2024

Annotated Example of a Typical REF Case Study

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REF (RESEARCH EXCELLENCE FRAMEWORK) CASE STUDY:

A REF (Research Excellence Framework) Case Study typically includes three key elements:

1. Quality of research outputs (e.g., publications, performances, exhibitions)
2. Impact of research beyond academia (e.g., on the economy, society, policy, culture, quality of life)
3. Research environment that supports the research.

These elements reflect the key characteristics of research excellence and are assessed to measure the impact and quality of research conducted within a department or institution.

Typical Format of a REF Case Study

To help you better understand what is expected, here is an annotated example

Institution: Glasgow Caledonian University		
Unit of Assessment: 13 - Architecture, Built Environment and Planning		
Title of case study: "Enhancing Urban Air Quality Through Green Infrastructure."		
Period when the underpinning research was undertaken: January 2014 - Ongoing		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title)	Period(s) employed by submitting HEI:
Prof. John Doe	Principal Investigator, Theme Leader	2010 – Present
Prof. Mike David	Co-Investigator, Director GUIL	2012 – Present
Jane Doe	Senior Lecturer, Built and Environment Engineering	2012 – Present

Period when the claimed impact occurred:

December 2015 – Present

Is this case study continued from a case study submitted in 2020?

No

1. Summary of the impact (indicative maximum 100 words)

This section should briefly state what specific impact is being described in the case study.

Annotated Example:

John Doe and his team's work demonstrated that Urban Air Quality can be enhanced through Green Infrastructure. Green Infrastructure has proven to be an effective and reliable method for improving Urban Air Quality [G1]. Following its first large-scale study in a Scottish city, the Scottish Government subsequently acted and rolled it out across the country. The Centre of Excellence Green Infrastructure and Urban Living (GIUL) [C1] stated, that GCU "played an important part in a wider programme of activity led by GIUL to establish a Green Infrastructure Protocol for enhancing Air Quality in Urban Regions in Glasgow." Work with the companies Urban Technologies and Green Infrastructure Sensing Solutions has led to a better understanding of the Protocol produced for fundamentally improving the air quality in Urban Cities by 30% and contributing to the emergence of a spin-out company.

2. Underpinning research (indicative maximum 500 words)

This section should outline the key research insights or findings that underpinned the impact, and provide details of what research was undertaken, when, and by whom. References to specific research outputs that embody the research described in this section, and evidence of its quality, should be provided in the next section.

Details of the following should be provided in this section:

- The nature of the research insights or findings which relate to the impact claimed in the case study.
- An outline of what the underpinning research produced by the submitted unit was (this may relate to one or more research outputs, projects or programmes).

- Dates of when it was carried out.
- Names of the key researchers and what positions they held at the institution at the time of theresearch (where researchers joined or left the HEI during this time, these dates must also be stated).
- Any relevant key contextual information about this area of research.

Annotated Example:

Research in engineering applications of green infrastructure in improving air quality in urban regions started in 2014 at GCU. This research has since involved more than 20 academics and research students. There are two research groups (Green Infrastructure Engineering (GIE) and Urban Region) that are part of the Building Technology Research Centre.

Doe's research contributions during this assessment period can be grouped into three main areas:

1. Building engineering using green infrastructure to increase quality of life.

2. Accurate performance evaluation of green infrastructure.

3. Application of green infrastructure in urban regions.

Buildings consume 32% (24% for residential and 8% for commercial) of the air quality consumption, 19% of total related CO2 emissions and 51% of total air quality consumption. The green infrastructure protocol developed at GCU (hardware and software) was shown to improve more than 30% of the air quality [R1].

In 2018 a project with Green Infrastructure Sensing Solutions Ltd. [G2], a Scottish company showed that with the green infrastructure protocol, better air quality could be achieved. This protocol was further expanded by using Cloud infrastructure to manage cooling in buildings [R2]. The project determined whether random neural networks (RNN's) could provide necessary intelligent self-learning (ISL) and adaptive management capability for autonomous carbon dioxide/ humidity/ temperature wireless sensors within buildings – energy and indoor air quality demand control and management with minimal human intervention [R3]. Urban Technologies Ltd bring significant experience in the use and deployment of wireless sensor networks for buildings, logistics and healthcare applications.

In 2020 this work was also extended [G1] to the urban building sector and led to the study of security threats in RNN's. This also resulted in a journal paper [R4] which reported on the use of RNN's with security, and how can we implement security on these networks. A pilot study was conducted in

implementing edge security using Random Neural Networks and

this led to the new KTP within IoT Engineering. The main findings were that a multi-layered approach for RNN's and IoT security is required with elements of security embedded in the edge networks [R4]. Human safety using secure occupancy was reported in [R5].

More recently the RNN's technology has been evaluated for disaster management [R6], and results have shown that due to its low power and wide area coverage, it would be the ideal solution for post-geological disaster implementation as a rapid response or as a backup for these

eventualities.

Doe and his team have generated nine journal publications in IEEE, ACM, and IET journals,

one patent, one spin-out company and presented at 15 international conferences.

3. References to the research (indicative maximum of six references)

This section should provide references to **key** outputs from the research described in the previoussection, and evidence about the quality of the research.

Include the following details for each cited output:

- Author(s).
- Title.
- Year of publication.
- Type of output and other relevant details required to identify the output (for examplejournal title and issue).
- Details to enable the panel to gain access to the output, if required (for example, a DOI orURL), or stating that the output is listed in REF2 or can be supplied by the HEI on request.

All outputs cited in this section must be capable of being made available to panels. If they are not available in the public domain or listed in REF2, the HEI must be able to provide them if requested by theREF team.

Evidence of the quality of the research must also be provided in this section. Guidance on this will be provided in the panel criteria documents. Where panels request details of key research grants or end-of-grant

reports, the following should be provided:

- Who the grant was awarded to.
- The grant title.
- Sponsor.
- Period of the grant (with dates).
- Value of the grant.

Annotated Example:

• R1. John Doe, Abby Janet, David Mike, Jane Doe, “Improving Energy Consumption of a Commercial Building with Random Neural Networks’’, IEEE IT Professional Journal, 2 (5), pp. 10-18, 2017. https://doi.org/10.110/MITP.2017.053891233

• R2. John Doe, Mike Jack, Burna David, David Mike, “Smart random neural network controller for HVAC using cloud computing technology”, IEEE Transactions on Industrial Informatics, 3 (1), pp. 51-60, 2018. https://doi.org/10.1209/TII.2018.25977647

• R3. John Doe, David Mike, Toll Chriss, Emmanuel Mike, Nasco Biscao, “Implementation of Cloud-Enabled Random Neural Network based Decentralized Smart Controller with intelligent sensor nodes for HVAC”, IEEE Internet of Things Journal, 4 (2), pp. 33-43, 2015. https://doi.org/10.1100/JIOT.2015.26287123

• R4. John Doe, Matt Williz, Fred Leo, “Design of Cloud-Enabled Random Neural Networks for Green Infrastructure”, ACM Transactions on Internet Technology (TOIT), Vol 6 (4), 2019. https://doi.org/10.1145/2990500

• R5. John Doe, William Murry, Jane Doe, “Air Quality and Green Infrastructure –A Survey and Novel Air Quality Monitoring Solution’’, Applied Building Engineering, Elsevier, 2019. https://doi.org/10.10106/j.aci.2019.12.001

• R6. John Doe, Jane Doe, Matty Whim, Alaska Blonde, “A survey on the role of Green Infrastructure on Air Quality”, In Durrani, T., Wang, W., Forbez, Z. (eds.) Geological Monitoring Based on Sensor Networks, pp. 37-46. Springaer Natural Hazards. Springaer, Singapore (2018).

https://doi.org/10.10077/978-981-13-09092-2_5

Grants Awarded:

• G1. (PI) J. Doe, M. David, R. Ramona (Total £150K 2014-2015). CENSIS (The Centre for Urban Planning and Green Infrastructure Sensing Solutions– supported by SFC), "Low cost/ power consumption Random Neural Controller for enhanced sensor intelligence in Building Air Quality Management Systems, Telehealth applications.
• G2. (PI) J. Doe, M. David, R. Burns (Total £300K 2014-2015). TSB (Technology Strategy Board), "Feasibility of enhancing air quality with green infrastructure".
• G3. (PI) J. Doe and M. David (Total: £145,000 Oct 2017- Sept 2018). KTP (Knowledge Transfer Partnership) (With Urban Technologies Ltd) Project Title: Radio- Frequency Identification (RFID) solution with energy harvesting for implementation in urban buildings.
• G4. (PI) J. Doe and O. Regha (Total: £161,000 Jan 2020- Sept 2021). KTP (Knowledge Transfer Partnership) (With Urban Technologies Ltd) Title of project: Realtime air quality monitoring using Deep learning and Random Neural Networks.

4. Details of the impact (indicative maximum 750 words)

This section should provide a narrative, with supporting evidence, to explain:

- how the research underpinned (made a distinct and material contribution to) the impact
- the nature and extent of the impact.

The following should be provided:

- A clear explanation of the process or means through which the research led to, underpinned or contributed to the impact (for example, how it was disseminated, how it came to influence users or beneficiaries, or how it came to be exploited, taken up or applied).
- Where the submitted unit', research was part of a wider body of research that contributedto the impact (for example, where there has been research collaboration with other institutions), the case study should specify the particular contribution of the submitted unit's research and acknowledge other key research contributions.
- Details of the beneficiaries – who or what community, constituency or organization has benefitted, been affected or

impacted on.

- Details of the nature of the impact – how they have benefitted, been affected or impactedon.
- Evidence or indicators of the extent of the impact described, as appropriate to the case being made.
- Dates of when these impacts occurred.

Annotated Example:

Impact 1. General policy to roll out the technology specific to application areas:

The research, development, and analysis of green infrastructure protocol for environmental sensing conducted by Glasgow Caledonian University has been instrumental in the development of Scottish smart cities.

GCU research has helped companies to develop smart solutions in cities for environmental sensing (air pollution) [C1], traffic management, building energy management [C2], intelligent lighting, and for the urban areas of developing countries. The first KTP project between GCU and Urban Technologies [G3] led to a pilot project in Glasgow in collaboration with Strathclyde University, Glasgow University, and GISS. As a direct result of these projects, the Scottish Government has rolled out green infrastructure protocol across Scotland and a neutral network infrastructure for environmental sensing, disaster recovery and smart cities has been developed. The UK government is now funding similar initiatives.

For specific projects and applications:

Urban Technologies published two White papers for their customers highlighting the benefits of green infrastructure protocol. GISS Solutions was able to implement its sensors for Schneider Electric. In Urban's White paper [C7] "the results encouraging in the assessment of the neutral network technology. For 'set and forget' sensing where two-way communication is not a requirement and where occasional missing packets are not an issue, the uplink success rate in a multi-gateway environment is very good." The (CEO) of Urban in an interview with IoT Now [C8], stated, "with Glasgow Caledonian University we are exploring the concept of improving air quality through green infrastructure and the irony hasn't

escaped us that we're looking to use energy from one radio source to power another. How cool is that?"

Impact 2. Creating new businesses, improving the performance of existing businesses from

Urban Technologies testimonial [C6]:

Green Infrastructure Sensing Solutions Ltd.: The project with GISS [G2], using Cloud infrastructure to manage cooling in buildings [R3] led to increased sales of GISS by over 15% [C9], and they are now entering the market of smart sensors. The AI developed by GCU and tested in real-world environments has been a major contributing factor to this development.

Urban Technologies: Work in collaboration with GCU through the two KTPs [G3, G4] established Urban Technologies as a key player in the green infrastructure sector [C3, C4]. It led to the creation of a Glasgow and subsequently Scottish green infrastructure network and consortium, which cemented the company's role in the improvement of urban area air quality growth of Scottish cities via pilot projects, bootstrapping Scotland and the validation of Geolocation on LoRa networks [C3, C4, C5], as well as the invalidation of RF power harvesting as a usable power source of LPWA. As a result of their expertise in LoRa developed through the KTPs (as well as cellular and satellite connectivity), Urban Technologies was acquired by ARM in June 2021. The combination of Urban's technology with Arm's Mbed IoT Device Management Platform will provide a basis for a combined physical and software platform. ARM claimed that customers would see several key benefits from the Stream acquisition and integration with ARM's Mbed IoT Device Management Platform, including:

• Single pane of glass that provides customer visibility and management capabilities throughout the device's lifecycle – deployment, connectivity, provisioning, management, and updates.

• SIM orchestration that communicates and connects policies enabling zero-touch onboarding that drives efficiencies and scale of IoT connections.

• Global aggregation across urban areas with different network types and flexible wireless connectivity options that can be optimized across devices, regions, and use cases that are deployed.

• Simplified monitoring and through APIs and automated controls.

• Connect and manage any device regardless of network type to steer reliable and trusted data, seamlessly push new updates and features, and optimize quality-of-service and latency for troubleshooting.

In the 2022 acquisition of ARM by Nvidia, the company was valued at $40bn (£31.2bn), an increase of $10bn over its value in 2016, before the acquisition of Urban Technologies.

5. Sources to corroborate the impact (indicative maximum of 10 references)

This section should list sources external to the submitting HEI that could if audited, provide corroboration of specific claims made in the case study. Sources provided in this section should not be asubstitute for providing clear evidence of impact in section 4; the information in this section will be usedfor audit purposes only.

This section should list sufficient sources that could if audited, corroborate key claims made about the impact of the unit's research. These could include, as appropriate to the case study, the following external sources of corroboration (stating which claim each source provides corroboration for):

- Reports, reviews, web links or other documented sources of information in the public domain.
- Confidential reports or documents (if listed, these must be made available by the HEI if audited).
- Individual users/beneficiaries who could be contacted by the REF team to corroborate claims*.
- Factual statements already provided to the HEI by key users/beneficiaries, that corroborate specific claims made in the case study and that could be made available to the REF team bythe HEI if audited*.

*** Where the sources are individuals who could be contacted or have provided factual statements to theHEI, the submitted case study should state only the organization (and, if appropriate, the position) of the individuals concerned, and which claim(s) they can corroborate. Their details (name, position, contact details) must be entered separately on the REF submission system and not on REF3b. Details ofa maximum of five**

individuals may be entered for each case study; these data will not be published as part of the submission.

Annotated Example:

- C1. Supporting statement from GIUL.
- C2. Herald Scotland, "Scottish green infrastructure protocol aims to tackle urban air quality issues", Monday 10 March 2016.
- C3. GIUL media release, "Glasgow pioneers' green infrastructure to enhance urban air quality", The Scotsman, 5 July 2016.
- C4. IoT Now, "Glasgow pioneers' green infrastructure to enhance urban air quality" LoRa network", 14 July 2017.
- C5. The National, "Glasgow to get urban air quality boost from Green infrastructure protocols", 6 July 2018.
- C6. Testimonials from CTO, Urban Technologies.
- C7. Green Infrastructure Protocol Performance in Generic Urban Scenarios – White Paper, Urban Technologies.
- C8. IoT Now Dec/Jan 2019/20, 5 (5), pp. 8-11.
- C9. Testimonial by ex-CEO of Green Infrastructure Sensing Solutions (GISS).

Previous submitted REF Impact case study database can be found here

New REF Guidance can be found here