapolated.
- M35: The stakeholders do not collect or calculate GHG emission data. This impact indicator (332004) has been calculated as avoided Co2e based on the miles travelled by the cargo bikes, a standard fuel efficiency of 50 miles per gallon (MPG), and using UK government conversion factor for petrol.
  Take standard fuel efficiency at 50 MPG =
  6,239 mi = 124.8 gallons = 567.4 litres * 2.19697 (2016 petrol conversion factor) = 1,246.6 Co2e
- NOx and CO data was not collected. These impacts were calculated using Euro 6 emission standards for diesel vehicles, with 0.5g/km CO and 0.08g/km NOx criteria multiplied by the distance travelled.
- The following modules have been amended to provide improved data: 332002 has been split into 332002a (number of journeys) and 332002b (distance travelled); 332003 has been split into 332003a (hours in use in total) and 332003b (hours in use per cargo bike).

Changes from M36 to M48

- No changes

Changes since M48 report

- No changes

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
332001	Reduced Greenhouse Gas Emissions	Number of cargo bikes provided by the scheme	Dimensionless integer	Cargo bike impact data	N
332002	Reduced Greenhouse Gas Emissions	Number of journeys made by cargo bikes within the scheme	Dimensionless integer	Cargo bike use data	N
332003	Reduced Greenhouse Gas Emissions	Average time cargo bikes are in use per day	hh:mm	Cargo bike use data	N
332004	Reduced Greenhouse Gas Emissions	Reduction in greenhouse gas emissions as a result of module implementation	tCO_2e	Cargo bike use data	Y
332005	Reduced Air Quality Pollutant Emissions	Reduction in NO_x emissions	g/vkm	Cargo bike use data	Y
332006	Reduced Air Quality Pollutant Emissions	Reduction in CO emissions	g/vkm	Cargo bike use data	Y
332007	Reduced traffic congestion	Number of journeys by motorised vehicles replaced by cargo bike journeys	Dimensionless integer	Cargo bike use data	N
332008	Evaluation of new technologies	Percentage of users satisfied with cargo bikes	Dimensionless decimal	Cargo bike user satisfaction data	N

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
332009	Evaluation of new technologies	Percentage of cargo bikes with GPS tracking	Dimensionless decimal	Cargo bike impact data	N

Table 3.3.5: Impact assessment indicators description for Module 332

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
33200A	Cargo bike use data	GPS tracking for cargo bikes within the scheme	332002 332003 332004 332005 332006 332007	MCC	Martine Tommis (m.tommis1@manchester.gov.uk)	Data collected by Autotrip tracker hardwired to the bike battery.	WP2 liaised with partners to understand how this data could be included in M60 report.
33200B	Cargo bike user satisfaction data	Data detailing user satisfaction with the Cargo Bikes	332008	MCC	Martine Tommis (m.tommis1@manchester.gov.uk)	WP3 has yet to define approach to capturing user satisfaction data	WP2 liaised with partners to support evaluation programme and understand how this data could be included in M60 report.
33200C	Cargo bike impact data	Data detailing impacts of the module including number of cargo-bikes within the scheme	332001 332009	MCC	Martine Tommis (m.tommis1@manchester.gov.uk)		

Table 3.3.6: Datasets description for Module 332

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
332001	Number of cargo bikes provided by the scheme	Dim. Int.	0	Jun 15 – May 16	4	Mar 17 – Feb 18	4	Nov 17 - Oct 18	4	Nov 18 – Oct 19	4	1	N/A	N/A
332002a	Number of journeys made by cargo bikes within the scheme	Dim. Int.	0	Jun 15 – May 16	1,989	Mar 17 – Feb 18	1,630	Nov 17 - Oct 18	874	Nov 18 – Oct 19	874	252	N/A	N/A
332002b	Distance travelled by cargo bikes within the scheme	km	0	Jun 15 – May 16	10,041	Mar 17 – Feb 18	9,708	Nov 17 - Oct 18	6,697	Nov 18 – Oct 19	6,697	1,932	N/A	N/A
332003a	Average time cargo bikes are in use per day	hh:mm	00:00	Jun 15 – May 16	07:40	Mar 17 – Feb 18	04:04	Nov 17 - Oct 18	02:42	Nov 18 – Oct 19	02:42	00:46	N/A	N/A
332003b	Average time each cargo bike is in use per day	hh:mm	00:00	Jun 15 – May 16	01:55	Mar 17 – Feb 18	01:01	Nov 17 - Oct 18	00:28	Nov 18 – Oct 19	00:28	00:08	N/A	N/A

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
332004	Reduction in greenhouse gas emissions as a result of module implementation	tCO_2e	0	Jun 15 – May 16	1.25	Mar 17 – Feb 18	1.00	Nov 17 - Oct 18	0.82	Nov 18 – Oct 19	0.82	0.24	N/A	N/A
332005	Reduction in NO_x emissions	g/vkm	0	Jun 15 – May 16	803	Mar 17 – Feb 18	777	Nov 17 - Oct 18	536	Nov 18 – Oct 19	536	155	N/A	N/A
332006	Reduction in CO emissions	g/vkm	0	Jun 15 – May 16	5,021	Mar 17 – Feb 18	4,854	Nov 17 - Oct 18	3349	Nov 18 – Oct 19	3,349	966	N/A	N/A
332007	Number of journeys by motorised vehicles replaced by cargo bike journeys	Dim. Int.	0	Jun 15 – May 16	1,989 (assumed 1:1)	Mar 17 – Feb 18	1630	Nov 17 - Oct 18	874	Nov 18 – Oct 19	874	252	N/A	N/A
332008	Percentage of users satisfied with cargo bikes	Dim. Int.	0.00	N/A	Post M36 monitoring	N/A	N/A	N/A	71%	Nov 18 – Oct 19	1	N/A	N/A	N/A

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
					as WP3									
332009	Percentage of cargo bikes with GPS tracking	Dim. Int.	0.00	Jun 15 – May 16	1.0	Mar 17 – Feb 18	1.0	Nov 17 - Oct 18	0%	Nov 18 – Oct 19	0	0	N/A	N/A

Table 3.3.7: Impact assessment for Module 332

3.4 ICT Modules

The Manchester ICT task group defined the scope of three modules to demonstrate the potential of ICTs as an enabler of innovation in the Corridor. The module descriptions and proposed impact indicators presented below have been revised as module scope was refined and lessons learnt.

1. Trialling a *data curation service:* This module recognises the increasing value of city data as an asset to be actively managed. It trialled an active data curation process to provide access to city data from multiple sources. This module investigated how this active curation process might operate in Manchester and trialled it to demonstrate the concept within the limits of the Triangulum project. The trial investigated the associated curation and governance processes and the technical architecture. Data curated within the trial was hosted on Manchester-i and other data platforms.

2. Developing a *data visualisation platform:* This module focused on developing a visualisation platform which will make city data (hosted on MANCHESTER-I and other data platforms) more accessible to non-specialists and demonstrate the potential for innovative application development.

3. Facilitating *data-enabled innovation challenges:* This module focused on using ICT and data to support and foster innovative data-enabled solutions to address issues and opportunities on the Corridor. In addition to data collected in Energy and Mobility a process was developed to capture "experience data" from stakeholders in the Corridor. Experience data and other data sources was made available to organisations and citizens through the Visualisation Platform to encourage innovative data-enabled solutions.

Table 3.4.1 presents a summary of the expected impacts of each module.

Module	Mechanism for creating impacts	Expected Impacts			
		Enhanced digital infrastructure	Increased commercial activity	Increased engagement with data	Increased environmental awareness and behaviour change
341: Data curation service	Providing access to data which can be used by citizens, businesses and government to create economic, social and environmental value.	*		*	
342: Data visualisation platform	Reducing the barriers to citizens, businesses and government using data in visual and experiential manner to create economic, social and environmental value.	*		*	
343: Data-enabled innovation challenges	Promoting use of the data curation service and visualisation platform to solve real-world issues.		*	*	*

Table 3.4.1: Expected impacts of Manchester ICT modules

3.4.1 Module 341: Data curation service (sub-task 3.4.1)

The implementation dates of the module

The module was implemented through the Manchester-i launch on 29th November 2017 [http://vm-pi-p03.ds.man.ac.uk/].

The indicators used for assessing the impacts and benefits and baseline conditions

Below Table 3.4.2 provides details of the impact indicators developed for this module and Table 3.4.3 identifies datasets used to calculate impacts.

Factors limiting progress towards defining the approach to calculating impacts, identifying associated datasets, and establishing impact

- The quantity of data downloaded from the service is based on an estimate using WP3's experience, as no data is currently being collected.

Changes from M36 to M48

- No changes

Changes from M48 to M60

- No changes

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
341001	Enhanced digital infrastructure	Total number of datasets openly accessible via the data curation service	Dimensionless integer	Data curation service metadata	N
341002	Enhanced digital infrastructure	Number of datasets relating to energy modules openly accessible via the data curation service	Dimensionless integer	Data curation service metadata	N
341003	Enhanced digital infrastructure	Number of datasets relating to mobility modules openly accessible via the data curation service	Dimensionless integer	Data curation service metadata	N
341004	Enhanced digital infrastructure	Number of real time[2] data feeds curated by the service	Dimensionless integer	Data curation service metadata	N
341005	Enhanced digital infrastructure	Quantity of data openly accessible via the data curation service	GB	Data curation service metadata	Y

[2] Data feeds which are updated hourly or more frequently

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
341006	Increased engagement with data	Number of data downloads from the data curation service	Dimensionless integer	Data curation use data	N
341007	Increased engagement with data	Number of users downloading data from the data curation service	Dimensionless integer	Data curation use data	Y
341008	Increased engagement with data	Number of visualisation options offered for viewing and interacting with the data hosted by the curation service	Dimensionless integer	Data curation use data	N
341009	Increased engagement with data	Quantity of data downloaded by users of the curation service	GB	Data curation use data	Y

Table 3.4.2: Impact assessment indicators description for Module 341

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
34100A	Data curation service metadata	Metadata detailing the form and quantity of data hosted by the service.	341001 341002 341003 341004 341005	UNIMAN	Ettore Murabito (ettore.murabito@manchester.ac.uk)	Form and format of data to be provided by WP3 remains to be confirmed	WP2 liaised with partner to understand whether this data could be included in the M60 report.
34100B	Data curation use data	Use data detailing number of users etc.	341006 341007 341008 341009	UNIMAN	Ettore Murabito (ettore.murabito@manchester.ac.uk)	Form and format of data to be provided by WP3 remains to be confirmed	WP2 liaised with partner to understand whether this data could be included in the M60 report.

Table 3.4.3: Datasets description for Module 341

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change
341001	Total number of datasets openly accessible via the data curation service	Dim. Int.	0	Dec 16 – Nov 17	13	Dec 2017	13	Nov 17 - Oct 18	9	Nov 18 – Oct 19	9	4	n/a
341002	Number of datasets relating to energy modules openly accessible via the data curation service	Dim. Int.	0	Dec 16 – Nov 17	3	Dec 2017	3	Nov 17 - Oct 18	1	Nov 18 – Oct 19	1	0.5	n/a
341003	Number of datasets relating to mobility modules openly accessible via the data curation service	Dim. Int.	0	Dec 16 – Nov 17	6	Dec 2017	4	Nov 17 - Oct 18	3	Nov 18 – Oct 19	3	1	n/a
341004	Number of real time[3] data feeds curated by the service	Dim. Int.	0	Dec 16 – Nov 17	13	Dec 2017	9	Nov 17 - Oct 18	296	Nov 18 – Oct 19	296	146	n/a
341005	Quantity of data openly accessible via the data curation service	GB	0	Dec 16 – Nov 17	0.22	Dec 2017	6	Nov 17 - Oct 18	0.4	Nov 18 – Oct 19	0.4	0	n/a

[3] Data feeds which are updated hourly or more frequently

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change
341006	Number of data downloads from the data curation service	Dim. Int.	0	Dec 16 – Nov 17	33	Dec 2017	156	Nov 17 - Oct 18	427	Nov 18 – Oct 19	427	211	n/a
341007	Number of users downloading data from the data curation service	Dim. Int.	0	Dec 16 – Nov 17	32	Dec 2017	140	Nov 17 - Oct 18	307	Nov 18 – Oct 19	307	151	n/a
341008	Number of visualisation options offered for viewing and interacting with the data hosted by the curation service	Dim. Int.	0	Dec 16 – Nov 17	2	Dec 2017	2	Nov 17 - Oct 18	4 from UNIMAN 4 for C&L (341001)	Nov 18 – Oct 19	8	4	n/a
341009	Quantity of data downloaded by users of the curation service	GB	0	Dec 16 – Nov 17	0.001	Dec 2017	0.005	Nov 17 - Oct 18	NK	Nov 18 – Oct 19	NA	NA	n/a

Table 3.4.4: Impact assessment for Module 341

3.4.2 Module 342: Data visualization platform (sub-task 3.4.2)

The implementation dates of the module

The module was implemented throughout 2017 through a series of videos and VR technologies, and collated through the Manchester-i launch on 29th November 2017.

Factors limiting progress towards defining the approach to calculating impacts, identifying associated datasets, and establishing impact

- The *ad hoc* nature of this module implementation has meant some difficulties with collecting impact indicator data. Therefore, the Manchester-i launch has been used as the point of implementation to allow start and end periods to be set.

Changes from M36 to M48

- No changes

Changes from M48 to M60

- No changes

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
342001	Enhanced digital infrastructure	Total number of visualisation services provided by the platform	Dimensionless integer	Visualisation platform metadata	N
342002	Enhanced digital infrastructure	Number of visualisation services provided by the platform which use data related to energy modules	Dimensionless integer	Visualisation platform metadata	N
342003	Enhanced digital infrastructure	Number of visualisation services provided by the platform which use data related to mobility modules	Dimensionless integer	Visualisation platform metadata	N
342004	Enhanced digital infrastructure	Total number of real time data feeds integrated into the visualisation platform	Dimensionless integer	Visualisation platform metadata	N
342005	Enhanced digital infrastructure	Number of real time data feeds related to energy modules and integrated into the visualisation platform	Dimensionless integer	Visualisation platform metadata	N
342006	Enhanced digital infrastructure	Number of real time data feeds related to mobility modules and integrated into the visualisation platform	Dimensionless integer	Visualisation platform metadata	N
342007	Increased engagement with data	Number of visualisation platform users	Dimensionless integer	Visualisation platform use data	Y

Table 3.4.5: Impact assessment indicators description Module 342

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
34200A	Visualisation platform metadata	Metadata detailing the form and quantity of data hosted by the service.	342001 342002 342003 342004 342005 342006	C&L	Michael King (michael.king@clicksandlinks.com)	Form and format of data to be provided by WP3 remains to be confirmed	WP2 liaised with partner to understand whether this data could be included in the M48 refresh, and the M60 report.
34200B	Visualisation platform use data	Use data detailing number of users etc.	342007	C&L	Michael King (michael.king@clicksandlinks.com)	Form and format of data to be provided by WP3 remains to be confirmed	WP2 liaised with partner to understand whether this data could be included in the M48 refresh, and the M60 report.

Table 3.4.6: Datasets description for Module 342

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change
342001	Total number of visualisation services provided by the platform	Dim. Int.	0	Dec 16 – Nov 17	2	Dec 2017	3	Nov 2018	4	Nov 18 – Oct 19	4	2	n/a
342002	Number of visualisation services provided by the platform which use data related to energy modules	Dim. Int.	0	Dec 16 – Nov 17	0	Dec 2017	1	Nov 2018	0	Nov 18 – Oct 19	0	0	n/a
342003	Number of visualisation services provided by the platform which use data related to mobility modules	Dim. Int.	0	Dec 16 – Nov 17	2	Dec 2017	2	Nov 2018	0	Nov 18 – Oct 19	0	0	n/a
342004	Total number of real time data feeds integrated into the visualisation platform	Dim. Int.	0	Dec 16 – Nov 17	13	Dec 2017	13	Nov 2018	0	Nov 18 – Oct 19	0	0	n/a

342005	Number of real time data feeds related to energy modules and integrated into the visualisation platform	Dim. Int.	0	Dec 16 – Nov 17	3	Dec 2017	3	Nov 2018	0	Nov 18 – Oct 19	0	0	n/a
342006	Number of real time data feeds related to mobility modules and integrated into the visualisation platform	Dim. Int.	0	Dec 16 – Nov 17	6	Dec 2017	6	Nov 2018	0	Nov 18 – Oct 19	0	0	n/a
342007	Number of visualisation platform users	Dim. Int.	0	Dec 16 – Nov 17	32	Dec 2017	4	Nov 2018	100+ (est)	Nov 18 – Oct 19	100	49	n/a

Table 3.4.7: Impact assessment for Module 342

3.4.3 Module 343: Data-enabled innovation challenges (sub-task 3.4.3)

The implementation dates of the module

The module was implemented at the first innovation challenge in February 2018.

Factors limiting progress towards defining the approach to calculating impacts, identifying associated datasets, and establishing impact

- This module was implemented in February 2018, and therefore no data was available at M36.
- First Innovation Challenge held in in February 2018. The second Innovation Challenge has been delayed due to issues with finding a suitable host venue and is scheduled for early 2019.

Changes from M36 to M48

- Updated impact data presented for 343003 and 343005.
- 343001, 343002 and 343004 removed as no data available to provide a baseline.
- 343005: Three exemplar apps developed with elements of behaviour change. However, these are proof of concept apps, and not production-ready, and were developed by Clicks and Links (partner) rather than by an external organisation.

Changes from M48 to M60

- No changes

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?	Comments
343001	Increased commercial activity	Number of apps developed by for-profit organisations in response to innovation challenges which use the data curation service and/or the visualisation platform.	Dimensionless integer	Innovation challenge participation and impact data	Y	Removed due to lack of baseline data.
343002	Increased commercial activity	Number of apps developed in response to innovation challenges which use the data curation service and/or the visualisation platform, and provide services to for- profit organisations.	Dimensionless integer	Innovation challenge participation and impact data	Y	Removed due to lack of baseline data.
343003	Increased engagement with data	Number of people participating in innovation challenges	Dimensionless integer	Innovation challenge participation and impact data	N	
343004	Increased engagement with data	Number of apps developed in response to innovation challenges which use the data curation service and/or the visualisation platform, and provide services to citizens.	Dimensionless integer	Innovation challenge participation and impact data	Y	Removed due to lack of baseline data.
343005	Increased environmental awareness and behaviour change	Number of apps developed in response to innovation challenges which use the data curation service and/or the visualisation platform, and seek to change user behaviour.	Dimensionless integer	Innovation challenge participation and impact data	Y	

Table 3.4.8: Impact assessment indicators description for Module 343

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
34300A	Innovation challenge participation and impact data	Data detailing the outcomes and impacts of the innovation challenge module.	343001 343002 343003 343004 343005	C&L	Michael King (michael.king@clicksandlinks.com)	Data collected manually (rather than sensor generated).	

Table 3.4.9: Datasets description for Module 343

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Deriv of rel chang (p.a.)
343003	Number of people participating in innovation challenges	Dim. Int.	0	n/a	n/a	n/a	16	Nov-18	50+	Nov 18 – Oct 19	50	16	n/a	n/a
343005	Number of apps developed in response to innovation challenges which use the data curation service and/or the visualisation platform, and seek to change user behaviour.	Dim. Int.	0	n/a	n/a	n/a	3	Nov-18	6	Nov 18 – Oct 19	6	3	n/a	n/a

Table 3.4.10: Impact assessment for Module 343

4 Eindhoven Impact at Module Level

Executive Summary

The Eindhoven report is organised into four sections.

Section 1 provides an overview of Eindhoven, and highlights Eindhoven smart city ambitions and initiatives including development of roadmaps in Eindhoven. Meanwhile, section 1 will summarise the evaluation results in Eindhoven.

Section 2-4 describes the Energy, Mobility and ICT modules in detail including objectives, socio-technical configurations, stakeholder structures and impact indicators with baseline data. The indicators to assess the impacts and benefits of the module and the current understanding of comparison between end conditions and baseline conditions, are presented with assessment tables.

4.1 Overview and initial assessment

Eindhoven has the ambition to be energy neutral by 2045 to contribute to a drastic reduction of the overall CO_2 emissions and to sustain human life in the city. With this target, Eindhoven engaged all stakeholders in its policy and decision-making processes at the centre of its policy processes. This is reflected in the city-wide commitment to follow the 'Natural Step' principles. On the road to a sustainable Eindhoven, these activities are guided by the 4 principles of the Natural Step, which are:

1) To use renewable materials, and reuse and recycling materials;
2) To use or produce no chemicals with negative effects on human health and the environment;
3) To protect nature and biodiversity, since they provide us with clean air, food, water, energy and medication;
4) To care for our citizens so they can lead secure, free and healthy lives, irrespective of their identity, beliefs, sex and background and make sure our activities do not harm others in the rest of the world.

Eindhoven's political commitment to offer its urban space as a living lab for innovative, co-created, solutions strongly supports this Smart City process. To date, Eindhoven has implemented a series of smart city initiatives based on the quadruple Helix Model (cooperation among universities, enterprises, government and citizens). These initiatives include development of thematic roadmaps for Energy, Lighting, the Sustainable Urban Mobility Plan ('Eindhoven Op Weg!') and the ICT-Kompas. These roadmaps set out the overall vision and strategic goals, as well as the expected timeline and means necessary to achieve these goals.

Triangulum projects created mainly two living labs in Eindhoven which are Strijp-S and Eckart-Vaartbroek area. 12 modules addressing energy, mobility and ICT perspectives are working on to reduce energy consumption and creating a better living environment for the city. The overall assessment table is shown in Table 1. The energy projects cover private/social house, office and public infrastructure upgrading. Based on the assessment, it can be conclude that, it is easier to reduce energy consumption by replacing existing infrastructures, such as implementing new technologies (building pipes to connect houses/offices with bio-mass factory; connect energy pipes with SANERGY). For office buildings, the old structure of the building could create additional problems once it is merged with new technologies such as sensors. For private and social house, the significant challenge is how to approach residents and persuade them to be on board for house renovation. After renovation, considering privacy issue, residents may not willing to install smart metering which lead to real energy consumption data cannot be gathered. (Whilst smart metering was promoted, it is illegal to force the installation unless there is PV installed on the roof. Ultimately, it is the residents' choice whether they would like to have smart metering or not). Even if they have a smart metering, they may refuse to share any energy consumption data. Comparison cannot be done easily without sufficient samples of energy consumption data considering weather conditions and yearly difference. Transportation as one important contributor to energy consumption, it is important to provide new technologies for improving the traffic efficiency. Providing additional traffic tools and promoting Electric Vehicles (EV) by installing more charging stations could help. Without disaggregated level travel information, limited conclusion could be drawn. Moreover, comparison is difficult to interpret unless there is a valid data collected systematically before and after the implementation. However the information does show promising perspectives. With the streaming sensor data availability, such as the occupancy data of parking slots and EV charging data, more insight understanding of people's travel behaviour could be captured. ICT projects provide the backbone for energy and mobility projects. Meanwhile it improves the citizens' quality of life by providing more fun facilities (such as 1km street light project). Overall, indicators could show a general picture before and after the implementation of a certain projects. For some projects, it is sufficient. It is necessary to mention that indicators have limited power of reflecting the whole decision making process, and success/failure learned during the process. Once a project involves more co-creations and/or slower progress, more research need to be done.

	#modules implemented	**#baseline indicator values available**	**#impact indicator values available**
Overall value	12/12	69/69	67/69
Energy	4/4	25/25	25/25
Mobility	2/2	12/12	11/12
ICT	6/6	32/32	31/32

Table 4.1.1: Overview assessment table

4.2 Energy Modules

Eindhoven has developed five modules to demonstrate development of energy infrastructures in district/area level. There are three modules of energy infrastructure in Strijp-S district, Module 4.2.2. The modules are:

- *Sustainable energy supply and soil sanitation (module 4.2.1):* VolkerWessels is implementing the technology called SANERGY, which is a combination approach of sustainable energy production and soil sanitation in Strijp-S. It will accelerate natural decomposition of pollutants and bringing the accelerate water into deeper layers of soil. Meanwhile, warmth – cold heat exchange will enable cooling in the summer and heating in the winter. This sustainable energy production will be used in the new apartment buildings as a sustainable energy source.
- *Optimization heat provision in existing buildings (module 4.2.2):* To replace the traditional heating system with renewable energy, VolkerWessels is building pipes to connect the buildings of Strijp-S to the new build biomass facility. It can provide renewable heating energy to an overall amount of 68,000 m2 within the strijp-S area, replacing a total of 13,3 Mio KWh of conventional heating.
- *Smart energy for offices (module 4.2.3):* Y-Con and OpenRemote are developing an office heating remote control system. VolkerWessels implements the system in Strijp-S. The purpose is to reduce energy consumption in office building and increase people's environment awareness at the same time.

There is one module of energy infrastructure located in Eckart-Vaartborek district. It is:

1. *Renovation of family homes & creation of participative society (module 4.2.4):* Woonbedrijf cooperated with KPN and WoonConnect are working on renovation around 74 houses with a total area of 11,198 m² in Eckart-Vaartbroek area. The purpose is to fulfil new regulatory requirements, reduce CO_2 emission and improve residents' quality of life.

Removed module:

Smart distribution of locally produced renewable energy (module 4.2.5): Local energy-production from renewable energy source will be placed in Eckart-Vaartbroek district by a co-creation process. The purpose of the module is to increase renewable energy percentage at district level and reduce CO_2 emission. (Note: this module has been removed due to issues with implementation. See **Fehler! Verweisquelle konnte nicht gefunden werden.** for more information).

The detailed information for each module is described in sections 3.1-3.5. Table 4.2.1 presents a summary of the expected impacts of these modules, and detailed module descriptions are provided below.

Modules	Mechanism for creating impacts	Expected impacts					
		Reducing (non-renewable) energy consumption	Reducing carbon emissions	Reducing energy bills	Fostering citizen engagement (Co-creation)	Developing a digital infrastructure	Improving the quality of life
Sustainable energy supply and soil Sanitation (Module 4.2.1)	The module will accelerate natural decomposition of pollutants and bringing the accelerate water into deeper layers of soil. This sustainable energy production will be used in the new apartment buildings as a sustainable energy source.	*	*	*	*		
Optimization heat provision existing build (Module 4.2.2)	The module will connect the buildings of Strijp-S to the new build biomass facility for providing renewable heating energy in Strijp-S area.	*	*				
Smart Energy for offices (Module 4.2.3)	A smart energy system for reducing energy consumption in office building.	*	*		*	*	
Renovation of family homes & creation of participative society (Module 4.2.4)	The module is working on renovation around 200 houses with a total area of 20,000 m² in Eckart-Vaartbroek area for improve the energy lable from F to B (or above) using co-creation method.	*	*	*	*		*
Smart distribution of Locally produced renewable energy (Module 4.2.5)	The module will install renewable energy production devices to increase renewable energy percentage at district level and reduce CO_2 emission.	*	*				

Table 4.2.1: Expected impacts of the Eindhoven Energy Modules

4.2.1 Module 421: Sustainable energy supply and soil sanitation (Subtask 4.2.1)

The implementation dates of the module

The module has been implemented in 2019.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

- 421001 - This indicator “Reducing energy bill for electricity” has been removed since there is no influence on electricity energy bill
- 421002 - This indicator has been changed from energy price for gas to energy bill for gas per month since no price will be influenced by this project. Only energy consumption would come from different resource, which will reduce their energy cost in the end.
- 421005 – To make the measurement more accurate, his indicator has been changed from “Total primary energy demand of connected buildings” to “Total primary energy demand of connected buildings **per month**”.
- 421007 - To make the measurement more accurate, this indicator has been changed from “Reduction in greenhouse gas emissions as a result of implementing the Sanergy” to “Reduction in greenhouse gas emissions as a result of implementing the Sanergy **per month**”. The calculation is based on “The Netherlands: list of fuels and standard CO_2 emission factors version of January 2017”. We assume the energy generated from Sanergy is CO_2 free. The energy produced by Sanergy which has been used for buildings are 17512*37% = 6479.44GJ. Based on the report 2017, 56.6kg/GJ CO_2 will be produced by using natural gas (dry). Therefore the reduction of CO_2 emission is 6479.44*56.6 = 366736.304

M60 Update

This sustainable energy production will be used in the new apartment buildings as a sustainable energy source within Triangulum. These two apartment buildings will be completed around 2023. Therefore, there should be no monitored data before the implementation of the buildings. The value we calculated for M48 report and before is based on historical energy consumption data in Strijp-S (existing buildings), which cannot reflect this module very well. But they still provide the overall situation in Strijp-S. Therefore, we keep the impact assessment table 4.5 as it was for M48 report and add another table named 4.5-2 to reflect the designed situation of the two new apartment buildings, particular for this module.

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
421002	Reduce energy bills	Heating price for consumer	€/year	Energy price data; Energy consumption data	Y
421003	Reduce energy consumption/ increase renewable energy	Percentage increase in use of renewable energy (energy generated on-site)	%	Energy consumption data	Y
421004	Reduce energy consumption/ increase renewable energy	Soil Sanitation	Years	Soil sanitation	N
421005	Reduce energy consumption/ increase renewable energy	Total primary energy demand of connected buildings	GJ/month	Energy consumption data	Y
421006	Reduced carbon emissions	Share of other renewable energy in the grid (solar, wind, biomass)	%	Energy consumption data	Y
421007	Reduced carbon emissions	Reduction in greenhouse gas emissions as a result of implementing the Sanergy	kg/month	Energy consumption data	Y

Table 4.2.2: Impact assessment indicators description for Module 421

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP02 steps taken
42100A	Energy price data	Energy price data from energy company	421002	Eneco/ Enexis	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	All data is regarding SANERGY implemented since 2009. The extension has been implemented in 2019.	Data has been updated after implementation of the extension part
42100B	Energy consumption data	Energy consumption data for each building in Strijp-S	421003 421005 421006 421007	Park Strijp Energy	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma		

					(n.wiersma@eindhoven.nl)		
42100C	Soil sanitation	Ground energy utilization and pollution reduction	421004	Philips/Arcadis	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)		

Table 4.2.3: Datasets description for Module 421

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
421002	Heating price for consumer per month	€/month	24808,67	2014Jan - 2014Dec	22421,30	2017Jan – 2017Oct	30408,07	2018Jan – 2018Dec	5599,40	1399,85	22,57%	0,06
421003	Percentage of renewable energy usage in the district (Sanergy generated on-site)	%	31	2014Jan - 2014Dec	11,38	2017Jan – 2017Oct	37	2018Jan – 2018Dec	0,06	0,02	19,35%	0,05
421004	Sanitation of soil	Years	+/- 30	2014Jan - 2014Dec	+/- 30	2017Jan – 2017Oct	+/- 30	2018Jan – 2018Dec	3,00	0,75	10,00%	2,50%
421005	Total primary energy demand of connected buildings per month	GJ/month	1459,33	2014Jan - 2014Dec	1318,90	2017Jan – 2017Oct	1788,71	2018Jan – 2018Dec	329,38	82,35	22,57%	0,06
421006	Share of other renewable energy in the grid (solar, wind, biomass)	%	0	2014Jan - 2014Dec	88,62	2017Jan – 2017Oct	63	2018Jan – 2018Dec	0,63	0,16	na	na
421007	Reduction in greenhouse gas emissions as a result of implementing the Sanergy per month	kg/month	256,05	2014Jan - 2014Dec	84,95	2017Jan – 2017Oct	374,59	2018Jan – 2018Dec	118,54	29,63	46,29%	0,12

Table 4.2.4: Impact assessment for Module 421

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	Designed value	Absolute change
421002	Heating price for consumer per month	€/month	0	2019Jan - 2019Dec	11793,75	11793,75
421003	Percentage of renewable energy usage in the new buildings (Sanergy generated on-site)	%	0	2019Jan - 2019Dec	61	61

421004	Sanitation of soil	Years	+/- 30	2019Jan - 2019Dec	+/- 30	0
421005	Total primary energy demand of connected buildings per month	GJ/month	0	2019Jan - 2019Dec	693,75	693,75
421006	Share of other renewable energy in the grid (solar, wind, biomass)	%	0	2019Jan - 2019Dec	0,39	0,39
421007	Reduction in greenhouse gas emissions as a result of implementing the Sanergy per month	kg/month	0	2019Jan - 2019Dec	23952,413	23952,41

Table 4.2.5-2: Impact assessment for Module 421

4.2.2 Module 422: Optimization of heat provision in existing buildings (Subtask 4.2.2)

The implementation dates of the module

The module was implemented by M14.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

422002 – To make the measurement more accurate, the indicator changed from 'Total primary heating energy demand of district' to 'Total primary heating energy demand of district per month'.

422003 – The indicator- "Total primary energy demand of district KWh/yr" has been removed since electricity energy demand will not be influenced by this project.

422004 – To make the measurement more accurate, the indicator changed from Net greenhouse gas emissions by steam/heating system to Net greenhouse gas emissions by steam/heating system per month. It is calculated based on "The Netherlands: list of fuels and standard CO_2 emission factors version of January 2017", 56.6kg/GJ CO_2 will be produced by using natural gas (dry). Therefore the CO_2 emission caused by central heating is 5623.58 * 56.6 = 312894.8kg. Since the energy served with Biomass pipe is differ from the buildings severed by SANERGY. Therefore the total gas consumption is different. The local green waste is being used to fire up the biomass central. Therefore after renovation, 'solid biomass' is going to use for generate heating. According to the CO_2 report 2017, per unit of solid biomass will produce 109.6 kg CO_2. In this case, CO_2 reduction is not applicable. Changing heating provider will increase CO_2 emission. Based on the Netherlands Energy efficiency report (2011), CO_2 emission per kWh generated (in gCO_2 /kWh) is 351. Therefore, net greenhouse gas emissions by electricity is 5546081*351/1000=1946674

422005 - The indicator – "Net greenhouse gas emissions by electricity" has been removed since net greenhouse gas emissions by electricity will not be influenced by this project.

M60 update

422004 – the indicator has been recalculated based on the table on Page 20 from SCIS – self-reporting guide_Nov2018. Based on the SCIS report the biogas produce $98gCO_2$ /kWh. While the domestic-gas (from gas tank) produce $305gCO_2$ /kWh. Therefore the net greenhouse gas emission was recalculated to make the M60 report consistent with SCIS platform. 1GJ = 277.778kWh.

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
422001	Reduce non- renewable energy consumption	Reliability of off-gas systems by biomass (energy generated on site）	%	Energy consumption data	N
422002	Reduce non- renewable energy consumption	Total primary heating energy demand of district	GJ/month	Energy consumption data	Y
422004	Reduced carbon emissions	Net greenhouse gas emissions by steam/heating system	kg/month	Energy consumption data	Y
422006	Reduced carbon emissions	Share of other renewable energy on the heating part (solar, wind, geothermal/SENERGY）	%	Energy consumption data	N/A

Table 4.2.6: Impact assessment indicators description for Module 422

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP02 steps taken
42200A	Energy consumption data	Energy consumption data for each building in Strijp-S	422001 422002 422004 422006	Park Strijp Energy	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	Data has not be shared in CDH due to privacy issues surrounding personal data.	

Table 4.2.7: Datasets description for Module 422

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change	Derived rate of absolute change (p.a.)	Relati chang
422001	Reliability of off-gas systems by biomass (energy generated on site)	%	0	2014Jan - 2014Dec	100	2017Jan – 2017Oct	100	2018Jan – 2018Dec	100	2019Jan – 2018Dec	100,00	20,00	--
422002	Total primary heating energy demand of district per month	GJ/month	5623,58	2014Jan - 2014Dec	2788,83	2017Jan – 2017Oct	4288,97	2018Jan – 2018Dec	3796,05	2019Jan – 2018Dec	-1827,53	-365,51	-32,50
422004	Net greenhouse gas emissions by steam/heating system per month	kg/month	476442,576	2014Jan - 2014Dec	236276,064	2017Jan – 2017Oct	363371,4	2018Jan – 2018Dec	321610	2019Jan – 2018Dec	-154832,53	-30966,51	-32,50
422006	Share of other renewable energy on the heating part in the district (SENERGY)	%	4,44%	2014Jan - 2014Dec	4,49%	2017Jan – 2017Oct	15,43%	2018Jan – 2018Dec	13,80%	2019Jan – 2018Dec	0,09	0,02	210,8 %

Table 4.2.8: Impact assessment for Module 422

4.2.3 Module 423: Smart energy for offices (Subtask 4.2.3)

The implementation dates of the module

The roll out of the smart energy management system was ready in M16 and was originally planned to finish in M21. However due to third party was resigned from the project due to technical reasons, the implementation of this module was on hold till M30. The implementation was postponed to 2018.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

The indicators for this module were redeveloped after the Amendment (AMD-646578-52) M34. Implementation was postponed to 2018.

M48 update

Sensors have been installed on the half of 6th floor. Each sensor includes 5 measurements which are: presence, CO_2, temperature, lights, and humidity.

The 7th floor is the reference/control group for energy consumption measurement. In total 29 sensors will be installed in the office building.

But also sensors (measure flow and temperature) within the ventilation ducts/shafts will be installed.

The sensors will be able to collect data based on individual offices, but it is not possible to adjust temperature and ventilation in individual room. The temperature and ventilation/flow will be adjusted on (half of the) floor level. The implementation and setup have done in September and October 2018. Sensor data was available since Nov. 2018.

They have monitored the amount of airflow which will be pumped/blown through the section on 6th and 7th floor separately. They also measured the temperature of the air which is blown in these sections. By knowing quantity and temperature we can calculate the used energy. This will be used to make the comparison.

There will be a tablet/interactive screen on the 6th floor. It will be used for users to give feedback to VW regarding the adjustment of the office environment. It is also possible to give feedback by emails.

M60 update

For indicator 423002, based on the information we received, it should be 24. (source: groups-sensors.xsxl);

Relative Power Calculation

- Air power: Φ = qv x Ƿw x cw x Δt

Φ = Power in kW

Qv =Air Volume Flow in m³/s

ρl = Air Density in kg/m³ (lucht 1,18….1,2)

Cl = Specific Heat in kJ/(kg.K) (lucht 1,006)
Δt = Temperature Difference in kelvin

1. Average Air Temperature is 21.58-degree Celsius/ 294.73 K omitting outliers (cell C2 to C9).

Source: https://www.worldweatheronline.com/eindhoven-weather/north-brabant/nl.aspx

2. Eindhoven, Netherlands visibility is going to be around 8 km i.e. 5 miles and an atmospheric pressure of 995 mb=0.981989 atmosphere

Source: https://www.worldweatheronline.com/eindhoven-weather/north-brabant/nl.aspx

3. Average annual monthly humidity in Eindhoven is 81%

Source: https://weather-and-climate.com/average-monthly-Humidity-perc,Eindhoven,Netherlands.
However, Room humidity is 41. 95%
Source - Room Humidty.xlsx

4. **ρl Air Density** = 1.16675 kg/m3 for relative humidity 81%
= 1.7125 kg/m3 for relative humidity 41.95%

Since this is basically a smart office, so we use the air density for relative humidity calculated for rooms, i.e. 41.95%
Source: https://www.omnicalculator.com/physics/air-density

For the average Air volume flow, we calculated the average air volume flow based on the average of Inlet and Outlet flow. Therefore the average air volume flow for the 6th floor is 8754.81m³/s while for the 7th floor 8828.81m³/s as shown in the table below.

Foor	SensorID	RoomTenant	Average Air volume flow m³/s	Average Air volume flow m³/s
6th	00-59-AC-00-00-15-0B-CA	Inlet	8.65554	8.75481
	00-59-AC-00-00-15-0B-D0	Outlet	8.85408	
7th	00-59-AC-00-00-15-0B-D1	Inlet	9.88974	8.82881
	00-59-AC-00-00-15-0B-D0	Outlet	7. 76788	

The air volume is assessed by the sensor.

For 6th floor temperature difference was calculated as 1.79-degree Celsius

6th floor Air power: Φ = qv x Ƥw x cw x Δt = 8.75m³/s *1.17125kg/m3 * 1.006 Kj/kg.K*1.79K
= 18.45 kW

For 7th floor temperature difference was calculated as 1.39-degree Celsius.

7th floor Air power: Φ = qv x Ƥw x cw x Δt =8.83m³/s* 1.17125kg/m3 * 1.006 Kj/kg.K*1.39K
= 14.46 kW (different baseline of temp difference as compared to 6th floor)

For sake of comparison we took 7th floor temperature difference and 6th floor temperature difference as 1.79 degree Celsius

7th floor Air power: $\Phi = qv \times Ƥw \times cw \times \Delta t =$ 8.83m³/s* 1.17125kg/m3 * 1.006 Kj/kg.K*1.79K = 18.62 kW

Energy Reduction % = (7th floor air power-6th floor Air power/7th floor air power)*100**= 0.95**

Impact indicator identifier	Impacts	Impact Indicators	Quant. Unit	Datasets to be used in impact calculation	Formula for impact calculation	Aligned with SCIS
423001	Developing a digital infrastructure	Nr. of sensors have been installed on floor 6	Dimensionless integer	Sensor	Counting	N
423002	Developing a digital infrastructure	Nr. of rooms have been involved in the living lab	Dimensionless integer	Sensor	Counting	N
423003	Reduce non-renewable energy consumption	Relative heating energy reduction percentage on average	%	Sensor	Average{(Energy consumption of floor 7 - Energy consumption of floor 6)/Energy consumption on floor 7}	N

Table 4.2.9: Impact assessment indicators description for Module 423

Dataset identifier	Dataset name	Dataset description	Related impact indicators	Dataset owner	Dataset contact	Comments	WP02 steps taken
42300A	Smart office sensor data	Dashboards of installed sensors in the Videolab	423001 424002 424003	Park Strijp Energy	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)		

Table 4.2.10: Datasets description for Module 423

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
423001	Nr. of sensors have been installed on floor 6	Dimensionless integer	0	2014Jan - 2014Dec	0	Till 2017 Dec	29	2018Jan-2018 Dec	29	2019Jan-2019 Dec	29,00	7,25	na	na
423002	Nr. of rooms have been involved in the living lab	Dimensionless integer	0	2014Jan - 2014Dec	0	Till 2017 Dec	24	2018Jan-2018 Dec	24	2019Jan-2019 Dec	26,00	6,50	na	na
423003	Relative heating energy reduction percentage on average	%	Not available	2014Jan - 2014Dec	Not available	Till 2017 Dec	Not available	2018Jan-2018 Dec	0.95	2019Jan-2019 Dec	Not available	Not available	Not available	Not available

Table 4.2.11: Impact assessment for Module 423

4.2.4 Module 424: Renovation of family homes & creation of participative society (Subtask 4.2.4)

The implementation dates of the module

The module began implementation in Eindhoven Eckart-Vaartbroek area in June/July 2017, and has been completed in 2019.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

424003 – To make the measurement more accurate, we changed the measuring unit from KWH/yr to KWH/yr/m2.

424004 – To make the measurement more accurate, we changed the measuring unit from m3/yr to m3/yr/m2.

424005 – Reduce (non-renewable) energy consumption and CO_2 reduction through material re-use (Nature step). This indicator is not applicable since no reuse of material related to CO_2 reduction. It has been removed.

424006 – To make the measurement more accurate, we changed the measuring unit from kg/yr tokg/yr/m2).

For impact indicator 424012 and 424013, the data collection is conducted from 2016 Jan until 2016 Apr. In total 250 dwellings have been approached and 199 dwellings were participated in the face to face interview. Each interview takes around 1.5 hours. The purpose of this interview is to understand how they are living in their current dwellings and how this can be improved. The satisfaction data for residence house is shown in Appendix-1. The satisfaction data for the neighbourhood is also shown in Appendix-1.

For 424012 (satisfaction of neighbourhood overall score), 12 perspectives are considered which are traffic, air quality, infrastructure, landscaping, atmosphere, buildings around, safety, neighbour, clearness, noise, layout and location. There are two variables which are traffic and noise do not apply for satisfaction score. We cannot interpret people's preference with the description provided in the survey. Therefore, to calculate the overall score, only 10 neighbourhood variables are used. The calculation method applied as below. Assume the score v_i (which is equal to 1 to 5) represent very bad situation to very good situation. a_{ij} is the percentage of neighbourhood variable j on score i . The total score equal to:

$$\left(\sum_{j=1}^{10} \sum_{i=1}^{5} v_i a_{ij}\right) \Big/ 10$$

Indicator 424013 is calculated based on the overall comfort value. It is equal to the average score. (1*3.02%+2*22.11%+3*43.72%+4*21.61%+5*0.5%) / (3.02%+22.11%+43.72%+21.61%+0.5%) = 2.94

The end value for 424012 and 424013 is not applicable at this moment, since only two houses have been renovated.

M60 update

The monitoring data was originally planned to collect via an Energy company named Enexis in Eindhoven. We managed to arrange the client agreement with residents if they are willing to share their energy data after renovation through Energy Company. Enexis agreed to cooperate as well. Before the amendment, we got 77 agreements out of 250 houses that are willing to share their energy data with us. There were two import events happened during the Triangulum project period. First, Woonbedrijf submitted an amendment to reduce the number of renovation houses within Triangulum. 26 households out of 74 still hold the agreements. For the 74 households, they also can choose freely when they would like to renovate their house. Therefore, we cannot guarantee that there is sufficient amount of time for monitoring. Moreover, GDPR was in place later. Enexis no longer can share any household energy data with us (WP2).

We looked for alternatives to collect household energy consumption data but there were some obstacles. First we tried to use 6 digital postal code energy data as monitoring data as shown in M48 report. However, the data is estimated energy consumption data. It is not the best data we can use for monitoring. Second, we try to collect the energy consumption data household by household for the agreed households. We were only able to get 6 out of 74. The M60 data is based on the estimated data from Woonbedrijf.

For Table 4.7: Impact assessment for Module 424 – based on real energy consumption data (6 postcode area – M48/collected data – M60), we made a joint decision with partner that the final assessment is based on the energy consumption data we collected from households door by door.

For indicator 424004, we changed the unit from m3/ m2(gas) to m3/ m2*yr (gas) in order to make it more clear and consistent with other indicators.

For indicator 424006, we changed the indicator name from Greenhouse gas emissions to Greenhouse gas emissions (CO_2) to make it clearer.

For table 4.15, the data of baseline, M36 and M48 are estimated based on open data of Enexis. The estimation is based on 359 houses. Apparently the number is much lower than the estimated energy consumption. The accuracy is relatively low. Therefore, we deleted the M36 and M48 values and replaced the baseline value to the estimated baseline value for the final comparison.

Based on these 6 houses' energy consumption data after renovation, we extrapolated the energy consumption for 74 houses. The detailed calculation is shown below.
First, we match the 74 houses type with the six sample houses. Out of the 74 renovated houses, 50 had solar panels installed, while the rest received only basic renovation; in our sample of 6 houses, 3 received a basic renovation, and the other three also received solar panels.
So, half of our sample will be used to extrapolate for the 24 basic renovations, and the other three will be used to determine data for the 50 dwellings with solar panels.

For indicator 424003: Use of local energy source - electricity (KWH/yr* m2)

With PV: 1501/150 = 10

Without PV: 1998.2/ 150 =13,3
The average is (10*50+13,3*24)/74 = 11.07

For indicator 424004: Use of local energy source - gas (m3/m2)

With PV: 1154m3/150m2 = 7,69 m3 / m2 per year
Without PV: 1163m3/150m2 = 7,75 m3 / m2 per year
The average is (7,69*50+7,75*24)/74 = 7,71

For indicator 424006: CO2 emission (Kg/yr* m2)
With PV: [(1501kwh * 617gCO2) + (12909kwh * 305gCO2)] / 1000 / 150 = 32,42kgCO2/sqm/yr
Without PV: [(1998kwh * 617gCO2) + (13010kwh * 305gCO2)] / 1000 / 150 =
34,67 kgCO2/sqm/yr

The average is: (32,42*50+34,67*24)/74 = 33,15

For indicator 424002: Reduction in energy bills (almost equal to the reduction of energy consumption)
The price for gas is €0,6334 per m3, and the price for electricity is € 0,1948 per kWh

Before renovation: (1844,266 * 0,1948) + (1561,37 * 0,6334) = 359,2+988,98 = 1348.18
After renovation: (1749,762 * 0,1948) + (1158,82 * 0,6334) = 340,85 + 734 = 1074.85
Percentage of reduction = (1348.18 -1074.85)/1348.18 = 20.27%

Impact indicator identifier	Impacts	Impact Indicator	Quant. Unit	Datasets to be used in impact calculation	Aligned with SCIS
424001	Reduce (non-renewable) energy consumption	Amount of buildings retrofitted / smartified	m2	Renovation choice set	N
424002	Reduce (non-renewable) energy consumption	Reduction in monthly energy bills	%	Renovation choice set	Y
424003	Reduce (non-renewable) energy consumption	Use of local energy sources (electricity)	KWH/yr/m2	Historical energy consumption data; Energy consumption data after renovation	Y
424004	Reduce (non-renewable) energy consumption	Use of local energy sources (gas)	m3/yr/m2	Historical energy consumption data; Energy consumption data after renovation	Y
424006	Reduced carbon emissions	Greenhouse gas emissions	Kg/yr/ m2	Historical energy consumption data; Energy consumption data after renovation	Y
424007	Reduced carbon emissions	Share of renewable energy on the grid (solar, wind, geothermal)	%	Installed renewable energy	Y
424008	Reduced carbon emissions	Smart meters installed and used	Dimensionless integer	Energy consumption data after renovation	N
424009	Fostering citizen engagement (co-creation)	Increase awareness of energy consumption by acceptance of renovation per year	Dimensionless integer	Renovation choice set	N
424010	Better quality of life	Affordable housing - increase in rent over cost of inflation	%	Renovation choice set	N
424011	Better quality of life	Payback periods for specific demonstration activities on average	Years	Renovation choice set	Y
424012	Better quality of life	Satisfaction of neighborhood – average score (1 lowest -5 highest)	Dimensionless integer	Dwelling conditions and satisfaction	N
424013	Better quality of life	Recorded satisfaction of residence houses - Average score (1 lowest -5 highest)	Dimensionless integer	Dwelling conditions and satisfaction	N

Table 4.2.12: Impact assessment indicators description for Module 424

Dataset identifier	Dataset name	Dataset description	Related impact indicators	Dataset owner	Dataset contact	Comments
42400A	Historical energy consumption data	Historical energy consumption data for household level (year based)	424003 424004 424006	TU/e, Woonbedrijf	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	Due to privacy issue, no household level data will be available. Only estimated energy consumption data can be used
42400B	Energy consumption data after renovation	Energy consumption data after the renovation of dwellings in Eckart/Vaartbroek	424003 424004 424006 424008	Residents	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	77 residents are willing to share their data with TU/e. Approach residents houses by houses together with Woonbedrijf after renovation
42400C	Dwelling conditions and satisfaction	Questionnaire data of current living condition and environment satisfaction	424012 424013	TU/e, Woonbedrijf	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	Between M48 and M60, a new round data collection was implemented.
42400D	Renovation choice set	Woonconnect data (including renovation choice option, energy reduction expectation, payback year etc..)	424001 424002 424009 424010 424011	Residents, Woonbedrijf	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	
42400E	Installed renewable energy	Renewable energy share for the whole Eckart/Vaartbroek district	424007	Woonbedrijf	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	

Table 4.2.13: Datasets description for Module 424

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
424001	Amount of buildings retrofitted / smartified	m2	0	2014Jan - 2014Dec	217	Till 2017 Oct	4,404	2018Jan-2018 Dec	11,198	Till 2019 Dec	11,198	2,240	na	na
424002	Reduction in energy bills on average	%	0	2014Jan - 2014Dec	48,9	Till 2017 Oct	61	2018Jan-2018 Dec	55	Till 2019 Dec	55	11	na	na
424003	Use of local energy sources	KWH/yr* m2 (electricity)	8.75	2014Jan - 2014Dec	5.4	Till 2017 Oct	3	2018Jan-2018 Dec	17.8	Till 2019 Dec	9.05	1.81	103,43 %	25,86%
424004	Use of local energy sources	m3/ m2*yr (gas)	16,00	2014Jan - 2014Dec	9,4	Till 2017 Oct	6	2018Jan-2018 Dec	63,02	Till 2019 Dec	47,02	9,40	293,88 %	58,78%
424006	Greenhouse gas emissions (CO_2)	Kg/yr* m2.	33,43	2014Jan - 2014Dec	19,8	Till 2017 Oct	13	2018Jan-2018 Dec	11,76	Till 2019 Dec	-21,67	-4,33	-64,82%	-12,96%
424007	Share of renewable energy on the grid (solar, wind, geothermal)	%	0	2014Jan - 2014Dec	58,52	Till 2017 Oct	68,00	2018Jan-2018 Dec	15,30	Till 2019 Dec	15,30	3,06	na	na
424009	Increase awareness of energy consumption by acceptance of renovation per year	Dimensionless integer	0	2014Jan - 2014Dec	2	Till 2017 Oct	42	2018Jan-2018 Dec	74	Till 2019 Dec	74,00	14,80	na	na

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
424010	Affordable housing - increase in rent over cost of inflation	%	0	2014Jan - 2014Dec	2	Till 2017 Oct	2,29	2018Jan-2018 Dec	2,29	Till 2019	2,29	0,46	na	na
424011	Payback periods for specific demonstration activities on average	Years	not applicable	2014Jan - 2014Dec	44.07	Till 2017 Oct	43,40	2018Jan-2018 Dec	43	Till 2019	na	na	na	na

Table 4.2.14: Impact assessment for Module 424 – based on estimated energy consumption data

Impact indicator identifie r	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M60 value	M60 value period	Absolut e change (Baselin e to M60)	Derived rate of absolut e change (p.a.)	Relativ e change	Derived rate of relative change (p.a.)
424002	Reduction in energy bills	%	0,0	2014Jan - 2014Dec	20,27	2018Jan - 2018 Dec	20,27	4,05	--	--
424003	Use of local energy sources	KWH/yr* m2. (electricity)	8,75	2014Jan - 2014Dec	11,1	2018Jan - 2018 Dec	2,32	0,46	26,51%	5,30%
424004	Use of local energy sources	m3/m2 (gas)	16,00	2014Jan - 2014Dec	7,71	2018Jan - 2018 Dec	-8,29	-1,66	- 51,81%	- 10,36%
424006	Greenhouse gas emissions	Kg/yr* m2.	33,43	2014Jan - 2014Dec	33.15	2018Jan - 2018 Dec	-0,28	-0,06	-0,84%	-0,17%
424012	Satisfaction of neighborhood – average score (1 lowest -5 highest)	Dim. Int.	3.32	2014Jan - 2014Dec	na	2018Jan- 2018 Dec	na	na	na	na
424013	Recorded satisfaction of residence houses - Average score (1 lowest -5 highest)	Dim. Int.	2.94	2014Jan - 2014Dec	na	2018Jan- 2018 Dec	na	na	na	na

Table 4.2.15: Impact assessment for Module 424 – based on real energy consumption data (6 postcode area – M48/collected data – M60)

Note: The calculation used 1m3 natural gas = 1,95kg CO_2; 1kwh = 0,435kg CO_2. The matching between postcode area and project area of Woonbedrijf is based on the table below.

5632 DE	Zuiderkruispad 1 - 25	100% in project
5632 DH	Planetenlaan 25 - 63	100% in project
5632 DJ	Kompasweg 1-21 Kompasweg 2-22	100% in project
5632 DK	Meteoorstraat 1 – 49	100% in project
5632 EB	Mercuriuslaan 40 – 78	Total: 40 houses In project : mercuriuslaan 64 – 78 → 8 houses https://www.postcode.nl/5632EB/40-78
5632 EC	Mercuriuslaan 80 - 132	100% in project
5632 EH	Mercuriuslaan 69 – 101	100% in project
5632 GA	Titanpad 2 -18	100% in project
5632 GD	Oberonstraat 1-23 Oberonstraat 2-32	Total 28 houses In project: Oberonstraat 2-32 → 16 houses https://www.postcode.nl/zoek/5632GD
5632 GE	Rigelstraat 1-17 Rigelstraat 2-24	Total 31 houses In project: Rigelstraat 1-17 → 9 houses https://www.postcode.nl/zoek/5632GE
5632 GH	Wegastraat 2-34	100% in project
5632 GK	Wegastraat 1-47	100% in project
5632 GL	Wegastraat 49-79	100% in project
5632 GM	Mirandastraat 1-23 Mirandastraat 2-28	Total 26 houses In project: Mirandastraat 2-26 → 13 houses Nr 28 is old storage room in use by project as storage. https://www.postcode.nl/zoek/5632GM
5632 GN	Saturnusweg 1-59	Total 30 houses In project: Saturnusweg 1-35 → 18 houses https://www.postcode.nl/5632GN/1-59

Table 4.2.16: The detailed information on the area codes of Woonbedrijf project

4.3 Mobility Modules

The Eindhoven mobility task group has developed two modules.

1. *Smart charging of electric vehicles (module 4.3.1):* an intelligent smart charging information service system developed through the implementation of smart charging facilities. The objective is to improve the EV charging facilities' efficiency and EV parking management.
2. *Mobility management (module 4.3.2)*: To improving mobility sustainability in Strijp-S. The project has developed an ICT based tool for real-time parking guidance system and a payment incentive for green alternatives and to stimulate car sharing.

Detailed information for each module is described in the sub-sections below. Table 4.3.1 presents a summary of the expected impacts of these two modules, and below detailed module descriptions are provided.

Modules	**Mechanism for creating impacts**	**Expected impacts**		
		Improvement of mobility	Developing a digital infrastructure	Improvement of EV charging efficiency
Smart Charging of electric vehicles (Module 4.3.1)	Replacing conventional electrical vehicle charging facilities with smart charging and parking management facilities and increasing the number of EV charging pools	*	*	*
Mobility Management (Module 4.3.2)	To improve the mobility sustainability in Stijp-S by developing smart parking guidance system and green alternative incentive system	*	*	

Table 4.3.1: Expected impacts of the Eindhoven Mobility Modules

4.3.1 Module 431: Smart charging of electric vehicles (Subtask 4.3.1)

The implementation dates of the module

The implementation of the new charging poles (20 connections) started in M18. In M23 the first 4 charging poles were installed and operational. The completed system which offers a dashboard for users and Mobility-S was implemented in 2018.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

Except for charging station 1, no data was able to be collected before start of the project. Therefore, the indicators of 431005(Transaction energy – Pool 2), 431006 (Transaction energy – Pool 3), 431007 (Transaction energy – Pool 4), 431008 (Monitoring transaction Nr of Pool1_connection1), 431009 (Monitoring transaction Nr of Pool1_connection2), 431010 (Monitoring transaction Nr of Pool2_connection1), 431011 (Monitoring transaction Nr of Pool2_connection2), 431012 (Monitoring transaction Nr of Pool3_connection1), 431013 (Monitoring transaction Nr of Pool3_connection2), 431014 (Monitoring transaction Nr of Pool4_connection1), 431015 (Monitoring transaction Nr of Pool4_connection2), 431016(Monitoring use of EV/FC charging by number of customers – Pool1), 431017(Monitoring use of EV/FC charging by number of customers – Pool2), 431018(Monitoring use of EV/FC charging by number of customers – Pool3), 431019(Monitoring use of EV/FC charging by number of customers – Pool4), 431020 (Improvement of parking efficiency by increasing number of EV parking reservation)have been removed. For newly installed charging stations, the charging data is available. In order to compare the charging efficiency, two new impact indicators are generated which are 431021 (Average transaction energy per pool) and 431022(Average monitoring transaction nr per pool).

M48 Update:

All facilities are implemented which include 8 slow charging poles (with 2 sockets each) and 1 fast-charging pole. For charging reservation system, due to the privacy issue, there might be alternative solution that has not been decided yet.

M60 Update:

The baseline situation should be the number of charging stations before the intervention. There were 8 charging pools in Strijp-s, but these stations are not owned/installed/managed by VW nor the municipality. Therefore, after the discussion with the project manager, the baseline situation reset as 0. It is consistent with the SCIS report.

To make the indicators more clearly, we changed 'Station' to 'Points'. Every station has two charging points. M36 value of 14 is number of charging points with 7 charging station.

For indicators 431002 and 421003, they are no longer meaningful. There is an application called Ecodap, by which users can find the location of charging points. However, this application has no reservation function now. For the type of charging, there is only DC charging modes. VW converts AC from buildings to DC for charging.

To make the data consistent with SCIS, we changed the value period of M36 and M48. Change we changed 2016NOV to 2016Dec, since we only have the data from 2016Dec. The total transaction energy 2017 Dec-2018 Nov: 33092.38kWh. Average transaction energy per pool 2017 Dec-2018 Oct: 33092.38kWh / 14=2363.74kWh. The total transaction energy 2018 Dec-2019 Nov was 56087.637kWh. Average transaction energy per pool 2018 Dec-2019 Nov: 56087.637/14=4006.26 kWh (source: D_171110 Marap cijfers(figures) rev november)

We changed the unit of indicator 431021 from “MWh/yr” to “kWh/yr”.

We changed the total transaction number 2016 Dec-2017Nov: 2598. Average transaction number per pool 2016 Dec-2017Nov: 2598/14= 186. The total transaction number 2017 Dec--2018 Nov: 3477. Average transaction number per pool 2017 Dec--2018 Nov: 3477/14= 248. The total transaction number 2018 Dec-2019 Nov: 3885. Average transaction energy per pool 2018 Dec-2019 Nov: 3885/14= 278 (source: D_171110 Marap cijfers(figures) rev november)

Impact indicator identifier	Impacts	Impact Indicator	Quant. Units	Datasets to be used in impact calculation	Aligned with SCIS
431001	Developing a digital infrastructure – for EV charging pools	Nr. of EV/FC charging stations	Dimensionless integer	Charging transaction data	Y
431002	Developing a digital infrastructure – for EV charging pools	Reservation system - Possibility of making reservation of charging	Yes/No	Charging transaction data	N
431003	Developing a digital infrastructure – for EV charging pools	Switch charging modes (AC/DC) - Possibility of choosing charging speed	Yes/No	Charging transaction data	N
431021	Improvement of EV charging efficiency	Average transaction energy per pool	MWh/yr	Charging transaction data	N
431022	Improvement of EV charging efficiency	Average monitoring transaction nr per pool	Nr/yr	Charging transaction data	N

Table 4.3.2: Impact assessment indicators description for Module 431

Dataset name	Dataset description	Required for impact calc. for indicators	Dataset owner	Dataset contact	Comments	WP2 steps taken
Charging transaction data*	Charging transaction data from charging stations at Strijp-S collected through fibre-optic backbone and data platform	431001 431002 431003 431021 431022	Charing company/ VW	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	Data for new charging poles are available by request	EV parking reservation data collected after implementation of the technology

Table 4.3.3: Datasets description for Module 431

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
431001	Nr. of EV/FC charging points	Nr.	0	2014Jan - 2014Dec	14	2016Nov-2017Nov	14	2017Dec - 2018Nov	14	2018Dec - 2019Nov	14,00	2,80	Na	Na
431002	Reservation system - Possibility of making reservation of charging	Yes/No	No	2014Jan - 2014Dec	No	2017Dec	No	2018Dec	No	2018Dec - 2019Nov				
431003	Switch charging modes (AC/DC) - Possibility of choosing charging speed	Yes/No	No	2014Jan - 2014Dec	No	2017Dec	No	2018Dec	No	2018Dec - 2019Nov				
431021	Average transaction energy per points	kWh/yr	0,00	2014Jan - 2014Dec	1277,32	2016Dec-2017Nov	2363,74	2017Dec - 2018Nov	4006,26	2018Dec - 2019Nov	4006,26	801,25	Na	Na
431022	Average monitoring transaction nr per points	Nr/yr	0,00	2014Jan - 2014Dec	186,00	2016Dec-2017Nov	248,00	2017Dec - 2018Nov	278	2018Dec - 2019Nov	278,00	55,60	Na	Na

Table 4.3.4: Impact assessment for Module 431

4.3.2 Module 432: Mobility management (Subtask 4.3.2)

The implementation dates of the module

The implementation started in M20 and was completed in M36.

The indicators to be used for assessing the impacts and benefits and baseline conditions

The mobility management project aims to improve mobility management in Strijp-S. Table 4.3.5, below, provides details of the indicators developed for this module and part of the baseline data. Table 4.3.6 identifies potential datasets that may be used to calculate quantifiable impacts for the indicators.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

432002 - The baseline value (percentage) is calculated by taking the average of 5 samples within a week, over a period of a year. The end value is based on Dec 2017 11^{th} – 17^{th}, the average occupancy is calculated which is 26.547 %, with a standard deviation of 21.34 %. Once the parking lots had not registered, the data has been dropped all the time. In total 66 out of 2058 unique timestamps have been dropped. The figure is shown below.

432003 – Before there were four (bus, train, bike, on foot) green mobility alternatives. After implementing bike sharing in Strijp-S, there are five now. To be more specific, there are 4 wooden e-bikes, 4 solar bikes and. Two alternatives bike share stations (Hopperpoints) which has 8 “locks” each and 6 bikes each were installed (we also have usage data of the usage of these stations) in 2018.

M60 update

For indictor 432002, the indicator is calculated based on the average weekday parking percentage provided by VW.

Impact indicator identifier	Impacts	Impact Indicators	Quant. Unit	Datasets to be used in impact calculation	Aligned with SCIS (Y/N)	Auto. calc.
432001	Improving mobility	Improvement of mobility parking efficiency by reducing parking lots	Dimensionless integer	Parking information	N	N
432002	Improving mobility	Improvement of mobility parking efficiency by increasing average parking occupancy percentage	%	Parking information	N	Y
432003	Improving mobility	Improving mobility management by increasing green mobility alternatives	Dimensionless integer	Parking information	N	N
432004	Improving mobility	Improving mobility management by providing car-pooling program	Yes/no	Parking information	N	N
432005	Developing a digital infrastructure	Availability of Reservation system	yes/no	Parking information	N	N
432006		Availability of Real-time information of parking space	yes/no	Parking information	N	N

Table 4.3.5: Impact assessment indicators description for Module 432

Dataset name	Dataset description	Required for impact calc. for indicators	Dataset owner	Dataset contact	Comments	WP2 steps taken
Parking information	Parking information about parking facilities Strijp-S	432001 432002 432003 432004 432005 432006	VW	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	The parking data is in CDH	

Table 4.3.6: Datasets potentially to be used in the calculation of impacts for Module 432

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
432001	Improvement of mobility parking efficiency by reducing parking lots	Dimensionless integer	1763	2014 Dec	1532	2017 Dec	1532	2018 Dec	1532	2019 Dec	-231,00	-46,20	-13,10%	-2,62%
432002	Average parking occupancy percentage per week	%	40	2015 Dec	26.54 (std. 21.34)	2017 Dec	28,61	2018 Dec	51,49	2019 Jan – 2019 Dec	11,49	2,30	28,73%	5,75%
432003	Improving mobility management by increasing green mobility alternatives	Dimensionless integer	4	2014 Dec	5	2017 Dec	5	2018 Dec	5	2019 Dec	1,00	0,20	25,00%	5,00%
432004	Improving mobility management by providing car-pooling program	Yes/no	No	2014 Dec	Yes	2017 Dec	Yes	2018 Dec	yes	2019 Dec	1,00	na	na	na
432005	Availability of Reservation system	yes/no	No	2014 Dec	Yes	2017 Dec	Yes	2018 Dec	Yes	2019 Dec	0.00	na	na	na
432006	Availability of Real-time information of parking space	yes/no	No	2014 Dec	Yes	2017 Dec	Yes	2018 Dec	Yes	2019 Dec	0.00	# na	na	na

Table 4.3.7: Impact assessment for Module 432

4.4 ICT Modules

Eindhoven has developed six modules to demonstrate development of ICT infrastructures in Eindhoven city level and district/area levels.

On Eindhoven city level, there are two modules:

- *Eindhoven smart city ICT open data platform (module 4.4.1):* Eindhoven municipality is continuing to develop an open data platform (based on Socrata platform) for hosting data generated by the Triangulum projects, and other related datasets. The aim of developing open data platform is to offer a platform where not only governmental organizations, but any party willing to offer its data according to agreed standards, can exchange data.
- *Smart city innovation fund (module 4.4.5):* TU/E - Innovation Lab (IL) together with VW / EIN, and supported by "BrightMove", will stimulate fund for SME's in Eindhoven and stimulate entrepreneurs to develop services. It focuses on stimulating pro-active consortia, on achieving impact from societal research and on developing activities in the field of entrepreneurship for students, research support and business development.

In Eckart-Vaartbroek district, there are two modules:

- *Interactive energy retrofit for dwellings (module 4.4.2):* the module is to develop a 3D-ICT tool to facilitate an interactive refurbishment process by allowing the tenants to manage their energy consumption.
- *Smart streetlights for a social interaction and health route (module 4.4.6):* To develop a 1-km social interaction and health pedestrian route around the pond through a park in the middle of Eckart-Vaartbroek neighbourhood. For this project, Eindhoven municipality are cooperated with KPN and Woonbedrijf. In order to create an ultimate integrated safety and quality public space, the route will be equipped with LED lighting and other additional functions such as WIFI and sensor to enable the use of smart connections with surrounding facilities and visitors,

In Strijp-S area, there are two modules:

- *Smart environment fibre-optic data infrastructure (module 4.4.3):* VW iCity and partners aim to develop the second phase of Backbone in Strijp-S to provide strong fibre-optic data infrastructure to enable a smart environment. The Backbone provides high-quality urban environment with possible service to all users in the area.
- *Public space sensor network (module 4.4.4):* In this task, a bottom up dialogue approach was conducted to understand inhabitants' needs. To improve the living environment, a smart sensor network was developed. The sensor network allows for the meaningful development of additional and innovative services. The aim of the project is to improve the citizen's quality of life.

Table 4.4.1 presents a summary of the expected impacts of each module, and below detailed module descriptions are provided.

Module	Mechanism for creating impacts	Expected Impacts					
		Fostering citizen engagement (Co-creation)	Developing a digital infrastructure	Promoting commercial activity	Wide scale deployment/ dissemination of project results	Improving the quality of life	Reducing carbon emissions
EHV facilitation smart city open data platform (Module 441)	Providing access to data which can be used by citizens, businesses and government to create economic, social and environmental value.	*	*				
Interactive process for dwellings in Eckart-Vaartbroek (Module 442)	The module 4.4.2 will provide the 3D ICT tool.	*			*	*	*
Second phase of implementation and integration of the fiber-optic data infrastructure (Module 443)	The module will develop the second phase of Backbone in Strijp-S		*				
Sensor network in the public space (Module 444)	The module will develop a smart sensor network to improve citizen's quality of life		*			*	
Stimulating development of innovative services/app's (Module 445)	It will stimulate fund for SME's in Eindhoven and stimulate entrepreneurs to develop services			*	*		
Smart streetlights social interaction & health route (Module 446)	The module will develop a 1-km social interaction and health pedestrian route around the pond through a park in the middle of Eckart-Vaartbroek neighbourhood					*	

Table 4.4.1: Expected impacts of the Eindhoven ICT Modules

4.4.1 Module 441: Eindhoven smart city ICT open data platform (subtask 4.4.1)

The implementation dates of the module

The module was implemented on M25.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

441001 - the indicator has been changed from "Smart apps developed using open data platform" to "Number of API calls of the top five data sets per month" The original impact indicator can no longer be measured, as the city has no way of telling who uses the data provided on the open data portal for what purpose. We can however see how many times the API's that provide data are called upon.

441003 - After discussion with Eindhoven municipality, this indicator has been changed from "Active view times does not make sense" to "number of times actively downloaded" which we agree providing more meaningful value for this indicator.

441005 - The reason for reduction for this indicator "Nr of data base of data" is data consolidation in larger datasets, and a clean-up of low-quality datasets has been implemented.

M60 update

The implementation date has confirmed with project manager that the Triangulum part has been implemented on M25.

For indicator 441002, the number is dramatically increased. The project manager Niels confirmed that in general the use increased. It is suspected that there are more automated views (so called 'bots') that generate a high number.

Impact indicator identifier	Impacts	Impact Indicators	Quant Unit	Datasets to be used in impact calculation	Aligned with SCIS
441001	Promoting commercial activities	Smart apps developed using open data platform.	Nr	Open data	Y
441002	Promoting commercial activities	Use of open data platform- Nr of viewed times (data.eindhoven.nl)	Nr	Open data	N
441003	Promoting commercial activities	Use of open data platform- Nr of active view times (data.eindhoven.nl)	Nr	Open data	N
441004	Developing a digital infrastructure	Nr of data base of portals	Nr	Open data	N
441005	Developing a digital infrastructure	Nr of data base of data files	Nr	Open data	N
441006	Developing a digital infrastructure	Platform functions(data.Eindhoven.nl)	Nr	Open data	N
441007	Developing a digital infrastructure	Data handling capability (Max)	Gb	Open data	N

Table 4.4.2: Impact assessment indicators description for Module 441

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators	Dataset owner	Dataset contact	Comments	WP02 next steps
44100A	Open data	Eindhoven open data platform data	441001 441002 441003 441004 441005 441006 441007	Eindhoven municipality	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	Data is provided by Eindhoven open data platform record	None

Table 4.4.3: Datasets potentially to be used in the calculation of impacts for Module 441

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
441001	Number of API calls of the top five data sets per month	Dimensionless decimal	508	2014 Jan – 2014 Dec	7167	2017 Jan-2017 Nov	467	2017 Dec–2018 Nov	1331	2018 Dec–2019 Nov	823,00	164,60	1,62	0,32
441002	Use of open data platform-Nr of viewed times per month (data.eindhoven.nl)	Dimensionless integer	21509	2014 Jan – 2014 Dec	26312	2017 Feb-2017 Nov	44000	2017 Dec – 2018 Nov	96000	2018 Dec–2019 Nov	74491,08	14898,22	3,46	0,69
441003	Nr of times actively downloaded per month (data.eindhoven.nl)	Dimensionless integer	8	2014 Jan–2015 June	65	2017 Feb-2017 Nov	1816	2017 Dec – 2018 Nov	3912	2018 Dec–2019 Nov	3903,70	780,74	470,33	94,07
441004	Nr of data base of portals	Dimensionless integer	4	2014 Jan – 2014 Dec	7	2017 Jan-2017 Nov	7	2017 Dec–2018 Nov	8	2018 Dec–2019 Nov	4,00	0,80	1,00	0,20
441005	Nr of data base of data files	Dimensionless integer	93	2014 Jan – 2014 Dec	63	2017 Jan-2017 Nov	123	2017 Dec – 2018 Nov	135	2018 Dec–2019 Nov	42,00	8,40	0,45	0,09

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
441006	Platform functions (data.eindhoven.nl)	Dimensionless integer	7	2014 Jan – 2014 Dec	4	2017 Jan - 2017 Nov	4	2017 Dec – 2018 Nov	4	2018 Dec – 2019 Nov	-3,00	-0,60	-0,43	-0,09
441007	Data handling capability (Max)	Gb	5	2014 Jan – 2014 Dec	5	2017 Jan - 2017 Nov	5	2017 Dec – 2018 Nov	5	2018 Dec – 2019 Nov	0,00	0,00	0,00	0,00

Table 4.4.4: Impact assessment for Module 441

4.4.2 Module 442: Interactive energy retrofit for dwellings (Subtask 4.4.2 + Subtask 4.4.3)

The implementation dates of the module

The implementation of this module started in M08 in several steps. The communication plan for Eckart Vaartbroek was finished in M15-M16. In M22, a customer journey is offered to ensure that the experience of the tenants with this new tool has started. The module has been completed by M48.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

The module aims to produce an interactive refurbishment process, allowing the tenants to manage their own renovation and energy consumption through the use of innovative ICT applications. Our focus of this module is to measure the replication progress, improvement of energy efficiency and improvements to the quality of life. However due to privacy issues and concerns of overburdening with information from the company's perspective, there is very limited access to residents. To distinguish this module from module 424, only private house owners were measured in this module. In M36, Woonconnect and TU/e agreed that 3 private houses as volunteers will share their information with us. This data has been used as the baseline. Since no renovation project has been done so far for any private houses, no information can be filled in for the end value. Detailed information refers to M36 report. However in M48, Woonconnect mentioned they don't have any knowledge about the renovation activities that are initiated by the use of WoonConnect, because WoonConnect enables the inhabitants to explore the possibilities of improving their houses and save energy, but is not a 'marketplace' where contracts are closed for the execution of the renovation. Also privacy issues (GDPR) are limiting the possibilities to monitor the results severely. If someone is insulating his roof and/or putting solar panels on it, they do not know what stimulated them to do so. Therefore indicators (442003, 442004, 442005 and 442008) cannot be monitored and be removed and replaced by three new indicators (442012, 442013, and 442014). The detailed names are mentioned in table 4.26.

To distinguish the impacts of Module 422 and Module 424, indicators of this module are focused on private house renovation. After several rounds of discussion with Woonconnect, indicators have to be modified. There are mainly two reasons for the modification: 1) privacy issue raised by private owners, Woonconnect and KPN; 2) least indicators capturing as many impacts as possible. Considering the privacy issue, the start value is based on volunteer samples which consist of three houses.

442003 - Wide scale deployment/ dissemination of project results by measuring the reduction in monthly energy bills of electricity on average has been removed. The energy price will not be changed in the near future. The energy consumption of electricity can reflect this indicator as well.

442004 - Wide scale deployment/ dissemination of project results by measuring the reduction in monthly energy bills of gas on average has been removed. The energy price will not be changed in the near future. The energy consumption of gas can reflect this indicator as well.

442005 - Wide scale deployment/ dissemination of project results by measuring payback periods for specific demonstration activities (Average payback year) has been removed due to privacy issues.

Update for M48:
As shown in Appendix 2, indicators (442003, 442004, 442005 and 442008) cannot be monitored. They don't have any knowledge about the renovation activities that are initiated by the use of WoonConnect, because WoonConnect enables the inhabitants to explore the possibilities of improving their houses and save energy, but is not a 'marketplace' where contracts are closed for the execution of the renovation. Also privacy issues (GDPR) are limiting the possibilities to monitor the results severely. If someone is insulating his roof and/or putting solar panels on it, they do not know what stimulated them to do so. Therefore all indicators are removed and replaced by three new indicators (442012, 442013, and 442014).

Update for M60:
There is no change from M48 to M60. The information has been confirmed by the partner KPN.

Impact indicator identifier	Impacts	Impact Indicators	Quant. unit	Datasets to be used in calculation	Aligned with SCIS	Comments
442001	Wide scale deployment/ dissemination of project results	Amount of buildings retrofitted / smartified from tenants	m2/yr	Woonconnect data private owners	N	Removed
442002	Wide scale deployment/ dissemination of project results	Amount of buildings retrofitted / smartified from private owners	Dimensionless integer	Woonconnect data private owners	N	Removed
442006	Reduced carbon emissions	Primary energy usage for electricity	KWH/yr/m2	Woonconnect data private owners	Y	Removed
442007	Reduced carbon emissions	Primary energy usage for gas	m3 /yr/m2	Woonconnect data private owners	Y	Removed
442008	Reduced carbon emissions	Greenhouse gas emissions	Kg/yr/m2	Woonconnect data private owners	Y	Removed
442009	Reduced carbon emissions	Share of renewable energy resource on grid	%	Woonconnect data private owners	Y	Removed
442010	Wide scale deployment/ dissemination of project results	Nr of private house owners have been approached	Dimensionless integer	Woonconnect data private owners	N	Removed
442011	Better quality of life	Overall satisfaction of their current houses (1-5)	Dimensionless integer	Woonconnect data private owners	N	Removed
4420012	Wide scale deployment/ dissemination of project results	Nr. of digital keys sent to households	Dimensionless integer	Woonconnect data private owners	N	New
4420013	Wide scale deployment/ dissemination of project results	Nr. Of activated digital keys by households	Dimensionless integer	Woonconnect data private owners	N	New
4420014	Wide scale deployment/ dissemination of project results	Nr. Of households that made a renovation scenario	Dimensionless integer	Woonconnect data private owners	Y	New

Table 4.4.5: Impact assessment indicators for Module 422

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
44200A	Woonconnect data private owners	Woonconnect data from private house owners	442012 442013 442014	KPN	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	New indicators have been generated in M48 with available data	

Table 4.4.6: Datasets description for Module 422

Impact indicator identifier	**Impact indicator**	**Quant. Unit.**	**Baseline value**	**Baseline value period**	**M36 value**	**M36 value period**	**M48 value**	**M48 value period**	**M60 value**	**M60 value period**	**Absolute change (Baseline to M60)**	**Derived rate of absolute change (p.a.)**	**Relative change**	**Derived rate of relative change (p.a.)**
442012	Nr. of digital keys sent to households	Dim. Int.	0	2014Jan - 2014Dec	993	2017Dec	993	2018Dec	993	2019Dec	993	248,25	na	na
442013	Nr. Of activated digital keys by households	Dim. Int.	0	2014Jan - 2014Dec	261	2017Dec	284	2018Dec	284	2019Dec	284	71,00	na	na
442014	Nr. Of households that made a renovation scenario	Dim. Int.	0	2014Jan - 2014Dec	na	2017Dec	174	2018Dec	174	2019Dec	174	43,50	na	na

Table 4.4.7: Impact assessment for Module 422

4.4.3 Module 443: Smart environment fibre-optic data infrastructure (Subtask 4.4.4)

The implementation dates of the module

The implementation includes two parts which are outdoor and indoor.

For outdoor implementation work, the preparation started in M22. A supplier was found in M23 and extension was ready around M26.

For indoor implementation work, the office-S network was finished in M24. The development of the Smart City Hub in the building Viedolab started in M21. It has been implemented from M28.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

None

M60 update

For outdoor implementation work, the preparation started in M22. A supplier was found in M23 and extension was ready around M26. The multimode network is now integrated into the single mode network. “Old” Mobility-S network is dismantled for 80%, the remaining 20% took place in M59. Integration of additional hardware in M59. Implementation of multiple security layers is in place (Firewall, RADIUS all redundant). Fine-tuning is an ongoing process.
Note:
443002* The previously mentioned number (270.000 is the total m2 area of Strijp-S). The updated value is the total area covered by fiber optic network;
443004* In total 14 camera systems are installed in place. There are 12 systems which are functionality differs from each other;
443005* The No of WiFi users are not included as users in the platform due to privacy issue.

Impact indicator identifier	Impacts	Impact Indicators	Quant. Unit	Datasets to be used in impact calculation	Aligned with SCIS	Auto.calc.
443001	Developing a digital infrastructure	Fibre-optic network expanded by connecting homes	Dimensionless integer	Fibre-optic network data	Y	N
443002	Developing a digital infrastructure	Fibre-optic network expanded by connecting offices	M_2	Fibre-optic network data	Y	N
443003	Developing a digital infrastructure	Fibre-optic network expanded by connecting lamp pole	%	Fibre-optic network data	N	N
443004	Fostering citizen engagement (Co-creation)	Nr of types of data available on the platform	Dimensionless integer	Fibre-optic network data	N	N
443005	Fostering citizen engagement (Co-creation)	Nr of users of soft platform	Dimensionless integer	Fibre-optic network data	Y	N

Table 4.4.8: Impact assessment indicators description for Module 443

Dataset name	Dataset description	Required for impact calc. for indicators:	Data set in CDH	Dataset owner	Dataset contact	Comments	WP2 steps taken
Fibre-optic network data	Fibre-optic network data from MPLS network	443001 443002 443003 443004 443005	N	VW	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)		

Table 4.4.9: Datasets description for Module 443

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
443001	Fibre-optic network expanded by connecting homes	Dimensionless integer	0	2014Jan - 2014Dec	200	2017Jan - 2017Dec	350	2018Jan - 2018Dec	350	2019Jan - 2019Dec	350,00	70,00	Na	Na
443002	Fibre-optic network expanded by connecting offices	M_2	0	2014Jan - 2014Dec	4750	2017Jan - 2017Dec	7050	2018Jan - 2018Dec	7050	2019Jan - 2019Dec	7050,00	1410,00	Na	Na
443003	Fibre-optic network expanded by connecting lamp pole	Dimensionless integer	154	2014Jan - 2014Dec	161	2017Jan - 2017Dec	172	2018Jan - 2018Dec	172	2019Jan - 2019Dec	18,00	3,60	0,12	0,02
443004	Nr of types of data available on the platform	Dimensionless integer	0	2014Jan - 2014Dec	9	2017Jan - 2017Dec	12	2018Jan - 2018Dec	12	2019Jan - 2019Dec	12,00	2,40	Na	Na
443005	Nr of users of soft platform	Dimensionless integer	0	2014Jan - 2014Dec	20	2017Jan - 2017Dec	30	2018Jan - 2018Dec	30	2019Jan - 2019Dec	30,00	6,00	Na	Na

Table 4.4.10: Impact assessment for Module 443

4.4.4 Module 444: Public space sensor network (Subtask 4.4.5)

The implementation dates of the module

The implementation started in M16 and was completed by M36.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

444006 – Improvement of quality of life by recorded happiness of residents and workforce. There was a workshop and group interview organized by VW. However, the workshop outcomes were not recorded in a systematic manner such as recording the interview data. This indicator has been removed.

M60 update

The module is complete.

Impact indicator identifier	Impacts	Impact Indicators	Quant. Unit	Datasets to be used in impact calculation	Formula for impact calculation	Aligned with SCIS
444001	Fostering citizen engagement (Co-creation)	Nr. of citizens involved in project-planning	Dim. Int.	Interview data	Counting	Y
444002	Developing a digital infrastructure	Improved public space by installing sound sensors	Dim. Int.	Sensor & App data	Counting	N
444003	Developing a digital infrastructure	Improved public space by installing video sensors	Dim. Int.	Sensor & App data	Counting	N
444004	Developing a digital infrastructure	Improved public space by installing water sensors	Dim. Int.	Sensor & App data	Counting	N
444005	Developing a digital infrastructure	Improved public street lighting by promoting App used by citizens	Dim. Int.	Sensor & App data	Counting	N

Table 4.4.11: Impact assessment indicators description for Module 444

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP02 next steps
44400A	Sensor & App data*	Sensor data and App data from residents at Strijp-S	444002 444003 444004 444005	VW/ residents	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)		
44400B	Qualitative questionnaire data	Dialoge beween VW and citizens for project-planning	444001	VW/ residents	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)		

Table 4.4.12: Datasets description for Module 444

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	De rat rel cha (p
444001	Nr. of citizens involved in project-planning	Dimensionless integer	0	2014Jan - 2014Dec	20	2017Oct	20	2018Dec	20	2019Dec	20,00	5,00	na	na
444002	Improved public space by install sound sensors	Dimensionless integer	0	2014Jan - 2014Dec	7	2017Oct	7	2018Dec	7	2019Dec	7,00	1,75	na	na
444003	Improved public space by install video sensors	Dimensionless integer	0	2014Jan - 2014Dec	15	2017Oct	18	2018Dec	18	2019Dec	18,00	4,50	na	na
444004	Improved public space by install water sensors	Dimensionless integer	0	2014Jan - 2014Dec	10	2017Oct	15	2018Dec	15	2019Dec	15,00	3,75	na	na
444005	Improved public street lighting by promoting App used by citizens	Dimensionless integer	0	2014Jan - 2014Dec	5	2017Oct	5	2018Dec	5	2019Dec	5,00	1,25	na	na

Table 4.4.13: Impact assessment for Module 444

*Note: 444003 The value includes sensors for car plate recognition. However due to privacy issue, the data is not online.

4.4.5 Module 445: Smart city innovation fund (Subtask 4.4.6)

The implementation dates of the module

In M17, the website of the iCity tender and the planning was prepared: http://strijps.nl/nl/icity-tender. In total 63 proposals were collected from which 42 were filled in correctly. The 20 best proposals were selected in M20. In M21 the first iCity Tender Event took place. Participants had to pitch their ideas in front of an independent jury that selected 19 participants that may enter into the second phase. In M24 the output from the first phase will be presented to the iCity Tender Committee. The best participants will be asked to present their progress during the 2nd iCity Tender Event in front of a jury. The 2nd iCity Tender Event was scheduled in M25.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

After discussion with the project manager of Subtask 4.4.6, the quantity unit of 445001 (Capital /operational expenditure of partners on energy, ICT and mobility) and 445004 (SMEs development Turnover) have been changed from €m to €m/yr and € to €/yr to better capture the change before and after implementing the project.

M60 update

No change.

Impact indicator identifier	Impacts	Impact Indicators	Quant. Unit	Datasets to be used in impact calculation	Aligned with SCIS
445001	Promoting commercial activity	Capital /operational expenditure of partners on energy, ICT and mobility	€m /yr	Innovative services	Y
445002	Promoting commercial activity	SMEs stimulated	Dimensionless integer	Innovative services	N
445003	Promoting commercial activity	Jobs created (Full time equivalent)	Dimensionless integer	Innovative services	Y
445004	Wide scale deployment/ dissemination of project results	SMEs development Turnover	€/yr	Innovative services	Y
445005	Wide scale deployment/ dissemination of project results	Generate large-scale investment - Venture capital	€	Innovative services	Y
445006	Wide scale deployment/ dissemination of project results	Generate large-scale investment - Commercial value	€	Innovative services	Y
445007	Wide scale deployment/ dissemination of project results	Software and application development (Nr. of apps registered)	Dimensionless integer	Innovative services	Y

Table 4.4.14: Impact assessment indicators for Module 445

Dataset identifier	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP02 next steps
44500A	Innovative services	Data on request - Stimulating the development of innovative services / applications	445001 445002 445003 445004 445005 445006 445007	VW	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)		

Table 4.4.15: Datasets description for Module 445

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
445001	Capital /operational expenditure of partners on energy, ICT and mobility	€m /yr	0	2016 Oct	50	2017 Oct	50	2018 Dec	50	2019 Dec	50,00	25,00	na	na
445002	SMEs stimulated	Dimensionless integer	0	2016 Oct	28	2017 Oct	28	2018 Dec	28	2019 Dec	28,00	14,00	na	na
445003	Jobs created (Full time equivalent)	Dimensionless integer	0	2016 Oct	28	2017 Oct	28	2018 Dec	28	2019 Dec	28,00	14,00	na	na
445004	SMEs development Turnover	€/yr?	0	2016 Oct	230	2017 Oct	230	2018 Dec	230	2019 Dec	230,00	115,00	na	na
445005	Generate large-scale investment - Venture capital	€	0	2016 Oct	40000	2017 Oct	40000	2018 Dec	0000	2019 Dec	40000,00	20000,00	na	na
445006	Generate large-scale investment - Commercial value	€	0	2016 Oct	0	2017 Oct	0	2018 Dec	0	2019 Dec	0,00	0,00	na	na
445007	Software and application development (Nr. of apps registered)	Dimensionless integer	0	2016 Oct	5	2017 Oct	5	2018 Dec	5	2019 Dec	5,00	2,50	na	na

Table 4.4.16 Impact assessment for Module 445

4.4.6 Module 446: Smart streetlights for social interaction and health route (Subtask 4.4.7)

The implementation dates of the module

The implementation started from M16 with an internal session using the "design thinking" method. M17 observations by the pond, along the water had been carried out and interviews were organized with key-persons in the district from different groups of people. By end of M17, a co-creation evening was organized with people living in the area where the most important functionalities of the pond were discussed and the focus themes were decided about. In M23 the first developed design was presented to the residents of the district. Final version of the "design" was presented to the residents on M25. The project was completely implemented at the beginning of M34.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

446001 - Besides the people signed in the signed list each time, based on rough estimation of Annemarie Totte (the project manager of Subtask 4.4.7), during the house visits they spoke to 10 people and during the observations, and around 50 people are involved.

446003 - The indicator is calculated based on three times observation. The observation document is attached in appendix 1. During May 2016, three random periods were selected to observe people behaviour on this route. The observer stands at a certain point and counted the number of people in their sight range. Meanwhile, they did interview with random selected passengers.

The system is not function until beginning of September 2018. There are 3 points where the sensors can be triggered to start. The counter on the starting signals have been installed in the beginning of September 2018. The end value is recorded from 1/9/2018 - 12/12/2018. The data cannot be recorded as 446003 (Improved public street lighting by sensing density of people in the street). Therefore, we created a new indicator 446005 (How many times the running system has been used per day).

M60 update

For indicator of 446005, the data is not published yet. The information can be retrieved later through the link: https://eindhoven.incijfers.nl/Jive?workspace_guid=8f0a7597-4da2-4103-8aa1-d935adc1939e

Impact indicator identifier	Impacts	Impact Indicators	Quant. Unit	Datasets to be used in impact calculation	Aligned with SCIS
446001	Fostering citizen engagement (Co-creation)	Adoption of co-creation procedure by involving citizens in the decision process	Nr.	Dialogue method	N
446002	Improving the quality of life	Improved public street lighting by installing lights pole	Nr	Sensor data	N
446003	Improving the quality of life	Improved public street lighting by sensing the density of people on the route	Nr. per m2	Sensor data	N
446004	Improving the quality of life	Recorded well-being of residents	Recorded overall well-being 1-10 (low to high)	District monitor	N
446005	Improving the quality of life	How many times the running system has been used per day	Dimensionless integer	Sensor data	N

Table 4.4.17: Impact assessment indicators for Module 446

Dataset identifier	Dataset name	Dataset description	Related impact indicators	Dataset owner	Dataset contact	Comments	WP02 next steps
44600A	Dialogue method	Interview data based on Dialogue method: Design thinking	446001 446003	Eindhoven municipality	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	Design thinking method was used to involve citizens: observations, interviews, house to house calls, and creative design events. Data is available.	
44600B	Sensor data	Sensor data from the running system	446002 446005	Eindhoven municipality	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	lighting poles sensor data is not available but running sensor data is available	
44600C	District monitor	Excerpt from district monitor data collected by the municipality on yearly basis ('Buurtmonitor')	446004	Eindhoven municipality	Dujuan Yang (D.Yang@TU/e.nl) & Niels Wiersma (n.wiersma@eindhoven.nl)	Data is available	

Table 4.4.18: Datasets description for Module 446

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
446001	Adoption of co-creation procedure by involving citizens in the decision process	Dim. Int.	0	2014 Dec	99	2017Oct	99	2017 Oct	99	2017 Oct	99,00	2,91	na	na
446002	Improved public street lighting by installing lights pole	Dim. Int.	0	2014Jan - 2014Dec	31	2017 Oct	31	2017 Oct	31	2017 Oct	31,00	0,91	na	na
446003	Improved public street lighting by sensing the density of people on the route Nr. Per min/Nr. per day	Dim. Int.	0,217	2014Jan - 2014Dec	na	na	na	na	na	na	na	na	na	na
446004	Recorded well-being of residents	1-10 (low to high)	6,7	2014Jan - 2014Dec	6,85	2017 Jan-2017 Dec	6,8	2017 Jan -2017 Dec		2019 Jan - 2019 Dec	na	na	na	na
446005	How many times the running system has been used per day	Dim. Int.	na	2014Jan - 2014Dec	na	2017Oct	83,94	Sept 2018 – Dec 2018	64,95	Dec 2018 – Nov 2019	na	na	na	na

Table 4.4.19: Impact assessment for Module 446

5 Stavanger Impact at Module Level

Executive Summary

The Stavanger report presents a strategic overview of the ongoing process of understanding the scope of the Triangulum modules being implemented in Stavanger, and the development of a set of indicators and data to assess the impacts of these modules. This report section is organised into four sections.

Section 1 provides a high-level description of the City of Stavanger, and highlights the smart city initiatives taking place which complement Triangulum. This section also identifies the potential of Triangulum modules to contribute to meeting city objectives. It offers an initial evaluation of the module impacts followed by a high-level overview of the impact assessment and monitoring activities to continue in Stavanger during 2019.

Section 2 describes the Energy modules in detail including objectives, socio-technical configurations and stakeholder structures. The indicators used for assessing the impacts and benefits of the module and the current understanding of impacts are then presented. Sections 3 and 4 provide module descriptions and impact indicators for the Mobility and ICT modules, respectively.

5.1 Overview and initial assessment

This section briefly assesses the local modules and their impacts. The progress of the Stavanger partnership in terms of module implementation and impact reporting is summarized in Table 5.1.1.

	#modules implemented	**#baseline indicator values available**	**#impact indicator values available**
Overall value	7/8	67/74	67/74
Energy	2/2	35/35	35/35
Mobility	2/2	18/21	18/21
ICT	3/4	14/18	14/18

Table 5.1.1: Implementation and impact reporting of Stavanger modules

Some key impacts achieved in Stavanger include the installation of Smart Gateways in 90 homes (Module 521), the increased reliance on renewable energy sources at municipal buildings (Module 522), and the ongoing collection of data from other modules to the cloud data platform (Module 544).

Please note, the Stavanger impact indicators were challenging to implement and evaluate due to a necessary emphasis and priority on data transfer to the cloud data platform and ongoing GDPR and third party data issues.

5.2 Energy Modules

The Energy task group defined the scope of three modules to demonstrate the potential of smart and low carbon energy technologies. The module descriptions and proposed impact indicators presented below have been revisited and revised since the M36 iteration of this report as module scope has been refined.

- *Module 521: Smart gateway.* Installation of smart gateways enabling automated metering, which provide opportunities for end users to manage lighting, heating and cooling in a way that can meet both individual and community-level energy goals. Additionally, this enables the energy provider to more precisely manage and plan the load variation
- *Module 522: Central energy plant. Use new energy sources and* reducing energy consumption of buildings by delivering a more efficient and less CO_2-emitting heating system for multiple buildings within the Stavanger municipality.

Table 5.2.1 presents a summary of the expected impacts of each energy module and below detailed module descriptions are provided.

Task Group	**Module**	**Expected impacts**				
		Reduce energy consumption of buildings	Increase utilisation of electric vehicles	Holistic residential solutions	Increase energy efficiency	Fostering citizen engagement with digital infrastructure
Energy	Module 521: Smart gateway	*			*	
	Module 522: Central energy plant.	*			*	

Table 5.2.1: Expected impacts of Stavanger Energy modules

5.2.2 Module 521: Smart gateway (Subtask 5.2.1)

The implementation dates of the module

The module was implemented in January 2016 and has been operating in the private households since.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

The gateways picked for module 521 turned out to fail in meeting necessary technical specifications during the roll-out of Automated Metering Systems. The gateways were however kept operating at the pilot sites in order to meet the DoA requirements, but the running of home automation services on top of that had to be taken over by a different vendor (Sensio). This caused limitations in the dataset structure.

The data collection started from 2017. The baseline values are based on data from pilots that were customers of Lyse Energisalg.

The values for the baseline are annual.

Changes since last report (M48)

No significant changes.

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
521001	Installation of smart gateways	Count of smart gateways installed	Dimensionless integer	Lyse smart gateway data set	N
521002	Reduced energy consumption. Buildings' consumption of electrical energy via smart gateway	Mean of annual energy consumption per residence	kWh	Lyse smart gateway data set	Y
521003		Variance of annual energy consumption per residence	MW^2h^2	Lyse smart gateway data set	N
521004		Mean of annual energy cost per residence	€ (NOK)	Lyse smart gateway data set + Energy price data	Y
521005		Variance of annual energy cost per residence	$€^2$ (NOK^2)	Lyse smart gateway data set + Energy price data	N
521006		Annual mean of electricity price per kWh	€ (NOK)	Lyse smart gateway data set + Energy price data	Y
521007		Annual variance of electricity price per kWh	$€^2$ (NOK^2)	Lyse smart gateway data set + Energy price data	N
521008	Flattening peak demand	Mean of intradiurnal mean of hourly energy consumption per residence	kWh	Lyse smart gateway data set	N
521009	Flattening peak demand	Mean of intradiurnal variance of hourly energy consumption per residence	$M W^2h^2$	Lyse smart gateway data set	N

Table 5.2.2: Impact assessment indicators description for Module 521

Dataset number	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
52100A	Lyse smart gateway dataset	Collection of sensor data from smart gateways installed.	521001 521002 521003 521004 521005 521006 521007 521008 521009	Lyse	Sindre Tøsse (Sindre.Tosse@lyse.no)	Data transfer was put on hold due to concerns over GDPR and awaited due diligence regarding appropriateness of Privacy impact assessment. Transfer to CDP may depend on extra resources to contract third-party data processor to undertake GDPR-compliant anonymization.	
52100B	Lyse smart gateway dataset (Continued)					After evaluation by an external data expert of the potential need for Privacy Impact Assessment, it was determined that this was not necessary given that data shared to UiS CDP does not provide a way to re-identify the homes where the smart gateways were installed. Furthermore, in M36 the values for impact indicators 521001 and 521002 were evaluated by Lyse and reported directly by module task group contact.	

52100C	Energy price data (Lyse)	Longitudinal dataset detailing the price per kilowatt hour of energy of Lyse residential customers over months.	521004 521005 521006 521007	Lyse	Sindre Tøsse (Sindre.Tosse@lyse.no)	Lyse suggests to use historical spot market prices made available by Nord Pool. (https://www.nordpoolgroup.com/ https://www.nordpoolgroup.com/Market-data1/#/nordic/table) This dataset was identified after the deadline for data intake for submissions leading up to the D2.5 report. However, this dataset is open and as such not affected by privacy concerns.	

Table 5.2.3: Datasets description for Module 521

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
521001	Count of smart gateways installed	Dimensionless integer	56	Jan 2017	N/A	N/A	56	Nov 2018	56	Nov 2019	0	0	0%	0%
521002	Mean of annual energy consumption per residence	kWh	12 805	Jan 2016 – Jan 2018	N/A	N/A	11 922	Feb 2017 – Nov 2018	9 467	Dec 2018 – Nov 2019	-3338	-3338	-26.06%	-26.06%
521003	Variance of annual energy consumption per residence	MW^2h^2	85 435 792	Jan 2016 – Jan 2018	N/A	N/A	81 513 685	Feb 2017 – Nov 2018	40 138 020	Dec 2018 – Nov 2019	-45297772	-45297772	-53.01%	-53.01%
521004	Mean of annual energy cost per residence	NOK	9 486	Jan 2016 – Jan 2018	N/A	N/A	9 747	Feb 2017 – Nov 2018	8 336	Dec 2018 – Nov 2019	-1150	-1150	-12.12%	-12.12%
521005	Variance of annual energy cost per residence	NOK^2	46 527 531	Jan 2016 – Jan 2018			54 972 785	Feb 2017 – Nov 2018	31 473 676	Dec 2018 – Nov 2019	-15053855	-15053855	-32.35%	-32.35%
521006	Annual mean of electricity price per kWh	NOK	0.251	Jan 2016 – Jan 2018			0.306	Feb 2017 – Nov 2018	0.402	Dec 2018 – Nov 2019	0.151	0.151	60.15%	60.15%
521007	Annual variance of electricity price per kWh	NOK^2	0.00305	Jan 2016 – Jan 2018			0.0108	Feb 2017 – Nov 2018	0.00768	Dec 2018 – Nov 2019	0.00463	0.00463	151.80%	151.80%
521008	Mean of intradiurnal mean of hourly energy consumption per residence	kWh	1.547	Feb 2017 – April 2018			1.360	Feb 2017 – Nov 2018	1.079	Dec 2018 – Nov 2019	-0.468	-0.468	-30.25%	-30.25%
521009	Mean of intradiurnal variance of hourly energy consumption per residence	$M W^2h^2$	0.865	Feb 2017 – April 2018			1.082	Feb 2017 – Nov 2018	0.535	Dec 2018 – Nov 2019	-0.33	-0.33	-38.15%	-38.15%

Table 5.2.4: Impact assessment for Module 521

5.2.3 Module 522: Central energy plant (Subtask 5.2.2)

The implementation dates of the module

The central energy plant (CEP) was completed for energy delivery to three administration buildings and the public swimming pool, owned by Stavanger municipality, Olav Kyrres gt 19 (OK19) including the public pool, Olav Kyrres gt 23 (OK23) and the City Hall, in June 2017. After a trial period of six months which the contractors have been responsible for monitoring and control, the municipality of Stavanger has overtaken responsibility from the operating centre in one year from January 2017. As of week 51 of 2018, OK19 is also connected to CEP. The contractual trial period of twelve months, which the contractors have supervised and controlled in collaboration with the municipality, was from January 2019 to December 2019. However, due to mixed function testing of technical systems, correct measurements were not available until March 2019.

Energy meters for all energy sources and delivery points (buildings) are installed to measure energy production. The energy plant will supply heating and cooling to three municipal buildings.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

The module is intended to have an impact of increasing the proportion of renewable energy used by municipal buildings. The impact indicators are intended to be derived from the data generated by the module itself, and from electric energy price data for the relevant time periods. Note that direct measurement carbon emissions measurement data does not exist, and could be estimated from energy consumption according to the method used in the municipality. The coefficients used to estimate carbon emissions are given by *City of the Future*'s guidelines for emissions from buildings (http://www2.stavanger.kommune.no/Documents/Natur%20og%20milj%c3%b8/Framtidens%20byer/FBprosjektavslutning_%c3%a5rsberetning2014_Stavanger.pdf).

Changes since last report (M48)

- Some baselines values and dates have been updated. The base line values are averaged from 2013-2015. The values for the baseline are annual. The list of updates are:
    - 522002a: The value is the calculated heat delivered from the old CEP to the ventilation systems in the offices in OK19.
    - 522002b: Calculated. The old CEP delivered all the thermal energy to the swimming. area, including the heating of tap water and the pool areas.
    - 522002c: Calculated - Only heat supplied from CEP. No tap water or cooling. OK23 had a separate cooling system.
    - 522002d: Calculated. The old CEP produced and delivered the about 60 % of the local heating and 100 % ventilation heating to City hall.
    - 522003a: calculated heating demand before the rehabilitation.

- 522003b: The old CEP did not deliver any cooling to OK19.
- 522003c: the value from before the rehabilitation.
- 522003e: No cooling was delivered to OK23 from old CEP, Cooling was produced by a local cooling unit that was removed during the rehabilitation of OK19.
- 522003f: from before the rehabilitation.
- 522004a-b: Invoiced costs electricity heat pump and EL boiler for the period 2014-2016. Summarized and deviated by 36 and multiplied by 12.
- 522004c: 522004a+522004b.
- 522006a: Calculated energy production from all energy sources in the new CEP (heat pump, solar heat, grey water and biogas).
- 522006b: Calculated cooling produced from CEP and delivered to OK19 and OK23. City Hall does not have cooling from CEP.
- 522007a: Calculated power consumption for energy production in new CEP.
- 522007b: Ventilation and room heating (all buildings) + tap water swimming pool + cooling OK19 office and OK23.
- 522007c: Free renewable energy produced by CEP (produced heat pump, solar and grey water minus energy consumption for production. Cooling is not included)
- 522008a-d: Calculated production
- 522009a: The calculated value is based on an assumption on how many users (80 000 who would use the showers in the swimming pool.
- 522009b: Calculated from the energy demand. Calculated water requirement heated (65 °C) for hot water for showers (80 000 users).

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
522001	Increased proportion of renewable energy sources	Percentage CO_2 reduction from new CEP	%	Stavanger Kommune Central Energy Plant m522 dataset. + A document is required to classify energy sources as renewable or not. + Static data for energy consumption prior to module implementation must be transferred separately.	Y
522002a-d		The total amount of energy supplied by the module and consumed by each building: (a) OK19 offices, heating and cooling; (b) OK19 swimming pool, heating; (c) OK23, heating and cooling; (d) City Hall, heating.	kWh	Stavanger Kommune Central Energy Plant m522 dataset. + Historical data from the overall +Energioppfølgingssystemet (EOS) dataset.	Y
522003a-f		The amount of energy consumed for heating or cooling by each building: (a) heating OK19 offices; (b) cooling OK19 offices; (c) heating OK19 swimming pool; (d) heating OK23 offices; (e) cooling OK23 offices; (f) heating City Hall.	kWh	Stavanger Kommune Central Energy Plant m522 dataset.	Y
522004a-c		Annual energy cost per source. (a) electricity (b) biogas (c) Total energy	€ (NOK)	Stavanger Kommune Central Energy Plant m522 dataset. + Price data.	Y
522005	CO_2 emission	Estimated total CO_2 emission per year produced by the module in operation.	Metric tonnes	Stavanger Kommune Central Energy Plant m522 dataset. + Emissions estimation reference publication.	Y
522006a-b	Increased proportion of renewable energy sources	The energy produced by the module for (a) heating and (b) cooling.	kWh (%)	Stavanger Kommune Central Energy Plant m522 dataset	Y
522007a-c	Increased proportion of renewable energy sources	Total energy (a) purchased and consumed by, (b) distributed by the module (c) Free renewable produced from the module	kWh (%)	Stavanger Kommune Central Energy Plant m522 dataset	Y
522008a-d	Increased proportion of renewable energy sources	Total energy produced by each of the energy sources in the module: (a) heat pump; (b) biogas; (c) solar; (d) greywater.	kWh (%)	Stavanger Kommune Central Energy Plant m522 dataset	Y
522009a-b	Increased proportion of renewable energy sources	Energy produced by the module and consumed to heat tap water.	kWh (%) m3	Stavanger Kommune Central Energy Plant m522 dataset	Y

Table 5.2.5: Impact assessment indicators description for Module 522

Dataset number	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
52200A	Stavanger Kommune Central Energy Plant (CEP) m522 dataset, a subset of EOS (Stavanger Kommune)	Module 522-relevant subset of data: CEP energy monitoring data subset of Energy Monitoring System (EOS) operated by Stavanger Kommune.	522001 522002a-d 522003a-f 522004a-c 522005 522006a-b 522007a-c 522008a-d 522009	Stavanger Kommune	michael.taoushanis@stavanger.kommune.no espen.svendsen@stavanger.kommune.no	The Central Energy Plant (CEP) task group has been proactive in establishing local mechanisms that forward data to the UiS on an ongoing basis, despite challenging network configurations at both institutions. The CEP task group have also been proactive in supporting the work of mapping the schema of the data source to the impact indicator calculations. Automated data transfer to UiS does require some troubleshooting and improvement. For the time being, the data transfer is done manually.	
52200B	Energy price data (Stavanger Kommune)	Longitudinal dataset detailing the costs arising from primary energy use in specified municipal buildings	522005	Stavanger Kommune	michael.taoushanis@stavanger.kommune.no espen.svendsen@stavanger.kommune.no	These values may most appropriately be collected in an automated way if practical. Otherwise, the values may be reported directly by the module task group for specific time periods.	
52200C	Emissions estimation reference publication.	Documentation as basis for coefficient to estimate CO2 emissions.	522005	Stavanger Kommune	michael.taoushanis@stavanger.kommune.no espen.svendsen@stavanger.kommune.no	The reference used is the final report (2014) of the project Cities of the future (Framtidens byer): http://www2.stavanger.kommune.no/Documents/Natur%20og%20milj%c3%b8/Framtidens%20byer/FBprosjektavslutning_%c3%a5rsberetning2014_Stavanger.pdf.	
52200D	Historical data from the overall Energy Monitoring System (EOS) dataset.		522002a-d	Stavanger Kommune	michael.taoushanis@stavanger.kommune.no espen.svendsen@stavanger.kommune.no	These values were reported directly by the module task group. These data are considered to have been captured for impact reporting purposes.	

Table 5.2.6: Datasets description for Module 522

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
522001	Percentage CO_2 reduction from new CEP	%	0	2013-15	66.64%	4/2017-12/2017	90,6%	1/2018-11/2018	87,5%	1/2019-10/2019	87.5	105	n/a	n/a
522002a	The total amount of energy supplied by the module and consumed by each building: (a) OK19 offices, heating and cooling.	kWh	318 161	2013-15	0	1/2017-12/2017	No data	1/2018-11/2018	382695	1/2019-10/2019	95210	114252	20.28%	24.34
522002b	The total amount of energy supplied by the module and consumed by each building: (b) OK19 swimming pool.	kWh	1771629	2013-15	0	1/2017-12/2017	No data	1/2018-11/2018	366010	1/2019-10/2019	-1601670	-1922004	-79.34%	-95.21
522002c	The total amount of energy supplied by the module and consumed by each building: (c) OK23, heating and cooling.	kWh	450000	2013-15	253450.0	1/2017-12/2017	479010	1/2018-11/2018	371850	1/2019-10/2019	-42050	-50460	-17.37%	-20.84
522002d	The total amount of energy supplied by the module and consumed by each building: (d) City Hall, heating.	kWh	379000	2013-15	305990.0	1/2017-12/2017	755754	1/2018-11/2018	593540	1/2019-10/2019	214540	257448	56.61%	67.93
522003a	The amount of energy consumed for heating or cooling by each building: (a) heating OK19 offices.	kWh	287485	2013-15	No value, electric heating	1/2017-12/2017	No value, electric heating	1/2018-11/2018	238925	1/2019-10/2019	-48560	-58272	-16.89%	-20.27
522003b	The amount of energy consumed for heating or cooling by each building: (b) cooling OK19 offices.	kWh	0	2013-15	No value	1/2017-12/2017	No value	1/2018-11/2018	143770	1/2019-10/2019	143770	172524	n/a	n/a
522003c	The amount of energy consumed for heating or cooling by each building: (c) heating OK19 swimming pool.	kWh	1771629	2013-15	No data	1/2017-12/2017	No data	1/2018-11/2018	366010	1/2019-10/2019	-1601670	-1922004	-79.34%	-95.21
522003d	The amount of energy consumed for heating or cooling by each building: (d) heating OK23 offices.	kWh	450000	2013-15	250150.0	1/2017-12/2017	442710	1/2018-11/2018	354050	1/2019-10/2019	-95950	-115140	-21.32%	-25.58
522003e	The amount of energy consumed for heating or cooling by each building: (e) cooling OK23 offices.	kWh	45900	2013-15	3300.0	1/2017-12/2017	36300.0	1/2018-11/2018	17800	1/2019-10/2019	53900	64680	-61.22%	-73.46
522003f	The amount of energy consumed for heating or cooling by each building: (f) heating City Hall.	kWh	379000	2013-15	305990.0	1/2017-12/2017	755754	1/2018-11/2018	593540	1/2019-10/2019	214540	257448	56.61%	67.93
522004a	Annual energy cost (a) electricity	€ (NOK)	966285	2013-15	0	1/2017-12/2017	372224	1/2018-11/2018	433482	1/2019-10/2019	-532803	-639363.6	-55.14%	-66.17
522004b	Annual energy cost (b) biogas	€ (NOK)	1035301	2013-15	0	1/2017-12/2017	376345	1/2018-11/2018	193051	1/2019-10/2019	-842250	-1010700	-81.35%	-97.62
522004c	Annual energy cost (c) Total energy	€ (NOK)	2001586	2013-15	0	1/2017-12/2017	748569	1/2018-11/2018	626533	1/2019-10/2019	-1375053	-1650063.6	-68.7%	-82.44
522005	Estimated total CO_2 emission per year produced by the module in operation.	Metric tonnes	544 (Calculated)	2013-15	36.02	1/2017-12/2017	53,52	1/2018-11/2018	71,5	1/2019-10/2019	-499.5	-599.4	-86.86%	-104.23
522006a	The energy produced by the module for (a) heating.	kWh	2123700	2013-15	598400.0	1/2017-12/2017	1279100	1/2018-11/2018	1737056	1/2019-10/2019	-550944	-661132.8	-18.21%	-21.85
522006b	The energy produced by the module for (b) cooling.	kWh	186700	2013-15	3300.0	1/2017-12/2017	36300.0	1/2018-11/2018	161570	1/2019-10/2019	142370	170844	-13.46%	-16.15
522007a	Total energy (a) purchased/delivered to the module.	kWh	816000	2013-15	955320.0	1/2017-12/2017	656698	1/2018-11/2018	692073	1/2019-10/2019	-217927	-261512.4	-15.19%	-18.23
522007b	Total energy (b) distributed/ energy needs from the module.	kWh	234000 2310400	2013-15	559464.0	1/2017-12/2017	1234792	1/2018-11/2018	1787105	1/2019-10/2019	1516195	1819434	663.72%	796.46
522007c	Total energy (c) Free renewable produced from the module	kWh	1494472	2013-15	336341.0	1/2017-12/2017	804553	1/2018-11/2018	1220434	1/2019-10/2019	-157566	-189079.2	-18.34%	-22.01
522008a	Total energy produced by the various sources in the module: (a) heat pump.	kWh	1692200	2013-15	465700.0	1/2017-12/2017	1095500	1/2018-11/2018	1614800	1/2019-10/2019	-35200	-42240	-4.57%	-5.48
522008b	Total energy produced by the various sources in the module: (b) biogas.	kWh	248900	2013-15	132700.0	1/2017-12/2017	183600	1/2018-11/2018	92550	1/2019-10/2019	-346100	-415320	-62.82%	-75.38
522008c	Total energy produced by the various sources in the module: (c) solar.	kWh	91300	2013-15	No value	1/2017-12/2017	No value	1/2018-11/2018	23230	1/2019-10/2019	-93800	-112560	-74.56%	-89.47

522008d	Total energy produced by the various sources in the module: (d) greywater.	kWh	91300	2013-15	No value	1/2017-12/2017	No value	1/2018-11/2018	6400	1/2019-10/2019	-126600	-151920	-92.99%	-111.59
522009a	Energy consumed to heat tap water.	kWh	365200	2013-15	No value	5/2017-12/2017	No value	1/2018-11/2018	73010	1/2019-10/2019	-456990	-548388	-80.01%	-96.01
522009b	Consumed tap water	M3	4800	2013-2015	No value	5/2017-12/2017	No value	1/2018-11/2018	590	1/2019-10/2019	-7010	-8412	-87.71%	-105.25

Table 5.2.7: Impact assessment for Module 522

5.3 Mobility Modules

The Stavanger Mobility task group defined the scope of two modules (see below). Hence, the module descriptions and proposed impact indicators presented below have been revisited and revised over the course of the project as module scope was refined.

- *Module 531: Battery bus demonstration.* Rogaland County Council will run a demo-project on battery busses. Lessons about using battery busses in the public transportation system will be documented, such as installing charging stations or differences in maintenance procedures from diesel buses.
- *Module 532: Electric vehicle charging.* The Stavanger Region has a high density of electric vehicles. To meet increased demand for charging capacity for electrical vehicles (EVs), several measures are implemented independently of the Triangulum process. In the corresponding task, emphasis is concentrated on home-based charging in 10 pilot homes.

Table 5.3.1, below, presents a summary of the expected impacts of the mobility modules, and below detailed module descriptions are provided.

Task Group	**Module**	**Expected impacts**				
		Reduce energy consumption of buildings	Increase utilisation of electric vehicles	Holistic residential solutions	Increase energy efficiency	Fostering citizen engagement with digital infrastructure
Mobility	Module 531: Battery bus demonstration		*		*	
	Module 532: Electric vehicle charging		*	*	*	

Table 5.3.1: Expected impacts of the Stavanger Mobility modules

5.3.1 Module 531: Battery bus demonstration (Subtask 5.3.1)

The implementation dates of the module

The module was implemented in December 2016, in the sense that the electric battery busses were delivered, and these buses have been operating in the Nord-Jæren bus fleet since.

The indicators used for assessing the impacts and benefits and baseline conditions

The module is intended to have an impact of providing and utilizing electric battery busses, and of reducing greenhouse gas emissions which would otherwise be cause by diesel busses. The greenhouse gas emissions thus avoided should be estimated based on the distance driven by the battery busses and a commissioned report by Asplan Vlak for Kolumbus that indicates 0.9 kg CO_2 equivalents per km driven by a diesel bus.

The distance data can be calculated from the Kolumbus Vehicle Monitoring (VM) dataset in various ways, though the most reliable way to do so has yet to be determined.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

- 531006d (Greenhouse gas/ pollution emissions spared annually by battery busses replacing diesel busses: (d) SOx.) not available as it needs to be calculated

Changes since last report (M48)

Nothing to report.

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
531001	Provision of battery buses	Total number of buses in relevant fleet	Dimensionless integer	Kolumbus VM dataset Kolumbus Drift	N
531002		Number of battery buses in relevant fleet	Dimensionless integer	Kolumbus VM dataset Kolumbus Drift	N
531003a		Battery buses annual purchasing cost per bus	Euros	Kolumbus Drift Battery buses purchase cost	N
531003b	Provision of battery buses	Battery buses annual maintenance and repairs cost per bus	Euros	Kolumbus Drift Battery buses purchase cost	N
531004	Reduced greenhouse gas/pollution emissions Reduced greenhouse gas/pollution emissions	Total annual fossil fuel consumption (litres of diesel) by normal diesel bus	Litres	Kolumbus Drift	N
531005		Total annual electrical load by battery buses	kWh	Kolumbus Drift	N
531006a 531006b 531006c 531006d 531006e 531006f		Greenhouse gas/ pollution emissions spared annually by battery buses replacing diesel buses: (a) CO_2; (b) CO; (c) NOx; (d) SOx; PM10 (e) and (f) PM.	Kg	Emissions estimation reference publication – report ordered by Kolumbus. Kolumbus Drift (odometer data) Kolumbus VM dataset (possibly).	N
531007a	Utilization of battery buses compared to conventional buses	Annual number of passengers in relevant fleet (region of Nord_Jæren)	Dimensionless decimal	APC (advanced passenger counting system)	
531007b	Utilization of battery buses compared to conventional buses	Mean of passenger kilometres (mean distance travelled per passenger) and annual number of passengers	km	APC (advanced passenger counting system)	N
531007c	Utilization of battery buses compared to conventional buses	Variance of passengers per bus ride	Dimensionless decimal	APC (advanced passenger counting system)	N
531008a	Bus service production	Total number of annual run kilometres per bus	Km per bus		
531008b	Bus service production	Total number of annual run kilometres per battery bus	Km per bus		

Table 5.3.2: Impact assessment indicators description for Module 531

Dataset Number	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps takenb
53100A	Kolumbus Drift	Kolumbus internal operations data and operators fleet management system (Saga).	531001 531002 531003 531004 531005 531006a-e	Kolumbus	Odd Vinje (odd.vinje@kolumbus.no)	Only select pieces of information can reasonably be shared from the company operations database to the CDP.	UiS researchers followed up with Kolumbus data set contact about getting the select data points required for impact indicator calculations.
53100B	Battery buses purchase cost data		531003a 531003b	Kolumbus	Odd Vinje (odd.vinje@kolumbus.no)		
53100C	Emissions estimation reference publication – report ordered by Kolumbus.	Coefficients to estimate greenhouse gas emissions spared will require a documented, evidence-based justification. "0.9 kg CO_2 equivalents per km driven, according to Asplan Viak report received by Kolumbus."	531006a-e	Kolumbus	Odd Vinje (odd.vinje@kolumbus.no)	*Calculations does not regard emissions variation for different types of diesel (biodiesel and normal diesel)*	Reference document: "Klimaregnskap for Kolumbus sin bussdrift. Nord-Jæren, 2016" by Asplan Viak
53100D	Kolumbus VM	Kolumbus bus monitoring system providing open, real-time data.	531006a-e	Kolumbus	Odd Vinje (odd.vinje@kolumbus.no)	This data set is being collected by the CDP, except temporary outages on the collection process and buses with tracking turned off – a significant proportion at any given time.	Continue data analysis to identify best what to estimate distances driven by buses, including rules on when to drop buses with inconsistent histories from evaluation.
53100E	APC advanced passenger counting system	APC is implemented and data is available from Jan 2017.	531007a-c	Kolumbus	Odd Vinje (odd.vinje@kolumbus.no)	APC is implemented and data is available from Jan 2017.	Data was available spring 2018. This is part of the data warehouse project in Kolumbus.
			531008a-b	Kolumbus	Odd Vinje (odd.vinje@kolumbus.no)		

Table 5.3.3: Datasets description for Module 531

impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
531001	Total number of buses in relevant fleet	Dimensionless integer	187	July 2016	187	Jan-Dec 2017	187	Jan-Dec 2018	187	Jan-Dec 2019	0	0	0%	0%
531002	Number of battery busses in relevant fleet	Dimensionless integer	5	2 from Apr 2015 3 from Dec 2016	5	Jan-Dec 2017	5	Jan-Dec 2018	5	Jan-Dec 2019	0	0	0%	0%

531003a	Battery buses purchasing cost, per bus	Euros	460,000		0	Jan-Dec 2017	0	J Jan-Dec 2018	0	Jan-Dec 2019	-460000	-460000	-100%	-100%
531003b	Battery busses annual maintenance and repairs cost per bus	Euros	8000		8000	Jan-Dec 2017	8000	Jan-Dec 2018	8000	Jan-Dec 2019	0	0	0%	0%
531004	Total annual fossil fuel consumption (litres of diesel) by normal diesel buses	Litres	5053745,0	Jan-Dec 2017	5053745,0	Jan-Dec 2017	5171204.7	Jan-Dec 2018	5668853	Jan-Dec 2019	615108	615108	12.17%	12.17%
531005	Annual electrical load by battery busses	kWh	95699,83	Jan-Dec 2017	95699,83	Jan-Dec 2017	150311,35	Jan-Dec 2018	185290	Jan-Dec 2019	89590.17	89590.17	93.61%	93.61%
531006a	Greenhouse gas/ pollution emissions spared annually by battery busses replacing diesel busses: (a) CO_2.	Metric tonnes	57.9	Jan-Dec 2017	57.9	Jan-Dec 2017	226.1	Jan-Dec 2018	192.9	Jan-Dec 2019	135	135	233.16	233.16
531006b	Greenhouse gas/ pollution emissions spared annually by battery busses replacing diesel busses: (b) CO.	Kg	130.4	Jan-Dec 2017	130.4	Jan-Dec 2017	490	Jan-Dec 2018	380.9	Jan-Dec 2019	250.5	250.5	192.1	192.1
531006c	Greenhouse gas/ pollution emissions spared annually by battery busses replacing diesel busses: (c) NOx.	Kg	34.76	Jan-Dec 2017	34.76	Jan-Dec 2017	130,61	Jan-Dec 2018	101.57	Jan-Dec 2019	66.81	66.81	192.2	192.2
531006d	Greenhouse gas/ pollution emissions spared annually by battery busses replacing diesel busses: (d) SOx.	Metric tonnes	0.43	Jan-Dec 2017	0.43	Jan-Dec 2017	1.64	Jan-Dec 2018	1.28	Jan-Dec 2019	1.21	1.21	281.4	281.4
531006e	Greenhouse gas/ pollution emissions spared annually by battery busses replacing diesel busses: (e) PM10.	Kg	0.25	Jan-Dec 2017	0.25	Jan-Dec 2017	0.97	Jan-Dec 2018	0.83	Jan-Dec 2019	0.58	0.58	232	232
531006f	Greenhouse gas/ pollution emissions spared annually by battery buses replacing diesel buses: (e) PM.	Kg	0.11	Jan-Dec 2017	0.11	Jan-Dec 2017	0.41	Jan-Dec 2018	0.32	Jan-Dec 2019	0.21	0.21	190.91	190.91
531007a	Annual number of passengers in relevant fleet (Nord_Jæren)	Passengers	15748742	Jan-Dec 2017	15748742	Jan-Dec 2017	17588188	Jan-Dec 2018	21100700	Jan-Dec 2019	5351958	5351958	33.98%	33.98%
531007b	Mean number of km travelled pr passengers	Km	3.11	Jan-Dec 2017	3.11	Jan-Dec 2017	5.33	Jan-Dec 2018	5.38	Jan-Dec 2019	2.27	2.27	72.99%	72.99%

531007c	Variance of km travelled per passenger	Dimensionless decimal	Data not available yet	Jan-Dec 2017		Jan-Dec 2017		Jan-Dec 2018	Data not available	Jan-Dec 2019	Data not available			
531008a	Total number of annual run kilometres per diesel bus	Km	68074	Jan-Dec 2017	68074	Jan-Dec 2017	67018	Jan-Dec 2018	66956	Jan-Dec 2019	-1118	-1118	-1.64%	-1.64%
531008b	Total number of annual run kilometres per battery bus	Km	9656.8	Jan-Dec 2017	9656.8	Jan-Dec 2017	36281.84	Jan-Dec 2018	28213.1	Jan-Dec 2019	18556.3	18556.3	192.15%	192.15%

Table 5.3.4: Impact assessment for Module 531

5.3.2 Module 532: Electric vehicle charging (Subtask 5.3.2)

The implementation dates of the module

The module was implemented in August 2017 and has been operating at the 10 households since. Although one of them does not communicate data and despite numerous attempts, it has been impossible to get in touch with the pilot household.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

The module aims to support the use of electric vehicles in road traffic. This indirectly supports the reduction of greenhouse gas emissions, by removing the need for combustion engine vehicles. Thus, the energy provided via EV charging could be used to estimate obviated greenhouse gas emissions. However, the type of combustion engine vehicle that has been replaced by such an electric vehicle is not obvious, and hence determining a relevant coefficient for estimating obviated greenhouse gas emissions is not simple. Nevertheless, the energy provided to EVs represents an impact on more sustainable mobility in the smart city.

Some of the data have been lacking from the households because the relevant data on EV charging had to be accessed via subcontractor Zaptec - the supplier of the smart chargers.

Changes since last report (M48)

No significant change.

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
532001	Installation of charging capacity	Number of chargers installed.	Dimensionless integer	Lyse EV charger dataset	Y
532002	Energy consumption via EV charger	Number of charging events per year	Dimensionless integer	Lyse EV charger dataset	
532003	Energy consumption via EV charger	Mean of time per charging event	Minutes	Lyse EV charger dataset	N
532004	Energy consumption via EV charger	Variance of time per charging event	$Minutes^2$	Lyse EV charger dataset	N

Table 5.3.5: Impact assessment indicators description for Module 532

Dataset Number	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
53200A	Lyse EV charger dataset	Collection of sensor data from EV chargers installed as part of module.	532001 532002 532003 532004	Lyse	Sindre Tøsse (Sindre.Tosse@lyse.no)	Transfer to CDP may depend on extra resources to contract third-party data processor to undertake GDPR-compliant anonymization. After evaluation by an external data expert of the potential need for Privacy Impact Assessment, it was determined that this was not necessary given that data shared to UiS CDP does not provide a way to re-identify the homes where the smart gateways were installed.	

Table 5.3.6: Datasets description for Module 532

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
532001	Installation of charging capacity	Dimensionless integer	N/A											
532002	Energy consumption via EV charger	Dimensionless integer	1523	Dec 2017-Jan 2019			1523	Dec 2017-Jan 2019	N/A	Feb 2019 – Nov 2019	0	0	0%	0%
532003	Energy consumption via EV charger	Minutes	672	Dec 2017-Jan 2019			672	Dec 2017-Jan 2019	N/A	Feb 2019 – Nov 2019	0	0	0%	0%
532004	Energy consumption via EV charger	Minutes[2]	383000	Dec 2017-Jan 2019			383000	Dec 2017-Jan 2019	N/a	Feb 2019 – Nov 2019	0	0	0%	0%

Table 5.3.7: Impact assessment for Module 532

5.4 ICT Modules

The ICT task group has developed four modules to demonstrate the potential of ICT as an enabler of innovation within Stavanger.

Hence, the module descriptions and proposed impact indicators presented below have been revisited and revised as the module scope was refined throughout the implementation period.

- ~~*Module 541: Innovative video (BLINK)*~~*.* This module was removed, as it has been moved into WP6.
- *Module 542: Data analytics toolkit.* This module focuses on using ICT and data to provide useful calculations and analytics. The module implementation has in effect been primarily in support of WP2 impact reporting. The module has showcased its utility for citizens and businesses to visualize their data and extract value from it.
- ~~*Module 543: Sustainable citizen service development.* Offering citizens decision support based on open data, via household display and/or apps. Providing truly personalized decision support would depend on the app interacting with correctly identified specific users over time.~~ This module has been reported without impacts due to GDPR concerns on the part of the data holder.
- *Module 544: Cloud data platform.* This module is developed to collect and maintain data from the Lighthouse cities in support of WP2 impact reporting. In the future, it is hoped to develop into providing computation capabilities to registered external users in the partnership.

Table 5.4.1 presents a summary of the expected impacts of each module, followed by detailed module descriptions. Note that the analytics toolkit is expected to enable impacts in all city objectives, but the realization of this indirect impact depends on external users exploiting the analytics toolkit. Since the data analytics toolkit depends on the cloud data platform, it will also have a tertiary indirect effect to the extent that the potential of the analytics toolkit is tapped.

Task Group	**Module**	**Expected impacts**				
		Reduce energy consumption of buildings	Increase utilisation of electric vehicles	Holistic residential solutions	Increase energy efficiency	Fostering citizen engagement with digital infrastructure
ICT	Module 541: Innovative video.					*
	Module 542: Data analytics toolkit.					*
	Module 543: Sustainable citizen service					*
	Module 544: Cloud data platform.					*

Table 5.4.1: Expected impacts of Stavanger ICT modules

5.4.1 Module 542: Data analytics toolkit (Subtask 5.4.2)

The implementation dates of the module

The module was designed and developed as far as possible in tandem with Module 544, on which Module 542 depends, from M09 through M32. Module 542 was implemented in M33 and is subsequently operating as a deployment on the CIPSI Computing Platform (CCP) at UiS, interfacing with the data collection framework in Module 544, also deployed on CCP.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

Changes since last report (M48)

- The dashboard is accessible from outside UiS

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
542001	Provision of analytics tools	Number of analytics tools	Dimensionless integer	Value of impact indicator reported directly by module task group contact.	N
542002	Utilization of analytics toolkit	Total number of registered users	Dimensionless integer	Value of impact indicator reported directly by module task group contact.	N
542003	Utilization of analytics toolkit	Number of external users	Dimensionless integer	Value of impact indicator reported directly by module task group contact.	N
542004	Utilization of analytics toolkit	Number of users for each demo service	Dimensionless integer	Value of impact indicator reported directly by module task group contact.	N
542005	Utilization of analytics toolkit	Number of apps for end users that involve the analytics toolkit	Dimensionless integer	Value of impact indicator reported directly by module task group contact.	N
542006	Utilization of analytics toolkit	Number of Triangulum modules that use the analytics toolkit	Dimensionless integer	Value of impact indicator reported directly by module task group contact.	N
542007	Utilization of analytics toolkit	Number of impact indicators calculated by data analytics toolkit for WP2 reporting.	Dimensionless integer	Value of impact indicator reported directly by module task group contact.	N
542008	Provision of analytics tools	Resources (e.g. number of vCPUs) supporting Module 542 on CCP.	Dimensionless integer	Value of impact indicator reported directly by module task group contact.	N

Table 5.4.2: Impact assessment indicators description for Module 542

Dataset name	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
54200A	Cloud Data Hub development and usage	Value of impact indicator reported directly by module task group contact.	542001 542002 542003 542004 542005 542006 542007 542008	University of Stavanger	Faraz Barzideh (faraz.barzideh@uis.no)	Documented in this report after inspecting system manually. Does not exist as an organized dataset.	
54200B	Data processing framework self-monitoring	The module is currently operating without self-monitoring of operationally relevant quantities.	None.	University of Stavanger	Faraz Barzideh (faraz.barzideh@uis.no)	Does not exist as an organized dataset. Some of the currently formulated impact indicators may be suitable for reporting via module self-monitoring data, but new impact indicators may be more valuable to develop along with self-monitoring.	

Table 5.4.3: Datasets description for Module 542

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	Derived rate of absolute change (p.a.)	Relative change	Derived rate of relative change (p.a.)
542001	Number of datasets stored in the platform	Dimensionless integer	2	Jan 2018	2	Jan 2018	4	Jan 2019	4	Jan 2020	2.0	2.0	+100%	+100%
542002	Total number of registered users	Dimensionless integer	2	Jan 2018	2	Jan 2018	2	Jan 2019	6	Jan 2020	4	4	+200%	+200%
542003	Number of external users	Dimensionless integer	0	Jan 2018	0	Jan 2018	0	Jan 2019	0	Jan 2020	0.0	0.0	n/a	n/a
542004	Number of users for each demo service	Dimensionless integer	2	Jan 2018	2	Jan 2018	2	Jan 2019	6	Jan 2020	4	4	+200%	+200%
542005	Number of apps for end users that involve the analytics toolkit	Dimensionless integer	0	Jan 2018	0	Jan 2018	0	Jan 2019	0	Jan 2020	0.0	0.0	n/a	n/a
542006	Number of Triangulum modules that use the analytics toolkit	Dimensionless integer	0	Jan 2018	0	Jan 2018	2	Jan 2019	2	Jan 2020	0.0	0.0	n/a	n/a
542007	Number of impact indicators calculated by data analytics toolkit for WP2 reporting.	Dimensionless integer	1	Jan 2018	1	Jan 2018	35	Jan 2019	35	Jan 2020	34.0	34.0	+3400%	+3400%
542008	Resources (e.g. number of vCPUs) supporting Module 542 on CCP.	Dimensionless integer	6	Jan 2018	6	Jan 2018	16	Jan 2019	16	Jan 2020	10.0	10 .0	+160%	+160%

Table 5.4.4: Impact assessment for Module 542

5.4.2 Module 543: Sustainable citizen service development (Subtask 5.4.3)

The implementation dates of the module

The module was implemented in January 2016 and has been operating in the households since.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

The module aims to have an impact of providing services to citizens who have volunteered to participate in the module task. The planned services include personalized home display, push button, and decision support (for sustainable transport choices). The impact of the module can be documented as the number of installations of each service, but due to the personal nature of user data, the potential of inferring secondary impacts is limited.

GDPR privacy issues caused some constraints, as pointed out above in 5.3.2.1.2.

Changes since last report (M48)

No significant changes

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
543001	Utilization of module technology	Number of buildings with software installed	Dimensionless integer	Currently unknown.	N
543002	Utilization of module technology	Number of buildings with hardware installed	Dimensionless integer	Currently unknown.	N
543003	Utilization of module technology	Mean of number of times used per day	Dimensionless decimal	Currently unknown.	N
543004	Utilization of module technology	Variance of number of times used per day	Dimensionless decimal	Currently unknown.	N

Table 5.4.5: Impact assessment indicators description for Module 543

Dataset number	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps taken
54300A	Home decision support	Lyse sustainable citizen service dataset	543001 543002 543003 543004	Lyse	Sindre Tøsse (sindre.tosse@lyse.no)	Transfer to CDP may depend on extra resources to contract third-party data processor to undertake GDPR-compliant anonymization.	

Table 5.4.6: Datasets description for Module 543

Impact indicator identifier	**Impact indicator**	**Quant. Unit.**	**Baseline value**	**Baseline value period**	**M36 value**	**M36 value period**	**M48 value**	**M48 value period**	**M48 value**	**M48 value period**	**Absolute change (Baseline to M60)**	**Derived rate of absolute change (p.a.)**	**Relative change**	**Derived rate of relative change (p.a.)**
543001	Number of buildings with software installed	Dimensionless integer	No data	January 2015	No data	Jan 2018	No data	Jan 2019	No data	No data				
543002	Number of buildings with hardware installed	Dimensionless integer	No data	January 2015	No data	Jan 2018	No data	Jan 2019	No data	No data				
543003	Mean of number of times used per day	Dimensionless decimal	No data	January 2015	No data	Jan 2018	No data	Jan 2019	No data	No data				
543004	Variance of number of times used per day	Dimensionless decimal	No data	January 2015	No data	Jan 2018	No data	Jan 2019	No data	No data				

Table 5.4.7: Impact assessment for Module

5.4.3 Module 544: Cloud data platform (D2.2)

The implementation dates of the module

The module was designed and developed from M09. Implementation began in earnest in M25, and an operational proof-of-concept was deployed from M33 and has been operating since.

Factors limiting progress towards establishing the baseline, defining the approach to calculating impacts, and identifying associated datasets

The module impacts the domain of ICT by providing resources to project partners and registered external users. The Cloud data platform provides on-demand access to a shared pool of storage, computational, and networking resources that constitute the CIPSI Computing Platform (CCP) at UiS. The module impact indicators are defined according to nominal capacities and actual utilization of these resources.

The impact indicators for this module are based on allocated resources. Currently, they are sufficient and so there has been no change in the values.

Progress since last report (M48)

Nothing significant

Impact indicator identifier	Impact	Impact indicator	Quant. unit	Datasets to be used in impact calculation	Aligned with SCIS?
544001	Data storage capacity	Nominal hardware storage capacity, HDD	Terabytes	UiS Triangulum cloud data platform interface	N
544002	Data storage capacity	Nominal hardware storage capacity, SSD	Terabytes	UiS Triangulum cloud data platform interface	N
544003	Data storage utilization	Number of Triangulum partners providing data via DIF specifications	Dimensionless integer	UiS Triangulum cloud data platform interface	N
544004	Computational capacity /resources	Number of physical cores	Dimensionless integer	UiS Triangulum cloud data platform interface	N
544005	Computational capacity /resources	Estimated number of virtual machines (VMs) possible	Dimensionless integer	UiS Triangulum cloud data platform interface	N
544006	Network capacity	Full bisection bandwidth	Gigabits per second	UiS Triangulum cloud data platform interface	N

Table 5.4.8: Impact assessment indicators description for Module 544

Dataset number	Dataset name	Dataset description	Required for impact calc. for indicators:	Dataset owner	Dataset contact	Comments	WP2 steps
54400A	UiS Triangulum cloud data platform interface	Value of impact indicator reported directly by module task group contact.	544003	University of Stavanger	Faraz Barzideh (faraz.barzideh@uis.no)	It may be possible but not necessarily useful to programmatically extract the number of unique indices stored at the CDP, but this number may not be guaranteed to reflect impact indicator 544003 as conceptualized without additional intervention or quality control.	UiS researchers de 544003 and additi indicators based o self-monitoring da collected.
54400B	The module is currently operating without self-monitoring of operationally relevant quantities.	None.	University of Stavanger	University of Stavanger	Speculative, does not exist as an organized dataset. Some of the currently formulated impact indicators may be suitable for reporting via module self-monitoring data, but new impact indicators may be more valuable to develop along with self-monitoring.		
54400C	Data centre requirements specification	Value of impact indicator reported directly by module task group contact.	544001-002 544004-006	University of Stavanger	Faraz Barzideh (faraz.barzideh@uis.no)		

Table 5.4.9: Datasets description for Module 544

Impact indicator identifier	Impact indicator	Quant. Unit.	Baseline value	Baseline value period	M36 value	M36 value period	M48 value	M48 value period	M60 value	M60 value period	Absolute change (Baseline to M60)	De ab ch
544001	Nominal hardware storage capacity, HDD	Terabytes	60.0	Feb 2017 – Dec 2017	60.0	Feb 2017 – Dec 2017	60.0	Jan 2018-Dec 2018	60.0	Jan 2019-Dec 2019	0.0	0.
544002	Nominal hardware storage capacity, SSD	Terabytes	1.6	Feb 2017 – Dec 2017	1.6	Feb 2017 – Dec 2017	1.6	Jan 2018-Dec 2018	1.6	Jan 2019-Dec 2019	0.0	0.
544003	Number of Triangulum partners providing data via DIF	Dimensionless integer	1	Feb 2017 – Dec 2017	5	Feb 2017 – Dec 2017	5	Jan 2018-Dec 2018	5	Jan 2019-Dec 2019	4	4
544004	Number of physical cores	Dimensionless integer	20	Feb 2017 – Dec 2017	20	Feb 2017 – Dec 2017	20	Jan 2018-Dec 2018	20	Jan 2019-Dec 2019	0.0	0.
544005	Estimated number of virtual machines (VMs) possible	Dimensionless integer	160	Feb 2017 – Dec 2017	160	Feb 2017 – Dec 2017	160	Jan 2018-Dec 2018	160	Jan 2019-Dec 2019	0.0	0.
544006	Full bisection bandwidth	Gigabits per second	40.0	Feb 2017 – Dec 2017	40.0	Feb 2017 – Dec 2017	40.0	Jan 2018-Dec 2018	40	Jan 2019-Dec 2019	0.0	0.

Table 5.4.10: Impact assessment for Module 544

6 District Level Monitoring

6.1 Approach to District Level Monitoring

The district-level monitoring approach for Triangulum comprises the aggregation of module-level impacts across each of the four innovation districts in the Lighthouse Cities. The following sections provide an overview of the innovation districts and the aggregated impact indicators for each one:

- Oxford Road, Manchester
- Strijp-S, Eindhoven
- Echart-Vaartbroek, Eindhoven
- Paradis/Hillevag, Stavanger

For each district amalgamated impacts from the modules are mapped onto the district level objectives as identified in the D2.3 baseline report.

6.2 Manchester

6.2.1 Introduction to Manchester Oxford Road district

The Corridor district is central to Manchester's knowledge economy and home to numerous knowledge-intensive enterprises and organisations. These actors create value in sectors including education, health, digital innovation, low carbon technologies, advanced materials, finance and the creative industries. The Corridor itself is a 243Ha area running south from St Peter's Square to Whitworth Park along Oxford Road with 70,000 students and 60,000 workers are based within this area. Corridor Manchester was formed in 2007 to generate growth and investment within the area, and was the first partnership of its kind in the UK. It now brings together key stakeholders within the district including Manchester City Council (MCC), The University of Manchester, Manchester Metropolitan University (MMU), Central Manchester University Hospitals NHS Foundation Trust (CMFT), Bruntwood, Manchester Science Partnerships (MSP), ARUP and The Royal Northern College of Music (RNCM). Three members of Corridor Manchester - MCC, UNIMAN and MMU – are members of the Triangulum consortium; alongside industry partners Siemens and Clicks and Links.

The objective of Corridor Manchester is, by 2025, for the district to be become "Manchester's cosmopolitan hub and world-class innovation district, where talented people from the city and across the world learn, create, work, socialise, live and do business; contributing to the economic and social dynamism of one of Europe's leading cities.". Furthermore, smart city initiatives that increase the social and environmental sustainability of the Corridor (such as the Triangulum modules) are expected to play an important role in achieving this objective. For example, the transformation of a section of Oxford Road to limit general traffic (i.e. cars and delivery vehicles) will promote a modal shift to public transport, cycling and walking within the Corridor. Other major programmes in planning or delivery include:

- the redevelopment of Oxford Road rail station;

- the redevelopment of the UNIMAN Northern campus and the MMU campus (including the John Dalton Complex);
- the extension of the Manchester Science Partnerships campus and the development of Clusterlabs 2 and 3 (part of the Life Science Enterprise Zone);
- the development of a new hospital through a £50m partnership between Nuffield Health and Manchester Metropolitan University;
- the redevelopment of a form BBC (British Broadcasting Corporation) site and First Street;
- the development of the Graphene Engineering Innovation Centre and Sir Henry Royce Advanced Materials Institute.

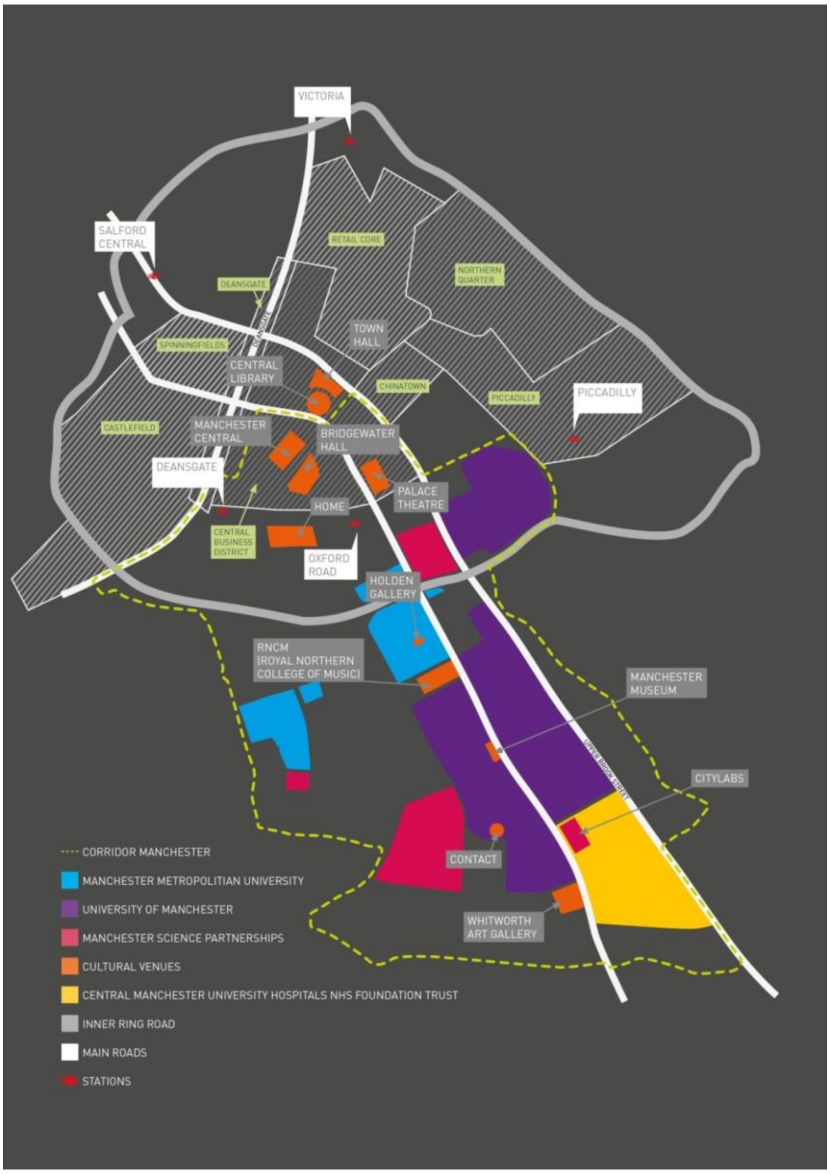


Figure 6.2.1: A map of the Corridor district

6.2.2 Aggregated Impacts at District Level

The following table presents aggregated module-level impacts across the district objectives for the Manchester Oxford Road district.

Task Group	Module	Contribution to district objectives						
		Reducing emissions of air quality pollutants	Reducing traffic congestion	Reducing carbon emissions	Reducing energy costs for partner organisations	Fostering economic growth	Developing a digital infrastructure	Fostering citizen engagement with digital infrastructure
Energy	321: Central energy controller			-1,835 tCO_2e	+£192,560			
	322: Energy optimisations in buildings			-412 tCO_2e	+£32,244			
	323: Additional energy resources			-34 tCO_2e	+£206,151			
Mobility	331: Electric vehicle procurement	-11,325g NOx -72,783g CO		-35.11 tCO_2e				
	332: Electric assist cargo bikes	-2,115g NOx -13,223g CO	4,493 car journeys replaced	-3.07 tCO_2e				
ICT	341: Data curation service					*	296 real time data feeds	616 downloads 479 users
	342: Data visualisation platform					*	4 visualisation platforms	+100 users
	343: Data-driven innovation challenges					6 apps developed	3 Innovation Challenges held	+50 participants

Table 6.2.1: Matrix mapping amalgamated module-level impacts against the Manchester Oxford Road objectives as set out in D2.3 baseline report

6.3 Eindhoven

Smart technology demonstrations have been implemented in two innovation districts within Eindhoven as part of Triangulum: Strijp-S and Eckart-Vaartbroek. The following sections outline each district in turn. The table below sets out which modules have been implemented in the two districts.

District	Module identifier	Module name
Strijp-S	421	Sustainable energy supply and soil sanitation
	422	Optimization of heat provision in existing buildings
	423	Smart energy for offices
	431	Smart charging of electric vehicles
	432	Mobility management
	441	Eindhoven smart city ICT open data platform
	443	Smart environment fibre-optic data infrastructure
	444	Public space sensor network
	445	Smart city innovation fund
Eckart-Vaartbroek	424	Renovation of family homes & creation of participative society
	442	Interactive energy retrofit for dwellings
	446	Smart streetlights for social interaction and health route

6.3.1 Introduction to Strijp-S

Stijp-S lies inside the ring road close to the city centre and Eindhoven Strijp-S station. Strijp-S comprises 27 hectares and is recognizable by 150,000 m2 of industrial heritage. The core of Strijp-S is formed by a sixty-meter wide urban iconic axis through the complex called 'Torenallee'. It has many trees, public spaces, with characteristic street lighting and furniture, ornamental kiosks, and two sculptural buildings. Parallel to the Torenallee are two urban boulevards with wide profiles and many trees which serve as high quality addresses for the new estates. Alongside one of the boulevards is an intimate square with various restaurants and bars and a multi-purpose field. It used to be a closed industrial site within the city, where Philips conducted R&D and produced consumer goods. The history of Strijp-S is closely intertwined with the growth of Philips and the local and regional economy.

The revitalization of the Philips Company's former industrial and business complex transformed the area into a new urban quarter to live, work, and play. The redevelopment of the area started in 2000 when Philips suspended its operations. Philips sold Strijp-S to Park Strijp Beheer in 2004. The buildings that were still in use by Philips were hired back. Since 2006, the redevelopment of Strijp-S has been ongoing. Existing buildings were demolished and new activities were introduced, notably the creative industries and the annual Dutch Design Week. A strong characteristic of the new neighbourhood is the combination of existing buildings with new buildings. In 2013, Strijp-S was honoured with the Dutch Gulden Feniks (Golden Phoenix) award in the 'Area Transformation' category. From 2010 to 2020, 15 building construction projects are planned in Strijp-S.

The development of Strijp-S is segmented into several phases. A visualization of the phases can be found at: http://www.strijp-s.nl/nl/ontwikkeling. Strijp-S will eventually include 285,000 m2 of residental áreas including studio, apartments, city dwellings, lofts; 90,000 m2 of offices; 30,000 m2 of comercial/leisure; and 30,000m2 of additional space. Temporary use is one of the characteristics which makes Strijp-S unique. It prevents decay and makes sure the complete area stays alive while it is being developed. Therefore Strijp-S has to be seen as one big organization, which is going to be upgraded in 4 phases. Original Schedule - Phase 1: 2010-2015; Phase 2: 2011-2016; Phase 3: 2013-2018; and Phase 4: 2020-2030.

The most essential part of the Strijp-S Masterplan is the area called ‘De Driehoek’ (the triangle). This area houses the catalysts from Strijp-S and is currently under development. The planned developments in ‘De Driehoek’ include:

- 2010: Klokgebouw (mixture of offices, studios, event locations, and a hotel)
- 2011: Apparatenfabriek (commercial functions on the lower level, a mix of offices and studios on the upper levels)
- 2011: Ketelhuis (restaurant, studio, exposition)
- 2012: Machinekamer (restaurant)
- 2013: Anton & Gerard (commercial functions on the lower level, mixture of dwelling, studio’s and offices on the upper levels)
- 2013: Leidingstraat (urban boulevard)
- 2015: Veemgebouw (food market, restaurants and parking)
- 2016: Kashba (small buildings with commercial activities on the lower level and apartments on the upper level)
- 2018: Angle (commercial functions on the lower level, apartments on the upper levels)
- 2018: City (commercial functions on the lower level, apartments on the upper levels)
- 2018: Condo (commercial functions on the lower level, apartments on the upper levels)
- 2020: Einstein (commercial functions on the lower level, student apartments on the upper levels)
- 2020: The Box / Transferium (parking garage with several commercial functions on the lower level)
- 2020: Tower (city icon, about100m tall, apartments and lofts with commercial functions on the main floor)
- 2020: Village (small buildings which combine commercial activities on the lower level and apartments on the upper level)

In the final Masterplan, ‘De Driehoek’ will house both ‘giants’ and ‘dwarfs’. The ‘giants’ will impress passengers and citizens, and function like icons which serve the collective memory of Eindhoven, while the ‘dwarfs’ provide room for a more humanistic scale.

Park Strijp Beheer (a joint venture between VolkerWessels (VW) and Eindhoven Municipality), Spoorzone bv (joint venture between Volker Wessels and ING), Trudo, Woonbedrijf and de Koning Beleggingen bv are jointly working on the development of Strijp-S. The objective of the partnership is to realise a vibrant, multifunctional, open and creative urban environment that can serve as a European Smart City Lighthouse District (Figure 6). In addition, the location of the area in the city requires an approach focusing on the reuse of existing infrastructures for an optimal support to create a mixed use area of citizens, SMEs and creative start-ups and entertainment serving the new economy. The economy will be sustainable in terms of energy consumption and mobility. Based on open innovation and co-creation work on the development and implementation of new energy service concepts, Strijp-S will be developed into an innovative Smart Energy Business City with an international reputation.

Figure 6.3.1: Development of Strijp-S (2015 - 2030)

6.3.2 Aggregated Impacts at District Level

The following table presents aggregated module-level impacts across the district objectives for the Strijp-S district.

Task group	Module (task number: module name)	Contribution to district objectives						
		Reducing energy consumption	Reducing carbon emissions	Developing a digital infrastructure	Improving mobility	Fostering citizen engagement (Co-creation)	Improving the quality of life	Sustainable economy
Energy	4.2.1: Sustainable energy supply and soil remediation	*	*					
	4.2.2: Optimization heat provision existing build	-1,800 GJ per month	-155,000 kg per month					
	4.2.3: Smart energy savings offices	* not available	*	29 sensors installed		*	*	
Mobility	4.3.1: Smart charging of electric vehicles			14 charging stations	*		*	
	4.3.2: Mobility management		*?	Real time information and reservation system	231 parking spaces removed		25% increase in green alternatives	
ICT	4.4.1: EHV facilitation smart city open data platform			50% more database portals 40% more data files		823 more API calls per month	c. 75,000 more views per month c. 4,000 downloads per month	
	4.4.3 Smart environment fibre-optic data infrastructure			Connected: 37,050 offices 350 homes 18 lamp posts		2 data types available	30 users	
	4.4.4: Sensor network in the public space			7 sound sensors 18 video sensors 15 water sensors		5 apps	20 citizens involved	

	4.4.5: Smart city innovation fund							28 SMEs stimulated €50m spend p.a.

Table 6.3.1: Matrix mapping amalgamated module-level impacts against the Strijp-S objectives as set out in D2.3 baseline report

6.3.3 Introduction to Echart-Vaartbroek

This area is a more traditional district, with thousands of single-family houses, many of which fall under social housing, constructed in the late 1960s and 1970s. In that period, Eindhoven and the rest of the Netherlands experienced rapid economic and population growth. Eckart-Vaartbroek is a good example of modern urban development characterized by a strict hierarchy in street layout, segregation of duties and the application of building templates. The district has its own amenities including schools, community centres, churches and shopping centres. Today, the district has a total of 4,553 houses in the selected area, 1.900 of which are owned and managed by the housing corporation Woonbedrijf, one of the partners in the Eindhoven consortium. The other houses, including 2653 apartments, are owned privately or by other housing organisations. The owner-occupied houses are located mainly on the outer edges of the district. The rented houses/apartments are located in the heart of the area around Almond Park.

Various social issues and problems exist in the neighbourhood. The significant issue for the district is that the family as the fundamental unit of society is now outdated. In Vaartbroek-Eckart this is noticeable problem. The housing, services, public space and social atmosphere do not fit well with the current mix of the population. The original inhabitants, many of whom are senior citizens, contrasts with the new groups of residents, young middle class families, often from other cultural backgrounds – request a quality upgrade of public space and social environment. Households now also have a different household composition in this area than when the neighbourhood was built. Traditionally the household consisted of a husband, wife and 2-4 children. Now the area includes many single-parent families, cohabiting couples and singles. Another problem involves security. The number of burglaries in the area is relatively high. This is partly due to the spatial design of the area, which has difficulty for community watching (the visibility in and around the parks is not good). Districts such as Eckart-Vaartbroek are numerous in Eindhoven as well as in other Dutch and European cities and are currently in transition. With an ageing and less wealthy population and an influx of residents with different ethnic backgrounds, this district is almost the opposite of Strijp-S.

The partners in Eckart-Vaartbroek include the municipality, Basisschool de Bijenkorf, Spilcentrum Mirabel, Woman Fight Club, Gezondheidscentrum Airborne, Lumensgroep, Parochie Woensel-Oost, Politie Woensel-Noord, Stadsdeelteam Woensel-Noord, Steunpunt 55+, Stichting wijkactiviteit Vaartbroek, Stichting zesde kolonne, Wijkraad Vaartbroek, Heesterakker & Bokt, Woonbedrijf, Wooninc., and De Cabine. The objective of the partnership is to improve the quality of life of residents in Eckart-Vaartbroek. To achieve this goal, the integration of citizens, urban planners, social groups and social housing providers are jointly developing the area. Woonbedrijf is one of the partners in Eckart-Vaarbroek and is also in the Eindhoven Triangulum consortium. Woonbedrijf are leading on the upgrade of around 200 to 250 houses in the area from energy label E and F to B (or higher). Eindhoven municipality will also cooperate closely with Woonbedrijf to improve public spaces and install renewable energy facilities.

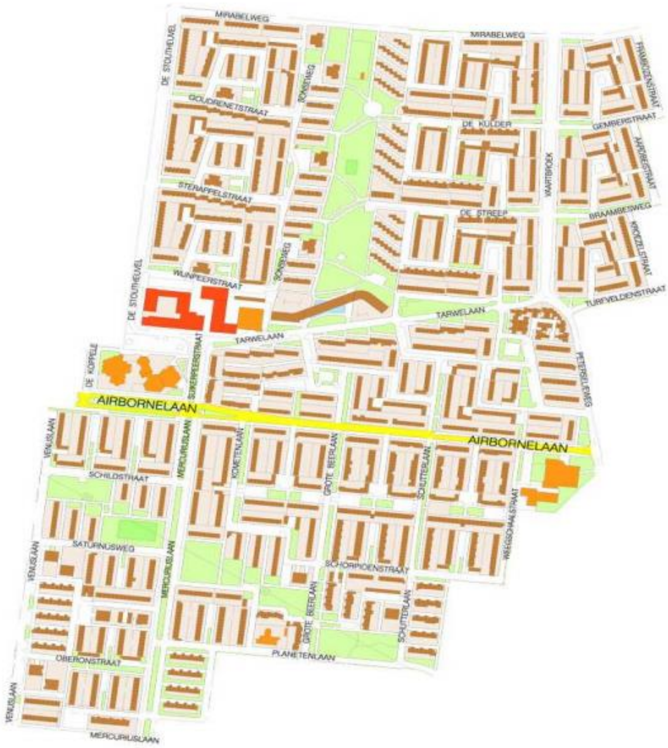


Figure 6.3.2: Map of Eckart-Vaartbroek (2015)

6.3.4 Aggregated Impacts at District Level

The following table presents aggregated module-level impacts across the district objectives for the Eckart-Vaartbroek district.

Task group	Module (task number: module name)	Contribution to district objectives					
		Reducing energy consumption	Reducing carbon emissions	Developing a digital infrastructure	Fostering citizen engagement (Co-creation)	Improving the quality of life	Fostering sustainable economy
Energy	4.2.4: Renovation of family homes Eckart - Vaartbroek & creation of participative society	*	-0.28 kg p.a. per m^2		*	-20% energy bill costs	
ICT	4.4.1: EHV facilitation smart city open data platform (as in Strijp-S table)			50% more database portals 40% more data files		823 more API calls per month	c. 75,000 more views per month c. 4,000 downloads per month
	Module 4.4.2: Interactive process for dwellings in Eckart-Vaartbroek				993 digital keys 284 keys activated	174 households made a renovation scenario	
	Module 4.4.6: Smart streetlights social interaction & health route			31 installed	99 citizens involved	*	

Table 6.3.2: Matrix mapping amalgamated module-level impacts against the Eckart-Vaartbroek objectives as set out in D2.3 baseline report

6.4 Stavanger

6.4.1 Introduction to Paradis/Hillevag

Stavanger holds the status as the European capital of Energy. The city aims at becoming one of Europe's foremost sustainable cities by integrating ICT, energy and mobility. The city of Stavanger has a long tradition of citizen involvement, which is crucial for developing smart, integrated solutions.

Stavanger has a well-developed ICT business cluster. The experience from deliveries to offshore industry combined with high speed fibre optics have led the region ahead to service development based on existing infrastructure in an innovative way. As the region expects a population growth of approximately 30% by 2030, integrated solutions will be the key to develop smart and sustainable solutions for citizens. The energy system is almost totally based on renewable sources (hydroelectric), hence energy storage is established through the fjord, lakes and falls connected to the production system. Smart grid components include load management, surveillance and data analysis.

In some relevant parts of the city, 60% of houses already have high-speed fibre solutions installed. The next step of transformation is integration by installing the smart generic gateway in public buildings and private homes. Stavanger holds the highest density of electrical cars in Europe, and the charging challenge for electrical vehicles is already a pressing issue. Through a variety of energy and mobility demos which build on the existing high speed ICT infrastructure, Stavanger aims at integrating energy and mobility solutions in an innovative and smart way. Citizens and replication are at the centre of the integration aim

In addition to Triangulum, Stavanger is the site of smart city initiatives including:

1. Smart City initiative led by the municipality to heat commercial buildings as well as municipal buildings in the city centre.
2. Nordic Edge Expo, an annual conference to promote knowledge exchange between businesses and other actors in the field of smart homes and smart cities.
3. Local start-up culture focusing on smart homes and smart cities, with events such as the Startupbootcamp Smart City & Living program.
4. Open data project in the city, including cooperation with Stavanger Hackathon.
5. VOF, an app where citizens can give information about errors in the municipal infrastructure.
6. Some parts of the city have installed waste containers with automatic sensors providing information about the amount of waste in the containers, and whether there is a need for waste collection.

Figure 6.4.1: Aerial graphic of Paradis/Hillevag area

6.4.2 Aggregated Impacts at District Level

The following table presents aggregated module-level impacts across the district objectives for the Paradis/Hillevag district.

Task Group	Module	Contributing to efforts to achieve objectives				
		Reduce energy consumption of buildings	Increase utilisation of electric vehicles	Holistic residential solutions	Increase energy efficiency	Fostering citizen engagement with digital infrastructure
Energy	Module 521: Smart gateway	-3,338 kWh p.a.			*	
	Module 522: Central energy plant	-1.6 million kWh p.a by swimming pool -1.37 million NOK total energy cost			-88% CO_2	
Mobility	Module 531: E-bus demonstration		18.5K km travelled per bus p.a. 2.3 km increase in journeys per user		135 tCO_2e saved p.a.	
	Module 532: Electric vehicle charging infrastructure upgrade		672 minutes consumption per charger		*	
ICT	Module 542: Data analytics toolkit					100% more datasets stored 200% more registered internal users
	Module 543: Sustainable citizen service development (no data due to GDPR issues)	*		*		*
	Module 544: Cloud data platform					60 TB storage

Table 6.4.1: Matrix mapping amalgamated module-level impacts against the Paradis/Hillevag objectives as set out in D2.3 baseline report

6.5 Assessing the Value of Triangulum Innovation Districts

The Triangulum project has deployed innovative technologies across four innovation districts that have delivered impacts that address all stated city objectives identified in D2.3 Baseline Report. This shows the effectiveness of innovation districts as spaces that can enable innovation through providing a supportive institutional environment. The challenge of innovating in a constrained geographical area is that benefits only accrue directly to the communities and organisations within that area. Ensuring innovations roll-out across other parts of the city is essential in terms of spreading benefits and contributing to the scaling up of impacts that is required to transform cities in the ways that are needed to meet climate change and green economy goals (Hodson et al. 2018[4]). The next section addresses these challenges by focusing on the softer impacts of the Triangulum project at the city level, which underpin the ability of the project to 'spread' its influence from the innovation districts to the wider city.

[4] Hodson, M., Evans, J. and Schliwa, G., 2018. Putting Urban Experiments into Context: Integrating urban living labs and city-regional priorities. In *Urban Living Labs* (pp. 37-51). Routledge.

7 City Level Monitoring

7.1 Approach to City Level Monitoring

City Level Monitoring (CLM) has been carried out to explore how the Triangulum project has impacted on the six participating cities in a variety of tangible, and less tangible, ways. This includes process learning, spin-off benefits, and mapping impacts against local policy drivers. The CLM approach has not sought to offer a quantitative or aggregated set of impact indicator results for each city, as this is already covered in the District Level Monitoring section. Rather, it attempts to capture the wider range of organisational changes and impacts that are required to underpin an urban transformation. This more innovative approach to city level impacts is a response to the huge increase in interest in urban transformation towards zero carbon cities since the project was conceived in 2014, and the growing interest of our city partners in WPs 3-5 concerning the learning that they have made through the process of implementing the project. Through consecutive GAs and other events since year two of the project, municipalities in particular have been highlighting this as the key impact on their city generated by involvement in the Triangulum project.

The CLM methodology has combined the following elements:

1. **Leveraged investments and wider value impacts**: tracking the spin-off benefits leveraged as a result of Triangulum, including inward investment, events, and jobs supported, based on partner feedback

2. **Governance and propagation impacts**: governance refers to the replication of processes, and propagation refers to the replication of solutions. The experience and insight of project partners was gathered through a municipal partner survey, follow-up consultations, an SCC Monitoring and Assessment workshop hosted at the University of Manchester in March 2019, and a focus group at the Triangulum Final Event in Stavanger in September 2019

3. **Scaling and contextualising module-level impacts**: a set of bespoke research activities in Manchester to contextualise module-level impacts within recent local net zero carbon policy drivers

7.2 Leveraged Investments and Wider Value

The table below captures the spin-off benefits that have been, at least in part, created by the Triangulum project, according to partner feedback. There are a range of leveraged funding and investments, events and conferences, and commercial spin-outs, as outlined below:

Type	Initiative	Description	Partners	Value
Spin outs	BABLE	Digital marketplace	9 SC projects	Turnover
	Smart Society Academy	Training courses for SC professionals	2 partners	GVA
	NORDIC EDGE	Conference and exhibition	32 partners	Turnover Jobs, GVA
H2020's	SMARTER TOGETHER	Quality of life demonstrator	29 partners	€29m funding 1,500 jobs
	UNaLab URBAN NATURE LABS	Nature-based solutions demonstrator	27 partners	€14m funding
	SYNCHRONICITY	Large scale IoT demonstrator and platform market-place	41 partners, 8 Euro cities, 11 countries, 4 continents	€3m funding
National demonstrator	cityverve	SC demonstrator, IoT Manchester	21 partners	£10m funding
	urban observatory	IoT Living Lab and sensing platform for urban infrastructure	58 partners	£8m funding
Regional growth initiatives	Brainport	Smart technology region – innovation centre, Eindhoven		GVA 3% growth p.a. 1% more productive than NL 40% annual patent apps
	SMART-BYEN Stavanger	Stavanger smart region		Jobs, GVA

Figure 7.2.1: Spin-off benefits of Triangulum

- **Bable Smart Cities**: a digital platform to support the sustainable development of cities in Europe and beyond. The aim is to create liveable, future proof and sustainable cities based on innovation and collaboration.
- **Smart Society Academy**: an educational umbrella for smart city related training at all levels of operation. It is a direct result from the work within the Dutch-German partnership through a Memorandum of Understanding at the Hightech Campus in Eindhoven and is powered by the Morgenstadt Community.

- **Nordic Edge**: an annual 3-day expo and conference focused on broadening the horizon and showcasing the Nordic collaboration model of cross-sector trust and citizen involvement through sharing Smart City ambitions and experiences between continents.

- **Smarter Together**: H202 project with a vision is to find the right balance between smart technologies and organisational governance dimensions in order to deliver smart and inclusive solutions and to improve citizen's quality of life. The project gathers the European Lighthouse cities Lyon, Munich, Vienna, the Follower cities Santiago de Compostela, Sofia, Venice as well as Kyiv and Yokohama as observer cities, which bring the perspective of East Europe and Asia.

- **UNA Lab**: H2020 project based on the establishment of Urban Living Lab (ULL) demonstration areas experimenting, demonstrating and evaluating a range of different nature-based solutions targeting climate change mitigation and adaptation along with the sustainable management of water resources. The front-runner cities, Eindhoven, Tampere and Genova, are joined by five follower cities, Stavanger, Prague, Castellón, Cannes and Başakşehir.

- **Synchronicity**: Funded under the Horizon 2020 programme and bringing together 41 partners, 8 European Cities and 11 countries over four continents. The project was created to help cities simplify the adoption of new services that tackle urban challenges using Internet of Things (IoT) and data technologies. It will create a harmonised market place for IoT enabled and urban data services. This synchronised market place will be created and demonstrated through pilot projects in eight European cities; Manchester, Helsinki, Eindhoven, Antwerp, Milano, Porto, Santander and Carrouge and three other partner cities in Mexico, USA and South Korea.

- **CityVerve**: an Innovate UK funded smart city project to explore how technology can be used to improve the lives of all Mancunians by helping to gather and share information in new and exciting ways, supporting everything from healthcare and transport to culture and the environment.

- **Manchester Urban Observatory**: The Manchester Urban Observatory, a collaboration between the three Faculties at The University of Manchester, will focus on deploying air quality sensors within the Oxford Road Corridor, an existing infrastructure testbed and urban living lab. Funded through the Engineering and Physical Sciences Research Council (EPSRC)/UK Collaboratorium for Research on Infrastructure and Cities (UKRIC).

- **Brainport Eindhoven**: smart region in Eindhoven with over 5,000 tech and IT companies and organisations in all sorts and sizes that work on the latest technologies and perform ground-breaking research.

- **Smart-Byen**: smart region in Stavanager with a roadmap for Smart City Stavanger, the desired direction for the development of the smart city, and a framework for implementation of the work.

In total Triangulum created leveraged benefits worth >€70m including five large funded research and innovation projects and three spin out companies. The Triangulum Exploitation Plan contains further detail on how Triangulum and its outputs have been further exploited by partners across the six cities.

7.3 Governance and Propagation

Drawing on best practice developed by the European Commission, an approach to capture the wider governance and propagation impacts of Triangulum across the six cities was developed and deployed with partners during the final 18 months of the project. It comprised a methodology to gather the experience and insight of project partners including:

- SCC Monitoring and Assessment workshop hosted at UNIMAN, March 2019
- Municipal partner survey, disseminated in summer 2019
- Follow-up consultations, carried out in summer 2019
- Focus group with city coordinators at the Triangulum Final Event in Stavanger, September 2019.

The approach has utilised the language and terminology developed within the EC CITIkeys framework, a set of guidance and a toolkit developed to promote consistency in the monitoring and evaluation of smart city demonstrator projects. The term governance refers to the replication of process, whilst the term propagation refers to the replication of solutions and technologies.

7.3.1 Development of approach

The approach to capturing the process learning impacts of Triangulum has been purposefully qualitative and unstructured, and was focused on engaging with partners in a number of formats during the final year of the project. The outputs included a series of qualitative transcripts and notes from the engagement with project partners, as well as the survey results. All outputs were analysed thematically to produce a set of key lessons learnt, insights and recommendations across the consortium.

1. **SCC Monitoring and Assessment workshop, March 2019**

The workshop was held at UNIMAN in March 2019, a timely opportunity at the start of the fifth and final year of Triangulum to share learning and drive optimal monitoring and assessment activities. It was open to the whole SCC Lighthouse community across all projects, not limited to Triangulum. A total of 17 participants attended with five of the SCC projects represented: RemoUrban, Replicate, Sharing Cities, IRIS, and Triangulum.

The workshop was aimed at colleagues responsible for monitoring and assessing impacts in the SCC Lighthouse projects, as well other key stakeholders and interested parties. It provided an opportunity to exchange approaches to monitoring and assessing impacts, and to discuss challenges and opportunities. The goals were to share best practice among the SCC Lighthouse projects and develop a shared agenda. The workshop was small and interactive to facilitate sharing ideas and expertise. Key topics were communicated in advance with attendees to focus the exchanges.

Key topics

- Monitoring and assessing at different spatial and temporal scales
- Measuring softer social impacts and trade-offs with hard impacts
- Moving from outcomes to impacts
- Capturing and upscaling benefits

- Alignment with needs of different partners
- Data and data management
- Complying with open data requirements
- Cross-SCC opportunities and collaborative research opportunities

Key messages

There was a strong consensus across attendees that there is a need to capture **process learning** in the projects. There is an opportunity to capture the governance, learning and institutional change processes and communicate these to the follower cities and more widely. The key messages in relation to process learning that were identified across the five SCC projects are:

- **Process learning** has been identified by Lighthouse City partners as *the most important and lasting outcome* of their participation in the SCC projects.
- **Process learning** involves organisations changing the ways in which they work in response to new experiences, and presents a major opportunity to accelerate the uptake of smart city solutions.
- **Process learning** has not been fully recognised or captured within the existing funding and project frameworks.

The Exchange discussions resulted in a shared agenda with an intention to develop a dedicated work stream to leverage the considerable amount of process learning that the SCC programme has generated. This is made up of the following actions:

1. **Capture and measure process learning and exploit as a use case.** Partner organisations involved in SCC projects have learnt how to become smarter through new ways of working in partnership (inter- and intra-partner organisation). This is one the most valuable assets to come out of the lighthouse projects in terms of leveraged benefits and legacy.
2. **Capture process learning around soft impacts (esp. social impacts).** Showcase the importance of stakeholder engagement and social impact methodologies and develop into a use case for replication. Identify how process learning facilitates leveraged investment and activities (e.g. new ways of working enable further project investment).
3. **Develop KPIs for process learning**. Identify KPIs and value capture techniques for process learning
4. **Exploit potential for cross-SCC project collaboration in relation to process learning at a meta-scale.** This activity realises value in two ways. First it enables vertical and horizontal project-project learning, and second it can be used to produce recommendations for how to transform processes to accelerate smart city adoption.

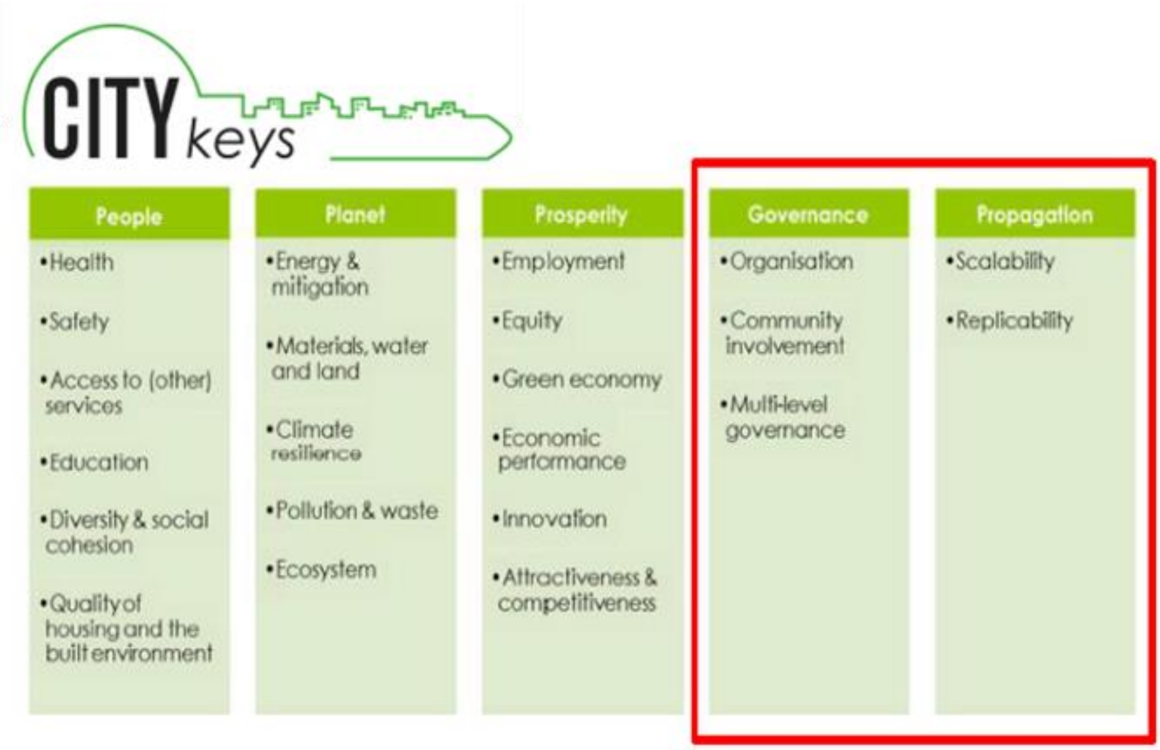
The results were disseminated as an output to the European Commission through the EIP-SCC Smart Cities Guidance Package https://eu-smartcities.eu/news/smart-city-guidance-package, engagement with the SCC1 Monitoring and Evaluation Task Group, and developed into a work stream to address process learning in the final year of the Triangulum project, which is described in the following sections.

2. City Level Monitoring survey, summer 2019

A City Level Monitoring (CLM) survey was designed to gather further insight from project partners into the impact of project involvement on:

- changes within the organisation
- how the project has propagated within the organisation
- how the project has propagated within the city
- how it has enabled other projects, initiatives or spin offs within and outside the city

The CLM survey was based on the EC CITYkeys framework, specifically the Governance and Propagation elements which have been modified for application to Triangulum. The other CITYkeys elements, People, Planet and Prosperity, were dealt with mainly through the module-level impact assessment activities.



The survey included a combination of quantitative scoring and rating Likert-style questions to produce quantitative metrics, as well as open-answer questions to elicit qualitative insight and gather key learning. Process learning was included as an important element of the survey, based on the results of the original workshop.

3. Municipal consultations, summer 2019

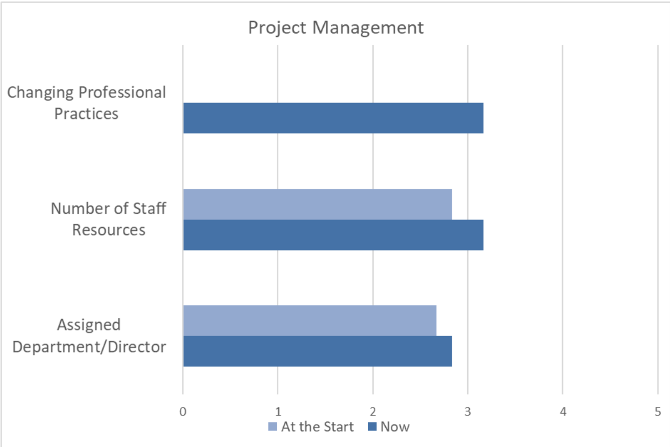
A series of consultations were carried out with municipal partners after the CLM survey results were collected. This was specifically to target partners from within municipalities in order to gather more insight and richer evidence of the impact of involvement in a large consortium project for city authorities. The consultations were mainly carried out over skype, apart from in Manchester where they were done in person.

4. Final Event focus group with municipal project managers, September 2019

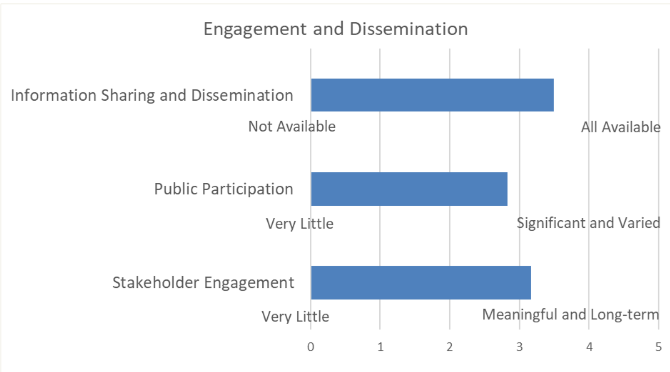
A focus group was carried out with project coordinators from across the six cities at the Final Event in Stavanger in September 2019. The session represented a final opportunity to gather the experience and insights of project partners at a late stage of the project (M56).

7.3.2 Quantitative results from the CLM survey

The CLM survey produced the following results from partners.

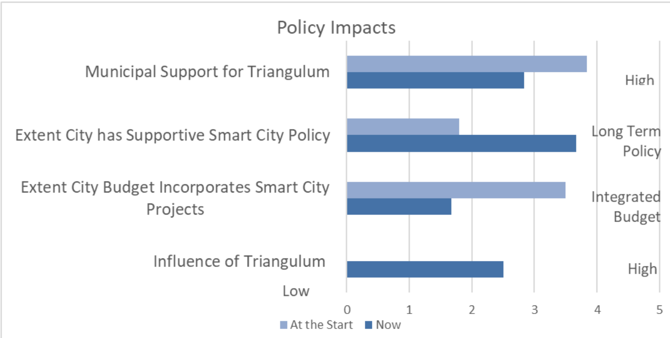


A small improvement is reported in the level of departmental or director oversight of the smart city agenda in the cities was reported at the end of Triangulum compared to before the project started. This is combined with an increase in the number of staff resources assigned to the smart city agenda towards the end of the project. Project partners also felt that the project has made a small impact on the professional practices within their institution.

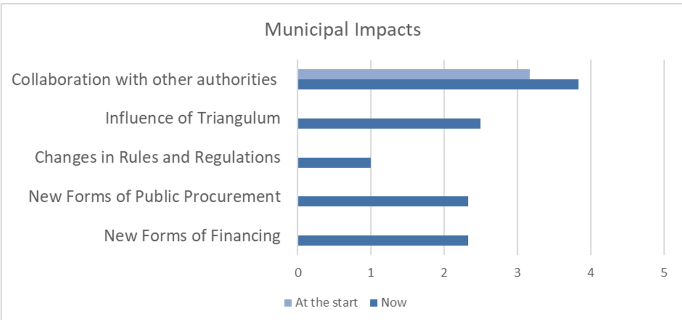


Partners agreed that information from the project was shared and disseminated to some extent. However, whilst there was little public participation within the project, partners did feel that stakeholder engagement undertaken through the project was more positive.

At a local scale, the partners felt that spin-off projects and initiaitves, as well as impacts on their own organisation were most signficant, followed by other organisations and other cities. In comparison, there was less consideration that economic or social imapcts were created as a result of Triangulum.



Triangulum appears to have impacted on municipalities mainly to increase the level of supportive policy for a smart cites agenda. However, this is combined with perceived decreases in municipal support or budgetary incorporation for smart city projects. This could be a reaction to the feeling that the project funding is not being replaced with committed resources. The influence of Triangulum overall on the cities is reported to below the neutral level, indicating that municipal partners do not feel it has succeeded in promoting new activity.



The level of collaboration within municipal partner organisations was reported to have increased over the course of Triangulum. However, the project was not reported to have had a significant influence, nor made significant changes to forms of public procurement, forms of financing, or rules and regulations.

7.3.3 Thematic synthesis of insights

The qualitative insights gathered through the survey, municipal interviews and final focus group are presented below according to the following key themes: expected benefits, actual experienced benefits, lessons learnt, process learning, and propagation both within and outside of project cities.

1. **Expected benefits**

The following sections outline the thematic insights relating to the benefits that partners expected to accrue when they decided to participate in Triangulum.

Municipal partners from Lighthouse Cities

- More efficient city living
- Digital transformation, innovation and experimentation

Municipal partners from Follower Cities

- Improved urban development
- Promotion for local economy
- Digital transformation of civil society

HEI partners

- Carbon reductions
- Development of innovative energy solutions
- Demonstrating technology that would inspire replication
- Implementing new technologies
- Sharing the lessons/issues with other cities
- Establishing data platforms to generate social value through the collection and dissemination of data from multiple streams
- Data platform as a project legacy leading to better decision-making, as well as public participation
- Data availability for social, scientific, and economic research
- Improved grid management with benefits for electric vehicle charging
- Energy and money saving technologies

Corporate/commercial

- Improved data visibility, data sharing and data interaction
- Technical results and integration into existing systems
- Flexible management of energy usage
- Research and development opportunities – exploitation
- Improved understanding and lessons learnt
- Better understand the mechanisms for learning
- Replication tool for other cities

2. Actual benefits

The following sections outline the thematic insights relating to the actual benefits that partners experienced as a result of participating in Triangulum.

Municipal partners from Lighthouse Cities

- Matured and strengthened relationships within the city consortiums leading to increased dedicated staffing across the project
- Participating in Triangulum allowed the city to become more confident in smart city status, and three of the municipal partners stated how being part of the project has allowed them to be confident in bidding for more smart projects
- Project management benefits around relationship building, task groups and collaboration
- Technical and environmental benefits including carbon reductions, energy savings and money savings from the technology implemented
- Tangible products such as the heated swimming pool, smart mobility and the battery, bringing softer benefits such as new ways of conceptualising renewable energy in cities
- Innovation in balancing energy grids to maintain stable grid management
- The cities are now looking at new forms of smart economic development
- Beneficial to learn how Follower Cities are implementing the technologies to promote better understanding of how tech can be implemented in different contexts, with lessons for their own cities.
- Good engagement with stakeholders which led to better business relationships, and consolidation of networks and innovation
- New, unexpected consortiums have emerged such as Stavanger's UNaLab
- Wider influence on the way partners can work alongside politicians, with new tools for communication and sharing.
- Wider benefits arounds community cohesion, improving people's health and physical activity levels through some of the technologies, helping the city to use data to solve problems

Municipal partners from Follower Cities

- The Follower City model meant they could learn without pressure to deliver, promoting good knowledge transfer
- Spin-off benefits in other projects where Prague is a LC, and Sabadell has gained entrance to the SCC-1 Community
- Useful site visits to LCs and multiple valuable visits from delegates which helped to gain more insight into other city contexts
- Participation in a cross-sector multi-organisation consortium showed what is possible at scale and inspired implementation, further replication and led to new projects/spin-offs
- Training missions allowed stakeholders to understand how to maximise the benefits of the project and led to new contacts and relationships with partners
- Increased smart city project discussion and uptake of the concept – Leipzig has developed a digital city unit, increased smart city policies within the city budget and increased support of smart city projects
- For Prague, insight into the working culture of other city units, has been a gateway into the smart city topic. This learning has led Prague to share its learnings with other cities, Brno and Ostrava, and to make links with the Universities for better collaboration
- Consistent high levels of support in Sabadell, with good collaboration leding to their position as an innovative city on the map of innovation (SCC-1 Community). Triangulum was key to this by providing new ideas around smart mobility, energy, economic development and ICT innovation. Participating in the project also inspired new forms of innovative procurement with other "innpulso" municipalities and "Coinnovem" contest of urban innovative ideas.

HEI partners

- Funding provided opportunity to experiment and to develop technologies at a wider scale than would have been possible
- MMU was able to match funding and gain ownership of the tech, reducing the risk of the technology being lost at the end of the project. This led to the university being more comfortable in investing in the technologies
- Technical benefits of implementation, such as reductions in energy usage and costs, and reductions in carbon emissions. Many feel the project had led to multiple small savings which will be significant by the end of the project.
- MMU reduced energy costs by charging the lithium ion battery at night when electricity costs are low, with better grid management keeping demand stable and promoting self-sufficiency on site
- Academic and estates staff understand each other better and are able to collaborate on projects more efficiently going forwards, through experience of collaborating, overcoming obstacles, and creating a productive working relationship
- Learning and teaching benefits of the project and technologies – MMU electrical engineering students learnt about the lithium ion battery as hands-on education
- Operational lessons and capacity building with estates staff building knowledge, such as how to operate load reductions on buildings, and learning from corporate partners to promote improved practices
- Data platforms as a project legacy – Manchester-I is a pioneering method of archiving data that would otherwise be left uncollated, and will have an enduring impact within Manchester
- The presentation and visualisation of data is likely to lead to ongoing energy reductions and has contributed to spin-off projects and other cases of data platform usage

Corporate/commercial

- Collaboration and cooperation between partners and relationship building that has promoted beneficial learning, with cases of project staff contacting each other and working hard to meet project aims
- Technology research and development, contributing to salaries and equipment.
- Project funding only part covers some salaries, encouraging those partners to seek alternative funding streams and continuing partnerships within new consortiums
- Peer-to-peer learning has taken place, with both soft learnings and administrative information being shared. Staff have supported learning-by-doing, including at FC training missions where more knowledge transfer took place than expected.
- Lessons about the wider effects of technology implementation and improving their understanding of energy efficiency
- Winning spin-off projects – Manchester's CityVerve, and Eindhoven's Morgenstadt assessments
- Commercial opportunities – Manchester SME partner secured further funding from another Triangulum city for technology development in another context, generating income and implementation skills; Eindhoven partner has developed a new approach to city development and replication, through knowledge and network benefits, and another partner has developed guidance resources for their technology to promote its implementation in a wider set of contexts

3. Lessons learnt

The following sections outline the thematic insights relating to the lessons learnt by partners as a result of participating in Triangulum.

Municipal partners from Lighthouse Cities

- Getting the right people in at the right time to do the job was essential – needs people who understand the role, what is needed, and how to implement it, e.g. at Manchester Art Gallery when an expert engineer was brought in to support the BMS implementation
- Leadership was key to the project's success, and sometimes a more authoritative approach was required to ensure deadlines were met and to standard. This was key to overcoming misunderstandings on job roles and confusion about finances, and conversations were needed to ensure everyone was on the same page. Members of staff across sectors suggested this could be solved by job roles being explained more clearly at bid stage
- Implementing technology that was correct for the setting was a central learning, repeated by municipal and corporate partners, to ensure money was not wasted, to save time on amendments and replacements, and provide more opportunity for observation and replication.
- Having a clear bid with clear goals and widely understood targets is central to project success. This requires engaging with all stakeholders early on as they have the understanding about what is and is not possible and can ensure the project design is feasible. There are associated challenges with staff turnover and keeping people within a project for the entire duration.
- Streamline the amendment process to reduce delays in the project.
- Clearer communication between project partners, including cross-city communication within sectors so partners in other countries are available for support. Partners from each LC stated this was something that could be done better.
- The number of intermediaries between partners and the funds should be reduced to streamline access to finance and reduce time delays.
- Horizontal decision-making and power sharing are essential for smart city implementation
- The smart city label is a process rather than a status that can be achieved, which is a sentiment shared by partners across sectors.
- Corporate partners need to be involved throughout the process to promote innovation, better partner management and added value
- Improved cultural understanding and communication would be beneficial for large scale consortium projects, e.g. public holidays in different contexts
- Administrative burden such as long amendment processes reduces willingness to continue these projects.
- Transferable skills, including administrative and governance learning, are very valuable in other projects.

Municipal partners from Follower Cities

- Knowledge transfer and organisational governance learnings were important for FC replication - Leipzig were better able to lobby politicians and public utility groups which was essential for their replication success.
- Challenging to replicate projects from one city to another, and understanding the issues and challenges felt by LCs was useful for FC implementation

- Maintaining a close relationship between LCs and FCs is useful for project implementation as they can observe and communicate more easily
- Some felt replication should be less of a focus, especially as FCs receive less funding than LCs. The focus could be on replication inspiration rather than direct replication, and plenty of time is needed for replication to take place so the processes can be understood.

Higher Education Institute (HEI) partners (in Triangulum this includes the universities of UNMIAN, MMU, TU/e and UiS)

- Staffing and resources can be a challenge – adding this scale of project on top of existing full-time responsibilities is problematic. A full-time project manager based at the HEI would be useful or even a city-level champion who represents the whole city.
- Supporting people to secure their buy-in is key to implementation especially for staff not involved in the bid writing process.
- Several university staff supported the notion of having more staff involved in bid writing and implementation, to reduce confusion on interpretation of the bid process.
- Using the right kind of language is important, and unnecessary technical jargon isolates some partners
- Open and short lines of communication to reduce barriers to people interacting and promote understanding
- Understanding the remit of partner involvement as designed in the bid is essential to avoid bringing in the wrong people or missing out a necessary partner, contributing to delays.
- Ensure funding streams are clear in the bid, to reduce confusion about proportion of pay and allocation of funding.
- Collaborative bids mean there is less available space to communicate individual needs and leads to potential miscommunications within the bid delivery. There were multiple issues with the proposal, and this could be a contributing factor.
- The project works well within a university context where students can interact and experience smart city technology implementation
- Some felt it is more effective to run Triangulum implementation alongside other projects/schemes on site, but this can limit options. If it is limited to locations where capital works are already being undertaken, the potential sites for development are low.
- Ownership of technology is important e.g. back-end maintenance for dashboards, maintaining the same operating systems etc
- Public dissemination of the results could be improved and would lead to good public relations and understanding of the project, promoting outreach and participation goals.
- Implementing smart city technology on old buildings and systems can be difficult with issues such as planning permission and asbestos regulations

Corporate/commercial

- Need to understand the context and scope of the technology and where its being implemented to avoid complications and delays. This includes being mindful of local rules and regulations is important for replication in different cities.
- User buy-in is essential for project development and people need to understand why they are involved
- Some suggest a move away from cost-based analysis to a model which incorporates more sustainability, environmental and social benefits. Others feel that cost should be central to development and project management.

- Suggestion that partners should be involved across multiple work packages to promote understanding across the entire project and allow for more collaboration.
- Mechanisms for change such as amendments need to occur more quickly to reduce likelihood that technologies become outdated.
- Better communication externally is needed to encourage better buy-in from the public.
- The structure of the consortium can be confusing for SMEs as there isn't a simple buyer-user structure
- Keeping people who wrote the bid on the project would reduce issues in interpreting the bid.
- Encouraging communication and involvement can be an issue when partners don't know each other that well. It is important for people to start interacting and working together from the start of the project to help it run more smoothly
- Being part of Triangulum has helped partners to conceptualise management and development differently, leading to greater creativity.

Coordinator

- A communication and dissemination group is useful for community outreach and participation, as seen by Stavanger and Eindhoven's Facebook group. This would allow for better public participation and stakeholder engagement as the public would better understand the project and how they can participate.
- An inter-sectoral and inter-cultural consortium presents communication challenges but overcoming them involves synchronising language and common denominators
- Management and governance present more of a challenge than the technical development of technology
- Planning implementation is difficult and demands some flexibility. Mapping progress is therefore helpful to support replication as challenges can be better anticipated.
- To avoid overambitious bids, more time and more communication between partners is needed to ensure feasibility and continuity on style.
- Introducing partners at the start of the project promotes relationship building and good project management
- Good documentation processes make it easier to share learning, both positive and negative. Partner cities should document mistakes and challenges as much as successes a sin some ways this is more useful
- Retaining staff where possible is key to retain learning and pass them on to other projects
- The smart city title isn't a status but a process
- There are often a range of barriers to good communication within municipality staff and the staff who implement projects such as Triangulum – this led to inefficiencies where implementing technologies requires other work streams to be disrupted. Making contact with city staff is important and in a language that is accessible. The closeness of project staff to city decision makers is also significant factor in implementing new technology and policies
- Implementation in practice is unpredictable, and time scales change within one city, and differ city to city. This requires careful consideration of geographical, political, social and economic context to work through.
- Considering the consumer of the smart city policy/technology is important, to gain consumer buy in, maintain good links to support staff, and getting the right people in at all stages of the project
- Many lessons emerged from this project and have been passed on to other project leaders, such as how to write bids more effectively and clearly, undertaking ethics applications,

avoiding misinterpretations and delays in amendments. Making staff roles clear within the proposal is as a key learning.

The figure below summarises the key lessons learnt through the Triangulum project. As it shows, the majority of these relate to the **processes** of smart urban governance.

Figure 7.3.1: Lessons learnt through the Triangulum project

4. Process learning

The following sections outline the thematic insights relating to the process learning impacts experienced by partners as a result of participating in Triangulum.

Municipal partners from Lighthouse Cities

- Range of process based learning has taken place due to Triangulum successes including through improved proposal writing, project design, and governance processes. This has helped the cities success in spin-off projects e.g. GrowGreen and CityVerve in Manchester, the Open Data Portal, Nordic Edge Expo, Smart City Roadmap and Smart City Office ++ in Stavanger.
- Manchester City Council is building on lessons of Triangulum and taking on the Project coordinator role for GrowGreen, generating further transferable management skills.
- Improved understanding of some of the wider context associated with the project, such as highlighting the lack of electric vehicle charging spaces on UoM campus, led to solutions being put in place.
- The influence of Triangulum in Manchester has been to create good examples of what is possible, forged new relationships and formed a basis for future development. This has led to new projects/bids being won, been fed into the Greater Manchester Energy plan, and seen increased awareness. The city has become more supportive of smart city policies
- There has been a new smart city office opened in Stavanger, which is better at communicating with politicians to get partners onboard and can share experiences and goals with them.

Municipal partners from Follower Cities:

- Triangulum has partly led to a new digital city unit being created in Leipzig. The replication tool was used in the city to build up new smart city projects to communicate to colleagues responsible for new urban development districts. They also reported strengthened relationships between the municipality and public utilities due to Triangulum participation, especially regarding the intelligent energy system.
- Sabadell reported that professional practices have changed with more cross-sectoral collaboration and information sharing between municipal departments and with other local stakeholders outside the Municipality. There have also been more structured methodologies for decision-making, including the Morgenstadt assessment and on-site assessment in Sabadell, and improved understanding of how innovation is managed in other municipalities. They have developed an information sharing page to promote this agenda further.

HEI partners:

- The Manchester-I platform is being used by other projects, including the Urban Observatory and CityVerve.

Corporate/commercial

- New processes for user-led change have been developed in response to the challenges faced when integrating technology into existing building management systems. This represents a social challenge rather than a technical one and they have designed a new approach to deal with this.
- The Manchester SME partner set up an office in Sabadell to develop their technology for a tourism context.

- Replication handbooks and processes were developed by a partner in Eindhoven to promote the technologies to be applied in other contexts. These resources would not have been developed without the Triangulum project, and they have designed different platforms for the different partners involved.
- Another Eindhoven partner has changed their organisational approach from having large scale meetings with lots of people to limiting attendance from one person per organisation to save time.

Project Management

- Spin-offs have demonstrated process learning, as Brainport partnerships, Bable and Smart Together projects took place due to Triangulum learnings.
- Fraunhofer practices have changed from checking each document and revising them individually, to cross-checking bids between cities to encourage learning about what is required peer-to-peer.
- The training missions took place in WP6 following telephone conferences with FCs and partners to build capacity and knowledge exchange regarding energy, mobility, ICT and governance needs. It also helped FCs bring local partners together with LC partners.

5. Propagation within cities

The following sections outline the thematic insights relating to the propagation impacts experienced by partners within their city, as a result of participating in Triangulum.

Municipal partners from Lighthouse Cities

- Exposing the lack of electric vehicle charging stations at sites across Manchester led to increased implementation of vehicle infrastructure. The municipality now has 3 electric vehicles following the city amendment which saves the city money from reduced fuel costs.
- Two of the municipal partners from Manchester stated that they were continuing the city's past work in smart development, with one stating they wanted to push the boundaries of the Oxford Road corridor as a European flagship group.
- Manchester are taking a coordinating role on another project that is taking place in the city. They also used Triangulum as a case study for CityVerve and gained confidence in smart city bid funding applications. Manchester have also replicated in Wuhan, China.
- Manchester's contract for electric cargo bikes could not be used in the Triangulum project and is being used in another context.

Municipal partners from Follower Cities

- It is challenging to replicate from LC to FC, due to differences in context. Leipzig found they were defining pilot projects too early when LCs were still implementing, and the processes did not align well.
- Leipzig stated that being involved in the Smart City discussion and cooperation between municipality, public utilities and city administrators was key to the development of the digital city unit.
- Sabadell reported their position as an innovative city before public administrations like the Government of Catalonia and Provincial Council of Barcelona has been useful. They have

been involved in city events such as "Sabatic" tech dissemination event, and "Coinnovem" urban innovative idea contest where the VR bike was showcased. 10 actions which conformed to the Triangulum implementation strategy of Sabadell would not have taken place without Triangulum.

- Sabadell has had to seek out additional sources of public funding for implementation, beyond the Triangulum funding, including public/private partnerships, free collaborations with students and networks of other cities. These have included further Horizon2020 projects, an ERDF consortium, joint public procurement with other "Innpulso" municipalities and informal/formal agreements with the Technical University of Eindhoven and Autonomous University of Barcelona.

HEI partners

- Siemens funding led to feasibility studies which allowed UNIMAN to bid for new funding for equipment, leading to more than they had anticipated initially.
- Manchester Urban Observatory and CityVerve have continued to use the data platform created by Triangulum, which pushes the project further and is continuing to open the data platform to the city. CityVerve was seen as a sister project to Triangulum, and whilst in some ways it diluted focus, it was a second outlet to the data pulled from the platform. The lessons learnt through the data platform led to a data visualisation platform within a new building management system, and this is anticipated to have wider replication potential at another University.
- A data display board was developed to display energy usage information in a UNIMAN building foyer, using the same format as the Triangulum dashboard.

Corporate/commercial

- CityVerve represented the successful leveraging of the smart city brand in Manchester, and was more high profile but with a shorter life cycle.
- A partner in Eindhoven developed a new way of conceptualising city development which makes them a better developer, and has led to new projects where they act as operator to share knowledge and capacity as a company.

6. Propagation outside of cities

The following sections outline the thematic insights relating to the propagation impacts experienced by partners outside their city, as a result of participating in Triangulum.

Municipal partners from Lighthouse Cities:

- Little knowledge or evidence of propagation outside of the partner cities
- Some collaboration with Wuhan, China, to implement smart city policies and practices in other geographies

7.4 Scaling and Contextualising Impacts

The third aspect of the city level monitoring approach was to explore ways to make the findings of the module-level impact assessment more accessible and transferable by scaling the evidence to show its potential significance in the context of local policy divers. The approach was to demonstrate the potential impact if the demonstrator technologies were adopted at scale, and how this could contribute towards local policy need. This was carried out through a case study in the Manchester context using the results at Year 4 (M48).

7.4.1 Manchester case study

Manchester City Council declared a climate emergency at the start of 2019. The Manchester declaration commits the council to become carbon neutral "by the earliest possible date" while working with partners across Greater Manchester to hit the wider city region's 2038 target. The council has also committed to reviewing all policies, processes and procedures, and making "climate breakdown" and the environment an integral part of all its decision making.

Research was carried out in 2018 by the local Tyndall Centre for Climate Research to calculate the city's Carbon budget. The research was based on the SCATTER approach, or 'Setting City Area Targets and Trajectories for Emissions Reduction'. It concluded that the City of Manchester Carbon budget is 15 $MtCO_2e$ cumulatively from 2018 to 2050. Urgent action is needed to put Manchester on a path to 'carbon neutrality' by 2038, initiating an immediate programme of mitigation delivering an annual average of 13% cuts in emissions.

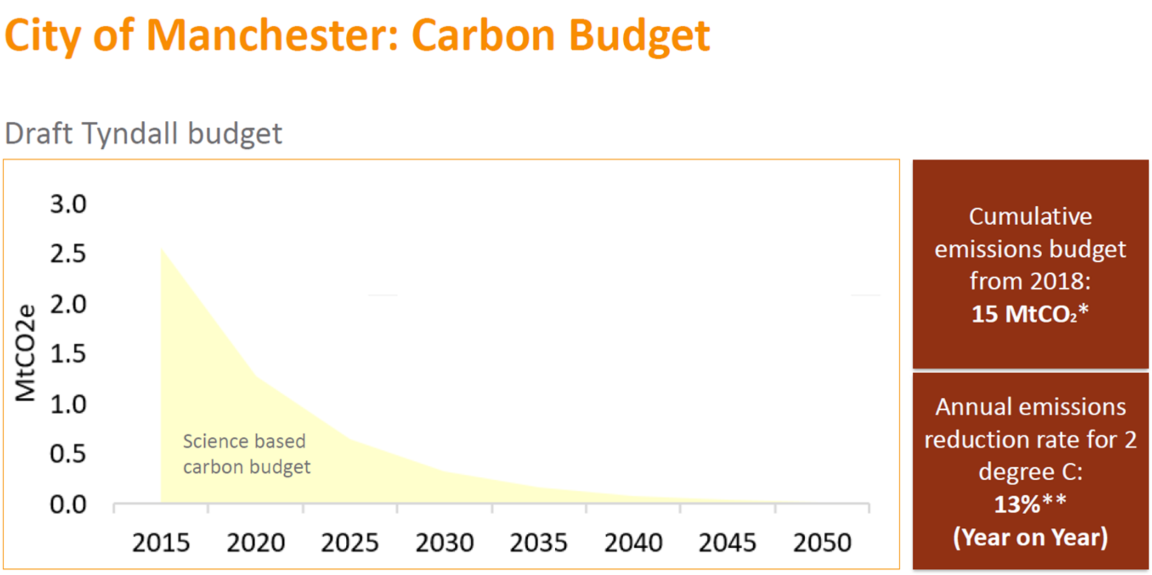


Figure 7.4.1: Manchester Carbon budget, SCATTER

Energy interventions

Through the Triangulum modules in Manchester, smart energy controllers have been implemented across five building assets, producing a 15% demand reduction, and saving 21 tCO_2e per year. If this was rolled out across 20,000[5] commercial premises in the city centre this 15% demand reduction would equate to a saving of 42,000 tCO_2e per year.

The modules have also seen 23,000m^2 building space optimised for smart energy interventions. If this was rolled out across 20,000 commercial city centre premises this would represent 370,000m^2 optimised commercial space.

Triangulum modules have also implemented solar PVs at MMU, generating 100,000 kWh energy p.a., meeting 3% of energy demand and saving 3 tCO_2e per year. If this was rolled out across 20,000 premises within Manchester it could generate in the region of 400000 MWh annually, and save 12,000 tCO_2e.

This represents a possible 54,000 tCO_2e avoided per year if energy interventions were rolled out across the city centre of Manchester. Mapping this against the timeframe of the city's Carbon budget, it equates to a saving of 1.7 million tCO_2e to 2050, or an 11.5% saving of the city's total Carbon Budget.

How would this help to address local policy drivers?

- **Local Industrial Strategy** – contribution to the transition to a cleaner built environment and boosting business productivity through greener energy and material efficiency. It would help meet the direct aim of making commercial buildings more energy efficient. Scaling-up renewable energy generation would help establish Greater Manchester as an energy transition region by building a whole system approach to energy supply through energy optimisation and generation.
- **Manchester Local Development Framework** – contributes towards the spatial principles of reducing CO_2 emissions through retrofitting building stock and making commercial space more efficient. It lo supports the aim of generating large-scale energy generation through the city, aimed at providing a mechanism to create low and zero carbon energy supplies which are cost affective for businesses and residents.
- **Greater Manchester Spatial Framework** – promotes the aim of retrofitting existing building stock and generating low carbon energy to meet the aim of decarbonizing Manchester's economy. The framework includes a carbon and energy plan which is positioned as a positive approach to renewable and low energy schemes. The framework aims for a balanced and smart electricity grid. Triangulum has identified geographical locations which could support energy assets, low carbon energy generation and a successful business model.

<u>Mobility interventions</u>

Triangulum has facilitated the procurement of 9 Electric Vehicles across the two universities. This increase in the EV fleet led to 30,000 miles being covered by EVs in 2018, avoiding 14 tCO_2e, 23.5kg CO and 2.8kg NOx. If this was rolled out to the 4 million miles travelled by logistics vehicles in the city centre over the course of a year,[6] 1,800 tCO2e, 500 kg NOx and 3,000 kg CO would be avoided. This

[5] This is a conservative estimate, acknowledging that not all premises in the city will be suitable for the interventions and taking into account varying building size.

[6] Based on conservative estimate that 6,000 LGVs enter Manchester city centre per day, equating to 12,000 miles per day based on the Last Mile principle (entry and exit), or 4 million miles per year.

represents over 60,000 tCO_2e avoided between 2018 and 2050, or 0.5% of Manchester's Carbon budget. Whilst this is a modest contribution towards the city's carbon budget, it is relevant to consider the broader benefits that would also be delivered.

How would this help to address local policy drivers?

- **Transport Strategy for Manchester City Centre** – policy focus is transport in and out of the city, with a key aim to reduce city wide congestion. EVs would help to reduce the volume of LGVs on the roads and contribute towards wider benefits of reduced congestion such as improved air quality.
- **Local Industrial Strategy** – the strategy includes a desire to create a partnership with local businesses that embeds low carbon travel principles in commercial practices. Triangulum has displayed the opportunity to not only meet low carbon travel principles but with direct possibility of upscaling.
- **Greater Manchester Spatial Framework** – clear aim to reduce congestion, improve air quality and move towards a low carbon city. EVs meet criteria helping to create a modern, greener Manchester.
- **Greater Manchester Clean Air Plan** – poor air quality contributes to the equivalent of 1,200 deaths a year in GM. The proposals to achieve legal levels of nitrous oxide by 2024, include reducing congestion, increasing cycling alternatives and expanding the electric vehicle network.

<u>Wider benefits</u>

The energy and mobility interventions demonstrated through Triangulum have the potential to transform Manchester into a city powered by clean growth. Not only do the combined and scaled interventions represent an approach to green Manchester's economy in a sustainable manner which contributes in a significant way to the city's Carbon Budget, there are also significant wider benefits including: air quality and public health improvements, jobs and skills creation and improvement, education and outreach opportunities, increased learning and awareness of environmental issues in the city, as well as an effective PR and branding strategy for the city.

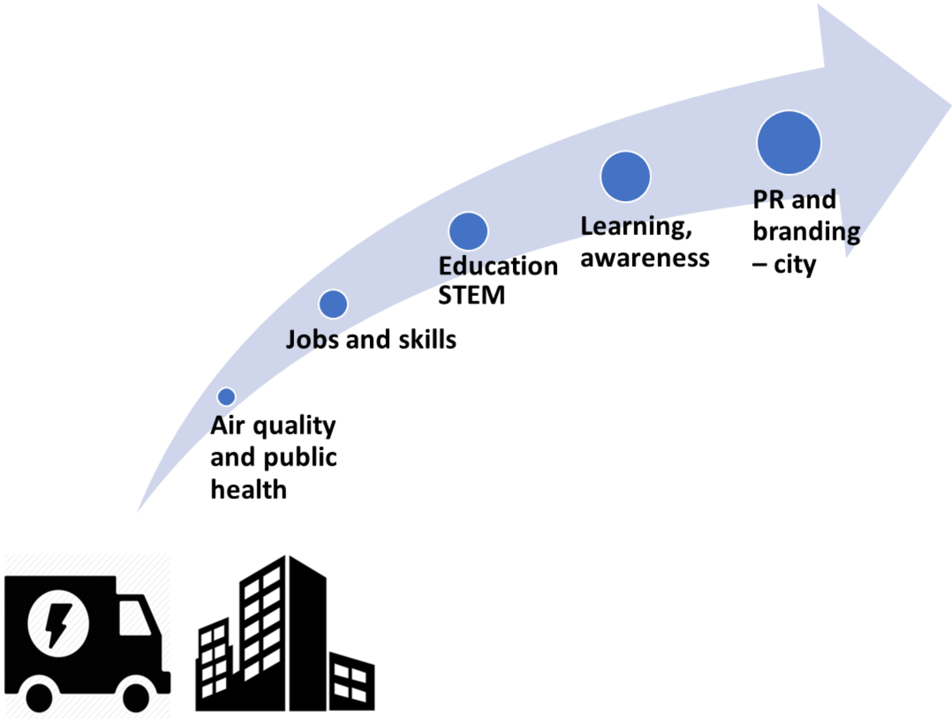


Figure 7.4.2: Wider benefits of scaled interventions

The scaled-up energy and mobility interventions would also contribute towards the aims of a much broader set of strategic policies in the city, including:

- Manchester Population Health Plan 2018-2027
- Greater Manchester Work and Skills Strategy
- Greater Manchester Transport Strategy 2040
- Manchester Zero Carbon Framework 2020-2038
- Greater Manchester Digital Strategy

7.5 Recommendations from the Triangulum Consortium

The city-level monitoring of Triangulum focused on the leveraged benefits of the project, the process learning and replication of ideas and technologies, and the need for scaling and contextualising impacts to promote their transferability to different city audiences.

The key messages are:

- The bid writing process is a critical step and ensuring it is clear with defined roles and responsibilities, based on early engagement across stakeholders is important
- Partners tended to anticipate technical and economic benefits from being involved in the project but found that the main benefits were related to relationships and networks, capacity building, and process learning
- Early stage communication between project partners is essential to build relationships and encourage communication between sectors and across cities

- Encouraging as much face to face interaction as possible is key to sharing learning and experiences in a meaningful way
- Understanding the context across different cities is important, both in terms of communication and project management, but also in terms of replicating solutions in different places
- The imbalance of funding across Lighthouse Cities and Follower Cities is an issue, and pressure to deliver for FCs does not seem proportionate
- There was a lack of public participation in certain cities, which was a missed opportunity
- Triangulum has given many cities the confidence to engage with key decision-makers on this agenda and promote change in how it is administered and delivered, even if this change is slow to be realised.
- Presenting project impact data in different ways to important to engage with different audiences and show the potential of the technological solutions at scale
- Replication within cities is just as important and commendable as replication in other cities
- Triangulum has acted as a kind of branding tool for some cities, and helped them to develop and secure a range of spin-off projects and initiatives from grants and inward investment, to expos, conferences and new start ups
- Process learning is being recognised as one of the key outputs of a smart city demonstrator project

The four priority areas to enable smart transformation through demonstration projects working across a consortium of different partners are:

1) Ensure **enabling policies and planning** are in place
2) Integrate smart solutions into **procurement** and **operating budgets**
3) Facilitate **peer-to-peer learning** among implementers (building managers, energy engineers, fleet managers) and incentivise to innovate
4) Understand what **engages the public**

8 Overall Synthesis of Impact

This section offers an overall synthesis across the project drawing on the module level, district level and city level impacts. A high-level comparison is useful to help understand the activities, approaches and progress in each city relative to the overall goals and scope of the Triangulum project.

8.1 Assessment of module level impacts

Progress completing indicator values

246 impact indicators have been finalised across the 27 modules implemented in the Lighthouse Cities. A total of 27 modules have been fully implemented out of 27 (100%; up from 86% at M48). 239 baselines have been set out of the 246 impact indicators required in total (97%; up from 87% in M48). 235 impact indicators have had impact values calculated (96%; up from 85.5% in M48). In terms of modules, 25 (93%; up from 86% in M48) have generated impacts. 85% of the modules have produced >24 months of monitoring data (compared to 59% at M48), and 96% of the modules have produced >12 months of monitoring data (compared to 89% at M48). One module in Stavanger was fully implemented but reported no data due to GDPR concerns that were unable to be resolved within the timeframe of the project.

Table 8.1.1 shows the overall progress in terms of implementing modules, setting baselines and securing impact values for the Lighthouse Cities and Triangulum project as a whole.

	#modules fully implemented	#baseline indicator values available	#impact indicator values available
MAN	8/8	103/103	101/103
EIN	12/12	69/69	67/69
STAV	7/7	67/74	67/74
Total	27/27	239/246	235/246

Table 8.1.1: M48 overview of baselines and impacts

Final impacts at M60

M60 represents the end of the official monitoring phase so the reporting of impacts at this stage is central to demonstrating impact and support learning within the Lighthouse Cities and the Follower Cities.

In Manchester: the main impacts achieved include:

- 6 months' worth of energy trials carried out in the final year (January to June 2019) showing significant potential for reducing energy demand and lowering GHGs, **10,300 m^2** optimised building space for smart energy interventions in MCC with over **400 tCO_2e**, and a further **35 tCO_2e** avoided GHGs as a result of PV energy generation

- Purchase of **10** Triangulum procured EVs has reduced GHG emissions by **35 tCO_2e** since 2016, and the overall impact of Triangulum has been to increase university share of fleets from **5% to 25%** with reduced GHG emissions of **over 125 tCO_2e, 11kg NOx,** and **70kg CO** through EVs. 4 cargo bikes made **4,493 journeys**, travelled **6,697 km** over a three-year period and saved **820 $kgCO_2e$**.
- Manchester-I data platform hosts **9 real time data feeds** and has 4 organisational users and **307 users** that have downloaded data **427 times**. Over **50 people** have attended the Innovation Challenges hosted in 2018 and 2019.

In Eindhoven: the main impacts include:

- In Strijp-S, biomass and Sanergy have replaced the old heating system and provided **100%** renewable energy for heating. In 2019, **14%** of all energy was generated by Sanergy. **14** EV charging stations have been implemented. The fiber-optic network has been expanded extensively with **350** home connections and **7,050** office connections. **40** sensors have been installed in Strijp-S. **28** SMEs have been created, and **€50m** additional investment per annum has been secured from partners.
- In Eckart Vaartbroek, for social housing, **11,200 m^2** buildings have been renovated, reducing GHG emissions by **20 %**. The estimated energy bill reduction in 2019 was **55%**. For the digital renovation platform of Woonconnect, **284** people (29%) used it, and **174** made a plan (scenario) for the renovation of their home.
- The Eindhoven open data platform has been viewed **96,000** times per month and actively downloaded **almost 4,000** times per month.

In Stavanger: the main impacts include:

- **56** smart gateways have been installed in residential buildings, and the Central Energy Plant (CEP) in Stavanger Commune has avoided a total of **500 tCO_2 p.a.** which represents an **87.5% reduction in CO_2** emissions.
- 5 battery buses have been deployed by the bus operator in the city, avoiding **135 tCO_2, 250 kgCO** and **66 kg NOx**.
- The Cloud Data Platform is not currently accessible externally, but it has **6** internal users, hosts **4** datasets, and currently has **35** completed impact indicators.
- Specific privacy issues and third party issues have hampered the collection of some missing data in Stavanger.

Across all three cities:

- The main Energy sector impacts are reduced local energy use with more demand being met by renewable sources, reduced energy costs, and decreased greenhouse gas emissions. Energy technologies have shown an ability to generate savings of up to 85% in municipal buildings (STAV), 20% in business premises (MAN) and 20% in residential (EIN). The Figure below shows the energy saving across the three Lighthouse Cities.

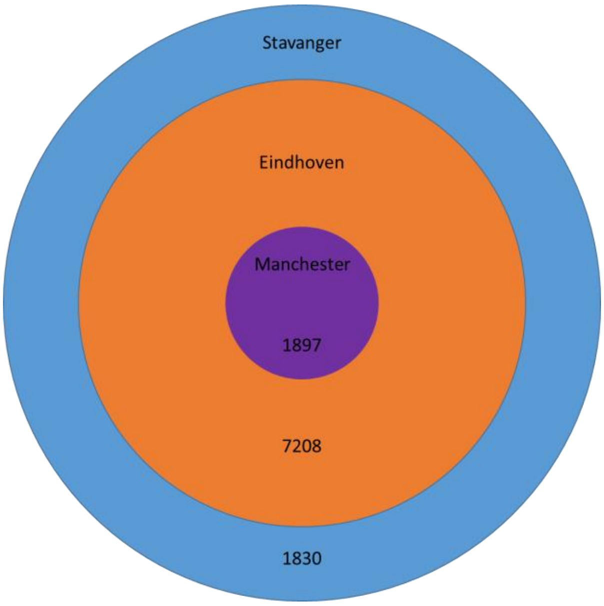


Figure 8.1.1: Energy savings GWh in each city. Total saved: 10936 GWh

- The main Mobility sector impacts are improvements in efficiency, and reduced greenhouse gas emissions (CO_2, NOx, CO). >5000 business journeys have been electrified or shifted to cargo bike, while four fleets comprising >300 vehicles (UNIMAN, MMU, Kolumbus and MCC) are now considering electrification.

- The main ICT sector impacts are increases in the availability of open data, data downloads, and improvements to fibre optic networks. >1000 citizens have been directly engaged in ICT modules across the Triangulum project, with >1.5m engagements with data platforms.

8.1.1 Assessment of missing data

A total of 24 modules have a complete baseline set in this report, out of a total of 27 modules (89%), with 3 module baselines partly or fully outstanding (none for Manchester, none for Eindhoven and three for Stavanger). 25 out of 27 modules have generated impacts partly or fully (93%).

All of the outstanding baselines are due to missing data, as a result of the modules not yet being implemented fully or because of privacy concerns. Third party and privacy issues have particularly affected energy modules in Stavanger, where partners have subcontracted data to third parties.

The inclusion of city level impacts, including leveraged value, process learning, and scaling and contextualising of impacts, has helped to set out some of the wider challenges but also the opportunities associated with smart city demonstration.

8.2 Assessment of district level impacts

At a district-level the modules that have been implemented generated impacts contributing to 26/26 city level objectives, as follows:

- For Oxford Road Corridor: modules have generated impacts that contribute to seven out of seven of the district objectives, with the energy and mobility modules performing particularly well.

- For Strijp-S: modules have generated impacts that contribute to eight out of eight of the district objectives, with the energy and ICT modules performing particularly well.

- For Eckart-Vaartbroek: modules have generated impacts that contribute to six out of six of the district objectives, with the energy and ICT modules performing particularly well.

- For Paradis/Hillevag: modules have generated impacts that contribute to five out of five of the district objectives, with the energy and mobility modules performing particularly well.

8.3 Assessment of city level impacts

The city-level monitoring of Triangulum focused on the leveraged benefits of the project (>€70m including five large funded research and innovation projects), the process learning and replication of ideas and technologies, and the need for scaling and contextualising impacts to promote their transferability to different city audiences. The key impacts associated with process learning impacts involve the organisational and professional changes that have been stimulated by Triangulum. These were identified in a survey of participants as the most important impacts of the project, and are critical in equipping cities with the skills and deep partnerships required to accelerate their low carbon transitions. The main impacts associated within scaling up and contextualising impacts are the potential for Triangulum interventions to be rolled out across the wider city contributing to a range of local policy drivers, as well as making a significant saving towards city Carbon Budgets.

The four priority areas to enable smart transformation through demonstration projects working across a consortium of different partners are:

1) Ensure **enabling policies and planning** are in place
2) Integrate smart solutions into **procurement** and **operating budgets**
3) Facilitate **peer-to-peer learning** among implementers (building managers, energy engineers, fleet managers) and incentivise to innovate
4) Understand what **engages the public**

9 Post M60 next steps

This section outlines the next steps beyond the official end of the project.

9.1 Future research

WP2 lists 42 separate exploitations of the Triangulum results in the Triangulum Exploitation plan, and much of this research is ongoing. UNIMAN researchers along with researchers from UCEEB Prague and colleagues a IPR are currently compiling a research paper on process learning and urban transformation associated with the SCC projects for a Special Issue of Urban Planning due out in 2020. UNIMAN will also build on the MANCHESTER-I data hub through the funded Manchester Urban Observatory to develop new use cases with MCC, learning from the experiences of Triangulum. MMU researchers will continue to work on data being produced by the MMU energy centre. TU/e researchers are continuing to work closely with Woonbedrijf on resident preferences and experiences in retrofit with a number of ongoing Masters projects. UiS researchers will continue to perform analytic work with Kolumbus in Stavanger to deliver value to their business model.

9.2 Continued reporting post M60 - SCIS

Modules that have been implemented with less than a 12-month reporting period can be reported through SCIS after M60. As outlined in Section 1, WP2 have created the SCIS templates for the affected modules and a 65 page guidebook (available at: https://www.dropbox.com/s/qb49gpwe88o3x73/SCIS%20guidebook%20for%20Triangulum%20partners.docx?dl=0) with easy to follow instructions to enable the responsible partners to report data at 12 months. Information on how to continue reporting through SCIS has been made available to all implementation partners. It is recommended that SCIS may want to keep a database that reminds relevant partners when a reporting period is closing and encourages them to submit new data.

10 Conclusion

The monitoring and assessment of smart city solutions has been identified by the European Commission and INEA as a priority to support the development of a functioning smart city market place in Europe. Triangulum has been in the official monitoring period (M36 to M60) for 24 months and offers a valuable and possibly unique opportunity to generate evidence and processes to address this need.

Triangulum has been hugely successful, implementing 27 modules and reporting impacts for 26 of them. Overall valuable lessons have been learnt concerning a range of technologies, and how to overcome the barriers to implementation that they face. More than Demonstrations in the four innovation districts showed the ability to contribute to every stated city priority, while at city level spin-offs have leveraged >€70m of research funding and stimulated regional development partnerships and an international expo. WP2 has achieved 42 exploitation activities including 7 MSc projects, 3 PhDs, 9 peer reviewed papers, 10 papers in conference proceedings and >€10m of research funding. Many of these are ongoing and each of the four universities is continuing to research Triangulum initiatives.

Key lessons include the need to include partners in monitoring and assessment from the start of the project and provide clear guidelines for the generation and handling of data that ensure access will be available. A second lesson involves the importance of soft impacts on the organisations involved in large innovation projects. Partners identified changes to the processes through which they operate and collaborate to be the most important and lasting impacts of the project. These elements can be considered under evaluation and are being developed through the SCC monitoring and evaluation task group, especially concerning the need for long term (i.e. beyond project) evaluation to enable projects to benefit from previous lessons. In the context of zero-carbon cities and the need to accelerate transition the ability of cities to collaborate more effectively is a critical topic for smart city development.

Overall this report captures a range of impacts at different levels that will be of use informing potential customers about technical performance in real world settings, municipalities in terms of district level impacts, and, more widely, a broad community of researchers, policymakers and funders who are interested in how innovation projects can better stimulate widespread and rapid urban transformations. In particular, the importance of capitalising on successful projects and embedding new ways of working at the city level have been identified as key accelerators of urban change.

11 Appendices

11.1 Appendix 1: Observations for Module 446

Observation 1		
Naam observator:	**Rob Woltinge**	
Tijdstip van observeren:	**20.00 tot 22.15**	
Datum:	**Thursday 24 May 2016**	
Weersomstandigheden:	**11C , dry, little wind and the end almost no wind**	
Time	**People**	Nr
20.00	adult male with dog (NW)	1
20.00	adult male with dog (NO)	1
20.05	nine trimmers (8 adult males, 1 adult female) (NO)	9
20.06	adult male with dog (NO) (interviewed, no. 1)	1
20.20	mature man (about 25 years) in wheelchair (NO)	1
20.28	young woman (+/- 30 with father +/- 60) (NO), feeding ducks (interviewed, no. 2)	2
20.35	two young people (men under 20) (NO)	2
20.40	two young people (under 20) on a bike (NO)	2
20.40	two adult women with dog (NO) (interviewed, no. 3)	2
20.45	two young people (men under 20) (NO)	2
20.47	adult male (about 30), with a thin hair (NO)	1
20.50	adult female (about 40) with younger female (under 20) with dog (NO)	2
20.55	adult male (+/- 40), trimming around the pond	1
21.06	adult male with dog, (ZW)	1
21.08	adult male and female with dog (NO) (interviewed, no. 4)	2
21.10	adult male with dog (NO)	1
21.24	mature man, phoning (NO)	1
21.24	two adult men, trim (ZW)	2
21.43	adult male with dog (ZW)	1
21.43	adult male with dog (NO) (interviewed, no. 5)	1
21.50	adult male (+/- 40), trim (NO)	1
22.10	adult man with dog, round around the lake	1
22.15	adult woman (+/- 30), walking (NO)	1
Duration: 135min	Total number	39

observation 2		
Naam observator:	**Yoka**	
Tijdstip van observeren:	**11.45-13.15**	
Datum:	**Sunday 22 May 2016**	
Weersomstandigheden:	**droog, 18 graden, geen wind, lekker weertje**	
Time	**People**	Nr
	1 child fishing (another one I spoke to)	1
	1 mum with a pram	1
	1 mommy with children who feed ducks (the daddy speaks)	9
	2 men with dogs	1
	4 joggers	1
	2 seniors feeding ducks.	2
	1 female	1
	1 male	1
	1 female	1
	1 female	1
	1 male	1
	1 female	1
Duration: 90min	Total number	16

Summary: based on observer, it really is a beautiful area, with all that green, young measuring cows and nice and quiet. Let's be careful about it! That was also the message in the conversations: they all like it very much and do not know how it can be done better or differently (except that we have to keep out cyclists). I will forward the photos later.

- To observe, I am standing on the path on the long side (side Luytelaer), there you can see everything
- It was pretty quiet, but according to some people I spoke it is busier during the week
- I did not appeal to joggers, they were not many and busy with other things
- The question 'When will you get to this lake' I (now) have misinterpreted. I thought we meant: at what kind of activity, but now I think we wanted to ask for a time.
- In the appendix the completed questions, I have addressed most of those whom I saw. Everyone wanted to participate.

observation 3		
Naam observator:	**Erik**	
Tijdstip van observeren:	**14.00-16.00**	
Datum:	**Wednesday 25 May 2016**	
Weersomstandigheden:	**droog, 18 graden, geen wind, beetje bewolkt af en toe een druppeltje**	
Time	**People**	Nr
Duration: 120min	Total number	20
It was very nice to do and since I'm not so well known in Eindhoven, I cycled almost in 1 time it is a very nice decorated area. The cycle path to the south of the lake has a kind of English landscape style with very nice large trees and a little sloping along the water with a stylized beautiful path. And that was also the message that came as a result of the few conversations I have had, people experience it all as beautiful there was indeed very economical and therefore indicate nothing to improve the whole in this quiet atmosphere except the cyclists try to keep out what are also mainly young people up to + -20 years who only see the path as a shortcut. It was very quiet and peaceful, about 20 people were passed from 14.00-16.00, most of them on the North side the path to the toilet. So if you would dare to characterize people. People who will feed the ducks with the children will experience it as nice and enjoy the lake. People who only have the goal to go shopping do that very quickly and experience the environment differently so they only go from a to b Two men who were fishing for two hours and who enjoy fishing in themselves. People who let dogs out and who experience it as walking through a beautiful area and have the goal to let doggie out. Cyclists mainly on the beautiful side (south side) English landscape style aim at a fast route to a-b who experience it only as quickly cycle through and if you observe them they hardly look around. I think there are usually a lot of young loosers you can observe in the area around the benches, which were nowhere near a short leg. On the footpath to the toilet people sit in the grass or stand on the fishing pier or sit on the benches behind the hedge. So the activity on the North side is a bit more like on the South side you could be able to translate it lives a little more. Passers who walk quickly over the English landscape path from a to b. Conclusion: Beautiful surroundings beautiful route one person experienced and experience the whole as beautiful / green / quiet peaceful and enjoy it and the other people both on foot and by bike experience the path (s) as functional do not have as much eye for the environment and in my opinion do not have so much connection with this environment. Those who have spoken are all of the opinion beautiful place nothing to do maybe a light pole and possibly cyclists.		

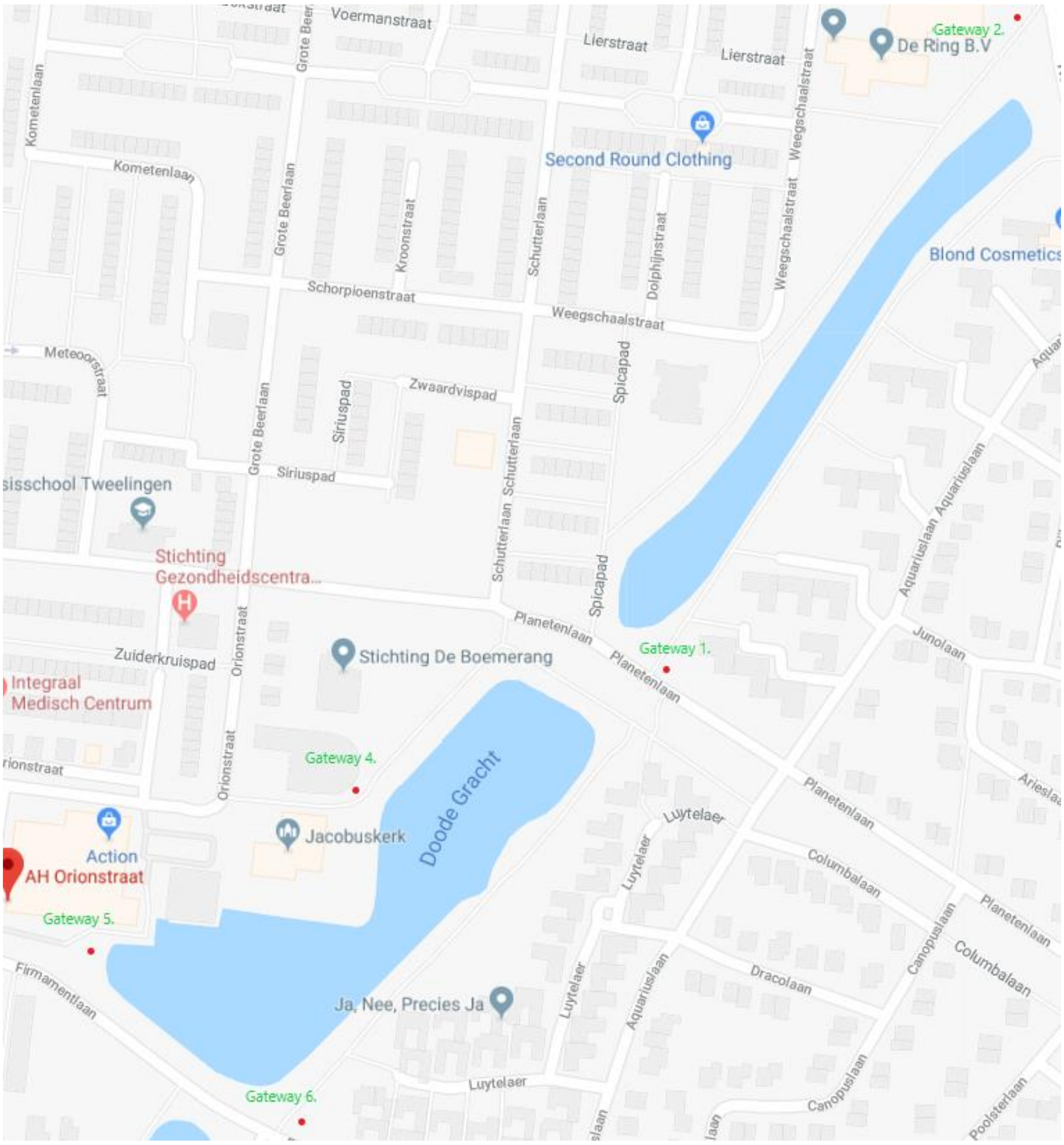
Data for Module 446, M48

Gateway 1 has 2 speeds, and only in one direction.
White 9 kmt. 2.200 times.
Red 7 kmt. 660 times.

Gateway 2 has 4 speeds, 2 in each direction.
White 9 kmt. 91 times.

Red 7 kmt. 220 times.
Green 12 kmt. 122 times.
Blue 4,5 kmt. 114 times.

Gateway 6 has 4 speeds, 2 in each direction.
White 9 kmt. 981 times.
Red 7 kmt. 1557 times.
Green 12 kmt. 1372 times.
Blue 4,5 kmt. 1329 times.



11.2 Appendix 2: Eindhoven email

From: Paul van Pelt [mailto:Paul.van.Pelt@tweesnoeken.nl]
Sent: maandag 10 december 2018 13:11
To: Yang, D. <D.Yang@TU/e.nl>; Saskia de Regt <Saskia.de.Regt@tweesnoeken.nl>
Cc: Vries, B. de <b.d.vries@TU/e.nl>
Subject: RE: gegevens voor TU/e

Hi Dujuan,

As we concluded earlier, we don't have any knowledge about the renovation activities that are initiated by the use of WoonConnect, because WoonConnect enables the inhabitants to explore the possibilities of improving their houses and save energy, but is not a 'marketplace' where contracts are closed for the execution of the renovation. Also privacy issues (GDPR) are limiting the possibilities to monitor the results severely. If someone is insulating his roof and/or putting solar panels on it, we have no way of telling what stimulated them to do so. So the answer to your questions is still the same as during the last report: we just don't know. There is 'circumstantial evidence' that WCT has a positive effect. People were still logging in in the past period (of course it gets less because the activation process is no longer supported, but still...) and we get requests from other inhabitants if we can digitalize their homes because they also want to look what's possible. (We have to disappoint them I'm afraid, because there is no funding).

Groeten,

Paul

11.3 Appendix 3: GDPR Roles within Triangulum

Figure 11.3.1 below depicts the GDPR roles relating to data management.

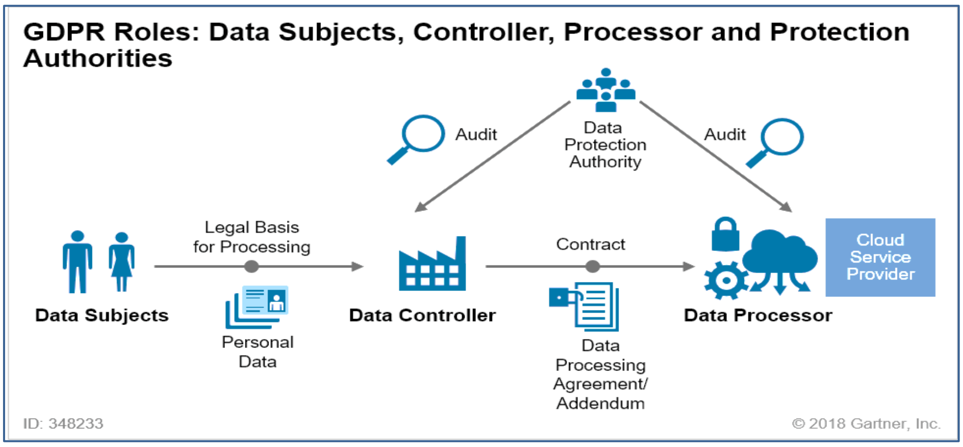


Figure 11.3.1: GDPR roles

Data Controller: The entity that determines the purposes, conditions and means of processing personal data. This includes all of the WP 3, 4 and 5 partners involved in delivering the modules in the Lighthouse Cities and who are collecting data relating to their impact. It also includes WP2 and WP6 who have generated independent data relating to assessment and replication activities.

Data Processor: The entity that processes data on behalf of a data controller. This includes WP2 who are processing data from partners, and the specific partners in each city responsible for hosting data platforms.

Data Subject: A natural person whose personal data is processed by a controller or a processor. This includes residents and professionals involved directly and indirectly in the project.

Personal Data Breach: A breach of security leading to the accidental or unlawful access to, destruction, misuse, etc. of personal data (72 hours to report a breach)

Data controllers and processors have a responsibility to ensure that they are handling data in accordance with GDPR rules.

11.4 Appendix 4: Policy and procedure audit

Checklist item	Indication of how essential	Policy/procedure put in place by partner	Link to document or document attached y/n	Date of last revision
Employee communications	All			
Audit of personal information held	All			
General Data Protection Policy in place	All			
Personal data retention procedure	All			
Personal data processing procedure	All			
Privacy notices/statements	All			
Consent procedures (inc. need to refresh consent)	All			
Data Subject Access Rights procedure	All			
Process for dealing with data breaches	All			
Privacy Impact assessments procedure	Large organisations			
Data Protection Officer (DPO)	Large organisations			
Employee training	All			
International considerations re cross-border processing	All			

11.5 Appendix 5: Triangulum PIA Screening form

TRIANGULUM PIA Screening Questions

The answers on this form will allow you to determine whether you will need to complete a Privacy Impact Assessment (PIA) for your module.

What is the module?	
Number and name of module.	
Who will answer any queries regarding the responses provided on this form?	

Provide details of any previous Privacy Impact Assessment or other form of personal data compliance assessment done on this module. If this is a change to an existing system, a PIA may have been undertaken during the project implementation.
Please provide your answers here:

The GDPR (General Data Protection Regulation) sets out the situations where the organisation will need to carry out a data protection impact assessment where the processing is considered high risk.

For the module, please answer the following:

Does your module involve processing of any Personal or Special Category data?	**Answer Yes or No**	**Sharing with others Yes or No**
1. It includes the processing of special category data (as defined in Article 9) which might reveal the racial or ethnic origin, political opinions, religious or philosophical beliefs, trade-union membership; data concerning health or sex life and sexual orientation; genetic data or biometric data.		
2. It includes the passwords for access to IT systems and websites, credit card details, passport numbers or any other ID number.		
3. It includes a set of personal data that when combined could become highly sensitive such as an email and password combination or that which is indirectly sensitive, such as nationality, country of origin and postcode.		
4. If you answered Yes to 1, 2 or 3, does it include the processing of Personal data processed on a large scale? (Think about the volume of data subjects processed, the number of processing operations or the geographical area to identify 'large scale').		

5. It includes datasets that have been matched or combined – e.g. originating from two or more data processing operations performed for different purposes and /or by different data controllers in a way that would exceed the reasonable expectations of the data subject.		
6. It includes data concerning vulnerable data subjects: i.e. because of the increased power imbalance between the data subject and data controller, meaning the individual may be unable to consent to, or oppose, the processing of his or her data.		

For the module, please answer the following:

Does the module undertake any of the following?	Answer Yes or No	Sharing with others Yes or No
1. Evaluation or scoring, including profiling and predicting especially from aspects concerning the data subjects performance at work, economic situation, health, personal preferences or interests, reliability or behaviour, location or movements.		
2. Automated-decision making with legal or similar significant effect upon a natural person ('data subject').		
3. Systematic monitoring: processing used to observe, monitor or control data subjects, including data collected through "a systematic monitoring of a publicly accessible area" – e.g. CCTV.		
4. Innovative use or applying technological or organisational (e.g. policies, changes to business processes, procedures etc.) solutions, such as combining the use of finger print and face recognition for improved physical access control.		
5. Data transfer across borders outside the EU, consider the possibility of further transfers or the likelihood of transfers based on exemption from or relaxation of a laws for specific situations set out in the GDPR, (this advice will change after we exit from the EU as we will be outside the EU ourselves then).		
6. Processing that in itself "prevents data subjects from exercising a right or using a service or contract".		

Further Information

GDPR Article 6 – Lawfulness of processing http://www.privacy-regulation.eu/en/article-6-lawfulness-of-processing-GDPR.htm
GDPR Article 9- Special categories of personal data http://www.privacy-regulation.eu/en/article-9-processing-of-special-categories-of-personal-data-GDPR.htm

Figure 11.5.1: Triangulum GDPR PIA Screening document